Errata

Title & Document Type: 3560A Portable Dynamic Signal Analyzer Operating and Service Guide

Manual Part Number: 03560-90016

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HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this manual copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

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HP 3560A
Operating & Service Guide

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Safety Summary

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements. This is a Safety Class 1 instrument.

Ground the Instrument

To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument is equipped with a three-conductor ac power cable. The power cable must either be plugged into an approved three-contact electrical outlet or used with a three-contact to two-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet. The power jack and mating plug of the power cable meet International Electrotechnical Commission (IEC) safety standards.

Do Not Operate in an Explosive Atmosphere

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

Keep Away from Live Circuits

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

Do Not Service or Adjust Alone

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

Do Not Substitute Parts or Modify Instrument

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Hewlett-Packard Sales and Service Office for service and repair to ensure the safety features are maintained.

Dangerous Procedure Warnings

Warnings accompany potentially dangerous procedures throughout this manual. Instructions contained in the warnings must be followed.

Safety Symbols

The following safety symbols are used throughout this manual and in the instrument. Familiarize yourself with each symbol and its meaning before operating this instrument.

General Definitions of Safety Symbols Used on Equipment or in Manuals

Instruction manual symbol. The product is marked with this symbol when it is necessary for the user to refer to the instruction manual to protect against damage to the instrument.

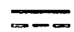
Indicates dangerous voltage (terminals fed from the interior by voltage exceeding 1000 volts must be so marked).

Protective ground (earth) terminal. Used to identify any terminal which is intended for connection to an external protective conductor for protection against electrical shock in case of a fault, or to the terminal of a protective ground (earth) electrode.

Low-noise or noiseless, clean ground (earth) terminal. Used for a signal common, as well as providing protection against electrical shock in case of a fault. A terminal marked with this symbol must be connected to ground in the manner described in the installation (operating) manual, and before operating the equipment.

Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.

Alternating current (power line).



Direct current (power line).

Alternating or direct current (power line).

Warning

The warning sign denotes a hazard. It calls attention to a procedure, practice, condition or the like, which if not correctly performed or adhered to, could result in injury or death to personnel.

Caution

The caution sign denotes a hazard. It calls attention to an operating procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product or the user's data.

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HP3560A Portable Dynamic Signal Analyzer

Operating and Service Guide

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Safety Summary

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Do Not Substitute Parts or Modify Instrument

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Hewlett-Packard Sales and Service Office for service and repair to ensure the safety features are maintained.

Dangerous Procedure Warnings

Warnings, such as the example below, precede potentially dangerous procedures throughout this manual. Instructions contained in the warnings must be followed.

Warning **Dangerous voltages, capable of causing death, are present in this instrument. Use extreme caution when handling, testing, and adjusting.**

HEWLETT PACKARD

Safety Symbols

The following safety symbols are used throughout this manual and in the instrument. Familiarize yourself with each symbol and its meaning before operating this instrument.

General Definitions of Safety Symbols Used On Equipment or In Manuals.

Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual in order to protect against damage to the instrument.

Indicates dangerous voltage (terminals fed from the interior by voltage exceeding 1000 volts must be so marked.)

OR — Protective conductor terminal. For protection against electrical shock in case of a fault. Used with field wiring terminals to indicate the terminal which must be connected to ground before operating equipment.

Low-noise or noiseless, clean ground (earth) terminal. Used for a signal common, as well as providing protection against electrical shock in case of a fault. A terminal marked with this symbol must be connected to ground in the manner described in the installation (operating) manual, and before operating the equipment.

OR — Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.

Alternating current (power line).

Direct current (power line).

Alternating or direct current (power line).

Warning **The WARNING sign denotes a hazard. It calls attention to a procedure, practice, condition or the like, which if not correctly performed or adhered to, could result in injury or death to personnel.**

Caution The CAUTION sign denotes a hazard. It calls attention to an operating procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product.

Note The NOTE sign denotes important information. It calls attention to procedure, practice, condition or the like, which is essential to highlight.

Herstellerbescheinigung

Hiermit wird bescheinigt, daß das Gerät/System

HP 3560A PORTABLE DYNAMIC SIGNAL ANALYZER

in Übereinstimmung mit den Bestimmungen von Postverfügung 1046/84 funkentstört ist.

Der Deutschen Bundespost wurde das Inverkehrbringen dieses Gerätes/Systems angezeigt und die Berechtigung zur Überprüfung der Serie auf Einhaltung der Bestimmungen eingeräumt.

Zusatzinformation für Meß- und Testgeräte

Werden Meß- und Testgeräte mit ungeschirmten Kabeln und/oder in offenen Meßaufbauten verwendet, so ist vom Betreiber sicherzustellen, daß die Funk-Entstörbestimmungen unter Betriebsbedingungen an seiner Grundstücksgrenze eingehalten werden.

Manufacturer's declaration

This is to certify that the equipment

HP 3560A PORTABLE DYNAMIC SIGNAL ANALYZER

is in accordance with the Radio Interference Requirements of Directive FTZ 1046/1984. The German Bundespost was notified that this equipment was put into circulation, the right to check the series for compliance with the requirements was granted.

Additional Information for Test- and Measurement Equipment

If Test- and Measurement is operated with unscreened cables and/or used for measurements on open set-ups, the user has to assure that under operating conditions the Radio Interference Limits are still at the border of his premises.

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Chapter 7: Adjustments

Chapter 8: Replaceable Parts

Chapter 9: Manual Backdating

Chapter 10: Circuit Descriptions

Chapter 11: Troubleshooting

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Installation

Introduction

This section of the *HP 3560A Operating & Service Guide* contains installation information, specifications and the operation verification and performance tests. In this chapter you will learn how to:

- Inspect your shipment for completeness and damage.
- Prepare the instrument for use.
- Recharge the battery pack.
- Use the carrying case.

This chapter also contains important safety information and lists some accessories and options you may be interested in using with your HP 3560A Portable Dynamic Signal Analyzer.

Safety Considerations

The HP 3560A Dynamic Signal Analyzer is a Safety Class II instrument. Although the instrument's design is in accordance with international safety standards, this manual contains information, cautions, and warnings that you must follow to ensure safe operation and retain the HP 3560A Dynamic Signal Analyzer in safe operating condition. Service must be performed by qualified, trained service personnel who are aware of the hazards involved (such as fire and electrical shock).

Instrument Description

The HP 3560A Portable Dynamic Signal Analyzer is a portable FFT-based instrument capable of measuring time domain and the frequency spectrum signals of both steady state and quickly changing signal sources. With two input channels, the HP 3560A provides a variety of frequency response measurements with a frequency range from 31.25 mHz to 40 kHz. The analyzer's battery operation, light weight (7 kg), and protected enclosure allow you to take measurements in harsh environments normally encountered in portable applications. The HP 3560A enclosure is dust and water resistant.

The HP 3560A also serves as a powerful analysis tool. The ICP input mode directly powers accelerometers, so external signal conditioning hardware is not required. Octave measurements, spectral map displays, and marker functions complete fill out the analyzer's measurement capability.

Analysis features provide the power needed to isolate mechanical noise and vibration signal sources. Octave measurements let you use standard acoustic techniques in characterizing signals. The octave measurements comply with ANSI S1.11 standard frequency bands and filter shapes.

Spectral map displays allow you to view your signal and how it changes as a function of time. The spectral map display combined with the external sampling capability of the HP 3560A make it easy to determine which vibration signals are related to the operating speed of the machine and which are fixed frequency signals due to other vibration modes such as structural resonances or oil whirl.

Variable block size, combined with variable frequency span and on-line zoom provide the tools necessary for data collection and viewing of frequency response functions when using impact test techniques. Coherance measurements and real/imaginary trace coordinates let you do further analysis. The analyzer is also equipped with a full set of trigger functions including pre-trigger and post-trigger. Time and RMS averaging improve signal-to-noise ratio and statistical accuracy.

You can print via the RS-232 the display, status screen, or catalog listing to an HP QuietJet, HP LaserJet, HP DeskJet, HP ThinkJet, or Epson FX-80 printer. The analyzer can also plot to HP-GL plotters via RS-232. The baud rate and parity bit are selectable. You can also transfer stored data to a computer via RS-232 and convert it to Hewlett-Packard's SDF (Standard Data Format) by using the SDF Utilities provided with the instrument. SDF lets you transport data to other Hewlett-Packard dynamic signal analyzers such as the HP 3566A, HP 3567A, and HP 35665A, and to third-party analysis packages for data analysis, comparisons and archiving. See "Transferring Data to a Personal Computer" in the *HP 3560A Getting Started Guide* for an example.

Installation

Installation

Introduction

Read this section to find out how to recharge the batteries and what operating environment you need to install the HP 3560A Dynamic Signal Analyzer. This section also includes instructions for cleaning the screen, how to use the carrying case, and information on storage and shipment.

Incoming Inspection

The HP 3560A Dynamic Signal Analyzer was carefully inspected both mechanically and electrically before shipment. It should be free of marks or scratches and, it should meet its published specifications upon receipt. The batteries must be recharged before you operate the analyzer the first time. The appropriate ac adapter for the country of destination is shipped with the instrument.

Inspect the analyzer for physical damage incurred in transit. If the analyzer was damaged in transit, save all packing materials, file a claim with the carrier, and call your Hewlett-Packard sales and service office.

Warning **If the analyzer is mechanically damaged, do not connect the analyzer to power.**

Installation

Packing List

The following list gives the items which should be included in all standard HP 3560A shipments. If any item is missing in your shipment, contact your HP representative. You should have 1 each of the following.

- HP 3560A Dynamic Signal Analyzer
- ac Adapter
- Carrying Case
  - Carrying Case
  - Waist Strap (inside accessory compartment)
  - Neck Strap (inside accessory compartment)
- *HP 3560A Operating & Service Guide*
- HP 3560A Getting Started Kit
  - *HP 3560A Getting Started Guide*
  - HP 3560A Typical Measurement Signals Cassette Tape
  - Headphone Jack Adapter Cable
- *HP 3560A Quick Reference Guide*
  (shipped inside carrying case accessory compartment)
- Standard Data Format Utilities
  3 1/2" disc
  5 1/4" disc
  Standard Data Format Utilities User's Guide

Incoming Tests

Finish incoming inspection by testing the electrical performance of the analyzer using the operation verification or performance tests in chapter 3. The operation verification test verifies the basic operating integrity of the analyzer. It takes about 5 minutes to complete this test. The performance tests verify that the analyzer meets all the performance specifications. It takes about 3 hours to complete these tests.

Battery Recharging

The analyzer is fully battery operated. The rechargeable NiCd battery pack comes already installed in the instrument and provides power for the HP 3560A. The battery pack holds a charge for approximately 6 hours of continued operation.

Note

The battery in the HP 3560A may not be fully charged when you receive it due to normal capacity loss during storage and shipment. To fully charge the battery, use the instructions below. The analyzer can be operated while you charge the battery.

The procedures outlined below explain how to recharge the battery pack. Use the ac adapter to charge the battery. It takes about 14 hours to charge a fully discharged battery pack. The battery pack can be recharged outside the HP 3560A if you use the battery charging adapter furnished with the optional Extra Battery Pack. The instrument can be operated while the ac adapter is connected without affecting the recharge time. Charging the extra battery pack while you use the analyzer provides the capability to operate the analyzer continually.

Warning

Do not use any other ac adapter than those listed in figure 1-3. The battery pack is designed specifically to work with an HP ac adapter; Hewlett-Packard is therefore not responsible for damages caused by using a non-HP ac adapter or a non-HP battery pack.

Caution When you are not recharging the HP 3560A, make sure you have the rubber cover for the ac adapter connector inserted to help protect the instrument from dirt, water, and electrostatic discharge.

To recharge the internal battery pack:

1. Verify that the ac power source voltage matches the input voltage on the ac adapter label.
2. Plug in the ac adapter to the ac power source.
3. Connect the ac adapter cable to the analyzer's battery charging socket labeled "ac adapter" located on the connector panel. See figure 1-1. The green LED beside the socket indicates the battery is charging.
4. Allow about 5 hours for the battery pack to be 80% charged or about 14 hours for a full charge. This charge typically lasts 6 hours for continual operation.

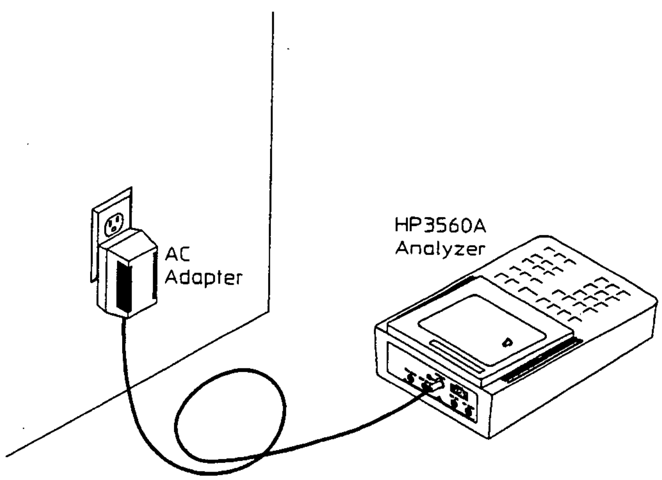

Figure 1-1.
Recharging the internal battery pack

To recharge the Extra Battery Pack:

1. Verify that the ac power source voltage matches the input voltage on the ac adapter label.
2. Plug in the ac adapter to a single-phase ac power source.
3. Connect the ac adapter cable to the battery charging adapter input. Connect the battery pack to the battery charging adapter output. See figure 1-2.
4. Allow about 5 hours for the battery pack to be 80% charged or about 14 hours for a full charge. This charge typically lasts 6 hours for continual operation.

To replace the internal battery pack of the HP 3560A:

1. Remove the discharged battery pack from the analyzer by using a coin to remove the two slotted screws on the analyzer's battery cover.
2. Lift the battery cover and carefully pull out the battery pack.
3. Disconnect the discharged battery pack by pressing down on the connector's locking tab while carefully separating the white plastic connector.
4. Connect the white plastic connector of the charged battery pack to the white connector in the instrument. Notice the polarization allows the connectors to mate only one way.
5. Place the charged the battery pack in its compartment, replace the battery cover, and secure the slotted screws.

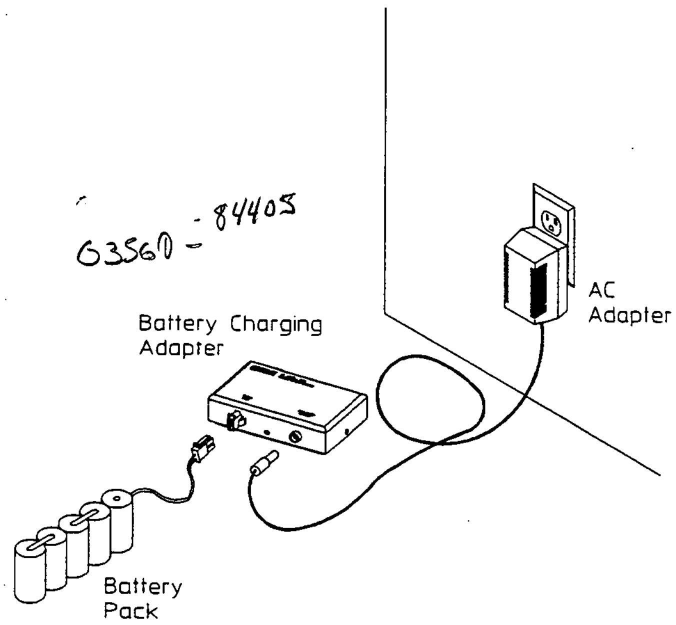

Figure 1-2.
Recharging the extra battery pack

Low Battery Indication

A "BAT" screen messages appears on the display when about 2 hours of operating time are remaining. The HP 3560A automatically turns off if the battery charge gets very low.

Warning

- **Do not short the battery.**
- **Do not incinerate. The battery can burst if you throw it into a fire.**
- **Do not put the battery pack within reach of children.**
- **Do not disassemble the battery.**

Grounding Requirements

Since the HP 3560A is battery operated, there is no need to ground the instrument while operating it. When you connect the instrument to an external device like a plotter, printer, or computer, the RS-232 connector and the BNC connectors are connected to ground internally. See "RS-232 Interface Connections" which follows for more information on RS-232.

Caution

When you are using transducers, make sure you electrically isolate each transducer by using non-metallic washers, nuts, or wax for securing the transducer to the device under test. This is especially important when you use both channels on the analyzer. Failing to electrically isolate the transducers may cause ground currents to form between channels which can introduce errors in the data.

The analyzer is equipped with an ac adapter for recharging the internal battery pack. The operating voltage of the ac adapter shipped with each analyzer depends on the country of destination. See figure 1-3 for the available ac adapter configurations.

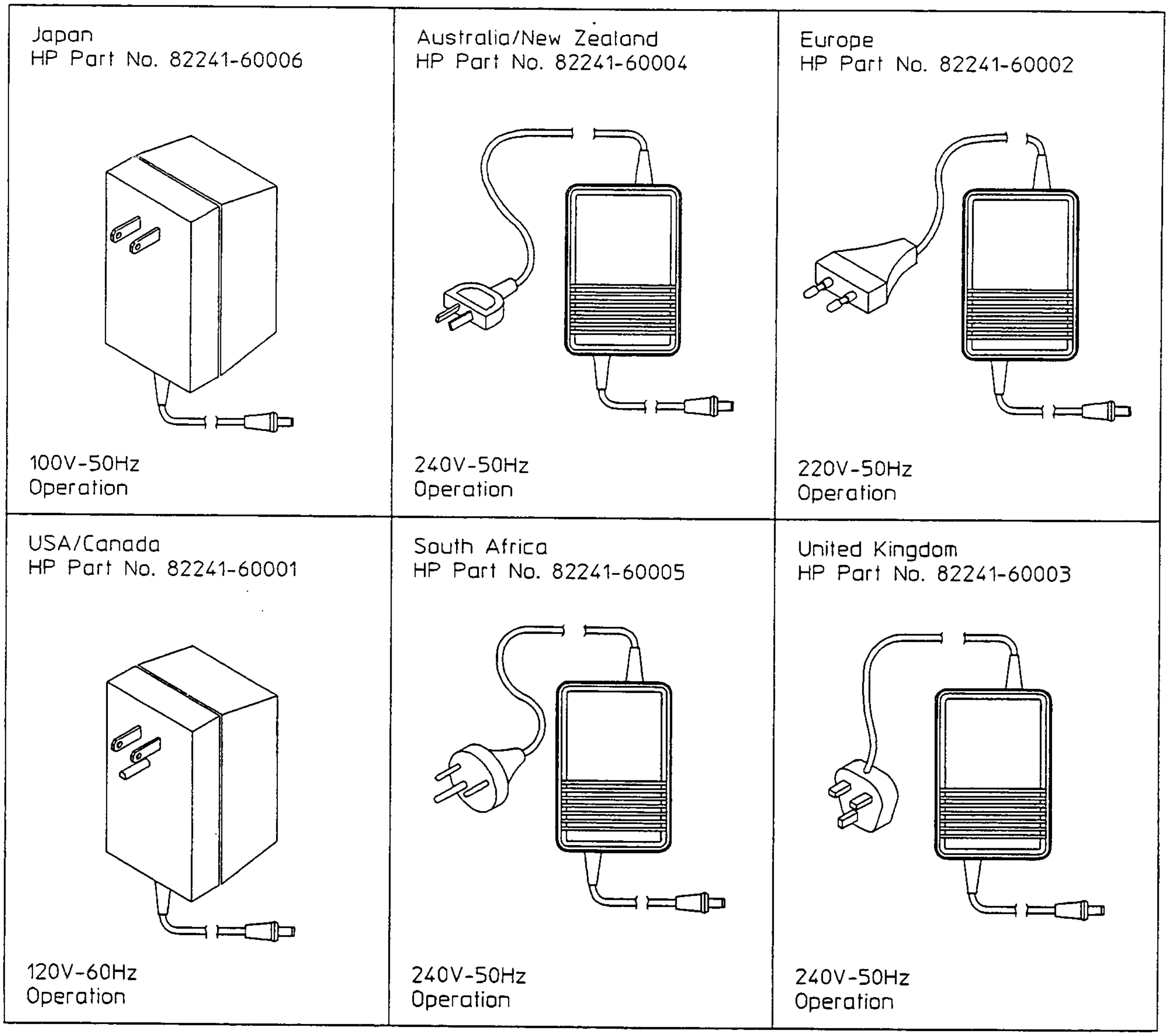

Figure 1-3.
AC Adapter Plug Configurations

Operating Environment

The operating and storage environment specifications for the analyzer are listed in chapter 2 under "General."

Warning **When recharging, do not expose the ac adapter to rain or other excessive moisture to prevent shock hazard.**

Although the analyzer enclosure water resistent, you should protect the analyzer from moisture and temperatures or temperature changes that cause condensation within the analyzer.

RS-232 Interface Connections

The analyzer is compatible with the RS-232 interface. Use this interface to send data to a printer, plotter, or computer. The HP 3560A is a 9-pin interface that conforms to EIA/TIA-562 and EIA/TIA-574 standards. Connect the analyzer to the RS-232 via the 9-pin RS-232 connector located on the connector panel. Figures 1-4 and 1-5 show the cabling, pin assignments, and connection instructions. The RS-232 connector on the HP 3560A is the same type and pin arrangement as the RS-232 connector on a PC-AT compatible computer. This is convenient for interchangeably connecting the printer to the computer and the analyzer.

For information on how to print and plot, see [PRINT] in the Dictionary Reference. Also refer to "Printing and Plotting" in the *HP 3560A Getting Started Guide*. For information on transferring data to a personal computer, see [XFER ONE] in the Dictionary Reference. Also refer to "Transferring Data to a Personal Computer" in the *HP 3560A Getting Started Guide*. The *Standard Data Format Utilities User's Guide* also gives important information on archiving and post-processing data. For information on programming the HP 3560A and sample programs, see [RS232] in the Dictionary Reference.

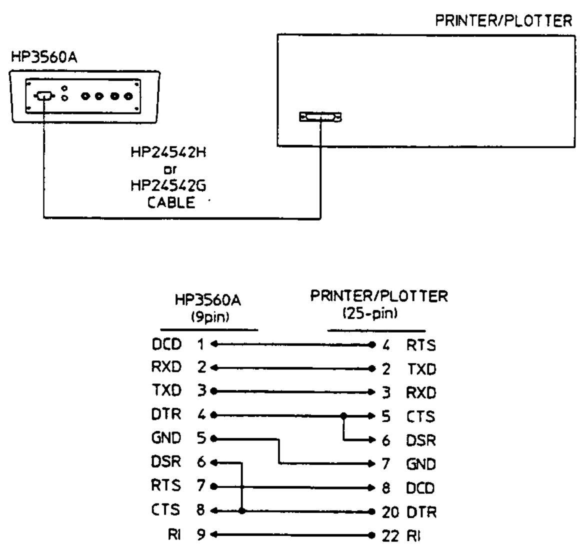

Figure 1-4.
Printer/Plotter RS232 Connection

* Use the HP 24542H cable with the HP 7550A plotter.

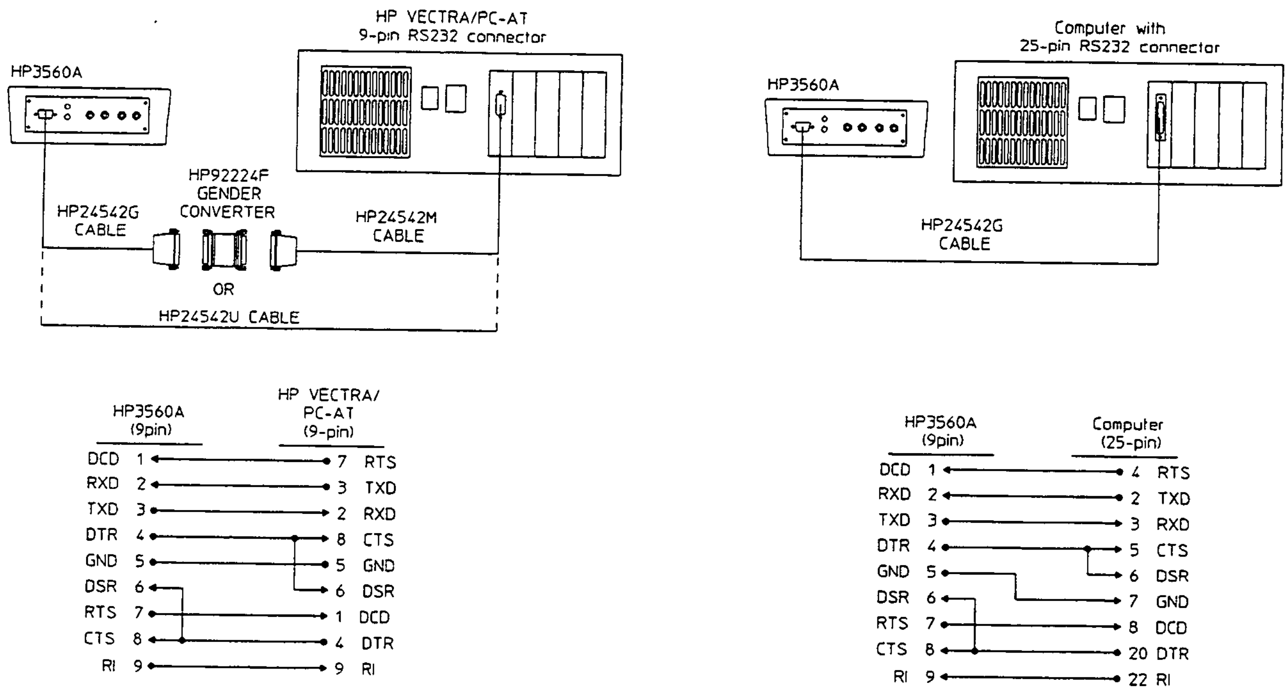

Figure 1-5.
Computer RS232 Connection

Note

Some printers indicate "buffer full" by switching a secondary RTS line; usually on pin 11 of the printer D (25-pin) connector. For correct handshaking with this type of printer, pin 11 should be connected to either CTS or DSR on the HP 3560A.

RS-232 Transmit (relevant signals TXD, CTS and DSR)

Set the PC, printer, or plotter baud rate, parity, and the number of bits to match the HP 3560A. Printer data is binary raster information, so you must select 8 data bits with no parity. For plotters, simply make sure the analyzer and plotter settings are the same. Refer to the operating guide of the printer or plotter for more information on how to change baud rate, parity, and number of data bits.

The HP 3560A operates a hardware handshake on either CTS or CTS + DSR inputs, depending on the [HANDSHAK] setting. Therefore, for the analyzer to transmit data on TXD, CTS (and possibly DSR) must be at RS-232 positive voltage level (between +3V and +12V). CTS and DSR can be driven by the receiving device connected to the instrument or can be strapped active. The HP 3560A ceases transmission when these lines are driven to RS-232 negative voltage level. Transmit handshaking can therefore be performed on either or both lines.

RS-232 Receive (relevant signals RXD, RTS, and DTR)

For printing or plotting, the HP 3560A never receives data from the RS-232. However, both the RTS and DTR outputs are set to RS-232 positive voltage level to enable reception of a character if it were transmitted. This is to prevent a sending device from being unable to transmit a character and therefore "hanging up", despite the fact that the HP 3560A may not react to any received character.

Note

The HP 3560A is configured as Data Terminal Equipment (DTE). When you connect the analyzer via the RS-232 port to another piece of equipment, make sure one is set to receive data and the other is set to transmit data.

For additional information on transferring data via RS-232, see the *HP 3560A Getting Started Guide*, "Plotting and Printing Measurement Results" and "Transferring Data to a Computer." Also see the *HP 3560A Operating & Service Guide* in the Dictionary Reference section under RS-232 for more information on setting RS-232 parameters.

Screen (LCD) Cleaning

The analyzer screen is covered with a plastic diffuser screen. This cover this is not removable by the operator. If a foreign material adheres itself to the screen

- Turn off the analyzer by pressing [**Shift**] [**Off**].
- Slightly dampen a soft, lint-free cloth with a mild detergent mixed in water.
- Carefully dry with a soft cloth.

Caution To prevent damage to the analyzer, do not use cleaning solutions other than the above.

Carrying Case

Instrument Installation

The analyzer can be used on a bench or in the field. For field use, the analyzer slips into the carrying case as shown in figure 1-6. This carrying case is really two cases in one. One side holds the instrument and the other side serves as an accessories compartment. This lets you carry all you need to the site, yet when you want to start using the instrument the accessory compartment zips off and lets you turn the carrying case into a light "skin-pack" for comfortable operation.

To install the instrument in the carrying case:

1. Unzip the front cover of the carrying case.
2. Flip back the clear plastic front panel cover and the elastic bracing straps. The clear plastic front panel cover adds protection from dirt, spills and fingerprints.
3. Place the instrument in its compartment and secure the the elastic bracing straps over the instrument (below the display but above the front panel keys).
4. Flip the plastic front panel cover over the keypad of the instrument and secure it to the elastic bracing strap.
5. Zip the front cover and carry the case using either the handle on the side or connect the neck strap and carry the case over your shoulder. The neck strap and waist straps are shipped inside the accessory compartment.

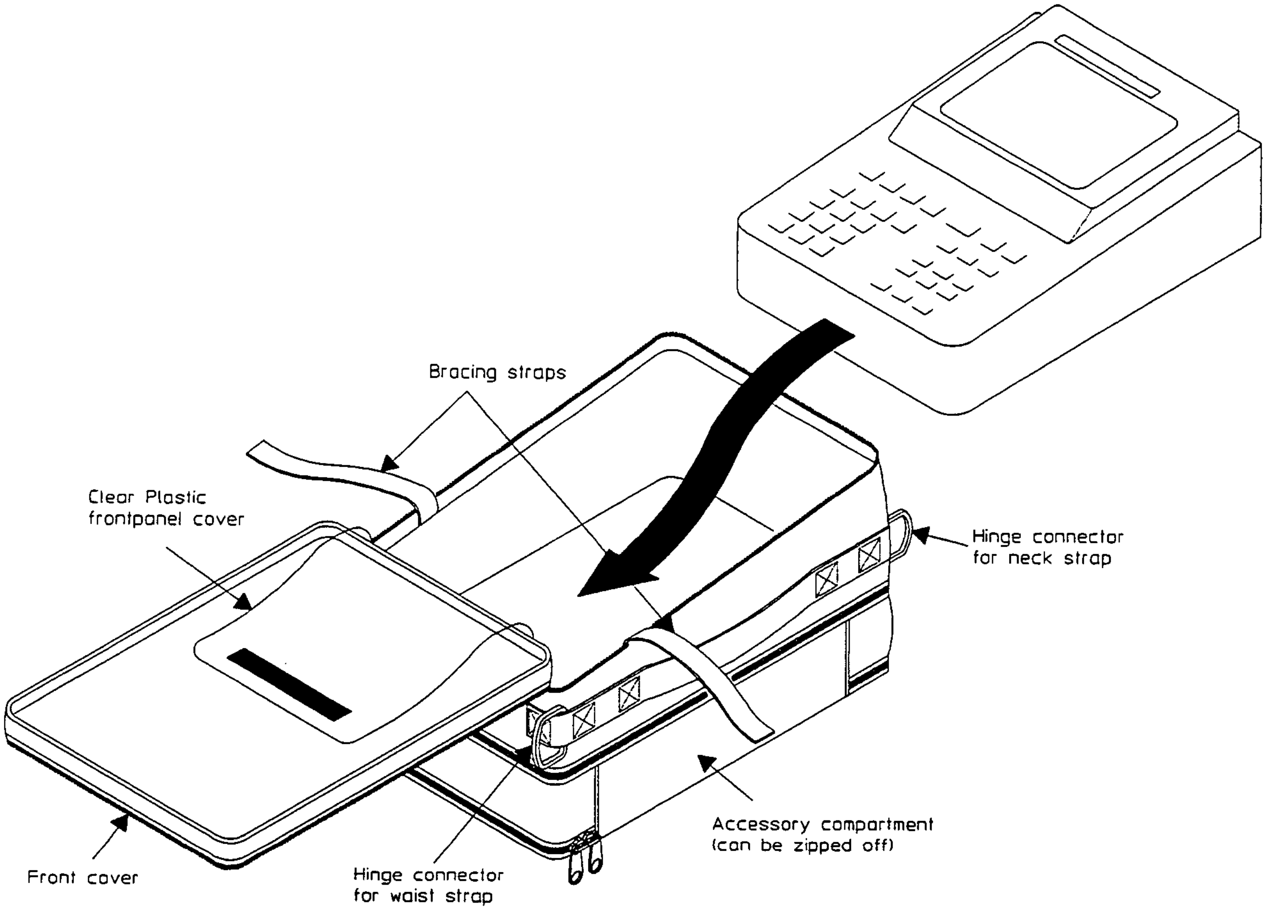

Figure 1-6.
Instrument Carrying Case Installation

Carrying Case Configurations

The carrying case has three configurations as shown in figure 1-7.

- Brief case configuration.
- Over-the-shoulder configuration.
- "Hands-free" operation configuration.

Obtain the configuration you want by arranging the neck and waist straps accordingly.

Brief Case Configuration Carry the instrument like a brief case. The neck and waist straps fit neatly in the accessory compartment. Transducers, light-weight cables, notes, and references like the *HP 3560A Quick Reference Guide* also fit in the accessory compartment. The small case size fits easily under an airplane seat.

Over-the-Shoulder Configuration When you need to climb or crawl to hard-to-reach places, use this configuration so both hands are free. Connect the neck strap to the connecting hinges on the stop side of the carrying case. Place it over your shoulder and adjust the strap to a convenient length.

Hands-Free Operation When you reach the measurement site, you can zip off the accessories compartment to make the case lighter and smaller. Adjust the neck strap to a convenient length so that you can easily operate the instrument in front of you. Connect one side of the waist strap to the hinge connector at the bottom of the carrying case. Pull the other end of the waist strap around your waist and connect it to the other hinge connector. Adjust the waist strap to fit snugly around your waist. Make the necessary connections to the device under test through the connector panel flap. This flap gives the HP 3560A connector panel extra protection. You are now ready to make measurements.

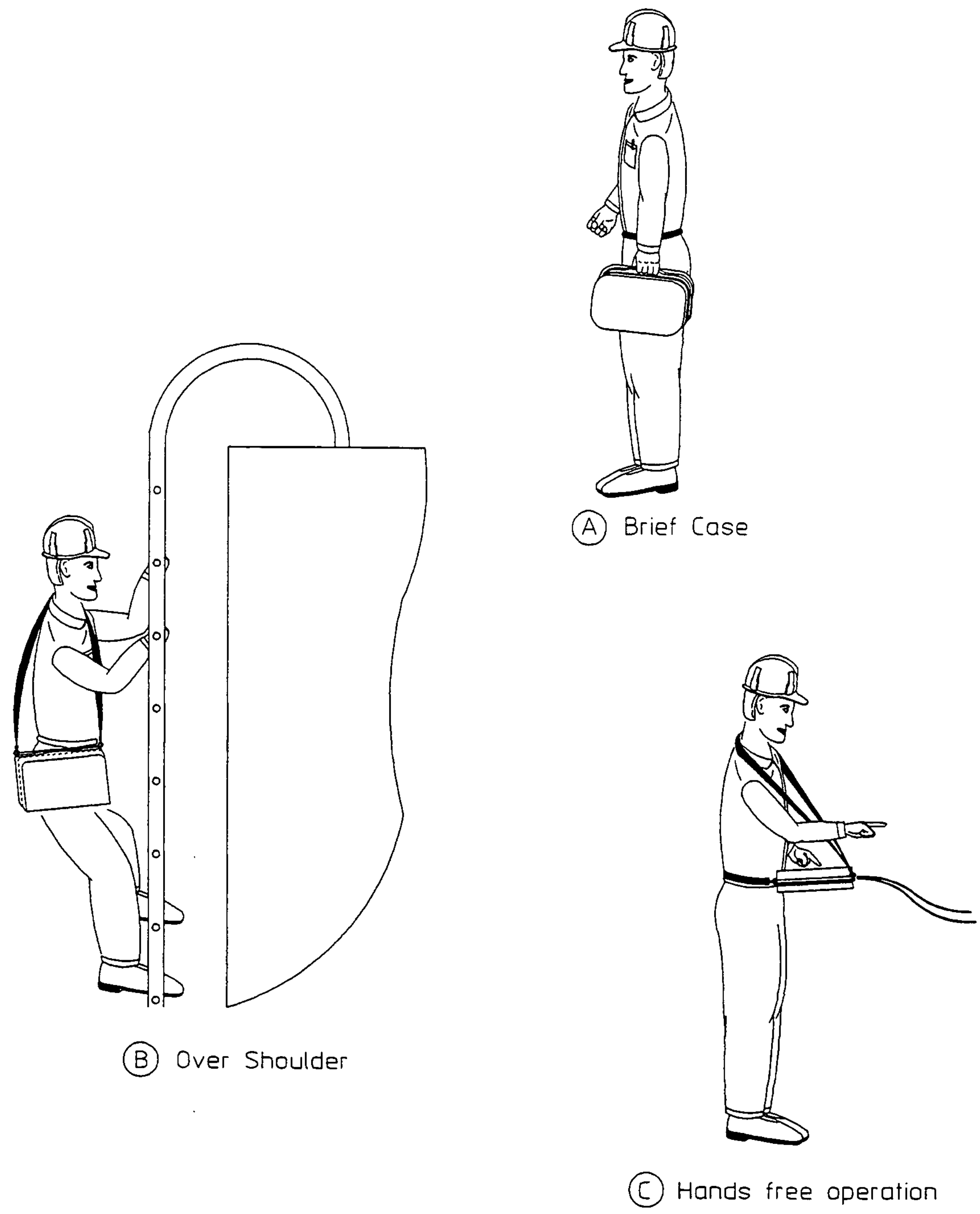

Figure 1-7.
Carrying case configurations

To clean the case exterior, use a mild soap and water solution and wipe with a clean rag.

Turning on the HP 3560A

Press the [ON] key which is adjacent to the lower right-hand corner of the display. The analyzer requires about 5 seconds to self-test while turning on.

For specific measurement information or other operating information, see the *HP 3560A Getting Started Guide* or turn to the Operation section of this manual.

Need Assistance?

If you need assistance, contact your nearest Hewlett-Packard Sales and Service Office listed in the HP Catalog, or contact your nearest regional office listed at the back of this guide. If you are contacting Hewlett-Packard about a problem with your HP 3560A Portable Dynamic Signal Analyzer, please provide the following information:

- Model Number: HP 3560A
- Serial number:
- Options:
- Firmware version (listed when the analyzer first turns on):
- Date the problem was first encountered:
- Circumstances in which the problem was encountered:
- Can you reproduce the problem?
- What effect does this problem have on you?

Storage and Shipment

Storage

Store the analyzer in a clean, dry, and static free environment. For other requirements, see environmental specifications in chapter 2.

Shipment

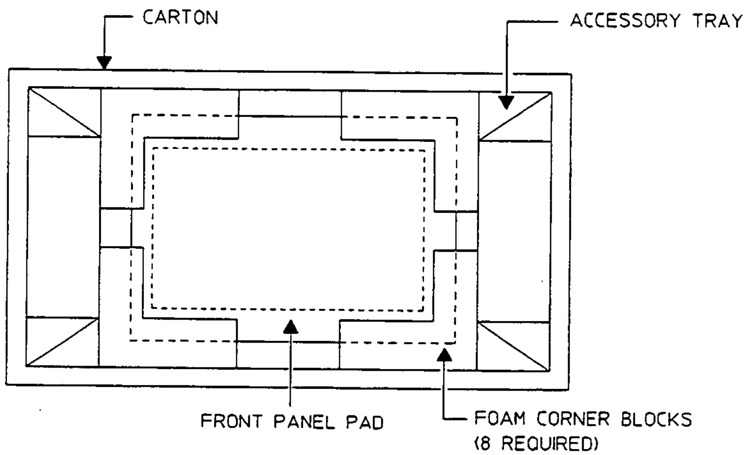

Figure 1-8.
Repacking for Shipment

- Containers and materials identical to those used in factory packaging are available through Hewlett-Packard offices, see figure 1-8. If the analyzer is being returned to Hewlett-Packard for service, attach a tag describing the type of service required, the return address, model number, and full serial number. Also, mark the container FRAGILE to ensure careful handling. In any correspondence, refer to the analyzer by model number and full serial number.

- If it is necessary to package the analyzer in a container other than original packaging, observe the following (use of other packaging is not recommended):
  - Protect the front panel with cardboard and wrap the analyzer in heavy paper or anti-static plastic.
  - Use a double-wall carton made of at least 350-pound test material and cushion the analyzer to prevent damage.
  - Identify the shipment as above and mark FRAGILE.

Caution Do not use styrene pellets in any shape as packing material for the analyzer. The pellets do not adequately cushion the analyzer and do not prevent the analyzer from shifting in the carton. In addition, the pellets create static electricity that can damage electronic components.

Serial Numbers

Hewlett-Packard makes frequent improvements to its products to enhance their performance, usability, or reliability, and to control costs. HP service personnel have access to complete records for each instrument model, based on the equipment's serial number. Whenever you contact HP about your analyzer, have the complete serial number available to ensure obtaining the most complete and accurate information possible.

A serial number label is attached to the bottom of the analyzer. The serial number has two parts — the prefix (the first four numbers and a letter) and the suffix (the last five numbers).

Options

The following options are available for the HP 3560A Dynamic Signal Analyzer:

- 0BN Extra Operating & Service Guide
- 0BH Extra Getting Started Guide (includes audio cassette tape and headphone jack adapter cable)
- W30 Adds an additional 2 years to standard warranty (for a total of 3-years warranty)

Accessories

The following accessories are available for the HP 3560A Dynamic Signal Analyzer.

Table 1-1. Accessories

Accessory	Part Number
Battery Pack	
Extra Battery Pack (includes battery pack and battery charging adapter)	HP 03560-84405 BATTERY ONLY P/N ↳ 1420-0504
Microphones	
Free field, standard sensitivity, 5 Hz to 40 kHz, 35-160 dB	HP 35220A
Free field, standard sensitivity, 5 Hz to 20 kHz, 20-145 dB	HP 35221A
Pressure, standard sensitivity, 5 Hz to 20 kHz, 35-160 dB	HP 35222A
Pressure, high sensitivity, 5 Hz to 10 kHz, 20-145 dB	HP 35223A
Pre-amplifier, 2 Hz to 200 kHz, ± 0.5 dB	HP 35224A
Microphone power supply (battery operated)	HP 35228A
1 kHz calibrator, 94 dB/104 dB	HP 35229A
Accelerometers	
General vibration, 10 mV/gg, 1 Hz to 9 kHz	HP 35200A
Machinery vibration, 50 mV/g, 1 Hz to 3 kHz	HP 35201A
Structural measurements and modal analysis	HP 35202A
Vibration in rugged environment	HP 35203A
Velocity Probes	
Handheld Industrial vibration	HP 35205A
Hammer Kits	
Hammer Kit with 0.3 lb hammer	HP 35207A
Hammer Kit with 3.0 lb hammer	HP 35208A
Manuals	
Operating & Service Guide	HP 03560-90013
Getting Started Guide (includes audio cassette and adapter cable)	HP 03560-84401
Quick Reference Guide	HP 03560-90012
ac Adapters	
United States	HP 82241-60001
Europe	HP 82241-60002
United Kingdom	HP 82241-60003
Australia	HP 82241-60004
South Africa	HP 82241-60005
Japan	HP 82241-60006

Recommended Test Equipment

Table 1-2 lists the recommended equipment for the HP 3560A Performance Tests, Adjustments and Troubleshooting Procedures. The Performance Tests verify that the analyzer meets its published specifications. The following chapters give the procedures for these tests. The Adjustments and Troubleshooting Procedures are in the Service section of this manual. You may substitute other equipment for the recommended model if it meets or exceeds the listed critical specifications. If you make substitutions, you may have to modify the procedures to accommodate the different operating characteristics.

Table 1-2. Recommended Test Equipment

Instrument	Critical Specifications	Recommended Model	Test Type[5]
AC Calibrator	Amplitude Accuracy: ± 1%	Fluke[1] 5200A Fluke[1] 5700A Datron[2] 4200A	P
Frequency Synthesizer	Frequency Accuracy: ± 50 ppm Sweep time: 0.02 sec	HP 3326A HP 3325B HP 3325A HP 3324A	O,P
Low Distortion Oscillator	Total Harmonic Distortion: − 66 dBc (0.05%) Amplitude: 3.5 mV_{rms} to 3.5 V_{rms}	HP 3326A HP 339A	P
Digital Voltmeter	5 1/2 digit True rms ac voltage: 30 Hz to 100 kHz; 0.1 to 500V ± 0.1%; Input Impedance: ≥ 1 MΩ dc voltage: 1 V – 300 V ± 0.1%	HP 3455A Alternate: HP 3456A HP 3457A HP 3478A HP 3468A/B	A,T
Frequency Counter	Frequency Accuracy: ± 0.5 Hz at 32 kHz Input Impedance: 1 MΩ	HP 5316B	A
Feedthrough/Termination (2 required)	Impedance: 50Ω	HP 11048C HP 10100C Pomona[3] 4119-50	P,A
Feedthrough/Termination[4] (1 required for HP 339A)	Impedance: 600Ω	HP 11095A	P
BNC Cable (3 required)	24 inch, 50Ω	HP 8120-1840	P
BNC Tee (1 required)		HP 1250-0781	P,A
Adapter (1 required)	BNC to dual banana	HP 1250-1264 HP 1251-2277	P

[1]Fluke, Everett, WA 98206-9090
[2]Datron, Simi Valley, CA 93065 or Norwich UK NR6 6JB
[3]Pomona Electronics, Pomona, CA 91766
[4]Necessary only for the HP 339A Oscillator – not for the HP 3326A.
[5]O = Operation Verification, P = Performance Tests, A = Adjustments, T = Troubleshooting

Specifications

Specifications describe the instrument's warranted performance. Specifications designated as "typical" reflect supplemental, non-warranted characteristics.

Frequency and Time

Frequency Range:	31.25 mHz to 40 kHz with alias protection
Frequency Accuracy:	± 0.02% of reading
Frequency Controls:	Zoom On – User selects a *center frequency and span.* The analyzer performs an FFT on the chosen portion of the data record. Zoom provides a way to concentrate the number of lines of resolution in the frequency band of interest. Zoom Off – In this mode the frequency measured is of the baseband span chosen. Frequency resolution is determined by dividing baseband span by resolution. Baseband spans start at 0 Hz.
Minimum Baseband Resolution:	50 Hz/1600 lines = 0.03125 Hz
Real-time Bandwidth: baseband, rms averaging Dual-Channel:	>2 kHz

Window Characteristics
(400 lines)

–3 dB Bandwidth (% of span)	
Uniform	0.25% of span
Hann	0.37% of span
Flat Top	0.9 % of span
Shape Factor (–60 dB BW/–3 dB BW)	
Uniform	716
Hann	9.1
Flat Top	2.6
Noise Equivalent Bandwidth	
Uniform	0.25% of span
Hann	0.375% of span
Flat Top	0.955% of span
Window Flatness	
Uniform	+0, –4.0 dB
Hann	+0, –1.5 dB
Flat Top	+0, –0.01 dB

Time Domain:

Anti-alias Filters:	Switchable in or out for all ranges (When the anti-alias filter is switched out, the signal is band-limited to 80 kHz before sampling.)
Sample Rate:	102.4 kHz/channel
Amplitude Resolution:	± 0.05% of input range

The instrument acts as a sampling digital-storage oscilloscope when operating in the time domain mode. TIME CH1/CH2 , and CH1–CH2 are time domain operations. Data is measured according to record length. Use the anti-alias filter ON/OFF selection to take advantage of the full frequency range of the HP 3560A for time domain measurements.

Amplitude and Input

(Specifications stated are at the center of the frequency bins, in dc coupling)

Full Scale Range: (autoranging or manually selectable for each channel in a 1,2,5 sequence)	± 5mV to ± 5V peak
Overload Detection:	Both channels with on-screen message
Absolute Amplitude Accuracy (50 Hz to 40 kHz baseband spans first 80% of span) Overall accuracy is the sum of absolute accuracy, window flatness and noise level data at a given frequency.	± 0.5 dB ± 0.025% of input range

Dynamic Range:
(16 rms averages, 50 Hz to 20 kHz baseband spans, internal sampling)

Alias Responses: (single out-of-band tone, ≤ 0 dBfs)	
0 to 70% of span	<–60 dBfs
Spurious or Residual Responses: (in-band, ≤ 0 dBfs input Rds = 50Ω, Backlight Off)	<–70 dBfs
Harmonic Distortion: (single in-band tone ≤ 0 dBfs)	
50 Hz – 10 kHz span	<–60 dBfs
20 kHz – 40 kHz span	<–50 dBfs
Noise Level: (PSD process, Flat Top window 5 mV range, Rds = 50Ω at 1 Hz on the 200 Hz Span)	<–100 dBV/√Hz
Residual DC Response Rds = 50 Ω	
5 mV to 20 mV Range	<–20dBfs
50 mV to 5 V Range	<–40dBfs

Channel-to-Channel Amplitude and Phase Match
(Frequency Response mode, 16 rms averages, Ch1 range = Ch2 range, 50 Hz to 20 kHz baseband spans)

0 to 50% of span	± 0.1 dB, ± 1.0° typical
0 to 80% of span	± 0.2 dB, ± 5.0°
Channel-to-Channel Crosstalk (Receive channel Rds = 50Ω)	<–85 dB (typical)

Input Characteristics

Number of data inputs	2 Channels
Input Impedance (high to low)	1 MΩ typical
Coupling	ICP Power, dc, ac
AC Coupling Attenuation	<3 dB @ 0.5 Hz typical
ICP Supply Current:	4 mA/20 V typical
Scaling	Engineering Units with these labels: g, in/s, m/s, in, m, lbf, kgf, SPL, psi, EU
Math Functions	Differentiation Integration, single/double

Octave Analysis

The measurement is made in synthesized 1/3 or 1/1 octave bands. Filter bandwidth, center frequency, and bandshape meet ANSI Std. S1.11-1966 (R 1975) type E Class II specifications. Acoustic Weighting (A-weighting) filter is available. The filter shape complies with definitions given in ANSI S1.4-1983 and IEC 651-1979.

Trigger

Trigger Sources:	Internal or External
Trigger Modes:	Freerun – processes data as quickly as possible using the internal clock Input channel – measurements triggered by the selected channel External Trigger – initiates measurement by a TTL pulse on the external trigger connector
Trigger Controls:	Single – Arms the instrument to capture and display only one data record upon trigger. Re-trigger – Gathers and displays a data record each time a valid trigger is received. Slope – Positive/negative Trigger Level – Variable, steps of 1% of range Pre-trigger delay – 0 to 4096 points Post-trigger delay – 0 to 4096 points

Sample Clock

Source:	Internal or External

External Sample:	The external clock connector allows synchronization of the sample clock to an external source (up to 100 kHz) with TTL levels such as the output of a shaft encoder. Minimum logic low time: 250 ns Minimum logic high time: 9.75μs

Measurement Averaging

RMS:	For each calculated frequency point, the displayed amplitude is averaged in a root-mean-square fashion. After a user-defined number of averages, the average process is completed and a final result is displayed.
RMS Exponential:	This type of averaging yields a weighted average with each record being weighted according to the time at which it was acquired. Exponential averaging continues indefinitely.
Peak Hold:	Holds the highest amplitude value of each frequency component of a spectrum compared to the previous spectrum.
Time Averaging:	Data is averaged as it is acquired by the instrument before processing. This type of averaging improves the signal-to-noise ratio for triggered measurements. Time averaging is used to uncover deterministic signals from the noisy background data.
Number of Averages:	1 to 4096
Average Controls:	Start, Pause/Continue, Fast Average, Time Record Preview

Data Formats, Displays and Markers

Data:	Time, CH1 – CH2 (time), Differentiated Time, Orbits (x vs. y), Spectrum, Frequency Response, Coherence, Cross-Correlation, Octave, 1/3 Octave, PSD
Formats:	Single, front/back, upper/lower, map with hidden line removal and baseline suppression of up to 99 traces.
Y-Coordinates:	Linear Mag, dB Mag, Log Mag (logarithimic data with linear readouts), Phase, Real, Imaginary
Units:	Volts, dBV, and EU (Engineering Units) with selectable labels; g, in/s, m/s, in, m, lbf, kgf, SPL, psi, EU
Scaling:	X-Axis – linear or log Y-Axis – auto or manual
Display Type:	LCD with fill, contrast, backlight and auto-shutdown 320 × 240 Pixels
Marker Functions:	Marker trace A, B, or both, marker to peak, harmonic markers (20 max), scroll display left or right, expanded x-axis display

Data Storage, Data Recall, Interface to PCs, Prints/Plots

Data is stored with a time-data stamp, data record number, and the type of data that was taken. The HP 3560A comes with 768 kBytes non-volatile RAM, enough storage for 500 state/trace combinations with 200 line spectra.
Traces may be selectively viewed on the analyzer or transferred via the RS-232 Interface to attached printers or to a personal computer.

Data Output Commands:

Transfer All	sends all records over RS-232
Transfer One	sends the selected record over RS-232
Print	prints/plots output over RS-232 to supported printers and plotters

Data Transfer

Every HP 3560A comes with a PC program to make your data transfer simple. The program formats the data into a PC file format called standard data format (sdf), which is supported by many HP products. Once data is in the sdf format, it may be converted for use in the HP 3566A, HP 3567A PC Spectrum/Network Analyzers, HP 35665A, or in other third-party software packages such as PC Matlab from The Mathwords and MATRIX$_X$ from Integrated Systems.

Interface type:	9-pin RS-232 conforming to EIA/TIA-562 and EIA/TIA-574
Baud Rates:	38400 / 19200 / 9200 / 4800 / 2400 / 1200
Parity (odd/even)	Data bits (7 / 8)
Supported Printers:	HP DeskJet, HP LaserJet, HP QuietJet, HP ThinkJet, Epson(R) Graphic with RS-232 interface
Supported Plotters:	HP-GL Plotters (such as HP 7550A) with RS-232 interface

General

Temperature	
Operating	+0° to 40°C
Battery Charging	+20° to 40°C
Storage	–20° to 50°C
Humidity (non-condensing)	5 to 95%
Altitude	
Operating	4600 m (15,000 ft)
Storage	<15000 m (50,000 ft)

Power

Type:	NiCd rechargeable battery (internal, removable), Battery Recharger/AC adapter included
Running time on full charge (Backlight off, typical use with auto shut-down capability on)	6 hours (typical)
Battery recharge	14 hours (typical)
Memory Backup	Lithium battery - 5 year backup (Option to delete lithium battery and use internal rechargeable NiCd for backup is available)

Physical

Size	11.75" × 8.25" × 3.75" 300 × 210 × 95mm
Weight (analyzer only)	3.2 kHz (7 lbs.)
Shipping Wt.	6.4 kg (14 lbs.)

Abbreviations:
dBV = dB relative to 1 volt rms.
dBfs = dB relative to full scale.
Rds = Source resistance or termination connected to the HP 3560A input
typical = typical, non-warranted performance specification included to provide general product information.

3

Operation Verification and Performance Tests

Introduction

This section contains the operation verification tests and the performance tests. Successfully completing the operation verification tests and the performance tests give you a high confidence level (>90%) that the HP 3560A Dynamic Signal Analyzer is operating properly and within specifications.

The performance tests provide the highest level of confidence and are used to verify that the HP 3560A Dynamic Signal Analyzer conforms to its published specifications. Some repairs require a performance test to be done after the repair (see the Service Section of this manual for this information).

Safety Considerations

Although the HP 3560A is designed in accordance with international safety standards, this manual contains information, cautions, and warnings that must be followed to ensure safe operation and to keep the unit in safe condition. The operation verification and performance test procedures must be performed by trained service personnel who are aware of the hazards involved (such as fire and electrical shock).

Test Duration

Operation verification requires approximately 15 minutes to complete. The performance tests require approximately 3 hours to complete.

Calibration Cycle

To verify the HP 3560A is meeting its published specifications, do the performance tests every 12 months.

Equipment Required

The equipment needed for the operation verification performance tests is listed in table 1-2. You can substitute other equipment for the recommended model if it meets or exceeds the listed critical specifications. If you make substitutions, you may have to modify the procedures to accommodate the different operating characteristics of the substitute. The equipment required for each test is also listed at the beginning of the test.

Measurement Uncertainty

The Performance Test Record contains a table listing the measurement uncertainty and ratio for each performance test using the recommended test equipment. The ratios listed for the recommended test equipment meet or exceed the measurement uncertainty ratio required by U.S. MIL-STD-45662A. The table also provides a place to record the measurement uncertainty and ratio for each performance test using equipment other than the recommended test equipment. The table may be reproduced without written permission of Hewlett-Packard.

Performance Test List

The following table lists the performance tests. The tests must be completed in the order in which they appear in the table. No warm up time is required. If any of the tests fail, the HP 3560A must either be adjusted or repaired. See the Service section for more information on adjustments and troubleshooting to the assembly level.

Table 3-1. Performance Test List

Performance Tests
#1. Turn on and Self Test
#2. Residual DC Response Test
#3. Noise and Spurious Signals Test
#4. Harmonic Distortion Test
#5. Amplitude Accuracy Test
#6. Amplitude and Phase Match
#7. Anti-Alias Filter Test
#8. Frequency Accuracy Test

Specifications and Performance Tests

The following table lists specifications and the performance test or tests that verify each specification.

Table 3-2. Specification and Performance Tests

Specification	Performance Test
Residual DC Response	#2. Residual DC Response Test
Dynamic Range Noise	#3. Noise and Spurious Signals Test
Spurious and Residual Responses	#3. Noise and Spurious Signals Test
Harmonic Distortion	#4. Harmonic Distortion Test
Absolute Amplitude Accuracy	#5. Amplitude Accuracy Test
Channel-to-Channel Amplitude Match	#6. Amplitude and Phase Match
Channel-to Channel Phase Match	#6. Amplitude and Phase Match
Alias Responses	#7. Anti-Alias Filter Test
Frequency Accuracy	#8. Frequency Accuracy Test

How To Do an Operation Verification or Performance Test

The operation verification test is simply a self test that is performed when you turn on the HP 3560A. You do not need external equipment or cabling to perform the operation verification. The performance tests check the specified performance of the analyzer in more detail. To minimize the time required to change instrument configurations between performance tests, do the tests in the order given. Record the results of each test in the "Performance Test Record." These test records may be reproduced without written permission of Hewlett-Packard.

If the operation verification test or a performance test fails, contact your local Hewlett-Packard sales and service office or have a qualified service technician see the "Service" section of the *HP 3560A Operating & Service Guide.*

Nomenclature for Hardkeys, Shift Functions, and Menu Items

To follow the tests, it is important to understand the difference between hardkeys, shift functions, and menu items.

Hardkeys are front-panel buttons whose functions are always the same. They either bring up a menu on the display or directly execute a function. Most hardkeys have a label printed directly on the key itself. Throughout this book, hardkeys are printed like this:

[**Hardkey**]

To perform the functions with blue labels, press the blue [**Shift**] hardkey followed by the hardkey below the label. These functions labeled in blue are called a *shift functions*. Shift functions are printed like hardkeys except all of the letters are capitalized like this:

[**SHIFT FUNCTION**]

Menu items are selections that appear on the instrument display when you press a hardkey. Select a menu item by moving the cursor to the column and row you want. Move the cursors with the [⇐], [⇒], [⇑], and [⇓] keys located directly adjacent to the display. Throughout this book, menu items are printed like this:

[MENU ITEMS].

Some menu items cycle through different settings. These menu items change settings each time you press the [**Enter**] key. Throughout this book, the selections are depicted as they *appear after you make the keypress*. For example, "toggle to [TIMEOUT] [ON]" means to press the [**Enter**] key until the word ON appears.

The column and row cursors allow you to pick menu items. The column cursor is a box type cursor. The row cursor is an inverse video cursor. Use the [⇐] and [⇒] keys to move to the column cursor to the menu item you want. Then use the [⇓] and [⇑] keys to move the row cursor to the item. When you have selected everything you want in the menu, press [**Start**] to activate the settings and start data acquisition, or select another hardkey to activate the settings and view another menu.

Some menu items allow you to enter values using the numeric keypad. In some cases the entry must be an integer as in the selection for the number of [TIME] averages. Other parameters like [VOLTS/EU] require you to enter a value in scientific notation. And other parameters like [CENTER] frequency let you enter decimal values but truncate the entry to the allowable field length. Once you have entered a number, pressing [**Enter**] terminates the entry. When you have selected everything you want in a menu, press another hardkey to look at different menus or press [**Start**] to return to the data display.

Operation Verification Test Procedure

A self test runs every time you turn on the analyzer. However, the following procedure runs a more extensive self test and displays the results. The procedure also gives some things to try if the analyzer display remains blank and it verifies that the backlight is working properly.

1.Turn instrument off. Hold down the [**7**] key while pressing [**On**]. Keep holding down the [**7**] key for 5 seconds after releasing [**On**].

   The analyzer will take approximately 20 seconds to perform the self test. If no error messages appear, the display should show the self test results as in figure 3-1. When the self tests are complete, a "Press ENTER to Continue" message appears.

   Press [**Enter**]. If there are no problems, skip to step 2.

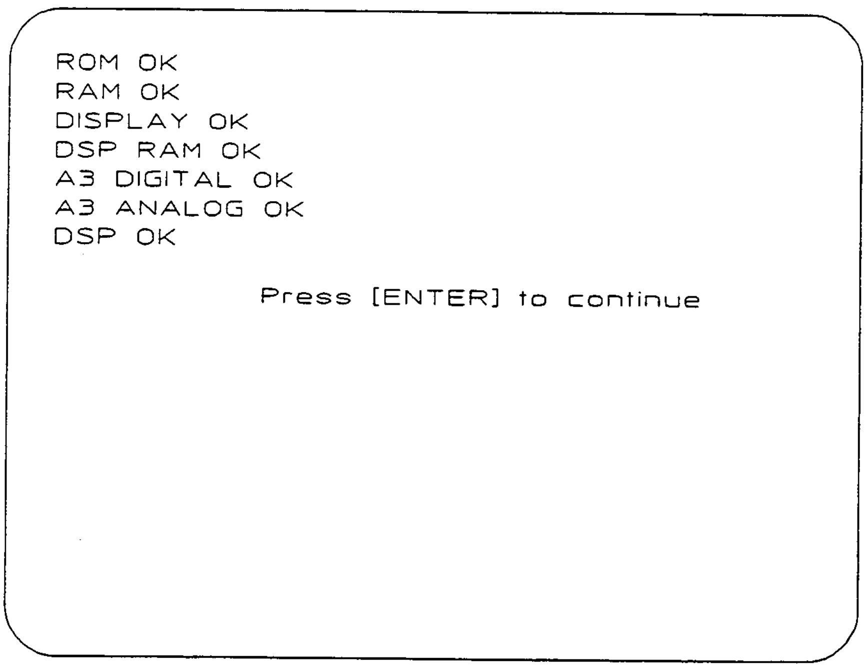

Figure 3-1
Self Tests Display

If there is a problem with the memory, a message such as "FAIL ROM TEST (A2)" will appear. Refer to the Service section of this manual for instructions on troubleshooting.

If the display is blank after running the self tests, adjust the display contrast by pressing the following keys.

[**Preset**]
[**Enter**]
[**Utility**]
[⇒] (press twice)
[⇓] (press twice)
This selects [CONTR:].

Repeatedly press [**Enter**] (up to seven times) to change the contrast adjustment.

If the display remains blank, connect the ac adapter and turn on the analyzer. The green LED should light when the ac adapter is connected. If the display responds, the battery needs recharged. Refer to the "Installation" chapter for instructions on battery recharging.

If there is still no display, try turning the analyzer off by pressing [**Shift**] and then [**OFF**]. Then press [**On**] while simultaneously holding down the [**Preset**] key.

2.Connect a 10 kHz, 1 Vrms (0dBV) signal to the channel 1 input.
Press [**Preset**]
[**Enter**].
The display should look like figure 3-2.

3.Move the 10 kHz signal to the channel 2 input.
Press [**Format**]
and in the [FORMAT] column, move the row cursor to [B ONLY].
Press [**Start**].
The display should look like figure 3-2.

4.Check the backlight operation by pressing the following keys.

[**Shift**]
[¤]

Turn it off by pressing the same keys again.

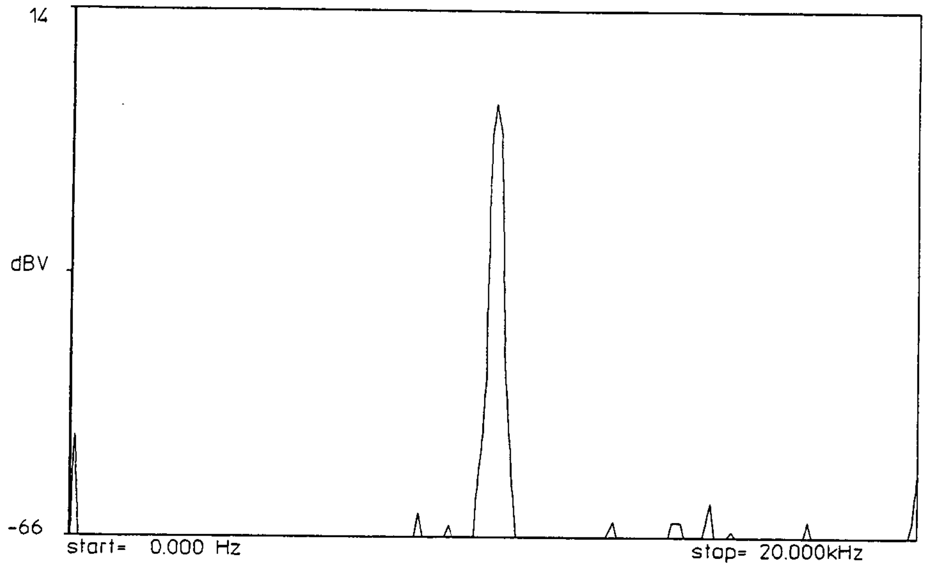

Figure 3-2.
Display with 10 kHz input signal.

Performance Tests

#1. Turn On and Self Test

Note

This test is a subset of the Operation Verification Test. If you already performed the Operation Verification Test, skip to Performance Test #2.

A power-up test runs every time you turn on the analyzer. However, the following procedure runs a more extensive self-test and displays the results. The procedure also gives some things to try if the analyzer display remains blank and it verifies that the backlight is working properly.

1. Hold down the [**7**] key while pressing [**On**]. Keep holding down the [**7**] key for 5 seconds after releasing [**On**].

   The analyzer will take approximately 20 seconds to perform the self test. If no error messages appear, the display should show the self test results as in figure 3-3.

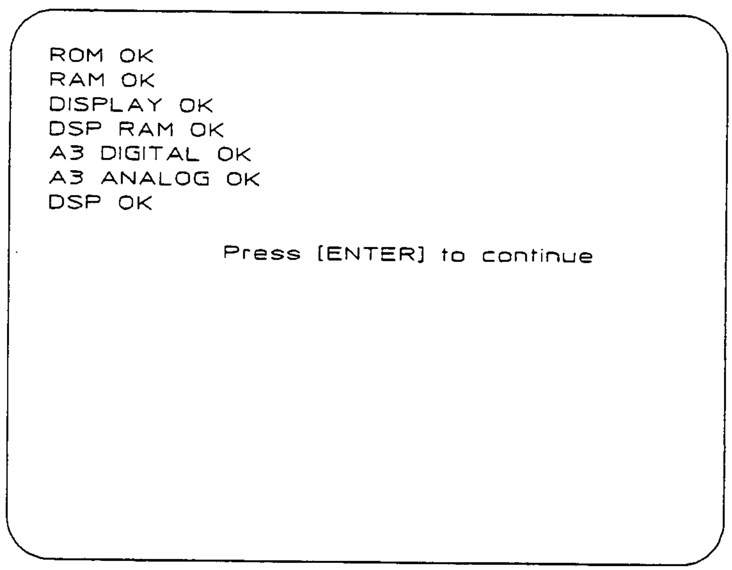

Figure 3-3.
Self Tests Display

If there is a problem with the memory, a message such as "FAIL ROM TEST (A2)" will appear. Refer to the Service section of this manual for instructions on troubleshooting.

When the self tests have completed, a "Press ENTER to Continue" message will appear. Press [**Enter**].

2.If the analyzer display remains blank, adjust the display contrast by pressing the following keys.

[**Preset**]
[**Enter**]
[**Utility**]
[⇒] (press twice)
[⇓] (press twice)

This selects [CONTR:].

Repeatedly press [**Enter**] (up to seven times) to change the contrast adjustment.

If there is no display, connect the ac adapter and turn on the analyzer. The green AC Adapter LED on the connector panel should light when the ac adapter is connected. If the display responds, the problem was the battery charge. Refer to the "Installation" chapter for instructions on battery recharging.

If there is still no display, try turning the analyzer off by pressing [**Shift**] and then [**OFF**]. Then press [**On**] while simultaneously holding down the [**Preset**] key.

#2. Residual DC Response Test

This test measures the level of residual dc offset generated within the HP 3560A. It verifies the Residual DC Response specification. If the test fails, suspect the A3 Analog assembly and refer to the Adjustments section of this manual for the A3 assembly.

Equipment Required

Equipment	Quantity
50Ω Feedthrough/Termination	2

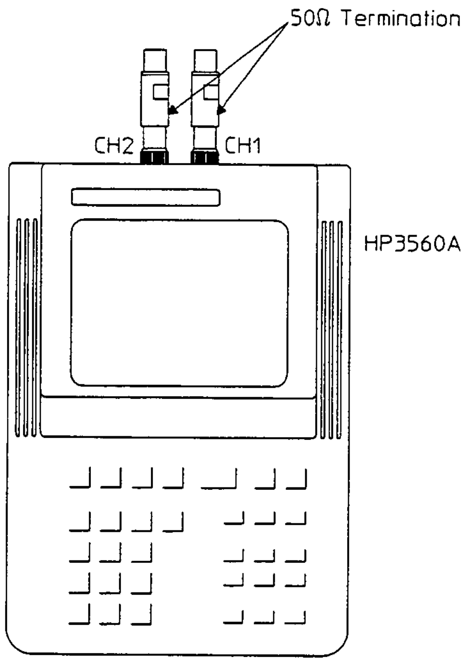

Figure 3-4.
Test Setup

Specification: <–20 dBfs (5 mV to 20 mV input ranges)
<–40 dBfs (50 mV to 5 V input ranges)

Procedure

1. Connect the 50Ω terminations to the CH 1 and CH 2 inputs.

2. Press the following keys:

[**Preset**]
[**Enter**]
[**Format**]
Set [FORMAT] to [A ABOVE B]
[**Avg**]
Set [TYPE] to [RMS]
Set [NUMBER:] to [5]
Set [FAST AVG] to [ON]

3. Repeat the next two steps for each of the settings listed below.

Table 3-3. Test Limits

[Input]		Test Limit
[RANGE1] & [RANGE2]	[COUPL1] & [COUPL2]	
5 mV	AC	< –69 dBV
5 mV	DC	< –69 dBV
50 mV	DC	< –69 dBV
5 V	DC	< –29 dBV

4. Press the following keys.

[**Input**]
Set [RANGE1] to appropriate value given by table 3-3.
Set [COUPL1] to appropriate value given by table 3-3.
Set [RANGE2] to appropriate value given by table 3-3.
Set [COUPL2] to appropriate value given by table 3-3.

5. Press [**Start**].

When the measurement is complete move the marker to 0 Hz and record the amplitude for each channel.
Compare the marker values with the test limits shown in table 3-3.

#3. Noise and Spurious Signals Test

This test measures the level of noise and spurious signals generated within the HP 3560A. It verifies the Spurious or Residual Response and the Noise specifications. If the test fails, suspect the A3 Analog assembly and refer to the *HP 3560A Operating and Service Guide* Troubleshooting section for the A3 assembly.

Equipment Required

Equipment	Quantity
50Ω Feedthrough/Termination	2

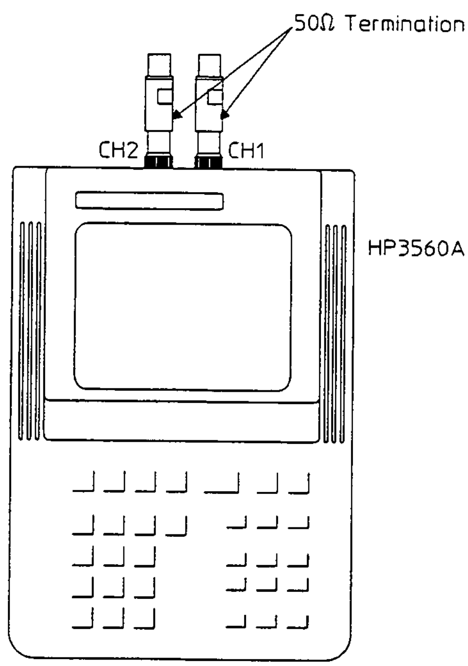

Figure 3-5.
Test Setup

Procedure

1. Connect the 50Ω terminations to the CH 1 and CH 2 inputs.
2. Press the following keys:

   [**Preset**]
   [**Enter**]
   [**Format**]
   Set [FORMAT] to [A ABOVE B]
   [**Freq**]
   Set [RESOLUTN] to [800 LINES]
   [**Avg**]
   Set [TYPE:] to [RMS]
   Set [NUMBER:] to [16]
   Set [FAST AVG] to [ON]
   [**Input**]
   Set [RANGE1] to [5 mV]
   Set [RANGE2] to [5 mV]

3. Press [**Start**].

   When the measurement is complete, move the marker to the largest spurious response between 400 Hz and 20 kHz. Record the amplitude and frequency.
   Press [**Enter**] to move the marker to channel 2, move the marker to the largest spurious response between 400 Hz and 20 kHz and record its amplitude and frequency.

Table 3-4. Spurious Signals Test Limits

Range	Test Limit
−49 dB to −70 dB	<−119 dBV

4. Set up for measuring noise at 1 Hz by pressing the following keys.

   [**Data**]
   Set [TRACE–A] to [PSD CH1]
   Set [TRACE–B] to [PSD CH2]
   [**Freq**]
   Set [BASEBAND] to [200 Hz]

5. Press [**Start**].

   When the measurement is complete move the marker to 1.0 Hz. Record the amplitude for each channel.
   Noise Test Limit: <−100 dBV/$\sqrt{Hz}$

#4. Harmonic Distortion Test

This test measures the harmonic distortion generated in the HP 3560A. It verifies the Harmonic Distortion specification using a low-distortion oscillator or a frequency synthesizer. To minimize the amount of frequency tuning you need to do on the HP 3560A, the frequencies you select for the oscillator or the synthesizer generate a harmonic at 36 kHz. If the test fails, suspect the A3 Analog assembly and refer to the Troubleshooting section of this manual.

Equipment Required

Equipment	Quantity
Low Distortion Oscillator	1
BNC Cables	2
BNC tee	1
Feedthrough termination (50Ω for HP 3326A or 600Ω for HP 339A)	1

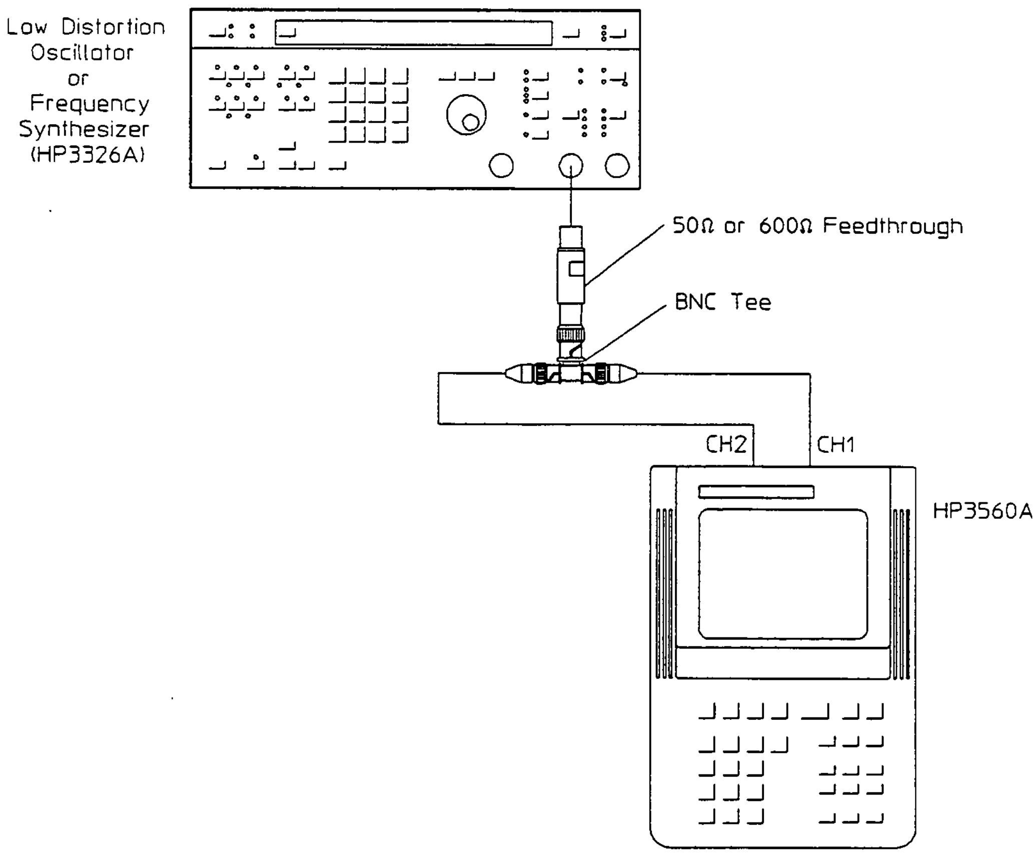

Figure 3-6.
Test Setup

Procedure

1. Connect the Low Distortion Oscillator output to both channel 1 and channel 2 inputs as shown in figure 3-6.

2. Press the following keys:

   [**Preset**]
   [**Enter**]
   [**Format**]
      Set [FORMAT] to [A ABOVE B]
   [**Freq**]
      Set [BASEBAND] to [40 kHz]
      Set [RESOLUTN] to [400 LINES]
   [**Avg**]
      Set [NUMBER:] to [5]
      Set [TYPE:] to [RMS]
      Set [FAST AVG] to [ON]

3. Repeat steps 4 through 6 for each of the following settings.

Table 3-5. Harmonic Distortion Test Limits (40 kHz Baseband)

[Input] [RANGE]	Oscillator Frequency	Oscillator Amplitude	Harmonic Number	Test Limit
5 V	18 kHz	3.0 Vrms	2nd	<–39 dBV
5 V	12 kHz	3.0 Vrms	3rd	<–39 dBV
5 mV	18 kHz	3.0 mVrms	2nd	<–99 dBV
5 mV	12 kHz	3.0 mVrms	3rd	<–99 dBV

4. Press the following keys:

   [**Input**]
      Set [RANGE1] to value given in table 3-5.
      Set [RANGE2] to value given in table 3-5.

5. Set the oscillator as follows:

   Frequency: See table 3-5.
   Amplitude: See table 3-5.

6. Press [**Start**].

   When the measurement is complete, move the marker to 36.0 kHz and record the amplitude for each channel. Compare each value to the test limits shown in table 3-5.

7. Press the following keys:

   [**Freq**]
   Set [BASEBAND] to [10 kHz].

8.Repeat steps 9 through 11 for each of the following settings.

Table 3-6. Harmonic Distortion Test Limits (10 kHz baseband)

[Input] [RANGE]	Oscillator Frequency	Oscillator Amplitude	Harmonic Number	Test Limit
5 mV	4.8 kHz	3.0 mV_{rms}	2nd	<–110 dBV
5 mV	3.2 kHz	3.0 mV_{rms}	3rd	<–110 dBV

9.Press the following keys:

[**Input**]

Set [RANGE1] to the value given in table 3-6.
Set [RANGE2] to the value given in table 3-6.

10.Set the oscillator as follows.

Frequency: see table 3-6.
Amplitude: see table 3-6.

11.Press [**Start**].

When the measurement is complete, move the marker to 9.6 kHz and record the amplitude for each channel. Compare each value to the test limits shown in table 3-6.

#5. Amplitude Accuracy Test

This test measures the amplitude accuracy and flatness of the HP 3560A. Using an ac calibrator, you will measure a signal with an exact amplitude on both input channels. This test verifies the Amplitude Accuracy specification. If the test fails, suspect the A3 Analog assembly and refer to the Adjustments section of this manual.

Equipment Required

Equipment	Quantity
AC Calibrator	1
BNC Cables	2
BNC Tee	1
BNC(f) to Dual Banana Adapter	1

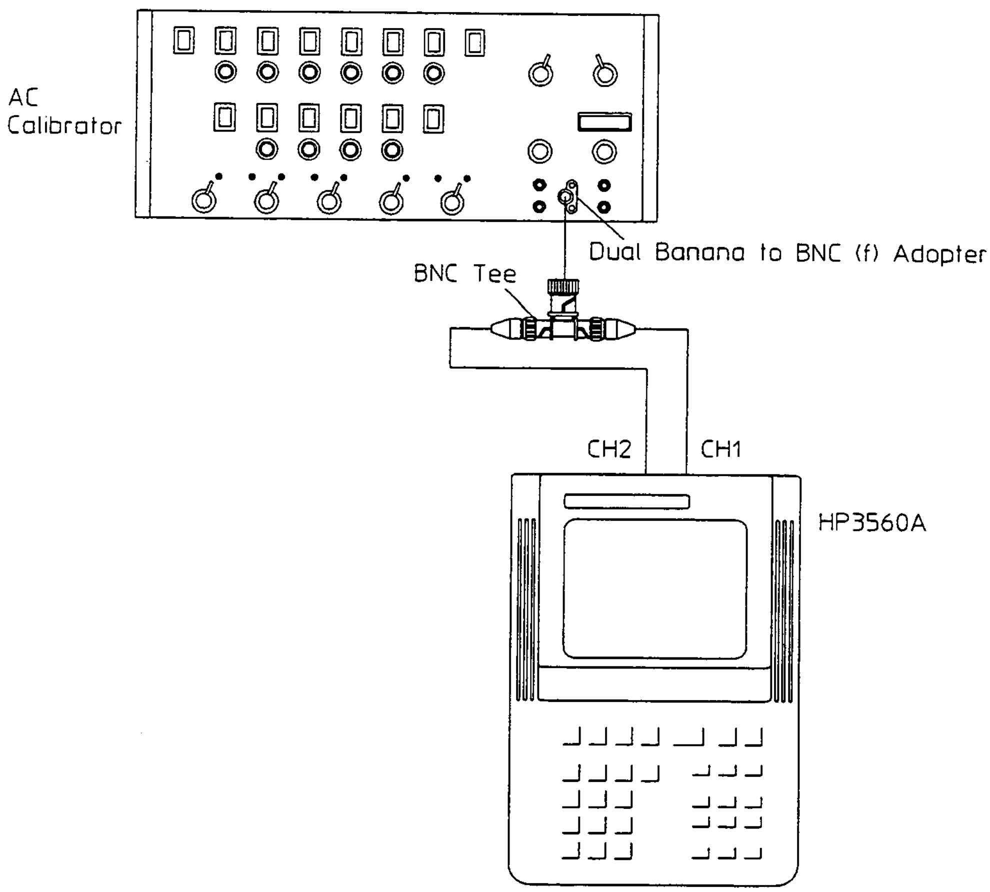

Figure 3-7.
Test Setup

Procedure

1.Connect the ac calibrator to both channel 1 and channel 2 as shown in figure 3-7.

2.Press the following keys:

[**Preset**]
[**Enter**]
[**Format**]
Set [FORMAT] to [A ABOVE B]

3.Repeat the next three steps for each of the settings listed below.

Table 3-7. Amplitude Accuracy Test Limits

[Input] [RANGE]	[Freq] [BASEBAND]	Calibrator Frequency	Calibrator Amplitude	Lower Limit	Upper Limit
2 V	20 kHz	16 kHz	1.0 Vrms	–0.5 dBV	+0.5 dBV
5 V	2 kHz	1000 Hz	3.1623 Vrms	+9.5 dBV	+10.5 dBV
2 V	20 kHz	1000 Hz	1.0 mVrms	–64.57 dBV	-57.00 dBV
5 mV	50 Hz	40 Hz	1.0 mVrms	–60.5 dBV	-59.5 dBV

4.Set the ac calibrator as follows:

Frequency: See table 3-7.
Amplitude: See table 3-7.

5.Press the following keys:

[**Freq**]
Set [BASEBAND] to the value given in table 3-7.
[**Input**]
Set [RANGE1] to the value given in table 3-7.
Set [RANGE2] to the value given in table 3-7.

6.Press [**Start**].

When the measurement is complete, move the marker to the test frequency and record the amplitude for each channel. See table 3-7 for the test limits.

7.The next three steps check the amplitude accuracy of the HP 3560A when it makes a zoomed measurement. Set the ac calibrator as follows:
Frequency: 19600 Hz
Amplitude: 1.0 Vrms

8.Press the following keys:

[**Freq**]

Set [ZOOM] to [ON]
Set [CENTER] to [20000]
Set [SPAN] to [1000]

[**Input**]

Set [RANGE1] to [2 V]
Set [RANGE2] to [2 V]

9.Press [**Start**]

When the measurement is complete, move the marker to the test frequency and record the amplitude for each channel.

Test Limits: –1.0 to +1.0 dBV

#6. Amplitude and Phase Match Test

This test measures the amplitude and phase match between channels 1 and 2. It verifies the Channel-to-Channel Amplitude and Phase Match specifications. If the test fails, suspect the A3 Analog assembly and refer to the Adjustments section in this manual.

You will apply a swept sine wave to both channels and make a frequency response measurement. This test also verifies that the external trigger input is operating.

Equipment Required

Equipment	Quantity
Synthesizer	1
BNC Cables	3
BNC tee	1
50Ω Feedthrough/Termination	1

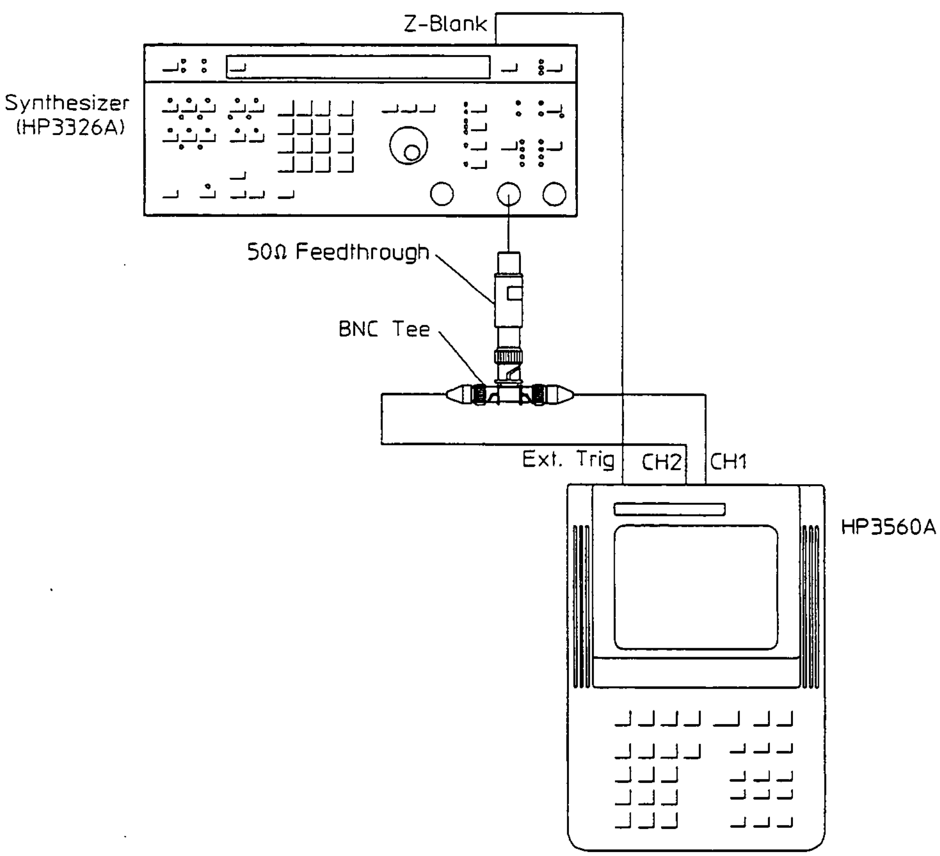

Figure 3-8.
Test Setup

Procedure

1. Connect the synthesizer output to both channel 1 and channel 2 inputs as shown in figure 3-8. Connect the synthesizer Z-BLANK output to the External Trigger input of the HP 3560A using a BNC cable.

2. Set up the synthesizer to output a continuously swept sine wave as follows:

   Amplitude: 1.0 Vrms
   Start Frequency: 0 Hz
   Stop Frequency: 25 kHz
   Sweep Time: 0.04 sec
   Continuous

3. Press the following keys on the HP 3560A:

   [**Preset**]
   [**Enter**]
   [**Data**]
      Set [TRACE–A] to [FREQ RESP]
      Set [TRACE–B] to [FREQ RESP]
      Set [Y–AXIS: A] to [dB MAG]
      Set [Y–AXIS: B] to [PHASE]
   [**Format**]
      Set [FORMAT] to [A ABOVE B]
   [**Freq**]
      Set [BASEBAND] to [20 kHz]
      Set [RESOLUTN] to [800 LINES]
      Set [WINDOW] to [UNIFORM]
   [**Input**]
      Set [RANGE1] to [2 V]
      Set [RANGE2] to [2 V]
   [**Trigger**]
      Set [SOURCE] to [EXTERNAL]
   [**Avg**]
      Set [NUMBER:] to [5]
      Set [TYPE:] to [RMS]
      Set [FAST AVG] to [ON]

4. Press [**Start**]

   When the measurement is complete, move the marker over the frequency ranges listed below and record the largest deviation from 0.0 dB and 0 degrees.

Table 3-8. Test Limits (100 Hz – 20 kHz)

Trace	Frequency Range	Lower Limit	Upper Limit
A	100 Hz to 16 kHz	–0.20 dB	+0.20 dB
B	100 Hz to 16 kHz	–5.0 deg	+5.0 deg

5.Change the synthesizer settings as follows:

Stop Frequency: 2.5 kHz
Sweep Time: 0.4 sec

6.Press the following keys on the HP 3560A:

[Freq]

Set [BASEBAND] to [2 kHz]

7.Press [**Start**]

When the measurement is complete, move the marker over the frequency ranges listed below and record the largest deviation from 0.0 dB and 0 degrees.

Table 3-9. Test Limits (10 Hz – 2 kHz)

Trace	Frequency Range	Lower Limit	Upper Limit
A	10 Hz to 1.6 kHz	–0.20 dB	+0.20 dB
B	10 Hz to 1.6 kHz	–5.0 deg	+5.0 deg

8.Change the synthesizer settings as follows:

Stop Frequency: 250 Hz
Sweep Time: 4 sec

9.Press the following keys on the HP 3560A:

[Freq]

Set [BASEBAND] to [200 Hz]

10.Press [**Start**]

When the measurement is complete (approximately 20 sec), move the marker over the frequency ranges listed below and record the largest deviation from 0.0 dB and 0 degrees.

