



Huntron Tracker Analog Signature Analysis Course Workbook

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Section 1. Introduction

BEFORE YOU USE THIS COURSE –

This course assumes that the user has basic knowledge on the use their Tracker interface and controls. We strongly suggest that you review the User's Manual for your Tracker model before beginning this course. All User's Manuals can be found on the Huntron Product Manual CD included with this course.

1-1 Using your Tracker with this Course

This section describes the basic Tracker operations necessary to complete the exercises in this course. Trackers with variable range capabilities can be used with this course. User's Manuals are located on the Huntron Product Manuals CD. Variable range Trackers are:

- Tracker 2700/2700S (User's Manual is located in the Obsolete Manuals folder)
- Tracker 2800
- Tracker 2800S
- Tracker 4000 (User's Manual is located in the Obsolete Manuals folder)
- ProTrack I Model 10 or 20 (User's Manual is located in the Obsolete Manuals folder)
- TrackerPXI (with Huntron Workstation installed on the Controller; User's Manual is located in the Obsolete Manuals folder)
- Tracker Model 30 (connected to PC with Huntron Workstation installed; User's Manual is located in the Obsolete Manuals folder)
- Tracker 3200S

Contacting Huntron

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1-2 Items needed

- Huntron Tracker (see compatible list above)
- One pair of Huntron Microprobes or equivalent test leads
- Common test lead or equivalent “easy-grabber” lead
- This Course book
- Huntron Tracker Training PCB (included with course)

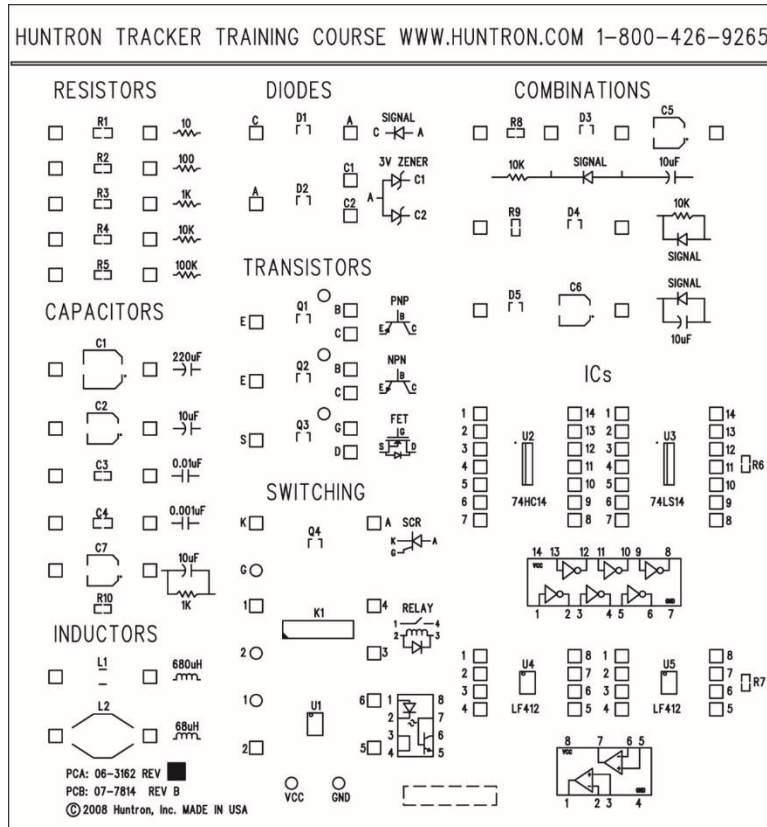


Figure 1-1 Huntron Tracker Training Board

1-3 General Tracker Setup

Huntron Trackers use the same style of front panel connections from one model to the next. They will have a Channel A, Channel B and Common connections that can use standard or shrouded banana plugs. This course will primarily use probes connected to the Channel A and Common front jacks.

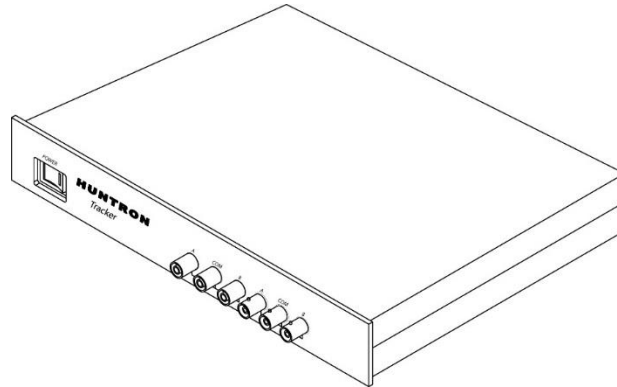


Figure 1-2 Channel A, Common (COM) and Channel B connections on Tracker Model 30

Any model specific exercises will be noted at that time. Several of the exercises will cover use of built-in Pulse Generators or DC Voltage Sources available on the Tracker 3200S, Tracker 4000, ProTrack, Tracker 2700/2700S and Tracker 2800/2800S.

For most the exercises in this course, a simple two probe approach will be used. This means that you will be manually probing directly across components on the Tracker Training Board. Figure 1-3 shows a typical two probe application.

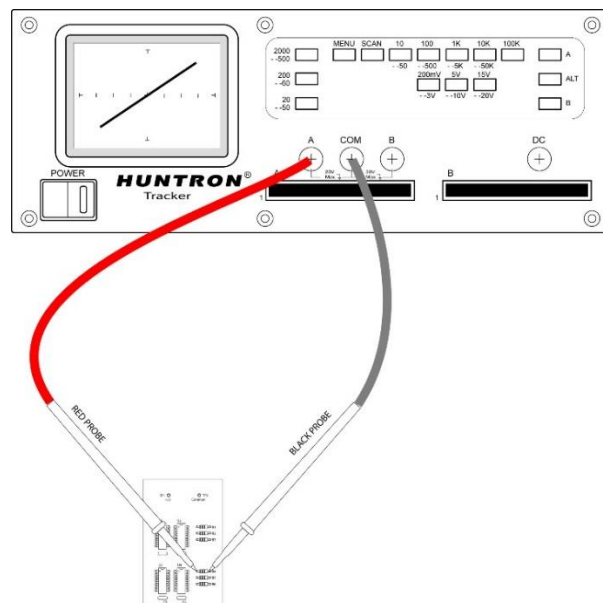


Figure 1-3 Typical two probe application testing a component such as a resistor. One probe (red) is connected to channel A and the other probe (black) is connected to Common.

1-4 Power-Up

Turn the Power switch of your Tracker to the “ON” position. Trackers with built-in displays can be used right away. Software controlled Trackers such as the Tracker Model 30 will also need to be connected to a PC with Huntron Workstation installed before continuing with the Training Course.

1-5 Channel Selection

There are two channels on your Huntron Tracker, channel **A** and channel **B**. These are selected by pressing the appropriate front panel button or select the desired channel in Huntron Workstation software.

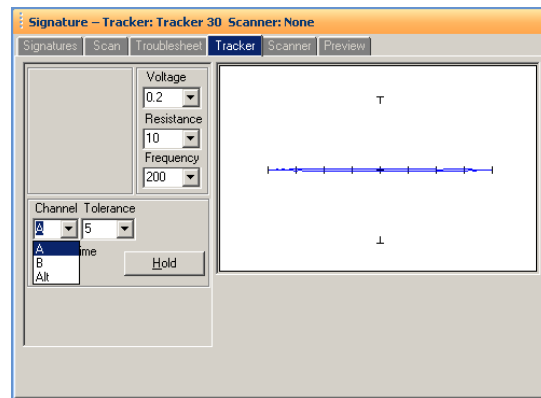


Figure 1-4 Channel A and Channel B shown on a Huntron ProTrack and in Workstation software

When using a single channel, the red probe should be plugged into the corresponding channel test terminal and the black probe or common test lead 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 or a common reference (i.e. cathode, ground). Following this procedure should assure that the signature appears in the correct quadrants of the Signature display.

1-6 Alternate and A+B Mode

The Alternate mode of a Tracker 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 or by selecting **ALT** mode in the Tracker window of the Workstation software (see figure 1-4). Figure 1-5 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.

The Tracker 3200S, ProTrack and Tracker 4000 also have an **A+B** mode that is similar to **ALT** mode but the A and B channel signatures are display at the same time. The Tracker 3200S will display Channel A in green and Channel B in red.

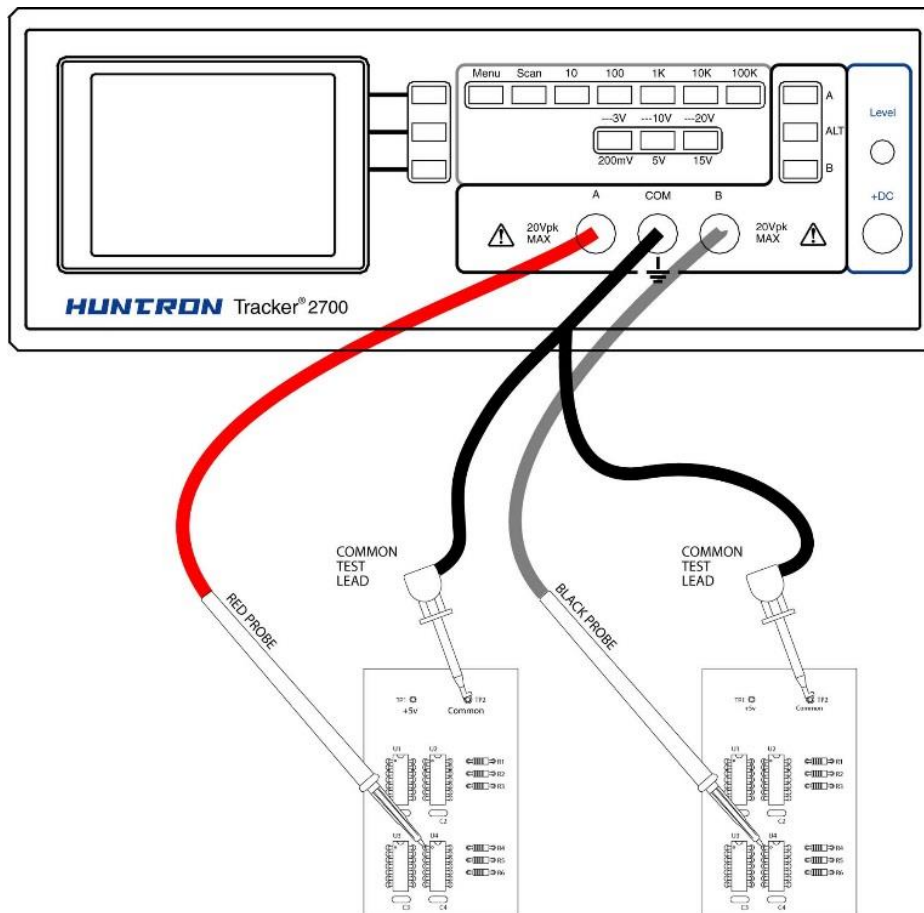


Figure 1-5 Typical Alternate mode application to compare the same points on two boards (shown using a Tracker 2700)

1-7 Resistance Selection

A Huntron Tracker is designed with multiple resistance ranges varying from 10Ω to $100k\Omega$. A resistance range is selected by pressing the appropriate button(s) on the Tracker front panel or by selecting a setting from the Resistance drop menu in the Workstation Tracker window (figure 1-6). When using a ProTrack or Tracker 4000, you will turn the encoder knob to change the resistance setting.

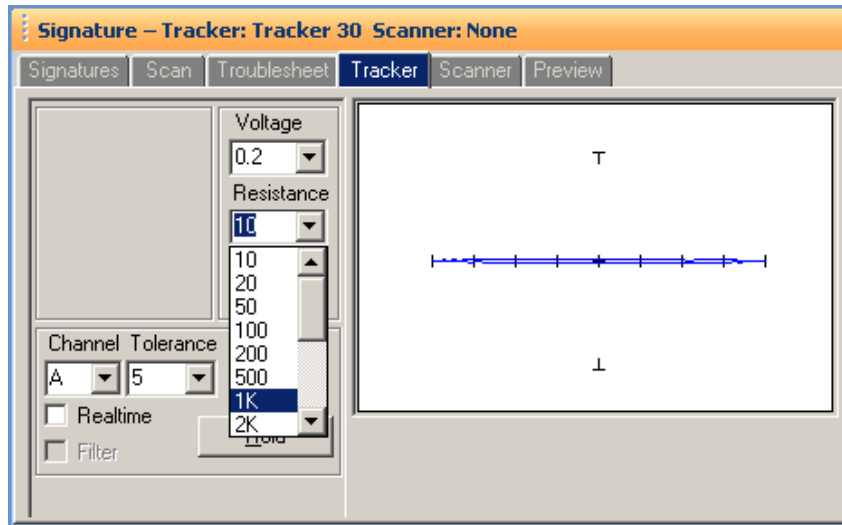


Figure 1-6 Selecting Resistance in the Workstation Tracker Tab

It is best to start with one of the middle resistance values (**i.e. 100Ω or $1k\Omega$**). If the signature on the display is close to an open (horizontal trace), set the Tracker 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. An optimum resistive signature is approximately at a 45° angle to the horizontal and vertical lines of the graticule.

1-8 Frequency Selection

The Tracker test signal frequencies will vary from **20Hz to 2000Hz (or 5000Hz for Tracker 3200S, ProTrack, Tracker 4000 and Tracker Model 30)** and can be selected by pressing the appropriate button(s) on the front panel or by selecting a setting from the Frequency drop menu in the Workstation Tracker window (figure 1-8). When using a ProTrack or Tracker 4000, you will turn the encoder knob to change the frequency setting.

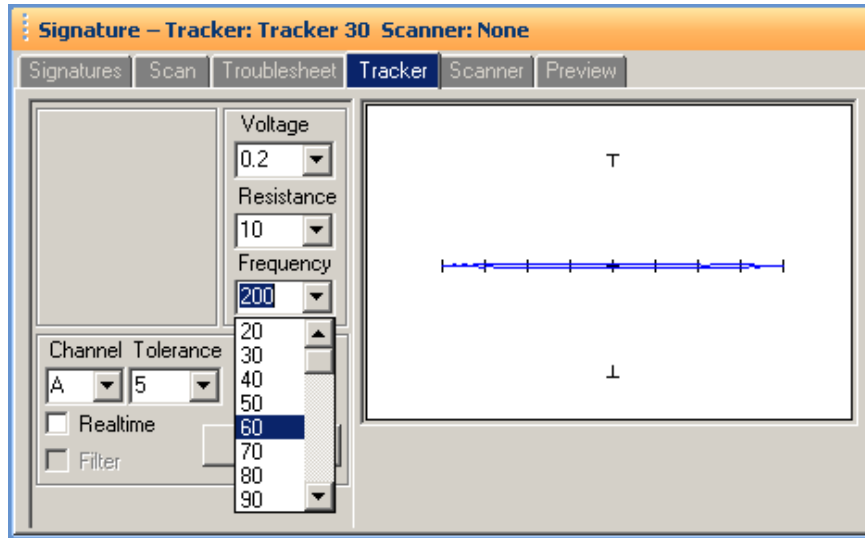


Figure 1-7 Selecting Frequency in the Workstation Tracker tab

Frequency is typically changed when testing reactive components such as capacitors or inductors. Changing frequency will affect the elliptical shape of the signatures displayed.

1-9 Voltage Selection

The Tracker voltage selection varies from **200mV** to **20V**. This controls the peak applied sine-wave voltage. The voltage setting can be selected by pressing the appropriate button on the front panel or by selecting a setting from the Voltage drop menu in the Workstation Tracker window (figure 1-8). When using a ProTrack or Tracker 4000, you will turn the encoder knob to change the voltage setting.

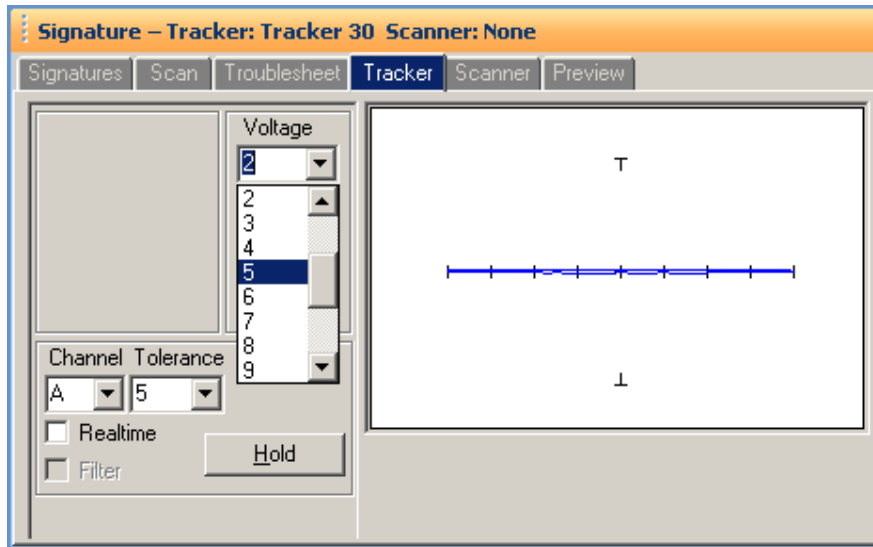


Figure 1-8 Selecting Voltage in the Workstation Tracker tab

All Trackers have a built-in function referred to as Smart Tracker Active Range (STAR) that will limit which voltage/resistance combinations can be selected. The purpose of STAR is to limit the amount of current available in any Tracker range combination to under 200mA.

1-10 Pulse Generator and DC Voltage Source

The built-in DC (direct current) voltage source of the Tracker 2700 and 2800 or the Pulse Generator on the Tracker 3200S, ProTrack and Tracker 4000 allows for 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 or Pulse Generator is connected to the control input of the device to be tested with the blue clip lead provided with your Tracker. In general use, a DC level from the DC voltage source or Pulse Generator is used. Figure 1-9 shows how to connect a Tracker to the device under test, using the DC voltage source.

