

Tracker **2500**

User's Manual

HUNTRON INSTRUMENTS, INC.

TRACKER[®] 2500

USER'S MANUAL

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ABOUT THIS MANUAL

This manual covers the general operation of the Tracker 2500.

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 2500 and other Huntron products.

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SECTION 1

INTRODUCTION AND SPECIFICATIONS

1-1. INTRODUCTION

The Huntron Tracker 2500, shown in Figure 1-1, is a versatile troubleshooting tool having the following features:

- Multiple test signal frequencies (20Hz, 50Hz or 60Hz, 200Hz, 2000Hz).
- Six voltage ranges (200mV, 2V, 3V, 5V, 10V, 15V).
- Five resistance ranges (10 Ω , 100 Ω , 1k Ω , 10k Ω , 100k Ω).
- Automatic resistance range scanning.
- STAR (Smart Tracker Active Range). Automatic lockout of certain ranges for limiting the maximum power output at the test terminals.
- Rate of channel alternation and range scanning is adjustable.
- DC voltage source for testing of three terminal devices.
- LED indicators for all functions.
- Dual channel capability for simple comparison testing.
- Large CRT display with easy to operate controls.

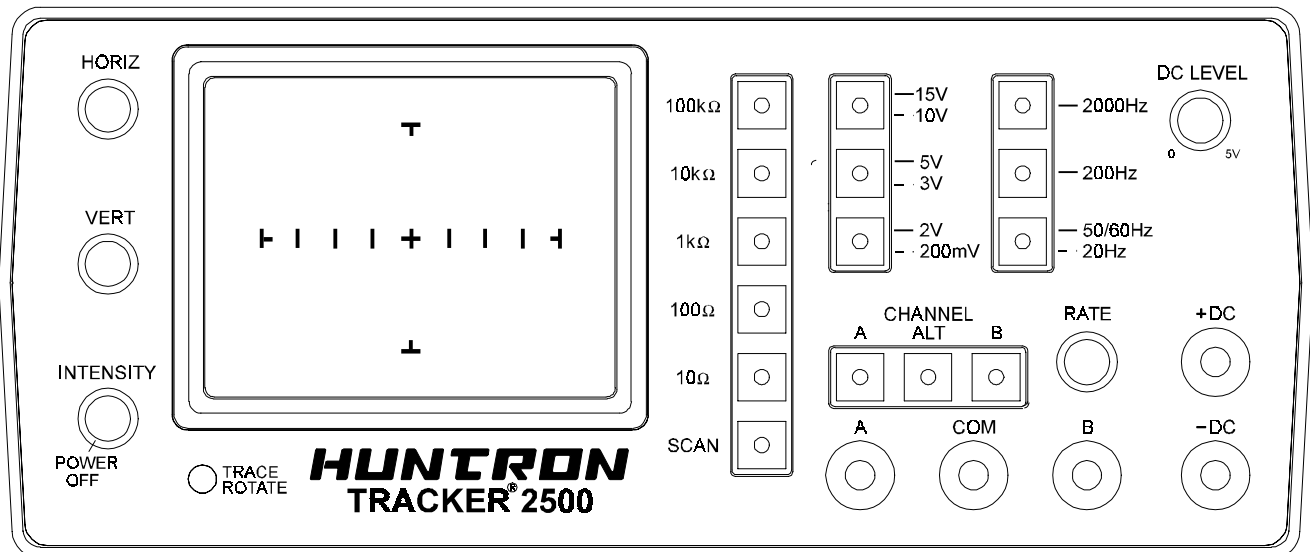


Figure 1-1. Huntron Tracker 2500.

1-2. SPECIFICATIONS

The specifications for the Tracker 2500 are listed in Table 1-1.

Table 1-1
Tracker 2500 Specifications

ELECTRICAL

Channels

Number	2 (A, B)
Alternation Rate	0.5Hz to 5Hz (synchronized to sinewave zero-crossing)
Protection	Automatic circuit breaker
Common	Isolated from earth ground

Test Signal

Waveform	Sine wave
Frequency	2000Hz 200Hz 50/60Hz 20Hz
Open Circuit Voltage(Peak AC)	15V 10V 5V 3V 2V 200mV
Source Resistance	100k Ω 10k Ω 1k Ω 100 Ω 10 Ω

Table 1-1 (continued)
Tracker 2500 Specifications

ELECTRICAL

Access

Channel A & B	Standard Red Banana jacks
Common	Standard Black Banana jack
DC Voltage Source	Standard Blue Banana jacks

Interfaces

Accessory	Switcher 410 compatible
-----------	-------------------------

Display

CRT	2.8in (7cm) diagonal Monochrome
-----	------------------------------------

DC Source

Outputs	Two resistively coupled
Level	0 to 5VDC
DC Mode Only	+/- DC outputs
Output Impedance	100 Ω (each output)
Short Circuit Current	50mA max. (each output)

Power Requirements

AC Line Voltage	115VAC/230VAC
Line Frequency	47Hz - 63Hz
Power	25 Watts max.
Line Protection	1/4A AGC fuse

Table 1-1 (continued)
Tracker 2500 Specifications

MECHANICAL

Size	9" W x 4" H x 11" D (23cm W x 10cm H x 28cm D)
Weight	6 lbs. (2.8 kg)

ENVIRONMENTAL

Altitude	<2000m (<6560')
Operating Temperature	0°C to +40°C (32°F to 104°F)
Storage Temperature	-20°C to +60°C (-4°F to +140°F)
Relative Humidity	0 to 80% from 0°C to +31°C (32°F to 88°F) Maximum R.H. decreases linearly to 50% at 40°C

1-3. SAFETY CONSIDERATIONS

This manual contains information, cautions, and warnings the user must follow to ensure safe operation, and to keep the instrument in safe condition.

WARNING

A warning denotes a hazard. It calls attention to a procedure or practice which, if not correctly performed or adhered to, could result in personal injury.

CAUTION

A caution also denotes a hazard. It calls attention to a procedure or practice which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the instrument.

1-4. LIST OF ACCESSORIES

The following accessories are available:

HUNTRON P/N	DESCRIPTION
99-0090	Switcher 410

To order any of the above items, or for further information, please contact Huntron.

NOTES:

SECTION 2 OPERATING INSTRUCTIONS

2-1. Introduction

This section describes the basic operation of the Tracker 2500.

2-2. Unpacking Your Instrument

Your instrument was shipped with the following items:

<u>QTY</u>	<u>DESCRIPTION</u>	<u>HUNTRON P/N</u>
1	Tracker 2500 User's Manual	21-1302
1	Power Cord, 115V/100V	98-0015
2	Micro Clip leads (blue)	98-0036
2	Common test leads (black)	98-0043
1	Huntron Probe Set (red & black)	98-0078

Check the shipment carefully and contact the place of purchase if anything is missing or damaged in shipment. If reshipment is necessary, please use the original shipping carton and packing foam. If these are not available, be sure that adequate protection is provided to prevent damage during shipment.

2-3. General Operation

Components are tested by the Tracker 2500 using a two terminal system (three terminal system when the built-in DC Voltage Source is used), where two test leads are placed on the leads of the component under test. The Tracker 2500 tests components in-circuit, even when there are several components in parallel.

CAUTION

The device to be tested must have all power turned off, and have all high voltage capacitors discharged before connecting the Tracker 2500 to the device. The maximum external fault voltage is 50VDC or 50V(peak AC).

The line fuse should only open when there is an internal failure inside the instrument. Therefore the problem should always be located and corrected before replacing this fuse.

2-4. Fuse Replacement

To replace the fuse, disconnect the Tracker 2500 from the power line. Remove the four case screws located on the underside of the case and lift off the top case half. The line fuse is located at the back of the main printed circuit board assembly behind the CRT. **Replace the fuse with a 1/4A AGC fuse.**

2-5. Physical Features

Before you begin to use the Tracker 2500, please take a few minutes to familiarize yourself with the instrument. All of the externally accessible features are discussed in Sections 2-6, 2-7 and 2-8.

2-6. Front Panel

The front panel of the Tracker 2500 is designed to make function selection easy. All push buttons are momentary action and have integral LED indicators that 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.

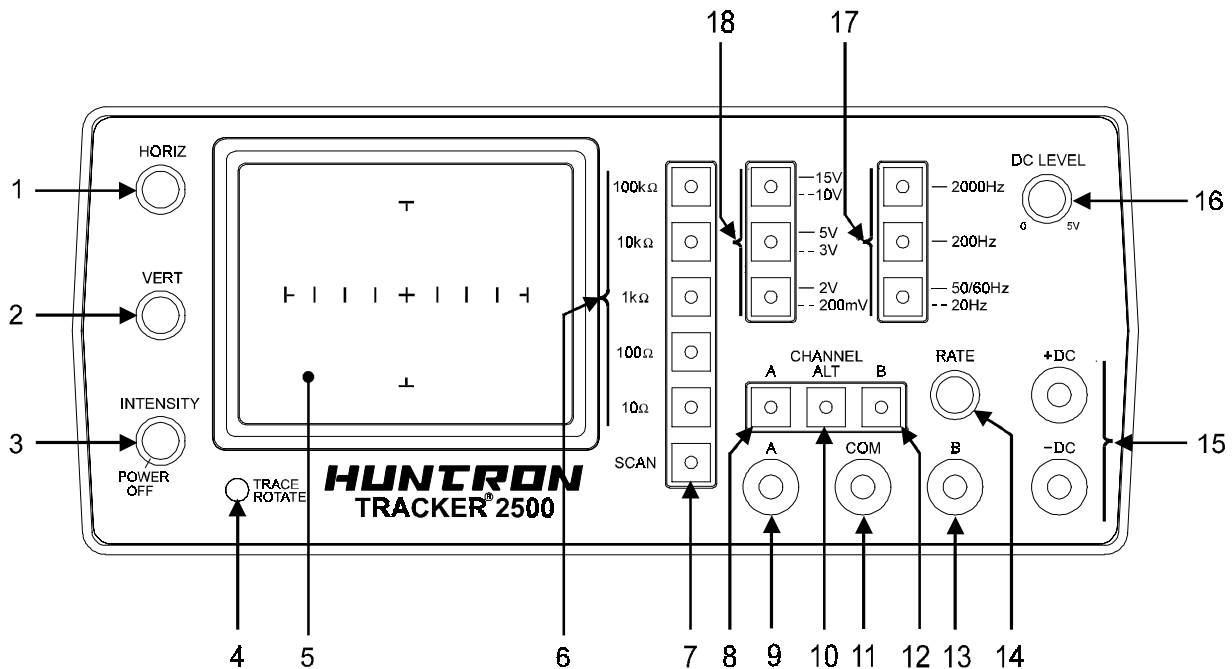


Figure 2-1. Tracker 2500 Front Panel With Callouts.

**Table 2-1
Front Panel Controls and Connectors**

Item No.	Name	Function
1	HORIZ Control	Controls the horizontal trace position of the CRT display.
2	VERT Control	Controls the vertical trace position of the CRT display.
3	Power On/Off Switch & INTENSITY Control	Power On/Off Switch. Also controls the intensity of the CRT display.
4	TRACE ROTATE	Controls the trace rotation of the CRT display.
5	CRT Display	Displays the component signatures produced by the Tracker 2500.
6	Resistance Selector Buttons	Selects one of five resistance ranges: 10, 100, 1k, 10k & 100k Ω .
7	SCAN Button	Initiates automatic scanning of the five resistances from lowest to highest. The scanning speed is determined by the RATE control (see item #14).
8	Channel A Button	Causes channel A to be displayed on the CRT.
9	Channel A Test Terminal	Test Terminal that is active when channel A is selected.
10	ALT Button	Causes the Tracker 2500 to alternate between channel A and channel B at a speed determined by the RATE control (see item #14).

Table 2-1 (continued)
Front Panel Controls and Connectors

Item No.	Name	Function
11	COM Terminal	Test terminal that is instrument common and the common reference point for both channel A and channel B.
12	Channel B Button	Causes channel B to be displayed on the CRT.
13	Channel B Test Terminal	Test terminal that is active when channel B is selected.
14	RATE Control	Controls the rate of channel alternation and/or range scanning.
15	+DC & -DC Terminals	DC Voltage Source output test terminals.
16	DC LEVEL Control	Controls the amplitude of the internal DC voltage source.
17	Frequency Selector Buttons	Selects a test signal frequency: 20, 50 or 60, 200, and 2000 Hz.
18	Voltage Selector Buttons	Selects a test signal voltage: 200 mV, 2, 3, 5, 10, or 15 Volts.

2-7. 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.

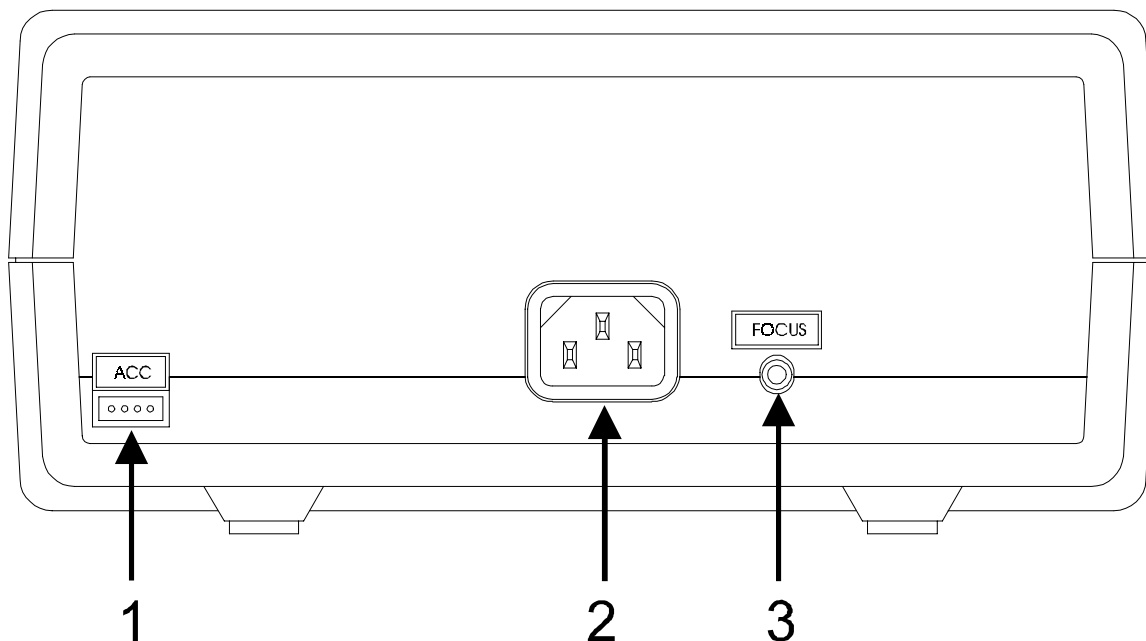


Figure 2-2. Tracker 2500 Back Panel With Callouts.

Table 2-2. Tracker 2500 Back Panel Connections.

Item No.	Name	Function
1	Accessory Output Connector	Connector which provides power and clock to Huntron accessory Switcher 410 (non CE)
2	Power Cord Connector	IEC standard connector that mates with any CEE-22 power cord
3	FOCUS Control	Controls the focus on the CRT display

2-8. CRT Display

The CRT displays the signature of the components being tested. The display has a graticule consisting of a horizontal axis which represents voltage, and a vertical axis which represents current. The axes divide the display 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). See Figure 2-3.

The horizontal axis is divided in eight divisions, which allow the operator to estimate the voltage at which changes in the signature occur. This is mainly useful in determining semiconductor junction voltages under either forward or reverse bias. Table 2-3 lists the approximate horizontal sensitivities for each range.

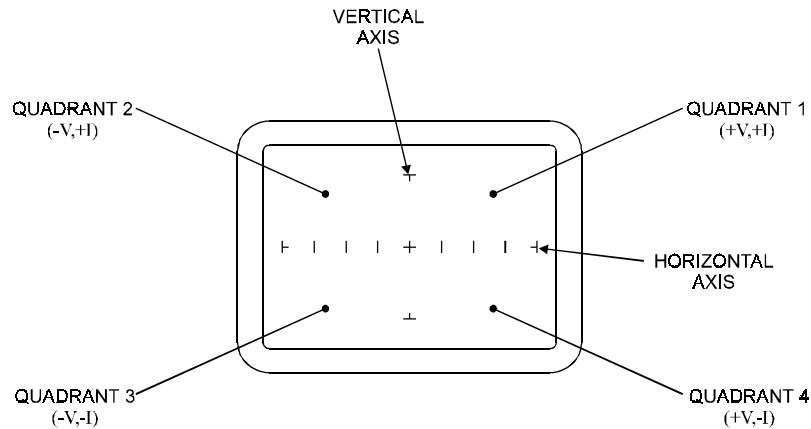


Figure 2-3. CRT Display.

Table 2-3 Tracker 2500 Horizontal Sensitivities

Range	Volts/Div
15 V	3.75
10 V	2.50
5 V	1.25
3 V	0.75
2 V	0.50
200 mV	0.05

2-9. Operation

The following sections explain how to use the front and back panel features. Use Sections 2-6 and 2-7 for the description and location of each control.

2-10. Initial Setup

Turn the Power/Intensity knob clockwise. The Tracker 2500 should come on with the LEDs for channel A, 50/60 Hz, 2V, and 1k Ω .

Focusing of the Tracker 2500 display is important in analyzing the test signatures. This is done by first turning the intensity control to a comfortable level and adjusting the focus control (back panel) for the narrowest possible trace.

Aligning the trace is important in determining which quadrants the portions of a signature are in. With a short circuit on channel A, adjust the trace rotation control until the trace is parallel to the vertical axis. Adjust the horizontal control until the vertical trace is even with the vertical axis. Open channel A, and adjust the vertical control until the horizontal trace is even with the horizontal axis. Once set, these adjustments should not have to be readjusted during normal operation.

The power is turned off by turning the Power/Intensity knob fully counterclockwise.

CAUTION:

It advisable to turn the Trace Intensity down when the Tracker 2500 is powered up and is in a prolonged idle state. This prevents burning a permanent trace on the CRT.

2-11. Resistance Selection

The Tracker 2500 is designed with five resistance ranges (**10 Ω , 100 Ω , 1k Ω , 10k Ω , and 100k Ω**). A resistance range is selected by pressing the appropriate button on the front panel. It is best to start with one of the middle resistance values (**i.e. 100 Ω or 1k Ω**). If the signature on the CRT display is close to an open (horizontal trace), go to the next higher resistance for a more descriptive signature. If the signature is close to a short (vertical trace), go the next lower resistance.

The **SCAN** feature sequences through the resistance ranges at a speed set by the **RATE** control. This feature allows the user to see the signature of a component in different resistance ranges while keeping his hands free to hold the test leads.

2-12. Channel Selection

There are two channels on the Tracker 2500 (channel **A** and channel **B**) which are selected by pressing the appropriate front panel button. When using a single channel, the red probe should be plugged into the corresponding channel test terminal and the black probe should be plugged into the common test terminal. When testing, the red probe should be connected to the positive terminal of a device (i.e. anode, +V, etc.) and the black probe should be connected to the negative terminal of a device (i.e. cathode, ground, etc.). Following this procedure should assure that the signature appears in the correct quadrants of the CRT display.

The Alternate mode of the Tracker 2500 is provided to automatically switch back and forth between channel A and channel B. This allows easy comparison between two devices or the same points on two circuit boards. The Alternate mode is selected by pressing the **ALT** button on the front panel, and the alternation frequency is varied by the Rate control. One of the most useful features of the Tracker 2500 is using the Alternate mode to compare a known good device with the same type of device that is of unknown quality. Figure 2-4 shows how the instrument is connected to a known good board and a board under test. This test mode uses the supplied common test leads to connect two equivalent points on the boards to the common test terminal. Note that the black probe is plugged into the channel B test terminal.

When using the ALTERNATE and SCAN features simultaneously, each channel is displayed before the range changes. Figure 2-5 shows the sequence of these changes.

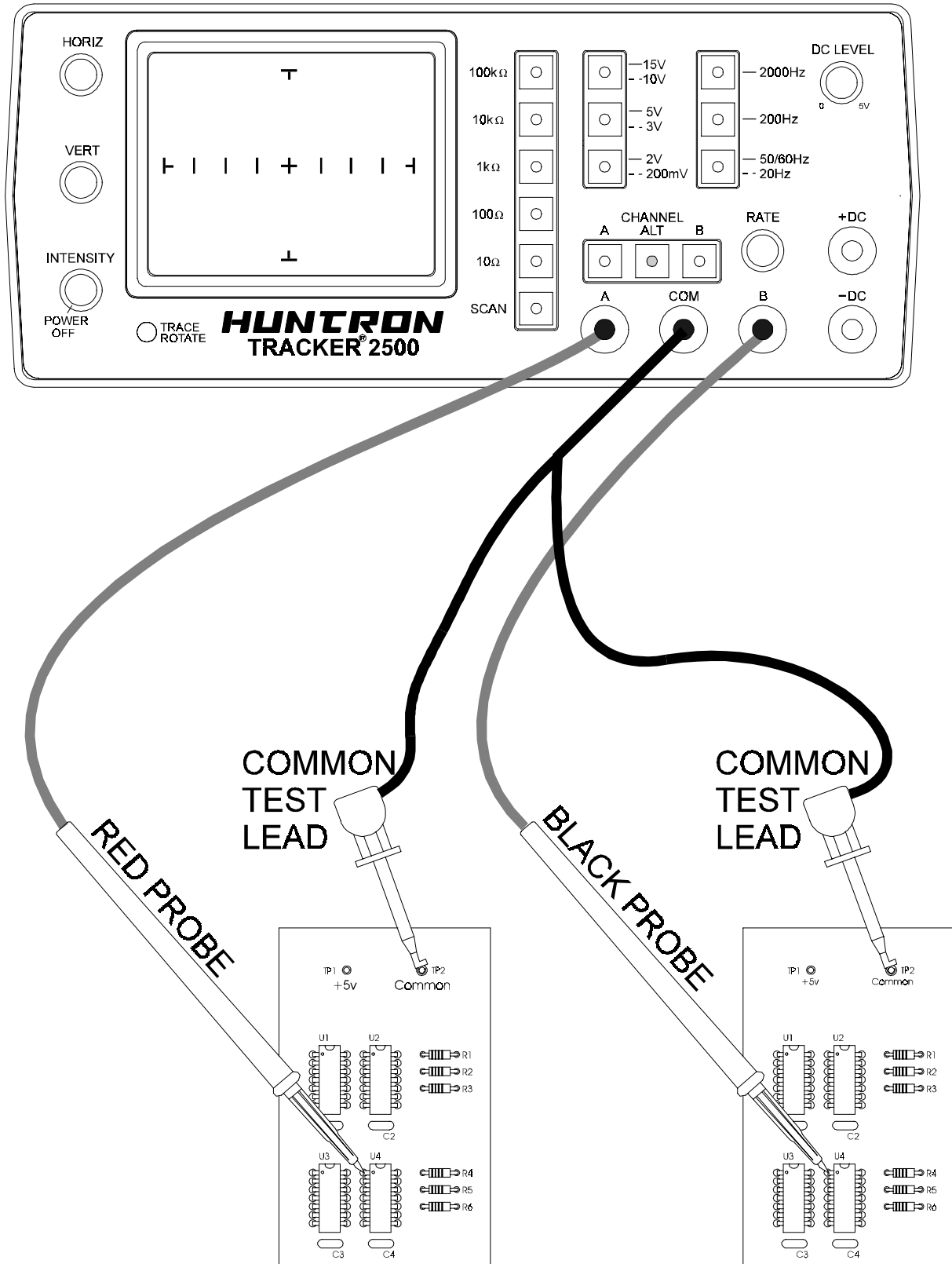


Figure 2-4. Alternate Mode Setup.

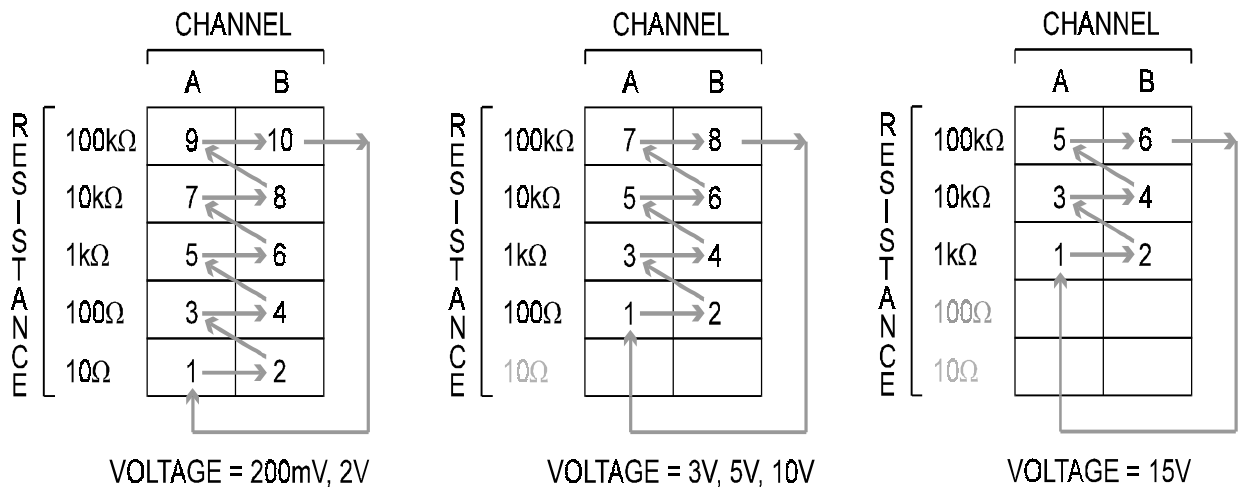


Figure 2-5. SCAN/ALTERNATE Sequence using STAR feature(see Section 3-7).

2-13. Frequency Selection

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

The lowest button, **50/60 Hz** or **20 Hz** is dual action. Press it once (steady LED indication) to select either 50 Hz or 60 Hz depending on the local power line frequency in use. In most cases this selection is the best one to use for general troubleshooting.

If you press this button again, then **20 Hz** is selected (blinking LED indication). This frequency allows you to see larger values of capacitance than 50/60 Hz.

The middle button, selects **200 Hz**. This frequency allows you to see smaller values of capacitance.

The top button, **2000 Hz**, selects that frequency only. Refer to Table 4-1 on minimum and maximum capacitor values that display signatures on the CRT.

2-14. Voltage Selection.

The voltage selector buttons (**2V/200mV**, **5V/3V**, **15V/10V**) allows the user to select the peak applied sine-wave voltage. Each button has a dual function. For example, pressing the **5V** button (**steady LED indication**) selects **5 Volts** as the test signal's peak value. Pressing it again (**blinking LED indication**) selects **3 Volts** as the test signals peak value.

2-15. DC Voltage Source

The built-in DC voltage source of the Tracker 2500 allows in-circuit testing of certain devices in their active mode. In addition to using the red and black probes, the output of the DC voltage source is connected to the control input of the device to be tested with one of the blue micro clips provided. The DC voltage source has two outputs, +DC and -DC. Figure 2-6 shows how to hook up the Tracker 2500 using the DC voltage source.

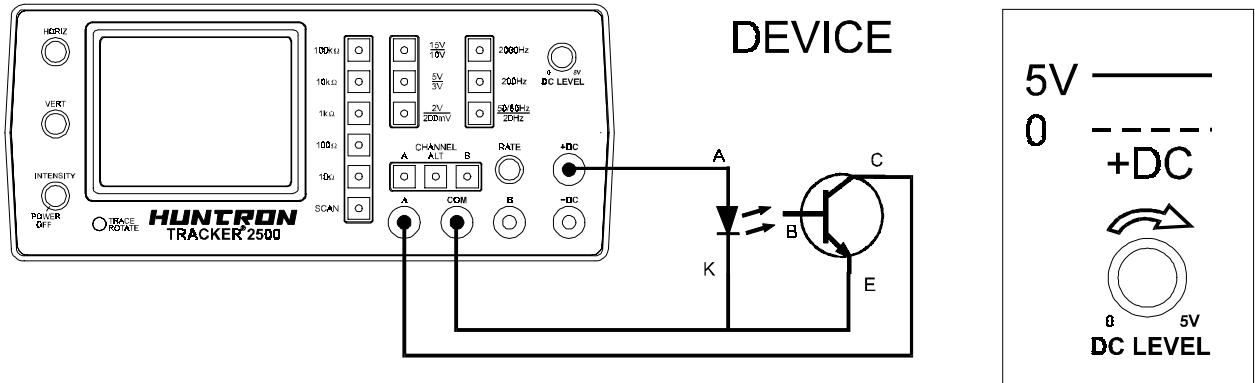


Figure 2-6. Tracker 2500 DC Source Typical Setup.