Table 3-10. Test Limits (10 Hz – 200 Hz)

Trace	Frequency Range	Lower Limit	Upper Limit
A	10 Hz to 160 Hz	–0.20 dB	+0.20 dB
B	10 Hz to 160 Hz	–5.0 deg	+5.0 deg

#7. Anti-Alias Filter Test

This test measures the ability of the anti-alias filters to reject frequencies which may cause aliasing. Using a frequency synthesizer, a signal known to cause an alias frequency is input to the HP 3560A. A spectrum measurement is done to determine how well the alias frequency is rejected.

Equipment Required

Equipment	Quantity
Synthesizer	1
BNC Cables	2
BNC tee	1
50Ω Feedthrough/Termination	1

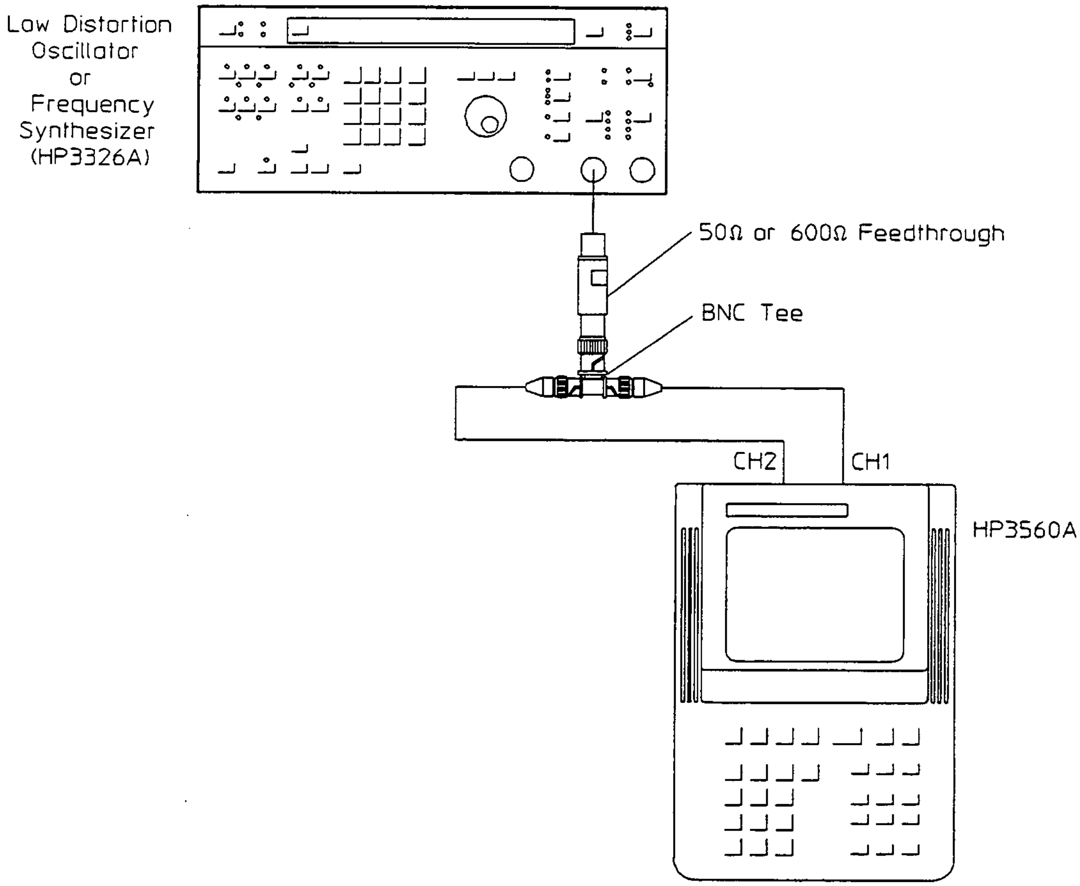

**Figure 3-9.
Test Setup**

Procedure

1.Connect the synthesizer output to both channel 1 and channel 2 inputs using BNC cables, BNC tee, and 50 ohm feedthrough/termination.

2.Set up the synthesizer to output a sine wave as follows:

Amplitude: 3.53 Vrms
Frequency: 18.60 kHz

3.Press the following keys.

[**Preset**]
[**Enter**]
[**Format**]
  [A ABOVE B]
[**Freq**]
  Set [BASEBAND] to [10 kHz]
  Set [RESOLUTN] to [400 LINES]
[**Input**]
  Set [RANGE1] to [5 V]
  Set [RANGE2] to [5 V]
[**Avg**]
  Set [NUMBER] to [5]
  Set [TYPE] to [RMS]
  Set [FAST AVG] to [ON]

4.Press [**Start**].
When the measurement is complete, move the marker to 7.0 kHz and record the amplitude for each channel.

Test Limits: <–49 dBV (11 dBV range – 60 dB)

#8. Frequency Accuracy Test

This test measures the frequency accuracy of the HP 3560A using a frequency synthesizer. It verifies the Frequency Accuracy Specification. If the test fails, suspect the A3 Main Processor assembly and refer to the Troubleshooting section in this manual.

Equipment Required

Equipment	Quantity
Frequency Synthesizer	1
BNC Cable	1
50Ω Feedthrough/termination	1

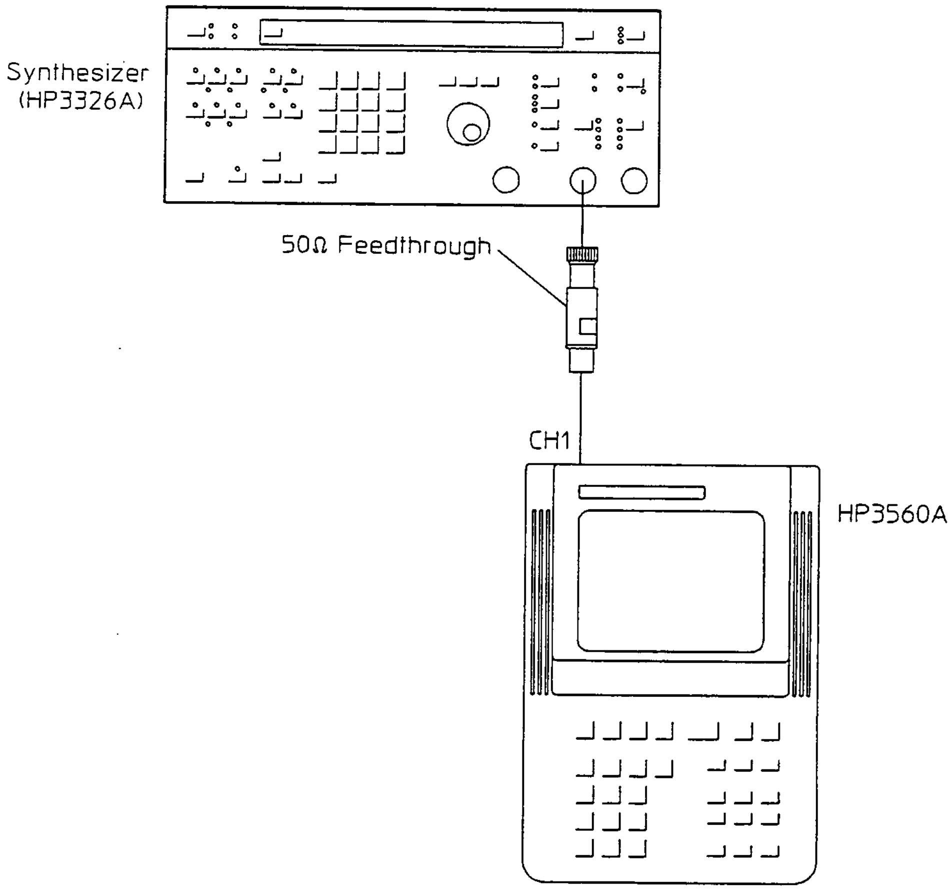

Figure 3-10.
Test Setup

Procedure

1.Connect the synthesizer output to the channel 1 input using the 50 Ω feedthrough as shown in figure 3-10.

2.Set up the synthesizer to output a sine wave as follows:

Amplitude: 1.0 Vrms
Frequency: 10 kHz

3.Press the following keys on the HP 3560A

[**Preset**]
[**Enter**]
[**Freq**]
Set [ZOOM] to [ON]
Set [CENTER] to [10000 Hz]
Set [SPAN] to [500 Hz]
Set [RESOLUTN] to [800 LINES]
Set [WINDOW] to [HANN]
[**Input**]
Set [RANGE1] to [2 V]

4.Press [**Start**]

When the measurement is complete, press
[**Shift**]
[**MKR PEAK**].
Record the marker frequency

Test Limits: 9998.0 Hz to 10002.0 Hz

Performance Test Record

Calibration Entity and Address ____

____

Test Performed By ____

Report Number ____

Customer ____

Test Date ____

Temperature ____

Humidity ____

Test Equipment:

AC Calibrator

Model ______________________________________
Calibration Due Date ____________________________

Frequency Synthesizer

Model ______________________________________
Calibration Due Date ____________________________

Low Distortion Oscillator

Model ______________________________________
Calibration Due Date ____________________________

Measurement Uncertainty

Trace:__________________________Report Number:_______________Test Date:__/__/__

Performance Test	Using Recommended Test Equipment		Using Other Test Equipment	
	Measurement Uncertainty	Ratio	Measurement Uncertainty	Ratio
1.Turn on Self Test	NA[1]	NA[1]	NA[1]	NA[1]
2. Residual DC Response Test	NA[1]	NA[1]	NA[1]	NA[1]
3. Noise and Spurious Signals Tests	NA[1]	NA[1]	NA[1]	NA[1]
4. Harmonic Distortion using HP 3326A using HP 339A	 <–80 dBc <–93 dBc	NA[2]		NA[2]
5. Amplitude Accuracy 2V range 5V range 5mV range	 ± 0.005 dB[3] ± 0.005 dB[3] ± 0.005 dB[3]	 >10:1 >10:1 >10:1		
6. Amplitude and Phase Match Test	NA[1]	NA[1]	NA[1]	NA[1]
7. Anti-Alias Test	± 0.1 dB	NA[1]		NA[1]
8. Frequency Accuracy	± 5 ppm	>10:1		

[1] internal test   [2] open-ended specification   [3] root-sum-squares calculation method

#1. Turn On and Self Test

PASS_____ FAIL_____

#2. Residual dc Response Test

PASS____ FAIL_____

Specification: < –20 dBfs 5 mV to 20 mV input ranges

< –40 dBfs 50 mV to 5V input ranges

[Input]		Measured Value		Test Limit
[RANGE1] & [RANGE2]	[COUPL1] & [COUPL2]	Channel 1 (Trace A)	Channel 2 (Trace B)	
5 mV	AC			< –69 dBV
5 mV	DC			< –69 dBV
50 mV	DC			< –69 dBV
5V	DC			< –29 dBV

#3. Noise and Spurious Signals Test

PASS____FAIL____

Specification	
Spurious Responses: ≤ 0 dBfs input, Rds = 50Ω, Backlight off: <–70 dBfs	**Noise:** PSD process, Flat Top window, 5 mV range, Rds = 50Ω, at 1 Hz on the 200 Hz span: –100 dBV/√Hz

Spurious Test

Marker frequency (between 400 Hz and 20 kHz)		Marker amplitude		Test Limit
Channel 1 (Trace A)	Channel 2 (Trace B)	Channel 1 (Trace A	Channel 2 (Trace B)	
				<–119 dBV

Noise test

Marker amplitude at 1 Hz		Test Limit
Channel 1 (Trace A)	Channel 2 (Trace B)	
		<–100 dBV√Hz

#4. Harmonic Distortion Test

PASS_____ FAIL_____

Specification: Single in-band tone ≤ 0 dBfs:
50 Hz – 10 kHz span: < –60 dBfs
20 kHz – 40 kHz span: < –50 dBfs

[Input] [RANGE]	Harmonic Number	Oscillator Frequency	Oscillator Amplitude	Marker Amplitude		Test Limit
				Channel 1	Channel 2	
5V	2nd	18 kHz	3.0 V_{rms}			<–39 dBV
5V	3rd	12 kHz	3.0 V_{rms}			<–39 dBV
5 mV	2nd	18 kHz	3.0 mV_{rms}			<–99 dBV
5 mV	3rd	12 kHz	3.0 mV_{rms}			<–99 dBV
5 mV	2nd	4.8 kHz	3.0 mV_{rms}			<–109 dBV
5 mV	3rd	3.2 kHz	3.0 mV_{rms}			<–109 dBV

#5. Amplitude Accuracy Test

PASS_____ **FAIL**_____

Specification: 50 Hz to 20 kHz Baseband Spans:

First 80% of span:
± 0.5 dB; ± 0.025% of input range

Baseband Accuracy

[Input] [RANGE]	[Freq] [BASEBAND]	Calibrator Frequency	Calibrator Amplitude	Marker Amplitude (at test frequency)		Lower Limit	Upper Limit
				Channel 1	Channel 2		
2 V	20 kHz	16 kHz	1.0 V_{rms}			–0.5 dBV	+0.5 dBV
5 V	2 kHz	1000 Hz	3.1623 V_{rms}			+9.5 dBV	+10.5 dBV
2 V	20 kHz	1000 Hz	1.0 mV_{rms}			–64.57 dBV	–57.00 dBV
5 mV	50 Hz	40 Hz	1.0 mV_{rms}			–60.5 dBV	–59.5 dBV

Zoom Accuracy

Marker Amplitude (at 19.6 kHz)		Test Limit
Channel 1	Channel 2	
		–1.0 to +1.0 dBV

#6. Amplitude and Phase Match Test

PASS_____ FAIL_____

Specification: Channel-to-channel amplitude match (Frequency response, 16 rms average channel 1 range = channel 2 range 50 Hz to 40 kHz baseband spans):
± 0.2 dB; ± 5.0° (0 to 80% of span)

Test Limits (100 Hz – 20 kHz)

Trace	Frequency Range	Largest Amplitude Deviation		Lower Limit	Upper Limit
		Amplitude	Phase		
A	100 Hz to 16 kHz			–0.20 dB	+0.20 dB
B	100 Hz to 16 kHz			–5.0 deg	+5.0 deg

Test Limits (10 Hz – 2 kHz)

Trace	Frequency Range	Largest Amplitude Deviation		Lower Limit	Upper Limit
		Amplitude	Phase		
A	10 Hz to 1.6 kHz			–0.20 dB	+0.20 dB
B	10 Hz to 1.6 kHz			–5.0 deg	+5.0 deg

Test Limits (10 Hz – 200 Hz)

Trace	Frequency Range	Largest Amplitude Deviation		Lower Limit	Upper Limit
		Amplitude	Phase		
A	10 Hz to 160 Hz			–0.20 dB	+0.20 dB
B	10 Hz to 160 Hz			–5.0 deg	+5.0 deg

#7. Anti-Alias Filter Test

PASS_____ FAIL_____

Specification Single out-of-band tone 0 dBfs 0 – 70% of span: < –60 dBfs

Marker Amplitude (7 kHz) Channel 1: ____________
Channel 2: ____________

Test Limit: <–49 dBV

#8. Frequency Accuracy Test

PASS_____ FAIL_____

Specification ± 0.02%

Marker Frequency	Test Limits	
	Upper	Lower
	10002.0 Hz	9998.0 Hz

Before You Begin

About the Analyzer

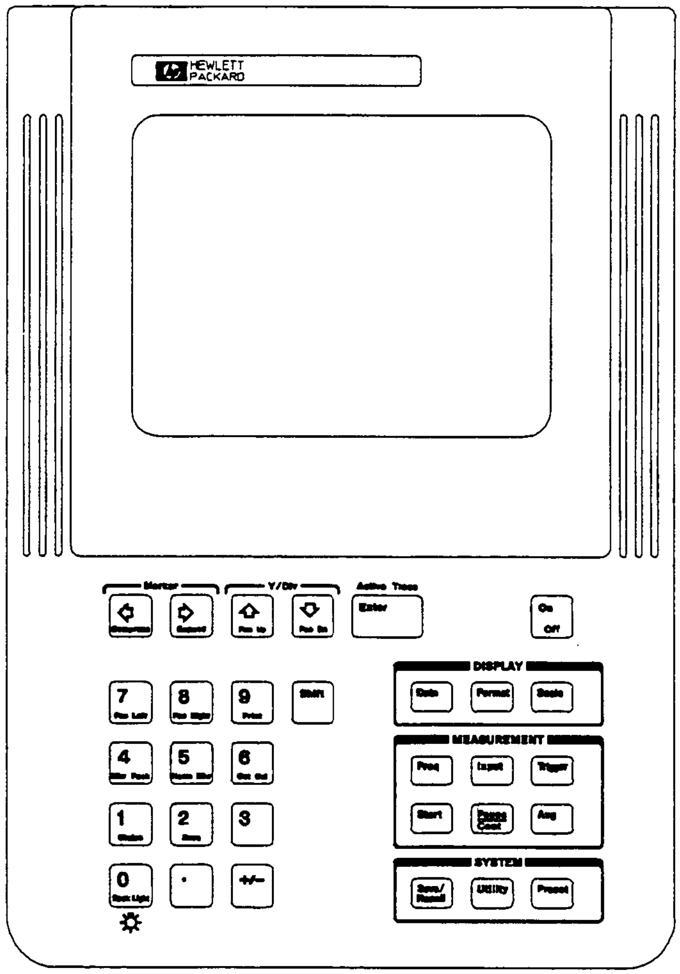

Figure 4-1.

The HP 3560A Portable Dynamic Signal Analyzer is a two-channel FFT based instrument capable of measuring steady state and quickly changing signals in the time and frequency domains. You can make network, two-channel spectrum, or single-channel spectrum measurements from 31.25 mHz to 40 kHz.

How to Use this Section

This section is the most complete source of information about the operation of the HP 3560A Dynamic Signal Analyzer. It contains information not included in the *HP 3560A Getting Started Guide*. Use this section as your single reference for operating information after you are familiar with the analyzer.

In this Operating Reference, you will find:

- A front panel and connector panel description.
- A brief operational overview.
- An alphabetical listing of each HP 3560A hardkey, menu item and connector panel item with a detailed description of each.
- A menu map for quick location of each menu item.

Please note that this Operation section is not a tutorial. To learn more about the analyzer, read the *HP 3560A Getting Started Guide*. Once you are familiar with the analyzer, the Dictionary Reference will probably be your main source of information.

Where to find additional information

To learn about the analyzer, read the *HP 3560A Getting Started Guide*. The "Getting Started Guide" provides an introduction to FFT analyzers and some basics you should know before using the HP 3560A.

For more information on machinery maintenance using vibration analysis, refer to the "Vibration Measurement Basics" section of this manual.

For installation instructions, specifications, operation verification and performance tests, see the Installation section of this manual.

For adjustment procedures, assembly/disassembly, replaceable parts and troubleshooting information, see the Service section in this manual.

For brief definitions of each hardkey, shift function, menu item and connector panel item, use the *HP 3560A Quick Reference Guide* included in this manual. It also gives vibration characteristic tables for reference on site. It is plastic coated and easily fits in the instrument's carrying case.

For detailed information on Standard Data Format (SDF) see the *Standard Data Format Utilities User's Guide* provided with this instrument.

Additionally, you will find application information in numerous Hewlett-Packard Application Notes. These are available from your local HP Sales and Service Office. In particular, you may want to request a copy of the following application notes.

- AN 243—The Fundamentals of Signal Analysis
- AN 243-1—Effective Machinery Maintenance Using Vibration Analysis. The Vibration Measurement Basics section of this manual is a copy of AN 243-1.
- PN 3561A-2—Acoustic Measurements with the HP 3561A

Front-Panel Overview

The analyzer's front panel keys are divided into several groups:

- Power Switch
- Cursor and Marker Control keys
- Display keys
- Measurement keys
- System keys
- Numeric entry keys
- Shift keys

There are also items on the connector panel:

- RS-232 connector
- AC Adapter socket
- Input connectors
- External Trigger connector
- External Sample connector

Front Panel Keys

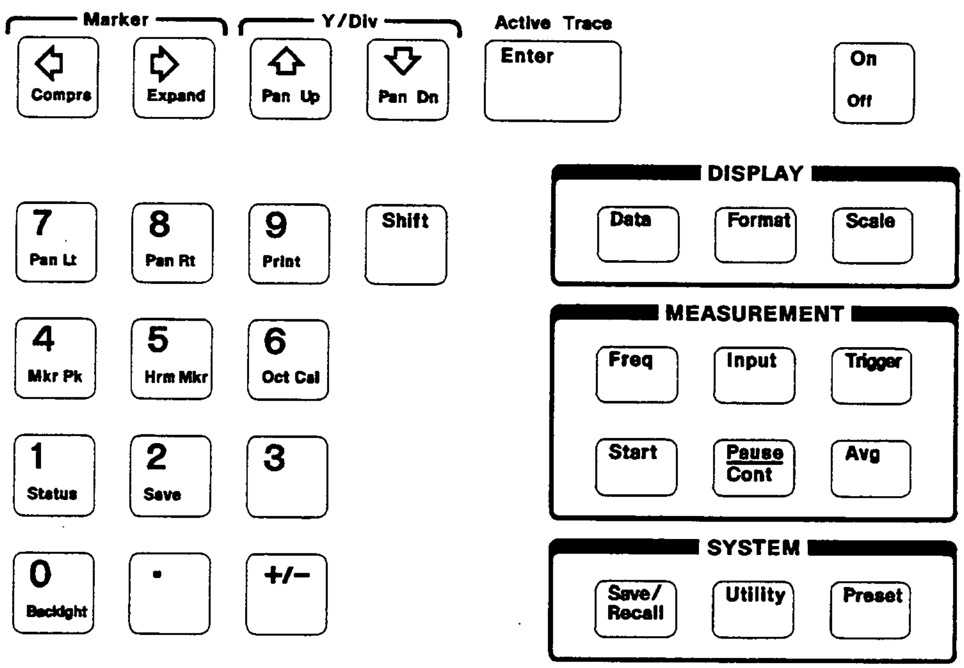

Figure 4-2.

Nomenclature for Hardkeys, Shift Functions, and Menu Items

Before you use this book, it is important to understand the difference between hardkeys, shift functions, and menu items.

Hardkeys are front-panel buttons whose functions are always the same. They either bring up a menu on the display or directly execute a function. Most hardkeys have a label printed in black directly on the key itself. Throughout this book, hardkeys are printed like this:

[**Hardkey**]

Some hardkeys also have blue labels. These are called Shift Functions which execute the function printed in blue when you previously press the blue [**Shift**] hardkey. Do not press [**Shift**] and the key simultaneously. Shift functions are printed like hardkeys except all of the letters are capitalized like this:

[**SHIFT FUNCTION**]

Menu items are selections that appear on the instrument display when you press a hardkey. Select a menu item by moving the cursor to the column and row you want. Move the cursors with the [⇑], [⇓], [⇐], and [⇒] keys located directly adjacent to the display. Throughout this book, menu items are printed like this:

[MENU ITEMS]

Some menu items toggle through different settings. These menu items change settings each time you press the [**Enter**] key. Throughout this book, toggle softkeys are depicted as they *appear after you make the keypress*. For example, "toggle to [TIMEOUT **ON**]" means to press the [**Enter**] key until the word ON appears.

Some menu items allow you to enter values using the numeric keypad. In some cases the entry must be an integer as in the selection for the number of [TIME] averages. Other parameters like [VOLTS/EU] require you to enter a value in scientific notation. And other parameters like [CENTER] frequency let you enter decimal values but truncate the entry to the allowable field length.

For an example of how to enter a value in scientific notation, see [VOLTS/EU] in the Dictionary Reference.

Selecting Menu Items

The column and row cursors allow you to pick menu items. The column cursors are box type cursors. The row cursors are inverse video cursors. Use the [⇒] and [⇐] keys to move the column cursor. Then use the [⇓] and [⇑] keys to move the row cursor. When you have selected everything you want in a menu, press another hardkey to look at a different menu or press [**Start**] to return to the display.

Figure 4-3.

Power Switch

Turn on the analyzer by pressing
[**On**]
and turn it off by pressing
[**Shift**]
[**Off**].

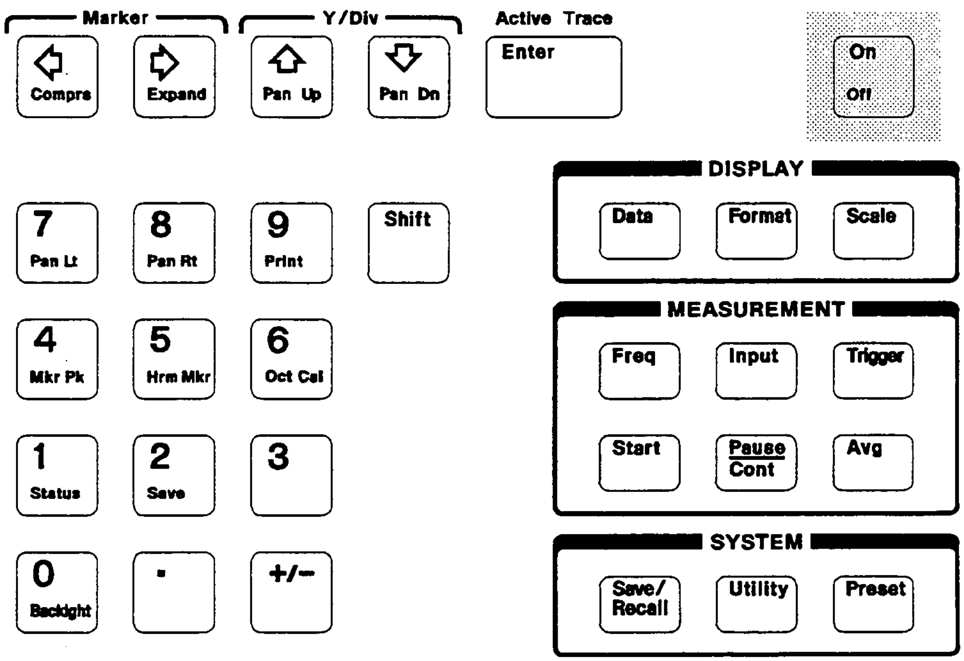

Figure 4-4.

Display Keys

Use these to specify how you want measurement results to be processed and displayed.

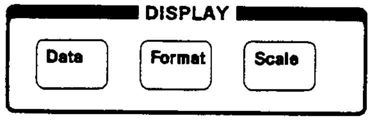

Figure 4-5.

Measurement Keys

Use these to set up and control measurements.

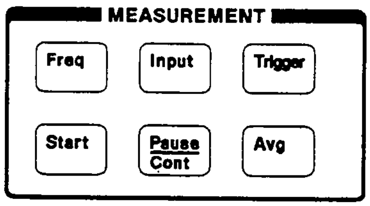

Figure 4-6.

System Keys

Use these for data storage and retrieval, setting RS-232 parameters, transferring data, setting up plotting and printing parameters, setting the instrument to a known (preset) state, setting the time and date, turning the timeout feature on and off, and controlling display features.

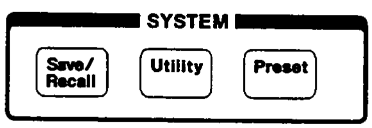

Figure 4-7.

Numeric Entry and Shift Keys

Use these to enter numeric values. Numeric entry keys are also used to select shift functions indicated by the blue lettering on the numeric keys. To select a shift function, press the [**Shift**] hardkey and then press the key you want.

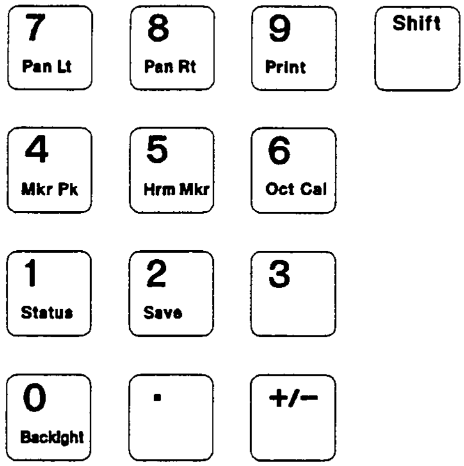

Figure 4-8.

Connector Panel Items

RS-232 Connector

The RS-232 interface is a 9-pin connector which allows direct display transfers to HP QuietJet or LaserJet printers, or RS-232 plotters. The printer or plotter must have an RS-232 connector on it. The pin assignments are shown in figure 4-9.

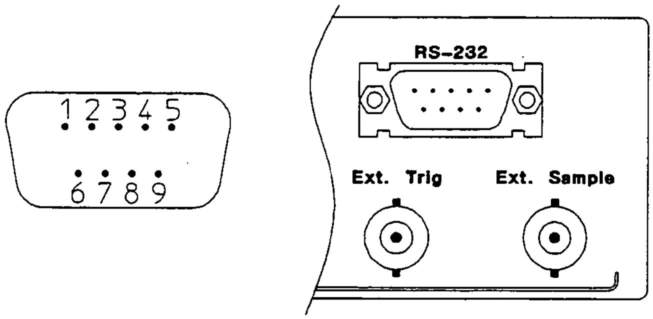

Figure 4-9.

Table 4-1. RS-232 Pin Assignments

Pin 1	DCD	data carrier detect*
Pin 2	RXD	receive data
Pin 3	TXD	transmit data
Pin 4	DTR	data terminal ready
Pin 5	GND	ground
Pin 6	DSR	data set ready
Pin 7	RTS	request to send
Pin 8	CTS	clear to send
Pin 9	RI	ring indicator*

* Not used by the HP 3560A

The HP 3560A RS-232 is a 9-pin interface that conforms to EIA/TIA-562 and EIA/TIA-574 standards. For RS-232 operations, the HP 3560A is configured as Data Terminal Equipment (DTE). When you connect the analyzer via the RS-232 port to another piece of equipment, make sure one is set to receive data and the other is set to transmit data.

You can also transport data to other Hewlett-Packard Dynamic Signal Analyzers like the HP 3566A and HP 3567A by converting HP 3560A data to Standard Data Format (SDF). The SDF conversion utility provided with the instrument makes this conversion simple. For an introduction to using the SDF Utilities, see "Transferring Data to a Personal Computer" in the *HP 3560A Getting Started Guide*.

To learn more about printing, plotting, or transferring data, see the Dictionary Reference section under the [**PRINT**], [**Utility**], and [RS232] headings.

AC Adapter Socket

The HP 3560A is supplied with an ac adapter for charging the internal battery pack. The battery pack stays charged for typically 6 hours of operation. A fully discharged battery takes 14 hours to completely recharge.

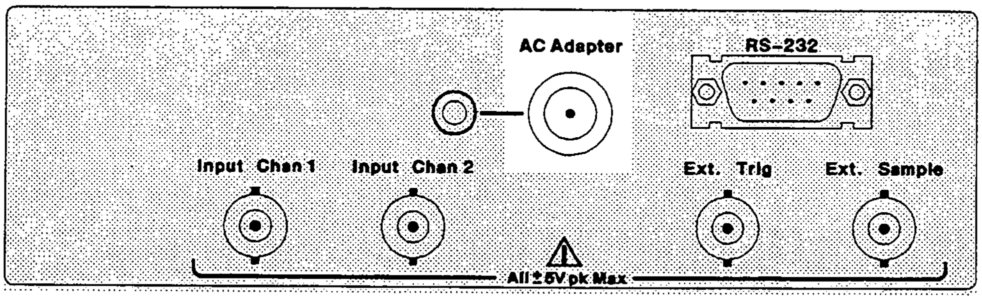

Figure 4-10.

See the Installation section for details on battery recharging. Also see Battery Charging in the Dictionary Reference for more information.

Input Connectors

The analyzer has two input channels. Both have input resistances of 1 MΩ. A 4 mA current source with 24 Vdc open circuit voltage is built-in on each channel for standard accelerometer coupling. The inputs can also be ac or dc coupled.

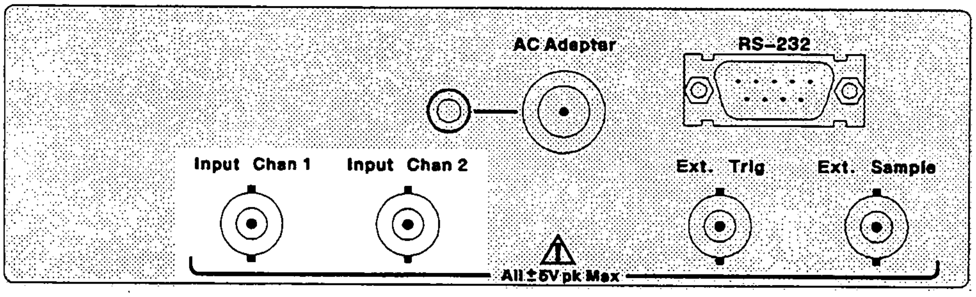

Figure 4-11.

External Trigger connector

Connect an external trigger signal here. If you select external triggering as the trigger source, the trigger signal controls when the analyzer begins a measurement. You can also select whether the measurement begins on the positive slope or negative slope of the triggering signal. The input can use TTL or CMOS logic level or an open-collector drive. For more details on the connector requirements, see External Trigger in the Dictionary Reference section.

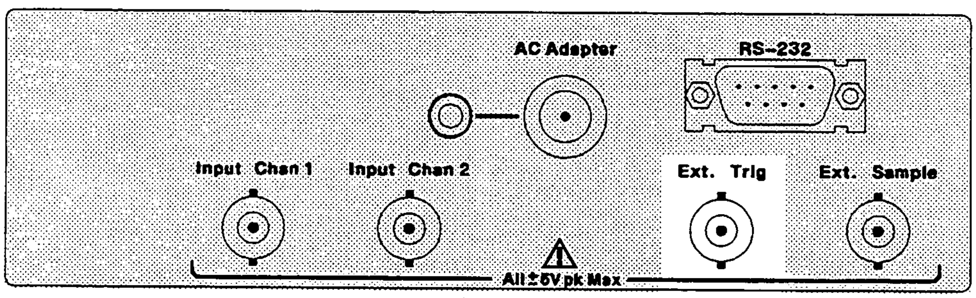

Figure 4-12

External Sample Connector

The External Sample input enables clock signals to control the sampling rate of the measurement. The analyzer will take one sample each time the signal applied to the External Sample connector goes from logic-low to logic-high (positive slope). You can use a TTL or CMOS logic level or an open-collector drive as the external sample signal. For more details on the connector requirements, see External Sample in the Dictionary Reference Section.

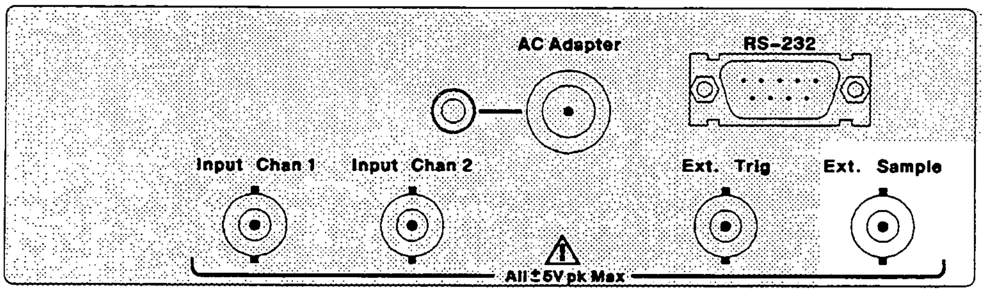

Figure 4-13.

Operational Overview

After you have worked through the examples in the *HP 3560A Getting Started Guide*, spend a few minutes experimenting with the various functions to get a better idea of the powerful functions available. This experimenting quickly reveals the simplicity of the instrument's operation.

At power-up, the HP 3560A displays the settings and data displayed when the instrument was last switched off. To set up a new measurement, press [PRESET] and confirm the key press by pressing [**Enter**]. Then use the hardkeys to display the menu selections.

Each hardkey in the DISPLAY, MEASUREMENT, and SYSTEM key sections displays a menu that shows all the options for that menu. Use the [⇐] and [⇒] cursor keys to move the inverse video cursor to the desired column. Use the [⇑] and [⇓] cursor keys to move the cursor to the desired item in a row. When you have selected all the items you want in the menu, press [**Start**] to return to the display or press a different hardkey to look at a different menu.

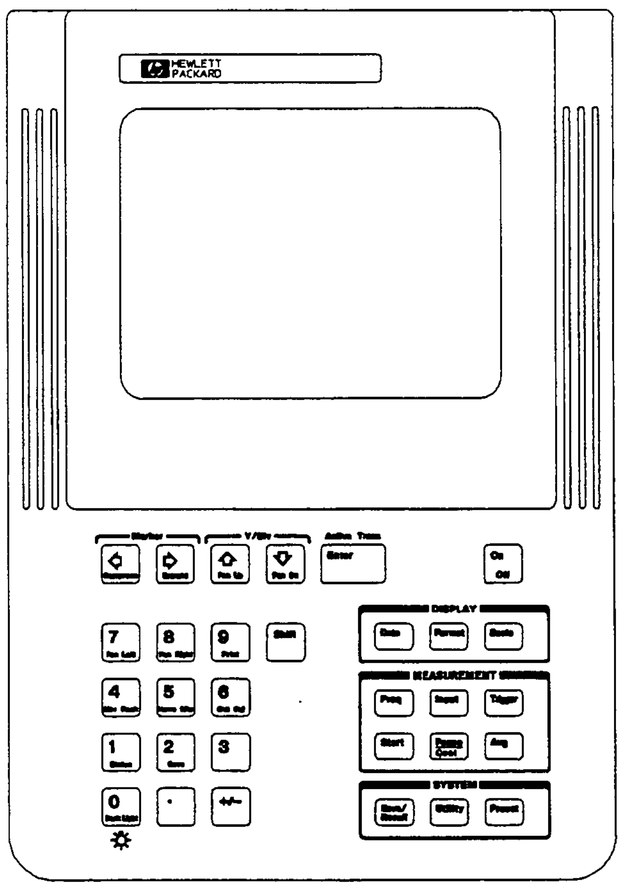

Figure 4-14.

Shift Function Overview

Use the [Shift] key to access the functions that appear in blue letters above the keys in the numeric keypad. Press [Shift] first and then press the key below the desired function. These functions immediately execute a task on the data currently displayed.

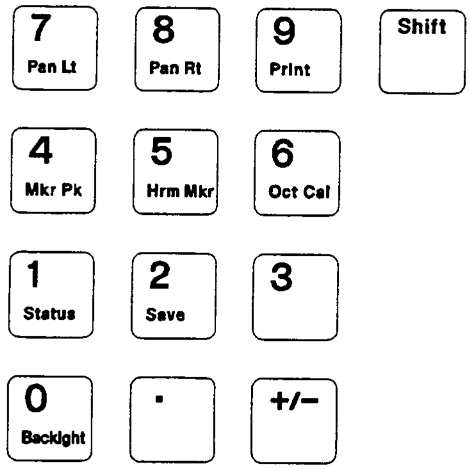

Figure 4-15.

The [PAN LEFT] and [PAN RIGHT] move the x-axis of the display to the left and right. Moving the x-axis like this is called panning the display.

The [PAN UP] and [PAN DN] move the y-axis of the display up and down.[1]

The [EXPAND] and [COMPRS] control the range of the x-axis for high resolution measurements.

[PRINT] sends the displayed data directly to a plotter or printer via the RS-232 port. The current time and date also appear on the printout.

[MKR PEAK] and [HARM MKR] control the position of the markers which appear as vertical lines on the display.

[STATUS] brings up a menu that shows the current settings (instrument status) of the HP 3560A.

[SAVE] is a fast and convenient way to sequentially save several sets of displayed data in memory. [SAVE] sequentially stores the currently displayed data under sequential register numbers.

[BACKLIGHT] turns the display's backlight on and off for work in poorly lighted environments.

[1]On some instruments, the [⇑] and [⇓] keys do not have " Pan Up " and " Pan Dn " labels.

Menu Overview

The remainder of this chapter describes the menu items for each hardkey. For details on a particular menu item, see the Dictionary Reference section which lists each hardkey, menu item and connector panel item in alphabetical order.

Display Hardkey Menus

[Data]

Use [**Data**] to select the signal processing algorithm and trace coordinates for trace A and B. The selections in this menu can also be used to reprocess data if the measurement is paused. For example, if you have paused the analyzer and you want to view the currently displayed data with different coordinates, simply press [**Data**] and select the desired coordinates under [Y-AXIS: A] or [Y-AXIS: B]. Return to the display by pressing [**Start**] or [**Data**]. The data then appears with the new coordinates applied.

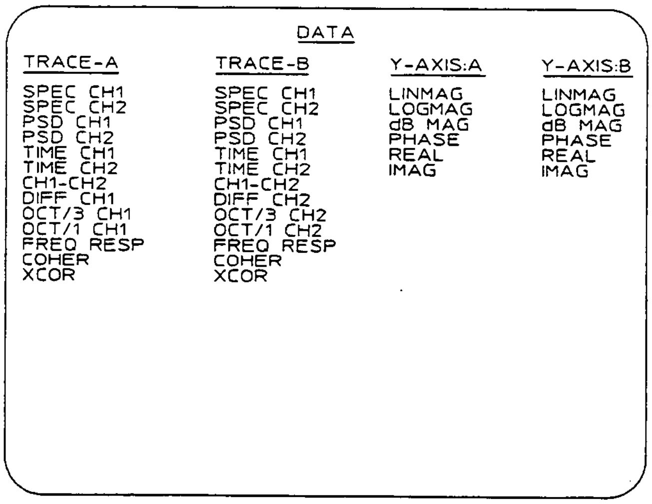

Figure 4-16.
Control data processing and displayed coordinates

[Format]

The [**Format**] menu lets you specify the way trace A and/or trace B are displayed. You can also display a spectral map of trace A or B which shows the spectrum as it changes with time. Spectral map lets you select the number of traces, the amount of suppression, and whether or not you want overlapping lines hidden. For time domain measurements, you can display y-axis data from channel 1 vs. y-axis data from channel 2 in an orbit display.

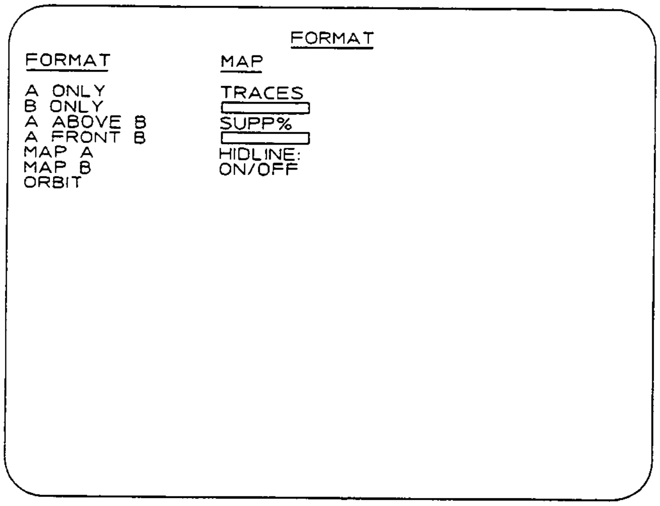

Figure 4-17.
Control the way trace data is displayed

[Scale]

To select the type of x- and y-axis units for trace A and B, use [**Scale**]. You can have a logarithmic or linear x-axis scale on spectral data. Enter your own y-axis scaling factor and select from several engineering units or use volts. [AUTOSCALE] takes care of scaling the data for you using the units you specify.

You can also adjust the y-axist scale while viewing a trace. Press [⇑] and [⇓] to change Y/DIV. Press [**Shift**] [⇑] and [⇓] to pan up or pan down.

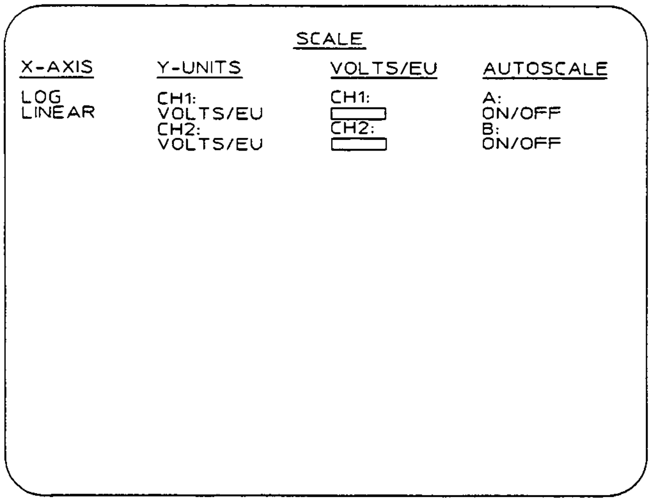

Figure 4-18.
Control scaling and units for the x- and y-axes

Measurement Hardkey Menus

[Freq]

[Freq] controls the frequency band, the [ZOOM] feature, number of lines (resolution), the type of window, the anti-aliasing filter, the internal or external sampling selection and the force/exponential window parameters. [ZOOM] lets you quickly take a close look at a portion of the frequency spectrum.

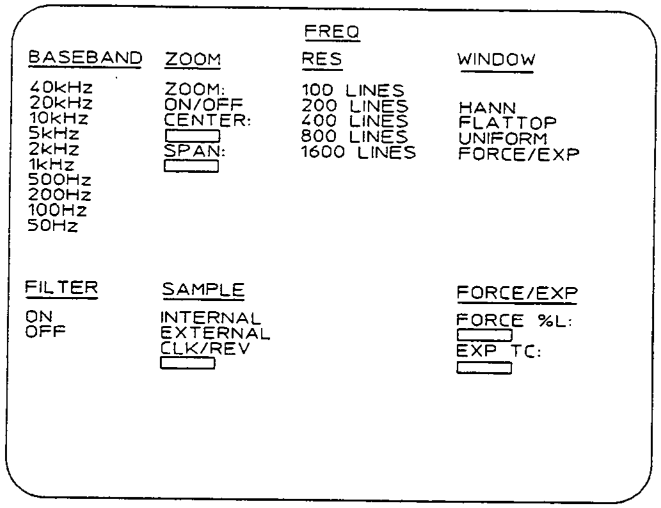

Figure 4-19.
Control frequency parameters, windowing, the anti-alias filter, zooming and the clock

[**Input**] Set the input sensitivity, coupling, integration level of both channels, and acoustic weighting filter with the [**Input**] menu.

Channel sensitivity covers three decades and each sensitivity value is bipolar meaning that a range of 5 volts is +5 volts to –5 volts. When you do not know the amplitude of the input signal, use [AUTO] and the analyzer will select an appropriate range. You can power standard Integrated Circuit Piezoelectric (ICP) type accelerometers from the internal driver by selecting [ICP] coupling. This constant current source supplies 4 mA and up to 24 Vdc open circuit voltage.

Caution To avoid damaging non-ICP devices, make sure you do not have [ICP] coupling selected in the [**Input**] menu before connecting devices to the channel 1 and channel 2 inputs. Pressing [Preset] also deselects [ICP] coupling. However, turning the HP 3560A off and on again does not deselect [ICP] coupling.

The selections under [INTEGR] change acceleration displays on both channels into velocity or displacement displays. Simply set [INTEGR] to [ONCE] for velocity displays or [TWICE] for displacement displays.

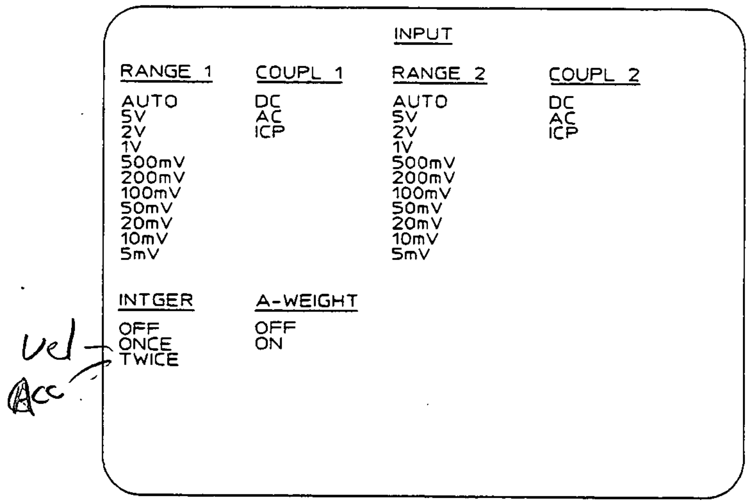

Figure 4-20.
Set input parameters and the level of integration

[Trigger]

The [**Trigger**] menu selects the signal condition which starts the measurement. You can use no trigger and free run the analyzer or use a trigger by specifying a trigger source, mode and point. The source of the triggering signal can be the signal at one of the input channels or an external trigger signal. For hand-held probe applications, you can also use the probe's trigger output to start data acquisition and then free run. Start a measurement only when a proper triggering condition first occurs or every time a proper triggering condition occurs by setting the trigger mode. Set the triggering point to ± 100% of the input range and on a positive or negative slope. Also, capture transient events by specifying a pre-trigger or post-trigger.

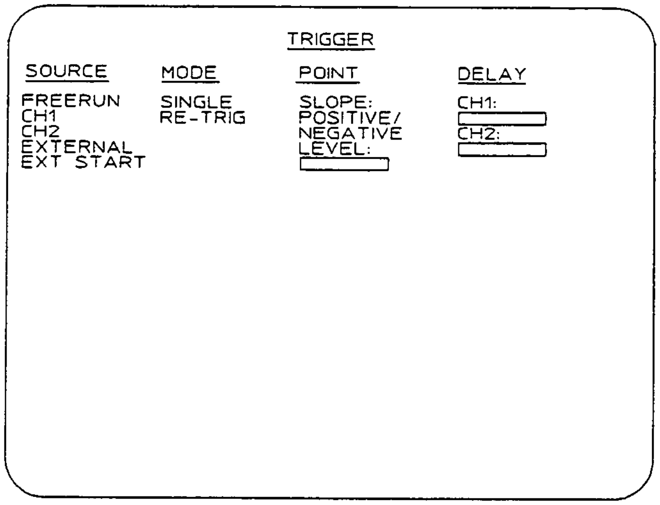

Figure 4-21.
Set parameters for the trigger

[Start]

Press [**Start**] to begin data acquisition when the triggering condition is satisfied. If you select autoranging in the [**Input**] menu, pressing [**Start**] causes the analyzer to perform the autoranging sequence. Although the autoranging sequence takes a few seconds, it can be convenient if the signal amplitude later changes and overranges one of the inputs. Then simply press [**Start**] again to perform another autorange.

Interrupt the measurement process by pressing any other hardkey. If you press [**Pause/Cont**] to pause a measurement and then look at a menu under another hardkey, pressing [**Start**] returns to the display without taking new data. Pressing [**Start**] again overrides the analyzer's pause condition and causes the analyzer to take new data. See [**Start**] in the Dictionary Reference for more information on using [**Start**] for re-processing data.

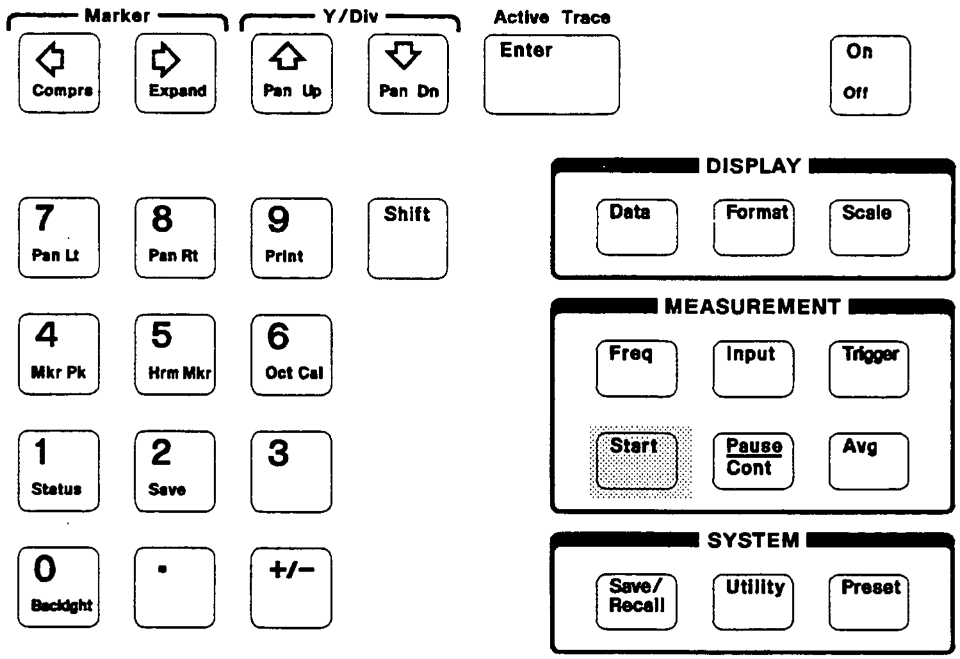

Figure 4-22.
Start a measurement

[Pause/Cont] To capture a certain event or signal, use the [**Pause/Cont**] key. Press [**Pause/Cont**] once to freeze the display. Press it again to continue taking measurements.

[Avg] Select the type of averaging or peak hold function for the measurement by using the selections in the [TYPE:] column. Enter the number of rms, time, or peak hold averages in the [NUMBER:] column. Turn on [FAST AVG:] to get the final results of the average in the least amount of time. No interrim results are displayed. [PREVIEW:] lets you accept or reject the currently displayed data in the average calculation.

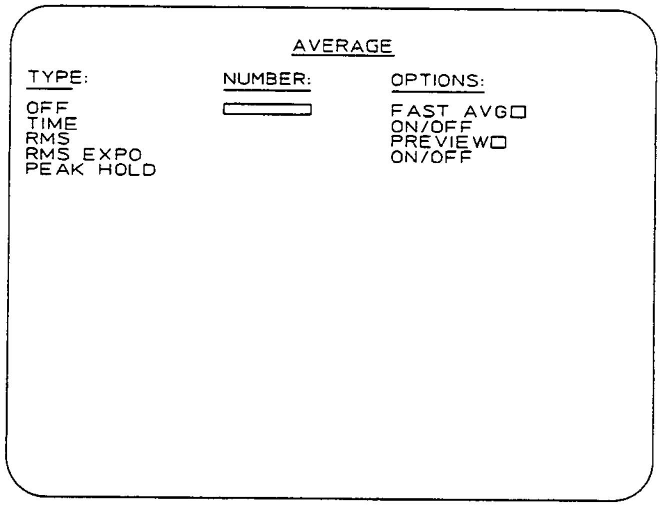

Figure 4-23.
Set averaging parameters

System Hardkey Menus

[Save/Recall] The HP 3560A's non-volatile storage for saving and recalling traces and instrument states lets you save and recall up to 500 traces and/or states with 200-line spectral resolution. Save trace data or an instrument state under a register number. The analyzer saves the current time and date along with the trace data or instrument state. **[Save/Recall]** also controls the register numbering and lets you erase stored data records or transfer stored data records to a personal computer via the RS-232 port.

Note

More lines of resolution yield a longer data record which means you can store fewer traces in analyzer memory.
Also, if you plan on storing data and transferring it to a computer for certain types of post-processing, store it as time domain data using the [CH1] or [CH2] processes in the [**Data**] menu. This is because the analyzer only stores the result of a spectral process — not the entire data record used to calculate the spectrum.

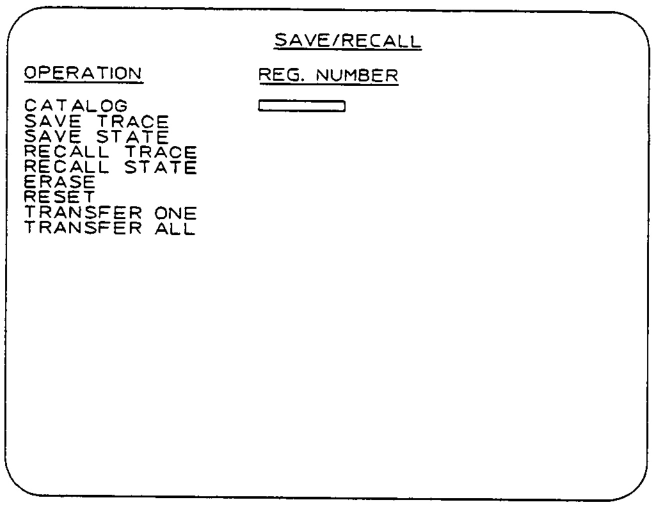

Figure 4-24.
Save and recall measured data

[Utility] A variety of functions are available through the [**Utility**] menu. Set the time, date, RS-232 parameters, liquid crystal display (LCD) features, and the recipient device for HP 3560A data transfers. You can also control the analyzer's timeout feature which conserves your battery charge by turning the HP 3560A off a period of time after no front panel key presses.

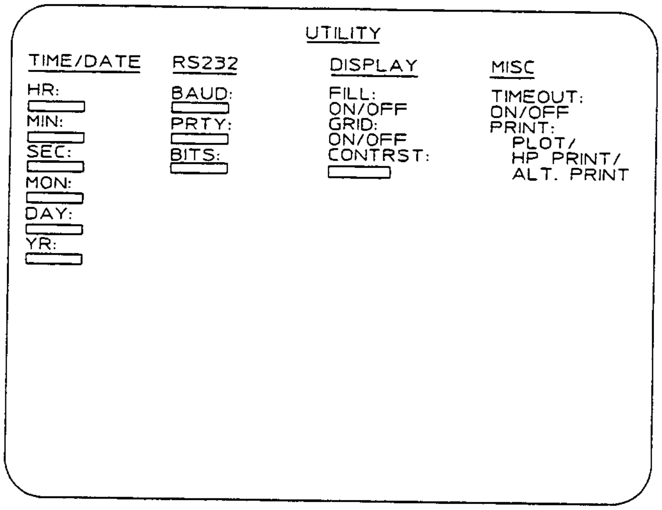

Figure 4-25.
Set various display and interface parameters

[Preset] Reset the analyzer to its default condition with [**Preset**]. Keep in mind that pressing [**Preset**] is not the same thing as turning the analyzer off and then on again. Turning the analyzer on recalls all settings used when the analyzer was last turned off. Use [**Preset**] to put the analyzer in a known state when you are setting up a new measurement. The default values are listed under [**Preset**] in the Key Reference. The first time you press [**Preset**], the analyzer does not interrupt the current measurement or change any settings. To avoid losing an instrument state or measured data due to inadvertantly pressing [**Preset**], a message appears on the display after the first press. Confirm your intention to preset the analyzer by pressing [**Enter**].

[Active Trace] Press the [**Enter**] key while viewing a trace to change the active trace between A or B . The active trace is indicated by "ACT → " on the display.

Status Line

These screen messages appear on the bottom line of the display.

```
1 OVER 2 OVER      T      R10        -- --        BAT
```

" 1 OVER "	Indicates channel 1 is overload. " **1 UNDER** " is displayed when channel 1 is under range.
" 2 OVER "	Indicates channel 2 is overload. " **2 UNDER** " is displayed when channel 2 is under range.
" T "	Will flash briefly whenever a trigger occurs. " **W** " is displayed when waiting for a trigger.
"R 10"	This field shows the measurement state. " **R** " indicates a real-time measurement is running. " **r** " is displayed for non-real time measurements. " **P** " is displayed when paused. " **10** " is the number of averages completed.
" -- "	These fields show the number of integrations or A-weighting for trace A and B. " -- " indicates none.
" BAT "	This appears when the instrument has about 1 hour of battery charge remaining.

Dictionary Reference

Use this alphabetical listing of the HP 3560A hardkeys, shift functions, menu items, and connector panel items to get a complete description of each feature. To help you look up words like a dictionary, the name of the item discussed first on each page appears at the top and serves as a key word.

AC Adapter

The ac adapter socket on the instrument's connector panel lets you use the analyzer's internal battery charger.

Battery Charging

The instrument is supplied with an internal battery charger and ac adapter for charging the NiCd battery pack. Use this ac adapter when you charge the battery. Do not use any other ac adapter. The battery typically stays charged for 6 hours during use. It takes 14 hours to completely charge a fully discharged battery. See the Installation section for more detail on battery charging.

Optimizing the Battery Charge

The HP 3560A has several features for maximizing battery charge and life.

1. Turning on [TIMEOUT] in the [**Utility**] menu automatically turns off the instrument if it is powered for 10 minutes without a key being pressed. However, if the instrument is waiting for a trigger, the analyzer does not turn off after 10 minutes. For example, if you select [SINGLE] as the trigger mode and the timeout feature is on, the analyzer will not turn off even after waiting 15 minutes for the triggering signal.

   To turn on automatic shutdown;

   a. Press [**Utility**].
   b. Move the column cursor to [MISC].
   c. Move the row cursor to [TIMEOUT].
   d. Toggle to [ON] by pressing [**Enter**].
   e. Press any hardkey to exit the menu.

2. When the instrument is not processing or collecting data, the internal electronics are switched into low power mode.

3. The instrument monitors battery condition and puts a low battery indication ("BAT") on the screen when there is approximately two hours run time remaining before you need to recharge. To prevent a very low battery charge condition that causes permanent damage to the internal batteries, the instrument automatically turns off when a dangerously low charge level remains.

Note

When you power up the instrument after a manual or automatic shutdown, all settings and data are reloaded exactly as before power was removed. In other words, switching the instrument off and on does not affect the menu selections or currently displayed data in any way.

Accelerometer Inputs

The HP 3560A has a built-in 24V, 4 mA constant current power supply which facilitates the interfacing of ICP (Integrated Circuit-Piezoelectric) type accelerometers. See [ICP] for details on accelerometer interface, mounting, and bias voltage.

[ALT. PRINT]

If you are using a graphics printer that is not Hewlett-Packard (such as an Epson Printer), select [ALT. PRINT] in the [**Utility**] menu to get a hardcopy of the currently displayed data. Pressing [**Shift**] [**PRINT**] outputs the graphics data via the RS-232 interface. Press [**Preset**] to abort the transfer. Figure 5-1 shows how to connect the HP 3560A to a printer with a 25-pin connector.

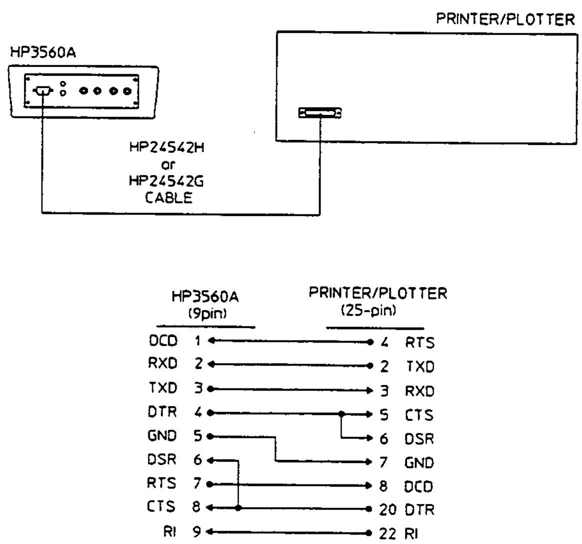

Figure 5-1.

* Use the HP 24542H cable for printers with a male 25-pin connector.

Note

Some printers indicate "buffer full" by switching a secondary RTS line, usually on pin 11 of the 25-pin connector. For correct handshaking with this type of printer, connect pin 11 of the printer to either CTS or DSR on the HP 3560A.

The printout lists band information in octave analysis. Also note that if you have harmonic cursors in a spectral process, peaks are not listed.

[AUTO]

Press [AUTO] in the [**Input**] menu to let the analyzer automatically choose the input range. This is convenient when you do not know the amplitude of the input signal. After you press [**Start**], it automatically adjusts the input range of the instrument to match the input signal. It does this by starting at the highest sensitivity (5mV), taking a record (assuming suitable triggering), checking that it does not saturate the input amplifiers, and decreasing the sensitivity level until there is no saturation. Then it latches to this sensitivity level and continues to gather data and process until you press a key. When you press [**Start**] again, this autorange process executes again.

[AUTO] is useful when a signal which has been stable at a particular amplitude level suddenly steps up or down while you are analyzing it. Simply press [**Start**], even while the instrument is taking and processing data, and the analyzer will autorange to the new signal level.

Note

Pressing [**Pause/Cont**] does *not* cause the input to autorange. Only pressing [**Start**] causes the analyzer to autorange.

When you are making several measurements on signals that are stable and in the same range, you can make measurements faster by manually setting the input range for each channel. Manually setting [RANGE1] and [RANGE2] eliminates the time it takes the analyzer to perform autoranging each time you [**Start**] a measurement. For example, on the first measurement you can select autoranging, make the measurement, and then press [**Shift**] [**STATUS**] to find which range is set for each channel. Then manually set these values in the [RANGE1] and [RANGE2] columns of the [**Input**] menu.

To select autoranging for channel 1;

1. Press [**Input**].
2. Move the column cursor to [RANGE1].
3. Move the row cursor to [AUTO].
4. Press any hardkey to exit the menu.

[AUTOSCALE]

Select [AUTOSCALE] to automatically scale the y-axis of trace A or B to the specified units. Even if you have selected automatic ranging for channels 1 and 2, further signal processing may result in a scale that is out of range or not large enough. With [AUTOSCALE] set on for trace A or B, the instrument takes care of the y-axis scale for you. With [AUTOSCALE] turned off, the analyzer chooses a y-axis scale based on the input range only. [AUTOSCALE] is performed once after a [**Start**] press. To [AUTOSCALE] the display again, press [**Start**] again.

To select automatic scaling for trace A;

1. Press [SCALE].
2. Move the column cursor to [AUTOSCALE]
3. Move the row cursor to [A:].
4. Toggle to [ON] by pressing [**Enter**].
5. Press any hardkey to exit the menu.

To adjust the scale manually, use the [⇑] and [⇓] keys. For spectrum displays, the data scales from the bottom grid line. For time domain displays, the data scales from the middle grid line.

[**Avg**]

Press [**Avg**] to select the type and number of averages appropriate for the kind of measurement you want to make. There are three types of averaging available.

- Time averaging
- rms averaging
- rms exponential averaging

Time averaging is performed on data before it is processed. The rms and rms exponential averages are performed after the data is taken and processed.

Select the number of averages by entering an integer between 1 and 4096 using the numeric keypad. For example, setting the number of time averages to 3 means 3 blocks of data are averaged and then processed. Setting the number of rms averages to 4 results means 4 processed data records are averaged before the final result show on the display. The display shows the average count as the analyzer computes each average.

There are two ways to stop the acquisition and averaging process.

1. Press the [**Pause/Cont**] key. This is useful when you want to view the data before the analyzer computes the total number of averages. For example, if you do not know how many averages are necessary before a certain event occurs, you can specify a large number of averages, start the measurement and then press the [**Pause/Cont**] key when the event occurs.
2. You can also stop averaging by selecting [SINGLE] as the trigger mode. This is useful when you know how many averages are required. For example, if you select 10 time averages and the [SINGLE] trigger mode, the averaging will stop once the complete "set" of averages are performed. Each average requires a valid trigger. In this case 10 sets of data are acquired and processed.

Caution

Make sure one or both channels do not overload during an average (i.e., a "1 OVER" or "2 OVER" message appears). If it does, the average measurement will not be valid.

The [TYPE:] column lets you choose time, rms, rms exponential, peak hold, or turn averaging off.

- [RMS] is an average which is derived from a series of processed data records. It takes the sum of all corresponding y-axis values of each processed data record and divides each value by the number of data records taken so far in the average. This averaging process is illustrated in Figure 7-2.

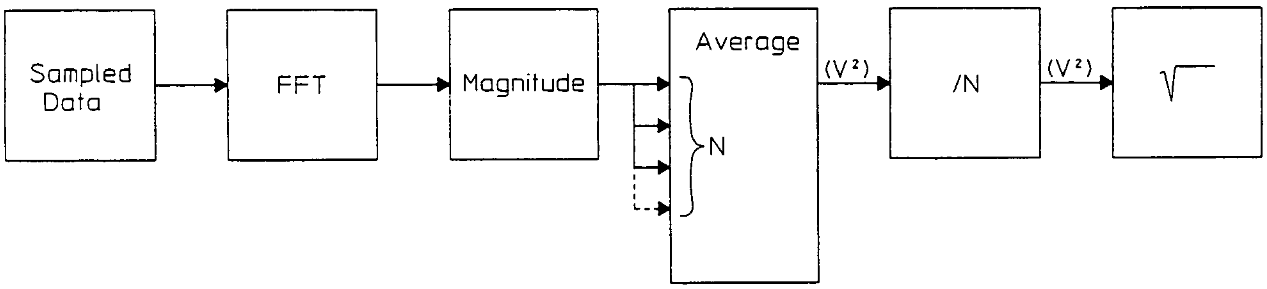

Figure 5-2.
rms Averaging Process

After the /N step, each value is still a "V^2" term. Therefore, the final step is to take the square root of each value. This is how rms (root-mean-square) averaging derives its name. rms averaging continues until the specified number of data records (N) have been taken. Both rms and rms exponential averaging increase the statistical accuracy of the data.

- [RMS EXPO] (Exponential) average is a "moving" average with each record being weighted according to the time at which it was acquired — the earlier the record, the less significance it has in the resulting average. Exponential averaging proceeds until the specified number of data records have been taken. Both rms and rms exponential averaging increase the statistical accuracy of the data.

- [PEAK HOLD] is not really an average but it maintains the maximum amplitude measured at each line. It acquires and processes data until the the analyzer takes the specified number of data records.

To select 10 [RMS] averaging;

1. Press [**Avg**].
2. Move the column cursor to [TYPE:].
3. Move the row cursor to [RMS].
4. Move the column cursor to [NUMBER:].
5. Enter **1 0** using the numeric keypad and press [**Enter**].
6. Press [**Start**] to return to the display or press any other hardkey to look at another menu.

Discussion

Most signals consist of a composition of two types of signals; deterministic signals which are usually the signals of interest and random signals which are generally considered noise. Examples of deterministic signals are speech, mechanical vibrations or sine waves. An example of an entirely random event is the sound of hissing air. Time averaging lets you find deterministic signals in the presence of random signals. rms and rms exponential averaging help you decide which signals occur the most often.

Time Averaging A time average means that data is averaged as it is acquired by the instrument and before it is presented to the selected algorithm for processing. Use time averaging when the signal is repetitive and a consistent trigger point is available. Time averaging improves the signal-to-noise ratio (SNR) of the signal you are analyzing when you are able to correctly trigger the signal. Time averaging on randomly triggered data has the opposite effect, making the final result meaningless. The following summarizes the properties of time averaging.

1. Time averaging is useful only when a signal contains a deterministic component.
2. Time averaging increases the signal-to-noise ratio (SNR) of the signal being analyzed. In other words, it increases the ratio of the deterministic part to the random part.
3. A trigger point synchronized to the deterministic part of the signal must be available.
4. Not available when ZOOM is ON.

rms Averaging rms and rms exponential averaging provide statistically more accurate estimates of the process being executed. It does not improve the signal-to-noise ratio but it lets you see which signals occur more often than others and gives their average amplitude value. You may notice that each time a process is executed, the individual values of the output usually vary to some degree. For example, the value in each line of a spectral output shows some variation in amplitude but approaches a mean value. rms and rms exponential averaging provide better estimates of this mean value. In other words, they smooth the estimate of the random portion of a signal but they do not uncover a deterministic signal which is buried in noise.

The following gives the properties of rms and rms exponential averaging.

1. They produce a statistically more accurate estimate of the signal amplitudes.
2. They do not improve signal-to-noise ratio.
3. You do not need to have a known trigger point to start data acquisition unless you are making an absolute phase measurement (relative to a fixed point).

Table 5-1. Summary of Averaging

Type	Advantages
Time	Increases S/N ratio
rms	Good for analyzing stationary data. Improves statistical accuracy.
rms Expo	Good for analyzing non-stationary data. Does not significantly improve statistical accuracy.
Peak Hold	Lets you examine dominant frequency components that vary with time.

[A-WEIGHT]

[A-WEIGHT] in the [**Input**] menu simulates how the human ear perceives sound by weighting octave analysis data. The American National Standards Institute (ANSI) has defined this acoustic weighting or A-Weighting function that takes into account the human ear's sensitivity to tones in the 500 Hz to 10 kHz range and reduced sensitivity at other frequencies. Turn on [A-WEIGHT] to apply the weighting function when you are making octave analysis measurements. An "AW" indicator appears when [A-WEIGHT] is turned [ON]. [A-WEIGHT] applies only to the [OCT CH1/CH2] and [OCT/3 CH1/CH2] data processes. Other data process selections ignore the [A-WEIGHT] setting. The acoustic weighting factors are listed in the discussion under [OCT CH1/CH2] and [OCT/3 CH1/CH2]. The filter shape complies with definitions given in ANSI S1.4-1983 and IEC 651-1979.

[BACKLIGHT]

If you are in a dark measurement environment, turn on the backlight by pressing [**Shift**] [¤]. Press [**Shift**] [¤] again to turn it off. The backlight turns off when the instrument turns off.

Note

Constant use of the backlight drains the battery charge and shortens operation time by about 25%. With the backlight off, the battery stays charged typically for 6 hours of constant use. With the backlight on, this time is shortened to 4 to 5 hours. If the battery charge is low, turning on the backlight can cause the analyzer to turn off.

[BASEBAND]

[BASEBAND] controls the frequency band of the data acquisition process. Frequency options range from 40 kHz to 50 Hz.

To select the 20 kHz frequency band;

1. Press [**Freq**].
2. Move the column cursor to [BASEBAND].
3. Move the row cursor to [20 kHz].
4. Press any hardkey to exit the menu.

This frequency band selection sets the cut-off frequency of the anti-aliasing filters equal to the frequency you select. It also sets the analyzer's sample rate. (The internal clock runs 2.56 times faster than the selected frequency.) For example, a frequency setting of 20 kHz sets the anti-alias filters to 20 kHz cut-off and the sampling rate to (20 × 2.56) kHz or 51.2 kHz per channel. This means each data point represents 1/51,200 seconds. If you choose a [RESOLUTN] setting of 1600 lines, the total number of sampling points is (1600 × 2.56) or 4096. Therefore, the total time for taking the data record is 4096/51,200 or 80 mS.

In the frequency domain, the [BASEBAND] you select equals the displayed frequency band. If you are operating the HP 3560A in the time domain, you can switch off the filters and the instrument behaves exactly as a 100 kHz sampling rate digital oscilloscope, but with greater resolution than conventional instruments.

Note When you turn on [ZOOM], the [BASEBAND] setting is ignored. To enable the [BASEBAND] setting, turn [ZOOM] off.

[BAUD]

You can modify RS-232 operation parameters in terms of baud rate, parity, and number of data bits. Select a baud rate of 38400, 19200, 9600, 4800, 2400, or 1200. For example, to change the baud rate to 1200;

1. Press [**Utility**].
2. Move the column cursor to [RS232].
3. Move the row cursor to [BAUD].
4. Toggle to **1 2 0 0** using the [**Enter**] key.
5. Press any hardkey to exit the menu.

[BITS]

You can modify RS-232 operation in terms of baud rate, parity, and number of data bits. The number of data bits can be 7 or 8. If you select an odd or even parity, you should set the number of data bits to 7. If you are using a printer or if you choose not to have a parity bit, select 8 as the number of data bits.

To set the number of data bits to 8;

1. Press [**Utility**].
2. Move the column cursor to [RS232].
3. Move the row cursor to [BITS].
4. Toggle to **8** using the [**Enter**] key.
5. Press any hardkey to exit the menu.

[CATALOG]

To list which register numbers currently have data stored in them, press [CATALOG] in the [**Save/Recall**] menu. To help identify what is stored in each register, the catalog also lists the time and date of storage, whether it is trace data or an instrument state, and the data process used to take the data. If no information appears by a register number or the number is not listed at all, that means the data has been erased and the register number is available for storing. See figure 5-3 for an example. The [⇑] and [⇓] keys let you scroll through the catalog if the list is longer than the display is able to show. Also, the [⇐] and [⇒] keys let you "page up" and "page down" through the list. [**Shift**] [⇑] brings up the first page and moves the cursor to the top. [**Shift**] [⇓] brings up the last page and moves the cursor to the bottom.

To view the catalog listing and recall a trace or state;

1. Press [**Save/Recall**].
2. In the [OPERATION] column, move the row cursor to [CATALOG].
3. Press [**Enter**] to view the catalog listing.
4. Select a register using the [⇑] and [⇓] keys.
5. Press [**Enter**] to automatically enter that register number under [REG NUMBER:] and return to the [**Save/Recall**] menu. Also notice that the row cursor in the [OPERATION] column automatically moves to [RECALL TRACE] or [RECALL STATE] depending on whether the catalog cursor was on an "S" (state) or "T" (trace).
6. Press [**Enter**] again to view the recalled trace.

CATALOG

REG	S/T	DATE	TIME	TRACE
1	S	91-03-06	13:58	SPEC CH1
2	T	91-03-06	09:10	FREQ RESP
11	S	91-03-20	10:00	SPEC CH1
11	T	91-03-20	10:01	SPEC CH1
12	T	90-03-20	10:15	TIME CH1
13	T	91-03-20	10:20	TIME CH2
14	T	91-03-20	10:22	FREQ RESP

Page 01/01 (< = or = > to change page)
Select register, then press <enter>

Figure 5-3.
Catalog Listing

[CENTER]

Use [CENTER] when you are making a [ZOOM] measurement to specify the frequency that will appear at the center of the display. Use the numeric keypad to enter the center frequency in Hz. For example, to turn on the zoom feature and enter a center frequency of 1.575 kHz:

1. Press [**Freq**].
2. Move the column cursor to [ZOOM].
3. Toggle [ZOOM] to [ON] using the [**Enter**] key.
4. Move the row cursor to [CENTER].
5. Enter **1 5 7 5** using the numeric keypad.

The analyzer only uses this center frequency value when you have turned on the [ZOOM] feature. You can enter the center frequency values from 0 Hz to 40000 Hz to the nearest 0.01 Hz but the analyzer rounds your entry to the center frequency resolution given in the table below. The center frequency resolution (or the ability to set the center frequency to an exact value) depends on the the highest frequency to be displayed in the zoom measurement. The highest frequency is given by the following:

[CENTER] + [SPAN]/2

The following table gives the center frequency resolution.

Table 5-2. Center Frequency Resolution

[CENTER] + [SPAN]/2	Center Frequency Resolution
< 400 Hz	0.25 Hz
< 4 kHz	2.50 Hz
< 40 kHz	25 Hz

Channel 1/2 Inputs

Channel 1 and Channel 2 BNC connectors receive input signals in the range ± 5V to ± 5 mV depending on the input range you specify. The input impedance at each input is 1 MΩ, except when you are using the accelerometer interface. The instrument displays a warning message if the amplitude of the input signal exceeds the specified sensitivity range.

[CH1]

To use the signal at channel 1 as the trigger source, select [CH1]. Selecting [CH1] means the analyzer begins a measurement when the channel 1 input signal meets the trigger conditions you have specified. See [SLOPE] and [LEVEL] for more information on setting the trigger condition.

[CH1 – CH2]

[CH1 – CH2] is a time domain function that displays the difference between channel 1 data and channel 2 data. The [CH1 – CH2] process is a signed arithmetic subtraction of channel 2 from channel 1. Out of range results are clipped. The subtraction occurs before the analyzer performs range scaling. Therefore, both channels should be set to the same [**Input**] range to get an accurate voltage difference. If the channels are on difference ranges, [CH1 – CH2] is computed by using values relative to full scale for each range.

See the discussion under [TIME CH1] about operating the HP 3560A in the time domain.

[CH2]

To use the signal at channel 2 as the trigger source, select [CH2]. Selecting [CH2] means the analyzer begins a measurement when the channel 2 input signal meets the trigger conditions you have specified.

[CLK/REV]

[CLK/REV] scales the x-axis to the number of pulses per revolution (ORDers) when you are using external sampling. For example, if you are measuring signals from a rotating shaft that is varying in speed and you want to synchronize the measurement by sampling the same number of times per revolution, the external sample feature is very useful. Connect a pulse encoder to a rotary shaft, apply the sample source of the pulse encoder to the External Sample input connector, and enter the number of pulses per revolution under [CLK/REV]. The number can be between 0 and 1024. See the discussion under [SAMPLE] for more information on order analysis.

To specify 100 clock pulses per revolution;

1. Press [**Freq**].
2. Move the column cursor to [SAMPLE].
3. Move the row cursor to [CLK/REV].
4. Enter **1 0 0**
   using the numeric keypad.
5. Press [**Enter**].
6. Move the row cursor to [EXTERNAL].
7. Press any hardkey to exit the menu.

[COHER]

Coherence is used to determine the amount of "similarity" between channels 1 and 2. It is a normalized frequency domain measurement of the correlation between two signals. In other words, [COHER] measures the power in the "response" channel that is caused by the power in the "reference" channel.

The output range is dimensionless and ranges from 0 to 1. Two fully coherent signals give an output of 1, implying that they are related by a linear transfer function. A coherence of 0 means that the signals have nothing to do with each other. Note that a number of averages is required for the coherence function to provide a reliable output. Coherence of one average is always 1 and is not a representation of the coherance.

Discussion

The coherence function is usually used as a method of checking that the results obtained by the transfer function [FREQ RESP] are valid.

A common problem in machinery vibration analysis is that vibration from one machine is transferred to another machine resulting in misleading analysis results. [COHER] can help with these problems by indicating the cause and effect relationship between vibrations at two locations.

Example Consider the transfer function of an electronic filter as illustrated in figure 5-4.

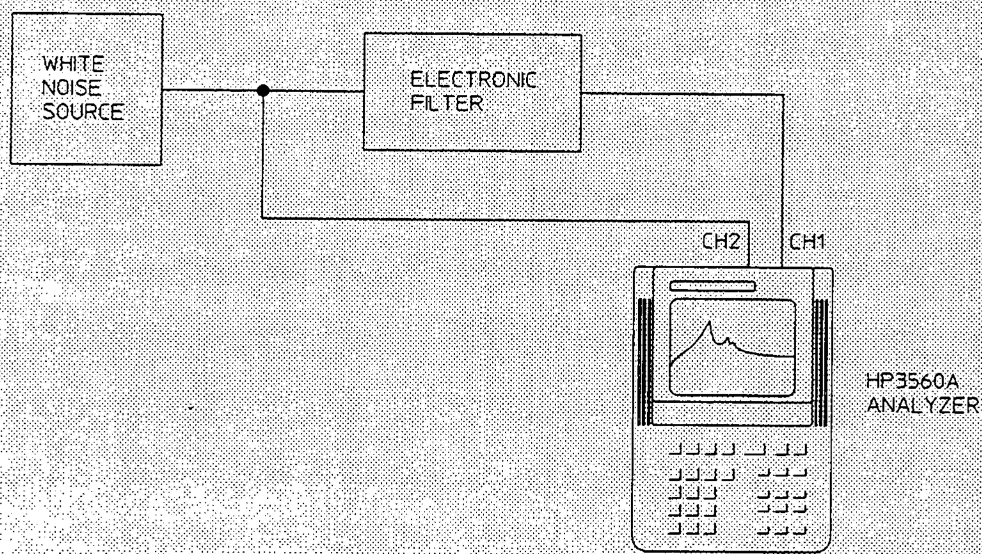

Figure 5-4.
Measurement setup

Figure 5-5 shows the measured frequency response (using [FREQ RESP]). Applying linear averaging reduces "noise" contribution, but the 1 kHz component remains.

Note To get meaningful results, you must average when you use [COHER]. Averaging also improves statistical accuracy.

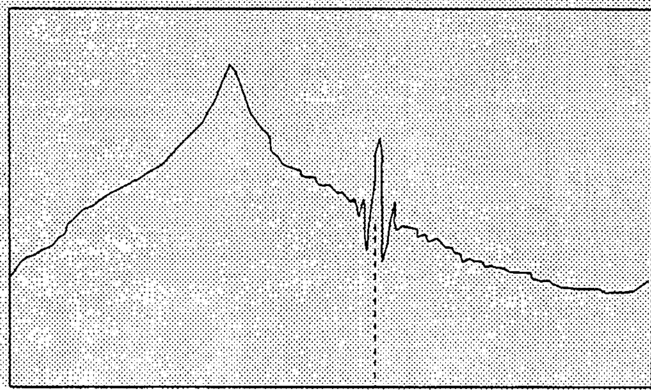

Figure 5-5.
Transfer function of an electronic filter

Making a coherence measurement on this data reveals whether the 1 kHz component is caused by the system. Figure 5-6 shows the coherence measurement.

Figure 5-6.
Coherence measurement

You can see that the 1 kHz component is not caused by the system, but must come from some outside disturbance or interference. However, the rest of the measurement is close to unity meaning the measured transfer function is a good representation of the system.

[COMPRESS]

Normally, the analyzer displays compressed data. Press [**Shift**] [**EXPAND**] to expand the spectrum to its full data record length. Then use the [**PAN RIGHT**] and [**PAN LEFT**] shift functions to view other portions of the expanded spectrum. [**Shift**] [**COMPRESS**] returns the display to its original compressed state.

[CONTR]

You can adjust the screen contrast in eight steps from 0 to 7, where 0 is the lightest and 7 is the darkest. To adjust the screen contrast;

1. Press [**Utility**].
2. Move the column cursor to [DISPLAY].
3. Move the row cursor to [CONTR].
4. Toggle to the desired contrast number using the [**Enter**] key.
5. Press any hardkey to exit the menu.

[COUPL1/2]

[COUPL1] and [COUPL2] are column headings in the [**Input**] menu that let you select the input coupling for channel 1 and channel 2.

There are three selections:

- [DC] couples the input signal directly to the input amplifiers.
- [AC] passes the input signal through a high pass filter with 3 dB point of 1 Hz.
- [ICP] selects the accelerometer interface which is a 4 mA constant current source with up to 24Vdc open circuit voltage. This enables the internal driver to power standard accelerometers.

See [ICP] for more information on the accelerometer interface.

Cursor keys

Use the cursor keys (or arrow keys) to move the inverse video cursors which select items when you are viewing a menu. First select a column in a menu using the [⇐] and [⇒] keys. Then move the cursor to the item you desire using the [⇑] and [⇓] keys. When you are viewing data on the display, the cursor keys control the marker.

[Data]

Press [**Data**] to modify the type of processing and y-axis coordinates for traces A and B. The [**DATA**] key lets you select which data process you want and on which trace you want it displayed. You can view some processes on either trace using either channel. For example, you can view spectral data on trace A or trace B and the data can come from either channel 1 or channel 2. The menus indicate this by having [SPEC CH1] and [SPEC CH2] in the both the [TRACE-A] and [TRACE-B] columns. See figure 5-7. Other processes can only be displayed on a specific trace. For example, you must view channel 2 octave analysis data on trace B since [OCT/3 CH2] only appears in the [TRACE-B] column.

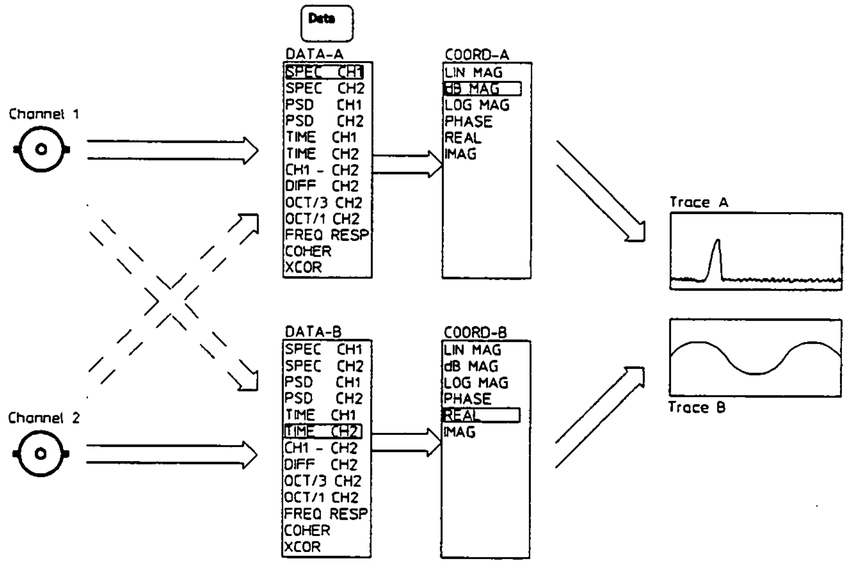

Figure 5-7.
Process and Trace Interrelations

Note

When you want to view data in the time domain, (using the [TIME CH1] or [TIME CH2] processes), set the coordinates for the corresponding trace to [REAL]. Similarly, when you view spectral data, make sure you select the appropriate coordinates for the trace.

For more information on specific processes and trace coordinates, see the specific name for details.

Discussion

Reprocessing Reprocessing can be carried out by the HP 3560A as long as the data is not stored data. Stored data must be post-processed by sending channel data via the RS-232 port to a computer or a PC-based Dynamic Signal Analyzer such as an HP 3566A, HP 3567A, or HP 35665A.

To perform reprocessing on the HP 3560A, you must do it at the time of the measurement. You can execute more than one process on the same data by performing the following.

1. Pause the measurement by pressing [**Pause/Cont**].
2. Select a different process or coordinate (usually in the [**Data**] menu).
3. Press [**Start**].

Note You cannot reprocess time records on the HP 3560A to get octave analysis data since octave analysis requires two data records for the calculation. You also cannot send time records to a computer for post-processing to get octave analysis data.

The display then shows the modified data. The analyzer does not take new data on the first press of [**Start**] because of the analyzer's paused condition. However, if you press [**Start**] a second time the analyzer will take new data and erase the current data.. If you want to keep the data before it is modified, save it in a register using [**Save/Recall**]. Then immediately perform the desired reprocessing because you cannot recall stored data and post-process it on the analyzer. Any post-processing on stored data must be done external to the HP 3560A by sending the data to a computer or a PC-based Dynamic Signal Analyzer and converting the data to Standard Data Format (SDF) using the SDF Utilities. Then you can perform any process on a stored data record taken in the time domain except octave analysis. Post-processing on stored frequency domain data is more limited since, unlike time domain data, spectral data is a subset of the total data record. See the *HP 3560A Getting Started Guide*, "Transferring Data to a Personal Computer" for more information on running the SDF Utilities.

[dB MAG]

Set the y-axis coordinates of traces A or B to logarithmic magnitude by selecting [dB MAG] in the [Data] menu. You can choose [dB MAG] whether the x-axis is frequency or time.

To select a logarithmic magnitude display with dB readout on trace A;

1. Press [Data].
2. Move the column cursor to [Y-AXIS: A].
3. Move the row cursor to [dB MAG].
4. Press any hardkey to exit the menu.

[dB MAG] displays are calculated from the linear data using the formula 20 LOG (V_{linear}). The display and marker annotation are in decibels. If you select Volts as the units in the [Scale] menu and [dB MAG] as the coordinates, dBV is used to represent decibels. If you are using the [EU] engineering unit, dBE is used.

[DELAY]

If you want to start data acquisition a period of time before or after the selected trigger point, use [DELAY]. Pre-triggering and post-triggering are both useful techniques for capturing signals.

