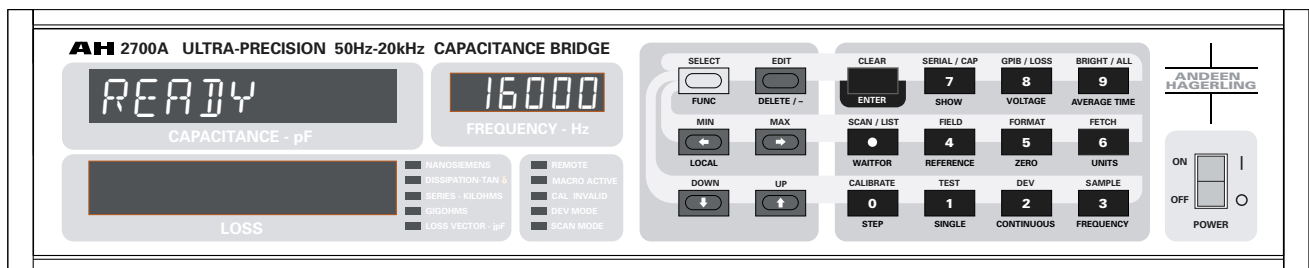


AH2700A

50 Hz - 20 kHz Ultra-Precision Capacitance Bridge

Operation and Maintenance Manual





AH2700A

50 Hz - 20 kHz Ultra-Precision Capacitance Bridge

Patent No. 4,772,844 and 6,204,673

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Serial Number _____



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This manual applies to
Serial Numbers 00001+
Firmware Version AH2X0200+

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2003 June



WARRANTY

Andeen-Hagerling Incorporated warrants the AH2700A to be free from defects in materials and workmanship and to operate within applicable published specifications for a period of three (3) years from the date of shipment, provided that it is properly used. This warranty does not apply to sealed devices which have been opened or to any item which has been repaired or altered without our authorization.

During the warranty period, we will repair, or at our option, replace any instrument which fails to meet its published specifications.

There will be no charge for parts, labor, or forward and return shipment during the first three months of this warranty.

There will be no charge for parts and labor during the fourth through thirty-sixth months of this warranty. Forward and return shipping and insurance will be paid by the customer during this period.

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THE REMEDIES PROVIDED HEREIN ARE THE BUYERS SOLE AND EXCLUSIVE REMEDIES. ANDEEN-HAGERLING INCORPORATED SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT OR ANY OTHER LEGAL THEORY.

DESIGN OF THIS MANUAL

This manual was written and formatted using FrameMaker publishing software running on a network of Macintosh and Intel computers. The schematics were drawn using PADS software. Parts layout drawings and the exploded view were created using Adobe Illustrator. The remaining three-dimensional illustrations were done using Vellum. A number of drawings combined results from several of these software packages.

The style chosen for this manual contrasts significantly with what is commonly found today. Many of today's manuals put very little content on each page and leave large open spaces for notes or whatever. Unfortunately, many more pages are then required to publish a given amount of material. Much more turning of pages is also required to find anything.

In contrast, the AH2700A manual style avoids wasting space and pages (and trees). A two column format ensures that readability is not lost. As a result, the entire manual fits in only one binder instead of the three binder set that would be required otherwise. We are especially interested in feedback about this style issue.

FEEDBACK

We are always eager to receive praise and/or criticism about this manual and product. It is your comments and suggestions that have helped guide the content of this manual and the design of the AH2700A. With your help this process will continue with new products.

We are also very interested in hearing about new ways that you have found to put the AH2700A to use.

Please feel free to contact us by e-mail, phone, FAX, or letter with your suggestions, comments, criticisms and questions.

SAFETY PRECAUTIONS

The following safety precautions must be observed while operating and servicing the AH2700A:

- This instrument is intended for use by qualified personnel who understand electrical shock and other hazards associated with electronic instrumentation. Failure to observe these precautions and other cautions and warnings in this manual may violate design safety standards and intended use of the instrument and may cause injury. Andeen-Hagerling Inc. assumes no liability for the customer's failure to comply with these precautions.
- Do not operate a damaged instrument. If there is any reason to suspect the instrument is physically damaged, unplug the instrument and do not use it until safe operation can be verified by service-trained personnel.
- Operating the instrument with externally applied DC Bias voltages can cause hazardous voltages to be present at the input connections of the instrument. Be certain that any external bias voltages are switched off and discharged if necessary before touching, connecting or disconnecting the input connectors.
- Do not substitute parts or modify the instrument. Doing so could violate built-in safety features.
- For operator safety, the instrument cabinet should be grounded. The 3-wire power line cord shipped with the instrument provides this protection when plugged into a properly grounded power receptacle. Do not attempt to defeat the power cord grounding.
- Operating personnel must not remove the instrument covers. Service and internal maintenance adjustments are to be made by qualified maintenance personnel.

The symbol shown below appears on the rear panel of the AH2700A capacitance bridge.



The presence of this symbol indicates that a possible safety issue exists with respect to the item that the symbol is located adjacent to. If you intend to use the item that is located next to the symbol, then it is important that you read the section of the manual about that item before proceeding to use it.

Throughout this manual you will see certain safety related messages. Their meanings are described below:



WARNING !

WARNINGS call attention to procedures or conditions that could cause bodily injury or death.



CAUTION

CAUTIONS call attention to procedures or conditions where damage to the instrument or irrecoverable loss of data could occur.

NOTE

NOTES call attention to important procedural details that deserve special attention by the reader.

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This chapter introduces the major capabilities of the AH2700A capacitance bridge and summarizes its specifications. It also discusses basic installation and the GPIB and serial interface options that are possible.

GENERAL DESCRIPTION

The AH2700A Ultra-Precision 50Hz-20kHz Capacitance Bridge is an extremely accurate and stable instrument used for precise measurement of capacitance and loss¹ over a range of frequencies. The unparalleled accuracy and stability is derived from the use of a carefully designed ratio transformer coupled with an extremely stable fused-silica standard capacitor that is contained in an internal temperature-controlled oven.

Measurements are made automatically, eliminating the cumbersome manual balancing previously associated with precision capacitance measurements. The bridge can be operated as a stand-alone instrument from the front panel controls. It can also be operated remotely from either of the built-in IEEE-1174 serial or GPIB remote device ports.

APPLICATIONS OF THE BRIDGE

The AH2700A Ultra-Precision 50Hz-20kHz Capacitance Bridge is designed to meet the critical requirements of the calibration and research laboratory, as well as those of manufacturing and incoming inspection where measurement precision is important. Some common applications are:

- Calibration work including use as a transfer standard in national, primary and secondary laboratories.
- Characterization of materials.
- Capacitance cytometry (measuring the DNA in individual biological cells).
- Measurements at cryogenic temperatures.
- Thermal expansion measurements for any type of matter, particularly metals, but also non-metals.
- Liquid and vapor level measurements.
- AC resistance measurements to 1000 teraohms.
- Displacement and strain measurements. Very small changes in dimensions are measurable, approaching the

1. The term "loss" is used to refer to the component of the impedance which is 90° out of phase with respect to the capacitive component. The AH2700A can report loss in units of conductance, dissipation factor, series or parallel resistance or loss vector (jpF).

diameter of an atomic nucleus. (This is less than a millionth of the wavelength of visible light.)

- Quality and characteristics of any insulating medium (solid, liquid or gas). The presence of contaminating water is particularly easy to detect. See ASTM D150 and D924.
- Research, development and production testing of capacitance or loss based sensors.
- Measurement of pressures ranging from high vacuum to high pressure.

There are many other applications to which the AH2700A and its predecessor the AH2500A have been applied and to which they could be applied.

FEATURES OF THE BRIDGE

The most important features of the AH2700A are summarized in the sections below.

Performance Characteristics

A summary of the AH2700A specifications is given here. Detailed specifications are given in Appendix C, "Performance Specifications".

- **Accuracy** at 1 kHz of 5 ppm
- **Stability** better than 1 ppm/year
- **True Resolution** at 1 kHz of 0.5 attofarad (0.000 0005 pF) and 0.15 ppm
- **Reportable Resolution** of 0.1 attofarad (10^{-7} pF)
- **Temperature coefficient** of 0.03 ppm /°C
- **Measures extremely low loss** at 1 kHz down to a dissipation factor of $1.5 \times 10^{-8} \tan \delta$, a conductance of 3×10^{-7} nanosiemens or a resistance up to 1.7×10^6 gigohms
- **Operating frequency** is 50.000Hz-20.000kHz $\pm 0.0025\%$ in discrete steps
- **Fast analog output** has a frequency response of 3kHz at 3db down at a test frequency of 12 or 16kHz. **As little as 0.4 second** required for full precision measurements.
- **As little as 30 milliseconds** required for repeated measurements on the same sample
- **Negative capacitance and loss ranges** measure negative values to allow for unusual samples or three terminal networks
- **No significant zero offset**

- **Less than 15 minutes warm-up** required after power-on for full precision
- **Quiet operation** is the result of careful thermal design which requires no cooling fan.

Measurement Features

- **Fully self-contained** — no external standard or other apparatus required for three-terminal measurements
- **Three-terminal BNC connections** minimize connector costs and number of cables
- **Two-terminal measurements** of any ungrounded device
- **Commutation** (test signal reversal) to minimize external power line or other periodic signal pickup
- **Autoranging** — one button or command takes all measurements
- **Selectable measurement time** to optimize speed vs. noise trade-off
- **Flexible analog output** generates capacitance and loss signals over a wide range of values and settings
- **Test voltage** is settable to an upper limit
- **Deviation measurements** of capacitance, loss, or both, expressed in absolute numbers or as percentages
- **Zero correction** of test fixture capacitance and loss
- **DC bias** may be externally applied up to ± 100 volts
- **Units of loss** are reportable as conductance, dissipation factor, series resistance, parallel resistance or loss vector

Interface and Control Features

- **IEEE-488 interface** included; external device can serve as controller or logger
- **IEEE-1174 serial interface** included; external device can serve as controller or logger
- **Non-volatile memory**, not DIP switches, used to store interface set-up data
- **Flexible reporting formats** for data to external devices
- **Programmable commands** can eliminate the need for an external controller and provide a simple way to sweep through a range of frequencies
- **Full or abbreviated commands** and error messages in English
- **Large alphanumeric displays** of capacitance and loss having variable brightness and eight digits each
- **Independent frequency display** having variable brightness and five digits
- **External trigger** capability
- **Parameter sets** allow measurement settings to be stored and recalled in groups

- **Sample switch port** provides for automated switching of unknown sample impedances

Calibration and Test Features

- **Automated internal calibration/verification**
- **Simple calibration/verification** against an external, traceable capacitor
- **Passcode hierarchy** for calibration control
- **Cable length compensation** is available
- **Comprehensive, power-up and operator initiated, diagnostic tests**
- **Non-volatile memory** used to store virtually all calibration data; eliminates reliability problems associated with trimmers
- **Cable length compensation** is available
- **Cal Invalid LED** shows when oven is not warmed-up or ambient temperature is too hot or cold

PATENT INFORMATION

The AH2700A is protected by U.S. Patent Nos. 4,772,844 and 6,204,673.

REQUIREMENTS

Operating Environmental Requirements

Operating Temperature Range

0° to 45°C

Operating Humidity Range

0 to 85% relative humidity, non-condensing

General

Operation should occur in a non-corrosive environment while adhering to the operating conditions above.

Storage Environmental Requirements

Storage Temperature Range

-40° to +75°C

Storage Humidity Range

0 to 60% relative humidity, non-condensing

General

Storage in a clean, non-corrosive environment while adhering to the storage conditions above is sufficient for short or long periods of time.

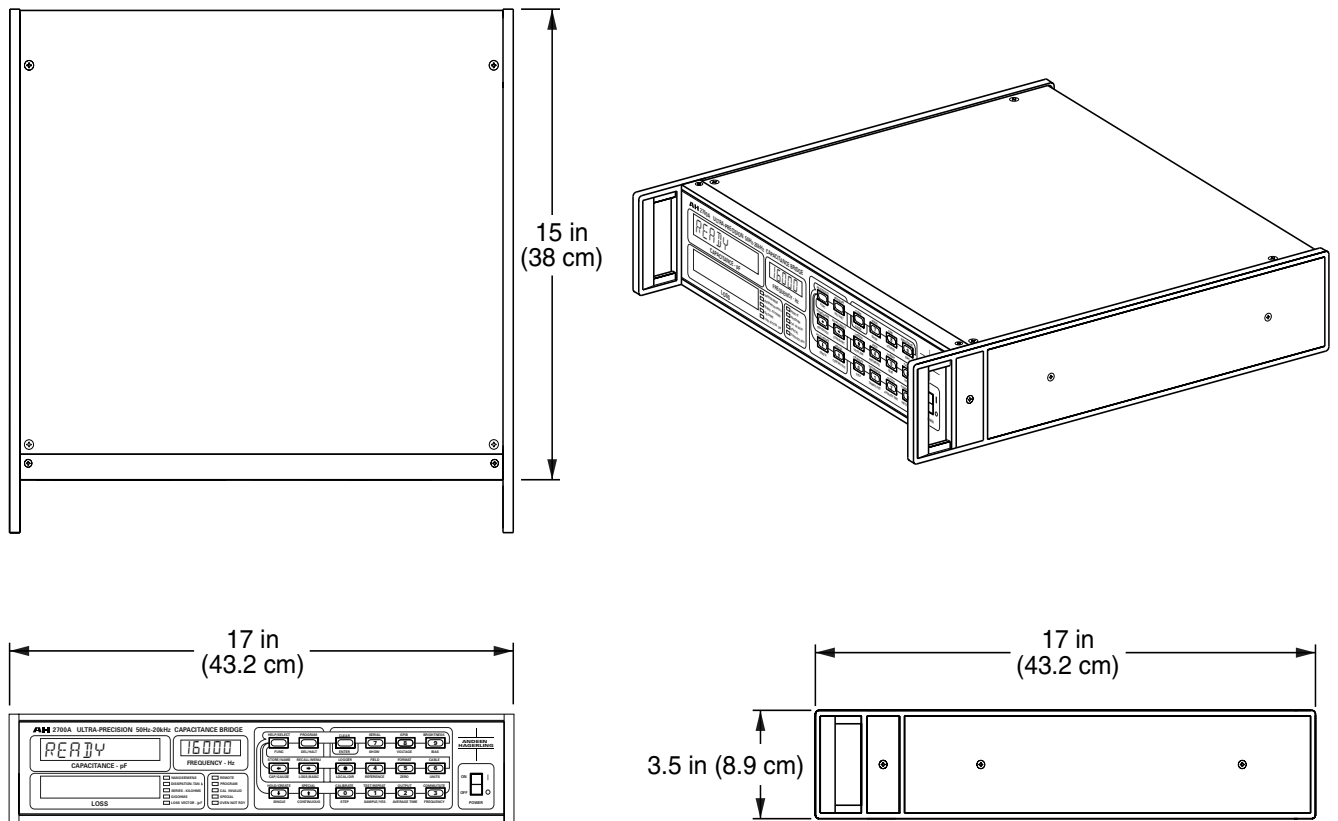


Figure 1-1 AH2700A external dimensions

Power Requirements

17 inches (43.2 cm) overall

Line Voltage

100, 120, 220 or 240 volts AC $\pm 10\%$

Weight

18 pounds (8.2 kg).

Line Frequency

48 to 440 Hz

Mounting

Hardware for rack mounting and a bail and feet for bench top use are provided.

Power Consumption

25 watts

EMC Conformity

Conforms to EN61326:1998 requirements.

PHYSICAL DESCRIPTION

Dimensions and Weight

Safety

Complies with EN61010: 1993 /A2: 1995 and is designed in accordance with UL1244. See the safety messages sheet at the front of this manual.

Height

3.5 inches (8.9 cm)

Width

17 inches (43.2 cm) when bench mounted

19 inches (48.3 cm) when rack mounted

Installation Category CE

The AH2700A line (mains) circuits are designed to withstand impulse overvoltages up to 1500V so that they are in Installation Category II. All remaining circuits in the AH2700A including all of the connections on the rear panel of the instrument are in Installation Category I.

Depth

15 inches (38 cm) deep behind the front panel

ITEMS USED WITH AH2700A

Items Furnished with the AH2700A

The AH2700A is shipped with the following items:

1. AH2700A Automatic Capacitance Bridge.
2. Power line cord.
3. Rack mounting kit.
4. Certificate of calibration.
5. Passcode sheet.
6. Operation and Maintenance manual.

Items Required for Operation and Maintenance

The required items are listed in three groups. The verification equipment list and the disassembly tools list stand by themselves. The maintenance and diagnostics list requires the items in the first two lists also.

Equipment and Accessories Required for Verification or Calibration

The following test equipment and accessories are required to verify or calibrate the AH2700A:

1. 0.5 to 1600 pF three-terminal capacitance standard having a traceable accuracy of 1 ppm. Andeen-Hagerling AH 1100/11A is recommended. See “Obtaining the Capacitance Verification Data.” on page 9-9 for a discussion of what is appropriate.
2. Andeen-Hagerling DCOAX-1-BNC (or equivalent) coaxial cable pair to connect to the device under test.
3. AC resistance standard having a value of 10 k Ω with an accuracy at 1.0 kHz of 0.005% See “Finding a Suitable AC Resistor Standard” on page 9-16 for a discussion of what is appropriate.
4. Digital frequency meter with an accuracy of 0.001% at one kilohertz
5. Digital multimeter with an AC voltage accuracy of 1% and an input impedance of at least 10 megohms.

Tools Required for Disassembly and Reassembly

The following tools are required to disassemble and reassemble the AH2700A:

1. #2 Phillips head screwdriver.
2. Torque screwdriver set to 18 in-lb (200 N-cm) with #2 Phillips head adapter - Utica TS-30 (or equivalent).
3. Right-angle torque wrench set to 18 in-lbs (200 N-cm) with a #2 Phillips bit.
4. Right-angle torque wrench set to 75 in-lbs (800 N-cm) with a deep 5/8 inch (16 mm) hex socket.

5. Integrated circuit insertion/extraction tool for 28 & 32 pin IC for replacing firmware.
6. Small diagonal cutter.
7. Soldering equipment.

Equipment and Accessories Required for Maintenance and Diagnostic Testing

1. A 5/64 inch or 2 mm hex key wrench for changing the power line voltage selector setting.
2. Metered and current limited lab DC power supply variable from 0-250 V.
3. BNC to dual male banana-plug cable to connect power supply to a female BNC jack.
4. Triggered DC-50 MHz oscilloscope and probe
5. Multimeter with an AC and DC voltage accuracy of 2% and an input impedance of at least 10 megohms.

UNPACKING AND INSPECTION

Your AH2700A was carefully examined and tested before it left the factory. If the shipping carton arrives in good apparent condition externally, the bridge and accessories should all be present, undamaged and in good working order. Examine the shipping carton for signs of visible damage. If the carton shows signs of damage, ask that the shipper’s representative be present as the carton is unpacked.

NOTE

We highly recommend that you save the original packaging for re-shipment of the bridge for calibration or repair. A substantial percentage of bridges shipped in packaging other than the original are improperly packed. Many of these are damaged as a result.

Unpack the bridge and check for damage such as scratches, dents and especially cracked or broken front panel handles. Verify that the items listed in “Items Furnished with the AH2700A” on page 1-4 are all present. Additional items such as a DCOAX-1-BNC coaxial cable may have been ordered. Check the packing list that is in the pocket on the outside of the shipping box to see if such additional items should be present.

Damaged Shipment Instructions

If the bridge is damaged, notify both the carrier and Andeen-Hagerling. Andeen-Hagerling will arrange for repair or replacement of the bridge while a damage claim is being processed. Save the shipping carton and packing materials for inspection by the carrier or to return the bridge if necessary.



WARNING !

If damage of any kind is visible or suspected, do not attempt to operate the bridge until its safety can be verified by a qualified technician.

INSTALLING THE BRIDGE

The AH2700A is ready for benchtop use as shipped. It has a bail on the bottom that can be swung down to raise the front of the bridge to a more convenient operating angle.

The bridge can be converted for mounting in a standard nineteen inch equipment rack using the rack mounting hardware kit supplied with the bridge.

Ventilation

The ventilation requirements of the AH2700A are typical of electronic measuring instruments. The AH2700A generates about 25 watts of heat. This heat is expected to be carried away by air currents. If the AH2700A is installed in a confined space, there must be provision to carry away the excess heat so that the temperature of the instrument is kept within its operating range.

Rack Mounting

To convert the bridge for rack-mounted operation, perform the following:

1. Refer to Figure 1-2.

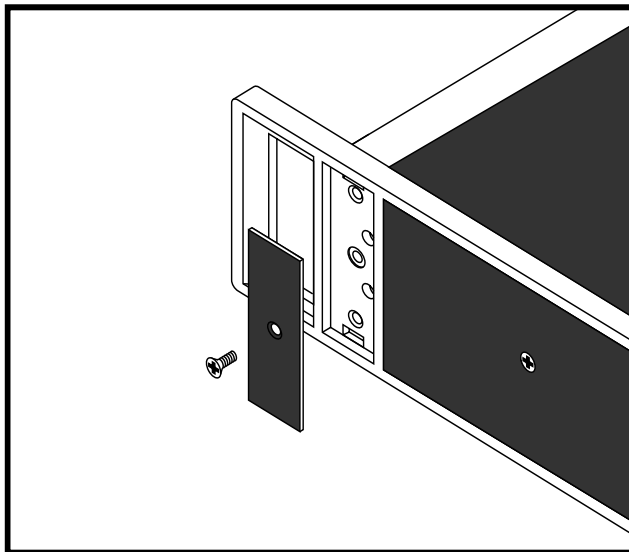


Figure 1-2 Cover plate removal

2. Remove the screws holding each of the two small cover plates and remove these plates.

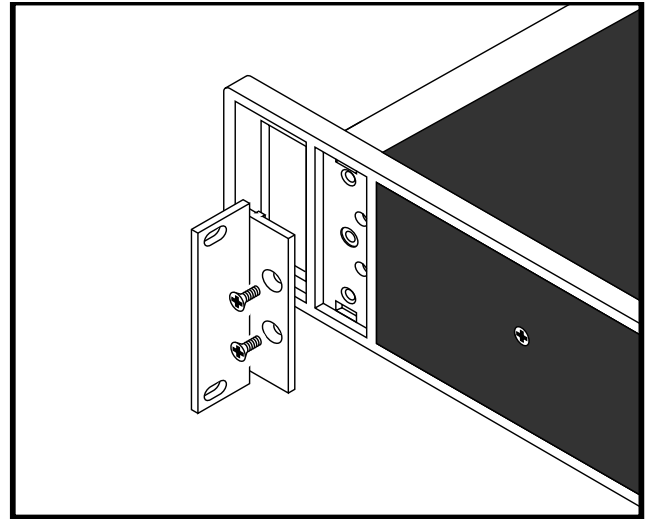


Figure 1-3 Rack mount adapter installation

3. Refer to Figure 1-3.
4. Attach each of the two rack mounting brackets using two screws each from the hardware kit.
5. Remove the bottom feet and the tilt bail. Save the parts in case you want to convert back to bench operation.
6. Install the bridge in the intended rack and secure with four screws from the rack mount hardware kit.

Power Line Cord

The bridge is shipped with a power line cord appropriate for its destination country. Since some countries do not have uniform power line connector standards, this line cord may not always be correct. If not, replace it with one that is appropriate for your location.



CAUTION

It is extremely important that the chassis grounds of all equipment being interconnected be properly grounded through the power cord of each piece of equipment. Ground pins on power cords must never be cut off or otherwise defeated. Failure to observe this will frequently cause serial or GPIB ports to be damaged if these ports are disconnected while the equipment is plugged in. Damage can occur even if the bridge is not powered on. The failure results from the ability of power line RFI filter capacitors to cause an ungrounded equipment chassis to float to a voltage midway between the voltages on the two input power lines. This can put the chassis voltage at 50 to 120 volts above ground (for line voltages of 100 to 240 volts) with enough current capacity to be a shock hazard and to cause damage to interface ports. (The AH2700A does not use such filter capacitors, but many other pieces of equipment do.)



WARNING !

For operator safety, the bridge cabinet should be grounded. The 3-wire power line cord shipped with the bridge provides this protection when plugged into a properly grounded power receptacle. Do not attempt to defeat the power cord grounding.

Choosing the Proper Fuse

There are two fuse current ratings suitable for use in your bridge. The correct fuse rating depends on the power line voltage that is to be used. The table below relates the power line voltage to the correct fuse rating.

Table 1-1 Power line fuse ratings

Line voltage	Fuse rating
100 or 120 VAC	0.5 A slo-blo (Littelfuse 313.500 or equivalent)
220 or 240 VAC	0.25 A slo-blo (Littelfuse 313.250 or equivalent)



CAUTION

The AH2700A is shipped with a power line fuse that is probably correct for its destination country. Since some countries do not have uniform power standards, this fuse may not always be correct. The fuse should be checked for the proper rating in the table above before applying power.



WARNING !

Do not ever substitute a fuse having a larger current rating than is indicated in the table. A fire hazard exists if this warning is not heeded.

Changing the Fuse and Voltage Values

The AH2700A incorporates a power line voltage selector module to quickly configure it for local line voltages. This power line entry module is located in the center of the rear panel as shown in Figure 1-8 on page 1-10. The voltage setting is indicated by the number on a card under the fuse in the power entry module. The voltage is set at the factory for the probable power line voltage for its destination country. Since some countries do not have uniform power standards, this line voltage setting may not always be correct.



CAUTION

The voltage selector setting should be checked prior to applying power to the bridge for the first time.

To change the fuse or voltage selector, proceed as follows:

1. Unplug the power line cord from its receptacle on the back of the bridge. Slide the plastic fuse cover to the right to expose the fuse and voltage selector circuit board.
2. Rotate the black plastic fuse-pull toward you to remove the fuse. This will expose a voltage value (100, 120, 220, or 240) on the selector circuit board. If the value is your desired operating voltage, then the voltage is set properly. If you don't need to change the operating voltage, skip to step five.
3. Remove the voltage selector circuit board with a 5/64 inch or 2 mm hex key wrench. This is done by putting the end of the key into the hole in the circuit board and using the bottom edge of the selector module to pry the board loose.
4. Select the desired voltage by orienting the circuit board so that the desired voltage value is facing up and is on the left side of the circuit board. Push the circuit board firmly back into the fuse block. The desired operating voltage value will be visible directly below the fuse.
5. Rotate the fuse-pull away from you, back into its normal position. Check the current rating of the fuse you removed against the rating given in the table in the previous section. If the rating is correct, then re-install the fuse by pressing it back in. If it is not correct, then install a fuse having the correct rating. Slide the fuse cover back over the fuse and plug the power line cord into its receptacle. The bridge is ready to power on.

Checking/Replacing the Fuse

To check or change the fuse, proceed as follows:

1. Unplug the power line cord from its receptacle on the back of the bridge. Slide the plastic fuse cover to the right to expose the fuse and voltage selector circuit board.
2. Rotate the black plastic fuse-pull toward you to remove the fuse. Rotate the fuse-pull away from you, back into its normal position.
3. Check the current rating of the fuse you removed against the rating given in the table in the previous section. If the rating is correct, then use an ohmmeter to check the continuity of the fuse. If it is continuous, then re-install the fuse. If the fuse rating is not correct or if the fuse is open, then install a new fuse having the correct rating. Note that the fuse must be a slo-blo type or you will have trouble with periodic fuse failures. Push

the cover back into the module and plug the power cord into its receptacle in the back of the bridge. The bridge is ready to power on.

REPAIR SERVICE

Andeen-Hagerling offers full repair and calibration services for the AH2700A. If you are uncertain as to whether your bridge needs repair or not, refer to Chapter 9, "Verification/Calibration" where you will find instructions about how to verify your bridge's performance. If you are sure there is a problem, but uncertain as to whether it might be repairable in your own facility, refer to Chapter 11, "Diagnosis and Repair".

If you conclude that you need to return the AH2700A to the factory for repair or calibration, we ask that you follow the simple procedure below:

1. Call or fax or e-mail the factory to obtain a Return Authorization number. You will be asked what needs to be done to the bridge and whom to contact if further information is needed by the factory. You will also be asked for the serial number of the bridge. This is found on its back panel. The phone number to call is 440-349-0370. The fax number is 440-349-0359. The e-mail address is info@andeen-hagerling.com
2. Attach a tag or label to the bridge containing the Return Authorization number, the name and address of your person to contact for additional information, a phone number and the work to be done.
3. Package the bridge as described in "Packaging for Shipment" below.
4. Make two shipping labels. Put one on the outside of the carton and one on the inside. Ship the carton to the following address:

Andeen-Hagerling Inc.
31200 Bainbridge Road
Cleveland, OH, 44139-2231 U.S.A.
5. It is suggested that you insure the bridge against shipping loss or damage. Shipping problems are not covered under the warranty.

Packaging for Shipment

If you need to ship the AH2700A, it is extremely important that there be at least three inches (8 cm) of a compliant cushioning material on all sides of the bridge. The handles which are part of the side castings are especially vulnerable if proper packing is not used.

To meet these requirements, a shipping carton that is *much* larger than the bridge itself is required. Using a strong shipping container such as a wood crate *will not compensate* for a lack of adequate cushioning material on all sides. If you do not have an adequate shipping container and compliant cush-

ioning material, you can obtain these things from Andeen-Hagerling.

NOTE

We highly recommend that you use either the original packaging or new packaging from Andeen-Hagerling for any shipping of the bridge. A substantial percentage of bridges shipped in packaging other than the original are improperly packed. Many of these are damaged in shipping as a result.

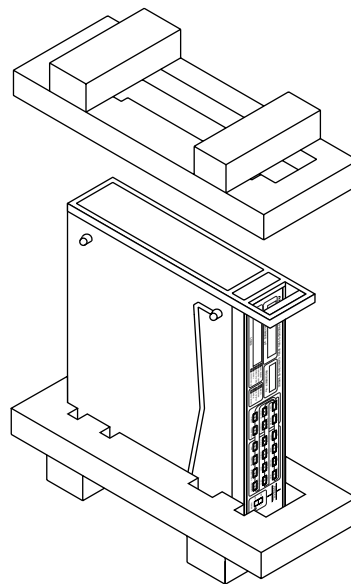


Figure 1-4 AH2700A foam inserts

If you use Andeen-Hagerling packaging, carefully press the foam inserts onto each side of the bridge exactly as shown in Figure 1-4. These may be a very tight fit. The bridge with foam inserts then goes into the carton as shown in Figure 1-5. The bridge can optionally first be sealed in a polyethylene bag for protection against moisture.

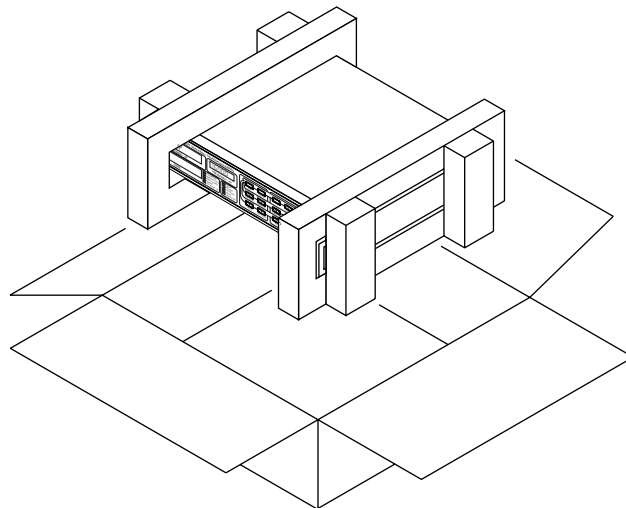


Figure 1-5 AH2700A packaging

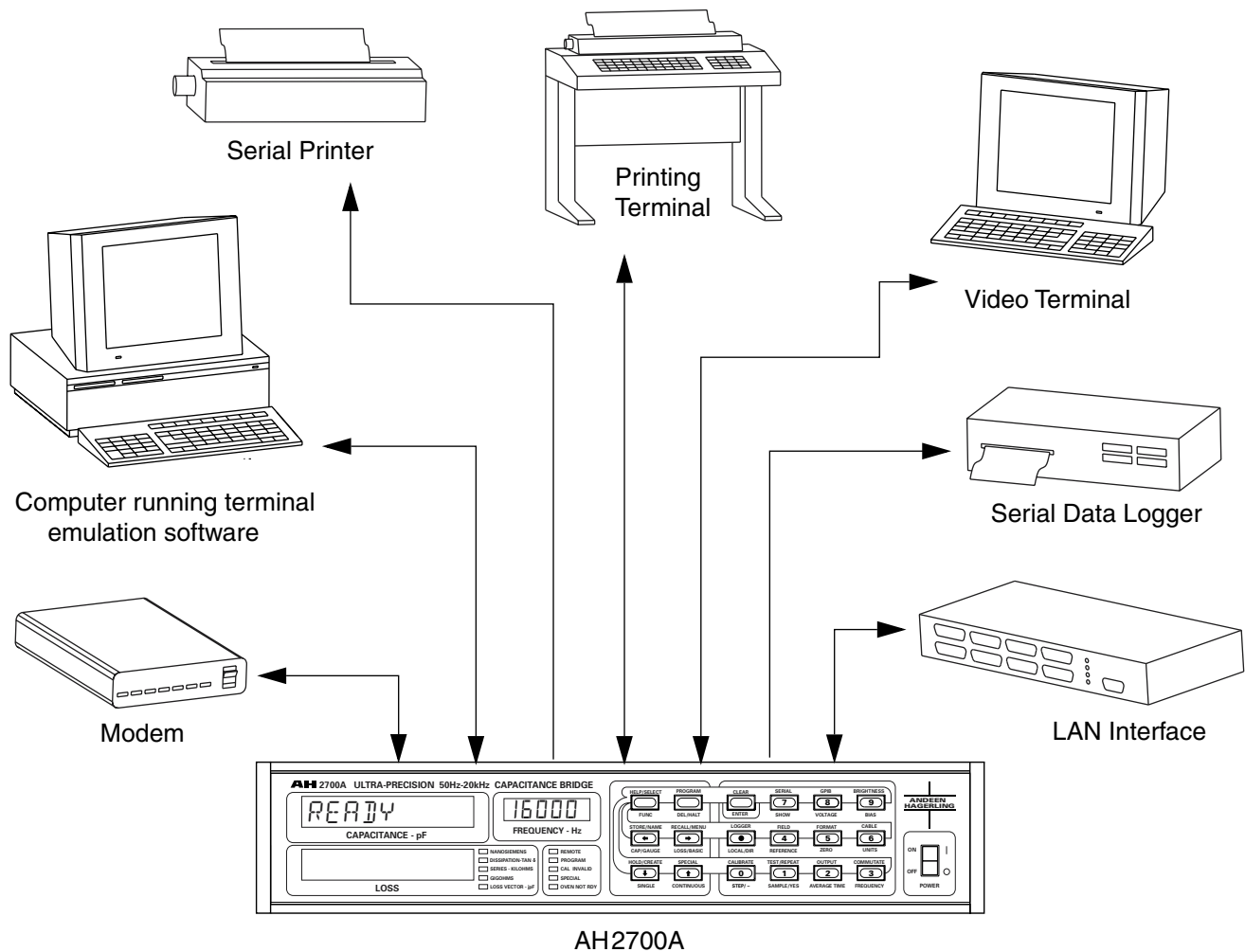


Figure 1-6 AH2700A connections to serial devices

CHOOSING REMOTE DEVICE COMMUNICATION OPTIONS

In addition to operation from the bridge's front panel the AH2700A can be operated from a variety of other remote devices ranging from simple dumb terminals to mainframe computers. Connection to these remote devices can be through direct connection to the device or can be indirect using a modem and data communications lines. Connection to the bridge is made through either the Serial or GPIB (IEEE-488) ports.

Serial Communication Options

The serial port allows many possible ways of communicating with remote devices. These options are shown schematically in Figure 1-6. The arrows in the figure indicate that two of the options will only *collect* data from the AH2700A (using its logging capability). The remaining five options allow remote control *and* data collection from the bridge. The options shown are:

1. **A dumb video terminal.** This is probably one of the simplest devices to connect. It provides a very friendly alternative to operation from the bridge's front panel, but does not offer any storage capability.
2. **A computer running terminal emulation software.** This method of operation is very similar to using a video terminal except that the software will probably allow you to save all communication between the computer and the bridge. If you have used your computer to access any dial-up computer services, the same software should be able to access your AH2700A. The situation is the same whether you are using a personal computer or a large mainframe. Naturally, custom written software will work also, but terminal emulation software will work without modification.
3. **A printing terminal with a serial interface.** A printing terminal is useful in much the same way as a video terminal except that a printed record of all results is produced. Since a printer may be much slower than a

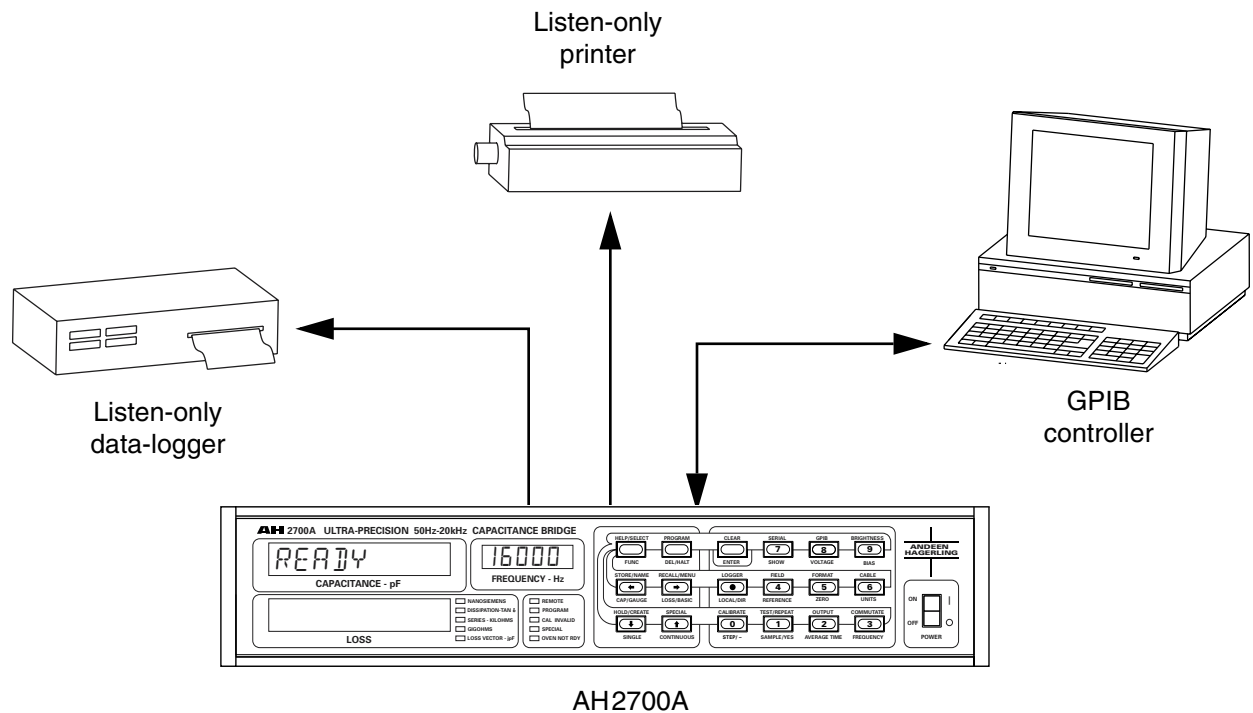


Figure 1-7 AH2700A connections to GPIB devices

video terminal, it is a good choice only when a printed record is really desired.

4. **A serial printer.** Any serial printer should work and will allow producing a printed record of all front panel operations. The AH2700A's flexible logging options are useful here.
5. **A serial data logger.** This is a less commonly available device, but is specifically designed to record data in printed or magnetic form. Large amounts of data may be recorded in magnetic form. Again, the AH2700A's flexible logging options are useful here.
6. **An asynchronous modem up to 9600 baud.** Connection to a modem allows operation with any of the previously mentioned devices over telephone lines.
7. **A LAN interface.** Serial port interfaces are now available for all common local area network standards. This is another way to connect over larger distances to any of the devices listed above.

The specifics of connecting and operating a remote serial device with the AH2700A are discussed in Chapter 7, "Serial/RS-232 Remote Operation". Some serial ports can be a challenge to make connection to due to a lack of standardization. However, once connected, most serial links require no programming to operate. The bridge is even easier to operate this way than from the front panel.

GPIB Communication Options

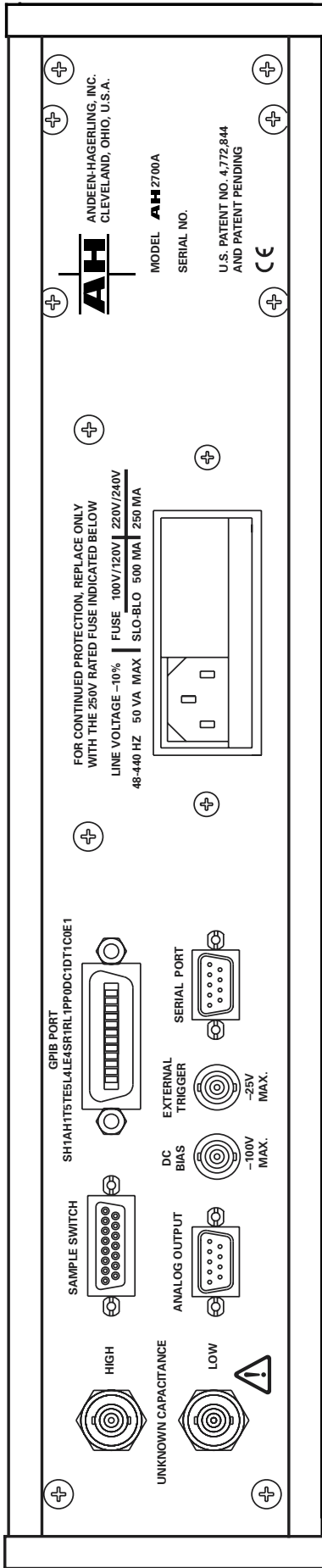
If you wish to use the GPIB interface, you will find it is more capable, more complex, and more difficult to learn to use

than the serial interface. It is not within the scope of this manual to present a tutorial on the GPIB interface. Many discussions of the GPIB bus have been published. GPIB controllers will often have good descriptions of the bus in their manuals. See the very beginning of Chapter 6, "GPIB/IEEE-488 Operation" for specific references.

The possible options available for operation of the AH2700A with the GPIB are shown in Figure 1-7. The arrows in the figure indicate that two of the options will only *collect* data from the AH2700A (using its talker-only and logging capabilities). The remaining option allows remote control and data collection from the bridge. The options shown are:

1. **A GPIB controller** or a computer having a GPIB interface. This is the most common way to operate instruments with the GPIB bus.
2. **A listen-only printer.** Some printers especially those made by Hewlett-Packard/Agilent Technologies may be available with GPIB interfaces. These are very easy to connect to the AH2700A. The AH2700A's flexible logging options are useful here.
3. **A GPIB data logger.** This is a less commonly available device, but is specifically designed to record data in printed or magnetic form. Large amounts of data may be recorded in magnetic form. Again, the AH2700A's flexible logging options are useful here.

The specifics of connecting and operating a remote GPIB device with the AH2700A are discussed in Chapter 6, "GPIB/IEEE-488 Operation".



} Power line module

Figure 1-8 AH2700A rear panel

Table 1-2 Identification of rear panel connectors

Rear Panel Connector	Used For
Power line module	Connection to power line
HIGH terminal output	Low impedance drive to DUT (Device Under Test) (HIGH power and voltage)
LOW terminal input	High impedance input from DUT (LOW power and voltage)
SAMPLE SWITCH	Connection to external sample switching system to select one of multiple inputs
DC BIAS	Connection to external power supply of up to ±100 VDC to bias the Device Under Test
EXT. TRG.	Connection to grounding switch or to a negative pulse to initiate a measurement or program
IEEE-488 PORT	Connects instrument to other GPIB devices
IEEE-1174 PORT	Connects instrument to other serial devices
ANALOG OUTPUT	Provides analog signals proportional to the capacitance and loss being measured

This chapter is intended to be helpful if you are using the AH2700A for the first-time. It discusses familiarization and simple single and continuous measurements using the front panel keypad and default parameter sets. It then describes some experiments to perform to help develop an intuitive grasp of the basic measurement concepts of the bridge (we often call the AH2700A instrument “The Bridge”). If you are already acquainted with the basic operation of the AH2700A, you can skip this chapter.

SOME TERMINOLOGY

There are many terms that have been used to describe the impedance to be measured that is connected to the AH2700A. Some of the more common of these are: “unknown”, “sample”, “unknown sample”, “unknown capacitance”, “unknown loss”, “unknown impedance”, and “DUT” (Device Under Test). Any of these terms may be used in this manual to identify the impedance to be measured.

BEFORE APPLYING POWER

If the bridge is being installed for the first time, be sure that it is correctly configured for the proper line voltage and has the correct fuse installed. See the sections beginning with “Choosing the Proper Fuse” on page 1-6 of Chapter 1, “Description and Installation” to check for proper configuration.



CAUTION

It is extremely important that the chassis grounds of all equipment being interconnected be properly grounded through the power cord of each piece of equipment. Ground pins on power cords must never be cut off or otherwise defeated. Failure to observe this will frequently cause RS-232 and GPIB ports to be damaged if these ports are disconnected while the equipment is plugged in. Damage can occur even if the bridge is not powered on. The failure results from the ability of power line RFI filter capacitors to cause an ungrounded equipment chassis to float to a voltage midway between the voltages on the two input power lines. This can put the chassis voltage at 50 to 120 volts above ground (for line voltages of 100 to 240 volts) with enough current capacity to be a shock hazard and to cause damage to interface ports. (The AH 2700A does not use such filter capacitors, but many other pieces of equipment do.)

APPLYING POWER

Turn the power switch on the front panel to the ON position and wait a few seconds for the words

DIGITAL
TESTPASS

to appear on the displays. During start-up, the bridge is performing internal self-tests of some of its circuitry. The test passed message appears when these tests are successful.

To make accurate measurements, you must ordinarily wait until the CAL INVALID indicator stops blinking, but for the following experiments, you may begin immediately.

KEYPAD AND DISPLAYS

Refer to the actual bridge front panel or to the front panel in Figure 2-1 on page 2-4 in the discussion below.

Front Panel Displays

The AH2700A uses two eight-digit, fourteen-segment, LED displays to show measurement results and other information. The bridge also uses a five-digit, seven-segment, LED display solely for displaying the measurement frequency. In addition, the bridge has two columns of LED's that show status information.

Capacitance and Loss Displays

Most of the time, the upper fourteen-segment display shows the measured capacitance result, usually in picofarads, with a floating decimal point. The lower display shows the measured loss result in one of five units that you can select. These are selectable with the UNITS command, an example of whose use occurs later in this chapter in the section titled “Measuring Loss” on page 2-11. See Appendix A, “Command Reference” for further details on how to use the UNITS command and any other command.

Both fourteen-segment displays are also used to show other information and error messages. Most information that can be sent to a remote device is also reportable on these displays. This is true even though a line sent to a remote device may have as many as 80 characters. Such longer lines are reported on the front panel displays by dividing the information on the line into smaller portions. These portions can then be shown one at a time on the front panel displays. Reporting

the contents of a line in this manner is like looking through a window at the line.

For this reason, the term “window” is used in this manual to describe the portion of a line currently being shown in the displays. The term “line” is used to describe any information shown on the front panel that is sent as a single line to remote devices. Some lines are displayable on the front panel in a single window, but others require as many as six windows.

Frequency Display

This seven-segment display is used solely for displaying the frequency of the test signal. If a measurement result is being shown in the capacitance and loss displays, then the frequency display will read out the frequency at which that measurement was made. If the front panel is displaying any other result or prompt, then this window will read out the frequency that will be used to make the *next* measurement. See “FREQUENCY OF THE TEST SIGNAL” on page 4-12 and Appendix A, “Command Reference” for further information on how to change the test frequency using the FREQUENCY command.

Status and Units Indicators

To the right of the fourteen-segment displays are two groups of five LED indicators. The left group of five usually shows the current loss units. The right group usually displays five unrelated status indications.

The REMOTE indicator is on when the bridge is being controlled remotely. The MACRO ACTIVE indicator is on when an AH2700A macro is running. The DEV MODE indicator is on when Deviation Mode is active. The SCAN MODE indicator is on when Scan Mode is active.

The CAL INVALID status indicator blinks on and off if the oven temperature goes out of range. Blinking normally occurs for about 15 minutes after the bridge is first powered on, but can also occur if the bridge is in an environment that is too hot or too cold. Measurements can be made when this indicator is on, but the calibration will not be accurate during such times.

Front Panel Brightness

The brightness of all the front panel displays is controlled using the BRIGHTNESS command. Individual brightness parameters ranging from 0 (off) to 9 (brightest) are entered to control the display brightness. Examples of how to set the brightness of the front panel displays are given later in this chapter in the sections titled “Qualifier Key Labels” on page 2-3 and in “Setting Display Brightness – An Example” on page 2-3. See Appendix A, “Command Reference” for a complete description of this command.

Front Panel Keypad

The AH2700A may be operated entirely from the front panel using the keypad on the right side.

In this manual, front panel keys are indicated by enclosing the key label name, such as **BRIGHTNESS** or **ENTER** within a box. A given key can have as many as four different labels printed on it and on the front panel, but only one will be shown in the box. Which label is recognized by the AH2700A is determined by the context in which the label is used and that is the label that will appear in the box.

The functions of the key labels can be organized into six different groups. These groups are described in the next six sections below.

Special Key Labels

The special key labels are **FUNC**, **EDIT**, **ENTER**, **CLEAR**, **DELETE**, **SELECT**, **↑**, **→**, **↓** and **←**. Each of these keys performs a special and unique function as described below.

The **FUNC** key (similar to a shift key) allows all other keys to have at least one additional label. Labels printed on the yellow background above a key require that the **FUNC** key be pressed prior to pressing the desired key. Note that the **FUNC** key is to be pressed and *released* before pressing the key having the desired label. The **FUNC** key is different from a shift key in this respect.

The **ENTER** key is used to terminate almost all commands. It functions very similarly to the return key on a computer keyboard in this respect.
















The **CLEAR** key label is above the **ENTER** key and is thus activated by the key sequence **FUNC CLEAR**. This key label can be used to perform three different functions. The first of these simply clears the current parameter value that you may have entered in the lower display. You may enter a new parameter value immediately after clearing the one that had been there.

The second clear function occurs when **FUNC CLEAR** is pressed. This simply aborts the current command entry sequence. If you made an entry error, this allows you to start entering another command sequence without completing the previous one. An example is given in the section titled “Correcting Erroneous Input – Examples” on page 2-5.

The **CLEAR** key is also used to perform the DEVICE CLEAR function by pressing **FUNC CLEAR FUNC CLEAR FUNC CLEAR**. The DEVICE CLEAR function immediately aborts any currently executing command, command line or macro. It is explained in more detail in Appendix A, “Command Reference”.

The **DELETE** key is used to delete the most recently entered digit of a number. Each time it is pressed, it will delete the right-most digit of any number being entered and shown on










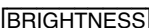














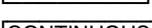



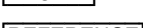
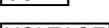


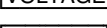



the display. In a different context, this key also starts the DELETE command. The two functions are unrelated.


The , ,  and  arrow keys are used to view different parts of what can be displayed on the front panel. The front panel can display a list consisting of one or more lines of data. Each line in the list consists of one or more windows. The  and  keys are used to move up and down through the lines of the list. The  and  keys are used to move left and right through the windows on a given line. If there is only one window, then these keys will have no effect. The  key will have no effect while the left-most window is being shown. Similarly, the  key will have no effect while the right-most window is being shown. Pressing  or     will initialize the display and inactivate the arrow keys.

Some kinds of result lines “remember” the last window that was being shown so that if that kind of result line is shown again, the window last associated with that line will also be shown. This is true of measurement, calibration and test result lines. It is also true of the windows of a macro that is being shown. This feature allows you to select a window of interest on a result line. That window will then be shown every time that kind of result line is shown.













Command Key Labels

The following labels are used as the first word of nearly all front panel commands that the AH2700A can execute. Some of these labels appear explicitly on the keypad. The rest are available only in a menu.










		
		
		
		
		
		
		
		
		
		
		
		

Most of these command labels can be followed by numeric parameters and/or qualifying label words. All of these command labels require that the  key be pressed to complete the entry of the command key sequence.





Numeric Key Labels

These key labels are: , , , , , , , , , ,  and the minus key which shares . These labels are all on the black keys on the right side of the keypad. These are used to enter numbers and numeric parameters.





Qualifier Key Labels

The qualifier key labels that appear on the keypad are: , ,  and . Many more are accessible in the menus. All of these labels are used to follow certain command key labels for the purpose of qualifying the command. For example, in the key sequence    , the  qualifier causes the brightness setting to apply only to the capacitance display rather than to both displays.

Immediate-Action Command Key Labels

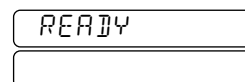
The immediate-action command labels are ,  and . These are commands that execute as soon as their key is pressed. These commands accept no qualifiers or parameters and are not terminated with the  key.






Parameter Modification Key Labels

The labels , , , and  are reserved for future use for modifying parameters.





ISSUING KEYPAD COMMANDS

The bridge will always accept commands that are issued to it when the display reads:



Most bridge commands are issued from the front panel by pressing a command key (sometimes preceded by the  key) followed by a numeric parameter and terminated by pressing the  key. Notice that most of the front panel keys have command names printed both above and below the keys. To issue a command printed below a key, simply press the key, enter a parameter (if any), and press the  key. To issue a command printed above a key, the  key must be pressed first. Then press the desired command key, enter the parameter (if any) and press the  key.

Setting Display Brightness – An Example

When using the BRIGHTNESS command, a number corresponding to the desired brightness of the display needs to be entered. To set the display for the minimum visible amount of brightness, press    . The word *READY* will be dimly lit, indicating that the command was properly carried out. To show the maximum brightness, press

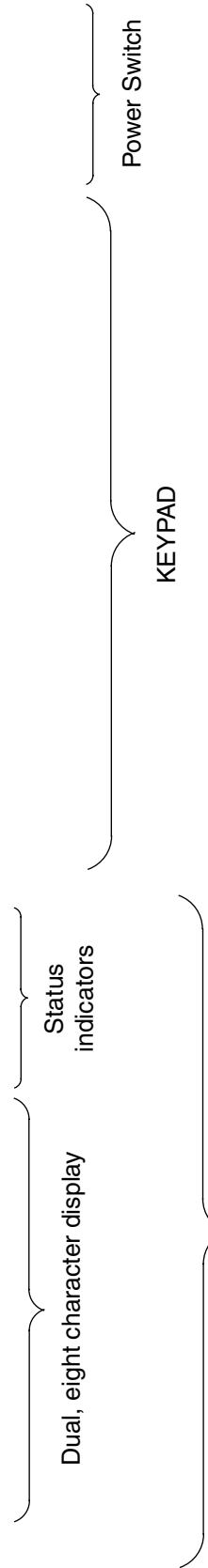
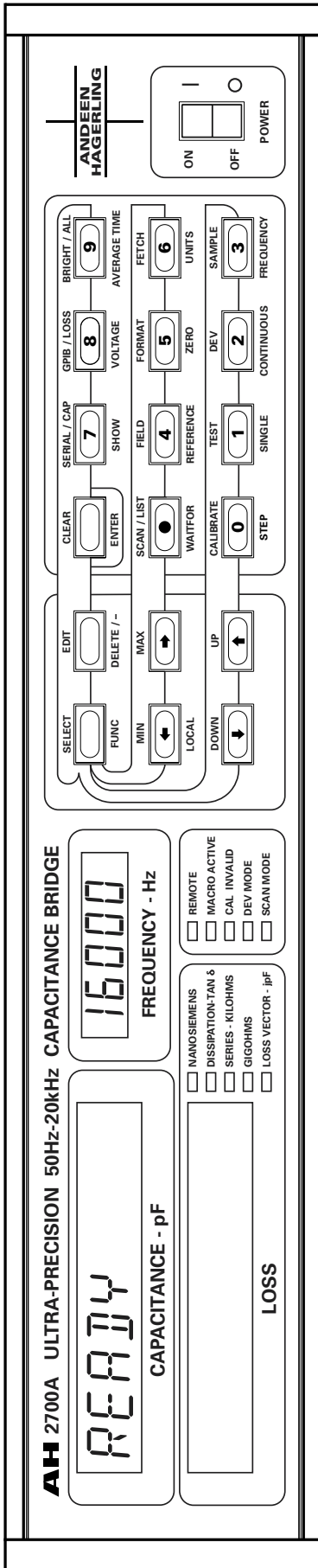


Figure 2-1 AH2700A front panel

[FUNC] [BRIGHT] [9] [ENTER]. The word *READY* will now appear very bright.

Correcting Erroneous Input – Examples

The [DEL] key is used to correct errors while entering parameters. Numbers that are entered from the keypad appear on the lower display, introduced from the right-most digit position. Enter the command [FUNC] [BRIGHT] [1] [2] [3] [4] [5] [6]. (We are picking arbitrary numbers to partly fill the display.) Do not press [ENTER]. You should see:

```
BRIGHT
123456
```

Now press [DEL] six times and you will notice that the numbers are deleted one by one from right to left. Now press [DEL] one more time and notice that nothing happens. The [DEL] key cannot delete the word *BRIGHT* in the upper display.

Suppose you would like to issue a command other than *BRIGHTNESS*. Press [FUNC] [CLEAR] [FUNC] [CLEAR] and notice that *BRIGHT* is replaced by *READY* in the upper display. The *BRIGHTNESS* command was not executed and the bridge is now ready to accept a new command.

Try entering [FUNC] [BRIGHT] [1] [0] [ENTER]. The display will read:

```
BAD
PARAMETER
```

meaning that the number 10 was not an allowable parameter. Another command can be entered at this time or the [ENTER] key can be pressed to make the display show *READY*.

Try entering [FUNC] [CABLE] [5] [5] [ENTER]. The display will read:

```
SYNTAX
ERROR
```

There is no *CABLE* command numbered 55 so a syntax error is reported. Another command can be entered at this time or the [ENTER] key can be pressed to make the display read *READY*.

Using Qualifying Labels – An Example

Suppose you would like to dim the lower display relative to the upper one. The [CAP] and [LOSS] qualifier labels will select the display to which the *BRIGHTNESS* command is to apply. Issue the command [BRIGHT] [LOSS] [5] [ENTER]. Notice that the lower display is now dimmer and that the upper display is unchanged. Issue the command [BRIGHT] [CAP] [5] [ENTER] to make them equal again.

Exploring a List with the SHOW command

The *SHOW* command can be used to display the values of virtually all parameters that can be entered with the various commands. In this example you will explore a list that contains the measurement related parameter lines. This list is called the Serial parameter set. The meaning of most of the parameters that you will see is not important at the moment and will be explained in later chapters. Issue the command [FUNC] [SHOW] [SERIAL] [ENTER]. The display will show:

```
SERIAL
BAUDRATE
BAUDRATE
1200
```

Notice that only the window showing *SERIAL BAUDRATE* will appear at first. Now press the [→] key to see the right-hand window showing *BAUDRATE 1200*. Pressing the [→] key again has no effect, but pressing the [←] key causes the left window to appear again. You can go back and forth between these two windows in this manner.

Now press the [↓] key. The display will show:

```
SERIAL
PARITY
PARITY
NONE
```

You will see only *SERIAL PARITY* at first. Again use [→] the and [←] keys to switch between the left-hand and right-hand windows.

Use the [↓] key to continue through the list. Press the [→] key after each step to see if the display will show more than one window. After a few more steps, you will reach a parameter line that shows the single window below in the displays:

```
NLOCKOUT
OFF
```

Notice that since there is only one window on this line, and pressing the [→] and [←] keys have no effect. In general each line in a display listing may consist of one, two, and in some cases even three or more windows. You can always navigate across a line by use [→] and [←] keys as illustrated above.

If you continue pressing the [↓] key at this point, nothing happens because you are at the end of the list, indicating that you have explored the entire Serial parameter set. If you press the [ENTER] key, the *READY* prompt will appear in the upper display and you are now able to enter another command. You can also get back to the *READY* prompt at any other time without stepping through an entire list just by pressing the [ENTER] key.

Alternatively, if you don't press the [ENTER] key you can continue to explore the list by pressing the [↑] key which will cause the display windows to move backward through the list.

The **SHOW** command is much easier to use on a remote device. There, issuing the command is all that is needed to show the entire list.

Showing a Single Parameter Line

It is not necessary to step through a parameter list to find a particular parameter line. Suppose the value of the Commutate parameter is desired. Press **[SHOW]** **[VOLTAGE]** **[ENTER]** and see on the display:



The **[→]** and **[←]** keys are used to go back and forth between the left and right windows.

ISSUING COMMANDS WITH MENUS

Andeen-Hagerling capacitance bridges AH2700A bridges using firmware versions AH2X0201 and above have an extensively revised set of commands. Most commands that existed before this firmware version still exist, but their syntax may have changed. In addition, many new commands have been added.

In order to add many new commands, it was necessary to make a major change to the operation of the front panel of the instrument since there was not room for more command words on the keypad. Most of the commands accepted by the AH2700A will now be found on the front panel in a system of menus.

Every AH2700A command is now constructed of a command header followed by one or more parameters. On remote devices, each command header consists of from one to four command words each of which is followed by a space. As many as nine parameters separated by commas may follow the command header.

On the front panel, the more commonly used commands may be directly entered from the keypad, but the remaining commands use words that can only be found in the menus. The menus contain all of the command words that are recognized by the front panel and essentially all that are recognized by remote devices as well.¹

To enter a command from the menus, the desired command words must be selected in sequence from a series of one to four menus. The menus are only accessible in Menu Mode which is not normally visible. To enter Menu Mode, press either the **[↓]** or **[↑]** key. This will, respectively, cause the first or last command word of the menu to appear in the lower front panel display. The menus are not circular; they have a beginning and an end, so your choice of **[↓]** versus **[↑]** will

1. The **DEFINE** command is not found on a menu since its parameters may include special characters that are only used by the serial port.

often affect how far you have to scroll through the menu to get to the command word you desire. To indicate that Menu Mode is active, a walking decimal point slowly moves from left to right through the display.

Once Menu Mode is active, pressing the **[↓]** or **[↑]** keys causes the menu to scroll so that the available command words may be seen one by one in the lower display. When you find the word you are looking for, press the **[→]** key to select it.

If it is possible to enter another command word following the one you selected, then the word you selected will appear in the upper display and the lower display will show a new menu which will again be indicated by a walking decimal point. You continue this process until you have selected all the command words that you want in your command header.

When you get to the stage where it is no longer possible to enter another command word, one of two things will happen:

1. The word **ENTER** will appear in the lower display. This indicates that it is not possible to enter any more command words. It also indicates no parameters can be entered either.

Your only option is to complete the command or to cancel it. Pressing **[ENTER]** will complete the command. Since the menus only present valid choices, pressing **[ENTER]** will usually cause the command to be executed also. Pressing **[FUNC]** **[CLEAR]** **[FUNC]** **[CLEAR]** will cause the command to be canceled.


2. The lower display will be blank and no walking decimal point appears. This indicates that the front panel is in Direct Entry Mode. This stage of command entry is used for entering parameter values.

Direct Entry Mode

In Direct Entry Mode, you may enter a decimal number directly from the keypad in the normal manner. If you make a mistake, use the **[DELETE]** key to delete one character at a time. If you want to clear all of what you entered into the lower display, press **[FUNC]** **[CLEAR]**. To accept the parameter value that you entered press the **[→]** key. To accept the current value of this parameter as it was before you entered this command, press the **[→]** key while the display is blank.



Even though the lower display is initially blank, there are usually some menu choices available in addition to your option to directly enter a parameter value. Pressing the **[↓]** key will cause the appearance of a parameter menu its walking decimal point. Additional pressing of the **[↓]** key will allow the remaining choices in this menu to be explored. If none are of interest, pressing the **[↑]** key repeatedly will return you to Direct Entry Mode with its blank lower display.







Multiple Parameter Entry

If the command you entered can accept more than one parameter, then a single numeric digit will appear in the rightmost position of the upper display. The previous position in this display will be blank. This digit indicates the position of the parameter to be entered in the command. This digit will always be a “1” immediately following entry of the command header. Every time you press , this digit will increment by one if another parameter exists whose value can be entered. If no further parameters exist, then `ENTER` will appear in the lower display.
















If the command you entered can accept only one parameter, then no numeric digit will appear in the rightmost position of the upper display.




Character Edit Mode

Sometimes the parameter to be entered is an alphanumeric string such as a filename. Alphanumeric parameters can only be entered from the keypad in Edit Mode. This mode is entered by pressing  . To indicate that Edit Mode is active, a single character will always be blinking in the lower display. The characters that can be entered in this mode are all 26 capital letters, all ten decimal digits and the underscore symbol (`_`).

In Edit Mode, the upper display usually shows the last command word that was entered and the lower display shows the word being edited. Only one character in this word can be edited at a time. This is the one that is blinking. It is called the cursor. The  and  keys are used to move through the alphanumeric character choices until the desired character appears. This list of choices is called the “character menu”. Pressing the  key will cause the blinking character to be selected and the character menu will move to next character position to the right. This process can continue until the desired word is constructed. Pressing  or   accepts the word in the lower display.




There are several other useful things to know about Edit Mode. There are:

1. You can also use all the direct entry characters (, , , , , , , , , , , ) and “-”, plus  in Edit Mode. This allows alphanumeric strings to be entered faster than strings that are alpha only. These keys *insert* the number that is pressed; they do not *replace* the blinking character.
2. The  and  keys can be used to move the character menu to any character position in your word. This allows correcting a character anywhere in the word without having to delete all the characters to the right of it.
3. Edit Mode can also be used to enter and edit numbers of all kinds. This option is available anywhere numeric entry is allowed. In addition to the ten decimal digits, the characters “E”, “-” and a decimal point are available in the character menu.

4. The character menu also contains a character with all segments lit. This character represents a blank. Selecting it with the  or  keys will cause that character position to be removed. The  key performs a similar function but it acts on the character position immediately to the left of the cursor.

More Menu Details

There are several other useful things to know about menus. These are:

1. You often do not need to follow the menus all the way to the end of the command syntax where `ENTER` is displayed. The  key can be pressed whenever a meaningful command syntax has been entered. This can be used, for example, to finish a command that accepts multiple parameters without having to enter or move past every one of its parameters.
2. Usually, Menu Mode must be started by explicitly pressing  or . However, if none of the second or following words of a command can be directly entered from the keypad (since no labels exist for them), then Menu Mode will be entered automatically.
3. A number of very useful and important menu-related features will be added to future versions of the AH2700A firmware.

Aborting Commands

Sometimes there is a need to immediately abort a command that will take a long time to execute rather than to wait for it to finish. The way in which this can be done will depend upon whether the command to be aborted is a query command or not.

A query command is any command that produces a result that can be sent to a remote device. All commands that take measurements or that show parameter values are query commands. Commands that only change parameter values are not query commands.

Any query command may be aborted simply by issuing another command. This is called a “query interrupt”. Any remaining results from the interrupted command are lost and the interrupting command begins executing immediately. If another command is issued while a non-query command is executing, the interrupting command will not be executed until after the non-query command is finished.

To abort a non-query command, a **DEVICE CLEAR** command must be issued. (This will also abort query commands.) On the front panel, this is done with the key sequence **[FUNC] [CLEAR] [FUNC] [CLEAR] [FUNC] [CLEAR]**. This sequence may be entered at any time, even in the middle of entering another command. When this is done, the front panel will display:

```

DEVICE
CLEAR

```

You can try this by issuing a time delay. Enter **[WAITFOR] [↓] ... [DELAY] [→] [3] [0] [0] [ENTER]** and observe a countdown timer on the front panel display starting with 300 seconds. Pressing random keys on the front panel will not interrupt the timer. Now if you enter **[FUNC] [CLEAR] [FUNC] [CLEAR] [FUNC] [CLEAR]**, the timer will stop immediately. For more about this command see “**DEVICE CLEAR**” on page A-15.

MAKING SINGLE MEASUREMENTS

The AH2700A has two measurement modes, the single measurement mode and the continuous measurement mode. When power is applied to a new AH2700A, the bridge is in the single measurement mode. Single measurements can be initiated from the front panel, from a remote device or (indirectly) from an externally supplied trigger pulse. In the single measurement mode a new measurement is started from the front panel each time the **[SINGLE]** key is pressed.

For the remainder of this chapter, set the frequency to 1000 Hz by entering **[FREQUENCY] [1] [0] [0] [0] [ENTER]**. Without attaching any capacitance or measurement cables to the bridge, press the **[SINGLE]** key. A *BUSY* message appears briefly, followed by the measurement result being displayed. For example:

```

000000 15
-00000002

```

Press the **[SINGLE]** key again and see that the previous result remains on the display until the new result is displayed. The bridge displays *BUSY* whenever a new measurement is started and more than ten seconds have elapsed since the last measurement.

In reality, each measurement produces a result having two windows such as:

```

000000 15      S = 1
-00000002      V = 15.0

```

The **[←]** and **[→]** keys are used to move between the two windows. The upper right window displays the sample number in case a sample switch is connected. The lower right window displays the AC test signal voltage that was actually used to make the measurement.

With no measurement cables connected to the bridge, the capacitance between the uncapped HIGH and LOW connectors on the rear panel is being measured. This capacitance is shown in the left upper display and should be in the range of +0.0000000 to +0.0000003 pF. The left lower display shows the loss which should be in the range of -0.0000006 to +0.0000006 nS. When the AH2700A is new, it will show loss using units of nanosiemens after power-on. An example of how to change the loss units is given in “**Measuring Loss**” on page 2-11.

You may want to take several single measurements to see the change in the capacitance and loss. The variation in the readings is caused mostly by externally generated noise entering the uncapped LOW input terminal of the bridge. The source of this noise is usually from nearby power lines and digital instruments and cables.

MAKING CONTINUOUS MEASUREMENTS

The AH2700A can be set to perform continuous measurements almost as easily as single measurements. When in continuous measurement mode, the bridge takes measurements continually with a period that you specify until it is manually halted. To initiate continuous measurements, press **[CONTINUOUS] [ENTER]**. Notice that the displays show a new pair of numbers at a rate of two or three per second. If the LOW input terminal was not deliberately left exposed (uncapped), there might not be enough noise to cause the displays to change with each measurement. The **CONTINUOUS** command makes it easy to quickly observe many readings and thus get a feeling for the amount of noise being picked up.

The bridge remains in continuous measurement mode until a key is pressed on the front panel. Pressing a key causes the measurement in progress to be immediately aborted. After a key has been pressed, the bridge waits for the rest of a command to be entered and then executes it. If the **[SINGLE]** key is pressed, the bridge will go back to single measurement mode and take one reading. If any other command is issued, continuous measurements will restart immediately following execution of the command. This allows the issuing of commands without having to exit and re-enter continuous measurement mode.

MEASUREMENT EXPERIMENTS

This section describes some simple experiments that show how to make actual measurements of capacitance and loss. The high sensitivity of the AH2700A and the meaning of various error messages is demonstrated.

Equipment Needed for Experiments

To perform the experiments that are described next, you will need a few commonly available items listed below.

- Obtain or make two coaxial cables about one meter long. They should have BNC connectors on one end and alligator clips on the other end. Identify the cables by labeling them with an “H” on one of the cables and an “L” on the other. The following manufacturer’s part numbers should work: Pomona Models 4531-C-36, 4532-C-36 or 5187-C-36 or E-Z-Hook Part Numbers 1020XR-36, 1021XR-36, 1020XH-36, 1021XH-36, 1029-36 or 1029M-36.
- An ordinary capacitor with a value between 100 and 10,000 pF. A more stable type such as a mica is preferable to most ceramic capacitors.
- A resistor in the range of 10 k Ω to 1 M Ω .

NOTE

The two coaxial cables recommended above are intended to be used primarily for educational purposes. Cables that do not make fully shielded connections should never, never be used for high precision measurements.

A rule-of-thumb for electrostatic shielding is that if you can see the wire or object that is intended to be shielded, then it isn’t. Furthermore, if there is only insulation or an ungrounded conductor between you and the wire or object then it isn’t shielded.

Connecting the Test Cables

Connect the BNC plugs on the ends of your coaxial cables to the connectors marked HIGH and LOW on the rear panel of the bridge. Connect the cable labeled “H” to the HIGH connector and the cable labeled “L” to the LOW connector. The HIGH connector is an output that supplies a sinusoidal test signal at the frequency the bridge is set to. The LOW connector is a sensitive input. Use a table or a flat work surface to lay the cables on.

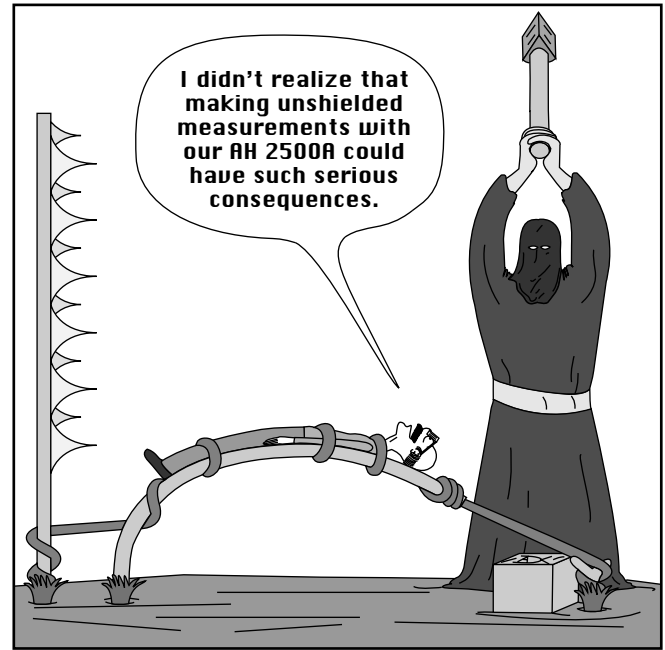


Figure 2-2 Possible effects of using unshielded apparatus for precision measurements



WARNING !

The AH2700A normally drives the high terminal with an AC signal. While the voltage level of this signal is not high enough to cause serious harm, (15.0 volts RMS maximum), it is enough to cause a mild shock, especially if one’s hands are damp or wet.

Demonstrating Noise Sensitivity

You can easily demonstrate that the LOW terminal is the terminal most sensitive to noise and interference.

Start a continuous measurement as described earlier. Note the capacitance reading resulting from the stray capacitance between the HIGH and LOW center conductor clips. Now touch the bare center conductor clip of the HIGH cable. Notice that the capacitance measurement increases, but no error message appears. Touching the bare clip makes your body part of the HIGH side of the stray capacitor thereby making the capacitor dimensions much larger and the capacitance somewhat larger.

Now touch only the center conductor clip of the LOW cable. You should see on your display the error message:

```
AC ON L
INPUT
```

or the message:

```
EXCESS
NOISE
```

These error messages indicate that too much noise is being picked up and it is interfering with the measurements. Your body is acting as an antenna. You have observed a very important difference between the HIGH and LOW connections to the bridge. Awareness of this difference can be very useful when designing, debugging or repairing capacitor fixtures.

If you now hold the bare coaxial cable shield clip of either cable while touching the LOW center conductor clip, the error message will probably go away. If it does not, you are in a fairly noisy environment. Connected in this manner, your body acts as a poor conductor which shunts most (but perhaps not enough) of its picked-up signal to the shield clip. You may want to verify that touching any screw on the case of the bridge has the same effect as touching the shield clip. (The same, that is, unless your hand or body is also moving closer to or further from a significant, nearby source of noise.) You have demonstrated one way in which an ungrounded connection can introduce noise into your measurements.

Low Frequency Noise

The error message `AC ON L INPUT` indicates that low-frequency noise is being picked up. This is a condition you might see if you are working in an area where there are power lines close by.

High Frequency Noise

The conditions that generated the `AC ON L INPUT` error message, may also generate an `EXCESS NOISE` error message. The `EXCESS NOISE` message indicates that high-frequency noise is being picked up. This situation might occur if you are working in an area where computer equipment is being operated.

Reducing the Effect of Noise – Averaging Time

Put the cables in a stable position on your work surface. Watch the capacitance and loss displays as measurements are being displayed and note the most positive and the most negative value shown in each display over a period of several minutes. Since a new AH2700A has a default average time of 4, these measurements were probably taken with that value.

To verify this, press `[SHOW] [AVERAGE TIME] [ENTER]`. You should see `AVERAGE 4` on the displays.

Now change the averaging time parameter to eight by pressing `[AVERAGE TIME] [8] [ENTER]`. This will cause each measurement to take sixteen times longer than at averaging time four. (If the measurements at average time four are too fast to read, change it to five or six and increase the longer averaging time by the same amount.) Since noise is proportional to the inverse of the square root of the measurement time, you will expect to see a factor of four less noise in your measurements at averaging time eight.

Now again, watch the capacitance and loss displays as measurements are being displayed and note the most positive and the most negative value shown in each display over a period of several minutes. The most positive value minus the magnitude of the most negative value should now be about one fourth what it was previously for both capacitance and loss results. You have demonstrated how the use of a longer averaging time can reduce the uncertainty of your measurements due to noise.

Demonstrating Measurement Sensitivity

Now, you will measure the capacitance between the two clips. Leaving the cables connected to the bridge, take the HIGH and LOW center conductor clips of each cable and lay them an inch apart on your work surface. Observe the measurement results. (If you did the previous experiment, you will want to restore the averaging time back to four.)

Now move the clips slightly closer together and observe that the capacitance increases. The closer together you move the clips, the higher the capacitance value reads.

Now move the clips further apart. As you move the clips further apart, the capacitance value decreases.

If you bridge the HIGH and LOW clips with your hand without actually touching either clip or any other conductor, your hand will serve as an intermediate conductor that will increase the capacitance.

If you touch a ground or shield with one hand and put your other hand between the HIGH and LOW clips, your hand will act as a shield. This will cause the capacitance to decrease.

These crude experiments demonstrate basic issues that are used to design precision capacitance measuring fixtures. These experiments are easily extended to more sophisticated configurations by constructing electrodes and shields from whatever materials happen to be readily available in your laboratory (or even in your kitchen).

Hard Measurement Errors

High to Low Shorts

While still making continuous measurements, connect the clips of the center conductor HIGH and LOW cables together. An error message showing:

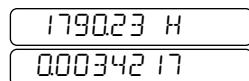


```
H TO L
SHORT
```

should appear, indicating that the HIGH terminal is shorted to the LOW terminal.

High to Ground Short

Now connect the capacitor that you collected earlier between the HIGH and LOW clips. Its capacitance and loss will be displayed on the front panel. Now connect the clip of either ground to the clip of the HIGH center conductor cable. An *H* error message should appear in the extreme right-hand position of the upper display as in the example below:



```
1790.23 H
000342 17
```

The dead short that you have created will cause the capacitance value to be seriously in error.

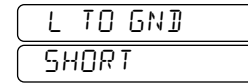
The *H* error message differs from most other error messages, in that it is one of the few that are displayed beside a measurement value. Rather than replacing the measurement, it appears with it. The *H* error message indicates that the impedance between the high center conductor and ground is too low. The measurement value may have some significance, but is usually not to be trusted.

Low to Ground Short

With the capacitor used in the previous experiment still connected, connect the LOW center conductor clip to one of the shields. You must do this without touching the LOW center conductor with any other conductor (or your fingers) that might introduce noise. You should observe that the measurement result does *not* change, nor is any error message reported. If you keep the LOW center conductor shorted to ground, you can even remove the capacitor entirely without changing the results reported by the bridge. The bridge is unable to distinguish the situation where its LOW terminal input is shorted to ground from the situation where the bridge is perfectly balanced. In both cases, the bridge sees no signal on its input. This is the most significant kind of external error that can occur which the bridge is not always able to detect.

Now change the averaging time parameter to seven by pressing **AVERAGE TIME** **7** **ENTER** and repeat this experiment. You will find that every time you short the LOW center con-

ductor to ground, the result of the *next* measurement will be the error message:



```
L TO GND
SHORT
```

indicating that the LOW terminal is shorted to ground. For averaging times of seven or higher, a test is performed at the beginning of every measurement that will detect a low-to-ground short.

Measuring R, C and combined R and C

Measuring Capacitance

Connect the center conductor clips of the HIGH and LOW coaxial cables to your capacitor of about 1000 pF. With the bridge still in continuous mode, record the measured capacitance value.

Measuring Loss

Now remove the capacitor and connect the center conductor clips of the HIGH and LOW cables to a resistor of approximately 100 k Ω .

Since loss is currently being displayed in nanosiemens, and the resistor value is in ohms, we want to change the loss units to display in gigohms for comparison purposes. Use the **UNITS** command to change loss units by pressing **UNITS** **4** **ENTER**. (The loss units parameters are numbered in the same order that the loss units indicators on the front panel are arranged.) Notice that the nanosiemens unit indicator turns off and the gigohms unit indicator turns on, meaning that the bridge is now displaying loss in gigohms. If your resistor is 100 k Ω , the lower display will show approximately 0.000100 G Ω . Record the measured loss value.

Measuring Parallel Capacitance and Loss

Now connect the center conductor clips of the HIGH and LOW coaxial cables to both the resistor and the capacitor connected in parallel. The displays should now read values that are close to the values recorded when the parts were measured individually. If this procedure were performed more carefully and if the bridge was perfect, there would be no difference in the individual versus combined readings. To the extent that the procedure is carefully performed, it is a demanding test of the bridge's capabilities.

To perform the experiment more carefully requires that *both* the capacitance *and* loss be recorded when each part is measured individually. The capacitances are added to get the expected capacitance value for the combined parts. The reciprocals of the resistances are added giving the reciprocal of the resistance value for the combined parts. (This is where the use of conductance units for loss measurements is preferable since nanosiemens can simply be added just the way the capacitance values are.)

Can you perform a similar experiment by combining the parts in series rather than in parallel? (This is a less precise experiment since there is a stray capacitance from the center node that cannot be eliminated.)

Two- Vs. Three-Terminal Connections

All of the experiments described so far have been of the two-terminal variety. The third terminal of a three-terminal device is used to ground an enclosure around that device. The enclosure contains the fields of the device and shields the device from external fields. None of the components measured so far have incorporated a three-terminal shield. As a result, you observed that all of these experimental configurations were very susceptible to externally generated noise and to changes in position, orientation, and proximity to other objects. A properly constructed three-terminal device will eliminate all of these effects. For a more detailed discussion of three-terminal measurements, see “THREE-TERMINAL MEASUREMENTS” on page 4-2.

The AH2700A can make floating two-terminal measurements at least as well as any other instrument, but it is difficult to take advantage of the AH2700A’s exceptional precision unless measurements are made on three-terminal devices. If a three-terminal fixed or decade capacitor and cabling is available, another experiment can be performed to show the enormous improvement that three-terminal devices offer.

Connect your three-terminal capacitor to the HIGH and LOW connectors on the back of the AH2700A using a DCOAX-1-BNC or equivalent cable. With the bridge in continuous mode, observe the readings. Any respectable three-terminal capacitor will produce readings with very little randomness. The least significant digit may hardly change at all.

Now try to induce changes into the reading. Move your hands in the vicinity of the cable and the capacitor. Touch the cable and the capacitor. You should see no effect. Move the cable to other positions. This should have no effect. If it does, the cable is probably defective. Try moving the capacitor to different positions. This should not cause a change in the readings if the capacitor is not bumped so as to change its value slightly. Try moving the capacitor to different orientations. All but the highest quality standards will change slightly as a result of orientation changes, especially capacitors having a gas dielectric. However, the changes will be fairly repeatable if the capacitor is handled gently. The noise level in the readings for all of these experiments should be consistently low.

The experiments you have performed were intended to improve your intuitive grasp of the sensitivity of the AH2700A and of the importance of making three-terminal rather than two-terminal measurements. Chapter 4, “Measurement Essentials” discusses these and other measurement issues in more detail.

Many of the AH2700A's commands accept groups of various numeric parameters. These parameters control the operation of the bridge. For convenience, these groups of parameters are collected into "parameter sets" to make it easy to change the bridge quickly to a new configuration, especially after power-on. Many of the parameter sets can be stored in permanent files within the bridge for later recall and use. This chapter describes the various sets and files and the commands necessary to change, show, store and recall them. To use the AH2700A with maximum efficiency, an understanding of parameter sets and files is essential. However, the bridge is easily used to make measurements with little understanding of sets and files. Thus if you are a first-time user, you may initially want to skip this chapter, but if you are a serious user, you will eventually want to read it.

This is the first chapter having command examples and command syntax definitions for remote devices. Since remote command entry is slightly different between GPIB versus serial devices, it is described in those chapters. For more information, see "REMOTE COMMAND ENTRY" on page 6-3 for GPIB usage, "REMOTE COMMAND ENTRY" on page 7-7 for serial usage and the beginning of Appendix A, "Command Reference" for the command description syntax.

FILES AND MEMORY

The concept of files as used in the AH2700A is very similar to that used by a computer. The main difference is that the AH2700A uses internal, non-volatile, writable memories (EEPROM) rather than disks in which to store its files. Macros and all but one parameter set type can be stored in these files. The working, writable memory of the bridge is RAM, the contents of which are lost when power is lost. The firmware that operates the bridge is located in read-only memory (Flash ROM or EPROM). Figure 3-1 helps to visualize these memory types. The EEPROM files, ROM files and Current RAM contents are labeled in the figure.

PARAMETER SET TYPES

Listed below are the seven types of parameter sets used in the AH2700A. You can directly change the parameters in all but the last one. All sets but the last one can also be saved as a file; the last one cannot be.

The **Basic Parameter Set** contains general information about how the bridge is configured and how results are reported.

The **Gauge Parameter Set** contains information about how capacitance and loss measurements are to be taken and how results are represented.

The **Serial Parameter Set** contains information such as the baud rate that is used to configure the Serial port.

The **GPIB Parameter Set** contains information such as the bus address that is used to configure the GPIB port.

The **Deviation Parameter Set** contains information that is used to configure the analog outputs.

The **Scan Parameter Set** contains information that is used to configure scanning parameter measurements.

Other Parameters contain some information that identifies the bridge and its current condition and status. These contain either fixed information or information which is maintained by the bridge. You cannot directly change this information.

Current Parameter Sets

There is one Current parameter set of each type (Basic, Gauge, Serial, GPIB, Deviation, and Scan) located in the bridge's RAM memory. These sets are shown in Figure 3-1. Their contents are also indicated in this figure. When a command is issued that changes a parameter, it is a parameter in one of the six Current parameter sets that gets changed. You issue commands to set and modify the parameters contained in the Current Basic, Gauge, Serial, GPIB, Deviation, and Scan parameter sets to meet your needs. Bridge operations are directly controlled by the values of the parameters in the Current parameter sets. Since the Current parameter sets are stored in RAM, the contents are lost when power to the bridge is removed.

Stored Parameter Files

The AH2700A allows you to create multiple versions of the Basic, Gauge, Serial, GPIB, Deviation, and Scan parameter sets which are stored as files. Storage in EEPROM memory prevents loss of the contents of the parameter files when the power is removed. Collections of parameters can be created and edited in the Current parameter sets, stored in a file and recalled back to the same Current parameter set. Stored parameter files must be recalled before they will control the operation of the bridge. Figure 3-1 shows examples of stored parameter files and a store and recall operation. These operations are discussed in more detail later under "WORKING WITH FILE CONTENTS" on page 3-11.

Power-on Parameter Files

When the bridge is first powered up, files of default parameters are used to make measurements. The parameters can be the factory-supplied default parameters or they can be parameter files of your creation. If you are always satisfied with the values in the default power-on parameter files, you may not need to learn more about parameter files. Figure 3-1 shows an example of what data is moved during power-on. See "Using Power-on Parameter Files" on page 3-12 for more information.

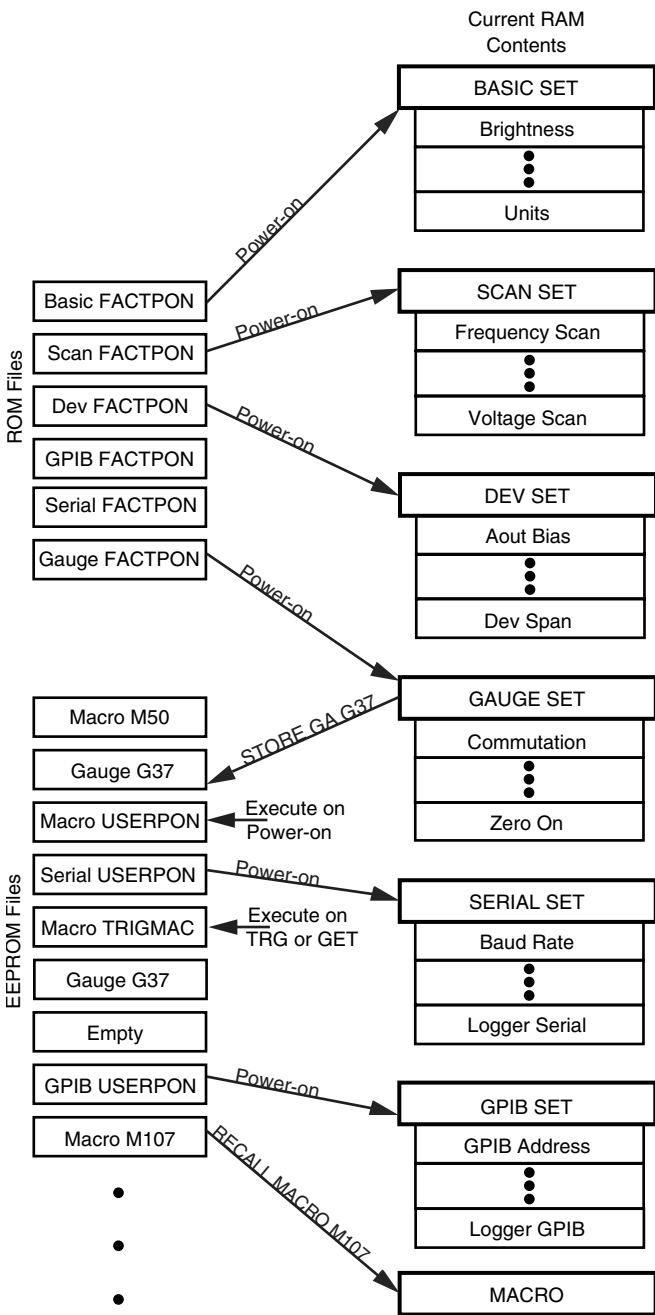


Figure 3-1 Pictorial conception of AH2700A stored files, structure of Current parameter sets and examples of typical operations

PARAMETER SET CONTENTS

Selected contents of the BASIC, GAUGE, SERIAL, and GPIB parameter sets are listed below.

The sections below give a brief description of each parameter or group of parameters. The description is followed by examples of the images of the parameters as the **SHOW** command displays them on the front panel and on remote devices. The examples use the parameter values in the default files stored in the AH2700A's permanent memory.

Some parameter groups have more than one window that can be displayed on the front panel. The **←** and **→** keys are used to move right and left and the **↑** and **↓** keys are used to move up and down through these windows. The lists show all the available windows side-by-side.

If a parameter group is modifiable, the command needed to do so is given. This command can be looked up in Appendix A, "Command Reference" where more information on the parameters in the group will be found.

Basic Parameter Set

The Basic parameter set contains the following parameters:

Brightness

The Brightness parameters control the brightness of the front panel displays. The brightness of the capacitance and loss displays can be controlled individually. The parameters are modified using the **BRIGHTNESS** command. On the front panel, **[SHOW] [FUNC] [BRIGHTNESS] [ENTER]** gives:

```

  BRIGHT
  C5 L5 O5
  
```

On remote devices, **SH BR** gives:

```

  BRIGHTNESS C=5 L=5 O=5
  
```

Field

The Field parameters contain information about which of the various measurement-related types of information get sent to a remote terminal or logging device. Changing the Field parameters does not affect the front panel displays. The parameters are modified using the **FIELD** command.

On the front panel, **[SHOW] [FUNC] [FIELD] [ENTER]** gives

```

  FIELD  SAMPLE
  SAMPLE OFF
  
```

↓

```

  FIELD  FREQ
  FREQ  ON
  
```



FIELD
CAP

CAP
9



FIELD
LOSS

LOSS
9



FIELD
VOLTAGE

VOLTAGE
ON



FIELD
MESSAGE

MESSAGE
ON

where the and buttons are used to move between the left and right display windows. On remote devices, SH FI gives:

```
FIELD SAMPLE      OFF
FIELD FREQ        ON
FIELD CAP         9
FIELD LOSS        9
FIELD VOLTAGE     ON
FIELD MESSAGE     ON
```

For more information, see “REMOTE DEVICE FORMATS” on page 5-5.

Format

The Format parameter controls the format and numeric notation of measurement results that are sent to remote devices. This parameter is modified using the FORMAT command. Changing the Format parameters does not affect the front panel displays. On the front panel, gives:

FORMAT
NOTATION

NOTATION
FLOATING



FORMAT
LABELING

LABELING
ON



FORMAT
IEEE4882

IEEE4882
OFF



FORMAT
FWIDTH

FLDWIDTH
FIXED

where the and buttons are used to move between the left and right display windows. On remote devices, SH FO gives:

```
FORMAT NOTATION FLOATING
FORMAT LABELING ON
FORMAT IEEE4882 OFF
FORMAT FWIDTH    FIXED
```

For more information, see “Numeric Notation” on page 5-8.

Wait For Trigger Mode

The Wait For Trigger Mode parameter controls the handling of external trigger pulses that arrive when no WAITFOR command has been executed to receive them. This parameter is modified using the WAITFOR TRGMODE command. On the front panel, gives:

WAITFOR
TRGMODE

TRGMODE
BUFFER

On remote devices, SH WAIT TRGMODE gives:

```
WAITFOR TRGMODE BUFFER
```

For more information, see “Handling Unexpected Trigger Pulses” on page 3-16.

Sample

The Sample parameter indicates which sample number is being measured when using a sample switch. The SAMPLE command is used to select the sample number. On the front panel, gives:

SAMPLE
NUMBER

NUMBER
1

On remote devices, SH SA gives:

```
SAMPLE NUMBER 1
```

For more information, see Appendix D, “Sample Switch Port”.

Wait For Sample

The Wait For Sample parameter is a delay time that occurs following each change of position of a sample switch by the **SAMPLE** command. The **WAITFOR SAMPLE** command is used to set this time. On the front panel, **[FUNC] [SELECT] [SHOW] [WAITFOR] [SAMPLE] [ENTER]** gives:

WAITFOR	0.00
SAMPLE	SEC

On remote devices, **SH WAIT SA** gives:

```
WAITFOR SAMPLE 0.00 SEC
```

For more information, see Appendix D, “Sample Switch Port”.

Test

The Test parameters determine which diagnostic self-tests are performed, the number of times they are repeated, what conditions cause them to stop, which results are reported. The test parameters are modified with the **TEST** command. On the front panel, **[FUNC] [SELECT] [SHOW] [TEST] [ENTER]** gives:

TEST	GRP 20
FLOOR	NUM 1



TEST	GRP 91
CEILING	NUM 6



TEST	1
TOTAL	



TEST	MODE
HALT	AT_END



TEST	TOTAL
HALT	1



TEST	REPORT
REPORT	ERR_SUM

where the **[←]** and **[→]** buttons are used to move between the left and right display windows.

On remote devices, **SH TE** gives:

```
TEST FLOOR      GRP= 20, NUM= 1
TEST CEILING    GRP= 91, NUM= 6
TEST TOTAL      1
TEST HALT MODE  AT_END
TEST HALT TOTAL 1
TEST REPORT     ERR_SUM
```

For more information, see “Selection of Options: the **TEST FORMAT** command” on page 11-7.

Note that the Floor, Ceiling, and Total parameters are not stored as part of any parameter set. The Floor and Ceiling parameters simply default to include all of the diagnostic self-tests and the Total parameter defaults to 1.

Units

The Units parameter contains a value that specifies the units in which measured loss values are displayed. It allows you to choose one of five different measurement units in which to display loss values. The **UNITS** command is used to change the units. On the front panel, **[SHOW] [UNITS] [ENTER]** gives:

UNITS
NS

On remote devices, **SH UN** gives:

```
UNITS      NS
```

For more information, see “DECIDING WHICH UNITS TO USE” on page 4-10.

Gauge Parameter Set

The bridge measures capacitance and loss using the parameter values in the Current Gauge set. These parameters determine what settings and features are used when each measurement is made. Most of these parameters are discussed in Chapter 4, “Measurement Essentials”

Average Time

The Average Time parameter contains a value that determines how many measurements are averaged to calculate the final capacitance or loss measurement result that is displayed. It is modified using the **AVERAGE** command. On the front panel, **[SHOW] [AVERAGE TIME] [ENTER]** gives:

AVERAGE
4

On remote devices, SH AV gives:

AVERAGE AVEREXP=4

For more information, see “MEASUREMENT SPEED VS. MEASUREMENT FLUCTUATION” on page 4-5.

Bias

The Bias parameter contains a value that controls whether a user-supplied external DC Bias voltage is connected through the bridge to the device under test. If such a voltage is connected, this parameter further specifies whether a 1 MΩ or a 100 MΩ internal series resistor is used to make the connection. This parameter is modified using the BIAS command. On the front panel, [FUNC] [SELECT] [SHOW] [BIAS] [ENTER] gives:

BIAS
OFF

On remote devices, SH BI gives:

BIAS OFF

For more information, see “UNKNOWN WITH DC VOLTAGE” on page 4-13.

Cable

The Cable parameters contain four values that correspond to the cable length, cable resistance, cable inductance and cable capacitance of the test cable that is used to connect to the device under test. All four parameters are used internally by the bridge to provide automatic cable compensation in the measured result. These parameters are modified using the CABLE command. On the front panel, [FUNC] [SELECT] [SHOW] [CABLE] [ENTER] gives:

CABLE LENGTH
LENGTH 100 M

Pressing the [↓] button gives:

CABLE RESIST
RESIST 40 MO/M

Pressing the [↓] button again gives:

CABLE INDUCT
INDUCT 110 UH/M

Pressing the [↓] button again gives:

CABLE CAP
CAP 100 PF/M

On remote devices, SH CAB gives:

CABLE LENGTH 1.00 M
CABLE RESISTNCE 40.0 MO/M
CABLE INDUCTNCE 1.10 UH/M
CABLE CAP 100 PF/M

For more information, see “SOURCES OF ERROR” on page 8-4.

Commutate

The Commutate parameter contains a value that indicates whether test signal commutation is in effect and, if so, what quality level of commutation is being used. This parameter is modified using the COMMUTATE command. On the front panel, [SHOW] [FUNC] [COMMUTATE] [ENTER] gives:

COMMUTATE
LINEREJ

On remote devices, SH COM gives:

COMMUTATE LINEREJ

For more information, see “REJECTING INTERFERING SIGNALS” on page 4-8.

Frequency

The Frequency parameter contains a value that is the frequency of the applied test signal that will be used to make the next measurement. This parameter is modified using the FREQUENCY command. On the front panel, [SHOW] [FREQUENCY] [ENTER] gives:

FREQUENCY
10000 HZ

Note that the above displayed value may differ from that shown in the Frequency display. The reason is that the Frequency display always shows the frequency used to take the last measurement whereas the value reported from the Current parameter set is the one that will be used to make the next measurement.

On remote devices, SH FR gives:

FREQUENCY 1200.0 HZ

For more information, see “FREQUENCY OF THE TEST SIGNAL” on page 4-12

Reference Mode / Point / Percent

The Reference Point parameters are the values of capacitance and loss that are subtracted from the measurements when reference result mode is enabled. A Reference Percent parameter determines whether the results are to be displayed as absolute deviations from the reference point values or as percentage deviations from the reference points. There is also an indicator as to whether reference mode is enabled or disabled. The Reference parameters are modified using several forms of the REFERENCE command. On the front panel, **[SHOW] [REFERENCE] [LIST] [ENTER]** shows that Reference Mode is disabled for both capacitance and loss:

REF	OFF
MODE	OFF

Pressing the **[↓]** key then shows the Reference Point parameter values for both capacitance and loss:

REF	00000000
POINT	00000000

Pressing the **[↓]** key again shows that when Reference Mode is enabled, the reference results will not be shown as percentage differences but rather as absolute differences from the Reference Point values shown above:

REF	OFF
PERCENT	OFF

On remote devices, **SH REF LIST** gives:

```
REF MODE      C=OFF  L=OFF
REF POINT    C=0.00000000 PF L=0.00000000 NS
REF PERCENT  C=OFF  L=OFF
```

For more information, see “RESULT MODES” on page 5-2.

Voltage

The Voltage parameter allows you to specify a maximum signal level to be applied. The bridge will measure the sample at a voltage equal to or less than this maximum. The bridge will report the actual voltage at which the measurement is taken. The parameter is modified using the VOLTAGE command. On the front panel, **[SHOW] [VOLTAGE] [ENTER]** gives:

VOLTAGE	HIGHEST
HIGHEST	150000 V

On remote devices, **SH U** gives:

```
VOLTAGE HIGHEST 15.0  V
```

For more information, see “VOLTAGE OF THE TEST SIGNAL” on page 4-12.

Zero Point / Mode

The Zero point parameters contain capacitance and loss values that may be used to compensate for stray impedance in a test fixture. There is also an indicator as to whether zero mode is enabled or disabled. The parameters are modified using several forms of the ZERO command. On the front panel, **[SHOW] [ZERO] [ENTER]** gives:

ZERO	00000000
POINT	00000000

Pressing the **[↓]** key then shows that zero mode is disabled:

ZERO	MODE
MODE	OFF

The **[←]** and **[→]** keys are used to select which of the left or right windows is displayed.

On remote devices, **SH Z** gives:

```
ZERO POINT    C=0.0000 PF L=0.0000 NS
ZERO MODE     OFF
```

For more information, see “COMPENSATING FOR STRAY FIXTURE IMPEDANCE” on page 4-12.

Serial Parameter Set

The Serial parameter set contains all the parameter definitions related to operation via the serial port. All the serial parameters are discussed in Chapter 7, “Serial/RS-232 Remote Operation”.

Basic Serial Communications Parameters

Among the Serial parameters are the fundamental communications settings used in conjunction with the serial port. The parameters are modified using the SERIAL command.

On the front panel, **[FUNC] [SELECT] [SHOW] [SERIAL] [ENTER]** gives:

SERIAL	BAUDRATE
BAUDRATE	9600

[↓]

SERIAL	PARITY
PARITY	NONE

[↓]

SERIAL	BITS
BITS	8



SERIAL	SBITS
SBITS	1



SERIAL	FILLCHAR
FILLCHAR	0



SERIAL	ECHO
ECHO	ON

Additional presses of the key would display the NRemote, NLockout, and Logger Serial parameter setting. These parameters in more detail later in this chapter.

On remote devices, SH SER gives the entire Serial parameter set:

```
SERIAL BAUDRATE 9600
SERIAL PARITY   NONE
SERIAL BITS     8
SERIAL SBITS    1
SERIAL FILLCHAR 0
SERIAL ECHO     ON
DEFINE          ERASE=^U DEL=DEL
                BACKSP=^H DCL=^E
                TERM=PRINT
NREMOTE        OFF
NLOCKOUT       OFF
LOGGER SERIAL   OFF
```

For more information, see “SERIAL COMMUNICATION PARAMETERS” on page 7-6.

Define

The Define parameter specifies which ASCII control characters are used for interactive editing via the serial port. The choice of characters is modified using the DEFINE command. On remote devices, SH DEF gives:

```
DEFINE          ERASE=^U DEL=DEL
                BACKSP=^H DCL=^E
                TERM=PRINT
```

For more information, see “Correcting Typing Errors” on page 7-10.

NRemote

When set to ON, the NRemote parameter *largely* disables front panel (local) control of the bridge. The NREMOTE and LOCAL commands may be issued from the serial port to change this parameter. The button will reset this parameter to OFF.

When displayed from the front panel as part of the Serial parameter set, the NRemote parameter setting will appear as follows:

NREMOTE
OFF

On remote devices, SH NREM gives:

```
NREMOTE        OFF
```

For more information, see “LIMITING FRONT PANEL ACCESS” on page 7-11.

NLockout

When set to ON, the NLockout parameter *totally* disables front panel (local) control of the bridge when the NRemote parameter is *also* set to ON. The NLOCKOUT command may be issued only from the serial port to change this parameter.

When displayed from the front panel as part of the Serial parameter set, the NLockout parameter setting will appear as follows:

NLOCKOUT
OFF

On remote devices, SH NLOCK gives:

```
NLOCKOUT       OFF
```

For more information, see “Selecting the Serial Control States” on page 7-12.

Logger Serial

The Logger Serial parameter determines whether results created in response to front panel commands are sent to the serial port. It also provides some control over what kind of results are sent. The Logger Serial parameter is modified with the LOGGER SERIAL command.

When displayed from the front panel as part of the Serial parameter set, the Logger Serial parameter setting will appear as follows:

LOGGER	SERIAL
SERIAL	OFF

On remote devices, SH LOG gives two lines, the first of which is:

```
LOGGER SERIAL   OFF
```

For more information, see “SERIAL DATA LOGGING” on page 7-13.

GPIO Parameter Set

The GPIO parameter set contains all the parameter definitions related to operation via the GPIO port. All the GPIO parameters are discussed in Chapter 6, “GPIO/IEEE-488 Operation”.

Basic GPIO Communications Parameters

Among the GPIO parameters are the fundamental communications settings used in conjunction with the GPIO port. These parameters are modified using the GPIO command.

On the front panel, **[FUNC]** **[SELECT]** **[SHOW]** **[GPIO]** **[ENTER]** gives:

[GPIO]	[ADDRESS]
[ADDRESS]	[28,28]
[↓]	
[GPIO]	[ADDRMODE]
[ADDRMODE]	[PRI_ONLY]
[↓]	
[GPIO]	[COMPATIB]
[COMPATIB]	[ON]
[↓]	
[GPIO]	[PROMPTS]
[PROMPTS]	[OFF]

Additional presses of the **[↓]** key would display the SRE Byte and the Logger GPIO parameter setting. These parameters in more detail later in this chapter.

On remote devices, **SH GP** gives the entire GPIO parameter set:

```
GPIO ADDRESS      28,28
GPIO ADDRMODE    PRI_ONLY
GPIO COMPATIB    ON
GPIO PROMPTS     OFF
SRE              MAU=0 EXE=0 RDY=0 PON=0
                URQ=0 CME=0 ONR=0
LOGGER GPIO      OFF
```

For more information, see “GPIO CONFIGURATION PARAMETERS” on page 6-1.

SRE Byte

The SRE parameter byte contains the GPIO service request enable mask. This mask determines which of the bits that are set in the GPIO device status register can cause a service request to occur. You can modify the GPIO service request enable mask using the SRE command, and thereby determine which bridge conditions or events can cause GPIO service requests to occur.

When displayed from the front panel as part of the GPIO parameter set, the SRE Byte parameter setting will appear as follows:

[SRE]	[M ERPUCN]
[BIN]	[00000000]

On remote devices, **SHOW SRE** gives:

```
SRE              MAU=0 EXE=0 RDY=0 PON=0
                URQ=0 CME=0 ONR=0
```

For more information, see “Service Requests” on page 6-7.

Logger GPIO

The Logger GPIO parameter determines whether results created in response to front panel commands are sent to the GPIO port. It also provides some control over what kind of results are sent. The Logger GPIO parameter is modified with the **LOGGER GPIO** command.

When displayed from the front panel as part of the GPIO parameter set, the Logger GPIO parameter setting will appear as follows:

[LOGGER]	[GPIO]
[GPIO]	[READINGS]

On remote devices, **SH LOG** gives two lines, the first of which is:

```
LOGGER GPIO      READINGS
```

For more information, see “GPIO DATA LOGGING” on page 6-15.

Deviation Parameter Set

The Deviation parameter set contains all the parameter definitions related to controlling the deviation subsystem and analog outputs.

Scan Parameter Set

The Scan parameter set contains all the parameter definitions related to controlling the scanning parameter measurements.

Other Parameters

The other parameters contain information that is specific to the bridge. These parameters are listed below.

Status

Status shows the settings of the bits in the status byte sent to the GPIO interface. On the front panel, **[FUNC]** **[SELECT]** **[SHOW]** **[STB]** **[ENTER]** gives:

[STATUS]	[M ERPUCO]
[BYTE BIN]	[0000 1000]

On remote devices SH STB gives:

```
STB          MAU=0 MSS=1 EXE=0 RDY=0
              PON=1 URQ=0 CME=0 ONR=1
```

For more information, see "STATUS REPORTING" on page 6-5.

Current Date and Time

The current date and time are maintained by the real time clock within the bridge. On the front panel, [FUNC] [SELECT] [SHOW] [DATE] [ENTER] gives:

```
DATE          YEARMQJY
YEARMQJY      20020527
```

For current time [FUNC] [SELECT] [SHOW] [TIME] [ENTER] gives:

```
TIME          HRMINSEC
HRMINSEC      03 47 10
```

On remote devices SH DATE and SH TIME give:

```
DATE YR MON DAY 2002 05 27
```

and

```
TIME HR MIN SEC 3 47 10
```

respectively.

Elapsed Time

The Elapsed Time contains approximately the total number of hours the bridge has been on since it was manufactured.

On the front panel, [FUNC] [SELECT] [SHOW] [STATUS] [ENTER] gives:

```
STATUS        HOURS
ELAPSED       15591
```

On remote devices SH STATUS gives:

```
ELAPSED HOURS 15591
```

Manufacturer Name

The Manufacturer Name contains the name of the manufacturer of the bridge. On the front panel, [FUNC] [SELECT] [SHOW] [MFGA] [ENTER] gives:

```
MANUFAC       ANDEEN-H
TURER         AGERLING
```

On remote devices SH MODEL gives:

```
MANUFACTURER ANDEEN-HAGERLING
```

Model Name and Options

The Model Name contains the model name of the bridge. The Options contains a string showing optional internal hardware or firmware installed in the bridge. On the front panel, [FUNC] [SELECT] [SHOW] [MODEL] [ENTER] gives:

```
MODEL         AH2700A
OPTIONS       CED
```

On remote devices SH MODEL gives:

```
MODEL/OPTIONS AH2700A CED-----
```

Serial Number

The Serial Number contains the serial number that is stamped into the rear panel of the bridge. On the front panel, [FUNC] [SELECT] [SHOW] [SN] [ENTER] gives:

```
SERIAL        00000100
NUMBER
```

On remote devices SH SN gives:

```
SERIAL NUMBER 00000100
```

Model Name and Options

The Model Name contains the model name of the bridge. The Options contains a string showing optional internal hardware or firmware installed in the bridge. On the front panel, [FUNC] [SELECT] [SHOW] [MODEL] [ENTER] gives:

```
MODEL         AH2700A
OPTIONS       CED
```

On remote devices SH MODEL gives:

```
MODEL/OPTIONS AH2700A CED-----
```

Showing the Special Set on Remote Devices

On remote devices, SH IDN gives:

```
MANUFACTURER ANDEEN-HAGERLING
MODEL/OPTIONS AH2700A CED-----
SERIAL NUMBER 00000100
ACTIVE FIRMWARE AH270125
```

The last line shows the version of the firmware which is currently active within the bridge.

WORKING WITH FILES

This section describes file naming conventions, how to list files currently stored in the bridge and how to add and delete them.

File Names

In order to distinguish one file from another, each file must have an identifier. The AH2700A does this with an identifier containing a file type followed by a file name. For parameter sets, the file type is the same as the parameter set type. The allowable file types are Basic, Gauge, Serial, GPIB, Deviation, Scan, and Macro.

The file name uses only alphanumeric characters and the underscore character. File names must begin with an alpha character and have a maximum of eight characters. Examples of allowable file identifiers are: BASIC FACTPON, GAUGE EXAMPLE1, SERIAL USERPON, GPIB XYX123 and MACRO M250. A file name of "FACTPON" is special and means that the file is permanently stored in ROM. For files in EEPROM, the file name can be anything other than "FACTPON".

Listing the File Names

Since one can not be certain what file names have been stored, it is essential to be able to get a list of those files that are currently in the bridge's EEPROM memory. The DIRECTORY command does this. On the front panel, press **[DIR]** **[ENTER]** and see:

```
GAUGE
USERPON
```

press **[↓]** and see:

```
BASIC
USERPON
```

press **[↓]** and see:

```
SERIAL
USERPON
```

press **[↓]** and see:

```
GPIB
USERPON
```

press **[↓]** and see:

```
DEV
USERPON
```

press **[↓]** and see:

```
SCAN
USERPON
```

press **[↓]** and see no change, then press **[ENTER]** and see:

```
READY
```

You have displayed the six parameter files in the EEPROM memory that were shipped with the bridge. There is one of each type of file. As discussed in "Using Power-on Parameter Files" on page 3-12, these happen to be the six files that will be read following power-on. (Remember that files may have been changed or added to since you received the bridge. This could make the directory listing totally different from what is shown above.)

If you have a lot of files, you may want to limit the types that the DIRECTORY command reports. You can do this by adding the desired file type following the DIRECTORY command. For example, the DIRECTORY GAUGE command will list only the Gauge parameter types.

If there are no files of the type you specify, then the message below appears:

```
FILE NOT
FOUND
```

The Permanent Files

The DIRECTORY command only shows the files stored in the EEPROM memory; not any stored in the RAM or permanent memory. There are six permanently stored files with the names: GAUGE FACTPON, BASIC FACTPON, SERIAL FACTPON, GPIB FACTPON, DEV FACTPON, and SCAN FACTPON. See "Power-on Parameter Files" on page 3-2 for an explanation of how these two collections of files are used by the bridge.

Adding Files

Files are created with the STORE command. To create a new file, the desired parameters must first exist in one of the Current parameter sets. The Current parameter sets always contain usable parameters that can serve as a starting point. To try an example, issue the command **[FUNC]** **[SELECT]** **[COMMUTATE]** **[ASYNC]** **[ENTER]**. This will change the commutate parameter in the Current Gauge set from LINEREJ to ASYNC. Now issue the command **[FUNC]** **[SELECT]** **[STORE]** **[GAUGE]** **[FUNC]** **[EDIT]** **[E]** **[X]** **[A]** **[M]** **[P]** **[L]** **[E]** **[ENTER]**. You have created a new file with the name GAUGE EXAMPLE. Figure 3-1 on page 3-2 shows this pictorially. If you issue a

DIRECTORY command and then step through the names, you will find a new entry:

```
GAUGE
EXAMPLE
```

The contents of this file are identical to those in the Current Gauge set since that is where they were copied from.

A Macro file is added in the same way. A Current macro must exist before the STORE command is issued.

Deleting Files

Suppose you want to delete the file you just created above. Issue the command `[FUNC] [SELECT] [DEL] [GAUGE] [EXAMPLE] [ENTER]`. If you again issue a DIRECTORY command and then step through the names, you will find that your new entry has vanished from the list.

If you want to delete all files of a given type, you can do this by adding the desired file type following the DELETE command. For example, the DELETE GPIB command will delete all the GPIB parameter files in the EEPROM. Whenever you try to delete more than one file, you will get an “Are you sure?” prompt. On the front panel this looks like:

```
ARE YOU
SURE?
```

If you want to continue with the operation, you must answer “yes” by pressing the `[YES]` key on the front panel. Pressing any other key is interpreted as “no”.

WORKING WITH FILE CONTENTS

Showing the Contents of a File

In “Exploring a List with the SHOW command” on page 2-5, you learned how to use the SHOW command to examine parameters both individually and in a Current parameter set. The form of the SHOW command that you used there examined parameters only in the Current parameter sets. This section shows how to examine parameters in any file.

The form of the SHOW command that will display parameter files or macros stored in files is:

```
STORE BASIC|DEV|GAUGE|GPIB|
SCAN|SERIAL|MACRO Filename
```

If the *Filename* is omitted, this command reduces to that used to show the Current parameter sets.

Issue the command `[SHOW] [GAUGE] [FACTPON] [ENTER]`. Use the `[↓]` key to see the entries in this GAUGE USERPON parameter file. Notice that one of the parameter entries is:

```
COMUTATE
LINEREJ
```

Now issue the command `[SHOW] [GAUGE] [ENTER]`. Use the `[↓]` key again to look at the entries in this the Current Gauge parameter set. Notice that one of the parameters is:

```
COMUTATE
ASYNC
```

This is the parameter that you entered in the earlier section, “Adding Files”. The differing display windows demonstrate that you really are looking at different parameter sets.

Changing the Contents of a Parameter File

A parameter file's contents can only be changed by copying them to a Current parameter set, making the changes in the Current set, and copying the contents back to the original file. The RECALL command will copy a file having a given file type to its corresponding Current location. After making changes in the Current set, the results are copied back using the STORE command. The STORE command will automatically overwrite an existing file having the same name.

For example, suppose you want to change the brightness to 9 in the BASIC USERPON file. Issue the command `[FUNC] [SELECT] [RECALL] [BASIC] [USERPON] [ENTER]` to copy the BASIC USERPON file into the Current Basic parameter set. Issue the command `[FUNC] [BRIGHTNESS] [9] [ENTER]` to change the brightness in the Current Basic parameter set. Notice that the brightness of the display increases. Now issue the command `[FUNC] [SELECT] [STORE] [BASIC] [USERPON] [ENTER]` to replace the original contents of the BASIC USERPON file with the contents having the modified brightness. The next section will demonstrate that you have actually made this change.

Using the Contents of a Parameter File

The bridge can only act on the contents of a parameter file when the contents are copied to the corresponding Current parameter set. To use the contents of the BASIC FACTPON file, issue the command `[FUNC] [SELECT] [RECALL] [BASIC] [FACTPON] [ENTER]`. This will cause the contents of this permanently stored file to overwrite the contents of the Current Basic parameter set. Notice that the brightness of the displays decreased immediately. By issuing the RECALL command, you have overwritten the brightness of 9 that you had left in the Current Basic parameter set with a brightness of 5 that was in the BASIC FACTPON file. The brightness change occurred immediately because the bridge is always updated

with the latest values of the parameters in the Current parameter sets.

Now issue the command **[FUNC] [SELECT] [RECALL] [BASIC] [USERPON] [ENTER]**. The brightness of the displays will have increased again because you recalled the higher brightness that you stored in “Changing the Contents of a Parameter File” above.

PARAMETER SET INITIALIZATION

Using Power-on Parameter Files

When power is first applied, the bridge looks to see if there are any parameter files having a file name of “USERPON” in the EEPROM memory. If so, the bridge will copy the contents of these files into the Current locations of the same file type in RAM memory. For any parameter file types that are not found with a file name of “USERPON”, the bridge will read the permanent ROM memory where a file of each file type having a file name of “FACTPON” always exists. The bridge will copy the contents of these remaining files into the Current locations of the same file type. Thus all Current locations are loaded at power-on with data from files named “USERPON” if they exist, and files named “FACTPON” otherwise.

Specifically, the BASIC USERPON, DEV USERPON, GAUGE USERPON, GPIB USERPON, SCAN USERPON, and SERIAL USERPON files stored in EEPROM memory will be loaded into the Current parameter sets in RAM if the files exist. For any that do not exist, the corresponding BASIC FACTPON, DEV FACTPON, GAUGE FACTPON, GPIB FACTPON, SCAN FACTPON, and SERIAL FACTPON files are loaded into the Current parameter sets instead.

This allows you to define your own power-on bridge characteristics simply by storing the desired power-on files with the file name “USERPON” for each desired file type.

Figure 3-1 on page 3-2 shows a power-on example where a SERIAL USERPON and a GPIB USERPON file exists in EEPROM and are loaded into RAM. No BASIC USERPON, GAUGE USERPON, DEV USERPON, or SCAN USERPON files exist so the BASIC FACTPON, GAUGE FACTPON, DEV FACTPON, and SCAN FACTPON files are loaded from ROM into RAM instead.

The RST Command

Another way to initialize some parameter sets is with the RST command. This command initializes a number of things in the bridge and in particular it resets the Current Basic, Deviation, Gauge and Scan parameter sets to their power-on contents. The Current Serial and GPIB parameter sets are not affected.

This command can be entered from the front panel with the key sequence **[FUNC] [SELECT] [RST] [ENTER]**. See page 33 of Appendix A, “Command Reference” for more information.

WORKING WITH MACROS

The AH2700A has the ability to create, store and execute simple macros. You can create macros consisting of collections of most of the available AH2700A commands. The bridge has no conditional instructions and therefore, any macros that are created do not have this capability either.

Purpose

The ability to create macros can help to automate simple, repetitive tasks. These macros, when used in conjunction with a logger or printing terminal, may be sufficient to eliminate the need for more complex hardware such as a personal computer or GPIB controller.

Macros are useful for automatically performing a number of sequential measurements where bridge settings are slightly different for each measurement. For example, one may want to measure each of many samples at six different voltage settings.

Another example is when multiple samples are to be measured with a sample switch. Macros allow the bridge to sequentially measure each sample position and, if necessary, to change bridge settings for each sample position. For example, each position might have a different zero error for which to compensate.

Macros are also very useful when executed as part of the power-on procedure or via an external trigger pulse or the GPIB bus GET command. These special capabilities are described later.

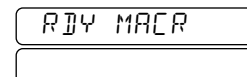
A more subtle but very important use of macros is to guarantee that desired results logged to remote GPIB devices are not lost. See “Receiving Every Response Message” on page 6-4.

Creating Macros

Macros are easily created by entering the command:

MACRO CREATE

The bridge will respond with a special “#” prompt when the command is entered from remote devices. When entered from the front keypad the display will show:



```
RDY MACR

```

At this point, the sequence of commands that is to form the macro can be entered in the normal manner. The bridge will continue to accept commands in this mode until it receives a blank line. This occurs as an **[ENTER]** from the front keypad, a CR from the serial port, or an EOL from the GPIB port.

If you enter an incorrect line, the only way to fix it is to start over. There is no way to edit these macros. For this reason, each individual macro should be kept short. Since macros can call macros, it is preferable to create several short macros rather than one long one.

Commands Not Allowed Within Macros

Not all AH2700A commands can be included in a macro. The commands below are not allowed and will produce a syntax error as soon as they are entered.

```
DELETE
DELETE MACRO
MACRO CREATE
RECALL MACRO
STORE MACRO
```

In addition, no **STORE** commands are allowed in any macro or submacro that repeats (is executed with an *MTotal* parameter value that is not equal to 1). Repeating macros are discussed later. The `END NOT OPERABLE` error message will be reported if a **STORE** command is detected in any macro that repeats.

Nesting Considerations

Macros can contain any of the commands that execute other (sub)macros. Macros can thus be nested one within another. This can occur to a nesting depth of eight. If this depth is exceeded, a `PRG NEST ERROR` will be reported.

Prompts Generated within Macros

Some AH2700A commands generate prompts. Outside macros, these prompts always cause execution to stop and must be answered before the command will continue. Inside macros, most of these prompts can be answered by the macro itself or they can prompt you for a response.

1. All other **TEST** commands that generate prompts will check the next command in the macro to see if it is a **STEP** or **SAMPLE** command. If so, the **STEP** or **SAMPLE** command will be executed and the **TEST** will continue. If not, you will be prompted with a message corresponding to the test being executed.
2. A number of calibration related commands require the entry of passcodes. You can include a passcode in a macro so that the macro will run without prompting if the passcode is correct. Even though a passcode can be stored in a macro, there is no way to read it even with the **SHOW MACRO** command.

Saving Macros

After your macro has been entered, it becomes the Current macro and is located in RAM. It can be executed in this location, but it will be lost if the power is lost.

The Current macro can be stored as a file in EEPROM memory using the command:

```
STORE MACRO Filename
```

where *Filename* is any alphanumeric string as described in “File Names” on page 3-10. If a macro file with the same *Filename* already exists in EEPROM memory, it will be overwritten by the new macro.

Recalling Macros

A macro can be recalled from EEPROM memory into the Current macro location and will overwrite the Current macro. The value of this operation is in changing the *Filename* of a macro since the Current macro can now be stored under a different name.

A macro can be recalled from EEPROM memory using the command:

```
RECALL MACRO Filename
```

Figure 3-1 on page 3-2 shows an example where **MACRO M107** is recalled.

If you are unsure of what macro files have been stored, the **DIRECTORY MACRO** command can be used to list them.

Showing the Contents of Macro Files

The following command will report the contents of any macro file:



```
SHOW MACRO [Filename]
```

The Current macro will be shown if no *Filename* is entered.

On Remote Devices

The contents of a macro file as reported to remote devices has a format that is virtually identical to that which was used to enter the commands from a remote device. The main difference is that only the three leading characters of each command word will be reported even though many more may have been entered. The other difference is that a space is printed in the first column of each result line where the “#” prompt was located when the commands were entered.

On the Front Panel Display

On the front panel display, the contents of each line of a macro file are shown in a group of up to three windows. An additional one at the right is used to display a line number for the command. As usual, each window of a line can be shown one-by-one by pressing the  and  keys. As with

remote devices, only the three leading characters of each command word will be shown. Pressing the **[ENTER]** key will abort the **SHOW** command at any time on the front panel.

Executing Macros

There are two fundamentally different ways of executing a macro. One is to let it run unattended at its maximum rate (unless limited by the **CONTINUOUS** qualifier discussed below). The other is to let it run until a result is generated at which time it stops and waits for you to cause it to continue. The choice will usually be determined by whether the results are to be recorded by a remote device or read from the front panel display.

Non-Stop Mode

The following command will execute any macro file:

```
MACRO RUN [Filename]
```

The Current macro will be executed if no *Filename* is entered.

The macro will execute in accordance with the Current settings of the macro setup parameters *MTotal* and *MStep*. These parameters control repetition and single-step macro execution respectively.

Single-Step Mode

The following command is used to control single-step macro execution mode:

```
MACRO SETUP MSTEP MStep
```

When *MStep* is set to **ON**, an executing macro will stop every time it reports a query result. When it stops, pressing the **[STEP]** key on the front panel keypad will cause it to continue.

On remote devices, a “/” prompt will be printed following the query result. Entering the **STEP** or **X** command will cause the macro to continue.

Setting *MStep* to **OFF** disables single-step macro execution mode. The default value for this parameter is **OFF**.

Repetitive Mode

The following command is used to control repetitive macro execution mode.

```
MACRO SETUP TOTAL MTotal
```

MTotal is the number of times the macro is to be executed. If *MTotal* is zero, the macro will be executed repeatedly until aborted by a **DEVICE CLEAR** command or query interrupt. The default value for this parameter is one.

Execution of Subprograms

Including **MACRO SETUP** commands within a parent macro provide a means for the parent macro to control the macro execution parameters pertaining to subsequent sub-macros (its children). Including a **MACRO SETUP** command within a child macro does not affect the settings for either the parent macro or for other children of that parent.

Information Available During Execution

An executing macro is indicated by a flashing units indicator. The LED that flashes is the one that would normally be lit to indicate the Current loss units. The flash rate is about two per second.

The number of windows shown in the front panel display is dependent upon the results produced by the command that a macro is executing at the moment. For example, a measurement will have two windows available and a test command will have six available. As with other results, these can be displayed one-by-one by using the **[←]** and **[→]** keys.

Aborting Macros Prematurely

The **DEVICE CLEAR** command can be used to abort any macro prematurely. This command is described in more detail in Appendix A, “Command Reference”.

Macros in the process of execution, may or may not behave like query commands. If the root macro or any of the subprograms that it calls contain a query command then the root macro will be query interruptible. If no query command is contained, then the macro will not be query interruptible. Thus, some macros can be aborted simply by entering another command while the macro is running.

SPECIAL MACROS

Two special macro filenames exist in the AH2700A. These are **MACRO USERPON** and **MACRO TRIGMAC**. Any macro stored as **MACRO USERPON** will be executed immediately after power-on. Any macro stored as **MACRO TRIGMAC** will be executed whenever the GPIB GET bus command or TRG commands are received. These macros are seen in Figure 3-1 on page 3-2.

Power-On Macros

Normally the AH2700A performs some tests of its digital circuitry immediately after power-on. This takes only a matter of seconds to complete. The bridge is then ready to execute commands. About fifteen minutes is required for the oven to warm up and stabilize before full precision measurements can be taken. These are the only events that occur if no **MACRO USERPON** file exists.

If a MACRO USERPON file does exist, it will be executed following completion of the digital circuitry tests. Since the AH2700A macro features are very flexible, there are a variety of possibilities here, some of which are:

- Use the WAITFOR DELAY command to delay 15 minutes until the oven has stabilized, configure the bridge to log its measurements to a remote device and then take measurements continuously.
- Perform some verifications and/or tests while the bridge is warming up. An internal calibration might be created and saved after warm-up so that the bridge is functioning optimally in its power-on environment.
- Recall parameter sets other than the default sets and then make further adjustments to the Current parameter settings.
- Use the SHOW command to log current device settings for routine documentation purposes while waiting for the bridge to warm up. This is an easy way to ensure that relevant bridge settings are recorded with each day's data run.
- Zero compensation values could be measured and stored as corrections for each setting of a sample switch.

The emphasis with all possibilities such as these is that they can occur fully automatically with no operator intervention.

The TRG/GET Macro

The GPIB implements a special bus command called Group Execute Trigger or GET. When a GPIB controller sends this command over the GPIB, all instruments that are addressed to listen will begin performing an operation. Thus the GET command is a convenient way of initiating simultaneous actions among a group of instruments.

An ordinary AH2700A command also exists which performs exactly the same function as the GPIB GET command. This is the “trigger” command which has the syntax:

TRG

Typically, in response to a GET or TRG command any instrument performs the basic function for which it is designed. In the case of the AH2700A, this is the SINGLE command. *This is the command that will be executed if no MACRO TRIGMAC file exists.*

If a MACRO TRIGMAC file *does* exist, then its contents will be executed when a GET or TRG command is received. Thus, the existence of a MACRO TRIGMAC file allows the GET and TRG commands to initiate much more complex operations than would otherwise be possible.

There is no special relationship between the GET or TRG commands and the external trigger input.

TIMING IN MACROS

It is possible to introduce delays at any point within a macro. These delay times can be specified by values contained within the macro or they can be specified to last until an external trigger pulse is received.

Specifying a Fixed Delay Time

Execution of the following command causes the bridge to execute no further commands until the specified period of time has elapsed.

WAITFOR DELAY Delay

The *Delay* parameter is the delay time until the bridge is to execute the next command. The maximum delay time is 99,999,999 seconds. Once this command is executed, it can only complete by timing out or it can be aborted with a DEVICE CLEAR command. Additional commands may be entered following the WAITFOR DELAY command, but they will not be executed until the WAITFOR DELAY command finishes.

Since this command is capable of hanging the bridge for a long time, its execution is indicated on the lower front panel display by a decrementing timer that shows the time remaining before the command completes. For example:

WAITFOR
599

Specifying the Display Time of a Result

You can set the amount of time that a result is displayed on the front panel by a macro using the WAITFOR DELAY command. This is done by simply putting a WAITFOR DELAY command *immediately* following the command whose displayed result time is to be set. Instead of showing the countdown timer on the front panel display, the bridge will show the result of the previous command instead.

Synchronizing to an External Trigger Pulse

Another version of the WAITFOR DELAY command described above can cause the bridge to stop executing commands until an external trigger pulse is received. This will occur if the command qualifier DELAY and the *Delay* parameter are omitted from the command. Immediately upon receiving the WAITFOR command, the bridge will wait indefinitely until an external trigger pulse is received. This is the *only* command that is affected by external trigger pulses.

The external trigger input is a BNC connector located on the back of the bridge. Any CMOS or TTL compatible negative edge-triggered signal applied to this input will be interpreted by the bridge as a trigger signal. This input is normally at +5 volts when nothing is connected to it. It can be shorted to ground with a switch to generate a trigger signal. If triggering

is done with logic devices, they must be capable of sinking at least 2 milliamperes of current at 0.4 volts or less in the low state and sourcing 100 microamperes at 2 volts or more in the high state.

Perhaps the most common application for an external trigger input is to take a single measurement for each trigger signal that is received. See “Initiating with an External Trigger Signal” on page 4-4 for an example. This is a simple but useful application of the `WAITFOR` command. It can also be used within macros to trigger much more complicated command sequences.



CAUTION

Voltages outside the range of -25 to +25 volts may damage the external trigger input.

Handling Unexpected Trigger Pulses

You have a choice of what happens to external trigger pulses that arrive when no `WAITFOR` command has been executed to receive them. The choice is to allow such pulses to be buffered or to report an error.

If the pulses are buffered, as many as 255 of them can be accumulated. Any trigger pulses that occur which would cause this number to overflow are ignored. Every time the `WAITFOR` command is executed with a non-zero buffer count, the buffer count will be decremented and the `WAITFOR` command will finish immediately.

Alternatively, if you choose to report an error, then each trigger pulse that is received with no waiting `WAITFOR` command will cause an “E” error. This is a soft error that will be added to the next measurement result. It will be shown as an “E” in the upper right corner of the front panel display.

You choose which way the trigger pulses are handled by executing the following command:

```
WAITFOR TRGMODE TrgMode
```

This causes external trigger pulses to be buffered as they come in if *TrgMode* is set to `BUFFER`. If *TrgMode* is set to `ERROR`, then no buffering occurs. The default value stored in the BASIC FACTPON parameter file is `BUFFER`.

Execution of this command clears the trigger buffer. As a result, this command should be placed at the beginning of any macro that will use buffered trigger pulses. This will ensure that the macro does not immediately “choke” on left-over trigger pulses.

A MACRO EXAMPLE

There is an easy way to control the display time of results in macros of any complexity. First, create a macro like:

```
SINGLE  
MACRO
```

Store this macro as `MACRO EXAMPLE`. This macro takes one measurement and then executes the `Current` macro once. Now use `MACRO EXAMPLE` as a subprogram in your main macro in every place where you want to take a measurement. If you create a *Current* macro that just has the `WAITFOR DELAY 1` command, then your main macro will pause for one second after every measurement. Since it is easy to change the `Current` macro, it is also easy to change the display time even if the measurement occurs in many places and in many subprograms.

INTRODUCTION TO PARAMETER SCANNING

Manual and Macro Measurements

The general command for setting the operating frequency is:

FREQUENCY *Freq*

where *Freq* is the operating frequency of the bridge in Hertz. Some applications require a set of measurements made across a series of different frequency settings. The choice of manually changing the frequency setting between each measurement is an appropriate one in many cases. However this manual method can be quite cumbersome when a particular series of measurement must be taken repeatedly and/or quickly.

One method for overcoming this difficulty is through the use of the bridge's MACRO feature. This feature provides the ability to create a program having an arbitrary but limited number of specific frequencies. If a large number of frequencies points were needed, then creation of macro could be tedious.

When the application calls for a set of measurements made across a series of frequencies and a series of sample switch setting combined, the situation takes on a new level of difficulty. For this and similar cases of multiple parameter scanning measurements, the manual and macro methods for scanning through the set of desired parameter combinations is clearly inadequate.

Parameter Scanning Measurements

The ability to easily setup and perform multidimensional scanning measurement across the frequency, sample switch number, and voltage parameters is provided by the Scan commands. Most of these commands fall into two groups; the setup commands and the execution commands.

The group of Scan setup commands contains three nearly identical sets of commands, one set for each of the three scannable parameters (frequency, sample switch number, and voltage). Corresponding to the three sets of Scan setup commands are three sets of 14 Scan setup parameters. These setup parameters are stored in and recalled from Scan parameter files. As with the Basis and Gauge parameter file type, Scan parameter files with the names FACTPON and USERPON contain default parameter values that are loaded at power-on.

The group of Scan execution commands contains numerous commands for performing single or multiple measurements. When one of these Scan execution commands is executed, each measurement is preceded by an iteration of one or more of the scanning parameters.

Several additional commands are available for examining and controlling some counting variables that are used by the

parameter scanning system to determine how many measurements are taken.

THE SCAN SETUP COMMANDS

This section presents some of the fundamental concepts that are common to parameter scanning in general. Frequency scanning is used as an example to illustrate the concepts.

Fundamentals of Scanning Setup

The STEP and SCAN commands change the value of the parameter(s) being scanned by stepping. Consider frequency for example. The parameter that controls the frequency is *Freq*. It is this parameter that holds either the frequency at which the last measurement was made or the frequency that was last entered or recalled. It is also this parameter (when coupled by setting *FCoupling* to be non-zero) that is changed by the scan execution commands *before* each measurement is started. As a result, manually changing the coupled *Freq* parameter will generally alter the course of the scan sequence. The current value of the coupled *Freq* parameter determines its next value. For the coupled *Freq* parameter, the next value is determined by the method shown in Table 3-3 on page 3-20.

Setting the Ceiling and Floor Values of a Series

The *FFloor* and *FCeiling* parameters are used to determine the lowest and highest values of a series, respectively. These lowest and highest values will never fall outside the values specified by *FFloor* and *FCeiling* but instead will be equal to or between *FFloor* and *FCeiling*. The runtime error *FLR [EIL INVR LI]* will be reported if *FFloor* > *FCeiling*. This error message will also occur if no points in the series exist between *FFloor* and *FCeiling*.

FFloor will be used to find the lowest value of the frequency scanning series. For example, if *FFloor* = 150 and *FDelta* = 2, then the generated series will be: 160, 600, 1600, ... Notice that 160 was selected as the first value in the series. It was selected because the value of *FFloor* at 150 is not one of the available frequencies, and 160 is the first value above 150.

The values in the series are computed starting with the value equal to or following *FFloor*. All subsequent values are found one-by-one by selecting from the appropriate column of Table 3-2 until a value is found that lies above the value of *FCeiling*. The value that lies above is rejected and the previously selected frequency is taken to be the highest value of the series.

Setting the Direction in which Scanning Occurs

The sign of the *FDelta* parameter is used to determine the direction in which the coupled parameter is changed when a STEP or SCAN is entered. Scanning can occur from a lower value to a higher value or it can occur from higher to lower. If *FDelta* is positive, frequency will be iterated toward from

lower to higher values; if negative, frequency will be iterated from higher to lower values. Changing the sign of *FDelta* only changes the scanning direction; the values of the frequency parameters in a series are never affected.

First/Last in the Series vs. Lowest/Highest

The extent of the frequency values contained in the series of frequency parameter values is determined mainly by the *FFloor* and *FCeiling* setup parameters. These setup parameters specify the very lowest and the very highest values that can exist in the series; by themselves, they say nothing about which end of the series is scanned *first* and which is scanned *last*. To answer this requires knowing the value of *FDelta*. If *FDelta* > 0, then the lowest value in the series will be scanned first and the highest last. If *FDelta* < 0, then the highest value in the series will be scanned first and the lowest will be last.

If scanning continues after the last value in the series is reached, then the loop begins again with the first value in the series. If stepping to the next frequency value in the series would cause it to go past the last value in the series, then the frequency parameter is “wrapped” by setting it to the first value in the series. More specifically, if *FDelta* > 0 and if stepping the frequency parameter would cause it to go above *FCeiling*, then the frequency parameter will be wrapped to the first value in the series which will be equal to or above *FFloor*. Similarly, if *FDelta* < 0 and if stepping the frequency parameter would cause it to go below *FFloor*, then the frequency parameter will be wrapped to the first value in the series which will be equal to or below *FCeiling*. Wrapping always occurs from last to first, but this can be a jump from the highest value in the series to the lowest or it can be from the lowest to the highest.

Setting the First Frequency Parameter Value

The frequency parameter can be manually set to any value within its range before or during scanning. The following situations can occur on the next step of the coupled parameter:

For *FDelta* > 0:

1. If the frequency parameter is below the lowest value in the series or is equal to or above the highest value, the next value will be the first and lowest one in the series.
2. If the frequency parameter is equal to or above the lowest value in the series but is less than the highest value, stepping will change the value of the frequency parameter to the value in the series immediately above the set value of the frequency parameter.

For *FDelta* < 0:

1. If the frequency parameter is above the highest value in the series or is equal to or below the lowest value, the next value will be the first and highest one in the series.

2. If the frequency parameter is equal to or below the highest value in the series but is more than the lowest value, stepping will change the value of the frequency parameter to the value in the series immediately below the set value of the frequency parameter.

For all *FDelta* values:

1. If the frequency parameter is before the first value in the series or is equal to or past the last value, the next value will be the first one in the series.
2. If the frequency parameter is equal to or past the lowest value in the series but is before the highest value, stepping will change the value of the frequency parameter to the value in the series immediately past the set value of the frequency parameter.

Notice that the above situations are described relative to the highest/lowest or first/last values in the series. Descriptions using *FFloor* / *FCeiling* are less useful since *FFloor* and/or *FCeiling* may or may not be members of the series.

If the frequency parameter is set to any value between the first and last values in the series, then a step will cause the next measurement to be taken at a value past the first one in the series but before or equal to the last. If the frequency parameter is already equal to the first value in the series when a step occurs, then the first value used will actually be the second value in the series. If you want to generate a series of measurements that starts with the first value in the series, then the frequency parameter must have a value that is before this first value or is equal to or past the last value in the series. In other words, any value outside the range defined by the first and last values in the series or equal to the last value will work.

Another way to handle this is to set the frequency parameter equal to the first value in the series. Scanning is then done by pressing the **[SINGLE]** key followed by the **[STEP]** or **[SCAN]** commands which are executed in the normal manner. The main deficiency with this solution is that pressing **[SINGLE]** does not cause the various scanning mode measurement count variables to increment. The result will be that an extra measurement will be taken at the end of the scan.

The Frequency Scan Setup Commands

The Frequency Scan Coupling Parameter

Frequency scanning is enabled with:

FREQUENCY **SCAN** **COUPLE** *FCoupling*

where *FCoupling* is used to couple frequency stepping to the scan execution commands and to enable those commands. The permitted values for *FCoupling* are 0, 1, 2, and 3. See “The Scan Coupling Parameters” on page 3-24 for a description of *FCoupling*.

The *FCoupling* default value in the Scan FACTPON parameter set is 0.

The Frequency Scan Delta Parameter

The following command specifies the magnitude and direction by which the frequency is changed before a measurement is to be taken using the STEP or SCAN commands:

FREQUENCY SCAN DELTA *FDelta*

The permitted values for *FDelta* are 1, 2, 3, 4, 6, and 12. These provide six different frequency densities: These values are essentially the number of frequency scan points per decade. If a bad value (including zero) is entered for *FDelta*, the common command error message “BAD PARAMETER” will be reported.

The *FDelta* default value in the Scan FACTPON parameter set is -12.

Selecting a Method to Set Frequency Spacing

Because the AH2700A currently provides a set of 33 discrete operating frequencies as shown in Table 3-1, only the DISCRETE method for spacing frequencies within a scanning set is currently available.

Table 3-1 The values of the 33 discrete frequencies.

n_D	$F_D(n_D)$	n_D	$F_D(n_D)$	n_D	$F_D(n_D)$
20	50	31	400	42	3000#
21	60	32	500	43	4000
22	70*	33	600	44	5000
23	80	34	700*	45	6000
24	100	35	800	46	7000*
25	120	36	1000	47	8000
26	140*	37	1200	48	10000
27	160	38	1400*	49	12000
28	200	39	1600	50	14000*
29	240?	40	2000	51	16000
30	300#	41	2400?	52	20000

Using only the frequencies in Table 3-1, the *FDelta* parameter allows specifying six different frequency densities. Values for *FDelta* of 1, 2, 3, 4, 6, and 12 are allowed. These values are the number of frequencies per decade. For each value of *FDelta*, Table 3-2 shows the first decade of all the possible frequencies given a lowest frequency of 100 Hz. If instead, the lowest frequency were 120 Hz, then the next frequency in column 1 would be 1200 Hz; in column 2 the next frequencies would be 400 Hz and 1200 Hz, in column 3 they would be 240, 600 and 1200 Hz, and so on. All of these frequencies are obtained by finding $n_x = n + FDelta$, then looking up $F_D(n_x)$ in Table 3-1.

If *FFloor* is exactly equal to a value in Table 3-1, then the lowest frequency is exactly *FFloor*. Otherwise the lowest frequency is the next value above *FFloor* in Table 3-1. This

lowest frequency is called the base frequency. Its corresponding value of n_D in Table 3-1 is called n_b . Notice that the base frequency does not depend on *FDelta*.

Table 3-2 The first decade of all discrete frequencies vs. *FDelta* given a starting frequency of 100 Hz

<i>FDelta</i> →	1	2	3	4	6	12
Discrete Frequencies in Hz vs. <i>FDelta</i>	100	100	100	100	100	100
						120
					140	140
				160		160
			200		200	200
						240
		300		300	300	300
						400
			500		500	500
				600		600
					700	700
						800
	1000	1000	1000	1000	1000	1000

Setting the Limiting Frequencies of a Series

The following command sets the *FFloor* parameter which is used to determine the lowest frequency of a series of frequencies:

FREQUENCY SCAN FLOOR *FFloor*

The lowest frequency in the series will be equal to or above the *FFloor* parameter. It is a five digit decimal number with units of Hz.

The following command sets the *FCeiling* parameter which is used to determine the highest frequency of a series of frequencies:

FREQUENCY SCAN CEILING *FCeiling*

The highest frequency in the series will be equal to or below the *FCeiling* parameter. It is a five digit decimal number with units of Hz.

The *FFloor* and *FCeiling* defaults in the Scan FACTPON parameter set are 50 Hz and 20 kHz respectively. The default for *FDelta* is -12 which will cause the scanning to be done by decreasing the frequency. The first frequency of each scan loop to be measured will be 20 kHz. The last frequency in each scan loop will be 50 Hz. Scanning from high frequencies to low gets results (and identifies problems) more quickly since low frequency measurements take much more time.

Table 3-3 Generating a series of frequencies

<i>FMethod</i> Value	<i>FDelta</i> Meaning	Available Frequencies	Given any <i>f</i> , find the next higher frequency	For <i>f</i> _{Given} , find the next lower frequency, <i>f</i> .
DISCRETE	Number of frequencies per decade	$f_D(n) = F_D\left(\frac{12}{\Delta}n + n_b\right)$	$f_{D+}(f) = f_D\{\lceil n_D(f) \rceil + 1\}$	$f_{D-}(f) = f_D\{\lfloor n_D(f) \rfloor - 1\}$

Notes: $\Delta = |FDelta|$ where *FDelta* is an integer. The sign of *FDelta* controls the direction in which scanning occurs.
 $f_D(n)$ is a functions used to generate the discrete frequencies where *n* is an integer.
 $n_b = \lceil N_D(f_{floor}) \rceil$ and $n_D(f) = \{N_D(f) - n_b\} \frac{\Delta}{12}$ where $F_D(n)$ is the frequency in Table 3-1 that corresponds to *n* and $N_D(f)$ is the value of n_D in Table 3-1 that corresponds to *f*.
 The delimiters $\lfloor x \rfloor$ and $\lceil x \rceil$ are the floor and ceiling functions, respectively, found in many programming languages.

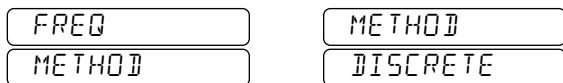
Showing the Scan Frequency Parameters

These parameters can be shown with the following commands which will report examples like those appearing below. Note that the parameter values shown are the defaults.

On the front panel, **[SHOW] [FREQUENCY] [SCAN] [ENTER]** first gives the value of *FCoupling* which determines if frequency scanning is enabled:



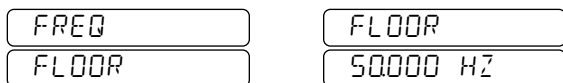
Pressing the **[↓]** key again gives the value of *FMethod* which is the spacing method used:



Pressing the **[↓]** key again gives the sign of the step direction and the number of frequencies per decade:



Pressing the **[↓]** key gives the *FFloor* parameter:



Pressing the **[↓]** key gives the *FCeiling* parameter:



On remote devices all possible results are:

```
>SHOW FREQ SCAN
FREQ COUPLING      0
FREQ METHOD         DISCRETE
FREQ DELTA         -12.000 PERDECADE
FREQ FLOOR         50.000 HZ
FREQ CEILING       20000.0 HZ
>SHOW SCAN FREQ COUPLE
FREQ COUPLING      0
>SHOW SCAN FREQ METHOD
FREQ METHOD         DISCRETE
>SHOW SCAN FREQ DELTA
FREQ DELTA         -12.000 PERDECADE
>SHOW SCAN FREQ FLOOR
FREQ FLOOR         50.000 HZ
>SHOW SCAN FREQ CEILING
FREQ CEILING       20000.0 HZ
```

Sample Number Scanning Setup

The sample number can be incremented or decremented before a measurement is made using the **STEP** or **SCAN** commands which are described later. The commands that control this sample number scanning are introduced below.

The Sample Scan Coupling Parameter

Sample scanning is enabled with:

```
SAMPLE SCAN COUPLE SCoupling
```

where *SCoupling* is used to couple sample number stepping to the scan execution commands. *SCoupling* is an integer ranging from 0 to 3. See “The Scan Coupling Parameters” on page 3-24 for a description of *SCoupling*.

The *SCoupling* default value in the Scan FACTPON parameter set is 0.

The Sample Scan Direction Parameter

Incrementing versus decrementing is controlled with the following command:

`SAMPLE SCAN DELTA SDelta`

where *SDelta* determines the direction in which the sample number is changed each time a scanning measurement is to be taken. *SDelta* is a floating point number. The *SDelta* parameter can have values of +1 or -1. When *SDelta* is positive, the sample number is scanned by incrementing it; when negative, it is decremented.

If a bad value is entered for *SDelta*, the common error message “BAD PARAMETER” will be reported rather than the more specialized message “DELTA CONFLICT”.

The *SDelta* default value in the Scan FACTPON parameter set is +1.

Entering the First and Last Sample Numbers

The following command will specify the lowest of a series of sample numbers:

`SAMPLE SCAN FLOOR SFloor`

where *SFloor* is a two digit integer.

The following command will specify the highest of a series of sample numbers:

`SAMPLE SCAN CEILING SCeiling`

where *SCeiling* is a two digit integer.

The *SFloor* and *SCeiling* defaults in the Scan FACTPON parameter set are 1 and 8 respectively.

Showing the Sample Scan Parameters

These parameters can be shown with the following commands which will report examples like those appearing below. Note that the parameter values shown are the defaults.

