TrackerPXI user's manual

P/N 21-1354
Rev. B, APRIL 2006

Thank you for purchasing a Huntron TrackerPXI!

Contacting Huntron

To obtain information about service, accessories and other products, contact:

>Huntron Inc.
>15720 Main Street, Suite#100
>Mill Creek, WA 98012
>USA

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

Huntron is also accessible by:

- ♦ FAX: 425-743-1360
- ♦ Internet E-mail: info@huntron.com
- ♦ Internet Home Page: www.huntron.com

HUNTRON, INC.
LIMITED WARRANTY

Huntron, Inc. believes in the quality of its products. Accordingly, Huntron provides the following non-transferable warranties for the benefit of the original end-use purchaser of the Huntron TrackerPXI instrument.

Huntron warrants that the Huntron TrackerPXI hardware shall be free from defects in material and workmanship for one (1) year from the date of purchase.

Huntron warrants that the diskette(s) containing the Huntron Workstation for Windows software shall be free from defects in material and workmanship for one (1) year from the date of purchase. Huntron further warrants that the software will perform in substantial conformance with the system specifications of the Huntron TrackerPXI at the time of purchase and for the period of one (1) year thereafter.

The above warranties are in lieu of all other warranties, express or implied, including all warranties of merchantability and/or fitness for a particular purpose. Huntron's liability under these warranties, including any damages sustained by the customer through malfunction or failure of the Huntron software, shall not exceed the amount of the purchase price of the Huntron TrackerPXI, regardless of the extent of any such damage, including any special, consequential, or incidental damages of any kind.

These warranties shall only apply to products in ordinary use. Huntron shall have no obligation under these warranties with respect to damage caused by accident, transportation, neglect, misuse, unauthorized alterations or repair, improper installation, or operating conditions.

Products purchased in the United States are to be returned to Huntron, Inc. at its factory, transportation prepaid. Products purchased outside the United States are to be returned to the source of purchase for Warranty repair.

Written notice of, and an explanation of the circumstances of, any defect believed to be covered by this agreement shall be provided promptly to Huntron by the customer following discovery of the defect. In satisfaction of its warranty liability, Huntron agrees to take reasonable and prompt action to correct the defect, either by repair or replacement, at its option.

WEEE and RoHS Status
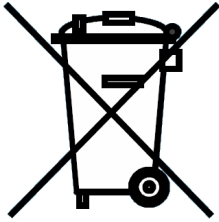
We, at Huntron are aware of the recycling needs for Waste Electronic and Electrical Equipment (WEEE) and Restriction of certain Hazardous Substances (RoHS) and are co-operating with systems established, worldwide for the collecting and recycling of our products.

Huntron has applied the Wheeled bin recycle mark (EN50419) to our products. At the present time, most European countries are not complete in their compliance with the European WEEE legislation and they do not have collective systems fully operational and registration initiated. Further recycling information will be added to our website www.huntron.com as it becomes available.

Huntron products, being electronic test equipment, are classified as monitoring and control instruments and are presently exempt from the RoHS directives. Huntron is currently using leaded solder in the construction of our products but we are working for total compliance to RoHS to be completed by July 2006.

Recycling is important to all communities, therefore we ask our customers to be responsible in recycling. Please check your local recycling laws for further information.

Section 1. Introduction

1-1 What is a TrackerPXI

A TrackerPXI is a troubleshooting instrument that fits into a **PXI** or **CompactPCI** chassis. This instrument uses a troubleshooting technique called **Analog Signature Analysis (ASA)** for applying a current limited sine-wave voltage to an un-powered circuit or electronic component. The resulting Current (I) and Voltage (V) characteristic (analog **Signature**) is then stored and displayed for comparisons to known good signatures of a good circuit card or electronic component. This comparison allows you to troubleshoot circuit cards and electronic components without applying external power or requiring circuit cards to "boot up".

Each pin of a component can have a unique signature. When components fail, their signatures change so troubleshooting using **ASA** is simply a matter of finding the defective component by analyzing its signature. The **TrackerPXI** and it's related software application implements the **ASA** technique of troubleshooting. It's **PXI** form factor allows a test engineers to apply **ASA** techniques to complement existing PXI based functional testing of electronic cards and components.

The built-in current limited stimulus sine-wave of the **TrackerPXI** ensures non-destructive testing and does not damage any components. **ASA** has many advantages as a proven, fast, and effective troubleshooting technique.

You can:

- Troubleshoot circuitry that cannot be powered up due to a shorted condition.

- Troubleshoot in a qualitative mode, allowing you to see physical problems with a suspect component.

- Compare device characteristics with known types for better matching.

- Investigate intermittent problems by seeing marginal indicators, such as small amounts of leakage, noise, etc.

- Eliminate risk of accidental shorting across other points during POWER ON testing which could further damage the component or other components on the board.

- Minimize the risk of shock hazard since the **ASA** troubleshooting approach requires no power applied to the circuitry.

- Perform preventative maintenance by seeing flaws in components that could possibly lead to untimely failures.

- Look at replacement components before they are installed in circuitry to reduce the risk of installing defective ones.

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

You can manually connect the **TrackerPXI** front panel test terminals directly to the circuit card or component that you are testing. Or you can automate the test process by connecting the **TrackerPXI** to a **Huntron Access Prober** which automatically moves a test probe over designated test points on a circuit card. The **TrackerPXI** can be connected via PXI relay switching cards that are in turn connected to existing bed-of-nails fixtures, thus allowing your existing board fixtures to be used for troubleshooting your circuit cards using the ASA technique.
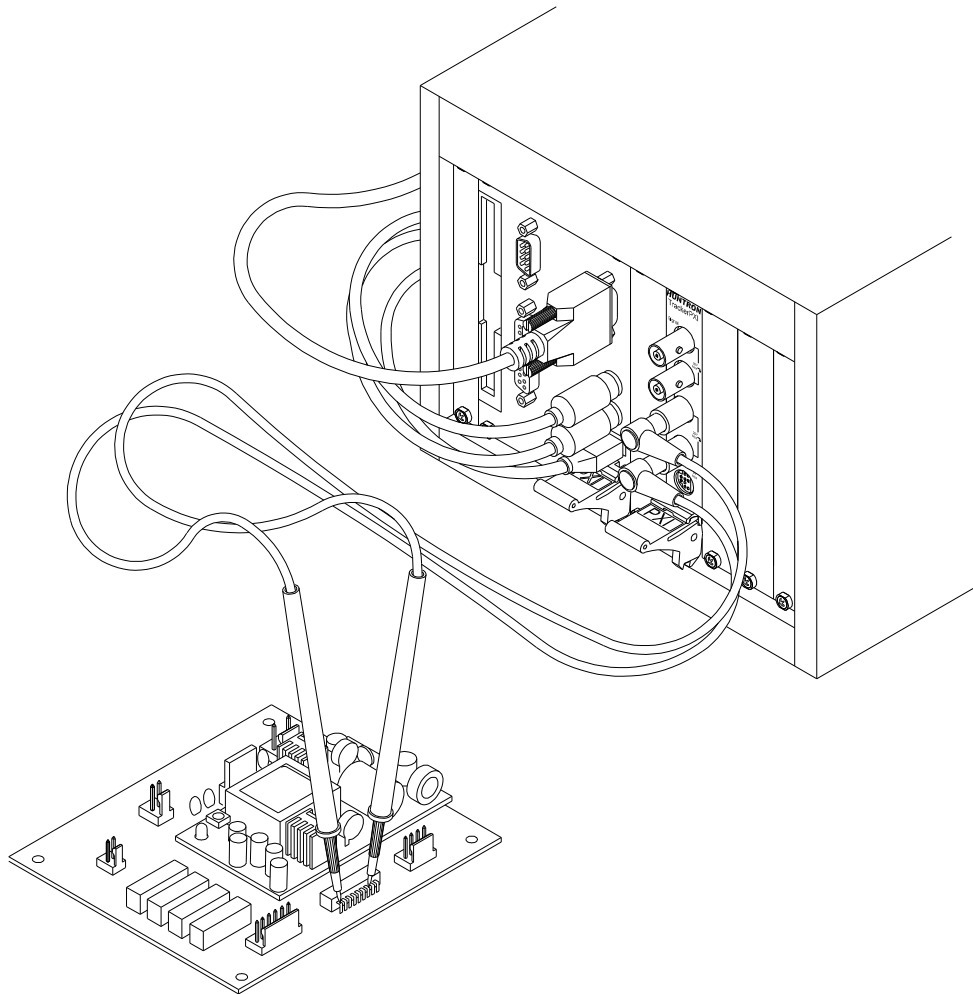
Fig. 1. Manual probing of un-powered circuit card using the TrackerPXI.
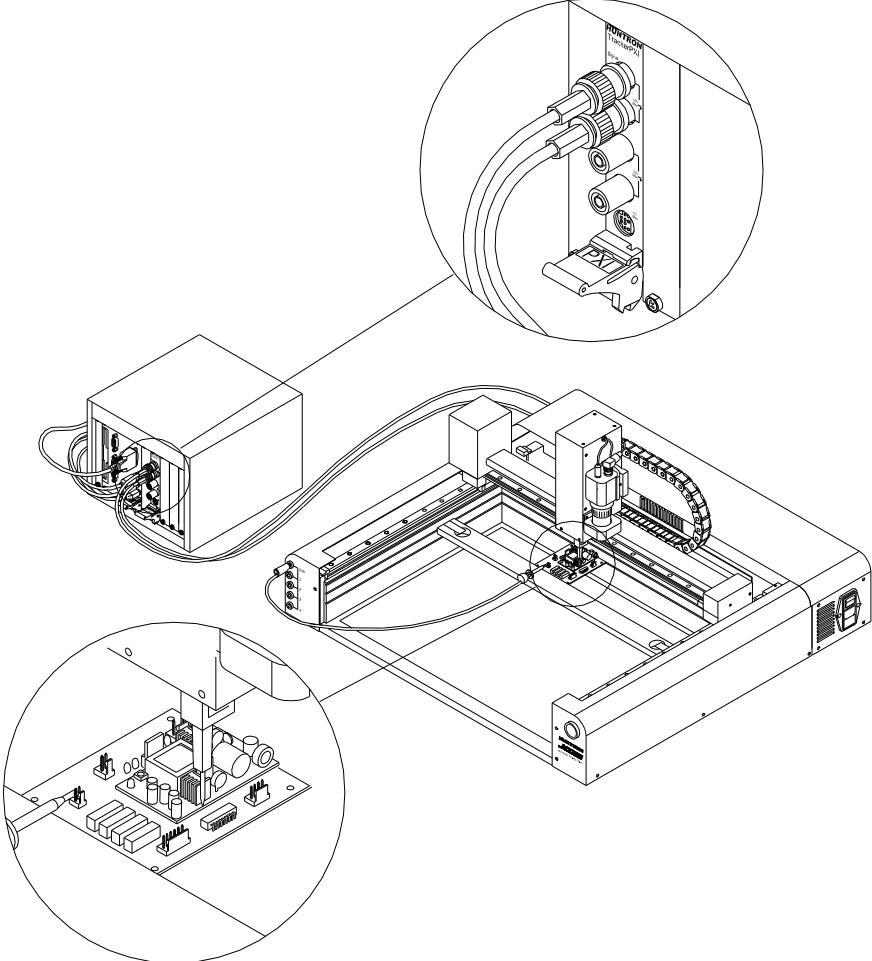

Fig. 2. Automatic probing of circuit card using the TrackerPXI and Huntron Access Prober.

1.2 Specifications

Electrical (Note: Test Signal is a sine wave.)	
Open Circuit Voltage (Vs):	
24 selections of peak voltage:	200mV, 400mV, 600mV, 800mV, 1V to 20V in 1V steps including 10V (Low), 15V (Med 1), 20V (Med 2)
Source Resistance (Rs):	
16 selections of resistance:	10Ω, 20Ω, 50Ω, 100Ω, 200Ω, 500Ω, 1kΩ, 2kΩ, 5kΩ, 10kΩ, 20kΩ, 50kΩ, 100kΩ, 54kΩ (Low), 1.2kΩ (Med 1), 26.7kΩ (Med 2)
Short circuit current (Vs divided by Rs)	
Maximum	200 mApk
Frequency (fs):	
40 selections of frequency:	20Hz to 190Hz in 10Hz steps; 200Hz to 1.9kHz in 100Hz steps; 2kHz to 5kHz in 1kHz steps
Channels	
Number	1
Connections	BNC (Sig.; Com.), banana (Sig.; Com.)
Overvoltage Protection	Circuit breaker
Auxillary Connection	9 pin mini jack with ground, Trigger IN, Trigger OUT, Calibration TP, Sine wave zero-crossing, Signal ON, Line IN and Line OUT
GENERAL	Requires 1 free size 3U PXI/compactPCI slot . Minimum CPU speed of PXI/CompactPCI computer is 1Ghz running Windows XP or Windows 2000.
Dimensions	6.3" W x 3.9" H (16cm W x 10cm H)
Warranty	1 year limited

Specifications subject to change without notice

Supplied Accessories

Huntron P/N	QTY	Description
98-0249	1 pair	Huntron Microprobes MP20
98-0043	1	Test Lead Black
06-5217	1	User's Manual CD

98-0465	1 set	Huntron Workstation 4.0 Software

1-3 Huntron Workstation Software

The Huntron Workstation software allows control of the TrackerPXI card and uses Windows-like features to implement the troubleshooting process using ASA techniques. Some examples of screen captures are shown below. Specific software details are covered in the Help file.
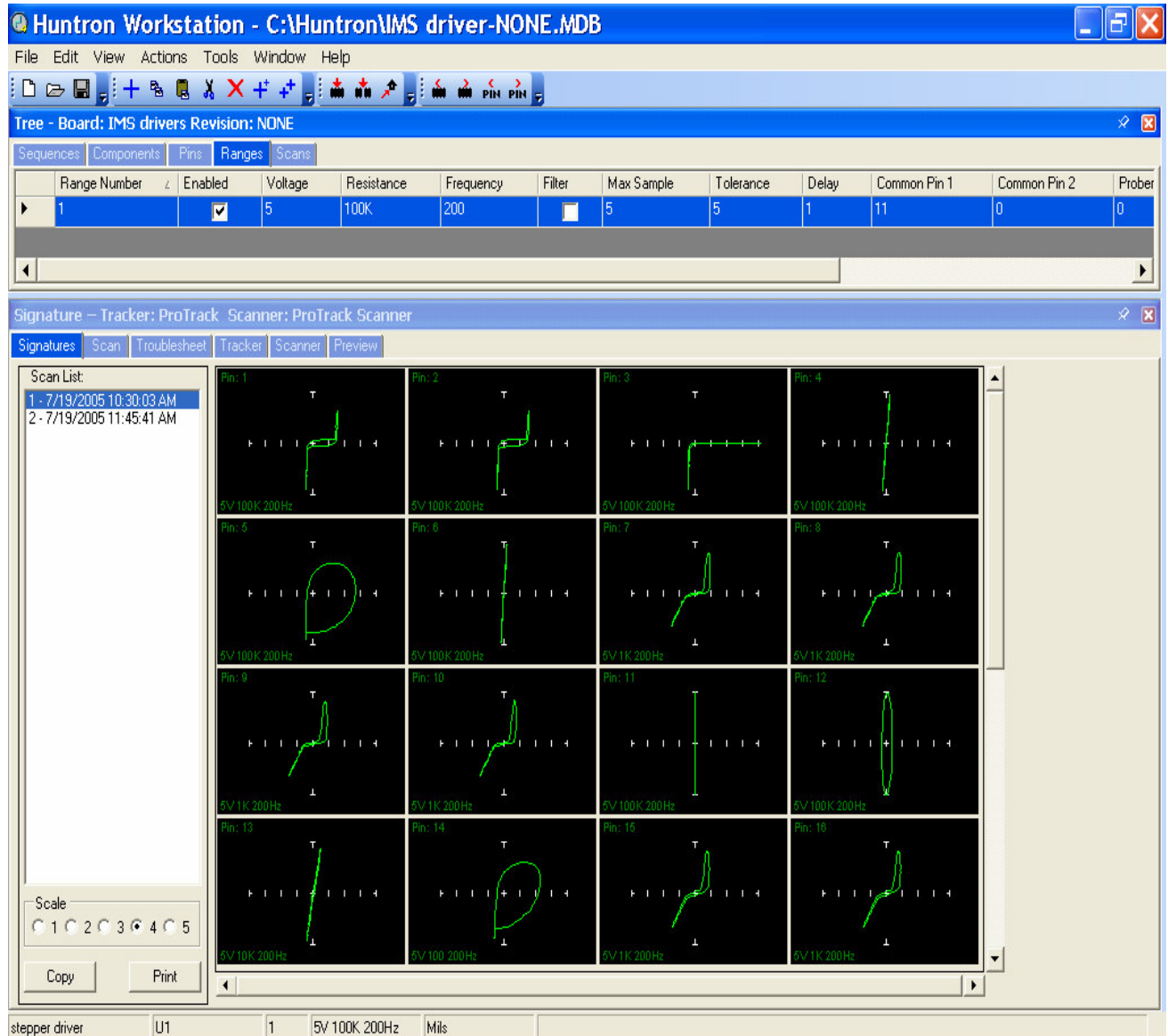

Fig 3. Reference Signatures of 16 pins are shown on a single screen. (update the sceen capture when the pxi hardware works with 4.0)
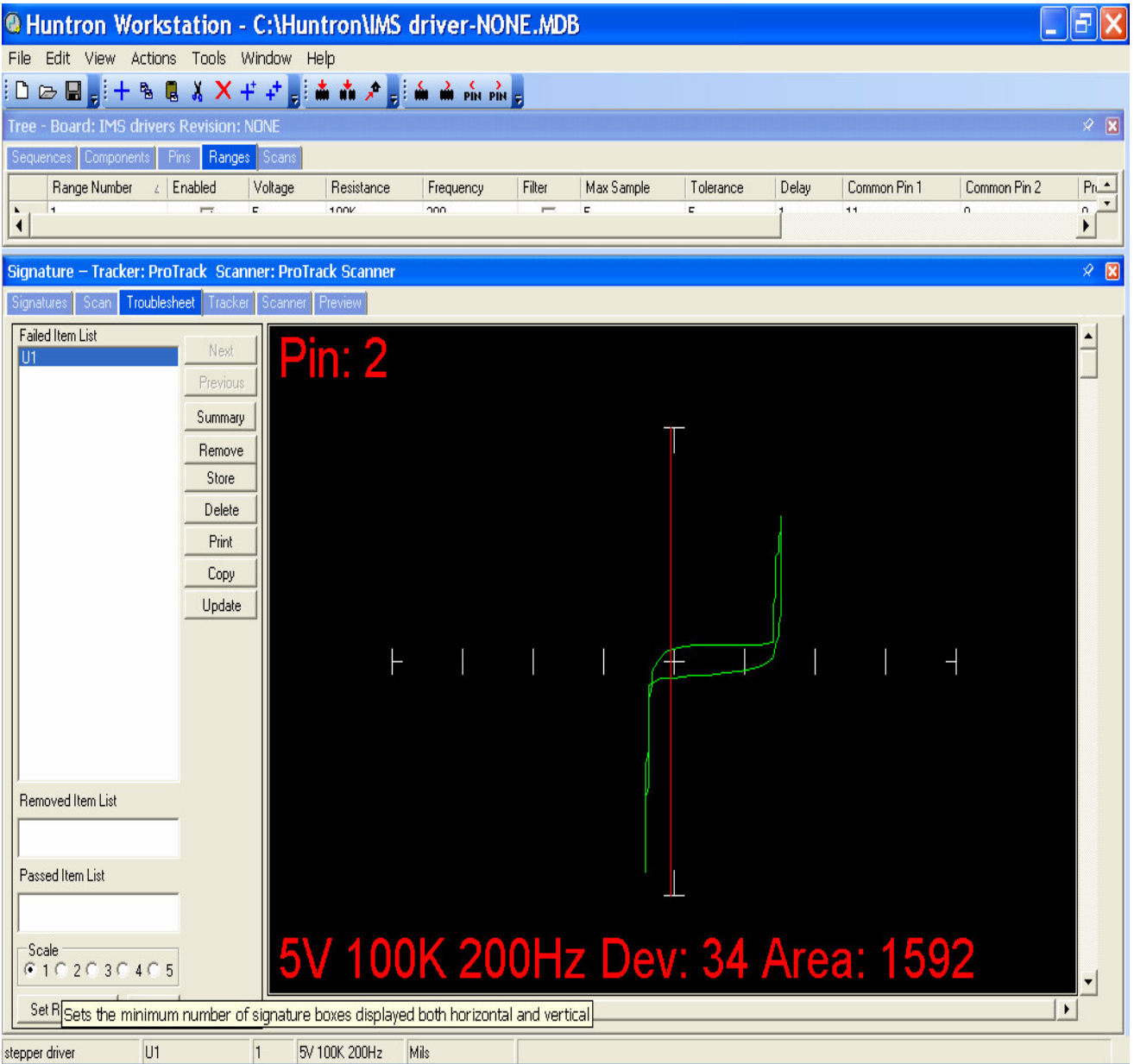
Fig 4. Signature of a failed pin. Green Signature is good. Red is suspect.
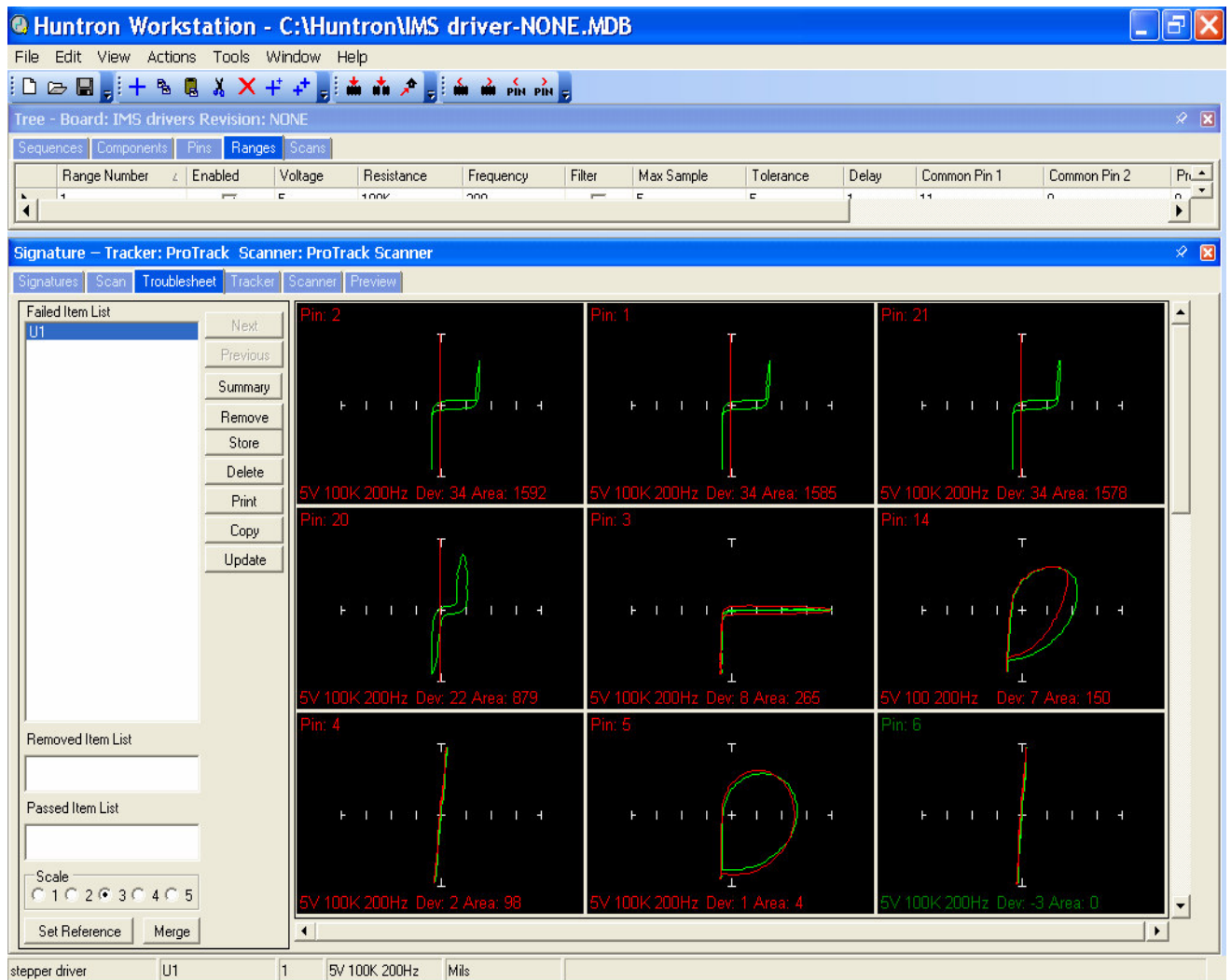
Fig 5. Signatures of all failed pins are displayed with the red (failed) signatures superimposed on the good (green) signatures and are sorted by the worst failures displayed first. The troublesheet for each circuit card can be stored.

