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Basic Techniques of Waveform Measurement Using an Oscilloscope

Editor's Note: This article is based on a three-part videotape series (HP p/n 90741D) originally developed to train customer technicians on the use and operation of an oscilloscope. While most of the references to controls are based on an HP 1740A Dual-Trace Oscilloscope, the information presented is basic and applies to the operation of other manufacturers' oscilloscopes as well.

Generally speaking, a technician becoming familiar with a piece of test equipment is concerned about three things:

- Knowing where and how to connect the test instrument,
- Knowing how to adjust the controls,
- And knowing how to interpret the data.

This article addresses these three basic concerns as they apply to the oscilloscope. Why the oscilloscope? Because it is probably one of the most versatile troubleshooting instruments you have on the bench. You can use it to measure voltage levels (from dc to microwave), phase differences, signal presence (or absence), logic highs or lows, frequency response, distortion, and complex waveform analysis (wave shape, overshoot, etc.) to name a few. We obviously can't show you how to use the scope in all these endeavors. We can, however, give you the basics to cover the three original concerns — how to connect it, adjust it, and read it.

Once these concepts are mastered, the only remaining hurdle for you is to locate the controls on the scope's front panel. Most manufacturers try to help you by grouping similar controls together and separating the different groups by color or lines on the front panel.

GETTING BACK TO THE BASICS

The oscilloscope presents a voltage vs. time display of a waveform on a cathode ray tube (CRT). Inside the CRT, an electron beam draws the waveform on a phosphor-coated screen. This screen presents three types of information: voltage information on the vertical or Y axis, time information on the horizontal or X axis, and intensity information on the Z axis. All oscilloscopes have controls to adjust the voltage, time and intensity information in order to present a meaningful picture on the CRT. Figure 1 shows a block diagram of the basic circuits that these controls operate.

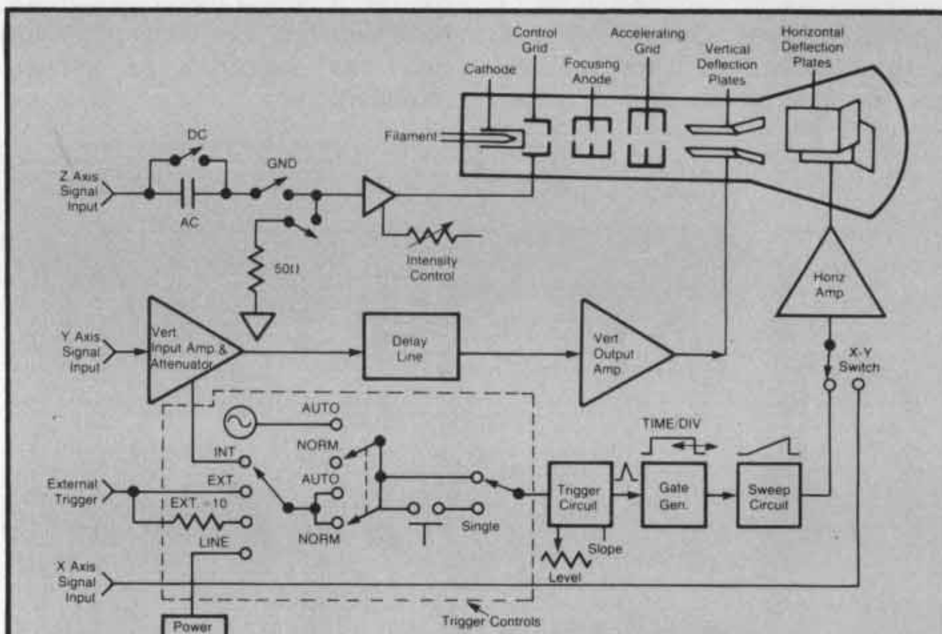

Figure 1. Block diagram of a basic oscilloscope

Part 1 of this article describes most of the basic controls of an oscilloscope and how to set them up to make a basic measurement. Part 2 will conclude the series with setting up a dual-trace oscilloscope to make typical period, pulse rise time, width, propagation delay, and time-delay phase measurements.

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The Vertical Input

As shown in Figure 1, the input signal is connected to the vertical input amplifier. The vertical amplifier either attenuates or amplifies the signal for convenient viewing.

The next block the incoming signal encounters is the delay line. The delay line allows the sweep generator circuitry time to start a sweep before the signal reaches the CRT vertical deflection plates. This coordination of vertical and horizontal timing by the delay line enables viewing of the leading edge of the signal. This will be explained in greater detail later on. The vertical output amplifier provides additional amplification that is required by the CRT vertical deflection plates.

The Time Axis

Although precise horizontal deflection rates are not required in many general purpose applications, the more sophisticated scope applications require precise control of the sweep timing with respect to the signal under test. This precise control increases time interval measurement accuracy and ensures horizontal stability of the trace. Lack of this stability is seen as "jitter."

Intensity

Intensity information is provided in the form of bias control to the grid controlling the density of the electron beam. If the negative bias is sufficient, the CRT is cut off eliminating the trace.

Now let's look at the front panel of an HP oscilloscope in Figure 2 and see how the controls that operate these circuits are identified and grouped on this particular model.

VERTICAL INPUT CONTROLS

The vertical input controls generally consist of an input coupling switch, calibrated attenuator, and position control. A dual-trace scope will also have switches to select single channel, dual channel, or various combinations.

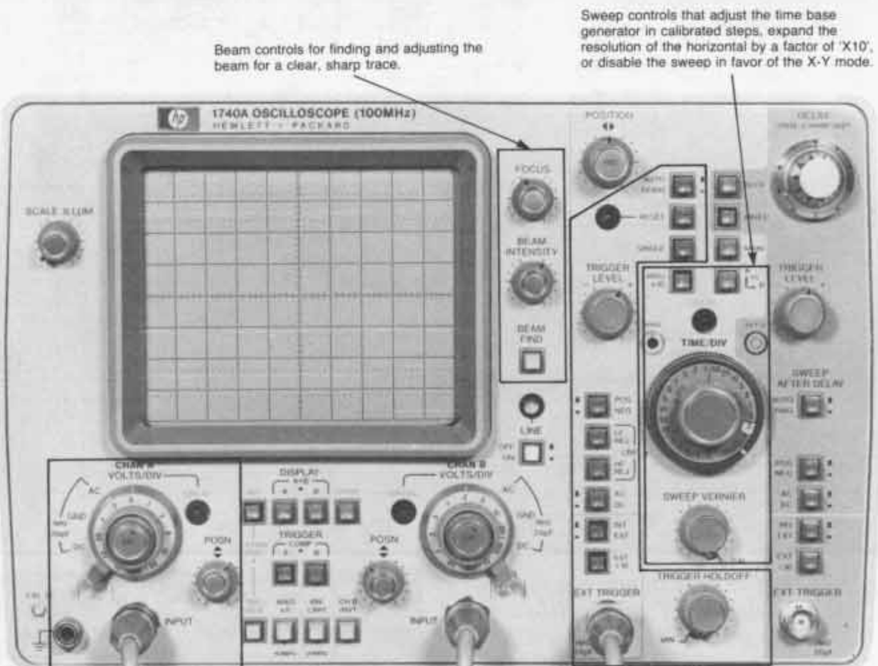


Figure 2. Front panel controls on HP 1740A Oscilloscope

The Input Coupling Switch

The Input Coupling Switch on our example 1740A Scope has four positions: AC, GND, DC and 50Ω. The AC and DC positions are designated high impedance which is typically one MΩ shunted by about 20 pF. This high input impedance, together with a standard 10 to 1 divider probe, increases the input impedance to 10 MΩ allowing you to measure waveforms with minimum circuit loading. Some scopes also allow you to select 50Ω input impedance, which is ideal for monitoring pulse and signal generators or other low impedance sources.

AC Position — The AC position couples the input signal through a dc blocking capacitor, allowing only the ac component to be viewed. AC coupling can be very useful when you want to measure a small ac signal superimposed on a large dc voltage. For example, to measure the small ac ripple voltage from a power supply, ac couple the signal to block the large dc component. Do not use the AC position to measure low frequency digital-type signals. The internal dc blocking capacitor will distort the waveform as shown in Figure 3.

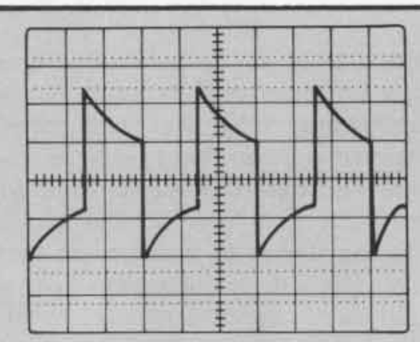


Figure 3. Distorted display as a result of trying to measure a low-frequency digital signal thru the input dc blocking capacitor (input switch in the AC position).

