

**HUNTRON, INC.**

# **TRACKER<sup>®</sup> 200**

## **USER MANUAL**

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P/N 21-1312**

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In North America, call 800-426-9265 or worldwide 425-743-3171.

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- ◆ FAX: 425-743-1360
- ◆ Internet E-mail: [huntron@huntron.com](mailto:huntron@huntron.com)
- ◆ Internet Home Page: <http://www.huntron.com>

## **ABOUT THIS MANUAL**

This manual covers the general operation of the Tracker 200.

This manual also covers the subject of troubleshooting using analog signature analysis (ASA) technology at the fundamental level. More in-depth and comprehensive hands-on instruction on ASA troubleshooting is available.

Contact Huntron for more information, applications and other training available for the Tracker 200 and other Huntron products.

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**Notes:**



# Introduction and Specifications

The Huntron Tracker 200 is an accessory to an oscilloscope which allows power off troubleshooting of electronic circuits by using the technique of Analog Signature Analysis.

This signature shows the V/I characteristics of an electronic device which when compared with a known good device, can assist in locating faulty components of a circuit without applying power to the board under test. This technique of troubleshooting simply involves the visual comparison of circuit signatures which can assist in isolating circuit failures due to opens, shorts, device leakage, ESD damage, power supply over-voltage and transients.

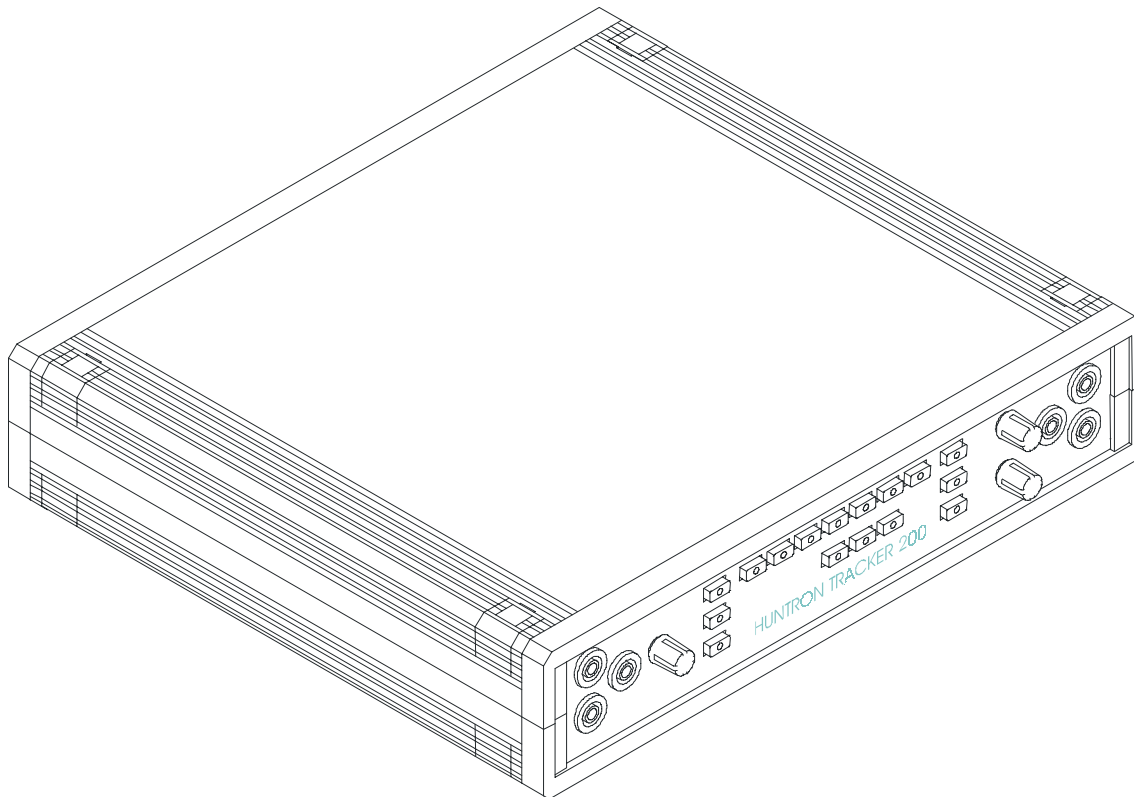


Figure 1-1. Tracker 200

## What is Analog Signature Analysis?

Analog Signature Analysis or ASA is a unique, power-off troubleshooting technique. It uses an alternating current (AC) sinewave stimulus to show the current (I) vs. voltage (V) characteristic of an unpowered component on a CRT. The IV characteristic is called an analog signature and each pin of a component can have a unique signature. When components fail, their signatures change so troubleshooting using ASA is simply a matter of finding the defective component by analyzing its signature. You can compare signatures of suspect components to signatures of known-good components.

Test current applied across a component is limited. When used carefully, this technique is non-destructive and does not damage any components. ASA has many advantages as a proven, fast, and effective troubleshooting technique.

You can:

- Troubleshoot circuitry that cannot be powered up due to a shorted condition.
- Troubleshoot in a qualitative mode, allowing you to see physical problems with a suspect component.
- Compare device characteristics with known types for better matching.
- Eliminate risk of accidental shorting across other points during POWER ON testing which could further damage the component or other components on the board.
- Minimize the risk of shock hazard since the ASA troubleshooting approach requires no power applied to the circuitry.
- Perform preventative maintenance by seeing flaws in components that could possibly lead to untimely failures.
- Look at replacement components before they are installed in circuitry to reduce the risk of installing defective ones.

The Huntron Tracker 200 graphically displays the analog signature when connected to two terminals of a component for visual interpretation. ASA may be universally applied to any type of passive component like a resistor, capacitor, or inductor, or a solid state semiconductor component like a diode, transistor, SCR, digital, analog, or mixed-signal IC. When troubleshooting a board, the resultant signature is a composite of various component signatures at a particular node in the circuitry. By understanding what different signatures mean, you can determine which components are faulty.

## Power Configuration



**CAUTION.** To avoid product damage, set the line selector switch to the correct position and install the correct fuse before applying line power.

### Line Selector Switch

The Line Selector Switch, located on the Tracker 200's back panel, selects between 100/115VAC and 230VAC. Slide the switch to the line voltage that you will be using.

### Line Fuse

The power entry module on the Tracker 200 includes the power switch (0 = OFF, 1 = ON), power cord connector, and a removable tray which holds the line fuse and a spare fuse. Make sure that replacement fuses are of the type and current rating specified. If necessary, insert the specified line fuse (see line fuse specification on page 1-9) into the fuse tray.

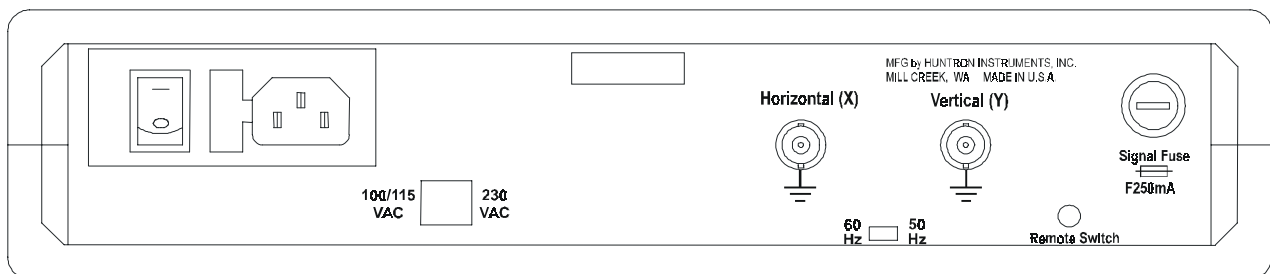


Figure 1-2. Back panel.

The line fuse should only open when there is a failure inside the instrument. Therefore the problem should always be located and corrected before fuse replacement. Be sure to always use a fuse with the type and rating specified on page 1-9.

## Signal Fuse Replacement

The Signal fuse is located on the back panel of the Tracker 200 in a panel mounted fuse holder. If the fuse opens, replace it with another 5 mm x 20 mm, F250 mA 250 V (IEC127-2/II type GDB) fuse.

## 50/60Hz Selector Switch

The 50/60Hz Selector Switch, located on the Tracker 200 back panel, is for indicating to the Tracker 200 what your line frequency is. Slide the switch to the setting that matches your line frequency.

## Unpacking Your Tracker 200

Your instrument was shipped with the following items:

**Table 1-2. Tracker 200 Shipping and Replaceable Parts List**

Part Number	Description	Quantity
98-0249*	Tracker Probes	1 pair
98-0043*	Black Ground Leads	2
98-0270*	Blue Clip Leads	2
98-0265* – 98-0016*	Power Cord (115V)/230V	1
21-1312*	Tracker 200 User Manual †	1

\* Replacements available from Huntron, Inc. See page 1-12 for ordering information.

Check the shipment carefully and contact the place of purchase if anything is missing. If there is shipping damage, then contact your freight company. If shipment is necessary, please use the original shipping carton and packing foam. If these are not available, be sure that the instrument is packed in a box with a minimum of two inches (5 cm) of cushioning material on all sides.

## Installation

The Tracker 200 requires a 2 channel Oscilloscope with X/Y capability for displaying the signature of the device under test.

1. The figure below shows a typical connection of a Tracker 200 to an oscilloscope.

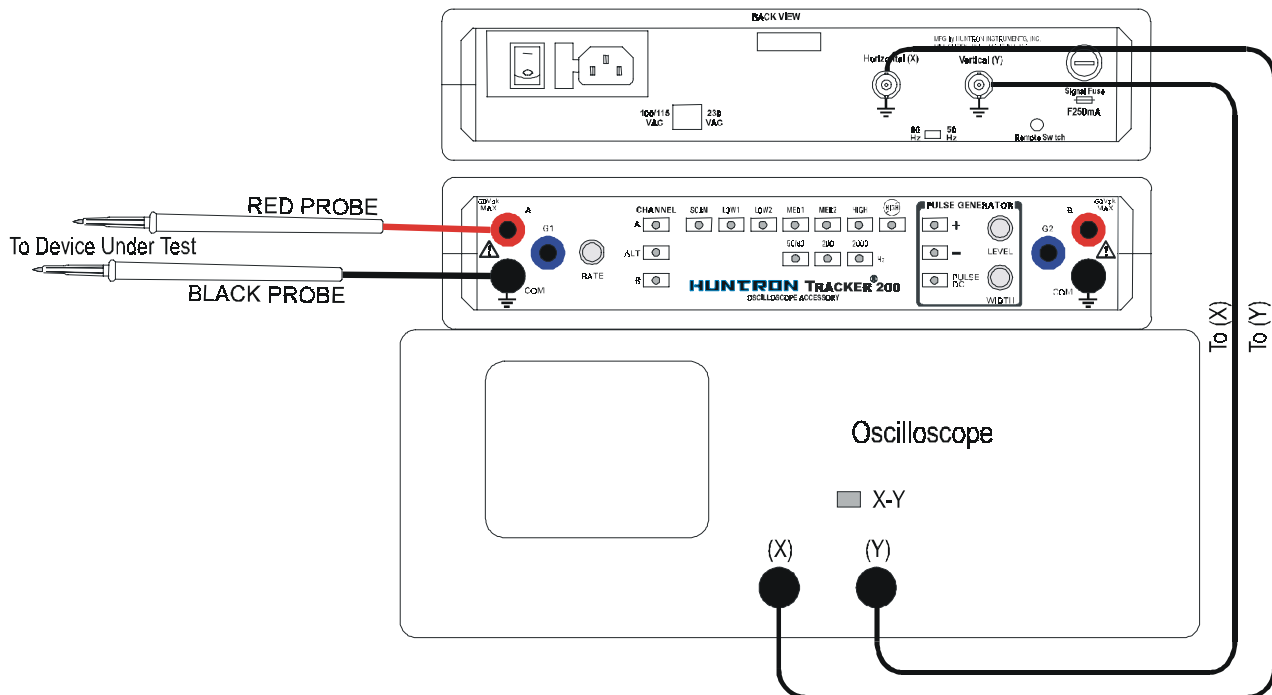


Figure 1-3. Typical Tracker 200-to-Oscilloscope connection.

2. Using BNC cables, connect the first oscilloscope channel 1 or X to the Horizontal (X) channel of the Tracker 200. Connect the second oscilloscope channel 2 or Y to the Vertical (Y) channel of the Tracker 200.
3. Connect the power cord to the Tracker 200 and switch the unit on.

4. Setup the oscilloscope as follows:

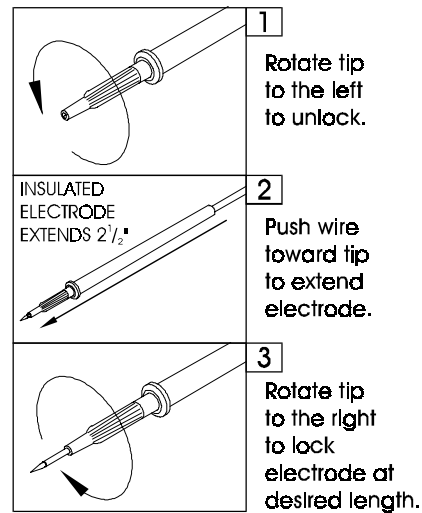
- 1 V/div vertical scale on each channel
- 5 ms/div time base
- Trigger on channel 1
- X/Y mode

The Tracker 200 will be in the LOW2 range. Adjust the Horizontal position so that the open circuit trace which should be a horizontal line is at the horizontal crosshair of the graticule. Connect the test probes to the front panel A and COM terminals of the Tracker 200. Short the test terminals. A vertical Trace will be displayed. Adjust the vertical position of the trace so that it is at the vertical crosshair of the graticule.

5. You are now ready to use the Tracker 200.

## Operating the Tracker 200

1. To select a test range, press one of the five range buttons.
2. To select a test frequency, press one of the three frequency buttons. All test ranges will then be using the selected frequency.
3. To compare two devices, connect the test terminal of channel A to the reference or good device. Plug the banana jack of a second test probe to the channel B test terminal. See Figure 1-4 for instructions on adjusting the probe tips. Connect the test probe to the suspect device. Connect the common lead to one of the COM terminals. Press the ALT button and set the speed at which channel A and B will switch by turning the RATE knob. The signature of Channel A will alternate with the signature of channel B for an easy visual comparison of the two signatures.



**Figure 1-4. Adjusting the Probe Tips.**

4. To avoid pressing each one of the test ranges, press the SCAN button. This will scan through all the test ranges one at a time.
5. The pulse generator is used to test gate fired devices like SCRs and Triacs. By connecting the G1 terminal to the gate of the device and applying the test terminal across the anode and cathode of the device, it is possible to actually turn the device on and look at the V/I characteristics of the device. This is particularly useful for power supplies where you are unable to turn on devices because the power supply is faulty on power up.
6. Refer to later chapters of this manual for details on testing resistors, capacitors, inductors, diodes, multiple component circuits, integrated circuits, SCRs and optocouplers.

## Specifications

The specifications for the Tracker 200 are listed in Table 1-1.

**Table 1-1. Tracker 200 Specifications**

<b>Electrical</b>	
Test Signal:	Sine wave
Open Circuit Voltage ( $V_o$ ):	60 V <sub>pk</sub> HIGH Range
	20 V <sub>pk</sub> MED 2 Range
	15 V <sub>pk</sub> MED 1 Range
	10 V <sub>pk</sub> LOW 2 Range
	3 V <sub>pk</sub> LOW 1 Range
Source Resistance ( $R_s$ ):	74 k $\Omega$ HIGH Range
	27.6 k $\Omega$ MED 2 Range
	1.24 k $\Omega$ MED 1 Range
	54 $\Omega$ LOW 2 Range
	10 k $\Omega$ LOW 1 Range
Frequency ( $F_s$ ):	50/60 Hz
	200 Hz
	2000 Hz
Channels:	
Number	2
Display modes	A, B, Alt
Overload Protection	Fuse: 5 mm x 20 mm, F250 mA, 250 V (IEC 127-2/II, type GDB)
Overvoltage Category	CAT I
Pulse Generator:	
Number of Outputs:	2
Level	0 V to +/- 5 V, open circuit
DC Mode	+/- DC Level
Pulse Mode	+/- or Composite
Frequency	Matches selected test signal frequency
Width (pulse mode)	2% to 50% duty cycle
Source resistance	100 $\Omega$ each output
Short circuit current	50 mA max. each output



Table 1-1. Tracker 200 Specifications (continued)

<b>Electrical (continued):</b>	
Power Requirements:	
Line Voltage	100/115 VAC or 230 VAC
Frequency	50 Hz to 60 Hz
Power	15 W maximum
Line Fuse	100/115 V: 5 mm x 20 mm, T160 mA, 250 V (IEC127-2/III, type GDC) 230 V: 5 mm x 20 mm, T160 mA, 250 V (IEC127-2/III, type GDC)
<b>Mechanical</b>	
Dimensions	11.5" W x 2.7" H x 10.2" D (29.1 cm W x 6.9 cm H x 25.9 cm D)
Weight	4.6 lbs (2.1 kg)
Shipping Weight	approx. 7 lbs (3.0 kg)
<b>Environmental</b>	
Indoor Use	
Altitude	<2000m (<6560')
Temperature	
Operating	0°C to +40°C (32°F to 104°F)
Storage	-50°C to +60°C (-58°F to 140°F)
Relative Humidity	< 80% up to 31°C, derated linearly to 50% at 40°C

**Table 1-1. Tracker 200 Specifications (continued)**

<b>Certifications and Compliances</b>	
EC Declaration of Conformity - EMC Directive	<p>Meets the intent of Directive 89/336/EC for Electromagnetic Compatibility. Compliance was demonstrated to the following specifications as listed in the Official Journal of the European Communities:</p> <p>EN 50081-1 Emissions:  EN 55011 Class B Radiated and Conducted Emissions</p> <p>EN 50082-1 Immunity:  IEC1000-4-2 Electrostatic Discharge  IEC1000-4-3 RF Electromagnetic Field  IEC1000-4-4 Electrical Fast Transient/Burst  IEC1000-4-5 Power Line Surge</p>
EC Declaration of Conformity - Low Voltage Directive	<p>Compliance was demonstrated to the following specification as listed in the Official Journal of the European Communities:</p> <p>Low Voltage Directive 73/23/EEC, as ammended by 93/68/EEC</p> <p>EN 61010-1:1993  Safety requirements for electrical equipment for measurement, control, and laboratory use</p>

Table 1-1. Tracker 200 Specifications (continued)

Certifications and Compliances (continued)	
Approvals	<p>USL (UL 3111-1, US Standard of Electrical Measuring and Test Equipment)</p> <p>CNL (CAN/CSA 22-2 No 1010.1-92, Canadian Standard for the Safety of Electrical Measuring and Test Equipment)</p>
Installation Category Descriptions	<p>Terminals on this product may have different category designations. The installation categories are:</p> <p>CAT III - Distribution-level mains (usually permanently connected). Equipment at this level is typically in a fixed industrial location.</p> <p>CAT II - Local-level mains (wall sockets). Equipment at this level includes appliances, portable tools, and similar products. Equipment is usually cord connected.</p> <p>CAT I - Secondary (signal level) or battery operated circuits of electronic equipment.</p>
Pollution Degree	2

**NOTE.** *Huntron, Inc. does not offer a Certificate of Traceable Calibration for the Tracker 200. The Tracker 200 is a troubleshooting tool and is not intended for use in calibration or conformance-testing applications.*

## Accessories

**1. Foot Switch P/N 98-0314**

The foot switch connects to the back panel of the Tracker 200. When the switch is depressed, the next test range is automatically selected. Using the foot switch is a convenient way of avoiding having to manually select the test range on the Tracker 200 front panel.

**2. BNC Cable 24 inches Long M/M P/N 98-0223**

2 BNC Cables are required for connecting the Tracker 200 to an oscilloscope. You can use longer length BNC Male-to-Male cables. Cables longer than 6 feet may cause undesirable capacitive signatures to be displayed on the oscilloscope CRT.

These accessories are not included with the Tracker 200. Parts are available from:

Huntron, Inc.  
15720 Mill Creek Blvd., Suite #100  
Mill Creek, WA 98012 U.S.A.  
Phone: 425-743-3171, or 1-800-426-9265 in the U.S.A.

e-mail: [sales@huntron.com](mailto:sales@huntron.com)

# A Quick Tour

The Huntron Tracker 200 is a versatile troubleshooting tool having the following features:

- Four test ranges and an additional low voltage (3 Volt) range for Low Power Surface Mounted devices.
- Two-channel pulse generator allowing the testing of gate fired devices.
- Three test frequencies to expand the range capability for testing capacitors and inductors.
- Two-channel comparison mode allowing the automatic switching between the reference signature and the suspect signature.
- Easy hookup to an oscilloscope with X/Y capability for displaying the signatures.

The Tracker 200 tests components using a two terminal system (three terminal system when the built-in pulse generator is used) where two leads are placed on the leads of the component under test. The Tracker 200 tests components in-circuit, even when there are several components in parallel.

All voltage sources in boards and systems must be in a power-off condition when using the Tracker 200. Electronic protection is a signal fuse connected in series with the channel A and B test terminals. Accidental contact of the test leads to active voltage sources, for example, line voltage, powered-up boards or systems, charged high voltage capacitors, etc., may cause the signal fuse to open. An open signal fuse is indicated by channel A and B showing a short-circuit signature at all times regardless if anything is connected across the probes. When this condition occurs, follow the directions in *Signal Fuse Replacement* on page 1-4 for replacing the signal fuse.



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**CAUTION.** *The device to be tested must have all power turned off, and have all high voltage capacitors discharged before connecting the Tracker 200 to the device.*

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Before you begin to use the Tracker 200, please take a few minutes to familiarize yourself with the instrument. All of the externally accessible features are discussed in the following sections.

## Front Panel

The front panel of the Tracker 200 is designed to ease access to its many features. All buttons are momentary action type and most have adjacent LED indicators to show which functions are active. Refer to Figure 2-1 and Table 2-1 for a detailed description of each item on the front panel.

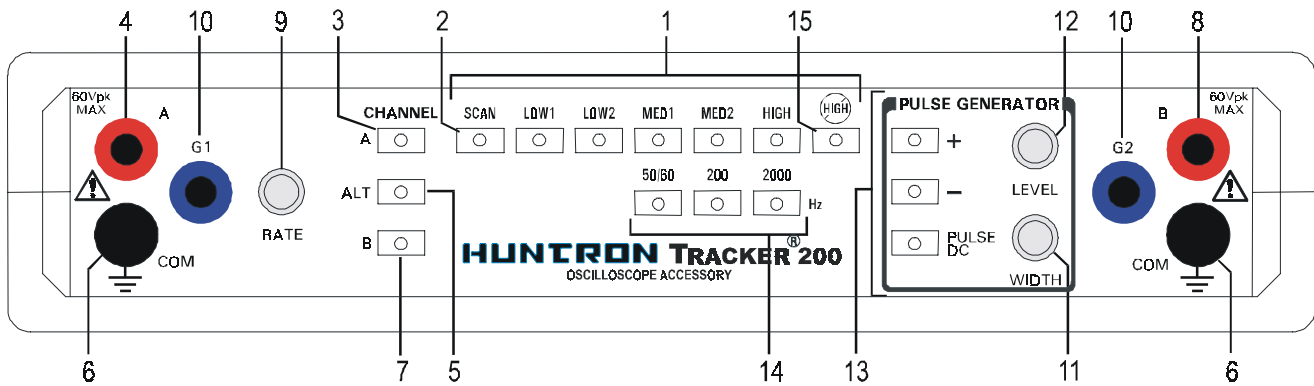


Figure 2-1. Tracker 200 Front Panel With Callouts.

Table 2-1. Front Panel Controls and Connections.