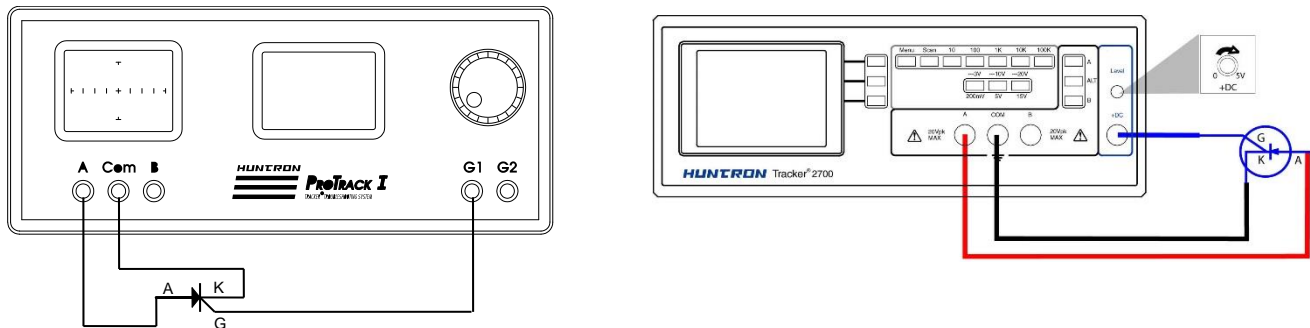


Figure 1-9 Typical Tracker Pulse Generator or DC Source Setup

The DC Voltage Source or Pulse Generator output is set using Level controls on the Tracker front panel, using the Pulse menu and encoder on a ProTrack or Tracker 4000 or using the Pulse Level setting in the Workstation Tracker tab. The level control varies the magnitude of output voltage from zero to 10 volts. The corresponding DC level will be displayed on the LCD.

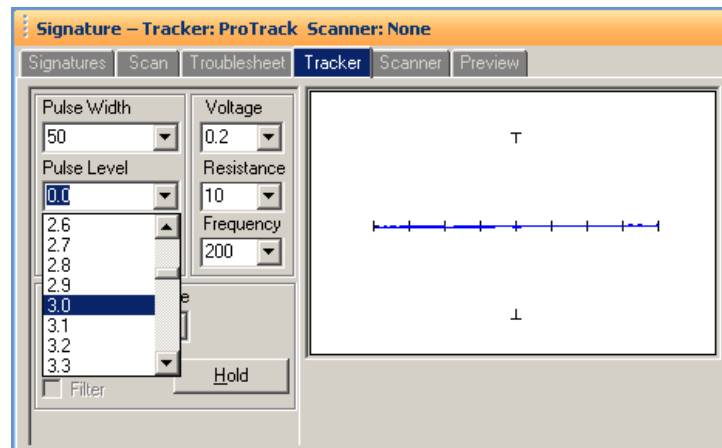


Figure 1-10 Selecting Voltage Level in Huntron Workstation Signature Pane/Tracker tab

1-11 Analog Signature Analysis (ASA) Basics

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

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

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

The next figure shows a simplified diagram of the Tracker'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'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 sole function of R_L .

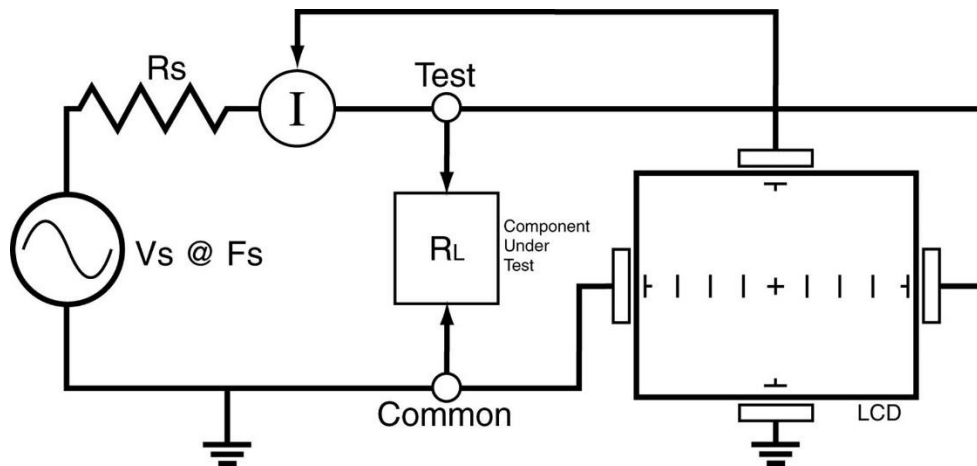


Figure 1-11: Tracker Core Circuit Block Diagram

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 , 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 Tracker signature information. The Tracker 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 or circuit node.

Horizontal Axis

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

The horizontal axis is divided up by small graticule lines similar to those on a conventional oscilloscope 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. Changing the V_s of the test range effectively acts the same as changing the Volts-per-division on an oscilloscope. Table 1-1 shows the volts per division for various Tracker voltage ranges.

Range	Volts/Div
20V	5.00
15 V	3.75
10 V	2.50
5 V	1.25
3 V	0.75
200 mV	0.05

Table 1-1 Tracker Horizontal Sensitivities

The Signature viewing area of the Tracker display can also be set up in quadrants to show positive and negative current and voltage characteristics. Refer to figure 1-12.

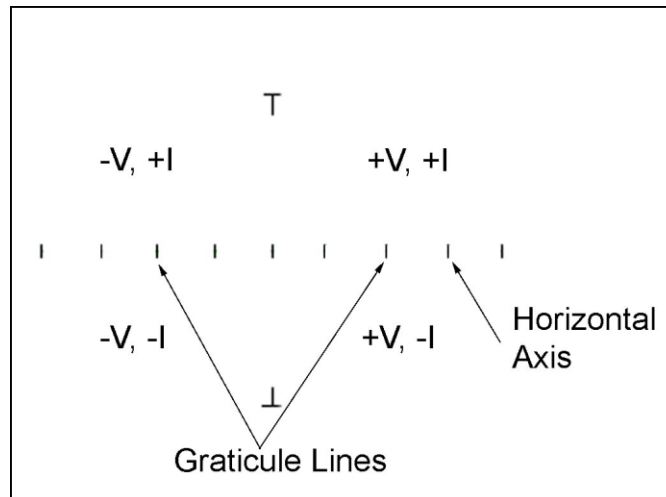


Figure 1-12. Display Horizontal Axis and Graticule Lines.

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 Tracker 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.

Exercise 1 – Horizontal Axis

1. Turn on the Tracker and observe the display. With nothing connected to its test terminals, the display trace is a horizontal line (that is, $R_L = \infty$) as shown in figure 1-13.

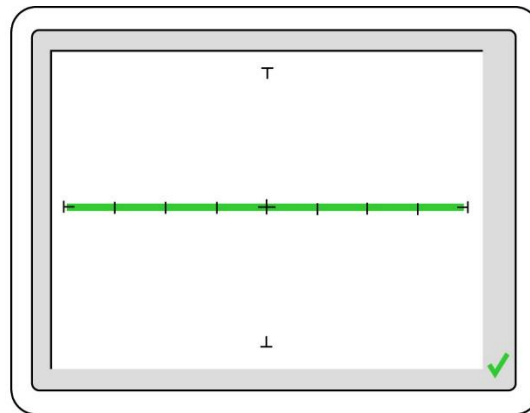


Figure 1-13 Tracker Display with Open Test Terminals.

Vertical Axis

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

When the R_L is zero ohms (0Ω) by shorting the output terminal to the common terminal, there is no voltage dropped across R_L causing no horizontal component to be displayed in the Tracker signature. This short circuit signature is a vertical line trace on the Tracker display.

Exercise 2 – Vertical Axis

Connect the red microprobe to the output channel A jack on the Tracker and the black microprobe to the Common jack. Touch and hold the probes together and observe the Tracker signature on the Tracker display.

You will see a vertical line trace in the middle of the Tracker display.

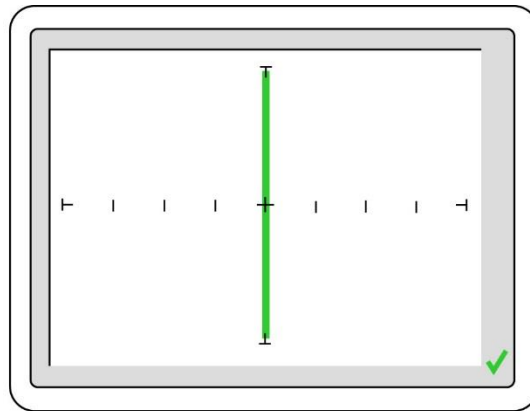


Figure 1-14 Display with Vertical Axis, Graticule Lines displaying a short circuit.

1-12 Four Basic Component Analog Signatures

All Tracker signatures are a composite of one or more of the four basic component signatures which are: resistance, capacitance, inductance and semi-conductance. Refer to Fig 1-15. Each one of these basic components responds differently to the Tracker's test signal. Recognizing these four basic unique signatures on the Tracker 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 usually form an approximate right angle. Semi-conductance signatures can show conduction in both forward and reverse-bias. This will form a zener semiconductor pattern which will show both junctions.

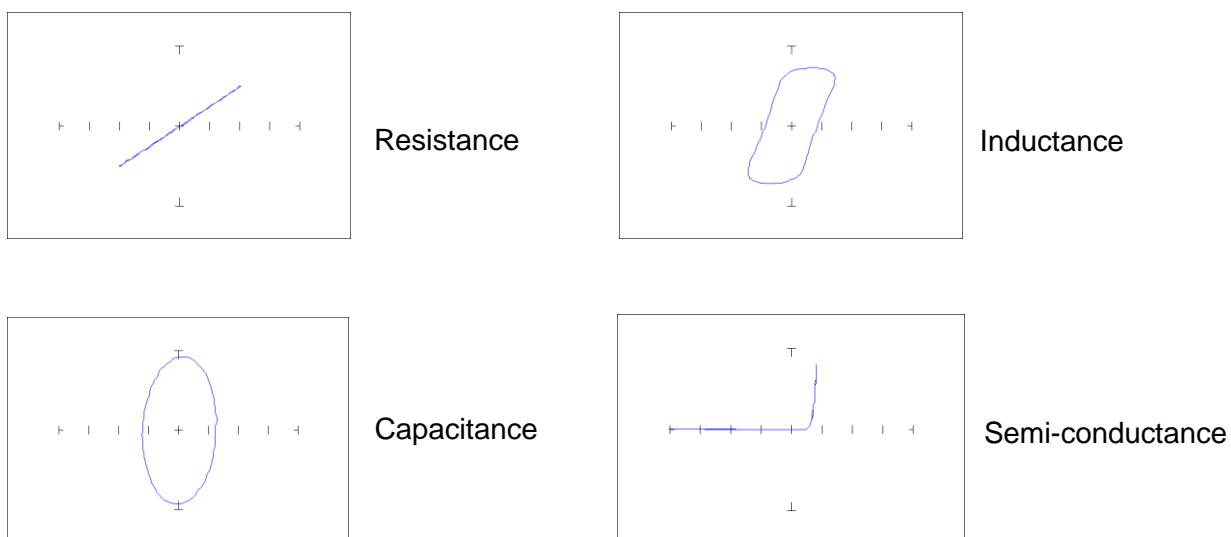


Figure 1-15 Analog Signatures of the Four Basic Components

1-13 Smart Tracker Active Range (STAR) feature

Huntron Trackers have a built-in operating feature called STAR (Smart Tracker Active Range). This important feature protects sensitive components from possible exposure to excessive power (for example, 15V and 10Ω). The table 1-2 specifies the active and disabled voltage & resistance test range combinations. **Note:** some range combinations from the Tracker 3200S, Tracker 4000 and ProTrack are not shown.

	10Ω	50Ω	100Ω	1kΩ	5kΩ	10kΩ	50kΩ	100kΩ
200mV	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled
3 V	Disabled	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled
5 V	Disabled	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled
10 V	Disabled	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled
15 V	Disabled	Disabled	Disabled	Enabled	Enabled	Enabled	Enabled	Enabled
20 V	Disabled	Disabled	Disabled	Disabled <input type="checkbox"/>	Disabled	Disabled <input type="checkbox"/>	Enabled	Enabled

Table 2-4. Valid Tracker Ranges (STAR)

Exercise 3 – Tracker STAR Feature

To illustrate the STAR feature, do the following:

1. Select the **200mV, 10Ω** range.
2. Press the **5V** button. Notice that the resistance range changes to **50Ω** automatically. The **5V** at **10Ω** range is disabled. In Huntron Workstation, the voltage drop menu will only display the voltages allowed the current resistance setting.

Now press the **15V** button. Notice that the **1kΩ** resistance is automatically selected. The **15V** at **50Ω** range is disabled and the next valid resistance range was activated at the selected voltage.

SECTION 2 TESTING RESISTORS

2-1 Testing Resistors - Introduction

The signatures displayed on a Tracker are a visual representation of Ohm's Law as it relates to the circuit under test. The amount of voltage applied to the circuit is shown along the horizontal axis and the induced current is shown along the vertical axis. Resistors will display a straight line signature because the relationship between voltage and current is linear. The slope of the signature changes as the Tracker resistance ranges changes or if the amount of resistance across the test leads changes.

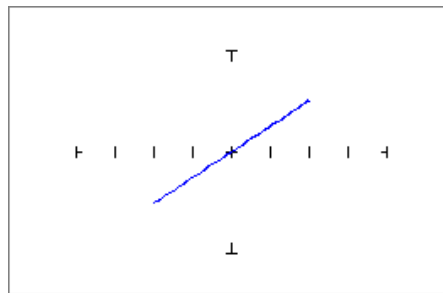


Figure 2-1 Typical Resistive Signature (image from Huntron Workstation shown)

This section will explore how different Tracker ranges interact with different resistance values. The following exercises are designed to teach Tracker operation and how resistive signatures relate to changes in test range voltage, resistance and frequency.

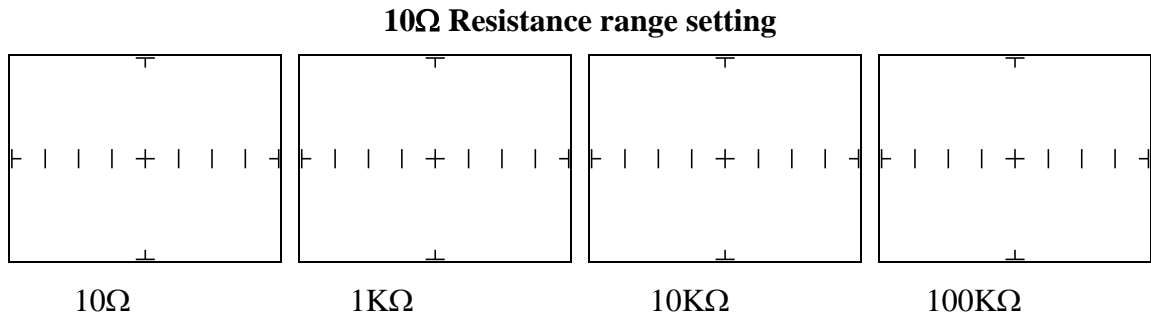
2-2 Changing Component Resistance Value

The following exercises will illustrate how changing the resistor value under test affects the signature displayed on the Tracker LCD.

Exercise 1: Testing at the 10 Ω resistance range

1. Set up your Tracker to test (See section 1-3). Set the range settings to 200mV, 10 Ω and 200Hz.
2. Using the Huntron Tracker Training board, connect the test leads to R1 (10 Ω).
3. Draw the signature in the signature box labeled 10 Ω .
4. Move the Tracker test leads to R3 (1K Ω).
5. Draw the signature in the signature box labeled 1K Ω .
6. Move the Tracker test leads to R4 (10K Ω).
7. Draw the signature in the signature box labeled 10K Ω .
8. Move the Tracker test leads to R5 (100K Ω).

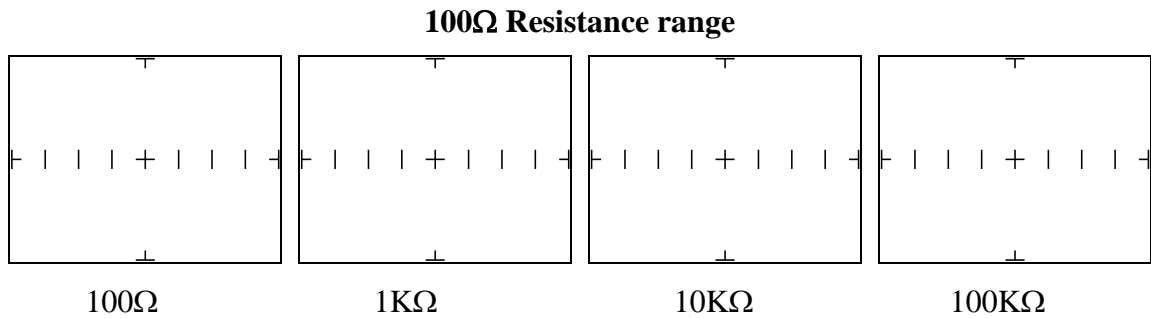
9. Draw the signature in the signature box labeled 100KΩ.



Note from the signatures drawn above that as the value of the resistance being tested increases, the signature displayed becomes more horizontal. Compare the signatures drawn to the signatures in Appendix A.

Exercise 2: Testing at the 100Ω resistance range

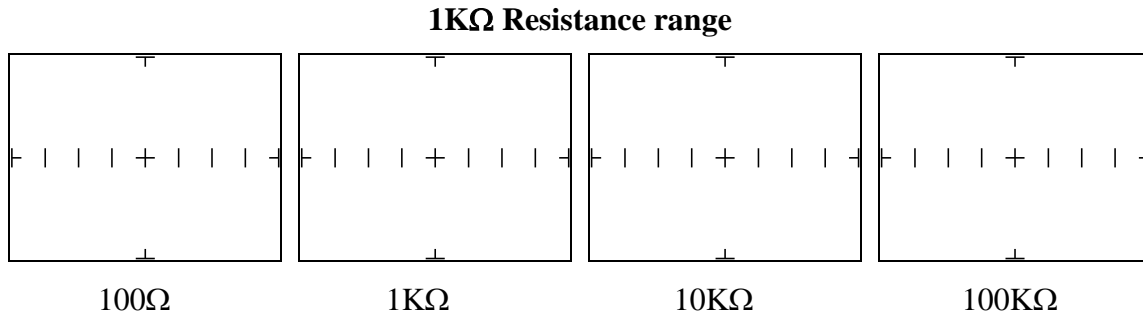
1. Change the Tracker resistance range from 10Ω to 100Ω.
2. On the Huntron Tracker Training board, connect the Tracker test leads to each of the resistors R2 - R5. Draw their corresponding signatures in the labeled signature boxes below.



