TECHNICAL MANUAL

FOR

MODEL 6500A

"DIGITAL TERAOHMMETER"

TM6500A-L-02
12 March 2003

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1 INTRODUCTION

This manual provides complete information on the installation and operation of the Guildline Instruments Model 6500A Digital Teraohmmeter. Also included is a general description of the theory of operation together with instructions for calibration. The Teraohmmeter is based on fundamental work performed by Dr. S. H. Tsao of the National Research Council of Canada, and is manufactured by Guildline Instruments.

1.1 FUNCTION DESCRIPTION

The Guildline Model 6500A Teraohmmeter is a microprocessor based, fully automated, high precision device for measuring high value resistors or very small DC currents. It combines the proven technology of the Guildline Model 9520 Teraohmmeter with the latest in microprocessor technology.

The main features of the model 6500A are:

- Auto ranging from 10^6 to 10^{15} Ohms.
- Auto ranging from 10^{-7} to 10^{-12} Amperes.
- Built in GPIB and RS-232C interfaces.
- Fully controllable through the bus interfaces.
- Internal software routines for measurement error compensation.
- Extensive self-diagnostics.
- User-friendly interface.

1.2 PHYSICAL DESCRIPTION

The Guildline 6500A Digital Teraohmmeter is housed in a vinyl-clad aluminium cabinet. All indicators and frequently used controls are located on the front panel together with two connectors for connection of the unknown resistor or current. The power connection is made through a detachable 3-conductor power cord, which plugs into the rear panel. Although the instrument is primarily intended for bench top use, front panel flanges are supplied to allow it to be mounted in a standard 19-inch cabinet.

1.3 PRINCIPLE OF OPERATION

The simplified block diagram of Figure 1.1 details the major components of the Teraohmmeter.

When measuring resistance, a known DC test voltage is supplied by the 6500A, which causes a current to flow through the unknown resistor into an integrator. The magnitude of this current is determined by the time required for the integrator output to pass between two different threshold voltage points. Knowing the test voltage and magnitude of the current, the microprocessor can determine the value of the unknown resistor. The test voltage is selectable from 10 standard values in the range ±1 to ±1000 volts. The standard values are 1, 2, 5, 10, 20, 50, 100, 200, 500, and 1000 volts.

Unknown currents can be measured by connecting the unknown current source output directly to the integrator input (the internal test voltage source is not used when measuring currents).

The stability of the Model 6500A depends on the stability of the applied test voltage, the integrator, the timing circuit and the threshold voltage detector at the integrator output. Fixed errors in the absolute values of these parameters are compensated during calibration by using a software calibration routine in conjunction with a set of external calibration resistors of known value. Guildline can provide the calibration resistors.

The Model 6500A is fully automated with an internal microprocessor to compute the measurements and make the error compensations. The calculated value of the unknown resistor is displayed on the front panel and is made available to instruments attached to the IEEE-488 control bus. The microprocessor can be operated from the front panel manual controls or from either one of the two communication control buses. When measuring resistance, a front panel selectable option allows the Model 6500A to provide increased accuracy by automatically computing the average of four sequential measurements made with test voltage polarity alterations. The computer average is displayed on the front panel and is made available to instruments on the control bus (GPIB or RS-232C).

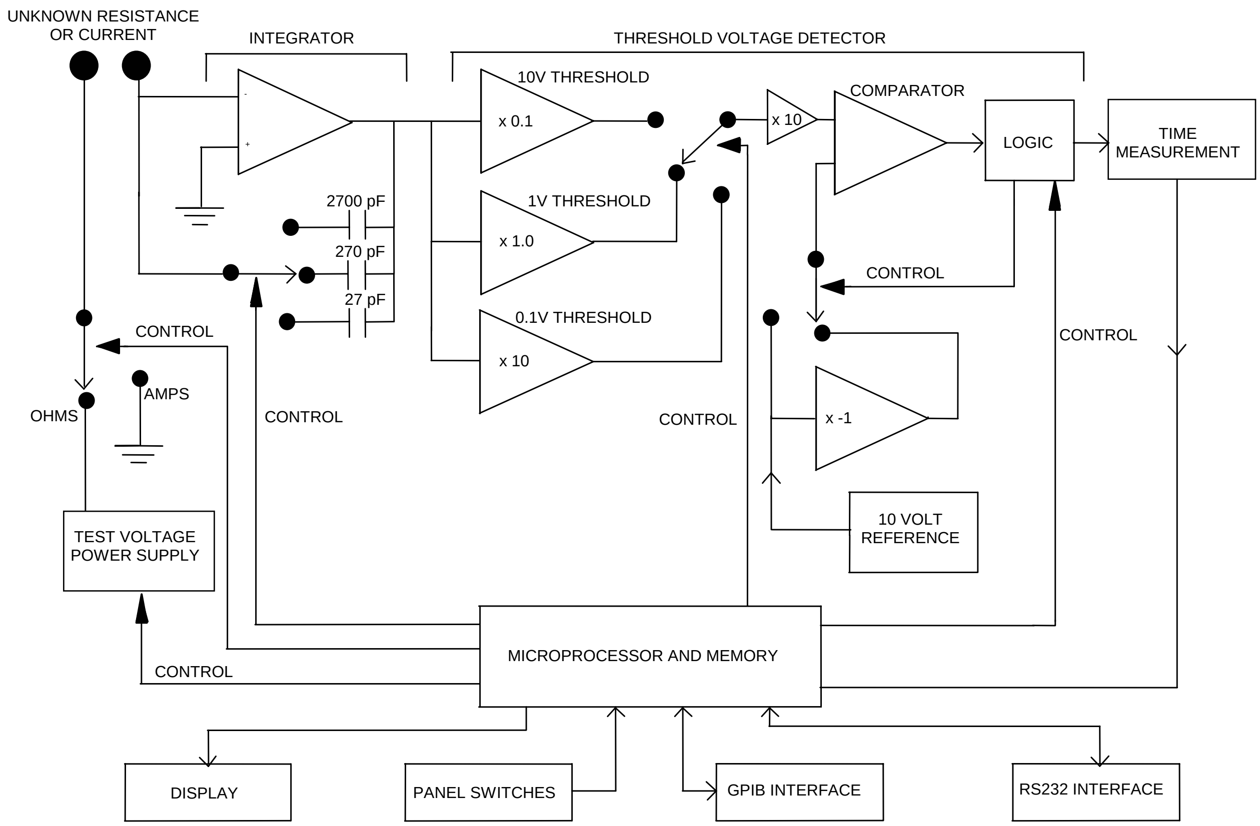


Figure 1.1: Simplified Block Diagram

1.4 MODES OF OPERATION

The Model 6500A is fully automated for simplicity and convenience. When specific measurement parameters are required the operator (or instruments on the control bus) can override this automatic feature.

The instrument can be set to take a continuous series of measurements or to take one measurement for each sample request. A sample request can be made with an external synchronizing signal fed to a rear panel connector or by the operator pressing a front panel push-button.

The number of resistance measurements made per data sample output is selectable to be either one or four (averaged). The resistance test voltage polarity is selectable. When measuring current, current flow in both directions can be accommodated.

The SOFCAL (software calibration) function permits the operator to calibrate the instrument, to examine the interface (GPIB or RS-232C) configuration and to review the calibration date and the software revision of the instrument.

1.5 CIRCUIT DISCUSSION

The Model 6500A Teraohmmeter measures high values of resistance by charging a small capacitor through the resistance to be measured. An operational integrator is shown in Figure 1.2. The equations for this integrator are as follows:

$$\frac{\text{delta } V_{out}(t)}{\text{delta } t} = \frac{V_{in}}{R \times C} \qquad (1)$$

(The equality is not exact but is extremely close when the voltage gain is high)

or:

$$R = \frac{V_{in} \times \text{delta } t}{C \times \text{delta } V_{out}} \qquad (2)$$

Where delta t = a change in time and delta V_{out} = a change in output voltage V_{out} over time delta t.

When current is being measured, V_{in} can be replaced by iR which simplifies (1) to the form:

$$i = \frac{C \times \text{delta } V_{out}}{\text{delta } t} \qquad (3)$$

In the Model 6500A:

- V_{in} is the test voltage for resistance measurement.

- C is a stable capacitor selected from the nominal values of 27 pF, 270 pF & 2700 pF.

- delta V_{out} is the potential difference between two threshold voltages placed symmetrically above and below ground ($V_{out} = 2V_{thresh}$ where V_{thresh} is selectable from 0.1 volt, 1 volt & 10 volts).

In equations (2) and (3), all terms are constant except R, i and delta t. Therefore delta t is proportional to R or inversely proportional to the current i. During normal operation the 6500A calculates the unknown resistance R or current i by taking measurements of the time delta t.

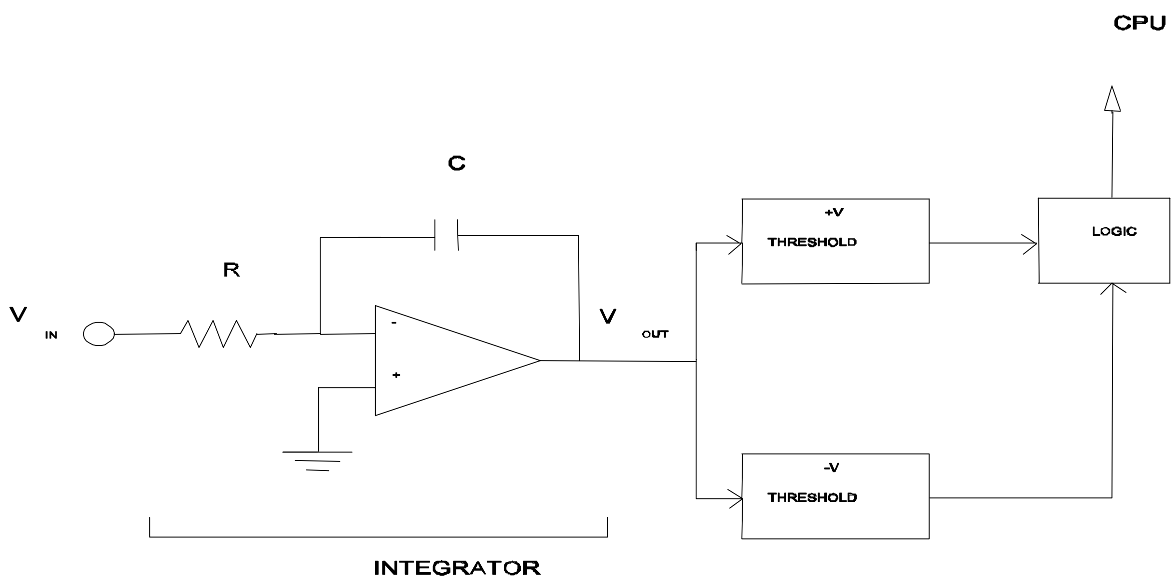


Figure 1.1: Operational Integrator

2 PERFORMANCE SPECIFICATIONS

2.1 GENERAL SPECIFICATIONS

Specifications for Guildline Instruments Model 6500A Teraohmmeter		
Storage Temperature	-30 - 70	°C
	-22 - 158	°F
Storage Humidity (non-condensing)	15 - 80	%RH
Operating Temperature	23 ± 5	°C
	73 ± 9	°F
Operating Humidity (non-condensing)	35 ± 15	%RH
Power Requirements	50	VA
Voltage Requirements	100, 120, 220, 240, ±10%	VAC
Frequency	47 through 63	Hz
Dimensions (width x depth x height)	444 X 500 X 89	mm
	17.5 X19.7 X 3.5	in
Weight	11.4	kg
	25	lbs

Table 2.1: General Instrument Specifications

Note: Add 11mm (0.4 in.) to height for bench top feet.

Resistance (Ohm)	Uncertainty
1 M < R	
1M ≤ R ≤ 10 M	350
10M < R ≤ 100 M	350
100 M < R ≤ 1 G	500
1 G < R	
1 G < R ≤ 10 G	700
10 G < R ≤ 100 G	1,000
100 G < R ≤ 1 T	2,000
1 T < R	
1 T < R ≤ 10 T	3,000
10 T < R ≤ 100 T	5,000
100 T < R ≤ 1 P	10,000
1 P < R	
1 P < R ≤ 10 P	100,000
10 P < R ≤ 100 P	500,000

Table 2.2: Resistance Measurement Uncertainty

Note: ±4°C of calibration temperature (1 year).

2.2 RESISTANCE MEASUREMENT SPECIFICATIONS

Note: The uncertainties listed in Table 2.2 are applicable after a one-hour warm-up period when using the autoranging mode of operation and when the current is no less than one picoampere through the unknown resistor.

Many types of high value resistors cannot be measured accurately with the 6500A in autoreverse mode because their actual resistance value changes slowly for a period of time after a polarity reversal. They can however be measured to the full 6500A accuracy by allowing sufficient settling time between polarity reversals. This is done under manual control (or through either the IEEE-488 or the RS-232C control bus) with an external average computation.

The accuracy is traceable to NRCC or NIST, (Canadian and U.S. national standards) at one calibration point and is inferred throughout the instrument range by the basic linearity and stability of the instrument.

2.3 PICOAMMETER MEASUREMENT SPECIFICATIONS

Range Ampere (A)	**Uncertainty ±%(percent)**
100 μA < I ≤ 1 mA	0.25
10 μA < I ≤ 100 μA	0.35
1 μA < I ≤ 10 μA	0.5
100 nA < I 1 μA	0.7
10 nA < I ≤ 100nA	1
1 nA < I ≤ 10nA	1
100 pA < I ≤ 1 nA	1
10 pA < I ≤ 100 pA	1
1 pA < I ≤ 10 pA	1
100 fA < I ≤ 1 pA	10
10 fA < I ≤ 100 fA	50
Input resistance : 100 kilohms	

Table 2.3: Current Measurement Uncertainty

Note: ±4°C of calibration temperature (1 year).

Note: The uncertainties listed in Table 2.3 are applicable after a 1- hour warm up period.

2.4 RESOLUTION

When the Model 6500A is used with short integration time periods, the measurement resolution is limited by the quantization error in the time measuring circuit (plus or minus one clock period). When the quantization error is not significant, the display resolution is truncated at a value commensurate with the short term measurement stability. The measurement resolution can be determined from Table 2.4.

Integrating Capacitor	**Display Resolution (Digits) Integration Time**				
pF	5.4 mSec	54 mSec	540 mSec	5.4 Sec	20000 Sec
27	3	4	4	3	3
270	3	4	6	5	5
2700	4	5	6	5	5
Subtract one digit for resistance measurements without auto-reverse mode					
Subtract two digits for current measurements					

Table 2.4: Measurement Resolutions (Digits)

Note: The measurements can be performed with reduced accuracy for integration times less than 5.4ms down to 1ms.

2.5 OTHER FEATURES

* Mounting: Bench top with extra flanges provided separately for 19-inch rack mounting.

* Input Connector: Front panel with rear panel access optional on request.

* Power Selection Switch: On rear panel.

* GPIB Bus Address: On rear panel.

2.6 ACCESSORY EQUIPMENT

2.6.1 ADAPTER FOR PENN AIRBORNE RESISTOR Model 65201

This accessory provides a stable shielded environment for measuring high resistances. The chamber dimensions and the terminal configuration have been specifically arranged to mount a PENN AIRBORNE resistor, but will also be suitable for a variety of other resistors.

The sample resistor should be connected between the "Source" and "R" terminals and the lid should be closed before any measurements are started.

CAUTION

Hazardous Voltages may be present at the SOURCE terminal. Ensure that the 6500A source is turned off before opening the 65201 cover.

Inside dimensions: 175 x 85 x 85 (mm)
6.75 x 3.375 x 3.375 (ins)

2.6.2 CALIBRATION RESISTORS

Precision Resistance Standards are available (see Table 2.5) for calibrating and verifying the 6500A. To meet the accuracy of the specification in Table 2.2 and Table 2.3 the 100 Megaohm resistor is recommended for calibration of error coefficients. The 1 Gigaohm or 10 Gigaohm resistor may also be used for calibration when the user is specifically interested in those measurement ranges. It must be noted that this will typically degrade the accuracy range(s) below their value due to their inherent increased uncertainty contribution.

Other Precision Resistance Standards are available in ascending decades from 100 Gigaohm to 100 Teraohm as well as special values on request. These precision resistors are typically used as check standards or transfer standards, and they verify accuracy of the 6500A at specific decade ranges..

Note: The 6500A SOFCAL feature will accept only Calibration Resistors of values of 80 MΩ > 11 GΩ for setting the error coefficients.

Model Number	Nominal Value (Ohm)	Nominal Initial Tolerance (±ppm)	Calibration Uncertainty @ 23°C ±1°C (±ppm)	Stability 12 months (±ppm)	Temp. Coef. 18-28°C (±ppm/°C)	Volt. Coef. (ppm/V)
65206/0	0 ohms	n/a	n/a		n/a	n/a
9336-100M	100 Mega	50	25	25	<5	<0.5
9336-1G	1 Giga	100	80	35	<6	<0.5
9336-10G	10 Giga	200	100	100	<25	<1
9336-100G	100 Giga	500	500	200	<250	<1
9337-1T	1 Tera	1000	1000	500	<300	<2
9337-10T	10 Tera	3000	4500	750	<500	<2
9337-100T	100 Tera	5000	5500	800	<800	<2

Table 2.5: Calibration Resistors

2.6.3 SAMPLE SHIELDED ENCLOSURE Model 65205

This accessory is similar to the Model 65201. It offers a large volume and is useful where dimensional compliance to the PENN AIRBORNE resistor is not required. This accessory provides a stable shielded environment for measuring high resistances and the leakage resistance of capacitors.

The connections to resistors are made identical to the Model 65201. The sample capacitor should be connected between the "Source" and "C" terminals. This inserts a 10 Mega ohm resistor in series with the Capacitor to limit inrush currents.

CAUTION

Hazardous voltages may be present at the SOURCE terminal. Ensure that the 6500A source is turned off before opening the 65205 cover.

Inside dimensions: 138 × 112 × 60 (mm)
5.375 × 4.375 × 2.375 (ins)

2.6.4 ADAPTER AND CABLE KIT Model 65210

This kit contains the following items:

- Two 60-inch (1.5 m) extension cables fitted with alligator clips on one end and a type N male connector on the other.

- Two 60-inch (1.5 m) extension cables fitted with a type N male connector on one end and a type N female connector on the other.

- Two type N male to BNC female adapters.

2.6.5 CALIBRATION KIT Model 65213

This kit contains the following items:

- Two 15-inch (0.5 m) extension cables with type N connectors.

- Type N connector to binding post adapter.

- One Zero Ohm link Model 65206/0

- One Precision resistor Model 9336/100M

3 INSTALLATION

3.1 INSTALLATION

The 6500A Teraohmmeter is an instrument intended to be used in a laboratory environment and is specified to be operated within an environmental temperature range of 23°C ±5°C with humidity levels in the range 45 ±5% RH. Higher humidity can degrade the accuracy of the instrument. The 6500A must be mounted with an angle of inclination of no more than 30°. Where the Teraohmmeter is to be used in a rack, attach the mounting brackets provided. "To attach the rack mounting flanges (brackets), the original screws holding the handles to the instrument are removed and the flanges attached over the handles with the longer screws supplied. The instrument has to be supported in the rack/cabinet with adjustable support angles or a support bar. In case of interference with other equipment mounted directly below the instrument, the 4 feet must be removed. This requires that the bottom skin of the instrument is lowered to get access to the nuts which hold the feet." Install the unit in the rack.

3.2 PRELIMINARIES

Pry open the power receptacle on the rear panel as shown in Figure 3.1.

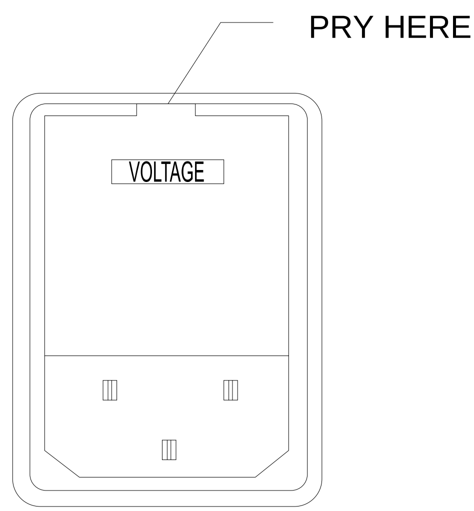


Figure 3.1: Opening the Power Receptacle

Check to see that the fuses inserted in the receptacle correspond to the correct type specified in Table 3.1.

Line Voltage	Fuse Type Required
100 V 120 V	1 Amp Slo-Blo (MDL_1A/250 V)
220 V 240 V	1/2 Amp Slo-Blo (MDL-1/2A/250 V)

Table 3.1: Power Fuse Selection

Only fuses of the specified type are to be used. Set the voltage selector drum so that the proper line voltage indication will be visible through the receptacle rear window when the receptacle cover is closed. This is important because the drum selects the proper transformer connection for the required voltage.

The supplied moulded line cord should be plugged into the 3 pin power receptacle on the rear panel of the instrument. Plug the line cord into a receptacle with the required voltage and a protective ground connection.

Where the moulded plug on the supplied line cord does not match the power outlet receptacle the plug may be removed and replaced with a 3-pin plug of the correct type.
The plug should be wired as follows:

Brown	-	High voltage
Blue	-	Neutral
Green/Yellow	-	Ground (Earth)

3.3 PRECAUTIONS

The instrument should be disconnected from the line supply before any attempt is made to remove the cover. Lethal voltages are present at several points within the instrument and under some operating conditions at the source connector. Therefore ONLY QUALIFIED PERSONNEL WHO ARE AWARE OF THE NECESSARY PRECAUTIONS SHOULD BE GIVEN ACCESS TO THIS EQUIPMENT.

Operation of the instrument with the cover removed will result in degraded performance due to the lack of shielding from radiated electrical interference.

3.4 CONTROLS AND INDICATORS

The front panel of the 6500A Teraohmmeter, as shown in Figure 3.2, has a prominent sixteen character alphanumeric display which provides a visual readout of data and status. Additional status information is presented by individual front panel LED lamps and a four character numeric display which shows the magnitude and polarity of the test voltage when it is present on the SOURCE connector.

3.4.1 SWITCH FUNCTIONS

3.4.1.1POWER

The on/off pushbutton is the only function which cannot be controlled by the GPIB and RS-232C bus interfaces.

3.4.1.2LOCAL

This key is used in the MEASURING mode to restore control from the bus interface to the front panel of the instrument. Note: it is possible for a GPIB remote controller to lock out this key.

During the setup of the instrument when operating in the manual SOFCAL mode, this key is used to enter the numeral zero (0).