	Name	Function
1	Range Selectors	Push buttons that select one of five impedance ranges: LOW1, LOW2, MED1, MED2 and HIGH
2	Scan Switch	Push button that initiates automatic scanning of the five ranges from LOW1 to HIGH. The scanning speed is determined by the RATE control (see item #9).
3	Channel A Switch	Selects channel A for display on the oscilloscope.
4	Channel A Test Terminal	Safety shrouded banana jack for channel A test signal.
5	ALT Switch	Causes the Tracker 200 to alternate between channel A and channel B at a speed determined by the RATE control (see item #9).
6	COM Test Terminal	Safety shrouded banana jack that is the instrument common and the common reference point for both channel A and channel B.
7	Channel B Switch	Selects channel B for display on the oscilloscope.
8	Channel B Test Terminal	Safety shrouded banana jack for channel B test signal.
9	RATE Control	Controls the speed of channel alternation and/or range scanning.
10	G1 & G2 Terminals	Pulse Generator dual outputs.
11	WIDTH Control	Controls the duty cycle of the pulse generator output.
12	LEVEL Control	Controls the amplitude of the pulse generator output.
13	Pulse Generator Selectors	Push buttons that select various output modes of the pulse generator: Positive(+), Negative (-) and PULSE/DC.
14	Frequency Selectors	Push buttons that select one of the three signal frequencies: 50/60 Hz, 200 Hz and 2000 Hz.
15	NO HIGH range Switch	Push button that activates a mode where it is not possible to enter the HIGH range either by manual or scan range selection.

## Back Panel

Secondary controls and connectors are on the back panel. Refer to Figure 2-2 and Table 2-2 for a detailed description of each item on the back panel

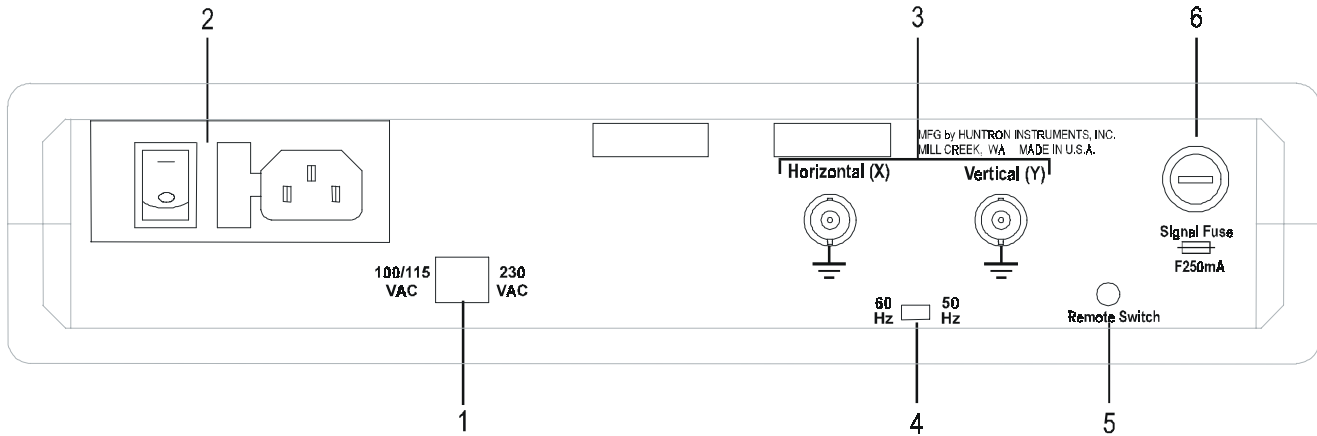


Figure 2-2. Tracker 200 Back Panel.

Table 2-2. Back Panel Connections.

	Name	Function
1	Input Voltage Selector	Select between 100/115 VAC and 230 VAC input voltage.
2	Power cord connector Power fuse holder Power switch	IEC standard connector that mates with any CDD-22 power cord. Power fuse holder and Power switch.
3	X & Y output	X & Y outputs connects to oscilloscope.
4	Input Hz selector	Select between 50 or 60 Hz input frequency
5	Remote Switch	Using the Foot Switch accessory, you can change to the next range in the scan sequence.
6	Signal Fuse	250 mA fuse.



## Oscilloscope Display

The Tracker 200 uses the display of any oscilloscope that is capable of displaying an untriggered XY waveform. The oscilloscope display can be divided into four quadrants. Each quadrant displays different portions of the signatures. Quadrant 1 displays positive voltage (+V) and positive current (+I), quadrant 2 displays negative voltage (-V) and positive current (+I), quadrant 3 displays negative voltage (-V) and negative current (-I), and quadrant 4 displays positive voltage (+V) and negative current (-I).

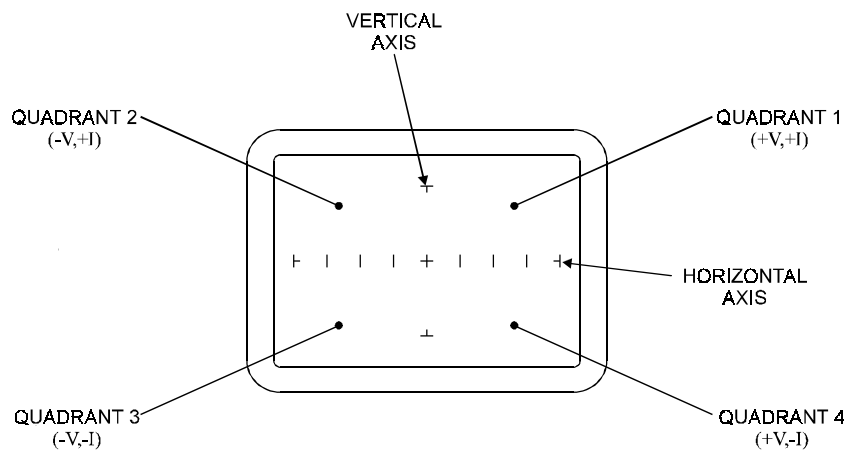


Figure 2-3. Oscilloscope Display.

## Initial Setups

The following setups assume that the Tracker 200 has been connected to an oscilloscope and the Tracker 200s power cord has been plugged into an appropriate wall socket.

## Power On

Turn the power on to your Tracker 200 using the power switch located on the rear panel. The Tracker 200 should come on with the LEDs for channel A, 50/60 Hz, LOW2 range and Pulse/DC illuminated.

## Range Selection

The Tracker 200 is designed with five impedance ranges (LOW1, LOW2, MED1, MED2 and HIGH). These ranges are selected by pressing the appropriate button on the front panel. It is best to start with one of the medium ranges (i.e. MED1 or MED2). If the signature on the oscilloscope display is close to an open (horizontal trace), go to the next higher range for a more descriptive signature. If the signature is close to a short (vertical trace), go to the next lower range.

---

**NOTE:** In HIGH range, up to 60  $V_{pk}$  is present on the A and B test terminals. When using the HIGH range, be careful not to touch probe tips or any circuits connected to the A or B test terminals.

---

The NO HIGH lock feature, when activated, prevents the instrument from entering the HIGH range in either the manual or scan mode.

The scan feature scans through the five ranges (four with the NO HIGH lock activated) at a speed set by the RATE control. This feature allows the user to see the signature of a component in different ranges while keeping hands free to hold the test leads.

## Frequency Selection

Three test frequencies can be selected by pressing the appropriate button on the front panel.

The 50/60 Hz button selects either 50 or 60 Hz depending on the position of the rear-panel switch. Set this switch to match the local power line frequency in use. In most cases this selection is the best one to use for general troubleshooting.

The 200 Hz button selects 200 Hz as the test signal frequency. This frequency also allows you to see smaller values of capacitance. The 2000 Hz button selects 2000 Hz as the test signal frequency. This frequency allows you to see even smaller values of capacitance.

The 200 Hz or 2000 Hz frequency selections may require you to adjust the oscilloscope time base to optimize the display.

## Channel Selection

There are two test signal channels in the Tracker 200, Channel A and Channel B. There are three buttons, **Alt**, **A** and **B** to select what channel will be displayed on the oscilloscope.

Before you view an analog signature on the Tracker 200, make sure that the analog signature is displayed in the correct quadrants on the display by following this procedure. When using a single channel, plug the red test probe into the corresponding channel test terminal and plug the black test probe into the common test terminal. When testing solid state or polarity sensitive components, place the red test probe to its positive terminal (i.e., anode, +V, etc.) and place the black probe to its negative terminal (i.e. cathode, -V, ground, etc.).

Push the corresponding channel button, **A** or **B** to view a single analog signature.

Push the **Alt** button to enable the Alternate display mode of the Tracker 200. This mode provides an automatic alternating display of channel A and channel B. It's easy to make a visual comparison of analog signatures for two of the same components or the same node points on two identical circuit boards when in Alt mode. Alternate display mode is one of the most useful features for comparing a known good device with an unknown device of the same type. The alternation frequency is varied by the RATE control. Refer to Figure 2-4 for an example on how to connect your test leads for comparison testing.

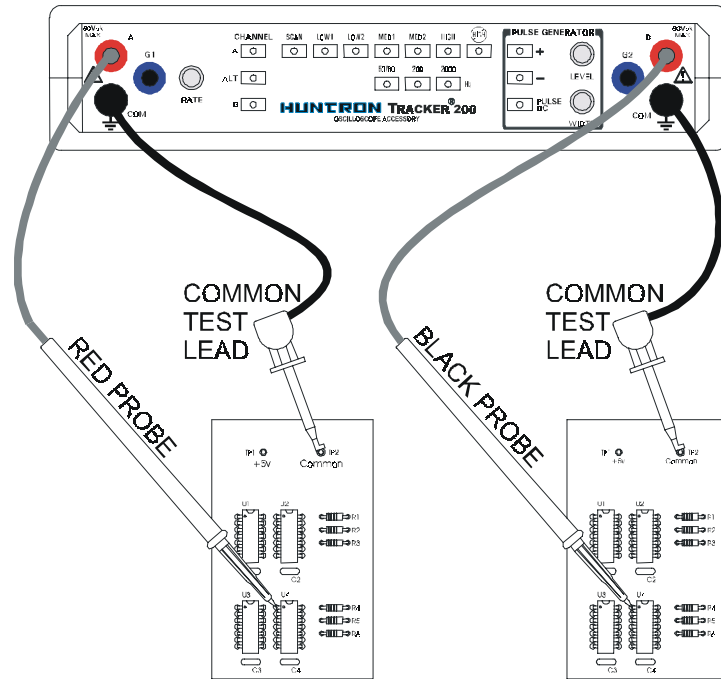
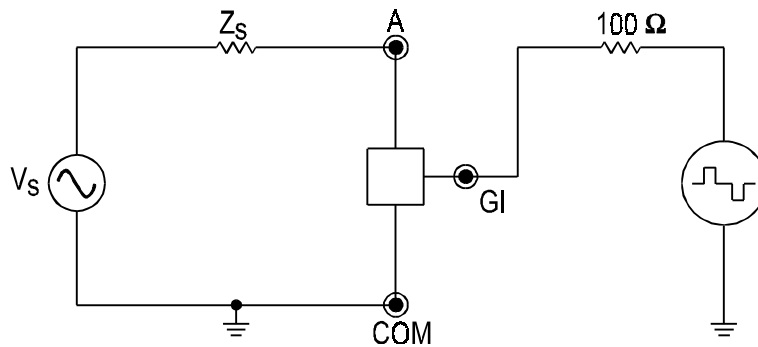


Figure 2-4. Comparison Testing with Alternate Display Mode.

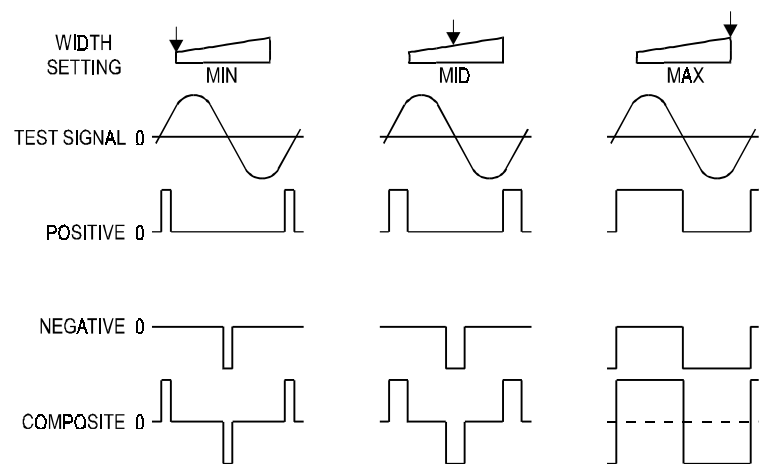
## Pulse Generator

The pulse generator is used to drive the control input of a device under test which provides a dynamic test for certain types of devices. The normal two terminal mode of using the Tracker 200 can be thought of as a static test since devices with three or more terminals are not tested in their active state. However, with the pulse generator, an in-circuit active test of a device is possible. Figure 2-5 shows the equivalent circuit of the pulse generator and the signal section with the display connections remove for clarity.



**Figure 2-5. Pulse Generator/Signal section Equivalent Circuit.**



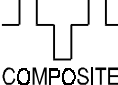
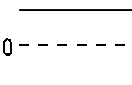
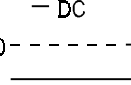
In pulse mode, this circuit uses the zero crossing of the test signal to trigger the start of a pulse. When positive (+) is enabled, a positive-going zero crossing triggers a positive pulse. When negative (-) is enabled, a negative-going zero crossing triggers a negative pulse. If both polarities are enabled, then both positive and negative pulses are produced on alternate zero crossings (composite pulses). Once triggered, the duration of a pulse is set by the width control. Figure 2-6 shows the waveforms for the three pulse polarity types at various settings of the width control.

**Figure 2-6. Pulse Generator Waveforms.**

The LEVEL control adjusts the peak of each pulse from zero to 5 Volts is absolute magnitude with the polarity dependent on the pulse polarity type selected. The maximum open circuit outputs are, therefore, 5 Volts peak-to-peak with either positive or negative enabled, and 10 Volts peak-to-peak when the composite pulse is activated.

When DC mode is selected, a zero to 5 Volt DC level is produced at G1 and G2. The polarity is again controlled by the positive and negative buttons. Pressing the positive button enables a positive DC output and disables the negative button. The negative button enables a negative DC output only when positive is off. Using this configuration, it is easy to change polarities with only one button: first press the negative button (which is remembered by the control logic) then press the positive button which switches the output polarity to positive. The next time the positive button is pressed, the positive output is turned off which re-enables the negative output. Therefore, each time the positive button is pressed the output polarity will toggle back and forth between positive and negative. The Width control has no effect in DC modes.

A variety of output waveforms is available using the pulse generator selector buttons as shown in Figure 2-7. First select the Pulse mode or the DC mode using the PULSE/DC button. In Pulse mode, the LED flashes at a slow rate, while in DC mode, the LED is continuously on. Then select the polarity of output desired using the positive (+) and negative (-) buttons. All three buttons function in a “push-on/push-off” mode and only interact with each other to avoid the NOT ALLOWED state.

POSITIVE	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>
NEGATIVE	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
PULSE <input checked="" type="radio"/>	OFF	 + PULSE	 - PULSE	 COMPOSITE PULSE
DC <input checked="" type="radio"/>	OFF	 + DC	 - DC	NOT ALLOWED

<input type="radio"/> - OFF	<input checked="" type="radio"/> - FLASHING	<input checked="" type="radio"/> - ON
-----------------------------	---	---------------------------------------

**Figure 2-7. Pulse Generator Selector Chart.**

Once the specific output type is selected, the exact output is set using the LEVEL and WIDTH controls. The LEVEL control varies the magnitude of the output amplitude from zero to 5 Volts (peak or DC). During Pulse mode, the WIDTH control adjusts the duty cycle of the pulse output from a low duty cycle to 50% maximum (square wave). The start of a pulse is triggered by the appropriate zero crossing of the test signal which results in the pulse frequency being equal to the selected test signal frequency. The end of a pulse is determined by the Width control setting which selects the duty cycle. The WIDTH control has no effect when DC mode is selected.

The pulse generator of the Tracker 200 has dual tracking outputs (G1 and G2) so that you can visually compare the analog signatures of two of these three or more terminal components by using the Alt mode. The following figure illustrates how to connect the Tracker 200 when using the pulse generator in ALT mode.

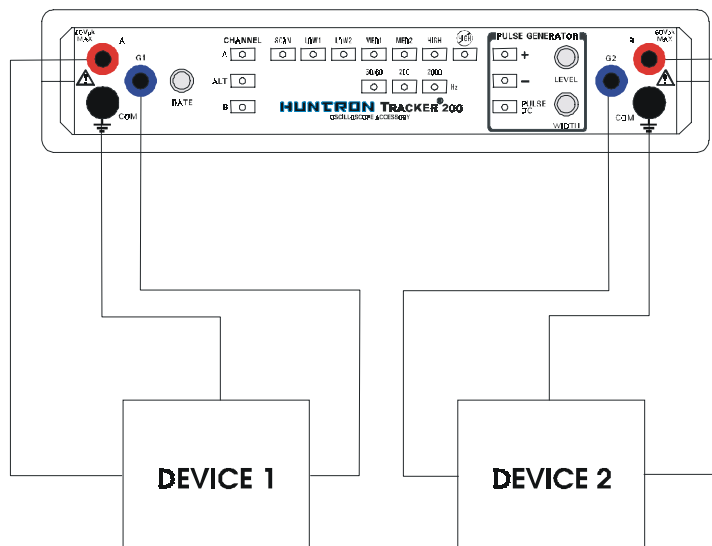


Figure 2-8. Comparison Testing with the Pulse Generator.

**Notes:**



# Using Your Tracker 200

Electronic troubleshooting is a skilled art, based largely on logical deduction, experience and intuition. The Huntron Tracker 200 uses Analog Signature Analysis or ASA to take full advantage of a technician's skills. ASA is the examination of the current verses voltage characteristic of a component under power-off conditions for the purpose of troubleshooting. The component's analog signature is displayed for visual analysis and indicates its relative health and condition. For solid state components, ASA enables you to visualize component leakage and substrate damage that is difficult to find with conventional test methods.

With ASA, you can troubleshoot components without applying power, saving circuits from possible further damage. By comparing the signatures of a questionable component with those of a known-good component, you can quickly locate failed and marginal components in most cases. You can troubleshoot and quickly find problems on circuit boards even if there is no schematic.

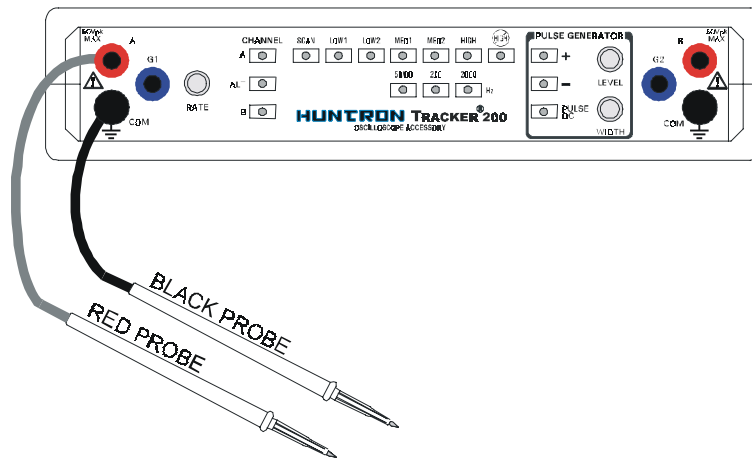


Figure 3-1. Tracker 200 with Test Probes.

## Basics of ASA - How it Works

Here's how ASA and power-off testing works:

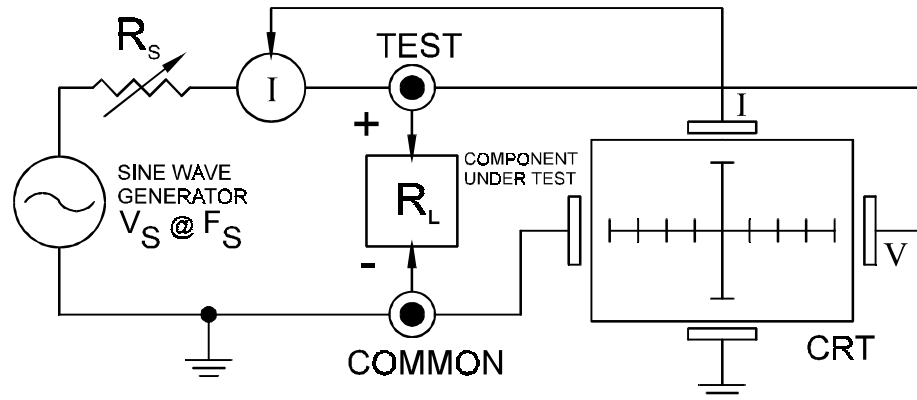
The Tracker 200 outputs a precision current-limited AC sine wave signal to a component and displays the resulting current flow, voltage drop and any phase shift on the oscilloscope X-Y display. The current flow causes a vertical trace deflection on the display, while the voltage across the component causes a horizontal trace deflection. This resultant trace on the display is called an analog signature.

Understanding the Tracker 200's basic core circuit is the key to understanding how analog signatures respond to different types of components. Since the induced current is a function of the impedance of the circuit, the analog signature displayed can be thought of as a visual representation of Ohm's Law,

$$V = IR$$

where V = voltage, I = current and R = resistance

The next figure shows a simplified diagram of the Tracker core circuit. The sine wave generator is the test signal source and is connected to a resistor voltage divider made up of  $R_S$  and  $R_L$ . The load impedance,  $R_L$ , is the impedance of the component under test.  $R_L$  is in series with the Tracker 200's internal or source impedance  $R_S$ . Because  $R_S$  is constant, both the voltage across the component under test and the current through it is a function solely of  $R_L$ .



$R_s$  = Source Resistance,  $V_s$  = Source Voltage,  
 $R_L$  = Load Resistance,  $F_s$  = Source Frequency.

**Figure 3-2. Tracker 200 Core Circuit Block Diagram.**

Each test signal or range has two parameters: source voltage  $V_s$ , and resistance  $R_s$  and source frequency  $F_s$ . When using ASA for troubleshooting, the objective is to select the range that will display the most descriptive analog signature information.

The Tracker 200 can readily accomplish this by changing the proper range parameter. The range of the test signal can be used to enhance or disregard semiconductor switching and avalanche characteristics. The  $F_s$  or frequency of the test signal source can be used to enhance or disregard the reactive factor (capacitance or inductance) of a component.

## Horizontal Axis

The voltage across the component under test controls the amount of horizontal trace deflection on the oscilloscope display. When the component under test is removed, creating an open circuit (e.g.,  $R_L = \infty$ ), the voltage at the output terminals is at its maximum and thus the trace on the display is a straight horizontal line with its maximum width.

When the test signal is positive, this means that the voltage and current are positive so the signature's trace is on the right hand side of the oscilloscope display. When the test signal is negative, the voltage and current are negative so the trace is in the left hand side of the display.

Turn on the Tracker 200 and observe the oscilloscope display. With nothing connected to its test terminals, the display trace is a horizontal line (that is,  $R_L = \infty$ ).

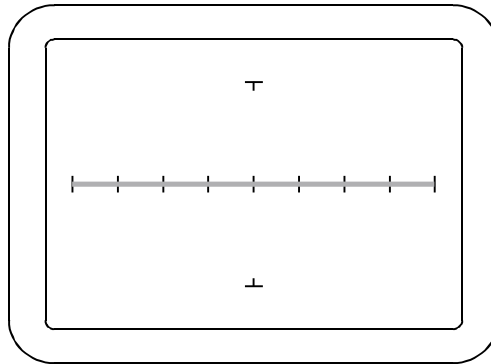


Figure 3-3. Tracker 200 CRT Display with Open Test Terminals.

## Vertical Axis

The amount of vertical trace deflection on the oscilloscope display is controlled by the voltage dropped across the internal impedance  $R_s$  of the Tracker 200. Because  $R_s$  is in series with the load  $R_L$ , this voltage will be proportional to the current flowing through  $R_L$ . This current that flows through the component under test is the vertical part of the analog signature.

When the  $R_L$  is zero ohms ( $0 \Omega$ ) as when you short an output terminal to the common terminal, there is no voltage dropped across  $R_L$ , so there is no horizontal component in the analog signature. This short circuit signature is a vertical line trace on the oscilloscope display.

1. Connect the red microprobe to the output channel A jack on the Tracker 200 and the black microprobe to the Common jack.
2. Touch and hold the probes together and observe the analog signature on the oscilloscope display.
3. You will see a vertical line trace in the middle of the oscilloscope display.