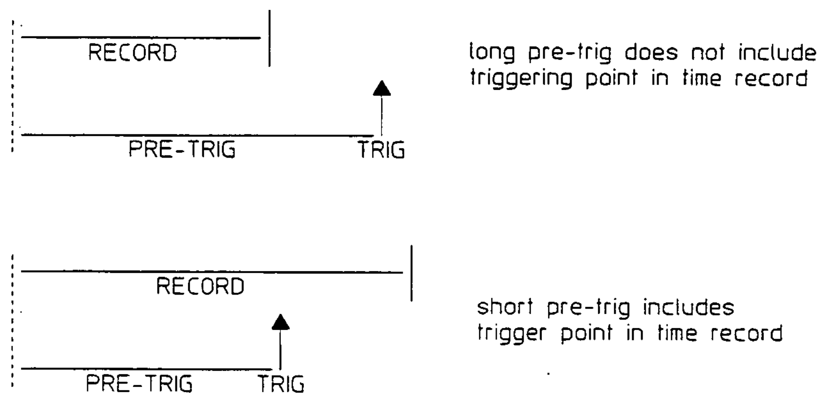

Figure 5-8.
Pre-trigger

Discussion

Pre-triggering Use pre-triggering for capturing transient signals which occur before an event. For example, to start a channel 1 measurement 20 sampling points before the trigger point, key in the following.

1. Press [**Trigger**].
2. Move the column cursor to [DELAY].
3. Move the row cursor to [CH1].
4. Key in **– 2 0** using the numeric keypad. The [+/-] key produces the minus sign.
5. Press any hardkey to exit the menu or [**Start**] to start the measurement.

Note The minus sign in step 4 indicates a PRE-trigger. If you give no minus sign, the analyzer assumes a post-trigger value.

With a pre-trigger setting, the analyzer continually captures data. This is particularly useful for transient analysis as shown in figure 5-9.

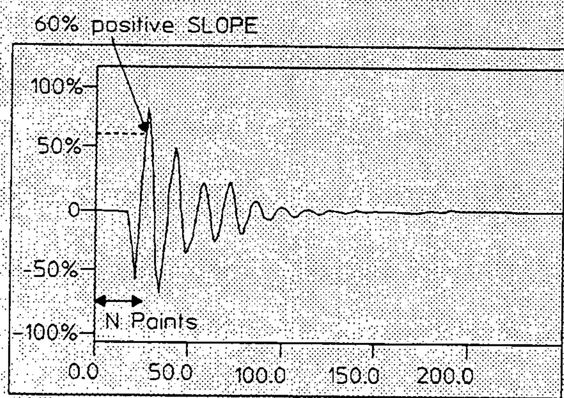

Figure 5-9.
Pre-Trigger on Transients

If you want to start a measurement a certain amount of time (t_p) in seconds before an event, you first need to know the current sample rate of the analyzer which is given by the following.

```
Sample Rate = [ BASEBAND ] × 2.56
```

The number of samples you enter under [DELAY] is then given by the following.

```
No. of samples = tp × Sample Rate
```

To get longer pre-trigger times , choose a smaller [BASEBAND].

Note When you use pre-trigger or post-trigger, use [BASEBAND] and not [ZOOM] to make the measurement to avoid confusion about the sample rate.

If you choose a pre-trigger time greater than the data record length, the trigger point will not be included in the acquired record. If the pre-trigger setting is less than the data record length, the trigger point will occur within the data record. This is useful when capturing transients using [SINGLE] trigger mode.

Caution When you use pre-trigger, do not also use [TIME] averaging. Using these two features together may result in inaccurate measurements, especially for measurements at the higher frequency ranges of the analyzer. Normally, [TIME] averaging synchronizes the first sample with the trigger. But with pre-triggering, this synchronization is not possible and the actual trigger point may be up to one sample off. This variance becomes significant at the higher frequencies.

If the trigger occurs before the analyzer has captured the required number of pre-trigger samples, it will trigger immediately and the beginning of the time record will be set to 0. This can cause unexpected results when using pre-trigger with continuous (not transient) signals.

Post-Triggering When one signal is always subject to a delay relative to another signal, like sound traveling from a loudspeaker to a microphone, you can delay channel 1 so that the two signals seem coincident.

To enter a post-trigger value, use the same steps as for pre-trigger except enter a positive number in step 4. Post-triggering captures the record the specified delay time after the trigger point. The same equations apply for post-trigger time as for pre-trigger time. Figure 5-10 illustrates post-triggering.

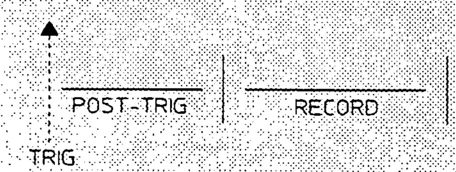

Figure 5-10.
Post-triggering

[DIFF CH1/CH2]

When you are making measurements in the time domain and you want to differentiate channel 1 or channel 2, select [DIFF CH1] or [DIFF CH2] in the menu for [**Data**]. The process differentiates the input data record with respect to time and adjusts the amplitude range of the display to accommodate the differentiated signal. For example, executing [DIFF CH1] on a waveform given by $Vsin(\omega t)$ (in volts) is $\omega Vcos(\omega t)$ (in volts/second).

To simulteneously differentiate channel 1 and channel 2, display both traces and then perform the differentiation. The key sequence follows.

1. Press [**Format**].
2. Move the column cursor to [FORMAT].
3. Move the row cursor to [A ABOVE B].
4. Press [**Data**].
5. Move the column cursor to [TRACE–A].
6. Move the row cursor to [DIFF CH1].
7. Move the column cursor to [TRACE–B].
8. Move the row cursor to [DIFF CH2].
9. Press [**Start**] to start the calculation.

Note

If the [**Pause/Cont**] has been pressed, you will need to press [**Start**] twice to start the measurement. The first press returns you to the display. The second press overrides the pause condition and starts the measurement.

Display

Use this group of hardkeys to specify how you want measurement results to be processed and displayed.

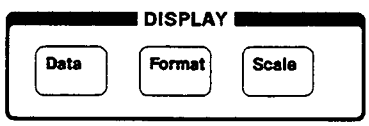

Figure 5-11.
Display Keys

[ERASE]

[ERASE] erases the contents of the specified register number. If both trace and state information is in the same register, [ERASE] erases both.

To erase register number 10;

1. Press [**Save/Recall**].
2. Move the column cursor to [REG NUMBER:].
3. Enter **1 0** using the numeric keypad.
4. Move the column cursor to [OPERATION].
5. Move the row cursor to [ERASE].
6. Press [**Enter**] and note the message.
7. Press [**Enter**] again to execute the erase.
8. Press any hardkey to exit the menu.

To erase the entire memory, use [RESET] in this menu.

Note

The status screen indicates the amount of the memory in percent available. Press [**Shift**] [**STATUS**] and look at "MFREE" to see this value.

[EXP TC:]

Use [EXP TC:] to set the exponential time constant (t_e) when you use the [FORCE/EXP] window. The *time constant* (t_e) parameter for the exponential window attenuates both channel 1 and channel 2 signals at a decaying exponential rate. Enter t_e for the exponential window by enter an integer from 0 to 10 under [EXP TC:]. Entering 6 means the final value of the exponential window is exp(-6) or 0.0025 times the level of the data. The higher the integer, the more the channel 1 and channel 2 traces will be exponentially decayed. To select 6 as the exponential time constant, perform the following.

1. Press [**Freq**].
2. Move the column cursor to [FORCE/EXP].
3. Move the row cursor to [EXP TC:].
4. Enter **6** using the numeric keypad and press [**Enter**].

See [FORCE/EXP] for an example of how to use [EXP TC:].

[EXPAND]

Normally, the analyzer displays compressed data. Press [**Shift**] [**EXPAND**] to expand the displayed spectrum to its full data record length. Then use the [**PAN RIGHT**] and [**PAN LEFT**] shift functions to view other portions of the expanded spectrum. [**Shift**] [**COMPRESS**] returns the display to its original compressed state.

[EXTERNAL]

To start data acquisition using a signal at the External Trigger connector, select [EXTERNAL] in the [**Trigger**] menu. The external trigger should be a TTL level signal. Trigger occurs on the rising or falling edge of the signal, depending on the specified [SLOPE] selection. Any duty cycle is accepted provided that the input level is at logic low level for at least 30 ns. The input is protected against overvoltage and has an internal pull-up resistor, allowing drive from open-collector sources. See External Trigger for more information about the connector's signal requirements.

Discussion

Using the external trigger in conjunction with other processes provides a very powerful, comprehensive analysis tool. There are three main features which external triggering helps facilitate:

- Time averaging for improving signal-to-noise ratio.
- Phase measurement for balancing in machinery vibration analysis.
- Data capture of transient events.

Time Averaging Time Averaging is a technique that can be used to reduce the level of noise and uncover low level signals that may be buried in noise. This type of averaging requires a synchronizing trigger; usually a once-per-rev pulse. If this trigger point is not reliable or synchronous with the signal of interest, then time averaging will simply null the signal as well as the noise. To get a meaningful time average, you must have a trigger that is synchronous with the low level signal you are trying to resolve. See the discussion under [**Avg**] for more information on how to use [EXTERNAL] trigger together with averaging. Another way to reduce noise is to use [XCOR] which does not require a synchronous triggering signal. See [XCOR] for more information.

Phase Measurement The complete frequency domain representation of a signal consists of an amplitude spectrum and a phase spectrum. While the amplitude spectrum indicates signal level as a function of frequency, the phase spectrum shows the phase relationship between spectral components. In machinery vibration analysis, phase is required for most balancing techniques. It is also useful for distinguishing the source of faults which happen to produce similar amplitude spectra.

To get a reliable phase measurement you must have a reference. In machinery analysis this reference is most often provided by a displacement or optical transducer which detects the passage of a keyway, screw, or reflecting surface. This reference signal is converted into a TTL compatible pulse and fed into the external trigger input of the HP 3560A. Every "pulse" represents one revolution, making it the perfect choice for the triggering signal.

Data Capture of Transient Events

In many applications, a transient signal such as a pulse is the most natural or appropriate stimulus for data acquisition. These application areas include sonar and seismic analysis, acoustic reverberation testing, and structural analysis.

You can capture transient information by using a pre-trigger on the transient signal or by using an external trigger.

Capture Using External Trigger Capture transient data by initiating (or triggering) the collection of data from an external trigger source which is related to the transient. For example, figure 5-12 illustrates a sea floor study in which an acoustic source periodically fires toward a sea bed. A group of hydrophones collects the reflection signals for subsequent analysis. However, in order to synchronize the acoustic source and the reflection collection, an independent reference trigger is used.

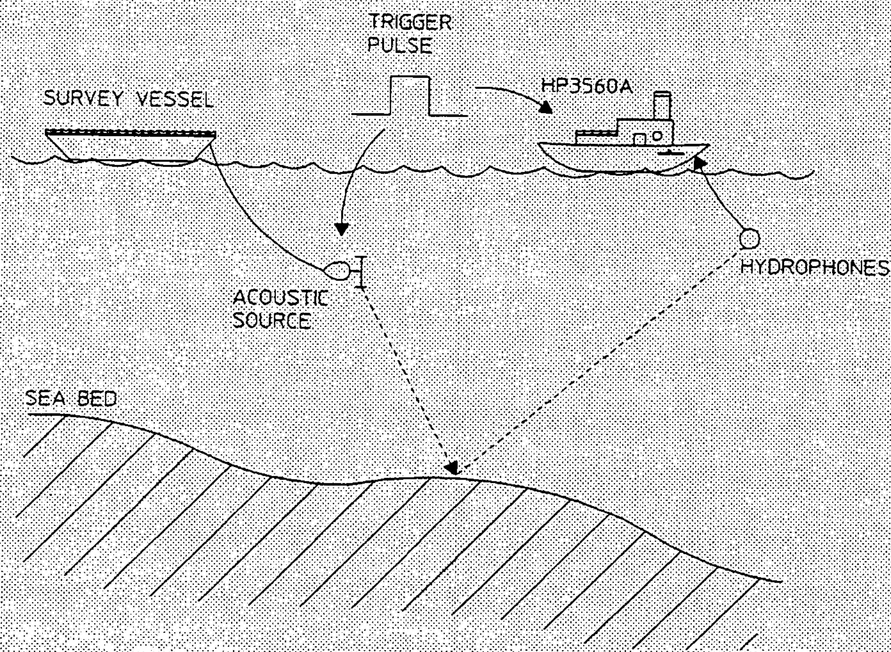

Figure 5-12.
Use of External Trigger

Caution When capturing an event, do not use automatic ranging on either channel. In other words, manually set the input range for both channels. Even if you are only taking data on one channel, make sure you have not selected [AUTO] on either channel. This will help assure that you do not miss an event while the analyzer performs the autorange routine.

Capture Using Pre-Trigger You can also initiate acquisition of data a period of time before the transient signal occurs. This provides some reassurance that the complete transient is captured. [DELAY] in the [Trigger] menu provides a pre-trigger. You simply define a trigger point unique to the transient signal and specify a pre-trigger time by using the [DELAY] feature. See [DELAY] for more information on setting up a pre-trigger.

External Sample/External Trigger Connectors

The External Trigger and External Sample inputs enable external trigger and sample signals to control the data acquisition functions of the instrument. External Trigger signals control when a measurement starts. External Sample signals control the sampling rate of the analyzer. Both inputs contain Schmitt triggers to ensure noise-free generation and can be driven by a standard TTL or CMOS logic level, or by an open-collector drive. The inputs are fitted with overvoltage diode protection and with 100 kΩ pull-up resistors to +5V.

Both inputs trigger on the positive going edge of the signal. The External Trigger input accepts any duty cycle provided that the input level is at logic low level for at least 30 ns.

Caution

The external sample signal must be at a logic low for a minimum of 250 ns, and a logic high for a minimum of 9.75 μs. Also, you may need to provide external aliasing protection.

See [SAMPLE] for more information on external sampling and [EXTERNAL] for more information on external triggering.

[EXT START]

[EXT START] is convenient for hand-held probe applications. It starts data acquisition the first time a suitable trigger occurs (e.g., from a probe trigger output applied to the external trigger input). After the initial trigger, the analyzer runs identical to [FREERUN]. If the probe test point needs to be more than an arms length away from the analyzer, [EXT START] lets you [**Start**] the analyzer and then it waits until the probe trigger occurs before taking data. A "W" indicator appears on the screen until the trigger occurs. This helps guard against having invalid data inadvertantly included an average measurement. To select [EXT START];

1. Press [**Trigger**].
2. In the [SOURCE] column, move the row cursor to [EXT START].
3. Press any hardkey to exit the menu.

[FAST AVG]

Turn on [FAST AVG] to obtain an average result as quickly as possible when you are using the [RMS], [RMS EXPO], or [PEAK HOLD] average types. With [FAST AVG] turned on, the analyzer does not update the display to give interrim average results until the specified average number is reached. If you are using [TIME] averaging, the [FAST AVG] setting does not apply. Turn on [FAST AVG] by performing the following.

1. Press [**Avg**].
2. Move the column cursor to [OPTIONS].
3. Move the row cursor to [FAST AVG].
4. Toggle to [ON] using the [**Enter**] key.
5. Press any hardkey to exit the menu.

[FILL:]

[FILL:] is in the [DISPLAY] column of the [**Utility**] menu. It lets you select a solid (filled) display or a line display. A filled display can help you see signals in very bright environments.

To select [FILL] without the grid;

1. Press [**Utility**].
2. Move the column cursor to [DISPLAY].
3. Move the row cursor to [FILL].
4. Toggle to [ON] by pressing [**Enter**].
5. Press any hardkey to exit the menu.

[FILTER]

[FILTER] switches the anti-alias filter in and out. The HP 3560A is alias protected to 40 kHz. The cut-off frequency of the anti-aliasing filters is set to the [BASEBAND] frequency setting.

Note

When you are using the HP 3560A as a digital storage oscilloscope, you should switch out the anti-aliasing filters to eliminate any degradation of sharp edges in the signal.

[FLATTOP]

Use the [FLATTOP] window type to get the best amplitude accuracy of all the window types. However, it gives the least amount of frequency resolution. See [WINDOW] for an explanation of the purpose of windowing and for a comparison of the four different types of windows available in the HP 3560A. The *HP 3560A Getting Started Guide* also discusses windowing in the "Spectrum Analyzer Basics" section.

Select [FLATTOP] windowing by performing the following.

1. Press [**Freq**].
2. Move the column cursor to [WINDOW].
3. Move the row cursor to [FLATTOP].
4. Press any hardkey to exit the menu.

[FORCE/EXP]

The [FORCE/EXP] window type is useful for measuring properties of mechanical structures during impact or hammer testing because it removes residual oscillations in lightly damped systems which have frequency responses that do not decay within one data record. Figure 5-13 gives the [FORCE/EXP] window shape representation. Notice in the figure that [FORCE/EXP] is a combination of two window types;

- The Force Window
- The Exponential Window

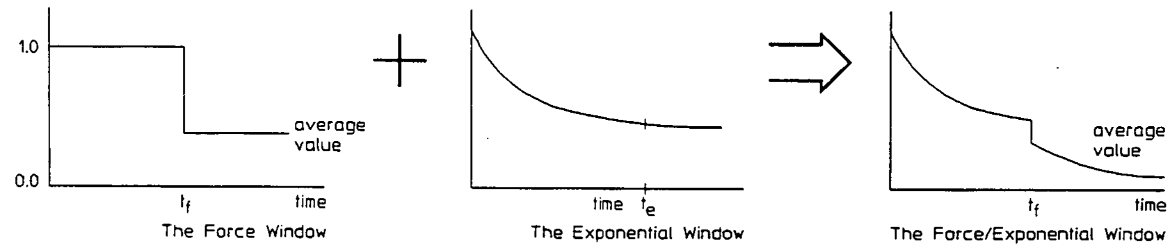

Figure 5-13.
The Force/Exponential Window

The *time constant* (t_e) and the *force time* (t_f) are both set under the separate [FORCE/EXP] column in the [**Freq**] menu.

The *time constant* (t_e) parameter for the exponential window attenuates both channel 1 and channel 2 signals at a decaying exponential rate. Enter t_e for the exponential window by enter an integer from 0 to 10 under [EXP TC:]. Entering 6 means the final value of the exponential window is exp(-6) or 0.0025 times the level of the data. The higher the integer, the more the channel 1 and channel 2 traces will be exponentially decayed.

The force window sets all channel 1 data after the *force time* (t_f) to a fixed value. This fixed value is the average value of the remaining portion of the data record from t_f to the end of the data record.
In equation form:

```
Data Record(t>tf) = Average{Data Record(t>tf)
```

The force window is applied to channel 1 only. Set the time period where you want the force window applied (t_f) under [FORCE %L:] as a percentage of the time record length. It can range from 0 to 100%. Determine [FORCE %L:] by making a trial impact and view the resulting input signal on channel 1 in the time domain. Calculate and enter [FORCE %L:] by the following procedures:

1. To calculate the [FORCE %L:] percentage by moving the marker to the desired point (past the impact response) and divide the marker value by the time record length. The time record length is the displayed stop time if the displayed is compressed (the default). If you are viewing an expanded display, press [**Shift**] [**COMPRESS**] and use this displayed stop time in the calculation. Enter this value in percent under [FORCE %L:] and press [**Enter**].

2. Return to an expanded display by pressing [**Shift**] [**EXPAND**].

Note

For impact testing using the [PREVIEW] feature, look for the overload indicator ("1 OVER" or "2 OVER") at the bottom of the display for each impact. If one of the channels overloads, press [0] to reject the overload data and try another impact or adjust the [**Input**] [RANGE] for the appropriate channel.
If you are using trigger delay, the time domain trace still starts at 0 seconds. Therefore trigger delay does not effect the way you set [FORCE %L:].

To select the [FORCE/EXP] window for impact testing;

1. Connect the input from the hammer to channel 1 and the output from the device under test to channel 2.
2. Press [**Freq**].
3. Move the column cursor to [WINDOW].
4. Move the row cursor to [FORCE/EXP].
5. Move the column cursor to [FORCE/EXP].
6. Enter an integer for [EXP TC:] and press [**Enter**].
7. Press [**Input**] and select [ICP] coupling for both channels. Select an appropriate [RANGE] for each channel. It may take some experimenting to get the right ranges for each channel but initially set them to some level.
8. Press [**Trigger**] and select [CH1] as the trigger [SOURCE] and [SINGLE] trigger [MODE].
9. To display the impact on trace A in the time domain and the frequency response on trace B, press [**Data**] and select [TIME CH1] in the [TRACE–A] column, [FREQ RESP] in the [TRACE–B] column, [REAL] in the [Y–AXIS: A] column, and [dB MAG] in the [Y–AXIS: B] column.
10. To make an average measurement, preview each data record, and accept or reject it for the average, press [**Avg**] and select [RMS] in the [TYPE] column. Enter the desired number of averages in the [NUMBER:] column. Move the column cursor to [OPTIONS] and move the row cursor to [PREVIEW]. Turn it [ON] by pressing [**Enter**].
11. Press [**Start**] and notice the "W" indicator waiting for the impact. Do a trial impact.
12. After each impact, press [**1**] to accept the data and use it in the average or press [**0**] to reject bad data due to overload, underload, a bad impact, or some other reason.

See [WINDOW] for information on other window types. For more information on impact testing, see the discussion under [FREQ RESP].

[FORCE %L:]

Use [FORCE %L:] to set the force window time (t_f) as a percentage of the time record length when you use the [FORCE/EXP] window. The force window multiplies each data point in the time record by 1 for $t<t_f$ and sets each data point to the average value of the remaining points in the time record for $t>t_f$. To set [FORCE %L:], make a trial impact first. Move the marker to the desired point on the display for t_f. Then calculate and enter the [FORCE %L:] value .

[**Format**]

Press [**Format**] to bring up a menu that controls the way you view traces A and B on the screen. You can view one trace at a time or both traces. When you view both traces, trace A can either be above trace B or in front of trace B. When you view both traces, toggle the active trace status by pressing [**Enter**]. The active trace is indicated by the "ACT →" message on the top or bottom message bar of the display. You can also select a spectral map of trace A or B which shows the spectrum of a trace as it changes over time. Spectral map lets you select the number of traces, the amount of suppression, and whether or not you want overlapping lines hidden. For time domain measurements, you can display y-axis data from channel 1 vs. y-axis data from channel 2 in an orbit display. See the name of each menu item (listed below) for more information.

- [A ONLY]
- [B ONLY]
- [A ABOVE B]
- [A FRONT B]
- [MAP A]
- [MAP B]
- [ORBIT]

[FREERUN]

To process input data as quickly as possible without waiting for any kind of triggering signal, select [FREERUN] as the trigger source.

[**Freq**]

Press [**Freq**] to control the following parameters.

- Frequency span.
- Resolution (number of lines displayed).
- Zooming (looking at a small portion of the spectrum).
- Windowing.
- Anti-alias filters.
- Sample clock.

With the anti-alias filters switched off, the HP 3560A behaves as a 100 kHz sampling rate digital oscilloscope, but with greater resolution than conventional instruments. See the *HP 3560A Getting Started Guide*, "Understanding the HP 3560A" for more information on time domain measurements. In a spectral process the [BASEBAND] equals the frequency band displayed.

[FREQ RESP]

[FREQ RESP] is a process in the [**Data**] menu which gives the frequency response (otherwise known as transfer function or transmissibility). It is a two channel process that gives the ratio of the output of a system (applied to channel 2) to the input of a system (applied to channel 1). The result is a dimensionless amplitude trace (V_{out}/V_{in}) versus frequency or phase trace ($\Theta_{out} - \Theta_{in}$) versus frequency. In other words, [FREQ RESP] measures the amplitude and phase difference between the input and output signals.

Applying averaging gives you a more "clean" frequency response curve and gives an improved estimate of the mean level of the curve. You can use any y-axis coordinate type with [FREQ RESP] (i.e., [LINMAG], [dB MAG], [PHASE], etc.)

To display the amplitude and phase response of channel 2 with respect to channel 1 (CH2/CH1), connect the reference signal to channel 1 and the output signal to channel 2. Set up the analyzer as follows.

1. Press [**Data**].
2. Move the column cursor to [TRACE–A].
3. Move the row cursor to [FREQ RESP].
4. Move the column cursor to [TRACE–B].
5. Move the cursor to [FREQ RESP].
6. Move the column cursor to [Y–AXIS: A].
7. Move the row cursor to [dB MAG].
8. Move the column cursor to [Y–AXIS: B].
9. Move the row cursor to [PHASE].

This gives the logarithmic magnitude response of CH2/CH1 on trace A and the phase response CH2/CH1 on trace B.

A common problem in machinery vibration analysis is that vibration from one machine in a series of machines is transferred to other machines resulting in misleading analysis results. The coherence function can help with these problems by indicating the cause and effect relationship between vibrations at two locations. Use it as a method of checking that the results obtained by the frequency response function are indeed valid. See the discussion under [COHER] for more information.

Discussion

Frequency Response is one of the most informative and widely used signal processing functions. For example, it serves as a means of characterizing;

- Electronic filter and amplifier performance.
- Control system behavior.
- Mechanical structures.

Hammer Test Application One of the main uses of frequency response is in the examination of natural frequencies and structural analysis.

You can determine the natural frequencies of a machine housing or foundation by performing what is occasionally referred to as a "bump" test. If you impact the housing with sufficient energy (typically with a block of wood), all the natural frequencies are excited. If you measure the response via a single channel, an imperfect impact may result in a misleading spectrum.

The frequency response function gives a more reliable way to make this measurement with an impact hammer. Typically, the analyzer setup would include the following settings (assuming you start from the [**Preset**] settings):

1. [**Freq**]
   [WINDOW]
      [FORCE/EXP]
   [FORCE/EXP]
      [EXP TC:] (set as desired)
2. [**Data**]
   [TRACE–A]
      [TIME CH1]
   [TRACE–B]
      [FREQ RESP]
3. [**Format**]
   [A ABOVE B]
4. [**Trigger**]
   [SOURCE]
      [CH1]
   [MODE]
      [SINGLE]
5. [**Avg**]
   [TYPE:]
      [RMS]
   [NUMBER:] (set as desired)
   [OPTIONS]
      [PREVIEW] [ON]
   Perform trial impact and move the marker to the point after the impact.
   Set [FORCE %L:] automatically by pressing [**Shift**] [**3**].

Figure 5-14 shows a hammer test for natural frequencies of a gearbox. The resulting frequency response is shown in figure 5-15.

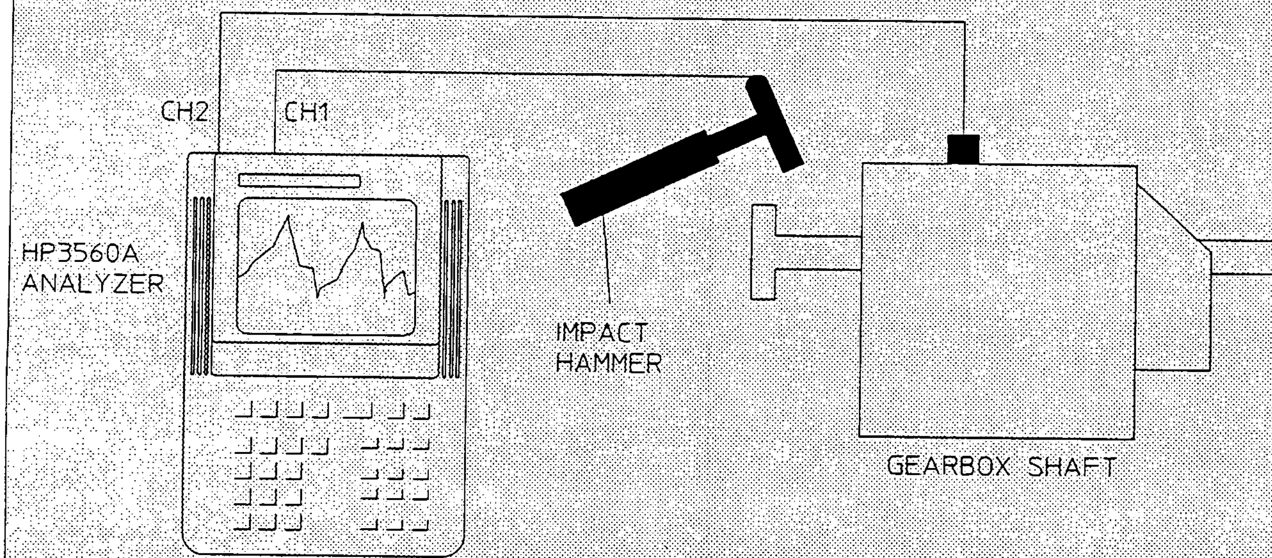

Figure 5-14.
Example using Impact Hammer

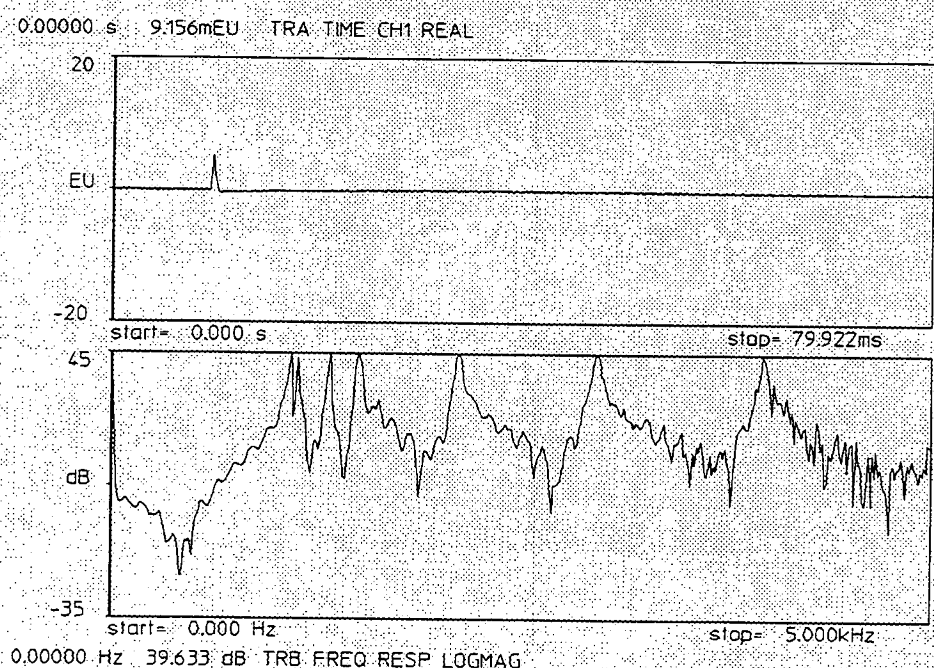

Figure 5-15.
Frequency Response using Impact Hammer

Since, gear defects often show up at their natural frequencies, this information is extremely useful.

Note Use the [FORCE/EXP] window for best results when you are doing a hammer test. Also, the [PREVIEW] feature lets you accept or discard data before it is used in an average.

Phase Measurements Comparative phase measurements are a powerful tool for analysis, especially for differentiating between fault mechanisms which produce similar vibration characteristics.

Consider the motor-pump combination in figure 5-16.

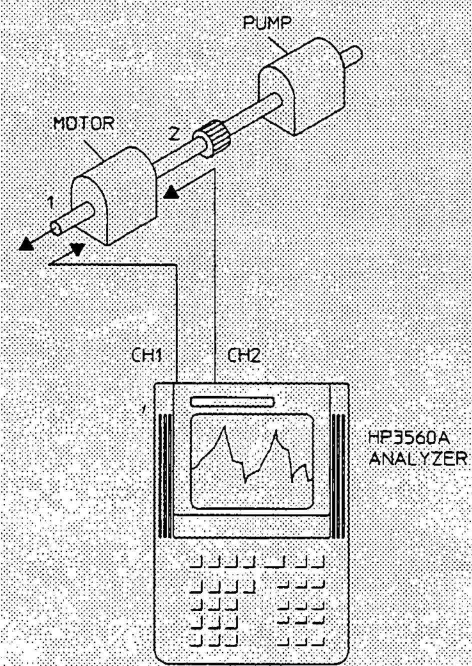

Figure 5-16.
Example using Phase Response

The amplitude of the vibrations may show a high level of vibration but leave you uncertain as to whether it is caused from imbalance or misalignment. The relative phase of axial vibration at points 1 and 2 will be 180° if misalignment is the problem. One way to make this measurement is to use an external trigger synchronized to the shaft as the reference signal and measure the phase at both points independently. However, using [FREQ RESP] eliminates the need for an external trigger since you only need to make two connections; one end to each channel. Then simply select [FREQ RESP] and choose [PHASE] as the coordinates of the displayed trace.

How Does the Instrument Calculate Frequency Response? The frequency response H(f) of a linear system quantifies the way spectral components of an input x(t) are modified and recombined in the system output y(t) as shown.

$$y(t) = h(t) * x(t)$$

Where * denotes the convolution operation and h(t) is the impulse response of the system.

In the frequency domain, the equivalent relationship is:

$$Y(f) = H(f) \quad X(f)$$

$$H(f) = \frac{Y(f)}{X(f)}$$

In systems which are subject to noise-like inputs or have an output which is corrupted by an undesirable random disturbance, the equation becomes:

$$H(f) = \frac{Y(f) + N(f)}{X(f)}$$

where N(f) is a random disturbance. This introduces an undesirable error into the measurement. Therefore, the HP 3560A calculates frequency response using the following equation.

$$\frac{\text{Cross-Spectrum}}{\text{spectrum}} = \frac{Sxy(f)}{Sx(f)}$$

where $S_{xy}(f)$ is the averaged Cross-Spectrum estimate and $S_x(f)$ is the average spectrum. Since $S_{xy}(f)$ reduces any uncorrelated signals between the two channels, the effect of N(f) is minimized. This is a commonly accepted method of calculating frequency response.

[GRID:]

Turn the display grid on and off using [GRID] in the [DISPLAY] column of the [**Utility**] menu. To turn the grid on perform the following.

1. Press [**Utility**].
2. Move the column cursor to [DISPLAY].
3. Move the row cursor to [GRID:].
4. Toggle to [ON] using [**Enter**].
5. Press [**Start**] to return to the data display.

[HANDSHAK:]

This configures the analyzer's RS-232 "handshake" (hardware flow control). The hardware handshaking prevents the HP 3560A from transmitting data faster than the receiver can process. You can select either CTS or CTS + DSR hardware handshaking. In addition to hardware handshaking, the HP 3560A responds to software flow control using XON and XOFF characters.

[HANN]

The [HANN] window produces narrow spectral lines and so is useful for accurate frequency measurement. It is the most generally used of the windows provided in the HP 3560A because it gives a good tradeoff between frequency resolution and amplitude accuracy. See [WINDOW] for an explanation of the purpose of windowing and for a comparison of the four different types of windows available in the instrument. Also, The *HP 3560A Getting Started Guide* discusses windowing in the "Spectrum Analyzer Basics" section.

Select the [HANN] window by performing the following.

1. Press [**Freq**].
2. Move the column cursor to [WINDOW].
3. Move the row cursor to [HANN].
4. Press any hardkey to exit the menu.

[HARM MKR]

[HARM MKR] is a shift function that lets you mark up to 20 multiples of a fundamental frequency which is specified by the main marker. The analyzer displays as many markers as the current frequency span allows. To position the main marker, use the [⇐] and [⇒] keys until the vertical line coincides with the fundamental signal. Then press [Shift] [HARM MKR] and up to 20 dashed vertical lines will appear at integer multiples of the main marker. See figure 5-17. To read out the frequency of each harmonic, move the main marker using the [⇐] and [⇒] keys.

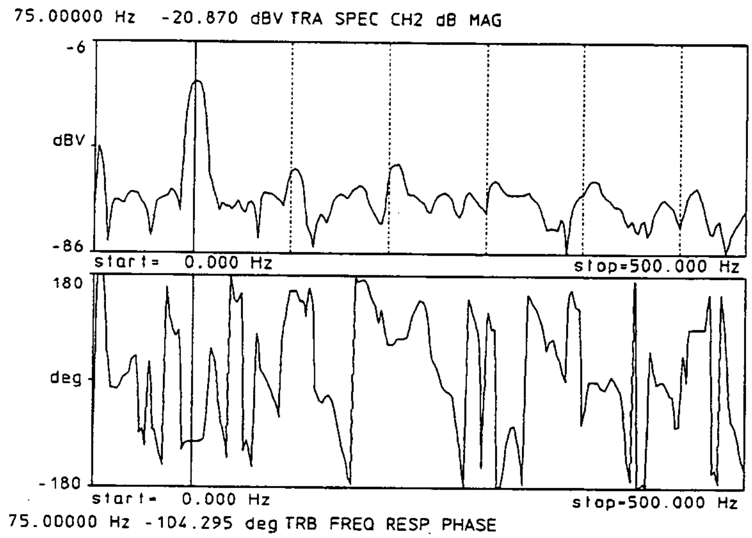

Figure 5-17.
Harmonic markers

Press [Shift] [HARM MKR] again to turn off the harmonic markers. You can not display harmonic markers in a spectral map.

[HARM MKR] serves a different function when you are using an octave analysis display.

[HIDLINE]

This function lets you display a spectral map that is free of overlapping lines. See figure 5-18.

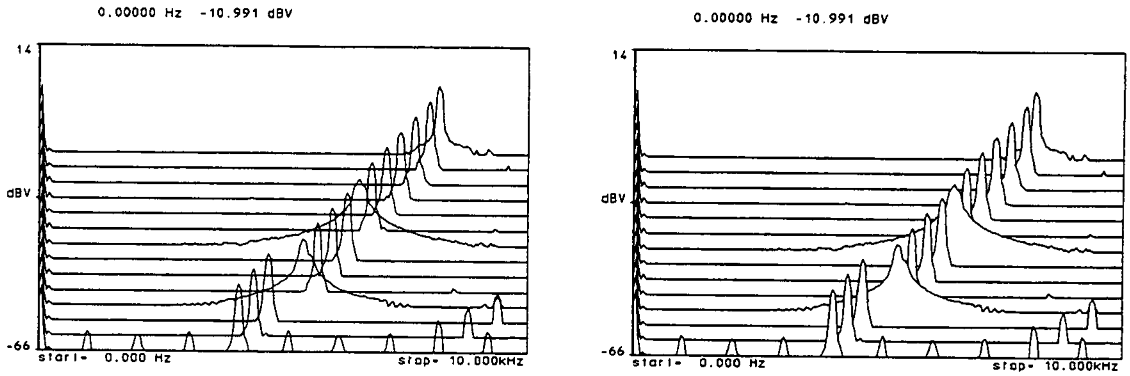

Figure 5-18.
Spectral map with [HIDLINE] set OFF and ON.

To turn on the hidden lines feature;

1. Press [**Format**].
2. Move the column cursor to [MAP].
3. Move the row cursor to [HIDLINE].
4. Press [**Enter**] to toggle to the [ON] position.
5. Press any hardkey to exit the menu.

Note

Turning on [HIDLINE] can slow down the refresh rate of the spectral map. For the best refresh rate, turn off [HIDLINE].

[HP PRINT]

If you are using a Hewlett-Packard printer, select [HP PRINT] in the [**Utility**] menu to get a hardcopy of the currently displayed data. Pressing [**Shift**] [**PRINT**] immediately executes the output of the graphics data via the RS-232 interface. Pressing [**Preset**] during the transfer aborts the transfer. See [**PRINT**] for details on how to connect the HP 3560A to a printer or plotter with a 25-pin RS-232 connector.

Note The printout lists band information in octave analysis. Also note that if you have harmonic cursors in a spectral process, peaks are not listed.

[ICP]

Select [ICP] in the [COUPL1/2] columns of the [**Input**] menu to use the accelerometer interface. The HP 3560A has a built-in 4 mA constant current power supply with up to 24 Vdc open circuit voltage which facilitates the interfacing of ICP (Integrated Circuit-Piezoelectric) type accelerometers. The accelerometer is ac coupled with a 3 dB cut-off of about 0.5 Hz. The interface is overvoltage protected.

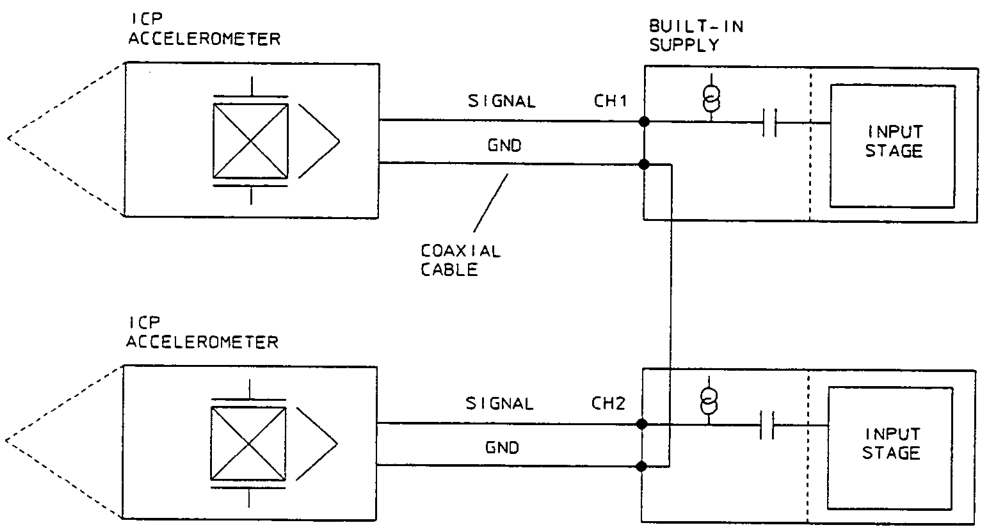

Figure 5-19.
Accelerometer interface

Caution

To avoid damaging non-ICP devices, make sure you do not have [ICP] coupling selected in the [**Input**] menu before connecting devices to the channel 1 and channel 2 inputs. Pressing [**Preset**] also deselects [ICP] coupling. However, turning the HP 3560A off and on again does not deselect [ICP] coupling.

An ICP type accelerometer has a built-in preamplifier micro-circuit which produces a high level output signal. As a result, these accelerometer systems:

- Significantly reduce cable noise.
- Allow for long cable length.
- Eliminate the requirement for costly charge amplifiers.

Notice the capacitive coupling in the accelerometer interface in figure 5-19. This eliminates any static signal components. This ac coupling circuit has its 3 dB point at about 0.5 Hz. Therefore, there is an inherent delay characterized by its time constant of at least 10 seconds (depending on the input range you select). After you press [ICP], wait for at least 20 – 30 seconds before you make a measurement.

To turn on the ICP supply for channel 2;

1. Press [**Input**].
2. Move the column cursor to [COUPL2].
3. Move the row cursor to [ICP].
4. Press any hardkey to exit the menu.

Discussion

There are several methods of fixing the accelerometer to the device under test including:

- A magnetic base mount.
- Quick-fit arrangement (permanently fitted stud).
- Hand-held probe.
- Permanently installed sensors.
- Wax.

Caution

To assure accurate results, make sure you electrically isolate the transducer by using non-metallic washers, nuts, or wax for securing the transducer to the device under test. This is especially important when you use both channels on the analyzer. Failing to electrically isolate the transducers can cause ground currents to form that may obscure data.

See the *Vibration Measurement Basics* section for more information on selecting and mounting transducers.

The [VOLTS/EU] feature in the [**Scale**] menu provides a convenient way to scale measurements to any engineering units you desire. This is particularly useful for scaling measurements taken from accelerometers, and where single or double integration is used to obtain velocity or displacement measurements (using [INTEGR] in the [**Input**] menu). See the scaling tables under [VOLTS/EU] for more information.

[IMAG]

Press [IMAG] to display the imaginary part of the measurement results on the y-axis of traces A or B. The x-axis is frequency or time.

For frequency domain measurements, the imaginary trace represents the imaginary part of the complex FFT data. See the *HP 3560A Getting Started Guide*, "Spectrum Analyzer Basics" and "Understanding the HP 3560A" for more information on the FFT process and trace coordinates.

For time waveforms, the imaginary part is equal to zero. However, if you use [ZOOM] to obtain the time record, the [IMAG] display can be difficult to interpret. This is because the [ZOOM] algorithm multiplies the time waveform by a cosine function. The frequency of this cosine function equals the center frequency of the [ZOOM]. This multiplication causes the imaginary part of the time waveform to have a non-zero value. [ZOOM] also causes the [REAL] and [IMAG] traces to be frequency-shifted. See [REAL] for more information.

To select imaginary coordinates for trace B;

1. Press [**Data**].
2. Move the column cursor to [Y-AXIS: B].
3. Move the row cursor to [IMAG].
4. Press any hardkey to exit the menu.

[**Input**]

Press [**Input**] to specify input sensitivity, coupling, and number of integrations to be performed on channels 1 and 2. See the name of each softkey in the [Input] menu for more information.

[INTEGRATE]

If you want to integrate results of a process like turning an acceleration trace into a velocity or displacement trace, use [INTEGRATE]. This column heading in the [Input] menu lets you select different levels of integration for both channels 1 and 2. Select no integration, single integration, or double integration. For example, if you are using a spectral process like [SPEC CH1] on an accelerometer input and you select one level of integration, the result is a velocity spectrum. Two integrations gives a displacement spectrum. The display indicates the level of integration you select by displaying "I1" or "I2" for single or double integration.

To select double integration for channel 1;

1. Press [**Input**].
2. Move the column cursor to [INTEGR].
3. Move the row cursor to [TWICE].
4. Press any hardkey to exit the menu.

The [INTEGRATE] choices change depending on the [Y-UNITS] setting in the [SCALE] menu. When [Y-UNITS] are not [g], the [INTEGRATE] choices are [OFF], [ONCE]and [TWICE]. When [Y-UNITS] are [g], the choices are [VEL m/s], [DISPL m] [VEL in/s], and [DISPL in]. These choices allow accelerometer measurements to be converted to velocity or displacement, in either metric or English units.

Integration is done in software on the data after it is converted to the frequency domain by the FFT. For one integration, each spectral line (or bin) is divided by $2\Pi f$, where f is the frequency in Hz of that bin. For two integrations, each spectral line is divided by $4\Pi^2 f^2$.

[LASER PLOT]

Use this selection under [PRINT:] in the [UTILITY] menu if your printer accepts HP-GL plotter commands. The analyzer will output an escape sequence to switch the printer to HP-GL language, before sending plotter commands.

[LEVEL]

[LEVEL] sets the trigger level to a percentage of the total input range. Enter an integer from -100 to +100. This means that a trigger level of 0 is equivalent to a trigger level of 0 Volts. If the specified input range is ± 5V, the [SLOPE] is [POSITIVE], and the trigger [LEVEL] is -20%, the analyzer will trigger when the triggering signal is at –1V. Figure 5-20 shows a 70% triggering point (positive slope) for a sinusoidal waveform.

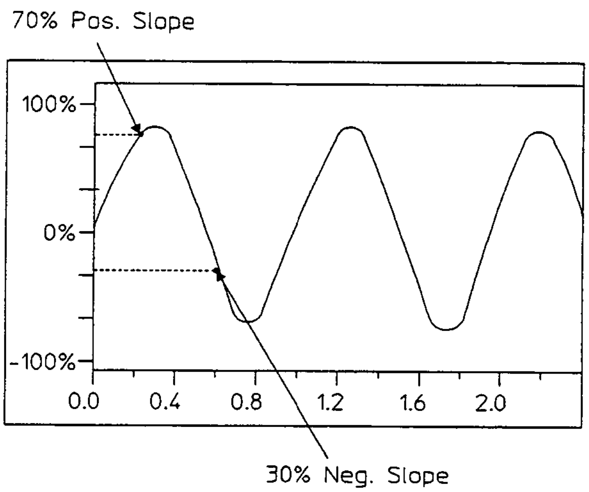

Figure 5-20.
Trigger Level = 70%

To set a 70% trigger level;

1. Press [**Trigger**].
2. Move the column cursor to [POINT].
3. Move the row cursor to [LEVEL].
4. Key in **7 0** using the numeric keypad
5. Press [**Enter**].
6. Press any hardkey to exit the menu

This level applies only to triggering generated internally from incoming signal data, not from the External Trigger input.

[KEY BEEP]

Enables and disables the key beeper. If the key beeper is on, the analyzer beeps each time you press a key.

[LINEAR]

You can have a linear or logarithmic scale for the x-axis of the display. To specify a linear scale;

1. Press [**Scale**].
2. Move the column cursor to [X-AXIS].
3. Move the row cursor to [LINEAR].
4. Press any hardkey to exit the menu.

Note The analyzer's frequency resolution is determined by the [BASEBAND] and [RESOLUTN] settings. For linear and logarithmic x-axis scales the number of points on the display is identical — both have a 320 points per display. The logarithmic scale simply displays these points on a logarithmic x-axis.

[LINES]

Select up to 1600 lines of resolution which sets the record length or number of data points to be collected for each channel.

```
Number of lines × 2.56 = data record length
```

You can have 100, 200, 400, 800, or 1600 lines. To select 400 lines;

1. Press [**Freq**].
2. Move the column cursor to [RESOLUTN].
3. Move the row cursor to [400 LINES].
4. Press any hardkey to exit the menu.

Actually the number of lines is 101, 201, 401, 801, and 1601 to include the endpoints of each baseband span.

Normally, if there are more lines of resolution than the analyzer can display, the analyzer displays a compressed spectrum. To view an expanded spectrum, press [**Shift**] [**EXPAND**]. Then use the [**PAN RIGHT**] and [**PAN LEFT**] shift functions to look at other portions of the expanded spectrum. Press [**Shift**] [**COMPRESS**] to return to a compressed spectrum.

For spectrum analysis, the number of lines is the number of points shown. However, in the time domain over twice as many points are shown. For example, in spectrum analysis, 800 lines of FFT data represent only the upper half of the "mirrored" output spectrum. The actual number of data points needed to produce 800 lines is 2.56 times 800 or 2048. Measurements in the time domain do not require this process so all 2048 data points can be displayed. See the *HP 3560A Getting Started Guide*, "Spectrum Analyzer Basics" for more information on how the FFT works.

[LINMAG]

Set the y-axis coordinates of traces A or B to linear magnitude by selecting [LINMAG] in the [**Data**] menu. You can choose [LINMAG] whether the x-axis is frequency or time.

To select a linear magnitude display of trace A;

1. Press [**Data**].
2. Move the column cursor to [Y–AXIS: A].
3. Move the row cursor to [LINMAG].
4. Press any hardkey to exit the menu.

If you have a linear magnitude display and are using engineering units, all points on the y-axis have a linear relationship regardless of the engineering units you have selected.

[LOG]

Press [LOG] in the [Scale] menu to specify a logarithmic scale for the x-axis. To specify a logarithmic scale;

1. Press [**Scale**].
2. Move the column cursor to [X-AXIS].
3. Move the row cursor to [LOG].
4. Press any hardkey to exit the menu.

Note

The analyzer's frequency resolution is determined by the [BASEBAND] and [RESOLUTN] settings. For linear and log x-axis scales the number of points on the display is identical. The logarithmic scale simply displays these points on a logarithmic x-axis.

Since the log of 0 Hz is minus infinity, a logarithmic scale with a [BASEBAND] setting which starts with 0 Hz shows the frequency of the first line instead of the nominal value of 0 Hz. For example, if you have a 10 kHz [BASEBAND], the first frequency shown on the logarithmic scale is labeled 31.25 Hz (10kHz/320 display points).

[LOGMAG]

[LOGMAG] sets the y-axis coordinates of traces A or B to logarithmic magnitude but gives y-axis and marker annotation in linear units (volts or engineering units).

To select a logarithmic magnitude display with annotation in linear units for trace A;

1. Press [**Data**].
2. Move the column cursor to [Y–AXIS: A].
3. Move the row cursor to [LOGMAG].
4. Press any hardkey to exit the menu.

[LOGMAG] coordinates are convenient for setting up the display to read in g's without giving up the data display range advantage of logarithmic displays. For example, if you have an accelerometer with a sensitivity of 10 mV/g;

1. Under the [**Scale**] menu, enter 10 mV/g (0.01) under [VOLTS/EU].
2. Select [g] as the engineering unit for the appropriate channel under [Y–UNITS].
3. Select [LOGMAG] in the [Y–AXIS: A] column of the [**Data**] menu.

Use [LOGMAG] whether the x-axis is frequency or time. The data for [LOGMAG] displays is calculated from the linear data using the formula 20 LOG (V_{linear}). The display annotation reads out in the selected [Y-UNITS].

[MAP]

[MAP] is a column in the [**Format**] menu that lets you choose parameters for displaying a spectral map. A spectral map lets you display successive spectral measurements and shows you how the spectrum changes with time. Use the spectral map feature when you want to analyze changes in up to 99 successive measurements. This can save you time and give you a trend analysis of your system. For example, spectral map provides an overall picture of machinery behavior during run-up or coast down, and allows you to identify important orders of vibration. See figure 5-21 for a sample run-up test using spectral map.

Specify the total number of successive measurements you want displayed (from 2 to 99) using [TRACES]. You can also specify the level at which you want to ignore low level signals. Enter this as a percentage of the y-axis display range for the trace you are viewing in spectral map form. Turning on [HIDLINE] gives a more three-dimensional view of the spectral map by eliminating overlapping lines.

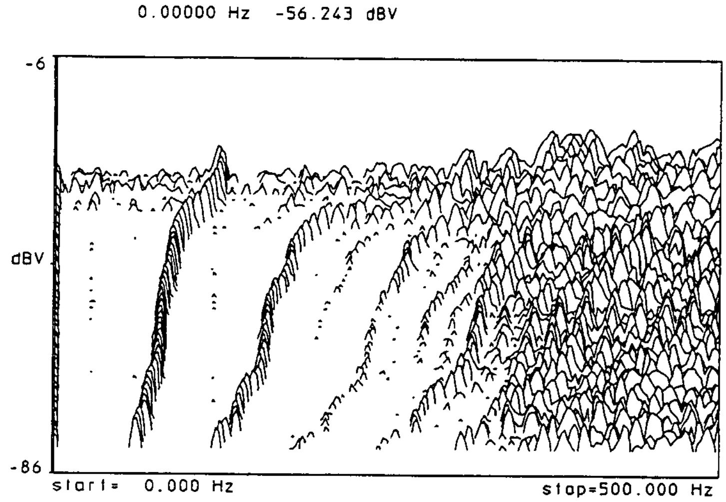

Figure 5-21.
Spectral map of run-up test

To get one map and stop acquisition after the last trace, select [SINGLE] as the trigger mode. For example, if you select 20 traces for the map and the [SINGLE] trigger mode, the map will stop once the complete "set" of traces are displayed. The specified trigger conditions must be met before the analyzer will take the data for each trace.

See the *HP 3560A Getting Started Guide* for an example of making an engine run-up measurement using spectral map.

Note

If you set up a TTL level external sampling signal whose frequency changes as a ratio of the rpm of the shaft, the spectral map feature can give you the frequency/amplitude spectrum versus rpm (i.e., an order analysis measurement). See [SAMPLE] for more information on order analysis. Otherwise, the z-axis is time.

[MAP A/B]

Press [MAP A] or [MAP B] to turn on the spectral map display format for trace A or trace B. Use the selections in the [MAP] column to modify the way the spectral map is displayed.

To select spectral map format for trace A;

1. Press [**Format**].
2. Move the column cursor to [FORMAT].
3. Move the row cursor to [MAP A].
4. Press any hardkey to exit the menu.

See [MAP] for an example spectral map display.

Measurement

Use this group of hardkeys to set up and control measurements.

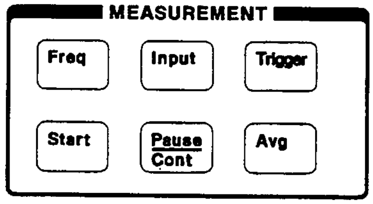

Figure 5-22.
Measurement Keys

[MKR PEAK]

Press [**Shift**] [**MKR PEAK**] to move the marker to the signal with the highest magnitude.

For displays with more than one trace, [MKR PEAK] moves the marker to the highest point of the active trace. The active trace is indicated by the "ACT → " message next to the active trace. When you are viewing both trace A and trace B, use the [**Enter**] key to toggle the active trace status.

Note

With a spectral map, the marker frequency value applies to all traces but the marker amplitude value applies only to the most recent (highest) trace. To read the marker amplitude of a lower trace, change [**Format**] [TRACES] to a lower number, so the trace becomes the highest

---

[MODE]

The trigger mode controls the repetition of data acquisition. Choose a or [RE-TRIG] or [SINGLE] trigger mode. [RE-TRIG] gathers and displays a data record each time the triggering signal satisfies the trigger selections. [SINGLE] "arms" the instrument to capture and display one record when it receives a suitable trigger. For measurements using the time average or spectral map features, [SINGLE] stops data acquisition after one "set" of time averages is taken, or one spectral map is complete. The specified trigger conditions must be met before the analyzer will take data for each average or spectral map trace.

To select [RE-TRIG] mode;

1. Press [**Trigger**].
2. Move the column cursor to [MODE].
3. Move the row cursor to [RE-TRIG].
4. Press any hardkey to exit the menu.

[OCT CAL]

Use [**Shift**] [**OCT CAL**] to calibrate octave analysis displays to a calibration tone. It adjusts the marker readout to the calibration tone value you enter in dB. All subsequent octave values read relative to this value. This calibration only applies to octave analysis processes when [Y-UNITS] are [SPL]. See the discussion under [OCT CH1/CH2] for an example of using [**Shift**] [**OCT CAL**].

[OCT/1 CH1/CH2] [OCT/3 CH1/CH2]

Measuring acoustic signals requires special techniques. An important consideration in acoustic analysis is frequency resolution. The human ear cannot detect two frequencies separated by a fixed difference at high frequencies as well as it can at low frequencies. Its response is logarithmic and is best characterised by using 1/3 octave analysis bands that become wider as the center frequency increases. These analysis bands have been used for a long time to measure acoustic signals and many noise specifications are written in terms of 1/3 and full octave analysis as defined by *ANSI Standard S1.11.** There is also an [A-WEIGHT] filter available for octave analysis measurements which simulates how the human ear perceives sound by weighting octave analysis data. See [A-WEIGHT] for more information.

The HP 3560A lets you select from full octave [OCT/1] and one-third octave [OCT/3] analyses in the [**Data**] menu. Full octave computes 10 frequency bands and one-third octave computes 31 bands. Both are single channel processes. The input signal can be from either channel 1 or channel 2. The [RESOLUTN] setting is ignored.

The range of bands calculated is determined by the [BASEBAND] setting in the [**Freq**] menu. Only the [5 kHz], [10 kHz], and [20 kHz] baseband spans are valid octave analysis spans. This frequency represents the highest band of the range which will be computed. For example, a [BASEBAND] setting of 10 kHz with OCT/3 will calculate 31 1/3 octave bands from 10kHz down and selects each band according to *ANSI standard S1.11.** (See the table at the end of the discussion for a list of these bands). In this example, the full range is 10 Hz to 10 kHz. See figure 5-23. Use the marker in the usual way to get accurate amplitude read-out at the top of the screen. The marker frequency readout gives the center frequency of the band. Table 5-4 summarizes the frequency ranges available.

Note

All bands are displayed on the screen simultaneously. In other words, there is no requirement for panning or scrolling the display using the arrow keys.

[ZOOM] does not work with octave analysis.

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* American National Standards Institute (ANSI)

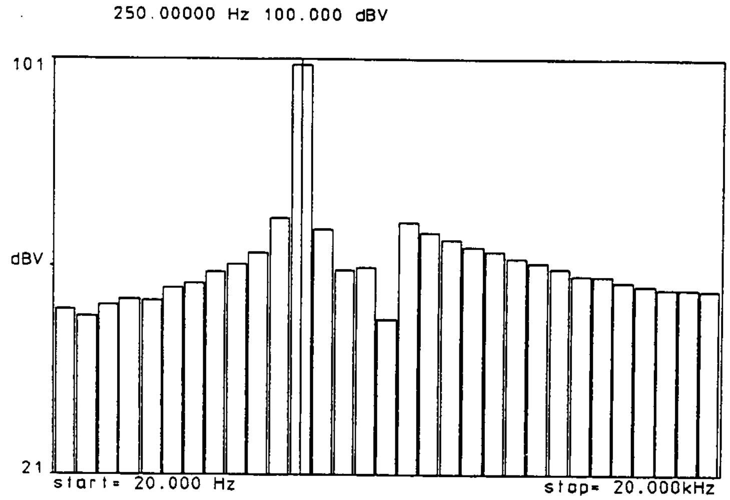


Figure 5-23.
Octave analysis measurement

Table 5-4. Octave and 1/3 Octave Ranges

Process	Baseband Frequency	Center Frequencies	Number of Bands
OCT/3	20 kHz	20 Hz - 20 kHz	31
	10 kHz	10 Hz - 10 kHz	
	5 kHz	5 Hz - 5 kHz	
OCT/1	20 kHz	31.5 Hz - 10 kHz	10
	10 kHz	16 Hz - 8 kHz	
	5 kHz	8 Hz - 4 kHz	

Note

As the table shows, only the 5 kHz, 10 kHz, and 20 kHz [BASEBAND] values are valid when you are using octave analysis.

To satisfy the resolution requirements, choose a record length of 2048 points (800 line resolution). For each octave analysis calculation, the analyzer computes two FFT's to provide the necessary resolution. First, the analyzer gathers data at the higher frequencies and computes an FFT. Then it gathers data at the lower frequencies and computes the second FFT. Then it processes both to provide an octave display. The low frequency FFT is sampled at a rate which is a tenth of the first FFT sampling rate. For example, if you select a 10 kHz span and the OCT/3 process, the first FFT will be sampled at 25.6 kHz. The second FFT will gather data at a rate of 2.56 kHz for the lower bands from 10Hz to 1kHz.

Note

Since there are two records gathered serially, the signal should be of a relatively stable nature.
For this same reason, you cannot reprocess time records on the HP 3560A to get octave analysis data. You also cannot send time records to a computer for post-processing to get octave analysis data.

To select 1/3 octave analysis and turn on A-weighting;

1. Press [**Data**].
2. Move the row cursor to [OCT/3 CH1] in both the [TRACE–A] or [TRACE–B] column.
3. Press [**Freq**].
4. In the [BASEBAND] column, select [5 kHz], [10 kHz], or [20 kHz].
5. Make sure [ZOOM] is turned [OFF].
6. If you want to use A-weighting, press [**Input**].
7. Move the column cursor to [A-WEIGHT] and move the row cursor to [ON].
8. Press any hardkey to exit the menu.

Discussion

Octave Analysis Calibration To calibrate an acoustic measurement, you must use a microphone calibrator. The typical calibrator is a pistonphone, which is a device that moves a piston in a cylinder to create an acoustic wave at a specific pressure or sound pressure level (SPL). The calibrator frequency and SPL can vary. Typical calibrator frequencies are 500 Hz, 250 Hz, and 1000 Hz and typical SPLs are 74, 84, 94, 114, and 124 dB. Figure 5-24 shows a typical calibration setup.

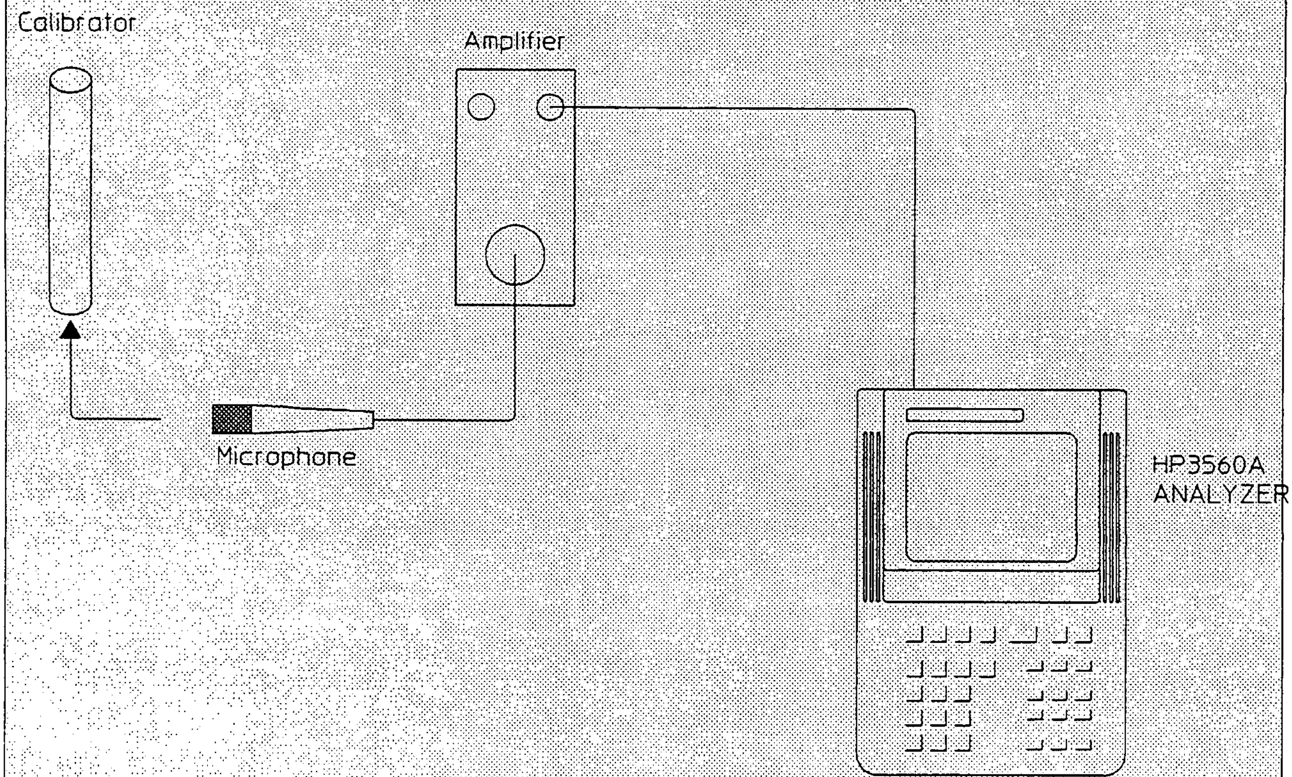


Figure 5-24.
Calibration setup

To perform a calibration;

1. Select the type of octave analysis you want as outlined in the steps above.
2. Press [**Scale**]
3. Move the column cursor to [Y-UNITS].
4. Toggle to [VOLTS]
   using the [**Enter**] key.

5. Place the microphone in the calibrator and press [**Start**] on the analyzer. Notice the single tone on the HP 3560A. Move the marker to this tone and note its value (in dBV). Use the marker value and the calibrator's SPL specification to ***manually*** calculate the proper scaling factor so that the marker reads SPL. This method is advantageous when you want the scaling factor applied to both octave analysis and narrowband measurements.

   The analyzer also lets you directly enter the calibrator's SPL. This method ***automatically*** changes the current marker value to the entered value. This method is advantageous when you want the calibration to apply to octave analysis measurements only.

6. To ***manually*** calculate the EU scale factor, use the following equation.

```
EU Scale Factor =
Measured Voltage/10^(Calibrator Specification/20)
```

   Most calibrators specify their SPL output in dB, which must then be converted to a linear ratio. This equation assumes the calibrator specification is given in dB, therefore the calibrator SPL is divided by 20 and raised as a power of 10.

   - Enter your calculated EU Scale Factor for channel 1 by pressing [**Scale**] and move the column cursor to [VOLTS/EU].
   - Move the row cursor to [CH1:] and enter the scaling factor in floating point notation according to the directions on the display.
   - Move the column cursor to [Y–UNITS] and move the row cursor to [CH1:]. Toggle to [SPL] using the [**Enter**] key.

7. To ***automatically*** calibrate the display, press [**Scale**] and move the column cursor to [Y–UNITS]. Move the row cursor to [CH1:] and toggle to [SPL] using the [**Enter**] key. Press [**Start**] to return the data display and measure the calibration signal. Move the marker to the calibration tone, and press [**Shift**] [**OCT CAL**]. Notice the message on the display, enter the calibrator's SPL in dB and press [**Enter**]. The marker now reads the value you just entered. The scaling factor applied appears under [VOLTS/EU] column in the [**Scale**] menu.

Note

When you have octave analysis data displayed, [**Shift**] [**OCT CAL**] changes the current marker reading to the value you enter via the numeric keypad. [**OCT CAL**] can only be used for octave analysis measurements.

To remove the calibration, press [**Scale**] and deselect [SPL] in the [Y-UNITS] column or change the [VOLTS/EU] value to 1.0.

Filter Bands For ANSI S1.11 – 1986

ANSI Band No.	Center Frequency (Hz)		A-Weighting (dB)
	1/3 OCTAVE	Octave	
7	5		—*
8	6.3		—*
9	8	8	—*
10	10		– 70.4
11	12.5		– 63.4
12	16	16	– 56.7
13	20		– 50.5
14	25		– 44.7
15	31.5	31.5	– 39.4
16	40		– 34.6
17	50		– 30.3
18	63	63	– 26.2
19	80		– 22.5
20	100		– 19.1
21	125	125	– 16.1
22	160		– 13.4
23	200		– 10.9
24	250	250	– 8.6
25	315		– 6.6
26	400		– 4.8
27	500	500	– 3.2
28	630		– 1.9
29	800		– 0.8
30	1000	1000	0
31	1250		+0.6
32	1600		+1.0
33	2000	2000	+1.2
34	2500		+1.3
35	3150		+1.2
36	4000	4000	+1.0
37	5000		+0.5
38	6300		– 0.1
39	8000	8000	– 1.1
40	10000		– 2.5
41	12500		– 4.3
42	16000	16000	– 6.6
43	20000		– 9.3

* The A-weighting attenuation for these frequency bands are greater than the dynamic range of the HP 3560A.

[OPERATION]

[OPERATION] is a column in the [**Save/Recall**] menu that lets you control the memory of the HP 3560A. The analyzer's non-volatile random access memory (RAM) can store up to 500 state/trace combinations with 200 line spectra. The functions under [OPERATION] let you [SAVE TRACE], [SAVE STATE], [RECALL TRACE], [RECALL STATE], [ERASE], [XFER ONE], and [XFER ALL] data records in the analyzer's memory. It also lets you view the contents of memory under [CATALOG]. Look under each function for more information on how they work.

[ORBIT]

Select [ORBIT] when you want to compare two input time waveforms in a Lissajous pattern. [ORBIT] displays y-axis data from trace A versus y-axis data from trace B. One of its uses is detecting assymmetries in rotating machinery. Figure 5-25 shows a typical shaft motion measurement setup. The displacement transducers are placed orthogonally and measure the shaft motion versus time. Figure 5-26 shows a typical orbit display which represents the motion of the shaft centerline. If you use external sampling, the display sampling can be synchronized to shaft rotation angle rather than time. Do this by attaching a shaft encoder directly to the rotor or a ratio synthesizer which synthesizes the pulses from an external tachometer signal as in figure 5-25. For example, if the pulse encoder gives 256 pulses per revolution, you would enter 256 under external sample in the [**Freq**] menu. Then each point on the orbit diagram would represent 360°/256 or 1.4°.

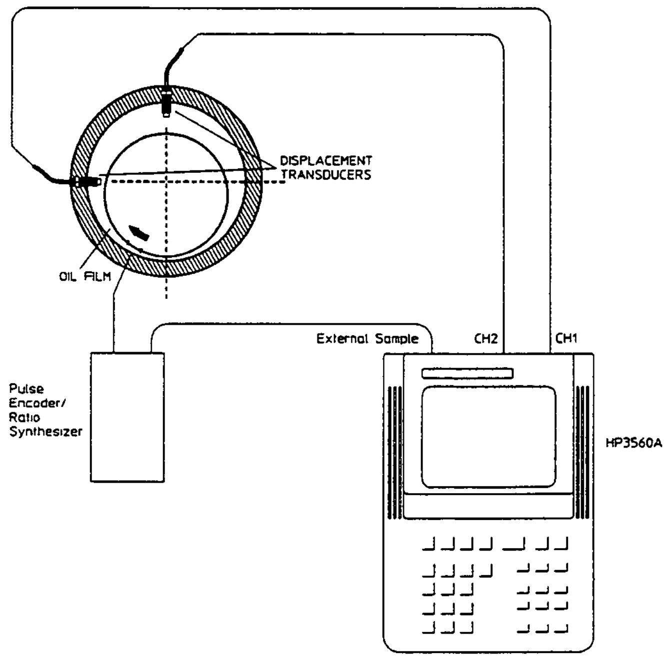


Figure 5-25.
Shaft Motion Measurement Setup

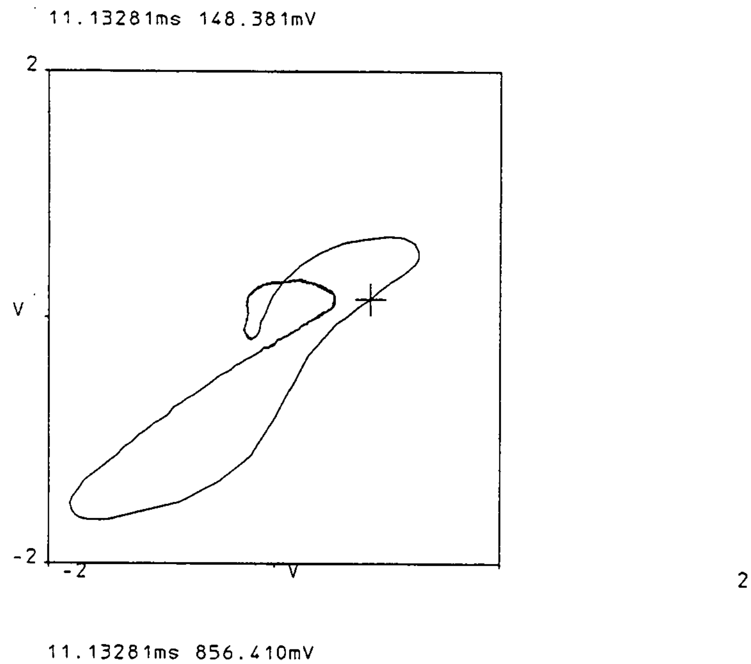


Figure 5-26.
Orbit Display

In this example, the axes are in units of volts per inch. The scaling for the engineering units depends on the displacement transducer you use.

Note

The orbit diagram assumes placement of one transducer on the vertical and the other on the horizontal. If the transducers are in a different orthogonal orientation, you must correct for this phase shift.

Also notice that the x- and y-axes must have the same range and resolution. In other words, choose the same input range for channel 1 and channel 2.

To set up the HP 3560A for this measurement;

1. Set up your measurement similar to figure 5-25.
2. Press [**Data**].
3. Move the column cursor to [TRACE–A].
4. Move the row cursor to [TIME CH1].
5. Move the column cursor to [TRACE–B].
6. Move the row cursor to [TIME CH2].
7. Move the column cursor to [Y–AXIS: A].
8. Move the row cursor to [REAL].
9. Move the column cursor to [Y–AXIS: B].
10. Move the row cursor to [REAL].

11. Press [**Format**].
12. Move the row cursor to [ORBIT].
13. If you are using external sampling, select it in the [**Freq**] menu and enter the number of pulses per revolution under external sample.
14. If you are using accelerometers instead of displacement transducers, select [TWICE] in the [INTEGR] column of the [**Input**] menu.

[PAN LEFT]

[**PAN LEFT**] is a shift function that pans or scrolls the display to the left. The display has 320 points on the x-axis. When you need higher resolution, you usually need a record length (selected by [RESOLUTN]) that is greater than the number of points on the display. This results in a display that is compressed to fit within 320 x-axis points. Press [**Shift**] [**EXPAND**] to expand the data and view only a portion of the full data record. Then use the [**PAN RIGHT**] and [**PAN LEFT**] shift functions to look at other portions of the expanded spectrum. Press [**Shift**] [**COMPRESS**] to return to a compressed spectrum.

Note Data Record Length = [RESOLUTN] setting × 2.56.

Press [**Shift**] [**PAN LEFT**] or [**Shift**] [**PAN RIGHT**] to view the other sections of data. This is called panning the display. You can pan the display whether you are viewing time domain or frequency domain data. Panning automatically stops at the beginning and end of the data record.

Note Another way to pan the display is to move the marker (using the [⇐] or [⇒] keys) to either edge of the display. New data is automatically moved in. If you want the marker to move faster, hold down the arrow key.

Normally, the displayed data is compressed. [**Shift**] [**EXPAND**] expands the spectrum to its full data record length. [**Shift**] [**COMPRESS**] displays the compressed spectrum again.

Discussion

Panning vs. Zooming Panning and zooming are both ways to take a close look at data. If you need high resolution for a measurement, either use zoom or choose a large data record and use panning. Panning lets you look at different sections of a data record that does not fit on the display. In other words, it scrolls a data record that is is too large to fit on the display. Choosing a large data record length is often necessary to get the resolution you need over some frequency range, especially at the higher frequency ranges. (The data record length depends on the [RESOLUTN] and [BASEBAND] settings). The full number of data points are sampled and FFT'ed, resulting in a display that is compressed. Press [**Shift**] [**EXPAND**] to expand the data, then use the [**PAN LEFT**] and [**PAN RIGHT**] shift functions to pan the display. The tradeoff for choosing a large data record is increased measurement time, expecially if you need high resolution at higher frequencies. A significant portion of this time is spent performing the FFT on the full data record.

When you know which portion of the data record you are interested in, using [ZOOM] can give you a speed advantage and higher resolution at higher frequencies than panning. The speed advantage comes from the fact that [ZOOM] lets you specify which part of the data record you are interested in and only performs an FFT on that portion. However, if you use [ZOOM] and decide to look at a different portion of the data record, you have to take a new data record. [ZOOM] gives higher resolution at higher frequencies because when you use panning, this means you have used a [BASEBAND] span setting which always starts a 0 Hz. For example, if you are only interested in the frequencies between 39 kHz and 40 kHz, and you use a [BASEBAND] span of 40 kHz and 1600-line resolution, each bin represents 25 Hz (40,000/1600). If you make a [ZOOM] measurement with the center frequency at 39.5 kHz and a frequency span of 500 Hz, and you use the same number of lines (1600), each bin represents 0.31 Hz (500/1600).

[PAN RIGHT]

[PAN RIGHT] is a shift function that pans or scrolls the display to the right. The display has 320 points on the x-axis. When you need higher resolution, you usually need a record length (selected by [RESOLUTN]) that is greater than the number of points on the display. This results in a display that is compressed to fit within 320 x-axis points. Press **[Shift] [EXPAND]** to expand the data and view only a portion of the full data record.

Note Data Record Length = [RESOLUTN] setting × 2.56.

Press **[Shift] [PAN RIGHT]** or **[Shift] [PAN LEFT]** to view the other sections of data. This is called panning the display. You can pan the display whether you are viewing time domain or frequency domain data. Panning automatically stops at the beginning and end of the data record.

Note Another way to pan the display is to move the marker (using the [⇐] or [⇒] keys) to either edge of the display. New data is automatically moved in. If you want the marker to move faster across the display, hold down the arrow key.

Normally, the displayed data is compressed. **[Shift] [EXPAND]** expands the spectrum to its full data record length. **[Shift] [COMPRESS]** displays a compressed data segment that is closest to the current marker position.

See the discussion under **[PAN LEFT]** to learn about the difference between panning and zooming.

[PAN UP] and **[PAN DN]**

These keys adjust the y-axis of the display by changing both the top and bottom values. Press **[Shift]** [⇑] to pan up and press **[Shift]** [⇓] to pan down. Use un-shifted [⇑] and [⇓] keys to adjust the y-axis of Y/DIV setting.

[PAN UP] and **[PAN DN]** only apply when the [Yaxis-A/B] is [LOGMAG] or [dBMAG], after the Y/DIV has been reduced.

[**Pause/Cont**]

Press [**Pause/Cont**] when you want to stop collecting and processing data. The first press pauses and displays the data. Pressing [**Pause/Cont**] again resumes data acquisition.

Putting the analyzer in a paused condition allows you to reprocess the currently displayed data. In other words, you can press [**Pause/Cont**] to freeze the display, exit to a menu to select different units or a different process, and press [**Start**] to return to the display with the different selection applied to the data. Pressing [**Start**] again overrides the pause condition and initiates data acquisition.

[PEAK HOLD]

[PEAK HOLD] is a selection in the [**Avg**] menu that holds the highest amplitude value for the specified number of data records. In other words, the analyzer compares the value of each frequency component of a new spectrum with the corresponding maximum values of the old spectrums and stores the maximum value. Consequently, at the end of the analysis each frequency line indicates the largest value encountered over the measurement time.

This feature is useful for analyzing time varying spectral lines like in frequency drift measurements and resonance identification.

Consider the example of a generator/turbine run-down experiment as in figure 5-27. With the turbine speed constant, the spectrum is dominated by the single spectral line at *f1* (top trace) which is harmonically related to the running speed of the machine.

During run-down the frequency *f1* decreases with speed and a "peak-hold" spectrum provides a plot of the variation in magnitude of this frequency. This "peak-hold" spectrum can help you diagnose and quantify the presence of machine vibration resonances.

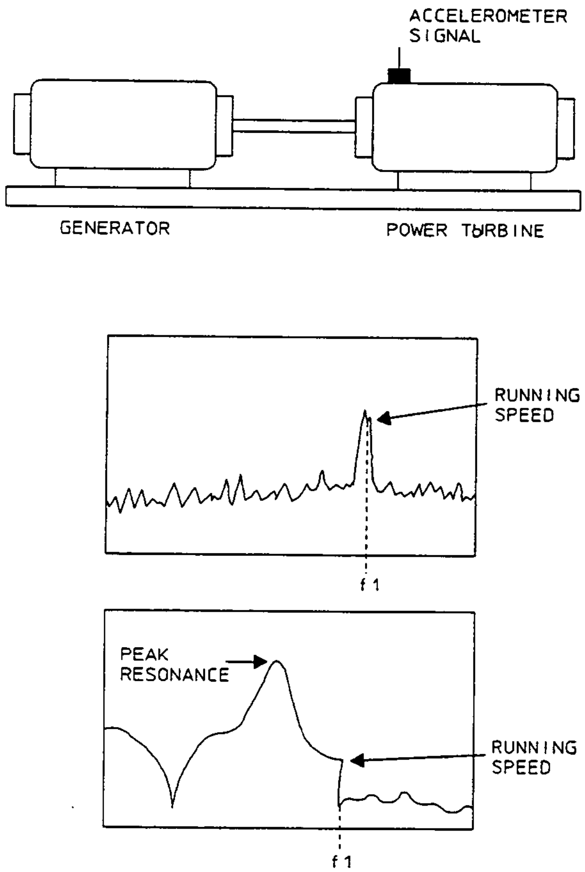


Figure 5-27.
Run-down test using [PEAK HOLD].

To select [PEAK HOLD] 10 measurements;

1. Press [**Avg**].
2. Move the row cursor to [TYPE:].
3. Move the row cursor to [PEAK HOLD].
4. Move the column cursor to [NUMBER:].
5. Key in **1 0** and press [**Enter**].
6. Press any hardkey to exit the menu.

[PHASE]

Set the y-axis coordinates of traces A or B to phase by selecting [PHASE] in the [Data] menu. For [PHASE], the x-axis must be frequency.

Phase is displayed in degrees (or radians). The analyzer scales the y-axis to ± 180 degrees. See figure 5-28.

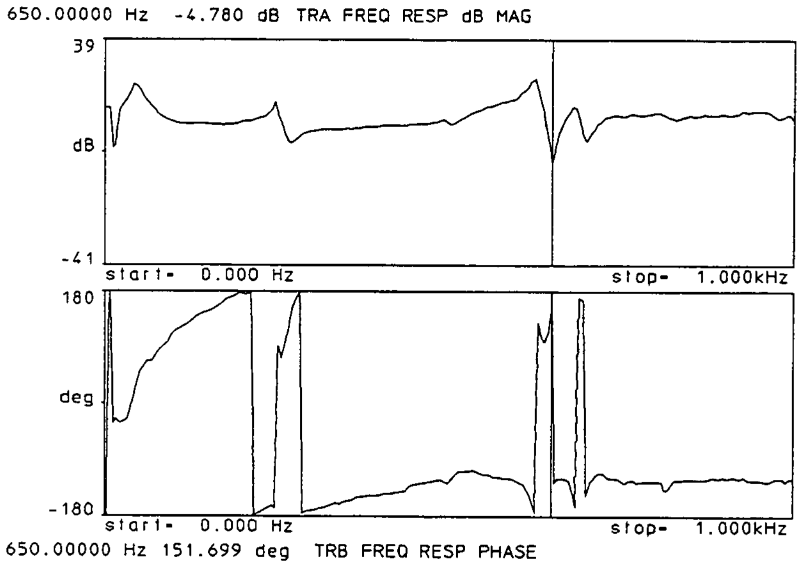


Figure 5-28.
Phase measurement

Note

The discontinuous areas on the phase trace are called phase wraps which allow the full trace to fit on the display. When the phase is greater than +180 degrees or less than – 180 degrees, the analyzer "wraps" the trace to – 180 degrees and +180 degrees, respectively.

To select a phase display of trace A;

1. Press [Data].
2. Move the column cursor to [Y-AXIS: A].
3. Move the row cursor to [PHASE].
4. Press any hardkey to exit the menu.

Phase accuracy is reduced for signal levels that are low relative to the full scale input range.

Discussion

The complete frequency domain representation of a signal consists of an amplitude spectrum and a phase spectrum. While the amplitude spectrum indicates signal level as a function of frequency, the phase spectrum shows the phase relationship between spectral components. In machinery vibration analysis, phase is required for most balancing techniques. It is also useful for differentiating between faults which produce similar amplitude spectra. However, for absolute phase to be meaningful, you need to use triggering that is related to the shaft speed. See the discussions under [SAMPLE] and [EXTERNAL] trigger for more information on obtaining a good reference signal.

[PLOT]

To get a hardcopy of the displayed data on an HP-GL plotter, select [PLOT] in the [MISC] column of the [**Utility**] menu. [PLOT] is a selection under [PRINT:] in this column. Pressing [**Shift**] [**PRINT**] outputs the graphics data via the RS-232 interface. Pressing [**Preset**] during the transfer aborts the transfer. The complete record is plotted and the grid can be turned on or off. See [**PRINT**] for instructions on how to set up the HP 3560A and a plotter. Figure 5-30 shows how to connect the HP 3560A to a printer or plotter with an RS-232 connector.

[POINT]

[POINT] is a column in the [**Trigger**] menu that lets you choose the signal conditions that satisfy the trigger. You can set the triggering point to a positive or negative slope and the level to an integer between +100 and -100. A trigger level of 50 is equivalent to half the positive range of the full scale input range. The full scale input range is selected in the [RANGE1/2] columns of the [**Input**] menu.

Figure 5-29 shows a 30% negative slope triggering point.

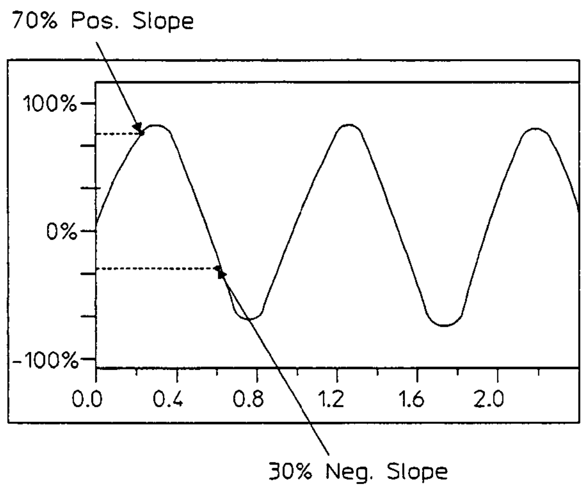


Figure 5-29.
Triggering point

Power Switch

Press [**On**] to power the HP 3560A and press [**Shift**] [**OFF**] to turn it off. Pressing two keys to turn off the analyzer guards against inadvertantly turning it off. When the [TIMEOUT] feature is turned on in the [**Utility**] menu, the instrument automatically turns off the analyzer after 10 minutes of no key presses to save the battery charge.

When you press [**On**], the analyzer does an internal self-test that takes several seconds and then it recalls the instrument settings and data that were used when the instrument was turned off. If the battery is not sufficiently charged when you turn on the instrument, the liquid crystal display will fade to blank. If the instrument powers but fails the self-test, refer to the Service section of this manual for instructions on troubleshooting.

[Preset]

Press [**Preset**] to reset the analyzer to its default values. Table 5-5 lists these default values. Keep in mind that pressing [**Preset**] is not the same thing as turning the analyzer off and then on again. Turning the analyzer on recalls all settings used when the analyzer was last turned off. Use [**Preset**] to put the analyzer in a known state when you are setting up a new measurement.

To avoid losing an instrument state or measured data due to inadvertantly pressing [**Preset**], a message tells you to press [**Enter**] to confirm your intention to preset the analyzer. The analyzer proceeds with the current measurement until you press [**Enter**]. Pressing any other hardkey cancels the preset and continues with the measurement uninterrupted.

Table 5-5. Default Instrument Settings

[Data]	TRACE–A: SPEC CH1	TRACE–B: SPEC CH2
	Y–AXIS: A: dB MAG	Y–AXIS: B: dB MAG
[Format]	FORMAT: A ONLY	MAP: TRACES: 10 SUPP%: 0 HIDLINE: OFF
[Scale]	X-AXIS: LINEAR	UNITS: VOLTS
[Freq]	BASEBAND: 20 kHz	ZOOM: OFF
	CENTER: 10 kHz	SPAN: 5 kHz
	RESOLUTN: 200 LINES	WINDOW: HANN
	FILTER: ON	SAMPLE: INTERNAL
	FORCE %L: 10	EXP TC: 4
[Input]	RANGE1: AUTO	COUPL1: DC
	RANGE2: AUTO	COUPL2: DC
	INTEGR: OFF	A-WEIGHT: OFF
[Trigger]	SOURCE: FREERUN	MODE: RE-TRIG
	SLOPE: POS	LEVEL: 0%
	DELAY CH1: 0	CH2: 0
[Avg]	TYPE: OFF	NUMBER: 1
[Save/Recall]	no changes	
[Utility]	FILL: OFF	GRID: OFF
[¤]	no change	

[PREVIEW:]

[PREVIEW:] is useful when you want to make sure all data used in an average is valid. When [PREVIEW:] is on, you can decide which data should be included in the accumulating average. This capability is often desired in structural tests using an impact hammer.

After each data record is collected, the analyzer displays channel 1 and channel 2 in the time domain. The analyzer waits until you respond by pressing either [**1**] or [**0**] on the numeric keypad. Pressing [**1**] means you accept the data from both channels for the average. When you accept a data record, the analyzer incorporates the data record in the average and updates the average display. Pressing [**0**] means the data from both channels is rejected and not included in the average. If one of the input channels overloads, this is a typical reason why you would reject data. When you reject data, the analyzer does not return to the previous display; rather, it leaves the rejected time record displayed until you change the display, take another data record, or restart the measurement.