Huntron Workstation software features.

- Create custom test routines for low volume manufacturing, repair and rework applications

- Support of optional utilities for test creation using PCB CAD data

- Easily create, modify and save Microsoft Access based test databases

- View, print and store test results immediately

- Interactive application panes automatically update as selections are made

- Includes an easy to use Test Only pane better suited to test execution in a production environment

Section 2. Installation

2-1 What you need to get started

To set up and use your TrackerPXI, you will need the following:
1) A Huntron TrackerPXI card.
2) One set of Microprobes (Huntron MP20).
3) Huntron Workstation Software purchased separately.
4) Your Pentium-based PXI or compactPCI chassis running Windows 2000 or Windows XP.
5) This manual. (TrackerPXI user's manual)
6) Getting started instructions for setting up a TrackerPXI and a TrackerPXI with a Huntron Access Prober. (These instructions are packaged with the hardware and are repeated in this manual.)

2-2 PC requirements.

The following requirements are provided to assist you in purchasing the correct computer system to use with the Huntron Workstation software and the TrackerPXI. These are the recommended minimum computer requirements:

- PXI or CompactPCI chassis with Pentium III or equivalent CPU.

- Microsoft Windows^{TM} 2000, XP.

- CDROM drive.

- 512MB RAM

- Hard disk with at least 1 GB free space.

- Windows 16 bit color capable VGA graphics card.

- VGA color monitor.

- 1 Free PXI or CompactPCI slot for the TrackerPXI card.

- For connecting to the Access Prober, you will also need:

  1 free serial (RS232) port for communicating with the Access Prober.

  One free PXI or CompactPCI slot for the camera frame grabber card.

2-3 Getting started instructions for setting up a TrackerPXI or a TrackerPXI with a Prober.

NOTE: Install the software before installing the PXI cards.

1. Power up your computer. Insert the software CD into the CDROM drive.

2. If your CD was configured for Auto-run, a menu will be displayed. Click the **Install Workstation** item. If no menu is displayed, run the **Huntron Workstation.exe** program located in the **Setup** folder on the CD.

3. A Huntron License Agreement form is displayed. If you agree, select the **"I accept the license agreement"** option. Click **Next**. The readme.txt file on the CD will be displayed. Click Next.

4. Enter your User information if desired. If you are allowing other users to logon and use the software, the default setting allows anyone who logs onto to this computer to use the software with full access. If you select "Only for me", other users who logon to this computer with a different user name will not have access to this software.

5. The default destination folder is **C:\Program Files\Huntron Workstation**. Click **Next** if you do not want to change the default folder.

6. Click **Next** to begin installation.

7. Click **Finish** when the "Huntron Workstation has been successfully installed" window is displayed.

8. Do not run the software at this point. The hardware must now be installed to complete the installation.

9. Power off the computer chassis. Install the TrackerPXI card in any available 5 V peripheral slot in your PXI or CompactPCI chassis.
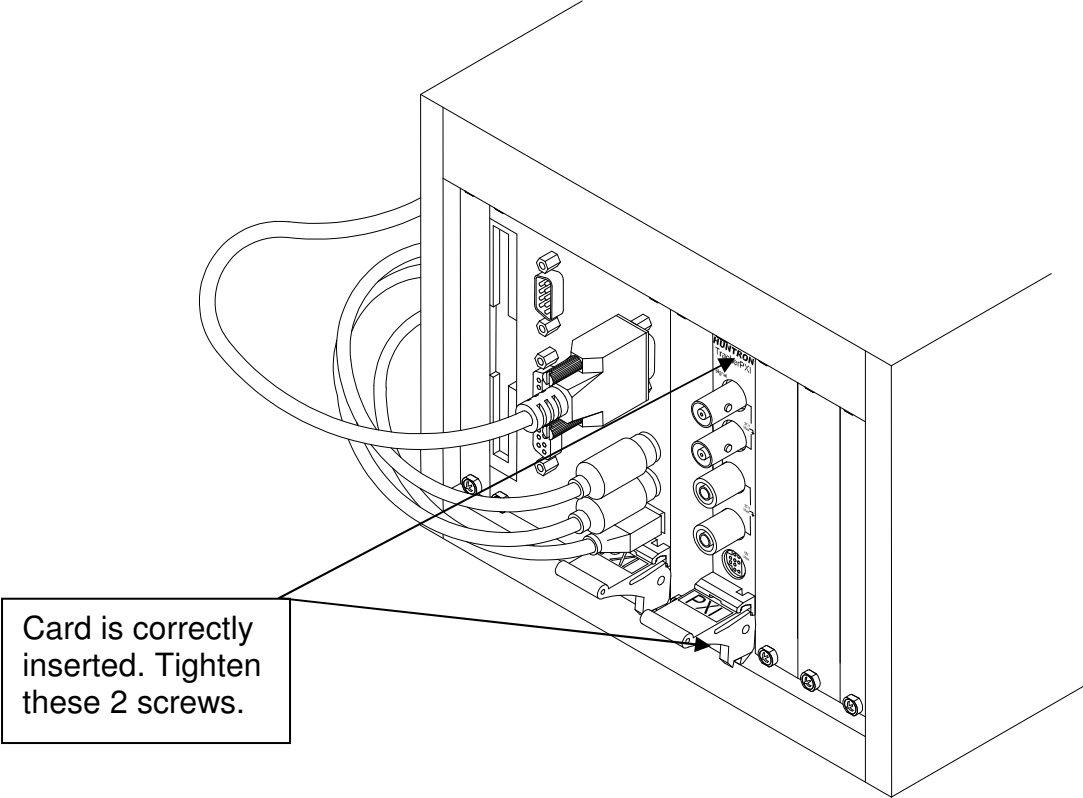
CAUTION: To avoid static electricity from damaging the TrackerPXI, ensure that you are properly grounded when handling the card.

Remove the filler panel of the slot that you have chosen to install the card.
Slide the TrackerPXI card in the selected slot. **Caution: Do not force the card into the slot**. The card should slide in easily and come to a stop when the card connector is about to make contact with the chassis. Hold the card injector/ejector handle and pull it upward to lock it in place. If the ejector/injector handle is difficult to pull upward, remove the card and re-insert it into the slot. Tighten the 2 screws as shown.

Card is not fully
inserted. Pull
upward to engage
the lock.
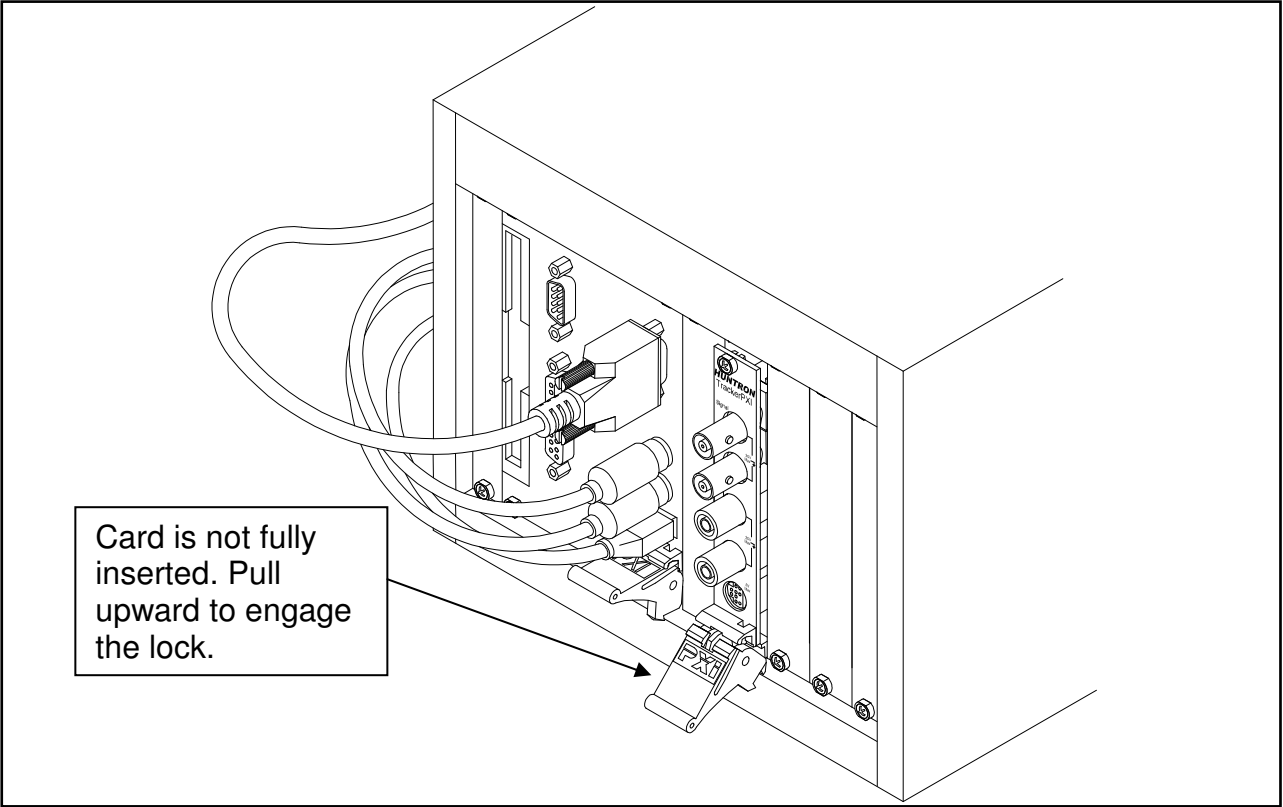
TrackerPXI not fully inserted.

Card is correctly
inserted. Tighten
these 2 screws.

Tracker PXI card fully inserted and locked into position.

Warning! Please ensure that all cables connected to the TrackerPXI card are no longer than 3 meters.

If you have a Prober, follow the instructions in the unpacking sheet and install the Prober. Install the Camera frame grabber card into the PXI chassis. Connect the following cables:
   a. **RS232 Cable** from the **computer serial port** to the **Prober Serial port**.
   b. **BNC cable** from Signal on the TrackerPXI to the **Signal port** on the Prober.
   c. **BNC Common cable** from **Common** on the **TrackerPXI** to **Common** on the Prober.
   d. BNC Camera cable from V1 port on the Sensoray Frame grabber card to the **Camera port on the Prober**.
   e. Connect all power cords.

Power up the Prober. Power up the computer. Do not remove the software CD. Ignore steps **11 to 14** if you do not have a Prober.

10. After Windows is booted, an **Add New Hardware** wizard prompts you to install a **"Sensoray Frame Grabber".** Click Next.
11. If the wizard prompts you to search for drivers, click **Next.** Check the CDROM drive for the search path and **uncheck all the other options**. Click **Next**.
12. When a message appears, indicating that the driver has not passed Windows Logo testing, click **"Continue anyway".** Click **Finish.**
13. You will be prompted to install the "**Sensoray X11 Frame Grabber Component**". Click **Next.** When a message appears indicating that the driver has not passed Windows Logo testing, click "**Continue anyway**". Click **Finish**.
14. You will be prompted to install the "**TrackerPXI**". Click **Next.** When a message appears indicating that the driver has not passed Windows Logo testing, click "**Continue anyway**". Click **Finish**.
15. Remove your Huntron Workstation CD. You are now ready to use the software.

16. An icon will be created on your windows desktop. Double click this icon to start the software.

17. The Huntron Workstation Activation dialog is displayed. This software is only licensed to be used on one TrackerPXI and/or one Prober. The activation codes are generated by Huntron and are specific to the TrackerPXI and hardware serial numbers. The activation codes are printed on the software CD. The activation codes can be e-mailed to you. If you do not know the activation codes, call Huntron technical support (425-743 3171) and provide the serial numbers for the TrackerPXI and the . TrackerPXI serial numbers start with a **RV.** serial numbers start with a **480**. From the e-mail text, copy and paste the activation codes into the correct boxes. If you have a Prober connected to the TrackerPXI, follow the calibration procedure in step 18. Ignore step 18 if you are using the TrackerPXI as a stand-alone unit.

NOTE: The TrackerPXI is already calibrated at the factory. However, if you are connecting a TrackerPXI to a Prober, you will need to calibrate it as a complete system.
If you have connected a TrackerPXI to a Prober, follow the steps below to calibrate the system.

18. TrackerPXI calibration with Prober connection.

To access the calibration window, click **Tools, Maintenance, TrackerPXI Diagnostics**.
Ensure that all cables are connected. Do **not click the Verify Hardware button**. This routine requires special hardware and test procedures.

Click the **Calibrate** button. The calibration routine will run for a few minutes. Do not power off any of the instruments at this time. This is an automatic process and does not require any user tweaking. After a successful calibration, click the **Verify Calibration** button. If you get a "successful verification", click **Close** to exit the Diagnostic window. If you get a "Verification Failed" message, Re-run the **Calibration** routine and run the **Verify Calibration** again. If it still fails, call Huntron Technical support.

19. Follow the software tutorial.

A software tutorial (**workstation tutorial.pdf**) is included in the software CD and in the default installed folder (**C:\program files\huntron workstation\documents**). The tutorial can also be accessed via the Help menu in the software. The tutorial will enable a new user to get acquainted with most of the software features. The help menu in the software will also assist you.
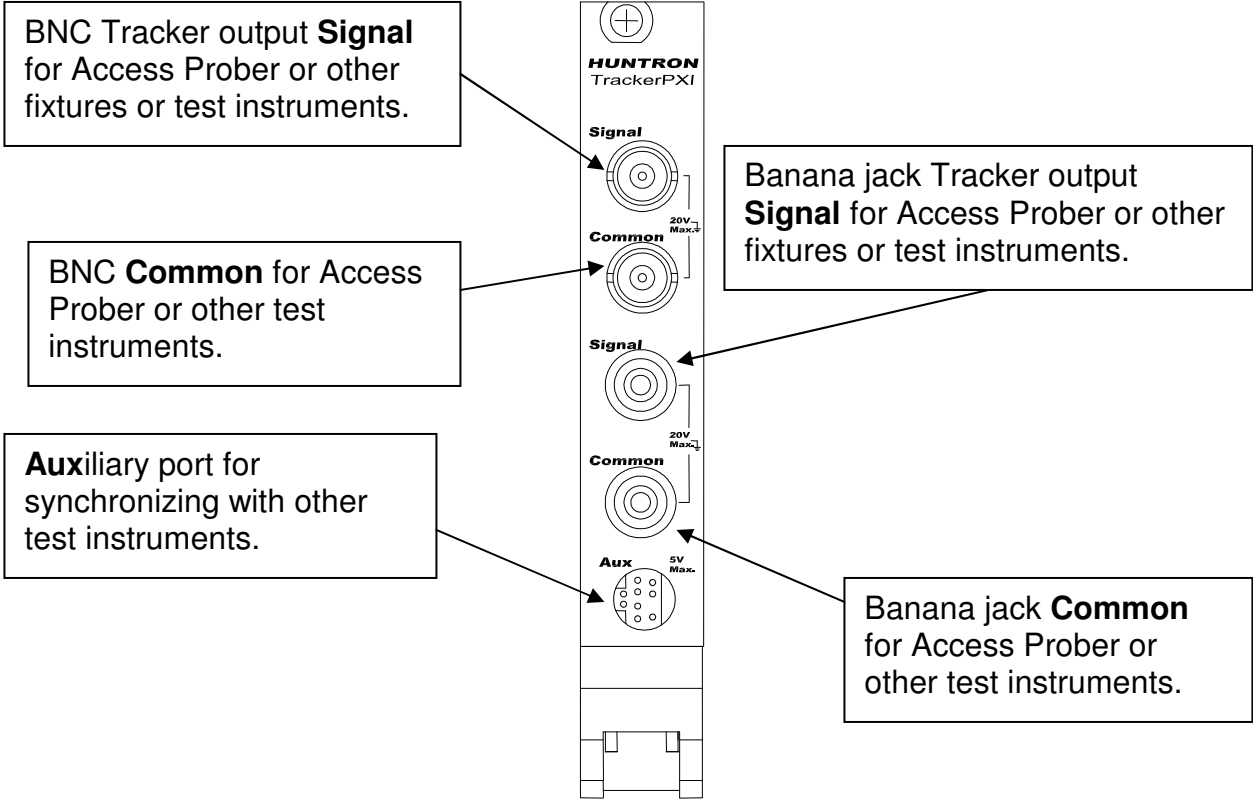
Whenever you need detailed information, click **Help** in the appropriate screens. The help feature is context sensitive, so you can click on the green highlighted text to get additional information on related topics.

All **user's manuals** are located in the Manual CD (06-5217) included in your package. Refer to the appropriate manual for the hardware you have.

If you need further assistance, call the Huntron Technical support at
1-(800)-426-9265 or (425) 743 3171
email: info@huntron.com

2-4 TrackerPXI Signal connections.

The TrackerPXI is a single channel Instrument. The two front panel BNC connectors are the Signal and Common connections for the Huntron Access Prober. The other 2 Banana jacks on the front panel are the Signal and Common connections for a set of Huntron Micro-probes. You can therefore manually probe using the Micro-probes without disconnecting the Access Prober BNC connections. The signal via the BNC or Banana jacks can be switched off via software control.

BNC Tracker output **Signal** for Access Prober or other fixtures or test instruments.

BNC **Common** for Access Prober or other test instruments.

Auxiliary port for synchronizing with other test instruments.

Banana jack Tracker output **Signal** for Access Prober or other fixtures or test instruments.

Banana jack **Common** for Access Prober or other test instruments.

HUNTRON
TrackerPXI

Signal

20V
Max.

Common

Signal

20V
Max.

Common

Aux   5V
Max.

2-5 Auxiliary (AUX) connector description.

The front panel Auxiliary (**AUX**) 9 pin Din connector pins are shown below. These pins can be used for synchronizing and triggering other external Functional Test Instrumentation.
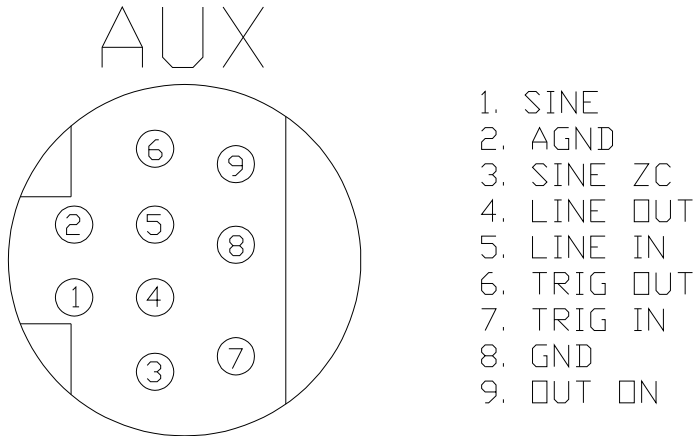
AUX

1. SINE
2. AGND
3. SINE ZC
4. LINE OUT
5. LINE IN
6. TRIG OUT
7. TRIG IN
8. GND
9. OUT ON

Fig 9. Front panel 9 pin Din connector pinouts.

Pin 1: SINE. Output Sine wave synchronized with the applied sine wave signal at the BNC Signal or Banana jack Signal connector. This signal can be enabled or disabled via software control.

Pin 2: AGND. Analog ground. This is the Common signal available at the front panel BNC Common or Banana jack Common connector. This signal can be enabled or disabled via software control.

Pin 3: SINE ZC. Output zero crossing signal for the sine wave signal of pin 1.

Pin 4: LINE OUT. Normally Low state. Can be driven to High state via software control for detection by external instrumentation.

Pin 5: LINE IN. Normally High state. Can be externally shorted to GND to drive it Low for detection by the TrackerPXI software.

Pin 6: TRIG OUT. Similar to LINE OUT.

Pin 7: TRIG IN. Similar to LINE IN.

Pin 8: GND. Reference ground for ZC, LINE OUT, LINE IN, TRIG OUT and TRIG IN.

Pin 9: OUT ON. Normally Low state. Automatically driven to High state whenever the output sine wave signals are present at the BNC SIGNAL or Banana SIGNAL connectors. Can be enabled via the TrackerPXI software.
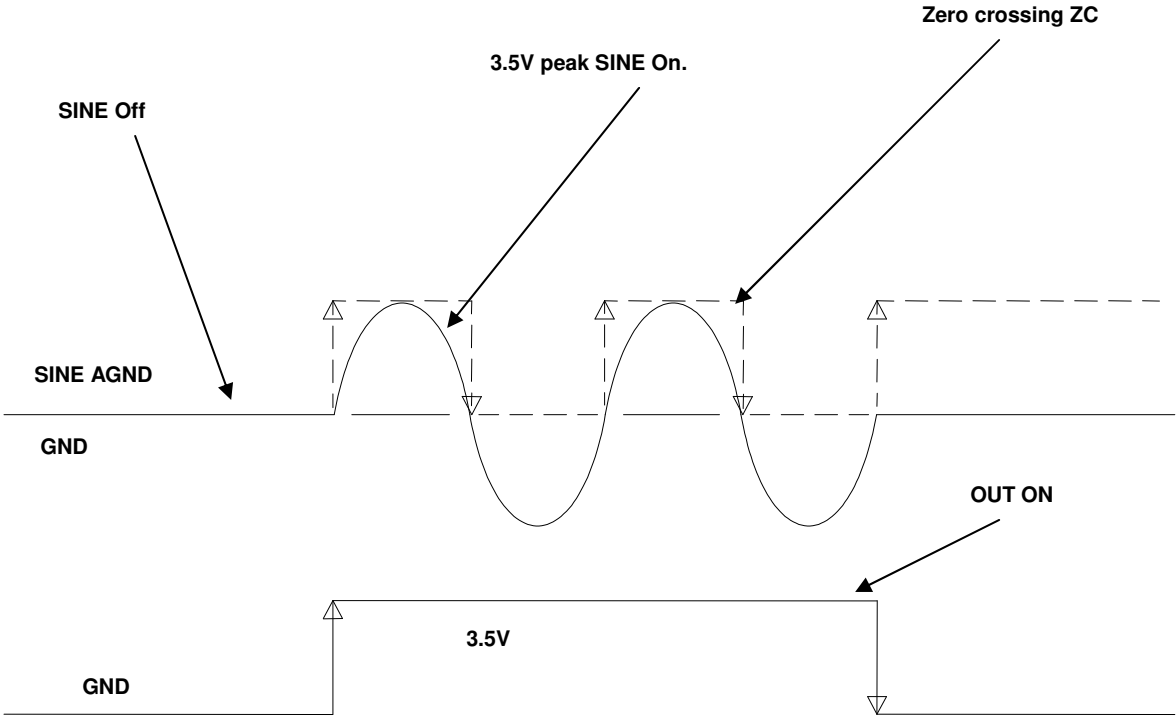
Fig 10. Signals SINE, ZC and OUT ON

SECTION 4 TESTING PASSIVE COMPONENTS

4-1. RESISTORS

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

• Apply test probes across a resistor
• Identify a pure resistive signature
• Analyze and predict resistive signatures

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

Put the red test lead in the **Signal** jack, and the black test lead in the **Common** jack.
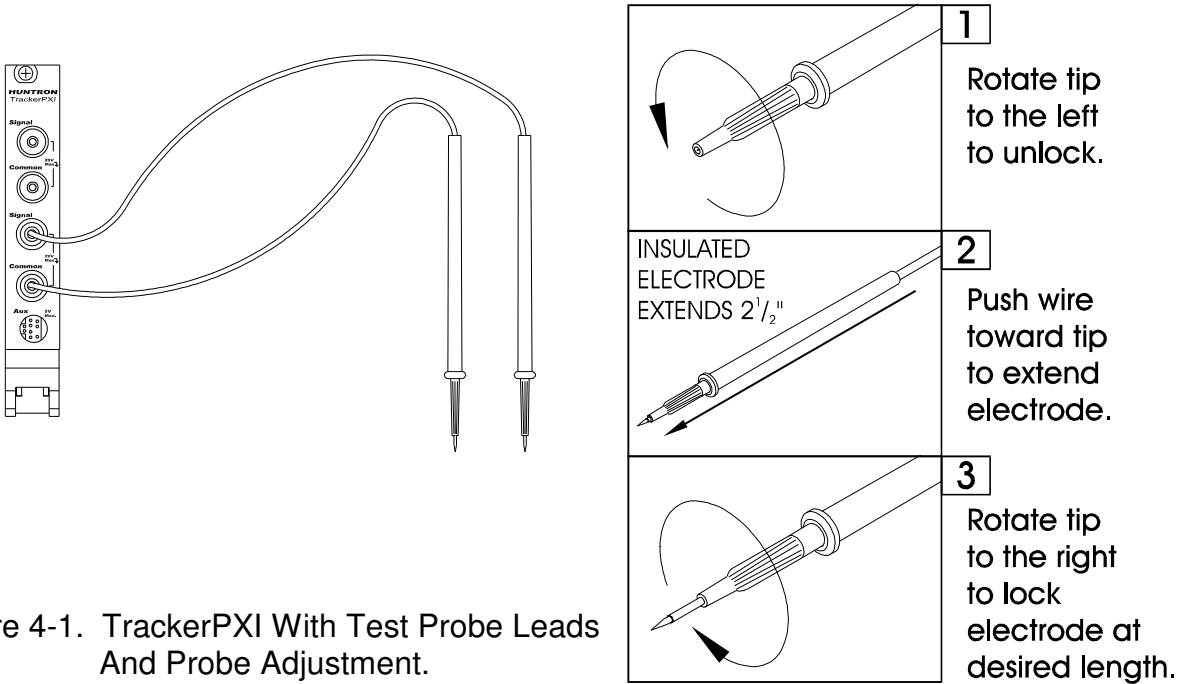
Figure 4-1. TrackerPXI With Test Probe Leads And Probe Adjustment.