GND Position — The ground (GND) position is useful when you want to set a ground or zero volts reference level on the CRT screen without disturbing the input signal connection. The input signal is internally disconnected and the vertical amplifier's input is grounded. This means that you can leave the input signal connected to your scope. You won't short it out when you switch to the ground position.

NOTE

High frequency signals can create special problems for switches in scopes as well as other instruments. Therefore, when measuring HF signals, it is probably safer to go ahead and disconnect the input before presetting the controls.

DC Position — The DC position allows you to view both dc and ac components of the input signal. For example, if you have set the 0 volts reference level at the center of the screen (using the GND position) and then switch to DC, the waveform will appear showing the ac component, if any, and the signal will offset either up or down depending on whether the dc component is positive or negative. DC coupling is also used when you are measuring digital-type signals or square waves.

50Ω Position — The 50Ω position is a dc input (no blocking capacitor) with the Xc of the input amplifier very large compared to 50 ohms. The 50Ω input is used to measure high speed pulses and square waves from 50 ohm sources with minimum distortion and VSWR reflections. Most oscilloscopes with a built-in 50Ω input have internal compensation that make it a better match than an external load.

The Input Attenuator Control

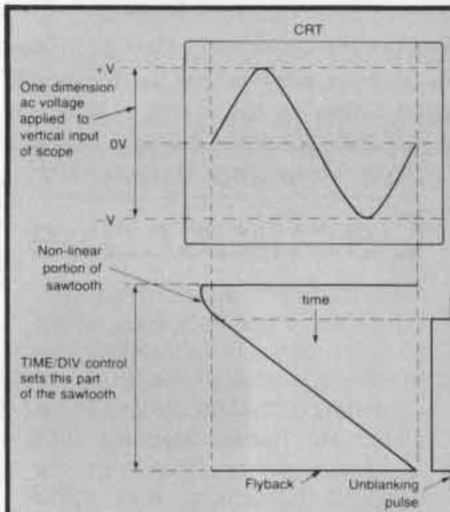
Most modern scopes use a combination of variable attenuation and adjustable vertical amplifier gain to control input signal levels. High level signals will require more attenuation/less gain so that the trace is not deflected off the screen, and low level signals will need less attenuation/more gain. The VOLTS/DIV control allows you to change the vertical sensitivity in calibrated fixed steps, from 20 volts per division to 5 millivolts per division on the 1740A. The vernier portion of the input attenuator provides continuous sensitivity control between the calibrated volts-per-division ranges. Whenever you move the vernier out of its detent position, the UNCAL light will be on, letting you know that the steps marked on the VOLTS/DIV dial are not calibrated.

Some scopes also have a vertical magnification control. MAG X 5 on the 1740A will allow you to increase the vertical sensitivity 5 times, from 5 mV to 1 mV per division, but with a reduction in bandwidth from 100 to 40 MHz. The vertical magnifier is useful when you're trying to measure low-level signals such as power supply ripple.

HORIZONTAL INPUT CONTROLS

The sweep generator, sometimes called the time-base generator, produces the sawtooth waveform which controls the rate the beam is drawn horizontally across the face of the CRT. The generator's most important function is to ensure linear beam movement, meaning the beam moves at the same rate from start to finish. Without this precise rate, accurate time measurements are not possible. Another factor of accuracy depends on the delay line. Its function is to delay the vertical input signal just enough so that the trace being displayed is the signal that started the sweep (see Figure 4).

Another function of the sweep generator is CRT unblanking. An unblanking pulse is a positive square wave that turns the trace on in relation to the rising portion of the sawtooth. What this means is that the trace is turned on during its left-to-right movement across the screen and then turned off during retrace (sometimes called flyback), which is when the beam resets from right-to-left. If the beam was not turned off in this manner, you would see the retrace lines with every sweep.



Note that there is a non-linear part to the sawtooth sweep. Also, at the end of deflection, the sweep tends to drive the horizontal power amplifier into saturation. The unblanking pulse is timed to eliminate both of these non-linear portions of the sawtooth to provide the best time interval measurement accuracy.

Figure 4. Development of a sinewave pattern on the CRT.

Sweep Speed Control

The sweep generator's sawtooth waveform is controlled by a front panel control called TIME/DIV or SEC/DIV. This calibrated control lets the operator select many different sweep speeds in order to view waveforms that vary from a few Hertz up to the bandwidth limit of the scope. The control is usually divided into steps in a 1-2-5 sequence covering the ranges of seconds, milliseconds, microseconds, and nanoseconds. These ranges correlate to how fast the beam is drawn across the CRT. The faster the beam is drawn across the CRT, the faster the time reference (i.e., the shorter the scale). For example, if the TIME/DIV control is set for 0.5 seconds-per-division, the time reference over the full 10 major divisions (vertical graticule on the CRT face) is 5 seconds. If it's set at 5 milliseconds-per-division, the full scale time reference is 50 milliseconds. Figure 4 shows how the sawtooth waveform produced by the sweep circuit develops a sinewave pattern on the CRT.

Part of the TIME/DIV control is a sweep vernier control that provides continuous adjustment of the sweep speed between the fixed TIME/DIV steps. Whenever you move the vernier out of its detent CAL position, the UNCAL light will be on letting you know that the steps marked on the TIME/DIV dial are not calibrated.

Another control that interacts with the sweep speed control is the horizontal magnifier. This control expands the sweep time by whatever factor the magnifier is labeled. For example, if your scope has a 10 division time axis (10 squares on the horizontal axis) and the magnifier has a factor of 'X 10', you would have an effective 100-division wide signal and a 10-division window. This also means the signal has 10 times the horizontal resolution as before.

Rise Time and Bandwidth

Oscilloscope Amplifier Considerations

Oscilloscope users generally consider a scope's bandwidth and rise time as its primary parameters. And rise time is usually considered the more important parameter when working with faster waveforms. This is mainly because the primary axis of the scope's display is the horizontal or time axis, and it offers the greatest resolution — less than 2% for timing measurements.

Why is the horizontal or time axis considered the major axis? Consider that the vertical axis has an 8cm window, whereas the horizontal axis has a 10cm window. 10cm provides more resolution than 8cm. Also, the range of the vertical axis (the HP 1740 for example) is 2,000 to 1 or from 1 mv/cm to 20 v/cm. The time axis has a range of 40,000,000 to 1 from 2 sec/cm to 50 ns/cm. This is 20,000 times greater than the vertical axis offers.

Signal bandwidth is of course defined as the frequency range in which signals are handled with less than a 3dB loss compared to midband performance. However, the vertical system of an oscilloscope is not flat like that of a voltmeter — it is Gaussian.

What does Gaussian response mean? It means that the vertical system of the scope alters the input signal and delays it in such a way that it produces a linear phase response. The linear phase response has a constant group delay so all the frequency components will reach the deflection plates at the same time. This results in minimum distortion of complex waveforms. Note that this Gaussian response is always falling in gain, therefore, accurate voltage measurements can only be made at dc. The frequency response will be down 1.5dB at 20% of the 3dB bandwidth, so 3% accurate amplitude measurements of sinewaves can't be made for frequencies greater than 20 MHz on a 100 MHz oscilloscope. However, the amplitude of a pulse is dc so accurate pulse amplitude measurements can be made up to the full bandwidth of the scope.

Constraints make bandwidth and rise time numerically related in well designed general purpose oscilloscopes. Bandwidth in megahertz multiplied by rise time in nanoseconds is approximately 0.35. Therefore, if your oscilloscope needs are defined in terms of one factor, for example rise time, dividing it into 0.35 will produce bandwidth.

In terms of rise time, scopes ideally should have a vertical system capable of responding at least three to five times as fast as the fastest applied step signal. In such a case, the rise time of the signal indicated on the scope will be in error by less than 2%. For example, if you are going to accurately measure 'X' microsecond pulses, the minimal requirements for scope bandwidth using the 5 times faster and 0.35 factors together can be estimated using the following rule of thumb:

$$\text{Bandwidth (minimal)} \quad \frac{1.70}{\text{Fastest Rise Time}}$$

But remember, very accurate absolute rise time measurements are not always important. *When simply comparing the rise times of two signals, scopes with a rise time equal to the rise time of the signals applied are usually considered adequate.*

In conclusion, it can be said that the modern oscilloscope with its Gaussian response is designed for pulse parameter analysis but not sinewave analysis. The characteristics of a sinewave can be better measured with instruments other than the oscilloscope. For true RMS, a voltmeter can give better amplitude measurements, a counter better frequency measurements, and a spectrum analyzer better distortion measurements. However, for a complex waveform such as a pulse, the oscillosocpe is clearly the best choise. The voltmeter can't respond fast enough to make this measurement. The trigger uncertainties of a counter mask its accuracy for pulse measurements, and nothing but a scope can measure parameters such as overshoot, droop, and ringing.