3.4.1.3SOFTCAL

This key places the instrument in the SOFCAL mode. The SOFCAL functions are described in Section 5 of this manual.

When in the SOFCAL mode, this key is used to enter the numeral one (1).

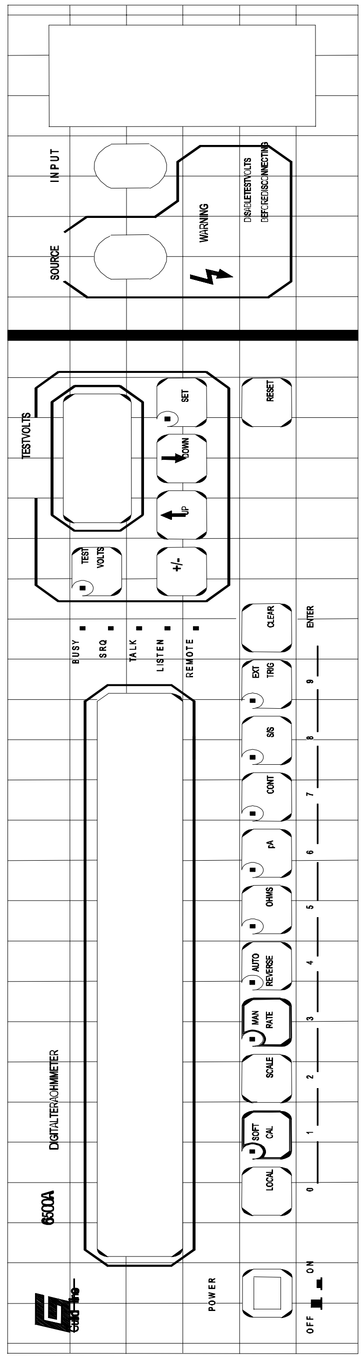


Figure 3.2: 6500A Front Panel

3.4.1.4SCALE

Used in the SOFCAL mode only for the purpose of entering the numeral two (2).

3.4.1.5MAN RATE

This key is an alternate action switch used to override the automatic ranging function of the instrument and allow the operator to select the internal integrating capacitor, voltage ramp threshold and test voltage (and hence the range) of the instrument. When the LED located at the corner of this key is lit, the instrument is in the manual mode and will not autorange.

When in the SOFCAL mode, this key is used to enter the numeral three (3).

3.4.1.6AUTOREVERSE

In the ohms MEASUREMENT mode, this is an alternate action key used to select a display derived from either a single measurement only (when Autoreverse inactive) or from an average of a group of four measurements with polarity reversals (when Autoreverse active) in order to improve the accuracy. When the LED located at the corner of this key is lit, the instrument is in the Autoreverse mode.

In the SOFCAL mode, this key is used to enter the numeral four (4).

3.4.1.7OHMS

In the MEASUREMENT mode, this is an alternate action key that activates or deactivates the resistance measurement function. When the LED located at the corner of the key is lit, the ohms mode is activated.

In the SOFCAL mode, this key is used to enter the numeral five (5).

3.4.1.8pA

In the MEASUREMENT mode,this is an alternate action key which activates or deactivates the current-measurement function. When the current measurement mode is activated the LED located at the corner of the key is lit and the SOURCE connector is disconnected from the test power supply and becomes the return path for the externally applied current under measurement. Note this key and the OHMS key are mutually exclusive: activating one mode will deactivate the other.

In the SOFCAL mode, this key is used to enter the numeral six (6)

3.4.1.9CONT

In the MEASUREMENT mode, this is an alternate action key that selects either a repetitive measurement (continuous) or a single measurement. When the LED located at the corner of the key is lit, the instrument makes repetitive measurements.

In the SOFCAL mode, this key is used to enter the numeral seven (7).

3.4.1.10 S/S

In the MEASUREMENT mode, this key allows the operator to manually (single step) trigger a single measurement or a single average of four measurements. This key and the CONT key are mutually exclusive (pressing one will automatically cancel the other).When the key is pressed,the LED located at the corner of the key will light until the triggered measurement is complete.

In the SOFCAL mode, this key is used to enter the numeral eight (8).

3.4.1.11 EXT TRIG

In the MEASUREMENT mode, this is an alternate action key that activates or deactivates the EXTernal TRIGger function. When the LED located at the corner of the key is lit the action is similar to the S/S function except the instrument will make one reading each time the signal wire in the rear panel EXT TRIG connector is grounded.

In the SOFCAL mode this key is used to enter the numeral nine (9).

3.4.1.12 CLEAR

In the MEASUREMENT mode, this key has two functions. One function aborts any function that is in progress and restarts the 6500A from a known internal state.

This is useful when the device under test has been disturbed in such a way as to invalidate the measurement and the time required to complete the measurement will be long.

The second function is used when the device under test is electrically charged before it is connected to the 6500A. This charge may cause the 6500A to "lock up" when the device is connected. This "lock up" condition can be remedied by pressing this key to restart the 6500A from a known internal state.

When in the SOFCAL mode, it is used as the ENTER key.

3.4.1.13 TEST VOLTS

This is an alternate action key that has an identical purpose in the OHMS MEASUREMENT and SOFCAL modes of operation. When the LED located at the corner of the key is lit, the internally derived test voltage will be present on the front panel SOURCE connector. To the right hand side of the key, the four digit LED display will display the magnitude of the voltage, when the key is activated. When the key LED is not lit, the test voltage will not be present at the SOURCE connector and the magnitude display will be turned off. **CAUTION IS REQUIRED BECAUSE POTENTIALLY LETHAL VOLTAGES MAY BE PRESENT AT THE "SOURCE" CONNECTOR.**

3.4.1.14 +/-

This key is used to change the polarity of the test voltage in the OHMS MEASUREMENT mode or to accommodate both current directions in the pA MEASUREMENT mode of operation.

It is also used to continue to the higher/lower select levels in the SOFCAL mode.

3.4.1.15 UP

This key is active in most instrument modes for selecting ranges, voltages etc.

In SOFCAL mode this key is used for scrolling through the possible choices at any given level.

3.4.1.16 DOWN

This key is active in most instrument modes for selecting ranges, voltages etc.

3.4.1.17 SET

This key is used to lock into a specific range, voltage etc. in most operating modes of the instrument.

In the SOFCAL mode this key is used to exit to the measurement mode.

3.4.1.18 RESET

This key is a software reset of the system which restores the hardware and software to the initial state, that was present at power turn-on.

3.4.2 STATUS INDICATOR LEDS

The five LEDs located between the main data display and the Test Volts display area of the front panel are used to show the status of the instrument and GPIB control interface.

3.4.2.1BUSY

This LED indicates that the instrument is in the process of autoranging or is taking a measurement.

3.4.2.2SRQ
This LED indicates when the instrument is generating a service request on the GPIB bus.

3.4.2.3TALK
This LED indicates when the instrument is addressed to send data out onto the GPIB bus.

3.4.2.4LISTEN
This LED indicates when the instrument is addressed to receive data from the GPIB bus.

3.4.2.5REMOTE
This LED indicates that front panel control is no longer available and that the GPIB bus is in exclusive control.

3.4.3 DISPLAYS

3.4.3.1MAIN DISPLAY
The main display is a 16 character vacuum-fluorescent display which shows the measured data and provides information to the operator during the software calibration and system initialization procedures.

3.4.3.2TEST VOLTS DISPLAY
The TEST VOLTS display is a four digit seven segment LED display which is used to display the voltage present at the SOURCE connector when the TEST VOLTS key is activated. During the self-test routine at start-up, the display will list all the available test voltages sequentially.

3.5 TERMINALS

3.5.1 SOURCE TERMINAL

Lethal voltages of up to 1000 volts may be present at this output and appropriate precautionary measures are necessary. **UNQUALIFIED OR UNINFORMED PERSONNEL SHOULD NOT BE GIVEN ACCESS TO THIS EQUIPMENT.**

The selected voltage is present at the SOURCE connector whenever the TEST VOLTS display indicates its numeric value. While the source can only generate three or four milliAmperes at a steady rate, the output filter capacitors, can produce considerably greater currents for short periods of time.

3.5.2 INPUT TERMINAL

The sensitivity and very high impedance of this terminal requires careful handling. Large static discharges to this connector should be avoided. One terminal of the unknown resistance or current is connected to this terminal.

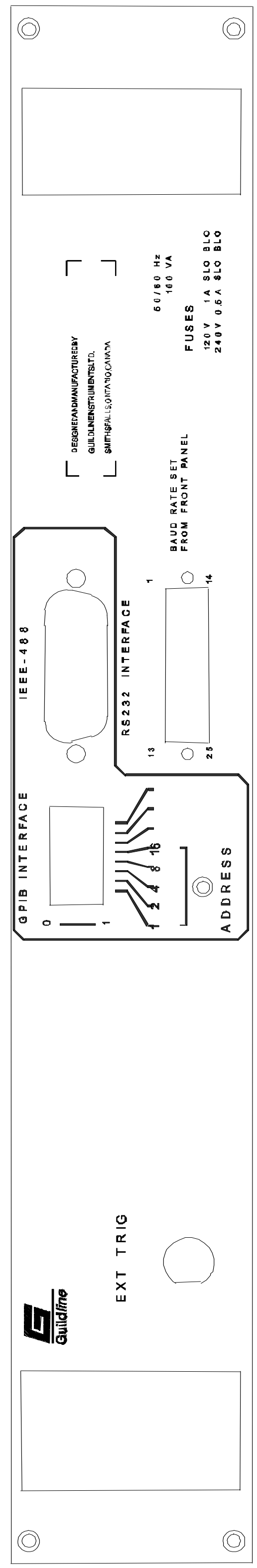


Figure 3.3: 6500A Back Panel

3.5.3 EXTERNAL TRIGGER TERMINAL

This rear panel connector shown in Figure 3.3 works in conjunction with the front panel EXT TRIG key to initiate a measurement each time the EXT TRIG signal pin in the connector is grounded. Internally, the centre conductor of the connector is supplied with +5V through an LED and a 330 ohm resistor. Figure 3.4 shows typical external trigger circuits.

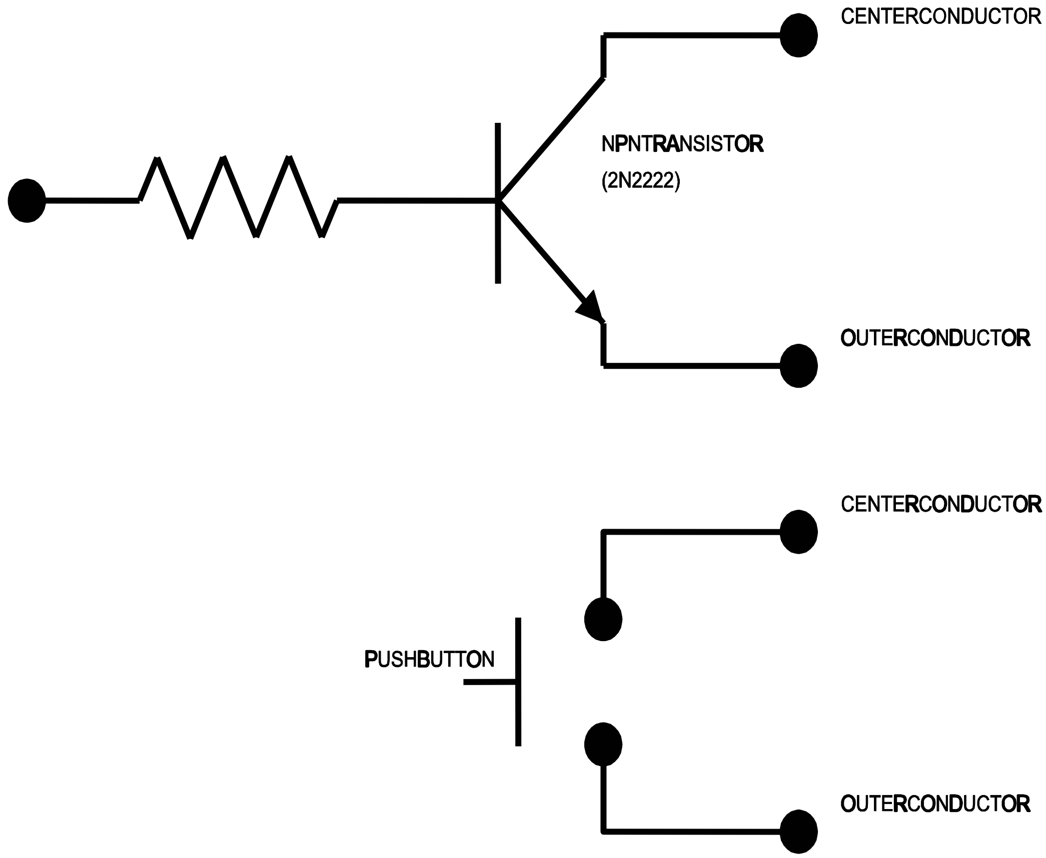


Figure 3.4: Typical External Trigger Circuits

4 INSTRUMENT OPERATION

The operation of this instrument is straightforward because it will prompt the operator for the next required key stroke or it will automatically perform the required function.

CAUTION
DANGEROUS VOLTAGES CAN BE PRESENT AT THE SOURCE CONNECTOR.
THIS EQUIPMENT MUST NOT BE OPERATED BY UNQUALIFIED PERSONNEL.

4.1 INITIALIZATION

When the instrument is turned on it performs a series of internal diagnostic checks. The internal diagnostics check the power supplies, reference voltage and system memory. A visual check of the Vacuum Fluorescent and LED displays is made by cycling each digit segment ON. Any errors found will be indicated on the main display and the unit should be serviced immediately.

If the display shows the message CORRECT CHK SUM ?, it indicates that the calibration data in the instrument memory has been corrupted and the operator should reenter the proper coefficients (see SOFCAL). Malfunctions visible on the front panel (such as non operating display segments) will not be apparent to the control unit and operation of the instrument will still be possible at the discretion of the operator.

4.2 MEASURING RESISTANCE

The 6500A Teraohmmeter is a very sensitive resistance measurement instrument hence care should be taken to shield any device which is to be measured. Inadequate shielding will result in noisy readings. The reader should consult APPENDIX 2 when large value resistances are to be measured.

4.2.1 RESISTANCE, AUTORANGING

The simplest approach to making a resistance measurement is to utilize the auto ranging capability of the 6500A Teraohmmeter. To measure a resistance with auto ranging:

1) Activate the POWER ON switch and wait for the self check to complete.

2) Deactivate AUTOREVERSE by pressing the alternate action key if that feature is not wanted.

   The auto reversing mode may give faulty readings when measuring very large value resistors because these resistors frequently have excessive charge storage characteristics. This is a problem with the resistors, not the 6500A (see Appendix A2).

3) Depress the OHMS key.

4) The instrument will suggest a maximum test voltage which will show on the main display with flashing numerals. If the suggested value is unsuitable for the device under test, the operator can select a different value by using the UP or DOWN keys. When the desired maximum test voltage value is displayed, it is saved by pressing the SET key. When auto ranging, the instrument will select a test voltage that will optimize the accuracy of the measurement but will not exceed the maximum test voltage selected by the operator.

5) The instrument will prompt the user to depress the TEST VOLTS key but connect the device to be tested before doing so: remember that **POTENTIALLY LETHAL VOLTAGES CAN BE PRESENT AT THE SOURCE CONNECTOR**.

6) Depress the TEST VOLTS key. The instrument will search for the optimum range within the constraints set by the maximum test voltage and proceed to take continuous measurements of the resistance of the device under test. When the measurement has been completed, **PRESS THE ALTERNATE ACTION TEST VOLTS SWITCH TO REMOVE THE TEST VOLTAGE BEFORE ATTEMPTING TO DISCONNECT THE DEVICE UNDER TEST.** If a number of devices are to be tested, always check to **VERIFY THAT THE TEST VOLTAGE IS NOT ACTIVATED BEFORE ATTEMPTING TO CONNECT OR DISCONNECT ANY DEVICE TO BE TESTED.**

7) The auto-reversing mode, under certain resistance/voltage conditions, may fail to select between two optimum range possibilities. This is due to charge storage characteristics associated with large value resistors. To overcome this situation simply press "MAN RATE" switch and the instrument will immediately select one of the two ranges and take continuous measurements of the resistance of the device under test.

4.2.2 RESISTANCE, MANUAL RANGING

Manual ranging of the 6500A Teraohmmeter is more complex than using the autoranging function. To fully understand the manual mode, Section 1.3 (Principle of Operation) should be reviewed.

The manual mode permits the operator to select the test voltage, the threshold voltage and the integration capacitor. The operator may also select these constants through the GPIB or RS-232C bus. The instrument then measures the integration time and calculates the value of the unknown resistance. If the operator selects inappropriate measurement constants, the full accuracy of the instrument may not be achieved. To make a good selection, an approximate value of the unknown resistor is required. This may be obtained from a prior knowledge or from a repetitive sequence of measurements starting from any assumed value.

The instrument works best if the integration time is between 0.5 and 5.0 seconds, however it will work at reduced accuracy with an integration time as short as 5.4 milliseconds or as long as 1000 seconds. The integration capacitor value may be selected from one of 27, 270 or 2700 picoFarads. The 2700 pF capacitor is the most stable and should be used if possible.

The threshold may be 0.1, 1 or 10 volts. The test voltage may be selected between the limits of 1 to 1000 volts in steps that are decimal multiples of 1, 2 and 5 of either polarity (±).

The integration time is affected by the selection of the capacitor, threshold and test voltage according to the formula:

$$T = \frac{2 \times C \times R \times V_{threshold}}{V_{source}}$$

Where: T is the integration time in seconds,

R is the unknown resistance in ohms,

C is the integrator capacitance in farads,

$V_{threshold}$ is the threshold voltage in volts,

V_{source} is the test voltage in volts.

The operator may use the timing diagram of Figure 4.1 to select the measurement constants without calculation. For example, if the unknown resistor value is approximately 100 Megaohms (100 M), the operator will find the sloping 100 Megaohm (100 M) line on the test voltage graph (top of the page). The intersection of the 100 M line with the horizontal 10 V test voltage line gives an input current of 100 nA (vertical line). Following the 100 nA line to the 2700 pF threshold voltage graph (center of page) it can be seen that selecting a 10 V threshold will give an integration time of 540 mS which is within the optimum range of 0.5 to 5 seconds. The selection of the 0.1 V threshold should be avoided because it would give an integration time of 54 mS.

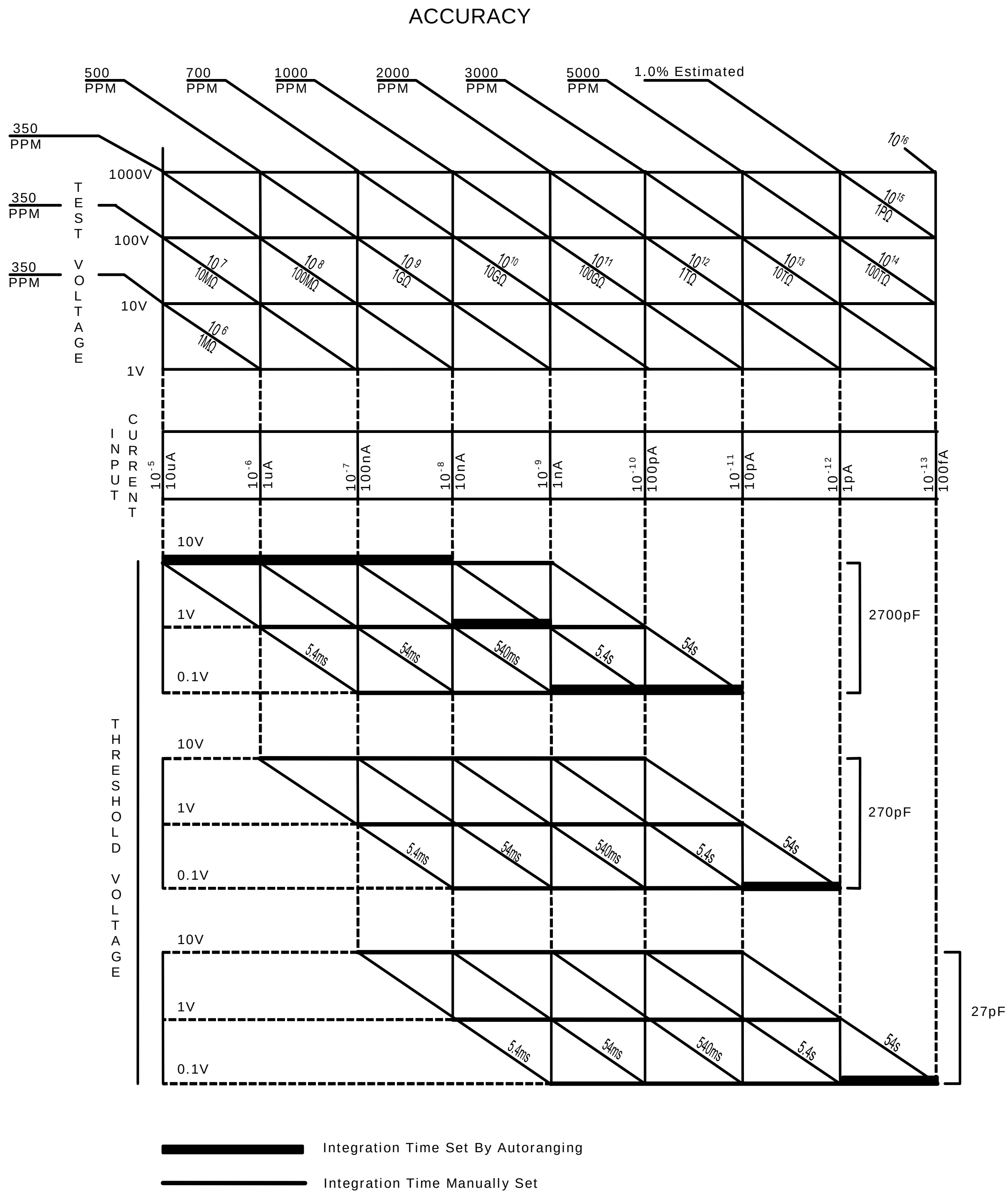


Figure 4.1: Time Diagram

To measure a resistance with manually selected constants:

1) Activate the POWER ON switch.

2) Activate the MAN RATE key.

3) Deactivate the AUTOREVERSE if that feature is not required.

   The autoreversing mode may give faulty readings when measuring a very large value of resistance because resistors of this type frequently have excessive charge storage characteristics.

4) Press the OHMS key.