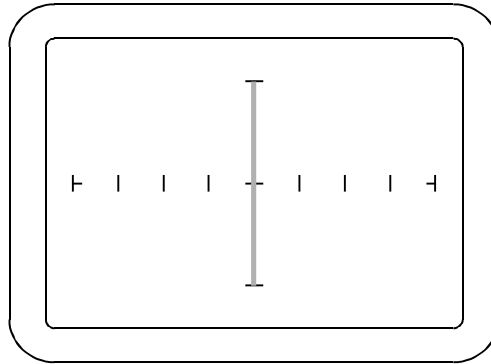


Figure 3-4. Tracker 200 Oscilloscope Display with Short Circuit Signature.

## Basic Analog Signatures - Open and Short

In ASA, the two most basic analog signatures are the open and the short. The open signature occurs when an output terminal is not connected to anything. The short signature occurs when an output terminal is directed connected to the common terminal. In the following figures, the upper screen represents the Tracker 200's oscilloscope X-Y display and the lower screen is a graphical plot of the sine wave test signal at the output terminal showing its current and voltage relationship. The current and voltage graphical plots are for illustration only and cannot be displayed on the display.

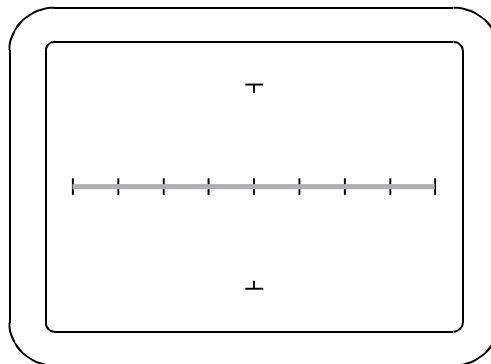


Figure 3-5. "OPEN" Analog Signature on Oscilloscope display (Horizontal Line).

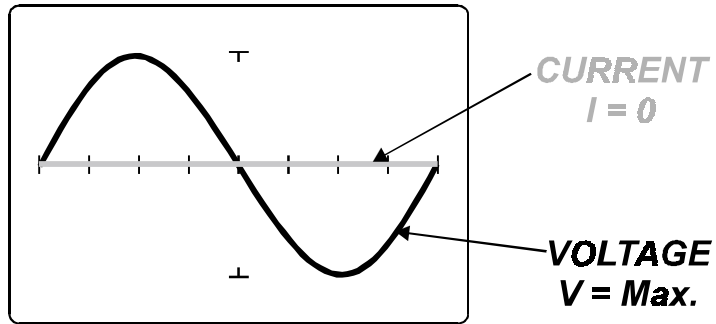


Figure 3-6. Test Signal (Open Circuit) with Current and Voltage Waveforms. Minimum Current and Maximum Voltage

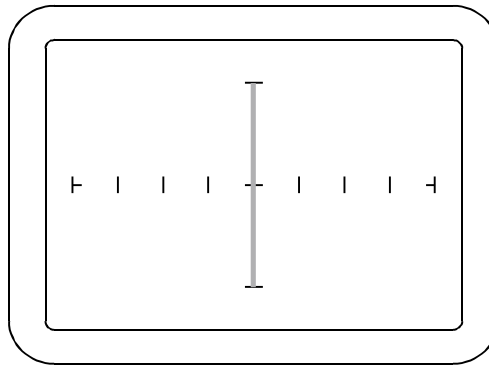


Figure 3-7. "SHORT" Analog Signature on the Oscilloscope Display (Vertical Line).

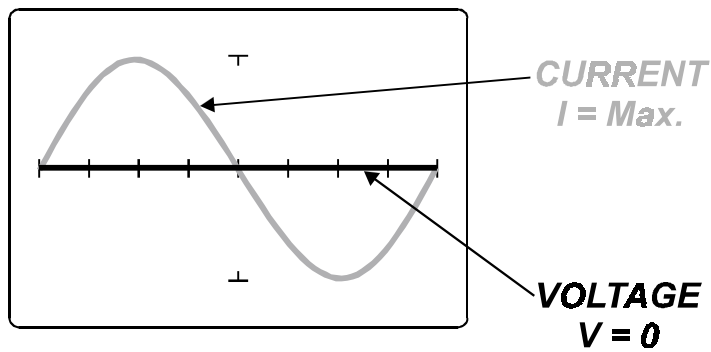


Figure 3-8. Test Signal (Short Circuit) with Current and Voltage Waveforms. Maximum Current and Minimum Voltage

## Four Basic Component Analog Signatures

All analog signatures are a composite of one or more of the four basic component signatures which are: resistance, capacitance, inductance and semiconductor. Each one of these basic components responds differently to Tracker 200's test signal, so recognizing these four basic unique signatures on the oscilloscope display are one of the keys to successful ASA troubleshooting. When components are connected together to form a circuit, the signature at each circuit node is a composite of the basic component signatures in that circuit. For example, a circuit with both resistance and capacitance will have a signature that combines the analog signatures of a resistor and capacitor. The signature of a resistor is always indicated by a straight line at an angle from 0 to 90 degrees. The signature of a capacitor is always in the form of a circle or ellipse shape. The signature of an inductor is also a circle or ellipsoid shape that may also have internal resistance. Finally, the semiconductor diode signature is always made up of two or more linear line segments that usually form an approximate right angle.

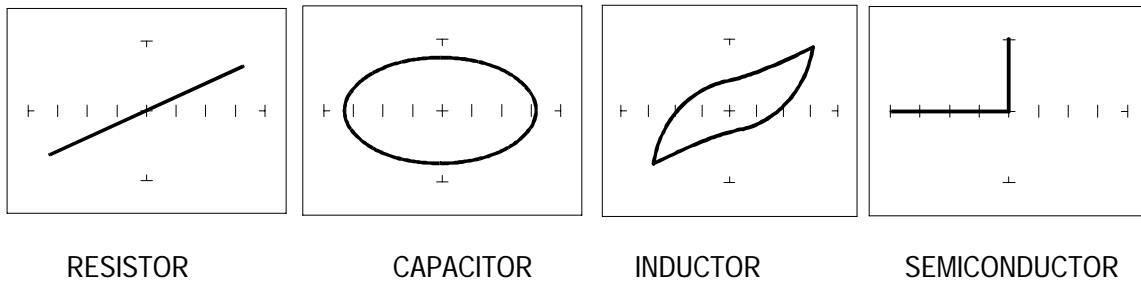


Figure 3-9. Analog Signatures of 4 Basic Components.

**Notes:**



# Testing Passive Components

## Resistors

Exploring how the Tracker 200 ranges interact with different resistance values is a good introduction on how basic ASA troubleshooting is applied. This section will briefly familiarize you with Tracker 200 basic operation and teach you how resistor signatures relate to both test range and the resistance of the circuit under test. After completing this section, you will know how to:

Apply test probes across a resistor

Identify a pure resistive signature

Analyze and predict resistive signatures

As you go through the following section, make a mental note on the relationship between the Tracker 200's test range parameters: voltage, resistance and frequency.

Turn power on to your Tracker 200. Put the red test lead in the **A** jack, and the black test lead in the **Common** jack.

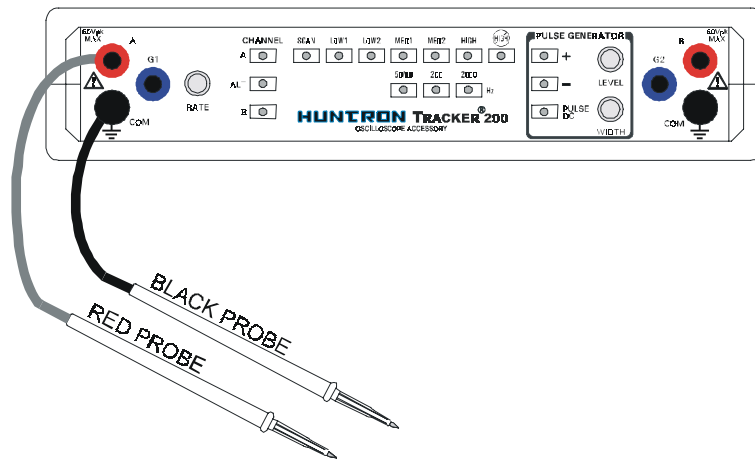


Figure 4-1. Tracker 200 with Test Probe Leads.

To display the analog signature of a resistor:

1. Press the LOW2 range button.
2. The LED will be on indicating that LOW2 range is active.
3. Place or clip a test lead on the opposite ends of a resistor and observe the signature on the Oscilloscope CRT display.

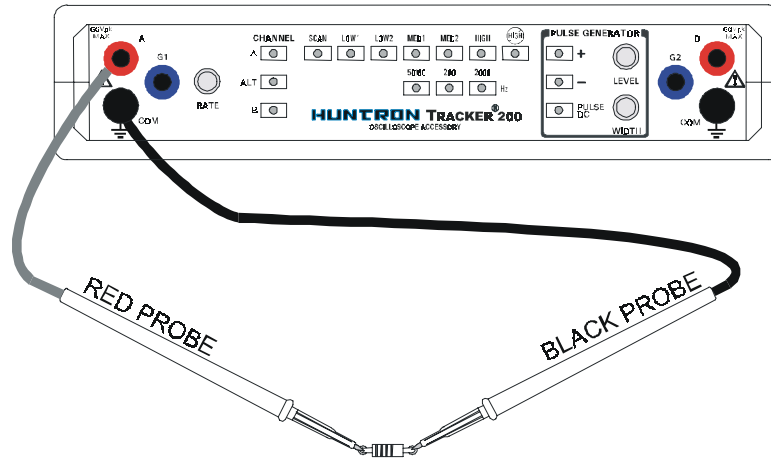


Figure 4-2. Tracker 200 Connected to a Resistor.

Below are four analog signatures of different resistors, 150, 1.5 k, 15 k and 150 k ohms in the upper four ranges. Note how the slope or angle of each analog signature changes with each resistor's value.

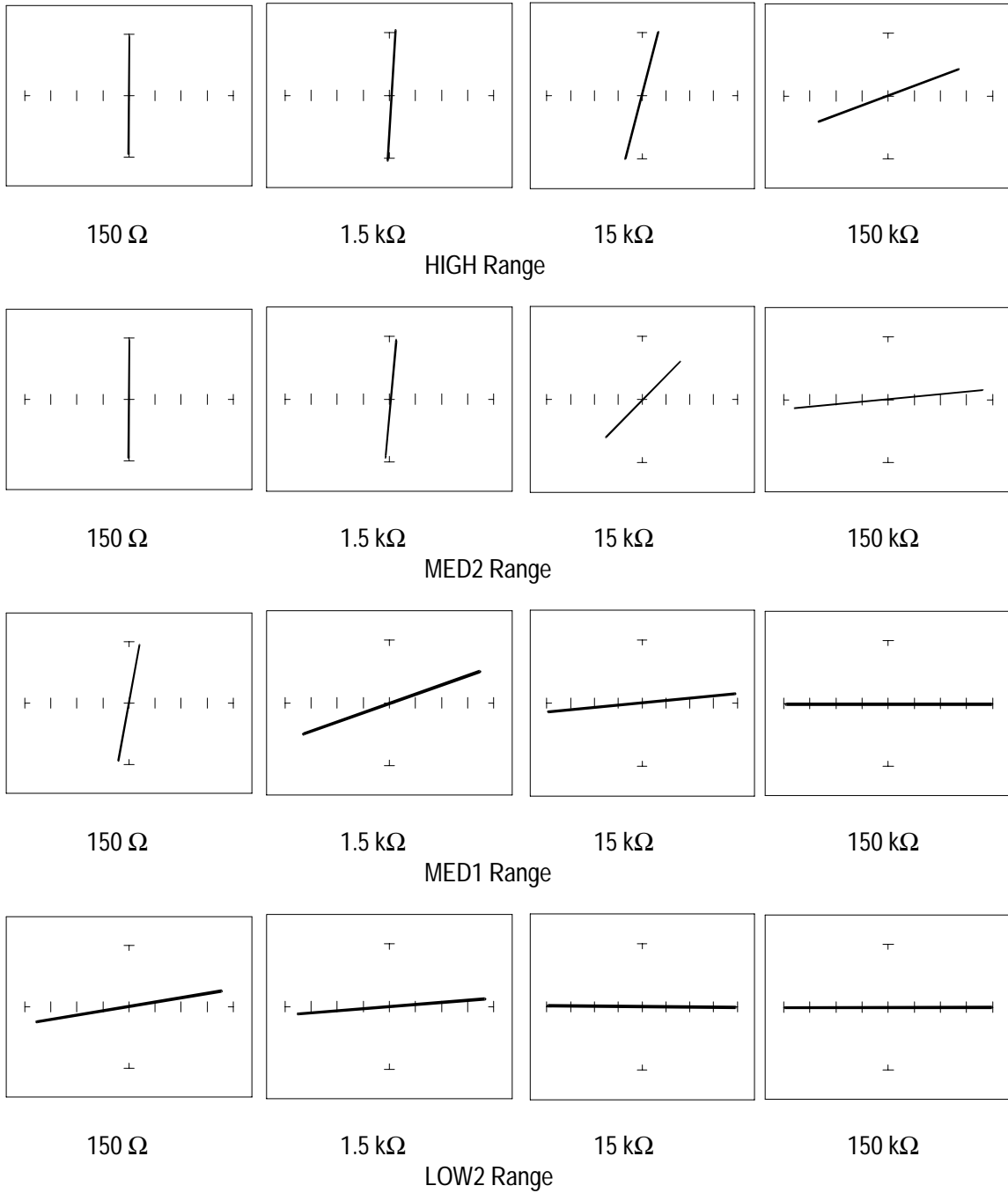
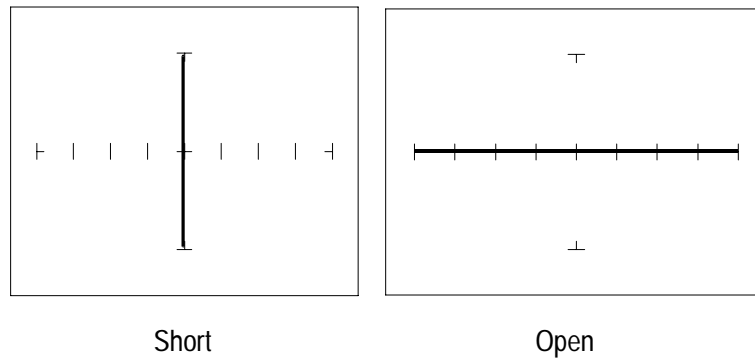


Figure 4-3. Signatures of Resistors in Different Ranges.

## Shorts and Opens, Resistor Faults

Two of the most common faults that occur in electronic components and circuits are shorts and opens. A short circuit is typically a  $0\ \Omega$  to  $10\ \Omega$  low resistive path between two points in a component or circuit that normally would have a higher resistance between them. An open circuit is a break between two points in a component or circuit that prevents current from flowing.



**Figure 4-4. Short and Open Signature.**

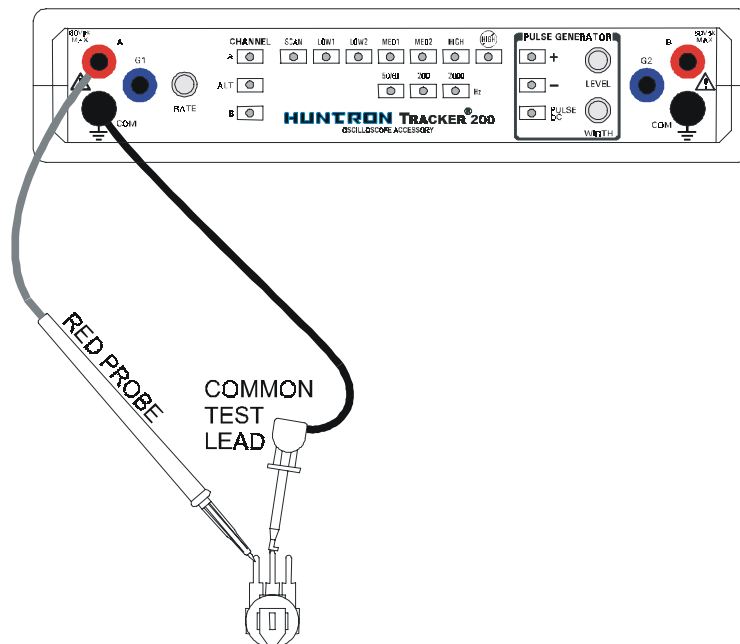
## Review

The signature of a purely resistive circuit is a straight line because the relationship between voltage and current in a purely resistive circuit is linear.

- This straight line signature can vary from
  - completely horizontal (an open)
  - completely vertical ( a short)
- As resistance increases
  - current decreases
  - the signature becomes more horizontal
- As the range increases
  - the volts per division of the horizontal axis increases
  - the internal resistance increases
  - the signature becomes more vertical

## Troubleshooting Applications

- The Tracker 200 is a fast and efficient continuity tester, providing real time information.
- The Tracker 200 will quickly locate resistor defects, shorts, opens and degradation that other testers cannot find.
- A majority of component failures are resistive in nature. This is important to remember; a component fault may only appear in one range because of the resistive nature of the fault.
- The Tracker 200's ability to determine the approximate fault resistance value greatly enhances the troubleshooting capability if the correct value is known.
- The Oscilloscope's CRT is a real time display and using the Tracker 200 for testing noisy or dirty potentiometer (variable resistors) is an excellent application. Connect Tracker 200's test terminals to one fixed pot lead and the other to the pot's wiper lead. Simply monitor the wiper signature while rotating the pot back and forth. A flawed pot would have the telltale



intermittent angular signature.

Figure 4-5. Using Tracker 200 to Test a Potentiometer.

The Tracker 200 can be used to adjust a potentiometer in circuit to an approximate operational setting. This application requires a known good board. Adjust each potentiometer on the board under repair to match the settings on a known good operational board. In most cases, the board under repair can now be powered up to an operational state where it can be adjusted to true specifications.

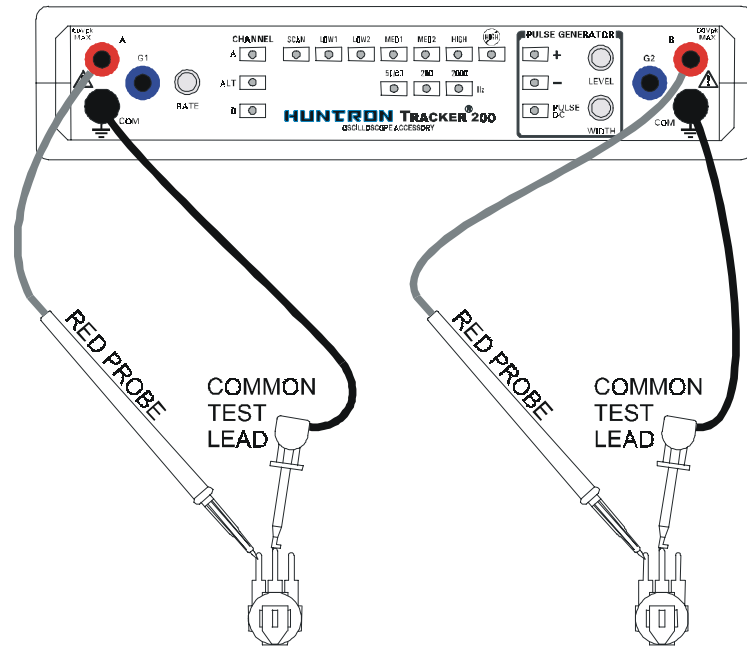


Figure 4-6. Using Tracker 200 to Compare Two Potentiometers.

## Capacitors

With a capacitor connected to the Tracker 200, the test signal across it responds quite differently than a resistor. The typical analog signature of a capacitor is an elliptical circular pattern and this is due to the fact that relationship between the test signal's current and voltage are non linear. The current's waveform is 90 degrees out of phase with respect to the voltage. The diagram below illustrates this basic principle for capacitors.

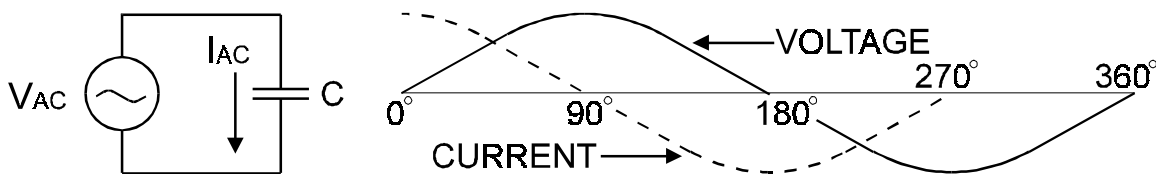


Figure 4-7. Capacitor Circuit with Test Signal's Current and Voltage Waveforms.

As the test signal's voltage crosses zero volts and becomes more positive, the current flowing in the circuit is at its maximum and becoming smaller. By the time the voltage has reached its maximum value, the current in the circuit has ceased flowing. As the voltage begins decreasing toward zero, the current begins increasing toward maximum. When the voltage reaches zero, the current is at its maximum value. Similarly, this same pattern follows as the voltage goes negative.

Because the current is at its maximum value when the voltage is at zero, the current leads the voltage. This is called phase shift and in a purely capacitive circuit, this phase shift equals  $90^\circ$ . This analog signature appears as a circular or elliptical waveform.

## Capacitor Analog Signatures

The goal of this part is to explore some capacitive signatures and to help you understand how capacitor signatures are related to:

The capacitance ( $\mu\text{f}$ ) of the circuit under test

The frequency ( $F_s$ ) of the test signal

The current range of the Tracker 200.

Turn power on to your Tracker 200. Plug the red test microprobe in the A jack, and the black test clip lead in the Common jack.



---

**CAUTION.** *The device to be tested must have all power turned off, and have all high voltage capacitors discharged before connecting the Tracker 200 to the device.*

---

Do the following to display the analog signature of a capacitor:

1. Press the LOW2 range button.
2. The button's LED will be on indicating that the LOW2 range is active.
3. Place or clip a test lead on the opposite ends of a resistor and observe the signature on the Oscilloscope's display.

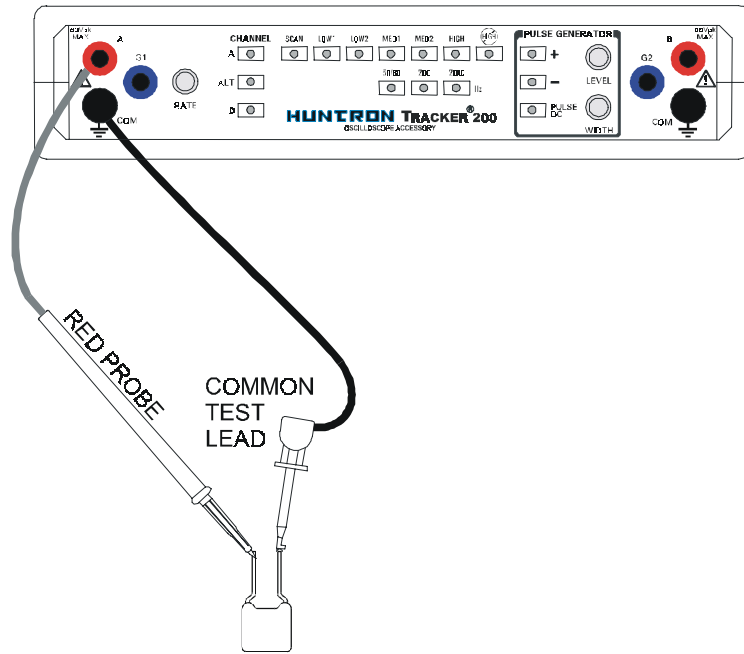


Figure 4-8. Tracker 200 with Test Probes Connected to a Capacitor.

## The Signatures of Different Capacitors in LOW2 Range

The figure below shows analog signatures for four different value capacitors, 1000  $\mu\text{f}$ , 100  $\mu\text{f}$ , 10  $\mu\text{f}$  and 1  $\mu\text{f}$ . The Tracker 200 LOW2 range is selected.

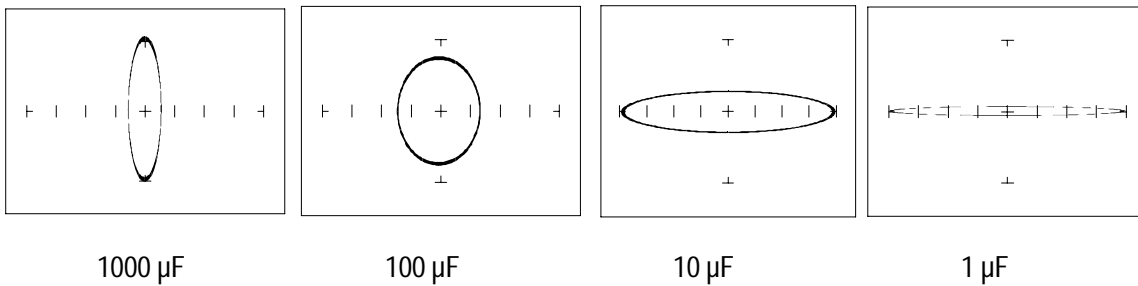


Figure 4-9. Signatures Of 4 Capacitors In the LOW2 Range.