On the front panel, `SHOW SAMPLE FUNC SCAN ENTER` first gives the value of *SCoupling* which determines if sample scanning is enabled:

SAMPLE	COUPLING
COUPLING	0

Pressing the `↓` key again gives the value of *SDelta* whose sign indicates the direction of sample scanning:

SAMPLE	DIRECTION
DELTA	1

Pressing the `↓` key gives the *SFloor* parameter indicating the lowest sample number in the series:

SAMPLE	FLOOR
FLOOR	1

Pressing the `↓` key gives the *SCeiling* parameter indicating the highest sample number in the series:

SAMPLE	CEILING
CEILING	8

On remote devices all possible results are:

```
>SHOW SCAN SAMPLE
SAMPLE COUPLING 0
SAMPLE DELTA 1 DIRECTION
SAMPLE FLOOR 1
SAMPLE CEILING 8
>SHOW SCAN SAMPLE COUPLE
SAMPLE COUPLING 0
>SHOW SCAN SAMPLE DELTA
SAMPLE DELTA 1 DIRECTION
>SHOW SCAN SAMPLE FLOOR
SAMPLE FLOOR 1
>SHOW SCAN SAMPLE CEILING
SAMPLE CEILING 8
```

The Voltage Scan Setup Commands

In frequency and sample scanning the scanning setup parameters alone determine exactly which frequency and sample number settings will be included in the scanning sequence. In voltage scanning, it is the value of the *VHighest* parameter which is being iterated during the scan. This parameter does not determine the actual voltage that will be applied to the DUT during the measurement, but rather serves only as an upper limit upon the applied voltage.

Table 3-4 Dependence of highest measurement voltage on capacitance and frequency.

	$C \leq 100 \text{ pF}$	$C > 100 \text{ pF}$ (Limited by ability of opposing bridge arm to balance)
$f \geq 1 \text{ kHz}$	$V = V_{\text{Highest}}$	$V \propto 1/C$
$f < 1 \text{ kHz}$ (Limited by transformer saturation)	$V \propto f$	$V \propto f/C$

When the capacitance of the DUT is above 100 pF, or the frequency is set above 1 kHz, the applied voltage will be reduced as described in Table 3-4. For capacitors below 100 pF measured at frequencies equal to or above 1 kHz the specified voltages will always be the ones that are actually

used. For all other conditions, the voltage actually used may be lower than the value specified by *VHighest*.

When the actual voltage used is less than *VHighest*, the soft error message `VOLTAGE REDUCED` is reported to remote devices. On the front panel, the character “R” is placed in the right-most character position of the capacitance display. These messages will be reported **only** if *VCoupling* is non-zero and if the `STEP` or `SCAN` command has been executed. In the event of a conflict with the `H TO GND SHORT` message, the latter will be reported.

The Voltage Scan Coupling Parameter

Voltage scanning is enabled with:

`VOLTAGE SCAN COUPLE VCoupling`

where *VCoupling* is used to couple voltage stepping to the scan execution commands and to enable those commands. *VCoupling* is an integer ranging from 0 to 3. See “The Scan Coupling Parameters” on page 3-24 for a description of *VCoupling*.

The *VCoupling* default value in the Scan FACTPON parameter set is 0.

The Magnitude and Direction of Voltage Steps

The command below determines the magnitude and direction by which the voltage is changed before a measurement is to be taken using the `STEP` or `SCAN` commands:

`VOLTAGE SCAN DELTA VDelta`

where *VDelta* is a non-zero floating point number. The meaning of *VDelta* depends on the value of *VMethod*. Table 3-5 describes these meanings for each of the four permitted values of the *VMethod* parameter.

The execution error “`DELTA CONFLICT`” will be reported if the value of *VDelta* is incompatible with *VMethod*. If a bad value (including zero) is entered for *VDelta*, the common command error message “`BAD PARAMETER`” will be reported.

The *VDelta* default value in the Scan FATCPON parameter set is 1.

Selecting the Method that Sets Voltage Spacing

The command

`VOLTAGE SCAN METHOD VMethod`

specifies the method by which the spacing of voltages is determined. The permitted values of *VMethod* are `DISCRETE`, `LOG10`, `LOG2`, and `LINEAR`.

The *VMethod* default value in the Scan FACTPON parameter set is `DISCRETE`.

Table 3-5 Values of *VMethod* and its methods for generating a series of voltages

<i>VMethod</i> Value	<i>VDelta</i> Meaning	Available Voltages	Given any <i>V</i> , find the next higher voltage	Given any <i>V</i> , find the next lower voltage
DISCRETE	Sign of the step direction	All in Table 3-6.	Look up the next higher voltage in Table 3-6.	Look up the next lower voltage in Table 3-6.
LOG10	Number of voltages per decade	$V_{10}(n) = 10^{n/\Delta}$	Next higher $V_{10} = 10^{\frac{[\Delta \log_{10} V] + 1}{\Delta}}$	Next lower $V_{10} = 10^{\frac{[\Delta \log_{10} V] - 1}{\Delta}}$
LOG2	Number of voltages per octave	$V_2(n) = 2^{n/\Delta}$	Next higher $V_2 = 2^{\frac{[\Delta \log_2 V] + 1}{\Delta}}$	Next lower $V_2 = 2^{\frac{[\Delta \log_2 V] - 1}{\Delta}}$
LINEAR	Increment to be added in volts	$V_L(n) = V_{\text{floor}} + n\Delta$	Use the next value in $V_L(n)$ that is above <i>V</i> .	Use the next value in $V_L(n)$ that is below <i>V</i> .

Notes: $\Delta = |VDelta|$. *VDelta* is an integer except when *VMethod* = `LINEAR` in which case *VDelta* is a floating-point number. The sign of *VDelta* controls the direction in which scanning occurs. $V_{\text{floor}} = VFloor$ in *V*. *n* is an integer. $V_D(n)$, $V_{10}(n)$, $V_2(n)$ and $V_L(n)$ are functions used to generate the discrete, \log_{10} , \log_2 and linear voltages. The delimiters $\lfloor x \rfloor$ and $\lceil x \rceil$ are the floor and ceiling functions, respectively, found in many programming languages.

Table 3-5 lists the allowed values and meanings of the *VMethod* parameter. This table also describes how the meaning of the *VDelta* parameter depends on *VMethod*. Finally, this table shows how a series of voltages is generated given *VMethod* and *VDelta*.

VMethod = DISCRETE

When the *VMethod* parameter is DISCRETE, the eleven ratio-transformer attenuator taps comprise the entire set of voltages that can be scanned. The taps and their corresponding voltage labels are listed in Table 3-6.

Table 3-6 The DISCRETE method values of the maximum tap voltages at 1 kHz and above.

Tap number	Tap voltage @ ≥ 1 kHz
1	15.0 V
2	7.50 V
3	3.00 V
4	1.50 V
5	0.750 V
6	0.250 V
7	0.100 V
8	0.030 V
9	0.010 V
10	0.003 V
11	0.001 V

For this method, the *VDelta* parameter specifies only the direction in which scanning will occur; the spacing is always from one tap voltage to an adjacent tap voltage. The *VDelta* parameter can only have values of +1 or -1.

VFloor will be used as the lowest voltage in the series if that voltage exists in Table 3-6. Otherwise, the next voltage in this table above *VFloor* will become the lowest voltage. Similarly, the value of *VCeiling* is compared directly to the values in Table 3-6 to determine the last tap in the series. These determinations are made with no compensation for measurement frequencies that are below 1 kHz.

VMethod = LOG10

When the *VMethod* parameter is set to LOG10, the spacing of the voltages is logarithmic with a base of 10. The *VDelta* parameter now specifies the number of voltages per decade. The equations used to calculate these voltages are given in Table 3-5.

VMethod = LOG2

When the *VMethod* parameter is set to LOG2, the spacing of the voltages is logarithmic with a base of 2. The *VDelta* parameter now specifies the number of voltages per octave. The equations used to calculate these voltages are given in Table 3-5.

VMethod = LINEAR

When the *VMethod* parameter is LINEAR, the spacing of the voltages is linear. The *VDelta* parameter now directly specifies the sign and the increment in volts by which the voltage is to be changed every time a measurement is made. This method is best for generating a more closely spaced series of voltages over a relatively narrow range.

Setting the First Voltage of a Series

The *VFloor* and *VCeiling* parameters are used to determine the lowest and highest voltages of a series. These lowest and highest voltages will never fall outside the values specified by *VFloor* and *VCeiling*; they will be equal to or between *VFloor* and *VCeiling*.

The following command sets the *VFloor* parameter:

VOLTAGE SCAN FLOOR *VFloor*

The lowest voltage in the series will be equal to or above the *VFloor* parameter. It is a five digit decimal number with units of volts.

The *VFloor* default in the Scan FACTPON parameter set is 0.030 V.

Setting the Last Voltage of a Series

The following command sets the *VCeiling* parameter:

VOLTAGE SCAN CEILING *VCeiling*

The highest voltage in the series will be equal to or below the *VCeiling* parameter. The *VCeiling* parameter is a five digit decimal number with units of volts.

The default in the Scan FACTPON parameter set are 15.00 V.

Showing the Voltage Scan Parameters

These parameters can be shown with the following commands which will report examples like those appearing below. Note that the parameter values shown are the defaults.

On the front panel, [SHOW] [VOLTAGE] [SCAN] [ENTER] first gives the value of *VCoupling* which determines if voltage scanning is enabled:



Pressing the [↓] key again gives the value of *VMethod* which is the spacing method used:



Pressing the **↓** key again gives the *VDelta* parameter:

VOLTAGE	DIRECTION
DELTA	1

Pressing the **↓** key gives the *VFloor* parameter:

VOLTAGE	FLOOR
FLOOR	0.0300 V

Pressing the **↓** key gives the *VCeiling* parameter:

VOLTAGE	CEILING
CEILING	15.000 V

On remote devices all possible results are:

```
>SHOW VOLT SCAN
VOLT COUPLING  0
VOLT METHOD    DISCRETE
VOLT DELTA    1 DIRECTION
VOLT FLOOR    0.0300 V
VOLT CEILING  15.000 V
>SHOW SCAN VOLT COUPLE
VOLT METHOD    DISCRETE
>SHOW SCAN VOLT METHOD
VOLT METHOD    DISCRETE
>SHOW SCAN VOLT DELTA
VOLT DELTA    1 DIRECTION
>SHOW SCAN VOLT FLOOR
VOLT FLOOR    0.0300 V
>SHOW SCAN VOLT CEILING
VOLT CEILING  15.000 V
```

The Scan Coupling Parameters

The three scannable parameters, *Freq*, *SNumber* and *VHighest* use the three **coupling** parameters *FCoupling*, *SCoupling* and *VCoupling* respectively, to enable the **STEP** and **SCAN** measurement commands (See “THE SCAN EXECUTION COMMANDS” on page 3-26) and to couple the stepping of these scannable parameters to the execution of the **STEP** and **SCAN** commands. The **STEP** and **SCAN** commands will make measurements only if one or more of the three coupling parameters is non-zero.

If just one of the coupling parameters is non-zero, then its corresponding scannable parameter will be stepped immediately before the **STEP** or **SCAN** command causes a measurement to be taken. The other two scannable parameters will not be changed.

If more than one of the coupling parameters is non-zero, then the coupled parameter corresponding to the coupling parameter having the lowest value will be stepped immediately before the **STEP** or **SCAN** command causes a measurement to be taken. The coupling parameter having the

second lowest value will have its corresponding coupled parameter stepped when wrapping occurs to the coupled parameter corresponding to the coupling parameter having the lowest value. The coupling parameter (if any) having the third lowest value will have its corresponding coupled parameter stepped when wrapping occurs to the coupled parameter corresponding to the coupling parameter having the second lowest value.

The effect is to provide a means of automatically scanning more than one scanning parameter. We will call this a multi-dimensional scan. For example suppose *FCoupling*=1, *SCoupling*=3 and *VCoupling*=0, then *Freq* (coupled by *FCoupling*) will be stepped every time the **STEP** or **SCAN** command causes a measurement to be taken. The *SNumber* parameter (coupled by *SCoupling*) will be simultaneously stepped every time *Freq* wraps from one end of the defined frequency series to the other. The *VHighest* parameter (coupled by *VCoupling*) will never be automatically stepped in this example.

The existence of two or more coupling parameters having the same non-zero value is not possible. Any attempt to set a coupling parameter to a non-zero value used by another coupling parameter will cause the values of the two coupling parameters to be swapped. For example, suppose that *FCoupling*=1 and *SCoupling*=3. Entering the command **SCAN FREQ COUP 3** will give *FCoupling*=3 and *SCoupling*=1.

The Scan Parameter Set

All of the scan setup parameters are stored in the Scan parameter set. The command for storing the current Scan parameter set is:

STORE SCAN *Filename*

where *Filename* is the name of the file to be created.

Filename may contain only alphanumeric and underscore characters, must begin with an alpha character, and may contain no more than eight characters total.

To recall a stored set of Scan parameter set, use the command:

RECALL SCAN *Filename*

where *Filename* is the name of the file to be recalled.

To display the contents of a Scan parameter set, use the command:

SHOW SCAN [*Filename*]

where *Filename* is the name of the file to be displayed. If *Filename* is omitted then the current Scan parameter set will be displayed.

The parameters are reported as a list beginning with the two stored scan execution parameters followed by the frequency setup, sample setup, and voltage setup parameter groups.

An example is:

```
>SHOW SCAN FILE FACTPON
SCAN TOTAL      0
SCAN STMODE     EACH
FREQ COUPLING   0
FREQ METHOD      DISCRETE
FREQ DELTA      -12.000 PERDECADE
FREQ FLOOR      50.000 HZ
FREQ CEILING    20000.0 HZ
SAMPLE COUPLING 0
SAMPLE DELTA    1 DIRECTION
SAMPLE FLOOR    1
SAMPLE CEILING  8
VOLT COUPLING   0
VOLT METHOD      DISCRETE
VOLT DELTA      1 DIRECTION
VOLT FLOOR      0.0300 V
VOLT CEILING    15.000 V
>
```

CONTROLLING CONTINUOUS EXECUTION

The scan execution commands described later in this chapter work in a way that is analogous to the conventional usage of the **SINGLE** and **CONTINUOUS** commands. Before describing the details of the Scan execution commands, some details pertaining to the **CONTINUOUS** command are presented

Starting Continuous Measurements

Continuous measurements are initiated with the following command:

CONTINUOUS [ON]

Entering **CONTINUOUS** by itself gives the ordinary **CONTINUOUS** command. The **ON** token is purely optional.

The **CONTINUOUS** command will never cause a coupled parameter to be iterated.

Stopping Continuous Measurements

The **CONTINUOUS** command can be stopped using either of the following commands:

SCAN OFF
or
CONTINUOUS OFF

These will terminate the current measurement and cause the instrument to wait for a new command.

The **CONTINUOUS** command can also be stopped by pressing the **SINGLE** key. **SINGLE** takes one more measurement and then terminates the scan sequence.

The **CONTINUOUS** commands will also be terminated when the **STEP** command is entered if one or more coupled parameters exists. The **STEP** command will bump the coupled parameter(s), take one more measurement and then terminate the scan sequence.

With either method of termination, the coupled parameters, the continuous count variable *Count*, and the scan count variables *ECount*, *Count1*, *Count2*, and *Count3* are left with the values that they had during the last measurement.

Specifying the Number of Continuous Readings

In Continuous Mode, the total number of measurements to be taken can be specified by entering the following command:

CONTINUOUS TOTAL *CTotal*

The *CTotal* parameter is the number of measurements to be completed. A value of zero for *CTotal* causes measurements to occur continuously until interrupted or stopped.

The *CTotal* parameter is stored in the Gauge Parameter Set. It's factory default setting is zero.

The Continuous Count Variable

The *CTotal* parameter does not do any counting; it is used only to set the initial value of a variable which does the actual counting. This variable is called *Count*. It records the number of individual measurements that have been made in Continuous mode. If *CTotal* is zero *Count* also counts all measurements made in Scan mode.

When the **CONTINUOUS RST** command described below is entered, *Count* is reset to zero. As measurements are taken, *Count* is incremented until *Count* would exceed *CTotal* so that *CTotal* measurements have been completed. This causes Continuous Mode to be terminated. If *CTotal* is zero, *Count* still increments but its value is never used to affect any other operation. The *Count* variable cannot be entered; it can only be reset or displayed. The *Count* variable is not stored in any parameter set.

Resetting the Continuous Count Variable

The *Count* variable can be reset using the following command:

CONTINUOUS RST

Entering **CONTINUOUS RST** causes the *Count* variable to be set to zero. The *Count* variable is not re-settable as a *secondary* consequence of the execution of any command. The only exception to this occurs when *Count* becomes equal to *CTotal* and *CTotal* is non-zero. In this case, execution of the **CONTINUOUS** command will cause *Count* to be reset.

Limiting the Measurement Rate

The measurement rate for continuous mode measurements can be limited by setting the minimum time from one measurement to the next:

CONTINUOUS INTERVAL *Interval*

The *Interval* parameter ensures that the time from the start of one measurement to the start of the next measurement. This same *Interval* parameter is applied to measurements made with the **SCAN** command. The *Interval* parameter is stored in the Gauge parameter set. Its default value is zero.

Showing the Continuous Execution Parameters

The values of *Interval*, *CTotal*, and *Count* can be shown collectively using the **SHOW CONTINUOUS** command. Individual show command for these three values are also available.

The command **SHOW CONTINUOUS INTERVAL** command is entered from the front panel as **[FUNC] [SELECT] [SHOW] [CONTINUOUS] [INTERVAL] [ENTER]** giving:

CONT	0.00000000
INTERVAL	SEC

The window shows the value of *Interval* which is the number of seconds between measurements made using the **CONTINUOUS** and **SCAN** commands.

The command **SHOW CONTINUOUS TOTAL** command is entered from the front panel as **[FUNC] [SELECT] [SHOW] [CONTINUOUS] [TOTAL] [ENTER]** giving:

CONT	TOTAL
TOTAL	0

The window shows the value of *CTotal* which is the number of measurements to be made.

The command **SHOW CONTINUOUS COUNT** command is entered from the front panel as **[FUNC] [SELECT] [SHOW] [CONTINUOUS] [COUNT] [ENTER]** giving:

CONT	COUNT
COUNT	0

The window shows the value of *Count* which is the actual number of measurements made since the **CONTINUOUS** command was entered.

All three values may be shown from a remote as follows:

```
>SHOW CO
CONT INTERVAL  0.00000000 SEC
CONT TOTAL    0
CONT COUNT    0
>
```

The **SHOW GAUGE** command will report the first two parameters above but not *Count*.

THE SCAN EXECUTION COMMANDS

The function of the scan execution commands is to make single or multiple measurements each of which is *preceded* by a change to the frequency (*Freq*), sample number (*SNumber*) and/or voltage (*VHighest*) parameters. The magnitude and direction of the change is specified by the scan setup parameters described in the previous sections. The scan setup parameters are enabled by the *FCoupling*, *SCoupling* and *VCoupling* parameters as described in “The Scan Coupling Parameters” on page 3-24.

Starting Automatically Scanned Measurements

Automatic scanning is initiated with the following command:

SCAN [ON]

Entering **SCAN** causes scanning to occur continuously using the existing values of the coupled parameters and the scan count variables *ECount*, *Count1*, *Count2*, and *Count3* which are described later. In many ways, the **SCAN** command mirrors the operation of the **CONTINUOUS** command. The **CONTINUOUS** and **SCAN** commands both make measurements until interrupted or terminated or until a set number of measurements have been made. The **ON** token is purely optional.

If no coupled parameters exist when **SCAN** is entered, then scanning does not start and the error message **NO COUPL PARAMETER** is reported.

Taking Individually Scanned Measurements

The following command will change the appropriate coupled parameters; it will increment the scan count variables *ECount*, *Count1*, *Count2*, and *Count3* which are described later and it will take a single measurement:

STEP

The **[STEP]** key (and X from remotes) require only one keypress; no **ENTER** key is needed. Except for its ability to change coupled parameters, the **STEP** command is analogous to the **SINGLE** command. Just as the **[SINGLE]** key causes an immediate action, so does the **[STEP]** key. Just as the **SINGLE** command has Q as an immediate-action key on remote devices, **STEP** has the X key. And just as the **SINGLE** command terminates Continuous mode after taking a measurement, **STEP** terminates Scan mode (but does not reset its parameters).

Note that **SINGLE** can be interspersed with **STEP** in any combination if one desires to take more readings using the same coupled parameters as were used by the last **STEP** command.

If no coupled parameters exist when **STEP** is entered, then no action is taken and the error message *NO COUPL PARAMETER* is reported.

If the scan count variables *ECount*, *Count1*, *Count2*, and *Count3* effectively reach the value of *STotal*, the only consequence of executing **STEP** will be to report a *[[COUNTMAX REACHE]]* error. This will continue to occur until the scan count variables *ECount*, *Count1*, *Count2*, and *Count3* are reset. If this behavior is not desirable, then *STotal* should be set to zero.

Stopping Scanned Measurements

The **SCAN** commands can be stopped using either of the following commands:

SCAN OFF
or
CONTINUOUS OFF

These will terminate the current measurement and cause the instrument to wait for a new command.

The **SCAN** command can also be stopped by pressing the **SINGLE** key. **SINGLE** takes one more measurement and then terminates the scan sequence.

The **SCAN** command will also be terminated when the **STEP** command is entered if one or more coupled parameters exists. The **STEP** command will bump the coupled parameter(s), take one more measurement and then terminate the scan sequence.

With either method of termination, the coupled parameters, the continuous count variable *Count*, and the scan count variables *ECount*, *Count1*, *Count2*, and *Count3* are left with the values that they had during the last measurement.

Interrupting Scanning

Scan mode measurements can be interrupted the same way ordinary Continuous mode measurements are: by entering any command. After an interrupting command is finished executing, in most cases continuous scanning will automatically resume. When it does, it will resume where it was interrupted. This resumption requires repeating the measurement that was in progress when scanning was interrupted. If the interrupting command is a query command entered from the keypad, then **ENTER** must be pressed to clear the last item in the display before scanning will resume.

Like the **CONTINUOUS** command, most commands can interrupt the **SCAN** command without terminating it. In particular, most commands that affect Scan mode settings can be used to adjust Scan mode on the fly.

Setting the Number of Scan Readings or Loops

The total number of measurements to be taken can be specified by entering either a measurement count or by entering a count of the number of times that a particular scan loop is to be executed. One of these totals can be specified using the following command:

SCAN TOTAL *STotal*

The *STotal* parameter is the number of measurements or scan loops to be completed. Which of these meanings *STotal* represents is determined by the value of *STMode* as described below. A value of zero for *STotal* causes measurements to occur continuously until interrupted or stopped.

The *STotal* parameter is stored in the Scan Parameter Set. It's factory default setting is zero.

The Scan Counts Variables

The *STotal* parameter does not do any counting; it is used only to set the initial value(s) of one to four of the scan count variables *ECount*, *Count1*, *Count2*, and *Count3* which do the actual counting. If there are no coupled scanning parameters then only *ECount* variable need be considered. It records the number of individual measurements that have been made since the last time it was reset using the **RST** or **SCAN RST** command.

When the **SCAN RST COUNTS** command described below is entered, all the scan count variables *ECount*, *Count1*, *Count2*, and *Count3* are reset to zero. As measurements are taken, these variables are incremented until *STotal* measurements or loops have been completed. This causes Scan Mode to be terminated and will cause any further **STEP** commands to be ignored. If *STotal* is zero, the scan count variables *ECount*, *Count1*, *Count2*, and *Count3* are still increment but their values is never used to affect any other operation. The values of these count variables cannot be entered; they can only be reset or displayed. Also the values of these variables are not stored in any parameter set.

Selecting a Scan Loop for Counting

While scanning is active, there are several quantities that *STotal* might represent. The following command allows one to select which is to be counted:

SCAN STMODE *STMode*

The *STMode* parameter specifies how *STotal* is interpreted when *STotal* is entered. It also specifies the format used to **SHOW** the scan count variables *ECount*, *Count1*, *Count2*, and *Count3*.

The permitted values for *STMode* are **EACH**, **INNER**, **SECOND**, and **THIRD**. These are described below:

EACH

With *STMode* set to **EACH**, *STotal* is interpreted as the total number of individual scanned measurement to be made

prior to automatic termination. Neither the number of coupled parameters nor the number of values in each parameters scan set will affect the total number of measurement to be made. The total number of measurements that have been made is maintained in *ECount* and the other Scan count variables *Count1*, *Count2*, and *Count3* will be zero.

INNER

With *STMode* set to INNER, *STotal* is interpreted as the number of complete passes through the first coupled loop. The total number of measurements will be calculated from the following expression:

$$STotal * SSize1$$

where *SSize1* is the number of allowed values in the scan set for the first coupled parameter. The total number of complete passes that have been made through the inner loop will be maintained in *Count1* and the number of measurements that have been made so far in the *current* pass through the loop will be maintained in *ECount*. The total number of measurements in this second case is then

$$Count1 * SSize1 + ECount.$$

SECOND

With *STMode* set to SECOND, *STotal* is interpreted as the number of complete passes through the second coupled loop. The total number of measurements will be calculated from the following expression:

$$STotal * SSize2 * SSize1$$

where *SSize1* and *SSize2* are the number of allowed values in the scan set for the first and second coupled parameters respectively. The total number of complete passes that have been made through the inner and second loops will be maintained in *Count1* and *Count2* respectively. The number of measurements that have been made so far in the *current* pass through the inner loop will be maintained in *ECount*. The total number of measurements in this second case is then

$$Count2 * SSize2 + Count1 * SSize1 + ECount.$$

THIRD

With *STMode* set to THIRD, *STotal* is interpreted as the number of complete passes through the third coupled loop. The total number of measurements will be calculated from the following expression:

$$STotal * SSize3 * SSize2 * SSize1$$

where *SSize1*, *SSize2* and *SSize3* are the number of allowed values in the scan set for the first, second, and third coupled parameters respectively. The total number of complete passes that have been made through the inner, second, and third loops will be maintained in *Count1*, *Count2*, and *Count3* respectively. The number of measurements that have been made so far in the *current* pass through the inner loop will be maintained in *ECount*. The total number of measurements in this second case is then

$$Count3 * SSize3 + Count2 * SSize2 + Count1 * SSize1 + ECount.$$

The value for *STMode* can be chosen independently of the number of coupled loops that exist, except that entering

values of *STMode* that are greater than the number of coupled parameters gives an immediate *MODE TOO BIG* command error. See “Scan Parameter Interactions” on page 3-29 for more about this.

Note that changing *STMode* will change *STotal* if *STotal* is non-zero and if there is at least one coupled parameter. The value of *STotal* is adjusted so that the total number of measurements to be made always stays the same. This allows *STMode* to be changed at any time during the execution of a scan without affecting the execution of the scan. However, the format of any reported Scan count variables *does* change to reflect the new value of *STMode*.

Of course, this assumes that no changes are made to the coupled parameters *couple*, *delta*, or *method*. If changes are made, then *STotal* will change if *STMode* is anything other than EACH and this change will not usually be what the user wants. One way to solve this is to zero *STotal*, *ECount*, *Count1*, *Count2* and *Count3* whenever the coupled parameters *couple*, *delta*, or *method* are changed while *STMode* is anything other than EACH. This will remind the user that the coupled parameters should be set up before a value for *STotal* is entered.

The *STMode* parameter is stored in the Scan Parameter Set. Its factory default setting is EACH.

Resetting Scan Count Variables and Parameters

The scan count variables *ECount*, *Count1*, *Count2*, and *Count3* along with the Scan parameters can be reset using the following command:

```
SCAN RST COUNTS|COUPLED|[ALL]
```

Entering **SCAN RST COUNTS** causes all the scan count variables *ECount*, *Count1*, *Count2*, and *Count3* to be set to zero.

Entering **SCAN RST COUPLED** causes any currently coupled parameters to be reset so that the first measurement taken with a **STEP** or **SCAN** command uses the first allowed value of the coupled parameter(s) equal to or above *Floor* if *Delta* > 0 or it uses the first allowed value equal to or below *Ceiling* if *Delta* < 0. Note that the innermost coupled parameter is not set to its first allowed value but rather to *ceiling* if *Delta* > 0 or to *Floor* if *Delta* < 0.

Entering **SCAN RST** has the same effect as entering both **SCAN RST COUNTS** and **SCAN RST COUPLED** commands.

The scan count variables *ECount*, *Count1*, *Count2*, and *Count3* are not re-settable as a *secondary* consequence of the execution of any command. The only exception to this occurs when the scan count variables *ECount*, *Count1*, *Count2*, and *Count3* become equal to the corresponding representation of *STotal* and *STotal* is non-zero. In this case, execution of the **SCAN** command will cause all of these scan count variables to be reset.

Showing the Scan Execution Parameters

The values of *STotal*, *STMode*, *ECount*, *Count1*, *Count2*, and *Count3* can be shown collectively using the **SHOW SCAN EXECUTE** command. Group show command for the parameter and variable groups are also available.

To show the values of the *STotal* and *STMode* parameters use the **SHOW SCAN TOTAL** command. This command is entered from the front panel as **[FUNC] [SELECT] [SHOW] [SCAN] [TOTAL] [ENTER]** giving:

SCAN	TOTAL
TOTAL	0

The first pair of windows shows the value of *STotal*. Depending on the value of *STMode*, this is either the number of measurements or the number of complete loop counts to be made. Pressing **[↓]** shows the value of *STMode* that is associated with *STotal*:

SCAN	STMODE
STMODE	EACH

The second pair of windows shows the value of *STMode* parameter. The exact meaning of *STotal* is dependent upon the value of *STMode*. If *STMode* equals *EACH*, then *STotal* is the total number of individual measurements to be made. If *STMode* does not equal *EACH*, then *STotal* is the number of complete innermost, second innermost or third innermost loop counts to be made. Which loop is used depends on the value of *STMode*.

Remember that changing *STMode* will change *STotal* if *STotal* is non-zero and if there is at least one coupled parameter. The value of *STotal* is adjusted so that the total number of measurements to be made always stays the same.

To show the values of the *ECount*, *Count1*, *Count2*, and *Count3* variables, use the **SHOW SCAN COUNTS** command. This command is entered from the front panel as **[FUNC] [SELECT] [SHOW] [SCAN] [COUNTS] [ENTER]** giving:

SCAN	ECount
ECount	0

The first pair of windows shows the value of *ECount* variable which holds the number of measurements.

Pressing the **[↓]** key gives:

SCAN	COUNT 1
COUNT 1	0

The second pair of windows shows the value of *Count1* variable which holds the number of complete innermost loop counts that have been made.

Pressing the **[↓]** key gives:

SCAN	COUNT2
COUNT2	0

The second pair of windows shows the value of *Count2* variable which holds the number of second innermost complete loop counts that have been made.

Pressing the **[↓]** key gives:

SCAN	COUNT3
COUNT3	0

The third pair of windows shows the value of *Count3* variable which holds the number of third innermost complete loop counts that have been made.

All five values may be shown from a remote as follows:

```
>SHOW SC EX
SCAN TOTAL      0
SCAN STMODE    EACH
SCAN ECount     0
SCAN COUNT1    0
SCAN COUNT2    0
SCAN COUNT3    0
>
```

The above examples assumes that all three scan loops have been enabled by coupling and therefore shows the maximum number of windows that can be reported. If fewer loops are enabled, then fewer of windows will be reported.

Note that omission of **EXECUTE** in the **SHOW SCAN EXECUTE** command will report the scan parameter set. The resulting report will contain the two parameters above but not the four scan count variables. The two parameters are shown because they are part of the Scan parameter set. The four scan count variables are not shown because they are not part of the scan parameter set.

Scan Parameter Interactions

An error condition will exist if *STMode* exceeded the number of coupled parameters. Entering values of *STMode* that are greater than the number of coupled parameters gives an immediate *MODE TOO BIG* command error. Reducing the number of coupled parameters by zeroing a coupling parameter immediately reduces the value of *STMode* correspondingly. These two actions ensure that the way *STotal* depends on *STMode* will always be defined.

To ensure that the value of *STotal* is always meaningful, *STotal* will be limited to zero if no coupled parameters exist and will be zeroed if the user adjusts any coupled parameters. This should remind the user that all coupled parameters are to be setup first before entering the values of *STotal* and *STMode* that are to be used. Otherwise, the values of *STotal*

and/or *STMode* may change since the meaning of *STotal* can depend on the coupled parameters.

In the report from **SHOW SCAN EXECUTE** shown below, all three scan loops were enabled by coupling.

```
SCAN TOTAL      20
SCAN STMODE     SECOND
SCAN ECOUNT     0
SCAN COUNT1     0
SCAN COUNT2     0
SCAN COUNT3     0
```



If only one coupled parameter had been enabled, then the last two lines of the report would be absent and the value of mode could not be higher than **INNER** as seen below:

```
SCAN TOTAL      20
SCAN STMODE     INNER
SCAN ECOUNT     0
SCAN COUNT1     0
```

The UP/DOWN Command Qualifiers

Several commands will allow the entry of **UP/DOWN** in place of numeric entry. These are **FREQUENCY**, **SAMPLE**, **VOLTAGE**, and **AVERAGE**. When **UP** is entered, the corresponding parameter will be increased; entering **DOWN** will decrease it.

Regarding the three scannable parameters frequency, sample number, and voltage the magnitude of the change will be determined by the settings of their respective Scan parameters. The actions of the **UP** and **DOWN** qualifiers function independently of the values of *FCoupling*, *SCoupling*, and *VCoupling*, their actions cannot be directly disabled.

From the front panel **UP** and **DOWN** are entered using the the  and  keys.

Frequency UP/DOWN Command Qualifiers

FREQUENCY UP|FREQUENCY UP|DOWN

changes the *Freq* parameter to the next frequency as determined by the frequency scan setup parameters.

Sample Number UP/DOWN Command Qualifiers

SAMPLE UP|DOWN

changes the *SNumber* parameter to the next sample number as determined by the sample scan setup parameters.

Voltage UP/DOWN Command Qualifiers

VOLTAGE UP|DOWN

changes the *VHighest* parameter to the next higher voltage as determined by the voltage scan setup parameters.

Frequency UP/DOWN Command Qualifiers

AVERAGE UP|DOWN

increments or decrements the *AverExp* parameter by one within the allowed range of 0 to 15.

This chapter discusses the fundamental technical aspects of making precision capacitance and loss measurements. It is intended for anyone who needs to know not only how to operate the AH2700A but also how to set it up to make precision measurements.

It is easy for an unskilled operator to make accurate capacitance and loss measurements with the AH2700A by simply connecting an unknown impedance or manufactured transducer between its HIGH and LOW terminals. However, for anyone who wishes to design or repair transducers, or who simply wants to increase his or her level of knowledge or confidence when making precision measurements, the basic principles of operation that the AH2700A uses to make measurements are important.

BASIC BRIDGE CIRCUITS

Unlike most other automatic capacitance meters produced today, the AH2700A incorporates a true *bridge* in the conventional sense of the word. For general information about bridge circuits see chapters 3 and 4 of Reference 14 in the Bibliography.

Construction of the Basic Bridge

The use of specially-wound ratio transformers and a temperature-controlled fused-silica capacitor in the basic bridge circuit are major contributors to the extremely high accuracy and precision that the AH2700A offers. The basic bridge circuit is shown in Figure 4-1.

A 50 Hz to 20 kHz sine wave generator excites the ratio transformer which forms legs 1 and 2 of the basic bridge. Both of these legs have many transformer taps to allow selection of precisely defined voltages to drive legs 3 and 4 of the bridge. Leg 3 consists of one of several fused-silica capacitors plus other circuitry that simulates a very stable resistor. Leg 4 contains the unknown impedance. The microprocessor in the AH2700A performs the task of selecting (or balancing) Taps 1 and 2 of the transformer and of selecting C_o and R_o so that the voltage present at the detector is minimized. The detector is capable of detecting both in-phase and quadrature voltages with respect to the generator voltage. This allows both resistive and capacitive components of the unknown impedance to be independently balanced. If the microprocessor is able to obtain this null (minimum voltage) condition, the unknown capacitance can then be determined since the ratio of the unknown capacitance (C_x) to C_o is equal to the ratio of the voltage on Tap 1 to the voltage on Tap 2. Similarly, the unknown resistance can be determined since

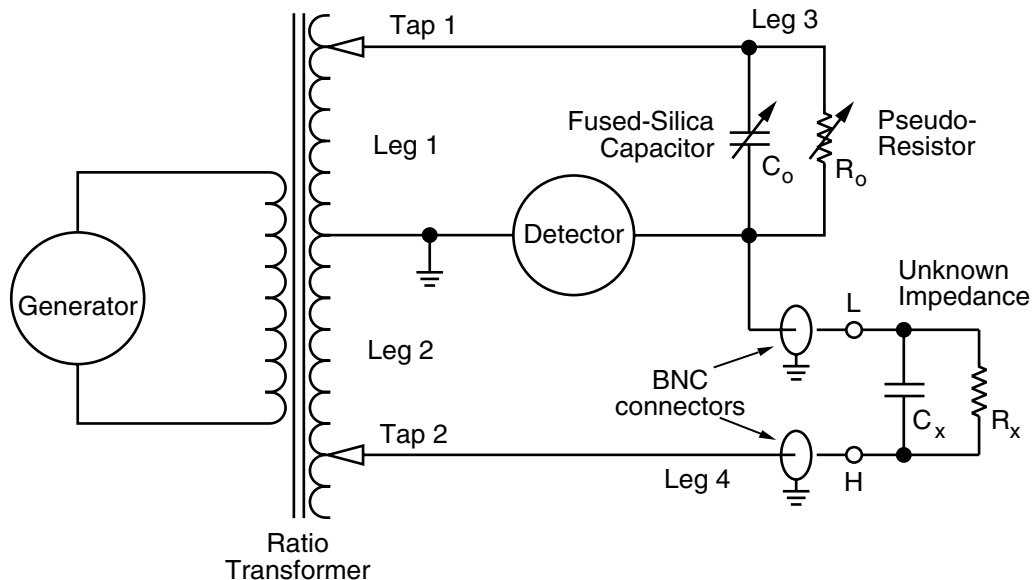


Figure 4-1 Basic bridge circuit

the ratio of the unknown resistance (R_x) to R_0 is equal to the ratio of the voltage on Tap 2 to the voltage on Tap 1. The microprocessor performs these calculations and displays the capacitance and loss results. For a more detailed description of the circuitry in the AH2700A, refer to Chapter 10, “Circuit Descriptions”.

Bridge Connection Issues

The connections to the unknown capacitance marked H (HIGH) and L (LOW) in the diagram correspond to the center conductors of the BNC connectors on the rear panel of the AH2700A. The grounds (shields) of the BNC connectors are connected to the junction of legs 1 and 2 and to the detector. Examining Figure 4-1 shows that the HIGH and LOW terminals are very different from each other. The HIGH terminal is switched directly to the ratio transformer and is a low impedance source of voltage which can range from 50 μ V to 15 V RMS. In contrast, the LOW terminal is a very high impedance input.

The voltage present on the LOW terminal can vary greatly when the bridge is not balanced. When the bridge is balanced, the signal on the LOW terminal is a few microvolts, but broadband noise at the LOW terminal is far greater in amplitude. The greater the capacitance of the LOW cable and the lower the unknown impedance, the more this noise will tend to be shunted to ground. If one were to connect an oscilloscope to the LOW terminal with the bridge balanced, a small, noisy signal would be displayed. The HIGH terminal would display a pure sine wave (but this is hard to measure cleanly in practice if the voltage is small).

Because of the small signal levels present on the LOW terminal, all connections to this terminal must be very well shielded against external electrical noise. Care must also be taken to minimize mechanically generated triboelectric voltages in the LOW cable. This is done by using low-noise cable and subjecting it to as little mechanical shock and vibration as possible. The HIGH cable requires no special treatment in this respect.

THREE-TERMINAL MEASUREMENTS

In the section “Two- Vs. Three-Terminal Connections” on page 2-10, the limitations of making two-terminal measurements were explored. Since the highest-precision capacitance measurements can only be made using three terminals, the discussion of the operation of the AH2700A will be concentrated on this method.

How the Bridge Makes Three-Terminal Measurements

The unknown impedance is measured between the center conductors of the BNC coaxial connectors on the rear panel of the bridge. The impedances between these center conductors and ground (bridge chassis) do not contribute to the measurement result. The reason for this is understood by referring to Figure 4-1.

If an impedance is added between the HIGH terminal and ground the only effect it has is to load the ratio transformer. Loading the ratio transformer is normally caused by the capacitance of the coaxial cable connected to the HIGH terminal. The ratio transformer has a sufficiently low impedance that this loading will cause a noticeable error only for long cable lengths, large unknown capacitance values and/or high measurement frequencies.

If an impedance is added between the LOW terminal and ground, the effect is to shunt the detector. For normal cable capacitance, this will reduce noise at the detector. If a resistor shunts the LOW terminal, its thermal noise will add to the noise that the detector sees.

Measurements other than Three-Terminal

Two-terminal measurements can be made by simply making no connection to the three-terminal ground; the unknown is placed between the HIGH and LOW terminals. This works only for unknown impedances where both terminals are free to float with respect to ground. If either terminal needs to be grounded or related to ground through a low impedance, the measurement cannot be made.

Some capacitance bridges use four- and five-terminal measurement techniques to sense and correct for voltage drops that occur in the cables that connect the unknown to the bridge. The voltage drops are the result of measuring low impedance unknowns and/or operating at high frequencies which causes relatively large currents to flow. The AH2700A uses only three terminals because the medium and high impedance ranges that it covers do not require four- or five-terminal techniques to obtain the required level of precision. Three-terminal measurements are much easier to make than four- or five-terminal measurements because of the reduced number of connections that are needed.

Three-Terminal Advantage over Two

To better understand the advantages of three-terminal measurements, we can represent a physical capacitor connected to the AH2700A as three separate capacitors as shown in Figure 4-2.

The direct capacitance C_{HL} , which appears between the HIGH and LOW terminals is the desired unknown three-terminal capacitance combined with whatever undesired stray capacitance may exist. The capacitors C_{HG} and C_{LG} represent the capacitance of the unknown capacitor plates to surrounding objects (such as the capacitor case and ground), of

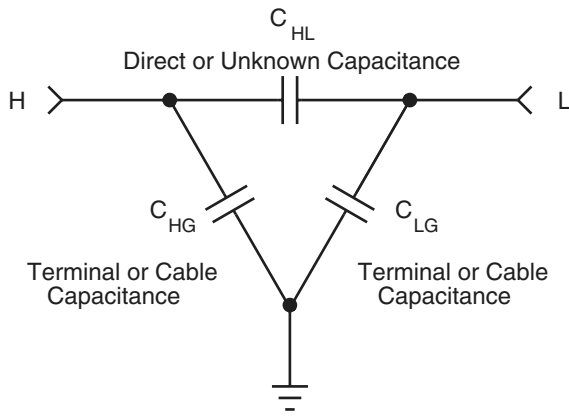


Figure 4-2 Simple three-terminal capacitor model

the coaxial cable center conductor to its shield, and of the center of the coaxial connector to ground. As we saw earlier, the stray capacitance does not affect the measured value of C_{HL} when three-terminal measurements are made.

Now consider what happens when the three-terminal measurement configuration is converted to a two-terminal measurement configuration by connecting the LOW terminal to ground. This eliminates C_{LG} and puts C_{HL} and C_{HG} in parallel so that two-terminal measurements cannot separate the two capacitances. C_{HG} contains stray capacitance caused by surrounding objects and also capacitance contributions from the coaxial cable that are proportional to the cable length. Therefore, C_{HL} cannot be measured accurately, unless it is much larger than C_{HG} . This is a very serious limitation to precise measurement.

NOTE

One of the most important consequences of this need to minimize C_{HG} is the choice and use of connecting cables. Precision three-terminal measurements are never, never, never, made with cables or structures that provide anything other than 100% shielding. This means, for example, that such measurements must never use clip leads or unshielded banana terminals even if only at the end of a coaxial cable. This also means that the quality of the shielding on any cable used should be explicitly determined by measuring the peek-through capacitance with your AH2700A. The result should be zero (i.e., unmeasurable).

Three-Terminal Construction Considerations

Figure 4-3 shows an ordinary two-terminal capacitor. Figure 4-4 shows a shield that was added to the two-terminal capacitor to make it three-terminal. The second figure illustrates that the shield completely surrounds the connections to the HIGH and LOW terminals of the bridge from the three-terminal capacitor. Although it is important to shield the LOW terminal connection from electrical noise, the primary

purpose of the shielding is to isolate the HIGH and LOW connections from each other. Any breaks in the shield that are sufficient to allow conductors connected to the LOW terminal to see conductors connected to the HIGH terminal (other than across the plates of the unknown capacitor itself) will create an undesired capacitance that adds to the measured value of the unknown capacitor, causing the measured value to be greater than the actual value. Changes in the physical geometry of the measurement system that affect the values of C_{HG} and C_{LG} (for example different cable lengths) will, ideally, have no effect on the measured value of the unknown capacitor. Changes in the internal geometry of the measurement system that affect the direct capacitance will be measured.

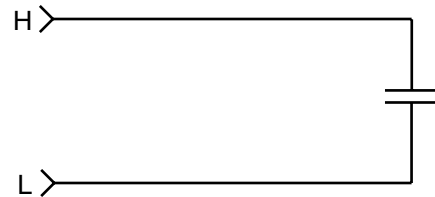


Figure 4-3 Common two-terminal capacitor

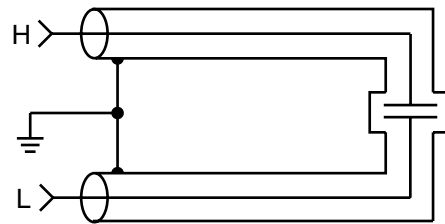


Figure 4-4 Ideal three-terminal capacitor

These internal changes can occur not only in the area and/or separation of the capacitor plates, but also in the shield geometry in a way that changes the direct electric field. They can also occur in the chemical nature or the physical geometry of the dielectric in which the direct electric field exists. The shield can even be configured to come between the capacitor plates so that only a small aperture remains in the shield. This would allow the direct capacitance to be made arbitrarily small.

Similar considerations also allow the loss associated with the direct capacitance to be limited to the loss that is actually part of the unknown capacitance. This is important when measurements of dielectric properties are being made. The insulating materials which are necessarily a part of the measurement setup (for example the polyethylene in the coaxial cable) must not contribute to the measured value for the direct loss. Conceptually, this is simply a matter of keeping undesirable dielectrics out of the field of the direct capacitor, but practically, it places constraints on the design of three-terminal capacitors and transducers. Figure 8-6 on page 8-3 shows an example of such an undesired dielectric.

INITIATING MEASUREMENTS

The rest of this chapter assumes that you are familiar with Chapter 2, “Basic and Initial Operation”.

Taking Measurements One at a Time

The command that initiates a single measurement from the front panel or a remote device is:

SINGLE or Q

This command accepts no parameters. The operation of the **SINGLE** command from the front panel is discussed in “MAKING SINGLE MEASUREMENTS” on page 2-6. In addition to the **SINGLE** command, pressing only the letter **Q** (for Question) without the return key will start a measurement on a serial device. This is more convenient for making repeated measurements.

Initiating with an External Trigger Signal

The simplest way to remotely trigger a new reading from the AH2700A is by using the external trigger input. The bridge does not default to this mode of operation but it is easily set up so that an external trigger signal causes a reading to be taken. To do this requires that a very simple macro be written and executed. The example below shows how:

```
>MACRO CREATE
#WAITFOR
#SINGLE
#
>STORE MACRO EXAMPLE
>MACRO SETUP TOTAL 0
>MACRO RUN EXAMPLE
  C=843.318 PF L=0.03721 NS
  C=843.320 PF L=0.03719 NS
  C=843.323 PF L=0.03721 NS
```

After the macro was created, it was saved as a **MACRO EXAMPLE** file. The macro was then executed repetitively. The **WAITFOR** command waits indefinitely for an external trigger pulse to occur. A measurement result will be reported by this macro for each pulse that is received. This is a simple application of the **WAITFOR** command. It can also be used within programs to trigger much more complicated command sequences. See “WORKING WITH PROGRAMS” on page 3-10 and especially “Synchronizing to an External Trigger Pulse” on page 3-14 for a more detailed description of the external trigger input and of the **WAITFOR** command.

Initiating with a *TRG/GET Macro

A new measurement can also be initiated with a ***TRG** command or a Group Execute Trigger (**GET**) from the GPIB. One way to do this requires that no **TRGMAC** macro file exists. If this is the case, then one measurement will be taken every time a **GET** from the GPIB or a ***TRG** command is issued.

The other way to use the ***TRG/GET** commands requires that a very simple macro be written and executed. The example below shows how:

```
>MACRO CREATE
#SINGLE
#
>STORE MACRO TRGMAC
>*TRG
  C=347.312 PF L=0.01021 NS
>
```

After this one-line macro was created, it was saved as a **TRGMAC** macro file. That special file is executed every time a ***TRG** command or a **GET** from the GPIB is issued. The advantage of this more complicated method is that you can write the macro to do many other things. See “WORKING WITH PROGRAMS” on page 3-10 and especially “The TRG/GET Program” on page 3-13 for more information.

Taking Measurements Continuously

In the continuous reading mode, the bridge takes measurements repetitively until temporarily interrupted with a command input or permanently stopped. The discussion below assumes that you are familiar with “MAKING CONTINUOUS MEASUREMENTS” on page 2-7. To put the bridge into continuous mode, enter the command:

CONTINUOUS [ON]

where the optional **ON** command qualifier may be omitted. The rate at which readings are taken depends upon the value of the *Interval* parameter which is set using the

CONTINUOUS INTERVAL *Interval*

command. If *Interval* is zero, readings are taken at the maximum rate. This maximum rate is determined primarily by the setting of the averaging time which is discussed in “Averaging Time” on page 4-6.

The *Interval* parameter represents the time from the beginning of one measurement to the beginning of the next measurement. As a result, this time must be chosen to be long enough so that it exceeds the time that the bridge requires to take a reading. If this is not the case, then readings will be taken at the maximum possible rate just as if the *Interval* parameter had been set to zero. The maximum *Interval* that can be entered is 99,999,999 seconds.

The action of the **CONTINUOUS** command is stopped with the command:

SINGLE or Q

In other words, the **CONTINUOUS** command enables continuous measurements and the **SINGLE** or **Q** command disables them. If continuous reading mode is active, issuing the **SINGLE** or **Q** command will cause a reading to be taken and will abort continuous measurements.

MEASUREMENT SPEED VS. MEASUREMENT FLUCTUATION

In most applications it is desirable not to spend any more time than necessary to make a measurement. In some applications, it is critically important to make measurements as fast as possible. The AH2700A has been optimized to make the fastest measurements possible within several fundamental constraints.

First, the measurement speed depends on the operating frequency of the AH2700A. The higher the frequency is set, the faster the measurements can be made. To make a very fast measurement still requires a minimum number of complete cycles of the test signal. Under ideal conditions, the bridge can report measurements so fast that it takes only about 40 cycles of the test signal. This is assuming that the ratio-transformer taps have already been set-up correctly.

If the ratio-transformers need to be balanced, then a number of relay settling times are involved so that several tenths of seconds are required. The first measurement of an unknown will require a minimum of about 0.3 seconds, most of which is used to balance the bridge.

Beyond these issues, there is a fundamental trade-off between the amount of fluctuation in the measurement results and the time taken per measurement. To reduce the effects of unavoidable input-amplifier noise and thereby to get the highest-quality measurements requires averaging (internally or externally) as many measurements as is practical over a period of time.

Understanding what the Bridge may do During a Measurement

Bridge Balancing Algorithms

The simple diagram of the basic bridge shown in Figure 4-1 suggests that the process of balancing the bridge is a simple one, but this is not the case. Bridge firmware does not control a straight-forward dual slope detector, it controls many decades of transformer taps of a true ratio-transformer bridge. Complex algorithms are required to balance the resistive and reactive components of the unknown over greater than twelve orders of magnitude. This is especially difficult when the unknown may be changing, may contain high noise levels or may exhibit negative resistive and/or reactive components. The balancing algorithm must always respond with a meaningful, precise measurement result or it must identify why a precise measurement is not possible and reply with an error message. Instead of meaningless results, the AH2700A has been designed to report either valid measurements or relevant error messages when the unknown differs from what the bridge expects to measure. All the while, measurements must occur as quickly as possible.

The many possible outcomes of an attempt to make a measurement cause the amount of time required to make a mea-

surement to vary. The time variation can range from under 30 milliseconds to about 40 minutes. Two factors account for most of the variation. One factor is the averaging time and the other is the use of cold-starts versus warm-starts.

Cold-Start

The terms “warm-start” and “cold-start” refer to the degree to which the bridge has previously been balanced. A cold-start means that the bridge is so far out of balance that the AH2700A must start its balancing algorithms from the beginning. For shorter measurement times which is the only range where warm-starts might be performed instead of a cold-start, a cold-start can *add* anywhere from about 0.25 to 0.6 seconds to the time needed to make a measurement.

Warm-Start

A warm-start means that the bridge is very close to being in balance so that the preliminary work done during a cold-start is complete. A warm-start requires from 0.027 to 0.85 seconds to perform. At the beginning of every measurement, the AH2700A attempts a warm-start. If a warm-start does not succeed, the bridge reverts to performing a cold-start.

Measurement Times

For time-critical applications, it is important to realize that the balancing algorithms of the AH2700A can take varying amounts of time to execute depending on the behavior of the unknown. If a problem occurs while a measurement is in progress such that the unknown prevents the bridge from balancing, the measurement attempt is aborted and up to three additional attempts are made using a cold-start each time. If all attempts fail, an error message is displayed. If any attempt succeeds, a measurement is displayed and the incident will be transparent to you except that the measurement can take as much as four times as long as the selected averaging time.

For well-behaved unknowns, the measurements will be performed in the normal time period nearly 100 percent of the time. If the unknown is slowly changing, a different transformer tap will occasionally need to be selected. Selecting a different transformer tap may cause the current measurement to be aborted, causing a cold-start followed by a normal measurement. When this occurs, the normal measurement time is increased by the time taken for the cold-start and the partially completed measurement. This occurs infrequently, but is apparent, particularly for short averaging times and is considered normal behavior.

When measuring noisy or poorly behaved unknowns, an occasional abnormally long measurement time may occur more frequently. Noise can introduce a spike or burst that causes the bridge to briefly appear unbalanced thereby requiring a cold-start. In summary, changing or noisy unknowns may require more time than a normal measurement time to display a result and you should consider this to be normal bridge operation.

Averaging Time

Averaging time is a measurement parameter that controls the reduction of the effects of random noise by internally averaging the noise over a period of time. Any high gain amplifier (like the detector connected to the LOW terminal of the AH2700A) generates random noise at its input. Amplifier noise is unavoidable and is the main reason for providing control over the averaging time. *Externally* generated noise can also be reduced by averaging if it is random.

Because of noise, measurements taken with a short averaging time will fluctuate more than those taken with longer averaging times. If the noise is truly random, the amount of variation in the measurements is inversely proportional to the square root of the time over which the results are averaged. Therefore, a four second averaging time gives a result that has half the variation from measurement to measurement as one taken with a one second time. Unknowns whose actual value changes slightly during the measurement time will show a measured value that is the average of the actual value during this time. This is true only for small changes in the unknown's value; changes which are large enough to require selecting a different ratio transformer tap may cause the measurement to be re-started or aborted.

You may ask why you should use the averaging abilities of the AH2700A rather than those of the computer that you may be using to capture data from the bridge. Indeed, for longer

measurement times, using your computer may be useful. However, for shorter averaging times, the AH2700A spends proportionately less time internally in the process of sampling and averaging the noise that it sees on the LOW terminal. Proportionately more time is spent preparing to take a measurement and in reporting the results. Thus the best results will always be obtained when the bridge is set to a longer averaging time so that it spends proportionately more of its time sampling its input. Due to this effect, the variation in the measurement results improves more rapidly than the inverse square root of the measurement time for short times.

Changing the Averaging Time

The total measurement time may be selected with the following syntax:

AVERAGE *AverExp*

Where the possible integer values of *AverExp* (average time exponent) are listed in Table 4-1. (The *AverExp* is not really an exponent, but it is helpful to think of it as such because the average time increases exponentially with *AverExp* though at an increasing rate at higher values of *AverExp*.) Table 4-1 shows the approximate cold-start and warm-start measurement times in seconds which result from the various values of *AverExp*. As the table implies, warm-start measurements are not performed for test frequencies below 600 Hz. Notice that

Table 4-1 Total measurement times in seconds where f is the test frequency in Hertz.

<i>Aver-exp</i>	Approximate Cold-start Measurement Time			Approximate Warm-start Measurement Time for $f \geq 600\text{Hz}$
	For $f \geq 600\text{Hz}$ or $(C \leq 0.165 \mu\text{F}$ or $G \leq 12,000/n\text{S})$	For $f < 600\text{Hz}$ and		
		$0.165 \mu\text{F} < C \leq 0.55 \mu\text{F}$ or $12,000 < G \leq 40,000/n\text{S}$	$C > 0.55 \mu\text{F}$ or $G > 40,000/n\text{S}$	
0	$0.28 + 80/f$	N/A	N/A	$0.027 + 11/f$
1	$0.29 + 110/f$	N/A	N/A	$0.033 + 23/f$
2	$0.30 + 150/f$	N/A	N/A	$0.042 + 42/f$
3	$0.33 + 200/f$	N/A	N/A	$0.058 + 75/f$
4	$0.37 + 260/f$	N/A	N/A	$0.085 + 130/f$
5	$0.44 + 350/f$	N/A	N/A	$0.12 + 230/f$
6	$0.58 + 520/f$	N/A	N/A	$0.18 + 400/f$
7	$0.82 + 820/f$	$1.6 + 1600/f$	$3.2 + 3200/f$	N/A
8	$1.2 + 1300/f$	$2.4 + 2600/f$	$4.8 + 5200/f$	N/A
9	$1.8 + 2200/f$	$3.6 + 4400/f$	$7.2 + 8800/f$	N/A
10	$3.0 + 3900/f$	$6.0 + 7800/f$	$12.0 + 16,000/f$	N/A
11	$5.0 + 7000/f$	$10.0 + 14,000/f$	$20.0 + 28,000/f$	N/A
12	$9.0 + 14,000/f$	$18.0 + 28,000/f$	$36.0 + 56,000/f$	N/A
13	$17.0 + 27,000/f$	$34.0 + 54,000/f$	$68.0 + 108,000/f$	N/A
14	$34.0 + 57,000/f$	$68.0 + 110,000/f$	$140.0 + 220,000/f$	N/A
15	$68.0 + 120,000/f$	$140.0 + 240,000/f$	$280.0 + 480,000/f$	N/A

every measurement time in the table consists of two contributions — a fixed term plus a variable term that is inversely proportional to frequency. Notice also that measurement times become very long for large capacitances and losses measured at frequencies below 600 Hz. Consequently, the measurement times vary widely and can be quite long at low frequencies.

The capacitance and loss values shown in Table 4-1 are approximate. These values vary by $\pm 10\%$ compared to the table from one serial number to another.

The **AVERAGE** command is so named because the bridge takes multiple internal sampling readings during this time and averages them to reduce the effects of noise before printing or displaying the result. Particularly for longer averaging times, most of the measurement time is spent doing averaging.

The default value of *AverExp* stored in the GAUGE FACT-PON parameter file is four which gives a warm-start time at 1 kHz of about $0.085 + 130/1000 = 0.2$ second.

Forcing a Cold-Start to get Highest Reliability

Since a cold-start requires a significant amount of time to perform, the bridge avoids doing it for the shorter averaging time settings. If the bridge senses that a well-behaved unknown impedance is connected and the averaging time is low, a cold start is done only on the very first measurement. Another cold-start will never be performed as long as the unknown appears to be well-behaved. In practice this works fine, but in theory, rare problems could occur.

The worst possibility is when a LOW to ground short occurs sometime following a cold-start and with an otherwise well-behaved unknown. The bridge still appears to be balanced since the input voltage has remained near zero. This will be true even if the unknown changes or is removed provided that the short is not interrupted. The bridge is “fooled” into reporting the same readings as before the short occurred even though the capacitor may have been removed.

This problem can be avoided by forcing the bridge to perform a cold-start for every measurement. Setting *AverExp* to be greater than or equal to 7 will force a cold-start to be performed for every measurement.

Unfortunately, this solution has more than just a time penalty. Performing a cold-start requires that relays be opened and closed for every cold-start. Being mechanical components, relays have a lifetime that is inversely-proportional (statistically) to the number of contact closures. It is therefore not desirable to arbitrarily perform *very large* numbers of cold-starts without some justification. By using warm-starts whenever possible for shorter measurement times, the AH2700A automatically minimizes this problem. You can further maximize the lifetime of your relays by not leaving your AH2700A needlessly running continuously at *AverExp* = 7 or higher for periods of days.

REJECTING INTERFERING SIGNALS

Usually noise problems are due to input amplifier noise or apparently random noise from external sources. However, the most insidious source of noise is that from an externally generated interfering signal whose frequency is very close to the sine wave that the AH2700A generates. If the interference is close but not identical in frequency to that of the bridge, beating effects can occur that cause measurement results to vary in a regular, periodic manner. If the interference is so close in frequency to that of the bridge that the phase difference between the two signals does not change significantly while a sequence of measurements is being taken, then a constant error may exist in every measurement in the sequence. This is the worst case because there is no clue in the measurement results that there is a problem.

You might think that it is improbable that an interfering signal could have a frequency that is nearly identical to that of the AH2700A, but that is not the case.

Interference from Other Instrumentation Operating at the Same Test Frequency

One kilohertz is a very popular test frequency. Many other impedance measuring instruments offer this frequency. If it is a modern instrument, the signal is likely to be derived from a quartz-crystal oscillator (as is the AH2700A's) and will therefore be very accurate. This high accuracy means that such an interfering signal will be very close in frequency to that of the AH2700A.

Just because there is another nearby signal with nearly the same frequency does not automatically pose a problem—there must still be a way of coupling it into the AH2700A. There are many ways this can happen. One interesting example occurs with some formerly popular ratio-transformer based capacitance bridges. These have fairly large ratio-transformers that are not well shielded. These transformers will radiate significant levels of magnetic EMI at their test frequency. Magnetic interference at 1 kHz is harder to shield against since it easily passes through non-ferrous metals. Such interference can be picked up by loops in any circuit even if they are formed of coaxial cable.

Interference from Power Lines

Most power line interference is obviously worst at 50 or 60 Hz. This is so far from frequencies of 1 kHz or higher that it is not a problem in any reasonably well shielded configuration. However, because so much power is involved, even higher harmonics of the fundamental power frequencies can be a problem. The 20th harmonic of 50 Hz is exactly 1.000 kHz. The 17th harmonic of 60 Hz is exactly 1.020 kHz. Since the frequency of electric power grids may be precisely controlled, a 1.000 kHz harmonic from 50 Hz power lines is an especially serious potential source of interference. Since power lines are everywhere in a laboratory, the possible prospects for coupling an interfering harmonic into a bridge are many.

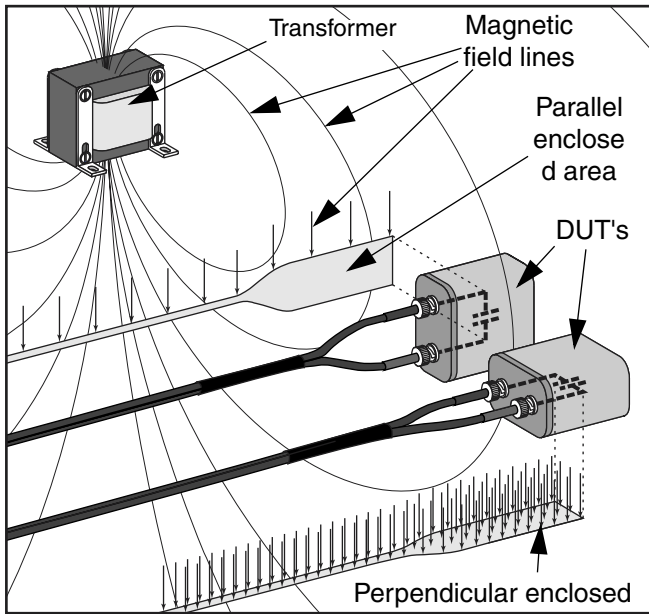


Figure 4-5 Magnetically-induced pickup into enclosed areas that are parallel and perpendicular to the field.

Naturally, the most serious power line interference occurs when the AH2700A is set to operate at exactly the same frequency as the power line. In this case, knowledge and application of every practical method of minimizing such interference is essential.

Minimizing the Coupling of Interference

The best way to avoid interference problems is not to couple the interference into the bridge in the first place. The ways of accomplishing this are:

1. Turn off the interference source.
2. Put a significant distance between the interference source and the bridge.
3. Reduce the coupling by shielding. Three-terminal construction should virtually eliminate any electrostatic coupling to an interference source. Shielding of magnetic interference is more difficult at one kilohertz and below. It requires carefully designed shielding using high-permeability ferro-magnetic alloys.
4. If the coupling is magnetic, reduce the enclosed area of the measurement circuit and orient the enclosed area so it is parallel to the field. Figure 4-5 shows a power transformer and some typical magnetic field lines that radiate from it. Two DUT's are located within this field at a point where the field lines are vertical. The field lines will penetrate the DUT's and the shielded coaxial cables.

The measurement circuit of the DUT on the right forms a loop whose enclosed area is oriented roughly perpendicular (normal) to the direction of the field lines. This

area is shown in an extracted form below this DUT with a *large* number of field lines passing through it.

The measurement circuit of the DUT on the left forms a loop whose enclosed area is oriented roughly parallel to the direction of the field lines. This area is shown in an extracted form to the left of this DUT with a *small* number of field lines passing through it.

The interference voltage induced in these measurement circuits is proportional to the number of field lines passing through their enclosed areas. The measurement circuit of the DUT on the right therefore picks up much more magnetic interference from the transformer than the DUT on the left. The figure demonstrates that the induced interference voltage can be reduced by *constructing* the measurement circuit so as to minimize the enclosed area and by *orienting* the circuit so that it intercepts as few field lines as possible.

5. A further reduction of interference is obtained with the commutate feature of the AH2700A explained next.

Optimizing Commutation

The AH2700A has a feature which allows it to reject the fundamental and harmonics of a regular signal from an external source. Such a signal may have the same or similar frequency and phase as the sine wave signal that the bridge uses. In this case, the “self-commutation” feature of the AH2700A should be effective for rejecting the interfering signal.

Alternatively, the interfering signal may have the same frequency and phase as the lines which power the AH2700A. In this case, the “line-commutation” feature of the AH2700A should be effective for rejecting the interfering signal.

In the case of self-commutation, the AH2700A commutates by periodically alternating (or reversing or commutating) the bridge signal to make it distinguishable from an otherwise synchronous or nearly synchronous interference signal. The desired signal from the DUT is measured for a time interval with the AH2700A bridge signal generator and detector set to a normal phase and then for the same length of time with the bridge signal generator and detector inverted (i.e. phase-advanced by 180°). The sum of the two measurements gives the desired result while rejecting the undesired signal (since it didn't invert when the desired signal did). Self-commutation is most effective when the interfering frequency (or its harmonics) is close to the AH2700A's bridge frequency.

In the case of line-commutation, the AH2700A also commutates by periodically advancing the phase angle of the bridge signal. However, line-commutation differs from self-commutation because it monitors the zero-crossings of the power line and uses this timing information to start each measurement period, whether normal or inverted, at exactly the same or 180° advanced phase angle of the bridge frequency. Line-commutation yields its most dramatic improvement when the fundamental frequency or a harmonic of the line from which

the AH2700A is powered is close to the AH2700A's bridge frequency.

A certain minimum number of cycles of the bridge frequency are required for each commutation phase period which puts limits on how fast commutating can be performed. Short averaging times do not allow enough time for commutating to be active. The rate at which commutation occurs is variable and depends mainly on the averaging time and the frequency in a complex way. The shortest time interval for a complete commutation cycle is on the order of 0.08 seconds or eight cycles of the bridge frequency whichever is longer. The longest time interval for a complete commutation cycle is on the order of 0.2 seconds or 20 cycles of the bridge frequency whichever is longer.

In most indoor environments, electromagnetic fields at power line frequencies are ubiquitous. In such environments, the line-commutate feature is so effective that it should be active whenever possible.

Although commutation should be enabled whenever possible, some control over this feature is provided with the following command:

`COMMUTATE OFF|LINEREJ|ASYNC`

The meanings of these values are listed in Table 4-2. LINEREJ should normally be used. If you want your measurements made with a continuous sine wave, then use OFF. Note that LINEREJ and ASYNC only *enable* commutation; these settings can not force commutation to occur if the averaging time setting is too short.

One reason for using any setting other than LINEREJ occurs when an interfering signal is present that has a fundamental or harmonic that is close to the bridge frequency. This signal might be coming from another AH capacitance bridge or from some other electronic instrument. If the frequency and phase of the interfering signal is constant, using ASYNC will strongly reject this interference. If the phase of the interfering signal is not constant as is the case with interference from a second AH capacitance bridge operating at or near the same bridge frequency, having commutation not set to OFF and taking measurements, then the rejection will be much lower. Commutation is only active while measurements are being made, otherwise, the phase of the bridge signal is constant.

Table 4-2 Commutation enable settings

Enable Setting	Commutation Method Enabled
OFF	Commutation disabled
LINEREJ	Line-commutation enabled
ASYNC	Self-commutation enabled

Commutation can not be active while the deviation processing feature is active. Therefore, activating the deviation processing feature will automatically disable commutating no matter what commutation setting has been applied.

Since it is so important that the line-commutation feature be active whenever possible, the default commutation setting the GAUGE FACTPON parameter file is LINEREJ.

DECIDING WHICH UNITS TO USE

You have some ability to select the units in which the measurement results are presented, especially in the case of the loss units. Capacitance is always displayed in units of picofarads unless Reference result mode is enabled in which case units of percent are available also. This mode is discussed in "Reference Result Mode" on page 5-2.

Five different loss units are normally available. When Reference result mode is enabled, units of percent deviation are also available. Understanding how the five units of loss are related to one another will help you to choose the most appropriate units for a given application.

Before getting into descriptions of each of the available units, it is important to understand that *all* capacitance and loss units on the AH2700A fall into one of the two major categories discussed below.

Series Versus Parallel Circuit Models

Real capacitors are not perfect. Real capacitors contain loss mechanisms that cause the parallel resistive component of their impedance to be less than the infinite value expected of an ideal capacitor. The leads and plates of capacitors (superconductors excluded) always contain some resistance that appears in series with the actual capacitance. The dielectric material in which the field between the capacitor plates exists also contains one or more loss mechanisms that appear in parallel with the actual capacitor. A model of a real capacitor might appear as shown in Figure 4-6 which contains both the series and parallel resistances.

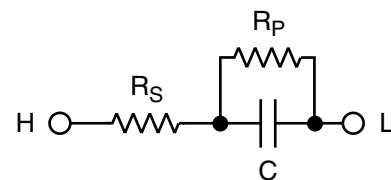


Figure 4-6 Capacitor model with both series and parallel resistances.

However, a capacitance bridge has no way of separately measuring these two resistances with a single measurement. For each individual measurement, a bridge must report either a series resistance or a parallel resistance but not both. Fortunately, it is possible to treat both of these resistances as if they were a single series resistance or as a single parallel

resistance. These equivalent circuits are shown in Figure 4-7 and Figure 4-8.

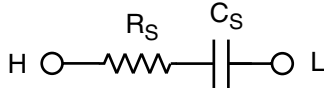


Figure 4-7 Capacitor model with loss represented by a single series resistor.

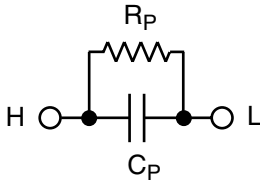


Figure 4-8 Capacitor model with loss represented by a single parallel resistor.

The hardware of the bridge makes its measurements in the form of parallel capacitance and loss. If you request that the results be reported in the series form, the bridge converts from parallel capacitance (C_P) and resistance (R_P) to series capacitance (C_S) and resistance (R_S) using the following equations:

$$C_S = (1 + D^2)C_P \quad \text{Eq. 4-1}$$

$$R_S = \frac{D^2 R_P}{1 + D^2} \quad \text{Eq. 4-2}$$

where the dissipation factor (D) is given by:

$$D = \frac{1}{\omega C_P R_P} \quad \text{Eq. 4-3}$$

and ω is 2π times the operating frequency of the bridge. D has the same value for series or parallel configurations. Since the bridge does these conversions, you should not need to use these equations yourself. However, it is instructive to realize that the conversion is somewhat messy and non-linear.¹

1. It can be hard to intuitively grasp why a single physical device may produce values for C_S and C_P that are different from each other and from C . One way to look at this is to realize that for a given measurement, the bridge can only report a result that *assumes* either a parallel model or a series model. If the actual device is accurately represented by the parallel model, for example, then the value for C_P reported by the bridge will be equal to the value for C in the model. The value for C_S reported by the bridge will not be equal to the value for C in the model because the model does not accurately represent the actual device. In other words, C_S and C_P may be thought of as *attempts* to report the actual value of C in the device. For most devices, either C_S or C_P will have a value that is close to C .

Deciding on the Circuit Model

It is important to understand that your choice of loss units also implicitly selects either the series or the parallel circuit model. Only a choice of series resistance units will cause the bridge to report its result in series units. All other units choices will cause parallel results to be reported. It is also important to understand that choosing units of series resistance affects not only the loss units and value, but also the value of the capacitance result. The capacitance units (usually picofarads) will not change, but the value will be a series value, not a parallel value. If the loss is zero ($D = 0$), the series and parallel capacitance values are the same. If the loss is significantly different from zero, the series and parallel capacitance values may deviate significantly from each other.

In reality, even a poor capacitor has a D that is less than 0.01. Any capacitor used as a standard will have a D that is smaller than 0.001 with really good standards having D on the order of 0.000,003. This means that for even the worst capacitors, C_S can be expected to differ from C_P by no more than D^2 or 0.01%. (Note that we are talking here about *capacitors* which are manufactured with the intention of having respectable properties.)

Usually, in a real capacitor, either the series or the parallel resistance dominates. Series resistance usually dominates for large capacitances/higher frequencies and parallel resistance usually dominates for small capacitances/lower frequencies. Thus the measurement of such a capacitor should, ideally, be chosen to give results in the form of series or parallel resistance to correspond to the nature of the actual capacitor. If the chosen model is a good representation of the actual device, then the measured loss values will tend to be independent of the frequency at which the measurement was taken. In reality, most devices will fit neither model well, but instead, may have a D that is relatively frequency independent.

Measurements on capacitance standards are *always* reported using the parallel model.

Since the AH2700A could measure a circuit such as that in Figure 4-6 over a range of frequencies, it would be possible to actually determine the values of both R_S and R_P . However, the bridge will not do this automatically and the methods needed to do this manually are beyond the scope of the discussion here.

Available Loss Units

The five loss units which you may select are described below. They are described in the same order as the units indicators appear on the front panel.

Conductance

Conductance (G) is a natural way to measure the loss of a capacitor because conductance is directly proportional to the amount of loss in the capacitor. The AH2700A uses units of nanosiemens to measure conductance. The conductance is a

parallel loss parameter and is the inverse of R_p . Units of nanosiemens are also the exact inverse of units of gigohms which are used to report R_p . Therefore one nanosiemens is the conductance produced by one gigohm. (The term Siemens replaces the older term Mhos).

Dissipation Factor

Dissipation factor is related to parallel capacitance and resistance by Eq. 4-3. Unlike the other parallel methods of expressing loss, dissipation factor is dependent on the capacitance value. A useful way to think of dissipation factor is as the ratio of the conductance to the capacitive susceptance (B):

$$D = -G/B \quad \text{where} \quad B = -\omega C_p \quad \text{Eq. 4-4}$$

Dissipation factor may be thought of simply as the ratio of the loss to the capacitance. If the capacitance and loss are the components of a vector having an angle δ , then D is $\tan \delta$.

Dissipation factor tends to describe a property of the unknown impedance that is essentially independent of the value of the capacitance. For a given kind of capacitor construction, doubling the value of the capacitor usually doubles the conductance also. This means that the dissipation factor will tend to be constant for a given type of capacitor while the capacitance and conductance will tend to change in proportion to the size of the capacitor. This makes dissipation factor useful for describing a given *type* of capacitor and also for characterizing dielectric materials. Conductance and resistance, in contrast, are better to use when measuring a *specific* capacitor.

Like all the other loss units, the dissipation factor can have either a positive or a negative sign. If the capacitance and loss are both negative then D will be positive. D is the inverse of the quality factor Q, ($Q = 1/D$).

Series Resistance

As explained above in “Deciding on the Circuit Model”, selecting series resistance units gives results that differ from all the other loss unit choices in important ways. Series resistance is reported by the AH2700A in units of kilohms.

The obvious utility of having series resistance units is in being able to measure devices whose series resistance is believed to comprise most of the total loss. In this case, it may be possible to accurately measure resistances that are not physically accessible by any other means.

Parallel Resistance

For those familiar with electronic circuitry where impedances are usually expressed as resistance measured in ohms, the most easily understood way to measure loss will probably be as parallel resistance (R_p). R_p is the inverse of the conductance ($R_p = 1/G$). The AH2700A displays resistance in units of gigohms (1 gigohm = 1 billion ohms). Notice that units of nanosiemens are the inverse of gigohms. See the discussion

in “Conductance” above for the relationship between conductance and parallel resistance.

It is important to understand that R_p as measured by the AH2700A will not usually have the same value as that obtained from a DC resistance measurement. In fact, the value measured by the AH2700A is likely to be much smaller, even by orders of magnitude. The reason is that the AH2700A measures the DC leakage resistance *combined* with the loss of the capacitor. However, R_p does serve to put a lower bound on the value of the DC resistance.

Loss Vector – an Alternative to Conductance

If you desire to report your capacitance and loss results as orthogonal vectors, the AH2700A provides units of G/ω jpF for this purpose. These units cause the measurement results to be reported as the two components of a complex admittance vector. The capacitance (or susceptance component) is still given in picofarads. Two components of the same vector should have the same units so that the loss (or conductance component) is also reported in picofarads. The phase angle between the conductance and the capacitance is 90 degrees. This is represented by “j” in complex terminology so the loss vector units are labeled as jpF rather than just pF. The magnitude of the loss vector is simply equal to G/ω .

Changing the Loss Units

The units of loss are selected with the following command syntax:

`UNITS LossUnit`

where *LossUnit* is **NS**, **DS**, **KO**, **GO**, or **JP**. The list below gives the corresponding units for the respective *LossUnit* numbers. The unit abbreviations are given in the column to the right.

NS - Nanosiemens	(nS)
DS - Dissipation factor ($\tan \delta$)	(dimensionless)
KO - Series resistance in kilohms	(k Ω)
GO - Parallel resistance in gigohms	(G Ω)
JP - G/ω in j picofarads	(jpF)

To make the *LossUnit* numbers easy to remember, they are assigned in the same order as they appear on the front panel unit indicator labels.

The UNITS command does not initiate a new measurement, but its execution will cause the previous measurement result to be *re-calculated* and reported using the new units selected. This provides a simple way to compare the results of different units settings on the same measurement. If you are not familiar with some of the available units settings, some experimentation with this command as applied to a given measurement may be helpful.

The default loss units in the BASIC FACTPON parameter file are nanosiemens.

COMPENSATING FOR STRAY FIXTURE IMPEDANCE

Some applications may require measuring the capacitance or loss of a device which is not directly connectable to the AH2700A. Such a device is often called the “Device Under Test” or DUT. Often, the DUT may only have contacts rather than cables or leads with which to make connections. Even if something better than contacts exists, it will usually not be three-terminal. In such a case, a fixture is used to hold the DUT, to make connection to it and to provide the proper cabling to carry three-terminal measurement signals to the bridge. In most cases, this fixture will have a capacitance and loss (impedance) of its own. Usually, some part of this fixture impedance will contribute to any measurements taken with the DUT mounted in the fixture.

The AH2700A offers a means of correcting the measurement result so that a constant fixture impedance is mathematically removed. This is called the “Zero compensation result mode” and is controlled by various forms of the ZERO command. This compensation mode allows you to directly *measure* the parallel fixture impedance and then to optionally remove that impedance from the measurement result. Alternatively, an impedance value for the fixture can be *entered* into the bridge rather than measured. Since the ZERO command is very similar to the REFERENCE command, both are described together in “RESULT MODES” on page 5-2 of Chapter 5, “Data Presentation”.

FREQUENCY OF THE TEST SIGNAL

The frequency of the sinusoidal signal applied by the AH2700A to the unknown is selectable in discrete steps in the range of 50 Hz to 20 kHz. The command used to specify the frequency at which measurements are to be taken is:

FREQUENCY *Freq*

Any value in the range of 50 Hz to 20 kHz may be entered, but the AH2700A will select and use the nearest available frequency from the following list: 50, 60, 70, 80, 100, 120, 140, 160, 200, 240, 300, 400, 500, 600, 700, 800, 1000, 1200, 1400, 1600, 2000, 2400, 3000, 4000, 5000, 6000, 7000, 8000, 10,000, 12,000, 14,000, 16,000, and 20,000 Hz.

When a measurement result is being displayed, the frequency window on the front panel of the AH2700A will always read out the frequency at which the measurement was made. If the front panel is displaying any other result or prompt, then the frequency window will read out the frequency that will be used to make the *next* measurement.

There are many situations where the frequency dependence of an unknown needs to be measured over a range of frequen-

cies. The Macro capabilities of the AH2700A described in “WORKING WITH PROGRAMS” on page 3-10 can be useful for automating this process without using an external controller. The AH2700A is originally shipped with a sample macro FREQSCAN in the EEPROM memory that, when executed, will sweep through all the available frequencies from highest to lowest taking one measurement at each frequency. To try this macro from the front panel, simply enter **[FUNC] [SELECT] [MACRO] [RUN] [FREQSCAN] [ENTER]**. The macro will immediately begin by taking a measurement at 20kHz and will continue as fast as it can until it finishes taking a reading at 50Hz. Since measurements at higher frequencies occur much faster than at low frequencies, this macro will initially run very quickly but will get slower and slower as it runs. This is a query macro so it can be terminated at any time by simply pressing **[ENTER]**.

VOLTAGE OF THE TEST SIGNAL

The AC RMS voltage applied to the unknown is largely automatically determined by the AH2700A. The voltage used to make a measurement is reported with that measurement’s results both on the front panel and on remote devices. The section “MAKING SINGLE MEASUREMENTS” on page 2-6 explains how to show this voltage on the front panel. Chapter 5, “Data Presentation” discusses the ways that the applied voltage is reported to remote devices.

Due to the nature of the technology that the AH2700A uses, it is not possible to specify the amplitude of the sinusoidal voltage that is applied to the unknown in the process of making a measurement, but it *is* possible to *limit* that voltage to a maximum value.

For frequencies equal to or above 1 kHz, capacitance values below about 110 pF and unless otherwise limited, the AH2700A will apply its maximum test signal of 15 volts to the unknown to make measurements. For frequencies below 1 kHz the bridge must reduce the operating voltage so that the ratio transformers do not saturate. For capacitances larger than about 110 pF, the bridge must reduce the applied voltage in order to balance the larger unknown device against the smaller reference capacitor in the bridge. The lower the frequency and the larger the capacitance, the smaller the applied voltage must be in order to balance the bridge. Unless otherwise limited, the AH2700A will always choose the largest possible voltage that will balance the bridge.

The range of capacitance that can be measured with a given voltage is listed in Table 4-3. These values are approximate and vary by $\pm 10\%$ compared to the table from one serial number to another. Each line in the table corresponds to a tap on the attenuator transformer in the bridge. The table shows ranges covering negative values because the bridge can measure negative values of capacitance and loss. These ranges cover all values between the listed limits no matter how small.

The same issues apply to loss measurements as for capacitance. The loss ranges are also shown in the table.

Limiting the Test Voltage

You can limit the voltage of the test signal applied to your unknown to a maximum value. This does not mean that the actual applied voltage will necessarily come close to the maximum value that you specify — it could be far lower. To use an extreme example, a voltage of 15 volts might be specified, but if the capacitance of the DUT is near the top of the AH2700A's range, as little as 50 microvolts may actually be used to measure the unknown. The command used to specify the limiting voltage is:

`VOLTAGE VHighest`

The *VHighest* parameter is the maximum AC voltage in volts RMS that the bridge will apply to the unknown while making a measurement. Any voltage may be entered, but the bridge will limit the maximum measurement voltage to a value equal to or below the amount specified. Table 4-3 lists the

Table 4-3 Capacitance and loss ranges for the preferred limiting voltages with $f \geq 1$ kHz. For $f < 1$ kHz, multiply Limit by f in kHz.

Limit (volts)	Capacitance range (pF)		Loss range (nS) f is in kHz	
	From	To	From	To
15.00	-11	+110	$-0.8f$	$+8f$
7.50	-22	+220	$-1.6f$	$+16f$
3.00	-55	+550	$-4f$	$+40f$
1.50	-110	+1100	$-8f$	$+80f$
0.750	-220	+2200	$-16f$	$+160f$
0.250	-660	+6600	$-48f$	$+480f$
0.100	-1650	+16,500	$-120f$	$+1200f$
0.030	-5500	+55,000	$-400f$	$+4000f$
0.010	-16,500	+165,000	$-1200f$	$+12,000f$
0.003	-55,000	+550,000	$-4000f$	$+40,000f$
0.001	-165,000	+1650,000	$-12,000f$	$+120,000f$

actual RMS voltages that the AH2700A uses for various ranges of capacitance and loss. Notice that for test frequencies below 1 kHz, the limiting voltage for a given capacitance or loss range decreases in proportion to the frequency.

Notice also that the size of the loss ranges scales directly in proportion to the test frequency. The preferred limiting voltage choices for $f \geq 1$ kHz are shown in the table. Entered voltages below 0.0003 volts will not be accepted.

The capacitance values listed are the largest that can be measured at the associated voltage. The maximum voltage specified does not always represent the maximum voltage ever

applied to the unknown; it does represent the maximum voltage that is used to get the final measurement result. Transient voltages as high as 0.1 volts can occur no matter what the maximum voltage is set to. The default value of *VHighest* in the GAUGE FACTPON parameter file is fifteen volts.

Using the table

Table 4-3 gives nearly all the information necessary to determine what voltage will actually be applied to the DUT given a particular combination of capacitance, loss, frequency and limiting voltage. Nevertheless, if you have access to an AH2700A, it will usually be much easier to just make a quick measurement and read the actual voltage used by the bridge even if you have to simulate the DUT.

If you want to use the table, it is important to understand that for many combinations of capacitance, loss, frequency and limiting voltage, the bridge can select from more than one line (tap) in the table. From this group, it will choose the *lowest* tap that *maximizes* the voltage applied to the DUT.

Some examples

1. Measure a 100 pF capacitor with a limiting voltage of 0.5 volts at a frequency of 1 kHz. According to Table 4-3, a 100 pF capacitor will be measured at 1 kHz using the 0.75V tap. The full limiting voltage of 0.5V will thus be used.
2. Measure a 100 pF capacitor with a limiting voltage of 0.5 volts at a frequency of 100 Hz. According to Table 4-3, a 100 pF capacitor will be measured at 100 Hz using the 7.5V tap since 7.5V times 0.1 kHz equals 0.75V. The full limiting voltage of 0.5V will thus be used.
3. Measure a 1000 pF capacitor with a limiting voltage of 6 volts at a frequency of 1 kHz. According to Table 4-3, a 1000 pF capacitor will be measured at 1 kHz using the 1.5V tap since this is the highest voltage available at this frequency. The actual voltage used of 1.5V will thus be only 1/4 of the selected limiting voltage of 6V.
4. Measure a 1000 pF capacitor with a limiting voltage of 15 volts at a frequency of 100 Hz. According to Table 4-3, the tap with the highest voltage that will measure a 1000 pF capacitor is the 1.5V tap. Since 100Hz will be used, the actual voltage from this tap will be reduced by 1.5V times 0.1 kHz equals 0.15V. The full limiting voltage will thus be reduced to 1% of its entered value of 15V.

UNKNOWNNS WITH DC VOLTAGE

The AH2700A allows DC voltages to be applied to or be bled from unknowns or to be left unaffected.

DC Bias Disabled

With the DC bias feature disabled, the bridge actively drives any residual DC voltage across the unknown to zero. The internal driving source can supply up to 10 microamperes. If the DC current supplied by the unknown capacitance exceeds 10 microamperes, the error message `DC ON L INPUT` will appear on the display. An external resistor to shunt the LOW terminal to ground might also work in this case, but would increase the amount of noise that the bridge sees.

Applying a DC Bias Voltage

The AH2700A allows a DC bias voltage of up to ± 100 volts to be applied to the unknown. This voltage is supplied externally between the center conductor of the DC bias connector on the back of the bridge and ground. In addition to making this external connection, it is also necessary to execute a command which closes an internal relay. When closed, this relay connects the external bias voltage through an internal series resistor to the LOW input of the bridge. Thus the LOW input may then have the same DC voltage as is applied to the external DC bias connector. The HIGH terminal of the bridge is always a low impedance DC ground.



CAUTION

The voltage connected to the DC bias input appears directly across the internal fused-silica capacitance standard. Application of voltages significantly in excess of 100 volts may damage or destroy the standard.



WARNING !

The voltage that you apply to the DC bias input will be passed to the LOW terminal. From there it will go to whatever unknown impedance and fixture you have connected. Be sure that your fixture and cable are constructed and insulated in a manner that will prevent personal contact with any DC voltages up to the ± 100 volt limit allowed for the bias input. The frame of the fixture and the shield of the cable should be grounded. Also, to preserve current-limit protection, do not shunt R603 or R604 with resistances smaller than 10k Ω . Failure to observe these warnings may result in a shock from the voltage applied to the DC bias connector or from the resulting DC charge stored on the capacitor being measured.

The command used to enable DC bias measurements and to select the value of the internal series resistor is:

`BIAS OFF|ILOW|IHIGH`

where the choices are:

- `OFF` Disabled (no series resistor connected)
- `ILOW` 100 megohm series resistor connected
- `IHIGH` 1 megohm series resistor connected

The choices are named according to the ability to feed increased levels of current into the unknown.

The default setting in the GAUGE FACTPON parameter file is OFF.

Optimizing the Series Resistance

The value chosen for the internal series resistor involves a compromise. The *larger* this value is, the smaller the noise will be in the resulting measurements. Thus for measurements which do not require a DC bias, the internal series resistor is not connected and the noise is thus held to a minimum. On the other hand, if there is any DC leakage in the unknown being measured, then a voltage divider is created which causes the voltage across the unknown to be less than the voltage applied to the external DC bias connector. To minimize *this* effect, the internal series resistor should be as *small* as possible. To allow you to optimize this trade-off, the value of the internal series resistor may be selected with the BIAS command to have a value of either 1 megohm or 100 megohms.

Another reason for wanting the series resistor to be smaller is the *time* required to charge the unknown capacitor to a bias voltage that is within an acceptable tolerance of your desired voltage. You can avoid this trade-off by using an *enable* value of two to rapidly charge your unknown, then switching to an *enable* value of one to take a low-noise reading.

To allow you to further optimize these trade-offs, the internal series resistors which are R604 and R603, on the preamp board can be shunted with resistors that you supply using the terminals provided for this purpose. Resistor values as low as 10 kilohms are practical. Since a current is flowing, to minimize noise, these should not be carbon composition, but rather carbon film or, better yet, metal film. Be aware that 100 volts across 10 kilohms dissipates one watt. Changing the value of the series resistors on the preamp board is something that should be done only by a person qualified to work on electronic circuits. See “DC Bias Resistor Tests” on page 11-24 to learn how to measure and/or change these resistors. For safety and performance reasons, it is extremely important to observe the warning and caution messages given there.

Measuring the Actual Applied DC Voltage

For unknowns that have some DC leakage, it is desirable to measure the actual DC voltage that is applied to the unknown. This is done by measuring the DC voltage between the LOW terminal and ground while the unknown is connected. Several considerations are important while doing this. A typical internal series resistor may have a resistance that is comparable to or larger than the input resistance of a typical voltmeter. Thus either the internal series resistor must be made small or the meter must be chosen to have an exceptionally high input impedance or both. If this is not possible, then the DC bias voltage across the unknown will change depending on whether the voltmeter is connected or not. The voltmeter can remain connected to the LOW terminal while the bridge takes readings if the voltmeter is shielded from external noise and from the HIGH terminal and if the voltmeter itself does not introduce an unacceptable amount of noise. If the internal resistance of the voltmeter is the only source of noise, then the higher this resistance is the better.

Charged Unknowns

Some unusual unknowns (like electrochemical devices) have the ability to generate a DC current which may be greater than what the input of the AH2700A can zero out under normal operation (i. e., with DC bias disabled). In this case, the solution is to enable the DC bias with the **BIAS** command. This allows at least 100 volts to exist across the unknown without affecting the measurement and thus preventing the `DC ON LOW INPUT` error message from appearing. The external bias connector can be left open or shunted to ground. The latter configuration would allow the internal series resistor to bleed off any excess charge that tended to build up on the unknown.

Input Protection

A number of protection devices are incorporated in the AH2700A to prevent charged capacitors or excessive external bias voltages from causing damage to the capacitance standard or the preamp which are both connected to the LOW input. If voltages much in excess of 100 volts are applied, a gas discharge device which is connected between the LOW input and ground will suddenly begin conducting to hold the voltage at the preamp input within range. This will not change a voltage applied to the DC bias connector but will very suddenly remove charge from any external capacitor having an excessive voltage.



CAUTION

Charged capacitors or low impedance power sources must not be connected between the HIGH terminal of the bridge and ground. Connection of such sources will cause them to discharge into the contacts of the attenuator relays which will damage these contacts.

This chapter explains the various ways that you can present capacitance and loss measurement data using the AH2700A.

The first part of this chapter explains variations in the ways in which measurement data can be presented that apply to both the front panel displays and to remote devices. How to control the number of significant figures that are reported is discussed. Methods of subtracting constant amounts from measurement results are also introduced.

The second major part of this chapter explains additional ways in which data can be presented on remote devices only. Topics discussed include the ways to control the number of columns and fields that are printed, the ways in which the data is labeled and punctuated and the numeric notation that is used.

SIGNIFICANT DIGITS

“Significant digits” refers to those digits in the measured result that are meaningful. The “most-significant digits” are at the beginning of a number and are always the most meaningful. The “least-significant digits” are at the end or right side of a number and are always the least meaningful. Often there are one or more digits at the right side of a measurement result that represent a level of performance that is beyond an instrument’s capabilities. In this manual, the term “significant digits” will be used to refer to all the digits in a measurement result except those that are beyond an instrument’s capabilities. This is a subjective concept since there is no accepted, rigorous method by which to separate one kind of digit from the other.

Automatic Limitations

When making measurements, the AH2700A monitors the amount of noise coming from the unknown impedance. It also monitors its internal systematic error contributions. Using these two error sources, it computes the maximum number of meaningful digits and rounds (rather than truncates) the results so that meaningless or misleading digits are not reported. If the meaningless digits are to the right of the decimal point they are replaced by a space. If they are to the left of the decimal point they are replaced with zeroes.

The AH2700A can report as many as ten digits in a measurement result. For many measurements, not all of these digits will be significant. The bridge’s ability to eliminate meaningless digits reduces the clutter in the results. More importantly, by eliminating meaningless or misleading digits, the bridge ensures that your time is not unintentionally wasted attempt-

ing to interpret such digits. Unfortunately, it is common practice by too many manufacturers to report many more digits than are meaningful or useful.

Reporting that Last Digit

It will sometimes happen that the bridge will not report as many digits as you would like for your measurements. This is most frustrating when the least-significant digit that you would like to get is sometimes reported and sometimes not. The obvious thing to try in this situation is to reduce the noise that the bridge sees by using one or more of the techniques discussed under “MEASUREMENT SPEED VS. MEASUREMENT FLUCTUATION” on page 4-5 and “REJECTING INTERFERING SIGNALS” on page 4-8. If you have applied the features described in those sections; if you are confident that your unknown sample is as noise-free as you can make it; if your application restricts you from increasing the averaging time any further; and if you would still like another digit to be reported, then you will need to consider the approach below.

It is important to understand that the AH2700A does not eliminate digits that contain useful information. The bridge is careful to always choose the number of digits that are reported such that at least one of the least-significant digits is noisy if there is noise in the measurement. This is extremely important because it allows you to *externally* average a number of measurement results to get a number having a higher resolution than the ones reported by the bridge. Such averaging would not be productive if the bridge did not leave some noise in its measurement results. One application of this is to obtain data of higher resolution by averaging the results of relatively fast, synchronously triggered measurements of an unknown sample that is being slowly modulated by some external influence.

Setting a Limit on the Significant Digits

The AH2700A normally reports all significant digits that it has available. Sometimes it is desirable to round off the measurement result to one with fewer significant digits. The FIELD command can be used to specify the number of significant digits (from one to nine) for the capacitance and loss values that are displayed on the front panel and sent to the remote devices. When you limit the number of significant digits in this way, the bridge will automatically round off the result to the number of digits you specify. This feature does not override the automatic limitations described above, it can only further limit the number of digits reported.

The number of significant digits to be reported is selected by changing the *FldCap* and *FldLoss* parameters with the FIELD command. The partial syntax of the FIELD command that changes the number of significant digits is:

```
FIELD , , , FldCap , FldLoss
```

The remaining syntax of the FIELD command is described in “Selecting which Fields to Send” on page 5-6. The *FldCap* and *FldLoss* parameters can have any value from zero to nine but choosing zero causes no result to be sent to remote devices. When counting significant digits, don’t include the decimal point, signs, or the exponential part of numbers expressed in scientific or engineering notation. The default numbers of significant digits for both capacitance and loss are stored in the BASIC FACTPON parameter file. Both default numbers are nine which is the maximum possible.

Examples

To show some examples of the effects of the FIELD command, consider a printout using the default *FldCap* and *FldLoss* parameters of nine.

```
C= 987.654321 PF L= 0.0012345 NS
```

If the command FIELD , , , 2 is executed, the printout would appear as:

```
C= 990.0 PF L= 0.0012345 NS
```

Notice that 987 was rounded to 990 and that the digits that were eliminated were replaced with spaces rather than being deleted. For fixed field width settings (see “Fixed/Variable Field Widths” on page 5-8), this example demonstrates that the FIELD command does not change the starting column numbers of the printed fields. Suppose that the command FI , , , .2 is entered next. The printout will be:

```
C= 990.0 PF L= 0.0012 NS
```

As another example, if the bridge measured a capacitance of 47834.891 PF and you change the number of significant digits to two, (FIELD , , , 2) the bridge will report the result as 48000. The same measurement following a FIELD , , , 6 command would report 47834.9.

RESULT MODES

The AH2700A can be placed into a “Reference result mode” where it reports deviations of capacitance and/or loss from a reference value that you entered *or* measured. These deviations can be presented in an absolute format or as a percentage of the reference values.

The bridge can also be placed into a “Zero result mode” in which compensation is made for stray capacitance and loss that exists in a test fixture used to measure the unknown impedance.

The Reference result mode and the Zero result mode can be active simultaneously.

The default mode of operation has all of the above features disabled. This mode is called the “Absolute result mode”. The default mode is contained in the Reference and Zero parameters in the GAUGE FACTPON parameter file.

Absolute Result Mode

Operation of the AH2700A is most commonly done in Absolute result mode. The measurements taken in Absolute result mode are the actual values of capacitance and loss as seen by the bridge. The values have not been corrected for stray fixture impedances or modified to adjust for other differences or offsets that may exist at the far end of the measurement cables.

Absolute result mode is active when Reference and Zero result modes are both disabled. As explained below, executing the commands REFERENCE OFF and ZERO OFF will cause Absolute mode to be active.

Reference Result Mode

When the AH2700A is operated in Reference result mode, measurement results are reported as a deviation from a reference value that you define.

There are two ways to enter the reference values. You can either enter them manually or the bridge can use the last measured capacitance and/or loss values as the new reference values. In addition, you can choose to report the measurement result as either the absolute deviation from the reference or as a percentage deviation from the reference.

Entering reference values does not necessarily mean that the values are being used to produce deviation results. Enabling Reference mode is a separate operation from entering the values. Entering the values only makes them available for future use. Reference result mode must be enabled to begin using the values to produce deviation results.

Entering Reference Values Manually

To manually enter the reference values, the command

```
REFERENCE POINT [Ref_Pt_C] , [Ref_Pt_L]
```

is used, where *Ref_Pt_C* and *Ref_Pt_L* are the desired reference values for capacitance and loss. The maximum length of the reference values that can be entered is nine digits.

When reference values are entered from a remote device, the values can be negative and may be entered in any of three numeric notations discussed later in “Numeric Notation” on page 5-8. The bridge will automatically detect which format is used.

The Current Units parameter settings are assumed when entering reference values. You can see what the Current units are by using the SHOW UNITS command. If you change the

units *after* entering reference values, these values will be converted to the new units. This is useful if you know the desired reference value(s) in one set of units but wish to make measurements in a different set of units.

The default reference values stored in the GAUGE FACTPON parameter file for capacitance is zero picofarads and for loss is zero nanosiemens.

Entering Reference Values Automatically

The version of the REFERENCE command shown below causes the *last* measured capacitance and/or loss values to become the reference values.

`REFERENCE FETCH [CAPILOSSIALL]`

If no command qualifier is included in the command, then both of the last measured capacitance and loss values are used as the new reference values.

Enabling Reference Result Mode

To enable reporting deviations one must enter a command with the syntax:

`REFERENCE [RefMod_C] , [RefMod_L]`

where the parameter values may be entered as either **ON** or **OFF**. These parameter values enable or disable Reference result mode respectively. Note the omitting a parameter value leaves the current setting unchanged.

This command does not initiate measurements, but its execution will cause the previous measurement result to be *re-calculated* and reported with Reference result mode enabled. If the bridge is not in continuous mode when the command is issued, a **SINGLE** or **CONTINUOUS** command must be entered to make the bridge report a *new* deviation measurement. All subsequent measurements will be reported in Reference mode until Reference mode is disabled.

The Reference-result-mode-enabled condition is stored as a part of each Gauge parameter set. The default value in the GAUGE FACTPON parameter file is the disabled condition.

Disabling Reference Result Mode

To disable Reference result mode, the command syntax is:

`REFERENCE OFF`

Execution of this command will cause the previous measurement result to be re-calculated and reported with Reference result mode disabled.

Selecting Reference Percent Format

The following command is used to enable and disable Reference percent format:

`REFERENCE PERCENT [Percnt_C] , [Percnt_L]`

where the permitted parameter values are **ON** and **OFF**. If either the capacitance and/or loss parameter is entered as a **ON**, then Reference percent format is enabled for the corresponding measurement quantity. This format will have no effect on any reported results unless Reference result mode is also enabled with the REFERENCE command. This will cause the previous measurement result to be re-calculated and reported.

Percent format causes the reference value to be subtracted from each measurement. The difference is then divided by the reference value and multiplied by 100. The calculation always starts with the Current units, but the final result is dimensionless, of course.

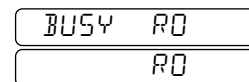
If either the capacitance and/or loss parameter is entered as a **OFF**, the corresponding Reference percent format is disabled.

If either parameter is not entered, then the setting for that measurement quantity will remain unchanged.

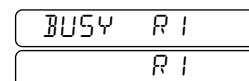
Indication of Reference Result Mode

To indicate to a remote device that Reference mode is enabled for capacitance results, the capacitance units indicator PF changes to R0PF. When the Reference result mode for loss is enabled, the loss units indicator (NS for example) becomes R0NS. When Reference percent format is enabled, the respective units identifiers are R1PF and R1NS.

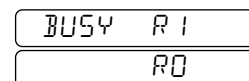
To indicate on the front panel that Reference mode is active, R0 is shown on the appropriate upper and/or lower displays whenever the BUSY message appears:



When Reference percent format is active then R1 is displayed with the BUSY message on the appropriate upper and/or lower displays:



These can also occur in mixed combinations such as:



Another way to see which mode and format is active is to use the **SHOW** command. See "REFERENCE value" on page A-32 for more information about showing the Reference parameters.

Zero Compensation Result Mode

Zero compensation result mode (or simply, Zero result mode) causes the AH2700A to compensate for residual capacitance and *parallel* loss effects that are usually inherent in test fixtures. For a discussion of where this mode might be useful see “COMPENSATING FOR STRAY FIXTURE IMPEDANCE” on page 4-12.

Zero result mode is identical to Reference result mode in many ways, but the mathematical compensation performed in Zero result mode is much more than just a simple subtraction. The compensation calculation performed is dependent upon the units currently in use and can be complicated. The calculations require *both* capacitance and loss Zero values. Thus, the Zero result mode differs from the Reference result mode by not allowing you to enter a capacitance value without a corresponding loss value or vice-versa.

Zero result mode can be used in combination with either Absolute result mode or Reference result mode. There are two ways to enter the Zero compensation values. You can enter the values manually or the bridge can use the last measured capacitance and loss values as the new Zero compensation values.

As in Reference result mode, it is important to understand that just entering Zero compensation values does not necessarily mean that the values are being used to produce Zero compensated results. Enabling Zero result mode is a separate operation from entering the Zero compensation values. Entering the Zero values only makes them available for future use. Zero result mode must be enabled to begin using the values to produce Zero compensated results.

Entering Zero Values Manually

To manually enter the Zero values the command

```
ZERO POINT Zer_Pt_C, Zer_Pt_L
```

is used, where *Zer_Pt_C* is the desired value of capacitance and *Zer_Pt_L* is the desired value of loss. Both *Zer_Pt_C* and *Zer_Pt_L* must be entered. The maximum length of these Zero values is nine digits.

When *Zer_Pt_C* and *Zer_Pt_L* are entered from a remote device, the values can be negative and may be entered in any of three numeric notations discussed later in “Numeric Notation” on page 5-8. The bridge will automatically detect which format is used.

The Current Units parameter settings are assumed when entering *Zer_Pt_L*. You can see what the Current Units are by using the SHOW UNITS command. If you change the units *after* entering the Zero values, these values will be converted to the new units. This is useful if you know the desired Zero value(s) in one set of units but wish to make measurements in a different set of units.

The default Zero values stored in the GAUGE FACTPON parameter file for *Zer_Pt_L* is zero picofarads and for *Zer_Pt_C* is zero nanosiemens.

Entering Zero Values Automatically

The version of the ZERO command shown below causes the last measured capacitance and loss values to become the Zero values.

```
ZERO FETCH
```

This command causes both the *last* measured capacitance and loss to be used as the new Zero values. This command is useful for measuring the stray impedance of a fixture when the fixture contains no DUT or a dummy DUT.

Enabling Zero Result Mode

To enable the reporting of Zero compensated results, you must enter the command:

```
ZERO ON
```

This command does not initiate measurements, but its execution will cause the previous measurement result to be *re-calculated* and reported with Zero result mode enabled. If the bridge is not in continuous mode when the command is issued, a SINGLE or CONTINUOUS command must be entered to make the bridge report a *new* Zero-compensated measurement. All subsequent measurements will be reported in Zero result mode until Zero result mode is disabled.

The Zero result mode enabled condition is stored as a part of each Gauge parameter set. The default value in the GAUGE FACTPON parameter file is the disabled condition.

Disabling Zero Result Mode

To disable Zero result mode use the following command:

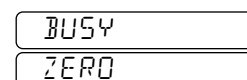
```
ZERO OFF
```

Execution of this command will cause the previous measurement result to be *re-calculated* and reported with Zero result mode disabled.

Indication of Zero Result Mode

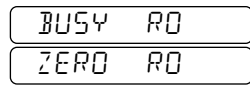
To indicate to a remote device that Zero result mode is enabled, the PF capacitance units indicator changes to ZPF and the loss units indicator (NS for example) becomes ZNS.

To indicate on the front panel that Zero result mode is enabled, the word ZERO is shown on the lower display whenever the BUSY message appears:



```
BUSY
ZERO
```

The Zero indicator will be combined with Reference mode indicators if Reference result mode is also enabled:



Another way to see which mode is active is to use the **SHOW** command. See “ZERO value” on page A-60 for more information about showing the Zero parameters.

FRONT PANEL FORMAT

Measurement results are displayed on the front panel in the formats described above. Unlike the remote device formats, you have no other control over the front panel formats. In almost all cases, the number formats used on the front panel are conventional. An exception to this is explained below.

Displaying Large Numbers with Large Uncertainties

As discussed in “Automatic Limitations” on page 5-1, the bridge always tries to display only digits which are meaningful and not excessively noisy. The display of meaningful resistance values presents a unique challenge in the case of parallel resistance because very small changes in conductance values translate into large changes in very large resistance values. This is due to the division that is required. In situations where the only possible resistance values that could be reported would be wildly varying, the AH2700A reports, instead, only the minimum resistance that the unknown impedance could have. To indicate this minimum resistance, a “greater than” symbol “>” on the front panel is displayed to the left of the resistance value R_p . This symbol is also used with results for $\tan \delta$, C_S , and R_S . See “Field Labels” on page 5-7 for the equivalent discussion for remote device formats.

REMOTE DEVICE FORMATS

Capturing measurement results on remote devices rather than on the front panel gives you greater flexibility in choosing what is reported and how it is formatted. The following sections describes the measurement result formats that are sent to remote devices and how you can customize these formats to meet your needs.

Result Line Format Options

Measurement results that are sent to remote devices can have up to nine significant digits reported versus the eight digits displayed on the front panel.

Measurement results that are sent to remote devices can contain up to six separate fields. A “field” is one number or string value including its associated labeling and punctuation.

The six fields that can be reported in the result line are the:

- Sample number.
- Test frequency.
- Measured capacitance value.
- Measured loss value.
- Actual test voltage used.
- Error code or error message.

You can further control what is sent in the result line by selecting the:

- Presence or absence of field and units labels.
- Punctuation style.
- Fixed vs. variable field widths.
- Numeric notation.

Full Measurement Result Format

A measurement result with all six fields enabled is sent as a single line to a remote device and looks like the following:

```
S=ss F=dddd.d HZ C=±d.dddddddd PF
L=±d.dddddddd NS U=d.dddd U [error message]
```

where:

- ss is a 2-digit sample number. This identifies the position of a sample switch if one is connected. See Appendix D, “Sample Switch Port” for more information.
- the d 's are the measured values of capacitance, loss and the applied test voltage respectively.
- “S=”, “F=”, “C=”, “L=” and “U=” are labels to identify the sample number, frequency, capacitance, loss and voltage values respectively.
- “HZ”, “PF”, “NS” and “U” are units identifiers (hertz, picofarads, nanosiemens and volts) for frequency, capacitance, loss and voltage values respectively. The “NS” label depends on the units selected and can alternately appear as “DS”, “KO”, “GO”, or “GM”.
- If there is an error, an *error message* is sent as the right-most field. If there is no error, no *error message* is sent.

The default measurement result format stored mostly by parameters in the BASIC FACTPON parameter file is identical to the full format described above except that the sample field is omitted.

When the serial port is used and echoing is enabled, a result line being sent to the serial port will begin with a single space character. This serves as a place holder for the prompt character (>) and improves the readability of fixed field width, mixed single and continuous measurements by keeping the data columns aligned.

Selecting which Fields to Send

The FIELD command allows you to select which of six fields in the result line are sent to the remote device. The field parameters allow you to selectively send or not send the sample number, frequency, capacitance, loss, voltage, and/or message fields. An error field will always be sent if an error occurs, but you can select whether it is sent as an English message or as a decimal code. The full syntax of the FIELD command which allows you to set and clear the Field parameters is:

```
FIELD FldSamp,FldFreq,FldCap,FldLoss,
      FldVolt,FldMsge
```

where each of the parameters in parentheses are binary settings having the following effects:

FldSamp enables sending the sample field when ON.

FldFreq enables sending the frequency field when ON.

FldCap disables sending the capacitance field when OFF. Values of 1 to 9 enable sending the capacitance field.

FldLoss disables sending the loss field when OFF. Values of 1 to 9 enable sending the capacitance field.

FldVolt enables sending the voltage field when ON.

FldMsge enables an *error message* to be sent when ON, or an *error code* to be sent when OFF.

As explained in “Setting a Limit on the Significant Digits” on page 5-1, this command also allows you to use the *FldCap* and *FldLoss* parameters to control the number of places that are displayed in the capacitance and loss fields.

The FIELD command uses multiple parameter entry so you only need to enter the values for the parameters that you wish to change. For example, to turn off the *FldSamp* and *FldVolt* fields you issue the `FO ON , , , OFF` command. The other parameters will not be changed. Multiple parameters are explained in “Multiple Parameters” on page A-1.

Field Selection Example

As an example, recall the default Field parameters from the BASIC FACTPON parameter file and show them by executing the command `REC BAS FACTPON;SH FI`. You will get the result:

```
FIELD SAMPLE      OFF
FIELD FREQ        ON
FIELD CAP         9
FIELD LOSS        9
FIELD VOLTAGE     ON
FIELD MESSAGE     ON
```

Notice that only the sample parameter is set to OFF. This means that the frequency, capacitance, loss, and voltage fields will all be sent to a remote device when a measurement

is taken. The exact format for this is shown in “Full Measurement Result Format” above.

Now suppose that you do not want to print the voltage field. Enter the command `FI , , , OFF` to disable sending the voltage field without affecting any other settings. If you take a measurement, your result will now see the fields:

```
F=dddd.d HZ C=±d.dddddddd PF
L=±d.dddddddd NS [error message]
```

Notice that the voltage field is gone. In the same manner, you can clear other parameters to inhibit sending the frequency, capacitance, loss, and/or sample fields.

Error Messages vs. Error Codes

The measurement result formats above included an *error message* in both cases. This *error message* will always appear to the right of any other information that is sent. If there is no error, no message is printed.

If the nature of the error is such that a meaningful measurement cannot be made (hard error), only the *error message* will appear on the line. If the error is one that does not prevent a measurement from being taken (soft error), the *error message* and the measurement result will both be sent.

If your results are to be analyzed by a computer, you might rather have an *error code* sent using the following format:

```
ee S=ss F=dddd.d HZ C=±d.dddddddd PF
L=±d.dddddddd NS U=d.dddd U
```

where *ee* is a 2-digit, decimal *error code*. Using this format, an *error code* always appears at the beginning of the line. The *error code* is sent as “00” if there is no error.

The *FldMsge* parameter described above allows you to select whether an *error message* or an *error code* is sent to remote devices. If *FldMsge* is set then an *error message* will be sent if one exists. If *FldMsge* is OFF then an *error code* will be always be sent. The command `FI , , , , OFF` is used to change the default to a format such as the one above.

As you can see, measurement result lines have either *error codes printed first* or *error messages printed last* depending on the setting of the Field parameters. This option arises from the differences between computer and human readability. When a *computer* is analyzing the data, an error indication should be the first data sent in the result string so that checking for an error condition before accepting the measurement result is easily done. In this case, an *error code* is typically used rather than an *error message*. When a *person* is visually reading the results instead of a computer, error messages are preferable. Since the messages are of variable length, they are reported last to allow orderly column alignment of the measurement results. A list of the error messages and their meaning is in Appendix B, “Error Messages”.

Field Labels

Each numeric value sent may have one or two labels next to it. A field identification label is sent preceding a value and a unit label may be sent following a value. The field labels sent preceding the corresponding values are “S=” to identify the sample number, “F=” for the test frequency, “C=” for the capacitance value, “L=” for the loss value, and “U=” for the voltage value. The unit labels are sent following the frequency, capacitance, loss and voltage values. The unit labels will be “HZ” for frequency, “PF” for capacitance, one of five different units specified by the Units parameter for loss, and “U” for the voltage value.

The **FORMAT** command gives you control over a variety of formatting options including the ability to enable or disable the sending of all of these labels. The full syntax of the **FORMAT** command which allows you to specify and clear the Format parameters is:

FORMAT *Notation, Labeling, IEEE4882, FldWidth*

where the parameters have the following effects:

<i>Notation</i>	specifies kind of numeric notation to be sent. Permitted values are FLOATING , SCI and ENG .
<i>Labeling</i>	enables labels to be sent when set to ON .
<i>IEEE4882</i>	enables IEEE-488.2 compatible punctuation when set to ON .
<i>FldWidth</i>	fixes field widths when set to FIXED . Permitted values are FIXED and VARIABLE .

This command uses multiple parameter entry so you only need to enter the values for the parameters that you wish to change. For example, to turn off the sending of labels, you issue the **F0 ,OFF** command. The other parameters will not be changed. Multiple parameters are explained in “Multiple Parameters” on page A-1.

The **FORMAT** command can be used to enable or disable the sending of all labels. When the *Labeling* parameter is set to **ON**, field labels and unit identifiers will be sent. When set to **OFF** they will not be sent. For example, the command **F0 ,OFF** will change the full format to:

```
ss dddd.d ±d.dddddddd ±d.dddddddd
d.dddd [error message]
```

where all the labeling has been removed from the result line. This option is useful when a computer is analyzing the measurement results. A computer doesn't need labels to help it to identify fields; it may need to be programmed to avoid processing such fields. The *Labeling* parameter also controls the results from other commands such as **SHOW**, **CALIBRATE** and **TEST**.

Both the field identification labels and the units labels have alternate forms that are used to convey additional information. The “=” symbol in the capacitance and loss field labels will be replaced with a “>” symbol in certain situations where the reported values are known to be larger than a certain amount but where it is not known by how much. This can occur when measuring series capacitance and when using loss units of dissipation factor, series kilohms and parallel gigohms. For more information, see “Displaying Large Numbers with Large Uncertainties” on page 5-5 and “Punctuation” below.

The units labels for the capacitance and loss fields can both be immediately preceded by the “Z”, “R”, “0” and “1” characters. The combinations that can appear are **R0**, **R1**, **Z**, **ZR0**, and **ZR1**. These characters are used to indicate that the Reference and/or Zero result modes are active. See “Indication of Reference Result Mode” on page 5-3 and “Indication of Zero Result Mode” on page 5-4 for more information.

Punctuation

The IEEE-488.2 standard defines how data is to be sent over the GPIB. Part of this definition specifies what will be described here as the “punctuation” of the data. Specifically, this standard specifies that fields are to be separated by commas rather than spaces and that strings are to be enclosed in quotation marks. If you desire your results to have this kind of punctuation, then you can set the *IEEE4882* parameter using the **FORMAT** command. For example, the command **F0 , ,ON** will change the full format to:

```
S=ss, F=dddd.d HZ, "C=", ±d.dddddddd PF, "L=",
±d.dddddddd NS, U=d.dddd U, ["error message"]
```

Notice that the space separators have become commas and the error message is enclosed in quotes. The “C=” and “L=” strings contain variable information since the “=” can sometimes be a “>” symbol. For this reason, these labels but no others are enclosed in quotes. The *IEEE4882* parameter also controls the punctuation of results from other commands.

Label and Punctuation Examples

The example in Figure 5-1 is a printout demonstrating the effects of the *Labeling* and *IEEE4882* parameters. First, the command **F1 OFF , OFF** turns off the sample number and frequency fields. Next, the command **F0 ,ON, OFF, FIXED** sets the *FldWidth* parameter to **FIXED** and specifies the *Labeling* and *IEEE4882* parameters for the first result line. The **FORMAT** command is then used three more times to set up all combinations of the *Labeling* and *IEEE4882* parameters to create the four example results shown in the figure. The first example with *Labeling* **ON** and *IEEE4882* **OFF** is optimized for human readability. It provides the maximum number of labels and the minimum punctuation clutter. The third example with *Labeling* **OFF** and *IEEE4882* **ON** is optimized for machine readability and IEEE-488.2 compatibility. It provides no labels and all the punctuation required by the

```

Labeling ON and IEEE4882 OFF:
FO ,ON,OFF,OFF
FO ,ON,OFF,FIXED
C=-0.4271 PF L>40000.0 GO U=15.0 U OVEN

Labeling ON and IEEE4882 ON:
FO ,ON,ON
"C=",-0.4271 PF,"L>",40000.0 GO,
                                U=15.0 U,"OVEN"

Labeling OFF and IEEE4882 ON:
FO ,OFF,ON
" ",-0.4271,">",40000.0,15.0,"OVEN"

Labeling OFF and IEEE4882 OFF:
FO ,OFF,OFF
-0.4271 >40000.0 15.0 OVEN

```

Figure 5-1 Examples of label and punctuation effects.

IEEE-488.2 standard. The remaining second and fourth examples show other variations that might be useful.

No matter which combination of *Labeling* and *IEEE4882* parameters is selected, the ">" symbol will always be sent if it is generated. On the other hand, the units labels with their possible "Z", "R", "Ø", and "1" characters are only sent if labeling is enabled.

Fixed/Variable Field Widths

The AH2700A allows you to determine whether fields sent to remote devices have a fixed or variable width.

When set to a fixed value, the field widths can be thought of as the number of *columns* available (but not necessarily used) to print the numbers in the fields. These field widths are independent of the number of significant places discussed in "SIGNIFICANT DIGITS" on page 5-1. The field width settings are only applicable to data sent to remote devices.

The AH2700A has as many as nine significant digits available for each measurement result for both capacitance and loss. This results in a total of ten digit columns being sent when the field width is fixed.

The main advantage of fixing the field widths is that this also fixes the starting column numbers of each field. This can greatly enhance the readability of columns of results.

The fields can also be set to send exactly the number of significant digits that are available. Since the number of significant digits can vary with each measurement, so can the width of such fields. The advantage of variable fields is that only significant characters are sent, not fill characters. This optimizes speed and memory usage. It also makes the results IEEE-488.2 compatible since no fill spaces are sent. The disadvantage is that the fields will not align into straight columns and will thus be harder to read when printed or displayed.

Field Width Examples

The example in Figure 5-1 is a printout demonstrating the effects of the *FldWidth* parameter. First, the `FIELD OFF,OFF,9,9,OFF` command sets the number of significant digits for capacitance and loss to the maximum (See "Setting a Limit on the Significant Digits" on page 5-1) and turns the remaining fields off. The `FORMAT` command then disables punctuation and enables labeling and fixed field widths.

```

FIELD OFF,OFF,9,9,OFF
FO ,ON,OFF,FIXED
C=140.427134 PF L= 0.000121 NS
C=140.427245 PF L= 0.000105 NS
C=140.42741 PF L=-0.0001 NS
C=140.42748 PF L=-0.00003 NS
FO ,,,VARIABLE
C=140.42749 PF L=-0.000022 NS
C=140.4275 PF L=0.000009 NS
C=140.4275 PF L=-0.000011 NS

```

Figure 5-2 Examples of field width effects.

In the first two measurement result lines, all nine significant digits are shown implying that a high quality measurement was made because all the possible significant digits were sent. In the next two result lines, fewer digits were sent even though no parameter changes were made. This implies that a measurement of lower quality was made which caused a loss of significant digits. Since the *FldWidth* parameter was set to `FIXED`, the number of *columns* sent remained *fixed*, even though the number of *digits* sent *changed*.

Next, the command `FO ,,,VARIABLE` was executed causing *all fields* to become variable width. Notice that all fields in the three lines following this command have no extraneous spaces whereas most fields in the four preceding lines do. (The space preceding the units' labels goes away if labeling is turned off.) Notice also that the columns in the three lines following the command are no longer straight.

Numeric Notation

The AH2700A is capable of both *accepting* input and *formatting* measurement results sent to remote devices in three different numeric notations. These notations are floating-point, scientific, and engineering.

The front panel always displays floating-point notation only. For results sent to remote devices, one of three kinds of numeric notation can be selected for use with frequency, capacitance, loss, resistance, inductance, voltage, length and hold time fields. These fields will all use whichever notation has been selected; the notation cannot be individually specified for different result fields.

Numbers received from remote devices will be accepted no matter which of the three notation types is used. The bridge will automatically sense which type is being sent.

Floating-Point Notation

Floating-point notation has been used in all of the examples given thus far in this chapter. It can be described as a string of characters beginning with an optional sign character. This is followed by one or more digits, followed by a decimal point and ending with one or more digits.

A specific example of a floating-point notation result is:

```
C=113.876543 PF L=0.0076543 NS U=15.0 U
```

Scientific Notation

Scientific notation can be described as a string of characters beginning with an optional sign character followed by exactly one digit and then a decimal point. A least one digit follows the decimal point, the number depending on the number of significant digits to be reported. The portion of the notation described thus far is called the mantissa. The mantissa is immediately followed with a capital “E”, then a sign character and finally two digits. The two digits are a base-ten exponent that indicates the factors of ten by which the mantissa is to be multiplied. If the sign following the E is negative then the mantissa is divided by factors of ten.

A specific example of a scientific notation result using the same numbers as in the last example is:

```
C=1.13876543E+02 PF L=7.6543E-03 NS
U=1.50E+01 U
```

Engineering Notation

Engineering notation is identical to scientific notation except that the mantissas will have from one to three digits to the left of the decimal point and the exponent will appear only in increments of three (i.e. -06, -03, +00, +03,+06, etc.). These exponents are useful because they correspond to engineering unit prefixes of micro, milli, kilo, mega, etc.

A specific example of an engineering notation result using the same numbers as in the last example is:

```
C=113.876543E+00 PF L=7.6543E-03 NS
U=15.0E+00 U
```

Selecting the Numeric Notation

The desired numeric notation to be sent to remote devices is selected by changing the *Notation* parameter with the **FORMAT** command. The *Notation* parameter can be set to 0, 1 or 2. The corresponding notations are:

<u>FLOATING</u>	Floating-point notation
<u>SCI</u>	Scientific notation
<u>ENG</u>	Engineering notation

The default notation stored in the **BASIC FACTPON** parameter file is **FLOATING**.

IEEE-488.2 Compatible Results

The various formatting options discussed in this chapter provide a wide range of ways to format your results. How you format results will be based largely upon whether they are to be read by a person or by a computer. If the results will be read by a person, then the formatting choices will probably be largely subjective, being based upon what you feel most comfortable reading.

If the results will be read by a computer, then there may be existing programs available to help analyze your data. Newer programs are likely to be able to accept data more easily if it is formatted in a standard way. If you are using the GPIB, the newer IEEE-488.2 standard defines the data formats, codes, and protocols that should be used.

If you decide that formatting your data to be IEEE-488.2 compatible is desirable, the AH2700A offers several possible formats. To do this you must disable labeling and enable compatible punctuation. You do this by setting the *Labeling* parameter to **OFF** and the *IEEE4882* parameter to **ON** using the **FORMAT** command. See the paragraphs about “Field Labels” and “Punctuation” above. The IEEE-488.2 standard also requires that there be no extraneous spaces in number fields. This is done by setting the *FldWidth* parameter to **VARIABLE**. See the paragraph about “Label and Punctuation Examples” above. Issuing the command **FOR , OFF , ON , VARIABLE** will correctly change all three of these format parameters.

Having executed this command, you now have a choice of any of the three available numeric notation formats. All three will now be IEEE-488.2 compatible. See the section about “Numeric Notation” above.

This chapter discusses operation of the AH2700A from the GPIB/IEEE-488 port. This chapter and this manual assume that you are familiar with operating instruments using a GPIB controller. The concentration here will be on those aspects of GPIB operation that are specific to the AH2700A. The major options that GPIB operation can give you are discussed in “GPIB Communication Options” on page 1-9 of Chapter 1.

If you are not familiar with GPIB operation, you will probably want to refer to other publications. If there is a GPIB controller in your lab, the better GPIB controller manuals will sometimes have good descriptions of the bus and how to use it. Many different computer languages are used with many different kinds of controllers to operate GPIB instruments. As a result, your GPIB controller manual should be your most important reference. It should explain not only general GPIB operation, but it will also explain the specifics of the controller and the interface language that it uses. The IEEE-488.1 standard specifies the lower-level operation of the GPIB bus operation. This standard is so widely accepted that, with a friendly controller, you should be able to avoid learning much about the hardware details of the GPIB bus.

If you do not yet have a GPIB controller, then you may want to refer to some general references. Many good tutorials and explanations of the GPIB bus have been published. We recommend numbers 1, 5 and 6 in the bibliography. Numbers 5 and 6 contain definitions of the GPIB (IEEE-488) bus standards. These are difficult reading (but very complete) and intended for use by instrument designers. Reference number 1 is quite readable.

The major topics discussed in this chapter are how to:

- Set the GPIB bus address using the GPIB command.
- Save the bus configuration parameters introduced in this chapter using the STORE command.
- Use the bridge’s abbreviated command syntax.
- Read response messages.
- Configure the bridge to operate in a friendly, interactive mode over the bus.
- Change the end-of-line separator, if desired.
- Initiate a GPIB service request.
- Interpret the bits in the GPIB status byte.
- Initialize the bridge over the bus.
- Connect to your GPIB port to log results from your bridge rather than to control your bridge. The **LOGGER** command controls this method of operation.

CONNECTING GPIB CABLING

The AH2700A has as standard equipment a GPIB interface whose connector is on the rear panel. Any GPIB controller may be connected to it. Devices with listen-only capability can also be connected to serve as loggers. Electrical connection is made with any standard GPIB cable having black metric screws. The IEEE-488.1 standard specifies that no more than 15 devices should be connected to the bus and that the total length of cable should not exceed two meters per device or 20 meters total, whichever is less.



CAUTION

It is extremely important that the chassis grounds of all interconnected equipment be properly grounded through the power cord of each piece of equipment. Ground pins on power cords must never be cut off or otherwise defeated. Failure to observe this will frequently cause the GPIB port to be damaged if the port is disconnected while the equipment is plugged in (but not necessarily powered on). The failure results from the ability of power line RFI filter capacitors to cause an ungrounded equipment chassis to float to a voltage midway between the voltages on the two input power lines. This can put the chassis voltage at 50 to 120 volts above ground (for line voltages of 100 to 240 volts) with enough current capacity to be a shock hazard and to cause damage to interface ports. (The AH2700A does not use such filter capacitors, but many other pieces of equipment do.)

GPIB CONFIGURATION PARAMETERS

Several GPIB variables must be set before you can operate the AH2700A via the GPIB bus. Fundamental variables which directly affect the ability of the GPIB to communicate are called GPIB configuration parameters. This section introduces the configuration parameters and explains how to set and permanently save each one. The two address parameters are explained in detail here, while the other parameters are explained as they are encountered throughout the chapter. Each explanation gives the default value of the parameter as stored in the GPIB FACTPON parameter file.

Setting the Configuration Parameters

The GPIB command is used to set the GPIB configuration parameters. The GPIB command can be entered from the front panel or from a remote device using the following full syntax:

GPIB [LIST] *Primary, Secondary, AddrMode, Compatib, Prompts*

The full GPIB command accepts five parameters which are described in different sections of this chapter. Each time the GPIB command is entered, it can be followed by any combination of its parameters provided that the place-holder comma are entered and that the order is preserved. As an example, the entry GPIB 12,,TALKONLY specifies a primary address of 12, the *AddrMode* parameter is set to TALKONLY, and the other three parameters left unchanged.

The GPIB configuration parameters can be changed from the GPIB controller, but the changes take effect immediately so you must be able to change the controller's expectations at the same time if communication between the controller and the bridge is not to be interrupted.

Once the GPIB configuration parameters have been correctly set, sending an addressed SINGLE command to the AH2700A from the GPIB controller should cause the bridge to take a measurement whose result will appear on the front panel of the bridge. The same measurement result should also be readable via the bus by the GPIB controller.

Primary Bus Address ...

If a GPIB controller is used to communicate with the bridge, a unique bus address must be specified for the bridge. This can be selected using the following partial syntax:

GPIB ADDRESS *Primary*

The primary bus address can have any value from 0 to 30 that is not used by another device on the bus. Primary bus addressing *only* is used as long as the *AddrMode* is set to PRI_ONLY. The default configuration is primary only with bus address 28.

Secondary Bus Address

In some cases, it may be desirable to enable a secondary address in addition to the primary address. If a secondary address is enabled, the primary/secondary address combination must be unique on the bus. The general syntax for entering both primary and secondary addresses is as follows:

GPIB ADDRESS *Primary, Secondary*

The secondary address can be selected by itself using the following partial syntax:

GPIB ADDRESS , *Secondary*

where omitting the *Primary* parameter leaves its corresponding value unchanged. The *Secondary* (secondary address) can have any value from 0 to 30. Secondary addressing is enabled by setting the *AddrMode* parameter to PNSCNDRY. This can be accomplished by the following command:

GPIB ADDRMODE *AddrMode*

For example, the commands "GPIB ADDRESS 10,20" and "GPIB ADDRMODE PNSCNDRY" would enable the primary/secondary address combination of 10, 20.

Permanently Saving Your Settings

All the parameters discussed in this chapter are stored in the GPIB parameter set. This set contains all the parameters that are used in conjunction with the GPIB port. An overview of this parameter set is given in Chapter 3, "Parameter and Program Files" in the section "GPIB Parameter Set" on page 3-6.

To permanently save all of the parameters related to operating via the GPIB bus in a way that will automatically restore them after power-on of your bridge, simply issue the command **[↑] ... [STORE] [GPIB] [USERPON] [ENTER]** from the front panel.

To better understand the ways in which you can save your serial device parameters, refer to "WORKING WITH FILE CONTENTS" on page 3-9 and especially "Power-on Parameter Files" on page 3-2 and "Using Power-on Parameter Files" on page 3-10.

STATES AND INDICATORS

The local, local-with-lockout, remote and remote-with-lockout IEEE-488.1 standard states are discussed in the sections below.

Local States

In the local state all of the keypad functions on the front panel can be used and the bridge will also respond to the GPIB controller. The bridge powers on in this state. The local state is indicated by the REMOTE LED on the front panel being off.

The local-with-lockout state functions identically to the local state. The only difference is that this state *remembers* the lockout condition so that if the controller returns the instrument to the remote states, the remote-with-lockout state will be entered automatically. The local-with-lockout state is entered from the local state only when the GPIB controller executes the LLO GPIB command. The local-with-lockout and remote-with-lockout states are exited only when the controller clears the REN bus line.

Remote States

The GPIB controller can cause the bridge to enter the remote state from the local state by setting the REN bus line and addressing the bridge. The bridge will indicate the remote state by illuminating the REMOTE LED on the front panel and will accept commands *only* from the GPIB controller.

In the remote state, all front panel keys with the exception of the **[LOCAL]** key are disabled. The front panel keys can be enabled by pressing the **[LOCAL]** key to cause the bridge to enter the local state. This will occur unless the remote-with-lockout state is active. The GPIB controller can cause the bridge to exit the remote state and enter the local state by executing the GTL GPIB command. It can also do this by clearing the REN bus line.

The remote-with-lockout state is entered from the remote state when the controller executes the LLO GPIB command. The remote-with-lockout state is entered from the local-with-lockout state when the controller addresses the bridge.

When in the remote-with-lockout state, the **[LOCAL]** key is disabled as well as all the other front panel keys, preventing *any* front panel activity from interfering with remote operation.

The GPIB controller can cause the bridge to exit the remote-with-lockout state and enter the local-with-lockout state by executing the GTL GPIB command. The controller can also cause the bridge to exit the remote-with-lockout state and enter the local state by clearing the REN bus line.

REMOTE COMMAND ENTRY

The entry of commands from a GPIB controller is identical to that from a remote serial device except that immediate-action keys described in the Serial Port Operation chapter are not as useful with the GPIB.

Basic Syntax

The AH2700A uses a command line entry style. The syntax and command words used closely parallel those used by the bridge's front panel. The AH2700A command *definition* syntax is described in "CONVENTIONS USED" on page A-1.

Command lines consist of a leading command word followed by optional command qualifier words followed by optional parameters which are usually numeric. Each command line is terminated with an end-of-line character or character sequence.

Command Word Entry

Since remote commands are named and spelled as they appear on the front panel, any commands described in this manual using key labels also describe the remote commands. When the front panel key label consists of two words, only the first word is used as the remote command word. The **[FUNC]** key has no equivalent on remote devices, of course.

Although commands are English words, it is rarely necessary to use the entire word. You need to use only the first few letters of the command. The minimum number of letters needed depends on the particular command and ranges from one to three letters. The minimum letters needed are underlined where each command is introduced in the text and in "Command Reference" on page A-1. If you do not type in enough letters, the bridge responds with the message **AMBIGUOUS WORD:**, followed by the offending characters that were entered. If more letters than the required minimum are entered, they must spell the command word correctly or the error message **ILLEGAL WORD:** will appear, followed by the illegal word that was entered.

Command words are separated from each other and from their associated parameters by spaces. Parameters are separated from each other by periods.

Examples

To illustrate the ideas above, consider the **BRIGHTNESS** command whose partial syntax is:

```
BRIGHTNESS [CAP | LOSS] Brit_
```

Several examples of valid command lines that might be sent from a GPIB controller are:

```
BRIGHT CAP 5
```

```
BR C 5
```

```
BRIG LOS 5
```

```
BR 5
```

All are terminated by an end-of-line character.

The entry **B 5** will return the error message:

```
AMBIGUOUS WORD: B
```

The entry **BRIHGT 5** will return the error message:

```
ILLEGAL WORD: BRIHGT
```

Additional Features

Query Commands

All AH2700A commands can be classified as query or non-query commands. A query command is one that generates a response message such as a measurement result. The most common examples of these on the AH2700A are the **SINGLE**, **CONTINUOUS** and **SHOW** commands. If a query command is interrupted by a new command, the query command is immediately aborted, any unread results are cleared from the bridge's output buffer and the new command begins to execute.

A non-query command will finish executing even if it is interrupted by a new command. The new command will be executed after execution of the non-query command is complete.

The concept of query commands is defined by the IEEE-488.2 standard and serves to ensure synchronization between the controller's commands and the responses from the controlled device. In other words, this scheme ensures that any response message received by a controller was generated by the most recently entered command and not by some earlier command. See "Aborting Commands" on page 2-6.

Entering Multiple Commands

Several commands can be entered on the same line separated by semicolons (;). As with individual commands, lines having multiple commands are not executed until an end-of-line character or character sequence is received. An immediate-action command such as **Q** or **X** can be entered anywhere on a multi-command line except as the first character and will not be executed until the whole line is received.

Each command line is either a query line or a non-query line. If a multi-command line contains any query commands, the whole command line is considered to be a query line. It will not be possible to predict which commands were executed and which were not if a query command line is interrupted by a new command.

Multi-command lines can be useful with commands that respond with a prompt. For example, every version of the **STORE CALIBRATE** command prompts for a passcode. The passcode can be entered after the command on the same line if the two are separated by a semicolon. Except for passcodes, any command that requires a response to a prompt will first check the next command on the line. If the next command is an acceptable response to the prompt then it will be used. If not, the next command will not be executed yet. Instead, the prompt will be produced and the bridge will wait for input. If you want to guarantee that a prompt is generated, insert the **SPECIAL** command word where the answer to the prompt would go on the command line.

Multi-command lines can also be used to guarantee that a command produces a result. The **TEST** command can be configured to produce no result unless a failure is detected. However, the command line **TEST; SHOW TEST** will always produce a result.

Input Buffer

All command messages including **GET** messages are stored in the bridge in an input buffer that can hold eighty characters. This means that the bridge will not buffer more than eighty characters ahead of what it is able to process. In addition, it will not accept a command line whose total length exceeds eighty characters. If the latter occurs, the error message **LINE TOO LONG** will be reported.

RESPONSE MESSAGES

All multi-character data is sent over the GPIB in the form of "messages". Data which is sent *from* the bridge to a controller or logger is sent in the form of "response messages". These messages consist of at least one ASCII character. The **END** of the message is indicated by simultaneously asserting the GPIB EOI bus wire during the transmission of the last character of the message which is a LF character (ASCII 0A_H).

A response message consists of one or more lines. Each line is terminated with a semicolon ";" or with CR and LF characters (ASCII 0D_H and 0A_H). The choice of line terminators used is selectable as described in "COMPATIBILITY MODE" on page 6-14.

Almost all query commands generate a single response message. If several commands are entered on a single line separated by semicolons, that command line produces only one response message for the line, not one for each command on the line.

The AH2700A has several commands that can generate multiple response messages. Among these is the **CONTINUOUS** command. The **CONTINUOUS** command generates response messages continuously until stopped by the **SINGLE** command.

Receiving Every Response Message

Some response messages can be lost if the controller or logger is not fast enough or if the controller is not programmed appropriately. However, you have control over what, if anything, is lost by the way in which you operate the bridge and the controller.

Once the controller or logger begins to read a response message, the bridge will wait indefinitely for the rest of the message to be read. This makes it impossible to lose *part* of a message due to a slow response from the controller or logger. On the other hand, if the bridge has a new response message to send before *any* of the previous message has been read, then the previous message will be overwritten by the new message. Thus controllers and loggers are guaranteed to receive *all* or *none* of a response message.

There are two ways in which you can lose a response message:

1. If the controller issues a new command to the bridge while the bridge is waiting for it to read (or finish reading) the last response message, the remainder of that message will be lost. This occurs when a query command is interrupted as described in "Query Commands" on page 6-3. The way that you program and operate your controller determines whether this situation ever occurs.
2. If the bridge is generating multiple response messages as it would from a **CONTINUOUS** command, some

messages can be lost if the controller or logger is not fast enough to keep up with the results generated by the bridge.

If it is important that every response message be received by a controller, then commands that generate multiple response messages should not be used. The **SINGLE** command, for example, should be used instead of the **CONTINUOUS** command.

If it is important that every response message be received by a logger, then, if necessary, the **WAITFOR DELAY** command should be used within a macro to add some delay time between each response message. This can slow the bridge down to the speed of the logger.

You *may not* want to capture every result. You may, for example, want to put the bridge into continuous mode so that new measurements are constantly reported to the front panel display while reading only a small fraction of these measurements with the controller.

Using a Multi-command Line to Create a Single Response

The most important difference between commands entered on a single line and commands entered each on their own line is in the response messages that they produce. Generally each command line produces, at most, one response message; except when the command line contains commands such as **CONTINUOUS** that produce multiple response messages.

In general, all commands entered on a single line will produce a single response message containing all the results generated by the commands on that line. No matter how slow your controller is, it will be sent all of this message if it reads any of it.

Using a Macro to Create One Response Message

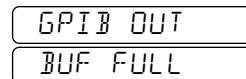
Placing your commands into an AH2700A macro is another way to guarantee that *all* results from a group of commands are received by a controller or logger. All programs produce a single response message. If a macro contains submacros, the results from all submacros are also contained in the single message produced by the main macro. See “WORKING WITH PROGRAMS” on page 3-10.

As an example, a macro containing the commands **TEST TOTAL** with the *TstTotal* parameter set to 50 will cause every result to be logged no matter how slow the logger is. The command by itself will lose results if the logger is not as fast as the bridge.

Output Buffer

The GPIB output buffer can hold response messages up to 680 characters in length. This is long enough to hold any individual measurement result, but it is not long enough to hold some **SHOW**, **TEST** and **MACRO** response messages. In the case where the length of the response message exceeds

the size of the output buffer, the controller or logger *must* begin reading the message *before* the buffer overflows. Otherwise, the entire message will be lost. Once the first character of the result is read, the AH2700A will not generate more results to put in the buffer until the space becomes available as a result of the controller’s reading what is there. If the controller starts to read the message but stops or pauses before finishing, the message



will appear in the front panel display after about ten seconds. This message will go away as soon as the controller or logger continues reading the message.

STATUS REPORTING

A common feature in GPIB instrumentation is the availability of a status byte that can be read by the GPIB controller at any time without disturbing other operations. Associated with this status byte is a service request enable mask byte which controls the ability to generate service requests that will asynchronously request attention from the controller. The most common use of serial polls and service requests is discussed in “Determining When to Read Results” on page 6-9 and in the subsections on “Serial Polling” and “Service Requests”.

Contents of the GPIB Status Byte

The AH2700A supports the serial poll features of the GPIB bus by assigning all of the available seven bits in its status byte (SB) register to indicate various events and conditions. To identify the meaning of each of these bits, assume that they are numbered with the least significant bit being zero and the most significant bit being seven. The meanings and functions are given in Table 6-1.

This table gives the full name and the abbreviated label used in this manual for each bit. The column labeled “Set when” describes the condition(s) required to set the corresponding bit. Similarly, the column labeled “Cleared when” describes the condition(s) required to clear the corresponding bit.

In general, service requests may be generated when one of these bits makes a transition from zero to one, from one to zero or both. The column labeled “Generates SRQ when” describes the transition required of the bit to cause a service request. This is discussed further in “The Service Request Enable Mask Byte” on page 6-7.

The meaning of bit six of the status byte depends upon whether it is read with a command or it is read by a serial poll. This is explained in the sections below.

The possible applications of the NVL, CmE, POn, and ExE bits are self-evident. See Appendix B, “Error Messages”, for

Table 6-1 Status byte register bit definitions and functions

Bit	Label	Name	Set when	Cleared when	Generates SRQ when
0	NVL	Oven Not Ready	Oven temperature is abnormal	Oven temperature returns to normal	set or cleared
1	CmE	CoMmand Error	An error in the entry of a command occurred. See Appendix B, “Error Messages” for a list.	STB? or RST is executed	set
2	URq	User ReQuest	The USER command is executed	STB? or RST is executed	set
3	POn	Power-ON	Line power to the bridge comes on	STB? or RST is executed	set
4	Rdy	ReaDY for command	A command line finishes its execution; see “INTERACTIVE OPERATION” on page 6-11	A new command line is received	set
5	ExE	EXecution Error	An error occurred executing a command. See Appendix B, “Error Messages” for a list.	STB? or RST is executed	set
6	RQS	ReQuest for Service	Service from controller is requested	Controller performs a serial poll	see text
6	MSS	Master Summary Status	Inclusive OR of the bit-wise combination of bits 1-7 of the SB and SRE registers is true or when the ONR status bit changes while the corresponding ONR bit in SRE register is set.	Inclusive OR of SB and SRE is false	see text
7	MAv	Message AVailable	A message is available in the GPIB output buffer	No message is in the GPIB output buffer.	set

a complete list of all the error conditions that can set the CmE and ExE bits. The MAv bit is the single most useful status bit. Its utility is discussed in “Determining When to Read Results” on page 6-9. Examples follow the discussion. The Rdy bit is probably the second most useful bit. Its utility is discussed in “INTERACTIVE OPERATION” on page 6-11. The use of the URq bit is discussed next.

A User Settable Status Bit

There is one bit in the AH2700A status byte that you can *directly* cause to be set by issuing a command. This is the User ReQuest (URq) bit (bit 2). The URq bit is set by executing the command:

USER

Once set, this bit will stay set until a STB? or RST command is executed.

This command allows you to indicate to the GPIB controller when certain conditions of your choosing occur. The USER command gives you the ability to indicate the initiation or completion of commands in command lines having more than one command or in AH2700A programs.

As an example, suppose an external trigger is to cause a measurement to occur. If the command line or macro executed is “WAITFOR; USER; SINGLE”, then the GPIB controller will be informed via the setting of the URq bit in the status register (or via an equivalent service request) that an external trigger has just initiated a new measurement.

Reading the Status with a Command

The status byte can be read with commands whose syntax is:

STB? or *STB?

The results from the STB? and *STB? command forms will be reported as individual binary bits and as a binary-weighted-decimal integer respectively.

These command also clear the four event status bits (CmE, URq, POn and ExE) in the status byte and the ONR *event* bit. These bits indicate the occurrence of *events* whereas the ONR, Rdy and MAv status bits represent *states or conditions*.

While not apparent by reading the table, there is both an ONR *status* bit and an ONR *event* bit. The ONR status bit always indicates the current condition of the oven. The ONR event bit is set when the ONR status bit changes. There is no way to read the ONR event bit.

These commands read the event bits in the status byte *immediately before they are cleared* so that no information can be lost between the time they are read and the time they are cleared. In addition to the STB? and *STB? commands described above, the following commands are also available for reading the status without clearing the event status bits:

*STB or SHOW STB

These report results are similar to the The STB? command is not available from the front panel of the AH2700A. How-

ever, the status can be read from the front panel using the **SHOW STB** command.

These commands will always return the most recent status byte value in the GPIB output buffer. The meanings of the status byte bits are independent of how the byte is read except for bit six. When these commands are used, bit six of the status byte is read as the Master Summary Status (MSS). This bit provides a summary of all the other status bits that have been enabled to cause service requests. The MSS bit does not necessarily indicate that a service request is pending. It only indicates that one was initiated and may or may not have been serviced. This is discussed in more detail in “Selecting What Can Make Requests” below.

Reading the Status with a Serial Poll

A serial poll is an operation performed by the GPIB controller to read the status byte(s) of a device or group of devices. More specifically, a serial poll is most often used to determine which devices are ready for service and what the nature of that service should be. The advantage of a serial poll is that it does not disturb the operations of the instrument that is being polled. The controller can either periodically perform a serial poll of all devices to determine their current status or the controller may do so only when interrupted by a service request from one of the remote devices.

The status information obtained with a serial poll will be identical to that obtained with the commands described above except for the value of bit six. When read using a serial poll, bit six is always the ReQuest for Service (RQS) bit, not the MSS bit. Bit six will be set if the bridge initiated a service request, and clear if it did not. Performing a serial poll clears the RQS bit but has no effect on any other bits in the status register including the MSS bit.

Reviewing the technical details required to perform a typical serial poll, the controller first sends an SPE GPIB command to the remote devices. This places the remote devices in serial poll mode. The controller then addresses each device one-by-one to talk. Each device returns its own status byte to the controller when its turn to talk comes. The controller can act on this status information immediately or save it for later analysis. When all the devices have been polled, the controller sends the SPD GPIB command followed by the UNT GPIB command.

Most controllers provide simple ways of performing serial polls. For examples, see “Controller Initiated / Serial Poll” on page 6-10 and “Non-Controller Initiated / Serial Poll” on page 6-11.

Service Requests

If the other devices in the system have the GPIB service request function in addition to the serial poll function, then the use of service requests in conjunction with the serial poll function is probably preferable to doing serial polls by themselves. To use service requests, your controller must first

enable this function in each of the desired individual instruments using the commands defined by the manufacturers of these instruments. The controller is then free to ignore the GPIB and perform other lower priority tasks. When one or more of the instruments on the bus requires service, it will assert the SRQ bus line which in turn will interrupt the controller. The controller then performs a serial poll in the manner described earlier. When the controller reads the status byte of the device that asserted the SRQ line, the device will release this line. If that device was the only requesting device, the line will become unasserted. If the controller is checking the SRQ line, it can terminate the poll at this time. The bits in the status byte read from the requesting device should indicate the nature of the service that the requesting device requires.

If more than one device on the bus had requested service, then the SRQ line will not become unasserted when the status byte of the first requesting device is read. For this reason, it is essential when there is more than one remote device on the bus with service requests enabled, for the controller to test the RQS bit (bit six) of the status byte that is received from each device. The requesting device(s) will always have this bit set and thus the controller can determine which devices need service even if there is more than one. The GPIB controller must service each request before another request can occur.

The next two sections explain how to enable service requests in the AH2700A. Examples of their use are given in “Controller Initiated / Service Request” on page 6-10, “Non-Controller Initiated / Service Request” on page 6-11 and “Two Interactive Macro Examples” on page 6-13

The Service Request Enable Mask Byte

To control which status changes can cause service requests to occur, the AH2700A contains a second register called the “Service Request Enable mask byte” abbreviated SRE. The bits in this register mirror those in the status byte except for bit six which is not used in the SRE byte.