5) The instrument will display a suggested maximum value for the test voltage. It is presumed that a number of items are to be measured using different test voltages but that the operator does not want to inadvertently exceed the value displayed. If the displayed maximum voltage is unsuitable, it can be modified with the UP or DOWN keys. When an acceptable value is displayed, press the SET key.

6) A suggested value for the integration capacitor is then displayed. A different value can be selected using the UP or DOWN keys. When an acceptable value is displayed, press the SET key.

7) A suggested value for the threshold voltage is then displayed. A different value can be selected with the UP or DOWN keys. An appropriate value is accepted by pressing the SET key.

8) The first device to be measured should be connected to the instrument.

9) The lowest possible test voltage will be displayed. If this value is unsuitable for the first device to be measured, different values can be selected using the UP or DOWN keys. When the correct value is displayed, it is saved with the SET key.

10) Using the integration parameters that the operator has selected, the instrument will display the optimum measurement range of resistance. If this is satisfactory, it is accepted by pressing the SET key. In most cases, the instrument will operate outside the indicated range with reduced accuracy. If the operator decides to move the instrument into a higher or lower range, it can be done by pressing the UP or DOWN keys which will return the instrument to step 6 allowing the operator to reconsider the choices made. When the most satisfactory range is displayed, it is accepted by pressing the SET key.

11) The instrument is ready to make a measurement and will prompt the operator to activate the TEST VOLTS key. The test voltage will then be applied to the device under test and the selected test voltage will be displayed. The instrument will begin to make continuous resistance measurements.

CAUTION
The instrument may be damaged if the Source connector is shorted to the instrument.

12) When the measurement is complete, the test voltage is removed by pressing the alternate action TEST VOLTS key. A number of devices can be measured with the previously selected integration parameters but the operator must be careful to deactivate the test voltage via the TEST VOLTS key before connecting or disconnecting any device under test.

The test voltage should be kept in the deactivated state whenever the instrument is not connected to an item to be measured.

13) If a different test voltage is required, press the UP key in order to return to step 9. If a complete reselection of integration parameters is required, press the UP, SET and UP keys sequentially to return to step 6.

4.3 MEASURING PICOAMPERES

The 6500A Teraohmmeter can be used to measure very low Direct Currents flowing to the centre pin of the input connector. The 6500A input resistance is approximately 100 Kilohms and will reduce the expected current flow significantly unless the resistance of the external circuit is much higher. To connect the unit as a picoAmmeter, the current source is fed into the center pin of the INPUT connector. The SOURCE connector pin is the current return path to the ground (or low side) of the external circuit.

A coaxial cable to the INPUT connector makes a simple approximation to the ideal circuit configuration when the center conductor is connected to the current source and the coaxial shield is connected to the ground of the external circuit. Noise pickup may cause a slight degradation of accuracy when using this coaxial cable configuration

4.3.1 AUTORANGING

The simplest technique for measuring low currents is to use the autoranging feature of the 6500A:

1. Connect the unknown current source.

2. Depress the pA key on the instrument. The 6500A will proceed to determine the correct range and take continuous measurements.

3. Slow changes in the magnitude of the unknown current will be tracked by the autoranging feature of the 6500A but if the current changes by a large step value, or if the polarity changes, the instrument must be forced to autorange again by pressing the pA key twice.

4.3.2 MANUAL RANGING

Manual ranging of the 6500A Teraohmmeter is more complex than the autoranging function. Reference to the Time Diagram shown in Figure 4.1 is useful when operating the 6500A, especially in the manual ranging mode. In order to manual range an approximate value of the current to be measured must be known.

Knowing the current the user must then select an integration capacitor, and an integration threshold voltage for the measurement. The integration capacitor value may be selected from one of 27, 270 or 2700 picofarads. The threshold may be 0.1, 1 or 10 volts.

The selection of the capacitor, and the threshold affects the integration time according to the formula:

$$T = \frac{2 \times C \times V_{threshold}}{I}$$

Where: T is the integration time in seconds,

I is the unknown current in amperes,

C is the integration capacitance in farads,

$V_{threshold}$ is the threshold voltage in volts.

The instrument works best if the integration time of the electrometer is between 0.5 seconds and 5 seconds however integration times as short as 5.4 milliseconds or as long as 1000 seconds may be used. The 2700 pF capacitor is the most stable and should always be used if possible.

The following steps can be used to measure current in the manual mode:

1. Press the MAN RATE key to allow manual ranging.

2. Press the pA key.

3. Select the integrator capacitor using the UP and DOWN keys, then press the SET key. If possible always select the 2700 pF capacitor for best instrument accuracy.

4. Select an integration threshold with the UP and DOWN keys then press the SET key.

5. The polarity of the current will be indicated at the extreme left hand side of the main display. It can be reversed by pressing the +/- key (the polarity convention used is such that for a positive polarity the INPUT connector centre pin is at a positive voltage with respect to ground (outer conductor shell).

6. The instrument will now display the polarity selected and the current range based on the integration parameters previously selected. Pressing the UP key will return the process to step 3) allowing a reselection of the integration parameters. If the range displayed is satisfactory press the SET key. The instrument will usually measure values outside the selected range at reduced accuracy.

7. The instrument will commence taking continuous measurements of the unknown current.

5 PURPOSE OF SOFCAL

SOFCAL is a computer program installed in the 6500A Teraohmmeter. Its primary purpose is to help calibrate the instrument and to determine instrument system errors so that measurements can be corrected digitally with data adjustment before they appear on the display or are fed to either of the two control busses. The secondary purpose of SOFCAL is to help manage the data flow in and out of the instrument.

When in the SOFCAL mode of operation, the front panel keys are redefined to do other functions. In addition to the normal keys three hidden keys not labelled on the front panel are enabled when in SOFCAL. These keys are located on the lower right hand side of the keyboard between the CLEAR and RESET keys as shown in Figure 5.1.

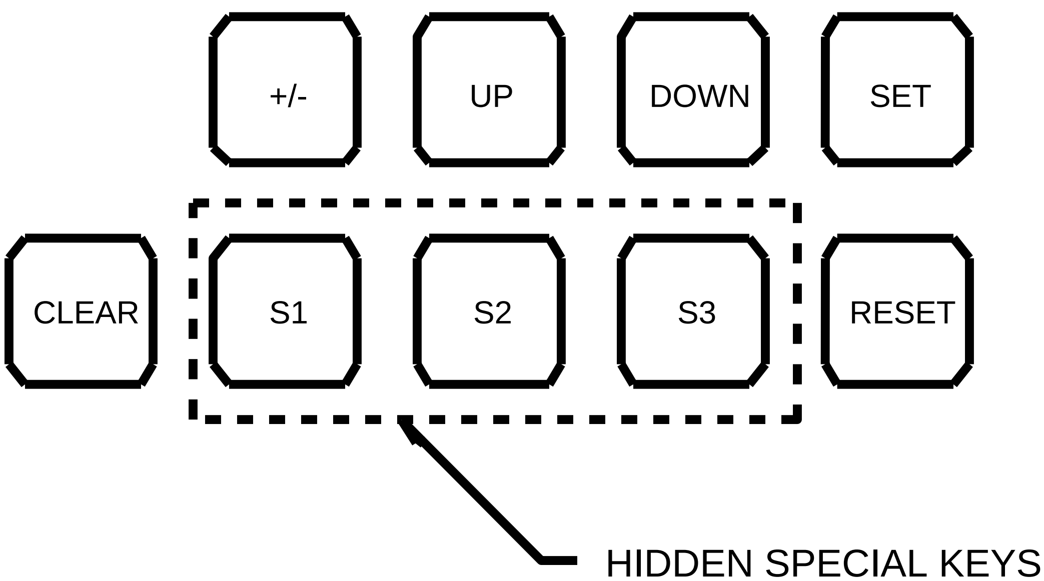


Figure 5.1: Location of Special Hidden Keyes

5.1 ERROR COMPENSATION

After each resistance reading the integration time is converted to a resistance. The conversion from time to resistance is achieved using the formula:

$$\text{Resistance} = \frac{V_{test} \times T_{integration}}{2 \times C_{integrator} \times T_{integrator}} - R_{protection}$$

Where: Resistance is the value of the unknown resistor

V_{test} is the test voltage from the 6500A source

$T_{integration}$ is the time for the integration

$C_{integrator}$ is the value of the integrator capacitor

$T_{integrator}$ is the threshold of the integrator

and

$R_{protection}$ is the value of the protection resistor.

The nominal value of each of the components in the equation are known except for the unknown resistance. The variances from the nominal value are also known. The 6500A system software calls up the nominal value of each component and multiplies each by a correction factor before computing the resistance value.

5.2 DETERMINING ERRORS

5.2.1 Rprotection ERROR

The value of the protection resistor is measured by the instrument during calibration using a short circuit connection between the source and input connectors of the 6500A and is stored in the instruments Non-Volatile memory.

5.2.2 Vtest ERROR

The variance of the test voltage from its nominal value is determined during calibration by selecting each possible output voltage and measuring its absolute value with a precision voltmeter. The variance of the output voltage from its nominal value is computed in Parts Per Million (ppm) and entered into the instruments Non-Volatile memory either from the front panel or through one of the bus interfaces (RS-232C or GPIB). It should be noted that there are twenty (20) different variances computed, and stored in the instrument, one for each voltage of each polarity.

5.2.3 Cintegrator ERROR

The exact value of the reference resistor (used during calibration to compute the capacitor and threshold variances) is entered into the instruments Non-Volatile memory either from the front panel (see section 5.6.3) or through one of the bus interfaces (see section 7.0).

The variance of each integration capacitor is computed by the instrument. A known Standard Reference resistor (100 Megohm) is connected between the instruments source and input terminals. The instrument then takes 20 readings of the Standard Reference resistance and computes an average resistance value with corrections for only the source voltage variance and the protection resistor. Using the average resistance value and the reference resistance value a number representing the variance of the capacitor from its nominal value is computed. The capacitor variance is automatically stored into the instruments Non-Volatile memory.

5.2.4 Tintegrator ERROR

The variance of the integration thresholds is also computed by the instrument. A known Standard Reference resistor (100 Megohm) is connected between the instruments source and input terminals. The instrument then takes 20 readings of the Standard Reference resistor and computes an average value with corrections for the source voltage variance, the integration capacitor variance and the protection resistor. The average value and the resistance value are used to compute a number representing the variance of the threshold from its nominal value. The threshold variance is automatically stored in the instruments Non-Volatile memory.

5.3 OUTLINE OF INSTRUMENT CALIBRATION

Complete details of the Calibration procedure are included in Chapter 6 of this manual. An outline of the instrument calibration procedure follows:

1. Enter the nominal value of the standard reference resistor into the instruments Non-Volatile memory (see section 5.6.7).

2. Assume that the protection resistor is its nominal value of 100 Kilohms and store this value into the instruments Non-Volatile memory (see section 5.6.3).

3. Determine each of the voltage source errors with an external precision voltmeter.

4. Enter each of the voltage source error values into the instruments Non-Volatile memory (see section 5.7.3 to enter the correction coefficients).
5. Measure the standard reference resistor using the 10.0 volt integration threshold and each of the three integrator capacitors.

6. Determine for each capacitor the integration capacitor variances and store these values into the instruments Non-Volatile memory (see section 5.6.4).

7. Measure the reference resistor with the 2700 PicoFarad integration capacitor and the 0.1 and 1 volt integration thresholds, determine the two threshold variances and store these values into the instruments Non-Volatile memory (see section 5.6.5).

8. Measure a short circuit to determine the actual value of the protection resistor, and enter this value into the instruments Non-Volatile memory (see section 5.6.3).

5.4 OPERATING LEVELS

In order to examine, modify or execute a portion of SOFCAL, the operator must go to the desired part of the SOFCAL program by a path that descends through different levels of choices. This concept is shown diagrammatically in Figure 5.2.

Each level in a path is called a branch. Some paths descend through more levels than others. When the instrument is at a particular SOFCAL branch, the operator can select any part of the branch by scrolling with the UP key. For example in Figure 5.2, if the operator enters SOFCAL and places the instrument at a position X, pressing the UP key repetitively will move the instrument SOFCAL choices sequentially to choices at positions Y, W, and back to X.

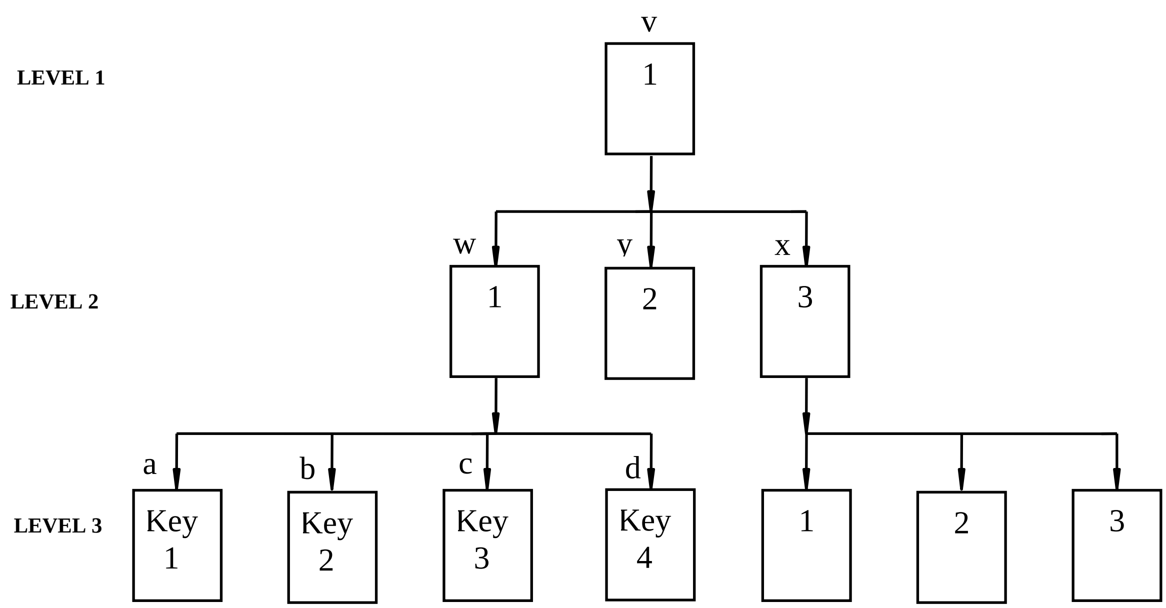
The instrument SOFCAL choice can also be moved directly to any SOFCAL position on the branch from any other position on the same branch by pressing the appropriate key. For example, the operator can move to position d from a, b or c by pressing the number 4 key once.

5.4.1 DESCENDING LEVELS

Each time the ENTER key (clear) is pressed, the 6500A moves down one level. For example in Figure 5.2 if the 6500A is at position V, pressing the ENTER key once will move it to the branch WXY. If the ENTER key is pressed while the 6500A is at any position in the bottom level of a path, it will usually execute the indicated function or allow a value to be examined or changed.

5.4.2 ASCENDING LEVELS

The 6500A can go upwards along a path if the operator presses the +/- key. For example, in Figure 5.2 if the 6500A is at position X, the operator can move it to V by pressing the +/-key once.



KEY	Menu Function
ENTER	- Accept Value Displayed - Execute Menu Function Displayed
+/-	- Ascend Level to Previous Level
UP	- Scroll to Positions Available on Current Menu Level
Numeric 0 - 9	- Go Directly to Menu Option Available on Current Menu Level

Figure 5.2: Typical SOFCAL Operating Levels

5.5 EXITING SOFCAL

Pressing the SET key while in the SOFCAL mode will return the instrument to normal operational waiting mode with SELECT OHMS/PA on the display.

5.6 SOFCAL NORMAL MODE

In this mode of SOFCAL, the GPIB and RS-232C formats may be examined or modified, various system error parameters may be examined or remeasured, the last 6500A calibration date can be displayed or changed and the instrument software revision level can be displayed.

This branch of SOFCAL can be entered by pressing the front panel SOFTCAL key. This will give a display that initially displays the message NORMAL MODE followed by the message SELECT FUNCTION. The mode message can be checked by pressing the ± key at any time.

The desired FUNCTION list may be displayed by scrolling with the UP key or the function activated directly by pressing a numeral key from the list shown in Table 5.1.

Key Number	Function
0	GPIB Status
1	Configure RS-232C
2	Zero Error (6500A input resistance)
3	Cap Error (integrating capacitor)
4	Thresh Error (threshold voltage)
5	Calibration Date
6	Reference Res

Table 5.1: SOFCAL Normal Mode Functions

Any of the above functions may be selected for examination or alternation by pressing the ENTER key once when the desired function is displayed. To exit back to the operational mode, press the SET key.

5.6.1 GPIB STATUS

When this function is selected, the GPIB address and talk/listen status can be examined. The GPIB status can only be changed with the rear panel GPIB INTERFACE switch. When the switch positions are altered, the display will reflect the change immediately, but the new status will not be in effect on the bus until the 6500A exits from the SOFCAL program (by pressing the SET key, RESET key or turning the power off momentarily).

The address and talk/listen status may be obtained by scrolling with the UP key or by direct key entry using the following menu:

Key Number	GPIB Status
0	GPIB address
1	talk/listen

Table 5.2: GPIB Status

The talk/listen status can be changed from the rear panel using the GPIB INTERFACE SWITCHES at position 6 and position 7. Table 5.3 details the GPIB options for switches 6 and 7.

Switch #6 Talk Only	Switch #7 Interface	Status
1	1	Talk Only
0	1	Talk And Listen
1	0	GPIB Not Configured
0	0	

Table 5.3: GPIB Talk Listen Switch Setting

The "1" position is selected when the lower part of the switch rocker is pushed in. The desired GPIB status should be verified visually on the display.

If the Talk Only mode is selected the GPIB controller will be configured to send each reading to the GPIB bus.

If any printing character is received on the RS-232C bus while the Talk Only switch is set, then each reading will be routed to the RS-232C output. This will cancel the routing of the readings to the GPIB.

5.6.2 CONFIGURE RS-232C

This function allows the operator to examine or alter the data format on the RS-232C bus. When this function is selected (by pressing the ENTER key once with the message CONFIGURE RS-232C in the display window), the various RS-232C format characteristics can be examined by scrolling with the UP key or by direct key entry from the following menu:

Number	DISPLAY
0	BAUD RATE status
1	DATA BITS status
2	STOP BITS status
3	PARITY status
4	ECHO status
5	FLOW CONTROL status

Table 5.4: Configure RS-232C

The status of any RS-232C format characteristic may be changed by the following procedures.

5.6.2.1BAUD RATE

The baud rate may be changed by pressing the ENTER key once while the message BAUD RATE is in the display window. The desired rate can then be selected from the display by scrolling with the UP key or by direct key entry from the following menu:

Key Number	BAUD RATE (BITS ersecond)
0	9600
1	50
2	75
3	110
4	150
5	300
6	600
7	1200
8	2400
9	4800

The desired rate will appear as a flashing value and is selected by pressing the ENTER key once when the rate is displayed in the display window. This will also cause an exit to the SOFCAL branch allowing the operator to change other RS-232C parameters.

5.6.2.2DATA BITS

The number of RS-232C data bits may be changed by pressing the ENTER key once while the message DATA BITS is in the display window. The desired number of data bits can then be selected from the display by scrolling with the UP key or by direct key entry from the following menu:

Key Number	DISPLAY
0	DATA BITS 8
1	DATA BITS 5
2	DATA BITS 6
3	DATA BITS 7

The desired number of data bits is selected by pressing the ENTER key once while the DATA BITS value is displayed in the display window. This will also return the 6500A to the SOFCAL branch allowing the operator to change other RS-232C parameters.

5.6.2.3STOP BITS

The number of stop bits may be changed by pressing the ENTER key once while the message STOP BITS is in the display window. The desired number of stop bits can then be selected from the display by scrolling with UP key or by direct key entry from the following menu:

Key Number	DISPLAY
0	STOP BITS 2
1	STOP BITS 1

The desired number of stop bits is selected with a single depression of the ENTER key while the STOP BITS value is in the display window. This will also exit to the SOFCAL branch allowing the operator to change other RS-232C parameters.

5.6.2.4PARITY

The parity check may be changed by pressing the ENTER key once while the message PARITY is in display window. The desired parity characteristic can then be selected from the display by scrolling with the UP key or by direct key entry from the following menu:

Key Number	DISPLAY
0	PARITY NONE
1	PARITY ODD
2	PARITY EVEN

The desired parity characteristic is selected by pressing the ENTER key once while the parity message is in the display window. This will also exit to the SOFCAL branch allowing the operator to change other RS-232C format characteristics.

5.6.2.5ECHO

The echo status may be changed by pressing the ENTER key once while the message ECHO status is in the display window. The desired echo characteristic is then brought to the display by scrolling with the UP key or by direct key entry from the following menu:

Key Number	DISPLAY
0	ECHO ON
1	ECHO OFF

When the desired echo status is visible on the display, it is selected by pressing the ENTER key once. This will also exit to the SOFCAL branch allowing the operator to change other RS-232C characteristics.

5.6.2.6FLOW CONTROL

The flow control status may be changed by pressing the ENTER key once while the flow control status is in display window. The desired flow control is brought to the display window by scrolling with the UP key or by direct key entry from the following menu:

Key Number	DISPLAY
0	X ON
1	RTS
2	RCK

When the desired flow control is in the display window, it is selected by pressing the ENTER key once. This will also exit to the SOFCAL branch allowing the operator to change the other RS-232C characteristics.

5.6.3 ZERO ERROR

This is the value of the internal resistance presented by the 6500A between the input connector and ground. The 6500A maintains a stored value for this resistance in its memory and subtracts it from all resistance measurements before the final value of the unknown resistance is put on the front panel display or made available at either control bus. If the ZERO ERROR resistance should change or if the stored value should become corrupted in the memory, the 6500A is capable of remeasuring the true value and entering the true value into memory.

5.6.3.1EXAMINING THE STORED ZERO ERROR

When the message ZERO ERROR is in the display window, the stored value can be displayed by pressing the ENTER key once. The display will then alternate between the stored value and the prompt SHORT CKT I/P (prompting the user to apply a short circuit between the input and source connectors). If it is not necessary to change the value, press the +/- key after the old value has been displayed. This will exit (without disturbing the stored value) to the SOFCAL branch where other NORMAL mode parameters can be changed.

5.6.3.2REMEASURING AND REENTERING THE ZERO ERROR

When the display alternates between the stored value and the prompt SHORT CKT I/P, the true value of zero error can be measured and the new value placed in memory in place of the stored value by connecting the short circuit and pressing the ENTER key once. This will initiate a series of automatic zero error measurements. During this two minute session, the 6500A calculates and displays a running average of the measurements. When all of the measurements are taken the 6500A places the final average value into its memory overwriting the old stored value and returns to a display alternating between the new stored value and the prompt SHORT CKT I/P (to short circuit the input).

