Tracker Training Course

Student Work Book

HUNTRON

Huntron Tracker Training Course

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Huntron would like to thank the Applied Technology Training Center in Everett, Washington for their assistance in creating this course.

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SECTION 1
INTRODUCTION

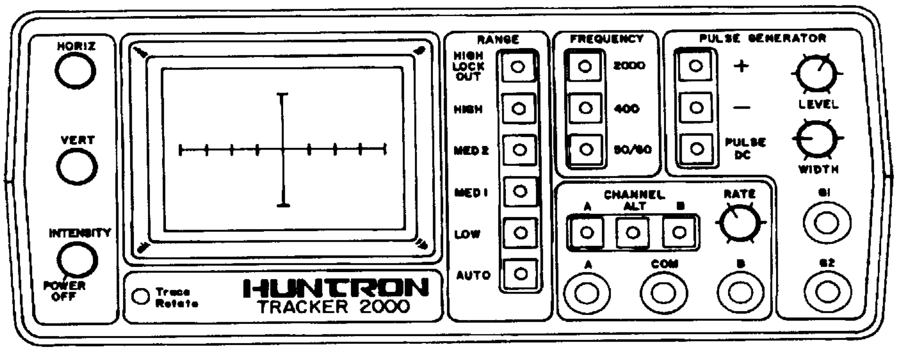


Figure 1-1. Huntron Tracker Model 2000.

1-1. INTRODUCTION

Welcome to the Tracker Training Manual. This self-study course is designed to introduce you to the operation of the Huntron Tracker 2000. We want you to become so comfortable with the Tracker that you will use it to troubleshoot the circuits you work with in your job. You'll learn by using the Tracker on a variety of circuits. Through repeated use, you will learn the characteristic display of different types of components, and be able to recognize some of the ways that they fail.

1-2. WHAT IS A TRACKER?

The Tracker 2000 is a modified curve tracer designed to allow nondestructive viewing of the quality of electronic components. In simple terms, a known stimulus is injected at two points, either in or out of circuit. The device, or devices between the two injection points react to this stimulus. The resultant voltage and current (V/I) characteristic is displayed on the Tracker CRT. Voltage results in horizontal deflection of the electron beam and current flow causes vertical deflection. If the material between the injection points is degraded or defective the V/I characteristic will differ from a device which has no degradation.

1-3. ABOUT THIS MANUAL

This manual is designed as a self-study tutorial. It starts with a short explanation of how the Tracker operates. Each section after that is focused on a specific type of component. There is an explanation, based on Ohm's Law, of how the particular type of component creates a particular display on the Tracker. There are also several exercises that will give you hands-on practice in using the Tracker to test that particular type of component. Each section builds on the material presented in previous sections. Later sections also contain troubleshooting exercises to help you develop your troubleshooting skills. The sections also contain questions to test your understanding with answers in the appendix. The sub-sections containing questions are marked with an asterisk, (e.g. *5-4.). At the end of the section total your score. If you are reviewing or feel you already understand the section, simply do the tests and move on when you feel confident. When you have completed the course, send in the "certificate of registration" and we will send you your certificate of completion.

1-4. HOW TO USE THIS MANUAL

This manual was designed for two types of users. If you are new to the Tracker 2000, we suggest you use the manual as a self-paced study guide. As a general guideline, allow 8-10 hours to complete the entire manual. We suggest this be done in four or five 2 hour sessions. By starting at the beginning and working through all the exercises, you will learn how to use the Tracker to troubleshoot a variety of electronic circuits.

If you have some experience using the Tracker, there is another way this manual can be used. The Table Of Contents lists each topic and the exercises that go with it. You can pick specific topics you wish to review, or new topics that you want to learn for the first time.

To verify your competence level simply take the self test at the end of each section. Review any sections where you have problems.

1-5. EQUIPMENT NEEDED

In addition to the Tracker 2000, you will need the test board that comes with this manual. Also recommended is the Tracker 2000 Operation and Maintenance Manual that came with your Tracker 2000. It contains a great deal of helpful information about Tracker operation. It also contains many detailed diagrams of typical display signatures arranged by type of component. These can be helpful when trying to determine the status of a component.

1-6. ABOUT HUNTRON

Huntron Instruments, Inc. manufactures and markets equipment and software for the board repair and field service industry. Its products are designed for troubleshooting and repairing electronic systems and components.

The company was started in 1976 by Mr. Bill Hunt. Bill invented the Huntron Tracker to make his job more efficient. Bill took advantage of his invention by further developing the technology and building a company around it. Since it was founded, Huntron has continued to develop and market, worldwide, products from the technicians point of view — products that make the process of troubleshooting electronic equipment easier, faster and more efficient.

1-7. CONTACTING HUNTRON

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

Huntron Instruments, Inc.
15720 Mill Creek Blvd.
Mill Creek, WA 98012

In the U.S., call (toll free) 800-426-9265 or 206-743-3171. Huntron is also accessible by fax at 206-743-1360. Outside the U.S., call your local distributor for service or assistance.

NOTES:

SECTION 2
TRACKER 2000 OPERATING INSTRUCTIONS

2-1. INTRODUCTION

This section describes the basic operation of the Tracker 2000. Take time to read this section carefully so you can take full advantage of all the troubleshooting capabilities of the 2000.

2-2. GENERAL OPERATION

Components are tested by the 2000 using a two terminal system (three terminal system when the built-in pulse generator is used), where two test leads are placed on the leads of the component under test. The 2000 tests components in-circuit, even when there are several components in parallel.

The 2000 is only intended for use in boards and systems with all voltage sources in a power-off condition. A 0.25 ampere signal fuse is connected in series with the channel A and B test terminals. Accidental contact of the test leads to active voltage sources (e.g. line voltage, powered-up boards or systems, charged high voltage capacitors, etc.), may cause this fuse to open, making replacement necessary. When the signal fuse blows, short circuit signatures will be displayed even with the test leads open.

CAUTION

> The device to be tested must have all power turned off, and have all high voltage capacitors discharged before connecting the 2000 to the device.

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

2-3. PHYSICAL FEATURES

Before you begin to use the 2000, please take a few minutes to familiarize yourself with the instrument. All of the externally accessible features are discussed in Sections 2-4, 2-5, and 2-6.

2-4. Front Panel

The front panel of the 2000 is designed to make function selection easy. All push buttons are momentary action and have integral LED indicators that show which functions are active. Refer to Figure 2-1 and Table 2-1 for a detailed description of each item on the front panel.

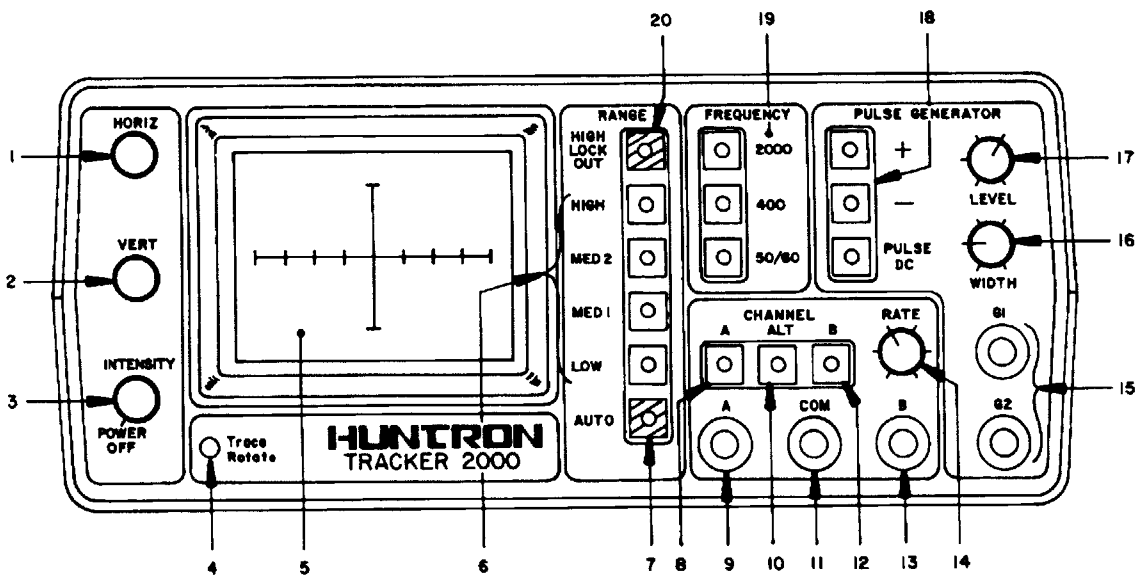


Figure 2-1. Front Panel.

Table 2-1
Front Panel Controls and Connectors

Item No.	Name	Function
1	HORIZ Control	Controls the horizontal position of the CRT display.
2	VERT Control	Controls the vertical position of the CRT display.
3	INTENSITY Control Power On/Off Switch	Controls the intensity of the CRT display. Power Switch: Rotate clockwise to turn on.
4	TRACE ROTATE Control	Controls the trace rotation of the CRT display.
5	CRT display	Displays the component signature produced by the 2000.
6	Range Selectors	Push buttons that select one of four impedance ranges: low, medium 1, medium 2, high.
7	AUTO Switch	Push button that initiates automatic scanning of the four ranges from low to high. The scanning speed is determined by the RATE control (see item #14).
8	Channel A Switch	Push button that causes channel A to be displayed.
9	Channel A Test Terminal	Fused test lead connector that is active when channel A is selected. All test lead connectors accept standard banana plugs.
10	ALT Switch	Push button that causes the 2000 to alternate between channel A and channel B at a speed determined by the RATE control (see item #14).
11	COM Test Terminal	Test lead connector that is instrument common and the common reference point for both channel A and channel B.
12	Channel B Switch	Push button that causes channel B to be displayed.
13	Channel B Test Terminal	Fused test lead connector that is active when channel B is selected.
14	RATE Control	Controls the rate of channel alternation and/or range scanning.
15	G1 and G2 Terminals	Pulse generator output test lead connectors.
16	WIDTH Control	Controls the duty cycle of the internal pulse generator.
17	LEVEL Control	Controls the amplitude of the internal pulse generator.
18	Pulse Generator Selectors	Push buttons that select various output modes of the pulse generator: Positive (+), Negative (-), PULSE/DC.
19	Frequency Selectors	Push buttons that select one of the three test signal frequencies: 50/60 Hz, 400 Hz, 2000Hz.
20	HIGH LOCKOUT Switch	Push button that activates a mode where it is not possible to enter the high range either by manual or automatic range selection.

2-5. Back Panel

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

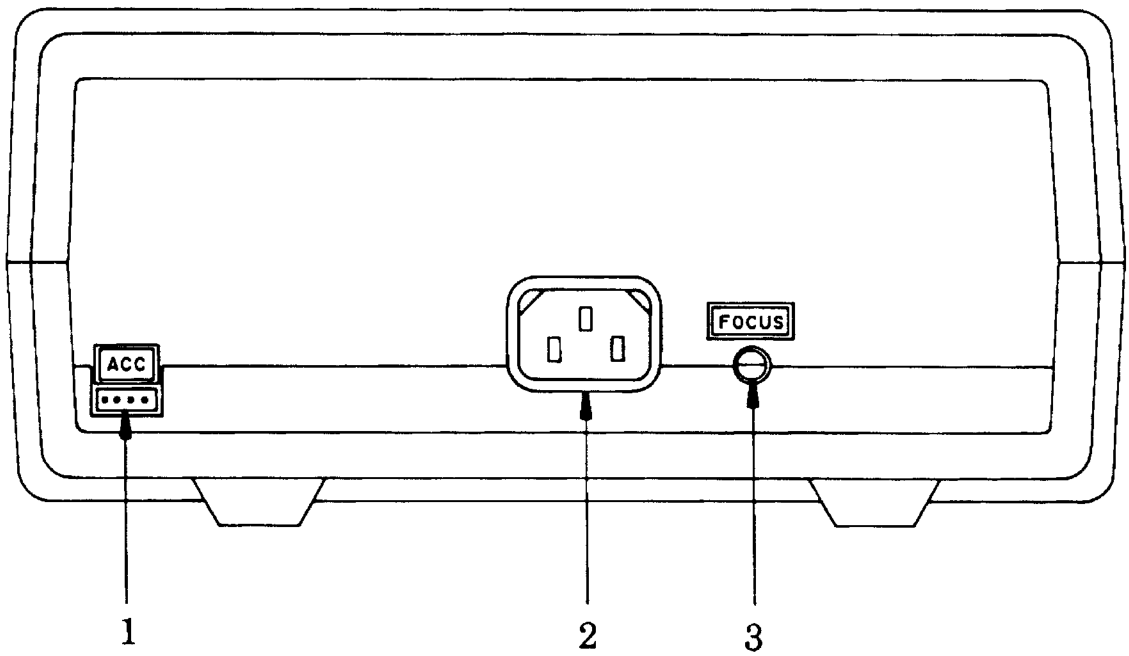


Figure 2-2. Back Panel.