1 Rotate tip to the left to unlock.

INSULATED ELECTRODE EXTENDS $2\frac{1}{2}$"

2 Push wire toward tip to extend electrode.

3 Rotate tip to the right to lock electrode at desired length.
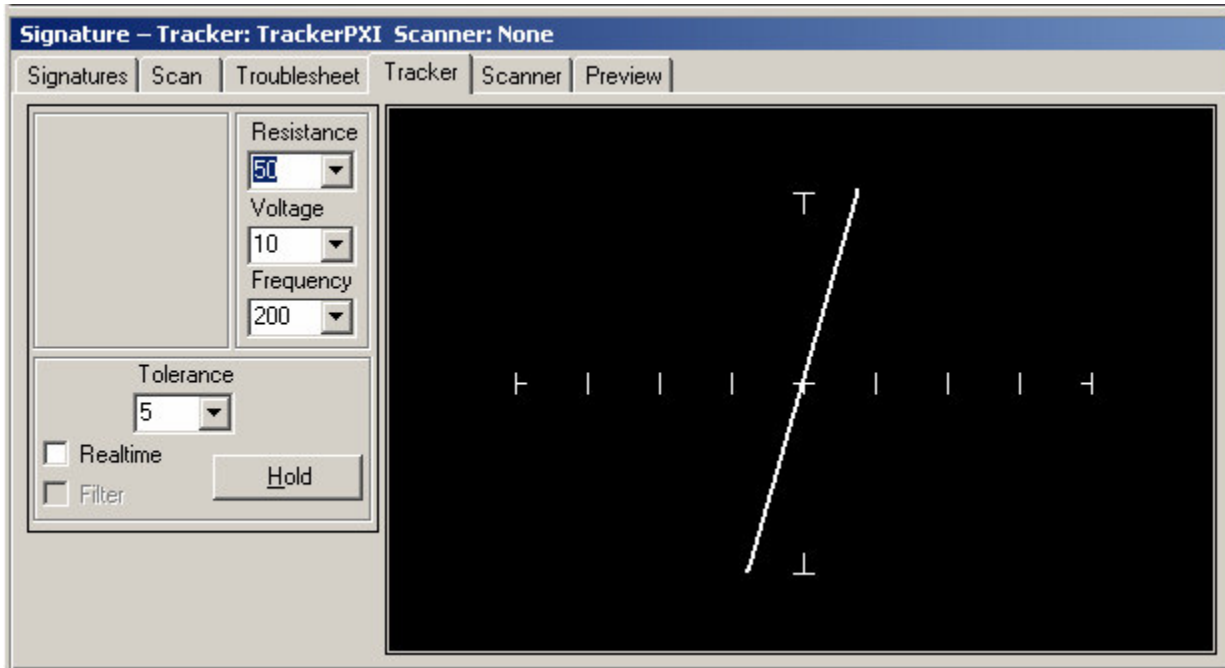
Figure 4-2. TrackerPXI – 50 ohm,10V range.

To display the analog signature of a resistor:

1. Select the 50 ohm range by clicking the Resistance dropdown button and selecting 50.

2. Place or clip a test lead on the opposite ends of a resistor and observe the signature.
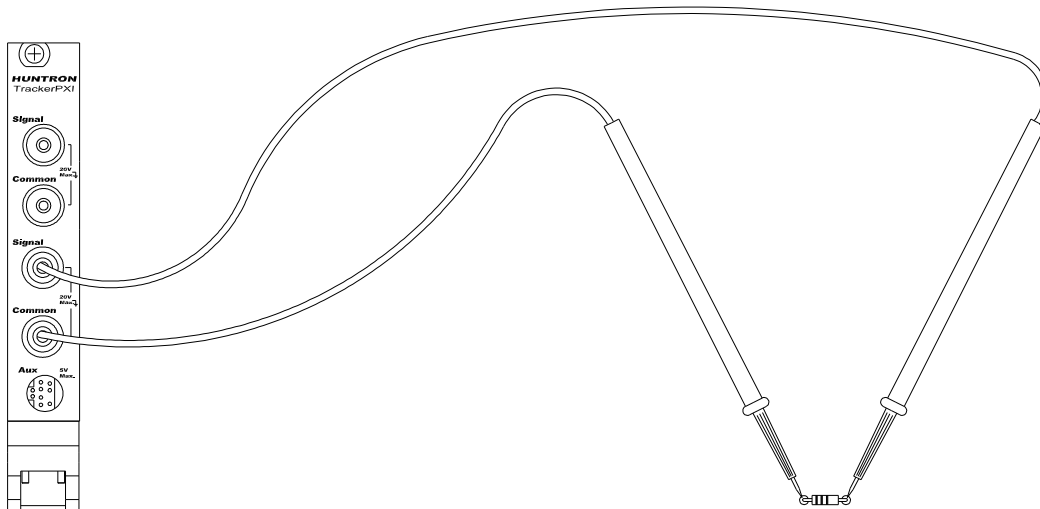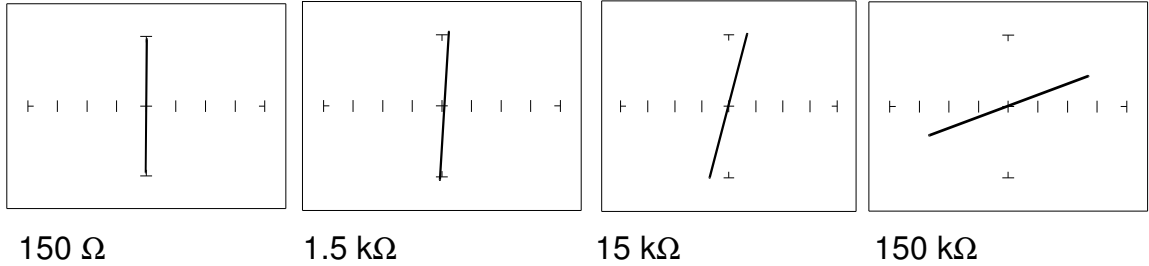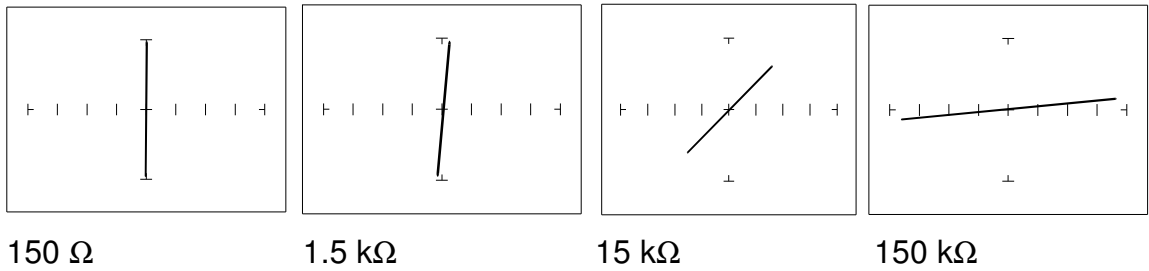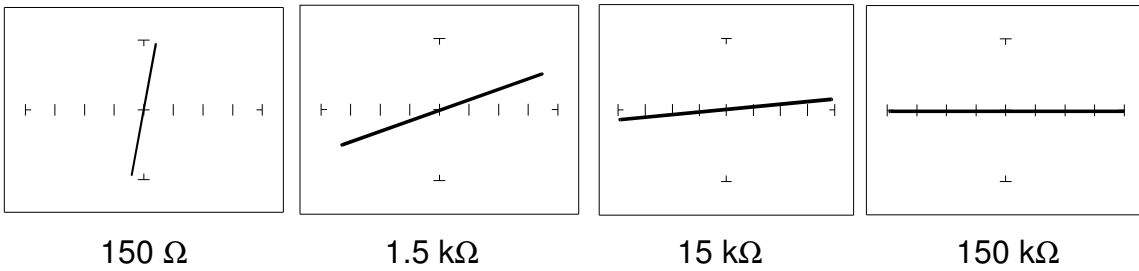

Figure 4-3. TrackerPXI Connected To A Resistor

Below are four analog signatures of different resistors, 150, 1.5 k, 15 k and 150 k ohms in each of the four pre-set Ranges. Note how the slope or angle of each analog signature changes with each resistor's value.
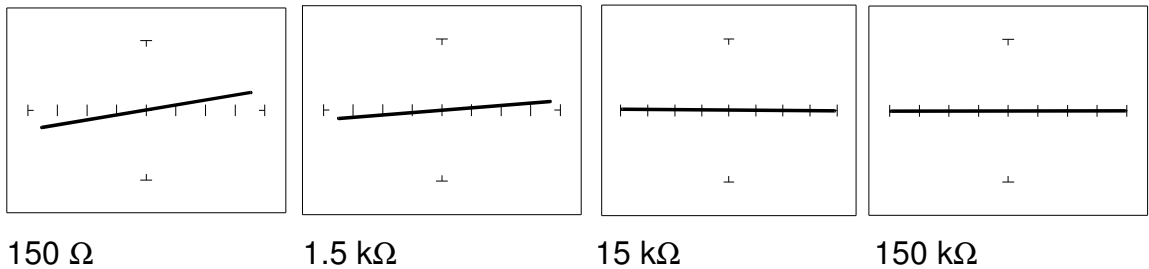
| 150 Ω | 1.5 kΩ | 15 kΩ | 150 kΩ |

Vs=20V, Rs=100kΩ (HV20) Range

| 150 Ω | 1.5 kΩ | 15 kΩ | 150 kΩ |

Vs=15V, Rs=27.6kΩ (MED2) Range

| 150 Ω | 1.5 kΩ | 15 kΩ | 150 kΩ |

Vs=15V, Rs=1.24kΩ (MED1) Range

| 150 Ω | 1.5 kΩ | 15 kΩ | 150 kΩ |

Vs=10V, Rs=54Ω (LOW) Range

Figure 4-4. Signatures Of Different Resistors In 4 pre-set ranges..

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

The Affect of R_S on Resistor Analog Signatures.

Select the 50Ω Range.

Observe the signatures for a 150 ohm resistor in the figure below as R_S varies. Note how these resistor signatures respond to changing TrackerPXI's internal resistance.
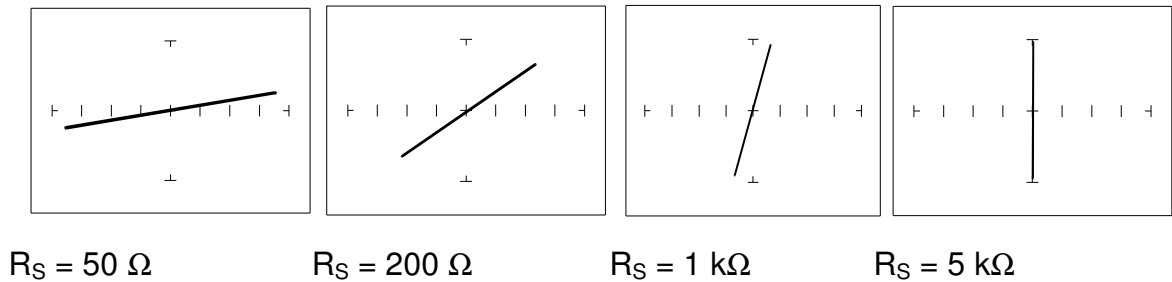

| $R_S = 50\ \Omega$ | $R_S = 200\ \Omega$ | $R_S = 1\ k\Omega$ | $R_S = 5\ k\Omega$ |

Figure 4-5. Affect Of Varying R_S On A Resistor Signature.
Vs=10V, Rs=54Ω (LOW)   Range, $R_L = 150\ \Omega$

The Affect of V_S on Resistor Analog Signatures.

Select the **50Ω** and **10V** range. Change the voltage range to 5V, 2V and 500mV

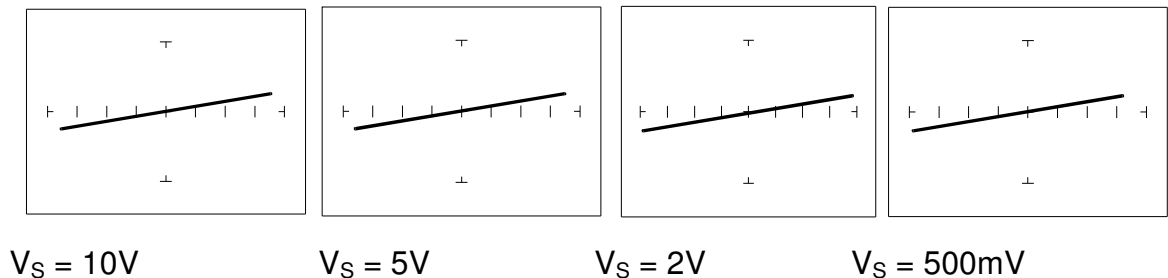| $V_S = 10V$ | $V_S = 5V$ | $V_S = 2V$ | $V_S = 500mV$ |

Figure 4-6. Affect Of Varying V_S On A Resistor Signature.
Vs=10V, Rs=54Ω (LOW)   Range, $R_L = 150\ \Omega$

Observe that these signatures do not change with the changing voltage. Note that Vs cannot be set above 10V because R_S is set to a value of 50 Ω. This limit on range parameter combinations is a result of the TrackerPXI's STAR feature, it protects components from possible excessive power. In order to set V_S to a higher voltage, you must change R_S to a higher value first.

The Affect of F_S on Resistor Analog Signatures.

Select the **50Ω** and **10V** range. Select the **Frequency** drop down button and vary the test range frequency F_S. Observe the resistor signatures in the following figures do not change as F_S changes.
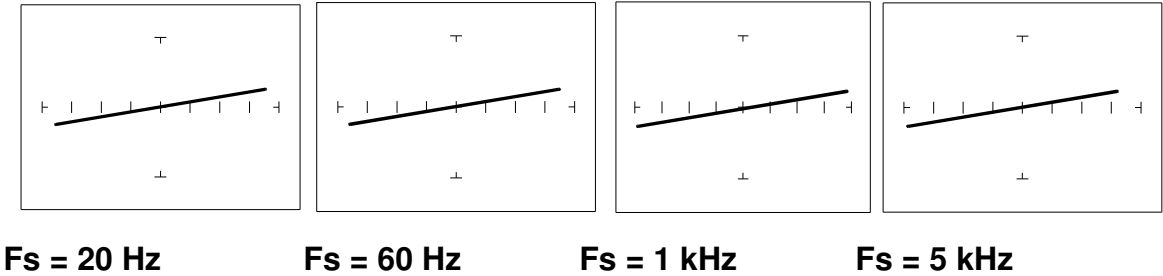

| **Fs = 20 Hz** | **Fs = 60 Hz** | **Fs = 1 kHz** | **Fs = 5 kHz** |

Figure 4-7. Affect Of Varying F_S On A Resistor Signature.
Vs=10V, Rs=50Ω, R_L = 150 Ω.

SHORTS AND OPENS, RESISTOR FAULTS

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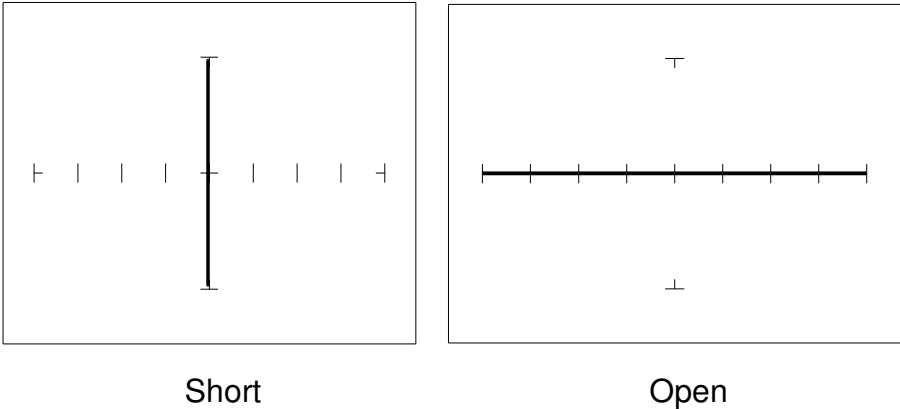

Short   Open

Figure 4-10. Short And Open Signature.

REVIEW

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

- This straight line signature can vary from

    – completely horizontal (an open)

    – completely vertical (a short)

- As resistance increases

    – current decreases

    – the signature becomes more horizontal

- As the range increases

    – the volts per division of the horizontal axis increases

    – the internal resistance increases

    – the signature becomes more vertical

TROUBLESHOOTING APPLICATIONS

- The TrackerPXI is a fast and efficient continuity tester, providing real time information.

- The TrackerPXI will quickly locate resistor defects, shorts, opens and degradation that other testers cannot find.

- A majority of component failures are resistive in nature. This is important to remember; a component fault may only appear in one range because of the resistive nature of the fault.

- The TrackerPXI's I ability to determine the approximate fault resistance value greatly enhances the troubleshooting capability if the correct value is known.
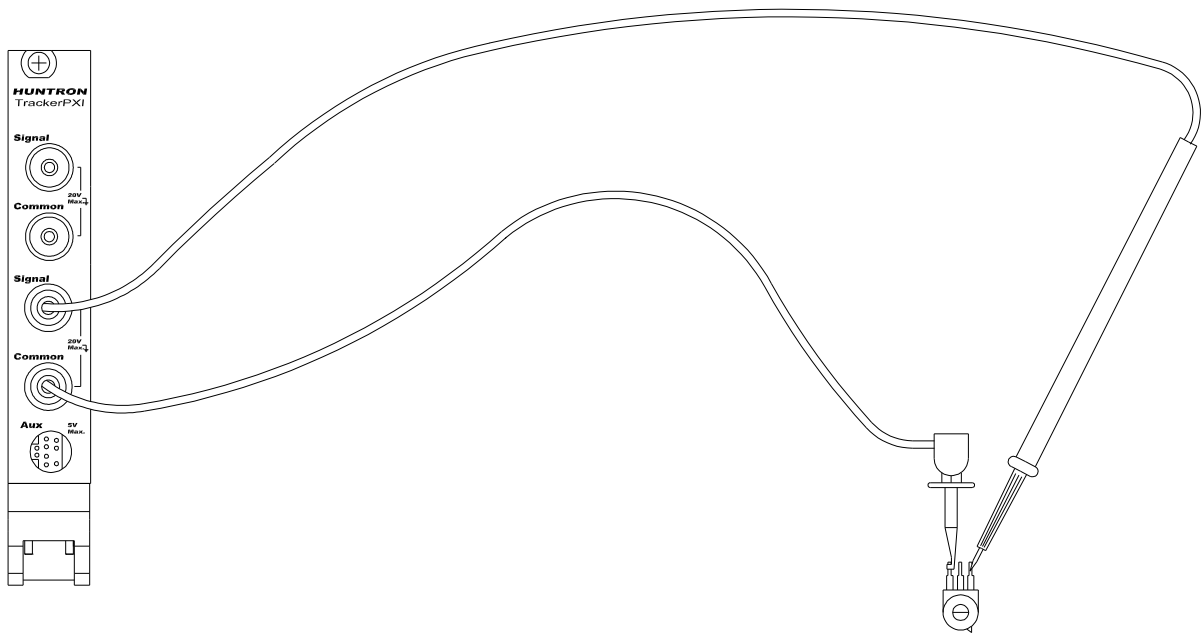
Figure 4-11. Using TrackerPXI To Test A Potentiometer.

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

4-2.   CAPACITORS

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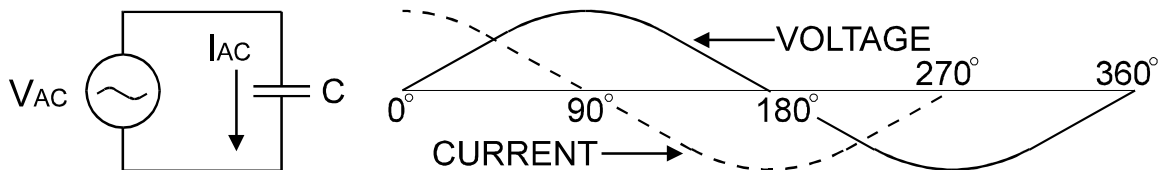

Figure 4-13. Capacitor Circuit With Test Signal's Current And Voltage Waveforms.

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

Because the current is at its maximum value when the voltage is at zero, the current leads the voltage. This is called phase shift and in a purely capacitive circuit, this phase shift equals 90°. On the TrackerPXI, this analog signature appears as a circular waveform. The actual shape and slope of the elliptical signature depends on the capacitance and impedance value of the component and the test signal's voltage, internal resistance and frequency.

CAPACITOR ANALOG SIGNATURES

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

- The capacitance (µf) of the circuit under test

- The frequency (F_s) of the test signal

- The voltage (V_s) of the test signal

- The internal resistance (R_s) of the TrackerPXI

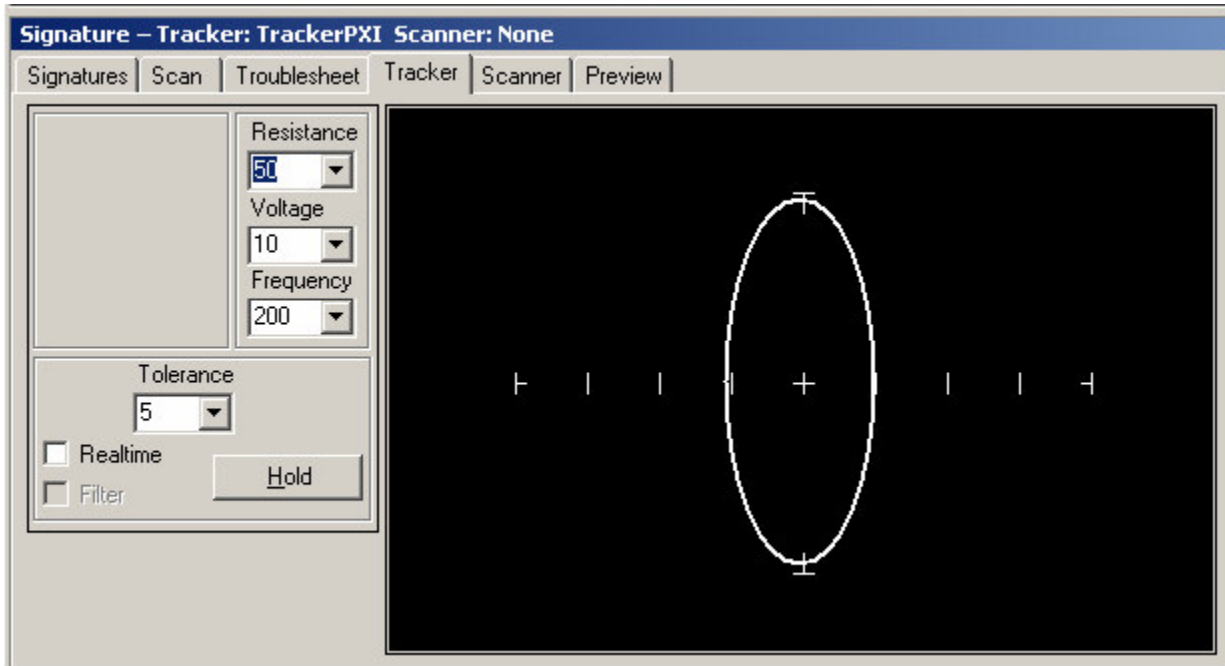Plug the red test microprobe in the Signal jack, and the black test clip lead in the Common jack.