When [PREVIEW:] is turned off, the average includes every time record and does not pause for verification. [PREVIEW:] works with all of the average types but it is disabled if the [MAP] or [ORBIT] features are selected. If [FREERUN] or [EXT START] is the trigger source, select the [SINGLE] trigger mode if you are using [PREVIEW:] so that new data does not immediately overwrite the average display after an accept or reject press. See [FORCE/EXP] or the impact testing discussion of under [FREQ RESP] for examples of using [PREVIEW].

[**PRINT**]

Press [**Shift**] [**PRINT**] to execute a direct plotter or printer output of the entire analyzer screen, including displayed markers. To get a hardcopy of the screen, use the following procedure.

1. Use the [PRINT] parameters in the [**Utility**] screen to specify whether you want to print or plot.
2. Make sure the HP 3560A baud rate, parity, and number of bits settings match the settings for the plotter or printer you are using. These settings appear in the HP 3560A [**Utility**] menu. Printer data is binary raster information, so you must select 8 data bits with no parity. For plotters, simply make sure the analyzer and plotter settings are the same. Refer to the operating guide of the printer or plotter for more information on how to change baud rate, parity, and number of data bits.
3. If you are viewing a menu, press [**Start**] once to return to the data display.
4. Connect the printer or plotter to the analyzer using the cable and pin connections shown in figure 5-30.
5. Press [**Shift**] [**PRINT**]. Pressing [**Preset**] during data transfer aborts the transfer. The printout also includes the following.
   - Date and time of the measurement
   - The settings in the [**Data**] menu
   - If the data has been saved or recalled, the register number.

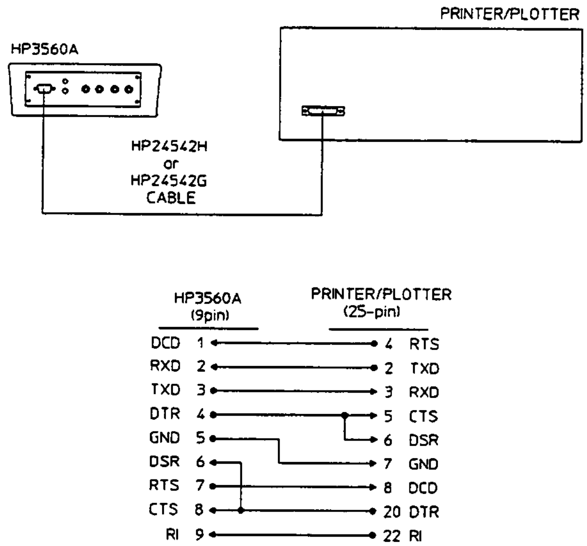


Figure 5-30.
PLOT/PRINT connection

* Use the HP 24542H cable with the HP 7550A plotter.

Note The printer or plotter must have an RS-232 connector. Printers and plotters with other interfaces will not work with the HP 3560A.

See [HP PRINT], [ALT.PRINT], [LASER PLOT] and [PLOT] for more information on each kind of output.

Note When you print the analyzer screen, you should also print the instrument settings used to produce the data. Press [**Shift**] [**STATUS**] to display the current instrument settings. Then use [**Shift**] [**PRINT**] again to get a hard copy and attach this to your data.

[PRTY]

You can modify RS-232 operation parameters in terms of baud rate, parity, and number of data bits. The parity can be even, odd, or none. If you select odd or even parity, you should set the number of data bits to If you choose not to have a parity bit, select 8 as the number of data bits.

To set an even parity;

1. Press [**Utility**].
2. Move the column cursor to [RS232].
3. Move the row cursor to [PRTY].
4. Toggle to [EVEN] by pressing [**Enter**].
5. Press any hardkey to exit the menu.

[PSD CH1/CH2]

[PSD CH1] and [PSD CH2] display the power spectral density (PSD) of either channel on trace A or trace B. Power spectral density is a standard way of measuring Gaussian (or white) noise. PSD normalizes each component of the power spectrum to produce a display that shows values normalized to 1 Hz. In other words, PSD takes each line (or bin) and approximates the power within a 1 Hz band centered at each bin. This is true regardless of the [BASEBAND] range or window you select. For y-axis units of volts, the PSD units are dBV/rHz for logarithmic coordinates or V^2/Hz for linear coordinates.

To measure the PSD of channel 1 on trace A;

1. Move the marker to the frequency of interest.
2. Press [**Data**].
3. Move the column cursor to [TRACE–A].
4. Move the row cursor to [PSD CH1].
5. Press any hardkey to exit the menu and note the marker amplitude readout. The display should look similar to figure 5-31.

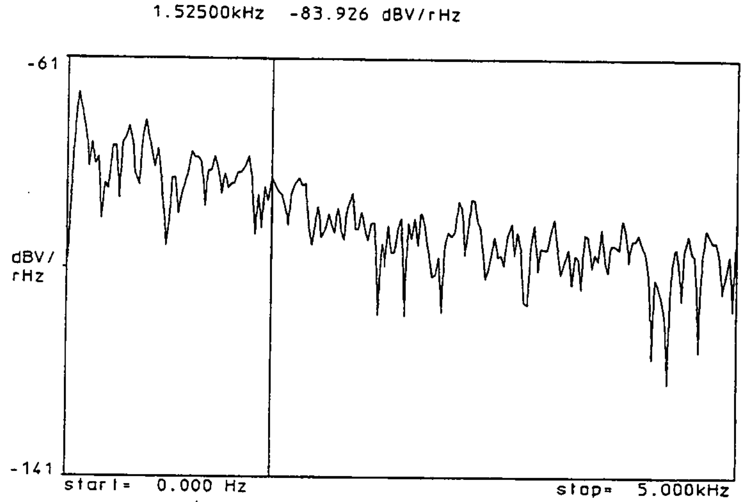


Figure 5-31.
Power Spectral Density measurement.

Discussion

Traditionally, swept-tuned analyzers used a tunable filter with a 3 dB bandwidth of 1 Hz to produce a display with a resolution of 1 Hz. After a while, power spectrum measurements with a 1 Hz bandwidth became an industry standard. However, FFT analyzers (like the HP 3560A) do not use tunable filters. In fact, the bandwidth at each line (or bin) varies with the frequency span and window you select. So to simulate a 1 Hz bandwidth at each bin, the analyzer uses an algorithm that divides by the square root of the actual bandwidth. The algorithm also corrects for the type of window you are using.

[RANGE1/2]

Use the selections under [RANGE1] and [RANGE2] in the [**Input**] menu to specify the sensitivity of channels 1 and 2. Channel sensitivity covers three decades in a 1, 2, 5 sequence from ± 5V (peak) to ± 5 mV (peak). Note that the sensitivities are bipolar. For example, a range of 5V means the total input range is +5V to – 5V.

Note

The input range is the only parameter on the analyzer that uses peak values. Spectral data with linear or logarithmic magnitude coordinates displays rms values.

You can let the analyzer automatically choose the input range by selecting [AUTO]. This is convenient when you do not know the amplitude of the input signal. It automatically adjusts the input range of the instrument to match the input signal by starting at the highest sensitivity (5 mV) and taking a record (assuming suitable triggering) at decreasing sensitivity levels until the input signal no longer causes saturation of the input amplifiers. Then it latches to this sensitivity level and continues to gather data and process until you press a key. When you press [**Start**] again, this autorange process executes again.

[AUTO] is useful when a signal which has been stable at a particular amplitude level suddenly steps up or down while you are analyzing it. Simply press [**Start**] and the analyzer will autorange to the new signal level. However, if you are averaging, the average number re-starts at 1.

Note

Pressing [**Pause/Cont**] does *not* cause the input to autorange. Only pressing [**Start**] causes the analyzer to autorange.

When you are making several measurements on signals that are stable and in the same range, you can make measurements faster by manually setting the input range for each channel. Manually setting [RANGE1] and [RANGE2] eliminates the time it takes the analyzer to perform autoranging each time you [**Start**] a measurement. For example, on the first measurement you can select autoranging, make the measurement, and then press [**Shift**] [**STATUS**] to find which range is set for each channel. Then manually set these values in the [RANGE1] and [RANGE2] columns of the [**Input**] menu.

The displayed range depends on the range setting and on whether [AUTOSCALE] is turned on. In addition, the display can be manually scaled by using the [⇑] and [⇓] keys. This changes the number of y-axis units per division relative to a fixed line on the display. For spectral measurements, the fixed line is the bottom grid. For time domain measurement, the fixed line is the middle grid.

[REAL]

Press [REAL] to display the real part of the measurement results on the y-axis of traces A or B. The x-axis can be frequency or time.

For frequency domain measurements, the real trace represents the real part of the complex FFT data.

For time waveforms with [ZOOM] off, [REAL] gives the complete representation of the waveform and the imaginary part is equal to zero. Therefore, you should select [REAL] when you are viewing time domain data.

Note

If you take a time record using [ZOOM], the [REAL] trace can be hard to interpret. The [ZOOM] algorithm multiplies the time waveform by a cosine function. The frequency of this cosine function equals the center frequency of the [ZOOM]. This results in a frequency-shifted [REAL] trace. For example, if your input is 2V dc, and you use [ZOOM], [REAL] would display a cosine wave. If your input is a 2V peak sine wave, the in-phase portions of the cosine wave would amplify the amplitude of the input time waveform and the out-of-phase portions of the cosine wave would subtract from the amplitude of input time waveform. This cosine multiplication also causes the imaginary part of the time waveform to appear to have a non-zero value.

To select real coordinates for trace B;

1. Press [**Data**].
2. Move the column cursor to [Y–AXIS: B].
3. Move the row cursor to [REAL].
4. Press any hardkey to exit the menu.

[RECALL STATE]

Press [RECALL STATE] to retrieve the instrument state stored in the specified register number. Recall an instrument state using the following procedure;

1. Press [**Save/Recall**].
2. If you know which register number you want to recall, move the column cursor to [REG NUMBER:] and key in an integer between 1 and 32767. Press [**Enter**]. Move the column cursor to [**OPERATION**] and move the row cursor to [**RECALL STATE**].
   Skip to step 3.
   If you do not know the register number, in the [OPERATION] column, move the row cursor to [CATALOG] and press [**Enter**].
   Move the row cursor to the state you want to recall and press [**Enter**]. Notice the register you just selected is automatically entered under [REG NUMBER:] and [RECALL STATE] is already selected in the [OPERATION] column.
3. Press [**Enter**] to execute the recall.

Caution When you recall an instrument state, it alters your current instrument settings. If you do not want to lose your current settings, store them using [SAVE STATE] before you recall any other instrument state.

[RECALL TRACE]

Press [RECALL TRACE] to retrieve the data record in the specified register number. Recall a data record using the following procedure;

1. Press [**Save/Recall**].
2. If you know which register number you want to recall, move the column cursor to [REG NUMBER:] and key in an integer between 1 and 32767. Press [**Enter**]. Move the column cursor to [**OPERATION**] and move the row cursor to [**RECALL TRACE**]. Skip to step 3.
   If you do not know the register number, in the [OPERATION] column, move the row cursor to [CATALOG] and press [**Enter**].
   Move the row cursor to the trace you want to recall and press [**Enter**]. Notice the register you just selected is automatically entered under [REG NUMBER:] and [RECALL TRACE] is already selected in the [OPERATION] column.
3. Press [**Enter**] to execute the recall.

Note You can recall data without altering your current instrument settings. [RECALL TRACE] does not recall the instrument state used to produce the data. To recall an instrument state, the state must have been stored using [SAVE STATE] and then recalled using [RECALL STATE].

The [**Data**] menu then indicates that the currently active trace is recalled data by the [RECALL] menu item in the appropriate [TRACE–A] or [TRACE–B] column. To deselect displaying the recalled data, move the row cursor to the desired menu item in the [TRACE–A] or [TRACE–B] column and press [**Start**] to return to the data display.

[REG NUMBER:]

When you store trace data (time or spectral data) or an instrument state, you store them under a register number. Specify the register number as an integer between 1 and 32767. Use the [CATALOG] feature to find which register numbers have data stored in them. If a register number does not appear in the [CATALOG] listing or if it appears but does not have a time/date of storage entry next to it, that register number is available for use. See [CATALOG] for an example listing. Once you select a register number, store trace data or an instrument state by using the following procedure;

1. Press [**Save/Recall**].
2. Move the column cursor to [REG NUMBER:].
3. Enter an integer between 1 and 32767.
4. Move the column cursor to [OPERATION].
5. Move the row cursor to [SAVE TRACE] to store trace data or [SAVE STATE] to store an instrument state.
6. Press [**Enter**] to execute the storage.
7. Press any hardkey to exit the menu.

The instrument has its own memory management system that takes care of records of different lengths being stored between existing records. For example, if a record of length 512 is stored in register number 4 and there are already records stored in 3 and 5, storing a record of length 1024 in register number 4 will not corrupt data in register numbers 3 and 5.

If you try to store data in a [REG NUMBER:] that has valid data, the following message appears.

" Press ENTER to Overwrite "

Pressing [**Enter**] overwrites the new data, but pressing any other key aborts the storage.

The time and date appears when you execute a storage and this information is kept with the stored data or state. When you recall data in a particular register number, the screen shows the time and date of storage. You can review the register numbers without recalling data by using the [CATALOG] feature. This lists the register numbers, the time and date they were stored, whether it is trace data or an instrument state, and (for trace data) the data process used to obtain the data. If a register number has been erased, no time and date information appears indicating that the register is empty and available for storage.

[RESOLUTN]

Select up to 1600 lines of resolution which sets the record length number of data points to be collected for each channel. You can have 100, 200, 400, 800, or 1600 lines. To select 400 lines of resolution;

1. Press [**Freq**].
2. Move the column cursor to [RESOLUTN].
3. Move the row cursor to [400 LINES].
4. Press any hardkey to exit the menu.

Normally, if there are more lines of resolution than the analyzer can display, the analyzer displays a compressed spectrum. To view an expanded spectrum, press [**Shift**] [**EXPAND**]. Then use the [**PAN RIGHT**] and [**PAN LEFT**] shift functions to look at other portions of the expanded spectrum. Press [**Shift**] [**COMPRESS**] to return to a compressed spectrum.

For spectrum analysis, the number of lines is the number of points shown. However, in the time domain over twice as many points are shown. For example, in spectrum analysis, 800 lines of FFT data represent only the upper half of the "mirrored" output spectrum. The actual number of data points needed to produce 800 lines is 2.56 times 800 or 2048. Measurements in the time domain do not require this process so all 2048 data points can be displayed. See the *HP 3560A Getting Started Guide*, "Spectrum Analyzer Basics" for more information on data processing using FFT.

[RESET]

Use [RESET] to erase all the contents of the analyzer's memory. The analyzer asks you if you really want to erase ALL of the memory to guard against inadvertant erasing.

To erase the analyzer's memory;

1. Press [**Save/Recall**].
2. Move the column cursor to [OPERATION].
3. Move the row cursor to [RESET].
4. Press [**Enter**] and note the message.
5. Press [**Enter**] again to execute the erase. (Pressing any other key aborts the erase.)

Caution Executing [RESET] sets all analyzer settings to their default values and erases all registers.

[RE-TRIG]

Control the repetition of data acquisition with the trigger mode. You can choose a [SINGLE] or [RE-TRIG] trigger mode. [RE-TRIG] gathers and displays a data record each time the triggering signal satisfies the trigger point selections. [SINGLE] "arms" the instrument to capture and display one record on receipt of a suitable trigger.

To select [RE-TRIG] mode;

1. Press [**Trigger**].
2. Move the column cursor to [MODE].
3. Move the row cursor to [RE-TRIG].
4. Press any hardkey to exit the menu.

[RMS]

[RMS] is an average which takes the sum of all corresponding y-axis values of each processed data record and divides each value by the number of data records taken so far in the average. It acquires and processes data until the specified number of data records have been taken. Both rms and rms exponential averaging increase the statistical accuracy of the data.

To select 10 [RMS] averages;

1. Press [**Avg**].
2. Move the column cursor to [NUMBER:] and enter **1 0** using the numeric keypad. Then press [**Enter**].
3. Move the column cursor to [TYPE:].
4. Move the row cursor to [RMS].
5. Press any hardkey to exit the menu.

Discussion

As an example of rms averaging consider figure 5-32. Diagram A is a spectrum with no averages. Diagram B shows the spectrum obtained by applying 20 rms averages. It also shows a significant improvement in the statistical quality of the measurement. Increasing the number of averages to 50 shows a more dramatic improvement in diagram C. In fact, you can now see a single sinusoidal component. With no averaging this component was hidden in the noise and with 20 averages it was barely perceptible.

The number of averages you choose is inversely related to the amount of normalized rms error, as shown in figure 5-32.

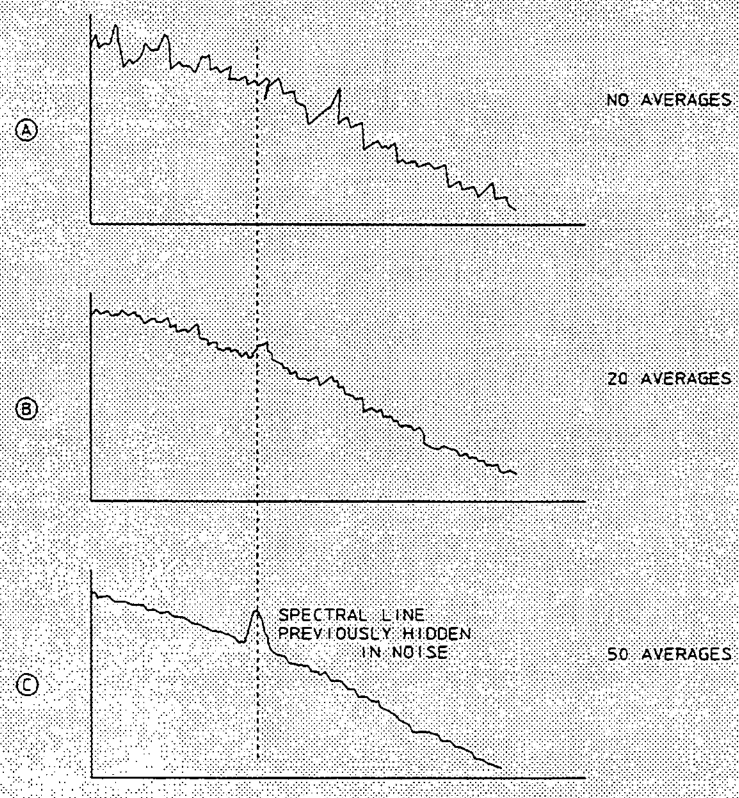


Figure 5-32.
RMS Averaging

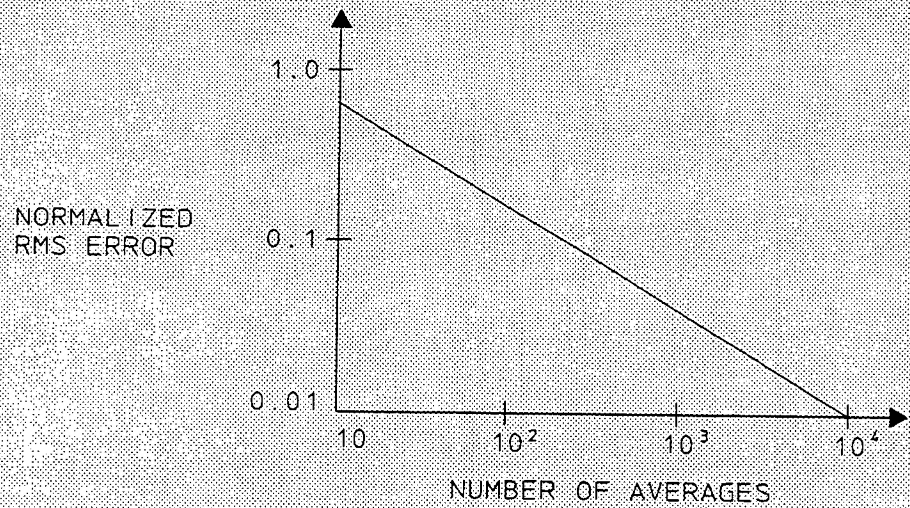


Figure 5-33.
Averages vs. Errors

See the discussion under [**Avg**] for more information on averaging.

[RMS EXPO]

[RMS EXPO] is a type of averaging that gives a weighted average with each record being weighted according to the time at which it was acquired—the earlier the record, the less significance it has in the resulting average. Exponential averaging proceeds indefinitely until interrupted by pressing any hardkey on the instrument.

To select [RMS EXPO] averaging;

1. Press [**Avg**].
2. Move the column cursor to [TYPE:].
3. Move the row cursor to [RMS EXPO].
4. Press any hardkey to exit the menu.

Discussion

RMS averaging can take a relatively long time to obtain stable estimates of the process being measured. During this time, if the system changes (as it would in a time varying process like a run-up/run-down test), then this can introduce significant errors. Consider figure 5-34.

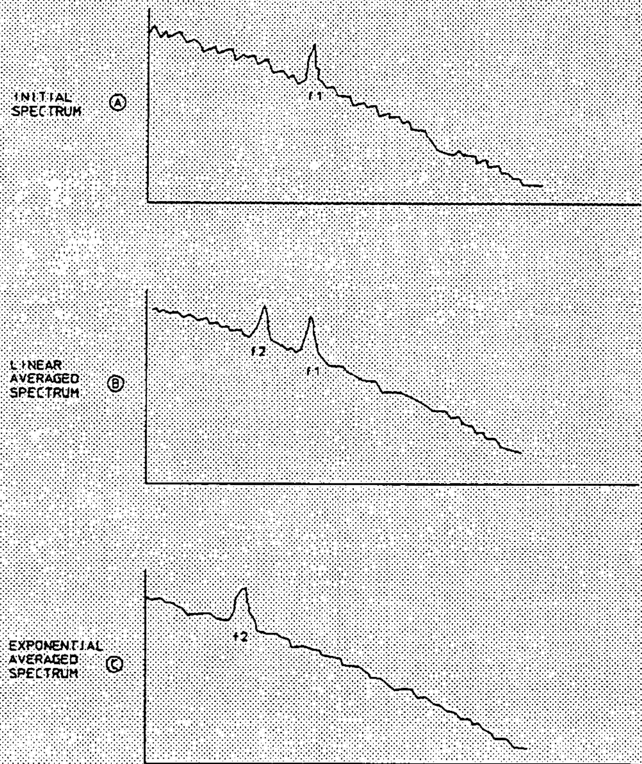


Figure 5-34.
Exponential averaging

Diagram A shows the initial spectrum of the system exhibiting low pass filtered Gaussian noise with a single spectral component at frequency f_1. If that component changes frequency from f_1 to f_2, rms averaging will produce the misleading estimate shown in diagram B.

In other words, rms averaging does not adapt to underlying changes in the system.

Diagram C shows the use of rms exponential averaging which is a "fading memory" feature. As time evolves, the information associated with the state of the system when it had a single spectral line at f_1 is gradually forgotten, and as the time progresses only the single line at f_2 shows.

Therefore, rms exponential averaging provides a single adaptive ability – it adapts to changes in the system being measured. However, because old data is forgotten, it gives less statistical accuracy than rms averaging.

See the discussion under [**Avg**] for more information on averaging.

[RS232]

Use this column in the [**Utility**] menu to select the baud rate, parity, and number of bits for RS-232 operation. Available baud rates are 38400, 19200, 9600, 4800, 2400, and 1200. Parity can be off, even, or odd. The number of data bits can be 7 or 8. (Use 7 if the parity is even or odd.)

RS-232 Connector

The RS-232 interface is a 9-pin connector on the connector panel that conforms to EIA/TIA-562 and EIA/TIA-574 standards. Use it to send data to a printer, plotter, or computer with a RS-232 connector. See figures 5-34 and 5-35 for cabling, pin assignments, and connection instructions. Proper cabling ensures correct enabling and handshaking between the devices.

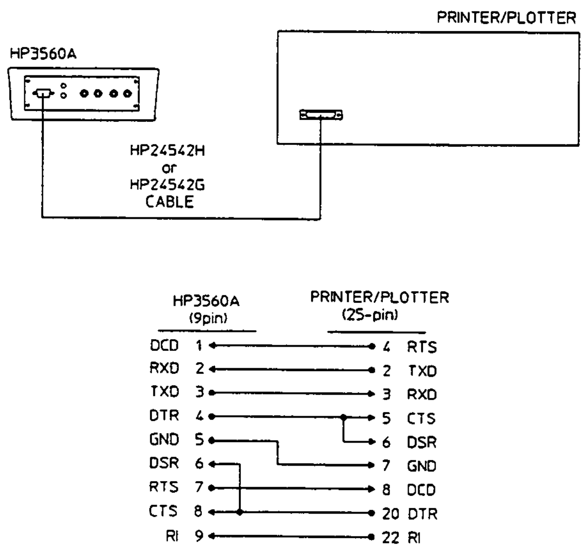


Figure 5-35.
Printer/plotter connection

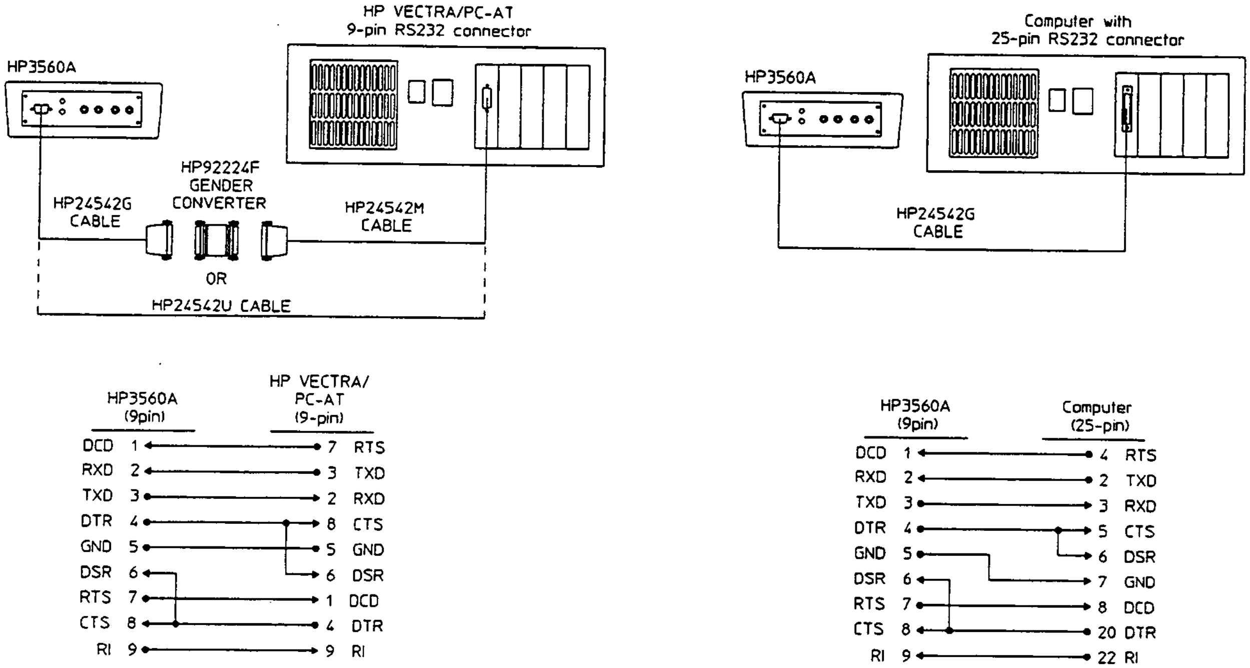


Figure 5-36.
Vectra/PC-AT connection

Note

Some printers indicate "buffer full" by switching a secondary RTS line; usually on pin 11 of the printer D (25-pin) connector. For correct handshaking with this type of printer, connect pin 11 to either CTS or DSR on the HP 3560A.

RS-232 Transmit (relevant signals TXD,CTS and DSR) The HP 3560A operates a hardware handshake on either CTS or CTS and DSR, depending on the [HANDSHAK:] setting. Therefore, for the analyzer to transmit data on TXD, CTS (and possibly DSR) must be at RS-232 positive voltage level (between +3V and +12V). CTS and DSR can be driven by the receiving device connected to the instrument or can be strapped active. The HP 3560A ceases transmission when these lines are driven to RS-232 negative voltage level. Transmit handshaking can therefore be performed on either or both lines.

RS-232 Receive (relevant signals RXD, RTS, and DTR) For printing or plotting, the HP 3560A never receives data from the RS-232. However, both the RTS and DTR outputs are set to RS-232 positive voltage level to enable reception of a character if it were transmitted. This is to prevent a sending device from "hanging up" by being unable to transmit a character. This can occur despite the fact that the HP 3560A may not react to the received character.

Discussion

Programming the HP 3560A

Control the HP 3560A via the RS-232 by using the commands listed below. There are commands that correspond to front panel key presses and other commands for facilitating remote operation. This section lists these commands, gives some programming tips and examples.

Front Panel Commands

The HP 3560A acknowledges each command character by "echoing" that character back to the controller. Characters that do not correspond to a command are ignored and not echoed.

Table A-1. Front Panel Commands

Key	Command Character
[0] – [9]	0 – 9
[.]	.
[+/-]	-
[Shift]	!
[⇐]	D* or l
[⇒]	C* or r
[⇑]	A* or u
[⇓]	B* or d
[Enter]	E
[Data]	Y
[Format]	F
[Scale]	S
[Freq]	Q
[Input]	I
[Trigger]	T
[Start]	G
[Pause/Cont]	P
[Avg]	V
[Save/Recall]	M
[Utility]	U
[Preset]	Z

*The A, B, C, and D commands correspond to the up, down, right, and left arrows, respectively, on an ANSI keyboard.

Remote Only Commands

In addition to the front panel commands, there are also some "remote only" commands. These are listed below.

Table A-2. "Remote Only" Commands

Function	Command Character
No action (but echo the character)	0x0D (Carriage Return) 0x0A (line feed) 0x20 (space)
Remote only keyboard disabled	R
Local keyboard enabled	L
Wait for update The character does not immediately echo. When the screen updates, it outputs "W".	W
X-axis marker movement Moves the marker to the specified <value> which is a decimal number representing a bin number. Terminate <value> with a semi-colon. To send the marker to a specific frequency or time convert to the corresponding bin number. For example, X3; moves the marker to the 300 Hz bin of a 20 kHz, 200 line spectrum. Any non-digit characters other than <space> cause this command to abort.	X <value> ;
marKer dump Returns the current marker reading. The format is an ASCII floating number followed by CR/LF. The marker units are not output, but the value is always in fundamental units (e.g., Volts, dB,, deg, EU); not scaled units (e.g., μV or mdB).	K
trace dump Returns all values for the active trace. Format is: <length>, <bin0>, <bin1>, ... <binN><cr><lf> Where <length> is the number of values to follow. Each value is a floating number, same as the marker dump.	J
iNformation line transfer Returns 3 lines of the display: the top line and the bottom 2 lines. Each line ends with <cr><lf>.	N
Identify Returns "HEWLETT-PACKARD,3560A,0,A.00.00" where "A.00.00" is the software revision.	?

What You Should Know

Synchronization

When remote commands come in faster than the analyzer can execute them, it stores the commands in a queue that can hold 64 characters. If the queue overflows, the analyzer does not echo the overflow characters. The analyzer does not do an RS-232 handshake for incoming characters. Therefore, take care not to overflow the queue.

When is the Queue Empty?

Since the characters are echoed as they are put *into* the queue, waiting for the echo does not guarantee the queue is empty. However, the "N", "K", and "W" commands send back their response when they are executed. Therefore, waiting for their response guarantees an empty queue.

Delay 4 Seconds After Preset ("Z")

After sending "Z" and then "E" ([**Enter**]) to confirm, no characters should be sent for 4 seconds to allow the analyzer to preset.

Keep Track of the Menu Cursors and Toggle Selections

Presetting the analyzer automatically moves the column cursors for all menus to the upper left column. However, any other time it is difficult to tell where the column cursor is in a menu. Use !l or !D ([**Shift**] [⇐]) to move the column cursor to the upper left column of the menu. Use !u or !A ([**Shift**] [⇑]) to select the first item in a column. When you are selecting an item in a toggle function, send "0" to select the first item of the selection.

Aborting RS-232 Outputs

When the analyzer is attempting to output RS-232 data, the output can be aborted by pressing [**Preset**] or sending Z.

Always Wait for the Echo

Wait for the echo of each individual character, not an entire string of characters. If the analyzer receives another character before it has echoed the current character, commands may be lost.

Programming Guidelines

1. Start from Preset ("ZE") and wait 4 seconds for the preset.
2. Send a string to set up the menu items. Output each character of the string and then wait for it to be echoed. If the string is longer than 64 characters it may be necessary to add some delay. For remote programming, it is often useful to select the [SINGLE] trigger mode and, for averaging, turn on the [FAST AVG] option.
3. Send "GW" and wait for the characters to echo. This starts the measurement and waits for the first screen update.
4. Use the "X" and "K" commands to move the marker and transfer its value.
5. Transferring the Status Screen (!1) and the current display (!9) are useful during remote control. Both !1 and !9 can be read into an array of strings. See the example programs at the end of this chapter.
6. After sending a "G" to start a measurement, do not send any other commands until the measurement actually starts. Any pending commands will cause the measurement to abort. One exception is the wait command "W". "GW" starts a measurement and waits for the first screen update.
7. The HP 3560A uses a hardware handshake for outgoing RS-232 data, including echoed characters. Both CTS and DSR must be at RS232 positive voltage level to allow the analyzer to echo the characters.
8. You can use a modem to contol the analyzer at a distant location. At the remote (analyzer) location, configure the modem for "Auto-answer ON", "No Result codes", and "No echo". Connect the modem to the analyzer using a modem cable such as HP 24542M.

RS-232 Alphabetical Command List

Table A-4. RS-232 Alphabetical Command List

Command	Description
0x0D	Ignore but echo
0x20	Ignore but echo
0xA0	Ignore but echo
!	[**Shift**]
-	[+/-]
.	[.]
0 – 9	[**0**] – [**9**]
?	Identify. Returns model number
A	[⇑]
B	[⇓]
C	[⇒]
D	[⇐]
d	[⇓]
E	[**Enter**]
F	[**Format**]
G	[**Start**]
I	[**Input**]
J	trace dump
K	marKer dump.
L	Local (keyboard enabled)
l	[⇐]
M	[**Save/Recall**]
N	iNformation line dump
P	[**Pause/Cont**]
Q	[**Freq**]
R	Remote only
r	[⇒]
S	[**Scale**]
T	[**Trigger**]
U	[**Utility**]
u	[⇑]
V	[**Avg**]
W	Wait for update.
X	X-axis marker movement.
Y	[**Data**]
Z	[**Preset**]

Example Program for HP 9000 Series 200/300 BASIC (RMB)

```
10  ! RE-SAVE "EXAMP60"
20  !
30  !
40  ! Example HP BASIC program to control the HP 3560A
50  ! via RS-232 commands.  This program is for "Rocky
60  ! Mountain BASIC" on HP 9000 Series 300 workstations.
70  !
80  ! This program assumes an HP 98644 Serial interface card
90  ! at select code 9 (or the built-in interface of an HP
100 ! 9000 Series 300 computer).
110 !
120 ! Conn the HP 3560A using a "null modem" or "printer" cable such as
130 ! an HP 24542G cable.  HP 9000 Series 300 computers will also require
140 ! an HP 98561-61604 cable.  Configure the HP 3560A for
150 ! Baud: 9600, Parity: none, Bits: 8.
160 !
170 !
180   DIM L1$[42],L2$[42],L3$[42]  !for 3 information dump lines
190   !
200   CONTROL 9,0;1                !Reset card
210   WAIT .1
220   CONTROL 9,3;9600             !Baud rate
230   CONTROL 9,4;3                !8 bits/char
240   ON ERROR GOTO Not_ux
250   IF POS(SYSTEM$("VERSION:OS"),"UX")>0 THEN
260     CONTROL 9,5;2+1            !Set RTS,DTR (HP-UX provides buffering)
270   END IF
280 Not_ux: OFF ERROR
290   !
300   !
310   ! Preset the analyzer
320   PRINT "Sending Preset"
330   CALL To3560("ZE")            !Preset, Enter
340   WAIT 4                      !Wait 4 seconds for the preset
350   !
360   PRINT "Setting up measurement"
370   CALL To3560("T !1r !u")      !Trigger mode is single
380   CALL To3560("V !1  !udd rr !u0E")  !Avg Type RMS, Options Fast ON
390   !
400   CALL To3560("GW")            !Start and wait for data
410   !
420   PRINT "Reading marker"
430   CALL To3560("X 10;")         !Move the marker to bin 10 (1kHz)
440   CALL To3560("K")             !Request marker transfer
450   ENTER 9;Marker_value         !Receive the marker value
460   PRINT "Marker value = ";Marker_value
470   PRINT
480   !
490   CALL To3560("N")             !Request the status line
```

```
500    ENTER 9;L1$,L2$,L3$            !Receive the status line
510    PRINT L1$
520    PRINT L2$
530    PRINT L3$
540    PRINT
550    !
560    PRINT "Reading trace"
570    CALL To3560("J")               !Request a trace transfer
580    ENTER 9 USING "#,K";T_length   !Determine the number of data points
590    ALLOCATE T(0:T_length-1)
600    ENTER 9;T(*)                   !Receive the data
610    PRINT "T(10) = ";T(10)
620    PRINT
630    END
640    !
650    !
660 To3560: SUB To3560(A$)
670    ! This subprogram sends a string of characters to the HP 3560A,
680    ! waiting for each character to be echoed.
690    FOR I=1 TO LEN(A$)
700      OUTPUT 9 USING "#,A";A$[I;1]
710      REPEAT
720        ENTER 9 USING "#,A";Echo$
730      UNTIL Echo$=A$[I;1]
740    NEXT I
750    SUBEND
```

Example Program for Quick BASIC

```
'EXAMP60.BAS
'Example Quick BASIC program to control the HP 3560A via RS-232
'commands.  This version is for Microsoft Quick BASIC.
'
'Connect the HP 3560A to the COM1 port on the personal computer
'using a "null modem" or "printer" cable such as the HP 24542U cable
'(or the HP 24542G or 24542H if your PC has a 25-pin connector).
'Convigure the HP 3560A for:
' Baud: 9600, Parity: none, Bits: 8.

DECLARE SUB To3560 (A$)
DIM Trace!(200)                    'for trace dump

'Open COM1 and specify baud rate, etc
OPEN "COM1:9600,N,8,1,RB4096" FOR RANDOM AS #1

'Preset the analyzer
PRINT "Sending Preset"
CALL To3560("ZE")                  'Preset and Enter keys
Start! = TIMER
DO
LOOP UNTIL (TIMER > Start! + 4)    'Wait 4 seconds

PRINT "Setting up measurement"
CALL To3560("T !1r !u")            'Trigger, Mode Single

CALL To3560("V !1 !udd rr !u0E")   'Avg, Type RMS, Options Fast ON

CALL To3560("GW")                  'Start and wait for data

PRINT "Reading marker"
CALL To3560("X 10;")               'Move the marker to bin 10 (1kHz)
CALL To3560("K")                   'Request a marker transfer
INPUT #1, Marker!                  'Read it
PRINT "Marker = "; Marker!

PRINT "Reading trace"
CALL To3560("J")                   'Request a trace transfer
INPUT #1, TLength%                 'Read the number of data point
FOR I% = 0 TO TLength% - 1
  INPUT #1, Trace!(I%)             'Read the trace
NEXT I%
PRINT "Trace(10) = "; Trace!(10)

CLOSE #1

END
```

```
SUB To3560 (A$)
  'This subprogram sends a string of characters to the HP 3560A and
  'waits for each character to be echoed.
  '
  FOR I% = 1 TO LEN(A$)
    Echo$ = ""
    Achar$ = MID$(A$, I%, 1)
    PRINT #1, Achar$;

    DO
      IF NOT EOF(1) THEN
        Echo$ = INPUT$(1, #1)       'Enter the echo
      END IF
    LOOP UNTIL Echo$ = Achar$
  NEXT I%

END SUB
```

[SAMPLE]

[SAMPLE] lets you choose internal or external sampling. Selecting [INTERNAL] sampling means the analyzer samples data 2.56 times the [BASEBAND] frequency setting. This is true for [BASEBAND] measurements. For [ZOOM] measurements, the sample rate depends on the [SPAN], and [CENTER] settings.

Selecting [EXTERNAL] sampling means the analyzer will sample data according to the TTL level signal present at the External Sample input on the connector panel. In this mode, the sample rate equals the external sample signal frequency. The display is then scaled by the specified [CLK/REV] value. The x-axis of the display then reads out in orders, indicated by an "ORD" label.

Note

The settings for [ZOOM] and [BASEBAND] do not apply to the sample rate when you use external sampling for order analysis. However, the [BASEBAND] setting is used to select the anti-alias filter bandwidth, so you should pick a [BASEBAND] setting that will include the highest frequency being measured (in Hz).

To select the internal sampling rate;

1. Press [**Freq**].
2. Move the column cursor to [SAMPLE].
3. Move the row cursor to [INTERNAL].
4. Press any hardkey to exit the menu.

In some applications you may want to synchronize the sample clock to an external source. For example, if you are measuring signals from a rotating shaft that is varying in speed and you want to synchronize the measurement by sampling the same number of times per revolution, the external sample feature is very useful. Connect a pulse encoder to a rotary shaft, apply the sample source of the pulse encoder to the External Sample input connector, and enter the number of pulses per revolution under [CLK/REV]. The number can be between 0 and 1024.

The External Sample input of the HP 3560A is overvoltage protected and has an internal pull-up resistor for open-collector drive. The input requires TTL levels and the external sample signal must be at a logic low for a minimum of 250 ns, and a logic high for a minimum of 9.75 μs. Also, you may need to provide external aliasing protection. See External Sample Input Connectors in this reference for a more detailed description of the input requirements.

See the discussion below for more details about using external sampling for order analysis. To use external sampling and enter the number of pulses per revolution;

1. Press [**Freq**].
2. Move the column cursor to [SAMPLE].
3. Move the row cursor to [CLK/REV].
4. Enter the number of pulses per revolution using the numeric keypad and press [**Enter**].
5. Move the row cursor to [EXTERNAL].
6. Press any hardkey to exit the menu.

Discussion

Order Analysis The External Sample input is useful in order analysis which is primarily used to observe harmonics of the running speed of a machine. Order analysis is a method of displaying the harmonics of a fundamental frequency even when that frequency is varying. First, you need to determine a scaling factor that represents the number of pulses which will be received by the External Sample input for one revolution of the machine shaft. Determine this number by using an optical encoder or magnetic pick-up on a gear. For example, if the optical encoder gives 100 pulses per revolution, the [CLK/REV] value should be 100. The number of orders (fundamental signal plus harmonics) which can be displayed is given by:

$$\text{Number of orders} = \frac{\text{CLK/REV}}{2.56}$$

Therefore, for a 100 pulse per revolution encoder, you can display 39 orders. Note that more pulses per revolution result in more orders being displayed.

Using the scaling factor, the frequency axis is displayed in orders and the time axis in points. The spectral map trace format is ideal for viewing order analysis results because it lets you concurrently see all the responses over the full rpm range. See [MAP] for more information on spectral map displays.

[SAVE]

Press [**Shift**] [**SAVE**] to store trace data in sequential register numbers. This serves as a shortcut when you want to quickly store data records because you do not have to refer to the [**Save/Recall**] menu.

To start an autostore sequence;

1. Select the start [REG NUMBER:] in the [Save/Recall] menu.
2. Press [**Start**] to collect the data. (It can be time or frequency domain data.)
3. Press [**Shift**] [**SAVE**] and the data is stored under the first register number.
4. Repeat steps 2 through 4 as much as you want and each data record will be stored in the next register number until memory is full.

The [**STATUS**] screen gives the amount of available memory.

[Save/Recall]

Press [**Save/Recall**] to display the menu that lets you control the analyzer's memory. You can control the register numbers and storage and retrieval of instrument settings and trace data. You can also erase data in one or all registers or transfer stored data via the RS-232 port. See each function name for more information.

[SAVE STATE]

Press [SAVE STATE] to save the current instrument settings, also called the instrument state, in the specified register number. This feature saves memory space when you store several sets of trace data that use the same instrument state. In such cases, store the instrument state only once.

Store the instrument settings under a register number. Each register can have both trace and state information stored in it. This can help you associate data with the instrument state used to produce the data. However, if you later want to erase trace data in a register, the [ERASE] command erases both state and trace data in the specified register. Therefore, you may want to store an instrument state in its own register. The analyzer also saves the time and date when the state information was saved.

Use the [CATALOG] feature to find which register numbers have already been used. If a register number does not appear in the [CATALOG] listing, that register number is available for use. See [CATALOG] for an example listing.

Store an instrument state by using the following procedure;

1. Press [**Save/Recall**].
2. Move the column cursor to [REG NUMBER:].
3. Enter an integer between 1 and 32767.
4. Move the column cursor to [OPERATION].
5. Move the row cursor to [SAVE STATE].
6. Press [**Enter**] to execute the storage.
7. Press any hardkey to exit the menu.

The instrument has its own memory management system that takes care of records of different lengths when they are stored between existing records. For example, if a record of length 512 is stored under register number 4 and records exist under registers 3 and 5, storing a record of length 1024 under register number 4 will not corrupt register numbers 3 and 5.

If you try to store data in a [REG NUMBER:] that has valid data, the following message appears.

" Press ENTER to Overwrite "

Pressing [**Enter**] overwrites the new data, but pressing any other key aborts the storage.

The [**STATUS**] screen gives the percentage of available memory. The following table indicates the amount of memory required for each trace storage and state storage.

Trace/State Memory Requirements

Resolution	% of memory	
	Trace	State
100-line	0.2	0.2
200-line	0.2	0.2
400-line	0.39	0.2
800-line	0.7	0.2
1600-line	1.35	0.2

[SAVE TRACE]

Use [SAVE TRACE] to store the currently displayed data in the active trace. The instrument also stores the current time and date with the trace data.

A subset of the instrument settings are stored with the data but these settings cannot be recalled by the instrument. This subset is called the data header and is only used when you transfer data to a personal computer for conversion to Standard Data Format (SDF) using the SDF Utilities. See [XFER ONE] for a list of the parameters in the data header.

Specify an integer between 1 and 32767 as the register number when you use [SAVE TRACE]. The memory lets you store both state and trace information in the same register. This can help you associate trace data with the instrument settings used to produce the data. However, if you later want to erase the trace data, the [ERASE] function erases all the contents of the register. Therefore, you may want to store instrument state and trace data in separate registers.

Use the [CATALOG] feature to find which register numbers have data stored in them. If a register number does not appear in the [CATALOG] listing or if it appears but does not have a time/date of storage entry next to it, that register number is available for use. See [CATALOG] for an example listing.

Once you select a register number, you can store trace data by using the following procedure;

1. Press [**Save/Recall**].
2. Move the column cursor to [REG NUMBER:].
3. Enter an integer between 1 and 32767.
4. Move the column cursor to [OPERATION].
5. Move the row cursor to [SAVE TRACE].
6. Press [**Enter**] to execute the storage. The current time and data appears by the register number to confirm that the storage has been made.
7. Press any hardkey to exit the menu.

The instrument has its own memory management system that takes care of records of different lengths when they are stored between existing records. For example, if a record of length 512 (200-line resolution) is stored under register number 4 and records exist under registers 3 and 5, storing a record of length 1024 (400-line resolution) under register number 4 will not corrupt register numbers 3 and 5. The amount of memory required to store each trace depends on the data record length which is 2.56 × [RESOLUTN]. The table under [SAVE STATE] shows the trace storage memory requirements for each resolution setting.

If you try to store data in a [REG NUMBER:] that has valid data, the following message appears.

" Press ENTER to Overwrite "

Pressing [**Enter**] overwrites the new data, but pressing any other key aborts the storage.

The [**STATUS**] screen gives the percentage of available memory.

Discussion

Post-Processing Stored Data By sending stored data to a personal computer via the RS-232 port, you can further analyze data and perform post-processing. To assure the full data record is transferred to the computer, the data should be stored as time domain data using any of the time domain functions such as [TIME CH1] or [TIME CH2] in the [**Data**] menu. In other words, to to post-process data the data record must look like "raw" channel data. The time domain data can be averaged. Stored spectral data represents less than half of the data record used to compute the spectral data. To download stored data to a host computer for post-processing or archiving, see the *HP 3560A Getting Started Guide*, "Transferring Data to a Personal Computer" and the *Standard Data Format Utilities User's Guide*.

Note

The HP 3560A cannot post-process stored data. Any further processing you wish to carry out must done before the data is stored. In other words, the HP 3560A cannot perform processes on recalled data. Refer to the discussion under [**Data**] for details on reprocessing.

[Scale]

Press [Scale] to display the menu that lets you control the scale of the x- and y-axes of traces A and B. Choose a logarithmic or linear scale for the x-axis. Set the y-axis units to volts or one of the engineering units and scale the y-axis to a specified scaling factor. [AUTOSCALE] lets the analyzer choose an appropriate display range for the processed data.

Screen Messages

The following messages appear on the status line which is the inverse video line at the bottom of the data display.

Screen Messages

Message	Description
"ACT →"	indicates which trace is the active trace.
"AW"	indicates the current octave analysis measurement is applying the acoustic weighting filter. A double dash "--" appears on the status line when the filter is not applied.
"BAT"	means the battery charge is low. This indicator appears when the instrument has about 2 hours to run on its present battery charge.
"i1" and "I2"	gives the level of integration for channels 1 and 2. Usually the level of integration is the same for both traces since the same level of integration is applied to both channels. However, when one of the traces is recalled, different levels of integration may appear. A double dash "--" appears when no integration is applied.
"P"	indicates the analyzer is paused.
"R" and "r"	"R" means the data update is in real-time*. "r" means the data update is not real-time. A number appearing after either messages indicates the average count.
"TRC A" and "TRC B"	label the displayed data as trace A and trace B.
"T"	indicates a trigger has occured.
"1 UNDER" and "2 UNDER"	appears when the input signal level is more than 12 dB below the selected range.
"W"	appears when you [Start] a measurement and the analyzer is waiting for a suitable trigger. When averaging, the W may appear between averages after processing is complete but before the next suitable trigger.
"1 OVER, 2 OVER, 1/2 OVER"	When an input level on either channel exceeds the sensitivity range, the message 1 OVER, 2 OVER, indicate that channel 1, channel 2, or both channels have overloaded. They disappear when the input level returns in range. These messages are particularly useful when a process is being carried out and the time domain data is not being observed..
"↑"	This means the [Shift] key has been pressed and the analyzer is waiting for the second key to be pressed. Pressing [Shift] again cancels the ↑ message.

"Real-time" means the analyzer continuously computes the Fourier spectra and outputs it to the display without causing any discontinuity in the analysis of the input data.

[**Shift**]

Use the blue [**Shift**] key to access the functions written in blue letters over keys on the front panel. Press the [**Shift**] key and then press the key under the function of interest to execute it. These are called "shift functions". When you press [**Shift**], a " ↑ " symbol appears on the screen indicating that the analyzer is waiting for you to press the other key. Pressing [**Shift**] again removes the symbol.

[SINGLE]

Control the repetition of data acquisition with the trigger mode. You can choose a [SINGLE] or [RE-TRIG] trigger mode. [RE-TRIG] gathers and displays a data record each time the triggering signal satisfies the trigger point selections. [SINGLE] "arms" the instrument to capture and display one record on receipt of a suitable trigger. For measurements using the time average or spectral map features, [SINGLE] stops data acquisition after one "set" of time averages is taken, or one spectral map is complete. The specified trigger conditions must be met before the analyzer will take data for each average or spectral map trace.

Caution

When capturing an event, do not use automatic ranging on either channel. In other words, manually set the input range for both channels. Even if you are only taking data on one channel, make sure you have not selected [AUTO] on either channel. This will help assure that you do not miss an event while the analyzer performs the autorange routine.

To select [SINGLE] mode;

1. Press [**Trigger**].
2. Move the column cursor to [MODE].
3. Move the row cursor to [SINGLE].
4. Press any hardkey to exit the menu.

[SLOPE:]

[SLOPE:] lets you specify whether you want the measurement to start on the positive or negative slope of the triggering signal. For example, the triggering signal in figure 5-37 shows a 70% positive slope and a 30% negative slope triggering points.

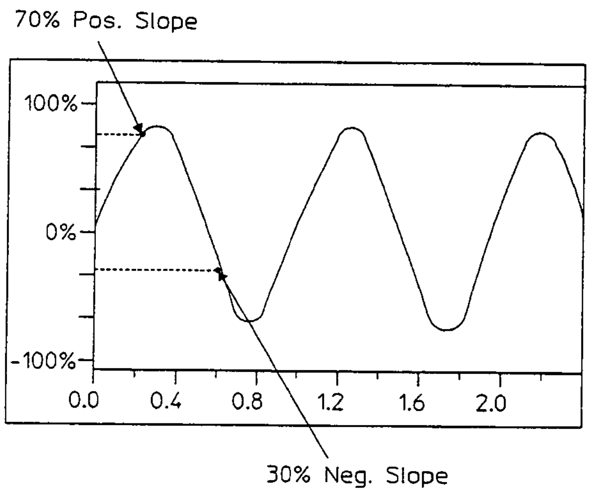


Figure 5-37.
Positive and Negative SlopeTriggering Points

To select a positive slope triggering point;

1. Press [Trigger].
2. Move the column cursor to [POINT].
3. Move the row cursor to [SLOPE:].
4. Toggle to [POSITIVE] by pressing [**Enter**].
5. Press any hardkey to exit the menu.

[SOURCE]

Use the selections in the [SOURCE] column of the [**Trigger**] menu to choose internal, external, or no triggering. [CH1] and [CH2] provide internal triggering. This lets you use one channel as a reference channel and the other as the channel for analysis. [EXTERNAL] in the [**Trigger**] menu uses the signal at the External Trigger connector as the source. Use internal and external triggering with periodic waveforms or transient events. When you want data acquisition to repeat as fast as possible without depending on a triggering signal, use [FREERUN]. [FREERUN] lets the analyzer start data acquisition as soon as the previous record is taken and processed. See the individual parameter selections for more information.

[SPAN]

Press [SPAN] when you are making a [ZOOM] measurement to specify the frequency bandwidth you want the analyzer to measure around the specified center frequency. Press the [**Enter**] key to toggle between the span selections which are in a 1, 2, 5 sequence. Choose from the following frequency spans.

Table 5-6. Selectable Frequency Spans for Zoom Measurements.

20 Hz	1 kHz
50 Hz	2 kHz
100 Hz	5 kHz
200 Hz	10 kHz
500 Hz	

The frequency spans available for a particular zoom measurement are dependent on the highest frequency to be displayed in the zoom measurement. This frequency is given by the following:

[CENTER] + [SPAN]/2

Table 5-7 lists the available spans according to the highest frequency to be displayed.

Table 5-7. Frequency Spans Available.

[CENTER] + [SPAN]/2	Zoom Spans Available
< 400 Hz	All spans
< 4 kHz	≥ 50 Hz
< 40 kHz	≥ 500 Hz

To turn on the zoom feature and set the span to 1 kHz;

1. Press [**Freq**].
2. Move the column cursor to [ZOOM].
3. Toggle [ZOOM] to [ON] using the [**Enter**] **key.**
4. Move the row cursor to [SPAN].
5. Press [**Enter**] until [1 kHz] appears.
6. Press any hardkey to exit the menu.

The analyzer only uses this frequency span value when you have turned on the [ZOOM] feature.

Discussion

When you decrease the [SPAN], you are looking at a smaller section of the data, but you do not change the number of lines (selected under [RESOLUTN]). For example, figure 5-38 shows a 200 Hz span with a resolution of 10 lines. Each line represents 20 Hz per line. Decreasing the span to 100 Hz still gives 10 lines but now each line represents 10 Hz. In other words, the resolution increases but the number of lines remains the same.

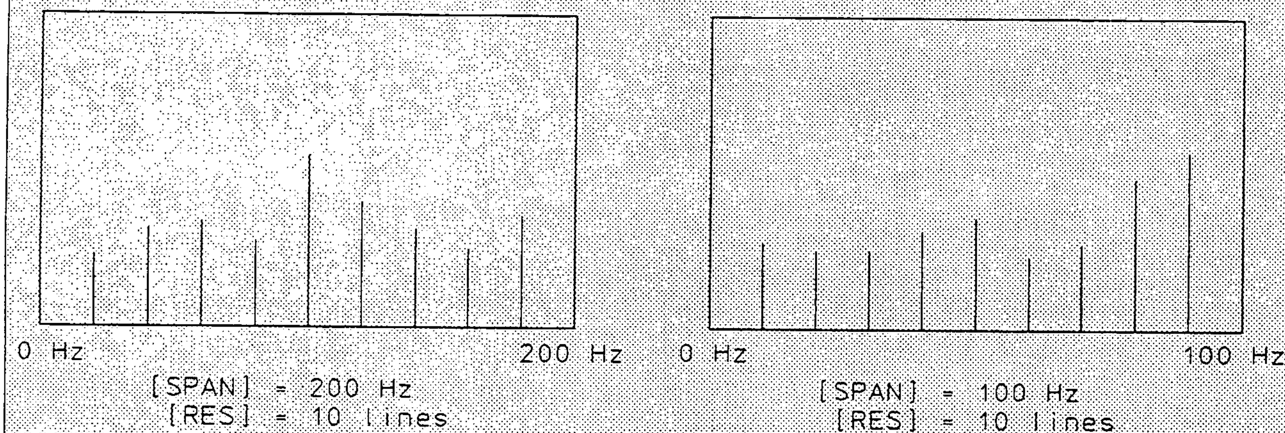


Figure 5-38.
Span does not effect the number of lines displayed

[SPEC CH1/CH2]

Use the [SPEC CH1] and [SPEC CH2] processes to display the amplitude and phase of a measurement from either channel on trace A and B. See figure 5-39.

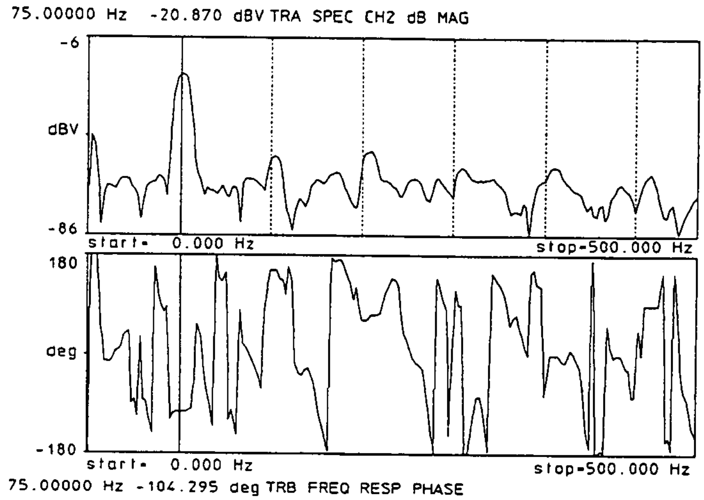


Figure 5-39.
Spectrum Measurement.

[SPEC CH1] and [SPEC CH2] let you display spectum data on either trace A or B since both selections appear in the [TRACE-A] and [TRACE-B] columns. Depending on the coordinates you choose for trace A and B, you can view this spectral data using any of the trace A and B coordinates. For example, if you select [SPEC CH1] in the [TRACE-A] column, and [dB MAG] in the [Y-AXIS: A] column, this displays the logarithmic magnitude of channel 1 on trace A. Similarly, if you select [SPEC CH1] in the [TRACE-B] column, and [PHASE] in the [Y-AXIS: B] column, this displays the phase of channel 1 on trace B. Then if you use the [A ABOVE B] trace format, you can view both the magnitude and phase of the same signal simultaneously.

Make sure you set up proper settings for [BASEBAND], [WINDOW] and [RESOLUTN], and turn on the anti-aliasing filter. For a given [BASEBAND] setting, the spectral resolution is defined by the number of lines ([RESOLUTN]). More lines give greater frequency resolution but longer data acquisition and processing time.

Use the selections under [**Data**] to get linear or logarithmic coordinates for the y-axis of the trace. Linear scaling displays volts (or engineering units), where 1 volt on the vertical axis is equivalent to a sine wave of 1 volt rms. Logarithmic scaling displays dBV, where O dBV is equivalent to a 1 volt rms sine wave. To convert a linear magnitude value which is in rms to a peak value, multiply by 1.414 ($\sqrt{2}$). To convert a logarmithmic magnitude value to a peak value, add 3.01 dB (10log{2}).

For linear coordinates, the range displayed is from 0 to the [RANGE] you select in the [**Input**] menu (unless [AUTOSCALE] is turned on and modifies the range to expand the data along the y-axis). For logarithmic coordinates, the display range is 80 dB where the top of the vertical axis is the logarithm of the [RANGE] setting and the bottom of the screen is 80 dB less. For example, a sensitivity of 5V results in 23 dBV at the top of the vertical axis and – 57 dBV at the bottom (unless [AUTOSCALE] is turned on and modifies the range to expand the data along the y-axis).

To look at low level signals, use averaging and expand the vertical axis from the bottom of the screen by pressing the [⇑] key. Repeat this until you get a satisfactory magnification. The [⇓] key reduces the magnification. The magnification stays until you exit the display. Turning on [AUTOSCALE] causes the analyzer to adjust the magnification for you.

The marker appears as a vertical line and gives a read out of amplitude and/or phase versus frequency. You can display up to 20 harmonic markers (i.e., ten even and ten odd) which are multiples of the fundamental frequency defined by the main marker. Position the main marker (using the arrow keys) over the fundamental signal. Then press [**Shift**] [**HARM MKR**] to display harmonic markers relative to the current marker position. To read the frequency of each harmonic marker, simply move the main marker.

[Start]

Press [**Start**] when you are ready to take a measurement. It starts the measurement process when the triggering condition is satisfied. Pressing a hardkey stops the measurement and displays a menu.

If you select autoranging in the [**Input**] menu, pressing [**Start**] causes the analyzer to perform the autoranging sequence. Although the autoranging sequence takes a few seconds, it can be convenient if your signal amplitude later changes and overranges one of the inputs. Then you simply press [**Start**] again to perform another autorange.

Also use [**Start**] to return to displaying data if you are viewing a menu. If you have paused the measurement and then pressed a hardkey to view a menu, pressing [**Start**] to return to the data display does not override the paused condition. If you made modifications to the menu such that the data that appeared when the analyzer was paused is no longer valid, i.e., if you changed the frequency span or input range, the analyzer will null the data that appeared before you accessed the menu. Otherwise, the data will be modified according to the changed you may have made in the menu. For example, if you paused the measurement and then changed the y-axis from [PHASE] to [dB MAG], the y-axis of the display and the data would be changed to logarithmic magnitude upon returning to the display by pressing [**Start**]. This allows you to reprocess data. See the discussion under [**Data**] for more information on reprocessing data.

[STATUS]

Press [Shift] [STATUS] to get a checklist of the instrument's current settings. Figure 5-40 shows an example.

HP3560A STATUS

INPUT CH1	5mV A	COUP CH1	DC
INPUT CH2	5mV A	COUP CH2	DC
INTEGR	OFF	A-WEIGHT	OFF
SPAN	20kHz	ZOOM	OFF
RESOLUTN	200 LINES	FILTER	ON
SAMPLE	INTERNAL	WINDOW	HANN
SLOPE	POSITIVE	LEVEL	0
DELAY 1	0	DELAY 2	0
TRIG SRC	FREERUN		
AVG TYPE	OFF	AVG NUMB	10
TRACE-A	SPEC CH1	TRACE-B	SPEC CH2
Yaxis-A	LOGMAG	Yaxis-B	LOGMAG
SCALE 1	VOLTS	SCALE 2	VOLTS
X-AXIS	LINEAR		
TIME:	14:42:06	MEM FREE	90%
DATE:	91-02-05		

Figure 5-40.
The Status screen

Things to Notice:

- MEM FREE indicates the amount of available memory in percent for saving records.
- If you select autoranging for channel 1 or 2, the letter "A" appears after the range value.

[SUPP%]

[SUPP%] stands for suppression percent. This parameter lets you ignore lower level portions of data when you display a spectral map. Specify it as a percentage of the displayed range. For example, if the displayed range is 80 dB (10 dB per grid line) and you want the map to ignore the lower 20 dB, specify 25% as the [SUPP%]. See figure 5-41 for an example.

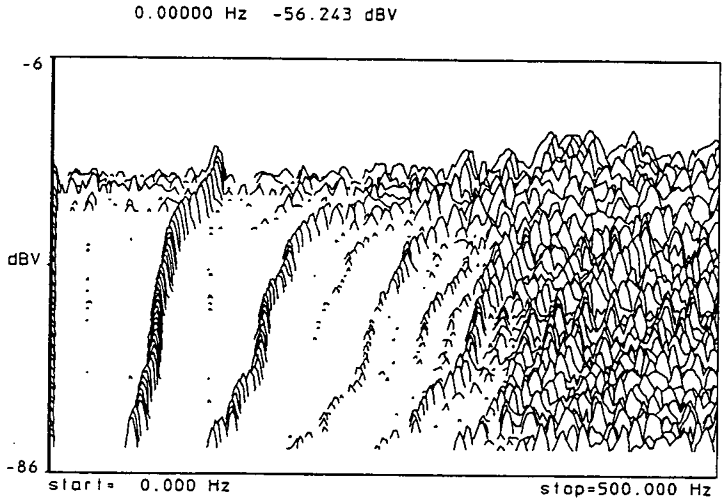


Figure 5-41.
Spectral map with 25% suppression.

To set 25% suppression;

1. Press [**Format**].
2. Move the column cursor to [MAP].
3. Move the row cursor to [SUPP%].
4. Key in **2 5** using the numeric keypad and then press [**Enter**].
5. Press any hardkey to exit the menu.

System

Use the hardkeys in the System section for:

- Storing and recalling data.
- Selecting RS-232 parameters and transferring data.
- Setting up plot and print parameters.
- Setting the instrument to a known (preset) state.

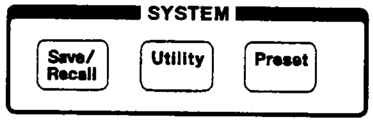


Figure 5-42.
System hardkeys

[TIME]

Select the number of time averages appropriate for your measurement by entering an integer between 1 and 4096 in the [TIME] column of the [**Avg**] menu.

A time average means that data is averaged as the instrument samples it and before it presents the data to the selected algorithm for processing. Use time averaging when the signal is repetitive and a consistent trigger point is available. Time averaging improves the signal-to-noise ratio (SNR) of the signal you are analyzing when you are able to trigger the signal correctly. Time averaging on randomly triggered data has the opposite effect, making the final result meaningless. The following summarizes the properties of time averaging.

1. Time averaging is useful only when a signal contains a deterministic component (i.e., a waveform that repeats or is periodic).
2. Time averaging increases the signal-to-noise ratio (SNR) of the signal. In other words, it increases the ratio of the deterministic part to the random part.
3. A trigger point synchronized to the deterministic part of the signal must be available.

Turning [FAST AVG] on has no effect on speed of [TIME] averages. [FAST AVG] effects the display update of processed data. Since the analyzer performs a [TIME] average on data before it is sent to the processor, [FAST AVG] has no effect. Use [FAST AVG] for the [RMS], [RMS EXPO], and [PEAK HOLD] average types.

Caution When you use pre-trigger, do not also use [TIME] averaging. Using these two features together may result in inaccurate measurements, especially for measurements at the higher frequency ranges of the analyzer. Normally, [TIME] averaging synchronizes the first sample with the trigger. But with pre-triggering, this synchronization is not possible and the actual trigger point may be up to one sample off. This variance becomes significant at the higher frequencies, and the time average is not available when ZOOM is ON.

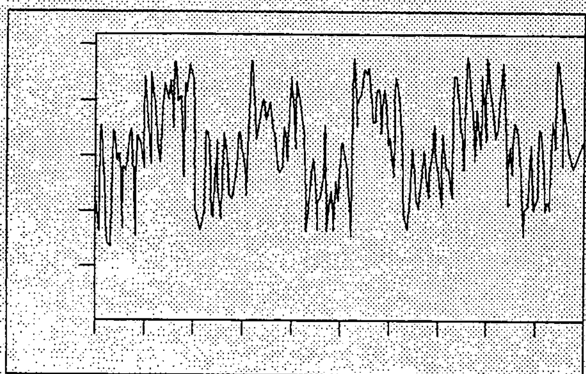
Discussion

Signals of interest are commonly buried in noise. Time averaging improves the SNR of a measurement if a reliable trigger signal is available which is synchronous with the period of the signal of interest.

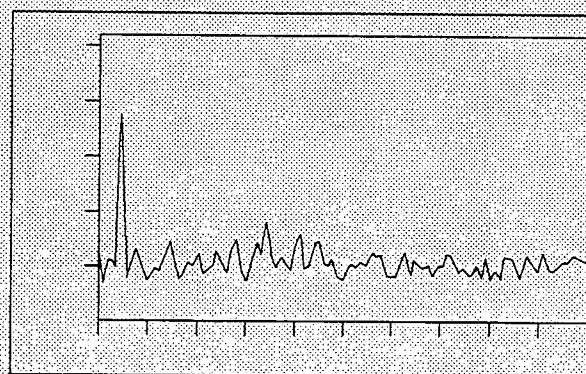
The trigger initiates the start of a data record. Therefore, the periodic part of the input is always the same in each data record, but noise varies. When you add a series of these triggered data records divided by the number of records taken, this is a time averaged measurement.

Since the periodic signal repeats itself exactly in each data record, it averages to its exact value. But since the noise is different in each data record, it tends to average to zero. The more averages you take, the closer the noise tends to zero, and the improvement of the SNR increases.

Figure 5-43 shows a measurement of a square wave buried in noise and its resulting spectrum. Figure 5-44 illustrates the improvement in both the time and frequency domain after 128 time averages.



Square wave buried in noise



Spectrum of square wave buried in noise

Figure 5-43.
Square wave buried in noise

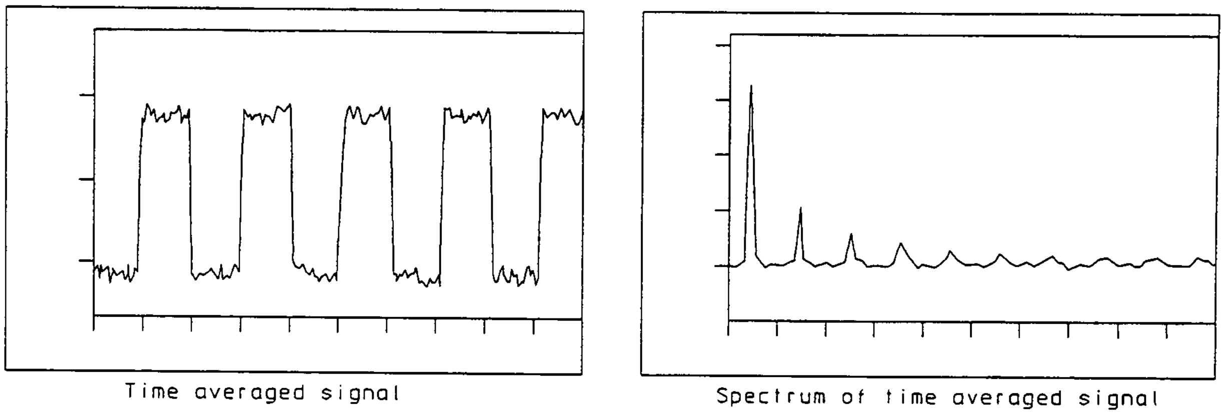


Figure 5-44.
Time averaging improves SNR

[TIME CH1/CH2]

[TIME CH1] is a selection in the [**Data**] menu which processes channel 1 data as time domain data.

Discussion

Operating in the time domain The instrument acts as a 102.4 kHz sampling rate digital storage oscilloscope when operating in time domain mode. [TIME CH1], [TIME CH2], [CH1 – CH2], and [DIFF CH1] are time domain processes. For all these processes, [REAL] is the most common trace coordinate to use. The analyzer does not use windowing for time domain processes and ignores any window setting. You can have single or two-channel operation when you use time domain processes.

[TIME CH1] records data on channel 1 according to the record length, [RESOLUTN], sensitivity [RANGE 1], and trigger conditions specified. Display both channels (trace A and trace B) using the [**Format**] menu selections. Move the marker using the [⇐] and [⇒] keys. The marker gives an accurate read out of amplitude and time. The analyzer linearly interpolates between sampling points to improve the visual representation and to prevent perceptual aliasing effects.

For [BASEBAND] measurements, the time domain display shows the data record as unfiltered data. However, for [ZOOM] measurements, the time display shows filtered time data where the displayed signal frequencies are relative to the [CENTER] frequency setting. For example, if the [CENTER] frequency setting is 6 kHz and there is a signal at 7 kHz, the time display would show a 1 kHz time domain signal. This can be useful for viewing modulation on a carrier.

For more information on time domain measurements, see the *HP 3560A Getting Started Guide*, "Understanding the HP 3560A" and "Your First Measurement".

Note

When you operate in the time domain, you should turn off the anti-alias filter (in the [**Freq**] menu). This is because the anti-alias filter cut-off frequency is set equal to the [BASEBAND] range, but the sampling rate of the data acquisition process is 2.56 times this range. For example, if the anti-alias filter is on and the [BASEBAND] setting is 20kHz, the incoming signals are band limited to 20 kHz because of the 20 kHz anti-alias cut-off frequency). With the filter turned off, the signals are sampled to 51.2kHz.

When you want to view data in the time domain, (using the [TIME CH1] or [TIME CH2] processes), set the coordinates for the corresponding trace to [REAL]. Similarly, when you view spectral data, make sure you select the appropriate coordinates for the trace.

[TIME/DATE]

Set the analyzer's internal clock using the [TIME/DATE] selections in the [**Utility**] menu. Adjust the time according to 24-hour clock format. To synchronize the clock to an exact time, set the time in advance and press the [**Enter**] key when you want the clock to start.

The date and time appear in the status screen and on all prints and plots of the analyzer screen. The date is given in year/month/day format.

[TIMEOUT]

[TIMEOUT] in the [**Utility**] menu automatically turns off the instrument a certain amount of time after no front panel keys have been pressed. If you turn on the instrument without ever pressing any other key, [TIMEOUT] turns off the instrument after only 2 minutes. This lets you save the battery charge in case the analyzer accidentally gets turned on. If you turn on the instrument and press any other key, [TIMEOUT] waits 10 minutes before automatically shutting the analyzer off. The only exception is when the instrument is waiting for a trigger in which case the analyzer does *not* turn off after 10 minutes. For example, if you select [SINGLE] as the trigger mode, and the timeout feature is on, the analyzer will not turn off even after waiting 15 minutes for the triggering signal.

To turn off automatic shutdown;

1. Press [**Utility**].
2. Move the column cursor to [MISC].
3. Move the row cursor to [TIMEOUT].
4. Toggle to [OFF] using [**Enter**].
5. Press any hardkey to exit the menu.

[TRACES]

Specify the number of traces you want displayed in a spectral map using [TRACES]. Enter an integer between 2 and 99. More traces give you a better feel for how the spectrum is changing over time but the refresh rate for the map decreases with more traces.

To select 20 traces for your spectral map;

1. Press [**Format**].
2. Move the column cursor to [MAP].
3. Move the row cursor to [TRACES:].
4. Enter **2 0** using the numeric keypad.
5. Press [**Enter**].
6. Press any hardkey to exit the menu.

See [MAP] for more information on spectral maps. Also see the *HP 3560A Getting Started Guide* and the *Vibration Measurement Basics* section for information on making engine run-up measurements using spectral map.

[Trigger]

Press [Trigger] to select the signal condition which starts the sampling process on both channels. The HP 3560A triggering features provide flexibility in the way you use internal and external triggering. Figure 5-45 shows the [Trigger] menu.

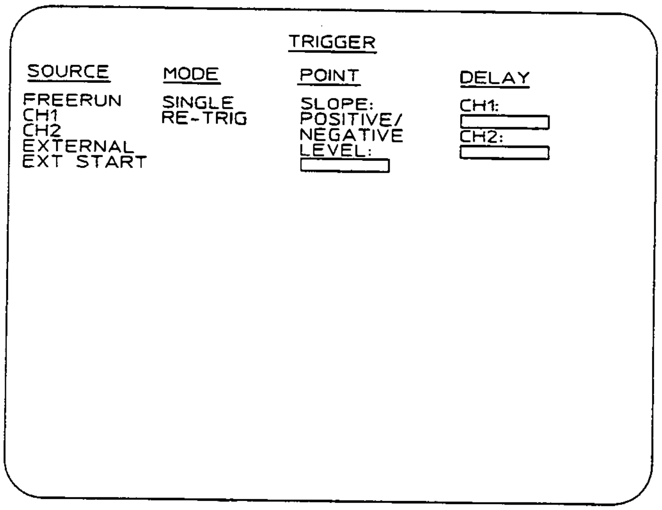


Figure 5-45.
Trigger menu

For more information on these features, refer to their descriptions in this key reference.

Discussion

When you use the trigger features in conjunction with other processes, triggering can facilitate improved signal-to-noise ratio (SNR), accurate phase measurements, and capture of transient events.

Improving SNR When you use time averaging to uncover low level signals that are buried in noise, this type of averaging requires a synchronizing trigger—usually a once-per-rev pulse. If this trigger point is not reliable or synchronous with the signal of interest, time averaging will simply null the signal as well as the noise.

See the discussions under [TIME] and [Avg] for more information.

Phase Measurement The complete frequency domain representation of a signal consists of an amplitude spectrum and a phase spectrum. While the amplitude spectrum indicates signal level as a function of frequency, the phase spectrum shows the phase relationship between spectral components. In machinery vibration analysis, phase is required for most balancing techniques. It is also useful for differentiating between faults which produce similar amplitude spectra.

However, for absolute phase to be meaningful you need a reliable triggering signal. In machinery analysis this triggering signal is most often provided by a displacement or optical transducer which detects the passage of a keyway, screw, or reflecting surface. This reference signal is converted into a TTL compatible pulse and fed into the external trigger input of the HP 3560A.

See [FREQ RESP] for more information on making phase measurements.

Capturing Transient Events In many applications, a transient signal such as a pulse is the most natural or appropriate stimulus for data acquisition. These application areas include sonar and seismic analysis, acoustic reverberation testing, and structural analysis.

You can capture transient information in two main ways:

1. By using an external trigger.
2. By using pre-trigger on the transient itself.

See the discussions under [EXTERNAL] (trigger) and [DELAY] for more information on how to capture transient events.

Caution

When capturing an event, do not use automatic ranging on either channel. In other words, manually set the input range for both channels. Even if you are only taking data on one channel, make sure you have not selected [AUTO] on either channel. This will help assure that you do not miss an event while the analyzer performs the autorange routine.

[TYPE:]

Select the type of averaging or peak hold function for the measurement by using the selections in the [TYPE:] column of the [**Avg**] menu.

Use rms averaging when making measurements on data that has a relatively high degree of randomness. It improves the statistical accuracy of the result. Examples of signals which are noise-like include speech, music, digital data, seismic data, and mechanical vibrations.

Select the number of averages or peak holds by entering an integer between 1 and 4096 in the [NUMBER:] column using the numeric keypad. rms and rms exponential averaging give a statistical average of data over time. The averaging occurs after sampling and processing. For example, setting the number of rms averages to 4 results in 4 data records that are sampled, processed and averaged. The number of averages computed is displayed on the screen at each update.

There are two types of rms averages and there is a peak hold function.

- [RMS] gives an accumulated sum of the records divided by the number of processed sample records. It keeps a running average of the processed records until the specified number of processed data records have been taken.

- [RMS EXPO] (Exponential) average is a weighted average with each record being weighted according to the time at which it was acquired — the earlier the record, the less significance it has in the resulting average. Exponential averaging proceeds indefinitely until interrupted by pressing any key on the instrument.

- [PEAK HOLD] is not really an average but it maintains the maximum amplitude measured at each line. It acquires and processes data until the specified number of data records have been taken.

To select 10 [RMS] averages;

1. Press [**Avg**].
2. Move the column cursor to [NUMBER], key in **1 0**, and press [**Enter**].
3. Move the column cursor to [TYPE:].
4. Move the row cursor to [RMS].
5. Press any hardkey to exit the menu.

See the discussion under [**Avg**] for more information on averaging.

[UNIFORM]

[UNIFORM] is useful for measuring transient signals. It is really no window at all, and is useful for "self-windowing" signals. [UNIFORM] is also called a rectangular window. Using this window for measuring transient signals produces less distortion. For example, figure 5-46 shows a transient signal. Figure 5-46 shows the result of applying the [HANN] window type to the transient signal. The resulting spectrum in figure 5-46 shows high amounts of distortion. Figure 5-46 shows the resulting spectrum with the [UNIFORM] window applied.

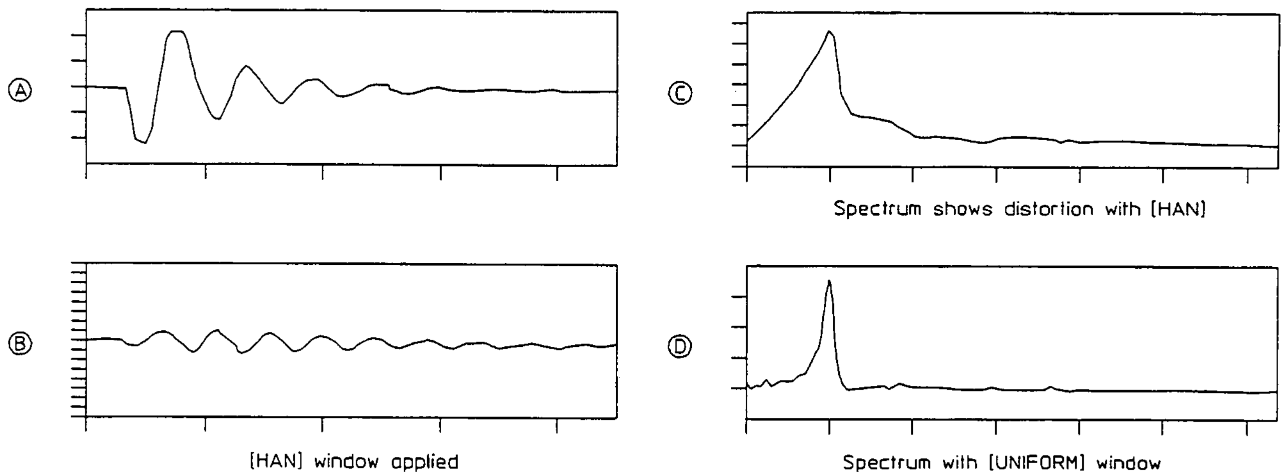


Figure 5-46.
Transient signal

To select the [UNIFORM] window type;

1. Press [**Freq**].
2. Move the column cursor to [WINDOW].
3. Move the row cursor to [UNIFORM].
4. Press any hardkey to exit the menu.

[**Utility**]

Press [**Utility**] to access a variety of functions. Set the time, date, RS-232 parameters, LCD display features, and the hardcopy device type for HP 3560A data transfers. Activating [TIMEOUT] turns off the instrument after 10 minutes of non-operation which can help save charge on the battery.

[VOLTS/EU]

Use [VOLTS/EU] to enter the scaling factor for the y-axis to the desired engineering units. This feature enables the analyzer to account for accelerometer (or other transducer) sensitivity. Enter the scaling factor as a floating point number between $2.00e^{-37}$ to $1.00e^{+12}$. For example, $3.45e^3$ represents the value 3450. Use [VOLTS/EU] to enter the scaling factor for the desired channel(s). Then select from one of several engineering units in the [Y–UNITS] menu. These include [g], [in/s], [m/s], [in], [m], [lbf] (foot-pound), [kgf] (kilogram-force), [SPL] (sound pressure level), [psi] (pounds per square inch), and [EU] (for any other type of engineering unit). Making this selection activates the [VOLTS/EU] scaling factor.

[LOGMAG] coordinates are convenient for setting up the display to read in g's without giving up the data display range advantage of logarithmic displays. For example, if you have an accelerometer with a sensitivity of 10 mV/g;

1. Under the [**Scale**] menu, enter 10 mV/g (0.01) under [VOLTS/EU].
2. Select [g] for the appropriate channel under [Y–UNITS].
3. Select [LOGMAG] in the [Y–AXIS: A] column of the [**Data**] menu.

This results in a logarithmic display of data but the annotation and marker readout read in g's. See [LOGMAG] for more information on this kind of coordinate.

On frequency traces, the maker reading is rms. Multiply this reading by $2\sqrt{2}$ if peak-to-peak values are desired. It is possible to divide the [VOLTS/EU] setting by $2\sqrt{2}$ so the maker readings are peak-to-peak, but this will result in incorrect scaling of the time traces.

To change a channel 1 accelerometer input measurement to a displacement measurement in inches, enter the proper scaling factor for the accelerometer under [VOLTS/EU]. If the accelerometer sensitivity is 10 mV/g, the [VOLTS/EU] scaling factor for an rms readout is 0.01. To set this up, perform the following.

1. Press [**Scale**].
2. Move the column cursor to [VOLTS/EU].
3. Move the row cursor to [CH1:].
4. Enter **0.01** using the numeric keypad.
5. Press [**Enter**].
6. Move the column cursor to [Y–UNITS].
7. Press [**Enter**] in the [CH1:] row until [g] appears.
8. Press [**Input**].
9. Move the column cursor to [INTEGR].
10. Move the row cursor to [DISPL in].
11. Press [**Start**].

When viewing time traces (which are not integrated), the analyzer will read in g's. However, when viewing frequency trace with [INTEGR] on, the analyzer will automatically apply the conversion factors and unit changes required to read velocity or displacement. This automatic unit convertion only operates when [Y–UNITS] is set to [g].

For acoustic measurements, you can enter a scaling factor in the manner described above to calibrate measurements to a calibration tone. However, this scaling factor applies to all measurements; even when you are not using octave analysis. An easy way to scale acoustic measurements relative to a calibration tone is outlined in the discussion under [OCT/3 CH1/CH2]. The display scaling described there is only in effect when performing octave analysis.

[WINDOW]

The HP 3560A lets you choose from four types of windowing functions; Uniform, Hann, Flat Top, and Force/Exponential. Use these windows when you are making spectrum measurements.

To select the [HANN] window type;

1. Press [**Freq**].
2. Move the column cursor to [WINDOW].
3. Move the row cursor to [HANN].
4. Press any hardkey to exit the menu.

Discussion

When the HP 3560A computes the FFT, it does it using a block of samples in the time domain called the data record. Moreover, the FFT algorithm assumes that this data record is repeated throughout time as illustrated in figure 5-47.

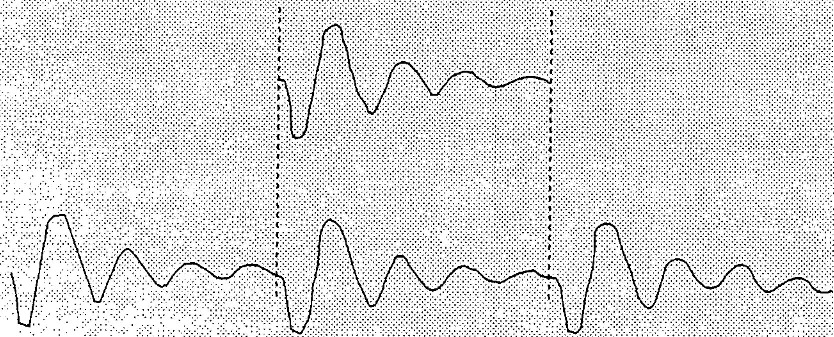


Figure 5-47.
FFT assumes record repeats

For this transient signal, repetition does not cause a problem. But for a continuous signal like a sine wave, this assumption causes problems unless the data record contains an integer number of cycles. Compare figures 5-48 and 5-49.

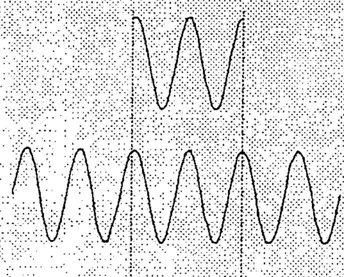


Figure 5-48.
Integer number of cycles

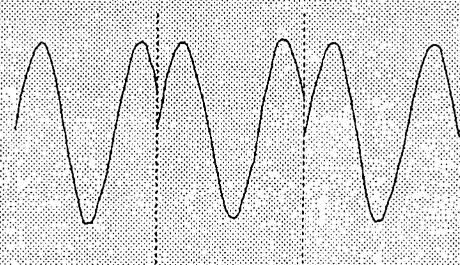


Figure 5-49.
Non-integer number of cycles

Having an integer number of cycles in a time record is extremely unusual. The effect of having a non-integer number of cycles in the time record shows up in the frequency domain and produces a smearing of energy throughout the frequency domain called leakage. Figure 5-51 is the resulting spectrum of a sine wave which is not periodic in the data record. This leakage problem can mask small signals close to the sine wave fundamental. Figures 5-50 and 5-51 contrast the effects of this leakage. The solution to this problem is called windowing.

Windowing forces the data at either end of the time record to zero. Figures 5-52 and 5-53 illustrate the results of applying a window to a sine wave.

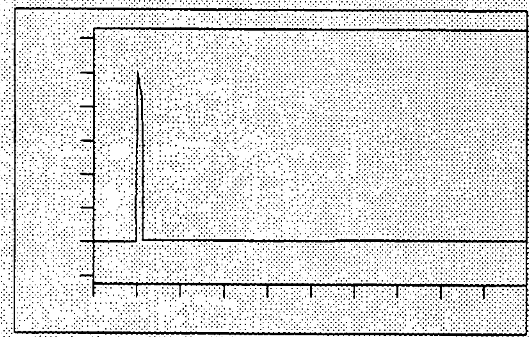


Figure 5-50.
Spectrum of a pure sine wave

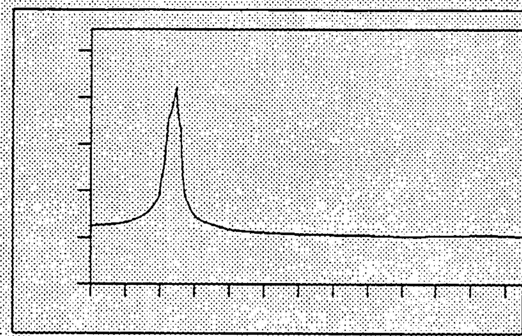


Figure 5-51.
Spectrum of Signal is not periodic in the time record

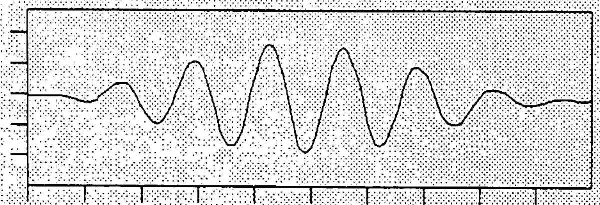


Figure 5-52.
Windowed Sine Wave in the Time Domain

Figure 5-53.
Spectrum of Windowed Sine Wave

Windowing slightly alters the data but gives vast improvement in the measurement of data that is not periodic in the time record.

Table 5-8 contrasts the HP 3560A window types in summary form. See each type of window for more information.