Press the +/- key to exit to the SOFCAL branch where other NORMAL mode parameters can be changed. It should be noted that if the zero error measurements are interrupted before completion, a check sum error may be generated which will cause subsequent power up diagnostic self-checks to fail. Should this occur, follow the instructions for checksum correction (paragraph 9.2).

5.6.4 CAP ERROR

This is the percentage error in the true value of the three integrating capacitors used in the 6500A. The three error values are stored in the instruments memory and are used to compensate resistance measurements. If the capacitor values should ever change or if the value in memory should become corrupted, the SOFCAL program is able to measure the true value and allow re-entry of the new Capacitor ERROR value into the 6500A memory in place of the old stored value.

5.6.4.1EXAMINING THE STORED CAP ERROR

When the message CAP ERROR is in the display window the stored values for the three capacitor errors may be examined by pressing the ENTER key once. This will cause the display to alternate between a display of one of the integrating capacitor errors and the prompt CONNECT REF RES (prompting the operator to connect the standard reference resistor - required for calibration).

All three capacitor errors may by examined by scrolling with the UP key or alternatively, the three values may be read in a sequence by direct key entry from the following menu:

Key Number	Display	Alternates To
0	27 PF	% error
1	270 PF	% error
2	2700 PF	% error

If the stored values do not need to be changed, press the +/- key once in order to exit without disturbing the values in memory to the SOFCAL branch where other NORMAL MODE parameters can be changed.

When the old stored value of one of the capacitors is being displayed, a new value can be measured by connecting the reference resistor (see 5.6.7) and pressing the

ENTER key once. The 6500A will make a series of resistance measurements of the reference resistor. Since an accurate measure of the reference resistor is already in the 6500A memory, any apparent discrepancies are translated to capacitor error by the 6500A. When all of the measurements are completed for this one selected capacitor, the 6500A calculates an average resistance, converts it into the capacitor error, enters the new value into memory in place of the old value and then proceeds to alternate the display between the new value and the prompt CONNECT REF RES. A new capacitor can then be selected for examination or remeasurement by scrolling with the UP key or using the key number as in paragraph 5.6.4.1. Exit to the SOFCAL branch where other NORMAL MODE parameters can be changed is made by pressing the +/- key once.

5.6.5 THRESH ERROR

This is the error of the threshold voltages occurring at the integrator output. The threshold error values for the 0.1, 1 and 10 volt thresholds are stored by the 6500A and are used to correct the unknown resistance and current measurements.

To examine stored values or to remeasure and enter new threshold error values, press the ENTER key when the message THRESH ERROR is in the display window. This will give a display alternating between a prompt to CONNECT REF OHMS (prompting the operator to connect the references resistor between the SOURCE and INPUT connectors) and the value of one of the threshold voltage errors.

Each threshold voltage can be examined without the reference resistor by scrolling with the UP key or by direct key entry from the following menu:

Key Number	DISPLAY
0	T 0.1 V error %
1	T 1 V error %

When a particular threshold voltage error (0.1, or 1 V) is being displayed, a new value can be obtained and entered into the memory by connecting the reference resistor and pressing the ENTER key once. This will reset the old stored value to zero and initiate a series of new measurements. When the measurements are complete, the 6500A will calculate an average value which will be stored in its memory and displayed at the front panel. It will also return to the SOFCAL branch with the other threshold voltages. It should be noted that interrupting the measurements before they are completed will generate a check sum error which will show whenever the 6500A does a self check. A new threshold can then be selected for examination or remeasurement by scrolling as detailed in Threshold Error key table listed above. Exit to the SOFCAL branch where other NORMAL MODE parameters can be changed is made by pressing the +/- key once.

5.6.6 CALIBRATION DATE

This is the date of last calibration. If a new calibration date is to be entered press the ENTER key. This will give a display of the last calibration day with the date flashing. A new day may be keyed in with the numeric keys and the ENTER key pressed once. The calibration month and year may be entered by scrolling with the UP key and then following the above procedure. Exit to the SOFCAL branch where NORMAL MODE parameters can be changed is made by pressing the +/- key once.

Note: This function is not available through external communications. It must be performed from the front panel.

5.6.7 REFERENCE RES

When the message REFERENCE RES is displayed in the display window, pressing the ENTER key will bring to the display the value that is stored in the REFERENCE RESISTOR memory location. By pressing the ENTER key again the number will flash and can be altered by pressing a new sequence of numbers. e.g. pressing 1 0 0 0 0 0 0 0 0 will cause 100.00000M to be the new pending number. Pressing the ENTER key will store the new value. Pressing the +/- key once will exit this function and return to the SOFCAL, NORMAL MODE setup menu level.

Note: ONLY values between 80M and 11G may be entered. If the value entered is invalid, a default value of 1G will be stored.

5.7 SOFCAL CALIBRATION MODE

In this mode of SOFCAL various systems error parameters may be examined and/or modified.

The calibration mode of SOFCAL is entered by pressing the SOFCAL key followed by the hidden special keys S2 and S3 keys. The S2 and S3 keys are not marked on the keyboard and are only active in the SOFCAL mode. They are located on the lower right side of the 6500A front panel between the CLEAR and RESET keys as shown in Figure 5.1. This will give a display that alternates between CALIBRATION MODE and SELECT FUNCTION. A function may be displayed by scrolling with the UP key or directly by pressing a numeral key from the following menu:

Key Number	Function
0	Serial Number
1	Software Rev
2	Output Errors

Any of the above functions may be selected for examination by pressing the ENTER key once when the desired function is displayed. To exit back to the OPERATE mode press the SET key.

5.7.1 SERIAL NUMBER

When the SERIAL NUMBER message is displayed, pressing the ENTER key will bring to the display the S/N that is stored in the memory. By pressing the ENTER key again the number will flash and may be altered by pressing a new sequence of numbers followed by pressing the ENTER key. Exit to the SOFCAL branch where other CALIBRATION MODE parameters can be changed is made by pressing the +/- key once.

5.7.2 SOFTWARE REVISION

This is the current revision level of software that has been installed in the 6500A. This information may be viewed only. It cannot be changed by the customer. Exit to the SOFCAL branch where other CALIBRATION MODE parameters can be changed is made by pressing the +/- key once.

5.7.3 OUTPUT ERRORS

When the message OUTPUT ERRORS is displayed in the display window pressing the ENTER key will bring the prompts MINUS VOLTAGES or PLUS VOLTAGES to the display window. The UP key will toggle the display between these prompts. If, when the prompt PLUS VOLTAGES is displayed, the ENTER key is pressed, the unit will display the error saved in memory of the +1 V test voltage. Pressing the ENTER key again will cause the error value to flash. A new value may now be entered by pressing the numeric keys followed by the ENTER key. Press the UP key to view the next test voltage error. The different test voltages are 1, 2, 5, 10, 50, 100, 200, 500, 1000 in both polarities (±). To measure the output test voltage error a DVM is connected to the output to measure the output test voltage. The following equation is used to calculate the value to enter for each output test voltage range.

$$\text{Test Voltage Error} = \text{number to be keyed into display} = \frac{\text{DVM reading} - \text{Ideal Voltage}}{\text{Ideal Voltage}} \times 10^6$$

Due to the large number of output test voltage points to be measured during calibration, it is recommended that the numbers are entered using one of the interface busses (GPIB or RS-232C).

6 VERIFICATION AND CALIBRATION

6.1. SPECIFICATION VERIFICATION

The procedures outlined in this section may be used to verify that the 6500A Teraohmmeter is operating within the limits stated in the specifications (chapter 2) of this manual. Performance verification may be performed when the instrument is first received to ensure that no damage or misadjustment has occurred during shipment. Verification may also be performed whenever there is a question of instrument accuracy or following calibration if necessary.

6.1.1 ENVIRONMENTAL CONDITIONS

Verification checks should be made only when the instrument is being operated within the operating limits of temperature and humidity specified in chapter 2 of this manual.

6.1.2 INITIAL CONDITIONS

A warm-up time of at least one hour must be allowed before beginning the verification process. If the instrument has been subjected to extremes of temperature outside the operating limits, additional time should be allowed for the instrument components to stabilize to their normal operating temperatures. Typically, it takes one additional hour to stabilize a unit that has been exposed to a temperature 10°C outside the specified temperature range.

6.1.3 RECOMMENDED TEST EQUIPMENT

Table 6.1 lists all test equipment required for the verification of the 6500A Teraohmmeter. Alternate equipment may be used as long as the substitute equipment has specifications as good as or better than the equipment listed.

Description	Specification	Manufacturers Model
Digital Voltmeter	±0.003% accuracy 20 Megohm input impedance (minimum)	Datron 1281 or Equivalent
Calibration Resistor	100 Megohm traceable to NRCC or NIST	Guildline 9336-100M Or Equivalent
Short Circuit	0 ohm link	Guildline 65206/0
Decade Resistor Box	calibrated to ±0.01% uncertainty	Guildline 9345/1G Or Equivalent

Table 6.1: Recommended Verification Test Equipment

6.1.4 CHECK CALIBRATION REPORT

The following paragraph details the procedures to be used to check the stored calibration coefficients against the coefficients listed on the instrument calibration report. If the instrument has been re-calibrated or adjustments made to the instrument after the date printed on the calibration report, the stored coefficients may not match the coefficients listed in the report. The user should verify the instrument against the most recent calibration report.

6.1.4.1TEST VOLTAGE COEFFICIENTS

- Reference should be made to paragraph 5.7
- Apply power to the instrument
- Verify that the unit passes all self tests and displays the message SELECT OHMS/PA
- Press the SOFCAL key
- Press Hidden key S2
- Press Hidden key S3 to enter SOFCAL calibration mode
- Verify the message CALIBRATION MODE is momentarily displayed followed by the prompt SELECT FUNCTION
- Press the numeric key #0
- Verify the prompt SERIAL NUMBER is displayed
- Press the ENTER key
- Verify that the serial number displayed matches the serial number printed on the rear of the instrument and on the instrument calibration report.
- Press the ± key to exit
- Press the numeric key #2
- Verify the prompt OUTPUT ERRORS is displayed
- Press the ENTER key
- Press the UP key until the message PLUS VOLTAGES is displayed
- Press the ENTER key

- Verify the error displayed for the 1 volt test voltage matches the value listed in the calibration report

- Press the UP key to check each test voltage error in turn

- Repeat the error checks for the MINUS VOLTAGES

- Press the SET key to exit to the prompt SELECT OHMS/PA

6.1.4.2 COMPONENT ERRORS

- Reference should be made to paragraph 5.6

- Press the SOFCAL key

- Verify the message NORMAL MODE is momentarily displayed followed by the prompt SELECT FUNCTION

- Press the numeric key #2

- Verify the prompt ZERO ERROR is displayed

- Press the ENTER key.

- Verify the value displayed matches the value listed in the calibration report for the ZERO COEFFICIENT

- Press the ± key to exit

- Press the numeric key #3

- Verify the prompt CAP ERROR is displayed

- Press the ENTER key

- Verify that the value displayed for each capacitor value matches the values listed in the calibration report for the CAPACITOR COEFFICIENT. The UP key is used to scroll through each of 3 capacitor values in turn.
- Press the ± key to exit

- Press the numeric key #4

- Verify the prompt THRESH ERROR is displayed

- Press the ENTER key

- Verify that the value displayed for each threshold value matches the values listed in the calibration report for the THRESHOLD COEFFICIENT. The UP key is used to scroll through each of 2 values in turn.

- Press the SET key to exit to the prompt SELECT OHMS/PA

6.1.5 TEST VOLTAGE VERIFICATION

Connect the Digital Voltmeter to the SOURCE connector of the 6500A under test.

Put the instrument into the SOFCAL DIAGNOSTIC MODE of operation (reference chapter 8 paragraph 8.10.2.) by pressing the key sequence :

SOFCAL
HIDDEN KEY S1
HIDDEN KEY S3
NUMERIC KEY #3

The prompt OUTPUT TEST will appear in the display window.

ENTER

Press the numeric key #0 to select the +1 V test voltage. (Key #0 will toggle + or - 1 V).

Press the ENTER key to turn the SOURCE output on.

Record the reading displayed by the DVM. Press the UP key to select the next test voltage followed by the ENTER key. Record each test voltage nominal value (Vnom) and the DVM reading (Vdvm) for each test voltage (+1 V through +1000 V and -1 V through -1000 V). Press the TEST VOLTS key to turn the SOURCE output OFF. Calculate the test voltage error value from the following expression :

$$\text{Error (ppm)} = \frac{V_{dvm} - V_{nom}}{V_{nom}} \times 10^6$$

For each test voltage verify that the Error (ppm) does not exceed the Limits (ppm) listed in the calibration report. There may be a difference between the absolute values of the measured Error (ppm) and the values listed in the report. These differences are acceptable only if they represent constant shift throughout the complete list of Errors.

The list of differences between the measured Error (ppm) and the reported Error (ppm) should be such that difference between each entry is within 100 ppm.

Press the SET key to exit to the prompt SELECT OHMS/PA.

6.1.6 OPERATIONAL CHECK

The operation of the Teraohmmeter display and indicators can be checked by performing an instrument RESET (pressing the RESET key) and observing the response. The Teraohmmeter will respond as detailed in Paragraph 4.1.

6.1.7 MEASUREMENT LINEARITY

Apply power to the instrument under test. For full accuracy checks the instrument should be powered for at least 1 hour in an environment not exceeding the limits detailed in paragraph 2. Connect a decade resistance box as specified in Table 6.1 to the Teraohmmeter SOURCE and INPUT terminals and set the decade box switches to 1 X 10^7 ohms.

Set the Teraohmmeter to OHMS measurement mode with the selected 10 V threshold, 2700 pF integrator capacitor and 1 V test voltage. Paragraph 4.2.2 details the steps required for manually setting up the measurement mode.

- Disable Autoreverse.
- Select + (positive) Test Volts.
- Record the average of 4 readings after equilibrium has been reached.
- Select - (negative) Test Volts.
- Record the average of 4 readings after equilibrium has been reached.
- The average of the positive and negative Test Voltage results should be within +/- 250 ppm of the true resistance value.
- Repeat the measurements with test resistances in the range 1 X 10^7 ohms through 10 X 10^7 ohms in steps of 1 X 10^7 ohms.

6.2 CALIBRATION PROCEDURE

This paragraph will describe procedures to be followed to calibrate the instrument. An outline of the calibration procedure is included as paragraph 5.3 of this manual.
The environmental conditions of chapter 2 apply during calibration and the initial conditions of paragraph 6.1.2 should be observed. Calibration of the Model 6500A Teraohmmeter should be carried out in the sequence described using the test equipment described in Table 6.2.

Description	Specification	Manufacturers Model
Digital Voltmeter	±0.003% accuracy 20 Megohm input impedance (minimum)	Datron 1281 or Equivalent
Calibration Resistor	100 Megohm traceable to NRCC or NIST	Guildline 9336-100M Or Equivalent
Short Circuit	0 ohm link	Guildline 65206/0

Table 6.2: Recommended Calibration Test Equipment

6.2.1 OUTPUT VOLTAGE CALIBRATION

Connect the Digital Voltmeter to the SOURCE connector of the 6500A under test.

Put the instrument into the SOFCAL DIAGNOSTIC MODE of operation (reference chapter 8 paragraph 8.10.2) by pressing the key sequence.

SOFCAL
HIDDEN KEY S1
HIDDEN KEY S3
NUMERIC KEY #3

The prompt OUTPUT TEST will appear in the display window.

ENTER

Press the numeric key #0 to select the +1 V test voltage (Key #0 will toggle + or - 1 V).

Press the ENTER key to turn SOURCE output on.

Allow sufficient time for the DVM reading to stabilize. Record the reading displayed by the DVM. Press the UP key to select the next test voltage. Record each test voltage nominal value (Vnom) and the DVM reading (Vdvm) for each test voltage (+1 V through +1000 V and -1 V through -1000 V). Press the TEST VOLTS key to turn the SOURCE output OFF. Calculate the test voltage error value from the following expression:

$$\mathbf{Error\ (ppm)} = \frac{V_{dvm} - V_{nom}}{V_{nom}} \times 10^6$$

For each test voltage record the Error (ppm) voltage coefficient.

- Press the SET key to exit to the SELECT OHM/PA message.

- Select the SOFCAL CALIBRATION MODE of operation by: Pressing the SOFCAL KEY, then the HIDDEN KEY S2, and the HIDDEN KEY S3.

- Reference paragraph 5.7

- Verify the message CALIBRATION MODE is momentarily displayed followed by the prompt SELECT FUNCTION.

- Press the numeric key #0.

- Verify the prompt SERIAL NUMBER is displayed.

- Press the ENTER key.

- Verify that the Serial Number displayed matches the serial number printed on the rear of the instrument and on the calibration report.

- Press the +/- key to exit.

- Press the numeric key #2.

- Verify the prompt OUTPUT ERRORS is displayed.

- Press the ENTER key.

- Press the UP key until the message PLUS VOLTAGES is displayed.

- Press the ENTER key.

- Verify the display indicates the 1 volt test voltage and its current error coefficient.

- Press the ENTER key. The rightmost digit of the displayed error coefficient will now flash.

- Use the numeric keys to enter the new test voltage coefficient (in ppm) calculated previously.

- Use the up key to change the polarity of the voltage coefficients.

Note: The previous coefficient value may be cleared out by entering zero's.

- Carefully check the entered number then press the ENTER key to accept and store the new coefficient.
- Press the UP key to view the next test voltage and its stored error coefficient.
- Press the ENTER key to edit the displayed value.
- Repeat the edit and re-entry of the test voltage error coefficients for all test voltage values and polarities.
- Press the SET key to exit to the prompt SELECT OHMS/PA.

6.2.2 CAPACITOR CALIBRATION

- Reference paragraph 5.6.4.
- Connect the 100 megohm reference resistor between the SOURCE and INPUT terminals of the instrument.
- Select the SOFCAL NORMAL MODE of operation by pressing the SOFCAL key.
- Press the numeric key #6. Verify the message REFERENCE RES is displayed.
- Press the ENTER key to display the value stored for the reference resistor.
- Press the ENTER key again to cause the displayed value to flash.
- Using the numeric keys enter the new value of the reference resistor.
- Press the ENTER key to accept/store the new value.
- Press the +/- key to exit to the REFERENCE RES prompt.
- Press the numeric key #5. Verify the message CALIBRATION DATE is displayed.
- Press ENTER to view the previous calibration date.
- Press ENTER to edit/re-enter the new calibration date.
- Press UP key to scroll day, month year.
- Press the ENTER key to accept the new calibration date.

- Press the +/- key to exit to the CALIBRATION DATE prompt.

- Press the numeric key #3. Verify the message CAP ERROR is displayed.

- Press the ENTER key to view the alternating message strings CONNECT REF RES and % ERROR.

- Press the UP key until the % error for the 2700 pF capacitor is displayed.
- Ensure that the 100 megohm reference resistor is connected. Press the ENTER key to start the automatic capacitor calibration sequence.

- When the calibration sequence is complete the instrument will prompt with the alternating messages CONNECT REF RES and % ERROR.

- Use the UP key to select and calibrate the 270 pF capacitor and 27 pF capacitor in order.

- Once the last (27 pF) capacitor error is known press the +/- key to exit the CAP ERROR prompt.

6.2.3 THRESHOLD CALIBRATION

- Reference paragraph 5.6.5

- Press the numeric key #4. Verify the message THRESH ERROR is displayed.

- Press the ENTER key to display the error stored for the 1 V threshold.

- Press the UP key until the 1 V threshold error is displayed.

- Ensure that the 100 megohm reference resistor is connected. Press the ENTER key to start the error measurement cycle.

- When the measurement is complete select the 0.1 V threshold value and repeat the measurement cycle.

- Press the +/- key to exit to the THRESH ERROR prompt when both threshold errors have been measured and (automatically) saved.

6.2.4 ZERO ERROR CALIBRATION

- Reference paragraph 5.6.3.

- Press the numeric key #2. Verify the message ZERO ERROR is displayed.

- Press the ENTER key to display the value stored for the input resistance.

- Remove the 100 megohm reference resistor and replace with a terminal 0 ohm link between SOURCE AND INPUT.

- Press the ENTER key to initiate the measurement cycle.

- When the measurement is complete press the +/- key to exit to the ZERO ERROR prompt.

- Press the SET key to accept all stored calibration coefficients. Verify the prompt SELECT OHMS/PA is displayed.

6.3 CALIBRATION REPORT

Prepare a tabulated results sheet similar to that shown in Table 6.3, using the data reported by the instrument during the calibration procedure of paragraph 6.2.

MODEL 6500A Teraohmmeter Serial Number: __________________

Correct checksums are:

CPU ROM: ____________________
MEM ROM: ____________________

Test Voltage (volts)	Error (ppm)	Limits ± (ppm)
1		1000
2		1000
5		1000
10		1000
20		1000
50		1000
100		1000
200		1000
500		1000
1000		1000
-1		1000
-2		1000
-5		1000
-10		1000
-20		1000
-50		1000
-100		1000
-200		1000
-500		1000
-1000		1000

Capacitor PF	Error (ppm)	Limits ± (ppm)
27		100000
270		80000
2700		20000

Threshold (Volts)	Error (ppm)	Limits ± (ppm)
0.1		10000
1.0		10000

Zero Coefficient: ________________________ ohms (Limits: 90 000 ohms to 110 000 ohms)

Dated:______________________

Calibrated by: __________________________

Table 6.3: Sample Calibration Report Format

7 INTERFACES

7.1 INTERFACE BUS OPERATION

The 6500A Teraohmmeter can be remotely controlled via two standard busses:

1. GPIB conforming to IEEE-488/1978.

2. A serial interface conforming to IEA RS-232C.

The GPIB address switches and connector are mounted on the rear panel of the instrument. The 6500A Configuration on the GPIB bus including the bus address is configured by the DIP panel mounted switch. Confirmation of the selected configuration can be checked using the front panel (see paragraph 5.6.1).

A connector for the RS-232C communication bus is also mounted on the rear panel. This serial port is configured using the controls on the front panel (see paragraph 5.6.2) of the instrument.

The 6500A Teraohmmeter can be operated in a system where there are both GPIB and RS-232C controllers attached to the instrument interfaces. In such a case the system programmer is cautioned that unpredictable results may occur since remote commands are processed by the 6500A on a first come, first served basis.