Figure 4-14. TrackerPXI Main Menu Screen.

⚠CAUTION

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

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

1. Select the **50Ω**, **10V** and **60Hz** range

2. Place or clip a test lead on the opposite ends of a capacitor and observe the signature.

THE SIGNATURES OF DIFFERENT CAPACITORS IN LOW RANGE

The figure below shows analog signatures for four different value capacitors, 1000 µf, 100 µf, 10 µf and 1µf. The TrackerPXI is in the **50Ω**, **10V** and **60Hz** range.
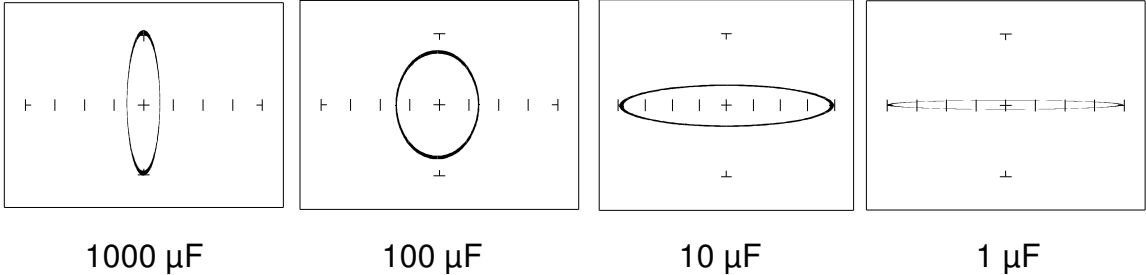
| 1000 µF | 100 µF | 10 µF | 1 µF |

Figure 4-16. Signatures Of 4 Capacitors In Low Range.
Vs=10V, Rs=50Ω Range

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

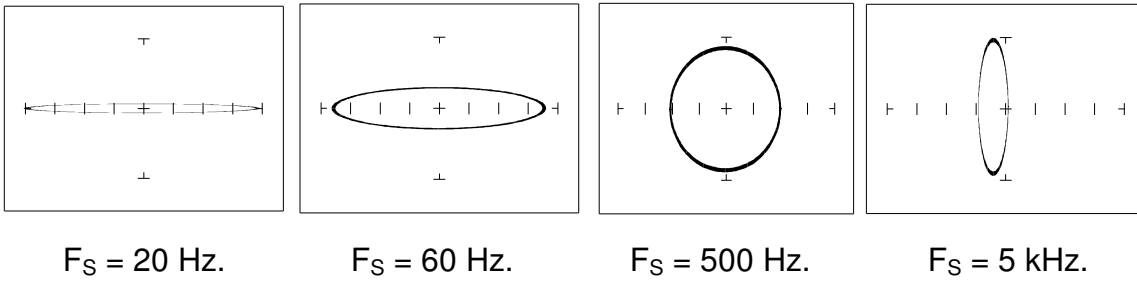**AFFECT OF FREQUENCY (F$_s$) ON THE SIGNATURE OF A 10 μF CAPACITOR**

| F$_S$ = 20 Hz. | F$_S$ = 60 Hz. | F$_S$ = 500 Hz. | F$_S$ = 5 kHz. |

Figure 4-17. Signatures Of A 10 μF Capacitor At Different Frequencies.
54Ω, **10V** and **60Hz** range (**LOW** Range)

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

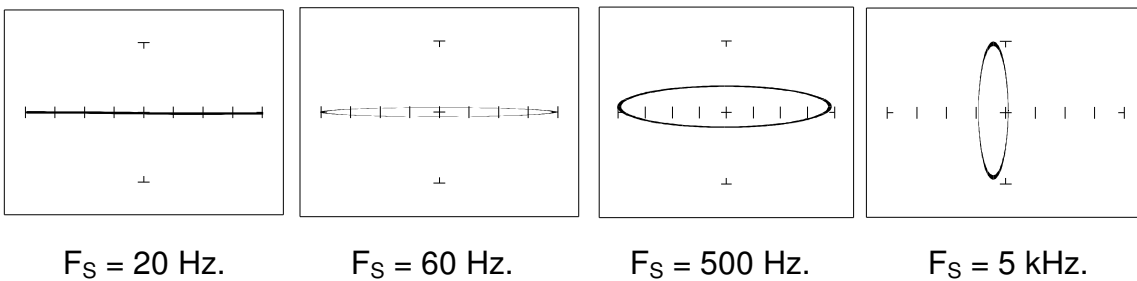**AFFECT OF FREQUENCY (F$_s$) ON THE SIGNATURE OF A 0.1 μF CAPACITOR**

| F$_S$ = 20 Hz. | F$_S$ = 60 Hz. | F$_S$ = 500 Hz. | F$_S$ = 5 kHz. |

Figure 4-18. Signatures Of A 0.1 μF Capacitor At Different Frequencies.
1.24KΩ, **15V** and **60Hz** range **(MED1** range)

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

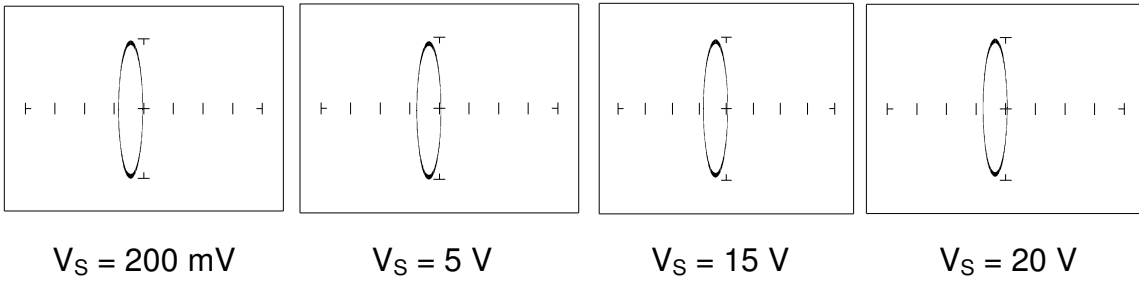## AFFECT OF VOLTAGE (V_S) ON THE SIGNATURE OF A 1 µF CAPACITOR

V_S = 200 mV	V_S = 5 V	V_S = 15 V	V_S = 20 V

Figure 4-19. Signatures Of A 1 µF Capacitor At Different Test Signal Voltages.
27.6 KΩ, **20V** and **60Hz** range (**MED2** Range)

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

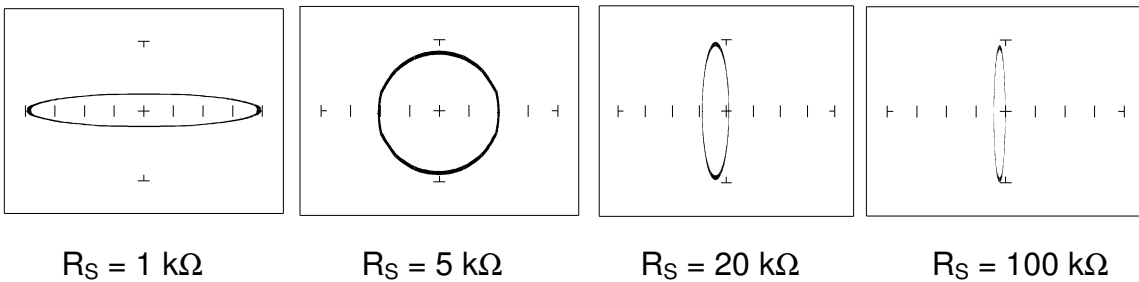## AFFECT OF RESISTANCE (R_s) ON THE SIGNATURE OF A 1µF CAPACITOR

R_S = 1 kΩ	R_S = 5 kΩ	R_S = 20 kΩ	R_S = 100 kΩ

Figure 4-20. Signatures Of A 1µF Capacitor At Different Internal Resistances.
1.24KΩ, **15V** and **60Hz** range **(MED1** range)

As the TrackerPXI's internal resistance R_S decreased, the capacitor's signature changes from a horizontal elliptical pattern to a vertical elliptical pattern. In ASA, a large internal resistance value results in a capacitor signature that looks similar to an open circuit. And likewise, a small internal resistance value results in a capacitor signature that's similar to a short circuit.

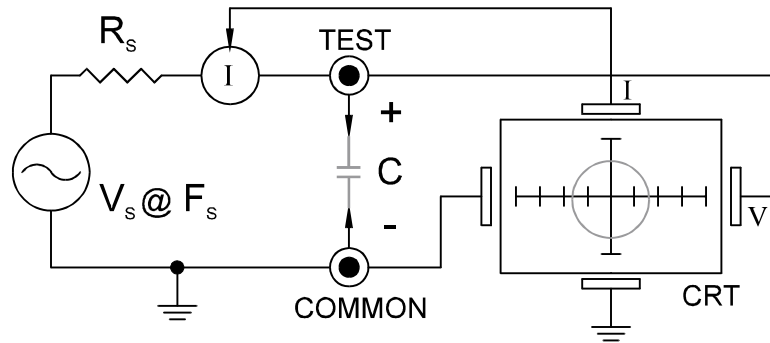**UNDERSTANDING CAPACITOR ANALOG SIGNATURES**

Figure 4-21. TrackerPXI Core Circuit Block Diagram With A Capacitor.

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

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

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

- Changing capacitance: As the capacitance of a circuit increases, the capacitive reactance X_C decreases. This means that when capacitance increases, the amount of current in the component or circuit will increase. On the TrackerPXI, the elliptical signature will become increasingly vertical that implies more current flow.

- Changing frequency F_S: As the frequency of the test signal increases, the capacitive reactance X_C will decrease and the amount of current in the circuit will increase. On the TrackerPXI, the elliptical signature will become increasingly vertical that implies more current flow.

- Changing voltage V_S: As the test signal voltage is changed from 200 mV to 20 V, the following occurs:

  - X_C of the capacitor is not affected

  - The applied V increases

  - The elliptical signature is not affected

- Changing source resistance R_S: As the resistance is changed from 1 kΩ to 100 kΩ, the following occurs:

    - X_C of the capacitor is not affected

    - V_S increases so current decreases proportionately

    - The elliptical signature becomes increasingly vertical
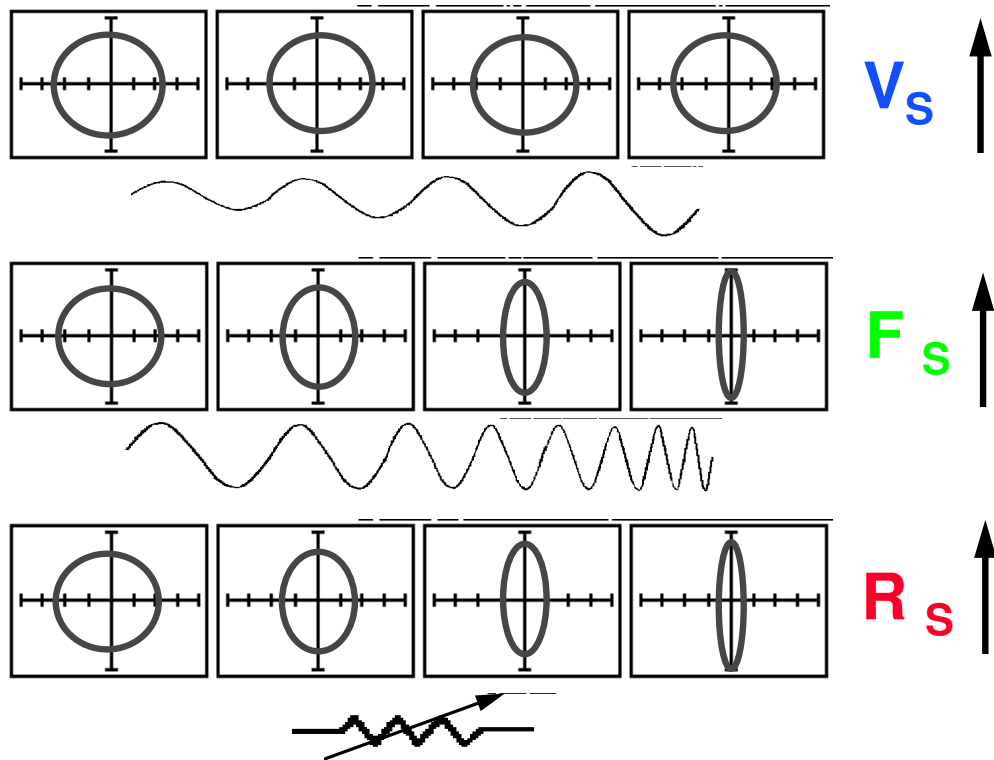
How Tracker Parameter Changes Affect Capacitive Signatures

Figure 4-22. Range Parameters Changes And Affects On Capacitive Signatures.

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

Table 4-1 shows the TrackerPXI's limits for the minimum and maximum capacitance values it can handle.

Table 4-1. TrackerPXI Minimum And Maximum Capacitor Values.

R_S	F_S = 20 Hz.	F_S = 5 kHz
100 kΩ	0.01 µF - 1 µF	10 pF - 0.01 µF
10 Ω	20,000 µF - 100 µF	0.1 µF - 100 µF

CAPACITOR FAILURES - LEAKAGE

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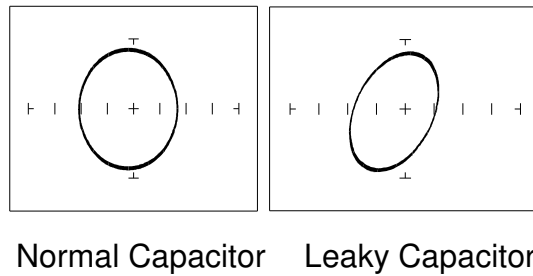

Normal Capacitor   Leaky Capacitor

Figure 4-23. Signatures Of A 100 µF Capacitor With Dielectric Leakage.
50Ω, **10V** and **60Hz** range (**LOW** Range)

This example only simulates the leakage flaw by adding a 100 Ω resistor in parallel to a 100 µF capacitor. It shows the signature change from a normal circular ellipse pattern to a sloped and depressed vertical pattern. The signature of a real capacitive leakage would be quite similar to this example.

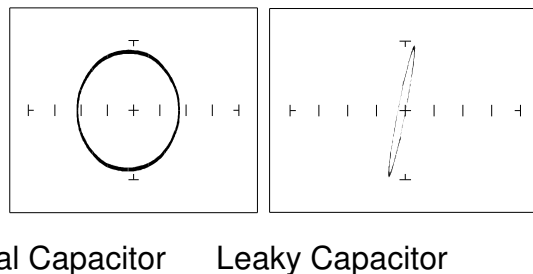Another example of capacitive leakage is shown for a 10 µF capacitor.

Normal Capacitor   Leaky Capacitor

Figure 4-24. Signatures Of A 10 µF Capacitor With Dielectric Leakage.
10 µF Range, $F_S =$ 60 Hz

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

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

REVIEW

- Capacitors have elliptical signatures due to the current and voltage phase shift.

- As the test signal's frequency increases, the capacitor's signature becomes more vertical due to decreasing X_C of the component.

- Capacitors with leakage flaws have their ellipses tilted diagonally due to an internal resistance in parallel with the capacitance.

APPLICATIONS

- The TrackerPXI can locate defective capacitors in or out of circuit. The ranges cover 10 pF to 20,000 μF.

- When analyzing a capacitor's signature, adjust the TrackerPXI's R_S and F_S for the most pronounced ellipse.

- The test signal frequency F_S can be changed to enhance a composite signature by emphasizing or de-emphasizing the capacitance.

- Besides resistance, faulty capacitor signatures often exhibit other irregularities such as non-symmetry, broken or distorted ellipse and saw-toothed shapes that can be seen in the signature display.

4-3. INDUCTORS

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

INDUCTOR ANALOG SIGNATURES

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

- The inductance (**L µH**) of the circuit under test

- The frequency (**F_S**) of the test signal

- The voltage (**V_S**) of the test signal

- The internal resistance (**R_S**) of the TrackerPXI

Plug the red test microprobe in the **Signal** jack, and the black test clip lead in the **Common** jack.

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

1. Select **50Ω**, **10V** and **60Hz** range (**LOW** Range)

2. Place or clip each test lead on the opposite ends of an inductor and observe the signature in the TrackerPXI signature display.

THE SIGNATURES OF DIFFERENT INDUCTORS IN 50Ω, 10V (LOW range) and 2KHz.

The figure below shows analog signatures for four different value inductors, 12,000 µH, 1200 µH, 120 µH and 12 µH in LOW range.
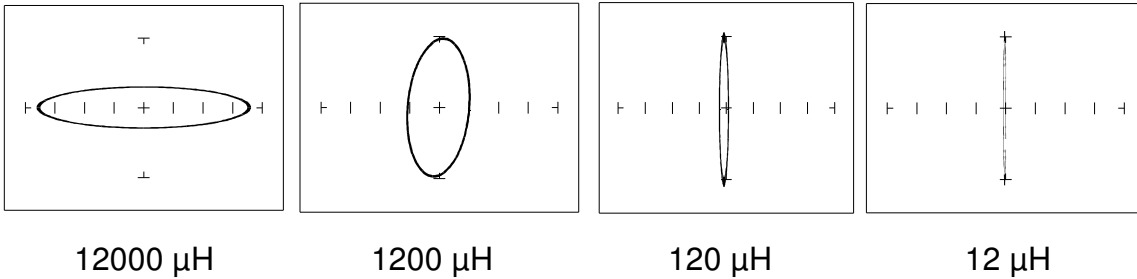

| 12000 µH | 1200 µH | 120 µH | 12 µH |

Figure 4-27. Signatures Of 4 Inductors. V_S = 10 V, R_S = 50 Ω, F_S = 2 kHz

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

AFFECT OF FREQUENCY F_S ON INDUCTOR SIGNATURES

| F_S = 60 Hz | F_S = 1 kHz | F_S = 5 kHz |
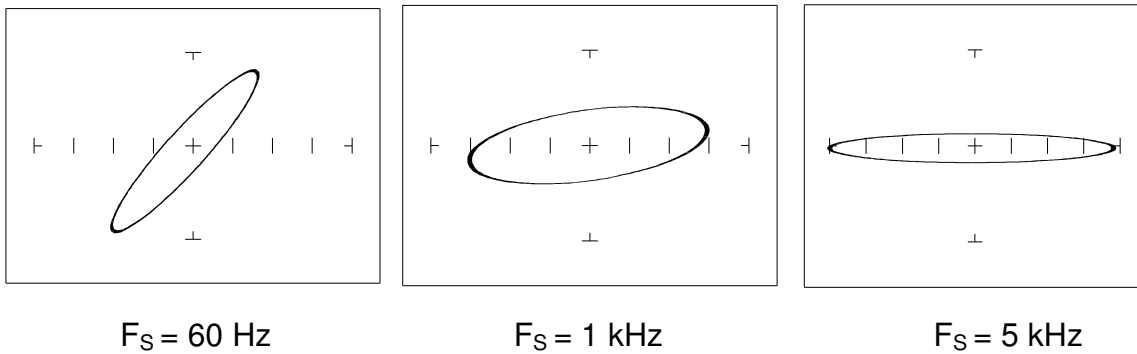
Figure 4-28. Affect of Varying F_S On Inductor Signatures.
54Ω, **10V** range (**LOW** Range), L = 12,000 µH

Note that the signature changes from a vertical position to a horizontal position as the frequency increases. This means the resistance of an inductor increases as frequency increases.
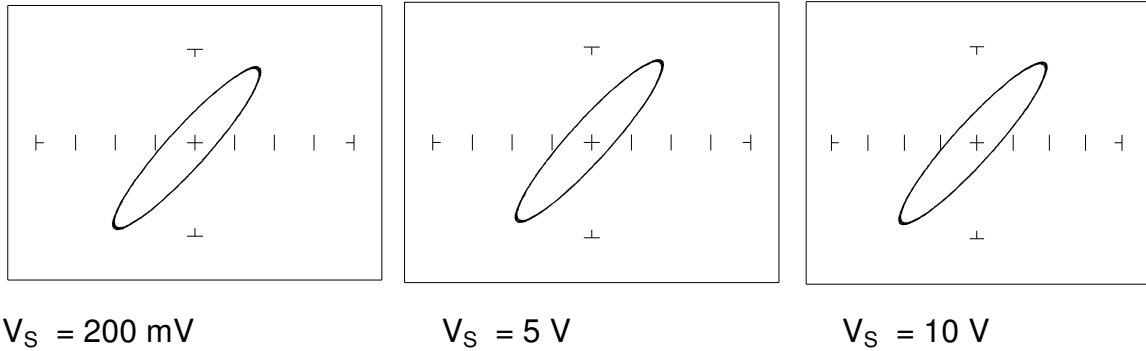
AFFECT OF VOLTAGE V_S ON INDUCTOR SIGNATURES

| V_S = 200 mV | V_S = 5 V | V_S = 10 V |

Figure 4-29. Affect Of Varying V_S On Inductor Signatures.
V_S = 10 V, R_S = 54 Ω, F_S = 60 Hz, L = 12,000 µH

Note that the signature does not change at the three test signal voltages. This means that the inductor's resistance is not affected by changes in the test voltage.
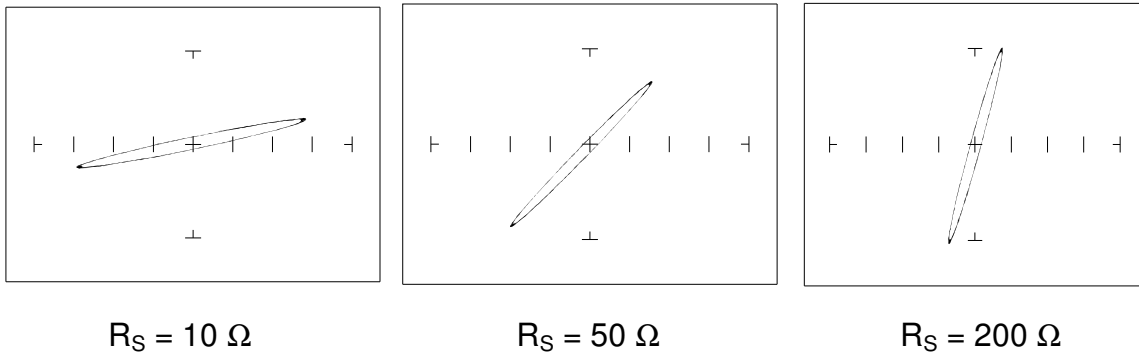
AFFECT OF INTERNAL RESISTANCE R_S ON INDUCTOR SIGNATURES

| R_S = 10 Ω | R_S = 50 Ω | R_S = 200 Ω |

Figure 4-30. Affect Of Varying R_S On Inductor Signatures.
V_S = 2V V, R_S = 54 Ω, F_S = 60 Hz, L = 12,000 µH

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

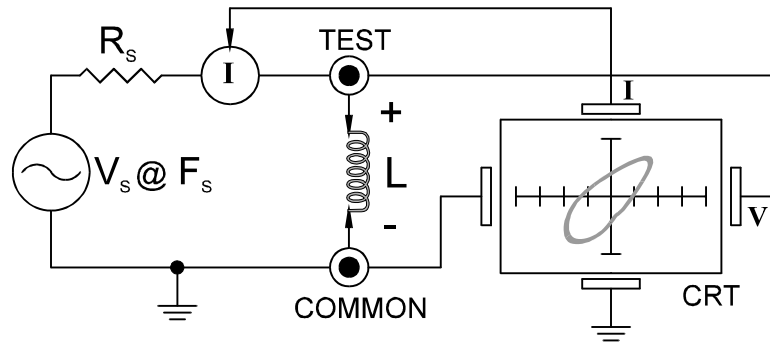## UNDERSTANDING INDUCTIVE SIGNATURES

Figure 4-31. TrackerPXI Tracker Core Circuit Block Diagram With An Inductor.