Note that as the capacitance values decrease, each signature changes from a vertical elliptical pattern to a horizontal elliptical pattern. In ASA, a large value capacitor has a signature that looks similar to a short circuit. And likewise, a small value capacitor has a signature that's similar to an open circuit.



## Understanding Capacitor Analog Signatures

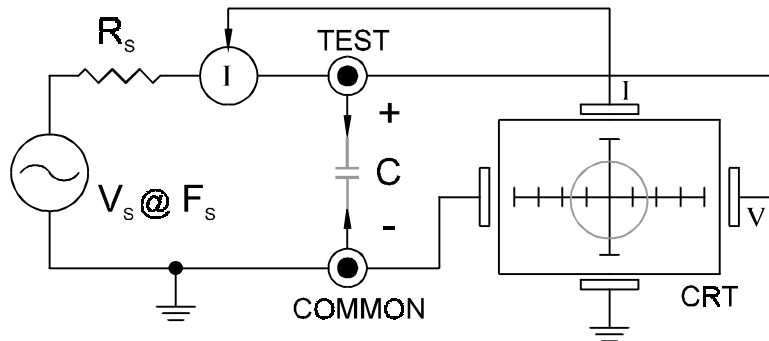


Figure 4-10. Tracker 200 Core Circuit Block Diagram With A Capacitor.

The Oscilloscope's CRT displays as a response to the test signal, an analog signature that represents the relationship between voltage, current and resistance of a component. For circuits that contain capacitors, the effective resistance is called capacitive reactance,  $X_C$ . The mathematical formula is:

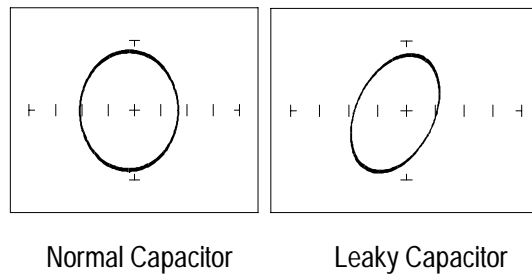
$$X_C = \frac{1}{2\pi fC}$$

$X_C$  is inversely related to both capacitance and frequency. So to review and summarize capacitive analog signatures up to this point:

- Changing capacitance: As the capacitance of a circuit increases, the capacitive reactance  $X_C$  decreases. This means that when capacitance increases, the amount of current in the component or circuit will increase. On the Tracker 200, the elliptical signature will become increasingly vertical that implies more current flow.
- Changing frequency  $F_S$ : As the frequency of the test signal increases, the capacitive reactance  $X_C$  will decrease and the amount of current in the circuit will increase. On the Tracker 200, the elliptical signature will become increasingly vertical that implies more current flow.
- Changing the range from LOW1 to HIGH the following occurs:
  - $X_C$  of the capacitor is not affected
  - $V_S$  increases so current decreases proportionately
  - The elliptical signature becomes increasingly vertical

## Capacitor Failures - Leakage

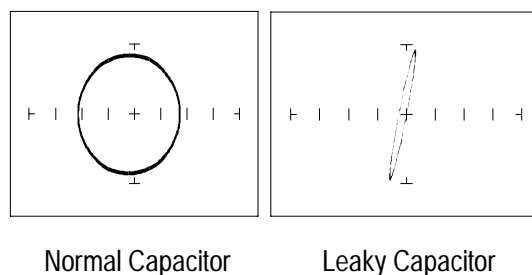
One common physical failure in capacitors is dielectric leakage. The dielectric or insulator in a capacitor normally acts as a non conductor between the capacitor's two plates. A flawed capacitor develops a conductive or leakage path between its two plates. This can be thought of as a resistance in parallel with the capacitance when observing its analog signature. The following examples show what some capacitor leakage problems may look like on the Tracker 200 display.



**Figure 4-11. Signatures of a 100  $\mu\text{F}$  Capacitor with Dielectric Leakage. LOW2 Range,  $F_s = 60 \text{ Hz}$**

This example only simulates the leakage flaw by adding a 100  $\Omega$  resistor in parallel to a 100  $\mu\text{F}$  capacitor. It shows the signature change from a normal circular ellipse pattern to a sloped and depressed vertical pattern. The signature of a real capacitive leakage would be quite similar to this example.

Another example of capacitive leakage is shown for a 10  $\mu\text{F}$  capacitor.



**Figure 4-12. Signatures of a 10  $\mu\text{F}$  Capacitor with Dielectric Leakage. LOW2 Range,  $F_s = 60 \text{ Hz}$**

Again, this example only simulates the leakage flaw by adding a 68  $\Omega$  resistor in parallel to a 10  $\mu\text{F}$  capacitor. It shows the signature change from a normal circular ellipse pattern to a sloped and depressed vertical pattern. The signature of a real capacitive leakage would be quite similar to this example.

As you can see from the two previous examples, adding resistance in parallel to a capacitor distorts the normal signature with a diagonal bend to it. This is our first look at a composite signature, the kind of signature the Tracker 200 displays when there are several components connected together in a circuit.

## Review

- Capacitors have circular or elliptical signatures due to the current and voltage phase shift.
- As the test signal's frequency increases, the capacitor's signature becomes more vertical due to decreasing  $X_C$  of the component.
- Capacitors with leakage flaws have their ellipses tilted diagonally due to an internal resistance in parallel with the capacitance.

## Applications

- The Tracker 200 can locate defective capacitors in or out of circuit. The ranges cover 10 pF to 20,000  $\mu$ F.
- When analyzing a capacitor's signature, adjust the Tracker 200's ranges and frequencies for the most pronounced ellipse.
- The test signal frequency  $F_S$  can be changed to enhance a composite signature by emphasizing or de-emphasizing the capacitance.
- Besides resistance, faulty capacitor signatures often exhibit other irregularities such as non-symmetry, broken or distorted ellipse and saw-toothed shapes that can be seen in on the CRT display.

## Inductors

Inductors, like capacitors, have elliptical analog signatures. Also like capacitors, an inductor's reactance (resistance to an AC test signal) is dependent on the test signal's frequency. Because of the way they are constructed using wire which some amount of resistance in it, it is hard to find a pure inductance. An inductor's analog signature will usually be an elliptical pattern with a some slope or tilt to it due to the resistance of the coil wire.

## Inductor Analog Signatures

The goal of this part is to explore some inductive signatures and to help you understand how inductor signatures are related to:

The inductance ( $L$  in  $\mu\text{H}$ ) of the circuit under test

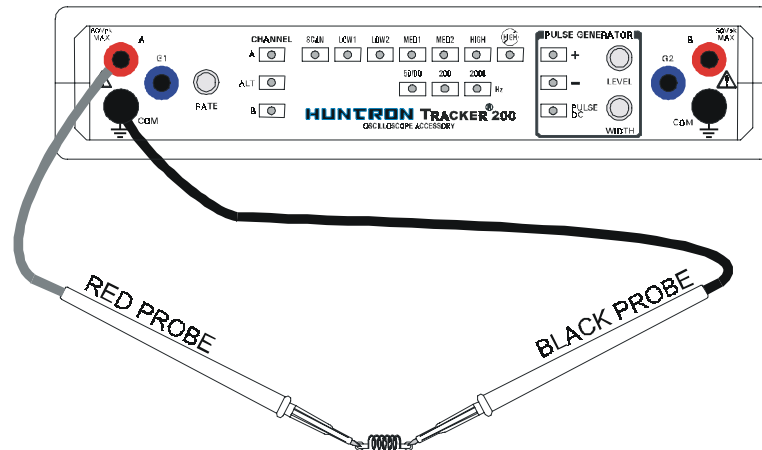
The frequency ( $F_S$  in Hz) of the test signal

The active range of the Tracker 200

Turn power on to your Tracker 200. Plug the red test microprobe in the **A** jack, and the black test clip lead in the **Common** jack.

Do the following to display the analog signature of an inductor:

1. Press the LOW2 range button.
2. The LED will be on to indicate that the LOW2 range is active.
3. Place or clip each test lead on the opposite ends of an inductor and observe the



signature on the Oscilloscope CRT display.

Figure 4-13. Tracker 200 with Probes to an Inductor.

## The Signatures of Different Inductors in LOW2 Range

The figure below shows analog signatures for four different value inductors, 12,000  $\mu\text{H}$ , 1200  $\mu\text{H}$ , 120  $\mu\text{H}$  and 12  $\mu\text{H}$  in LOW2 range.

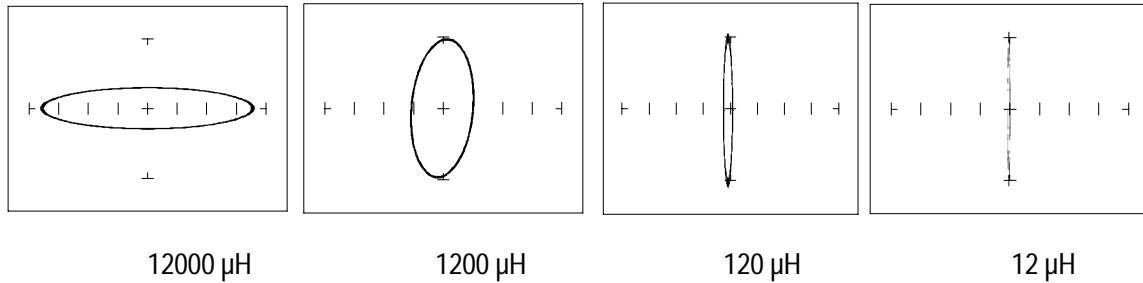


Figure 4-14. Signatures of 4 Inductors in LOW2 Range. 2000 Hz

Note that as the inductance values decrease, each signature changes from a horizontal elliptical pattern to a vertical elliptical pattern. In ASA, a large value inductor has a signature that looks similar to an open circuit. And likewise, a small value inductor has a signature that's similar to a short circuit.

## Effect of Frequency $F_s$ on Inductor Signatures

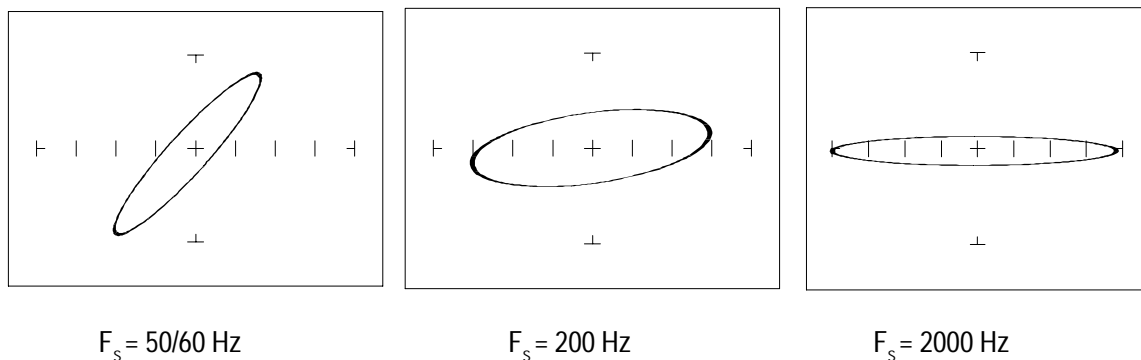


Figure 4-15. Effect of Varying  $F_s$  on Inductor Signatures in LOW2

Note that the signature changes from a vertical position to a horizontal position as the frequency increases. This means the resistance of an inductor increases as frequency increases.

## Understanding Inductive Signatures

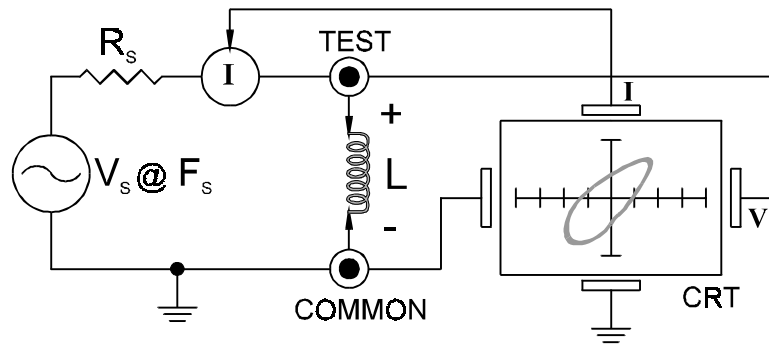


Figure 4-16. Tracker 200 Core Circuit Block Diagram with an Inductor.

The Tracker 200's block diagram shows an inductor between the test terminals. The current is represented by the vertical axis and is derived as a series current that flows through Tracker 200's internal resistance,  $R_s$ . The voltage is represented by the horizontal axis and is derived as a voltage across the inductor.

The formula for the reactance  $X_L$  of an inductor is:

$$X_L = 2\pi fL$$

As the test signal frequency increases, the inductive reactance  $X_L$  becomes larger. As a result, the inductor's analog signature will change from a rounder elliptical to a flatter resistive type pattern. The size and shape of the ellipse depend on the inductor value, test signal frequency, and the selected ranges internal resistance  $R_s$ .

Since inductors in reality are not pure inductors, the elliptical signatures they form on the oscilloscopes display are sometimes distorted. Inductors constructed with a ferrite core makes the inductive characteristics different from those constructed without. The Tracker 200 responds with a unique analog signature for each inductor type.

## Review

- Inductors display elliptical signatures similar to capacitors. Since the inductor also exhibits resistance, due to its construction, the ellipse may be tilted.
- As the Tracker 200 test signal's frequency is increased, the ellipse signature becomes flatter. This response is opposite to that of a capacitor.

- As the Tracker 200 range increases, an inductor's signature becomes more vertical (like the capacitor signature).
- When an inductor has a ferrite core, its signature distorts from a non ferrite inductor's ellipse.

## Applications

- The Tracker 200 is excellent for troubleshooting inductors. It can reveal shorted or open windings in large variety of inductive components.
- Components that are inductors or have inductive characteristics can be found in many real world applications. For example, some of these are power transformers, relays, solenoids, flybacks, speakers, magnetic sensors, stepping motors and motor windings.
- The best technique for testing inductors is the comparison of a known good component's signature to a suspect component. For example, a motor armature has typically numerous windings so every winding should have a similar analog signature. This fact is true whether it's from an elevator or a tape deck. The armature of a DC motor can be tested by simply connecting to the motor brush leads and then adjusting the test range for the most pronounced or descriptive signature. Slowly turn the armature. Observe the Oscilloscope's CRT display. This test will check continuity, the inductance, and the condition of each brush contact without disassembling the motor.
- A computer switching power supply contains inductors. For example, a computer is reported "dead." To make a quick diagnosis of the possible problem first make sure the computer is disconnected from AC power. Then connect the red and black test probes across the prongs on the AC line cord going to the computer. Turn the computer power switch to the On position. If there is a response on the ProTrack display, adjust the test range for the most pronounced inductive signature. Flick the power switch off and on and watch for noisy switch contacts. If there is no response, start by checking each component up to the primary winding of the transformer. With this technique, we have just verified the AC cord, the AC noise filter, the fuse, the power switch and the primary winding of the transformer, without removing the cover of the computer.
- Another simple test for a speaker or microphone is to apply the Tracker 200 signal in LOW2 range to the device input leads and listen for the 60 Hz tone or audible hum.
- To test solenoids, connect the test probes to the coil leads and manually move the plunger or activator in and out while observing if its signature changes.

## Electromechanical Switching Components

Switches are electrical devices that either stop or allow current to flow in a circuit. They are either in an on or off state. Switching devices come in all types and sizes. There are simple mechanical switches, relays, optical switches, and many kinds of semiconductor switches. They are different because each uses a different kind of stimulus to turn them on or off. Because there are so many kinds of switching devices, there is no single testing procedure that will test them all completely. With the Tracker 200, the test signal can be setup so that the switch's analog signature will verify its switching function. The goal of this section is to develop a test strategy using ASA to test the switching function. This is not a complete test, but it will be enough to determine whether or not the device is functioning as a switch.

## Manually Operated Mechanical Switches

A mechanical switch has two states: it is either open or closed. When open, no current can flow; when closed, it acts as a short and allows current to flow. The Tracker 200 can test the switching function of mechanically activated switches easily. Unlike the DVM that samples and gives a continuity measurement, the Tracker 200 displays real time activity so if a switch has noisy or intermittent operation, its analog signature on Tracker 200's display will reflect these conditions.

Turn power on to your Tracker 200. Plug the red test microprobe in the A jack, and the black test clip lead in the Common jack.

Do the following to display the analog signature of a mechanical switch:

1. Press the LOW2 range button.
2. The LED will be on indicating that the LOW2 range is activated.
3. Place or clip each test lead to the switch leads and observe its signature on the CRT display.
4. Turn the switch to its on or off position.



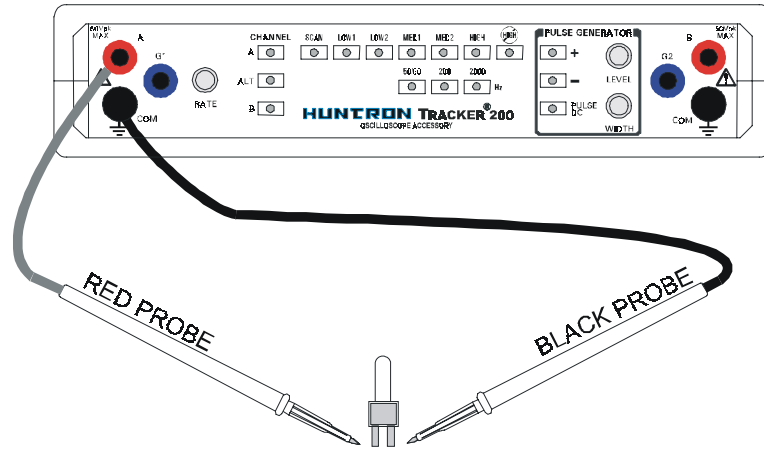


Figure 4-17. Tracker 200 with Probes to an Elastomeric Switch - SPST Type.

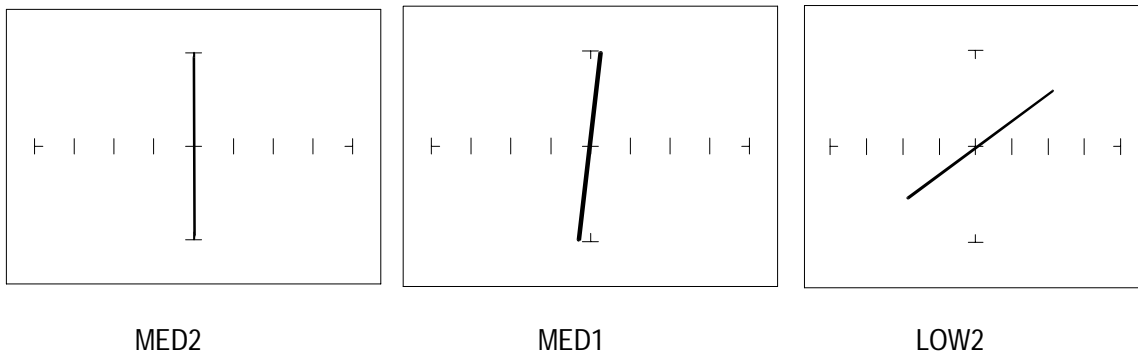


Figure 4-18. Signatures of a Keyboard Pushbutton Conductive Elastomer Switch. SPST Type, "ON" position,

Note that as the ranges change from **MED2** to **MED1** to **LOW2**, the signature tilts away from the vertical. This characteristic is similar to other components with internal resistance.

## Review

The elastomeric switch has significant internal resistance.

- As the test signal's voltage decreases with each range change, the volts per division of the horizontal axis also decreases so that its analog signature becomes more pronounced. This is caused by the small voltage drop across the switch's internal resistance.

## Electromechanical Relays

A relay is a switch that's activated by an electrical control input. The relay consists of switch contacts, magnets and an electromagnetic coil. The Tracker 200 can test the coil part of the relay by looking at its inductive analog signature. You can also connect the Tracker 200's pulse generator to the magnetic coil of a 5V relay, while at the same time connecting Tracker's test signal to the relay contacts, to test the relay's switching action directly.

## Relay Coil Test

Do the following:

1. Press the LOW2 button .
2. Press the 2000 Hz button.
3. Connect the black test lead from Tracker 200's COMMON terminal to one side the relay coil (normally, the minus lead).
4. Connect the red test lead from Tracker 200's TEST terminal to the other side of the relay coil (normally, the plus lead).

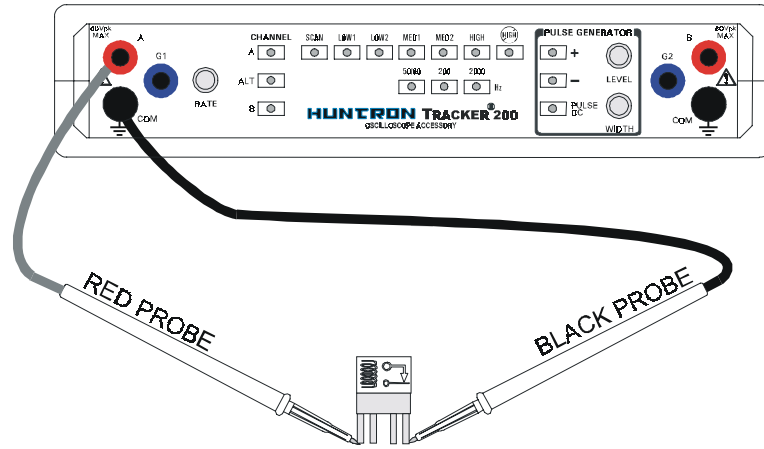


Figure 4-19. Tracker 200 with Test Leads Connected to Relay's Coil.

Observe the analog signatures of a magnetic reed type relay in the following figure.

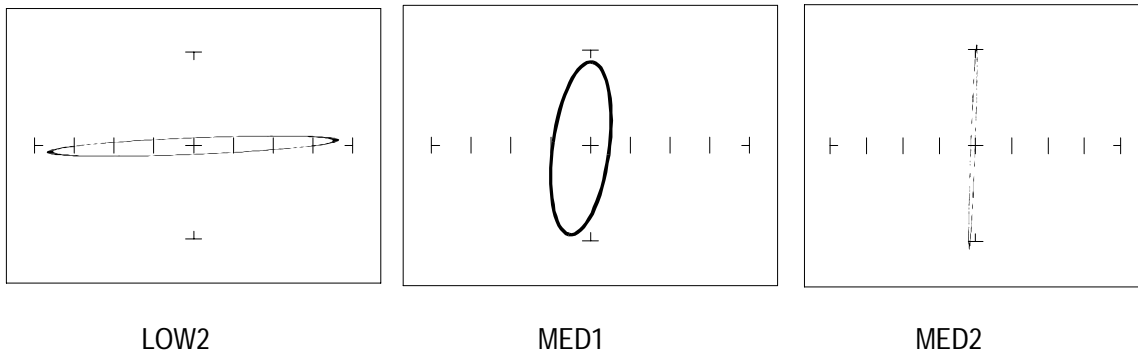


Figure 4-20. Signatures Of A Magnetic Reed Relay Coil.

Note the characteristic inductive oval in **LOW2** and **MED1** ranges. When applying Tracker 200's test signal to the coil, there may be an audible ringing sound generated from the relay under test from the switch contacts being excited.

## Using the Pulse Generator to Test a 5V Reed Relay

Do the following:

1. Press the LOW2 button.
2. Connect the Tracker 200 pulse generator output G1 to the positive (+) lead of the relay coil.

3. Connect the Tracker 200's COMMON to the relay's negative (-) lead).
4. Connect the black test lead from Tracker 200's COMMON terminal to one side of the relay switch contact.
5. Connect the red test lead from Tracker 200's TEST terminal to the other side of the relay switch contact.
6. Press Pulse/DC button on the Tracker 200.
7. Press the + button to activate the positive DC output (+ blue LED should be on).
8. Rotate the Level knob slowly and watch the relay's signature for a short circuit. At this point, turn the knob back and forth and watch the relay's signature change between an open and a short.