7.2 INTERFACE BUS HARDWARE

7.2.1 IEEE-488/1978 (GPIB)

The IEEE-488 interfacing standard applies to the interfacing of instrumentation systems (or portions of them) in which the:

1. Data exchanged between the interconnected instrumentation are digital.

2. Number of devices connected to one continuous bus does not exceed 15.

3. Total transmission path length over interconnecting cables does not exceed 20 m.

4. Data rate across the interface on any signal line does not exceed 1 megabits per second.

7.2.1.1GPIB CONTROLLER

There can be only one designated controller on the GPIB bus for a maximum of 15 devices. This device exercises overall bus control and is capable of both receiving and sending data. The rest of the devices are designated as listener, talker or talker/listener.

The controller can address other devices and command them to listen, address one device to talk and wait until data are sent. Data routes are set up by the controller but it need not take part in the data interchange.

7.2.1.2INTERCONNECTING CABLE AND GPIB CONNECTOR

The interconnecting cable of the GPIB bus consists of 24 conductors, 16 conductors are signal paths and eight are ground. Table 7.1 details the signal names and corresponding pin connections. The individual cable assembly may be up to four meters long and should have a plug/receptacle type connector at each end of the cable. Each connector assembly is fitted with a pair of captive locking screws.

Pin No.	Name	Description
1	DI01	Data Input/Output line 1
2	DI02	Data Input/Output line 2
3	DI03	Data Input/Output line 3
4	DI04	Data Input/Output line 4
5	E0I	End Or Identify
6	DAV	DAta Valid
7	NRFD	Not Ready for Data
8	NDAC	Not Data Accepted
9	IFC	InterFace Clean
10	SRQ	Service ReQuest
11	ATN	AttentioN
12	SHIELD	Screening on Cable (Connected to Safety Ground)
13	DI05	Data Input/Output line 5
14	DI06	Data Input/Output line 6
15	DI07	Data Input/Output line 7
16	DI08	Data Input/Output line 8
17	REN	Remote Enable
18	GND	Wire or twisted pair with DAV
19	GND	Wire of twisted pair with NRFD
20	GND	Wire of twisted pair with NDAC
21	GND	Wire of twisted pair with IFC
22	GND	Wire of twisted pair with SRQ
23	GND	Wire of twisted pair with ATN
24	GND	Instrument Logic Ground

Table 7.1: GPIB Connector Pin Designations

The GPIB interface defines 5 management signal lines, 8 data input/output signal lines and 3 handshake signal lines for transfer of data.The function of each signal line group is summarized below:

Data Input/Output lines - The 8 data lines (DIO1 through DIO8) form the data bus over which the various devices communicate under the supervision of the bus controller. The message bytes are carried on the DIO signal lines in a bit-parallel, byte serial form, asynchronously and bidirectionally.

Handshake Lines (or Data Byte Control) - Three interface lines are used to effect the transfer of each byte of data on the DIO signal lines from a talker, controller or one or more listeners. These signal lines are: NDAC (Not Data ACcepted), IFC (InterFace Clear) and ATN (ATtentioN).

Data Management Signal Lines - Five interface signal lines control data flow on the bus. These signal lines are :

1. DAV (Data Valid) is used to indicate the condition of (availability and validity) of information on the DIO signal lines.

2. NRFD (Not Ready For Data) is used to indicate the condition of readiness of devices to accept data.

3. SRQ (Service ReQuest) is used by a device to indicate the need for attention or to interrupt the current sequence of events.

4. REN (Remote ENable) is used by a controller in conjunction with other messages to select between two alternate sources of device programming data.

5. EOI (End Or Identify) is used by a talker to indicate the end of a multiple byte transfer sequence or by a controller in conjunction with ATN to execute a polling sequence.

7.2.1.3ADDRESS AND TALK/LISTEN SELECTION

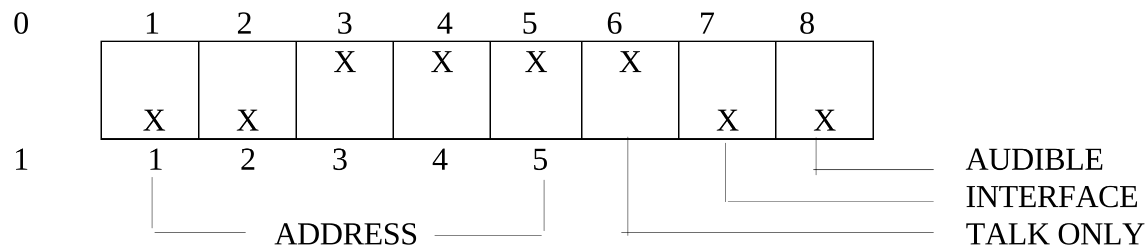
A rear panel DIP switch allows the user to select the GPIB address or Talk/Listen mode as desired. The first five switch positions are used to set the GPIB address. The next switch (position 6) selects Talk only mode, if this is desired. The switch position (position 7) marked "Interface" enables the GPIB interface, and the last switch (position 8) enables or disables the audible annunciator.

To select a bit or a function, press the switch rocker in at the bottom.

If any changes are made in the switch positions, the instrument must either be powered up again or given a software reset via the "RESET" key before the changes take effect. The switches are only read during the initialization or power up phase and hence no changes will be reflected without a restart.

GPIB SETUP Example Switch Settings for - Address 3
- Talk/Listen Mode
- GPIB interface selected
- Annunciator enabled

X means rocker is pressed in.



If there is no controller and the 6500A is hooked up to a printer for hard copy then the Talk-only mode should be selected. For the GPIB interface to be enabled the "Interface" switch (position 7) should be in the ON (or 1) position.

7.2.1.4INTERFACE FUNCTIONS

The 6500A is programmed with the following GPIB functions:

SH1 - Source Handshake
AH1 - Acceptor Handshake
T5 - Basic Talker, Serial Poll, Talk Only mode, Unaddressed in MLA
TEO - No address extension talker mode.
L4 - No Listen Only
SR1 - Service request
RL1 - Remote/Local
PPO - No Parallel Poll capability
DC1 - Device Clear
CO - Not a controller

7.2.2 RS-232C PIN DESIGNATIONS

Pin	Name	Function	Direction
1	CHG	Chassis Ground	-
2	TxD	Transmit Data	In
3	RxD	Receive Data	Out
4	RTS	Request To Send	In
5	CTS	Clear to Send	Out
6	DSR	Data Set Ready	Out
7	GND	Signal Ground	-
8	DCD	Data Carrier Detect	Out
20	DTR	Data Terminal Ready	In

The 6500A Teraohmmeter is data communication equipment (DCE), ie. TxD is an input.

7.3 INTERFACE BUS SOFTWARE

The 6500A is capable of processing many different remote commands. In general any command which can be identified will be processed. In the following sections the portions of the commands shown in upper case characters are required and the portions shown in lower case characters are optional. Punctuation marks such as asterisk (*) and question mark (?) are required parts of commands. The command parser in the instrument uses white space (such as spaces and tabs) to delimit words, hence it is important not to embed whitespace into commands. A quick reference table to the remote commands with some definitions is given in paragraph 7.3.3.

7.3.1 SERIAL POLL REGISTER

The serial poll register can be accessed by the GPIB system controller with a serial poll command. In addition the contents of the serial poll register may be read from either the GPIB or the RS-232C interfaces with the "*STB?" command.

MSB							LSB
7	6	5	4	3	2	1	0

The serial poll register is organized as eight single bit flags where flag zero is the least significant bit of the register and flag 7 is the most significant bit of the register. Each flag has a specific meaning as outlined in Table 7.2.

Flag Bit Number	**Description**
7.	Unused
6.	SRQ (service request) - set when SRE mask OR Serial Poll Register is not zero
5.	ES (event summary) - set when a measurement is completed - cleared when “Value?” command xecuted
4.	MAV (message available) - set when GPIB transmit buffer is not empty - cleared when GPIB transmit buffer is empty
3.	IFL (input buffer full) set when the input buffer is more than 80% full cleared when the input buffer is less than 20% full
2.	CRC (calculating CRC) set at beginning of CRC computation cleared at end of CRC computation
1.	RDY (ready)

	set when 6500 has stable reading (busy LED off) cleared when 6500 working (busy LED on)
0.	DSP (display changed) set when the contents of the display changed cleared when “Display?” command executed

Table 7.2: Serial Poll Register

7.3.2 COMMANDS

7.3.2.1*IDN?

This command instructs the instrument to reply with a self identification. The identification reply is comprised of four parts separated with commas. The first part is the manufacturer (Guildline), the second part is the model number of the instrument (6500A), the third part is the instruments serial number and the fourth part is the internal software revision level

7.3.2.2*SRE? - SERVICE REQUEST ENABLE QUERY

This command allows a programmer to determine the current contents of the Service Request Enable Register. A decimal number between 0 and 63 or between 128 and 191 will be returned.

7.3.2.3*SRE <nr1> - SERVICE REQUEST ENABLE COMMAND

The service request enable command allows the 6500A to generate a service request on the GPIB interface under a limited set of conditions. The limitations on the conditions are defined by the numeric parameter (nr1) following the *SRE command. The numeric parameter is a decimal integer in the range 1-255. The numeric parameter when expressed in base 2 (binary) represents the bit values of the Service Request Enable Register. For all bits (except bit 6) a bit value of one (1) indicates an enabled condition and a bit value of zero (0) represents a disabled condition. *SRE? is the companion query. Figure 7.1 details the bit operation of the SRE register.

7.3.2.4 *STB? - READ STATUS BYTE QUERY

This command allows the programmer to read the status byte and master summary bits of the SERIAL POLL REGISTER (or STATUS BYTE REGISTER) Table 7.2.

The response from this command is a decimal integer in the range 0-255. This decimal integer when expressed in base 2 (binary) represents the bit values in the Status Byte Register. Note that the Master Summary Status bit and Not SRQ is reported in bit 6. The Status Byte Register can also be read with the Read serial Poll hardware command on the GPIB interface.

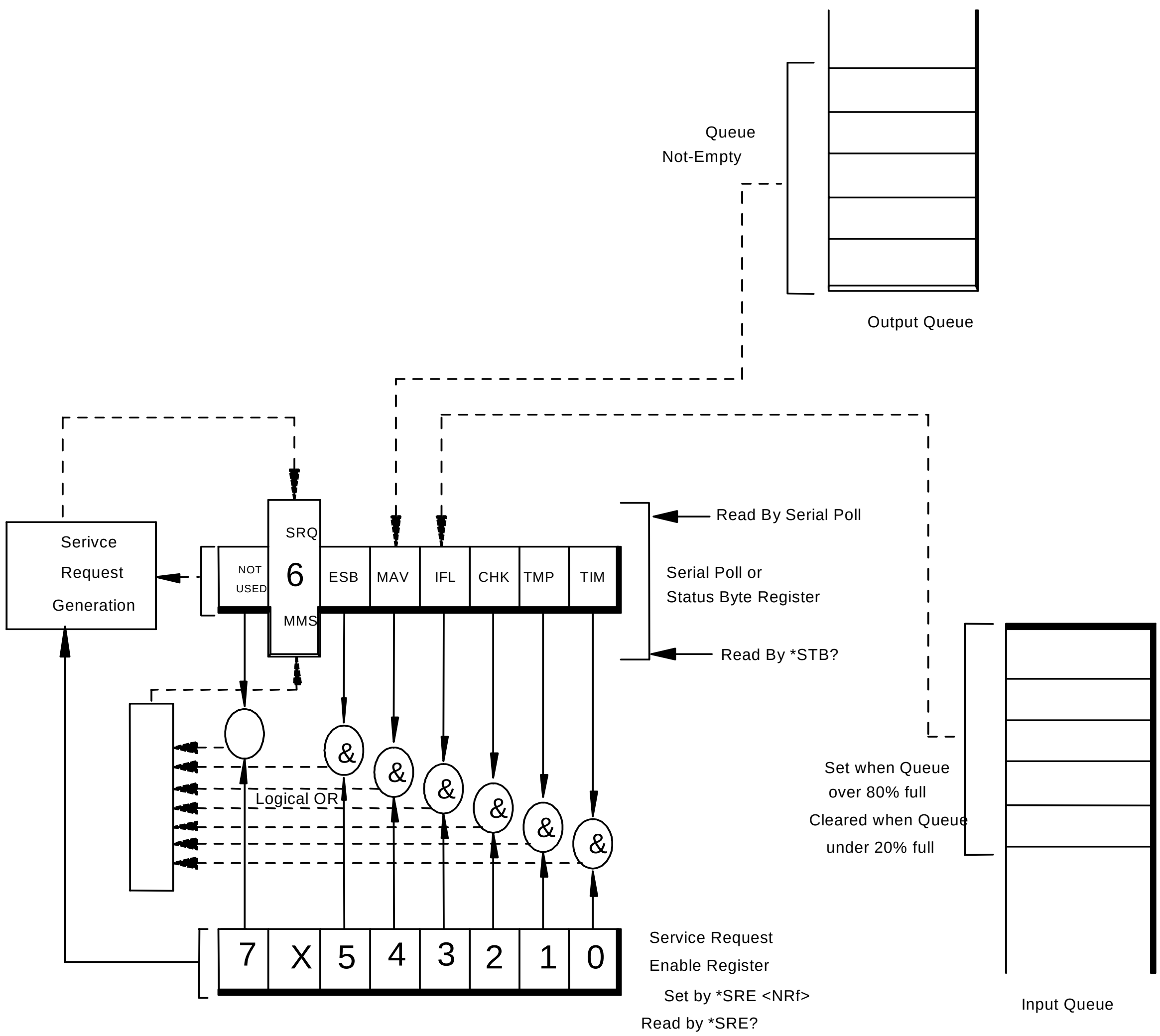


Figure 7.1: Service Request Enable Register Bit Operation

7.3.2.5 ANALOGUEVOLTS? <CHANNEL>

This command allows the programmer to read the internal voltages of the 6500A on the Analogue side of the opto-isolators. The internal voltages available and their corresponding channel numbers are listed in Table 7.3.

CHANNEL	FUNCTION
0	+5 V DC supply
1	-5 V DC supply
2	+15 V DC supply
3	-15 V DC supply
4	Precharge Voltage
5	High Voltage Monitor
6	Integrator Output
7	10 volt Reference

Table 7.3: Analogue Volts Query

7.3.2.6 BEEP [<nr1>]

The beep command instructs the instrument to produce an audible tone lasting <nr1> milliseconds. The beep time can be between 1 and 30,000 milliseconds. If the beep time is not supplied a 100 millisecond tone will be produced. Several beep commands in a row will produce a longer tone with no pauses, however the amount of time outstanding should never exceed 30,000 milliseconds.

7.3.2.7 CHECKSUM? 0/1

This command computes the checksum for one of the two ROMs on the 6500A. Note: Computing the checksums is computationally intensive and will take either 17 or 34 seconds (dependant upon ROM size). A status bit in the status byte is set during the computation period to inform the controller that no commands are being processed. The correct value for the checksum is dependant upon software revision and will be printed on the calibration report with each 6500A.

Checksum Parameter	Description
0	CPU card ROM checksum
1	Memory card ROM checksum

Note: Wait at least 30 seconds then read 6500A.

7.3.2.8 CAPACITOR?

The result from this query command displays the current capacitor selected in the electrometer.

7.3.2.9 CAPACITOR <nr1>

This command allows the programmer to select the value of the integration capacitor. Values are expressed in picoFarads. When this command is executed manual ranging mode is implied.

Capacitor Value <nr1>	**Capacitor Selected**
27	27 picofarad
270	270 picofarad
2700	2700 picofarad

7.3.2.10 DIGITALVOLTS? <CHANNEL>

This command allows the programmer to read the internal voltages of the 6500A on the Digital side of the opto-isolators.

Channel	**Function**
0	+ 5 V DC supply
1	-5 V DC supply
2	+15 V DC supply
3	- 15 V DC supply

7.3.2.11 DISPLAY?

This command allows an instrument on the bus to read the message that is displayed on the front panel of the 6500A. An instrument programmer can determine when the message on the front panel display has changed by examining the status byte with either the *STB or with a serial poll.

7.3.2.12 DISPLAY <STRING>

This command gives an instrument programmer the ability to change the characters on the front panel display of the 6500A. In general if <string> is less than 16 characters, then the characters will be converted to upper case and the string will be centered on the display. If the <string> is longer than 16 characters then only the first 16 characters will be displayed in upper case. The default centring and conversion to upper case can be disabled by enclosing the string in double quotes ("). A double quote character can be displayed by placing two double quote characters in a row ("").

7.3.2.13 EROMCHECKSUM?

This command computes a checksum for the data (calibration coefficients) in the non-volatile RAM. This computed checksum is compared with the checksum stored in the non volatile RAM, if the checksums match a pass indication is returned otherwise a fail indication is returned.

7.3.2.14 IDENTIFY?

This command is a synonym for the *IDN? command paragraph 7.3.2.1.

7.3.2.15 LOCAL?

This query command will return the status of the Local flag (ON or OFF).

7.3.2.16 LOCAL ON/OFF

This command will enable (ON) or disable (OFF) the front panel controls of the 6500A. Note: It is NOT possible to disable the "TEST VOLTS " key, this is an operator safety feature.

7.3.2.17 MAXVOLTAGE?

This query command will return the current setting of the maximum test voltage.

7.3.2.18 MAXVOLTAGE <nr1>

This command will set the maximum test voltage for the auto range software. The maximum voltage will be set to the voltage equal to or just less than the magnitude of the numeric parameter <nr1>.

7.3.2.19 MEASURE?

This command will return a flag indicating whether the instrument is measuring ohms or amperes.

7.3.2.20 MEASURE OHMS/AMPS/STOP

This command will start or stop a measurement. If autoranging is in effect a "Measure Ohms" or "Measure Amps" command will cause the instrument to auto range and make a measurement. If the autoreverse flag is in effect the instrument will make 4 readings. If the continuous flag is in effect the instrument will make repeated measurements.
The "Measure Stop" command will stop measurements.

7.3.2.21 OUTPUTVOLTAGE?

This command will return the current output voltage.

7.3.2.22 OUTPUTVOLTAGE <nr1>

This command will set the output test voltage. Execution of this command will place the instrument in manual range mode.

Value <nr1>	Voltage
0	No voltage
1	1 V
2	2 V
5	5 V
10	10 V
20	20 V
50	50 V
100	100 V
200	200 V
500	500 V
1000	1000V

7.3.2.23 POLARITY?

This query will report the output test voltage polarity (positive or negative) and the status of the autoreverse flag.

7.3.2.24 POLARITY +/-/AUTO
This command will set the instruments polarity.

Parameter	Description
+	Instrument will generate a positive test voltage (not autoreversing)
-	Instrument will generate a negative test voltage (not autoreversing)
Auto	Instrument will autoreverse (ohms mode only)

7.3.2.25 RANGE?
This query command returns the currently selected range mode.

7.3.2.26 RESET
This command has the same effect as a power on reset or pushing the RESET key. After a reset command the 6500A will execute its power on diagnostics. Care should be taken not to send further commands to the 6500A until after if has completed its diagnostic tests.

7.3.2.27 RANGE AUTO/MANUAL
This command allows the programmer to set either autoranging mode or manual ranging mode. A typical scenario for measuring multiple resistors of about the same value might be to allow the instrument to auto range for the first resistor, then to send the "Range Manual" command, this will lock the current range settings. For subsequent measurements the autoranging time will be saved.

7.3.2.28 SOFCAL
Must be expanded to one of the following.

7.3.2.28.1 SOFCAL CAPACITOR <nr1> [<nr1>]
Sets or displays the error coefficients for integration capacitors where the parameters <nr1> and [<nr1>] are defined as <selection> and [<error>]. Selection is defined as:

Selection	**Cap. Value**
0	27 pf
1	270 pf
2	2700 pf

If no value is enterd for [<error>] then it is interpreted as a query for the selected capacitor error. [<error>] value is accepted as ppm correction of nominal value.

7.3.2.28.2 SOFCAL DATE ?
Requests Calibration date of instrument in YYYY/MM/DD format.

7.3.2.28.3 SOFCAL PROTECTION [<nr1>]
Sets or displays the value of the instrument input protection resistor.

7.3.2.28.4 SOFCAL REFERENCE [<nr3>]
Sets or displays the value of reference resistor used for calibration of the instrument.

7.3.2.28.5 SOFCAL SERIAL [<nr1>]
Sets or displays the instruments serial number.

7.3.2.28.6 SOFCAL THRESHOLD <nr1> [<nr1>]
Sets or displays the error coefficients for the threshold voltages where the parameters <nr1> and [<nr1>] are defined as <selection.> and [<error>]. Selection is defined as:

Selection	Voltage Range
0	0.1V
1	1.0V
2	10.0V

If no value is entered for [<error>] then it is interpreted as a query for the selected threshold error. [<error>] value is accepted as ppm correction of nominal value.

7.3.2.28.7 SOFCAL VOLTAGE <nr1> <nr1> [<nr1>]

Sets or displays the instruments output test-voltage error coefficients.

Where the parameters <nr1> <nr1> [<nr1>] are defined as: <polarity> <range> [<error ppm>]. For +ve voltages <polarity> = 0 and for -ve voltages <polarity> = 1. The <range> value is defined by the following table:

Output Voltage	<range>
1 V	0
2 V	1
5 V	2
10 V	3
20 V	4
50 V	5
100 V	6
200 V	7
500 V	8
1 000 V	9

7.3.2.29 THRESHOLD?

This query command reports the currently selected integrator threshold.

7.3.2.30 TRIGGER CONTINUOUS/SINGLE/EXTERNAL

This command has the same effect as pushing the equivalent key on the front panel. Repeated single measurements can be selected by repeatedly sending the command "Trigger Single".

7.3.2.31 TIME?

This query command reports the actual integration time in seconds for the most recent readings. This value is not corrected. If the instrument is in autoreverse mode the time reported will be for the last of the four readings.

7.3.2.32 TRIGGER?

This query command reports the status of the trigger mode.

7.3.2.33 HV_START

This command enables the high voltage output for testing purposes. This command will normally only be used by the factory calibration software.

7.3.2.34 HV_CONTINUE

This command must be sent repetitively after HV_START command to maintain the high voltage output. If this command is not received periodically the high voltage output will shut down. This is a safety feature.

7.3.2.35 HV DISABLE

This command is the companion to the HV_START command. HV DISABLE will shut down the high voltage output.

7.3.2.36 THRESHOLD <nr3>

This command accepts as its parameter a single number which selects the integrator threshold. Execution of this command places the instrument in manual range mode.

Parameter <nr3>	**Threshold Selected**
0.1	0.1Volts
1.0	1.Volts
10.0	10.Volts

7.3.2.37 VALUE

This query command returns the value of the most recent reading either in ohms or amperes.