Table 5-8. Window summary

	Uniform	Hann	Flat Top	Force/Exponential
Leakage Performance	Poor	Relatively Good	Good	*
Highest Sidelobe	− 13 dB	− 32 dB	− 93 dB	*
Frequency Resolution	Good	Relatively Good	Poor	*
Noise Bandwidth	1.00	1.50	3.77	*
Sidelobe Fall Off	− 20 dB/decade	− 60 dB/decade	0 dB/decade	*
Max Ampl. Error	3.9 dB	1.4 dB	< 0.01	*
Uses	Transient & Self-windowing data	General Purpose	Accurate measurement of amplitude calibration	Impact Testing

* These values change depending on the exponential time constant ([EXP TC:]) you enter under [FORCE/EXP].

[X-AXIS]

Press [X-AXIS] to specify a linear or a logarithmic scale for the x-axis.

To specify a logarithmic scale;

1. Press [**Scale**].
2. Move the column cursor to [X-AXIS].
3. Move the row cursor to [LOG].
4. Press any hardkey to exit the menu.

Note The analyzer's frequency resolution is determined by the [BASEBAND] and [RESOLUTN] settings. For linear and logarithmic x-axis scales, the number of points on the display and the resolution are identical. The logarithmic scale simply displays these points on a logarithmic x-axis.

Since the log of 0 Hz is minus infinity, a logarithmic scale of a [BASEBAND] setting which always starts at 0 Hz shows the frequency of the first line instead of the nominal value of 0 Hz. For example, if you have a 10 kHz [BASEBAND] setting, the first frequency shown on the logarithmic scale is labeled 31.25 Hz (10kHz/320 display points).

[XCOR]

Press [XCOR] to find periodic signals that are common to both channel 1 and channel 2. Cross-correlation takes the data record from one channel and passes it over the data record from the other channel. This gives the average interrelation between a signal input on channel 1 and a time shifted version of a second signal input on channel 2.

To select a trace A display of the cross-correlation between channel 1 and channel 2;

1. Press [**Data**].
2. Move the cursor to [XCOR] (in the [TRACE–A] column).
3. Press any hardkey to exit the menu.

Caution Do not use [1600-LINE] resolution for the cross-correlation process.

For example, the pipe leak detection example in figure 5-54 shows a cross-correlation measurement between channel 1 and channel 2.

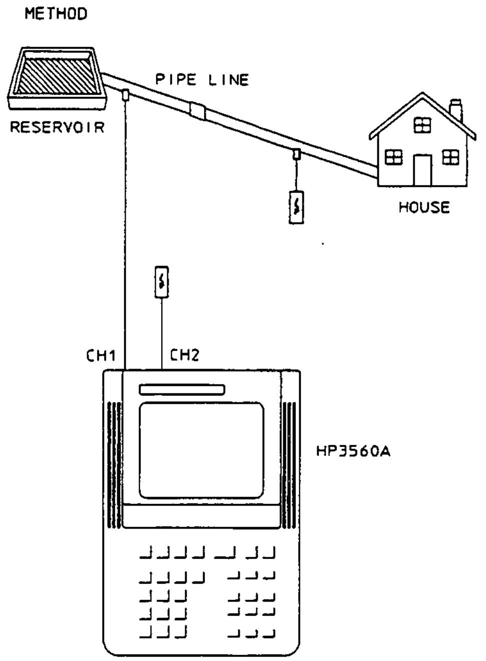


Figure 5-54.
Pipe Leak Detection

The cross-correlated output in figure 5-55 shows the time delay (at the spike) which indicates the difference in the acoustic emission path length between each sensor.

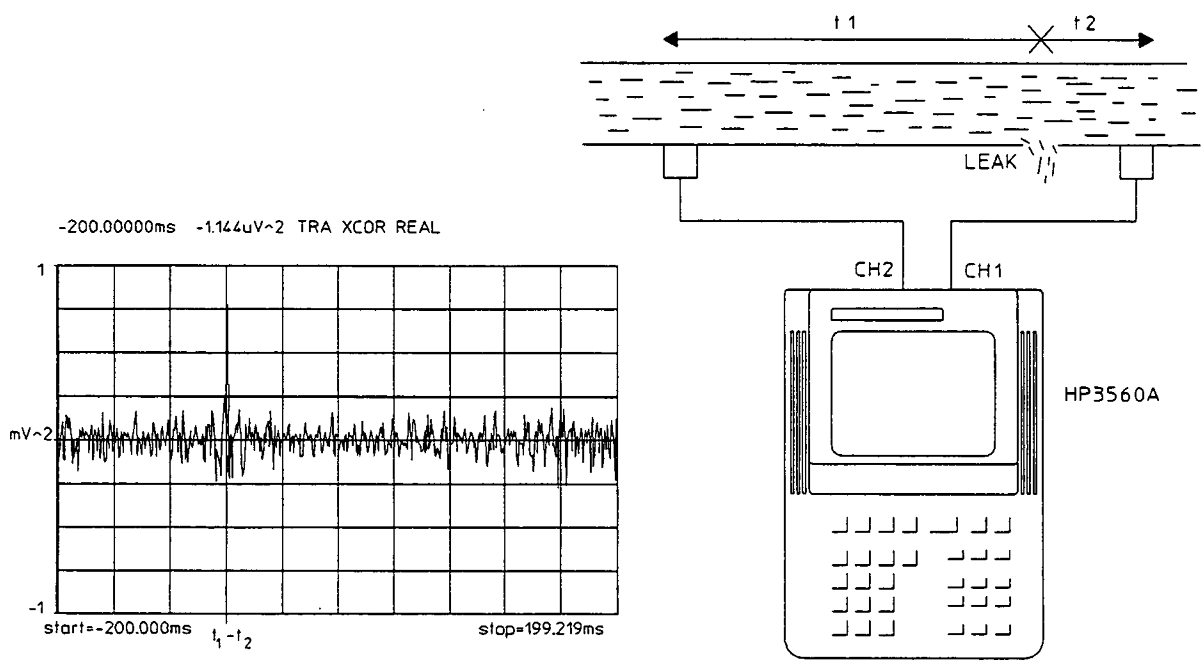


Figure 5-55.
Cross-correlation of pipe leak

By knowing the materials involved, you can convert this time delay to a distance and then pinpoint the position of the leak.

[XCOR] indicates both negative and positive time delays so either channel can be the input signal. In other words, exchanging the signals to channel 1 and channel 2 results in a [XCOR] display that is reversed around the zero time axis.

Cross-correlation is also effective for reducing the effects of noise in network analysis applications, where the stimulus is cross-correlated with the response. This noise reduction occurs without the need for a trigger.

Selecting [XCOR] in the [TRACE–A] column displays the cross-correlation on trace A (with channel 1 as the reference). Selecting it in the [TRACE–B] column displays the cross-correlation on trace B (also with channel 1 as the reference).

[XFER ALL]

Use this key to send all stored data records to a computer via the RS-232 connector. Each data record consists of a data block and a header block which has the instrument settings used to acquire the data as shown in figure 5-56.

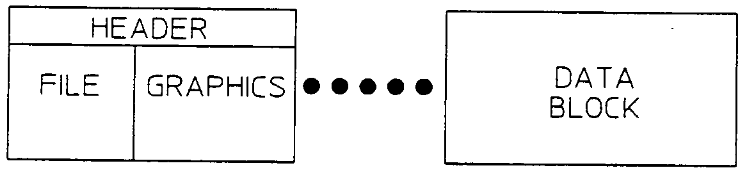


Figure 5-56.

See [XFER ONE] for the header format. [XFER ALL] does not transfer data that is stored as state information only (using [SAVE STATE]). Any pertinent information on the trace data is transferred in the header.

The HP 3560A comes with utilities that convert instrument data to Standard Data Format (SDF) on your personal computer. Performing this conversion makes the data transportable to other HP Dynamic Signal Analyzers such as the HP 3566A, HP 3567A, and HP 35665A for data comparisons and archival. To learn how to run the utilities, see the *HP 3560A Getting Started Guide*, "Transferring Data to a Personal Computer" and the *Standard Data Format Utilities User's Guide*.

Figure 5-57 shows how to connect an HP Vectra or a similar personal computer to the HP 3560A.

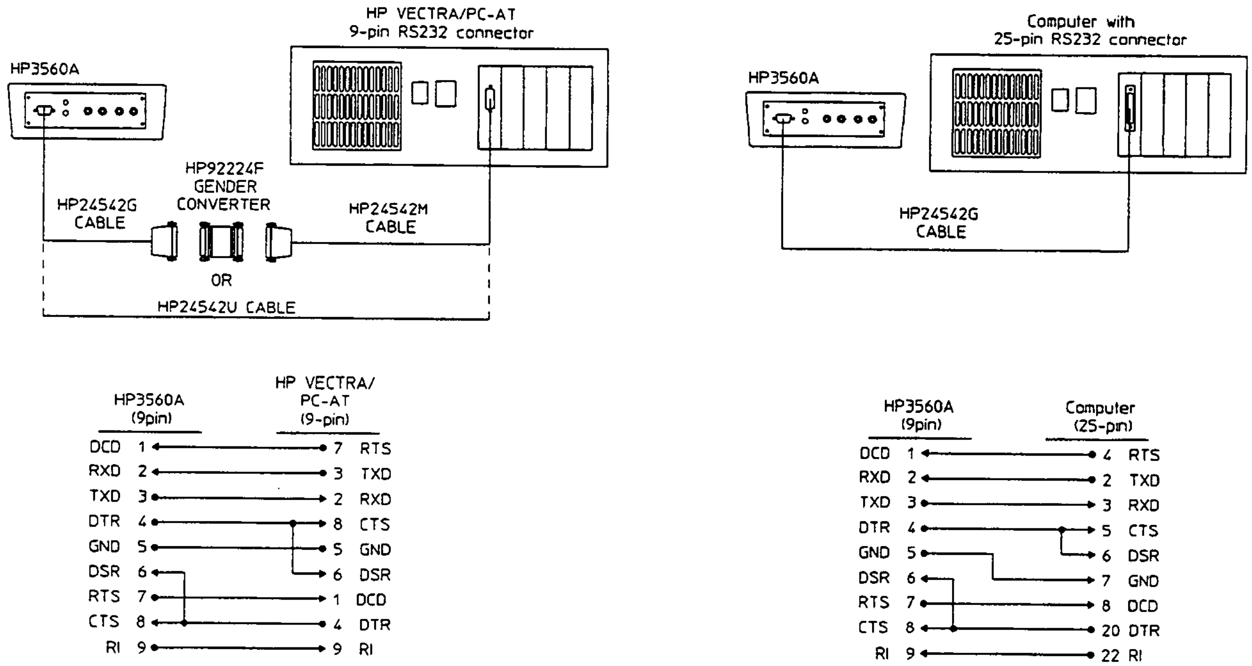


Figure 5-57.

[XFER ONE]

[XFER ONE] transfers the data record in the specified register number to a computer via the RS-232 connector. Execute [XFER ONE] by executing the following.

1. Press [**Save/Recall**].
2. Set the [REG NUMBER:] to the desired register number.
3. Move the column cursor to [OPERATION].
4. Move the row cursor to [XFER ONE].
5. Press [**Enter**] to execute the transfer.

Abort the data transfer by pressing any hardkey.

Each data record consists of a header block and a data block. The header block consists of a file header and a graphics header. See figure 5-56. The file header gives the date and time of storage and the size of the file header, graphics header, and data block. The graphics header contains the instrument settings used to acquire the data. After the graphics header is the data block which first gives the y-axis real values and then the y-axis imaginary values. The x-axis data must be generated.

The file header, graphics header and data block are transferred in Intel Hex Format. After this data is downloaded and converted to binary (using the DOWNLOAD and X32TOBIN command of the SDF Utilities) it is in the format given in tables 5-9 through 5-12.

Table 5-9. File Header Format

Field Index	Binary Index	Field Name/Description	Data Type	Range/Units
1	1:7	filename — non-null terminated string	char[7]	
2	8:10	extension — non-null terminated string	char[3]	
3	11	hour	char	0 – 23
4	12	minute	char	0 – 59
5	13	second	char	0 – 59
6	14	day	char	1 – 31
7	15	month	char	1 – 12
8	16	year	char	0 – 99
9	17:18	headerSize	short	A.00.00, 32 bytes
10	19:20	dataSize	short	0 – 16384
11	21:22	machineID	short	A.00.00, 0x3560
12	23:28	version — null terminated string	char[6]	A.00.00
13	29:30	graphSize	short	A.00.00, 182 bytes

Table 5-10. Graphics Header Format

Field Index	Binary Index	Field Name/Description	Data Type	Range/Units
1	1:2	x — internal use only	unsigned short	
2	3:4	y — internal use only	unsigned short	
3	5:6	xsize — internal use only	unsigned short	
4	7:8	ysize — internal use only	unsigned short	
5	9:10	x_read — internal use only	unsigned short	
6	11:12	y_read — internal use only	unsigned short	
7	13:14	index — internal use only	short	
8	15:16	total — internal use only	short	
9	17:18	viewstart	unsigned short	0 – 4095
10	19:20	viewend	unsigned short	0 – 4095
11	21:22	data_length	unsigned short	0 – 4096
12	23:24	cursor_pos — internal use only	unsigned short	
13	25:26	fill — internal use only	short	
14	27:28	grid — internal use only	unsigned short	
15	29:36	fundamental — internal use only	double	
16	37:44	prescale — internal use only	double	
17	45:46	pre_sc — internal use only	unsigned short	
18	47:48	max — internal use only	unsigned short	
19	49:50	min — internal use only	short	
20	51:52	min_real — internal use only	short	
21	53:54	max_real — internal use only	short	
22	55:56	min_imag — internal use only	short	
23	57:58	max_imag — internal use only	short	
24	59:62	round_tab — unused	char far*	
25	63:66	boost_tab — unused	char far*	
26	67:68	boost_no — internal use only	unsigned short	
27	69:72	real — unused	short far*	
28	73:76	imag — unused	short far*	
29	77:80	ybuf — unused	unsigned short far*	

Table 5-10. Graphics Header Format Continued

Field Index	Binary Index	Field Name/Description	Data Type	Range/Units
30	81:88	xf — x scale factor	double	
31	89:96	xo — x scale offset	double	
32	97:100	xunit — null terminated string	char[4]	Possible unit values are "s", "Hz", "pts", or "ORD"
33	101:108	yf — y scale factor	double	
34	109:116	yo — y scale offset	double	
35	117:120	yunit — null terminated string	char[4]	Possible unit values are "V", "g", "in", "in/s", "m", "m/s", "lbf", "kgf", "psi", "SPL", or "EU". Because of field length restrictions the following strings are mapped to a single character: "^2" — 0xfd "/s" — 0xfe "^2/" — 0xff
36	121:124	title — unused	char far*	
37	125	process	unsigned char	0 – 255 0x00 SPEC CH1 (spectrum channel 1) 0x01 SPEC CH2 (spectrum channel 2) 0x02 PSD CH1 (power spectral density channel 1) 0x04 PSD CH2 (power spectral density channel 2) 0x08 TIME CH1 (time domain channel 1) 0x10 CH1 - CH2 (subtract CH2 from CH1) 0x20 DIFF CH1 (differentiate channel 1) 0x40 OCT/3 CH1 (1/3 octave channel 1) 0x80 OCT/1 CH1 (full octave channel 1) 0x11 FREQ RESP (frequency response CH2/CH1) 0x22 COHER (coherance) 0x44 XCOR (cross-correlation) 0x88 TIME CH2 (time domain channel 2) 0x99 DIFF CH2 (differentiate channel 2) 0xac OCT/1 CH2 (full octave channel 2) 0xbb OCT/3 CH2 (1/3 octave channel 2)
38	126	coordinate — internal use only	unsigned char	
39	127:130	connect_fn — unused	void far*	
40	131:134	yreadfn — unused	void far*	
41	135:138	xreadfn — unused	void far*	
42	139:142	yscale_fn — unused	void far*	
43	143:146	view_fn — unused	void far*	
44	147:150	ylabel_fn — unused	void far*	
45	151:154	prescale_fn — unused	void far*	
46	155:158	xor_cursor — internal use only	void far*	
47	159:182	state	STATE _INFO	See the detail table for STATE_INFO

Table 5-11. Detail Table for STATE_INFO

Field Index	Binary Index	Field Name/Description	Data Type	Range/Units
1	1:4	centerFreq — center frequency	float	0 – 40000
2	5:8	scale1 — engineering unit scaling factor for channel 1	float	200e–39 – 1e12
3	9:12	scale2 — engineering unit scaling factor for channel 2	float	200e–39 – 1e12
4	13:14	avgNum — average number	short	1 – 4096
5	15:16	delay1 — time delay for pre-trigger or post trigger for channel 1	short	–4096 – +4096
6	17:18	delay2 — time delay for pre-trigger or post trigger for channel 2	short	–4096 – +4096
7	19:24	bits	STATE_BITS	see detail table for STATE_BITS

Table 5-12. Detail Table for STATE_BITS

Field Index	Binary Index	Field Name/Description	Data Type	Range/Units
1		span	unsigned:5	0 – 12 span values: 0x00 – 40kHz 0x01 – 20kHz 0x02 – 10kHz 0x03 – 5kHz 0x04 – 4kHz (NOT USED) 0x05 – 2kHz 0x06 – 1kHz 0x07 – 500 Hz 0x08 – 400 Hz (NOT USED) 0x09 – 200 Hz 0x0a – 100 Hz 0x0b – 50 Hz 0x0c – 20 Hz
2	1	avgType	unsigned:3	0 to 4 average type values: 0x00 – OFF 0x01 – TIME 0x02 – EXP 0x03 – RMS 0x04 – PEAK
3		range1	unsigned:4	1 – 10
4	2	range2	unsigned:4	1 – 10 Range Values: 0x00 – AUTO (NOT USED) 0x01 – 5V 0x02 – 2V 0x03 – 1V 0x04 – 500 mV 0x05 – 200mV 0x06 – 100mV 0x07 – 50mV 0x08 – 20mV 0x09 – 10mV 0x0a – 5mV
5		winType	unsigned:2	0 – 8 Window types: 0x00 – HANN 0x01 – UNIFORM 0x02 – FORCE/EXP 0x03 – FLATTOP
6		coupling1	unsigned:2	0 – 3
7		coupling2	unsigned:2	0 – 3 Coupling values: 0x00 – DC 0x01 – AC 0x02 – GND (NOT USED) 0x03 – ICP
8	3	overload1	unsigned:2	Overload values: 0 = no overload; 1 = overload

Table 5-12. Detail Table for STATE_BITS Continued

Field Index	Binary Index	Field Name/Description	Data Type	Range/Units
9		overload2	unsigned:2	Overload values: 0 = no overload; 1 = overload
10		unit1	unsigned:1	0 (off) or 1 (on)
11		unit2	unsigned:1	0 (off) or 1 (on)
12		filterOn	unsigned:1	0 (off) or 1 (on)
13	4	blockLen	unsigned:3	0 – 4 Block Length values: 0x00 – 256 0x01 – 512 0x02 – 1024 0x03 – 2048 0x04 – 4096
14		forceLen	unsigned:7	0 – 100
15	5	expFactor	unsigned:4	0 – 10
16		weighting	unsigned:3	0 – 4 Weighting values: 0x00 – No-Weighting 0x01 – Integrate once 0x02 – Integrate twice 0x03 – A-Weighting
17		zoommode	unsigned:1	0 (off) or 1 (on)

The data block that follows the file and graphics headers is y-axis data. First the y-axis real values are given and then the y-axis imaginary values follow. The data type of each y-axis value is short.

To easily compare and archive data, use the SDF utilities provided with the instrument which convert HP 3560A output data to Standard Data Format (SDF). Data in SDF is compatible with other HP Dynamic Signal Analyzers such as the HP 3566A/3567A Multichannel Spectrum/Network Analyzer. To learn how to use the SDF utilities, see the *HP 3560A Getting Started Guide*, "Transferring Data to a Personal Computer" and the *Standard Data Format Utilities User's Guide.*

Discussion: Intel Hex Format

The HP 3560A uses the Intel Hex Format for data transfer. The HP 3560A uses only the data record and end of file records of the Intel Hex Format. The **data record** specifies the offset portion of the offset load address and the data to be loaded. Its format is as follows.

Intel Hex Data Record Format

Record Mark	Record Length	Load Address	Record Type	Data	Checksum
':'	2 char	4 char	'00'	1 to 255 bytes	2 char

The Record Mark field contains the ASCII character ':'.

The Record Length field contains two ASCII characters which specifies the number of data bytes in the Data field. Each data byte is described by two ASCII characters. The high order digit comes first. The maximum number is 255 decimal or FFH and is represented by the ASCII characters 'FF'. For example, a record length of 8fH is represented by the ASCII characters '8F'.

The Load Address field contains four ASCII characters which specifies the load address at which the data in the Data field are to be placed. This field specifies the offset portion of the 8086 base:offset address. The base is zero. The high order digit comes first. For example, the offset 4800 decimal or 12c0H is represented by the ASCII characters '12C0'.

The Record Type field contains the ASCII characters '00'.

The Data field contains the data. Two ASCII characters represent one data byte. The high order of the digit pair comes first. For example, the data byte 00101101 binary or 2DH is represented by ASCII characters '2D'.

The Checksum field contains two ASCII characters. The high order digit comes first. This field contains the ASCII representation of the two's complement of the modulo 256 sum of all the data bytes in the record including the Record Length, Load Address, Record Type and Data fields.

Consider the following Data Record example:

:200000002020202020333754524 30A011104045B2000B6046035563031323900B6004C617A

32 (20H) data bytes are to be loaded with no offset (0000H). The data bytes are: 20H 20H 20H 20H 20H 33H 37H 54H 52H 43H 0AH 01H 11H 04H 04H 5BH 20H 00H B6H 04H 60H 35H 56H 30H 31H 32H 39H 00H B6H 00H 4CH 61H

The **End Of File** Record specifies the end of the hex file. Its format is as follows:

Intel Hex End Of File Record Format

Record Mark	Record Length	Load Address	Record Type	Checksum
':'	'00'	'0000'	'01'	'FF'

- The Record Mark field contains the ASCII character ':'.
- The Record Length field contains the ASCII character '00'.
- The Load Address field contains the ASCII character '0000'.
- The Record Type field contains the ASCII character '01'.
- The Checksum field contains the ASCII character 'FF'.

The following is an End Of File Record:

:00000001FF

[Y-AXIS: A/B]

[Y-AXIS: A] and [Y-AXIS: B] are column headings in the [**Data**] menu that let you select different ways of looking at y-axis data on trace A and trace B.

You can look at:

- Linear Magnitude (marker reads out in Volts).
- Logarithmic Magnitude (marker reads out in dBV).
- Phase (marker reads out in degrees).
- Real part of the data (unitless).
- Imaginary part of the data (unitless).

When you are displaying both traces, you can use any combination of coordinates for each trace. If you are using an [VOLTS/EU], the marker reads out in dBE.

Refer to the specific coordinate name for more information on each. Also see the *HP 3560A Getting Started Guide*, "Understanding the HP 3560A" for more information on coordinate types.

[Y-UNITS]

Press [Y-UNITS] in the [**Scale**] menu to set the y-axis units of channel 1 or 2 to [VOLTS] or one of several engineering units. These include [g], [in/s], [m/s], [in], [m], [lbf] (foot-pound), [kgf] (kilogram-force), [SPL] (sound pressure level), [psi] (pounds per square inch), and [EU] (for some other type of engineering unit).

Note

Selecting one of the engineering units simply activates the scaling factor entered under [VOLTS/EU] and labels the display with that unit. It does not normally perform any additional scaling for you.

An exception is when [Y-UNITS] is [g] and integration is turned on in the [**Input**] menu. In this case, the analyzer will convert accelerometer measurements (in g's) to velocity (in meters/second or inches/second) or displaycement (in meters or inches). See [VOLTS/EU] for an example of engineering units.

To set the y-axis units to volts;

1. Press [**Scale**].
2. Move the column cursor to [Y-UNITS].
3. Toggle to [VOLTS] using [**Enter**].
4. Press any hardkey to exit the menu.

[ZOOM]

Use [ZOOM] to take a closer look at spectral data when you want to look at a certain portion of the data record. Select one of 11 different frequency spans and position the frequency span where you want by specifying a center frequency. When you use [ZOOM] the analyzer only takes a data record that corresponds to the center frequency and frequency span you specify. It then performs an FFT on this reduced size data record.

The number of available frequency spans and the center frequency resolution are both dependent on the highest frequency to be displayed in the zoom measurement. This frequency is given by the following:

[CENTER] + [SPAN]/2

Table 5-10 gives the available spans and center frequency resolution for each frequency cutoff.

Table 5-10. Zooming Limitations

[CENTER] + [SPAN]/2	Center Frequency Resolution	Zoom Spans Available
< 400 Hz	0.25 Hz	All spans
< 4 kHz	2.50 Hz	≥ 50 Hz
< 40 kHz	25 Hz	≥ 500 Hz

The smaller the frequency span you choose, the better you will be able to resolve signals on the display. Toggle between several span values from 20 Hz to 10 kHz in a 1, 2, 5 sequence. See [CENTER] and [SPAN] for more information. Also see the discussion under [TIME CH1/CH2] for more information on making time domain measurements using [ZOOM].

Note

When you turn on [ZOOM], the analyzer ignores the [BASEBAND] setting. To enable the [BASEBAND] setting, turn [ZOOM] off.

Also note that time averaging does not work for zoomed measurements. However, all other types of averaging work with zoomed measurements.

Discussion

Panning vs. Zooming Panning and zooming are both ways to take a close look at data. If you need high resolution for a measurement, either use zoom or choose a large data record and use panning. Panning lets you look at different sections of a data record that does not fit on the display. In other words, it scrolls a data record that is is too large to fit on the display. Choosing a large data record length is often necessary to get the resolution you need over some frequency range, especially at the higher frequency ranges. (The data record length depends on the [RESOLUTN] and [BASEBAND] settings). The full number of data points are sampled and FFT'ed, resulting in a display that is compressed. Press [**Shift**] [**EXPAND**] to expand the data, then use the [**PAN LEFT**] and [**PAN RIGHT**] shift functions to pan the display. The tradeoff for choosing a large data record is increased measurement time, expecially if you need high resolution at higher frequencies. A significant portion of this time is spent performing the FFT on the full data record.

When you know which portion of the data record you are interested in, using [ZOOM] can give you a speed advantage and higher resolution at higher frequencies than panning. The speed advantage comes from the fact that [ZOOM] lets you specify which part of the data record you are interested in and only performs an FFT on that portion. However, if you use [ZOOM] and decide to look at a different portion of the data record, you have to take a new data record. [ZOOM] gives higher resolution at higher frequencies because when you use panning, this means you have used a [BASEBAND] span setting which always starts at 0 Hz. For example, if you are only interested in the frequencies between 39 kHz and 40 kHz, and you use a [BASEBAND] span of 40 kHz and 1600-line resolution, each bin represents 25 Hz (40,000/1600). If you make a [ZOOM] measurement with the center frequency at 39.5 kHz and a frequency span of 500 Hz, and you use the same number of lines (1600), each bin represents 0.31 Hz (500/1600).

Menu Map

Use this menu map as a quick reference for finding which menu items appear under which hardkeys.

Display Keys

Data

TRACE–A	TRACE–B	Y-AXIS–A	Y-AXIS–B
SPEC CH1	SPEC CH1	LINMAG	LINMAG
SPEC CH2	SPEC CH2	LOGMAG	LOGMAG
PSD CH1	PSD CH1	dB MAG	dB MAG
PSD CH2	PSD CH2	PHASE	PHASE
TIME CH1	TIME CH1	REAL	REAL
TIME CH2	TIME CH2	IMAG	IMAG
CH1 – CH2	CH1 – CH2		
DIFF CH1	DIFF CH2		
OCT/3 CH1	OCT/3 CH2		
OCT/1 CH1	OCT/1 CH2		
FREQ RESP	FREQ RESP		
COHER	COHER		
XCOR	XCOR		

Format

FORMAT	MAP
A ONLY	TRACES
B ONLY	
A ABOVE B	SUPP%:
A FRONT B	
MAP A	HIDLINE:
MAP B	ON/OFF
ORBIT	

Scale

X-AXIS	Y-UNITS	VOLTS/EU	AUTOSCALE
LOG	CH1:	CH1:	A:
LINEAR	EU[1]/VOLTS		ON/OFF
	CH2:	CH2:	B:
	EU[1]/VOLTS		ON/OFF

[1] Selectable engineering unit labels include g, in/s, m/s, in, m, lbf, kgf, SPL, psi, and EU.

Measurement Keys

Freq

BASEBAND	ZOOM	RESOLUTN	WINDOW
40 kHz	ZOOM:	100 LINES	HANN
20 kHz	ON/OFF	200 LINES	FLATTOP
10 kHz	CENTER:	400 LINES	UNIFORM
5 kHz		800 LINES	FORCE/EXP
2 kHz	SPAN:	1600 LINES	
1 kHz			
500 Hz	**FILTER**	**SAMPLE**	**FORCE/EXP**
200 Hz	ON	INTERNAL	FORCE %L:
100 Hz	OFF	EXTERNAL	
50 Hz		CLK/REV:	EXP TC:

Input

RANGE1	COUPL 1	RANGE 2	COUPL 2
AUTO	DC	AUTO	DC
5V	AC	5V	AC
│	ICP	│	ICP
│		│	
5mV		5mV	
INTEGRATE[1]	**A-WEIGHT**		
OFF	OFF		
ONCE	ON		
TWICE			

Trigger

SOURCE	MODE	POINT	DELAY
FREERUN	SINGLE	SLOPE:	CH1:
CH1		POSITIVE/	
CH2		NEGATIVE	
EXTERNAL	RE-TRIG	LEVEL:	CH2:
EXT START			

Avg

TYPE:	NUMBER	OPTIONS
OFF		FAST AVG:
TIME		ON/OFF
RMS		PREVIEW:
RMS EXPO		ON/OFF
PEAK HOLD		

[1] When [Y-UNIT] is [g], [INTEGRATE] choices become [VEL m/s], [DISPL m], [VEL in/s], and [DISPL in].

System Keys

Save/Recall

OPERATION	REG NUMB:
CATALOG	NUMBER:
SAVE TRACE	
SAVE STATE	
RECALL TRACE	
RECALL STATE	
ERASE	
RESET	
XFER ONE	
XFER ALL	

Utility

TIME/DATE	RS232	DISPLAY	MISC
HR:	BAUD:	FILL: ON/OFF	TIMEOUT: ON/OFF
MIN:	PRTY:	GRID: ON/OFF	PRINT: HP PRINT/
SEC:	BITS: SEVEN/EIGHT	CONTR: 0 – 7	ALT. PRINT/ PLOT LaserPlot
MON: 1 – 12	HANDSHAK: CTS CTS+DSR		KEY BEEP: ON/OFF
DAY: 1 – 31			
YR: 0 – 99			

6

General Information

Introduction

This Service section contains all the information required by service personnel to adjust and service the HP 3560A Dynamic Signal Analyzer. It also gives circuit descriptions and shows how to assemble and disassemble the analyzer.

How to Use this section

The service section is divided into six chapters. Each section and topic is listed below.

Table 6-1

Chapter	Topic	Includes
6	General Information	Instrument Identification Accessories Supplied Safety Considerations Equipment Required
7	Adjustments	Adjusts to specifications in Installation section, chapter 2.
8	Replaceable Parts	Lists all parts in HP 3560A to assembly level
9	Backdating	Adapts the manual to older units.
10	Circuit Descriptions	Explains theory of operation
11	Service	Assembly troubleshooting data

Instrument Identification

The HP 3560A Dynamic Signal Analyzer has its serial number on the bottom cover. Hewlett-Packard uses a two-section serial number consisting of a four digit prefix and a five digit suffix separated by a letter designating the country in which the instrument was manufactured (A = U.S.A.; G = West Germany; J = Japan; U = United Kingdom). The prefix is the same for all identical instruments and changes only when a major instrument change is made. The suffix, however, is assigned sequentially and is unique to each instrument.

This manual applies to instruments which serial numbers indicated on the title page. If changes have been made since this manual was printed, a yellow "Manual Change" supplement will define the changes and explain to adapt the manual to the newer instruments. In addition, backdating information adapts the manual for instruments with serial numbers lower than those listed on the title page.

Accessories Supplied

Depending on the country of destination, one of the following ac adapters is supplied with the HP 3560A Dynamic Signal Analyzer.

Table 6-2

ac Adapters	
United States	HP 82241-60001
Europe	HP 82241-60002
United Kingdom	HP 82241-60003
Japan	HP 82241-60006
Australia	HP 82241-60004
South Africa	HP 82241-60005

Safety Considerations

Although the HP 3560A Dynamic Signal Analyzer is designed in accordance with international safety standards, this manual contains information, cautions, and warnings that must be followed to ensure safe operation and to keep the unit in safe condition. Service and adjustments must be performed by trained service personnel who are aware of the hazards involved (such as fire and electrical shock).

Warning

When you are operating the HP 3560A Dynamic Signal Analyzer, do not remove the bottom or top enclosures or in any other way access the interior of the analyzer. The battery cover is the only part of the instrument that you may routinely need to remove to replace the battery pack. There are no operator controls inside the analyzer.

Equipment Required

Table 1-2 in the Installation section lists the recommended equipment needed to adjust and troubleshoot the HP 3560A Dynamic Signal Analyzer. You may substitute other equipment for the recommended model if it meets or exceeds the listed critical specifications. If you make substitutions, you may have to modify the procedures to accommodate the different operating characteristics.

Adjustments

Introduction

This section contains the adjustment procedures for the HP 3560A Dynamic Signal Analyzer. Use these adjustments to return the HP 3560A to specified operating accuracy after repair or for periodic maintenance.

Note

Before you make adjustments, fully charge the battery and allow 15 minutes for the analyzer to warm up.

Safety Considerations

Although the HP 3560A Dynamic Signal Analyzer is designed in accordance with international safety standards, this manual contains information, cautions, and warnings that must be followed to ensure safe operation and to keep the unit in safe condition. Service and adjustments must be performed by trained service personnel who are aware of the hazards involved (such as fire and electrical shock).

Warning

The adjustment procedures that follow should only be performed by trained service personnel at a static free station.

Equipment Required

See chapter 1, "Installation," in this manual for tables listing recommended test equipment. Any equipment which meets the critical specifications given in the tables may be substituted for the recommended model.

Make sure the analyzer's battery is fully charged.

Adjustment Locations

As an adjustment aid, adjustment locators appear at the beginning of each adjustment procedure. These locators are simplified illustrations of the assembly showing the locations of the test points and adjustable components.

Adjustment Summary

Table 7-1 lists all the adjustments. Perform them in the order listed since certain adjustment results assume the previous adjustment has been performed. Any deviation from this order is not recommended. If any of the adjustment results are unattainable, replace the assembly.

Before you begin the adjustment procedures, you must remove the battery and bottom cover. For information on battery and bottom cover removal, see the Disassembly/Assembly portion of "Replaceable Parts."

Table 7-1. Adjustments

Adjustment Procedure	Assembly	Component
#1. First Stage Input Offset	A3	R106/TP12 R105/TP22
#2. Second Stage Input Offset	A3	R107/TP13 R108/TP23
#3. ADC Offset	A3	R103/TP16 R101/TP26
#4. ADC Gain	A3	R104 R102
#5. Real Time Clock Timebase	A2	TP1/TP2 C18

If The Adjustment Fails

There are five major adjustment procedures. If any of the first four fail, replace the A3 assembly. If only the last test fails, replace the A2 assembly.

Adjustment Procedures

#1. First Stage Input Offset

This procedure adjusts the DC offsets of each of the two input channels (1 and 2).

Equipment Required: DC Voltmeter
50Ω Feedthroughs (2 required)

Adjustments and Locations

	Assembly	Adjustment Location	Test Point Location
Channel 1	A3	R106	TP12
Channel 2	A3	R105	TP22

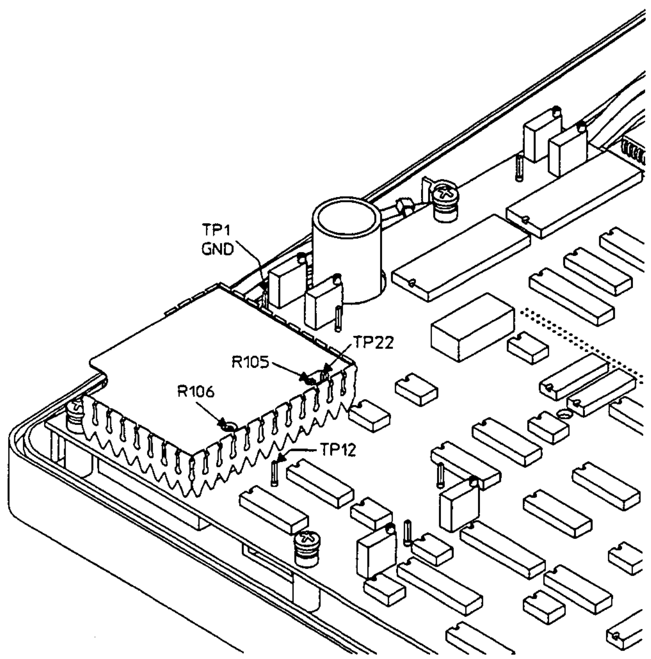


Figure 7-1.
First Stage Input Offset Adjustment Locator

Procedure

1. Connect a 50Ω feedthrough to the Channel 1 and Channel 2 Inputs of the HP 3560A.

2. Pressing the following keys.

   [**Preset**]
   [**Enter**]
   [**Input**]
   Set [RANGE1] to [5 mV]
   Set [RANGE2] to [5 mV]
   [**Start**]

3. Set the voltmeter to read volts dc, with at least a 100 μV resolution.

4. Connect the voltmeter low input to the analog ground at A3 TP1.

5. Connect the voltmeter high input to A3 TP12, and adjust R106 for a reading of zero volts dc, $\pm 500\mu$V.

6. Move the voltmeter high input from A3 TP12 to A3 TP22, and adjust R105 for a reading of zero volts dc, $\pm 500\mu$V.

#2. Second Stage Input Offset

This adjustment sets the DC offset the second stage of channel 1 and the second stage of channel 2.

Equipment Required: DC Voltmeter
50Ω Feedthroughs (2 required)

Adjustments and Locations

	Assembly	Adjustment Location	Test Point Location
Channel 1	A3	R107	TP13
Channel 2	A3	R108	TP23

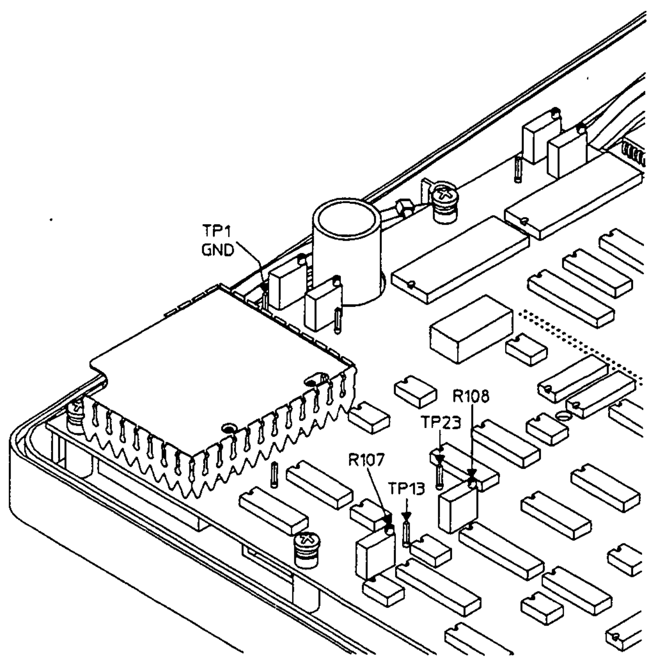


Figure 7-2.
100 kHz LPF Offset Adjustment Locator

Procedure

1.Connect a 50Ω feedthrough to the Channel 1 and Channel 2 Inputs of the HP 3560A.

2.Pressing the following keys.

[**Preset**]
[**Enter**]
[**Input**]
Set [RANGE1] to [5 mV]
Set [RANGE2] to [5 mV]
[**Start**]

3.Set the voltmeter to read volts dc, with at least 1 mV resolution.

4.Connect the voltmeter low input to the ground at A3 TP1.

5.Connect the voltmeter high input to A3 TP13, and adjust R107 for a reading of zero volts dc, ± 30 mV.

6.Move the voltmeter high input from A3 TP13 to A3 TP23, and adjust R108 for a reading of zero volts dc, ± 30mV.

#3. Analog-to-Digital Converter Offset

This adjustment sets the offsets of the input channel's ADC circuits

Equipment Required: DC Voltmeter
50Ω Feedthroughs (2 required)

Adjustments and Locations

	Assembly	Adjustment Location	Test Point Location
Channel 1	A3	R103	TP16
Channel 2	A3	R101	TP26

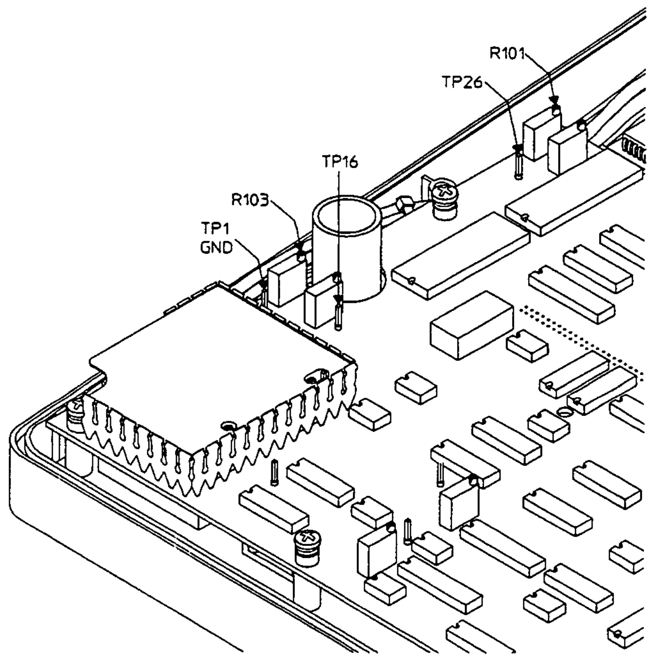


Figure 7-3.
ADC Offset Adjustment Locator

Procedure

1. Connect a 50Ω feedthrough to the Channel 1 and Channel 2 Inputs of the HP 3560A.
2. Pressing the following keys.
   [**Preset**]
   [**Enter**]
   [**Input**]
      Set [RANGE1] to [5 mV]
      Set [RANGE2] to [5 mV]
   [**Start**]
3. Set the voltmeter to read volts dc, with at least 1 mV resolution.
4. Connect the voltmeter low input to the ground at A3 TP1.
5. Connect the voltmeter high input to A3 TP16 and adjust R103 for a reading of zero volts dc, ± 30 mV.
6. Move the voltmeter high input from A3 TP16 to A3 TP26, and adjust R101 for a reading of zero volts dc, ± 30mV.
7. Remove the voltmeter test leads from the A3 test points.

#4. Analog-to-Digital Converter Gain

This adjustment sets the offsets of the input channel's ADC circuits

Equipment Required: AC Source
50Ω Feedthroughs (2 required)

Adjustments and Locations

	Assembly	Adjustment Location	Test Point Location
Channel 1	A3	R104	LCD Display
Channel 2	A3	R102	LCD Display

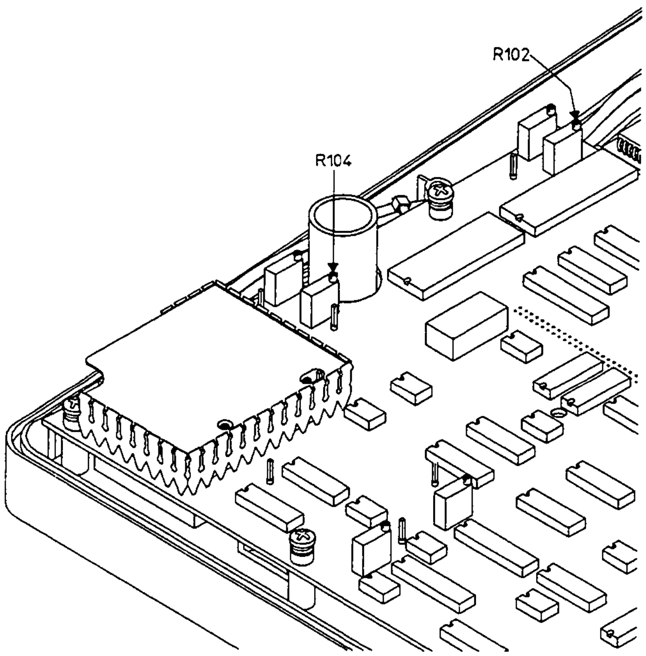


Figure 7-4.
ADC Gain Adjustment Locator

Procedure

1:Connect the source output to the Channel 1 and Channel 2 inputs using the 50Ω feedthroughs.

2.Pressing the following keys.

[**Preset**]
[**Enter**]
[**Format**]
[A ABOVE B]
[**Input**]
Set [RANGE1] to [2 V]
Set [RANGE2] to [2 V]
[**Start**]

3.Set the source as follows.

Amplitude: 1 Vrms
Frequency: 10 kHz

4.Press the following on the HP 3560A.

[**Shift**]
[**MKR PEAK**]
Make sure the marker moves to the 10 kHz signal.

5.Adjust R104 to a channel 1 marker reading of 0 dBV ± 40 mdBV.

6.Make the trace B (channel 2) marker active and move it to the signal peak by pressing:

[**Enter**]
[**Shift**]
[**MKR PEAK**]
Make sure the marker moves to the 10 kHz signal.

7.Adjust R102 for a marker reading of 0 dBV ± 40 mdBV.

#5. Real-time Clock Timebase

This adjustment sets the frequency of the crystal oscillator of the real-time clock.

Equipment Required: Frequency Counter

Adjustments and Locations

Assembly	Adjustment Location	Test Point Location
A2	C18	TP2

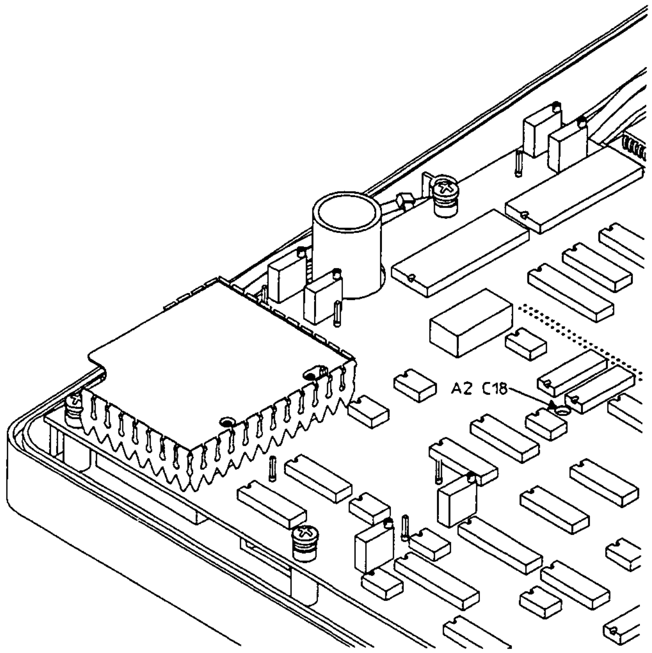


Figure 7-5.
Real-Time Clock Adjustment Locator

Procedure

1.Turn off the HP 3560A by pressing:

[**Shift**]
[**Off**]

2.Set the frequency counter for a display resolution of at least 0.1 Hz.

3.Connect the high input of the frequency counter to A2 TP2.

4.Connect the low input of the frequency counter to ground A2 TP1.

5.Adjust the counter sensitivity for a consistent reading, about 32768 Hz.

6.Adjust A2 C18 for a counter reading of 32768 Hz ± 0.1 Hz.

Replaceable Parts

Introduction

This section contains information for ordering replacement parts for the HP 3560A Dynamic Signal Analyzer. This section also contains instructions for disassembly and assembly of the analyzer. These illustrations also show reference desiginator numbers for the hardware.

Replacement parts are listed in the following three tables:

- Assemblies
- Cables
- Hardware

Caution Many of the parts listed in this section are static sensitive. Use the appropriate precautions when removing, handling, and installing all parts to avoid unnecessary damage.

Ordering Information

Note See the final pages in the back of this manual for a list of Hewlett-Packard sales and service office locations and addresses.

Ordering Non-Listed Parts

To order a part that is NOT listed in the replaceable parts tables, indicate the instrument model number, instrument serial number, description and function of the part, and the quantity of the part required. Address the order to the nearest Hewlett-Packard sales and service office.

Direct Mail Order System

Within the U.S.A., Hewlett-Packard can supply parts through a direct mail order system. Advantages of the Direct Mail Order System are:

- Direct ordering and shipment from the HP Parts Center.
- No maximum or minimum on any mail order. There is a minimum order for parts ordered through a local HP sales and service office when the orders require billing and invoicing.
- Transportation charges are prepaid. A small handling charge is added to each order.
- No invoicing. A check or money order must accompany each order.
- Mail order forms and specific ordering information are available through your local Hewlett-Packard sales and service office.

Table 8-1. Abbreviations Used

Abbreviations			
A	ampere(s)	ns	nanosecond(s) = 10^{-9} seconds
com	common	p	peak
dep	deposited	pF	picofarad(s) 10^{-12} farads
F	farad(s)	pot	potentiometer
FET	field effect transistor	p-p	peak-to-peak
GHz	gigahertz = 10^{+9} hertz	R	resistor
gnd	ground(ed)	rms	root-mean-square
H	henry(ies)	V	volt(s)
Hz	hertz (cycle(s) per second)	var	variable
ID	inside diameter	W	watts
kΩ	kilohm(s) = 10^{+3} ohms		
kHz	kilohertz = 10^{+3} hertz		
L	inductor		
mA	milliampere(s) = 10^{-3} amperes		
MHz	megahertz = 10^{+6} hertz		
MΩ	megohms(s) = 10^{+6} ohms		
mfr	manufacturer		
ms	microsecond		
mV	millivolt(s) = 10^{-6} volts		
μF	microfarad(s)		
μs	microsecond(s)		
μV	microvolt(s) = 10^{-6} volts		
nA	nanoampere(s) = 10^{-9} amperes		

Table 8-2. Manufacturers' Code Numbers

Mfr No.	Mfr Name	Address
00955	Koszegi Products Inc.	South Bend, IN 46624
01924	ITW Fastex	Des Plaines, IL 60016
02916	Colorado Container	Denver, CO 80216
06363	Oudensha America Inc.	Elk Grove Village, IL 60007
06925	Sherwood Enterprises Inc.	Longmont, CO 80501
13115	Citizen Watch Co.	Tokyo, JP
03418	Molex Incorporated	Lisle, IL 60532
28480	Hewlett-Packard Company	Palo Alto, CA 94304
09655	Chomerics Shielding Technologies	Carson
L2276	Syndetek Corporation	Spokane, WA 99202
L3606	Kasho	San Francisco, CA 94105
L3914	Instrument Plastics Limited	Maidenhead Berkshire, UK

Assemblies

To order an assembly listed in Table 8-3, quote the Hewlett-Packard part number, the check digit (CD), indicate the quantity required, and address the order to the nearest Hewlett-Packard sales and service office. The check digit verifies that an order has been transmitted correctly, ensuring accurate and timely processing of the order. The first time a part is listed in the table, the quantity column lists the total quantity of the part used in the analyzer. See Table 8-2 for a table listing the manufacturers' code numbers and the corresponding names and addresses.

Table 8-3. Assemblies

Ref.Des.	HP Part Number	CD	Qty	Description	Mfr. Code	Mfr. Part Number
A1	03560-69501	3	1	DSP KEYBOARD	28480	03560-69501
A2	03569-69502	4	1	MAIN CPU	28480	03569-69502
A3	03560-69503	5	1	ANALOG	28480	03560-69503
MP201	1990-1429	9	1	DSPL 6.5" LCD 320X240 W/BKLGT	13115	CG-3202400K-01

Cables

To order a part listed in Table 8-4, quote the Hewlett-Packard part number, the check digit (CD), indicate the quantity required, and address the order to the nearest Hewlett-Packard sales and service office. The check digit verifies that an order has been transmitted correctly, ensuring accurate and timely processing of the order. The first time a part is listed in the table, the quantity column lists the total quantity of the part used in the analyzer. See Table 8-2 for a table listing the manufacturers' code numbers and the corresponding names and addresses.

Table 8-4. Cables

Ref.Des.	HP Part Number	CD	Qty	Description	Mfr. Code	Mfr. Part Number
MP301	03560-61609	2	1	CABLE-DISPLAY	28480	03560-61609
MP302	03560-61602	5	1	CBL-ASM FHSG/FSKT 2 CKT 350MM	28480	03560-61602
MP303	03569-61603	5	1	CBL-CHARGER	28480	03569-61603
MP304	03569-61604	6	1	CBL-ASM FHSG1DSUB 7CKT 410MM	L2276	03569-61604
MP305	03560-61605	5	1	CBL-BACKLIGHT	28480	03560-61605
MP306	03560-61607	0	1	CBL-ASM CXL FBNC1STP 180MM ML	L2276	03560-61607
MP307	03560-61608	1	1	CBL-INPUTS	L2276	03560-61608
MP401	8160-0710	7	2	RFI-COND-ELAST .053IN DIA	57003	10-04-3560-1215
MP402	1251-8026	0	1	CONN-POST TYPE .100-PIN-SPCG 12-CONT	27264	22-12-2124
MP403	8160-0271	5	2	GSKT-RFI .062IN OD ROUND ELAST	57003	10-04-2561-1215

Hardware

To order a part listed in Table 8-5, quote the Hewlett-Packard part number, the check digit (CD), indicate the quantity required, and address the order to the nearest Hewlett-Packard sales and service office. The check digit verifies that an order has been transmitted correctly, ensuring accurate and timely processing of the order. The first time a part is listed in the table, the quantity column lists the total quantity of the part used in the analyzer. See Table 8-2 for a table listing the manufacturers' code numbers and the corresponding names and addresses. For hardware reference desiginator numbers, see the disassembly/assembly illustrations following this table.

Table 8-5. Hardware

Ref.Des.	HP Part Number	CD	Qty	Description	Mfr. Code	Mfr. Part Number
MP100	03560-34302	5	1	PLT-NAME "3560A"	06363	03560-34302
MP100	5959-5702	7	1	NAMEPLATE, BLANK	28480	5959-5702
MP101	03569-40201	5	1	TOP MOULDING	06925	03569-40201
MP102	03569-40202	6	1	BASE MOULDING	06925	03569-40202
MP103	03560-44101	3	1	BATTERY COVER	06925	03560-44101
MP104	03569-29301	8	1	LNZ-LCD WINDOW	L3914	03569-29301
MP106	0403-0764	9	4	MOLD-BMPR PVC BLACK	01924	BLACK M22
MP107	03560-80401	2	1	LABEL-BASE MOULDING	28480	03560-80401
MP109	1990-1455	1	1	OPT-HERMETIC LED GREEN PNL MNT	28480	1990-1455
MP110	1440-0215	4	1	HANDLE	02170	1440-0215
MP111	03560-80407	8	1	REAR LABEL	11373	03560-80407
MP202	03560-41902	6	1	KYPD ELASTOMERIC "3560A"	L3606	03560-41902
MP203	1420-0504	2	1	BAT-NICAD, 5 D CELLS 6V NOM	28480	1420-0504
MP204	03560-36705	6	1	GASKET-DISPLAY	28480	03560-36705
MP501	03560-31001	5	1	CASE-CARRYING	00955	03560-31001
MP502	03560-90013	3	1	MANL-OPERATING & SERVICE	28480	03560-90013
MP503	03560-84401	0	1	GETTING STARTED KIT	28480	03560-84401
MP503	9211-2417	5	1	PKG-CTN OPF 200S11.75X9.75X1.0	02916	
MP503	03560-90001	9	1	MANL-GETTING STARTED GUIDE	28480	03560-90001
MP503	03560-95901	8	1	GETTING STARTED AUDIO TAPE	28480	03560-95901
MP503	03560-61606	9	1	CBL-ASM CXL MBNC1MPNO 925MM ML	28480	03560-61606
MP504	03560-48301	3	2	CUSHION	28480	03560-48301
MP504	03560-90002	0	1	MANL-REFERENCE GUIDE	28480	03560-90002
MP505	03560-48302	4	1	TRAY	28480	03560-48302
MP506	9211-5862	0	1	PKG-CTN RSC 275S22.3X19.3X12.3	28480	9211-5862
MP507	03563-84410	4	1	SDF UTILITIES	28480	03563-84410

Disassembly Instructions

The HP 3560A contains three major assemblies:

- A1 Main Processor Assembly
- A2 Digital Signal Processor (DSP) Assembly
- A3 Input Assembly

It also has a Liquid Crystal Display (LCD) and a rechargeable battery pack.

Use the following instructions for assembly removal and replacement of each assembly.

Warning **Turn off the analyzer and make sure the ac adapter is not connected to the connector panel before disassembly or assembly of the HP 3560A Dynamic Signal Analyzer. Only qualified service personnel should assemble or disassemble the HP 3560A.**

Caution Do not connect or disconnect ribbon cables from circuit assemblies with the analyzer turned on or with the ac adapter connected. To protect circuits from static discharge, remove or replace HP 3560A assemblies only at static-protected work stations.

Battery Pack Removal

1.Place the instrument on a flat surface with the front panel side down.

2.Remove the two screws from the battery cover plate as shown in figure 8-1.

3.Lift the battery pack out of its compartment and disconnect the battery cable by pinching or pressing down on the connector's locking device.

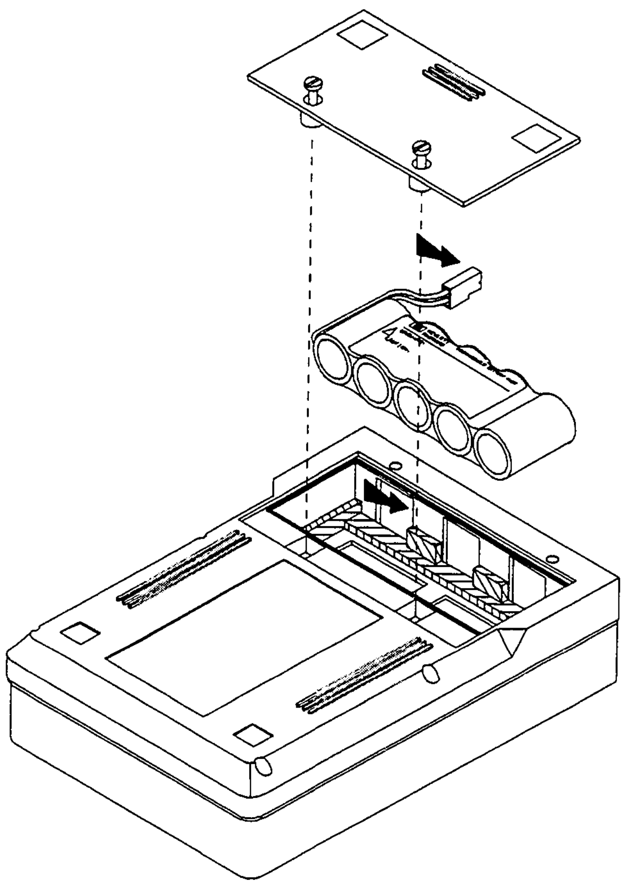


Figure 8-1.
Battery Pack Removal

Bottom Cover Removal

1. Remove the six screws from the perimeter of the bottom cover as shown in figure 8-2.
2. Carefully lift off the bottom cover and feed the battery cable through the opening above the battery pack compartment.

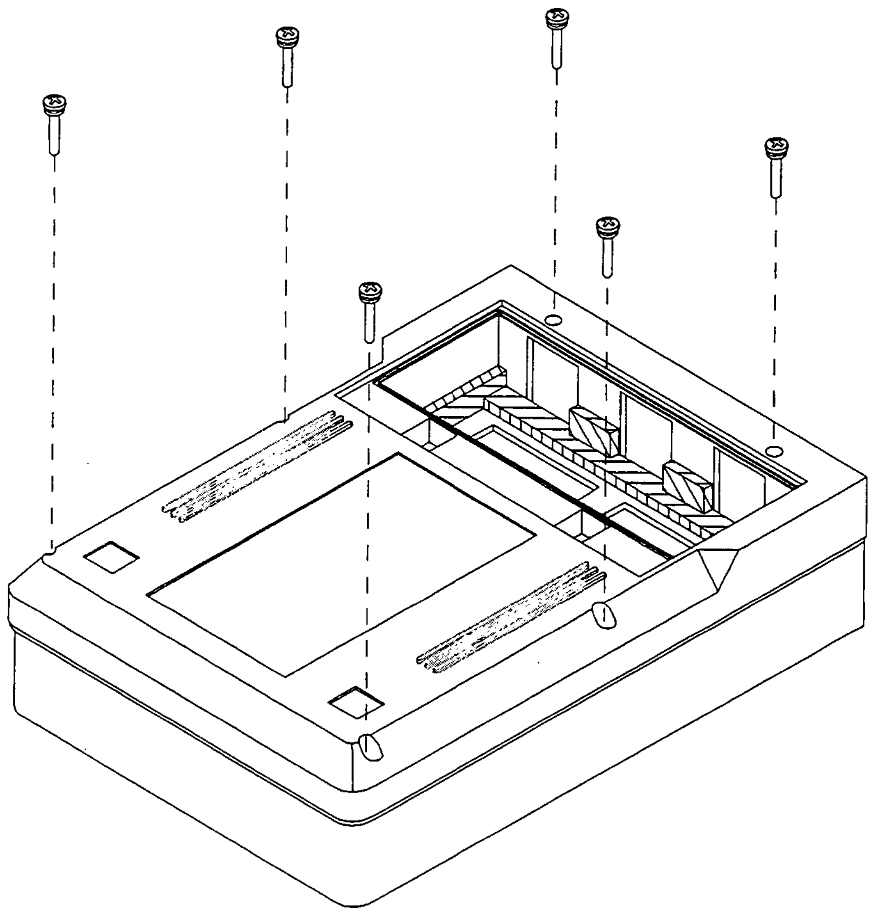


Figure 8-2.
Bottom Cover Removal

A3 Analog Assembly Removal

Caution

Be careful when removing and installing the six screws from the A3 assembly. When turning the screws in, turn the screw only 1/4 turn after you feel resistance. If any part of the insert breaks, it can be fixed by using five minute epoxy.

1.Remove the six screws holding the A3 assembly as shown in figure 8-3.

2.Disconnect the Input Cable at P2 and the Trigger Cable at P1.

3.Pull the A3 assembly away from the lower assemblies. It may help to place your tumb on the large capacitor shown at the left of figure 8-3 as you pull the A3 assembly up. (You will use one of the six A3 assembly screws as a backout screw for removing the A2 assembly.)

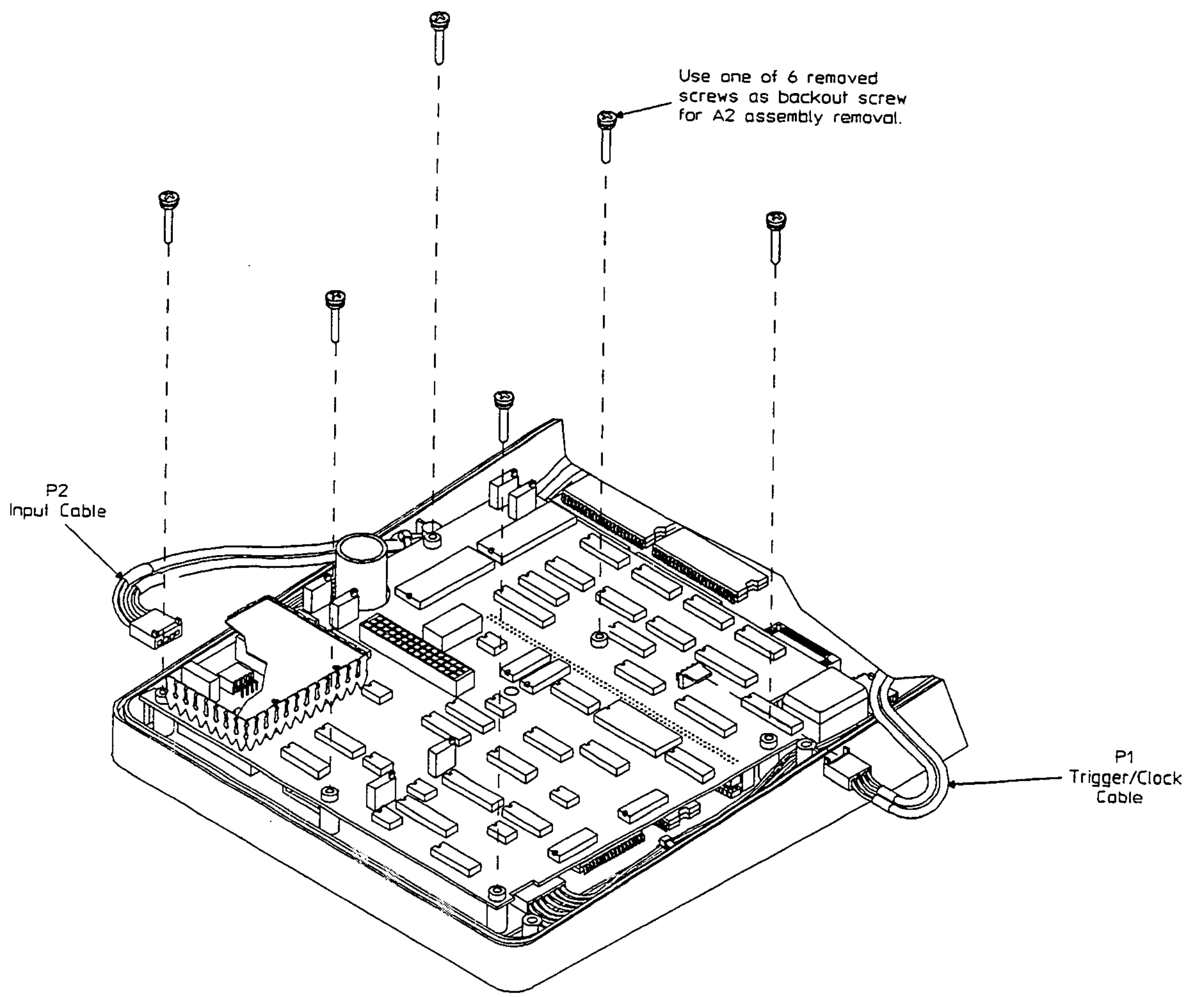


Figure 8-3.
A3 Assembly Removal

A2 Main Assembly Removal

1. Remove the two screws holding the A2 assembly as shown in figure 8-4.
2. Disconnect the Battery Cable at P6, the Charger Cable at P3, the Backlight Cable at P5, and the RS-232C Cable at P1.
3. Install one of the screws in the special slot in the board as shown and turn until the A2 assembly is lifted off the main connector (center of the assembly).
4. Remove the A2 assembly.

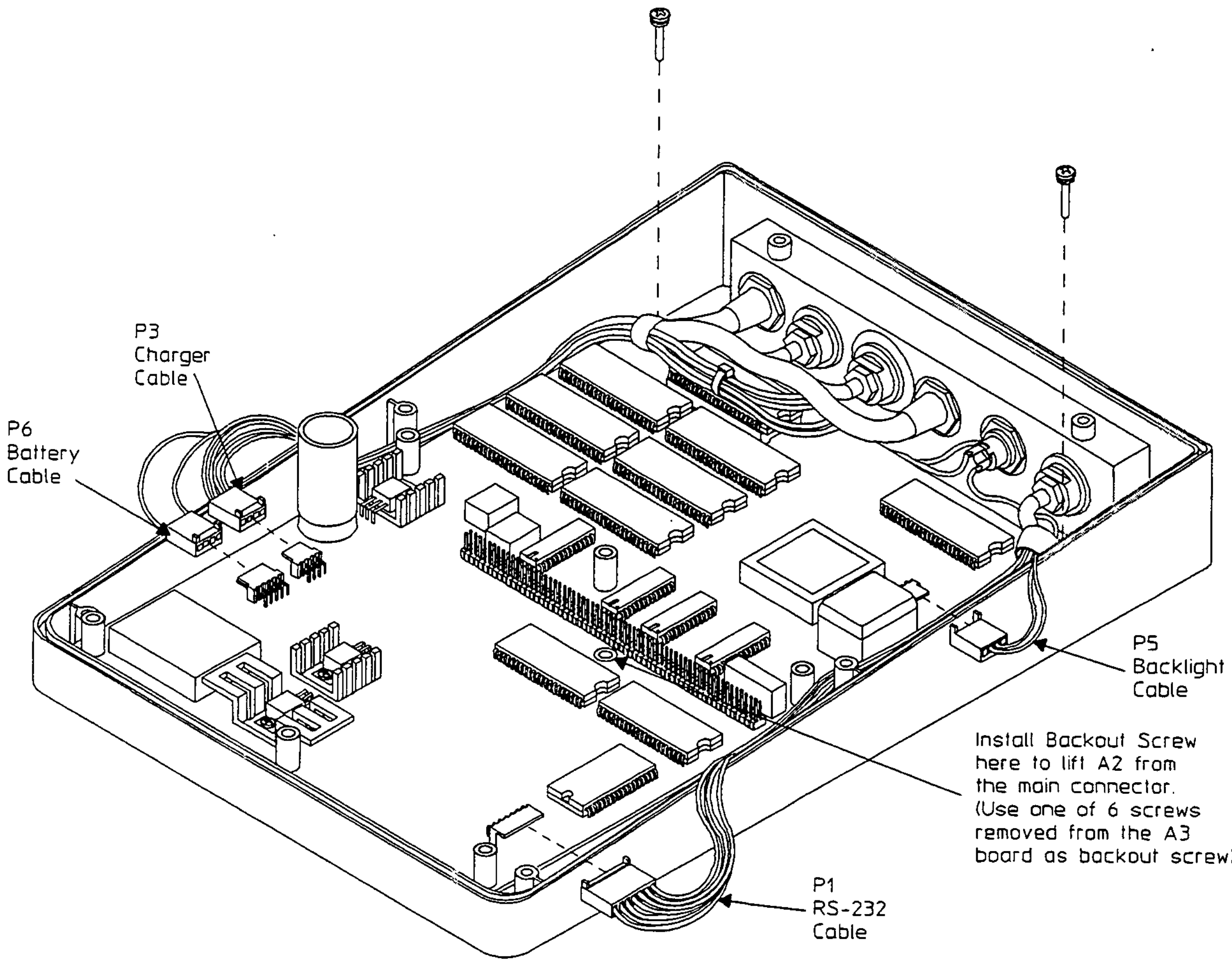


Figure 8-4.
A2 Assembly Removal

A1 DSP Assembly Removal

1.Remove the three screws holding the A1 assembly as shown in figure 8-5.

2.Carefully disconnect the LCD driver cable and push it through the slot so it is under the A1 assembly as shown in figure 8-5.

3.Remove the A1 assembly.

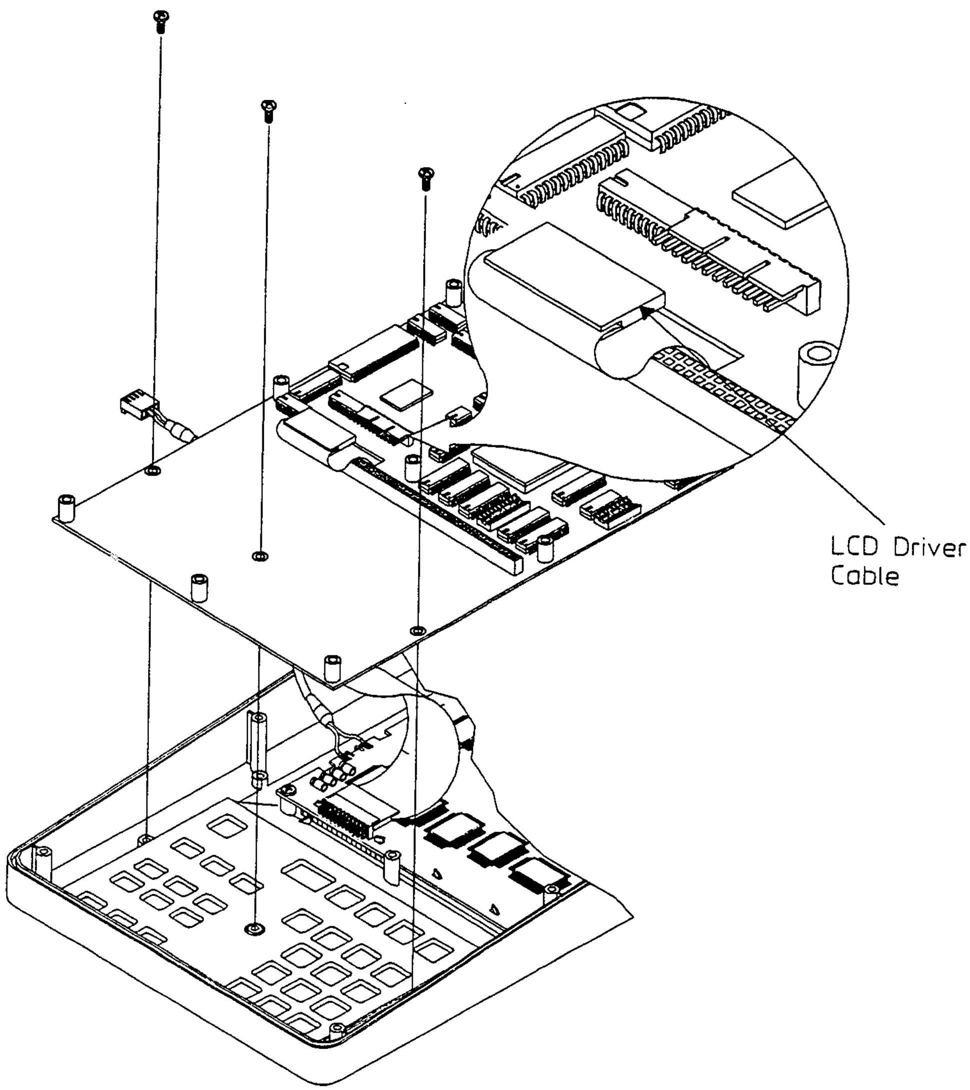


Figure 8-5.
A1 Assembly Removal

LCD Display Removal

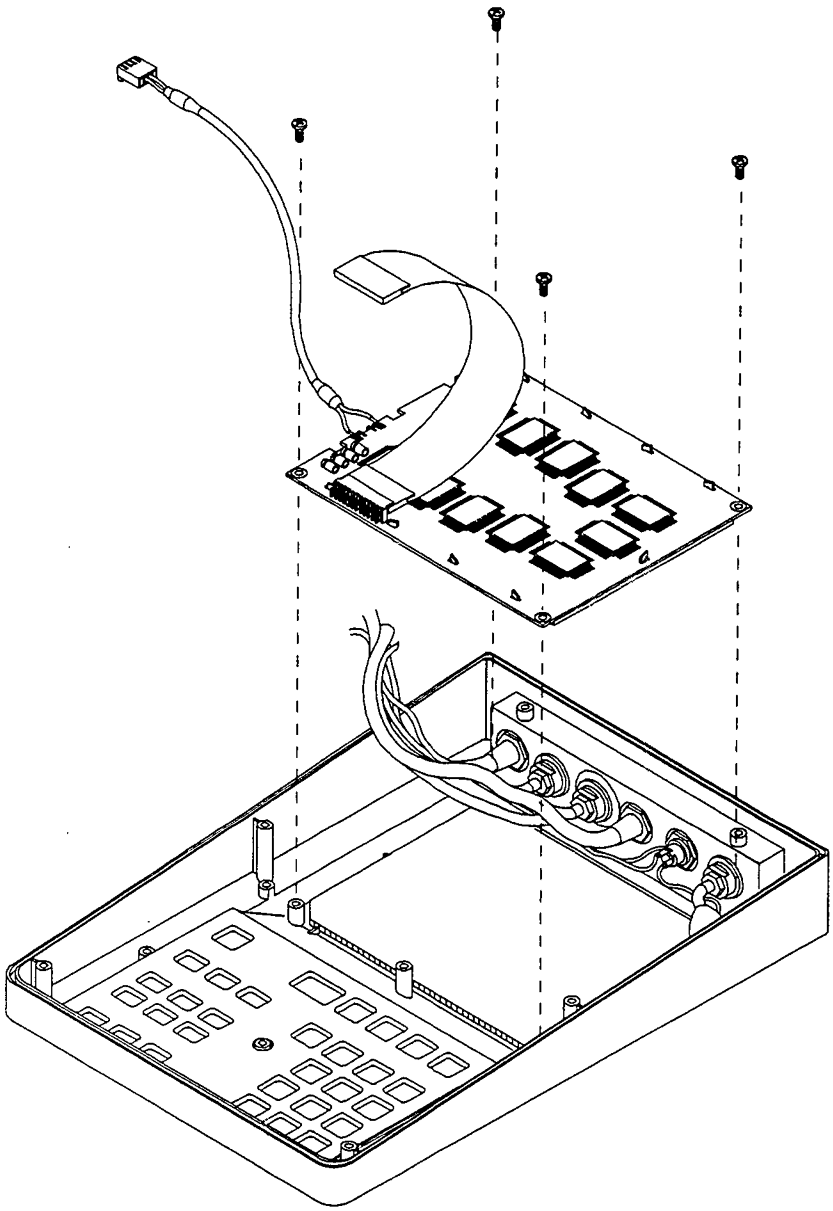


**Figure 8-6.
LCD Display Removal**

Manual Backdating

Introduction

This section provides information necessary to modify this manual for instruments that differ from those currently being produced. The information in this section documents earlier instrument configurations and associated servicing procedures.

With the information provided in this section, this manual can be corrected so that it applies to any earlier version or configuration of the instrument. Later versions of the instrument are documented in the Manual Changes Supplement.

Manual Changes Supplement

As Hewlett-Packard continues to improve the performance of the HP 3560A, corrections and modifications to the manual may be required. Required changes are documented by a yellow Manual Changes supplement and/or revised pages. To keep the manual up-to-date, periodically request the most recent supplement, available from the nearest Hewlett-Packard sales and service office (for office locations, see the listing at the back of this manual).

Serial Number 3236A00697 and lower

There are two groups of changes for these instruments: front panel and rear panel. On the front panel, the shift functions are printed on the panel rather than on the keys, and some of the names are slightly different. On the rear panel, the connectors are in different locations.

Chapter 1

The ac adapter connector is in a different location on the rear panel. Refer to the following illustration, which replaces figure 1-1 (page 1-6).

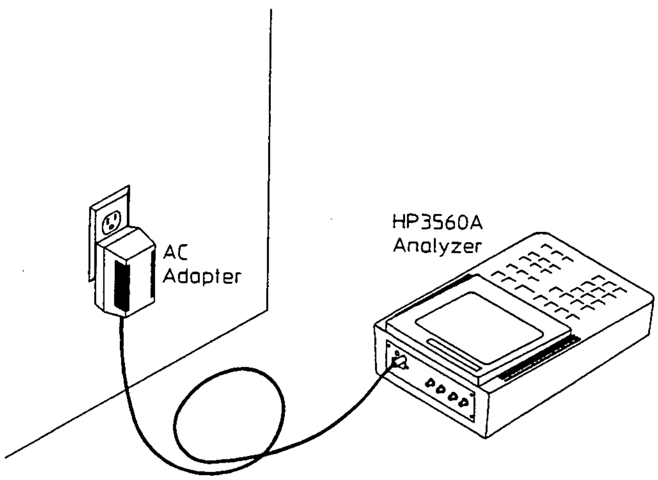


Figure 1-1.
Recharging the internal battery pack

Chapter 4

Earlier instruments had the shift functions printed in blue above the keys rather than on the keys, and some of the names were slightly different. Refer to the following illustration, which replaces these front panel illustrations: figures 4-2, 4-4, 4-8, 4-15, 4-22, and all others that show the front panel.

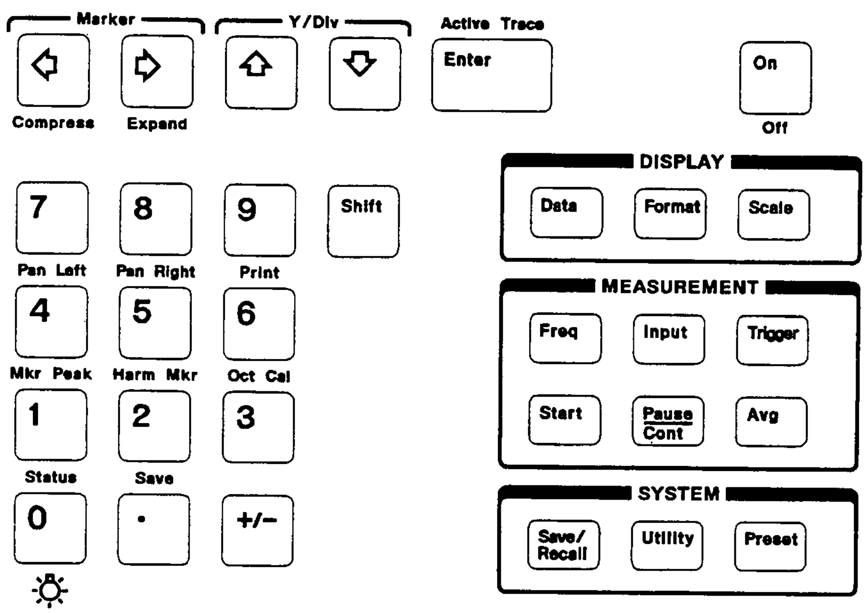


Figure 9-1.

These same instruments also had a different rear panel.

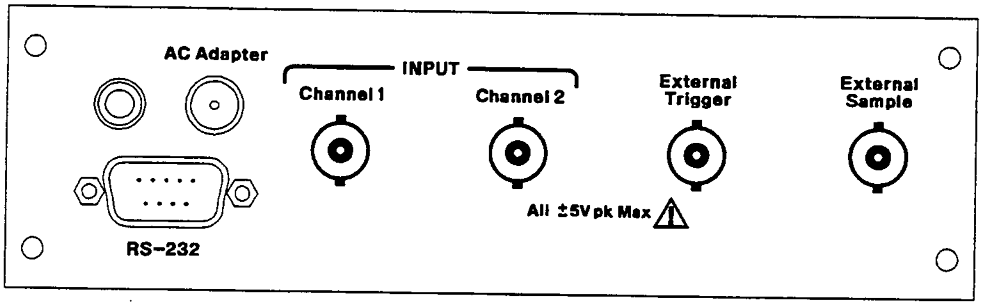


Figure 9-2.

Chapter 8

The parts listed in the following two tables are different for earlier instruments.

Table 8-4. Cables

Ref.Des.	HP Part Number	CD	Qty	Description	Mfr. Code	Mfr. Part Number
Change:						
MP303	03560-61603	6	1	CBL-CHARGER	28480	03560-61603
MP304	03560-61604	7	1	CBL-ASM FHSG1DSUB 7CKT 410MM	L2276	03560-61604

Table 8-5. Hardware

Ref.Des.	HP Part Number	CD	Qty	Description	Mfr. Code	Mfr. Part Number
Change:						
MP101	03560-40201	6	1	TOP MOULDING	06925	03560-40201
MP102	03560-40202	7	1	BASE MOULDING	06925	03560-40202
MP104	03560-29301	3	1	LNZ-LCD WINDOW	L3914	03560-29301
MP202	03560-41901	5	1	KYPD ELASTOMERIC "3560A"	L3606	03560-41901
Add:						
MP105	03560-00201	2	1	SHTF PANEL-REAR	28480	03560-00201
MP205	03560-44102	4	1	COVER, CONDUCTIVE	28480	03560-44102
Delete:						
MP110	1440-0215	4	1	HANDLE	02170	1440-0215
MP111	03560-80407	8	1	REAR LABEL	11373	03560-80407

Replace figure 8-3 (page 8-10) with the following illustration.

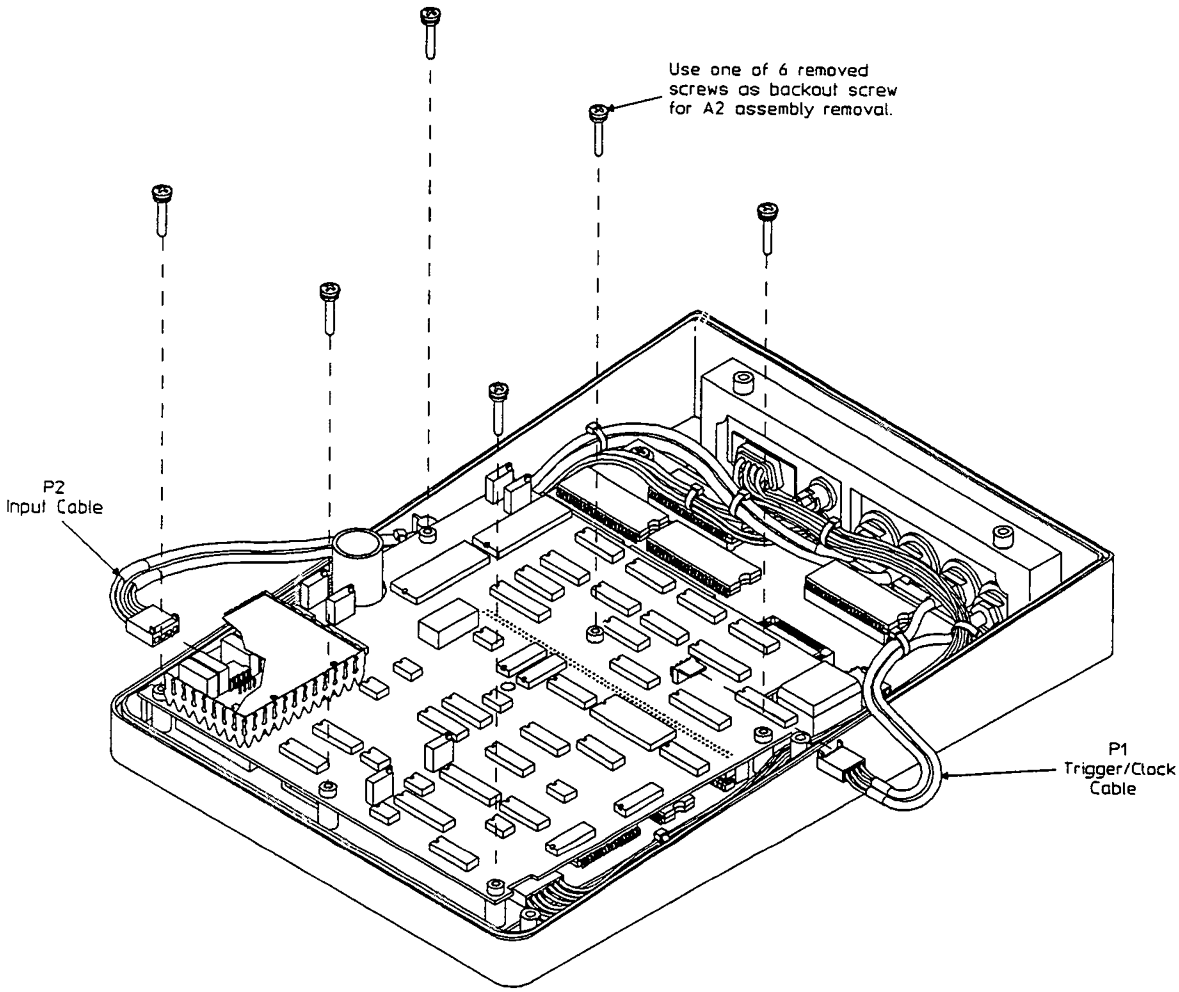


Figure 8-3.
A3 Assembly Removal

Replace figure 8-4 (page 8-11) with the following illustration.

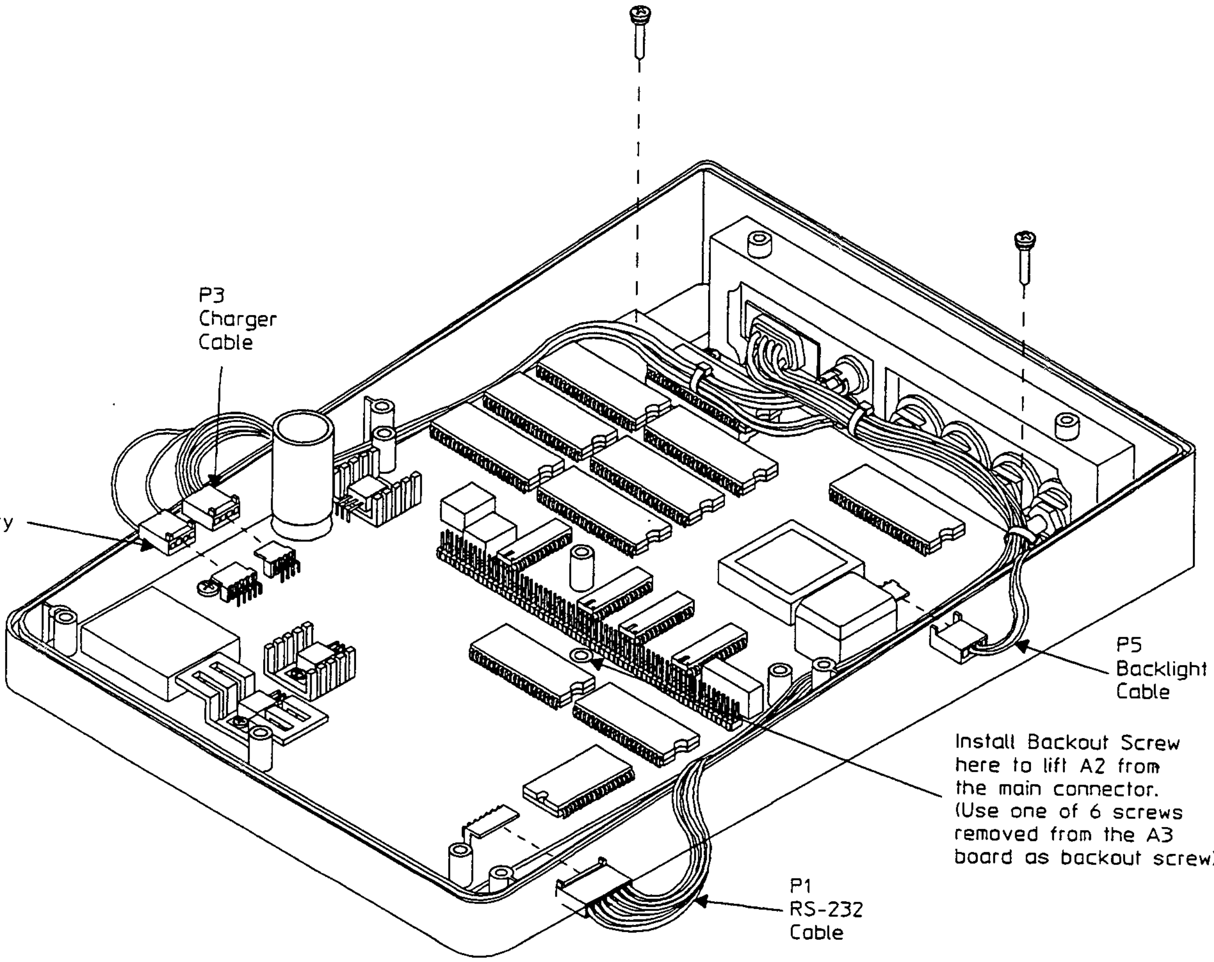


Figure 8-4.
A2 Assembly Removal

Replace figure 8-5 (page 8-12) with the following illustration.