Measuring Rise Time

High-speed, precisely timed sweeps provide data of fundamental importance in waveform analysis. For example, one of the basic characteristics of a square wave or pulse is its rise time as shown in Figure 5.

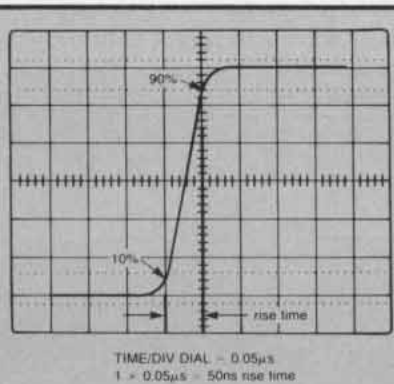


Figure 5. Rise time measurement.

Rise and fall times are usually measured between the 10% and 90% amplitude points on the leading or trailing edge of the pulse. These two points are generally accepted as industry standards for waveform measurement. To make rise time measurements easier, the HP 1740A scope has 10% and 90% dotted lines engraved on the faceplate for pulse amplitudes of both 6 and 8 divisions.

The first step in measuring rise time is to adjust the vertical controls so that pulse height is six divisions. Then use the TIME/DIV and horizontal position controls to expand the sweep speed and position the leading edge of the pulse to intersect the bottom 10% amplitude point with a convenient vertical graticule line (see Figure 5). Read the rise time by measuring the time between the 10% and 90% points. The example shown in Figure 5 is one division times 0.05 microseconds which equals a rise time of 50 nanoseconds.

How accurate is this measurement? Always remember when measuring rise time that the vertical amplifier of your scope has its limits. Many times a new technician will make the mistake of trying to measure the rise time of a 10 kHz pulse train with a 500 kHz scope (sounds reasonable), without realizing that the actual rise time of the pulse is faster than the vertical amplifier can respond to. Refer to your operating manual for rise time specifications. If you don't have a manual use the following rule of thumb:

Bandwidth x Rise Time = .35

Therefore, if you have a 500 kHz scope, don't try and measure rise times faster than .7μs. In fact, the vertical system of your scope should be two to five times faster than the rise time of the applied signal. In such a case, the rise time of the signal indicated on the scope will be in error by less than two percent.

Measuring Pulse Width

Measuring the pulse width of a digital signal is accomplished by using the TIME/DIV control and other sweep circuit controls as necessary to make the pulse as high and wide as possible to take advantage of the full scale accuracy of the instrument.

The first step in measuring pulse width is to adjust the vertical controls so that pulse height is six divisions (i.e., enough height to easily see the 50% point). Then use the TIME/DIV control to expand the sweep speed so that one pulse is in the center of the screen. Do not move the vernier control out of its CAL position. Pulse width is measured at the 50% amplitude points. Use the vertical and horizontal position controls to center the pulse around the center horizontal graticule line with the pulse's leading edge over a convenient vertical graticule. Count the number of divisions between the 50% points and multiply that times the main sweep speed read from the TIME/DIV dial. The example shown in Figure 6 is eight divisions times 0.5 microseconds which equals a pulse width of 4 microseconds (8 div. $\times$ 0.5 μs = 4.0 μs). To determine the accuracy of this measurement, look up the main time base accuracy specification of your scope and multiply it by the final full scale setting. For example, an accuracy figure from the manual of 3% full scale would be 0.03 times full scale on our scope. Full scale is determined by multiplying the TIME/DIV dial setting times full scale on the CRT (0.5 μs per div. $\times$ 10 div. = 5.0 μs). So 5.0 microseconds times 0.03 accuracy equals 150 nanoseconds (0.03 $\times$ 5 μs = 150 ns). The pulse shown in Figure 6 then is 4.0 μs $\pm$ 150 ns.

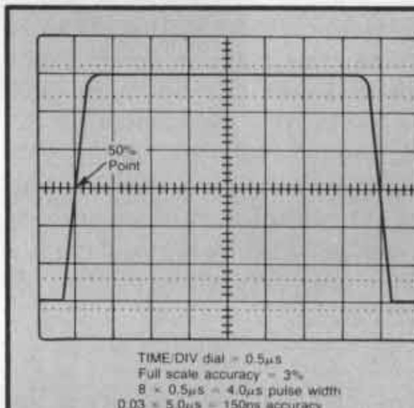


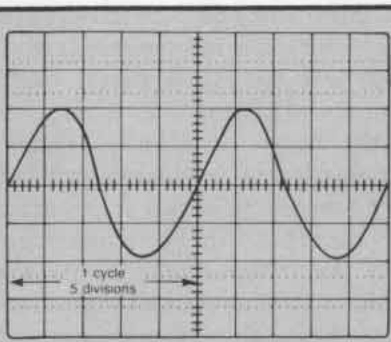
Figure 6. Pulse width measurement of a square wave.

Part 2 of this series will show you how to make the same measurement using other controls to obtain greater accuracy.

Frequency Measurements

Frequency is the reciprocal of the time period for one cycle. For example, the time period of the signal shown in Figure 7 is obtained by counting the number of horizontal divisions covered by one cycle (five) and multiplying that times the setting of the TIME/DIV control (0.2 ms). Then take the reciprocal.

$$f = \frac{1}{t} = \frac{1}{5 \times 0.2\ \text{ms}} = \frac{1}{10^{-3}} = 1.0\ \text{kHz}$$



TIME/DIV dial = 0.2ms

$f = \frac{1}{t} = \frac{1}{5 \times 0.2\text{ms}} = \frac{1}{10^{-3}} = 1\text{kHz}$

Figure 7. Frequency (time period) measurement of a sinewave.

X-Y Operation

The X-Y mode of operation is a two-dimensional representation of two ac voltages. The vertical or 'Y' input signal deflects the beam up and down while the horizontal or 'X' input signal replaces the scope's sweep generator and deflects the beam horizontally. A third dimension can be added by modulating the beam's intensity through the 'Z' axis.

One of the more common uses of the X-Y mode is to generate Lissajous patterns to check phase. For example, the transistor checker discussed in the Sept.-Oct. and Nov.-Dec. 1974 issues of Bench Briefs provides a Lissajous pattern that indicates the voltage-to-current characteristic of a diode junction. Another more sophisticated use is in the area of circuit frequency response where you turn your scope into a simple network analyzer.

Figure 8 shows some of the various Lissajous patterns you can expect using the X-Y mode. Note that Figure 8f shows what is commonly called a "bow-tie" pattern and is the result of the deflection voltages having a 1:2 frequency ratio. To obtain the ratio of vertical and horizontal deflection frequencies from any Lissajous pattern, count the number of horizontal tangent points, and divide this number by the number of vertical tangent points. If you use this method, always make certain that the trace contains visible crossovers, that they are not masked by trace coincidence; that is, the horizontal tangent points don't fall together.

Figure 9 represents a frequency response curve and is obtained by connecting a sweep generator to both the input of the circuit under test and the 'X' axis. The output of the circuit is connected to the 'Y' axis. The oscilloscope becomes a simple network analyzer that is a swept receiver that provides a visual display