The DC Voltage Source output is set using the DC Level control. The level control varies the magnitude of output amplitude from zero to + or - 5 volts DC.

2-16. Huntron Switcher 410 Connections

Refer to Figure 2-7 for the interconnection diagram to use the Huntron Switcher 410 with the Tracker 2500. The two terminals marked TRACKER on the 410 are connected to either channel of the Tracker 2500 using the double banana plug cable supplied with the 410. Select the channel the Switcher is connected to. The accessory cable, which comes with the 410, is connected between the Accessory output connector (Tracker 2500 back panel) and the two jacks on the 410 marked INPUT 8VDC-12VDC and EXT CLK. Each of the three connectors on the cable are different so that the cable can only be hooked up the correct way.

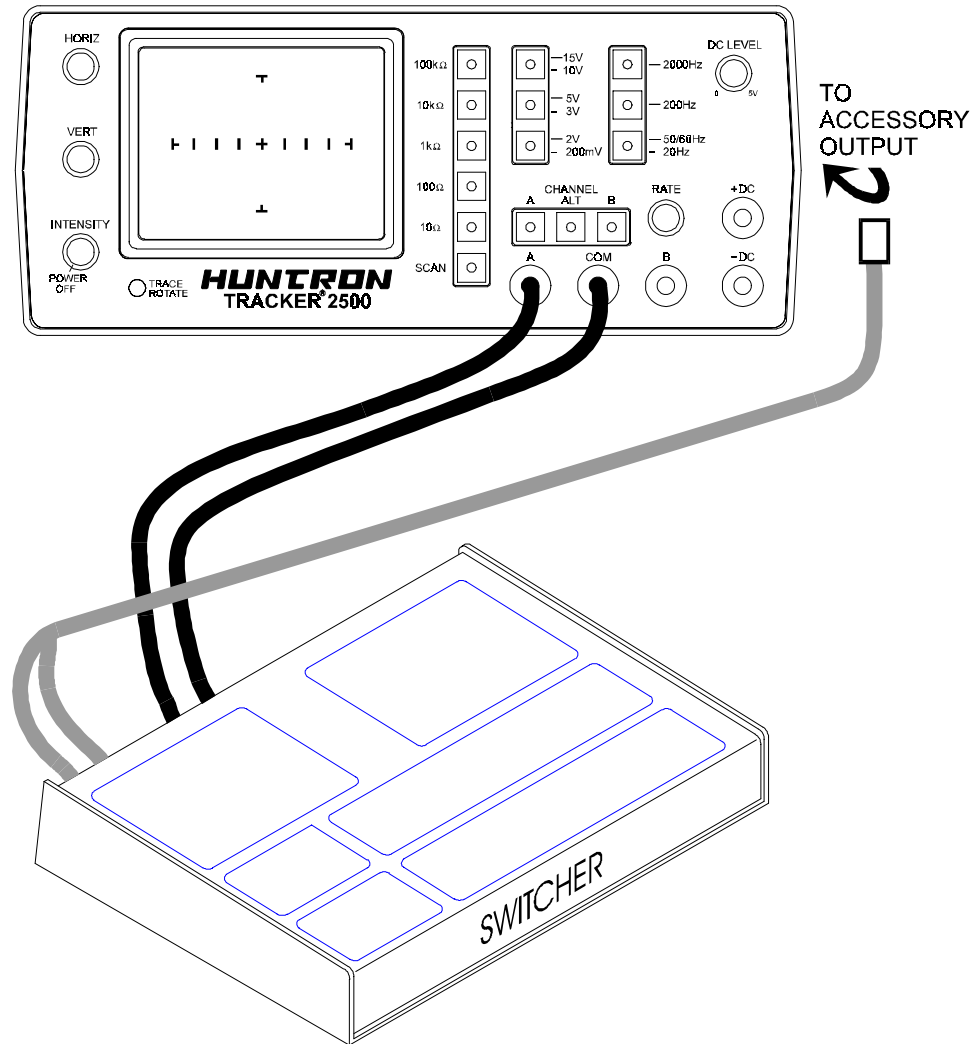


Figure 2-7. Tracker 2500 to Switcher 410 Connection.

The Accessory Cable supplies the 410 with power and a clock signal controlled by the Rate control on the Tracker 2500.

To use the 410, set the TRACKER/OFF/EXTERNAL switch to TRACKER which illuminates the TRACKER LED. The REF/ALT/TEST switch when set to either REF or TEST is used in the normal manner, i.e. the selected device is continuously connected through the 410 to the Tracker 2500 and signatures can be viewed by selecting a common pin and pressing the button for a particular IC pin number. When the REF/ALT/TEST switch is set to ALT, the 410 will alternate between the reference device and the test device at a frequency determined by the Rate control of the Tracker 2500. The Rate control on the 410 is disabled in this mode. If the Auto scanning feature of the Tracker 2500 is activated, the alternation rate of the 410 will be synchronized with the range scanning rate of the Tracker 2500. This activates a similar scanning sequence to that shown in Figure 2-5, except that forty different points on two devices can be easily examined instead of one point on two devices with the Tracker 2500 alone.

For best results, 50/60 Hz should be selected when using the 410.

2-17. Tracker Training

For ordering and further information contact Huntron.

2-18. External Cleaning And Lubrication

WARNING

To avoid electric shock or instrument damage, never get water inside the case. To avoid instrument damage, never apply solvents to the instrument.

Should the Tracker 2500 case require cleaning, wipe the instrument with a cloth that is lightly dampened with water or mild detergent solution. The Tracker 2500 requires no lubrication.

2-19. Storage Instructions

For optimum protection, store unit indoors in a dry place.

NOTES:

SECTION 3 USING YOUR TRACKER 2500

3.1 Introduction

Electronic troubleshooting is a skilled art, based largely on logical deduction, experience and intuition. The Huntron Tracker 2500 uses Analog Signature Analysis or ASA to take full advantage of a technician's skills. ASA is the examination of the current versus 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.

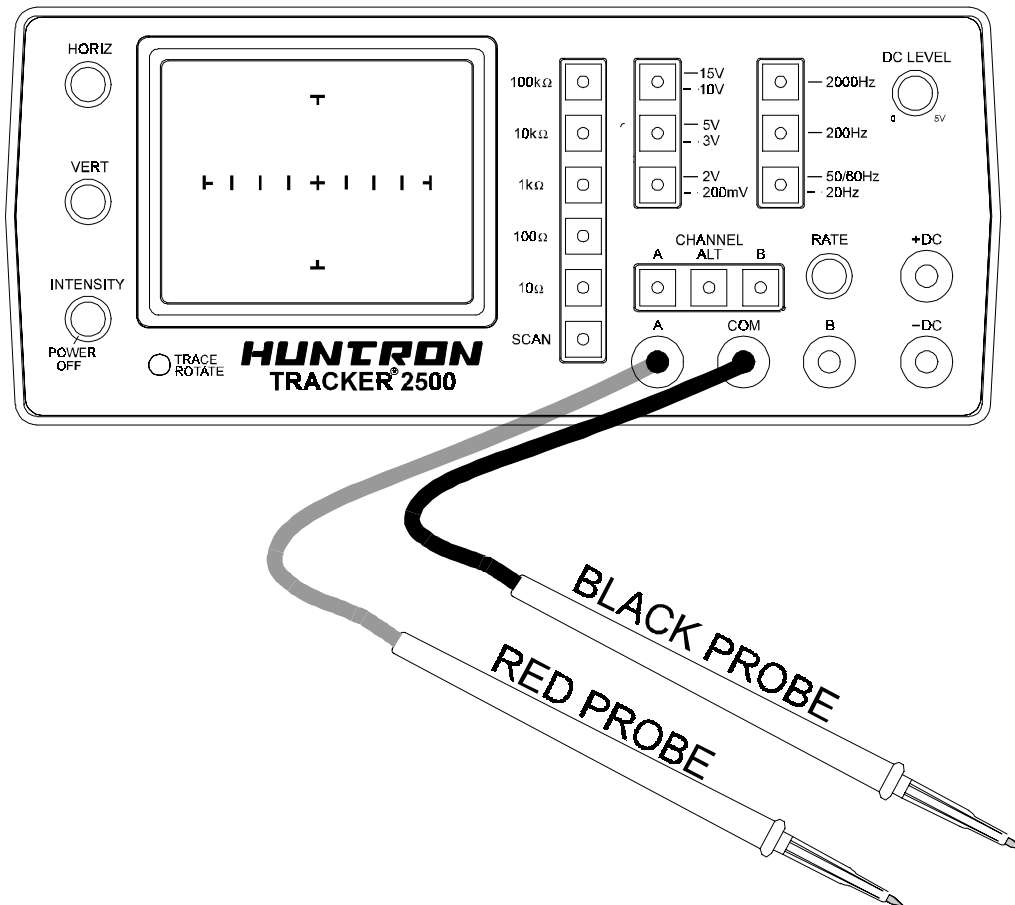


Figure 3-1. Tracker 2500 with Test Probes.

3-2 Basics Of Asa - How It Works

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

The Tracker 2500 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 internal CRT's 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 2500'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,

$$V = IR \text{ where } V = \text{voltage, } I = \text{current and } R = \text{resistance}$$

The next figure shows a simplified diagram of the Tracker's 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 2500'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 .

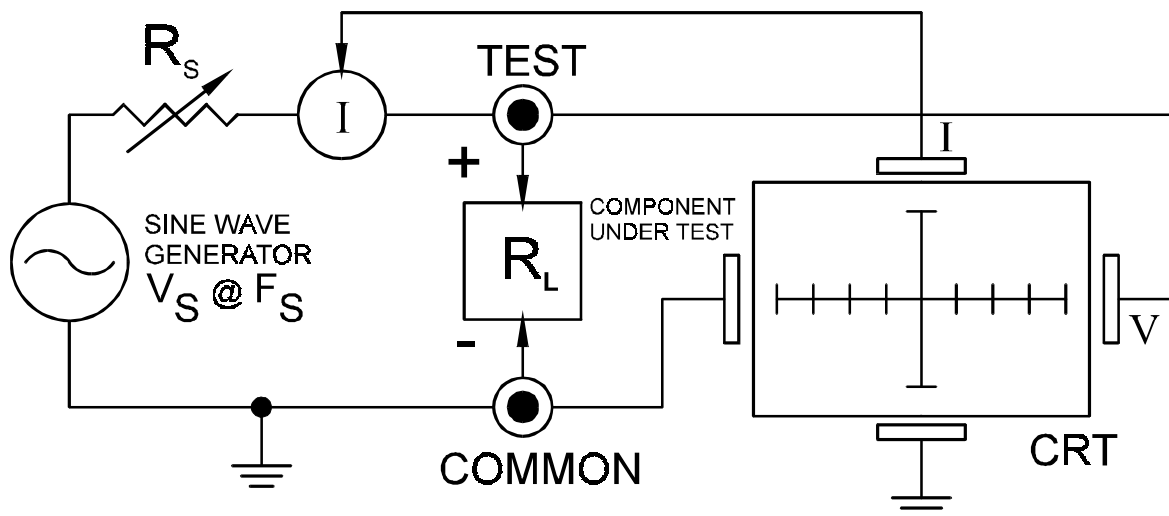


Figure 3-2. Tracker 2500 Core Circuit Block Diagram.
 R_s = Source Resistance, V_s = Source Voltage,
 R_L = Load Resistance, F_s = Source Frequency.

Each test signal or range has three 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 2500 can readily accomplish this by changing the proper range parameter. The source voltage V_s 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.

3-3 Horizontal Axis

The voltage across the component under test controls the amount of horizontal trace deflection on the CRT display. When the component under test is removed, creating an open circuit (e.g., $R_L = 0$), 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.

The horizontal axis is divided up by small graticule lines similar to those on a conventional CRT. Each mark is approximately 1/4 of the peak range voltage. For example, in the 10 V range, each division is approximately 2.5 V. You can use these graticule marks to get a rough estimate of the voltage drop across the component under test.

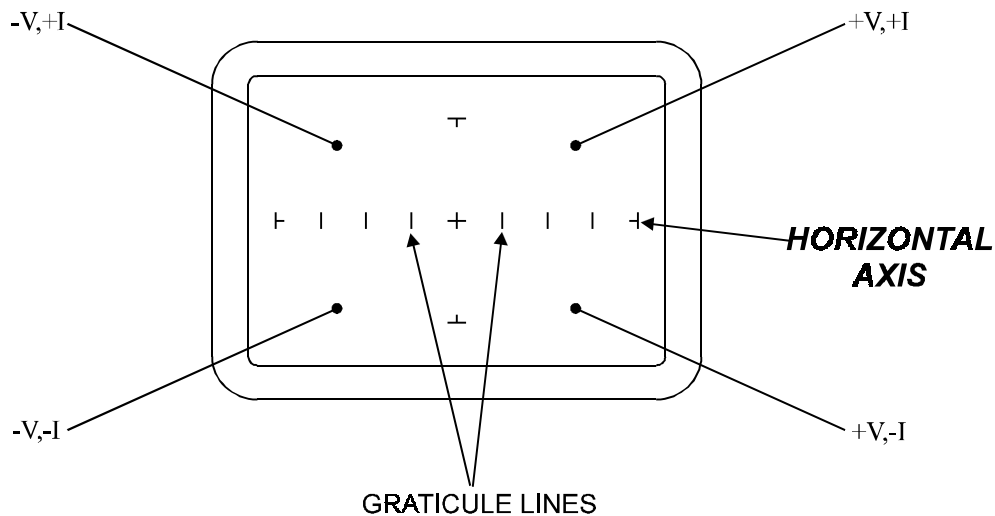


Figure 3-3. CRT Display Horizontal Axis And Graticule Lines.

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 CRT 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 2500 and observe the CRT display. With nothing connected to its test terminals, the display trace is a horizontal line (that is, $R_L=0$).

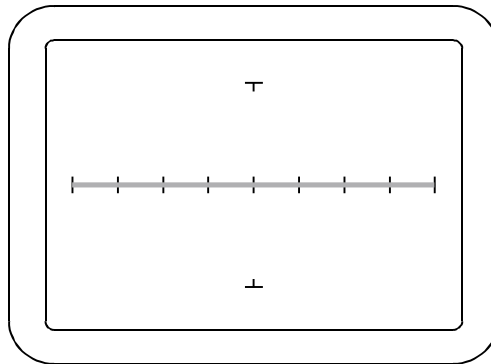


Figure 3-3. Tracker 2500 CRT Display with Open Test Terminals.

3-4 Vertical Axis

The amount of vertical trace deflection on the CRT display is controlled by the voltage dropped across the internal impedance R_s of the Tracker 2500. 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 (0Ω) 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 CRT display.

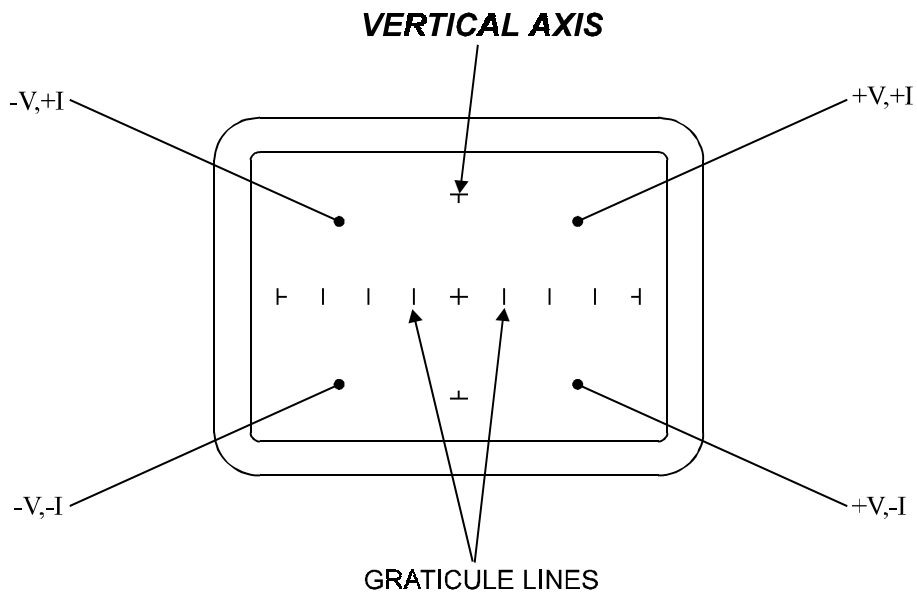


Figure 3-5. CRT Display With Vertical Axis And Graticule Lines.

1. Connect the red microprobe to the output channel A jack on the Tracker 2500 and the black microprobe to the Common jack.
2. Touch and hold the probes together and observe the analog signature on the CRT display.
3. You will see a vertical line trace in the middle of the CRT display.

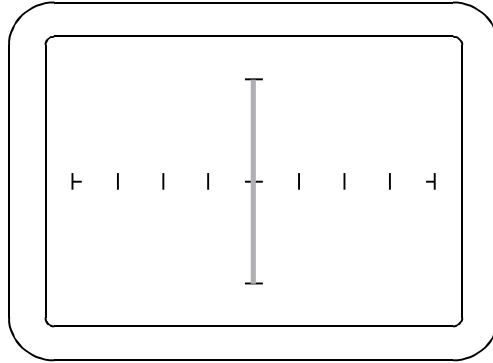


Figure 3-6. Tracker 2500 CRT Display with Short Circuit Signature.

3-5 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 directly connected to the common terminal. In the following figures, the upper screen represents the Tracker 2500's CRT 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 shown in Figs. 3-8 and 3-10 are for illustration purposes only and cannot be displayed on the CRT.

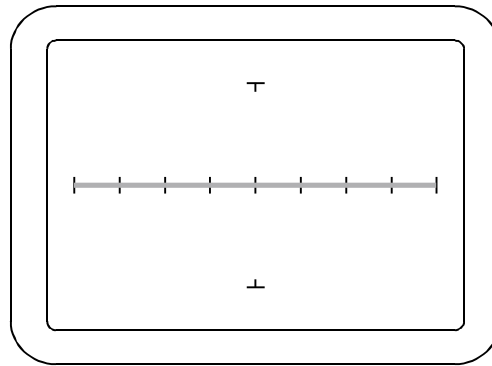


Figure 3-7. "OPEN" Analog Signature On CRT Display (Horizontal Line).

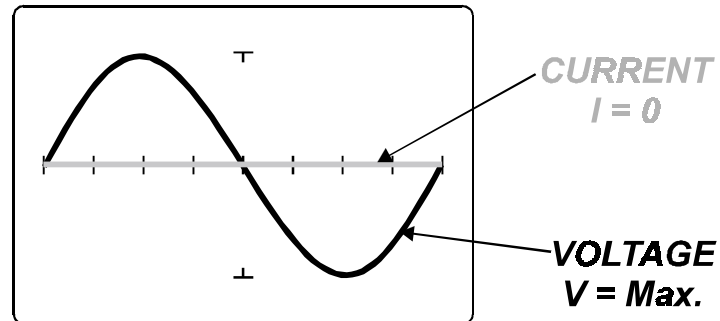


Figure 3-8. Test Signal (Open Circuit) With Current And Voltage Waveforms. Minimum Current And Maximum Voltage

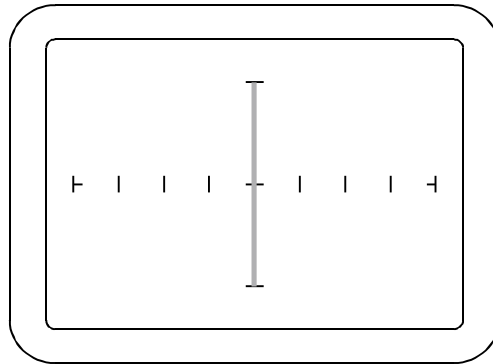


Figure 3-9. "SHORT" Analog Signature On CRT Display (Vertical Line).

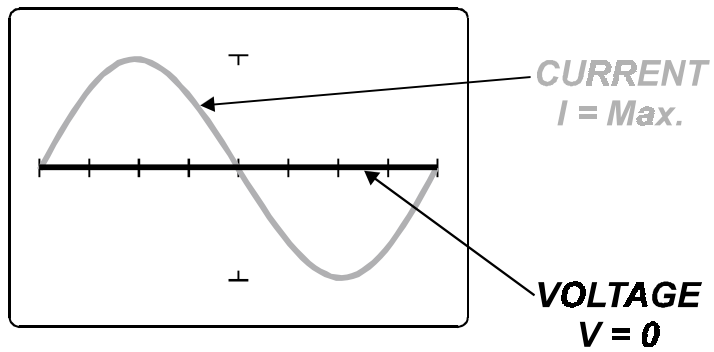


Figure 3-10. Test Signal (Short Circuit) With Current And Voltage Waveforms. Maximum Current And Minimum Voltage

3-6 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. Refer to Fig 3-9. Each one of these basic components responds differently to the Tracker 2500's test signal. Recognizing these four basic unique signatures on the CRT display is 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 most of the time form an approximate right angle.

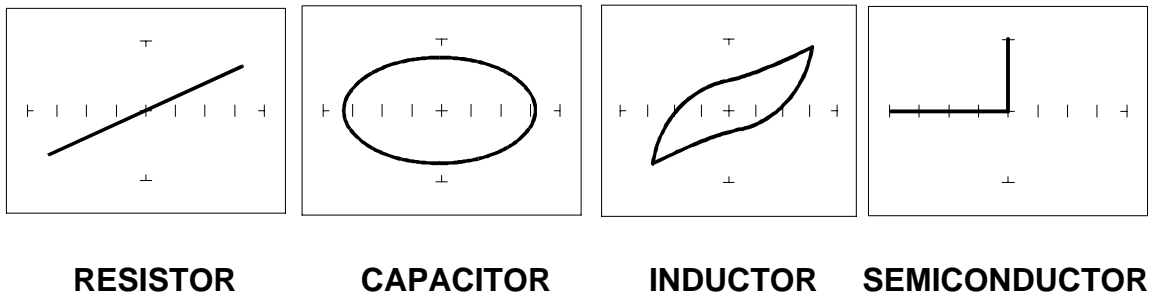


Figure 3-9. Analog Signatures of 4 Basic Components.

3-7 Smart Tracker Active Range (STAR) feature.

The Tracker 2500 has a built-in operating feature called STAR (**S**mart **T**racker **A**ctive **R**ange). This important feature protects sensitive components from possible exposure to excessive power (for example, 15V and 10Ω).

The table below specifies the active and disabled voltage & resistance test range combinations.

	10 Ω	100 Ω	1kΩ	10kΩ	100kΩ
200mV	√	√	√	√	√
2 V	√	√	√	√	√
3 V	Disabled	√	√	√	√
5 V	Disabled	√	√	√	√
10 V	Disabled	√	√	√	√
15 V	Disabled	Disabled	√	√	√

Table 3-1. Valid Tracker 2500 Ranges (STAR)

To illustrate the STAR feature, do the following:

1. Select the **2V, 10Ω** range. This is a valid range shown by the LEDs being lit up on the **2V** and **10Ω** button.
2. Press the **5V** button. Notice that the **5V** LED is on and the resistance range changes to **100Ω** automatically. The **5V, 10Ω** range was disabled.
3. Now press the **15V** button. Notice that the **1kΩ** resistance is automatically selected. The **15V, 100Ω** range was disabled and the next valid resistance range was activated at the selected voltage.

SECTION 4

TESTING PASSIVE COMPONENTS

4-1. Resistors

Exploring how the Tracker 2500 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 2500 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

Turn power on to your Tracker 2500. Put the red test lead in the **A** jack, and the black test lead in the **Common** jack.

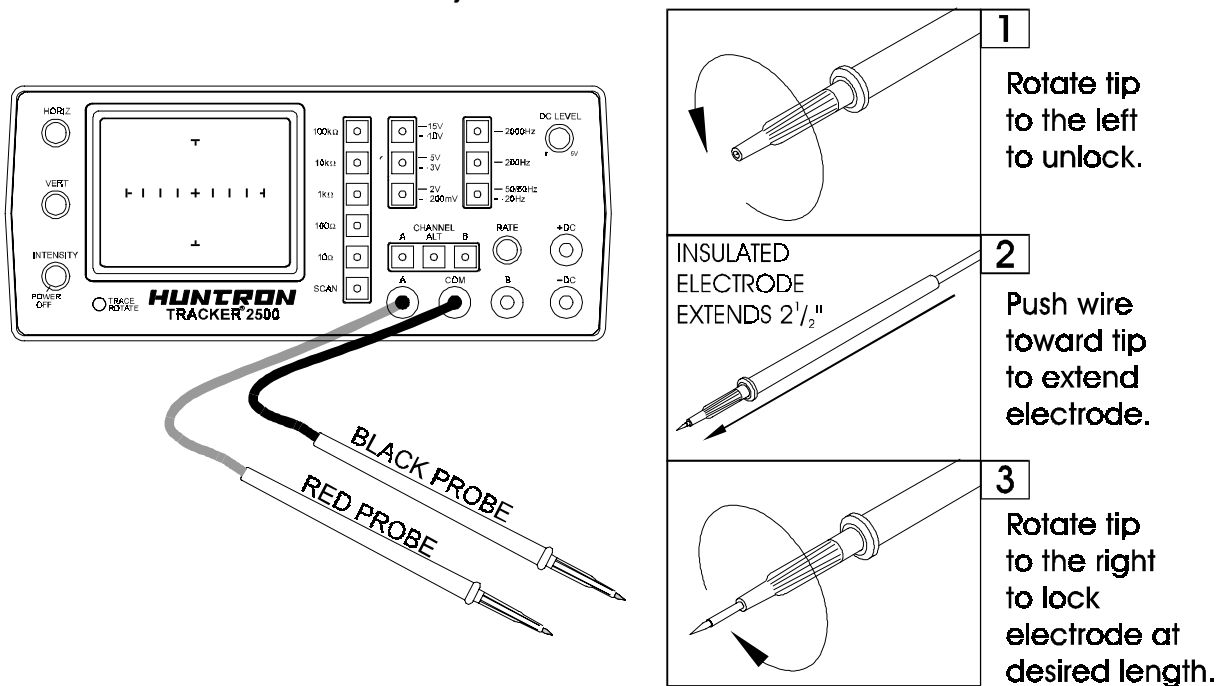


Figure 4-1. Tracker 2500 With Test Probe Leads And Probe Adjustment.