The SRE byte is used to determine which bit changes in the status byte are allowed to send a service request to the GPIB controller. Any bits which are set in the SRE byte will allow certain changes in the corresponding bits in the status byte to cause a service request. Which status changes (set or clear) that are actually allowed to cause a service request are listed for each bit in the column labeled “Generates SRQ when” in Table 6-1.

Selecting What Can Make Requests

To specify which of the bits in the AH2700A status byte are allowed to initiate a service request, the following command can be issued only from a remote device to set bits in the SRE byte:

SRE *MAv* , *ExE* , *Rdy* , *POn* , *URq* , *CmE* , *ONR*

where each label that is entered is a one if transitions in that status condition are to cause a service request and zero if not.

This command uses multiple parameters as described in “Multiple Parameters” on page A-1. The example `SRE ,1,,,0,1` will enable the *ExE* and *CmE* error event bits to cause service requests. The *URq* event status bit will be disabled and all other SRE bits will be left as they were.

The binary parameter accepted by the `SRE` command shown above is easier to use and more flexible than the conventional binary weighted decimal that is standard. If you prefer to use the standard, enter the command:

`*SRE SREMask`

The *SREMask* (binary-weighted-decimal mask) value can have any value from 0 to 255. When this value is translated to binary, the bit positions that are ones will cause the corresponding service requests to be allowed. The only exception is bit position six which is ignored. The default value of the service request enable mask stored in the GPIB FACTPON parameter file is zero.

Note that under certain conditions it is possible for the AH2700A to cause extraneous service requests. This is not a problem provided that the controller always performs a serial poll after each service request to verify that a new reason for service has actually occurred. Note also that all status bits must be treated like *states*, not *events*, since *multiple* service requests might occur for the same status bit.

Reading the Service Request Enable Byte

The current value of the service request enable mask can be read using the commands:

`SHOW SRE`
or
`*SRE?`

When using the first form of the command the value will be reported as individual binary bits. When using the second form of the command the value will be reported as binary-weighted-decimal integer format.

MAKING GPIB MEASUREMENTS

This section discusses the various ways that a GPIB controller can be programmed to initiate measurements and read results from the AH2700A. There is not much that is unique to the AH2700A presented in this section. With the exception of the exact command syntax, everything discussed here is typical of other GPIB measuring instruments. This section should be helpful if you are not very familiar with GPIB operation and are looking for some examples to get started with.

Initiation of Measurements

There are two fundamentally different ways of initiating measurements in a GPIB environment. Either the GPIB controller can initiate them or something else can initiate them.

Controller Initiated Measurements

A GPIB controller has two ways of initiating measurements.

1. One way is to use the `SINGLE` or `TRG` commands to start a measurement. These AH2700A commands are each capable of initiating a single measurement. They are described in more detail in “Taking Measurements One at a Time” on page 4-4.
2. A measurement can also be initiated from the controller with a `GET` (Group Execute Trigger) GPIB command if the bridge is addressed to listen. The `GET` command will be executed by the bridge in the remote or in the local states. This command has the ability to simultaneously trigger a number of devices that are connected to the GPIB bus. This can be useful for fast GPIB devices, but offers little advantage with the AH2700A.

The common characteristic of the `SINGLE`, `TRG` and `GET` commands is that the controller initiated these commands and therefore, the controller “knows” when the corresponding results are expected to be available.

Non-Controller Initiated Measurements

There are several ways that measurements can be initiated without the GPIB controller being involved. These are:

1. The bridge can be programmed so that a signal on the external trigger input of the AH2700A can initiate a measurement.
2. The `SINGLE` key on the front panel of the bridge can initiate a measurement.
3. The `CONTINUOUS` command will cause the AH2700A to initiate readings on its own at a rate specified when the command is entered. Although the GPIB controller could issue this command, the resulting readings cannot be considered to be controller initiated. The controller would “know” the *rate* at which measurements would be taken, but it would not “know” *when* the results would be available.
4. Macro files in the AH2700A can initiate more complex measurement sequences. The `TRG` and `GET` commands also have this ability.

The common characteristic of the external trigger, front panel `SINGLE` key and `CONTINUOUS` commands and possibly of the programmed command sequences, is that the controller did not initiate these commands. Therefore, the controller “does not know” when the corresponding results are expected to be available without its getting more information.

Synchronization

Perhaps the most important reason for distinguishing between controller and non-controller initiated measurements is the effect upon synchronization. It is frequently critical to know that a given measurement result was caused by a particular initiation event and not by the initiation event preceding or following the desired event. Synchronization occurs when the result read by the GPIB controller is always caused by the desired initiation event.

When the controller initiates each individual measurement, synchronization is automatically obtained if the controller does not initiate another measurement until the result from the current measurement has been read. (To guarantee synchronization, it is essential that a measuring instrument automatically aborts query commands which are interrupted by other commands.)

When the controller does not initiate each individual measurement, it will have no way to maintain synchronization unless other information or signals can be used.

Determining When to Read Results

Once a measurement has been initiated, the AH2700A will then spend anywhere from under 30 milliseconds to about 2500 seconds making the requested measurement. The GPIB controller then has three methods available to read the result from the bridge. These are discussed in the three sections below in increasing order of performance.

Hanging the Bus

The simplest way for a GPIB controller to get results from a bridge is to initiate a data transfer from the bridge anytime a measurement result is expected to be forthcoming. This will cause the GPIB bus to be hung until a result becomes available from the bridge. There is little disadvantage to this approach *if* no other devices on the bus need to be serviced during this time and *if* the controller does not need the processing time for another task.

Serial Polling

The GPIB controller can be programmed to periodically perform a serial poll of the status bytes of all the active devices on the bus. Such polling could read the status byte of the AH2700A to see if a result is available. If the MAv bit in the status byte is set, then the measurement has been completed and it (or an error message) can be read by the controller.

When there are a number of devices on the GPIB bus, a disadvantage to this approach is that controller programs may have to be carefully written to ensure that the status byte is checked often. Otherwise, if measurements are not controller-initiated, data may be lost since the most recent measurement result will overwrite any unread previous result.

Service Requests

The highest performance method is to use the service request interrupt capability of the GPIB bus. With the MAv bit of the AH2700A service request enable mask set, the GPIB controller will be interrupted every time a measurement result becomes available. This allows the controller to start a measurement and then perform other tasks until a service request occurs. The controller then does a serial poll to find out which device caused the interrupt. If it finds that the RQS bit (bit six) in the AH2700A status byte was set then it knows that the AH2700A generated a service request to the controller. The controller should then check the other bits in the status byte to see if the expected measurement result is available or if some kind of error has occurred instead or in addition. If it finds the MAv bit set and no error bits set, then the measurement result can be read from the bridge and assumed to be valid.

Using service requests almost always minimizes the amount of GPIB controller processing time used. The amount of time spent doing GPIB bus operations is also almost always minimized.

Six Examples

Each section below gives one example of a program having the characteristics given in its section title. The programs show several different examples of both controller and non-controller initiated measurements. All programs are written in TransEra HTBASIC which emulates an HP9000 series 200/300 workstation. The AH2700A default parameters are assumed.

None of the example programs in this chapter test the status byte for errors because all errors generate a result, even for commands that are not ordinarily query commands. Thus it is only necessary to report any results that become available in order to catch any error messages that might occur. For examples using a serial poll, it is only necessary to test the MAv bit to detect a possible error message. The ExE and CmE error bits need not be checked if MAv is checked and if the corresponding result is reported.

Controller Initiated / Bus Wait

The first example, shown in Figure 6-1, is the very simplest. This program contains a short loop which issues a SINGLE command to the AH2700A, then immediately sets up a data transfer from the bridge. The controller then waits as long as necessary for the measurement result to be returned. When it is, the controller reports the result and starts the loop again.

```
100 DIM A$(80)
110 OUTPUT 728; "SINGLE"
120 ENTER 728; A$
130 PRINT A$
140 GOTO 110
150 END
```

Figure 6-1 A simple controller-initiated program.

Pros and cons:

- Simplest to implement.
- No readings are ever lost.
- Maximum measurement rate if controller initiates readings before bridge finishes measurements.
- Wastes controller execution time if controller initiates readings before bridge finishes measurements.
- Wastes bus operation time if controller initiates a reading before bridge finishes a measurement.

Controller Initiated / Serial Poll

The second example, shown in Figure 6-2, uses the GPIB GET command to initiate a measurement. A GET macro in the AH2700A producing a *single* measurement result is assumed to exist. An example is given in “Initiating with a TRG/GET Program” on page 4-4. After measurement initiation, the controller stays in the serial poll program loop until the MAV bit (bit seven) in the AH2700A status byte is set. When this occurs, the result is reported and the main program loop is started again.

```
100 DIM A$[80]
110 OUTPUT 728; "GPIB , , , ON, OFF "
120 TRIGGER 728          !ISSUE A "GET"
130 S=SPOLL(728)
140 IF NOT BIT(S,7) THEN GOTO 130
150 ENTER 728; A$
160 PRINT A$
170 GOTO 120
180 END
```

Figure 6-2 A GET-initiated, serial poll program.

Pros and cons:

- No readings are ever lost.
- High measurement rate.
- Wastes controller execution time.

Controller Initiated / Service Request

The third example, shown in Figure 6-3, uses the TRG command to initiate each measurement. As in the previous example, an appropriate GET macro such as that in “Initiating with a TRG/GET Program” on page 4-4 is assumed to exist. After service requests are enabled and the initial TRG command is issued, the controller program is free to execute any other code that might be useful.

When the bridge has a result, it will generate a service request which will cause the controller to begin executing the program’s interrupt code. This code will poll the instruments on the bus to see which have the RQS bit (bit six) set. When the controller finds this bit set in the AH2700A’s status byte, it will check the MAV bit (bit seven) to see if the measurement completed. If so, the result is reported, a TRG command is issued again to start another measurement, and the

controller returns to the code that was executing at the time of the service request interrupt.

```
100 DIM A$[80]
110 ON INTR 7 GOSUB 170
120 OUTPUT 728; "GPIB , , , ON, OFF "
130 OUTPUT 728; "SRE 1;TAG"
140 ENABLE INTR 7;2
150 GOTO 150          !IDLE LOOP
170 STATUS 7,1; S !CLEAR CONTROLR STATUS
180 S=SPOLL(728)
190 IF NOT (BIT(S,6) AND BIT(S,7))
    THEN GOTO 230
200 ENTER 728; A$
210 PRINT A$
220 OUTPUT 728; "TAG"
230 ENABLE INTR 7;2
240 RETURN
250 END
```

Figure 6-3 A controller-initiated program using service requests.

Pros and cons:

- Minimizes controller execution time.
- No readings are ever lost.
- High measurement rate.
- Minimizes effects on operation of other GPIB devices.

Non-Controller Initiated / Bus Wait

The fourth example, shown in Figure 6-4, is similar to the first except that measurements are started with the CONTINUOUS command. This command is issued once at the top of the program. Since the default value for the continuous interval time parameter *Interval* is zero, the bridge will take measurements at a rate determined by the AVERAGE command.

The program contains a short loop which immediately sets up a data transfer from the bridge. The controller then waits as long as necessary for the measurement result to be returned. When it is, the controller reports the result and starts the loop again. If the time used by the controller to read and report the result is less than the time used by the bridge to make a measurement, then no measurement results will be missed.

```
100 DIM A$[80]
110 OUTPUT 728; "CONTINUOUS"
120 ENTER 728; A$
130 PRINT A$
140 GOTO 120
150 END
```

Figure 6-4 A simple non-controller-initiated program.

Pros and cons:

- Simple to implement.
- Front panel display always shows the latest measurement independent of the controller’s actions.

- No readings are ever lost only if the controller consistently begins reading the bridge before the bridge finishes the next measurement.
- Maximum measurement rate if controller initiates readings before bridge finishes measurements.
- Wastes controller execution time if controller initiates readings before bridge finishes measurements.
- Wastes bus operation time if controller initiates a reading before bridge finishes a measurement.

Non-Controller Initiated / Serial Poll

The example in Figure 6-5 is similar to that in Figure 6-2 except that the measurements are assumed to be initiated by signals entering the external trigger input of the AH2700A. This example creates an external trigger macro and stores it in `MACRO EXAMPLE`. This macro file causes a single measurement to occur for each external trigger pulse or contact closure. As in the previous example, if the time used by the controller to read and report the result is less than the time used by the bridge to make a measurement, then no measurement results will be missed. However, trigger pulses can be lost (ignored) if they occur too rapidly. See “Handling Unexpected Trigger Pulses” on page 3-14 for more information.

```

100 DIM A$[80]
110 OUTPUT 728; "MACRO CREATE"
120 OUTPUT 728; "WAITFOR"
130 OUTPUT 728; "SINGLE"
135 WAIT .1 !NEED AFTER QUERY IN MACRO
140 OUTPUT 728; ""
150 OUTPUT 728; "STORE MACRO EXAMPLE"
160 OUTPUT 728; "MACRO RUN EXAMPLE"
170 S=SPOLL(728)
180 IF NOT BIT(S,7) THEN GOTO 170
190 ENTER 728; A$
200 PRINT A$
210 GOTO 160
220 END

```

Figure 6-5 A non-controller-initiated macro using serial polls.

Pros and cons:

- Front panel display always shows the latest measurement independent of the controller’s actions.
- No readings are ever lost due to a slow controller since the `WAITFOR` command synchronizes the controller to the external trigger buffer.
- High measurement rate.
- Wastes controller execution time.

Non-Controller Initiated / Service Request

The example in Figure 6-6 is similar to that in Figure 6-3 except that the measurements are assumed to be initiated by a person that has executed a command from the front panel of the bridge. This can be any command or AH2700A macro that generates measurement results.

```

100 DIM A$[80]
110 ON INTR 7 GOSUB 180
120 OUTPUT 728; " GPIB , , , ON, OFF; SRE 1 "
130 OUTPUT 728; " LOG GPIB READINGS "
140 LOCAL 728
150 ENABLE INTR 7;2
160 GOTO 160 ! IDLE LOOP
170 !
180 STATUS 7,1; S ! CLEAR CONTROLR STATUS
190 S=SPOLL(728)
200 IF NOT (BIT(S,6) AND BIT(S,7))
    THEN GOTO 230
210 ENTER 728; A$
220 PRINT A$
230 ENABLE INTR 7;2
240 RETURN
250 END

```

Figure 6-6 A non-controller-initiated program using service requests.

The controller program enables service requests and then causes a GPIB GTL bus command to be executed. This puts the bridge in the local state so that commands entered on the front panel will be accepted. The program could have unasserted the GPIB REN line instead of causing a GPIB GTL bus command to be executed.

This program changes the Logger GPIB configuration to its default value of `READINGS` in case it has been changed to `OFF`. Otherwise, the controller will not receive any results.

Pros and cons:

- Minimizes controller execution time.
- Front panel display always shows the latest measurement independent of the controller’s actions.
- No readings are ever lost only if the controller consistently begins reading the bridge before the bridge finishes the next measurement.
- High measurement rate.
- Minimizes effects on operation of other GPIB devices.

INTERACTIVE OPERATION

It is possible to program your GPIB controller so that you can converse interactively with your AH2700A just as you would from the front panel of the bridge or via the serial port. Such programming can communicate even while other GPIB and controller operations are going on.

Benefits

Interactive communication can be very useful in the following situations:

1. You are just learning how to use the bridge and want to explore its commands.

2. You know how to use the bridge and its commands, but want to experiment with bridge parameters to determine what is best for your application.
3. You have written a program, but it doesn't work. You can use an interactive program (like the example given later) to test the ideas in the program you wrote.
4. Your use of the bridge is not sufficiently structured or your applications are too varied to justify writing programs for your controller. Nevertheless, you want the advantages of seeing your commands and results on your GPIB controller screen and you want the option of saving them to a file or printer.
5. You want *one* program that can access virtually all of the bridge's features.
6. You want to fully calibrate the bridge via the GPIB. This *requires* interactive operations.

If any of the above situations apply, you will benefit from running an interactive program on your GPIB controller.

Establishing Interactive Operation

An interactive program operates by accepting a command line that you type into your GPIB controller. When you press the RETURN key on your keyboard, the interactive program sends your command line to the AH2700A. The bridge executes the command line and may or may not produce a result for you to read. If a result is available, an interactive program will read it and display it on your GPIB controller screen. Whether or not a result was available, a prompt is shown on your screen to indicate that the bridge is ready for you to enter another command line. This loop can continue indefinitely.

A second feature is required of an interactive program to handle the case where you might want to interrupt a CONTINUOUS command or other command. Your controller may require that its interactive program execute a command such as INPUT to be able to read its keyboard. While a CONTINUOUS command is executing, an interactive program will not put a prompt on your GPIB controller screen or attempt to read its keyboard. Without this, you are unable to enter a new command line to interrupt the bridge. As a result, an interactive program must have the ability to recognize a special key or key sequence from your keyboard. When this key sequence is pressed, the program will put a new command line prompt on your GPIB controller screen and request input from the keyboard. The bridge will be interrupted after a complete command is entered in response to this prompt.

The key to communicating interactively is in having a way for the GPIB controller to determine that the bridge is ready for another command. The AH2700A provides two ways to do this:

1. The Status Byte Register contains a Rdy bit that is set when the bridge is waiting to receive another command.

2. An optional prompt string can be sent to the GPIB when the bridge is ready to receive another command.

The GPIB controller can be programmed to use either or both of these detection methods to communicate interactively. In either case, it is necessary to monitor the MAV status bit. The use of these two methods is discussed below.

Using the Rdy and MAV Status Bits

A program running on a GPIB controller can communicate interactively by using the MAV and Rdy bits. The MAV bit tells the controller when to read and display a result from the AH2700A. The Rdy bit tells the controller when to show a prompt on its screen to indicate that another command line can be entered. On some controllers the Rdy bit may also be essential for telling the program when to request input from its keyboard. The Rdy bit provides a simple way to determine when the bridge is ready to receive a command, but it does not pass any other information. The Rdy and MAV bits can be monitored with a serial poll or with service requests.

Enabling the GPIB Prompts Feature

You can configure your bridge to send all the same prompt strings to the GPIB port as are sent to the serial port. This is useful because many of these prompts contain information that suggests what to do next.

GPIB prompts are enabled and disabled with the commands:

```
GPIB , , , , Prompts
or
GPIB PROMPTS Prompts
```

The prompts feature is enabled when the *Prompts* parameter bit is set to a ON. The default value of the *Prompts* parameter stored in the GPIB FACTPON parameter file is OFF.

When the *Prompts* parameter is set to ON, each prompt generated by the bridge is appended as the last line of any query result. If there is no associated query result, then a message is sent that contains only the prompt. These prompts provide much more information than the Rdy bit, but add complexity to any results sent from the bridge. For this reason, they are best suited for human readability whereas the Rdy bit by itself is more optimum for machine readability.

Two Interactive Macro Examples

The examples in Figure 6-7 and Figure 6-8 will allow interactive communication with the AH2700A via a GPIB controller. The first program uses only serial polls; the second uses service requests. Like the previous examples, these programs are also written in HTBASIC.

```
10 ! A MACRO TO COMMUNICATE
20 ! INTERACTIVELY WITH THE AH2700A
30 ! USING ONLY SERIAL POLLING.
40 !
100 DIM A$[3000]
110 DIM B$[100]
120 ! F11 KEY FORCES COMMAND MODE
130 CONFIGURE KEY 133 TO NUM("1")
140 ON KEY 1 GOTO 910
150 ! ENABLE PROMPTS TO BE SENT:
160 OUTPUT 728; "GPIB , , , ON, ON"
170 !
300 ! BEGIN MAIN LOOP
310 S=SPOLL(728)
320 ! TEST MAV STATUS BIT:
330 IF BIT(S,7) THEN GOTO 510
340 ! TEST RDY STATUS BIT:
350 IF BIT(S,4) THEN GOTO 920
360 GOTO 310
370 !
500 ! PROCESS RESULT FROM AH2700A
510 ENTER 728 ; A$
520 I=POS(A$, ";")
530 IF I=0 THEN 600
540 B$=A$[1,I-1]
550 PRINT B$ !SHOW A LINE AT A TIME
560 A$=A$[I+1,LEN(A$)]
570 GOTO 520
600 PRINT A$; !SHOW LAST LINE OF RESULT
610 IF BIT(S,4) THEN GOTO 920
620 PRINT !FORCE NEW LINE IF NO PROMPT
630 GOTO 310
640 !
900 ! DCL AND COMMAND INTERRUPT
910 PRINT "CMD>";
920 S=SPOLL(728) !TURN OFF 2500 TALK LED
930 B$="" !ELIMINATE PREVIOUS INPUT
940 INPUT B$
950 ! CONTROL E RESETS AH2700A:
960 IF B$[1]<>CHR$(5) THEN GOTO 990
970 CLEAR 728
980 GOTO 920
990 OUTPUT 728; B$
1000 PRINT B$
1010 GOTO 310
1020 END
```

Figure 6-7 A program that allows interactive operation with the AH2700A using only serial polling.

Both programs first configure the AH2700A so that it is in GPIB compatibility mode and so that prompt messages will be sent. Near the top of each program, the `ON KEY 1` instruction was executed to make the “F11” key special. Pressing the F11 key on the GPIB controller's keyboard causes a `COMMAND INTERRUPT` routine to be executed. This routine first displays a “CMD>” prompt on the controller's screen. After a command line is entered in response, the program sends the line to the AH2700A where it is executed.

If a `^E` is entered instead, a Device Clear is sent to the bridge and the controller will continue to wait for a command line to be input.

When the AH2700A is done executing the command line, it sets its MAV bit and possibly its Rdy bit also. If the `OUTPUT 728; "SRE 1, , 1"` instruction was executed as in the program of Figure 6-8, then a service request will also occur. The controller then reads the bridge's status byte with a serial poll. The controller tests the MAV bit in the status byte. If it is set, the controller reads the result from the bridge and displays it on the controller's screen. If the Rdy bit is also set, then the controller prompts for another command input. Otherwise, the controller returns to wait for the MAV or Rdy bit to become set again.

In these programs, the message result processing routine looks for any semi-colon (;) characters that might be in the message sent by the bridge. These are used to delineate each line of characters of the message that is shown on the GPIB controller's screen. If the bridge is not run in compatibility mode, then this code must search for line feed characters (LF or 10) rather than semicolons. Many controllers are more sophisticated and would not require this translation.

These programs are “hung” in a loop until a command line is entered, but a more sophisticated rewrite of this program might allow the controller to do other things while it is waiting for a command line to be entered.

Both programs will work as they stand without enabling prompt messages to be sent. They will simply be less friendly to use since less information will be shown on the controller screen.

Sometimes the Rdy and MAV bits are both set together in the status byte. Other times they are set separately so that two readings of the status byte are required to detect them. Depending on exactly how the interactive program works, this difference can leave the TALK LED on the bridge's front panel on in one case and off in the other. Since it is more meaningful to have the TALK LED off when no talking is actually occurring, line 910 in both programs is used only to ensure that the AH2700A is untalked when prompts are displayed.

```

10 ! A MACRO TO COMMUNICATE
20 ! INTERACTIVELY WITH THE AH2700A
30 ! USING SERVICE REQUESTS.
40 !
100 DIM A$[3000]
110 DIM B$[100]
120 CONFIGURE KEY 133 TO NUM("1") ! F11
130 ON KEY 1 GOSUB 820
140 ON INTR 7 GOSUB 310
150 ! ENABLE PROMPTS TO BE SENT:
160 OUTPUT 728; " GPIB , , , ON, ON"
170 ! SET MAV AND RDY SRE BITS:
180 OUTPUT 728; "SRE 1, , 1"
190 ENABLE INTR 7;2
200 !
210 GOTO 210 ! IDLE LOOP
220 !
300 ! PROCESS SERVICE REQUESTS
310 STATUS 7,1; S ! CLEAR CONTROLA STATUS
320 S=SPOLL(728)
330 ! TEST RQS STATUS BIT:
340 IF BIT(S,6) THEN GOSUB 510
350 ON KEY 1 GOSUB 820 !GOSUB
360 ENABLE INTR 7;2
370 RETURN
380 !
500 ! REPORT ANY RESULT FROM AH2700A
510 ON KEY 1 GOTO 820 !GOTO
520 ! TEST MAV STATUS BIT:
530 IF BIT(S,7) THEN GOTO 610
540 ! TEST RDY STATUS BIT:
550 IF BIT(S,4) THEN GOTO 910
560 RETURN
570 !
600 !PROCESS RESULT FROM AH2700A
610 ENTER 728 ; A$
620 I=POS(A$, ";")
630 IF I=0 THEN 700
640 B$=A$[1, I-1]
650 PRINT B$ !SHOW A LINE AT A TIME
660 A$=A$[I+1, LEN(A$)]
670 GOTO 620
680 !
700 PRINT A$; !SHOW LAST LINE OF RESULT
710 IF BIT(S,4) THEN GOTO 910
720 PRINT !FORCE NEW LINE IF NO PROMPT
730 RETURN
740 !
800 ! DCL AND COMMAND INTERRUPT
810 OFF INTR 7
820 PRINT "CMD>";
830 GOSUB 910
840 ON INTR 7 GOSUB 310
850 RETURN
860 !
900 ! TEST INPUT FOR ^E DEVICE CLEAR
910 S=SPOLL(728) !TURN OFF 2500 TALK LED
920 B$="" !ELIMINATE PREVIOUS INPUT
930 INPUT B$
940 IF B$[1]<>CHR$(5) THEN GOTO 970
950 CLEAR 728
960 GOTO 920
970 OUTPUT 728; B$
980 PRINT B$
990 RETURN
999 END

```

Figure 6-8 A program that allows interactive operation with the AH2700A using service requests.

COMPATIBILITY MODE

The IEEE-488.2 standard requires that result lines are separated with semicolons (;) rather than LF characters (ASCII 0A_H). For message results having multiple lines totaling more than about 80 characters the use of semicolons as separators makes such a result harder to display and print. Most other conventions require LF as a line terminator.

Using an abbreviated form of the command introduced in “Setting the Configuration Parameters” on page 6-2, or a more straight forward alternative form, the AH2700A allows you to choose between compatibility and convenience. These commands

GPIB , , , Compatib
and
GPIB COMPATIB Compatib

selects compatibility mode when *Compatib* is set to ON. In compatibility mode, all result lines are separated with semicolons. With compatibility mode set to OFF, all result lines are separated with LF characters. All messages are terminated with LF^END no matter how compatibility mode is set. (A message consists of one or more result lines.)

The default compatibility parameter value stored in the GPIB FACTPON parameter file is OFF.

INITIALIZING THE BRIDGE

There are three different initialization functions that can be issued to the AH2700A from the GPIB bus. These are the Interface Clear GPIB command (IFC), the DCL and SDC Device Clear GPIB commands and the RST bridge command. The DCL and SDC commands have the same effect on the bridge.

These three initialization commands form a hierarchy in the sense that it may be necessary (due to some malfunction) to issue a lower command before the next will be accepted. The RST command might not be accepted before an SDC or DCL command is issued. The SDC or DCL commands might not be accepted before an IFC command is issued.

Interface Clear

The interface clear (IFC) command is communicated from the GPIB controller via a dedicated line on the GPIB bus. This command will clear parts of the AH2700A GPIB interface to the extent required to be able to (at least) accept a DCL or SDC command.

Device Clear Commands

The execution of a general DCL (Device Clear) command from the GPIB controller will cause all remote devices on the bus with this capability including the AH2700A to reset their internal command processing related functions. The controller may also address an instrument to be a listener and then

issue an SDC (Selective Device Clear) GPIB command to reset the same functions in that instrument only. The GPIB device clear commands have exactly the same effect as a ^E character from the serial port and the **[FUNC] [CLEAR] [FUNC] [CLEAR] [FUNC] [CLEAR]** front panel key sequence.

The items reset include:

- The GPIB input buffer
- The GPIB output buffer
- Command processing functions
- Result formatting functions

The RST Command

The effect of this AH2700A command is to put all measurement circuitry and all higher control sections of the bridge except for the bus control circuitry into the same state as at power-on. The POn status bit is *not* set when this command is executed. In fact, it is cleared.

Bridge parameters in the Basic, Gauge Deviation, and Scan parameter sets are set to their power-on values as contained in the parameter sets named FACTPON or USERPON. Parameters in the GPIB and Serial parameter sets are *not* initialized. See “PARAMETER SET INITIALIZATION” on page 3-10 for a more detailed explanation of power-on parameters.

GPIB DATA LOGGING

The AH2700A can send all commands that are entered and all measurement data that is initiated from the front panel to the GPIB port with or without the help of a GPIB controller. This allows you to keep a log of some or all bridge activity without necessarily having a GPIB controller. You can, instead, connect a GPIB printer or other GPIB logging device (logger) to the GPIB port.

The logger should be able to read fast enough to handle the maximum data rate that the bridge is expected to produce. If it is not fast enough, all result lines will still be complete, but some lines will be lost. See “Receiving Every Response Message” on page 6-4 for more information.

Enabling/Disabling GPIB Logging

Logging to the GPIB port is enabled and disabled with the following command:

```
LOGGER GPIB
OFF|READINGS|RESULTS|CMD5_TOO
```

Descriptions of the allowable options are listed in Table 6-2. This table is identical to the corresponding serial port Table 7-2 on page 7-12.

The default value for the GPIB logger option stored in the GPIB FACTPON parameter file is READINGS. This enables

Table 6-2 Permitted logger option values

Value	Messages Sent to Logger
OFF	None (logging is disabled)
READINGS	Measurement results only
RESULTS	All results (measurement and show)
CMDS_TOO	All commands and all results

logging to a remote GPIB device. This is a different default value from the serial port case. The reason is discussed in the next section.

Logging to a Controller

Logging to a GPIB controller is simple. Once logging has been enabled with the LOGGER GPIB command from the front panel, all the controller has to do is to read the results. To create some results to read, use the CONTINUOUS command, also from the front panel. The program that does the reading can have any of the three basic non-controller initiated forms given earlier in “Six Examples” on page 6-9.

The AH2700A defaults to logging only measurement results to the GPIB port, no matter what is there to take them. This makes working with the GPIB port a little friendlier since if any measurements have been taken, there will always be a measurement result there for the controller to read whether the controller “asked” for it or not. The LOGGER GPIB command can be used to change this default so that either no results are sent unless asked for by the controller or so that more kinds of results are sent without the controller asking for them.

Logging to a Non-Controller

Although the default logging setting sends measurement results to the GPIB port, a GPIB controller is normally required to be able to read these results. However, if data logging is the only function that is desired (no commands issued by a controller), it is possible to log results without a GPIB controller by putting the bridge into talk-only mode. This is useful if you have a printer or other logging device that has a GPIB port that can be set to listen-only.

Talk-Only Mode

If a listen only logging device such as a printer, is used instead of a GPIB controller, then the AH2700A *AddrMode* parameter must be set to a TALKONLY to put the AH2700A in talk-only mode. This mode causes the bridge’s GPIB port to send results without having to first be addressed. As a consequence, there can be no other talkers on the bus at the same time. The commands to set and clear talk-only mode are

```
GPIB , , AddrMode
and
GPIB ADDRMODE AddrMode
```

Talk-only mode will be set when *AddrMode* is entered as a TALKONLY. The mode will be disabled when *AddrMode* is entered as PRI_ONLY or PNSCNDRY. The default *AddrMode* parameter value stored in the GPIB FACTPON parameter file is PRI_ONLY.

Operating the AH2700A via the serial port is often the simplest, friendliest and least expensive method of obtaining a remote control link. A serial link will also run much greater distances than a GPIB link. Because serial data communications are so widely used, there are a wide variety of possible computing devices to which the AH2700A may be connected. See “Serial Communication Options” on page 1-8 of Chapter 1, “Description and Installation” for a more detailed discussion of the advantages of using the serial port and of the many possible configurations.

This chapter discusses how to setup and operate your AH2700A via the serial port. Specifically, the major topics discussed are how to:

- Specify a cable to connect between a remote serial device and your AH2700A.
- Set the communication parameters using the SERIAL command.
- Save the serial configuration parameters introduced in this chapter by using the STORE SERIAL command.
- Optimize keyboard usage on your serial device using the DEFINE command.
- Limit front panel access to your AH2700A using the LOCAL, NREMOTE, and NLOCKOUT commands.
- Use your serial device to log results from your bridge rather than to control your bridge. The LOGSERIAL command controls this method of operation.

CABLE CONNECTION ISSUES

Finding or building the right cable to connect two serial devices to each other is, on the average, 90% of the effort required to establish a serial link. First, a cable must be found that will mechanically fit between the AH2700A and the remote device. Unfortunately, this, by itself, is not usually sufficient to make a serial link operate. Making serial connections is fairly easy, but two issues often trip the inexperienced user. One issue is that the DTE/DCE identity of the serial devices to be linked must be known so that transmit lines are connected to receive lines and vice-versa. The other issue is that unconnected handshake lines can prevent operation even if they are not intended to be used. Neither of these issues is difficult to handle if you read enough of this section.

A further complication is the fact that in spite of having been around for decades and in spite of being extremely simple compared to modern technology, serial communication standards are still evolving. The RS-232C-1971, EIA-232D-

1986, EIA/TIA-232E-1991 and TIA/EIA-232F-1997 standards with their 25 pin connectors served as guidelines for many years. However, in the 1980's, personal computers began using 9-pin serial connectors since most of the lines specified in the 232 standard are not used. This became so popular that it was recognized by a new standard called TIA/EIA-574-1990. By the year 2000, 9-pin and 25-pin serial connections were both commonly used. The TIA/EIA-574 standard was followed by another standard intended specifically for specifying serial data communication to test instrumentation. This is IEEE-1174-2000. All of these standards use RS-232 compatible voltage levels, but the 574 and 1174 standards both specify 9-pin connectors. This is why the AH2700A uses a 9-pin serial connector rather than the 25-pin connector used by the older AH 2500A.

For an *excellent and concise* discussion of RS-232 interfacing, see pages 720-726 of Reference 4 in the bibliography. For a thorough discussion of this topic, see Reference 11.

Specifying a Serial Cable

Finding or building the right cable involves selecting the right length, the right connectors, and the correct configuration of conductors inside.

Cable Length

The maximum length of a serial cable is related in an inverse manner to the baud rate. In practice, a length of 50 feet (15 meters) will work safely at 9600 baud while in practice, 250 feet (75 meters) will work at 9600 baud if the cable doesn't have too much capacitance. Much longer lengths are possible at reduced baud rates. Operation at the highest baud rates of which the AH2700A is capable of should use a low capacitance cable that is no more than a few meters long.

Note that ribbon cable with insulation displacement connectors will not work over long distances. (Using ribbon cable requires that signal conductors not run side-by-side in the cable; they must be spaced with a ground conductor to work reliably over even short distances. No serial connector pinout in common use supports such an alternating signal/ground arrangement.) See Appendix A of Reference 10 which has some graphs and a good discussion of cable lengths for several serial transmission methods.

Type of Connectors

In addition to the 25-pin and 9-pin D connectors mentioned above, the RJ-11, RJ-45, MMJ and other telephone connectors have come into common use. DIN connectors are used on Macintosh and other computers where space is at a pre-

Table 7-1 Cable pinouts from the AH2700A to other common serial ports.¹

AH2700A DE-9	Pin Signal Name	Pin Signal Function	Should Connect to 1174 Signal	IEEE-1174 DCE DE-9	Intel PC DTE DE-9	Standard DCE DB-25	Standard DTE DB-25	Apple Mac Mini-DIN-8
1 ²	RLSD ³	Received line signal detector	DTR	1 or 6	4	6	20	
2	RXD	Received data	TXD	2	3	3	2	3
3	TXD	Transmitted data*	RXD	3	2	2	3	5
4 ²	DTR	Data terminal ready*	RLSD	4	1 & 6	20	6 & 8	
5	GND	Signal ground	GND	5	5	7	7	4
7 ²	RFR ⁴	Ready for receiving*	CTS	7	8	4	5	
8 ²	CTS	Clear to send	RFR	8	7	5	4	

1. A cable is constructed so that the connector that mates to the AH2700A uses the pinout in the first column. The pinout for the connector that mates to the remote device is chosen from one of columns five through eight.

2. These rows are for reference only and are not connected in the AH2700A.

3. Historically called DCD.

4. Historically, the RTS circuit used this pin.

mium. There are only de facto standards to define the pinouts for some these connectors.

The AH2700A has on its rear panel a serial port using an IEEE-1174 standard 9 pin male DE-9 connector. You therefore will need a cable with a female mate to this connector, plus a mate at the other end of your cable to whatever connector is on your remote device.

Connector Pinouts

Table 7-1 lists connector pinouts for a cable to link one of a number of the most common remote serial device ports to the AH2700A. The first or left-most column in the table lists the pinout of the male DE-9 connector on the rear panel of the AH2700A. Since mating connectors always have the same pin numbering, this pinout is also that of the female DE-9 needed at the bridge end of the cable. Note that only three pins are actually used on the AH2700A; the remainder may sometimes be used on other IEEE-1174 devices. The next two columns in this table list the names and functions of the signals found on these pins. The fourth column gives the IEEE-1174 names of the pins that should be connected to the remote end of the cable. The remaining columns list the corresponding pinouts of connectors that will mate with the remote devices or ports which are indicated at the head of each column. These columns contain the pinouts for an IEEE-1174 DCE port, an Intel/IBM PC serial port, TIA/EIA-232 standard DCE and DTE 25 pin D ports, and the Macintosh mini-DIN-8 port.

If your remote serial device (controller) has one of these ports, then this table shows how to make a corresponding cable. All that is required is that the pins of your mating female DE-9 connector use the pinout in the left-most column of the table to connect to the corresponding pins of the

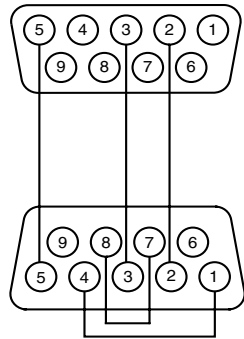
column at the right whose port you will link to. An IEEE-1174 DTE device will drive (or transmit on) the lines identified with asterisks (*) in the signal function column in the table *if* these lines are implemented in the device. The AH2700A drives only pin 3.

If your remote device has a DE-9 connector and is DCE, then column five in the table shows a simple one-to-one correspondence of pins between the bridge and a remote device that also has a DE-9 connector. This allows using an ordinary straight-through cable having at least the conductors listed in the table. The connections for such a cable are shown in Figure 7-1. If you can't determine if your remote port is DCE or if you don't understand this term, read "Identifying Your Remote Serial Port" on page 7-4 below.

If your remote device has a DE-9 connector and is DTE, then the example in column six of the table shows that two connections inside the cable are simply reversed. Making cables of this nature is time-consuming. Fortunately, a product called a "null modem" performs exactly this function and can easily be purchased.

A null modem can be either a cable or a short adapter. It is intended to connect two DTE devices together. (It will also connect two DCE devices together.) When inserted in place of or in series with a straight-through cable, a null modem will ensure that all of the input pins are driven by corresponding output pins. While there are actually many available variations in the pinouts, all of the commercially available null modem variations that we have seen are compatible with the AH2700A. This is true because the bridge does not use these lines for data flow control. A schematic for the null modem whose connections are given in column six of Table 7-1 is shown in Figure 7-2. This schematic shows that pins 1 and 4 and pins 7 and 8 are interconnected on the remote device end

Female DE-9 connector to AH2700A

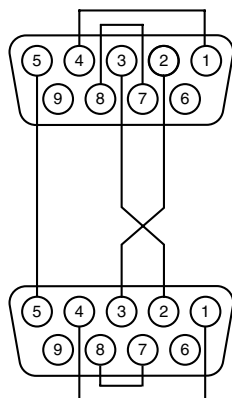


Male DE-9 connector to remote DCE device

Figure 7-1 Straight-through 9-pin DTE-to-DCE cable

of the cable. In most cases, these two connections will not be needed. They are only provided in case the remote device uses handshaking lines which cannot be disabled (see “Handshake Lines” on page 7-5). Since this cable has identical connectors on either end, these handshaking connections are also shown on the bridge end of the cable even though the bridge doesn’t need them. This way the ends of the cable need not be identified since either end of the cable can go to either device.

Female DE-9 connector to AH2700A

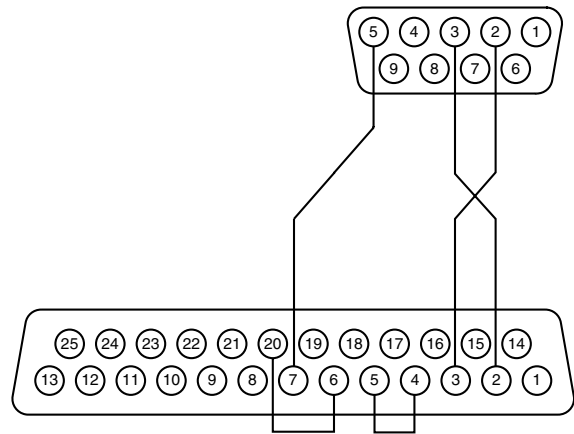


Female DE-9 connector to remote DTE device

Figure 7-2 A simple 9-pin null modem

The seventh column in the table gives the pinout needed to specify a cable to connect to a DCE device with a 25 pin D connector. The schematic for this cable is shown in Figure 7-3. This schematic shows that pins 4 and 5 and pins 6 and 20 are interconnected on the remote device end of the cable. Here again, these two connections will probably not be needed but are only provided in case the remote device uses

Female DE-9 connector to AH2700A



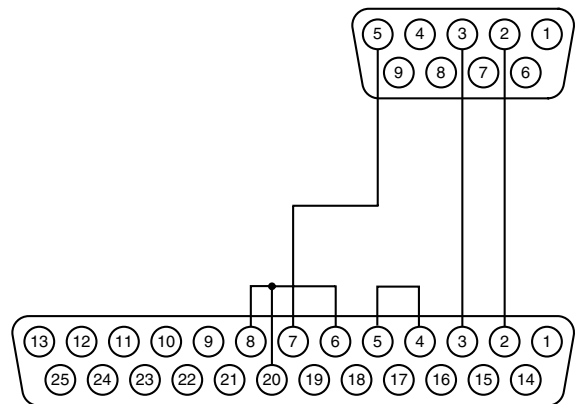
Male DB-25 connector to remote DCE device

Figure 7-3 Straight-through mixed-pin cable

handshaking lines which cannot be disabled (see “Handshake Lines” on page 7-5).

The eighth column in the table gives the pinout needed to specify a cable to connect to a DTE device with a 25 pin D connector. The schematic for this cable is shown in Figure 7-4. This schematic shows that pins 4 and 5 and pins

Female DE-9 connector to AH2700A



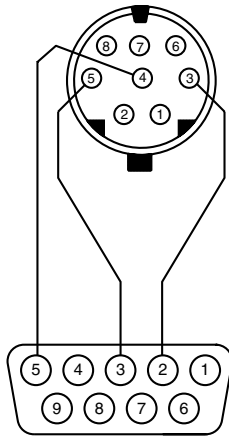
Female DB-25 connector to remote DTE device

Figure 7-4 A mixed-pin null modem

6, 8 and 20 are interconnected on the remote device end of the cable. Yet again, these extra connections will probably not be needed but are only provided in case the remote device uses handshaking lines which cannot be disabled. This schematic shows another kind of null modem – one that has a different connector on each end. There are commercial versions of this in the form of a cable. Such a cable can also be constructed from a series of commercially available adapters.

Macintosh computers implement the RS-422 standard which specifies differential drivers and receivers. RS-422 is not really TIA/EIA-232 voltage level compatible, but will communicate if connected as shown in the table and if the distance is not too long and the environment is not too noisy. It is desirable to connect pin 4 to pin 8 on the mini-DIN-8 connector. This shorts the positive, differential, data receive input to ground so it doesn't pick up noise. The schematic for this Macintosh cable is shown in Figure 7-5.

Mini-DIN-8 connector to Macintosh computer



Female DE-9 connector to AH2700A

Figure 7-5 Serial cable to Macintosh computer

One commonly used pin is not listed in Table 7-1. On the DB-25 connector this is pin one and is called the frame ground. Common usage just connects the frame ground on one connector to the frame ground on the other. For a TIA/EIA-232 cable using 25-pin connectors, this means connecting pin 1 to pin 1. For an IEEE-1174 cable using 9-pin connectors, this means connecting the connector shields to the cable shield since there is no pin assigned to carry the frame ground. For both kinds of cable, the metal connector shields should make the frame ground continuous across mating connectors. This should cause the chassis of the AH2700A to be connected to the frame ground of the remote device.

Note that the TIA/EIA-232-F standard specifies that the frame ground pin on the DCE device is *not* to be connected. The standard does not explain this but it says that EMI considerations are beyond its scope. Therefore, we recommend that cable shields be grounded somehow but we make no recommendation as to how the frame ground should be connected to remote devices. It is, however, extremely important that the signal grounds always be connected to each other.

⚠ CAUTION

It is extremely important that the chassis grounds of all equipment being interconnected be properly grounded through the power cord of each piece of equipment. Ground pins on power cords must never be cut off or otherwise defeated. Failure to observe this will frequently cause serial ports to be damaged if the serial link is disconnected while the equipment is plugged in (but not necessarily powered on). The failure results from the ability of power line RFI filter capacitors to cause an ungrounded equipment chassis to float to a voltage midway between the voltages on the two input power lines. This can put the chassis voltage at 50 to 120 volts above ground (for line voltages of 100 to 240 volts) with enough current capacity to be a shock hazard and to cause damage to interface ports. (The AH2700A does not use such filter capacitors, but many other pieces of equipment do.)

You may not find the information in Table 7-1 to be sufficient to specify a cable because your remote device is not listed or because you are not sure if it is listed. The next section explains how to identify the most important characteristics of a serial port.

Identifying Your Remote Serial Port

If your remote device has a serial port using a DB-25 or DE-9 connector, you may be uncertain as to whether it is DCE or DTE. If you aren't sure which you have, you won't know which column in Table 7-1 to use to specify your cable. The discussion below will refer only to a DB-25 or DE-9, but the same principles apply to ports of all kinds.

DTE and DCE

There are two basic kinds of serial devices. One is called Data Terminal Equipment or DTE. Examples are video terminals and printing terminals. The other is called Data Communication Equipment or DCE, of which modems are examples. The intent of the TIA/EIA-232 standard is that a DTE always be connected to a DCE. This is usually what is happening for connection to modems, but in reality, all possible combinations of DTE and DCE devices are commonly connected.

A DTE should have a connector with male pins and a DCE should have a connector with female pins. Unfortunately, this is usually but not always true and therefore can not be used to determine the DCE/DTE nature of a connector.

Although the gender of your remote serial port will suggest which kind of data equipment it is, if you have a DC voltmeter, you can reliably determine its kind. (A serial breakout box is even better than a voltmeter.) The trick is to measure the voltage (with respect to pin 5 on a DE-9 or pin 7 on a DB-25) on pins two and three to determine which is the transmit pin. The transmit pin will have a negative level larger than

four volts. The other pin will be the receive pin and it will have a voltage near zero. For a DE-9 connector, referring to columns five and six in the table and using the labels in column four, if pin 2 is the transmit pin, then the port is DCE. If pin 3 is the transmit pin then the port is DTE. For a DB-25 connector, referring to columns seven and eight in the table and using the labels in column four, if pin 2 is the transmit pin, then the port is DTE. If pin 3 is the transmit pin then the port is DCE.

Having made this identification, you should be able use the table to specify the pinout of a cable that will work. However, having made this identification, you may want to make some additional measurements which may allow you to apply some shortcuts described in the “Controlling Data Flow” section below.

Handshake Lines

If your remote serial port does not implement handshake lines, you will be able to take a shortcut described in the section below. The handshake lines are listed in the table as RFR/RTS, CTS, RLSD/DCD/CD, and DTR.

The best way to determine how your remote port implements handshake lines is to read the documentation that you have about that port. This is important because some ports may allow you to disable these lines. If there is a way to disable them with a switch setting or with software, you should do so.

If you can't find information which specifies the implementation of your remote port's handshake lines, then you can find the information yourself using a DC voltmeter as was done in the last section. In this case, a voltmeter can be used to determine whether some handshake lines on your remote port are actually *driven* or whether they are not connected.

First identify the column of the table that you believe applies to your remote port. Using this column, measure the voltage with respect to ground on the four handshake pins on your remote port connector. If handshaking is implemented, one or more of the handshake pins will be driven to a positive or negative voltage level larger than four volts.

If *any* pins are driven, then to be safe, you must conclude that some handshake lines are implemented. (Looking for input pins on a port by measuring their voltage is less useful. The expected lower voltages make the results harder to interpret.) If no handshake pins are driven, then you can be fairly confident that your remote serial port does not implement any handshaking signals. If this is the case, then the shortcut described in “Eliminating Handshake Lines” is available to you below.

Controlling Data Flow

At faster data rates, some kind of handshaking scheme is required to control the flow of data between two serial devices. The AH2700A uses the Control-S and Control-Q, ASCII characters for regulating the flow of data between it and a remote device. The bridge sends a Control-S when it wants the flow of data being sent to it to stop and sends a Control-Q when the data is to resume. Similarly, the bridge will stop sending data when it receives a Control-S and will continue only after receiving a Control-Q. This is the most common method. Any remote device connected to the AH2700A *must* use the Control-S and Control-Q characters for data flow control. Otherwise, the baud rate will have to be set very low.

Eliminating Handshake Lines

As discussed above, handshaking is an essential function in most serial data links. However, the use of hardware lines (as opposed to flow control characters) to perform handshaking is unnecessary and undesirable in most modern serial ports, including that of the AH2700A. The reason is that a TIA/EIA-232 serial link, using flow control characters, will work just as well without handshake lines. Eliminating the use of unnecessary handshake lines also removes the unnecessary complexity associated with them.

If you are sure that your remote serial device does not implement any handshake lines or if you can disable them, then your serial link will be easier to complete. The shortcut that you can take here is to simply not make any connections to any of the handshake pins on either end of your cable. This is true even for the cable connections shown in the cable wiring figures. You *only* need to connect lines to pins two, three and to the signal ground pin on the bridge even though more lines may be listed in the table. This allows you to use a cable having only three conductors rather than eight.

Alternatively, you also have the choice of using a cable that may have many more conductors than the three that you need without being concerned about how the unused conductors are connected. If pins two and three are properly handled as described in the next section below, this will allow using a straight-through 9 or 25 conductor cable. General purpose cables and especially ribbon cables may have all 9 or 25 pins connected.

Be aware that it is important not to attempt the above shortcuts unless you are certain that the handshake lines on your remote serial device are not implemented. Using a cut-and-try approach here could be *very* troublesome because active handshake lines that are not properly connected can produce very intermittent symptoms. This is especially true of undriven lines that are connected to handshake inputs. Such lines will pick up noise that is then fed to the inputs.

SERIAL COMMUNICATION PARAMETERS

A number of variables such as baud rate, parity, number of stop bits and others, must be set to conform to the settings of the corresponding variables in your remote device. Fundamental variables such as these which directly affect the ability of the serial link to communicate are called communication parameters. This section explains the function of each communication parameter, states the default value of each parameter as stored in the SERIAL FACTPON parameter file, and explains how to set and permanently save each one.

Setting the Serial Parameters

The SERIAL command is used to set all the serial communication parameters. The SERIAL command can be entered from the front panel or from a remote device using the following list syntax:

```
SERIAL [LIST] Rate, Parity, Bits, SBits, Fill, Echo
```

The list SERIAL command uses six parameters which are described in the sections below. Each time the SERIAL command is entered, it can be followed by any combination of its parameters provided that place-holder periods are entered and that the order is preserved. As an example, the entry SERIAL , 000 , 8 , , 4 specifies odd parity, an 8 bit character, and 4 fill characters with the other four parameters left unchanged. See "Positional Parameters" on page A-1 for more information about this method of parameter entry.

The communication parameters can be changed from the serial port, but the changes take effect immediately so you must be able to change the communication parameters of the remote device at the same time if the communication link is not to be interrupted.

Once the serial link has been correctly established, sending a carriage return character from the remote device should cause the bridge to send the character sequence "CR, LF, >", which should cause a ">" prompt to appear on the remote device.

Baud Rate

The Rate is the rate in bits per second at which the data is sent and received. This can be selected using the following partial syntax:

```
SERIAL [LIST] Rate  
or  
SERIAL BAUD Rate
```

The Rate can have one of the following values: 50, 75, 110, 135, 150, 300, 600, 1200, 1800, 2400, 3600, 4800, 7200, 9600, 19200, 38400, 57600 or 115200 with 9600 being the default. All digits of the desired value must be entered even though only the first two digits are reported by the SHOW command.

Parity

The Parity parameter controls whether a parity bit is sent as part of the serial data byte or not. Parity is not tested when characters are received no matter how the Parity parameter is set. The Parity parameter can be changed with the command syntax:

```
SERIAL , Parity  
or  
SERIAL PARITY Parity
```

The Parity parameter can be set to no parity, odd parity or even parity using the settings NONE, ODD or EVEN, respectively. The default is NONE for no parity.

Character Length

The Bits parameter determines the number of bits in each serial data byte. This can be selected using the following partial command syntax:

```
SERIAL , , Bits  
or  
SERIAL BITS Bits
```

The Bits parameter can be 7 or 8 bits with the default being 8.

Stop Bits

The SBits parameter is the number of serial bits sent at the end of each serial byte. This can be selected using the following partial command syntax:

```
SERIAL , , , SBits  
or  
SERIAL SBITS SBits
```

The SBits parameter can be 1, or 2. A one always indicates 1 stop bit. A two indicates 1 stop bit if the word length is 8 with parity selected, and 2 stop bits in all other configurations.

The default is 1.

Fill Characters

Some older, unbuffered printers need extra time at the end of each line for the carriage to return. Sending empty characters at the end of each line can provide this extra time. The Fill parameter determines the number of fill characters (nulls) sent following each CR, LF character combination. The number of fill characters can be selected using the following partial command syntax:

```
SERIAL , , , , Fill  
or  
SERIAL FILL Fill
```

The Fill parameter can range from 0 to 9 with the default being 0.

Command Echoing

You may choose whether or not to have commands echoed to remote serial devices. The *Echo* parameter determines whether characters entered on a serial device are echoed by the AH2700A back to that device.

If data acquisition is being controlled by a computer, command echoing is normally disabled since a computer typically has little use for the echoed characters. If you are working interactively with the bridge, it is important to be able to see the commands that have been typed in. Since lack of echoing effectively disables all interactive communication, it should always be enabled for human interactions, but it makes computer data acquisition easier if it is disabled.

When the remote device is a half-duplex serial device, the device itself will probably echo the commands. For half-duplex devices, echoing should be disabled, otherwise double characters may occur.

If the remote device is a full-duplex terminal then echoing should be enabled.

If command echoing is unknowingly disabled, it may give you the impression that the bridge or the remote device is not working. To test for this, you can type a return character on the remote keyboard. If command echoing is not disabled, a prompt ">" will be printed at the beginning of the line indicating that the remote device is receiving characters and the bridge is ready to receive a command. If nothing is printed, the **SHOW** command should be entered at the remote keyboard followed by a carriage return even though the characters you enter are not echoed and therefore you do not see them. The **SHOW** command will be accepted when echoing is disabled even though no direct evidence in the form of a response on the screen or printer will appear. If the serial link is working, then several lines will be printed since the **SHOW** command always prints something.

The partial syntax of the **SERIAL** commands shown below can be used to change the *Echo* parameter:

```
SERIAL , , , , Echo  
or  
SERIAL ECHO Echo
```

When the *Echo* parameter is set to **ON**, command echoing is enabled. When *Echo* is set to **OFF**, echoing is disabled. The *Echo* parameter is set to **ON** as the default so that echoing is enabled.

First-Time Serial Link Operation

If you have connected a cable between your AH2700A and your remote serial device, and have set all the communication parameters with the **SERIAL** command, you are now ready to try to operate the bridge from your remote serial device. If your serial device is a dumb video terminal or printing terminal, you can simply press the **RETURN** key and expect to see a prompt (>) printed at the beginning of a

line on the terminal. Once you see the prompt, you can enter any of the AH2700A commands that you are familiar with and expect to see the corresponding results.

If your serial device is actually a computer, then you have additional things to set. Usually, in addition to setting the communication parameters of your computer's serial port, you will also have to run a program that makes your computer emulate a dumb terminal. There are many commercially available programs that will perform this function for you. It used to be that if you connected your computer to a modem to access a remote service, the program that made that connection work would probably also make your computer "talk" to your AH2700A. In fact, the bridge could be run at the far end of a modem link using your computer in exactly the same configuration as was used to access a remote service.

Permanently Saving Your Settings

All the parameters discussed in this chapter are stored in the Serial parameter set type. This set type contains all the parameters that are used in conjunction with the serial remote device port. An overview of this parameter set type is given in Chapter 3, "Parameter and Program Files" in the section titled "Baud Parameter Set" on page 3-6.

To permanently save all of the parameters related to operating the remote serial device in a way that will automatically restore them after power-on of your bridge, simply issue the command **[FUNC] [SELECT] [STORE] [SERIAL] [USERPON] [ENTER]** from the front panel.

To better understand the ways in which you can save your serial device parameters, refer to "WORKING WITH FILE CONTENTS" on page 3-9 and especially "PARAMETER SET INITIALIZATION" on page 3-10.

REMOTE COMMAND ENTRY

The entry of commands from a remote serial device is identical to that on a GPIB controller except that most of the immediate-action keys described later in this section are not directly executable from a GPIB controller's keyboard without special programming of the controller. GPIB controllers also have their own methods of correcting typing errors.

All of the discussion in this section applies if your remote serial device is a dumb terminal or some other device that behaves like a dumb terminal. Computers may be configured to be "dumb" or "smart". If you are using a computer that is configured to be smart, it may have its own methods for editing keyboard input and may only be able to send serial results in the form of whole lines. If so, this will put you in the same position as if you were operating a GPIB controller. The immediate-action keys described below will not be readily executable and the section about "Correcting Typing Errors" will not be useful.

A dumb terminal configuration is preferable unless the alternative has obvious and significant advantages.

Basic Syntax

The command line entry style used by the AH2700A will be familiar if you have used command line entry on a small computer or terminal. The syntax and command words used also closely parallel those used by the bridge's front panel. The AH2700A command *definition* syntax is described in "CONVENTIONS USED" on page A-1.

Commands consist of a leading command word followed by optional command qualifier words followed by optional parameters which are usually numeric and ended with a carriage return character. Only two special commands described below require no termination character. The carriage return character (CR) is entered by pressing the RETURN or ENTER key on the keyboard of the remote serial device.

The AH2700A does not act on command lines until it receives a carriage return. This allows you to edit commands before terminating the command line. This editing is described in detail in "Correcting Typing Errors" below.

Command Word Entry

Since remote commands are named and spelled as they appear on the front panel, or on the front panel menus, any commands described in this manual using key labels also describe the remote commands. When the front panel key label consists of two words, only the first word is used as the remote command word with the exception of the BIAS command. The **FUNC** key has no equivalent on remote devices, of course.

Although commands are English words, it is rarely necessary to type the entire word. You need to type only the first few letters of the command. The minimum number of letters needed depends on the particular command and ranges from one to three letters. The minimum letters needed are underlined where each command is introduced in the text and in Appendix A, "Command Reference". If you do not type in enough letters, the bridge responds with the message **AMBIGUOUS WORD:**, followed by the offending characters that were entered. If more letters than the required minimum are entered, they must spell the command word correctly or the error message **ILLEGAL WORD:** will appear, followed by the illegal word that was entered.

Command words are separated from each other and from their associated parameters by spaces. Parameters are separated from each other by periods.

Immediate-Action Keys

A RETURN must terminate all command lines from the serial port with only two exceptions. The front panel has several immediate-action keys. The immediate-action function of two of these is duplicated on remote serial devices. These front panel keys are the SINGLE and STEP keys. These

same command words can be entered from a remote device, but they will require termination with the RETURN key. This multiple-key sequence defeats the desired immediate-action effect. As a result, two single character commands are available on remote serial devices. These are Q and X which perform the same function in a single keystroke as the SINGLE and STEP commands, respectively.

Examples

To illustrate the ideas above, consider the BRIGHTNESS command whose syntax is:

```
BRIGHTNESS [CAP | LOSS] Brit_
```

Several examples of valid command lines that might be entered from a remote terminal are:

```
BRIGHT CAP 5
```

```
BR C 5
```

```
BRIG LOS 5
```

```
BR 5
```

All are terminated by a RETURN.

The entry **B 5** will return the error message:

```
AMBIGUOUS WORD: B
```

The entry **BRHGT 5** will return the error message:

```
ILLEGAL WORD: BRHGT
```

Additional Features

Entering Multiple Commands

Several commands can be entered on the same line separated by semicolons (;). As with individual commands, lines having multiple commands are not executed until a RETURN is received. An immediate-action command such as Q or X can be entered anywhere on a multi-command line except as the first character and will not be executed until the whole line is received. The commands are always executed in the order in which they appear on the command line.

Multi-command lines can be useful with commands that respond with a prompt. For example, every version of the STORE CALIBRATE command prompts for a passcode. The passcode can be entered after the command on the same line if the two are separated by a semicolon. Except for passcodes, any command that requires a response to a prompt will first check the next command on the line. If the next command is an acceptable response to the prompt then it will be used. If not, the next command will not be executed yet. Instead, the prompt will be produced and the bridge will wait for input. If you want to guarantee that a prompt is generated,

insert the **SPECIAL** command word where the answer to the prompt would go on the command line.

Multi-command lines can also be used to guarantee that a command produces a result. The **TEST** command can be configured to produce no result unless a failure is detected. However, the command line **TEST; SHOW TEST** will always produce a result.

Inserting Comments

When commands are being printed or recorded, it may be desirable to insert comments between the command lines. This is done by starting a line with a percent (%) character. Text or other non-control characters following the percent character are ignored until a **RETURN** is entered.

Query Commands

All AH2700A commands can be classified as query or non-query commands. A query command is one that generates a response message such as a measurement result. The most common examples of these on the AH2700A are the **SINGLE**, **CONTINUOUS** and **SHOW** commands. If a query command is interrupted by a new command, the query command is immediately aborted and the new command begins to execute. See “Aborting Commands” on page 2-6.

A non-query command will finish executing even if it is interrupted by a new command. The new command will be executed after execution of the non-query command is complete.

Each command line is either a query line or a non-query line. If a multi-command line contains any query commands, the whole command line is considered to be a query line. It will not be possible to predict which commands were executed and which were not if a query command line is interrupted by new command.

Input Buffer

All command messages are stored in the bridge in an input buffer that can hold eighty characters. This means that the bridge will not buffer more than eighty characters ahead of what it is able to process. In addition, it will not accept a command line whose total length exceeds eighty characters. If the latter occurs, the error message **LINE TOO LONG** will be reported.

Correcting Typing Errors

The AH2700A offers several of the most common ways of correcting typing errors during keyboard entry. You have the option of selecting the ways that work best with your remote device. The options given below assume that your remote serial device behaves like a dumb terminal.

Customizing the Editing Keys

To accommodate the wide variety of serial remote devices that might be used with the AH2700A, the bridge allows you to define which keys or control characters are used to perform editing. This is done from the remote device using the **DEFINE** command after your serial link is properly functioning.

Any characters may be used for these functions except for Control-A (^A), CR, LF, Control-Q (^Q), Control-S (^S) and the Current erase and delete keys.

The characters that can be changed with the **DEFINE** command can be shown with the **SHOW DEFINE** command. This command is not available from the front panel and the defined characters will not appear in the list of Serial parameters when the list is shown on the front panel.

Defining a Key to Delete Characters

The delete key deletes the last character typed and can be used as many times as needed to delete all the way back to the beginning of the line that you are entering.

The default key (stored in the **SERIAL FACTPON** parameter file) which one must press to delete the character just entered is the **DELETE** (or **RUBOUT**) key. This is the key which produces a character with the ASCII hexadecimal code 7F. If your keyboard cannot generate this code, then you can choose some other code with the command:

```
DEFINE DELETE DelChar
```

The *DelChar* parameter may be entered in one of three ways. It may be entered directly by simply pressing the desired delete key. If it is to be a control key, it may be entered as the corresponding letter preceded by an up arrow (^). Finally, it may be entered as the word **DELETE** if it is to be the ASCII delete character.

For example, **DEF DEL Y** would define Y as the delete key. The command **DEF D ^Y** would define Control-Y as the delete key, where “^” and “Y” were entered explicitly. To restore the **DELETE** (or **RUBOUT**) key to its original default function the actual delete character may be typed in or entered as the word **DELETE**. You could type **DEF DEL DEL** to do this.

Selecting Delete Key Behavior

The default handling of the **DELETE** key will work on a printer or video terminal. When the **DELETE** key is pressed, a backslash (\) is printed followed by the character that was deleted. If the **DELETE** key is pressed again, only the deleted character is printed. This continues until the next character to be entered is typed which causes a second backslash to be printed. Thus the deleted characters appear in reverse order within the backslashes. For example: **CORREC-**
SHUN\NUHS\TION. After the N was typed the **DELETE** key was pressed four times followed by **TION**. Obviously, this scheme does not take advantage of a video screen's ability to

overwrite a character and thus there are better techniques if you use a video screen.

To change the DELETE handling between use with a video terminal and use with a printer, enter the command:

```
DEFINE TERMINAL TermType
```

The *TermType* parameter is entered as either VIDEO or PRINTER depending on which kind of device is connected to the serial port. The default is PRINTER.

If VIDEO is selected, it may be necessary to redefine the backspace character using the command:

```
DEFINE BACKSPACE BackSpChar
```

where the *BackSpChar* parameter is the code that causes the cursor on your video terminal to be backspaced by one character position. The default *BackSpChar* stored in the SERIAL FACTPON parameter file is Control-H (^H).

The *BackSpChar* parameter may be entered in one of three ways. It may be entered directly by simply pressing the key which produces the desired backspace code. If it is to be a control key, it may be entered as the corresponding letter preceded by an up arrow (^). Finally, it may be entered as the word DELETE if it is to be the ASCII delete character.

The character that you enter must cause the cursor to move left by one place. When the bridge receives a DELETE key code, it will send the sequence backspace-space-backspace which backs the cursor over the character to be deleted, writes a space over it, and finally positions the cursor under the space that was written.

Erasing Lines

Pressing the ERASE key causes the contents of the entire current line except for the prompt character to be deleted. The default character used to delete the current command line is Control-U (^U). If this is not acceptable then you can redefine the erase character with the command:

```
DEFINE ERASE EraseChar
```

The *EraseChar* parameter may be entered in one of three ways. It may be entered directly by simply pressing the desired erase key. If it is to be a control key, it may be entered as the corresponding letter preceded by an up arrow (^). Finally, it may be entered as the word DELETE if it is to be the ASCII delete character.

Aborting Command Execution

The execution of any command or macro may be aborted from the serial port with the DEVICE CLEAR command. The default character (stored in the SERIAL FACTPON parameter file) that is used to issue the DEVICE CLEAR

command is Control-E (^E). If this is not acceptable then you can redefine this character with the command:

```
DEFINE DCL DevClrChar
```

The *DevClrChar* parameter may be entered in one of three ways. It may be entered directly by simply pressing the desired key. If it is to be a control key, it may be entered as the corresponding letter preceded by an up arrow (^). Finally, it may be entered as the word DELETE if it is to be the ASCII delete character.

The DEVICE CLEAR command is not needed to abort query commands since entry of any command will abort a query command. However, the DEVICE CLEAR command is the only way to prematurely abort non-query commands such as HOLD or CALIBRATE from the serial port. The serial port ^E command has exactly the same effect as the FUNC CLEAR FUNC CLEAR FUNC CLEAR front panel key sequence and the GPIB DCL command.

LIMITING FRONT PANEL ACCESS

The AH2700A can be set to limit the ability to enter commands from the bridge's front panel keypad. This can be important if your remote serial device is taking data and you want to prevent anyone from disturbing your measurements by pressing keys on the bridge's keypad.

Serial Control States

The bridge operates in one of four serial control states which determine the degree of front panel access. These states discussed below are applicable *only* to serial operation. The GPIB interface has fully analogous capabilities in the form of its own set of REMOTE/LOCAL and LOCKOUT features.

Serial Local State

In the Serial Local State, the bridge will accept all commands that are entered from either the front panel keypad or from a remote serial device. In this state, the front panel keypad and the remote serial device can be thought of as both having simultaneous control over the bridge. The Serial Local State (without lockout) is stored as the default in the SERIAL FACTPON parameter file.

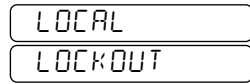
Serial Remote State

In the Serial Remote State, the bridge will accept all commands that are entered from a remote serial device but will ignore all attempted command entries from the front panel keypad except for one. That one is the LOCAL key. The front panel display will continue to be updated with whatever the bridge is measuring.

The REMOTE indicator on the front panel is illuminated while the bridge is in the Serial Remote State.

Serial Remote State with Lockout

In the Serial Remote with Lockout State, the bridge will accept all commands that are entered from a remote serial device but will ignore *all* attempted command entries from the front panel keypad with no exceptions. Even the **LOCAL** key is ignored. If the **LOCAL** key is pressed, the front panel display will show:



indicating that there is currently no way to establish operation of the bridge from the front panel.

Serial Local State with Lockout

The Serial Local State with Lockout is operationally identical to the Serial Local State in all respects. The *only* distinction between the two states is that the serial lockout parameter is *enabled* in the Serial Local State with Lockout and is *disabled* in the Serial Local State. There is no observable effect from these differences until one of the serial remote states is entered.

Selecting the Serial Control States

The commands introduced in the four sections below are used to select the Remote/Local and the Lockout states.

Selecting the Serial Remote States

The Serial Remote State and the Serial Remote State with Lockout are selected using the command:

NREMOTE

This command (NetworkREMOTE) can be entered from the remote serial device, but not from the front panel. If the NREMOTE command is issued when the bridge is in the Serial Local State, the Serial Remote State will be entered. If the NREMOTE command is issued when the bridge is in the Serial Local State with Lockout, the Serial Remote State with Lockout will be entered. Notice that the effect of this latter situation is that the bridge will go from totally unrestricted local behavior to being fully locked out from the front panel; the Serial Remote State is bypassed.

Selecting the Serial Local States

The Serial Local State and the Serial Local State with Lockout are selected using the command:

LOCAL

If the bridge is in the Serial Remote State, this command can be entered from the remote serial device *and* from the front panel. When entered from the front panel, the **LOCAL** key has an immediate effect; the **ENTER** key does not need to be pressed. If the LOCAL command is issued when the bridge is

in the Serial Remote State, the Serial Local State will be entered.

If the bridge is in the Serial Remote State with Lockout, this command can be entered *only* from the remote serial device because front panel entry of all commands is locked out in this state. If the LOCAL command is issued when the bridge is in the Serial Remote State with Lockout, the Serial Local State with Lockout will be entered.

Setting the Serial Lockout States

The Serial Remote State with Lockout and the Serial Local State with Lockout are selected using the command:

NLOCKOUT ON

This command (NetworkLOCKOUT) can be entered from the remote serial device, but not from the front panel. If the NLOCKOUT command is issued when the bridge is in the Serial Remote State, the Serial Remote State with Lockout will be entered. If the NLOCKOUT command is issued when the bridge is in the Serial Local State, the Serial Local State with Lockout will be entered.

Clearing the Serial Lockout States

The Serial Remote State and the Serial Local State are selected using the command:

NLOCKOUT OFF

This command can be entered from the remote serial device, but not from the front panel. If the NLOCKOUT HALT command is issued when the bridge is in the Serial Remote State with Lockout, the Serial Remote State will be entered. If the NLOCKOUT OFF command is issued when the bridge is in the Serial Local State with Lockout, the Serial Local State will be entered.

Saving and Showing the Serial States

The serial control states are saved as part of the Serial parameter sets. The Remote and Lockout state parameters can be determined using the SHOW NREMOTE and SHOW NLOCKOUT commands. The remote state parameter is a ON when the bridge is in the Serial Remote State or the Serial Remote State with Lockout. Similarly, the lockout state parameter is a ON when the bridge is in the Serial Remote State with Lockout or the Serial Local State with Lockout.

Because these states can be permanently stored, they can also be automatically recalled during power-on. This makes it possible to set the SERIAL USERPON parameter file so that the front panel is always disabled after power-on. Be aware that the only way to restore front panel access is through a remote device or via a special maintenance procedure described in Table 11-2 on page 11-4.

Power-on lockout can be useful even when the bridge is not connected to *any* remote device. The bridge can be configured to automatically run a dedicated macro continuously after power-on with the front panel locked out. A remote device would be required for setup, but not for operation.

SERIAL DATA LOGGING

The AH2700A can send all commands that are entered and all measurement data that is initiated from the front panel to the serial port. This allows you to keep a log of some or all bridge activity by connecting a serial printer or other serial logging device (logger) to the serial port.

The capture speed of the logger must be high enough to receive all the data at the baud rate at which it is sent. Otherwise, the baud rate must be reduced or the logger must use the Control-S and Control-Q handshaking characters to synchronize the data flow between the bridge and the logger. Low data transmission rates to the logger may cause the front panel display rate to be slower also. The effect can be very noticeable at low baud rates. Extraneous Control-S characters coming into the serial port when logging is enabled can cause the bridge to hang indefinitely until it receives a Control-Q character.

Enabling/Disabling Serial Logging

Logging to the serial port is enabled and disabled with the following command:

```
LOGGER SERIAL
OFF|READINGS|RESULTS|CMDS_TOO
```

The configuration selection controls what, if anything, is logged to the serial port. The allowable values of this setting and the corresponding messages sent are listed in Table 7-2.

Table 7-2 Serial logger settings

Setting	Messages Sent to Logger
OFF	None (logging is disabled)
READINGS	Measurement results only
RESULTS	All results (measurement and show)
CMDS_TOO	All commands and all results

This table is identical to the corresponding GPIB Table 6-2 on page 6-15. The default *content* parameter stored in the SERIAL FACTPON parameter file is OFF so that logging to a remote serial device is disabled.

This chapter introduces concepts which will help you interpret the meaning of your three-terminal measurements. Several additional commands are introduced here in case you need the ultimate in accurate measurements. The discussions here assume you are familiar with the AH2700A.

The equations used in this chapter assume that you are familiar with how to apply complex algebra to network calculations. This turns out to be much easier than it might look at first. If you need help, there are literally hundreds of books that discuss basic theory. Reference 8 in the bibliography has some good theoretical discussions including wye-delta transformations on p. 195. Chapter 9 of this reference also has an interesting discussion of capacitors and capacitance.

INTERPRETING MEASUREMENT RESULTS

Sometimes it is desirable to convert raw measurement results from the AH2700A to another form. A different form may better model the unknown sample (as in the case of series versus parallel configurations), or it may simply make a physical process more comprehensible (as in the case of negative capacitances and conductances).

Trusting the Results

Obviously, there is no point performing complicated calculations on measurement results unless they are meaningful. In particular, some users are surprised when they discover that the AH2700A capacitance result *really* reads capacitance and the loss result *really* reads loss. There seems to be a tendency to not expect the bridge to be capable of *truly* separating the capacitance result from the loss result. In fact, it does this very well to the limit of its specifications. The bridge can almost be thought of as two distinct instruments, one that measures capacitance and one that measures loss.

The practical effect of this is that the bridge is very good at isolating the capacitive contributions of an unknown impedance from the loss contributions. Obviously, this is essential for understanding complicated unknown impedances, but it can also be a big help with diagnosing transducer and cable problems. You may only be interested in measuring the capacitance, for example, but if you are having a problem, it may be the *loss* reading that holds the answer! Even if your interest is only in the capacitance, monitoring the loss for any unexplained changes will give you increased confidence in your capacitance results.

In most cases, a change in your capacitance reading is a result of a change in the capacitance or inductance of your unknown impedance or of its connecting cables. A problem with stray capacitance is a common possibility.

In most cases, a change in your loss reading is a result of a change in the dielectric loss or resistance of your unknown impedance or of its connecting cables. A problem with bad connections is a common possibility.

There are ways in which a change in dielectric loss or resistance can cause a change in the *capacitance* reading. There are also ways in which a change in capacitance or inductance can cause a change in the *loss* reading. The existence of such interactions implies a complicated unknown impedance or possibly a connecting cable problem. Understanding the theoretical basis of these interactions is the subject of the next section.

WYE-DELTA TRANSFORMATIONS

The three-terminal measurement method used by the AH2700A allows one to use wye-delta transformations to gain a better understanding of certain impedance configurations.

Suppose that the circuit of Figure 4-2 on page 4-3 is generalized so that the three capacitors are replaced with admittances as shown in Figure 8-1. It is possible to convert between this delta network and the one shown in Figure 8-2 which is a wye network using the equations below:

$$Y_{HL} = \frac{Y_H Y_L}{Y_H + Y_L + Y_G} \quad \text{Eq. 8-1}$$

$$Y_{HG} = \frac{Y_H Y_G}{Y_H + Y_L + Y_G} \quad \text{Eq. 8-2}$$

$$Y_{LG} = \frac{Y_L Y_G}{Y_H + Y_L + Y_G} \quad \text{Eq. 8-3}$$

$$Y_H = \frac{Y_{HL} Y_{HG} + Y_{HL} Y_{LG} + Y_{HG} Y_{LG}}{Y_{LG}} \quad \text{Eq. 8-4}$$

$$Y_L = \frac{Y_{HL} Y_{HG} + Y_{HL} Y_{LG} + Y_{HG} Y_{LG}}{Y_{HG}} \quad \text{Eq. 8-5}$$

$$Y_G = \frac{Y_{HL} Y_{HG} + Y_{HL} Y_{LG} + Y_{HG} Y_{LG}}{Y_{HL}} \quad \text{Eq. 8-6}$$

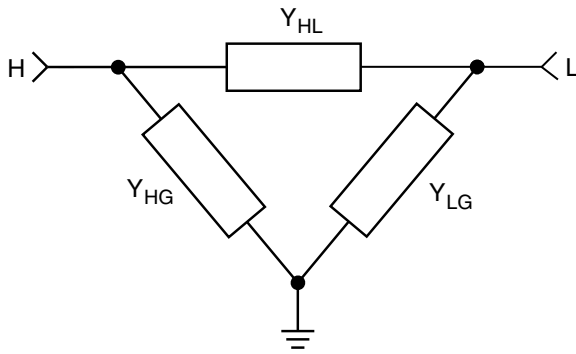


Figure 8-1 Delta network

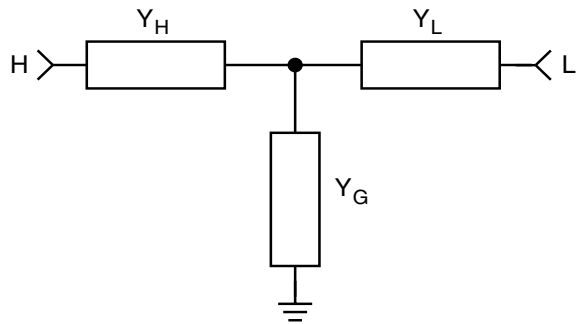


Figure 8-2 Wye network

This transformation is very powerful because three-terminal measurements are fundamentally of the delta variety whereas real unknown samples are sometimes of the wye variety. The AH2700A measures Y_{HL} only, while excluding Y_{HG} and Y_{LG} . In contrast, some samples behave like they are connected in a wye network and can only be understood that way.

As an example, suppose that a wye network consists only of resistors so that:

$$Y_G = \frac{1}{R_G} \text{ and } Y_H = Y_L = \frac{1}{R} \quad \text{Eq. 8-7}$$

By applying Eq. 8-1:

$$Y_{HL} = \frac{R_G}{R(2R_G + R)} \quad \text{Eq. 8-8}$$

Suppose further that $R = 1$ megohm and that $R_G = 1$ ohm. This gives $Y_{HL} = 10^{12}$ ohms (1 teraohm). This demonstrates that by starting with some readily available resistor values, one can construct a wye network which, when measured by the AH2700A, will appear to be a resistor far larger than is commonly available. Since the AH2700A can measure extremely large resistances, one use of wye networks could be in making performance and calibration checks of the bridge.

8-2 Advanced Measurements

Interpretation of Negative Capacitance

The AH2700A is capable of displaying negative capacitance and loss for values up to 10% of the corresponding full scale positive values. Negative values, particularly negative loss values, are not expected to be seen with most impedance measurements. However, negative values may be encountered more often than you might expect. They are as meaningful as positive values and can be useful if you understand them.

Negative capacitance values can be interpreted in two ways. The common interpretation is simply that a negative capacitance is an inductance. This assumes that the capacitive reactance and the inductive reactance are equal, that is:

$$j\omega L = \frac{1}{j\omega C} \quad \text{Eq. 8-9}$$

where L is the inductance, j is the square root of -1 and ω is 2π times the frequency. This reduces to:

$$L = \frac{-1}{\omega^2 C} \quad \text{Eq. 8-10}$$

and shows that the more negative the capacitance, the smaller the inductance will be. Since the largest negative capacitance the AH2700A can measure is $-0.15 \mu\text{F}$, the smallest inductance that could be measured is 0.42 milliHenries (at 20 kHz). While inductances of this size and above are made, they are in the upper range of what is commonly manufactured today. These values are usually beyond what could be considered to be a stray circuit inductance. This means that any negative capacitances that are measured by the AH2700A should not be interpreted as inductances unless a large inductance has been explicitly included in the unknown sample. See "INDUCTANCE MEASUREMENTS" on page 8-8 for a discussion about measuring real inductors.

The second interpretation of negative capacitance (and of negative loss) requires the use of wye-delta transformations. Consider the circuit in Figure 8-3.

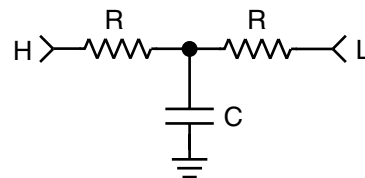


Figure 8-3 RCR wye network

Two resistors R which are in series have their center point tied to ground through a capacitor C. Eq. 8-1 may be used to calculate the admittance that this network would present to the H and L terminals of the bridge. The result is:

$$Y_{HL} = \frac{\frac{2}{R} - j\omega C}{4 + \omega^2 C^2 R^2} \quad \text{Eq. 8-11}$$

The real (conductance) term is positive in this result while the imaginary (capacitive susceptance) term is negative. For normal resistors and capacitors the conductance and susceptance are both positive. For this to be true, R must be positive and C must be negative. Since R and C are what the bridge measures, we have found a simple network which produces negative capacitance readings for all positive values of R and C!

Actual Situations

Although this network has been analyzed as a lumped circuit, it is representative of any resistor which has a distributed capacitance to ground. Since most resistors have some capacitance to ground, this effect would seem to be quite common. However, the calculation did not allow for any shunt capacitance between the H and L terminals or for any capacitance shunting the resistors. Such shunting capacitances will have a positive contribution and will often overwhelm the negative effect in a real resistor. Therefore, details in the stray capacitances of the unknown sample will ultimately determine whether the measured capacitance is positive or negative. An example of a configuration which will produce a negative capacitance is that of an ordinary resistor whose body passes through a closely fitting hole in a grounded plane such as that shown in Figure 8-4. The stray capacitance across the resistor can be made nearly zero by choosing the correct hole diameter.

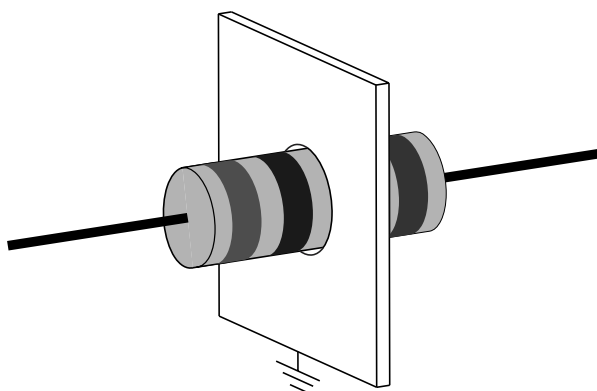


Figure 8-4 Resistor through a grounded plane

Interpretation of Negative Loss

Now consider a second case using the circuit in Figure 8-5. Two capacitors C which are in series have their center point

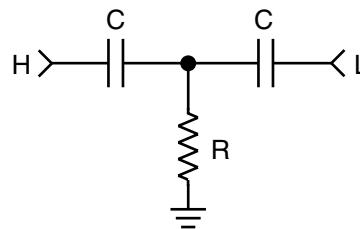


Figure 8-5 CRC wye network

is tied to ground through a resistor R. Eq. 8-1 can again be used to calculate the admittance that this network would present to the H and L terminals of the bridge. The result is:

$$Y_{HL} = \frac{-\omega^2 C^2 R + 2jR^2 \omega^3 C^3}{1 + 4R^2 \omega^2 C^2} \quad \text{Eq. 8-12}$$

The real (conductance) term is negative in this result while the imaginary (capacitive susceptance) term is positive. For normal resistors and capacitors, the conductance and susceptance are both positive. This leads to the conclusion that R must be negative and C must be positive in this equation. Since R and C are what the bridge actually measures, we have found a simple network which produces negative loss readings for all positive values of R and C.

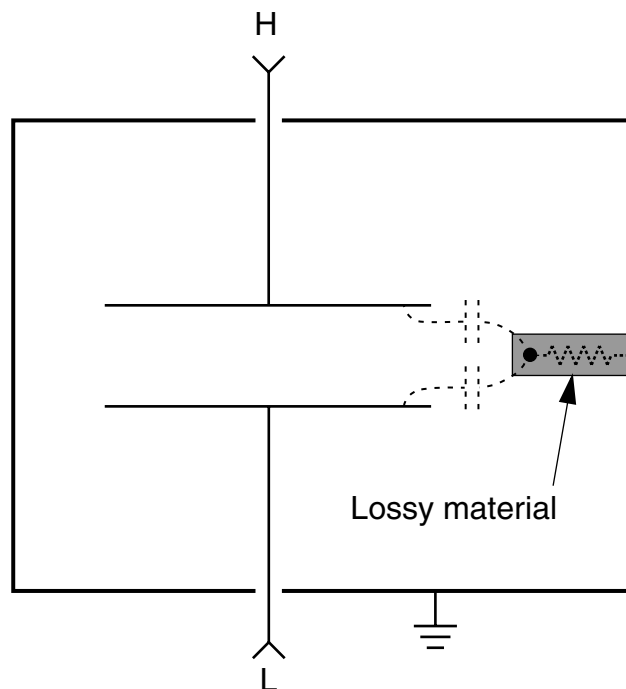


Figure 8-6 Shielded capacitor showing CRC network formed by stray capacitances to nearby lossy material

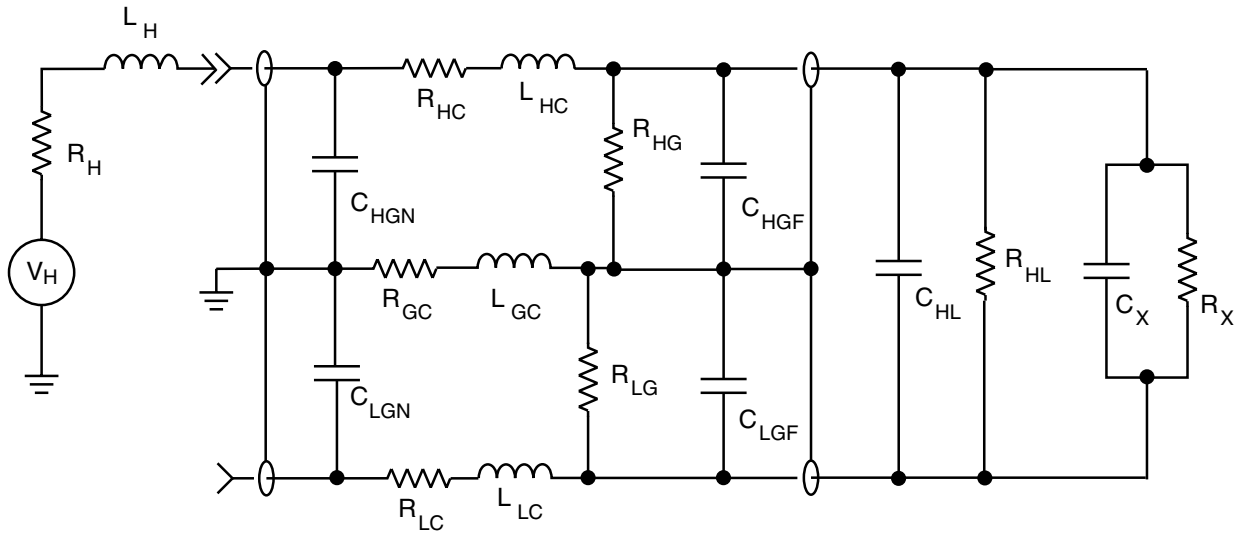


Figure 8-7 Advanced 3-terminal equivalent circuit

Actual Situations

At least two physical situations can be represented by this network. First, any loss to ground within the unknown sample measurement area which is coupled capacitively to the H and L terminals could behave like this network. A loss mechanism like this can be physically *outside* the actual sample specimen yet still within the field between the H and L terminals. See Figure 8-6. Examples include a piece of wood, an insect, a hand or, more likely, an insulating support. A second situation occurs when the sample itself has a distributed loss to ground within its own dielectric. This could be a meaningful effect in the sample.

This calculation assumed no series loss between the H and L terminals. If a loss exists, it will make a positive contribution to the measured reading. If the contribution is large enough, it can overwhelm the negative contribution so that no net negative loss is observed. Whether or not this occurs will depend largely on the particular sample. There are many materials with sufficiently low loss to easily allow the negative contribution to dominate and consequently, negative losses are not uncommon.

SOURCES OF ERROR

To better understand what kinds of errors can occur when connecting three-terminal impedances to the AH2700A, Figure 8-7 shows a circuit model of such a connection. The schematic diagram shows all of the major circuit elements that have already been discussed in “THREE-TERMINAL MEASUREMENTS” on page 4-2 and also some new ones that usually have more subtle effects. The unknown impedance to be measured is represented by C_X and R_X . Undesirable stray capacitance or leakage resistance that contributes to the unknown is represented by C_{HL} and R_{HL} . The extent of

coverage of the shielding braid in coaxial cables is not always 100%. To minimize C_{HL} , coaxial cables having a high shield coverage must be chosen to carry the H and L terminal signals.

The leakage resistances in the cable dielectric are indicated by R_{HG} , and R_{LG} . These resistances should be very high in most test configurations and therefore, should not have any significant effect.

The cable capacitances occur from the center conductors to the shields and are proportional to the length of the cable. These capacitances are modeled by placing half at the *near* end as C_{HGN} and C_{LGN} and half at the *far* end as C_{HGF} and C_{LGF} .

The series resistances of the center conductors of the coaxial cables are represented by R_{HC} and R_{LC} . The series resistance of the shielding braid is indicated by R_{GC} . Assuming the connectors on the ends of the cables are in good condition, all three of these resistances will be proportional to the length of the cable.

The inductances of the center conductors of the cables are represented by L_{HC} and L_{LC} . The inductance of the shielding braid is indicated by L_{GC} .

The voltage at the H terminal is supplied by the source V_H driven through an effective resistance R_H and inductance L_H . All of the series resistances in this drawing and the inductance combine with the cable capacitances to cause small errors in the measured results which increase with the length of the cables and with C_X .

Table 8-1 Approximate uncorrected cable error in capacitance (in ppm) and loss (in $10^{-6} \tan \delta$) vs. length and unknown capacitance at 1 kHz

Length	1 pF	10 pF	100 pF	1000 pF	10000 pF	100000 pF	1000000 pF
1 m	0.04* (C in ppm)	0.01	0.01	0.04	0.40	4.0	40
	0.30* ($10^{-6} \tan \delta$)	0.04	0.09	0.50	5.0	50	500
2 m	0.15*	0.02	0.02	0.09	0.8	8.0	80
	1.3*	0.15	0.20	1.1	10	100	1000
3 m	0.40*	0.05	0.03	0.15	1.3	12	120
	3.0*	0.35	0.35	1.5	15	150	1500
5 m	1.3*	0.18*	0.08	0.25	2.0	20	200
	11*	1.1*	0.80	3.0	25	250	2500
10 m	8.0*	0.8*	0.25	0.60	4.0	40	400
	70*	7.0*	2.0	7.0	50	500	5000
20 m	60*	6.0*	1.3	1.5	9	80	800
	500*	50*	5.0	16	100	1000	10000
30 m	200*	20*	2.0	2.5	14	120	1200
	1500*	150*	10	30	160	1500	15000
50 m	800*	80*	8.0	6.0	25	200	–
	7000*	700*	50	70	280	2500	–
100 m	6500*	650*	55*	20	60	400	–
	60000*	6000*	400*	220	650	5000	–

Effects of Error Sources

Cable Length

For errors caused by L_{HC} , L_{LC} , R_{HC} and R_{LC} the amount of error is proportional to the cable length if the unknown capacitance C_X is much larger than the cable capacitances C_{HGF} or C_{LGF} . If the unknown capacitance C_X is much smaller than the cable capacitances, the error is proportional to the square of the cable length.

Cable Resistance

The presence of $R_H + R_{HC} + R_{LC}$ causes the measured loss to be larger than it should be by an amount that is proportional to the unknown capacitance C_X plus the cable capacitances C_{HGF} or C_{LGF} .

Cable Inductance

The presence of $L_H + L_{HC} + L_{LC}$ causes the measured capacitance to be larger than it should be by an amount that is proportional to $(L_{HC} + L_{LC})(C_X + C_{HGF})$. Unlike all the other model parameters, L_{HC} , L_{LC} and L_{GC} can change in response to changes *outside* of the cables. The reason is that at 1 kHz, the skin-depth is much greater than the thickness of the coaxial shield. Therefore, the shield does not contain the *magnetic* field generated by the center conductor of the cable. Because the field penetrates the shield, the proximity of other conduc-

tors and especially steel can affect the value of L_{HC} , L_{LC} and L_{GC} . In addition, there will also be some sensitivity to interference from externally generated magnetic fields.

These effects will be minimized by minimizing the area enclosed by the coaxial cables. The use of Andeen-Hagerling DCOAX dual coaxial cable will minimize and standardize these effects.

Cable Shield Impedance

The presence of R_{GC} and L_{GC} causes the measured loss to be more negative than it should be by an absolute amount. It causes the capacitance to be larger than it should be due to the predominantly capacitive cable load. This error is independent of C_X and R_X and varies approximately as the cube of the cable length. Fortunately, it is fairly stable and can be subtracted out as a zero correction.

Connectors: Type 874 vs. BNC

The AH2700A uses BNC connectors rather than type 874 for two reasons. First, type 874 connectors today are literally as much as 100 times more expensive than BNC connectors. Second, BNC connectors are much smaller and therefore more compatible with modern electronic instruments.

Traditionally, type 874 connectors have been commonly used for high precision capacitance measurements. While the hermaphroditic design of these connectors makes them friendly

to use, they offer no performance advantage over BNC's at 1 kHz and for the impedance range measured by the AH2700A. (At high frequencies they have some advantages.)

Both types of connectors have failure mechanisms that can cause subtle problems. The type 874 center pin is attached with a nut that compresses against a piece of insulating plastic. This plastic yields over time so that the nut becomes loose and makes the electrical connection of the center pin unreliable.

BNC plugs have a splined cylinder just inside the outer bayonet. These splines are the contacts that mate the shield between the plug and a jack. Unfortunately, the metallurgy of these splines often leaves something to be desired. They frequently yield and thereby lose enough contact pressure to affect the ground connection. Fortunately, there are six of these splines in each plug and in the case of the AH2700A, there are two BNC connectors having a parallel ground path. Since it is rare for all twelve splines to make poor contact, properly assembled BNC connectors have proven to be quite reliable when used with the bridge.

Connectors fail because the resistance in the connector or between connectors becomes too large. Since loss is a measure of resistance, a failing connector will be revealed by AH2700A measurements as an increase in the loss. A failing connector will not affect the capacitance measurement until the effect on the loss component is large.

CABLE ERROR CORRECTIONS

The AH2700A can automatically correct for errors caused by the connecting coaxial cables. For the bridge to be able to perform these corrections, you must enter four parameters which describe the cable used to connect the bridge to the device under test. These are cable length, resistance, inductance and capacitance per meter of length. In addition, you must use the ZERO SINGLE and ZERO commands to correct the cable zero offset.

Setting up the Corrections

The cable resistance, capacitance, and inductance parameters are called the "cable electrical parameters". Changing these parameters and the cable length is described below.

Extent of Correction

The extent to which the errors shown in Table 8-1 can be corrected is variable. The major contributor to this variation is the accuracy of the numbers used for the cable electrical parameters. Typical accuracies will correct the cable errors by an order of magnitude. If extra efforts are made to ensure that each number is accurate, it is possible to correct the cable errors by two orders of magnitude. The cable correction model used by the bridge cannot go beyond this level.

Changing the Cable Length

The length of cable between the bridge and the unknown sample determines the amount of cable resistance, capacitance and inductance that must be corrected for. Consequently, the length in meters of one of the cables can be entered from a remote device using the syntax:

`CABLE LENGTH Length_M`

or from the front panel:

`[FUNC] [SELECT] [CABLE] [LENGTH] Length_M`

Cable *Length_M* can be entered to the nearest hundredth of a meter up to a maximum of 999.99 meters. The default cable *Length_M* in the GAUGE FACTPON parameter file is one meter.

Changing the Cable Resistance

Cable resistance is the resistance (in milliohms) of the center conductor of one meter of the cable that is used to connect the AH2700A to the unknown capacitance. Cable resistance is changed using the command:

`CABLE RESISTANCE mO/M`

or from the front panel:

`[FUNC] [SELECT] [CABLE] [RESISTANCE] mO/M`

The value of *mO/M* (resistance/meter) can range from 0 to 9999.0 milliohms per meter. The default resistance in the GAUGE FACTPON parameter file is 40 milliohms per meter.

Changing the Cable Inductance

Cable inductance is the inductance of the center conductor in microhenries per meter of cable that is used to connect the AH2700A to the unknown capacitance. Cable inductance is changed using the command:

`CABLE INDUCTANCE uH/M`

or from the front panel:

`[FUNC] [SELECT] [CABLE] [INDUCTANCE] uH/M`

The value of *uH/M* (inductance/meter) can range from 0.00 to 99.99 microhenries per meter. The default value in the GAUGE FACTPON parameter file is 1.10 microhenries per meter.

Changing the Cable Capacitance

Cable capacitance is the capacitance in picofarads per meter of cable that is used to connect the AH2700A to the unknown capacitance. Cable capacitance is changed using the command:

`CABLE CAPACITANCE pF/M`

or from the front panel:

`[FUNC] [SELECT] [CABLE] [CAPACITANCE] pF/M`

The value of pF/M (capacitance/meter) can range from 0.0 to 999.9 picofarads per meter. The default value in the GAUGE FACTPON parameter file is 100.0 picofarads per meter.

Measuring the Zero Offset Error

The zero error of the cable is measured by using the ZERO FETCH command in the standard manner described in “Zero Compensation Result Mode” on page 5-4. As described there, (and unlike the other cable correction commands) this mode must be explicitly activated with the ZERO command before it will affect the measurement results. The ZERO commands will, of course, also allow you to correct for whatever residual impedance exists in any fixture at the far end of your cable. (The ZERO command can not (and need not) correct for the cable capacitance *itself*. It corrects for a much smaller and more complicated effect that *depends* on that capacitance.)

Physical Configuration

It is important that the cable-pair shields are connected together at the *far* end of the cable. The cable correction calculations made by the bridge will only be correct if this is the case.

Another important consideration is that the cable *must* be routed to its final position before any testing or measurements are performed with it. The routing of the cable influences especially the capacitive error which is due to C_{HG} , C_{LG} and L_{GC} . This routing sensitivity occurs because L_{GC} is affected by the proximity of the cable to metal and other wiring.

Testing Parameter Importance

If you have read how to change the cable parameters above, you will be able to confidently determine the individual importance of any of the cable parameters for your particular application. You need to connect your AH2700A using your cables to one of your typical unknown samples. Make a series of measurements while varying the values of the cable parameters. See if you can detect in your measurements the effect of changing the cable parameter values.

In particular, try changing any parameters that you think might be important for your particular configuration. The effects of the electrical cable parameters should be tried with the $Length_M$ parameter being set to the length of your cable.

You should compare the effect of a default cable parameter value to the effect of that same parameter being set to zero. Since the cable corrections are small, your sample will have to be more stable than the magnitude of the cable corrections or you will not be able to detect their effect. If you either can't detect the cable effects in your measurements or they are too small to be of concern, then you can use the default values in the GAUGE FACTPON parameter file and not be concerned any further with cable corrections.

Determining the Parameters of your Cable

If you have decided that cable corrections are necessary in your application, then you will want to read this section.

If you are using a standard one meter Andeen-Hagerling DCOAX-1-BNC cable then the default parameters from the GAUGE FACTPON parameter file will be correct for this cable. In other words, if you have not created a GAUGE USERPON parameter file, then when the bridge is turned on, it will automatically have chosen the correct cable parameters. See Chapter 3 titled “Parameter and Program Files” if you want to learn how to make your bridge power-on with the correct parameter settings.

If you are using an Andeen-Hagerling DCOAX cable of a length other than one meter and you want to set the cable parameters correctly, then you will have to use the CABLE LENGTH command to change the $Length_M$ parameter. The cable electrical parameters will still be correct without making any changes.

If you are using any other type of cable and you want to set the cable parameters correctly, you will have to determine the parameters for your cable. If your cable is RG-58 or similar, the three default electrical parameters will be very close to those for your cable. If that is the case, you may want to just set the $Length_M$ parameter and forget about adjusting the electrical parameters.

Determining the $Length_M$ is trivial provided that you understand that the $Length_M$ is that of the *pair* and *not of the sum* of two single coaxial cables. The capacitance/meter and the resistance/meter are usually available for any commercially made cables. They are not hard to measure if published specifications cannot be found. In either case you must understand that these parameters are for a *single* piece of coaxial cable and *not for the sum* of two single coaxial cables. The resistance/meter can vary significantly since some cables such as RG-59 and RG-62 have only a copper-coated *steel* center conductor rather than solid *copper* such as RG-58.

Determining the inductance/meter is *not* easy because the correct specification will *not* be published. You may find an inductance specification but it will *not* be what you are looking for. The problem, as was discussed in “Cable Inductance” on page 8-5, is that the inductance at 1 kHz is dependent on more factors than just the construction of the cable. *Calculating* the inductance would be difficult even for the simplest configurations. *Measuring* it is more practical *if* the measurement can be made at one kilohertz.

To make the measurement, tie the unknown sample ends of the cable together so that the center conductors are connected to each other. At the other end, measure the inductance between the open H and L cable ends as shown in Figure 8-8. The cable shields can be connected in parallel with the center conductors, but this will not have a significant effect. This measurement will be very difficult for short cables such as one meter since the inductive component of the impedance will be small in an absolute sense *and* will be small relative to the resistance of the cable. Few instruments will be capable of making this measurement for short cables at 1 kHz. Having measured the inductance and the length of the cable, it is then simple to calculate a number for the inductance/ meter parameter.

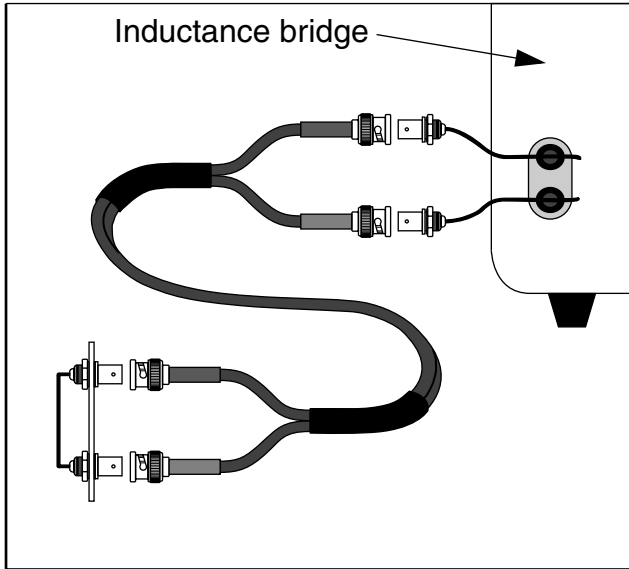


Figure 8-8 Measurement of cable inductance

CALIBRATION AT OTHER FREQUENCIES

Since AH bridges can make capacitance measurements more accurately than any other current products *at any frequency*, there is a desire to be able to use them as the basis for calibration of capacitors at frequencies other than those within their range of operating frequencies. This can in fact be done with four-terminal capacitance standards and is used by one of the world's largest electronic instrument manufacturers to perform NIST traceable calibrations.

This method requires the use of a network analyzer that covers the frequency range of interest. The method is described in reference 7 in the bibliography. This is a brief and highly technical discussion for the advanced user who wants to pursue this topic further.

INDUCTANCE MEASUREMENTS

As discussed in “Interpretation of Negative Capacitance” on page 8-2, a negative capacitance may be interpreted as an inductance. You can, in fact, use your AH2700A to make accurate measurements of large inductors.

Unlike capacitors, an important contributor to the loss of inductors is the resistance of the wire used to make the inductor. For air-core inductors with a low stray capacitance, this is the primary loss mechanism. The most accurate circuit model is then a resistor in series with an inductor. You should, therefore, measure inductors with your AH2700A set to units of series-kilohms. This will allow you to directly read the series resistance of an inductor connected between the HIGH and LOW terminals of the bridge. For air-core inductors such as a Leeds & Northrup 1520-C Brooks Inductometer (no longer made), this value will be in close agreement with DC measurements.

Calculating the Inductance

The inductance can be determined by inserting the measured negative capacitance value at 1 kHz into Eq. 8-2 and calculating the result. This leads to dividing the magnitude of your measured negative capacitance in picofarads into 25330.3 to give an inductance in henries. Table 8-2 shows the conversions for popular values.

Measurement of Large Inductances

Although the AH2700A has the necessary range to measure extremely large inductances, the accuracy of the measurement decreases as the inductance increases and eventually becomes useless for obtaining an inductance value. The problem occurs when the capacitive reactance of the DUT becomes significant relative to its inductive reactance. Because these have opposite signs, they tend to cancel one another so that the instrument sees a reactance that is bigger than the inductive component. (The measured capacitance is smaller than it would otherwise be.)

If the reactances are equal at 1 kHz, then self-resonance occurs and the DUT is effectively a resistor. When this occurs, the measured capacitance value tells nothing about the actual capacitance or inductance of the DUT; it simply is an indication of resonance. A lower measurement frequency would be required to avoid the resonance point.

Table 8-2 goes down to -10 pF, but this should be well past the resonance point for real devices. The stray capacitance for large inductors increases rapidly with inductance because of the large number of turns that are required. As a result, most inductors will not read accurately above about 10 H using this method.

Table 8-2 Negative capacitance to inductance conversion table at 1 kHz

Capacitance		Inductance
-120000.	pF	0.21109 H
-100000.	pF	0.25330 H
-50661.	pF	0.50000 H
-50000.	pF	0.50661 H
-25330.	pF	1.0000 H
-20000.	pF	1.2665 H
-12665.	pF	2.0000 H
-10000.	pF	2.5330 H
-5066.1	pF	5.0000 H
-5000.0	pF	5.0661 H
-2533.0	pF	10.000 H
-2000.0	pF	12.665 H
-1266.5	pF	20.000 H
-1000.0	pF	25.330 H
-506.61	pF	50.000 H
-500.00	pF	50.661 H
-253.30	pF	100.00 H
-200.00	pF	126.65 H
-126.65	pF	200.00 H
-100.00	pF	253.30 H
-50.661	pF	500.00 H
-50.000	pF	506.61 H
-25.330	pF	1000.0 H
-20.000	pF	1266.5 H
-12.665	pF	2000.0 H
-10.000	pF	2533.0 H

Loss and Q-factor

On the other hand, the measured series resistance *is* a meaningful value for the DUT at 1 kHz. In fact, the series resistance should be a meaningful 1 kHz measurement whenever the bridge is able to report a reading above or below resonance. The series resistance in this case will *not* likely be in good agreement with the DC value because the large stray capacitance implies a substantial loss in the insulation that covers the wire of the inductor.

The bridge can also be used to measure the Q-factor of a large inductor above or below resonance. This is done by setting the bridge to units of dissipation factor (D). The Q-factor is just the reciprocal of the dissipation factor ($Q = 1/D$). This measurement should be valid for any result reported by the bridge, but as with the series resistance setting, the capacitance reading will only be meaningful for smaller inductance values.

MEASURING LARGE CAPACITORS AT LOW FREQUENCIES

Measuring capacitors larger than about 0.1 μF at frequencies less than about 200 Hz is more demanding for the AH2700A than any other combination of frequency and capacitance. The reason is that very small voltages must be used to make these measurements. Why is this true? There are two issues that conspire to create this situation.

Large Ratio-Transformer Ratios

The first and most important issue is that the largest reference capacitor in the AH2700A is 100 pF. To balance this 100 pF capacitor directly against a large unknown capacitor requires using very large transformer ratios. The worst case occurs with 1 μF capacitors where the transformer ratio must be at least 10,000. This means that effectively, this transformer must have 10,000 turns and the voltage from only one of these turns will be used to drive the 1 μF capacitor. That means that if the entire 10,000 turn winding can be driven by a maximum of 15 volts, then the voltage driving the unknown capacitor will be $15/10,000 = 1.5$ mV. (In reality, some extra margin is needed so the AH2700A uses two cascaded ratio transformers to achieve a ratio of 15,000. This gives 1.0 mV across a 1 μF capacitor.)

Low Ratio-Transformer Saturation Voltages

A second issue conspires to make the measurement voltage even lower. Ratio transformers must be operated in their linear range. This is accomplished by limiting the driving voltage so that the transformer does not saturate. At 1 kHz this voltage is 15 V in the AH2700A. Unfortunately, the saturation voltage of a transformer is directly proportional to the frequency of the driving voltage. This means that measurements made with the AH2700A at 50 Hz require that the ratio transformer be driven by a maximum of $15 \times 50 / 1000 = 0.75$ volts.

The worst case measurement situation therefore is with 1 μF at 50 Hz where the voltage applied to the unknown capacitor by the AH2700A can be no more than $1.0/20 = 50 \mu\text{V}$! This low voltage demands that all sources of noise and interference be as low as possible in order to achieve an acceptable signal to noise ratio. Even under this worst case condition, the AH2700A achieves a level of precision measured in hundreds of ppm.

Operational Consequences

As mentioned above, all sources of noise must be limited. The general methods for doing this have been described in detail in "REJECTING INTERFERING SIGNALS" on page 4-7.

The AH2700A automatically does what it can to optimize the measurement of large capacitors at low frequencies by not allowing any measurements to be made without fully com-

mutating the detected signal. In order that it have time to adequately average the signal, the bridge will also not allow unrealistically fast measurements to be attempted. For example, measurements made with $AverExp = 4$ will take much longer at frequencies at or below 500 Hz even though this setting is normally reasonably quick at higher frequencies.

For measurements of large capacitors at low frequencies, there is one source of noise that requires particular attention. This is low-frequency interference from magnetic coupling. In this case, low-frequency interference will usually be power line related and its worst sources will be power transformers and power supplies. For discussions of how to reduce this kind of interference, see “Interference from Power Lines” on page 4-7 and “Minimizing the Coupling of Interference” on page 4-8. Magnetic noise can radiate for a meter or more from power transformers weighing only a few kilograms. Magnetic interference is also generated at the power line frequency and its harmonics by current loops in power supplies. Magnetic deflection yokes in video monitors are another important source of low frequency magnetic interference.

Making matters worse at power frequencies is that interference is not well shielded by non-ferrous metals. As an example, a GR1413 decade capacitor box must be located at least 0.3 meter from the AH2700A because the power supply and transformer in the bridge will induce interference in this decade box even though this decade box is made of thick aluminum and has a second aluminum box inside the first.

Bridge Design Alternatives

Are ratio-transformer capacitance bridges having fused-silica reference capacitors always limited in this way? The answer is basically “yes”, although the limitations are partly the result of engineering trade-offs.

It is possible to make ratio-transformers that work at almost any voltage. The more turns on a transformer, the higher its saturation voltage will be. The problem is that accurate ratio transformers must not have too many turns. Otherwise, the inductances and stray capacitances reduce the accuracy of its voltage ratios. If a ratio-transformer is optimized for 50 Hz, for example, it will perform poorly at higher frequencies. The ratio-transformers in the AH2700A are optimized to be accurate over the entire frequency range of the bridge, not just at one end of its frequency range.

Another design alternative is to use a larger reference capacitor. This could have the advantage of allowing the application of a voltage of just about any magnitude to the unknown. Any reference capacitor must be extremely stable. Fused-silica reference capacitors currently offer the greatest stability and are reliable and relatively economical. The problem is that economical designs for such capacitors that are much larger than 100 pF do not exist. This leaves the possibility of using a larger, but less stable, capacitor as a secondary internal reference that would be calibrated periodically against the primary internal fused-silica reference capacitor. This solution could certainly be made to work, but it would be more com-

plex and would sacrifice the measurement reliability that the AH2700A achieves by *directly* comparing its fused-silica standard against even the very largest capacitors that it is able to measure.

This chapter describes how to verify that your AH2700A is properly calibrated and how to re-calibrate it if a verification shows that recalibration is needed. Several issues regarding “when to calibrate” and “what standards to use” for calibration are discussed. The bridge's ability to use either its factory capacitance and transformer calibrations or the most recent versions of these is described. Finally, the passcode structure used to protect the calibrations is presented.

GENERAL ISSUES

Recommended Equipment and Accessories

The following list gives the tools and equipment required to verify/calibrate the AH2700A.

1. 0.5 to 1600 pF three-terminal capacitance standard having a traceable accuracy of 1 ppm. See “Obtaining the Capacitance Verification Data.” on page 9-7 for a discussion of what is appropriate.
2. Dual, low noise, low inductance, one meter, coaxial cables with male BNC ends. Andeen-Hagerling DCOAX-1-BNC is recommended.
3. AC resistance standard having a value of 10 k Ω with an accuracy at 1.0 kHz of 0.005%. See “Finding a Suitable AC Resistor Standard” on page 9-9 for a discussion of what is appropriate.
4. Digital multimeter with an AC voltage accuracy of 1%.
5. Digital frequency meter with an accuracy of 0.001% at one kilohertz

Types of Calibrations/Verifications

There are a number of procedures required to verify adequate calibration of an AH2700A. These can be grouped into the various types listed below.

1. Internal - verifies numerous internal calibration points, especially related to the DAC (or RTMDAC). See “ANALOG CIRCUITS BLOCK DIAGRAMS” on page 10-2 for an introduction to the DAC circuitry.
2. Capacitance - verifies that the internal reference standards are calibrated relative to a traceable standard.
3. Loss - verifies that the internal phase shifters are accurately producing a 90 degree phase shift.

4. Frequency - verifies that the frequency of the test signal is within tolerance.
5. Output voltage - verifies that the voltage of the test signal is within tolerance.

The capacitance and internal calibrations are all maintained by values stored in an EEPROM (re-writable, non-volatile memory). The loss calibration is derived from the capacitance and internal calibrations using a patented phase-shifting technique. The test signal frequency is determined by a quartz oscillator and a digital divider.

Calibration versus Verification

Definitions

A complete calibration of the AH2700A accomplishes two major functions:

- Makes all measurements taken with a given AH2700A consistent with each other.
- Makes all measurements taken consistent with and traceable to national and international standards.

The internal calibrations accomplish the first function. The capacitance and output voltage calibrations accomplish the second function. A calibration accomplishes these things by making permanent adjustments to a bridge.

A verification is a test of whether a bridge is sufficiently well calibrated and fully functional. A verification does not adjust a bridge, but its results may show cause to perform a calibration or repair. The loss, frequency and voltage checks are only verifications because they are not adjustable.

Availability of the Verification Option

Conventionally, a calibration has typically involved making some kind of measurement of a calibratable quantity (called a calibration point here) within an instrument, the result of which is compared against the desired value for that measurement. If the measured and desired values are close enough, no actual adjustment of the instrument being calibrated is needed. In this case, a *verification* has been performed. If the measured and desired values are different, then an adjustment of the instrument is made. In this case, a *calibration* has been performed. When a calibration/verification involves physically adjusting a variable control, the choice of verifying *or* calibrating is always available.

Using firmware, today's instruments can calibrate dozens and even hundreds of internal instrument settings automatically.

DEV FROM LAST INT:	CAL AGE = 345 HRS	TEMP = -5.1 C
DEV FROM ORIG CAP:	CAL AGE = 12345 HRS	TEMP = -4.6 C

Figure 9-1 Example of results of SHOW CAL command sent to remote devices

DEV FROM	CAL AGE	TEMP
LAST INT	345 H	-5.1 C
DEV FROM	CAL AGE	TEMP
ORIG CAP	12345 H	-4.6 C

Figure 9-2 Example of results of SHOW CAL as displayed on front panel

This can make it impractical to provide the option of calibrating *or* verifying each calibration point.

Firmware Calibration/Verification

The AH2700A uses three-step procedures to perform the firmware calibrations. These steps are:

1. Make calibration point measurements to obtain data that is suitable for calibrating the bridge. This data is referred to here as “verification” data until it is permanently stored.
2. Allow examination of this data to determine if a calibration is needed or if a verification is sufficient.
3. If the decision of the previous step is to calibrate, then permanently store the new verification data (into the EEPROM) by overwriting the current calibration data.

These steps are executed using versions of the CALIBRATE, SHOW CALIBRATE and STORE CALIBRATE commands, respectively. These commands are all introduced in this chapter. All versions of the STORE CALIBRATE commands require passcodes since these are the commands that actually change the calibration of a bridge. Since the other calibration commands require no passcodes, anyone can *verify* the calibration of the bridge at any time.

In other words, after using the CALIBRATE commands to obtain the internal and capacitance verification data, you can use the SHOW CALIBRATE commands to create a report that summarizes this verification data relative to previously stored calibration data. If the newly obtained data does not deviate significantly from the stored calibration data, then the calibration state of the bridge may be considered to be verified. If the newly obtained data *does* deviate significantly from the currently stored calibration data, then you will probably want to use the STORE CALIBRATE commands to replace the currently stored calibration data with the newly obtained data. As explained in “Selecting Update vs. Factory Cal Data” on page 9-9, you may alternately or additionally change your bridge's selection of Factory versus Update capacitance calibration data.

Reasons for Verifying Only

In some applications, it is important that a bridge's measurements not change suddenly from one day to the next, even by tiny amounts. In other words, the day-to-day *stability* may be more important than the long-term stability or the accuracy. In cases such as this, the ability to verify without calibrating can be essential. A verification can prove that a bridge has not suffered an unexpected shift in its measurements, yet a verification will not change the bridge's measurements in any way. It might be more helpful for a verification to follow and document a small drift in a bridge rather than to try to periodically correct it. Each such correction would cause a tiny offset in the bridge's measurements that might be undesirable. The bottom line is that the decision between calibration and verification is dependent on the application.

In general, the above comments apply mostly to the capacitance calibration rather than the internal calibration. The latter corrects for changes over time and for differences in ambient temperature. The errors which are corrected by the internal calibration occur mostly in the linearity of the AH2700A. An inadequate internal calibration will affect the linearity by causing small offsets, steps, or staircase effects in the measurements as a function of the actual capacitance or loss value. Since such errors are too complex to predict or externally correct, it is desirable to perform frequent internal calibrations to minimize them.

Your experience may lead you to believe that internal calibrations are not important, because the effects are not easily observed. However, if you make a series of measurements which happen to be near a step in your bridge's behavior, an inadequate internal calibration may cause the measurements to have a double-valued characteristic. As a result, for maximum precision, **internal calibrations should be performed every month or two** even if the ambient temperature is constant.

Deciding When to Calibrate/Verify

Traceability Calibration/Verification

If your application requires traceability, you will probably want to perform a complete verification/calibration every year or two. Experience has shown that the stability of the internal reference standards and of the ratio transformers in the AH2700A is sufficient that a traceable verification/calibration performed every year or two is conservative. A change in these components that causes the bridge to fail its accuracy specification within three years is considered to be a *failure* of those components, not just a drift. Of course, calibration/verification must identify failures also. Therefore, critical applications must perform traceable verification/calibrations with a frequency related to the criticality of the application. The bottom line is that you must be the ultimate judge based on your requirements and experience.

Internal Consistency Calibration

While the reference capacitors and ratio transformers in the AH2700A are very stable, there are many other components that are less stable. These components will drift over time and with changes in temperature. Fortunately, each of these components that can affect performance is automatically verified relative to the reference capacitors and ratio transformers when an internal verification is performed.

Without actually taking the time to perform an internal verification, there is no way to know for certain if an internal calibration should be done. However, it is possible to check the elapsed operating time and the change in temperature relative to when the last internal calibration was done. This is done using the `SHOW CALIBRATE RELATIVE` command introduced below.

Ambient Temperature and Internal Cal's





Unlike other high-precision instruments, the AH2700A is capable of operating to its full specifications over a temperature range that is much wider than that found in calibration laboratories. The qualification to this statement is that for highest precision and linearity, an internal calibration should be performed after the bridge has stabilized at the temperature at which it is to be operated. If it was recently calibrated near this temperature, then a new calibration is unnecessary. The `SHOW CALIBRATE RELATIVE` command is very useful here for easily identifying whether the bridge is being operated near the temperature at which its last internal calibration was performed.

Comparing Previous Calibration Conditions

The approximate elapsed *operating* time and the change in temperature relative to when the last internal, capacitance

and transformer calibrations were done can be determined by issuing the command:

`SHOW CALIBRATE [RELATIVE]`

The results of this command as reported to remote devices are shown in Figure 9-1. The results of the `SHOW CAL REL` command are displayable on the front panel in two lines of three windows each. An example is shown in Figure 9-2. Each window is accessible using the , ,  and  keys in the normal manner.

The first line gives the deviation of current conditions from those under which the previous internal calibration was made. The approximate elapsed *operating* time in hours from the last internal calibration is given following `"CAL AGE ="`. The difference between the current temperature and that during the last internal calibration follows `"TEMP ="`.

The second line specifies the same information relative to the capacitance calibration. This line additionally specifies whether the capacitance calibration in current use is the factory one or an updated one. This is indicated with a label reading `"FACTORY"` or `"UPDATE"`, respectively, preceding the `"CAP"` label. The meaning of these labels is discussed in "Selecting Update vs. Factory Cal Data" on page 9-9.

Preliminaries

Before performing any verifications, the AH2700A and its environment must be stable. The `OVEN NOT READY` indicator on the front panel must not be on. The bridge must have been powered on for at least one hour.

In addition, the bridge should be verified in a thermal environment that is as close as possible to that in which it will actually be operated. This means that the covers must be on the bridge, since that is presumably how it is normally operated. The bridge must be in the same physical orientation as it is normally operated. That is, it should not be verified while sitting on its side if it is normally operated in a horizontal position.

Carrying the thermal considerations one step further, the *very highest* precision requires that the bridge have its *internal* verification performed in its operating environment, not in a calibration lab unless that is where it is normally operated. This is particularly important if these environments might be significantly different. An example is the case where the bridge is normally operated in a rack on a factory floor. The rack is an additional enclosure that can trap heat and which will usually contain other instruments which are additional sources of heat. The rack environment may thus be substantially warmer than the calibration lab environment.

DEV FROM LAST INT:		CAL AGE =	34 HRS	TEMP =	-3.8 C	BIGGEST CHANGE = 19%	
CAL POINT	I DEV FROM LAST CAL	Q DEV FROM LAST CAL	I DEV FROM ORIG CAL	Q DEV FROM ORIG CAL	I RANGE USED	Q RANGE USED	
R192	5%	1%	7%	0%	-24%	0%	

Figure 9-3 Example of results of SHOW CAL INTERNAL command sent to remote devices

DEV FROM LAST INT	CAL AGE 34 H	TEMP -3.8 C	BIGGEST CHANGE 19 PER
R192 05 LAST 01	R192 07 ORIG 00	R192 -24 USED 00	

Figure 9-4 Example of results of SHOW CAL INTERNAL command displayed on front panel

INTERNAL CALIBRATION

An internal verification checks for drift and temperature changes in dozens of internal components. It does this by intercomparing these components against the internal fused-silica capacitance standard and the main ratio transformer.

Simplified Procedure

The following pages describe not only how to perform an internal verification, but also how to interpret all of the information that such a verification can provide. If you know that you just want to perform an internal calibration without any verification checks or other data gathering or interpretation, then you can skip most of the next few pages. Simply do the following:

1. Issue the `CALIBRATE INTERNAL` command described below.
2. Issue the `SHOW CALIBRATE INTERNAL` command described below in “Internal Verification Results” .
3. Check that the report produced in the previous step reveals no calibration point that exceeds 100% of its calibratable range as described in “Identifying the Point with the Largest Correction” on page 9-6.
4. Issue the `STORE CALIBRATE INTERNAL` command followed by a passcode to permanently save the new verification data as described in “Saving the Internal Verification Data” on page 9-6.

Obtaining the Internal Verification Data

Obtaining the internal verification data only requires that a command be entered. No special external connections are required. The LOW input terminal is internally disconnected during the verification measurements so it doesn’t matter what is connected to it. The HIGH output terminal is inter-

nally grounded so it doesn’t matter what impedance is connected to it either. The command that initiates the internal verification measurement is:

`CALIBRATE INTERNAL`

The verification measurement procedure takes about eight minutes. The front panel will display `CALIBRATE BUSY` during this process and will show `READY` when the procedure has successfully completed.

If the procedure fails, the front panel will show the message `INT CAL FAILURE`. This indicates that a hardware failure has occurred. If this happens, refer to Chapter 11 titled “Diagnosis and Repair”.

Internal Verification Results

The AH2700A reports the largest current internal verification error. The one internal calibration point that is furthest from its nominal value is also shown.

To get a report summarizing the new internal verification data obtained with the `CAL INTERN` command, issue the command:

`SHOW CALIBRATE INTERNAL`

If you had not previously issued a `CAL INTERNAL` command, the front panel will show the message `CAL DATA ABSENT` indicating that no new internal verification data exists.

Internal Verification Summary

The `SHOW CALIBRATE INTERNAL` command will produce the report shown in Figure 9-3 on remote devices. The equivalent windows in Figure 9-4 can be shown on the front panel.

SHOW CAL INTERNAL or CAPACITANCE vs SHOW CAL RELATIVE

The first two fields in the line of the SHOW CAL INTERNAL (or SHOW CAL CAPACITANCE command introduced later) report beginning “DEU FROM” give the elapsed operating time and the temperature difference between the conditions used to obtain the currently stored calibration values and the conditions used to obtain the new verification data. Note that this is similar but not identical to the results reported by the SHOW CAL RELATIVE command. That command compares the conditions used to obtain the currently stored calibration data with *current* conditions. These two reports will give nearly identical results if the SHOW CAL RELATIVE command is issued soon before or after the CAL INTERNAL command is executed (or CAL CAPACITANCE command introduced later). That way the time and temperatures will be the same. On the other hand, if the SHOW CAL RELATIVE command is issued at a different time or temperature from that of the CAL INTERNAL (or CAPACITANCE) command, then the time and temperature results from the SHOW CAL RELATIVE and SHOW CAL INTERNAL (or CAPACITANCE) command will differ.

Checking the Biggest Cal Point Change

The last field in the first line of the report shown in Figure 9-3 reports the percent deviation in the calibration point that had the biggest change between the currently stored internal calibration values and those just obtained with the CAL INTERNAL command. This change is the value of most interest in the entire report. The larger this change is, the greater the need to update the internal calibration values.

This change is a combination of the effects of time and of any difference in the temperature at which the two sets of internal calibration data were obtained. If a significant change has occurred and it has been many months since an internal calibration has been done, then it is desirable to save a new calibration. On the other hand, if a significant change has occurred but an internal calibration was just done only days ago, then the change is likely to be the result of temperature differences. In this case, it may make sense to save the new verification data only if you intend to operate the bridge at the new verification temperature.

A change greater than 100% *requires* saving the new internal verification values *if* the specifications are not to be exceeded *at the temperature* at which the verification data was obtained.

Interpreting the Calibration Point Data

This section describes the meaning of the calibration point data for internal verifications.

The bottom line in Figure 9-3 contains internal verification data. There are two lines above the bottom line that provide headers for the columns of data. Figure 9-3 shows only the

one internal calibration point that is *furthest* from its nominal value.

The Reference Labels

The first field in each line of the reports is the reference label for the calibration point. For many points, this number is identical to the reference label in the parts lists and schematic diagrams. For the remaining calibration points, no corresponding single parts exist.

Meaning of the “I” and “Q” Pairs

The remaining fields in the report occur in “I” and “Q” pairs. These pairs represent the two components of a vector. Vector components are reported here because that is how the correction values are internally represented.

The “I” or in-phase value is that component of the error which is in phase with the desired output characteristic of the calibration point. The “Q” or quadrature value is that component of the error which differs in phase by 90 degrees with respect to the desired output characteristic of the calibration point.

In the case of a resistor, the in-phase error is in the resistance and the quadrature error is in the stray capacitance across the resistor. In the case of a capacitor, the in-phase error is in the capacitance and the quadrature error is in the loss of the capacitor. In the case of a ratio transformer, the in-phase error is that component of the divided voltage from a given tap that is in phase with the signal applied to the transformer. The quadrature error is the component of the divided voltage from this tap that is 90 degrees out of phase with respect to the signal applied to the transformer. Any three-terminal network is interpreted in a similar manner to this ratio transformer example.

The Range-Used Pair

The right-most I and Q pair in the report gives *the* values used to make the firmware calibration corrections. These values are expressed as the percentage of the available firmware correction range that is required to compensate for the deviation of the part or assembly from its nominal value.

A value of 0% means that the calibration point has exactly the value that it is expected to have (as measured by the calibration circuitry of the bridge).

The Deviation Pairs

The first I and Q pair in each line of the report gives the current change for this part relative to the *last* calibration value pair that is currently stored. For internal calibrations, it is this stored pair that is currently being used to make corrections.

The second I and Q pair in each line gives the current change for this part relative to the *factory* calibration value pair that was first stored in the bridge when it was manufactured. For internal verifications, this stored pair of values is available for historical purposes only. It is not used to make any correc-

tions. It is used to help determine what the total drift in this internal calibration point has been since the date of manufacture or the date of replacement of A101 or C210.

A 0% deviation represents the best correction of which the calibration firmware is capable. By definition, the deviation of every internal verification value at the moment that the verification data is generated by the `CAL INTERNAL` command is 0%.

Scatter in the Deviation Values

If you try to study the verification deviation data (not the range used) you will soon discover that some of the numbers change significantly from one verification to the next. It is important to understand that many of the deviation values are highly magnified. In many cases, the noise in the input amplifier of the bridge determines the amount of scatter in the deviation values. It is this noise that causes the deviations to change from one verification to the next even when the bridge stays at a constant ambient temperature. As a result, it is not productive to try to draw conclusions about the verification data near the level of this noise.

The normal amount of scatter varies from one calibration point to another.

Identifying the Point with the Largest Correction

The last line in Figure 9-3 reports the one internal calibration point that is *furthest* from its nominal value. The corresponding line in Figure 9-5 can be identified as the one internal calibration point having the largest magnitude in the “I RANGE USED” and “Q RANGE USED” columns. In this example, that calibration point is R192 which has a magnitude of 24%. This calibration point has the largest correction value of all the internal calibration points in the bridge. Having a large correction value does not degrade the performance of the bridge provided that it does not exceed 100%.

If either the I or Q percent of range for this calibration point exceeds 100% and the internal verification was performed within the bridge's specified operating temperature range of 0 to 45 °C, then the bridge may be considered to have a hardware failure.

For points that exceed 100% of range, it will usually still be possible to perform a verification unless the 100% limit is greatly exceeded. The offending part should be identified and replaced before the bridge can be properly calibrated. See Chapter 11 titled “Diagnosis and Repair” for general instructions.

The reported percent-of-range-used includes both the change in the part since the time of first calibration during manufacture of the bridge *and* the initial tolerance of the part at the time that the bridge was manufactured. A calibration point may therefore report a substantial percentage but still be very stable (and thus fully acceptable). To identify a part as being unstable requires the information from several verification reports taken over a period of time. Only then can a possible

drift in a calibration point be distinguished from the initial manufactured tolerance of a part.

It is important to understand that a part that appears to be less stable than others, might only appear that way over a limited range of ambient temperatures. A part that has a larger temperature coefficient than it should may not appear in this report over a narrow range of temperatures, yet might require a large correction at all other temperatures.

Effect of Temperature on Internal Verifications

The AH2700A specifications assume an internal calibration at the ambient operating temperature.

By obtaining and reporting internal verification data at several different ambient temperatures you should easily be able to observe the effect on the deviations of the calibration points. Ambient temperature changes of 3 °C will cause deviations above the noise level of the data. Ambient temperature changes of 10 °C will likely cause deviations larger than 100% that will prevent the bridge from meeting its published specifications.

Saving the Internal Verification Data

The internal verification data obtained with the `CAL RELATIVE` command can permanently replace the current data by issuing the command:

```
STORE CALIBRATE INTERNAL
```

You will be prompted for a passcode immediately after issuing this command. You may enter any of the *three* allowed passcodes as explained in “THE CALIBRATION PASS-CODES” on page 9-11. This command takes a few seconds to execute and will display the `READY` prompt when it is finished. After this command is executed, all subsequent measurements will use the new calibration data. If *no* new internal verification data exists then the front panel will show the message `CAL DATA ABSENT`.

CAPACITANCE CALIBRATION

The capacitance calibration corrects for drift in the fused-silica standard inside the AH2700A. This calibration requires the presence of new internal verification data. If no new internal verification data is present, then the capacitance verification will automatically generate (but not store) such data in addition to obtaining the capacitance verification data. For maximum precision, the capacitance verification should be performed under the same environmental conditions as a *new* internal verification. This is true even if you intend to store only the capacitance verification data and not the internal verification data.

```

CAP UPDATE = 1
DEV FROM UPDT CAP:   CAL AGE =   345 HRS   TEMP = -5.1C   C = -0.71 PPM
DEV FROM ORIG CAP:   CAL AGE = 12345 HRS   TEMP = -4.6C   C = -0.71 PPM

```

Figure 9-5 Example of results of SHOW CAL CAPACITANCE command sent to remote devices

CAP			
UPDATE 1			
DEV FRO	CAL AGE	TEMP	CAP
UPDT CAP	345 H	-5.1 C	-0.71 PPM
DEV FRO	CAL AGE	TEMP	CAP
ORIG CAP	12345 H	-4.6 C	-0.71 PPM

Figure 9-6 Example of results of SHOW CAL CAPACITANCE command displayable on front panel

Obtaining the Capacitance Verification Data.

Obtaining the capacitance verification data for the bridge requires that a high-accuracy capacitance transfer standard be connected to the bridge. Due to the extremely high accuracy that is possible with the AH2700A, there is an issue of what is available to use as a capacitance standard.

You need access to one of three realistic transfer standard configurations. These are:

1. A high-accuracy, fused-silica standard capacitor such as an Andeen-Hagerling AH 1100/11A having a traceable calibration performed at 1 kHz.
2. A gas-dielectric, stacked-plate capacitor such as a GR 1404 having a traceable calibration performed at 1 kHz.
3. A second AH2700A or an AH 2700A or AH 2500A with a traceable calibration performed at 1 kHz and a gas-dielectric, stacked-plate capacitor.

If you have access to the first kind of transfer standard and you are satisfied with its level of traceability, you can use such equipment to both verify and calibrate an AH2700A to the limit of its specifications.

If you have access to the second kind of transfer standard, you can perform a *verification* of your AH2700A, but only to an accuracy level of about 30 ppm. This is true even if the capacitor was freshly calibrated by a primary lab. The problem is that these capacitors are prone to suddenly changing their value in response to thermal and mechanical environmental stress by amounts as high as about 30 ppm. Unfortunately, such stresses tend to occur during shipping to and from the primary cal lab. Verification to 30 ppm may be suffi-

cient for some applications, but it is more than an order of magnitude worse than the AH2700A is capable of.

If you have access to the third transfer standard configuration, you can perform a verification/calibration that is nearly as good as in the first case. A gas-dielectric capacitor is quite suitable for making short-term transfers of capacitance values from one AH bridge to another if the gas-dielectric capacitor is kept at a constant temperature and not moved. Ideally, the value of the gas-dielectric capacitor should be the same as the value of the capacitor that was used to calibrate the AH bridge that is providing the traceable source value.

The value of your standard must be in the range of 0.5 to 1600 pF. Values of 10.0 pF and above are preferred since the measurement uncertainty at lower values will begin to limit the attainable accuracy. For example, a 1.0 pF standard will add 1 ppm to the uncertainty of the verification.

When you are ready to obtain the verification data, use a DCOAX-1-BNC to connect your capacitance transfer standard to your AH2700A. If you use any other cable, it should be one meter long and must have an internal, coaxial shield with 100% coverage. If you use a pair of single cables, then they should be twisted around each other to minimize their inductance. Make sure that the CABLE command parameters are set correctly since this will cause an error otherwise.

If your transfer standard is another AH bridge, use it to carefully measure your gas-dielectric capacitor at 1 kHz, carefully record the value and finally connect the gas-dielectric capacitor to the AH2700A to be verified/calibrated.

When the desired capacitor is connected, issue the command:

```
CALIBRATE CAPACITANCE CapValue
```

where *CapValue* is the value of the connected standard capacitor in picofarads. The value may be entered from remote devices in any floating-point or scientific notation. A *BAD PAR* error will be reported if *CapValue* is not in the range of 0.5 to 1600 pF.

After this command is entered, the bridge will spend about 20 seconds making the verification measurement. If no new internal verification data exists, then about eight minutes will be added to this time. The front panel will display *CAL BRATE BUSY* during this time. The front panel will show *READY* when the procedure has successfully completed.

If the value of the connected standard as measured by the bridge disagrees with the Factory calibration of the bridge by more than 0.01% then the message *UPDT STD ERROR* will be displayed on the front panel. An error of this magnitude is most likely due to entering an incorrect value for the connected transfer standard. Otherwise, such an error is considered to be a hardware failure and is beyond the correction ability of the bridge's firmware.

Capacitance Verification Report

To get a report summarizing the new capacitance verification data obtained with the CAL CAPACITANCE command, issue the command:

```
SHOW CALIBRATE CAP
```

This will produce the report shown in Figure 9-5 on remote devices. The equivalent windows in Figure 9-6 can be shown on the front panel. If you had not previously issued a CALIBRATE CAPACITANCE command, the front panel will show the message *CAL DATA ABSENT* indicating that no new capacitance verification data exists.

The second and third lines of the capacitance verification report are each similar to the first line of the internal verification report. The capacitance verification report has two lines instead of one because the AH2700A maintains two sets of capacitance calibration data. One is the Update set and the other is the Factory set. The bridge can use either set of data. The set in use is indicated by the first line of the report where a one indicates the Update set and a zero indicates the Factory set. See “Selecting Update vs. Factory Cal Data” below for more information.

The relative time and temperature verification conditions for each of these two sets of data are given. The same comments apply to the SHOW CAL CAPACITANCE command as were discussed for the SHOW CAL INTERNAL command in “SHOW CAL INTERNAL or CAPACITANCE vs SHOW CAL RELATIVE” on page 9-5.

Checking the Capacitance Verification Change

The most important numbers in the capacitance verification report are the ones at the end of the second and third lines. These show the deviation of the new verification capacitance value from the stored Update and Factory capacitance calibration values, respectively. The deviations are given in ppm. These numbers give the factor by which every capacitance measurement taken by the bridge will be changed (relative to the old values) if the new verification data is saved.

You should understand that these deviations represent the sum of four sources of error:

1. The absolute error in the old calibration values (Factory or Update).
2. The drift in the bridge in the time between obtaining the old calibration values and the new verification value.
3. The change in temperature of the bridge between the time that the old calibration values were obtained and the time that the new verification value was obtained. This introduces an error of as much as 0.03 ppm/°C.
4. The absolute error in the new verification value.

Of course, there is no way to know how much error was contributed by each source. A knowledge of the relative degree of confidence in each source is usually the most there is to go on. A high degree of confidence should be placed in the Factory calibration value and in the bridge's ability to maintain that value. Deviations of the new verification value from the Factory value of more than about *two* ppm should be treated with skepticism.

Saving the Capacitance Verification Data

The new capacitance verification data obtained with the CAL CAPACITANCE command can permanently replace the current data by issuing the command:

```
STORE CALIBRATE CAPACITANCE
```

You will be prompted for a passcode immediately after issuing this command. You may enter either of the *two* allowed passcodes as explained in “THE CALIBRATION PASS-CODES” on page 9-11. This command takes a few seconds to execute and will display the *READY* prompt when it is finished. If *no* new capacitance verification data exists then the front panel will show the message *CAL DATA ABSENT*. This command does *not* store any internal verification data even though it may have generated such data.

The new verification data is immediately stored as Update capacitance calibration data. Executing this command will also *automatically* set the *CSource* parameter to UPDATE. All subsequent measurements will use the new calibration data *only* if the *CSource* parameter remains set to UPDATE.

NOTE

It is important to understand that the bridge maintains two sets of capacitance calibration data. The currently selected set determines which of two (usually totally different) calibration sources has calibrated the bridge. If this setting is not what you intend for it to be, then your capacitance calibration source will not be what you think it is.

Selecting Update vs. Factory Cal Data

The AH2700A maintains two sets of capacitance calibration data. One is the Update set and the other is the Factory set. The bridge can use either set of data. The set currently in use is determined by the setting of the *CSource* parameter. This parameter is stored in the EEPROM with the other calibration data.

When the bridge is manufactured, the Update and Factory calibration data sets are identical. If the bridge is later re-calibrated with new capacitance data, this data will overwrite the data in the Update capacitance set but not in the Factory capacitance set. This allows the bridge to be re-calibrated without losing the Factory calibration values. This is useful because the Factory values should be very accurate and are therefore useful as references. It is also useful to keep the Factory values for historical purposes.

The *CSource* parameter may be changed with the following command:

```
STORE CALIBRATE SOURCE CAP CSource
```

You will be prompted for a passcode immediately after issuing this command. You may enter either of the *two* allowed passcodes as explained in “THE CALIBRATION PASS-CODES” on page 9-11. The *CSource* parameter is entered as “UPDATE” if the Update capacitance calibration data is to be used to take measurements. When *CSource* is entered as “FACTORY”, the Factory capacitance calibration data will be used. The value of *CSource* can be determined with the SHOW CALIBRATE RELATIVE and SHOW CALIBRATE CAPACITANCE commands.

Saving All Verification Data

The new internal and capacitance verification data obtained with the CAL INTERNAL and/or CAL CAP commands can permanently replace the current data by issuing the command:

```
STORE CALIBRATE [ALL]
```

Only new sets of verification data that are present will be stored. You will be prompted for a passcode immediately after issuing this command. You may enter either of the *two* allowed passcodes as explained in “THE CALIBRATION PASSCODES” on page 9-11. This command takes a few sec-

onds to execute and will display the *READY* prompt when it is finished. The new verification data is stored in the same way as if a STORE CALIBRATE INTERNAL and STORE CALIBRATE CAPACITANCE command were both executed. This command *automatically* sets the value of the *CSource* parameter to UPDATE if that data was stored. If no new verification data exists then the front panel will show the message *CAL DATA ABSENT*.

Verifying Cap Accuracy at other Frequencies

It is expensive to obtain high accuracy capacitance calibrations of reference capacitors at frequencies other than 1 kHz. However, if you are fortunate to have access to such a calibrated reference capacitor, it is a simple matter to check the calibration of your AH2700A at whatever frequencies the reference capacitor was calibrated to.

To do this, for each frequency for which calibration data exists for your reference capacitor, set your AH2700A to the same frequency and take a reading with the average time set to at least 7. The reading should agree with the calibration data to within the sum of the uncertainty of the calibration data plus the uncertainty in the accuracy of the AH2700A as given in the specifications appendix of this manual. Add cross-reference to accuracy spec paragraph.

The capacitance calibration of the AH2700A is not adjustable at frequencies other than 1 kHz. Therefore, if the accuracy of the bridge is within specification at 1 kHz but is not within specification at some other frequency, then this is considered a failure which can only be corrected by repairing the bridge.

LOSS VERIFICATION

This section describes how to verify the phase shifter circuitry in the bridge. There is no adjustment that can be made so this is a pass/fail test.

Finding a Suitable AC Resistor Standard

This verification requires a three-terminal AC resistance standard with a value of 10.000 k Ω and an accuracy of 0.005% at 1 kHz. The actual value is not critical, but the accuracy of the value is important. This is not a commonly available standard so several ways of finding such a standard will be described.

1. The most expensive solution is to identify a commercial product that meets these specifications and to buy it. There are products that are physically capable of meeting these specifications, but usually the published specifications do not make this clear. The Tegam/ESI SR104 is one product that does claim to meet this specification. It will also be difficult to get direct calibrations of such products at 1 kHz.

2. A slightly easier approach may be to use a resistance standard or decade resistor that is known to be very frequency independent from DC to 1 kHz. This can be used as a transfer standard to transfer the DC value to 1 kHz. There are commercial products that give the resistance error as a function of frequency. If such a product is calibrated at DC with an accurate standard, it will then be sufficient at 1 kHz. The initial accuracy and long-term stability of the transfer standard is not important since it will be calibrated anyway. The frequency independence is what matters.

The transfer standard should be a three-terminal device which means that it should be fully shielded. Often, these products are housed in a metal case but use unshielded banana jack connectors of which the SR104 is an example. If a banana jack is provided that is grounded to the case and if it has a standard 0.75 inch spacing from one of the two jacks that connect to the resistance, then commonly available BNC-to-banana adapters can be used to connect the coaxial cables from the bridge to the resistance transfer standard. One Pomona Model 1645 BNC-female-to-shielded-dual-banana-plug adapter and one Pomona 1269 BNC-female-to-dual-banana-plug adapter will work. Since the resistance standard may have only three banana jack posts, the ground on one of the banana plugs would not be connected to anything. The shielded adapter should be connected to the LOW terminal.

Care should be used when a decade resistance box is used as the transfer standard. Boxes that have decade resistors above 10 k Ω per step may be too frequency dependent to use. Even though such higher values would not be needed for this test, their stray capacitance is present even if they are not switched in.

3. The least expensive approach is to make your own transfer standard. This is actually easy to do. The key component is a 10 k Ω resistor that is stable and frequency independent. Common resistors such as a type RN55C (50 ppm/ $^{\circ}$ C) will work. A type RN55E (25 ppm/ $^{\circ}$ C) will work better. A type RNC90Y will work very well. The lower their temperature coefficient, the easier it is to transfer a value from DC to 1 kHz without having to worry about room temperature changes.

The best choice is to buy a high quality precision resistor that is already specified to the desired level of accuracy. Types that use the RNC90Y style construction are excellent. DO NOT use a wire wound resistor unless it is non-inductively wound. If your resistor has a metal case, the case must be grounded.

An ordinary resistor is easily converted to a three-terminal one by installing the resistor in a metal box. A box with a female BNC connector at each end such as Pomona Model 2390 is suitable. The resistor should be located in the middle of the box to minimize stray capacitance to the box. DO NOT trim the value of the

transfer resistor by paralleling with resistors having megohms of resistance. Such resistors are probably much more frequency dependent.

Once this resistor box is calibrated at DC to an accuracy of 0.005%, it is ready to use. A resistor box made this way should be calibrated at DC before *every* verification. Furthermore, if there is concern about its stability or about room temperature variations, then its value should be rechecked *after* the verification is performed.

Performing the Verification

Once a trustworthy resistance standard is in hand, the actual verification is simple to perform.

To do this, set the frequency to 1 kHz, the averaging time to 10 and the loss units to series-kilohms. Connect the standard and take a few measurements. They should all read 10.000 k Ω to within 0.02%. If this check fails, it might be that the ambient temperature is now too different from that at which the last internal calibration was performed. If this check still fails after verifying the internal calibration, the loss measurements may be failing the accuracy specifications of the bridge. To correct this, the AH2700A (or its main board) must be returned to the factory for repair. See “REPAIR SERVICE” on page 1-7 and “Main Board (A101) Removal and Installation” on page 12-8.

CHECK HIGH TERMINAL VOLTAGE

Issue the command `VOLTAGE 1 5 ENTER` then take a measurement with nothing connected to the measurement terminals. This will leave the HIGH terminal with 15 volts present. Using an AC meter with an accuracy of 1% or better, measure the voltage from the HIGH terminal center conductor to ground. If the HIGH terminal output voltage is not within 5% of the nominal value (15 \pm 0.75 volts), it should be considered a failure. To correct this, the AH2700A should be returned to the factory for repair. See “REPAIR SERVICE” on page 1-7.

CHECK THE BRIDGE FREQUENCY

At the time the output signal level is checked as directed in the previous section, the frequency of this signal can be checked also. This is done by setting the frequency to 1 kHz, setting Commutate to OFF, connecting a digital frequency meter to the HIGH terminal and taking a reading. The frequency should read 1.00000 \pm 0.000025 kHz. If it is marginally outside the tolerance, then the 25.65 MHz crystal oscillator Y401 is probably out of tolerance. If it is off by much more, then there is a failure in the processor board A301 or the MUX board A401. See the chapter titled “Diagnosis and Repair” on page 11-1 for general repair information. Don’t forget to return the Commutate parameter to LINEREJ when you are done with this test.

THE CALIBRATION PASSCODES

The AH2700A uses three different passcodes to control access to the commands which change the calibration data. These passcodes are:

1. The Owner passcode. This is the highest level passcode. This passcode cannot be changed. It is accepted by every command which requires a passcode. It is the only passcode accepted by the `STORE PASSCODE` commands which are used to change the other passcodes.
2. The Calibrator passcode. This is the intermediate level passcode. This passcode is accepted by every version of the `STORE CALIBRATE` command.
3. The User passcode. This is the lowest level passcode. This passcode is accepted *only* by the `STORE CALIBRATE INTERNAL` command.
4. The Replace passcode. This passcode is only accepted by the `STORE CALIBRATE REPLACE Standard-Value` command. See “Main Board Installation Procedure” on page 12-8 or “Standard Capacitor Installation Procedure” on page 12-12 for more information.

These passcodes are intended to be applied in a specific way. The Owner passcode should be held by the owner of the bridge and revealed to no one else. If the owner of the bridge is the only user and the only person to ever perform a calibration, then this will usually be the only passcode that ever needs to be used.

If the owner wishes to assign the responsibility of fully calibrating the bridge to another person, then the owner should give that person the Calibrator passcode. The owner can change the Calibrator passcode after the person doing the calibrating is finished.