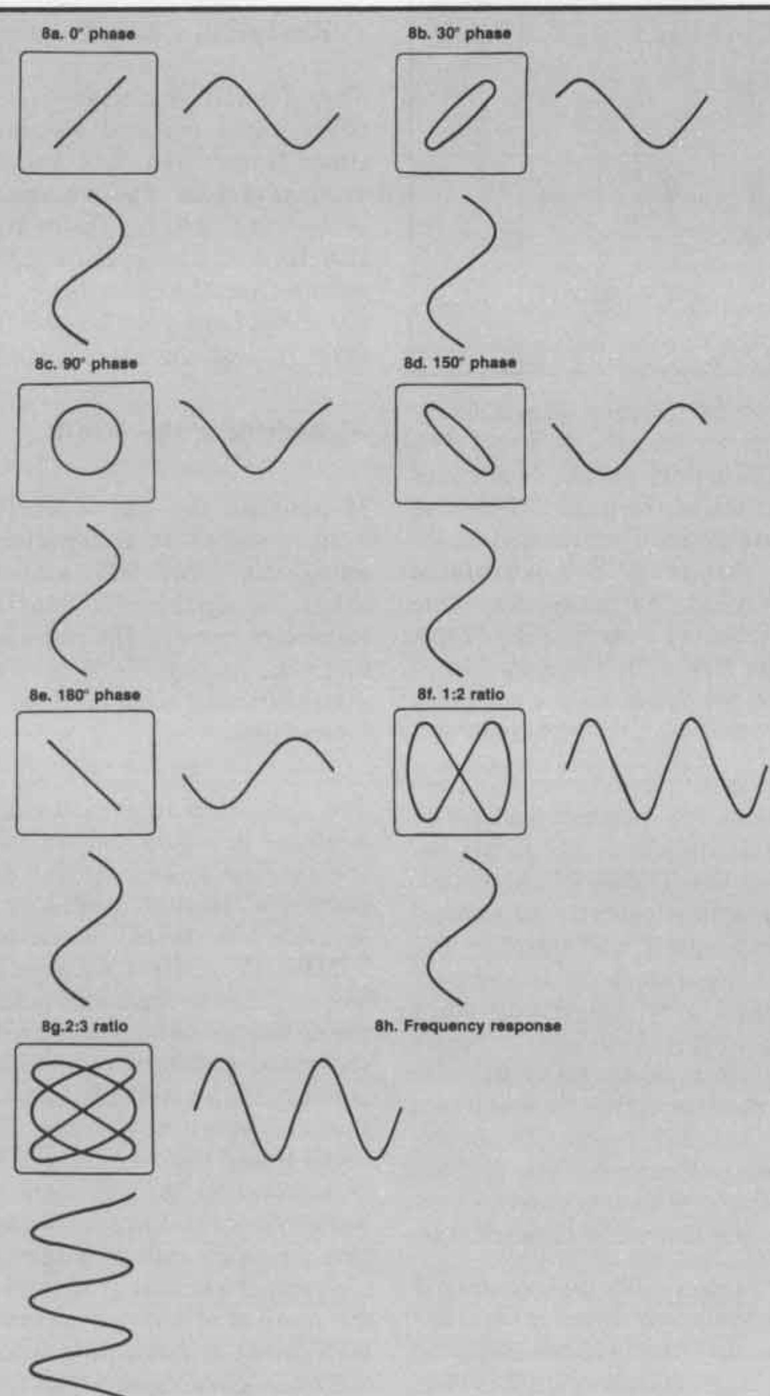


Figure 8. X-Y mode of operation showing typical examples of Lissajous patterns.

of amplitude versus frequency. It shows how energy is distributed as a function of frequency.

NOTE

X-Y operation is limited by horizontal amplifier frequency response and phase difference between the horizontal and vertical amplifiers. Refer to your operating manual for specifications.

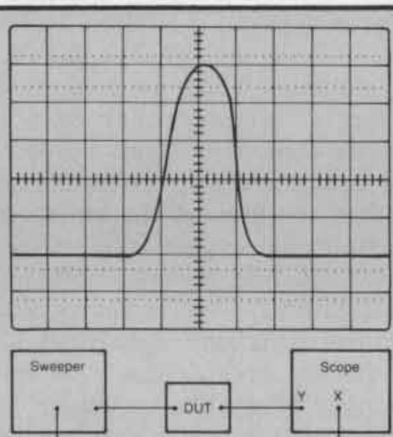


Figure 9. X-Y mode of operation showing a simple network analyzer-type pattern of a frequency response curve

TRIGGER CONTROLS

The purpose of the trigger circuit is to produce a stable display. This is accomplished by synchronizing the sweep signal discussed earlier so that each trace is written right on top of the previous one. You see one single trace, but it is actually being refreshed on each sweep.

Several controls allow you to select the source, positive or negative mode, and level of the synchronizing trigger signal as shown in the simplified diagram Figure 1. The following table is an abbreviated description of the basic controls and their functions.

Auto/Normal

This switch is probably the greatest source of "pilot error" in oscilloscope operation. In simple terms, Normal mode requires a trigger signal to generate a sweep — Auto does not.

Auto Mode — The Auto mode selects an internal oscillator or multivibrator that is used to trigger the sweep generator in order to produce a reference baseline — if there is no other trigger source. As soon as you select one of the three trigger sources (internal, external, or line) that trigger source is used to start the sweep generator. If the trigger source frequency is below approximately 40 Hertz, you must switch to the Normal mode to obtain stable triggering. Stated another way, the Auto mode is used to obtain a reference baseline when you are adjusting the controls for focus, intensity, position, and dc reference. It also keeps the baseline on the CRT if you remove the input signal.

Normal Mode — The Normal mode requires a trigger signal from one of the three sources (internal, external, or line) in order to generate a reference baseline or sweep. The "pilot error" mentioned earlier usually occurs when you have set the scope up for internal triggering and the mode switch is in the normal position. If you don't have a signal connected to the vertical input of the scope, you won't have a trigger signal — hence no trace. This loss of trace with loss

BASIC TRIGGERING CONTROLS

Typical Name	Positions	Functions
Mode	AUTO	Connects sweep to multivibrator so sweep free-runs in absence of adequate trigger signal.
	NORMAL	Connects trigger circuit to one of three sources: input signal, external signal, or line.
	SINGLE	Sweep will start only upon the occurrence of the trigger signal that meets the conditions of level and slope after the button is pushed.
Source	INT	Uses sample of input signal to start sweep.
	EXT	Uses sample of some external signal to start sweep. External signal is usually related to input signal.
	EXT ÷ 10	Same as EXT except attenuates external signal by a factor of 10.
	LINE	Uses sample of power source. Useful for viewing events related to power line frequency.
Trigger level	VARIABLE −1.5v to +1.5v (EXT) −15v to +15v (EXT÷10)	Permits selection of triggering at any point (level) on the positive- or negative-going edge of the displayed waveform.
Slope	POS (+) NEG (−)	Sets up the triggering circuit so that the displayed signal is triggered on the positive- or negative-going edge.

of input can be a valuable troubleshooting aid. Say, for example, you are probing a circuit looking only for presence or absence of a signal. If you adjust the trigger level control for an optimum level, and then probe a point in the circuit that has no signal present, there will be nothing to trigger the display and the screen will be blank. Figure 1 shows a simplified representation of how the trigger controls are interlocked.

Trigger Level and Slope

Trigger Level and Slope controls allow you to select any point on the positive or negative edge of the displayed waveform to trigger the sweep circuit (see Figure 10). Usually, when the scope is in the Internal Trigger mode, the level control will select any point on the vertical waveform displayed. With external trigger signals, the control has a ± voltage limit (refer to the operating manual).

Internal Trigger

When the switch is set for Internal Triggering, it means that a portion of the input signal is tapped off, as shown in Figure 1, and sent to the trigger circuit. The CRT will display a *portion* of the input signal related to the first occurrence of a positive or negative slope of the input signal (depending on how you have set the Slope and Level controls). **This allows you to view a time event related to the input signal.** If you are using a dual-channel scope, you must know which input channel will trigger the sweep circuit and use that channel for your input. Part 2 of this article will explore some of the various triggering options available for dual-channel viewing.

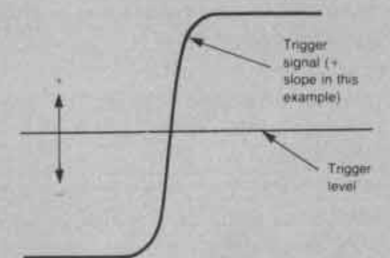


Figure 10. Trigger level control varies the voltage level to the trigger circuit. This figure shows that positive slope has been selected.

If you are using the internal trigger mode for troubleshooting, you may have to re-adjust the trigger level control to maintain a trace as you probe different points in the circuit under test. The reason this occurs is because the trigger circuit has been initially adjusted (by you) to trigger the sweep at some positive or negative voltage level. Therefore, as you move the probe from point-to-point monitoring different signal levels, the voltage level to the trigger circuit is also constantly changing. To eliminate this inconvenience, use the External Trigger mode and connect the external trigger to a low rep rate timing signal from the circuit under test. In a digital circuit, use a sub-multiple of the clock pulse rate.

External Trigger

When the switch is set for External Triggering, you must provide a signal to a connector on the scope marked EXT TRIGGER. If the signal voltage exceeds the input voltage limit (refer to your manual), then use the EXT ÷ 10 trigger input. A good rule-of-thumb is use a 10:1 probe on EXT and no probe on EXT ÷ 10. This will help prevent saturation of the trigger comparitor. The External Trigger signal is usually derived from a low rep-rate timing signal related to the input signal. The CRT will display the input signal on each occurrence of the trigger signal. **This allows you to view an event time-related to the trigger source.** The Trigger Level and Slope controls work the same for an external triggered signal as an internal triggered signal.

One method of viewing the time relationship between the input signal and external trigger signal is with a dual-channel scope. Use one input to look at the signal and one input to look at the trigger. You must know which input channel will trigger the sweep circuit and use that channel for the trigger input. Then set the source switch for INT.