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

The formula for the reactance X_L of an inductor is:

$$X_L = 2\pi fL$$

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

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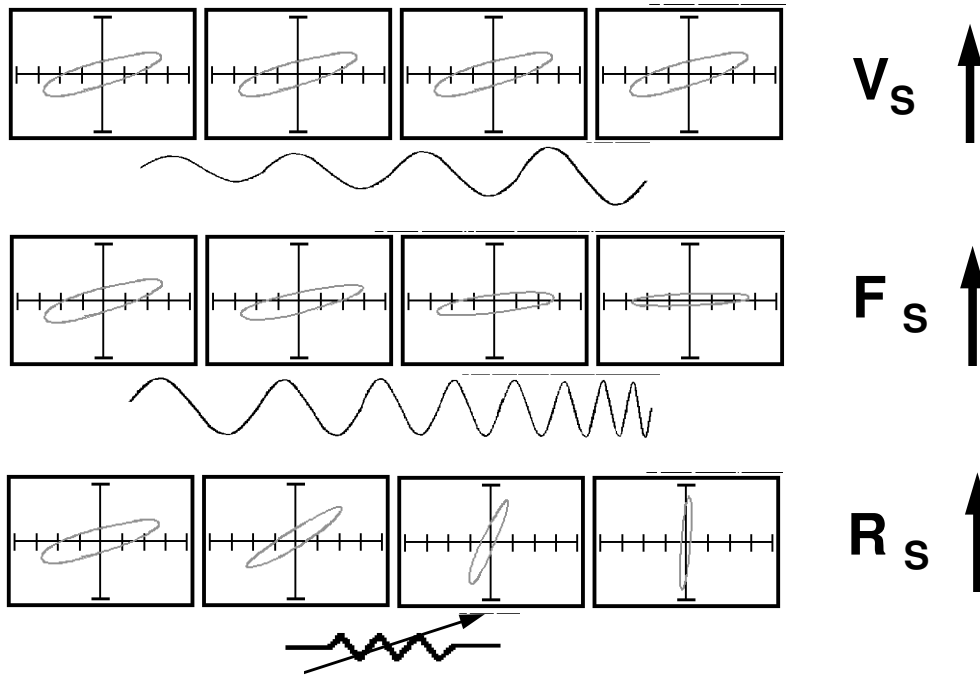
How Tracker Parameter Changes affect Inductive Signatures

Figure 4-32. Range Parameters Changes And Affects On Inductive Signatures.

Table 4-2. TrackerPXI Minimum And Maximum Inductor Values.

R_S	$F_S = 20$ Hz.	$F_S = 5$ kHz
100 kΩ	100H – 1000H	50mH – 1000mH
10 Ω	1H – 100H	1uH – 10mH

REVIEW

• Inductors display elliptical signatures similar to capacitors. Since the inductor also exhibits resistance, due to its construction, the ellipse may be distorted.

• As the TrackerPXI test signal's frequency is increased, the ellipse signature becomes flatter. This response is opposite to that of a capacitor.

• As the TrackerPXI internal resistance R_S increases, an inductor's signature becomes more vertical (like the capacitor signature).

• When an inductor has a ferrite core, its signature distorts from a non ferrite inductor's ellipse.

APPLICATIONS

- The TrackerPXI is excellent for troubleshooting inductors. It can reveal shorted or open windings in large variety of inductive components.

- Components that are inductors or have inductive characteristics can be found in many real world applications. For example, some of these are power transformers, relays, solenoids, flybacks, speakers, magnetic sensors, stepping motors and motor windings.

- The best technique for testing inductors is the comparison of a known good component's signature to a suspect component. For example, a motor armature has typically numerous windings so every winding should have a similar analog signature. This fact is true whether it's from an elevator or a tape deck. The armature of a DC motor can be tested by simply connecting to the motor brush leads and then adjusting the test range for the most pronounced or descriptive signature. Slowly turn the armature. Observe the TrackerPXI's signature display. This test will check continuity, the inductance, and the condition of each brush contact without disassembling the motor.

- A computer switching power supply contains inductors. For example, a computer is reported "dead." To make a quick diagnosis of the possible problem first make sure the computer is disconnected from AC power. Then connect the red and black test probes across the prongs on the AC line cord going to the computer. Turn the computer power switch to the On position. If there is a response on the TrackerPXI signature display, adjust the test range for the most pronounced inductive signature. Flick the power switch off and on and watch for noisy switch contacts. If there is no response, start by checking each component up to the primary winding of the transformer. With this technique, we have just verified the AC cord, the AC noise filter, the fuse, the power switch and the primary winding of the transformer, without removing the cover from the computer.

- Another simple test for a speaker or microphone is to apply the TrackerPXI signal in $V_S = 10$ V, $R_S = 50$ Ω, $F_S = 60$ Hz (LOW) range to the device input leads and listen for the 60 Hz tone or audible hum.

- To test solenoids, connect the test probes to the coil leads and manually move the plunger or activator in and out while observing if its signature changes.

4-4.   ELECTROMECHANICAL SWITCHING COMPONENTS

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

MANUALLY OPERATED MECHANICAL SWITCHES

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

Plug the red test microprobe in the **Signal** jack, and the black test clip lead in the **Common** jack.

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

1. Select the V_S = 10 V, R_S = 50 Ω, F_S = 60 Hz range button.

2. Place or clip each test lead to the switch leads and observe its signature on the TrackerPXI signature display.
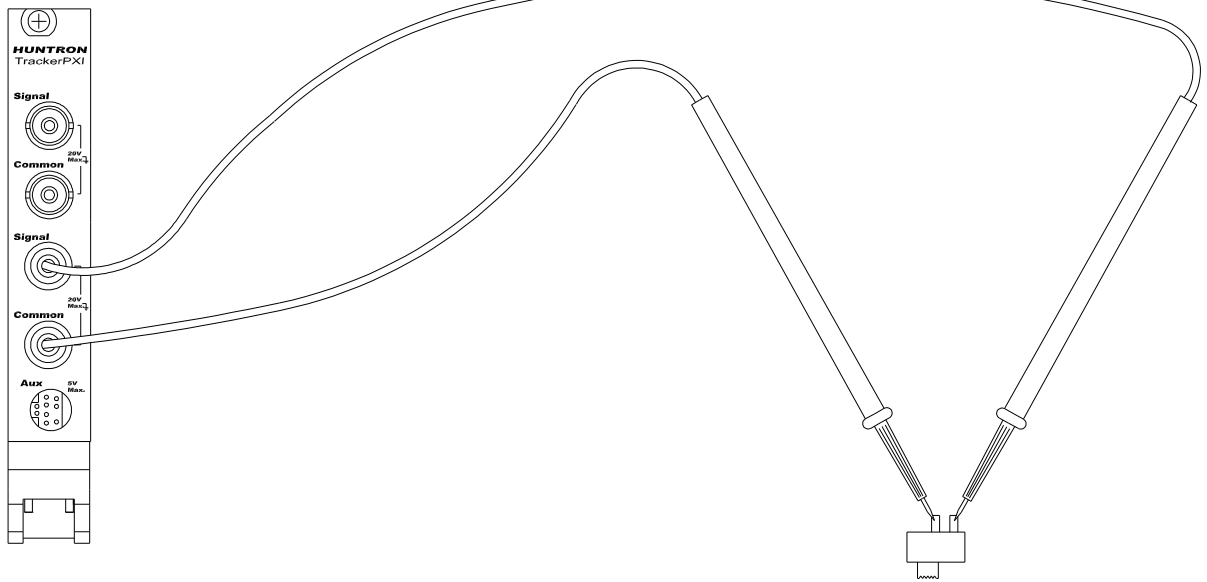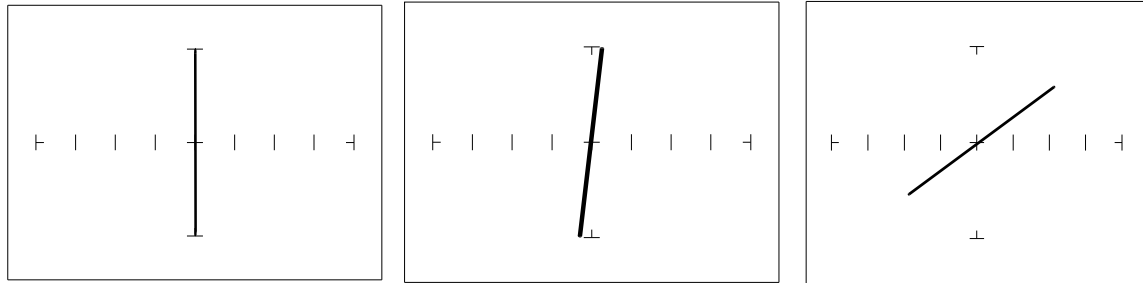
3. Turn the switch to its on or off position.

Figure 4-34. TrackerPXI With Probes To A Mechanical Switch - SPST Type.

27.6KOhm (MED2)   **1.26 KOhm (MED1)**   **50 Ohm (LOW)**

Figure 4-35. Signatures Of A Keyboard Pushbutton Conductive Elastomer Switch. SPST Type, "ON" position.

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

REVIEW

- The switch has internal resistance.

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

ELECTROMECHANICAL RELAYS

A relay is a switch that's activated by an electrical control input. The relay consists of switch contacts, magnets and an electromagnetic coil. The TrackerPXI can test the coil part of the relay by looking at its inductive analog signature.

RELAY COIL TEST

Do the following:

1. Select the **V$_S$ = 10 V, R$_S$ = 50 Ω, F$_S$ = 1 Khz** range.

2. Connect the black test lead from TrackerPXI's **Common** jack to one side the relay coil (normally, the minus lead).

3. Connect the red test lead from TrackerPXI's **Signal** jack to the other side of the relay coil (normally, the plus lead).
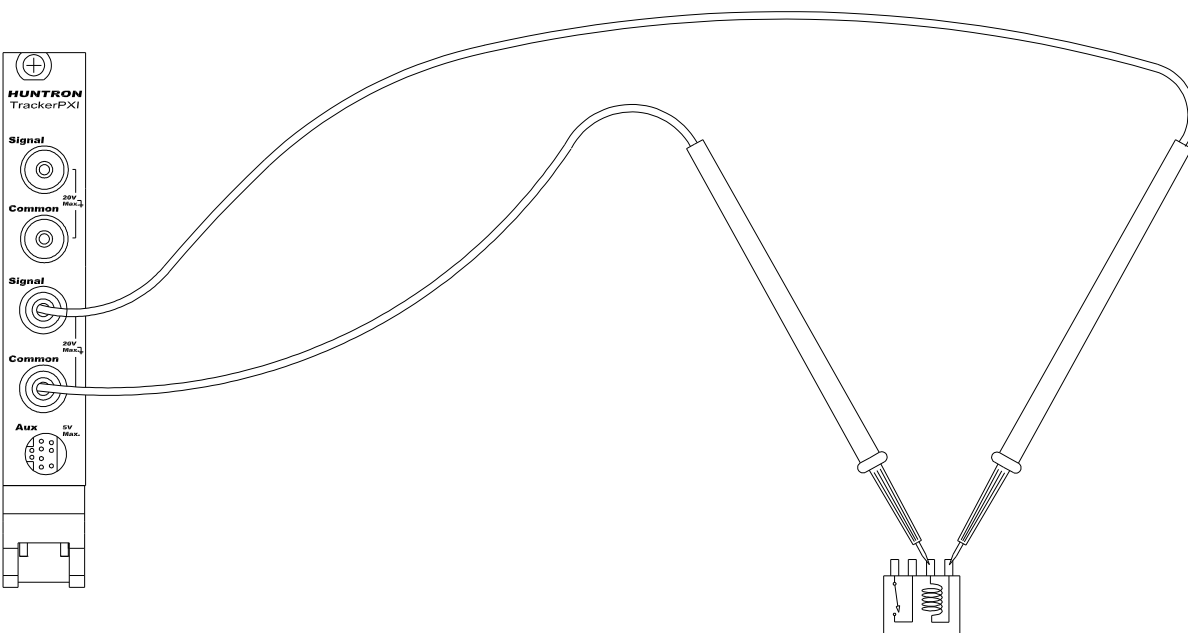
Figure 4-36. TrackerPXI With Test Leads Connected To Relay's Coil.

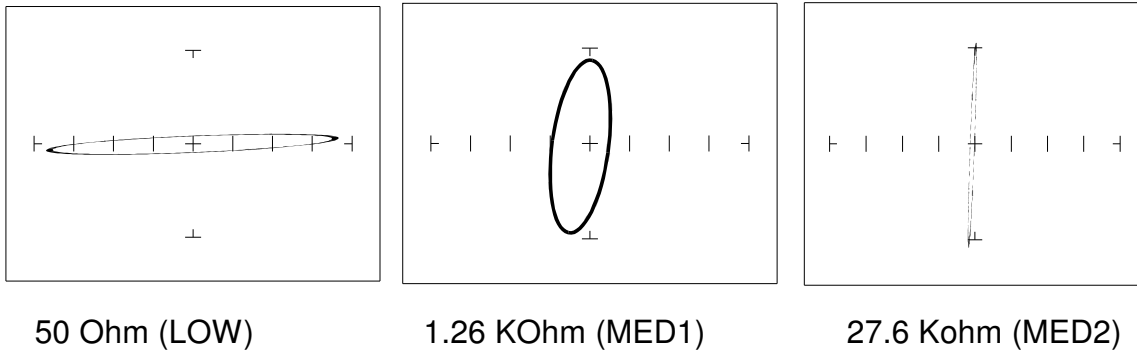Observe the analog signatures of a magnetic reed type relay in the following figure.

| 50 Ohm (LOW) | 1.26 KOhm (MED1) | 27.6 Kohm (MED2) |

Figure 4-37. Signatures Of A Magnetic Reed Relay Coil.
F_S = 1 kHz

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

REVIEW

- The TrackerPXI can test switches in real time. This makes an excellent test for microswitches, power switches, control switches, pressure and heat sensor switches.

- As the mechanical switch closes, watch for erratic or discontinuous signature. Switch bounce will display as multiple closure signatures. Resistive contacts will display a resistive signature in LOW range.

SECTION 5 TESTING DISCRETE SEMICONDUCTORS

5-1.   DIODES

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

DIODE SCHEMATIC SYMBOL

CATHODE   ANODE

N   P

-              +

Figure 5-1. Diode And Schematic Symbol.

DIODE ANALOG SIGNATURES

Diode signatures demonstrate the fundamental operation of a semiconductor junction. There is a threshold or forward voltage V_F (about 0.6V for a silicon diode) at which the diode begins to conduct current. The diode acts as an open circuit and no current flows as long as the voltage differential between the anode and cathode is below that threshold. As the anode to cathode voltage becomes more positive, the diode will begin to conduct current. Once current begins to flow in the diode, very small increases in anode voltage will cause very large increases in current. In analog signature analysis, this is called the "knee" effect in a which is characteristic of a good semiconductor junction.
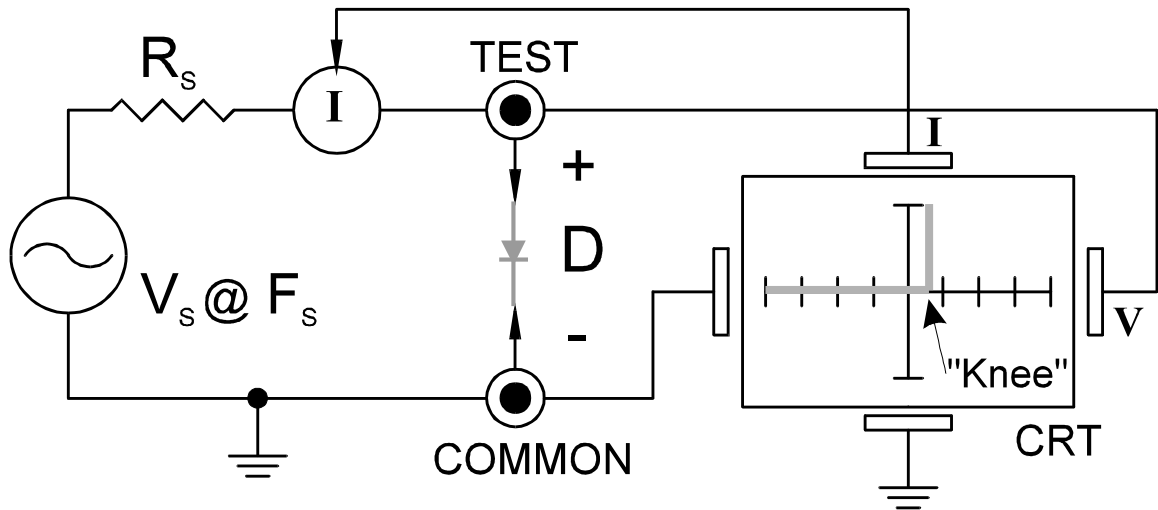
Figure 5-2. TrackerPXI Core Circuit Block Diagram With A Diode.

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

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

1. Select **50Ω**, **10V** and **60Hz** range (**LOW** Range).

2. Place or clip the red test lead from the TrackerPXI's **Signal** jack to anode lead of the diode.

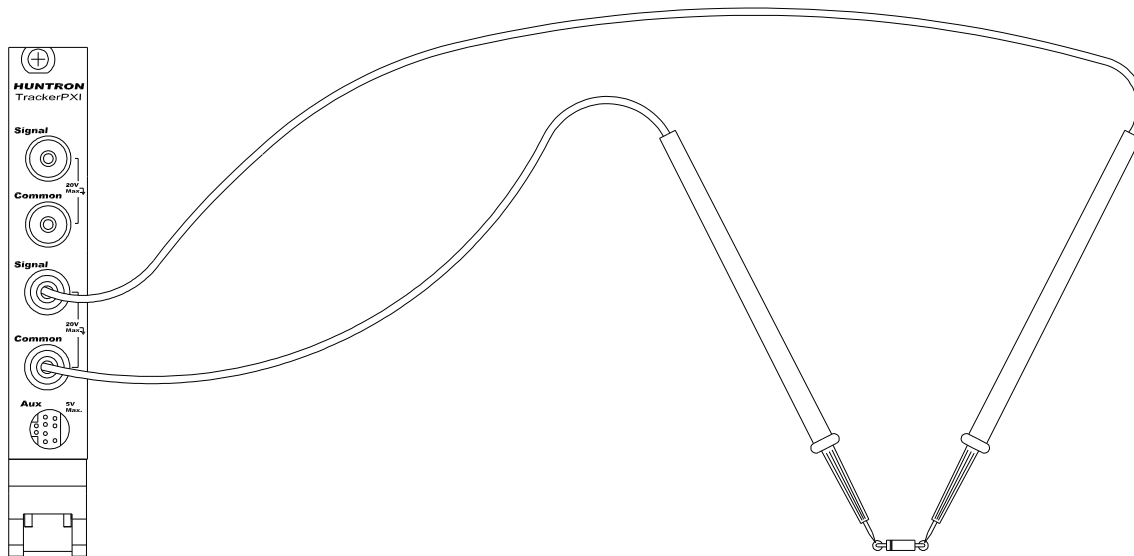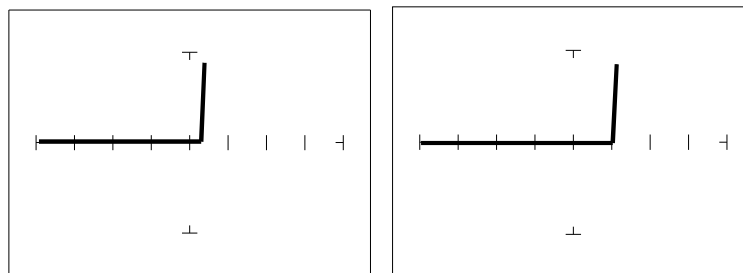3. Place or clip the black test lead from the TrackerPXI's **Common** jack to anode lead of the diode.

Figure 5-4. TrackerPXI With Probes To A Diode.

V_S = 10 Volts V_S = 3 Volts

Figure 5-5. Signature of a 1N914 type Silicon Diode.
50Ω and **60Hz** range.

The diode signatures are similar to each other. In the 50 Ohm range, the test signal voltage is 10 V_P. Each horizontal division on the display equals approximately 2.5 V. In this range the diode's signature shows that its threshold or forward voltage is approximately 0.6 Volts. By lowering the test voltage to 3 V with the encoder, the 0.6 volt threshold is clearly visible for easier analysis.

AFFECTS OF FREQUENCY (F$_S$) ON THE DIODE SIGNATURE

With the **3V**, **54 Ω** range selected and the test signal frequency of 60 Hz, the signature of the diode is shown on the left figure below. Changing only the test signal frequency to 5 kHz displays the signature on the right. At F$_S$ = 5 kHz, the diode's signature has slight circular loop added to it. This loop in the signature is due to a physical characteristic of diodes called junction capacitance.

60 Hz   5 kHz
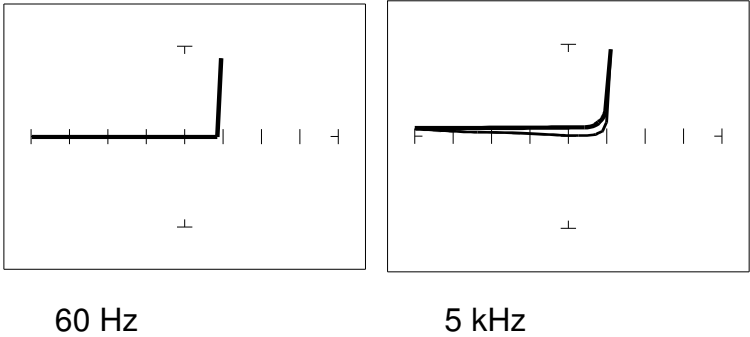
Figure 5-6. Signature Of A 1N914 Diode At Different Range Frequencies.
V$_S$ = 3 V, R$_S$ = 54 Ω.

AFFECTS OF INTERNAL RESISTANCE (R_S) ON THE DIODE SIGNATURE

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

RS = 54 Ω   100 kΩ
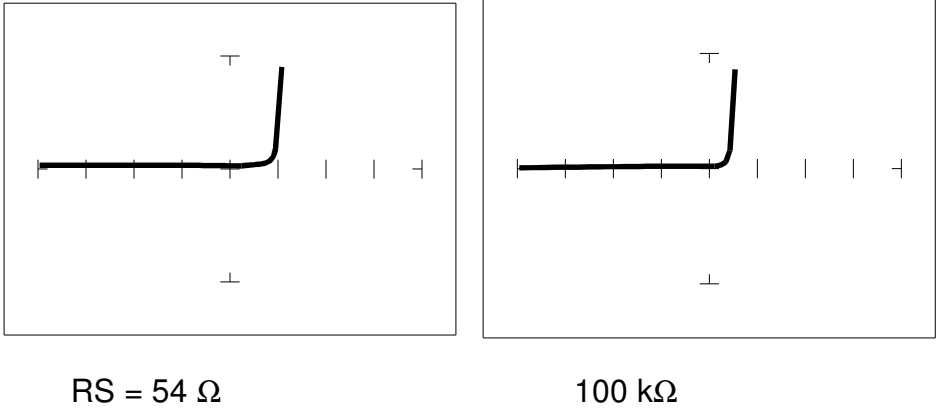
Figure 5-7. Signature Of A 1N914 Diode At Different Range Resistances.
V_S = 3 V, F_S = 60 Hz.

UNDERSTANDING DIODE SIGNATURES

Figure 5-8 reviews the TrackerPXI's three range parameters and how they affect the diode signature.
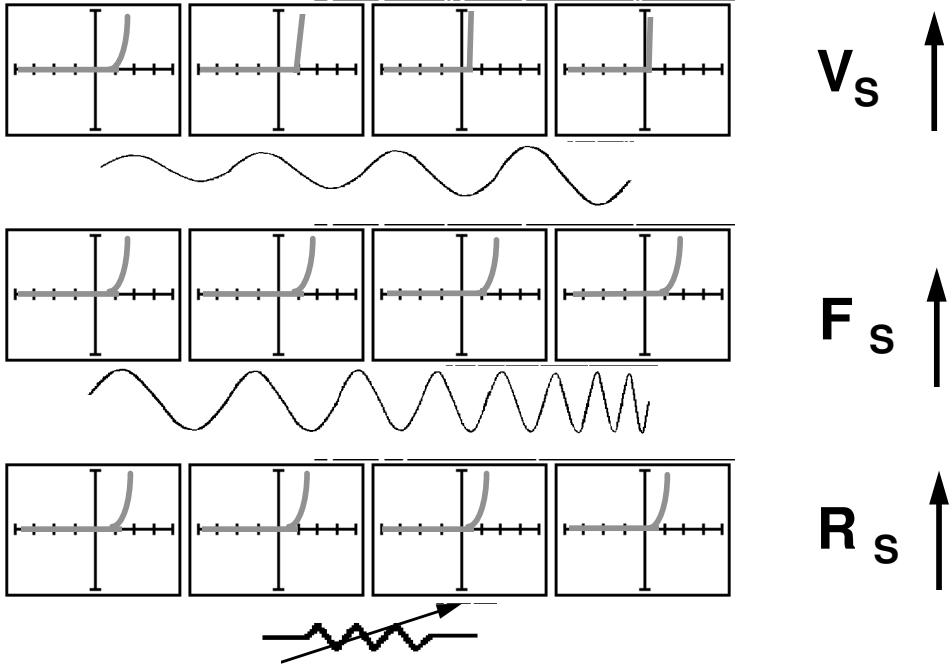
How Tracker Parameter Changes affect Diode Signatures

Figure 5-8. Range Parameters Changes and Affects On Diode Signatures.