Note that the signature of the 100Ω resistor is showing a typical angled, straight line resistive signature but the other resistor signatures are still relatively flat. Compare the drawn signatures to those in Appendix A.

Exercise 3: Testing at the 1KΩ resistance range

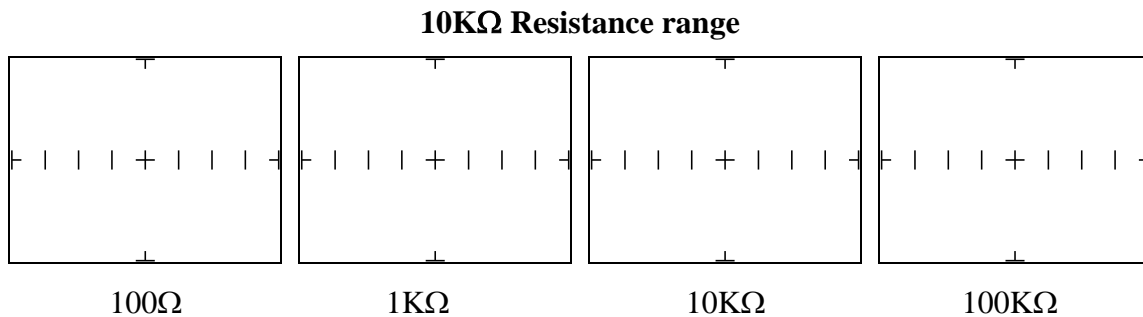
1. Change the Tracker resistance range from 100Ω to 1KΩ.
2. On the Huntron Tracker Training board, connect the Tracker test leads to each of the resistors R2 – R5 and draw their corresponding signatures in the labeled signature boxes below.



Note that the signature of the 100Ω is now more vertical. The 1KΩ resistor is showing typical angled, straight line resistive signature but the other resistor signatures are still relatively flat. Compare the drawn signatures to those in Appendix A.

Exercise 4: Testing at the 10KΩ resistance range

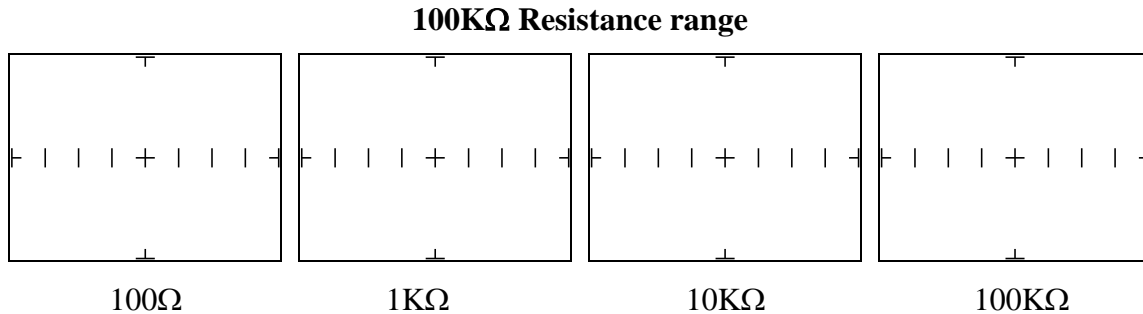
1. Change the Tracker resistance range from 1KΩ to 10KΩ.
2. On the Huntron Tracker Training board, connect the Tracker test leads to each of the resistors R2 – R4 and draw their corresponding signatures in the labeled signature boxes below.



Note that the signatures of the 100Ω and 1KΩ resistors are showing almost vertical, straight line resistive signatures. The 10KΩ resistor is showing a typical straight line angled signature and the 150KΩ resistor is relatively flat. Compare the drawn signatures to those in Appendix A.

Exercise 5: Testing at the 100KΩ resistance range

1. Change the Tracker resistance range from 10KΩ to 100KΩ.
2. On the Huntron Tracker Training board, connect the Tracker test leads to each of the resistors R2 – R4 and draw their corresponding signatures in the labeled signature boxes below.



Note that the signatures of the 10KΩ and 100KΩ resistors are showing typical angled, straight line resistive signatures but the 100Ω and 1KΩ resistor signatures are almost vertical. You may also see slight capacitance (loop signature) as the resistance value is increased. Compare the drawn signatures to those in Appendix A.

2-3 Resistive Signatures - Changing Voltage and Frequency

Exercise 6: Effects of changing range voltage on resistive signatures

1. Connect the Tracker test leads to R4 (10KΩ) and set the Tracker resistance range to 10KΩ. An angled, straight line signature should be displayed on the Tracker.
2. Change the Tracker voltage range to 5V and observe the signature. Change the voltage range to 10V and observe the change.

Note that the signature does not change when voltage is varied. The resistive load across the test leads remains unchanged compared to the internal source resistance of the Tracker.

Exercise 7: Effects of changing range frequency on resistive signatures

1. Connect the Tracker test leads to R4 (10KΩ) and set the Tracker resistance range to 10KΩ. An angled, straight line signature should be displayed on the Tracker.
2. Change the Tracker frequency range to 2000Hz. and observe the signature. Change the frequency range to 20Hz. and observe the change.

Note that the signature does not change when frequency is varied. The resistive load across the test leads remains unchanged compared to the internal source resistance of the Tracker.

2-4 Review for resistive signatures

- The signature of a purely resistive circuit will display a straight line signature because the relationship between voltage and current in a purely resistive circuit is linear.
- This straight line signature can vary from a completely horizontal (open circuit) to completely vertical (short circuit).
- As resistance across the test leads increases, the current decreases and the signature will become more horizontal.
- As the Tracker range resistance increases, a resistive signature becomes more vertical.

SECTION 3 Testing Capacitors

3-1 Introduction

Unlike resistive circuits, the relationship between induced voltage, current and capacitance is not linear. In a capacitive circuit, current is at its maximum when voltage across the component is at zero. When voltage across the component is at its maximum, current in the circuit is at zero. This “time delay” is a function of the capacitive reactance where the current leads the voltage. This relationship and the resulting Tracker signature is shown in figure 3-1.

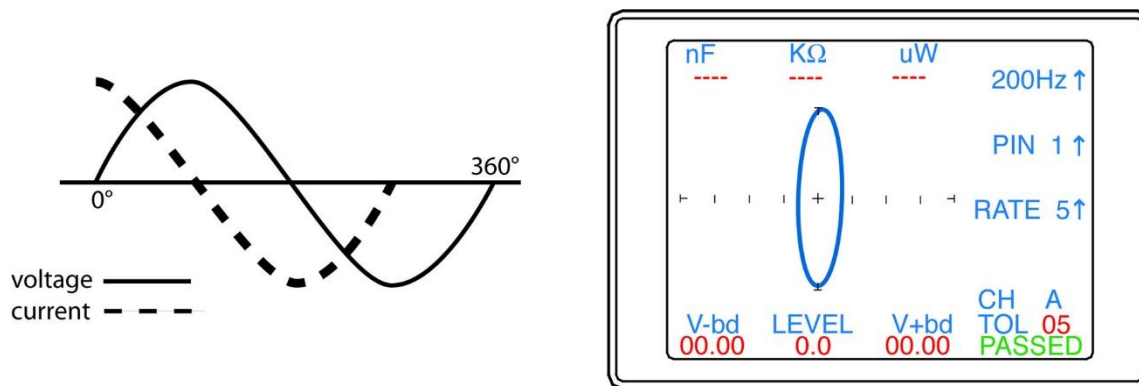


Figure 3-1 Waveforms and signature (Tracker 2700 display shown) of typical capacitor

The time delay in a capacitive circuit causes the Tracker signature to be displayed as an elliptical shape. The width of the ellipse is directly related to the value of the capacitor being tested and the range parameters set on the Tracker.

3-2 Changing Component Capacitance Value

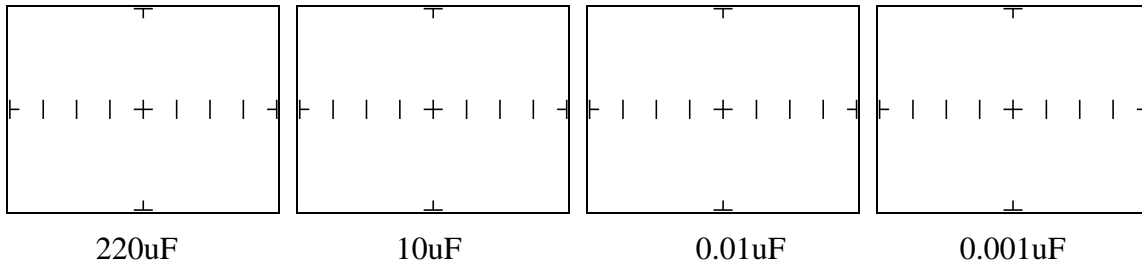
The following exercises will illustrate how changing the capacitor value under test affects the signature displayed on the Tracker display.

Exercise 1: Testing at the 10Ω resistance range

1. Set up your Tracker to test (See section 1-3). Set the range settings to 200mV, 10Ω and 200Hz.
2. Using the Huntron Tracker Training board, connect the test leads to C1 (220uF).
3. Draw the signature in the signature box labeled 220uF.

4. Move the Tracker test leads to C2 (10uF).
5. Draw the signature in the signature box labeled 10uF.
6. Move the Tracker test leads to C3 (0.01uF).
7. Draw the signature in the signature box labeled 0.01uF.
8. Move the Tracker test leads to C4 (0.001uF).
9. Draw the signature in the signature box labeled 0.001uF.

10Ω Resistance range

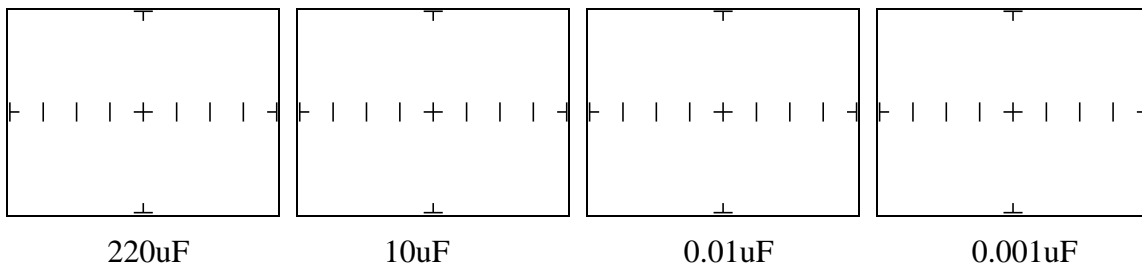


Note from the signatures drawn above that as the value of the capacitance being tested decreases, the signature displayed becomes more horizontal. This range is best suited for large capacitor values. Compare the signatures drawn to the signatures in Appendix A.

Exercise 2: Testing at the 100Ω resistance range

1. Change the Tracker resistance range from 10Ω to 100Ω.
2. On the Huntron Tracker Training board, connect the Tracker test leads to each of the capacitors C1, C2, C3 and C4. Draw their corresponding signatures in the labeled signature boxes below.

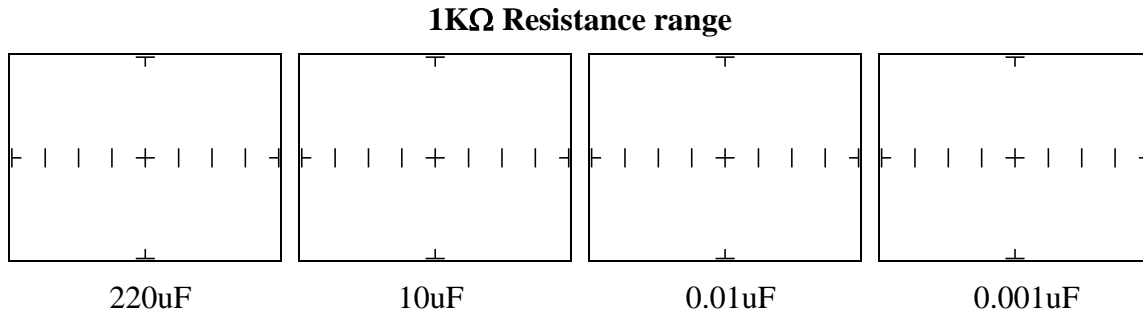
100Ω Resistance range



Note that elliptical signatures are displayed for the 220uF and 10uF. Compare the drawn signatures to those in Appendix A.

Exercise 3: Testing at the 1KΩ resistance range

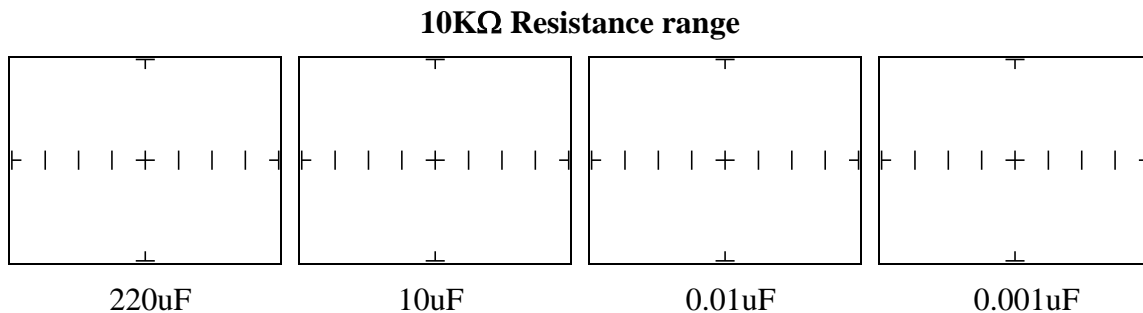
1. Change the Tracker 2700 resistance range from 100Ω to 1KΩ.
2. On the Huntron Tracker Training board, connect the Tracker test leads to each of the capacitors C1, C2, C3 and C4. Draw their corresponding signatures in the labeled signature boxes below.



Note that the 10uF and 0.01uF capacitors display a typical elliptical signature. The signatures displayed for the other components appear either as a vertical or horizontal line. Compare the drawn signatures to those in Appendix A.

Exercise 4: Testing at the 10KΩ resistance range

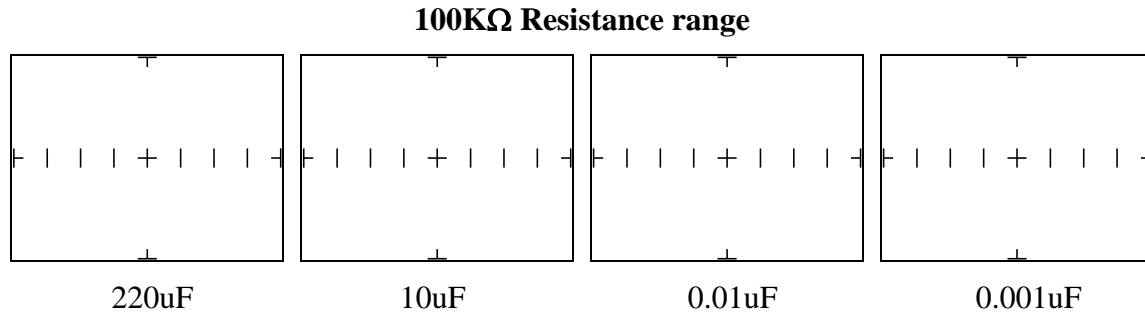
1. Change the Tracker resistance range from 1KΩ to 10KΩ.
2. On the Huntron Tracker Training board, connect the Tracker test leads to each of the capacitors C1, C2, C3 and C4. Draw their corresponding signatures in the labeled signature boxes below.



Note that the signature of the 0.01uF capacitor displays a typical elliptical signature and the .001uF capacitor is now showing a very slight elliptical shape. Compare the drawn signatures to those in Appendix A.

Exercise 5: Testing at the 100K Ω resistance range

1. Change the Tracker resistance range from 10K Ω to 100K Ω .
2. On the Huntron Tracker Training board, connect the Tracker test leads to each of the capacitors C1, C2, C3 and C4. Draw their corresponding signatures in the labeled signature boxes below.



Note that the signatures of the 0.01uF and .001uF capacitors display an elliptical signature. The signatures displayed for the other components will appear as a vertical line. Compare the drawn signatures to those in Appendix A.

Exercise 6: Effects of changing range voltage on capacitive signatures

1. Connect the Tracker test leads to C2 (10uF) and set the Tracker resistance range to 100 Ω . A circular capacitive signature should be shown on the Tracker display.
2. Change the Tracker voltage range to 3V and observe the signature. Change the voltage range to 5V and observe the change.

Note that the signature does not change when voltage is varied. The capacitive reactance across the test leads remains unchanged compared to the internal source resistance of the Tracker.

Exercise 7: Effects of changing range frequency on capacitive signatures

1. Connect the Tracker test leads to C1 (220uF) and set the Tracker resistance range to 10 Ω . A narrow, elliptical signature should be displayed on the Tracker.
2. Change the Tracker frequency range to 20Hz. and observe the signature. Change the frequency range to 2000Hz. and observe the change.

Note that the signature changes when the test frequency is varied since the capacitive reactance is a function of frequency. Lower frequencies work better for testing larger capacitances.