If you are going to use an external trigger signal, it is advised that you first look at that signal on the input of your scope. You must determine if it has a dc component or noise greater than the trigger level you are trying to set up (or possibly exceeding the limit of the input). For example, the trigger level range of your scope may be ± 1.5 volts (±15 through EXT ÷ 10). If you try to use an external trigger signal with a dc component greater than 1.5 volts, you won't be able to trigger the sweep unless you block that dc. Some scopes have ac coupling (selectable) built in — other do not. At any rate, you *must* use dc coupling for trigger signals below about 20 Hz.

Your external trigger signal may also have power line pick-up or possibly RF noise. In either case, you need to filter out the unwanted portion in order to obtain a stable display. Some scopes have built-in filters while others do not. The point is, if you use external triggering, make certain the signal is clean.

Line Trigger

In the Line mode, the display is triggered by a sample of the power line which is usually 50 or 60 Hertz. Line triggering is often used when you want to determine if there's any relationship between the displayed signal and the line frequency (often called power line hum).

Trigger Holdoff

Some oscilloscopes may have this specialized variable control that is used in conjunction with the Trigger Level control. Trigger Holdoff increases the time between sweeps and helps stabilize the display when internally triggering off a complex digital signal or RF signal.

PUTTING IT ALL TOGETHER

Now that you have an idea of what all the basic controls are for, let's put them all together in step-by-step order to actually set up your scope.

1. Turn-On and Preset (before the signal is connected)

- Turn on the power and allow approximately 30 seconds for warm up.
- Preset the trigger mode switch to Auto and turn the intensity control up.
- If there's still no display, use the beam finder together with the horizontal and vertical position controls to bring the trace to center screen.
- Adjust the intensity control to a comfortable viewing level. Adjust the focus control for sharpest trace.
- Adjust the input attenuator control to its highest setting. This will prevent the trace from being deflected off screen if the signal has a large dc component or is a very large ac signal.
- Set the input coupling switch according to the following criteria:
  - — 50Ω if the source is a pulse or signal generator.
  - — DC if the source is a low-frequency digital signal (square wave).
  - — AC if the source has a large DC component that needs blocking or for general purpose probing.
- Connect the input signal and adjust the input attenuator control to obtain a reasonable display.
- Adjust the sweep speed control until you get a display you can recognize.

2. Fine Tuning

The following steps are contingent on the type of oscilloscope that you have. A lot of brands won't have all of the controls that we have been discussing, and some brands may have more. The point is, the theory is the same regardless of what the control is called or even if you have one.

NOTE

The following axioms apply when you are using an external trigger signal.

Axiom #1: The trigger signal must be clean and free of noise. If your scope has built-in filters, use them.

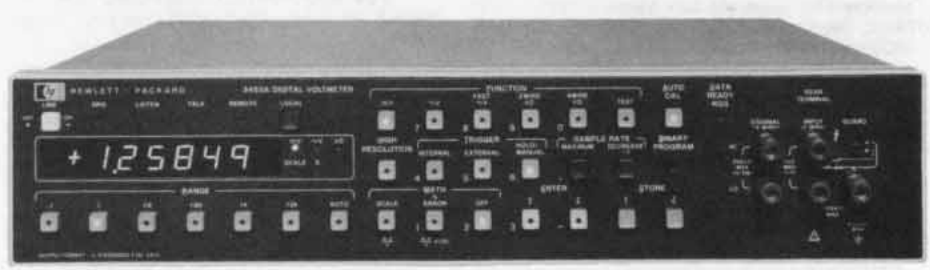
Axiom #2: If the trigger signal has a large dc component, it must be blocked by a capacitor (e.g., 0.1 μF). If your scope has ac/dc selection built into the trigger input controls, use the ac position to block the unwanted dc component.

- Select the trigger source. You can trigger the sweep from an external, internal or line frequency signal.
- If the frequency of the trigger signal is less than approximately 40 Hertz, change the mode switch to Normal.
- If you have selected external trigger, select either ac or dc trigger coupling. Use ac if the trigger signal contains a large dc component. Use dc if the trigger signal frequency is less than 20 Hertz.
- Always use the EXT ÷ 10 input if you are not using a divider probe to connect the external trigger signal to the scope.

Part 2 will go into more detail on triggering and probe equalization in preparation to making measurements.

3455A Digital Voltmeter

Does your 3455A "hang-up" in its turn-on mode? Or does it sometimes display out-of-spec low frequency readings when in normal AC, or intermittently read incorrect data when autoranging? If so, there are some resistor/capacitor changes listed in service notes 3455A-7A and 3455A-15 that can correct and improve the voltmeter's reliability. Order the 3455A service notes with the order form at the rear of *Bench Briefs*.



supplement to

BENCH BRIEFS SERVICE NOTE INDEX

Need Any Service Notes?

Here's the latest listing of Service Notes available for Hewlett-Packard products. To obtain information for instruments you own, remove the order form and mail it to the HP distribution center nearest you.

140T DISPLAY
140T-10. Serials 1752A and below. Modification to prevent oscillations in the -12.6 volt power supply.

141T DISPLAY
141T-9. Serials 1850A and below. Modification to prevent oscillations in the -12.6 volt power supply.
141T-10. Serials 1850A and below. Modification to prevent noise in the low voltage power supplies.

204C/D OSCILLATOR
204C/D-3B. Serials 204C and 204C-H20: 0989A18215 and below and 204D: 1105A05485 and below. Modification to accept NI-CAD batteries, Option 002 only.
204C/D-4. Safety. Serials 204C: 0989A14605 and below, 204C-H20, Option 02: 0989A14855 and below and 204D: 1105A03415 and below. Modification to improve safety grounding.

209A OSCILLATOR
209A-8. Safety. Serials 1045A05846 and below. Modification to improve safety grounding.

214B PULSE GENERATOR
214B-2. Serials 1846G 00321 and below. Power supply modification.

608E/F SIGNAL GENERATORS
608E/F-20. 608E: Serials 1826A and below and 608F: all serials. Preferred part replacement for series regulator transistor Q1.

612A SIGNAL GENERATOR
612A-11. Serials 1826A and below. Preferred part replacement for series regulator transistor Q1.
612A-12. Serials 1914A and below. Modification for improved external modulation frequency accuracy.

680 STRIP CHART RECORDER
680-7-S. All serials before 1200. Modification to improve safety grounding.
680-8. All serials. Preferred gear plate in transmission assemblies.

1200A/B OSCILLOSCOPE
1200A/B-5A. All serials. Preferred replacement for high voltage oscillator A6Q4.

1201A/B OSCILLOSCOPE
1201A/B-5A. All serials. Preferred replacement for high voltage oscillator A6Q4.

1202A/B OSCILLOSCOPE
1202A/B-2A. All serials. Preferred replacement for high voltage oscillator A6Q4.

1205A/B OSCILLOSCOPE
1205A/B-2A. All serials. Preferred replacement for high voltage oscillator A6Q4.

1207A/B OSCILLOSCOPE
1207A/B-5A. All serials. Preferred replacement for high voltage oscillator A6Q4.

1208A OPTION H11 PERSISTENCE 'SCOPE
H11-1208A-12. Serials 1306A and below. Preferred replacement for high voltage oscillator A6Q4.
H11-1208A-13. Serials 1330A and below. Preferred replacement for high voltage oscillator A6Q4.

1215A/B OSCILLOSCOPE
1215A/B-1A. All serials. Preferred replacement for high voltage oscillator A6Q4.

1217A/B OSCILLOSCOPE
1217A/B-2A. All serials. Preferred replacement for high voltage oscillator A6Q4.

1302A DISPLAY
1302A-1. Serials 1643A and below. Preferred parts replacement to increase the reliability of the X and Y amplifiers.

1304A DISPLAY
1304A-1. Serials 1715A and below. Preferred parts replacement to increase the reliability of the Z amplifier.

1333A X-Y DISPLAY
1333A-6. All prefixes. Preferred parts replacement to improve reliability of Z-axis amplifier.

1335A X-Y DISPLAY
1335A-10. All prefixes. Preferred replacement to improve reliability of Z-axis amplifier.

1350A GRAPHICS TRANSLATOR
1350A-5. All serials. Program modification to eliminate a bright spot which appears on screen when writing into location 2047 or the data in location 2047 is not displayed.

1600A LOGIC STATE ANALYZER
1600A-2. Serials 1714A05004 and below. Modification to prevent incorrect data storage into "B" table.

1640A SERIAL DATA ANALYZER
1640A-7. All serials. Preferred parts replacement for 8251 model USARTs.

1722A/B OSCILLOSCOPE
1722A-4A. All serials. Extender board kit to facilitate troubleshooting.
1722A-6A. All serials. Preferred replacement for attenuator detent wheel.