Some applications may require that an internal calibration be performed frequently. This will be especially true for high precision work or for operation where the bridge's internal calibration needs to track significant changes in ambient temperature. In such cases, the owner may want to allow the operator to perform internal calibrations only. The owner can do this by providing the operator with the User passcode. The owner can change the User passcode after the operator is finished taking measurements.

If the main board or capacitance standard is replaced, then the Replace passcode will be required to re-calibrate the bridge. The consequences of using this passcode are that *totally new internal and capacitance calibrations are performed and all past calibration history is lost*. Due to the irreversible consequences of mis-using this capability, this passcode (and therefore the Owner passcode) must be tightly controlled. Like the other changeable passcodes, the owner can give this passcode to a repair person. When the repair is finished, the owner should change the Replace passcode.

Changing the User Passcode

The User passcode can be changed with the command:

```
STORE PASSCODE USER UserCode
```

After entering this command, you will be prompted for a passcode with the front panel message `ONR CODE`. You must enter the Owner passcode. If the wrong passcode is entered, the message `WRB PASSCODE` will appear on the front panel.

After entering the correct Owner passcode, the User passcode will be replaced by the *UserCode*, a six digit number entered along with the command.

If you are working from a remote device, you will also be prompted for the Owner passcode. The characters that you enter for the Owner passcode will not be echoed.

Changing the Calibrator Passcode

The Calibrator passcode can be changed with the command:

```
STORE PASSCODE CALIBRAT CalCode
```

This command functions identically to the `STORE PASSCODE USER` command except that six digit number entered as *CalCode* will become the new Calibrator passcode.

Changing the Replace Passcode

The Replace passcode can be changed with the command:

```
STORE PASSCODE REPLACE ReplCode
```

This command functions identically to the `STORE PASSCODE USER` command except that six digit number entered as *ReplCode* will become the new Replace passcode.

This chapter describes the detailed workings of the circuitry of the AH2700A. If you have not read “BASIC BRIDGE CIRCUITS” on page 4-1 and preferably all of Chapter 4, “Measurement Essentials”, you should do so before starting to read the analog circuit sections of this chapter. The basic bridge circuit that is used by the AH2700A is explained and shown there in Figure 4-1 on page 4-1. The analog circuitry described in this chapter is an elaboration of the basic bridge shown in that figure.

This chapter describes the AH2700A on two levels of detail. The higher level is based on block diagrams. There are three fundamental block diagrams presented: the Digital Circuits block diagram, the Bridge Circuits block diagram and the Signal Processing block diagram. The Analog block diagram is shown as two figures. One is the complete Analog Circuits Block Diagram shown in Figure F-2 on page F-5. The other is a more detailed diagram of the ratio transformer multiplying digital-to-analog converter shown in Figure 10-1 on page 10-3. The Signal Processing diagram shows the preamplifier and Digital Signal Processor flow of data. These diagrams accurately reflect all circuits of the AH2700A and should provide sufficient understanding of the internal hardware operation of the AH2700A for all but repair purposes.

The lower level description of the circuitry is based on the schematic diagrams of the individual boards of the AH2700A presented in Appendix F, “Drawings and Parts Lists”. An understanding at this level of detail is intended for maintenance purposes or to grasp a fine point of the AH2700A’s operation.

CAUTION

*The descriptions given in this chapter are intended to help understand and maintain the instrument. Subtle design considerations are **not** discussed and therefore the information given here is not suitable for making modifications to the instrument. Consult the factory before attempting any possible modifications.*

Notation

Every schematic in Appendix F, “Drawings and Parts Lists”, has a border showing the numbers one through four horizontally and the letters A through D vertically. These establish a coarse reference grid. The current chapter uses references such as “U321 in area 2B4” to mean that chip U321 is located on the second page of the schematic in grid square B4. This same notation is also used within a multi-page sche-

matic in places where signals go from one page to another. This helps locate the signal name on the referenced page.

DIGITAL PROCESSOR CIRCUITS BLOCK DIAGRAM

The block diagram of the digital processor circuitry is shown in Figure F-1 on page F-3. This is a diagram of the circuitry contained on the processor, display and keypad circuit boards. The operation of the circuits is conventional and straightforward in most respects.

Buses

The diagram shows individual signal interconnections as single lines. Five groups of signal lines called buses are shown as double lines. Labels in each bus indicate the kind of signals in that bus. If not all the signals in a bus connect to a block, then labels in the stubs that connect the bus to the block indicate which lines from that bus actually connect to the block.

The names of the five major buses are: Address, Data, Selection including Read / Write, TPU Lines and Serial Peripheral Interface (SPI) Bus. The Address bus contains the processor address signals (A0-A19). The Data bus contains the processor data signals (D0-D15). The Selection bus contains the CS- signals for memory and I/O device selection plus the read/not-write signal (R-/W). The TPU lines are signals to or from the processor to control timing related functions. The Serial Peripheral Bus is used to send data to the front panel display, to set up the relays and DACs on the Main board plus preamp, and set up the A/D converter on the Multiplexer board and read its results. With the exception of the R-/W signal, the “high true” vs. “low true” distinction is ignored by the block diagrams and the related discussion.

Clock Signals

The processor clock is 22.1184 MHz which is also used as the baud rate for the serial port. The DSP 20 MHz clock is doubled internally to run at 40 MHz giving 25 ns. cycle time per instruction. The 40 MHz is also used by the GPIB interface IC. The CODEC clock of 25.65 MHz sets the bridge frequency sample rate of 50097.66 samples per second.

Processor and Memory

A 68332 microprocessor is used with different kinds of memory (RAM, Flash, EPROM, and EEPROM) to form the basic computing circuitry. A power-reset circuit (U304) will reset the processor if the 5 volt supply falls too low. This reset signal is also routed to all other circuits in the AH2700A that need to be initialized on power-up.

Digital Signal Processor

A 2181 DSP is used to generate all the analog drive signals in the 2550A. It also processes the preamplifier output to prepare the bridge unbalance results for processing by the 68332. The DSP also monitors the phase relationship between the in-phase and quadrature signals, adjusting the quadrature as needed to insure proper phase relationships. The DSP communicates with the CPU over the 16 bit data bus.

Rear Panel Interfaces

The GPIB (U312) interface is implemented with integrated circuit (IC) designed specifically for this function. The serial IEEE 1174 interface is developed within the 68332 microprocessor and is converted to RS232 levels by U317, U320. The sample switch interface is implemented with an octal latch (U314) and some common line driver IC's (U316, U317 and U319). The sample switch strobe line is driven by a TPU line from the processor. The external trigger input is readable by the processor using one of the TPU lines.

Front Panel Keypad

The keypad is on a separate circuit board on the front panel connected to the processor board with a ribbon cable. The keypad switches (SW501-SW518) are connected in a two-dimensional array. This array is scanned by the microprocessor PE0-4 outputs and read back via a buffer U310.

Front Panel Display

The data to set up the display is set over the SPI Display bus. After the long bit pattern is sent, it is latched into nine 8 bit LED driver latches.

The display is on a separate circuit board on the front panel connected to the processor board with a ribbon cable. The display consists of eight, dual 14-segment LED displays (DS501- DS508) and two quad plus one LED displays (DS514 - DS517). All the LED's are connected in a two-dimensional array which is driven using a multiplexed method. The anodes are driven by 4 transistors (Q501a,b-Q502a,b) which are controlled by bits in the serial data message. The cathodes of the displays are driven directly by nine octal latches (U501-U508, U511).

Analog Measurement Interface

This interface (J303) connects to all of the analog measurement circuitry in the AH2700A. The processor board uses two serial SPI buses, one controls the main board relays, digital to analog IDAC, QDAC, and the preamp relays and gain settings. The other serial bus controls the multiplexer A/D converter input selection and gain. It then reads back the output of the 14 bit A/D serially.

The digital signals to and from the DSP are converted to analog with 16 bit stereo CODECs. Each CODEC has two 16 bit A/D and D/A converters. The serial data between the DSP and the four CODECs is via a 4 wire bus DT0, DR0, SCLK0, RFS0, for data from the DSP and from the CODEC, clock and framing signals.

CAPACITANCE BRIDGE CIRCUITS BLOCK DIAGRAMS

The Capacitance Bridge Circuits Block Diagram of the AH2700A is shown in Figure F-3 on page F-7. This is a diagram of the circuitry contained on the multiplexer, main and preamp circuit boards and part of the capacitance standard assembly.

This diagram contains two major blocks that are essentially identical to one another. Each is called a "Ratio Transformer Multiplying Digital-to-Analog Converter" and is abbreviated as "RTMDAC" or just "DAC". An RTMDAC is shown in more detail in Figure 10-1 on page 10-3.

Many blocks are connected by short arrows with the word "control". These arrows are used to indicate the presence of binary control lines set up via the SPI bus latches from the processor to control functions in the associated block.

If there is a "most important part" in the AH2700A, it must be the main ratio transformer (T101) shown near the left side of the main analog block diagram, Figure F-2 on page F-5. As shown in the basic bridge circuit in Figure 4-1 on page 4-1, this transformer forms two of the four legs of the bridge. It also is responsible for the extremely high linearity and ratio stability of the AH2700A.

Sine Wave Driver

The main ratio transformer is energized with a precision, one kilohertz, sine wave from the DSP driven CODECs.

The main transformer drivers (U102, U103 and U104) provide the power required to drive T101 near its saturation voltage. Should anything load T101 to the extent that the drivers cannot fully energize the transformer, the overload detector (U105) will produce a signal I-OVRLD that indicates a "high to ground short" problem.

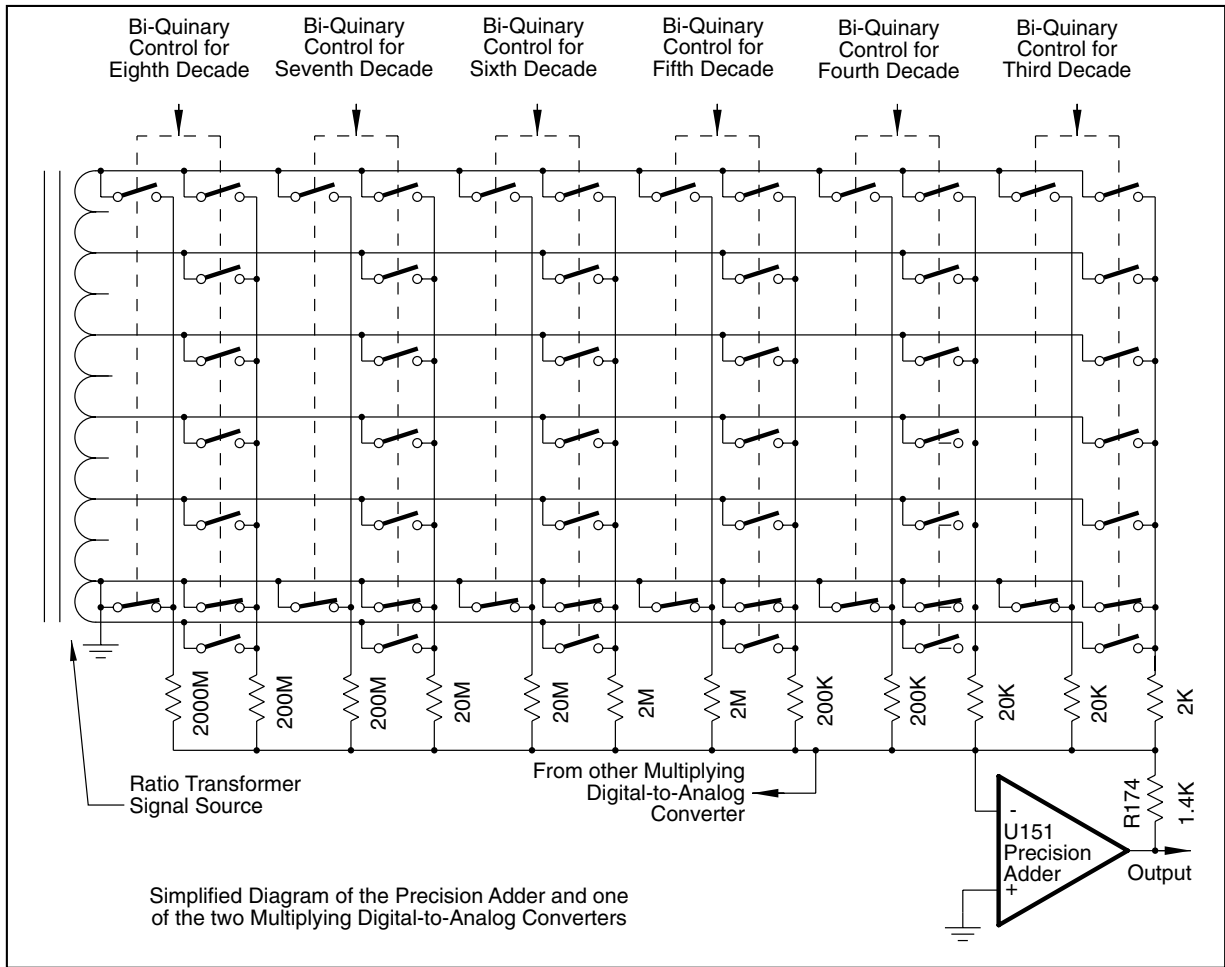


Figure 10-1 Ratio transformer multiplying D to A converter (RTMDAC)

The output voltage from the main transformer is measured with a precision rectifier (U106, 107, 108) to properly set the voltage at the High terminal. The dc level is measured by the A/D on the multiplexer board.

Attenuator Leg of the Bridge

The lower left leg of the basic bridge circuit in Figure 4-1 on page 4-1 is the attenuator (ATN) leg. Effectively, the function of this leg is to select the range of capacitance or loss that the AH2700A is to measure. This requires selecting one voltage from a wide range of transformer taps. That voltage is connected to the external DUT (Device Under Test) through the HIGH terminal on the rear panel of the bridge.

The attenuator must provide the widest possible range of voltages since it is this range that is largely responsible for the wide range of capacitances that the AH2700A can measure. The higher attenuator voltages are provided by a winding on the main ratio transformer (T101) having six taps. To get much lower voltages, a *single* turn winding on the main transformer drives another transformer (T103) called the

attenuator transformer. This 250 turn transformer divides the single turn voltage from the main transformer into an additional 250 parts. The attenuator transformer has five more taps that provide voltages as small as 0.3 millivolts. The actual maximum voltage level may be controlled by the user in a continuously variable manner. The DSP is commanded to vary the level as desired.

All of the attenuator taps are selected using reed relays. These preserve the low output impedance of the two ratio transformers. This low impedance allows one to think of the DUT as being driven by the HIGH terminal of the bridge.

Variable Leg of the Bridge

The upper left leg of the basic bridge circuit in Figure 4-1 on page 4-1 is called the variable leg. It is the most complex leg. After the attenuator leg has been set to the optimum range that corresponds to the value of the DUT, the variable leg must be adjusted so as to reduce the bridge imbalance to a minimum.

Since the DUT will have both a capacitance and a loss, the variable leg must be able to independently balance both of these quantities. Since the AH2700A uses capacitance (as opposed to resistance) standards as references, any current resulting from the capacitance of the DUT will have the same phase as currents flowing directly from T101 through the reference capacitors. Thus the part of the variable leg of the bridge that balances the capacitive current from the DUT is called the “in-phase” part. The loss current from the DUT is balanced by the “quadrature” part of the variable leg. The currents flowing in the quadrature leg are 90° out of phase with currents flowing in the in-phase leg.

In-Phase Relays and RTMDAC

The in-phase part of the variable leg can be adjusted to a precision of eight decades. The two most significant decades (RD’s) use reed relays that directly switch voltages from the main ratio transformer to reference capacitors A and B. There are 12 taps from 10.0v to 0.0v and -1.0v. These two decades are identical except that the reference capacitors differ by a factor of ten from each other. The current through a reference capacitor is very precisely proportional to the selected transformer voltage times the value of that reference capacitor.

The remaining decades use the in-phase RTMDAC, also called the “IDAC”. Figure 10-1 on page 10-3 shows one of the RTMDAC’s combined with the operational amplifier (U151). This amplifier, when combined with input and feedback resistors, forms a precision adder. The adder functions in the textbook manner where the output voltage is the sum of each input voltage multiplied by the feedback resistance (R174B) and divided by the corresponding input resistance. This makes the precision adder and the associated input and feedback resistors, combined with the driven reference capacitor (C210C), functionally equivalent to a set of reference capacitors. The value of an equivalent reference capacitor is equal to the value of C210C times the value of R174B divided by the value of an input resistor. The actual value of the RTMDAC 5th to 8th decade resistors are smaller due to interstage attenuators but the results are the same.

To reduce the number of switching elements, each full decade in the RTMDAC’s uses a bi-quinary scheme. This requires the ability to switch an input resistor of the adder to seven different ratio transformer taps related to each other by voltage ratios of -1, 0, 2, 4, 6, 8, and 10. A second input resistor that is ten times larger is switched to taps having voltage ratios of 0 or 10. Switching these two resistors to the available transformer tap combinations will give the equivalent of any integer ratio from -1 to 10. This gives a total of twelve choices, the same as with the two most significant relay decades. All switching in the RTMDAC’s is done with CMOS analog switches rather than relays.

Quadrature Phase-Shifter and RTMDAC

The quadrature part of the variable leg (also called the “QDAC”) is virtually identical to the in-phase part except for two important respects. First, the quadrature part lacks the two most significant relay decades found in the in-phase part. This prevents the AH2700A from measuring large capacitors that also have a high loss. However, large, quality capacitors are not likely to have a high loss.

Second, the ratio transformer that drives the QDAC is not the main ratio transformer (T101), but rather an auxiliary one (T102) driven by a signal that is accurately shifted in phase by 90° by the DSP. This phase-shifted RTMDAC driving a reference capacitor is functionally equivalent to an un-phase-shifted RTMDAC driving a reference resistor. The QDAC is virtually identical to the IDAC.

The signal that drives T102 is created by the DSP to be 90° out of phase with the in-phase drive signal. The Main and Quad transformer outputs (T101, T102) are sampled and fed back to the DSP to automatically correct for phase differences. This insures that the two signals will always be 90° apart even as the drive amplifiers experience phase shifts.

Internal Calibration

To achieve the highest possible accuracy without using any more high precision components in its construction than necessary, the AH2700A uses sophisticated firmware to internally and automatically calibrate components of lesser precision. These components are calibrated against the very stable ratio transformers and against the largest reference capacitor. The largest reference capacitor is, in turn, intended to be periodically calibrated against primary or other very accurate standards. The interconnections needed to perform these internal calibrations are all shown in the block diagrams.

Every full decade in the variable leg of the bridge has the ability to select transformer taps having ratios of -1 and 10. This feature allows adjacent decades to be compared. If a given decade is set to -1 and the adjacent decade of lesser significance is set to 10, the sum of the results should be zero. The summation occurs at the center node of the bridge. Any non-zero result that is present here can be amplified and measured by the preamplifier and DSP. The magnitude of the result is stored by the processor and is used to correct the decade of lesser significance. This scheme allows calibration of all the decades relative to the most significant one. The quadrature decades may be calibrated against the in-phase decades by commanding the DSP to generate the quadrature in phase with main instead of 90° offset used for normal measurements.

SIGNAL PROCESSING BLOCK DIAGRAM

The Signal Processing Circuits Block Diagram is shown in Figure F-2 on page F-5. The components that comprise this part of the AH2700A are described below.

Preamp

The function of the preamplifier is to amplify the wide range of imbalance voltages that can exist at the center node of the bridge, particularly the nanovolt level signals that occur when the bridge is nearly balanced. While taking measurements, the LoCnect (K601-603) relays connect the center node of the bridge directly to one end of the DUT via the LOW terminal. With no DC bias voltage applied, the bias enable relay (K609) connects the input of the preamplifier to the DUT. If a charged capacitor is connected to the input of the bridge, the DC on low detector will report that condition. This detector will also report the presence of low frequency AC noise.

The output of the preamplifier is further amplified by a wide-range, programmable gain amplifier. The ratio of the minimum to the maximum gain of this amplifier is one thousand. The signal is then passed through a two-stage, broad band amplifier. The amplifier falls off about 10 db at 20 kHz. The low frequency response is controlled by the processor to fit the measurement situation.

Provision is made to apply a dc bias to the DUT via selectable bleeder resistor values of 1 or 100 megohms. The user supplies the voltage via a connector on the rear panel.

The preamplifier output is converted to a differential signal before routing to the multiplexer board. There it passes through a lowpass anti-alias filter before entering the CODEC. The 16 bit digital signals share a common 4 wire serial bus to the DSP. There it is filtered, phased detected and further processed before sending the data to the CPU processor.

Multiplexer and A/D.

The A/D also measures 20 inputs to the multiplexer, several of which have already been identified. The DAC TEMP signal comes from a temperature sensor in the area of the RTM-DAC's. Similarly temperature sensors are located in the preamp, on the main board near the I/QDAC buffers and on the multiplexer board near the CODECs and will be used for temperature corrections. The OVEN signal indicates whether the oven in which the reference capacitors reside is at operating temperature. The power supply voltages at the main board are measured individually +5, +12, -12v. Three signals in the I and Q drive circuitry are used during the test routines to isolate potential problems. These three test points are normally grounded by U102, U116 to reduce noise on the board.

The signals are switched one at a time through three eight-input multiplexers (MUX) (U418) or (MAIN) (U109,U110) to a programmable gain amplifier (U419 and U420). The gain

is set to maximize the signal levels for measurement by the following 14 bit analog-to-digital converter (U421). Both the selection and gain are set up by the processor using the SPI bus and 8 bit latch (U423). The digital result is returned to the processor over the serial bus.

Analog Out

To produce voltages proportional to the unbalance of the bridge for analog out operation the DSP drives two CODECs with digital signals representing the desired "DC" output value. These outputs are amplified and sent to the rear panel connector. These two CODECs are driven by the same serial 12.825MHz. bus that drives the other CODECs.

Individual Board Descriptions

POWER SUPPLY

The power supply schematic is shown in Figure F-8 on page F-21. The power supply is a simple linear type to minimize the creation of unnecessary electrical noise (EMI). The power supply consists of a power line module, a transformer, and a printed circuit board. The power line module allows the selection of four different line voltages with which to power the AH2700A. These different operating voltages are obtained by connecting the two primary windings of the transformer in series or parallel and by connecting to either all the turns of one of these windings or to 83% of the turns. The power line module is located on the rear panel of the AH2700A and contains an easily accessible fuse. The power transformer has two center-tapped secondary windings. One of these windings feeds a full-wave diode bridge (U704). The two outputs of this bridge each charge a 3300 μ F capacitor (C705 and C706). These capacitors provide two sources of unregulated power of about +24 and -24 volts. Each of these sources feeds a regulator, (U701 and U702) the outputs of which provide a source of regulated +12 and -12 volt power.

The other winding of the transformer feeds two diodes that charge a 15,000 μ F capacitor (C711). Three capacitors (C703, C704, and C715) plus a resistor (R702) are present to attenuate EMI generated by the AH2700A processor that might otherwise be conducted outside through the line cord. The voltage on C711 is regulated by U703 to provide five volt power for the logic circuits of the AH2700A. A crowbar circuit (Q701, VR701, R701, and C714) protects the logic circuits from overvoltage in the event that U703 fails. The crowbar works by detecting an overvoltage and responds by shorting the 5 volt supply to ground. This happens within microseconds and will cause the fuse (F702) to open.

PROCESSOR BOARD

The processor board contains essentially all of the high speed digital logic used in the AH2700A. It is located on the top side of the AH2700A chassis.

Processor and Memory

The 68332 Processor operates at 22.1184Mhz which is used for the serial data port clock. The Address bus is 20 bits wide A0-A19. However for 16 bit devices the A0 line is not used. The data bus is 16 bits wide. 8 bit devices only access the high D15-D8 bits. The 68332 has internal chip select circuitry that develops /CS- signals according to programmed setup. These signals are used to select the RAM, EPROM, Flash memory, EEPROM, DSP, GPIB, Time or Sample Switch latch and Keyboard data. The high 5 bits of the address selection logic A24-A20 are used internally by the chip select logic and do not leave the processor.

Memory

Four memory devices are on the 68332 address and data buses. The program usually starts in the boot mode from the EPROM which is only 8 bits wide. The cpu runs slowly until it determines which page of the Flash memory is to be used. This mode is also used to load a new update from the serial port or EPROM into the Flash memory. The Flash memory is 16 b wide and fast enough to run the processor at full speed. The RAM is used for temporary values, while permanent calibration data is kept in the EEPROM. The EEPROM is protected by enabling the Chip Select write logic only when the EEPROM is to be written and disabling it at all other times.

Reset Circuitry

The Reset Generator U304 resets the 68332 until the +5 v logic supply is correct. The processor controls the I/O Reset line to clear many of the devices on the main and other boards during startup.

Digital Signal Processor

The DSP plus four CODECs on the multiplexer board are used to generate all the analog bridge frequency signals. It also provides the digital filtering and phase detection of the preamplifier output for the balancing of the bridge. The DSP is controlled as a device on the 68332 bus. The processor communicates with the DSP over the 16 bit data bus. It can read or write to any DSP address, and loads the entire DSP program into the DSP internal program and data memory during the startup process. Once the DSP program is loaded and startup tests completed, the DSP begins generating I and Q drive digital signals to the four CODECs which convert between the digital and analog modes.

The DSP is commanded to generate the proper bridge measurement frequency and level by the 68332. The DSP can also be commanded to alternate the bridge measurement

phase to reduce interference. It also can alternate phase synchronously with the power line to further reduce power line interference. The signal from TPU 5 (developed from a sample of the power line voltage) is used by the DSP to perform the synchronous noise reduction.

The processor writes commands to the DSP memory and reads back data from specific memory locations. the cpu TPU6 line is used to handshake the data interchange process.

The DSP sends data serially to the four CODECs on the multiplexer board at a 12.825 megabit/sec. rate to provide 50098.66 samples/sec. The four wire serial bus sends data to and from the CODECs with a synchronous clock and framing signal.

I/O

The 68332 has a number of I/O ports. PE0-4 are used to scan the keyboard. The key response is read back via octal buffer (U310) which also reads the status of the option jumpers JP304-306.

A green LED on the processor board is connected to PE7. This enables the processor to display a coded startup error indication should the display fail to work.

Serial data from the RS232 driver and receiver is connected to TXD, RXD lines. They are processed by an internal UART function to get the 8 bit data at a programmable bit rate. The RXD line also is connected to TPU 0 where is used to determine the incoming bit rate.

Serial Peripheral Interface

The main control functions of the bridge are sent over the Serial Peripheral Interface(SPI). There are four devices on the SPI bus: Serial EEPROM, Display, Main and Preamp Control, and Mux A/D control. For each device a long message is sent along with clock pulses. At the end of the message a latch pulse transfers the serial shifted data to an output latch where it remains until the next latch signal. As data is shifted it does not affect the latched data until the latch signal is received. The main and mux boards each have their own select, data clock and latch signals. This keeps the noise out of the analog main board except when a new setup of relays, IDAC and QDAC is made. Then it will be quiet when readings are taken. More details of each device are covered in the description for that board.

Time Processing Unit

The processor is equipped with a Time Processing Unit (TPU). It is an autonomous controller that the processor can use to generate or detect signals. It is used for these functions:

TPU 0 detects the width of serial RS232 to obtain the bit rate. TPU 3 starts the A/D converter on the MUX board. TPU 5 sends power line zero crossing signals to the DSP. TPU 6 is

the DSP and processor handshake line, TPU 7 monitors the power line zero crossing detector to measure line frequency and generate a 1ms. pulse on TPU 5. TPU 10 detects changes on the trigger rear panel connector. TPU 11 provides the handshake / trigger to the Sample Switch. TPU 12, 13 provide serial data Output and Input to the Sample Switch using an internal UART function in the TPU. TPU 14 tells the display to load the data shifted on the SPI bus. This allows the processor to vary the display brightness,

Sample Switch

The sample switch port is a general purpose interface having eight parallel output lines and one output control line. The latter is intended to serve as a strobe line. Eight of these nine lines are taken from an octal latch (U314 in area 4D4). The control line comes from TPU11. These signals serve as inputs to type 1488 line drivers (U316, U317 and U319 in area 4D3) which provide levels at the rear panel connector of about +12 and -12 volts. Power supplies of +24, -24, and +5v of the AH2700A are available at this port so that limited amounts of power can be provided to external devices. In addition provision is made to send and receive serial data developed within the processor TPU. See Appendix D, "Sample Switch Port" for a complete description of how to make connection to this interface and of how to use the AH2700A to control these lines.

Time of Day Clock

To notify the user that re-calibration is needed, at time of day clock is provided. It operates with a 32,768 Hz crystal. To keep it ticking when the power is off, a 1 Farad capacitor is used instead of batteries. This will keep time for 1 to 3 months without powering up the instrument.

GPIB

A single GPIB controller with integrated driver IC is used to controls the 16 wires of the GPIB. It is controlled by reading and writing to the many internal registers of the TNT4882 IC. It uses a 40MHz clock provided by the DSP which doubles the 20.0 MHz oscillator frequency.

FRONT PANEL (KEYPAD AND DISPLAY BOARDS)

The display and keypad boards are mounted directly behind the front panel of the AH2700A. The keypad board simply holds the switches in place and connects them in a two-dimensional array. The keyboard switches are periodically driven one at a time by the PE0 - 4 outputs of the 68332. The CPU then reads back the resulting data via U 310 octal buffer. This enables the CPU to determine which key is pressed. The three pages of schematics for these boards start with Figure F-16 on page F-41.

As described in the SPI section the data to be displayed is delivered to the display board on a serial data bus with clock and a latch signal. The long data message includes bits for each of the groups of 14 segment displays, plus decimal point and four bits which are designated to drive one of the four groups of digits at a time. After the data is shifted into the serial shift registers under control of the DSCK clock signal, it is latched to the LED output driver by the DSLATCH signal. That comes from the processor's TPU so that it may be accurately timed to vary the brightness.

Most of the display board is used to mount and drive eight dual 14-segment, common anode, LED displays. The sixteen 14-segment digits are wired in an array of four groups having four digits each. The anodes of every fourth digit are tied together. The ten single LED indicators are also multiplexed in the same manner. Four FET transistors (Q50a,b-Q502a,b in area 1D2) each drive one of these groups of anodes from the 5 volt power supply. Four extra serial shift register latch bits control these four transistors.

The cathodes of identical segment positions of the first four digits are tied together; the cathodes of identical segment positions of the fifth through eight digits are tied together, and so on. Since each digit has a decimal point, each of these groups of four sequential digits has 15 cathode lines whose currents must be selectively sunk to ground. This is done with 8 octal latches (U501-U508), two for each group of sequential digits. The 16th line is used for one of the anode driver lines. The current through each group of four LED's is limited by an 82 Ω resistor in series with each output of each of these 8 octal latches. The resistors are contained in 8 resistor networks (R501-R508). The 10 single LED indicators also are connected into the matrix and have their own resistor network (R510) and shift reg. latch (U511).

There are thus a total of nine octal shift register latches that control the 14-segment displays and individual indicators. Fifteen lines of each group sink the cathode currents and the 16th controls the anode currents. The microprocessor illuminates the 14-segment displays every fourth digit at a time. It does this by loading the nine octal latches that control the cathodes and the anode selection with the data for every fourth digit. It then latches the output for 2.1 milliseconds. This illuminates the desired LED segments. The microprocessor reloads the data in the latches anytime from 0.1 to 2.1 milliseconds after having been loaded, depending on the value of the Brightness *level* parameter. Since the data is inverted, the display is blanked for the remainder of the 2.1 millisecond period. The microprocessor performs this operation every 2.1 milliseconds, four times, before the cycle repeats. The cycle occurs 120 times per second which is fast enough that the viewer is not aware that the segments are not being simultaneously illuminated.

The display segments are not designed to be driven continuously at the current levels used by the AH2700A without causing possible damage to them. A monostable (U509 in 1A3) protects against this event by disabling the LED output

drivers unless the microprocessor is continuously latching new data.

PREAMP BOARD

The two page schematic of the preamp board begins with Figure F-31 on page F-85. The circuits on the preamplifier (preamp) board are discussed in the order in which the signal flows through them. In addition, since the output of the preamplifier board goes directly to the multiplexer board, the discussion of this signal flow continues in the next section on the multiplexer board. The control of the 10 relays and other setup of the preamp is done using the SPI bus that is extended from the main board. Two 8 bit shift register latches control the preamp. One is an 8 bit relay driver while the other latch controls various logic levels. Single pole ruthenium reed relays are used to avoid the microphonics associated with the armature relays used in earlier bridges.

Input Protection

Protection circuitry at the input of the preamp is essential not only to protect the preamplifier circuitry against excessive voltages applied to the LOW terminal of the AH2700A, but also to protect the fused-silica reference capacitors which are connected directly to the LOW terminal. The reference capacitors are protected by a gas-discharge device (E601 in area 1C4) that will attempt to limit the LOW terminal voltage to less than 140 volts with respect to ground. This not only protects against excess voltages applied to the LOW terminal, but also against those applied to the DC BIAS input.

The Op Amp (U602 in 1C1) at the input of the preamp must be protected against relatively low voltages. This is done using two diode strings, one for positive overloads (Q602, D603, D605 and D606) and one for negative overloads (Q601, D601, D602 and D604). These diode strings will clamp the input voltage to about ± 3 volts. The current through these diode strings is limited by a series resistor (R612).

A 100 ohm resistor (R609) protects the calibrate / discharge relay (K604 in 1C4) contacts. In calibrate mode, this relay shorts the LOW terminal to ground through R609. If the AH2700A were measuring a charged capacitor at the moment that K604 was closed, essentially the full charge of the capacitor would be absorbed by R609. (The HIGH terminal has very low impedance and would dissipate very little of the charge.)

DC Bias

The DC bias circuitry is shown in area 1D3. The original values of the bleeder resistors (R604 and R603) are 1.0 megohm and 100 megohms, but these can be removed and other values substituted. A two stage filter (R601, C601, R602 and C602) reduces any noise that might be present in an external bias power supply.

In the event that measurements are to be made with a DC bias applied to the DUT, the NoBias relay (K609) open, will insert a blocking capacitor between the DUT and the input of the preamplifier. Another relay (K606) connects the DC bias input to the DUT through a bleeder resistor. If a lower bleeder value is desired, another relay (K607) parallels the lower valued 1 Meg. (R604) with the higher valued 100Meg. (R603). When no bias is applied to the DUT, the low input is directly connected to the preamp U602 by K609. The source of the bias bleeder is grounded by K608 to reduce noise injection.

Operate/Calibrate Relay

To perform internal calibrations, the LOW terminal of the AH2700A must be disconnected from the internal circuitry. De-energizing the LoCnect relays (K601-603 in area 1C3) opens this connection. The Cal/Disch relay (K604) also shorts the LOW terminal to ground through R609 so that no signal from the LOW terminal can be capacitively coupled across the open relay contacts.

Another relay AtnTst (K605) connects a shunt capacitor from Low to ground. The shunting action of this capacitor causes a substantial reduction of the voltage at the input to the preamp. This ability is needed by certain test routines whose action would otherwise overload the preamp. This is also used during tests to apply a signal from the Attenuator transformer via main board relays (K140, 141). This eliminates the external apparatus required to test previous models of the bridge.

Preamplifier

The preamp uses a low noise Burr Brown 627 op amp set to 29 times gain to amplify the small unbalance signal at the summing junction.

DC on Low Detector

Amplifier (U603A in 1B1) is used to detect the presence of DC voltages on the LOW terminal. When detected, U603A drives the LOW terminal through a 200 megohm or 2 Gigohm (for low frequency) resistance (R614 or R613) to attempt to discharge small DC voltages that may be present across the DUT. For larger DC voltages on the LOW terminal, the output of U603A will be greater. This will cause the LOW terminal to be driven harder through a 320 k Ω resistance (R615 and R621) as a result will turn on one of two diodes (Q601 or Q602). FETs are used as diodes to obtain a very low capacitance and still handle moderate currents. This ensures that larger excess DC voltages are removed quickly. Filter network (R616 and C608) prevent noise from being fed back to the input of the preamp.

The filtered output of U603A passes through a buffer U603B to isolate the signal. This signal (DCONL) is sent to the A/D on the multiplexer board where its voltage can be read by the processor. This allows the processor to detect and report situ-

ations where a persistent DC voltage exists on the LOW terminal. It shares a multiplexer port with a clamp voltage detector selected by U611C.

Programmable Gain Amplifier

To accommodate the wide range of voltages present on the LOW terminal, a programmable (variable) gain amplifier (ACG) follows the preamp. This is implemented using an operational amplifier (op-amp) and a 1-of-8 CMOS analog switch (U605 and U606 in 2B3 and 2C3). The processor uses the analog switch to set the value of the feedback resistance for the op-amp. The switch shunts the unused part of the feedback resistance. The smallest feedback resistance is set with a trimpot to compensate for the variability of the internal resistance of the analog switch. The gain of this stage is simply the sum of all the unshunted feedback resistors (R616-R625) divided by the 30 k Ω input resistor (R624).

Flat Gain Amplifier

The signal from the programmable gain amplifier is passed to a two stage amplifier. Each stage (U608 and U609) is a low pass amplifier with a gain of 17 times and a total rolloff of about 10 db at 20 kHz. The low frequency response is controlled by the processor. It changes the input and output coupling capacitors value via the SPI controlled 8 bit latch. The output is clamped to +/- 5.5 volts with D607 and D608. D609 provides the negative clamp voltage. This limits large voltages from overloading the CODEC. The signal voltage at the clamp can be measured with the A/D converter on the multiplexer board to help the bridge software set the variable gain. The preamp output signal is then converted to a differential signal to be routed as PAMPOUT to the CODEC U411 on the multiplexer board.

MULTIPLEXER BOARD

The three page schematic of the multiplexer board begins with Figure F-20 on page F-53. Most of the circuitry on the multiplexer board is used to process the CODEC input and output signals.

CODEC

The CODECs are 16 bits wide and the left and right channels are treated as differential signals to eliminate the common mode noise signals. The outputs are filtered with two low pass Chebyshev filters to reduce high frequency noise. Similarly, the inputs are filtered to reduce alias problems.

Two of the four CODEC outputs provide the differential in-phase and quadrature drive signals to the main board. The two remaining outputs are used for the Cap and Loss Analog out which is amplified by U415 before delivery to the rear panel Analog Out connector.

One of the CODEC inputs converts the preamp differential signal to digital format for the DSP to process and deliver

numeric results to the 68332. The remaining two CODEC inputs are used to sample the IDAC, QDAC drive signals to allow the DSP to adjust the phase difference so they are exactly 90° out of phase. The fourth input is not used.

In-Phase and Quadrature drive

The In-phase and Quadrature drive signals from the DSP are delivered to the CODECs U401, U406 via a serial data bus at 12.825 Mbits per sec. This bus is shared with the other two CODECs used for analog output signals. Each drive develops a differential signal that is filtered with a two stage Chebyshev low pass filter to remove high frequency noise. The I and Q differential drive signals are then routed to the main board to drive the main and quadrature transformers T101 and T102.

Analog Out

To develop two dc signals proportional to the unbalance of the bridge, two CODEC channels are used (U411, U416). One for Cap, the other for Loss. These signals are amplified by U415A&B to produce signals that can range from -10.5 to +10.5 volts under the control of the DSP. The DSP can be put into a special mode of operation where the variation of the unbalance of the bridge is delivered as Cap and Loss to the analog out connector. The process uses the DSP phase detector and rotates the result to obtain Cap and Loss separately.

Preamp Input

The differential signal from the preamp passes through a low-pass filter (U413). This provides some anti-alias filtering before entering the CODEC U411. The differential signal is converted inside the DSP to single by subtracting the left and right signals. The DSP then filters, phase detects and sums the data before sending it to the 68332 for further processing.

Phase Adjuster Sense

To insure that the in phase and quadrature signals are 90° apart, a sample of both T101 (In phase) and T102 (Quadrature) from the main board are sent through the CODECs U401 and U406 to the DSP for processing. If differences in phase or amplitude are detected, the DSP changes the Q drive to correct the difference.

Multiplexer

To measure a number of voltages in the bridge a selection of one of 24 is made under control of the processor via the SPI bus and an 8 bit latch U423. The multiplexer (MUX U418 in area 1D3) uses a common 1-of-8 CMOS analog switch. This multiplexer output is paralleled with two 1-of-8 multiplexers on the main board U109, U110. Their input sources are identified in the discussion on the Analog Block Diagram in "Multiplexer and A/D." on page 10-5.

Programmable Gain Amplifier

A two stage RC filter reduces high frequency noise that may be present on some of the selected inputs. The op-amp (U419 in 1D2) and 1-of-8 analog switch (U420) create a programmable gain, DC amplifier. The processor can set the gain to be one, two, or four times using the same 8 bit latch that controls the source selection. The analog switch connects the negative input of the op-amp to a tap on a series connected string of resistors (R478-R481). The feedback resistance between the output (pin 6) and the negative input (pin 2) of the op-amp divided by the input resistance from the negative input (pin 2) of the op-amp to ground gives the gain of the amplifier. Unity gain is a special case which is achieved by connecting R477 directly between the output and the negative input with no input resistor connected to ground. The remaining four inputs of U420 are not used.

Analog-to-Digital Converter

The single chip analog-to-digital converter (A/D) (U421 in 1D1) produces a serial 14-bit output that is sent over the SPI bus to the 68332. The reference for the A/D is provided by a 4.096 volt reference generator U422. This reference voltage times 0.99 is applied to one of the multiplexer inputs as a check.

MAIN BOARD

The main board and the standard cell assembly form three of the four legs of the basic bridge shown in Figure 4-1 on page 4-1. Only the leg which contains the DUT is not on the main board because the DUT is external to the bridge. The six page detailed schematic of the main board begins with Figure F-24 on page F-69.

The discussion of the generation of the bridge frequency starts with the DSP section in the processor board description, followed by the In-Phase and Quadrature Drive section of the multiplexer board and continues in the order of the signal flow immediately below.

CODEC Filter

A switchable low pass filter reduces the high frequencies that exist in the I and Q drive signals. These are remnants of the 50098 KHz sample rate. This conventional filter is built using U101, U102 and associated components in area 1D2.

Main Transformer and Driver

The input to the main transformer driver is a differential to single ended gain stage (U101 in area 1D2). The DSP can vary the drive voltage that drives the main transformer (T101) so that the maximum voltage available from the HIGH terminal of the AH2700A is 15 volts. The main transformer is designed so that it begins to saturate at only a few volts above that level.

The forty turn primary of the main transformer (T101 in 1D1) is driven by a push-pull amplifier (U103 and U104 in areas 1D2 and 1C1) which produces a 10 volt RMS signal across it. A 1000 μ F blocking capacitor (C102) prevents any DC currents from flowing through T101.

An amplifier (U105) compares the difference between the desired sine wave and the actual main transformer voltage as measured from a tap (IP08). The amplifier magnifies the difference voltage by a factor of ten. This voltage is rectified by a diode (D105) which charges a 0.1 μ F capacitor (C111). This rectified voltage is used to create the I_OVRLD signal which can be read by the processor using the A/D on the multiplexer board. The presence of an I_OVRLD signal indicates that T101 is overloaded, usually as a result of too much current flowing from the HIGH terminal to ground. When this occurs, the processor reports the "high to ground short" error by placing an "H" in the upper right corner of the front panel capacitance display. A resistor divider (R117 and R118) ensures that the I_OVRLD signal does not exceed the range of the inputs of the multiplexer (U110).

The main ratio transformer (T101) has five windings. The most important characteristic of T101 is that the voltage per turn for every turn of every winding is the same. This is true for every turn to an extremely high degree of precision. This is true even if some current is being drawn from the transformer causing the voltage per turn to decrease slightly; the voltage per turn will decrease equally for all turns. Only if excessive currents are drawn will the voltage per turn start to become unequal among the windings.

Quadrature Transformer Driver

The quadrature transformer driver (U117 in area 1B2) gets its differential input signal from the output of CODEC U411 via filters on the multiplexer board. The function of the quadrature transformer driver is to provide sufficient current to drive the quadrature ratio transformer (T102).

The 2 volt signal from the differential to single ended amplifier goes to pin 3 of U115 where it is compared against the signal on pin 2 of U115 which comes from the 0.8 tap (QP08) on the quadrature ratio transformer, T102. The output of U115 on pin 6 produces a signal with an amplitude that causes the voltage across T102 (QP10) to be 2.5 volts.

A blocking capacitor (C133) is in series with T102 to prevent any significant DC current from flowing through T102. Diodes (D110, D111) limit the voltage that can exist across C133.

The two op-amps (U114A & B in 1A1) are used to correct for DC offset voltages in the amplifiers of the differential amplifier. It is DC coupled to the quadrature transformer driver so that the driver will amplify any DC offsets fed to its input. To cancel these, the output of U115 is connected to an integrator (U114B). The integrated output is inverted (U114A) and fed to the negative input of U115 in such a way as to cancel any DC voltages applied to the positive input of

U115. The integrator output continually adjusts until there is no DC voltage at the input to U114A. This insures that the blocking capacitor, C133, has only a very small DC voltage across it so that the diodes, D110 and D111, do not conduct. Should the Q output be overloaded due to trouble, the Q_OVRLD signal may be measured by the A/D on the mux board to indicate problems.

I Q Sample Select

The DSP analyzes the sampled I and Q (IP10, QP10) signals and adjusts the Q phase and magnitude to be exactly 90° out of phase and equal amplitude. To reduce effects of sample circuit variations, half of the adjust data samples are made with I, Q straight through the U111 selector. The second half of the samples have I and Q reversed, thus cancelling differences in each channel. The sampled signals are converted to differential signals then passed to the CODECs on the multiplexer board.

RTMDAC's

The basic operation of the RTMDAC's is discussed in the section "In-Phase Relays and RTMDAC" on page 10-4.

The IDAC and the QDAC of the main board schematics in Figure F-26 on page F-73 and Figure F-27 on page F-75, respectively, are very similar to each other. They may, at first, appear to be very different from the simplified diagram in Figure 10-1 on page 10-3, but schematically, they are very similar to that figure. The schematics look different from the simplified diagram because the signal lines in the schematics are bussed and because the analog switch IC's are shown in the schematics rather than the individual switching elements.

There are two kinds of analog switch IC's used. One is the 4053 which can connect one of two inputs to a common output. The other is the 4051 which can connect one of eight inputs to a common output. The 4053's are used in the "bi" part of the bi-quinary switching scheme. The 4051's are used in the "quinary" part of the bi-quinary switching scheme. In addition to their quinary function of selecting the five 0.2, 0.4, 0.6, 0.8 and 1.0 taps of the ratio transformers, each 4051 also can select the 0.0 tap (ground) and the -0.1 tap. Thus each 4051 actually selects a total of seven taps.

The processor controls the decade setup via the SPI bus. Each bi-quinary decade has four bits of one of six of the 8 bit shift register latches. Three of these bits are used to control one 4051 and the fourth bit is used to control one section of a 4053.

The biggest difference between the simplified diagram in Figure 10-1 and the actual schematic is in the large value resistors shown on the simplified diagram. The schematics do not show any large value resistors. Instead, they show resistive dividers that accomplish the same thing. These dividers allow smaller resistors to be tied to the common terminals of the analog switches of lesser significance.

The two RTMDAC's share a single precision adder (U151 in area 3B1). The entire switched resistor network of both RTMDAC's feeds into the input of U151. Similarly, two resistive dividers are each shared by both RTMDAC's. The divider using R169 and R189 (in area 3B2) causes any 1 MΩ resistors that are tied to the common point between R169 and R189 to have the same effect as a 2 MΩ resistor connected directly to the negative input of U151. Similarly, the divider using R165 and R166 (in area 3B3) causes any 2MΩ resistors that are tied to the common point between R165 and R166 to have the same effect as a 20 MΩ resistor connected directly to the negative input of U151. And lastly R183, 184 cause any 2 MΩ resistors that are connected to the common R183,184 point to have the same effect as a 200 MΩ resistor. The operation of this area of the circuit is much easier to understand by referring to the simplified diagram in Figure 10-1.

For most of each RTMDAC, the on-resistance of the analog switches is small compared to the resistors in series with them so that the effects of the on-resistance can be ignored. However, for the most significant two decades with resistors of 200 KΩ or less this is not true. As a result, these decades use follower IC's consisting of LM318's or LM353's to reduce the effective output impedance of the analog switches substantially below that of the analog switches by themselves.

All of the analog switches in the RTMDAC's are powered from ±5 volt supplies provided by two regulators (U120 and U118 in area 3A4). These supplies are used to reduce noise and because the voltage capabilities of the analog switches are not sufficient to operate from ±12 volt supplies.

Decade Relay Banks

The basic operation of the decade relay banks (RD's) is discussed in the section "In-Phase Relays and RTMDAC" on page 10-4 and is shown in the Analog Circuits Block Diagram Figure F-2 on page F-5. The schematic is in the upper half of sheet five of the main board schematic drawings shown in Figure F-28 on page F-77. The Analog Block Diagram shows the analog part of this circuit without any simplifications.

The relays are controlled by three 8 bit shift register latch relay drivers. Each relay is assigned a bit position so any combination of relays may be operated under control of the processor. Under normal operation only one relay of a bank is operated at a time. The most significant decade can connect the nominally 100pf reference capacitor to any tap on the main transformer to give ratios of 10.0 to 0 and -0.1. The second decade similarly switches a nominal 10pf reference capacitor to the same set of voltages.

Attenuator

The basic operation of the attenuator (ATN) is discussed in the section “Attenuator Leg of the Bridge” on page 10-3, and is shown in the Analog Circuits Block Diagram in Figure F-2 on page F-5. The schematic is in the lower left corner of sheet five of the main board schematic drawings shown in Figure F-28 on page F-77. The Analog Block Diagram shows the analog part of this circuit without any significant simplifications. The selection of the attenuator relays uses two serial shift register latches and operates in exactly the same manner as described above for the decade relay banks.

Oven Controller

The oven controller controls the power that keeps the standard cell assembly at a very constant and repeatable temperature when the AH2700A is operating. The schematic for the oven controller is located on sheet six of the main board schematic diagrams shown in Figure F-29 on page F-79.

The oven controller is a purely linear design. Its input is taken from a high-stability resistance bridge (R201, R202, R203 and RT201 in area 6C4) located on the standard cell assembly. The voltage at the junction of R203 and the thermistor, RT201, is an indication of the cell temperature. The magnitude of this negative voltage decreases as the cell temperature increases. The processor monitors this voltage via U203 as a buffer and hence the cell temperature via the OVEN-TEMP line. Resistors R201 and R202 form a high stability divider against which to compare the cell temperature. The objective is to raise the temperature of the cell until the voltage at the center points of the two arms of the bridge is precisely equal.

The high precision op-amp (U201) compares the two halves of the resistance bridge. This op-amp is configured as an integrator using an 0.47 μF capacitor (C202) and a 33 $\text{M}\Omega$ resistor (R206) to produce a long time constant. As the cell reaches its operating temperature, the output of U201 will stabilize at a DC level which reflects the amount of power needed to keep the cell at its operating temperature.

The next stage (U202) is a linear amplifier with several lead and lag circuits that are needed to make the controller stable. The dynamic behavior of the controller is designed to be underdamped, with the oscillations falling at least a factor of three on every cycle. A resistor (R210) biases the positive input of U202 slightly negatively so that the output of U202 is also shifted negatively. This is done because U202 operates from symmetrical plus and minus 12 volt power supplies but drives a power circuit operating between ground and -24 volts. The op-amp, U202, drives a transistor (Q203) which gives an additional gain of about ten. The transistor, Q203, drives a darlington transistor pair (Q201 and Q202) which control the current through the heater on the cell. The power transistor, Q201, is located on the cell since a significant amount of power is dissipated by this transistor which helps to heat the cell.

STANDARD CELL ASSEMBLY

The standard cell assembly consists of three fused-silica capacitors enclosed in a hermetically sealed cell. This cell is located in an insulated box which allows the cell to be very precisely temperature controlled. A flexible circuit is attached to this cell that holds and makes connection to some of the parts associated with the oven controller described above.

Reference Capacitors

The three reference capacitors (C210A, C210B and C210C) are connected to the rest of the bridge as discussed in the section “In-Phase Relays and RTMDAC” on page 10-4 and as shown in the Capacitance Bridge Circuits Block Diagram in Figure F-3 on page F-7. The details of the interconnections are shown in area 5B2 in Figure F-28 on page F-77.

The three reference capacitors are tied to a common point (STCOM). This is carefully shielded and brought out of the standard cell oven box through a coaxial cable to the preamp board. The other ends of the three reference capacitors are brought out of the standard cell oven box via the flexible circuit. A connector (P214) on the end of the flexible circuit plugs into the main board.

The purpose of this chapter is to describe how to repair an AH2700A that is suspected of having a problem. If there is no reason to suspect that a problem exists, then there will be little reason to read any of this chapter.

If you believe that your AH2700A is functioning properly, but you wish to verify this, see Chapter 9, “Verification/Calibration”. It is important to know that the function of calibrating or verifying a bridge is a totally different operation from the diagnostic tests described in this chapter.

The routines that verify the AH2700A perform *very demanding* tests that will only pass if the bridge is performing to its published specifications. On the other hand, the diagnostic tests described in this chapter perform few demanding tests. Almost all of these tests are *simple* in nature. Each test is designed to exercise as little circuitry as possible so that if a test fails, only a small amount of circuitry is suspect.

REPAIR PHILOSOPHY

You can approach the problem of diagnosing and repairing the AH2700A in at least four different ways or in any combination thereof. These are:

1. Send the bridge to the factory for repair.
2. Identify the subassembly that needs repair and send that to the factory.
3. Identify and replace the subassembly that has failed.
4. Identify and replace the specific component that has failed (resistor, IC, etc.).

Which of these you choose will depend on the time and expense involved in shipping to and from the factory, your ability to stock spare subassemblies, and your access to local repair expertise.

The repair philosophy of this chapter supports all of the above options. The self-tests built into the AH2700A are capable of localizing many failures well enough to be able to perform repairs by replacing either the lowest level part that has failed or the subassembly that contains the part. Whether this is practical or not depends upon the particular failure and your available expertise.

Consult the Factory

If you are able to, a brief discussion with the factory (via phone, e-mail or fax) will often determine whether or not a problem is easy to fix locally. Since the factory maintains historical failure statistics, the factory can often help by identifying a particular part that is the likely source of failure

CLEANING

Your AH2700A should not require cleaning often. When it does, gentle water-based, household-style cleaners can be used to remove dust and finger prints. Dilute isopropyl alcohol can be used also. Do not allow any water or cleaning fluid to flow into the instrument or into the contacts in its connectors. This is easy to control by using only a damp (not soaked) cloth for cleaning.

Connector contacts should not normally require cleaning. If they do, only commercially-available contact cleaners designed for this purpose should be used.

PRELIMINARY TROUBLESHOOTING

If you believe your bridge has a problem and you have not read this chapter previously, you will want to familiarize yourself with this section first.

Abbreviations Used

There are a number of terms used in this chapter to describe, primarily, different major sections of the circuitry in the bridge. Some of these terms are too long to use frequently so a number of abbreviations have been defined to use in their place. Table 11-1 lists these abbreviations. In addition, many signal names are used that are not listed in this table but which are found in Chapter 10, “Circuit Descriptions” and in the schematics in Appendix F, “Drawings and Parts Lists”. Major subassembly names and their reference numbers are shown in Figure 11-3 and Figure 11-4 at the end of this chapter.

Safety

The areas of the AH2700A that can affect safety are the power supply and the DC bias circuit. Other than the printed circuit boards themselves, these areas use mostly standard, commercially available parts. The exception is the power transformer which must be purchased from Andeen-Hagerling, Inc. to preserve all safety ratings.

Table 11-1 Some abbreviations used in this chapter

Abbreviation	Full name	Description	Applies to
=>	Implies	One thing <i>implies</i> another thing	relationships
ACG	AC Gain	The variable gain control circuit in the preamp	U605, U606, U610
A/D	Analog-to-Digital Converter	14-bit analog-to-digital converter used to read many signals in the bridge. Also used to refer to sigma-delta A/D converters found in each CODEC	U419-U422
ATN	ATteNuator	The circuit used to drive the HIGH terminal	U155, U156, K113-120, K133-136
calc	calculate	Applies to calculations to be reported as test results	
CODEC	Coder/Decoder	Integrated circuits containing delta-sigma A/D and D/A converters	U401, U406, U411, U416
DAC	Digital-to-Analog Converter	Shortened abbreviation for “RTMDAC”; not to be confused with “D/A”	Sheets 3 & 4 of main board schematics
D/A	Digital-to-Analog Converter	Sigma-delta D/A converters found in each CODEC	U401, U406, U411, U416
DCG	DC Gain	The variable gain control circuit on MUX board	U419, U420, U423
Flash	Flash memory	A kind of memory that holds data permanently, yet can be erased and rewritten without being removed	U318
FS	Full Scale	The largest signal that can be measured by an A/D	U418-422
IDAC	In-phase DAC	The half of the RTMDAC that selects voltages from the main ratio transformer	Sheet 3 of main board schematics
mag	magnitude	Usually applies to magnitude of a signal (as opposed to its I or Q components) as read by a CODEC	U401, U406, U411, U416
max	maximum	Usually used to mean the larger of two signals	
MSD	Most Significant Decade	The most significant decade of one of the DAC's	U121, U122B, U124, U125, U140C-143
MSRD	Most Sig. Relay Decade	The most significant relay decade	U153-154, K121-132
MUX	MUltipleXer	The circuit that selects the signal read by the A/D	U109, U110, U418
p/o	part of	Only part of the item following “p/o” is applicable	
QDAC	Quadrature DAC	The half of the RTMDAC that selects voltages from the quadrature ratio transformer	Sheet 4 of main board schematics
QSPI	Queued Serial Peripheral Interface	A serial interface used by the CPU to communicate with other internal circuits in the bridge.	Originates on Sheet 1 of the processor board schematics
RD	Relay Decade	One of two groups of twelve relays used to select voltages from the main ratio transformer	U152-154, K101-112, K121-132
RTMDAC	Ratio-Transformer Multiplying Digital-to-Analog Converter	The RTMDAC circuit used to precisely select voltages from the main and quadrature transformers. See “RTMDAC’s” on page 10-15.	Sheets 3 & 4 of main board schematics
SCI	Serial Communication Interface	A serial interface within the CPU chip that supports the IEEE-1174 connector on the backpanel	Sheets 1 & 4 of processor schematics
TPU	Time Processing Unit	A sophisticated timing control circuit located within the CPU chip and managing 16 CPU pins	U313

Recommended Tools and Equipment

The following list gives the minimum tool and equipment requirements needed to diagnose a problem in the AH2700A.

1. Phillips #2 screwdriver
2. Multimeter with an DC voltage range of 250 volts and an input impedance of at least 10 megohms. Plus AC voltage range of up to 50v.
3. Metered and current limited 0-250VDC, variable, lab power supply.
4. BNC to dual male banana plug cable to connect power supply to a female BNC jack.
5. Triggered DC-50 MHz oscilloscope and probe
6. Andeen-Hagerling DCOAX-1-BNC (or equivalent) coaxial cable pair with male BNC ends.
7. Tools suitable for soldering and unsoldering parts on printed circuit boards.

While there are certainly other items that might be useful, if the ones listed aren't sufficient to find the problem, chances are that other or more powerful tools won't either. The kinds of problems that may be encountered require the skill to be in the technician, not the test equipment.

Before You Start

Significant diagnostic work can be performed on an AH2700A on either of two levels.

1. All of the diagnostic self-test routines can be performed without removing the covers of the bridge. Thus, you may be able to isolate the area in which a failure has occurred *without* opening the bridge.
2. After everything possible has been done with the covers still on the bridge, further diagnostic and repair work can only be done by working inside. This should only be done by an experienced technician in order to protect both the worker and the equipment.



WARNING !

Voltages high enough to cause a serious shock may be present in three areas of the bridge. All but the DC bias connector are normally covered even when the top and bottom covers of the bridge have been removed. However, further disassembly can expose these voltages. These exist in the area of the power line module, the front panel power switch, and in the preamp box and on the DC bias connector if an external DC bias is applied. See Figure 11-3 and Figure 11-4 at the end of this chapter for the location of these four areas.

Understanding the Circuitry

Any serious troubleshooting requires a good understanding of how the suspected circuits operate. The relevant sections of Chapter 10, "Circuit Descriptions" should be read. The relevant parts of the block diagrams and schematics in Appendix F, "Drawings and Parts Lists" should be studied before attempting any repairs.

Removal of Covers

While the removal of covers is fairly straightforward, there are a few tricks in Chapter 12 that will make the job easier and will reduce the chances of damaging the bridge in the process. For the reasons given in the caution message below, it is important to understand the correct way to remove the covers so that unnecessary disassembly is avoided.



CAUTION

Unlike many low-frequency instruments, the chassis of the AH2700A is considered to be part of its precision measurement circuitry. For this reason, the screws that hold the printed circuit boards and the various mechanical parts together must be considered to be critical components. Not only must every single screw that is removed be replaced, but these screws must be torqued to the values listed herein using a calibrated torque screwdriver where specified. It is extremely important that all work inside the AH2700A strictly follow the procedures in Chapter 12, "Disassembly/Reassembly".

Ground Reference Points

Every printed circuit board assembly except for the power supply and keypad has a convenient ground post. This provides for easy connection of a ground test lead such as that on an oscilloscope probe. The post is a round turret-style and is identical on all boards. This post style is not used for any other purpose in the bridge. The recommended ground reference point on the power supply is the negative end of the largest capacitor C711. This end is in the middle of the board. All ground reference points are identified in Figure 11-3 on page 11-53 and Figure 11-4 on page 11-54 at the end of this chapter.

Table 11-2 Actions to take in response to possible failure symptoms

Symptoms	Possible problems	Actions to take
No indicators illuminate on the bridge front panel.	No power from line.	Check power line.
	Bridge fuse is blown.	Replace fuse with proper size. See “Checking/Replacing the Fuse” on page 1-6.
Bridge fuse blows soon after power-on.	Bridge power supply (A701) is overloaded.	Unplug A701 output P702. If fuse still blows, repair or replace A701 or T701. Otherwise, further isolate the excess load by unplugging other subassemblies.
	Bridge power supply is defective.	Repair or replace A701 or T701.
No indicators illuminate on the bridge front panel, but fuse is OK and power line has power.	Processor bd. (A301) failed. A501 unplugged	Check the 5V power supply at connector J302 on A301. If it is within 4%, repair or replace A301.
	Five volt power supply is bad on A701.	Check/replace 5V PS fuse (F702). Check/replace 5V regulator (U703) and diodes CR701 and CR702
	Check flashing LED DS301 on A301.	Flash count gives indication of trouble. See “Startup Tests” on page 11-17 for further analysis.
Bridge does not indicate completion of the power-on self tests by putting a message on the front panel display.	Processor board (A301) failure.	Check the 5V power supply at connector J302 on A301. If it is within 4%, repair or replace A301.
Bridge completes power-on self-tests but reports an error message on its display.	The reported error message indicates the problem.	The power-on self tests are described in section “Startup Tests” on page 11-17. Refer to that section to proceed further.
Bridge completes the power-on self-tests successfully by reporting <i>DIGITAL TESTPASS</i> on front panel display, but won't accept commands from the front panel keypad.	Keypad (A502) is locked out, keypad is defective or U310 on processor board (A301) is defective.	Press LOCAL . If <i>LOCAL LOCKOUT</i> appears then Nremote and Nlocout <i>states</i> are set in the Serial parameter set. Clear these settings from a remote port. Check/replace W506 or U310. Otherwise replace A502 or A301.
Bridge gets an <i>H</i> error indication on the front panel with each measurement result.	HIGH terminal is overloaded by a low impedance to ground.	Disconnect the HIGH and LOW cables to the bridge.
Bridge gets an <i>H</i> error indication on the front panel with each measurement result with nothing connected to the HIGH and LOW terminals.	An ATN or RD relay is stuck closed,	Run the Relay Decade and Attenuator diagnostic tests with particular attention to the stuck reed tests.
Bridge gets error message (other than <i>H</i>) on the front panel with each measurement result and with nothing connected to the HIGH and LOW terminals.	A problem exists somewhere in the measurement circuitry in A101, A401, A601, C210, or interconnecting cables.	Perform the tests described “Checking Power Supply Voltages” on page 11-5. If these are correct, then run all the diagnostic self-tests described in this chapter. Actions to be taken in response to tests that fail are described with the individual test descriptions.
Bridge may appear to be working, but fails calibration/verification.		
CAL INVALID front panel indicator never goes out.	The oven, its controller, or the oven monitor has drifted or failed.	Run the diagnostic self-tests. If they pass, the oven or its control circuit on the main board is bad.
Bridge exhibits an intermittent failure.	A loose or corroded contact or mechanical damage exists somewhere.	Run all non-interventional diagnostic self-tests and any that require intervention that are suspected of being relevant. While running these tests, subject the instrument to whatever environmental stress seems to trigger the intermittent behavior. The most common stresses that cause intermittents are vibration and temperature changes.

Troubleshooting Basic Symptoms

If your bridge exhibits a specific symptom, you should look up the recommended actions to take in Table 11-2. This table will direct you to try some additional manual tests or to begin performing the diagnostic self-tests. Whatever actions are suggested by this table should be performed before trying any diagnostic self-tests. Conclusions suggested later, related to self-test failures, *assume* that this table has been consulted.

Checking Power Supply Voltages

The voltages produced by all the power supplies and power regulators in the AH2700A are easily checked. All but two power sources are required to have a tolerance of $\pm 4\%$. The remaining two are the unregulated sources labeled as +24V and -24V. In reality, they may range in magnitude from 20 to 32 volts depending largely on the power line voltage. The points that are recommended for checking these voltages are identified in Figure 11-3 on page 11-53 and Figure 11-4 on page 11-54 at the end of this chapter.

Any power sources found to be out of tolerance *must* be fixed before proceeding with any further tests. In many cases, a failed regulator is the problem, but you must also be on the lookout for excess loading of a power source. Power is provided to the SAMPLE SWITCH connector, so that is a possible source of excess loading if anything is connected to it.

The bridge contains three unregulated power supplies (+8V, +24V, -24V). From these, nine regulated voltages are generated of which three originate on the power supply board (A701). The remainder are generated using small, local regulators. On the preamp these are U613, U614 and U615; on the main board are U118 and U120; and on the MUX board is U424.

DIAGNOSTIC TEST ESSENTIALS

The AH2700A contains about 400 individual self-tests that it can perform. These are arranged into over 50 groups. The names of these groups are listed in Table 11-6 on page 11-13.

The purpose of these tests is two-fold. First, they are intended to help find and fix a probable failure that has previously been determined to exist. Second, these tests are intended to verify that the bridge is operating properly qualitatively. In other words, these tests check that every digital signal line can be set to both binary states and that important analog signal lines have approximately the right signal levels. These tests are not intended to check the precision of any circuitry. For that, the procedures described in Chapter 9 may be used to verify that the bridge is capable of making precision measurements.

Most of these tests are very simple and can be executed rapidly and repeatedly to create signals that are easily observable and interpretable on an oscilloscope, if needed. The measurement circuitry is reset at the beginning of each test so that a scope loop can be set up that sees all signals involved

in performing each test. Each test functions *independently* of all other tests.

NOTE

If an oven not ready condition causes the Cal Invalid indicator to be flashing at the start of tests it will not go out. This is due to the principle of not changing the setup at the end of a test. This means the A/D cannot be switched to read the oven controller voltage and note that the oven temperature had stabilized.

Initiating Self-tests: the TEST command

All of the self-tests are initiated with the following command syntax:

```
*TST?  
or  
TEST  
or  
TEST SINGLE [TstGrp, TstNum]  
or  
TEST FLOOR TstFlGrp, TstFlNum  
or  
TEST CEILING TstCeGrp, TstCeNum  
or  
TEST TOTAL TstTotal
```

TstFlGrp

The number of the group containing the first or only test to be executed.

TstFlNum

The number within the first or only group of the first or only test to be executed

TstCeGrp

The number of the group containing the last test to be executed.

TstCeNum

The number within the last group of the last test to be executed

TstTotal

The number of times all the specified tests are to be executed. If *TstTotal* = 0 is entered, the tests are executed indefinitely.

The test parameter options allow the following possibilities:

1. Issue the *TST? command with no parameters. This causes all tests that do not require intervention or observation to be executed. Additionally, this version of the *TST? command will not run any tests that are affected by external connections to the HIGH, LOW or DC BIAS connections on the back panel of the instrument.
Example: *TST?

- Issue the **TEST SINGLE** command with only the *TstGrp* parameter. This causes only the tests having that test group number to be executed.
Example: `TEST SINGLE 32`
- Issue the **TEST SINGLE** command with the *TstGrp*, *TstNum* parameters. This causes only the one specified test to be executed.
Example: `TEST SINGLE 35, 4`
- Issue the **TEST** command after specifying the **TEST FLOOR** *TstFlGrp*, *TstFlNum* and **TEST CEILING** *TstCeGrp*, *TstCeNum* parameters.

The range of valid test group numbers is not contiguous. As a result, it is possible to enter test number ranges that do not start and/or end on a valid test group number. Nevertheless, there may be executable test numbers within the entered range. If such tests are found, they will be executed. If not, a **BAD PARAMETER** error will be reported.

Execution of the tests can be aborted at any time with the **DEVICE CLEAR** command.

Format of the Test Results



As explained later, you can choose whether all tests or just failed tests report a result. A result contains three or four basic kinds of information.

- The number of the test that was executed is reported along with a count of the number of times that the tests have been repeated.
- The reported result gives two values which form a window. A third value is reported which indicates that the test passed if the value is within the window and that the test failed otherwise.
- Most of the result consists of test variables that show the exact state of every settable bit in the measurement circuitry of the bridge at the time when the test completed. This information can be important for establishing the exact state of the bridge if a failure occurs.
- The number of tests that have failed (FCNT) and the group and number of the last test to have failed (LTF) are reported on the front panel display. FCNT is zeroed and LTF is cleared each time a **TEST** command is executed unless the command is part of a macro. In that case, FCNT and LTF are initialized only at the beginning of the root macro. This allows failure information to accumulate in macros which contain complicated test sequences.

All of the variables reported by each test result are listed in Table 11-3. The format of these variables is given in this table and the number of characters used to report each variable is indicated by the number of letters in the entries in the format column. The way in which these variables are formatted on the front panel and on remote devices is given in the next two sections. The values that each of these test variables can have



are listed in Table 11-4 on page 11-9. The precise effect of setting a variable to each value is also listed in this table.

Front Panel Format

Each test result is displayed on the front panel as eight separate windows in the order and format shown in Figure 11-1. You can examine each window in the usual manner by pressing the  and  keys each time you want to advance from one window to the next. The frequency used while performing a test is shown in the frequency window that is located to the right of the main pair of windows.

Thirteen of the variables have labels preceding them. These are *C=*, *TST=*, *pppf=*, *S*, *M*, *LQ=*, *HI=*, *G*, *HP*, *K*, *T*, *B*, *L*, *J*, *D*, *ER*, *CF*, *FCNT=*, and *LTF=*. These are all constants except for *pppf*.

The default window visible in the front panel display while tests are running is the first one which shows the repeat count and the group and number of the currently executing test. This window gives a real-time display of the progress of the tests.

In addition, the  and  keys may be used to move through the eight display windows while the tests are actually running. This allows monitoring *vvv* while repeating a single test to check for sensitivity to various stimuli in real-time.

Remote Device Format

Each test result is sent to a remote device as a *single* line having the format shown below.

```
C=cccccc TST=gg.nn LQ=lll pppf=vvv HI=hhh
  Ss Mmm Gpd HPw Kk Tt Bb Ll Jj Dy ERx
  CFz r1r2i1i2i3i4i5i6 a q1q2q3q4q5q6 F=fffff
```

Most of the test variables are decimal, but *a*, *r*, *i* and *q* can also have some hexadecimal values. Eighteen of the variables have labels preceding them. These are *C=*, *TST=*, *LQ=*, *pppf=*, *HI=*, *S*, *M*, *G*, *HP*, *K*, *T*, *B*, *L*, *J*, *D*, *ER*, *CF* and *F=*. These are all constants except for *pppf*.

Format of the Summary Line

After the last test in *each* test cycle has been executed and optionally reported, a summary line may optionally be sent to remote devices. After the last test in the *last* test cycle of a repeated test has been executed and reported, one summary line will be sent to the front panel.

The repeat count, the failure count, and the group and number of the last test failure are reported. These are described in more detail in item four of "Format of the Test Results" on page 11-6. The **SHOW TEST** command can report all of the available information about the last test failure.

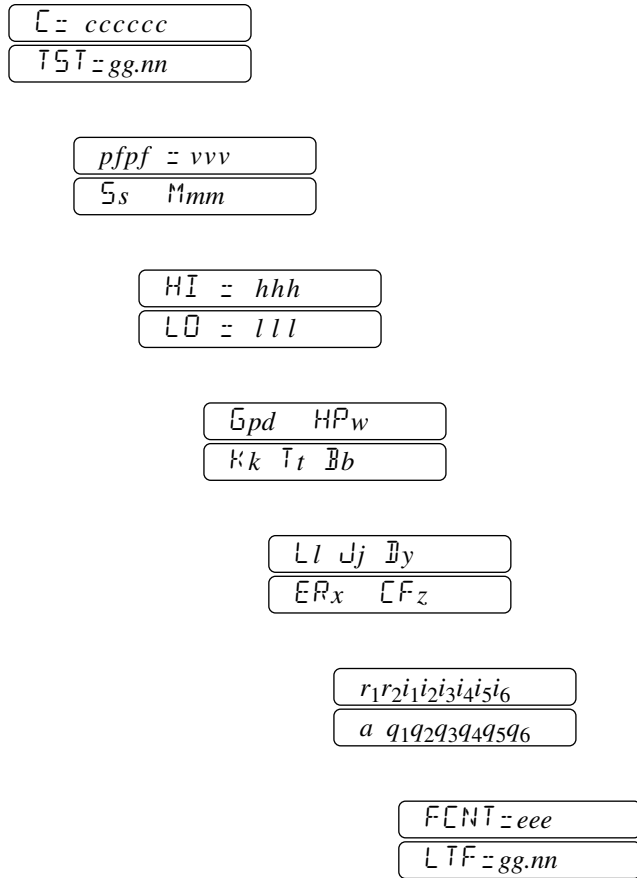


Figure 11-1 Test Result Format on Front Panel

Front Panel Summary Format

The format of the summary line on the front panel display is:



The `TST=END` words distinguish the first window of the summary line from that of an ordinary result line.

Remote Device Summary Format

The format of the summary line on a remote device is:

`C=ccccc TST=99.99 FCNT=eee LTF=gg.nn`

The test group and number is always `99.99` on this line (rather than `END`) so that it is easily identified as the summary line by a program running on a remote device.

Fetching the Last Test Failure: the SHOW TEST command

The data for the last test that failed can be re-displayed by issuing the command:

`SHOW TEST [FETCH]`

This command does not provide any new information, it only re-displays exactly the test failure result line and most recent summary line that was previously shown. It is useful if the failed test was not printed or if the front panel display was not set to halt on a test failure. This command allows test failure data to be retrieved even though it may have been accidentally or intentionally overwritten by other results on the front panel. If no test failure occurred, then the test group and number will be 0.0.

This command is also useful at the end of a macro or multi-command line to guarantee that a result will be sent to a GPIB controller. It also forces a summary line to be sent in case the “reported results” parameter discussed below is set to one to disable the summary line.

Selection of Options: the TEST REPORT command

You have a choice of several options in the way the `TEST` command is executed. These are:

- The `TEST` command can be set to halt on several different conditions. Generally, front panel operation requires that testing stop so that a test result on the front panel is not overwritten by later information. Since this is not usually an issue for results sent to a remote device, testing there should automatically resume after each test failure is reported.
- The `TEST` command can be set to report the results from all tests or just from those that failed. Usually, only failed tests are of interest, but sometimes it is useful to see how the test variables were set when a test passed. Knowing why one test passed can help understand why another test failed.
- The `TEST` command can be set so that it not only reports no results at all, but so that the bridge does not even make any readings with its A/D unless such measurements are critical for the test to be useful. By not making any readings, the number of data and strobe signals sent to the measurement circuitry per test cycle is greatly reduced. This is essential if an oscilloscope is to be able to easily show only the signals most relevant to a particular test. See “Making Measurements on a Specific Test State” on page 11-17.

Table 11-3 Test variables reported by the TEST results

Format	Name	Description
<i>C=cccccc</i>	Repeat count	Shows number of times the test(s) have been executed
<i>TST=gg.nn</i>	Test	Shows test group.number of currently executing test
<i>HI=hhh</i>	Hi limit	High limit of test window
<i>pfpf</i>	PASS/ FAIL	Indicates whether <i>vvv</i> was within the test window
<i>vvv</i>	Value	Value measured or derived from running the test. Holds <i>END</i> or <i>0000</i> on the summary line.
<i>LO=lll</i>	Lo limit	Low limit of test window
<i>Ss</i>	Value source	Source of reading reported by Value
<i>Mmm</i>	MUX	MUX channel selected
<i>Gp</i>	ACG	Preamp AC gain setting
<i>d</i>	DCG	Mux DC gain setting
<i>HPw</i>	High/ higher pass	Preamp high/higher pass filter states
<i>Kk</i>	Preamp states	Normal, cal/disch, and bleeder relay states
<i>Tt</i>	Atn/Pi test relays	Attenuator/Pi-net relay test states
<i>Bb</i>	Bias	DC bias relay states
<i>L l</i>	Drive Level	Transformer Drive Level
<i>Jj</i>	Phase Angle	QDAC phase angle relative to IDAC phase
<i>Dy</i>	DSP special operations	Controls Q-adjust & Quad-shift functions
<i>ERx</i>	Enable Readings	Enables Reading of three transformer drive signals
<i>CFz</i>	Codec filter	Codec lo-pass I-drive Filter enabled
<i>r₁r₂</i>	RD	Relay decade positions selected
<i>i₁i₂i₃i₄i₅i₆</i>	IDAC	In-phase DAC setup value
<i>a</i>	ATN	Attenuator tap selected
<i>q₁q₂q₃q₄q₅q₆</i>	QDAC	Quadrature DAC setup value
<i>F=fffff</i>	Frequency	Test signal frequency (Hz)
<i>eee</i>	Error count (FCNT=)	Shows the number of tests that have failed since the start of a TEST or MACRO command.

Table 11-3 Test variables reported by the TEST results

Format	Name	Description
<i>gg.nn</i>	Test (LTF=)	Shows test group.number of the Last Test Failure.

These options may be selected with the command:

TEST HALT MODE *HltOnCnd*
or
TEST HALT TOTAL *ErrTotal*

where *HltOnCnd* indicates the action at the completion of each test. The effects of each setting are listed.

- ALL** Execution of the tests will halt on every occurrence of any test result.
- AT_END** Test execution does not halt until all tests are finished.
- ON_ERR** Execution of the tests will halt on every occurrence of an error report (test FAIL). However if *ErrTotal* is set >1, then it will only halt after each *ErrTotal* errors have been detected.

ErrTotal

The “*ErrTotal*” parameter can be set to any value from 1 to 999. It specifies the number of test failures required to cause the test sequence to halt. The default value is 1.

Pressing **[STEP]** on the front panel causes tests to continue.

When tests are executed from a remote device and a “halt on condition” occurs, the normal “>” prompt is replaced with a “+” prompt. Either the **STEP** or **X** command can be issued in response to this prompt to cause the tests to continue.

The default value of the *HltOnCnd*, *ErrTotal*, and *RsltMode* parameter is stored in the BASIC FACTPON parameter file as **AT_END, 1, ERR_SUM**.

TEST REPORT *RsltMode*

where *RsltMode* is the format of the reported results. The effects of each setting are listed.

- ALL** All results, failed or not, are sent to remote devices and are shown on the front panel.
- ERR** Only any error result lines are sent to remote devices. All results, failed or not, are shown on the front panel. To guarantee that a message is sent to a GPIB controller, **SHOW TEST** should be appended to the command line.
- ERR_SUM** Only error results and the test summary line are sent to remote devices. All test results, failed or not, are shown on the front panel.

SCOPE No test results are measured or reported. The word *SCOPE* is displayed in place of the upper line of the PASS/FAIL window on the front panel.

Table 11-4 Test variable values showing functions and activated parts & pin numbers. (Sheet 1 of 8)

Variable value	Part-pin selected	Function
<i>pfpf</i> = PAS S	N/A	“PASS” indicates that <i>vvv</i> was within the test window
<i>pfpf</i> = FAI L	N/A	“FAIL” indicates that <i>vvv</i> was outside the test window
<i>s</i> = 0	U421	MAX194 A/D takes reading
<i>s</i> = 1	U401	AD1847 codec takes reading
<i>s</i> = 2	U406	AD1847 codec takes reading
<i>s</i> = 3	U411	AD1847 codec takes reading
<i>s</i> = 4	U401 & U406	AD1847 codecs take readings
<i>s</i> = 5	U313-9	MC68332 reads AC line
<i>m</i> = 0	U418-13	Selects CAPFDBCK signal
<i>m</i> = 1	U418-14	Selects LOSSFDBCK signal
<i>m</i> = 2	U418-15	Selects ground
<i>m</i> = 3	U418-12	Selects 4.055V signal
<i>m</i> = 4	U418-1	Selects 1847 TEMP signal
<i>m</i> = 5	U418-5	Selects 9.5V AC line signal
<i>m</i> = 6	U418-2	Selects ground
<i>m</i> = 7	U418-4	Selects ground
<i>m</i> = 10	U109-13	Selects OVEN-TEMP signal
<i>m</i> = 11	U109-14 U610	Selects DCONL signal
<i>m</i> = 12	U109-15	Selects PTEMP signal
<i>m</i> = 13	U109-12	Sel. MAIN-LOPASS signal
<i>m</i> = 14	U109-1	Selects DAC-TEMP signal
<i>m</i> = 15	U109-5	Selects I/QDAC BUFFER TEMP signal
<i>m</i> = 16	U109-2	Selects ground
<i>m</i> = 17	U109-4	Selects ground
<i>m</i> = 20	U110-13	Selects +5V/2 supply
<i>m</i> = 21	U110-14	Selects +12V/4 supply
<i>m</i> = 22	U110-15	Selects -12V/4 supply
<i>m</i> = 23	U110-12	Selects Q_IN_LPF signal
<i>m</i> = 24	U110-1	Selects RECTMAIN signal
<i>m</i> = 25	U110-5	Selects I_IN_LPF signal

Table 11-4 Test variable values showing functions and activated parts & pin numbers. (Sheet 2 of 8)

Variable value	Part-pin selected	Function
<i>m</i> = 26	U110-2	Selects I_OVRLD signal
<i>m</i> = 27	U110-4	Selects Q_OVRLD signal
<i>m</i> = 51	U109-14 U610-4	Selects CLAMPV
<i>m</i> = 60	U403A	Selects left codec channel
<i>m</i> = 61	U403B	Selects right codec channel
<i>m</i> = 62	U403A&B	Selects both codec channels
<i>m</i> = 70	U313-9	Measures AC line frequency
<i>m</i> = 80	U411	Measures preamp signal magnitude
<i>p</i> = 0	U603-13	ACG is set to the minimum
<i>p</i> = 1	U603-14	ACG is 10/3× the min.
<i>p</i> = 2	U603-15	ACG is 10× the min.
<i>p</i> = 3	U603-12	ACG is 100/3× the min.
<i>p</i> = 4	U603-5	ACG is 100× the min.
<i>p</i> = 5	U603-4	ACG is 1000/3× the min.
<i>p</i> = 6	U603-2	ACG is 1000× the min.
<i>d</i> = 0	U412-13	Set DCG to 1×
<i>d</i> = 1	U412-14	Set DCG to 2×
<i>d</i> = 2	U412-15	Set DCG to 4×
<i>d</i> = 3	U412-12	Set DCG to 8×
<i>w</i> = 0	U604,611	Highest pass preamp filter
<i>w</i> = 1	U604-10 U611-10	Higher pass preamp filter
<i>w</i> = 2	U604-10,11 U611-10,11	High pass preamp filter
<i>k</i> = 0	U601-12 U601-16 U601-17	LoCnect relays K601-603 are closed, Cal/Disch relay K604 is open, 200 Meg relay K610 is closed
<i>k</i> = 1	U601-16 U601-17	LoCnect relays K601-603 are closed, Cal/Disch relay K604 is closed, 200 Meg relay K610 is closed
<i>k</i> = 2	U601-17	LoCnect relays K601-603 are open, Cal/Disch relay K604 is closed, 200 Meg relay K610 is open
<i>k</i> = 3	U601-12 U601-17	LoCnect relays K601-603 are open, Cal/Disch relay K604 is closed, 200 Meg relay K610 is closed

Table 11-4 Test variable values showing functions and activated parts & pin numbers. (Sheet 3 of 8)

Variable value	Part-pin selected	Function
$t = 0$	U601, U155	AtnTst relay K605 is open; Pi-net relays K140, K141 are open
$t = 1$	U601-13, U155	AtnTst relay K605 is closed enabling C603 shunt; Pi-net relays K140, K141 are open
$t = 2$	U601-13, U155-11	AtnTst relay K605 and Pi-net relays K140, K141 are closed
$b = 0$	U601-15	K606 is open. Close K608 & 609 to disable bias; K607 is open to isolate R604
$b = 1$	U601-14	K606 is closed. Open K608 & 609 to enable bias; K607 is open to isolate R604
$b = 2$	U601-14, 18	K606 is closed. Open K608 & 609 to enable bias. K607 is closed to connect R604.
$b = 3$	U601-14, 15, 18	K606-K609 are all closed to test K608 closure
$l = 9$	N/A	Set main transf. drive to full
$l = 8$	N/A	Set main transf. drive to 1/2
$l = 7$	N/A	Set main transf. drive to 1/4
$l = 6$	N/A	Set main transf. drive to 1/8
$l = 5$	N/A	Set main transf. drive to 1/16
$l = 4$	N/A	Set main transf. drive to 1/32
$l = 3$	N/A	Set main transf. drive to 1/64
$l = 2$	N/A	Set main transf. drive =1/128
$l = 1$	N/A	Set main transf. drive =1/256
$l = 0$	N/A	Set only Q transformer drive level to overload
$j = 0$	N/A	QDAC lags IDAC by 0°
$j = 1$	N/A	QDAC lags IDAC by 90°
$j = 2$	N/A	QDAC lags IDAC by 180°
$j = 3$	N/A	QDAC lags IDAC by 270°
$y = 0$	U111	Q-Adjust active
$y = 1$	U406	Quad-Shift enabled
$y = 2$	U111-9&16	Q-Adjust disabled, I/Q flip = 0
$y = 3$	U111-1&8	Q-Adjust disabled, I/Q flip = 1
$y = 4$	U111 unselected	Q-Adjust disabled, I/Q flip = open

Table 11-4 Test variable values showing functions and activated parts & pin numbers. (Sheet 4 of 8)

Variable value	Part-pin selected	Function
$x = 0$	U102, U116	A/D readings of drive circuitry disabled/shorted
$x = 1$	U102-8,9 U116-8,9	A/D readings of drive circuitry enabled/unshorted
$z = 0$	U102, U116	1600Hz lo-pass codec filter disabled
$z = 1$	U102-1,16 U116-1,16	1600Hz lo-pass codec filter enabled
$r_1 = 0$	K131	Switch M0.0 to C210A
$r_1 = 1$	K130	Switch M0.1 to C210A
$r_1 = 2$	K129	Switch M0.2 to C210A
$r_1 = 3$	K128	Switch M0.3 to C210A
$r_1 = 4$	K127	Switch M0.4 to C210A
$r_1 = 5$	K126	Switch M0.5 to C210A
$r_1 = 6$	K125	Switch M0.6 to C210A
$r_1 = 7$	K124	Switch M0.7 to C210A
$r_1 = 8$	K123	Switch M0.8 to C210A
$r_1 = 9$	K122	Switch M0.9 to C210A
$r_1 = A$	K121	Switch M1.0 to C210A
$r_1 = C$		No connection to C210A
$r_1 = F$	K132	Switch M-0.1 to C210A
$r_2 = 0$	K111	Switch M0.0 to C210B
$r_2 = 1$	K110	Switch M0.1 to C210B
$r_2 = 2$	K109	Switch M0.2 to C210B
$r_2 = 3$	K108	Switch M0.3 to C210B
$r_2 = 4$	K107	Switch M0.4 to C210B
$r_2 = 5$	K106	Switch M0.5 to C210B
$r_2 = 6$	K105	Switch M0.6 to C210B
$r_2 = 7$	K104	Switch M0.7 to C210B
$r_2 = 8$	K103	Switch M0.8 to C210B
$r_2 = 9$	K102	Switch M0.9 to C210B
$r_2 = A$	K101	Switch M1.0 to C210B
$r_2 = C$		No connection to C210B
$r_2 = F$	K112	Switch M-0.1 to C210B
i_1 is even	U122-2	Switch IP 0.0 to U121 pin 3
i_1 is odd	U122-1	Switch IP 1.0 to U121 pin 3
$i_1 = 0$ or 1	U124-13	Switch IP 0.0 to U125 pin 3
$i_1 = 2$ or 3	U124-14	Switch IP 0.2 to U125 pin 3
$i_1 = 4$ or 5	U124-15	Switch IP 0.4 to U125 pin 3
$i_1 = 6$ or 7	U124-12	Switch IP 0.6 to U125 pin 3

Table 11-4 Test variable values showing functions and activated parts & pin numbers. (Sheet 5 of 8)

Variable value	Part-pin selected	Function
$i_1 = 8 \text{ or } 9$	U124-1	Switch IP 0.8 to U125 pin 3
$i_1 = A \text{ or } B$	U124-5	Switch IP 1.0 to U125 pin 3
$i_1 = E \text{ or } F$	U124-4	Switch IP-0.1 to U125 pin 3
$i_2 \text{ is even}$	U122-5	Switch IP 0.0 to U133 pin 3
$i_2 \text{ is odd}$	U122-3	Switch IP 1.0 to U133 pin 3
$i_2 = 0 \text{ or } 1$	U123-13	Switch IP 0.0 to U126 pin 3
$i_2 = 2 \text{ or } 3$	U123-14	Switch IP 0.2 to U126 pin 3
$i_2 = 4 \text{ or } 5$	U123-15	Switch IP 0.4 to U126 pin 3
$i_2 = 6 \text{ or } 7$	U123-12	Switch IP 0.6 to U126 pin 3
$i_2 = 8 \text{ or } 9$	U123-1	Switch IP 0.8 to U126 pin 3
$i_2 = A \text{ or } B$	U123-5	Switch IP 1.0 to U126 pin 3
$i_2 = E \text{ or } F$	U123-4	Switch IP-0.1 to U126 pin 3
$i_3 \text{ is even}$	U122-12	Switch IP 0.0 to R168
$i_3 \text{ is odd}$	U122-13	Switch IP 1.0 to R168
$i_3 = 0 \text{ or } 1$	U127-13	Switch IP 0.0 to U133 pin 5
$i_3 = 2 \text{ or } 3$	U127-14	Switch IP 0.2 to U133 pin 5
$i_3 = 4 \text{ or } 5$	U127-15	Switch IP 0.4 to U133 pin 5
$i_3 = 6 \text{ or } 7$	U127-12	Switch IP 0.6 to U133 pin 5
$i_3 = 8 \text{ or } 9$	U127-1	Switch IP 0.8 to U133 pin 5
$i_3 = A \text{ or } B$	U127-5	Switch IP 1.0 to U133 pin 5
$i_3 = E \text{ or } F$	U127-4	Switch IP-0.1 to U133 pin 5
$i_4 \text{ is even}$	U131-12	Switch IP 0.0 to R164
$i_4 \text{ is odd}$	U131-13	Switch IP 1.0 to R164
$i_4 = 0 \text{ or } 1$	U128-13	Switch IP 0.0 to R167
$i_4 = 2 \text{ or } 3$	U128-14	Switch IP 0.2 to R167
$i_4 = 4 \text{ or } 5$	U128-15	Switch IP 0.4 to R167
$i_4 = 6 \text{ or } 7$	U128-12	Switch IP 0.6 to R167
$i_4 = 8 \text{ or } 9$	U128-1	Switch IP 0.8 to R167
$i_4 = A \text{ or } B$	U128-5	Switch IP 1.0 to R167
$i_4 = E \text{ or } F$	U128-4	Switch IP-0.1 to R167
$i_5 \text{ is even}$	U131-5	Switch IP 0.0 to R162
$i_5 \text{ is odd}$	U131-3	Switch IP 1.0 to R162
$i_5 = 0 \text{ or } 1$	U129-13	Switch IP 0.0 to R138
$i_5 = 2 \text{ or } 3$	U129-14	Switch IP 0.2 to R138
$i_5 = 4 \text{ or } 5$	U129-15	Switch IP 0.4 to R138
$i_5 = 6 \text{ or } 7$	U129-12	Switch IP 0.6 to R138
$i_5 = 8 \text{ or } 9$	U129-1	Switch IP 0.8 to R138
$i_5 = A \text{ or } B$	U129-5	Switch IP 1.0 to R138
$i_5 = E \text{ or } F$	U129-4	Switch IP-0.1 to R138

Table 11-4 Test variable values showing functions and activated parts & pin numbers. (Sheet 6 of 8)

Variable value	Part-pin selected	Function
$i_6 \text{ is even}$	U131-2	Switch IP 0.0 to R161
$i_6 \text{ is odd}$	U131-1	Switch IP 1.0 to R161
$i_6 = 0 \text{ or } 1$	U130-13	Switch IP 0.0 to R160
$i_6 = 2 \text{ or } 3$	U130-14	Switch IP 0.2 to R160
$i_6 = 4 \text{ or } 5$	U130-15	Switch IP 0.4 to R160
$i_6 = 6 \text{ or } 7$	U130-12	Switch IP 0.6 to R160
$i_6 = 8 \text{ or } 9$	U130-1	Switch IP 0.8 to R160
$i_6 = A \text{ or } B$	U130-5	Switch IP 1.0 to R160
$i_6 = E \text{ or } F$	U130-4	Switch IP-0.1 to R160
$a = 0$	K136	Sets ATN to 0.0 V tap
$a = 1$	K135	Sets ATN to 0.001 V tap
$a = 2$	K134	Sets ATN to 0.003 V tap
$a = 3$	K133	Sets ATN to 0.01 V tap
$a = 4$	K120	Sets ATN to 0.03 V tap
$a = 5$	K119	Sets ATN to 0.1 V tap
$a = 6$	K118	Sets ATN to 0.25 V tap
$a = 7$	K117	Sets ATN to 0.75 V tap
$a = 8$	K115	Sets ATN to 1.5V tap
$a = 9$	K116	Sets ATN to 3.0V tap
$a = A$	K114	Sets ATN to 7.5V tap
$a = B$	K113	Sets ATN to 15 V tap
$a = C$	none	Sets ATN to open
$q_1 \text{ is even}$	U140-5	Switch Q 0.0 to U142 pin 3
$q_1 \text{ is odd}$	U140-3	Switch Q 1.0 to U142 pin 3
$q_1 = 0 \text{ or } 1$	U143-13	Switch Q 0.0 to U141 pin 3
$q_1 = 2 \text{ or } 3$	U143-14	Switch Q 0.2 to U141 pin 3
$q_1 = 4 \text{ or } 5$	U143-15	Switch Q 0.4 to U141 pin 3
$q_1 = 6 \text{ or } 7$	U143-12	Switch Q 0.6 to U141 pin 3
$q_1 = 8 \text{ or } 9$	U143-1	Switch Q 0.8 to U141 pin 3
$q_1 = A \text{ or } B$	U143-5	Switch Q 1.0 to U141 pin 3
$q_1 = E \text{ or } F$	U143-4	Switch Q-0.1 to U141 pin 3
$q_2 \text{ is even}$	U140-12	Switch Q 0.0 to R191
$q_2 \text{ is odd}$	U140-13	Switch Q 1.0 to R191
$q_2 = 0 \text{ or } 1$	U144-13	Switch Q 0.0 to U134 pin 3
$q_2 = 2 \text{ or } 3$	U144-14	Switch Q 0.2 to U134 pin 3
$q_2 = 4 \text{ or } 5$	U144-15	Switch Q 0.4 to U134 pin 3
$q_2 = 6 \text{ or } 7$	U144-12	Switch Q 0.6 to U134 pin 3
$q_2 = 8 \text{ or } 9$	U144-1	Switch Q 0.8 to U134 pin 3

Table 11-4 Test variable values showing functions and activated parts & pin numbers. (Sheet 7 of 8)

Variable value	Part-pin selected	Function
$q_2 = A \text{ or } B$	U144-5	Switch Q 1.0 to U134 pin 3
$q_2 = E \text{ or } F$	U144-4	Switch Q-0.1 to U134 pin 3
$q_3 \text{ is even}$	U140-2	Switch Q 0.0 to R188
$q_3 \text{ is odd}$	U140-1	Switch Q 1.0 to R188
$q_3 = 0 \text{ or } 1$	U145-13	Switch Q 0.0 to R190
$q_3 = 2 \text{ or } 3$	U145-14	Switch Q 0.2 to R190
$q_3 = 4 \text{ or } 5$	U145-15	Switch Q 0.4 to R190
$q_3 = 6 \text{ or } 7$	U145-12	Switch Q 0.6 to R190
$q_3 = 8 \text{ or } 9$	U145-1	Switch Q 0.8 to R190
$q_3 = A \text{ or } B$	U145-5	Switch Q 1.0 to R190
$q_3 = E \text{ or } F$	U145-4	Switch Q-0.1 to R190
$q_4 \text{ is even}$	U149-5	Switch Q 0.0 to R186
$q_4 \text{ is odd}$	U149-3	Switch Q 1.0 to R186
$q_4 = 0 \text{ or } 1$	U146-13	Switch Q 0.0 to R187
$q_4 = 2 \text{ or } 3$	U146-14	Switch Q 0.2 to R187
$q_4 = 4 \text{ or } 5$	U146-15	Switch Q 0.4 to R187
$q_4 = 6 \text{ or } 7$	U146-12	Switch Q 0.6 to R187
$q_4 = 8 \text{ or } 9$	U146-1	Switch Q 0.8 to R187
$q_4 = A \text{ or } B$	U146-5	Switch Q 1.0 to R187
$q_4 = E \text{ or } F$	U146-4	Switch Q-0.1 to R187
$q_5 \text{ is even}$	U149-2	Switch Q 0.0 to R182
$q_5 \text{ is odd}$	U149-1	Switch Q 1.0 to R182
$q_5 = 0 \text{ or } 1$	U147-13	Switch Q 0.0 to R185
$q_5 = 2 \text{ or } 3$	U147-14	Switch Q 0.2 to R185
$q_5 = 4 \text{ or } 5$	U147-15	Switch Q 0.4 to R185
$q_5 = 6 \text{ or } 7$	U147-12	Switch Q 0.6 to R185
$q_5 = 8 \text{ or } 9$	U147-1	Switch Q 0.8 to R185
$q_5 = A \text{ or } B$	U147-5	Switch Q 1.0 to R185
$q_5 = E \text{ or } F$	U147-4	Switch Q-0.1 to R185
$q_6 \text{ is even}$	U149-12	Switch Q 0.0 to R181
$q_6 \text{ is odd}$	U149-13	Switch Q 1.0 to R181
$q_6 = 0 \text{ or } 1$	U148-13	Switch Q 0.0 to R180
$q_6 = 2 \text{ or } 3$	U148-14	Switch Q 0.2 to R180
$q_6 = 4 \text{ or } 5$	U148-15	Switch Q 0.4 to R180
$q_6 = 6 \text{ or } 7$	U148-12	Switch Q 0.6 to R180
$q_6 = 8 \text{ or } 9$	U148-1	Switch Q 0.8 to R180

Table 11-4 Test variable values showing functions and activated parts & pin numbers. (Sheet 8 of 8)

Variable value	Part-pin selected	Function
$q_6 = A \text{ or } B$	U148-5	Switch Q 1.0 to R180
$q_6 = E \text{ or } F$	U148-4	Switch Q-0.1 to R180
<i>ffff</i>	N/A	Test frequency in Hz

THE INDIVIDUAL DIAGNOSTICS

This section describes the self-tests initiated by the TEST command. Included are what each individual diagnostic self-test does, what parts are tested and what parts are suspect when a test fails. This information is presented in a number of sections, each of which contains a table which covers a different major body of tests. In some cases, little more information than is contained in each table is needed, but special setup and interpretation instructions are given where appropriate. The sections, tables, and test groups and numbers in the tables are presented in the order in which the tests are executed. All test group titles are listed in Table 11-6.

Effective use of these tests assumes that you have read “PRELIMINARY TROUBLESHOOTING” on page 11-1 and “DIAGNOSTIC TEST ESSENTIALS” on page 11-5 with special attention to Table 11-2 on page 11-4.

Information Common to all the Tests

Reference Numbers

Most of the test descriptions in the tables contain reference designators to specific parts in the AH2700A. These refer-

ence numbers are identified on the parts lists and schematics in Appendix F, “Drawings and Parts Lists”. The system used to assign the reference numbers is identified in Table 11-5.

Table 11-5 Identification of reference number series

Reference number series	Associated printed circuit board or assembly
1xx	Main PC board except for oven circuit
2xx	Capacitance standard assembly and oven circuit on main board
3xx	Processor PC board
4xx	MUX/CODEC PC board
5xx	Front panel PC boards & some MUX/CODEC PC board capacitors
6xx	Preamp PC board
7xx	Power supply PC board and transformer
9xx	Chassis and related parts

Table 11-6 Test groups executed by the TEST command, showing those requiring intervention or observation. (Sheet 1 of 2)

Test group	Test group title	Intr/obs	Assemblies tested
19	Display Test	O	A501
20	First tests to see if A/D (U421) functions		A401
21	Test DCG settings and values of OVEN and CODEC temperature monitor lines		A401
22	Test power supply DC voltage levels		A401, A701
23	Test power supply ripple		A401, A701
24	Compare ambient temperature sensors		A401, A101, A601
25	Test the power line frequency detector		A301
30	Test generation of I-drive signal and test main ratio-transformer driver circuit		A401, A101
31	Check the I-phase precision rectifier		A401, A101
32	Test I-drive filters		A401, A101
33	Test main ratio transformer overload (OVRLD) detector , 15.75 volt drive	I	A401, A101
34	Test that quadrature transformer drive gives expected levels		A401, A101
35	Test I/Q and Q/I sense lines with Q-Adjust Disabled		A401, A101
36	Test Q-drive waveform and filters		A401, A101
37	Test quadrature ratio transformer overload (OVRLD) detector		A401, A101
38	Test quad-shift		A401, A101
40	Test ability of preamp to make and read null signals	N	A601
41	Test ability of upper half of bridge to make and read null signals		A401, A101, A601
42	Test ability of upper half of bridge to make and read non-zero signals		A401, A101, A601
43	Test DC BIAS circuits	I	A601

**Table 11-6 Test groups executed by the TEST command,
showing those requiring intervention or observation. (Sheet 2 of 2)**

Test group	Test group title	Intr/ obs	Assemblies tested
44	Test preamp shunt		A601
45	Other preamp input tests		A601
46	Preamp low frequency roll-off tests		A601
47	Test clamp voltage levels and DC offset		A601
48	Test Preamp Gain ratios at 1.0 and 20 kHz		A601
49	Test Preamp Phase at 1.0 and 20 kHz		A601
50	Test A/D and CODEC for all codes		A401
51	Test A/D and CODEC for linearity		A401
52	Test Quadrature phase shift at 1 kHz		A101, A401
53	Test Quadrature phase shift at 20 kHz		A101, A401
60	Test that each switch element in IDAC can cause a change		A101
61	Test that each switch element in QDAC can cause a change		A101
62	Test gain ratios of IDAC		A101
63	Test gain ratios of QDAC		A101
70	Test MSRD for a stuck closed relay		A101
71	Test second MSRD for a stuck closed relay		A101
72	Test MSRD for any change between open and selected states		A101
73	Test second MSRD for any change between open and selected states		A101
74	Test relative signal levels from MSRD		A101
75	Test relative signal levels from second MSRD		A101
80	Test ATN for presence of any stuck closed relays		A101
81	Test ATN for stuck closed relays and set up for meter measurement		A101
82	Test ATN for a stuck open or closed relay		A101
83	Test ATN for correct voltage ratios		A101
84	Attenuator relay pair tests, Test Voltage ratio with Open vs. Closed relay		A101
85	Attenuator relay pair tests, Test repeatability		A101
90	Test Analog output Cap channel dc voltages		A401
91	Test Analog output Loss channel dc voltages		A401

Ordering of the Tests

The order in which the tests have been designed to execute is important because the conclusions drawn about a test are based on the assumption that all previous tests *probably* passed. In practice, this means that the first test to fail (i.e. the one having the lowest number) is the one most likely to indicate the source of a failure. All subsequent test failures may merely be indirect consequences of the first test failure. Parts and/or signals listed as being suspect on FAIL assume that all previous tests have passed. Otherwise, parts listed previously are also suspect.

Test Descriptions

The test descriptions given for the tests in the following tables are necessarily brief. They contain enough information to identify what each test does, but not enough to fully define the test. More information is contained in the test results which show the test setup when the test completed. Note that the descriptions in the tables describe what the *bridge* will do, not what the *operator* is to do.

Most tests *end* by having a CODEC or A/D make a reading. Since this usually happens, the *last* reading of a test is not explicitly described. However, a number of tests take *two* A/D readings. In this case, the first reading is described and the second is implied. The internal test setup for the second read-

ing is assumed to be the same as that for the first unless described otherwise.

Tests that Require Operator Intervention

Most of the self-tests can be performed without operator intervention and so can be run individually or in groups for long periods of time, if desired. These tests use the bridge in its test/calibration mode which opens the LoCnect relays (K601-603) and closes the K604 shunt relay in the preamp. This disconnects and shunts the LOW terminal so that *it doesn't matter* what is externally connected to it. Tests that require that there be *nothing* connected to the HIGH, LOW or BIAS connectors on the back panel are labeled with an “N” in Table 11-6. These tests will *not* prompt the operator to disconnect anything that is attached to these connectors. For all

versions of the TEST command except for “*TST?”, the operator must ensure that nothing is attached to these connectors before running the tests. To learn more about the versions of the TEST command that can run the intervention tests, see “Initiating Self-tests: the TEST command” on page 11-5.

Tests that require operator intervention or observation are labeled with an “I” or an “O” respectively in Table 11-6. These tests will display a request on the front panel and send the request to the remote devices. After the request has been satisfied, pressing the **[STEP]** key on the front panel will cause tests to continue. The **STEP** or **X** command on GPIB devices and the **STEP** command or the **X** key on IEEE-1174 serial devices will have the same effect.

Table 11-7 Startup Digital tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
1	Setup to catch unexpected interrupts		
1.1	Setup for unexpected exception error. Report “INTERUPT ERROR <i>nnn</i> ” if unexpected interrupt occurs during any of the remaining digital tests. “ <i>nnn</i> ” is the interrupt vector.	None specifically verified	Many
2	ROM tests		
2.4	Compare complements in ROM Date/Time stamp area.	U311A, U318, U321	U311, U318, U321
2.5	Test ROM checksum.	U311A, U318, U321	U311, U318, U321
3	RAM tests		
3.2	Write, read, verify all of RAM once for each of the following hexadecimal patterns: 55555555, AAAAAAAA, 33333333, CCCCCCCC, 0F0F0F0F, F0F0F0F0, 00FF00FF, FF00FF00, 0000FFFF, FFFF0000, FFFFFFFF, 00000000, leaving it clear.	U302B, U315	U302, U315
3.3	Read lowest address, check that it is zero, write all ones to it, increment and repeat until highest address is reached; read highest address, check that it is all ones, write all zeroes to it, decrement and repeat until lowest address is reached.	U302B, U315	U302, U315
4	Queued Serial Module (QSM) tests		
4.1	Loopback test the SCI.	U313	U313
4.2	Loopback test the QSPI.	U313	U313
4.3	Initialize SCI. Fails if transmitter does not become ready soon enough.	U313	U313
6	TPU tests		
6.1	Download/read/verify program TPU RAM.	U313	U313
6.3	Write/read/verify parameter RAM, leaving it cleared.	U313	U313
6.4	Load parameter RAM and load/read/verify control registers for all channels, starting programs.	U313	U313
6.5	Wait for channel programs to initialize. Sample switch Data Valid line goes true.	U313	U313

Table 11-7 Startup Digital tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
7	<i>Display tests</i>		
7.2	Loopback test the display QSPI.	U302A, U303A, U307C, U501-508, U510-511	U302, U303, U307, U501-508, U510-511
7.4	Light the Green test LED	U313, DS301	DS301
10	<i>Flash memory tests</i>		
10.2	Verify FLASH device ID code.	U311A, U318	U311, U318
10.3	Read / Verify bank 0 (ROM) stamp and checksums	U311A, U318	U311, U318
10.4	Read / Verify bank 1 (Flash 0) stamp and checksums	U311A, U318	U311, U318
10.5	Read / Verify bank 2(Flash 1) stamp and checksums	U311A, U318	U311, U318
11	<i>Real-time clock/calendar tests</i>		
11.2	Initialize and detect super cap discharge	U309, C301	U309, C301
11.3	Write/read/verify time clock registers.	U309	U309
11.4	If super cap, C301, wasn't discharged, compare CPU vs. RTC frequency ratio.	U309, Y301	U309, Y301
12	<i>DSP tests</i>		
12.2	Write/read/verify DM (data memory) data.	U306A, U308	U306, U308
12.3	Write/read/verify PM (program memory) data.	U306A, U308	U306, U308
12.4	Set up/clear down DM (data memory) addresses, leaving it clear.	U306A, U308	U306, U308
12.5	Set up/clear down PM (program memory) addresses, leaving it clear.	U306A, U308	U306, U308
12.6	Load program and go, see if DSP executes.	U306A, U308	U306, U308
12.7	Try signal line DSPOP from DSP (PF1) to TPU (6).	U306A, U308	U306, U308
12.8	Compare CPU vs. DSP frequency ratio.	U306A, U308, Y302	U306, U308, Y302
13	<i>Bridge tests</i>		
13.4	Wait for master CODEC to initialize.	U401	U401
13.5	Compare DSP vs. CODEC frequency ratio.	U401, Y401	U401, Y401
13.6	Write/read/verify all CODEC data.	U401, U406, U411, U416	U401, U406, U411, U416
13.7	Loopback test bridge QSPI (first try to contact MAIN and PREAMP boards).	U132, U135-139, U152-156, U307A,F, U306B, U302C,D, U303B, U601, U610	U132, U135-139, U152-156, U307, U306, U302, U303, U601, U610
14	<i>GPiB tests</i>		
14.2	Write/read/verify some registers.	U311B, U312	U311, U312
14.3	National Instruments official test.	U311B, U312	U311, U312

Table 11-7 Startup Digital tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
15	<i>EEPROM tests</i>		
15.3	Check block CRCs.	U322	U322
15.4	Check file system integrity.	U322	U322
15.5	Verify EEPROM read reliability by reading entire ROM contents 16 times.	U322	U322
16	<i>Calibration data tests</i>		
16.1	Load Factory Calibration data.	U322	U322
16.2	Load User Internal Calibration data.	U322	U322
16.3	Load User Capacitance Calibration data.	U322	U322
16.4	Load User Transformer Calibration data.	U322	U322

The prompt that is sent or displayed usually requires that just one action be performed before the **[STEP]** key is pressed to continue. In some cases, more than one action is required. In these cases, the prompt will indicate only the *last* action that is to be performed. It is up to the operator to be aware of tests that require more than one action. An example is the “DC Bias Resistor Tests” on page 11-28. Both of these tests require that an external shunt be connected, an external DC voltage be applied, and finally that a meter reading be taken. The prompt *READ VLT FOR R603* is asking only for the last action, but all three actions must be completed before the **[STEP]** key is pressed to continue the tests.

Making Measurements on a Specific Test State

When each test is finished executing, it leaves the bridge in the final configuration for that test. This is the configuration shown in the test result line. This allows meter or logic probe measurements to be made on the bridge as it was configured for the last test of a series.

Startup Tests

When the bridge is powered up, a series of tests are performed to determine that the bridge will function and there is nothing grossly defective with the hardware. These initial tests do not check the calibration, or measurement accuracy, but do check the digital circuits. They are called tests 1 through 16. They are listed in Table 11-7

In order to perform any tests, the microprocessor must be able to read instructions from the EPROM. This requires the 16 bit data and 19 bit address busses must work along with the EPROM, Flash and CPU. The CPU clock must be running and /reset line must be high.

Since the display may not be working before test 7.2, the earlier tests use the green LED DS301 on the processor board to display the test that failed. It does this by blinking the Test Group Number, pausing, then blinking out the sub test number that failed. The process waits about 30 seconds then tries again to restart and try once more. Once test 7.2 passes, the

test name and number is sent to the front panel display. If it fails, the word “Test” is replaced with “Error”. For example if test 12.3 failed the front panel would display *DSP ERROR.3*

Should a message appear before “Digital Test Passed” there is trouble. The message shown is near the initialization test that failed. If nothing is displayed, remove the top cover and check the green LED DS301 on the processor board near U309. If it is blinking, count the first group of flashes, and the second group of flashes to make *test group. test*. This is the test that failed before the display was determined to be operational. Check Table 11-7 on page 11-15

Display Test

The initial display test only verifies that the display board is present and data can be sent serially through it and returned to the processor. It does not verify that any of the LED’s light. To check the LEDs test 19 must be run and the results observed. The first 65 display tests determine if any of the multiplexed lines are crossed with other lines and the last test checks if any segments do not light. The first test lights only one segment at a time of the left four character positions of the Cap display. The tests proceed to successive groups of 4 characters until all are done. The sixthfifth test illuminates each status one at a time. The last test lights all LEDs to check that none are defective. The display should be watched carefully for cases where more than one LED becomes lit. If this occurs, some kind of short or addressing problem is to be suspected. If a single LED segment does not light when it should, the failure is in that segment or the connection to it. If groups of LED’s fail to light, then the failure is in the driver circuits.

Processor Tests

The processor tests are the most basic of all the tests because if these do not pass, it may not even be possible to run any other tests. It is this group of tests that is executed immediately after the AH2700A powers on. Test group 1 in Table 11-7 on page 11-15 describes these tests.

Table 11-8 Display Tests

19	Test Front Panel Display		
19.1	Test left 4 characters of Cap display one segment at a time		
19.2	Test right 4 characters of Cap display one segment at a time		
19.3	Test left 4 characters of Loss display one segment at a time		
19.4	Test right 4 characters of Loss display one segment at a time		
19.5	Test each digit of Frequency display one segment at a time		
19.6	Test each status LED one at a time		
19.7	All segments are illuminated for about 0.6 seconds		

If these tests are initiated by the TEST command the prompt *ARE YOU SURE* will appear on the front panel. You must press the **[YES]** key (**[1]**) if you want the tests to be executed. This question is asked because everything stored in RAM will be initialized when these tests are run. GPIB and RS-232 communications will also be initialized. Due to the special nature of these tests, they are only reported to the front panel and to the RS-232, but not the GPIB. The RS-232 is initialized to the default parameters in ROM. If the processor tests pass, the message *CPU TEST PASSED* appears on the front panel display when all the tests are finished. The display will be blank until then but the column of LED indicators to the right will be active. If any tests fail, the first test to fail will report an error message to the front panel. These messages and their meanings are all listed in Table 11-7 on page 11-15. The format of these error messages is totally different from all others generated by the TEST command.

Front Panel Tests

Test group 19 can be run if the front panel display appears to have a problem. This test will illuminate each LED in the column to the right of the numeric displays and also each segment of every LED digit. This test does not report any errors and therefore has no value unless its effects are carefully observed by watching the front panel.

The test tries to illuminate one and only one LED at a time. The display should be watched carefully for cases where more than one LED becomes lit. If this occurs, some kind of short or addressing problem is to be suspected. If a single LED segment does not light when it should, the failure is in that segment or the connection to it. If groups of LED's fail to light, then the failure is in the driver circuits.

A/D and D/A Conversion and MUX Tests

The tests listed in Table 11-9 on page 11-19 are the first analog tests performed on any of the measurement circuitry. The measurement circuitry is considered to consist of the MUX board (A401), the main board (A101), the preamp board (A601) and the capacitance standard assembly (C210). The QSPI serial data loop that runs through these boards was already tested by test number 13.7. Unless noted otherwise, results obtained with the A/D represent the average of 1000 A/D readings taken over a period of 50 mS.

First Attempts to Use A/D.

In test group 20, the A/D (U421) must be able to take some accurate readings. The MUX (U418) must also be able to select the correct voltages. The MUX's U109 and U110 and their power regulators U118 and U120 must not interfere with U418.

Complete DCG vs. A/D Tests

Test group 21 checks all of the DCG (DC Gain) settings using the A/D. The first and fourth tests measure the magnitude of the source voltages used by the remaining tests in this group. These source voltages come from the oven and CODEC temperature sensors respectively. A failure could be caused by the A/D, DCG or from an inaccurate source voltage. In particular, Test 21.1 tries to make an accurate measurement of the oven temperature. If an oven problem is suspected, the next section explains how to directly measure the value of the OVEN voltage.

NOTE

Tests 21.1, 21.2 and 21.3 can not be expected to pass until the oven has reached its normal operating temperature.

The second, third and fifth tests compare the ratios of adjacent DCG settings using the A/D to make the measurements. Each test requires that the A/D be working well enough to take two measurements whose ratio is 1/2. Because these are ratio measurements, the source voltages are not important but they must produce values within the A/D's range. Since these are effectively comparisons of the A/D against the DCG, a failure could be from either.

Manual Oven Circuit Tests

The OVEN voltage should be $-0.537V \pm 5\%$. This can be measured at U203 pin 6 on the main board as shown in Figure 11-4 at the end of this chapter. If this voltage is out of tolerance, either the oven assembly (C210) is bad or the related circuitry on A101 is defective. If the oven controller is functioning, the OVEN voltage will be identical (after warm-up) with the R201/R202 reference voltage on pin 6 of J114 shown in the same figure. If the oven controller is functioning, the voltage driving Q201 will be 2 to 7V more positive

than the -24V power supply (after oven warm-up). This can be measured on pin 3 of J114 shown in the figure. If the oven controller is suspected of having dynamic control problems, the signal to look at is pin 6 of U202 which is shown in the figure. If there are any signals here which are changing at a rate faster than 1Hz, then the controller has a problem.

Power Supply DC Level Tests

Test group 22 checks the DC voltage levels of the three main regulated DC power supplies. As usual, 1000 readings are taken over a period of 50 mS. The reported result is the average of these readings.

Power Supply Ripple Tests

Test group 23 checks the AC ripple on the three main regulated DC power supplies. The A/D takes 1000 readings over a period of 50 mS. The reported result is the highest one of these readings minus the lowest one.

Compare the Ambient Temperature Sensors

There are four ambient temperature sensors in the AH2700A. Test group 24 checks that these four sensors all read similarly. The temperature difference between three pairs of sensors is reported. Typically, the CODEC sensor, U410, is the

Table 11-9 First MUX and A/D tests (A401)

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
20	<i>First tests to see if A/D (U421) functions</i>		
20.1	Set U418 MUX input to ground	U421 reads 0.0V	U418-U424, U109, U110, U118, U120
20.2	Set U418 MUX to read 4.055V reference voltage	U421 reads 4.055V	U418-U424
20.3	Set U418 MUX to read +peak voltage from AC line	U421 sees the +peak	U418-U424
20.4	Set U418 MUX to read -peak voltage from AC line	U421 sees the -peak	U418-U424
20.5	Set U418 MUX to read max positive voltage from AC line	U421 reads max +volts	U418-U424
20.6	Set U418 MUX to read max negative voltage from AC line	U421 reads max -volts	U418-U424
21	<i>Test DCG settings and values of OVEN and CODEC temperature monitor lines</i>		
21.1	Select OVEN with U418 MUX, Set DCG=1	DCG=1, A/D value	U418-U424, OVEN
21.2	Select OVEN, compare DCG=1 against DCG=2	Relative DCG 1/2	U418-U424
21.3	Select OVEN, compare DCG=2 against DCG=4	Relative DCG 2/4	U418-U424
21.4	Select CODEC temp. with U418 MUX, Set DCG=8	DCG=8, A/D value	U418-U424, U410
21.5	Select CODEC temp., Compare DCG=4 against DCG=8	Relative DCG 4/8	U418-U424
22	<i>Test power supply DC voltage levels</i>		
22.1	Set U110 MUX to +5V/2 input, read average DCV in 50 mS	+5V P. S. DC level	A701, U703, U110
22.2	Set U110 MUX to +12V/4 input, read average DCV in 50 mS	+12V P. S. DC level	A701, U701, U110
22.3	Set U110 MUX to -12V/4 input, read average DCV in 50 mS	-12V P. S. DC level	A701, U702, U110
23	<i>Test power supply ripple</i>		
23.1	Set U110 MUX to +5V/2 input, read peak-to-peak ACV	+5V P. S. ripple	A701, U703, C711
23.2	Set U110 MUX to +12V/4 input, read peak-to-peak ACV	+12V P. S. ripple	A701, U701, C705
23.3	Set U110 MUX to -12V/4 input, read peak-to-peak in ACV	-12V P. S. ripple	A701, U702, C706
24	<i>Compare ambient temperature sensors</i>		
24.1	Measure difference between I/Q DAC buffer temperature sensor and CODEC temperature sensor.	CODEC and I/Q DAC temperatures agree	U109, U119, U410, U418
24.2	Measure difference between I/Q DAC buffer temperature sensor and DAC temperature sensor.	DAC and I/Q DAC temperatures agree	U109, U119, U150
24.3	Measure difference between I/Q DAC buffer temperature sensor and preamp temperature sensor.	Preamp and I/Q DAC temperatures agree	U109, U119, U607
25	<i>Test the power line frequency detector</i>		
25.1	Measure the frequency of the power line	Power frequency OK	U313, U320

warmest followed by the I/Q DAC buffer sensor, U119, the DAC sensor, U150, and the preamp sensor, U607. The relative temperatures seen by these sensors will be affected by the orientation of the chassis and possibly by other heat sources outside the AH2700A.

Test the Power Line Frequency Detector

Test 25.1 checks that the power line frequency detector sees a power line frequency that is within the allowed range of operation for the AH2700A (48 to 440 Hz). This detector uses a TPU line on the CPU. This detector is also used to synchronize measurements with the power line to reduce noise interference.

I-Phase Generation and Drive Tests

These are part of test group 30 and are all non-interventional tests except for test 33.2. These tests are listed in Table 11-10 on page 11-21.

Test I-Drive Generation and Main Ratio-Transformer Driver

Tests 30.1 and 30.2 measure a 1 kHz signal that drives the main-ratio transformer. These are the first tests that signals are delivered from the CODEC's on the MUX board. If the I-drive signals are missing from their sources at CODEC U401 pins 28 and 30, the lines from the DSP to all four CODEC's should be checked for pulses. The IDRIVE+ signal should be precisely 180° out of phase with IDRIVE-. The AC RMS voltage at U101 pin 6 is about 1.8V. U405 pin 1 and pin 7 should be 0.5V. If 30.1 is toward the high edge of the range, 30.2 should be at the low edge of its range. This will occur if the I Drive calibration has not been set during a Cal 1 operation.

Test 30.3 checks that the average of the I-drive signal is about 0.0 volts. If there is DC bias at this point, there is a mismatch between the L and R CODEC outputs or one of the Chebyshev filters U404 or U405 has a problem.

Tests 30.4 and 30.5 check that the main ratio-transformer drivers produces adequate signal levels for both polarities. The voltage at U103 pin 6 and U104 pin 6 should be 5.0Vrms giving 10.0Vrms across the primary of the main ratio-transformer.

Test 30.6 checks to see that the main ratio-transformer is being driven by a sine wave. It does this by measuring both the rectified average and the peak-to-peak voltages. The ratio of these should be 3.14 (π).

Check the I-phase Precision Rectifier

Test group 31 checks the behavior of the circuit that generates the RECTMAIN signal.

Test 31.1 checks that RECTMAIN produces nearly zero volts output for nearly 1/256 of normal input voltage.

Test 31.2 checks that RECTMAIN produces the expected signal level when fed with the full I-drive signal.

Test 31.3 checks that the RECTMAIN circuit is linear by checking the ratio of the output voltages obtained for half and full I-drive signals.

Test the I-drive Filters

Test group 32 checks the behavior of the CODEC filter comprised of U101 and U102. This group also tests the I-drive filters on the MUX board comprised of U404 and U405.

Test 32.1 checks that inserting the CODEC filter reduces the signal level by the expected amount. The signal at U101 pin 6 should be about 1.15 Vrms at 3200 Hz.

Test 32.2 checks that the Chebyshev filters are essentially flat between 1kHz and 10 kHz. The signals at U405 pins 1 and 7 should both be about 0.26 Vrms and U101 pin 6 should be about 0.9 Vrms at 10 kHz.

Test 32.3 checks that the Chebyshev filters roll off by about 0.97 from 10 kHz to 20 kHz. To locate trouble, compare the + and - drive channels which should be symmetrical.

Main Transformer Overload Detector Tests

Test group 33 checks the ability to detect when excess current is required to drive the main ratio transformer. The circuit using U105 accomplishes this by creating the I_OVRD signal which is read by the A/D via the MUX.

Test 33.1 checks that the I_OVRD signal is low when the main ratio transformer is not overloaded. If this test fails when no overload is expected to be present, either the I_OVRD detector is generating a false signal or the transformer current really is excessive. Excess current can be caused by a short of some kind in the main ratio transformer or by this transformer being overdriven, but it is most commonly caused by a relay that is stuck closed in the RD's or ATN circuits. Stuck relays in these circuits are specifically dealt with by test groups 60, 70 and 72.

Test 33.2 is used to verify that an overload can be created and detected. This test requires that an external load with a sufficiently low resistance be placed between the HIGH terminal and ground. An ordinary 50Ω BNC terminator plugged into the HIGH terminal is all that is needed. The following procedure is used:

1. Wait for the prompt `CONN TER TO HIGH` to appear.
2. Plug a 50-500Ω BNC terminator into the HIGH terminal.
3. Press the **[STEP]** key to cause the test routine to complete the test by checking the I_OVRD signal.
4. When the `DISCONN SETUP` prompt appears, unplug the 50Ω terminator from the HIGH terminal.
5. Press the **[STEP]** key to report the test result or to continue execution of tests.

Table 11-10 Main ratio transformer generator and driver tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
30	<i>Test generation of I-drive signal and test main ratio-transformer driver circuit</i>		
30.1	Select I_IN_LPF; find positive peak voltage in 1000 readings	I-drive positive voltage drive level is OK	U101, U102, U110, U401, U404, U405
30.2	Select I_IN_LPF; find negative peak voltage in 1000 readings	I-drive negative voltage drive level is OK	U101, U102, U110, U401, U404, U405
30.3	Select I_IN_LPF; check that average voltage is zero	I-drive signal is symmetrical	U101, U102, U110, U401, U404, U405
30.4	Select MAIN_LOPASS; find positive peak voltage in 1000 readings	Main transformer positive drive level is OK	U103, U104
30.5	Select MAIN_LOPASS; find negative peak voltage in 1000 readings	Main transformer negative drive level is OK	U103, U104
30.6	Select MAIN_LOPASS; find rectified average and peak-to-peak voltages; ratio should be 3.14 (π)	Main transformer drive signal is sinusoidal	U101-U104, U401, U404, U405
31	<i>Check the I-phase precision rectifier</i>		
31.1	Select RECTMAIN, drive rectifier at 1/256 of normal drive level, measure average DC level	RECTMAIN has no DC offset	U106-U108
31.2	Select RECTMAIN, drive rectifier at normal drive level, measure average DC level	RECTMAIN sees expected signal level	U106-U108
31.3	Select RECTMAIN, drive rectifier at normal drive level then at half of normal, measure ratio of average DC levels	RECTMAIN is linearly related to its input signal	U106-U108
32	<i>Test I-drive filters</i>		
32.1	Select RECTMAIN and set $f=3200\text{Hz}$, measure ratio of average DC levels with CODEC filter disabled then enabled	CODEC filter lowers signal by expected amount	U101, U102 U106-U108
32.2	Select RECTMAIN, set $f=1\text{kHz}$ then to 10kHz, measure ratio of average DC levels	Chebyshev MUX board I-drive filters are flat	U404, U405 U106-U108
32.3	Select RECTMAIN, set $f=10\text{kHz}$ then to 20kHz, measure ratio of average DC levels	Chebyshev I-drive filters rolloff by correct amount	U404, U405 U106-U108
33	<i>Test main ratio transformer overload (OVRD) detector</i>		
33.1	Select I_OVRD, set all ATN and RD relays to open, measure average DC level	I_OVRD signal is not generated on no overload	U101-U105, U152-U156, K101-136

Table 11-10 Main ratio transformer generator and driver tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
33.2	Select I_OVRLD; close ATN relay K113; prompt to load HIGH to ground with a terminator using the message: <code>CONFIRM TO HIGH</code> . Measure I_OVRLD after operator presses <code>[STEP]</code> key. Prompt for disconnection of setup with <code>DISCONFIRM SETUP</code> .	I_OVRLD signal is generated on overload	U101, U105, U155, K113
33.3	Select RECTMAIN, adjust I-drive magnitude so that M-1.0 delivers 15.75 Vrms	Main ratio transformer can be driven at 15.75V	U101-U105, U152-U156, K101-136
33.4	Perform test 33.3 to again set transformer drive level for 15.75 v; select I_OVRLD, measure average DC level	Main ratio transformer can be driven at 15.75V without causing OVRLD	U101-U105, U152-U156, K101-136
33.5	Select RECTMAIN; set $f=120\text{Hz}$; measure average DC level	Main transformer can be driven to expected level	U101-U105, C101, C102, K101-136
33.6	Select RECTMAIN, set $f=120\text{Hz}$; measure ratio of peak-to-peak to rectified average voltage	Main transformer signal is sinusoidal at 120 Hz	U101-U105, U152-U156, K101-136
33.7	Select I_OVRLD, set $f=120\text{Hz}$; select I_OVRLD, measure average DC level	Main ratio transformer can be driven at 120 Hz without causing OVRLD	U101-U105, U152-U156, K101-136

A failure of this test is probably in the U105 overload detection circuit. However, since no ATN tests have been previously performed, a failure could also result from no overload being generated if K113 does not close.

Test 33.3 checks that the main ratio transformer can deliver 15.75 volts. This is done by measuring the precision rectifier output to get the I-drive magnitude. The result can then be used to calculate the value needed to adjust I-drive to get 15.75 volts at M-1.0 of the main transformer. The precision rectifier output is measured again to check that it reached the calculated value. The rectifier measures the average at the IP 1.0 tap which is 1/6 of full output. The average voltage should be 2.36v dc when 15.75 v RMS is delivered to High terminal.

Test 33.4 repeats the setup of test 33.3 to cause the main ratio transformer to again deliver 15.75 volts at K113 contact. This time the I_OVRLD signal is checked to verify that no overload has occurred. If this test fails but no earlier ones do, then the main ratio transformer is probably saturating. If saturation is suspected, check that the driving voltage between U103 pin 6 and U104 pin 6 is really no more than 10.5 Vrms while this test is running. Also check that no dc current is passing through the main transformer.

Test 33.5 checks that the main ratio transformer can be driven to the expected voltage level at 120 Hz. It is driven at 120/1000 of its normal level.

Test 33.6 checks that the main ratio transformer is sinusoidal at 120 Hz. The ratio of the peak-to-peak versus the rectified average voltage should be 3.14 (π).

Test 33.7 checks that the I_OVRLD detector is not activated when the main ratio transformer is driven at 120 Hz.

Q-Phase Generation and Drive Tests

These tests are listed in Table 11-11 on page 11-23. These are all non-interventional tests. Most of these tests are special because most have the Q-adjust feature disabled. This makes it easy to follow the signal flow with an oscilloscope while the tests are running.

Quadrature Transformer Drive Tests

Test group 34 checks the ability of the quadrature drive circuitry to generate acceptable peak voltages with an acceptable offset voltage. These tests check that the signal was getting from the CODEC U406 through the Chebyshev filters U408 and U409 to U117 on the main board. The signals at U409 pins 1 and 7 should both be 2.0Vrms and U117 pin 6 should be 5.0Vrms.

I/Q and Q/I Sense Lines Tests

Test group 35 checks that the I/Q and Q/I sense lines for the Q-phase adjuster have signals with minimal noise, that they are of the proper magnitude, that they are symmetrical, that normal and inverted differential signals are of similar voltage, and finally with the phase adjuster enabled, the total I signal sensed equals the total Q signal sensed.

Most of the tests are run twice; once with the I/Q flip-switch set to zero (tests 35.11-35.32 with /FL0 = true and /FL2 = false) and once with it set to one (35.41-35.62 with /FL0 = false and /FL2 = true).

Tests 35.1-35.4 check that the I/Q and Q/I sense lines are not noisy. If any of these tests fail, check U112 and U113 pins 1 and 7. These pins should have less than 200mV p-p with no DC offset.

Table 11-11 Quadrature transformer generator and driver tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
34	<i>Test that quadrature transformer drive gives expected levels</i>		
34.1	Select Q_IN_LPF, disable Q-adjust, measure max voltage	Q-drive gives expected positive peak voltage	U406, U408, U409, U110, U116, U117
34.2	Select Q_IN_LPF, disable Q-adjust, measure min voltage	Q-drive gives expected negative peak voltage	U406, U408, U409, U110, U116, U117
34.3	Select Q_IN_LPF, disable Q-adjust, measure average voltage	Q-drive has acceptable DC offset voltage	U406, U408, U409, U110, U116, U117
35	<i>Test I/Q and Q/I sense lines with Q-Adjust Disabled</i>		
35.1	Select U401 left CODEC input, disable Q-adjust, set flip-switch open, measure peak-to-peak signal	I/Q_SW+ gives expected null signal level	U401-U403, U111, U113
35.2	Select U401 right CODEC input, disable Q-adjust, set flip-switch open, measure peak-to-peak signal	I/Q_SW- gives expected null signal level	U401-U403, U111, U113
35.3	Select U406 left CODEC input, disable Q-adjust, set flip-switch open, measure peak-to-peak signal	Q/I_SW+ gives expected null signal level	U402, U406, U407, U111, U112
35.4	Select U406 right CODEC input, disable Q-adjust, set flip-switch open, measure peak-to-peak signal	Q/I_SW- gives expected null signal level	U402, U406, U407, U111, U112
35.11	Select U401 left CODEC input, disable Q-adjust, set flip-switch to zero, measure peak-to-peak signal	I/Q_SW+ gives expected signal level	U401-U403, U111, U113, IP10
35.12	Select U401 right CODEC input, disable Q-adjust, set flip-switch to zero, measure peak-to-peak signal	I/Q_SW- gives expected signal level	U401-U403, U111, U113, IP10
35.13	Select U406 left CODEC input, disable Q-adjust, set flip-switch to zero, measure peak-to-peak signal	Q/I_SW+ gives expected signal level	U402, U406, U407, U111, U112, QP10
35.14	Select U406 right CODEC input, disable Q-adjust, set flip-switch to zero, measure peak-to-peak signal	Q/I_SW- gives expected signal level	U402, U406, U407, U111, U112, QP10
35.21	Select U401 left CODEC input, disable Q-adjust, set flip-switch to zero, measure ratio of +peak to -peak of signal	I/Q_SW+ signal is symmetrical	U401-U403, U111, U113, IP10
35.22	Select U401 right CODEC input, disable Q-adjust, set flip-switch to zero, measure ratio of +peak to -peak of signal	I/Q_SW- signal is symmetrical	U401-U403, U111, U113, IP10
35.23	Select U406 left CODEC input, disable Q-adjust, set flip-switch to zero, measure ratio of +peak to -peak of signal	Q/I_SW+ signal is symmetrical	U402, U406, U407, U111, U112, QP10
35.24	Select U406 right CODEC input, disable Q-adjust, set flip-switch to zero, measure ratio of +peak to -peak of signal	Q/I_SW- signal is symmetrical	U402, U406, U407, U111, U112, QP10
35.31	Select U401 CODEC inputs, disable Q-adjust, set flip-switch to zero, measure ratio of peak-to-peak signal from left input versus right input	I/Q_SW+ and I/Q_SW- make equal signal levels	U401-U403, U111, U113, IP10
35.32	Select U406 CODEC inputs, disable Q-adjust, set flip-switch to zero, measure ratio of peak-to-peak signal from left input versus right input	Q/I_SW+ and Q/I_SW- make equal signal levels	U402, U406, U407, U111, U112, QP10
35.41	Select U401 left CODEC input, disable Q-adjust, set flip-switch to one, measure peak-to-peak signal	I/Q_SW+ gives expected signal level	U401-U403, U111, U113, QP10
35.42	Select U401 right CODEC input, disable Q-adjust, set flip-switch to one, measure peak-to-peak signal	I/Q_SW- gives expected signal level	U401-U403, U111, U113, QP10
35.43	Select U406 left CODEC input, disable Q-adjust, set flip-switch to one, measure peak-to-peak signal	Q/I_SW+ gives expected signal level	U402, U406, U407, U111, U112, IP10

Table 11-11 Quadrature transformer generator and driver tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
35.44	Select U406 right CODEC input, disable Q-adjust, set flip-switch to one, measure peak-to-peak signal	Q/I_SW- gives expected signal level	U402, U406, U407, U111, U112, IP10
35.51	Select U401 left CODEC input, disable Q-adjust, set flip-switch to one, measure ratio of +peak to -peak of signal	I/Q_SW+ signal is symmetrical	U401-U403, U111, U113, QP10
35.52	Select U401 right CODEC input, disable Q-adjust, set flip-switch to one, measure ratio of +peak to -peak of signal	I/Q_SW- signal is symmetrical	U401-U403, U111, U113, QP10
35.53	Select U406 left CODEC input, disable Q-adjust, set flip-switch to one, measure ratio of +peak to -peak of signal	Q/I_SW+ signal is symmetrical	U402, U406, U407, U111, U112, IP10
35.54	Select U406 right CODEC input, disable Q-adjust, set flip-switch to one, measure ratio of +peak to -peak of signal	Q/I_SW- signal is symmetrical	U402, U406, U407, U111, U112, IP10
35.61	Select U401 CODEC inputs, disable Q-adjust, set flip-switch to one, measure ratio of peak-to-peak signal from left input versus right input	I/Q_SW+ and I/Q_SW- make equal signal levels	U401-U403, U111, U113, QP10
35.62	Select U406 CODEC inputs, disable Q-adjust, set flip-switch to one, measure ratio of peak-to-peak signal from left input versus right input	Q/I_SW+ and Q/I_SW- make equal signal levels	U402, U406, U407, U111, U112, IP10
35.71	Enable Q-adjust, from U401 CODEC inputs, measure sum of the peak-to-peak signals from left & right inputs; from U406 CODEC inputs, again measure the sum of the peak-to-peak signals from left & right inputs; find the ratio of these sums.	Combined I/Q_SW+ and I/Q_SW- and combined Q/I_SW+ and Q/I_SW- signals have equal levels	U401-U409, U111-U113, IP10, QP10

Tests 35.11-35.14 check that the I/Q and Q/I sense lines have the correct signal magnitude. This is the first test of the quadrature transformer output QP10, so its driver could have a problem if 35.13 and 35.14 fail but 35.11 and 35.12 pass. The voltages of QP10 and IP10 should both be 2.5Vrms. The signal at U112 and U113 pins 1 and 7 should be 2.5Vrms. The signals on pins 1 and 7 of U403 and U407 all should be 0.75Vrms with a DC offset of 2.0 to 2.5V. This is also the first test of the CODEC A/D conversion process.

Tests 35.21-35.24 check that the I/Q and Q/I sense lines are not badly distorted and that the positive peak is about equal to the negative peak.

Tests 35.31-35.32 check the ratios of the peak-to-peak signal levels of the positive (left) and negative (right) channels for each of the I/Q and Q/I sense lines. These ratios should be close to one. If there is a problem, compare the positive and corresponding negative signals.

Tests 35.41-35.62 are exact replicas of tests 35.11-35.32 except that the flip-switch, U111, is changed from zero to one. A failure in one of these sets should be matched by a failure in the other set unless U111 is bad or the problem is intermittent.

Test 35.71 is the first test that has the DSP perform the Q-adjust procedure which is the normal operating mode for the bridge. The Q-adjust procedure causes IP10 and QP10 to be precisely equal in magnitude and shifted in phase by 90° from each other. If all previous tests pass but this one fails,

examine the sense lines carefully to ensure that all signals are equal in magnitude and have little noise.

Quadrature Transformer Filter, Overload and Quad-Shift Tests

Test groups 36-38 check auxiliary circuitry that supports the quadrature driver circuits. These tests are listed in Table 11-12 on page 11-25.

Quadrature Transformer Filter Tests

Test 36.1 checks that QP10 from the quadrature transformer produces a sinusoidal signal. This is done with the Q-phase-adjuster operating.

Test 36.2 checks that the low-pass CODEC filter for the quadrature channel reduces the signal level by 60% at 3200 Hz.

Test 36.3 checks that the Chebyshev filters, U408 and U409, on A401 are flat from 1 kHz to 10 kHz.

Test 36.4 checks that the Chebyshev filters roll off by about 0.97 from 10 kHz to 20 kHz. To locate trouble, compare the + and - drive channels which should be symmetrical.

Test 36.5 Sets I drive to make 15.75 volts at M-1.0. Then check that the adjusted Q waveform peak to average ratio is good. The peak to avg. is done inside the dsp by monitoring the Q/I sample select port. If the waveform is poor, check the output of U115 for overload.

Table 11-12 Quadrature ratio transformer filter, overload, and quad-shift tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
36	<i>Test Q-drive waveform and filters</i>		
36.1	Select U406 left CODEC input; find rectified average and peak-to-peak voltages; ratio should be 3.14 (π)	Quadrature transformer signal is sinusoidal	U115, U117
36.2	Select U406 left CODEC input; disable Q-adjust; set $f=3200\text{Hz}$, measure ratio of peak-to-peak signal levels with CODEC filter disabled then enabled	CODEC filter lowers signal by expected amount	U116, U117
36.3	Select U406 left CODEC input; disable Q-adjust; set $f=1\text{kHz}$ then to 10kHz , measure ratio of peak-to-peak signal levels	Chebyshev MUX board Q-drive filters are flat	U408, U409
36.4	Select U406 left CODEC input; disable Q-adjust; set $f=10\text{kHz}$ then to 20kHz , measure ratio of peak-to-peak signal levels	Chebyshev Q-drive filters rolloff by correct amount	U408, U409
36.5	Set I drive so main transformer delivers 15.75 volts, Check if Q adjusted to high voltage has good waveform.	Q driver can deliver sufficient output.	U114, U115
36.6	Set I drive so main transformer delivers 15.75 volts, Check if Q samples match I samples at high voltage.	Sample switch U111-U113 work at full voltage	U111 - U113
37	<i>Test quadrature ratio transformer overload (OVRD) detector</i>		
37.1	Wait 5 sec. for OVRD detector to settle; select Q_OVRD, disable Q-adjust; set $f=50\text{ Hz}$; measure average DC level	Q_OVRD signal is not generated on no overload	U114, U115
37.2	Select Q_OVRD; disable Q-adjust; set $f=50\text{ Hz}$; drive quadrature transformer very hard, measure average DC level	Q_OVRD signal is generated on overload	U114, U115, U117
38	<i>Test quad-shift</i>		
38.1	Wait 6 sec. for OVRD detector to settle; enable quad-shift; select Q_OVRD; set $f=120\text{ Hz}$; measure average DC level	Q_OVRD signal is not generated on no overload	U114, U115
38.2	Enable quad-shift; set $f=120\text{ Hz}$; measure ratio of peak-to-peak signals with U401 CODEC input selected then with U406 input selected	Quad-shift increases Q-drive level over I-drive level by expected ratio	U401-U409, U111-U113, IP10, QP10
38.3	Select U411 CODEC left and right inputs; enable quad-shift; set $f=120\text{ Hz}$; measure ratio of magnitudes with IDAC 4th MSD set to IP 0.8 using U128, then with QDAC 4th MSD set to QP0.1 using U146	Quad-shift magnitudes are equal after compensation by DAC's	U401-U409, U111-U113, IP10, QP10, DAC circuitry

Test 36.6 again sets I drive to make 15.75 volts at M-1.0. Then check that the I and Q samples match with the Q adjust in operation. If this fails, possibly the sample select followers U112 and U113 are not delivering full voltage without distortion.

Quadrature Transformer Overload Tests

Test group 37 checks the quadrature transformer overload detector at low frequency.

Test 37.1 checks that no overload signal is generated. If this fails, look for obvious distortion in the signals associated with the quadrature transformer. This test and test 38.1 have a five second delay at their start to ensure that the overload circuit has settled. This is needed due to the long settling time of U114B.

Test 37.2 drives the quadrature ratio transformer very hard causing the core to go into saturation. It is only possible to

saturate the Q transformer at low frequencies. This should cause an overload indication. A failure of this test could be a failure of the overload detector circuit or it could mean that the quadrature transformer driver isn't able to drive the transformer hard enough.

Quadrature Transformer Quad-Shift Tests

Test group 38 checks the quad-shift feature. In these tests, the quadrature transformer is driven to produce eight times more voltage than the main ratio transformer at 120 Hz.

Test 38.1 checks that no overload signal is generated. If this fails, look for obvious distortion in the signals associated with the quadrature transformer.

Test 38.2 checks that the signal level on QP10 is eight times larger than that on IP10. CODECs U401 and U406 are used to directly measure these two signals.

Test 38.3 performs the same kind of test as the previous one but using very different circuitry. In this test, the IDAC and QDAC are used to adjust the voltages levels from IP10 and QP10 respectively so that they are the same level. These adjusted voltages are fed to CODEC U411 via the preamp circuit. This CODEC need only verify that the magnitudes of the two signals are equal. If this is the first test to fail, the problem is likely to be in the preamp or the DAC circuits since these have not yet been tested.

First Tests of Upper Half of Bridge

At this point, as many tests of relatively simple circuits have been done as possible and it is time to make the first test of the bridge as a whole, minus the attenuator (ATN) circuits. The upper half of the bridge is shown as legs one and three in Figure 4-1 on page 4-1. Note that test group 40 requires that nothing be connected to the LOW input terminal and that these two tests will not be executed by the TEST command if it is run with no parameters.

Zero Tests

Test groups 40 and 41 appear to be simple because they merely require a roughly zero result for each test. Test group 40 uses the preamp for the first time and except for a small number of failure possibilities, should not depend on the performance of the main board, A101. However, test group 41 has the first tests to use the RD's and DAC to drive a null signal through the capacitance standard, C210, into the preamp and through the preamp CODEC, U411, to the DSP. Even though the driving signal is intended to be zero, any failure of one of the large number of components in the RD's and DAC could cause this assumption to be false. The preamp must also be sufficiently quiet (low noise) for the tests to pass. Since so many parts are involved for the first time in test groups 40 and 41, it is impractical to suggest where to look for the cause of a failure without carefully studying which tests failed. More information may also be needed from later tests.

Test group 40 is intended to test that the preamp alone does not generate excessive noise. The two tests in this group not only set the IDAC, QDAC and relay decades to zero, they also use K604 to shunt the input with 100 Ω to ground. If either of these tests fail, it may still be that the preamp input sees an extraneous signal. In this case, a very useful manual test that can be performed, is to run both tests with the LOW terminal input shorted to ground. The resistance of this short is not critical, but must not contain loops that might pick up noise. A BNC zero-ohm terminator is perfect for the job.

TEST REPEAT should be run with this short in place. If either test continues to fail, the preamp is too noisy or is picking up a stray signal or in the case of test 40.2, the CODEC U411 is finding a signal that isn't supposed to be there. At this point, an oscilloscope might be helpful for tracing the source of the extraneous signal. Note that the preamp cover

plate must be in place to provide adequate shielding whenever the U411 CODEC is making measurements.

If either test passes with the short in place, the DAC or RD's may not be able to set up a zero value and/or K604 may not be shunting R609 to ground. A failure of the DAC or RD's will probably be narrowly isolated by later DAC or RD self-tests.

Test group 41 checks for zero signal level at the input of the preamp in four different ways. The first three tests use the DCONL, CLAMPV and CODEC signals respectively to see if a zero is detected. If all three of these tests fail, then it may be that A101 is unable to produce a zero signal. If only one of these tests that fails, it is likely that the circuitry that generates the detection signal is at fault.

Test 41.4 sets the AC gain to its maximum to take a closer look at the zero signal level at the preamp input. This test is the first to shunt the AtnTst 10nF capacitor C603 across the input. This capacitor should further reduce the noise at the input.

Non-zero Tests

Test group 42 contains the first tests to use the RD's and DAC to select a non-zero signal from the main ratio transformer and to detect this signal with the A/D, U421, or to send it through the capacitance standard (C210), into the preamp and through the U411 CODEC to the DSP. The number of components that could cause this test to fail is even larger than in the previous test group. Now the main ratio transformer must be energized with a sinewave signal and all the circuitry of the previous test group must be able to pass a signal. (The previous two test groups may pass even if some circuits are dead since those tests are only looking for a signal level of zero.)

If this test group fails, most subsequent tests will fail also, but the generator tests of test group 30 will be meaningful. They will demonstrate whether the main ratio transformer is energized or not.

If the main ratio transformer is energized, it is unlikely that the signal is not reaching the preamp. The reason is that both the DAC and RD's are selecting signals from the main ratio transformer. This provides three independent paths to the preamp. Thus, if the transformer is energized and the test is failing, the problem is likely to be in the preamp. An oscilloscope should be useful to trace the problem. The signal levels fed to the preamp for test group 42 are large enough to be visible on a scope throughout the entire signal path.

Test 42.1 checks that signal is present after U602 and U603. After this test finishes, a distorted waveform of about $\pm 3V$ peak should be observable at U602 pin 6. A waveform of about $\pm 4V$ peak should be observable at U603 pin 1 and one of about $\pm 0.5V$ peak at U603 pin 7.

Test 42.2 checks that signal is present after U605, U608 and U609. After this test finishes, a distorted waveform of about ± 4 to $\pm 5V$ peak should be observable at U609 pin 6.