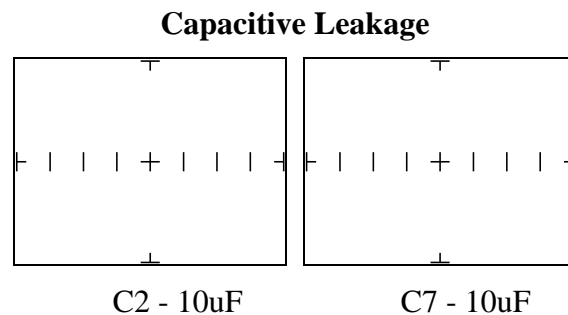
3. Connect the test leads to C4 (0.001uF). Change the Tracker resistance to 100K Ω . An elliptical signature will be displayed on the Tracker display.
4. Change the Tracker frequency to 20Hz and observe the Tracker display.

Note that the signature changes when the Tracker frequency is varied since the capacitive reactance is a function of frequency. Higher frequencies work better for testing smaller capacitances.

Exercise 8: Simulated Capacitive Leakage Failure

A typical failure for capacitors is component leakage. This is especially true for electrolytic capacitors as they age. This exercise will simulate a capacitive leakage failure and the associated signatures.

1. Set the Tracker resistance range to $1\text{K}\Omega$.
2. On the Huntron Tracker Training board, connect the Tracker Common to the GND post near the bottom edge of the board. Hold the Channel A test lead to the right side pad from capacitor C2 and draw the signature in the box below labeled C2-10uF.
3. Move the Channel A test lead to the right side pad from C7 and draw the signature in the box below labeled C7-10uF.



Note that the signatures of C2 and C7 capacitors appear different from each other in that C7 is showing an angled orientation when compared to C2. This resistor R10 connected in parallel with C7 is simulating how a capacitive leakage problem would be displayed on a Tracker. Capacitive leakage or dielectric failure is a common type of failure especially in electrolytic capacitors. Compare the drawn signatures to those in Appendix A.

3-3 Review for capacitive signatures

- The signature of a capacitor will display an elliptical or circular signature because the relationship between voltage and current in a capacitive circuit is out of phase.
- As the internal Tracker test resistance changes, the reactive load across the test leads changes in relation to the internal source resistance and will cause the displayed signature to change.
- As test frequency increases, the signature will become more vertical due to decreasing capacitive reactance within the capacitor being tested. High frequencies work best for small capacitor while low frequencies work well for large capacitors. Use the information presented in table 3-1 as guide for the minimum and maximum limits that the Tracker can display usable signatures. Note: The values may vary depending on the type of Huntron Tracker used.

Tracker range settings	Minimum capacitive value	Maximum capacitive value
10Ω, 20Hz	100uF	13000uF
100KΩ, 5KHz.	100pF	.01uF

Table 3-1 Min/Max. Capacitance Values

- Radial lead electrolytic capacitors can be test by touching the exposed metal top of the component. This method is best utilized using the A versus B comparison of known good and suspect circuit boards. Use a higher resistance setting such as 10KΩ.
- One common capacitive failure type is capacitive leakage where the signature will appear to be tilted at an angle. This is indicating internal resistance and is primarily an issue with electrolytic capacitors.

Section 4 Testing Inductors

4-1 Introduction

Similar to capacitors, the relationship between induced voltage, current and inductance is not linear. In an inductive circuit, voltage and current are out of phase with current lagging voltage. This “time delay” is a function of the inductive reactance where the voltage leads the current. This relationship and a common inductive Tracker signature are shown in figure 4-1.

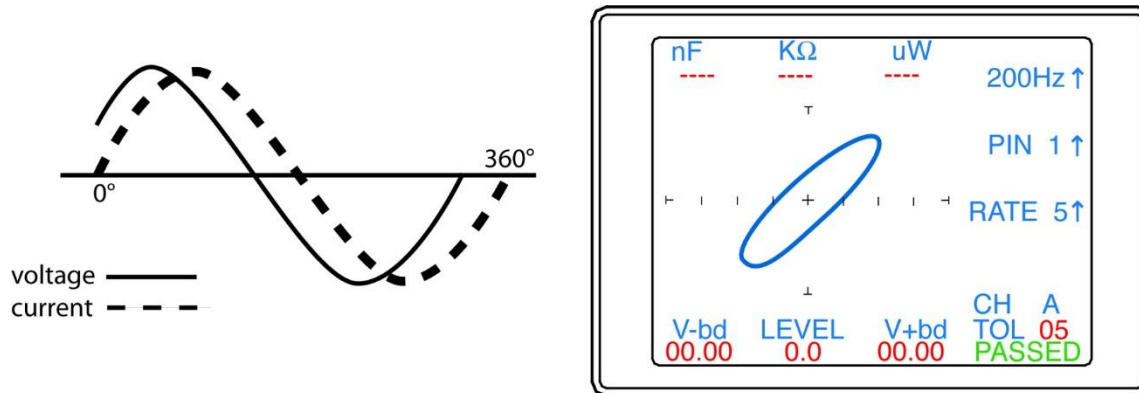


Figure 4-1 Waveform and Signature (Tracker 2700 display shown) from Inductor

The time delay in an inductive circuit causes the Tracker signature to be displayed as an elliptical shape. The width of the ellipse is directly related to the value of the inductor being tested and the range parameters set on the Tracker. Since pure inductors are theoretical, most inductive signatures exhibit a resistive tilt caused by the resistance of the wire used to construct the component and some degree of distortion such as the “egg” shape shown in figure 4-1 caused by inductive hysteresis.

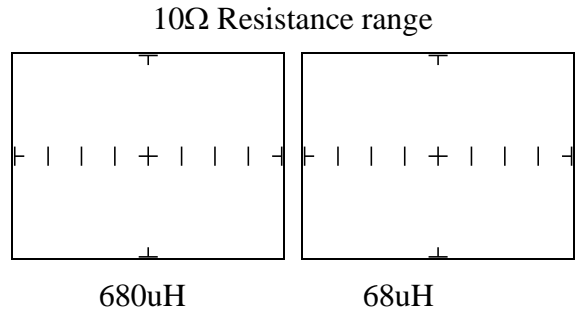
4-2 Changing Component Inductance Value

The following exercises will illustrate how changing the inductor value under test affects the signature displayed on the Tracker LCD.

Exercise 1: Testing at the 10Ω resistance range

1. Set up your Tracker to test (See section 1-3). Set the Tracker range settings to 200mV, 10Ω and 2000Hz.
2. Using the Huntron Tracker Training board, connect the test leads to L1 (680uH).
3. Draw the signature in the signature box labeled 680uH.

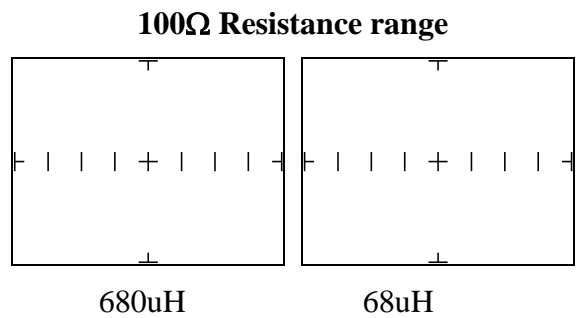
4. Move the Tracker test leads to L2 (68uH).
5. Draw the signature in the signature box labeled 68uH.



Note from the signatures drawn above that as the value of the inductance being tested decreases, the signature displayed becomes more vertical. The width of the signature will also change. Compare the signatures drawn to the signatures in Appendix A.

Exercise 2: Testing at the 100Ω resistance range

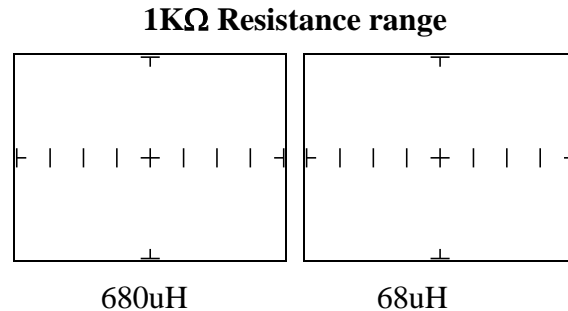
1. Change the Tracker resistance range from 10Ω to 100Ω.
2. On the Huntron Tracker Training board, connect the Tracker test leads to each of the inductors L1 and L2. Draw their corresponding signatures in the labeled signature boxes below.



Note that the elliptical signatures have changed in both angle and shape when compared to the signatures using the 10Ω Tracker resistance setting. Compare the drawn signatures to those in Appendix A.

Exercise 3: Testing at the 1KΩ resistance range

1. Change the Tracker resistance range from 100Ω to 1KΩ.
2. On the Huntron Tracker Training board, connect the Tracker test leads to each of the inductors L1 and L2. Draw their corresponding signatures in the labeled signature boxes below.



Note that the signatures are now very close to vertical. This particular resistance setting is not suitable for testing these two inductors. The 10KΩ and 100KΩ resistance settings will also display vertical signatures. Compare the drawn signatures to those in Appendix A.

Exercise 4: Effects of changing range voltage on inductive signatures

1. Connect the Tracker test leads to L1 (680uH) and set the Tracker resistance range to 100Ω. An elliptical inductive signature should be displayed on the Tracker.
2. Change the Tracker voltage range to 3V and observe the signature. Change the voltage range to 5V and observe the change.

Note that the signature changes very little when voltage is varied. The inductive reactance across the test leads remains relatively unchanged compared to the internal source resistance of the Tracker.

Exercise 5: Effects of changing range frequency on resistive signatures

1. Connect the Tracker test leads to L1 (680uH) and set the Tracker resistance range to 10Ω (the voltage will automatically change to 200mV). A tilted, elliptical signature should be displayed on the Tracker.
2. Change the Tracker frequency range to 20Hz. and observe the signature. Change the frequency range to 2KHz. and observe the change.

Note that the signature changes when the test frequency is varied since the inductive reactance is a function of frequency. Higher frequencies work better for testing larger inductances.

Exercise 6: Finding the correct range for an inductor

1. Connect the Tracker test lead to pin 3 and the common lead to pin 2 of the K1 relay. These are the connections for the wire coil internal to the relay component.
2. Set the Tracker voltage to 200mV.
3. Adjust the Tracker resistance and frequency range settings to what you feel is the best signature. Aim for an elliptical shape that exhibits a resistive tilt. Indicate your range settings below.

Resistance:

Frequency:

Compare your range settings to those listed in Appendix A. The value of the inductor internal to the relay is higher than the inductors L1 and L2 tested previously.

4-3 Review for inductive signatures

- The signature of an inductor will display an elliptical or circular signature because the relationship between voltage and current in an inductive circuit is out of phase. The signature will typically display a resistive tilt caused by the resistance of the wire used to construct the component.
- As the internal Tracker test resistance changes, the reactive load across the test leads changes in relation to the internal source resistance and will cause the displayed signature to change.
- As test frequency increases, the signature will become more horizontal due to increasing inductive reactance within the inductor being tested. High frequencies work best for large inductor values while low frequencies work well for small inductor values. Use the information presented in table 4-1 as guide for the minimum and maximum limits that the Tracker can display usable signatures.

Tracker range settings	Inductive value
10 Ω , 20Hz	50uH
100K Ω , 2KHz.	10+ H

Table 4-1 Min/Max. Capacitance Values

- Because inductors come in various types and values and can exhibit wide varieties of signature distortion, troubleshooting inductive components is best accomplished using A channel versus B channel comparisons.

Section 5 Testing Diodes

5-1 Introduction

Diodes semiconductors are the basic building block of all other semiconductors (i.e. transistors, integrated circuits). Diodes are formed by creating a junction between P-type and N-type semiconductive materials. The resulting component exhibits polarity and will conduct electrical current in one direction but not the other. Current flows in a diode when the voltage on the positive terminal (anode) is more positive than the negative terminal (cathode). This characteristic is reflected in the Tracker signature displayed. A typical diode signature is shown in figure 5-1.

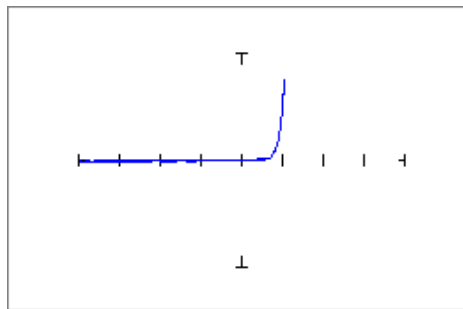


Figure 5-1 Diode Construction and Typical Diode Signature (shown on Huntron Workstation display)

Diode signatures reflect the basic nature of a semiconductor junction. There is a threshold voltage at which the diode begins to conduct, typically 0.6V for a silicon based component. As long as the anode to cathode voltage differential remains below the threshold, the diode will act as an open circuit. As the anode to cathode voltage increases positively the diode will begin to conduct. Once the current flow begins, very small increases in anode voltage will cause very large increases in current flow. This is called the “knee” effect and is characteristic of a good semiconductor junction. The knee effect is reflected in the Tracker signature between the horizontal and vertical portions of the signature. This may also be referred to as the “breakdown” point.

The graticule of the Tracker display is divided into divisions. Each side from the center has four divisions. The left side is negative voltage and the right side is positive voltage. Refer to figure 5-2.

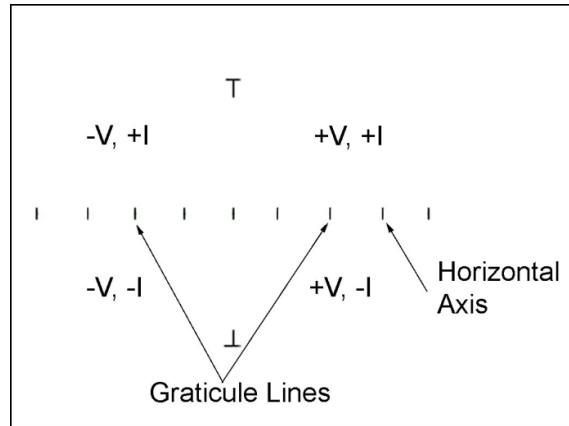


Figure 5-2 Tracker Graticule display

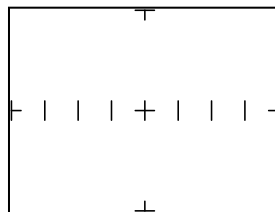
As an example, if the Tracker is set to 3V this means that the left side from center to the far left edge of the graticule is -3V. The center to the far right edge of the graticule is +3V. Dividing the voltage by four (the number of divisions on each side) will provide the “volts per division” value. In this example the volts per division would 3V divided by 4 which equals 0.75V. With this knowledge, you can calculate the voltage at which a diode will breakdown by observing where the diode conducts in relation to the graticule division marks.

5-2 Diode Signatures and Breakdown Voltage (V_{bd})

The following exercise will illustrate how a diode signature is displayed on the Tracker display and how to calculate the diode breakdown voltage.

Exercise 1: Typical diode signature and breakdown voltage

1. Set up your Tracker to test (See section 1-3).
2. Set the Tracker range settings to 3V, 100 Ω , 200Hz.
3. Connect the Tracker Common lead to the GND post on the Tracker Training Board.
4. Hold the channel A Tracker test lead to the right side pad of D1 labeled “A” (for anode).
5. Draw the signature in the signature box labeled Diode D1 and calculate the positive and negative breakdown voltages (V_{-bd} and V_{+bd}).



Diode D1

D1 V_{-bd} :

D1 V_{+bd} :

The Huntron Tracker 2700, Tracker 2800, Tracker 3200S and the Huntron Workstation software have a feature called SigAssist™. SigAssist will try to calculate breakdown voltages based on the signature shape. To use SigAssist on the Tracker 2700, Tracker 2800 or Tracker 3200S, use the LCD menus to enable the “Values” display. In Huntron Workstation, you can right-click the displayed signature and select “SigAssist” from the menu.

Breakdown voltage can also be calculated visually by observing where the breakdown point occurs on the horizontal axis. In Exercise 1, the Tracker voltage range was set to 3Vpk. This means that the voltage from the center of the graticule to the left or right edge is 3Vpk (see figure 5-3).

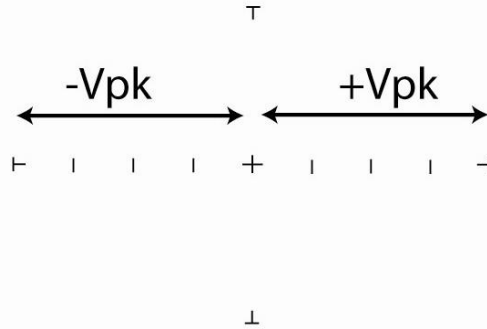


Figure 5-3 Tracker graticule

There are four divisions to each side of the graticule center (0.0Vpk) so if the peak voltage is divided by four, the voltage per division can be calculated. In this exercise the volts per division would be: $3V_{pk}/4 = 0.75V$ per division. The signature of D1 shows the breakdown point occurring slightly before the first division mark so the visual breakdown voltage is roughly 0.6-0.7Vpk.

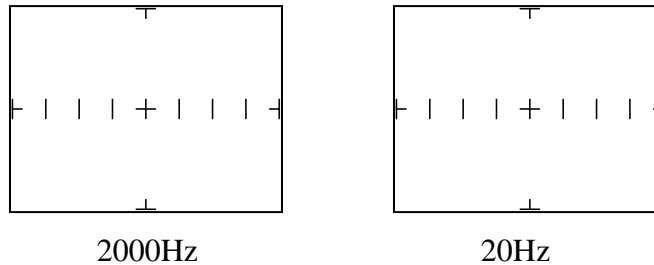
5-3 Effects of Changing Tracker Settings on Diode Signatures

The following exercises illustrate how a diode signature changes in response to variation of Tracker frequency, resistance and voltage settings.

Exercise 2: The effects of changing frequency

1. Set the Tracker range settings to 3V, 100 Ω , 200Hz.
2. Connect the Tracker channel A test lead to the diode D1 (right side pad) and observe the signature.
3. Change the Tracker frequency to 2000Hz and draw the signature in the box labeled 2000Hz.
4. Change the frequency to 20Hz and draw the signature in the box labeled 20Hz.