If the relay does not activate and you know that it is known good, then connect both pulse generator outputs G1 and G2 in parallel to the relay coil terminal for more output drive current. This will effectively double the drive current available to the device.

## Review

- The Tracker 200 can test switches in real time. This makes an excellent test for microswitches, power switches, control switches, pressure and heat sensor switches.
- As the mechanical switch closes, watch for erratic or discontinuous signature. Switch bounce will display as multiple closure signatures. Resistive contacts will display a resistive signature in LOW2 range.

# Testing Discrete Semiconductors

## Diodes

The most basic type of solid state semiconductor component is the diode. Diodes are formed by creating a junction between p-type and n-type semiconductor material. The pn junction gives diodes and semiconductor components polarity characteristics that allow them to conduct current when an external voltage is applied. They conduct current in one direction, but not in the other. Current flows in a diode when the positive terminal (anode) is made more positive than the negative terminal (cathode). Figure 5-1 shows how the diode symbol indicates the polarity of the diode.

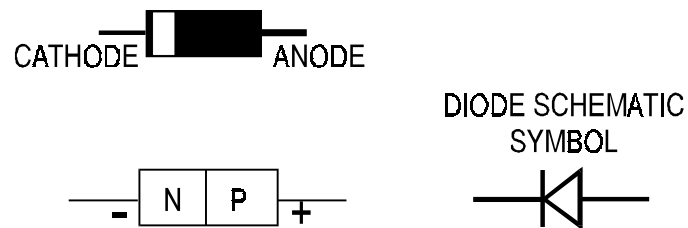


Figure 5-1. Diode and Schematic Symbol.

## Diode Analog Signatures

Diode signatures demonstrate the fundamental operation of a semiconductor junction. There is a threshold or forward voltage  $V_F$  (about 0.6V for a silicon diode) at which the diode begins to conduct current. The diode acts as an open circuit and no current flows as long as the voltage differential between the anode and cathode is below that threshold. As the anode to cathode voltage becomes more positive, the diode will begin to conduct current. Once current begins to flow in the diode, very small increases in anode voltage will cause very large increases in current. In analog signature analysis, this is called the “knee” effect in a which is characteristic of a good semiconductor junction.

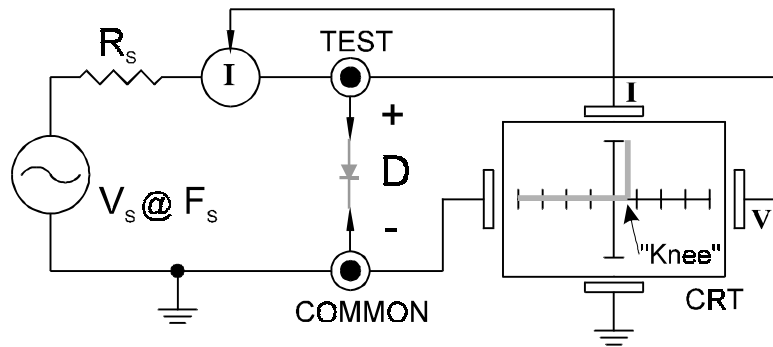


Figure 5-2. Tracker 200 Core Circuit Block Diagram with a Diode.

You can see this "knee" signature on some diodes in the next section.

Do the following to display the analog signature of a diode:

1. Turn power on to your Tracker 200.
2. Press the LOW2 range button.
3. Place or clip the red test lead from the Tracker 200's A test terminal to anode lead of the diode.
4. Place or clip the black test lead from the Tracker 200's Common terminal to anode lead of the diode.

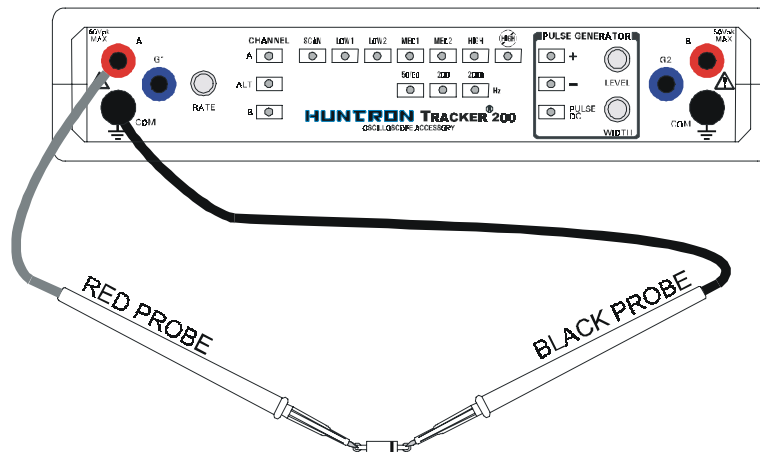


Figure 5-3. Tracker 200 with Probes to a Diode.

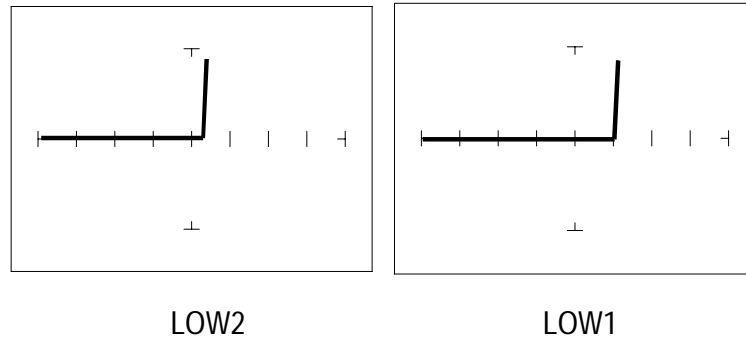


Figure 5-4. Signature of a 1N914 Type Silicon Diode.

## Effect of Frequency ( $F_s$ ) on the Diode Signature

With the LOW2 range selected and the test signal frequency of 60 Hz, the signature of the diode is shown on the left figure below. Changing only the test signal frequency to 2000 Hz displays the signature on the right. At  $F_s = 2000$  Hz, the diode's signature has slight circular loop added to it. This loop in the signature is due to a physical characteristic of diodes called junction capacitance.

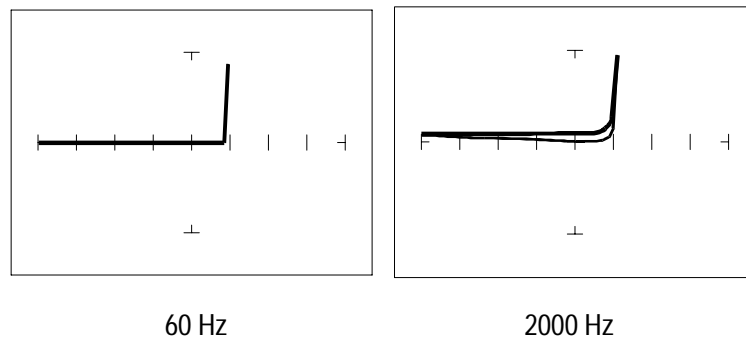


Figure 5-5. Signature of a 1N914 Diode at Different Frequencies.

## The Composite Diode Signature

A composite analog signature is a combination of several components connected together in an electronic circuit. Up to this point, we have been showing you what the basic component signatures look like out of circuit. In the real world of electronics troubleshooting, components are connected together in a circuit and when testing with ASA, the signatures are a composite that may appear quite complex. However, with knowledge of ASA fundamentals and experience you

will find that even the most complex looking signatures can be analyzed quickly and efficiently.

This section will introduce you to some examples of composite diode signatures.

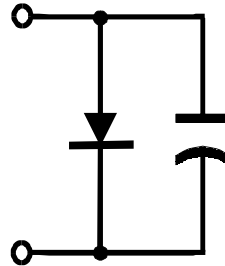
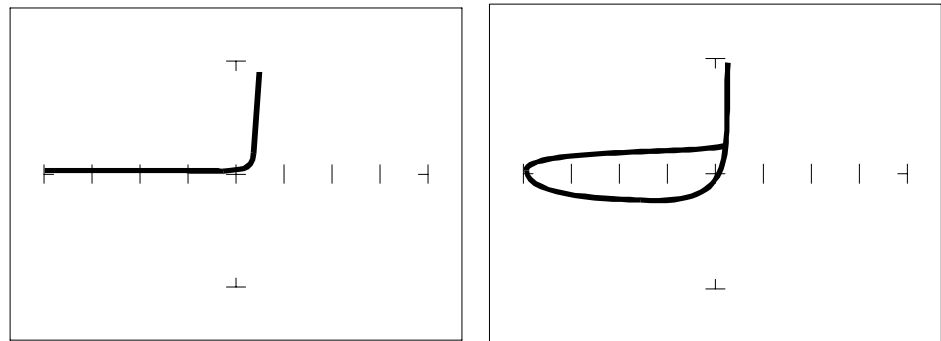


Figure 5-6. Composite Model of a Diode and Capacitor in Parallel.



LOW2 Range, Fs = 60 Hz

LOW2 Range, Fs = 2000 Hz

Figure 5-7. Composite Signature - 1N914 Diode and 1  $\mu$ F Capacitor in Parallel. LOW2 Range.

The signature on the left shows only the diode signature because the test signal frequency is set below any visible contribution due the capacitive reactance. The composite signature in the center consists of the distinctive loop of the capacitor and the "knee" pattern of the diode. The signature on the right shows only the capacitor signature because the test signal voltage is below the diode's turn on level. When multiple components are connected together, it's important to realize that the Tracker 200 has the ability to selectively display the signature of a single component.

## Diode Failures

Diodes can fail in a number of ways, and each type of failure will cause the signature to change. The defective diodes often appear as open and short signatures. Two other types of flaws are internal resistance and leakage.



## Internal Resistance Flaw in a Diode

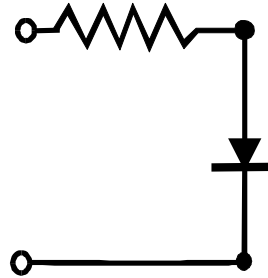


Figure 5-8. Defective Diode Model With A Small Series Resistor.

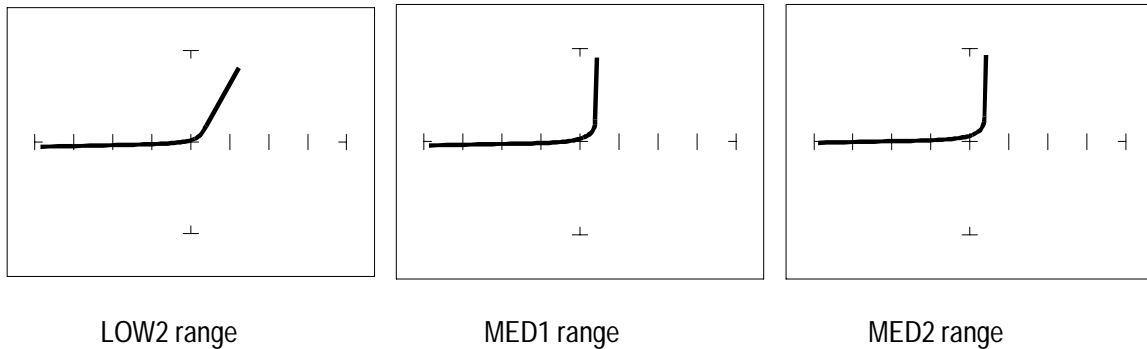


Figure 5-9. Defective Diode Signature with a 50  $\Omega$  Series Resistor.

The LOW2 range shows that there is a resistive component to the signature when the diode is conducting. This is the result of a defect in the diode's internal PN junction. The resistance is visible only in LOW2 range because the voltage drop across it is small. In the other two ranges, the resistance is masked due to the internal resistances being too large to show such a small voltage drop.

## Internal Leakage Flow in a Diode

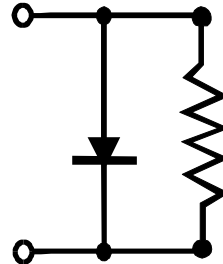


Figure 5-10. Defective Diode Model with an Internal Leakage Resistance.

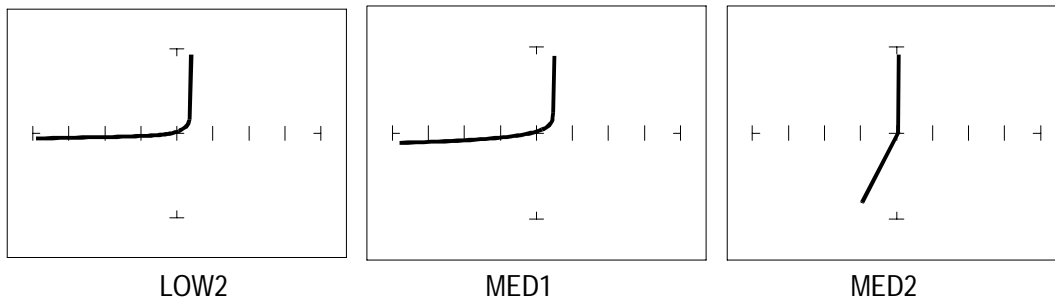


Figure 5-11. Signature of a Diode with Internal Leakage Flow. 1N914 Diode with a 10 kΩ Resistor in Parallel.

Notice that in LOW2 range there does not seem to be any problem, but that in both medium ranges, you can see the diode conducting when it should be acting like an open. This is called leakage. The diode acts like a diode when it is forward biased. When reverse biased, the diode acts like a resistor when it should be acting as an open.

## Zener Diodes

Normal switching and signal diodes conduct when forward biased only. When reverse biased, they act as opens unless they are operated outside design limits. If this condition occurs then so much voltage is applied that they break down and can no longer prevent current flow.

A zener diode is a different type of diode and is designed for operation when reverse biased (diode's cathode connected to positive and anode to negative), but under carefully controlled conditions. When the zener diode is forward biased (diode's cathode connected to negative and anode connected to positive), they act as regular diodes and begin to conduct at approximately 0.6V.

When reverse biased, they act as an open until the applied voltage reaches their specified zener voltage, at which time the zener diode begins to conduct current. Even if the reverse voltage is increased, the voltage across the zener remains constant. It is this feature of zener diodes that allows them to be used as voltage regulators and references. Because they conduct in both directions, the zener diode's analog signature has two knees, one at 0.6V and the other at the zener voltage of the diode. In ASA terminology, this two knee signature is known as the classic "chair" pattern that is common in many solid state semiconductor components.

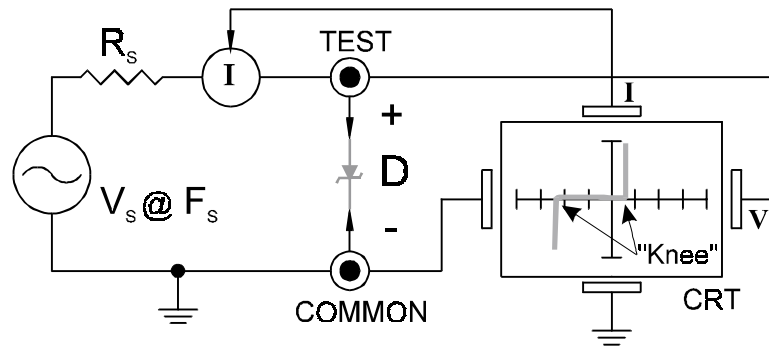


Figure 5-12. Tracker 200 Core Circuit Block Diagram with a Zener Diode.

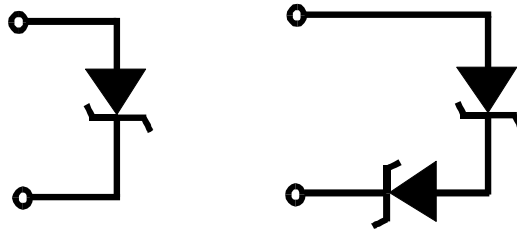
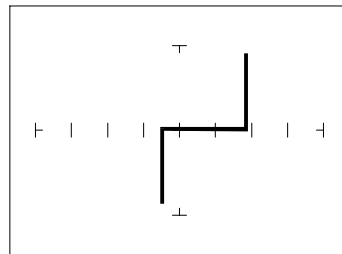
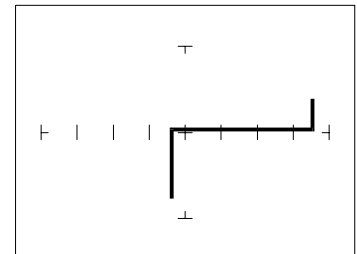


Figure 5-13. Single Zener Diode and 2 Zener Diodes in Series.



Single 1N5239B Zener Diode



Zener Diodes in Series, 1N5239B

Figure 5-14. Signature of a Single Zener Diode and 2 Zener Diodes in Series. MED2 Range

Since each horizontal division on the CRT graticule (in MED2 range) is approximately 5 volts, from the signature on the left you can estimate that this is about a 9 volt zener diode. The signature at the right is the signature of two zener diodes connected in series. The Zener voltage ( $V_Z$ ) of this circuit is the sum  $V_Z$  of each of the separate diodes. The signature shows this voltage to be approximately 18 volts.

## Review

- Diodes conduct current in one direction (forward biased) and not the other. The diode's analog signature displays this characteristic as the “knee” effect or pattern.
- Diodes have polarity, an anode and a cathode.
- Diode defects, other than opens and shorts, are usually resistive.
- A diode in series or parallel with a resistor or capacitor will create a composite signature displaying both characteristics. The Tracker 200 makes it easier to separate these characteristics from composite signatures using the two parameters, range and  $F_S$ .
- Zener diodes are special diodes that conduct when reverse biased at a specific voltage.

## Applications

- Diode damage or degradation can appear as a loss of sharpness or rounding in the “knee”.
- While faulty diodes display resistive current and voltage legs, they are usually nonlinear or curved.
- The polarity of an unmarked diode can be determined by the orientation of the display with a known diode.
- The Tracker 200 can be used to identify an unknown Zener diode. If the zener diode is damaged, locate a good one, possibly on another board or in the same circuit and use the Tracker 200 to approximate the voltage.

## Transistors

A bipolar transistor is a three layer device. There are two basic types. A pnp transistor has a layer of n-type silicon material sandwiched between two layers of p-type material. A npn transistor has a layer of p-type silicon material sandwiched between two layers of n-type material. Figure 5-15 shows the relationship between type of material and circuit symbol for a pnp and a npn transistor.

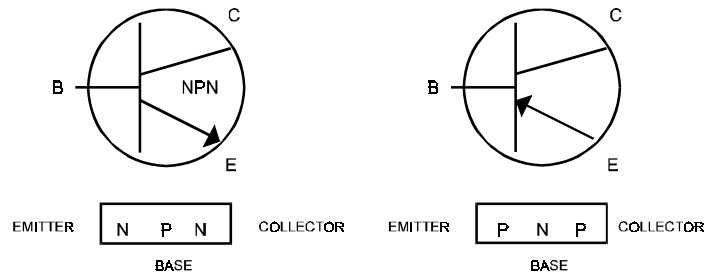


Figure 5-15. Diagram Of A NPN And PNP Bipolar Transistor.

## Bipolar Transistor Signatures

In order to better understand the signatures that transistors create on the Tracker 200, we can model these devices in terms of equivalent diode circuits. These are shown in figure 5-16. These figures show that the collector-based junction analog signature looks similar to a diode signature, and the emitter-base junction signature looks similar to a zener diode signature. Because we have already seen the signatures of these two types of junctions when we tested diodes, they should be familiar to you.

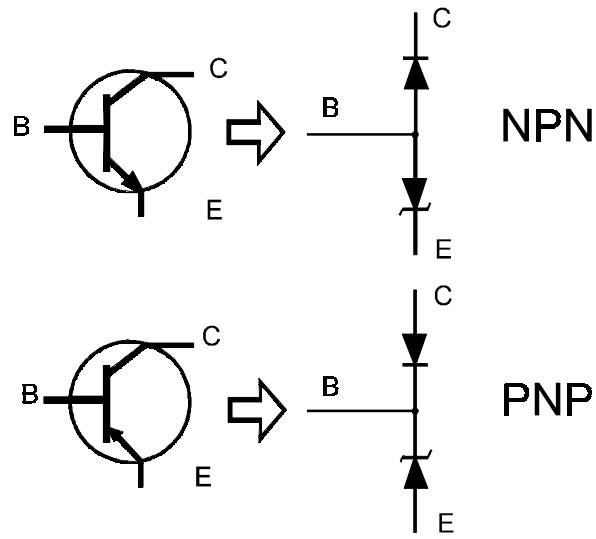


Figure 5-16. NPN and PNP Bipolar Transistors Equivalent Circuits.

## Bipolar Transistor Base-Collector Signatures



**CAUTION.** A high-frequency bipolar transistor can be degraded by excessive reverse current in its base-emitter junction. The degradation results in a loss of current gain ( $hFE$ ). To minimize the possibility of degrading a high-frequency bipolar transistor, use only the MED 2 range when probing its terminals..

Do the following to display the analog signatures of a bipolar transistor:

1. Turn power on to your Tracker 200.
2. Press the MED2 range button.
3. Place or clip the red test lead from the Tracker 200's A test terminal to collector lead of the transistor.
4. Place or clip the black test lead from the Tracker 200's Common terminal to base lead of the transistor.

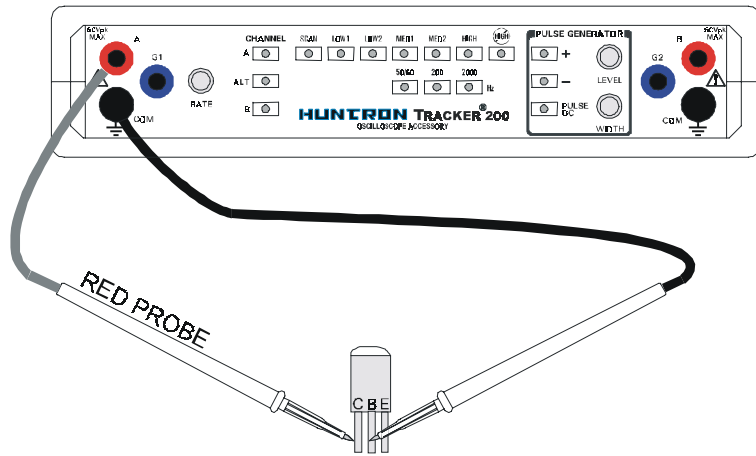
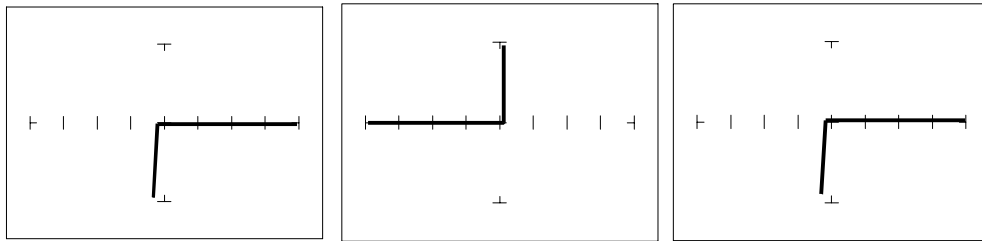


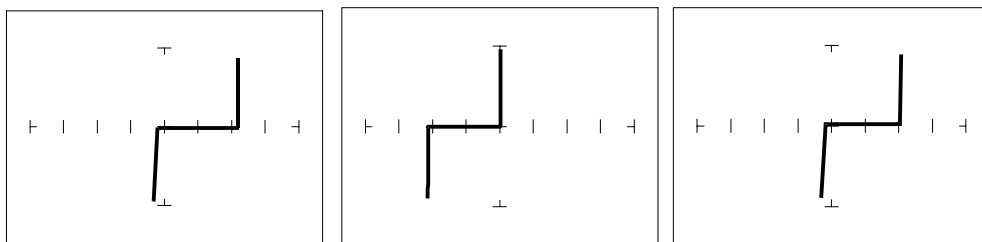
Figure 5-17. Tracker 200 Connected to the Collector and Base Leads of a Transistor.