Table 11-13 First system tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
40	<i>Test ability of preamp to make and read null signals</i>		
40.1	With R609 shunting input, select DCONL, read average of absolute value of all samples, should get zero. Operator ensures that nothing is connected to the LOW terminal.	Cal/Disch shunt & preamp input can produce zero	K601-604, U601-U603, U611, R609
40.2	With R609 shunting input, ACG=0, select CODEC U411, read preamp signal magnitude, should get zero. Operator ensures that nothing is connected to the LOW terminal.	Cal/Disch shunt & preamp can produce zero	K601-604, U602-U612, U411-U413
41	<i>Test ability of upper half of bridge to make and read null signals</i>		
41.1	With DAC and RD's set to zero, select DCONL, read average of absolute value of all samples, should get zero	DAC and RD's can produce zero	A101, A601
41.2	With DAC and RD's set to zero, select CLAMPV, read average of absolute value of all samples, should get zero	DAC and RD's can produce zero	A101, A601
41.3	With DAC and RD's set to zero, ACG=0, select CODEC U411, read preamp signal magnitude, should get zero	DAC and RD's can produce zero	A101, A601
41.4	With DAC and RD's set to zero, set AtnTst so C603 shunts input, ACG=6, select CODEC U411, read preamp signal magnitude, should get zero	DAC and RD's can produce a good zero	A601
42	<i>Test ability of upper half of bridge to make and read non-zero signals</i>		
42.1	Set 2nd MSRD to 0.1, MSD of IDAC and QDAC to 1.0, select DCONL, measure peak-to-peak signal level	A101 can make signal and DCONL can detect it	A101, U601-U603, U611
42.2	Set 2nd MSRD to 0.1, MSD of IDAC and QDAC to 1.0, select CLAMPV, measure peak-to-peak signal level	A101 can make signal & CLAMPV can detect it	A101, U601-U606, U608-U611
42.3	Set 2nd MSRD to 0.1, MSD of IDAC and QDAC to 1.0, select CODEC U411, read preamp signal magnitude	A101 can make signal and preamp can detect it	A101, U601-U606, U608-612, U411-413

Test 42.3 checks that signal gets through the preamp and is measured by the CODEC, U411. The output signals from the preamp, PAMPOUT+ and PAMPOUT-, are measurable on the MUX board at R449 and R448 respectively. These signals should be clipped waveforms of about $\pm 3V$ peak. If either of these signals is non-existent, then the problem must be in the preamp. Otherwise, the problem is on the MUX board. At U413 pins 1 and 7, these signals should be about $\pm 1.2V$ peak with a 2.0 to 2.5 volt DC offset.

Preamp Tests

The first testing of the preamp was done previously in test groups 40 to 42. However, failures of those tests may have been caused by a problem on the main board or the MUX board rather than solely by a problem on the preamp. The tests in this section assume that the tests in test groups 40 to 42 all passed so that any failures seen in this section may be attributed to the preamp alone.

The first group of preamp tests, 43, differ from the tests in other test sections because six of these tests require the external connection of a voltmeter and a DC power supply. These are therefore interventional tests and will not be executed when the TEST command is issued with no parameters.



WARNING !

The voltages used in these tests present a shock hazard. The voltage to which you set your DC power supply will also be present at several points inside the bridge as shown in Figure 11-4 at the end of this chapter.



CAUTION

The voltages used in this test can cause serious damage to your bridge if improperly applied. Make sure that these voltages are only applied to the DC BIAS input connector. As an added precaution, you can set the current-limit on the power supply as low as possible while still maintaining the required test voltage.

NOTE

Removal and replacement of the preamp cover and disassembly and reassembly of the preamp must be done according to the procedures in Chapter 12, “Disassembly/Reassembly” with special attention to “HIGH and LOW Cable (W902 and W901) Removal and Installation” on page 12-11. Subtle performance degradation may occur otherwise.

DC Bias Resistor Tests

The value of the series bias resistors (R603 and R604) can be directly measured externally with an ohmmeter. The value of these resistors is 100 and 1 megohms, respectively. The ohmmeter used must be able to measure resistance at least as high as the higher value expected to be found. However, ohmmeters that can read this high are not found in many labs, so a different way of measuring the resistors will be described here.

The following measurement procedure is required when the AH2700A displays each prompt that results from running tests 43.1 and 43.2:

1. Wait for the prompt for the test to appear (READ ULT FOR R603 or R604).
2. Shunt the LOW terminal to ground using a BNC to banana-jack adapter with a 100 k Ω resistor between the posts. **WARNING!** If the resistor fails to make connection, one banana post will have the full voltage that is applied to the DC BIAS input.
3. Use a DC power supply to connect a 100V level between the DC BIAS input and ground.
4. Read the voltage across the 100 k Ω resistor.
5. Remove the DC bias and the 100 k Ω shunt.
6. Press the **[STEP]** key to continue execution of the tests.

The 100 k Ω resistor and R603 or R604 form a voltage divider which divides the applied 100 volts to the level read by the meter. Test 43.1 selects R603. If R603 is 100 megohm, the voltage will be divided by 1000 and test 43.1 passes if the meter reads between about 0.08 and 0.12 volts. Test 43.2 selects R604 in parallel with R603. If R604 is 1 megohm, the voltage will be divided by about 11 and test 43.2 passes if the meter reads between about 7.6 and 10.2 volts. The bridge always reports a PASS for these tests since it makes no measurements.

Measuring these resistors can be useful not only for checking the proper functioning of the preamp circuitry, but also to see if either series resistor has been changed by someone and if so, to what value. See “Optimizing the Series Resistance” on page 4-14 for more information.

If the value of R603 or R604 is not correct or not what is desired, the original resistors may be shunted or replaced

with other values. These resistors may be located by reference to the preamp assembly drawing in Figure F-30 on page F-84. Next to each resistor is a pair of forked solder terminals. Any resistor soldered to these terminal pairs will parallel the corresponding original resistor. You may add or replace these resistors with any value of your choice providing that it is not less than 10k Ω . An original resistor can be replaced by clipping its leads to remove it. Its replacement would then be soldered into the adjacent forked terminals.

Calibration and Discharge Relay

When closed, the calibration and discharge relay, K604, connects a 100 Ω shunt, R609, across the preamp input. When this relay closes, any charge that exists on an externally connected capacitor is discharged into R609.

The following procedure is used to run test 43.3:

1. Wait for the prompt `READ LO 0.02V` to appear.
2. Connect a voltmeter between the LOW input terminal and ground. A BNC to banana-jack adapter might be helpful here.
3. Use a power supply to connect a 100V level between the DC BIAS input and ground.
4. Verify that the meter reads less than 0.02 volts.
5. Disconnect the meter and power supply from the bridge.
6. Press the **[STEP]** key to continue execution of tests.

If the voltage in step four was correct, R609 is present and K604 closed. The bridge always reports a PASS for this test since it makes no measurements.

High Voltage Protection Test

This test checks that it is possible to exceed the upper limit on the DC bias voltage specification without causing damage to the bridge.



WARNING !

The voltages used in these tests present a shock hazard. The voltage to which you set your DC power supply will also be present at several points inside the bridge as shown in Figure 11-4 at the end of this chapter.

The following procedure is used to run test 43.4:

1. Wait for the prompt `CONNECT DC TO BIAS` to appear.
2. Connect a voltmeter between the LOW input terminal and ground. A BNC to banana jack adapter might be helpful here. The input impedance of the meter must be known and must be at least 10 megohms.

Table 11-14 Preamp DC bias tests (A601)

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
43	<i>Test DC BIAS circuits</i>		
43.1	Select high impedance bias with K606 closed, K607-K609 open, prompt with message: <i>READ VLT FOR R603</i> . Operator applies 100V to DC BIAS input and reads DC voltage from LOW terminal to ground while shunted by 100kΩ.	K606 closes, K607-K609 open, R603, high impedance BIAS connection is made	C604, U601, U613, K606-K609, R603
43.2	Select low impedance bias with K606, K607 closed, K608, K609 open, prompt with message: <i>READ VLT FOR R604</i> . Operator applies 100V to DC BIAS input and reads DC voltage from LOW terminal to ground shunted by 100kΩ.	K606, K607 close, K608, K609 open, R604, low impedance BIAS connection is made	C604, U601, U613, K606-K609, R604
43.3	Prompt for connection of 100 volts to DC BIAS input with message: <i>READ LO 100V</i> . Operator tests LOW terminal for less than 0.02 volts to ground.	R609 is good, K604 closes.	R609, U601, U613, K601-K604
43.4	Prompt for connection of 250 volts to DC BIAS input with message: <i>CONN DC TO BIAS</i> . Operator tests for no more than 180 volts on LOW terminal.	E601 limits voltage	C604, U601, U613, K601-K603, K606-K609
43.5	Prompt for connection of 100 volts to DC BIAS input with message: <i>READ LO 100V</i> . Operator tests for 100 volts on LOW input. Check DCONL when [STEP] key is pressed.	DCONL not detected, C604 blocks DC voltage	C604, U601, U613, K609
43.6	Checks that K608 really grounds no bias line. Prompt to disconnect setup with <i>DISCONNECT SETUP</i> .	K608	K608

3. Connect a variable, metered, 250 volt lab power supply between the DC BIAS input and ground. **WARNING!** The voltage applied by this supply will also be present on whatever you have connected to the LOW terminal.
4. Slowly increase the voltage of the power supply while watching its voltmeter and the one you have connected to the LOW input terminal. Somewhere in the range of 100 to 180 volts, your voltmeter should suddenly drop in value and then remain constant while you continue to increase the voltage of your lab supply. Note the voltage on your meter just before the sudden drop occurred. (After the sudden drop occurs, the voltage is actually a sawtooth with the peak voltage being the breakdown voltage of E601.)
5. Disconnect the meter and power supply from the bridge.
6. Press the **[STEP]** key to continue execution of tests. The bridge always reports a PASS for this test since it makes no measurements.

The voltage read on the LOW terminal in step four of the procedure must never exceed 180 volts. This voltage should be lower than that applied by the power supply because the overvoltage protector (E601) should limit the voltage. It is extremely important that this protector work correctly since it protects the capacitance standard (C210) from excessive voltages and static discharges.



CAUTION

The voltages used in the following test can cause serious damage to your bridge if improperly applied. Make sure that these voltages are only applied to the DC BIAS input connector.

As an added precaution, you can set the current-limit on the power supply as low as possible while still maintaining the required test voltage.

DC Bias Blocking Test

If the AH2700A is working correctly, it should be possible to apply DC bias voltages to the DC BIAS input with no observable effect on the measurement circuitry.

The following procedure is used to run test 43.5:

1. Wait for the prompt *READ LO 100V* to appear.
2. Connect a voltmeter between the LOW input terminal and ground. A BNC to banana-jack adapter might be helpful here. The input impedance of the meter must be known and must be at least 10 megohms.
3. Use a power supply to connect a 100V level between the DC BIAS input and ground. **WARNING!** 100V should also be present on whatever you have connected to the LOW terminal.
4. Read the voltage on the meter.

5. Press the **[STEP]** key to cause the test routine to complete the test by checking the DCONL signal.

If your meter has an infinite input impedance, you should have measured exactly the same voltage on the LOW terminal as you connected to the DC BIAS connector. If your meter has a 10 megohm input impedance, you should have measured a voltage that is about 91% of that which you connected to the DC BIAS connector. The test routine checks the DCONL line to ensure that the applied DC voltage is totally blocked by C604 from entering the high gain amplifier.

DC No Bias Test

Test 43.6 tests that the 100v dc bias is shorted out when no bias is selected. K608 is operated to ground the bias source. Then DCONL signal is checked to see if any voltage appears. That would indicate a failure of K608 to ground the bias source.

1. The 100v bias is still applied from previous test 43.5
2. When the *DISCONNECT SETUP* prompt appears, disconnect the meter and power supply from the bridge.
3. Press the **[STEP]** key to report the test result or to continue execution of tests.

Preamp Shunt Tests

Test group 44 checks the 100Ω resistor, R609, and its associated relay, K604, which are used to shunt the LOW input to ground. Since R609 is connected directly to the LOW input, it is possible for either test in this group to fail if external connections are made to the LOW input. In particular, larger capacitances will cause test 44.2 to fail. For this reason, the tests in test group 44 are considered to be interventional and will not be executed if the TEST command is issued with no parameters.

Test 44.1 checks that the presence of this shunt greatly reduces the magnitude of the signal seen by the preamp.

Test 44.2 checks that the absence of this shunt allows a large signal to be seen that comes from the main board, A101.

Other Preamp Input Tests

In order to perform the RD, ATN and some other tests, the gain of the preamp must be reduced below its normal minimum. This is accomplished by shunting the preamp input to ground with a capacitor, C603, using K605 as the switch. Test 45.1 checks that this shunt is able to reduce the preamp gain by a sufficient amount. If this test fails, the shunt circuit is the problem.

The input resistance of the preamp is determined by R613 (2GΩ) or by R614 (200MΩ) in parallel with R613. K610 is used to put these two resistors in parallel. Test 45.2 measures the ratio of the preamp gains with and without R614 connected.

To check that K609 shorts C604, a low frequency signal is applied to the preamp. A difference should be noted when K608 opens leaving only C604 to pass the signal.

Preamp Low-Frequency Roll-Off Tests

Test group 46 checks two switched high-pass RC filters. The first is associated with U604A and U604B. The second is associated with U611A and U611B. Each of the three tests in this group measures the ratio of the preamp gains at two frequencies for a particular switch setting.

Test Clamp Voltage levels and DC Offset

Test group 47 uses tests 47.1 and 47.2 to check that the clamp circuit can limit the signal to acceptable levels. These tests simultaneously verify that the amplifiers (U605, U608, U609), preceding the clamp circuitry have enough gain to drive the clamp circuit to its clamping limits. The waveform at the junction of D607 and D608 should be a severely clipped wave with clamp levels of ±5.7 volts. Test 47.3 measures the DC offset on the CLAMPV line that is generated by U605, U608 and U609. The voltage at U609 pin 6 should be less than +/1 0.3 volts.

Preamp vs. DAC Tests


The tests in test groups 48 and 49 are the most complete check of the ACG (AC Gain) circuit, U606, in the preamp. All of these tests rely upon the correct functioning of the DAC circuitry. Therefore, any failures might actually result from a problem in the DAC rather than one in the preamp. Only if there are no failures in test groups 60-63 can it be assumed that test failures here result from a problem in the preamp.

Test group 48 is divided into two subgroups which are identical except that the first is performed at 1 kHz and the second at 20 kHz. The first test in each subgroup verifies that the lowest gain setting of the ACG circuit works and has nominally the right gain. The remaining tests in each subgroup check each ACG setting to see that it has the correct gain ratio relative to its neighbors. The tests are performed by using the DAC to generate different test voltages. Failures in subgroup tests 48.2-48.7 should be pursued by checking U606 and its associated divider resistors. Failures only in subgroup tests 48.12-48.17 should be pursued by checking the frequency compensation capacitors associated with U606.

Test group 49 follows the same pattern as test group 48 but checks for excessive phase shift between different preamp gain settings at 20 kHz. The first test verifies that the lowest gain setting of the ACG circuit works and has nominally the right gain. The remaining tests check each ACG setting to see that they have acceptable phase shift relative to the lowest gain setting (ACG0). Failures in group 49 should be pursued by checking the frequency compensation capacitors associated with U606.

Table 11-15 Preamp tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
44	<i>Test preamp shunt</i>		
44.1	Set 2nd MSRD to 0.1, MSD of IDAC and QDAC to 1.0, close K604 so R609 shunts LOW input, select CODEC U411, read preamp signal magnitude	R609 shunt kills DAC and RD signals within expected limit	U610, K604, R609
44.2	Set 2nd MSRD to 0.1, MSD of IDAC and QDAC to 1.0, open K604 so R609 does not shunt LOW input, select CODEC U411, read preamp signal magnitude	K604 contacts will open	K604, U601
45	<i>Other preamp input tests</i>		
45.1	Set 2nd MSRD to 0.1, MSD of IDAC and QDAC to 1.0, select CODEC U411, read ratio of preamp signal magnitude with K605 closed so C603 shunts LOW, then with K605 open	K605, C603(10nF) attenuate input signal by at least expected ratio	K605, C603, R610, U601
45.2	Set 1st MSD of IDAC and QDAC to 1.0, $f = 50\text{Hz}$, select CODEC U411, read ratio of preamp signal magnitude with K610 closed so R614 shunts R613, then with K610 open	K610, R614(200M Ω) attenuate input signal by expected ratio	K610, R603, R604, U601
45.3	Checks that K609 shorts C604. Test at 50 Hz and see that preamp output drops to about 80% of previous value when K609 is open.	K609	K609, C604, R611
46	<i>Preamp low frequency roll-off tests</i>		
46.1	Set 2nd MSD of IDAC and QDAC to 0.4, set HP=0, select CODEC U411, read ratio of preamp signal magnitude with $f = 1000\text{Hz}$ then with $f = 400\text{Hz}$	U604, U611 produce expected signal ratio for high frequency roll-off	U604, U610, U611
46.2	Set 2nd MSD of IDAC and QDAC to 0.4, set HP=1, select CODEC U411, read ratio of preamp signal magnitude with $f = 1000\text{Hz}$ then with $f = 240\text{Hz}$	U604, U611 produce expected signal ratio for high frequency roll-off	U604, U610, U611, C614, C632
46.3	Set 2nd MSD of IDAC and QDAC to 0.4, set HP=2, select CODEC U411, read ratio of preamp signal magnitude with $f = 1000\text{Hz}$ then with $f = 240\text{Hz}$	U604, U611 produce expected signal ratio for high frequency roll-off	U604, U610, U611, C614, C616, C630, C632
47	<i>Test clamp voltage levels and DC offset</i>		
47.1	Set 2nd MSD of IDAC and QDAC to 1.0, set Gp=2, select CLAMPV, measure positive peak voltage	D607 clamps positive voltages	D607, U605, U608, U609
47.2	Set 2nd MSD of IDAC and QDAC to 1.0, set Gp=2, select CLAMPV, measure negative peak voltage	D608, D609, R640 clamp positive voltages	D608, D609, R640, U605, U608, U609
47.3	With DAC and RD's set to zero, set Gp=6, select CLAMPV, find average of absolute values of all readings	U605, U608, U609 have acceptable DC offset	U605, U608, U609

A failure of the low gain ratio test 48.2 indicates that the trimpot R631 may need adjustment. This is done by issuing TEST TOTAL 0; TEST HALT MODE AT_END; TEST SINGLE 48,2 so the gain ratio will be shown continuously even if it is causing an error. The  key can then be used to make the front panel show the second window in the test result which contains the gain ratio value as read by the U411 CODEC. The trimpot may then be adjusted while watching the gain ratio value in the upper display. The allowable window values for the gain ratio are shown in the third window of the test result. If the gain ratio value cannot be brought

within the acceptable window of values, then a hardware failure has occurred. The adjustment of this pot is not part of the cal procedures since the worst consequence is that the bridge will run slowly or even hang up; incorrect measurement results will never be reported since measurement results always use higher gains that are not affected by R631.

Table 11-16 Preamp versus DAC tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
48	<i>Test preamp gain ratios against DAC at 1.0 and 20.0 kHz</i>		
48.1	Set ACG to zero, set $f=1\text{kHz}$, set DAC so U411 CODEC reads magnitude at $\sim 33\%$ of FS	ACG and DAC work at these settings	preamp, DAC
48.2	Set ACG to zero, set $f=1\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 1	ACG1/ACG0 magnitude ratio is acceptable	U605, U606, U610, DAC, R624-R633
48.3	Set ACG to 1, set $f=1\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 2	ACG2/ACG1 magnitude ratio is acceptable	U605, U606, U610, DAC, R624-R633
48.4	Set ACG to 2, enable C603 shunt set $f=1\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 3	ACG3/ACG2 magnitude ratio is acceptable	U605, U606, U610, DAC, R624-R633
48.5	Set ACG to 3, enable C603 shunt, set $f=1\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 4	ACG4/ACG3 magnitude ratio is acceptable	U605, U606, U610, DAC, R624-R633
48.6	Set ACG to 4, enable C603 shunt, set $f=1\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 5	ACG5/ACG4 magnitude ratio is acceptable	U605, U606, U610, DAC, R624-R633
48.7	Set ACG to 5, enable C603 shunt, set $f=1\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 6	ACG6/ACG5 magnitude ratio is acceptable	U605, U606, U610, DAC, R624-R633
48.11	Set ACG to zero, set $f=20\text{kHz}$, set DAC so U411 CODEC reads magnitude at $\sim 10\%$ of FS	ACG and DAC work at these settings	preamp, DAC
48.12	Set ACG to zero, set $f=20\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 1	ACG1/ACG0 magnitude ratio is acceptable	U605-606, C620-623 C617, U610, DAC
48.13	Set ACG to 1, set $f=20\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 2	ACG2/ACG1 magnitude ratio is acceptable	U605-606, C620-623 C617, U610, DAC
48.14	Set ACG to 2, enable C603 shunt, set $f=20\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 3	ACG3/ACG2 magnitude ratio is acceptable	U605-606, C620-623 C617, U610, DAC
48.15	Set ACG to 3, enable C603 shunt, set $f=20\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 4	ACG4/ACG3 magnitude ratio is acceptable	U605-606, C620-623 C617, U610, DAC
48.16	Set ACG to 4, enable C603 shunt, set $f=20\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 5	ACG5/ACG4 magnitude ratio is acceptable	U605-606, C620-623 C617, U610, DAC
48.17	Set ACG to 5, enable C603 shunt, set $f=20\text{kHz}$, set DAC so U411 CODEC reads $\sim 10\%$ of FS, then set ACG to 6	ACG6/ACG5 magnitude ratio is acceptable	U605-606, C620-623 C617, U610, DAC
49	<i>Test preamp phase shift against IDAC at 20.0 kHz</i>		
49.1	Set $f=20\text{kHz}$, set ACG to zero, set IDAC so U411 CODEC reads magnitude at $\sim 25\%$ of FS	ACG and DAC work at these settings	preamp, IDAC
49.2	Set $f=20\text{kHz}$, set ACG to zero, set IDAC so U411 CODEC reads $\sim 25\%$ of FS, then set ACG to 1	ACG1/ACG0 phase shift is less than 2°	U605, U606, U610, IDAC
49.3	Set $f=20\text{kHz}$, set ACG to zero, set IDAC so U411 CODEC reads $\sim 25\%$ of FS, then set ACG to 2	ACG2/ACG0 phase shift is less than 2°	U605, U606, U610, IDAC
49.4	Set $f=20\text{kHz}$, set ACG to zero, set IDAC so U411 CODEC reads $\sim 25\%$ of FS, then set ACG to 3	ACG3/ACG0 phase shift is less than 2°	U605, U606, U610, IDAC
49.5	Set $f=20\text{kHz}$, set ACG to zero, enable C603 shunt, set IDAC so U411 CODEC reads $\sim 25\%$ of FS, then set ACG to 4	ACG4/ACG0 phase shift is less than 2°	U605, U606, U610, IDAC
49.6	Set $f=20\text{kHz}$, set ACG to zero, enable C603 shunt, set IDAC so U411 CODEC reads $\sim 25\%$ of FS, then set ACG to 5	ACG5/ACG0 phase shift is less than 2°	U605, U606, U610, IDAC
49.7	Set $f=20\text{kHz}$, set ACG to zero, enable C603 shunt, set IDAC so U411 CODEC reads $\sim 25\%$ of FS, then set ACG to 6	ACG6/ACG0 phase shift is less than 2°	U605, U606, U610, IDAC

Comparison Tests

All of the 50 series test groups differ from virtually all of the other diagnostic tests in one important respect: the 50 series tests check certain sections of the bridge by using other sections of the bridge that have not been previously tested.

Therefore, any failures in this series of tests may be caused by the circuitry explicitly being tested or such failures may result from problems in other circuitry that has not yet been tested.

Table 11-17 A/D vs. CODEC tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
50	<i>Test that A/D can generate all possible codes</i>		
50.1	Set A/D to read CAPFDBCK (U411) signal, adjust CAPFDBCK to try to get A/D to see all possible codes. See text.	U421 can generate all codes, CODEC U411 can make most voltages.	U411, U412, U414, U415, U418-U421
51	<i>Test A/D linearity vs. analog output CODECS</i>		
51.1	Set A/D to read CAPFDBCK (U411) signal, U411 CODEC makes 64 levels over the full A/D scale, check linearity of A/D results. See text.	A/D and U411 compare linearly over A/D's FS	U411, U412, U414, U415, U418-U421
51.2	Set A/D to read LOSSFDBCK (U416) signal, U416 CODEC makes 64 levels over the full A/D scale, check linearity of A/D results. See text.	A/D and U416 compare linearly over A/D's FS	U412, U415-U417, U418-U421
51.3	Set A/D to read CAPFDBCK (U411) signal, U411 CODEC makes 64 levels over 1/32 of the full A/D scale, check linearity of A/D results. See text.	A/D and U411 compare linearly over 1/32 of A/D's FS	U411, U412, U414, U415, U418-U421
51.4	Set A/D to read LOSSFDBCK (U416) signal, U416 CODEC makes 64 levels over 1/32 of the full A/D scale, check linearity of A/D results. See text.	A/D and U416 compare linearly over 1/32 of A/D's FS	U412, U415-U417, U418-U421

Test that A/D Generates All Codes

In test 50.1, CODEC U411 tries to set up every voltage necessary for the A/D to generate all of its 16384 possible codes. This is a two-pass process. First, the CODEC spends on the order of a second generating a sweep voltage which the A/D reads as fast as it can. The A/D should find about 90% of all possible codes during this sweep. In the second pass, the CODEC tries one at a time to zero in on the as yet missing codes. The second pass takes about half of the total time used for the test. The test passes if no missing codes are found. Failure is reported as 1, success as 0.

If this test fails, either the CODEC can't make all the needed voltage levels, the A/D can't make all the needed codes from the voltage levels, or there is a fault in the signal path between the CODEC and the A/D. Excessive loading of an analog output channel can also cause this test to fail. If a gross failure occurs, running test groups 90 and 91 may be helpful since they are simple diagnostic tests whereas test groups 50 and 51 are really complex performance tests.

Test A/D Linearity vs. Analog Output CODECS

Test group 51 compares the linearity of the A/D with two different CODECS. These comparisons are made over the full scale range of the A/D and over the lowest 1/32 of the

A/D's range. This test reports the deviation of the least linear point measured. If this worst point is reported as being greater than 100, then the test fails. Most measured points are near 10 or less. If a test in this group fails, check the same parts as suggested in test 50.1.

Test QDAC/IDAC Phase Shift for All Four Quadrants

Test groups 52 and 53 verify that the phase of the QDAC drive signal can be shifted by 0°, 90°, 180° and 270° relative to the IDAC drive signal for frequencies of 1.0 and 20.0 kHz. Of course, these tests are also checking that the phase shifts can be correctly measured. Much of the instrument must be functioning for these tests to pass so it is hard to make specific suggestions as to what to check if any of these tests fail.

Test group 52 should pass if all of test group 35 passes. If group 52 does not pass, then check for marginally passed tests in test group 35 to further isolate the problem.

If failures occur in test group 53, there could be problems with the high frequency rolloff of the filters in the I/Q or Q/I sense lines going from the main board to the U401 and U406 CODECS on the mux board.

Table 11-18 Phase-shift generation tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
52	<i>Test that QDAC/IDAC phase shift is correct for all four quadrants at 1kHz</i>		
52.1	Set IDAC MSD to 0.4, select preamp CODEC, read signal and compute its phase; then set QDAC/IDAC phase shift to 0°, QDAC MSD to 0.4, read preamp and compute phase shift	QDAC/IDAC 0° phase shift is correctly generated and detected at 1 kHz	See text
52.2	Set IDAC MSD to 0.4, select preamp CODEC, read signal and compute its phase; then set QDAC/IDAC phase shift to 90°, QDAC MSD to 0.4, read preamp and compute phase shift	QDAC/IDAC 90° phase shift is correctly generated and detected at 1 kHz	See text
52.3	Set IDAC MSD to 0.4, select preamp CODEC, read signal and compute its phase; then set QDAC/IDAC phase shift to 180°, QDAC MSD to 0.4, read preamp and compute phase shift	QDAC/IDAC 180° phase shift is correctly generated and detected at 1 kHz	See text
52.4	Set IDAC MSD to 0.4, select preamp CODEC, read signal and compute its phase; then set QDAC/IDAC phase shift to 270°, QDAC MSD to 0.4, read preamp and compute phase shift	QDAC/IDAC 270° phase shift is correctly generated and detected at 1 kHz	See text
53	<i>Test that phase is correct for all four quadrants at 20kHz</i>		
53.1	Set IDAC MSD to 0.4, select preamp CODEC, read signal and compute its phase; then set QDAC/IDAC phase shift to 0°, QDAC MSD to 0.4, read preamp and compute phase shift	QDAC/IDAC 0° phase shift is correctly generated & detected at 20 kHz	See text
53.2	Set IDAC MSD to 0.4, select preamp CODEC, read signal and compute its phase; then set QDAC/IDAC phase shift to 90°, QDAC MSD to 0.4, read preamp and compute phase shift	QDAC/IDAC 90° phase shift is correctly generated & detected at 20 kHz	See text
53.3	Set IDAC MSD to 0.4, select preamp CODEC, read signal and compute its phase; then set QDAC/IDAC phase shift to 180°, QDAC MSD to 0.4, read preamp and compute phase shift	QDAC/IDAC 180° phase shift is correctly generated & detected at 20 kHz	See text
53.4	Set IDAC MSD to 0.4, select preamp CODEC, read signal and compute its phase; then set QDAC/IDAC phase shift to 270°, QDAC MSD to 0.4, read preamp and compute phase shift	QDAC/IDAC 270° phase shift is correctly generated & detected at 20 kHz	See text

Main Board Tests

At this point, if all prior tests have been run, then all have been completed on all major assemblies except for the main board. Except as noted, all the main board tests are designed to localize problems on the main board. Failures of any of these tests are not likely to help identify failures on other boards.

There are many simple, independent, firmware testable circuits on the main board. As a result, most of the likely failures on this board can be repaired without replacing the board.

The main board tests assume that the rest of the bridge is functioning because many of the other circuits are required to do the main board tests. These tests involve selecting particular DAC and RD settings, the precision sum of which produces a result at the input of the preamp. This sum is amplified, detected, and then read by the CODEC, U411, for comparison against a window of acceptable values.

Test for Stuck DAC Switches

This large body of tests consisting of groups 60 and 61 checks each bit position of the DAC one at a time. Each of these tests simply looks for *any* change to occur as a result of changing the given analog switch from the zero voltage transformer tap to each of the other taps. Each test passes provided that a detectable change occurred. These tests are intended to find any analog switch elements that do not change in response to a command from the microprocessor.

A failure of a *single* test indicates a failed analog switch element or its connection to the transformer. In this case, the exact pin number associated with the failure is identified by the test.

A failure of *several* closely related tests requires identifying the meaning of the pattern of the failures. The pattern is likely to indicate a failure of the latch that controls the analog switch, of the interconnection between the two, or of a digital input of the analog switch.

All of these tests are looking for differences relative to the case where all DAC control digits are set to zero. As a result, the case of an analog switch stuck while connected to a trans-

former zero line is not explicitly reported. However, this case will produce its own characteristic symptoms. These symp-

oms show up as the failure of *all* other tests that try to produce a change relative to the stuck zero line.

Table 11-19 Stuck DAC tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
60	<i>Test that each switch element in MSD of IDAC can cause a change</i>		
60.1	Set IDAC MSD to IP 0.0 using U124, ACG=1, U411 reads magnitude; then set U124 to IP 1.0	A change is seen => U124 pin 5 connects	U132, U124, U125
60.2	Set IDAC MSD to IP 0.0 using U124, ACG=1, U411 reads magnitude; then set U124 to IP 0.8	A change is seen => U124 pin 1 connects	U132, U124, U125
60.3	Set IDAC MSD to IP 0.0 using U124, ACG=1, U411 reads magnitude; then set U124 to IP 0.6	A change is seen => U124 pin 12 connects	U132, U124, U125
60.4	Set IDAC MSD to IP 0.0 using U124, ACG=1, U411 reads magnitude; then set U124 to IP 0.4	A change is seen => U124 pin 15 connects	U132, U124, U125
60.5	Set IDAC MSD to IP 0.0 using U124, ACG=1, U411 reads magnitude; then set U124 to IP 0.2	A change is seen => U124 pin 14 connects	U132, U124, U125
60.6	Set IDAC MSD to IP 0.0 using U124, ACG=1, U411 reads magnitude; then set U124 to IP -0.1	A change is seen => U124 pin 4 connects	U132, U124, U125
60.7	Set IDAC MSD to IP 0.0 using U122B, ACG=1, U411 reads magnitude; then set U122B to IP 1.0	A change is seen => U122 pin 1 connects	U132, U122, U121
	<i>Test that each switch element in second MSD of IDAC can cause a change</i>		
60.11	Set IDAC 2nd MSD to IP 0.0 using U123, ACG=0, U411 reads magnitude; then set U123 to IP 1.0	A change is seen => U123 pin 5 connects	U132, U123, U126
60.12	Set IDAC 2nd MSD to IP 0.0 using U123, ACG=0, U411 reads magnitude; then set U123 to IP 0.8	A change is seen => U123 pin 1 connects	U132, U123, U126
60.13	Set IDAC 2nd MSD to IP 0.0 using U123, ACG=0, U411 reads magnitude; then set U123 to IP 0.6	A change is seen => U123 pin 12 connects	U132, U123, U126
60.14	Set IDAC 2nd MSD to IP 0.0 using U123, ACG=0, U411 reads magnitude; then set U123 to IP 0.4	A change is seen => U123 pin 15 connects	U132, U123, U126
60.15	Set IDAC 2nd MSD to IP 0.0 using U123, ACG=0, U411 reads magnitude; then set U123 to IP 0.2	A change is seen => U123 pin 14 connects	U132, U123, U126
60.16	Set IDAC 2nd MSD to IP 0.0 using U123, ACG=0, U411 reads magnitude; then set U123 to IP -0.1	A change is seen => U123 pin 4 connects	U132, U123, U126
60.17	Set IDAC 2nd MSD to IP 0.0 using U122C, ACG=0, U411 reads magnitude; then set U122C to IP 1.0	A change is seen => U122 pin 3 connects	U132, U122
	<i>Test that each switch element in third MSD of IDAC can cause a change</i>		
60.21	Set IDAC 3rd MSD to IP 0.0 using U127, set ACG=2, U411 reads magnitude; then set U127 to IP 1.0	A change is seen => U127 pin 5 connects	U136, U127, U133
60.22	Set IDAC 3rd MSD to IP 0.0 using U127, set ACG=2, U411 reads magnitude; then set U127 to IP 0.8	A change is seen => U127 pin 1 connects	U136, U127, U133
60.23	Set IDAC 3rd MSD to IP 0.0 using U127, set ACG=2, U411 reads magnitude; then set U127 to IP 0.6	A change is seen => U127 pin 12 connects	U136, U127, U133
60.24	Set IDAC 3rd MSD to IP 0.0 using U127, set ACG=2, U411 reads magnitude; then set U127 to IP 0.4	A change is seen => U127 pin 15 connects	U136, U127, U133
60.25	Set IDAC 3rd MSD to IP 0.0 using U127, set ACG=2, U411 reads magnitude; then set U127 to IP 0.2	A change is seen => U127 pin 14 connects	U136, U127, U133
60.26	Set IDAC 3rd MSD to IP 0.0 using U127, set ACG=2, U411 reads magnitude; then set U127 to IP -0.1	A change is seen => U127 pin 4 connects	U136, U127, U133

Table 11-19 Stuck DAC tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
60.27	Set IDAC 3rd MSD to IP 0.0 using U122A, set ACG=2, U411 reads magnitude; then set U122A to IP 1.0	A change is seen => U122 pin 13 connects	U136, U122
<i>Test that each switch element in fourth MSD of IDAC can cause a change</i>			
60.31	Set IDAC 4th MSD to IP 0.0 using U128, set ACG=4, U411 reads magnitude; then set U128 to IP 1.0	A change is seen => U128 pin 5 connects	U136, U128
60.32	Set IDAC 4th MSD to IP 0.0 using U128, set ACG=4, U411 reads magnitude; then set U128 to IP 0.8	A change is seen => U128 pin 1 connects	U136, U128
60.33	Set IDAC 4th MSD to IP 0.0 using U128, set ACG=4, U411 reads magnitude; then set U128 to IP 0.6	A change is seen => U128 pin 12 connects	U136, U128
60.34	Set IDAC 4th MSD to IP 0.0 using U128, set ACG=4, U411 reads magnitude; then set U128 to IP 0.4	A change is seen => U128 pin 15 connects	U136, U128
60.35	Set IDAC 4th MSD to IP 0.0 using U128, set ACG=4, U411 reads magnitude; then set U128 to IP 0.2	A change is seen => U128 pin 14 connects	U136, U128
60.36	Set IDAC 4th MSD to IP 0.0 using U128, set ACG=4, U411 reads magnitude; then set U128 to IP -0.1	A change is seen => U128 pin 4 connects	U136, U128
60.37	Set IDAC 4th MSD to IP 0.0 using U131A, set ACG=4, U411 reads magnitude; then set U131A pin 13 to IP 1.0	A change is seen => U131 pin 13 connects	U136, U131
<i>Test that each switch element in fifth MSD of IDAC can cause a change</i>			
60.41	Set IDAC 5th MSD to IP 0.0 using U129, set ACG=6, U411 reads magnitude; then set U129 to IP 1.0	A change is seen => U129 pin 5 connects	U138, U129
60.42	Set IDAC 5th MSD to IP 0.0 using U129, set ACG=6, U411 reads magnitude; then set U129 to IP 0.8	A change is seen => U129 pin 1 connects	U138, U129
60.43	Set IDAC 5th MSD to IP 0.0 using U129, set ACG=6, U411 reads magnitude; then set U129 to IP 0.6	A change is seen => U129 pin 12 connects	U138, U129
60.44	Set IDAC 5th MSD to IP 0.0 using U129, set ACG=6, U411 reads magnitude; then set U129 to IP 0.4	A change is seen => U129 pin 15 connects	U138, U129
60.45	Set IDAC 5th MSD to IP 0.0 using U129, set ACG=6, U411 reads magnitude; then set U129 to IP 0.2	A change is seen => U129 pin 14 connects	U138, U129
60.46	Set IDAC 5th MSD to IP 0.0 using U129, set ACG=6, U411 reads magnitude; then set U129 to IP -0.1	A change is seen => U129 pin 4 connects	U138, U129
60.47	Set IDAC 5th MSD to IP 0.0 using U131A, set ACG=6, U411 reads magnitude; then set U131A to IP 1.0	A change is seen => U131 pin 3 connects	U138, U131
<i>Test that each switch element in sixth MSD of IDAC can cause a change</i>			
60.51	Set IDAC 6th MSD to IP 0.0 using U130 and U131, set ACG=6, U411 reads magnitude; then set U130 to IP 0.4 and U131A to IP 1.0	A change is seen => U131 pin 1 and U130 pin 15 connect	U138, U130, U131
61	<i>Test that each switch element in MSD of QDAC can cause a change</i>		
61.1	Set QDAC MSD to IP 0.0 using U143, ACG=1, U411 reads magnitude; then set U143 to IP 1.0	A change is seen => U143 pin 5 connects	U135, U143, U141
61.2	Set QDAC MSD to IP 0.0 using U143, ACG=1, U411 reads magnitude; then set U143 to IP 0.8	A change is seen => U143 pin 1 connects	U135, U143, U141
61.3	Set QDAC MSD to IP 0.0 using U143, ACG=1, U411 reads magnitude; then set U143 to IP 0.6	A change is seen => U143 pin 12 connects	U135, U143, U141
61.4	Set QDAC MSD to IP 0.0 using U143, ACG=1, U411 reads magnitude; then set U143 to IP 0.4	A change is seen => U143 pin 15 connects	U135, U143, U141

Table 11-19 Stuck DAC tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
61.5	Set QDAC MSD to IP 0.0 using U143, ACG=1, U411 reads magnitude; then set U143 to IP 0.2	A change is seen => U143 pin 14 connects	U135, U143, U141
61.6	Set QDAC MSD to IP 0.0 using U143, ACG=1, U411 reads magnitude; then set U143 to IP -0.1	A change is seen => U143 pin 4 connects	U135, U143, U141
61.7	Set QDAC MSD to IP 0.0 using U140C, ACG=1, U411 reads magnitude; then set U140C to IP 1.0	A change is seen => U140 pin 3 connects	U135, U140, U142
<i>Test that each switch element in second MSD of QDAC can cause a change</i>			
61.11	Set QDAC 2nd MSD to IP 0.0 using U144, ACG=0, U411 reads magnitude; then set U144 to IP 1.0	A change is seen => U144 pin 5 connects	U135, U144, U134
61.12	Set QDAC 2nd MSD to IP 0.0 using U144, ACG=0, U411 reads magnitude; then set U144 to IP 0.8	A change is seen => U144 pin 1 connects	U135, U144, U134
61.13	Set QDAC 2nd MSD to IP 0.0 using U144, ACG=0, U411 reads magnitude; then set U144 to IP 0.6	A change is seen => U144 pin 12 connects	U135, U144, U134
61.14	Set QDAC 2nd MSD to IP 0.0 using U144, ACG=0, U411 reads magnitude; then set U144 to IP 0.4	A change is seen => U144 pin 15 connects	U135, U144, U134
61.15	Set QDAC 2nd MSD to IP 0.0 using U144, ACG=0, U411 reads magnitude; then set U144 to IP 0.2	A change is seen => U144 pin 14 connects	U135, U144, U134
61.16	Set QDAC 2nd MSD to IP 0.0 using U144, ACG=0, U411 reads magnitude; then set U144 to IP -0.1	A change is seen => U144 pin 4 connects	U135, U144, U134
61.17	Set QDAC 2nd MSD to IP 0.0 using U140A, ACG=0, U411 reads magnitude; then set U140A to IP 1.0	A change is seen => U140 pin 13 connects	U135, U140
<i>Test that each switch element in third MSD of QDAC can cause a change</i>			
61.21	Set QDAC 3rd MSD to IP 0.0 using U145, ACG=2, U411 reads magnitude; then set U145 to IP 1.0	A change is seen => U145 pin 5 connects	U137, U145
61.22	Set QDAC 3rd MSD to IP 0.0 using U145, ACG=2, U411 reads magnitude; then set U145 to IP 0.8	A change is seen => U145 pin 1 connects	U137, U145
61.23	Set QDAC 3rd MSD to IP 0.0 using U145, ACG=2, U411 reads magnitude; then set U145 to IP 0.6	A change is seen => U145 pin 12 connects	U137, U145
61.24	Set QDAC 3rd MSD to IP 0.0 using U145, ACG=2, U411 reads magnitude; then set U145 to IP 0.4	A change is seen => U145 pin 15 connects	U137, U145
61.25	Set QDAC 3rd MSD to IP 0.0 using U145, ACG=2, U411 reads magnitude; then set U145 to IP 0.2	A change is seen => U145 pin 14 connects	U137, U145
61.26	Set QDAC 3rd MSD to IP 0.0 using U145, ACG=2, U411 reads magnitude; then set U145 to IP -0.1	A change is seen => U145 pin 4 connects	U137, U145
61.27	Set QDAC 3rd MSD to IP 0.0 using U140B, ACG=2, U411 reads magnitude; then set U140B to IP 1.0	A change is seen => U140 pin 1 connects	U137, U140
<i>Test that each switch element in fourth MSD of QDAC can cause a change</i>			
61.31	Set QDAC 4th MSD to IP 0.0 using U146, ACG=4, U411 reads magnitude; then set U146 to IP 1.0	A change is seen => U146 pin 5 connects	U137, U146
61.32	Set QDAC 4th MSD to IP 0.0 using U146, ACG=4, U411 reads magnitude; then set U146 to IP 0.8	A change is seen => U146 pin 1 connects	U137, U146
61.33	Set QDAC 4th MSD to IP 0.0 using U146, ACG=4, U411 reads magnitude; then set U146 to IP 0.6	A change is seen => U146 pin 12 connects	U137, U146
61.34	Set QDAC 4th MSD to IP 0.0 using U146, ACG=4, U411 reads magnitude; then set U146 to IP 0.4	A change is seen => U146 pin 15 connects	U137, U146

Table 11-19 Stuck DAC tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
61.35	Set QDAC 4th MSD to IP 0.0 using U146, ACG=4, U411 reads magnitude; then set U146 to IP 0.2	A change is seen => U146 pin 14 connects	U137, U146
61.36	Set QDAC 4th MSD to IP 0.0 using U146, ACG=4, U411 reads magnitude; then set U146 to IP -0.1	A change is seen => U146 pin 4 connects	U137, U146
61.37	Set QDAC 4th MSD to IP 0.0 using U149C, ACG=4, U411 reads magnitude; then set U149C to IP 1.0	A change is seen => U149 pin 3 connects	U137, U149
<i>Test that each switch element in fifth MSD of QDAC can cause a change</i>			
61.41	Set QDAC 5th MSD to IP 0.0 using U147, ACG=6, U411 reads magnitude; then set U147 to IP 1.0	A change is seen => U147 pin 5 connects	U139, U147
61.42	Set QDAC 5th MSD to IP 0.0 using U147, ACG=6, U411 reads magnitude; then set U147 to IP 0.8	A change is seen => U147 pin 1 connects	U139, U147
61.43	Set QDAC 5th MSD to IP 0.0 using U147, ACG=6, U411 reads magnitude; then set U147 to IP 0.6	A change is seen => U147 pin 12 connects	U139, U147
61.44	Set QDAC 5th MSD to IP 0.0 using U147, ACG=6, U411 reads magnitude; then set U147 to IP 0.4	A change is seen => U147 pin 15 connects	U139, U147
61.45	Set QDAC 5th MSD to IP 0.0 using U147, ACG=6, U411 reads magnitude; then set U147 to IP 0.2	A change is seen => U147 pin 14 connects	U139, U147
61.46	Set QDAC 5th MSD to IP 0.0 using U147, ACG=6, U411 reads magnitude; then set U147 to IP -0.1	A change is seen => U147 pin 4 connects	U139, U147
61.47	Set QDAC 5th MSD to IP 0.0 using U14B9, ACG=6, U411 reads magnitude; then set U149B to IP 1.0	A change is seen => U149 pin 1 connects	U139, U149
<i>Test that each switch element in sixth MSD of QDAC can cause a change</i>			
61.51	Set QDAC 6th MSD to IP 0.0 using U148 and U149A, set ACG=6, U411 reads magnitude; then set U148 to IP 0.4 and U149A to IP 1.0	A change is seen => U148 pin 15 and U149 pin 13 connect	U139, U148, U149

Check Voltage Ratios from DAC

The second large body of tests consisting of groups 62 and 63 checks the ratios of voltages selected from the transformers. For the most part, the tests compare voltage ratios of adjacent transformer taps. The tests start with the highest transformer tap to the MSD of the IDAC. Selection of this tap is compared against the tap having the next lower voltage. The CODEC A/D U411 checks that the ratio of these voltages is approximately correct. The comparison process continues with each pair of adjacent transformer taps, going from the MSD of the IDAC through the least significant. The process is repeated in precisely the same way for the QDAC.

A failure in these test groups with no failure in groups 60 or 61 may indicate a change in an associated precision DAC resistor, but this is not likely. The reason is that while these groups of tests check the resistors much better than the previous groups of tests, the resistors are still crudely measured relative to that done by the verification process described in “INTERNAL CALIBRATION” on page 9-4.

A more likely cause of failure is some kind of addressing problem. The previous body of tests looked for *any* change at all. The current body of tests look for the *right* change. This

means that the current body of tests will detect a situation where the wrong transformer line was selected. These tests will also detect a situation where more than one transformer line is somehow selected (presumably with more than one analog switch IC).

Table 11-20 Voltage Ratio DAC tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
62	<i>Test gain ratios of MSD of IDAC</i>		
62.1	Set MSD of IDAC to IP 1.0 using U124, set ACG=1, enable AtnTst shunt, U411 reads magnitude	IDAC sees reasonable signal level at this setting	U132, U124, U125
62.2	Set IDAC MSD to IP 1.0 using U124, set ACG=1, enable AtnTst shunt, U411 reads magnitude; then set U124 to IP 0.8	IDAC MSD generates correct 10/8 ratio	U132, U124, U125
62.3	Set IDAC MSD to IP 0.8 using U124, set ACG=1, enable AtnTst shunt, U411 reads magnitude; then set U124 to IP 0.6	IDAC MSD generates correct 8/6 ratio	U132, U124, U125
62.4	Set IDAC MSD to IP 0.6 using U124, set ACG=1, enable AtnTst shunt, U411 reads magnitude; then set U124 to IP 0.4	IDAC MSD generates correct 6/4 ratio	U132, U124, U125
62.5	Set IDAC MSD to IP 0.4 using U124, set ACG=2, enable AtnTst shunt, U411 reads magnitude; then set U124 to IP 0.2	IDAC MSD generates correct 4/2 ratio	U132, U124, U125
62.6	Set IDAC MSD to IP 0.2 using U124, set ACG=3, enable AtnTst shunt, U411 reads magnitude; then set U124 to IP -0.1	IDAC MSD generates correct 2/1 ratio	U132, U124, U125
62.7	Set IDAC MSD to IP 0.2 using U124, set ACG=3, enable AtnTst shunt, U411 reads magnitude; then set U124 to IP 0.0 & set U122B to IP 1.0	IDAC MSD generates correct 2/1 ratio	U132, U122, U121
	<i>Test gain ratios of second MSD of IDAC</i>		
62.11	Set MSD of IDAC to IP -0.1 using U124, set ACG=0, U411 reads magnitude, then set U124 to IP 0.0 and set 2nd MSD of IDAC to IP 1.0 using U123	IDAC MSD relative to 2nd MSD generates correct 1/1 ratio	U132, U123, U126
62.12	Set IDAC 2nd MSD to IP 1.0 using U123, set ACG=0, U411 reads magnitude; then set U123 to IP 0.8	IDAC 2nd MSD generates correct 10/8 ratio	U132, U123, U126
62.13	Set IDAC 2nd MSD to IP 0.8 using U123, set ACG=0, U411 reads magnitude; then set U123 to IP 0.6	IDAC 2nd MSD generates correct 8/6 ratio	U132, U123, U126
62.14	Set IDAC 2nd MSD to IP 0.6 using U123, set ACG=0, U411 reads magnitude; then set U123 to IP 0.4	IDAC 2nd MSD generates correct 6/4 ratio	U132, U123, U126
62.15	Set IDAC 2nd MSD to IP 0.4 using U123, set ACG=1, U411 reads magnitude; then set U123 to IP 0.2	IDAC 2nd MSD generates correct 4/2 ratio	U132, U123, U126
62.16	Set IDAC 2nd MSD to IP 0.2 using U123, set ACG=2, U411 reads magnitude; then set U123 to IP -0.1	IDAC 2nd MSD generates correct 2/1 ratio	U132, U123, U126
62.17	Set IDAC 2nd MSD to IP 0.2 using U123, set ACG=2, U411 reads magnitude; then set U123 to IP 0.0 and set U122C to IP 1.0	IDAC 2nd MSD generates correct 2/1 ratio	U132, U122, U133
	<i>Test gain ratios of third MSD of IDAC</i>		
62.21	Set 2nd MSD of IDAC to IP -0.1 using U123, set ACG=2, U411 reads magnitude; then set U123 to IP 0.0 and set 3rd MSD of IDAC to IP 1.0 using U127	IDAC 2nd MSD relative to 3rd MSD generates correct 1/1 ratio	U136, U127, U133
62.22	Set IDAC 3rd MSD to IP 1.0 using U127, set ACG=2, U411 reads magnitude; then set U127 to IP 0.8	IDAC 3rd MSD generates correct 10/8 ratio	U136, U127, U133
62.23	Set IDAC 3rd MSD to IP 0.8 using U127, set ACG=2, U411 reads magnitude; then set U127 to IP 0.6	IDAC 3rd MSD generates correct 8/6 ratio	U136, U127, U133
62.24	Set IDAC 3rd MSD to IP 0.6 using U127, set ACG=2, U411 reads magnitude; then set U127 to IP 0.4	IDAC 3rd MSD generates correct 6/4 ratio	U136, U127, U133
62.25	Set IDAC 3rd MSD to IP 0.4 using U127, set ACG=3, U411 reads magnitude; then set U127 to IP 0.2	IDAC 3rd MSD generates correct 4/2 ratio	U136, U127, U133

Table 11-20 Voltage Ratio DAC tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
62.26	Set IDAC 3rd MSD to IP 0.2 using U127, set ACG=4, U411 reads magnitude; then set U127 to IP -0.1	IDAC 3rd MSD generates correct 2/1 ratio	U136, U127, U133
62.27	Set IDAC 3rd MSD to IP 0.2 using U127, set ACG=4, U411 reads magnitude; then set U127 to IP 0.0 and set U122A to IP 1.0	IDAC 3rd MSD generates correct 2/1 ratio	U136, U124
<i>Test gain ratios of fourth MSD of IDAC</i>			
62.31	Set 3rd MSD of IDAC to IP -0.1 using U127, set ACG=4, U411 reads magnitude, then set U127 to IP 0.0 and set 4th MSD of IDAC to IP 1.0 using U128	IDAC 3rd MSD relative to 4th MSD generates correct 1/1 ratio	U136, U128
62.32	Set IDAC 4th MSD to IP 1.0 using U128, set ACG=4, U411 reads magnitude; then set U128 to IP 0.8	IDAC 4th MSD generates correct 10/8 ratio	U136, U128
62.33	Set IDAC 4th MSD to IP 0.8 using U128, set ACG=4, U411 reads magnitude; then set U128 to IP 0.6	IDAC 4th MSD generates correct 8/6 ratio	U136, U128
62.34	Set IDAC 4th MSD to IP 0.6 using U128, set ACG=4, U411 reads magnitude; then set U128 to IP 0.4	IDAC 4th MSD generates correct 6/4 ratio	U136, U128
62.35	Set IDAC 4th MSD to IP 0.4 using U128, set ACG=5, U411 reads magnitude; then set U128 to IP 0.2	IDAC 4th MSD generates correct 4/2 ratio	U136, U128
62.36	Set IDAC 4th MSD to IP 0.2 using U128, set ACG=6, U411 reads magnitude; then set U128 to IP -0.1	IDAC 4th MSD generates correct 2/1 ratio	U136, U128
62.37	Set IDAC 4th MSD to IP 0.2 using U128, set ACG=6, U411 reads magnitude; then set U128 to IP 0.0 and set U131A to IP 1.0	IDAC 4th MSD generates correct 2/1 ratio	U136, U123
<i>Test gain ratios of fifth MSD of IDAC</i>			
62.41	Set 4th MSD of IDAC to IP -0.1 using U128, set ACG=4, U411 reads magnitude, then set U128 to IP 0.0 and set 5th MSD of IDAC to IP 1.0 using U129	IDAC 4th MSD relative to 5th MSD generates correct 1/1 ratio	U138, U129
62.42	Set IDAC 5th MSD to IP 1.0 using U129, set ACG=4, U411 reads magnitude; then set U129 to IP 0.8	IDAC 5th MSD generates correct 10/8 ratio	U138, U129
62.43	Set IDAC 5th MSD to IP 0.8 using U129, set ACG=4, U411 reads magnitude; then set U129 to IP 0.6	IDAC 5th MSD generates correct 8/6 ratio	U138, U129
62.44	Set IDAC 5th MSD to IP 0.6 using U129, set ACG=4, U411 reads magnitude; then set U129 to IP 0.4	IDAC 5th MSD generates correct 6/4 ratio	U138, U129
62.45	Set IDAC 5th MSD to IP 0.4 using U129, set ACG=5, U411 reads magnitude; then set U129 to IP 0.2	IDAC 5th MSD generates correct 4/2 ratio	U138, U129
62.46	Set IDAC 5th MSD to IP 0.2 using U129, set ACG=6, U411 reads magnitude; then set U129 to IP -0.1	IDAC 5th MSD generates correct 2/1 ratio	U138, U129
62.47	Set IDAC 5th MSD to IP 0.2 using U129, set ACG=6, U411 reads magnitude; then set U129 to IP 0.0 and set U131C to IP 1.0	IDAC 5th MSD generates correct 2/1 ratio	U138, U131
<i>Test gain ratios of sixth MSD of IDAC</i>			
62.51	Set IDAC 5th MSD to IP 1.0 using U131C, set ACG=6, U411 reads magnitude; then set U131C to IP 0.0 and set IDAC 6th MSD using U131B to IP 1.0 and U130 to IP 0.4	IDAC 5th MSD relative to 6th MSD generates correct 2/1 ratio	U138, U131, U130
63	<i>Test gain ratios of MSD of QDAC</i>		
63.1	Set MSD of QDAC to Q 1.0 using U143, set ACG=1, enable AtnTst shunt, U411 reads magnitude channels	QDAC sees reasonable signal level at this setting	U135, U143, U141

Table 11-20 Voltage Ratio DAC tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
63.2	Set QDAC MSD to Q 1.0 using U143, set ACG=1, enable AtnTst shunt, U411 reads magnitude; then set U143 to Q 0.8	QDAC MSD generates correct 10/8 ratio	U135, U143, U141
63.3	Set QDAC MSD to Q 0.8 using U143, set ACG=1, enable AtnTst shunt, U411 reads magnitude; then set U143 to Q 0.6	QDAC MSD generates correct 8/6 ratio	U135, U143, U141
63.4	Set QDAC MSD to Q 0.6 using U143, set ACG=1, enable AtnTst shunt, U411 reads magnitude; then set U143 to Q 0.4	QDAC MSD generates correct 6/4 ratio	U135, U143, U141
63.5	Set QDAC MSD to Q 0.4 using U143, set ACG=2, enable AtnTst shunt, U411 reads magnitude; then set U143 to Q 0.2	QDAC MSD generates correct 4/2 ratio	U135, U143, U141
63.6	Set QDAC MSD to Q 0.2 using U143, set ACG=3, enable AtnTst shunt, U411 reads magnitude; then set U143 to Q -0.1	QDAC MSD generates correct 2/1 ratio	U135, U143, U141
63.7	Set QDAC MSD to Q 0.2 using U143, set ACG=3, enable AtnTst shunt, U411 reads magnitude; then set U143 to Q 0.0 and set U140C to Q 1.0	QDAC MSD generates correct 2/1 ratio	U135, U140, U142
<i>Test gain ratios of second MSD of QDAC</i>			
63.11	Set MSD of QDAC to Q -0.1 using U143, set ACG=0, U411 reads magnitude, then set U143 to Q 0.0 and set 2nd MSD of QDAC to Q 1.0 using U144	QDAC MSD relative to 2nd MSD generates correct 1/1 ratio	U135, U144, U134
63.12	Set QDAC 2nd MSD to Q 1.0 using U144, set ACG=0, U411 reads magnitude; then set U144 to Q 0.8	QDAC 2nd MSD generates correct 10/8 ratio	U135, U144, U134
63.13	Set QDAC 2nd MSD to Q 0.8 using U144, set ACG=0, U411 reads magnitude; then set U144 to Q 0.6	QDAC 2nd MSD generates correct 8/6 ratio	U135, U144, U134
63.14	Set QDAC 2nd MSD to Q 0.6 using U144, set ACG=0, U411 reads magnitude; then set U144 to Q 0.4	QDAC 2nd MSD generates correct 6/4 ratio	U135, U144, U134
63.15	Set QDAC 2nd MSD to Q 0.4 using U144, set ACG=1, U411 reads magnitude; then set U144 to Q 0.2	QDAC 2nd MSD generates correct 4/2 ratio	U135, U144, U134
63.16	Set QDAC 2nd MSD to Q 0.2 using U144, set ACG=2, U411 reads magnitude; then set U144 to Q -0.1	QDAC 2nd MSD generates correct 2/1 ratio	U135, U144, U134
63.17	Set QDAC 2nd MSD to Q 0.2 using U144, set ACG=2, U411 reads magnitude; then set U144 to Q 0.0 and set U140A to Q 1.0	QDAC 2nd MSD generates correct 2/1 ratio	U135, U140
<i>Test gain ratios of third MSD of QDAC</i>			
63.21	Set 2nd MSD of QDAC to Q -0.1 using U144, set ACG=2, U411 reads magnitude; then set U144 to Q 0.0 and set 3rd MSD of QDAC to Q 1.0 using U145	QDAC 2nd MSD relative to 3rd MSD generates correct 1/1 ratio	U137, U145
63.22	Set QDAC 3rd MSD to Q 1.0 using U145, set ACG=2, U411 reads magnitude; then set U145 to Q 0.8	QDAC 3rd MSD generates correct 10/8 ratio	U137, U145
63.23	Set QDAC 3rd MSD to Q 0.8 using U145, set ACG=2, U411 reads magnitude; then set U145 to Q 0.6	QDAC 3rd MSD generates correct 8/6 ratio	U137, U145
63.24	Set QDAC 3rd MSD to Q 0.6 using U145, set ACG=2, U411 reads magnitude; then set U145 to Q 0.4	QDAC 3rd MSD generates correct 6/4 ratio	U137, U145
63.25	Set QDAC 3rd MSD to Q 0.4 using U145, set ACG=3, U411 reads magnitude; then set U145 to Q 0.2	QDAC 3rd MSD generates correct 4/2 ratio	U137, U145
63.26	Set QDAC 3rd MSD to Q 0.2 using U145, set ACG=4, U411 reads magnitude; then set U145 to Q -0.1	QDAC 3rd MSD generates correct 2/1 ratio	U137, U145

Table 11-20 Voltage Ratio DAC tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
63.27	Set QDAC 3rd MSD to Q 0.2 using U145, set ACG=4, U411 reads magnitude; then set U145 to Q 0.0 and set U140B to Q 1.0	QDAC 3rd MSD generates correct 2/1 ratio	U137, U140
<i>Test gain ratios of fourth MSD of QDAC</i>			
63.31	Set 3rd MSD of QDAC to Q -0.1 using U145, set ACG=4, U411 reads magnitude; then set U145 to Q 0.0 and set 4th MSD of QDAC to Q 1.0 using U146	QDAC 3rd MSD relative to 4th MSD generates correct 1/1 ratio	U137, U146
63.32	Set QDAC 4th MSD to Q 1.0 using U146, set ACG=4, U411 reads magnitude; then set U146 to Q 0.8	QDAC 4th MSD generates correct 10/8 ratio	U137, U146
63.33	Set QDAC 4th MSD to Q 0.8 using U146, set ACG=4, U411 reads magnitude; then set U146 to Q 0.6	QDAC 4th MSD generates correct 8/6 ratio	U137, U146
63.34	Set QDAC 4th MSD to Q 0.6 using U146, set ACG=4, U411 reads magnitude; then set U146 to Q 0.4	QDAC 4th MSD generates correct 6/4 ratio	U137, U146
63.35	Set QDAC 4th MSD to Q 0.4 using U146, set ACG=5, U411 reads magnitude; then set U146 to Q 0.2	QDAC 4th MSD generates correct 4/2 ratio	U137, U146
63.36	Set QDAC 4th MSD to Q 0.2 using U146, set ACG=6, U411 reads magnitude; then set U146 to Q -0.1	QDAC 4th MSD generates correct 2/1 ratio	U137, U146
63.37	Set QDAC 4th MSD to Q 0.2 using U146, set ACG=6, U411 reads magnitude; then set U146 to Q 0.0 and set U149C to Q 1.0	QDAC 4th MSD generates correct 2/1 ratio	U137, U149
<i>Test gain ratios of fifth MSD of QDAC</i>			
63.41	Set 4th MSD of QDAC to Q -0.1 using U146, set ACG=4, U411 reads magnitude; then set U146 to Q 0.0 and set 5th MSD of QDAC to Q 1.0 using U147	QDAC 4th MSD relative to 5th MSD generates correct 1/1 ratio	U139, U147
63.42	Set QDAC 5th MSD to Q 1.0 using U147, set ACG=4, U411 reads magnitude; then set U147 to Q 0.8	QDAC 5th MSD generates correct 10/8 ratio	U139, U147
63.43	Set QDAC 5th MSD to Q 0.8 using U147, set ACG=4, U411 reads magnitude; then set U147 to Q 0.6	QDAC 5th MSD generates correct 8/6 ratio	U139, U147
63.44	Set QDAC 5th MSD to Q 0.6 using U147, set ACG=4, U411 reads magnitude; then set U147 to Q 0.4	QDAC 5th MSD generates correct 6/4 ratio	U139, U147
63.45	Set QDAC 5th MSD to Q 0.4 using U147, set ACG=5, U411 reads magnitude; then set U147 to Q 0.2	QDAC 5th MSD generates correct 4/2 ratio	U139, U147
63.46	Set QDAC 5th MSD to Q 0.2 using U147, set ACG=6, U411 reads magnitude; then set U147 to Q -0.1	QDAC 5th MSD generates correct 2/1 ratio	U139, U147
63.47	Set QDAC 5th MSD to Q 0.2 using U147, set ACG=6, U411 reads magnitude; then set U147 to Q 0.0 and set U149B to Q 1.0	QDAC 5th MSD generates correct 2/1 ratio	U139, U149
<i>Test gain ratios of sixth MSD of QDAC</i>			
63.51	Set QDAC 5th MSD to Q 1.0 using U149B, set ACG=6, U411 reads magnitude; then set U149B to Q 0.0 and set QDAC 6th MSD using U149A to Q 1.0 and U148 to IP 0.4	QDAC 5th MSD relative to 6th MSD generates correct 2/1 ratio	U139, U149, U148

Test Relay Decade (RD) for Stuck Relays

Test groups 70 and 71 use the overload detector (U105) to identify a stuck relay in either relay decade. These tests try to find a situation where more than one relay can be closed in a given RD (Relay Decade). If this occurs, the closed relays will directly short a winding of the main ratio transformer, requiring much more than the normal current to drive the transformer.

These tests operate by closing each relay in a RD one at a time. If any relay in that decade is stuck closed, then *all* the tests for that decade will fail (detect an overload) *except* for the test that attempts to close the relay that is stuck closed. Closing the relay that is already stuck closed will be the only test in the group which has only one relay closed, all other tests will have two closed (assuming only one relay is stuck closed).

Test Decade Relay Positions for any Change

Test groups 72 and 73 check for any relay that is stuck closed *or* open. This is done by comparing the case where all relays are open with the cases where each relay is closed one at a time. The tests look for *any* change between the two cases. If any change is seen, then the selection logic is capable of selecting something and a relay is capable of going from open to closed.

Test Adjacent Relays for Relative Signal Level

Test groups 74 and 75 check each RD to ensure that of any two adjacent relays, the one intended to connect to the higher transformer tap generates a signal level that is higher also.

A failure of these tests only, probably indicates that the selection logic is not selecting the right relays.

Table 11-21 Relay Decade (RD) tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
70	<i>Test MSRD for a stuck closed relay</i>		
70.1	Set MSRD to M1.0, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K121	If a relay in this decade is stuck closed, the symptom will be that OVRLD will be detected for every test for this decade except for the one that is really stuck. In other words, if just one test passes, the <i>passed</i> relay is bad.
70.2	Set MSRD to M0.9, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K122	
70.3	Set MSRD to M0.8, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K123	
70.4	Set MSRD to M0.7, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K124	
70.5	Set MSRD to M0.6, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K125	
70.6	Set MSRD to M0.5, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K126	
70.7	Set MSRD to M0.4, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K127	
70.8	Set MSRD to M0.3, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K128	
70.9	Set MSRD to M0.2, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K129	
70.10	Set MSRD to M0.1, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K130	
70.11	Set MSRD to M0.0, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K131	
70.12	Set MSRD to M-0.1, 2nd MSRD open, select I_OVRLD	Suspect on PASS: K132	
71	<i>Test second MSRD for a stuck closed relay</i>		
71.1	Set 2nd MSRD to M1.0, MSRD open, select I_OVRLD	Suspect on PASS: K101	If a relay in this decade is stuck closed, the symptom will be that OVRLD will be detected for every test for this decade except for the one that is really stuck. In other words, if just one test passes, the <i>passed</i> relay is bad.
71.2	Set 2nd MSRD to M0.9, MSRD open, select I_OVRLD	Suspect on PASS: K102	
71.3	Set 2nd MSRD to M0.8, MSRD open, select I_OVRLD	Suspect on PASS: K103	
71.4	Set 2nd MSRD to M0.7, MSRD open, select I_OVRLD	Suspect on PASS: K104	
71.5	Set 2nd MSRD to M0.6, MSRD open, select I_OVRLD	Suspect on PASS: K105	
71.6	Set 2nd MSRD to M0.5, MSRD open, select I_OVRLD	Suspect on PASS: K106	
71.7	Set 2nd MSRD to M0.4, MSRD open, select I_OVRLD	Suspect on PASS: K107	
71.8	Set 2nd MSRD to M0.3, MSRD open, select I_OVRLD	Suspect on PASS: K108	
71.9	Set 2nd MSRD to M0.2, MSRD open, select I_OVRLD	Suspect on PASS: K109	
71.10	Set 2nd MSRD to M0.1, MSRD open, select I_OVRLD	Suspect on PASS: K110	
71.11	Set 2nd MSRD to M0.0, MSRD open, select I_OVRLD	Suspect on PASS: K111	
71.12	Set 2nd MSRD to M-0.1, MSRD open, select I_OVRLD	Suspect on PASS: K112	

Table 11-21 Relay Decade (RD) tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
72	<i>Test MSRD for any change between open and selected states</i>		
72.1	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude	MSRD generates reasonable open signal	K121-132, U153, U154
72.2	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M1.0	K121 changes state	K121, U154
72.3	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.9	A/D sees a change => K122 changes state	K122, U154
72.4	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.8	A/D sees a change => K123 changes state	K123, U154
72.5	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.7	A/D sees a change => K124 changes state	K124, U154
72.6	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.6	A/D sees a change => K125 changes state	K125, U154
72.7	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.5	A/D sees a change => K126 changes state	K126, U154
72.8	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.4	A/D sees a change => K127 changes state	K127, U154
72.9	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.3	A/D sees a change => K128 changes state	K128, U154
72.10	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.2	A/D sees a change => K129 changes state	K129, U153
72.11	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.1	A/D sees a change => K130 changes state	K130, U153
72.12	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.0	A/D sees a change => K131 changes state	K131, U153
72.13	Set MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M-0.1	A/D sees a change => K132 changes state	K132, U153
73	<i>Test second MSRD for any change between open and selected states</i>		
73.1	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude	MSRD generates reasonable open signal	K101-112, U152, U153
73.2	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M1.0	A/D sees a change => K101 changes state	K101, U153
73.3	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.9	A/D sees a change => K102 changes state	K102, U153
73.4	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.8	A/D sees a change => K103 changes state	K103, U153
73.5	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.7	A/D sees a change => K104 changes state	K104, U153
73.6	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.6	A/D sees a change => K105 changes state	K105, U152
73.7	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.5	A/D sees a change => K106 changes state	K106, U152
73.8	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.4	A/D sees a change => K107 changes state	K107, U152

Table 11-21 Relay Decade (RD) tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
73.9	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.3	A/D sees a change => K108 changes state	K108, U152
73.10	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.2	A/D sees a change => K109 changes state	K109, U152
73.11	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.1	A/D sees a change => K110 changes state	K110, U152
73.12	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.0	A/D sees a change => K111 changes state	K111, U152
73.13	Set 2nd MSRD to open, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M-0.1	A/D sees a change => K112 changes state	K112, U152
74	<i>Test relative signal levels from MSRD</i>		
74.1	Set MSRD to M1.0, enable AtnTst shunt, U411 reads magnitude	MSRD generates signal, K121, p/o U153, U154	K121, U153, U154
74.2	Set MSRD to M1.0, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.9	MSRD generates 9<10, K122, p/o U154	K122, U154
74.3	Set MSRD to M0.9, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.8	MSRD generates 8<9, K123, p/o U154	K123, U154
74.4	Set MSRD to M0.8, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.7	MSRD generates 7<8, K124, p/o U154	K124, U154
74.5	Set MSRD to M0.7, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.6	MSRD generates 6<7, K125, p/o U154	K125, U154
74.6	Set MSRD to M0.6, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.5	MSRD generates 5<6, K126, p/o U154	K126, U154
74.7	Set MSRD to M0.5, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.4	MSRD generates 4<5, K127, p/o U154	K127, U154
74.8	Set MSRD to M0.4, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.3	MSRD generates 3<4, K128, p/o U154	K128, U154
74.9	Set MSRD to M0.3, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.2	MSRD generates 2<3, K129, p/o U153	K129, U153
74.10	Set MSRD to M0.2, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.1	MSRD generates 1<2, K130, p/o U153	K130, U153
74.11	Set MSRD to M0.1, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.0	MSRD generates 0<1, K131, p/o U153	K131, U153
74.12	Set MSRD to M0.0, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M-0.1	MSRD generates 0<1, K132, p/o U153	K132, U153
75	<i>Test relative signal levels from second MSRD</i>		
75.1	Set MSRD to M0.1, enable AtnTst shunt, U411 reads magnitude; then set MSRD to M0.0, 2nd MSRD to M1.0 and again read max of I & Q	2nd MSRD relative to MSRD makes 1/1 ratio, K101, p/o U153	K101, U153
75.2	Set 2nd MSRD to M1.0, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.9	2nd MSRD makes 9<10, K102, p/o U153	K102, U153
75.3	Set 2nd MSRD to M0.9, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.8	2nd MSRD makes 8<9, K103, p/o U153	K103, U153
75.4	Set 2nd MSRD to M0.8, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.7	2nd MSRD makes 7<8, K104, p/o U153	K104, U153

Table 11-21 Relay Decade (RD) tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
75.5	Set 2nd MSRD to M0.7, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.6	2nd MSRD makes 6<7, K105, p/o U152, U153	K105, U152, U153
75.6	Set 2nd MSRD to M0.6, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.5	2nd MSRD makes 5<6, K106, p/o U152	K106, U152
75.7	Set 2nd MSRD to M0.5, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.4	2nd MSRD makes 4<5, K107, p/o U152	K107, U152
75.8	Set 2nd MSRD to M0.4, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.3	2nd MSRD makes 3<4, K108, p/o U152	K108, U152
75.9	Set 2nd MSRD to M0.3, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.2	2nd MSRD makes 2<3, K109, p/o U152	K109, U152
75.10	Set 2nd MSRD to M0.2, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.1	2nd MSRD makes 1<2, K110, p/o U152	K110, U152
75.11	Set 2nd MSRD to M0.1, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M0.0	2nd MSRD makes 0<1, K111, p/o U152	K111, U152
75.12	Set 2nd MSRD to M0.0, enable AtnTst shunt, U411 reads magnitude; then set 2nd MSRD to M-0.1	2nd MSRD makes 0<1, K112, p/o U152	K112, U152

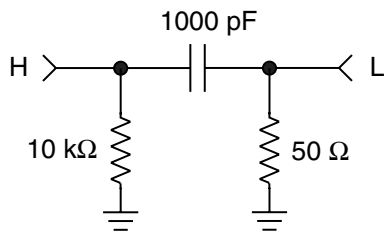


Figure 11-2 Schematic of internal PI network

Attenuator Tests

These tests should be run if an “H” error is being reported during normal measurements or if measurements cannot be made anywhere within *one* of the capacitance ranges listed in Table 4-3 on page 4-13.

The Internal PI Network

All but the first two of the group 80 series attenuator (ATN) tests connect an internal PI network between the HIGH and LOW terminals. The network consists of a 1000 pF capacitor, C607, connected between the HIGH and LOW terminals. The HIGH terminal is shunted to ground with a 10 kΩ resistor, R195. The LOW terminal is shunted to ground by a 47Ω resistor, R610. The schematic of this network is shown in Figure 11-2.

Test for Any Stuck Closed Relays in ATN

Test group 80 uses the overload detector to check for the presence of a stuck closed relay in the attenuator. Each of these two tests simply closes one of the two highest ATN relays and then checks the I_OVRLD line. If any other ATN relay is also closed, I_OVRLD will show it. This test does not identify which relay was stuck closed, only that one or more are stuck closed somewhere in the attenuator. Nevertheless, this information is useful when combined with the results of test group 82 since that group is unable to distinguish a stuck closed relay from one that is stuck open.

Test for Specific Stuck Closed or Open Relays

Two test groups are involved here. Test group 81 has one preliminary test that basically checks that the internal PI network produces the expected signal levels. This test will also fail if certain ATN relays are stuck closed, but the previous test group is more suitable for this purpose.

This test is also useful because, when it is finished, it leaves all the attenuator relays open and it leaves the 10 kΩ resistor of the PI network shunting the HIGH terminal to ground. This means that a meter reading of the AC voltage on the HIGH terminal should be less than 0.3 mV. If a higher voltage is read by the meter, then it is because an attenuator relay is stuck closed. The voltage read by the meter should be exactly the same as the transformer tap voltage selected by the stuck relay. The relationship between transformer tap voltages and the relays that select these is given in test group 82 of Table 11-22. For example, suppose the meter reads 1.5 volts. Then test number 82.4 shows that the 1.5 V transformer tap is selected by relay K116 and that is the relay that is stuck. Note that this test works well with the voltages that

Table 11-22 Attenuator tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
80	<i>Test ATN for presence of any stuck closed relays</i>		
80.1	Set both RD's open, ATN to 15V tap, select I_OVRLD	no I_OVRLD => no ATN relays stuck closed	U155, U156, K113-120, K133-36
80.2	Set both RD's open, ATN to 7.5V tap, select I_OVRLD		
81	<i>Test ATN for stuck closed relays and set up for meter measurement</i>		
81.1	Connect internal PI network, set ATN to open, U411 reads magnitude	No ATN relays 0.03V or greater stuck closed	U155, U156, K113-120, K133-36
82	<i>Test ATN for a stuck open or closed relay</i>		
82.1	Connect internal PI network, set ATN to open, U411 reads magnitude, then set ATN to 15V tap	All taps open vs. ATN at 15V tap changes reading	U155, K113 stuck open or closed
82.2	Connect internal PI network, set ATN to open, U411 reads magnitude, then set ATN to 7.5V tap	All taps open vs. ATN at 7.5V tap changes reading	U156, K114 stuck open or closed
82.3	Connect internal PI network, set ATN to open, U411 reads magnitude, then set ATN to 3.0V tap	All taps open vs. ATN at 3.0V tap changes reading	U156, K116 stuck open or closed
82.4	Connect internal PI network, set ATN to open, U411 reads magnitude, then set ATN to 1.5V tap	All taps open vs. ATN at 1.5V tap changes reading	U156, K115 stuck open or closed
82.5	Connect internal PI network, set ATN to open, U411 reads magnitude, then set ATN to 0.75V tap	All taps open vs. ATN at 0.75V changes reading	U155, K117 stuck open or closed
82.6	Connect internal PI network, set ATN to open, U411 reads magnitude, then set ATN to 0.25V tap	All taps open vs. ATN at 0.25V changes reading	U155, K118 stuck open or closed
82.7	Connect internal PI network, set ATN to open, U411 reads magnitude, then set ATN to 0.1V tap	All taps open vs. ATN at 0.1V tap changes reading	U155, K119 stuck open or closed
82.8	Connect internal PI network, set ATN to open, U411 reads magnitude, then set ATN to 0.03V tap	ATN taps open vs. ATN at 0.03V changes reading	U155, K120 stuck open or closed
82.9	Connect internal PI network, set ATN to open, U411 reads magnitude, then set ATN to 0.01V tap	All taps open vs. ATN at 0.01V changes reading	U155, K133 stuck open or closed
82.10	Connect internal PI network, set ATN to open, U411 reads magnitude, then set ATN to 0.003V tap	All taps open vs. ATN at 0.003V changes reading	U156, K134 stuck open or closed
82.11	Connect internal PI network, set ATN to open, U411 reads magnitude, then set ATN to 0.001V tap	All taps open vs. ATN at 0.001V changes reading	U156, K135 stuck open or closed
83	<i>Test ATN for correct voltage ratios</i>		
83.1	Connect internal PI network, set ATN to 15V tap; U411 reads magnitude	Reading is within expected range	U155, K113

Table 11-22 Attenuator tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
83.2	Connect internal PI network, set ATN to 15V tap, U411 reads magnitude; then set ATN to 7.5V tap	15/7.5 ratio is correct	U155, U156, K113, K114
83.3	Connect internal PI network, set ATN to 7.5V tap, U411 reads magnitude; then set ATN to 3.0V tap	7.5/3.0 ratio is correct	U156, K114, K116
83.4	Connect internal PI network, set ATN to 3.0V tap, U411 reads magnitude; then set ATN to 1.5V tap	3.0/1.5 ratio is correct	U156, K115, K116
83.5	Connect internal PI network, set ATN to 1.5V tap, U411 reads magnitude; then set ATN to 0.75V tap	1.5/0.75 ratio is correct	U155, U156, K115, K117
83.6	Connect internal PI network, set ATN to 0.75V tap, U411 reads magnitude; then set ATN to 0.25V	0.75/0.25 ratio is correct	U155, K117, K118
83.7	Connect internal PI network, set ATN to 0.25V tap, U411 reads magnitude; then set ATN to 0.1V tap	0.25/0.1 ratio is correct	U155, K118, K119
83.8	Connect internal PI network, set ATN to 0.1V tap, U411 reads magnitude; then set ATN to 0.03V tap	0.1/0.03 ratio is correct	U155, K119, K120
83.9	Connect internal PI network, set ATN to 0.03V tap, U411 reads magnitude; then set ATN to 0.01V	0.03/0.01 ratio is correct	U155, K120, K133
83.10	Connect internal PI network, set ATN to 0.01V tap, U411 reads magnitude; then set ATN to 0.003V	0.01/0.003 ratio is correct	U155, U156, K133, K134
83.11	Connect internal PI network, set ATN to 0.003V tap, U411 reads magnitude; then set ATN to 0.001V	0.003/0.001 ratio is correct	U156, K134, K135

come from higher transformer taps, but the lowest taps produce so little voltage that this test will be difficult to use.

Test group 82 contains tests that check each ATN relay one by one. These tests check for any relay that is stuck closed *or* open. Each test first sets all ATN relays open, then reads the same signal magnitude that was read in the previous test group (81). Each test then compares this baseline reading with the magnitude reading taken with one relay closed. If *any* change in the reading is detected, the test passes. The detection of a change indicates that the selection logic is capable of selecting something and a relay is capable of going from open to closed.

Check Attenuator Voltage Ratios

Test group 83 compares the voltages produced by adjacent attenuator settings. Test 83.1 just uses the A/D to measure the signal magnitude resulting from setting the ATN to 15 V tap but with reduced drive so the output is about 7.5 volts. This value is also measured as the starting point for test 83.2 which checks the 15/7.5 tap ratio.

In each test of group 83 but the first, the A/D reads the voltages produced by adjacent attenuator settings, calculates the ratio and compares it against the expected value. These tests are not intended to detect small errors in the ratios; that is the job of the verification/calibration routines. A failure of these tests only, probably indicates that the selection logic is not selecting the right relays.

Attenuator Relay Pair Tests

Test groups 84 and 85 take a close look at the resistance of the attenuator relay contacts and of the repeatability of those contact resistances, respectively.

These tests operate the attenuator relays in an unusual manner. In normal operation, only one attenuator relay is closed at a time. Closing more than one at a time could damage the relay contacts due to the high currents that might flow. Nevertheless, each of these tests involves closing two relays at a time, but the voltage applied to the main ratio transformer is limited so that no damage occurs. This method causes enough current to flow through the relay contacts to get reasonable measurements of the very low contact resistance of these relays.

Each of these tests pairs the relay under test with a “buddy” relay. In each test, the buddy relay is first closed followed by operations that are performed on the relay under test. If a test fails, there is no way to know from that test alone whether the failure occurred in the relay under test or in its buddy. For this reason, each relay under test is paired with two buddies. The first twelve tests in each test group use one set of buddies while the second twelve tests use the other set of buddies.

Each test connects the internal pi network to the input of the preamp so that the low signal levels at the output of the attenuator relays can be measured.

In test group 84, the voltage produced by the closure of the buddy relay is compared with the voltage produced with both

the buddy relay and the relay under test closed. There should be a substantial difference in voltage at the H terminal between these two cases unless the relay under test has a much higher resistance than the buddy relay.

In test group 85, the voltage is read with both the buddy relay and the relay under test closed. The relay under test is then

opened and re-closed and the voltage read again. If the contact resistance of the relay under test is repeatable, then the ratio of the two readings should be one. If there is any concern about the reliability of these relays and since repeatability is, by its nature, a statistical property, this test group should be run a number of times to get better statistics.

Table 11-23 Attenuator relay pair tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
84	<i>Test voltage ratio with open vs. closed relay</i>		
84.1	Connect internal PI net, close K114 buddy, U411 reads mag; then close K113, read mag again, calculate ratio of readings	Correct ratio => K113 and K114 have low ohms	K113 or K114
84.2	Connect internal PI net, close K113 buddy, U411 reads mag; then close K114, read mag again, calculate ratio of readings	Correct ratio => K113 and K114 have low ohms	K113 or K114
84.3	Connect internal PI net, close K114 buddy, U411 reads mag; then close K116, read mag again, calculate ratio of readings	Correct ratio => K114 and K116 have low ohms	K114 or K116
84.4	Connect internal PI net, close K116 buddy, U411 reads mag; then close K115, read mag again, calculate ratio of readings	Correct ratio => K115 and K116 have low ohms	K115 or K116
84.5	Connect internal PI net, close K119 buddy, U411 reads mag; then close K117, read mag again, calculate ratio of readings	Correct ratio => K117 and K119 have low ohms	K117 or K119
84.6	Connect internal PI net, close K119 buddy, U411 reads mag; then close K118, read mag again, calculate ratio of readings	Correct ratio => K118 and K119 have low ohms	K118 or K119
84.7	Connect internal PI net, close K120 buddy, U411 reads mag; then close K119, read mag again, calculate ratio of readings	Correct ratio => K119 and K120 have low ohms	K119 or K120
84.8	Connect internal PI net, close K119 buddy, U411 reads mag; then close K120, read mag again, calculate ratio of readings	Correct ratio => K119 and K120 have low ohms	K119 or K120
84.9	Connect internal PI net, close K119 buddy, U411 reads mag; then close K133, read mag again, calculate ratio of readings	Correct ratio => K119 and K133 have low ohms	K119 or K133
84.10	Connect internal PI net, close K119 buddy, U411 reads mag; then close K134, read mag again, calculate ratio of readings	Correct ratio => K119 and K134 have low ohms	K119 or K134
84.11	Connect internal PI net, close K119 buddy, U411 reads mag; then close K135, read mag again, calculate ratio of readings	Correct ratio => K119 and K135 have low ohms	K119 or K135
84.12	Connect internal PI net, close K119 buddy, U411 reads mag; then close K136, read mag again, calculate ratio of readings	Correct ratio => K119 and K136 have low ohms	K119 or K136
84.21	Connect internal PI net, close K116 buddy, U411 reads mag; then close K113, read mag again, calculate ratio of readings	Correct ratio => K113 and K116 have low ohms	K113 or K116
84.22	Connect internal PI net, close K116 buddy, U411 reads mag; then close K114, read mag again, calculate ratio of readings	Correct ratio => K114 and K116 have low ohms	K114 or K116
84.23	Connect internal PI net, close K113 buddy, U411 reads mag; then close K116, read mag again, calculate ratio of readings	Correct ratio => K113 and K116 have low ohms	K113 or K116
84.24	Connect internal PI net, close K114 buddy, U411 reads mag; then close K115, read mag again, calculate ratio of readings	Correct ratio => K114 and K116 have low ohms	K114 or K116
84.25	Connect internal PI net, close K118 buddy, U411 reads mag; then close K117, read mag again, calculate ratio of readings	Correct ratio => K118 and K119 have low ohms	K118 or K119
84.26	Connect internal PI net, close K117 buddy, U411 reads mag; then close K118, read mag again, calculate ratio of readings	Correct ratio => K117 and K118 have low ohms	K117 or K118
84.27	Connect internal PI net, close K133 buddy, U411 reads mag; then close K119, read mag again, calculate ratio of readings	Correct ratio => K119 and K133 have low ohms	K119 or K133

Table 11-23 Attenuator relay pair tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
84.28	Connect internal PI net, close K133 buddy, U411 reads mag; then close K120, read mag again, calculate ratio of readings	Correct ratio => K120 and K133 have low ohms	K120 or K133
84.29	Connect internal PI net, close K120 buddy, U411 reads mag; then close K133, read mag again, calculate ratio of readings	Correct ratio => K120 and K133 have low ohms	K120 or K133
84.30	Connect internal PI net, close K120 buddy, U411 reads mag; then close K134, read mag again, calculate ratio of readings	Correct ratio => K120 and K134 have low ohms	K120 or K134
84.31	Connect internal PI net, close K120 buddy, U411 reads mag; then close K135, read mag again, calculate ratio of readings	Correct ratio => K120 and K135 have low ohms	K120 or K135
84.32	Connect internal PI net, close K120 buddy, U411 reads mag; then close K136, read mag again, calculate ratio of readings	Correct ratio => K120 and K136 have low ohms	K120 or K136
85	<i>Test repeatability</i>		
85.1	Connect internal PI net, close K114 buddy, U411 reads mag; then open and close K113, read mag again, calculate ratio	Correct ratio => K113 has repeatable low ohms	K113
85.2	Connect internal PI net, close K113 buddy, U411 reads mag; then open and close K114, read mag again, calculate ratio	Correct ratio => K114 has repeatable low ohms	K114
85.3	Connect internal PI net, close K114 buddy, U411 reads mag; then open and close K116, read mag again, calculate ratio	Correct ratio => K116 has repeatable low ohms	K116
85.4	Connect internal PI net, close K116 buddy, U411 reads mag; then open and close K115, read mag again, calculate ratio	Correct ratio => K115 has repeatable low ohms	K115
85.5	Connect internal PI net, close K119 buddy, U411 reads mag; then open and close K117, read mag again, calculate ratio	Correct ratio => K117 has repeatable low ohms	K117
85.6	Connect internal PI net, close K119 buddy, U411 reads mag; then open and close K118, read mag again, calculate ratio	Correct ratio => K118 has repeatable low ohms	K118
85.7	Connect internal PI net, close K120 buddy, U411 reads mag; then open and close K119, read mag again, calculate ratio	Correct ratio => K119 has repeatable low ohms	K119
85.8	Connect internal PI net, close K119 buddy, U411 reads mag; then open and close K120, read mag again, calculate ratio	Correct ratio => K120 has repeatable low ohms	K120
85.9	Connect internal PI net, close K119 buddy, U411 reads mag; then open and close K133, read mag again, calculate ratio	Correct ratio => K133 has repeatable low ohms	K133
85.10	Connect internal PI net, close K119 buddy, U411 reads mag; then open and close K134, read mag again, calculate ratio	Correct ratio => K134 has repeatable low ohms	K134
85.11	Connect internal PI net, close K119 buddy, U411 reads mag; then open and close K135, read mag again, calculate ratio	Correct ratio => K135 has repeatable low ohms	K135
85.12	Connect internal PI net, close K119 buddy, U411 reads mag; then open and close K136, read mag again, calculate ratio	Correct ratio => K136 has repeatable low ohms	K136
85.21	Connect internal PI net, close K116 buddy, U411 reads mag; then open and close K113, read mag again, calculate ratio	Correct ratio => K113 has repeatable low ohms	K113
85.22	Connect internal PI net, close K116 buddy, U411 reads mag; then open and close K114, read mag again, calculate ratio	Correct ratio => K114 has repeatable low ohms	K114
85.23	Connect internal PI net, close K113 buddy, U411 reads mag; then open and close K116, read mag again, calculate ratio	Correct ratio => K116 has repeatable low ohms	K116
85.24	Connect internal PI net, close K114 buddy, U411 reads mag; then open and close K115, read mag again, calculate ratio	Correct ratio => K115 has repeatable low ohms	K115
85.25	Connect internal PI net, close K118 buddy, U411 reads mag; then open and close K117, read mag again, calculate ratio	Correct ratio => K117 has repeatable low ohms	K117

Table 11-23 Attenuator relay pair tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
85.26	Connect internal PI net, close K117 buddy, U411 reads mag; then open and close K118, read mag again, calculate ratio	Correct ratio => K118 has repeatable low ohms	K118
85.27	Connect internal PI net, close K133 buddy, U411 reads mag; then open and close K119, read mag again, calculate ratio	Correct ratio => K119 has repeatable low ohms	K119
85.28	Connect internal PI net, close K133 buddy, U411 reads mag; then open and close K120, read mag again, calculate ratio	Correct ratio => K120 has repeatable low ohms	K120
85.29	Connect internal PI net, close K120 buddy, U411 reads mag; then open and close K133, read mag again, calculate ratio	Correct ratio => K133 has repeatable low ohms	K133
85.30	Connect internal PI net, close K120 buddy, U411 reads mag; then open and close K134, read mag again, calculate ratio	Correct ratio => K134 has repeatable low ohms	K134
85.31	Connect internal PI net, close K120 buddy, U411 reads mag; then open and close K135, read mag again, calculate ratio	Correct ratio => K135 has repeatable low ohms	K135
85.32	Connect internal PI net, close K120 buddy, U411 reads mag; then open and close K136, read mag again, calculate ratio	Correct ratio => K136 has repeatable low ohms	K136

A single, infrequent, incident of a failed test will not provide enough information to conclusively identify a bad relay. It will suggest but not prove that the relay under test is unreliable. The failed test and some or all related tests should be put in a test loop and exercised to try to identify the culprit. This may reveal a bad relay, but exercising these relays can also have a healing effect that may last for months.

Analog Output Tests

Test groups 90 and 91 check the two analog output channels by using the A/D (U421) to read various voltages that the analog output CODECS are programmed to generate. All but two of these tests simply read the same channel on which the signal was generated. The two exceptions are tests 90.2 and 91.2 which check for a cross-connection by looking for zero volts on one channel while 6.0 volts is generated on the *other* channel. Tests 90.1 - 90.4 and 91.1 - 91.4 check for broad ranges of voltage. The polarity must be correct and a large voltage variation is acceptable. Tests 90.5, 90.6, 91.5, 91.6 are more demanding. They each measure the output voltage for a specific code then scale to get +/- 10.5 volts and measure to check that the full range can actually be obtained.

These tests should pass with a cable connected to the analog output connector provided that this connection does not cause too much resistive or capacitive loading.



Exercising the AH2700A relays may be beneficial within limits. Exercising them for many days will begin to shorten their life. When exercising relays, it is a good idea not to set TstTotal = 0 so that the bridge does not run for days unintentionally.

Table 11-24 Analog output tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
90	<i>Test analog output capacitance channel</i>		
90.1	CODECS U411, U416 generate 0.0V, set A/D to read CAPFDBCK signal	U411 can generate 0.0V; A/D correctly reads it	U411-U414, U418
90.2	CODEC U411 generates 0.0V, U416 generates 6.0V, set A/D to read CAPFDBCK signal	There is isolation between Cap and Loss	U411-U414, U418
90.3	CODEC U411 generates 6.0V, U416 generates 0.0V, set A/D to read CAPFDBCK signal	U411 can generate 6.0V; A/D correctly reads it	U411-U414, U418
90.4	CODEC U411 generates -6.0V, U416 generates 0.0V, set A/D to read CAPFDBCK signal	U411 can generate -6.0V; A/D correctly reads it	U411-U414, U418
90.5	CODECS U411, U416 generate +10.5V, set A/D to read CAPFDBCK signal	U411 can generate 10.5V; A/D correctly reads it	U411-U414, U418

Table 11-24 Analog output tests

Test no.	Description	Parts/signals verified on PASS	Parts/signals suspect on FAIL
90.6	CODECS U411, U416 generate -10.5V, set A/D to read CAPFDBCK signal	U411 can make -10.5V; A/D correctly reads it	U411-U414, U418
91	<i>Test analog output loss channel</i>		
91.1	CODECS U411, U416 generate 0.0V, set A/D to read CAPFDBCK signal	U416 can generate 0.0V; A/D correctly reads it	U412, U415-U418
91.2	CODEC U416 generates 0.0V, U411 generates 6.0V, set A/D to read CAPFDBCK signal	U416 can generate 0.0V; A/D correctly reads it	U412, U415-U418
91.3	CODEC U416 generates 6.0V, U411 generates 0.0V, set A/D to read CAPFDBCK signal	U416 can generate 6.0V; A/D correctly reads it	U412, U415-U418
91.4	CODEC U416 generates -6.0V, U411 generates 0.0V, set A/D to read CAPFDBCK signal	U416 can generate -6.0V; A/D correctly reads it	U412, U415-U418
91.5	CODECS U411, U416 generate +10.5V, set A/D to read CAPFDBCK signal	U416 can generate 10.5V; A/D correctly reads it	U412, U415-U418
91.6	CODECS U411, U416 generate -10.5V, set A/D to read CAPFDBCK signal	U416 can make -10.5V; A/D correctly reads it	U412, U415-U418

Front of AH2700A

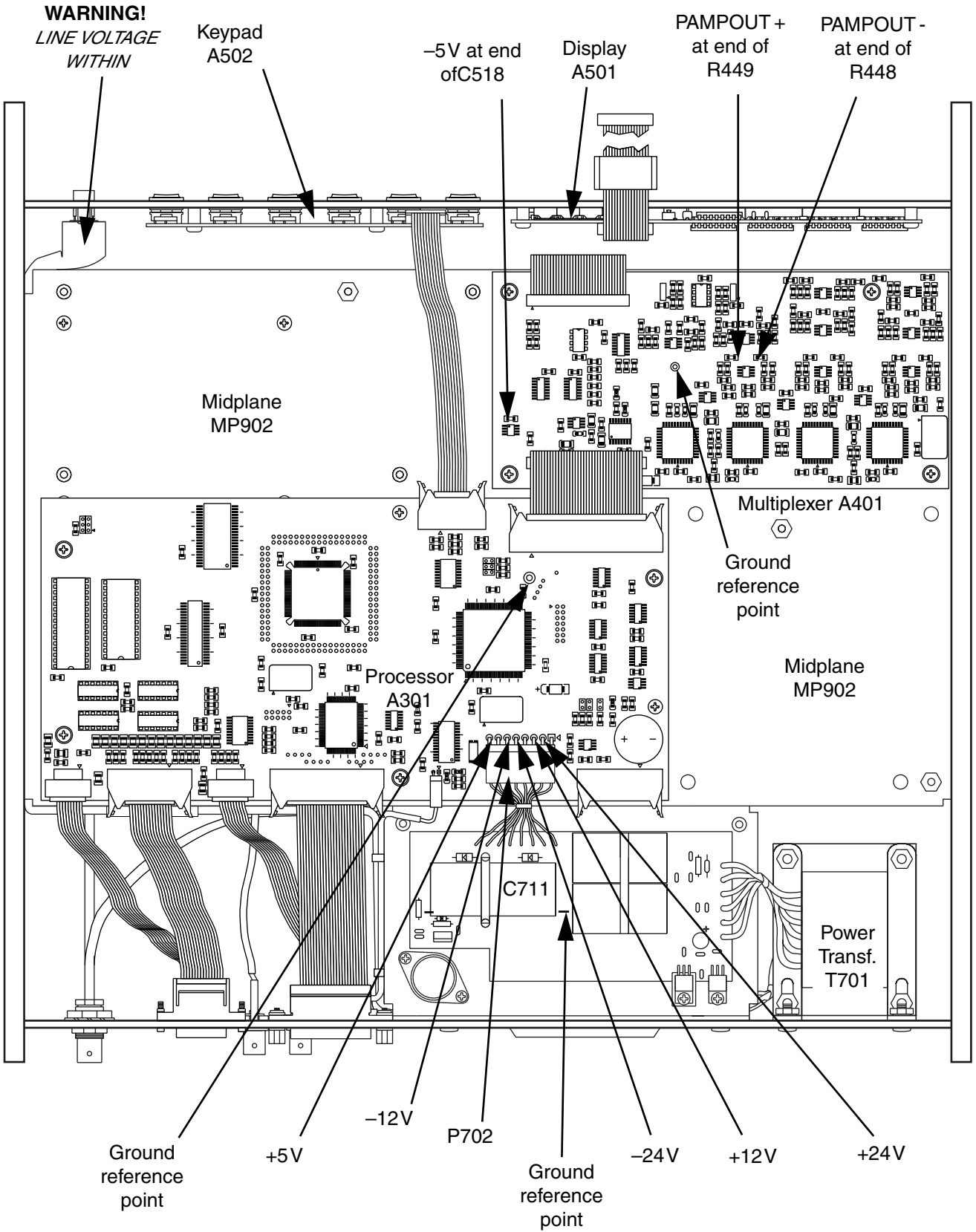


Figure 11-3 AH2700A top view showing power and other test points

Front of AH2700A

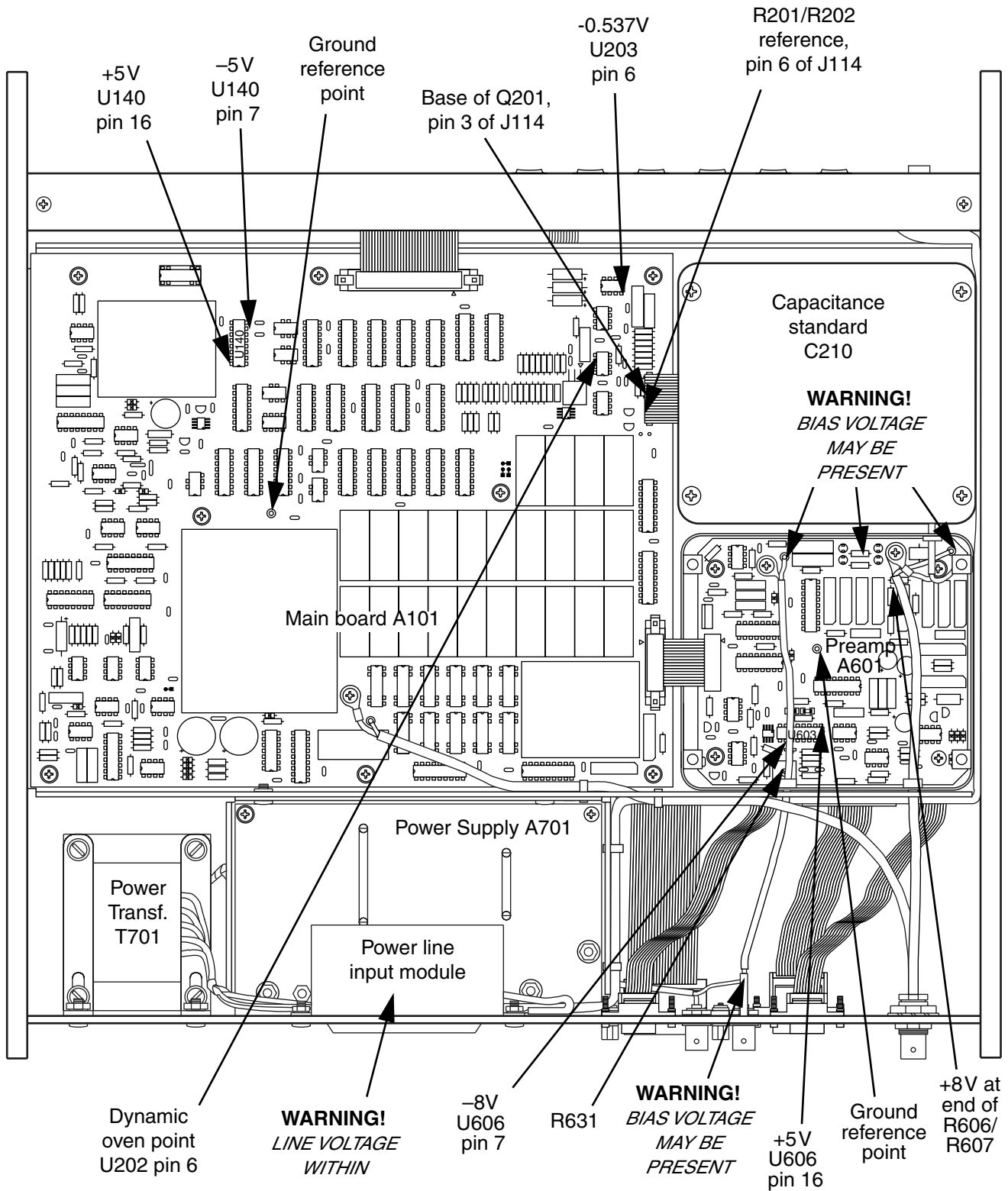


Figure 11-4 AH2700A bottom view showing power and other test points

NOTE

This chapter describes how to remove and replace the major subassemblies comprising the AH2700A that are field replaceable. Field replaceable subassemblies are those that may be replaced without adversely affecting the factory calibration. These include the power supply board (A701), processor board (A301) firmware, display board (A501), keypad board (A502), preamp board (A601), and HIGH and LOW cables (W902 and W901). Because replacement of certain other critical subassemblies will adversely affect the factory calibration, and thus must be accompanied by a replacement of the factory calibration, they are considered to be not field replaceable. This chapter includes instructions for removal and reinstallation of the major subassemblies comprising the AH2700A that not field replaceable. These instructions are appropriate for use only when there is a need to temporarily remove and then reinstall a not field replaceable subassembly (i.e. for inspection purposes). The not field replaceable subassemblies are the processor board (A301), multiplexer board (A401), main board (A101), and standard capacitor (A201).

This chapter describes how to remove and reinstall all the major subassemblies that comprise the AH2700A. For an experienced technician, much of what is described here will be obvious. However, there are a number of subtleties that are specific to the AH2700A that must be correctly dealt with if the instrument is not to be damaged and its performance is not to be impaired. For this reason, no matter how much experience you may have, you are cautioned to read the sections in this chapter that apply to any repairs that you attempt to perform.

WARNING !

The information in this section is for the use of trained service personnel only. Electrical shock and other hazards may be present. Do not attempt to perform these procedures unless you are qualified to do so. Remove the power line cord before removing the covers or removing or replacing any boards.

Tools and Equipment Required

You need the following tools to perform the disassembly/reassembly procedures that follow.

1. #2 Phillips head screwdriver.
2. Small flat blade screwdriver.
3. Torque screwdriver set to 18 in-lbs (200 N-cm) with a #2 Phillips bit.
4. Right-angle torque wrench set to 18 in-lbs (200 N-cm) with a #2 Phillips bit.
5. Right-angle torque wrench set to 75 in-lbs (800 N-cm) with a deep 5/8 inch (16 mm) hex socket.
6. Diagonal cutters.
7. Integrated circuit insertion/extraction tool for 28 & 32-pin IC for replacing firmware.
8. Soldering equipment if you are replacing the power supply (A701) assembly.

Integrated Circuit Removal Techniques

It is easy to damage a printed circuit board in the process of trying to remove an integrated circuit (IC). The damage usually results from trying to “save” the IC which requires heating all of its pins simultaneously. This is a difficult process which always applies more heat to the circuit board than is needed and often applies enough to cause damage.



CAUTION

Replacement of surface-mount (SMT) parts is a task requiring special tools and techniques, a description of which is beyond the scope of this manual. The following description applies to Dual-Inline-Package (DIP) parts only.

Since the AH2700A circuit boards are much more valuable than any IC on them, no attempt should ever be made to “save” an IC. With this philosophy, any DIP IC can easily be removed with a minimal possibility of damaging the circuit board that it is on. The steps in this process are:

1. Working from the parts-side of the circuit board with a fine pair of diagonal cutters, clip each lead of the IC that is to be removed. The clipping must be done as close to the *body* of the IC as possible. When all are clipped, the (now leadless) body of the IC will come right out.

2. A soldering iron can now heat each lead from the solder-side of the circuit board while a fine pair of pliers used from the parts-side of the board pulls the clipped lead from the plated-through hole when the solder has melted.
3. The solder is now ready to be removed from the holes, but no flux is on the solder. This will make it flow with more difficulty than otherwise. Applying a little fresh rosin-core solder to each hole will greatly improve the solder's ability to flow.
4. A solder-sucker can now remove the solder from each plated-through hole. The fresh flux applied in the previous step should cause the cleared holes to be clean and shiny.



CAUTION

To prevent static damage to the instrument, always observe the following anti-static techniques when handling any boards or assemblies.

Anti-static Handling Techniques

Electrostatic discharge (ESD) can be a cause of electronic component failure. It can occur at static levels below human perception and can affect both passive and active devices. The following guidelines should be observed when handling assemblies used in the AH2700A.

1. The workbench should be covered with a conductive mat that is connected to earth ground through a 1 Megohm resistor.
2. You should wear a conductive wrist strap that is attached to earth ground through a 1 megohm resistor.
3. Metal equipment at the workstation must be grounded, including shelving and soldering and de-soldering equipment. One common ground should be provided at the workstation.
4. Non-conductors such as plastics and cardboard should not be present at the workstation and there should not be rugs or carpet on the floor.
5. Anti-static material should always be used for shipping, storing and transporting electronic assemblies.

Hardware Used for Disassembly and Reassembly

Table 12-1 lists the hardware used in the disassembly/reassembly procedures described in this chapter.



CAUTION

The chassis of the AH2700A forms an integral part of its circuitry. Printed circuit boards and other components must make very low resistance contact at their points of attachment to the chassis. All screws that are loosened must be re-tightened to the value of torque specified by the procedures. Failure to do so can cause subtle performance problems. (Don't even think about not installing all the screws!)

Screws holding printed circuit boards will become looser with time due to relaxation in the circuit board. This is acceptable, but only emphasizes the need to fully tighten any screws that are loosened during repair.

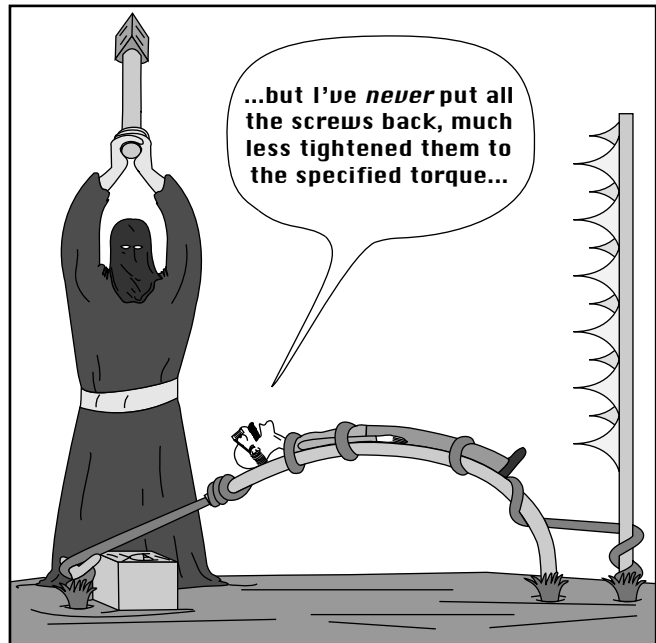


Figure 12-1 Consequences of sloppy workmanship

Table 12-1 Hardware used in disassembly/reassembly

Part	Used for
6-32 x 1/4 Phillips pan-head screw	Mounting Keypad and Display boards. Securing HIGH coaxial cable shield.
6-32 x 1/4 Phillips oval-head screw	Large, brown, vinyl-covered side panels.
6-32 x 3/8 Phillips oval-head screw	Small, brown, vinyl-covered side covers.
6-32 x 1/2 Phillips oval-head screw	Top and bottom bezels.
6-32 x 7/16 Phillips truss-head screw	Top and bottom covers.
6-32 x 3/8 Phillips pan-head screw	Mounting all boards except Keypad and Display boards. Securing LOW input shield, standard capacitor coax shield, and bias coax shield. Front feet.
8-32 x 3/8 Phillips pan-head screw	Preamp cover. Power supply assembly mounting. Lockwashers required with power supply.

REMOVAL AND INSTALLATION PROCEDURES

Removal and Installation of Covers

Prior to Cover Removal

1. Remove all external equipment connections from the AH2700A.
2. Disconnect the power line cord from the AH2700A.

Top Cover Removal Procedure

1. Place the instrument top side up with the front panel facing you.
2. Identify the two bezel screws with the help of Figure 12-2. Loosen these screws two turns.
3. Remove the four screws holding the large, brown top cover.
4. Refer to Figure 12-2. Place the instrument on end as shown in the figure, with the front panel facing down and the top cover facing you.
5. Remove the top cover by pulling straight up.

Bottom Cover Removal Procedure

1. Place the instrument bottom side up with the front panel facing you.
2. Loosen the two bottom bezel screws two turns. These screws are in a position opposing that shown in Figure 12-2.
3. Remove the four bottom cover screws holding the large, brown bottom cover.
4. Refer to Figure 12-2. Place the instrument on end as shown in the figure, with the front panel facing down but with the bottom cover facing you.
5. Remove the bottom cover by pulling straight up. If you feel resistance at about the position of the cover shown in the figure, check to see if the screws holding the front feet are interfering with the edge of the midplane or with the rear panel. If they are, pull the center of the bottom cover toward you enough to allow the screws to clear the midplane or rear panel. The midplane is easily identified as MP902 in the exploded parts view Figure F-4 on page F-11.

Top Cover Installation Procedure

1. Refer to Figure 12-2. Place the instrument on end with the front panel facing down and the top of the bridge facing you.
2. Install the top cover by sliding it *straight* down. If you feel resistance, be sure that the cover is straight. Slight misalignment is enough to cause it to bind in its track.
3. Place the bridge top side up with the front panel facing you.



CAUTION

Over-tightening the cover screws may permanently deform the cover. Use only enough force to tighten the screws and not deform the cover. DO NOT use a torque screwdriver on these screws.

4. Install but do not tighten the four 6-32 x 7/16 truss-head top cover screws.
5. Securely tighten the two screws holding the bezel.
6. Tighten the four top cover screws. See the caution above.
7. Calibration requirements for replacement of individual subassemblies are given in the associated procedures. If you are uncertain as to whether you have done anything that may require additional calibration, it is a good idea to perform verifications on the bridge as described in Chapter 9, "Verification/Calibration".

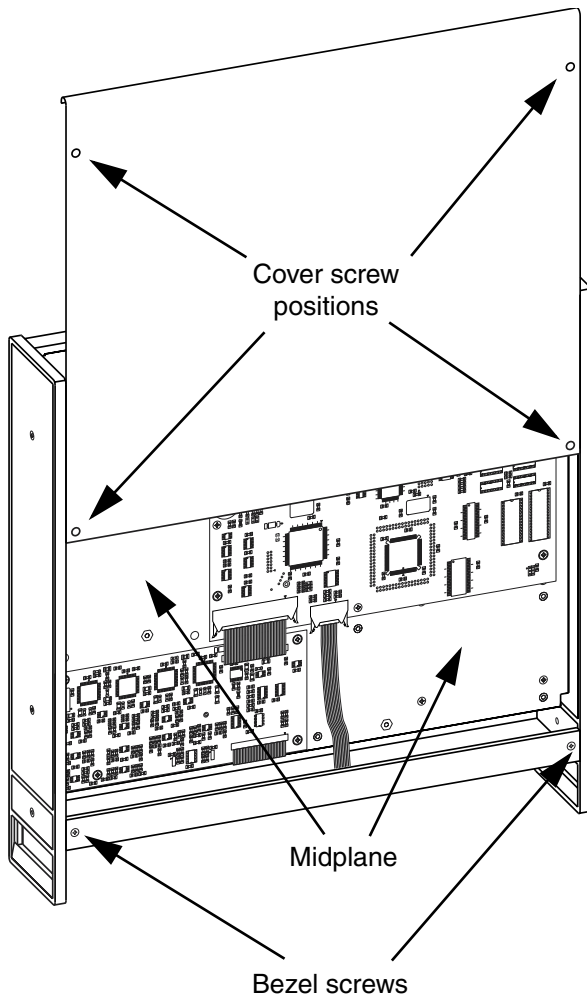


Figure 12-2 Cover removal and installation

Bottom Cover Installation Procedure

1. Refer to Figure 12-2. Place the bridge on end as shown in the figure with the front panel facing down but with the bottom of the bridge facing you.
2. Install the bottom cover by sliding it *straight* down. If you feel resistance, be sure that the cover is straight. Slight misalignment is enough to cause it to bind in its track. If you still feel resistance, check to see if the screws holding the front feet are interfering with the midplane or the rear panel. If they are, pull the center of the bottom cover towards you enough to allow the screws to clear the edge of the midplane or rear panel. The midplane is easily identified as MP902 in the exploded parts view Figure F-4 on page F-11.
3. Place the bridge bottom side up with the front panel facing you.
4. Install but do not tighten the four 6-32 x 7/16 truss-head top cover screws.



CAUTION

Over-tightening the cover screws may permanently deform the cover. Use only enough force to tighten the screws and not deform the cover. DO NOT use a torque screwdriver on these screws.

5. Securely tighten the two screws holding the bezel.
6. Tighten the four bottom cover screws. See the caution above.
7. Calibration requirements for replacement of individual subassemblies are given in the associated procedures. If you are uncertain as to whether you have done anything that may require additional calibration, it is a good idea to perform verifications on the bridge as described in Chapter 9, "Verification/Calibration".

Power Supply (A701) Removal and Installation

Power Supply Removal Procedure

1. Remove the top and bottom covers using the procedures in "Removal and Installation of Covers" on page 12-3.
2. Place the bridge bottom side up with the rear panel facing you.
3. Refer to Figure 12-3. Remove the two screws and lockwashers holding the power supply assembly to the midplane.
4. Place the bridge top side up with the rear panel facing you.
5. Unplug the power connector that is attached to J302 on the processor board (A301).
6. Using a pair of diagonal cutters, cut off the six wire leads from the power transformer secondary windings as close to the power supply board as possible.
7. Using a pair of diagonal cutters, cut off and remove the two cable ties holding the power switch cable (W701) and external trigger coaxial cable (W918).
8. Remove the two screws and lockwashers holding the power supply assembly (A701) to the rear panel and remove the power supply assembly from the bridge.

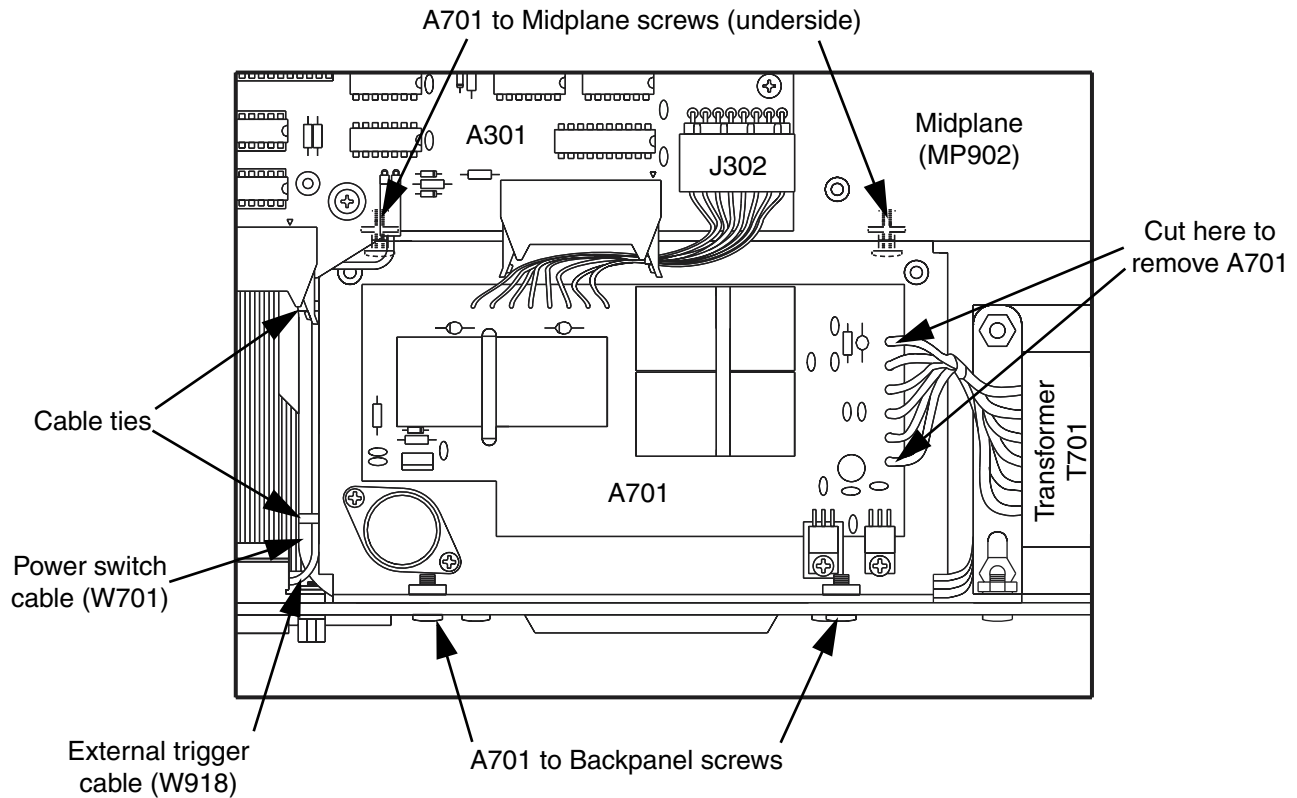


Figure 12-3 Power supply assembly (A701) detail

Power Supply Installation Procedure

1. Place the bridge top side up with the rear panel facing you.
2. Carefully strip 1/8 inch of insulation from the ends of the power strip transformer leads. This must be done *very* gently since the leads are easily pulled out of the transformer.
3. Refer to Figure 12-3. Orient the power supply assembly (A701) and place it into the bridge chassis. Install the two 8-32 x 3/8 pan-head screws and two #8 lockwashers that attach the power supply assembly to the rear panel. The lockwashers go on the outside of the back panel.
4. Plug the power connector from the power supply assembly into J302 of the processor board (A301).
5. Put the stripped ends of the power transformer leads into the holes on the power supply board according to the wire color codes near the holes. These will be soldered to the opposite side of the board.
6. Turn the bridge over so the bottom is facing up and the rear panel is towards you.
7. Install the two 8-32 x 3/8 pan-head screws and two #8 lockwashers that attach the power supply assembly to the midplane. The lockwashers must be directly under the heads of the screws.
8. Stand the bridge with the front panel facing down and the bottom of the bridge towards you.
9. Using a torque wrench, tighten these two screws and the two that attach the power supply to the rear panel to 18 in-lbs (200 N-cm).
10. Lay the bridge down with the bottom facing up and the rear panel towards you.
11. Solder the six wires from the power transformer secondary windings to the pads of the printed circuit board.
12. Using two cable ties, secure the power switch cable and the external trigger cable to the power supply assembly at each of the two sets of holes in the power supply frame.
13. Check the power supply voltages using the procedure described in "Checking Power Supply Voltages" on page 11-4.

14. If the voltages are now correct, then install the covers using the procedures in “Removal and Installation of Covers” on page 12-3.
15. If no other change was made to the bridge, the calibration should not have changed. Refer to Chapter 9, “Verification/Calibration” if you need to verify this.

Processor Board (A301) Firmware Replacement

NOTE

This is a procedure to upgrade firmware versions higher than AH2X0200. A different set of instructions is needed to upgrade from firmware versions below AH2X0200. Firmware versions above AH2X0200 use a new command syntax.

General Information

From time to time, improved firmware is made available for the Andeen-Hagerling 2700A Bridge. The firmware controls the basic operations of the instrument but an upgrade does not include calibration data and other data files on the user's instrument. So a firmware upgrade can improve performance, but re-calibration may be necessary or desirable. The owner must also determine whether an upgrade is worth doing, as this would inevitably cause disruption of an instrument in service and perhaps not fill any real needs. Andeen-Hagerling can advise the owner about the improvements in the firmware and/or the necessity to re-calibrate from any particular version to another.

There are 3 ways to install 2700A Bridge Firmware:

1. Return the unit to the factory. (Costs of round-trip shipping, customs, duties, taxes, etc., are paid by the user)
2. Obtain a new ROM chip from the factory. Install the chip in the unit.
3. Obtain the firmware from the factory as a file via e-mail. Install the file in the unit via the serial port.

The firmware replacement procedures described here may be carried out in the field without disturbing either the user's stored parameter and program files (as described in Chapter 3, “Parameter and Program Files”), or the calibration of the instrument. The rest of this document is concerned with installing firmware as a ROM chip or e-mailed file.

How Firmware Banks Work

The command `SHOW FIRMWARE` reports on the status of the three firmware banks. The instrument is running the firmware in the bank marked `ACTIVE`. Each bank contains a version of bridge firmware, or is empty. The running bank is selected (and the instrument restarted) with the command `STORE FIRMWARE RUN RunBank` where `RunBank` is ROM, FLASH1, or FLASH2.

In normal operation, FLASH1 or FLASH2 is running. The firmware in FLASH1 and FLASH2 can be changed, but only while running ROM. While running ROM, measurements are not allowed. FLASH1 and FLASH2 can be changed in two ways: either by copying from ROM with the `STORE FIRMWARE ROM, ToBank` command, or via a file transferred through the serial port with the `STORE FIRMWARE SERIAL, ToBank` command. The two FLASH banks are completely independent from each other, and each can hold a complete copy of firmware. FLASH1 and FLASH2 are provided so that a new, unfamiliar firmware version can be tried in one bank without disturbing the old, familiar version in the other bank. The old version may be restored by selecting its bank as the running bank at any time, thus aborting the installation procedure.



CAUTION

Observe the handling methods described in “Anti-static Handling Techniques” on page 12-2 when replacing the ROM.

Installing Firmware from a ROM

This procedure describes the steps required to install and activate firmware that has been supplied in the form of a replacement ROM.

For this, you need the ROM chip, a screwdriver, a chip pulling tool and the owner passcode. The procedure assumes you are typing command via a remote terminal to the bridge. Each of the command entries are to be followed by the ENTER key on your terminal. The owner passcode, or ONR CODE, is asked for several times during the upgrade. Please keep it handy during the process. When entering the owner passcode, your keystrokes will not be shown on the screen for security purposes. This will keep the passcode from being observed by unauthorized personnel. Also, please note that if typing mistakes are made during a line command (while using the PC in a terminal emulation mode), the delete or back space keys will not work unless they are set up before hand.

1. Unplug the instrument.
2. Remove the top cover using the “Top Cover Removal Procedure” on page 12-3.
3. Place the bridge top side up with the rear panel facing you.
4. Refer to Figure 12-5 on page 12-16. Locate the processor board (A301) and on it locate the ROM labeled U321. Using an integrated circuit extractor or a small flat-blade screwdriver, carefully pry the ROM loose from its socket. Make sure it comes straight up out of the socket to avoid bending the pins in case you should need to re-install it later.

5. To prevent static electricity from ruining the new ROM, touch your finger to the frame of the instrument and the package containing the new ROM.
6. Remove the replacement ROM from the conductive foam in which it is shipped and orient it so the semicircular notch indicating pin 1 faces toward you. The notch end of the ROM will match up with the notch symbol silk-screened underneath the socket if the ROM is oriented properly. Align the pins and insert the ROM into the socket U321. Make sure all of the pins are inserted in the socket holes. (Put the old chip in the package from the new chip.)
7. Replace the top cover and screws. Plug-in the instrument and turn it on.
8. Enter the command **SHOW FIRMWARE** and write down the listing from this command for later reference. *ACTIVE* indicates the bank that the instrument is running.
9. Select **FLASH1** or **FLASH2** as the destination for the new firmware. The **FLASH** bank that is not currently active is recommended as the destination for the replacement firmware. This choice provides the most straightforward path back to the previous firmware version should you encounter difficulties while attempting to copy or activate the replacement firmware.
10. Enter the command **STORE FIRMWARE RUN ROM** and enter the owner passcode, as required. The instrument will restart and run from the ROM. The prompt will change from *READY* to *READY BANK ROM* on the front panel and from ">" to "**BANK ROM>**" on remotes.
11. Enter the command **STORE FIRMWARE ROM**, *Run-Bank* where *RunBank* is **FLASH1** or **FLASH2** selected for the new firmware, and enter the owner passcode. This command copies the ROM to the selected bank and usually takes about 10 seconds (but could take much longer).
12. Enter the command **SHOW FIRMWARE** and see that the new bank has been updated,
13. Enter the command **STORE FIRMWARE RUN Bank** and the instrument will restart and run the bank selected. If the instrument reports a *CAL DATA ERROR* message, be sure to perform the calibration described below.
14. Enter the command **SHOW FIRMWARE** and see that the new bank is running.
15. If you upgraded from **FLASH1** to **FLASH2**, you can revert back to the old firmware in **FLASH1** if something goes wrong. If you upgraded from **FLASH 2** to **FLASH1**, you can revert back to **FLASH 2** if necessary. If both **FLASH1** and **FLASH2** get ruined, you can reinstall the old ROM and repeat this procedure.

To install firmware as an e-mailed file

This procedure describes the steps required to install and activate firmware that has been supplied in the form of a computer file to be downloaded from a computer through the AH2700A's serial port.

For this, you need to have a computer, serial port, cable to the instrument, a terminal emulation program, the e-mailed file, and the owner passcode. The owner passcode, or **ONR CODE**, is asked for several times during the upgrade. Please keep it handy during the process. When entering the owner passcode, your keystrokes will not be shown on the screen for security purposes. This will keep the passcode from being observed by unauthorized personnel. Also, please note that if typing mistakes are made during a line command (while using the PC in a terminal emulation mode), the delete or back space keys will not work unless they are set up before hand.

1. Copy the e-mailed file to a place that is easy to remember, such as the "Desktop" if using Windows or a Macintosh.
2. Refer to Chapter 7, "Serial Port Operation". Establish serial communication with the bridge using a terminal emulation program running on the computer that has access to a copy of the file containing the replacement firmware to be downloaded.
3. The baud rate of the terminal emulation program and the serial port must be the same. Enter the command **SHOW SERIAL** and note the baud rate. The following steps involve restarting the instrument and since the instrument's baud rate can be set temporarily, it might be changed. To be sure, enter the command **STORE SERIAL USERPON** so the current baud rate is saved permanently. The instrument's baud rate can be changed, temporarily, to 9600, for example, with the command **SERIAL BAUD 9600**.
4. Enter the command **SHOW FIRMWARE** and write down the listing from this command for later reference. *ACTIVE* indicates the bank that the instrument is running.
5. Select **FLASH1** or **FLASH2** as the destination for the new firmware. The **FLASH** bank that is not currently active is recommended as the destination for the replacement firmware. This choice provides the most straightforward path back to the previous firmware version should you encounter difficulties while attempting to copy or activate the replacement firmware.
6. Enter the command **STORE FIRMWARE RUN ROM** and enter the owner passcode, as required. The instrument will restart and run the ROM bank. The prompt will change from *READY* to *READY BANK ROM* on the front panel and from ">" to "**BANK ROM>**" on remotes.

Please note the following before proceeding

- Once the **STORE FIRMWARE SERIAL, ToBank** command and passcode are entered, the clock is ticking. The instrument waits 10 seconds then sends the letter C to signal that it is ready to receive. The instrument repeats this 10 times, waiting a total of 100 seconds before it gives up. Don't panic.
 - If 100 seconds is not enough time to start the transfer before this instrument gives up, try first setting up everything for sending with the terminal emulation program except the final keystroke, then enter the instrument's command from the front panel, then give that final keystroke.
 - If for some reason the transfer needs to be aborted, the terminal emulation program will provide a way to do this. If the instrument does not seem to respond to this, enter the device clear command from the front panel, or key in Ctrl+X on the terminal emulation program, or wait out the 100 seconds.
7. Enter the command **STORE FIRMWARE SERIAL, ToBank** where *ToBank* is FLASH1 or FLASH2 selected for the new firmware, and enter the owner passcode.
 8. Start sending the file with the terminal emulation program:
 - a. On the program's menu, find the transfer command to send a file.
 - b. Select the file (that was put on the Desktop)
 - c. Select a protocol (XMODEM or YMODEM)
 - d. Select a mode if required (BINARY is better than ASCII)
 - e. Press Enter or Return to make it go.
 9. If the transfer does not seem to work, consider these things:
 - a. If something goes wrong, the transfer must be aborted and the **STORE FIRMWARE SERIAL, ToBank** command must be redone.
 - b. If for some reason the transfer needs to be aborted, the terminal emulation program will provide a way to do this. If the instrument does not seem to respond to this, enter the device clear command from the front panel, or key in Ctrl+X on the terminal emulation program, or wait out the 100 seconds.
 - c. The terminal emulation program will show the progress of the transfer as it occurs. Be patient and let the transfer run its course. At 9600 baud and a firmware file of about 500 kbytes, the transfer may take about 10 minutes. Higher baud rates transfer quicker. YMODEM and XMODEM-1K are faster than plain XMODEM.
 - d. If the transfer fails and the terminal emulation program offers many flavors of XMODEM and YMODEM protocols, go back and re-enter the **STORE FIRMWARE**

SERIAL, ToBank command and start sending the file but try a different protocol.

e. If the transfer begins badly, the instrument preserves the bank's pre-existing contents. After that, if the transfer fails, the bank is marked "empty."

f. In rare cases, the instrument may receive the complete transfer, even if the terminal emulation program seems to fail at the very end. If this is suspected, proceed to the next step. The instrument will report the true status of the new bank.

10. Enter the command **SHOW FIRMWARE** and see that the new bank has been updated.
11. Enter the command **STORE FIRMWARE RUN RunBank**, where *RunBank* is FLASH1 or FLASH2 and the instrument will restart and run the bank selected. If the instrument reports a `CALL DATA ERROR 1` message, be sure to perform the calibration described below.
12. Enter the command **SHOW FIRMWARE** and see that the new bank is running.
13. If you upgraded from FLASH1 to FLASH 2, you can revert back to the old firmware in FLASH1 if something goes wrong. If you upgraded from FLASH2 to FLASH1, you can revert back to FLASH2 if necessary. If both FLASH1 and FLASH2 get ruined, you can reinstall the firmware from the ROM (see installing firmware from ROM procedure above, but skip physically opening the instrument) or you can get an older version from Andeen-Hagerling.

Processor Board (A301) Removal and Installation

NOTE

Because replacement of this subassembly must be accompanied by a replacement of the factory calibration, it is not field replaceable. The removal and reinstallation instructions below are appropriate for use only when there is a need to temporarily remove and then reinstall the subassembly (i.e. for inspection purposes).

Processor Board Removal Procedure

1. Remove the top cover using the "Top Cover Removal Procedure" on page 12-3.
2. Place the bridge top side up with the rear panel facing you.
3. Refer to Figure 12-5 on page 12-16. Unplug the power supply power connector from J302.

4. Unlatch and unplug the six ribbon cable assemblies in the following order from J306, J304, J303, J313, J305, J320 and J312. Unplug the external trigger cable (W918) from J318.
5. Remove the six screws holding the processor board and remove the board.

Processor Board Installation Procedure

1. Place the bridge top side up with the rear panel facing you.
2. Refer to Figure 12-5 on page 12-16. Orient the processor board (A301) and install the six 6-32 x 3/8 pan-head mounting screws.
3. Using a torque screwdriver, tighten the six screws to 18 in-lbs (200 N-cm).
4. Plug the external trigger cable (W918) into J318 of the processor board. The orientation of the plug in the socket does not matter.
5. Plug in and latch the ribbon cable from the keypad assembly (A502) into J306.
6. Plug in and latch the ribbon cable from the multiplexer assembly (A401) into J303.
7. Plug in and latch the ribbon cable from the display assembly (A501) into J304.
8. Plug in and latch the GPIB cable assembly (W913) into J313.
9. Plug in and latch the sample switch cable assembly (W905) into J305.
10. Plug in the RS-232 cable assembly (W912) into J312.
11. Plug in the Analog Output cable assembly (W920) into J320.
12. Plug in the power supply (A701) power connector into J302.
13. Install the top cover using the “Top Cover Installation Procedure” on page 12-3.
14. The bridge should now be operational. Refer to Chapter 9, “Verification/Calibration” if you need to verify this.

Display Board (A501) Removal and Installation

Display Board Removal Procedure

1. Remove both covers using the procedures in “Removal and Installation of Covers” on page 12-3.
2. Place the bridge bottom side up with the rear panel facing you.

3. Remove the two screws holding the lower edge of the display board.
4. Place the bridge top side up with the rear panel facing you.
5. Remove the two screws holding the top bezel and remove the top bezel.
6. Refer to Figure 12-5 on page 12-16. Unlatch and unplug the ribbon cable from J304 on the processor board (A301).
7. Remove the two screws holding the upper edge of the display board and remove the board.

Display Board Installation Procedure

1. Refer to Figure 12-5 on page 12-16. Orient the display board (A501) and install it from the top side of the bridge. Install the two pan-head 6-32 x 1/4 screws that hold the upper edge of the board in place.
2. Plug the display board ribbon cable into J304 on the processor board and latch it.
3. Place the bridge bottom side up with the rear panel facing you. Install the two pan-head 6-32 x 1/4 screws that hold the lower edge of the board.
4. Place the bridge on end with the front panel facing down and the bottom facing you. While supporting the front panel from below so as not to bend it, tighten the two lower screws to 18 in-lbs (200 N-cm). The front panel is easily supported by squeezing it with one hand up against the bottom bezel.
5. Turn the bridge so the front panel is facing down and the top is facing you. While again supporting the front panel from below, tighten the two upper screws to 18 in-lbs (200 N-cm).
6. Install the top bezel but do not tighten the screws.
7. Install the covers using the procedures in “Removal and Installation of Covers” on page 12-3.

Keypad Board (A502) Removal and Installation

Keypad Board Removal Procedure

1. Remove both covers using the procedures in “Removal and Installation of Covers” on page 12-3.
2. Place the bridge bottom side up with the rear panel facing you.
3. Refer to Figure 12-6 on page 12-17. Remove the bottom bezel (MP921).
4. Remove the two screws holding the lower edge of the keypad board.

- Place the bridge top side up with the rear panel facing you.
- Refer to Figure 12-5 on page 12-16. Unlatch and unplug the ribbon cable from J306 on the processor board.
- Remove the two screws holding the upper edge of the keypad board and remove the board.

Keypad Board Installation Procedure

- Place the bridge top side up with the rear panel facing you.
- Refer to Figure 12-6 on page 12-17. Orient the keypad board (A502) and install it from the top side of the bridge. Install the two pan-head 6-32 x 1/4 screws that hold the upper edge of the board in place.
- Plug the ribbon cable into J306 on the processor board (A301) and latch it.
- Place the bridge bottom side up with the rear panel facing you. Install the two pan-head 6-32 x 1/4 screws that hold the lower edge of the board.
- Turn the bridge so the front panel is facing down and the top is facing you. While supporting the front panel from below so as not to bend it, tighten the two upper screws to 18 in-lbs (200 N-cm). The front panel is easily supported by squeezing it with one hand up against the top bezel.
- Turn the bridge so the front panel is facing down and the bottom is facing you. While again supporting the front panel from below, tighten the two upper screws to 18 in-lbs (200 N-cm).
- Turn the bridge so the bottom side is up and the front panel is facing you. Install the bottom bezel but do not tighten the screws.
- Install both covers using the procedures in “Removal and Installation of Covers” on page 12-3.

Multiplexer Board (A401) Removal and Installation

NOTE

Because replacement of this subassembly must be accompanied by a replacement of the factory calibration, it is not field replaceable. The removal and reinstallation instructions below are appropriate for use only when there is a need to temporarily remove and then reinstall the subassembly (i.e. for inspection purposes).

Multiplexer Board Removal Procedure

- Remove both covers using the procedures in “Removal and Installation of Covers” on page 12-3.
- Place the bridge bottom side up with the front panel facing you.
- Refer to Figure 12-6 on page 12-17. Unlatch and unplug the ribbon cable that is attached to J110 on the main board (A101).
- Place the bridge with the top side up and the front panel facing you.
- Refer to Figure 12-5 on page 12-16. Unlatch and unplug the display board ribbon cable from J304 on the processor board to allow access to J303 on the processor board.
- Unlatch and unplug the ribbon cable that is attached to J303 on the processor board (A301).
- Remove the four screws holding the multiplexer board and remove the board.

Multiplexer Board Installation Procedure

- Place the bridge top side up with the front panel facing you.
- Refer to Figure 12-5 on page 12-16. Orient the multiplexer board (A401) and install it from the top side of the bridge. Route the ribbon cable from J410 on the multiplexer board down between the display board and the midplane. This cable will be attached to the main board (A101) later. Install the four 6-32 x 3/8 pan-head screws to hold the multiplexer board in place.
- Tighten all four screws to 18 in-lbs (200 N-cm).
- Plug the ribbon cable from J403 on the multiplexer board (A401) into J303 on the processor board (A301) and latch it.
- Plug the display board ribbon cable into J304 on the processor board and latch it.
- Turn the bridge over so the bottom side is up and the front panel is facing you.
- Refer to Figure 12-6 on page 12-17. Plug the ribbon cable from J410 on the multiplexer board into J110 on the main board (A101) and latch it.
- Install both covers using the procedures in “Removal and Installation of Covers” on page 12-3.

Main Board (A101) Removal and Installation

NOTE

Because replacement of this subassembly must be accompanied by a replacement of the factory calibration, it is not field replaceable. The removal and reinstallation instructions below are appropriate for use only when there is a need to temporarily remove and then reinstall the subassembly (i.e. for inspection purposes).

Main Board Removal Procedure

1. Remove the bottom cover using the “Bottom Cover Removal Procedure” on page 12-3.
2. Place the bridge bottom side up with the rear panel facing you.
3. Refer to Figure 12-6 on page 12-17. Unplug the HIGH coaxial cable (W902) center conductor pin from socket J111.
4. Remove the screw holding the HIGH coaxial cable (W902) shield near socket J111. Set this screw aside for later. It is shorter than all the other main board screws.
5. Unlatch and unplug the preamp (A601) ribbon cable from J107.
6. Unlatch and unplug the ribbon cable from the multiplexer board (A401) from J110.
7. Unplug the flexible circuit connector on the standard capacitor (C210) from J114 on the main board.
8. Remove the eight screws holding the main board to the midplane and remove the main board.

Main Board Installation Procedure

1. Place the bridge bottom side up with the rear panel facing you.
2. Orient the main board (A101) as shown in Figure 12-6 on page 12-17. Install the eight 6-32 x 3/8 pan-head screws holding the main board to the midplane. Then tighten these screws to 18 in-lbs (200 N-cm).
3. Plug the ribbon cable from the multiplexer board (A401) into J110 and latch it.
4. Plug the ribbon cable from the preamp board (A601) into J107 and latch it.
5. Plug the flexible circuit connector on the standard capacitor into J114 on the main board.
6. Install the 6-32 x 1/4 pan-head screw holding the HIGH coaxial cable (W901) shield near socket J111 and then tighten it to 18 in-lbs (200 N-cm).



CAUTION

DO NOT use a longer screw to hold the HIGH coaxial cable (W901) shield. This shield terminal must not short to the midplane or subtle problems will occur. A longer screw could also distort or break the main board.

7. Plug in the HIGH coaxial cable center conductor pin into socket J111.
8. Install the bottom cover using the “Bottom Cover Installation Procedure” on page 12-4.
9. After the main board has been re-installed, then only an internal calibration need be performed. An internal calibration is especially important if any parts were replaced. See “INTERNAL CALIBRATION” on page 9-4 for an explanation of this procedure.
10. If there is any reason to believe that the main board is not fully functional after having been re-installed, it may be desirable to verify the loss calibration as described in “LOSS VERIFICATION” on page 9-16.

Preamp Board (A601) Removal and Installation

Preamp Board Removal Procedure

1. Remove the bottom cover using the “Bottom Cover Removal Procedure” on page 12-3.
2. Place the bridge bottom side up with the rear panel facing you. Refer to Figure 12-6 on page 12-17.
3. **Mark the preamp cover top** so it can be replaced with the same side up. Remove the four screws holding the preamp cover to the preamp enclosure.
4. Refer to Figure 12-4. Unplug the LOW coaxial cable (W901) center conductor pin from J608.
5. Unplug the standard capacitor (C210) coaxial cable center conductor pin from J609.
6. Remove the screw holding the LOW coaxial cable shield (W901) and the standard capacitor (C210) coaxial cable shield.
7. Unlatch and unplug the ribbon cable going to J107 on the main board (A101).
8. Unplug the DC bias coaxial cable (W619) center conductor pin from J619.
9. Remove the screw holding the DC bias coaxial cable (W619) shield near J619.
10. Remove the four screws holding the preamp board (A601) and remove the board.

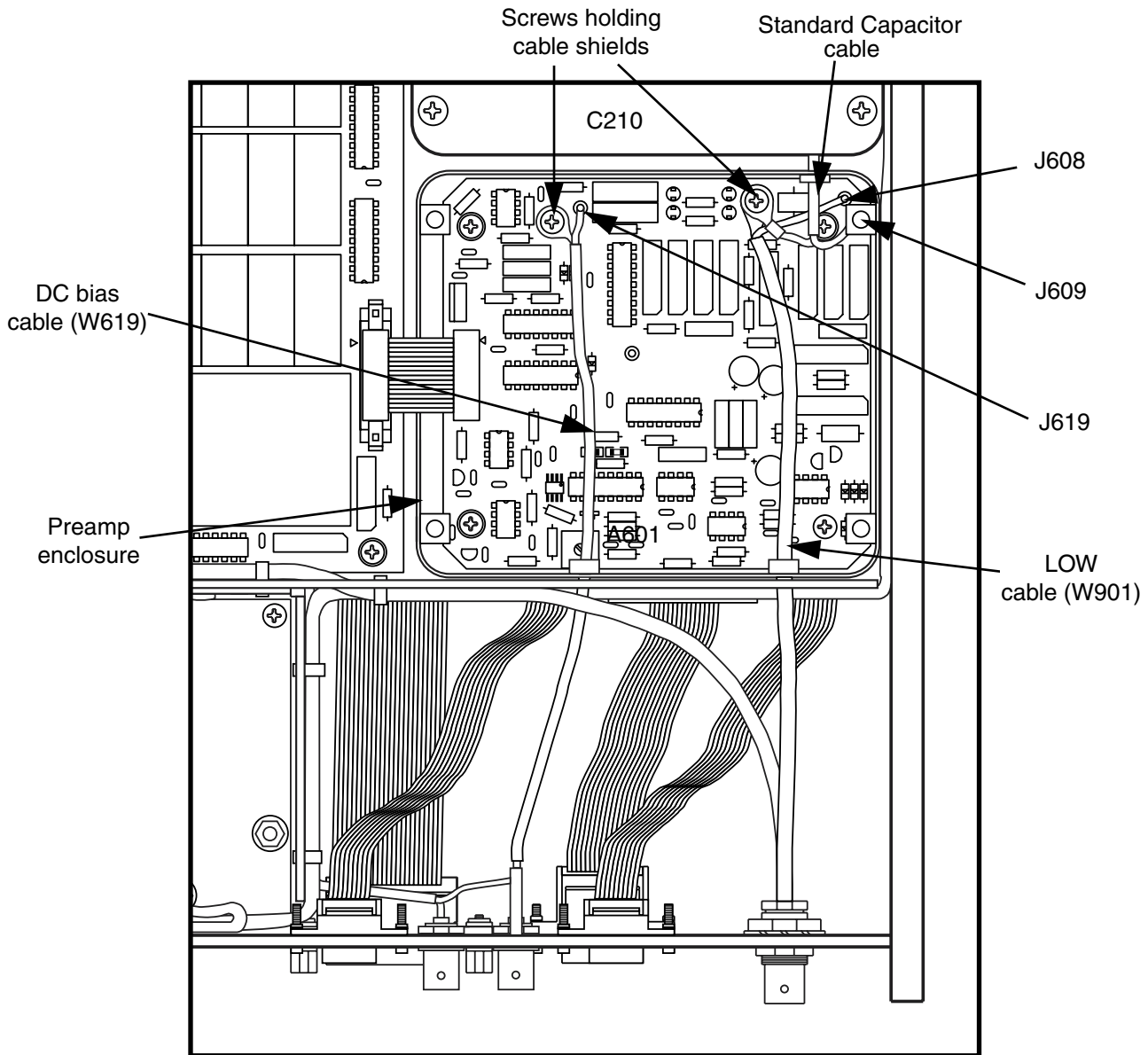


Figure 12-4 Preamp assembly (A601) detail

Preamp Board Installation Procedure

1. Place the bridge bottom side up with the rear panel facing you.
2. Orient the preamp board (A601) as shown in Figure 12-4 and install the four 6-32 x 3/8 pan-head screws holding the preamp board. Tighten these screws to 18 in-lbs (200 N-cm).
3. Install the 6-32 x 3/8 pan-head screw holding the DC bias coaxial cable (W619) shield near J619 and tighten it to 18 in-lbs (200 N-cm). Hold the terminal lug as the screw is being tightened so that the lug doesn't rotate against other parts.
4. Plug the DC bias coaxial cable center conductor pin into J619.
5. Plug the preamp board ribbon cable into J107 on the main board (A101).
6. Install the 6-32 x 3/8 pan-head screw holding the LOW coaxial cable (W901) shield and the standard capacitor (C210) coaxial cable shield. The lug on the LOW terminal cable shield should be next to the board and the lug on the standard capacitor cable shield should be on top. Orient the LOW cable and lugs as shown in the figure. Tighten the screw to 18 in-lbs (200 N-cm) while maintaining the lug orientations.
7. Install the LOW coaxial cable center conductor pin into J608.
8. Route the standard capacitor cable center conductor under the LOW terminal cable center conductor and install the pin into J609.

9. Replacement of the preamp does *not* require adjustment of the trimpot on the board. This trimpot (R631) is set at the factory and only requires adjustment if the diagnostic self-tests indicate a problem.
10. Orient the preamp cover with your marked side up. This is done to ensure that the anodizing does not prevent the cover from making good electrical contact with the preamp enclosure. Install the four 8-32 x 3/8 pan-head preamp cover screws hand tight. **DO NOT** overtighten or use a torque screwdriver. The cover will be distorted if excess torque is used.

NOTE

If the preamp cover does not make good electrical contact with the preamp enclosure, the preamp will not be adequately shielded. This can cause measurements to be noisier than they should be. If poor electrical contact is suspected, the anodizing can be broken through by rotating the four preamp screws back and forth as they are being tightened.

11. Install the bottom cover using the “Bottom Cover Installation Procedure” on page 12-4.
12. Replacement of the preamp board requires that an internal calibration be performed on the bridge. See “INTERNAL CALIBRATION” on page 9-4.

HIGH and LOW Cable (W902 and W901) Removal and Installation

HIGH and LOW Cable Removal Procedure

1. Perform steps 1-6 of the “Preamp Board Removal Procedure” on page 12-11.
2. Refer to Figure 12-6 on page 12-17. Unplug the HIGH coaxial cable (W902) center conductor pin from socket J111.
3. Remove the screw holding the HIGH coaxial cable (W902) shield near socket J111. Set this screw aside for later. It is shorter than all the other main board screws.
4. Using a pair of diagonal cutters, cut off and remove the two cable ties that hold the HIGH coaxial cable to the midplane.
5. Using a socket wrench with a 5/8 inch deep socket, remove the two nuts that hold the BNC connectors at the ends of W901 and W902 to the rear panel.
6. Remove the HIGH cable (W902) and its lockwasher.
7. Loosen the plastic bushing at the point where the LOW cable (W901) passes through the preamp enclosure. Remove the LOW cable and its lockwasher taking the bushing with them.