THE COMPOSITE DIODE SIGNATURE

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

This section will introduce you to some examples of composite diode signatures.
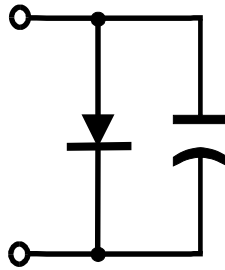
Figure 5-9. Composite Model Of A Diode And Capacitor In Parallel.

V_S = 10 V, F_S = 20 Hz V_S = 10 V, F_S = 1 kHz V_S=200 mV, F_S = 1 kHz
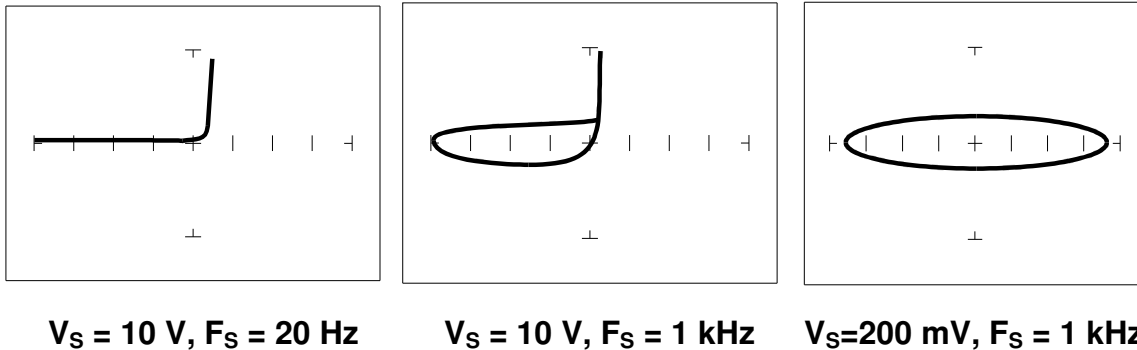
Figure 5-10. Composite Signature - 1N914 Diode And 1 μF Capacitor In Parallel.

The signature on the left shows only the diode signature because the test signal frequency is set below any visible contribution due the capacitive reactance. The composite signature in the center consists of the distinctive loop of the capacitor and the "knee" pattern of the diode. The signature on the right shows only the capacitor signature because the test signal voltage is below the diode's turn on level. When multiple components are connected together, it's important to realize that the TrackerPXI has the ability to selectively display the signature of a single component.
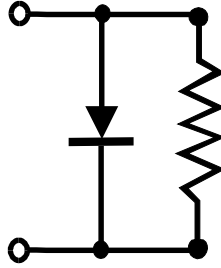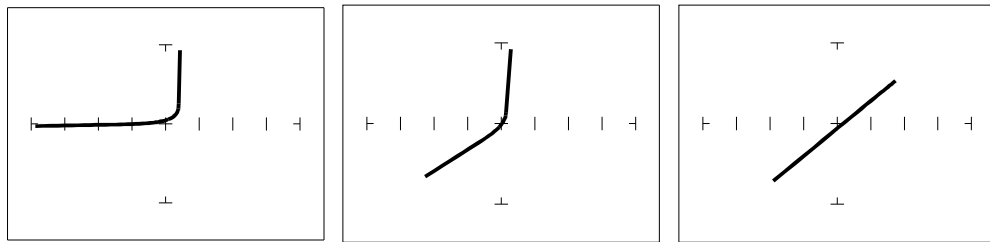
Figure 5-11. Composite Model Of A Diode And Resistor In Parallel.

V_S = 10 V, R_S = 50 Ω V_S = 10 V, R_S = 1 kΩ V_S = 200 mV, R_S = 1 kΩ

Figure 5-12. Composite Signature - 1N914 Diode And 1.5 kΩ Resistor In Parallel.
          F_S = 60 Hz

The signature on the left shows only the diode signature because the test signal resistance
is set below any visible contribution due the 1.5 kΩ resistor. The composite signature in the
center consists of the distinctive slope of the resistor and the "knee" pattern of the diode.
The signature on the right shows only the resistor signature because the test signal voltage
is below the diode's turn on level. Again, when multiple components are connected together,
it's important to realize that the TrackerPXI has the ability to selectively display the signature
of a single component.

DIODE FAILURES

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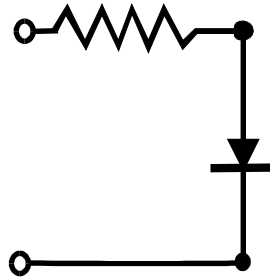
INTERNAL RESISTANCE FLAW IN A DIODE

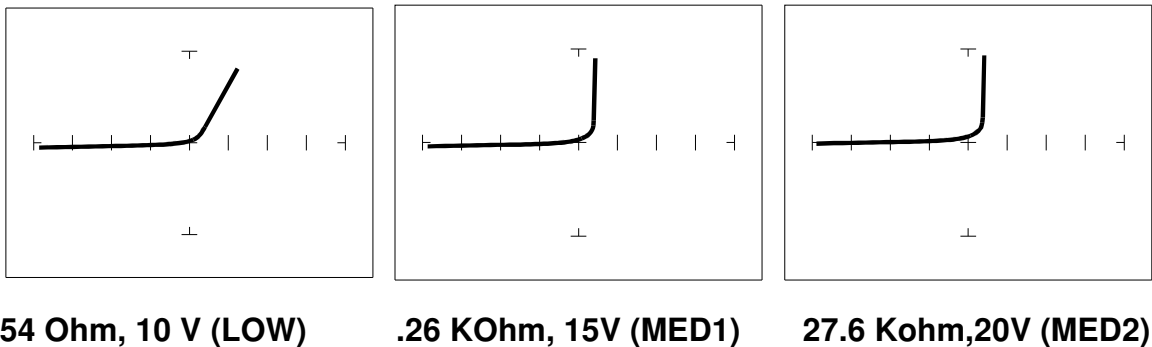Figure 5-13. Defective Diode Model With A Small Series Resistor.

54 Ohm, 10 V (LOW)   .26 KOhm, 15V (MED1)   27.6 Kohm,20V (MED2)

Figure 5-14. Defective Diode Signature With A 50 Ω Series Resistor.

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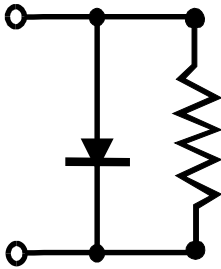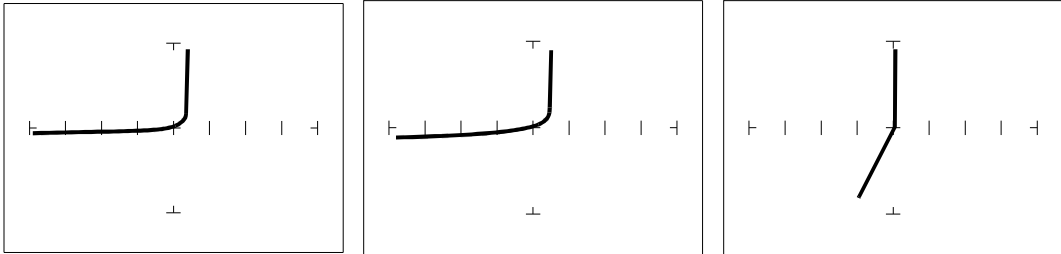
INTERNAL LEAKAGE FLAW IN A DIODE

Figure 5-15. Defective Diode Model With An Internal Leakage Resistance.

54 Ohm, 10 V (LOW)   1.26 KOhm, 15V (MED1)   27.6 Kohm,20V (MED2)

Figure 5-16. Signature Of A Diode With Internal Leakage Flaw.
1N914 Diode With A 10 kΩ Resistor In Parallel.

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

ZENER DIODES

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

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

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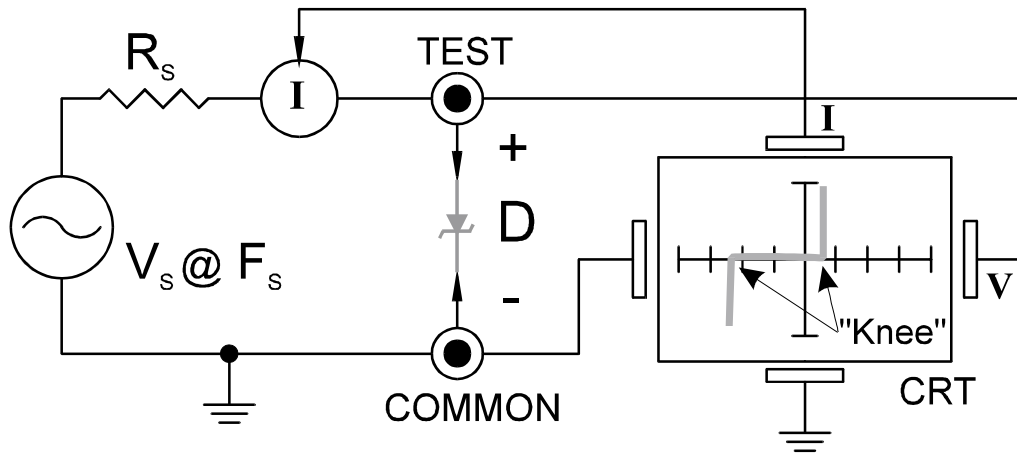

Figure 5-17. TrackerPXI Core Circuit Block Diagram With A Zener Diode.
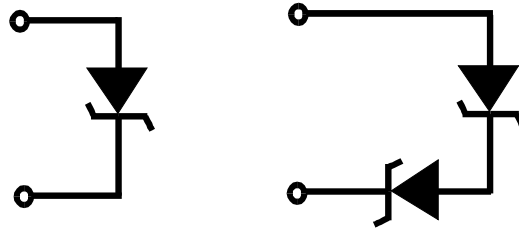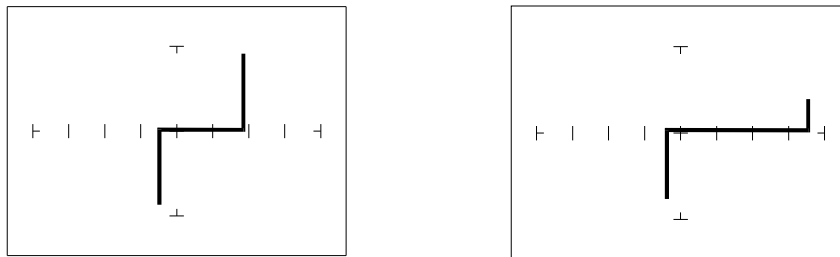
Figure 5-18. Single Zener Diode And 2 Zener Diodes In Series.

Single 1N5239B Zener Diode   2 Zener Diodes in Series, 1N5239B

Figure 5-19. Signature Of A Single Zener Diode And 2 Zener Diodes In Series.
20V, 27.6 KOhm (MED2) Range

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

REVIEW

- Diodes conduct current in one direction (forward biased) and not the other. The diode's analog signature displays this characteristic as the "knee" effect or pattern.

- Diodes have polarity, an anode and a cathode.

- Diode defects, other than opens and shorts, are usually resistive.

- A diode in series or parallel with a resistor or capacitor will create a composite signature displaying both characteristics. The TrackerPXI makes it easier to separate these characteristics from composite signatures using the three parameters F_S, R_S and V_S.

- Zener diodes are special diodes that conduct when reverse biased at a specific voltage.

APPLYING WHAT WE HAVE LEARNED

- Diode damage or degradation can appear as a loss of sharpness or rounding in the "knee".

- While faulty diodes display resistive current and voltage legs, they are usually nonlinear or curved.

- The polarity of an unmarked diode can be determined by the orientation of the display with a known diode.

- The TrackerPXI can be used to identify an unknown zener diode. If the zener diode is damaged, locate a good one, possibly on another board or in the same circuit and use the TrackerPXI to approximate the voltage.

- Look for the zener effect when checking voltage regulators such as the 7805 type. This can help determine an unknown or faulty device.

- The TrackerPXI can be used to test and determine the four pin connections on a bridge rectifier, (AC1, AC2, + and -).

5-2.   TRANSISTORS

A bipolar transistor is a three layer device. There are two basic types. A PNP transistor has a layer of n-type silicon material sandwiched between two layers of p-type material. An NPN transistor has a layer of p-type silicon material sandwiched between two layers of n-type material. Figure 5-20 shows the relationship between type of material and circuit symbol for a PNP and an NPN transistor.
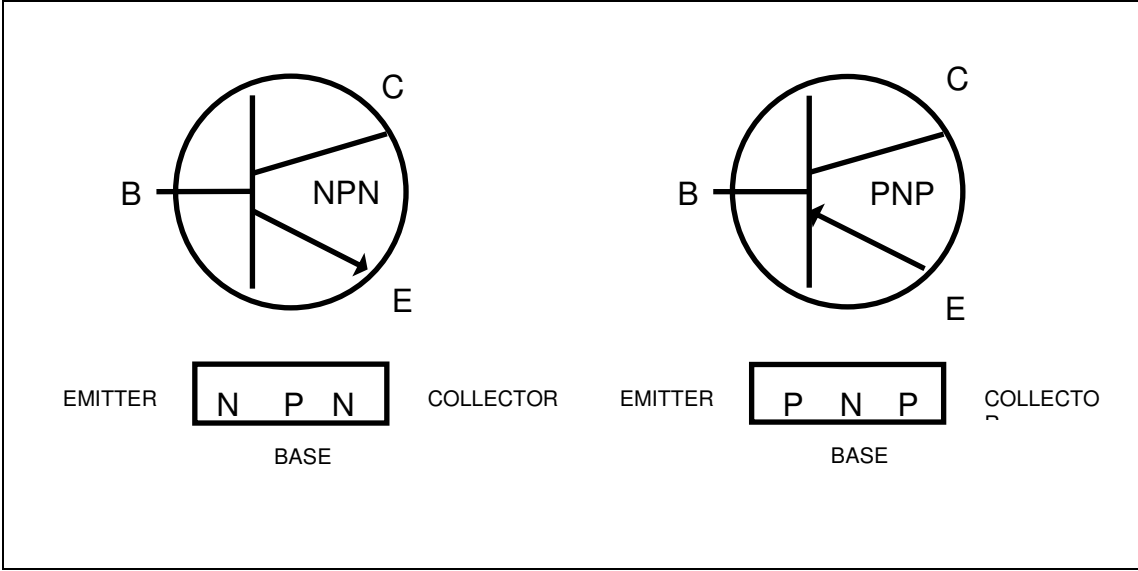

Figure 5-20. Diagram Of An NPN And PNP Bipolar Transistor.

IMPORTANT NOTE

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

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

Suggestions to minimize effects on bipolar transistors:

1. Use 5 Volts or less for testing the base-emitter or collector-emitter.

2. If using 6 Volts or greater, then keep the duration of the test as short as possible.

3. Identify the base, emitter and collector pins of the device and then test the collector-base junction to determine whether it is an NPN or PNP. Since the emitter is not tested there will be no effect on h_{FE} regardless of the selected voltage.

BIPOLAR TRANSISTOR SIGNATURES

In order to better understand the signatures that transistors create on the TrackerPXI, we can model these devices in terms of equivalent diode circuits. These are shown in figure 5-21. These figures show that the collector-based junction analog signature looks similar to a diode signature, and the emitter-base junction signature looks similar to a zener diode signature. Because we have already seen the signatures of these two types of junctions when we tested diodes, they should be familiar to you.
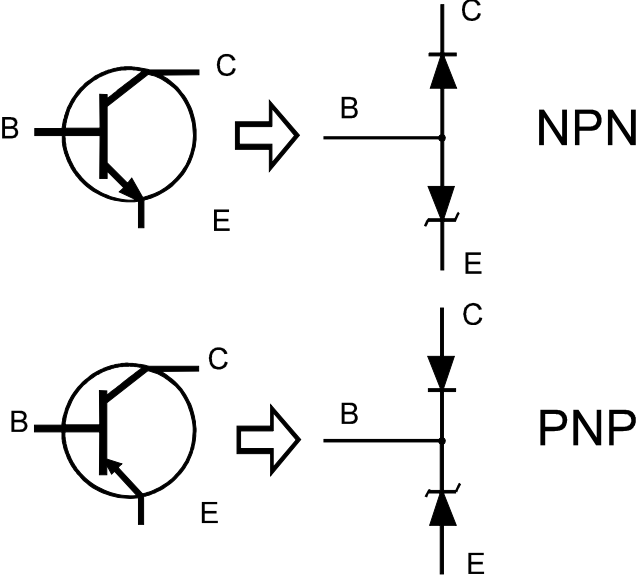
Figure 5-21. NPN And PNP Bipolar Transistors' Equivalent Circuits.

BIPOLAR TRANSISTOR BASE-COLLECTOR SIGNATURES

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

1. Select the **1.26 KOhm, 15V (MED1)** range.

2. Place or clip the red test lead from the TrackerPXI's **Signal** jack to collector lead of the transistor.

3. Place or clip the black test lead from the TrackerPXI's **Common** jack to base lead of the transistor.
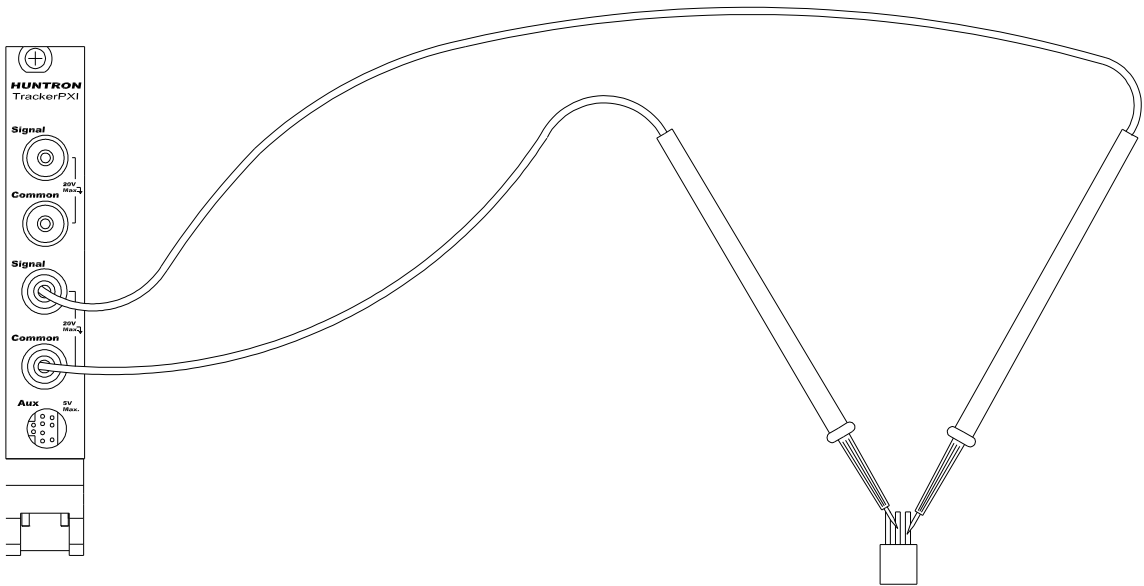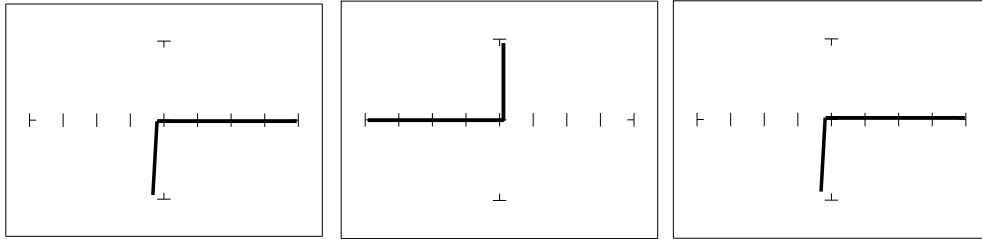
Figure 5-23. TrackerPXI Connected To The Collector And Base Leads Of A Transistor.

Diode 1N914   PNP Transistor 2N3906 NPN Transistor PN2222A

Figure 5-24. Signature Of A Diode And Collector-Base Of A Transistor.
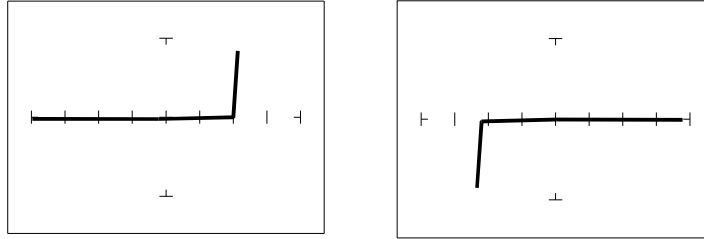**1.26 KOhm, 15V (MED1)** Range

Notice that the collector-base signature of a NPN transistor is identical to the signature of diode. The collector-base signature of a PNP transistor, which has opposite polarity from a NPN, looks similar to a diode with its polarity reversed. These are the signatures we expected from our circuit modeling. We can do the same kind of comparison with the emitter-base circuits.
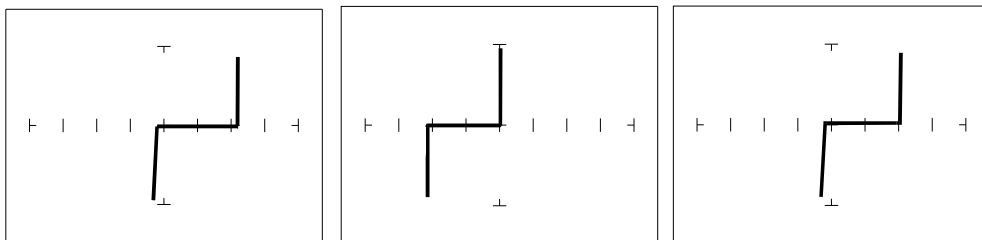
Zener Diode 1N5239B PNP Transistor 2N3906 NPN Transistor PN2222A

Figure 5-25. Signature Of A Diode And Emitter-Base Of A Transistor.
1.26 KOhm, 15V (MED1) Range

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

PNP Transistor - 2N3906   NPN Transistor - PN2222A

Figure 5-26. Signature Of The Collector-Emitter Of A PNP And NPN Transistor.
1.26 KOhm, 15V (MED1) Range, Emitter To Common.

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

All bipolar junction transistors have essentially the same looking signatures.

IDENTIFYING UNKNOWN TRANSISTORS

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

Do the following:

1. Select **20V, 27.6 KOhm** (**MED2)** range with **60 Hz Frequency**.
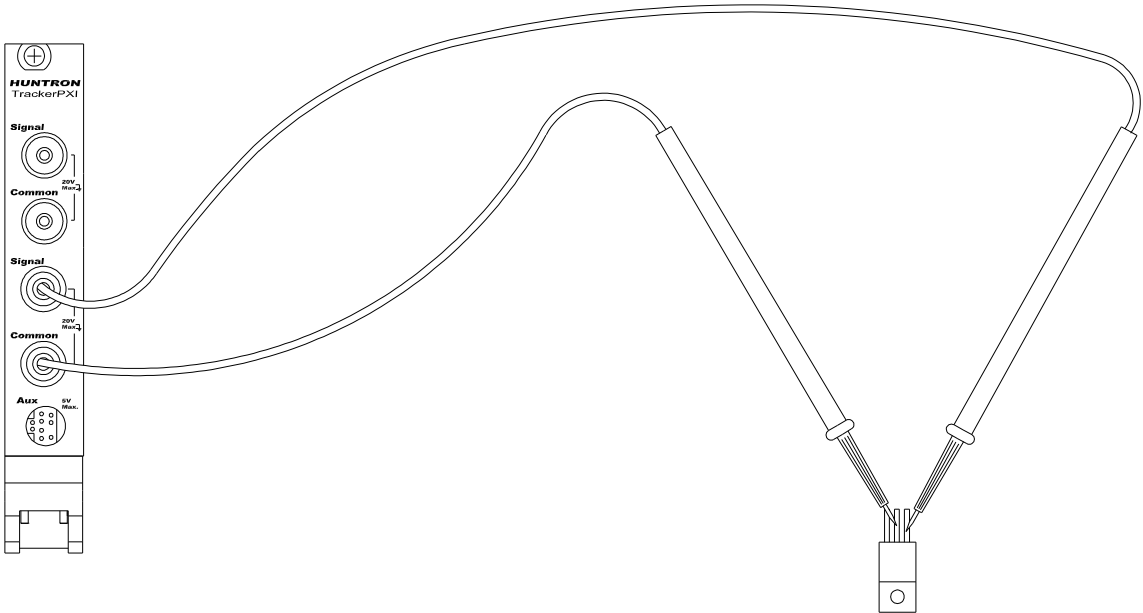

Figure 5-27. TrackerPXI With Probes To An Unmarked Transistor.