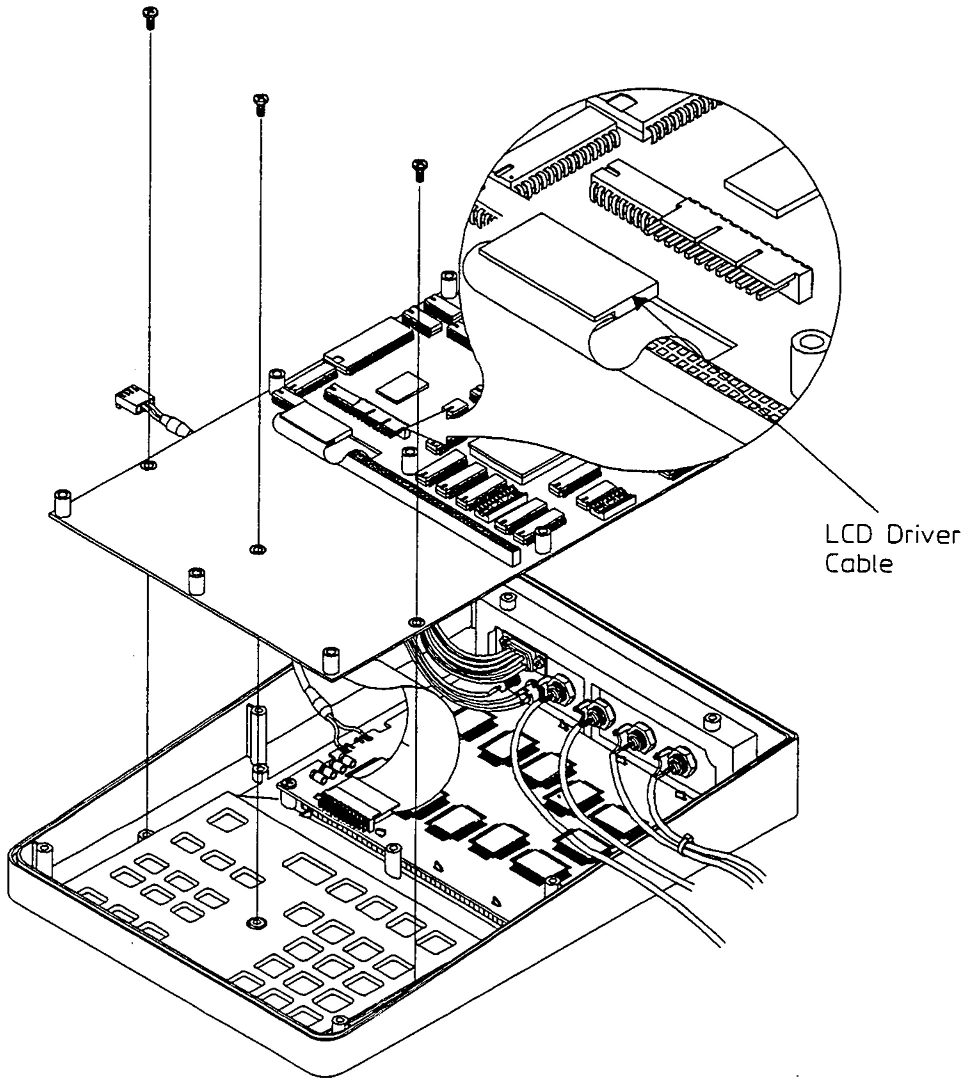


Figure 8-5.
A1 Assembly Removal

Replace figure 8-6 (page 8-13) with the following illustration.

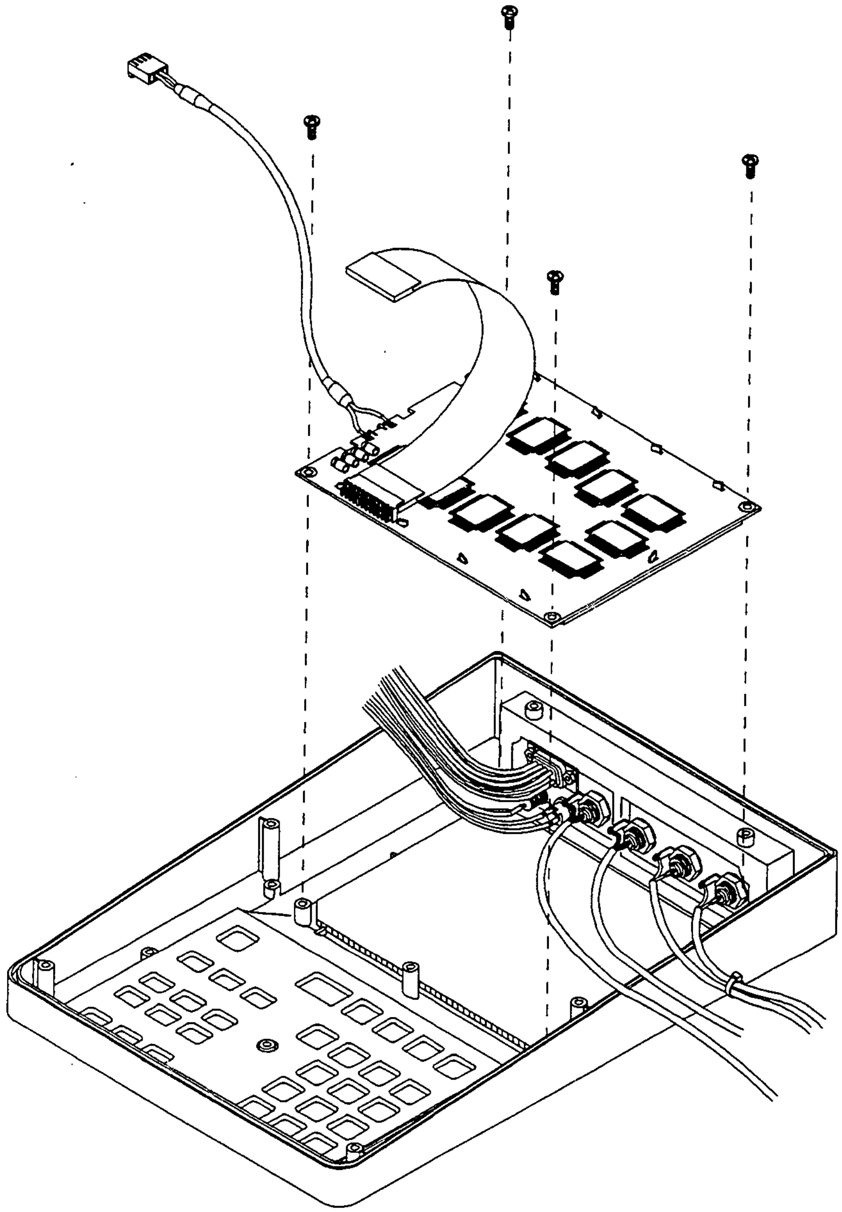


Figure 8-6.
LCD Display Removal

Chapter 11

Replace figure 11-1 (page 11-6) with the following illustration.

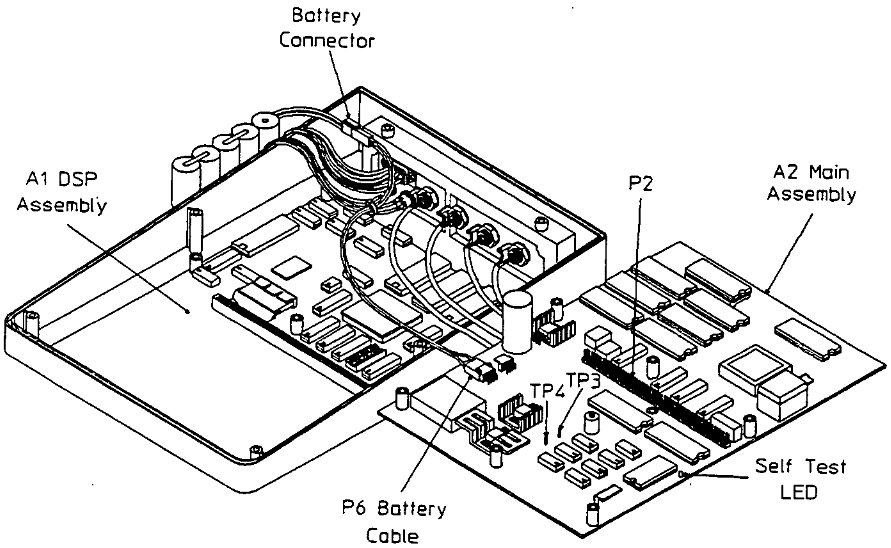


Figure 11-1.
Power up the A2 Main Assembly

Software Revision A.00.00

This version, the software does not support the following features:

- [Laser Plot] setting under [PRINT:] in [UTILITY] menu.
- XON/XOFF handshaking for RS 232.
- [HANDSHAK:] in [UTILITY] menu. Revision A.00.00 is always CTS +DSR.
- Variable y-axis grid spacing.
- Logarithmic-spaced y-axis grid lines.
- [Pan Up] and [Pan Dn] adjustment of the y-axis.
- Automatic conversion of g units when using the [INTEGRATE] menu.
- [KEY BEEP] in the [UTILITY] menu. The beeper will not function in older analyzers that are upgraded with recent software.
- Improved coherence computation.
- Correct x-axis scaling of 1/1 octave traces after recall.
- Correct transfer of map files when memory is more than 50% full.

10

Circuit Descriptions

Introduction

This chapter contains the overall instrument description and individual assembly descriptions for the HP 3560A Portable Dynamic Signal Analyzer. The overall instrument description lists the assemblies in the HP 3560A and describes the instrument's overall block diagram. The assembly descriptions give additional information for each assembly.

Overall Instrument Description

The HP 3560A Portable Dynamic Signal Analyzer is a powerful two-channel spectrum analyzer equivalent in performance and accuracy to instruments many times its size and weight. Its rugged enclosure lets you carry out sophisticated measurements in the most hostile environments. The menu driven setup procedures enable you to quickly master all control, measurement and display features. In fact, you should only rarely have to refer to this manual.

The high-contrast LCD dot matrix display allows alphanumeric and graphic representation on its 320 × 240 pixel format. The display is protected by a watertight and anti-glare scratch resistant window which provides high impact resilience. The elastomeric keypads also tolerate high impacts without damage and provide tactile feedback even when you operate it wearing gloves. The enclosure resists moisture and dust ingression and can be cleaned by simply wiping with a damp cloth.

The waist and neckstrap attached to the HP 3560A carrying case give comfortable support and operation of the instrument. The neckstrap can also be used as a shoulder strap when you to transport the instrument with you hands free.

Measurement processing is carried out by a 24-bit digital signal processor allowing rapid manipulation of data and calculation of complex mathematical processes. The non-volatile static RAM retains stored data when the instrument is switched off. All switching of the internal measurement circuitry is performed by menu prompted entry from the front panel keypads. Clearly annotated prompts make operation of the HP 3560A much easier.

The large memory of the HP 3560A facilitates sophisticated processing algorithms and lets you store several measurements for later inspection or for downloading via the RS-232 interface. You can directly print or plot measurement results or transfer data to a personal computer. The HP 3560A is supplied with the Standard Data Format (SDF) Utilities which make HP 3560A data transportable to other Hewlett Packard Dynamic Signal Analyzers such as the HP 3566A/3567A Multichannel Spectrum/Network Analyzer or to other third party software packages for data comparisons and archival.

The HP 3560A is powered from an internal battery pack which allows approximately 6 hours operation when fully charged. Recharge the batteries by connecting the ac adapter provided to the ac adapter socket. The instrument can be powered with the ac adapter connected when the battery charge is low.

Overall Block Diagram

Figure 10-1 shows the overall block diagram for the analyzer. The HP 3560A utilizes a purely static CMOS design throughout to achieve reliable and low power consumption operation.

Channel 1 and channel 2 inputs are switched via dc, ac, or accelerometer coupling to an electronically programmable gain amplifier covering 3 decades. The output of the gain amplifier passes through one of several pre-filters and then into the main anti-alias filter. Output of the sample & hold (S/H) amplifier drives a 12-bit A/D converter, the output of which is available to the digital signal processor (DSP).

The trigger source routes either internally from channel 1 or channel 2, externally, or freely runs under the control of the processor. Internal triggering is entirely analog so that when a trigger occurs, the data acquisition process of the A/D converters always begins at the same point. This technique is more precise than digital triggering which can be in error by up to one sample period. The only exception is pre-trigger mode, where the analyzer acquires data prior to a legitimate trigger. The trigger level resolution is one part in 256 but it is scaled to one point in 200 for easier operator control.

The digital signal processor (DSP) reads data from the A/D converters and computes the Fast Fourier Transform (FFT). During zoom analysis, the DSP digitally heterodynes the samples and performs a second anti-aliasing function before computing the FFT. DSP data and programs are stored in the 24-bit × 128 k-word DSP Random Access Memory (RAM).

The Main Processor section uses 16-bit processing and data transferring. A second lithium battery provides backup of the static memory and real time clock. Batteries are protected against fault current discharge caused by internal component failure.

High efficiency linear regulators provide primary instrument power. The instrument monitors battery charge at two levels.

1. The first causes a warning message to be displayed on the screen when about 2 hours of charge time remain.

2. The second shuts down the instrument to prevent an over-discharge condition on the internal batteries.

If the timeout feature is turned on, it automatically turns the instrument off 10 minutes after no key presses. This saves the battery charge if you inadvertently leave the instrument turned on after you operate it. In addition, the timeout feature will turn off the instrument after only 2 minutes of no key presses if the instrument was turned on but no other keys were pressed, i.e., the instrument was turned on but not operated. This gives the battery charge additional protection in case the instrument is inadvertently turned on. The only exception to this 10 minute/2 minute timeout is if the machine is waiting for a trigger or if you turn off the [TIMEOUT] feature.

The **Main Processor** controls the analyzer. The following is a partial list of the operations it performs:

- Configures the assemblies.
- Controls the Display assembly.
- Controls the operation of the Digital Signal Processor.
- Initiates the power-up sequence.
- Monitors for a front panel keystroke.
- Monitors the assemblies for overloads or other error conditions.
- Runs the self tests.

The **Memory** contains RAM and ROM for the CPU. The RAM is static is does not require refresh.

The **Display** offers a view of the processed data. It consists of the liquid crystal display (LCD) assembly, a display controller IC, display RAM, and backlight inverter.

The **Keyboard** allows interaction with the analyzer. It consists of an elastomeric keypad and a keyboard controller IC.

The **Power Supply** provides the dc voltages shown in figure 10-4.

The instrument casing is electro-dagged which provides excellent RFI protection. The casing is also water and dust resistant. The casing and keypads are also resistant to most industrial chemicals and can withstand high temperatures.

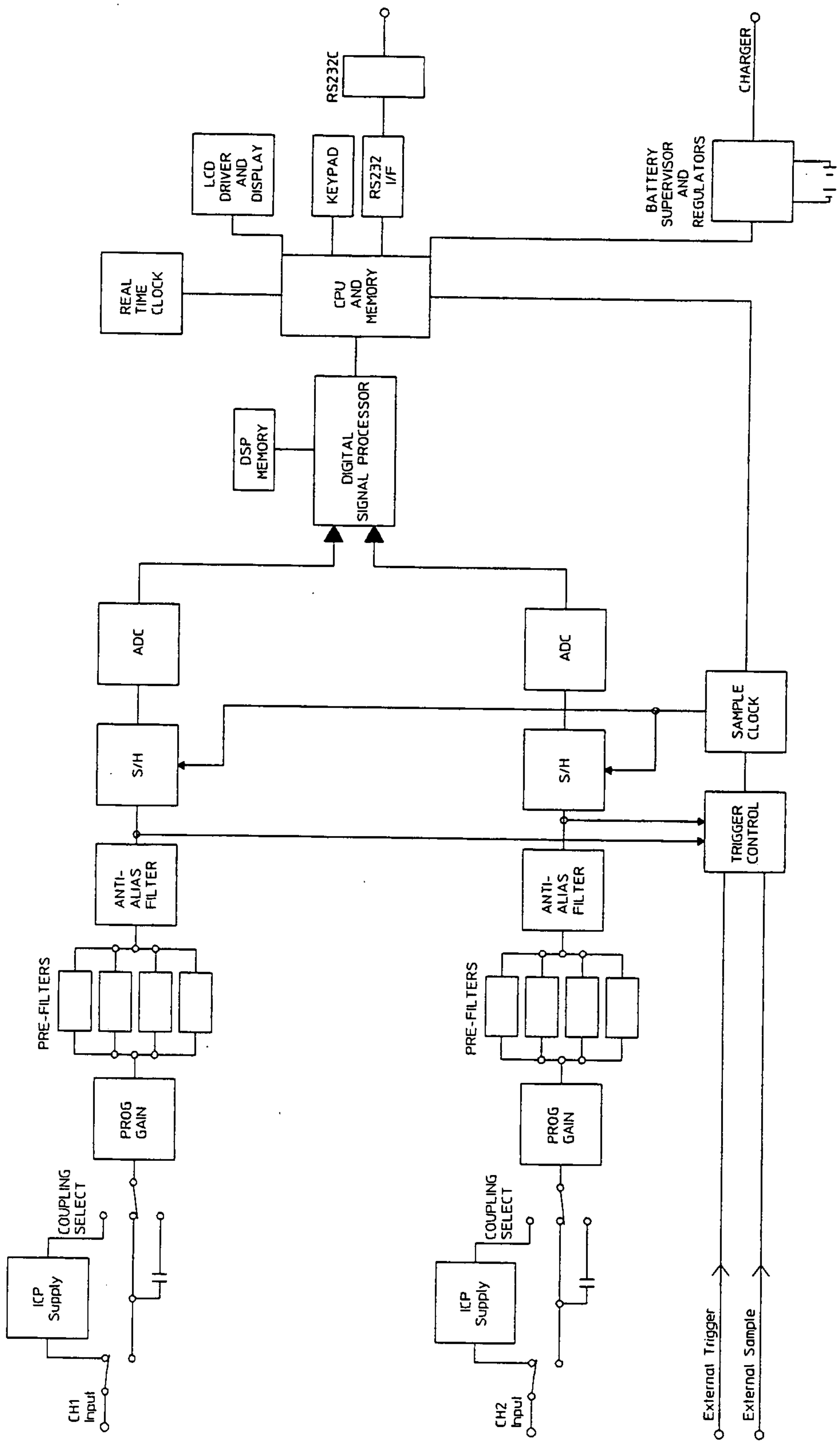


Figure 10-1.
Overall Block Diagram

Assembly Descriptions

The HP 3560A Spectrum Analyzer consists of the assemblies shown below.

- A1 Digital Signal Processing/Keyboard
- A2 Main Processor Board
- A3 Analog Board
- LCD Display
- Connector Panel
- Battery Pack

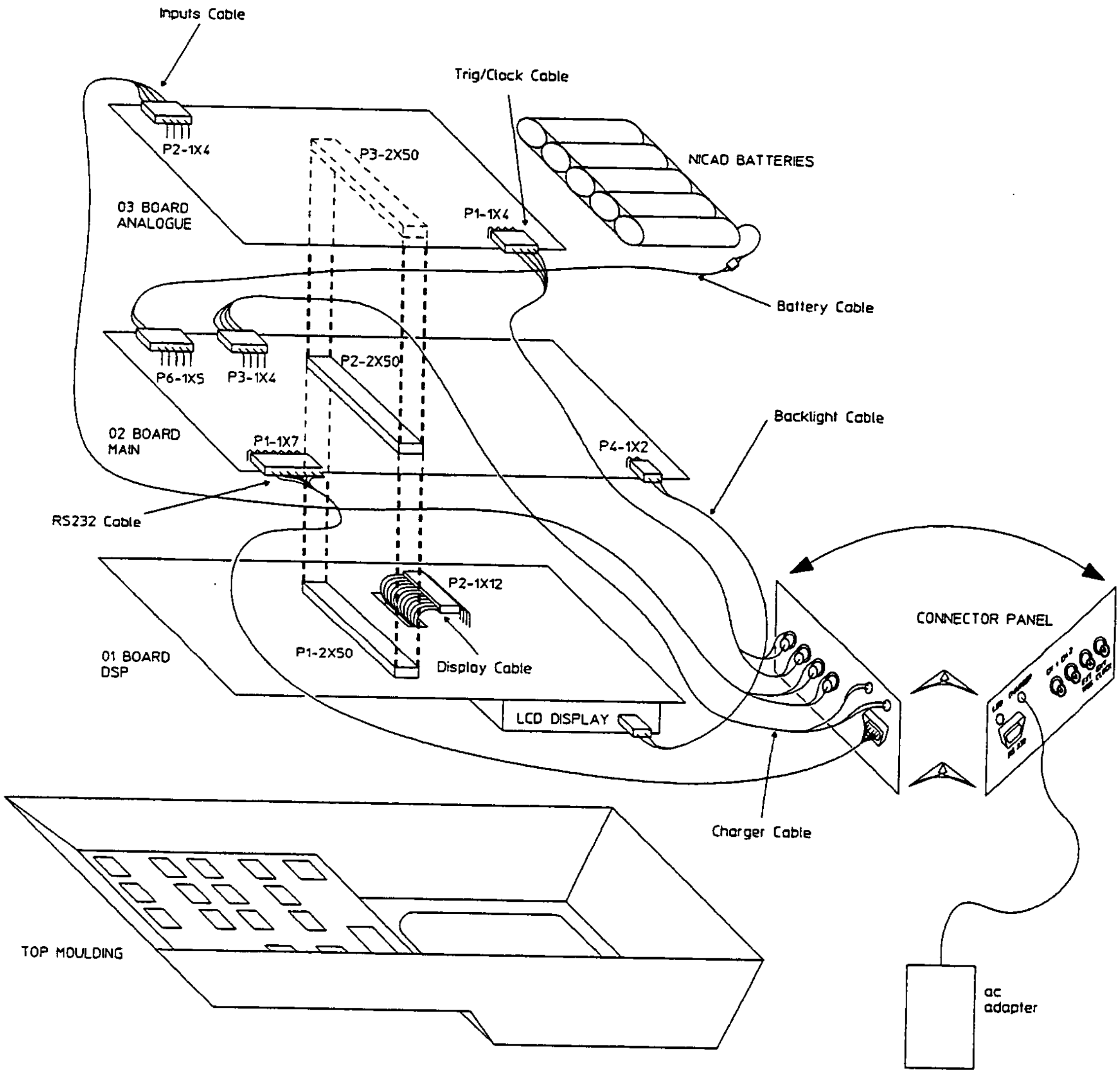


Figure 10-2.
Assembly block diagram and connections

HP Part Number	Description
03560-61601	Display Cable
03560-61602	Battery Cable
03560-61603	Charger Cable
03560-61604	RS232 Cable
03560-61605	Backlight Cable
03560-61607	Input Cable
03560-61608	Trig/Clock Cable

Note

In this section, the block diagrams show the connector numbers for signals routed through the cables.

A1 Digital Signal Processing/Keyboard

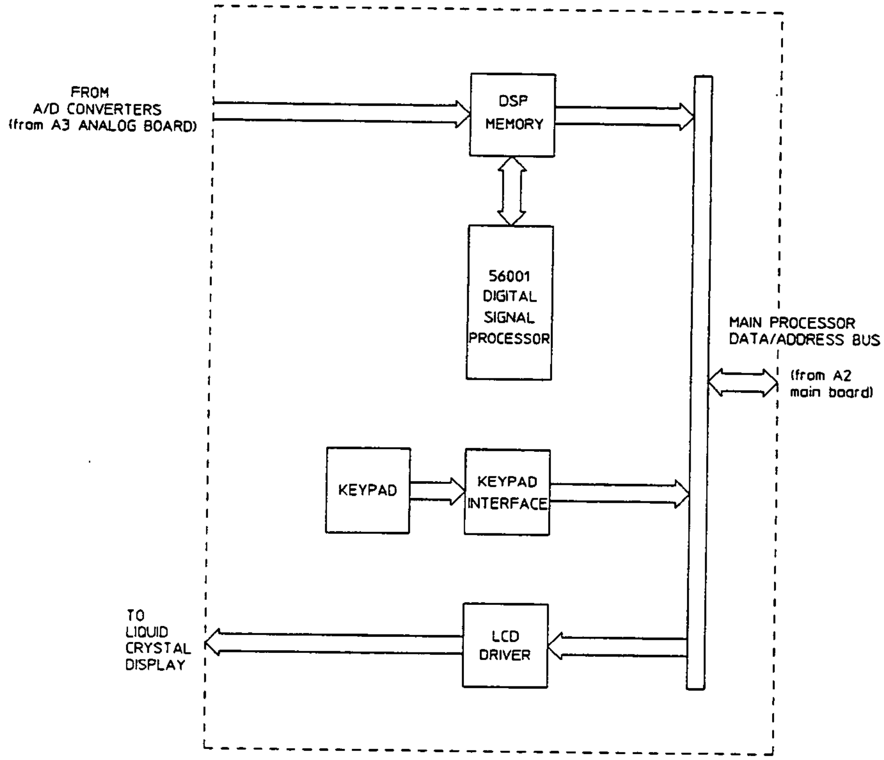


Figure 10-3.
A1 DSP/Keyboard Block Diagram

The digital signal processor (DSP) reads data from the A/D converters and computes the Fast Fourier Transform (FFT). During zoom analysis, the DSP digitally heterodynes the samples and performs a second anti-aliasing function before computing the FFT. DSP data and programs are stored in the 24-bit × 128 k-word DSP Random Access Memory (RAM).

A2 Main Processor Board

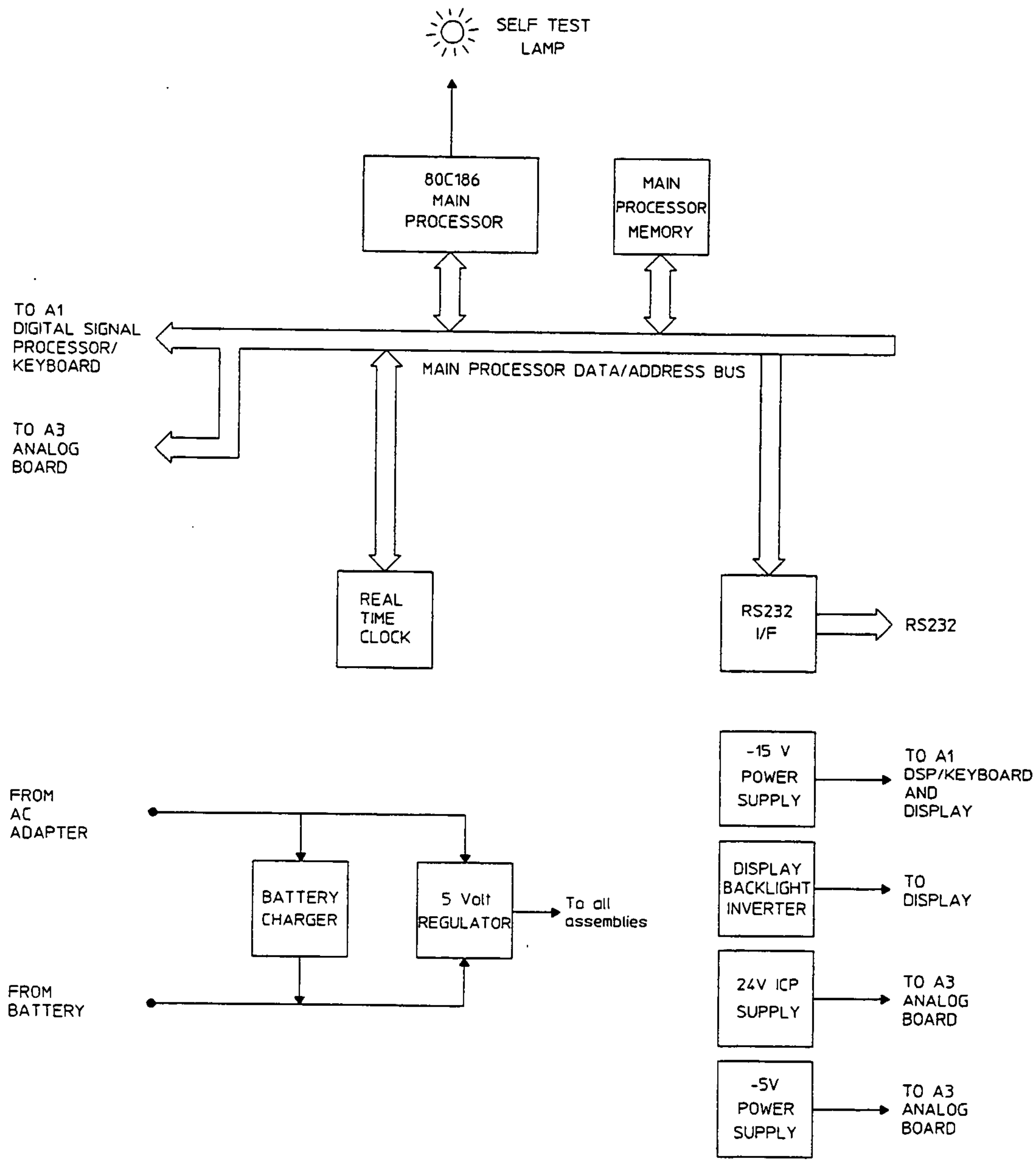


Figure 10-4.
A2 Main Processor Block Diagram

The Main Processor section uses 16-bit processing and data transferring. The assemlby's dc-to-dc converters generate −5, −15, and +24 volts for other assemblies. A second lithium battery provides backup of the static memory and real time clock. Batteries are protected against fault current discharge caused by internal component failure.

A3 Analog Board

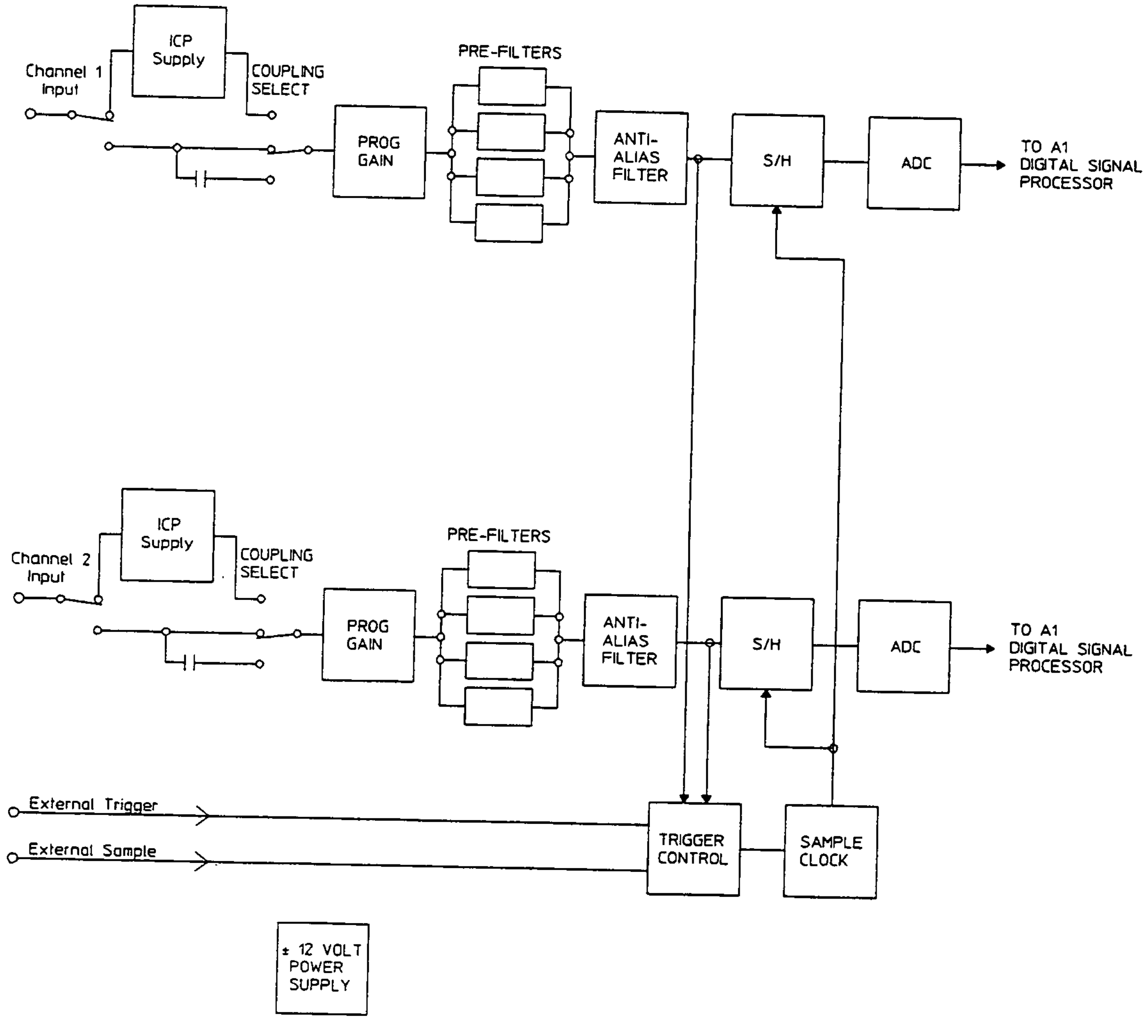


Figure 10-5.
A3 Analog Block Diagram

Channel 1 and channel 2 inputs are switched via dc, ac, or accelerometer coupling to an electronically programmable gain amplifier covering 3 decades. The output of the gain amplifier passes through one of several pre-filters and then into the main anti-alias filter. Output of the sample & hold (S/H) amplifier drives a 12-bit A/D converter, the output of which is available to the digital signal processor (DSP).

The trigger source routes either internally from channel 1 or channel 2, externally, or freely runs under the control of the processor. Internal triggering is entirely analog so that when a trigger occurs, the data acquisition process of the A/D converters always begins at the same point. This technique is more precise than digital triggering which can be in error by up to one sample period. The only exception is pre-trigger mode, where the analyzer acquires data prior to a legitimate trigger. The trigger level resolution is one part in 256 but it is scaled to one point in 200 for easier operator control.

ROM Update Procedure

1.Follow the instructions for battery pack removal in the "Disassembly Instructions" of Chapter 8.

2.Remove the two ROMs using an IC extractor tool.

3.Install the new ROMs. Note the "U1" and "U2" markings near pin1 on the circuit board. The ROM IC packages have an indentation near pin 1.

4.Re-install the battery pack and replace the battery cover.

Troubleshooting

Introduction

This section contains troubleshooting tests that isolate failures to the assembly. These tests include initial verification, power-on test, self tests, and tests for miscellaneous failures and failing performance tests. This section also contains self-test descriptions.

Safety Considerations

The HP 3560A Dynamic Signal Analyzer is a Safety Class II instrument. Although this instrument has been designed in accordance with international safety standards, this manual contains information, cautions, and warnings that must be followed to ensure safe operation and retain the HP 3560A Portable Dynamic Signal Analyzer in safe operating condition. Service must be performed by trained service personnel who are aware of the hazards involved (such as fire and electrical shock).

Warning **Under no circumstances should an operator remove any covers, screws, shields or in any other way access the interior of the HP 3560A Dynamic Signal Analyzer (except the battery cover). There are no operator controls inside the analyzer.**

Caution Do not connect or disconnect cables with the analyzer turned on. Power transients caused by connecting or disconnecting a cable can damage circuit assemblies.

Equipment Required

- Digital Multimeter (1% accuracy)

How to Use This Section

Use the following steps to isolate failures to the assembly. See the disassembly/assembly illustrations in "Replaceable Parts," to determine how to disassemble and assemble the analyzer.

1. Review "Safety Considerations" and "Troubleshooting Hints."
2. Determine which troubleshooting test to start with by comparing your analyzer's symptoms to the symptoms in "Choosing a Troubleshooting Test."
3. Follow the recommended troubleshooting procedure until you locate the faulty assembly.
4. Replace the faulty assembly, and do the required adjustments and tests listed in "What to Do After an Assembly Is Replaced."

Troubleshooting Hints

- Cables can cause intermittent hardware failures.
- The LED blink routine will delay before and after blinking so you can distinguish these blinks from the power-on flash.
- If the instrument turns on with a normal display, but then immediately stops taking measurements ("hangs"), it may be due to corrupt data in memory. Try turning the analyzer off and then on again. While the "checking memory" message appears, repeatedly press [**Enter**]. This causes the instrument to not recall the last instrument state from memory.

Choosing a Troubleshooting Test

Use table 11-1 to determine which troubleshooting test to begin with.

Test 1. Dead Instrument Test determines whether the source of the problem is the A3, A2, or A1 assembly.

Test 2. Display Test determines whether the source of the problem is the A1 DSP Board or the LCD display assembly.

Test 3. Battery Test determines whether the source of the problem is the ac adapter, A2 Main Board, charging circuits or battery pack charging capacity.

Note

The troubleshooting tests in this section assume only one independent failure. Multiple failures can cause false results.

Table 11-1. Troubleshooting Guide

Symptom	Troubleshooting Test
Screen remains blank when analyzer turns on	Test 1. Dead Instrument Test
Screen defective Screen remains blank but relays "click"	Test 2. Display Test
Battery will not charge	Test 3. Battery Test
Trigger fails External trigger fails External sample fails	Self Tests If the Self Tests pass, suspect the A3 Analog assembly or a cable problem.
Nonvolatile states not saved after power cycled	Self Tests If the Self Tests pass, suspect the A2 Main assembly.
Screen Defective Intermittent problem	Self Tests
RS-232 fails	Suspect the A2 Main assembly.
Input fails	Self Tests If the Self Tests pass, suspect the A3 Analog assembly.
Performance test fails	Self Tests If the self tests pass, perform the Adjustments. If the problem persists, suspect the A3 Analog assembly.
Backlight fails	Test 2. Display Test If the Display Test passes, suspect the A2 Main assembly.

What to Do After an Assembly Is Replaced

After replacing an assembly, do the following:

1. Reinstall all assemblies and cables that were removed during troubleshooting.
2. Do the required adjustments listed in table 11-2 (see the Adjustments chapter in this section for individual adjustment procedures).
3. Cycle power on the HP 3560A.
4. Perform the Operation Verification test which is in the Installation section of this manual.
5. Do the required performance tests listed in table 11-2 (the performance tests are in the Installation section).

Table 11-2. Required Adjustments and Performance Tests

Assembly Replaced	Adjustments	Performance Tests
A1	None	Operation Verification
A2	#5. Real Time Clock	#8. Frequency Accuracy
A3	#1. First Stage Input Offset #2. Second Stage Input Offset #3. Analog -to-Digital Converter Offset #4. Analog -to-Digital Converter Gain	All
LCD Display	None	Operation Verification

Test 1. Dead Instrument Test

Before starting Test 1. Dead Instrument Test, check that the battery is charged by connecting the ac adapter. If the green AC Adapter LED on the analyzer's connector panel does not come on, go to "Test 3. Battery Test". For information on battery recharging, see the Installation section.

Use this test to check signals that are vital to the operation of the analyzer. The test uses a self test LED on the A2 Main assembly which normally flashes once when you turn the analyzer on and then remains on when the analyzer is operating (unless there is RS232 activity). When the analyzer's self tests run, this LED blinks a variable amount of times to indicate the source of problems to the assembly level.

1. Remove the battery cover, battery, bottom cover, and A3 Analog assembly as outlined in the "Assembly/Disassembly" portion of the "Replaceable Parts" chapter.
2. Reconnect the battery at the battery connector.
   Press [**On**].
3. With the A3 Analog assembly removed, the following messages should appear.

   FAILED DIGITAL TEST (A3)

   If only this message appears, the other assemblies are working fine and the A3 Analog assembly is the problem.
4. If the display remains blank, remove the A2 Main assembly from the instrument.

Caution Isolate the A2 Main assembly electrically to prevent any shorting of its pins or traces.

5. Connect the battery cable (P6) to the A2 Main assembly as shown in figure 11-1. Short TP4 "PWRUP" to TP3 "GND" to turn on the A2 Main assembly (or short pins 10 and 7 of U28). Watch the self test LED for 20 seconds. It may flash once at first and then blink. Count the blinks to identify the failure.

Table 11-3. Self Test Led Troubleshooting

Blinks	Failure
2	A2 Main assembly ROM checksum
4	A2 Main assembly RAM
6	A1 DSP assembly display

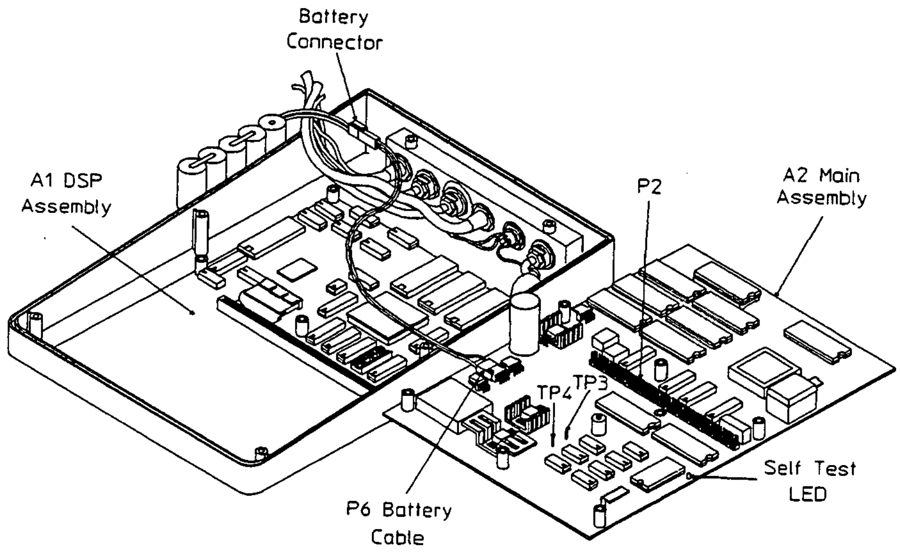


Figure 11-1.
Power up the A2 Main Assembly

With the A2 Main assembly disconnected from the A1 DSP assembly, the LED should blink 6 times. This means the A2 Main assembly is working. If the LED did not blink 6 times, replace the A2 Main assembly.

6.Check the dc voltage at the following pins of the P2 connector on the A2 Main assembly. Use TP1 "GND" for ground.

Table 11-4. P2 Connector Voltages

P2 Pin	Voltage
9	5 ± 0.4
10	–5 ± 0.4
14	5 ± 0.4
15	25 ± 5
16	–17 ± 5

If any of the voltages are incorrect, replace the A2 Main assembly.

7.If the A2 Main assembly is working properly, do the following.

- Remove the short between TP4 and TP3.
- Reconnect the A2 Main assembly to the A1 DSP assembly.
- Turn the instrument on while watching the LED.

You should see no blinks. If six blinks occur, this indicates a failure of A1 DSP assembly.

Test 2. Display Test

If the screen is defective, perform this Display Test. Display problems can be caused by either the A1 DSP assembly or the LCD Display assembly.

1. Press [**On**] while watching the self test LED on the A2 Main board.
2. If it blinks 6 times, the problem is with the A1 DSP assembly. If it does not blink and the relays click after a few seconds, the problem is with the LCD Display assembly.

Test 3. Battery Test

Perform this test if the battery will not charge.

1. Connect the ac adapter to an ac power source and the HP 3560A. If the green LED above the AC Adapter connector does not light, suspect the ac adapter, the A2 Main assembly, or associated cables.
2. To check the charging circuits, leave the ac adapter connected at least 14 hours to allow the battery pack to fully charge. Open the battery compartment and feel the temperature of the battery pack. It should feel warm. If not, suspect the A2 Main assembly.
3. To check the battery capacity, fully charge the battery pack (as described in the previous step) and then disconnect the ac adapter. Press the following front panel keys.
   [**On**]
   [**Utility**]
   Move the column cursor to [MISC]
   Set [TIMEOUT:] to [OFF]
   If a measurement is running, press [**Pause/Cont**].

Leave the analyzer on and in this state for 6 hours. If it does not stay on, suspect the battery pack.

Troubleshooting using the Self Tests

A self test runs every time you turn on the analyzer. However, the following procedure runs a more extensive self test and displays the results.

1. Hold down the [7] key while pressing [On]. Keep holding down the [7] key for 5 seconds after releasing [On].

   The analyzer will take approximately 20 seconds to perform the self test. If no error messages appear, the display should show the self test results as in figure 11-2.

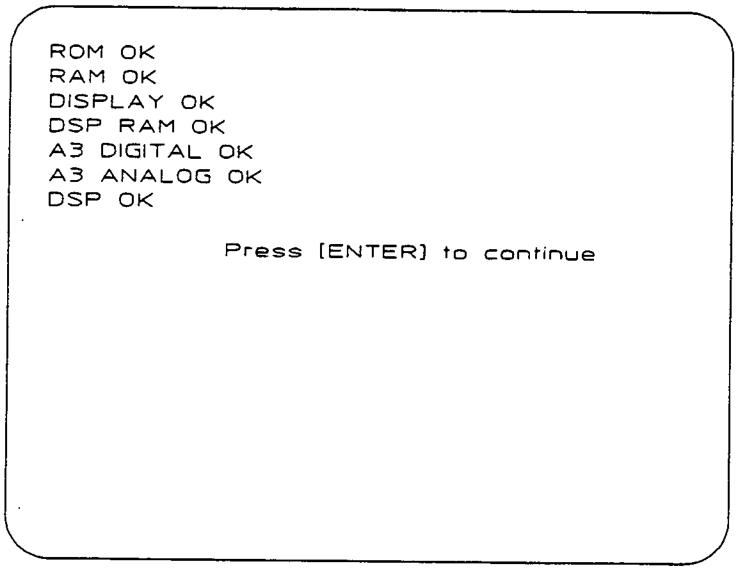


Figure 11-2.

If there is a problem with the memory, an error message such those shown in the following table will appear. The assembly most likely to cause the failure is indicated in parenthesis.

Table 11-5. Error Messages

Error Message	Assembly to be Replaced
FAILED ROM TEST	A2
FAILED RAM TEST	A2
FAILED DISPLAY TEST	A1
FAILED DSP RAM TEST	A1
FAILED DIGITAL TEST	A3
FAILED ANALOG TEST	A3
FAILED DSP TEST	A1

When the self tests have completed, a "Press ENTER to Continue" message will appear. Press [Enter].

Self-Test Descriptions

At power-on the main processor on the A2 assembly performs power-up tests. Holding down the [7] key as you turn the analyzer on initiates a longer (20 second) self-test.

ROM Test does a checksum on the ROMs. A failure blinks the self test LED 2 times and reports an error at the end of the display test.

RAM Test does a non-destructive test of RAM on the A2 Main assembly. A failure blinks the self test LED 4 times and reports an error at the end of the display test.

Display Test checks the display controller and its RAM. A failure blinks the self test LED 6 times. If the A1 DSP assembly is not connected, this is the first failure expected. After this test, the display is assumed to work and subsequent failures are reported on the display. Any previous test failures should be reported on the display with messages such as the following.

FAILED ROM TEST (A2)
FAILED RAM TEST (A2)
FAILED DISPLAY TEST (A1)

DSP RAM Test checks the RAM on the A1 DSP assembly. A failure produces the following message.

FAILED DSP RAM TEST (A1)

Analog Board Digital Test checks the A3 Analog assembly by writing and reading registers in the timer chip (U23). If the A3 Analog assembly is disconnected, this is the first "failure" expected. A failure produces the following message.

FAILED DIGITAL TEST (A3)

Analog Board Analog Test checks the analog circuits by measuring the trigger level DAC with the channel 2 ADC. A failure produces the following message.

FAILED ANALOG TEST (A3)

DSP Test checks the DSP by instructing it to execute a simple program. A failure produces the following message.

FAILED DSP TEST (A1)

Stuck Key Test checks for a front panel key pressed down. A failure produces the following message.

KEY DOWN Code = xx

Table 11-6. Key Codes

Key	Code
[0]	0
[1]	1
[2]	2
[3]	3
[4]	4
[5]	5
[6]	6
[7]	7
[8]	8
[9]	9
[.]	10
[+/-]	11
[⇐]	12
[⇒]	13
[⇓]	14
[⇑]	15
[Data]	16
[Freq]	17
[Start]	18
[Recall]	19
[Format]	32
[Input]	33
[Pause/Cont]	34
[Utility]	35
[Scale]	36
[Trigger]	37
[Avg]	38
[Preset]	39
[Enter]	40
[Shift]	48

Data Integrity Test performs a checksum on the data stored in RAM. A failure produces the following message.

Check sum error(s):
DISK ERROR:
press key to start diskfix

This message may occur if the analyzer is turned off while saving data.

Technical Note 243-1

This section contains a technical note which is derived from Hewlett-Packard Application Note 243-1, "Effective Machinery Maintenance Using Vibration Analysis" (literature number 5953-5113). For additional copies, contact your local sales office.

Dynamic Signal Analyzer Applications

Table of Contents

4 Vibration Characteristics of Common Machinery Faults

5 Advanced Analysis and Documentation

Chapter 1

Introduction

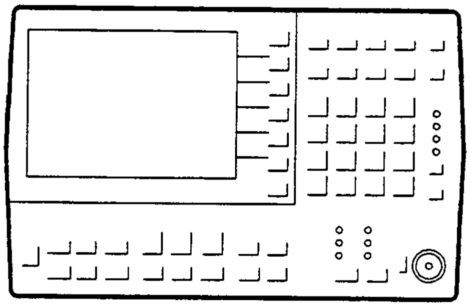


Figure 1-1

Dynamic Signal Analyzers (DSAs) are the ideal instrument for analyzing machinery vibration.

In the traditional approach to maintenance, scheduling repairs is difficult because the need for repair usually cannot be assessed without disassembling the machine. If a problem is serious enough to be readily apparent, damage has probably already occurred. Without a means to externally determine machine condition, scheduling is inaccurate: machines in perfect working order are taken out of service, while machines on the verge of failure are ignored. Modern technology provides a number of methods for externally determining the condition of machinery. The most effective of these is vibration analysis.

When a defect such as a bad bearing occurs in a machine, the result is an increase in vibration level. By regularly measuring this level, defects can be detected before they have a chance to cause extensive damage or failure. More importantly, the characteristics of the vibration are unique to the specific defect. By analyzing the vibration signal, the nature of the defect can often be determined. The key advantage of this approach is that need for repair and the specific nature of any problems can be assessed without disassembling the machine, or even taking it out of service.

The implementation of machinery vibration analysis has been made practical by the development of analysis instruments we call Dynamic Signal Analyzers (see figure 1-1). Machinery vibration is a complex combination of signals caused by a variety of internal sources of vibration. The power of Dynamic Signal Analyzers (DSAs) lies in their ability to reduce these complex signals to their component parts. In the example of figure 1-2, vibration is produced by residual imbalance of the rotor, a bearing defect, and meshing of the gears each occurring at a unique frequency. By displaying vibration amplitude as a function of frequency (the vibration spectrum), the DSA makes it possible to identify the individual sources of vibration.

Dynamic Signal Analyzers can also display vibration amplitude as a function of time (figure 1-3), a format that is especially useful for investigating impulsive vibration (e.g., from a chipped gear). The spectral map format (figure 1-4) adds a third dimension to vibration amplitude versus frequency displays. The third dimension is most often rpm, but can also be time or load—any variable that changes the vibration characteristics of the machine. DSAs can be connected to computers for automatic data storage and analysis, and are available in lightweight (less than 35 lbs) models that are ideal for machinery vibration analysis.

This Technical Note is a primer on analyzing machinery vibration with Dynamic Signal Analyzers. Each of the important steps in the analysis process, from selecting the right vibration transducer to interpreting the information displayed by the DSA, is covered. The techniques described provide insight into the condition of machinery that eliminates much of the guesswork from maintenance and troubleshooting. Primary benefits and the focus of the note are in the area of machinery maintenance; however, the techniques presented also have important benefits for machinery development and manufacturing.

In the next two sections, we will discuss the benefits of machinery maintenance programs based on vibration analysis, and the organizational philosophy of the note.

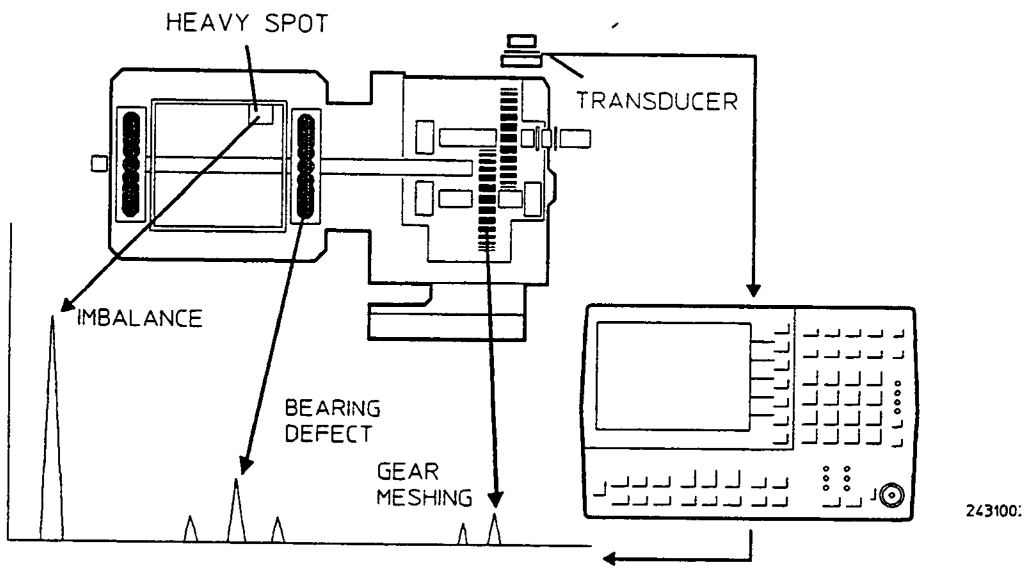


Figure 1-2

The individual components of vibration are shown in DSA displays of amplitude versus frequency.

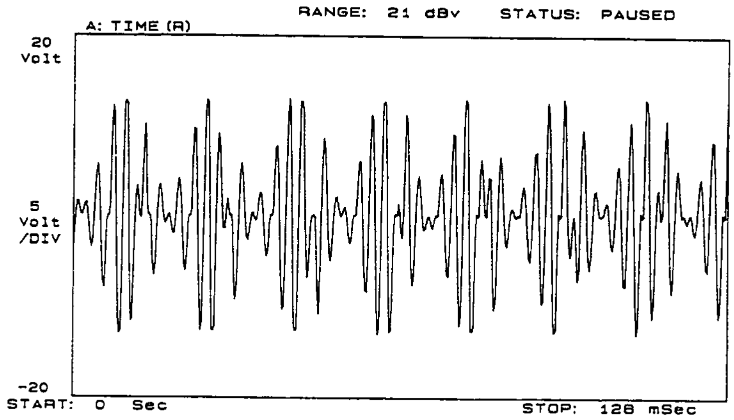


Figure 1-3

DSA displays of amplitude versus time are especially useful for analyzing impulsive vibration that is characteristic of gear and rolling element bearing defects.

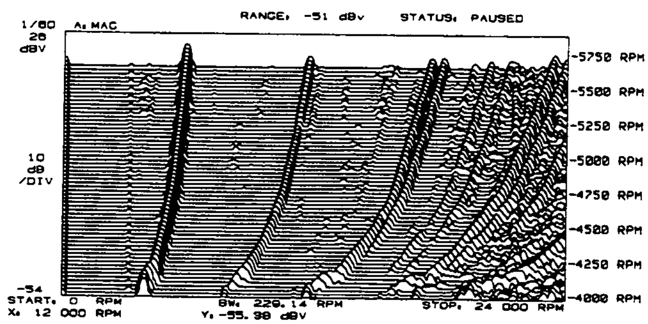


Figure 1-4

DSA map displays illustrate changes in vibration with rpm, load or time. This map is a collection of vibration measurements made during a machine runup.

1.1 Machinery Maintenance Based on Vibrational Analysis

The objective of maintenance is to keep machines running, especially those that are critical to plant production. Unexpected catastrophic failures cause both loss of production, and large repair bills. The classic maintenance strategy for avoiding such failures is to periodically disassemble critical machines for inspection and rebuilding. This process results in costly down time, often to inspect machines that are in perfect working order. Because the process is expensive, it is only applied to a few critical machines, which usually account for a small percentage of maintenance expense. In addition, faulty reassembly or damage in transit from the repair shop sometimes results in a machine in worse condition than before the maintenance.

A more effective approach is to schedule repairs on the basis of machine condition, as determined by vibration analysis. This "predictive" maintenance strategy can be applied to all the major machines in a plant, and has proven its effectiveness in hundreds of maintenance organizations. In a typical program, overall vibration level is measured regularly with a vibration meter and compared to established severity limits (section 5.1) or past readings. The vibration level of critical machinery is often monitored on a continuous basis, and compared against preset limits. If an excessive level is detected, a Dynamic Signal Analyzer is used to determine the severity and nature of the problem (see figure 1-5).

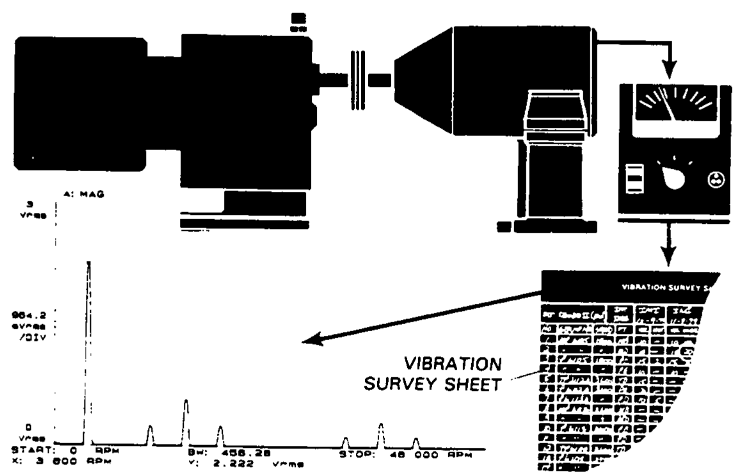


Figure 1-5

In a typical predictive maintenance program, vibration level is measured on a regular basis and compared with past readings. When an excessive level is detected, a DSA is used to determine the nature and severity of the problem.

Analysis is a critical part of the process for several reasons:

- Overall vibration level can change with load and operating speed, thereby presenting a misleading picture of machine condition. Analysis of the vibration spectrum indicates whether or not a serious problem exists. This is an important step in avoiding unnecessary repairs.
- Taking a machine out of service for repairs can rarely be done without some impact on production, so it is important to know just how severe the problem is. Analysis can help you decide, for example, whether the machine can be run until the next scheduled plant shut-down. Thus analysis is valuable in maximizing the effectiveness of a maintenance program.
- Repair time is minimized because the nature of the problem is known. Technicians won't spend valuable time looking for the fault, and the necessary replacement parts can be ordered prior to disassembly.

The advantages of analysis make it appropriate in some cases to monitor the levels of individual components (rather than overall vibration level) to detect faults. Monitoring individual components also gives earlier warning of failure. This is an especially important consideration in highly loaded machines using rolling element bearings, whose condition can deteriorate rapidly.

The benefits of a predictive maintenance program based on vibration analysis are summarized in table 1-1. Several authors, including Jackson [reference title 18] and Mitchell [reference title 3], provide details on establishing a program of predictive maintenance.

Table 1-1

Economic benefits of a Predictive Maintainance Program

Catastrophic Failures Avoided	Increased production Large repair bills avoided Improved plant safety
Planned Repairs	Improved repair quailty Overtime expense reduced Smaller spare parts inventory (time to order parts)
Insight Into Machine Problems	Faster repairs (knowledge of the problem before assembly) Determine the cause of chronic failures

1.2 Using This Technical Note

The technical note is organized around four key steps in the analysis process shown in figure 1-6:

1 Converting the vibration to an electrical signal

2 Reducing it to its components

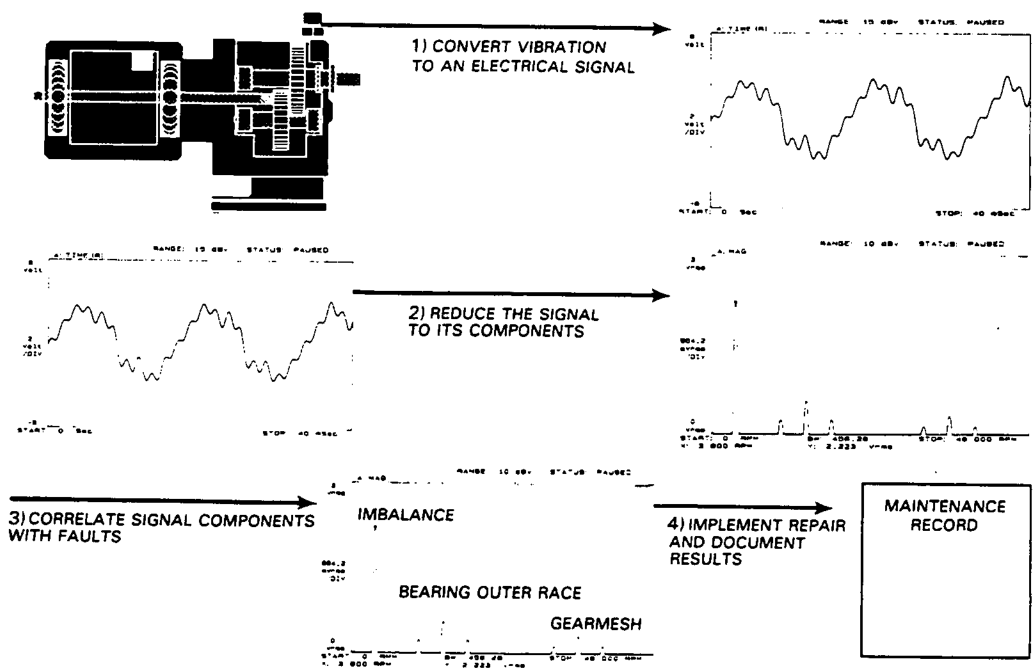
3 Correlating those components with machine defects

4 Implementing necessary repairs and documenting the results

Each of these steps is vital to analysis, and viewing the process in this manner promotes a systematic approach that increases the probability of success. The contents of each chapter, and their relation to the steps in figure 1-6, are discussed in the following.

Figure 1-6

The process of machinery vibration analysis consists of four steps, each critical for success.



Chapter 2: Converting Vibration to an Electrical Signal. Vibration is converted to an electrical signal with transducers, and effective analysis requires that a signal accurately represents the vibration. This chapter gives you the information needed to select the correct transducer.

Chapter 3: Reducing Vibration to its Components: The Frequency Domain. The key to successful analysis is reduction of the complex signal to simple components. As shown in figure 1-2, this is best done with a display of vibration amplitude vs. frequency—a perspective known as the frequency domain.
The objective of this chapter is to provide a good working knowledge of the frequency domain.

Chapter 4: Characteristic Vibration of Common Machinery Faults. Each type of machine fault has distinctive characteristics that can be used for identification. This chapter describes the characteristics of nine common machinery faults.

Chapter 5: Advanced Anaylsis and Documentation. This chapter focuses on solving some of the practical problems encountered in machinery vibration analysis, such as assessing fault severity and analyzing multiple faults. Thorough documentation including baseline vibration levels, engineering data, and maintenance history is an essential part of a predictive maintenance program.

Chapter 6: Dynamic Signal Analyzers. DSAs feature measurement capabilities that make them the ideal instrument for machinery vibration analysis. This chapter explains why these capabilities are important, and describes key aspects of each.

Two subjects beyond the scope of the note are rotor dynamics, and the vibration characteristics of specific types of machinery. Rotor dynamics is required for complete analysis of the rotors used in most turbomachinery (i.e., flexible rotors), although most of the information in this note still applies (we will note circumstances when it does not). Reference titles 24 through 29 serve as good introductions to the subject of rotor dynamics.

Understanding the vibration characteristics of specific types of machinery is important for effective analysis. This information can be obtained from machinery manufacturers, and from well documented experience with the same or similar machines.

The analysis of machinery vibration is not an easy task, and you will not be able to predict every failure, or analyze every fault. You will, however, be able to significantly reduce the number of unexpected failures with savings in maintenance and lost production that will return the cost of analysis instrumentation many times over. This note will begin a successful machinery analysis program.

Chapter 2

Converting Vibration to an Electrical Signal

Before analysis can begin, vibration must be converted to an electrical signal—a task performed by vibration transducers. The key considerations in obtaining a signal that accurately represents the vibration are:

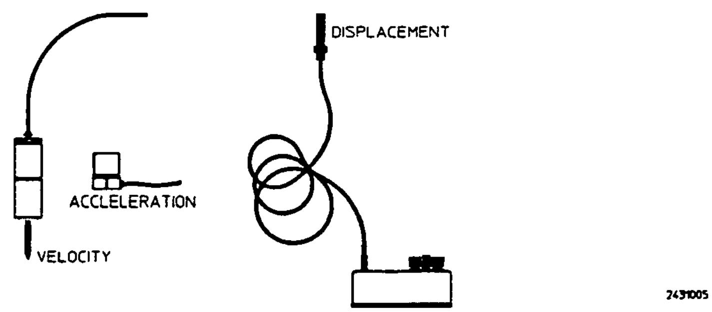
- Selecting the right type of transducer
- Locating and installing it correctly

Three types of transducers commonly used for machinery vibration are shown in figure 2-1. They are differentiated by the parameter measured (i.e., displacement, velocity, or acceleration), and by the machine component measured (i.e., shaft or housing). Selection depends on the characteristics of the machine and its expected faults. Installation requires correct placement, secure mounting, and proper signal conditioning.

This chapter begins with a discussion of basic vibration concepts that are fundamental to understanding transducers, and their installation. This is followed by a description of each of the three types of transducers, and a procedure for selecting the type that best fits the application. The final section of the chapter provides transducer installation guidelines.

Figure 2-1

Three types of transducers are commonly used to convert machinery vibration to an electrical signal.



2.1 Vibration Basics

Before starting our discussion of the details of transducers and vibration analysis, it is important to establish some basic concepts. The three topics we will focus on are:

1 **Vibration Parameters**. Using commercially available transducers, we can measure the displacement, velocity, or acceleration of vibration. Selecting the right parameter is critical for effective analysis.

2 **Mechanical Impedance.** What we can measure with transducers is the response of the machine to vibration forces caused by defects, not the forces themselves. The mechanical impedances of the machine shaft and housing determine how they will respond to vibration forces, and can alter significantly the characteristics of the signal we measure.

3 **Natural Frequencies.** When a structure is excited by an impact, it will vibrate at one or more natural frequencies. These frequencies are important because they limit the operating frequency range of velocity and acceleration transducers, and because they can cause large changes in vibration response with changes in rpm.

Vibration Parameters

We will start our discussion of vibration parameters by examining the vibration produced by simple imbalance. Referring to the machine rotor in figure 2-2, note that the heavy spot produces a rotating force that appears sinusoidal from any fixed reference position. At points A and C, the force in the direction of the reference is zero. At points B and D it is at positive and negative maximums, respectively.

The response of the rotor to such a force is a displacement which moves the center of rotation away from the geometric center (figure 2-3).

NOTE This applies to shafts that do not bend in operation (i.e., rigid shafts). Flexible shafts respond somewhat differently to imbalance forces (see figure 3-13).

A displacement measurement performed on the rotor results in approximately the same waveform as the force, with a signal amplitude approximately proportional to the magnitude of the force. It is not exactly the same because the dynamics of the rotor affect the response. This is an important point in vibration analysis, and is discussed in more detail in the next section.

The velocity and acceleration parameters of the vibration are offset in phase relative to displacement—an important consideration when using phase for analysis. Phase relationships are shown in figure 2-4.

Figure 2-2

A heavy spot on a machine motor results in a rotating vector that appears sinusoidal from a fixed reference.

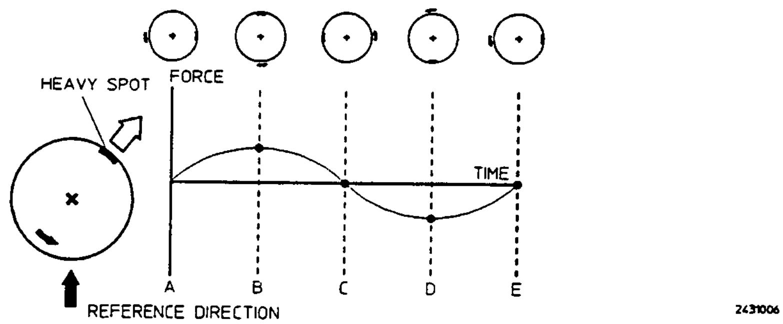
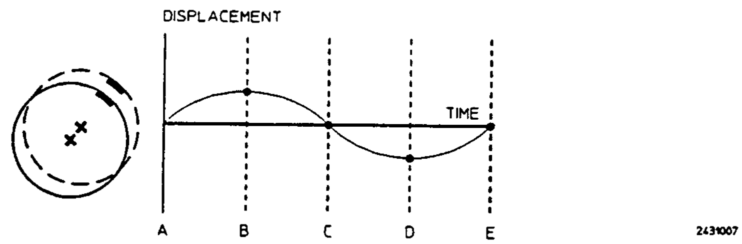


Figure 2-3

The imbalance force produces a vibration whose displacement has approximately the same waveform as the force itself.



Velocity, for example, is offset from displacement by 90° (one complete cycle is 360°). At point B, when the displacement is maximum, the velocity is zero. At point C, when displacement is zero, velocity is maximum. Following the same reasoning, acceleration can be shown to be offset 90° from velocity, and thus 180° from displacement.

The amplitude of the vibration parameters also varies with rpm—an important consideration in transducer selection. Velocity increases in direct proportion to speed, while acceleration increases with the square of speed. This variation with speed, and the phase relationships shown in figure 2-4 are illustrated in the equations below. In these equations, which apply only to sinusiodal vibration, A is the vibration amplitude and f is the rotor frequency of rotation.

$$\text{Displacement} = A \times \sin(2\pi ft)$$

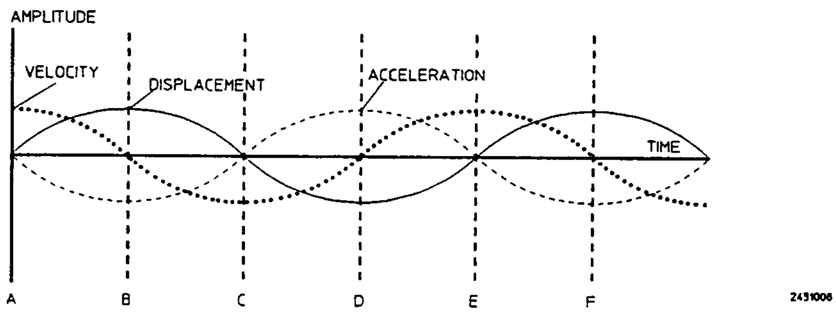
$$\text{Velocity} = 2\pi f\, A \times \cos(2\pi ft)$$

$$\text{Acceleration} = -(2\pi f)^2 A \times \sin(2\pi ft)$$

The three vibration parameters are thus closely related and, in fact, can be derived from each other by a Dynamic Signal Analyzer (see section 6.6). However, the variation in vibration amplitude with machine speed and transducer limitations often mean that only one of the parameters will supply the information necessary for analysis.

Figure 2-4

Velocity and acceleration of the vibration are offset 90° and 180° in phase from displacement.



The impact of variation in amplitude with speed is illustrated in figure 2-5. In this example, potentially dangerous vibration levels are present in a low-speed fan and a high-speed gearbox. The two items to note are:

- Displacement and acceleration levels differ widely.
- Velocity is relatively constant.

From the first, we can conclude that frequency considerations are important in selecting a vibration parameter. Acceleration is not a good choice for very low frequency analysis, while displacement does not work well for high frequencies. Note that these are limitations of the vibration parameter, not the transducer. Frequency range limitation of transducers are also an important consideration in parameter selection, and are discussed in section 2.2.

The fact that velocity is a good indicator of damage, independent of machine speed, implies that it is a good parameter for general monitoring work. That is, a vibration limit can be set independent of frequency. (Velocity remains constant with damage level because it is proportional to the enegry content of the vibration.) Velocity is also a good parameter for analysis, but the upper frequency limitation of velocity transducers can be a problem for gear and high-speed blade analysis.

Figure 2-5

Two cases that illustrate the variation of the vibration parameters with machine speed.

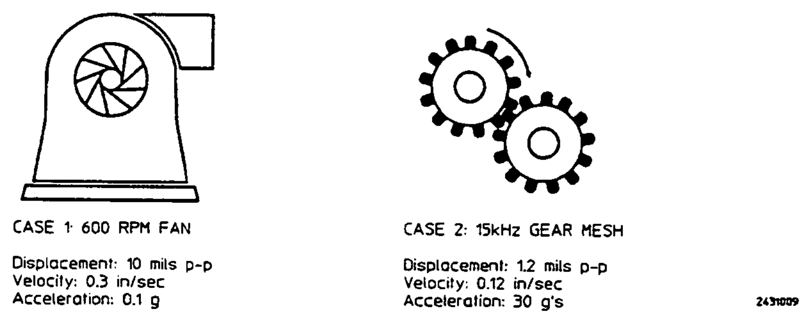
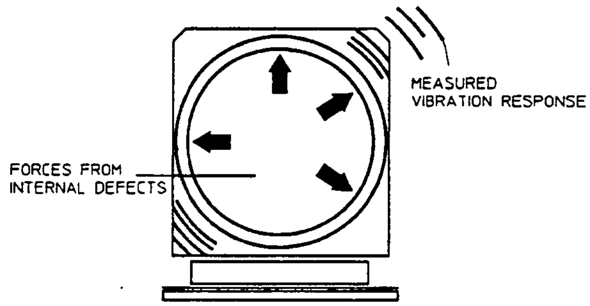


Figure 2-6
Vibration measured on a machine is the response to a defect force, not the force itself.



Mechanical Impedance

A key point illustrated by figure 2-3 is that we are measuring the *response* of the machine to a vibration force, not the force itself. Thus the response characteristics of the machine—its mechanical impedance—have a direct impact on the measured vibration. The two key results of this are:

- If the response is small, the vibration will be difficult to analyze.
- If response changes drastically with frequency, changes in running speed can produce misleading changes in measured vibration level.

These are important considerations in the selection and installation of transducers.

The most common example of low level response involves machines with relatively light rotors and fluid-film bearings, mounted in heavy casings. Very little shaft vibration is transmitted to the casing, and shaft vibration must be measured directly (see figure 2-7). Rolling element bearings are much stiffer than most fluid-film bearings, and transmit shaft (and their own) vibration to the machine case well. An example of mechanical impedence that changes noticeably with speed is shown in figure 2-8. This measurement shows how the ratio of acceleration response to input force might vary with frequency on a machine. Note that measurements made at speeds A and B would differ markedly in amplitude, even if the source of vibration remained the same. This illustrates why simple level measurements made on a machine whose speed varies can be misleading.

Figure 2-7

A relatively light shaft turning in fluid-film bearings transmits little vibration to the machine housing. Its vibration must be measured directly with a displacement transducer.

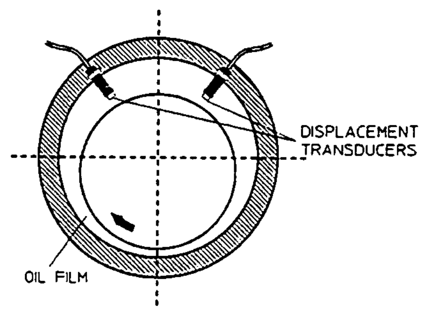
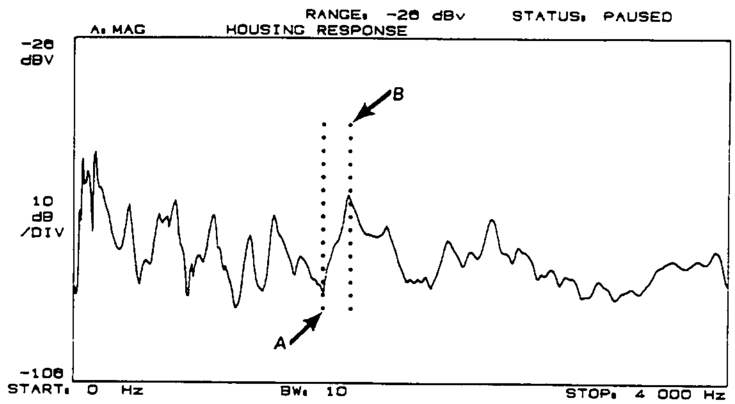


Figure 2-8

A plot of the vibration response versus frequency for a machine housing shows how measured vibration level can change with rpm. A defect force at frequency B produces a much larger vibration response than the same force level at frequency A.



Natural Frequencies

In the plot of figure 2-8, the response peaks occur at natural frequencies. These are the frequencies at which a structure will vibrate "naturally" when hit with an impact. A good illustration of natural frequency vibration is a tuning fork, which is designed to vibrate at a specific frequency when impacted (See figure 2-9). When a vibration force occurs at a natural frequency, the structure will resonate (i.e., respond with a large amplitude vibration).

Natural frequencies relate to machinery vibration analysis in three important areas:

- Resonances of the structure can cause changes in vibration level with rpm.
- The dynamics of rotating shafts change significantly near natural (or "critical") speeds.
- Resonances limit the operating frequency range of velocity transducers and accelerometers.

Changes in vibration response with frequency are shown in figure 2-8. Shafts which operate above or near a natural frequency are classified as flexible, and are discussed briefly in section 3.4. Natural frequency limits on the useful frequency range transducers are described in the next section on transducers.

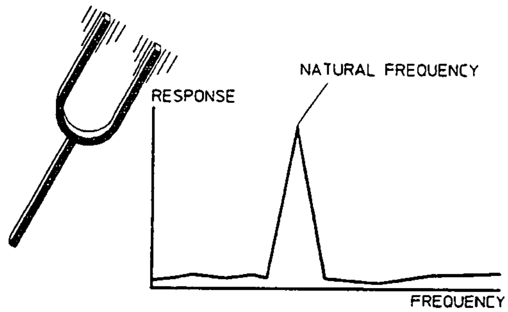


Figure 2-9
When excited by an impact, a tuning fork vibrates at its natural frequency.

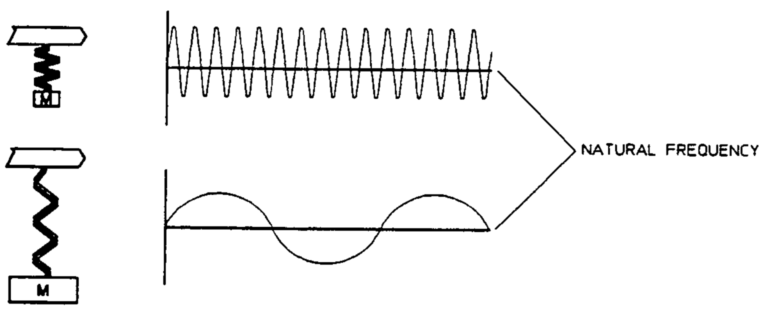


Figure 2-10
The natural frequency of a simple mechanical system varies with mass and stiffness.

A relationship worth noting at this point is the variation in natural frequency with mass and stiffness. The equation for the natural frequency of the simple mechanical system in figure 2-10 is given below, where k is stiffness and m is mass. Note that natural frequency goes up with increasing stiffness and decreasing mass. If you think of piano wires or guitar strings, the tight, lightweight ones are higher in frequency than the loose heavy ones. This relationship is important when determining a solution to resonance problems.

$$\text{Natural Frequency} = \sqrt{\frac{k}{m}}$$

2.2 Transducers

In this section, each of the three types of transducers shown in figure 2-1 will be described. We will discuss how each one works, its important characteristics, and the most common applications.

Displacement Transducers

Noncontacting displacement transducers (also known as proximity probes), like the one in figure 2-11, are used to measure relative shaft motion directly. A high frequency oscillator is used to set up eddy currents in the shaft without actually touching it. As the shaft moves relative to the sensor, the eddy current energy changes, modulating the oscillator voltage. This signal is demodulated, providing an output signal proportional to displacement. This is illustrated in figure 2-12.

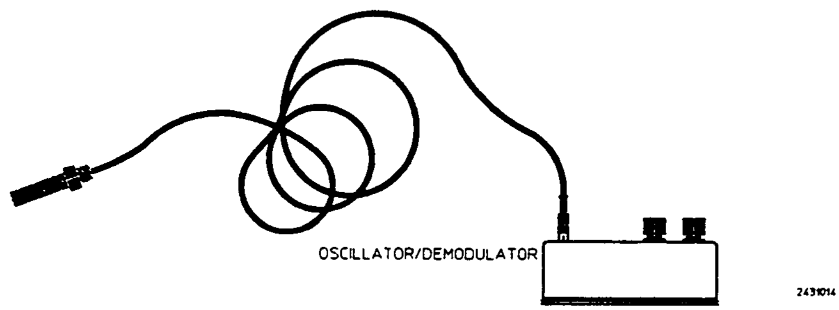


Figure 2-11

Noncontacting displacement transducers include a probe and an oscillator/ demodulator module.

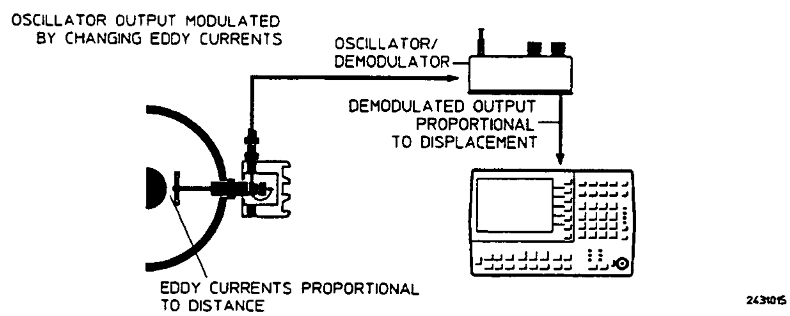


Figure 2-12

Schematic diagram of a typical noncontacting displacement transducer installation.

Key characteristics of displacement transducers:

(a) Displacement transducers measure *relative* motion between the shaft and the mount, which is usually the machine housing. Thus, vibration of a stiff shaft/bearing combination that moves the entire machine is difficult to measure with a displacement transducer alone.

(b) Signal conditioning is included in the electronics. Typical outputs are on the order of 200 mV/mil or 8 mV/micron (1 mil is 0.001 inches; 1 micron is 0.001 millimeter).

(c) Shaft surface scratches, out-of-roundness, and variation in electrical properties all produce a signal error. Surface treatment and run-out subtraction can be used to solve these problems [reference titles 10,11].

(d) Installation is sometimes difficult, often requiring that a hole be drilled in the machine.

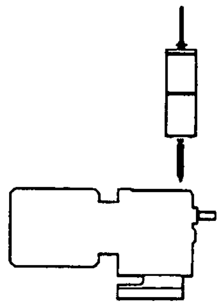
(e) The output voltage contains a dc offset of approximately 10 volts, requiring the use of ac coupling for sensitive measurements. ac coupling is a feature of all DSAs, and simply means that an input capacitor is used to block dc. The practical disadvantage of ac coupling is reduced instrument response below 1 Hz (60 rpm).

Noncontacting displacement probes are used on virtually all turbomachinery because their flexible bearings and heavy housings result in small external response. Some gas turbines, especially those in aircraft use, use relatively stiff rolling element bearings, and can thus use housing-mounted transducers (velocity and acceleration) effectively.

Displacement transducers are also commonly used as tachometer signals by detecting the passage of a keyway (see section 3.4).

Figure 2-13

A typical velocity transducer with extention probe installed.



Velocity Transducers

Velocity transducers were the first vibration transducers, and virtually all early work in vibration severity was done using velocity criteria. Velocity transducer construction is shown in figure 2-14. The vibrating coil moving through the field of the magnet produces a relatively large output voltage that does not require signal conditioning. The size of the voltage is directly proportional to the velocity of the vibration. As shown in figure 2-15, the spring-mass-damper system is designed for a natural frequency of 8 to 10 Hz, which allows the magnet to stay essentially fixed in space. This establishes a lower frequency limit of approximately 10 Hz (600 rpm). The upper frequency limit of 1000 to 2000 Hz is determined by the inertia of the spring-mass-damper system.

Figure 2-14

Velocity transducer output is a current generated in the coil as it moves through the field of the stationarymagnet.

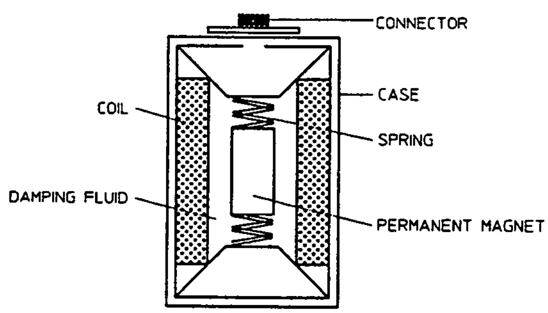
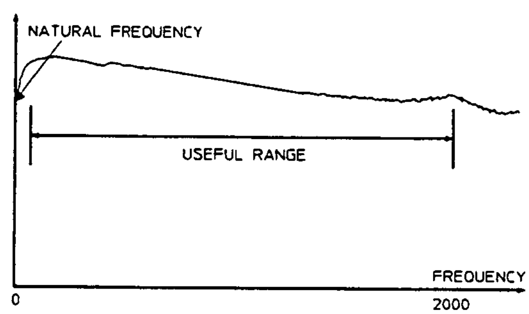


Figure 2-15

Frequency response of a typical velocity transducer. Note that the natural frequency of the magnet-spring-damper system is below the operating range.



Key characteristics of velocity transducers:

(a) The frequency range of approximately 10 Hz to 1000 Hz is ideal for most machinery work. Major applications outside this frequency range are gears, and blading on high-speed turbomachinery. The lower frequency limit can be extended slightly by compensating for the roll-off. (Note that phase measures will be in error because of the 180° phase shift at the natural frequency.)

(b) Installation of velocity transducers is relatively noncritical, and extension probes and magnetic mounts work well. In addition, no signal conditioning is required.

(c) Because they are an electro-mechanical device with moving parts, velocity transducers can change calibration over time and wear out. High temperature operation can also cause changes in calibration.

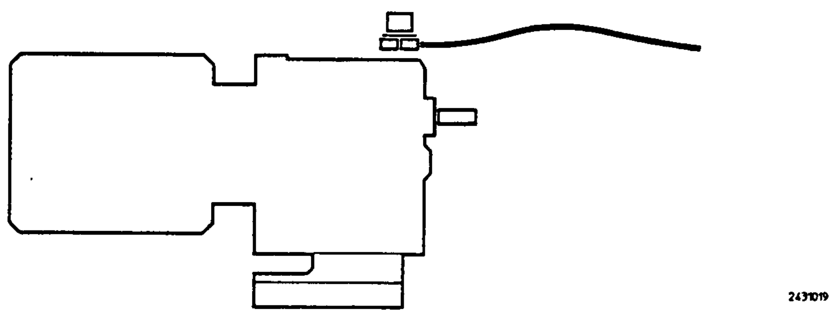
Velocity transducers were once the standard for vibration monitoring work on machines other than turbomachinery, and they are especially good for the hand-held measurements. Their popularity has declined somewhat because accelerometers are typically more rugged, and offer wider frequency response.

Accelerometers

Accelerometers are a popular transducer for general vibration analysis because they are accurate and rugged, and available for a wide range of applications. Construction of a simple accelerometer is shown in figure 2-17. The vibrating mass applies a force on the piezoelectric crystal that producers a current proportional to the force (and thus to acceleration).

Figure 2-16

Accelerometers feature wide frequency range and ruggedness. They should be securely mounted on a flat surface for best results.



The frequency response of a typical accelerometer is shown in figure 2-18. Note that the natural frequency is *above* the operating range (it is below the operating range in velocity transducers). Operation should be limited to about 30% of the natural frequency.

Figure 2-17

The output current of an accelerometer is produced by the force of the accelerating mass squeezing the piezoelectric crystal stack. The force–and thus the output current–is proportional to acceleration.

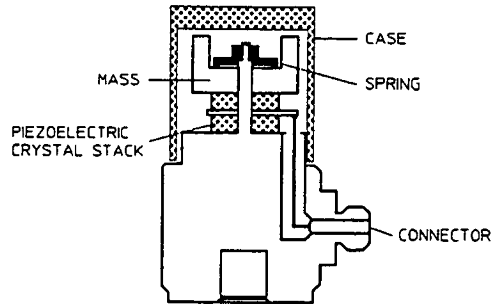


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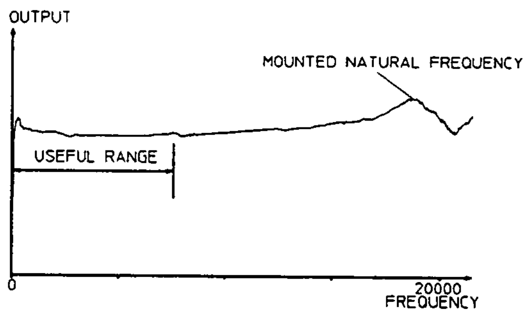
Figure 2-18

Accelerometer–high frequency response is limited by the natural frequency of the spring-mass system.



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Accelerometer sensitivity is largely dependent on the size of the mass, with a larger mass producing more output. High output is especially important for increasing the usability of accelerometers at low frequencies. However, in our previous discussion of natural frequency, we noted that natural frequency decreases as mass increases. Thus increased sensitivity tends to move the operating range down in frequency.

Accelerometer output is a low-level, high impedance signal that requires signal conditioning. The traditional method has been to use a change amplifier, as shown in figure 2-19. However, accelerometers are available with built-in signal conditioning electronics that require only simple current-source supply. These accelerometers sometimes referred to as ICP (for Integrated Circuit Piezoelectric), can be directly connected to a compatible DSA (figure 2-20). Another advantage of the ICP accelerometer is that expensive low-noise cable required to connect traditional accelerometers to the change amplifier is not required. This is especially important when long cables are involved.

Figure 2-19

Traditional accelerometers require an external charge amplifier for signal conditioning.