Diode 1N914 PNP Transistor 2N3906 NPN Transistor PN2222A

Figure 5-18. Signature of a Diode and Collector-Base of a Transistor. MED1 Range

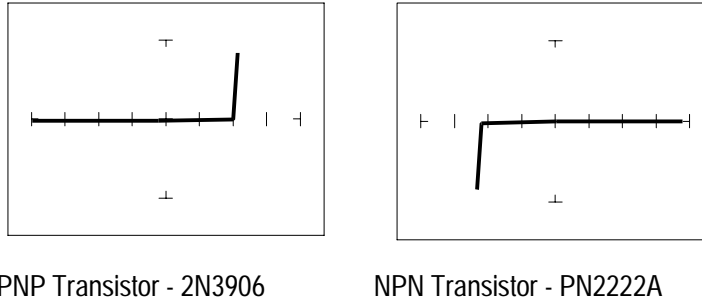
Notice that the collector-base signature of a NPN transistor is identical to the signature of diode. The collector-base signature of a PNP transistor, which has opposite polarity from a NPN, looks similar to a diode with its polarity reversed. These are the signatures we expected from our circuit modeling. We can do the same kind of comparison with the emitter-base circuits.



Zener Diode 1N5239B PNP Transistor 2N3906 NPN Transistor PN2222A

Figure 5-19. Signature of a Diode and Emitter-Base of a Transistor. MED1 Range

We can see that the base-emitter signature of the NPN transistor is nearly identical to the signature of the zener diode. The emitter-base signature of a PNP transistor is also nearly identical but opposite in polarity to the zener diode.



**Figure 5-20. Signature of the Collector-Emitter of a PNP and NPN Transistor. MED1 Range, Emitter to Common.**

You can see that the collector-emitter signature of a PNP transistor looks like a forward biased diode with the knee at approximately +7 volts. The collector-emitter signature of a NPN transistor looks similar to a reverse biased diode with the knee at approximately -7 volts.

All bipolar junction transistors have essentially the same looking signatures.

## Identifying Unknown Transistors

Sometimes, we need to identify unknown transistors. We may need to replace one in a circuit for which we do not have a schematic. The Tracker 200 makes this a relatively simple procedure because each type of junction has a characteristic signature. This makes it possible to identify each of the terminals and the polarity of the transistor.




---

**CAUTION.** *A high-frequency bipolar transistor can be degraded by excessive reverse current in its base-emitter junction. The degradation results in a loss of current gain (hFE). To minimize the possibility of degrading a high-frequency bipolar transistor, use only the MED 2 range when probing its terminals.*

*The gate in many power MOSFET transistors is not internally protected and can be damaged by excessive gate-to-source voltage. To minimize the possibility of damage, use only the LOW 2 or MED 1 range when probing power MOSFET transistors.*

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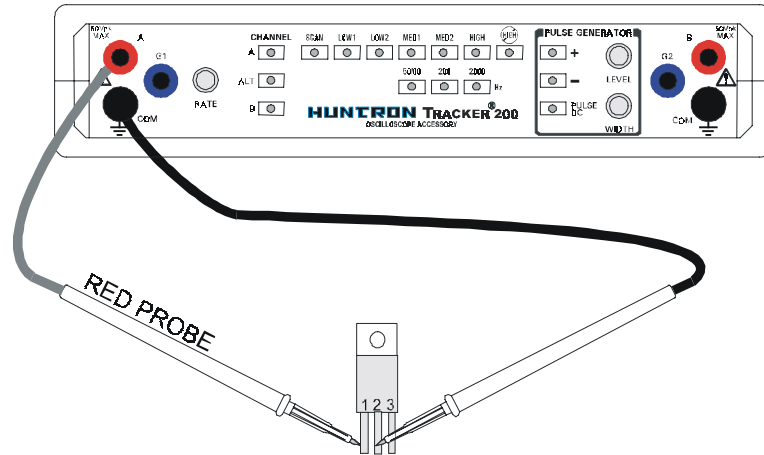


Figure 5-21. Tracker 200 with Probes to an Unmarked Transistor.

Do the following:

1. Probe pin 1 with the red probe and pin 2 with the black probe.
2. Identify the signature.

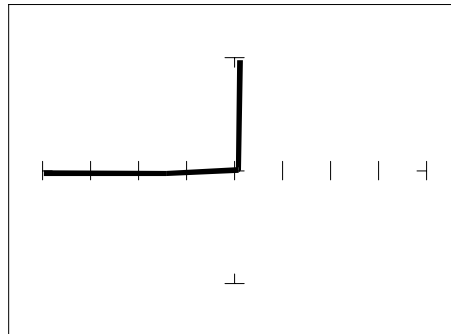


Figure 5-22. Signature of Pins 1 and 2 of an Unknown Transistor, MED2 Range.

3. This looks like a collector-base signature. What you do not know yet is which pin is the collector and which pin is the base.
4. Probe pin 3 with the red probe and pin 2 with the black probe.
5. Identify the signature.

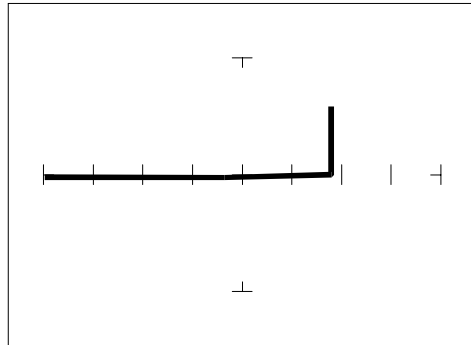


Figure 5-23. Signature of Pins 3 and 2 of an Unknown Transistor, MED2 Range.

6. This looks like a collector-emitter signature.
7. Now that you know that pin 2 of the unknown transistor is the collector. Place the black probe to the base on pin 1 and move the red probe to the emitter on pin 3. A base to emitter signature will be displayed. This transistor is a NPN type since the base-emitter signature matches a NPN transistor.

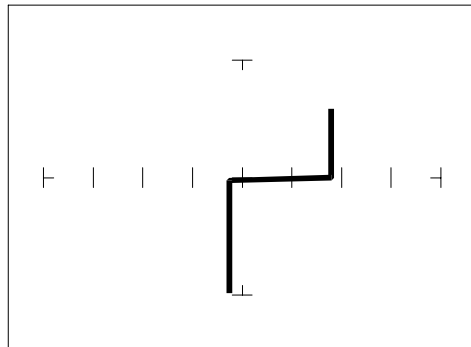


Figure 5-24. Signature of Pins 1 and 3 of an Unknown Transistor, MED2 Range.

## Darlington Bipolar Transistor Signatures

The Darlington transistor is basically two transistors paired together in a special configuration. The emitter of the first transistor is connected to the base of the second transistor. The collectors of both transistors are connected together. The base of the first transistor serves as the external base lead and the emitter of the second transistor serves as the external emitter lead. A block diagram of a darlington transistor and its analog signature are shown in the following figures.

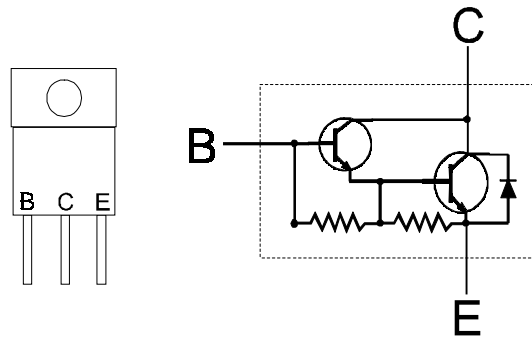


Figure 5-25. Diagram of a Darlington Transistor.

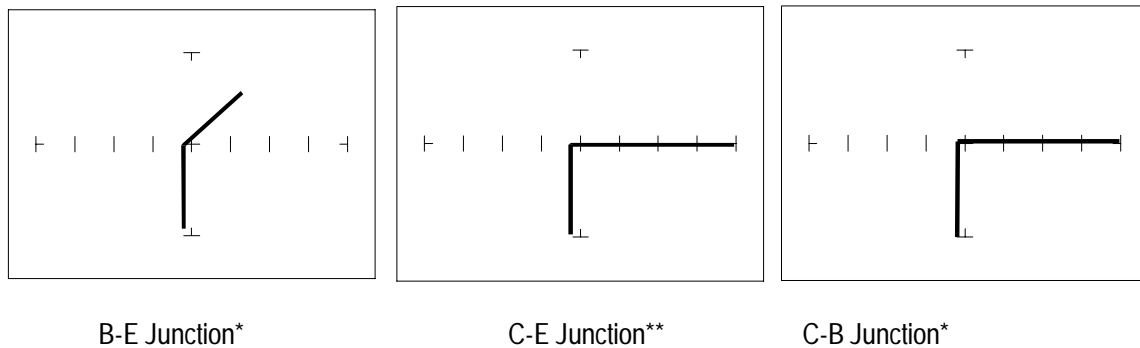


Figure 5-26. Signature of a Darlington Transistor, TIP112 NPN Type. MED2 Range, Base to Common\*, Emitter to Common\*\*

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*NOTE. The B-E junction has a sloped leg bend in its signature caused by internal resistors R1 and R2.*

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## Using the Pulse Generator to Test Transistor Operation




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*CAUTION. The following technique can inject up to 50 ma into the base of a transistor, which is sufficient current to damage small, high-frequency transistors. To avoid damage, do not use this technique if the  $I_c$  maximum specification for the transistor is 50 ma or less.*

---

Figure 5-27 shows the test circuit for a NPN transistor using the pulse generator to drive the base. The constant current signature produced is similar to that produced by a transistor curve tracer except that only one curve is shown instead of a family of curves. This technique can be useful for functionally testing and matching transistor gain characteristics.

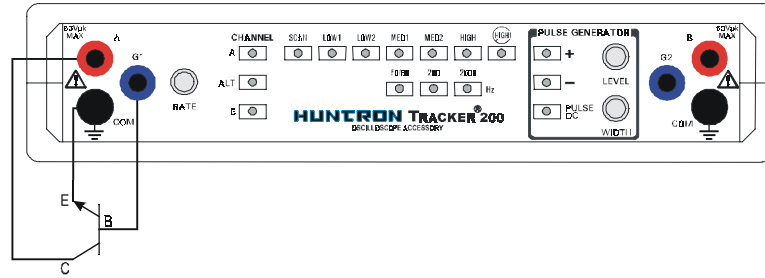
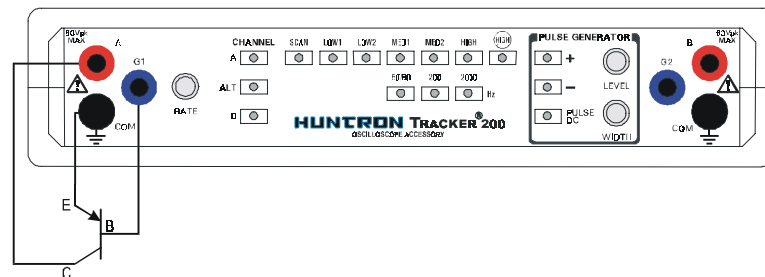


Figure 5-27. Pulse Generator Test Circuit for a NPN Transistor.

Figure 5-28 shows the test setup for a PNP transistor. As for the NPN transistor,



this signature will be the result of the collector-base junction of the transistor.

Figure 5-28. Pulse Generator Test Circuit for a PNP Transistor.

## Analyzing the Active Characteristics of a Transistor

Setup:

1. Setup the test circuit shown in figure 5-27 or 5-28 depending on what type of bipolar transistor you wish to test.
2. Connect the blue grabber test lead from G1 on the Tracker 200 to the transistor's base lead.
3. Press the MED1 range button.
4. Set the frequency to 60 Hz.

Do the following:

1. Press the Pulse/DC button.

2. Press the + button for testing PNP type transistors, or the - button for NPN testing.
3. Rotate the level knob until the transistor switches on (short circuit signature).

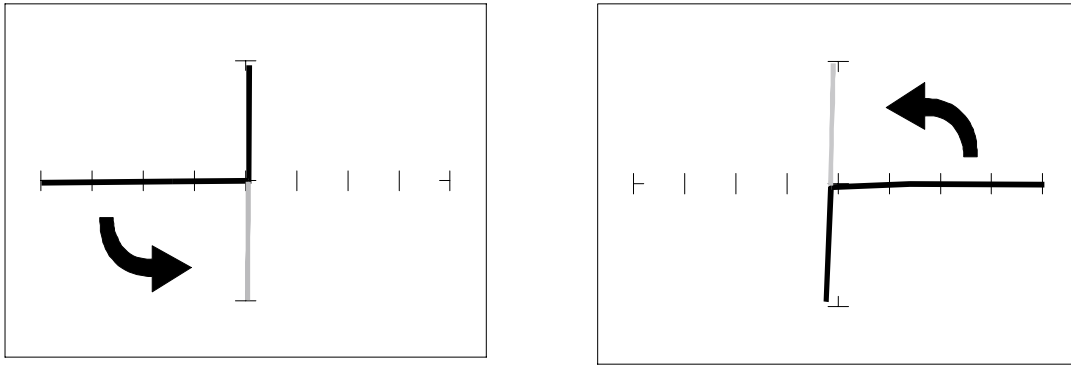


Figure 5-29. Testing Transistors with the Pulse Generator - DC Mode, MED1 Range.

4. Press the Pulse/DC button again to select pulse. The Pulse/DC button LED will flash on and off.
5. Use the Width knob to adjust the pulse width of the pulse generator output.

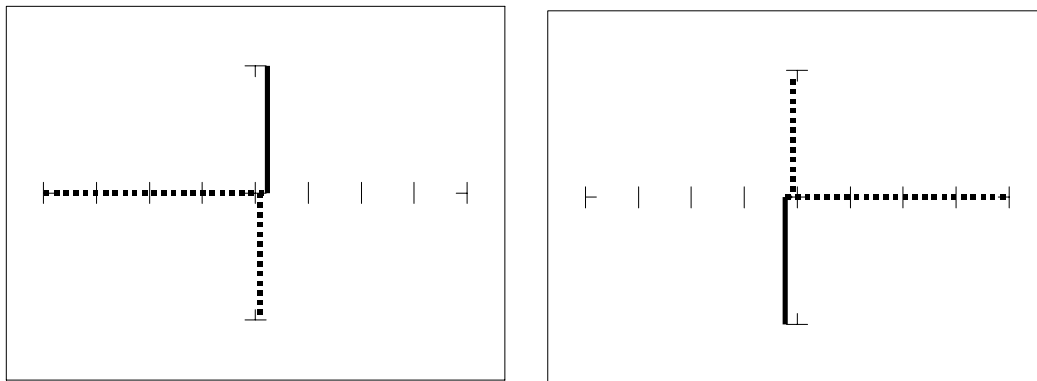


Figure 5-30. Testing Transistors with the Pulse Generator - Pulse Mode.

6. Look at the transistor's signature change as the duty cycle changes. The figure above shows these signatures as dotted lines. This composite signature shows multiple operating states as the base stimulus varies. The transistor is actually being switched on and off by the Tracker 200.

## Review

- A PNP bipolar transistor consists of a layer of N-type silicon sandwiched between two layers of P-type silicon.
- A NPN bipolar transistor consists of a layer of P-type silicon sandwiched between two layers of N-type silicon.
- To test a transistor, the base-emitter (B-E), collector-base (C-B) and collector-emitter (C-E) junctions all need to be examined.
- The transistor signature resembles the diode signatures previously examined. They have polarity and may exhibit the Zener effect.

## Applications

- Transistors will display the same type of faulty signature as diodes, with a rounded “knee” and non-linear or resistive current and voltage legs.
- The Tracker 200 can be used to determine the type of transistor; bipolar, Darlington, FET, etc.
- The Tracker 200 can be used to identify the polarity of a transistor (PNP or NPN).
- The Tracker 200 can be used to determine the base, collector and emitter on an unknown transistor.
- The Tracker 200 can be used to match the gain (beta) of two transistors.
- The above techniques of identification are invaluable when repairing foreign electronics and systems without schematics.
- Use the MED2 range when testing high frequency (RF) transistors.
- Use the LOW 2 or MED1 range when testing power MOSFET transistors.

## Optical Switches

There are two types of optical switches: phototransistors and optocouplers. Phototransistors can be used in two modes depending on the application. It can be used as either a light activated transistor or as a light activated diode. In either mode, light is used to turn it on and allow current to flow.

The optocoupler consists of a light emitting diode and a phototransistor in the same package. They are electrically isolated. When the diode is turned on by an

external signal, it radiates light. This light falls on the phototransistor base junction that results in the device turning on.

## Phototransistors

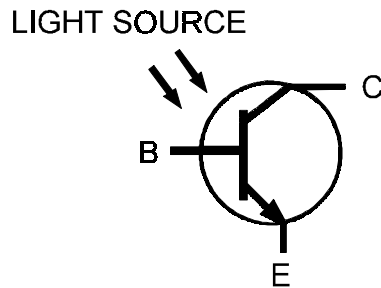


Figure 5-31. Phototransistor Schematic Diagram.

Do the following to display the analog signature of a phototransistor:

1. Press the MED1 range button.
2. Place or clip the red test lead from the Tracker 200's A test terminal to collector lead of the component.
3. Place or clip the black test lead from the Tracker 200's Common terminal to

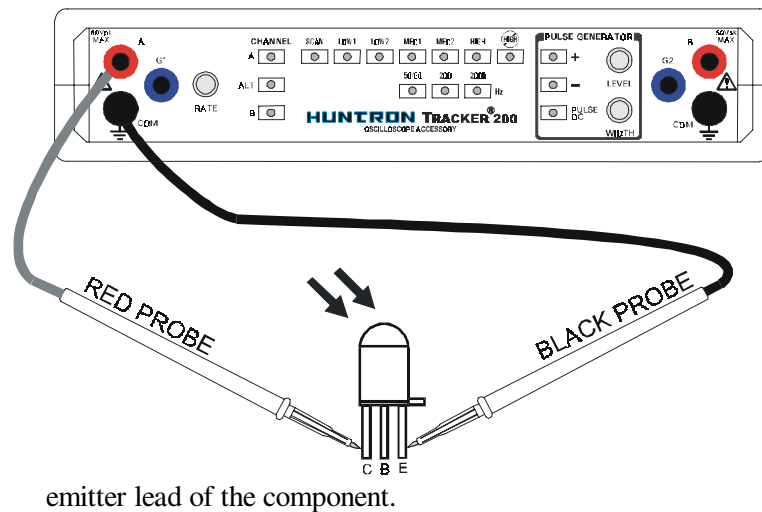
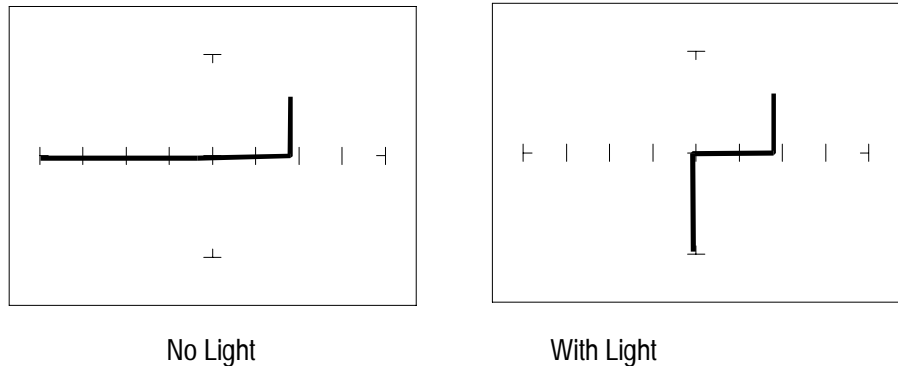


Figure 5-32. Tracker 200 with Test Probes to a Phototransistor.



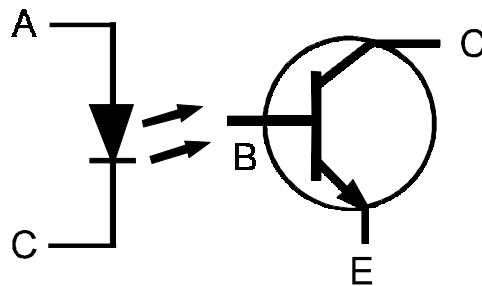


**Figure 5-33. Signatures of a NPN Phototransistor - MRD3056 Type. MED1, C-E Junction**

The phototransistor's signature is similar to a diode's signature in reverse breakdown mode when not activated by light and as a short signature when activated by a bright external light.

## Optocoupler Dynamic Testing

The Tracker 200's pulse generator can perform a dynamic test of optocouplers. Apply the pulse generator's output to the control input of a switching device and connect Tracker 200's test leads across the component's switch terminals. Observe the optocoupler's signature for on and off states.



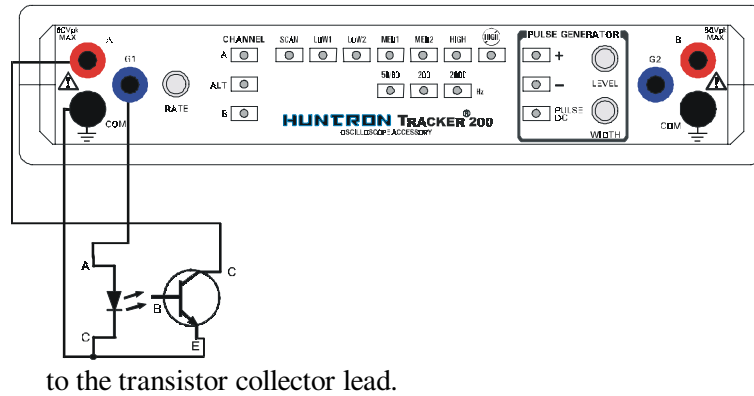
**Figure 5-34. Diagram of an Optocoupler.**

## Optocoupler Signatures

Do the following to display the analog signature of a optocoupler:

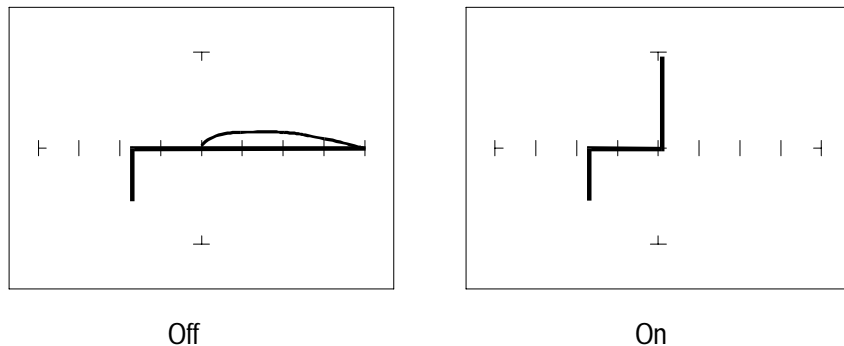
1. Press the MED1 range button.

2. Connect the black test lead or easy grabber from Tracker 200's Common test terminal to the transistor emitter lead and the diode cathode lead of the optocoupler.
3. Connect the red test lead or easy grabber from Tracker 200's A test terminal



**Figure 5-35. Pulse Generator Test Circuit for an Optocoupler.**

4. Connect the pulse generator G1 output with the blue easy grabber test clip to the diode anode lead.
5. Press the Pulse/DC button and press the + button to select a positive DC voltage level. These buttons should not be flashing.
6. Rotate the Level knob until it is approximately half way.
7. Notice that the Junction turns on and off as you vary the DC level above and below its on state voltage level.



**Figure 5-36. Signatures of an Optocoupler - 4N33 Type MED1**

## SCRs and Triacs

A SCR and triac are semiconductor components that are used in switching applications. A SCR (silicon controlled rectifier) is used for DC switching circuits. A triac is used for AC switching circuits. This section will demonstrate how to dynamically test these components.

### Silicon Controlled Rectifiers (SCRs)

The SCR is a switching semiconductor device that conducts positive current only. Its symbol and equivalent circuit can be seen below. When the gate (G) is at the same voltage level as the cathode (K), the SCR acts as an open. When the gate is forced more positive than the cathode, positive current flows between the anode (A) and the cathode.

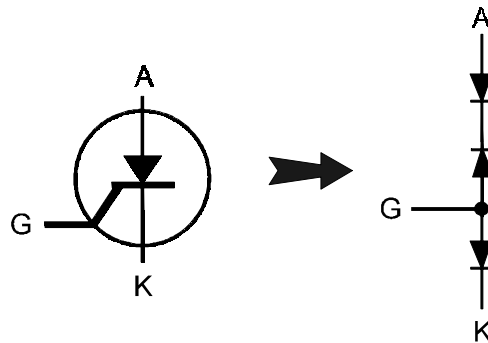


Figure 5-37. Diagram of a Silicon Controlled Rectifier.