Table 2-2
Back Panel Controls and Connectors

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

2-6. CRT Display

The CRT displays the signature of the component being tested. The display has a graticule consisting of a horizontal axis which represents voltage, and a vertical axis which represents current. The axes divide the display into four quadrants. Each quadrant displays a different portion of the signature. Quadrant 1 displays positive voltage (+V) and positive current (+I), quadrant 2 displays negative voltage (-V) and positive current (+I), quadrant 3 displays negative voltage (-V) and negative current (-I), and quadrant 4 displays positive voltage (+V) and negative current (-I). See Figure 2-3.

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

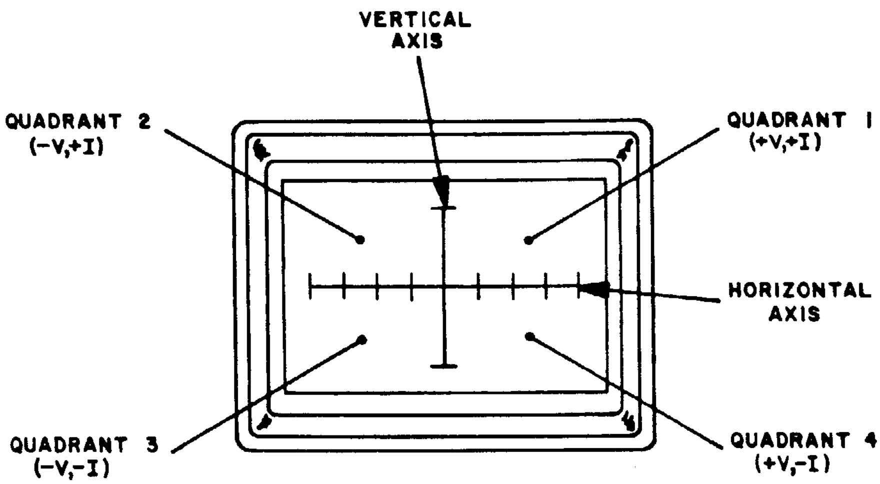


Figure 2-3. CRT Display.

Table 2-3
Horizontal Sensitivities

Range	Volts/Div
High	~15.0
Medium 2	~5.0
Medium 1	~3.75
Low	~2.5

2-7. OPERATION

The following sections explain how to use the front and back panel features. Use Sections 2-4 and 2-5 for the description and location of each control.

2-8. Initial Setup

Turn the Power/Intensity knob clockwise. The 2000 should come on with the channel A, 50/60 Hz, low range, and pulse/DC LEDs illuminated.

Focusing of the 2000 display is important in analyzing the test signatures. This is done by first turning the intensity control to a comfortable level and then adjusting the focus control (back panel) for the narrowest possible trace.

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

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

2-9. Range Selection

The 2000 is designed with four impedance ranges (low, medium 1, medium 2, and high). These ranges are selected by pressing the appropriate button on the front panel. It is best to start with one of the medium ranges (i.e. medium 1 or medium 2). If the signature on the CRT display is close to an open (horizontal trace), go to the next higher range for a more descriptive signature. If the signature is close to a short (vertical trace), go the next lower range.

The High Lockout feature, when activated, prevents the instrument from entering the high range in either the manual or Auto mode.

The Auto feature scans through the four ranges (three with the High Lockout activated) at a speed set by the Rate control. This feature allows the user to see the signature of a component in different ranges while keeping hands free to hold the test leads.

2-10. Channel Selection

There are two channels on the 2000 (channel A and channel B) which are selected by pressing the appropriate front panel button. When using a single channel, the red probe should be plugged into the corresponding channel test terminal and the black probe should be plugged into the common test terminal. When testing, the red probe should be connected to the positive terminal of a device (i.e. anode, +V, etc.) and the black probe should be connected to the negative terminal of a device (i.e. cathode, ground, etc.). Following this procedure should assure that the signature appears in the correct quadrants of the CRT display.

The Alternate mode of the 2000 is provided to automatically switch back and forth between channel A and channel B. This allows easy comparison between two devices or the same points on two circuit boards. The Alternate mode is selected by pressing the ALT button on the front panel, and the alternation frequency is varied by the Rate control. One of the most useful features of the 2000 is using the Alternate mode to compare a known good device with the same type of device that is of unknown quality. Figure 2-4 shows how the instrument is connected to a known good board and a board under test. This test mode uses the supplied common test leads to connect two equivalent points on the boards to the common test terminal. Note that the black probe is plugged into the channel B test terminal.

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

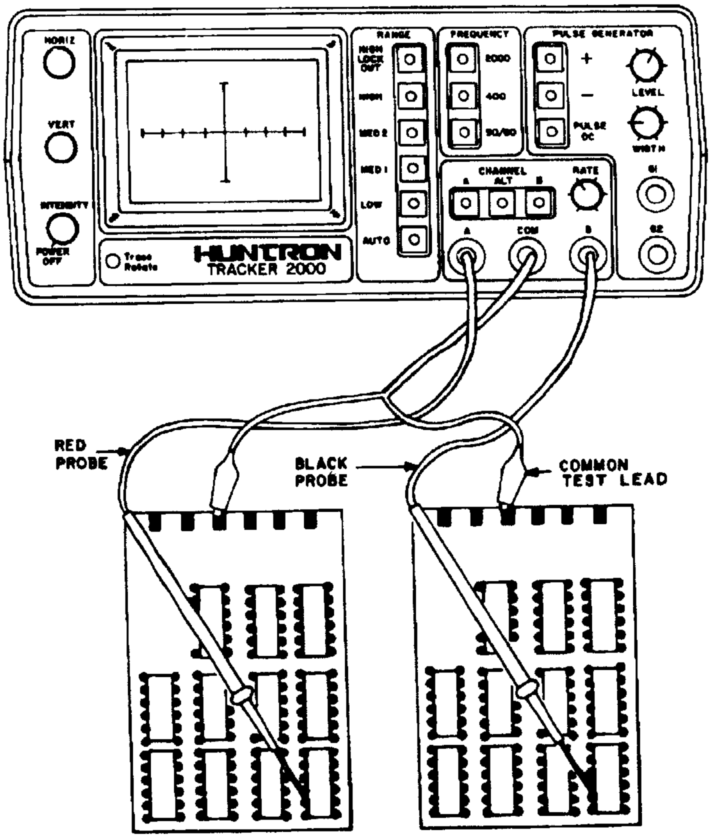


Figure 2-4. Alternate Mode Setup.

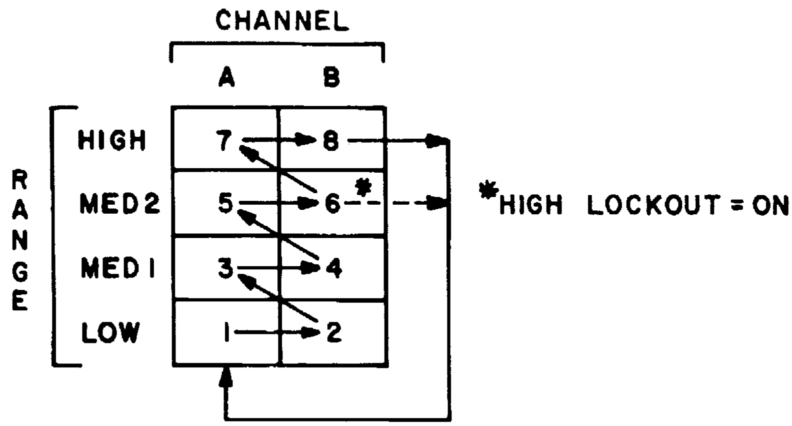


Figure 2-5. Auto/Alternate Sequence.

2-11. Frequency Selection

The 2000 has three test signal frequencies (50/60 Hz, 400 Hz, and 2000 Hz), which are selected by pressing the appropriate button on the front panel. In most cases the 50/60 Hz test signal is the best to start with. The other two frequencies are generally used to view small amounts of capacitance or large amounts of inductance.

2-12. Pulse Generator

The built-in pulse generator of the 2000 allows dynamic, in-circuit testing of certain devices in their active mode. In addition to using the red and black probes, the output of the pulse generator is connected to the control input of the device to be tested with one of the blue micro clips provided. The pulse generator has two outputs (G1 and G2) so three terminal devices can also be tested in the Alternate mode. Figure 2-6 shows how to hook up the 2000 in the Alternate mode using the pulse generator.

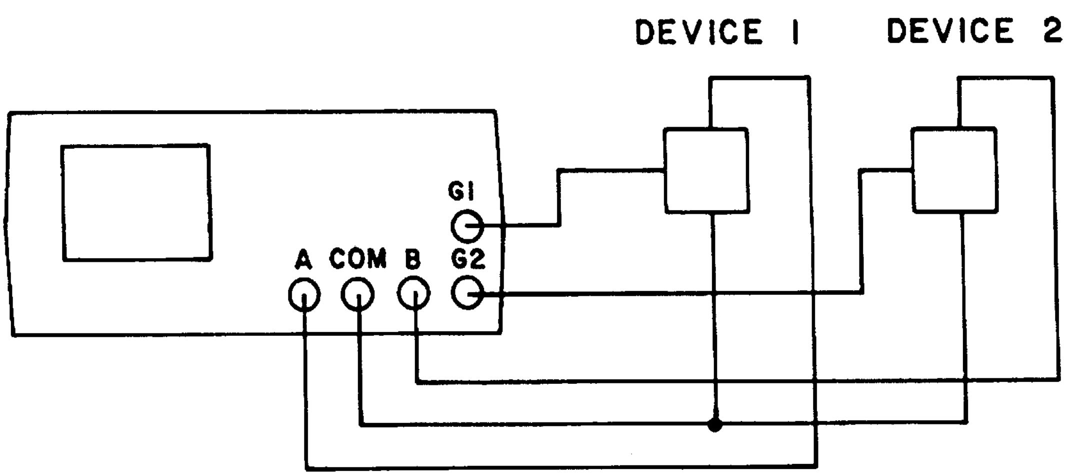


Figure 2-6. Pulse Generator Comparison Mode.