To display the analog signature of a resistor:

1. Press the appropriate resistance range button. Select the **2V** voltage range.
2. Place or clip a test lead on the opposite ends of a resistor and observe the signature on the Tracker 2500 CRT display. (Make sure Channel A is selected)

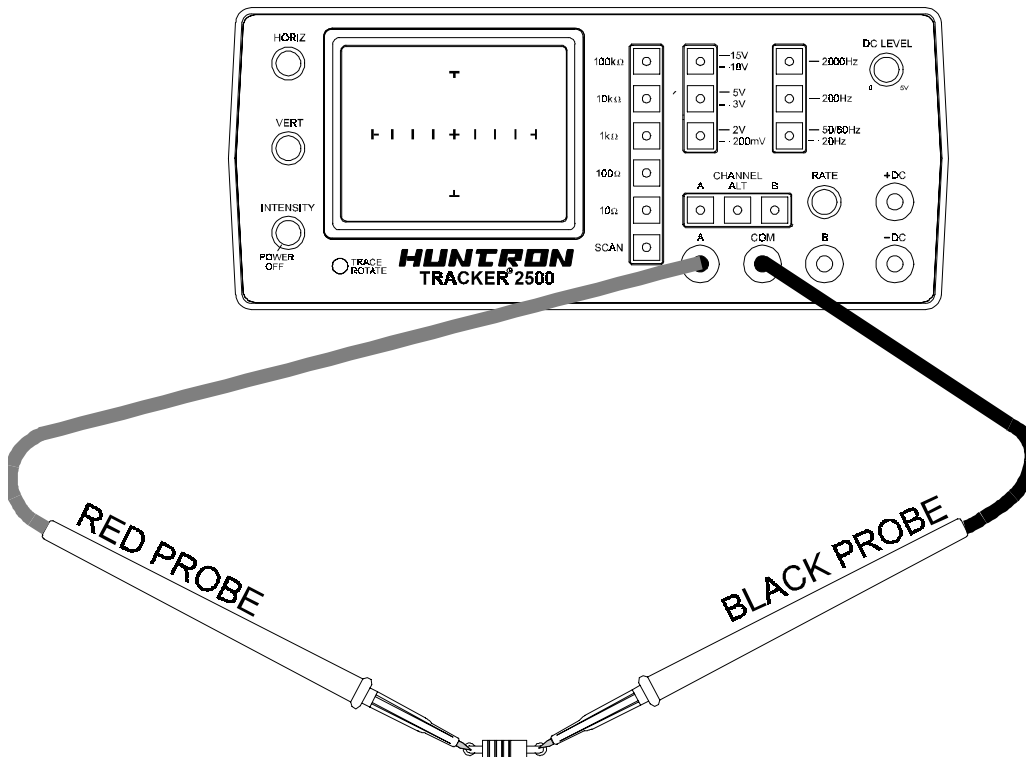


Figure 4-2. Tracker 2500 Connected To A Resistor.

Below are four analog signatures of different resistors, 150Ω, 1.5kΩ, 15kΩ and 100kΩ in each of the five Resistance ranges. Note how the slope or angle of each analog signature changes with each resistor's value.

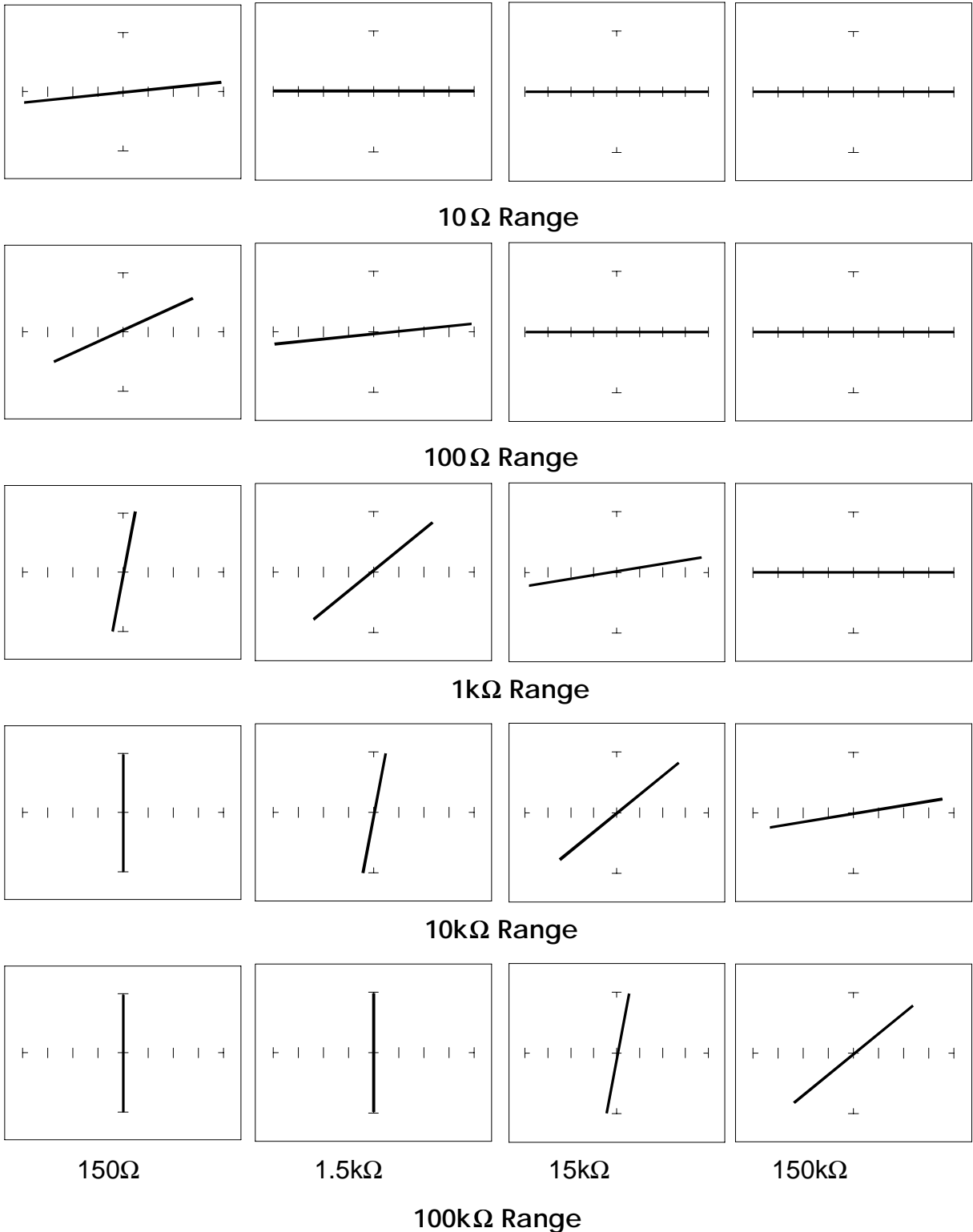


Figure 4-3. Signatures Of Different Resistors.

The diagram below shows the basic functional parameters of the Tracker 2500. The applied sine-wave voltage is V_s at a frequency of F_s . The source resistance R_s limits the current to the device-under-test.

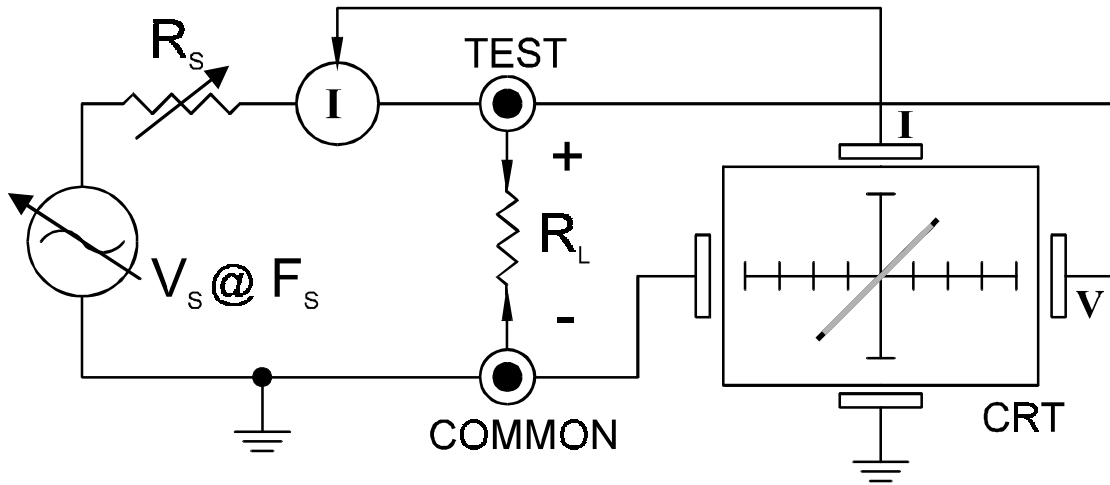


Figure 4-4. Tracker Core Circuit Block Diagram With A Resistor.

Now that you have an idea of what the signatures of different resistor values look like in different ranges, the next part will give you an idea of what happens when you vary R_s source resistance, V_s source voltage and F_s source frequency of the Tracker 2500 and how it affects the resistive analog signature.

The Effect of V_s on Resistor Analog Signatures.

Press the **15V/10V** button. The 15V range is indicated by the LED on the button being continuously on. To select the 10V range press this button again. Notice that the LED is now flashing on and off.

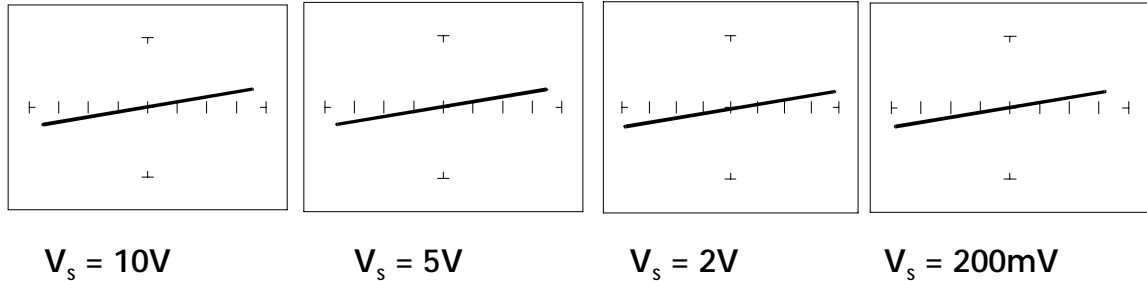


Figure 4-5. Effect Of Varying V_s On A Resistor Signature.
 100Ω Range, $R_L = 150\Omega$

Observe that these signatures do not change with the changing voltage. Note that when V_s is set at 15V, the resistance range R_s automatically changes to 1kΩ. This limit on range parameter combinations is a result of the Tracker 2500's STAR feature, it protects components from possible excessive power (see section 3-7). In order to set V_s to a higher voltage, you must change R_s to a higher value first.

The Effect of F_s on Resistor Analog Signatures.

Press the **200 Hz** button to change the frequency of the applied test signal. Observe that the resistor signatures in the following figures do not change as F_s changes.

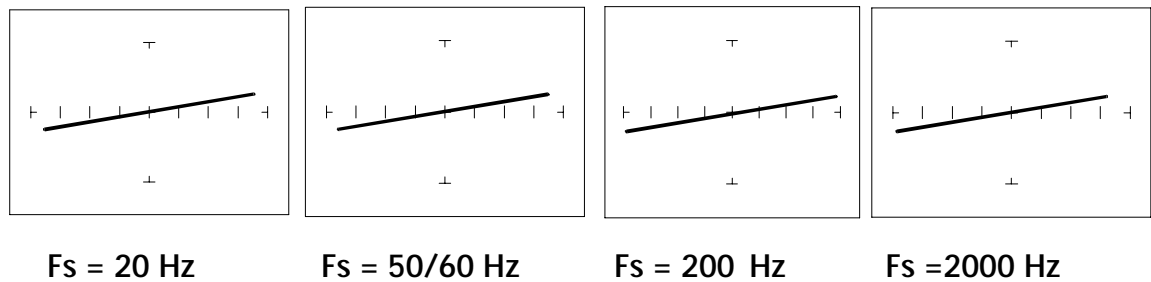


Figure 4-6. Effect Of Varying F_s On A Resistor Signature.
 100 Ω Range, $R_L = 150\Omega$

Understanding Resistive Signatures

The Tracker 2500's signature is a visual representation of Ohm's Law in the circuit under test. The amount of voltage applied to the circuit is shown along the horizontal axis, and the resultant current is shown along the vertical axis. The signature is a straight line because the relationship between voltage and current in a purely resistive circuit is linear. The slope changes as we change the internal resistance of the Tracker 2500.

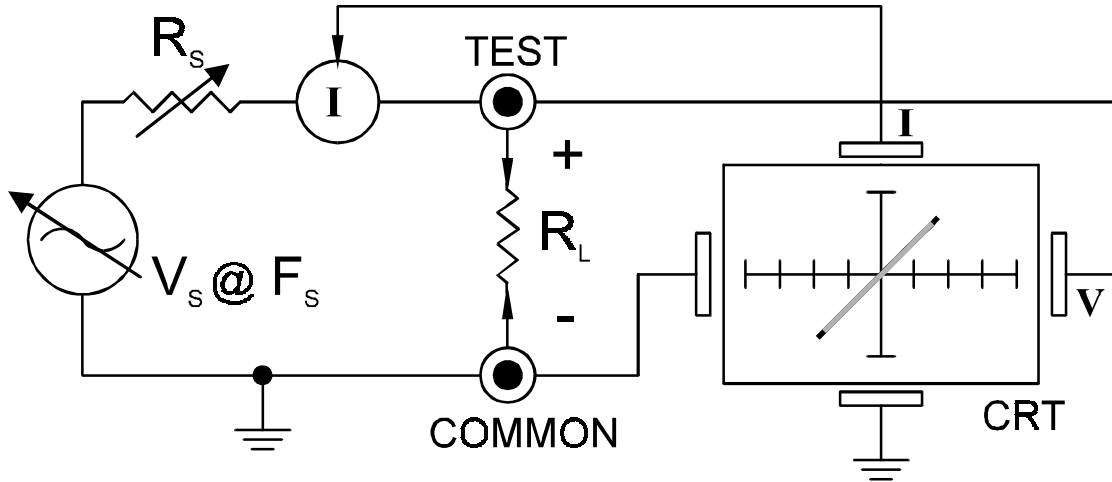
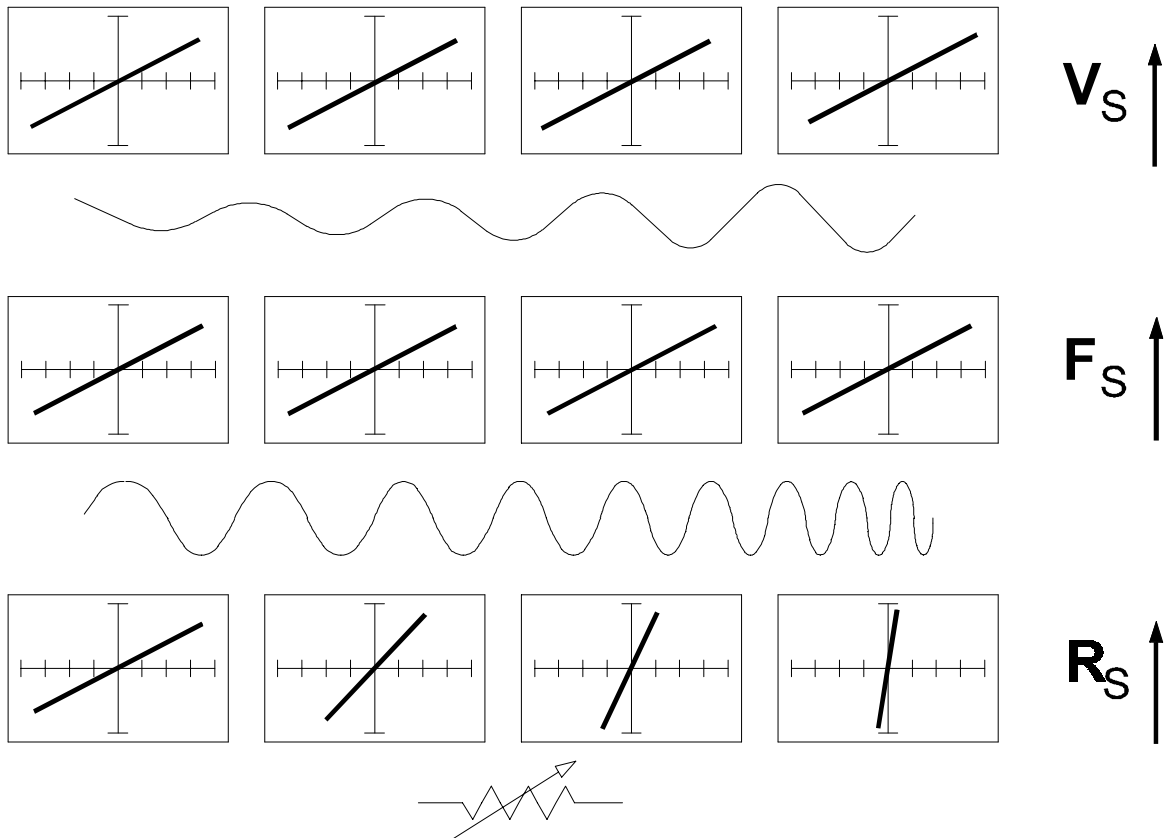


Figure 4-7. Tracker Core Circuit Block Diagram With A Resistor.

The next figure shows what happens to the CRT display when the different parameters change. The parameter values increase from left to right displaying source voltage (V_s), source frequency (F_s), and source resistance (R_s).

A pure resistance across the test terminals will cause the trace on the Tracker 2500 CRT to rotate in a counter clockwise direction around its center axis from horizontal open circuit position (high value resistance) to a vertical short circuit (low value resistance). The degree of rotation is a function of the resistance value.



How Range Parameter Changes Effect Resistive Signatures

Figure 4-8. Range Parameters Changes And Effects On Resistive Signatures.

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 Ω to 10 Ω 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.

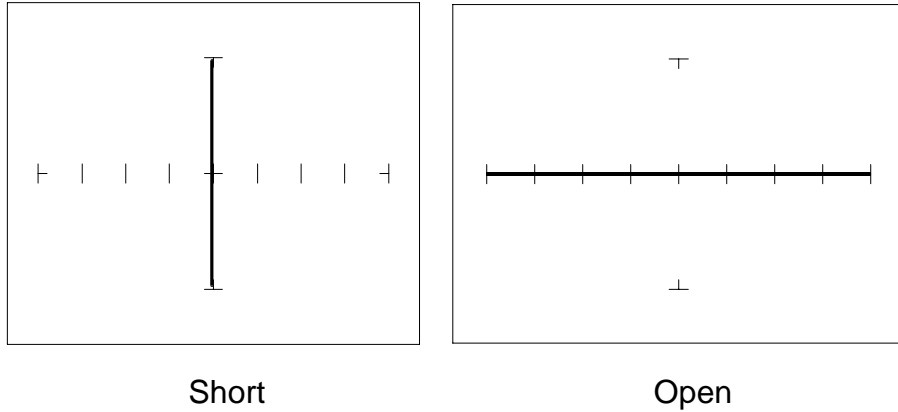


Figure 4-9. Short And Open Signature.

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 voltage increases
 - the volts per division of the horizontal axis increases
 - the internal resistance increases
 - the signature becomes more vertical

Troubleshooting Applications

- The Tracker 2500 is a fast and efficient continuity tester, providing real time information.
- The Tracker 2500 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 2500's ability to determine the approximate fault resistance value greatly enhances the troubleshooting capability if the correct value is known.
- The Tracker 2500's CRT is a real time display and using the Tracker 2500 for testing noisy or dirty potentiometer (variable resistors) is an excellent application. Connect Tracker 2500'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.

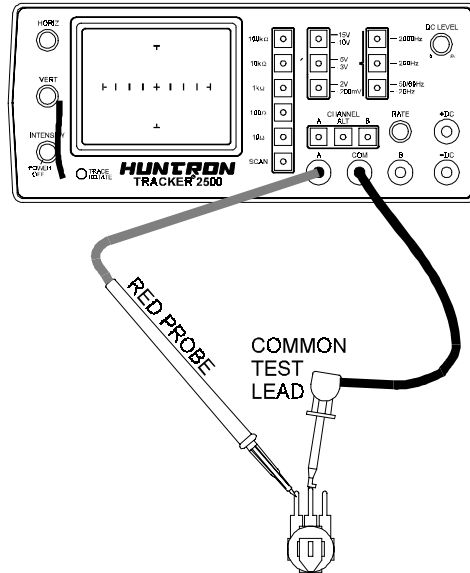


Figure 4-10. Using Tracker 2500 To Test A Potentiometer.

- The Tracker 2500 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.

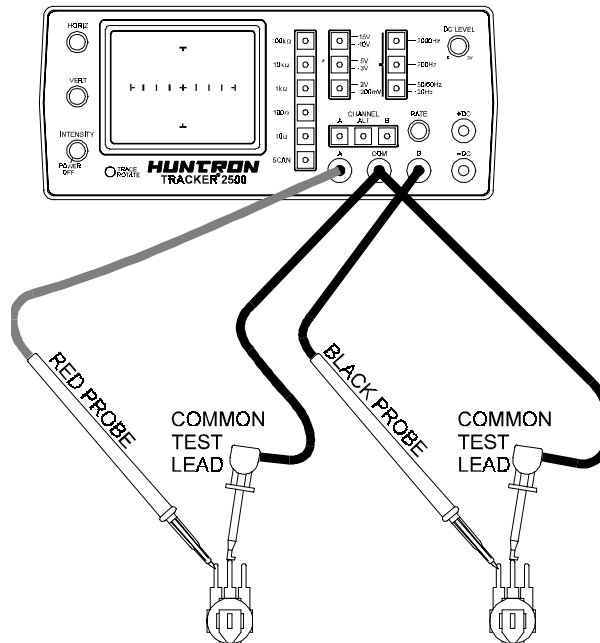


Figure 4-11. Using Tracker 2500 To Compare Two Potentiometers.

4-2. Capacitors

With a capacitor connected to the Tracker 2500, 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.

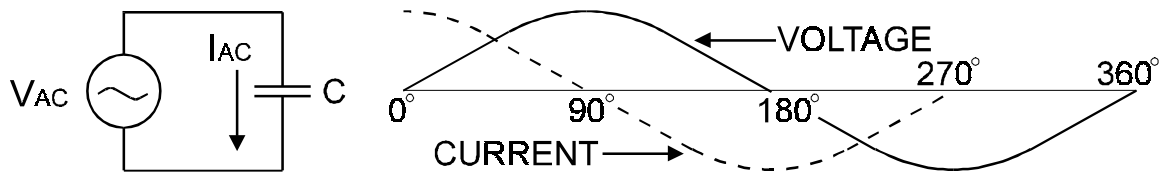


Figure 4-12. Capacitor Circuit With Test Signal's Current And Voltage Waveforms.

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° . On the Tracker 2500, this analog signature appears as a circular waveform. The actual shape and slope of the elliptical signature depends on the capacitance and impedance value of the component and the test signal's internal resistance and frequency.

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 (μf) of the circuit under test
- The frequency (F_s) of the test signal
- The voltage (V_s) of the test signal
- The internal resistance (R_s) of the Tracker 2500

Turn power on to your Tracker 2500. 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 2500 to the device.

Input Protection

The Tracker 2500 has input protection circuitry which protects the Tracker 2500's test terminals from external excessive voltage. The Tracker 2500 is a power-off tester requiring no other external power being applied to the device-under-test. For example, testing large valued capacitors may still have a charge in them and can cause potential damage to the Tracker. This situation is avoided by the Tracker's test signal turning automatically off when external voltage is present. This indication is displayed by all the resistance buttons LEDs flashing. The Tracker will reset to its normal operating mode once the external voltage is removed.

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

1. Press the **15/10V** button so that the button's LED is blinking indicating that the 10V range is active.
2. Press the **100Ω** Button.
3. Place or clip a test lead on the opposite ends of a capacitor and observe the signature on the Tracker 2500's CRT display.

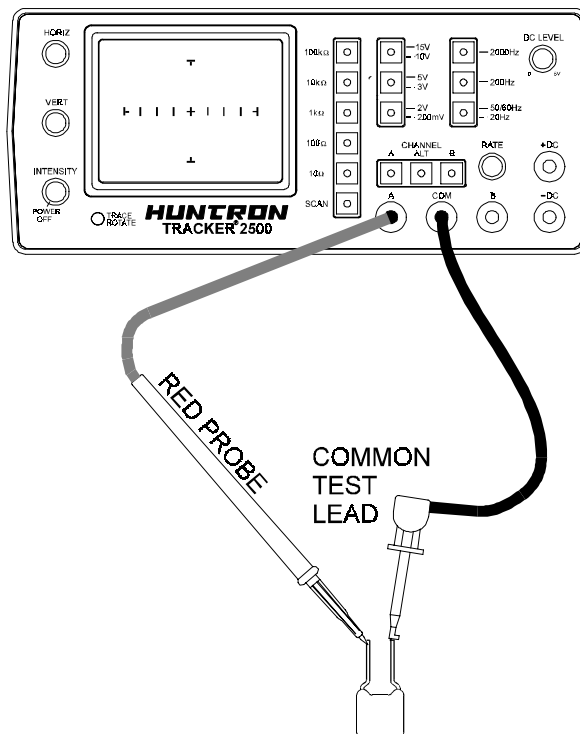


Figure 4-13. Tracker 2500 With Test Probes Connected To A Capacitor.

The Signatures Of Different Capacitors In Low Range

The figure below shows analog signatures for four different value capacitors, 1000 μf , 100 μf , 10 μf and 1 μf . The Tracker 2500 **10V/100 Ω** range is selected.

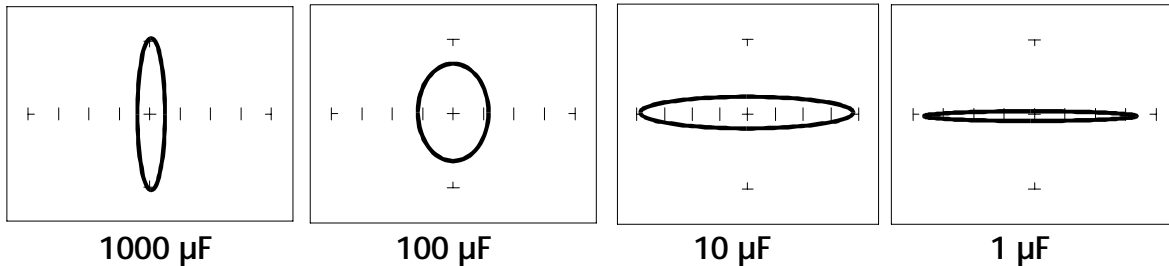


Figure 4-14. Signatures Of 4 Capacitors in the 10V, 100 Ω Range,
 $F_s=60$ Hz.

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.

Effect Of Frequency (F_s) On The Signature Of A 10 μ F Capacitor

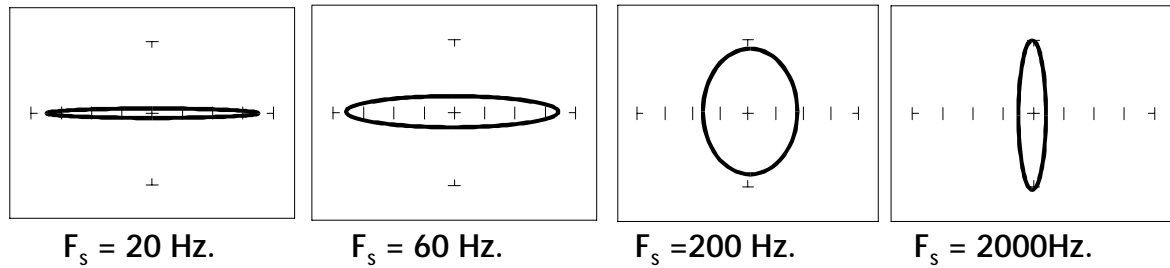


Figure 4-15. Signatures Of A 10 μ F Capacitor At Different Frequencies.
10V, 100 Ω Range

Note that as the test signal frequency increases, the 10 μ F capacitor's signature changes from a horizontal elliptical pattern to a vertical elliptical pattern. In ASA, a capacitor at a low test frequency has a signature that looks similar to an open circuit. And likewise, the same capacitor at a high frequency has a signature that's similar to a short circuit.