HIGH and LOW Cable Installation Procedure

1. Place the bridge bottom side up with the rear panel facing you.
2. Refer to Figure 12-6. Put the HIGH cable (W902) in place and route it through the long, rectangular hole in the midplane. Place the special large lockwasher between the BNC connector and the inside of the rear panel. Make sure that this area is clean and shiny since extremely good electrical contact is required.
3. Install the nut that holds the BNC connector at the end of W902 to the rear panel. Using a torque wrench with a 5/8 inch deep socket, tighten the nut to 75 in-lbs (800 N-cm).
4. Install the 6-32 x 1/4 pan-head screw holding the HIGH coaxial cable (W902) shield near socket J111 and then tighten it to 18 in-lbs (200 N-cm).



CAUTION

DO NOT use a longer screw to hold the HIGH coaxial cable (W901) shield. This shield terminal must not short to the midplane or subtle problems will occur. A longer screw could also distort or break the main board.

5. Plug in the HIGH coaxial cable center conductor pin into socket J111.
6. Use two small cable ties to hold the HIGH cable at each end of the long hole in the midplane through which this cable passes. Each tie should go through a pair of small holes in the midplane.
7. Refer to Figure 12-4. Put the LOW cable with its lockwasher and plastic bushing in place. The special large lockwasher goes between the BNC connector and the inside of the rear panel. Snap the bushing into the hole in the preamp enclosure through which the LOW cable passes.
8. Install the nut that holds the BNC connector at the end of W901 to the rear panel. Using a torque wrench with a 5/8 inch deep socket, tighten the nut to 75 in-lbs (800 N-cm).
9. Complete this procedure by performing steps 6-11 of the “Preamp Board Installation Procedure” on page 12-12.

Standard Capacitor (C210) Removal and Installation

NOTE

Because replacement of this subassembly must be accompanied by a replacement of the factory calibration, it is not field replaceable. The removal and reinstallation instructions below are appropriate for use only when there is a need to temporarily remove and then reinstall the subassembly (i.e. for inspection purposes).

NOTE

Do not open the standard capacitor assembly. There are no user-serviceable parts inside the standard capacitor assembly and opening it will void your warranty. All repairs to the standard capacitor assembly must be done by the factory.

Standard Capacitor Removal Procedure

1. Remove both covers using the procedures in “Removal and Installation of Covers” on page 12-3.
2. Remove the processor board (A301) using the “Processor Board Removal Procedure” on page 12-8.
3. Place the bridge bottom side up with the rear panel facing you.
4. **Mark the preamp cover top** so it can be replaced with the same side up. Remove the four screws holding the preamp cover to the preamp enclosure.
5. Unplug the standard capacitor (C210) coaxial cable center conductor pin from J609 on the preamp board (A601).
6. Remove the screw holding the LOW input coaxial cable shield and the standard capacitor coaxial cable shield near J608 on the preamp board (A601).
7. Unplug the standard capacitor’s flexible circuit connector from J114 on the main board (A101).
8. Place the bridge on edge so the right side is down and the front panel is facing you.
9. While holding the standard capacitor so it doesn’t fall, remove the four screws on the top side of the midplane that hold the standard capacitor assembly.
10. Carefully feed the standard capacitor coaxial cable through the hole in the preamp enclosure and remove the standard capacitor from the bridge.

Standard Capacitor Installation Procedure

1. Place the bridge on edge so the right side is down and the front panel is facing you.
2. Orient the standard capacitor assembly as in Figure 12-6 on page 12-17. Feed the standard capacitor coaxial cable through the hole in the preamp enclosure and align the standard capacitor over the mounting holes in the midplane.
3. Hold the standard capacitor in position and install the four mounting screws from the top side of the midplane, through the midplane and into the standard capacitor mounting holes.
4. Place the bridge top side up with the front panel facing you and then tighten the four standard capacitor mounting screws to 18 in-lbs (200 N-cm).
5. Install the processor board (A301) using the “Processor Board Installation Procedure” on page 12-9
6. Place the bridge bottom side up with the rear panel facing you.
7. Plug the standard capacitor’s flexible circuit connector into J114 on the main board (A101).
8. Refer to Figure 12-4 on page 12-12. Install the 6-32 x 3/8 pan-head screw holding the LOW input coaxial cable shield and the standard capacitor coaxial cable shield on the preamp board (A601). The lug on the LOW terminal cable shield should be next to the board and the lug on the standard capacitor cable shield should be on top. Orient the LOW cable and lugs as shown in the figure. Tighten the screw to 18 in-lbs (200 N-cm) while maintaining the lug orientations.
9. Plug the standard capacitor (C210) coaxial cable center conductor pin into J609 on the preamp board (A601).
10. Orient the preamp cover with your marked side visible. This is done to ensure that the anodizing does not prevent the cover from making good electrical contact with the preamp enclosure. Install the four 8-32 x 3/8 pan-head preamp cover screws hand tight. **DO NOT** overtighten or use a torque screwdriver. The cover will be distorted if excess torque is used.

NOTE

If the preamp cover does not make good electrical contact with the preamp enclosure, the preamp will not be adequately shielded. This can cause measurements to be noisier than they should be. If poor electrical contact is suspected, the anodizing can be broken through by oscillating the four preamp screws back and forth as they are being tightened.

11. Install both covers using the procedures in “Removal and Installation of Covers” on page 12-3.
12. After the original standard capacitor has been re-installed, then a capacitance verification should be performed. See “CAPACITANCE CALIBRATION” on page 9-9 for an explanation of this procedure.
5. Put the brown vinyl-covered side panel (MP914) in place. Install the two 6-32 x 1/4 oval-head screws to hold the side panel to the casting and tighten securely.

Install the top and bottom covers using the procedures in “Removal and Installation of Covers” on page 12-3.

Side Casting (MP913) Removal and Installation

Side Casting Removal Procedure

1. Remove the top and bottom covers using the procedures in “Removal and Installation of Covers” on page 12-3.
2. Place the bridge with the side facing up that has the casting to be removed.
3. Refer to the exploded parts view Figure F-4 on page F-11. Locate parts MP913 and MP914 in the lower left corner of the figure. Remove the two oval-head screws holding the brown vinyl-covered side panel (MP914) to the casting and remove the panel.
4. Locate the small brown cover panel MP915 (or ear MP910 if you are using rack-mounting) in the figure. Remove the screw holding MP915 (two screws for MP910) to the casting and remove the panel or ear.
5. Remove the eight flat-head screws that hold the side casting (MP913) to the rest of the instrument and remove the casting. The bridge should be handled with care at this point since the front panel is now only supported at one end.

Side Casting Installation Procedure

1. Place the bridge with the side facing up that to receive the side casting.
2. Refer to the exploded parts view Figure F-4 on page F-11. Put the side casting (MP913) in place so that the grooves that hold the top and bottom covers face toward the interior of the bridge. (There is only one kind of side casting as opposed to having right and left versions.)
3. Install the eight flat-head 6-32 x 3/8 screws to hold the casting. Tighten all eight screws to 18 in-lbs (200 N-cm). Be sure to observe the note about screws and their tightening on page 2 of this chapter.
4. Put the small brown cover panel MP915 (or ear MP910 if you are using rack-mounting) in place. Install the 6-32 x 3/8 oval-head screw to hold MP915 (or the two 10-32 oval-head screws to hold MP910) to the casting and tighten securely.

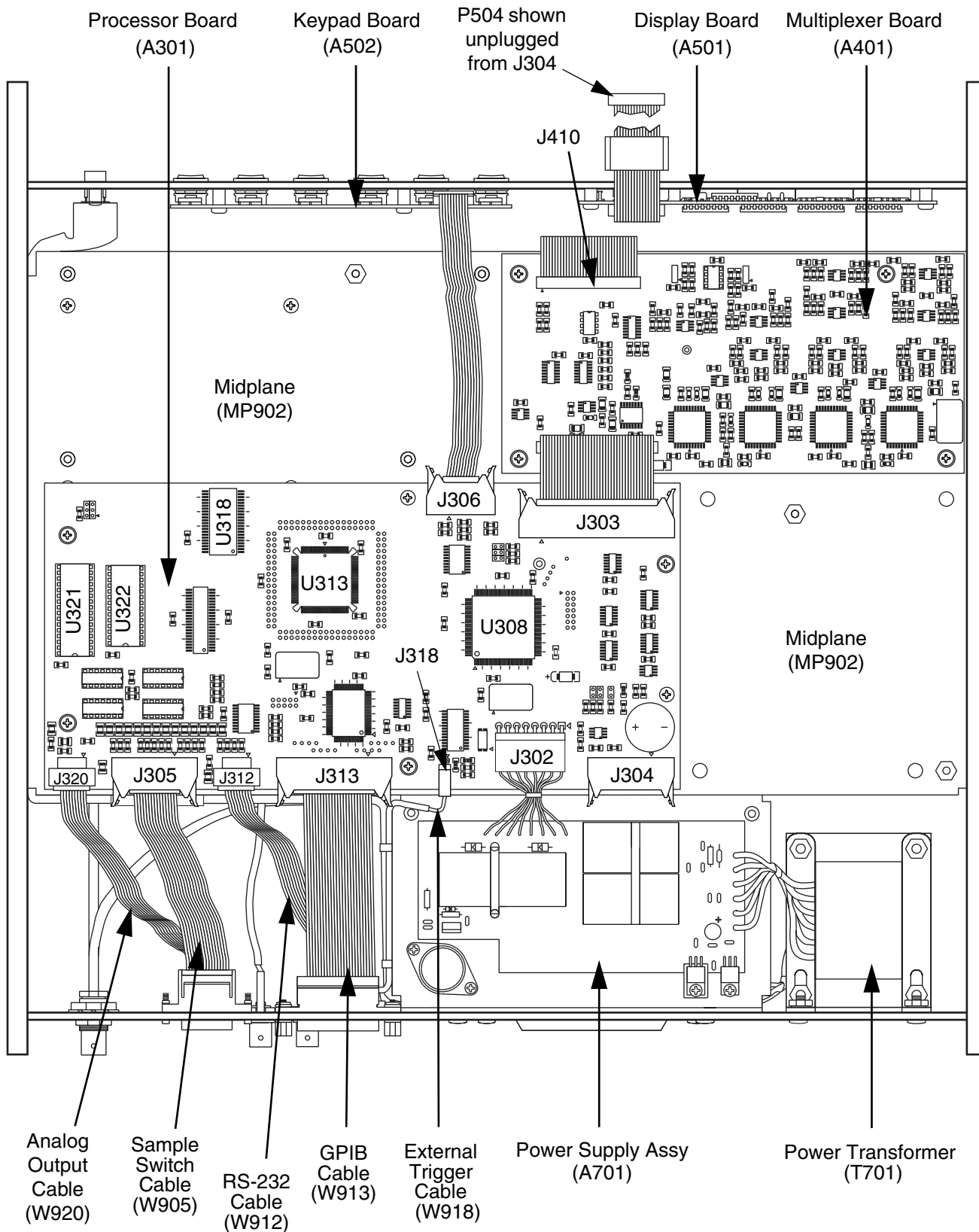


Figure 12-5 AH2700A top view with bezel removed.

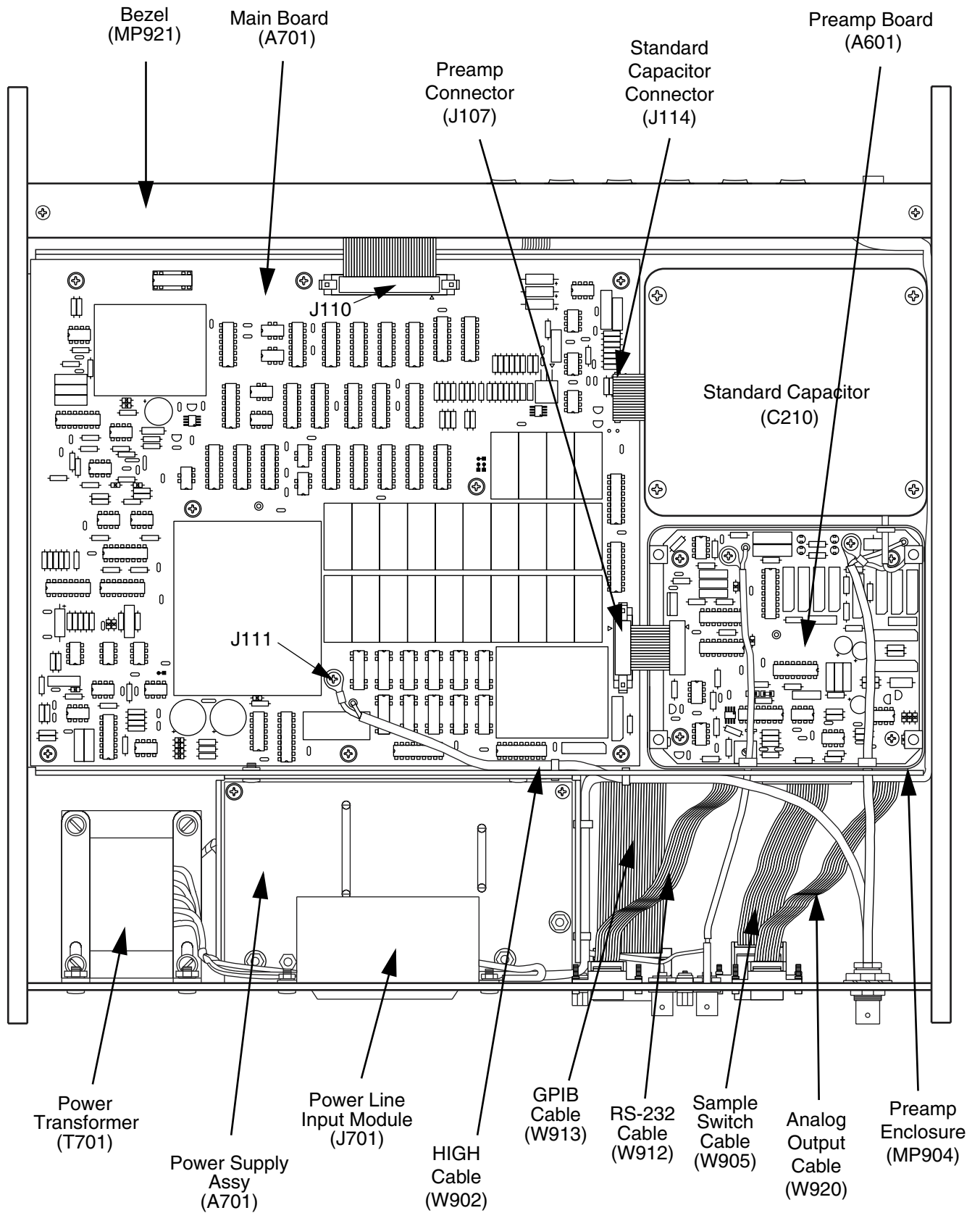


Figure 12-6 AH2700A bottom view with bezel in place.

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Glossary

Accuracy The degree to which a measuring device agrees with accepted standards.

A/D Analog-to-Digital converter. An integrated circuit inside the bridge that digitizes analog signals.

Bridge This term is used interchangeably with “AH2700A” to identify the instrument. The term also has a more specific meaning when it is used to identify a particular electrical circuit having four legs, a generator and a detector.

Calibration Used here to mean the process of adjusting or correcting the bridge so that it meets its specifications. Most corrections are stored in EEPROM memory.

Chassis The collection of metal parts that comprise the frame or box of the AH2700A.

Current parameter set One of the four sets of parameters that directly control the settings used by the bridge.

DAC Digital-to-Analog-Converter. In this manual, DAC refers to a special circuit that generates precise AC voltages controlled by digital signals from a microprocessor.

Dielectric The material that exists in the electric field of a capacitor.

Display Refers to the LED display on the front panel of the bridge.

DUT The Device Under Test being measured by the bridge.

EEPROM An Electrically-Erasable, PROgrammable, non-volatile Memory integrated circuit used for semi-permanent data storage in the bridge.

EPROM An ultraviolet-Erasable, PROgrammable Memory integrated circuit used for permanent storage of the firmware that runs the bridge.

External trigger input A BNC connector on the back of the bridge that can receive pulses for the purpose of synchronizing AH2700A commands.

File A collection of data stored in EEPROM or ROM memory. This data can consist of parameter sets or programs.

File type A file can be of one of six types. These types describe the kind of data in the file. The types are: Basic, Gauge, Output, Serial, GPIB and Program.

Firmware The program code that is executed by the microprocessor in the bridge. This code is contained in three EPROM's and tells the microprocessor how to make the bridge work.

Fused-silica capacitance standard A special capacitor that uses fused silica as its dielectric to achieve a very stable capacitance value.

GPIB Stands for General Purpose Instrument Bus. This is a convenient abbreviation for the instrument communications bus defined by the IEEE-488.1 standard.

HIGH terminal The terminal on the back of the bridge that provides a low-impedance signal with which to drive the unknown impedance.

IEEE-488.1 This is a standard defined by the Institute of Electrical and Electronic Engineers to describe the popular method of interconnecting test equipment for control purposes. The standard was previously called the IEEE-488-1978.

IEEE-488.2 This is a newer standard defined by the Institute of Electrical and Electronic Engineers to extend the IEEE-488.1 standard. The newer standard covers standard codes, formats, protocols, and common commands.

IEEE-1174 A new standard for serial data communication interfaces intended specifically for instrumentation. First published in the year 2000.

Keypad The three by six array of buttons on the front panel of the AH2700A.

LED A Light Emitting Diode produces light and is used as an indicator. These are used to create the front panel display of the AH2700A.

Line Describes a single line of data sent to remote devices or displayed on the front panel in one or more windows.

Linearity The degree to which an increase or decrease in an actual quantity is exactly proportionally represented in the corresponding measured quantity. In other words, if an actual quantity doubles in size, how exactly does the measure of that quantity also double. (This is measurement linearity.)

Loss The component of the impedance which is 90° out of phase with respect to the capacitive component.

LOW terminal The terminal on the back of the bridge that provides a high-impedance input to connect to the unknown impedance.

Non-volatile memory Any memory that does not lose its contents when power is lost.

Option-E An optionally available version of the AH2500A that offers Enhanced precision and calibration features.

Parameter An AH2700A variable that you can set to various values with a command. Every parameter is part of a set. Each parameter controls a particular aspect of the bridge's operation when the parameter is in the current parameter set.

Parameter set A collection of AH2700A parameters. There are five kinds of parameter sets used by the bridge: Basic, Gauge, Output, Serial, and GPIB. These can be stored and recalled for later use.

PPM Parts Per Million. This is equal to 0.0001%.

Precision A loosely defined term meaning "exact".

Program Means a list of AH2700A commands that have been entered into memory and which can be executed by the bridge. "Macro" is a commonly used synonym.

Query command An IEEE-488.2 concept meaning any command that will send a result to a remote device when the command is issued from that device. Non-query commands send no results.

RAM Stands for "Random Access Memory" and is used as the bridges working memory. Its contents are lost when power is lost.

Ratio transformer A special transformer that divides AC voltages with great linearity and stability.

Remote device This IEEE 488.1 term is used from the perspective of the bridge. It refers to any device connected to the bridge with which data is being exchanged. This can be a controller, logger or an intermediate interface. The remote device can be connected to the serial or GPIB port.

Resolution The smallest change that can be detected in a measured quantity.

ROM Stands for "Read Only Memory". It refers to memory whose contents cannot be changed by any means. The term is also used more loosely to include EPROM memory.

Sample A synonym for DUT, unknown, unknown sample etc. (An A/D can also "sample" a signal, but this is a totally different meaning of the word.)

Stability The ability to remain constant with time. In the case of the AH2700A, stability is considered to be independent of temperature. In other words, comparisons of stability are made without changing the temperature.

Temperature coefficient The change in a quantity for a unit change in its temperature.

Three-terminal impedance An impedance that uses two signal terminals and a ground terminal. Usually, the impedance between the two signal terminals is desired and the impedances between either signal terminal and ground are parasitic. In the case of the AH2700A, the ground terminal is always intended to connect to a shield

and a three-terminal impedance is usually thought of as a shielded two-terminal impedance.

Two-terminal impedance An impedance that is only defined between two signal terminals.

Unknown A convenient abbreviated term for "unknown sample", "unknown capacitance", "unknown loss", "unknown impedance", "DUT" etc.



Unknown capacitance The quantity or device being measured by the bridge.

Unknown impedance The quantity or device being measured by the bridge.

Unknown loss The quantity or device being measured by the bridge.

Unknown sample The quantity or device being measured by the bridge.

Verification Used here to mean the process of gathering and presenting data that indicates how close the bridge meets its specifications.

Window Sometimes there is more information on a line to be displayed on the front panel of the bridge than will fit at one time. This information is divided into groups which can be shown one at a time. Each group is called a "window" and consists of the contents of the upper and lower front panel LED displays. You can move right and left one at a time through the windows by pressing the  and  keys.

Calibration Data, Notes, Etc.

This tab section is reserved for your convenience. It may be useful for storing calibration certificates, calibration data, and any other notes related to your AH2700A.

This chapter contains the detailed descriptions for all commands used in the AH2700A capacitance bridge.

CONVENTIONS USED

The command syntax descriptions use the conventions below.

Most commands start with a root command word and are followed by various combinations of command qualifier words and parameter values.

Command words are shown as **COMMAND**.

UNDERLINES are used to indicate the minimum number of characters that can be typed to execute a command when operating the bridge from a remote device.

Front panel keypad command and qualifier words and numbers are shown enclosed in a box to indicate a key or sequence of keys to be pressed to enter a command. The **[ENTER]** key is an example. Boxed font notation is also used to indicate front panel menu selections. Examples illustrating menu entry mode can be identified by the leading **[FUNC]** **[SELECT]** key combination which is used to place the instrument into menu entry mode.

Some commands have command qualifiers that limit the action of the command to a specific display or device. An example is the **CAP** and **LOSS** qualifiers which can select either the capacitance (upper) display or loss (lower) display. Another example is the **SERIAL** and **GPIB** qualifiers which limit the action of a command to the Serial or GPIB ports, respectively. The **SERIAL** and **GPIB** words are also used as root command words.

Most commands have one or more parameters associated with them. Parameters that you can enter are shown *like this*. When entering a parameter *like this*, you substitute an actual value.

Parameters and command qualifiers may be required or optional, depending on the particular command. Required parameters and command qualifiers are shown without surrounding brackets.

Brackets [] are used to indicate that the enclosed parameter or command qualifier is optional. You can select any or all optional parameters or command qualifiers. Some of these options are nested, in which case an inner option cannot be selected unless all outer options surrounding it are also used.

Parameters and command qualifiers may be part of a list separated by the character “|”. You can make one choice from the list.

Some commands have a different syntax depending on whether they are entered from the front panel or from a

remote device. These are noted in the command descriptions. An example is the **CABLE** command.

Multiple Parameters

Certain commands used in the AH2700A have multiple parameters associated with them. An example of this kind of command is the **SERIAL LIST** command which has several communications parameters associated with it. The values for those parameters must be entered in a specific order. When you want to enter values other than the leading value or values, commas (,) are used as placeholders for the missing values. Since a comma may not be directly entered from the front panel, the **[>]** key is used in its place. For example, *Bits* is the third parameter for the **SERIAL** command. If operating from a remote device and you want to change the *Bits* parameter, leaving the other parameters as they are, you must enter **SERIAL LIST ,,7** to change the length to 7 bits. To make this same change using the front panel you must enter **[FUNC] [SERIAL] [>] [>] [7]**. The two commas (or **[>]** keys) in this example act as placeholders for the *Rate* and *Parity* parameters. These two parameters are left unchanged when this command is executed. This scheme saves having to re-enter parameters that you do not wish to change. Multiple parameters are indicated with commas between the parameter names in the command descriptions.

Numeric Entry Notation

Most parameters are entered as integers or occasionally as alphanumeric strings.

Some parameters can be entered with a decimal point as a part of the number. Such parameters can be entered in two basically different notation formats. One is as a floating point number which simply consists of some digits and one decimal point. An example is “123.45678”. The other format consists of a signed mantissa and a signed exponent separated by an “E”. An example is “+12.345678E+01”. Parameters that will automatically accept values in either of these formats are identified by “(floating point)” at the end of the header line for that parameter. For more information on notation formats, see “Numeric Notation” on page 5-8.

COMMANDS

The following pages contain all of the commands used in the AH2700A. Most of the paragraph headings should be self-explanatory. Query commands are discussed in “Aborting Commands” on page 2-6, in “Query Commands” on page 6-3 for the GPIB port and in “Query Commands” on page 7-10 for the Serial port.

AOUT BIAS

Description

The capacitance and loss analog outputs on the rear panel can each be fed from any one of three internal sources; the deviation subsystem, the bias voltage source, or the zero voltage source. This command sets the output level produced by the capacitance and/or loss bias voltage sources.

Syntax

```
AOUT BIAS CAP|LOSS ABias_C|ABias_L
      or
      AOUT BIAS [ALL] ABias_A
      or
      AOUT BIAS [ABias_C] , [ABias_L]
```

Qualifiers

CAP	Set the output level from the capacitance bias voltage source in volts.
LOSS	Set the output level from the loss bias voltage source in volts.
ALL	Set the output levels from both the capacitance and loss bias voltage sources in volts. This qualifier may be omitted.

Note: When using the double parameter form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Parameters

<i>ABias_C</i>	The output voltage level for capacitance bias voltage source in volts.
<i>ABias_L</i>	The output voltage level for loss bias voltage source in volts.
<i>ABias_A</i>	When used, the value of this bias voltage parameter is applied to both the capacitance and loss bias voltage sources.

The permitted range for these three parameters is -10.5 V to +10.5 V.

Default Value *ABias_C*: 0 and *ABias_L*: 0

Parameter Set Dev

Query Cmd? No

Comments

- Use the AOUT SOURCE *ASrc_* command with *ASrc_* set BIAS to connect one or both of the internal bias voltage sources to the rear panel analog outputs.
- This command affects no other deviation or analog output related parameters. Conversely, to other commands affect the value of the *ABias_* parameters that are set by this command.
- Any voltage changes caused by this command will always be fast since no filtering is performed by the output driver amplifier.
- This command can be used to set the levels of analog marker signals at the analog outputs. Other uses include the calibration and verification of devices connected to the analog outputs.

Related Commands

All AOUT and DEV commands.

Description

Set the upper and lower bounds, respectively, of the capacitance and loss channel output voltages in volts. These output voltage bounds correspond directly to the upper and lower bounds of the deviation capacitance and loss spans in pF and jpf respectively.

Syntax

```
AOOUT BOUND UPPER|LOWER CAP|LOSS
ABndUp_C | ABndUp_L | ABndLo_C | ABndLo_L
or
AOOUT BOUND UPPER|LOWER
( ABndUp_C , ABndUp_L ) | ( ABndLo_C , ABndLo_L )
```

Qualifiers

UPPER	Set the upper output voltage bound of the capacitance and/or loss span.
LOWER	Set the lower output voltage bound of the capacitance and/or loss span.
CAP	Set the upper or lower output voltage bound of the capacitance span.
LOSS	Set the upper or lower output voltage bound of the loss span.

Parameters

<i>ABndUp_C</i>	The upper output voltage bound of the capacitance span in volts. Corresponds to the <i>DBndUp_C</i> input bound.
<i>ABndUp_L</i>	The upper output voltage bound of the loss span in volts. Corresponds to the <i>DBndUp_L</i> input bound.
<i>ABndLo_C</i>	The lower output voltage bound of the loss span in volts. Corresponds to the <i>DBndLo_C</i> input bound.
<i>ABndLo_L</i>	The lower output voltage bound of the loss span in volts. Corresponds to the <i>DBndLo_L</i> input bound.

The permitted range for these four parameters is -160 V to +160 V.

Note: When using the second form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value None

Parameter Set Dev

Query Cmd? No

Comments

- When the voltage at the capacitance analog output is equal to *ABndUp_C*, the measured capacitance value will be equal to *DBndUp_C*. Likewise for *ABndLo_C* and *DBndLo_C*.
- When the voltage at the loss analog output is equal to *ABndUp_L*, the measured capacitance value will be equal to *DBndUp_L*. Likewise for *ABndLo_L* and *DBndLo_L*.
- The analog output voltage protection limits may prohibit the voltage at the analog outputs from covering the spans specified by the analog output voltage bounds.
- Other capacitance or loss parameters immediately affected by this command include the corresponding *AoutPt_* and *ASpan_* parameters.
- Changes to the capacitance or loss *ASpan_* parameters immediately affect the corresponding *ABndUp_* and *ABndLo_* parameters.
- The relative values of the *ABndUp_* and *ABndLo_* parameters may not be reversed from what would normally be expected. That is, the value of *DBndUp_* parameter greater than or equal to the value of corresponding *ABndLo_* parameter. If a condition involving the reversal of these parameters is detected, then the execution error `BOUNDIS REVERSE` will be reported.
- Even though the relative values of the *ABndUp_* and *ABndLo_* parameters may not be reversed, the corresponding values of the input bound parameters *DBndUp_* and *DBndLo_* may be reversed.
- When the relative positions of the *DBndUp_* and *DBndLo_* parameters are reversed, the corresponding values of *CFact_* and *DSpan_* are negative.

Related Commands

All AOOUT and DEV commands.

AOUT BOUND (continued)

Front Panel Examples

FUNC **SELECT** **AOUT** **BOUND** **UPPER** **CAP**
1 0 0 **ENTER**

A B N D U P _ C
1 0 0

FUNC **SELECT** **AOUT** **BOUND** **LOWER** **CAP**
MINUS 1 0 0 **ENTER**

A B N D L O _ C
- 1 0 0

FUNC **SELECT** **AOUT** **BOUND** **UPPER** **LOSS**
1 0 **ENTER**

A B N D U P _ C
1 0

FUNC **SELECT** **AOUT** **BOUND** **LOWER** **LOSS**
MINUS 1 0 **ENTER**

A B N D L O _ C
- 1 0

FUNC **SELECT** **SHOW** **AOUT** **BOUND** **ENTER**

AOUT	10000 V
BOUND UP	1000 V



AOUT	-- 10000 V
BOUND LO	-- 1000 V

The **←** and **→** keys are used to move between the two windows.

Remote Device Examples

```
>AOUT BOUND UPPER CAP 100
>AOUT BOUND LOWER CAP -100
>AOUT BOUND UPPER LOSS 10
>AOUT BOUND LOWER LOSS -10
>SHO AOUT BOUND
  AOUT BOUND UP   C= 100.0 V   L= 10.0 V
  AOUT BOUND LO   C=-100.0 V  L=-10.0 V
>
```


Description

Sets the input to output voltage conversion factor for the capacitance and loss voltage output channels in V/pF and V/jpF respectively. This command gives a direct means of controlling the sensitivity of the voltage outputs to changes in the DUT.

Syntax

`AOUT CFACTOR CAP|LOSS CFact_C | CFact_L`
or
`AOUT CFACTOR [CFact_C], [CFact_L]`

Qualifiers

CAP	Set the input to output voltage conversion factor for capacitance.
LOSS	Set the input to output voltage conversion factor for loss.

Parameters

<i>AFact_C</i>	The input to output voltage conversion factor for capacitance in V/pF.
<i>AFact_L</i>	The input to output voltage conversion factor for loss in V/jpF.

These parameters are signed numbers.

Note: When using the second form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value None

Parameter Set Dev

Query Cmd? No

Remote Device Examples

```
>AOUT CFACTOR CAP 20
>AOUT CFACTOR LOSS 10
>SHO AOUT CFACTOR
  AOUT CFACTOR  C= 20.00 U/PF L= 10.00 U/JP
>
```

Related Commands

All AOUT and DEV commands.

Comments

- Other capacitance or loss parameters immediately affected by this command include the corresponding *DBndUp_*, *DBndLo_*, and *DSpan_* parameters.
- Changes to the capacitance or loss *DBndUp_*, *DBndLo_*, and *DSpan_* input parameters immediately affect the corresponding *CFact_* parameter.
- Changes to *CFact_* and other deviation related parameters do not affect the value of the corresponding *ASpan_*, *ABndUp_*, or *ABndLo_* parameters. The relative independence of these three output parameters is intended to protect from unintended change to an output voltage could cause a malfunction or damage to a connected system.
- The relationship between the *ASpan_*, *DSpan_*, and *CFact_* parameters is as follows:
$$CFact_ = ASpan_ / DSpan_.$$
- Even though the relative values of the *ASpan_* parameters are prohibited from taking on negative values, the corresponding *DSpan_* are not similarly restricted. A negative *DSpan_* parameter value thus results in a negative value for the corresponding *CFact_* parameter.
- Even though the values of the *CFact_* parameters are automatically computed based upon *ASpan_* and *DSpan_*, and the value of this command lies in its ability to adjust the sensitivity of the analog output channels in a direct way.

AOUT LIMIT

Description

Sets the upper and lower protection limits, respectively, of the capacitance and loss channel output voltages in volts. These protection limits apply only to voltage levels produced by the deviation subsystem. They do not limit the output derived from internal bias voltage sources.

Syntax

```
AOUT LIMIT UPPER|LOWER CAP|LOSS
ALimUp_C | ALimUp_L | ALimLo_C | ALimLo_L
      or
AOUT LIMIT UPPER|LOWER [ALL]
      ALimUp_A | ALimLo_A
      or
AOUT LIMIT UPPER|LOWER
(ALimUp_C, ALimUp_L) | (ALimLo_C, ALimLo_L)
```

First Qualifier

UPPER	Set the upper output voltage protection limit for the capacitance and/or loss span.
LOWER	Set the lower output voltage protection limit for the capacitance and/or loss span.

Second Qualifier

CAP	Set the upper or lower output voltage protection limit for the capacitance span.
LOSS	Set the upper or lower output voltage protection limit for the loss span.
ALL	Set the upper or lower output voltage protection limit for both the capacitance and loss span. This optional qualifier. may be omitted with identical results.

Parameters

<i>ALimUp_C</i>	The upper output voltage protection limit for the capacitance span in volts.
<i>ALimUp_L</i>	The upper output voltage protection limit for the loss span in volts.
<i>ALimLo_C</i>	The lower output voltage protection limit for the loss span in volts.
<i>ALimLo_L</i>	The lower output voltage protection limit for the loss span in volts.
<i>ALimUp_A</i>	The upper output voltage protection limit for both the capacitance and loss spans in volts.
<i>ALimLo_A</i>	The lower output voltage protection limit for both the capacitance and loss spans in volts.

Parameters (continued)

The permitted range for the three upper limit parameters is 0 V to +10.5V. The permitted range for the three lower limit parameters is -10.5 V to 0 V.

Note: When using the third form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value +10.5 V and -10.5 V for the upper and lower protection limit parameters respectively.

Parameter Set Dev

Query Cmd? No

Comments

- The analog output voltage protection limits are provided to prevent an analog output voltage whose source is a deviation signal from exceeding the specified voltage limits. If any deviation value tries to drive an analog output voltage outside its specified limits, the resulting voltage will be set instead to the value of the limit that was exceeded. This is called “clipping”.
- The analog output voltage protection limits may prohibit the voltage at the analog outputs from covering the spans specified by the analog output voltage bounds.
- No other capacitance or loss parameters are affected by this command. Conversely, no other command affects the output voltage protection limit parameters.
- Exceeding one of these limits will also cause a soft error to be reported to the front panel or remote devices if any of these channels are producing measurement results.
- Note that the analog output voltage protection limits only apply to voltages produced by deviation signals; they do not limit voltages produced by *ABias_* settings.

Related Commands

All AOUT and DEV commands.

AOUT LIMIT ERROR

Description

The analog outputs levels for the capacitance and loss channels may not exceed the upper and lower voltage protection limits. This command is used to enable and disable the error reporting associated with this voltage clipping capability.

Syntax

```
AOUT LIMIT ERROR CAP ALimEr_C  
or  
AOUT LIMIT ERROR LOSS ALimEr_L  
or  
AOUT LIMIT ERROR [ALimEr_C] , [ALimEr_L]
```

Second Qualifier

CAP	Enable or disable the error reporting for voltage protection limit clipping on the capacitance channel.
LOSS	Enable or disable the error reporting for voltage protection limit clipping on the loss channel.

Parameters

<i>ALimEr_C</i>	When set to ON , voltage protection limit clipping on the capacitance channel will be reported as an error. When set to OFF , voltage protection limit clipping on the capacitance channel will not be reported as an error.
<i>ALimEr_L</i>	When set to ON , voltage protection limit clipping on the loss channel will be reported as an error. When set to OFF , voltage protection limit clipping on the loss channel will not be reported as an error.

The permitted values for the these parameters are **ON** and **OFF**. **ON** enables error reporting while **OFF** disables it.

Note: When using the third form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value **ON** for *ALimEr_C* and *ALimEr_L*.

Parameter Set Dev

Query Cmd? No

Comments

- The analog output voltage protection limits are provided to prevent an analog output voltage whose source is a deviation signal from exceeding the specified voltage limits. If any deviation value tries to drive an analog output voltage outside its specified limits, the resulting voltage will be set instead to the value of the limit that was exceeded. This is called “clipping”.
- If enabled, exceeding one of these output voltage protection limits will cause an error to be reported at the front panel and any connected remote devices in real time when producing measurement results.
- No other capacitance or loss parameters are affected by this command. Conversely, no other command affects the output voltage protection limit error reporting parameters. This independence includes the *ASrc_* parameters.
- As with all other deviation mode measurement errors, the analog output voltage protection limit errors can be reported even when the *ASrc_* analog output source parameters are set to **GROUND** and **BIAS**.
- As with all other deviation mode measurement errors, the analog output voltage protection limit errors are only reported as a result of executing one of the measurement initiation commands. If no measurement results have been initiated then no deviation mode measurement errors will be reported.
- The deviation mode measurement errors are associated with exceeding the deviation and output bounds are always enabled. That is, exceeding the deviation bounds during a measurement always produces an error message.
- On remote devices the voltage protection limit error messages will be reported with the regular measurement results utilizing the following format:
CAP|LOSS TO HIGH|LOW
- On the front panel the voltage protection limit errors will be reported using special up/down arrow symbols that occupy only the right most digit position. The symbols will appear in the capacitance or loss displays indicating in which channels the clipping occurred.
- These error messages provide no distinction between voltage protection limit errors and bound errors.

Related Commands

All AOUT and DEV commands.

AOUT SOURCE

Description

The each of the capacitance and loss analog outputs on the rear panel can be fed from any one of three internal sources; the deviation subsystem, the bias voltage source, or the zero voltage source. This command selects which among these three sources is connected to each of the rear panel analog outputs.

Syntax

```
AOUT_SOURCE CAP|LOSS ASrc_C | ASrc_L
           or
           AOUT_SOURCE [ALL] ASrc_A
           or
           AOUT_SOURCE [ASrc_C] , [ASrc_L]
```

Qualifiers

CAP	Select the internal source for the capacitance analog output.
LOSS	Select the internal source for the loss analog output.
ALL	Set the internal source for both the capacitance and loss analog outputs. This qualifier may be omitted.

Parameters

<i>ASrc_C</i>	The voltage source for capacitance analog output.
<i>ASrc_L</i>	The voltage source for loss analog output.
<i>ASrc_A</i>	When used, the value of this voltage source parameter is applied to both the capacitance and loss analog outputs.

The permitted values for each of these three parameters are GROUND, BIAS, and DEV.

Note: When using the third form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value *ASrc_C*: DEV and *ASrc_L*: DEV

Parameter Set Dev

Query Cmd? No

Comments

- Use the **AOUT BIAS** command in conjunction with this command to manually control the output levels from the analog outputs.
- This command affects no other deviation or analog output related parameters. Conversely, no other commands affect the values of the *ASrc_* parameters that are set by this command.
- Any voltage changes caused by this command will always be fast since no filtering is performed by the output driver amplifier.
- This command can be used to provide analog marker signals at the analog outputs. Other uses include the calibration and verification of devices connected to the analog outputs.

Related Commands

All AOUT and DEV commands.

Description

Sets the distance between the upper and lower analog output voltage bounds for capacitance and/or loss in volts. These analog output voltage spans correspond directly to the input deviation capacitance and loss spans.

Syntax

```
AOUT_SPAN CAP|LOSS ASpan_C | ASpan_L
           or
           AOUT_SPAN [ALL] ASpan_A
           or
           AOUT_SPAN [ASpan_C] , [ASpan_L]
```

Qualifiers

CAP	Set the output voltage span for capacitance.
LOSS	Set the output voltage span for loss.
ALL	Set the output voltage span for both capacitance and loss. This qualifier may be omitted.

Parameters

<i>ASpan_C</i>	The output voltage span for capacitance in volts. Corresponds to the <i>DSpan_C</i> input span.
<i>ASpan_L</i>	The output voltage span for loss in volts. Corresponds to the <i>DSpan_L</i> input span.
<i>ASpan_A</i>	When used, the value of this output voltage span parameter is applied to output voltage span parameters for both the capacitance and loss channels.

The permitted range for these three parameters is 0 V to 320 V.

Note: When using the third form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value None

Parameter Set Dev

Query Cmd? No

Comments

- Other capacitance or loss parameters immediately affected by this command include the corresponding *ABndUp_*, *ABndLo_*, and *CFact_* parameters.
- Changes to the capacitance or loss *ABndUp_* and *ABndLo_* output bound parameters immediately affect the corresponding *ASpan_* parameter.
- Changes to *CFact_* and other deviation related parameters do not affect the value of the corresponding *ASpan_*, *ABndUp_*, or *ABndLo_* parameters. The relative independence of these three output parameters is intended to protect from unintended change to an output voltage could cause a malfunction or damage to a connected system.
- The relationship between the *ASpan_*, *ABndUp_*, and *ABndLo_* parameters is as follows:

$$ASpan_ = ABndUp_ - ABndLo_$$
- Because of the restriction on the *ABndUp_* relative to *ABndLo_*, *ASpan_* is prohibited from taking on negative values. If a condition involving the reversal of output bound parameters is detected, then the execution error `ABOUNDS REVERSE` will be reported.
- The relationship between the *ASpan_*, *DSpan_*, and *CFact_* parameters is as follows:

$$CFact_ = ASpan_ / DSpan_$$
- Even though the relative values of the *ASpan_* parameters are prohibited from taking on negative values, the corresponding *DSpan_* are not similarly restricted. A negative *DSpan_* parameter value thus results in a negative value for the corresponding *CFact_* parameter.
- The *AoutPt_* always lies at a fixed position relative to the corresponding *ASpan_* as determined by corresponding *DPosit_* parameter. The relationship is as follows:

$$AoutPt_ = (ABndUp_ + ABndLo_) / 2 + DPosit_ * ASpan_ / 2.$$

Related Commands

All AOUT and DEV commands.

AVERAGE

Description

Sets the approximate time used to make a measurement.

Syntax

AVERAGE *AverExp*
or
AVERAGE UP|DOWN

Qualifiers

- UP change the *AverExp* parameter to the next higher value.
- DOWN change the *AverExp* parameter to the higher value.

Parameters *AverExp*

The allowable *AverExp* (average time exponent) parameter value is an integer from 0 to 15. Table A-1 shows the approximate cold-start and warm-start measurement times in seconds corresponding to the values of *AverExp*. As the table implies, warm-start measurements are not performed for test frequencies below 600 Hz. Notice that every measurement

Table A-1 Measurement Times in Seconds where f is the test frequency in Hertz.

<i>Aver-exp</i>	Approximate Cold-start Measurement Time	Approximate Warm-start Measurement Time for f≥600Hz
0	0.28 + 80/f	0.027 + 11/f
1	0.29 + 110/f	0.033 + 23/f
2	0.30 + 150/f	0.042 + 42/f
3	0.33 + 200/f	0.058 + 75/f
4	0.37 + 260/f	0.085 + 130/f
5	0.44 + 350/f	0.12 + 230/f
6	0.58 + 520/f	0.18 + 400/f
7	0.82 + 820/f	N/A
8	1.2 + 1300/f	N/A
9	1.8 + 2200/f	N/A
10	3.0 + 3900/f	N/A
11	5.0 + 7000/f	N/A
12	9.0 + 14,000/f	N/A
13	17.0 + 27,000/f	N/A
14	34.0 + 57,000/f	N/A
15	68.0 + 120,000/f	N/A

time in the table consists of two contributions — a fixed term plus a variable term that is inversely proportional to frequency. Consequently, the average times vary widely and can be quite long at low frequencies.

Default Value 4

Parameter Set Gauge

Query Cmd? No

Front Panel Examples

AVERAGE TIME 5 ENTER

Set the average time parameter to five.

SHOW AVERAGE TIME ENTER

Displays the following window:

```
AVERAGE
5
```

Remote Device Examples

>AU 7

Set the averaging time parameter to seven.

>SH AU

```
AVERAGE          AVEREXP=7
```

>

Comments

- Adding one to the averaging time parameter as much as doubles the measurement time.
- For *AverExp* = 4, the warm-start measurement time at 1 kHz is about 0.2 second.
- Lengthening the averaging time reduces the effects of random noise at the expense of measurement speed.

References

See “MEASUREMENT SPEED VS. MEASUREMENT FLUCTUATION” on page 4-5 and specifically “Averaging Time” on page 4-6.

Related Commands none

Description

Enables or disables a user-supplied DC bias voltage of up to ± 100 VDC to be applied to the measured unknown. The external source is connected to the rear panel DC BIAS input. This command also selects the value of an internal resistor that is placed in series with the externally applied voltage source.

Syntax

BIAS OFF|ILOW|IHIGH

Qualifiers

OFF	Disabled (no series resistor connected).
ILOW	100 megohm series resistor connected.
IHIGH	1 megohm series resistor connected.

Default Value OFF (Disabled)

Parameter Set Gauge

Query Cmd? No

Comments

- Useful when measuring capacitances that exhibit DC voltage-dependent properties.

WARNING !

The voltage that you apply to the DC bias input will be passed to the LOW input terminal. From there it will go to whatever unknown impedance and fixture you have connected. Be sure that your fixture and cable are constructed in a manner that will prevent personal contact with any applied, high DC voltages. The frame of the fixture and the shield of the cable should be grounded.

CAUTION

The voltage connected to the DC bias input appears directly across the internal fused-silica capacitance standard. Application of voltages significantly in excess of 100 volts may damage or destroy the standard.

Front Panel Examples

[FUNC] [SELECT] [BIAS] [IHIGH] [ENTER]
Enables DC bias and selects the 1 M Ω series resistor.

[FUNC] [SELECT] [SHOW] [BIAS] [ENTER]
Displays the following window:

```

BIAS
IHIGH
    
```

Remote Device Examples

```

>BI IHIGH
Enables DC bias and selects the 100 M $\Omega$  series resistor.

>SH BI
  BIAS           IHIGH
>
    
```

References

See “UNKNOWN WITH DC VOLTAGE” on page 4-13 and especially “Applying a DC Bias Voltage” on page 4-13.

Related Commands none

BRIGHTNESS

Description

Sets the overall brightness of all the front panel displays. Also sets the brightness of the front panel capacitance and/or loss displays individually.

Syntax

```
BRIGHT [ALL] Brit_All
      or
BRIGHT CAP Brit_Cap
      or
BRIGHT LOSS Brit_Los
      or
BRIGHT OTHERS Brit_Oth
```

Qualifiers

[ALL]	Parameter will apply to all displays. Because this qualifier is optional it may be omitted.
CAP	Parameters will apply to the capacitance display only.
LOSS	Parameters will apply to the loss display only.
OTHERS	Parameters will apply to all but the cap and loss displays.
LIST	Individual values of each of the three key brightness parameters may be applied using this single command syntax.

Parameters *Brit_All, Brit_Cap, Brit_Los, Brit_Oth*

All of the above brightness parameters work in a similar fashion. Permitted values are the numbers from 0 to 9. Zero turns the display off and sets the status and units indicators to the same brightness as level one. Numbers from 1 to 9 correspond to increasing brightness with 9 being the maximum brightness.

Default Value 5 (Medium brightness)

Parameter Set Basic

Query Cmd? No

Comments

- If power is applied to the bridge, there is always at least one LED illuminated on the front panel. This fact can be used as a power indicator.

Front Panel Examples

```
BRIGHT 5 ENTER
```

Sets the brightness of all displays to medium.

```
BRIGHT CAP 9 ENTER
```

Sets the brightness of the upper display to the maximum. Leaves the other displays unchanged.

```
BRIGHT LOSS 2 ENTER
```

Sets the brightness of the lower display to be dim. Leaves the other displays unchanged.

```
SHOW BRIGHT ENTER
```

Displays the following window:

```
BRIGHT
  9  2  05
```

The brightness level of the upper display is shown as 9, that of the lower display as 2 and that of the other displays as 05.

Remote Device Examples

```
>BR 0
```

Sets the brightness level of all displays to off except for the status LED's which are set to minimum brightness.

```
>SH BR
  BRIGHTNESS      C=0 L=0 O=0
>
```

References

See "KEYPAD AND DISPLAYS" on page 2-1 and "Setting Display Brightness – An Example" on page 2-4.

Related Commands none

Description

Compensates for the characteristics of longer cables or cables used to connect the bridge to larger capacitances.

Syntax

`CABLE LENGTH` *Length_M*
 or
`CABLE RESISTANCE` *mO/M*
 or
`CABLE INDUCTANCE` *uH/M*
 or
`CABLE CAPACITANCE` *pF/M*

Parameters

Length_M (Floating Point)
 is the length (in meters) of the coaxial cable pair connected between the bridge and the device under test. The length can be entered to the nearest hundredth of a meter up to a maximum length of 999.99 meters. The default length is one meter.

mO/M (Floating Point)
 is the resistance (in milliohms) of the center conductor of one meter of one side of a cable pair. The value of resistance can range from 0 to 9999.0 milliohms per meter. The default resistance is 40 milliohms per meter.

uH/M (Floating Point)
 is the inductance (in microhenries) per meter of cable. The value of inductance can range from 0.00 to 99.99 microhenries per meter. The default value is 1.10 microhenries per meter.

pF/M (Floating Point)
 is the capacitance (in picofarads) of one meter of one side of a cable pair. The value of capacitance can range from 0.0 to 999.9 picofarads per meter. The default value is 100 picofarads per meter.

Parameter Set Gauge

Default Value 1,40,1.10,100

Query Cmd? No

Comments

- The CABLE commands are only useful for higher *accuracy* measurements of larger capacitance values and longer cable lengths and/or with higher frequencies.
- Longer cables also cause a zero error. The ZERO SINGLE command is used to make this correction.

Front Panel Examples

`[FUNC] [SELECT] [CABLE] [LENGTH] [3] [ENTER]`

Sets the bridge to compensate for a 3 meter cable length.

`[FUNC] [SELECT] [CABLE] [RESISTANCE] [3] [.] [1] [ENTER]`

Sets the bridge to compensate for cable with resistance of 3.1 milliohms per meter. (The result is rounded.)

`[FUNC] [SELECT] [SHOW] [CABLE] [ENTER]`

Displays the following windows:

CABLE	LENGTH
LENGTH	300 M

↓

CABLE	RESIST
RESIST	3.1 MO/M

↓

CABLE	INDUCT
INDUCT	1.10 UH/M

↓

CABLE	CAP
CAP	100 PF/M

Remote Device Examples

>CAB LEN 10

Sets the bridge to compensate for a 10 meter cable length.

>CABL RES 6.0E+01

Sets the bridge to compensate for 60 milliohms per meter.

>SH CAB

```
CABLE LENGTH      10.00 M
CABLE RESISTNCE   60.0  MO/M
CABLE INDUCTNCE   1.10  UH/M
CABLE CAP          100   PF/M
```

>

References

See "CABLE ERROR CORRECTIONS" on page 8-6

Related Commands

ZERO, ZERO POINT, and FREQUENCY

CALIBRATE

Description

Causes the bridge to produce correction values for one of three different kinds of calibrations/verifications.

Syntax

CALIBRATE INTERNAL

creates verification data for many internal calibration points.

or

CALIBRATE CAPACITANCE *CapValue*

creates capacitance verification data to calibrate the AH2700A against an external standard capacitor at 1 kHz. The external standard must have a value in the range of 0.5 to 1600 pF.

Parameters *CapValue* (Floating Point)

The *CapValue* parameter is the **exact** value of the external standard capacitor connected to the bridge.

Default Value None

Parameter Set None

Query Cmd? No

Comments

- The subject of calibration must be thoroughly understood before using these commands. It is essential to first read much of Chapter 9, “Verification/Calibration”.

Front Panel Examples

FUNC **SELECT** **CALIBRATE** **CAP**
9 9 . 9 9 **ENTER**

Create capacitance calibration data using an external standard capacitor which has an accurately known and traceable value of 99.99000 pF.

See the **SHOW CALIBRATE** command for more information.

Remote Device Examples

```
>CAL CAP 10.00034
```

Use a 10.00034 pF external standard.

See the **SHOW CALIBRATE** commands for more information about reporting calibration data.

References

See “Obtaining the Internal Verification Data” on page 9-5 and “Obtaining the Capacitance Verification Data.” on page 9-9.

Related Commands

SHOW CALIBRATE, **STORE CALIBRATE**,
STORE CALIBRATE CREATE,
STORE CALIBRATE SPECIAL

Description

Clears a partially entered command or parameter when used from the front panel. Aborts entry of a command from the serial device.

Front Panel Syntax

FUNC **CLEAR** **FUNC** **CLEAR**

Serial Device Syntax

^U

Parameters None

Query Cmd? No

Comments

- When in the process of entering a parameter from the front panel, the first entry of this command will clear the parameter value. A second entry of the command will then clear the command itself.
- The serial device syntax is not recognized when sent from a GPIB controller. Such controllers usually provide their own methods for editing commands.
- By using the **DEFINE** command, almost any character can be selected for this function from the serial port. Ctrl-U is the default.

Front Panel Examples

FUNC **SELECT** **STORE** **CALIBRATE**

CALIBRATE

FUNC **CLEAR** **FUNC** **CLEAR**

READY

The clear function was used to abort entry of the **STORE CALIBRATE** command.

Serial Device Examples

```
>MACRO AVERAGE 345 ^U  
>
```

Entry of the command was aborted with the ^U character (which is not actually shown).

References

See “Correcting Erroneous Input – Examples” on page 2-4 and “Erasing Lines” on page 7-11.

Related Commands

DEFINE

COMMUTATE

Description

The commutate feature periodically reverses the applied bridge signal. This makes the bridge signal distinguishable from external interference near either the line or bridge frequency. The bridge then rejects the interference.

Syntax

```
COMMUTATE OFF|LINEREJ|ASYNC
```

Qualifiers

OFF	Commutation disabled.
LINEREJ	Line-commutation enabled.
ASYNC	Self-commutation enabled.

Default Value LINEREJ

Parameter Set Gauge

Query Cmd? No

Comments

- Rejects noise due to regular signals with fundamentals or harmonics near the line or bridge frequency.
- Setting commutation to LINEREJ is usually essential for making measurements at or near the power line frequency or its harmonics.
- Setting commutation to ASYNC is best for rejecting signals from other equipment having a frequency or harmonic near the bridge frequency.
- If you want your measurements made with a continuous sine wave, then set commutation to OFF.
- Note that setting to commutation to LINEREJ or ASYNC only enables commutation; these settings can not force commutation to occur if the average time setting is too short.
- Commutation will always be automatically disabled when the deviation processing feature is in use.

Front Panel Examples

```
[FUNC] [SELECT] [COMMUTATE] [LINEREJ] [ENTER]
```

```
[FUNC] [SELECT] [SHOW] [COMMUTATE] [ENTER]
```

Displays the following window:

```
COMMUTATE
LINEREJ
```

Remote Device Examples

```
>COM LINEREJ
```

Commutate the bridge signal using line-commutation.

```
>COM OFF
```

Turn the commutate feature off.

```
>SH COM
```

```
COMMUTATE LINEREJ
```

```
>
```

References

See “REJECTING INTERFERING SIGNALS” on page 4-7.

Related Commands none

NOTE

The operation of the COMMUTATE command was changed and significantly enhanced with the addition of the line-commutate feature. This feature is capable of rejecting line-related noise by as much as 54 db (500 times). This first appeared in firmware version AH2X0119 which was shipped beginning in June 2002.

Description

Initiates measurements which are taken continuously, one after another.

Syntax

`CONTINUOUS [ON]|OFF`

Note: 1 and 0 may be substituted for ON and OFF respectively.

Qualifiers

- ON Initiates continuous measurements.
- OFF Stops continuous measurements.

Query Cmd? Yes

Since the CONTINUOUS command is a query command, any command will interrupt execution of the CONTINUOUS command. However, the bridge will revert to taking measurements continuously after the interrupting command (other than SINGLE or Q) finishes executing.

Comments

- The SINGLE or Q commands provide alternative means for stopping continuous measurements.
- The quickest way to stop the CONTINUOUS command is with a DEVICE CLEAR command.
- Use the CONTINUOUS INTERVAL command to control the rate at which continuous measurements are made.

References

See “MAKING CONTINUOUS MEASUREMENTS” on page 2-7 and “Taking Measurements Continuously” on page 4-4.

Related Commands

CONTINUOUS INTERVAL, CONTINUOUS TOTAL, CONTINUOUS RST, Q, SINGLE

Front Panel Examples

`CONTINUOUS` `ENTER`

Takes measurements at a rate determined by the CONTINUOUS INTERVAL command.

72298653	5=01
002977	150 V

72322100	5=01
002910	150 V

72222083	5=01
003002	150 V

72322083	5=01
002980	150 V

The `←` and `→` keys are used to move between the two windows.

The left window shows the capacitance and loss. The second window shows the sample number and the voltage used to make the measurement. A third window which is not printed above can also be shown. It contains the Reference and Zero settings for the measurement shown. The `←` and `→` keys are used to select which window of each set of three is shown in the front panel display.

`SINGLE`

Stops taking continuous measurements.

Remote Examples

```
>C0
C=10.342956 PF L=0.0004591 NS
C=10.342958 PF L=0.0004592 NS
>C=10.342958 PF L=0.0004592 NS
>
```

The Q command (which does not echo to the serial port) was used to abort the CONTINUOUS command. Measurements were being taken as fast as the averaging time setting would allow.

CONTINUOUS INTERVAL

Description

Sets the measurement rate for continuous measurements. Provides a way to directly enter the time from the start of one measurement to the start of the next measurement.

Syntax

`CONTINUOUS INTERVAL Interval`

Parameters *Interval* (Floating Point)

This parameter is the time from the start of one measurement to the start of the next entered in seconds and tenths of seconds. The maximum time interval is 99,999,999 seconds.

Default Value 0 (Runs as fast as averaging time will permit)

Parameter Set Gauge

Query Cmd? No

Comments

- If the *Interval* parameter is zero, measurements are taken at the maximum rate allowable by the AVERAGE command's *AverExp* parameter.
- If the *Interval* parameter does not exceed the averaging time, then the latter will determine the rate at which measurements are made.

Related Commands

CONTINUOUS, CONTINUOUS RST, CONTINUOUS TOTAL, Q, SINGLE

Description

Resets the value of the continuous mode measurement count variable *CCount* to zero.

Syntax

CONTINUOUS RST

Parameters None

Default Value 0 (Run until interrupted)

Parameter Set None

Query Cmd? No

Comments

- A count of the individual continuous mode measurements is maintained by the *CCount* variable.
- The value of the continuous count variable *CCount* cannot be entered and is not stored in any parameter set.
- If the value of the *CTotal* parameter is nonzero, continuous mode measurements will be automatically terminated when *CCount* reaches *CTotal*. Also the value of *CCount* will automatically be reset to zero at the entry of every **CONTINUOUS** command
- If the value of the *CTotal* parameter is zero, the value of *CCount* will still be incremented with each measurement but there will be no automatic termination of the continuous mode measurements based upon the value of *CCount*. In this case, *CCount* also counts all measurements made in Scan mode.
- If the value of the *CTotal* parameter is zero, the continuous mode measurements must be terminated by entry of a command such as **CONTINUOUS OFF**.
- The value of the continuous count variable *CCount* may manually reset to zero by using the **CONTINUOUS RST** command.
- The values of *CTotal* and *CCount* may be shown using the **SHOW CONTINUOUS TOTAL** and **SHOW CONTINUOUS COUNT** commands respectively.

References

See “MAKING CONTINUOUS MEASUREMENTS” on page 2-7 and “Taking Measurements Continuously” on page 4-4.

Related Commands

CONTINUOUS, CONTINUOUS TOTAL

CONTINUOUS TOTAL

Description

Sets the total number of measurement to be taken when the CONTINUOUS command is executed.

Syntax

CONTINUOUS TOTAL *CTotal*

Parameters *CTotal*

This parameter is the number of measurements to be completed. A value of zero for *CTotal* causes measurements to occur continuously until interrupted or stopped.

Default Value 0 (Run until interrupted)

Parameter Set Gauge

Query Cmd? No

Comments

- A count of the individual continuous mode measurements is maintained by the *CCount* variable.
- The value of the continuous count variable *CCount* cannot be entered and is not stored in any parameter set.
- If the value of the *CTotal* parameter is nonzero, continuous mode measurements will be automatically terminated when *CCount* reaches *CTotal*. Also the value of *CCount* will automatically be reset to zero at the entry of every CONTINUOUS command
- If the value of the *CTotal* parameter is zero, the value of *CCount* will still be incremented with each measurement but there will be no automatic termination of the continuous mode measurements based upon the value of *CCount*. In this case, *CCount* also counts all measurements made in Scan mode.
- If the value of the *CTotal* parameter is zero, the continuous mode measurements must be terminated by entry of a command such as CONTINUOUS OFF.
- The value of the continuous count variable *CCount* may manually reset to zero by using the CONTINUOUS RST command.
- The values of *CTotal* and *CCount* may be shown using the SHOW CONTINUOUS TOTAL and SHOW CONTINUOUS COUNT commands respectively.

Related Commands

CONTINUOUS, CONTINUOUS RST, Q, SINGLE

Description

Allows redefinition of certain special purpose ASCII key codes used with the serial port. These are particularly useful with remote video terminals attached to the serial port.

Syntax

```

DEFINE ERASE EraseChar
      or
DEFINE DELETE DelChar
      or
DEFINE BACKSPACE BackSpChar
      or
DEFINE DCL DevClrChar
      or
DEFINE TERMINAL TermType

```

Parameters

The key code required by the first four versions of the DEFINE command may be entered in one of three ways. It may be entered directly by simply pressing the key which produces the desired code. If it is to be a control key, it may be entered as the corresponding letter preceded by an up arrow (^). Finally, it may be entered as the word DELETE if it is to be the ASCII “delete” character. Some characters may not be chosen including ^A, ^J, ^M, ^Q and ^S.

EraseChar

Is the key code that causes the current command line on a remote video terminal to be erased. The default erase line character is control U (^U).

DelChar

Is the key code that causes the character to the left of the cursor on a printing or video terminal to be erased. The default delete character is the ASCII delete (or rubout) key.

BackSpChar

Is the key code that causes the cursor on a video terminal to backspace one character position. The backspace is used in combination with the delete key to remove the deleted character from the screen of a video terminal. The default backspace character is control H (^H).

DevClrChar

Is the key code that aborts execution of all currently queued commands. The default device clear character is control E (^E).

TermType

Tells the bridge whether a video terminal or hard-copy printer is attached to the serial port. When configured as a printer, character deletion uses backslashes (\) to delineate any characters that were deleted by the delete key. The *TermType* parameter is entered as either VIDEO or PRINTER. The default terminal type is PRINTER.

Default Value See individual parameters above.

Front Panel Examples

The DEFINE command cannot be entered nor can its parameters be shown from the front panel.

Serial Remote Device Examples

```

>DEF DEL ^H
Set delete key code to be control H.

>DEF TE P
Define terminal as a hardcopy printer.

>SH DEF
  DEFINE ERASE=^U DEL=DEL BACKSP=^H
          DCL=^E TERM=PRINT
>

```

Parameter Set Serial

Query Cmd? No

Comments

- The DEFINE command has no value with a GPIB controller since the characters affected are only recognized from the serial port. GPIB controllers usually have their own methods for editing commands.

References

See “Correcting Typing Errors” on page 7-10.

Related Commands

SERIAL, CLEAR, DELETE, DEVICE CLEAR

DELETE DelChar

Description

Deletes the last character typed from a remote terminal or the last numeric digit or decimal point entered from the front panel.

Front Panel Syntax

DELETE

Serial Device Syntax

DelChar

The *DelChar* is definable using the **DEFINE** command. In other words, you can select which key serves as the delete key. Keyboards usually have a key intended to perform this function.

Parameters None

Default Value

Serial device syntax uses the ASCII “delete” character.

Query Cmd? No

Comments

- The serial device Delete key code is not recognized when sent from a GPIB controller. Such controllers usually provide their own methods for editing commands.
- The **DELETE DelChar** command shares the **DELETE** key label on the front panel with the **DELETE File-name** command, but otherwise, these commands have no connection with each other.

Front Panel Examples

REFERENCE **CAP** **3** **.** **1** **1** **1**

CAP
3.111

DELETE **DELETE** **DELETE** **DELETE**

CAP
3

1 **.** **1** **1**

CAP
3.111

The **DELETE** key was pressed four times to delete “.111”. The deleted characters were replaced with “.111” so as to move the decimal point right by one place relative to the original entry.

Remote Device Examples

>REFER\REF\EF
>

The delete key was pressed four times to back up to the “FE” that was reversed during entry.

References

See “Correcting Erroneous Input – Examples” on page 2-4.

Related Commands

DEFINE

DELETE Filename

Description

Deletes a parameter or macro file in EEPROM memory.

Syntax

```
DELETE BASIC|DEV|GAUGE|SCAN|SERIAL  
      |GPIB|MACRO|ALL Filename|ALL
```

Qualifiers

BASIC	Delete Basic parameter file(s).
DEV	Delete Deviation parameter file(s).
GAUGE	Delete Gauge parameter file(s).
SCAN	Delete Scan parameter file(s).
SERIAL	Delete Serial parameter file(s).
GPIB	Delete GPIB parameter file(s).
MACRO	Delete Macro file(s).
ALL	Delete files of <i>all</i> filetypes with the specified <i>Filename</i> . Deletes <i>all</i> files of <i>all</i> filetypes and initializes the file space when used in conjunction with the ALL parameter value.

Parameters *Filename*

This is the name of the file to be deleted. If ALL is entered as a parameter value in place of a filename, then all files of the specified type will be deleted. The ARE YOU SURE? prompt will be shown if ALL is entered. You must answer YES or YES to this prompt if the operation is to complete. If you are working from the GPIB and are not using prompts, your reply to the ARE YOU SURE? prompt can be appended as "; YES" to your command. For example, DELETE MACRO ALL; YES.

Default Value None

Parameter Set None

Query Cmd? No

Comments

- If you are unsure what filenames can be deleted, issue the DIRECTORY command to get a list of all of them.
- If you are unsure of the contents of a particular file, you can use the SHOW command to examine the contents.

Comments (continued)

- The DELETE DelChar command shares the **DELETE** key label on the front panel with the DELETE *Filename* command, but otherwise, these commands have no connection with each other.
- *Filename* may contain only alphanumeric and underscore characters, must begin with an alpha character, and may contain no more than eight characters total.

Front Panel Examples

FUNC **SELECT** **DIRECTORY** **ENTER**

Displays the following windows:

GAUGE
USERPON



BASIC
USERPON



BASIC
USERPON

The second ↓ had no effect which shows that only two files exist in EEPROM memory.

FUNC **SELECT** **DELETE** **GAUGE** **ALL** **ENTER**

ARE YOU
SURE?

YES **ENTER**

Deletes all Gauge parameter files.

FUNC **SELECT** **DIRECTORY** **ENTER**

Displays only the following window:

BASIC
USERPON



BASIC
USERPON

Now only one file exists in EEPROM memory.

DELETE Filename (continued)

Remote Examples

```
>SHOW MACRO EXAMPLE
AVE 7
SIN
>DELETE MACRO EXAMPLE
>SH MACRO EXAMPLE
FILE NOT FOUND
>
```

This example shows that initially there is a two-line macro in EEPROM memory. The macro is then deleted. Another **SHOW** command is then not able to find a macro file having a filename of "EXAMPLE".

References

See Chapter 3, "Parameter and Macro Files" and specifically "Deleting Files" on page 3-9.

Related Commands

DIRECTORY, RECALL, SHOW, STORE

Description

Enables or disables Deviation Processing Mode (DPM). When enabled, DPM takes capacitance and loss measurements very rapidly and converts them to analog voltages that are proportional to the measured capacitance and loss. This is a special mode of operation that functions as a high-speed alternate to the normal measurements initiated with the SINGLE and CONTINUOUS commands.

Syntax

`DEV MODE DevEnab`

Parameters

DevEnab Permitted values are ON and OFF. ON enables the DPM mode. OFF disables the DPM mode and causes the most recently measured analog values of capacitance and loss to be held.

Default Value OFF

Parameter Set None

Query Cmd? No

Comments

- Immediately after being entered, the DEV MODE ON command always causes the analog processing subsystem to be calibrated.
- Note that analog output signals will not be present on the analog output connector unless the bridge has been set to the DPSSC and/or DPSSL states.
- DPM mode only works with loss units of μpF .
- DPM mode is not compatible with the ZERO command being active.
- DPM mode is not compatible with the commutate feature being active.

Related Commands

All AOUT and DEV commands.

DEV AUTO

Description

This command provides settings that determine whether deviation measurements are based on input quiescent points selected by the user or by an automatic assignment from the deviation initialization that occurs immediately after the DEV MODE ON command is executed.

Syntax

```
DEV AUTO CAP|LOSS DAutoP_C | DAutoP_L
or
DEV AUTO [DAutoP_C] , [DAutoP_L]
```

Qualifiers

CAP	Enables or disables automatic assignment of the capacitance value associated with the deviation input quiescent point.
LOSS	Enables or disables automatic assignment of the loss value associated with the deviation input quiescent point.

Parameters

<i>DAutoP_C</i>	When set to ON the capacitance value associated with the deviation input quiescent point, <i>DevPt_C</i> , is automatically set equal to the capacitance value of the DUT upon initialization of the deviation subsystem. When set to OFF the current value of <i>DevPt_C</i> is used without modification.
<i>DAutoP_L</i>	When set to ON the loss value associated with the deviation input quiescent point, <i>DevPt_L</i> , is automatically set equal to the loss value of the DUT upon initialization of the deviation subsystem. When set to OFF the current value of <i>DevPt_L</i> is used without modification.

Note: When using the second form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value None

Parameter Set Dev

Query Cmd? No

Comments

- The location of the deviation input quiescent point may be determined by any one of several means. Included among these is an automatic mode where the capacitance and/or loss values associated with the deviation input quiescent point are automatically set equal to the capacitance and loss values measured from the DUT. This measurement is done at the time when the deviation subsystem is activated via DEV MODE ON command.
- Although this command has no immediate effects upon any of the other analog output or deviation parameters, it should be noted that automatic assignment of the deviation input quiescent point will affect not only the *DevPt_* values but also the associated *DBndUp_* and *DBndLo_* deviation bound parameters.
- Even with automatic assignment of the *DevPt_*, the relative positioning of the *DevPt_* within the corresponding *DSpan_* will be preserved in accordance with the value of the corresponding *DPosit_* parameter. This preservation will be accomplished by automatically adjusting the *DBndUp_* and *DBndLo_* input bound parameters.
- Neither automatic nor manual changes to the *DevPt_* parameters will affect the value of the corresponding *ASpan_*, *ABndUp_*, or *ABndLo_* parameters. The relative independence of these three output parameters is intended to protect from unintended change to an output voltage could cause a malfunction or damage to a connected system.
- Because the bridge balance point *DBalPt_* is always located directly at the midpoint between the upper and lower deviation boundaries *DBndUp_* and *DBndLo_*, it will be affected by automatic assignment of the deviation input quiescent point.
- The primary advantage of automatic assignment of the deviation input quiescent point is that it eliminates the need to manually compensate for a slowly drifting DUT. This can be especially helpful when applied to a capacitance or loss channel whose measurement values are of little or no interest because it helps to eliminate input boundary related error messages.

Related Commands

All AOUT and DEV commands.

Description

Sets the minimum time interval during which measurement samples are averaged in the deviation N data stream case or during which the occurrence of an error is watched for in the deviation E data stream case.

Syntax

DEV **AVERAGE** *DAvgTime*

Parameters

DAvgTime is a linear parameter with units of seconds. It can be set in increments of the I & Q sample time.

Default Value 0.10 sec

Parameter Set Dev

Query Cmd? No

Comments

- The *DAvgTime* parameter affects only the N and E datastreams.
- The deviation subsystem utilizes a simple averaging process to produce digital data that may be much slower than in the I & Q data stream but which has less noise since as much as 100% of the data from the I & Q data stream is averaged to make the N data stream.

Front Panel Examples

FUNC **SELECT** **DEV** **AVERAGE TIME** **1** **ENTER**

DAVGTIME
1

FUNC **SELECT** **SHOW** **DEV** **AVERAGE TIME** **1** **ENTER**

DEV 100000
AVERAGE SEC

Remote Device Examples

```
>DEV AVERAGE 1  
>SHO DEV AVERAGE  
DEV AVERAGE 1.00000 SEC  
>
```

References

Related Commands

All AOUT and DEV commands.

DEV BOUND

Description

Sets the upper and lower bounds of the deviation capacitance and loss spans in pF and jpF respectively. The capacitance and loss bounds correspond directly to the analog output voltage bounds for capacitance and loss respectively.

Syntax

```
DEV BOUND UPPER|LOWER CAP|LOSS
DBndUp_C | DBndUp_L | DBndLo_C | DBndLo_L
or
DEV BOUND UPPER|LOWER
(DBndUp_C , DBndUp_L) | (DBndLo_C , DBndLo_L)
```

Qualifiers

UPPER	Set the upper bound of the capacitance and/or loss span.
LOWER	Set the lower bound of the capacitance and/or loss span.
CAP	Set the upper or lower bound of the capacitance span.
LOSS	Set the upper or lower bound of the loss span.

Parameters

<i>DBndUp_C</i>	The upper bound of the capacitance span in pF. Corresponds to the <i>ABndUp_C</i> voltage bound.
<i>DBndUp_L</i>	The upper bound of the loss span in jpF. Corresponds to the <i>ABndUp_L</i> voltage bound.
<i>DBndLo_C</i>	The lower bound of the loss span in jpF. Corresponds to the <i>ABndLo_C</i> voltage bound.
<i>DBndLo_L</i>	The lower bound of the loss span in jpF. Corresponds to the <i>ABndLo_L</i> voltage bound.

Note: When using the second form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value None

Parameter Set Dev

Query Cmd? No

Comments

- When the voltage at the capacitance analog output is equal to *ABndUp_C*, the measured capacitance value will be equal to *DBndUp_C*. Likewise for *ABndLo_C* and *DBndLo_C*.
- When the voltage at the loss analog output is equal to *ABndUp_L*, the measured capacitance value will be equal to *DBndUp_L*. Likewise for *ABndLo_L* and *DBndLo_L*.
- The analog output voltage protection limits may prohibit the voltage at the analog outputs from covering the spans specified by the analog output voltage bounds.
- Other capacitance or loss parameters immediately affected by this command include the corresponding *CFact_*, *DevPt*, and *DSpan_* parameters.
- Changes to the capacitance or loss *CFact_*, *DevPt*, and *DSpan_* parameters immediately affect the corresponding *DBndUp_* and *DBndLo_* parameters.
- The relative values of the *DBndUp_* and *DBndLo_* parameters may be reversed from what would normally be expected. That is, the value of *DBndUp_* parameter may be less than the value of corresponding *DBndLo_* parameter.
- Even though the relative values of the *DBndUp_* and *DBndLo_* parameters may be reversed, the corresponding values of the analog output voltage bound parameters *ABndUp_* and *ABndLo_* may not be reversed. That is, the value of *ABndUp_* parameter must be greater than or equal to the value of corresponding *ABndLo_* parameter.
- When the relative positions of the *DBndUp_* and *DBndLo_* parameters are reversed, the corresponding values of *CFact_* and *DSpan_* are negative.

Description

Sets the capacitance an/or the loss values for the input quiescent point to the most recent measurement value.

Syntax

```
DEV FETCH CAP|LOSS|[ALL]
```

Qualifiers

CAP	Fetch the capacitance value from the most recent measurement and assign it to the capacitance value of the input quiescent point <i>DevPt_C</i> . Leave the <i>DevPt_L</i> unchanged.
LOSS	Fetch the loss value from the most recent measurement and assign it to the loss value of the input quiescent point <i>DevPt_L</i> . Leave the <i>DevPt_C</i> unchanged.
ALL	Fetch both the capacitance and loss values from the most recent measurement and assign them to the capacitance and loss values of the input quiescent point <i>DevPt_C</i> and <i>DevPt_L</i> , respectively. This qualifier is completely optional and thus may be omitted with no change to the function of the command.

Default Value None

Parameter Set Dev

Query Cmd? No

Comments

- The location of the deviation input quiescent point may be determined by any one of several means. Included among these is a manual mode where the capacitance and/or loss values associated with the deviation input quiescent point are either manually entered as numerical values or are manually fetched from the most recent DUT measurement value.
- The capacitance or loss parameters immediately affected by this command are *DevPt_*, *DBndUp_* and *DBndLo_*. The other analog output and deviation parameters remain unaffected.
- Neither automatic nor manual changes to the *DevPt_* parameters will affect the value of the corresponding *ASpan_*, *ABndUp_*, or *ABndLo_* parameters. The relative independence of these three output parameters is intended to protect from unintended change to an output voltage could cause a malfunction or damage to a connected system.
- The *DevPt_* always lies at a fixed positions relative to the corresponding *DSpan_* parameters as determined by corresponding *DPosit_* parameters. The relationships are expressed as follows:

$$DevPt_ = (DBndUp_ + DBndLo_) / 2 + DPosit_ * DSpan_ / 2.$$
- The bridge balance point *DBalPt_* is always located directly at the midpoint between the upper and lower deviation boundaries *DBndUp_* and *DBndLo_*. The relationships are expressed as follows:

$$DBalPt_ = (DBndUp_ + DBndLo_) / 2.$$
- Because the bridge balance point *DBalPt_* is always located directly at the midpoint between the upper and lower deviation boundaries *DBndUp_* and *DBndLo_*, they will be affected by fetching assignment for the deviation input quiescent point.
- The primary advantage of fetching an assignment of the deviation input quiescent point is that it eliminates the need to manually enter numerical values to compensate for a slowly drifting DUT. This can be especially helpful when applied to a capacitance or loss channel whose measurement values are of little or no interest because it helps to eliminate input boundary related error messages.

Related Commands

All AOUT and DEV commands.

DEV FORMAT

Description

Sets the deviation format applied to deviation results reported to both the front panel and remote devices.

Syntax

```
DEV FORMAT CAP|LOSS DForm_C | DForm_L
           or
           DEV FORMAT [ALL] DForm_A
           or
           DEV FORMAT [DForm_C], [DForm_L]
```

Qualifiers

CAP	Set the deviation format for capacitance. The entered parameter will be applied to the <i>DForm_C</i> parameter.
LOSS	Set the deviation format for loss. The entered parameter will be applied to the <i>DForm_L</i> parameter.
ALL	Set the deviation format for both capacitance and loss. The entered parameter will be applied to both the <i>DForm_C</i> and the <i>DForm_L</i> parameters. This qualifier may be omitted with identical results.

Parameters

- 0** Deviation measurement results are reported in absolute pF and jpF units. A measurement values at the input quiescent point will be reported as *DevPt_C* pF and *DevPt_L* jpF.
- 1** Deviation measurement results are reported as simple differences from the input quiescent point in units of pF and jpF. A measurement values at the input quiescent point will be reported as 0 pF and 0 jpF.
- 2** Deviation measurement results are reported as differences from the input quiescent point as a percentage of the input quiescent point. A measurement values at the input quiescent point will be reported as 100% for both capacitance and loss.
- 3** Deviation measurement results are reported as differences from the input quiescent point as a percentage of the deviation input span. Measurement values at the *DBndLo_* and *DBndUp_* bounds will be reported as -50% and +50% respectively.
- 4** Deviation measurement results are reported as differences from the input quiescent point as a percentage of the deviation input span. Measurement values at the *DBndLo_* and *DBndUp_* bounds will be reported as -100% and +100% respectively.

Note: When using the third form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value *DForm_C*: 0, *DForm_L*: 0

Parameter Set Dev

Query Cmd? No

Comments

- This command affects no other deviation or analog output related parameters. Additionally the deviation format parameters are not affected by other deviation and analog output related commands.
- This command works in together with the REFERENCE FORMAT and REFERENCE PERCENT commands to control the format of the deviation measurement results reported both to the front panel display and to remote devices.
- This command has no effect on analog output voltages.
- The formats specified by this command have no effect upon measurement results made with the deviation mode disabled.
- The *DForm_*, *RefMod_*, and *Percnt_* parameters affect the format of the deviation measurement results.
- Deviation measurement results made with the reference mode *disabled* are accompanied by a two character deviation result format identification label. The first character is “D” and the second is the value of *DForm_* parameter.
- Deviation measurement results made with the reference mode *enabled* are accompanied by a four character deviation result format identification label. The first two characters of this label are identical to the format identification label that appears with non-reference mode measurement results. The additional two characters consist of an “R” and the value of the *Percnt_* parameter.
- The deviation result format identification and the units labels are combined for remote devices using the following syntax:

[D0|D1|D2|D3|D4][R0|R1](PF|JP)

- On the front panel, the deviation result format identification labels are shown in both the Busy and Mode windows. The syntax used in these windows, a modified form of that which is used on remote devices, is shown below:

BUSY (0|1|2|3|4)[R0|R1]
 DEV (0|1|2|3|4)[R0|R1]

and

MODE (0|1|2|3|4)[R0|R1]
 DEV (0|1|2|3|4)[R0|R1]

Related Commands

All AOUT and DEV commands.

DEV MARGIN

Description

Sets the deviation margin which controls the ability of the bridge to handle deviations outside of the input deviation bounds without encountering overloading of the preamplifier.

Syntax

`DEV MARGIN DMargin`

Parameters

DMargin is the dimensionless ratio of the preamplifier span to the magnitude of the input deviation span. The permitted range of values is 1.0 to 20.0.

Default Value 1.0

Parameter Set Dev

Query Cmd? No

Comments

- When the input deviation exceeds the preamplifier span the bridge experiences a preamplifier overload error condition. Such an error will result in the appearance of the `PREAMP OVERLOAD` message on the front panel.
- Preamplifier overload errors are classified as fatal, or hard, errors because they prohibit the production of measurement results. This is in contrast with input boundary errors which are classified as soft because they do not the production of measurement results.
- The magnitude of the input deviation span is related to the input deviation span parameter by the following expression:
$$| DSpan | = (DSpan_C^2 + DSpan_L^2)^{1/2}.$$
- The magnitude of the input deviation span is related to the input deviation span parameter by the following expression:
$$| DSpan | = (DSpan_C^2 + DSpan_L^2)^{1/2}.$$
- The deviation margin factor, *DMargin*, is related to the preamplifier span and the magnitude of the input deviation span by the following expression:
$$DMargin = PreampSpan / | DSpan |.$$
- In situations where a high sensitivity (*CFactor*) is desired in the presence of noise spikes, an unacceptable number of error messages may be generated as a result of momentarily exceeding the range of the preamp. Where *DMargin* can have the following values:
- Enlarging the preamplifier span is useful in situations where a high sensitivity (*CFactor*) is desired in the presence of noise spikes. In this situation the *DMargin* can be increased to avoid the generation of an unacceptably large number of error messages.
- The user should keep in mind that while increasing the *DMargin* reduces susceptibility to noise from the standpoint of the generation of error messages, it reduces the signal-to-noise ratio by the same proportion.

Related Commands

All AOUT and DEV commands.

Description

Sets the capacitance and loss values for the input quiescent point.

Syntax

```

DEV POINT CAP|LOSS DevPt_C | DevPt_L
      or
DEV POINT [DevPt_C] , [DevPt_L]
    
```

Qualifiers

CAP	Set the capacitance value corresponding to the input quiescent point.
LOSS	Set the loss value corresponding to the input quiescent point.

Parameters

<i>DevPt_C</i>	The capacitance value of the input quiescent point in pF. Corresponds to the <i>AoutPt_C</i> output quiescent capacitance voltage.
<i>DevPt_L</i>	The loss value of the input quiescent point in jpF. Corresponds to the <i>AoutPt_L</i> output quiescent loss voltage.

Note: When using the second form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value None

Parameter Set Dev

Query Cmd? No

Comments

- The capacitance or loss parameters immediately affected by this command are the corresponding *DBndUp_* and *DBndLo_*. The other analog output and deviation parameters remain unaffected.
- Changes to the *DevPt_* parameters do not affect the value of the corresponding *ASpan_*, *ABndUp_*, or *ABndLo_* parameters. The relative independence of these three output parameters is intended to protect from unintended change to an output voltage could cause a malfunction or damage to a connected system.
- Changes to the capacitance and loss *DBndUp_* and *DBndLo_* input bound parameters immediately affect the corresponding *DevPt_* parameter.
- Changes to a capacitance or loss *DPosit_* position parameter also immediately affect the corresponding *DevPt_* parameter.
- Changes to most of the analog output related parameters including *CFact_*, *ASpan_*, *ABndUp_*, and *ABndLo_* do not affect the corresponding *DevPt_* parameter.
- The *DevPt_* always lies at a fixed positions relative to the corresponding *DSpan_* parameters as determined by corresponding *DPosit_* parameters. The relationships are expressed as follows:

$$DevPt_ = (DBndUp_ + DBndLo_) / 2 + DPosit_ * DSpan_ / 2.$$
- The *DPosit_* parameters not only determine the positions of the quiescent capacitance and loss points within their respective input spans, but they also determine the positions of the quiescent voltage points within their respective output voltage spans.
- The bridge balance point *DBalPt_* is always located directly at the midpoint between the upper and lower deviation boundaries *DBndUp_* and *DBndLo_*. The relationships are expressed as follows:

$$DBalPt_ = (DBndUp_ + DBndLo_) / 2.$$

Related Commands

All AOUT and DEV commands.

DEV POSITION

Description

Sets the positions of the quiescent capacitance and loss points within their respective input spans as well as the positions of the corresponding quiescent voltage points within their respective output voltage spans.

Syntax

```
DEV POSITION CAP|LOSS DPosit_C | DPosit_L
           or
DEV POSITION [DPosit_C] , [DPosit_L]
```

Qualifiers

CAP	Set the position of the capacitance quiescent point between the upper and lower bounds of the capacitance input span.
LOSS	Set the position of the loss quiescent point between the upper and lower bounds of the loss input span.

Parameters

<i>DPosit_C</i>	The relative position of the input quiescent point between the upper and lower bounds of the capacitance input span. Decimal numbers in the range of -1.0 to +1.0 are permitted.
<i>DPosit_L</i>	The relative position of the input quiescent point between the upper and lower bounds of the loss input span. Decimal numbers in the range of -1.0 to +1.0 are permitted.

Note: When using the second form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value 0.0

(At the center of the span and congruent with the bridge balance point)

Parameter Set Dev

Query Cmd? No

Comments

- The capacitance or loss parameters immediately affected by this command are the corresponding *DevPt_* and *AoutPt_*.
- This is the only command that can change the position of a quiescent point relative to a span. This relative independence of the *DevPt_* parameters means that no matter how the other DEV commands are used, the relative positions will always be preserved.
- The *DPosit_* parameters not only determine the positions of the quiescent capacitance and loss points within their respective input spans, but they also determine the positions of the quiescent voltage points within their respective output voltage spans.
- The *DevPt_* always lies at a fixed positions relative to the corresponding *DSpan_* parameters as determined by corresponding *DPosit_* parameters. The relationships are expressed as follows:
$$DevPt_ = (DBndUp_ + DBndLo_) / 2 + DPosit_ * DSpan_ / 2.$$
- The input quiescent points for capacitance and/or loss may be placed directly at the corresponding upper and lower deviation boundaries *DBndUp_* and *DBndLo_* by setting the values of the *DPosit_C* and/or *DPosit_L* parameters to +1.0 and -1.0 respectively.
- The bridge balance point *DBalPt_* is always located directly at the midpoint between the upper and lower deviation boundaries *DBndUp_* and *DBndLo_*. The relationships are expressed as follows:
$$DBalPt_ = (DBndUp_ + DBndLo_) / 2.$$
- The input quiescent points for capacitance and/or loss may be placed directly at the corresponding bridge balance points *DBalPt_* by setting the values of the *DPosit_C* and/or *DPosit_L* parameters to 0.0.

Related Commands

All AOUT and DEV commands.

Description

Sets the 3 db down point of the analog output frequency roll off limit.

Syntax

DEV ROLLOFF *DRolloff*

Parameters

DRolloff The 3 db down point of the analog output frequency roll off limit in Hz. The maximum permissible value is 20,000 Hz and the minimum permissible value is 1/3600 Hz.

Default Value 20,000 Hz

Parameter Set Dev

Query Cmd? No

Comments

- The value of the *DRolloff* limit affects all deviation results, both analog and digital. This command sets the maximum possible roll off frequency. This frequency will be used only if the bridge frequency is high enough. If the bridge frequency is not high enough, then the highest allowable roll off will be used.
- The **SHOW DEV ROLLOFF** command shows the specified roll off frequency *DRolloff*. The actual roll off frequency used may be lower, but will never be higher.
- No other capacitance or loss parameters are affected by this command.
- Even though the highest permissible value for *DRolloff* is 20,000 Hz, the highest achievable 3 db frequency *DRolloffMax* is given by the following expression:
$$DRolloffMax = 0.3 * \text{Minimum}(Freq, 28 \text{ kHz} - Freq)$$
where *Freq* is the bridge frequency in Hz.
- Note that the maximum achievable roll off will be achieved when *Freq* equals 14,000 Hz bridge. At this frequency the actual roll off frequency used will be 4200 Hz unless limited by a lower setting of the *DRolloff* parameter.
- In addition to delays caused by the roll off frequency there is an additional signal delay of about 0.7 to 0.9 ms.built into the deviation measurement system.

Related Commands

All AOUT and DEV commands.

DEV SPAN

Description

Sets the distance between the upper and lower bounds of the input deviation capacitance and loss spans in pF and jpf respectively. These deviation spans correspond directly to the analog output voltage spans for capacitance and loss respectively.

Syntax

```
DEV SPAN CAP|LOSS DSpan_C | DSpan_L
           or
           DEV SPAN [DSpan_C] , [DSpan_L]
```

Qualifiers

CAP	Set the size of the input deviation span for capacitance.
LOSS	Set the size of the input deviation span for loss.

Parameters

<i>DSpan_C</i>	The output voltage span for capacitance in pF. Corresponds to the <i>ASpan_C</i> analog output voltage span.
<i>DSpan_L</i>	The output voltage span for loss in jpf. Corresponds to the <i>ASpan_L</i> analog output voltage span.

Note: When using the second form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value None

Parameter Set Dev

Query Cmd? No

Comments

- Other capacitance or loss parameters immediately affected by this command include the corresponding *DBndUp_*, *DBndLo_*, and *CFact_*.
- Changes to the *DSpan_* parameters do not affect the value of the corresponding *ASpan_*, *ABndUp_*, or *ABndLo_* parameters. The relative independence of these three output parameters is intended to protect from unintended change to an output voltage could cause a malfunction or damage to a connected system.
- Changes to the capacitance or loss *DBndUp_* and *DBndLo_* output bound parameters immediately affect the corresponding *DSpan_* parameter.
- Changes to most of the analog output related parameters including *CFact_*, *ASpan_*, *ABndUp_*, and *ABndLo_* also affect the corresponding *DSpan_* parameter.
- The relationship between the *DSpan_*, *DBndUp_*, and *DBndLo_* parameters is as follows:
$$D_{Span_} = D_{BndUp_} - D_{BndLo_}$$
- The relationship between the *ASpan_*, *DSpan_*, and *CFact_* parameters is as follows:
$$C_{Fact_} = A_{Span_} / D_{Span_}$$
- Even though the relative values of the *ASpan_* parameters are prohibited from taking on negative values, the corresponding *DSpan_* are not similarly restricted. A negative *DSpan_* parameter value thus results in a negative value for the corresponding *CFact_* parameter.
- The *DevPt_* always lies at a fixed position relative to the corresponding *DSpan_* as determined by corresponding *DPosit_* parameter. The relationship is as follows:
$$DevPt_ = (D_{BndUp_} + D_{BndLo_}) / 2 + D_{Posit_} * D_{Span_} / 2.$$

Related Commands

All AOUT and DEV commands.

Description

During deviation mode measurements either an E (Error) or an N (Normal) data stream will be sent to the display and any connected remote devices. This command selects between these two data streams.

Syntax

`DEV STREAM DStream`

Parameters

DStream The permissible values are NORMAL and ERROR corresponding to the N and E data streams respectively.

Default Value NORMAL

Parameter Set Dev

Query Cmd? No

Comments

- This command has no effect upon any of the other analog output or deviation parameters.
- Also this command has no effect on analog output voltages.
- The N data stream reports all available *averaged* deviation data and also reports any errors that might occur with that data. Each result in the N data stream represents the average of n_A high speed samples, one or more of which may or may not have caused an error condition. Each result consists of an error-free deviation measurement, a deviation measurement plus a soft error, or only a hard error message.
- The E data stream reports only results containing errors. Each result in the E data stream represents a single, high speed sample which by itself caused an error condition. Each result consists either of a deviation measurement plus a soft error, or it consists only of a hard error message.
- For the E data stream one result, at most, is generated for each *DAvgTime* interval. If no error occurred in that time interval, then no result is generated. If more than one error was detected during a given time interval, then only the most recent error is reported. If a soft error occurs, the E data stream will also report the *unaveraged* data sample that caused the error.
- The E data stream allows one to capture any error conditions that might occur in the analog output voltages or in the N data stream without being inundated with normal data. This is especially useful for capturing any errors that occur in the analog output data stream.

Related Commands

All AOUT and DEV commands.

DEVICE CLEAR

Description

Immediately aborts execution of any command or macro. The bridge is left in a state that should accept a new command.

Front Panel Syntax

[FUNC] [CLEAR] [FUNC] [CLEAR] [FUNC] [CLEAR]

Serial Device Syntax

DevClrChar

The *DevClrChar* is definable using the **DEFINE** command. In other words, you can select which key serves as the device clear key.

Default Value

Serial device syntax uses the ASCII control E (^E) character.

GPIB Device Syntax

DCL or SDC universal IEEE-488.1 GPIB commands

Parameters None

Query Cmd? No

Comments

- The GPIB syntax that issues a Device Clear (DCL) or Selective Device Clear (SDC) GPIB command is dependent on the controller. Consult your controller manual for this syntax.
- If the **DEVICE CLEAR** command does not have the desired effect, it may be necessary to execute the **RST** command which will reset the bridge to its power-on state.

Front Panel Examples

[FUNC] [CLEAR] [FUNC] [CLEAR] [FUNC] [CLEAR]

DEVICE
CLEAR

[ENTER]

READY

The device clear function was used to abort something. The **[ENTER]** key was then pressed to get the **READY** prompt.

Serial Device Examples

>WAIT
^E
>

The **WAITFOR** command caused the bridge to hold for an external trigger pulse. The hold condition was aborted by entering the ^E character.

References

See “Device Clear Commands” on page 6-15 and “Aborting Command Execution” on page 7-11.

Related Commands

DEFINE, CLEAR

Description

Lists a directory of the files stored in the EEPROM memory. The information consists of the file type and file number.

Syntax

DIRECTORY [**BASIC**|**DEV**|**GAUGE**|**GPIB**|**SCAN**|**SERIAL**|**MACRO**|**ALL**]

Qualifiers

BASIC	List only Basic parameter files.
DEV	List only Deviation parameter files.
GAUGE	List only Gauge parameter files.
GPIB	List only GPIB parameter files.
SCAN	List only Serial parameter files.
SERIAL	List only Serial parameter files.
MACRO	List only Macro files.
ALL	List all files of all file types. Entering no qualifier also results in the listing of all file of all file types.

Parameters None

Query Cmd? Yes

Comments

- Filenames may contain only alphanumeric and underscore characters, must begin with an alpha character, and may contain no more than eight characters total.
- If no files exist, the error message "FILE NOT FOUND" or "29" will be reported.
- Files stored in RAM or ROM are not displayed by the DIRECTORY command.

Front Panel Examples

FUNC **SELECT** **DIRECTORY** **ENTER**

```
GPIB
USERPON
```



```
MACRO
EXAMPLE1
```



```
MACRO
EXAMPLE2
```



```
MACRO
EXAMPLE2
```

The third ↓ did not reveal a fourth file. Therefore, the DIRECTORY command has revealed that there are three files in the EEPROM memory, one contains a GPIB parameter set and the other two are macros. This GPIB parameter set is number one which is one of the non-volatile, power-on sets.

Remote Device Examples

```
>DI
  GPIB          USERPON
  MACRO         EXAMPLE1
  MACRO         EXAMPLE2
>DIR GPIB
  GPIB          USERPON
>DI MACRO
  MACRO         EXAMPLE1
  MACRO         EXAMPLE2
>
```

References

See "Listing the File Names" on page 3-8.

Related Commands

DELETE Filename, MACRO, RECALL, STORE

FETCH

Description

Recalls the last deviation measurement result.

Related Commands

All AOUT and DEV commands.

Syntax

FETCH

Default Value None

Parameter Set None

Query Cmd? No

Comments

- If *DStream* the parameter is set to **NORMAL**, then the most recent deviation measurement result will be reported. If no measurement has been taken yet, then the message `NO DATA FOUND` will be reported.
- If *DStream* the parameter is set to **ERROR**, then the most recent deviation error result since the time the Deviation Mode was last enabled will be reported. If no such error has occurred, then the message `NO ERROR FOUND` will be reported.
- Like the **SINGLE** command, the **FETCH** command can be executed in single or continuous mode. Unlike **SINGLE** command, the **FETCH** command does not cause continuous mode to exit so that pressing **[ENTER]** will cause the display to return to showing new deviation results.
- **FETCH** may be used repeatedly to manually sample the E or N data streams without interruption the measurement process.
- The **FETCH** command may be used to suspend real time tracking of Continuous Mode deviation results on the LED display and remote device. These results can be difficult to read from the display even at relatively large settings of the *DAvgTime* parameter. Entering **FETCH** command will cause the most recent result to effectively freeze on the display. **FETCH** can be used repeatedly this way to keep up with the latest results. Pressing **[ENTER]** will revert to real time tracking on the display and remote device.
- With the *DStream* parameter set to **ERROR**, the **FETCH** command is very useful for quickly determining if an error has occurred since enabling the deviation measurement mode. Executing the **FETCH** command after any quantity of analog and/or Deviation Normal Mode measurements have been taken will either report the most recent error or will report a `NO ERROR FOUND` message.

Description

Controls which fields are sent to serial or GPIB ports. Also controls the number of significant digits reported for capacitance and/or loss measurements to the front panel and remote devices.

Syntax

FIELD SAMPLE *FldSamp*
 or
FIELD FREQUENCY *FldFreq*
 or
FIELD CAPACITANCE *FldCap*
 or
FIELD LOSS *FldLoss*
 or
FIELD VOLTAGE *FldVolt*
 or
FIELD MESSAGE *FldMsge*
 or
FIELD [LIST] *FldSamp, FldFreq, FldCap, FldLoss, FldVolt, FldMsge*

Parameters

- FldSamp*** enables sending the sample field when set to ON. Permitted values are ON and OFF.
- FldFreq*** enables sending the frequency field when set to ON. Permitted values are ON and OFF.
- FldCap*** enables sending the capacitance field when non-zero. Also sets the number of significant digits (from 1 to 9) reported for capacitance. OFF may be substituted for 0 to disable the capacitance field.
- FldLoss*** enables sending the loss field when non-zero. Also sets the number of significant digits (from 1 to 9) reported for loss. OFF may be substituted for 0 to disable the capacitance field.
- FldVolt*** enables sending the voltage field when set to ON. Permitted values are ON and OFF.
- FldMsge*** enables an error *message* to be sent when set to ON, or an error *code* to be sent when set to OFF.

(When using the LIST command qualifier, or no command qualifier, skipping the entry of any parameter value will preserve the current value for that parameter. Multiple parameters values may be skipped.)

Query Cmd? No

Default Value OFF,ON,9,9,ON,ON

(All fields included with the maximum number of significant digits for both capacitance and loss.)

Parameter Set Basic

Comments

- Each of the *FldSamp*, *FldFreq*, *FldVolt* and *FldMsge* parameters is entered as either as ON or OFF. On enables printing of the corresponding field. OFF disables printing of the corresponding field.
- The AH2700A reports measurement values so that all capacitance and loss digits displayed are meaningful or significant. The *FldCap* and *FldLoss* parameters can cause the bridge to round the result to a lower number of significant digits, but cannot cause it to display more digits than are meaningful.
- If ASCII error messages are enabled, errors are reported as messages *following* the result line. If ASCII error messages are disabled, then the result line will be *preceded* by a two digit error code. The error code will be zero if there are no errors.

FIELD (continued)

Front Panel Examples

FUNC **FIELD** **→** **→** **3** **→** **3** **ENTER**

Sets the number of significant places in cap and loss to three.

SHOW **FUNC** **FIELD** **ENTER**

Displays the following windows

FIELD	SAMPLE
SAMPLE	OFF



FIELD	FREQ
FREQ	ON



FIELD	CAP
CAP	3



FIELD	LOSS
LOSS	3



FIELD	VOLTAGE
VOLTAGE	ON



FIELD	MESSAGE
MESSAGE	ON

The **←** and **→** keys are used to move between the two windows.

ENTER

SINGLE

043
00373

Remote Examples

```
>SH FI
FIELD SAMPLE      OFF
FIELD FREQ        OFF
FIELD CAP          9
FIELD LOSS         9
FIELD VOLTAGE     OFF
FIELD MESSAGE     ON
>SI
C=10.342956 PF L=0.0004591 NS OVEN
>FIELD ,,5,5,,OFF
>SH FI
FIELD SAMPLE      OFF
FIELD FREQ        OFF
FIELD CAP          5
FIELD LOSS         5
FIELD VOLTAGE     OFF
FIELD MESSAGE     OFF
>SI
15 C=10.342 PF L=0.0004592 NS
>
```

The **FIELD** command was used to change the capacitance and loss places from 9 to 5. Notice that setting the number of places is not the limiting factor for the loss result since only four places are shown even when 9 were allowed. The **FIELD** command was also used to change from sending an error message (**OVEN**) at the end of the result line to reporting an error code (15) at the beginning.

References

See “**REMOTE DEVICE FORMATS**” on page 5-5. See also “**SIGNIFICANT DIGITS**” on page 5-1 and specifically “**Setting a Limit on the Significant Digits**” on page 5-1.

Related Commands

FORMAT

Description

Controls the format and numeric notation of results which are sent to serial or GPIB ports. Front panel results are not affected.

Syntax

```

FORMAT NOTATION Notation
      or
FORMAT LABELING Labeling
      or
FORMAT IEEE4882 IEEE4882
      or
FORMAT FWIDTH FldWidth

```

FORMAT [LIST] *Notation, Labeling, IEEE4882, FldWidth*

Parameters

Notation specifies the type of numeric notation to be used for capacitance, loss, frequency, voltage and cable results. The *Notation* parameter can be set to FLOATING, SCI or ENG.

Labeling enables labels to be sent when set to ON and conversely disables labels when set to OFF. Permitted values are ON and OFF.

IEEE4882 enables IEEE-488.2 compatible punctuation when set to ON. Permitted values are ON and OFF.

FldWidth fixes field widths when set to FIXED. Permitted values are FIXED and VARIABLE.

(When using the LIST command qualifier or no command qualifier, skipping the entry of any parameter value will preserve the current value for that parameter. Multiple parameters values may be skipped.)

Notice: 0 and 1 may be substituted for OFF and ON respectively.

Default Value FLOATING,ON,OFF,FIXED

Parameter Set Basic

Query Cmd? No

Comments

- Labels consist of the field identifier (S=, C=, L= etc.) and the measurement units (PF, NS and V, for example). Labels in SHOW command results are affected also.
- The effect of IEEE-488.2 compatible punctuation is to substitute commas for spaces as field separators and to enclose messages and other string variables in quotes. This affects both GPIB and serial results.
- When *FldWidth* is VARIABLE, no fill spaces are sent. These spaces keep the measurement results aligned in neat columns.
- Only *results* are affected by the *Notation* parameter. The notation of numeric values that are *entered* is automatically detected and appropriately interpreted.

Front Panel Examples

[FUNC] [SELECT] [FORMAT] [FWIDTH] [VARIABLE]

Displays the following window:

```

FWIDTH
VARIABLE

```

[ENTER]

The *FldWidth* parameter was set to VARIABLE, making the field widths variable. The [ENTER] key was then pressed to complete the command and get the *READY* prompt.

[SHOW] [FUNC] [FORMAT] [ENTER]

Displays the following windows:

```

FORMAT      NOTATION
NOTATION    ENGINEER

```

↓

```

FORMAT      LABELING
LABELING    ON

```

↓

```

FORMAT      IEEE4882
IEEE4882    OFF

```

↓

```

FORMAT      FWIDTH
FWIDTH      OFF

```

The [←] and [→] keys are used to select which of the left or right windows is displayed.

FORMAT (continued)

Remote Examples

```
>SH FO
  FORMAT NOTATION FLOATING
  FORMAT LABELING ON
  FORMAT IEEE4882 OFF
  FORMAT FWIDTH    FIXED
>SI
  F=1000 HZ C= 843.31863 PF L= 0.03721 NS
>FORMAT NOTATION ENG
>SI
  F= 1.0000E+03 HZ C= 8.4331863E+02 PF
                                L= 3.756E-02 NS
>FORMAT ENG,,ON,
>SI
  F= 1.0000E+03 HZ,"C=", 843.31868E+00 PF,
                                "L=", 37.44E-03 NS
>SH FO
  FORMAT NOTATION ENGINEERING
  FORMAT LABELING ON
  FORMAT IEEE4882 ON
  FORMAT FWIDTH    FIXED
>
```

The above examples show floating-point, scientific, and engineering notation results, respectively. The last two result lines also show IEEE-488.2 compatible punctuation. Note the additional commas and quotation marks. Note also that “F=” has no quotation marks while “C=” and “L=” do. The reason is that the latter two are variables whereas the former is not.

References

See “REMOTE DEVICE FORMATS” on page 5-5 and “Numeric Notation” on page 5-8.

Related Commands

FIELD

Description

Sets the test frequency at which measurements are to be taken.

Syntax

FREQUENCY *Freq*
or
FREQUENCY UP|DOWN

Qualifiers

UP change the *Freq* parameter to the next available frequency as determined by the scan setup parameters.

DOWN change the *Freq* parameter to the next available frequency as determined by the scan setup parameters.

Parameters

Freq This parameter specifies the desired test frequency. The bridge will select the nearest available frequency at which measurements can be taken.

Default Value 1000.0 Hz (Floating Point)

Parameter Set Gauge

Query Cmd? No

Front Panel Examples

FREQUENCY 1 5 9 1 . 5

Displays the following window:

```
FREQUENCY
15915
```

ENTER

The *Freq* parameter was set to 1591.5, The ENTER key was then pressed to complete the command and get the *READY* prompt.

SHOW FREQUENCY ENTER

Displays the following window:

```
FREQUENCY
16000 HZ
```

The selected frequency of 1600.0 Hz is the closest one available to the 1591.5 that was entered.

Comments

- The AH2700A is a discrete frequency bridge offering the following test frequencies: 50, 60, 70, 80, 100, 120, 140, 160, 200, 240, 300, 400, 500, 600, 700, 800, 1000, 1200, 1400, 1600, 2000, 2400, 3000, 4000, 5000, 6000, 7000, 8000, 10,000, 12,000, 14,000, 16,000, and 20,000 Hz.
- Entering a value for *Freq* between 50 Hz and 20 kHz will cause the bridge to select the nearest frequency in the above list at which to operate.
- The AH2700A has a third display window that shows only the test frequency. If a measurement result is being displayed then this window will read out the frequency at which that measurement was made. If the front panel is displaying any other result or prompt, then this window will read out the frequency that will be used to make the *next* measurement.
- The AH2700A is originally shipped with a macro in the EEPROM memory that, when executed, will sweep through all the available frequencies from lowest to highest taking one measurement at each frequency. The name of this macro is FREQSCAN.
- The higher the frequency, the shorter the cable length must be to get accurate results. If the cable length selected by the cable command is too long for the frequency selected, a warning message will be reported every time a measurement is started. Cables that are too long can resonate at higher frequencies causing serious measurement errors.

Remote Examples

```
>FREQ 1233.15
>SH FR
FREQUENCY 1200.0 HZ
>SI
F= 1200.0 HZ C= 843.31863 PF
L= 0.03721 NS
```

The selected frequency of 1200.0 is the closest one available to the 1233.15 that was entered.

References

See "FREQUENCY OF THE TEST SIGNAL" on page 4-13

Related Commands

MACRO RUN, CABLE, SCAN

FREQUENCY SCAN COUPLE

Description

Enables or disables the automatic scanning of the frequency parameter. Also positions frequency parameter within the scanning hierarchy for multidimensional scanning.

Syntax

```
FREQUENCY SCAN COUPLE FCoupling
```

Parameters *FCoupling*

The permitted values along with their meanings are listed below:

0	disabled scanning for frequency.
1	enables scanning for the frequency. Positions the frequency parameter within the scanning hierarchy such that the frequency will be stepped immediately before each STEP or SCAN command causes a measurement to be taken.
2	enables scanning for frequency. Within a multidimensional scanning scheme, positions frequency within the scanning hierarchy such that the frequency parameter will be stepped only when the STEP or SCAN command causes wrapping of the coupled parameter whose coupling parameter is set to 1.
3	enables scanning for frequency. Within a multidimensional scanning scheme, positions frequency within the scanning hierarchy such that the frequency parameter will be stepped only when the STEP or SCAN command causes wrapping of the coupled parameter whose coupling parameter is set to 2.

Default Value 0

Parameter Set Scan

Query Cmd? No

Comments

- The three scannable parameters *Freq*, *SNumber* and *VHighest* use the three **coupling** parameters *FCoupling*, *SCoupling* and *VCoupling* respectively, to enable the STEP and SCAN measurement commands and to couple the stepping of these scannable parameters to the execution of the STEP and SCAN commands. The STEP and SCAN commands will make measurements

only if one or more of the three coupling parameters is non-zero.

- If *FCoupling* is the only non-zero coupling parameter, then the *Freq* parameter will be stepped immediately before the STEP or SCAN command causes a measurement to be taken. *SNumber* and *VHighest* parameters will not be affected by the STEP and SCAN commands.
- If more than one of the coupling parameters is non-zero, then the coupled parameter corresponding to the coupling parameter having the lowest value will be stepped immediately before the STEP or SCAN command causes a measurement to be taken. The coupling parameter having the second lowest value will have its corresponding coupled parameter stepped when wrapping occurs to the coupled parameter corresponding to the coupling parameter having the lowest value. The coupling parameter (if any) having the third lowest value will have its corresponding coupled parameter stepped when wrapping occurs to the coupled parameter corresponding to the coupling parameter having the second lowest value.
- The existence of two or more coupling parameters having the same non-zero value is not possible. Any attempt to set a coupling parameter to a non-zero value used by another coupling parameter will cause the values of the two coupling parameters to be swapped.

Front Panel Examples

```
FUNC SELECT FREQUENCY SCAN COUPLE 1 ENTER  
FUNC SELECT SAMPLE SCAN COUPLE 2 ENTER  
FUNC SELECT VOLTAGE SCAN COUPLE 3 ENTER
```

Frequency and voltage will be iterated most and least frequently respectively.

Remote Device Examples

```
>FREQUENCY SCAN COUPLE 1  
>SAMPLE SCAN COUPLE 2  
>VOLTAGE SCAN COUPLE 3  
>
```

Frequency and voltage will be iterated most and least frequently respectively.

References

See Appendix D, “Sample Switch Port” and specifically “Selecting a Sample Switch Position” on page D-1.

Related Commands

FREQUENCY SCAN DELTA, FREQUENCY SCAN FLOOR/CEILING, SAMPLE SCAN COUPLE, VOLTAGE SCAN COUPLE, STEP, SCAN, FREQUENCY

FREQUENCY SCAN DELTA

Description

For frequency scanning, only the 33 discrete frequencies are available. This frequency set is arranged logarithmically with 12 frequencies per decade over the span of 50 Hz and 20,000 Hz. This command sets the number of frequencies per decade to be scanned as well as the direction in which the frequency parameter is change.

Syntax

FREQUENCY SCAN DELTA *FDelta*

Parameters *FDelta*

The permitted values 1, 2, 3, 4, 6, and 12 provide six different frequency densities: These values are the number of frequencies per decade. For each value of *FDelta* the table below shows the first decade of all the possible frequencies given a lowest frequency of 100 Hz. If instead, the lowest frequency were 120 Hz, then the next frequency in column 1 would be 1200 Hz; in column 2 the next frequencies would be 400 Hz and 1200 Hz, in column 3 they would be 240, 600 and 1200 Hz, and so on.

Table A-2 Discrete frequencies vs. FDelta

<i>FDelta</i> →	1	2	3	4	6	12
Discrete Frequencies in Hz vs. <i>FDelta</i>	100	100	100	100	100	100
						120
					140	140
				160		160
			200		200	200
						240
		300		300	300	300
						400
			500		500	500
				600		600
					700	700
						800
	1000	1000	1000	1000	1000	1000

When the value of *FDelta* is positive the *Freq* parameter will be iterated in the direction of increasing values. Conversely, when the value of *FDelta* is negative the *Freq* parameter will be iterated in the direction of decreasing values.

Default Value -12

Parameter Set Scan

Query Cmd? No

Comments

- If a value other than 1, 2, 3, 4, 6, or 12 is entered for *FDelta*, the common error message “BAD PARAMETER” will be reported.
- The AH2700A is a discrete frequency bridge offering the following 33 test frequencies:
50, 60, 70, 80, 100, 120, 140, 160, 200, 240, 300, 400, 500, 600, 700, 800, 1000, 1200, 1400, 1600, 2000, 2400, 3000, 4000, 5000, 6000, 7000, 8000, 10,000, 12,000, 14,000, 16,000, and 20,000 Hz.
- If *FFloor* is exactly equal to one of the 33 discrete frequencies, then the lowest frequency is exactly *FFloor*. Otherwise the lowest frequency is the next discrete frequency value above *FFloor*. This lowest frequency is called the base frequency.

Front Panel Examples

```
FUNC SELECT FREQUENCY SCAN COUPLE 1 ENTER
FUNC SELECT FREQUENCY SCAN DELTA MINUS 6
ENTER
```

```
FUNC SELECT FREQUENCY SCAN FLOOR
1 2 0 0 ENTER
```

```
FUNC SELECT FREQUENCY SCAN CEILING
2 0 0 0 0 ENTER
```

The frequency parameter will be iterated toward decreasing frequency values with each execution of the **STEP** and **SCAN** commands. The scanned frequencies will consist of 1200, 1600, 2400, 4000, 6000, 8000, 12,000, and 16,000 Hz.

Remote Device Examples

```
>FREQUENCY SCAN COUPLE 1
>FREQUENCY SCAN DELTA -6
>FREQUENCY SCAN FLOOR 1200
>FREQUENCY SCAN CEILING 20000
>
```

The frequency parameter will be iterated toward decreasing frequency values with each execution of the **STEP** and **SCAN** commands. The scanned frequencies will consist of 1200, 1600, 2400, 4000, 6000, 8000, 12,000, and 16,000 Hz.

References

See Appendix D, “Sample Switch Port” and specifically “Selecting a Sample Switch Position” on page D-1.

Related Commands

FREQUENCY SCAN COUPLE, FREQUENCY SCAN FLOOR/CEILING, SAMPLE SCAN COUPLE, VOLTAGE SCAN COUPLE, SCAN, STEP, FREQUENCY

FREQUENCY SCAN FLOOR / CEILING

Description

Sets the highest and lowest frequency values to be used when scanning the frequency parameter.

Syntax

FREQUENCY SCAN FLOOR *FFloor*
 or
FREQUENCY SCAN CEILING *FCeiling*

Parameters

FFloor is a five digit decimal number in units of Hz. The lowest frequency value used in the scan series will be equal to or greater than the value entered for this parameter.

FCeiling is a five digit decimal number in units of Hz. The highest frequency value used in the scan series will be equal to or less than the value entered for this parameter.

Default Value *FFloor*: 50 Hz
FCeiling: 20,000 Hz

Parameter Set Scan

Query Cmd? No

Comments

- The AH2700A is a discrete frequency bridge offering the following 33 test frequencies:
 50, 60, 70, 80, 100, 120, 140, 160, 200, 240, 300, 400, 500, 600, 700, 800, 1000, 1200, 1400, 1600, 2000, 2400, 3000, 4000, 5000, 6000, 7000, 8000, 10,000, 12,000, 14,000, 16,000, and 20,000 Hz.
- If *FFloor* is exactly equal to one of the 33 discrete frequencies, then the lowest frequency is exactly *FFloor*. Otherwise the lowest frequency is the next discrete frequency value above *FFloor*. This lowest frequency is called the base frequency.
- If *FCeiling* is exactly equal to one of the 33 discrete frequencies, then the highest frequency is exactly *FCeiling*. Otherwise the highest frequency is the next discrete frequency value below *FCeiling*.

References

See Appendix D, "Sample Switch Port" and specifically "Selecting a Sample Switch Position" on page D-1.

Related Commands

FREQUENCY SCAN COUPLE, FREQUENCY SCAN DELTA, SAMPLE SCAN COUPLE, STEP, SCAN

Front Panel Examples

```
FUNC SELECT FREQUENCY SCAN COUPLE 1 ENTER
FUNC SELECT FREQUENCY SCAN DELTA MINUS 6
ENTER
```

```
FUNC SELECT FREQUENCY SCAN FLOOR
1 1 0 0 ENTER
FUNC SELECT FREQUENCY SCAN CEILING
1 9 0 0 0 ENTER
```

The frequency parameter will be iterated toward decreasing frequency values with each execution of the STEP and SCAN commands. The scanned frequencies will consist of 1200, 1600, 2400, 4000, 6000, 8000, 12,000, and 16,000 Hz.

```
FUNC SELECT SHOW FREQUENCY SCAN FLOOR
ENTER
```

```
FREQ FLOOR
FLOOR 11000 HZ
```

```
FUNC SELECT SHOW FREQUENCY SCAN CEILING
ENTER
```

```
FREQ CEILING
CEILING 19000 HZ
```

Remote Device Examples

```
>FREQUENCY SCAN COUPLE 1
>FREQUENCY SCAN DELTA -6
>FREQUENCY SCAN FLOOR 1100
>FREQUENCY SCAN CEILING 19000
>SHOW FREQUENCY SCAN
FREQ COUPLING 1
FREQ METHOD DISCRETE
FREQ DELTA -6
FREQ FLOOR 1100.0 HZ
FREQ CEILING 19000.0 HZ
>
```

The frequency parameter will be iterated toward decreasing frequency values with each execution of the STEP and SCAN commands. The scanned frequencies will consist of 1200, 1600, 2400, 4000, 6000, 8000, 12,000, and 16,000 Hz.

Description

Sets the communications parameters for the GPIB (IEEE-488) port.

Syntax

```
GPIB [SELF] ADDRESS Primary, Secondary
      or
GPIB ADDRMODE AddrMode
      or
GPIB COMPATIB Compatib
      or
GPIB PROMPTS Prompts
      or
GPIB [LIST] Primary, Secondary, AddrMode, Compatib, Prompts
```

Parameters

Primary

is the primary GPIB address. It can have any value from 0 to 30.

Secondary

is an optional secondary GPIB address and can range from 0 to 30.

AddrMode

controls the GPIB addressing mode. Permitted values are TALKONLY, PRI_ONLY, and PNSCNDRY. When set to TALKONLY, results can be sent to a “listen only” device such as a printer or logger. When set to PRI_ONLY, the instrument may be addressed only by its primary address. When set to PNSCNDRY, the instrument may be addressed by both its primary and secondary addresses. PRI_ONLY is the default value.

Compatib

selects compatibility mode when set to ON. In compatibility mode, all result lines are separated with semicolons. With compatibility mode off, all result lines are separated with CR and LF characters. All messages are terminated with CR, LF^END no matter how compatibility mode is set. The default value is OFF.

Prompts

makes all prompt messages available to the GPIB when set to a ON. This is intended for use with the interactive mode of operation. The Rdy status bit is used to distinguish a prompt message from all others. The default value is OFF.

(When using the LIST, ADDRESS, or no command qualifiers skipping the entry of any parameter value will preserve the current value for that parameter. Multiple parameters values may be skipped.)

Note: 0 and 1 may be substituted for OFF and ON respectively when setting the *Compatib* and *Prompts* parameters.

Default Values 28,28,PRI_ONLY,ON,OFF; See above.

Parameter Set GPIB

Query Cmd? No

Comments

- The settings of this command affect only GPIB operations.
- The SHOW GPIB command shows all the parameters in the GPIB parameter set rather than just those entered by the GPIB command.

Front Panel Examples

FUNC SELECT GPIB ADDRESS 2 2 ENTER

Sets the primary GPIB address to 22.

FUNC SELECT GPIB LIST → → → OFF ENTER

Disable compatibility mode.

SHOW FUNC GPIB ENTER

Displays the following windows:

GPIB	ADDRESS
ADDRESS	22, 28

↓

GPIB	ADDRMODE
ADDRMODE	PRI_ONLY

↓

GPIB	COMPATIB
COMPATIB	OFF

↓

GPIB	PROMPTS
PROMPTS	OFF

↓

SRE	M ERPUCN
BIN	00 10 100 1

↓

LOGGER	GPIB
GPIB	OFF

The ← and → keys are used to select which of the left or right windows is displayed.

GPIB (continued)

Remote Device Examples

```
>GP ,15,,ON,
```

Set the secondary address to 15 and enable compatibility mode.

```
>SH GP
```

```
 GPIB ADDRESS      28,15
 GPIB ADDRMODE     PRI_ONLY
 GPIB COMPATIB     ON
 GPIB PROMPTS      OFF
 SRE               MAU=0 EXE=0 RDY=0 PON=0
                  URQ=0 CME=0 NVL=0
 LOGGER GPIB       OFF
>
```

References

See “GPIB CONFIGURATION PARAMETERS” on page 6-1, “GPIB DATA LOGGING” on page 6-15, and “STATUS REPORTING” on page 6-5.

Related Commands

LOGGER GPIB, SHOW STB, SRE, USER

Description

Reports bridge identification information including the manufacture name, model number, option codes, serial number, and firmware revision number.

Syntax

*IDN?
or
IDN?

Both forms of this command are equivalent.

Qualifiers None

Parameters None

Parameter Set None

Query Cmd? Yes

Comments

- Pressing **[ENTER]** will abort a multi-line show that is in progress on the front panel.
- Pressing the **[←]** or **[→]** keys moves from window to window on a given line on the front panel. The **[↑]** and **[↓]** keys are used to go from one result line to the next
- The *IDN?, IDN?, and SHOW IDN commands are equivalent.

Front Panel Examples

The IDN? command is available from the front panel via menus. Use the equivalent SHOW IDN command when operating from the front panel.

[FUNC] **[SELECT]** **[SHOW]** **[IDN]** **[ENTER]** gives:

MANUFAC	ANDEEN-H
TURER	AGERLING

[↓] gives:

MODEL	AH2700A
OPTIONS	CEJ

[↓] gives:

SERIAL	00000100
NUMBER	

[↓] gives:

ACTIVE	BANK FL 1
FIRMWARE	AH270125

The **[←]** and **[→]** keys are used to select which of the left or right windows is displayed.

Remote Device Examples

```
>SH IDN
MANUFACTURER      ANDEEN-HAGERLING
MODEL/OPTIONS     AH2700A CEJ-----
SERIAL NUMBER     00000100
ACTIVE FIRMWARE   AH270125
>
```

References

See “Special Parameter Set” on page 3-7.

Related Commands

SHOW IDN

Description

This command allows the selection of what front panel initiated commands and results are to be logged to the GPIB and/or serial ports.

Syntax

```
LOGGER SERIAL|GPIB
      OFF|READINGS|RESULTS|CMDS_TOO
```

First Qualifiers

SERIAL	The Second Qualifier will affect data logged to the serial port only.
GPIB	The Second Qualifier will affect data logged to the GPIB port only.

Second Qualifiers

OFF	Logging is disabled for the remote device specified by the First Qualifier.
READINGS	Only measurement results will be logged to the remote device specified by the First Qualifier.
RESULTS	All results will be logged to the remote device specified by the First Qualifier.
CMDS_TOO	All commands and all results will be logged to the remote device specified by the First Qualifier.

Default Values

Serial: OFF, GPIB: READINGS
All logging disabled to the serial port; logging enabled to the GPIB port of measurement results only.

Parameter Set Serial, GPIB

Query Cmd? No

Comments

- “Measurement results only” (READINGS) refers to logging only the sample number, capacitance, loss and voltage values and error messages.
- “All results” (RESULTS) refers to measurement, calibration and test results and also results from the DIRECTORY command and all versions of the SHOW command.
- “All commands and results” (CMDS_TOO) refers to all results logged with RESULTS. In addition, commands entered from the front panel are themselves logged.
- Logging to the GPIB channel can be done by connecting a “listen only” device. This requires that the AH2700A be placed in the “talk only” state using the GPIB command.

Front Panel Examples

```
FUNC [SELECT] [LOGGER] [SERIAL] [READINGS] [ENTER]
```



This causes all results to be logged to the serial port.

```
FUNC [SELECT] [SHOW] [LOGGER] [SERIAL] [ENTER]
```

```

  [LOGGER] [SERIAL]
  [SERIAL] [READINGS]

```

The  and  keys are used to select which of the left or right windows is displayed.

Remote Device Examples

```
>LOG GP READ (Enable logging of measurement
              results only to the GPIB port.)
>LOG SE OFF (Stop logging to the serial port.)
>SH LOG
  LOGGER SERIAL OFF
  LOGGER GPIB READINGS
>
```

References

See “GPIB DATA LOGGING” on page 6-15 and “SERIAL DATA LOGGING” on page 7-13.

Related Commands

GPIB

MACRO CREATE

Description

This command is used to create a macro.

Syntax

```
MACRO CREATE
.
.
.
blank line ends entry
```

A macro is created by first issuing this command. The command lines of the macro are entered next. When all the lines of the macro have been entered, macro entry is terminated by entering a blank macro line.

Parameters None

Parameter Set None

Query Cmd? No

Comments

- The commands below are not allowed in macros:
DELETE ALL
DELETE MACRO
MACRO CREATE
RECALL MACRO
STORE MACRO
- Macros can call submacros to a nesting depth of eight.
- Individual macros cannot be edited. However, a macro can contain many short submacros, each of which is easy to delete and re-create.
- There are no conditional commands for macros to use.
- No form of the STORE command is allowed in a macro that repeats.
- Use the STORE command to store named macros files for later use.

Front Panel Examples

FUNC **SELECT** **MACRO** **CREATE** **ENTER**

READY MC

FUNC **SELECT** **UNITS** **DF** **ENTER**

FUNC **SELECT** **WAITFOR** **ENTER**

SINGLE **ENTER**

ENTER

(Terminate macro entry.)

READY

This macro sets units to dissipation factor, waits for an external trigger pulse to occur and then takes a single measurement.

Remote Examples

```
>MACRO CREATE
#AVERAGE 7
#WAIT DELAY 900
#SINGLE
#ZERO FETCH
#ZERO ON
#WAIT DELAY 180
#SINGLE
#
>
```

References

See “WORKING WITH MACROS” on page 3-10 and specifically “Creating Macros” on page 3-10.

Related Commands

MACRO RUN, MACRO SETUP, RECALL MACRO, SHOW MACRO, STORE, TRG

Description

Executes a macro.

Syntax

MACRO RUN [*Filename*]

Parameters

Filename Use this parameter to specify the name of the file to be executed. If *Filename* is not entered, the current macro will be executed.

Default Value None

Parameter Set None

Query Cmd?

A macro is considered to be a query command and is therefore query interruptible if it or any of its submacros contain a query command.

Comments

- An executing macro is indicated by illumination of the MACRO ACTIVE LED indicator.
- Macros may be executed in a number of modes including the single-step, non-stop and repetitive execution modes. The **MACRO SETUP** can be used to change the execution mode prior to executing the **MACRO RUN** command.
- Including **MACRO RUN** commands within a parent macro provide a means for the parent macro to execute submacros (its children). Macros can call submacros to a nesting depth of eight.
- Including **MACRO SETUP** commands within a parent macro provide a means for the parent macro to control the execution parameters pertaining to subsequent submacros (its children).
- *Filename* may contain only alphanumeric and underscore characters, must begin with an alpha character, and may contain no more than eight characters total.

References

See "WORKING WITH MACROS" on page 3-10 and specifically "Executing Macros" on page 3-12.

Related Commands

DIRECTORY, MACRO CREATE, MACRO SETUP, SHOW MACRO, TRG

Front Panel Examples

FUNC **SHOW** **MACRO** **EXAMPLE** **ENTER**

WRI

↓

SIN

ENTER

(Macro **EXAMPLE** waits for an external trigger pulse then takes a single measurement.)

FUNC **SELECT** **MACRO** **SETUP** **TOTAL** **0** **ENTER**

(Subsequent macros will repeat endlessly.)

FUNC **SELECT** **MACRO** **RUN** **EXAMPLE** **ENTER**

2.1749274
0.004768

(Macro **EXAMPLE** will repeatedly take a measurement every time an external trigger pulse occurs.)

Remote Examples

```
>SHOW MACRO PARENT
SIN
ZER FET
ZER ON
MAC SET TOT 2
MAC RUN CHILD
>SHOW MACRO CHILD
SAM 1
SIN
SAM 2
SIN
>MACRO RUN PARENT
S= 3 C= 12.149284 PF L= 0.0000005 DS
S= 3 C= 0.0000000 ZPF L= 0.0000000 ZDS
S= 1 C= 900.64128 ZPF L= 0.0000055 ZDS
S= 2 C= 781.33979 ZPF L= 0.0000029 ZDS
S= 1 C= 900.64142 ZPF L= 0.0000054 ZDS
S= 2 C= 781.33981 ZPF L= 0.0000032 ZDS
>
```

In the example above, macro **PARENT** is executed once. It calls macro **CHILD** and executes it twice. A zero value is taken from sample 3 and used to correct readings from samples 1 and 2.

MACRO SETUP

Description

Sets up parameters used to control single-step and repetitive macro execution modes.

Syntax

`MACRO SETUP TOTAL MTotal`
or
`MACRO SETUP MSTEP MStep`

Qualifiers

TOTAL	Sets up the <i>MTotal</i> parameter that is used to control the repetitive macro execution mode.
MSTEP	Sets up the <i>MStep</i> parameter that is used to controls the single-step macro execution mode.

Parameters

<i>MTotal</i>	is the number of times the macro is to be executed. If <i>MTotal</i> is zero, the macro will be executed repeatedly until aborted by a DEVICE CLEAR command or query interrupt.
<i>MStep</i>	Is normally set to OFF. Setting this parameter to ON causes the macro to stop on every occurrence of a query result. Pressing the <code>STEP</code> key on the front panel keypad will cause the macro to continue.

Default Value *MTotal*: 1, *MStep*: OFF
(non single-step and non repetitive)

Parameter Set None

Query Cmd?

A macro is considered to be a query command and is therefore query interruptible if it or any of its submacros contain a query command.

Related Commands

MACRO CREATE, MACRO RUN, SHOW MACRO, STORE, TRG

Comments

- Including MACRO RUN commands within a parent macro provide a means for the parent macro to execute submacros (its children). Macros can call submacros to a nesting depth of eight.
- Macros may be executed in a number of modes including the single-step, non-stop and repetitive execution modes. The MACRO SETUP can be used to change the execution mode prior to executing subsequent MACRO RUN commands.
- Including MACRO SETUP commands within a parent macro provide a means for the parent macro to control the macro execution parameters pertaining to subsequent submacros (its children).
- Including a MACRO SETUP command within a child macro does not affect the settings for either the parent macro or for other children of that parent.
- An executing macro is indicated by illumination of the MACRO ACTIVE LED indicator.

Description

Prevents the front panel **LOCAL** key from changing the bridge from a Serial Remote State to a Serial Local State.

Syntax

NLOCKOUT **ON|OFF**

Qualifiers

ON	Causes bridge to enter the Serial Local State with Lockout or the Serial Remote State with Lockout.
OFF	Causes the bridge to enter the Serial Local State or the Serial Remote State.

Parameters

No parameters are entered. However, the **SHOW SERIAL** and **SHOW NLOCKOUT** commands will report **ON** if the **NLOCKOUT ON** command has been executed and **OFF** if the **NLOCKOUT OFF** command was executed.

Note: 0 and 1 maybe substituted for **OFF** and **ON** respectively.

Default Value OFF (not locked out)

Parameter Set Serial

Query Cmd? No

Comments

- This command is intended to be issued only from a remote serial device. It is not available from the front panel and has no effect from the GPIB port.
- When in the Remote Serial State, this command causes all front panel keys to be ignored until a **LOCAL** or **NLOCKOUT OFF** command is issued from the controlling serial device.
- The **NLOCKOUT** commands should not be issued to the bridge from a GPIB controller since such controllers have their own set of commands for such functions. The GPIB controller command may have similar spelling but its command would be issued to the controller, not to the bridge.

Front Panel Examples

The **NLOCKOUT** command is not available from the front panel. It can, however, be shown from the front panel. Enter the key sequence:

SHOW **FUNC** **SERIAL** **ENTER**

and get:

```
NLOCKOUT
OFF
```

Serial Remote Examples

```
>SH NREM;SH NLOC      (Start with Local state,
NREMOTE              OFF   front panel is fully
NLOCKOUT             OFF   operable.)
>NREM ON              (Enter Remote state,
>SH NREM;SH NLOC      front panel except
NREMOTE              ON    LOCAL key is
NLOCKOUT             OFF   inoperable.)
>NLOC ON              (Enter Remote With
>SH NREM;SH NLOC      Lockout state, front
NREMOTE              ON    panel and LOCAL key
NLOCKOUT             ON    are inoperable.)
>LOCAL                (Enter Local With
>SH NREM;SH NLOC      Lockout state, front
NREMOTE              OFF   panel is fully operable.)
NLOCKOUT             ON
>NREM ON              (Enter Remote With
>SH NREM;SH NLOC      Lockout state, front
NREMOTE              OFF   panel and LOCAL key
NLOCKOUT             ON    are again inoperable.)
>LOC;NLOC OFF        (Enter Local state,
>SH NREM;SH NLOC      front panel is fully
NREMOTE              OFF   operable.)
NLOCKOUT             OFF
>
```

The above examples demonstrate all combinations of the Serial Remote and Serial Lockout states.

References

See "LIMITING FRONT PANEL ACCESS" on page 7-11 and specifically "Setting the Serial Lockout States" on page 7-12 and "Clearing the Serial Lockout States" on page 7-12.

Related Commands

LOCAL, NREMOTE

NREMOTE

Description

Places the bridge in the *Serial Remote State*. This state disables all front panel keys except the **LOCAL** key. The **LOCAL** key is also disabled if the **NLOCKOUT** command has been issued.

Syntax

NREMOTE

Parameters

No parameters are entered. However, the **SHOW SERIAL** and **SHOW NREMOTE** commands will report a **REMOTE** if this command has been executed and a **LOCAL** if the **LOCAL** command was executed.

Default Value OFF (Local)

Parameter Set Serial

Query Cmd? No

Comments

- This command is intended to be issued only from a remote serial device. It is not available from the front panel and has no effect from the GPIB port.
- The **REMOTE** LED indicator is illuminated when the bridge is in the *Serial Remote State*.
- This command causes front panel keys to be ignored until the **LOCAL** front panel key is pressed (if lockout is not in effect) or until a **LOCAL** command is issued from the controlling serial device.
- The **NREMOTE** command should not be issued to the bridge from a GPIB controller since such controllers have their own set of commands for such functions. The GPIB controller command may have similar spelling but its command would be issued to the controller, not to the bridge.

Front Panel Examples

The **NREMOTE** command is not available from the front panel. It can, however, be shown from the front panel. Enter the key sequence:

FUNC **SELECT** **SHOW** **NREMOTE** **ENTER**

and get:

NREMOTE
OFF

Serial Remote Examples

```
>NREM                                (Enter Remote state)
>SH NREM
  NREMOTE                                ON
>LOCA                                (Exit Remote state)
>SH NREM
  NREMOTE                                OFF
>
```

The **SHOW** command reports the effects of the **NREMOTE** command on its parameter.

References

See “LIMITING FRONT PANEL ACCESS” on page 7-11 and specifically “Selecting the Serial Remote States” on page 7-12.

Related Commands

LOCAL, **NLOCKOUT**

Description

Causes the bridge to execute a single measurement by pressing only *one* key on the keyboard of a remote serial device. If continuous readings were being taken, then the Q command aborts them after taking another measurement.

Syntax Q (no RETURN key is used)

Parameters None

Query Cmd? Yes

Comments

- The Q command is *not* equivalent to the TRG or GPIB GET commands.
- The Q command is shortened from “Question”.
- The Q command produces exactly the same result as the SINGLE command but is more convenient to use from the serial port than the SINGLE command.
- This command will only work in an AH2700A macro if it is not the first character. A space can precede it if you desire to enter it by itself on a macro line.

Front Panel Examples

The SINGLE key is used on the front panel instead of Q.

Serial Remote Examples

```
>SI
C=843.318636 PF L=0.03721 NS
>SI
C=843.318642 PF L=0.03722 NS
>C=843.318647 PF L=0.03734 NS
>C=843.318652 PF L=0.03715 NS
>C=843.318661 PF L=0.03721 NS
>
```

The last three measurement results above were initiated with the Q command. Notice that the command was not echoed. Unlike the SINGLE commands further above, the Q command also did not cause any wasteful, nearly blank lines to be printed.

References

See “Taking Measurements One at a Time” on page 4-4.

Related Commands

CONTINUOUS, SINGLE, TRG

RECALL

Description

Recalls previously stored parameter and macro files into current, executable RAM memory.

Syntax

```
RECALL BASIC|DEV|GAUGE|GPIB|SCAN|  
SERIAL|MACRO Filename
```

Qualifiers

BASIC	Recall a file containing Basic parameters.
DEV	Recall a file containing Dev parameters.
GAUGE	Recall a file containing Gauge parameters.
GPIB	Recall a file containing GPIB parameters.
SCAN	Recall a file containing Scan parameters.
SERIAL	Recall a file containing Serial parameters.
MACRO	Recall a file containing a macro.

Parameters

<i>Filename</i>	This is the name of the file to be recalled. The name has only digits and contains no more than eight.
-----------------	--

Default Value None

Parameter Set None

Query Cmd? No

Comments

- Recalling one of the parameter files (BASIC, DEV, GAUGE, GPIB, SCAN, or SERIAL) causes the parameters in that file to be copied to the current parameters. This allows the copied parameters to be edited.
- Unlike parameter files, the only purpose in recalling a macro file is to store it under a different filename. There is no way to edit a macro file. Such files can only be created and deleted.
- If you are unsure what filenames are available for recall, use the DIRECTORY command to get a list of all that have been stored.
- If you are unsure of the contents of a particular file, you can use the SHOW command to examine the contents.
- In addition to the filenames listed by the DIRECTORY command, a filename of "FACTPON" exists in ROM for each of the six parameter file types. These contain the default parameter values.

Comments (continued)

- *Filename* may contain only alphanumeric and underscore characters, must begin with an alpha character, and may contain no more than eight characters total.

Front Panel Examples

```
SHOW AVERAGE TIME ENTER
```

Displays the following window:

AVERAGE
7

```
ENTER
```

```
FUNC SELECT RECALL GAUGE FACTPON ENTER
```

Recalls the GAUGE FACTPON parameter file which includes the *AvgExp* parameter.

```
SHOW AVERAGE TIME ENTER
```

Displays the following window showing that the *AvgExp* parameter has been replaced with one from the GAUGE FACTPON parameter file:

AVERAGE
4

Remote Examples

```
>SHOW MACRO  
>RECALL MACRO EXAMPLE  
>SH MACRO  
AVE 8  
SIN  
>
```

The above example shows that initially there is no macro in RAM. MACRO EXAMPLE is then recalled and a second SHOW command reveals that the contents of MACRO EXAMPLE are in RAM memory.

References

See Chapter 3, "Parameter and Macro Files" and specifically "Using the Contents of a Parameter File" on page 3-9.

Related Commands

DIRECTORY, SHOW, STORE

Description

Changes bridge mode between “Absolute result mode” and “Reference result mode.” Reference result mode reports deviation results as simple or percent differences referenced to capacitance or loss values of your choice.

Syntax

```
REFERENCE CAP RefMod_C
or
REFERENCE LOSS RefMod_L
or
REFERENCE [ALL] RefMod_A
or
REFERENCE [RefMod_C] , [RefMod_L]
```

Qualifiers

CAP	Causes Reference result mode to apply to capacitance results. The loss results are not affected.
LOSS	Causes Reference result mode to apply to loss results. The capacitance results are not affected.
All	Causes Reference result mode to apply to both capacitance and loss results.

Parameters

<i>RefMod_C</i>	enables Reference result mode for the capacitance when set to ON and conversely disables Reference result mode for capacitance when set to OFF . Permitted values are ON and OFF .
<i>RefMod_L</i>	enables Reference result mode for the loss when set to ON and conversely disables Reference result mode for loss when set to OFF . Permitted values are ON and OFF .
<i>RefMod_A</i>	enables Reference result mode for both capacitance and loss when set to ON and conversely disables Reference result mode for both capacitance and loss when set to OFF . Permitted values are ON and OFF .

Note: 1 and 0 may be substituted for **ON** and **OFF** respectively.

Note: When using the fourth form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value OFF, OFF (Absolute result mode for both capacitance and loss.)

Parameter Set Gauge

Query Cmd? Yes

Comments

- Enabling Reference result mode is a separate operation from entering the Reference value(s).
- Reference capacitance and loss values can be entered (and stored) and not be enabled. Enabling Reference result mode later will then automatically report the difference of the measured value(s) from the Reference value(s).
- When any form of the REFERENCE command is issued it will re-display the last measurement taken with the new Reference settings in effect.
- This command operates similarly to the ZERO command.

Remote Examples

```
>REF POINT CAP 700
>REF POINT LOSS 0.028
>SI
C= 734.498542 PF L= 0.02824 NS
>REF CAP ON
C= 34.498542 R0PF L= 0.02824 NS
>REF LOSS ON
C= 34.498542 R0PF L= 0.00024 R0NS
>REF OFF
C= 734.498542 PF L= 0.02824 NS
>SI
C= 734.498561 PF L= 0.02873 NS
>SHOW REF
REF MODE        C=OFF L=OFF
REF POINT      C=700.000000 PF L=0.000000 NS
REF PERCENT    C=OFF L=OFF
>
```

Reference values were manually entered and a measurement taken. Reference mode was first enabled for capacitance, then loss was included. The results of these changes were automatically reported after each change. Reference mode was then exited causing the same result to be reported as for the original measurement. The result is *exactly* the same since no *new* measurement was taken. The actual measurement which follows shows small changes due to noise.

REFERENCE (continued)

Front Panel Examples

SINGLE

(Take measurement in window below.)

71450208
002925

REFERENCE **FUNC** **FETCH** **ENTER**

(Get measured values.)

FUNC **SELECT** **REFERENCE** **ALL** **ON** **ENTER**

(Show the differences.)

00000000
000000

SINGLE

(Show new measurement results below.)

--0000048
000014

This shows the changes between the **SINGLE** measurements.

FUNC **SELECT** **SHOW** **REFERENCE** **ENTER**

Displays the following windows:

REF	ON
MODE	ON

FUNC **SELECT** **SHOW** **REFERENCE** **POINT** **ENTER**

Displays the following windows:

REF	71450208
POINT	002925

FUNC **SELECT** **SHOW** **REFERENCE** **PERCENT** **ENTER**

Displays the following windows:

REF	OFF
PERCENT	OFF

The **←** and **→** keys are used to select which of the left or right windows is displayed.

References

See “Reference Result Mode” on page 5-2 and specifically “Enabling Reference Result Mode” on page 5-3 and “Disabling Reference Result Mode” on page 5-3.

Related Commands

REFERENCE POINT, REFERENCE PERCENT, ZERO and ZERO POINT.

REFERENCE PERCENT

Description

Selects whether Reference result mode reports simple differences or percent differences.

Syntax

```
REFERENCE PERCENT CAP Percnt_C
or
REFERENCE PERCENT LOSS Percnt_L
or
REFERENCE PERCENT [ALL] Percnt_A
or
REFERENCE PERCENT [Percnt_C] , [Percnt_L]
```

Qualifiers

- CAP** Causes the Reference result mode to report in percent differences for the capacitance field when *Percnt_C* is set to ON. Alternatively causes the Reference result mode to report in simple differences for the capacitance field when *Percnt_C* is set to OFF.
- LOSS** Causes the Reference result mode to report in percent differences for the loss field when *Percnt_L* is set to ON. Alternatively causes the Reference result mode to report in simple differences for the loss field when *Percnt_L* is set to OFF.
- ALL** Causes the Reference result mode to report in percent differences for both the capacitance and loss fields when *Percnt_A* is set to ON. Alternatively causes the Reference result mode to report in simple differences for both the capacitance and loss fields when *Percnt_A* is set to OFF.

Parameters

Percent differences are reported when the corresponding parameter is ON. Simple differences are reported when the corresponding parameter is OFF.

Note: When using the fourth form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value OFF, OFF (Simple differences for both capacitance and loss.)

Parameter Set Gauge

Query Cmd? No

Comments

- Percent format causes the Reference value to first be subtracted from each measurement. The difference is then divided by the Reference value and multiplied by 100. The calculation always starts with the current units, but the final result is dimensionless, of course.
- The effects of the REFERENCE PERCENT command can be observed by issuing the REFERENCE command. This will report the current measurement results in the current differences format.
- Results reported as percentages have special labeling on both the front panel display and remote devices.
- Selecting simple versus percent differences is a separate operation from enabling Reference result mode and from entering the Reference value(s).
- The kind of differences to report for capacitance and loss can be entered (and stored) and not be enabled. Enabling Reference result mode later will then automatically report the desired kind of differences of the measured value(s) from the Reference value(s).

REFERENCE PERCENT (continued)

Front Panel Examples

SINGLE

FUNC **SELECT** **REFERENCE** **FETCH** **ALL** **ENTER**

(Get measured values.)

FUNC **SELECT** **SHOW** **REFERENCE** **POINT** **ENTER**

Displays the following windows:

REF	71450208
POINT	002925

FUNC **SELECT** **REFERENCE** **PERCENT** **ALL** **ON** **ENTER**

(Report percent differences for both capacitance and loss)

FUNC **SELECT** **SHOW** **REFERENCE** **PERCENT** **ENTER**

(Show the effects.)

REF	ON
PERCENT	ON

REFERENCE **ON** **ENTER**

(Enable Reference mode for both and re-display the results.)

00000000
000000

FUNC **SELECT** **SHOW** **REFERENCE** **ENTER**

Displays the following windows:

REF	ON
MODE	ON

SINGLE (*BUSY* is displayed until measurement finishes.)

BUSY R1
R1
-0000007
000014

The *BUSY* display shows the result mode indicators.

[The **←** and **→** keys are used to select which of the left or right windows is displayed.

Remote Examples

```
>REF POINT CAP 700
>REF POINT LOSS 0.028
>SI
  C= 734.498542 PF L= 0.02824 NS
>REF ON
  C= 34.498542 R0PF L= 0.00024 R0NS
>REF PER ALL ON (Change the differences format.)
>REF ON (Show the effects of the change.)
  C= 4.6968837 R1PF L= 0.85 R1NS
>SI
  C= 4.6969147 R1PF L= 0.83 R1NS
>SH REF
  REF MODE C=ON L=ON
  REF POINT C=700.000000 PF L=0.028000 NS
  REF PERCENT C=ON L=ON
>
```

Reference values were manually entered and a measurement taken. Reference mode was enabled and reported the simple differences between the entered and measured values. The difference format was then changed to percent. Issuing the **REFERENCE** command again reported new results. The unit labels indicate which modes are active for each line. Finally, a new measurement was taken with percent differences still enabled.

References

See “Reference Result Mode” on page 5-2 and specifically “Selecting Reference Percent Format” on page 5-3 and “Indication of Reference Result Mode” on page 5-3.

Related Commands

REFERENCE, **REFERENCE POINT**, **ZERO POINT** and **ZERO**.

REFERENCE POINT

Description

Provides manual and automatic ways to enter capacitance and/or loss Reference points.

Syntax

`REFERENCE POINT CAP Ref_Pt_C`
or
`REFERENCE POINT LOSS Ref_Pt_L`
or
`REFERENCE POINT [Ref_Pt_C] , [Ref_Pt_L]`

is used to enter Reference values manually, or

`REFERENCE FETCH [CAP|LOSS|ALL]`

uses the last-measured capacitance and/or loss values as Reference values. These last-measured values are taken after any possible Zero corrections are applied.

Qualifiers

CAP	Causes the value entered as <i>Ref_Pt_C</i> or the last capacitance value measured to be used as the capacitance Reference.
LOSS	Causes the value entered as <i>Ref_Pt_L</i> or the last loss value measured to be used as the loss Reference.
ALL	Causes both the last-measured capacitance and loss values to be used as Reference values. This qualifier is only used with the REFERENCE FETCH command.

Parameters *Ref_Pt_C* and *Ref_Pt_L*

These are the values of the capacitance and loss to be used as the Reference point. They are floating point values and assumed to be entered in the current units. The maximum value that can be entered in any units is 99,999,999.

Note: When using the third form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value 0, 0

(Reference point values for both capacitance and loss are zero.)

Parameter Set Gauge

Query Cmd? No

Comments

- Entering the Reference point value(s) is a separate operation from actually using them by enabling Reference result mode. This makes it easier to enter and exit Reference result mode.
- This command is similar to the ZERO POINT command.
- The bridge performs all Reference calculations *after* performing any Zero calculations that might be enabled.

Front Panel Examples

`FUNC` `SELECT` `RECALL` `GAUGE` `FACTPON` `ENTER`
(Initialize parameters)

`SINGLE`
(Takes measurement in window below.)

71450208
002925

`REFERENCE` `FUNC` `FETCH` `ENTER`
(Get measured values.)

`REFERENCE` `CAP` `ON` `ENTER`
(Enable Reference result mode for capacitance only.)