Changing Frequency – diode D1 signatures

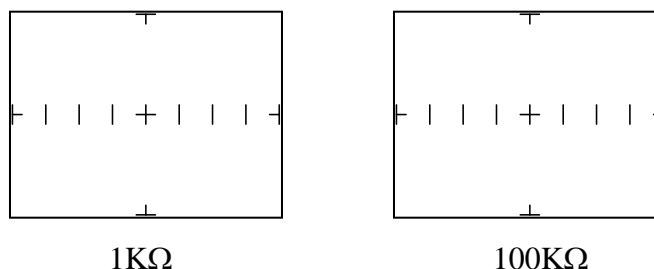


Note that the signature changes very little when changing from the Tracker's highest frequency to its lowest. The voltage characteristics inherent to a diode are not sensitive to changes in Tracker frequency. Compare the drawn signatures to those shown in Appendix A.

Exercise 3: The effects of changing resistance

1. Set the Tracker range settings to 3V, 100 Ω , 200Hz.
2. Connect the Tracker channel A test lead to the diode D1 (right side pad) and observe the signature.
3. Change the Tracker resistance to 1K Ω and draw the signature in the box labeled 1K Ω .
4. Change the resistance to 100K Ω and draw the signature in the box labeled 100K Ω .

Changing Resistance – diode D1 signatures

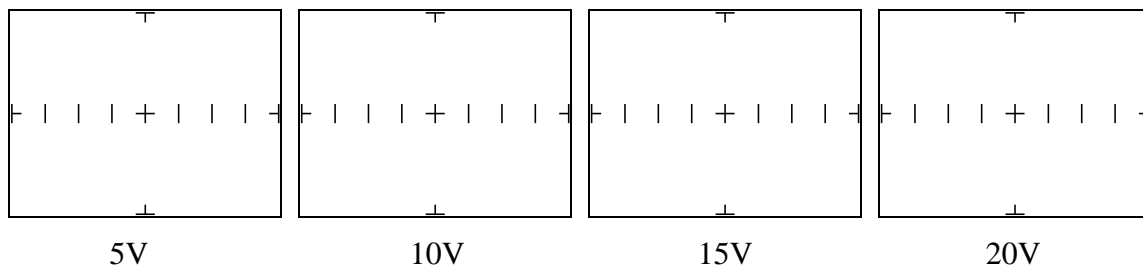


Note that the signature changes very little when the Tracker resistance is varied from a low setting to a high setting. The slight variation observed is due to the change in available current from the Tracker. Since a diode has either very high or very low resistive characteristics depending on the voltage potential across the component, changing the Tracker resistance setting will have little effect. Compare the drawn signatures to those shown in Appendix A.

Exercise 4: The effects of changing voltage

1. Set the Tracker range settings to 3V, 100 Ω , 200Hz.
2. Connect the Tracker channel A test lead to the diode D1 (right side pad) and observe the signature.
3. Change the Tracker voltage to 5V and draw the signature in the box labeled 5V.
4. Change the Tracker voltage to 10V and draw the signature in the box labeled 10V.
5. Change the Tracker range to 15V, 1K Ω and draw the signature in the box labeled 15V.
6. Change the Tracker range to 20V (and 20K Ω if using Workstation) and draw the signature in the box labeled 20V.

Changing Voltage – diode D1 signatures



Note that the signature appears to change its breakdown point but actually the horizontal voltage scale is changing. As the voltage increases, the volts per division increases making the diode signature change. In the top voltage of 20Vpk the volts per division is 5V. Compare the drawn signatures to those shown in Appendix A.

5-4 Diode Failures

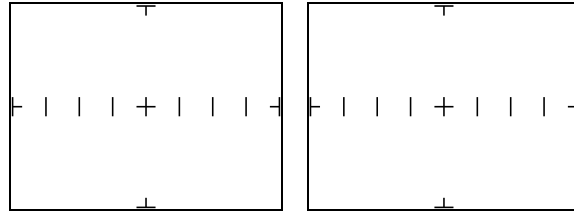
Other than open or short circuits, semiconductor failures are generally resistive in nature. On the Huntron Tracker Training Board, diode faults can be simulated by adding resistors in parallel or series to simulate diode leakage or internal resistance problems.

Exercise 5: Simulating Internal Resistance in a Diode

1. Set the Tracker range settings to 3V, 10K Ω , 200Hz.
2. Connect the Common test lead to the left side pad of resistor R8 in the Combinations section of the Tracker Training Board.
3. Connect the Tracker channel A to the pad to the right of diode D3 in the Combinations section.

4. Observe and draw the signature display in the box labeled Internal Resistance
5. Move the Common test lead to the right side pad of resistor R8 and draw the signature in the box labeled No Internal Resistance.

Simulated Internal Resistance failure



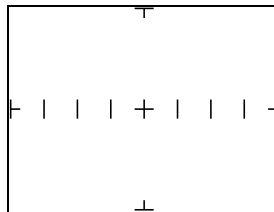
Internal Resistance No Internal Resistance

Note that the vertical portion of the first signature is angled indicating the presence of internal resistance (in this case a series resistor). The vertical portion of the signature returns to normal in the second signature when the series resistor is removed from the circuit. Compare the drawn signatures to those shown in Appendix A.

Exercise 6: Simulating Leakage in a Diode

1. Set the Tracker range settings to 3V, 10KΩ, 200Hz.
2. Connect the Common test lead to the left side pad of resistor R9 in the Combinations section of the Tracker Training Board.
3. Connect the channel A lead to the pad to the right side of D4.
4. Observe and draw the signature display in the box labeled Diode Leakage.

Simulated Diode Leakage failure



Diode leakage

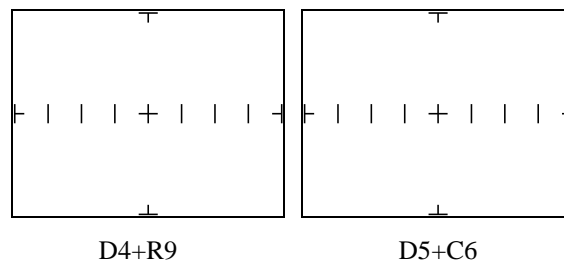
Note that the horizontal portion of the signature is angled indicating the presence of diode leakage (in this case simulated by adding a 10KΩ resistor in parallel). This signature indicates that there is current flow through the device when it should be in a non-conducting state. Compare the drawn signature to those shown in Appendix A.

5-5 Composite Diode Signatures

Signatures that exhibit characteristics of several different types of components that are interconnected are called composite signatures. For example, a diode in parallel with a resistor (as experienced in the last exercise) will display a composite signature because characteristics of both a semiconductor and a resistor are shown in the signature. Composite signatures are more indicative of the signatures experienced in the “real world” of in-circuit troubleshooting.

Exercise 7: Parallel Diode combinations

1. Set the Tracker range settings to 3V, 10K Ω , 200Hz.
2. Connect the Tracker Channel A test lead to the right side pad of the diode D4 + R9 component (parallel) combination in the Combinations section of the Training Board. Place the Common probe of the left side pad of the same circuit. Observe and draw the signature displayed in the box labeled D4+R9.
3. Change the Tracker resistance setting to 100 Ω .
4. Move the Tracker Channel A probe to the right side pad of the diode D5 + C6 component combination in the Combinations section of the Training Board. Place the Common probe of the left side pad of the same circuit. Observe and draw the signature displayed in the box labeled D5+C6.



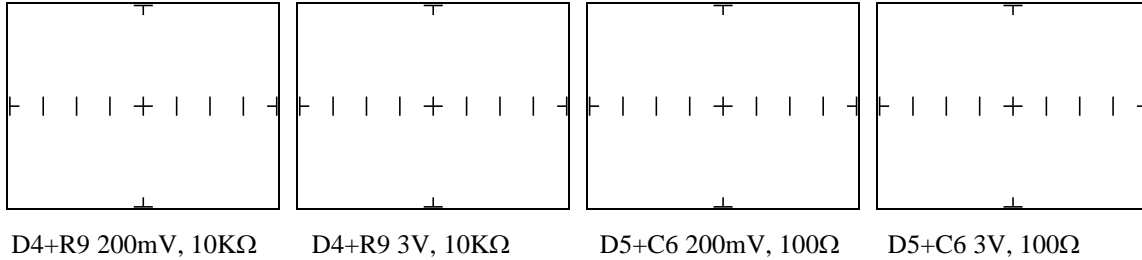
By viewing the signature progression as components are added in parallel with D4 or D5, you can see the effect of added resistance or capacitance on the horizontal portion of the signature. These types of signatures are common when troubleshooting components while in-circuit. Compare the drawn signatures to those shown in Appendix A.

To illustrate the strength of variable ranges in the Tracker to enhance or retard various portions of a composite signature try the following exercises.

Exercise 8: Adjusting Range with Parallel Diode combinations

1. Lower the Tracker voltage setting to 200mV and change the resistance to 10K Ω . Observe and draw the signature of the D4 + R9 combination in the box labeled D4+R9 200mV, 10K Ω .
2. Change the Tracker voltage setting to 3V. Observe and draw the signature in the box labeled D4+R9 3V, 10K Ω .
3. Change the Tracker voltage to 200mV and the resistance setting to 100 Ω and place the probes across the D5 + C6 circuit. Observe and draw the signature in the box labeled D5+C6 200mV, 100 Ω .

- Change the Tracker voltage setting to 3V and place the probes across the D5 + C6 circuit. Observe and draw the signature in the box labeled D5+C6 3V, 100Ω.



These steps illustrate how by manipulating the Tracker range settings, signatures of the parallel components can be examined individually or in combination. Steps 1 and 3 are examples of “passive” testing where the test voltage is set below the 0.6V breakdown threshold of most silicon semiconductors. This essentially takes the diode out of the signature equation. Also observed is the method where by changing the resistance setting, the individual capacitor and resistor signatures can be isolated. An example of this is shown in the D4+R9 200mV, 10KΩ signature where the resistor is clearly displayed with little effect from the parallel diode. Compare the drawn signatures to those shown in Appendix A.

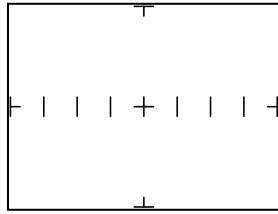
5-6 Zener Diodes

Standard diodes conduct when forward biased only and act as an open when reversed biased.

A zener diode is designed to conduct current when both forward and reversed biased. When forward biased it acts much like a standard diode and begin to conduct current with the forward voltage reaches approximately 0.6V. When reversed biased, they act as an open until the reverse voltage reaches their rated zener voltage at which time they begin to conduct current. For example, a 5V zener diode will begin to conduct reverse current when the reverse bias voltage reaches 5V. Even if the voltage increases higher than 5V, the measured voltage drop across the component will remain at 5V. This is a feature of zener diodes that allows them to be used as voltage regulators. Because they conduct in both directions, expect their Tracker signature to display two breakdown points or “knees”.

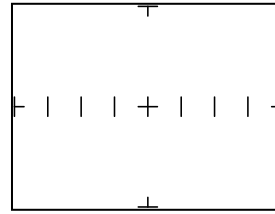
Exercise 9: Zener diode signatures

- Set the Tracker ranges settings to 10V, 10KΩ, 200Hz.
- Connect the Tracker channel A test lead to the right side pad (pad C1) of zener diode D2 and the Common lead to the left side pad (A).
- Observe and draw the signature displayed in the box labeled zener diode D2. Also, based on information presented in exercise 1 of this section, visually calculate the reverse breakdown voltage and enter the value in the field labeled D2 V-bd.
- Move the Common lead to the other right side pad of zener diode D2 (pad C2). Observe and draw the signature displayed in the box labeled zener diode D2 (C1+C2) and visually calculate the reverse breakdown voltage and enter the value in the field labeled D2 (C1+C2) V-bd.



Diode D2

D2 V-bd:



Diode D2 (C1+C2)

D2 (C1+C2) V-bd:

Note that the signature displayed has two voltage breakdown points. This type of signature is commonly referred to as a “zener pattern” or “zener signature”. Zener signatures are the most common type of signature encountered when testing integrated circuits (ICs). The signature of D2 (C1+C2) is actually two zener diodes in series essentially combining the voltage their ratings.

5-7 Review for Diode Signatures

- The signature of a diode will display a forward breakdown point referred to as a “knee”. Zener diodes will have both a forward breakdown point and a reverse breakdown relating to its rated voltage.
- Diodes have polarity with the positive connection being the anode and the negative connection being the cathode. The signature will reverse if the component or test leads are reversed.
- Failures in diodes and other semiconductive components are usually resistive in nature. These faults usually require setting the Tracker resistance range to a higher value such as 10KΩ. In some cases, the failure may appear as a rounding of the “knee”.
- The horizontal graticule can be used to approximate the breakdown voltage of a diode. Divide the Tracker voltage setting by 4 to determine the horizontal volts per division.
- The flexibility of the Tracker ranges allows for enhancing and retarding parts of a composite signature for components being tested in-circuit.

Section 6 Testing Transistors

6-1 Introduction

A bipolar junction transistor is a three layer device of which there are two types. A PNP transistor has a layer of N type material inserted between two layers of P type material. A NPN transistor has a layer of P type material inserted between two layers of N type material. Figure 6-1 below illustrates their construction and also shows the schematic symbol used to represent both PNP and NPN transistors.

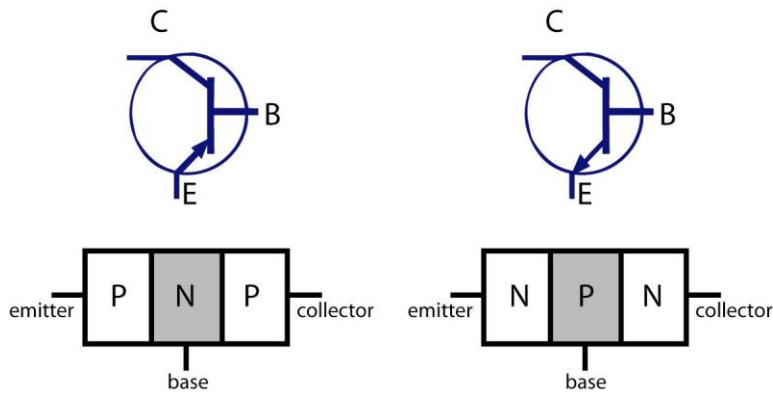


Figure 6-1 Transistor construction

In order to better understand the nature of transistor signatures we can model these devices in the terms of equivalent diode circuits shown in figure 6-2. This diagram shows the collector to base junction appears as a simple diode signature and the base to emitter junction appears as a zener diode signature. These signatures should be familiar to you from the previous section on diodes.

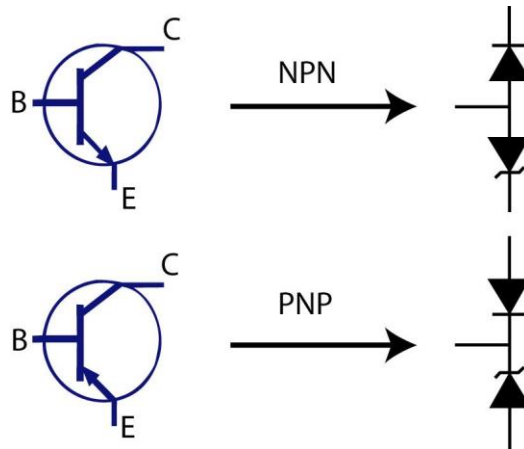


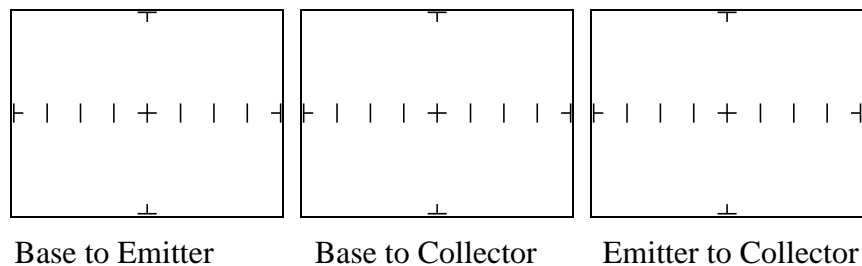
Figure 6-2 Transistor equivalent circuits

6-2 PNP and NPN Transistor Signatures

The following exercise will illustrate how NPN and PNP transistor signatures are displayed on the Tracker.

Exercise 1: Typical transistor signatures - PNP

1. Power on the Tracker.
2. Connect the Tracker Common lead to the base (B) lead on transistor Q1 on the Tracker Training Board.
3. Set the Tracker range settings to 10V, 1K Ω , 200Hz.
4. Hold the channel A Tracker test lead to the emitter (E) lead on Q1.
5. Draw the signature in the signature box labeled Base to Emitter.
6. Move the channel A Tracker test lead to the collector (C) lead on Q1. Draw the signature in the box labeled Base to Collector.
7. Move the Tracker common lead to the collector lead on Q1. Move the channel A Tracker test lead to the emitter lead. Draw the signature in the box labeled Emitter to Collector.

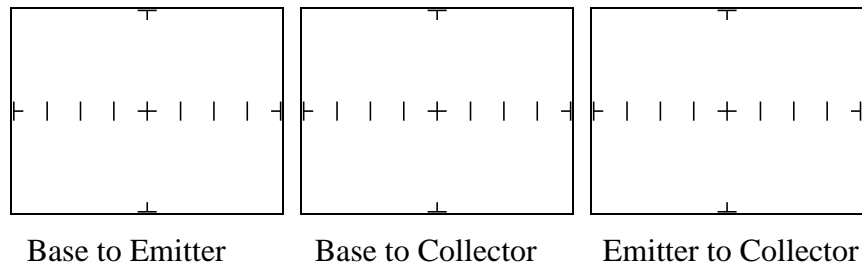


Note that the signatures displayed in Exercise 1 reflect the equivalent PNP circuit shown in figure 6-2. Also note that the reverse breakdown point shown on the emitter to collector signature is the same as the reverse breakdown for the base to emitter signature.

Exercise 2: Typical transistor signatures - NPN

1. Connect the Tracker Common lead to the base (B) lead on transistor Q2 on the Tracker Training Board.
2. Set the Tracker range settings to 10V, 1K Ω , 200Hz.
3. Hold the channel A Tracker test lead to the emitter (E) lead on Q2.
4. Draw the signature in the signature box labeled Base to Emitter.
5. Move the channel A Tracker test lead to the collector (C) lead on Q2. Draw the signature in the box labeled Base to Collector.