Effect Of Frequency (F_s) On The Signature Of A 0.1 μ F Capacitor

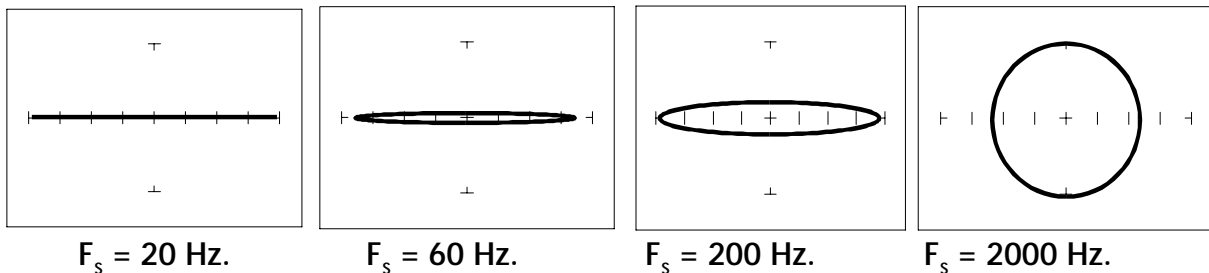


Figure 4-16. Signatures Of A 0.1 μ F Capacitor At Different Frequencies.
15V, 1k Ω Range.

Note that as the test signal frequency increases, each signature changes from a horizontal elliptical pattern to a vertical elliptical pattern. In ASA, a small value capacitor at a low test frequency has a signature that looks similar to a open circuit. Likewise, a small value capacitor at a high test frequency has a signature that's similar to an short circuit. The signature of the 0.1 μ F capacitor is similar to the 10 μ F capacitor in shape but not in size due to the differences in their value.

Effect Of Voltage (V_s) On The Signature Of A $1\ \mu\text{F}$ Capacitor

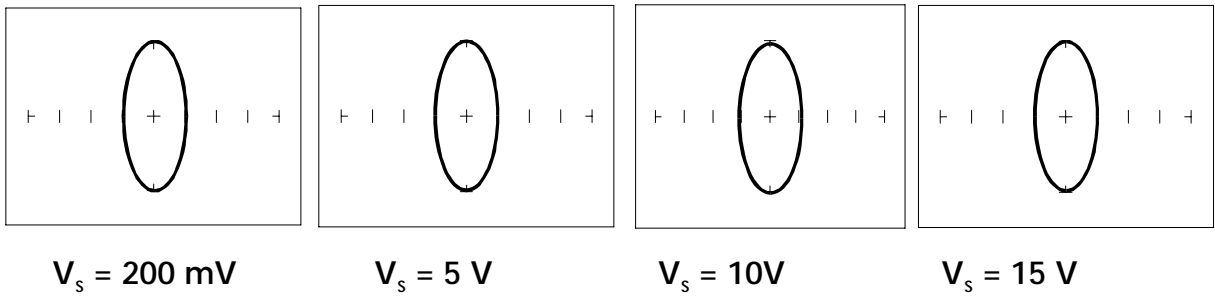


Figure 4-17. Signatures Of A $1\ \mu\text{F}$ Capacitor At Different Test Signal Voltages. $10\text{k}\Omega$ Range, $F_s = 60\text{Hz}$

As V_s , the test signal voltage increases from low to high, the signatures did not change.

Effect Of Resistance (R_s) On The Signature Of A $1\ \mu\text{F}$ Capacitor

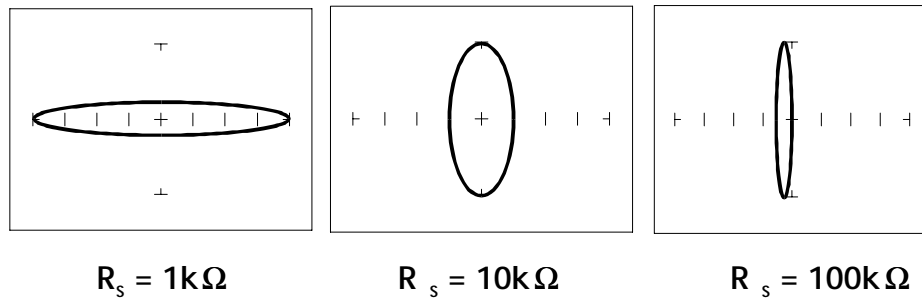


Figure 4-18. Signatures Of A $1\ \mu\text{F}$ Capacitor At Different Internal Resistances. $15\ \text{V}$ Range, $F_s = 60\text{Hz}$

As the Tracker 2500's internal resistance R_s increased, the capacitor's signature changes from a horizontal elliptical pattern to a vertical elliptical pattern.

Understanding Capacitor Analog Signatures

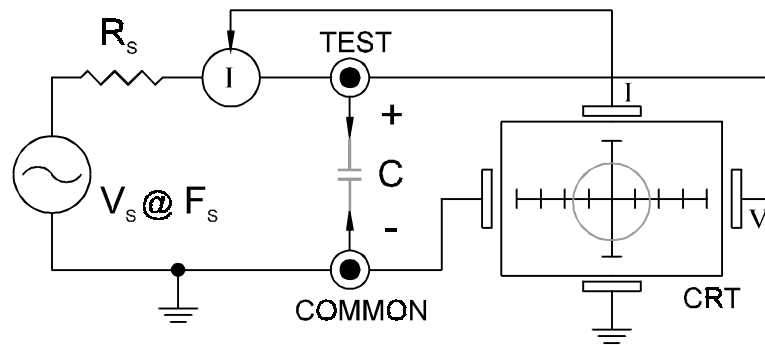


Figure 4-19. Tracker Core Circuit Block Diagram With A Capacitor.

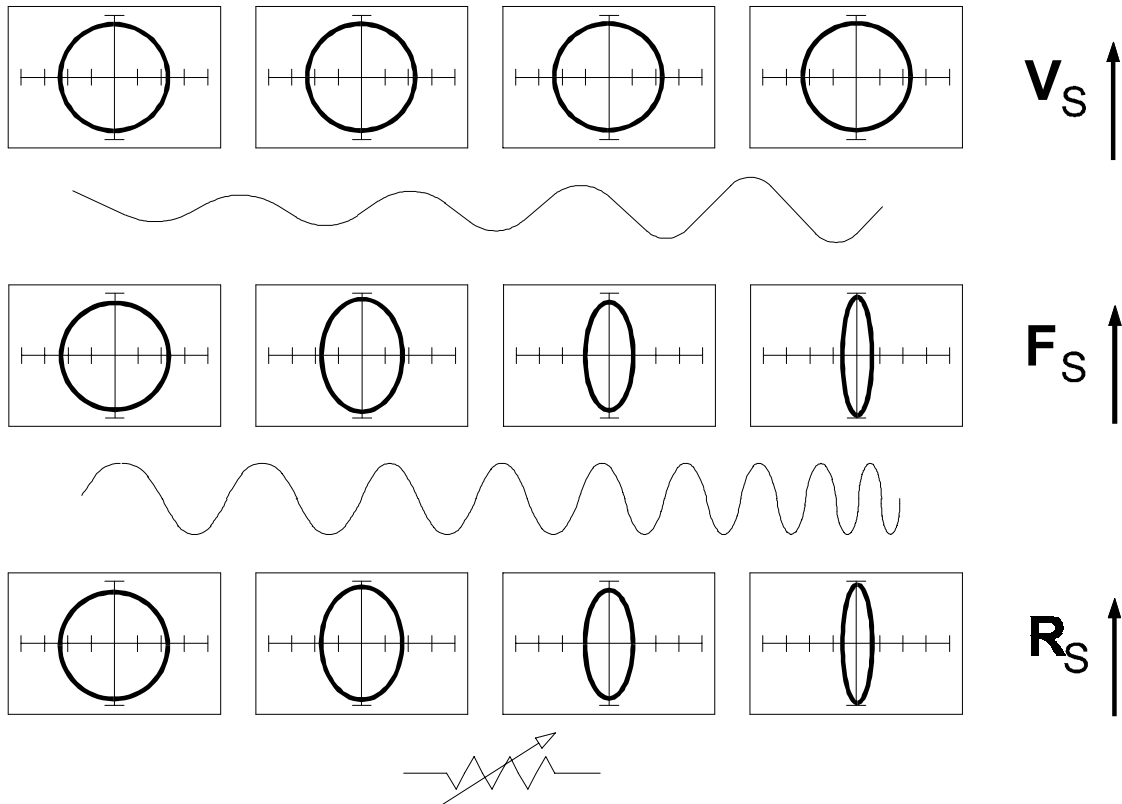
The Tracker 2500 CRT displays as a response to its test signal, an analog signature that represents the relationship between voltage, current and resistance of a component. For circuits that contain capacitors, the effective resistance is called capacitive reactance, X_C . The mathematical formula is:

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

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 2500, the elliptical signature will become increasingly vertical which 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 2500, the elliptical signature will become increasingly vertical which implies more current flow.
- Changing voltage V_s : As the test signal voltage is changed from 200 mV to 20 V, the following occurs:
 - X_C of the capacitor is not affected
 - The applied Voltage increases
 - The elliptical signature is not affected

- Changing source resistance R_S : As the resistance is changed from 1 k Ω to 100 k Ω , the following occurs:
 - X_C of the capacitor is not affected
 - The elliptical signature becomes increasingly vertical



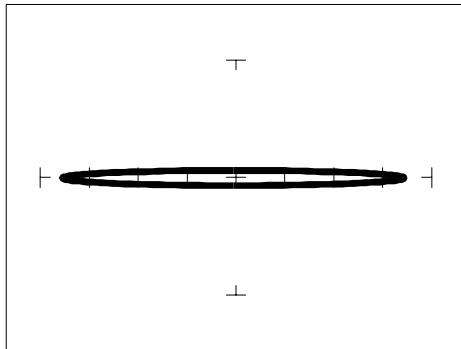
How Range Parameter Changes Effect Capacitive Signatures

Figure 4-20. Range Parameters Changes And Effects On Capacitive Signatures.

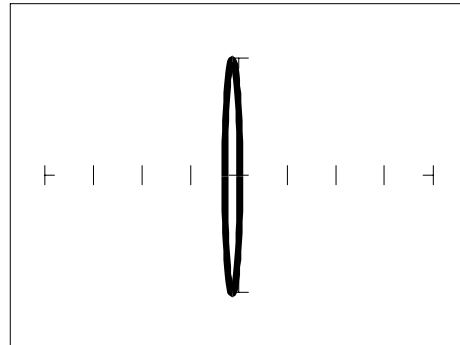
The figure above shows how the three variable parameters affect the capacitive signature. Frequency F_S and internal resistance R_S has the greatest effect, while increasing voltage V_S has no effect.

Minimum and Maximum Capacitor Values

The Tracker 2500 will display a “loop” type signature for the following range of capacitor values. For example, when $V_s = 200\text{mV}$, $R_s = 100\Omega$ and $F_s = 20\text{Hz}$, a thin **horizontal “loop”** type signature will be displayed when the capacitor being tested is $2\mu\text{F}$. As the test capacitance increases in value, the loop becomes bigger until it is a **thin vertical loop**. The maximum capacitance is now $1000\mu\text{F}$. If you test a $2000\mu\text{F}$ capacitor, the vertical loop starts to approach a “short” type signature. From the table below, in order to see the loop for a $2000\mu\text{F}$ capacitor, change the resistance range to 10Ω .



Capacitance = $2\mu\text{F}$



Capacitance= $1000\mu\text{F}$

Fig 4.21 Minimum And Maximum Capacitance That Will Display A Loop Type Signature. $V_s=200\text{mV}$, $R_s=10\Omega$, $F_s=20\text{Hz}$.

Notice that a change in voltage has no effect on the shape of the capacitor's signature. The 200mV voltage range is ideal for testing capacitors because all the resistance ranges are available.

V_s	R_s	$F_s=20\text{Hz}$	$F_s=2000\text{Hz}$
200mV	10Ω	$47\mu\text{F}$ to $10000\mu\text{F}$	$0.47\mu\text{F}$ to $100\mu\text{F}$
200mV	100Ω	$2\mu\text{F}$ to $1000\mu\text{F}$	$0.047\mu\text{F}$ to $22\mu\text{F}$
200mV	$1\text{k}\Omega$	$0.47\mu\text{F}$ to $100\mu\text{F}$	7nF to $2.2\mu\text{F}$
200mV	$10\text{k}\Omega$	$0.047\mu\text{F}$ to $27\mu\text{F}$	500pF to 220nF
200mV	$100\text{k}\Omega$	4nF to $2.2\mu\text{F}$	47pF to 22nF

Table 4-1 Tracker 2500 Minimum And Maximum Capacitor Values That Will Display A “Loop” On The CRT.

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 2500 display.

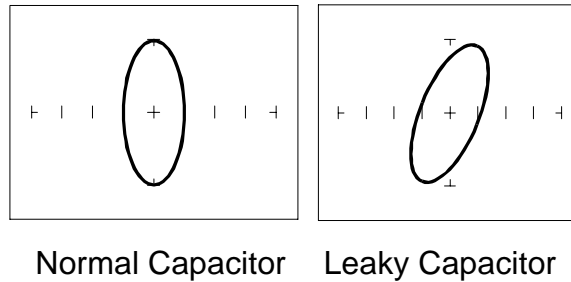


Figure 4-22. Signatures Of A 100 μF Capacitor With Dielectric Leakage.
10V, 100 Ω Range, $F_s = 60$ Hz

This example only simulates the leakage flaw by adding a 100 Ω resistor in parallel to a 100 μF 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 μF capacitor.

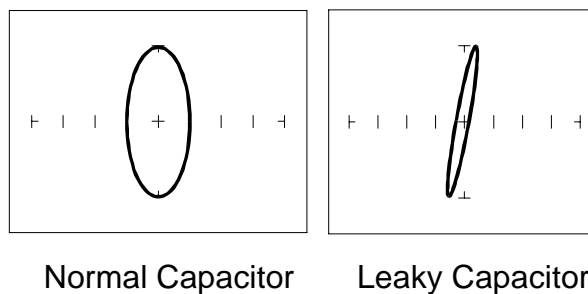


Figure 4-23. Signatures Of A 10 μF Capacitor With Dielectric Leakage.
10V, 100 Ω Range, $F_s = 60$ Hz

Again, this example only simulates the leakage flaw by adding a 68 Ω resistor in parallel to a 10 μF 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 2500 displays when there are several components connected together in a circuit.

Review

- Capacitors have 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 2500 can locate defective capacitors in or out of circuit. The ranges cover 10 pF to 20,000 μ F.
- When analyzing a capacitor's signature, adjust the Tracker 2500's R_S and F_S 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 on the CRT display.

4-3. Inductors

Inductors, like capacitors, have elliptical analog signatures and respond to Tracker 2500's test signal non-linearly. 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 has some amount of resistance in it, it is hard to find an inductor with 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 μH of the circuit under test
- The frequency F_s of the test signal
- The voltage V_s of the test signal
- The internal resistance R_s of the Tracker 2500

Signatures Of Different Inductors.

The figure below shows analog signatures for four different value inductors, 12,000 μH , 1200 μH , 120 μH and 12 μH in the 10V, 100 Ω Range.

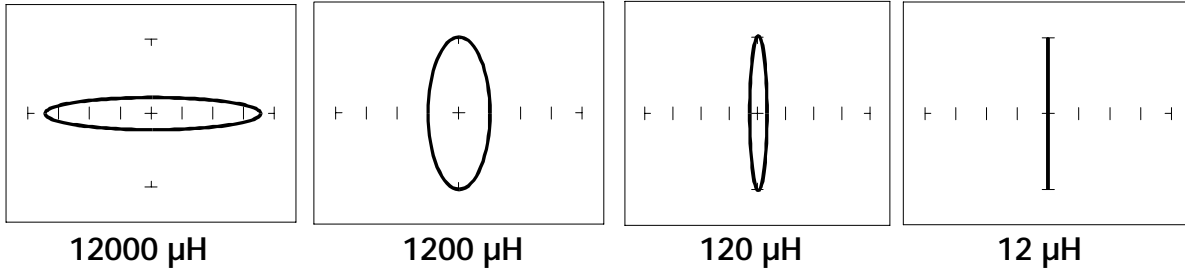


Figure 4-24. Signatures Of 4 Inductors In the 10V, 100 Ω Range.
 $F_s = 2000\text{Hz}$

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

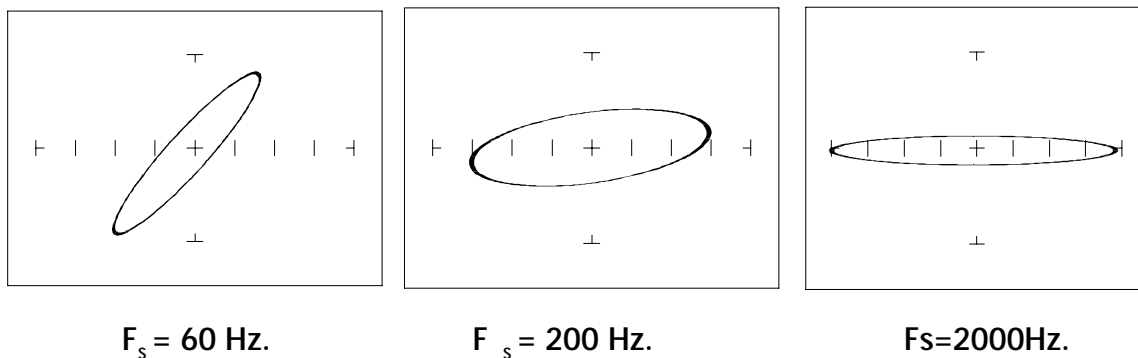


Figure 4-25. Effect of Varying F_s On Inductor Signatures.
 10V, 100 Ω Range, $L = 12,000 \mu\text{H}$

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.

Effect Of Voltage V_s On Inductor Signatures

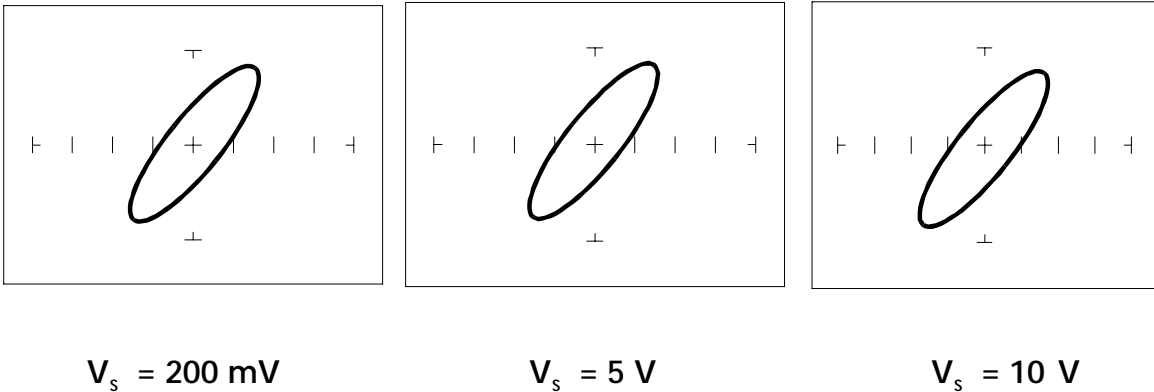


Figure 4-26. Effect Of Varying V_s On Inductor Signatures.
 100Ω Range, $F_s = 60 \text{ Hz}$, $L = 12,000 \mu\text{H}$

Note that the signature does not change at the three test signal voltages. This means that the inductor's resistance is not affected by changes in the test voltage.

Effect Of Internal Resistance R_s On Inductor Signatures

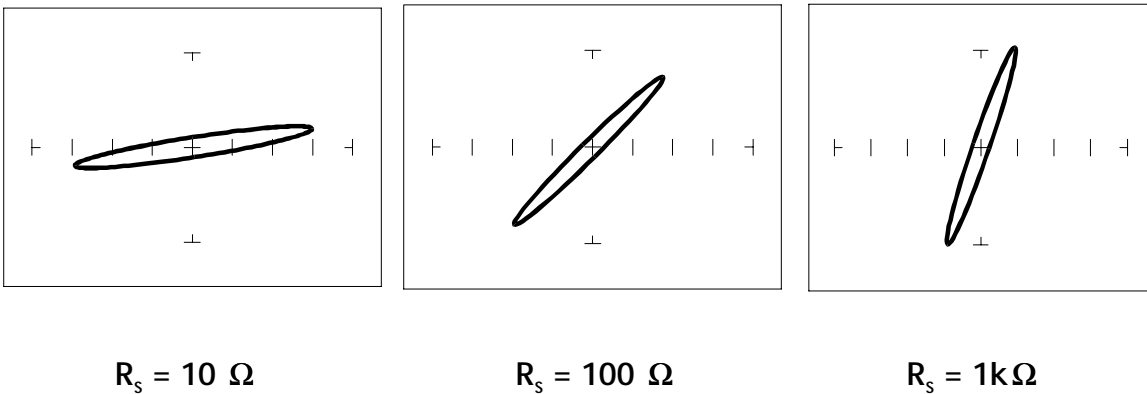


Figure 4-27. Effect Of Varying R_s On Inductor Signatures.
 $V_s = 2 \text{ V}$, $F_s = 60 \text{ Hz}$, $L = 12,000 \mu\text{H}$

Note that the signature changes from a horizontal to a vertical position as the Tracker 2500's internal resistance R_s increases. This means the inductor's resistance can be analyzed by matching it with the Tracker 2500's test signal resistance.

Understanding Inductive Signatures

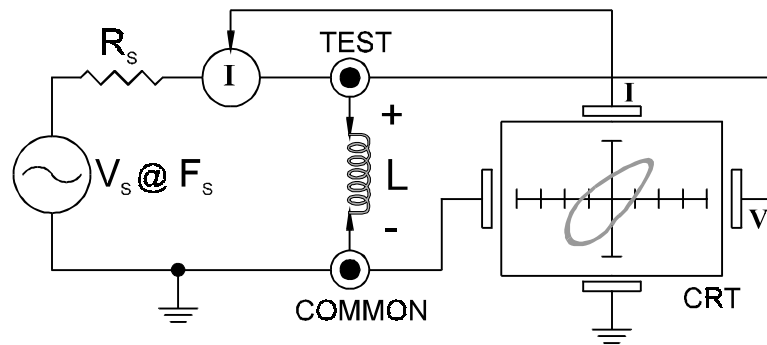


Figure 4-28. Tracker Core Circuit Block Diagram With An Inductor.

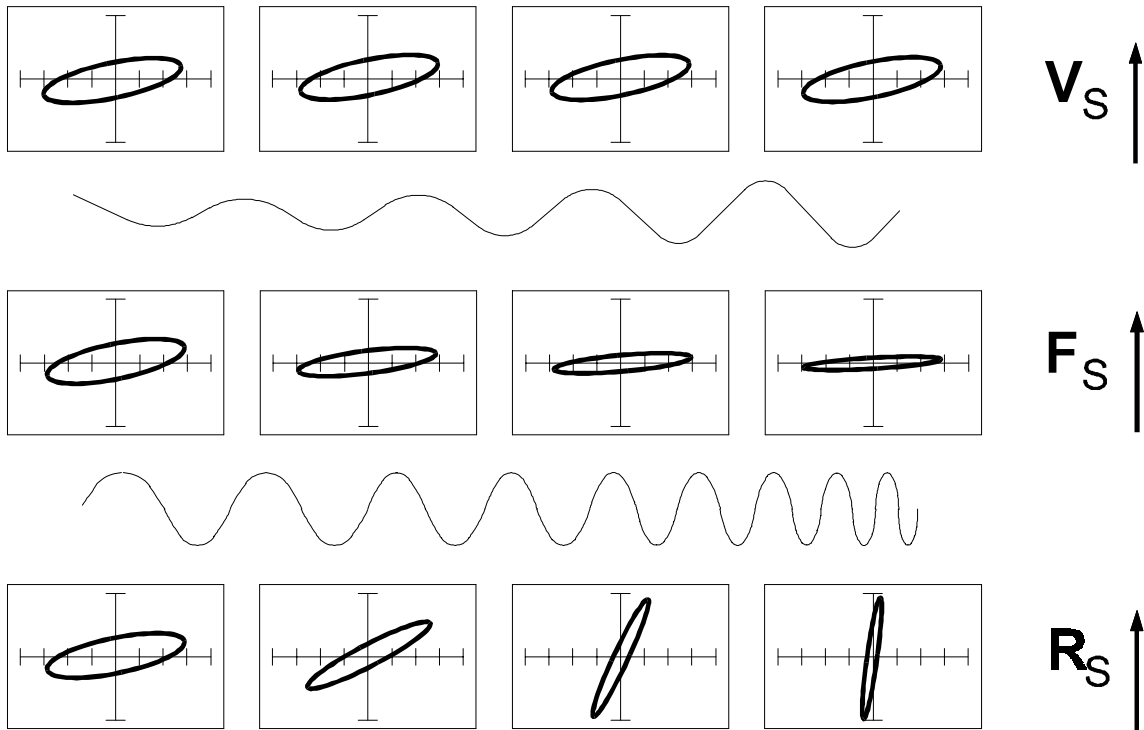
The Tracker 2500's block diagram shows an inductor between the test terminals. The current is represented by the vertical axis and is derived as a series current that flows through Tracker 2500's internal resistance, R_s . The voltage is represented by the horizontal axis and is derived as a voltage 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 resistance R_s .

Since inductors in reality are not pure inductors, the elliptical signatures they form on the Tracker 2500 display usually is distorted. Inductors constructed with a ferrite core makes the inductive characteristics different from those constructed without. The Tracker 2500 responds with a unique analog signature for each inductor type.



How Range Parameter Changes Effect Inductive Signatures

Figure 4-29. Range Parameters Changes And Effects On Inductive Signatures.

Minimum and Maximum Inductor Values

The Tracker 2500 will display an elliptical or “loop” type signature for the following range of inductor values. For example, when $V_s = 200\text{mV}$, $R_s = 10\Omega$ and $F_s = 20\text{Hz}$, a thin **vertical loop** type signature will be displayed when the inductor being tested is **100 μH** . As the test inductance increases in value, the loop becomes bigger until it is a thin **horizontal loop**. The maximum inductance that will display a loop in the above range is **150mH**. If you test a **500mH** inductor, the vertical loop at this range starts to approach a “open” type signature. From the table below, in order to see the loop for a **500mH** inductor, change the resistance range to **100 Ω** . To see a larger loop, the ideal range would be **10V, 1k Ω and 20Hz**.

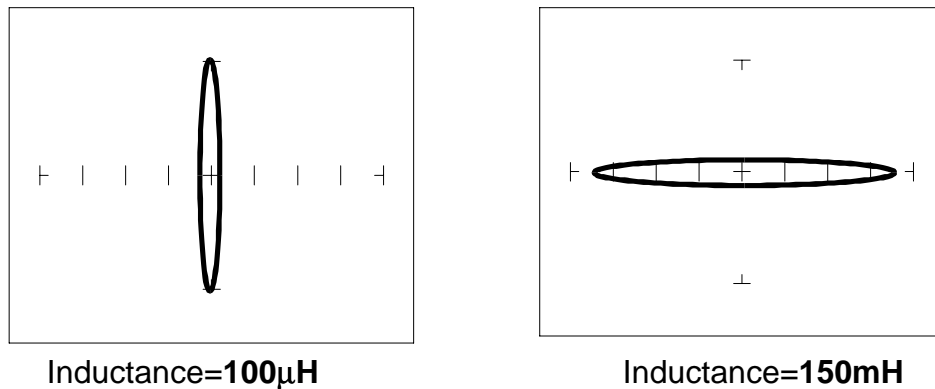


Fig. 4-30 Minimum And Maximum Inductance That Will Display A Loop Type Signature.
 $V_s=200\text{mV}$, $R_s=10\Omega$, $F_s=20\text{Hz}$.