1744A OSCILLOSCOPE
1744A-1. Serials 1915A and below. Modification to reduce "write-through" and defocusing.

2804A QUARTZ THERMOMETER
2804A-2. All serials. Modification to prevent random reset.

3060A BOARD TEST SYSTEM
3060A-1. All serials. Proper configuration to prevent missing characters on 2640B CRT.

3437A SYSTEM VOLTMETER
3437A-3. All serials. Service procedure to fix sticky front panel pushbuttons.
3437A-4. Serials 1630A02270 and below. Recommended replacement for A2U124.

3455A DIGITAL VOLTMETER
3455A-7A. Serials 1622A05650 and below. Modification to improve turn-on reliability.
3455A-15. Serials 1622A06300 and below. Modifications to improve true RMS low frequency response and data reliability.
3455A-16. Serials 1622A05300 and below. Procedure to replace relay A10K1.

3465A/B DIGITAL MULTIMETER
3465A-5. All serials. Replacement part numbers for 3465A batteries: Battery P/N for HP use: 00035-60024. Customer use: Accessory 82001A.
3465B-2. All serials. Replacement part numbers for 3465B batteries: Battery P/N for HP use: 00091-60013. Customer use: Accessory 82033A.

3581C (C MODEL ONLY) WAVE ANALYZER
3581A/C-5. Serials 1411A01107 and below, and serials 1411A01110, 1411A01113, 1411A01114, 1411A01115. Audio amplifier modification to improve performance.

3582A SPECTRUM ANALYZER
3582A-2. Serials 03582-00151 to 03582-00810. Addition of diodes to protect transistor Q10 on A13 PCB.

3745A/B SELECTIVE LEVEL MEASURING SET
3745A/B-18C. Serials 1812U and below. Retrofit kit for special option H07.
3745A/B-20C. Serials 1812U and below. Retrofit kits for special options H15 and H16.
3745A/B-23B. Serials 1815U, 1831U and 1836U. Modification to prevent possible remote start-up problem.
3745A/B-30. Serials 1920U and below. Preferred replacement of Memory Assembly A109.
3745A/B-31. 3745A — Serials below 1930U-00347 and 3745B — Serials below 1924U-00201. Preferred replacement of capacitor A311C3.
3745A/B-32A. 3745A — Serials below 1930U-00362 and 3745B — Serials below 1924U-00201. Preferred replacement of integrated circuit A211IC6.

3747A/B SELECTIVE LEVEL MEASURING SET
3747A/B-3A. Serials 1804U and below. Addition of 10MHz crystal filter assembly to improve performance.
3747A/B-6A. Serials 1924U and below. preferred replacement of capacitor A319A1C2.
3747A/B-7B. Serials below 1916U. Preferred replacement of 256-bit shift registers on XY Driver A601.
3747A/B-8. Serials 1924U and below. Preferred replacement of Memory Assembly A109.
3747A/B-9. Serials 1915U-00129 and below. Modification to prevent unstable input autoranging.
3747A/B-10. 3747A — Serials below 1924U-00139 and 3747B — Serials below 1924U-00115. Preferred replacement of capacitor A311C3.
3747A/B-11. 3747A — Serials below 1924U-00139 and 3747B — Serials below 1924U-00110. Preferred replacement of integrated circuit A211IC6.
3747A/B-12. All serials. Installation of Option 022 to facilitate C-Message weighted filter and phase jitter.

3770A AMPLITUDE/DELAY DISTORTION ANALYZER
3770A-37A. All serials. Retrofitting instructions for Option 001, +10dBm switch.

3771A/B DATA LINE ANALYZER
3771A/B-4A. Serials below 1926U. Modification to prevent gain hits from causing dropouts.
3771A/B-6. Serials below 1937U-00160 (3771A) and 1937U-00123 (3771B). Preferred replacement of E1 Mains Module.
3771A/B-7. All serials. Retrofitting instructions for Option 061, Rack Mount.
3771A/B-8. All serials. Preferred replacement of switches A38S1 and A40S1.
3771A/B-9. All serials. Table of link positions for 3771A, 3771B and options.

3779A/B PRIMARY MULTIPLEX ANALYZER
3779A-10. Serial 1919U-00155 and below. Modification to prevent breakdown of A32U2 at switch-on.
3779A-11. Serials 1919U-00170 and below. Modification to prevent failure of integrated circuit A9U3.

3779A-12. Serials 1919U-00160 and below. Modification to the A1 assembly to allow the NKT solid state switches to be run off +15V rather than +12V supplies.
3779A-13. Serials 1936U-00185 and below. Preferred replacements of relays A1K1-K6; A8K1; A9K1-K5, K7, K9, K10; A31K1, and A37K1-K4.
3779B-10. Serials 1919U-00175 and below. Modification to prevent failure of integrated circuit A32U2 at switch-on.
3779B-11. Serials 1919U-00190 and below. Modification to prevent failure of the integrated circuit A903.
3779B-12. Serials 1919U-00160 and below. Modification to the A1 Assembly to allow the NKT solid state switches to be run off +15V rather than +12V supplies.
3779B-13. Serials 1941U-00220 and below. Preferred replacement of relays A1K1-K6; A8K1; A9K1-K5, K7, K9, K10; A31K1, and A37K1-K4.

3780A PATTERN GENERATOR/ ERROR DETECTOR

3780A-17A. All serials. Retrofit kit instructions for Option 100.
3780A-18. Serials below 1804U-00523. Retrofit kit to incorporate equaliser and attenuator in existing Option 100.

4944A TRANSMISSION IMPAIRMENT MEASURING SET

4944A-1. All serials. Field installation of Option 010, HP-IB.

4960A PAIR IDENTIFIER

4960A-2-S. Serials 1706A00340 and below equipped with selectable line voltage inputs. Modification to prevent AC line voltages @ front panel connectors.
4960A-3. Serials 1706A00325 and below. Modification to allow selectable line voltage input.
4960A-4. Serials 1706A00300 and below. Modification to remove power from line switching relays during power down.

4960B PAIR IDENTIFIER

4960B-1-S. Serials 1737A00750 and below. Modification to prevent AC line voltages appearing @ front panel connectors.
4960B-2. Serials 1737A00733 and below. Modification to remove power from line switching relays during power down.

5045A DIGITAL IC TESTER

5045A-10A. Serials 1748A00345 and below. Power supply modification to prevent overvoltage adjustment conditions.

5328A UNIVERSAL COUNTER

5328A-25A. Serials 1936A12973 or 1818U01980 and below (Option 041). Modification to improve DAC settling time.

5340A FREQUENCY COUNTER

5340A-13. Serial 1928A and below. Preferred replacement for A17 direct count amplifier.

5342A MICROWAVE FREQUENCY COUNTER

5342A-14. All serials. Information to aid in troubleshooting and repair of A26 sampler driver assembly.
5342A-15. All serials. Modification to check for A15 HP-IB SRQ Jumper in the event of no response to SRQ.
5342A-16. All serials. Power supply adjustment procedures.
5342A-17. IF troubleshooting information.
5342A-18. All serials before 1916. Preferred replacements for power supply capacitors C6 and C9.
5342A-19. Modification to add ground connection to EFC line to improve stability on Option 001 units.

5370A UNIVERSAL TIME INTERVAL COUNTER

5370A-3. Serials 1848A00490 and below. Preferred parts replacements to improve accuracy.
5370A-4. All serials. New adjustment procedure for input assemblies, A3, A4.
5370A-5. Serials 1848A00530 and below. Replacement of fuse F1 to improve electrical protection. (230 VAC) F1 fuse: 1.25A fast blow 2110-0094 and (110/115 VAC) F1 fuse: 2.50 fast blow 2110-0083.
5370A-7. Preferred replacements of external trigger start, and stop slope switches.

6206B DC POWER SUPPLY

6206B-2. Serials between 8M2352 and 1928A 05690. Preferred replacement of transistor Q4.

7220A/S GRAPHICS PLOTTERS

7220A/S-1, 7221B/S-1, 9872B/S-1. All serials. Special instructions for adjusting pen travel and pen height.

7221A GRAPHIC PLOTTERS

7221A-8/9872A-10. Serials 1913A-02831 and below. Modification to prevent Confidence Test failure indicating defective internal I/O PCA.

7221B/S GRAPHICS PLOTTERS

7220A/S-1, 7221B/S-1, 9872B/S-1. All serials. Special instructions for adjusting pen travel and pen height.

7402A OSCILLOGRAPHIC RECORDERS

7402A-10/7404A-3. All serials. Cleaning procedure to prevent pen clogging after long-term storage.
7402A-11/7404A-4. All serials. Instructions to place Scotch tape across the chart directly below pen tips to prevent pen clogging.