Do the following:

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

2. Identify the signature.

3. This looks like a collector-base signature. What you do not know yet is which pin is the collector and which pin is the base?
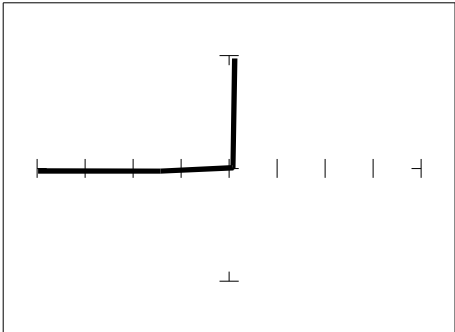

Figure 5-28. Signature Of Pins 1 And 2 Of An Unknown Transistor.

4. Probe pin 3 with the red probe and pin 2 with the black probe.

5. Identify the signature.
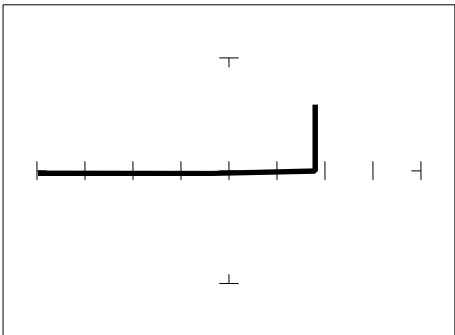
6. This looks like a collector-emitter signature.

Figure 5-29. Signature Of Pins 3 And 2 Of An Unknown Transistor.

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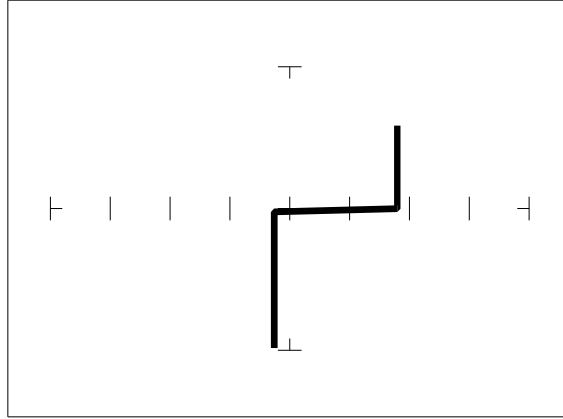

Figure 5-30. Signature Of Pins 1 And 3 Of An Unknown Transistor.

DARLINGTON BIPOLAR TRANSISTOR SIGNATURES

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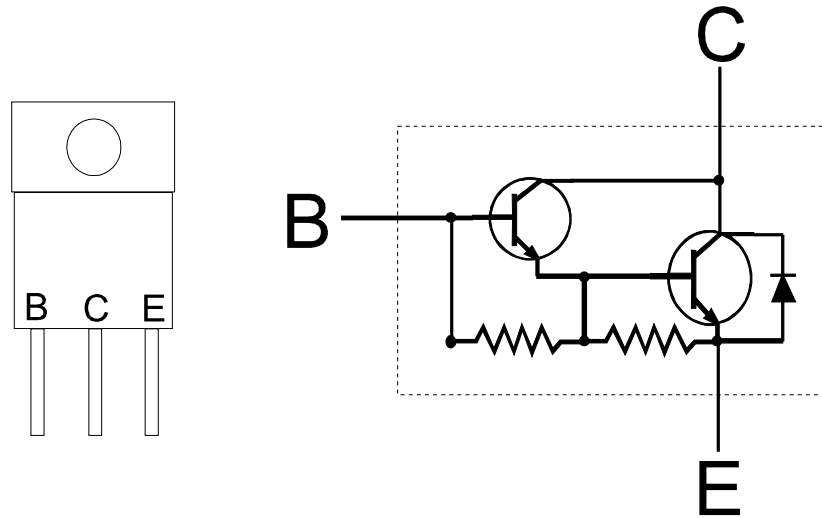

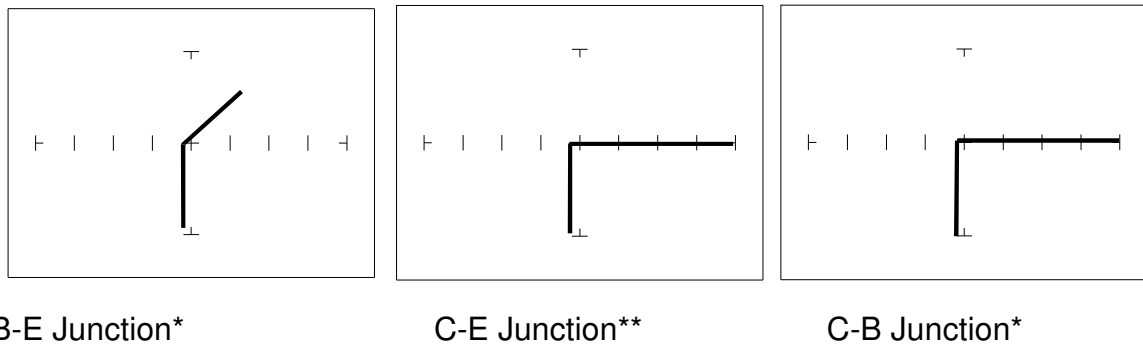Figure 5-31. Diagram Of A Darlington Transistor.

B-E Junction*   C-E Junction**   C-B Junction*

Figure 5-32. Signature Of A Darlington Transistor, TIP112 NPN Type.
20V, 27.6 KOhm (MED2) Range.

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

REVIEW

• A PNP bipolar transistor consists of a layer of N-type silicon sandwiched between two

layers of P-type silicon.

- A NPN bipolar transistor consists of a layer of P-type silicon sandwiched between two layers of N-type silicon.

- To test a transistor, the base-emitter (B-E), collector-base (C-B) and collector-emitter (C-E) junctions all need to be examined.

- The transistor signature resembles the diode signatures previously examined. They have polarity and may exhibit the Zener effect.

APPLYING WHAT WE HAVE LEARNED

- Transistors will display the same type of faulty signature as diodes, with a rounded "knee" and non-linear or resistive current and voltage legs.

- The TrackerPXI can be used to determine the type of transistor; bipolar, Darlington, FET, etc.

- The TrackerPXI can be used to identify the polarity of a transistor (PNP or NPN).

- The TrackerPXI can be used to determine the base, collector and emitter on an unknown transistor.

- The TrackerPXI can be used to match the gain (beta) of two transistors.

- The above techniques of identification are invaluable when repairing foreign electronics and systems without schematics.

5-3.   SOLID STATE SWITCHING COMPONENTS

OPTICAL SWITCHES

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

The optocoupler consists of a light emitting diode and a phototransistor in the same package. They are electrically isolated. When the diode is turned on by an external signal, it radiates light. This light falls on the phototransistor base junction that results in the device turning on.
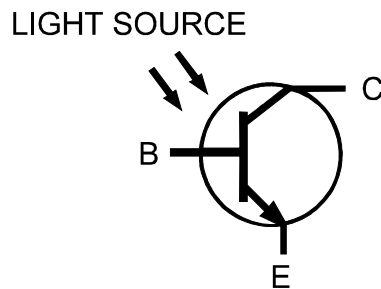
PHOTOTRANSISTOR

LIGHT SOURCE

Figure 5-37. Phototransistor Schematic Diagram.

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

1. Select the **1.26 KOhm, 15V (MED1)** range

2. Place or clip the red test lead from the TrackerPXI's **Signal** jack to collector lead of the component.

3. Place or clip the black test lead from the TrackerPXI's **Common** jack to emitter lead of the component.
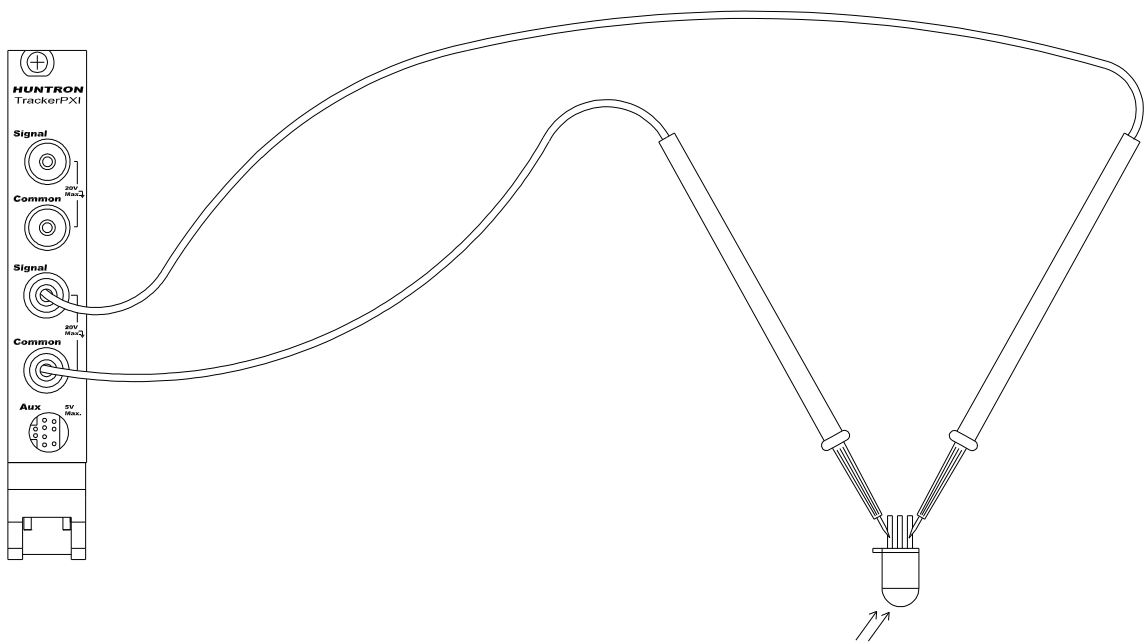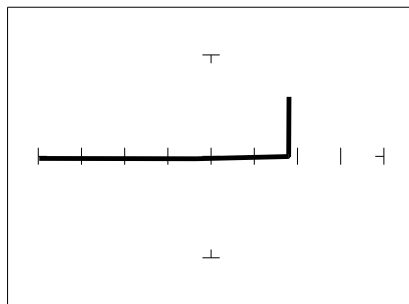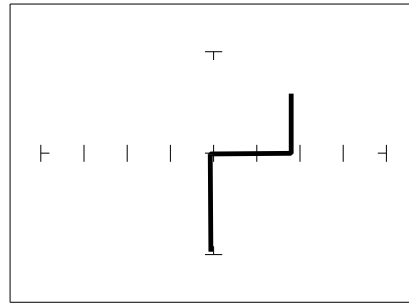
Figure 5-39. TrackerPXI With Test Probes To A Phototransistor.

No Light   With Light

Figure 5-40. Signatures Of A NPN Phototransistor - MRD3056 Type.
15V, 1.26 KOhm (MED1) range, C-E Junction

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

SCRS AND TRIACS

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

Silicon Controlled Rectifiers (SCR's)

The SCR is a switching semiconductor device that conducts positive current only. Its symbol and equivalent circuit can be seen below. When the gate (G) is at the same voltage level as the cathode (K), the SCR acts as an open. When the gate is forced more positive than the cathode, positive current flows between the anode (A) and the cathode.
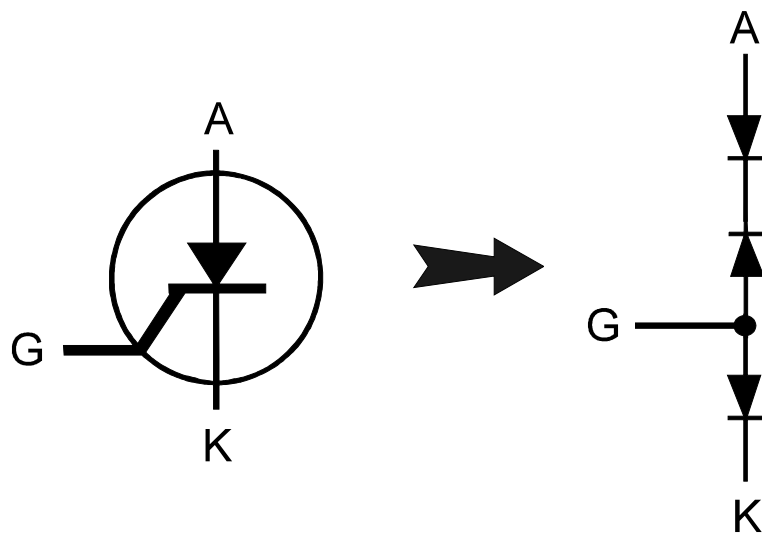
Figure 5-45. Diagram Of A Silicon Controlled Rectifier.

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

1. Select the **20V, 27.6 KOhm** (**MED2)** range with **60 Hz Frequency.**

2. The yellow LED will be on next to the MED2 range once activated.

3. Place or clip the red test probe from the TrackerPXI's **Signal** jack to gate lead (G) of the component.
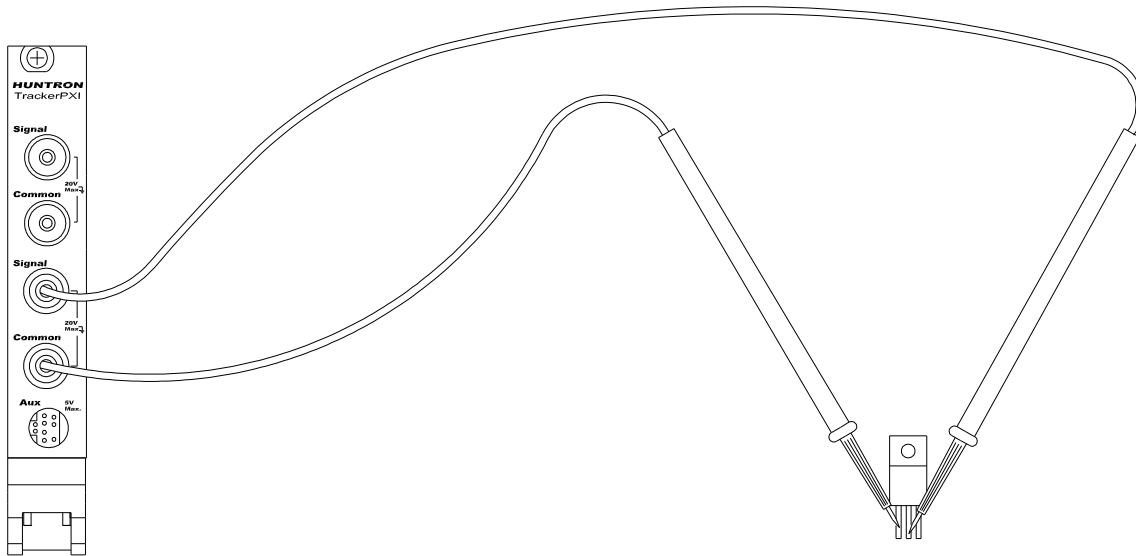
Figure 5-47. TrackerPXI With Test Leads To A SCR.

Observe the gate-anode signature of the SCR.

1. Move the black test probe from the SCR's anode lead to cathode lead (K) of the component.

2. Observe the gate-cathode signature of the SCR.

3. Place the red test probe to the SCR's anode lead and the black test probe to the SCR's cathode lead.
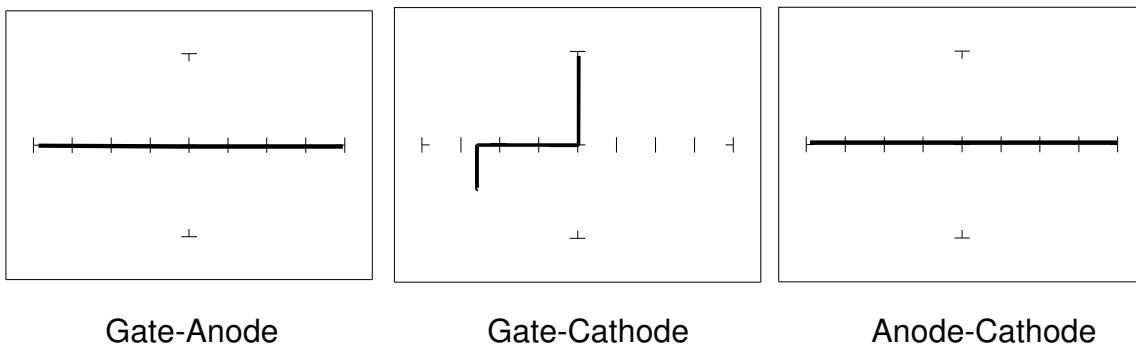
4. Observe the SCR's anode-gate signature.

Gate-Anode   Gate-Cathode   Anode-Cathode

Figure 5-48. Signatures Of A SCR - C106B Type.
20V, 27.6 KOhm (MED2) range.

SECTION 6   TESTING INTEGRATED CIRCUITS

6-1.   DIGITAL INTEGRATED CIRCUITS

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

INTEGRATED CIRCUIT FAILURES

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

- EOS   Electrical Over Stress. The IC's maximum electrical specifications   have been exceeded. This condition may result in the IC   developing internal shorts and opens.

  - ESD   Electrostatic Discharge. Repeated exposure may cause internal resistance to develop in the IC junctions. This internal resistance may vary from 5 kΩ to 25 kΩ with a typical value of 20 kΩ. ESD exposure can cause internal flaws such as resistance, opens and   shorts.

- Dendrites   A process flaw that results in particles growing between conductors on a substrate causing shorts.

- Ionic   Contamination introduced at the time of manufacturing that
  Contamination   develops into leakage between substrate channels. This causes 5 kΩ to 25 kΩ of resistance.

- Purple Plague   Destructive interaction between gold and aluminum metal layers. Junction connections become very brittle and may cause internal opens.

- Corrosion or   Another process flaw in which aluminum metalization causes
  Electromigration   pinholes, corrosion and resistance. This will create opens and resistance.

DIGITAL INTEGRATED CIRCUIT SIGNATURES

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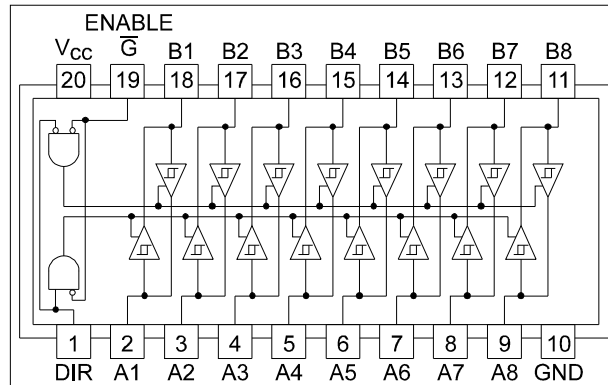

Figure 6-1. Digital IC 74LS245 Block Diagram.

• Circuit 1 - Pins 2 through 9 and 11 through 18 are all the same function. Each pin is connected to both an input and an output of a buffer.

• Circuit 2 - Pins 1 and 19, although they have different names, are both enables and are inputs to AND gates.

• Circuit 3 - Power supply ground input, pin 10.

• Circuit 4 - Power supply V_{CC} input, pin 20.

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

SIGNATURES OF A DIGITAL IC

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

1. Select the **20V, 10KOhm, 200Hz** Range (**TTL3).**

2. Place or clip the black test lead from the TrackerPXI's **Common** jack to the IC's ground pin. For this example, the ground pin of the 74LS245 is pin 10.

3. Use the red test lead from the TrackerPXI's **Signal** jack. Probe each pin of the IC and view its signature on TrackerPXI's signature display. For this example, pins 2 to 9 and 11 to 18 are all buffer circuits so they will have identical signatures. (Note: This is only for ICs out of circuit.)

4. Use the red test lead from the TrackerPXI's **Signal** jack. Probe the enable input pins of the IC and view their signatures on the signature display. For this example, the enable pins of the 74LS245 are pin 1 and 19 and will have the same signatures. (Note: This is only for ICs out of circuit.)

5. Change the range to **10V, 100 Ohm, 200Hz (TTL1).** Use the red test lead from the TrackerPXI's **Signal** jack. Probe the power supply V_{CC} input pin and view its signature on the signature display. For this example, the V_{CC} pin of the 74LS245 is pin 20.
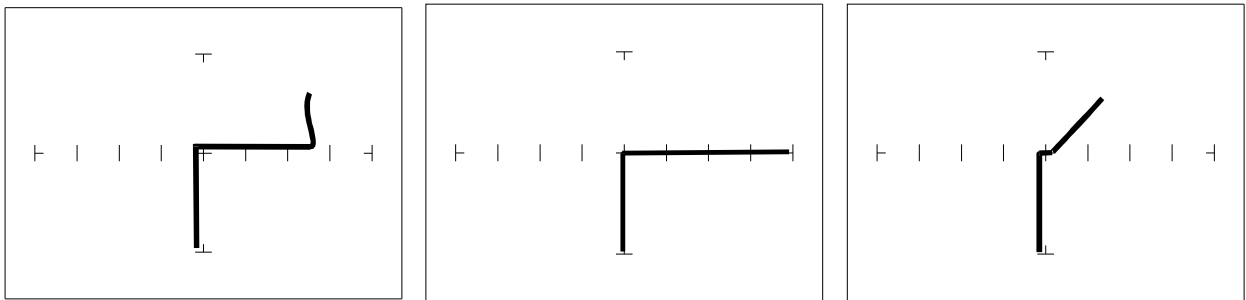
Buffer pins - TTL3 range   Enable pins - TTL3 range V_{CC} Power pin - TTL1 range

20V, 10K Ohm, 200Hz   20V, 10K Ohm, 200Hz   10V, 100 Ohm, (TTL1).

Figure 6-3. Signatures of A Digital IC, 74LS245.
TTL Group, Ground Pin To Test Common

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

SIGNATURES FOR DIFFERENT LOGIC CHIP FAMILIES

There are a wide variety of logic circuit families. Each has its special functions, advantages, and limitations. They range from TTL and its variations (F, LS, S, etc.), emitter-coupled logic

(ECL), to the complementary metal oxide semiconductor (CMOS) and its variations (C, HC, HCT, VC, etc.).