V_s	R_s	$F_s = 20\text{Hz}$	$F_s = 2000\text{Hz}$
200mV	10 Ω	100 μH to 150mH	4.7 μH to 15mH
200mV	100 Ω	10mH to 500mH	4.7 μH to 150mH
200mV	1k Ω	300mH to 10H	3mH to 700mH
200mV	10k Ω	*	22mH to 1H
200mV	100k Ω	*	300mH to 10+ H
2V	10 Ω	2.2 μH to 100mH	100 μH to 3mH
2V	100 Ω	2.2mH to 500mH	4.7 μH to 150mH
2V	1k Ω	22mH to 10H	2.2 mH to 700mH
2V	10k Ω	*	30mH to 10H
2V	100k Ω	*	300mH to 10+ H
5V	100 Ω	2.2mH to 500mH	2.2 μH to 47mH
5V	1k Ω	22mH to 10H	3mH to 700mH
5V	10k Ω	*	22mH to 10 H
5V	100k Ω	*	300mH to 10+ H
10V	100 Ω	1mH to 500mH	4.7 μH to 22mH
10V	1k Ω	22mH to 1H	3.3mH to 500mH
10V	10k Ω	300mH to 10H	47mH to 10+ mH
10V	100k Ω	*	10+ H
15V	1k Ω	22mH to 1H	4.7mH to 500mH
15V	10k Ω	500mH to 10H	22mH to 1 H
15V	100k Ω	*	300 mH to 10+ H

* - Signature is a short with no discernible loop.
10+ indicates that the inductance is more than 10 H.

Table 4-2. Tracker 2500 Minimum And Maximum Inductor Values That Will Display A Loop Type Signature.

Review

- Inductors display elliptical signatures similar to capacitors. Since the inductor also exhibits resistance, due to its construction, the ellipse may be distorted.
- As the Tracker 2500 test signal's frequency is increased, the ellipse signature becomes flatter. This response is opposite to that of a capacitor.
- As the Tracker 2500 internal resistance R_s 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 2500 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. A few examples 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 Tracker 2500'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 Tracker 2500's 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 2500 signal in 10V, 100 Ω , 60 Hz 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.

4-4. 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 2500, 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 2500 can test the switching function of mechanically activated switches easily. Unlike the DVM that samples and gives a continuity measurement, the Tracker 2500 displays real time activity so if a switch has noisy, resistive or intermittent operation, its analog signature on Tracker 2500's display will reflect these conditions.

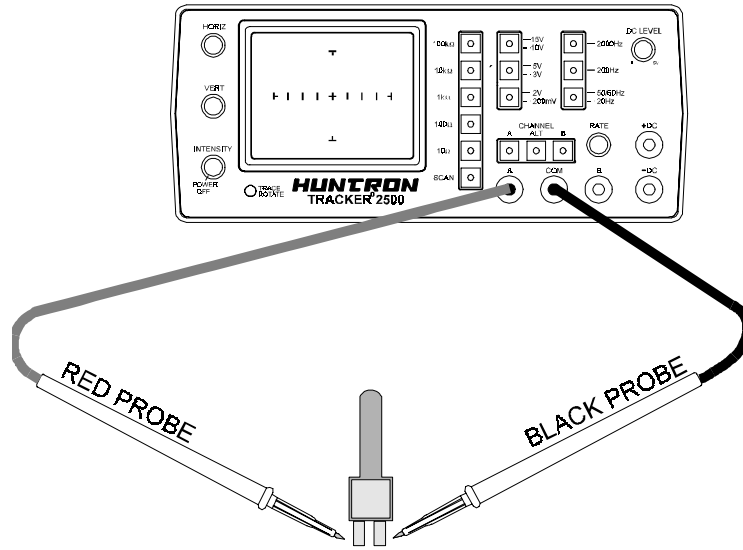
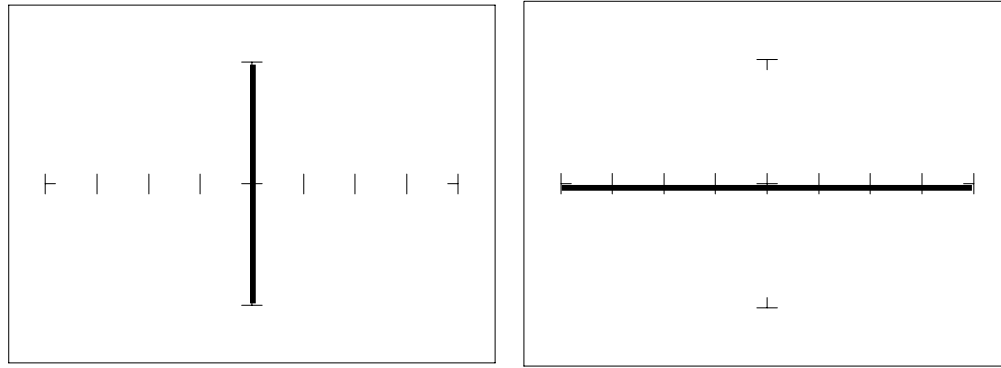


Figure 4-31. Tracker 2500 With Probes To A Mechanical Switch - SPST Type.



10V,100 Ω . Switch "On"

10V, 100 Ω . Switch "Off"

Figure 4-32. Signatures Of A Push-button Switch. SPST Type.

Review

- The switch displays an open or short circuit signature.
- Dirty or damaged switch contacts will show a resistive or erratic signature..

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 2500 can test the coil part of the relay by looking at its inductive analog signature. You can also connect the Tracker 2500's DC Source to the magnetic coil and while at the same time connecting the Tracker's test signal to the relay contacts to test the relay's switching action directly.

Relay Coil Test

Do the following:

1. Select the 10V, 100 Ω , 2000Hz. range.
2. Connect the black test lead from Tracker 2500's COMMON terminal to one side the relay coil (normally, the minus lead).
3. Connect the red test lead from Tracker 2500's TEST terminal to the other side of the relay coil (normally, the plus lead).

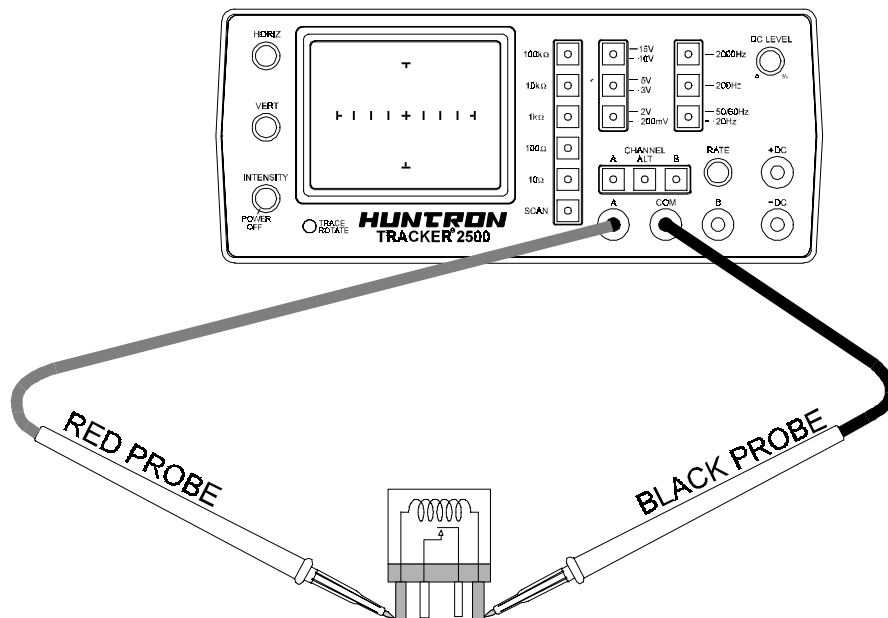


Figure 4-33. Tracker 2500 With Test Leads Connected To Relay's Coil.

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

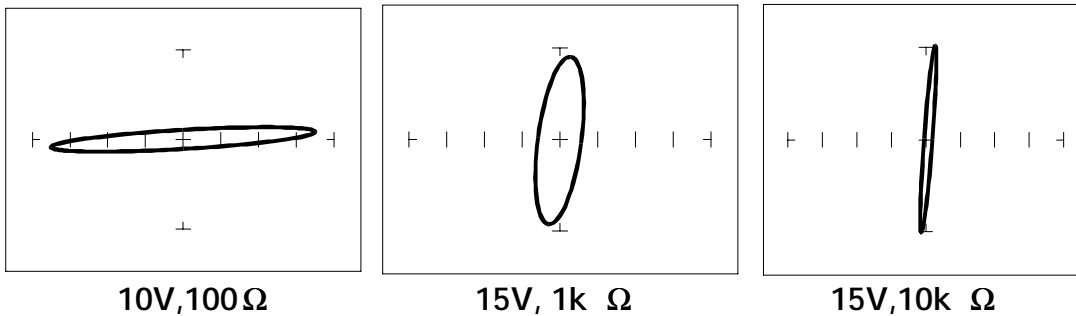


Figure 4-34. Signatures Of A Magnetic Reed Relay Coil.
 $F_s = 2000 \text{ Hz}$.

When applying Tracker 2500'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 Dc Source To Test A Reed Relay

Note that the maximum output voltage of the DC source is 5 Volts, so the relay coil must be of a 5 Volt type.

Do the following:

1. Select the 10V, 100 Ω range.
2. Connect the Tracker 2500 DC Source output +DC to the positive (+) lead of the relay coil.
3. Connect the Tracker 2500 COMMON to the relay's negative (-) lead).
4. Connect the black test lead from Tracker 2500's COMMON terminal to one side of the relay switch contact.
5. Connect the red test lead from Tracker 2500's TEST terminal to the other side of the relay switch contact.
6. Rotate the DC level knob all the way counter-clockwise. Now rotate the knob slowly clockwise and observe the relay contacts' signature. When a short circuit signature (vertical line) is displayed, turn the DC level knob back and forth and watch the relay's signature change between an open and a short.

Review

- The Tracker 2500 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.

Notes:

SECTION 5

TESTING DISCRETE SEMICONDUCTORS

5-1. 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.

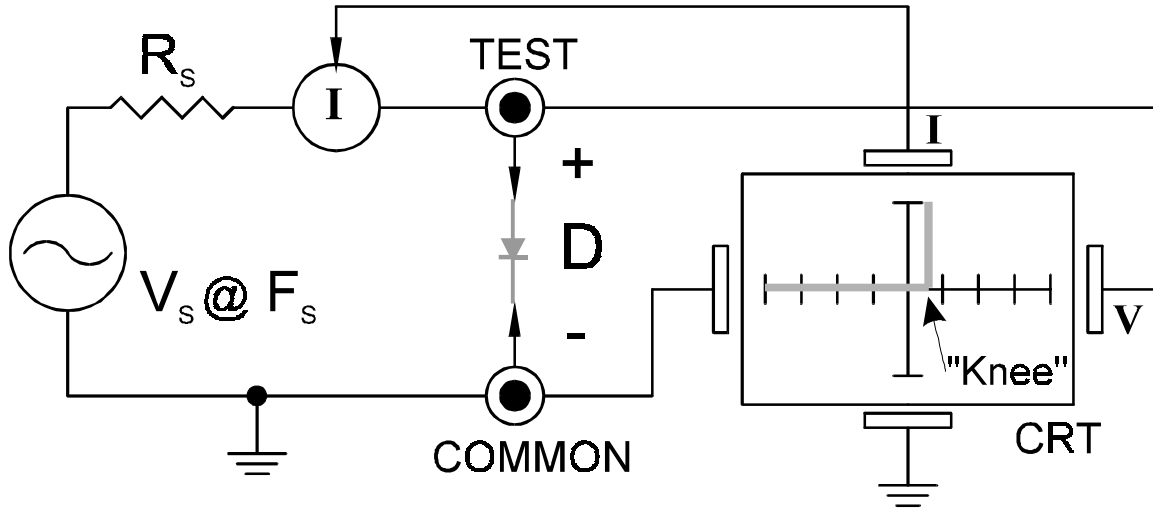


Figure 5-2. Tracker Core Circuit Block Diagram With A Diode.

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

1. Turn power on to your Tracker 2500.
2. Select the 10V, 100 Ω Range. Press the 50/60 Hz button.
3. Place or clip the red test lead from the Tracker 2500's A test terminal to anode lead of the diode.
4. Place or clip the black test lead from the Tracker 2500's Common terminal to cathode lead of the diode.

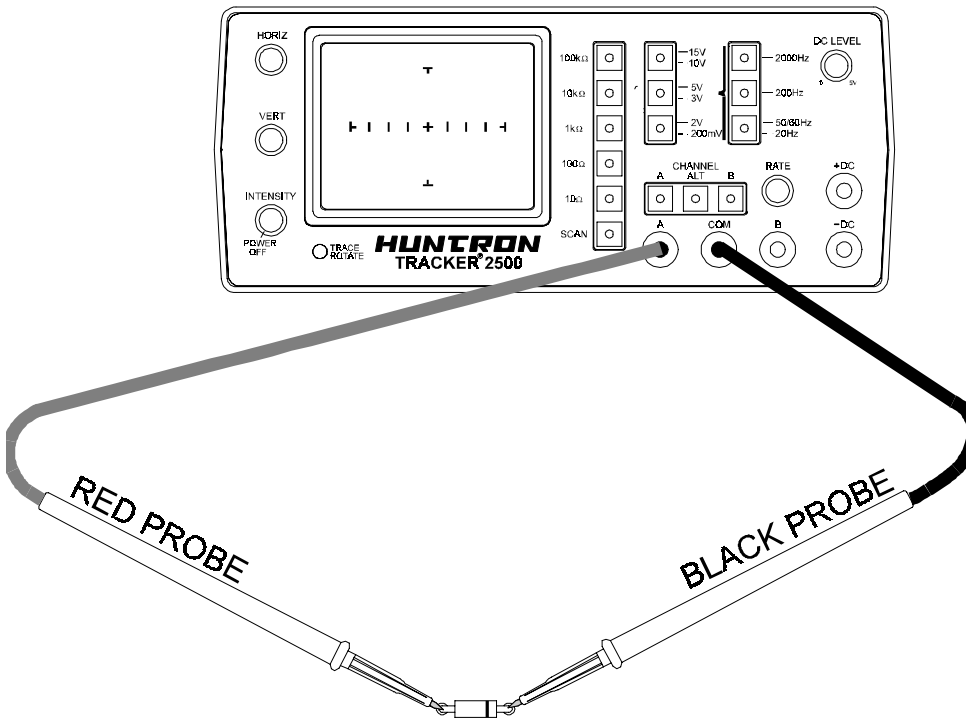
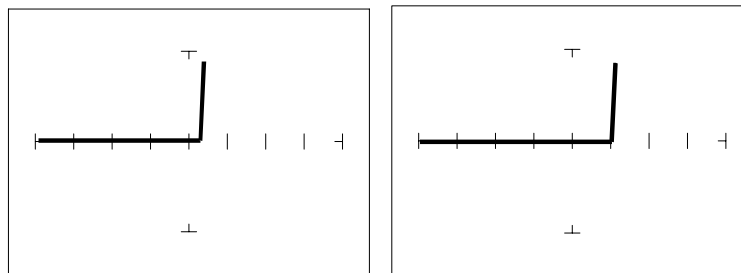


Figure 5-3. Tracker 2500 With Probes To A Diode.



$V_s = 10 \text{ Volts}$

$V_s = 3 \text{ Volts}$

Figure 5-4. Signature Of A 1N914 Type Silicon Diode.
 $R_s = 100 \Omega$, $F_s = 60 \text{ Hz}$

The diode signatures shown above are similar. The test signal voltage for the signature on the left is 10 V_p . Each horizontal division on the display equals approximately 2.5 V. In this range the diode's signature shows that its threshold or forward voltage is approximately 0.6 Volts. By selecting the 3V test signal voltage, the 0.6 volt threshold is clearly visible for easier analysis.

Effects Of Frequency (F_s) On The Diode Signature

Signatures of the same diode at different frequencies are shown below.

At $F_s = 2000\text{Hz}$, the diode's signature has a slight circular loop added to it. This loop in the signature is due to a physical characteristic of diodes called junction capacitance.

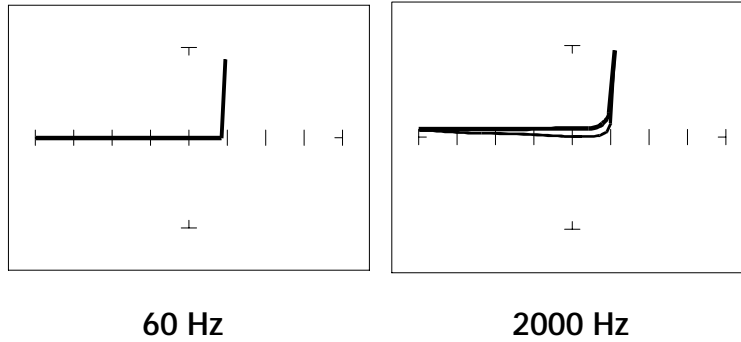


Figure 5-5. Signature Of A 1N914 Diode At Different Range Frequencies.
 $V_s = 3\text{ V}$, $R_s = 100\ \Omega$

Effects Of Internal Resistance (R_s) On The Diode Signature

Changing Tracker 2500's internal resistance R_s moves the vertical knee portion of the diode's analog signature. As R_s increases, the knee of the signature moves inward toward the origin. R_s controls the current that's flowing through the diode so the forward diode voltage changes in response to the current change.

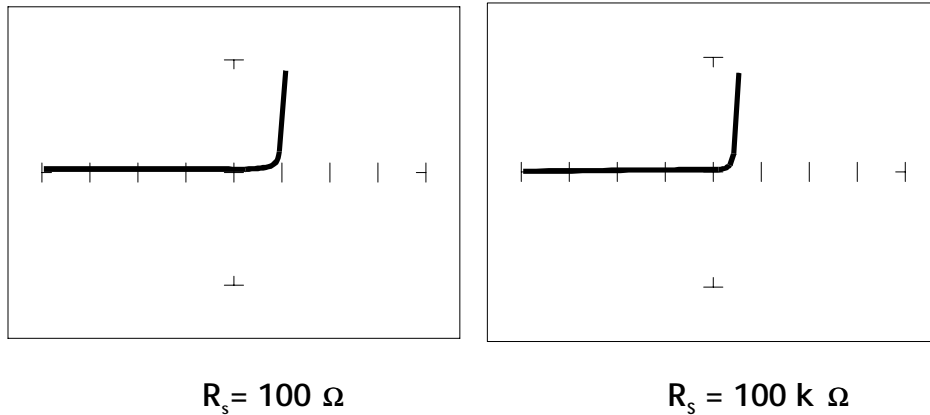


Figure 5-6. Signature Of A 1N914 Diode At Different Range Resistances.
 $V_s = 3 \text{ V}$, $F_s = 60 \text{ Hz}$

Understanding Diode Signatures

Figure 5-7 reviews the Tracker 2500's three range parameters and how they affect the diode signature.

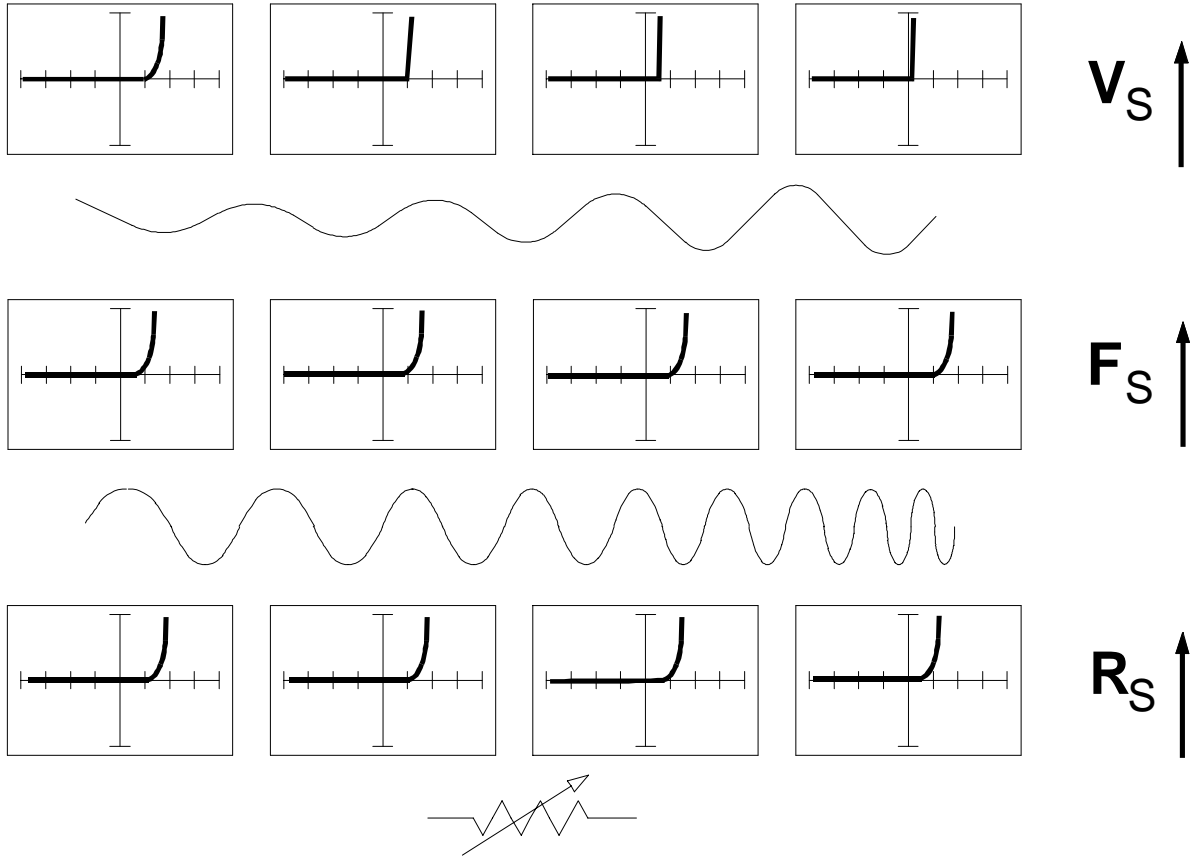


Figure 5-7. Range Parameters Changes and Effects On Diode Signatures.

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.

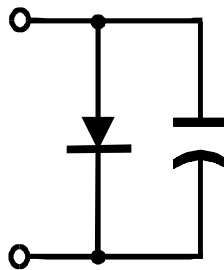
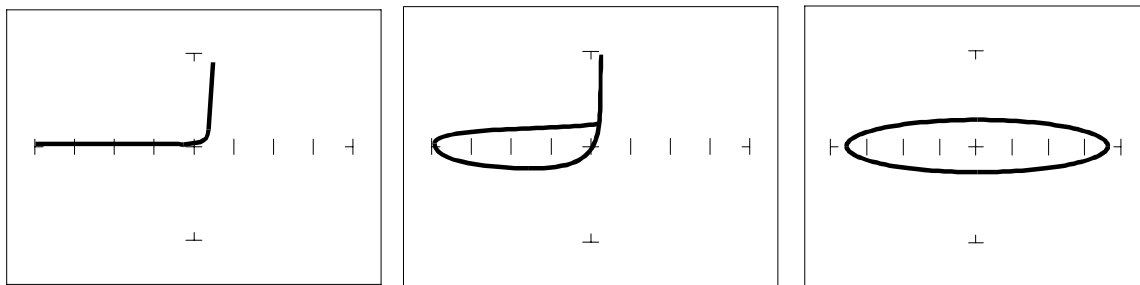


Figure 5-8. Composite Model Of A Diode And Capacitor In Parallel.



$V_s=10V, F_s=20Hz$

$V_s=10V, F_s=200Hz$

$V_s=200mV, F_s=200Hz$

Figure 5-9. Composite Signature - 1N914 Diode And 1 μF Capacitor In Parallel.
 $R_s = 100 \Omega$

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 voltage threshold. When multiple components are connected together, it's important to realize that the Tracker 2500 has the ability to selectively display the signature of a single component.

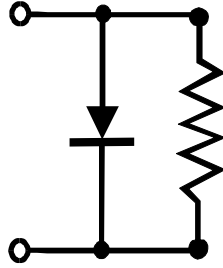


Figure 5-10. Composite Model Of A Diode And Resistor In Parallel.

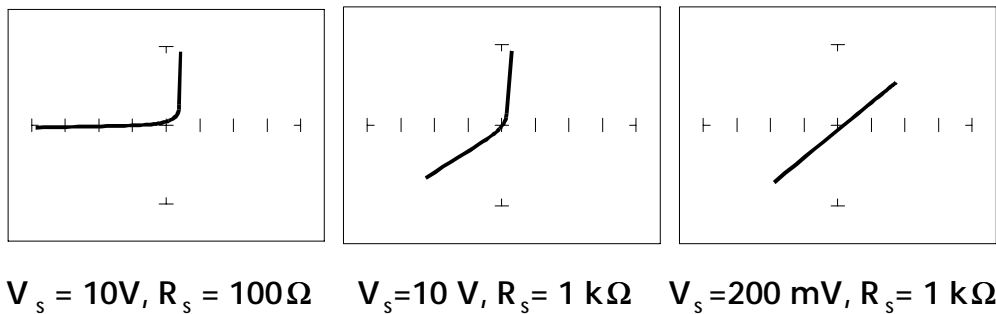


Figure 5-11. Composite Signature - 1N914 Diode And 1.5 k Ω Resistor In Parallel.
 $F_s = 60\text{ Hz}$

The signature on the left shows only the diode signature because the test signal resistance is set below any visible contribution due the 1.5 k Ω resistor. The composite signature in the center consists of the distinctive slope of the resistor and the "knee" pattern of the diode. The signature on the right shows only the resistor signature because the test signal voltage is below the diode's threshold voltage. Again, when multiple components are connected together, it's important to realize that the Tracker 2500 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

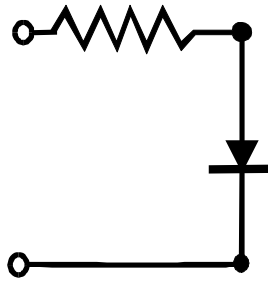


Figure 5-12. Defective Diode Model With A Small Series Resistor.

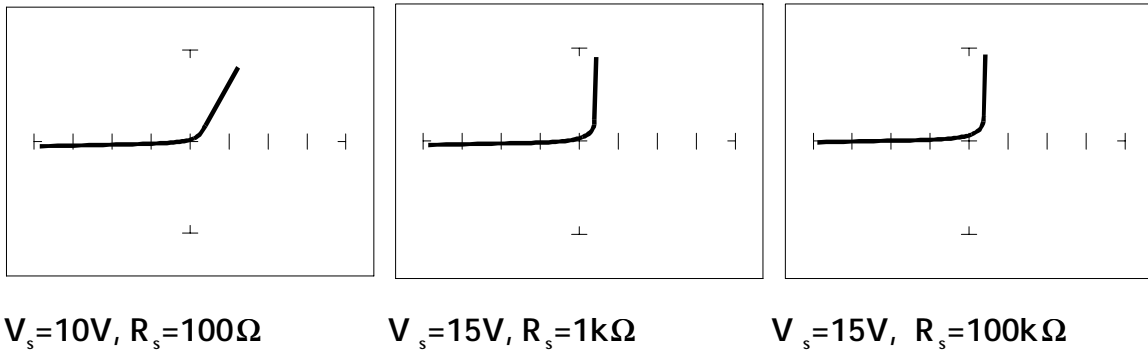


Figure 5-13. Defective Diode Signature With A 50 Ω Series Resistor.

The 10V, 100 Ω 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 this range because the voltage drop across it is small. In the other two ranges, the diode's series resistance is masked due to the internal resistances being too large to show such a small voltage drop.

Internal Leakage Flow In A Diode

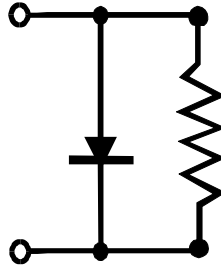


Figure 5-14. Defective Diode Model With An Internal Leakage Resistance.