6. Move the Tracker common lead to the collector lead on Q2. Move the channel A Tracker test lead to the emitter lead. Draw the signature in the box labeled Emitter to Collector.



Note that the signatures displayed reflect the equivalent NPN circuit shown in figure 6-2 and are opposite in polarity when compared to the signatures observed in Exercise 1. Also note that the reverse breakdown point shown on the emitter to collector signature is the same as the reverse breakdown for the base to emitter signature.

6-3 Using the Pulse Generator or DC Voltage Source to Test Transistor Operation

Trackers with a DC Voltage Source or Pulse Generator can be used to assist in testing transistor operation. Functioning as a basic curve tracer, voltage is applied to the base of the device while monitoring the collector-emitter signature shown on the Tracker display. The constant current signature produced is similar to those 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 testing function and matching transistor gain. Figure 6-3 shows the test circuit for a NPN transistor using the DC voltage source to drive the base.

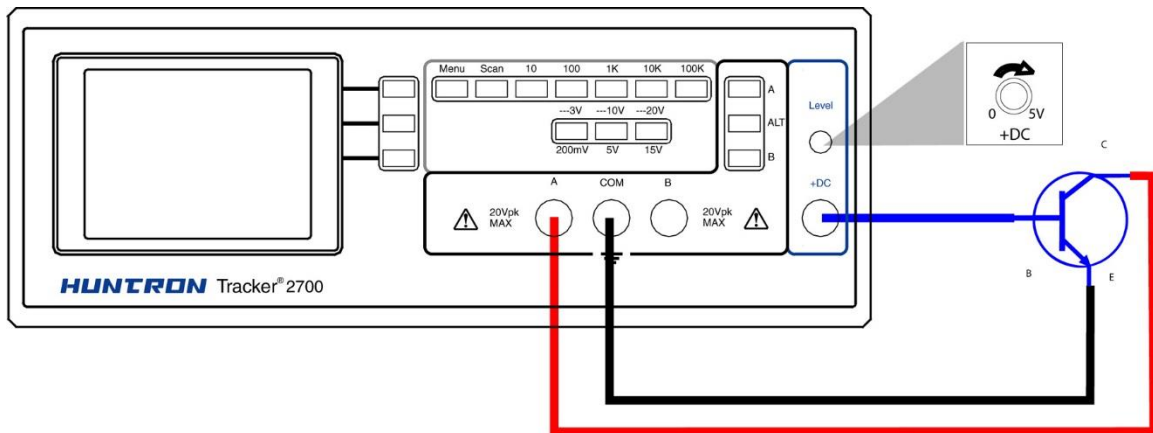


Figure 6-3 Testing a transistor with a DC Voltage Source (Tracker 2700 shown)

Exercise 3: Displaying transistor gain

1. Setup the test circuit as shown in figure 6-3 connecting the DC voltage source or Pulse Generator to the base of Q2, channel A to the emitter and common to the collector.
2. Set the Tracker range settings to 5V, 100 Ω and 200Hz.
3. For Trackers that use a Pulse Generator, set the type to DC and the polarity for +. Very slowly increase the DC voltage. Observe the signature reaction on the Tracker display. Note that as the voltage to the base increases the impedance of the emitter-collector connection decreases.

6-4 Review for Transistor Signatures

- The signatures of a transistor will display a forward breakdown point and a reverse breakdown point.
- Transistors have polarity and the signatures will reverse if the component or test leads are reversed. NPN and PNP transistors will display signatures that exhibit reversed polarity when compared to each other.
- Failures in transistors and other semiconductive components are usually resistive in nature. These faults usually require setting the Tracker resistance range to a higher value such as 10K Ω . In some cases, the failure may appear as a rounding of the “knee”.
- Trackers can be used to determine transistor type (bipolar, Darlington, etc.), polarity (PNP or NPN), or pin configuration (base, emitter, collector) and also be used as a basic curve tracer for matching transistor pairs.
- The flexibility of the Tracker ranges allows for enhancing and retarding parts of a composite signature for components being tested in-circuit.

Section 7 Testing the Operation of Switching Devices

7-1 Introduction

Switches are electrical devices that either stop or allow current flow within a circuit. In the world of electronics, “switching” is often referred to as a basic function that can be performed by a variety of devices. All of these devices are similar in that they are either on or off. They are different because of the way they are turned on or off.

Switching devices come in many different configurations from simple mechanical switches such as relays to semiconductive devices such as optocouplers or SCRs. Because of this variety of switching devices, each type is tested in a unique way. Using a Tracker to test switching devices allows us to ignore the differences and concentrate more on the switching function itself. This section will explore how different switching devices are tested and also how the DC voltage source or Pulse Generator can be used to gate these devices.

7-2 Testing Switch Devices with the DC Voltage Source or Pulse Generator

Many switching devices are voltage controlled. Devices such as relays respond to a changing voltage to turn the switch on and off. Semiconductive switches such as SCRs and TRIACs respond to voltages above a certain level to activate the switching function. All of these types of devices can be tested dynamically using the Tracker DC Voltage Source or Pulse Generator to apply a control voltage that will activate the switching function.

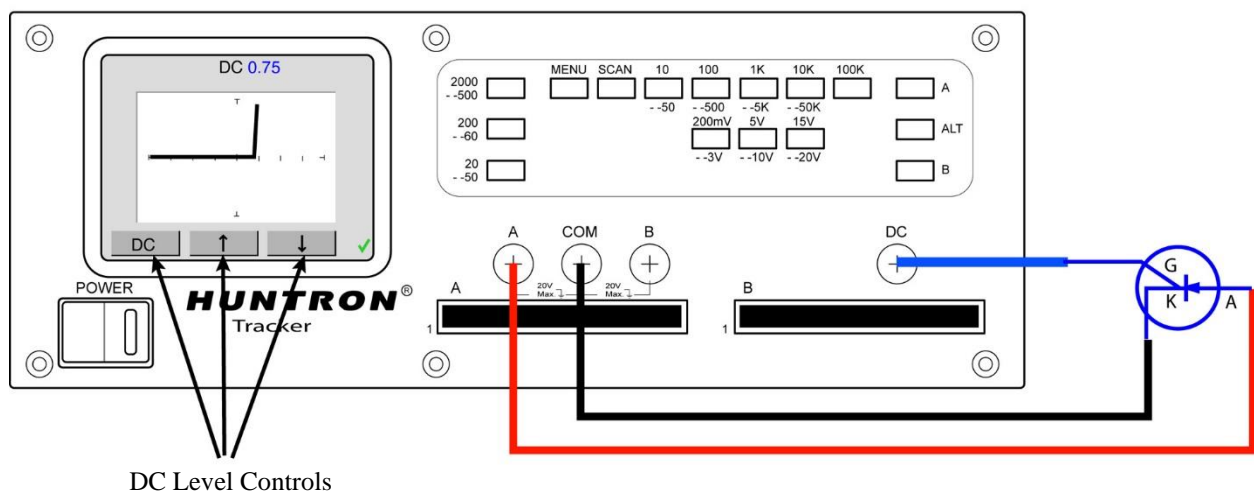
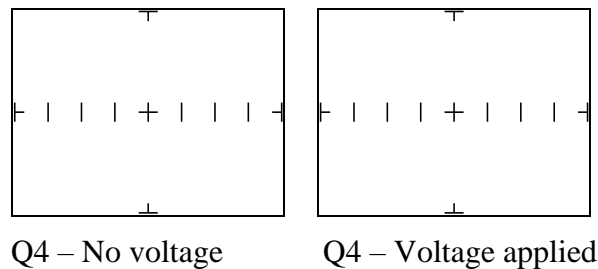


Figure 7-1 Testing a SCR with a Tracker (Tracker 2800S shown)

Exercise 1: Testing a Silicon Controlled Rectifier (SCR)

1. Set the Tracker range settings to 5V, 100Ω, 200Hz.
2. Connect the Tracker Common lead to connection K (cathode) of SCR Q4.
3. Connect the channel A Tracker test lead to connection A (anode) on SCR Q4.
4. Connect a lead from the DC Voltage Source or Pulse Generator (set to + DC output) connection on the Tracker to connection G (gate) on SCR Q4. Draw the signature displayed in the box labeled “Q4- No voltage”.
5. Slowly increase the DC Voltage until you see the signature change. Draw the signature displayed in the box labeled “Q4 – Voltage applied”.



Silicon controlled rectifiers are essentially a voltage controlled diode. If the gate is at the same voltage level as the cathode then the SCR acts as an open. When the voltage level applied to gate is more positive than the cathode (typically at 0.6V), current flows between the anode and cathode.

Testing a TRIAC is very similar to the SCR test with the exception that you see the cathode to anode signature bias in two directions (similar to a zener diode). This because a TRIAC is a bidirectional switched device.

Exercise 2: Testing a Relay

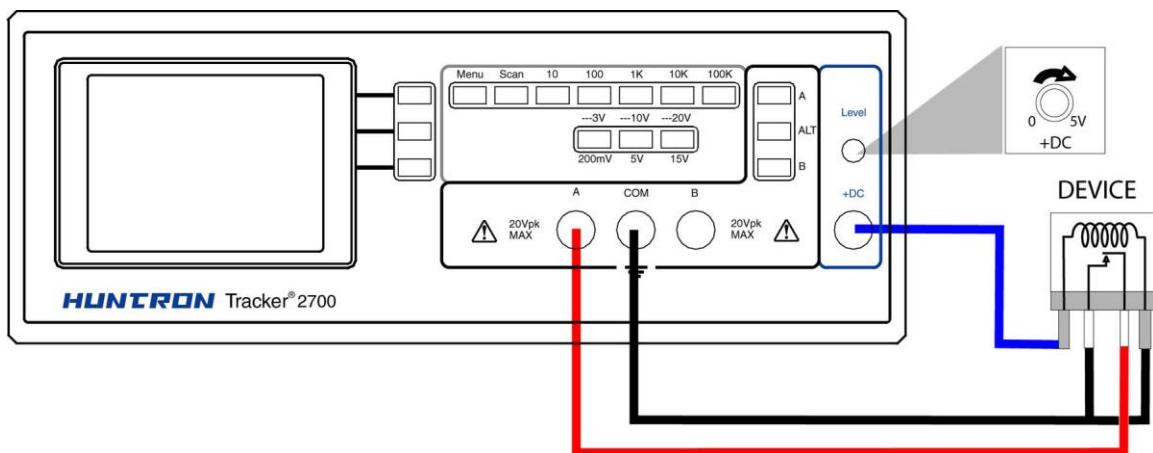


Figure 7-2 Testing a Relay with the Tracker voltage source (Tracker 2700 shown)

1. Connect the Tracker Common lead to the GND connection on the bottom center portion of the Tracker Training Board.
2. Set the Tracker range settings to 5V, 100Ω, 200Hz.

3. Connect the channel A Tracker test lead to pin 4 of the K1 relay.
4. Connect a lead from the +DC or Pulse Generator (set to + DC output) on the Tracker front panel to pin 2 on the K1 relay.
5. Slowly rotate the DC Voltage source knob until you see the signature change.

Note that the signature becomes a short circuit when the voltage is increased enough to activate the mechanical switch. The voltage level that activates the relay can vary depending on component design. This relay is “normally open” meaning that the switch contacts are in an open position when the device is in a non-powered state. “Normally closed” relays will show a short circuit signature across the switch contacts when in a non-powered state. The voltage level necessary to activate a relay will vary depending on the construction of the device.

Exercise 3: Testing an Optocoupler (optical switch)

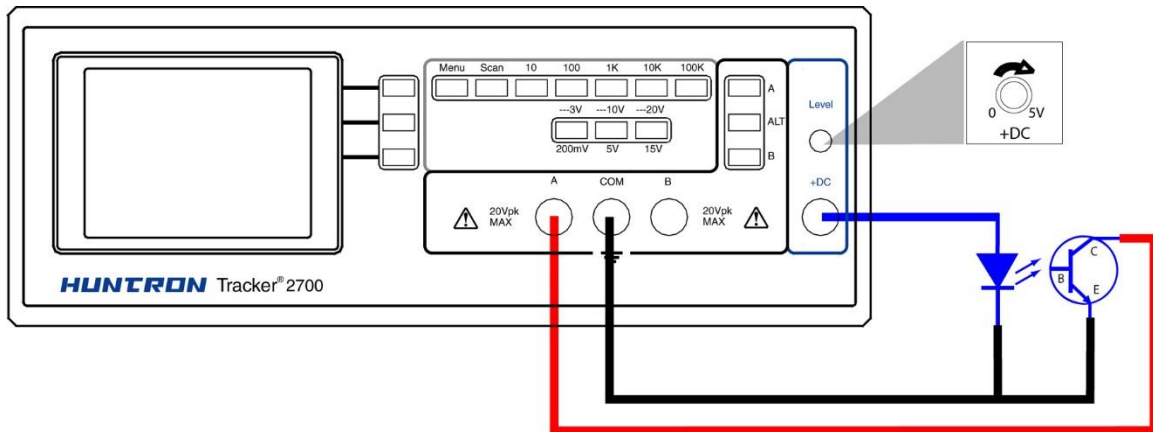
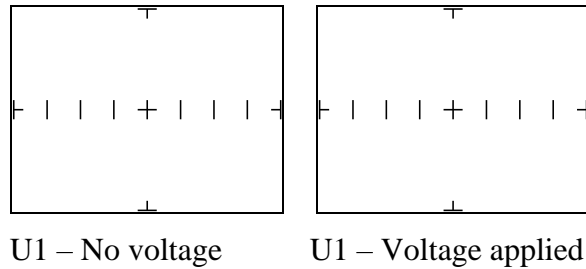


Figure 7-3 Testing an optocoupler with a DC Voltage source (Tracker 2700 shown)

1. Connect the Tracker Common lead to the GND connection on the bottom center portion of the Tracker Training Board.
2. Set the Tracker range settings to 5V, 100Ω, 200Hz.
3. Connect the channel A Tracker test lead to pin 6 of the U1 optocoupler.
4. Connect a lead from the +DC or Pulse Generator (set to + DC output) connection on the Tracker front panel to pin 1 on the U1 optocoupler. Draw the signature displayed in the box labeled “U1 – No voltage”.
5. Increase the DC voltage to 5VDC. You should see the signature change. Draw this signature in the box labeled “U1 – Voltage applied”.



When the voltage applied by the DC Voltage source reaches a certain level the optocoupler will bias and the signature will change. Also note that the optocoupler reacts in a similar way to the common transistor in part 6-3 of the Testing Transistors section.

7-3 Review for Switching Devices

- Trackers will test switches in real time. This makes it an excellent method for detecting noise, contact bounce, resistance and intermittent contact. Test for these types of problems in a low resistance setting such as 10Ω.
- Testing SCRs and TRIACs can sometimes be problematic. Utilizing the DC voltage source or pulse generator to bias these devices allows you to actively view their operation. Their typical application (high current switching) makes these devices high fatality components and susceptible to degradation and eventual failure.
- Relays are an electrically controlled switch that can be easily tested by using the Tracker DC voltage source or pulse generator to activate the device while monitoring the signature of the switch contacts.
- Operation of an optocoupler can be tested using the Tracker and the built-in DC voltage source or pulse generator. Optocouplers are common used to isolate parts of a circuit board and come in a wide variety of configurations.

Section 8 Testing Integrated Circuits

8-1 Introduction

One of the strongest ongoing trends in electronics today is the push towards making everything smaller. Where digital circuits were once made from discrete transistors, hundreds of these same digital circuits can be embedded on a small chip. This trend will only intensify so it is important to understand how a Huntron Tracker can be used with this type of circuitry.

8-2 Why an Integrated Circuit (IC) Fails

Nothing mysterious happens to a working semiconductor when it fails or suffers degradation. All failures affect the basic nature of these devices to conduct current. The most common causes of IC failures are:

EOS: Electrical Over Stress. The ICs electrical specifications have been exceeded. This can cause opens and shorts.

ESD: Electrostatic Discharge. Repeated exposure causes resistance to build in the device junctions. The range of resistance varies from $5K\Omega$ to $25K\Omega$ with a typical value of $20K\Omega$. ESD will cause resistance, opens and shorts.

Dendrites: Hair-like particles that grow between conductors on a substrate causing shorts.

Ionic Contamination: Contamination introduced at the time of manufacturing that develops into leakage between substrate channels. This can cause $5K\Omega$ to $25K\Omega$ of resistance.

Purple Plague: Interaction between gold and aluminum will cause junctions to become very brittle causing opens.

Corrosion or Metallization: Aluminum metallization can cause electromigration, pinholes, corrosion and resistance. This will cause opens and resistance.

8-3 Digital Integrated Circuit Signatures

Digital integrated circuits chips are made from semiconductor transistors on a common substrate. Since they are semiconductors, their signatures are variations on the basic diode and transistor signatures observed in earlier parts of this course. Most logic ICs contain multiple circuits of the same type on one chip. These chips often only have a few different signatures despite the fact that they may have many pins. This can make troubleshooting easier by providing easy to find signatures to use for comparison. For example, the integrated circuit schematic shown in figure 8-1 is a 74LS245 Octal transceiver or bi-directional bus buffer.

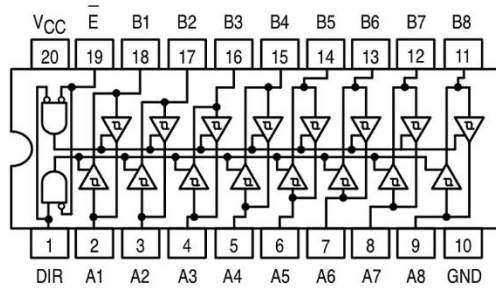


Figure 8-1 74LS245 Octal Transceiver

By examining the circuit drawing closely, four different pin types can be identified. Pins 2 through 9 and 11 through 18 are all connected to both an input and output of a buffer. Pins 1 and 19 are both enable lines and inputs to AND gates (although their names are different). Pin 10 is ground and pin 20 in Vcc. Each pin type will display a signature typical for that circuit and can be used for comparison when testing the other similar pins. For example, the signatures of the address lines A1 through A8 should all have similar signatures.