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

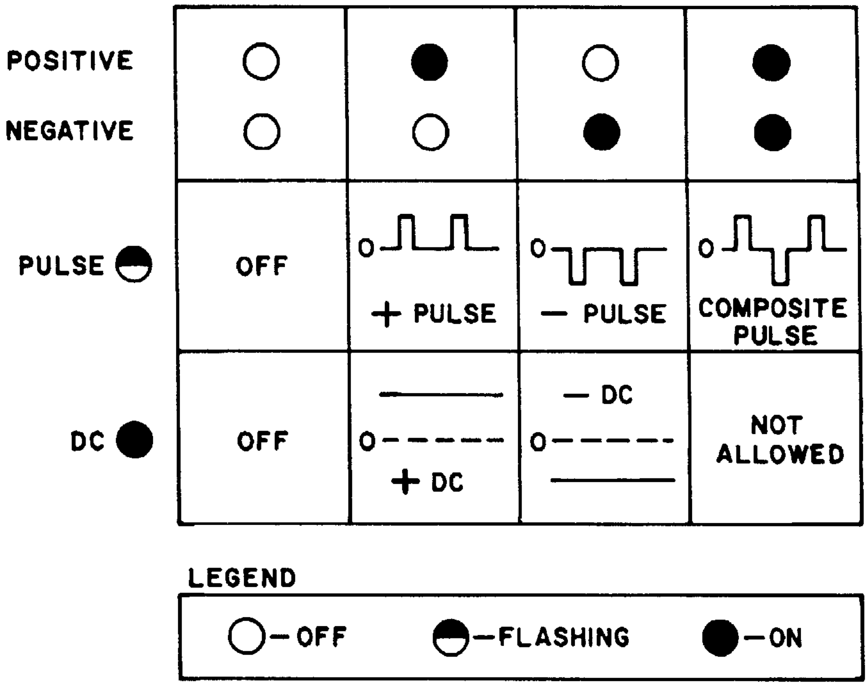


Figure 2-7. Pulse Generator Selector Chart.

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

SECTION 3
BASIC TRACKER THEORY

3-1. INTRODUCTION

The Huntron Tracker is an electronic troubleshooting instrument that can visually display the health of an electronic component or circuit. It is always used with the circuit being tested in a power-off condition. The term used for this type of troubleshooting is Analog Signature Analysis or ASA.

The Tracker outputs a sine wave (AC) stimulus to an electronic component or component group and displays the resulting current flow, voltage drop and phase difference in that circuit. The display shows the simultaneous result of the voltage across the circuit under test and the induced current through it. Since the induced current is a function of the impedance of the circuit, the Tracker display can be thought of as a visual representation of Ohm's Law (E=IR) where E=voltage, I=current, and R=resistance. In the following text, voltage will be referred to as V.

3-2. OUTPUT VOLTAGE RANGES

The Tracker can output four different AC voltages to the probes. These are called "Ranges", and are accessed by buttons marked LOW, MED1, MED2 and HIGH on the Tracker's front panel. Each output range has an internal source impedance (Z_S) that limits the current that is output to the circuit under test. Table 3-1 shows that Z_S increases greatly as the voltage range is increased.

Table 3-1
Output Voltage and Source Impedance for Each Range

Range	Output (V_{peak})	Z_S
High	60V	74kΩ
Medium 2	20V	27kΩ
Medium 1	15V	1.2kΩ
Low	10V	54Ω

3-3. DISPLAY CIRCUIT

Understanding the display circuit is the key to understanding how the Tracker reacts to different kinds of circuit components. Figure 3-1 shows a block diagram of the Tracker display circuit. It is drawn as a voltage divider. The load impedance (Z_L) is the impedance of the circuit under test. This impedance is in series with the internal, or source impedance (Z_s) of the Tracker. Because Z_s is constant, both the voltage across the load, and the amount of current through it is a function solely of Z_L.

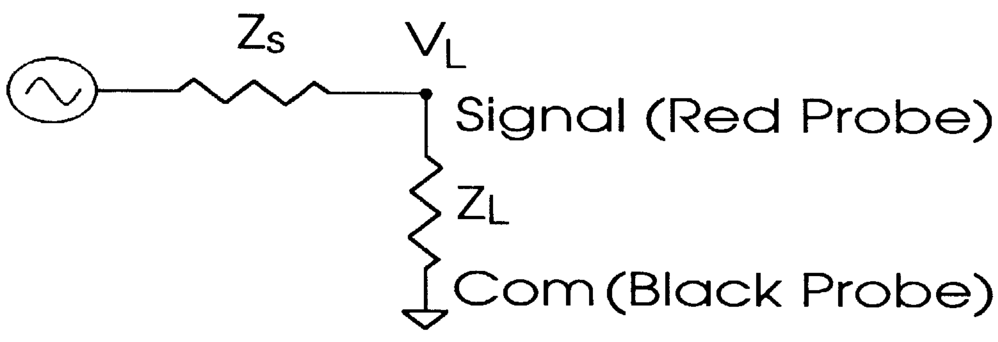


Figure 3-1. Tracker Display Circuit Block Diagram.

The voltage across the load (V_L) controls the amount of horizontal movement of the display. Figure 3-2 shows Z_L as an open. No current flows through Z_s, and all the voltage is present at the probe leads. The trace moves only horizontally. When the sine wave is positive, the trace is in the right hand side of the display. When the sine wave is negative, the trace is in the left hand side of the display. When it is at 0V, the trace is in the middle.

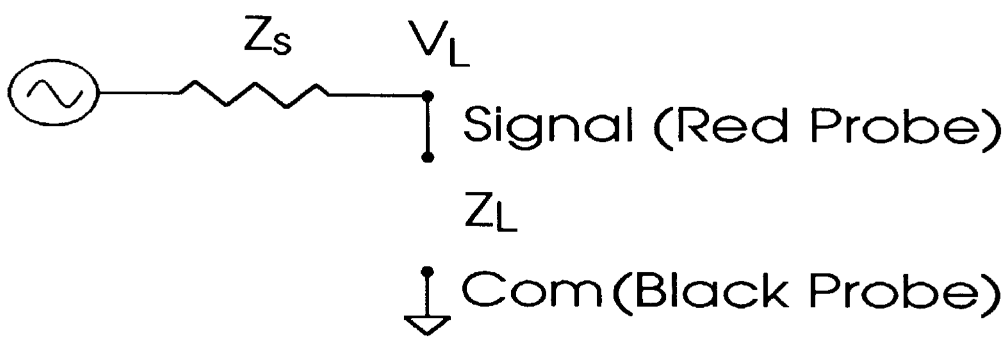


Figure 3-2. Block Diagram of an Open.

The horizontal axis is divided by small graticule lines like an oscilloscope. Each mark is approximately 1/4 of the peak voltage. In Low Range, for example, since Vp = 10V, each division is approximately 2.5V. You can use these graticule marks to get a rough estimate of the amount of voltage that is being dropped across the load.

The amount of vertical deflection is controlled by the voltage dropped across the internal impedance (Z_S) of the Tracker. Because Z_S is in series with the load, this voltage will be proportional to the current flowing through the load.

Figure 3-3 shows the display circuit with a short across the load. No voltage is dropped across Z_L, so there is no horizontal component to the display. All the voltage is dropped across Z_S, so the trace is a vertical line on the display.

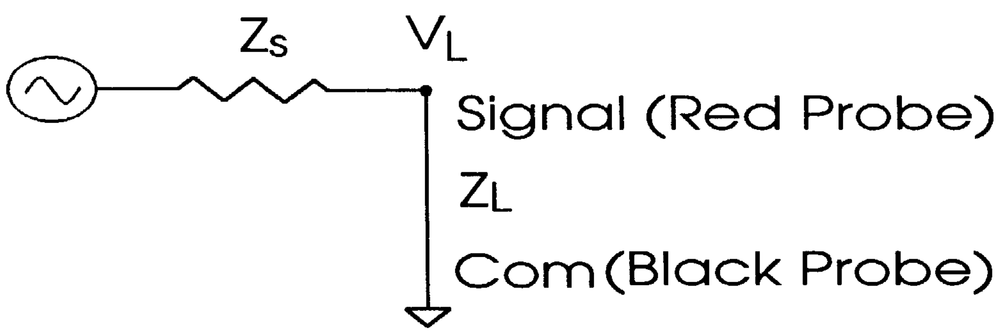


Figure 3-3. Block Diagram of a Short.

The following two exercises will confirm the description above.

3-4. Exercise 1 - Horizontal Axis

1. Turn on the Tracker and observe the display.

2. You will see a horizontal line in the middle of the CRT screen. This displays maximum voltage.

3. Use the VERTICAL (up and down) adjustment to center this trace if it is not already centered.

3-5. Exercise 2 - Vertical Axis

1. Connect the red probe to the red "A" jack on the Tracker and the black probe to the COM jack.

2. Touch the probes together and observe the display.

3. You should see a vertical line in the middle of the CRT screen. This displays maximum current.

4. Use the HORIZ (side to side) control to adjust this trace if necessary.

3-6. THE BASIC COMPONENTS

There are four basic electronic properties that the Tracker can test: resistance, capacitance, inductance and semi-conductance. Each of these behaves differently as the sine wave is applied, so each shows a different waveform on the display. Because of the uniqueness of the display, created by each of the different electronic properties, these displays are referred to as "signatures". Circuits that have more than one type of component in them, have signatures that are composites of the elements in that circuit. For example, a circuit with both resistance and capacitance will have a signature that mixes the characteristic signatures of resistance and capacitance. (You will see what this looks like later in the course).

The goal of this course is to train you to recognize the kinds of signatures that various component and component groups display. This is the first step toward effective use of the Tracker for troubleshooting. The second step, which we will introduce later in the course, is to use comparison testing on circuits whose signatures you do not recognize. With these two skills, you will be able to use the Tracker to quickly troubleshoot even very complex circuits.

3-7. REVIEW

- The Tracker applies an AC signal to a device or circuit that is not powered up, and displays the result on the CRT screen. This display is called a "signature".

- Current is displayed along the vertical axis and voltage is displayed along the horizontal axis.

- The signature shows the relationship between the applied voltage, induced current and the impedance of the circuit under test. This relationship is Ohm's Law (V=IR).

  — Changing the range changes:
    - the voltage output to the circuit under test
    - the source impedance in series with the output
    - the volts per division of the display

- Each type of circuit component displays a characteristic signature.

NOTES:

SECTION 4
TRACKER TRAINER TUTORIAL BOARD

4-1. INTRODUCTION

The board consists of components organized into sections that parallel the course. The electronic components are of various size and construction to emphasize the versatility of the Tracker. It is strongly suggested that at the beginning of each section all switches be set to the NORMAL position. The board has a common ground connection to all components except for the three legged devices. The board also has a V_{CC} connection for the logic section that can be used as a common.