7.3.3 REMOTE COMMAND QUICK REFERENCE TABLE

<> encloses a keyword
[] encloses an optional item
/ indicates a choice (OR)
:== means "is defined as"
<digit> :== 0/1/2/3/4/5/6/7/8/9
<char> :== A...Z/a...z
<string> :== ["]<str>["]
<str> :== <char>[<str>]
<sign> :== +/-
<prom> :== 0/1
<channel>:== 0...7
<nr1> :== <digit>[<nr1>]
<nr3> :== [<sign>]<nr1>[.[<nr1>]][E/e[<sign>]<nr1>]

	*IDN?	-	display identity of unit
	*SRE?	-	display Service Request Enable register
	*SRE <nr1>	-	set Service Request Enable register bits
	*STB?	-	display Serial Poll Status byte
	AnalogueVolts?<channel>	-	display internal analogue voltages
	Beep [<nr1>]	-	produce audible tone
*	CHecksum? 0/1	-	compute ROM checksum (CRC)
	Capacitor?	-	display selected integration capacitor
	Capacitor <nr1>	-	set integration capacitor
	DigitalVolts? <channel>	-	display internal digital voltages
	Display?	-	display contents of Front panel display
	Display <string>	-	set contents of front panel display
	EromChecksum?	-	display non-volatile memory checksum (CRC)
	HV_START	-	enable High Voltage output
	HV_CONTINUE	-	keep High Voltage On
	Hv disable	-	disable High Voltage Output
	Identify?	-	display identity of unit
	Local?	-	display status of local flag
	Local ON/OFF	-	enable or disable front panel control
	MaxVoltage?	-	display the maximum test voltage
	MaxVoltage <nr1>	-	set the maximum test voltage
	Measure?	-	display measurement mode
	Measure OHms/AMps/Stop	-	set measurement mode
	OutputVoltage?	-	display output voltage
	OutputVoltage <nr1>	-	set measurement voltage
	Polarity?	-	display measurement polarity

• **Buffer will return CRC after approx. 30 second delay.**

Polarity +/-/Auto	-	set measurement polarity

Range?	-	display ranging mode
RESET	-	reset the instrument
Range AUto/MAnual	-	set ranging mode
SOFCAL CAPACITOR <nr1>[<nr1>]	-	set/display capacitor errors
SOFCAL DATE ?	-	display the calibration date
SOFCAL PROTECTION [<nr1>]	-	set/display value of the protection resistor
SOFCAL REFERENCE [<nr3>]	-	set/display value of reference resistor
SOFCAL SERIAL [<nr1>]	-	set/display serial number
SOFCAL THRESHOLD <nr1>[<nr1>]	-	set/display threshold errors
SOFCAL VOLTAGE <nr1><nr1>[<nr1>]	-	set/display output errors
THreshold?	-	display the measurement threshold
TRigger Continuous/Single/External -	-	set trigger mode
Time?	-	display the integration time
TRigger?	-	display trigger status
THreshold <nr3>	-	set the measurement threshold
Value?	-	display the measurement value

8 SERVICE

8.1 SERVICE

This chapter is intended not only as a description of the circuitry which makes up the model 6500A Digital Teraohmmeter but also as a guide for trouble-shooting each of the printed circuit boards in the instrument. The fastest method of trouble-shooting the instrument is to possibly exchange printed circuit boards (pcb) with a known functional instrument to determine which pcb is faulty, then repair the faulty pcb. However this is not always possible. This chapter presents the descriptions of the pcbs in the order that they should be tested. Each pcb description is presented here in the order that the pcb functions should be tested.

Throughout the chapter it is assumed that the reader is familiar with standard test equipment and no attempt is made to explain the operation of the test equipment. In addition no attempt will be made to reproduce detailed manufacturers integrated circuit data except possibly in the most general sense.

The text of this chapter makes frequent references to the schematic drawings. While reading about specific circuits, it is suggested that the related drawing be readily available.

Within this chapter the syntax used by the "C" programming language is used to describe the address of devices as seen by the CPU. In this syntax the leading '0x' indicates that the number following is a base sixteen (16) number. As an example 0x7E is the same as 126 decimal.

8.1.1 COVER REMOVAL

Remove the upper skin of the instrument by removing the two Allen screws securing the upper cover to the rear panel and sliding the cover toward the rear while lifting at rear of upper skin.

8.2 DUAL POWER SUPPLY

The Dual Power Supply (Guildline Drawing No. 18411.01.04) is designed to supply DC power to the instrument. There are two separate sets of supply voltages (+5 V, -5 V, +15 V, -15 V) which are isolated from each other. The section of the supply intended to supply the digital section of the instrument has a larger current capacity and a power failure detection circuitry.

Output Name	Voltage (Volts)	Current (Amps)	Reference Terminal (GND)
+5 V Digital	+5	1.5	G1
-5 V Digital	-5	0.5	G2
+15 V Digital	+15	0.5	G2
-15 V Digital	-15	0.5	G2
+5 V Analogue	+5	0.5	G3
-5 V Analogue	-5	0.5	G3
+15 V Analogue	+15	0.5	G3
-15 V Analogue	-15	0.5	G3

Table 8.1: Dual Power Supply Outputs

The three different grounds can be linked to each other through the use of jumper straps on the power supply. Normally G1 and G2 are linked together.

Although Table 8.1 above lists the maximum current which can be drawn from any given output the maximum current cannot be drawn from all outputs simultaneously. The +5 V Digital and +15 V Digital outputs can supply their maximum currents at any time without restrictions. However restrictions do exist for the other voltages. The other voltages are in pairs (such as +15 V Analogue and +5 V Analogue, or -15 V Analogue and -5 V Analogue) and each supply pair can only supply a total of 0.5 A. As an example, consider the supply pair -15 V and -5 V Digital, if the current drawn from the -15 V Digital output is 0.350 A then the maximum allowable current draw from the -5 V Digital output is 0.15 A. If the current drawn from a given output exceeds the maximum allowed then the output may go out of regulation (i.e. provide lower voltage than normal) or the regulator integrated circuit may overheat. If the regulator overheats it will shut down (supply 0 volts) until it cools sufficiently to resume operation.

8.2.1 VOLTAGE SELECTION

The power supply input voltage can be selected so that the 6500A can operate on 100, 120, 220 or 240 volt AC. The 100 volt option is selected by connecting the AC line across the 100 volt winding and by connecting the 20 volt winding in series opposing with the 120 volt winding (to give an effective 100 volt winding) and connecting the effective 100 volt winding in parallel with the 100 volt winding. The 120 volt option is selected by connecting the two primaries in parallel.

The 220 volt option is selected by connecting the 120 volt winding in series with the 100 volt winding and leaving the 20 volt winding disconnected. The 240 volt option is selected by connecting the two primary windings in series. Care should be taken to ensure that the correct winding polarities are observed when making the series or parallel connections.

The power connector on the rear panel contains a series of switches which will connect the windings in any of the required series/parallel configurations.

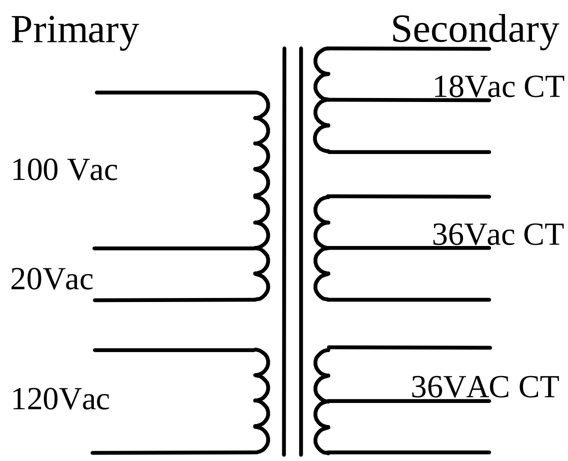


Figure 8.1: Input Transformer

In order to verify that the power connector and transformer are wired correctly an ohmmeter is required. Connect the ohmmeter across the two AC input terminals and measure the DC resistance as the input voltage selector drum is set to each position. The DC resistance should increase as the voltage setting is increased (the instrument power switch should be in the ON position). Typical resistance values are shown in Table 8.2.

Selector Drum Position (VAC)	Approximate DC Resistance (Ohms)
110	5.6
120	5.7
220	18
240	20

Table 8.2: Typical DC Resistance of AC Input

8.2.2 RECTIFIERS AND FILTERS

The AC input voltage is rectified with solid-state rectifiers and filtered with electrolytic filter capacitors. The +5 V Digital supply has 6600 microfarads of filtering and each of the other supplies has 1000 microfarads of filtering.

The correct operation of the rectifiers and filter capacitors can be verified with an oscilloscope by measuring the peak-to-peak AC ripple voltage and its frequency at the filter capacitors. The frequency of the AC ripple voltage should be double the line supply frequency. The magnitude of the ripple should be less than the maximum shown in Table 8.3 below. If the current loading on a given output is above its normal level then the AC ripple will exceed the values given in Table 8.3.

Capacitor Number	**Terminal**	**Ripple (millivolts peak-to-peak)**
C1	+	100
C11	+	100
C29	+	100
C16	-	100
C34	-	100

Table 8.3: Maximum Allowable Ripple Voltage at Filter Capacitors

If the ripple frequency is not double the line frequency, then the associated rectifiers should be replaced. If the AC ripple voltage exceeds the value given in Table 8.3, then the associated filter capacitor should be replaced or the cause of possible excess current loading identified and removed.

8.2.3 LINEAR REGULATORS

The final regulated voltages from the power supply are produced by conventional three-terminal regulator integrated circuits. These regulators have built-in references and will only generate one output voltage value. The correct operation of the eight three-terminal regulators can be determined by measuring each output with a DC voltmeter and comparing the values with Table 8.4.

Nominal Voltage	Minimum (volts)	Maximum (volts)
+5	4.75	5.25
-5	-5.25	-4.75
+15	14.50	15.50
-15	-15.50	-14.50

Table 8.4: Supply Voltage Tolerances

If any of the supply voltages should fail to be at its correct value, then the associated regulator should be replaced.

8.3 CENTRAL PROCESSING UNIT (CPU)

The internal central processing unit (Guildline Drawing Number 18221.02.04) (hereafter referred to as the CPU) in the model 6500A digital Teraohmmeter is built up from conventional digital circuitry and is based on the Intel iAPX8088 processor.

After the power is turned on the first step the processor performs is to fetch its first instruction from location 0xFFFF0. The first section of code executed is a power on diagnostic routine which validates the correct operation of the processor, the on board ROM, RAM, interrupt controller, the parallel port and the timer. The correct completion of this test is seen as all sixteen vacuum-fluorescent displays being on for about one second.

The power up self-tests are performed entirely on the CPU pcb and require a reasonably functional display as an output device. The detailed steps for the power up CPU self-test are as follows:

1. Initialize the 81C55

2. Turn on all of the LED indicators on the display pcb
(including the audible indicator).

3. Perform a simple read/write test of the 0x100 bytes of RAM located in the 81C55.

4. Turn off the audible indicator on the display pcb.

5. Initialize the 82C59 interrupt controller, and place interrupt vectors into the tested memory.

6. Turn on all of the vacuum-fluorescent displays.

7. Turn on the seven segment LED displays.

8. Wait for one half second by counting interrupts from the 81C55 timer.

9. Turn off all of the vacuum-fluorescent displays and LEDs on the display pcb.

10. Start execution of the system diagnostics programme (See paragraph 8.10).

If any of the above steps should fail, the programme will halt and the display indicators will remain as they have been set, hence giving an indication of the failure cause. As an example if step 1 should fail then all of the displays will be in their power-up condition (randomly on or off) and the programme will not proceed.

8.3.1 PROCESSOR

The processor on the CPU pcb is a CMOS version of the iAPX8088 processor. The processor has an 8 bit wide data bus and has a 20 bit wide address bus. The processor can address up to 1 million bytes of memory. In addition there exists a separate address space which allows for up to 64k bytes of input/output devices.

All of the start up routines for the processor self-test are contained in the on-board EPROM.

8.3.2 ADDRESS MAP

A portion of the addressing range of the processor is used by devices located on the CPU pcb. These devices include memory (both RAM and ROM) as well as input/output devices.

Address	Function
0xFFFFF 0xF0000	On board ROM 64K bytes
0x00100 0x00000	On board RAM 256 bytes

Table 8.5: CPU Memory Address Allocations

Address	Function
0xFFFF	
0x0203	82C52 Baud Rate Control Register
0x0202	82C52 Modem Control Register
0x0201	82C52 Control/Status Register
0x0200	82C52 Data Register
0x0101	82C59 Control Register 1
0x0100	82C59 Control Register 0
0x0005	81C55 Timer Count Register (Low Byte)
0x0004	81C55 Timer Count Register (High Byte)
0x0003	81C55 Port C
0x0002	81C55 Port B
0x0001	81C55 Port A
0x0000	81C55 Control/Status Register

Table 8.6: CPU Input/Output Address Allocations

The chip selects for each of the devices on the CPU pcb are generated by decoding the control and address signals. This decode function is performed within the PAL decoder (U1) and the three input OR gate U12.

8.3.3 CLOCK GENERATOR

The CPU oscillator and processor clocks are generated by the 82C84 clock chip which operates with a 14.745600 MHz crystal. This operating frequency has been selected since it is an integer multiple of the frequency of the RS-232C baud rate. The processor operates with a clock that has a 33% duty cycle (the waveform is high 33% of the time). This clock is easily generated by dividing the crystal frequency by three, hence the processor clock frequency of 4.915200 MHz. The peripheral clock (PCLK) frequency is one-half of the processor clock rate and hence is 2.457600 MHz. The 82C84 IC generates a power-on reset which is compatible with the 80C88 timing requirements. In addition the 82C84 can generate a wait signal which will slow the rate of memory access for slow memories or peripherals.

Correct operation of the 82C84 can be verified with an oscilloscope by examining pin 8 to see a 33% duty cycle clock at 4.915200 MHz (203.5 ns period). At pin 2 the oscilloscope should see a 2.45760 MHz square wave (407 ns period) and at pin 10 an active high pulse with a period of about 1 second should be observed after power up.

8.3.4 MEMORY

The on-board memory of the CPU card is made up of 64k bytes of EPROM and 256 bytes of RAM. The EPROM is a 27C512 and the RAM is contained in the 81C55 chip.

Correct operation of the memory chips is verified by the diagnostic programs after power is applied.

8.3.5 INTERRUPT CONTROL UNIT

The interrupt control integrated circuit is a type 82C59. This chip has 8 interrupt inputs. When one of the interrupt inputs becomes active (rising edge) the interrupt controller interrupts the processor. After the processor completes its current instruction it acknowledges the interrupt. During the interrupt acknowledge cycle the interrupt controller generates an interrupt vector which the CPU uses to determine which section of code to execute.

Normally only the Tx ready and the Rx ready outputs of the 82C52 and the interrupts from the timer in the 81C55 are wired to the interrupt controller. All other interrupt sources come from external pcbs through the external bus interface.

Correct operation of the interrupt controller and the timer input is determined by the power on diagnostic routine.

8.3.6 RS-232C INTERFACE

The RS-232C interface on the CPU pcb is controlled by U5 which is an 82C52. This chip has a built in baud rate generator and the transmit and receive rates are derived from the PCLK. The internal logic levels on the CPU pcb are not compatible with the required signal levels of the RS-232C Interface ICs U6 and U9, which are type 1489 receivers and 1488 drivers respectively. These IC's translate the signal levels on the RS-232C lines to a level compatible with the CPU.

The RS-232C interface is configured as data communications equipment (DCE), hence pin 2 (TxD) of the RS-232C connector is an input. The RS-232C pinouts and signal directions are given in paragraph 7.2.2.

8.3.7 PARALLEL INTERFACE

The CPU parallel interface is part of U3 which is an 81C55. The parallel port is configured by the initialization software to operate with ports A and B as outputs and port C as an input.

Since the parallel port drives the display its correct operation can be readily determined by visually observing the display.

8.3.8 BUS INTERFACE

The CPU bus interface (for communication with other cards in the system) is through the 96-pin DIN connector on the card. The configuration of the outer two pin rows (rows A and C) correspond to the pinout, level and timing requirements of the National Semiconductor Cimbus. The center row of contacts (row B) is configured to the Guildline extensions of this bus.

The address, data and control signals on the bus are driven by 74HC245 drivers/receivers. The address and control buses are bidirectional so that other bus masters (such as DMA controllers) can access the memory and input/output devices on the CPU pcb, however this feature is not used in the 6500A system.

8.4 KEYBOARD AND DISPLAY

The keyboard and display pcb (Guildline Drawing Number 18225.01.04) provide an input/output facility for the model 6500A CPU. The sixteen-digit/sixteen-segment vacuum-fluorescent display provides an easily read general purpose output device. This display is augmented by a number of special purpose LED indicators and a four-digit seven-segment LED display.

The circuitry on the display pcb is as simple as possible and the CPU is expected to generate all of the control signals necessary to refresh the display. The keyboard is a simple matrix keyboard and the CPU provides the scan functions.

8.4.1 VACUUM-FLUORESCENT DISPLAY

The vacuum-fluorescent display is a glass envelope with a heater and is similar to a classical vacuum tube triode. The heater requires 8 volts and each anode and cathode require 28 volts drive. The high voltage (28 V) is generated by a switching power supply module (ERG Inc. E705-.28V8.). The anodes and cathodes are driven by four Exar 6118P (U8, U9, U12 and U13) driver chips.

The scan rate selected for the 16 segments is 55 hertz. If the scan rate is slower, the display appears to flicker; if the scan rate is higher, the CPU cannot handle the processing load. In order for the CPU to illuminate a given segment of a given digit of the display it is necessary to perform several steps.

1. Put the data for the lower 8 segments onto the port A outputs.

2. Set port B bit 3 low (this disables the display) and set port B bits 0-2 to 5 (this causes U11 to sample the data output in step 1).

3. Set port B bits 0-3 to 0 (this causes U11 to hold the data output in step 1).

4. Put the data for the upper 8 segments onto the port A outputs.

5. Set port B bits 0-3 to 6 (this causes U7 to sample the data output in step 4).

6. Set port B bits 0-2 to 0 (this causes U7 to hold the data output in step 4), set port B bits 4-7 to the number of the digit to be lit (digit 0 is the rightmost display and digit 16 is the leftmost display), and set port B bit 3 to 1 to enable the display.

The circuitry associated with U14 (D1, R5, R6 and C1) is a retriggerable one-shot integrated circuit which will extinguish the vacuum-fluorescent display if the CPU is not periodically refreshing the display.

Correct operation of the vacuum-fluorescent display can be determined visually by observing its behaviour during the power-up sequence.

8.4.2 LED INDICATORS

There is provision for up to 28 LED indicators on the display card however not all are used. The LEDs are arranged in four banks of eight LEDs. In order for the CPU to turn on any one of the LEDs the following steps must be taken.

1. Output the data for the bank of 8 LEDs to port A. All 8 LEDs must be set at the same time. If the data bit is zero for a given LED then that LED will be turned ON.

2. Output the number of the LED bank on bits 0-3 of port B, where 1 selects U5, 2 selects U6, 3 selects U3 and 4 selects U2 (this causes the latch to sample the data output in step 1).

3. Output 0 on bits 0-3 of port B (this causes the LED bank to hold the data output in step 1).

It should be noted that there is no way for the CPU to read back the data on the LED displays therefore it is up to the CPU to maintain a list of the current settings. The 6500A operational software keeps such a list and refreshes the LED latches as it refreshes the vacuum-fluorescent displays.

8.4.3 LED DISPLAY

The data from the LED display is presented to the inputs of the 7-segment decoder (U1) during S0, S1, S2 and S3 display times. The lower 3 parts of the LED display are standard 7- segment displays and are handled by the 7-segment decoder. The most significant digit can display +/-1. In order to display a -1 the number 3 is output, a +1 uses an 8 as output and 1 uses a 1 as output.

8.4.4 AUDIBLE INDICATOR

The audible indicator is wired the same as one of the LEDs, internally the indicator contains an oscillator so only power need be applied for a tone output.

8.4.5 KEYBOARD

The keyboard is a 4 x 6 matrix. In order to scan the keys the processor outputs one of the PB4-PB7 lines low and reads back the PC0-PC5 signals. Each of the four columns are scanned 60 times per second, and a key must be scanned as low on two consecutive scans to be considered pressed. This effectively debounces the switch action.

8.4.6 EXTERNAL TRIGGER CIRCUIT

The 4N26 opto-isolator (U15) is wired such that when pins 1 and 2 of J5 are shorted, a key (column 4, row 0) appears to be pressed. The same rules for scanning keys outlined in paragraph 8.4.5 apply to the opto-isolator input.

8.5 MEMORY INPUT/OUTPUT CIRCUIT BOARD

The memory input/output pcb (Guildline Drawing Number 18222.02.04) (hereafter called the MIO pcb) contains a GPIB bus interface, a twelve (12) bit digital to analogue converter, a parallel interface, and three (3) sockets which can each be configured as one of random access memory (RAM), electrically programmable read only memory (EPROM) or electrically erasable programmable read only memory (EEROM).

8.5.1 ADDRESS MAP

A portion of the addressing range of the processor is used by devices located on the MIO pcb these devices include memory (RAM or ROM) as well as input/output devices.

The chip select for each of the devices on the MIO pcb are generated by decoding the control signals and the address signals. This decode function is performed within the PAL decoder (U9) and the four input OR gate (U12)

Address	Size	Use/Device
0xFFFFF		
0x10000		
0x08000	32K bytes	On board ROM
0x04000	16K bytes	Available but not used memory
0x02000	8K bytes	On board Non-volatile memory
0x00100	8K bytes	On board RAM
0x00000	256 bytes	Not available (used on CPU card)
0xFFFF		
0xC037 0xC036 0xC035 0xC034 0xC033 0xC032 0xC031 0xC030		GPIB data register GPIB parallel poll register GPIB instrument status register GPIB address register GPIB auxiliary command register GPIB mode register GPIB interrupt cause GPIB interrupt register

0xC013 0xC012 0xC011 0xC010		82C55 command/status register 82C55 port C 82C55 port B 82C55 port A
0xC001 0xC000		ADC567 high byte ADC567 low byte
0x0000		

Table 8.7: Address Allocations for Memory Input/Output Circuit Boards

8.5.2 MEMORY INTEGRATED CIRCUITS

A factory programmed ROM is installed at U5. The software contained in this memory is the invariant operating instructions for the instrument. A RAM memory device is installed at U10. This IC stores the temporary decision information created by the operator as various modes of operation are selected. This information is erased each time the power is applied or the instrument is reset. A RAM memory is also installed at U14, but it is mounted on a lithium battery powered smart socket that prevents data loss when power is turned off. In effect, the IC is thereby made to have a non-volatile memory. This IC is used to store calibration coefficients. The expected life of the lithium battery is approximately 10 years. When the battery is eventually depleted, the entire socket (Dallas Semiconductor part number DS1213) is replaced and calibration coefficients are restored by having the instrument recalibrate itself with an external reference resistor. The circuit board has nine configuration pins located beside each memory (U5, U10 & U14). Jumper wires are connected between the pins to configure the circuit board for the memory IC's used. A map of the pin locations is shown in Table 8.8 (due to board space limitations, not all of the pins are labelled).