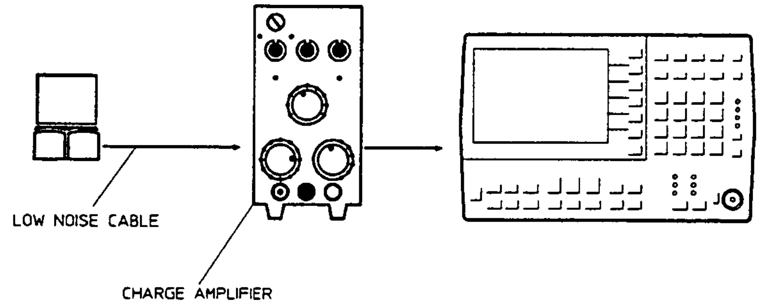
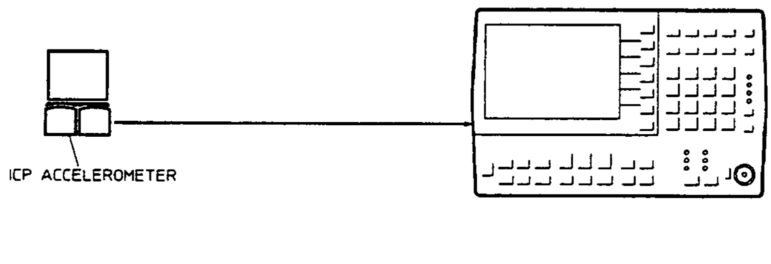


Figure 2-20

Integrated Circuit Piezoelectric (ICP) accelerometers, with built-in signal conditioning, can be connected directly to a compatible DSA.



Key characteristics of accelerometers:

(a) Accelerometers offer the broadest frequency coverage of the three transducer types. Their weakness is at low frequency, where low levels of acceleration result in small output voltages. Their large output at high frequencies also tends to obscure lower frequency defects when overall level is measured (this is not a problem with wide dynamic range of DSAs).

(b) Accelerometers require signal conditioning; however as noted above, the development of the ICP accelerometer has eliminated this disadvantage.

(c) The low frequency response of piezoelectric accelerometers is limited to approximately 5 Hz. Piezoresistive and cantilever-beam accelerometers are available that respond down to dc, although it is worth remembering that acceleration level is low at very low frequencies.

(d) Accelerometers are very sensitive to mounting, and should never be hand-held. They should be securely attached with a threaded stud, high strength magnet, or industrial adhesive. The mounting surface should be flat and smooth, preferably machined.

2.3 Selecting The Right Transducer

Selecting the right transducer for an application is a straightforward process that is described below. Table 2-1 in the next section is a guide for the application of transducers to several general types of machinery.

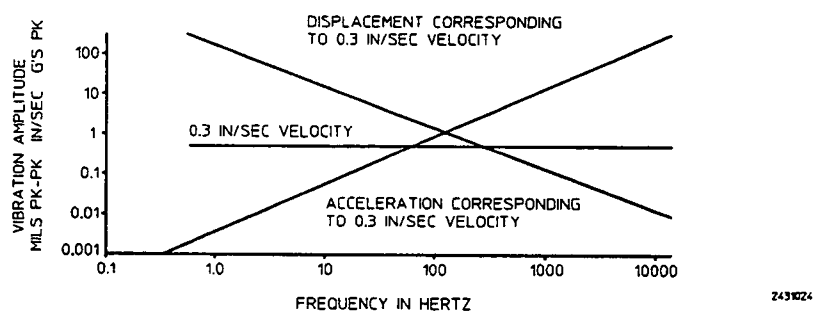
Step 1: Determine The Parameter Of Interest If you are interested in monitoring a critical clearance or relative displacement, the only choice is a displacement transducer. Although acceleration and velocity can be converted to displacement, it will be an absolute measurement, rather than the relative measurement given by a displacement transducer. If the parameter is a quantity other than a clearance or relative displacement, go on to the next step.

Step 2: Mechanical Impedance Considerations If the vibration is not well transmitted to the machine case, you must use a displacement transducer to measure the shaft directly. This will be the case with a flexible rotor-bearing system working in a heavy casing. If the shaft is not accessible (as an internal shaft in a gearbox), or the rotor-bearing system is stiff, you should use a casing-mounted velocity or acceleration transducer. In borderline cases, it may be appropriate to use both absolute and relative motion transducers.

If steps 1 and 2 indicate a displacement transducer, it is the one that will provide the best results. If a housing-mounted acceleration or velocity transducer is indicated, go on to step 3.

Figure 2-21

A vibration nomograph shows how the levels of displacement and acceleration change with frequency, relative to the level of velocity. Note that the acceleration response is very low at 1 Hz (less than 100 μV with a 10 mV/g accelerometer).



Step 3: Frequency Considerations If the frequency of the expected vibration is greater than 1000 Hz, you must use an accelerometer. (You will have a much better idea of frequencies to expect after reading chapter 4.) If the vibration will be in the range of 10 Hz to 1000 Hz, either velocity or acceleration transducers can be used. The vibration nomograph of figure 2-21 can be used to determine whether an accelerometer will produce sufficient output.

In general, use a velocity transducer if:

- Overall level is being measured to detect defects.
- The transducer will be hand-held.
- The machinery being analyzed is low-speed (i.e., less than 1200 rpm).

Use an accelerometer if:

- High frequency (above 1000 Hz) blading or gear defects are being analyzed.
- Structural response is being measured.
- Long transducer life (more than 2 years) is required.
- High temperatures are encountered (although high temperature velocity transducers are available). Note that the operating temperature range of ICP accelerometers is usually limited to 250° F (120° C).

After the type of transducer has been determined, consult transducer manufacturers for specific model recommendations.

2.4 Installation Guidelines

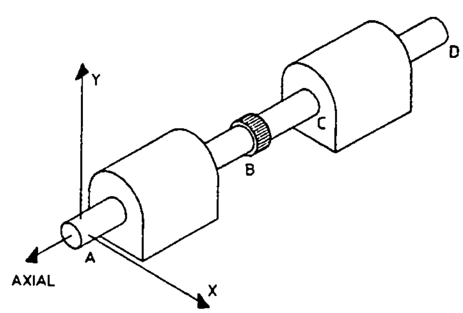
After the transducer has been selected, it must be properly installed for best results. Figure 2-22 is an example machine combination that is used for the application summary of table 2-1. The machine could be a small motor and pump, or a steam turbine and generator. In general, the number of transducers used on a machine combination is determined by how critical the machine is to the process, and how expensive it is to repair or replace. Table 2-1 is intended to show typical applications, and should be used only as a guide.

Proper mounting of the transducer to the machine is also critical, especially with displacement and acceleration transducers, and manufacturer's recommendations should be followed closely. One particular caution: the transducer should never be mounted to a sheet metal cover, since resonances may easily be in the operating speed range.

Table 2-1
Transducer Application Summary

Machine Description	Transducer	Location
Steam turbine/large pump or compressor with fluid film bearings	Displacement	Radial horizontal and vertical at A,B,C,D. Redundant axial at A and D.
Gas turbine or medium size pump	Displacement Velocity	Radial horizontal and vertical at A and B. Radial horizontal or vertical at A and B.
Motor/fan both with fluid-film bearings.	Displacement or Velocity	One radial at each bearing. One axial displacement to detect thrust wear.
Motor/pump or compressor with rolling element bearings.	Velocity or Acceleration	One radial at each bearing. One axial, usually on motor to detect thrust wear.
Gearbox with rolling element bearings.	Acceleration	Transducers mounted as close to each bearing as possible.
Gearbox shafts with fluid film bearings.	Displacement	Radial horizontal and vertical at each bearing. Axial to detect thrust wear.

Figure 2-22
Transducer locations referenced in table 2-1.



Chapter 3

Reducing Vibration to its Components: The Frequency Domain

The signal obtained from a machinery vibration transducer is a complex combination of responses to multiple internal (and sometimes external) forces. The key to effective analysis is to reduce this complex signal to individual components, each of which can then be correlated with its source. Techniques for reducing vibration to its components are the subject of this chapter, while the process of correlation is discussed in chapters 4 and 5.

Two analysis perspectives are available for determining the components of vibration:

1 The ***time domain*** view of vibration amplitude versus time

2 The ***frequency domain*** view of vibration amplitude versus frequency

While the time domain provides insight into the physical nature of the vibration, we will see that the frequency domain is ideally suited to identifying its components. The advantage of Dynamic Signal Analyzers for machinery analysis is their ability to work in both domains.

This chapter begins with a discussion of the relationship between the time and frequency domains. Spectral maps, which add the dimension of machine speed or time to the frequency domain, are presented next. The frequency phase spectrum, an important complement to the more familiar aplitude spectrum, is discussed in the following section. This chapter closes with a description of the instruments available for frequency domain analysis. Information on the time and frequency domains in this application note is focused on machinery vibration. For a more general discussion of the subject, refer to *Hewlett-Packard Application Note AN 243.*

3.1 The Time Domain

Figure 3-1

A time domain representation of vibration due to rotor imbalance.

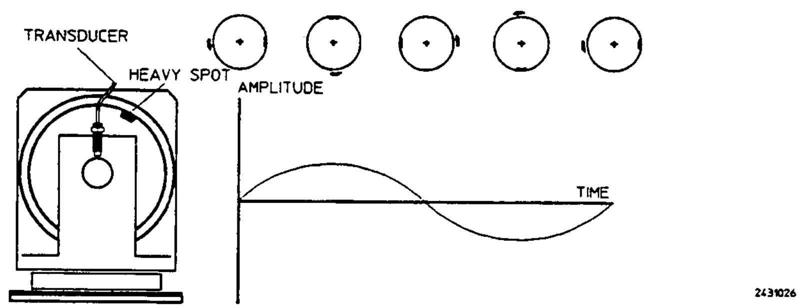
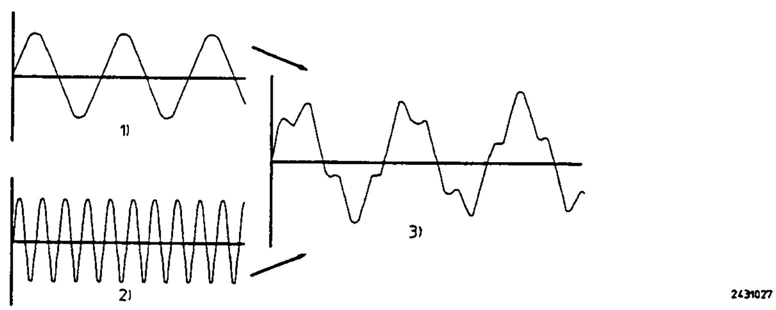


Figure 3-2

Waveform (3) is the combination of signals (1) and (2). The nature of these components is hidden in the time domain view of their sum.



One way to examine vibration more closely is to observe how its amplitude varies with time. The time domain display of figure 3-1 clearly shows how vibration due to an imbalance rotor varies with time (we are using a displacement transducer to simplify the phase relationship). The amplitude of the signal is proportional to the amount of imbalance, and the cycle repeats once per revolution. This signal is easy to analyze because we are using an idealized example with a single source of vibration—real world vibration signals are much more complex.

When more than one vibration component is present, analysis in the time domain becomes more difficult. This situation is illustrated in figure 3.2, where two sine wave frequencies are present. The result of this combination is a time domain display in which the individual components are difficult to derive.

The time domain is a perspective that feels natural, and provides physical insight into the vibration. It is especially useful in analyzing impulsive signals from bearing and gear defects, and truncated signals from looseness. The time domain is also useful for analyzing vibration phase relationships. However, the individual components of complex signals are difficult to determine.

A perspective that is much better suited to analyzing these components is the frequency domain.

3.2 The Frequency Domain

Figure 3-3

The relationship between the time and frequency domains.

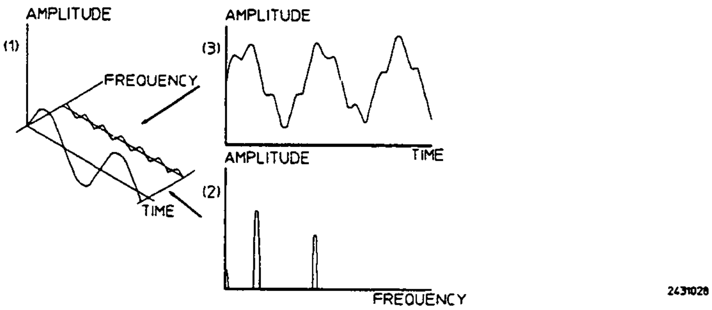


Figure 3-3(1) is a three-dimensional graph of the signal used in the last example. Two of the axes are time and amplitude that we saw in the time domain. The third axis is frequency, which allows us too visually separate the components of the waveform. When the graph is viewed along the frequency axis, we see the same time domain picture we saw in figure 3-2. It is the summation of the two sine waves, which are no longer recognizable.

However, if we view the graph along the time axis as in figure 3-3(2), the frequency components are readily apparent. In this view of amplitude versus frequency, each frequency component appears as a vertical line. Its height represents its amplitude and its position represents its frequency. This frequency domain representation of the signal is called the *spectrum* of the signal.

The power of the frequency domain lies in the fact that *any* real world signal can be generated by adding up sine waves. (This was shown by Fourier over one hundred years ago.) Thus, while the example we used to illustrate the frequency domain began as a summation of sine waves, we could perform a similar reduction to sine wave components for any machinery vibration signal. It is important to understand that the frequency spectrum of a vibration signal completely defines the vibration—no information is lost by converting to the frequency domain (provided phase information is included).

A Machinery Example

Figure 3-4

Machinery vibration viewed in the time and frequency domains.

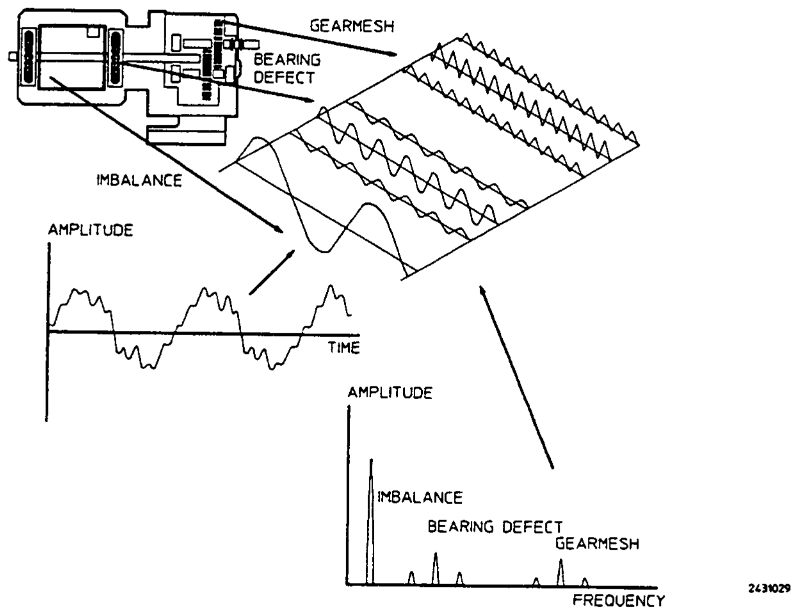


Figure 3-4 should give you better insight into frequency domain analysis applied to machinery. The internal sources of vibration in this example are rotor imbalance, a ball bearing defect, and reduction gear meshing. For purposes of illustration in this example, the sources of vibration and their resulting frequency components have been somewhat simplified. (Details of the frequency components that each of these defects produce are given in chapter 4.)

Imbalance produces a sinusoidal vibration at a frequency of once per revolution. If we assume a single defect in the outer race of the ball bearing, it will produce an impulsive vibration each time a ball passes over the defect—usually around four times per revolution. To simplify the example, we will assume that this is a sine wave. The two smaller sine waves around this frequency are caused by interaction (modulation) of the bearing defect force with the imbalance force. These signals are called *sidebands*, and occur often in machinery vibration. They are spaced at increments of plus and minus running speed from the defect frequency. These components are often referred to as *sum and difference* frequencies, and are discussed in section 5.3. The gear mesh frequency appears at running speed multiplied by the number of teeth on the main shaft gear, which we have assumed to be ten. The running speed sidebands around the gear meshing frequency usually indicate eccentricity in the gear. While this is a greatly simplified view of machinery vibration, it demonstrates the clarity with which vibration components can be seen in the frequency domain.

Early Warning of Defects

As we pointed out in the introduction, many maintenance programs use DSAs to monitor machinery vibration in the frequency domain. This is because the low level vibration produced during the early stages of some defects cannot be detected by an overall vibration meter. (In effect, it is "buried" by the relatively large residual imbalance component.) This is especially true of rolling element bearings, and is one of the reasons this particular fault is one of the most difficult to detect.

An advantage of the frequency domain is that low level signals are easy to see—even in the presence of signals 1000 times larger. This is illustrated in the time and frequency domain displays of figure 3-5, where the low level signals that are readily apparent in the frequency domain cannot be seen in the time domain. A key to this capability is *logarithmic* display of amplitude. In this display format, amplitude is expressed in decibels, or *dB*. (See the following explanation of dB and the need for logarithmic scales.)

While most people prefer the more natural feel of a linear (i.e., non-logarithmic) display, logarithmic displays are an aid to earliest detection of defects such as those characteristic of rolling element bearings. Example spectra in this note will use both logarithmic and linear amplitude scales.

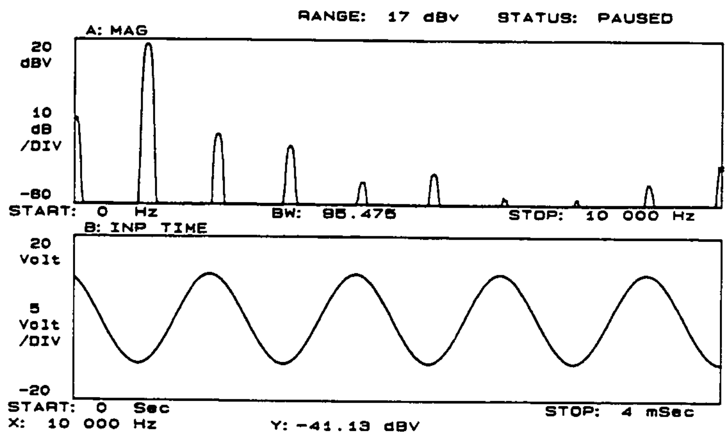


Figure 3-5

Small signals that are hidden in the time domain are readily apparent in the frequency domain. By using a logarithmic (dB) amplitude scale, signals which vary in level by a factor of over 1000 can be displayed simultaneously.

The Need for Decibels (dB)

An advantage of the frequency domain is the ability to resolve small signals in the presence of large ones. To utilize this capability, we must use a logarithmic (dB) amplitude scale.

Suppose we wish to measure a defect component that is 0.1% (1/1000) of the residual imbalance component. If we set the fundamental to full scale on a 4 inch (10 centimeter) screen, the smaller component would be only 0.004 inch (0.1 millimeter) tall. Such a signal would be difficult to see, let alone accurately measure. Yet many analyzers are available with the ability to measure signals even smaller than this. Since we want to be able to see all the components easily at the same time, the only answer is to change our amplitude scale. A logarithmic scale would compress our large signal amplitude and expand the small ones, allowing all components to be displayed at the same time.

Alexander Graham Bell discovered that the human ear responded logaritymically to power difference and invented a unit, the Bel to help him measure the ability of people to hear. One tenth of a Bell, the deciBel (dB) is the most common unit used in the frequency domain today.

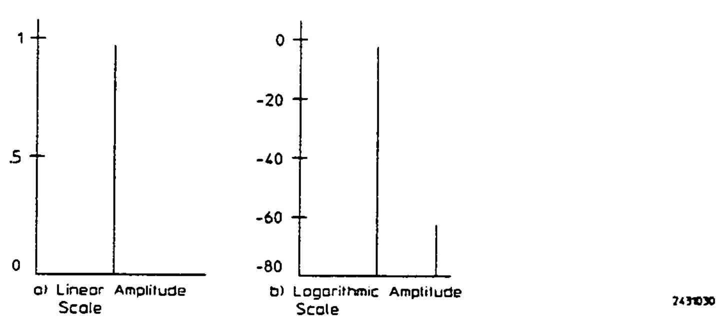
A table of the relationship between volts, power and dB is given in table 3-1. From the table, we can see that our 0.1% component is 60 dB below the residual imbalance component. If we had an 80 dB display as in figure 3-13, the 0.1% defect component would occupy 1/4 of the screen, not 1/1000 as in a linear display.

Table 3-1
The relationship between decibels, power and voltage.

dB	Power Ratio	dB	Voltage Ratio
+20	100	+40	100
+10	10	+20	10
+3	2	+6	2
0	1	0	1
–3	1/2	–6	1/2
–10	1/10	–20	1/10
–20	1/100	–40	1/100

dB = 10 Log (Power Ratio) = 20 Log (Voltage Ratio)

Figure 3-6
Small signals can be measured with a logarithmic amplitude scale.



Spectrum Examples

Figure 3-7

Examples of frequency spectra common in all machinery vibration.

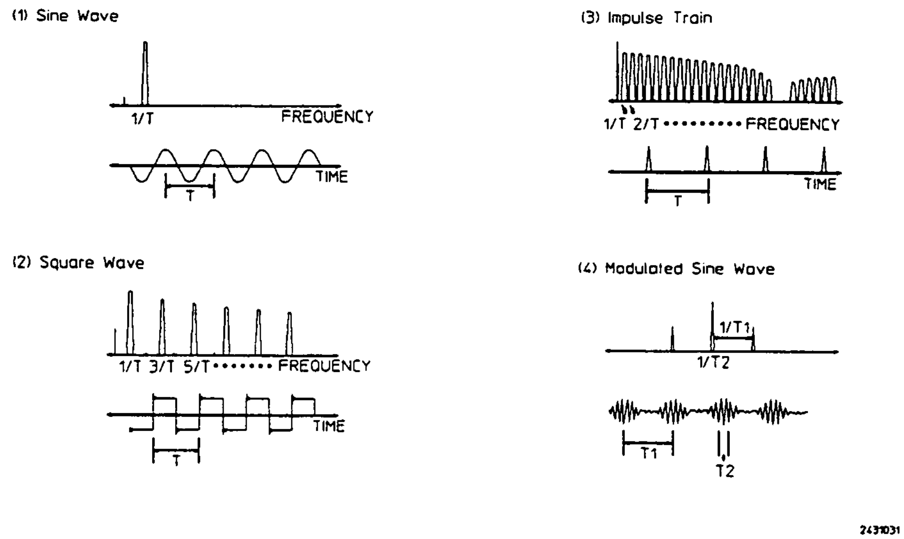


Figure 3-7 shows the time and frequency domain of four signals that are common in machinery vibration.

1 The frequency spectrum of a pure sine wave is a single spectral line. For a sine wave of period T seconds, this line occurs at 1/T Hz.

2 A square wave, which is much like the truncated signal produced by mounting or bearing cap looseness, is made up of an infinite number of *odd harmonics.* Harmonics are components which occur at frequency multiples of a fundamental frequency. In machinery analysis, we usually refer to harmonics as orders of the fundamental running speed. Because square wave type signals from machinery are not ideal, their spectra often contain both odd and even harmonics.

3 Bearing and gear defects usually produce impulsive signals that are typified by harmonics in the frequency domain. These harmonics are spaced at the repetition rate of the impulse.

4 Finally, as mentioned above, many defects are modulated by residual imbalance. The frequency spectrum of a modulated signal consists of the signal being modulated (the carrier), surrounded by sidebands spaced at the modulating frequency.

3.3 Spectral Maps

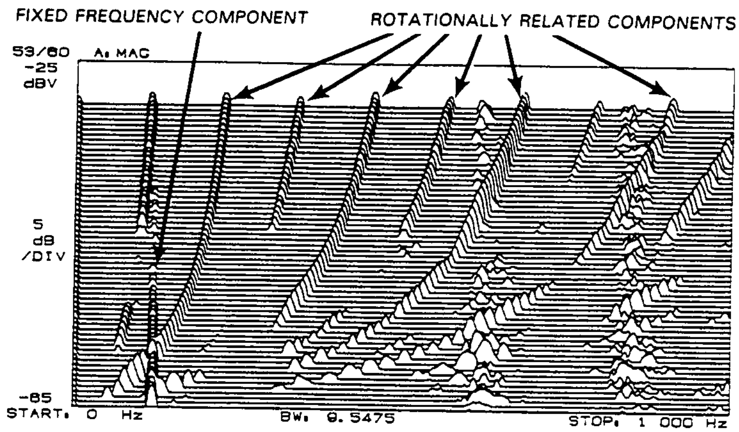


Figure 3-8

Spectral maps show variation in the vibration spectrum with time or rpm.

The vibration characteristics of a machine depend on its dynamics and the nature of the defect. The change of these characteristics with machine speed has two important implications for analysis:

1 The vibration resulting from a defect may not appear in all speed ranges.

2 Insight into the nature of a defect may be obtained from observing the change in vibration with speed. Spectral maps, such as the one in figure 3-8, are three dimensional displays that effectively show variation in the vibration spectrum with machine speed.

Spectral maps (also known as cascade plots) usually consist of a series of vibration spectra measured at different speeds. A variety of other parameters, including time, load, and temperature, are also good third dimensions for maps. The most common method for mapping the variation in vibration with rpm is to measure successive spectra while the machine is coasting down or running up in speed. The map in figure 3-8 was made on a Hewlett-Packard DSA with this capability built in.

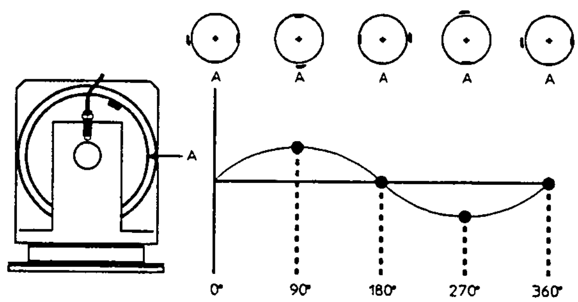
In addition to showing how vibration changes with speed, spectral maps quickly indicate which components are related to rotational speed. These components will move across the map as speed changes, while fixed frequency components move straight up the map. This feature is especially useful in recognizing machine resonances, which occur at fixed frequencies.

3.4 The Phase Spectrum

The complete frequency domain representation of a signal consists of an amplitude spectrum and a phase spectrum. While the amplitude spectrum indicates signal level as a function of frequency, the phase spectrum shows the phase relation between spectral components. In machinery vibration analysis, phase is required for most balancing techniques. It is also useful in differentiating between faults which produce similar amplitude spectra. DSAs are unique among commonly used frequency domain analyzers in providing both amplitude and phase spectra.

Figure 3-9

The phase of the imbalance signal corresponds to the direction of the displacement. One 360° rotation of the rotor corresponds to one 360° cycle of the signal.



The concept of phase relationships is most easily seen in the time domain. In figure 3-9, phase notation has been added to the waveform we used in our first time domain example. One 360° cycle of the rotor corresponds to one cycle of the vibration signal. This relationship holds regardless of where we start on the circle, but absolute phase numbers mean nothing without a reference. In figure 3-9, we have defined the reference point as A.

Just as we can define the phase of a signal relative to a reference point on a rotor, we can define the relative phase of two signals. The signals shown in figure 3-10 are separated by 1 quarter of a cycle, or 90°. We say that the phase of the trace A *leads* that of trace B because its peak occurs first.

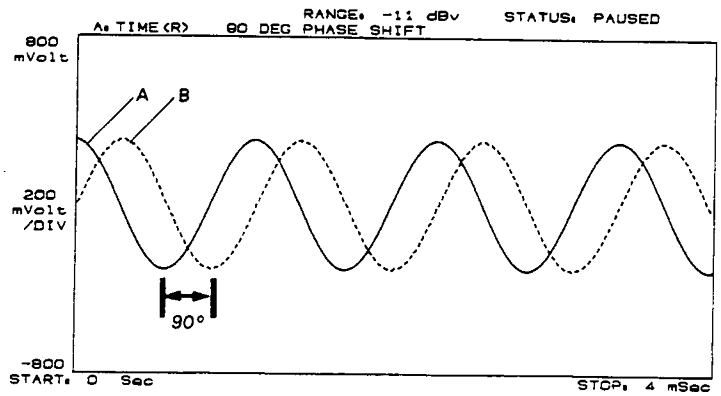


Figure 3-10

Two sine waves with a phase relationship of 90.

In the frequency domain, each amplitude component has a corresponding phase. Figure 3-11 is a DSA display of our imbalance example, indicating a 90° phase relationship between the frequency component and the trigger signal (amplitude is shown as a dashed line). Single-channel DSAs require trigger delay to read phase relative to a trigger correctly—refer to operating instructions.

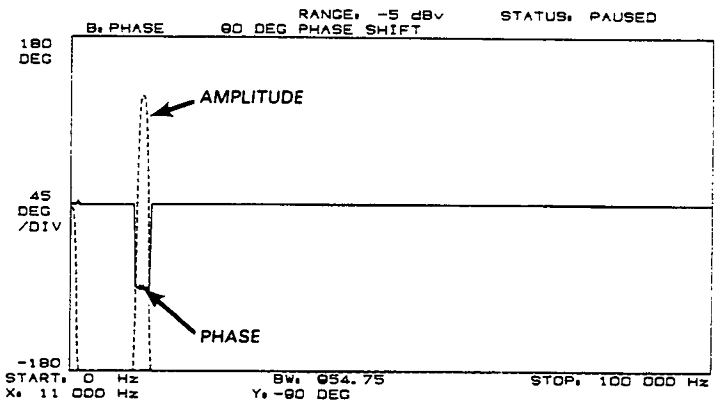


Figure 3-11

DSA frequency domain display of a 90° phase relationship. Referring to figure 3-11, this is the phase of trace B when trace A is used to trigger the measurement.

NOTE

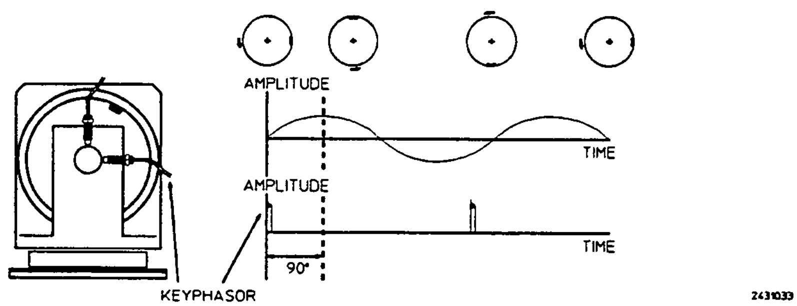
The phase is –90° because the peak of the signal occurs *after* the trigger.

Balancing

The most common application for the phase spectrum is in balancing. Recall from figure 3-9 that we need a reference for absolute phase to be meaningful. In machinery analysis, this reference is most often provided by a Keyphasor TM—a displacement or optical transducer which detects the passage of a keyway, set screw, or reflecting surface. Figure 3-12 shows a keyphasor added to our example machine. With the transducer 90° *behind* the keyphasor (in the direction of rotation), and the keyphasor and heavy spot lined up, the resulting time domain waveforms are offset in phase by 90°. The corresponding phase spectrum of the vibration signal is shown in figure 3-11. In this case, the keyphasor is used to trigger the measurement.

Figure 3-12

Since the heavy spot on the rotor passes the transducer 90° after the keyway passes the keyphasor, the signal lags the keyphasor pulse by 90°. The corresponding frequency domain phase spectrum is shown in figure 3-11.



Figures 3-11 and 3-12 indicate the location of the heavy spot relative to the keyway. This information can be used in balancing to locate a compensation weight opposite the heavy spot. Once the relationship between vibration amplitude and imbalance weight has been determined, all the information needed for single-plane balancing can be obtained with one measurement. For balancing, you should remember that changing the vibration parameter, or moving the keyphasor relative to the transducer, will introduce a phase change that must be taken into account. (Vibration parameter phase relationships are described in section 2.1).

Other Applications of Phase

The phase spectrum is also useful for differentiating between defects that produce similar amplitude spectra. In section 4.4, we will describe how axial phase measurement can be used to differentiate between imbalance and misalignment. Section 5.2 explains how the relative stability of phase can be used to gain insight into the nature of defects.

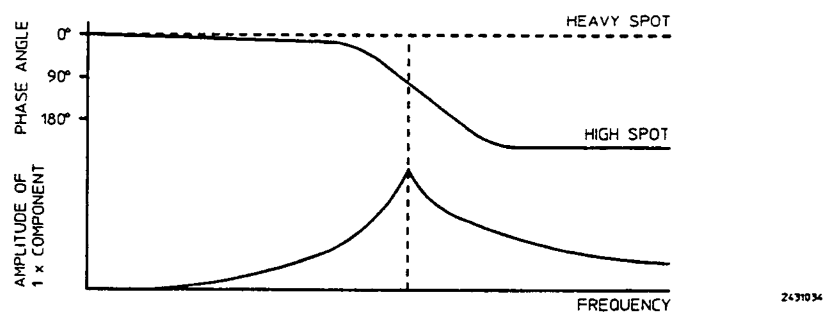
Rigid and Flexible Rotors

We mentioned in the introduction that flexible rotors required an understanding of shaft dynamics for complete analysis. As the name implies, a flexible rotor is one which bends during operation. This bending occurs at a natural frequency of the rotor, usually referred to as a critical speed. A flexible rotor has several critical speeds, each with a specific bending shape. These shapes are called modes, and can be predicted through modeling. The distinction between rigid and flexible rotors is important because the dynamics of a rotor change significantly as it approaches and passes through a critical speed. The amplitude of the vibration response peaks, and the phase response shifts by 180°.

This phase shift is shown in the plot of figure 3-13 (commonly referred to as a Bode plot). When phase is measured at a speed well above the critical, the high spot measured by the displacement transducer is at a point *opposite* the imbalance —a phase shift of 180°. When operating speed is near the critical, phase response will be shifted between 0° and 180°, depending on the dynamics of the rotor.

Figure 3-13

The vibration response of a flexible rotor shifts 180° in phase as rpm passes through a critical speed.



Accurate interpretation of phase spectra measured on flexible rotors requires an understanding of rotor dynamics that is beyond the scope of this application note. Unless otherwise noted, *all statements about the use of phase in analysis refer only to rigid rotors* (those which operate well below the first critical speed).

3.5 Frequency Domain Analyzers

Instruments which display the frequency spectrum are generally referred to as spectrum analyzers, although DSAs are also commonly referred to as real time or FFT analyzers. There are three basic types of spectrum analyzer:

1 Parallel filter

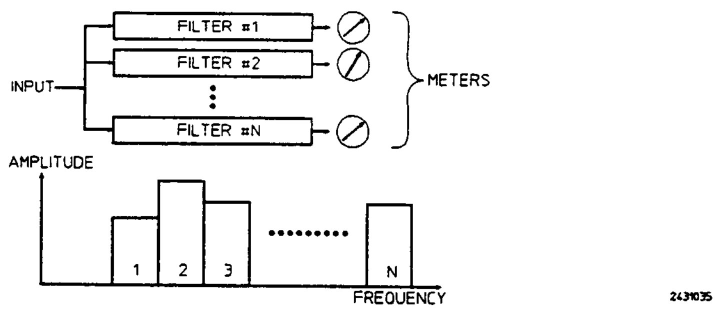
2 Swept filter

3 DSA

This section will give a short description of each, along with advantages and disadvantages. For a more detailed discussion, refer to *Hewlett-Packard Application Note AN 243.*

Figure 3-14

Parallel filter analyzers have insufficent frequency resolution for machinery analysis.



A simple block diagram of a parallel filter analyzer is shown in figure 3-14. These analyzers have several built-in filters that are usually spaced at 1/3 or 1 octave intervals. This spacing results in resolution that is proportional to frequency. For a 1/3 octave analyzer, resolution varies from around 20 Hz at low frequencies to several thousand Hertz (kHz) at high frequency. A variation of the parallel filter analyzer that is sometimes used in machinery work has several filters that can be individually selected.

Parallel filter analyzers are usually relatively low in cost and battery operated, but their resolution is not nearly good enough for analysis. This is especially true for gear and bearing analysis, where frequency resolution of a few Hertz is often required. Electrical problems in induction motors often require frequency resolution of a few Hertz. (Section 6.2 describes the importance of frequency resolution for machinery analysis.)

Swept filter analyzers use a tuneable filter, much like a radio receiver. The block diagram for this type of analyzer is shown in figure 3-15. The frequency resolution of these instruments is on the order of 5 Hz—better than parallel filter analyzers, but not good enough for complete vibration analysis. Their operation, however, is much slower than the parallel filter analyzers. This is because transient responses in the filter must be allowed to settle at each new frequency. This slow operation increases the time required to complete a vibration survey. Also, because of the time required to sweep through the frequency spectrum, swept filter analyzers can miss short duration events.

Figure 3-15

Swept filter analyzers provide better frequency resolution than parallel filter analyzers, but are too slow for machinery analysis.

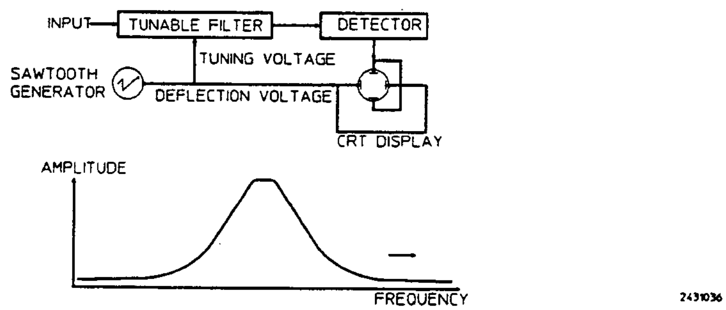
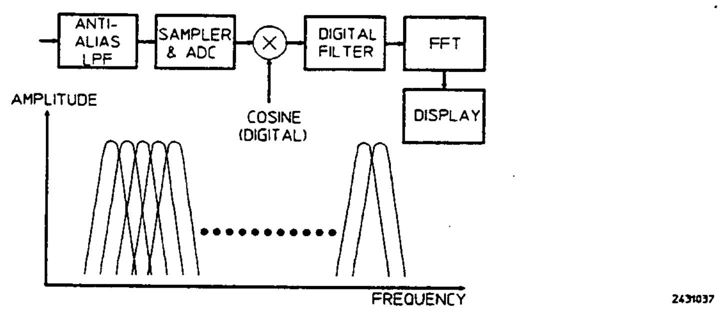


Figure 3-16

DSAs digitally simulate hundreds of parallel filters, providing both high speed and excellent frequency resolution. DSAs also provide time and phase displays not available on the other frequency domain analyzers.



DSAs use digital techniques to effectively synthesize a large number of parallel filters. The large number of filters (typically 400) provides excellent resolution, and the fact that they are parallel means that measurements can be made quickly. DSAs also provide both time and phase spectrum displays, and can be connected directly to computers for automated measurement. For these reasons, DSAs are the best frequency domain analyzer for vibration analysis.

Chapter 4

Vibration Characteristics of Common Machinery Faults

In the last chapter, we saw how the vibration signal can be reduced to simple components using the frequency domain. In chapters 4 and 5, we'll take the next step in analysis—correlating these components with specific machine faults. This chapter provides the basic theory, while chapter 5 addresses some of the common problems encountered in analysis.

Each machine defect produces a unique set of vibration components that can be used for identification. This chapter describes these vibration patterns (or "signatures") for the most common machinery defects. Where appropriate, frequency calculation formulas and details of spectrum generation are also included. The descriptions will give you the basic information needed to correlate vibration components with defects; the details provide insights that will improve your ability to analyze usual situations.

The tables in section 4.10 summarize the vibration pattern descriptions of chapter 4. It is important to understand, however, that correlation is rarely as easy as matching vibration components on a DSA display with those in a table. Machinery dynamics, operating condition (e.g. load and temperature), multiple faults, and speed variation all affect vibration, complicating the correlation process. Methods of dealing with these problems are the subject of chapter 5.

Converting a vibration spectrum to a detailed report on machine condition is the most challenging aspect of vibration analysis. Chapters 4 and 5 are a starting point, providing a basis for building your skills through experience.

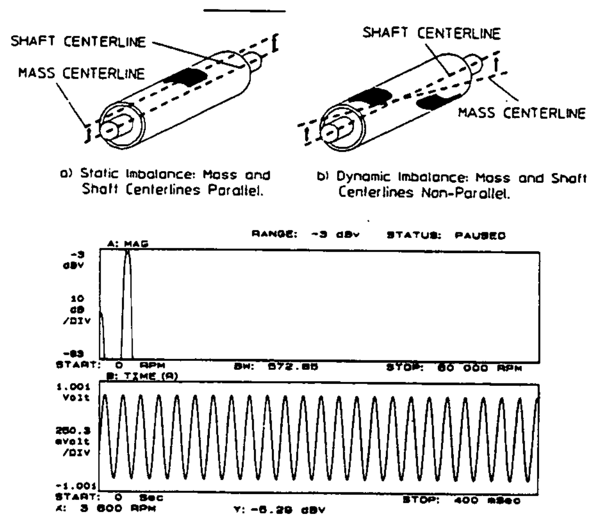
4.1 Imbalance

Rotor imbalance exists to some degree in all machines, and is characterized by sinusoidal vibration at a frequency of once per revolution. In the absence of high resolution analysis equipment, imbalance is usually first to get the blame for excessive once per revolution vibration—vibration that can be caused by several different faults. In this section, we will discuss characteristics that can be used to differentiate these faults from imbalance, eliminating unnecessary balancing jobs.

Phase plays a key role in detecting and analyzing imbalance, and it is important to remember the phase shifts associated with flexible rotors (see figure 3-13). A state of imbalance occurs when the center of mass of a rotating system does not coincide with the center of rotation. It can be caused by a number of things, including incorrect assembly, material buildup, and rotor sag. As shown in figure 4-1, the imbalance can be in a single plane (static imbalance) or multiple planes (couple imbalance). The combination is usually referred to as dynamic imbalance. In either case, the result is a vector that rotates with the shaft, producing the classic once per revolution vibration characteristic.

Figure 4-1

Imbalance, whether static or dynamic, results in a spectral peak at a frequency of once per revolution (1×).



Distinguishing Characteristics of Imbalance

The key characteristics of the vibration caused by imbalance are:

(a) It is sinusoidal at a frequency of once per revolution (1×)

(b) It is a rotating vector

(c) Amplitude increases with speed

These characteristics are very useful in differentiating imbalance from faults that produce similar vibration.

The vibration caused by pure imbalance is a once per revolution sine wave, sometimes accompanied by low-level harmonics. The faults commonly mistaken for imbalance usually produce high-level harmonics, or occur at a higher frequency. In general, if the signal has harmonics above once per revolution, the fault is not imbalance. However, high-level harmonics can occur with large imbalance forces, or when horizontal and vertical support stiffnesses differ by a large amount (see section 4.4).

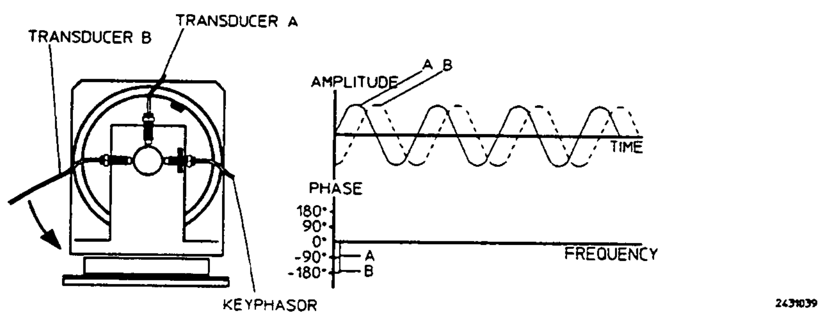
Because the imbalance force is a rotating vector, the phase of vibration relative to a keyphasor follows transducer location, while amplitude changes little. As shown in figure 4-2, moving the transducer 90° can result in a 90° change in phase reading, with approximately the same amplitude. Two such readings made on directional vibration (e.g., caused by looseness) will vary widely in amplitude.

NOTE

The amplitudes obtained from these two readings can vary with support stiffness and running speed. With flexible rotors, small speed variations between the two measurements will result in a phase relation very different from the one pictured.

Figure 4-2

The rotating nature of the imbalance force results in a phase reading (relative to a keyphaser) that follows transducer location. This is useful in differentiating imbalance from faults which produce directional vibration.



Faults Commonly Mistaken For Imbalance

The following faults are often mistaken for imbalance because they result in increased levels of vibration at running speed. However, each has distinctive characteristics which can be used for identification.

A. **Misalignment** The key characteristics that identify misalignment are a large second harmonic component, and a high level of axial vibration. Bent shafts and improperly seated bearings are special cases of misalignment, and produce similar vibration. The relative phase of axial vibration due to misalignment, measured at the ends of the shaft, is typically 180°. These signals are usually in phase when the shaft is out of balance (see section 4.4).

B. **Load Variation** Uneven loading in material handling machines and retained fluid in pumps result in imbalance. Higher machine loading can also cause an increase in running speed vibration level. The key to correct interpretation of these increases is a good understanding of the machine's operating characteristics. When measuring baseline vibration, it is important to check variation with key operating parameters such as load, pressure, and temperature. If the variation is significant, it can be roughly characterized by taking baseline spectra under a variety of operating conditions.

C. **Mechanical Looseness** The vibration spectrum that results from looseness almost always includes higher harmonics, although these can be damped out in a belt-driven machine. Since looseness is usually highly directional, it can be identified by relatively large level changes with transducer location (see section 4.5).

D. **Resonance** A machine resonance (natural frequency) at running speed will produce a high 1× vibration level. Resonance is usually identifiable because vibration level will be significantly reduced at frequencies higher or lower than Pitch Diameter resonance. Resonances are usually the result of installation faults (see section 4.8).

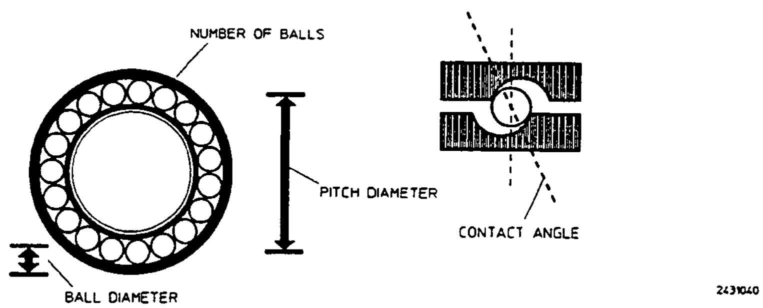
E. **Excessive Clearance in Fluid-Film Bearings** The increase in running speed vibration level is usually accompanied by higher frequency harmonics.

4.2 Rolling Element Bearings

Rolling element (anti-friction) bearings are the most common cause of small machinery failure, and overall vibration level changes are virtually undetectable in the early stages of deterioration. However, the unique vibration characteristics of rolling element bearing defects make vibration analysis an effective tool for both detection and analysis.

Figure 4-3

Using the parameters shown, the basic frequencies resulting from rolling element bearing defects can be computed.



The specific frequencies that result from bearing defects depend on the defect, the bearing geometry, and the speed of rotation. The required bearing dimensions are shown in figure 4-3, and are usually available from the bearing manufacturer. Included in this section is a computer program that computes the expected frequencies given bearing parameters and rotational speed.

CAUTION

Parameters for the same model number bearing can change with manufacturer.

A problem in detecting the early stages of failure in rolling element bearings is that the resulting vibration is low level, and often masked by higher level vibration. If monitoring is performed with a simple vibration meter (or in the time domain), these low levels will not be detected and unpredicted failures are inevitable (see figure 3-5). A good solution is regular monitoring of critical machinery with a DSA, since the high resolution and dynamic range can show components as small as 1/1000 the amplitude of higher level vibration.

NOTE

Specialized vibration meters are available for early detection of bearing defects. These depend on filtering or special transducers to heavily weight readings toward bearing frequencies. These instruments usually detect defects earlier than normal meters, although readings can sometimes be misleading, and they cannot replace DSA's for analysis.

An added benefit of early detection is that indications of the cause of failure, which may be obliterated in later stages, are still visible. An example of this would be false brinelling caused by excessive vibration on a stationary machine. By understanding the cause of problems such as this, the source of chronic failures can be determined.

Frequencies Generated by Rolling Element Bearing Defects

Formulas to calculate the frequencies resulting from bearing defects are given in table 4-1 (refer to figure 4.3). The formulas assume a single defect, rolling contact, and a rotating shaft with fixed outer race. The results can be expressed in orders of rotation by leaving out the (RPM/60) term. The BASIC program in figure 4-4 will compute the bearing frequencies automatically. Again, remember that bearing parameters can change with manufacturer.

Table 4-1
Bearing Characteristic Frequencies

Defect on outer race (Ball pass frequency outer)	$= \frac{(n)}{2} \frac{(RPM)}{60} \left(1 - \frac{Bd}{Pd} \cos\varphi\right)$	(1)
Defect on inner race (Ball pass frequency inner)	$= \frac{(n)}{2} \frac{(RPM)}{60} \left(1 + \frac{Bd}{Pd} \cos\varphi\right)$	(2)
Ball defect (Ball spin frequency)	$= \frac{(Pd)}{2Bd} \frac{(RPM)}{60} \left[1 - \left(\frac{Bd}{Pd}\right)^2 \cos^2\varphi\right]$	(3)
Fundamental train frequency	$= \frac{1}{2} \frac{(RPM)}{60} \left(1 - \frac{Bd}{Pd} \cos\varphi\right)$	(4)

Pd = Pitch diameter
Bd = Ball diameter
n = Number of balls
φ = Contact angle

Figure 4-4

A BASIC program to compute bearing characteristic frequencies. The specific unit used in line 170 and 180 is not critical, as long as it is the same for both.

```
10 ! Bearing frequency calculation program for HP 85
20 !
30 DIM D$[32]
40 DEG @ CLEAR
50 DISP "Enter bearing description:"
60 INPUT D$
70 DISP "Enter ball diameter, pitch dia-  meter:"
80 INPUT B,P
90 DISP "Enter contact angle, # of balls:"
100 INPUT A,N
110 DISP "Enter RPM (0 for ORDERS)"
120 INPUT F
130 IF F=0 THEN L$=" Orders" ELSE L$=" Hertz"
140 IF F=0 THEN F=60
150 F=F/60 ! Convert RPM to Hz
160 PRINT D$
170 PRINT USING "14A,2DZ.3D,7A" ; "Ball diameter:",B," inches"
180 PRINT USING "15A,2DZ.3D,7A" ; "Pitch diameter:",P," inches"
190 PRINT USING "14A,2DZ.D,8A" ; "Contact angle:",A," degrees"
200 PRINT USING "16A,DD" ; "Number of balls:",N
210 IF F>1 THEN PRINT USING "6A,5DZ.DD,4A" : "Speed:",F*60," rpm"
220 PRINT "          --------------"
230 IMAGE 17A,4DZ.2D,7A
240 PRINT USING 230 : "Ball pass--outer:",F/2*N*(1-B/P*COS(A)),L$
250 PRINT USING 230 : "Ball pass--inner:",F/2*N*(1+B/P*COS(A)),L$
260 PRINT USING 230 : "Ball spin:",F/2*(P/(2*B))*(1-(B/P*COS(A))^2),L$
270 PRINT USING 230 : "Fund. train:",F/2*(1-B/P*COS(A)),L$
280 PRINT USING "4/"
290 END
```

If bearing dimensions are not available, inner and outer race defect frequencies can be approximated as 60% and 40% of the number of balls multiplied by running speed, respectively. This approximation is possible because the ratio of ball diameter to pitch diameter is relatively constant for rolling element bearings.

While it isn't necessary to understand the derivation of these formulas, two points of explanation may give you a better feel for them.

- Since the balls contact both the shaft-speed inner race and the fixed outer race, the rate of rotation relative to the shaft center is the average, or 1/2 the shaft speed. This is the reason for the factor of 1/2 in the formulas in table 4-1.
- The term in parentheses is an adjustment for the diameter of the component in question. For example, a ball passes over defects on the inner race more often than those on the outer race, because the linear distance (which is proportional to diameter) is shorter.

The fundamental train frequency, which occurs at a frequency lower than running speed, is usually caused by a severely worn cage.

Rolling element bearing frequencies are transmitted well to the machine case (because the bearings are stiff), and are best measured with accelerometers or velocity probes. For bearings which provide axial support, axial measurements often provide the vest sensitivity to defect vibration (because machines are usually more flexible in this direction).

An interesting new development in bearing transducers [reference title 13] involves high sensitivity displacement probes which measure the actual deflection of the bearing outer race. This measurement is very sensitive to bearing defects, and eliminates the effects of case impedance. Installation, however, requires disassembly of the machine.

Factors That Modify Frequency Characteristics

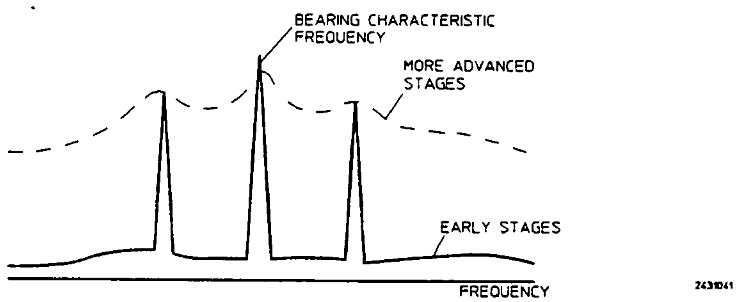


Figure 4-5

As bearing defects progress, the vibration becomes like random noise, and spectral peaks tend to disappear.

While the computation of characteristic bearing frequencies is straightforward, several factors can modify the vibration spectrum that results from bearing defects:

(a) Bearing frequencies are usually modulated by residual imbalance, which will produce sidebands at running frequency (see figure 4-11). Other vibration can also modulate (or be modulated by) bearing frequencies, and bearing spectra often contain components that are sums or differences of these frequencies (see section 5.3).

(b) As bearing wear continues and defects appear around the entire surface of the race, the vibration will become much more like random noise, and discrete spectral peaks will be reduced, or disappear completely. This will also be the case with roughness caused by abrasive wear or lack of lubrication. Another variation that occurs in advance stages is concentration of the defect energy in higher harmonics of the bearing characteristic frequency (see figure 4-8).

(c) Some of these frequencies will appear in the vibration spectrum of a good bearing. This is usually due to production tolerances, and does not imply incipient failure. Comparison with a baseline spectrum will help to avoid misinterpretation.

(d) To modify the formulas for a stationary shaft and rotating outer race, change the signs in the first two formulas in table 4-1.

(e) Contact angle can change with axial load, causing small deviations from calculated frequencies.

(f) Small defects on stationary races which are out of the load zone will often only produce noticeable vibration when loaded by imbalance forces (i.e., once per revolution).

Example Spectra

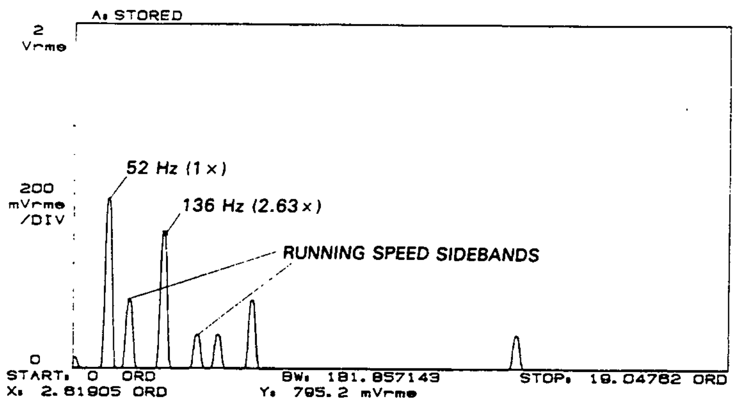
Figure 4-6

Bearing data and characteristic frequencies for the spectrum of figure 4-74-7.

Ball diameter:	0.156 inches	Ball pass--outer:	2.63 Orders
Pitch diameter:	0.625 inches	Ball pass--inner:	4.37 Orders
Contact angle:	0.0 degrees	Ball spin:	0.94 Orders
Number of balls:	7	Fund. train:	0.38 Orders

Figure 4-7

Spectrum resulting from a single defect in the outer race of a bearing. The sidebands at running speed are characteristic of bearing defects.



The example spectrum of figure 4-7 is the result of a defect in the outer race. A printout of bearing data and the characteristic frequencies, computed with the program given above, appears in figure 4-6. Note that the sidebands at running speed which are characteristic of most bearing spectra.

The spectrum in figure 4-8 is also the result of a defect in the outer race. In this example, the characteristic ball pass frequency has disappeared, but its harmonics remain. The component around 200 Hz is gearmesh vibration.

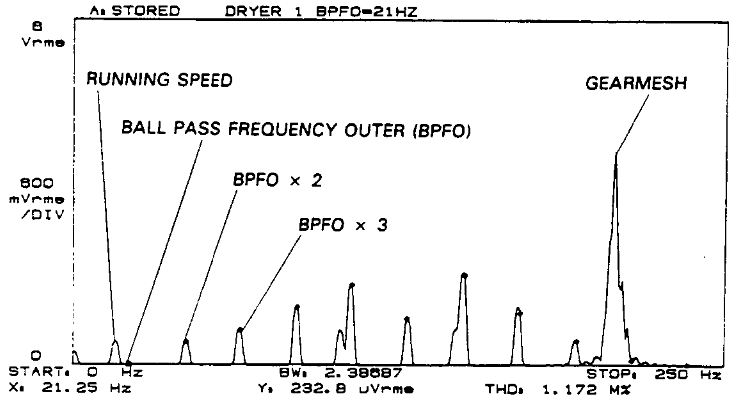


Figure 4-8

In this example of an outer race defect, the component at the ball pass (outer race) frequency has disappeared, but its harmonics remain. This is characteristic of advanced stages of a defect.

Some Details of Spectrum Generation

To give you a better insight into how bearing spectra are generated, we'll take a look at some simulated bearing signals and their resulting spectra. The characteristics we will focus on are:

(a) The impulsive nature of bearing vibration (which produces high frequency components)

(b) The effect of multiple defects

(c) Modulation of the bearing characteristic frequencies by running speed.

In contrast to the sinusoidal vibration produced by imbalance, vibration produced by bearing defects is impulsive, with much sharper edges. The effect of these sharp edges is a large number of higher frequency harmonics in the frequency spectrum. In figure 4-9, the lower trace is a time display of a simulated defect and the upper trace is the corresponding frequency spectrum. The defects are spaced at 1 msec intervals, resulting in a harmonic spacing of 1 kHz (1/1 msec) in the frequency spectrum.

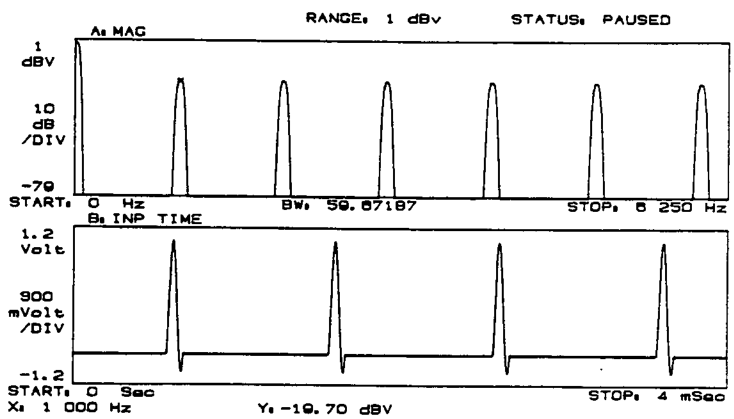


Figure 4-9

The impulsive nature of bearing defects produces a large number of harmonics spaced at the characteristic frequency.

The important consequences of the high frequency content are:

(a) The sensitivity of accelerometers to high frequency vibration implies that a large amount of energy outside the range of characteristic bearing frequencies will be included in measurements with these transducers. This is not a problem when analysis is performed with a DSA, but it does make overall vibration measurements misleading (i.e., the reading includes vibration responses not necessarily related to defects). For this reason, velocity is a better choice for monitoring vibration level. Velocity can be derived from acceleration by integration (see section 6.6), or measured directly with a velocity transducer.

(b) High frequency resonances in the bearing and machine structure may be generated, resulting in non-order related components not produced by other defects (except gears). One type of vibration meter designed for early detection of bearing defects depends on these high frequencies (20-50 kHz) to excite the natural frequency of a special accelerometer. (With no exciting frequency in this range, the output of the transducer is very low.) This type of instrument can produce misleading results if the accelerometer is not carefully mounted, or if the defect is such that little high frequency energy is produced.

(c) High frequency content tends to indicate the seriousness of the flaw, since shallow defects will tend to be more sinusoidal, producing fewer high frequency defects.

Multiple Defects and Running Speed Sidebands

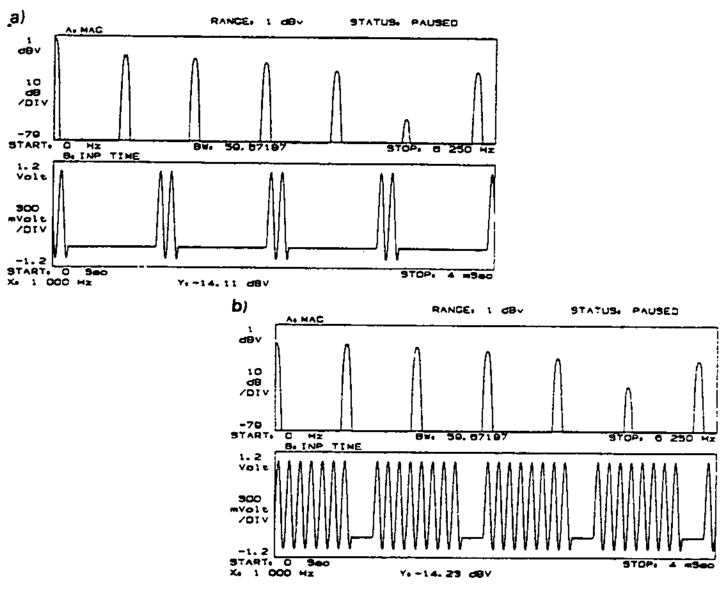


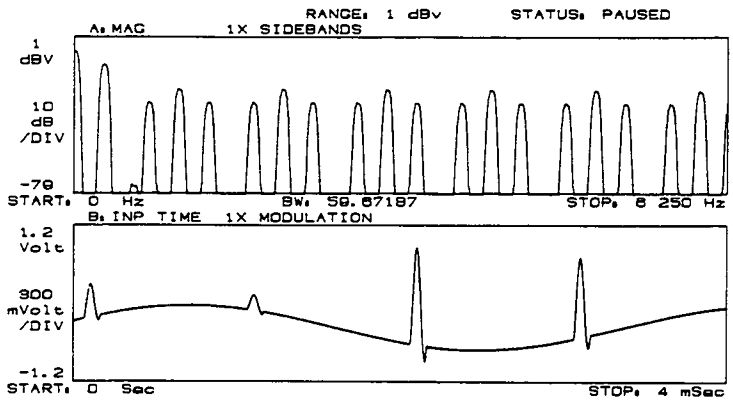
Figure 4-10

Two simulated examples of multiple defects. Note that the harmonic spacing remains at the characteristic frequency.

The characteristic spectrum of multiple bearing defects is difficult to predict, depending heavily on the exact nature of the defects. Figures 4-10 (a) and (b) show two simulated multiple defects and their resulting spectra. Note that as long as the sequence repeats itself at the appropriate characteristic frequency, the spacing of the harmonics will be at that frequency. In this case, only the harmonic amplitudes will change.

Figure 4-11

Bearing frequencies are almost always modulated by residual imbalance at running speed.



Every machine has some residual imbalance which will amplitude modulate the bearing frequencies. In figure 4-11, a bearing defect pulse is being modulated by imbalance. The imbalance component appears at the 280 Hz running speed, and as sidebands around the bearing frequency harmonics. This type of spectrum is common with bearing defects. Note that other defects, such as looseness or misalignment, will also modulate the bearing frequencies.

4.3 Oil Whirl In Fluid-film Bearings

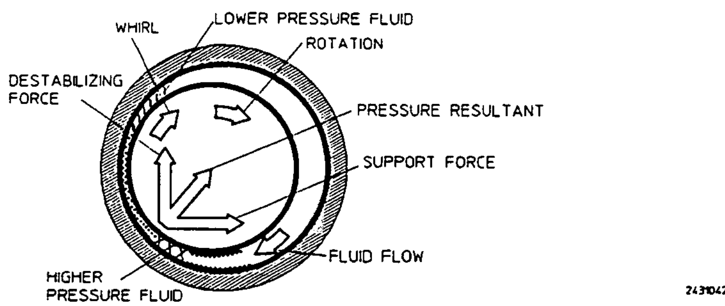
Rotors supported by fluid-film bearings are subject to instabilities not experienced with rolling element bearings. When the instability occurs in a flexible rotor at a critical speed, the resulting vibration can be catastrophic. Several mechanisms exist for producing instabilities, including hysteresis, trapped fluid, and fluid-film bearings [reference titles 25, 26]. In this section we will discuss only fluid-bearing instabilities, which are the most common.

A basic difference exists between vibration due to instability, and vibration due to other faults such as imbalance. Consider the case of shaft imbalance. Vibration of the shaft is a *forced response* to the imbalance force, occurs at the same frequency, and is proportional to the size of the force. Instability, on the other hand, is a self-excited vibration that draws energy into vibratory motion that is relatively independent of rotational frequency. The difference is subtle, but has a profound effect on measures taken to cure the problem.

Oil Whirl and Whip

Figure 4-12

A pressure differential in fluid-film bearings produces a tangential force that results in whirl.



Deviations from normal operating conditions (attitude angle and eccentricity ratio) are the most common cause of instability in fluid-film bearing supported rotors. As shown in figure 4-12, the rotor is supported by a thin film of oil. The entrained fluid circulates at about 1/2 the speed of the rotor (the average of shaft and housing speeds). Because of viscous losses in the fluid, the pressure ahead of the point of minimum clearance is lower than behind it. This pressure differential causes a tangential destabilizing force in the direction of rotation that results in a whirl—or precession—of the rotor at slightly less than 1/2 rotational speed (usually 0.43—0.48).

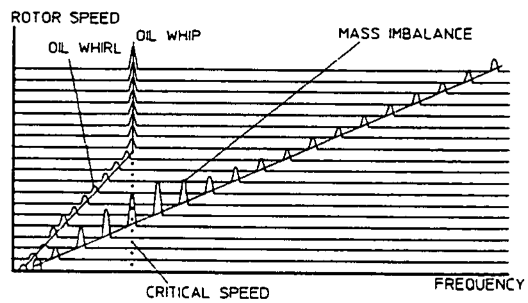
Whirl is inherently unstable, since it increases centrifugal forces which in turn increase whirl forces. Stability is normally maintained through damping in the rotor-bearing system. The system will become unstable when the fluid can no longer support the shaft, or when the whirl frequency coincides with a shaft natural frequency.

Changes in oil viscosity or pressure, and external preloads are among the conditions that can lead to a reduction in the ability of the fluid to support the shaft. In some cases, the speed of the machine can be reduced to eliminate instability until a remedy can be found. Stability sometimes involves a delicate balance of conditions, and changes in the operating environment may require a bearing redesign (e.g., with tilting pad or pressure dam designs).

Whirl may also cause instability when the shaft reaches twice critical speed. At this speed, the whirl (which is approximately 1/2 running speed) will be at the critical speed, resulting in a large vibration response that the fluid film may no longer be able to support. The spectral map of figure 4-13 illustrates how oil whirl becomes unstable oil whip when shaft speed reaches twice critical. Whirl must be suppressed if the machine is to be run at greater than twice the critical speed.

Figure 4-13

A spectral map showing oil whirl becoming oil whip instability as shaft speed reaches twice critical.



4.4 Misalignment

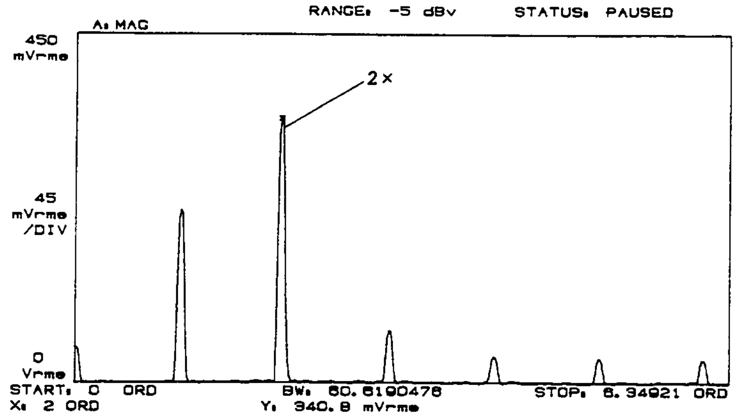


Figure 4-14

Alignment problems are usually characterized by a large 2x running speed component, and a high level of axial vibration.

Vibration due to misalignment is usually characterized by a 2× running speed component and high axial levels. When a misaligned shaft is supported by rolling element bearings, these characteristic frequencies may also appear. Phase, both end to end on the machine and across the coupling, is a useful tool for differentiating misalignment from imbalance.

Misalignment takes two basic forms:

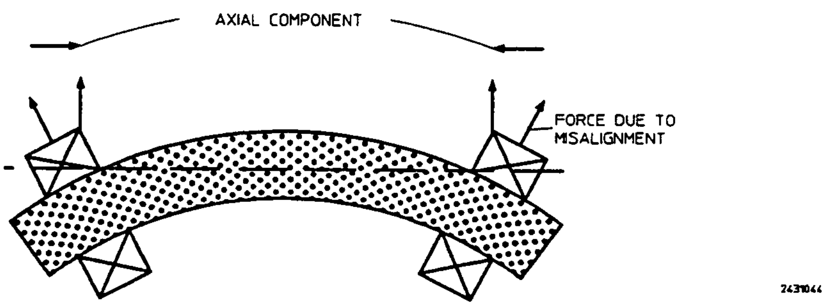
1 Preload from a bent shaft or improperly seated bearing

2 Offset of the shaft center lines of machines in the same train

Flexible couplings increase the ability of the train to tolerate misalignment; however, they are not a cure for serious alignment problems.

Figure 4-15

A bent or misaligned shaft results in a high level of axial vibration.



The axial component of the force due to misalignment is shown in figure 4-15. Machines are often more flexible in the axial direction, with the result that high levels of axial vibration usually accompany misalignment. These high axial levels are a key indication of misalignment.

High second harmonic vibration levels are also a common result of misalignment. The ratio of 1× to 2× component levels can be used as an indicator of severity [reference title 3]. Second harmonics are caused by stiffness in asymmetry in the machine and its supports, or in the coupling. This asymmetry causes a sinusoidal variation in response level—a form of rotating impedance vector. The vibration that results from the rotating force and impedance vectors contains a component at twice the rotating frequency, as shown in figure 4-14.

Vibration due to misalignment often also contains a large number of harmonics, much like the characteristic spectra of looseness and excessive clearance. The key distinguishing feature is a high 2× component, especially in the axial direction.

Using Phase to Detect Misalignment

As shown in figure 4-15, the axial vibration at each end of the machine, (or across the coupling), is 180° out of phase. This relationship can be used to differentiate misalignment from imbalance, which produces in-phase axial vibration. This test cannot be used in the radial direction, since imbalance phase varies with the type imbalance. Relative phase can be measured with a single-channel DSA using a keyphasor reference, or directly with a dual-channel DSA (see section 6.8).

Several notes of caution relative to phase measurements are appropriate at this point.

(a) Machine dynamics will affect phase readings, so that the axial phase relationship may be 150° or 200° rather than precisely 180°.

(b) Transducer orientation is important. Transducers mounted axially to the outside of the machine will most often be oriented in opposite directions. If this is the case, a 180° phase relationship will be measured as 0°.

(c) The phase relationships described hold only for rigid rotors. using phase for diagnostics on flexible rotors requires knowledge of the rotor's dynamics.

(d) Great care must be exercised when measuring relative phase with a single channel DSA. Two measurements are required, each referenced to the shaft with a keyphasor. These measurements must be made at the same speed unless trigger delay or external sample control (section 6.7) is used. In general, you should make more than one measurement at each point to insure that phase readings are repeatable.

4.5 Mechanical Looseness

Mechanical looseness usually involves mounts or bearing caps, and almost always results in a large number of harmonics in the vibration spectrum. Components at integer fractions of running speed may also occur. Looseness tends to produce vibration that is directional, a characteristic that is useful in differentiating looseness from rotational defects such as imbalance. A technique that works well for detecting and analyzing looseness is to make vibration measurements at several points on the machine (velocity transducers works well for this). Measured vibration level will be highest in the direction and vicinity of the looseness.

The harmonics that characterize looseness are a result of impulses and truncation (limiting) in the machine response. Consider the bearing shell in figure 4-16. When it is tight, the response to imbalance at the transducer is sinusoidally varying. When the mounting bolt is loose, there bill be truncation when the looseness is taken up. While these waveforms are idealized, the mechanism for producing harmonics should be clear. The general term for deviation from expected behavior, as when the sinusoidal vibration is interrupted by a mechanical limit, is non-linearity.

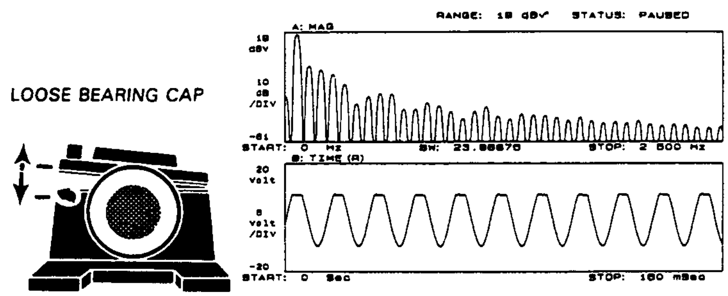


Figure 4-16

Looseness usually results in a truncated waveform that produces a spectrum with a large number of both odd and even numbered harmonics.

Belt drives present one situation where looseness does not result in a large number of harmonics. In this case, the impacts and sharp truncation are damped by the belt, and the resulting vibration is largely once per revolution. The directionality that usually accompanies looseness results in vibration levels that vary significantly with transducer direction. In other words, while imbalance response is usually about the same in horizontal and vertical directions, looseness in a mount that produces a large vertical component may produce a much smaller horizontal component.

4.6 Gears

Gear problems are characterized by vibration spectra that are typically easy to recognize, but difficult to interpret. The difficulty is due to two factors:

1 It is often difficult to mount the transducer close to the problem

2 The number of vibration sources in a multi-gear drive result in a complex assortment of gear mesh, modulation, and running frequencies

Because of the complex array of components that must be identified, the high resolution provided by DSA is a virtual necessity. It is helpful to detect problems early through regular monitoring, since the advanced stages of gear defects are often difficult to analyze. Baseline vibration spectra are helpful in analysis because high level components are common even in new gearboxes. Baseline spectra taken when the gearbox is in good condition make it easier to identify new components, or components that have changed significantly in level.

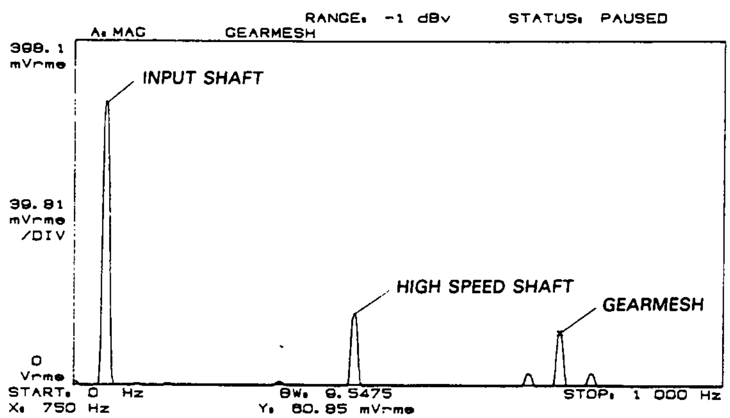


Figure 4-17

The characteristic spectrum of a gearset in good condition contains components due to running speed of both shafts, and gear meshing frequency.

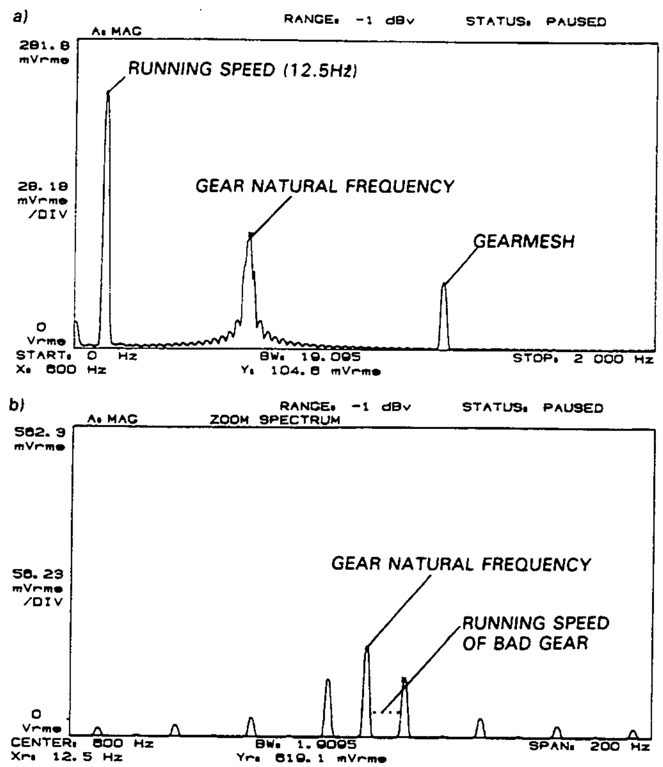


Figure 4-18

Gear natural frequencies, excited by impulses from large defects, are often the only indication of problems. The zoom spectrum in b) shows the natural frequency, with sidebands that correspond to running speed of the bad gear.

Characteristic Gear Frequencies

A. Gear Mesh This is the frequency most commonly associated with gears, and is equal to the number of teeth multiplied by rotational frequency. Figure 4-18 is a simulated vibration spectrum of a gearbox with a 15 tooth gear running at 3000 rpm (50Hz), has gearmesh frequency of $15 \times 50 = 750$ Hz. This component will appear in the vibration spectrum whether the gear is bad or not. Low level running speed sidebands around the gearmesh frequency are also common. These are usually caused by small amounts of eccentricity or backlash.

The amplitude of the gearmesh component can change significantly with operating conditions, implying that gearmesh level is not a reliable indicator of condition. On the other hand, high level sidebands or large amounts of energy under the gearmesh or gear natural frequency components (figure 4-18), *are* a good indication that a problem exists.

B. Natural Frequencies The impulse that results from large gear defects usually excites the natural frequencies of one or more gears in a set. Often this is the key indicator of a fault, since the amplitude of the gearmesh frequency does not always change. In the simulated vibration spectrum of figure 4-18, the gearmesh frequency is 1272 Hz. The broadband response around 600 Hz is centered on a gear natural frequency, with sidebands at the running speed of the bad gear. The high resolution zoomed spectrum of figure 4-18b) shows this detail.

C. Sidebands Frequencies generated in a gearbox can be modulated by backlash, eccentricity, loading, bottoming, and pulses produced by defects. The sidebands produced are often valuable in determining which gear is bad. In the spectrum of figure 4-18b), for example, the sidebands around the natural frequency indicate that the bad gear has a running speed of 12.5 Hz. In the case of eccentricity, the gearmesh frequency will usually have sidebands at running speed.

Hints On Gear Analysis

The following hints may be useful in analyzing gear problems.

A. Select and Mount Transducers Carefully If gearmesh or natural frequencies above 2000 Hz are expected, use an accelerometer. Mounting should be in the radial direction for spur gears, axial for gears that take a thrust load, and as close to the bearing as possible.

B. Determine Natural Frequencies Since recognition of natural frequencies is so important for analysis, take every opportunity to determine what they are. This can be done by impacting the shaft of the assembled gearbox, and measuring the vibration response of the housing. This measurement should be done with a two-channel DSA for best results (section 6.8), but a single-channel measurement will give you an idea of the frequencies to expect.

C. Identify Frequencies Take the time to diagram the gearbox, and identify gearmesh and shaft speed frequencies. Even if you don't know the natural frequencies, shaft speed sidebands will often indicate the bad gear.

4.7 Blades And Vanes

Problems with blades and vanes are usually characterized by high fundamental vibration or a large number of harmonics near the blade or vane passing frequency. Some components of passing frequency (number of blades or vanes × speed) are always present, and levels can vary markedly with load. This is especially true for high speed machinery, and makes recording of operating parameters for historical data critical. It is very helpful in the analysis stage to have baseline spectra for several operating levels.

If a blade or vane is missing, the result will typically be imbalance, resulting in high 1× vibration. For more subtle problems such as cracked blades, changes in the vibration are both difficult to detect and difficult to quantify. Detection is a problem, especially in high speed machinery, because blade vibration can't be measured directly. Strain gauges can be used, but the signal must be either telemetered or transferred through slip rings. Doppler detection techniques show promise, but have not been sufficiently developed for practical use. Indirect detection produces a spectrum that is the result of complex interactions that may be difficult to explain. This, combined with the large variation of levels with load, makes spectra difficult to analyze quantitatively.

One characteristic that often appears in missing- or cracked-blade spectra is a large number of harmonics around the blade passing frequency. Figure 4-19 shows how a space in the vibration signal greatly increases the number of harmonics without changing the fundamental frequency.

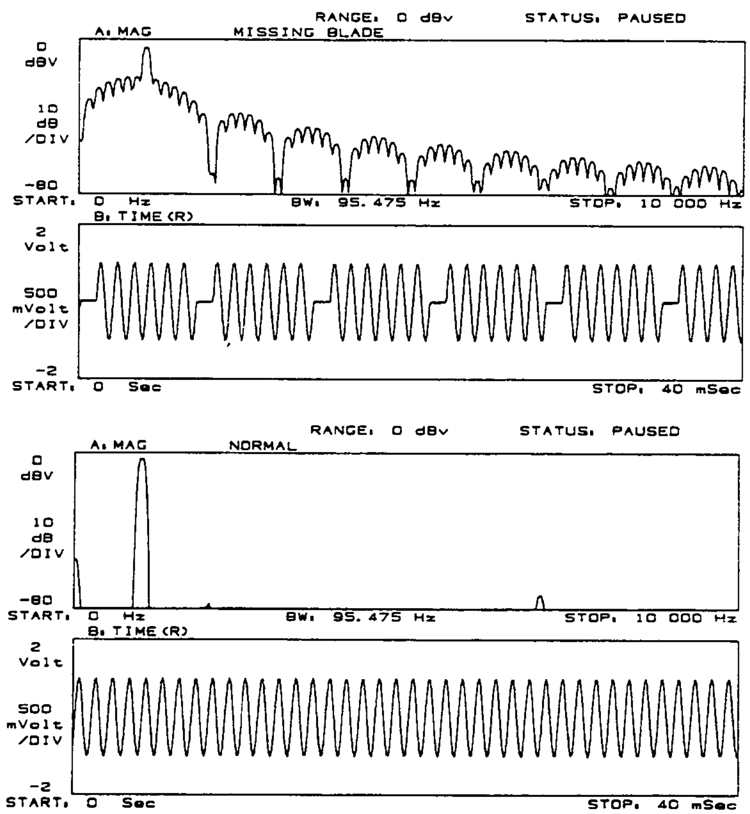


Figure 4-19

A space in the vibration signal caused by a missing blade results in a large number of harmonics. A missing blade usually also causes enough imbalance to significantly increase the 1x level.

4.8 Resonance

Problems with resonance occur when natural frequencies of the shaft, machine housing, or attached structures are excited by running speed (or harmonics of running speed). These problems are usually easy to identify because levels drop appreciably when running speed is raised or lowered. Spectral maps are especially useful for detecting resonance vibration because the strong dependence on rotational speed is readily apparent (see figure 4-20).

Phase is also a useful tool for differentiating resonances from rotationally related components. Say, for example, that you encounter a high level vibration at 16 times running speed. If the vibration is rotationally related (e.g. a blade passing frequency), the phase relative to a keyphasor signal or residual imbalance will be constant. If the vibration is a resonance, the phase will not be constant. This is a useful technique when it is not practical to vary the speed of the machine.

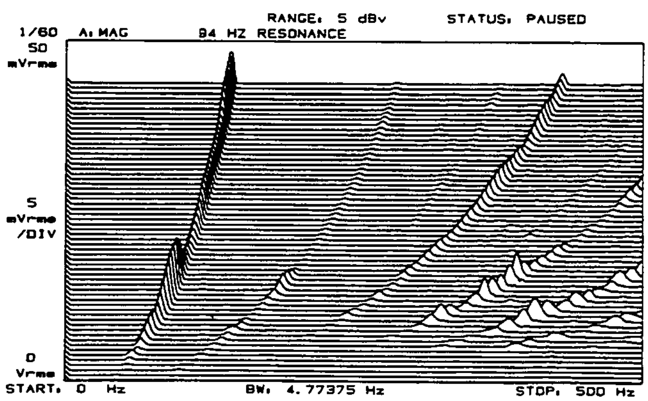
Piping is one of the most common sources of resonance problems. When running speed coincides with a natural frequency, the resulting vibration will be excessive and strain on both the pipe and the machine can lead to early failure. The most logical approach is to change the natural frequency of the pipe. It can be raised by making the pipe shorter or stiffer (e.g. by adding a support), or lowered by making the pipe longer (see figure 2-10). The same rules apply to any attached structure.

Shaft resonance problems in high speed machinery are sometimes caused by changes in the stiffness provided by fluid-film bearings, or by the effects of machines added to the train. Bearing wear, for example, can reduce the stiffness of the shaft/bearing system, and lower the resonant frequency to running speed. Coupling changes can raise or lower torsional natural frequencies to running speed.

The dynamics of these situations can be quite complex, and are beyond the scope of this note. The key is to understand that maintenance and installation related factors can alter assumptions made in the rotor design.

Figure 4-20

Spectral maps are expecially useful for analyzing vibration due to resonances.



4.9 Electric Motors

Excessive vibration in electric motors can be caused by either mechanical, or electromagnetic defects. The latter can be quickly isolated by removing power: vibration caused by electrical or magnetic defects will disappear. The high frequency resolution of DSAs is key for analyzing electrical problems in induction motors, since running speed and powerline related components are often very closely spaced (see section 6.2 on resolution).

Vibration caused by electrical problems in induction motors can be analyzed to determine the nature of the defect reference title [20]. In general, a stationary defect such as a shorted stator produces 120 Hz vibration (100 Hz with a 50 Hz powerline). A rotating defect, such as a broken rotor bar, produces 1× vibration with 2× slip frequency sidebands. (Slip frequency = line synchronous frequency – running frequency.)

The vibration spectrum of induction motors always contains significant components at powerline frequency times the number of poles. Baseline vibration signatures taken on machines in good condition are the vest criteria for judging the relative severity of these levels.

4.10 Summary Tables

Tables 4-2 and 4-3 summarize the vibration characteristics information in this chapter. This information should be used as a guide only, since the vibration resulting from specific defects can be modified by machinery dynamics.

Table 4-2
Phase Characteristics of Common Vibration Sources.

Source	Characteristics*
Rolling element bearing defect	Unstable
Electrical	Unstable; unless synchronous motor.
Gear mesh	Unstable
Imbalance	Stable, unless caused by uneven loading or cavitation. Phase follows transducer location (4.1)
Looseness	Unstable; may be highly directional
Misalignment	Stable; relation between axial phase at shaft ends should be approximately 180°.
Oil Whirl	Unstable
Resonance	Unstable; large phase change with change in speed in rpm.

*Relative to running speed

Table 4-3
Vibration Frequencies Related to Machinery Faults

Frequency	Possible Cause	Comments
1 × rpm	Imbalance	Steady phase that follows transducer. Can be caused by load variation, material buildup, or pump cavitation
	Misalignment or Bent Shaft	High axial levels, ~ 180° axial phase relation at the shaft ends. Usually charactized by high 2× level.
	Strain	Caused by casing or foundation distortion, or from attached structures (e.g., piping).
	Looseness	Directional — changes with transducer location. Usually high harmonic content and random phase.
	Resonance	Drops off sharply with changes in speed. From attached structures or changes in attitude angle or eccentricity ratio.
	Electrical	Broken rotor bar in induction motor. 2× slip frequency sidebands often produced.
2 × rpm	Misalignment or Bent Shaft	High levels of axial vibration
Harmonics	Looseness	Impulsive or truncated time waveform; large number harmonics.
	Rubs	Shaft contacting machine housing
Sub-rpm	Oil Whirl	Typically 0.43-0.48 rpm; unstable phase
	Bearing cage	See formula in table 4-1.
N × rpm	Rolling element bearings	See formulas table 4-1. Usually modulated by running speed of bad gear.
	Gears	Gearmesh (teeth × rpm); usually modulated by running speed of bad gear.
	Belts	Belt × running speed and × 2 running.
	Blades/vanes	Blades/vanes × rpm; usually present in normal machine. Harmonics usually indicate that a problem exists
N × powerline	Electrical	Shorted stator; broken or eccentric rotor.
Resonance	Several sources, including shaft, casing, foundation and attached structures. Frequency is proportational to stiffness and inversely proportional to mass.	

Chapter 5

Advanced Analysis and Documentation

Chapters 1 through 4 provide the basic information needed for the analysis of machinery vibration. Chapter 5 contains practical information that will help in determining specific defects, and in assessing their severity.

5.1 Practical Aspects Of Analysis. A discussion of 5 practical aspects of successful analysis.

5.2 Using Phase For Analysis. We have discussed the importance of phase in analyzing defects such as imbalance and misalignment. This section is an extension of that discussion, and an introduction to the related concept of time averaging.

5.3 Sum And Difference Frequencies. Multiple defects often produce vibration components that are sums and differences of the defect characteristic frequencies.

5.4 Speed Normalization. A common problem when making direct spectral comparisons is shift in frequency of vibration components caused by changes in running speed. This section discusses solutions to the problem.

5.5 Baseline Data Collection. Records of vibration spectra taken when a machine is in good condition save significant amounts of time in analysis. This section presents guidelines for collecting baseline data.

5.1 Practical Aspects Of Analysis

In the literature and discussions on the subject of machinery vibration analysis, several factors are regularly mentioned as keys to success. In this section, we will discuss five of these factors:

1 Documentation

2 Machinery Knowledge

3 Severity Criteria

4 Instrumentation

5 Analysis Personnel

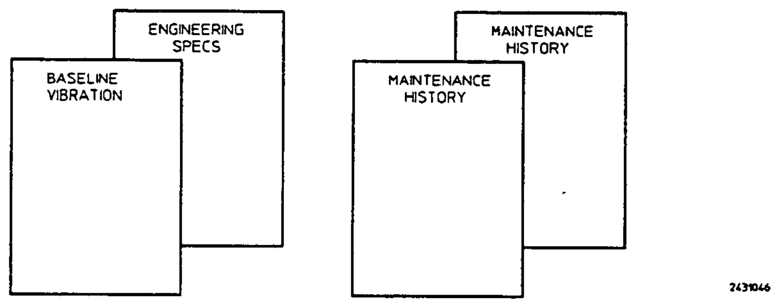


Figure 5-1

Complete documentation consists of baseline vibration spectra, maintenance history, and engineering data.

1. Documentation. Thorough documentation often provides the information required to successfully analyze a vibration problem. Complete documentation includes baseline vibration spectra, maintenance history, and engineering data.

The baseline vibration measurements made on a machine in good condition provide a reference for detecting changes which indicate problems—and for identifying significant components when problems do occur. Without this information, you could easily waste time determining the source of a vibration component that is contained in the spectrum of a good machine. Baseline data collection is discussed in section 5.5.

Maintenance history includes records of machine failures, and vibration spectra before and after repairs. These records form a library of known defects and vibration spectra that is invaluable in analysis. You should, for example, be able to immediately identify a defect that has occurred previously in a machine. These records also provide insights into design or specification changes that will improve reliability.