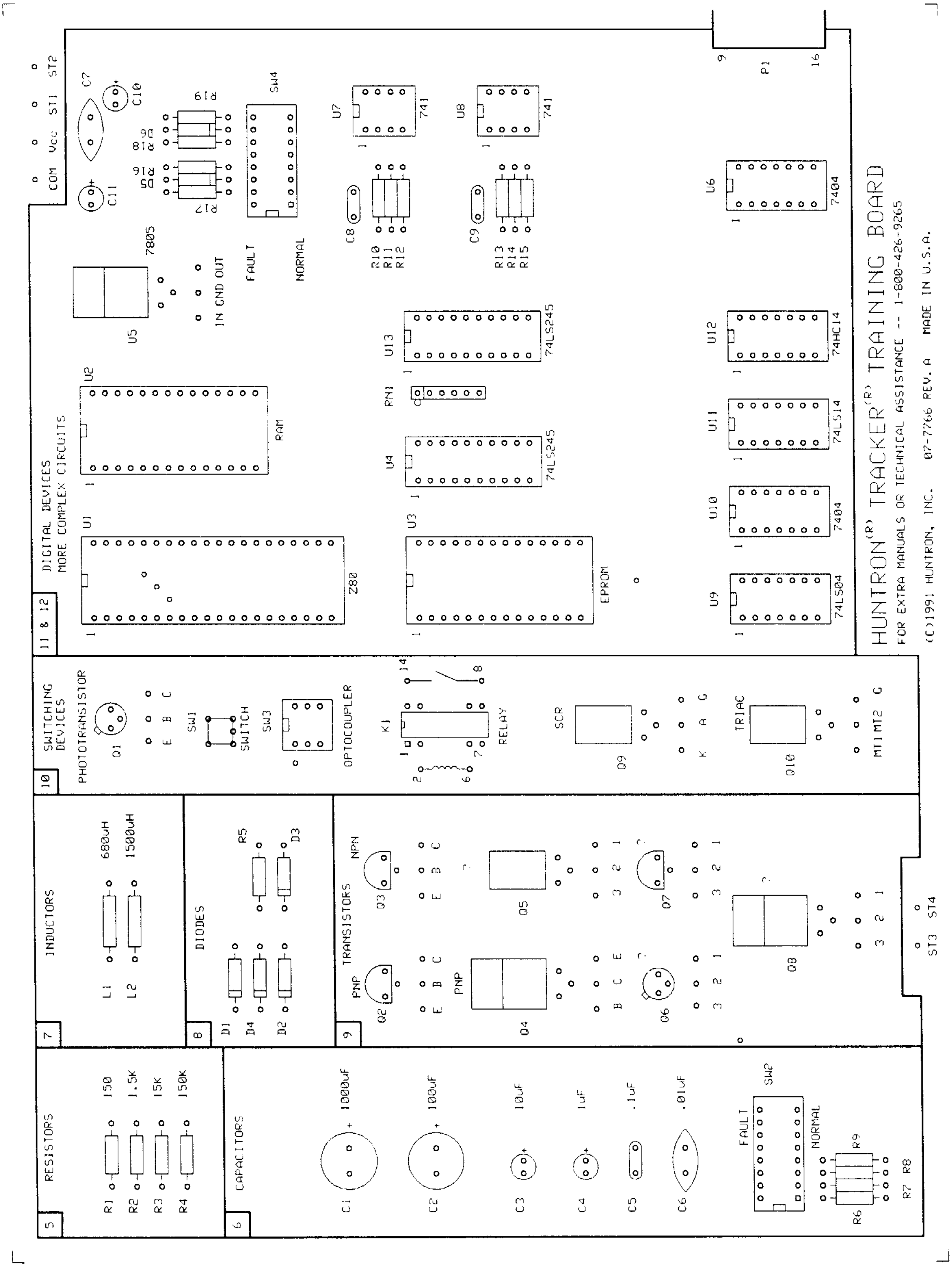


Figure 4-1. Component locator for the Training Board.

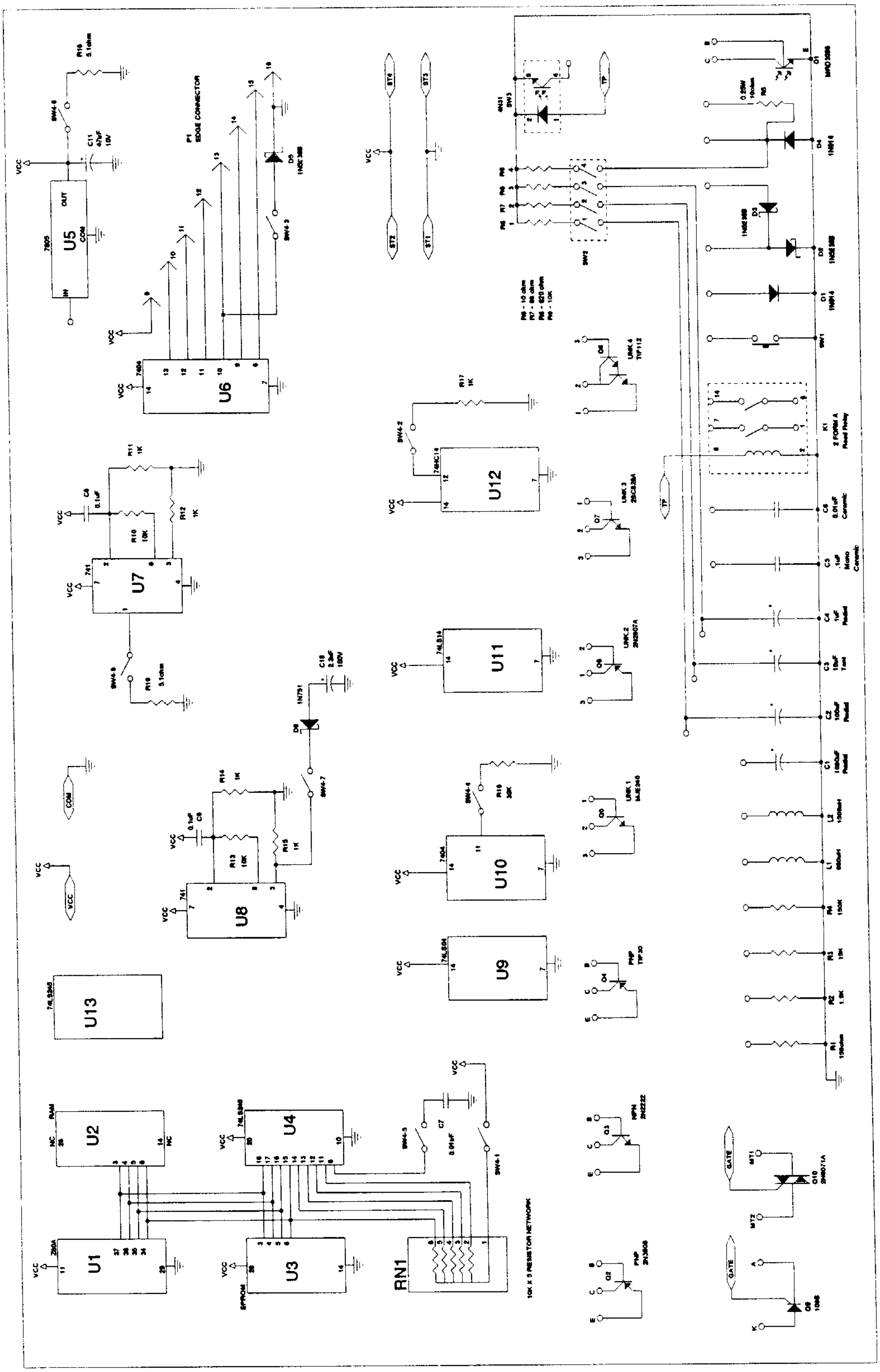


Figure 4-2. Training Board Schematic.

Notes:

SECTION 5
TESTING RESISTORS

5-1. INTRODUCTION

We are going to start by exploring how the Tracker's ranges interact with different resistance values. The purpose of these exercises is to familiarize you with the Tracker's operation and to teach you how resistor signatures are related to both test voltage and the resistance of the circuit under test. In each of these exploratory exercises we will ask you to:

- Apply test probes across a resistor.
- Draw the signature that you see on the Tracker display.

As you do these exercises, pay attention to the relationship between Voltage, Resistance and Current.

5-2. Exercise 1 - Using the LOW Range (10Vp)

Setup:

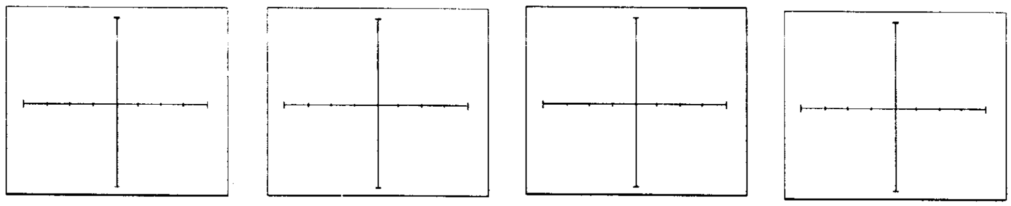
1. Put the red probe in the A jack, and the black probe in the COM jack.
2. Set the frequency to 50/60Hz.
3. Set all switches on the training board to their <u>off</u> positions.

Do the following:

1. Set the range to LOW.
2. Place the probes on the leads of each resistor. Observe the signatures on the Tracker display. Notice how they change as you change from one resistor to another.

3. Below are four diagrams of the Tracker display. Each of them has a resistance value under it. Draw the signature of each resistor in its correct place.

Low Range



150 1.5k 15k 150k

5-3. Exercise 2 - Using the MED 1 Range (15Vp)

Setup

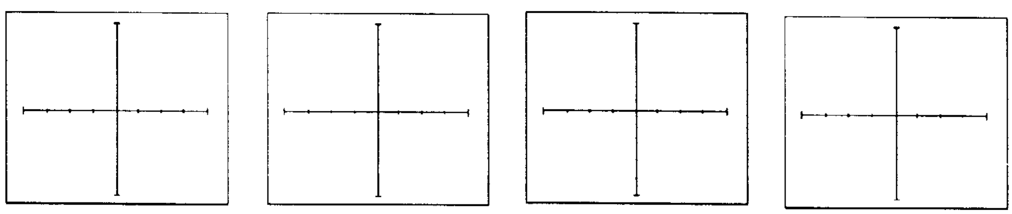
1. Change to the MED 1 range.

Do the following:

1. Place the probes on each of the resistor leads and observe the signatures at this range. Observe also, how this group of signatures is different from the signatures you got using Low range.

2. Draw the signature of each resistor.

Med 1 Range



150 1.5k 15k 150k

5-4. Exercise 3 - Using the MED 2 Range (20Vp)

Setup:

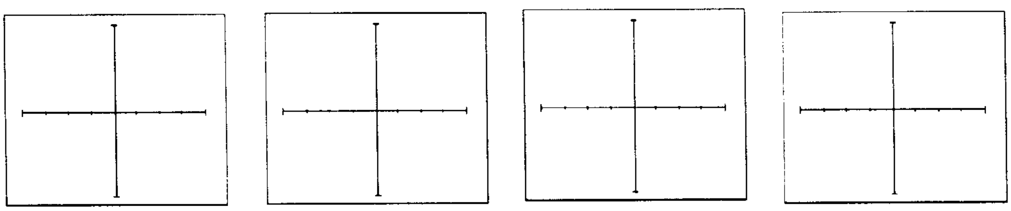
1. Change to the MED 2 range.

Do the following:

1. Place the probes on each of the resistor leads and observe the signatures at this range. Again compare these with the signatures you saw using the LOW and MED 1 ranges.

2. Draw the signature of each resistor.

Med 2 Range



150 1.5k 15k 150k

5-5. Exercise 4 - Using the HIGH Range (60Vp)

Setup:

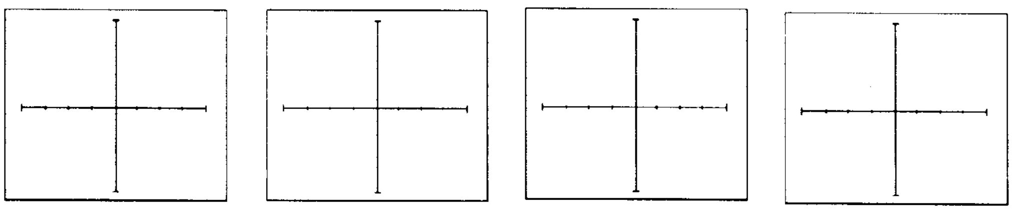
1. Change to the HIGH range.

Do the following:

1. Place the probes on each of the resistor leads and observe the signatures at this range. Again, compare these with the signatures you saw with the other three ranges.

2. Draw the signature of each resistor.

High Range



150 1.5k 15k 150k

*5-6. Questions

1a. What is the shape of a resistor signature?____________________

1b. Explain briefly why you think it is this shape. ____________________

____

____

2a. Describe how the signature changes as the resistance you are measuring gets higher?

____

2b. Why do you think this is so? ______________________________

____

3a. Describe how the signature changes as you change the voltage being applied to each resistor from LOW range to HIGH range?

___

3b. Explain briefly why you think this is so? ___

___

___

Now give yourself two points for each question correctly answered. The answers are in appendix B.

Points, [ ]/6.