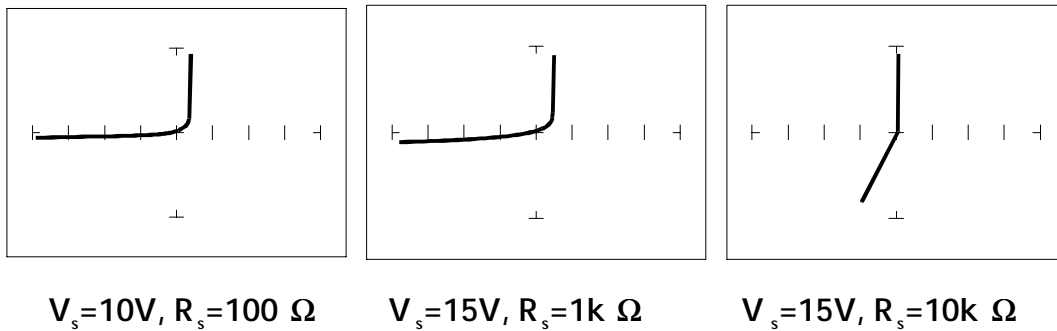


Figure 5-15. Signature Of A Diode With Internal Leakage Flow.
1N914 Diode With A 10 kΩ Resistor In Parallel

Notice that in the 10V, 100 Ω range there does not seem to be any problem, but that in the other two 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, it acts as an open circuit until the applied voltage reaches its 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. This characteristic of a zener diode allows it to be used as a voltage regulator and reference. The Zener diode conducts in both directions, resulting in its analog signature having 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.

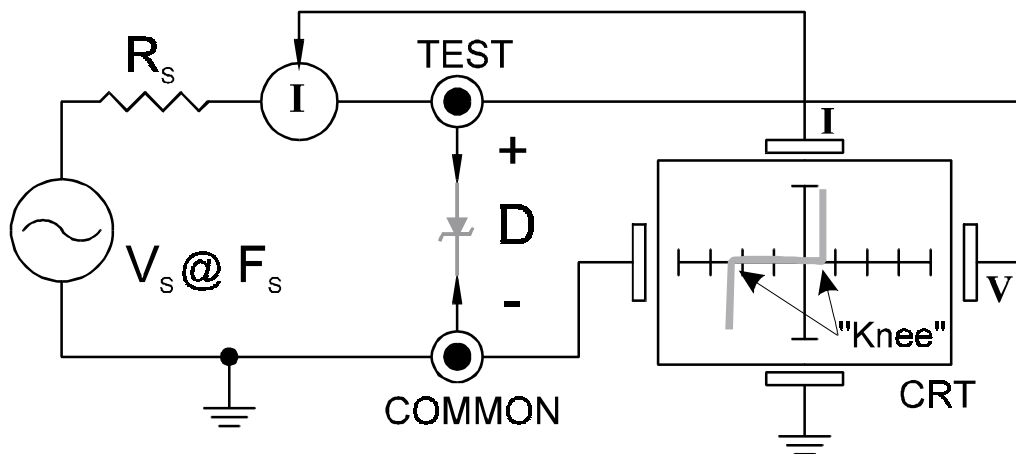


Figure 5-16. Tracker Core Circuit Block Diagram With A Zener Diode.

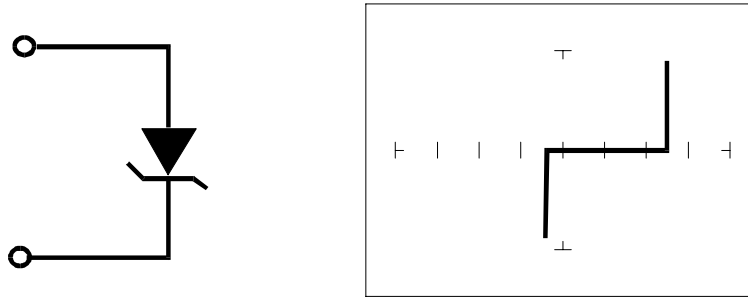


Figure 5-17. Single Zener Diode 1N5239B And Signature

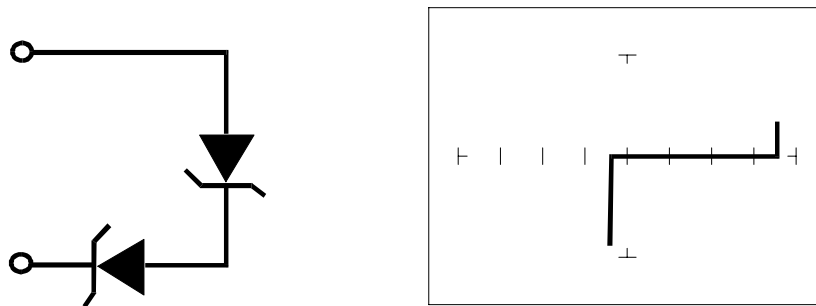


Figure 5-18. Two Zener Diodes In Series And Signarure.

Since each horizontal division on the CRT graticule (in 15V, 1k Ω range) is approximately 3.75 Volts, you can estimate that this is about a 9 volt zener diode. By connecting two Zener diodes in series, the rated voltage thesholds are doubled.

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 2500 makes it easier to separate these characteristics from composite signatures by adjusting F_s , R_s and V_s .
- Zener diodes are special diodes that conduct when reverse biased at a specific voltage.

Applying What We Have Learned

- 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 2500 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 2500 to approximate the voltage.
- Look for the zener effect when checking voltage regulators such as the 7805 type. This can help determine an unknown or faulty device.
- The Tracker 2500 can be used to test and determine the four pin connections on a bridge rectifier, (AC1, AC2, + and -).

5-2. 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. An NPN transistor has a layer of p-type silicon material sandwiched between two layers of n-type material. Figure 5-19 shows the relationship between type of material and circuit symbol for a PNP and a PNP transistor.

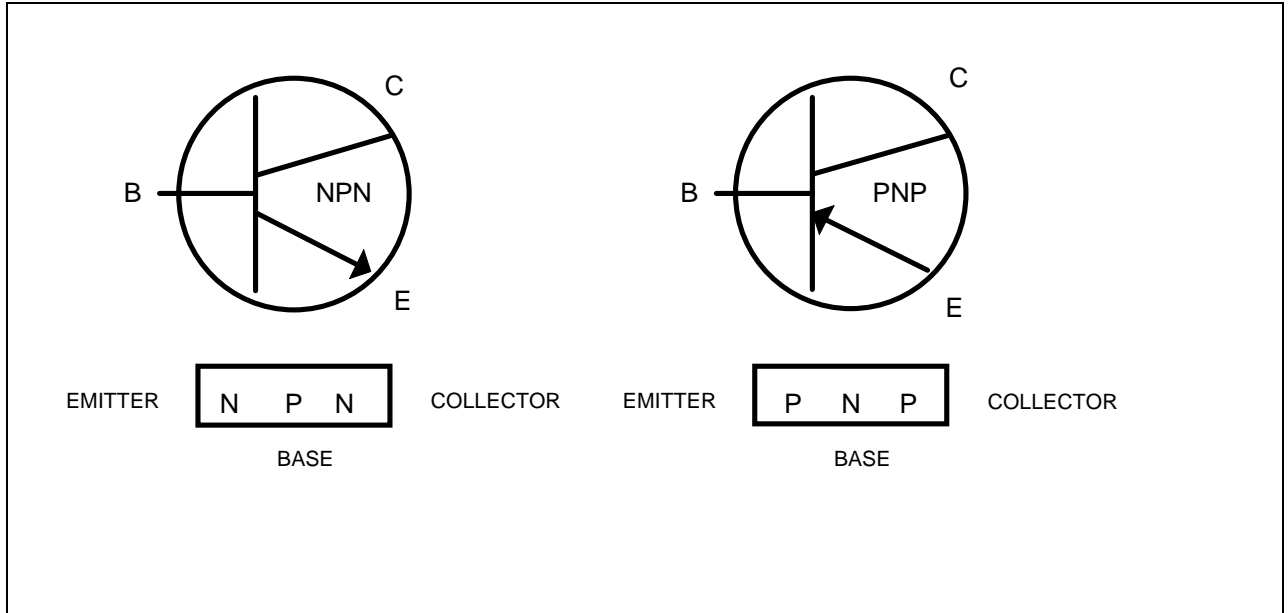


Figure 5-19. Diagram Of An NPN And PNP Bipolar Transistor.

Important Note

Use of this instrument may alter the current gain (h_{FE} or β) of a bipolar transistor whenever the emitter is tested. Either the base-emitter or collector-emitter test circuits satisfy this criterion. While heating of the device due to the current produced by the instrument may cause a temporary change in h_{FE} (most noticeable in the low range), a permanent shift in h_{FE} may occur whenever the base-emitter junction is forced into reverse breakdown (~6-20 Volts). If the voltage is above 6 Volts, then the magnitude of the shift depends on the duration of the test and the resistance selected. Reducing the voltage to 5 Volts or less will avoid this problem.

Most bipolar transistor circuit designers take into account a wide variation in h_{FE} as a normal occurrence and design the related circuitry to function properly over the expected range of h_{FE} . The effects mentioned above are for the most part much smaller than the normal device variation so that the use of this instrument will have no effect on the functionality of good devices and can fulfill its intended purpose of a means to locate faulty components. However, some circuits may depend on the h_{FE} of the particular part in use e.g. instrumentation that is calibrated to certain h_{FE} value, or precision differential amplifiers with matched transistors. In such instances, this instrument should not be used as its use may cause the h_{FE} to shift outside the limited range where calibration can correct for any change.

Suggestions to minimize effects on bipolar transistors:

1. Use 5 Volts or less for testing the base-emitter or collector-emitter.
2. If using 6 Volts or greater, then keep the duration of the test as short as possible.
3. Identify the base, emitter and collector pins of the device and then test the collector-base junction to determine whether it is an NPN or PNP. Since the emitter is not tested there will be no effect on h_{FE} regardless of the selected voltage. Then use the three terminal test described in the "Using The DC Source To Test Transistor Operation" later in this section.

Bipolar Transistor Signatures

In order to better understand the signatures that transistors create on the Tracker 2500, we can model these devices in terms of equivalent diode circuits. These are shown in figure 5-20. These figures show that the collector-base junction analog signature looks similar to a diode signature and the emitter-base junction signature looks similar to a zener diode signature.

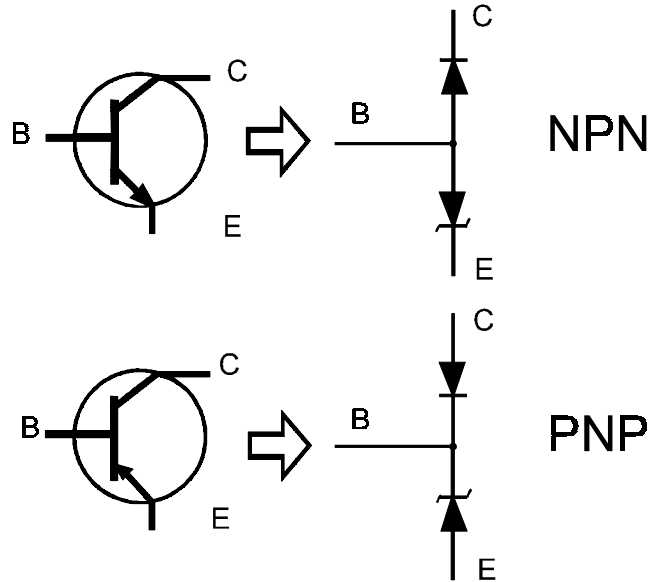


Figure 5-20. NPN And PNP Bipolar Transistors' Equivalent Circuits.

Bipolar Transistor Base-Collector Signatures

1. Select the **15V, 10k Ω** range.
2. Place or clip the red test lead from the Tracker 2500's A test terminal to the Collector lead of the transistor.
3. Place or clip the black test lead from the Tracker 2500's Common terminal to Base lead of the transistor.

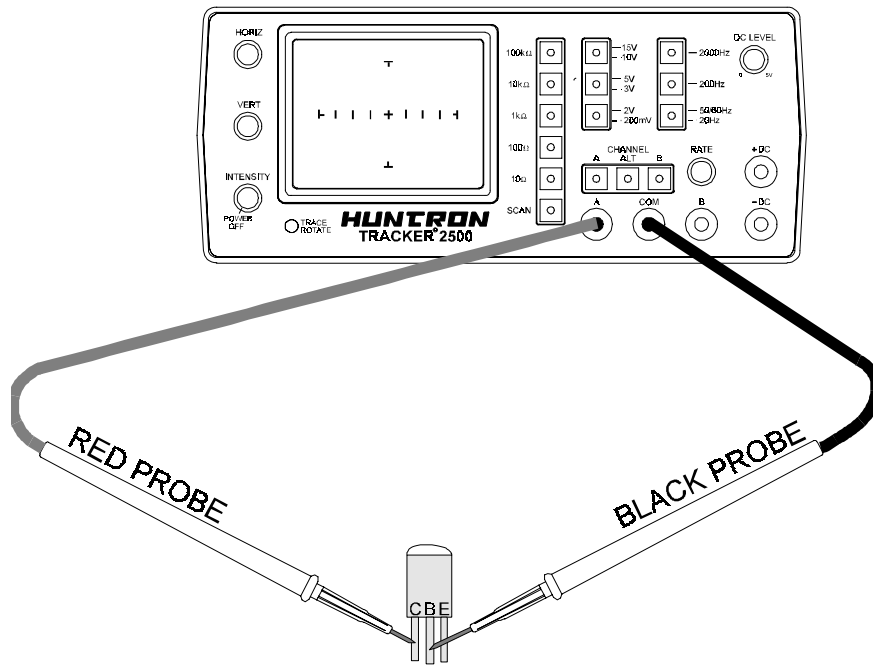


Figure 5-21. Tracker 2500 Connected To The Collector And Base Leads Of A Transistor

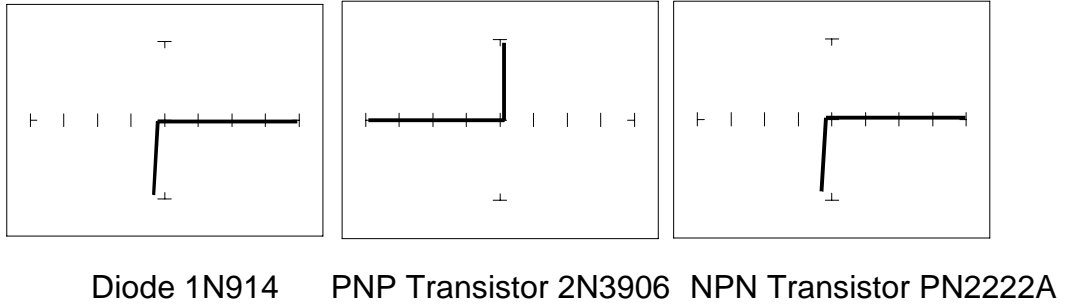


Figure 5-22. Signature Of A Diode And Collector-Base Of A Transistor.
15V, 10kΩ Range.

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.

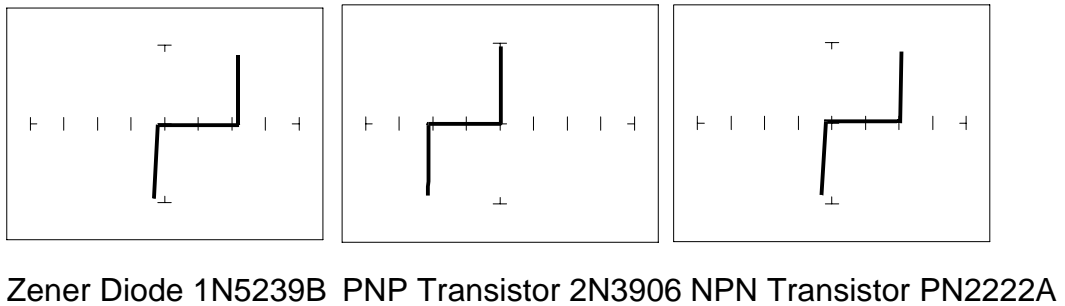
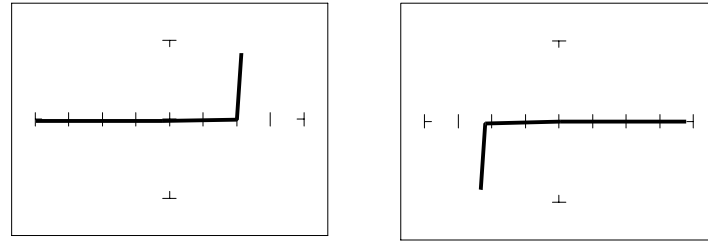


Figure 5-23. Signature Of A Diode And Emitter-Base Of A Transistor.
15V, 10kΩ Range

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.



PNP Transistor - 2N3906 NPN Transistor - PN2222A

Figure 5-24 Signature Of The Collector-Emitter Of A PNP And NPN Transistor.
15V, 10k Ω 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 2500 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.

Do the following:

1. Select the 15V, 10k Ω Range.
2. Set the frequency to 60 Hz.

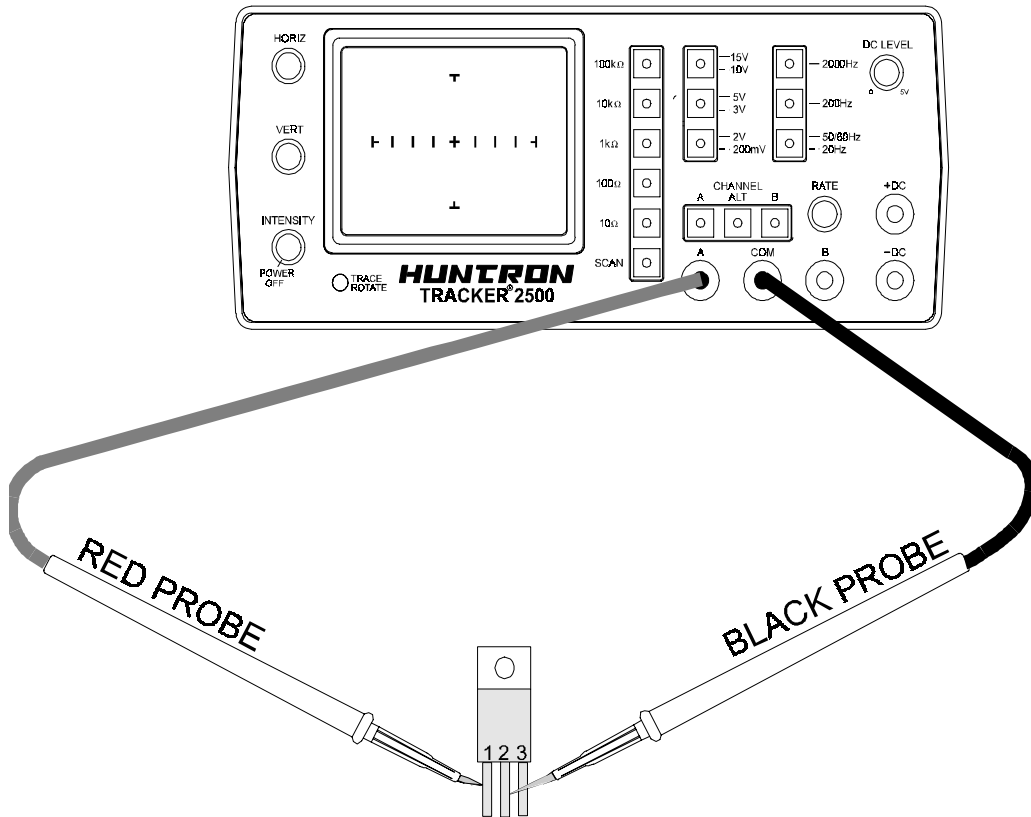


Figure 5-25. Tracker 2500 With Probes To An Unmarked Transistor.

Do the following:

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

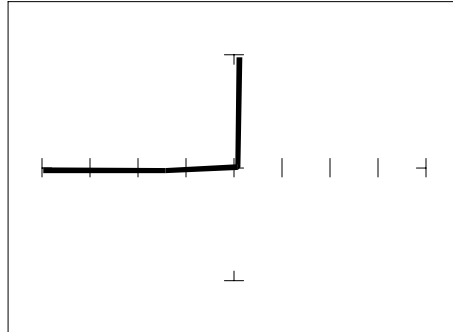


Figure 5-26. Signature Of Pins 1 And 2 Of An Unknown Transistor.

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.

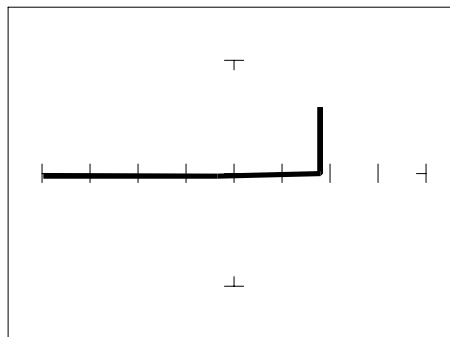


Figure 5-27. Signature Of Pins 2 And 3 Of An Unknown Transistor.

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.

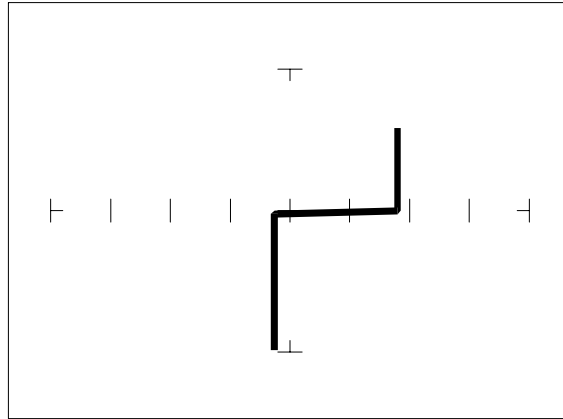


Figure 5-28. Signature Of Pins 1 And 3 Of An Unknown Transistor.

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.

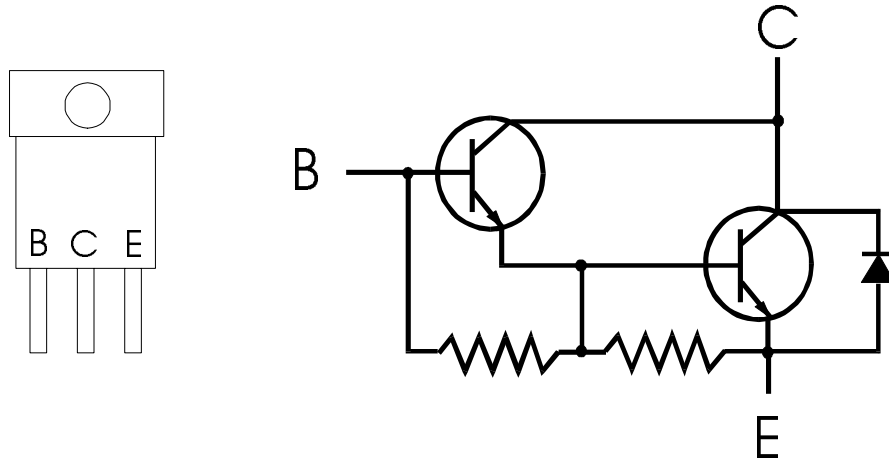


Figure 5-29. Diagram Of A Darlington Transistor.

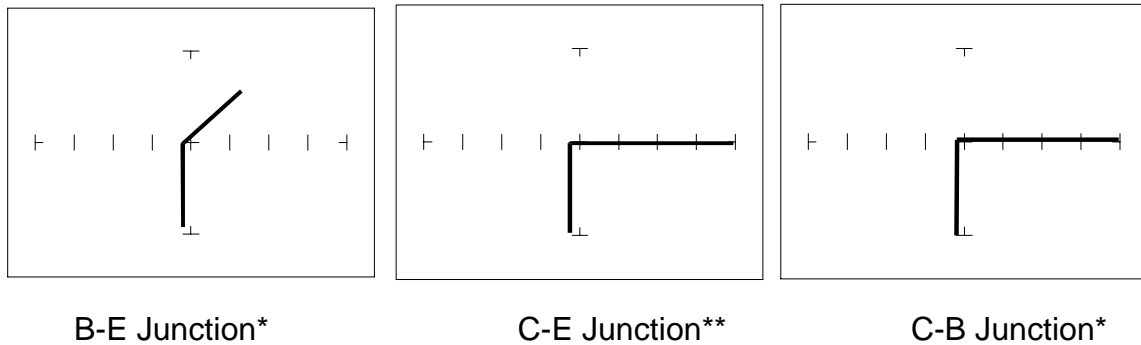


Figure 5-30. Signature Of A Darlington Transistor, TIP112 NPN Type.
 15V, 10k Ω Range
 Base To Common*, Emitter To Common**

Note that the B-E junction has a sloped leg bend in its signature caused by internal resistors R1 and R2.

Using The Dc Source To Test Transistor Operation

Figure 5-31a shows the test circuit for an NPN transistor using the DC Source 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.

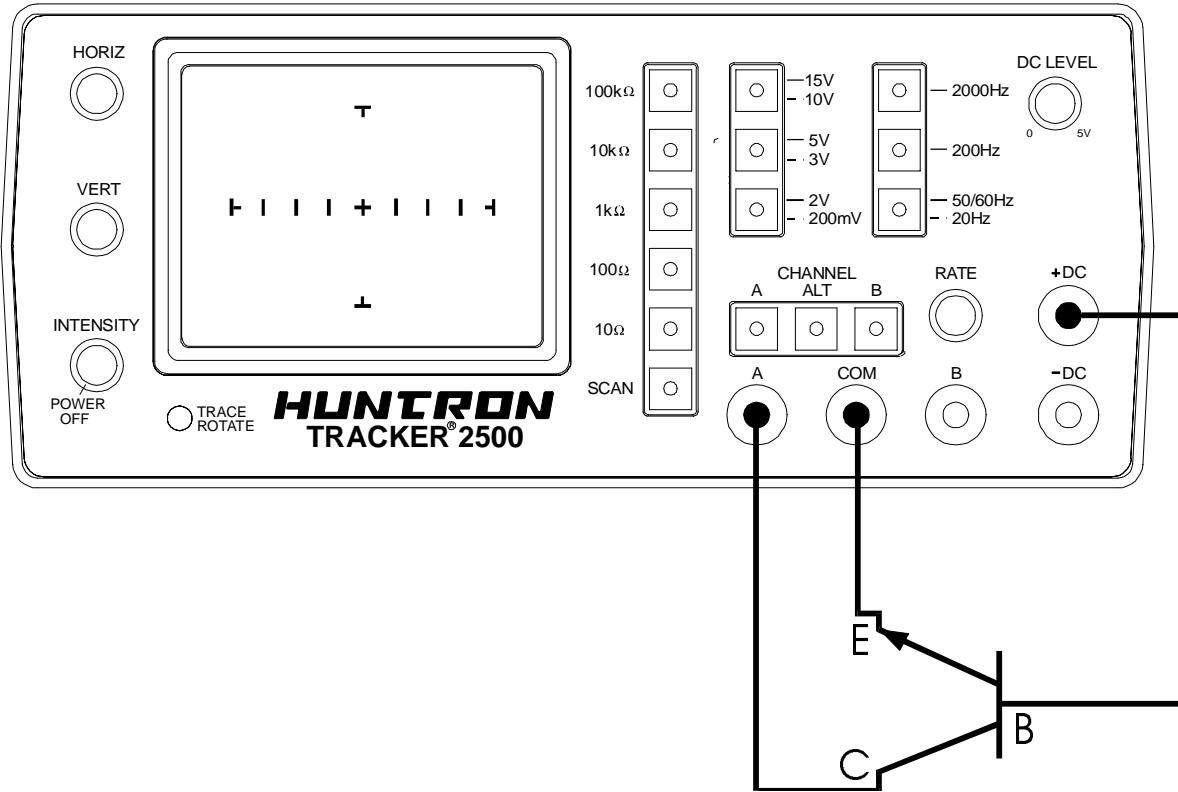


Figure 5-31a. DC Source Test Circuit For An NPN Transistor

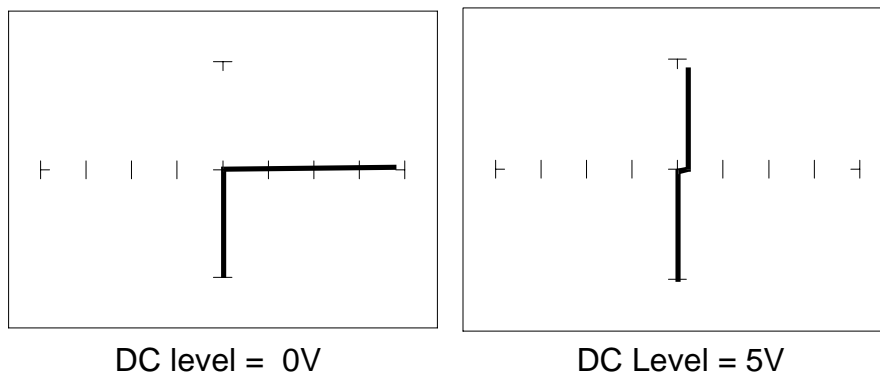


Figure 5-31b. Signatures For Test Circuit With An NPN Transistor

Figure 5-32a 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.