00000000
002925

`FUNC` `SELECT` `SHOW` `REFERENCE` `ENTER`
Displays the following windows:

REF ON
MODE OFF

↓
Displays the following windows:

REF 71450208
POINT 002925

↓
Displays the following windows:

REF OFF
PERCENT OFF

The ← and → keys are used to select which of the left or right windows is displayed.

REFERENCE POINT (continued)

Remote Examples

```
>RECALL GAUGE FACTPON      (Initialize Reference
                             parameters.)
>REF POINT CAP 700
>REF POINT LOSS 0.03
>SHOW REF
  REF MODE      C=OFF L=OFF
  REF POINT     C=700.000000 PF L=0.030000 NS
  REF PERCENT   C=OFF L=OFF
>
```

The capacitance and loss Reference values were manually entered. All the Reference parameters were then reported.

References

See “Reference Result Mode” on page 5-2 and specifically “Entering Reference Values Manually” on page 5-2 and “Entering Reference Values Automatically” on page 5-3.

Related Commands

REFERENCE, REFERENCE PERCENT, ZERO POINT and ZERO.

Description

Causes the bridge to reset.

Syntax

RST
or
*RST

The two forms of this command are equivalent.

Parameters None

Query Cmd? No

Comments

- The effect of this AH2700A command is to put all higher control sections of the bridge except for the serial and GPIB interfaces into the same state as at power-on.
- Bridge parameters in the Basic, Gauge, Deviation, and Scan parameter sets are set to their power-on values as contained in the parameter sets named FACTPON or USERPON. Where parameter sets named USERPON are present in the instrument, their contents are used for initialization. Otherwise the settings contained in the FACTPON parameter files are used. Parameters in the current GPIB and Serial parameter sets are not initialized.
- The GPIB POn status bit is *not* set when this command is executed.
- The power-on macro does not execute in response to the RST command.
- The RST command may do more than is needed. In some cases, the DEVICE CLEAR command will be the more appropriate command to use.
- A *RESET* message appears on the front panel when this command is executed.

Front Panel Examples

[FUNC] [SELECT] [RST] [ENTER]

Shows the front panel message below:

RESET

Execution of this command from remote devices will show this front panel message as well.

Remote Device Examples

```
>SH BASIC
  BRIGHTNESS      C=5 L=3 F=5
  FIELD SAMPLE     ON
  FIELD FREQ       ON
  FIELD CAP        9
  FIELD LOSS       9
  FIELD VOLTAGE    ON
  FIELD MESSAGE    ON
  FORMAT NOTATION  FLOATING
  FORMAT LABELING  ON
  FORMAT IEEE4882  OFF
  FORMAT FWIDTH    FIXED
  WAITFOR TRGMODE  BUFFER
  WAITFOR SAMPLE   0.01 SEC
  SAMPLE NUMBER    2
  TEST HALT MODE   AT_END
  TEST HALT TOTAL  1
  TEST REPORT      ERR_SUM
  UNITS            GO
>RST
>SH BASIC
  BRIGHTNESS      C=5 L=5 F=5
  FIELD SAMPLE     OFF
  FIELD FREQ       ON
  FIELD CAP        9
  FIELD LOSS       9
  FIELD VOLTAGE    ON
  FIELD MESSAGE    ON
  FORMAT NOTATION  FLOATING
  FORMAT LABELING  ON
  FORMAT IEEE4882  OFF
  FORMAT FWIDTH    FIXED
  WAITFOR TRGMODE  BUFFER
  WAITFOR SAMPLE   0.0 SEC
  SAMPLE NUMBER    1
  TEST HALT MODE   AT_END
  TEST HALT TOTAL  1
  TEST REPORT      ERR_SUM
  UNITS            NS
>
```

The contents of the current Basic parameter set is shown before and after execution of the RST command. This command resets the parameters to their default values.

References

See "INITIALIZING THE BRIDGE" on page 6-14 and specifically "The RST Command" on page 6-15.

Related Commands

DEVICE CLEAR

SAMPLE

Description

Selects which external unknown sample to measure. Operates only in conjunction with the sample switch port.

Syntax

`SAMPLE SNumber`
or
`SAMPLE UP|DOWN`

Qualifiers

- UP** change the *SNumber* parameter to the next available sample as determined by the scan setup parameters.
- DOWN** change the *SNumber* parameter to the next available sample as determined by the scan setup parameters.

Parameters *SNumber*

This specifies the number of the sample to be measured. It can have any value from 1 to 64. However, values of this parameter larger than eight will cause all sample switch data lines to be false. Values from one to eight will cause one of the eight sample switch data lines to be true. The number of the selected sample switch data line is one less than the value of the *SNumber* parameter.

Default Value 1

Parameter Set Basic

Query Cmd? No

Comments

- With an external sample switch, this command provides for unattended measurements of multiple unknown samples. The MACRO commands of the bridge combined with a logging device can do this. Alternatively, a remote GPIB or serial controller can also work.
- The control lines provided on the sample switch port are intended for controlling sample switches. However, a custom designed interface could be created to control many other simple devices.
- The *DelaySmp* parameter set by the WAITFOR SAMPLE command can affect the operation of the SAMPLE command. Therefore, the WAITFOR SAMPLE command should be understood if only to ensure that its delay time was not left set to a needlessly large value.

- This command will be accepted in place of a STEP or X command in response to a prompt from a TEST command.

Front Panel Examples

`[FUNC] [SELECT] [SAMPLE] [6] [ENTER]`
(Select sample number 6.)

`[FUNC] [SELECT] [SHOW] [SAMPLE] [ENTER]`

SAMPLE	NUMBER
NUMBER	6

Remote Device Examples

```
>SA 1 (Select sample number 1.)
>SI
S= 1 C= 734.498542 PF L= 0.02824 DS
>SA 2 (Select sample number 2.)
>SI
S= 2 C= 900.64128 PF L= 0.0000055 DS
>SA 3 (Select sample number 3.)
>SI
S= 3 C= 781.33981 PF L= 0.0000032 DS
>SA 4 (Select sample number 4.)
>SI
S= 4 C= 440.18054 PF L= 0.0000062 DS
>SH SA
SAMPLE NUMBER 4
>
```

This is an example of the most common usage of the SAMPLE command where four samples are measured in sequence.

References

See Appendix D, "Sample Switch Port" and specifically "Selecting a Sample Switch Position" on page D-1.

Related Commands

MACRO, WAITFOR SAMPLE, STEP, X

SAMPLE SCAN COUPLE

Description

Enables or disables the automatic scanning for the sample switch number parameter. Also positions sample switch number parameter within the scanning hierarchy for multidimensional scanning.

Syntax

`SAMPLE SCAN COUPLE SCoupling`

Parameters *SCoupling*

The permitted values along with their meanings are listed below:

0	disabled scanning for the sample switch port.
1	enables scanning for the sample switch port. Positions the sample switch port within the scanning hierarchy such that the sample switch will be stepped immediately before each STEP or SCAN command causes a measurement to be taken.
2	enables scanning for the sample switch port. Within a multidimensional scanning scheme, positions the sample switch port within the scanning hierarchy such that the sample switch will be stepped only when the STEP or SCAN command causes wrapping of the coupled parameter whose coupling parameter is set to 1.
3	enables scanning for the sample switch port. Within a multidimensional scanning scheme, positions the sample switch port within the scanning hierarchy such that the sample switch will be stepped only when the STEP or SCAN command causes wrapping of the coupled parameter whose coupling parameter is set to 2.

Default Value OFF

Parameter Set Scan

Query Cmd? No

Comments

- The three scannable parameters *Freq*, *SNumber* and *VHighest* use the three **coupling** parameters *FCoupling*, *SCoupling* and *VCoupling* respectively, to enable the **STEP** and **SCAN** measurement commands and to couple the stepping of these scannable parameters to the execution of the **STEP** and **SCAN** commands. The

STEP and **SCAN** commands will make measurements only if one or more of the three coupling parameters is non-zero.

- If *SCoupling* is the only non-zero coupling parameter, then the *SNumber* parameter will be stepped immediately before the **STEP** or **SCAN** command causes a measurement to be taken. *Freq* and *VHighest* parameters will not be affected by the **STEP** and **SCAN** commands.
- If multiple coupling parameters are non-zero, then the coupled parameter corresponding to the coupling parameter having the lowest value will be stepped immediately before the **STEP** or **SCAN** command causes a measurement to be taken. The coupling parameter having the second lowest value will have its corresponding coupled parameter stepped when wrapping occurs to the coupled parameter corresponding to the coupling parameter having the lowest value. The coupling parameter (if any) having the third lowest value will have its corresponding coupled parameter stepped when wrapping occurs to the coupled parameter corresponding to the coupling parameter having the second lowest value.
- The existence of two or more coupling parameters having the same non-zero value is not possible. Any attempt to set a coupling parameter to a non-zero value used by another coupling parameter will cause the values of the two coupling parameters to be swapped.

Front Panel Examples

```
[FUNC] [SELECT] [FREQUENCY] [SCAN] [COUPLE] [1] [ENTER]
[FUNC] [SELECT] [SAMPLE] [SCAN] [COUPLE] [2] [ENTER]
[FUNC] [SELECT] [VOLTAGE] [SCAN] [COUPLE] [3] [ENTER]
```

Frequency and voltage will be iterated most and least frequently respectively.

Remote Device Examples

```
>FREQUENCY SCAN COUPLE 1
>SAMPLE SCAN COUPLE 2
>VOLTAGE SCAN COUPLE 3
>
```

Frequency and voltage will be iterated most and least frequently respectively.

References

See Appendix D, “Sample Switch Port” and specifically “Selecting a Sample Switch Position” on page D-1.

Related Commands

SAMPLE SCAN FLOOR/CEILING/DELTA, FREQUENCY SCAN COUPLE, VOLTAGE SCAN COUPLE, STEP, SCAN, SAMPLE

SAMPLE SCAN FLOOR / CEILING / DELTA

Description

Sets the highest and lowest sample switch numbers to be used during scanning, as well as the direction in which the sample number is changed each time a scanning measurement is to be taken.

Syntax

SAMPLE SCAN FLOOR *S*Floor
 or
SAMPLE SCAN CEILING *S*Ceiling
 or
SAMPLE SCAN DELTA *S*Delta

Parameters

- S*Floor** is a two digit integer that sets the lowest sample switch number in the series to be used when scanning the sample switch port.
- S*Ceiling** is a two digit integer that sets the highest sample switch number in the series to be used when scanning the sample switch port.
- S*Delta** sets the direction in which the sample number is iterated. Permitted values are +1 and -1 for incrementing and decrementing respectively.

Default Value *S*Delta: +1
 *S*Floor: 1
 *S*Ceiling: 8

Parameter Set Scan

Query Cmd? No

Comments

- If a value other than +1 or -1 is entered for *S*Delta, the common error message “BAD PARAMETER” will be reported.
- The *S*Floor and *S*Ceiling parameters can have any values from 1 to 64. However, values of these parameters larger than eight will cause all sample switch data lines to be false. Values from one to eight will cause one of the eight sample switch data lines to be true.

References

See Appendix D, “Sample Switch Port” and specifically “Selecting a Sample Switch Position” on page D-1.

Related Commands

SAMPLE SCAN COUPLE, FREQUENCY SCAN COUPLE, VOLTAGE SCAN COUPLE, STEP, SCAN, SAMPLE

Front Panel Examples

```

FUNC SELECT SAMPLE SCAN COUPLE 1 ENTER
FUNC SELECT SAMPLE SCAN FLOOR 2 ENTER
FUNC SELECT SAMPLE SCAN CEILING 4 ENTER
FUNC SELECT SAMPLE SCAN DELTA MINUS 1 ENTER

```

```

SAMPLE      COUPLING
COUPLING    1

```

```

FUNC SELECT SHOW SAMPLE SCAN DELTA ENTER

```

```

SAMPLE      DIRECTION
DELTA       -1

```

```

FUNC SELECT SHOW SAMPLE SCAN FLOOR ENTER

```

```

SAMPLE      FLOOR
FLOOR       2

```

```

FUNC SELECT SHOW SAMPLE SCAN FLOOR ENTER

```

```

SAMPLE      CEILING
CEILING     4

```

In this example the sample switch number will be decremented with each execution of the STEP and SCAN commands. The scanned set of sample switch numbers will consist of 2, 3, and 4.

Remote Device Examples

```

>SAMPLE SCAN COUPLE 1
>SAMPLE SCAN FLOOR 2
>SAMPLE SCAN CEILING 4
>SAMPLE SCAN DELTA -1
>SHOW SAMPLE SCAN
SAMPLE COUPLING 1
SAMPLE DELTA -1 DIRECTION
SAMPLE FLOOR 2
SAMPLE CEILING 4
>

```

In this example the sample switch number will be decremented with each execution of the STEP and SCAN commands. The scanned set of sample switch numbers will consist of 2, 3, and 4.

Description

Initiates scanning parameter measurements which are taken continuously, one after another. Also provides a means for discontinuing those measurements.

Syntax

`SCAN [ON]|OFF`

Qualifiers

ON	Initiates continuous parameter scanning measurements.
OFF	Stops continuous parameter scanning measurements and wait for a new command.

Note: 1 and 0 may be substituted for ON and OFF respectively.

Query Cmd? Yes

Since the `SCAN ON|OFF` command is a query command, any command will interrupt execution of the `SCAN ON` command. However, the bridge will revert to taking measurements continuously after the interrupting command (other than `STEP`, `X`, `SINGLE` or `Q`) finishes executing.

Comments

- Entering `SCAN` causes scanning parameter measurements to occur continuously using the existing values of the coupled parameters and the `ECOUNT`, `COUNT1`, `COUNT2`, `COUNT3` scan count variables.
- If no coupled parameters exist when `SCAN` is entered, then scanning does not start and the error message `NO COUPL PARAMETER` is reported.
- The `ON` qualifier is purely optional. Entry of `SCAN ON` and `SCAN` have an identical meaning.
- The `STEP` or `X`, and `SINGLE` or `Q` commands provide alternative means for stopping continuous scanning parameter measurements. Following termination, the values of the `ECOUNT`, `COUNT1`, `COUNT2`, `COUNT3` scan count variables will reflect the quantity of measurements completed.

Related Commands

`SCAN STMODE`, `SCAN TOTAL`, `SCAN RST`, `Q`, `X`, `STEP`, `SINGLE`, `FREQUENCY SCAN`, `SAMPLE SCAN`, `VOLTAGE SCAN`

SCAN RST

Description

Resets the values of the *SCount* scanning mode measurement count variables to zero and/or resets the coupled scanning parameters so that scanning will begin from the lowest or highest values in their respective scan sets.

Syntax

`SCAN RST COUNTS|COUPLED|[ALL]`

Qualifiers

- COUNTS** causes the four *SCount* scanning count variables to the reset to zero.
- COUPLED** causes each coupled parameters to be reset so that the first measurement taken with a **STEP** or **SCAN** command uses the lowest or highest allowed parameter value in its respective scan set. The lowest values will be used when the direction of the scan is toward increasing values, and conversely the highest values will be used when the direction of the scan is toward decreasing values.
- ALL** combines the actions of both the **COUNTS** and **COUPLED** qualifiers. Because **ALL** is a completely optional qualifier, omitting it has the same effect as including it.

Parameters None

Default Value None

Parameter Set None

Query Cmd? No

Comments

- The count of the scanning mode measurements is maintained by four *SCount* variables; *ECount*, *Count1*, *Count2*, and *Count3*.
- The values of the *SCount* scanning count variables cannot be entered and are not stored in any parameter set.
- Nonzero values of the *STotal* parameter are used to control automatic termination of parameter scanning measurement sequences, both single dimensional and multi dimension. Automatic terminations are made when the value of a selected *SCount* variable reaches *STotal*. The selection of *SCount* variable is made using the **SCAN STMODE** command.
- If the value of the *STotal* parameter is nonzero, the values of the *SCount* variables will automatically be reset to zero at the entry of every **SCAN** command.

Comments (continued)

- If the value of the *STotal* parameter is zero, the values of the *SCount* variables will still be incremented with each measurement even though there will be no automatic termination of the scanning mode measurements based upon a comparison of their values with *STotal*.
- If the value of the *STotal* parameter is zero, the continuous mode measurements must be terminated by entry of a command such as **SCAN OFF**.
- The values of *STotal*, *STMode*, and the four *SCount* frisbees may be shown using the **SHOW SCAN TOTAL**, **SHOW SCAN STMODE**, and **SHOW SCAN COUNT** commands respectively.

Related Commands

SCAN, **SCAN STMODE**, **SCAN TOTAL**, **Q**, **X**, **STEP**, **SINGLE**, **FREQUENCY SCAN**, **SAMPLE SCAN**, **VOLTAGE SCAN**

Description

During scanning measurements, the number of individual measurement as well as number of passes through the various scan loops is maintained by the four *SCount* variables; *ECount*, *Count1*, *Count2*, and *Count3*. Automatic termination of a scanning measurement sequence occurs when the value of one of these *SCount* variables matches the value of the *STotal* parameter.

This command sets the *STMode* parameter which specifies the *SCount* variable to be used to in this comparison for automatic termination.

Syntax

```
SCAN STMODE STMode
```

Parameters

STMode specifies which of the four *SCount* variables will be used in the comparison with *STotal* to effect automatic termination of a scan sequence. The permitted values are EACH, INNER, SECOND, and THIRD. These values correspond to *ECount*, *Count1*, *Count2*, and *Count3* respectively.

Default Value EACH

Parameter Set Scan

Query Cmd? No

Comments

- The count of the scanning mode measurements is maintained by four *SCount* variables; *ECount*, *Count1*, *Count2*, and *Count3*.
- With *STMode* set to EACH, *STotal* is interpreted as the total number of individual scanned measurement to be made prior to automatic termination. Neither the number of coupled parameters nor the number of values in each parameters scan set will affect the total number of measurement to be made.
- With *STMode* set to INNER, *STotal* is interpreted as the number of complete passes through the first coupled loop. The total number of measurements will be calculated from the following expression:

$$STotal * SSize1$$
 where *SSize1* is the number of allowed values in the scan set for the first coupled parameter.

Comments (continued)

- With *STMode* set to SECOND, *STotal* is interpreted as the number of complete passes through the second coupled loop. The total number of measurements will be calculated from the following expression:

$$STotal * SSize2 * SSize1$$
 where *SSize1* and *SSize2* are the number of allowed values in the scan set for the first and second coupled parameters respectively.
- With *STMode* set to THIRD, *STotal* is interpreted as the number of complete passes through the third coupled loop. The total number of measurements will be calculated from the following expression:

$$STotal * SSize3 * SSize2 * SSize1$$
 where *SSize1*, *SSize2* and *SSize3* are the number of allowed values in the scan set for the first, second, and third coupled parameters respectively.
- The values of the scanning count variables *ECount*, *Count1*, *Count2*, and *Count3* may be manually reset to zero by using the `SCAN RST` command.
- The values of *STotal*, *STMode*, and the four *SCount* variables may be shown using the `SHOW SCAN TOTAL`, `SHOW SCAN STMODE`, and `SHOW SCAN COUNT` commands respectively.
- Entering a value of *STMode* that is greater than the number of coupled parameters gives an immediate `MODE TOO BIG` command error.

Related Commands

SCAN STMODE, SCAN TOTAL, SCAN RST, Q, X, STEP, SINGLE, FREQUENCY SCAN, SAMPLE SCAN, VOLTAGE SCAN

SCAN TOTAL

Description

Sets the total number of measurement to be taken when the SCAN command is executed.

Syntax

`SCAN TOTAL STotal`

Parameters

CTotal This parameter sets the number of parameter scanning measurements to be completed. A value of zero for *CTotal* causes measurements to occur continuously until interrupted or stopped.

Default Value 0 (Run until interrupted)

Parameter Set Scan

Query Cmd? No

Comments

- The count of the scanning mode measurements is maintained by four *SCount* variables; *ECount*, *Count1*, *Count2*, and *Count3*.
- The values of the four *SCount* variables cannot be entered and are not stored in any parameter set.
- Nonzero values of the *STotal* parameter are used to control automatic termination of parameter scanning measurement sequences, both single dimensional and multi dimension. Automatic terminations are made when the value of a selected *SCount* variable reaches *STotal*. The selection of *SCount* variable is made using the SCAN STMODE command.
- If the value of the *STotal* parameter is nonzero, scanning mode measurements will be automatically terminated when a selected *SCount* variable reaches *STotal*. Also the values of all *SCount* variable will automatically be reset to zero at the entry of every SCAN command.
- If the value of the *STotal* parameter is zero, the values of the *SCount* variables will still be incremented with each measurement but there will be no automatic termination of the scanning mode measurements based upon a comparison of their values with *STotal*.
- If the value of the *STotal* parameter is zero, the continuous mode measurements must be terminated by entry of a command such as SCAN OFF.
- The values of the scanning count variables *SCount* may be manually reset to zero by using the SCAN RST command.

Comments (continued)

- The values of *STotal*, *STMode*, and the four *SCount* variables may be shown using the SHOW SCAN TOTAL, SHOW SCAN STMODE, and SHOW SCAN COUNT commands respectively.

Related Commands

SCAN STMODE, SCAN TOTAL, SCAN RST, Q, X, STEP, SINGLE, FREQUENCY SCAN, SAMPLE SCAN, VOLTAGE SCAN

Description

Set the communications parameters for the serial interface.

Syntax

```

SERIAL BAUD Rate
      or
SERIAL PARITY Parity
      or
SERIAL BITS Bits
      or
SERIAL SBITS SBits
      or
SERIAL FILL Fill
      or
SERIAL ECHO Echo
      or

```

SERIAL [**LIST**] *Rate* , *Parity* , *Bits* , *SBits* , *Fill* , *Echo*

Parameters

Rate

is the baud rate in bits/sec and can be one of the following: 110, 135, 150, 300, 600, 1200, 1800, 2400, 3600, 4800, 7200, 9600, 19200, 38400, 57600, or 115200. The default is 9600.

Parity

controls a parity bit in each character that is sent. It can be set to **NONE** for no parity, **ODD** for odd parity, or **EVEN** for even parity. The default is **NONE** for no parity.

Bits

is the optional number of data bits in each serial character, and can be optionally set to 7, or 8. The default is 8.

SBits

controls the number of stop bits ending each character. This may be set to 1 or 2, which usually represents 1 or 2 stop bits respectively. An exception occurs when setting the number of stop bits to 2. When the word length is 8 and parity is odd or even, 1 stop bit is sent. The default is 1.

Fill

is the optional number of null characters sent at the end of each line, and ranges from 0 to 9 characters. The default is 0.

Echo

optionally determines whether commands are echoed back to the serial device. An **ON** enables echoing and an **OFF** disables it. The default is **ON**. 0 and 1 may be substituted for **OFF** and **ON** respectively.

(When using the **LIST** command qualifier or no command qualifier, skipping the entry of any parameter value will preserve the current value for that parameter. Multiple parameters values may be skipped.)

Default Values 96,NONE,8,1,0,ON

Parameter Set Serial

Query Cmd? No

Comments

- The settings of this command affect *only* serial port operations.

Remote Device Examples

```
>SER 19200      (Set baud rate to 19200 baud.)
```

```
>SE , , 7      (Set bits/character to seven.)
```

```

>SH SER
SERIAL BAUDRATE 19200
SERIAL PARITY   NONE
SERIAL BITS     7
SERIAL SBITS    1
SERIAL FILLCHAR 0
SERIAL ECHO     ON
DEFINE          ERASE=^U DEL=DEL
                BACKSP=^H DCL=^E
                TERM=PRINT

NREMOTE        OFF
NLOCKOUT       OFF
LOGGER SERIAL  OFF
>

```

The **SHOW SERIAL** command shows all the parameters in the Serial parameter set rather than just those entered by the **SERIAL** command.

SERIAL (continued)

Front Panel Examples

FUNC **SELECT** **SERIAL** **BAUD** **1** **2** **0** **0** **ENTER**
Sets baud rate to 1200 baud.

FUNC **SELECT** **SERIAL** **→** **→** **→** **→** **→** **OFF**
ENTER
Disable echoing.

FUNC **SELECT** **SHOW** **SERIAL** **ENTER**
Displays the following windows:

SERIAL	BAUDRATE
BAUDRATE	1200



SERIAL	PARITY
PARITY	NONE



SERIAL	BITS
BITS	8



SERIAL	SBITS
SBITS	1



SERIAL	FILLCHAR
FILLCHAR	0



SERIAL	ECHO
ECHO	OFF



NREMOTE
OFF



NLOCKOUT
OFF



LOGGER	SERIAL
SERIAL	OFF

The **←** and **→** keys are used to select which of the left or right windows is displayed.

Only the first two digits of the baud rate are reported by the **SERIAL** command. These windows are actually the first result line from the **SHOW ParameterSet** command described on page A-66.

References

See Chapter 7, “Serial/RS-232 Remote Operation” and specifically “SERIAL COMMUNICATION PARAMETERS” on page 7-6.

Related Commands

DEFINE, **LOCAL**, **NLOCKOUT**, **LOGGER**, **NREMOTE**

Description

Compares verification data just produced by the CAL INTERNAL or CAL CAP commands against data that is stored from past calibrations.

Syntax

```
SHOW CALIBRATE [RELATIVE]|INTERNAL|CAP
```

Qualifiers

RELATIVE

Reports current bridge conditions relative to those at the time of the last calibrations. Entering no qualifier is equivalent to entering the RELATIVE qualifier.

INTERNAL

Reports bridge conditions at the time of a recently performed CAL INTERNAL command relative to those at the time of the last internal calibration. This command also reports the internal calibration point that had the biggest change between those at the time of a recently performed CAL INTERNAL command relative to those at the time of the last internal calibration.

CAP

Reports bridge conditions at the time of a recently performed CAL CAP command relative to those at the time of both the stored Original and Update capacitance calibrations. This command also reports the deviation in the capacitance obtained with the recent CAL CAP command relative to those at the time of both the stored Original and Update capacitance calibrations.

Parameters None

Query Cmd? Yes

Comments

- The subject of calibration must be thoroughly understood before use of these commands is attempted. It is essential to first read much of Chapter 9, "Verification/Calibration."

Related Commands

CALIBRATE, STORE CALIBRATE
STORE CALIBRATE CREATE,
STORE CALIBRATE SPECIAL

SHOW DATE

Description

Reports current the current date as maintained by the real time clock inside the bridge.

Syntax

SHOW DATE

Parameters None

Parameter Set Special

Query Cmd? Yes

Comments

- The current date is reported as the year, month, and day in Universal Coordinated Time.
- The date and time settings are stored using the **STORE DATE** and **STORE TIME** commands respectively.

Front Panel Examples

[FUNC] [SELECT] [SHOW] [DATE] [ENTER]

DATE	YEAR.MO.DY
YEAR.MO.DY	2002.05.27

Remote Device Examples

```
>SHO DATE
DATE YR MON DAY 2002 05 27
>
```

The above example shows the same data as was used in the front panel example.

References

See “Special Parameter Set” on page 3-7.

Related Commands

SHOW TIME, STORE DATE

SHOW FIRMWARE

Description

Reports the version number of all firmware versions currently stored in the bridge. Also reports which of these is currently being executed.

Syntax

`SHOW FIRMWARE`

Parameters None

Query Cmd? Yes

Comments

- Pressing `[ENTER]` will abort a multi-line show that is in progress on the front panel.
- The `[↑]` and `[↓]` keys are used to go from one result line to the next.
- An asterisk(*) following the bank number marks the bank that contains the firmware that is currently executing

Front Panel Examples

`[FUNC]` `[SELECT]` `[SHOW]` `[FIRMWARE]` `[ENTER]` gives:

FIRMWARE	BANK ROM
INACTIVE	AH270 120

`[↓]` gives:

FIRMWARE	BANK FL 1
ACTIVE	AH270 125

`[↓]` gives:

FIRMWARE	BANK FL2
INACTIVE	AH270 121

The `[←]` and `[→]` keys are used to select which of the left or right windows is displayed.

In this example the active firmware is located in the FLASH1 memory bank and its version is identified as AH270125. The contents of the ROM and FLASH2 memory banks are also identified by their respective versions, and are marked as inactive.

Remote Device Examples

```
>SH FIRMWARE
BANK ROM           AH2X0120, INACTIVE
BANK FLASH1       AH2X0125, ACTIVE
BANK FLASH2       AH2X0121, INACTIVE
```

This example has the same data as in the front panel example.

References

See “Special Parameter Set” on page 3-7.

Related Commands

STORE FIRMWARE

SHOW Identification

Description

Reports bridge identification information including the manufacture name, model number, option codes, serial number, and firmware revision number.

Syntax

SHOW IDN
or
SHOW MFGR
or
SHOW MODEL
or
SHOW SN

Qualifiers

IDN	All of the identification information including the manufacture name, model number, option codes, serial number, and revision number for the active firmware will be reported.
MFGR	Only the manufacture name will be reported.
MODEL	Only the model number will be reported.
SN	Only the serial number will be reported.

Parameters None

Query Cmd? Yes

Comments

- Pressing **[ENTER]** will abort a multi-line show that is in progress on the front panel.
- Pressing the **[←]** or **[→]** keys moves from window to window on a given line on the front panel. The **[↑]** and **[↓]** keys are used to go from one result line to the next.
- The *IDN?, *IDN, and SHOW IDN commands are equivalent.

References

See “Special Parameter Set” on page 3-7.

Related Commands

IDN, SHOW FIRMWARE

Front Panel Examples

[FUNC] **[SELECT]** **[SHOW]** **[IDN]** **[ENTER]** gives:

MANUFAC	ANDEEN-H
TURER	AGERLING

[↓] gives:

MODEL	AH2700A
OPTIONS	CEJ

[↓] gives:

SERIAL	00000100
NUMBER	

[↓] gives:

ACTIVE	BANK FL1
FIRMWARE	AH270125

[FUNC] **[SELECT]** **[SHOW]** **[MFGR]** **[ENTER]** gives:

MANUFAC	ANDEEN-H
TURER	AGERLING

[FUNC] **[SELECT]** **[SHOW]** **[MODEL]** **[ENTER]** gives:

MODEL	AH2700A
OPTIONS	CEJ

[FUNC] **[SELECT]** **[SHOW]** **[SN]** **[ENTER]** gives:

SERIAL	00000100
NUMBER	

The **[←]** and **[→]** keys are used to select which of the left or right windows is displayed.

Remote Device Examples

```
>SH IDN
  MANUFACTURER      ANDEEN-HAGERLING
  MODEL/OPTIONS     AH2700A CED-----
  SERIAL NUMBER     00000100
  ACTIVE FIRMWARE   AH270125
>SH MFGR
  MANUFACTURER      ANDEEN-HAGERLING
>SH MODEL
  MODEL/OPTIONS     AH2700A CED-----
>SH SN
  SERIAL NUMBER     00000100
>
```

SHOW MACRO

Description

Reports the contents of the current macro or of any macro file.

Syntax

SHOW **MACRO** [*Filename*]

Parameters

Filename





This is the name of the file from which the macro is to be read. The name has only digits and contains no more than eight.

Default Value

If no *Filename* is entered, the contents of the current macro are reported.

Query Cmd? Yes

Comments

- On the front panel display, the contents of each line of a macro file are shown in a group of from one to three windows. The next window to the right is used to display a line number for the command. As usual, each window of a line can be shown one-by-one by pressing the  or  keys. The  and  keys are used to go from one command line to the next.
- Only the leading three characters of each command word will be reported even though many more may have been entered.
- Pressing the **ENTER** key will abort the **SHOW** command at any time on the front panel.
- If you are unsure of what macro files have been stored, the **DIRECTORY MACRO** command can be used to list them.
- *Filename* may contain only alphanumeric and underscore characters, must begin with an alpha character, and may contain no more than eight characters total.

References

See "WORKING WITH MACROS" on page 3-10 and specifically "Showing the Contents of Macro Files" on page 3-11.

Related Commands

DIRECTORY, **MACRO CREATE**,
MACRO RUN

Front Panel Examples

FUNC **SELECT** **SHOW** **MACRO** **ENTER**

UNI	1
DF	





WAI	2



SIN	3

ENTER

READY

The  and  keys are used to move between the two windows.

The contents of the current macro created on the front panel in the example given is in the **MACRO CREATE** command description on page A-41 are shown above. Each line can have as many as four windows, but only two are reported in this example. For convenience, the right-most window assigns a line number for the command line.

Remote Device Examples

```
>SHOW MACRO
AVE 7
WAI DEL 900
SIN
ZER FET
ZER ON
WAI DEL 180
SIN
>
```

The contents of the current macro created on a remote device in the example given in the **MACRO CREATE** command description on page A-41 are shown above.

SHOW Parameter

Description

Reports parameter values associated with individual commands. These parameter values are reported from current parameter sets only. The parameter set types from which values can be reported are Basic, Dev, Gauge, Scan, Serial and GPIB.

Syntax

SHOW Parameter

Qualifiers

Parameter Name of the command that sets the parameter that is to be reported.

Query Cmd? Yes

Comments

- Pressing **ENTER** will abort a multi-line show that is in progress on the front panel.
- Pressing **←** or **→** moves the front panel display left or right from window to window on a given line.
- Pressing **↑** or **↓** moves the front panel display from result line to result line.

Front Panel Examples

Front panel examples of the **SHOW Parameter** command are given for every parameter throughout this command reference. Refer to the page having the associated command name heading.

SHOW **UNITS** **ENTER**

UNITS
NS

ENTER

READY

The value of the units parameter was reported.

Remote Device Examples

Remote device examples of the **SHOW Parameter** command are given for every parameter throughout this command reference. Refer to the page having the associated command name heading.

```
>SHOW WAIT
  WAITFOR          BUFFER
>WAIT TRGMODE ERROR
>SH WAIT
  WAITFOR          ERROR
>RECALL BASIC FACTPON
>SH WAIT
  WAITFOR          BUFFER
>
```

The above example first shows the current **WAITFOR TRGMODE** value as **BUFFER**. This parameter is then changed to **ERROR** in the current parameter set and the parameter is shown again. The factory default Basic parameter set is then recalled. The **SHOW** command is repeated to see that the current value of the **WAITFOR TRGMODE** parameter was changed back to **BUFFER** by the recall operation.

References

See Chapter 3, "Parameter and Macro Files" for more examples.

Related Commands

SHOW ParameterSet

SHOW ParameterSet

Description

Reports the entire contents of the selected parameter set. This set can be either a current set or any stored parameter set. The parameter set types from which values can be reported are Basic, Dev, Gauge, Scan, Serial and GPIB.

Syntax

```
SHOW [BASIC|DEV|GAUGE|SCAN|SERIAL|GPIB  
      |ALL] [LIST] [Filename]
```

Qualifiers

None	The parameters to be reported will be read from the current Gauge parameter set. No <i>Filename</i> will be accepted.
BASIC	All parameters in the specified file having a Basic filetype will be reported.
DEV	All parameters in the specified file having a Dev filetype will be reported.
GAUGE	All parameters in the specified file having a Gauge filetype will be reported.
SCAN	All parameters in the specified file having a Scan filetype will be reported.
SERIAL	All parameters in the specified file having a Serial filetype will be reported.
GPIB	All parameters in the specified file having a GPIB filetype will be reported.
ALL	All of the current parameter sets will be reported beginning with the current GAUGE parameter set. No <i>Filename</i> will be accepted.

Parameters *Filename*

This is the name of the file from which the parameters are to be read. The name has only digits and contains no more than eight.

Default Value

If no *Filename* is entered, the parameters in the selected *current* parameter set type are reported.

Query Cmd? Yes

Comments

- Pressing **[ENTER]** will abort a multi-line SHOW command that is in progress on the front panel.
- Pressing the **[←]** or **[→]** keys moves from window to window on a given line on the front panel. The **[↑]** and **[↓]** keys are used to go from one result line to the next.

Comments (continued)

- If you are unsure what filenames and types are available to be read, issue the DIRECTORY command to get a list of all that have been stored.
- *Filename* may contain only alphanumeric and under-score characters, must begin with an alpha character, and may contain no more than eight characters total.

References

See “Exploring a List with the SHOW command” on page 2-5.

Related Commands

DIRECTORY, SHOW Parameter

Front Panel Examples

Front panel examples of the SHOW Parameter command are given for every parameter in this command reference. Refer to the page having the associated command name heading.

SHOW STATUS

Description

Reports current bridge status information including the approximate elapsed time since the bridge was manufactured.

Syntax

SHOW STATUS

Parameters None

Parameter Set None

Query Cmd? Yes

Front Panel Examples

[FUNC] [SELECT] [SHOW] [STATUS] [ENTER] gives:

STATUS	HOURS
ELAPSED	15591

Remote Device Examples

```
>SH STATUS
  ELAPSED HOURS   15591
>
```

References

See “Special Parameter Set” on page 3-7.

Related Commands

SHOW DATE, SHOW TIME

Description

Reports the value of the GPIB status byte in binary format without affecting the value of the byte.

Syntax

`SHOW STB`

Parameters None

Parameter Set None

Query Cmd? Yes

Comments

- Unlike the `STB?` and `*STB` commands, the `SHOW STB` command does not clear the `CmE`, `URq`, `POn`, and `ExE` bits in the GPIB status byte.
- The `STB?` and `*STB?` commands show the contents of the status byte register in binary and binary-weighted-integer formats respectively.
- The `MAv` and `Rdy` bits will always be zero when read with the `SHOW STB` command.

Front Panel Examples

`[FUNC]` `[SELECT]` `[SHOW]` `[STB]` `[ENTER]` gives:

STATUS	M ERPUCO
BYTE BIN	0000 1000

The `[←]` and `[→]` keys are used to select which of the left or right windows is displayed.

Remote Examples

```
>SH STB
STB                MAV=0 MSS=1 EXE=0 RDY=0
                   PON=1 URQ=0 CME=0 NUL=1
```

(Check to see which bits are set in the GPIB status byte.)

```
>STB?
STB                MAV=0 MSS=1 EXE=0 RDY=0
                   PON=0 URQ=0 CME=0 NUL=1
```

(Clears any of the four event status bits if set.)

```
>*STB?
STB BWDECIMAL    65
```

(View the GPIB status byte as a binary-weighted-decimal integer.)

References

See “STATUS REPORTING” on page 6-5 and specifically “Reading the Status with a Command” on page 6-6. See also “STATUS REPORTING” on page 6-5.

Related Commands

`STB?`, `GPIB`, `SRE`, `USER`

SHOW TIME

Description

Reports current the current time as maintained by the real time clock inside the bridge.

Syntax

SHOW TIME

Parameters None

Parameter Set Special

Query Cmd? Yes

Comments

- The current date should be entered as the year, month, and day in Universal Coordinated Time.
- The date and time settings are stored using the STORE DATE and STORE TIME commands respectively.

References

See “Special Parameter Set” on page 3-7.

Related Commands

SHOW DATE, STORE TIME

Front Panel Examples

FUNC **SELECT** **SHOW** **TIME** **ENTER**

TIME	HRMINSEC
HRMINSEC	03 47 10

Remote Device Examples

```
>SHO TIME
TIME HR MIN SEC  3 47 10
>
```

Description

Causes the bridge to take a single measurement. If continuous readings were being taken, then executing the **SINGLE** command stops continuous measurements after taking another measurement.

Syntax SINGLE

Parameters None

Query Cmd? Yes

Comments

- The Q command produces exactly the same result as the **SINGLE** command and is more convenient to use from the serial port.
- The **SINGLE** command is *not* equivalent to the TRG or GPIB GET commands.



Front Panel Examples

SINGLE (Take a measurement and show in the windows below.)

95 183 125
002774

S= 1
150 V

MODE R00
ZERO R00

The left window shows the capacitance and loss. The upper middle window displays the sample number in case a sample switch is connected. The lower middle window displays the test voltage that was used to make the measurement. The right-most windows display the Reference and Zero mode indicators. The  and  keys are used to move between the three windows.

Remote Device Examples

```
>SI
F=2400 HZ C=843.318636 PF L=0.03721 NS
>SI
F=2400 HZ C=843.318642 PF L=0.03722 NS
>
```

References

See “Taking Measurements One at a Time” on page 4-4.

Related Commands

CONTINUOUS, Q, TRG

*SRE

Description

Sets and clears bits in the GPIB service request enable mask byte.

Syntax

SRE *MAv, ExE, Rdy, POn, URq, CmE, NVL*
or
*SRE *SREMask*

The first version of the command accepts binary bits specifying which enable bits are to be set or cleared. The comma following *MAv* must always be entered. Each of the seven multiple parameters is entered as either a 1 or a 0. A 1 enables the service request bit and a 0 disables it. Alternatively, ON and OFF may be substituted for 1 and 0 respectively.

The later version accepts a standard GPIB binary-weighted-decimal representation of the enable mask. Any value from 0 to 255 is allowed.

Parameters

The table below gives the relationship between the binary parameters in the first version of the **SRE** command to the status bit name. The binary weight of each status bit name is also given for use with the second version of the command.

Table A-3 Service Request Enable mask register bit definitions and functions

Bit	Label	Name	Generates SRQ when	Binary weight
0	<i>NVL</i>	cal iNVaLid	set or cleared	1
1	<i>CmE</i>	CoMmand Error	set	2
2	<i>URq</i>	User ReQuest	set	4
3	<i>POn</i>	Power-ON	set	8
4	<i>Rdy</i>	ReaDY for command	set	16
5	<i>ExE</i>	EXecution Error	set	32
7	<i>MAv</i>	Message AVailable	set	128

Default Value 0 (No service requests enabled.)

Parameter Set GPIB

Query Cmd? No

Comments

- The first (binary) version of the **SRE** command allows setting and/or clearing only the bits to be changed. The second (binary-weighted-decimal) version deletes the old mask and replaces it with the mask that is entered.
- This command can only be entered from a remote device and is only useful with a GPIB controller.
- When a *SREMask* entry is translated to binary, the bit positions that are ones will cause the corresponding service requests to be allowed. The only exception is bit position six which is ignored.
- The value of the *SREMask* can be shown in binary format by use of the SHOW SRE or SRE? commands.
- The value of the *SREMask* can be shown in binary-weighted-decimal format by use of the *SRE? command.

Front Panel Examples

Not enterable from the front panel, but can be shown.

[FUNC] **[SELECT]** **[SHOW]** **[SRE]** **[ENTER]** gives:

SRE	M ERPUCN
BIN	0000 100 1

The **[←]** and **[→]** keys are used to select which of the left or right windows is displayed.

Remote Device Examples

```
>SHOW SRE
SRE          MAU=0 EXE=0 RDY=0 PON=0
              URQ=0 CME=0 NUL=0
```

```
>SRE ,1,,1,,1
(Enable ExE, POn and CmE.)
```

```
>SHOW SRE
SRE          MAU=0 EXE=1 RDY=0 PON=1
              URQ=0 CME=1 NUL=0
```

```
>SRE 1,0
(Enable MAv, disable ExE.)
```

```
>SHOW SRE
SRE          MAU=1 EXE=0 RDY=0 PON=1
              URQ=0 CME=1 NUL=0
```

```
>*SRE 17
(Set SREMask to exactly 17.)
```

```
>SHOW SRE
SRE          MAU=0 EXE=0 RDY=1 PON=0
              URQ=0 CME=0 NUL=1
```

```
>*SRE?
SRE BWDECIMAL 17
>
```

This example shows how to both change and show mask settings in both binary and binary-weighted-decimal. Changing mask bits with the binary entry method is also demonstrated.

References

See “STATUS REPORTING” on page 6-5 and specifically “Service Requests” on page 6-7.

Related Commands

STB?, SHOW STB, GPIB COMPATIB, GPIB LIST, USER

*STB?

Description

Shows and clears the four event status bits in the GPIB status byte.

Syntax *STB? or STB?

Parameters None

Parameter Set Special

Query Cmd? No

Comments

- Both forms of the command clear the CmE, URq, POn, and ExE bits in the GPIB status byte, a string of eight binary bits with the meaning shown in Table A-3 below.
- The STB? and *STB? commands show the contents of the status byte register in binary and binary-weighted-decimal formats respectively.
- Unlike the STB? and *STB commands, the SHOW STB command does not clear the event status bits in the GPIB status byte.

Front Panel Examples

The STB? and *STB? commands are not available from the front panel. Use The SHOW STB command to report the value of the GPIB status byte in binary format.

Remote Examples

```
>SH STB
STB                    MAU=0 MSS=1 EXE=0 RDY=0
                                PON=1 URQ=0 CME=0 NVL=1
```

(Check to see which bits are set in the GPIB status byte.)

```
>STB?
STB                    MAU=0 MSS=1 EXE=0 RDY=0
                                PON=0 URQ=0 CME=0 NVL=1
```

(Clears any of the four event status bits if set.)

```
>*STB?
STB BWDECIMAL        65
```

(View the GPIB status byte as a binary-weighted-decimal integer.)

References

See “STATUS REPORTING” on page 6-5 and specifically “Reading the Status with a Command” on page 6-6. See also “STATUS REPORTING” on page 6-5.

Related Commands

GPIB COMPATIB, SRE, USER, SHOW STB

Table A-4 Status byte register bits reported by *STB? command.

Bit	Label	Name	Set when	Cleared when	Generates SRQ when
0	NVL	cal iNVaLid	Oven temperature is abnormal	Oven temperature returns to normal	set or cleared
1	CmE	Command Error	An error in the entry of a command occurred. See Appendix B, “Error Messages” for a list.	STB? or RST is executed	set
2	URq	User Request	The USER command is executed	STB? or RST is executed	set
3	POn	Power-On	Bridge power comes on	STB? or RST is executed	set
4	Rdy	Ready for command	A command line finishes its execution; see “INTERACTIVE OPERATION” on page 6-12	A new command line is received	set
5	ExE	Execution Error	An error occurred executing a command. See Appendix B, “Error Messages” for a list.	STB? or RST is executed	set
6	MSS	Master Sum- mary Status	Inclusive OR of the bit-wise combination of bits 1-7 of the SB and SRE registers is true or when the NVL status bit changes while the corresponding NVL bit in SRE register is set.	Inclusive OR of SB and SRE is false	N/A, see RQS bit
7	MAv	Message Available	A message is available in the GPIB output buffer	No message is in the GPIB output buffer.	set

Description

Steps through operations when using the **MACRO** or **TEST** commands; iterates coupled parameter values and executes a single measurement when parameter scanning is enabled.

Syntax STEP

Parameters None

Query Cmd?

Execution of the **STEP** command usually produces a query result, but this is dependent on what root command is being executed. The **TEST** command, for example, can be set to halt on every test without sending a result.

Comments

- The **X** command produces exactly the same result as the **STEP** command but is more convenient to use from the serial port than the **STEP** command.
- This command tells the bridge to continue after waiting for you to perform an external action. The latter occurs with the **TEST** commands.
- The **X** command will do nothing if there is no active root command waiting for input. This allows the **X** command to be used in macros where the need for it may be uncertain. It should cause no harm if it is not needed.
- This command will only work in an AH2700A macro if it is not the first character. A space can precede it if you desire to enter it by itself on a macro line.
- A **STEP** command following an AH2700A macro will not be processed even if the macro contains a command that is looking for **X** as a reply. In other words, in the command line “**MACRO;STEP**”, the **STEP** will never have any effect no matter what the contents of the macro.
- The **STEP** command functions as a single measurement execution command when frequency, sample number, and/or highest voltage parameter scanning are enabled. Execution of this command causes iteration of the coupled parameters in accordance with the scanning setup parameters followed by a single measurement. Each execution of parameter scanning measurement increments the *Counts* variables.
- Execution of the **STEP** command during continuous parameter scanning measurements terminates those measurement without resetting the associated parameters.
- If no coupled parameters exist when **STEP** is executed, then no action is taken and the error message *NO COUPL PARAMETER* is reported.

Comments (continued)

- If the *Counts* variables effectively reach the value of *STotal*, the only consequence of executing **STEP** will be to report a *COUNTMAX REACHED* error. This will continue to occur until the *Counts* variables are reset. If this behavior is not desirable, then *STotal* should be set to zero.

Front Panel Examples

The **STEP** key is used instead on the front panel.

Serial Remote Examples

For some examples see “DC BIAS High Voltage Tests” on page 11-19.

References

See “Single-Step Mode” on page 3-12, “Selection of Options: the **TEST** command” on page 11-7, and Chapter 9, “Verification/Calibration.”

Related Commands

MACRO, **X**, **TEST**, **FREQUENCY SCAN**, **SAMPLE SCAN**, **FREQUENCY SCAN**

STORE

Description

Stores a current parameter set or macro in EEPROM memory.

Syntax

```
STORE BASIC|DEV|GAUGE|GPIB|
      SCAN|SERIAL|MACRO Filename
```

Qualifiers

BASIC	Save the current Basic parameter set to a file.
DEV	Save the current Dev parameter set to a file.
GAUGE	Save the current Gauge parameter set to a file.
GPIB	Save the current GPIB parameter set to a file.
SCAN	Save the current Scan parameter set to a file.
SERIAL	Save the current Serial parameter set to a file.
MACRO	Save the current macro to a file.

Parameters *Filename*

This is the name of the file to be stored. The name can contain a maximum of eight characters. The name “FACTPON” is reserved for parameter files stored in ROM. Parameter files stored with the name “USERPON” will be recalled upon power-on. FACTPON parameter files will be recalled upon power-on in the absence of USERPON files with the same type. A macro file stored with the name “USERPON” will be executed upon power-on. A macro file stored with the name “TRIGMAC” will be executed upon reception of a TRG command or a GPIB GET command.

Default Value None

Parameter Set None

Query Cmd? No

Comments

- If you are unsure of what filenames are already in use, issue the DIRECTORY command to get a list of all that have been stored.
- Storing a new file using a name and type that already exists will cause the old file to be overwritten with the new one. No warning is given when this happens.
- If you are unsure of the contents of a particular file, you can use the SHOW command to examine its contents.

Comments (continued)

- *Filename* may contain only alphanumeric and underscore characters, must begin with an alpha character, and may contain no more than eight characters total.
- Filenames may be entered from the front panel by placing the instrument into the character editing mode. Following entry of the STORE MACRO command, use the [FUNC] [EDIT] key combination to place the instrument into the character editing mode.

Front Panel Examples

[AVERAGE TIME] [7] [ENTER]
Sets the *AverExp* parameter to 7.

[FUNC] [SELECT] [STORE] [GAUGE] [USERPON] [ENTER]
Stores the current Gauge parameter set including the *AverExp* parameter into Gauge file USERPON.

[AVERAGE TIME] [3] [ENTER]
Sets the *AverExp* parameter to 3.

[FUNC] [SELECT] [STORE] [GAUGE]
 [FUNC] [EDIT] [E] [X] [A] [M] [P] [L] [E] [ENTER]
Stores the current Gauge parameter set including the *AverExp* parameter into Gauge file EXAMPLE.

[SHOW] [AVERAGE TIME] [ENTER]
Displays the following window:

```
AVERAGE
  3
```

[FUNC] [SELECT] [RECALL] [GAUGE] [USERPON] [ENTER]
Recalls the following window showing that the *AverExp* parameter in the GAUGE USERPON file has changed from four to seven:

```
AVERAGE
  7
```

[FUNC] [SELECT] [RECALL] [GAUGE] [EXAMPLE] [ENTER]
Recalls the following window showing that the *AverExp* parameter in the GAUGE USERPON file has changed from four to seven:

```
AVERAGE
  3
```


Remote Device Examples

```
>SHOW MACRO EXAMPLE
  FILE NOT FOUND
>SH MACRO
  AVE 8
  SIN
>STORE MACRO EXAMPLE
>SHOW MACRO EXAMPLE
  AVE 8
  SIN
>
```

This example shows that initially there is no macro with a file name of "EXAMPLE", but that there is a two-line macro in RAM. The current macro is then stored in macro file EXAMPLE. Another SHOW command reveals that the contents of the current macro are now also in macro file EXAMPLE.

References

See Chapter 3, "Parameter and Macro Files" and specifically "Adding Files" on page 3-8.

Related Commands

DELETE Filename, DIRECTORY, RECALL, SHOW

STORE CALIBRATE

Description

Causes the AH2700A to save the verification values obtained with the CALIBRATION commands.

Syntax

`STORE CALIBRATE INTERNAL|CAP|[ALL]`

this is the commonly used command version. It performs the functions listed in the qualifiers section below.

Qualifiers

ALL	Overwrites the previous calibration data with whatever new verification data has been produced by the last CALIBRATE INTERNAL and/or CALIBRATE CAP commands. Entering no qualifier has the same effect as entering ALL.
INTERNAL	Overwrites only the previous internal calibration data with that produced by the last CALIBRATE INTERNAL command.
CAP	Overwrites only the previous Update capacitance calibration data with that produced by the last CALIBRATE CAP command.

Parameters None

Query Cmd? No

Related Commands

CALIBRATE, SHOW CALIBRATE,
STORE CALIBRATE SOURCE

Front Panel Examples

`[FUNC] [SELECT] [STORE] [CALIBRATE] [INTERNAL] [ENTER]`

PASSCODE

`[1] [2] [3] [4] [5] [6]`

PASSCODE
123456

`[ENTER]`

This example shows the passcode prompt resulting from the entry of a STO CAL INTERNAL command. This is followed by the entry of the “123456” passcode. The Update capacitance calibration data is overwritten after the `[ENTER]` key is pressed.

Remote Device Examples

```
>STO CAL INTERNAL  
PASSCODE>171717  
(The passcode is not actually echoed.)  
>  
Saves new internal calibration data.
```

Comments

- The subject of calibration must be thoroughly understood before using these commands is attempted. It is essential to first read much of Chapter 9, “Verification/Calibration.”
- A User or higher passcode is required if CALIBRATE INTERNAL data is being overwritten. A Calibrator or higher passcode is required if CALIBRATE CAP data is being overwritten.
- Entry of three bad passcodes in a row will cause all further passcodes to be rejected until power-on occurs.
- If the Update capacitance calibration data is stored, the CSource parameter is set to UPDATE. This new capacitance calibration data will change the actual calibration of the bridge *only* if the CSource parameter remains set to UPDATE.
- If the Factory capacitance calibration data is stored, the CSource parameter is set to FACTORY. This new capacitance calibration data will change the actual calibration of the bridge *only* if the corresponding CSource parameter remains set to FACTORY.

STORE CALIBRATE SOURCE

Description

Selects the source of data for the capacitance calibration. You can select the Factory capacitance calibration corresponding to the calibration done at the time of original manufacture or the Updated capacitance calibration done subsequently.

Syntax

`STORE CALIBRATE SOURCE CAP CSource`

changes the *CSource* parameter. Requires the Owner or Calibrator passcode.

Parameters

Allowed values are `UPDATE` and `FACTORY`. When set to `UPDATE`, the bridge uses the corresponding Update capacitance calibration data. When set to `FACTORY`, the bridge uses the corresponding Factory capacitance calibration data.

Default Value None

Parameter Set None

Query Cmd? No

Comments

- The function of the *CSource* parameter must be thoroughly understood before changing it.
- Passcodes entered on remote serial devices in response to a passcode prompt will not be echoed.
- The `STORE CALIBRATE` command automatically sets the corresponding *CSource* parameter to `UPDATE` if new Update calibration capacitance data is stored.
- Entry of three bad passcodes in a row will cause all further passcodes to be rejected until power-on occurs.

References

See “Selecting Update vs. Original Capacitance Calibration Data” on page 9-11 and “Selecting Update vs. Original Capacitance Calibration Data” on page 9-11.

Related Commands

`CALIBRATE`, `SHOW CALIBRATE`,
`STORE CALIBRATE`,
`STORE PASSCODE`

Front Panel Examples

```
FUNC SELECT STORE CALIBRATE SOURCE CAP
FACTORY ENTER
```

```
PASSCODE

```

```
1 2 3 4 5 6
```

```
PASSCODE
123456
```

```
ENTER
```

```
READY

```

In the above example the *CSource* capacitance calibration parameter is set to `FACTORY`. This example shows the passcode prompt resulting from the entry of a `STORE CALIBRATE SOURCE CAP FACTORY` command. This is followed by the entry of “123456” which was accepted as the correct passcode.

```
FUNC SELECT SHOW CALIBRATE CAP ENTER
```

```
CSOURCE
FACTORY
```

This example shows the value of the capacitance *CSource* parameter as the first window of a multi-window result. This command will show this window only if calibration data has been generated. The `SHOW CAL` command will report the *CSource* parameters even if no data has been generated.

Remote Device Examples

```
>STO CAL CAP SOURCE CAP UPDATE
PASSCODE>123456 (Passcode is not actually echoed.)
>
```

The capacitance calibration *CSource* parameter is set to `UPDATE` so the Update capacitance calibration data is used.

```
>SHO CAL CAP
CAP CSOURCE UPDATE
DEV FROM UPDT CAP: CAL AGE = 345 HRS
TEMP = -5.1C C = -0.71 PPM
DEV FROM ORIG CAP: CAL AGE = 12345 HRS
TEMP = -4.6C C = -0.71 PPM
>
```

The above example shows the value of the capacitance *CSource* parameter on the first line of the three line result.

STORE DATE

Description

Sets the date.

Syntax

STORE DATE *Year, Month, Day*

Requires the Owner or Calibrator passcode.

Parameters

<i>Year</i>	Sets the year from 1970 to 2069
<i>Month</i>	Sets the number of the month from 1 to 12
<i>Day</i>	Sets the day of the month.

Default Value None

Parameter Set Special

Query Cmd? No

Comments

- The current date should be entered as the year, month, and day in Universal Coordinated Time.
- The date is stored relative to the instant that the **ENTER** key is pressed immediately following the entry of the *Day* parameter. Whatever time is taken to enter the passcode will not affect the date that is actually stored.
- The internal realtime clock does not use a battery but it will run for weeks without power being applied to the bridge. However, if the bridge is not powered on for a few minutes every month the clock will be reset to read all zeros.
- Since the clock is used to track the age of the calibration data, it is important that it be set if the bridge has been powered off for too long.
- The clock automatically adjusts for leap years.
- Passcodes entered on remote serial devices in response to a passcode prompt will not be echoed.
- Entry of three bad passcodes in a row will cause all further passcodes to be rejected until power-on occurs.

References

See “Special Parameter Set” on page 3-7.

Related Commands

SHOW DATE, SHOW TIME, STORE TIME

Front Panel Examples

FUNC **SELECT** **STORE** **DATE**
2 0 0 3 → 0 5 → 2 7

YEAR.MO.DY
2002.05.27

ENTER 1 2 3 4 5 6

(The clock starts ticking at the moment that the **ENTER** key is pressed but the new setting is not made permanent until the passcode is accepted.)

PASSCODE
123456

ENTER

READY

In the above example a new date is entered. This example shows the resulting passcode prompt. This is followed by the entry of “123456” which was accepted as the correct passcode.

FUNC **SELECT** **SHOW** **DATE** **ENTER**

DATE YEAR.MO.DY
YEAR.MO.DY 2002.05.27

The SHOW DATE command now reports the updated date.

Remote Device Examples

```
>STO DATE 2002,5,27
PASSCODE>123456 (Passcode is not actually echoed.)
>SHO DATE
DATE YR MON DAY 2003 05 27
>
```

The above example shows the same data as was used in the front panel example.

STORE FIRMWARE

Description

Used only to change or upgrade the firmware. Copies firmware from the serial port or the internal ROM memory bank to one of the two FLASH memory banks. Also selects the memory bank from which the bridge will operate. Use of this command requires the Owner passcode.

Syntax

```
STORE FIRMWARE COPY FromBank, ToBank
or
STORE FIRMWARE RUN RunBank
or
STORE FIRMWARE [LIST] FromBank, ToBank,
RunBank
```

Qualifiers

COPY	Copies firmware from the <i>FromBank</i> to the <i>ToBank</i> . If successful, the instrument will automatically restart from the <i>ToBank</i> . Must be running from the ROM bank to use this qualifier.
RUN	Causes the instrument to restart from the <i>RunBank</i> .
LIST	Copies firmware from the <i>FromBank</i> to the <i>ToBank</i> . If successful, the instrument will automatically restart from the <i>RunBank</i> . Must be running from the ROM bank to use this qualifier.

Parameters

<i>FromBank</i>	Selects the source from which firmware is to be copied. Permitted values are <u>ROM</u> and <u>SERIAL</u> .
<i>ToBank</i>	Selects the flash ROM memory bank into which firmware is to be copied. Permitted values are <u>FLASH1</u> and <u>FLASH2</u> .
<i>RunBank</i>	Selects the ROM memory bank containing firmware which the bridge is to run and causes the bridge to immediately restart. Permitted values are <u>ROM</u> , <u>FLASH1</u> , and <u>FLASH2</u> .

Default Value None

Query Cmd? No

Comments

- A version of the firmware always exists in the ROM memory bank but measurements cannot be taken when running from this memory bank. The ROM memory bank must be activated in order to use the STORE FIRMWARE COPY and STORE FIRMWARE LIST versions of this command.
- A version of the firmware also exists in one or both of the FLASH memory banks. One of these banks must be activated in order to use the bridge to make measurements.
- The bridge will be fully functional when running from a version of firmware located in either of the FLASH memory banks. This choice allows testing a new firmware version without having to overwrite the old version.
- Passcodes entered on remote serial devices in response to a passcode prompt will not be echoed.
- Entry of three bad passcodes in a row will cause all further passcodes to be rejected until power-on occurs.

Related Commands

SHOW FIRMWARE

STORE PASSCODE

Description

Allows creating new calibration passcodes.

Syntax

`STORE PASSCODE USER UserCode`
or
`STORE PASSCODE CALIBRAT CalCode`
or
`STORE PASSCODE REPLACE ReplCode`

Qualifiers

- USER** Allows changing the *UserCode* passcode if you know the Owner passcode. The **USER** passcode is the lowest level passcode and is accepted only by the **STORE CALIBRATE INTERNAL** command.
- CALIBRAT** Allows changing the *CalCode* passcode if you know the Owner passcode. The **CALIBRAT** passcode is an intermediate level passcode and is accepted by every version of the **STORE CALIBRATE** command.
- REPLACE** Allows changing the *ReplCode* passcode if you know the Owner passcode. The **REPLACE** passcode is an intermediate level passcode and is only accepted by the **STORE CALIBRATE REPLACE** command.

Parameters

The *UserCode*, *CalCode*, and *ReplCode* passcodes are six digit numbers.

Query Cmd? No

Comments

- Passcodes entered in response to a prompt on remote serial devices will not be echoed.
- The Owner passcode can be entered as a part of the command on the same line by separating the command and Owner passcode by with a semicolon. The Owner passcode entered in this way will be echoed to a serial device.
- Entry of three bad owner passcodes in a row will cause all further passcodes to be rejected until power-on occurs.

Front Panel Examples

`FUNC SELECT STORE PASSCODE USER`
`6 5 4 3 2 1 ENTER`

ONR CODE

`1 2 3 4 5 6`

ONR CODE
123456

`ENTER`

This example shows the Owner passcode prompt resulting from the entry of a **STO PASSCODE USER** command. This is followed by the entry of a “123456” Owner passcode. In this example the bridge accepted this as the correct passcode. The old *UserCode* passcode is replaced with the new “654321” *UserCode* passcode after the `ENTER` key is pressed.

Remote Device Examples

```
>STO PASSCODE CALIBRAT 123123  
OWNER CODE>123456
```

Change the Calibrator passcode to “123123”. The Owner passcode above are not actually echoed if the remote device is connected to the serial port.

```
>STO PASSCODE CALIBRAT 123123;123456
```

This performs the same function as the previous example.

References

See “Changing the User Passcode” on page 9-17, “Changing the Calibrator Passcode” on page 9-18, and “Changing the Replace Passcode” on page 9-18.

Related Commands

CALIBRATE,
SHOW CALIBRATE,
STORE CALIBRATE,
STORE CALIBRATE SOURCE.
STORE CALIBRATE REPLACE

STORE TIME

Description

Sets the time.

Syntax

`STORE TIME Hour, Minute, Second`

Requires the Owner or Calibrator passcode.

Parameters

Hour Sets the hour of the day from 0 to 23
Minute Sets the minute of the hour
Seconds Sets the seconds of the hour

Default Value None

Parameter Set Special

Query Cmd? No

Comments

- The current date should be entered as the year, month, and day in Universal Coordinated Time.
- The time is stored relative to the instant that the `ENTER` key is pressed immediately following the entry of the *Second* parameter. Whatever time is taken to enter the passcode will not affect the time that is actually stored.
- The internal realtime clock does not use a battery but it will run for weeks without power being applied to the bridge. However, if the bridge is not powered on for a few minutes every month the clock will be reset to read all zeros.
- Since the clock is used to track the age of the calibration data, it is important that it be set if the bridge has been powered off for too long.
- The clock automatically adjusts for leap years.
- Passcodes entered on remote serial devices in response to a passcode prompt will not be echoed.
- Entry of three bad passcodes in a row will cause all further passcodes to be rejected until power-on occurs.

References

See “Special Parameter Set” on page 3-7.

Related Commands

STORE DATE, SHOW DATE, SHOW TIME

Front Panel Examples

`FUNC` `SELECT` `STORE` `TIME` `3` `→` `4` `7` `→` `1` `0`

HRMINSEC
03 47 10

`ENTER` `1` `2` `3` `4` `5` `6`

(The clock starts ticking at the moment that the `ENTER` key is pressed but the new setting is not made permanent until the passcode is accepted.)

PASSCODE
123456

`ENTER`

READY

In the above example a new time is entered. This example shows the resulting passcode prompt. This is followed by the entry of “123456” which was accepted as the correct passcode.

`FUNC` `SELECT` `SHOW` `TIME` `ENTER`

TIME HRMINSEC
HRMINSEC 03 47 10

The SHOW TIME command now reports the updated time.

Remote Device Examples

```
>STO TIME 3,47,10  
PASSCODE>123456 (Passcode is not actually echoed.)  
>SHO TIME  
TIME HR MIN SEC 3 47 10  
>
```

The above example shows the same time as was used in the front panel example.

TEST

Description

Performs a selection of diagnostic tests on the internal circuitry of the bridge. Effective use of this command requires an understanding of Chapter 11, “Diagnosis and Repair.” Also determines which test results are reported and what conditions cause execution of the tests to halt (pause).

Syntax

```
TEST
or
TEST FLOOR TstFlGrp, TstFlNum
or
TEST CEILING TstCeGrp, TstCeNum
or
TEST TOTAL TstTotal
or
TEST HALT MODE HltOnCnd
or
TEST HALT TOTAL ErrTotal
or
TEST REPORT RsltMode
```

Qualifiers

None	Use to begin execution of the sequence of tests defined by the floor and ceiling parameters. These tests will be repeated as specified by the <i>TstTotal</i> parameter. This is the only form of the command that initiates execution of the tests.
FLOOR	Use to specify the first or only test to be executed.
CEILING	Use to specify the last tests to be executed.
TOTAL	When used without the HALT qualifier specifies the number of times the sequence of tests defined by the floor and ceiling parameters are to be executed. When used with the HALT qualifier specifies the number of test failures required to cause the test sequence to halt.
MODE	Use to specify the conditions under which the TEST command will be automatically halted.
REPORT	Use to specify the contents of test results reported to remote devices.

Parameters

TstFlGrp

The number of the group containing the first or only test to be executed.

TstFlNum

The number within the first or only group of the first or only test to be executed

TstCeGrp

The number of the group containing the last test to be executed.

TstCeNum

The number within the last group of the last test to be executed

TstTotal

The number of times all the specified tests are to be executed. If zero is entered, the tests are executed indefinitely.

HltOnCnd

The “halt on condition” parameter can be set to the values below. The effects of each setting are listed. If an *HltOnCnd* condition occurs, a “+” prompt will be sent to remote devices. The STEP or X commands may be entered in response to this prompt to cause execution to continue. The permitted values are as follows:

<u>AT_END</u>	Test execution does not halt until all tests are finished.
<u>ON_ERR</u>	Execution of the tests will halt after <i>ErrTotal</i> errors have been detected. If <i>ErrTotal</i> is one, then execution will halt on every error.
<u>ALL</u>	Execution of the tests will halt on every occurrence of any test result.
<u>TOTAL</u>	Halt after the <i>ErrTotal</i> test failures have occurred.

ErrTotal

The “error total” parameter can be set to any value from 1 to 999. It specifies the number of test failures required to cause the test sequence to halt.

Parameters (continued)

RsltMode

The “reported results” parameter can be set to the values below. The effects of each setting are listed.

<u>SCOPE</u>	No test results are measured or reported. The word <i>SCOPE</i> is displayed in place of the upper line of the PASS/FAIL window on the front panel.
<u>ERR</u>	Only any error result lines are sent to remote devices. All results, failed or not, are shown on the front panel. To guarantee that a message is sent to a GPIB controller, SHOW TEST should be appended to the command line.
<u>ERR_SUM</u>	Only error results and the test summary line are sent to remote devices. All test results, failed or not, are shown on the front panel.
<u>ALL</u>	All results, failed or not, are sent to remote devices and are shown on the front panel.

Default Value

The four floor/ceiling/group/number parameters default to cover all the possible tests.

TstTotal defaults to 1.

HltOnCnd defaults to **AT_END**.

ErrTotal defaults to 1.

RsltMode defaults to **ERR_SUM**.

Parameter Set



The four floor/ceiling/group/number parameters and the *TstTotal* parameter are not stored as part of any parameter set. If other than the default values are desired, they must be entered after every power-up or **RST** command.

The remaining three parameters *HltOnCnd*, *ErrTotal*, and *RsltMode* are stored in the Basic parameter set.

Query Cmd?

Yes, but if the *RsltMode* parameter is set to **SCOPE** then a **SHOW TEST [FETCH]** command should be added to the command line to guarantee a result. For example:
TEST; SH TE.

Comments

- Each test result is reported in seven windows on the front panel. These may be viewed one-by-one by pressing the  and  keys while tests are running or after they finish. This allows real-time monitoring of the results.
- The **SHOW TEST [FETCH]** command will re-display the failure report for the last test that failed.
- Certain tests can erase or overwrite RAM memory. In these cases, you are prompted with an “Are You Sure?” message. This must be answered with a **YES** to allow the test to proceed.
- The **SHOW TEST** command will display the values of the parameters associated with the **TEST** commands.
- Using the ***TST?** command causes all tests to be executed that do not require intervention. The ***TST?** command is not affected by the parameters associated with the **TEST** command.
- Using the **TEST** command causes all of the selected tests, including those that require operator intervention, to be executed.
- The “halt on condition” feature is essential for reading individual error results from the front panel. Most of these would be overwritten in less than a second otherwise.

TEST (continued)

Front Panel Examples

FUNC **SELECT** **TEST** **REPORT** **ERR** **ENTER**

This command sets the *TResult* parameter to ERR. The next command will show the test format parameters.

FUNC **SELECT** **SHOW** **TEST** **ENTER** gives:

TEST	GRP 20
FLOOR	NUM 1



TEST	GRP 91
CEILING	NUM 6



TEST	1
TOTAL	



TEST	MODE
HALT	AT_END



TEST	TOTAL
HALT	1



TEST	REPORT
REPORT	ERR_SUM

The **←** and **→** keys are used to select which of the left or right windows is displayed.

Remote Device Examples

```
>SHO TEST
TEST FLOOR      GRP= 20, NUM= 1
TEST CEILING    GRP= 91, NUM= 6
TEST TOTAL      1
TEST HALT MODE  AT_END
TEST HALT TOTAL 1
TEST REPORT     ERR_SUM
```

(Shows the current test parameter values.)

```
>TEST TOTAL 10
(Sets the TstTotal parameter value to 10 to repeat the test
sequence 10 times.)
```

```
>SHO TEST
TEST FLOOR      GRP= 20, NUM= 1
TEST CEILING    GRP= 91, NUM= 6
TEST TOTAL      10
TEST HALT MODE  AT_END
TEST HALT TOTAL 1
TEST REPORT     ERR_SUM
```

(Shows the revised test parameter values.)

```
>TEST REPORT ERR
(Sets the RsltMode parameter value to ERR to report only
error result lines. The next command shows the updated
parameter set.)
```

```
>SHO TEST
TEST FLOOR      GRP= 20, NUM= 1
TEST CEILING    GRP= 91, NUM= 6
TEST TOTAL      10
TEST HALT       AT_END
TEST HALT TOTAL 1
TEST REPORT     ERR
```

(Shows the revised test parameter values.)

>

References

See Chapter 11, “Diagnosis and Repair” and specifically “Initiating Self-tests: the TEST command” on page 11-5. See Also see Chapter 11, “Diagnosis and Repair” and specifically “Selection of Options: the TEST command” on page 11-7.

Related Commands

CALIBRATE, SHOW CALIBRATE, STEP, TEST SINGLE, X, *TST?

Description

Performs a selected diagnostic test on the internal circuitry of the bridge. Effective use of this command requires an understanding of Chapter 11, “Diagnosis and Repair.”

Syntax

```
TEST SINGLE TstGrp, TstNum
```

Parameters

<i>TstGrp</i>	The number of the group containing the test to be executed.
<i>TstNum</i>	The number within the group of the test to be executed

Default Value

When omitted, the parameter values default to the previously entered values. If no previously entered values are available, then an error message is reported.



Parameter Set None

These parameters are not stored as part of any parameter set. If other than the default values are desired, they must be entered after every power-up or RST command.

Query Cmd?

Yes, but if the *RsltMode* parameter is set to SCOPE then a SHOW TEST command should be added to the command line to guarantee a result. For example:
TEST SINGLE;SH TE.

Comments

- The three parameters associated with the TEST command, *HltOnCnd*, *ErrTotal*, *RsltMode*, affect which test results are reported and what conditions cause execution of the tests to halt (pause).
- The *TstTotal* parameter associated with the TEST command sets the number of times the specified test is executed.
- Each test result is reported in seven windows on the front panel. These may be viewed one-by-one by pressing the  and  keys while tests are running or after they finish. This allows real-time monitoring of the results.
- The SHOW TEST [FETCH] command will re-display the failure report for the last test that failed.
- Certain tests can erase or overwrite RAM memory. In these cases, you are prompted with an “Are You Sure?” message. This must be answered with a YES to allow the test to proceed.
- The SHOW TEST command will display the values of the parameters associated with the TEST commands.

References

See Chapter 11, “Diagnosis and Repair” and specifically “Initiating Self-tests: the TEST command” on page 11-5.

Related Commands

CALIBRATE, SHOW CALIBRATE, STEP,
TEST, X, *TST?

*TRG

Description

The TRG command produces exactly the same result as the GPIB GET command. Both of these execute a **MACRO RUN TRIGMAC** command. Since a macro can contain any AH2700A command or combination of commands, the TRG or GET commands provide a convenient way of initiating any bridge operation.

Syntax *TRG or TRG

Parameters None

Default Value If a macro TRIGMAC file does not exist, a **SINGLE** command will be executed every time a TRG or GET command is issued.

Query Cmd? Dependent upon the contents of macro number two.

Comments

- *TRG an alternative and completely equivalent form of the TRG command.
- The TRG command is *not* equivalent to the **SINGLE** command. However, the TRG command can function identically if macro TRIGMAC does not exist or if it consists of one **SINGLE** command.

Front Panel Examples

If a macro filename of "TRIGMAC" exists, then the following key sequence will run the macro:

FUNC **SELECT** **TRG** **ENTER**

An identical result could be produced with the key sequence:

FUNC **SELECT** **MACRO** **RUN** **TRIGMAC** **ENTER**

Remote Device Examples

```
>MACRO CREATE
#SA 1;SI
#SA 2;SI
#SA 3;SI
#SA 4;SI
#
>STORE MACRO TRIGMAC
>TRG
  S= 1 C= 843.318636 PF L= 0.03721 NS
  S= 2 C= 431.587114 PF L= 0.01378 NS
  S= 3 C= 187.615845 PF L= 0.00831 NS
  S= 4 C= 52.827906 PF L= 0.00558 NS
>
```

The above example shows the creation of a macro that automatically selects sample numbers one through four and takes one measurement after the selection of each sample. The macro was stored with the name TRIGMAC and a TRG command was issued that caused the macro to be executed.

References

See "WORKING WITH MACROS" on page 3-10 and especially "The TRG/GET Macro" on page 3-13. See also "Initiating with a TRG/GET Macro" on page 4-4.

Related Commands

Q, MACRO CREATE, MACRO RUN, SINGLE, STORE

Description

Performs all diagnostic tests on the internal circuitry of the bridge that require no operator intervention. Effective use of this command requires an understanding of Chapter 11, “Diagnosis and Repair.”

Syntax

*TST?



Qualifiers None

Parameters None

Default Value None

Query Cmd? Yes

Comments

- Each test result is reported in seven windows on the front panel. These may be viewed one-by-one by pressing the  and  keys while tests are running or after they finish. This allows real-time monitoring of the results.
- The `SHOW TEST [FETCH]` command will re-display the failure report for the last test that failed.
- Upon successful completion of the `*TST?` command, the bridge will be returned to its state prior to the execution.
- Using the `*TST?` command causes all tests to be executed that do not require intervention. The `*TST?` command is not affected by the parameters associated with the `TEST` command.
- Using the `TEST` command causes all of the selected tests, including those that require operator intervention, to be executed.

Related Commands

`CALIBRATE`, `SHOW CALIBRATE`, `STEP`,
`TEST`, `X`, `TEST`, `TEST SINGLE`

UNITS

Description

Selects the units that will be used to report the *loss* component of the measurements.

Syntax

`UNITS LossUnit`

Parameters *LossUnit*

The list below gives the corresponding units for the respective *LossUnit* parameter.

<u>NS</u>	Nanosiemens	(nS)
<u>DS</u>	Dissipation factor or $\tan\delta$	(dimensionless)
<u>KO</u>	Series resistance in kilohms	(k Ω)
<u>GO</u>	Parallel resistance in gigohms	(G Ω)
<u>JP</u>	G/ ω	(jpF)

Note: The numerical values 1, 2, 3, 4, and 5 may substituted for NS, DS, KO, GO, and JP respectively.

Default Value NS (nanosiemens)

Parameter Set Basic

Query Cmd? Yes

Comments

- When any form of the UNITS command is issued it will re-display the last measurement taken with the new units setting in effect.
- Capacitance is *always* displayed in units of picofarads or as percent deviation from a Reference value.
- Loss is always displayed in one of the five units in the list above or as percent deviation from a Reference value.
- The *LossUnit* parameter values are in the same order as the top-to-bottom ordering of the front panel unit indicator labels.
- Changing the *LossUnit* parameter will not usually cause the capacitance value to change. However, the series capacitance value of lossy unknowns is different from the parallel capacitance value. This is demonstrated in “Front Panel Examples” on this page.

References

See “DECIDING WHICH UNITS TO USE” on page 4-10 and specifically “Changing the Loss Units” on page 4-12.

Related Commands None

Front Panel Examples

`FUNC SELECT UNITS NS ENTER`

50688658

1492437

`FUNC SELECT UNITS DS ENTER`

50688658

00468603

`FUNC SELECT UNITS KO ENTER`

50699965

1468 122

`FUNC SELECT UNITS GO ENTER`

50688658

00006700

`FUNC SELECT UNITS JP ENTER`

50688658

2375287

`SHOW UNITS ENTER`

UNITS

JP

Note that UNITS KO affected the capacitance value also.

Remote Device Examples

```
>UNITS NS
C= 454.688993 PF L= 0.01744 NS
>UNIT DF
C= 454.688993 PF L= 0.00000611 DS
>UNI KO
C= 454.688993 PF L= 0.002137 KO
>UN GO
C= 454.688993 PF L= 57.34 GO
>UN JP
C= 454.688993 PF L= 0.002776 JP
>SHO UN
UNITS JP
>
```

This example shows the same measurement displayed using all five unit types with automatic re-display.

Description

Execution of this command sets the User ReQuest (URq) bit in the GPIB status byte. This provides a means by which a user-specified event can be signaled to a remote controller.

Syntax

USER

Parameters None

Query Cmd? No

Comments

- This command cannot be entered from the front panel.
- The URq bit is cleared by the execution of a STB? or RST command.
- The USER command is primarily useful when the AH2700A is connected to a GPIB controller, but it may also be useful with the front panel or serial port. Although the USER command cannot be executed directly from the front panel, it *can* be included in a macro which *is* executable from the front panel.
- This command is probably most useful when included in an AH2700A macro.

Related Commands

MACRO CREATE, STB?, SRE

VOLTAGE

Description

Limits the amplitude of the test voltage applied by the bridge to the device under test.

Syntax

VOLTAGE *VHighest*
or
VOLTAGE UP|DOWN

Qualifiers

UP change the *VHighest* parameter to the next available voltage as determined by the scan setup parameters.

DOWN change the *VHighest* parameter to the next available voltage as determined by the scan setup parameters.

Parameters *VHighest* (Floating Point)

This is the maximum AC voltage in volts RMS that the bridge will apply to the DUT. Any voltage may be entered, but the bridge will limit the maximum measurement voltage to a value equal to or below the amount specified. Table A-4 below lists the voltages that the AH2700A prefers to use.

Table A-5 Capacitance and loss ranges for the preferred limiting voltages with $f \geq 1$ kHz. For $f < 1$ kHz, multiply Limit by f in kHz.

Limit (volts)	Capacitance range (pF)		Loss range (nS) <i>f</i> is in kHz	
	From	To	From	To
15.00	-11	+110	-0.8 <i>f</i>	+8 <i>f</i>
7.50	-22	+220	-1.6 <i>f</i>	+16 <i>f</i>
3.00	-55	+550	-4 <i>f</i>	+40 <i>f</i>
1.50	-110	+1100	-8 <i>f</i>	+80 <i>f</i>
0.750	-220	+2200	-16 <i>f</i>	+160 <i>f</i>
0.250	-660	+6600	-48 <i>f</i>	+480 <i>f</i>
0.100	-1650	+16,500	-120 <i>f</i>	+1200 <i>f</i>
0.030	-5500	+55,000	-400 <i>f</i>	+4000 <i>f</i>
0.010	-16,500	+165,000	-1200 <i>f</i>	+12,000 <i>f</i>
0.003	-55,000	+550,000	-4000 <i>f</i>	+40,000 <i>f</i>
0.001	-165,000	+1650,000	-12,000 <i>f</i>	+120,000 <i>f</i>

Default Value 15 volts

Parameter Set Gauge

Query Cmd? No

Comments

- The voltage limits listed in the table are the preferred voltage limits since they are made using higher IDAC and QDAC voltages. These preferred voltages result in better signal-to-noise ratios than any lower voltages that you might choose.
- Entered voltages below 0.3 mV will not be accepted.

Front Panel Examples

VOLTAGE **5** **ENTER** (Set highest voltage to 5 volts.)

SHOW **VOLTAGE** **ENTER**

VOLTAGE	HIGHEST
HIGHEST	5.00000 V

The maximum voltage was limited to 5.0 volts.

SINGLE (Take measurement in windows below.)

95 183 125	5.01
002774	150 V

The value of capacitance measured caused the actual voltage used to be 1.50 volts. The **←** and **→** keys are used to select which of the above windows is shown.

VOLTAGE (continued)

Remote Device Examples

```
>V 1      (Set the voltage to no more than one volt.)
```

```
>SI
```

```
F= 1000.0 HZ C= 193.8724 PF U=1.0 V
```

```
>SH V
```

```
VOLTAGE HIGHEST 1.00 V
```

```
>
```

The voltage was selected to be one volt. From the table, the highest voltage allowable for a capacitance of 193 pF at 1 kHz is 7.5 volts. Since 7.5 volts is greater than 1.0, the measurement that was taken actually used the full 1.0 volts.

```
>FR 50
```

```
>SI
```

```
F= 50.0 HZ C= 193.8698 PF U=0.375 V
```

```
>
```

The frequency was lowered, but the voltage selected was still one volt. From the table, the highest voltage allowable for a capacitance of 193 pF at 0.05 kHz is $7.5 \times 0.05 = 0.375$ volts. Since 0.375 volts is less than 1.0, the measurement that was taken used the reduced voltage of 0.375.

```
>FREQ 8000; FIELD , ,OFF,9
```

```
>SI
```

```
F= 8000.0 HZ L= 558.93 NS U=0.75 V
```

```
>
```

The frequency was raised and the loss field was enabled in place of the capacitance field. Dividing the measured loss by the frequency gives $558.9/8 = 69.8$. From the table, this is less than 120 which gives a voltage of 0.75 which was the voltage used to make the measurement.

References

See "VOLTAGE OF THE TEST SIGNAL" on page 4-12 and specifically "Limiting the Test Voltage" on page 4-13

Related Commands

SCAN

VOLTAGE SCAN COUPLE

Description

Enables or disables the automatic scanning of highest voltage parameter. Also positions the highest voltage parameter within the scanning hierarchy for multidimensional scanning.

Syntax

VOLTAGE SCAN COUPLE *VCoupling*

Parameters *VCoupling*

The permitted values along with their meanings are listed below:

0	disabled scanning for voltage.
1	enables scanning for the voltage. Positions the voltage parameter within the scanning hierarchy such that the voltage will be stepped immediately before each STEP or SCAN command causes a measurement to be taken.
2	enables scanning for voltage. Within a multidimensional scanning scheme, positions voltage within the scanning hierarchy such that the voltage parameter will be stepped only when the STEP or SCAN command causes wrapping of the coupled parameter whose coupling parameter is set to 1.
3	enables scanning for voltage. Within a multidimensional scanning scheme, positions voltage within the scanning hierarchy such that the voltage parameter will be stepped only when the STEP or SCAN command causes wrapping of the coupled parameter whose coupling parameter is set to 2.

0, 1, 2, and 3 can be substituted for these parameter values respectively.

Default Value 0

Parameter Set Scan

Query Cmd? No

Comments

- The three scannable parameters *Freq*, *SNumber* and *VHighest* use the three **coupling** parameters *FCoupling*, *SCoupling* and *VCoupling* respectively, to enable the **STEP** and **SCAN** measurement commands and to couple the stepping of these scannable parameters to the execution of the **STEP** and **SCAN** commands. The

STEP and **SCAN** commands will make measurements only if one or more of the three coupling parameters is non-zero.

- If *VCoupling* is the only non-zero coupling parameter, then the *VHighest* parameter will be stepped immediately before the **STEP** or **SCAN** command causes a measurement to be taken. *Freq* and *SNumber* parameters will not be affected by the **STEP** and **SCAN** commands.
- If more than one of the coupling parameters is non-zero, then the coupled parameter corresponding to the coupling parameter having the lowest value will be stepped immediately before the **STEP** or **SCAN** command causes a measurement to be taken. The coupling parameter having the second lowest value will have its corresponding coupled parameter stepped when wrapping occurs to the coupled parameter corresponding to the coupling parameter having the lowest value. The coupling parameter (if any) having the third lowest value will have its corresponding coupled parameter stepped when wrapping occurs to the coupled parameter corresponding to the coupling parameter having the second lowest value.
- The existence of two or more coupling parameters having the same non-zero value is not possible. Any attempt to set a coupling parameter to a non-zero value used by another coupling parameter will cause the values of the two coupling parameters to be swapped.

Front Panel Examples

```
FUNC SELECT FREQUENCY SCAN COUPLE 1 ENTER
FUNC SELECT SAMPLE SCAN COUPLE 2 ENTER
FUNC SELECT VOLTAGE SCAN COUPLE 3 ENTER
```

Frequency and voltage will be iterated most and least frequently respectively.

Remote Device Examples

```
>FREQUENCY SCAN COUPLE 1
>SAMPLE SCAN COUPLE 2
>VOLTAGE SCAN COUPLE 3
>
```

Frequency and voltage will be iterated most and least frequently respectively.

References

See Appendix D, “Sample Switch Port” and specifically “Selecting a Sample Switch Position” on page D-1.

Related Commands

VOLTAGE SCAN FLOOR/CEILING/DELTA, VOLTAGE SCAN METHOD, FREQUENCY SCAN COUPLE, SAMPLE SCAN COUPLE, STEP, SCAN, VOLTAGE

VOLTAGE SCAN FLOOR / CEILING / DELTA

Description

For voltage scanning, one can generally specify only a set of highest voltages to be used rather than a set of actual voltages to be used. The parameter corresponding to the highest voltage is *VHighest*.

This command determines not only the magnitude and direction by which the *VHighest* parameter is changed before each measurement is to be taken using the **STEP** or **SCAN** commands, but also the high and low boundaries of the range over which the *VHighest* parameter is scanned.

Note: The behavior of this command is highly dependent upon the value of *VMethod*. To conserve space, only the behavior commensurate with a *VMethod* setting of **DIS-CREATE** will be provided here. See the section on Voltage Scanning for a complete description.

Syntax

```
VOLTAGE SCAN FLOOR VFloor
      or
VOLTAGE SCAN CEILING VCeiling
      or
VOLTAGE SCAN DELTA VDelta
```

Parameters

- VFloor*** is a five digit decimal number that determines the lowest voltage in the *VHighest* parameter scanning series.
- VCeiling*** is a five digit decimal number that determines the highest voltage in the *VHighest* parameter scanning series.
- VDelta*** sets the direction in which the *VHighest* parameter is iterated. The permitted values +1 and -1 corresponding to incrementing and decrementing the attenuator tap number respectively.

Default Value *VFloor*: 0.030 V
 VCeiling: 15.000 V
 VDelta: +1

Parameter Set Scan

Query Cmd? No

Comments

- The voltages available for voltage scanned measurements are those provided by the eleven attenuator transformer tap positions.

Tap number	Tap voltage @ ≥ 1 kHz
1	15.0V
2	7.50V
3	3.00V
4	1.50V
5	0.750V
6	0.250V
7	0.100V
8	0.030V
9	0.010V
10	0.003V
11	0.001V

- The *VDelta* parameter specifies only the direction in which scanning will occur; the spacing is always from one attenuator tap to an adjacent tap.
- If *VFloor* is exactly equal to one of the 11 discrete voltages, then the lowest voltage is exactly *VFloor*. Otherwise the lowest voltage is the next discrete voltage value above *VFloor*. This lowest voltage is called the base voltage.
- If *VCeiling* is exactly equal to one of the 11 discrete voltages, then the highest voltage is exactly *VCeiling*. Otherwise the highest voltage is the next discrete voltage value below *VCeiling*.
- For capacitors below 100 pF measured at frequencies equal to or above 1 kHz the listed voltages will always be the ones that are actually used. For all other conditions, the voltage actually used may be lower than the specified value.

	C ≤ 100 pF	C > 100 pF
f ≥ 1 kHz	V = listed	V ∝ 1/C
f < 1 kHz	V ∝ f	V ∝ f / C

VOLTAGE SCAN FLOOR / CEILING / DELTA

Comments (continued)

- When the specified voltage is too high to use, the soft error message `VOLTAGE REDUCED` is reported to remote devices. On the front panel, the character “R” is placed in the right-most character position of the capacitance display. These messages will be reported **only** if *VCoupling* is non-zero and if the `STEP` or `SCAN` command has been executed. In the event of a conflict with the `H TO GND SHORT` message, the latter will be reported.
- The meaning of *VDelta* depends on the value of *VMethod*. The execution error “`DELTA CONFLICT`” will be reported if the value of *VDelta* is incompatible with *VMethod*. If a bad value (including zero) is entered for *VDelta*, the common command error message “`BAD PARAMETER`” will be reported.

Related Commands

VOLTAGE SCAN COUPLE, VOLTAGE SCAN METHOD, SCAN, STEP, VOLTAGE

VOLTAGE SCAN METHOD

Description

For voltage scanning, one can generally specify only a set of highest voltages to be used rather than a set of actual voltages to be used. The parameter corresponding to the highest voltage is *VHighest*.

This command determines the method used to establish the spacing between the voltage values in the scanning set for the *VHighest* parameter.

Syntax

VOLTAGE SCAN METHOD *VMethod*

Parameters *VMethod*

DISCRETE enables scanning through the voltages corresponding to the eleven ratio-transformer attenuator taps. For this method only, it is *taps* rather than specific voltages that are scanned.

LOG10 enables base 10 logarithmic voltage spacing. For this setting the *VDelta* parameter is a signed integer that specifies both the number of voltage scan points per decade and the direction of the scan.

LOG2 enables base 2 logarithmic voltage spacing. For this setting the *VDelta* parameter is a signed integer that specifies both the number of voltage scan points per octave and the direction of the scan.

LINEAR enables linear voltage spacing. For this setting the *VDelta* parameter is a signed decimal number that specifies both the direction and the magnitude by which the voltage is to be changed every time a measurement is made.

Default Value DISCRETE

Parameter Set Scan

Query Cmd? No

Comments

- Voltage scanning involves scanning the *VHighest* parameter. This parameter specifies the highest voltage that may be used for a measurement. When the measurement frequency is at or below 1 kHz, and the measured capacitance is at or below 100 pF, then the actual measurement voltage used will be equal to the value of the *VHighest* parameter.

Comments (continued)

- When the measurement frequency is above 1 kHz, or the measured capacitance above 100 pF, then the actual measurement voltage used will be reduced from that specified by the value of the *VHighest* parameter, as follows:

	$C \leq 100 \text{ pF}$	$C > 100 \text{ pF}$ (Limited by ability of opposing bridge arm to balance)
$f \geq 1 \text{ kHz}$	$V = \text{constant}$	$V \propto 1/C$
$f < 1 \text{ kHz}$ (Limited by transformer saturation)	$V \propto f$	$V \propto f/C$

- When the actual measurement voltage is reduced from that which is specified by the *VHighest* parameter, then the soft error message `VOLTAGE REDUCED` is reported to remote devices. On the front panel, the character "R" is placed in the right-most character position of the capacitance display. These messages will be reported **only** if *VCoupling* is non-zero and if the `STEP` or `SCAN` command has been executed. In the event of a conflict with the `H TO GND SHORT` message, the latter will be reported.
- When *VMethod* is set to DISCRETE, the voltages available for voltage scanned measurements are those provided by the eleven attenuator transformer tap positions.

Tap number	Tap voltage @ $\geq 1 \text{ kHz}$
1	15.0V
2	7.50V
3	3.00V
4	1.50V
5	0.750V
6	0.250V
7	0.100V
8	0.030V
9	0.010V
10	0.003V
11	0.001V

In this case the *VDelta* parameter specifies only the direction in which scanning will occur; the spacing is always from one attenuator tap to an adjacent tap.

VOLTAGE SCAN METHOD (continued)

<i>VMethod</i> Value	<i>VDelta</i> Meaning	Available Voltages	Given any V, find the next higher voltage	Given any V, find the next lower voltage
DISCRETE	Sign of the step direction	11 discrete tap voltages shown in the proceeding table.	Look up the next higher voltage from the 11 discrete tap voltages shown in the proceeding table.	Look up the next lower voltage from the 11 discrete tap voltages shown in the proceeding table.
LOG10	Number of voltages per decade	$V_{10}(n) = 10^{n/\Delta}$	Next higher $V_{10} = 10^{\frac{\lfloor \Delta \log_{10} V \rfloor + 1}{\Delta}}$	Next lower $V_{10} = 10^{\frac{\lceil \Delta \log_{10} V \rceil - 1}{\Delta}}$
LOG2	Number of voltages per octave	$V_2(n) = 2^{n/\Delta}$	Next higher $V_2 = 2^{\frac{\lfloor \Delta \log_2 V \rfloor + 1}{\Delta}}$	Next lower $V_2 = 2^{\frac{\lceil \Delta \log_2 V \rceil - 1}{\Delta}}$
LINEAR	Increment to be added in volts	$V_L(n) = V_{\text{floor}} + n\Delta$	Use the next value in $V_L(n)$ that is above V.	Use the next value in $V_L(n)$ that is below V.

Notes: $\Delta = |VDelta|$. *VDelta* is an integer except when *VMethod* = LINEAR in which case *VDelta* is a floating-point number. The sign of *VDelta* controls the direction in which scanning occurs. $V_{\text{floor}} = VFloor$ in V. n is an integer. $V_D(n)$, $V_{10}(n)$, $V_2(n)$ and $V_L(n)$ are functions used to generate the discrete, \log_{10} , \log_2 and linear voltages. The delimiters $\lfloor x \rfloor$ and $\lceil x \rceil$ are the floor and ceiling functions, respectively, found in many programming languages.

Comments (continued)

- The table above lists the allowed values of the *VMethod* parameter along with their meanings. The table also describes the dependency of *VDelta* upon *VMethod*.
- When *VMethod* is set to LOG10 and LOG2, the voltages used for voltage scanned measurements may be calculated using the appropriate equations from the table on the following page. In both cases the *VDelta* parameter sets the density of scan points (in points per decade or octave) as well as the direction of the scan.
- When *VMethod* is set to LINEAR, the voltages used for voltage scanned measurements are equally spaced as specified by the magnitude of the *VDelta* parameter. This method is best when for generating a closely spaced series of voltages over a relatively narrow range. As is usually the case, the sign of the *VDelta* parameter establishes the direction of the scan.
- The meaning of *VDelta* depends on the value of *VMethod*. The execution error "DELTA CONFLICT" will be reported if the value of *VDelta* is incompatible with *VMethod*. If a bad value (including zero) is entered for *VDelta*, the common command error message "BAD PARAMETER" will be reported.

Related Commands

VOLTAGE SCAN COUPLE, VOLTAGE SCAN FLOOR/CEILING/DELTA, SCAN, STEP, VOLTAGE

Description

Execution of this command causes the bridge to do nothing further until an external trigger pulse is received.

Syntax

WAITFOR

Parameters None

Default Value None

Parameter Set None

Query Cmd? No

Comments

- Once this command is executed, it can only complete normally or be aborted with a **DEVICE CLEAR** command.
- This command and particularly its delay feature are mainly useful with the **MACRO** commands.
- Additional commands may be entered following the **WAITFOR** command, but they will not be executed until the **WAITFOR** command finishes.
- The **WAITFOR** is the *only* commands that configure the instrument to respond to external trigger pulses.
- When the **WAITFOR** command is active, the word "**WAITFOR**" will usually be displayed on the front panel. The exception occurs when the **WAITFOR** command *immediately* follows a query command within a macro. In this case, the front panel display continues to show the result produced by the query command instead.

References

See "TIMING IN MACROS" on page 3-13 and "Initiating with an External Trigger Signal" on page 4-4.

Related Commands

MACRO, WAITFOR TRGMODE

Front Panel Examples

[FUNC] [SELECT] [WAITFOR] [ENTER]



The **WAITFOR** command begins executing immediately after being entered. While executing, the instrument is waiting for an external trigger pulse.

Remote Examples

```
>WAIT
>SI;SI
  C=28843.316E+00 PF L=537.43E-03 NS
  C=28843.317E+00 PF L=537.44E-03 NS
>
```

In the above example, the **WAITFOR** command specified that the instrument would for an external trigger pulse before executing the next command line. During the wait, no prompt appears and no commands other than a **DEVICE CLEAR** will produce an immediate response. The two **SINGLE** commands were entered before the delay time expired and thus were not echoed to the serial port as they were entered. They were echoed and began executing the moment the external trigger pulse occurred.

```
>WAIT
>SI
>SI
  C=28843.315E+00 PF L=537.43E-03 NS
>
```

This second example is almost identical to the first, but only one measurement result is produced instead of two even though two **SINGLE** commands were entered. Since **SINGLE** is a query command, the second command interrupted and aborted the first.

```
>WAIT;SI
>C=28843.317E+00 PF L=537.44E-03 NS
>
```

In this third example, the **WAITFOR** command specified that an external trigger must occur before continuing. A single measurement was taken as soon as a trigger pulse occurred. Until the occurrence of a trigger pulse, no prompt would appear, but any subsequent command entry would abort the **WAITFOR** command. This would occur since the presence of the **SINGLE** command makes the line a query command line.

WAITFOR DELAY

Description

Execution of this command causes the bridge to do nothing further for either a specified period of time.

Syntax

WAITFOR **DELAY** *Delay*

Parameters

Delay This floating point parameter is the delay time until the bridge is to execute the next command. The maximum delay time is 99,999,999 seconds. The delay may be entered to the nearest tenth of a second.

Default Value None

Parameter Set None

Query Cmd? No

Comments

- Once this command is executed, it can only complete normally or be aborted with a **DEVICE CLEAR** command.
- This command and particularly its delay feature are mainly useful with the **MACRO** commands.
- Additional commands may be entered following the **WAITFOR DELAY** command, but they will not be executed until the **WAITFOR DELAY** command finishes.
- When the **WAITFOR DELAY** command is active, the word “*WAITFOR*” will usually be displayed on the front panel followed by the remaining delay time, if any was entered. The exception occurs when the **WAITFOR DELAY** command *immediately* follows a query command within a macro. In this case, the front panel display continues to show the result produced by the query command instead. This allows the **WAITFOR DELAY** command to control the length of time that results generated by macros are displayed.

Front Panel Examples

FUNC **SELECT** **WAITFOR** **DELAY** **3** **0** **ENTER**

WAITFOR
29.2

The **WAITFOR DELAY** command begins executing immediately after being entered. The time remaining is shown on the display as 29.2 seconds.

Remote Examples

```
>WAIT DELAY 50
>SI;SI
  C=28843.316E+00 PF L=537.43E-03 NS
  C=28843.317E+00 PF L=537.44E-03 NS
>
```

In the above example, the **WAITFOR DELAY** command specified a delay time of 50 seconds before executing the next command line. During the delay, no prompt appears and no commands other than a **DEVICE CLEAR** will produce an immediate response. The two **SINGLE** commands were entered before the delay time expired and thus were not echoed to the serial port as they were entered. They were echoed and began executing the moment the delay time expired.

```
>WAIT DELAY 50
>SI
>SI
  C=28843.315E+00 PF L=537.43E-03 NS
>
```

This second example is almost identical to the first, but only one measurement result is produced instead of two even though two **SINGLE** commands were entered. Since **SINGLE** is a query command, the second command interrupted and aborted the first.

References

See “**TIMING IN MACROS**” on page 3-13 and “**Initiating with an External Trigger Signal**” on page 4-4.

Related Commands

MACRO

WAITFOR SAMPLE

Description

Specifies a time delay that automatically occurs after each execution of the **SAMPLE** command. This provides a settling time for sample switch relays to stabilize after being switched.

Syntax

WAITFOR **SAMPLE** *DelaySmp*

Parameters *DelaySmp* (Floating Point)

This *DelaySmp* parameter is entered in seconds to the nearest hundredth.

Default Value 0.0 sec

Parameter Set Basic

Query Cmd? No

Comments

- The *DelaySmp* time specified by this command occurs as a part of the **SAMPLE** command. That **SAMPLE** command will not finish until the delay time has expired. This holds off any further operations.
- The *DelaySmp* time occurs every time the **SAMPLE** command is executed and is therefore the same no matter what sample number has been selected. If some samples require a longer settling time than others, additional settling time can be provided by executing the **WAITFOR DELAY** command after executing the **SAMPLE** command for the slower samples.
- If the **SAMPLE** command is executed with a long delay time, you must wait for this time to elapse or abort the **SAMPLE** command with a **DEVICE CLEAR** command.

Front Panel Examples

FUNC **SELECT** **WAITFOR** **SAMPLE** **•** **0** **3** **ENTER**

FUNC **SELECT** **SHOW** **WAITFOR** **SAMPLE** **ENTER**

WAITFOR
SAMPLE

0.03
SEC

Remote Examples

```
>WAIT SA 0.1  
>SH WAIT SA  
  WAITFOR SAMPLE 0.10 SEC  
>
```

References

See “Signal Timing” on page D-1 and specifically “Changing the Settling Time” on page D-2.

Related Commands

WAITFOR DELAY, **SAMPLE**

WAITFOR TRGMODE

Description

This command determines what happens to external trigger pulses that arrive when no **WAITFOR** command has been executed to receive them. This command allows such pulses to be buffered or to report an error. Execution of this command clears the trigger buffer.

Syntax

WAITFOR TRGMODE *TrgMode*

Parameters

TrgMode Permitted values are **BUFFER** and **ERROR**. Setting *TrgMode* to **BUFFER** causes external trigger pulses to be buffered as they come. When set to **ERROR**, external trigger pulses will be to be reported as an error.

Default Value BUFFER

Parameter Set Basic

Query Cmd? No

Comments

- With *TrgMode* set to **BUFFER**, the trigger buffer can hold up to 255 unprocessed trigger events. Any trigger pulses that occur which would cause this number to overflow are ignored.
- With *TrgMode* set to **ERROR**, any unexpected trigger pulses that are received will be reported as an “E” error as part of the next measurement result. This will appear in the upper right corner of the front panel display. This error is not possible with *TrgMode* set to **BUFFER**. This error event can be detected only by taking a measurement.
- The **SHOW WAITFOR** command only reports the parameter associated with the **WAITFOR TRGMODE** command, not the parameter associated with the **WAITFOR DELAY** command.

Front Panel Examples

FUNC **SELECT** **WAITFOR** **TRGMODE** **ERROR** **ENTER**

Set the *TrgMode* parameter to **ERROR** to disable trigger buffering.

SHOW **WAITFOR** **TRGMODE** **ENTER**

WAITFOR	TRGMODE
TRGMODE	ERROR

Use the **SHOW** command to see that the *TrgMode* parameter is **BUFFER**.

SINGLE (Take a measurement and show in window below.)

95 183 12E
002774

Note that an “E” is shown in the upper right corner of the display indicating that an unexpected external trigger pulse was received.

Remote Examples

```
>WAIT TRGMODE ERROR
>SH WAIT
  WAITFOR TRGMODE ERROR
>
```

References

See “Handling Unexpected Trigger Pulses” on page 3-14.

Related Commands Other **WAITFOR** versions.

Description

Steps through operations when using the **MACRO** or **TEST** commands; iterates coupled parameter values and executes a single measurement when parameter scanning is enabled. This occurs by pressing *only* the X key on the keyboard of a remote serial device.

Syntax X (no RETURN key is used)

Parameters None

Query Cmd?

Execution of the X command usually produces a query result, but this is dependent on what root command is being executed. The **TEST** command, for example, can be set to halt on every test without sending a result.

Comments

- The X command produces exactly the same result as the **STEP** command but is more convenient to use from the serial port than the **STEP** command.
- This command tells the bridge to continue after waiting for you to perform an external action. The latter occurs with the **TEST** commands.
- The X command is shortened from “eXecute”.
- The X command will do nothing if there is no active root command waiting for input. This allows the X command to be used in macros where the need for it may be uncertain. It should cause no harm if it is not needed.
- This command will only work in an AH2700A macro if it is not the first character. A space can precede it if you desire to enter it by itself on a macro line.
- An X command following an AH2700A macro will not be processed even if the macro contains a command that is looking for X as a reply. In other words, in the command line “**MACRO;X**”, the X will never have any effect no matter what the contents of the macro.
- The X command functions as a single measurement execution command when frequency, sample number, and/or highest voltage parameter scanning are enabled. Execution of this command causes iteration of the coupled parameters in accordance with the scanning setup parameters followed by a single measurement. Each execution of parameter scanning measurement increments the *CCount* variables.
- Execution of the X command during continuous parameter scanning measurements terminates those measurement without resetting the associated parameters.

Comments (continued)

- If no coupled parameters exist when X is entered, then no action is taken and the error message *NO COUPL PARAMETER* is reported.
- If the *Counts* variables effectively reach the value of *STotal*, the only consequence of executing **STEP** will be to report a *COUNTMAX REACHED* error. This will continue to occur until the *Counts* variables are reset. If this behavior is not desirable, then *STotal* should be set to zero.

Front Panel Examples

The STEP key is used instead on the front panel.

Serial Remote Examples

For some examples see “DC BIAS High Voltage Tests” on page 11-19.

References

See “Single-Step Mode” on page 3-12, “Selection of Options: the **TEST** command” on page 11-7, and Chapter 9, “Verification/Calibration.”

Related Commands

MACRO, **STEP**, **TEST**, **FREQUENCY SCAN**, **SAMPLE SCAN**, **FREQUENCY SCAN**

ZERO

Description

Enables or disables the Zero compensation result mode. When enabled, the Zero compensation result mode compensates for residual capacitance and *parallel* loss effects that are usually inherent in test fixtures.

Syntax

`ZERO Zer_Mode`

Parameters `Zer_Mode` ON and OFF enable and disable the Zero compensation result mode respectively. 1 and 0 may be substituted for ON and OFF respectively.

Default Value OFF (disabled)

Parameter Set Gauge

Query Cmd? Yes

Comments

- Enabling Zero compensation result mode is a separate operation from entering the Zero values.
- Zero compensation capacitance and loss values can be entered (and stored) without being enabled. Subsequent enabling of Zero compensation result mode will then use the Zero compensation values to correct the measured values.
- When any form of the ZERO command is issued it will re-display the last measurement taken with the new Zero compensation settings in effect.
- This command is similar to REFERENCE command.
- Zero compensation result mode is identical to Reference result mode in many ways, but the mathematical compensation performed in Zero compensation result mode is much more than just a simple subtraction. The compensation calculation performed is dependent upon the units currently in use and can be complicated. The calculations require *both* capacitance and loss Zero values. Thus, the Zero compensation result mode differs from the Reference result mode by not allowing you to enter a capacitance value without a corresponding loss value or vice-versa.
- Zero compensation result mode may be used in combination with Reference result mode. They will each function independently of the other.

References

See “Zero Compensation Result Mode” on page 5-4 and specifically “Enabling Zero Result Mode” and “Disabling Zero Result Mode”

Front Panel Examples

SINGLE

(Take measurement in window below.)

71450208
002925

FUNC **SELECT** **ZERO** **FETCH** **ENTER**

(Get zero compensation values from the measurement.)

ZERO **ON** **ENTER**

(Enable Zero compensation result mode and show compensated result.)

00000000
000000

SINGLE

(Show new measurement results below.)

--0000048
000014

This shows the changes between **SINGLE** measurements.

Remote Device Examples

```
>ZERO POINT 700,0.0000046
>SI
  C= 744.17194  PF L= 0.0000051  DS
>Z ON
  C= 44.171937 ZPF L= 0.0000138 ZDS
>Z OFF
  C= 744.17194  PF L= 0.0000051  DS
>SI
  C= 744.17205  PF L= 0.0000055  DS
>
```

Zero compensation values were manually entered and a measurement taken. Zero compensation result mode was enabled causing the compensated version of the previous result to be reported. Zero compensation result mode was then disabled causing the *exactly* the same value to be reported as for the original measurement. The actual measurement which follows shows small changes that are likely due to noise.

Notice that the Zero compensated result was L= 0.0000138 ZDS whereas Reference result mode would have reported L= 0.0000005 R0DS. This is an example of how different these two result modes can be.

Related Commands

REFERENCE and ZERO POINT.

Description

Provides manual and automatic ways to enter capacitance and loss Zero compensation values.

Syntax

ZERO POINT [*Zer_Pt_C*], [*Zer_Pt_L*]

is used to enter Zero compensation values manually, or

ZERO FETCH

uses the last-measured capacitance and loss values before any Reference corrections have been applied.

Parameters

Zer_Pt_C (Floating Point)

This is the value of the capacitance to be used as a Zero compensation value. The value is assumed to be entered in the current units. The maximum value that can be entered is 99,999,999.

Zer_Pt_L (Floating Point)

This is the value of the loss to be used as a Zero compensation value. The maximum value that can be entered in any units is 99,999,999.

Note: When using the first form of the command, also referred to as the vector form of the command, skipping the entry of either parameter value will preserve the current value for that parameter.

Default Value 0, 0

(The default Zero compensation values for both capacitance and loss are both zero and Zero compensation result mode is disabled.)

Parameter Set Gauge

Query Cmd? No

Comments

- This command is similar to the REFERENCE POINT command.
- The bridge performs all Zero calculations *before* performing any Reference calculations that might be enabled.

Front Panel Examples

SINGLE (Takes measurement in window below.)

1450208
002925

ZERO FUNC FETCH ENTER
(Get zero compensation values from the measurement.)

ZERO ON ENTER
(Enable Zero compensation result mode and show compensated result.)

00000000
000000

SHOW ZERO ENTER
(Show the effects.)

ZERO	1450208
POINT	002925

↓ gives:

ZERO	MODE
MODE	ON

The ← and → keys are used to select which of the left or right windows is displayed.

ENTER

READY

SINGLE
(Takes measurement in window below.)

-000007
000002

This result was compensated using the entered Zero values.

ZERO POINT (continued)

Remote Examples

```
>ZERO POINT 4.5,0.0025
>ZERO OFF
>SH Z
  ZERO POINT  C=4.5000000 PF L=0.002500 NS
  ZERO MODE   OFF
>
```

The capacitance and loss Zero compensation values were manually entered. The **SHOW** command then confirmed their values, showing maximum precision results since there is no uncertainty in an entered result. Zero compensation result mode is currently disabled as indicated by “OFF”.

References

See “Zero Compensation Result Mode” on page 5-4 and specifically “Entering Zero Values Manually” and “Entering Zero Values Automatically.”

Related Commands

REFERENCE, REFERENCE POINT, and ZERO.

This appendix explains the various error messages and codes that can occur in the process of normal operation of the AH2700A. Error messages that occur as a result of executing the self-test routines after power-on or by issuing the TEST command are explained in Chapter 11 titled “Diagnosis and Repair”. The section “Processor and Front Panel Tests” on page 11-14 contains Table 11-7 on page 11-14 which lists the possible power-on self-test messages.

Error Messages vs. Error Codes

Error messages are always reported as English text on the front panel. Results sent to remote devices can also report error messages as text or as a decimal error code. The way to choose which form is to be sent is explained in “Error Messages vs. Error Codes” on page 5-6.

This appendix contains three tables of error messages. The content of the first table (Table B-1) is identical with the combined contents of the second two tables (Table B-2 and Table B-3). The difference is that the first table is arranged alphabetically and the remaining two are arranged by error code.

Measurement vs. Command/Data Errors

The error messages may be divided into two types. One error type results from an inability of the bridge to make a valid measurement. These are usually the result of connecting an unknown impedance that the bridge is unable to measure. However, these can also indicate a problem with the bridge if the unknown impedance is good.

The second kind of error is a result either of entering an improper command or as a result of problems associated with reading, moving or storing data within the bridge.

Measurement errors are listed separately in Table B-2 on page B-7 arranged by error code. Command/data errors are listed separately in Table B-3 on page B-9 and are also arranged by error code.

Error vs. Informative/Prompt Messages

The first three tables in this appendix list error messages. Table B-4 on page B-12 lists some informative messages and prompts. Informative messages are only sent to the front panel display. These are often used to explain what the bridge is currently doing, especially for time consuming operations that give no other indication. Prompts tell you what to do next. Prompts for the TEST commands are not included in this table.

GPIB Status Bits

Errors cause one (and only one) of three bits in the GPIB status byte to be set. These are the CME (CoMmand Error), EXE (EXecution Error) and NVL (Cal Invalid) error bits. Which of these bits is set by a given error is indicated in the first column of all tables in this appendix. See “STATUS REPORTING” on page 6-5 for more information about status bits.

The Meaning of Measurement Errors

When the AH2700A senses that it cannot provide meaningful measurement values, it attempts to identify and report the nature of the problem in the form of one of about a dozen error messages. This is a difficult and imperfect process due to the poorly defined nature of some of the error conditions that can occur at the measurement terminals of the bridge. Thus the error messages will correctly describe the error condition most of the time, particularly if a well defined sample is present. The remainder of the time these messages may not always be helpful. The error messages are not intended to identify the nature of strange or unusual samples.

Some measurement errors or conditions are reported to the front panel as a single letter which appears in the upper right corner of the display. These are shown in the tables here as a display filled with eights except for the upper or lower right corner.

Numeric Errors

Another kind of error can occur when a number is generated that is too big to work with or to report. This can occur even when a valid measurement has been made. The cause is usually the result of a division. This kind of error can easily occur when units of $\tan \delta$, R_p , C_s , and R_s have been selected. Changing the units should convert the result to a reportable value.

When an error of this type occurs, all nines are displayed in the upper and/or lower displays of the front panel. On a remote device, all nines will be reported in the mantissa of the number.

Note that this error differs from that where a greater than symbol precedes the number. The greater than symbol indicates a *range* of values having a reported minimum absolute value and a maximum absolute value that is infinite. All nines indicates a *single* value that is too large to report.

Table B-1 Error messages arranged alphabetically

Error code	Status bit	Front panel error message	Explanation
193	EXE	ABOUNDS REVERSAL	DEV mode <i>AoutBoundUpper</i> is less than <i>AoutBoundLower</i> for either cap or loss. This is checked during DEV initial setup.
		ABOUNDS REVERSAL	
01	EXE	AC ON L INPUT	Too much externally generated noise with a frequency below 100 Hz is being sensed at the measurement terminals. This kind of noise is almost always caused by excess coupling to the AC power lines. See “Low Frequency Noise” on page 2-8.
		AC ON L INPUT	
18	EXE	AMBIGUOUS WORD: AAA	Not enough letters were entered for this command to be distinguishable from another, similar command. The questionable letters follow the error message as “AAA”. This error cannot occur on the front panel. See “Command Word Entry” on page 6-3 or “Command Word Entry” on page 7-9.
19	CME	BAD PARAMETER: BB	A valid command was entered, but the parameter that followed was either of the wrong type (alpha vs. numeric) or it was out of range.
		BAD PAR	
20	CME	BAD PASSCODE	The passcode that was entered in response to the passcode prompt was not correct. If three incorrect passcodes are entered in a row, then all subsequent passcode entries will report this error until the bridge's power is cycled.
		BAD PASSCODE	
		BUTTON BUF FULL	This message will be briefly displayed when the front panel keypad buffer is full. This can occur when a number of commands are entered but are not able to be executed. This happens when these commands follow a non-query command such as WAITFOR.
21	CME	CAL DATA ABSENT	The command that was entered requires that new calibration data be present in RAM. The corresponding CALIBRATE command must be executed first.
		CAL DATA ABSENT	
22	EXE	CAL DATA ERROR C	An error has occurred while reading the calibration data from the EEPROM. C can be 0, 1, or 2 for errors in the Original, Internal, or Capacitance Update data, respectively.
		CAL DATA ERROR C	
	EXE	CAP DEV TOO HIGH	In DEV mode the cap is greater than the <i>DevBoundUpper-Cap</i> parameter. The rightmost Cap position has an up arrow symbol
		88888888 88888888	
	EXE	CAP DEV TOO LOW	In DEV mode the cap is less than the <i>DevBoundLowerCap</i> parameter. The rightmost Cap position has a down arrow symbol.
		88888888 88888888	

Table B-1 Error messages arranged alphabetically

Error code	Status bit	Front panel error message	Explanation
03 CAP TOO HIGH	EXE	CAP TOO HIGH	The capacitance of the unknown impedance exceeds the maximum that the AH2700A can measure. The most positive measurable capacitance is 1.2 μ F.
04 CAP TOO NEG	EXE	CAP TOO NEG	The capacitance of the unknown impedance is more negative than what the AH2700A can measure. The most negative measurable capacitance is -0.12 μ F
26 CMD NOT OPERABLE	CME	CMD NOT OPERABLE	The command that was entered is not compatible with the options present on this bridge or with the ROM version that is installed. This error also occurs if attempts to STORE macro commands which contain various commands such as DELETE, MACRO CREATE etc..
180 COUNT MAX REACHED	EXE	COUNTMAX REACHED	The SCAN mode Count has reached the <i>stotal</i> value.
05 DC ON L INPUT	EXE	DC ON L INPUT	There is an unallowable DC component to the voltage on the LOW terminal. If this voltage is supposed to be present, then the BIAS command can be used to block the DC component.
177 DELTA CONFLICT	EXE	DELTA CONFLICT	The SCAN mode value of <i>fdelta</i> , <i>sdelta</i> , or <i>vdelta</i> is invalid.
157 DEV CONFLICT	EXE	DEV CONFLICT	A command was issued which conflicted with DEV mode.
160 DEV INIT FAILURE	EXE	DEV INIT FAILURE	The initialization of the DEV mode failed. It may be that the value of the DUT is out of range of the setup parameters.
188 DEV SPAN TOO BIG	EXE	DEV SPAN TOO BIG	An attempt was made to set the span of the DEV mode greater than values where reasonable results can be obtained. This is checked during DEV initial setup.
27 E	EXE	EEEEEEEE EEEEEEEE	An external-trigger overrun has occurred. The bridge received at least one external trigger pulse but no WAIT-FOR command was waiting for it. This can only occur when the <i>TrgMode</i> parameter associated with the WAIT-FOR command is set to ERROR. The “E” message is only reported following a measurement result. See “Handling Unexpected Trigger Pulses” on page 3-14.

Table B-1 Error messages arranged alphabetically

Error code	Status bit	Front panel error message	Explanation
28	EXE	EEPROM ERROR	An error has occurred while reading the EEPROM during power-on.
06	EXE	ERRATIC INPUT	The software is unable to properly balance the bridge due to excess noise or a rapidly changing unknown sample.
07	EXE	ECESS NOISE	Too much externally generated noise with a frequency near the measurement frequency is being picked up at the measurement terminals. See “High Frequency Noise” on page 2-8.
29	CME	FILE NOT FOUND	A file name was entered that did not match any file name in memory having the requested file type. Use the DIR command to see what files are in memory. See “WORKING WITH FILES” on page 3-8
178	EXE	FLR CEIL INVALID	The SCAN mode <i>floor</i> is greater than <i>ceiling</i> . This is checked during the SCAN initial setup.
09	EXE	8888888H 88888888	The impedance between the HIGH terminal and ground is too low. Check that these terminals are not shorted together. Measurement results are still reported when this error occurs. The error is indicated on the front panel by showing an “H” in the upper right corner of the display. See “High to Ground Short” on page 2-9.
10	EXE	H TO L SHORT	The impedance between the HIGH and LOW terminals is very low. Check that these terminals are not shorted together. See “High to Low Shorts” on page 2-9.
31	CME	ILLEGAL WORD: XXX	The command word that was entered is not one that is recognized by the AH2700A. This error cannot occur on the front panel. See “Command Word Entry” on page 6-3 or “Command Word Entry” on page 7-9.
11	EXE	INDETERM OFFSCALE	The unknown impedance appears to be off-scale but is either so far off or so unusual that the nature of the off-scale condition is indeterminate.
32	EXE	INT CAL FAILURE	A hardware fault has caused the internal calibration procedure to fail.

Table B-1 Error messages arranged alphabetically

Error code	Status bit	Front panel error message	Explanation
12	EXE	L TO GND SHORT	The impedance between the LOW terminal and ground is too small. Check that these terminals are not shorted together. This error message will not appear unless the measurement begins with a cold start. See “Low to Ground Short” on page 2-9.
		L TO GND SHORT	
194	EXE	LIMITS REVERSAL	In DEV mode the <i>AoutLimitUpper</i> is less than the <i>AoutLimitLower</i> for either Cap or Loss channel. This is checked during DEV initial setup.
		LIMITS REVERSAL	
38	CME	LINE TOO LONG	The command message entered was too long. Command lines may not exceed 78 characters in length.
		LINE TOO LONG	
	EXE	LOSS DEV TOO HIGH	In DEV mode the loss is greater than the <i>DevBoundUpperLoss</i> parameter. The rightmost Loss position has an up arrow symbol
		LOSS DEV TOO HIGH	
	EXE	LOSS DEV TOO LOW	In DEV mode the loss is less than the <i>DevBoundUpperLoss</i> parameter. The rightmost Loss position has a down arrow symbol
		LOSS DEV TOO LOW	
13	EXE	LOSS TOO HIGH	The loss of the unknown impedance exceeds the maximum that the AH2700A can measure. The most positive measurable conductance is 60,000 nS.
		LOSS TOO HIGH	
14	EXE	LOSS TOO NEG	The loss of the unknown impedance is more negative than what the AH2700A can measure. The most negative measurable conductance is -6000 nS.
		LOSS TOO NEG	
34	CME	MAC NEST ERROR	A macro tried to call a sub-macro that was already nested to the maximum depth of eight. Don’t nest your macros so deeply. Did a macro call itself? See “Nesting Considerations” on page 3-11.
		MAC NEST ERROR	
161	CME	MODE TOO BIG	The number of SCAN <i>modes</i> is greater than the number of <i>coupling</i> parameters.
		MODE TOO BIG	
179	EXE	NO COUPLED PARAMETER	No <i>coupled</i> parameters were entered before the SCAN command was issued. This is checked during SCAN initial setup..
		NO COUPLED PARAMETER	

Table B-1 Error messages arranged alphabetically

Error code	Status bit	Front panel error message	Explanation
33	EXE	OUT OF SPACE	The store command you attempted requires more memory than is available. To make more room, delete some parameter sets or some macros. Also can be caused by entering a macro that is too long.
15	NVL	OVEN	The oven containing the internal capacitance standard is not at its operating temperature. This error is shown on the front panel with the CAL INVALID indicator. Either the bridge has not warmed up yet or it is in an environment that is too hot or too cold. You can take measurements with this error, but they will be less accurate.
	EXE	PREAMP OVERLOAD	The bridge unbalance in the DEV mode has exceeded the setup parameters..
35	CME	SYNTAX ERROR: \$\$\$	The command that was entered may have used valid command words, but either an expected word was not found or an unexpected word was found. The word “\$\$\$” is where the problem occurred. If you are having trouble using the front panel, make sure it displays READY before you start entering a command.
158	CME	UNITS CONFLICT	DEV mode must run with UNITS = jp (5)..
37	EXE	UPDATE STD ERROR	The value entered for the external calibration capacitor is in disagreement with the original value by more than 0.01%. Either the incorrect value was entered, the calibration capacitor is seriously in error or the bridge needs repair.
159	CME	ZERO CONFLICT	DEV mode must not be entered when the ZERO command is active.

Table B-2 Measurement error messages arranged by error code

Error code	Status bit	Front panel error message	Explanation
00			No Error
01	EXE	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">AC ON L</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">INPUT</div>	Too much externally generated noise with a frequency below 100 Hz is being sensed at the measurement terminals. This kind of noise is almost always caused by excess coupling to the AC power lines. See “Low Frequency Noise” on page 2-8.
03	EXE	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">CAP TOO</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">HIGH</div>	The capacitance of the unknown impedance exceeds the maximum that the AH2700A can measure. The most positive measurable capacitance is 1.2 μ F.
04	EXE	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">CAP TOO</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">NEG</div>	The capacitance of the unknown impedance is more negative than what the AH2700A can measure. The most negative measurable capacitance is -0.12 μ F
05	EXE	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">DC ON L</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">INPUT</div>	There is an unallowable DC component to the voltage on the LOW terminal. If this voltage is supposed to be present, then the BIAS command can be used to block the DC component.
06	EXE	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">ERRATIC</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">INPUT</div>	The software is unable to properly balance the bridge due to excess noise or a rapidly changing unknown sample.
07	EXE	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">EXCESS</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">NOISE</div>	Too much externally generated noise with a frequency near the measurement frequency is being picked up at the measurement terminals. See “High Frequency Noise” on page 2-8.
09	EXE	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">8888888H</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">88888888</div>	The impedance between the HIGH terminal and ground is too low. Check that these terminals are not shorted together. Measurement results are still reported when this error occurs. The error is indicated on the front panel by showing an “H” in the upper right corner of the display. See “High to Ground Short” on page 2-9.
10	EXE	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">H TO L</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">SHORT</div>	The impedance between the HIGH and LOW terminals is very low. Check that these terminals are not shorted together. See “High to Low Shorts” on page 2-9.
11	EXE	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">INDETERM</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">OFFSCALE</div>	The unknown impedance appears to be off-scale but is either so far off or so unusual that the nature of the off-scale condition is indeterminate.

Table B-2 Measurement error messages arranged by error code

Error code	Status bit	Front panel error message	Explanation
12 L TO GND SHORT	EXE	L TO GND SHORT	The impedance between the LOW terminal and ground is too small. Check that these terminals are not shorted together. This error message will not appear unless the measurement begins with a cold start. See “Low to Ground Short” on page 2-9.
13 LOSS TOO HIGH	EXE	LOSS TOO HIGH	The loss of the unknown impedance exceeds the maximum that the AH2700A can measure. The most positive measurable conductance is 60,000 nS.
14 LOSS TOO NEG	EXE	LOSS TOO NEG	The loss of the unknown impedance is more negative than what the AH2700A can measure. The most negative measurable conductance is -6000 nS.
15 OVEN	NVL		The oven containing the internal capacitance standard is not at its operating temperature. This error is shown on the front panel with the CAL INVALID indicator. Either the bridge has not warmed up yet or it is in an environment that is too hot or too cold. You can take measurements with this error, but they will be less accurate.

Table B-3 Command and data error messages arranged by error code

Error code	Status bit	Front panel error message	Explanation
18	CME	<div style="border: 1px solid black; padding: 2px; margin-bottom: 2px;"> </div> <div style="border: 1px solid black; padding: 2px;"> </div>	Not enough letters were entered for this command to be distinguishable from another, similar command. The questionable letters follow the error message as “AAA”. This error cannot occur on the front panel. See “Command Word Entry” on page 6-3 or “Command Word Entry” on page 7-9.
		Remote error message: AMBIGUOUS WORD: AAA	
19	CME	<div style="border: 1px solid black; padding: 2px; margin-bottom: 2px;">BAD PAR</div> <div style="border: 1px solid black; padding: 2px;"> </div>	A valid command was entered, but the parameter that followed was either of the wrong type (alpha vs. numeric) or it was out of range.
		Remote error message: BAD PARAMETER: BB	
20	CME	<div style="border: 1px solid black; padding: 2px; margin-bottom: 2px;">BAD</div> <div style="border: 1px solid black; padding: 2px;">PASSCODE</div>	The passcode that was entered in response to the passcode prompt was not correct. If three incorrect passcodes are entered in a row, then all subsequent passcode entries will report this error until the bridge's power is cycled.
		Remote error message: BAD PASSCODE	
		<div style="border: 1px solid black; padding: 2px; margin-bottom: 2px;">BUTTON</div> <div style="border: 1px solid black; padding: 2px;">BUF FULL</div>	This message will be briefly displayed when the front panel keypad buffer is full. This can occur when a number of commands are entered but are not able to be executed. This happens when these commands follow a non-query command such as WAITFOR.
21	CME	<div style="border: 1px solid black; padding: 2px; margin-bottom: 2px;">CAL DATA</div> <div style="border: 1px solid black; padding: 2px;">ABSENT</div>	The command that was entered requires that new calibration data be present in RAM. The corresponding CALIBRATE command must be executed first.
		Remote error message: CAL DATA ABSENT	
22	EXE	<div style="border: 1px solid black; padding: 2px; margin-bottom: 2px;">CAL DATA</div> <div style="border: 1px solid black; padding: 2px;">ERROR C</div>	An error has occurred while reading the calibration data from the EEPROM. C can be 0, 1, or 2 for errors in the Original, Internal, or Capacitance Update data, respectively.
		Remote error message: CAL DATA ERROR C	
26	CME	<div style="border: 1px solid black; padding: 2px; margin-bottom: 2px;">CMD NOT</div> <div style="border: 1px solid black; padding: 2px;">OPERABLE</div>	The command that was entered is not compatible with the options present on this bridge or with the ROM version that is installed. This error also occurs if attempts to STORE macro commands which contain various commands such as DELETE, MACRO CREATE etc..
		Remote error message: CMD NOT OPERABLE	
27	EXE	<div style="border: 1px solid black; padding: 2px; margin-bottom: 2px;">BBBBBBBE</div> <div style="border: 1px solid black; padding: 2px;">BBBBBBBE</div>	An external-trigger overrun has occurred. The bridge received at least one external trigger pulse but no WAITFOR command was waiting for it. This can only occur when the <i>TrgMode</i> parameter associated with the WAITFOR command is set to ERROR. The “E” message is only reported following a measurement result. See “Handling Unexpected Trigger Pulses” on page 3-14.
		Remote error message: E	

Table B-3 Command and data error messages arranged by error code

Error code	Status bit	Front panel error message	Explanation
28	EXE	EEPROM ERROR	An error has occurred while reading the EEPROM during power-on.
		EEPROM ERROR	
29	CME	FILE NOT FOUND	A file name was entered that did not match any file name in memory having the requested file type. Use the DIR command to see what files are in memory. See “WORKING WITH FILES” on page 3-8
		FILE NOT FOUND	
31	CME	ILLEGAL WORD: XXX	The command word that was entered is not one that is recognized by the AH2700A. This error cannot occur on the front panel. See “Command Word Entry” on page 6-3 or “Command Word Entry” on page 7-9.
32	EXE	INT CAL FAILURE	A hardware fault has caused the internal calibration procedure to fail.
		INT CAL FAILURE	
33	EXE	OUT OF SPACE	The store command you attempted requires more memory than is available. To make more room, delete some parameter sets or some macros. Also can be caused by entering a macro that is too long.
		OUT OF SPACE	
34	CME	MAC NEST ERROR	A macro tried to call a sub-macro that was already nested to the maximum depth of eight. Don’t nest your macros so deeply. Did a macro call itself? See “Nesting Considerations” on page 3-11.
		MAC NEST ERROR	
35	CME	SYNTAX ERROR: SSS	The command that was entered may have used valid command words, but either an expected word was not found or an unexpected word was found. The word “SSS” is where the problem occurred. If you are having trouble using the front panel, make sure it displays READY before you start entering a command.
		SYNTAX ERROR	
37	EXE	UPDATE STD ERROR	The value entered for the external calibration capacitor is in disagreement with the original value by more than 0.01%. Either the incorrect value was entered, the calibration capacitor is seriously in error or the bridge needs repair.
		UPDT STD ERROR	
38	CME	LINE TOO LONG	The command message entered was too long. Command lines may not exceed 78 characters in length.
157	EXE	DEV CONFLICT	A command was issued which conflicted with DEV mode.
		DEV CONFLICT	

Table B-3 Command and data error messages arranged by error code

Error code	Status bit	Front panel error message	Explanation
158 UNITS CONFLICT	CME	UNITS CONFLICT	DEV mode must run with UNITS = jp (5)..
159 ZERO CONFLICT	CME	ZERO CONFLICT	DEV mode must not be entered when the ZERO command is active.
160 DEV INIT FAILURE	EXE	DEV INIT FAILURE	The initialization of the DEV mode failed. It may be that the value of the DUT is out of range of the setup parameters.
161 MODE TOO BIG	CME	MODE TOO BIG	The number of SCAN modes is greater than the number of coupling parameters.
177 DELTA CONFLICT	EXE	DELTA CONFLICT	The SCAN mode value of <i>fdelta</i> , <i>sdelta</i> , or <i>vdelta</i> is invalid.
178 FLOOR CEILING INVALID	EXE	FLR CEIL INVALID	The SCAN mode <i>floor</i> is greater than <i>ceiling</i> . This is checked during the SCAN initial setup.
179 NO COUPLED PARAMETER	EXE	NO COUPL PARAMETR	No <i>coupled</i> parameters were entered before the SCAN command was issued. This is checked during SCAN initial setup..
180 COUNT MAX REACHED	EXE	COUNTMAX REACHED	The SCAN mode Count has reached the <i>stotal</i> value.
188 DEV SPAN TOO BIG	EXE	DEV SPAN TOO BIG	An attempt was made to set the span of the DEV mode greater than values where reasonable results can be obtained. This is checked during DEV initial setup.
193 ABOUNDS REVERSAL	EXE	ABOUNDS REVERSAL	DEV mode <i>AoutBoundUpper</i> is less than <i>AoutBoundLower</i> for either cap or loss. This is checked during DEV initial setup.

Table B-3 Command and data error messages arranged by error code

Error code	Status bit	Front panel error message	Explanation
194	EXE	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">LIMITS</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">REVERSAL</div>	In DEV mode the <i>AoutLimitUpper</i> is less than the <i>AoutLimitLower</i> for either Cap or Loss channel. This is checked during DEV initial setup.

Table B-4 Some informative messages and prompts arranged alphabetically

Remote prompt	Display message	Meaning
00		No Error
ARE YOU SURE?	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">ARE YOU</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">SURE?</div>	Some commands ask this question before beginning an irreversible operation such as erasing memory to confirm that you really want to perform the operation. Answer with a “YES” if you want to continue.
	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">BUSY</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;"> </div>	A measurement is in progress. See “Indication of Reference Result Mode” on page 5-3 and “Indication of Zero Result Mode” on page 5-5 for an explanation of the alternate forms of this message. The Analog Output can also affect this message.
CAL CODE>	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">CAL CODE</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;"> </div>	This is a prompt requesting entry of the Calibrator passcode.
	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">CALBRATE</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">BUSY</div>	A calibration operation is in progress.
EXE CAP DEV TOO HIGH	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">88888888</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">88888888</div>	In DEV mode the cap is greater than the <i>DevBoundUpperCap</i> parameter. The rightmost Cap position has an up arrow symbol
EXE CAP DEV TOO LOW	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">88888888</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">88888888</div>	In DEV mode the cap is less than the <i>DevBoundLowerCap</i> parameter. The rightmost Cap position has a down arrow symbol.
	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">DEVICE</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">CLEAR</div>	A DEVICE CLEAR operation has been executed.
	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">GPIB OUT</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">BUF FULL</div>	The GPIB output buffer is full. This can only occur after a result has begun to be read by the GPIB controller or logger. If the controller or logger then reads no more of the result over a period of ten seconds then this message will appear on the front panel. It will go away if the controller or logger resumes reading the message.

Table B-4 Some informative messages and prompts arranged alphabetically

Remote prompt	Display message	Meaning
	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">LOCAL</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">LOCOU</div>	This message appears on the front panel display if the LOCAL key has been pressed but a remote device has locked out the other channels.
<p style="text-align: right;">EXE</p> <p>LOSS DEV TOO HIGH</p>	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">88888888</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">88888888</div>	In DEV mode the loss is greater than the <i>DevBoundUpperLoss</i> parameter. The rightmost Loss position has an up arrow symbol
<p style="text-align: right;">EXE</p> <p>LOSS DEV TOO LOW</p>	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">88888888</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">88888888</div>	In DEV mode the loss is less than the <i>DevBoundUpperLoss</i> parameter. The rightmost Loss position has a down arrow symbol
<p>ONR CODE></p>	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">ONR CODE</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;"> </div>	This is a prompt requesting entry of the Owner passcode.
<p>PASSCODE></p>	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">PASSCODE</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;"> </div>	Any attempt to permanently change the calibration of the bridge requires that a passcode be entered. This message is the prompt that requests that code.
<p style="text-align: right;">EXE</p> <p>PREAMP OVERLOAD</p>	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">PREAMP</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;">OVERLOAD</div>	The bridge unbalance in the DEV mode has exceeded the setup parameters..
<p>USR CODE></p>	<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 2px;">USR CODE</div> <div style="border: 1px solid black; padding: 2px; width: fit-content;"> </div>	This is a prompt requesting entry of the User passcode.

INTERPRETING THE SPECIFICATIONS

The performance specifications of the AH2700A are given in the form of a fairly complicated set of equations. These equations, taken by themselves, are not easy to interpret. However, they do provide specifications that are an unusually precise description of an electronic instrument.

To more easily interpret these equations, they have been programmed into a spreadsheet to allow their evaluation in regions of interest to you.

Please go to www.andeen-hagerling.com to download a copy.

Notation: The specifications are grouped according to whether the unknown is modeled as a resistor in parallel with a capacitor or in series with it.

Parallel: “C” is the value of the unknown (parallel) capacitance in picofarads ($\text{pF} = 10^{-12} \text{ F}$). Also used are attofarads ($\text{aF} = 10^{-6} \text{ pF}$) and microfarads ($\mu\text{F} = 10^6 \text{ pF}$).

“G” is the value of the unknown loss expressed as a conductance in nanosiemens ($\text{nS} = 10^{-9} \text{ S}$).

“D” is the value of the unknown loss expressed as a dissipation factor ($\tan \delta$). D has no units.

“R_p” is the value of the unknown loss expressed as a parallel resistance in gigohms ($\text{G}\Omega = 10^9 \Omega$).

Series: “C_S” is the value of the unknown series capacitance in picofarads ($\text{pF} = 10^{-12} \text{ F}$)

“R_S” is the value of the unknown loss expressed as a series resistance in kilohms ($\text{k}\Omega = 10^3 \Omega$).

Misc: “f” is the frequency in kilohertz ($\text{kHz} = 10^3 \text{ Hz}$).

“ ω ” equals $2\pi f$.

“t” is the measurement time in seconds.

“V” is the AC test signal voltage in volts applied across the unknown. Its upper limit is selectable to have any value from 30 mV to 15 V.

“ppm” means Parts Per Million.

General:

The expressions which give the uncertainty for accuracy, linearity, stability, resolution, and temperature coefficient give absolute rather than statistical uncertainties. Absolute uncertainties are the most conservative of those in common use. Andeen-Hagerling guarantees repair within the warranty period of any AH2700A whose measured errors repeatedly exceed these uncertainties. The expressions may be evaluated for particular values of capacitance (C or C_S), loss (G, D, R_p, R_S or G/ω), test voltage (V), and measurement time (t). Except for absolute resolution, G/ω shares the same equations as G. Only the resolution expressions contain the measurement time. However, the other uncertainty expressions assume that the measurement time has been set to be long enough so that these other uncertainties are not limited by the resolution specification. In other words, specifications such as accuracy may be limited by the resolution rather than the accuracy expression if the measurement time is set too short.

Many of the expressions include an error contribution from cable effects. This cable is assumed to be an AH-DCOAX cable that is up to two meters in length. Where these one or two cable error contribution terms exist, they may be identified by their enclosure within a pair of braces “{}”. This pair will always be the inner of two pairs of braces.

Most of the uncertainty expressions can be evaluated by direct substitution of the values of capacitance, loss and voltage as if they were read directly from the AH2700A. The instrument reports these values in the units given in the notation section above. Some expressions also require the dissipation factor, D, which, if it is not directly available, can be calculated using one of the following relations:

$$D = G/\omega C, \quad D = 1/\omega C R_p \quad \text{or} \quad D = \omega C_S R_S \times 10^{-6}$$

For low values of capacitance and loss, the maximum allowable test voltage set by the user (usually 15 volts) can be substituted for every occurrence of V in the uncertainty expressions. For larger values of capacitance and loss, if the voltage value is not taken from a measurement result, then the value of V automatically chosen by the AH2700A must be determined from the AC Test Signal Voltage Table. The following equations may be used to convert to the units of C and G used in the table from units other than those used in the table.

Given units of:	D:	use	G = ωCD
	R _p :		G = 1/R _p
	R _S :		G = ωC _S D/(1+D ²)
	C _S :		C = C _S /(1+D ²)

Accuracy, stability, linearity and resolution specifications assume a recent internal calibration at the operating temperature. All specifications are valid only for positive values of capacitance and loss.

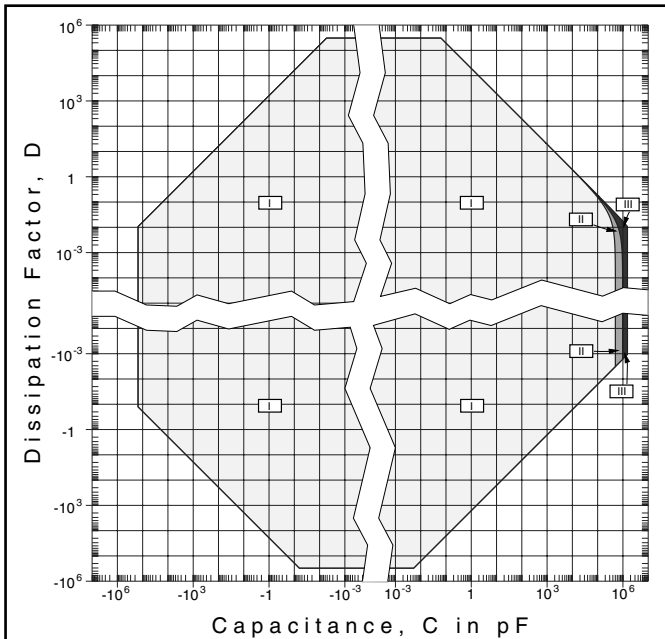


Figure 1. Measurable values of C and D are enclosed within shaded areas. II and III are examples of specific frequencies.

- Region I applies to all frequencies
- Regions I&II apply to frequencies below 10kHz
- Regions I,II&III apply to frequencies below about 3 kHz

Range:*

Parallel: C: $-0.0016/D \mu\text{F}$ to $+10/(f+D/0.0019) \mu\text{F}$
for $3 \times 10^5 \geq D \geq 0.01$
 $-0.15 \mu\text{F}$ to the lesser of $+1.5 \mu\text{F}$
or $+10/(f+D/0.0019) \mu\text{F}$ for $-0.001 \leq D < 0.01$
 $-0.15 \mu\text{F}$ to $+0.0016/|D| \mu\text{F}$ for $-0.1 \leq D < -0.001$
 $-0.019/|D| \mu\text{F}$ to $+0.0016/|D| \mu\text{F}$ for $-3 \times 10^5 \leq D < -0.1$

The capacitance range is also graphed in Figure 1.

G: See Table C-1.
D: See Figure 1 and the equations for C above.
R_p: $-8 \times 10^{-5} \text{ G}\Omega$ to $-1.7 \times 10^6 \text{ G}\Omega$
and $+8 \times 10^{-6} \text{ G}\Omega$ to $+1.7 \times 10^6 \text{ G}\Omega$ @ 1 kHz

Series: C_s: See Figure 2 for the range at 1kHz.
R_s: See Figure 2 for the range at 1kHz.

*The ranges of all measurable variables except R_p cover a region defined by negative numbers for the lower limit and positive numbers for the upper limit. This is due to the AH2700A's ability to

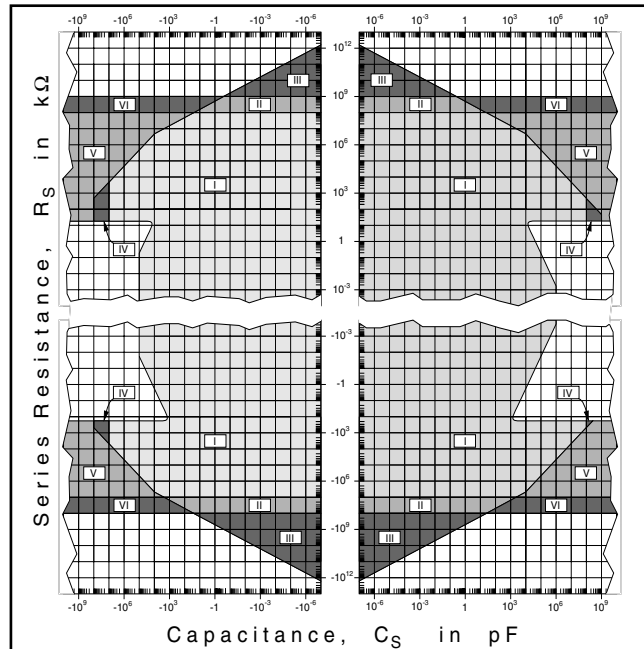


Figure 2. The values of C_s and R_s are measurable in the six shaded regions. In five of these regions, one or both of the measured values are too large to report on the AH2700A's display. In three of these five regions, one or both values are also too large to send to any remote devices. The table below shows what can be reported in each region. A "Display" entry means that the result can be shown on the instrument's display. A "Remotes" entry means that the result can be reported to an IEEE-1174 or IEEE-488 device.

	C _s	R _s
I	Display & Remotes	Display & Remotes
II	Display & Remotes	Remotes only
III	Display & Remotes	Neither
IV	Remotes only	Display & Remotes
V	Neither	Display & Remotes
VI	Neither	Remotes only

*Regions V and VI extend to infinity to the right and left because the resistance associated with an infinite C_s is measurable even though C_s itself is not reportable.

measure both positive and negative values of capacitance and loss. Other instruments typically measure only positive values and have ranges which cover a region defined by small positive numbers for the lower limits to large positive numbers for the upper limits. For the AH2700A, the small numbers corresponding to the lower limits of other instruments are given by the AH2700A's resolution specifications in absolute units.

Front Panel Display Limitations:

(The front panel display may further limit the range and resolution of the capacitance and loss.)

Capacitance: 0.1 aF is best display resolution for C and C_S.

Loss: *G:* 10⁻⁷ nS is best conductance display resolution.

D: 10⁻⁷ is best dissipation display resolution.

R_S: 10⁻⁷ kΩ is best series resistance display resolution.

R_P: 10⁻⁷ GΩ is best parallel resistance display resolution.

Remote Device Reporting Limitations:

Capacitance: 0.01 aF is best resolution for C and C_S.

Loss: *G:* 10⁻⁸ nS is best conductance resolution.

D: 10⁻⁸ is best dissipation resolution.

R_S: 10⁻⁷ kΩ is best series resistance resolution.

R_P: 10⁻⁸ GΩ is best parallel resistance resolution.

Frequencies: 50, 60, 80, 100, 120, 160, 200, 240, 320, 400, 500, 600, 800 Hz and 1.0, 1.2, 1.6, 2.0, 2.4, 3.2, 4.0, 5.0, 6.0, 8.0, 10, 12, 16 and 20 kHz ± 0.005%.

Sensitivity to changes in power line voltage:

Capacitance: ± 0.002 ppm per 1% change in line voltage.

Loss: Not measurable.

DC Bias: Up to ±100 volts may be applied to the unknown through the external DC bias input.

AC Test Signal Voltages: Any voltage from 0.030 to 15 V may be entered to a resolution of 0.1%. The available ranges

for a given entered voltage are on the line in Table C-1 having the next highest voltage. The AH2700A will automatically use the lesser of the user's selected voltage or the highest voltage listed in the table which provides sufficient range to be able to measure the capacitance and loss of the unknown. The voltages listed have tolerances of ±5%.

Operating temperature range: 0° to 45°C

Storage temperature range: -40° to +75°C

Humidity: 0 to 85% relative humidity, non-condensing

Power requirements: 25 watts, 48 to 440 Hz, 85 to 115, 102 to 138, 187 to 253 and 204 to 276 volts rms

Packaging: The instrument is 3.5 inches (8.9 cm) high and 15 inches (38.1 cm) deep behind the front panel. Hardware for rack mounting and a bail for bench top use are provided.

Weight: 18 pounds (8.2 kg)

Safety and EMC conformity: conforms to EN61326:1998 and EN 61010-1: 1993/A2: 1995

Patents: The AH2700A is covered by U.S. Patent No. 4,772,844 and 6,204,673

Warranty: The AH2700A is covered by a three year warranty. Forward and return shipping is covered during the first three months of the warranty.

Note: Specifications are subject to change without notice.

Table C-1 Capacitance and conductance ranges for the preferred limiting voltages with $f \geq 1$ kHz. For $f < 1$ kHz, multiply Limit by f in kHz. A_T and A_C are used by the specification equations.