5-7. UNDERSTANDING RESISTIVE SIGNATURES

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

5-8. Predicting Results

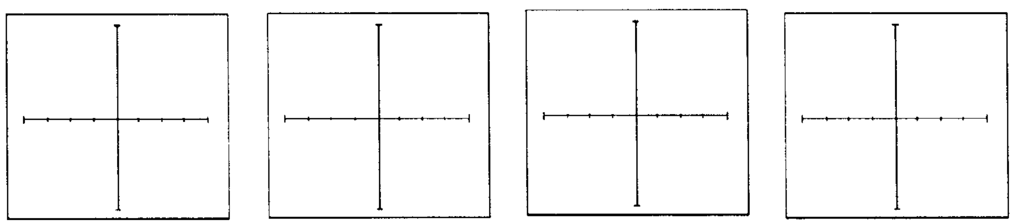
In the next two exercises we are going to ask you to draw the signatures you expect to see on the Tracker display before actually probing the circuit. You will then use the probes and draw the signatures that you see on the display. You can then compare what you predicted with what you actually saw. This will give you a pretty good idea of how well you are doing.

*5-9. Exercise 5 - How Changing the Range Changes the Signature

1. Below are four Tracker display diagrams.

2. Assume that you are viewing the 15k resistor on the test board using each of the ranges. Without looking back at your previous work, draw the signatures you would expect to see on the Tracker's display as you probe this resistor using all the ranges.

15K Resistor - predicted signatures



Low	Med 1	Med 2	High
10Vp	15Vp	20Vp	60Vp

3. Now use the Tracker to probe this resistor using all the ranges. Draw the actual signatures on the same diagrams as your predicted signatures. How well did you do with your predictions?

4. Now give your self a score for how well you did. One point for each correct signature.

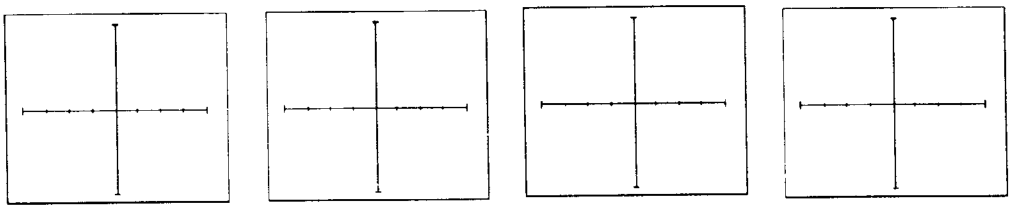
Points [ ]/4

*5-10. Exercise 6 - How Changing the Resistance Changes the Signature

1. Here are another four diagrams.

2. Draw the signatures you would expect to see if you took all of your signatures using Medium 1 range, and tested all four resistors on the board.

Med 1 Range - predicted signatures



150 1.5k 15k 151k

3. Now use the Tracker to probe these resistors. Draw the actual signatures on the same diagrams as your predicted signatures. How well did you do with your predictions?

4. Now give yourself a score for how well you did. One point for each correct signature.

Points [ ]/4

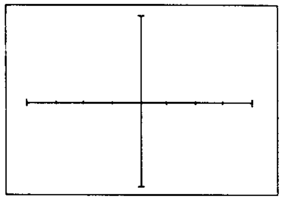
5-11. SHORTS AND OPENS

Now, let's extend what has been discussed so far. Two of the most common faults that occur in electronic systems are shorts and opens. A short is a 0Ω path between two points that should have some resistance between them. An open is a break in a circuit that prevents current from flowing.

*5-12. Exercise 7 - Signature of a Short

On the diagram below, draw the trace you would expect to see if you were applying voltage to a short.

Signature of a short

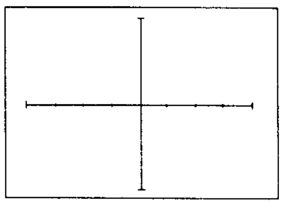


1. Explain briefly why you expect to see this kind of signature.

*5-13. Exercise 8 - Signature of an Open

On the diagram below, draw the trace you would expect to see if you were applying voltage across an open.

Signature of an open



1. Explain briefly why you expect to see this kind of signature.

Let's test your predictions. We can simulate a short by touching the probes together, and an open by holding them apart. Do that now and observe the signatures. How did you do? Give yourself one point for each correct prediction.

Points [ ]/2

Total Points [ ]/16. It is suggested that you review the section again if you didn't score at least 12 of the possible 16 points.

5-14. 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) to
  - — 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 signature becomes more vertical

5-15. APPLYING WHAT WE HAVE LEARNED

- The Tracker is a fast and efficient continuity tester, providing real time information.
- The Tracker will quickly locate visually imperceptible resistor defects, shorts, opens and degradation.
- Most component failures are resistive in nature. This is important to remember; a component fault may only appear in one range because of the resistive nature of the fault.
- The Tracker's real time display makes an excellent test for noisy or dirty pots (variable resistors). Simply monitor the wiper while rotating the pot back and forth. Watch for the telltale intermittent angular trace.
- The Tracker can be used to rough adjust a pot into an operational setting. Simply adjust each pot on a test board to match the settings on a known operational board using the "Compar-A-Trace" feature. This procedure will allow the test board to be powered up to an operating mode and functionally fine adjusted.

SECTION 6
TESTING CAPACITORS

6-1. INTRODUCTION

Capacitors introduce a new element to our testing: time delay. When we apply an AC voltage to a purely resistive circuit, we can see that the current in the circuit varies with the applied voltage. This is because the relationship between induced voltage, resistance, and current is linear: as the voltage changes the current flowing through the resistors changes with no time lag.

In capacitive circuits, however, the relationship between induced voltage, capacitance, and current is not linear. Current is at its maximum just as the voltage across the capacitor is at 0V. When the voltage across the capacitor is at its maximum, the current in the circuit is 0A.

Consider the diagram below:

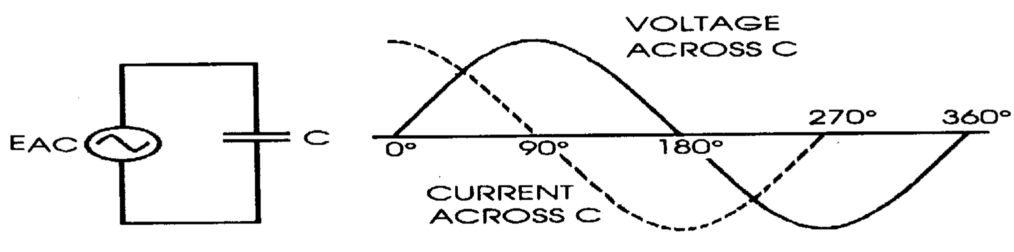


Figure 6-1. Capacitive Circuit and VI Waveform.

As our applied voltage crosses 0V and becomes more positive, the current flowing in the circuit is at its maximum and becoming smaller. By the time the applied voltage has reached its maximum value, the current in the circuit has ceased flowing. As the applied voltage begins decreasing, toward 0V, the current begins increasing toward maximum. And, when the voltage reaches 0V, the current is at its peak. Furthermore, this same pattern follows as the voltage goes negative. Because the current is at its maximum value when voltage is at 0V, we say that the current leads the voltage.

This is called "phase shift" and, in a purely capacitive circuit, this phase shift equals 90°. On the Tracker, this relationship appears elliptical. The actual shape and slope of the ellipse depends on the values of capacitance being probed, and the voltage and frequency of the test signal.

Let's look at the signatures of some capacitors and see what they look like.

6-2. CAPACITIVE SIGNATURES

We're going to start by exploring capacitive signatures. These exercises will help you understand how capacitor signatures are related to:

- The capacitance of the circuit under test
- The frequency of the input signal
- The voltage range used

In each of these exploratory exercises we will ask you to:

- Apply probes across the capacitor
- Draw the signature that you see on the Tracker display

6-3. Exercise 1 - Effects of Changing Capacitance

Setup:

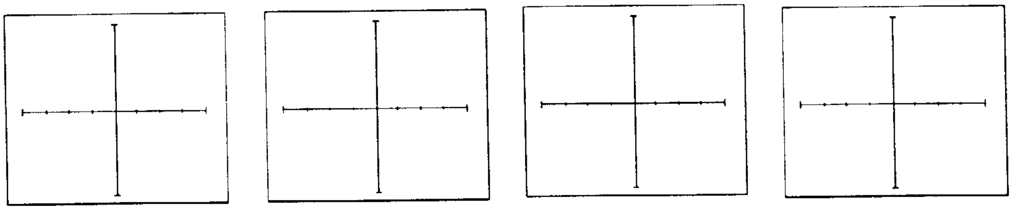
1. Set the range to LOW.
2. Set frequency to 50/60 Hz (the line frequency in your area will determine which frequency you actually get).
3. Connect the COM lead to a ground point on the board.
4. Set all switches on the training board to off.

Do the following:

1. Use the red lead to probe each of the capacitors.

2. Draw the results below.

Low Range - 50/60 Hz



1μF 10μF 100μF 1000μF

*6-4. Questions

1. As the capacitance increased, how did the signature change?

____

2. Explain briefly why you think this happens. ______________

____

____

Points, [ ]/2

6-5. Exercise 2 - Effects of Changing Test Frequency on a 10μF Capacitor

Set up:

1. Set the range to LOW.

2. Start with the 50/60 Hz output signal.

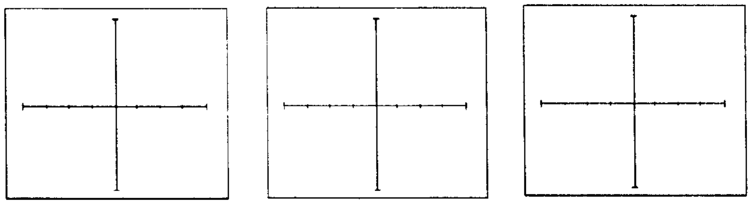
Do the following:

1. Put your red probe on the test point by the 10μF capacitor.

2. Observe the signature, then switch to 400Hz and 2000Hz.

3. Draw the results below.

Low Range - 10μF capacitor



50/60 Hz 400 Hz 2000 Hz

6-6. Exercise 3 - Effects of Changing Frequency on a 1μF Capacitor

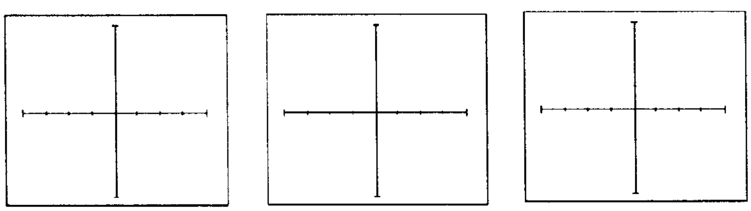
Setup:

1. Set the range to MED1.
2. Start with the 50/60 Hz output signal.

Do the following:

1. Put your red probe on the test point by the 1μF capacitor.
2. Observe the signature, switch to 400 Hz and 2000 Hz.
3. Draw the results below.

Med 1 Range - 1μF capacitor



50/60Hz 400Hz 2000Hz

*6-7. Questions

1. As the frequency of your test signal increased, how did the signature change? ______________________________

____

2. Explain briefly why you think this happens. ____________________

____

____

Points, [ ]/2

*6-8. Exercise 4 - Effects of Changing Range

Setup:

1. Start with the range set to LOW.

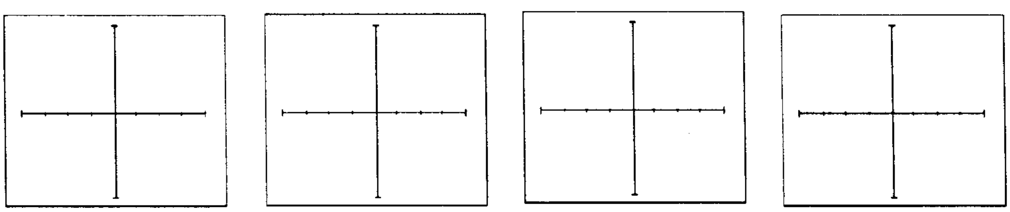
2. Set the frequency to 50/60Hz.