Do the following to display the analog signature of an SCR:

1. Press the MED2 range button.
2. Place or clip the red test probe from the Tracker 200's A test terminal to gate lead (G) of the component.

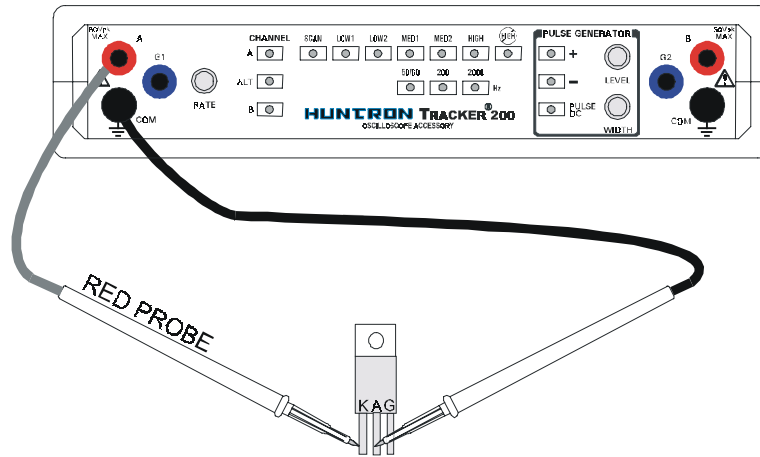
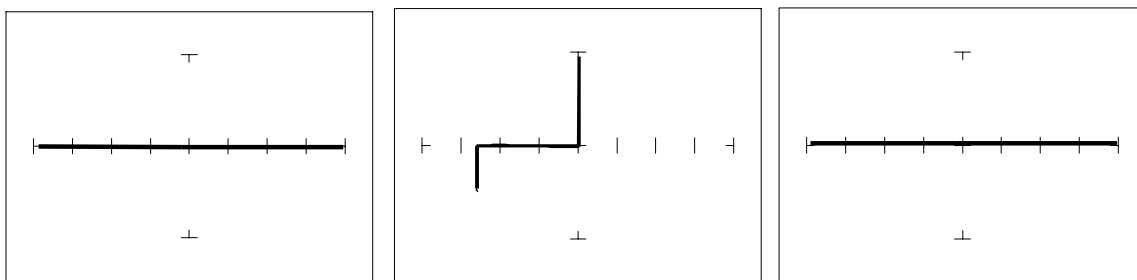


Figure 5-38. Tracker 200 with Test Leads to an SCR.

3. Place or clip the black test probe from the Tracker 200's Common terminal to anode lead (A) of the component.
4. Observe the gate-anode signature of the SCR.
5. Move the black test probe from the SCR's anode lead to cathode lead (K) of the component.
6. Observe the gate-cathode signature of the SCR.
7. Place the red test probe to the SCR's anode lead and the black test probe to the SCR's cathode lead.
8. Observe the SCR's anode-gate signature.



Gate-Anode

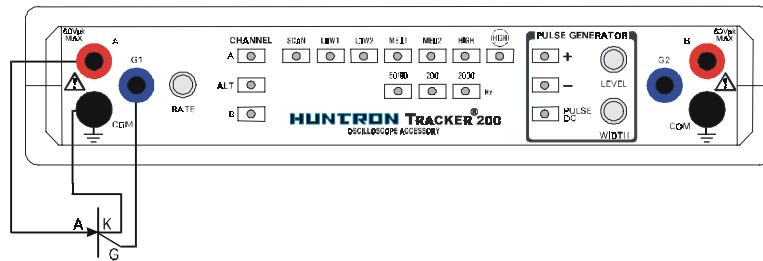
Gate-Cathode

Anode-Cathode

Figure 5-39. Signatures of an SCR - C106B Type. MED2 Range.

## Active Testing of an SCR

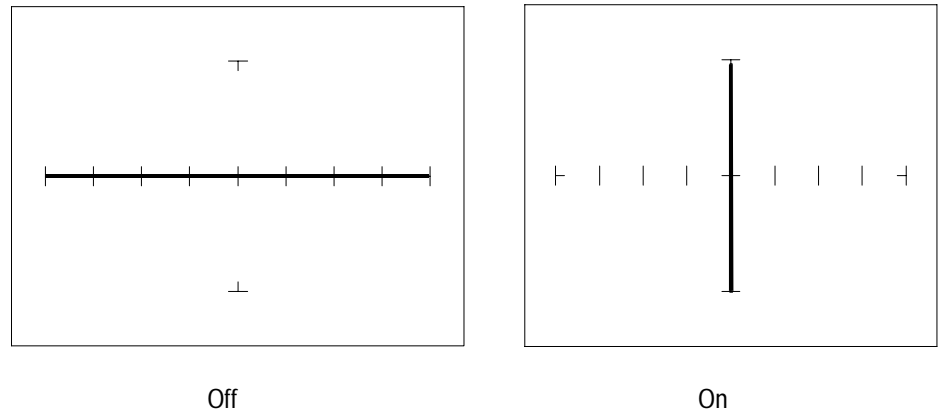
Connect the SCR to the Tracker 200 as illustrated below:



**Figure 5-40. Pulse Generator Test Circuit for a SCR.**

Do the following to dynamically test a SCR using the Tracker 200:

1. Press the MED1 range button.
2. Set the frequency to 50/60 Hz.
3. Press Pulse/DC and press + for selecting DC positive pulse generation voltage. The Pulse/DC LED should be on and not flashing.
4. Connect the blue easy grabber from Tracker 200 pulse generator G1 output terminal to the component's gate lead.
5. Connect the red test probe from Tracker 200 A test terminal to the SCR's anode lead.
6. Connect the black test probe from Tracker 200 Common test terminal to the SCR's cathode lead.
7. Turn the Level knob clockwise to increase the voltage level from 0.0VDC.

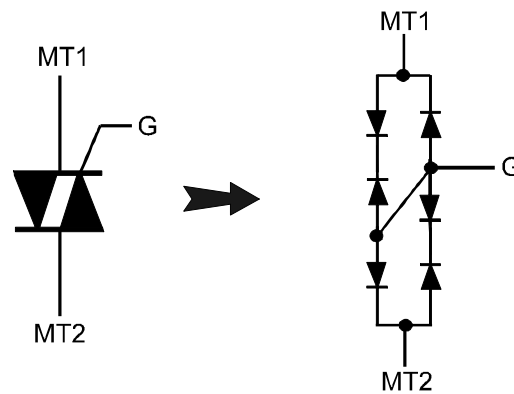


**Figure 5-41. Signature of a SCR (C106B Type ) with the Pulse Generator Test. MED1 Range**

Observe that as the test voltage increases to about 0.6 volts, the SCR begins to turn on. Watch its signature change from an open signature to a short signature.

## Triacs

The TRIAC is a device designed to switch an AC current with either positive or negative gate control pulses.

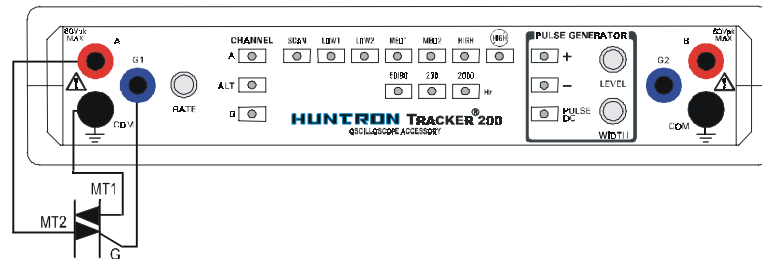


**Figure 5-42. Diagram and Symbol of a TRIAC.**

The next section demonstrates how to dynamically test a triac with the Tracker 200's pulse generator.

## Active Testing of Triacs

Connect the Tracker 200 to the TRIAC as shown in figure 5-43.



**Figure 5-43. Pulse Generator Test Circuit for a TRIAC.**

Do the following to dynamically test a TRIAC using the Tracker 200:

1. Press the MED2 range button.
2. Set the frequency to 50/60 Hz.
3. Press the Pulse/DC button twice so that the LED flashes.
4. Press the + and - buttons. This invokes both positive and negative going pulses.
5. Connect the blue easy grabber from Tracker 200's pulse generator G1 output terminal to the gate lead on the component.
6. Connect the red test probe from Tracker 200's A test terminal to the triac's MT2 lead.
7. Connect the black test probe from Tracker 200's Common test terminal to the triac's MT1 lead.
8. Turn the Level knob clockwise to increase the voltage level.
9. Observe the TRIAC begin to conduct first in a forward direction and then in a reverse direction. You will see that the TRIAC is turned on by pulses of either polarity.

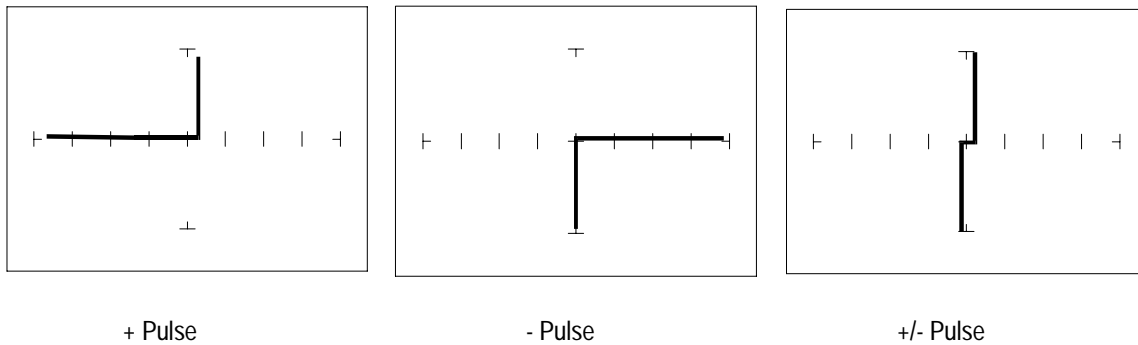


Figure 5-44. TRIAC Signatures with the Pulse Generator Test. MED2 Range.

## Review

- Solid state photosensitive switch components are turned on by light.
- SCRs and TRIACs are solid state switches that are turned on by a control input pin called a gate. SCRs conduct current in one direction while TRIACs conduct current in both directions.

## Applications

- The Tracker 200 can also dynamically test optocouplers and phototransistors. These components are commonly found in isolation and switching circuits. Their operation can slowly deteriorate making them intermittent. This type of problem is extremely difficult to troubleshoot. With analog signature analysis, the Tracker 200 will detect small amounts of degradation in an optocoupler's LED and the phototransistor's emitter-collector junction.
- The SCR and TRIAC can also be a problem to troubleshoot. They may be used to switch large currents. Quite often these components are susceptible to degradation and eventual failure. The Tracker 200 can easily show these failures.



**Notes:**

# Testing Integrated Circuits

## Digital Integrated Circuits

Digital integrated circuit (IC) chips are made from transistors on a common substrate. Their analog signatures are typically variations of the discrete diode and transistor signatures. Most logic ICs contain multiple circuits on one chip. These chips can have pins from 14 to over 200, although quite often many pins share quite similar signatures. This can make troubleshooting easier by giving us an easy-to-find signature to use as a comparison.

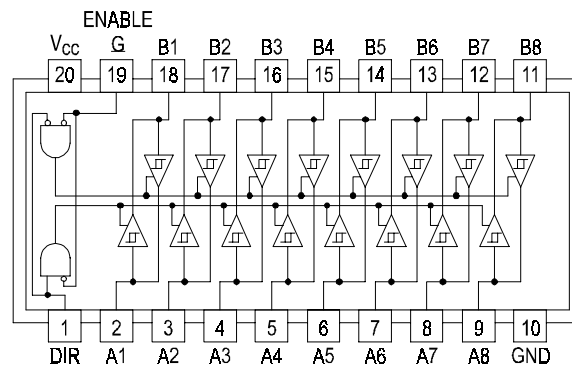
## Integrated Circuit Failures

A functioning IC may stop working for a number of reasons. Some of the most common causes of IC failures are:

- EOS (Electrical Over Stress) occurs when the IC's maximum electrical specifications have been exceeded. This condition may result in the IC developing internal shorts and opens.
- ESD (Electrostatic Discharge) may cause internal resistance to develop in the IC junctions. This internal resistance may vary from 5 k $\Omega$  to 25 k $\Omega$  with a typical value of 20 k $\Omega$ . ESD exposure can cause internal flaws such as resistance, opens and shorts.
- Dendrites are a process flaw that results in particles growing between conductors on a substrate causing shorts.
- Ionic Contamination is contamination introduced at the time of manufacturing that develops into leakage between substrate channels. This causes 5 k $\Omega$  to 25 k $\Omega$  of resistance.
- "Purple Plague" is a destructive interaction between gold and aluminum metal layers. Junction connections become very brittle and may cause internal opens.
- Corrosion or Electromigration is another process flaw in which aluminum metalization causes pinholes, corrosion and resistance. This will create opens and resistance.

## Digital Integrated Circuit Signatures

Before we examine the analog signatures of an IC, let's study the block diagram of a 74LS245 octal bi-directional bus buffer to introduce some basic concepts. This IC is a member of the low power Schottky transistor-transistor logic family (LSTTL). Examine the block diagram for this chip below. You will see that there are only four different kinds of circuits on this chip.



**Figure 6-1. Digital IC 74LS245 Block Diagram.**

- Circuit 1 - Pins 2 through 9 and 11 through 18 are all the same function. Each pin is connected to both an input and an output of a buffer.
- Circuit 2 - Pins 1 and 19, although they have different names, are both enables and are inputs to AND gates.
- Circuit 3 - Power supply ground input, pin 10.
- Circuit 4 - Power supply  $V_{CC}$  input, pin 20.

Each circuit type will produce a different analog signature. Because there are only four types of circuits on the chip, there will be only four unique analog signatures when out of circuit.

## Signatures of a Digital IC

Do the following to display the analog signatures of a digital IC (out of circuit):

1. Press the MED1 range button.
2. Place or clip the black test lead from the Tracker 200's Common terminal to the IC's ground pin. For this example, the ground pin of the 74LS245 is pin 10.
3. Use the red test lead from the Tracker 200's A test terminal. Probe each pin of the IC and view its signature on Oscilloscopes CRT display. For this example, pins 2 to 9 and 11 to 18 are all buffer circuits so they will have identical signatures. (Note: This is only for ICs out of circuit.)
4. Use the red test lead from the Tracker 200's A test terminal. Probe the enable pins of the IC and view their signatures on the display. For this example, the enable pins of the 74LS245 are pin 1 and 19 and will have the same signatures. (Note: This is only for ICs out of circuit.)
5. Probe the power supply VCC input pin and view its signature on the CRT display. For this example, the VCC pin of the 74LS245 is pin 20.

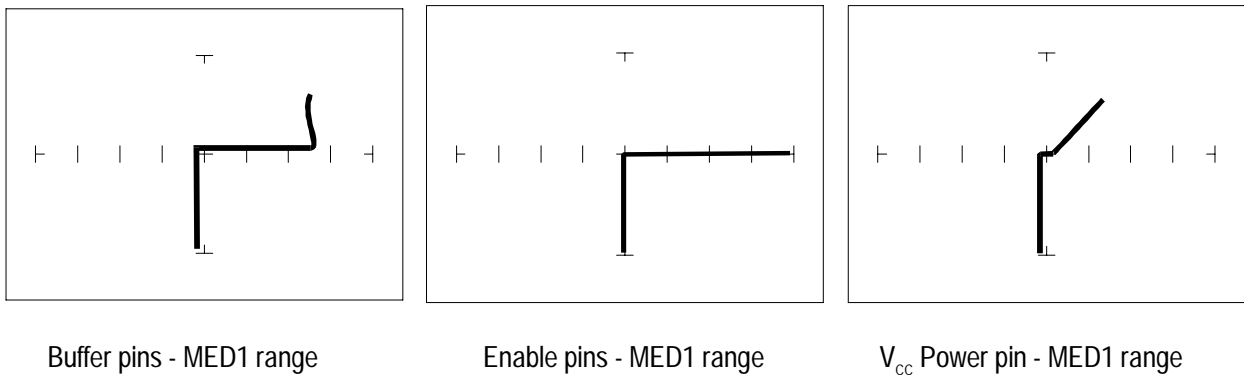


Figure 6-2. Signatures of a Digital IC, 74LS245. Ground Pin to Test Common

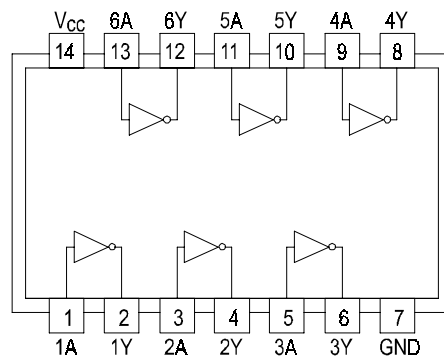
Compare these signatures with other signatures of discrete components such as transistors and diodes. Note that there are quite a few similarities here.

## Signatures for Different Logic Chip Families

There are a wide variety of logic circuit families. Each has its special functions, advantages, and limitations. They range from TTL and its variations (F, LS, S, etc.), emitter-coupled logic (ECL), to the complementary metal oxide semiconductor (CMOS) and its variations (C, HC, HCT, VC, etc.).

## Comparing Two TTL Families

Although the logic function is the same, there are differences in the circuitry of each logic family. These differences can be readily seen in their signatures using the Tracker 200.



**Figure 6-3. Diagram of 7404 & 74LS04.**

We will illustrate these concepts with the following example of two hex inverters, a 7404 and a 74LS04 from different logic families. From the logic diagram below, you can see that they have the same logic functions and pin order. The difference is that the LS chip uses Schottky transistors in its internal construction for increased performance and reduced power consumption. Note that there are only four types of circuit connections and therefore only four signatures on this chip: inverter inputs, inverter outputs, V<sub>CC</sub> and ground.

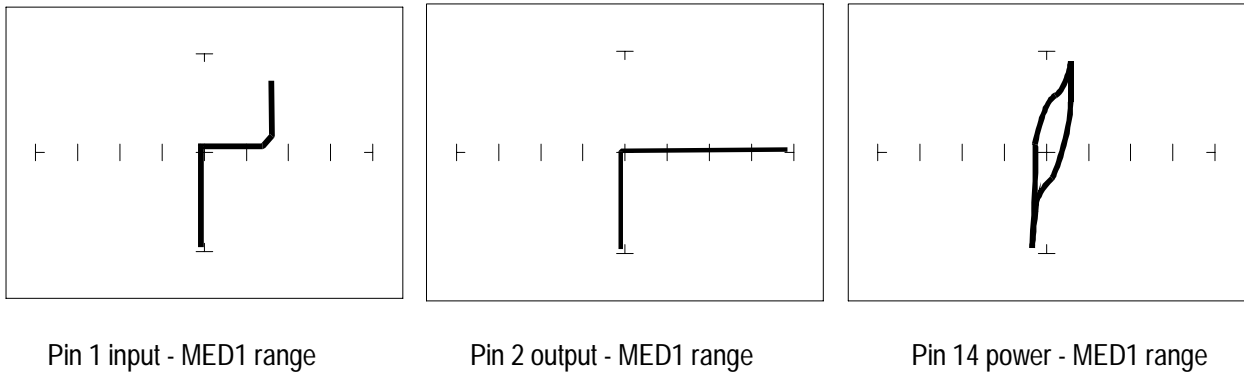


Figure 6-4. Signatures of a 7404 Hex Inverter.

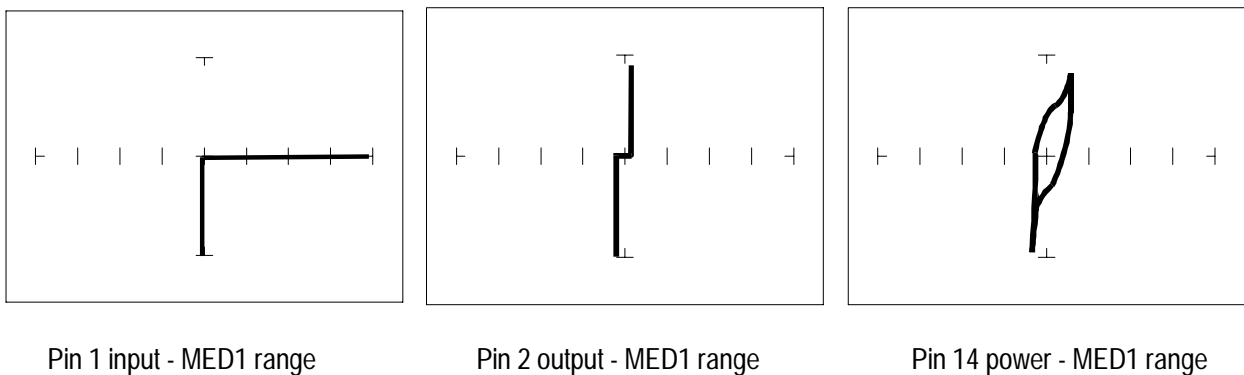
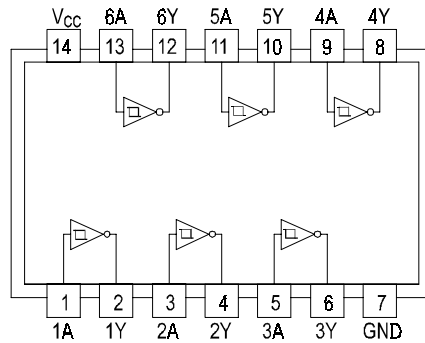


Figure 6-5. Signatures of 74LS04 Hex Inverter.

Note the differences between the two logic families. They have the same logic function but different construction, therefore different signatures. To test one of these chips without another reference chip available just compare each input's signature with the other five inputs. Similarly, compare each output's signature with the other five outputs.

## CMOS Logic Family

CMOS circuits are constructed differently than TTL circuits. The inputs to CMOS transistors are capacitive due to the use of field-effect transistors (FET) instead of bipolar transistors used in TTL.



**Figure 6-6. 74HC14 Block Diagram.**

In this example, we will choose a 74HC14 Schmitt Trigger Hex Inverter. The HC designation means that it's a member of the high-speed CMOS logic family. From the block diagram of this part, you can see that it has only four different circuit functions. They are inverter input, inverter output, power supply VCC input, and power supply ground.

Do the following to display the analog signatures of a digital IC:

1. Press the MED1 range button.
2. Set the test signal frequency to 60 Hz, if needed.
3. Place or clip the black test lead from the Tracker 200's Common terminal to the IC's ground pin. For this example, the ground pin of the 74HC14 is pin 7.
4. Use the red test lead from the Tracker 200's A test terminal and probe each pin of the IC. For this example, pins 1, 3, 5, 9, 11, and 13 are all input buffer circuits so they will have identical signatures. (Note: This is only for ICs out of circuit.)
5. Similarly, use the red test lead and probe the output buffer pins 2, 4, 6, 8, 10, and 12. These pins will have the same signatures. (Note: This is only for ICs out of circuit.)
6. Use the red test lead from the Tracker 200's A test terminal and probe the power supply VCC input pin. For this example, the VCC pin of the 74HC14 is pin 14.

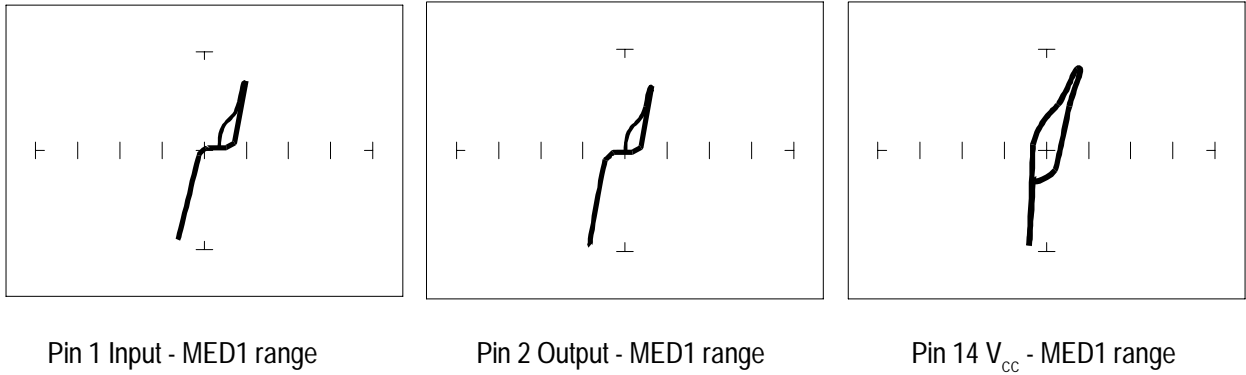


Figure 6-7. Signatures of a 74HC14 CMOS Hex Inverter.