Engineering data includes bearing and gear parameters used to calculate characteristic frequencies, and machine dynamic models used to predict vibration response. Also useful are manufacturer's data on vibration limits and characteristics. This data will not always be easy to obtain—the key is to collect the available data before problems occur.

Computers are a virtual necessity for efficiently keeping the records described above. Several companies offer software for this purpose that will work on a variety of computers and DSAs.

2. **Machinery Knowledge**. The design and operating characteristics of a machine determine both the type of defects that are possible, and the vibration response to those defects. Vibration analysis is difficult without a working knowledge of these characteristics. Another important consideration is the effect of changes in operating conditions on measured vibration. By understanding how vibration changes with such variables as load and temperature, you will be better able to determine whether an increased level of vibration is due to a defect, or to a change in operating conditions.

The best sources of information on these characteristics are the manufacturer of the machine, and plant records of machinery defects and their associated vibration. Courses on machine maintenance and design from manufacturers can provide insight into both possible defects, and the mechanisms of vibration response for specific machines. Several baseline spectra taken under different operating conditions are useful for documenting the effects of changing operating parameters.

3. **Severity Criteria.** Once a defect has been detected and identified, its severity must be determined for the repair to be most effectively scheduled. We have already mentioned the variability of vibration level with changes in speed and operating parameter, which makes it difficult to assign severity solely on the basis of level. On the other hand, the appearance of vibration components at key frequencies—such as those which characterize bearing defects—is a good indication that problems exist.

Assessment of vibration severity should consider both the level of vibration, and its characteristics. References for severity include published vibration standards, and historic vibration measurements.

Table 5-1 is an example of a published vibration standard. This particular standard is from the International Standards Organization (ISO). To make the standard more applicable to a wide range of machines, a distinction is made in the severity criteria between soft and hard supports. The essential problem with such published standards is that they are too general to be used for high accuracy judgements of vibration severity. Where one machine may operate normally at a vibration level of 0.1 in/sec, that vibration level in another machine may indicate imfailure. Thus, unless the standard is for a specific machine, it is best used only as a guideline.

Table 5-1
Tables of vibration severity, like this one published by the ISO*, are most useful as guidelines rather than absolute limits.

Vibration in./sec	Severity mm/sec	Support Classification Hard Supports	Support Classification Soft Supports
.017	0.45	good	good
.028	0.71		
.044	1.12		
.071	1.8	satisfactory	
.11	2.8		satisfactory
.18	4.5	unsatisfactory	
.28	7.1		unsatisfactory
.44	11.2	impermissible	
.71	18.0		impermissible
1.10	28.0		
2.80	71.0		

Historic vibration measurements are an excellent reference for severity measurements, because they are specific to the machine in question. While absolute vibration limits for a machine may not be known, there is a high probability that large changes in vibration level indicate a problem. The process of monitoring vibration level for changes is referred to as trend analysis. Since vibration level in a good machine is variable, it isn't always obvious how much change is tolerable. The best approach is to analyze the statistics of variability for each machine, and base change limits on that. An increase in vibration that exceeds two standard deviations is usually a sign of trouble. In the absence of this type of analysis, you can use a factor of 2 (6 dB) increase as an approximate change limit.

When a significant change is detected, vibration level and other key operating parameters should be monitored regularly. The rate of change of these parameters is often a good indication of the severity of the problem.

4. Instrumentation The large reductions in machinery downtime and maintenance expense provided by vibration analysis make it unwise to sacrifice capability to save a small amount of capital investment. A DSA should have all the key machinery analysis features discussed in chapter 6. A computer and applicable software that can automatically store vibration spectra and analyze trends can quickly pay for itself. It is important, however, to limit equipment to a manageable quantity. A program can fail to pay back its investment quickly if too much equipment is purchased without real insight into analysis and monitoring requirements. Also keep in mind that some skill is required for analysis, and that this skill is required for analysis, and that this skill can take time to develop.

5. People The quality and effectiveness of a vibration analysis program is most often limited by the availability of capable personnel. Successful programs are characterized by people who are properly trained and given a chance to develop analysis expertise.

5.2 Using Phase For Analysis

Table 5-2
Phase Characteristics of Common Vibration Sources

Source	Characteristics
Rolling element bearing defect	Unstable
Electrical	Unstable, unless sychronous motor
Gear mesh	Unstable
Imbalance	Stable, unless caused by uneven loading or cavation. Phase follows transducer location (see section 4.1)
Looseness	Unstable; may be highly directional
Misalignment	Stable; relation between axial phase at shaft ends should be approximately 180°.
Oil Whirl	Unstable
Resonance	Unstable; large phase change with change in speed in rpm.

The usefulness of the phase spectrum as a means for differentiating between defects with similar amplitude spectra has already been discussed. We will present a more general discussion of the subject in this section. Time averaging, a powerful processing technique related to phase, will also be described.

In general, the phase of vibration caused by a defect will either be stable or unstable relative to a keyphasor. The nature of this relationship is shown in table 5-2 (a reproduction of table 4-2). Figure 5-2 is a sequence of vibration spectra that shows phase for imbalance (1×), and running speed harmonics, and unstable phase for powerline-related components. Also, the relative phase relationship between vibration at different points on a machine can be used to differentiate between faults—as in the case of misalignment and imbalance (see section 4.4).

Instrumentation required for phase measurements is shown in figure 5-3. The keyphasor senses shaft rotation and serves as the phase reference. The phase of vibration that is synchronous (i.e., an integer multiple) with rotation is constant, while that of nonsynchronous vibration varies. Relative phase measurements can be made sequentially, as long as the same reference (i.e., keyphasor) is used (see section 6.8 on easier relative phase measurements with dual-channel DSA). Running speed should remain constant between measurements to minimize the phase effects of mechanical impedance. Relative phase measurements on flexible rotors *must* include considerations of shaft dynamics.

The keyphasor, which is usually a proximity sensor that detects a keyway or setscrew, provides a clean signal for triggering. It is required because the vibration signal is usually not suitable as a trigger source: although its largest component is usually 1× rpm imbalance, noise in the spectrum adds uncertainty to level, and thus trigger timing. If a keyphasor is not available, it may be possible to use a band-pass or low-pass filter to reduce the level of noise and higher frequency components in the vibration signal to make it usable as a trigger.

When measuring relative phase between two ends of a machine, it is important to mount the transducers with the same orientation. When measuring axial vibration, for example, if both transducers face the machine, they are mounted 180° out of phase. Thus vibration due to misalignment, which you would expect to be 180° out of phase, will be measured as inphase.

Time averaging is explained in section 6.4, and is a powerful technique for eliminating nonsynchronous components from a vibration spectrum. It is most useful for reducing the level of background noise, especially vibration from other machines. It must be used with care, however, since it will reduce the level of all vibration components that are nonsynchronous, including bearing and gear frequencies. In the plot of figure 5-4, a time averaged spectrum (dashed line) is overlaid on a non-averaged spectrum. The synchronous components have not changed in level, while the nonsynchronous background noise components are greatly reduced.

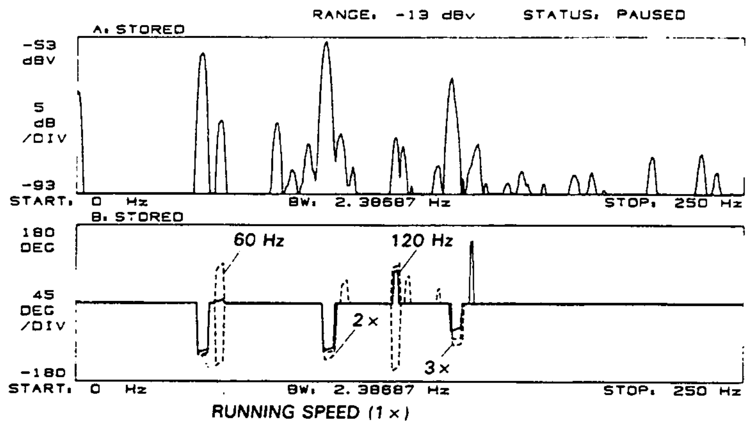


Figure 5-2

A sequence of vibration spectra with phase shows constant phase for imbalance (1x and harmonics), and unstable phase for powerline components (60 Hz harmonics).

Figure 5-3

Instrumentation setup for phase measurements and time averaging.

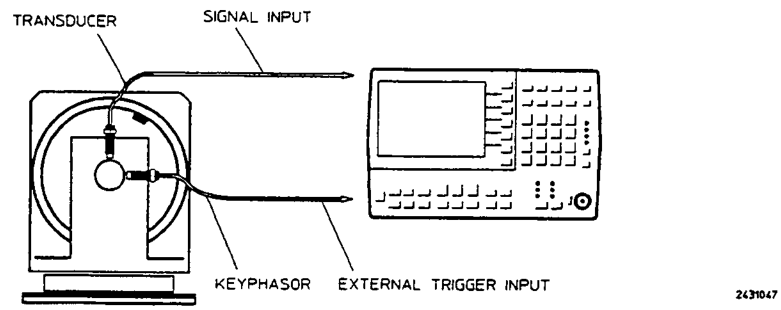
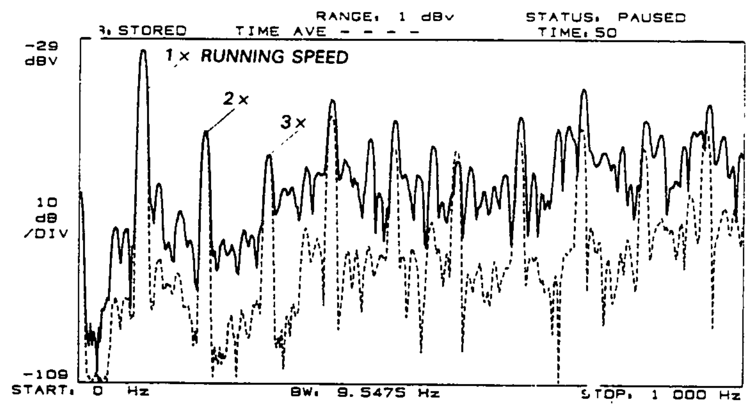


Figure 5-4

Time averaging is effective in reducing the level of background vibration.



5.3 Sum And Difference Frequencies

Vibration spectra often contain components that are the result of interaction between multiple vibration mechanisms. These components appear as sum and difference frequencies of the mechanisms involved, and can be useful as indications of specific problems, especially in gears and bearing. When the major frequency components are closely spaced, the difference frequency is often audible. These "beat" frequencies are common in rotating machinery.

In figure 5-5, the difference between running speed at 144 Hz and the 2nd harmonic of the line frequency at 120 Hz is 24 Hz. This component appears at 24 Hz, and as sidebands around the harmonics of rotational speed.

The exact mechanisms which generate sum and difference frequencies are not well understood, and a complex mathematical analysis is beyond the scope of this note. However, you can get a feel for the interactions involved by thinking of them as a form of amplitude modulation. In the trigonometric identity below, it is apparent that the interaction of one frequency with another results in sum and difference frequencies.

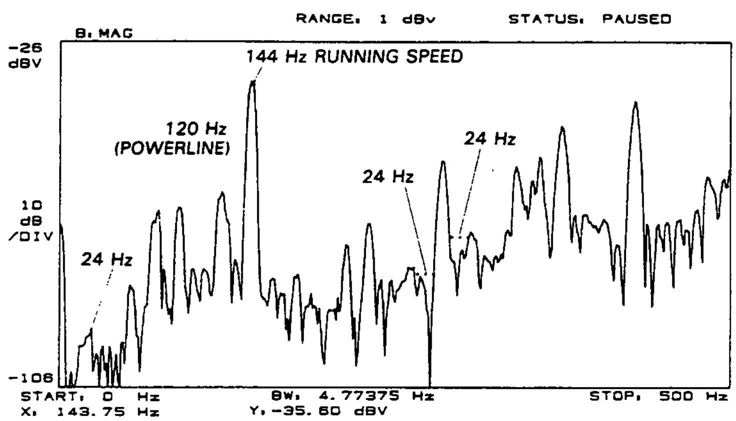
$$\cos(f1)*\cos(f2) = 1/2[\cos(f1 + f2) + \cos(f1-f2)]$$

If one of the signals contains a large number of harmonics, then multiple sum and difference frequencies will appear. This is illustrated in the figure 5-6. Phase can be an aid in identifying sum and difference frequencies, since it will be unstable unless the phase of both sources is stable.

The most common faults indicated by sum and difference frequencies are associated with rolling element bearing and gears.

Figure 5-5

A vibration spectrum with sum and difference frequencies. The 24 Hz difference between rotational frequency and the 120 Hz powerline component appears both as a discrete signal, and as sidebands around rotational speed harmonics.

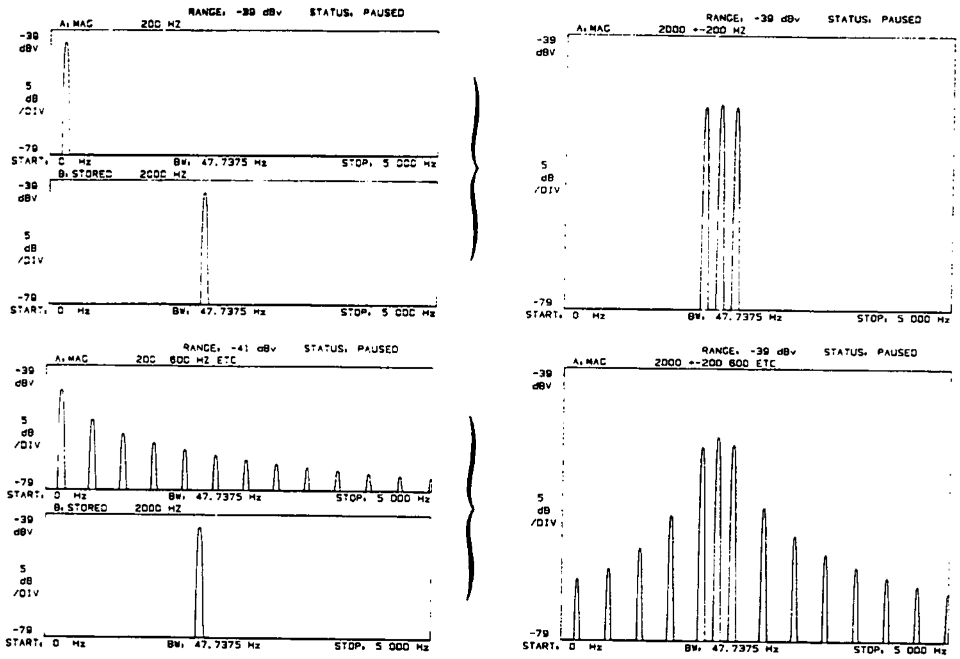


A. Rolling Element Bearings Defects in rolling element bearings are almost always modulated by residual imbalance. As the wear progresses, and characteristic frequencies are replaced by noise, these running frequency sidebands may be the only indication of trouble (see section 4.2).

B. Gears As pointed out in section 4.6, gear defects often appear as gear natural frequencies with sidebands at running speed of the defective gear. These running speed sidebands may also appear around the gearmesh frequency.

Figure 5-6

The number of sum and difference components depends on the number of harmonics in the signals involved.



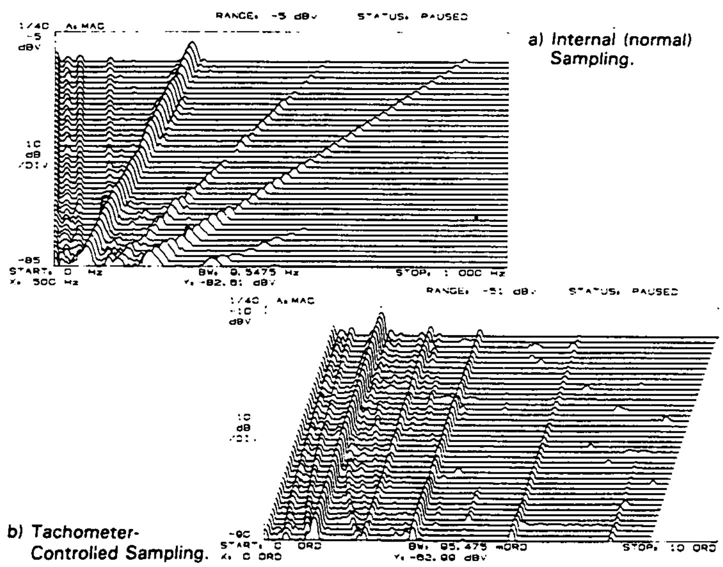
5.4 Speed Normalization

A common problem in machinery vibration analysis is running speed variation—both long-term and short-term. Short-term variations in speed make real-time analysis difficult. Long-term variations make point-by-point comparisons between current and baseline spectra virtually impossible. External sample control (also known as order tracking) can be used to compensate for both problems while the measurement is in progress. Relatively small long-term variations can be normalized out after the measurement is completed.

External sample rate control locks the analysis process to a tachometer signal, and is especially applicable when large speed variations are encountered. The details of controlling the sample rate of a DSA externally are given in section 6.7. A good way to illustrate the effects of external sample control is with spectral maps made in external and normal sample modes, as shown in figure 5-7. These maps were made during a run-up. Note in the normal sample mode map of (a), rotational speed-related components move to the right as speed increases, while fixed frequency components (e.g. powerline related) move straight up. In the external sample control map of (b), rotational speed-related components move straight up the map, while fixed frequency components move to the left (they are relatively lower in frequency as speed increases).

Figure 5-7

Two spectral maps of a machine run-up illustrate the effect of external sample rate control.



The main advantage of external sample control is that real time displays of the vibration spectrum remain fixed with speed. Also, the 15% amplitude variation with frequency which DSAs without a high accuracy window experience is avoided (see section 6.2). The disadvantages are that frequency calibration is lost, and a keyphasor and multiplier are required. Frequency calibration is critical for analyzing fixed frequency vibration due to resonances and electrical defects. Frequency can also be normalized to rotational speed after a measurement. In figure 5-8, note that the frequency axis and marker readout are in terms of orders of rotation (multiples of running speed) rather than frequency. This normalization does not work in real time, and resolution is not a constant percentage of running speed (as with external sample control). However, frequency information is retained, and a keyphasor signal is not required.

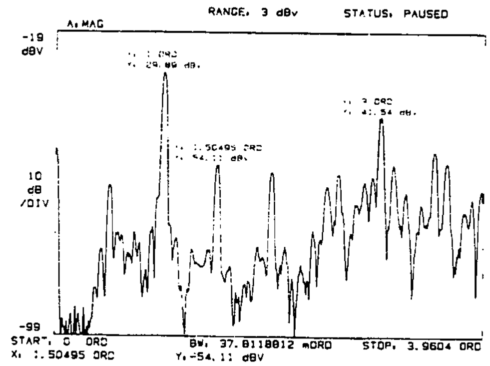


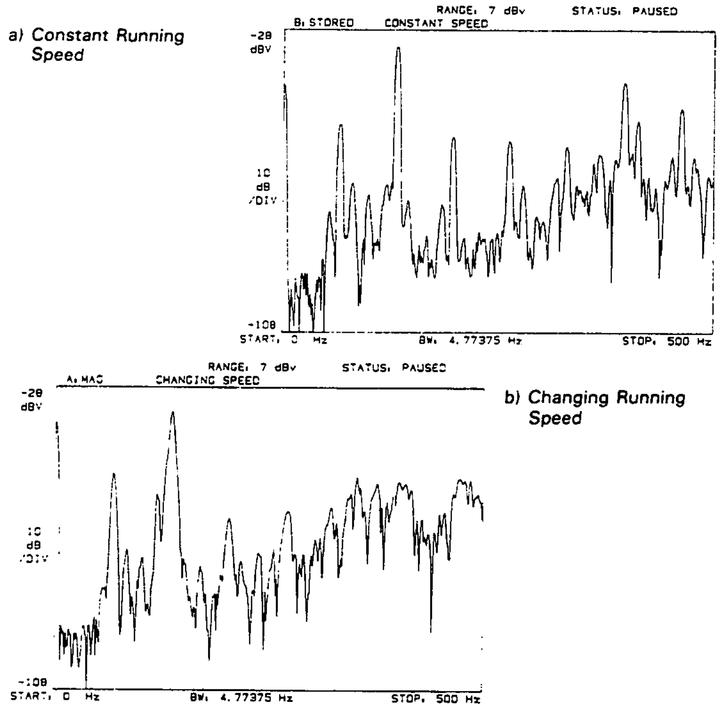
Figure 5-8

DSA display in which the horizontal (frequency) axis is calibrated in multiples (orders) of running speed.

Short-term speed variation causes a broadening of components in the vibration spectrum, as shown in figure 5-9. As speed changes during the sampling interval for one measurement, the DSA is effectively analyzing several different spectra. This results in the broadened spectral components of figure 5-9b.

Figure 5-9

Short-term speed variation results in a broadening of spectral components (b).



5.5 Baseline Data Collection

Baseline vibration spectra are reference data that represent normal machine condition, and are essential for effective analysis. In the event of trouble, they quickly indicate the frequency components that have changed. Without the baseline data, you can easily waste time analyzing spectral components that are present in normal operation. Baseline data are also the basis for trend monitoring, being a much more specific indicator of normal vibration than generalized vibration severity charts. To be most useful, the guidelines below should be followed for collecting baseline data. The key objective of the process is to understand the characteristics of the machine before a problem occurs.

A. Normalize For Speed. Normalizing the vibration spectrum for speed is required for direct spectrum comparison. Section 5.4 discussed the alternative methods for accomplishing this. Whichever method is chosen, provision should be made when taking baseline data.

A spectral map of a run-up or coast-down can also be useful in dealing with changes in speed. Such a map can quickly show how vibration level changes with speed, and the resonances and other fixed frequencies that should be expected in the vibration spectrum.

B. Be Complete. You can't take baseline data after the machine has a problem, so it is important to take all the data you can when it is operating normally. Follow the guidelines in chapter 2 for transducer selection and placement. For machines with rolling element bearing or gears, consider taking high and low-frequency spectra. The low-frequency spectrum (e.g., 500 Hz) provides good resolution for most analysis, while the high frequency spectrum (e.g., 0 - 5 kHz) will provide a baseline for the higher frequencies that can indicate problems with bearings and gears.

In addition to vibration data, operating parameters such as pressure and load, and bearing and gear parameters should be collected. Also, any information available from the machine manufacturer regarding vibration characteristics and failure mechanisms should be included.

C. Check Statistical Accuracy. This just means that one measurement may not be representative of normal operation. For example, an adjacent machine may be vibrating excessively when baseline signatures are taken, or an older machine may already have excessive vibration levels.

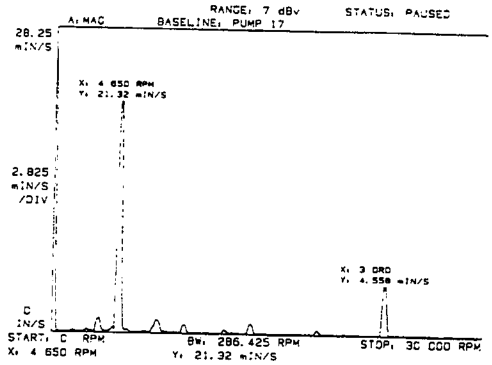
The best approach is to take several spectra over time, and perform a statistical analysis to yield mean and standard deviation. This results in a representative average level, and also provides a quantitative basis (e.g., 1 or 2 standard deviations) for determining whether a change in level is significant. The accuracy of these statistics can be improved by updating them with data from regular vibration monitoring data.

D. Document The Effect Of Load Variation. This is not strictly required, but can be invaluable when determining whether a change is due to a fault, or just a change in load.

E. Update Regularly. Baseline data should be updated after major repairs or changes in operating conditions.

Figure 5-10

Baseline data should include fully documented vibration spectra and engineering data, such as bearing and gear parameters, which can be invaluable for analysis.



Chapter 6

Dynamic Signal Analyzers

Chapter 6 describes the important measurement capabilities of DSAs as they relate to machinery vibration analysis. For a more detailed discussion of DSAs and how they work, refer to *Hewlett-Packard Application Note AN 243.*

6.1 Measurement Speed. Machinery vibration is a dynamic phenomenon that can change quickly—so quickly that slower swept spectrum analyzers may completely miss key events. DSAs can capture a typical vibration signal and transform it to the frequency domain in less than 1 second.

6.2 Frequency Resolution. Closely spaced machinery vibration signals often must be resolved for accurate analysis.

6.3 Dynamic Range. Vibration components that are the first indications of trouble are often very small relative to vibration from residual imbalance or other machines. The wide dynamic range of DSAs allows them to resolve signals less than 1/1000 the level of background vibration or residual imbalance.

6.4 Digital Averaging. Machinery vibration signals often contain large amounts of background vibration that can reduce accuracy and obscure small signals. The digital averaging feature of DSAs can be used to reduce both of these effects.

6.5 HP-IB*. The Hewlett-Packard Interface Bus is a standardized interface that makes it easy to connect a DSA to a digital plotter for hard-copy results, or to a computer for automated data storage and analysis.

6.6 User Units And Units Conversion. DSA displays can be calibrated in vibration units such as inches/second and rpm. Units of vibration amplitude can also be converted to other parameters (e.g., acceleration to velocity) using the post-processing capabilities of DSAs.

6.7 External Sample Rate Control. By controlling data sampling rate with a tachometer pulse, the frequency axis can be normalized to rotational speed. This is convenient for real time analysis of machines whose speed varies widely.

6.8 Two-channel Enhancements. While single-channel DSAs are most commonly used for machinery analysis, dual-channel DSAs provide important enhancements such as real time phase comparision and transfer function measurements.

6.1 Measurement Speed

Speed is important in machinery analysis because vibration characteristics can change quickly. This is illustrated in the spectral map of figure 6-1, where measurements of a machine run-up spaced at 0.5 second intervals show significant variation. Speed is also important for reducing the time required to characterize a machine. A high resolution measurement (500 Hz bandwidth) takes about 2 minutes with a swept analyzer; it takes less than 1 second with a DSA. The time differential can be significant when vibration is measured at multiple points.

The time required to make a measurement with a DSA is determined by two factors: (1) measurement resolution, and (2) transform computation time. High resolution measurements require a long data sampling time (resolution of events spaced at 1 second intervals requires a 1 second measurement time). This is a physical fact, independent of the design of the DSA. Computation time, however, varies widely among DSAs, and can make a noticeable difference in measurement time. Computation time is usually expressed in terms of *real time bandwidth*—the frequency span at which data sampling and computation times are equal (higher real time bandwidth implies faster computation).

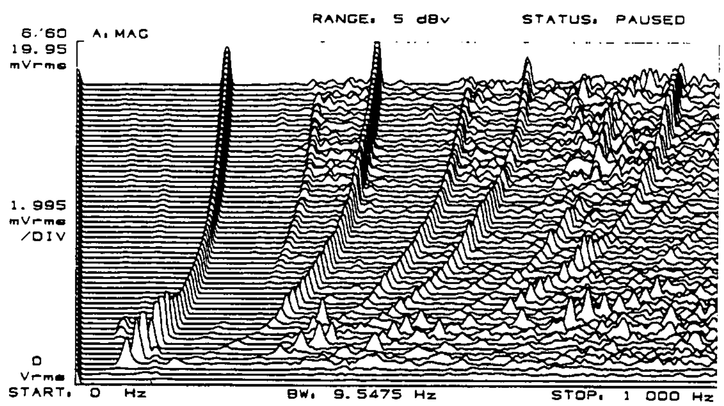


Figure 6-1

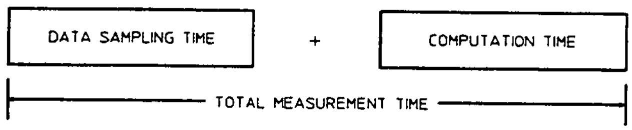
Machinery vibration spectra can change very quickly, as this spectral map of a run-up test illustrates. Slower swept spectrum analyzers can miss these changes.

Real Time Bandwidth Example

Suppose you were making measurements with a 2,000 Hz frequency span. The data sampling time for this span on DSAs with 400 line resolution (see section 6.2) is 0.200 seconds, then sampling would never have to stop to let the computation catch up. (This computation time would correspond to a real time bandwidth of 2000 Hz.) If the computation time were 1 second (a real time bandwidth of 400 Hz), the analyzer would miss large amounts of data while waiting for the computation.

Figure 6-2

Total DSA measurement time is the sum of data sampling time and computation time. While sampling time is fixed for a given resolution, computation times vary widely among available DSAs.

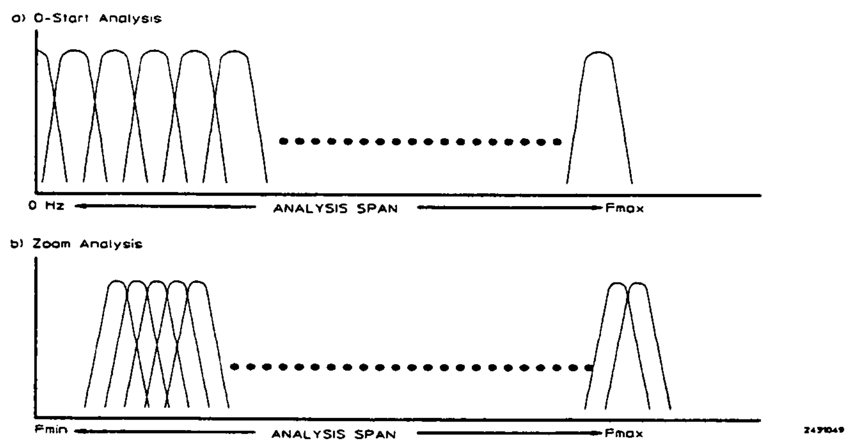


6.2 Frequency Resolution

High resolution is required for analysis when vibration signals are closely spaced, or when the frequency of a component must be read with high precision. A common example of closely spaced signals are the 1× and powerline components of induction motor vibration, which can be separated by a few Hertz. The sidebands around rolling element bearing and gear frequencies are also often closely spaced. High precision is required when the characteristic vibration frequencies of two possible sources are close together, as in the case of a bearing frequency and a running speed harmonic.

Figure 6-3

Frequency resolution in a DSA is determined primarily by the number of filters, and the ability to zoom. In a zoom measurement, the component of interest is made the center frequency of the analysis, allowing the use of an arbitrarily narrow frequency span.



Frequency resolution in a DSA is determined primarily by the number of filters (or lines of resolution), and the ability to zoom. The filters of a DSA are shown in figure 6-3. Signals must lie in different filters to be resolved, so resolution depends on the spacing of the filters. Since the number of filters is fixed, filter spacing is determined by the number of filters and the analysis span. More filters imply better resolution for a given span.

If the span required for the desired resolution is too narrow to include all the frequencies of interest, then the analysis must start at a frequency above zero. This process is referred to as zooming (because it involves zooming in on a arbitrary center frequency), and is a feature of most newer DSAs. Ideally, the zoom feature should allow frequency spans down to 1 Hz to be centered on any frequency in the analysis range.

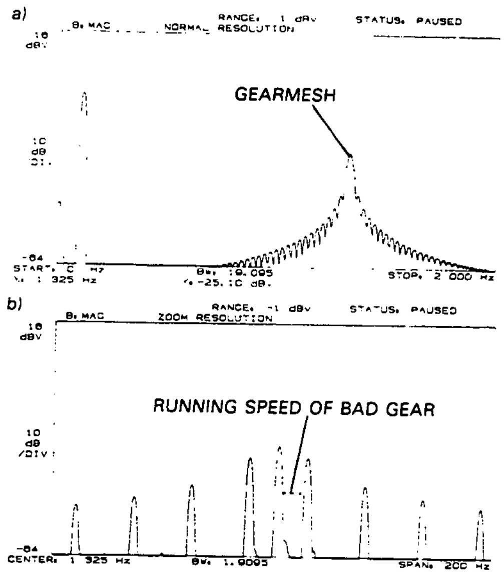


Figure 6-4

An example gear vibration spectrum that illustrates the need for zoom. The sidebands around gearmesh often indicate the bad gear, but are too closely spaced to resolve in (a). The zoom measurement in (b) centers a narrower frequency span on the gear mesh, increasing resolution.

The gear spectrum in figure 6-4 illustrates why the ability to zoom is so important. In the low resolution spectrum (a), the sidebands around the gearmesh frequency indicate a problem, but the exact spacing (which will indicate which gear has the defect) is difficult to determine. Since the gearmesh is at a relatively high frequency, a span narrow enough to resolve the sidebands cannot cover the entire frequency range starting at 0 Hz. Thus we must zoom on the gearmesh frequency to complete the analysis. (See section 4.6 for more information on gear analysis.)

Window Functions

Frequency resolution is also affected by the shape of the filters—determined in a DSA by the window function selected. The window function shapes the input data to compensate for discontinuities in the sampling process (see *Hewlett-Packard Application Note AN 243*). Figure 6-5,6-6, and 6-7 show the same vibration spectrum measured with the three windows commonly available on DSAs.

A. The Flat Top window is optimized for level accuracy, with a response variation with frequency of 1% (0.1 dB). This is the window to use unless maximum frequency resolution is required, or you are capturing a transient.

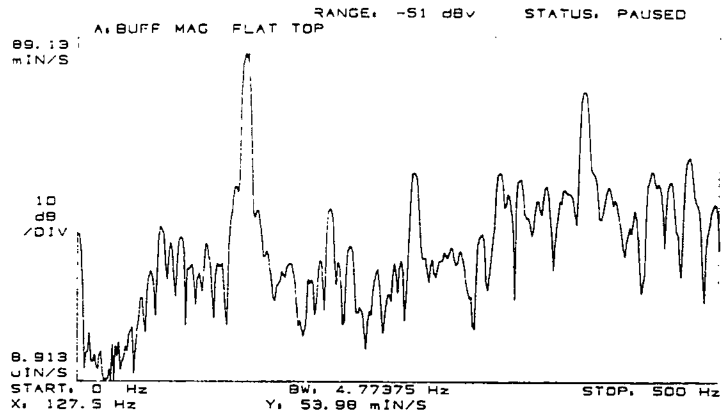


Figure 6-5

The Flat Top window is optimized for amplitude accuracy.

B. The Hanning window provides improved frequency resolution (note the Bandwidth notation at the bottom of the display), but sacrifices amplitude accuracy. Variation with frequency is approximately 15% (1.5 dB).

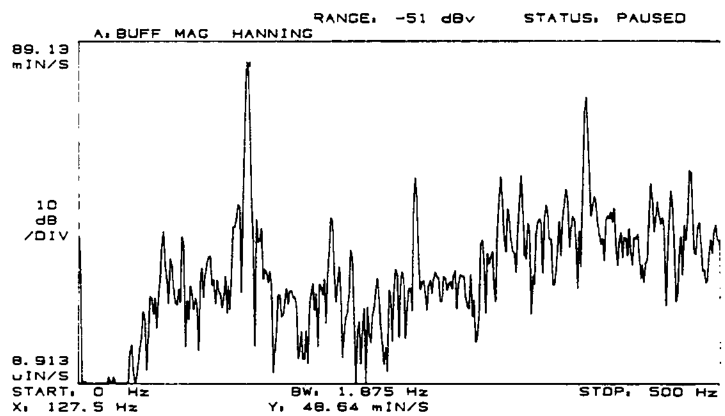


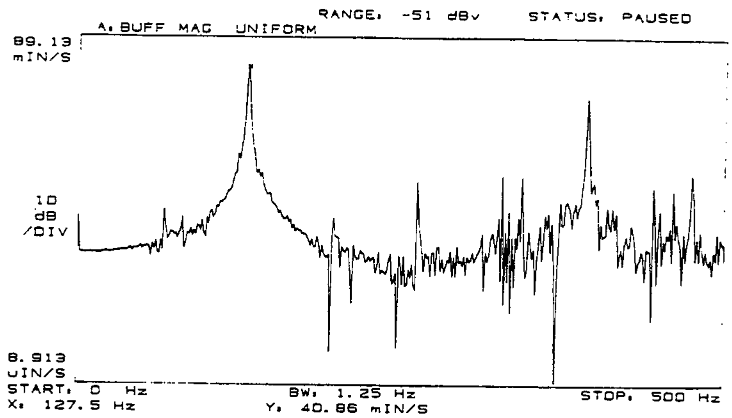
Figure 6-6

The Hanning window provides better frequency resolution than the Flat Top window, but amplitude accuracy is reduced.

C. The Uniform window provides no weighting, and should be used only for transients or specialized signals. The wide skirts, known as leakage, severely restrict frequency resolution. (Leakage is what weighting in the other two window functions eliminates.)

Figure 6-7

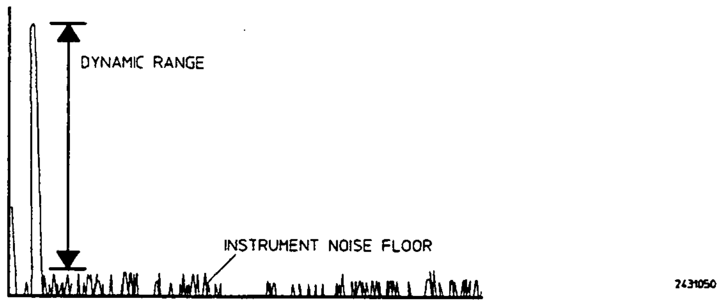
Leakage (wide filter skirt) is a problem with the Uniform window, and it should only be used for transients or specialized signals.



6.3 Dynamic Range

Figure 6-8

Dynamic range is defined as the ratio between the largest and smallest signals that can be analyzed at the same time.

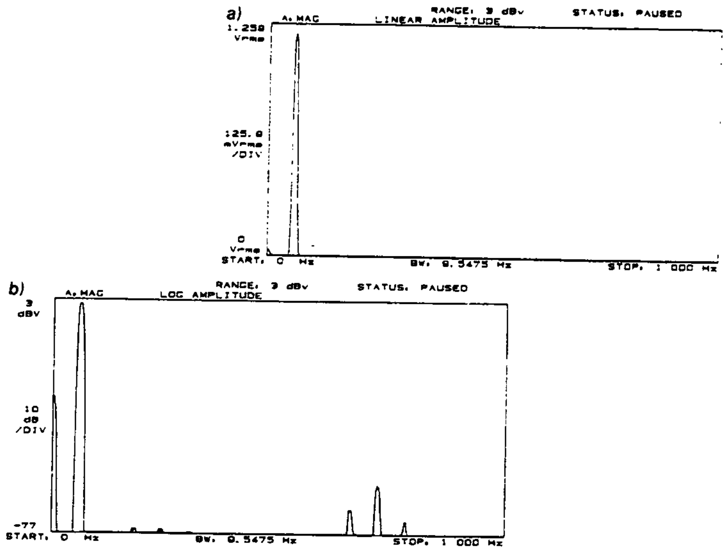


Dynamic range is another aspect of resolution. It is a measure of the ability to analyze small signals in the presence of large ones, as shown in figure 6-8. DSAs feature wide dynamic range, with most able to display signals that differ in amplitude by factors of 1000 or more. Logarithmic (dB) display scales are used to take advantage of this measurement capability (see the explanation of dB on page 3-8).

Wide dynamic range is important for analyzing low-level vibration signals in the presence of large residual imbalance components. Dynamic range is also important when the component to be analyzed is small compared to the total power level. That is, a large number of relatively low level signals result in a high total power level that limits input sensitivity in the same way a single large signal would. This is often the case, for example, when analyzing low frequency vibration with an accelerometer.

Figure 6-9

Bearing characteristic frequencies that are easily seen in the logarithmic (dB) amplitude display of (b) are not visible in the linear amplitude display of (a).



This situation is shown in the displays of figure 6-9. Here, an accelerometer is being used to check for bearing west. As pointed out in section 2.1, acceleration response increases with frequency, resulting in an accelerometer output that often has a large high-frequency energy content. This energy limits input sensitivity, and can easily result in bearing frequencies 40 dB (a factor of 100) below full scale. These low level signals are clear on the logarithmic display (b), but not visible on the linear display of (a).

6.4 Digital Averaging

Machinery vibration spectra often contain large levels of background noise, vibration from adjacent machines, or components that vary in amplitude. Three types of digital averaging are available to reduce the problems that these conditions imply for analysis.

A. rms. The result of an rms average of successive spectra is an improved estimate of the main level of vibration components. rms averaging should be used when component levels vary significantly.

B. Time. While rms averaging reduces the variance of signal levels, it does nothing to reduce unwanted background noise. This background noise may mask low level components, or add unrelated components to the spectrum. Time (or synchronous) averaging effectively reduces components that are not related to the trigger, which is usually a keyphasor. Time averaging should be used when background noise or vibration from adjacent machines interferes with analysis.

C. Peak. It is often desirable to hold peak vibration levels during a run-up or coast-down, or over a period of time. The result of peak averaging is a display of the maximum level at each frequency point (recall that most DSAs display 400 frequency points for any selected span).

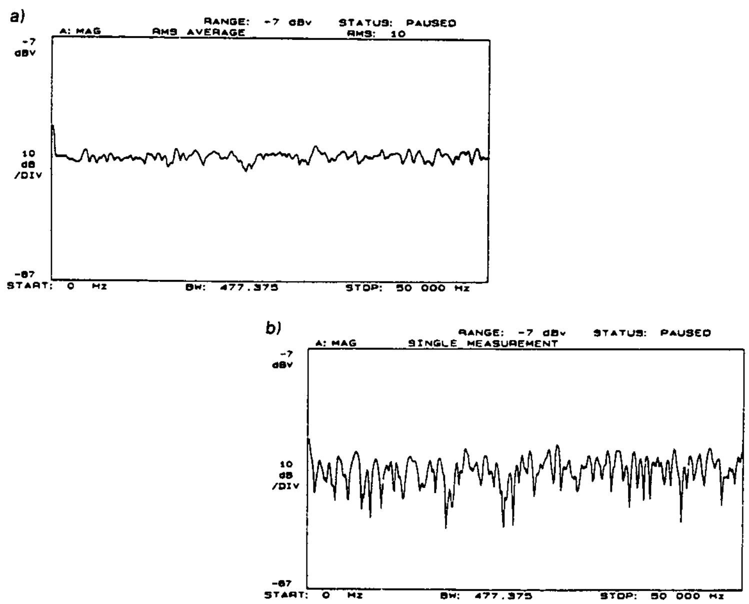
rms Averaging

Because noise can cause spectral components to vary widely in amplitude, a single measurement is not statistically accurate. While watching the components vary in amplitude, you could visually average them and determine the mean level. This is essentially what rms averaging does, and the more averages you take, the better the accuracy will be. rms averaging can be thought of as amplitude averaging, since phase is ignored. (rms, or root mean square, is the square root of the mean of the squared spectra.) The effect of rms averaging is shown in figure 6-10.

rms averaging improves the statistical accuracy of a noisy spectrum, and does not require a trigger, but it does not actually reduce the noise level.

Figure 6-10

When rms averaging is performed, components which vary in amplitude converge to their mean value, providing a better statistical estimate of amplitude.



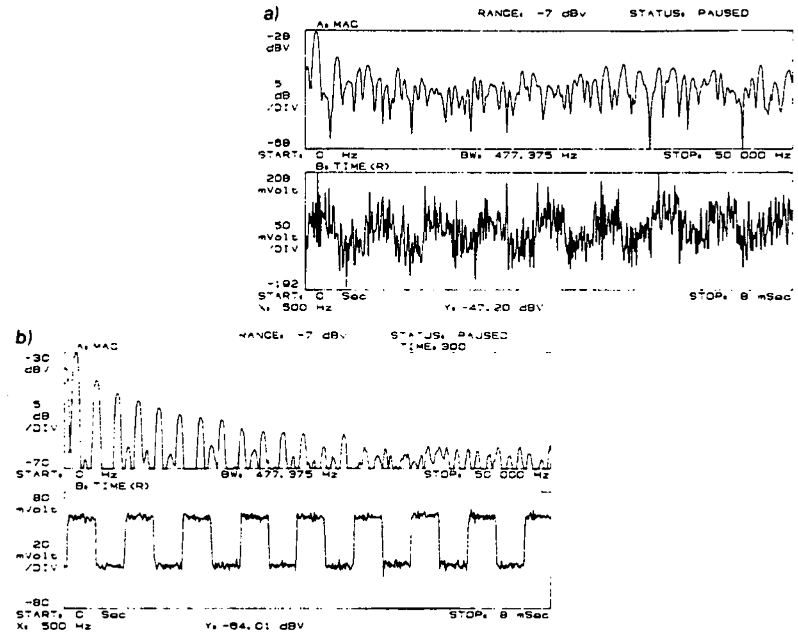
Time Averaging

Time averaging is a technique that can be used to reduce the level of noise, and thus uncover low level signals that may have been obscured by the noise. Sometimes referred to as linear averaging, this type of averaging requires a synchronizing trigger—usually a keyphasor.

Time averaging can be implemented in either the time or frequency domains, but the time domain is traditional (thus the name). In this form, the blocks of time data that are transformed by the analyzer to the frequency domain are averaged before the transformation. Signals that are fixed in the time record (i.e., synchronous with the trigger) will remain, while nonsynchronous signals eventually average to zero. This is shown in figures 6-11 (a) and (b), where time averaging a noisy square wave has reduced the noise level, while keeping the square wave intact. An example with a machinery spectrum can be found in section 5.2.

Figure 6-11

The time averaged displays in (b) show a reduction in the level of components that are nonsynchronous with the trigger.

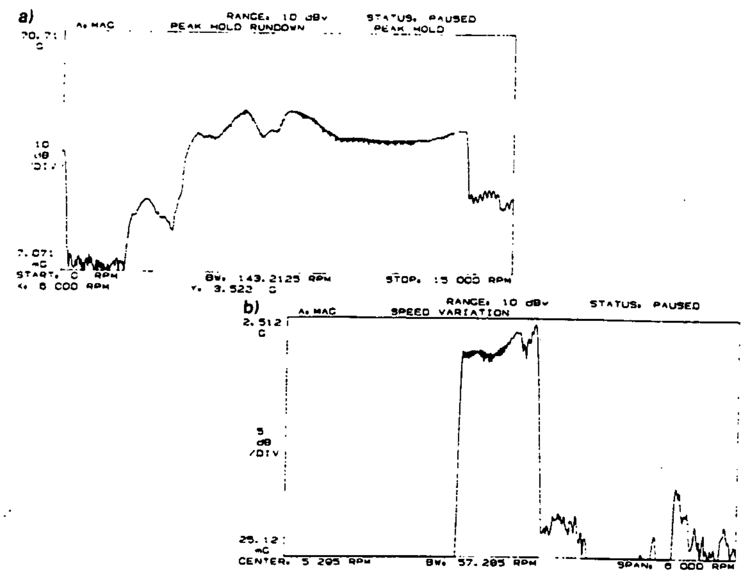


Peak Hold

Peak hold is a function usually grouped with averaging in DSAs. By displaying the maximum level at each frequency over a number of samples, this feature provides a history of peak levels. Two applications are shown in figure 6-12. In (a), peak hold has been used during a machine coast-down, providing a simple track of the maximum level (which is usually 1× rpm). The display in (b) is a peak hold over a relatively long period that shows the range of speed variation of a nominally constant speed motor. This could be used, for example, as an indication of load variation. Peak hold is also useful for recording momentary vibration peaks (e.g., from startups or load changes).

Figure 6-12

Peak hold used (a) to track peak level during a coastdown, and (b) to indicate variation in speed over time.

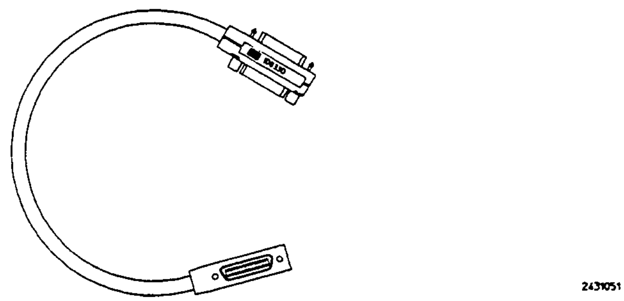


6.5 HP-IB

The Hewlett-Packard Interface Bus (HP-IB) is a standardized interface that can be used to connect digital plotters and computers to DSAs. (A cable and connector are shown in figure 6-13.) Because of the large number of computers, plotters and instruments that are compatible with this interface, the possibilities for automatic data storage, presentation, and analysis are virtually unlimited. Some of these are discussed in the following.

Figure 6-13

A standardized cable and connector simplify HP-IB interface connections.



Digital Plotters

Digital plotters produce high quality copies of DSA displays, complete with annotation. They are no more expensive than their analog counterparts, and many DSAs can interface to them directly, with no controller required. (All of the example DSA plots in this note were made on a digital plotter.) An advantage of these plotters over video display printers is that poor resolution, which results in the same stairstep effect as seen in raster scan displays, is eliminated.

Computer Data Storage and Analysis

A common problem encountered when starting a vibration monitoring program is that large amounts of data must be stored. Plots of vibration spectra can be stored in a file, but several months of data can result in a rather cumbersome file. A much better solution is to use a computer to store the data on tape or disc. Data stored in this fashion can be automatically recalled for comparison purposed or further analysis. Once vibration data is in the computer, it can be analyzed and displayed in virtually any way you desire. Several companies offer software that is specifically designed for storage and analysis of machinery vibration data.

Instrument Systems

The variety of compatible HP-IB instruments make possible automatic systems for test and monitoring. In figure 6-14, a scanner is connected to a number of permanently installed transducers. The computer switches the scanner to each transducer at regular intervals, and can decide to take a number of actions (e.g. sound an alarm, shut down the machine, store the data) depending on how the data compares with stored vibration severity limits.

A system for automatic machine run-up tests is shown in figure 6-15. A digital to analog converter provides a programmable dc level to control speed, which is monitored by a frequency counter. When the speeds desired for the test are reached, the computer triggers the DSA to make a measurement. The plot from such a setup is shown in figure 6-16.

Figure 6-14

HP-IB system for scanning a number of transducers. Such a system can be configured to take appropriate action (e.g. sound an alarm or remove power) when current vibration levels exceed pre-defined limits.

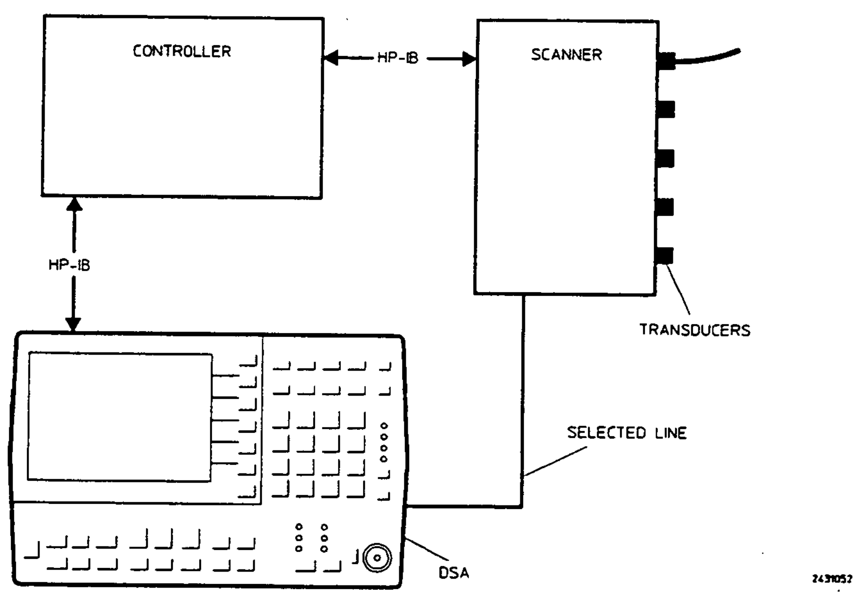


Figure 6-15

An instrument system for performing run-up tests automatically.

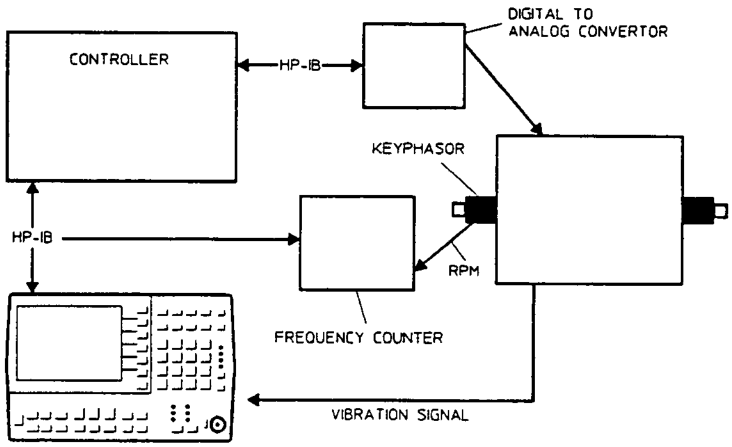
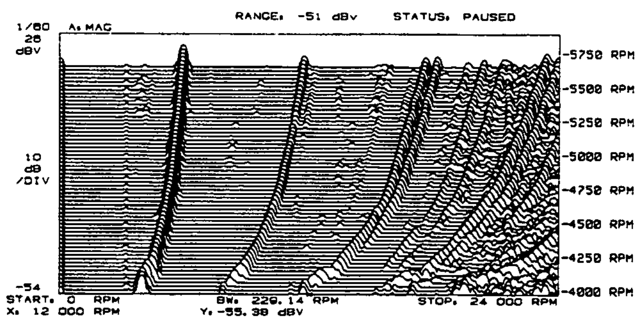


Figure 6-16

A spectral map made with the system of figure 6-15.



6.6 User Units And Units Conversion

Vibration displays are easier to interpret if they are presented in units that are relevant to machinery. DSAs provide the capability for user calibration of amplitude units, and a selection of units for the frequency axis. DSAs can also convert spectra from one vibration parameter to another through integration and differentiation.

User units calibration is accomplished by entering a calibration factor, such as 10 mV/g. The DSA performs the conversion and displays the vibration spectrum in the desired units, usually labeled as "EU"(Engineering Units). Some newer DSAs have provision for custom labeling of user defined units (e.g., in/sec, g).

The frequency units used for machinery vibration analysis include Hertz, rpm, and orders. Orders refer to "orders of rotation", and are harmonics of the rotating speed. Figure 6-17 illustrates calibration of the frequency axis in orders. Orders are handy for analysis because most vibration problems are order-related. By using external sample control, orders can be fixed on the display while speed changes (see section 6.7).

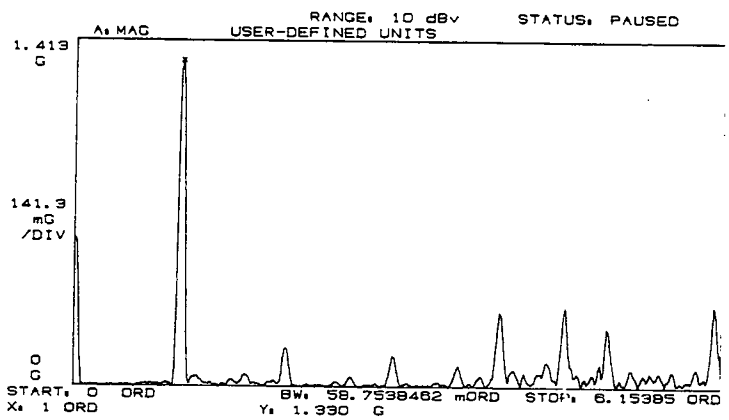


Figure 6-17

A machinery vibration spectrum calibrated in user-defined amplitude units (EU), and orders (harmonics) of rotational speed.

Referring to the formulas for displacement, velocity, and acceleration in section 2.1, it should be apparent that they are related by frequency and a phase shift. For example, acceleration can be converted to velocity through division by $j(2\pi f)$. This operation is commonly referred to as artificial integration (the "j" term is an operator that implies a 90° phase shift), and is a feature of most DSAs. Figure 6-18 shows an integrated acceleration spectrum overlaid on an actual velocity spectrum measured at the same point.

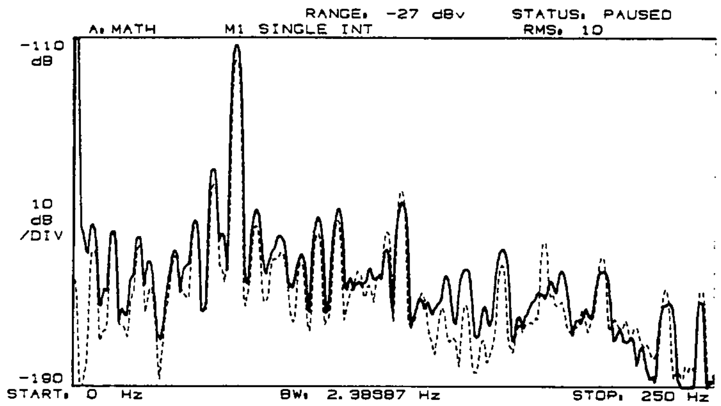


Figure 6-18
A comparison between an integrated acceleration spectrum and an actual velocity spectrum (dashed line).

Table 6-1 summarizes vibration parameter conversion. Two things to note about these conversions: (1) integrating absolute velocity will not result in relative displacement (i.e., integrated measurements from a case-mounted velocity transducer will not give the same result as a displacement transducer that measures the shaft directly), and (2) differentiation is usually not recommended, since noise in the spectrum to be differentiated tends to give misleading results.

Table 6-1
Vibration Parameter Conversions

Conversion	Operator	Description
Acceleration→ velocity	$1/j\omega$	Single integration
Acceleration→ displacement	$-1/\omega^2$	Double integration
Velocity→ displacement	$1/j\omega$	Single integration
Velocity→ acceleration	$j\omega$	Differentiation
Displacement→ velocity	$j\omega$	Differentiation
Displacement→ acceleration	$-\omega^2$	Double differentiation

In general, while these conversions often work well, it is best to make the initial measurement using the desired end-result parameter.

6.7 External Sample Control

One of the complications encountered in analyzing rotating machinery is variation in speed. For machines that will operate over a wide range of speeds, it is desirable to measure vibration over the entire range. With a fixed frequency axis, spectral components are constantly moving with changes in speed, making interpretation difficult. For machines that run at nominally constant speed, even small changes can make point-for-point comparison with baseline spectra difficult.

The problem of wide speed variation can be solved after the data is collected with a spectral map plot. The frequency display can be normalized (i.e., calibrated in fixed location orders of rotation) through software manipulation. However, the only way to normalize the frequency display in real time is with external sample control. By controlling data sampling rate with a signal tied to rotating speed, the display will have a fixed calibration in orders of rotation. (See section 5.4 for a discussion of the relative merits of each method.)

Figure 6-19

Instrumentation setup for controlling sample rate externally.

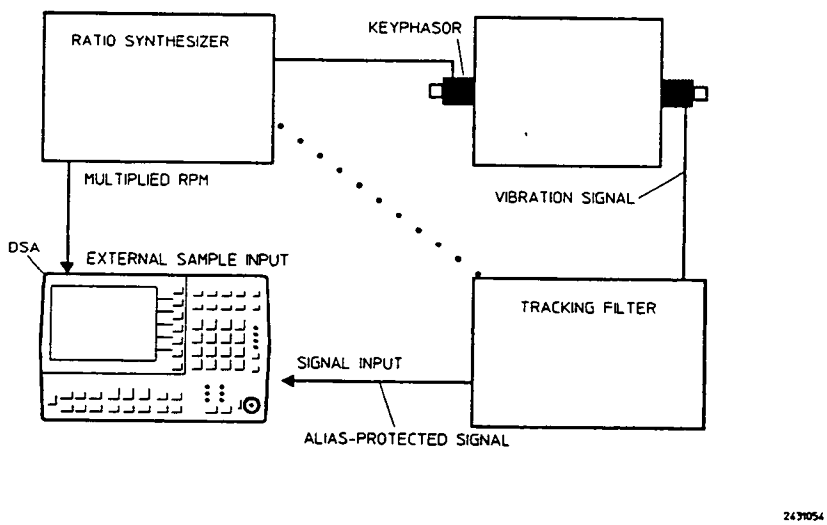


Figure 6-19 shows the instrumentation required for controlling sample rate externally. Typically, a once/revolution pulse multiplied by a ratio synthesizer is used for sample control. The ratio synthesizer is required because DSAs typically sample at a rate of 2.56 times the frequency span. Since it is usually desirable to look at several orders, the once per revolution tach pulse must be multiplied by 2.56 times the number of orders to be analyzed. An important requirement for the ratio synthesizer is anti-aliasing protection. Aliasing occurs when the data sample rate is too slow, allowing high frequency signals to be misinterpreted as low frequency signals. Thus the spectrum may appear to have components that are not really there. Aliasing is avoided if a filter is used to limit input signals to frequencies less than 1/2 the sample rate. (See *Hewlett-Packard Application Note AN 243* for more information on aliasing.)

If the speed range of the analysis is limited to approximately 20%, aliasing can be avoided by using high ratio synthesizer factors. Hewlett-Packard DSAs use a fixed frequency low pass filter on the input to provide aliasing protection for the broadest frequency span (highest sample rate). If the ratio synthesizer factor is adjusted so that the sample rate at the highest machine speed is equal to the analyzer's highest sample rate, the input low pass filter will provide alias protection. This protection ranges from complete at the maximum speed to very little at around 80% of the maximum speed.

For example, if the maximum machine speed is 3600 rpm (60 Hz), and the maximum analyzer sample rate is 256 kHz, the required ratio synthesizer factor for a once per revolution tach pulse is 256 kHz/60Hz = 4266.7.

As machine speed is reduced from the maximum (and sample rate thus decreases), alias protection is reduced. At a speed of 80% of maximum, this results in alias components typically 20 dB below full scale (10% of full scale).

NOTE

Some newer Hewlett-Packard analyzers (for example, the HP 35665A Dynamic Signal Analyzer and the HP 3566A/3567A PC Spectrum Network Analyzer) do not require an external ratio synthesizer or tracking filter for external tracking control. These newer analyzers require only a tachometer signal to accomplish this synchronization. To learn more, refer to the following:

- Potter, Ron and Gribler, Mike. "Computed Order Tracking Obsoletes Older Methods." Reprint from *Proceedings of the 1989 Noise and Vibration Conference*, SAE Technical Paper Series (reprint number 891131).
- Potter, Ron. "A New Order Tracking Method for Rotating Machinery." *Sound and Vibration*, September 1990

6.8 Dual-channel Enhancements

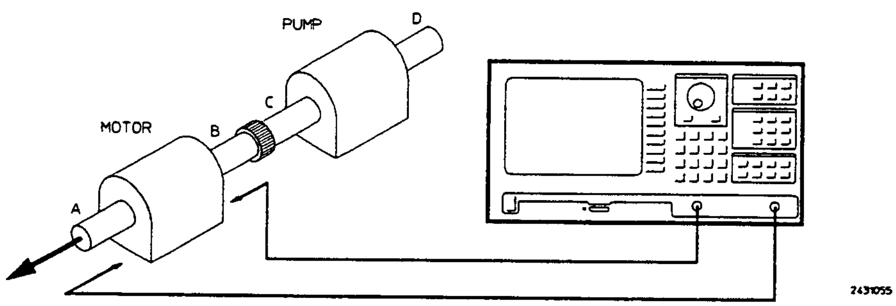
A dual-channel DSA is much more than two separate analysis channels, because it can measure the amplitude and phase relationships between two signals. This relationship is most commonly called the transfer function. It is especially useful for performing real time phase comparisons, and identifying the source of vibration in a machine train. The transfer function can also be used to determine natural frequencies of shafts, gears, and machine housings that can be critical for analysis. Finally, some dual-channel DSAs can display shaft orbits. These displays give insight into the path of the shaft as it rotates, and are especially useful in high-speed machinery. For a more general discussion of dual-channel DSA capabilities, refer to *Hewlett-Packard Application Note AN 243.*

Real Time Comparisons

Comparative phase measurements are a powerful tool for analysis, especially for differentiating between similar forms of vibration (see sections 4.4 and 5.2). This measurement is made both easier and more accurate with a dual-channel DSA. Referring to the motor-pump combination in figure 6-20, suppose that you are not sure whether the high vibration level is due to imbalance or misalignment. As pointed out in section 4.4, the relative phase of axial vibration at A and B will be 180° if misalignment is the problem (assuming a rigid-rotor). With a single-channel analyzer, you would use a key phasor as a reference, and measure the two ends one at a time. With a dual-channel analyzer, all you have to do is connect an end to each channel and measure the transfer function phase. (This connection is diagrammed in figure 6-20.) Thus, relative phase measurements can be made with a single-channel DSA, but are much easier (and less error-prone) with a dual-channel DSA.

Figure 6-20

Misalignment is indicated by a 180° phase relation between A and B. For transducers oriented as shown (180 ° relation), the relative phase will be 0°.



Cause and Effect Relationships: The Coherence Function

A common problem in machinery vibration analysis is that vibration form one machine in a train is transferred to the other machines. The coherence function can help with these problems by indicating the cause and effect relationship between vibration at two locations.

The coherence display covers a range of 0 to 1, and indicates the percentage of power in channel B that is coherent with channel A. Let's suppose that vibration levels at points A and D on the motor pump combination of figure 6-20 are similar, and rather high. You would like to know whether they are independent or related. A low value of coherence between vibration components from A and D indicates that they are not related. A high coherence value for a component implies that there may be a causal relationship. (The high coherence component could, for example, be from a third source of vibration.) Coherence measured between end points on a motor and pump is shown in figure 6-21. Note that coherence is high for all the major vibration components except 240 Hz, indicating that this vibration is not from the motor. The technique will not work 100% of the time, and you will have to get a feel for what constitutes a high level of coherence, but it may save time in disconnecting machines to isolate the source of vibration.

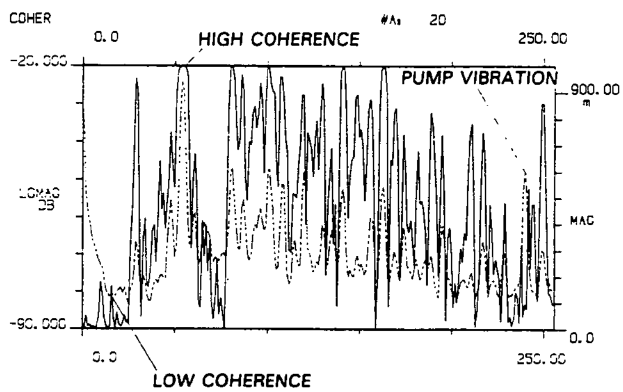


Figure 6-21

Coherence measured between a pump and motor clearly indicates which components are unrelated.

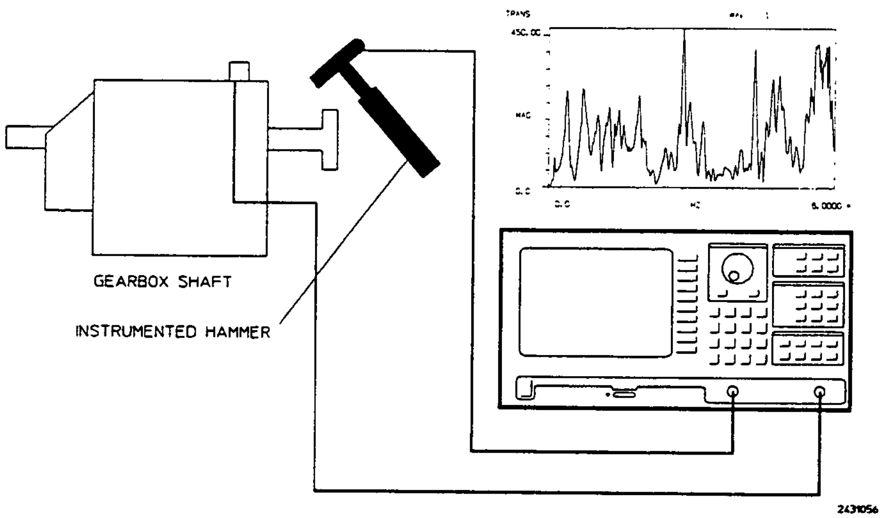
Natural Frequency Measurements

The natural frequencies of a machine housing or foundation can be easily determined through what is sometimes referred to as a "bump" test. Recall from figure 3-6 that impulsive signals produce a broad spectrum of harmonics. If the housing is impacted with sufficient energy (typically with a block of wood), all the natural frequencies will be excited. The response can be measured with a single-channel DSA, but an imperfect impact may result in a misleading spectrum.

A better way to make this measurement is with a dual-channel analyzer and instrumented hammer. This is shown digramatically in figure 6-22, where the natural frequencies of a gearbox are being determined. As we saw in section 4.6, gear defects often show up at their natural frequencies, so this information is valuable. *Hewlett-Packard Application Note AN 243* contains more detailed information on measuring the response of mechanical structures.

Figure 6-22

The transfer function of a gearbox can be measured with an instrumented hammer and a two-channel DSA.

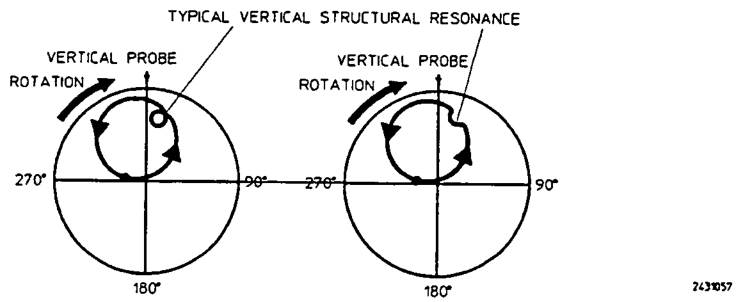


Orbits

Some dual-channel DSAs have the ability to display orbit diagrams, as shown in figure 6-23. These are useful for gaining insight into rotor motion in turbo-machinery. The subject of orbit interpretation is covered well in reference [29].

Figure 6-23

The orbit capability of some two-channel DSAs provides insight into rotor motion in machines with fluid-film bearings.



Glossary

Acceleration. The time rate of change of velocity. Typical units are ft/sec/sec, meters/sec/sec, and G's (1G = 32.17 ft/s/s = 9.81 m/s/s). Acceleration measurements are usually made with accelerometers.

Accelerometer. Transducer whose output is directly proportional to acceleration. Most commonly use piezoelectric crystals to produce output.

Aliasing. A phenomenon which can occur whenever a signal is not sampled at greater than twice the maximum frequency component. Causes high frequency signals to appear at low frequencies. Aliasing is avoided by filtering out signals greater than 1/2 the sample rate.

Alignment. A condition whereby the axes of machine components are either coincident, parallel or perpendicular, according to design requirements.

Amplification Factor (synchronous). A measure of the susceptibility of a rotor to vibration amplitude when rotational speed is equal to the rotor natural frequency (implies a flexible rotor). For imbalance type excitation, synchronous amplification factor is calculated by dividing the amplitude value at the resonant peak by the amplitude value at a speed well above resonance (as determined from a plot of synchronous response vs. rpm).

Amplitude. The magnitude of dynamic motion or vibration. Amplitude is expressed in terms of peak-to- peak, zero-to- peak, or rms. For pure sine waves only, these are related as follows rms = 0.707 times zero-to-peak; peak-to-peak = 2 times zero-to-peak. DSAs generally read rms for spectral components, and peak for time domain components.

Anti-aliasing Filter. A low-pass filter designed to filter out frequenices higher than 1/2 the sample rate in order to prevent aliasing.

Anti-Friction Bearing. See Rolling Element Bearing.

Asymetrical Support. Rotor support system that does not provide uniform restraint in all radial directions. This is typical for most heavy industrial machinery where stiffness in one plane may be substantially different than stiffness in the perpendicular plane. Occurs in bearings by design, or from preloads such as gravity or misalignment.

Asynchronous. Vibration components that are not related to rotating speed (also referred to as nonsynchronous).

Attitude Angle (steady-state). The angle between the direction of steady-state preload through the bearing centerline, and a line drawn between the shaft centerline and the bearing centerline. (Applies to fluid-film bearings.)

Auto Spectrum (Power Spectrum). DSA spectrum display whose magnitude represents the power at each frequency, and which has no phase. rms averaging produces an auto spectrum.

Averaging. In a DSA, digitally averaging several measurements to improve accuracy or to reduce the level of asynchronous components. Refer to definitions of rms, time, and peak hold averaging.

Axial. In the same direction as the shaft centerline.

Axial Position. The average position, or change in position, of a rotor in the axial direction with respect to some fixed reference position. Ideally the reference is a known position within the thrust bearing axial clearance or float zone, and the measurement is made with a displacement transducer observing the thrust collar.

Balancing Resonance Speed(s). A rotative speed that corresponds to a natural resonance frequency.

Balanced Condition. For rotating machinery, a condition where the shaft geometric centerline coincides with the mass centerline.

Balancing. A procedure for adjusting the radial mass distribution of a rotor so that the mass centerline approaches the rotor geometric centerline.

Band-pass Filter. A filter with a single transmission band extending from lower to upper cutoff frequencies. The width of the band is determined by the separation of frequencies at which amplitude is attenuated by 3 dB (0.707).

Bandwidth. The spacing between frequencies at which a band-pass filter attenuates the signal by 3 dB. In a DSA, measurement bandwidth is equal to [(frequency span)/(number of filters) x (window factor)]. Window factors are: 1 for uniform, 1.5 for Hanning, and 3.63 for Flat Top.

Baseline Spectrum. A vibration spectrum taken when a machine is in good operating condition; used as a reference for monitoring and analysis.

Blade Passing Frequency. A potential vibration frequency on any bladed machine (turbine, axial compressor, fan, etc.). It is represented by the number of blades times shaft rotating frequency.

Block Size. The number of samples used in a DSA to compute the Fast Fourier Transform. Also the number of samples in a DSA time display. Most DSAs use a block size of 1024. Smaller block size reduces resolution.

Bode. Rectangular coordinate plot of 1 x component amplitude and phase (relative to a keyphasor) vs. running speed.

BPFO, BPFI. Common abbreviations for ball frequency of defects on outer and inner bearing races, respectively.

Bow. A shaft condition such that the geometric centerline of the shaft is not straight.

Brinneling (false). Impressions made by bearing rolling elements on the bearing race; typically caused by external vibration when the shaft is stationary.

Calibration. A test during which known values of the measured variable are applied to the transducer or readout instrument, and output readings varied or adjusted.

Campbell Diagram. A mathematically constructed diagram used to check for coincidence of vibration sources (i.e. 1 x imbalance, 2 x misalignment) with rotor natural resonances. The form of the diagram is a rectangular plot of resonant frequency (y-axis) vs excitation frequency (x-axis). Also known as an interference diagram.

Cascade Plot. See Spectral Map.

Cavitation. A condition which can occur in liquid-handling machinery (e.g. centrifugal pumps) where system pressure decrease in the suction line and pump inlet lowers fluid pressure and vaporization occurs. The result is mixed flow which may produce vibration.

Center Frequency. For a bandpass filter, the center of the transmission band.

Charge Amplifier. Amplifier used to convert accelerometer output impedance from high to low, making calibration much less dependent on cable capacitance.

Coherence. The ratio of coherent output power between channels in a dual-channel DSA. An effective means of determining the similarity of vibration at two locations, giving insight into the possibility of cause and effect relationships.

Constant Bandwidth Filter. A band-pass filter whose bandwidth is independent of center frequency. The filters simulated digitally in a DSA are constant bandwidth.

Constant Percentage Bandwidth. A band-pass filter whose bandwidth is a constant percentage of center frequency. 1/3 octave filters, including those synthesized in DSAs, are constant percentage bandwidth.

Critical Machinery. Machines which are critical to a major part of the plant process. These machines are usually unspared.

Critical Speeds. In general, any rotating speed which is associated with high vibration amplitude. Often, the rotor speeds which correspond to natural frequencies of the system.

Critical Speed Map. A rectangular plot of system natural frequency (y-axis) vs bearing or support stiffness (x-axis).

Cross Axis Sensitivity. A measure of off-axis response of velocity and acceleration transducers.

Cycle. One complete sequence of values of a periodic quantity.

Damping. The quality of a mechanical system that retrains the amplitude of motion with each successive cycle. Damping of shaft motion is provided by oil in bearings, seals, etc. The damping process converts mechanical energy to other forms, usually heat.

Damping, Critical. The smallest amount of damping required to return the system to its equilibrium position without oscillation.

Decibels (dB). A logarithmic representation of amplitude ratio, defined as 20 times the base ten logarithm of the ratio of the measured amplitude to a reference. dbV readings, for example, are referenced to 1 volt rms. db amplitude scales are required to display the full dynamic range of a DSA.

Degrees Of Freedom. A phrase used in mechanical vibration to describe the complexity of the system. The number of degrees of freedom is the number of independent variables describing the state of a vibrating system.

Digital Filter. A filter which acts on data after it has been sampled and digitized. Often used in DSAs to provide anti-aliasing protection after internal re-sampling.

Differentiation. Representation in terms of time rate of change. For example, differentiating velocity yields acceleration. In a DSA, differentiation is performed by multiplication by $j\omega$, where ω is frequency multiplied by 2π. (Differentiation can also be used to convert displacement to velocity.)

Discrete Fourier Transform. A procedure for calculating discrete frequency components (filters or lines) from sampled time data. Since the frequency domain result is complex (i.e., real and imaginary components), the number of points is equal to half the number of samples.

Displacement. The change in distance or position of an object relative to a reference.

Displacement Transducer. A transducer whose output is proportional to the distance between it and the measured object (usually the shaft).

DSA. See Dynamic Signal Analyzer.

Dual Probe. A transducer set consisting of displacement and velocity transducers. Combines measurement of shaft motion relative to the displacement transducer with velocity of the displacement transducer to produce absolute motion of the shaft.

Dual Voting. Concept where two independent inputs are required before action (usually machine shutdown) is taken. Most often used with axial position measurements, where failure of a single transducer might lead to an unnecessary shutdown.

Dynamic Motion. Vibratory motion of a rotor system caused by mechanisms that are active only when the rotor is turning at speeds above slow roll speed.

Dynamic Signal Analyzer (DSA). Vibration analyzer that uses digital signal processing and the Fast Fourier Transform to display vibration frequency components. DSAs also display the time domain and phase spectrum, and can usually be interfaced to a computer.

Eccentricity, Mechanical. The variation of the outer diameter of a shaft surface when referenced to the true geometric centerline of the shaft. Out-of-roundness.

Eccentricity Ratio. The vector difference between the bearing centerline and the average steady-state journal centerline.

Eddy Current. Electrical current which is generated (and dissipated) in a conductive material in the presence of an electromagnetic field.

Electrical Runout. An error signal that occurs in eddy current displacement measurements when shaft surface conductivity varies.

Engineering Units. In a DSA, refers to units that are calibrated by the user (e.g., in/s, g's).

External Sampling. In a DSA, refers to control of data sampling by a multiplied tachometer signal. Provides a stationary display of vibration with changing speed.

Fast Fourier Transform (FFT). A computer (or microprocessor) procedure for calculating discrete frequency components from sampled time data. A special case of the discrete Fourier transform where the number of samples is constrained to a power of 2.

Filter. Electronic circuitry designed to pass or reject a specific frequency band.

Finite Element Modeling. A computer aided design technique for predicting the dynamic behavior of a mechanical system prior to construction. Modeling can be used, for example, to predict the natural frequencies of a flexible rotor.

Flat Top Filter. DSA window function which provides the best amplitude accuracy for measuring discrete frequency components.

Fluid-film Bearing. A bearing which supports the shaft on a thin film of oil. The fluid-film layer may be generated by journal rotation (hydrodynamic bearing), or by externally applied pressure (hydrostatic bearing).

Forced Vibration. The oscillation of a system under the action of a forcing function. Typically forced vibration occurs at the frequency of the exciting force.

Free Vibration. Vibration of a mechanical system following an initial force – typically at one or more natural frequencies.

Frequency. The repetition rate of a periodic event, usually expressed in cycles per second (Hz), revolutions per minute (rpm), or multiples of a rotational speed (orders). Orders are commonly referred to as 1 x for rotational speed, 2 x for twice rotational speed, etc.

Frequency Response. The amplitude and phase response characteristics of a system.

G. The value of acceleration produced by the force of gravity.

Gear Mesh Frequency. A potential vibration frequency on any machine that contains gears; equal to the number of teeth multiplied by the rotational frequency of the gear.

Hanning Window. DSA window function that provides better frequency resolution than the flat top window, but with reduced amplitude accuracy.

Harmonic. Frequency component at a frequency that is an integer multiple of the fundamental frequency.

Heavy Spot. The angular location of the imbalance vector at a specific lateral location on a shaft. The heavy spot typically does not change with rotational speed.

Hertz (Hz). The unit of frequency represented by cycles per second.

High Spot. The angular location on the shaft directly under the vibration transducer at the point of closest proximity. The high spot can move with changes in shaft dynamics (e.g., from changes in speed).

High-pass Filter. A filter with a transmission band starting at a lower cutoff frequency and extending to (theoretically) infinite frequency.

Hysteresis. Non-uniqueness in the relationship between two variables as a parameter increases or decreases. Also called deadband, or that portion of a system's response where a change in input does not produce a change in output.

Imbalance. Unequal radial weight distribution on a rotor system; a shaft condition such that the mass and shaft geometric centerlines do not coincide.

Impact Test. Response test where the broad frequency range produced by an impact is used as the stimulus. Sometimes referred to as a bump set.

Impedance, Mechanical. The mechanical properties of a machine system (mass, stiffness, damping) that determine the response to periodic forcing functions.

Influence Coefficients. Mathematical coefficients that describe the influence of system loading on system deflection.

Integration. A process producing a result that, when differentiated, yields the original quantity. Integration of acceleration, for example, yields velocity. Integration is performed in a DSA by dividing by $j\omega$, where ω is frequency multiplied by 2π. (Integration is also used to convert velocity to displacement).

Journal. Specific portions of the shaft surface from which rotor applied loads are transmitted to bearing supports.

Keyphasor. A signal used in rotating machinery measurements, generated by a transducer observing a once-per-revolution event. The keyphasor signal is used in phase measurements for analysis and balancing. (Keyphasor is a Bently Nevada trade name.)

Lateral Location. The definition of various points along the shaft axis of rotation.

Lateral Vibration. See Radial Vibration.

Leakage. In DSAs, a result of finite time record length that results in smearing of frequency components. Its effects are greatly reduced by the use of weighted window functions such as flat top and Hanning.

Linearity. The response characteristics of a linear system remain constant with input level. That is, if the response to input a is A, and the response to input b is B, then the response of a linear system to input (a + b) will be (A + B). An example of a non-linear system is one whose response is limited by mechanical stop, such as occurs when a bearing mount is loose.

Lines. Common term used to describe the filters of a DSA (e.g., 400 line analyzer).

Linear Averaging. See Time Averaging.

Low-pass Filter. A filter whose transmission band extends from dc to an upper cutoff frequency.

Mechanical Runout. An error in measuring the position of the shaft centerline with a displacement probe that is caused by out-of-roundness and surface imperfections.

Micrometer (MICRON). One millionth (.000001) of a meter. (1 micron = 1 x E-6 meters = 0.04 mils.)

MIL. One thousandth (0.001) of an inch. (1 mil = 25.4 microns.)

Modal Analysis. The process of breaking complex vibration into its component modes of vibration, very much like frequency domain analysis breaks vibration down to component frequencies.

Mode Shape. The resultant deflected shape of a rotor at a specific rotational speed to an applied forcing function. A three-dimensional presentation of rotor lateral deflection along the shaft axis.

Modulation, Amplitude (AM). The process where the amplitude of a signal is varied as a function of the instantaneous value of another signal. The first signal is called the carrier, and the second signal is callled the modulating signal. Amplitude modulation produces a component at the carrier frequency, with adjacent components (sidebands) at the frequency of the modulating signal.

Modulation, Frequency (FM). The process where the frequency of the carrier is determined by the amplitude of the modulating signal. Frequency modulation produces a component at the carrier frequency, with adjacent components (sidebands) at the frequency of the modulating signal.

Natural Frequency. The frequency of free vibration of a system. The frequency at which an undamped system with a single degree of freedom will oscillate upon momentary displacement from its rest position.

Nodal Point. A point of minimum shaft deflection in a specific mode shape. May readily change location along the shaft axis due to changes in residual imbalance or other forcing function, or change in restraint such as increased bearing clearance.

Noise. Any component of a transducer output signal that does not represent the variable intended to be measured.

Nyquist Criterion. Requirement that a sampled system sample at a frequency greater than twice the highest frequency to be measured.

Nyquist Plot. A plot of real vs. imaginary spectral components that is often used in servo analysis. Should not be confused with a polar plot of amplitude and phase of 1 x vibration.

Octave. The interval between two frequencies with a ratio of 2 to 1.

Oil Whirl/Whip. An unstable free vibration whereby a fluid-film bearing has insufficient unit loading. Under this condition, the shaft centerline dynamic motion is usually circular in the direction of rotation. Oil whirl occurs at the direction of rotation. Oil whirl occurs at the oil flow velocity within the bearing, usually 40–49% of shaft speed. Oil whip occurs when the whirl frequency coincide with (and becomes locked to) a shaft resonant frequency. (Oil whirl and whip can occur in any case where fluid is between two cylindrical surfaces.)

Orbit. The path of the shaft centerline motion during rotation. The orbit is observed with an oscilloscope connected to x and y-axis displacement transducers. Some dual-channel DSAs also have the ability to display orbits.

Oscillator-demodulator. A signal conditioning device that sends a radio frequency signal to an eddy-current displacement probe, demodulates the probe output, and provides output signals proportional to both the average and dynamic gap distances. (Also referred to as Proximitor, a Bently Nevada trade name.)

Peak Hold. In a DSA, a type of averaging that holds the peak signal level for each frequency component.

Period. The time required for a complete oscillation or for a single cycle of events. The reciprocal of frequency.

Phase. A measurement of the timing relationship between two signals, or between a specific vibration event and a keyphasor pulse.

Piezoelectric. Any material which provides a conversion between mechanical and electrical energy. For a piezoelectric crystal, if mechanical stresses are applied on two opposite faces, electrical charges appear on some other pair of faces.

Polar Plot. Polar coordinate representation of the locus of the 1 x vector at a specific lateral shaft location with the shaft rotational speed as a parameter.

Power Spectrum. See Auto Spectrum.

Preload, Bearing. The dimensionless quantity that is typically expressed as a number from zero to one where a preload of zero indicates no bearing load upon the shaft, and one indicates the maximum preload (i.e., line contact between shaft and bearing).

Preload, External. Any of several mechanisms that can externally load a bearing. This includes "soft" preloads such as process fluids or gravitational forces as well as "hard" preloads from gear contact forces, misalignment, rubs, etc.

Proximitor. See Oscillator/Demodulator.

Radial. Direction perpendicular to the shaft centerline.

Radial Position. The average location, relative to the radial bearing centerline, of the shaft dynamic motion.

Radial Vibration. Shaft dynamic motion or casing vibration which is in a direction perpendicular to the shaft centerline.

Real Time Analyzer. See Dynamic Signal Analyzer.

Real Time Rate. For a DSA, the broadest frequency span at which data is sampled continuously. Real time rate is mostly dependent on FFT processing speed.

Rectangular Window. See Uniform Window.

Relative Motion. Vibration measured relative to a chosen reference. Displacement transducers generally measure shaft motion relative to the transducer mounting.

Repeatability. The ability of a transducer or readout instrument to reproduce readings when the same input is applied repeatedly.

Resolution. The smallest change in stimulus that will produce a detectable change in the instrument output.

Resonance. The condition of vibration amplitude and phase change response caused by a corresponding system sensitivity to a particular forcing frequency. A resonance is typically identified by a substantial amplitude increase, and related phase shift.

Rolling Element Bearing. Bearing whose low friction qualities derive from rolling elements (balls or rollers), with little lubrication.

Root Mean Square (rms). Square root of the arithmetical average of a set of squared instantaneous values. DSAs perform rms averaging digitally on successive vibration spectra.

Rotor, Flexible. A rotor which operates close enough to, or beyond its first bending critical speed for dynamic effects to influence rotor deformations. Rotors which cannot be classified as rigid rotors are considered to be flexible rotors.

Rotor, Rigid. A rotor which operates substantially below its first bending critical speed. A rigid rotor can be brought into, and will remain in, a state of satisfactory balance at all operating speeds when balanced on any two arbitrarily selected correction planes.

RPM Spectral Map. A spectral map of vibration spectra versus rpm.

Runout Compensation. Electronic correction of a transducer output signal for the error resulting from slow roll runout.

Seismic. Refers to an inertially referenced measurement or a measurement relative to free space.

Seismic Transducer. A transducer that is mounted on the case or housing of a machine and measures casing vibration relative to free space. Accelerometers and velocity transducers are seismic.

Signal Conditioner. A device placed between a signal source and a readout instrument to change the signal. Examples: attenuators, preamplifiers, charge amplifiers.

Signature. Term usually applied to the vibration frequency spectrum which is distinctive and special to a machine or component, system or subsystem at a specific point in time, under specific machine operating conditions, etc. Used for historical comparison of mechanical condition over the operating life of the machine.

Slow Roll Speed. Low rotative speed at which dynamic motion effects from forces such as imbalance are negligible.

Spectral Map. A three-dimensional plot of the vibration amplitude spectrum versus another variable, usually time or rpm.

Spectrum Analyzer. An instrument which displays the frequency spectrum of an input signal.

Stiffness. The spring-like quality of mechanical and hydraulic elements to elasticity deform under load.

Strain. The physical deformation, deflection, or change in length resulting from stress (force per unit area).

Subharmonic. Sinusoidal quantity of a frequency that is an integral submultiple of a fundamental frequency.

Subsynchronous. Component(s) of a vibration signal which has a frequency less that shaft rotative frequency.

Time Averaging. In a DSA, averaging of time records that results in reduction is asynchronous components.

Time Record. In a DSA, the sampled time data converted to the frequency domain by the FFT. Most DSAs use a time record of 1024 samples.

Torsional Vibration. Amplitude modulation of torque measured in degrees peak-to-peak referenced to the axis of shaft rotation.

Tracking Filter. A low-pass or band-pass filter which automatically tracks the input signal. A tracking filter is usually required for aliasing protection when data sampling is controlled externally.

Transducer. A device for translating the magnitude of one quantity into another quantity.

Transient Vibration. Temporarily sustained vibration of a mechanical system. It may consist of forced or free vibration or both. Typically this is associated with changes in machine operating condition such as speed, load, etc.

Transverse Sensitivity. See Cross-Axis Sensitivity.

Trigger. Any event which can be used as a timing reference. In a DSA, a trigger can be used to initiate a measurement.

Unbalance. See Imbalance.

Uniform Window. In a DSA, a window function with uniform weighting across the time record. This window does not protect against leakage, and should be used only with transient signals contained completely within the time record.

Vector. A quantity which as both magnitude and direction (phase).

Waterfall Plot. See Spectral Map.

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243 The Fundamentals of Signal Analysis.
The time, frequency, and modal domains are explained without rigorous mathematics. Provides a block-diagram level understanding of DSAs.

245-1 Signal Averaging with HP 3582A Spectrum Analyzer.
Provides an understanding of the signal averaging techniques commonly used in DSAs, and how they can be used to improve accuracy and signal-to-noise ratio.

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