Do the following:

1. Put your red probe on the test point by the 1µF capacitor.

2. Switch to Med 1 range, then to Med 2 range, and lastly to High range. Draw the results below.

1µF Capacitor - frequency = 50/60Hz



Low	Med 1	Med 2	High
10Vp	15Vp	20Vp	60Vp

Question

1. As the voltage of the test signal increased, how did the signature change?

____

Points, [ ] / 1

6-9. UNDERSTANDING CAPACITIVE SIGNATURES

Remember that the Tracker displays the relationship between applied voltage, resistance and current in a circuit. In capacitive circuits the effective resistance is called Capacitive Reactance, X_c, and is inversely related to both capacitance and frequency. The actual formula is

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

How does this relate to the exercises we have just conducted?

- Changing capacitance (Exercise 1): As the capacitance of a circuit increases, the capacitive reactance decreases. This means that as capacitance increases, the amount of current in the circuit will increase. On the Tracker, the ellipse will become increasingly vertical (more current flow).
- Changing frequency (Exercises 2 & 3): As the frequency of the applied voltage increases, the capacitive reactance will decrease and the amount of current in the circuit will increase. On the Tracker, the ellipse will become increasingly vertical (more current flow).
- Changing applied voltage range (Exercise 4): As the range is changed from Low to High, the following occurs:
  - — X_c of the capacitor stays the same
  - — The applied V increases 6 times
  - — Z_s increases around 1000 times so current decreases proportionately
  - — Volts/division of the horizontal display increases 6 times

Note:

To help you choose the correct range and frequency to use, consult the manual that came with the Tracker 2000. Figure 6-2 shows the signatures for a 0.22µF capacitor using all the range and frequency combinations. Table 6-1 shows the range of capacitors that can be tested with each combination of range and frequency.

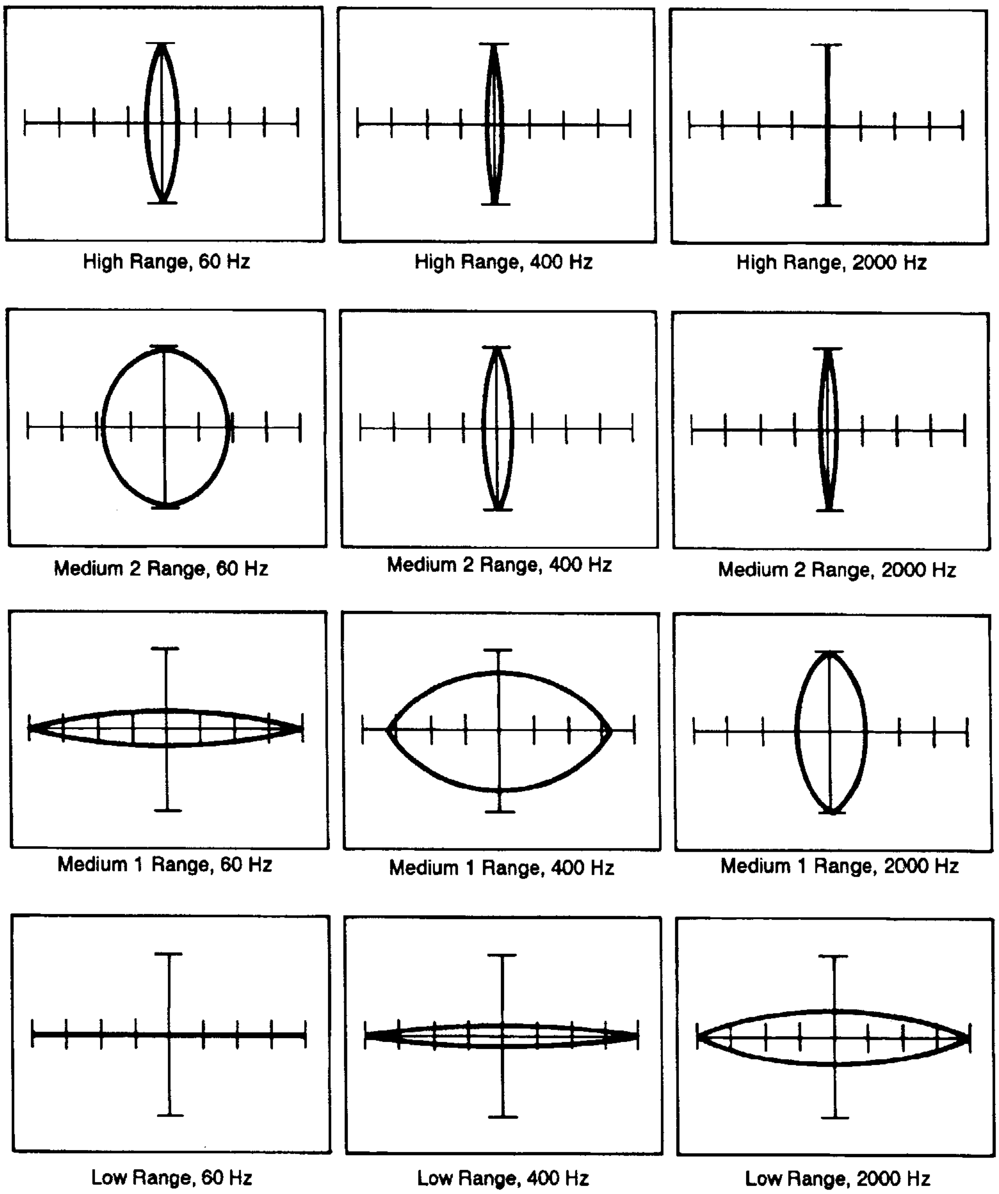


Figure 6-2. Signatures of a 0.22µF Capacitor.

Table 6-1
Min/Max Capacitance Values

RANGE	TEST FREQUENCY		
	50/60 Hz	400 Hz	2000 Hz
HIGH	.001µF - 1µF	500pF - .1µF	100pF - .02µF
MEDIUM 2	.01µF - 2µF	.001µF - .5µF	200pF - .05µF
MEDIUM 1	.2µF - 50µF	.02µF - 5µF	.005µF - 1µF
LOW	5µF - 2000µF	.5µF - 100µF	.2µF - 25µF

6-10. CAPACITOR FAILURES - LEAKAGE

One common failure in capacitors is that they develop leakage. Thinking in terms of our basic electrical properties, this means that they develop a resistance in parallel with their capacitance. Here are three exercises that will show you what capacitor leakage problems look like on the Tracker display.

*6-11. Exercise 5 - Capacitor Leakage

Setup:

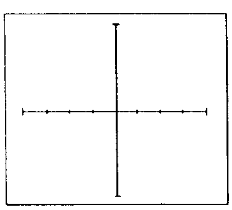
1. Set the range to LOW.

2. Set the frequency to 50/60Hz.

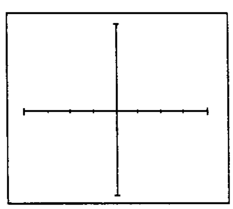
Do the following:

1. Put your red probe on the test point by the 100µF capacitor.

2. Toggle switch 1 and watch the display. Draw the results below:



Capacitance
only



Resistance
in parallel

Question

1. As you added a 100Ω resistor in parallel to the 100µF capacitor, how did the signature change?

____

2. Briefly explain why you think this happens. ____________________

____

____

____

Points, [ ]/2

*6-12. Exercise 6 - Capacitor Leakage

Setup:

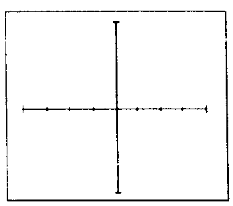
1. Set the range to LOW.

2. Set the frequency to 400Hz.

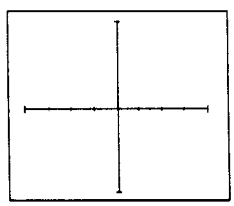
Do the following:

1. Put your red probe on the test point by the 10µF capacitor.

2. Toggle switch 2 and watch the display. Draw the results below:



Capacitance only



Resistance in parallel

Question

1. As you added a 68Ω resistor in parallel to a 10μF capacitor, how did the signature change?

____

2. Briefly explain why you think the signature you saw while doing exercise 5 is different from the signature you saw while doing exercise 4.

____

____

____

Points, [ ]/2

As you can see from the two examples above, adding resistance in parallel to capacitance skews the signature toward the diagonal. This is our first look at a composite signature, the kind of signature we see when there are several elements in the circuit.

*6-13. Exercise 7 - Testing Your Understanding

Setup:

1. Set the range to MED 1.

2. Set the frequency to 50/60Hz.

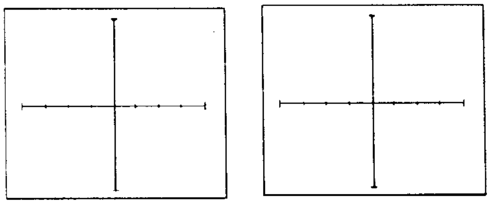
Do the following:

1. Put the red probe on the test point by the 1μF capacitor.

2. Draw the signature in the display box.

3. Draw the signature you predict when a 620Ω resistor is added in parallel with the 1μF capacitor.

4. Toggle switch 3 and watch the display. Draw the results below:



Capacitor only | Your prediction | Observed signature

5. Now give yourself a score for how well you did. One point for the correct signature.

Points, [ ] / 1

Total Points [ ] / 10. It is suggested that you review the section again if you didn't score at least 7 of the possible 10 points.

6-14. REVIEW

- Capacitors have elliptical signatures due to capacitive phase shift.
- As the test frequency increases, the signature becomes more vertical due to decreasing X_C of the capacitor.
- Leaking capacitors have their ellipses tilted toward the diagonal due to the resistance in parallel with the capacitance.

6-15. APPLYING WHAT WE HAVE LEARNED

- The Tracker can locate defective capacitors in or out of circuit. The ranges cover 100pF to 2000μF.
- When viewing a capacitor signature adjust the range and frequency for the most pronounced ellipse.
- The three test signal frequencies can be used to enhance a composite signature by emphasizing or de-emphasizing the capacitance.

- Besides resistance, faulty capacitors exhibit numerous other irregularities, lack of symmetry, intermittent and or distorted ellipse, saw teeth, rooster tails and sharp vees on the signature. See Appendix A.

- Notice that the 1000µF, the 100µF and the 1µF caps are radial lead capacitors with metal tops. A quick test of these kind of capacitors can be made by touching the probe to the metal top.

6-16. Exercise 8 - Testing Radial Lead Capacitors

Setup:

1. Set the range to MED 2.

2. Set frequency to 50/60 Hz.

Do the following:

1. Touch the red probe to the metal tops of the 1000µF, the 100µF and the 1µF capacitors.

2. Observe the signatures.

This tests the internal electrolyte between the can body and the negative lead while ignoring the circuit components that the capacitor is connected to by its positive lead. The most effective way to use this technique is A/B comparison, comparing a known good to a suspected bad.

- Capacitors in parallel can be a problem to troubleshoot. Once you spot the bad signature, you need to isolate the defective capacitor. First use hot and cold (heat gun, canned coolant) while monitoring the bad signature. Changing the temperature of a defective device often causes a corresponding change in the signature. Second, physically isolate the device by trace bisection or leg lifting. If you have a dead short, use a shorts locator like the Huntron Shortrack. See Appendix F for more information on the Huntron Shortrack.

SECTION 7
TESTING INDUCTORS

7-1. INTRODUCTION

Inductors, like capacitors, react to a changing voltage in a non-linear fashion. Also like capacitors, their reactance (resistance to an AC sine wave) changes as the sine wave frequency changes. Because of the way they are made (a wound wire) it is hard to find a pure inductance; there is usually some resistance in parallel caused by the resistance of the wire winding. This resistance, of course, shows up in the Tracker signature.

7-2. INDUCTOR SIGNATURES

There are two inductors on the circuit board which we will test in order to learn about inductor signatures.