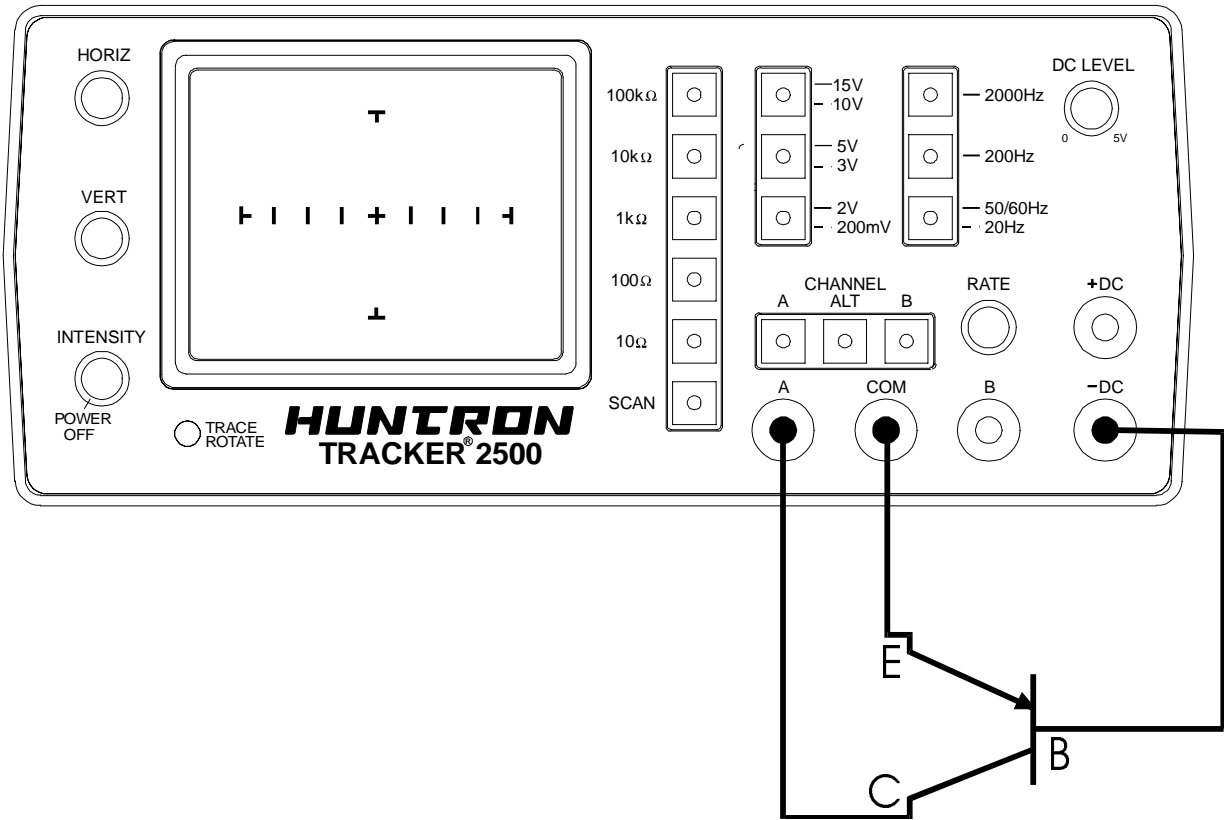


Figure 5-32a. DC Source Test Circuit For A PNP Transistor.

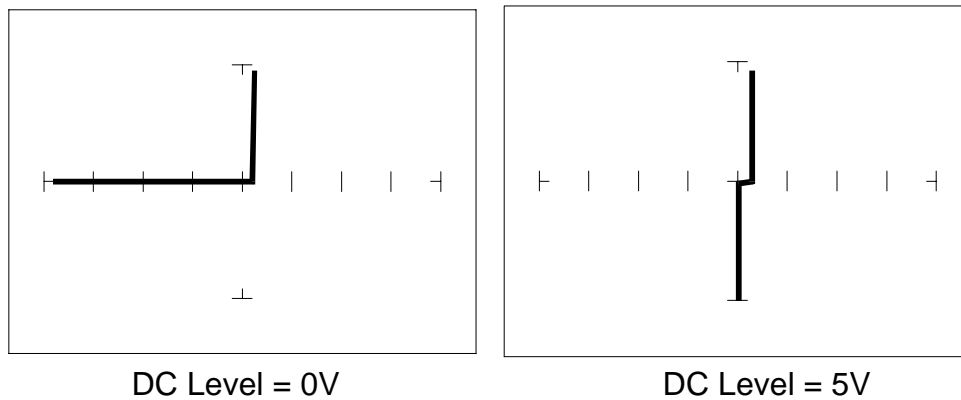


Fig 5-32b. Test Circuit Signatures for PNP Transistor.

Applying What We Have Learned

- 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 2500 can be used to determine the type of transistor; bipolar, Darlington, FET, etc.
- The Tracker 2500 can be used to identify the polarity of a transistor (PNP or NPN).
- The Tracker 2500 can be used to determine the base, collector and emitter on an unknown transistor.
- The Tracker 2500 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.

5-3. Solid State Switching Components

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.

Optocoupler Dynamic Testing

The Tracker 2500's DC Source can perform a dynamic test of optocouplers. Apply the DC Source's output to the control input of a switching device and connect Tracker 2500's test leads across the component's switch terminals. Observe the optocoupler's signature for on and off states.

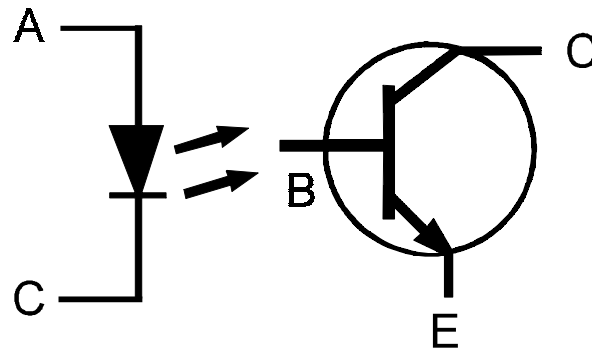


Figure 5-33. Diagram Of An Optocoupler.

Optocoupler Signatures

1. Select the 10V, 1k Ω range.
2. Connect the black test lead or easy grabber from the Tracker 2500'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's A to the transistor collector lead.
4. Connect the DC Source +DC output using the blue easy grabber test clip to the diode anode lead.

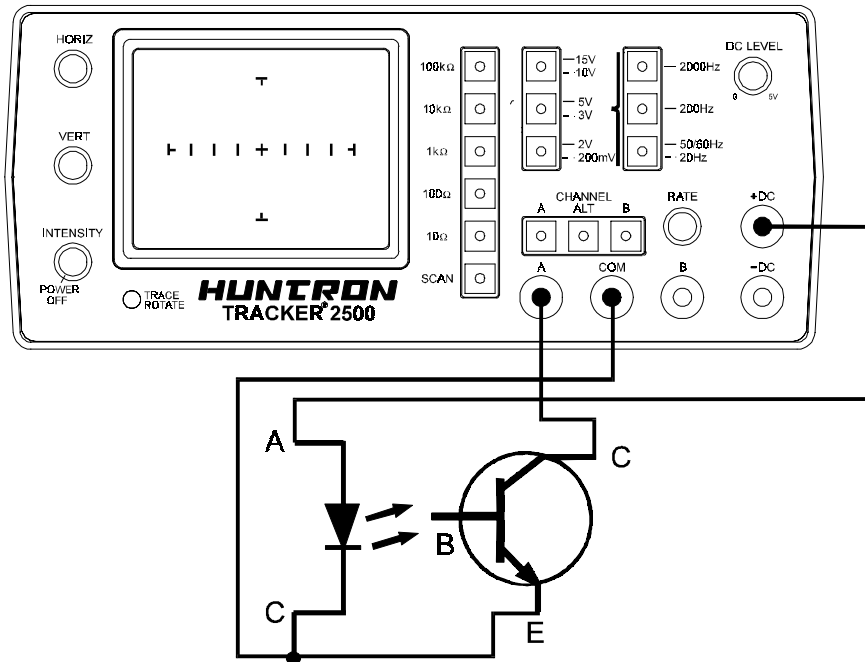
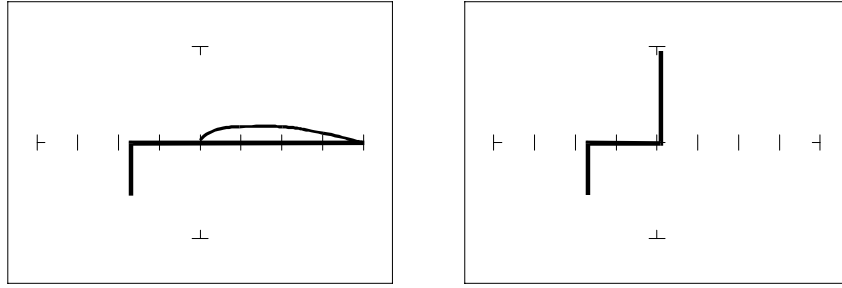


Figure 34. DC Source Test Circuit For An Optocoupler.

5. Rotate the DC level knob all the way counter-clockwise to start at 0 V DC.
6. Rotate the knob clockwise to approximately halfway.



DC Level = 0V

DC level = 5V

Figure 5-35. Signatures Of An Optocoupler - 4N33 Type
10V, 1k Ω Range

SCRs And Triacs

SCRs and triacs 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 (SCR's)

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.

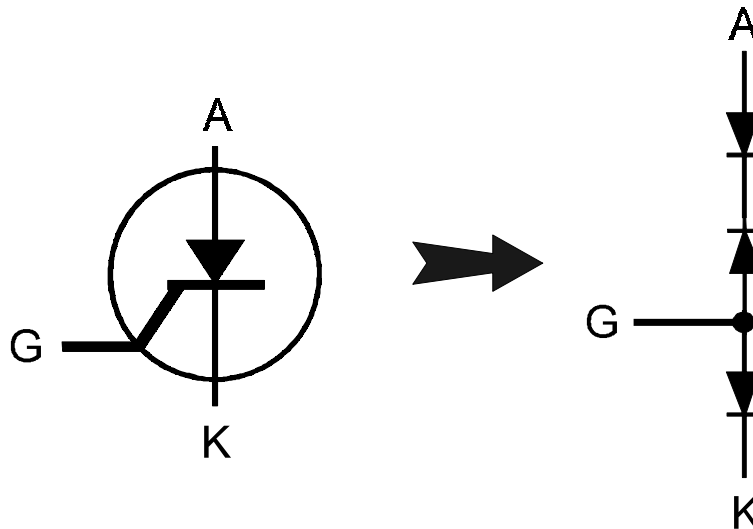


Figure 5-36. Diagram Of A Silicon Controlled Rectifier.

1. Select the 15V, 10k Ω range.
2. Place or clip the red test probe from the Tracker 2500's A test terminal to gate lead (G) of the component.

- Place or clip the black test probe from the Tracker 2500's Common terminal to anode lead (A) of the component.

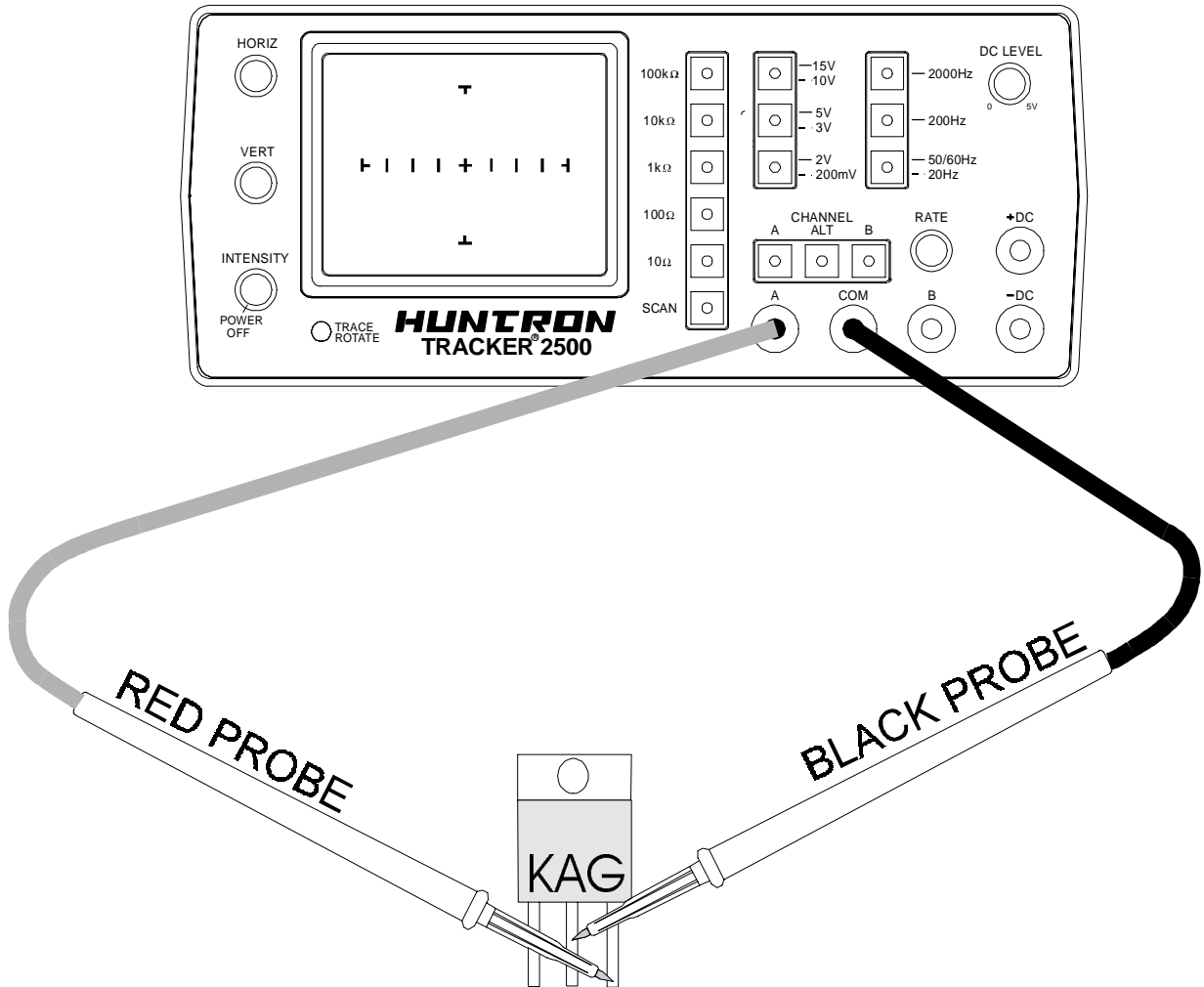


Figure 5-37. Tracker 2500 With Test Leads To A SCR.

- Observe the gate-anode signature of the SCR.
- Move the black test probe from the SCR's anode lead to cathode lead (K) of the component.
- Observe the gate-cathode signature of the SCR.
- Place the red test probe to the SCR's anode lead and the black test probe to the SCR's cathode lead.
- Observe the SCR's anode-gate signature.

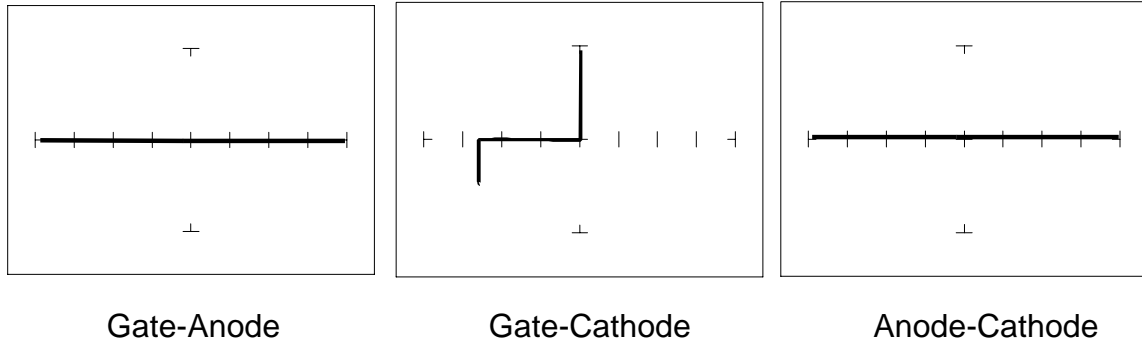


Figure 5-38. Signatures Of A SCR - C106B Type.
15V, 10k Ω Range.

Active Testing Of An SCR

Connect the SCR to the Tracker 2500 as illustrated below:

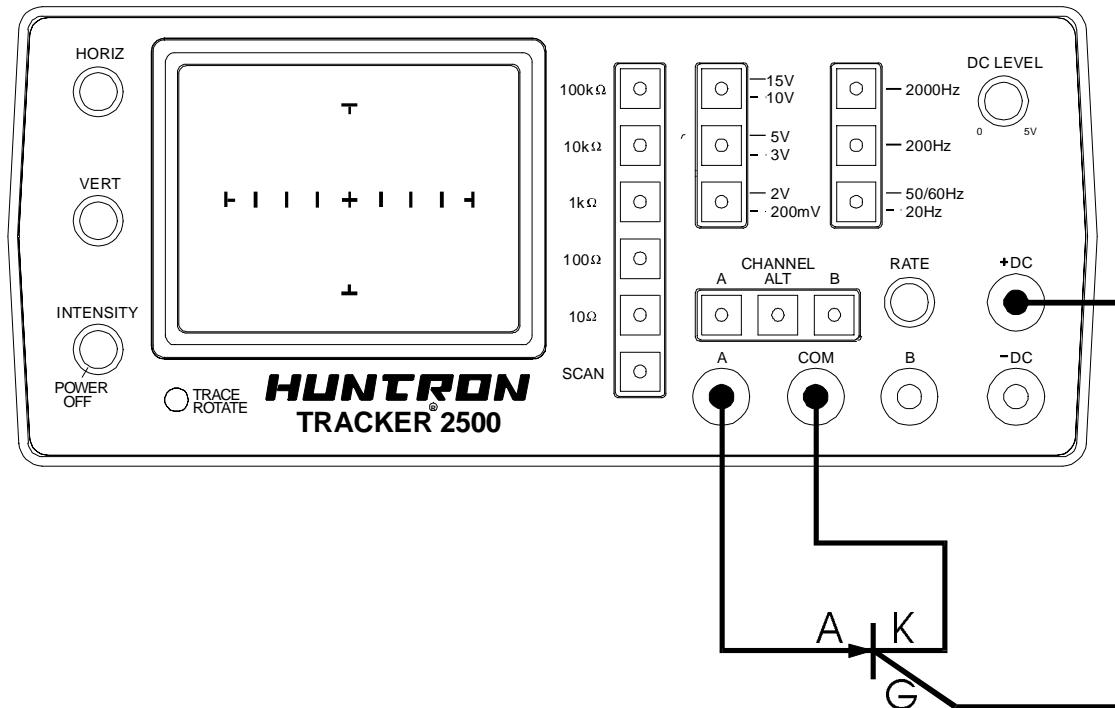


Figure 5-39. DC Source Test Circuit For A SCR.

Do the following to dynamically test a SCR using the Tracker 2500:

1. Select the 10V, 1k Ω range.
2. Set the frequency to 60 Hz.
3. Connect the blue easy grabber from Tracker 2500's DC Source +DC output terminal to the component's gate lead.
4. Connect the red test probe from Tracker 2500's A test terminal to the SCR's anode lead.
5. Connect the black test probe from Tracker 2500's Common test terminal to the SCR's cathode lead.
6. Turn the DC Level knob clockwise to increase the voltage level from 0 VDC.

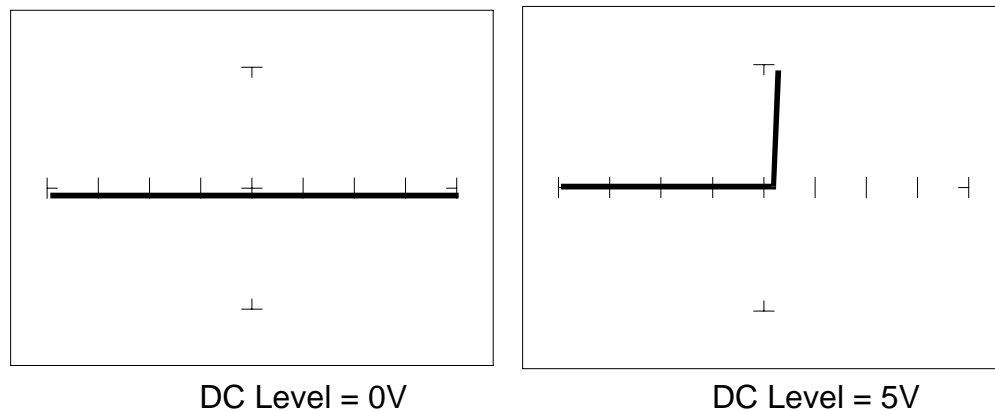


Figure 5-40. Signature Of A SCR (C106B Type) With The DC Source Test. 10V, 1k Ω range.

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

Applying What We Have Learned

- The Tracker 2500 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 2500 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 2500 can easily show these failures.

Triacs are similar to SCRs and defective ones can be found in a similar.

SECTION 6

TESTING INTEGRATED CIRCUITS

6-1. 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. In this section, it is important to understand how the Tracker 2500 and ASA respond to these circuits.

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. The IC's maximum electrical specifications have been exceeded. This condition may result in the IC developing internal shorts and opens.
- **ESD** Electrostatic Discharge. Repeated exposure may cause internal resistance to develop in the IC junctions. This internal resistance may vary from 5 k Ω to 25 k Ω with a typical value of 20 k Ω . ESD exposure can cause internal flaws such as resistance, opens and shorts.
- **Dendrites** A process flaw that results in particles growing between conductors on a substrate causing shorts.
- **Ionic Contamination** Contamination introduced at the time of manufacturing that develops into leakage between substrate channels. This causes 5 k Ω to 25 k Ω of resistance.
- **Purple Plague** Destructive interaction between gold and aluminum metal layers. Junction connections become very brittle and may cause internal opens.
- **Corrosion or Electromigration** Another process flaw in which aluminum metalization causes pinholes, corrosion and resistance. This will create opens and resistance.

Important Note:

Occasionally, the signatures of ICs may exhibit discontinuities or fuzziness due to oscillation. Most often this occurs in the zener or avalanche breakdown region of the signature. To obtain a more stable signature, simply reduce the selected test voltage until you are below zener breakdown.

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.

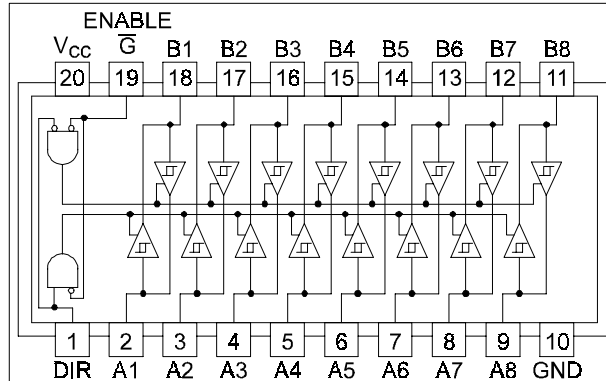


Figure 6-1. Digital IC 74LS245 Block Diagram.

- 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

1. Select the 15V, 10k Ω range.
2. Place or clip the black test lead from the Tracker 2500'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 2500's A test terminal. Probe each pin of the IC and view its signature on Tracker 2500's 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 2500's A test terminal. Probe the enable input pins of the IC and view their signatures on the CRT 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. Select the 10V, 100 Ω range. Use the red test lead from the Tracker 2500's A test terminal. Probe the power supply V_{CC} input pin and view its signature on the CRT display. For this example, the V_{CC} pin of the 74LS245 is pin 20.

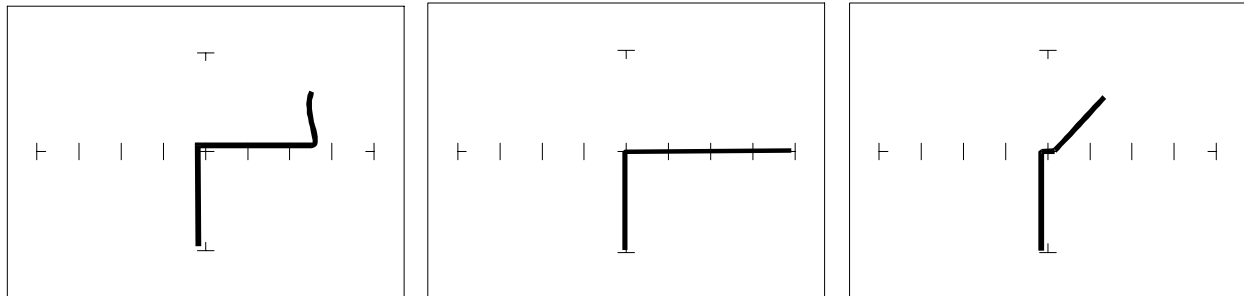
Buffer pins - 15V,10k Ω Enable pins - 15V,10k Ω V_{CC} Power pin - 10V,100 Ω

Figure 6-2. Signatures of A Digital IC, 74LS245.
Common To Pin 10 (Gnd)

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 2500.

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_{CC} and ground.

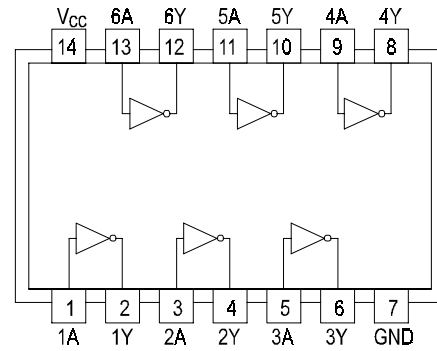
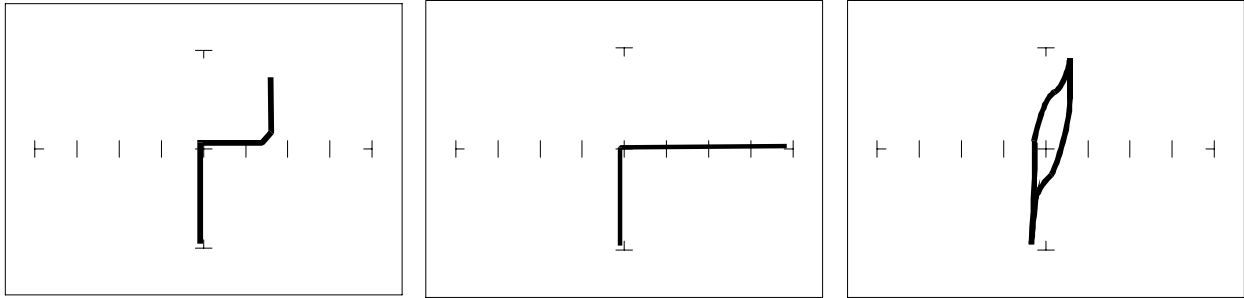
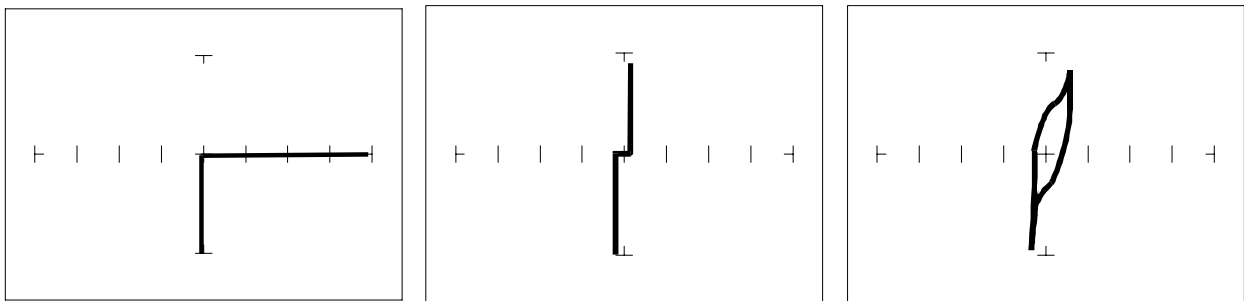


Figure 6-3. Diagram Of 7404 & 74LS04.