7404A OSCILLOGRAPHIC RECORDER

7404A-2. Serials 1906A and above. Wiring change to improve 50Hz operation.
7402A-10/7404A-3. All serials. Cleaning procedure to prevent pen clogging after long-term storage.
7402A-11/7404A-4. All serials. Instructions to place Scotch tape across the chart directly below pen tips to prevent pen clogging.

8170A LOGIC PATTERN GENERATOR

8170A-1. Serials 1915G 0216 to 1915G 00235. Modification to improve battery back-up to prevent partial memory loss.
8170A-2. Serials 1739G 00215 and below. Modification to improve battery back-up to prevent partial memory loss after replacement of A13 by ROMs.

8662A SYNTHESIZED SIGNAL GENERATOR

8662A-1. Serials 1850A00127 and below. Preferred replacement of output attenuator.

8672A SYNTHESIZED SIGNAL GENERATOR

8672A-4. All serials. Retrofitting front or rear panel RF output.
8672A-5. All serials. Exchange assembly for reference oscillator.
8672A-7. All serials. New part number for A1DT1 leveling detector.

8691A/B THRU 8695A/B RF-UNITS

8691-4A-8B, 8695-7A-7B and 8691-5B-6B. All serials. Preferred BWO replacement.

8696A AND 8697A RF UNITS

8691-4A-8B, 8695-7A-7B and 8691-5B-6B. All serials. Preferred BWO replacement.

8754A NETWORK ANALYZER

8754A-1A. Serials 1825A00175 and below. Recommended installation of heat sink insulator for A7 Source Board Assembly.
8754A-3. Serials 1914A00325 and below. Recommended replacement of integrated circuit A1209 in the event of crystal marker failure.

9571A — DTS 70

9571A-5. All serials. Software procedures to allow configuration between discs with 256 tracks versus discs with 203 tracks.
9571A-9. All serials. Software procedure to modify the driver mapping table for power fail EQT.

9872A GRAPHIC PLOTTERS

7221A-8/9872A-10. Serials 1914A-04301 and below. Modification to prevent Confidence Test failure indicating defective internal I/O PCA.

9872B/S GRAPHICS PLOTTERS

7220A/S-1, 7221B/S-1, 9872B/S-1. All serials. Special instructions for adjusting pen travel and pen height.

37201A HP-IB EXTENDER

37201A-1. Serials 1914U-00269 and below. Modification to prevent intermittent hang-up at switch on.

59306A RELAY ACTUATOR

59306A-7. Serials 1920A02380 and below. Solder the wires of A2W1 to the solder lugs to prevent intermittent connection to rear terminals.

59309A HP-IB DIGITAL CLOCK

59309A-4. Preferred replacement of HP-IB boards, P/N 59309-60005 revisions A, B, and C to prevent internal short near U14.

59403A COMMON CARRIER INTERFACE

59403A-4. All serials. Service hint to isolate 12 volt power supply failure.

63005C DC POWER SUPPLY

63005C-3, 63315D-3. Serials 1919A-02434 and below. Modification to improve stability below 5°C.
63005C-3, 63315D-3. Serials 1917A-01213 and below. Modification to improve stability below 5°C.

Attention 5420A Owners

This issue of *Bench Briefs* contains several service notes that may be of interest to you. Of primary importance is service note 5420A-21 that groups all necessary modifications that are important to the reliability of the 5420A Digital Signal Analyzer.

Owners of the 5420A can order the service notes with the order form located on the last page of *Bench Briefs*.

Also available are three application notes designed to help you obtain maximum use from your 5420A.

AN 240-0 TIME AND FREQUENCY DOMAIN MEASUREMENTS

Defines, discusses, and illustrates a wide range of important measurements made by the 5420A Digital Signal Analyzer using sampled data techniques. Includes Time Record Averaging, Auto and Cross Correlation, Auto and Cross Spectrum, Transfer Function, and more.

AN 240-1 FEEDBACK CONTROL SYSTEM MEASUREMENTS

Illustrates the application of the 5420A Digital Signal Analyzer to both time and frequency domain measurements of feedback systems.

Safety-Related Service Notes

Service Notes from HP relating to personal safety and possible equipment damage are of vital importance to our customers. To make you more aware of these important notes, they are printed on paper with a red border, and the service note number has a "-S" suffix. In order to make you immediately aware of any potential safety problems, we are highlighting safety-related service notes here with a brief description of each problem. Also, in order to draw your attention to safety-related service notes on the service note order form at the back of *Bench Briefs,* each appropriate number is highlighted by being printed in color.

204C/D, 209A OSCILLATORS AND 680 STRIP CHART RECORDER

Hewlett-Packard Corporate Standards have been changed to require an instrument to be able to pass 25 amps through the safety earth ground. Instruments with serial numbers below those listed below were manufactured before this safety standard came into being. While there does not appear to be a hazard with the old circuit design, we are notifying our customers that a modification is available and can be made at customer's expense, if desired.

204C — 0989A14605 and below
204C-H20, Option 02 — 0989A14855 and below
204D — 1105A03415 and below
209A — 1045A05846 and below
608 — All serials before 1200

The modification consists of installing a solder lug to a chassis point and connecting a 18 GA GRN/YEL wire from the power line connector earth terminal to the solder lug. For complete detailed instructions, order the appropriate service notes using the form at the back of *Bench Briefs*.

4960A/B Pair Identifier

A potential shock hazard may exist on 4960A/B Pair Identifiers with the following serial numbers:

4960A serials 1706A00340 and below
4960B serials 1737A00750 and below

It is possible for the AC power transformer primary leads to be punctured by component leads on the A6 Switch Board assembly. This would allow **ac line voltages** to appear at the front panel telephone line connectors. Installation of an insulator, HP Part #04960-00212, removes this hazard.

For complete detailed instructions, please order the appropriate service notes using the form at the back of *Bench Briefs*.

Includes a technique for obtaining the open loop gain from data taken with the loop closed and the system in normal operation. Several practical examples are illustrated.

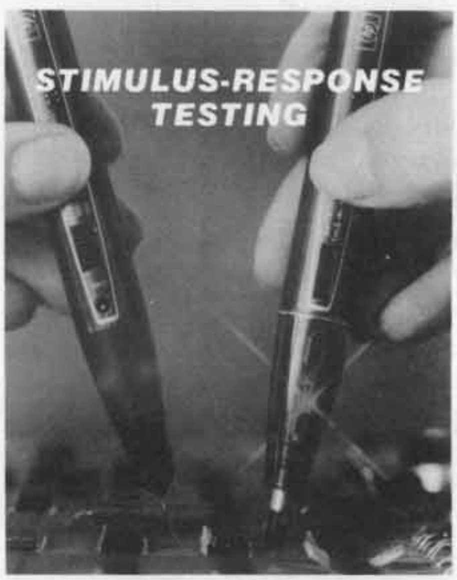
AN 240-2 IMPROVING ACCURACY OF STRUCTURAL RESPONSE MEASUREMENTS

Illustrates how to identify and correct mass loading and accelerometer loading errors. Shows the "ideal" measurement system where the test system and exciter appear on separate sides of the load cell. Describes "real" measurement set-ups and how to correct for mass loading in both shaker and impact test systems.

STIMULUS-RESPONSE TESTING USING THE IC TROUBLESHOOTERS

FAULT	STIMULUS	RESPONSE	TEST METHOD
Shorted Node[1]	Pulser[2,3]	Current Tracer[3]	• Pulse node • Follow current pulses to short
Stuck Data Bus	Pulser[2]	Current Tracer	• Pulse bus line • Trace current to device holding the bus in a stuck condition
Signal Line Short to Vcc or Ground	Pulser	Probe[3] Current Tracer	• Pulse and probe test point simultaneously • Short to Vcc or Ground cannot be overridden by pulsing • Pulse test point and follow current pulses to the short with tracer
Vcc to Ground Short	Pulser	Current Tracer	• Remove power from test circuit • Disconnect electrolytic bypass capacitors • Pulse across Vcc and ground using accessory connectors provided • Trace current to fault
Suspected Internally Open IC	Pulser[2]	Probe	• Pulse device input • Probe output for response
Solder Bridge	Pulser[2]	Current Tracer	• Pulse suspect line(s) • Trace current pulses to the fault (Light goes out when solder bridge passed)
Sequential Logic Fault in Counter or Shift Register	Pulser	Clip[3]	• Circuit clock de-activated • Use Pulser to enter desired number of pulses • Clip onto counter or shift register and verify device's truth table

1. A node is an interconnection between two or more IC's.
2. Use the Pulser to provide stimulus, or use normal circuit signals, whichever is most convenient.
3. 547A Current Tracer 545A/10525E,T Logic Probe
   548A Logic Clip 546A/10526T Logic Pulser



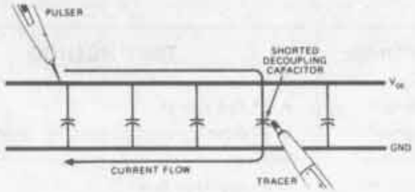
IC TROUBLESHOOTING TOOLS

In the digital troubleshooting world the idea of stimulus-response testing is a relatively new one. Tools to measure logic states have existed for quite some time, but forcing a state change, especially on a line being held LOW is something that was difficult prior to the introduction of HP Logic Pulsers. To accomplish such a task meant disconnecting a device's input from the circuit, and then pulsing the input with a source. In practical terms the technician often unsoldered and lifted an IC leg, or cut a circuit trace, then used a pulse generator to drive a gate's input.