Limit	Capacitance range	Range of G; f is in kHz	A_T	A_C
15.00 V	-11 to +110 pF	-0.8 f to +8 f nS	0	0
7.50 V	-22 to +220 pF	-1.6 f to +16 f nS	0	0
3.00 V	-55 to +550 pF	-4 f to +40 f nS	0	0
1.50 V	-110 to +1100 pF	-8 f to +80 f nS	0	0
0.750 V	-220 to +2200 pF	-16 f to +160 f nS	0	0
0.250 V	-660 to +6600 pF	-48 f to +480 f nS	0	0
0.100 V	-1650 to +16,500 pF	-120 f to +1200 f nS	5	0.01
0.030 V	-5500 to +55,000 pF	-400 f to +4000 f nS	10	0.03
0.010 V	-16,500 to +165,000 pF	-1200 f to +12,000 f nS	15	0.1
0.003 V	-55,000 to +550,000 pF	-4000 f to +40,000 f nS	20	0.3
0.001 V	-165,000 to +1,650,000 pF	-12,000 f to +120,000 f nS	30	1

Resolution in absolute units:*

Parallel:

$$C: \left\{ \frac{C}{20} \left[2 + \frac{1}{f} \right] + \frac{1.5}{V} \left[4 + \frac{1}{f} + 5n_c \right] + \frac{n_v C}{V} + \frac{50G}{\omega} + (1 + 10A_C) \frac{f^2 C}{500} \left[1 + \frac{1700}{200 + CV} \right] \right\} \times 10$$

$$G: \left\{ 50G + \omega \left[\frac{C}{20} \left(2 + \frac{1}{f} \right) + \frac{1.5}{V} \left(4 + \frac{1}{f} + 5n_c \right) + \frac{n_v C}{V} + 8 \times 10^{-6} f C^2 + (3 + 50A_C) \frac{fC}{50} \left(1 + \frac{1700}{200 + CV} \right) \right] \right\} \quad \text{Divide result by } \omega \text{ to get absolute resolution for } G/\omega$$

$$D: \left\{ (1 + D^2)^{1/2} \left[50D + \frac{1}{20} \left(2 + \frac{1}{f} \right) + \frac{1.5}{CV} \left(4 + \frac{1}{f} + 5n_c \right) + \frac{n_v}{V} + 8 \times 10^{-6} f C + (3 + 50A_C) \frac{f}{50} \left(1 + \frac{1700}{200 + CV} \right) \right] \right\}$$

$$R_p: \left\{ 50R_p + \omega R_p^2 \left[\frac{C}{20} \left(2 + \frac{1}{f} \right) + \frac{1.5}{V} \left(4 + \frac{1}{f} + 5n_c \right) + \frac{n_v C}{V} + 8 \times 10^{-6} f C^2 + (3 + 50A_C) \frac{fC}{50} \left(1 + \frac{1700}{200 + CV} \right) \right] \right\}$$

Series:

$$C_s: \left\{ \frac{C_s}{20} \left[2 + \frac{1}{f} \right] + \frac{1.5}{V} \left[4 + \frac{1}{f} + 5n_c \right] (1 + D^2) + \frac{n_v C_s}{V} + 50DC_s + (1 + 10A_C) \frac{f^2 C_s}{500} \left[1 + \frac{1700}{200 + CV} \right] \right\}$$

$$R_s: \left\{ 50R_s + 1.3 + \frac{R_s}{D} \left[\frac{1}{20} \left(2 + \frac{1}{f} \right) + \frac{1.5}{C_s V} \left(4 + \frac{1}{f} + 5n_c \right) (1 + D^2) + \frac{n_v}{V} + (3 + 50A_C) \frac{f}{50} \left(1 + \frac{1700}{200 + CV} \right) \right] \right\} \times$$

where $n_c = 1.4t^{-1/2}$ and $n_v = 0.01(1+0.1/f)(R_s+10)^{1/2}(1+D^2)^{1/2}t^{-1/2}$. A_C is found in Table C-1.

The series resistance R_s needed for n_v may be calculated using $R_s = D \times 10^6 / (\omega C(1+D^2))$.

Resolution in ppm:*

Parallel:

$$C: \frac{1}{20} \left[2 + \frac{1}{f} \right] + \frac{1.5}{CV} \left[4 + \frac{1}{f} + 5n_c \right] + \frac{n_v}{V} + 50D + (1 + 10A_C) \frac{f^2}{500} \left[1 + \frac{1700}{200 + CV} \right]$$

$$G: 50 + \frac{\omega}{G} \left\{ \frac{C}{20} \left[2 + \frac{1}{f} \right] + \frac{1.5}{V} \left[4 + \frac{1}{f} + 5n_c \right] + \frac{n_v C}{V} + 8 \times 10^{-6} f C^2 + (3 + 50A_C) \frac{fC}{50} \left[1 + \frac{1700}{200 + CV} \right] \right\}$$

$$D: \frac{(1 + D^2)^{1/2}}{D} \left\{ 50D + \frac{1}{20} \left[2 + \frac{1}{f} \right] + \frac{1.5}{CV} \left[4 + \frac{1}{f} + 5n_c \right] + \frac{n_v}{V} + 8 \times 10^{-6} f C + (3 + 50A_C) \frac{f}{50} \left[1 + \frac{1700}{200 + CV} \right] \right\}$$

$$R_p: 50 + \omega R_p \left\{ \frac{C}{20} \left[2 + \frac{1}{f} \right] + \frac{1.5}{V} \left[4 + \frac{1}{f} + 5n_c \right] + \frac{n_v C}{V} + 8 \times 10^{-6} f C^2 + (3 + 50A_C) \frac{fC}{50} \left[1 + \frac{1700}{200 + CV} \right] \right\}$$

Series:

$$C_s: \frac{1}{20} \left[2 + \frac{1}{f} \right] + \frac{1.5}{C_s V} \left[4 + \frac{1}{f} + 5n_c \right] (1 + D^2) + \frac{n_v}{V} + 50D + (1 + 10A_C) \frac{f^2}{500} \left[1 + \frac{1700}{200 + CV} \right]$$

$$R_s: 50 + \frac{1.3}{R_s} + \frac{1}{D} \left\{ \frac{1}{20} \left[2 + \frac{1}{f} \right] + \frac{1.5}{C_s V} \left[4 + \frac{1}{f} + 5n_c \right] (1 + D^2) + \frac{n_v}{V} + (3 + 50A_C) \frac{f}{50} \left[1 + \frac{1700}{200 + CV} \right] \right\}$$

*Resolution is the smallest *repeatable* difference in readings that is *guaranteed* to be measurable at *every* capacitance or loss value. Useful resolution is typically a factor of ten better. A_C is found in Table C-1.

Non-linearity in ppm:

Parallel:

$$C: \pm \left\{ \frac{1}{20} \left[2 + \frac{1}{f} \right] + \frac{1.5}{CV} \left[4 + \frac{1}{f} \right] + 50D + \frac{f^2}{200} \left[1 + \frac{1700}{200 + CV} \right] + \{ 1.5 \times 10^{-6} f^{2.5} C \} \right\}$$

$$G: \pm \left\{ 50 + \frac{\omega}{G} \left[\frac{C}{20} \left(2 + \frac{1}{f} \right) + \frac{1.5}{V} \left(4 + \frac{1}{f} \right) + 8 \times 10^{-6} f C^2 + \frac{fC}{6} \left(1 + \frac{1700}{200 + CV} \right) \right] + \left\{ \frac{1.2 \times 10^{-4} \omega f C^2}{G} \right\} \right\}$$

$$D: \pm \left\{ \frac{(1 + D^2)^{1/2}}{D} \left[50D + \frac{1}{20} \left(2 + \frac{1}{f} \right) + \frac{1.5}{CV} \left(4 + \frac{1}{f} \right) + 8 \times 10^{-6} f C + \frac{f}{6} \left(1 + \frac{1700}{200 + CV} \right) \right] + \left\{ \frac{(1 + D^2)^{1/2}}{D} [1.2 \times 10^{-4} f C] \right\} \right\}$$

$$R_p: \pm \left\{ 50 + \omega R_p \left[\frac{C}{20} \left(2 + \frac{1}{f} \right) + \frac{1.5}{V} \left(4 + \frac{1}{f} \right) + 8 \times 10^{-6} f C^2 + \frac{fC}{6} \left(1 + \frac{1700}{200 + CV} \right) \right] + \{ 1.2 \times 10^{-4} \omega f R_p C^2 \} \right\}$$

Series:

$$C_s: \pm \left\{ \frac{1}{20} \left[2 + \frac{1}{f} \right] + \frac{1.5}{C_s V} \left[4 + \frac{1}{f} \right] (1 + D^2) + 50D + \frac{f^2}{200} \left[1 + \frac{1700}{200 + CV} \right] + \{ 1.5 \times 10^{-6} f^{2.5} C \} \right\}$$

$$R_s: \pm \left\{ 50 + \frac{1.3}{R_s} + \frac{1}{D} \left[\frac{1}{20} \left(2 + \frac{1}{f} \right) + \frac{1.5}{C_s V} \left(4 + \frac{1}{f} \right) (1 + D^2) + \frac{f}{6} \left(1 + \frac{1700}{200 + CV} \right) \right] + \left\{ \frac{20}{R_s} \right\} \right\}$$

Non-linearity is the deviation from a best fit straight line through a plot of the measured quantity versus the actual quantity. The test signal voltage is assumed to be constant.

Accuracy in ppm following calibration:

Parallel:

$$C: \pm \left\{ \frac{1}{2} \left[8 + \frac{1}{f} + f \right] + \frac{1.5}{CV} \left[4 + \frac{1}{f} \right] + 200D + \frac{f^2}{100} \left[1 + \frac{1700}{200 + CV} \right] + A_T \left[f + \frac{1}{f} \right] + \left\{ 3 \times 10^{-6} f^{2.5} C + \frac{f^2}{4C} \right\} \right. \quad A_T \text{ is found in Table C-1.}$$

$$G: \pm \left\{ 200 + \frac{\omega}{G} \left[\frac{C}{2} \left(2 + \frac{1}{f} + f \right) + \frac{1.5}{V} \left(4 + \frac{1}{f} \right) + \frac{fC^2}{3300} + \frac{fC}{3} \left(1 + \frac{1700}{200 + CV} \right) + A_T C \left(f + \frac{1}{f} \right) \right] + \left\{ \frac{\omega f}{G} \left[2 \times 10^{-4} C^2 + \frac{f}{4} \right] \right\} \right.$$

$$D: \pm \left\{ \frac{(1+D^2)^{1/2}}{D} \left[200D + \frac{1}{2} \left(2 + \frac{1}{f} + f \right) + \frac{1.5}{CV} \left(4 + \frac{1}{f} \right) + \frac{fC}{3300} + \frac{f}{3} \left(1 + \frac{1700}{200 + CV} \right) + A_T \left(f + \frac{1}{f} \right) \right] + \left\{ \frac{(1+D^2)^{1/2} f}{D} \left[2 \times 10^{-4} C + \frac{f}{4C} \right] \right\} \right.$$

$$R_p: \pm \left\{ 200 + \omega R_p \left[\frac{C}{2} \left(2 + \frac{1}{f} + f \right) + \frac{1.5}{V} \left(4 + \frac{1}{f} \right) + \frac{fC^2}{3300} + \frac{fC}{3} \left(1 + \frac{1700}{200 + CV} \right) + A_T C \left(f + \frac{1}{f} \right) \right] + \left\{ \omega R_p f \left[2 \times 10^{-4} C^2 + \frac{f}{4} \right] \right\} \right.$$

Series:

$$C_s: \pm \left\{ \frac{1}{2} \left[8 + \frac{1}{f} + f \right] + \frac{1.5}{C_s V} \left[4 + \frac{1}{f} \right] (1 + D^2) + 200D + \frac{f^2}{100} \left[1 + \frac{1700}{200 + CV} \right] + A_T \left[f + \frac{1}{f} \right] + \left\{ 3 \times 10^{-6} f^{2.5} C + \frac{f^2 (1 + D^2)}{4C_s} \right\} \right.$$

$$R_s: \pm \left\{ 200 + \frac{50}{R_s} + \frac{1}{D} \left[\frac{1}{2} \left(2 + \frac{1}{f} + f \right) + \frac{1.5}{C_s V} \left(4 + \frac{1}{f} \right) (1 + D^2) + \frac{f}{3} \left(1 + \frac{1700}{200 + CV} \right) + A_T \left(f + \frac{1}{f} \right) \right] + \left\{ \frac{30}{R_s} + \right.$$

The length of the cables connecting the 2700A to the unknown has a negligible effect on the accuracy for *small* capacitances. This assumes that the coaxial shield on these cables has 100% coverage. If uncorrected by the CABLE command, cables similar to RG-58 will increase the capacitance readings at 1 kHz by about 40 ppm per meter of cable pair and per μF of capacitance being measured.

The accuracy Y years following calibration may be calculated from the expression A + YS where A is the desired accuracy expression from above and S is the corresponding stability per year below.

Stability in ppm per year:

Parallel:

$$C: \pm \left\{ \frac{1}{10} \left[8 + \frac{1}{f} + f \right] + \frac{1}{2CV} \left[4 + \frac{1}{f} \right] + 30D + \left\{ 10^{-6} f^{2.5} C + \frac{f^2}{20C} \right\} \right.$$

$$G: \pm \left\{ 30 + \frac{\omega}{G} \left[\frac{C}{10} \left(2 + \frac{1}{f} + f \right) + \frac{1}{2V} \left(4 + \frac{1}{f} \right) + 5 \times 10^{-5} f C^2 \right] + \left\{ \frac{\omega f}{G} \left[3 \times 10^{-5} C^2 + \frac{f}{20} \right] \right\} \right.$$

$$D: \pm \left\{ \frac{(1+D^2)^{1/2}}{D} \left[30D + \frac{1}{10} \left(2 + \frac{1}{f} + f \right) + \frac{1}{2CV} \left(4 + \frac{1}{f} \right) + 5 \times 10^{-5} f C \right] + \left\{ \frac{(1+D^2)^{1/2} f}{D} \left[3 \times 10^{-5} C + \frac{f}{20C} \right] \right\} \right.$$

$$R_p: \pm \left\{ 30 + \omega R_p \left[\frac{C}{10} \left(2 + \frac{1}{f} + f \right) + \frac{1}{2V} \left(4 + \frac{1}{f} \right) + 5 \times 10^{-5} f C^2 \right] + \left\{ \omega R_p f \left[3 \times 10^{-5} C^2 + \frac{f}{20} \right] \right\} \right.$$

Series:

$$C_s: \pm \left\{ \frac{1}{10} \left[8 + \frac{1}{f} + f \right] + \frac{1}{2C_s V} \left[4 + \frac{1}{f} \right] (1 + D^2) + 30D + \left\{ 10^{-6} f^{2.5} C + \frac{f^2 (1 + D^2)}{20C_s} \right\} \right.$$

$$R_s: \pm \left\{ 30 + \frac{8}{R_s} + \frac{1}{D} \left[\frac{1}{10} \left(2 + \frac{1}{f} + f \right) + \frac{1}{2C_s V} \left(4 + \frac{1}{f} \right) (1 + D^2) \right] + \left\{ \frac{5}{R_s} + \frac{f^2 (1 + D^2)}{20DC_s} \right\} \right.$$

Temperature coefficient relative to change in ambient temperature in ppm per °C:

Parallel:

$$C: \pm \left\{ \frac{1}{400} \left[8 + \frac{1}{f} + f \right] + 20D + \frac{A_T}{33} \left[f + \frac{1}{f} \right] + \frac{200}{2 + 6CV(2 + 1/f)} + \left\{ 10^{-7} f^{2.5} C + \frac{f^2}{100C} \right\} \right\}$$

$$G: \pm \left\{ 20 + \frac{\omega C}{G} \left[\frac{3}{400} \left(2 + \frac{1}{f} + f \right) + 3 \times 10^{-6} f C + \frac{A_T}{33} \left(f + \frac{1}{f} \right) \right] + \frac{400}{4 + VG(2 + 1/f)/\omega} + \left\{ \frac{\omega f}{G} \left[2 \times 10^{-6} C^2 + \frac{f}{100} \right] \right\} \right\}$$

$$D: \pm \left\{ \frac{(1+D^2)^{1/2}}{D} \left[20D + \frac{3}{400} \left(2 + \frac{1}{f} + f \right) + 3 \times 10^{-6} f C + \frac{A_T}{33} \left(f + \frac{1}{f} \right) \right] + \frac{200}{2 + 6CV(2 + 1/f)} + \frac{400}{4 + CVD(2 + 1/f)} + \left\{ \frac{(1+D^2)^{1/2} f}{D} \left[2 \times 10^{-6} C + \frac{f}{100C} \right] \right\} \right.$$

$$R_p: \pm \left\{ 20 + \omega C R_p \left[\frac{3}{400} \left(2 + \frac{1}{f} + f \right) + 3 \times 10^{-6} f C + \frac{A_T}{33} \left(f + \frac{1}{f} \right) \right] + \frac{400}{4 + V(2 + 1/f)/\omega R_p} + \left\{ \omega R_p f \left[2 \times 10^{-6} C^2 + \frac{f}{100} \right] \right\} \right\}$$

Series:

$$C_s: \pm \left\{ \frac{1}{400} \left[8 + \frac{1}{f} + f \right] + 20D + \frac{A_T}{33} \left[f + \frac{1}{f} \right] + \frac{200}{2 + 6C_s V(2 + 1/f)/(1 + D^2)} + \left\{ 10^{-7} f^{2.5} C + \frac{f^2 (1 + D^2)}{100C_s} \right\} \right\}$$

$$R_s: \pm \left\{ 20 + \frac{0.5}{R_s} + \frac{1}{D} \left[\frac{3}{400} \left(2 + \frac{1}{f} + f \right) + \frac{A_T}{33} \left(f + \frac{1}{f} \right) \right] + \frac{400}{4 + C_s VD(2 + 1/f)/(1 + D^2)} + \left\{ \frac{0.3}{R_s} + \frac{f^2 (1 + D^2)}{100DC_s} \right\} \right\}$$

where A_T is found in Table C-1.

SELECTED SPECIFICATIONS IN GRAPHICAL FORM

Specifications versus frequency:

The ten graphs on this and the following two pages are plots versus frequency of the accuracy, resolution in ppm, non-linearity, stability and temperature coefficient specifications. These plots were generated by using the specification equations presented on the previous two pages. Each graph contains a set of curves for various values of capacitance. These capacitance values range from one femtofarad up to one microfarad. It is easy to see that the specifications tend to be best for capacitance values in the region of 10 pF to 1 nF and worst at either extreme of capacitance. The five graphs of capacitance specifications at the left side of each page apply for small values of dissipation factor ($D < 0.001$). Each curve was plotted using the maximum possible voltage.

Accuracy specifications versus C and loss:

The three graphs on the last page in the left column are contour plots of the accuracy of capacitance(C) versus C and conductance(G). The graph at the top applies at 100 Hz, the middle one at 1 kHz and the bottom one at 10 kHz. The accuracy in the area within or below each contour is equal to or better than the labeled accuracy (in percent) for that contour. These graphs show that the accuracy of C

depends not only on the value of C but also on the value of the loss. Each contour was plotted using the maximum possible voltage.

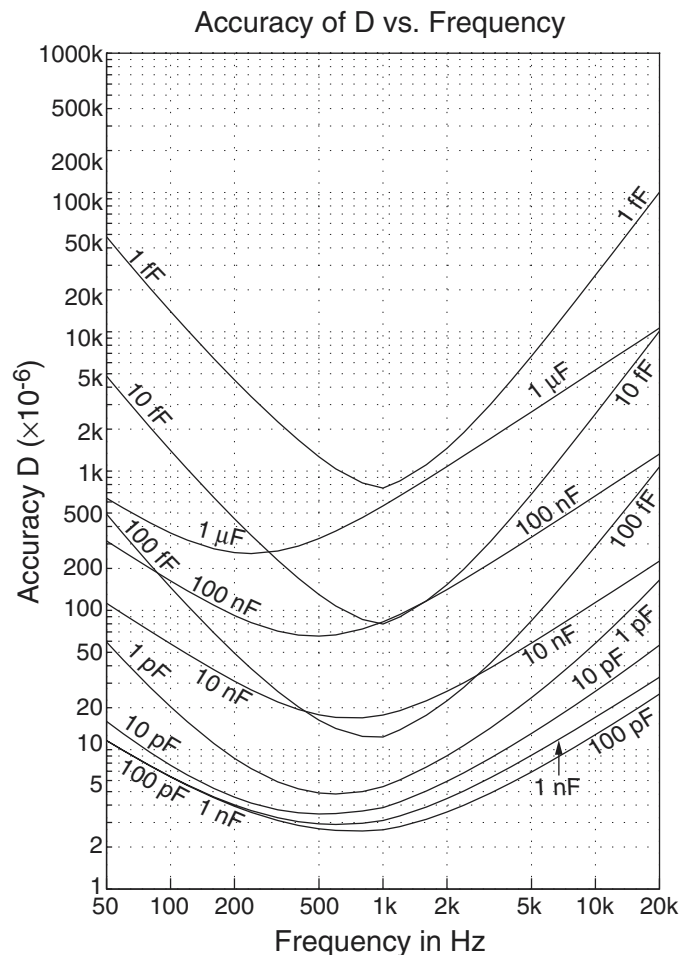
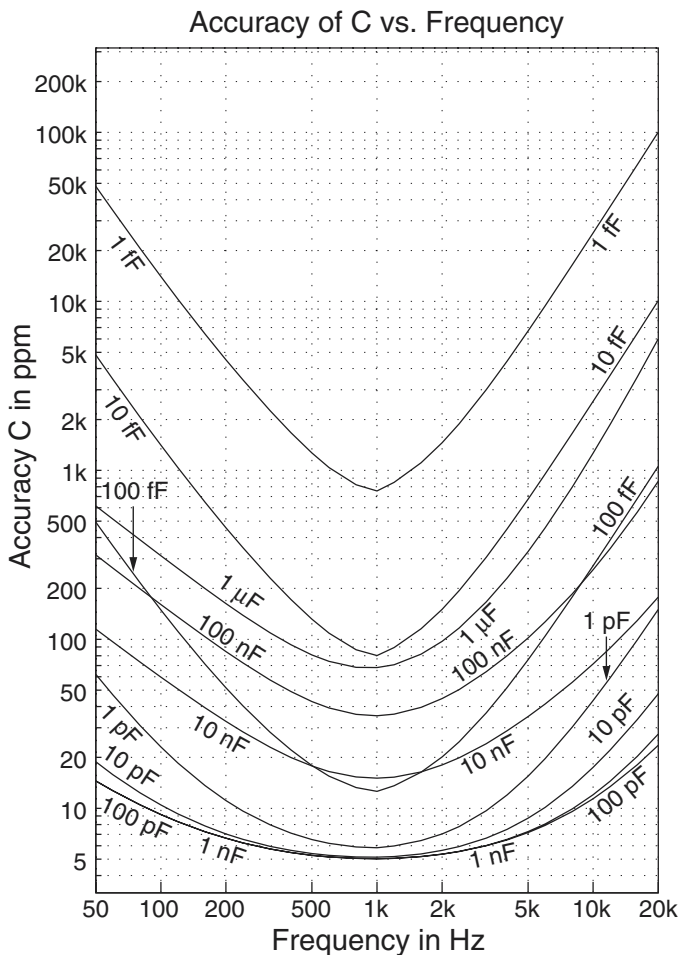
The graph at the top of the right column on the last page is a contour plot of the accuracy of the dissipation factor(D) versus C and D. The accuracy in the area within each contour is equal to or better than the labeled accuracy (in percent) for that contour. This graph shows that the accuracy of D depends not only on the value of D but also on the value of C.

Accuracy specifications at various voltages:

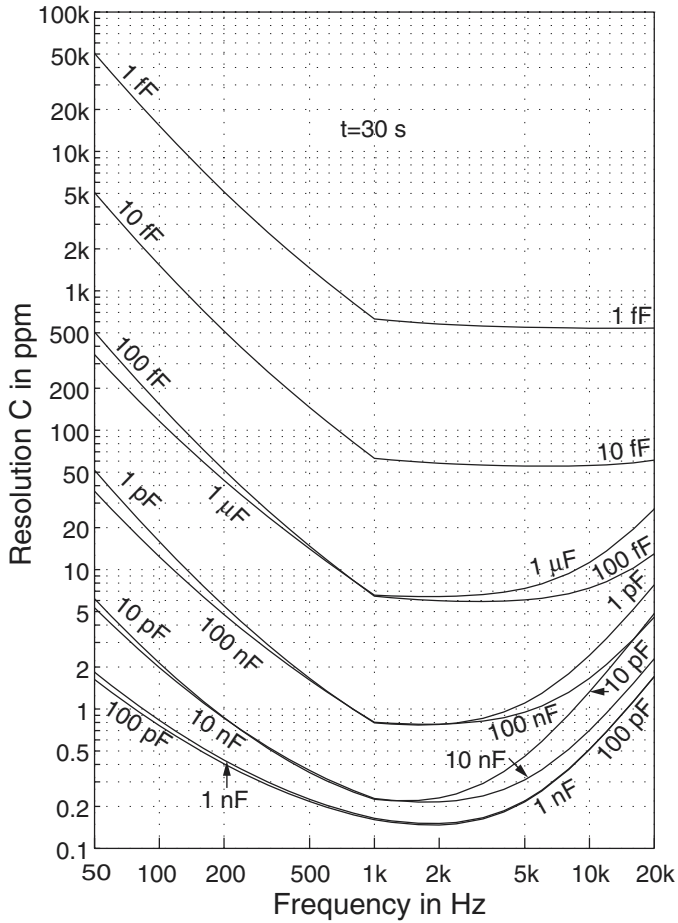
The middle graph in the right column on the last page is a contour plot of the accuracy of C versus C and G. The accuracy in the area within or below each contour is equal to or better than 0.001%.

The bottom graph in the right column on the last page is a contour plot of the accuracy of D versus C and D. The accuracy in the area within each contour is equal to or better than 0.03%.

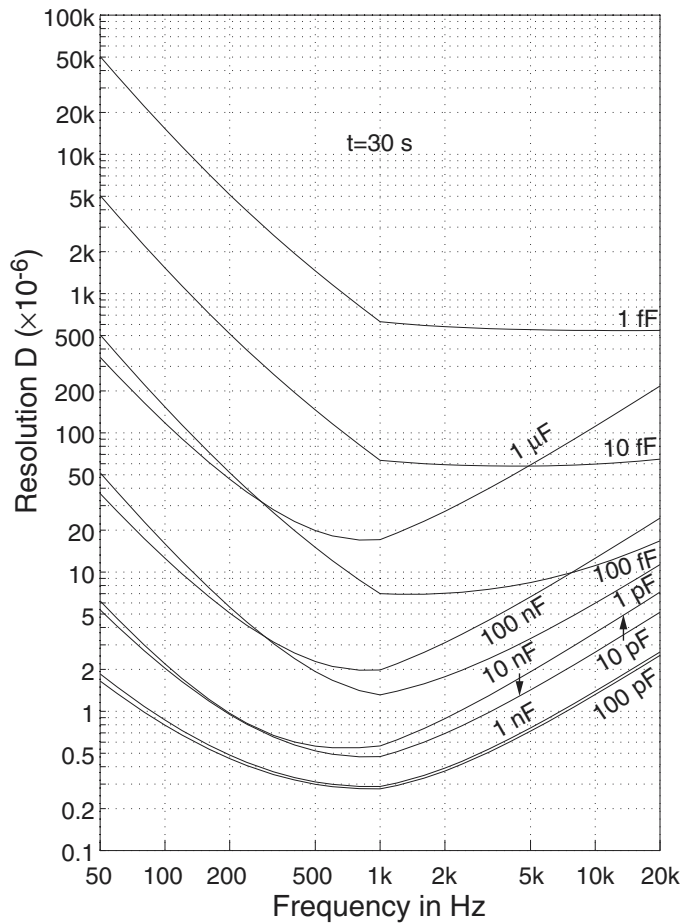
These graphs show how the accuracy of C and D depends on the measurement voltage. Each contour represents operation at the labeled voltage which is one of the voltages in Table C-1 on page 3.



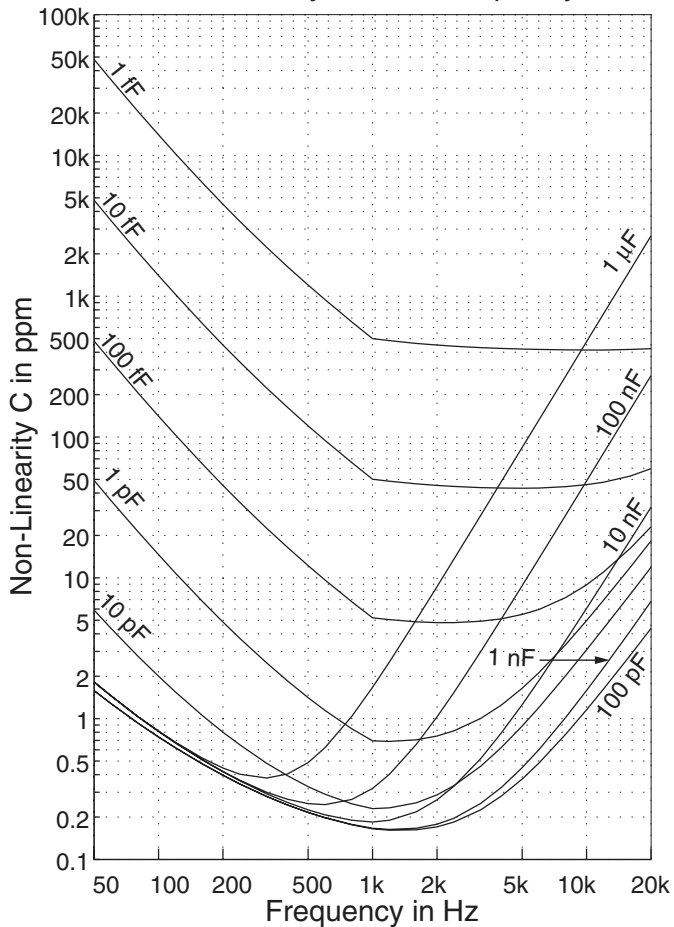
Resolution of C vs. Frequency



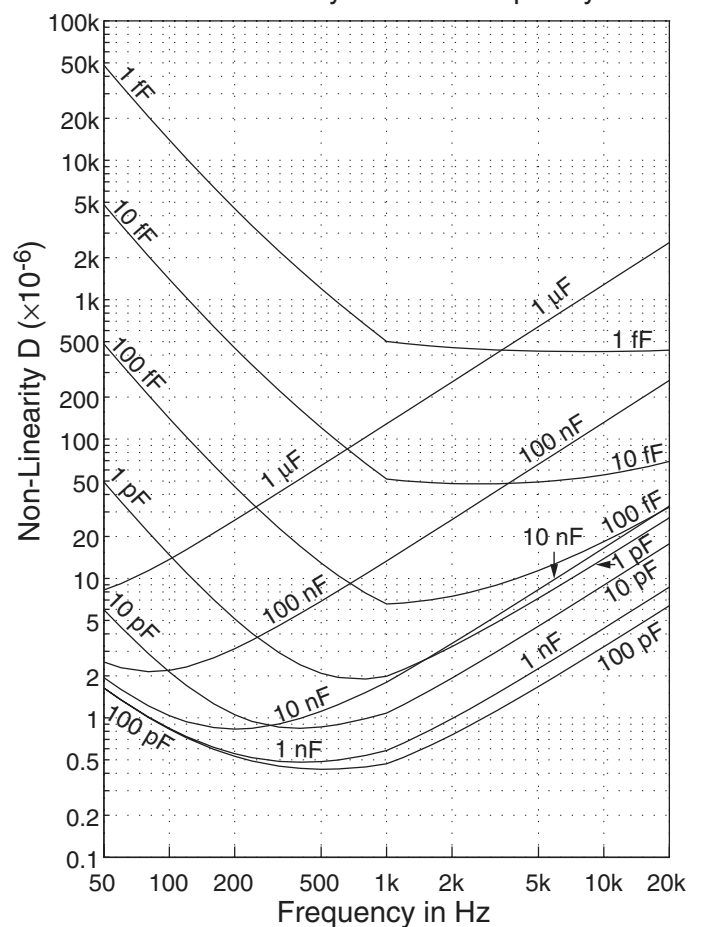
Resolution of D vs. Frequency



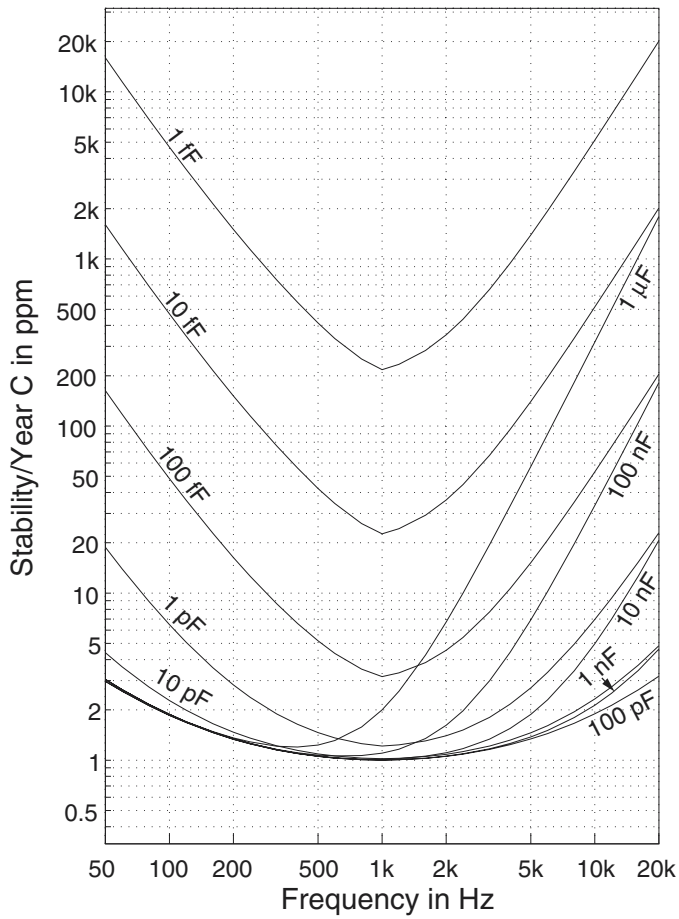
Non-Linearity of C vs. Frequency



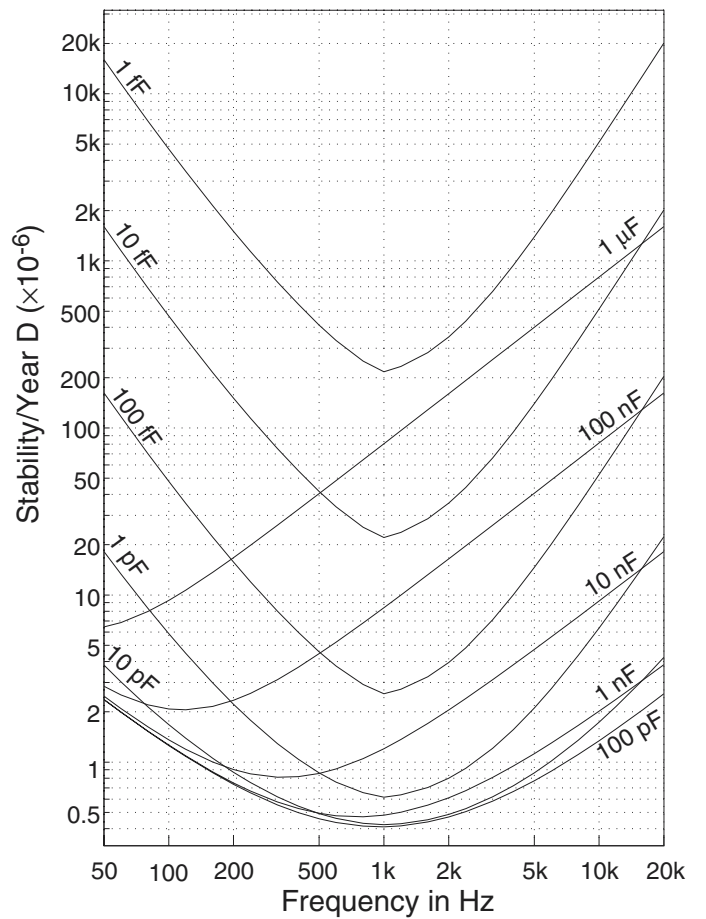
Non-Linearity of D vs. Frequency



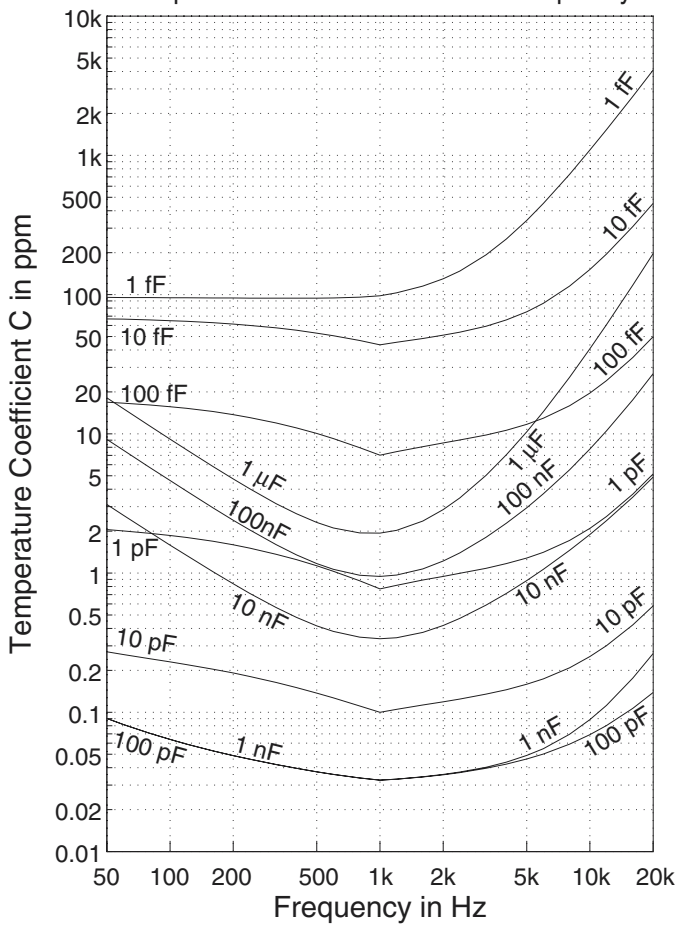
Stability/Year of C vs. Frequency



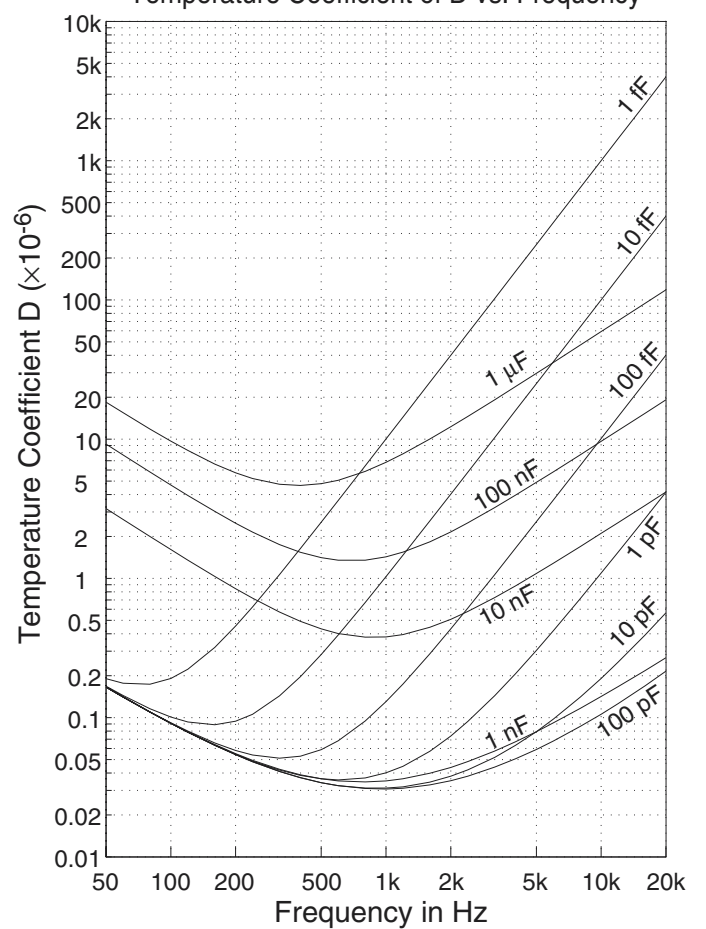
Stability/Year of D vs. Frequency

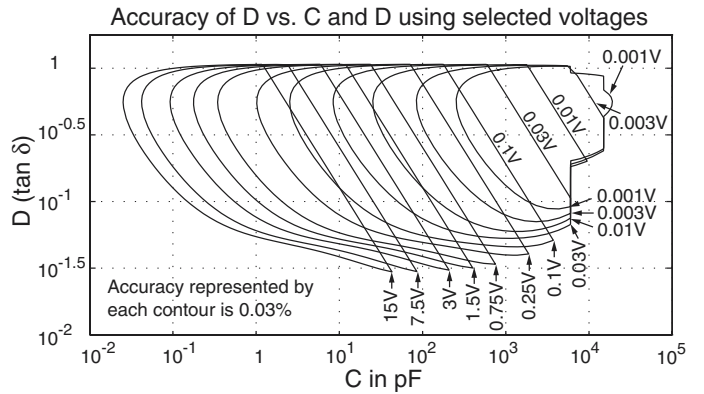
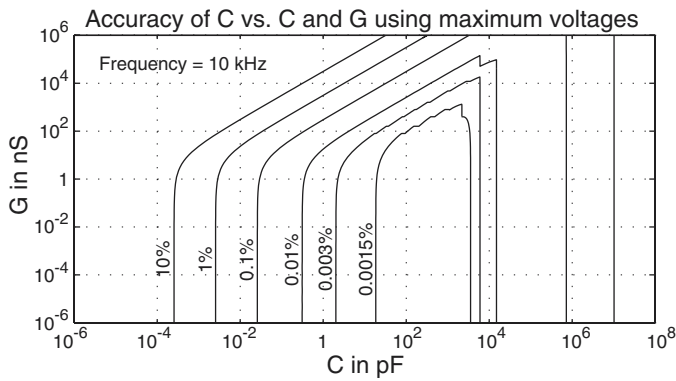
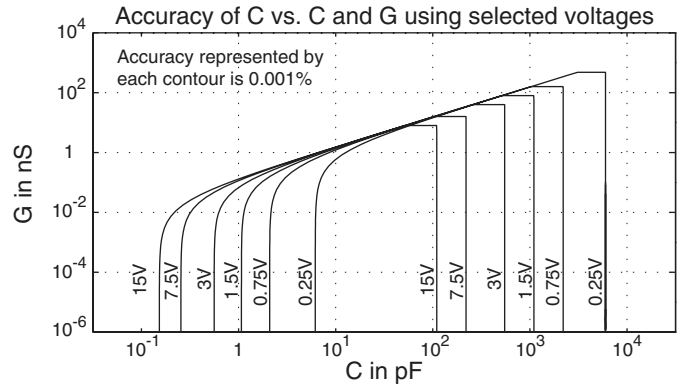
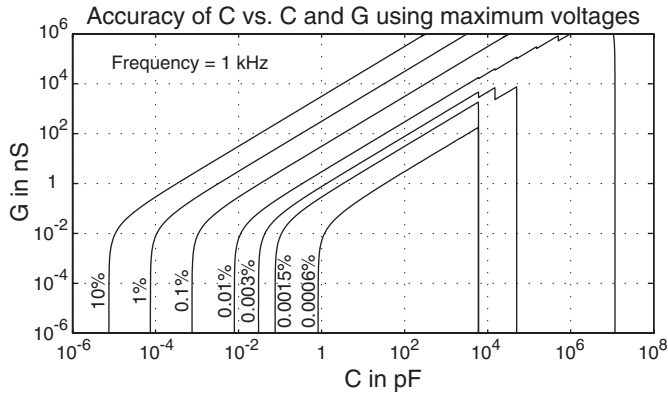
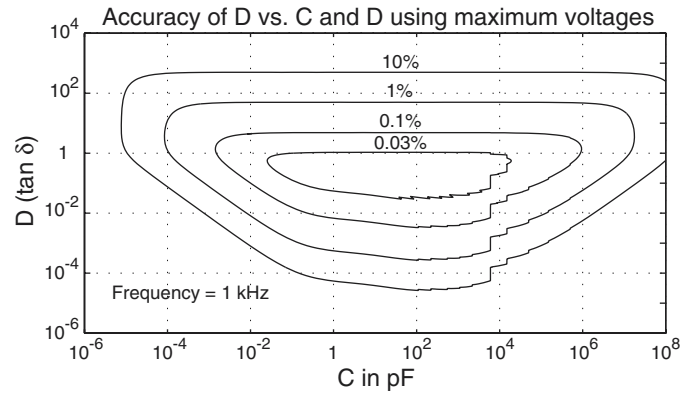
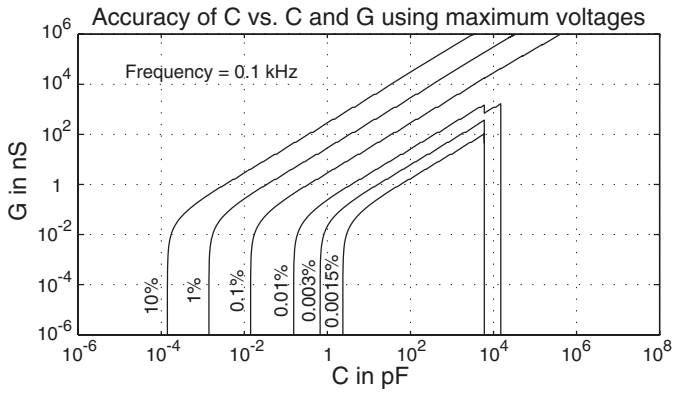


Temperature Coefficient of C vs. Frequency



Temperature Coefficient of D vs. Frequency





The AH2700A incorporates a connector on its rear panel that is intended to provide signals to control an external coaxial switch. Such a switch is useful for selecting among several unknown samples. An AH2700A command is provided to allow program control of such a switch.

At the time of publication of this manual, Andeen-Hagerling does not manufacture a sample switch. However, such a product is planned. If you are interested, watch for announcements.

In the meantime, the sample switch port can be used to control sample switches of your own design. It is also not difficult to build an interface to commercially available products if you have some electronics experience.

Basic Operation

The sample switch port is a parallel port with eight data lines and a strobe line. These lines use RS-232 drivers that produce ± 12 volt signal levels. Five power lines are also present. These can provide up to 100 mA of current to external devices. The two 24 volt power supplies are unregulated. The other three supplies are well regulated.

The eight data lines are decoded so that only one line is true at a time. The lines are high-true which means that one line will always produce +12 volts and all the rest will produce -12 volts. These data lines can be connected directly to non-inverting relay driver circuits with no further decoding or other logic. This allows one of up to eight relays to be selectively closed.

Connector Description

The connector on the backpanel is a fifteen pin female “D” style. The pinout of this connector is given in Table D-1.

Selecting a Sample Switch Position

The data line that is true is selected with the following command:

SAMPLE *Number*

The *Number* parameter specifies the sample to be measured. It can have any value from 1 to 64, however, values of this parameter larger than eight will cause all sample switch data lines to be false. Values from one to eight will cause one of the eight sample switch data lines to be true. The number of the selected sample switch signal name is one less than the value of the *Number* parameter. These values are listed in Table D-1. The default value of the sample switch *Number*

Table D-1 Sample switch connector pinouts

Pin No.	Signal Name	Signal Description	True for Number
1	SD0	Sample Switch Data 0	1
2	SD2	Sample Switch Data 2	3
3	SD4	Sample Switch Data 4	5
4	SD6	Sample Switch Data 6	7
5	GND	Ground	
6	+5V	+5 Volt Power	
7	+24V	+24 Volt Power	
8	+12V	+12 Volt Power	
9	SD1	Sample Switch Data 1	2
10	SD3	Sample Switch Data 3	4
11	SD5	Sample Switch Data 5	6
12	SD7	Sample Switch Data 7	8
13	SC	Sample Switch Data Valid	
14	-12V	-12 Volt Power	
15	-24V	-24 Volt Power	

parameter stored in the BASIC FACTPON parameter file is 1.

The utility of the SAMPLE command may be greatly enhanced when used with the AH2700A’s macro features. Obviously, the SAMPLE command is also useful when incorporated into macros run on remote controllers.

Signal Timing

The sample switch port has two timing issues. One is the timing of the strobe line relative to the data lines. The other is amount of time to wait after changing the sample switch setting before taking a measurement. This is called the settling time.

The Strobe Line Timing

If the sample switch data lines directly control relay driver circuits with no logic in between, then the Sample Switch Data Valid line will not be used. On the other hand, if the data from the sample switch data lines is to be externally latched, then the Sample Switch Data Valid line will be required to strobe the latch.

The Data Valid line is true when the sample switch data is stable and false when it may not be. The Data Valid line goes false (-12V) 250 microseconds before the data lines change. It goes true again (+12V) 250 microseconds after they change. If the data is to be strobed into a latch, this would normally be done by using the false-to-true transition of the Data Valid line.

Changing the Settling Time

A time delay can be specified that automatically occurs after each execution of the SAMPLE command. This provides a settling time for sample switch relays to stabilize after being switched. The syntax of the command that specifies this delay is:

```
WAITFOR SAMPLE DelaySmp
```

This *Delay* parameter is entered in seconds to the nearest hundredth.

The SAMPLE command will not finish until the delay time has expired. This holds off any further operations.

The *DelaySmp* time is the same no matter what sample number has been selected. If some samples require a longer settling time than others, additional settling time can be provided by executing the `WAITFOR DelaySmp` command after executing the SAMPLE command for the faster samples.

If the SAMPLE command is executed with a long delay time, you must wait for this time to elapse or abort the SAMPLE command with a DEVICE CLEAR command.

The default value of the sample switch *DelaySmp* parameter stored in the BASIC FACTPON parameter file is 0.0 seconds.

This appendix is reserved for options that will become available for the AH2700A.

Table F-1 Manufacturer identification list

Mfg ID	Manufacturer name
00779	AMP INC
01295	TEXAS INSTRUMENTS
03508	GE CO.
04713	MOTOROLA INC
05245	CORCOM
06383	PANDUIT CORP
06665	PRECISION MONOLITHICS
06776	ROBINSON-NUGENT INC
0APZ0	LITE-ON
0CVK3	ALLEGRO MICRO SYSTEMS
0GP37	COM CLOK
0LUT2	TOYOCOM USA INC
0UR04	TOSHIBA AMERICA INC
13919	BURR-BROWN
14936	GENERAL INSTRUMENT CORP
17856	SILICONIX INC
18310	CONCORD ELECTR CORP
18612	VISHAY RESISTORS
19080	ROBISON ELECTRONICS INC
1ES66	MAXIM INTEGRATED PROD.
1UCW6	CENTRAL TECHNOLOGIES
20940	MICRO-OHM CORP
22526	BERG SYSTEMS INTL
24355	ANALOG DEVICES
25088	SIEMENS (USA) INC
27014	NATIONAL SEMICONDUCTOR
28480	HEWLETT-PACKARD CO
31433	KEMET ELECTRONICS CORP
32559	BIVAR
34335	ADVANCED MICRO DEVICES
34371	HARRIS CORP
3A557	AEG-TELEFUNKEN
44648	SAMSUNG SEMICONDUCTOR
46384	PENN ENGINEERING & MFG.
4J977	ANDEEN-HAGERLING
4U402	ROEDERSTEIN ELECTRONICS
50088	ST-MICRO (SGS)
50773	FAIRCHILD SEMICONDUCTOR
54473	PANASONIC
55680	NICHICON AMERICA INC
56289	SPRAGUE

Table F-1 Manufacturer identification list

Mfg ID	Manufacturer name
56637	RCD
5F520	PANEL COMPONENTS INC
60991	MICROCHIP
62798	HITACHI AMERICA LTD
63060	VICTOREEN
64667	NATIONAL INSRTUMENTS
66182	INTERFET
67318	MEPCO/PHILIPS
68919	WIMA
70097	CATALYST SEMICONDUCTOR
70903	BELDEN WIRE & CABLE
71482	CLARE C.P.CORP
71590	CENTRALAB/PHILIPS
71707	COTO WABASH
74868	AMPHENOL CORP
75915	LITTELFUSE INC
77569	NORTHAMERICAN PHILIPS
7W718	MARQUARDT SWITCHES INC
7X328	SGS/THOMSON MICROELEC
80207	C&K COMPONENTS INC
80294	BOURNS INC
91637	DALE ELECTRONICS INC
96095	AVX/KYOCERA GRP INC
SG260	SIEKO EPSON CORP

Table F-2 Capacitance bridge parts list

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
A001	042-0009	CAPACITANCE BRIDGE FINAL ASSEMBLY	4J977	042-0009
F701	006-XXXX	FUSE, PICK FROM FUSE F701 PICK LIST	4J977	006-XXXX
MAN	039-0005	MANUAL, 2550A OPERATION AND MAINT	4J977	039-0005
PKG1	038-0001	CARTON, CARDBOARD PRINTED	4J977	038-0001
PKG2	038-0002	INSERTS, FOAM FOR SHIPPING CARTON	4J977	038-0002
W903	030-XXXX	LINE CORD, PICK FROM LINE CORD W903 PICK LIST	4J977	030-XXXX

Table F-3 Fuse (F701) pick list

Voltage	A-H P/N	F701 fuse value	Mfg ID	Mfg P/N
100-120 V	006-0001	FUSE, 0.50 A 250 V	75915	313.500
220-250 V	006-0003	FUSE, 0.25 A 250 V	75915	313.250

Table F-4 Line cord (W903) pick list

Country	Voltage	A-H P/N	W903 line cord	Mfg ID	Mfg P/N
AUSTRALIA	240 V	030-0060	LINE CORD, AUSTRALIA	5F520	86516070
CONTINENTAL EUROPE	220 V	030-0061	LINE CORD, CONT EUROPE	5F520	86511052
DENMARK	220 V	030-0062	LINE CORD, DENMARK	5F520	86536040
INDIA	220 V	030-0063	LINE CORD, INDIA	5F520	86559011
ISRAEL	230 V	030-0064	LINE CORD, ISRAEL	5F520	86558010
ITALY	220 V	030-0065	LINE CORD, ITALY	5F520	86531031
SWITZERLAND	220 V	030-0066	LINE CORD, SWISS	5F520	86515050
U.S., JAPAN	120 V	030-0011	LINE CORD, U.S.,JAPAN	70903	17250
UNITED KINGDOM	240 V	030-0067	LINE CORD, U.K.	5F520	86552007

Table F-5 Capacitance bridge exploded view parts list

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
A101	041-0018	A101 BOARD ASSEMBLY, MAIN	4J977	041-0018
A301	041-0019	A301 BOARD ASSEMBLY, PROCESSOR	4J977	041-0019
A401	041-0020	A401 BOARD ASSEMBLY, MULTIPLEXER	4J977	041-0020
A501	041-0021	A501 BOARD ASSEMBLY, DISPLAY	4J977	041-0021
A502	041-0008	A502 BOARD ASSEMBLY, KEYPAD	4J977	041-0008
A601	041-0017	A601 BOARD ASSEMBLY, PREAMP	4J977	041-0017
A701	041-0007	A701 BOARD ASSEMBLY, POWER SUPPLY	4J977	041-0007
C210	002-0010	CAPACITOR, STANDARD ASSY 80 PF	4J977	002-0010
HK101	025-1001	KIT, HARDWARE, BOARD MOUNTING	4J977	025-1001
J701	004-0038	MODULE, POWER LINE INPUT	05245	6VM4C
J918	004-0033	JACK, BNC UG-1094	74868	31-221
J919	004-0033	JACK, BNC UG-1094	74868	31-221
MP902	036-9005	MIDPLANE ASSY	4J977	036-9005
MP904	036-9007	DEEP DRAWN BOX ASSY, PREAMP	4J977	036-9007
MP905	036-0005	COVER, DEEP DRAWN BOX	4J977	036-0005
MP906	036-0006	COVER, POWER LINE CONNECTION	4J977	036-0006
MP908	036-0034	PANEL, REAR COMMON	4J977	036-0034
MP909	036-0033	PANEL, FRONT 2550	4J977	036-0033
MP9XX	036-0010	CABINET KIT; SEE CABINET KIT PARTS LIST	4J977	036-0010
T701	003-0001	TRANSFORMER, POWER	4J977	003-0001
W619	030-0048	CABLE ASSY, COAXIAL, DC BIAS	4J977	030-0048
W701	030-0045	CABLE ASSY, POWER SWITCH	4J977	030-0045
W901	030-0046	CABLE ASSY, COAXIAL, LOW INPUT	4J977	030-0046
W902	030-0047	CABLE ASSY, COAXIAL, HIGH INPUT	4J977	030-0047
W905	030-0042	CABLE ASSY, RIBBON, 16-PIN SOCKET TO 15-PIN D	4J977	030-0042
W912	030-0066	CABLE ASSY, RIBBON, 10-PIN SOCKET TO 9-PIN D Male	4J977	030-0066
W913	030-0044	CABLE ASSY, RIBBON, 24-PIN SOCKET TO GPIB	4J977	030-0044
W918	030-0049	CABLE ASSY, COAXIAL, EXTERNAL TRIGGER	4J977	030-0049
W920	030-0067	CABLE ASSY, RIBBON, 10-PIN SOCKET TO 9-PIN D Fem	4J977	030-0067

Table F-6 Cabinet kit (MP9XX) parts list

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
HK102	025-1002	KIT, HARDWARE, CABINET	4J977	025-1002
MP910	036-0011	KIT, RACK MOUNTING	4J977	036-0011
MP912	036-0012	BAIL, INSTRUMENT	4J977	036-0012
MP913	036-0013	CASTING, SIDE, FITS EITHER SIDE	4J977	036-0013
MP914	036-0023	PANEL, SIDE LARGE	4J977	036-0023
MP915	036-0024	PANEL, SIDE SMALL	4J977	036-0024
MP916	036-0016	BRACKET, MOUNTING FRONT	4J977	036-0016
MP917	036-0017	BRACKET, MOUNTING REAR	4J977	036-0017
MP918	036-0018	FEET, FRONT, PAIR	4J977	036-0018
MP919	036-0019	FEET, REAR, PAIR	4J977	036-0019
MP920	036-0020	BEZEL, TOP, AND BOTTOM ARE SAME	4J977	036-0020
MP921	036-0021	COVER, TOP	4J977	036-0021
MP922	036-0022	COVER, BOTTOM	4J977	036-0022

Table F-7 Power supply assembly (A701) parts list

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
C703	002-0001	CAPACITOR, 1.0 μ F 100V CER Z5U	71590	CZ30C105Z
C704	002-0001	CAPACITOR, 1.0 μ F 100V CER Z5U	71590	CZ30C105Z
C705	002-0002	CAPACITOR, 3300 μ F 35V ALUM	55680	TLB1V332M
C706	002-0002	CAPACITOR, 3300 μ F 35V ALUM	55680	TLB1V332M
C707	002-0003	CAPACITOR, 0.33 μ F 50V CER Z5U	96095	SR215E334ZAT
C708	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	71590	CZ20C104Z
C709	002-0003	CAPACITOR, 0.33 μ F 50V CER Z5U	96095	SR215E334ZAT
C710	002-0003	CAPACITOR, 0.33 μ F 50V CER Z5U	96095	SR215E334ZAT
C711	002-0005	CAPACITOR, 15000 μ F 15V ALUM	55680	TLB 1C 153M
C712	002-0003	CAPACITOR, 0.33 μ F 50V CER Z5U	96095	SR215E334ZAT
C713	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	71590	CZ20C104Z
C714	002-0003	CAPACITOR, 0.33 μ F 50V CER Z5U	96095	SR215E334ZAT
C715	002-0001	CAPACITOR, 1.0 μ F 100V CER Z5U	71590	CZ30C105Z
C716	002-0001	CAPACITOR, 1.0 μ F 100V CER Z5U	71590	CZ30C105Z
C717	002-0001	CAPACITOR, 1.0 μ F 100V CER Z5U	71590	CZ30C105Z
CR701	009-0001	RECTIFIER, 3A 1N5624	03508	A15F
CR702	009-0001	RECTIFIER, 3A 1N5624	03508	A15F
F702	006-0002	FUSE, 3A PICO	75915	251003
MP901	036-9006	POWER SUPPLY FRAME ASSY	4J977	036-9006
Q701	022-0001	THYRISTOR, 3A 50V	04713	C122A1
R701	001-0001	RESISTOR, 470 Ω 1/4W 5% CARBON	20940	RCR07G471JS
R702	001-0004	RESISTOR, 10 Ω 1/4W 5% CARBON	20940	RCR07G100JS
RV701	033-0001	VARISTOR, 40 AMP, 39 V 10% V39MA2B	03508	V39MA2B
U701	007-0001	IC, LM340, +12V REGULATOR, 4% TO-220	27014	LM340T-12
U702	007-0002	IC, 7912, -12V REGULATOR, 4% TO-220	04713	MC7912CT
U703	007-0003	IC, LM323K, +5V REGULATOR, 4% TO-3	7X328	LM323K
U704	007-0004	RECTIFIER, BRIDGE 1A	14936	W02G
VR701	010-0001	DIODE, ZENER 1N5232B, 5.6V 0.5 W 5%	04713	1N5232B
W702	030-0050	CABLE ASSY, 8-WIRE POWER SUPPLY	4J977	030-0050

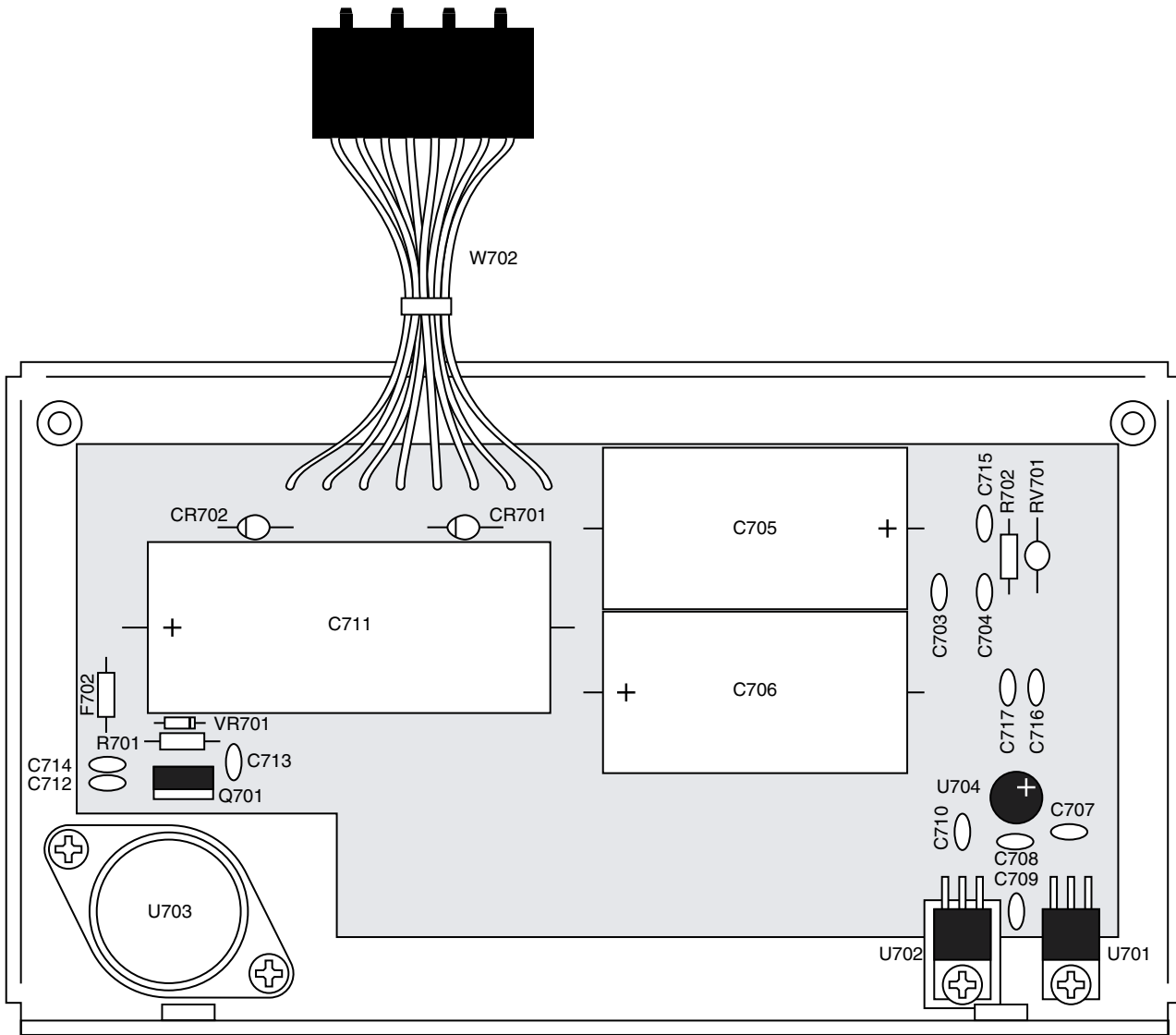


Figure F-7 Power supply (A701) assembly dwg

Table F-8 Processor board (A301) parts list (Sheet 1 of 4)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
C301	002-0054	CAPACITOR, 1.0 F 5.5v	54473	EEC-F5R5U105
C302	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C303	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C304	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C305	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C306	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C307	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C308	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C309	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C310	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C311	002-0043	CAPACITOR, 22 µF 16V TANT 10%, SMD	56289	293D226X9016D2T
C312	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C313	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C314	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C315	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C316	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C317	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C318	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C319	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C320	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C321	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C322	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C323	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C324	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C325	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C326	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C327	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C328	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C329	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C330	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C331	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C332	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C333	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C334	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C335	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C336	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C337	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C338	002-0030	CAPACITOR, 0.1 µF 50V CER Z5U, SMD	96095	12065C104KATMA
C340	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C342	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C343	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C344	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C345	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C346	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C347	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C348	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C349	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C350	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C351	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C352	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200

Table F-8 Processor board (A301) parts list (Sheet 2 of 4)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
C353	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C354	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C355	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C356	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C357	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
C358	002-0031	CAPACITOR, 47pf, COG 5% SMD	77569	1206CG470J9B200
D301	009-0003	DIODE, 1N4148, SMD	27014	FDLL4148
D302	009-0003	DIODE, 1N4148, SMD	27014	FDLL4148
D303	009-0003	DIODE, 1N4148, SMD	27014	FDLL4148
DS301	015-0007	LED, GREEN, SMD	0APZ0	LTST-C150GKT
J302	004-0011	CONNECTOR, 8 PIN AMP MODU RT ANGLE	00779	87632-8
J303	004-0008	HEADER, 40-PIN RIGHT ANGLE W / LATCHES	06383	050-040-053A
J304	004-0006	HEADER, 16-PIN RIGHT ANGLE W / LATCHES	06383	050-016-053A
J305	004-0006	HEADER, 16-PIN RIGHT ANGLE W / LATCHES	06383	050-016-053A
J306	004-0010	HEADER, 10-PIN RIGHT ANGLE W / LATCHES	06383	050-010-053A
J312	004-0035	HEADER, 10-PIN RIGHT ANGLE	06383	057-010-053
J313	004-0009	HEADER, 26-PIN RIGHT ANGLE W / LATCHES	06383	050-026-053A
J318	004-0032	HEADER POST, 2-PIN RIGHT ANGLE	22526	68015-236
J320	004-0035	HEADER, 10-PIN RIGHT ANGLE	06383	057-010-053
JP302	004-0031	HEADER POST, 2-PIN	22526	65500-136
JP303	004-0031	HEADER POST, 2-PIN	22526	65500-136
JP304	004-0031	HEADER POST, 2-PIN	22526	65500-136
JP305	004-0031	HEADER POST, 2-PIN	22526	65500-136
JP306	004-0031	HEADER POST, 2-PIN	22526	65500-136
JP307	004-0031	HEADER POST, 3-PIN	22526	65500-136
JP308	004-0031	HEADER POST, 3-PIN	22526	65500-136
L301	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L302	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L303	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L304	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L305	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L306	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L307	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L308	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L309	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L310	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L311	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L312	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L313	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L314	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L315	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L316	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L317	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
L318	008-0004	INDUCTOR, 4.7μH, SMD	1UCW6	CTMC1210-4R7J
R301	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R302	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R303	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R304	001-0078	RESISTOR, 820 Ω ,1/4 W, 5%, SMD	56637	MC1206 8200-JT
R305	001-0078	RESISTOR, 820 Ω ,1/4 W, 5%, SMD	56637	MC1206 8200-JT
R306	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT

Table F-8 Processor board (A301) parts list (Sheet 3 of 4)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
R307	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R308	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R309	001-0078	RESISTOR, 820 Ω ,1/4 W, 5%, SMD	56637	MC1206 8200-JT
R310	023-0057	RESISTOR, 30.1 kΩ ,1/4 W, 1%, SMD	56637	MC1206 3012-FT
R311	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R312	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R313	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R314	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R315	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R316	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R317	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R318	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R319	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R320	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R321	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R322	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R323	001-0078	RESISTOR, 820 Ω ,1/4 W, 5%, SMD	56637	MC1206 8200-JT
R324	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R325	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R326	001-0078	RESISTOR, 820 Ω ,1/4 W, 5%, SMD	56637	MC1206 8200-JT
R327	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R328	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R329	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R330	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R331	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R332	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R333	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R334	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R335	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R338	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R339	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R340	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R341	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
R342	001-0083	RESISTOR, 10 kΩ ,1/4 W, 5%, SMD	56637	MC1206 1002-JT
TP301	024-0001	TEST POINT, GROUND	18310	10-209-2-01
U301	007-0062	IC, 25C040, SERIAL EEPROM, SMD	60991	25LC040/SN
U302	007-0079	IC, 74HC08, QUAD TWO INPUT AND GATE, SMD	77569	74HC08D
U303	007-0081	IC, 74HC125, QUAD TRI-STATE BUFFER, SMD	77569	74HC125D
U304	007-0072	IC, MC34064, RESET GENERATOR, SMD	04713	MC34064D-5
U305	007-0081	IC, 74HC125, QUAD TRI-STATE BUFFER, SMD	77569	74HC125D
U306	007-0080	IC, 74HC32, QUAD TWO INPUT OR GATE, SMD	77569	74HC32D
U307	007-0078	IC, 74HC04, HEX INVERTER, SMD	77569	74HC04D
U308	007-0061	DIGITAL SIG. PROCESSOR, 2181 20 MHZ,SMD	24355	ADSP2181KS-160
U309	007-0085	IC, BQ4845, TIME OF DAY CLOCK, SMD	01295	BQ4845S-A4
U310	007-0083	IC, 74HC541, OCTAL TRI-STATE BUFFER, SMD	77569	74HC541D
U311	007-0078	IC, 74HC04, HEX INVERTER, SMD	77569	74HC04D
U312	007-0086	IC, TNT4882, GPIB CONTROLLER, DRIVER, SMD	64667	TNT4882-BQ
U313	007-0074	MICROPROCESSOR, 68332 25 MHZ, SMD	04713	MC68332GCFC25
U314	007-0082	IC, 74HC374, OCTAL LATCH, SMD	50773	74HC374DW
U315	007-0088	RAM, HM621664, 16 BIT X 65,536 WORDS, SMD	62798	HM621664HBJP-15

Table F-8 Processor board (A301) parts list (Sheet 4 of 4)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
U316	007-0092	IC, 1488E, QUAD RS-232 DRIVER ESD-PROTECT	1ES66	MAX1488ECPD
U317	007-0092	IC, 1488E, QUAD RS-232 DRIVER ESD-PROTECT	1ES66	MAX1488ECPD
U318	007-0090	FLASH MEM, 29F800A, 16 B X 512K WORDS, SMD	34335	AM29F800BB-70SC
U319	007-0092	IC, 1488E, QUAD RS-232 DRIVER ESD-PROTECT	1ES66	MAX1488ECPD
U320	007-0093	IC, 1489E, QUAD RS-232 RCVR ESD-PROTECT	1ES66	MAX1489ECPD
U321	007-0063	EPROM, 27C040, 8 BIT X 512K	34335	AM27C040-150DC
U322	007-0089	EEPROM, 28C256, PROGRAMMED FOR BRIDGE BY S/N	70097	CAT28C256P-15
X316	014-0007	SOCKET, IC 14-PIN, SOLDER	00779	2-641599-2
X317	014-0007	SOCKET, IC 14-PIN, SOLDER	00779	2-641599-2
X319	014-0007	SOCKET, IC 14-PIN, SOLDER	00779	2-641599-2
X320	014-0007	SOCKET, IC 14-PIN, SOLDER	00779	2-641599-2
X321	014-0013	SOCKET, IC 32-PIN, SOLDER 0.6IN	4J977	014-0013
X322	014-0006	SOCKET, IC 28-PIN, SOLDER 0.6IN	4J977	014-0006
Y301	018-0007	XTAL, 32.768 KHZ .02%, SMD	SG260	MC406-32.768K-E2
Y302	018-0004	OSCILLATOR, 20.0 MHZ .005% TTL DIP	0GP37	CM12AF-20.0000 MHZ
Y303	018-0005	OSCILLATOR, 22.1184 MHZ .005% TTL DIP	0GP37	CM12AF-22.1184 MHZ
	005-0026	SHORTING JUMPERS (7 PCS)	22526	71363-202

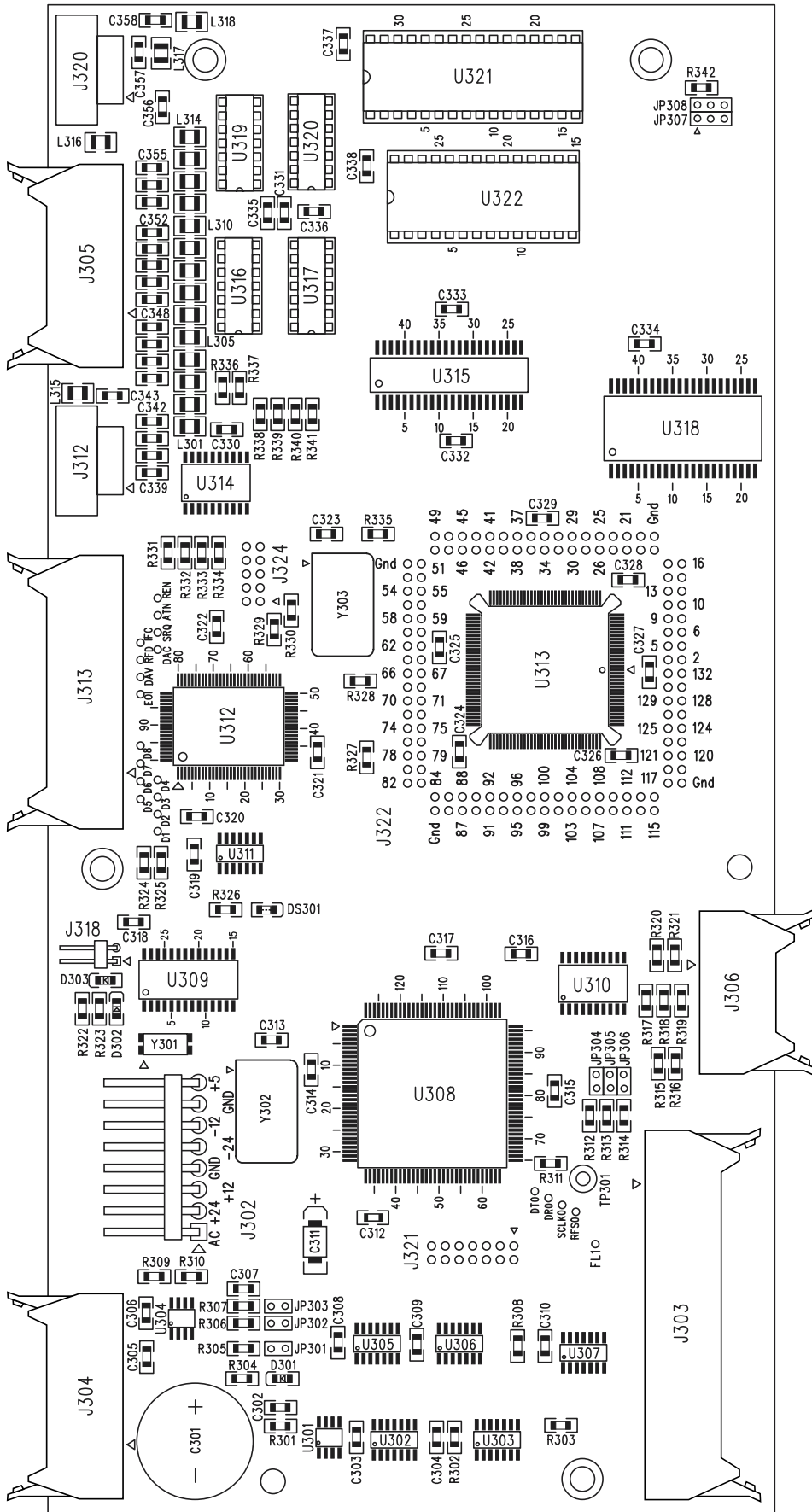


Figure F-9 Processor board (A301) assembly dwg

Table F-9 Keypad board (A502) parts list

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
SW501	012-0003	SWITCH, BLACK WITH "1" LEGEND	7W718	6450-0015
SW502	012-0004	SWITCH, BLACK WITH "2" LEGEND	7W718	6450-0025
SW503	012-0005	SWITCH, BLACK WITH "3" LEGEND	7W718	6450-0035
SW504	012-0006	SWITCH, BLACK WITH "4" LEGEND	7W718	6450-0045
SW505	012-0007	SWITCH, BLACK WITH "5" LEGEND	7W718	6450-0055
SW506	012-0008	SWITCH, BLACK WITH "6" LEGEND	7W718	6450-0065
SW507	012-0009	SWITCH, BLACK WITH "7" LEGEND	7W718	6450-0075
SW508	012-0010	SWITCH, BLACK WITH "8" LEGEND	7W718	6450-0085
SW509	012-0011	SWITCH, BLACK WITH "9" LEGEND	7W718	6450-0095
SW510	012-0002	SWITCH, BLACK WITH "0" LEGEND	7W718	6450-0105
SW511	012-0013	SWITCH, BLACK WITH "." LEGEND	7W718	6450-0315
SW512	012-0017	SWITCH, BLACK WITHOUT LEGEND	7W718	6450-0005
SW513	012-0012	SWITCH, YELLOW WITHOUT LEGEND	7W718	6450-0007
SW514	012-0016	SWITCH, DARK GRAY WIHOUT LEGEND	7W718	6450-0003
SW515	012-0018	SWITCH, DARY GRAY WITH UP ARROW	7W718	6450-0003 W/UP ARROW
SW516	012-0019	SWITCH, DARK GRAY WITH DOWN ARROW	7W718	6450-0003 W/DOWN ARROW
SW517	012-0020	SWITCH, DARK GRAY WITH LEFT ARROW	7W718	6450-0003 W/LEFT ARROW
SW518	012-0021	SWITCH, DARK GRAY WITH RIGHT ARROW	7W718	6450-0003 W/RIGHT ARROW
W506	030-0012	CABLE ASSY, RIBBON, 10-PIN	4J977	030-0012

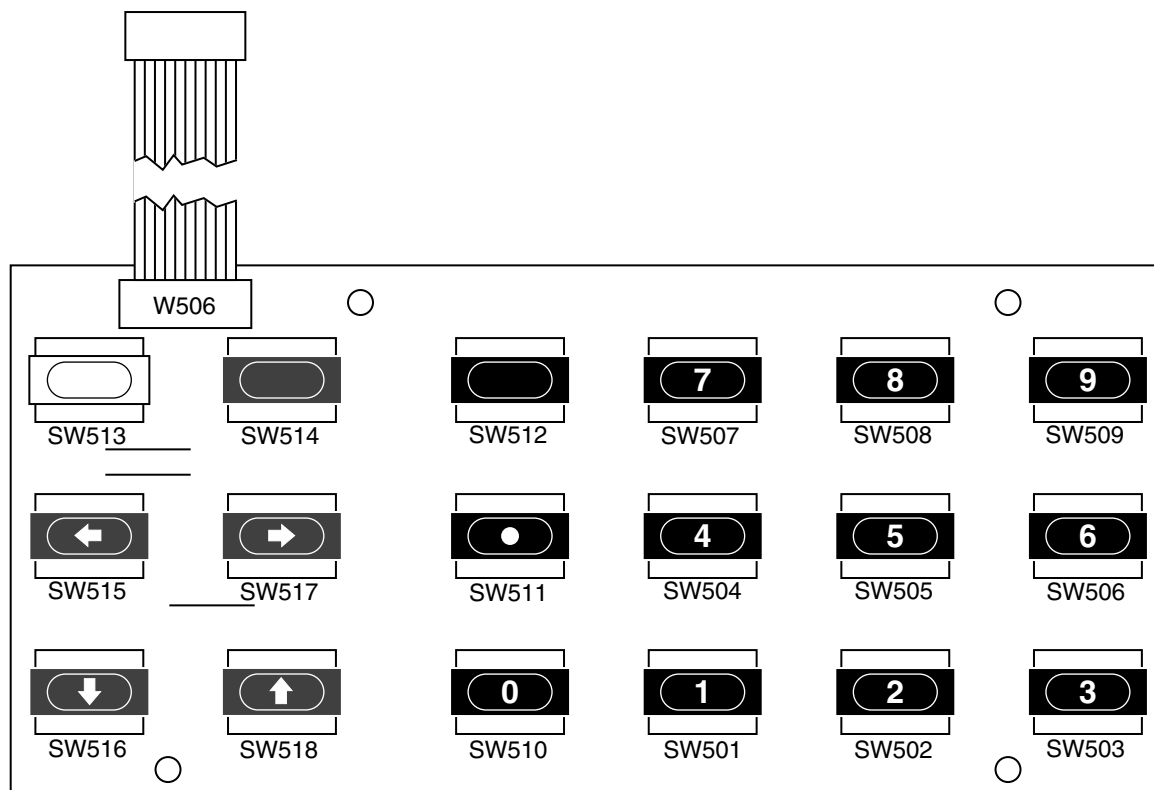


Figure F-14 Keypad board (A502) assembly dwg

Table F-10 Display board (A501) parts list

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
C501	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C502	002-0025	CAPACITOR, 120 pF 50V CER COG 10%	96095	SR151A121KAA
C503	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C504	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C505	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C506	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C507	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C508	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C509	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C510	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C511	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C512	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C513	002-0004	CAPACITOR, 0.1 μ F 50V CER Z5U	96095	SR205E104MAA
C514	002-0043	CAPACITOR, 22 μ F 16v TANT 10%, SMD	56289	293D266X9016D2T
DS501	015-0005	DISPLAY, 14-SEG LED, 0.56 IN ORANGE	0APZ0	LTP-3786E
DS502	015-0005	DISPLAY, 14-SEG LED, 0.56 IN ORANGE	0APZ0	LTP-3786E
DS503	015-0005	DISPLAY, 14-SEG LED, 0.56 IN ORANGE	0APZ0	LTP-3786E
DS504	015-0005	DISPLAY, 14-SEG LED, 0.56 IN ORANGE	0APZ0	LTP-3786E

Table F-10 Display board (A501) parts list

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
DS505	015-0005	DISPLAY, 14-SEG LED, 0.56 IN ORANGE	0APZ0	LTP-3786E
DS506	015-0005	DISPLAY, 14-SEG LED, 0.56 IN ORANGE	0APZ0	LTP-3786E
DS507	015-0005	DISPLAY, 14-SEG LED, 0.56 IN ORANGE	0APZ0	LTP-3786E
DS508	015-0005	DISPLAY, 14-SEG LED, 0.56 IN ORANGE	0APZ0	LTP-3786E
DS509	015-0006	DISPLAY, 7-SEG LED, 0.40 IN ORANGE	28480	HDSP-F401
DS510	015-0006	DISPLAY, 7-SEG LED, 0.40 IN ORANGE	28480	HDSP-F401
DS511	015-0006	DISPLAY, 7-SEG LED, 0.40 IN ORANGE	28480	HDSP-F401
DS512	015-0006	DISPLAY, 7-SEG LED, 0.40 IN ORANGE	28480	HDSP-F401
DS513	015-0006	DISPLAY, 7-SEG LED, 0.40 IN ORANGE	28480	HDSP-F401
DS514	015-0002	DISPLAY, LED, 4 SECTION, RED, DIP	28480	HLMP-2620
DS515	015-0004	DISPLAY, LED, 1 SECTION, RED , DIP	28480	HLMP-2300F
DS516	015-0002	DISPLAY, LED, 4 SECTION, RED, DIP	28480	HLMP-2620
DS517	015-0004	DISPLAY, LED, 1 SECTION, RED , DIP	28480	HLMP-2300F
Q501	007-0087	DUAL FET TRANSISTOR, SMD	17856	SI9933DY
Q502	007-0087	DUAL FET TRANSISTOR, SMD	17856	SI9933DY
R501	016-0001	RESISTOR NETWORK, 82 Ω 10% 16 PIN DIP	80294	4116R-1-820
R502	016-0001	RESISTOR NETWORK, 82 Ω 10% 16 PIN DIP	80294	4116R-1-820
R503	016-0001	RESISTOR NETWORK, 82 Ω 10% 16 PIN DIP	80294	4116R-1-820
R504	016-0001	RESISTOR NETWORK, 82 Ω 10% 16 PIN DIP	80294	4116R-1-820
R505	016-0001	RESISTOR NETWORK, 82 Ω 10% 16 PIN DIP	80294	4116R-1-820
R506	016-0001	RESISTOR NETWORK, 82 Ω 10% 16 PIN DIP	80294	4116R-1-820
R507	016-0001	RESISTOR NETWORK, 82 Ω 10% 16 PIN DIP	80294	4116R-1-820
R508	016-0001	RESISTOR NETWORK, 82 Ω 10% 16 PIN DIP	80294	4116R-1-820
R509	016-0001	RESISTOR NETWORK, 82 Ω 10% 16 PIN DIP	80294	4116R-1-820
R510	016-0001	RESISTOR NETWORK, 82 Ω 10% 16 PIN DIP	80294	4116R-1-820
R517	001-0085	RESISTOR, 120 kΩ 1/4W 5% CARBON, SMD	56637	MC1206 1203-JT
R518	001-0081	RESISTOR, 4.7 kΩ 1/4W 5% CARBON,SMD	56637	MC1206 4701-JT
R522	001-0081	RESISTOR, 4.7 kΩ 1/4W 5% CARBON,SMD	56637	MC1206 4701-JT
R523	001-0081	RESISTOR, 4.7 kΩ 1/4W 5% CARBON,SMD	56637	MC1206 4701-JT
R524	001-0081	RESISTOR, 4.7 kΩ 1/4W 5% CARBON,SMD	56637	MC1206 4701-JT
R525	001-0081	RESISTOR, 4.7 kΩ 1/4W 5% CARBON,SMD	56637	MC1206 4701-JT
TP501	024-0001	TEST POINT, GROUND	18310	10-209-2-01
U501	007-0071	IC, 4794B, 8 BIT SHIFT REG, LED DRIVER	77569	HEF4794BPN
U502	007-0071	IC, 4794B, 8 BIT SHIFT REG, LED DRIVER	77569	HEF4794BPN
U503	007-0071	IC, 4794B, 8 BIT SHIFT REG, LED DRIVER	77569	HEF4794BPN
U504	007-0071	IC, 4794B, 8 BIT SHIFT REG, LED DRIVER	77569	HEF4794BPN
U505	007-0071	IC, 4794B, 8 BIT SHIFT REG, LED DRIVER	77569	HEF4794BPN
U506	007-0071	IC, 4794B, 8 BIT SHIFT REG, LED DRIVER	77569	HEF4794BPN
U507	007-0071	IC, 4794B, 8 BIT SHIFT REG, LED DRIVER	77569	HEF4794BPN
U508	007-0071	IC, 4794B, 8 BIT SHIFT REG, LED DRIVER	77569	HEF4794BPN
U509	007-0076	IC, 74HC423, DUAL MONOSTABLE	77569	74HC423N
U510	007-0071	IC, 4794B, 8 BIT SHIFT REG, LED DRIVER	77569	HEF4794BPN
U511	007-0071	IC, 4794B, 8 BIT SHIFT REG, LED DRIVER	77569	HEF4794BPN
W504	030-0065	CABLE ASSY, RIBBON, 16-PIN W/FERRITE CORE	4J977	030-0065
	025-0050	BIVAR SPACERS -(16 PCS)	32559	336-300

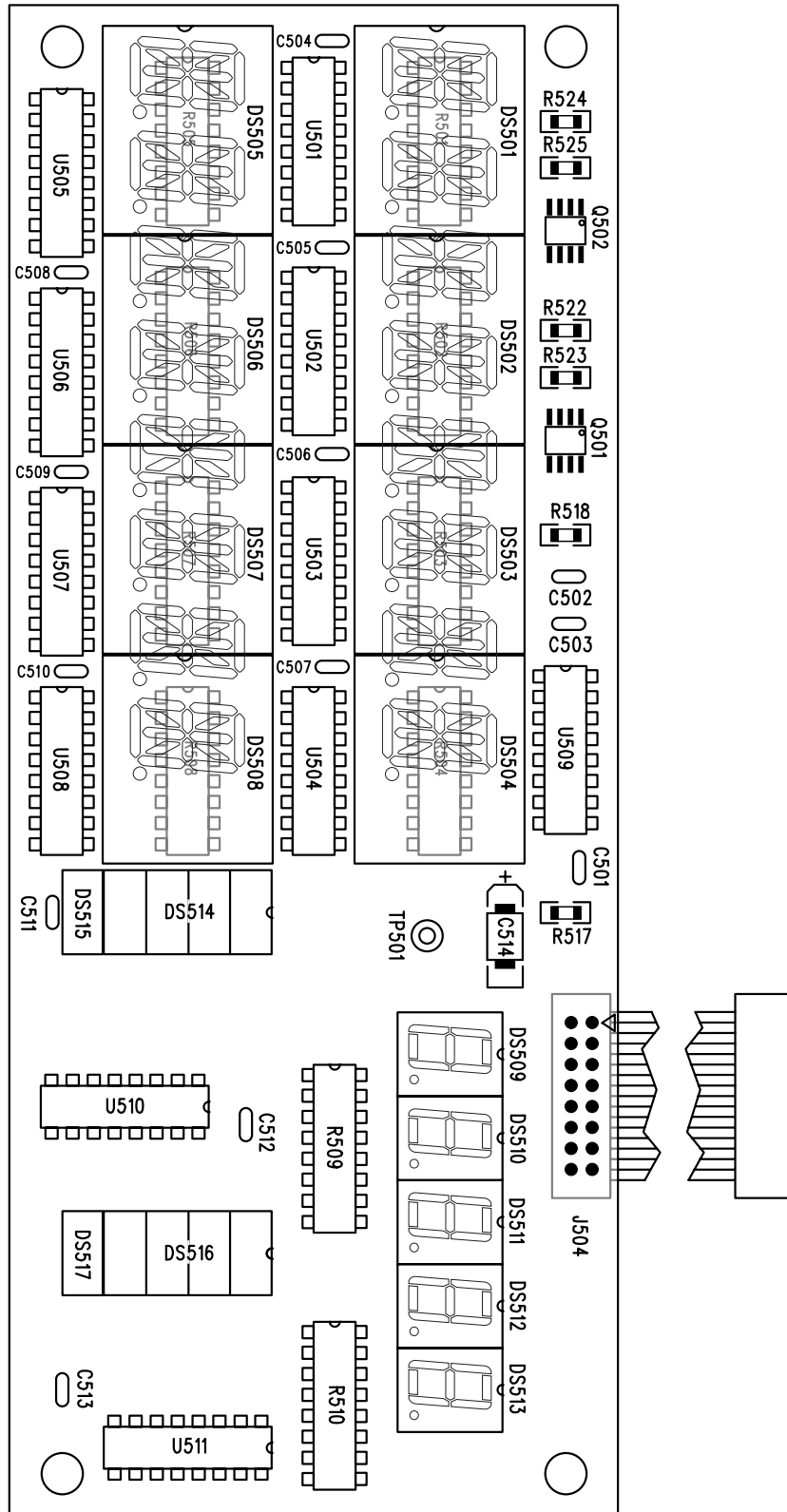


Figure F-15 Display board (A501) assembly dwg

Table F-11 Multiplexer board (A401) parts list (Sheet 1 of 5)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
C401	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C402	002-0045	CAPACITOR, 10 µF 16V TANT 20%, SMD	56289	293D106X0016B2W
C403	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C404	002-0045	CAPACITOR, 10 µF 16V TANT 20%, SMD	56289	293D106X0016B2W
C405	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C406	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C407	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C408	002-0044	CAPACITOR, 1.0 µF 16v TANT 20%, SMD	56289	293D105X0025A2W
C409	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C410	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C411	002-0044	CAPACITOR, 1.0 µF 16v TANT 20%, SMD	56289	293D105X0025A2W
C412	002-0044	CAPACITOR, 1.0 µF 16v TANT 20%, SMD	56289	293D105X0025A2W
C413	002-0044	CAPACITOR, 1.0 µF 16v TANT 20%, SMD	56289	293D105X0025A2W
C414	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C415	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C416	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C417	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C418	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C419	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C420	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C421	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C422	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C423	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C424	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C425	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C426	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C427	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C428	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C429	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C430	002-0045	CAPACITOR, 10 µF 16V TANT 20%, SMD	56289	293D106X0016B2W
C431	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C432	002-0045	CAPACITOR, 10 µF 16V TANT 20%, SMD	56289	293D106X0016B2W
C433	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C434	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C435	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C436	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C437	002-0044	CAPACITOR, 1.0 µF 16v TANT 20%, SMD	56289	293D105X0025A2W
C438	002-0044	CAPACITOR, 1.0 µF 16v TANT 20%, SMD	56289	293D105X0025A2W
C439	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C440	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C441	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C442	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C443	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C444	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C445	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C446	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C447	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C448	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C449	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C450	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA

Table F-11 Multiplexer board (A401) parts list (Sheet 2 of 5)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
C451	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C452	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C453	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C454	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C455	002-0045	CAPACITOR, 10 μF 16V TANT 20%, SMD	56289	293D106X0016B2W
C456	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C457	002-0045	CAPACITOR, 10 μF 16V TANT 20%, SMD	56289	293D106X0016B2W
C458	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C459	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C460	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C461	002-0044	CAPACITOR, 1.0 μF 16v TANT 20%, SMD	56289	293D105X0025A2W
C462	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C463	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C464	002-0044	CAPACITOR, 1.0 μF 16v TANT 20%, SMD	56289	293D105X0025A2W
C465	002-0044	CAPACITOR, 1.0 μF 16v TANT 20%, SMD	56289	293D105X0025A2W
C466	002-0044	CAPACITOR, 1.0 μF 16v TANT 20%, SMD	56289	293D105X0025A2W
C467	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C468	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C469	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C470	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C471	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C472	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C473	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C474	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C475	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C476	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C477	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C478	002-0031	CAPACITOR, 47 pF 50V COG 5%, SMD	77569	1206CG470J9B200
C479	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C480	002-0031	CAPACITOR, 47 pF 50V COG 5%, SMD	77569	1206CG470J9B200
C481	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C482	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C483	002-0045	CAPACITOR, 10 μF 16V TANT 20%, SMD	56289	293D106X0016B2W
C484	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C485	002-0045	CAPACITOR, 10 μF 16V TANT 20%, SMD	56289	293D106X0016B2W
C486	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C487	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C488	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C489	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C490	002-0044	CAPACITOR, 1.0 μF 16v TANT 20%, SMD	56289	293D105X0025A2W
C491	002-0044	CAPACITOR, 1.0 μF 16v TANT 20%, SMD	56289	293D105X0025A2W
C492	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C493	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C494	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C495	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C496	002-0030	CAPACITOR, 0.1 μF Z5U, SMD	96095	12065C104KATMA
C497	002-0055	CAPACITOR, 1000 pF 50V COG 5%, SMD	54473	ECU-V1H102JCH
C498	002-0031	CAPACITOR, 47 pF 50V COG 5%, SMD	77569	1206CG470J9B200
C499	002-0031	CAPACITOR, 47 pF 50V COG 5%, SMD	77569	1206CG470J9B200
C500	002-0043	CAPACITOR, 22 μF 16V 10% TANT,SMD	56289	293D226X9016D2T

Table F-11 Multiplexer board (A401) parts list (Sheet 3 of 5)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
C501	002-0045	CAPACITOR, 10 µF 16V TANT 20%, SMD	56289	293D106X0016B2W
C502	002-0045	CAPACITOR, 10 µF 16V TANT 20%, SMD	56289	293D106X0016B2W
C503	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C504	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C505	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
C506	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C507	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C508	002-0032	CAPACITOR, 150 pF 50V COG 5% SMD	96095	12061A151JATMA
C509	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C510	002-0045	CAPACITOR, 10 µF 16V TANT 20%, SMD	56289	293D106X0016B2W
C511	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C512	002-0044	CAPACITOR, 1.0 µF 16v TANT 20%, SMD	56289	293D105X0025A2W
C513	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C514	002-0045	CAPACITOR, 10 µF 16V TANT 20%, SMD	56289	293D106X0016B2W
C515	002-0045	CAPACITOR, 10 µF 16V TANT 20%, SMD	56289	293D106X0016B2W
C516	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C517	002-0035	CAPACITOR, 0.33 µF Z5U, SMD	96095	12063E334ZATMA
C518	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C519	002-0030	CAPACITOR, 0.1 µF Z5U, SMD	96095	12065C104KATMA
C520	002-0033	CAPACITOR, 470 pF 50V COG 5%, SMD	96095	12061A471JATMA
D401	009-0003	DIODE, IN4148, SMD	27014	FDLL4148
D402	009-0003	DIODE, IN4148, SMD	27014	FDLL4148
L401	008-0003	INDUCTOR, 0.22 µH, SMD	1UCW6	CTMC1210-R22J
L402	008-0003	INDUCTOR, 0.22 µH, SMD	1UCW6	CTMC1210-R22J
R401	023-0053	RESISTOR, 3.01 kΩ 1% MF, SMD	56637	MC1206 3011-FT
R402	001-0077	RESISTOR, 470 Ω 1/4W 5% CARBON, SMD	56637	MC1206 4700-JT
R403	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R404	001-0077	RESISTOR, 470 Ω 1/4W 5% CARBON, SMD	56637	MC1206 4700-JT
R405	023-0053	RESISTOR, 3.01 kΩ 1% MF, SMD	56637	MC1206 3011-FT
R406	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R407	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R408	023-0053	RESISTOR, 3.01 kΩ 1% MF, SMD	56637	MC1206 3011-FT
R409	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R410	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R411	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R412	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R413	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R414	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R415	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R416	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R417	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R418	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R419	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R420	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R421	001-0075	RESISTOR, 0.47 Ω 1/4W 5% CARBON, SMD	54473	ERJ-8RQJR47
R422	023-0053	RESISTOR, 3.01 kΩ 1% MF, SMD	56637	MC1206 3011-FT
R423	001-0077	RESISTOR, 470 Ω 1/4W 5% CARBON, SMD	56637	MC1206 4700-JT
R424	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R425	001-0077	RESISTOR, 470 Ω 1/4W 5% CARBON, SMD	56637	MC1206 4700-JT
R426	023-0053	RESISTOR, 3.01 kΩ 1% MF, SMD	56637	MC1206 3011-FT

Table F-11 Multiplexer board (A401) parts list (Sheet 4 of 5)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
R427	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R428	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R429	023-0053	RESISTOR, 3.01 kΩ 1% MF, SMD	56637	MC1206 3011-FT
R430	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R431	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R432	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R433	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R434	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R435	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R436	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R437	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R438	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R439	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R440	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R441	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R442	023-0052	RESISTOR, 2.21 kΩ 1% MF, SMD	56637	MC1206 2211-FT
R443	001-0077	RESISTOR, 470 Ω 1/4W 5% CARBON, SMD	56637	MC1206 4700-JT
R444	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R445	001-0077	RESISTOR, 470 Ω 1/4W 5% CARBON, SMD	56637	MC1206 4700-JT
R446	023-0052	RESISTOR, 2.21 kΩ 1% MF, SMD	56637	MC1206 2211-FT
R447	023-0052	RESISTOR, 2.21 kΩ 1% MF, SMD	56637	MC1206 2211-FT
R448	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R449	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R450	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R451	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R452	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R453	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R454	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R455	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R457	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R458	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R459	023-0043	RESISTOR, 3 terminal 20.0 kΩ +10.0 kΩ 1% MF	18612	VSR144 10K/20K
R460	023-0058	RESISTOR, 59.0 kΩ 1% MF, SMD	56637	MC1206 5902-FT
R461	023-0058	RESISTOR, 59.0 kΩ 1% MF, SMD	56637	MC1206 5902-FT
R462	001-0075	RESISTOR, 0.47 Ω 1/4W 5% CARBON, SMD	54473	ERJ-8RQJR47
R463	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R464	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R465	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R466	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R467	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R468	023-0056	RESISTOR, 15.0 kΩ 1% MF, SMD	56637	MC1206 1502-FT
R469	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R470	023-0058	RESISTOR, 59.0 kΩ 1% MF, SMD	56637	MC1206 5902-FT
R471	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R472	023-0058	RESISTOR, 59.0 kΩ 1% MF, SMD	56637	MC1206 5902-FT
R473	023-0043	RESISTOR, 3 terminal 20.0 kΩ +10.0 kΩ 1% MF	18612	VSR144 10K/20
R474	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R475	001-0086	RESISTOR, 47 kΩ 1/4W 5% CARBON, SMD	54473	ERJ-8GEYJ473
R476	001-0086	RESISTOR, 47 kΩ 1/4W 5% CARBON, SMD	54473	ERJ-8GEYJ473
R477	001-0084	RESISTOR, 22 kΩ 1/4W 5% CARBON, SMD	56637	MC1206 2202-JT

Table F-11 Multiplexer board (A401) parts list (Sheet 5 of 5)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
R478	023-0054	RESISTOR, 4.02 kΩ 1% MF, SMD	56637	MC1206 4021-FT
R479	023-0051	RESISTOR, 2.00 kΩ 1% MF, SMD	56637	MC1206 2001-FT
R480	023-0050	RESISTOR, 1.00 kΩ 1% MF, SMD	56637	MC1206 1001-FT
R481	023-0050	RESISTOR, 1.00 kΩ 1% MF, SMD	56637	MC1206 1001-FT
R482	001-0076	RESISTOR, 10 Ω 1/4W 5% CARBON, SMD	56637	MC1206 10R0-JT
R483	001-0077	RESISTOR, 470 Ω 1/4W 5% CARBON, SMD	56637	MC1206 4700-JT
R484	001-0076	RESISTOR, 10 Ω 1/4W 5% CARBON, SMD	56637	MC1206 10R0-JT
R485	023-0055	RESISTOR, 10.0 kΩ 1% MF, SMD	56637	MC1206 1002-FT
R486	023-0061	RESISTOR, 100 Ω 1% MF, SMD	54473	ERJ-8ENF1000V
TP401	024-0001	TEST POINT, GROUND	18310	10-209-2-01
U401	007-0096	CODEC, 1847 16 BIT STEREO, SMD	24355	AD1847JP
U402	007-0069	IC, LM358, DUAL JFET OP AMP, SMD	27014	LM358D
U403	007-0094	MAX4126, DUAL JFET RAIL TO RAIL OP AMP, SM	1ES66	MAX4126ESA
U404	007-0094	MAX4126, DUAL JFET RAIL TO RAIL OP AMP, SM	1ES66	MAX4126ESA
U405	007-0094	MAX4126, DUAL JFET RAIL TO RAIL OP AMP, SM	1ES66	MAX4126ESA
U406	007-0096	CODEC, 1847 16 BIT STEREO, SMD	24355	AD1847JP
U407	007-0094	MAX4126, DUAL JFET RAIL TO RAIL OP AMP, SM	1ES66	MAX4126ESA
U408	007-0094	MAX4126, DUAL JFET RAIL TO RAIL OP AMP, SM	1ES66	MAX4126ESA
U409	007-0094	MAX4126, DUAL JFET RAIL TO RAIL OP AMP, SM	1ES66	MAX4126ESA
U410	007-0064	IC, LM35D SMD, TEMPERATURE SENSOR, SMD	27014	LM35DM
U411	007-0096	CODEC, 1847 16 BIT STEREO, SMD	24355	AD1847JP
U412	007-0069	IC, LM358, DUAL JFET OP AMP, SMD	27014	LM358D
U413	007-0094	MAX4126, DUAL JFET RAIL TO RAIL OP AMP, SM	1ES66	MAX4126ESA
U414	007-0094	MAX4126, DUAL JFET RAIL TO RAIL OP AMP, SM	1ES66	MAX4126ESA
U415	007-0060	IC, AD822, DUAL JFET RAIL TO RAIL OP AMP	24355	AD822AN
U416	007-0096	CODEC, 1847 16 BIT STEREO, SMD	24355	AD1847JP
U417	007-0094	MAX4126, DUAL JFET RAIL TO RAIL OP AMP, SM	1ES66	MAX4126ESA
U418	007-0073	IC, CD4051, 8-CHAN ANALOG SWITCH, SMD	04713	MC14051BD
U419	007-0045	IC, LF411, LO-OFFSET BI-FET OP AMP	27014	LF411CN
U420	007-0073	IC, CD4051, 8-CHAN ANALOG SWITCH, SMD	04713	MC14051BD
U421	007-0091	IC, MAX194, 14-BIT A/D CONVERTER, SMD	1ES66	MAX194ACWE
U422	007-0095	IC, MAX6241, 4.096V REFERENCE GEN., SMD	1ES66	MAX6241ACSA
U423	007-0084	IC, 74HC594, 8 BIT SHIFT REG, LATCH, SMD	77569	74HC594D
U424	007-0065	IC, 79L05A, -5V LOW-POWER REG. 4%, SMD	27014	LM79L05ACM
W403	030-0041	CABLE ASSY, RIBBON, 40-PIN	4J977	030-0041
W410	030-0040	CABLE ASSY, RIBBON, 34-PIN	4J977	030-0040
X415	014-0008	8 PIN SOCKET	00779	2-640463-2
Y401	018-0006	OSCILLATOR, 25.65 MHZ 0.002% DIP	0GP37	CM32AF-25.6500MHZ

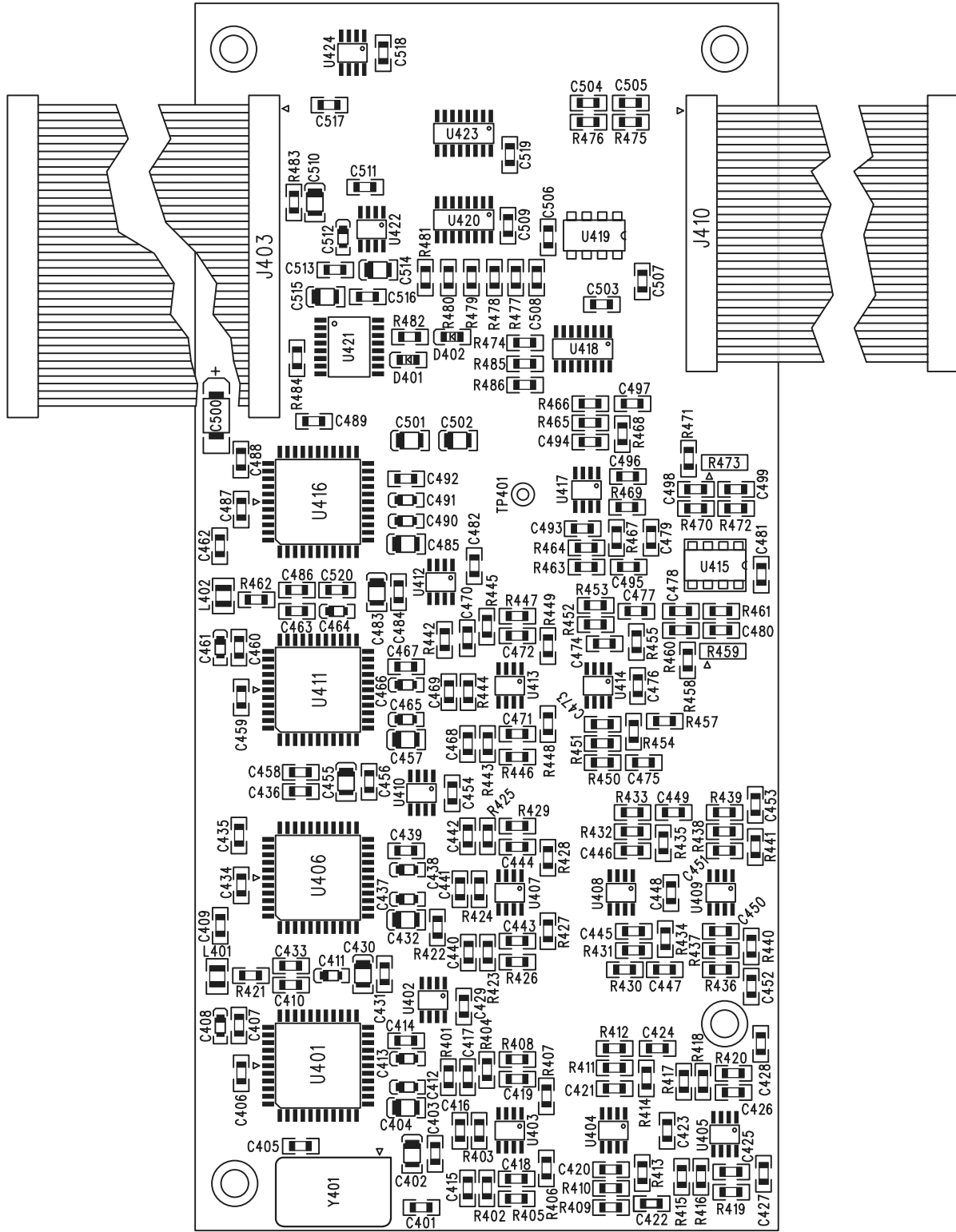


Figure F-19 Multiplexer board (A401) assembly dwg

Table F-12 Main board (A101) parts list (Sheet 1 of 7)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
C101	002-0051	CAPACITOR, 1000 µF 25V ALUMINUM	55680	UPL1E102MHH
C102	002-0051	CAPACITOR, 1000 µF 25V ALUMINUM	55680	UPL1E102MHH
C103	002-0001	CAPACITOR, 1.0 µF 100V, CERAMIC Z5U	96095	SR301E105MAA
C104	002-0039	CAPACITOR, 10 pF 50V CER COG 5%	96095	SR155A100JAA
C105	002-0006	CAPACITOR, 0.001 µF 50V CER X7R 10%	96095	SR151C102KAA
C106	002-0053	CAPACITOR, .0033 µF 50V MYLAR 5%	4U402	MKT1822-233/404
C107	002-0053	CAPACITOR, .0033 µF 50V MYLAR 5%	4U402	MKT1822-233/404
C108	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C109	002-0025	CAPACITOR, 120 pF 50V CER COG 10%	31433	C315C121K1G5CA
C110	002-0025	CAPACITOR, 120 pF 50V CER COG 10%	31433	C315C121K1G5CA
C111	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C112	002-0018	CAPACITOR, 0.001 µF 250V MYLAR 5%	4U402	MKT1822-210/404
C113	002-0016	CAPACITOR, 22 pF 50V CER COG 5%	96095	SR155A220JAA
C114	002-0039	CAPACITOR, 10 pF 50V CER COG 5%	96095	SR155A100JAA
C115	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C116	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C117	002-0018	CAPACITOR, 0.001 µF 250V MYLAR 5%	4U402	MKT1822-210/404
C118	002-0039	CAPACITOR, 10 pF 50V CER COG 5%	96095	SR155A100JAA
C119	002-0024	CAPACITOR, 10 µF 20V TANT 10%	56289	150D106X9020B2
C120	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C121	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C122	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C123	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C124	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C125	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C126	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C127	002-0001	CAPACITOR, 1.0 µF 100V, CERAMIC Z5U	96095	SR301E105MAA
C128	002-0025	CAPACITOR, 120 pF 50V CER COG 10%	31433	C315C121K1G5CA
C129	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C130	002-0001	CAPACITOR, 1.0 µF 100V, CERAMIC Z5U	96095	SR301E105MAA
C131	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C132	002-0015	CAPACITOR, 470 pF 50V CER COG 5%	96095	SR151A471JAA
C133	002-0050	CAPACITOR, 220 µF 16V ALUMINUM	55680	UPL1C221MPH
C134	002-0053	CAPACITOR, .0033 µF 50V MYLAR 5%	4U402	MKT1822-233/404
C135	002-0053	CAPACITOR, .0033 µF 50V MYLAR 5%	4U402	MKT1822-233/404
C136	002-0018	CAPACITOR, 0.001 µF 250V MYLAR 5%	4U402	MKT1822-210/404
C137	002-0025	CAPACITOR, 120 pF 50V CER COG 10%	31433	C315C121K1G5CA
C138	002-0025	CAPACITOR, 120 pF 50V CER COG 10%	31433	C315C121K1G5CA
C139	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C140	002-0003	CAPACITOR, 0.33 µF 50V CER Z5U	96095	SR215E334ZAA
C141	002-0003	CAPACITOR, 0.33 µF 50V CER Z5U	96095	SR215E334ZAA
C142	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C143	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C144	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C145	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C146		CAPACITOR, Factory option		
C147	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C148		CAPACITOR, Factory option		
C149	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C150	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA

Table F-12 Main board (A101) parts list (Sheet 2 of 7)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
C151		CAPACITOR, Factory option		
C152	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C153	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C154	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C155	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C156	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C157	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C158	002-0028	CAPACITOR, 22 µF 16V TANT 20%	31433	T110B226M015AS
C159	002-0024	CAPACITOR, 10 µF 20V TANT 10%	56289	150D106X9020B2
C160	002-0024	CAPACITOR, 10 µF 20V TANT 10%	56289	150D106X9020B2
C161	002-0056	CAPACITOR, 15 pF 50V CER COG 5%	54473	ECU-S2A150JCA
C162	002-0056	CAPACITOR, 15 pF 50V CER COG 5%	54473	ECU-S2A150JCA
C163	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C164	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C165	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C166	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C167	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C168	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C169		CAPACITOR, Factory option		
C170	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C171	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C172	002-0025	CAPACITOR, 120 pF 50V CER COG 10%	31433	C315C121K1G5CA
C201	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C202	002-0029	CAPACITOR, 0.47 µF 100V MYLAR 10%	4U402	MKT1822-447/015
C203	002-0006	CAPACITOR, 0.001 µF 50V CER X7R 10%	96095	SR151C102KAA
C204	002-0020	CAPACITOR, 0.1 µF 100V MYLAR 5%	4U402	MKT1822-410/014
C205	002-0008	CAPACITOR, 0.0033 µF 50V CER X7R 10%	96095	SR151C332KAA
C206	002-0020	CAPACITOR, 0.1 µF 100V MYLAR 5%	4U402	MKT1822-410/014
C207	002-0008	CAPACITOR, 0.0033 µF 50V CER X7R 10%	96095	SR151C332KAA
C208	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C209	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C250	002-0055	CAPACITOR, 0.001 µF 50V CER COG SMD	54473	ECU-V1H102JCH
C251	002-0055	CAPACITOR, 0.001 µF 50V CER COG SMD	54473	ECU-V1H102JCH
C252	002-0055	CAPACITOR, 0.001 µF 50V CER COG SMD	54473	ECU-V1H102JCH
C253	002-0055	CAPACITOR, 0.001 µF 50V CER COG SMD	54473	ECU-V1H102JCH
C254	002-0055	CAPACITOR, 0.001 µF 50V CER COG SMD	54473	ECU-V1H102JCH
C255	002-0055	CAPACITOR, 0.001 µF 50V CER COG SMD	54473	ECU-V1H102JCH
C256		CAPACITOR, Factory option		
C257		CAPACITOR, Factory option		
C258		CAPACITOR, Factory option		
C259		CAPACITOR, Factory option		
D101	009-0002	DIODE, 1N914	03508	1N914
D102	009-0002	DIODE, 1N914	03508	1N914
D103	009-0002	DIODE, 1N914	03508	1N914
D104	009-0002	DIODE, 1N914	03508	1N914
D105	009-0002	DIODE, 1N914	03508	1N914
D106	009-0002	DIODE, 1N914	03508	1N914
D107	009-0002	DIODE, 1N914	03508	1N914
D108	009-0002	DIODE, 1N914	03508	1N914
D109	009-0002	DIODE, 1N914	03508	1N914

Table F-12 Main board (A101) parts list (Sheet 3 of 7)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
D110	009-0002	DIODE, 1N914	03508	1N914
D111	009-0002	DIODE, 1N914	03508	1N914
D112	009-0002	DIODE, 1N914	03508	1N914
J107	004-0020	HEADER, 16-PIN, STRAIGHT, W/ LATCHES	06383	050-016-153A
J110	004-0012	HEADER, 34-PIN, STRAIGHT, W/ LATCHES	06383	050-034-153A
J111	004-0015	CUP JACK	18310	09-9006-1-03 GOLD
J114	004-0019	HEADER POST, 9-PIN	06776	NSH-36SA-S2-TG30
K101	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K102	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K103	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K104	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K105	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K106	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K107	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K108	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K109	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K110	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K111	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K112	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K113	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K114	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
K115	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
K116	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
K117	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
K118	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
K119	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
K120	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
K121	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K122	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K123	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K124	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K125	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K126	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K127	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K128	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K129	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K130	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K131	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K132	020-0001	RELAY, REED, 5V FORM 2A	71707	7102-05-1000
K133	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
K134	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
K135	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
K136	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
K140	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
K141	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
K199	020-0003	RELAY, REED, 5V FORM 1A, MERC WETTED	71482	MSS2-1A05
L101	008-0002	INDUCTOR, 120 μ H 2-10 Ω DC RESISTANCE 10%	91637	IR-2 120UH 10%
Q202	011-0008	TRANSISTOR, NPN, MPS3904	04713	MPS3904
Q203	011-0010	TRANSISTOR, PNP, PN2907A	7X328	2N2907A
R101	001-0033	RESISTOR, 10 k Ω 1/4W 5% CARBON	56637	CF25 10K 5% B

Table F-12 Main board (A101) parts list (Sheet 4 of 7)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
R102	001-0033	RESISTOR, 10 kΩ 1/4W 5% CARBON	56637	CF25 10K 5% B
R103	001-0027	RESISTOR, 47Ω 1/4W 5% CARBON	56637	CF25 47 5% B
R104	023-0024	RESISTOR, 43.2 kΩ 1% MF	56637	GP55 43.2K 1% 100PPM
R105	023-0011	RESISTOR, 15.8 kΩ 1% MF	56637	GP55 15.8K 1% 100PPM
R106	001-0001	RESISTOR, 470 Ω 1/4W 5% CARBON	56637	CF25 470 5% B
R107	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R108	023-0039	RESISTOR, 34.8 kΩ 1% MF	56637	GP55 34.8K 1% 100PPM
R109	001-0010	RESISTOR, 470 kΩ 1/4W 5% CARBON	56637	CF25 470K 5% B
R110	023-0025	RESISTOR, 69.8 kΩ 1% MF	56637	GP55 69.8K 1% 100PPM
R111	023-0033	RESISTOR, 698 kΩ 1% MF	56637	GP55 698K 1% 100PPM
R112	023-0018	RESISTOR, 10.0 kΩ 1% MF	56637	GP55 10K 1% 100PPM
R113	023-0018	RESISTOR, 10.0 kΩ 1% MF	56637	GP55 10K 1% 100PPM
R114	023-0046	RESISTOR, 17.8 kΩ 1% MF	56637	GP55 17.8K 1% 100PPM
R115	023-0046	RESISTOR, 17.8 kΩ 1% MF	56637	GP55 17.8K 1% 100PPM
R116	001-0005	RESISTOR, 100 kΩ 1/4W 5% CARBON	56637	CF25 100K 5% B
R117	001-0011	RESISTOR, 33 kΩ 1/4W 5% CARBON	56637	CF25 33K 5% B
R118	001-0033	RESISTOR, 10 kΩ 1/4W 5% CARBON	56637	CF25 10K 5% B
R119	001-0005	RESISTOR, 100 kΩ 1/4W 5% CARBON	56637	CF25 100K 5% B
R120	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R121	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R122	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R123	023-0018	RESISTOR, 10.0 kΩ 1% MF	56637	GP55 10K 1% 100PPM
R124	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R125	001-0008	RESISTOR, 4.7 kΩ 1/4W 5% CARBON	56637	CF25 4.7K 5% B
R126	001-0017	RESISTOR, 220 kΩ 1/4W 5% CARBON	56637	CF25 220K 5% B
R127	001-0017	RESISTOR, 220 kΩ 1/4W 5% CARBON	56637	CF25 220K 5% B
R128	023-0018	RESISTOR, 10.0 kΩ 1% MF	56637	GP55 10K 1% 100PPM
R129	023-0018	RESISTOR, 10.0 kΩ 1% MF	56637	GP55 10K 1% 100PPM
R130	023-0022	RESISTOR, 30.1 kΩ 1% MF	56637	GP55 30.1K 1% 100PPM
R131	023-0022	RESISTOR, 30.1 kΩ 1% MF	56637	GP55 30.1K 1% 100PPM
R132	023-0018	RESISTOR, 10.0 kΩ 1% MF	56637	GP55 10K 1% 100PPM
R133	023-0018	RESISTOR, 10.0 kΩ 1% MF	56637	GP55 10K 1% 100PPM
R134	001-0006	RESISTOR, 3.3 MΩ 1/4W 5% CARBON	56637	CF25 3.3M 5% B
R135	001-0006	RESISTOR, 3.3 MΩ 1/4W 5% CARBON	56637	CF25 3.3M 5% B
R136	001-0008	RESISTOR, 4.7 kΩ 1/4W 5% CARBON	56637	CF25 4.7K 5% B
R137	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R138	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R139	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R140	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R141	001-0011	RESISTOR, 33 kΩ 1/4W 5% CARBON	56637	CF25 33K 5% B
R142	001-0005	RESISTOR, 100 kΩ 1/4W 5% CARBON	56637	CF25 100K 5% B
R143	001-0033	RESISTOR, 10 kΩ 1/4W 5% CARBON	56637	CF25 10K 5% B
R144	001-0005	RESISTOR, 100 kΩ 1/4W 5% CARBON	56637	CF25 100K 5% B
R145	023-0032	RESISTOR, 402 kΩ 1% MF	56637	GP55 402K 1% 100PPM
R146	001-0033	RESISTOR, 10 kΩ 1/4W 5% CARBON	56637	CF25 10K 5% B
R147	001-0017	RESISTOR, 220 kΩ 1/4W 5% CARBON	56637	CF25 220K 5% B
R148	001-0001	RESISTOR, 470 Ω 1/4W 5% CARBON	56637	CF25 470 5% B
R149	023-0027	RESISTOR, 100 kΩ 1% MF	56637	GP55 100K 1% 100PPM
R150	001-0052	RESISTOR, 270 Ω 1/4W 5% CARBON	56637	CF25 270 5% B
R151	001-0008	RESISTOR, 4.7 kΩ 1/4W 5% CARBON	56637	CF25 4.7K 5% B

Table F-12 Main board (A101) parts list (Sheet 5 of 7)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
R152	001-0054	RESISTOR, 680 Ω 1/4W 5% CARBON	56637	CF25 680 5% B
R153	001-0005	RESISTOR, 100 kΩ 1/4W 5% CARBON	56637	CF25 100K 5% B
R154	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R155	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R156	023-0018	RESISTOR, 10.0 kΩ 1% MF	56637	GP55 10K 1% 100PPM
R157	023-0018	RESISTOR, 10.0 kΩ 1% MF	56637	GP55 10K 1% 100PPM
R160	023-0035	RESISTOR, 2.0 MΩ 1% MF	56637	GP55 2M 1% 100PPM
R161	001-0088	RESISTOR, 20 MΩ 1/4W 5% CARBON	56637	CF25 20M 5% B
R162	023-0035	RESISTOR, 2.0 MΩ 1% MF	56637	GP55 2M 1% 100PPM
R163	023-0035	RESISTOR, 2.0 MΩ 1% MF	56637	GP55 2M 1% 100PPM
R164	023-0035	RESISTOR, 2.0 MΩ 1% MF	56637	GP55 2M 1% 100PPM
R165	023-0059	RESISTOR, 649 kΩ 1% MF	56637	GP55 649K 1% 100PPM
R166	023-0042	RESISTOR, 1.0 MΩ 1% MF	56637	GP55 1M 1% 100PPM
R167	023-0042	RESISTOR, 1.0 MΩ 1% MF	56637	GP55 1M 1% 100PPM
R168	023-0042	RESISTOR, 1.0 MΩ 1% MF	56637	GP55 1M 1% 100PPM
R169	023-0060	RESISTOR, 4.99 MΩ 1% MF	56637	GP55 4.99M 1% 100PPM
R170	023-0030	RESISTOR, 200.0 kΩ 0.1% MF	91637	RN55C2003B
R171	023-0030	RESISTOR, 200.0 kΩ 0.1% MF	91637	RN55C2003B
R172	023-0004	RESISTOR, 20.00 kΩ 0.01% VISHAY S102C	18612	S102C 20.000K 0.01%
R173	023-0004	RESISTOR, 20.00 kΩ 0.01% VISHAY S102C	18612	S102C 20.000K 0.01%
R174	023-0002	RESISTOR, 1.4/2.0 kΩ 0.01% VISHAY S102C DUAL	18612	VHD144, 1.4K/2.0K 0.01%
R180	023-0035	RESISTOR, 2.0 MΩ 1% MF	56637	GP55 2M 1% 100PPM
R181	001-0088	RESISTOR, 20 MΩ 1/4W 5% CARBON	56637	CF25 20M 5% B
R182	023-0035	RESISTOR, 2.0 MΩ 1% MF	56637	GP55 2M 1% 100PPM
R183	023-0048	RESISTOR, 422 kΩ 1% MF	56637	GP55 422K 1% 100PPM
R184	023-0035	RESISTOR, 2.0 MΩ 1% MF	56637	GP55 2M 1% 100PPM
R185	023-0035	RESISTOR, 2.0 MΩ 1% MF	56637	GP55 2M 1% 100PPM
R186	023-0035	RESISTOR, 2.0 MΩ 1% MF	56637	GP55 2M 1% 100PPM
R187	023-0042	RESISTOR, 1.0 MΩ 1% MF	56637	GP55 1M 1% 100PPM
R188	023-0042	RESISTOR, 1.0 MΩ 1% MF	56637	GP55 1M 1% 100PPM
R189	023-0030	RESISTOR, 200.0 kΩ 0.1% MF	91637	RN55C2003B
R190	023-0030	RESISTOR, 200.0 kΩ 0.1% MF	91637	RN55C2003B
R191	023-0030	RESISTOR, 200.0 kΩ 0.1% MF	91637	RN55C2003B
R192	023-0020	RESISTOR, 20.00 kΩ 0.1% MF 10PPM/C	91637	PTF-56-20K0B-T13
R193	023-0020	RESISTOR, 20.00 kΩ 0.1% MF 10PPM/C	91637	PTF-56-20K0B-T13
R194	023-0003	RESISTOR, 2.000 kΩ 0.1% MF 10PPM/C	91637	PTF-56-2K00B-T13
R195	001-0033	RESISTOR, 10 kΩ 1/4W 5% CARBON	56637	CF25 10K 5% B
R196	001-0008	RESISTOR, 4.7 kΩ 1/4W 5% CARBON	56637	CF25 4.7K 5% B
R204	001-0011	RESISTOR, 33 kΩ 1/4W 5% CARBON	56637	CF25 33K 5% B
R205	001-0011	RESISTOR, 33 kΩ 1/4W 5% CARBON	56637	CF25 33K 5% B
R206	001-0007	RESISTOR, 33 MΩ 1/4W 5% CARBON	63060	MOX-200003305J
R207	001-0050	RESISTOR, 1 MΩ 1/4W 5% CARBON	56637	CF25 1M 5% B
R208	001-0069	RESISTOR, 10 MΩ 1/4W 5% CARBON	56637	CF25 10M 5% B
R209	001-0006	RESISTOR, 3.3 MΩ 1/4W 5% CARBON	56637	CF25 3.3M 5% B
R210	001-0069	RESISTOR, 10 MΩ 1/4W 5% CARBON	56637	CF25 10M 5% B
R211	001-0006	RESISTOR, 3.3 MΩ 1/4W 5% CARBON	56637	CF25 3.3M 5% B
R212	001-0069	RESISTOR, 10 MΩ 1/4W 5% CARBON	56637	CF25 10M 5% B
R213	001-0008	RESISTOR, 4.7 kΩ 1/4W 5% CARBON	56637	CF25 4.7K 5% B
R214	001-0001	RESISTOR, 470 Ω 1/4W 5% CARBON	56637	CF25 470 5% B
R215	001-0011	RESISTOR, 33 kΩ 1/4W 5% CARBON	56637	CF25 33K 5% B

Table F-12 Main board (A101) parts list (Sheet 6 of 7)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
R250	001-0079	RESISTOR, 1 kΩ 1/4W 5% CARBON SMD	56637	MC1206 1001-JT
R251	001-0081	RESISTOR, 4.7 kΩ 1/4W 5% CARBON SMD	56637	MC1206 4701-JT
R252	001-0084	RESISTOR, 22 kΩ 1/4W 5% CARBON SMD	56637	MC1206 2202-JT
R253	001-0079	RESISTOR, 1 kΩ 1/4W 5% CARBON SMD	56637	MC1206 1001-JT
R254	001-0079	RESISTOR, 1 kΩ 1/4W 5% CARBON SMD	56637	MC1206 1001-JT
R255	001-0084	RESISTOR, 22 kΩ 1/4W 5% CARBON SMD	56637	MC1206 2202-JT
R256	001-0079	RESISTOR, 1 kΩ 1/4W 5% CARBON SMD	56637	MC1206 1001-JT
R257	001-0084	RESISTOR, 22 kΩ 1/4W 5% CARBON SMD	56637	MC1206 2202-JT
R258	001-0079	RESISTOR, 1 kΩ 1/4W 5% CARBON SMD	56637	MC1206 1001-JT
R259	001-0081	RESISTOR, 4.7 kΩ 1/4W 5% CARBON SMD	56637	MC1206 4701-JT
R260	001-0079	RESISTOR, 1 kΩ 1/4W 5% CARBON SMD	56637	MC1206 1001-JT
R261	001-0084	RESISTOR, 22 kΩ 1/4W 5% CARBON SMD	56637	MC1206 2202-JT
R262	001-0081	RESISTOR, 4.7 kΩ 1/4W 5% CARBON SMD	56637	MC1206 4701-JT
T101	003-0002	TRANSFORMER, RATIO, MAIN	4J977	003-0002
T102	003-0003	TRANSFORMER, RATIO, QUADRATURE	4J977	003-0003
T103	003-0004	TRANSFORMER, RATIO, ATTENUATOR	4J977	003-0004
TP101	024-0001	TEST POINT, GROUND	18310	10-209-2-01
U101	007-0007	IC, LF351, WIDE BAND JFET OP AMP	27014	LF351N
U102	007-0013	IC, HI201, QUAD ANALOG SWITCH	34371	HI3-0201-5
U103	007-0045	IC, LF411, LO-OFFSET BI-FET OP-AMP	27014	LF411CN
U104	007-0045	IC, LF411, LO-OFFSET BI-FET OP-AMP	27014	LF411CN
U105	007-0045	IC, LF411, LO-OFFSET BI-FET OP-AMP	27014	LF411CN
U106	007-0045	IC, LF411, LO-OFFSET BI-FET OP-AMP	27014	LF411CN
U107	007-0045	IC, LF411, LO-OFFSET BI-FET OP-AMP	27014	LF411CN
U108	007-0045	IC, LF411, LO-OFFSET BI-FET OP-AMP	27014	LF411CN
U109	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U110	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U111	007-0013	IC, HI201, QUAD ANALOG SWITCH	34371	HI3-0201-5
U112	007-0018	IC, LF353, DUAL JFET OP-AMP	27014	LF353N
U113	007-0018	IC, LF353, DUAL JFET OP-AMP	27014	LF353N
U114	007-0018	IC, LF353, DUAL JFET OP-AMP	27014	LF353N
U115	007-0041	IC, LM318, HIGH SPEED OP-AMP	27014	LM318N
U116	007-0013	IC, HI201, QUAD ANALOG SWITCH	34371	HI3-0201-5
U117	007-0007	IC, LF351, WIDE BAND JFET OP AMP	27014	LF351N
U118	007-0010	IC, 79L05A, -5V LOW-POWER REGULATOR 4%	04713	MC79L05ACP
U119	007-0064	IC, LM35D, TEMPERATURE SENSOR, SMD	27014	LM35DM
U120	007-0009	IC, 78L05, +5V LOW-POWER REGULATOR 4%	04713	MC78L05ACP
U121	007-0041	IC, LM318, HIGH SPEED OP-AMP	27014	LM318N
U122	007-0042	IC, CD4053B, TRIPLE SPDT CMOS MUX	27014	CD4053BCN
U123	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U124	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U125	007-0041	IC, LM318, HIGH SPEED OP-AMP	27014	LM318N
U126	007-0041	IC, LM318, HIGH SPEED OP-AMP	27014	LM318N
U127	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U128	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U129	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U130	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U131	007-0042	IC, CD4053B, TRIPLE SPDT CMOS MUX	27014	CD4053BCN
U132	007-0077	IC, 74HC594, 8 BIT SERIAL SHIFT REG, LATCH	77569	74HC594N
U133	007-0018	IC, LF353, DUAL JFET OP-AMP	27014	LF353N

Table F-12 Main board (A101) parts list (Sheet 7 of 7)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
U134	007-0041	IC, LM318, HIGH SPEED OP-AMP	27014	LM318N
U135	007-0077	IC, 74HC594, 8 BIT SERIAL SHIFT REG, LATCH	77569	74HC594N
U136	007-0077	IC, 74HC594, 8 BIT SERIAL SHIFT REG, LATCH	77569	74HC594N
U137	007-0077	IC, 74HC594, 8 BIT SERIAL SHIFT REG, LATCH	77569	74HC594N
U138	007-0077	IC, 74HC594, 8 BIT SERIAL SHIFT REG, LATCH	77569	74HC594N
U139	007-0077	IC, 74HC594, 8 BIT SERIAL SHIFT REG, LATCH	77569	74HC594N
U140	007-0042	IC, CD4053B, TRIPLE SPDT CMOS MUX	27014	CD4053BCN
U141	007-0041	IC, LM318, HIGH SPEED OP-AMP	27014	LM318N
U142	007-0041	IC, LM318, HIGH SPEED OP-AMP	27014	LM318N
U143	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U144	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U145	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U146	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U147	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U148	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U149	007-0042	IC, CD4053B, TRIPLE SPDT CMOS MUX	27014	CD4053BCN
U150	007-0064	IC, LM35D, TEMPERATURE SENSOR, SMD	27014	LM35DM
U151	007-0041	IC, LM318, HIGH SPEED OP-AMP	27014	LM318N
U152	007-0070	IC, UCN5841A, SER. SHIFT REG. RELAY DRIVER	0CVK3	UCN5841A
U153	007-0070	IC, UCN5841A, SER. SHIFT REG. RELAY DRIVER	0CVK3	UCN5841A
U154	007-0070	IC, UCN5841A, SER. SHIFT REG. RELAY DRIVER	0CVK3	UCN5841A
U155	007-0070	IC, UCN5841A, SER. SHIFT REG. RELAY DRIVER	0CVK3	UCN5841A
U156	007-0070	IC, UCN5841A, SER. SHIFT REG. RELAY DRIVER	0CVK3	UCN5841A
U157	007-0098	IC, 74HC14, HEX SCHMITT INVERTER	77569	74HC14N
U201	007-0047	IC, OP07-EP, PRECISION OP-AMP	24355	OP-07EP
U202	007-0007	IC, LF351, WIDE BAND JFET OP AMP	27014	LF351N
U203	007-0045	IC, LF411, LO-OFFSET BI-FET OP-AMP	27014	LF411CN
X199	014-0007	SOCKET, 14 PIN	00779	2-641599-2
	025-0001	PRESS NUT - (1 PC)	46384	KFS2-632

Table F-13 Preamp board (A601) parts list (Sheet 1 of 3)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
C601	002-0048	CAPACITOR, 0.1 µF 400V MYLAR 5%	4U402	MKT1822-410/404
C602	002-0048	CAPACITOR, 0.1 µF 400V MYLAR 5%	4U402	MKT1822-410/404
C603	002-0049	CAPACITOR, 0.01 µF 250V POLYCARBONATE 5%	68919	MKC4- .01/400/5%
C604	002-0018	CAPACITOR, 0.001 µF 250V MYLAR 5%	4U402	MKT1822-210/404
C605	002-0050	CAPACITOR, 220 µF 16V ALUMINUM	55680	UPL1C221MPH
C606	002-0050	CAPACITOR, 220 µF 16V ALUMINUM	55680	UPL1C221MPH
C607	002-0036	CAPACITOR, 1000 pF 5% COG	96095	SR211A102JAA
C608	002-0020	CAPACITOR, 0.1 µF 100V MYLAR 5%	4U402	MKT1822-410/014
C609	002-0036	CAPACITOR, 1000 pF 5% COG	96095	SR211A102JAA
C610	002-0050	CAPACITOR, 220 µF 16V ALUMINUM	55680	UPL1C221MPH
C611	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C612	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C613	002-0036	CAPACITOR, 1000 pF 5% COG	96095	SR211A102JAA
C614	002-0017	CAPACITOR, 0.022µF 5% MYLAR	4U402	MKT1822-322/404
C615	002-0047	CAPACITOR, 0.01 µF 400V MYLAR 5%	4U402	MKT1822-310/404
C616	002-0020	CAPACITOR, 0.1 µF 100V MYLAR 5%	4U402	MKT1822-410/014
C617	002-0041	CAPACITOR, 47 pF COG 5%	96095	SR155A470JAA
C618	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C619	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C620	002-0037	CAPACITOR, 2.2 pF COG +- .25PF SMD	54473	ECU-V1H2R2CCM
C621	002-0038	CAPACITOR, 4.7 pF COG +- .25PF SMD	54473	ECU-V1H4R7CCM
C622	002-0039	CAPACITOR, 10 pF COG 5%	96095	SR155A100JAA
C623	002-0040	CAPACITOR, 22 pF COG 5%	96095	SR155A220JAA
C624	002-0042	CAPACITOR, 470 pF COG 5%	96095	SR155A471JAA
C625	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C626	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C627	002-0042	CAPACITOR, 470 pF COG 5%	96095	SR155A471JAA
C628	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C629	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C630	002-0020	CAPACITOR, 0.1 µF 100V MYLAR 5%	4U402	MKT1822-410/014
C631	002-0047	CAPACITOR, 0.01 µF 400V MYLAR 5%	4U402	MKT1822-310/404
C632	002-0017	CAPACITOR, 0.022µF 5% MYLAR	4U402	MKT1822-322/404
C633	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C634	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C635	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C636	002-0003	CAPACITOR, 0.33 µF 50V CER Z5U	96095	SR215E334ZAA
C637	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
C638	002-0003	CAPACITOR, 0.33 µF 50V CER Z5U	96095	SR215E334ZAA
C639	002-0003	CAPACITOR, 0.33 µF 50V CER Z5U	96095	SR215E334ZAA
C640	002-0004	CAPACITOR, 0.1 µF 50V CER Z5U	96095	SR205E104MAA
D601	009-0002	DIODE, 1N914	03508	1N914
D602	009-0002	DIODE, 1N914	03508	1N914
D603	009-0002	DIODE, 1N914	03508	1N914
D604	009-0002	DIODE, 1N914	03508	1N914
D605	009-0002	DIODE, 1N914	03508	1N914
D606	009-0002	DIODE, 1N914	03508	1N914
D607	009-0002	DIODE, 1N914	03508	1N914
D608	009-0002	DIODE, 1N914	03508	1N914
D609	010-0003	DIODE, ZENER. 5.1 V 1N5231 5%	3A557	1N5231
E601	033-0002	ARRESTOR, SURGE 145V 20%	25088	EC-145

Table F-13 Preamp board (A601) parts list (Sheet 2 of 3)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
J608	004-0015	CUP JACK	18310	09-9006-1-03 GOLD
J609	004-0015	CUP JACK	18310	09-9006-1-03 GOLD
J619	004-0015	CUP JACK	18310	09-9006-1-03 GOLD
K601	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
K602	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
K603	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
K604	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
K605	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
K606	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
K607	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
K608	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
K609	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
K610	020-0004	RELAY, 5V SPST, RUTHENIUM REED, SIP	71482	DSS4-1A05
Q601	011-0013	JFET, N-CHAN, J230, INTERFET J231, J230	66182	J231 or J230
Q602	011-0013	JFET, N-CHAN, J230, INTERFET J231, J230	66182	J231 or J230
R601	001-0032	RESISTOR, 22 kΩ 1/4W 5% CARBON	56637	CF25 22K 5% B
R602	001-0032	RESISTOR, 22 kΩ 1/4W 5% CARBON	56637	CF25 22K 5% B
R603	001-0015	RESISTOR, 100 MΩ 1/4W 5% CARBON	63060	MOX-200001006J
R604	001-0050	RESISTOR, 1.0 MΩ 1/4W 5% CARBON	56637	CF25 1M 5% B
R605	001-0042	RESISTOR, 220 Ω 1/4W 5% CARBON	56637	CF25 220 5% B
R606	001-0027	RESISTOR, 47 Ω 1/4W 5% CARBON	56637	CF25 47 5% B
R607	001-0027	RESISTOR, 47 Ω 1/4W 5% CARBON	56637	CF25 47 5% B
R608	001-0027	RESISTOR, 47 Ω 1/4W 5% CARBON	56637	CF25 47 5% B
R609	001-0073	RESISTOR, 100 Ω 1/4W 5% CARBON	56637	CF25 100 5% B
R610	001-0027	RESISTOR, 47 Ω 1/4W 5% CARBON	56637	CF25 47 5% B
R611	001-0073	RESISTOR, 100 Ω 1/4W 5% CARBON	56637	CF25 100 5% B
R612	001-0001	RESISTOR, 470 Ω 1/4W 5% CARBON	56637	CF25 470 5% B
R613	001-0072	RESISTOR, 2 GIGOHM	63060	MOX250-23 2000MΩ 5%
R614	001-0071	RESISTOR, 200 MΩ 5%	63060	MOX200 200MΩ 5%
R615	001-0005	RESISTOR, 100 kΩ 1/4W 5% CARBON	56637	CF25 100K 5% B
R616	001-0016	RESISTOR, 15 kΩ 1/4W 5% CARBON	56637	CF25 15K 5% B
R617	023-0044	RESISTOR, 249 Ω 1% MF	56637	GP55 249 1% 100PPM
R618	023-0016	RESISTOR, 6.98 kΩ 1% MF	56637	GP55 6.98K 1% 100PPM
R619	023-0027	RESISTOR, 100 kΩ 1% MF	56637	GP55 100K 1% 100PPM
R620	023-0047	RESISTOR, 49.9 kΩ 1% MF	56637	GP55 49.9K 1% 100PPM
R621	001-0017	RESISTOR, 220 kΩ 1/4W 5% CARBON	56637	CF25 220K 5% B
R622	001-0073	RESISTOR, 100 Ω 1/4W 5% CARBON	56637	CF25 100 5% B
R623	001-0008	RESISTOR, 4.7 kΩ 1/4W 5% CARBON	56637	CF25 4.7K 5% B
R624	023-0022	RESISTOR, 30.1 kΩ 1% MF	56637	GP55 30.1K 1% 100PPM
R625	023-0029	RESISTOR, 200 kΩ 1% MF	56637	GP55 200K 1% 100PPM
R626	023-0025	RESISTOR, 69.8 kΩ 1% MF	56637	GP55 69.8K 1% 100PPM
R627	023-0007	RESISTOR, 698 Ω 1% MF	56637	GP55 698 1% 100PPM
R628	023-0009	RESISTOR, 2.00 kΩ 1% MF	56637	GP55 2K 1% 100PPM
R629	023-0016	RESISTOR, 6.98 kΩ 1% MF	56637	GP55 6.98K 1% 100PPM
R630	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R631	017-0002	TRIMPOT, 200 Ω 10% CERMET	80294	3386P-1-201
R632	001-0042	RESISTOR, 220 Ω 1/4W 5% CARBON	56637	CF25 220 5% B
R633	001-0087	RESISTOR, 82 Ω 1/4W 5% CARBON	56637	CF25 82 5% B
R634	023-0045	RESISTOR, 1.21 kΩ 1% MF	56637	GP55 1.21K 1% 100PPM
R635	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM

Table F-13 Preamp board (A601) parts list (Sheet 3 of 3)

Ref	A-H P/N	Description	Mfg ID	Mfg P/N
R636	023-0045	RESISTOR, 1.21 kΩ 1% MF	56637	GP55 1.21K 1% 100PPM
R637	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R638	023-0045	RESISTOR, 1.21 kΩ 1% MF	56637	GP55 1.21K 1% 100PPM
R639	023-0022	RESISTOR, 30.1 kΩ 1% MF	56637	GP55 30.1K 1% 100PPM
R640	001-0016	RESISTOR, 15 kΩ 1/4W 5% CARBON	56637	CF25 15K 5% B
R641	023-0045	RESISTOR, 1.21 kΩ 1% MF	56637	GP55 1.21K 1% 100PPM
R642	023-0022	RESISTOR, 30.1 kΩ 1% MF	56637	GP55 30.1K 1% 100PPM
R643	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R644	023-0019	RESISTOR, 20.0 kΩ 1% MF	56637	GP55 20K 1% 100PPM
R645	001-0017	RESISTOR, 220 kΩ 1/4W 5% CARBON	56637	CF25 220K 5% B
RT601	019-0004	THERMISTOR, 170 Ω at 25 DEG C	54473	ERT-D2FGL171S
TP601	024-0001	TEST POINT, GROUND	18310	10-209-2-01
U601	007-0070	IC, UCN5841A, SER. SHIFT REG. RELAY DRIVER	0CVK3	UCN5841A
U602	007-0068	IC, BB627, LOW NOISE OP AMP	13919	OPA627AP
U603	007-0018	IC, LF353, DUAL JFET OP AMP	27014	LF353N
U604	007-0042	IC, CD4053B, TRIPLE SPDT CMOS MUX	27014	CD4053BCN
U605	007-0045	IC, LF411, LO-OFFSET BI-FET OP-AMP	27014	LF411CN
U606	007-0015	IC, CD4051B, 8-CHAN ANALOG SWITCH	27014	CD4051BCN
U607	007-0064	IC, LM35D, TEMPERATURE SENSOR, SMD	27014	LM35DM
U608	007-0045	IC, LF411, LO-OFFSET BI-FET OP-AMP	27014	LF411CN
U609	007-0007	IC, LF351, WIDE BAND JFET OP AMP	27014	LF351N
U610	007-0077	IC, 74HC594, 8 BIT SERIAL SHIFT REG, LATCH	77569	74HC594N
U611	007-0042	IC, CD4053B, TRIPLE SPDT CMOS MUX	27014	CD4053BCN
U612	007-0018	IC, LF353, DUAL JFET OP AMP	27014	LF353N
U613	007-0097	IC, 7808, +8V REGULATOR 4%	04713	MC7808CT
U614	007-0066	IC, 79L08A, -8V LOW-POWER REGULATOR 4%	50088	L79L08AC
U615	007-0009	IC, 78L05A, +5V LOW-POWER REGULATOR 4%	04713	MC78L05ACP
W607	030-0038	CABLE ASSY, RIBBON, 16-PIN	4J977	030-0038
	024-0002	SLOTTED TERMINAL (4 PCS)	18310	10-489-2-01
	025-0001	PRESS NUTS (2 PCS)	46384	KFS2-632

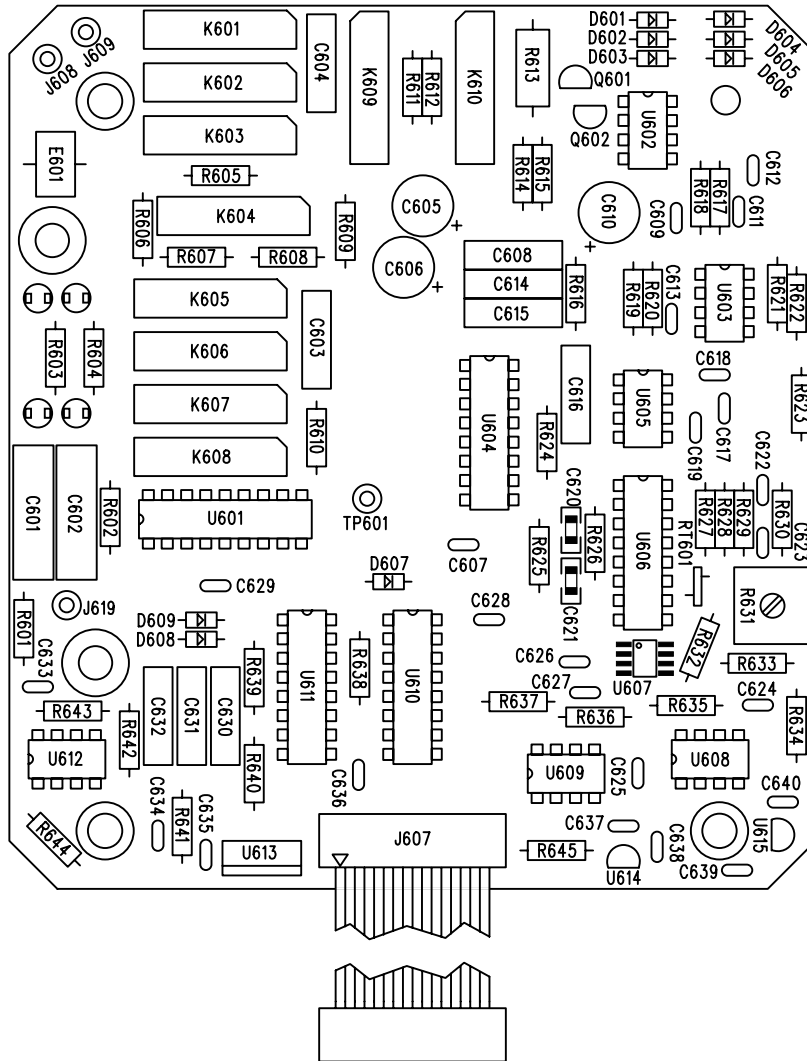


Figure F-30 Preamp board (A601) assembly dwg