This same thought process can be used when examining the 74LS14 and 74HC14 ICs used on the Tracker Training Board.

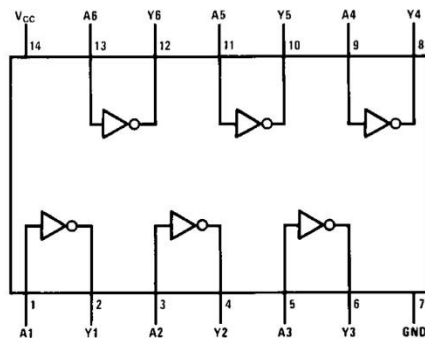
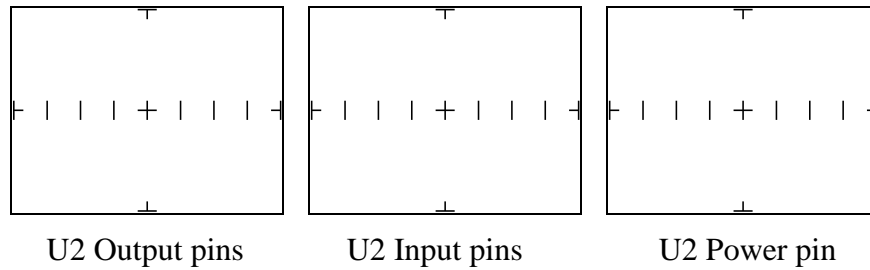


Figure 8-2 74XX14 Hex Inverter IC Pin-out

Exercise 1: Examining signatures of a logic IC

1. Connect the Tracker Common to the GND connection on the Tracker Training Board.
2. Set the Tracker range settings to 5V, 500Ω, 200Hz.
3. Using the channel A Tracker test lead, probe pins 2, 4, 6, 8, 10 and 12 (these are inverter output pins) on U2 74HC14 IC. Since they are all connected to the same type of circuit, the same signature should be displayed. Draw the signature displayed in the box labeled “U2 Output pins”.
4. Set the Tracker range settings to 5V, 10KΩ, 200Hz and probe pins 1, 3, 5, 9, 11 and 13 (these are the inverter output pins) and draw the signature observed in the box labeled “U2 Input pins”.

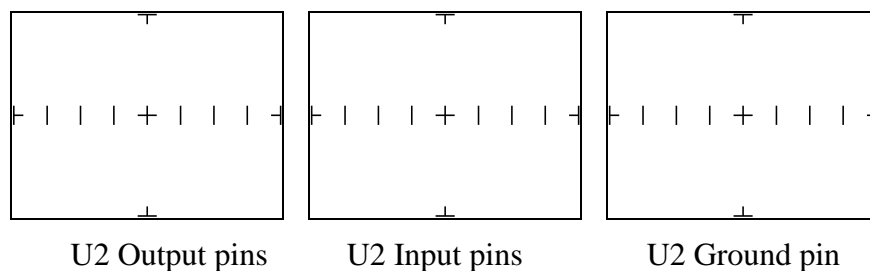
5. Probe pin 14 (Vcc). Draw the signature observed in the box labeled “U2 Power pin”.



Note that the signature patterns displayed match the circuit type shown in Figure 8-2. When troubleshooting this device, similar pins could be compared against each other.

Exercise 2: Testing TTL circuits with reference to Vcc

1. Move the Tracker Common probe to the Vcc connection near the bottom center portion of the Tracker Training Board.
2. Set the Tracker range settings to 5V, 10KΩ, 200Hz.
3. Using the channel A Tracker test lead, probe pins 2, 4, 6, 8, 10 and 12 on U2 74HC14 IC. Since they are all connected to the same type of circuit, the same signature should be displayed. Draw the signature displayed in the box labeled “U2 Output pins”.
4. Probe pins 1, 3, 5, 9, 11 and 13 and draw the signature observed in the box labeled “U2 Input pins”.
5. Probe pin 7 (GRND). Draw the signature observed in the box labeled “U2 Ground pin”.



Testing ICs with reference to Vcc may show fault differences not shown when testing with a GND reference. Though this is not common, it is possible. A good practice may be to start testing with GND as the common reference and using Vcc as a secondary alternative.

8-4 Signatures of Different IC Families

TTL is considered to be one of the primary logic IC families. However, there are other types of ICs that are not TTL but perform very similar functions. Although the logic is the same, there are several differences in the circuitry of each type and these differences are reflected in the Tracker signatures.

To examine these signature differences in logic IC circuit types, the signatures of two different hex inverters will be investigated. U2, a 74HC14, and U3, a 74LS14, are both hex inverters and have identical truth tables. Figure 8-3 shows that pin arrangement and logic functions are the same but the 74LS14 uses Schottkey transistors and has higher power consumption whereas the 74HC14 use CMOS (complementary metal-oxide-semiconductor) technology for faster switching speed and reduced power consumption.

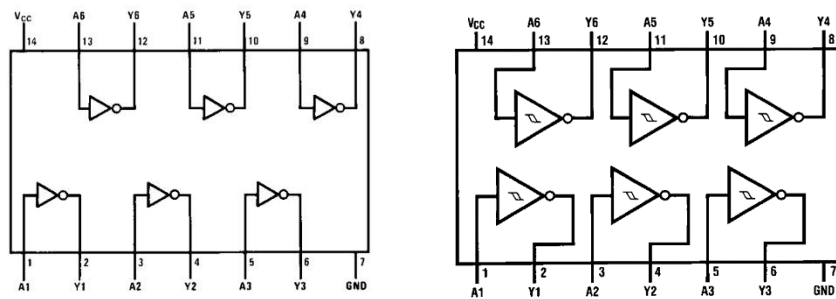
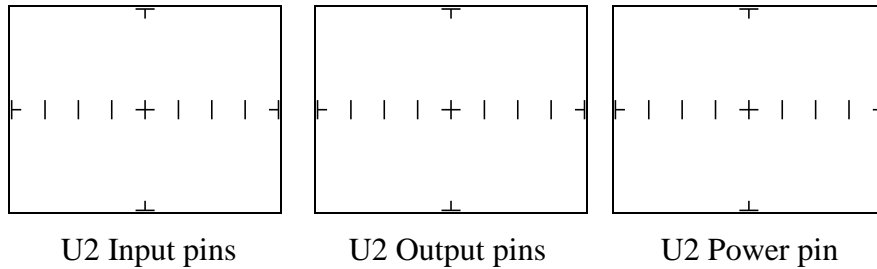


Figure 8-3 74XX14 Pin out configurations (LS on left, HC on right)

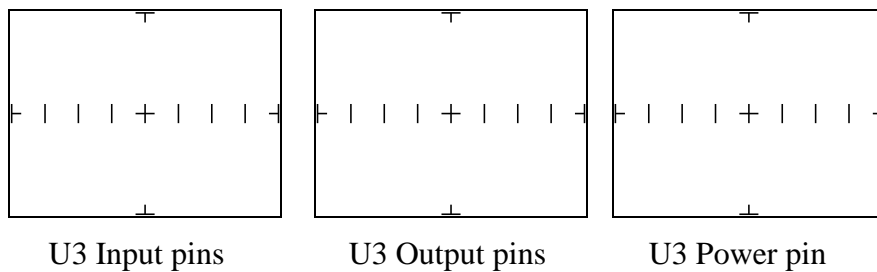
Note that there are only four types of circuit connections; input, output, power (V_{cc}) and ground. This means that there will only four types of signatures displayed when testing the individual component pins.

Exercise 3: Comparing Two Hex Inverter ICs

1. Set the Tracker range settings to 3V, 10K Ω , 200Hz.
2. Connect the Tracker Common lead to GND connection located on the bottom center portion of the Tracker Training Board.
3. Using the channel A Tracker test lead, probe U2 pins 1, 3, 5, 9, 11 and 13 noting that each pin has the same signature. Draw the signature observed signature in the box labeled “U2 Input pins”.
4. Now probe U2 pins 2, 4, 6, 8, 10 and 12 noting that each pin has the same signature. Draw the signature displayed in the box labeled “U2 Output pins”.
5. Probe pin 14 and draw the signature displayed in the box labeled “U2 Power pin”.



6. Using the channel A Tracker test lead, probe U3 pins 1, 3, 5, 9, 11 and 13 noting that each pin has the same signature. Draw the signature observed signature in the box labeled “U3 Input pins”.
7. Now probe U3 pins 2, 4, 6, 8, 10 and 12 noting that each pin has the same signature. Draw the signature displayed in the box labeled “U3 Output pins”.
8. Probe pin 14. Draw the signature displayed in the box labeled “U3 Power pin”.



Exercise 4: Use ALT mode to Compare Two ICs

Try using the ALT mode to make direct comparisons between U2 and U3.

1. Connect the COM lead to the Tracker Training Board GND connections.
2. Press the ALT button to put the Tracker into alternation mode or select ALT from the Channel menu of the Tracker tab in Huntron Workstation.
3. Use Channel A to test U2 and Channel B to test U3.

Step through the IC pins and note how the signature differences are displayed.

Because of the differences in the internal construction of the two inverter ICs, the similar pins have different signatures. To test one of these ICs without a comparison IC, one only needs to compare each input against the other input pins and each output pin against the other five output pins. The basic idea is to identify the patterns displayed in the signatures of similar pins.

8-5 Testing Analog ICs

Of all of the analog ICs in use today, operational amplifiers, commonly called “op amps” are probably the most common and present another troubleshooting challenge. Each pin can display a different signature on the Tracker. These signatures are a result of the internal architecture of the IC and the connected circuit elements.

Op amps are best tested by comparing component signatures on a bad board with those on a known good board. In conjunction with the Tracker’s ALT mode, problems can be isolated quickly.

In the next exercise, U4 will be used as the known good component for signature comparison when looking for a simulated fault on U5. U4 and U5 are LF412 op amps and are configured as shown in figure 8-4.

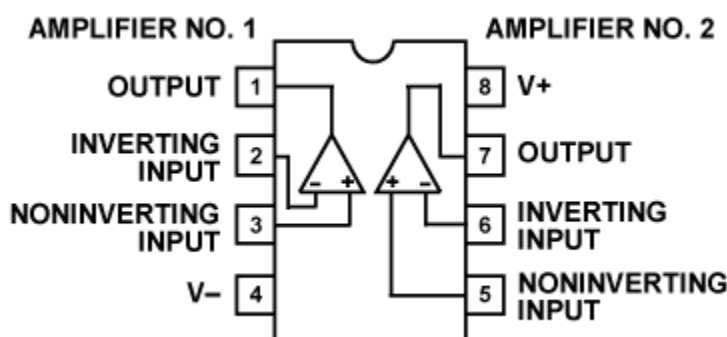


Figure 8-4 LF412 Operation Amplifier Pin configuration

Exercise 5: Op Amp signatures

1. Set the Tracker range settings to 5V, 1K Ω , 200Hz.
2. Connect the Tracker Common lead to VCC connection located on the bottom center portion of the Tracker Training Board. Connect the red probe to channel A and the black probe to channel B.
3. Set the Tracker to ALT mode by pressing the ALT button.
4. Using the red channel A probe on U4 and the black channel B probe on U5, test pin 1 on both U4 and U5. The signature on both pins should be similar.
5. Move the test probes to pin 2 on both components and compare signatures. Continue with the remaining pins until all pins have been compared. Which component and pin shows a fault?

6. How would you describe the difference in signatures on the faulty pin?

Note that similar pins have similar signatures when compared against each other.

The fault on pin 5 of U5 is caused by a resistive short to Vcc. Of course this fault is simulated by adding a 1K Ω resistor tied to the VCC line but this type of fault is indicative of the types experienced in the real world.

Op amps can also be checked using other methods that can be explored independently. One method is to test the op amp using the output pin as the common reference while making a signature comparison between the – and + pins of the device. This method works well when an op amp is isolated from power and ground. When there is more than one op amp in a package (“dual” and “quad” op amps), compare the op amps against each other looking for significant differences. This comparison technique will also work well with comparator ICs.

Another alternative worth investigation is to use the Tracker DC voltage source to functionally operate the op amp by applying voltage to the +V or –V pin while monitoring the signature on the output.

8-6 Review of Testing Integrated Circuits

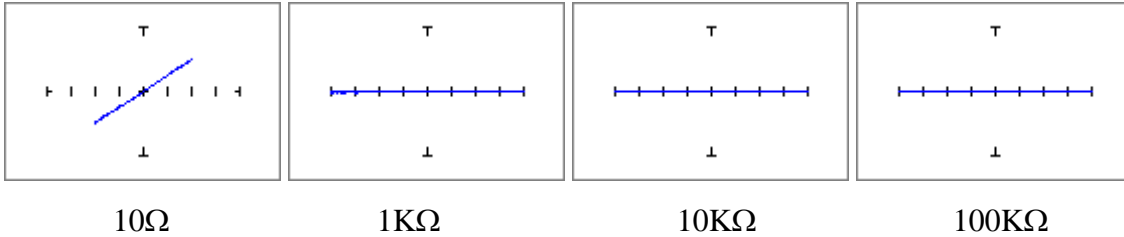
- Digital ICs can fail in several ways but the failures are generally resistive in nature. Using a resistance range setting of 5K Ω to 20K Ω will help find these types of problems.
- Having information about a digital ICs pin-out can help troubleshoot the component. In many cases, a digital IC will have only a few unique signatures such as input, output, voltage and ground pins. It is an easy task to compare similar pins against each other looking for similarities. A difference in signatures may indicate a problem.
- ICs with the same logic table but different design structure (i.e. 74LS14 versus a 74HC14) will typically show different signatures when comparing the same pins. The internal circuit construction causes these differences.
- Using the Tracker ALT (alternating) mode makes the comparison of two digital ICs quick and easy. Comparisons can be made at the pin level (i.e. comparing similar pins on the same component) or at the component level (i.e. comparing the same component on a good versus bad circuit board).
- Troubleshooting microprocessor bus circuitry can be difficult and success depends on good troubleshooting skills and ability to isolate problems to the component level. Knowledge of the board under test, a good visual inspection and using a Tracker in comparison mode will help deal with detecting problems in bus circuits.
- Comparing similar bus lines against one another can lead to a fault without having to memorize every possible signature. Address lines should exhibit the same signatures as well as data lines. If schematic diagrams are not available, find the pin-out configuration for various ICs to help determine which pins are address lines, data lines and control lines. Use the Tracker ALT mode to easily compare one bus line against the other similar lines.
- When comparing bus lines, watch for patterns that indicate whether a signature is good or suspect. Also note that if a bussed component has more than one bad signature besides a faulty bus line then that component is likely to be the actual failure.

- Begin testing complex boards by probing its connectors. In many cases, faults caused by outside influences can be detected and traced back from the connector to a faulty component.
- Treat SMT devices the same as their through-hole equivalents but realize that a lower test voltage will likely be needed to obtain a useful signature. Try testing SMT devices at 3 volts or lower.
- When attempting isolate the faulty component on a bus, it may be necessary to use a unique pin on an IC as the common reference. Pins such as chip enable, output enable, row address strobe and column address strobe are all unique bus pins.

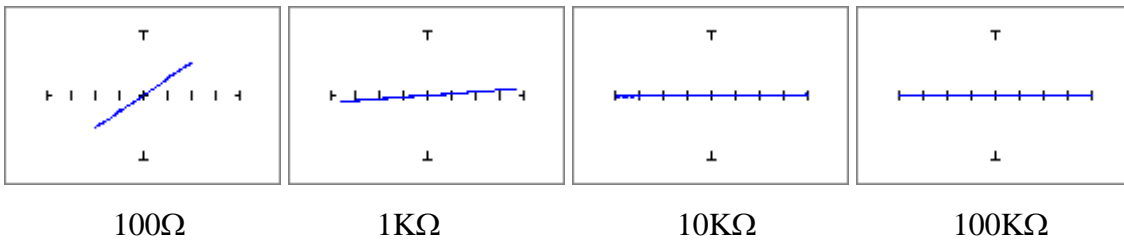
Appendix A Training Course Exercise Signatures

Section 2 Testing Resistors

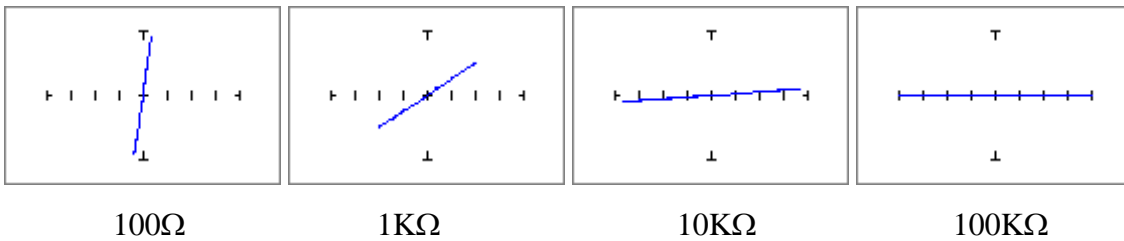
Exercise 1: Testing at the 10Ω resistance range



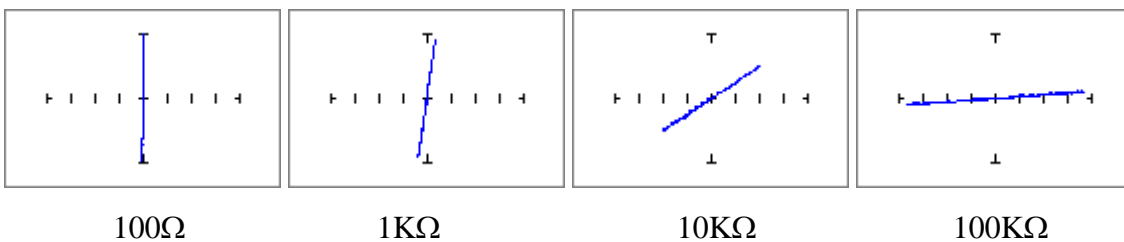
Exercise 2: Testing at the 100Ω resistance range