## CMOS Components and Test Signal Frequency $F_s$

CMOS logic circuits inherently have a significant amount of internal capacitance. This junction capacitance is visible in the CMOS signatures when using the Tracker 200. Capacitance in CMOS circuitry may be emphasized or de-emphasized by changing the frequency of the test signal.

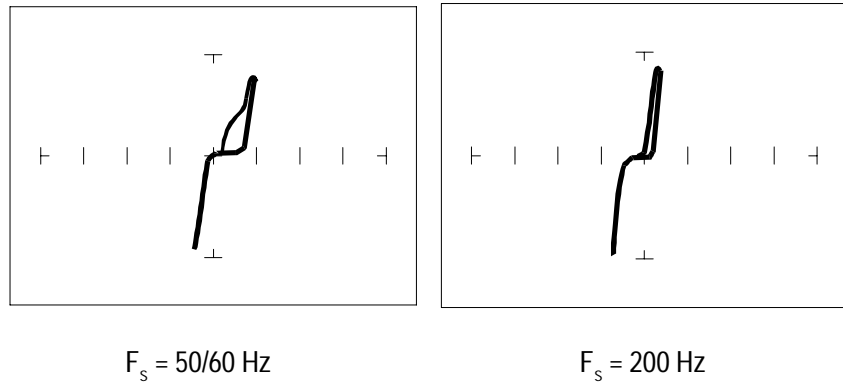


Figure 6-8. Signatures of a 74HC14 Input Pin at Different Frequencies.



## Troubleshooting Digital Logic ICs

The Tracker 200's ALT mode makes comparing digital IC signatures quick and simple. Instead of having to remember the specific signatures of a good component, all that's needed is to have a reference component or board along side the one that's suspect. This section gave many examples of signatures from TTL, Schottky TTL and CMOS logic families. Although from first inspection, these signatures appear to be complex, remember that each of the ICs in the examples had really only four unique signatures (buffer input, buffer output, power supply VCC and power supply ground). We can use this characteristic to develop an effective model for troubleshooting digital logic chips.

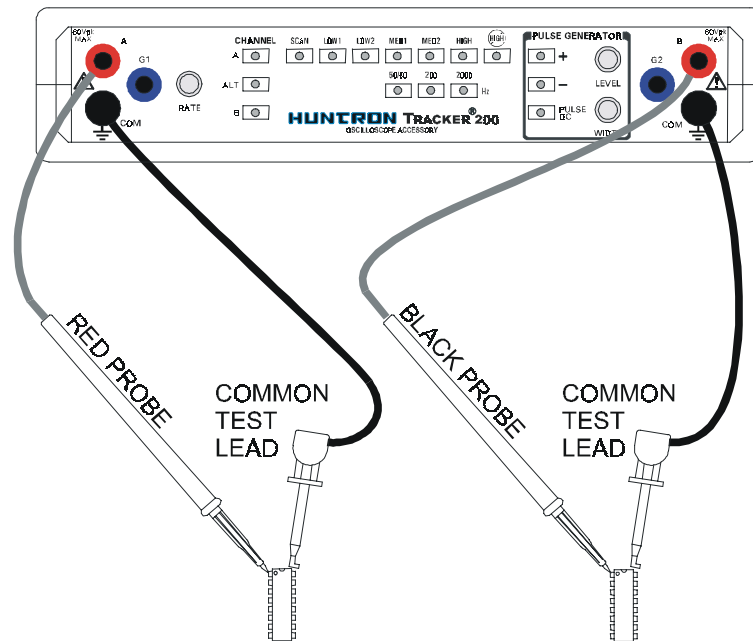


Figure 6-9. Tracker 200 with Test Leads Setup for Comparing 2 ICs.

## Comparison Testing for Digital ICs

Do the following to setup comparison testing and display the analog signatures of a digital IC:

1. Press the MED1 range button.
2. Set the test signal frequency to 50/60 Hz.
3. Place or connect the black or blue ground clip lead from the Tracker 200's Common terminal to both reference and suspect IC or boards ground pin.
4. Place or clip the black test lead from the Tracker 200's B test terminal to the suspect IC's pin. For this example, start with pin 1 of the suspect IC.
5. Place or clip the red test lead from the Tracker 200's A test terminal to the reference or known good IC's pin. For this example, start with pin 1 of the known good IC.
6. Push the Channel A button. Observe the signature. This is the signature of the pin of the known good component.
7. Push the Channel B button. Observe the signature. This is the signature of the pin of the suspect component.

Or press the Alt button to display the A and B channels alternately. Rotate the Rate knob to change the speed of alternating between the two channels.

8. Visually compare the reference signature (channel A) with the suspect signature (channel B).
9. Keep the red probe on pin 1, an input pin. Probe all the other input pins of the suspect component with the black probe until you have identified all the pins that have signatures that are the same as pin 1.
10. Move the red probe on pin 2, an output pin. Probe all the other output pins of the suspect component with the black probe until you have identified all the pins that have signatures that are the same as pin 2.

## Review

- Integrated circuits are complex devices that are built using basic electronic components.
- The IC signatures resemble zener diodes.
- There are many causes for IC failures and the Tracker 200 can display its "health" as resistive leakage, an open or a short.
- Functionally identical pins on a single IC out-of-circuit will display the same signature.
- The most common point for reference is ground, but  $V_{CC}$  or another point might give a more informative signature.
- Different logic families exhibit different characteristic signatures.
- To simplify the large number of signature variations, use the comparison test strategy with the Tracker 200. The Tracker 200 features alternately switching display of the A and B channels to allow comparison of two individual signatures

## Applications

- Testing for faulty IC's is one of the more common uses for the Tracker 200. A technician can compare IC's in or out of circuit.

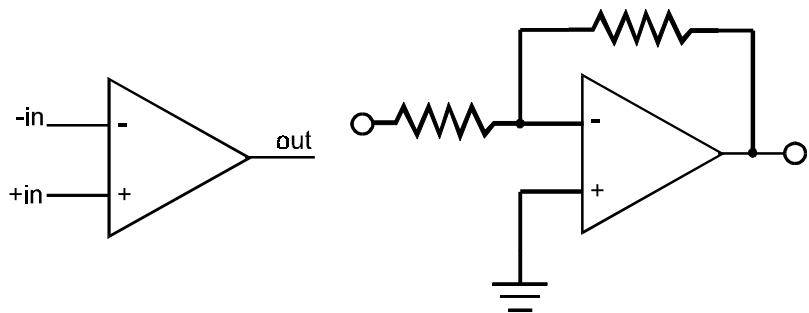
## Analog Circuits

Analog components and circuits represent another family of integrated circuit components and include operational amplifiers (op amps), comparators, references, regulators, timers and many other specialized functions. These components and circuits present more troubleshooting challenges that are unique to this particular family of ICs.

### Op Amps

Frequently, each pin of an op amp creates a different signature on the Tracker 200. This signature is the result of the internal design of the chip and both the internal and external circuit elements connected to it. This type of analog component typically has many internal junctions connected to each pin and each pin may also be connected to numerous external components.

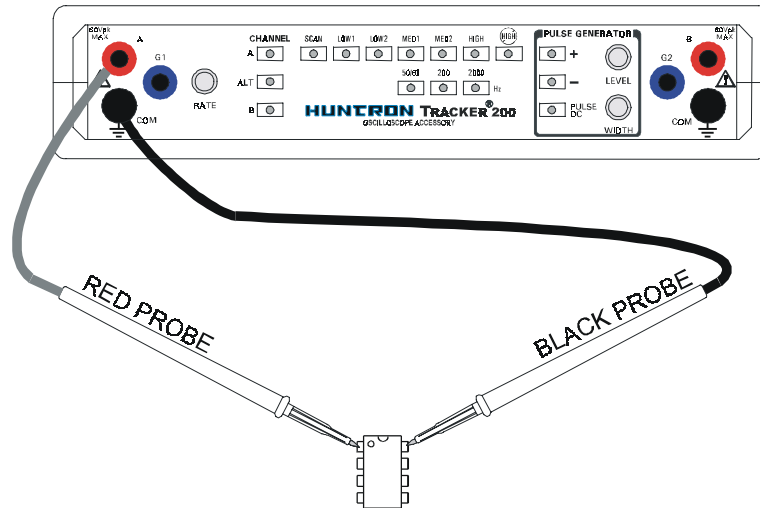
The following example will demonstrate ASA with a commonly used 741 type op amp. In this case it is configured as an inverting amplifier circuit as in the schematic below.



**Figure 6-10. Op Amp Symbol and Schematic Diagram of an Inverter Circuit.**

We will examine the signatures of this analog IC and present some troubleshooting concepts for this type of component.

## Op Amp Signatures



**Figure 6-11. Tracker 200 with Test Leads to an Op Amp.**

Do the following to display the analog signatures of an op amp:

1. Press the MED1 range button.
2. Set the test signal frequency to 50/60 Hz.
3. Place or clip the black test lead from the Tracker 200's Common terminal to the IC's ground or a power supply pin. For this example, the negative power supply pin of the 741 is pin 4 and the positive power supply is pin 8.
4. Use the red test lead from the Tracker 200's A test terminal and probe each pin of the IC.
5. Observe that the signature of each of the op amp's pins are unique.

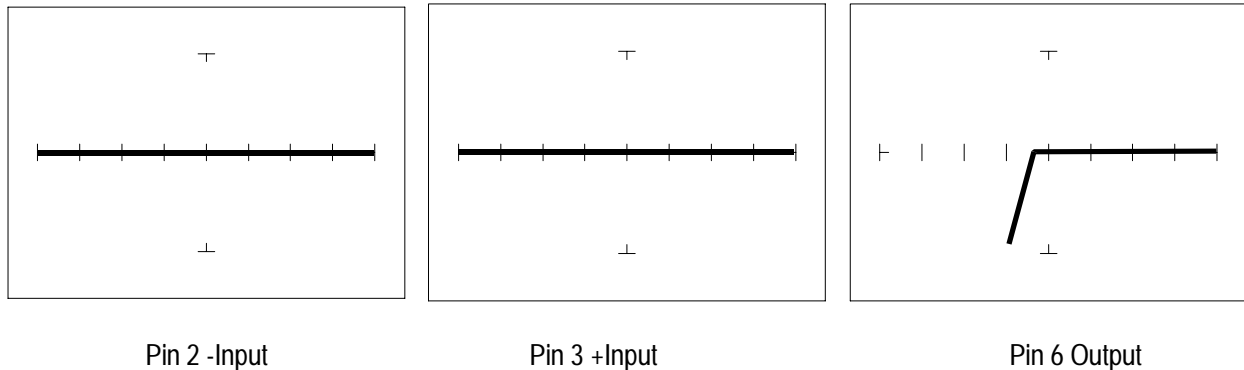


Figure 6-12. Signatures of an Op Amp (741 Type) in LOW2 Range.

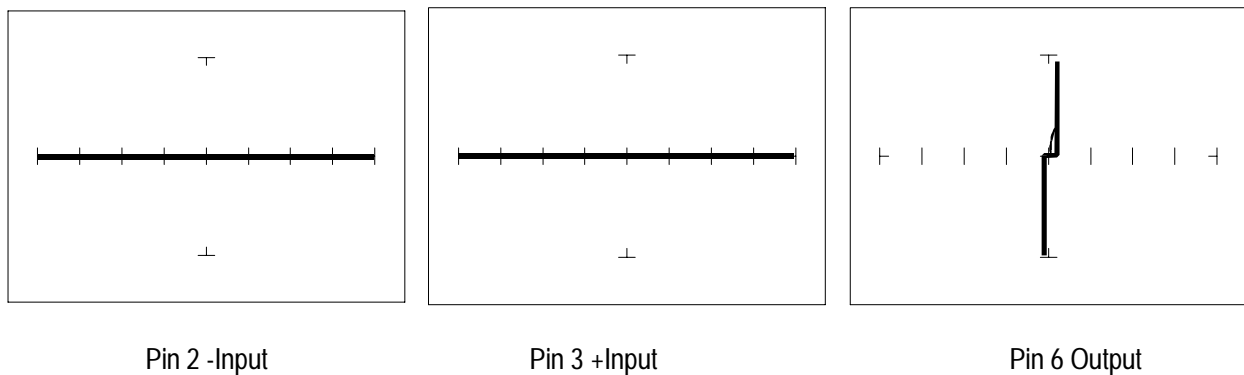


Figure 6-13. Signatures of an Op Amp (741 Type) in MED2 Range. Common to Pin 4.

## Troubleshooting Op Amp Circuits

Troubleshooting an op amp in-circuit may be very challenging. These circuits usually have numerous connections that act as feedback or compensation loops. This results in almost an infinite number of possible analog signatures. Use the comparison test method when troubleshooting op amps in-circuit. In this case, components on a suspect board is compared to those on a known good board. The Tracker 200 can help locate the defective component quickly.

The op amp has three main terminals; + input, - input and output. An alternative way to test an op amp is to connect the Tracker 200's Common terminal to the op amp's output while making a comparison with the red test probe to the "+" and then the "-" leg. This eliminates problems encountered when probing op-amps that are isolated from power and common. When there is more than one op amp in a package, compare one with the other. The dual op amp and quad op amps are very common. This technique also works with comparators.

## Linear Voltage Regulators

Voltage regulators are commonly found in many electronic assemblies. One of the most popular integrated circuit of this type is the three terminal device like the 7805, a +5 volt DC regulator.

The next figure shows the schematic and pin layout of the 7805 regulator. Different manufacturers implement their products with different topologies and manufacturing processes. So it's not unexpected that the same functionally equivalent component from different manufacturers may have different signatures.

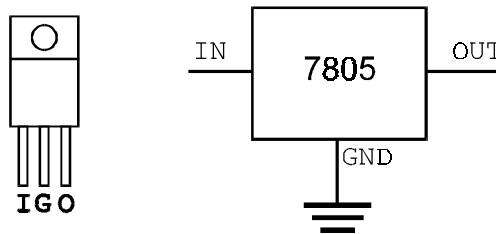


Figure 6-14. Diagram and Symbol of a Linear Voltage Regulator, 7805.

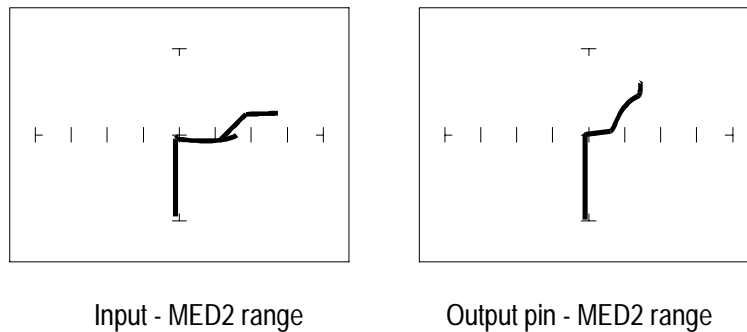
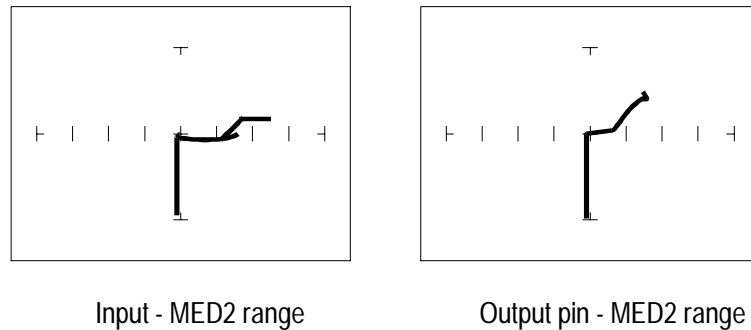


Figure 6-15. Signatures of a 7805 Voltage Regulator by SGS Thomson. Ground Pin to Common.



**Figure 6-16. Signatures of a 7805 Voltage Regulator by Motorola. Ground Pin to Common.**

## Review

- Integrated circuits are complex devices that are built using basic electronic components.
- The IC signatures resemble zener diodes.
- There are many causes for IC failures and the Tracker 200 can display its "health" as resistive leakage, an open or a short.
- Functionally identical pins on a single IC out-of-circuit will display the same signature.
- The most common point for reference is ground, but  $V_{CC}$  or another point might give a more informative signature.
- Different analog IC families exhibit different characteristic signatures.

## Applications

- Testing for faulty IC's is one of the more common uses for the Tracker 200. A technician can compare IC's in or out of circuit.



## Low Voltage

There is a new family of logic that offers lower dynamic power consumption, lower operating voltages, higher output drive, faster AC speed, lower noise and better dynamic thresholds than HC CMOS. These features make this family attractive for low power applications such as battery operated portable applications (that is, laptop computers, pagers, phones, etc.).

In order to achieve this new improved level of performance, the manufacturers of this LV (low voltage) family of logic ICs have redesigned the internal structure of the device. Some manufacturers have changed the input structure by eliminating the input protection diode to VCC. Similarly, the design of the output structure also has changed by eliminating the output protection diode to VCC and replacing it with a N-Channel pull-up transistor. As a result of these changes, the analog signatures of the LV logic family are different from the conventional HC logic family.

The Tracker 200 has the built-in "SMT" test range group which has been optimized for this LV logic. SMT is an abbreviation for surface mount technology and refers to the physical IC package type in which the LV logic family is commonly available.

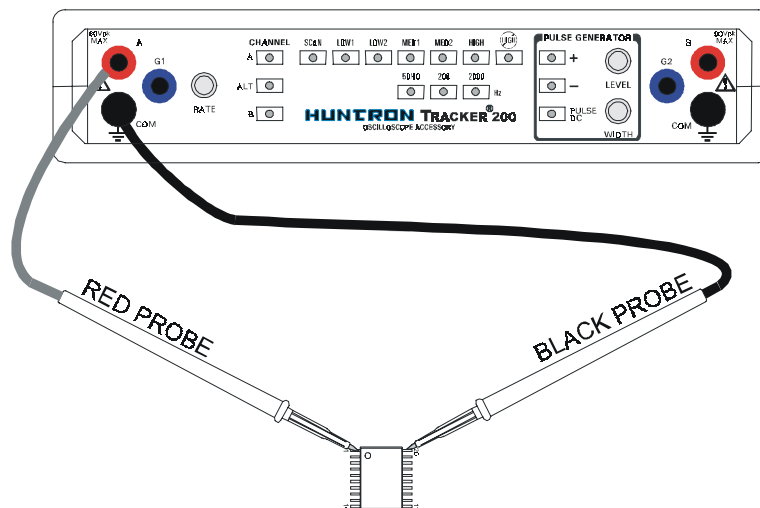
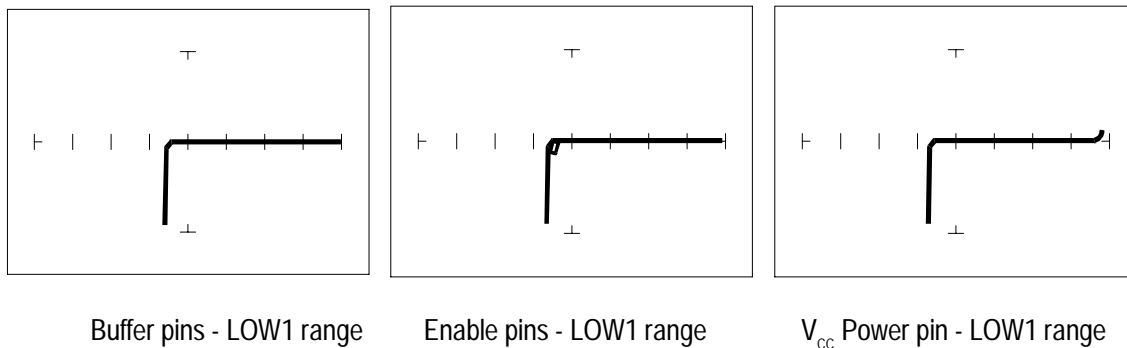


Figure 6-17. Tracker 200 with Test Probes to a 20 Pin Surface Mount IC.

1. Press the LOW1 range button.
2. Set the test signal frequency to 50/60 Hz.

3. Place or clip the black test lead from the Tracker 200's Common terminal to the IC's ground pin. For this example, the ground pin of the 74LVQ245 is pin 10.
4. Use the red test lead from the Tracker 200's A test terminal and probe each pin of the IC. For this example, pins 2 to 9 and 11 to 18 are all buffer circuits so they will have identical signatures. (Note: This is only for ICs out of circuit.)
5. Use the red test lead from the Tracker 200's A test terminal and probe the enable input pins. For this example, the enable pins of the 74LVQ245 are pin 1 and 19 and will have the same signatures. (Note: This is only for ICs out of circuit.)
6. Use the red test lead from the Tracker 200 A test terminal and probe the power supply VCC input pin. For this example, the VCC pin of the 74LVQ245 is pin 20.



**Figure 6-18. Signatures of a Low Voltage IC (74LVQ45 Type). Ground Pin to Common.**

The LOW1 test range has been developed to enhance the resistive fault signatures that are commonly found when troubleshooting this logic family. The test signal voltage  $V_S$  is lower than the LOW2 range to ensure that most descriptive signature is displayed. A higher  $V_S$  may result in a signature going toward a short with would mask out flaws. The short signature can be attributed by the LV family's lower voltage characteristics.

Compare these signatures with the CMOS logic family and other discrete components such as transistors and diodes. Note that these signatures have some common similarities with the other components analog signatures we have already seen.

## Review

- Integrated circuits are complex devices that are built using basic electronic components.
- The IC signatures resemble regular and zener diode signatures.
- There are many causes for IC failures and the Tracker 200 can display its "health" as resistive leakage, an open or a short.
- Functionally identical pins on a single IC out-of-circuit will display the same signature.
- The most common point for reference is ground, but  $V_{CC}$  or another point might give a more informative signature.

## Applications

- Testing for faulty IC's is one of the more common uses for the Tracker 200. A technician can compare IC's in or out of circuit.

# General Safety Summary

Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it. To avoid potential hazards, use this product only as specified.

*Only qualified personnel should perform service procedures.*

## To Avoid Fire or Personal Injury

**Use Proper Power Cord.** Use only the power cord specified for this product and certified for the country of use.

**Use Proper Voltage Setting.** Before applying power, ensure that the line selector is in the proper position for the power source being used.

**Connect and Disconnect Properly.** Do not connect or disconnect probes or test leads while they are connected to a voltage source.

**Ground the Product.** This product is grounded through the grounding conductor of the power cord. To avoid electric shock, the grounding conductor must be connected to earth ground. Before making connections to the input or output terminals of the product, ensure that the product is properly grounded.

**Observe All Terminal Ratings.** To avoid fire or shock hazard, observe all ratings and markings on the product. Consult the product manual for further ratings information before making connections to the product.

Do not apply a potential to any terminal, including the common terminal, that exceeds the maximum rating of that terminal.

**Do Not Operate Without Covers.** Do not operate this product with covers or panels removed.

**Use Proper Fuse.** Use only the fuse type and rating specified for this product.

**Avoid Exposed Circuitry.** Do not touch exposed connections and components when power is present.

**Do Not Operate With Suspected Failures.** If you suspect there is damage to this product, have it inspected by qualified service personnel.

**Do Not Operate in Wet/Damp Conditions.**

**Do Not Operate in an Explosive Atmosphere.**

**Keep Product Surfaces Clean and Dry.**

**Symbols and Terms** Terms in this Manual. These terms may appear in this manual:



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**WARNING.** *Warning statements identify conditions or practices that could result in injury or loss of life.*

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**CAUTION.** *Caution statements identify conditions or practices that could result in damage to this product or other property.*

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**Terms on the Product.** These terms may appear on the product:

DANGER indicates an injury hazard immediately accessible as you read the marking.

WARNING indicates an injury hazard not immediately accessible as you read the marking.

CAUTION indicates a hazard to property including the product.

**Symbols on the Product.** The following symbols may appear on the product:



WARNING  
High Voltage



Protective Ground  
(Earth) Terminal



CAUTION  
Refer to Manual



Fuse