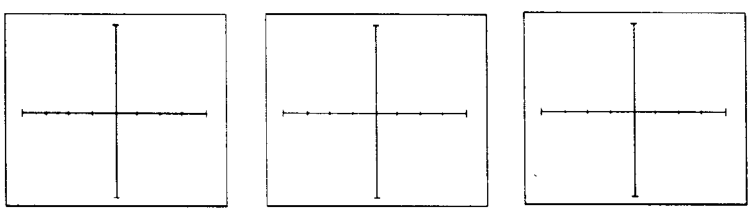
7-3. Exercise 1 - Inductor Signatures at Three Frequencies

Setup:

1. Set the range to LOW.
2. Set frequency to 50/60 Hz.

Do the following:

1. Put your red probe on the test point by the 680µH inductor.
2. Switch to 400 Hz, then to 2000 Hz and record results below.



50/60 Hz 400 Hz 2000 Hz

*7-4. Questions

1. How does the signature change as the frequency increases? _______

____

2. Explain briefly why this happens? ___________________________

____

3. Can you name another inductor on the test board besides the two mentioned in this section?

____

Points, [ ] / 3

7-5. UNDERSTANDING INDUCTIVE SIGNATURES

Remember the schematic of the Tracker display circuit in the introduction. The voltage for the vertical (current) axis is taken across the internal impedance (Z_s) of the Tracker, while the voltage for the horizontal (voltage) axis is taken across the load impedance (R_L).

The formula for the reactance of an inductor is:

$$X_l = 2\pi fL$$

X_l increases as inductance and/or frequency increase. In terms of Tracker signatures, two things happen. First, as inductance and/or frequency increase, X_l becomes larger both in itself and as a part of R_L. As a result, the signature will begin to look less resistive and move inductive (elliptical). Figure 7-1 shows signatures of a 250 mH inductor in each range and frequency.

Since inductors in reality are not true inductors, the ellipse they form on the Tracker display may be distorted. The addition of a ferrite core will also change the inductive characteristics and cause the Tracker display to respond accordingly. Figures 7-2, 7-3 and 7-4 show the response from a 490 mH ferrite core inductor.

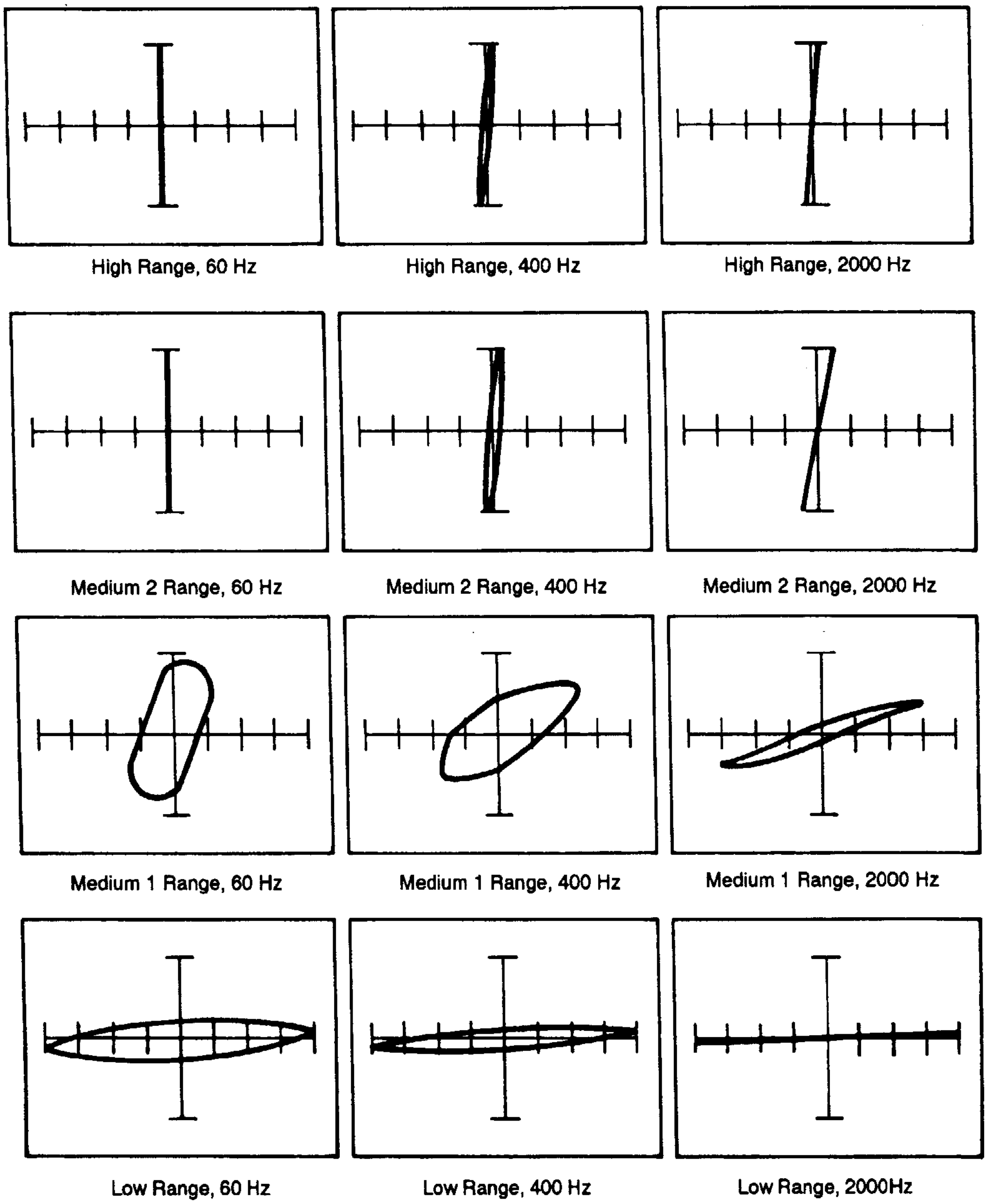


Figure 7-1. Signatures of a 250mH Inductor.

Ferrite inductors can be checked with the 2000, but produce a signature that differs from the previously described inductor. Ferrite inductors operate well at high frequencies, but saturate at low frequencies. Figure 7-2 shows the signatures of a 490mH ferrite inductor tested at 60 Hz. In low and medium 1 range the signatures show distortion. However, in medium 2 and high range, the impedance of the inductor is low compared with the internal impedance of the 2000 so the signatures are a "split" vertical trace. Figures 7-3 and 7-4 show the signatures of a ferrite inductor at 400 Hz and 2000 Hz respectively.

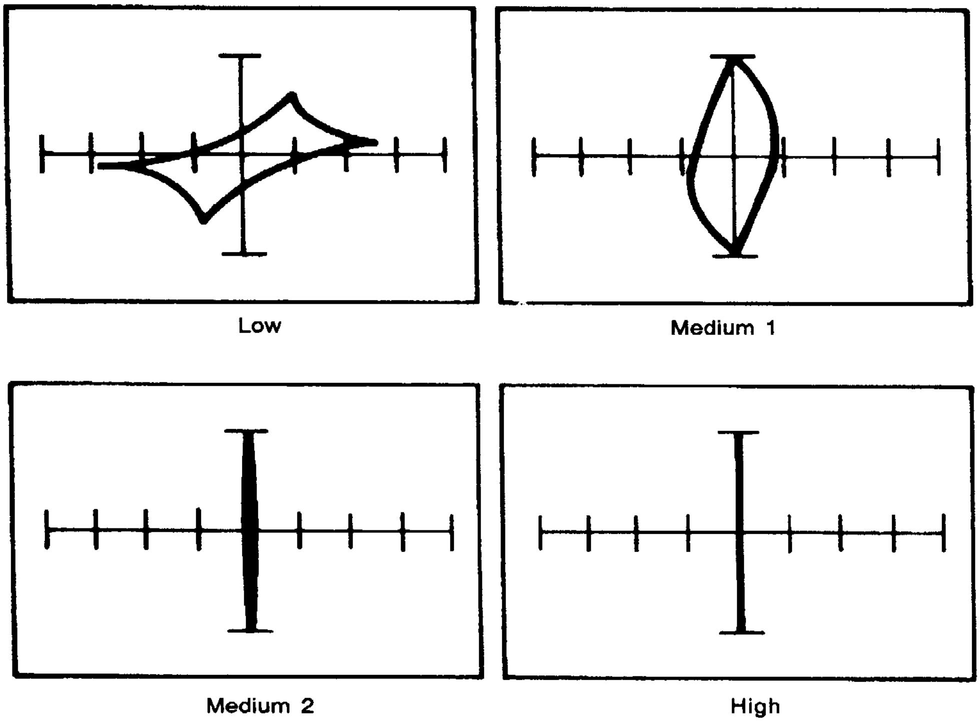


Figure 7-2. Signatures of a 490mH Ferrite Inductor Tested at 60Hz.

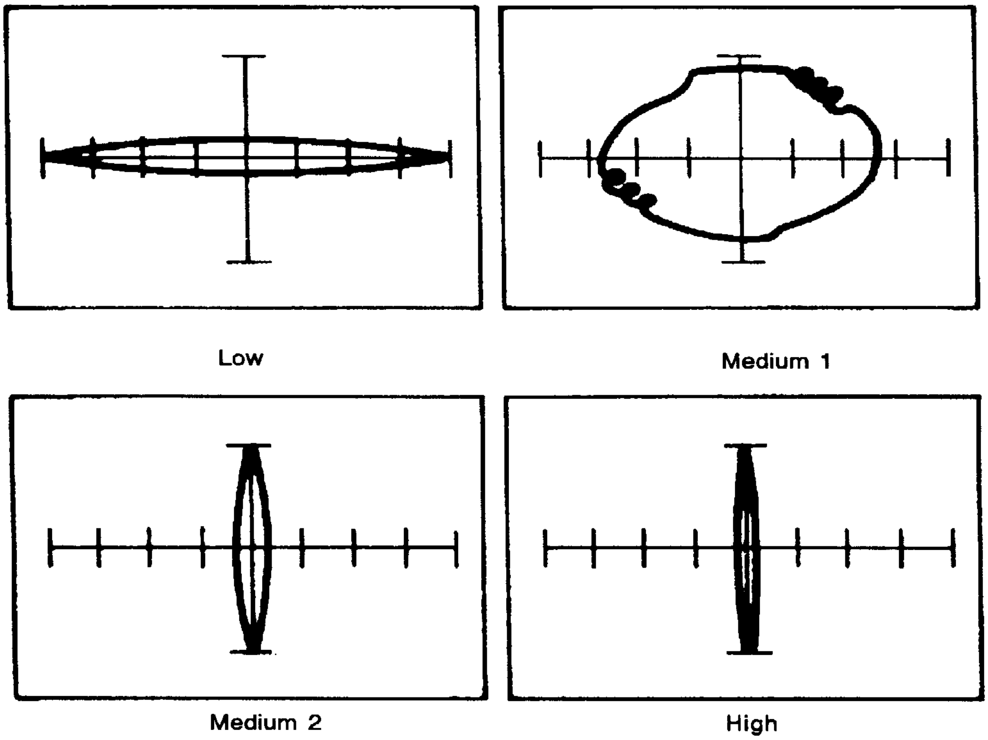


Figure 7-3. Signatures of a 490mH Ferrite Inductor at 400Hz.