Memory Input/Output				
		Pin 27		
WR	0	0	0	A14
Pin 26	0	0	0	+5V
A13	0	0	0	Pin 1
		RDY		

Table 8.8: Map of Memory Configuration Pins

Note: Center pin is also +5 V.

Table 8.9 shows which pins are connected together for the three memories used.

Reference Designator	Part Number	Jumper	Memory Application
U5	Typically Intel 27C256 with Guildline Software	A14 to 27	ROM with operating software (non-volatile)
U10	Toshiba TC5565PL or equivalent	WR to 27 26 to +5V	RAM with mode selection data volatile)
U14	Toshiba TC5565PL in smart socket (see text)	WR to 27 26 to +5V	RAM with calibration coefficients (non-volatile)

Table 8.9: Memory Configuration Jumpers

A factory programmed logic array (PAL) is placed at U9. This IC manages the addressing of the memory and input-output (I/O) IC's.

Correct operation of the RAM devices on the MIO pcb is determined by the diagnostic software at the time power is applied. The correct operation of the ROM on the MIO pcb can be determined by using the checksum test under SOFCAL(TM) (see paragraph 8.10.2).

8.5.3 GPIB INTERFACE

The GPIB interface is made up of a Motorola 68488 GPIB controller (U11), two MC3447 drivers (U3 and U7) and a 74HC373 transparent latch (U2). The controller and drivers are connected to the GPIB bus as described in their data sheets and the 74HC373 transparent latch is connected to the bank of switches on the rear panel. These four chips form a complete functional GPIB interface.

The GPIB controller can be used with the direct memory access (DMA) interface. In the Model 6500A the DMA request is not used.

The GPIB interface hardware is tested by connecting a system controller to the GPIB bus and exercising the instrument from the bus. The switch register can be tested by examining the GPIB address with SOFCAL(TM) (see paragraph 5.6.1) and toggling each of the switches while watching the instrument display.

8.5.4 PARALLEL INTERFACE

The parallel interface on the MIO pcb is controlled by an Intel 82C55 parallel port chip.

The operation of this chip is checked by the self-test software as part of the fast ADC check when power is first applied.

8.5.5 DIGITAL TO ANALOGUE CONVERTER

The MIO pcb has provision for a twelve (12) bit digital to analogue converter (Analogue Devices ADC567), which could be used for a chart recorder output, however this feature is not used on the model 6500A Teraohmmeter and the necessary components (U1, U4, VR1, VR2, R1, R2, C3, C4, and C5) are not installed on the MIO pcb.

8.6 COUNTER INPUT/OUTPUT

The counter input/output (CIO) pcb (Guildline Drawing Number 18435.01.04) has onboard two 20-bit parallel ports, six 16-bit programmable counters, an eight-bit digital to analogue converter, an eight-channel analogue to digital converter and a "watchdog" timer. In addition most of the parallel outputs have open collector relay drivers which can drive loads of 200 milliamperes.

8.6.1 ADDRESS MAP

A portion of the addressing range of the processor is used by input/output devices located on the CIO pcb. The address map is listed in Table 8.10.

Device	Address	Usage
	0xFFFF	
U1	0xFF03 0xFF02 0xFF01 0xFF00	8536 Control port 8536 port A 8536 port B 8536 port C
U4	0xFE03 0xFE02 0xC011 0xC010	8536 Control port 8536 port A 8536 port B 8536 port C
U5	0xFD00	Watch Dog
U19	0xFC02	D to A Converter
	0x0000	

Table 8.10: Input/Output Address Usage

The chip selects for each of the devices on the CIO pcb are generated by decoding the control signals and the address signals. This decode function is performed within the PAL decoder (U3).

8.6.2 PARALLEL INTERFACE

The parallel interface is built up from two Zilog programmable parallel port chips (Z8536A). The interface to these chips is through a 74HC245 bus buffer (U2) and the timing for the control signals (the write strobe specifically) is modified by the 74HC74 dual flip-flop (U16).

Most of the parallel port outputs are taken through National Semiconductor DS3658 relay driver chips to the connectors located on the back of the pcb. Some of the parallel port bits are used for special functions such as the channel select for the analogue to digital converter or to read the counter prescaler.

Testing of the parallel port devices is accomplished by connecting a LED indicator pcb to the outputs of the relay drivers and executing the SOFCAL(TM) relay driver tests (see paragraph 8.10.2.7).

8.6.3 COUNTERS

The Zilog parallel port chips (Z8536) each contain three counters (16-bit each) which can be programmed to count or time external events or to output variable duty cycle square waves. In order to access the control signals for the counters some of the twenty parallel port bits must be reassigned.

Two of the counters in U1 are chained together and programmed to count the clock output from the 20 megahertz crystal oscillator (U15) and prescaler (U6). When the four-bit prescaler and the two 16-bit counters are all chained together this forms a 36-bit counter which is used for timing the integration times on the electrometer assembly. A 36-bit counter with a 20 megahertz clock will count for 3,436 seconds before overflowing.

The counters are the last piece of hardware to be tested in the 6500A system. They are tested by connecting a known resistor to the 6500A front panel and reading the resistance value computed by the 6500A.

8.6.4 DIGITAL TO ANALOGUE CONVERTER

The digital to analogue converter is built with a National Semiconductor DAC0830 which is an eight (8) bit converter (U19). The voltage reference for the converter is built up of two LM336-2.5 voltage reference chips (VR1 and VR2).

The converter's digital data comes from the data bus through the 74HC245 bus buffer U2.

If a more accurate converter is desired, U19 can be replaced by a pin compatible twelve-bit converter from National Semiconductor (DAC1230).

The correct operation of the DAC0830 is verified automatically when the digital test volts are checked at the time main power is first applied.

8.6.5 ANALOGUE TO DIGITAL CONVERTER AND MULTIPLEXER

The analogue to digital conversion is made up of a 14051 analogue multiplexer (U17) and an LM311 comparator (U20). The processor selects the desired channel (1 of 8) by outputting the channel number on port A of U1.

The processor then compares the output of the Digital to Analogue converter with the unknown input voltage. By using a software successive approximation, the processor can determine the input voltage on any of the eight channels.

8.6.6 WATCHDOG TIMER

The watchdog timer is made up of two retriggerable one-shots (U5). The first one-shot has a time constant of about 1.5 seconds. The microprocessor is programmed to trigger this watchdog about once every 100 ms, to reset the time out. If the processor fails to select the watchdog timer, for a period of 1.5 seconds the first timer's output will go high and trigger the second timer. The second timer has a time constant of about 0.5 seconds, when the output is active (high) transistor Q1 will pull the microprocessor reset line low. At the end of the reset pulse the microprocessor will restart.

Under normal operating conditions the first one-shot should NEVER time out and hence the second one-shot will not reset the microprocessor.

8.7 OPTO-ISOLATOR

The opto-isolator pcb (Guildline Drawing Number 18410.01.04) is the L-shaped board physically located beside the pcb cage. The function of this pcb is twofold, first it electrically isolates the control signals between the microprocessor and the analogue pcbs. Secondly it digitizes the analogue signals from the analogue pcbs for the microprocessor.

The isolation of the microprocessor signals from the analogue signals is necessary in order to reduce ground loops from the GPIB bus to the analogue inputs. It also reduces the electrical noise on the analogue power supplies.

8.7.1 ISOLATOR CHANNELS

Most of the signals which must be isolated travel from the microprocessor to the analogue pcbs. These signals are isolated with quad opto-isolator integrated circuits (ILQ-74). The signals which do not pass through opto-isolators are used to drive relay coils which are not connected to the analogue circuit.

The LED current limiting resistor values are selected to prevent saturation of the phototransistors outputs. Sometimes, the forward current transfer ratio of a given isolator may be lower than normal and the channel may not function properly. In that case the opto-isolator should be replaced.

Some of the isolator channels are normally open and some are normally closed (depending upon the arrangement of output photo-transistor and resistors). Be aware of the correct normal polarity before deciding that a channel is defective.

The isolator channels can be tested by activating the SOFCAL relay tests and observing the outputs with an oscilloscope.

8.7.2 HIGH SPEED ISOLATOR CHANNELS

The opto-isolator channels returning information from the analogue circuitry are built up of HCPL-2631 high speed dual opto-isolator integrated circuits. The resistor values used with the HCPL-2631 opto-isolators have been selected to optimize the response speed. The opto-isolator channels can be tested by observing the flow of data with an oscilloscope.

8.7.3 ANALOGUE MULTIPLEXER

The opto-isolator pcb can rapidly measure several input voltages. These voltages are multiplexed to the analogue-to-digital converter (U8) through a CD14051 analogue multiplexer IC (U21). The input voltages are reduced to approximately one third (1/3) through a resistor prescaler. This is done so that the multiplexer can measure voltages in the range of +/- 15 volts (the CD14051 multiplexer has a dynamic range of +/- 5 volts).

After the multiplexer, the input voltage is buffered through an LM741 op-amp IC (U16) arranged in a non-inverting impedance buffer configuration. This is necessary so that the low input impedance of the analogue to digital converter will not affect the accuracy of the voltage prescaler.

The prescaler, multiplexer and buffer can be tested by observing the output of the buffer with an oscilloscope and stepping through each of the eight (8) inputs with the SOFCAL analogue voltage tests.

8.7.4 ANALOGUE TO DIGITAL CONVERTER

The analogue to digital conversion is performed by an ADC80H (U8), this is a 12-bit converter with a serial bit stream output (the parallel outputs are not used).

When each conversion is complete, the "STATUS" signal on pin 22 of U8 goes positive, this triggers a 74123 one-shot IC (U9, pin 1) which after a short delay triggers a second 74123 one-shot (U9, pin 9). The output of the second one-shot is used to start the next conversion. This cycle repeats itself approximately 1000 times per second.

The serial output data and the data bit clock are taken from the ADC80H (U8, pin 26 & 23 respectively) through an opto-isolator (U2) to a pair of 74HC164s (U12 & 13 respectively). The conversion complete signal (status, pin 22) is also taken through the opto-isolator (U3, HPCL2631) and used to latch the parallel data from the 74HC164s into two 74HC373s (U14 & U15). The latched parallel data is sent to the microprocessor (via J4) along with the status signal.

8.7.5 HIGH VOLTAGE WATCHDOG

The high voltage watchdog is made up of a 14538 (or 4538) retriggerable one-shot, a transistor and a Relay (U22, Q1 & K1 respectively). This circuit ensures operator safety by turning the high voltage power supply off when the microprocessor fails to provide a steady supply of trigger pulses to the one-shot.

When the processor wishes to enable the high voltage output, a short trigger pulse is sent (pin 5) of the 14538 one-shot. The falling edge of the trigger pulse causes a positive polarity gate signal to appear at pin 6 of the one-shot. The output of the one-shot energizes the relay through the 2N4400 transistor, opening the relay contacts (relay pins 1 & 7). This enables the generation of high voltage by applying power to the high voltage DC-to-DC converter. In order to keep the high voltage output enabled, the microprocessor must generate a new trigger edge for the one-shot before each gate from the one-shot expires (at least every 100 ms). If the microprocessor fails to do this then the high voltage will be shut down.

There is an extremely low probability of trigger pulses being available with a defective microprocessor because of a second watchdog circuit on the counter I/O circuit card that resets the microprocessor when irrational behaviour is detected in the CPU.

8.8 HIGH VOLTAGE SUPPLY

The High Voltage Supply pcb (Guildline Drawing Number 18388.01.04) is located directly behind the source connector on the front panel. The pcb is sprayed with a polystyrene plastic coating after assembly. This helps prevent high voltage arcing as the Teraohmmeter ages and collects dust.

8.8.1 HIGH VOLTAGE MODULE

The high voltage is generated by an encapsulated module (A5) on the circuit board. The output voltage of this module is proportional to its input voltage. The maximum output current the module can supply continuously is 3 mA. Transistor Q1 is an emitter follower which drives the high voltage module. The opto-isolator circuit board can disable the high voltage module by grounding the base of Q1 through pin 6 of J1.

8.8.2 DIVIDER CHAIN

R4 to R15 are connected in series with R4 being terminated at a reference voltage (-10 V) derived from the electrometer circuit board via J3 pin 4. The voltage at the junction of R4 and R5 is dependent upon the values of the resistors R4 to R15, the reference voltage and the output voltage at K4 pin 8. Any voltage present at junction of R4 and R5 is amplified by A2, A1, Q1 and A5 and applied to K4 pin 8, thereby reducing the voltage at the junction of R4 and R5. Since the gain of the amplifier loop is very high, the voltage at the junction of R4 and R5 is very nearly zero and the voltage at K4 pin 8 is nearly constant at 1000 volts. K3, A1, K1 and K2 allow the output voltage polarity to be reversed by signals derived from the microprocessor via the opto-isolator circuit board and J1 pins 3 and 4.

Output voltage errors are proportional to the errors of the resistors R4 to R15. The resistors used to build this resistor divider chain are very stable wire wound resistors. These resistors will have a small error from their nominal values. These errors are measured when the instrument is calibrated and stored in the instruments non-volatile memory.

8.8.3 VOLTAGE MONITOR

Amplifier A3 monitors the voltage at the 1 V tap on the resistor divider chain. This information is sent to the microprocessor through the analogue-to-digital convertor on the opto-isolator pcb.

8.8.4 OUTPUT SELECTION

The output of the high voltage pcb is selected by enabling one of the relays (K4-K13), this selects one voltage from the resistor divider chain.

A ground reference (0 V output for pA mode) is generated by grounding K14 pin 4 with a signal derived from J1 pin 5. This is a buffered signal generated by the CPU (OUT-DSBL).

8.9 ELECTROMETER

The electrometer pcb (Guildline Drawing Number 18230.02.04) is the heart of the measurement section of the 6500A Teraohmmeter. This pcb accepts a small current as an input and converts this current to a digital pulse. The length of time the digital pulse is active is proportional to the magnitude of the current.

8.9.1 FIXED REFERENCE

The electrometer generates a fixed 10 volt reference. This reference is used to drive the high voltage card and the electrometer thresholds, hence if the reference changes value, the high voltage and the thresholds will change proportionally and the length of the electrometer output pulse will not change.

The basic reference is a zener diode (D1) with an integral constant temperature heater. This zener voltage is actively scaled to 10 volts by amplifier A1. The selection of the scaling ratio is done after the card has been built since each zener is slightly different. Typically the magnitude of the 10 volt output voltage is set within 10 ppm of its nominal voltage. The components R3 and C1 form a passive filter which helps to reject high frequency noise from the zener diode.

The correct operation of the reference voltage can be determined by measuring the voltage at test point 1 with respect to test point 0 (ground) with a precision voltmeter.

8.9.2 PROGRAMMABLE REFERENCE INVERTER

The 10 volt reference used by the electrometer circuit board must be reversible. In order to generate either a positive or a negative 10 volt reference a programmable inverter is provided. The programmable inverter is made up of an amplifier (A2) two analogue gates (A4 sections 2 and 3) and associated resistors. The polarity of the output is determined by the +/- signal generated by the CPU automatically or by command from the front panel +/- key or the control bus. The potentiometer (RV1) adjusts the balance between the positive and the negative reference output. This control should be adjusted manually so that the two reference output voltages (measured at test point 4) are within ten parts-per-million of each other.

Proper operation of this circuit can be verified with an accurate voltmeter by measuring the voltages at test point 4 and changing the polarity with the SOFCAL Offset Adjust command.

8.9.3 PROGRAMMABLE THRESHOLD INVERTER

The thresholds for the electrometer are generated through a second programmable inverter. The thresholds will change as the reference output (J3 pin 4) from the electrometer changes. The inversion error in this circuit is not adjustable but is cancelled by the threshold error compensation software in the 6500A.

The programmable threshold inverter is build up of an amplifier (A3), two analogue gates (A4 sections 1 and 4) and associated resistors. Correct operation of this circuit can be easily verified with an oscilloscope connected to test point 3 during normal operation of the 6500A.

8.9.4 ELECTROMETER

The electrometer is built up of an amplifier (A6), an input protection resistor (R21), and a capacitor which is selectable from one of 27 pF (C5), 270 pF (C4) and 2700 pF (C3) via relays K1, K2 and K3 respectively. The choice of capacitor affects the sensitivity of the electrometer, with smaller capacitors giving greater sensitivity.

8.9.5 PROGRAMMABLE PRECHARGE

The normal operation of the electrometer is to precharge the integration capacitor (one of C5, C6 or C7) to a predetermined voltage. The precharge voltages are selectable from 12 volts, 1.2 volts and 0.15 volts.

The electrometer is in precharge mode when relay K7 is closed. The precharge voltage is selected by closing one of the three analogue gates (A5 sections 1, 2 and 4).

8.9.6 PROGRAMMABLE GAIN

The output of the electrometer is amplified by a gain of 1, 10 or 100. The gain is selected by the micro processor by closing one of the relays K4, K5 and K6.

The gain circuit comprises an amplifier (A8) which has a constant gain of 10, preceded by one of (a) an attenuator (R22), (b) a direct pass through, or (c) a gain of ten (A7, R23 and R24). When relay K4 is closed the one tenth attenuator is selected giving an overall gain of 1. When relay K5 is closed the pass through is selected giving an overall gain of 10. When relay K6 is closed the gain of ten is selected giving an overall gain of 100.

The attenuator circuitry can be tested by selecting various thresholds and observing the output at test point 2, the observed waveform should always be just over 10 volts. The ramp test point is always near 10 volts due to the fact that the gain and precharge selection is in tandem, hence if a precharge voltage of 1 volt is selected then a gain of 10 is selected giving an output voltage of 10 volts.

Errors in the gain ratios are determined by the calibration software and the final readings are compensated to cancel these errors. If the threshold errors are excessively large then this circuitry may be faulty.

8.9.7 LEVEL COMPARATOR

The level comparator A9, compares the output of the programmable gain section with the output from the programmable threshold inverter. The output of the comparator (A9) is cleaned up by the Schmidt trigger (U3 pin 5) and presented to the finite state machine.

The correct operation of the level comparator can be verified with an oscilloscope connected to pin 6 of U1 and observing a TTL level square wave.

8.9.8 FINITE STATE MACHINE

The finite state machine is built around a 4-bit counter (U1) and a PAL (U2). This circuitry generates the final output pulse which is sent to the micro for timing.

The operation of the state machine is as follows:

1) The microprocessor requests that a measurement be started by activating the control signal RL7. This signal is cleaned up by Schmidt triggers U3 pin 12 and U3 pin 8 then presented to the PAL and the counter. In order to observe the operation of this circuitry on oscilloscope should be triggered from this signal since all subsequent actions depend on this start signal.

2) About 50 nS after RL7 becomes active the PAL activates the CLK output (U2 pin 19) which causes the counter to advance from 0 to 1. Simultaneously the PAL lowers the relay output (U2 pin 14) which releases the precharge from the electrometer.

3) The delay circuit (U3 pin 2, U3 pin 4 and R33 and C6) causes the DTin input of the PAL to follow Q0 from the counter with a small delay (about 50 uS). After DTin matches Q0 at the pal the PAL deactivates the CLK output. The state machine is now at state 1.

4) Eventually the output of the programmable gain stage will cross the first threshold level and the output of the comparator will change. When the COMP input to the PAL changes level the PAL activates the CLK output, simultaneously the PAL instructs the programmable threshold inverter to invert the threshold level presented to the comparator. This causes the counter to advance to count 2 and the output of the comparator to return to its normal state. The PAL also sets the Ain output high which starts the external timer.

5) The delay circuit causes the DTin input of the PAL to follow the Q0 output of the counter after a short delay. During this delay time, transitions on the PAL COMP input are ignored. At the end of the delay time the CLK output from the PAL is cleared.

6) Eventually the COMP input to the PAL changes its level again. At this time the CLK output is activated, the RELAY signal is cancelled (returning the integrator to its precharge state), the programmable threshold inverter is returned to its normal state, and the Ain output is lowered (stopping the external timer). This completes the measurement cycle.

8.9.9 INPUT OFFSET ADJUST

- For the Offset and Bias adjustments, turn the RAMP display on see sections 8.10.2 and 8.10.2.5.

- Connect a grounding plug to the Input terminal.

- Press the key MAN RATE to select manual rate adjustment.

- Press the key PA to select current mode operation.

- Select the integrator capacitor value of 27 pF.

- Select the Threshold voltage of 0.1 V with a positive (+) polarity.

- Select the measurement range by pressing the UP or DOWN key until the prompt 1P-10P AMPS is displayed.

- Press the SET key to accept the selection.

- Monitor the reading in the main display window and wait a few minutes for the thermal on the input terminal to settle.

- The display will show 10 pA per microvolt of offset. That is a displayed value of 320 pA means that there is 32 µV of offset.
- Adjust potentiometer P3, the trimpot towards the front panel, until the displayed reading is less than 20 pA.

8.9.10 INPUT BIAS CURRENT ADJUST

- This is done immediately after the Input Offset Adjust and with the same settings used in the Input Offset Adjust.

- Disconnect the short circuit at the Input terminal and leave the Input terminal open.

- You may have to toggle the +/- key a few times to see the current ramp, which could be <u>extremely</u> slow, on the order of 10 to 20 minutes for I_{bias} less than 10 fA.

- Adjust potentiometer P4, the trimpot towards the back panel, until the displayed reading is less than 10 fA. This potentiometer has an adjustment of about 25 fA per turn.

- It is possible to adjust P4 for 0 fA I_{bias}, but this is a calculated adjustment on P4 as you may have to wait up to an hour to see any ramping taking at all, or you may have overshot slightly and changed the bias current's polarity.

- As an aside, the observed 60/50 hertz hum on the RAMP display should be no worse than 10 counts peak to peak. If it is worse than this there is a problem with the shielding provided by the top skin of the instrument.

8.10 DIAGNOSTIC SOFTWARE

The diagnostic software incorporated in the model 6500A Teraohmmeter is very extensive. It can detect and identify many defects within the instrument. Many of the self-tests take very little time and are run automatically at power up time (or when the RESET key is pressed). Some of the other self-tests are more time consuming and are only run on command either from the keyboard or from one of the remote interfaces (RS-232C or GPIB).