Pin 1 input - 15V,10kΩ Pin 2 output - 15V,10kΩ Pin 14 power - 10V, 100Ω

Figure 6-4. Signatures Of A 7404 Hex Inverter. Common To Pin 7(Gnd)



Pin 1 input - 15V,10kΩ Pin 2 output - 15V,10kΩ Pin 14 power - 10V,100Ω

Figure 6-5. Signatures Of A 74LS04 Hex Inverter. Common To Pin 7 (Gnd)

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.

In this example, we will choose a 74HC14 Schmidt 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 V_{CC} input, and power supply ground.

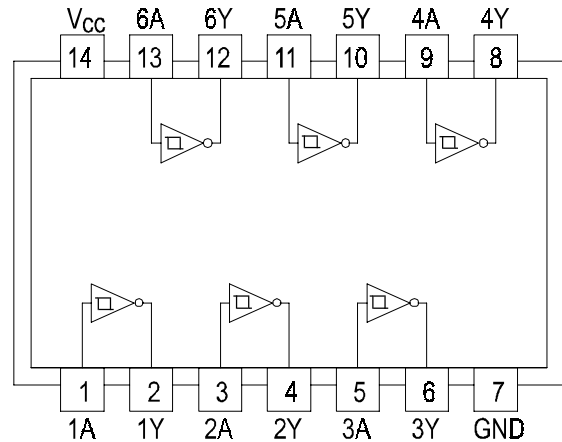
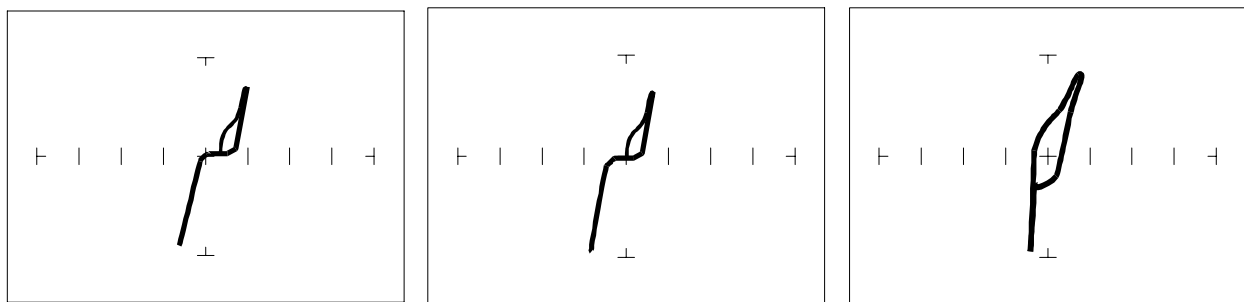


Figure 6-6. Diagram Of 74HC14

1. Select the **10V, 100Ω** Range.
2. Set the test signal frequency to **60 Hz**.
3. Place or clip the black test lead from the Tracker 2500'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 2500'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 2500's A test terminal and probe the power supply V_{CC} input pin. For this example, the V_{CC} pin of the 74HC14 is pin 14.



Pin 1 Input - 10V,100Ω

Pin 2 Output - 10V,100Ω

Pin 14 V_{CC} - 10V,100Ω

Figure 6-7. Signatures Of A 74HC14 CMOS Hex Inverter. Common to Pin 7(GND)

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 2500. Capacitance in CMOS circuitry may be emphasized or de-emphasized by changing the frequency of the test signal.

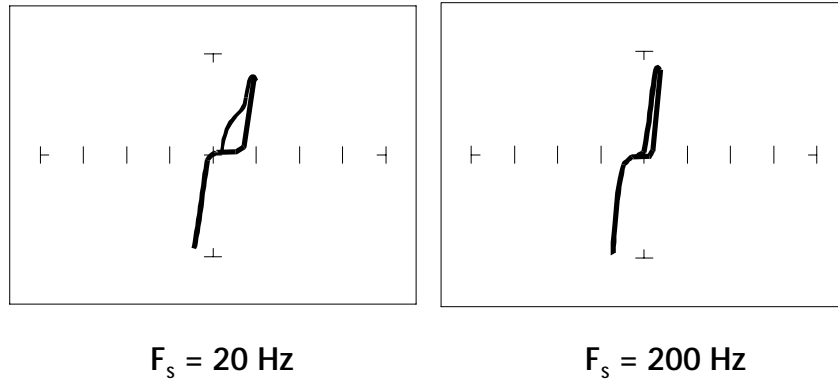
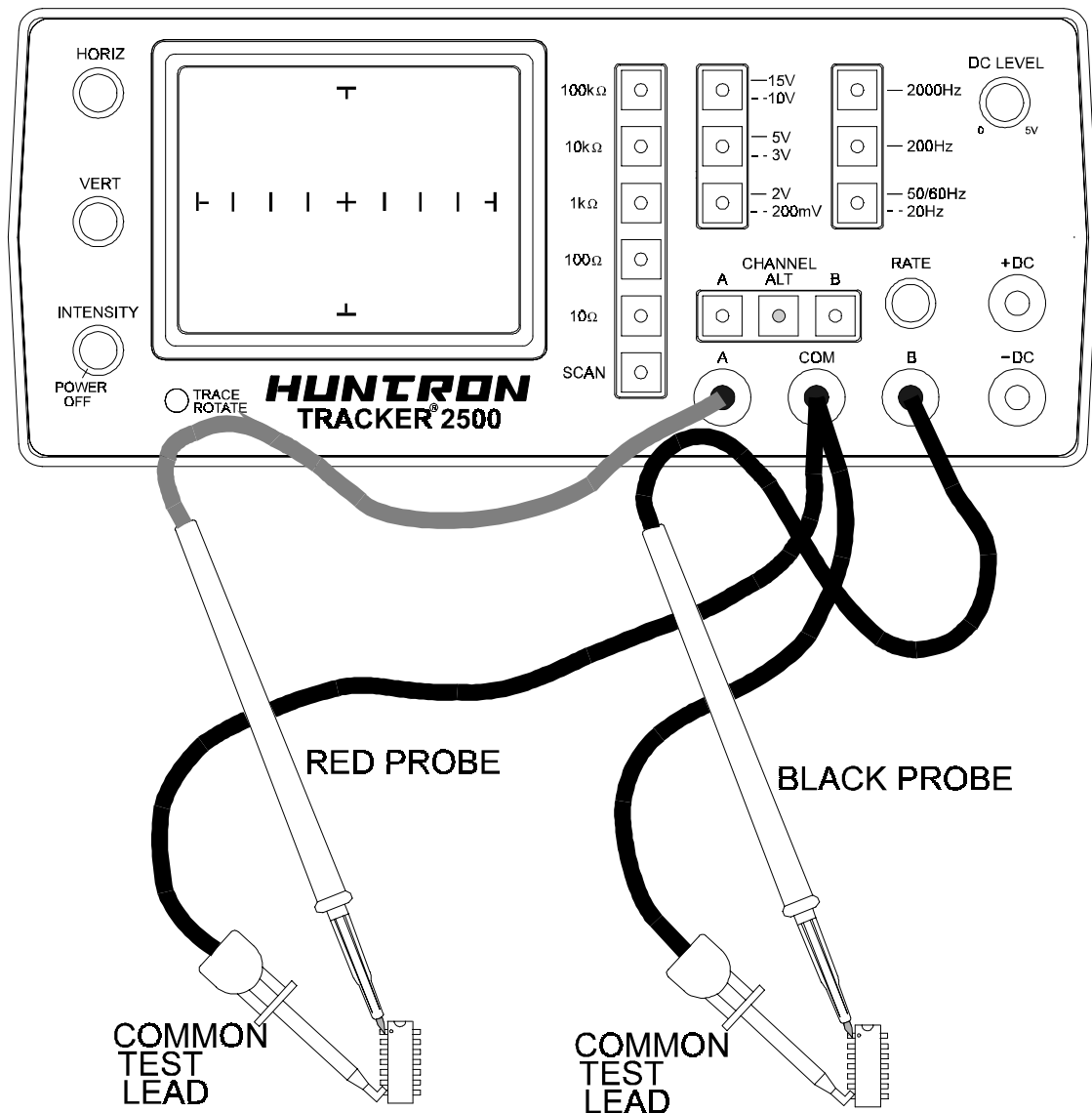


Figure 6-8. Signatures Of A 74HC14 Input Pin At Different Frequencies.
10V, 1K Ω Range

Troubleshooting Digital Logic ICs

Comparison testing is a very powerful and effective test strategy when troubleshooting digital logic using ASA. The Tracker 2500's Alt feature makes this technique 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 2500 With Test Leads Setup For Comparing 2 ICs.

Comparison Testing For Digital ICs

1. Set the test signal frequency to 60 Hz.
2. Place a black clip lead from the Tracker 2500's Common terminal to both reference and suspect IC or boards ground pin.
3. Place the black test lead from the Tracker 2500's B test terminal to the suspect IC's pin. For this example, start with pin 1 of the suspect IC.
4. Place the red test lead from the Tracker 2500'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.
5. Push the Channel **A** button. Observe the signature. This is the signature of the pin of the known good component.
6. Push the Select the **10V, 100Ω** Range.
7. Channel **B** button. Observe the signature. This is the signature of the pin of the suspect component.
8. Press the press the **Alt** button to display the A and B channels on the CRT alternately. If needed, rotate the Rate knob to adjust the display speed.
9. Visually compare the reference signature (channel A) with the suspect signature (channel B).
10. 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.
11. 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 2500 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 2500. The Tracker 2500 features alternate switching and display of the A and B channels to allow comparison of two individual signatures.
- Testing for faulty IC's is one of the more common uses for the Tracker 2500. A technician can compare IC's in or out of circuit.

6-2. 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 2500. 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.

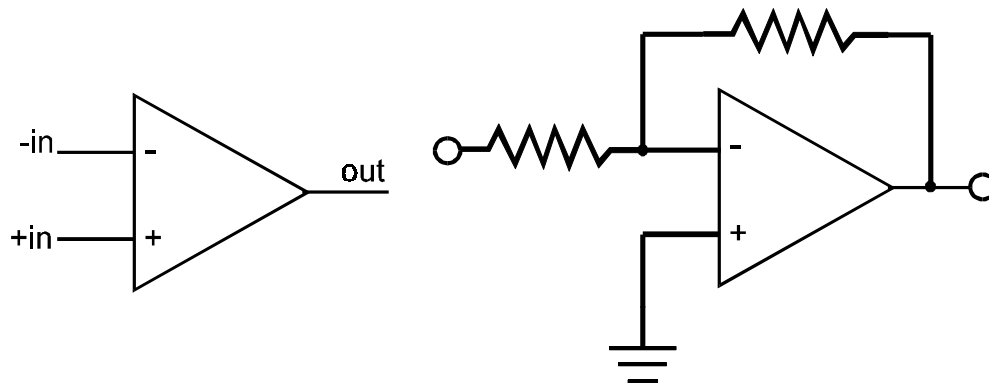


Figure 6-10. Op Amp Symbol And Schematic Diagram Of An Inverter Circuit.

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

Op Amp Signatures

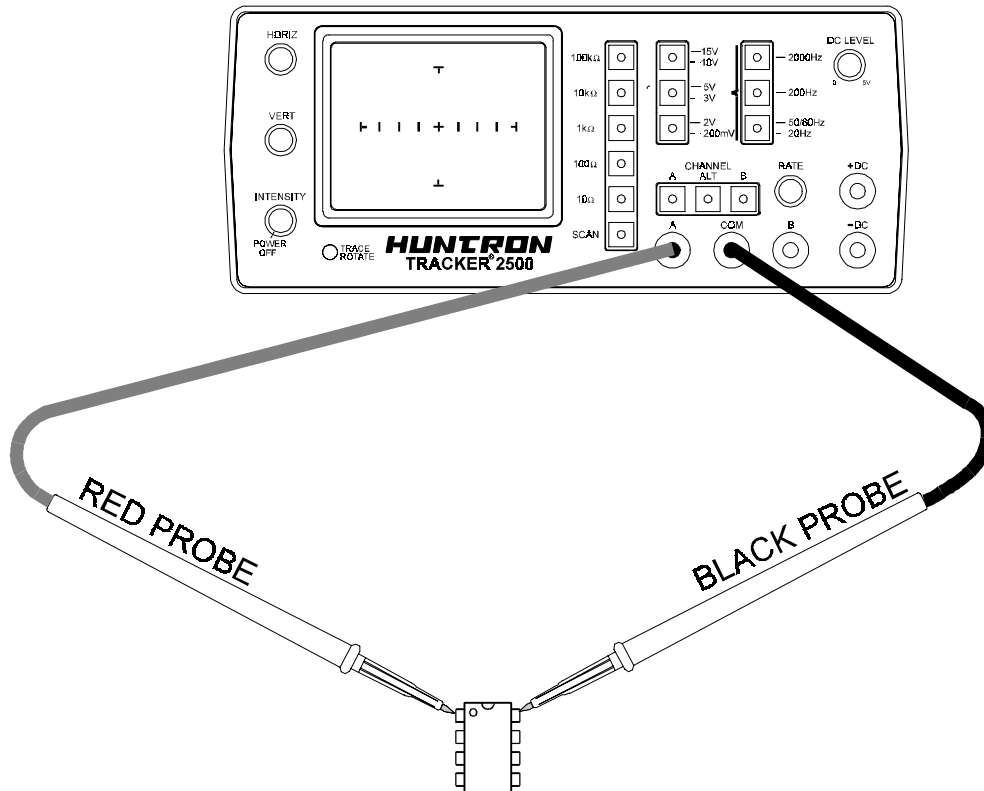


Figure 6-11. Tracker 2500 With Test Leads To An Op Amp.

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

1. Select the **15V, 1kΩ** range.
2. Set the test signal frequency to **60 Hz**.
3. Place or clip the black test lead from the Tracker 2500'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 2500'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.

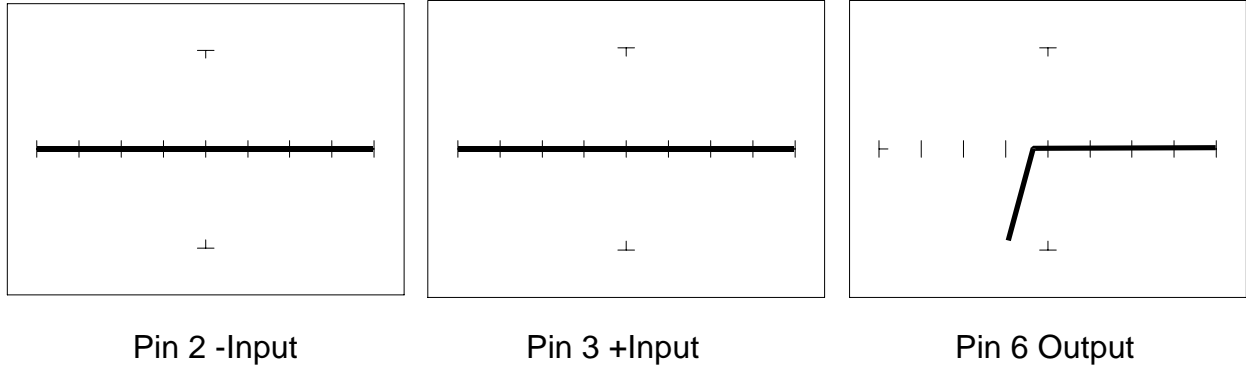


Figure 6-12. Signatures Of An Op Amp (741 Type)
10V, 100Ω Range, Common to Pin 4

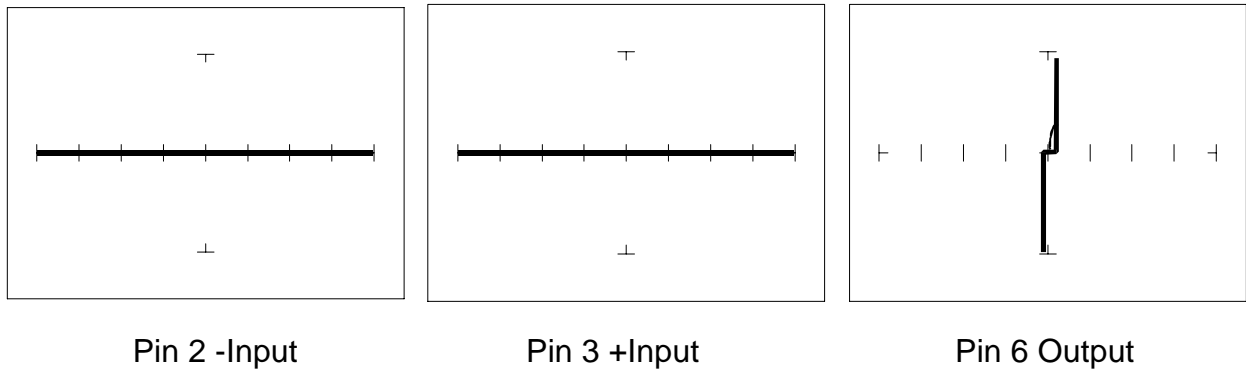


Figure 6-13. Signatures Of An Op Amp (741 Type)
15V, 10kΩ Range. Common to Pin 4

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 2500 can help locate the defective component quickly.

The op amp has three main terminals; + input, - input and output. An alternative way to perform ASA on the op amp is to connect Tracker 2500'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.

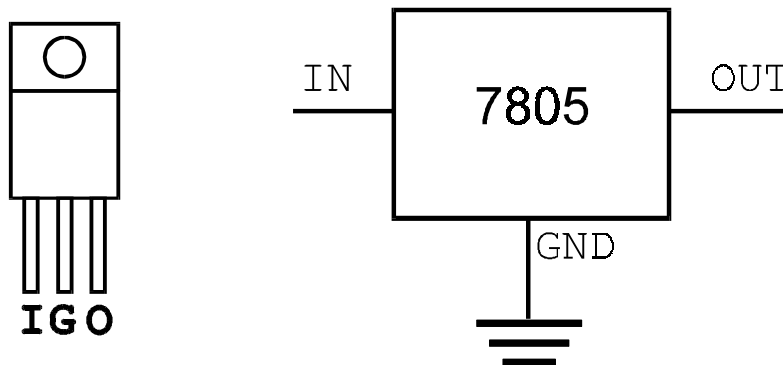


Figure 6-14. Diagram And Symbol Of A Linear Voltage Regulator, 7805 Type.

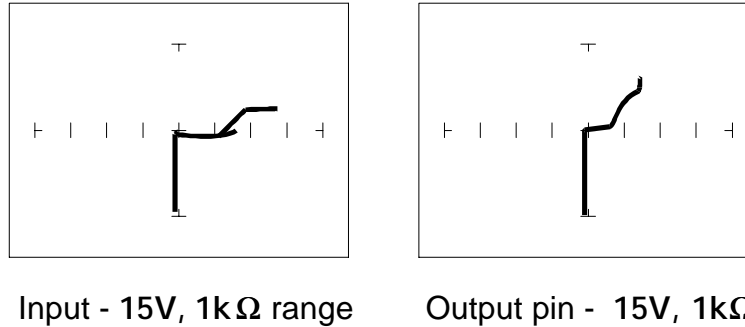


Figure 6-15. Signatures Of A 7805 Voltage Regulator By SGS Thomson.
Ground Pin To Common

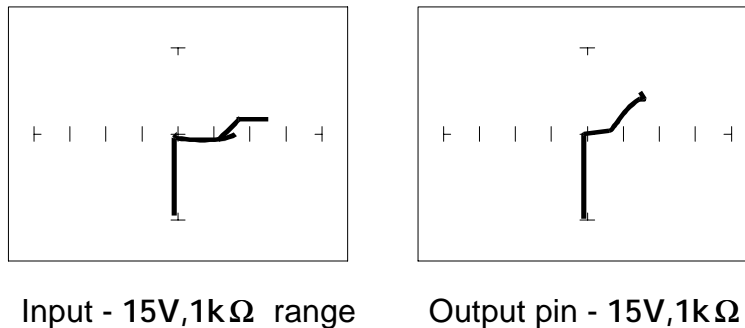


Figure 6-16. Signatures Of A 7805 Voltage Regulator By Motorola.
Ground Pin To Common

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 2500 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.
- To simplify the large number of signature variations, use the comparison test strategy with the Tracker 2500. The Tracker 2500 features alternate switching and display of the A and B channels to allow comparison of two individual signatures.

6-3. 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 V_{CC} . Similarly, the design of the output structure also has changed by eliminating the output protection diode to V_{CC} 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 2500 has the built-in "3V" test range 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.

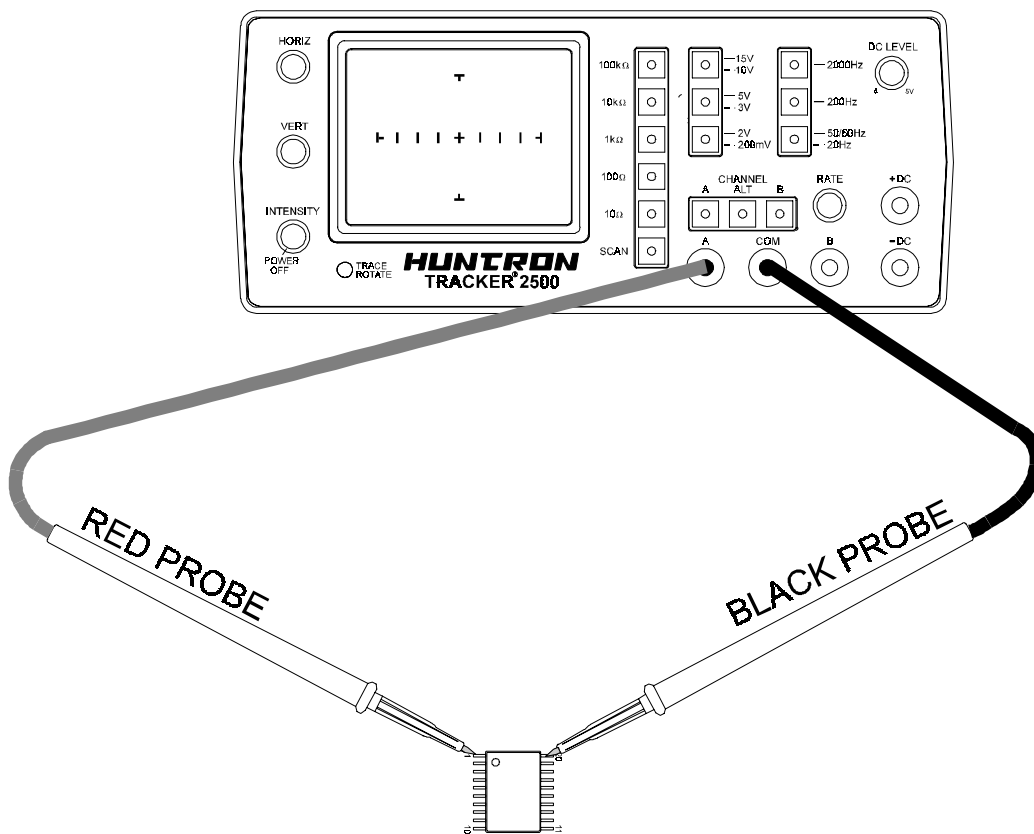


Figure 6-17. Tracker 2500 With Test Probes To A 20 Pin Surface Mount IC.

1. Select the **3V 10k Ω** Range.
2. Set the test signal frequency to **60 Hz**.
3. Place or clip the black test lead from the Tracker 2500'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 2500'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 2500'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 2500's A test terminal and probe the power supply V_{CC} input pin. For this example, the V_{CC} pin of the 74LVQ245 is pin 20.

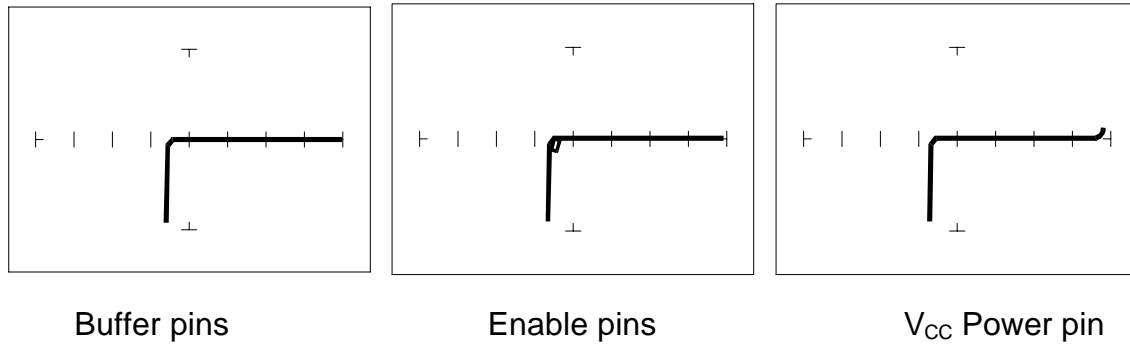


Figure 6-18. Signatures Of A Low Voltage IC (74LVQ45 Type).
3V, 10k Ω Range, Ground Pin To Test Common

The **2V and 3V** test ranges (**100k Ω , 10k Ω , 1k Ω , 100 Ω**) have 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 to ensure that the most descriptive signature is displayed. A higher V_S may result in a signature going toward a short which would mask out flaws. The short signature can be attributed to 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 signature we have seen already.

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 2500 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.
- To simplify the large number of signature variations, use the comparison test strategy with the Tracker 2500. The Tracker 2500 features alternate switching and simultaneous display of the A and B channels to allow comparison of two individual signatures.

SECTION 7 MAINTENANCE

7-1. INTRODUCTION

This section provides information on user maintenance items for this instrument.

7-2. EXTERNAL CLEANING AND LUBRICATION



To avoid electric shock or instrument damage, never get water inside the case. To avoid instrument damage, never apply solvents to the instrument.

Should the Tracker 2500 case require cleaning, wipe the instrument with a cloth that is lightly dampened with water or mild detergent solution. The instrument requires no lubrication.

7-3. STORAGE INSTRUCTIONS

For optimum protection, store the unit indoors in a dry place.

7-4. SERVICE INFORMATION

The conditions of the Tracker 2500 Warranty are given at the front of this manual. Malfunctions that occur within the limits of the warranty will be corrected at no cost to the purchaser exclusive of one-way shipping costs to Huntron Inc. Huntron service is also available for repair of instruments that are beyond the warranty period. In either case, please describe clearly the problems encountered with the instrument.

For in-warranty or out of warranty service call 800-426-9265 (in North America) or 425-743-3171 to describe the malfunction and request an RMA number and shipping instructions prior to shipment. This number must be clearly displayed on the exterior of the shipping carton. Only parcels displaying an RMA number will be accepted.

Huntron is also accessible
Fax at 425-743-1360,
Internet E-mail at huntron@huntron.com
Internet Home Page at <http://www.huntron.com>

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