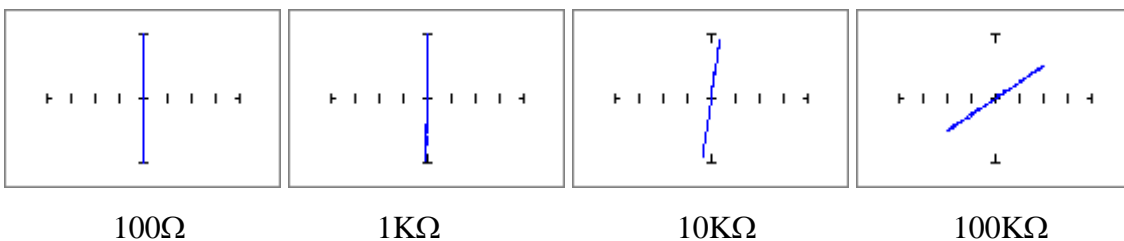
Exercise 3: Testing at the 1KΩ resistance range



Exercise 4: Testing at the 10KΩ resistance range

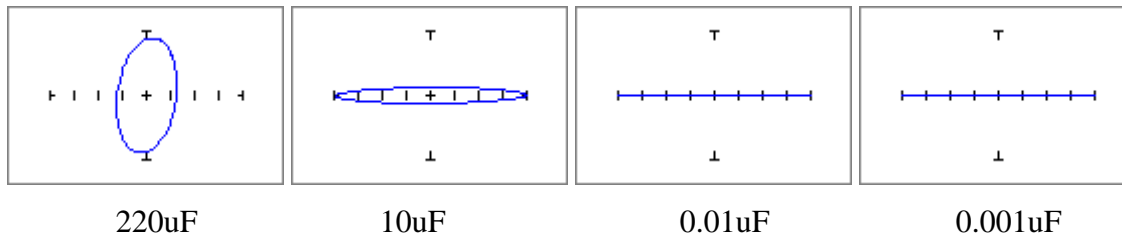


Exercise 5: Testing at the 100KΩ resistance range

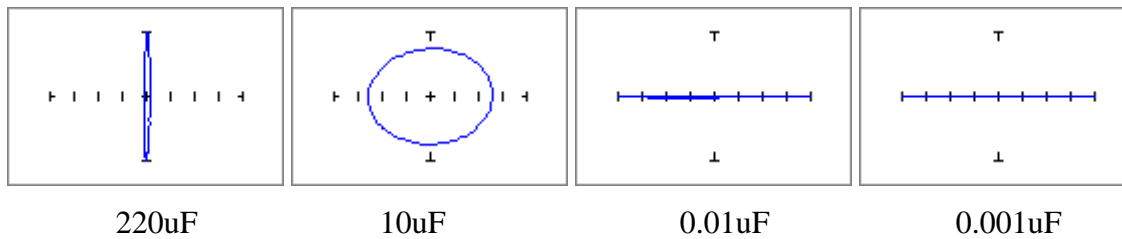


Section 3 Testing Capacitors

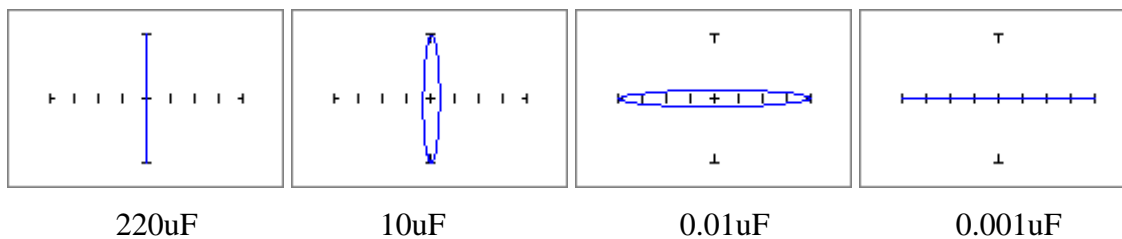
Exercise 1: Testing at the 10Ω resistance range



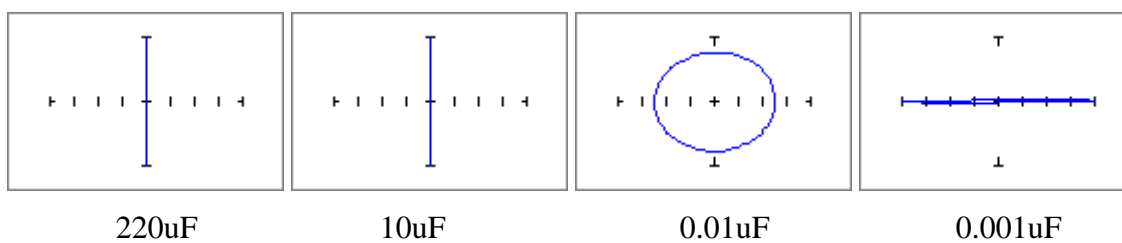
Exercise 2: Testing at the 100Ω resistance range



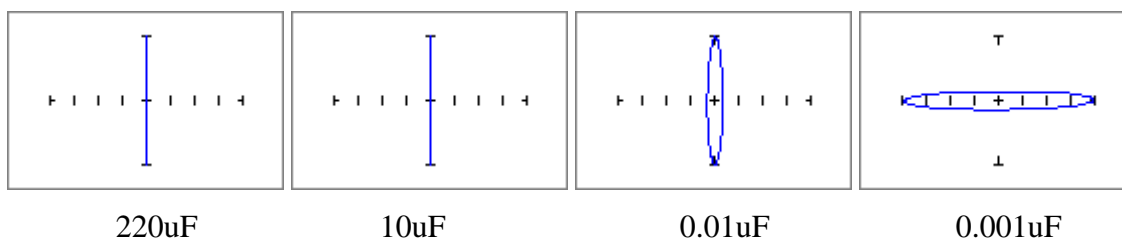
Exercise 3: Testing at the 1KΩ resistance range



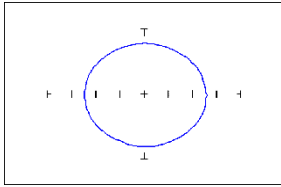
Exercise 4: Testing at the 10KΩ resistance range



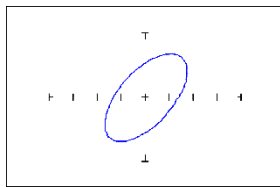
Exercise 5: Testing at the 100KΩ resistance range



Exercise 8: Simulating Capacitive Leakage (rev. C and later Training Board)



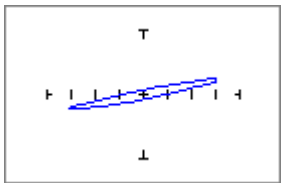
C7 - 10uF



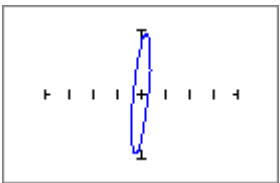
C7 - 10uF

Section 4 Testing Inductors

Exercise 1: Testing at the 10Ω resistance range

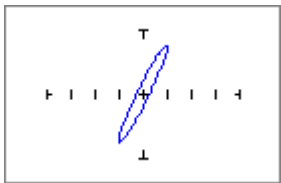


680uH

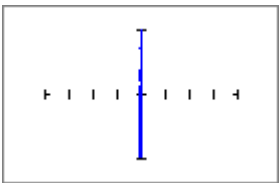


68uH

Exercise 2: Testing at the 100Ω resistance range

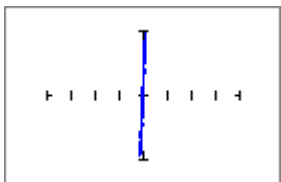


680uH

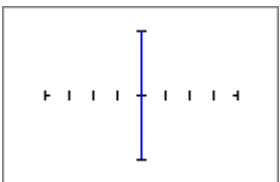


68uH

Exercise 3: Testing at the 1KΩ resistance range



680uH



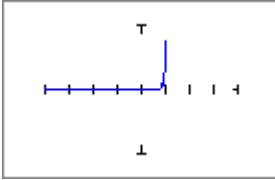
68uH

Exercise 6: Finding the correct range for an inductor

Resistance: 500Ω to 2KΩ will work well Frequency: 2KHz

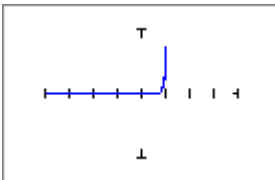
Section 5 Testing Diodes

Exercise 1: Typical diode signature and breakdown voltage

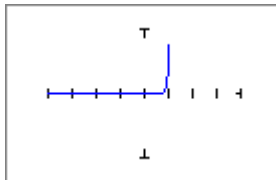


D1 V-bd: 0.0V D1 V+bd: aprox. 0.6V

Exercise 2: The effects of changing frequency

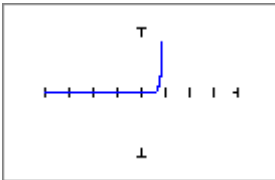


2000Hz

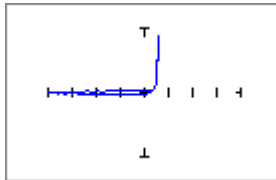


20Hz

Exercise 3: The effects of changing resistance

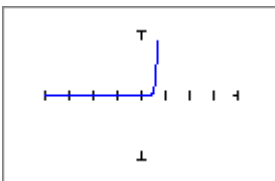


1KΩ

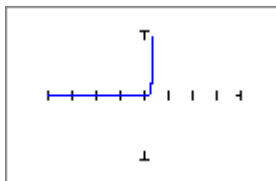


100KΩ

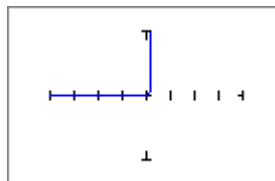
Exercise 4: The effects of changing voltage



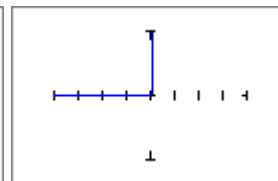
5V



10V

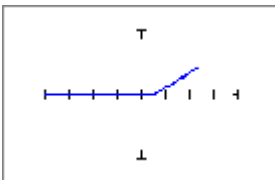


15V

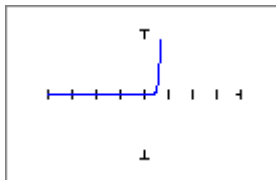


20V

Exercise 5: Simulating Internal Resistance in a Diode

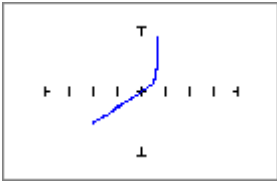


Internal Resistance



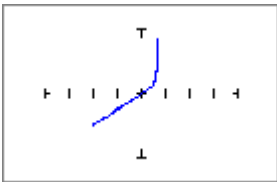
No Internal resistance

Exercise 6: Simulating Leakage in a Diode

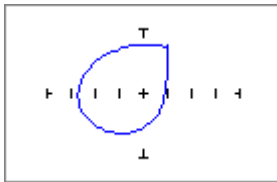


Diode Leakage

Exercise 7: Parallel Diode combinations

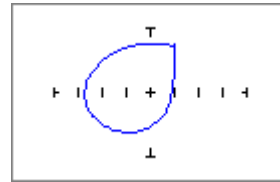
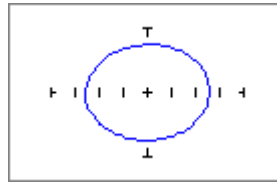
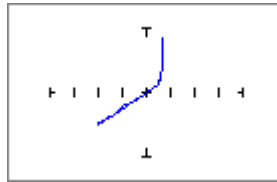
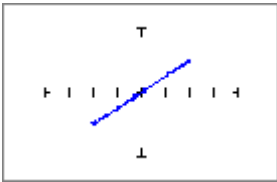


D4+R9



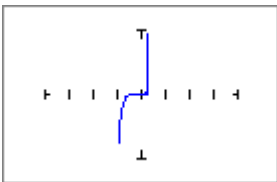
D5+C6

Exercise 8: Adjusting Range with Parallel Diode combinations

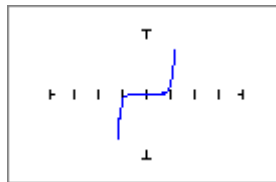


D4+R9; 200mV, 10KΩ D4+R9; 3V, 10KΩ D5+C6; 200mV, 100Ω D5+C6; 3V, 100Ω

Exercise 9: Zener diode signatures



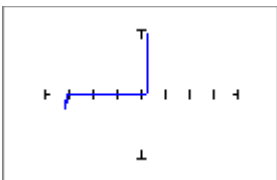
Diode D2 V-bd: approx. 2V



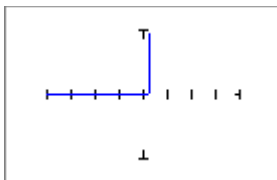
Diode D2 (C1+C2) V-bd: approx. 4V

Section 6 Testing Transistors

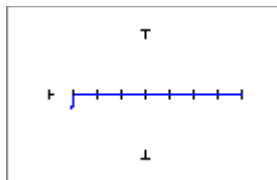
Exercise 1: Typical transistor signatures – PNP



B to E

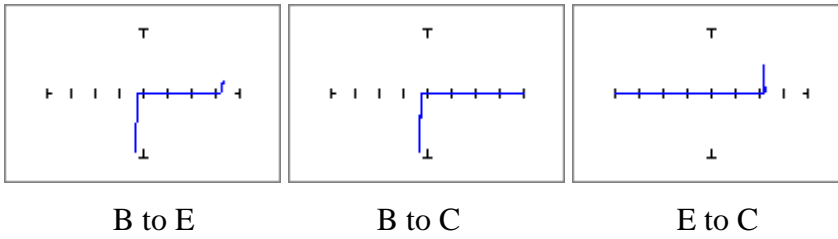


B to C



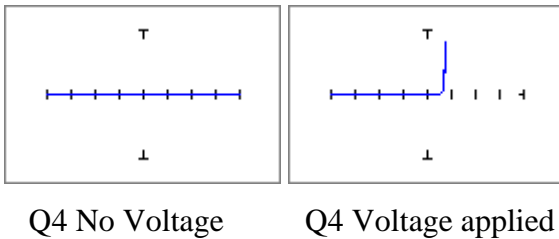
E to C

Exercise 2: Typical transistor signatures – NPN

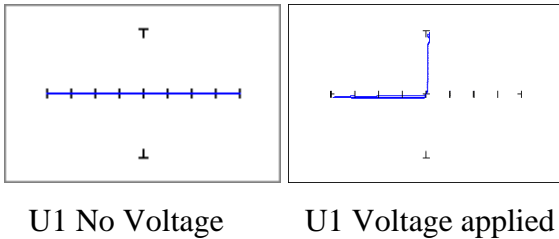


Section 7 Testing the Operation of Switching Devices

Exercise 1: Testing a Silicon Controlled Rectifier (SCR)

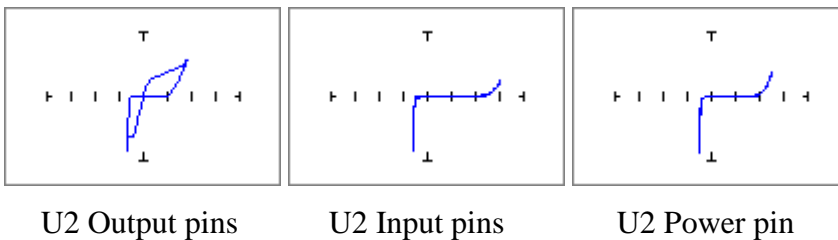


Exercise 3: Testing an Optocoupler (optical switch) for Rev. C Trainer Board

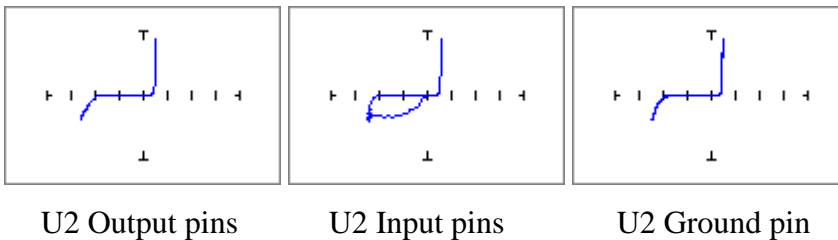


Section 8 Testing Integrated Circuits

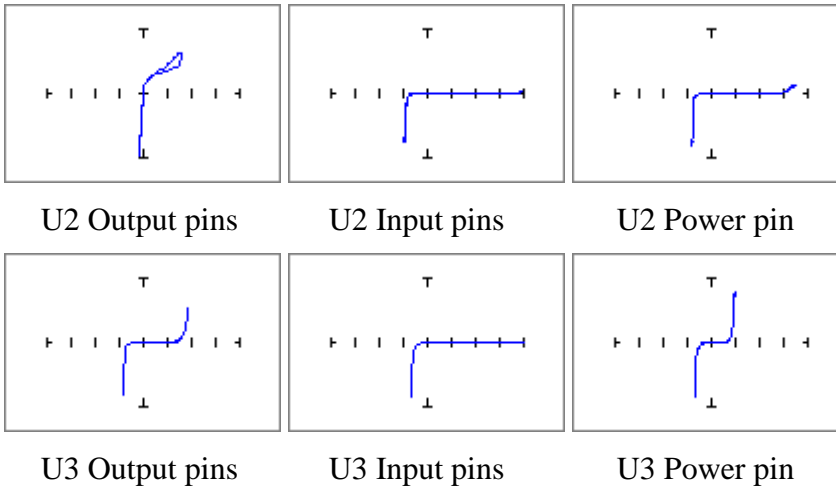
Exercise 1: Examining signatures of a logic IC



Exercise 2: Testing TTL circuits with reference to Vcc



Exercise 3: Comparing Two Hex Inverter ICs



Exercise 5: Op Amp signatures

Step 5: U5 is showing a resistive fault on pin 5; this is a simulated fault by attaching a 1K Ω resistor from pin 5 to Vcc.

Step 6: The signature is resistive when compared to the same diode signature on pin of U4