8.10.1 Power-Up Self-Tests

After power up, the instrument starts execution of a series of self-tests, these tests are described in the order they are executed and the possible diagnostic messages from each test are listed with the test.

After The CPU self-test is complete the following steps are performed by the main routine:

1. The processor disables interrupts.

2. All RAM is initialized to zero.

3. The interrupt vectors are written into RAM.

4. The variables which are not zero are initialized.

5. The hardware self-test is performed.

6. The data in the non-volatile memory is checked.

7. The instrument begins normal operation.

Of these seven steps the hardware self-test is the most extensive and time consuming. The main steps of the hardware self-test are as follows:

1. The 82C59 interrupt controller is initialized.

2. The RS-232C controller chip is initialized.

3. The GPIB controller chip is initialized.

4. The 81C55 timer is initialized.

5. The 82C55 parallel port is initialized.

6. The Z8536 chips are initialized.

7. The Audible enable switch on the rear panel is read.

8. Interrupts are enabled. At this point the interrupt software will start refreshing the vacuum-fluorescent display and interrupts from the remote controller ports will be acknowledged.

9. Writing to the non-volatile memory is disabled.

10. All of the LEDs on the front panel are turned on.

8.10.2 SOFCAL DIAGNOSTIC MODE

The 6500A Teraohmmeter has three modes of operation associated with the SOFCAL function. The first two modes are described in Section 5.6 SOFCAL NORMAL MODE and in Section 5.7 SOFCAL CALIBRATION MODE. The third mode of SOFCAL operation is entered by pressing the SOFCAL key followed by pressing the S1 key and then the S3 key (see Figure 5.1: Location of Special Hidden Keys).

On entering the SOFCAL DIAGNOSTIC MODE of operation the main display window will display the message DIAGNOSTIC MODE for approximately 5 seconds, after which time the prompt SELECT FUNCTION will be displayed. The functions made available in this mode of operation are listed in Table 8.11 and can be displayed by using the UP key to scroll through the list of options. The functions can be stepped to directly by pressing the appropriate numeric key listed in Table 8.11.

Key Number	Function
0	Digital Power Supply
1	Analogue Power Supply
2	Offset adjust
3	Output Voltage Source Test
4	Ramp Display
5	ROM Checksum
6	Relay tests
7	ROM tests

Table 8.11: Diagnostic Mode

Pressing the ± key will return to the display the SOFCAL MODE of operation message. The functions listed in Table 8.11 can be selected for examination or change by pressing the ENTER key once when the desired function is displayed. To EXIT from this mode to the OPERATE mode for Resistance/current measurement the SET key should be pressed.

8.10.2.1 DIGITAL VOLTS

When the message DIGITAL VOLTS is displayed in the display window, pressing the ENTER key will allow the digital power supply voltages to be examined. The digital power supply to be examined can be selected by pressing the UP key to scroll to the voltage of interest or by pressing the key from the following Table:

Key Number	Function
0	+5V Digital Power Supply
1	-5V Digital Power Supply
2	+15V Digital Power Supply
3	-15V Digital Power Supply

Pressing the ± key will exit back to the function select level to display the message DIGITAL VOLTS.

8.10.2.2 ANALOGUE VOLTS

When the message ANALOGUE VOLTS is displayed in the display window, pressing the ENTER key will allow the analogue power supply voltages to be examined. The analogue power supply to be examined can be selected by pressing the UP key to scroll to the voltage of interest or by pressing the key from the following Table:

Key Number	Function
0	+5V Analogue Power Supply
1	-5V Analogue Power Supply
2	+15V Analogue Power Supply
3	-15V Analogue Power Supply
4	Precharge Electrometer Card
5	High Voltage Monitor (HV card)
6	10V Reference (Electrometer)
7	RAMP

Pressing the ± key will exit back to the function select level to display the message ANALOGUE VOLTS.

8.10.2.3 OFFSET ADJUST

Option installed but not used.

8.10.2.4 OUTPUT TEST

When the message OUTPUT TEST is displayed in the display window, pressing the ENTER key will allow the SOURCE Test Voltages to be examined. The Test Voltages at the SOURCE connector are selected by pressing the UP key to scroll to the Test Voltage of interest or by pressing the key listed in the following Table:

Key Number		Function
0	Select	1V Test Voltage
1	Select	2V Test Voltage
2	Select	5V Test Voltage
3	Select	10V Test Voltage
4	Select	20V Test Voltage
5	Select	50V Test Voltage
6	Select	100V Test Voltage
7	Select	200V Test Voltage
8	Select	500V Test Voltage
9	Select	1000V Test Voltage

For each Test Voltage selected the main display will indicate the value of the voltage at the 1 volt tap on the high voltage potential divider chain.

The ZERO (0) key when pressed will toggle the test voltage polarity but will also return the absolute value to 1 V; Pressing the ENTER key will turn the output to the SOURCE connector ON.

Pressing the key TEST VOLTS will turn the output to the SOURCE connector OFF.
Pressing the ± key will exit back to the function select level to display the message TEST VOLTS.

8.10.2.5 RAMP DISPLAY

When the message RAMP DISPLAY is displayed in the display window, pressing the ENTER key will allow the selection of a clock face or integrator ramp voltage to be displayed during the instrument measurement cycle. Selection of the ramp display mode is achieved by pressing the keys listed in the following Table:

Key Number	Function
0	Select RAMP DISPLAY ON (display ramp voltage)
1	Select RAMP DISPLAY OFF (display clock face)

The selection is made by pressing the ENTER key at the displayed message RAMP DISPLAY ON (or RAMP DISPLAY OFF) causing the word ON (or OFF) to flash. Pressing the key 0 or 1 will select ON or OFF respectively. Press ENTER to stop flashing and accept the selection. Press ± to return to function select level.

8.10.2.6 ROM CHECKSUMS

When the message ROM CHECKSUMS is displayed in the display window, pressing the ENTER KEY will select the checksum mode. Pressing the ENTER key again will initiate the calculation of the instrument Read Only Memory devices. There are two ROM devices installed in the 6500A. The first ROM checked will be the CPU ROM pressing the UP key will allow testing of the MEMory ROM. At the conclusion of the calculation the value of the checksum is displayed.

Pressing the ± key will exit back to the function select level to display the message ROM CHECKSUMS.

8.10.2.7 RELAY TESTS

When the message RELAY TESTS is displayed in the display window, pressing the ENTER key will allow testing of the Relay Drivers in the 6500A Counter I/O card. The Driver integrated circuits are labelled U1 and U4. Pressing the UP key will toggle between the testing of driver U1 and U4. During testing, the display will indicate the device being tested (U1 or U4) and the corresponding connector (J11 or J12 respectively). An incrementing counter will also be displayed indicating the pin of the relay driver device being tested.

Pressing the ± key will exit back to the function select level to display the message RELAY TESTS.

8.10.2.8 RAM TESTS

When the message RAM TESTS is displayed in the display window, pressing the ENTER key will allow testing of the 6500A Random Access Memory. Pressing the ENTER key again will initiate the RAM TEST. Sixteen banks of memory will be tested. For each bank tested the display will indicate the bank number and the message PASS or FAIL.

The ± key will exit the test mode back to the function select level to display the message RAM TESTS.

9 TROUBLE SHOOTING AND MAINTENANCE

9.1 PREVENTATIVE MAINTENANCE

Preventative maintenance consists of cleaning and visual inspection of the instrument. Preventative maintenance performed on a regular basis will prevent instrument breakdown and will improve the reliability of this instrument. The severity of the environment to which the 6500A is subjected determines the frequency of maintenance. A convenient time to perform preventative maintenance is preceding recalibration of the instrument.

The 6500A should be cleaned as often as operating conditions require. Accumulation of dirt in the instrument can cause overheating and component breakdown. Dirt on components acts as an insulating blanket and prevents efficient heat dissipation. It also provides an electrical conduction path which may result in instrument failure. The dress skins provide protection against dust in the interior of the instrument. Operation without these panels in place necessitates more frequent cleaning.

When airborne contaminants settle on the electrometer circuit and its associated front panel connector symptoms such as an inability of the 6500A to display values of very high resistances are observed. When this happens, full performance of the 6500A can be restored by cleaning both sides of the electrometer circuit board and the insulating bushing inside the front panel connector.

CAUTION

Avoid the use of chemical cleaning agents which might damage the plastics used in this instrument. In particular, avoid chemicals which contain benzene toluene, xylene or similar solvents.

Periodically inspect the instrument for general cleanliness. Remove the cover and clean out any accumulated dust with a soft brush, at the same time check for discoloured or damaged wiring. Check all screws and hardware for tightness.

9.2 NON VOLATILE MEMORY CHECKSUM

The model 6500A Teraohmmeter contains a bank of memory into which certain operating data are written and stored. This memory is non-volatile in that data are kept even when power is removed from the instrument.

The integrity of the data in this memory is checked on power up and on an instrument RESET by comparing a stored checksum value with a calculated value. The two checksum values should agree. Occasionally, the stored checksum value may not agree with the newly calculated value (on RESET or Power Up) due to an operator error in entering new data into the non-volatile (NV) RAM or when the non-volatile (NV) RAM battery is low.

When this occurs the 6500A will display the message "EEROM DATA BAD" and will beep 10 times. This message will then be replaced with the alternating message prompts "CORRECT CHKSUM" or "0 - NO 1 - YES". Pressing the 1 (one) key (responding yes) will accept the NV RAM data as valid, causing the 6500A to calculate a new checksum, overwrite the old stored value accept NV RAM data, and continue to the measurement mode of operation.

Pressing the 0 (zero) key (responding NO) will cause the alternating messages "CLEAR EEROM ?" and "0 - NO 1 - YES" to appear in the display window. Responding NO by pressing the 0 (zero) key will cause the 6500A to accept the bad checksum and continue to the measurement mode of operation. Pressing the 1 (one) key will cause the 6500A to clear to zero all data stored in the NV RAM prior to continuing to the measurement mode of operation.

9.3 TROUBLESHOOTING

Sympton	Possible Cause
No display	Instrument not plugged into source of AC power. Instrument not powered ON. Power Supply fuse blown. Cable between CPU pcb and Display pcb loose. Faulty connector on cable between CPU and Display pcb. Faulty Display pcb. Faulty CPU pcb. Faulty Power Supply pcb.
Display on but no Keyboard response	Keyboard switches locked out by remote controller. Cable between CPU and Display pcb loose. Faulty connector on cable between CPU and Display pcb. Faulty Display pcb.
Display on but only partial Keyboard response	Cable between CPU and Display pcb faulty. Faulty Display pcb.
Instrument does not beep when key switch pressed. .	Audible configuration switch on rear panel in closed position. Jumper E4 not installed on Display pcb. Faulty Display pcb.
GPIB no response	Incorrect address set on rear panel switches. Talk/Listen mode not selected. GPIB cable not connected to instrument properly. Cable from rear panel address switch to MIO pcb faulty. Faulty MIO pcb. Faulty CPU pcb.
RS-232C no response	Incorrect baud rate set. Talk/Listen mode not selected. RS-232C cable not connected to instrument properly. Cable from rear panel RS-232C connector to CPU pcb faulty. Faulty CPU pcb.

9.4 ERROR MESSAGES

Display Message	Comment
RAM FAILURE XX	RAM Test Failure in bank XX where XX is in the range 01 through 16.
FAST ADC FAILURE	Interrupt from the ADC has not been generated or has not been recognized
ADC NOT RUNNING	ADC converter not running correctly.
ADC OFFSET X.YZ	Ground (zero volt) input to MUX is out of range or MUX output offset magnitude too large. The measured offset is displayed as X.YZ volts.
ADC GAIN XXXX	The 10 V reference channel is measured and determined to be out of range. The measured unacceptable gain is displayed as XXXX.
ADC RATE XXX KHZ	The ADC interrupt rate is out of range as either too slow or too fast. The measured unacceptable rate is displayed as XXX KHZ.
+ 5 Volts X.XX	+ 5 V analogue power supply out of limits; measured X.XX V.
- 5 Volts X.XX	- 5 V analogue power supply out of limits; measured X.XX V.
+ 15 Volts X.XX	+ 15 V analogue power supply out of limits; measured X.XX V.
- 15 Volts X.XX	- 15 V analogue power supply out of limits; measured X XX V.
PRECHARGE X.XX	Precharge Voltage out of limits; measured X.XX V.
HV MON X.XX	High Voltage monitoring point out of limits; measured X.XX V.
10 V REF X.XX	10 volt Reference point out of limits; measured X.XX V.
RAMP X.XX	Ramp Reference point out of limits; measured X.XX V.

Display Message	Comment
+ 5 Volts X.X	+ 5 V digital power supply out of limits; measured X.X V.
- 5 Volts X.X	- 5 V digital power supply out of limits; measured X.X V.
+ 15 Volts X.X	+ 15 V digital power supply out of limits; measured X.X V.
- 15 Volts X.X	- 15 V digital power supply out of limits; measured X.X V.

10 PARTS LISTS

MODEL 6500A

PL18322.02.02	General Assembly
PL18221.02.02	CPU
PL18222.02.02	Memory I/O
PL18225.01.02	Display
PL18230.01.02	Electrometer
PL18388.01.02	High Voltage
PL18410.01.02	Opto-isolator
PL18411.01.02	Power Supply
PL18435.01.02	Counter I/O
PL19068.01.02	Voltage Monitor Reset

11 DRAWINGS

18221.02.04	CPU
18222.02.04	Memory I/O
18225.01.04	Display
18230.02.04	Electrometer
18322.02.02	General Assembly
18388.01.04	High Voltage
18410.01.04	Opto-isolator
18411.01.04	Power Supply
18435.01.04	Counter I/O
19068.01.04	Voltage Monitor Reset

12 APPENDICES

12.1 APPENDIX 1 - SAMPLE BUS CONTROL PROGRAM

```
100 REM BASIC Example Program - for Guildline Teraohmmeter
105 REM
112 REM You MUST merge this code with DECL.BAS.
115 REM
120 REM Assign a unique identifier to device and
125 REM store in variable DVM%.
130 REM
135     BDNAME$ = "TOHM"
140     CALL IBFIND (BDNAME$, TOHM%)
145 REM
150 REM Check for error on IBFIND call.
155 REM
160      IF TOHM% < 0 THEN GOSUB 2000
170 REM
180 REM Clear the device.
190     CALL IBCLR (TOHM%)
195 REM
200 REM Check for an error on each GPIB call to be
210 REM safe.
215 REM
220     IF IBSTA% < 0 THEN GOSUB 3000
230 REM
240 REM Reset the TOhm meter so we must what state
250 REM the internals are set to (defaults).
255 REM
260     WRT$ = "RESET" : CALL IBWRT (TOHM%, WRT$)
270     IF IBSTA% <0 THEN GOSUB 3000
280 REM
290 REM Sleep for a while so that the TOhm meter can finish
295 REM
300     FOR I=1 TO 10000 :NEXT I
320 REM
330 REM Tell the TOhm meter to measure resistance
340 REM
350     WRT$ = "MEASURE OHMS" : CALL IBWRT (TOHM%,WRT$)
360     IF IBSTA% < 0 THEN GOSUB 3000
380 REM
390 REM Loop on reading the status byte until
400 REM the TOhm meter says that the reading is complete
```

```
410 REM
420     CALL IBRSP (TOHM%,SPR%)
430     IF IBSTA% < 0 THEN GOSUB 3000
440 REM
450 REM Now test the status byte (SPR%).
460 REM If SPR% has bit 5 set then the TOhm meter
470 REM has finally finished its reading otherwise loop
         around
480 REM
490     IF SPR% AND &H20 THEN GOTO 500
495     GOTO 420
500 REM
510 REM Ask the TOhm meter to give us the next measurement
520 REM
525     WRT$ = "VALUE?" : CALL IBWRT (TOHM%,WRT$)
526     IF IBSTA% < 0 THEN GOSUB 3000
530     RD$ = SPACE$(48) : CALL IBRD (TOHM%,RD$)
540     IF IBSTA% < 0 THEN GOSUB 3000
550 REM
560 REM Print out the reading and loop around to catch
570 REM the next reading
580 REM
585     PRINT VAL(MD$(RD$,12,15))
590     GOTO 420
2000 REM A routine at this location would notify
2010 REM you that the IBFIND call failed, and
2020 REM refer you to the handler software
2030 REM configuration procedures.
2040     PRINT "IBFIND ERROR" : RETURN
3000 REM An error checking routine at this
3010 REM location would, among other things,
3020 REM check IBERR to determine the exact
3030 REM cause of the error condition and then
3040 REM take action appropriate to the
3050 REM application. For errors during data
3060 REM transfers, IBCNT may be examined to
3070 REM determine the actual number of bytes
3080 REM transferred.
3090     PRINT "GPIB ERROR" : RETURN
5000 END
```

12.2 APPENDIX 2

12.2.1 LARGE VALUE RESISTOR MEASUREMENT TECHNIQUE

The measurement of very large value resistors presents special challenges for the operator. The measurement is often rendered meaningless unless certain precautions are taken.

12.2.2 ENVIRONMENT

The test equipment and the test sample should be located in a clean dry area where the temperature is relatively constant near 23°C. The air humidity should be between 20 and 40% R.H. Ionized air and ionizing radiation should not be present in the test area.

12.2.3 SAMPLE PREPARATION

It is very important to prepare the test sample properly so that unwanted parallel leakage paths are reduced as much as possible. The condition of the insulation surface between the sample terminals is very critical since this usually forms a significant source of electrical leakage. The surface must be dry and free of conductive salts or other deposits.

12.2.4 TEST LEAD ROUTING

Although it is good general practice to use shielded test leads (shielded wires with the shields connected to ground) it is especially important with higher value test resistors. Shielded test leads shunt unwanted leakage current away from the electrometer circuit.

12.2.5 CAPACITIVE TEST SAMPLES

Test samples that store electrical charges and have long time constants cannot be measured using the autoreverse feature of the teraohmmeter. Instead, the 6500A should have its autoreverse key deactivated (LED dark) until a stable resistance reading is displayed with one test voltage polarity. The reading should be recorded and an average computed with the next reading using the reverse polarity. The autoreverse key is then pressed to initiate a test voltage polarity reversal. When the polarity reversal is displayed the key should be pressed once again to lock the test voltage into the reverse polarity. The resistance display reading must then be allowed to restabilize at a new value.

The true resistance of the sample is the numerical average calculated from the two readings taken. This technique allows the sample sufficient time to be measured properly.

12.2.6 ELECTROMETER CIRCUIT CLEANLINESS

See Chapter 9.

12.3 APPENDIX 3 - Application Note GI2001001A (28 March 2001)

12.3.1 CALIBRATION:

Overall performance can be enhanced by utilizing the Model 9336/100M Resistance Standard as the reference for the SofCal calibration of the Teraohmmeter.

Model 9336/100M specifications are as follows:

Temperature Coefficient: < +/-5 ppm/deg. C.
Calibration Uncertainty: +/-25 ppm
Stability, 12 Months: +/-25 ppm

12.3.2 ENHANCED MEASUREMENT CAPABILITY:

Utilizing the Model 6500A as a transfer standard can substantially reduce measurement uncertainties. The Model 9336 and 9337 series resistance standards can be used to provide a short-term calibration of the 6500A at a particular resistance decade value. The short-term calibration correction for the 6500A can then be used to remove the systematic error from subsequent measurements.

Typical short-term uncertainties and additional uncertainties are listed below:

Resistance Value	6500A Uncertainty	9336/7 Uncertainty	Total Transfer Uncertainty
(Ohms)	(+/-ppm)	(+/-ppm)	(+/-ppm)
10M	10	25	35
100M	10	50	60
1G	10	125	135
10G	10	225	235
100G	20	900	920
1T	30	1300	1330
10T	50	5000	5050
100T	80	6200	6280

12.3.3 CALIBRATION KIT:

A calibration kit is now available which includes a Model 9336/100M Resistance Standard along with the following items needed for the procedure:

-Type N to Binding Post adapter for the Source terminal voltage calibration.
-A Zero Ohm link to calibrate the zero ohm offset coefficient.
-A pair of 0.5M Type N extender leads to connect the calibrating resistor away from the elevated temperature area of the 6500A front panel connectors.

12.3.4 PRACTICAL POINTS OF INTEREST:

For best measurement results, do not connect the resistor directly to the SOURCE and INPUT terminals of the 6500A. Most high value resistors have a very significant temperature coefficient and when mounted directly to the front panel of the 6500A the local elevated temperature around the front panel area will affect the measured value. The use of a set of remote cables will allow the resistor to be placed where the actual temperature can be controlled and measured. Remote cables for this purpose are included in the Model 65210 Lead Set option.

The Model 65205 Shielded Sample Enclosure is ideal for measurement of individual resistance elements and also for measurement of leakage resistance of capacitors. In the enclosure the element is shielded from electrical interference and also from air drafts which would other wise cause readings to be unstable.

The Model 65201 is a shielded enclosure designed to accommodate Penn Airborne Type 9A5100 resistors which some laboratories may still be using.

12.3.5 CALIBRATION PROCEDURE NOTES:

The Model 6500A Teraohmmeter should be calibrated annually for best results. The calibration procedure includes adjustment of the voltage and current offsets of the input electrometer and calibration of the source output voltages. The final part of the calibration involves the use of the internal SofCal feature.

The SofCal feature makes use of a known 100Megaohm resistance standard to determine correction coefficients for the three integrating capacitor values and the three integration threshold voltages. A Zero Ohm link is used to correct for any zero offset error.

After the SofCal procedure is completed the Teraohmmeter verification can be performed, if a complete set of calibrated decade values of resistance are available. This will increase the confidence level of the calibration and also allow correction factors to be used if desired. The Model 9336 series of resistance standards are recommended for values up to 100Gigaohms. The Model 9337 series is available for values from 1 Teraohm to 10 Petaohms.

12.3.6 OPTIMIZED MEASURMENT PARAMETERS:

For optimum results when measuring high value resistances with the Model 6500A it is recommended that the following parameters be selected. Note that the Guildline calibration facility uses these parameters for calibration of high value Resistance Standards.

OHMS VALUE	CAPACITOR	THRESHOLD	VOLTAGE	MODE
1M to 100M	2700 pF	10 V	1 V	AUTOREV
1 G	2700 pF	10 V	10 V	AUTOREV
10 G	2700 pF	10 V	100 V	AUTOREV
100 G	2700 pF	10 V	1000 V	AUTOREV
1 T	2700 pF	1 V	1000 V	MANREV
10 T	270 pF	1 V	1000 V	MANREV
100 T	27 pF	1 V	1000 V	MANREV
1 P	27 pF	1 V	1000 V	MANREV
10 P	27 pF	0.1 V	1000 V	MANREV