COMPARING TWO TTL FAMILIES

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

We will illustrate these concepts with the following example of two hex inverters, a 7404 and a 74LS04 from different logic families. From the logic diagram below, you can see that they have the same logic functions and pin order. The difference is that the LS chip uses Schottky transistors in its internal construction for increased performance and reduced power consumption. Note that there are only four types of circuit connections and therefore only four signatures on this chip: inverter inputs, inverter outputs, V_{CC} and ground.
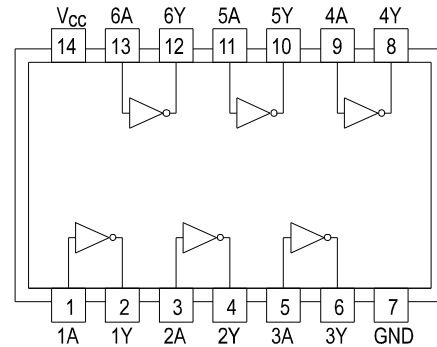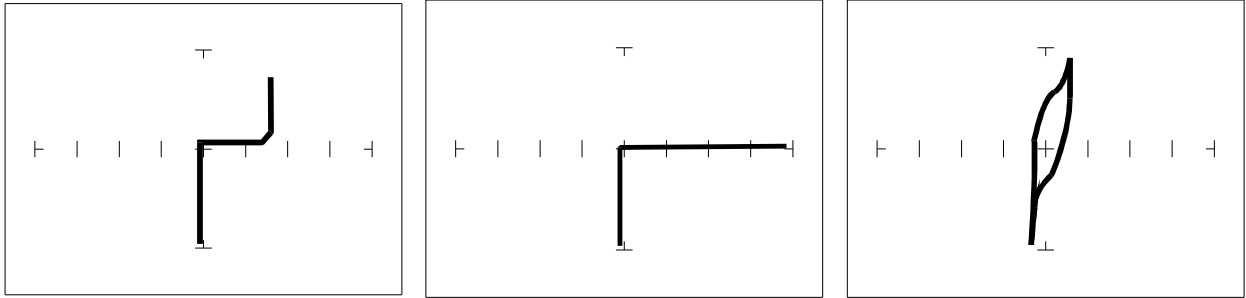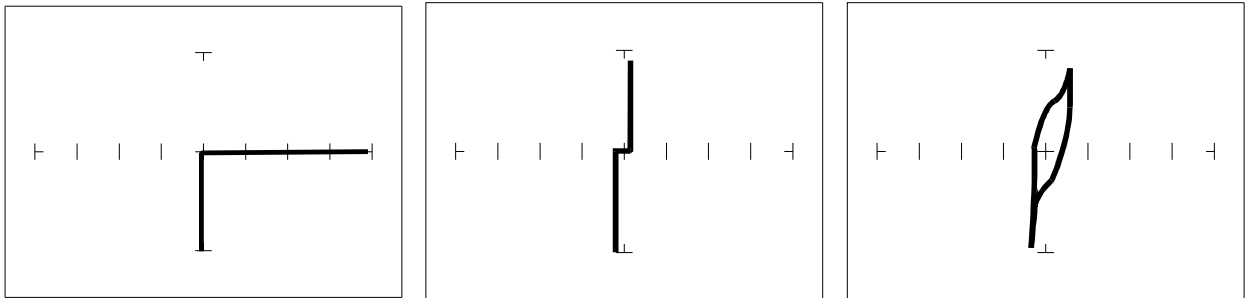
Figure 6-4. Diagram Of 7404 & 74LS04.

Pin 1 input - TTL3 range   Pin 2 output - TTL3 range   Pin 14 power - TTL1 range

20V, 10K Ohm, 200Hz   20V, 10K Ohm, 200Hz   10V, 100 Ohm, (TTL1)

Figure 6-5. Signatures Of A 7404 Hex Inverter.

Pin 1 input - TTL3 range   Pin 2 output - TTL3 range   Pin 14 power - TTL1 range

20V, 10K Ohm, 200Hz   20V, 10K Ohm, 200Hz   10V, 100 Ohm, (TTL1)

Figure 6-6. Signatures Of A 74LS04 Hex Inverter.

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

CMOS LOGIC FAMILY

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

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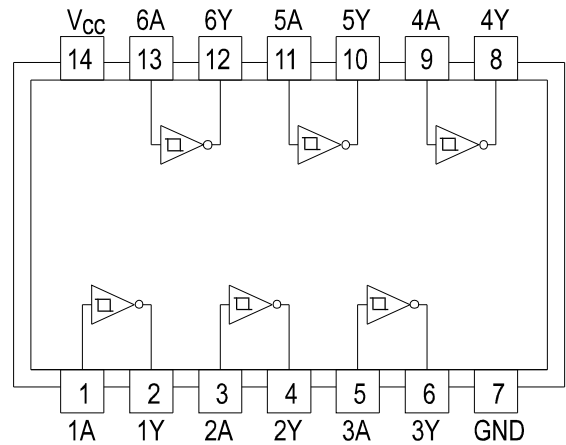

Figure 6-7. 74HC14 Block Diagram.

Do the following to display the analog signatures of a

1. Select the **50Ω** and **10V, 60 Hz** range. (MOS1)

2. Place or clip the black test lead from the TrackerPXI's **Common** jack to the IC's ground pin. For this example, the ground pin of the 74HC14 is pin 7.

3. Use the red test lead from the TrackerPXI's **Signal** jack and probe each pin of the IC. For this example, pins 1, 3, 5, 9, 11, and 13 are all input buffer circuits so they will have identical signatures. (Note: This is only for ICs out of circuit.)

4. Similarly, use the red test lead and probe the output buffer pins 2, 4, 6, 8, 10, and 12. These pins will have the same signatures. (Note: This is only for ICs out of circuit.)

5. Use the red test lead from the TrackerPXI's **Signal** jack and probe the power supply V_{CC} input pin. For this example, the V_{CC} pin of the 74HC14 is pin 14.
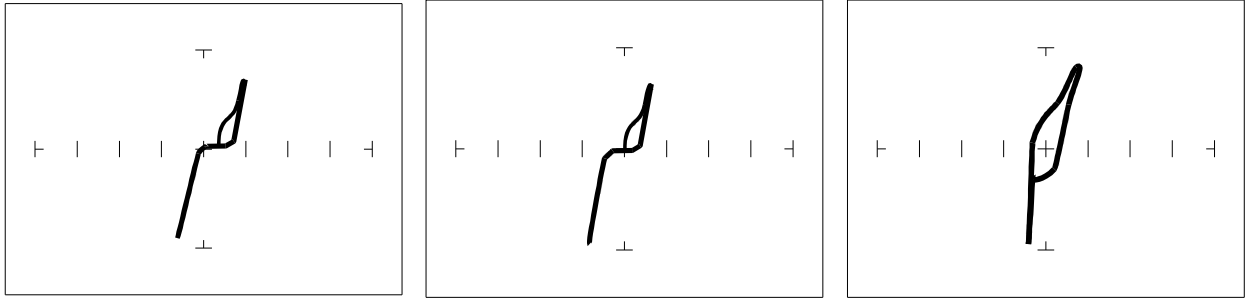
Pin 1 - Input.   Pin 2- Output   Pin 14 - V$_{CC}$

50Ω, 10V, **60Hz** (MOS1) Range

Figure 6-9. Signatures Of A 74HC14 CMOS Hex Inverter.

CMOS COMPONENTS AND TEST SIGNAL FREQUENCY F$_S$

CMOS logic circuits inherently have a significant amount of internal capacitance. This junction capacitance is visible in the CMOS signatures when using the TrackerPXI. Capacitance in CMOS circuitry may be emphasized or de-emphasized by changing the frequency of the test signal.
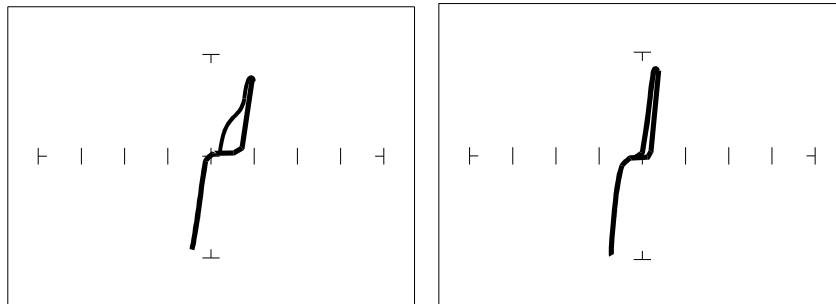
F$_S$ = 20 Hz   F$_S$ = 400 Hz

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

TROUBLESHOOTING DIGITAL LOGIC ICS

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

1. Select the **50Ω**, **10V and 60 HZ** range

2. Place or connect the black or blue ground clip lead from the TrackerPXI's **Common** jack to both reference and suspect IC or boards ground pin.

3. Place or clip the red test lead from the TrackerPXI's A test terminal to the reference or known good IC's pin. For this example, start with pin 1 of the known good IC.

4. Observe the signature. This is the signature of the pin of the known good component.

5. Keep the red probe on pin **1**, an input pin. Probe all the other input pins of the suspect component with the black probe until you have identified all the pins that have signatures that are the same as pin **1**.

6. Move the red probe on pin **2**, an output pin. Probe all the other output pins of the suspect component with the black probe until you have identified all the pins that have signatures that are the same as pin **2**.

REVIEW

- Integrated circuits are complex devices that are built using basic electronic components.

- The IC signatures resemble zener diodes.

- There are many causes for IC failures and the TrackerPXI can display its "health" as resistive leakage, an open or a short.

- Functionally identical pins on a single IC out-of-circuit will display the same signature.

- The most common point for reference is ground, but V_{CC} or another point might give a more informative signature.

- Different logic families exhibit different characteristic signatures.

6-2.   ANALOG CIRCUITS

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

OP AMPS

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

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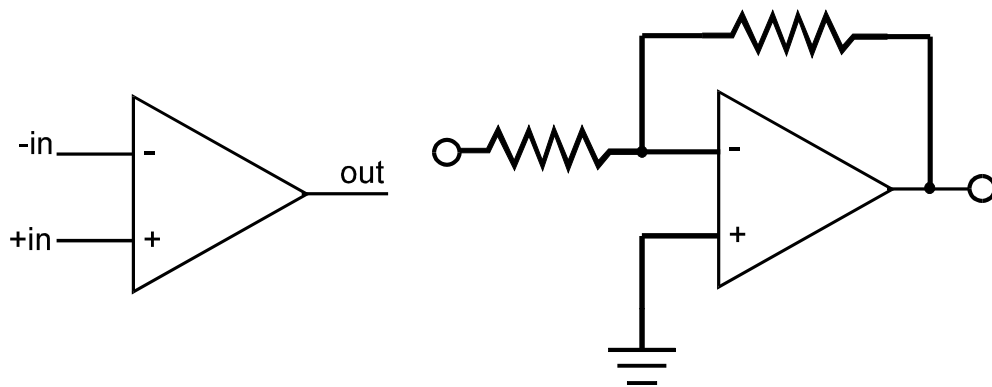

Figure 6-13. Op Amp Symbol And Schematic Diagram Of An Inverter Circuit.

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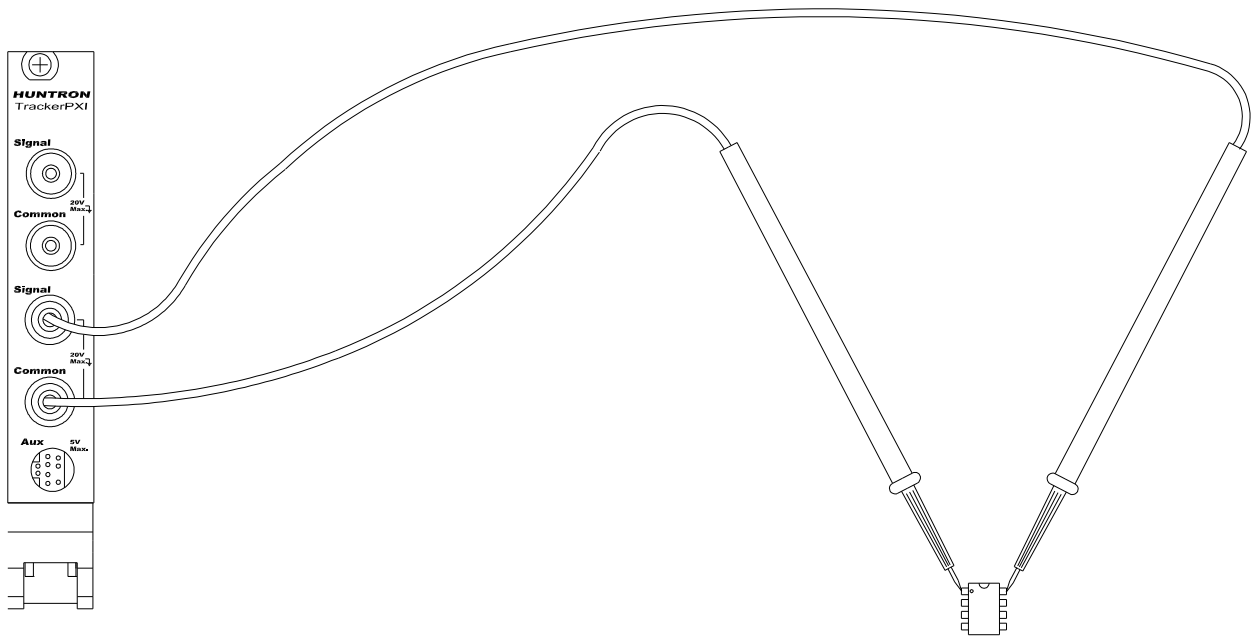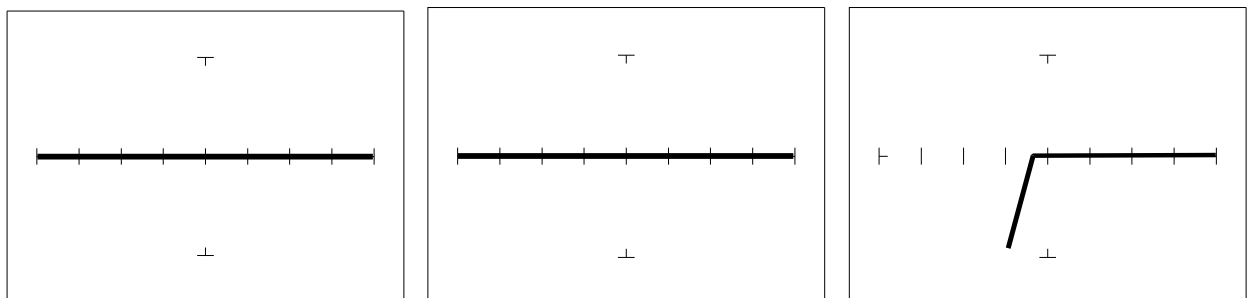
OP AMP SIGNATURES

Figure 6-14. TrackerPXI With Test Leads To An Op Amp.

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

1. Select the **1.26 KOhm, 15V, 60 Hz (MED1)** range

2. Place or clip the black test lead from the TrackerPXI's **Common** jack to the IC's ground or a power supply pin. For this example, the negative power supply pin of the 741 is pin 4 and the positive power supply is pin 8.

3. Use the red test lead from the TrackerPXI's **Signal** jack and probe each pin of the IC.

4. Observe that the signature of each of the op amp's pins are unique.

Pin 2 -Input   Pin 3 +Input   Pin 6 Output

Figure 6-15. Signatures of an Op Amp (741 Type) in 10V, 50 Ohm, 60 Hz
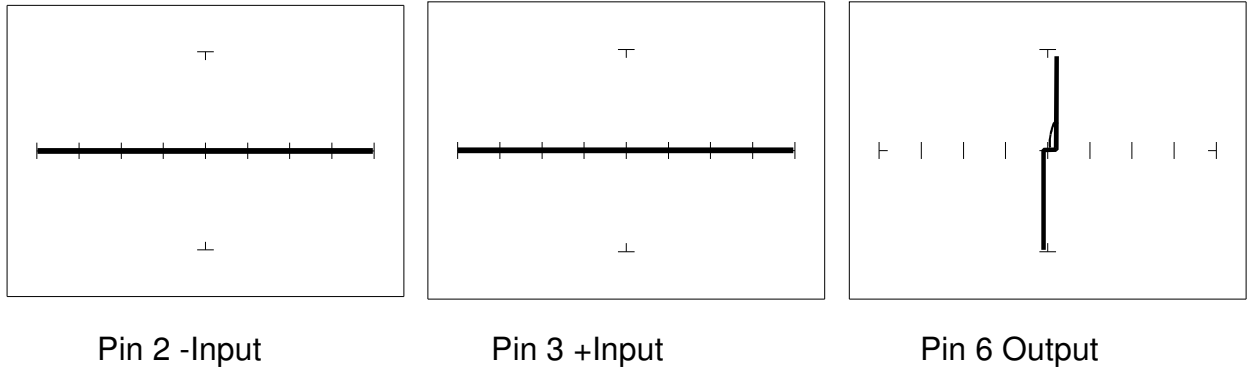(LOW) range. Common to Pin 4.

Pin 2 -Input   Pin 3 +Input   Pin 6 Output

Figure 6-16. Signatures of an Op Amp (741 Type) in 20V, 27.6K Ohm, 60Hz (MED2) range.
Common to Pin 4.

TROUBLESHOOTING OP AMP CIRCUITS

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

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

LINEAR VOLTAGE REGULATORS

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

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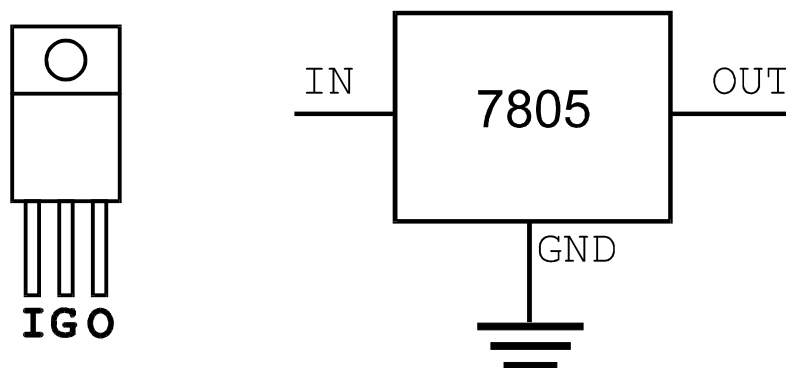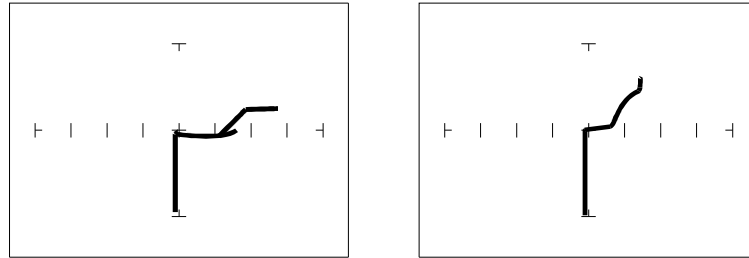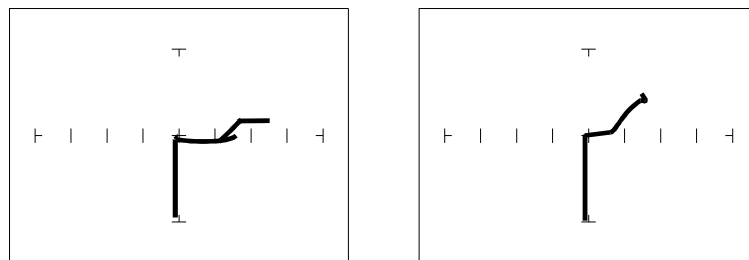

Figure 6-17. Diagram And Symbol Of A Linear Voltage Regulator, 7805 Type.

Input pin   Output pin

Figure 6-18. Signatures Of A 7805 Voltage Regulator By SGS Thomson.
15V, 1K Ohm, 200Hz (TTL2) range, Ground Pin To Common

Input   Output pin

Figure 6-19. Signatures Of A 7805 Voltage Regulator By Motorola.
15V, 1K Ohm, 200Hz (TTL2) range, Ground Pin To Common

REVIEW

• Integrated circuits are complex devices that are built using basic electronic components.

• The IC signatures resemble zener diodes.

• There are many causes for IC failures and the TrackerPXI can display its "health" as resistive leakage, an open or a short.

• Functionally identical pins on a single IC out-of-circuit will display the same signature.

• The most common point for reference is ground, but V_{CC} or another point might give a more informative signature.

• Different analog IC families exhibit different characteristic signatures.

6-3.   LOW VOLTAGE

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

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

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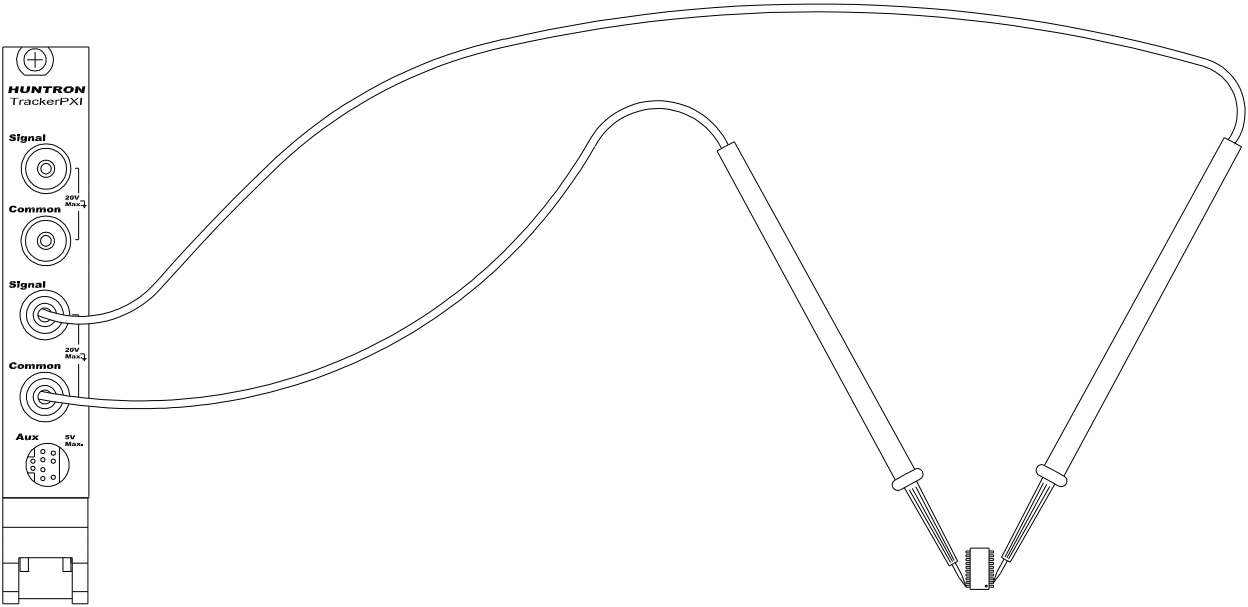

Figure 6-20. TrackerPXI With Test Probes To A 20 Pin Surface Mount IC.

Do the following to view signatures of low voltage logic:

1. Select the **3V, 10K Ohm, 60 Hz** (SMT3) Range.

2. Place or clip the black test lead from the TrackerPXI's **Common** jack to the IC's ground pin. For this example, the ground pin of the 74LVQ245 is pin 10.

3. Use the red test lead from the TrackerPXI's **Signal** jack and probe each pin of the IC. For this example, pins 2 to 9 and 11 to 18 are all buffer circuits so they will have identical signatures. (Note: This is only for ICs out of circuit.)

4. Use the red test lead from the **Signal** jack and probe the enable input pins. For this example, the enable pins of the 74LVQ245 are pin 1 and 19 and will have the same signatures. (Note: This is only for ICs out of circuit.)

5. Use the red test lead from the TrackerPXI's **Signal** jack and probe the power supply V_{CC} input pin. For this example, the V_{CC} pin of the 74LVQ245 is pin 20.

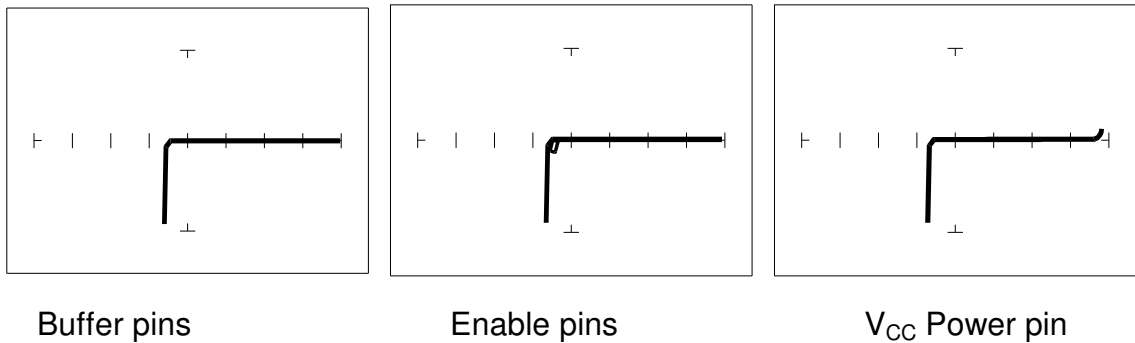| Buffer pins | Enable pins | V_{CC} Power pin |

Figure 6-22. Signatures Of A Low Voltage IC (74LVQ45 Type).
3V, 10K Ohm, 60 Hz, Ground Pin To Test Common

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

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

REVIEW

- Integrated circuits are complex devices that are built using basic electronic components.

- The IC signatures resemble regular and zener diode signatures.

- There are many causes for IC failures and the TrackerPXI can display its "health" as resistive leakage, an open or a short.

- Functionally identical pins on a single IC out-of-circuit will display the same signature.

- The most common point for reference is ground, but V_{CC} or another point might give a more informative signature.