The "why" of such destructive techniques has to do with the internal structure of standard TTL gates. A TTL gate in its LOW state is a saturated transistor to ground. To move a TTL output HIGH requires a great deal of current drive. The catch here is that continuous high current tends to destroy the TTL gate's output transistor. So, it was usually safer and easier to simply disconnect a driver from a circuit and replace it with a low current stimulus tool. The logic pulser changed this because it delivers both high current and low total energy by generating very short pulses sufficient to momentarily override TTL logic LOW states. Pulse width is never sufficiently long to degrade a gate's performance (the pulser will usually generate a TTL HIGH for only about 500 nanoseconds).

To help show how straightforward digital stimulus-response testing can be, the following table outlines seven node and gate troubleshooting problems and how pulsers and other IC troubleshooters would be used to pinpoint the fault.

Vcc-Gnd Shorts

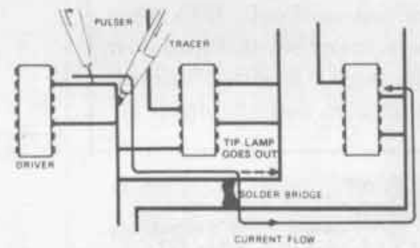


Shorts between Vcc and ground on a PC board can typically be located by using some of the following troubleshooting techniques:

1. Remove power from the circuit. Power the pulser and tracer from a 5-volt supply.
2. Lift one side of the electrolytics on the supply bus. This speeds up troubleshooting time by a factor of ten (electrolytics "eat" pulses creating many different current paths).
3. Pulse across the power supply pins or across components in the corners. Use the cables and grabbers provided with the pulser for this purpose so your hands are free to move the tracer around. Moving the pulsing point around from corner to corner and tracing current from the pulsing point helps speed fault location on tough-to-solve faults.
4. Because you're pulsing into a short, there is lots of current available. Put tracer sensitivity to 1 amp.
5. Some boards are powered through more than one connector, so parallel current paths can exist. Moving the pulsing point around is helpful because the current path can change between the pulsing point and the short.
6. Sometimes a current path will seem to disappear. Possible causes are:
   a) The PC board trace becomes wider and current "fans out," lessening the field intensity under the tracer tip.
   b) The current may pass through a plated-through hole in the PC board.
   c) Current "branches" and goes to several different places via several different paths; thereby lessening current density in the path you've been following.
7. When you think you've located the fault, verify it by moving the pulsing point to the short. No current paths should be detected elsewhere on the board if you pulse directly across a short.

As non-destructively as possible, remove the suspected component and verify that the Vcc to ground short no longer exists.

Solder/Gold/Copper Bridge Faults

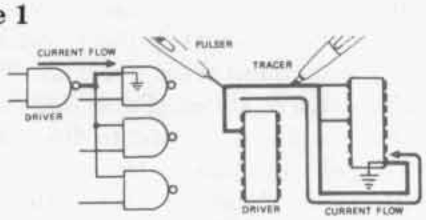


With higher density PC boards, the occurrence of shorts between two nodes or a node and a ground has become commonplace.

1. Pulse the driver output on faulty node at desired pulse rate.
2. Adjust sensitivity of the current tracer at the node driver output; use the tracer to follow current pulses to short.
3. The light on the tracer will go out when the solder bridge is passed.

Node and Gate Troubleshooting Examples

Example 1



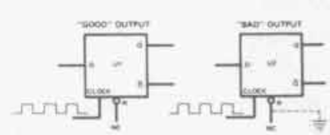
A frequently occurring troubleshooting symptom is a stuck node. In this example, the problem is to determine if the driver is dead, or if a shorted input is clamping the node to a fixed value.

a) Use the probe and pulser to test the node's logic state and to see if the state can be changed (shorts to Vcc or Gnd cannot be overridden by pulsing). In this example, the state couldn't be changed.

b) Set the current tracer reference level by adjusting tracer sensitivity until the light just lights with pulser on 100 Hz mode.

c) Use the current tracer to follow the current path to the fault.

Example 2



Here are two D-Flip-Flops. One works normally, the other doesn't change output state although input conditions are identical for both.

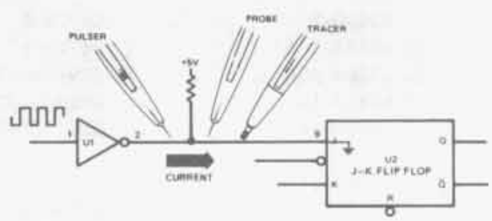
a) Use the pulser at the D input and probe Q and $\overline{Q}$ to see if the outputs change. (In this actual example, they didn't.)

b) The Reset line in the above case was found to be stuck in a LOW state by using a logic probe. Pulsing and probing simultaneously indicated the Reset line couldn't be driven HIGH, indicating the line was shorted to ground.

c) Further use of pulser and current tracer showed that the area near the Reset line drew current when pulsed and that the D-Flip-Flop would not perform operations when the Reset line was pulsed.

d) Using the pulser and tracer, the operator found a hairline solder bridge from the Reset line to ground.

Example 3

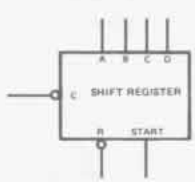


The node between U1 and U2 was stuck LOW when measured by a logic probe, although probing revealed pulse activity at U1's input.

a) Probe U1 pin 2. If no voltage activity is present, pulse pin 2 and see if the node's state can be changed.

b) In this case the state couldn't be altered using a pulser so current was traced from U1-2 to U2-9, the J-K flip-flops input.

Example 4



Outputs A, B, C, and D are LOW; other circuit inputs appear normal.

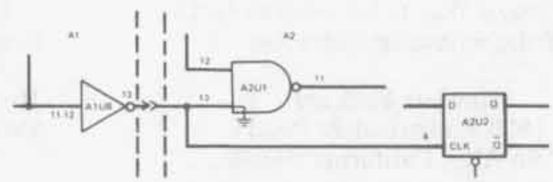
a) Use the probe and pulser to make sure A, B, C, and D aren't grounded (probe and pulse each pin — if ungrounded the states will be changed by the pulses).

b) Probe other pins on the IC and check for normal/abnormal indications.

c) Measure current at pins A, B, C, and D by pulsing each pin, and tracing to see if current flow is indicated from the pulser to the Shift Register.

d) In this example all signals are normal except A, B, C, and D. They are stuck LOW, and are not indicating current flow, which suggests an internal failure in the IC, and not in the circuits connected to it.

Example 5



Pin 13 of U1 is being held LOW. (In this case the node consisting of A1U8-13, A2U1-13 and A2U2-4 is spread over two PC boards.)

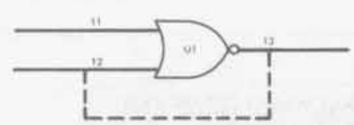
a) Use the HP-10529A Comparator to find the faulty node. The comparator is clipped onto the suspected IC and uses the in-circuit signals to drive an identical IC installed inside the comparator. The comparator identifies A1U8-13 as bad allowing you to troubleshoot further.

b) Probing and pulsing the node indicates it is stuck LOW.

c) Pulsing and current tracing at A1U8-13 indicates current is flowing toward PC board A2.

d) A2U1 is sinking current and holding the node LOW. As a result, U2 is not being clocked. The comparator located the failure (A1 U8 pin 13), but it required the tracer to indicate current flow to verify A2U1 as the cause.

Example 6



U1 tests bad using the probe and pulser. The problem is to find out the nature of the fault **before removing** what appears to be an internally shorted IC.

a) Pulse pin 12, and observe with the probe that pin 13 changes state but in the wrong direction (12 and 13 are in the **same** state).

b) Pulse pin 12 and read current at pin 13, then, reverse the two instruments. Current is identical in both directions.

c) Pins 12 and 13 are shorted together by a solder bridge on the back of the circuit board. Although originally located by pulser and probe, the tracer adds important information that keeps you from removing the IC.

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