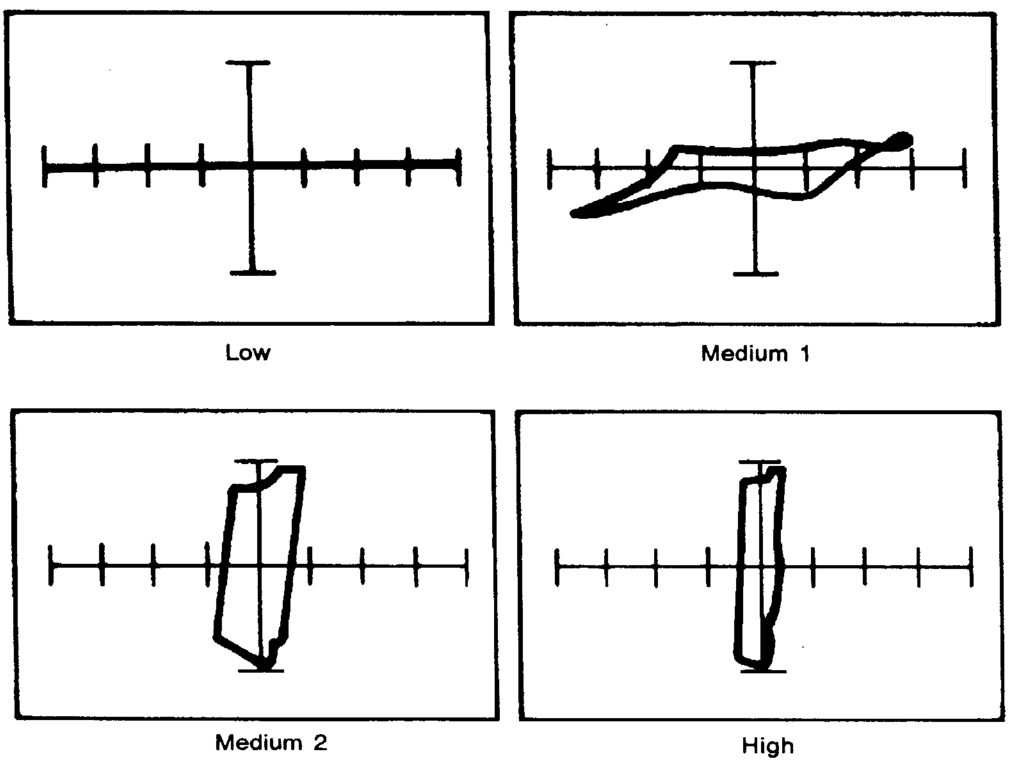


Figure 7-4. Signatures of a 490mH Ferrite Inductor at 2000Hz.

*7-6. Exercise 2 - Predicting Inductive Signatures

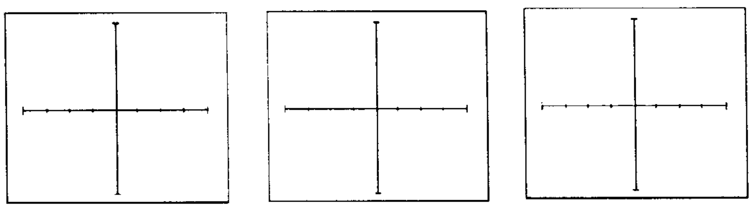
Setup:

1. Set the range to LOW.
2. Set the frequency to 400 Hz.

Do the following:

1. Put your red probe on the test point by the 1500μH inductor.
2. Draw the signature in the display box below.
3. Draw the signature you predict when the frequency is changed to 50/60 Hz and then 2000 Hz.

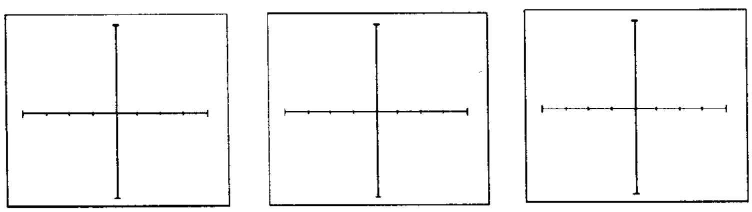
1500μH Inductor predicted signatures



50/60 Hz   400 Hz   2000 Hz

5. Use the probe at all three frequencies and record the results below.

1500μH Inductor actual signatures



50/60 Hz   400 Hz   2000 Hz

6. Now give yourself a point for each correct signature.

Points, [ ] / 3

Total Points, [ ]/6. It is suggested that you review the section again if you didn't score at least 4 of the possible 6 points.

7-7. AUTO RANGING

One question that new users often ask is, "How do you know which range to use?" The answer is, "It depends on the circuit being tested." There is, however, a feature of the Tracker 2000, that can make it easier to find the correct range. This is called the AUTO RANGE feature. Here's how it works:

7-8. Exercise 3 - Using Auto Range

Setup:

1. Set the test frequency to 2000 Hz.

Do the following:

1. Push the RANGE button marked AUTO.
2. Notice how the Tracker 2000, cycles through all the ranges. The speed with which it does this is controlled by the RATE knob just above and to the right of where your probes are plugged in. Practice changing the rate until you find the rate that feels right for you.
3. Probe the 1500µH inductor. Watch how the signature changes as the range changes.
4. Press the button labeled HIGH LOCK OUT and observe the effect on the Tracker's operation.
5. Repeat this procedure and probe the coil on K1, pin 6.

7-9. REVIEW

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

- As the Tracker frequency is increased, the ellipse signature becomes more rounded. This response is opposite to that of a capacitor.

- As the range is increased the inductor signature becomes more vertical, the same as the capacitor.

- When an inductor has a ferrite core, the signature is distorted from the normal ellipse.

7-10. APPLYING WHAT WE HAVE LEARNED

- The Tracker is an excellent troubleshooting device for inductors. It can reveal shorted or open windings.

- Inductors are not always obvious in our world. Some are listed here. Can you think of more? Power transformers, relays, solenoids, flybacks, speakers, magnetic sensors, stepping motors and motor windings.

- The best technique for testing inductors is comparison. Compare a known good to a suspect device. This is easier than it may seem. A motor armature will have numerous windings, every winding should have a similar signature. Whether it powers an elevator or a tape deck, this holds true. The armature of a DC motor can be probed by simply hooking to the brush leads and adjusting for the most pronounced signature. Slowly turn the armature. This will display continuity, the inductance, and the condition of each brush contact without disassembling the motor.

- Here is another time saving example. A computer is turned in for repair. It is reported "dead". To make a quick determination of the possible problem we would do the following. With the computer unplugged from AC power, connect the red and black Tracker probe across the prongs on the AC cord going to the computer. Turn the power switch on. If there is a response on the Tracker screen, adjust for the most pronounced inductive signature. Flick the power switch off and on and watch for noisy contacts. If there is no response, start by checking each component up to the primary winding of the transformer. With this technique, we have just verified the AC cord, the AC noise filter, the fuse, the power switch, and the primary winding of the transformer, without removing the cover of the computer.

- Another simple test for a speaker or microphone is to apply the Tracker signal in LOW range to the device input leads and listen for the 60 Hz hum.

- To test solenoids or Hall effect switches simply monitor the inductive coil display and move the plunger in and out. The signature will change accordingly.

NOTES:

SECTION 8
TESTING DIODES

8-1. INTRODUCTION

Semiconductor diodes are formed by creating a junction between P-type and N-type semiconductor material. As a result, diodes, and all semiconductor components, have polarity. 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 8-1 shows how the diode symbol indicates the polarity of the diode.

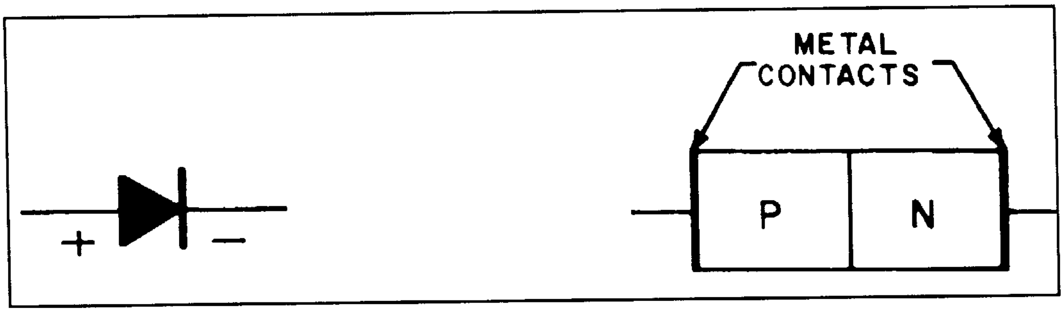


Figure 8-1. Diode Symbol.

8-2. DIODE SIGNATURES

Diode signatures reflect the basic nature of a semiconductor junction. There is a threshold voltage (about 0.6V for a silicon diode) at which the diode begins to conduct. As long as the anode-cathode voltage differential is below that threshold, the diode acts like an open and no current flows. As the anode to cathode voltage is made more positive, the diode will begin to conduct. Once current begins to flow in the diode, very small increases in anode voltage will cause very large increases in current. This is called the "knee" effect and is characteristic of a good semiconductor junction. You can see this knee effect on two identical diodes in the next exercise.

8-3. Exercise 1 - Diode Signatures

Setup:

1. Set the range to LOW.

2. Set the frequency to 50/60Hz.

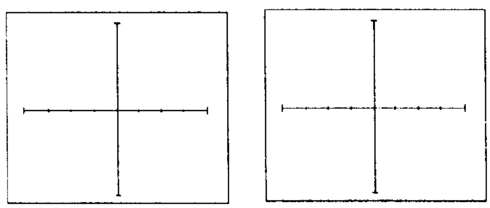
3. Connect the COM lead to a COM point on the Trainer Tutorial Board.

Do the following:

1. Put your red probe on the test point next to D1. Draw the signature in the appropriate display box.

2. Put your red probe on the test point next to D4. Draw the signature in the appropriate display box.

Diode signatures



D1 D4

The signatures of the two diodes you probed are upside down mirror images of each other. This is because the second diode is reversed in the circuit. Its anode is tied to COM so it is forward biased when the voltage from the red lead is -0.6V.

NOTE

In Low Range, which we just used, the voltage at the probe is 10Vp. Each horizontal division on the display = 2.5V. In this range, therefore, we can see that the threshold voltage of our diodes, the voltage at which they begin to conduct is approximately 0.6V.

8-4. DIODE FAILURES

Diodes can fail in a number of ways, and each type of failure will cause the signature to change in a predictable manner. We've already seen the characteristic signatures of opens and shorts, so these types of failures will be obvious to you. Two other types of diode failure are: internal resistance and leakage.

8-5. Exercise 2 - Internal Resistance in a Diode

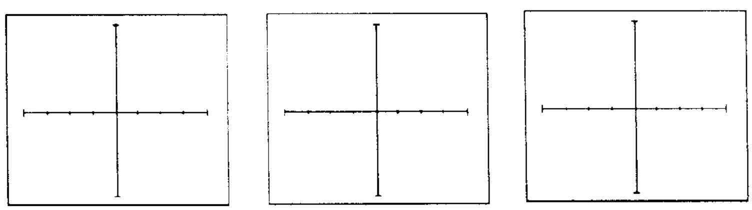
Setup:

1. Set the range to LOW
2. Set the frequency to 50/60Hz.

Do the following:

1. Place the red probe on the test point next to R5, and draw what you see below.
2. Repeat using MED 1 range and MED 2 range.
3. To give you a better feel for the effect of the range chosen on the resulting signature, use the Auto Range feature with the HIGH range locked out.

Internal resistance



LOW MED 1 MED 2

In LOW range, but not in either of the two medium ranges, we can see that there is a resistive component to the signature when the diode is conducting. This is the result of a defect in the P-N junction. The resistance only shows in LOW range because the voltage drop across it is small. In higher ranges, the volts per division of the display is too great to show such a small voltage drop.

8-6. Exercise 3 - Internal Leakage

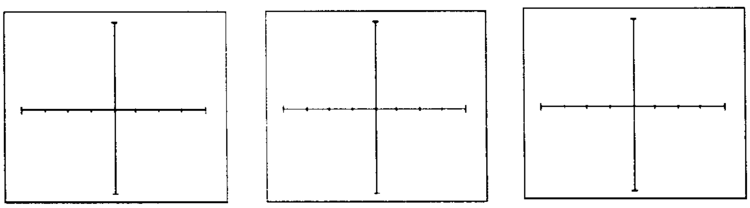
Setup:

1. Use AUTORANGE (with HIGH LOCKOUT) for this test.
2. Set the frequency to 50/60 Hz.

Do the following:

1. Place the red probe on the test point next to D4.
2. Toggle switch 4 on and off and watch the resulting display.
3. Draw what you see below when switch 4 is on.

Diode leakage



LOW MED 1 MED 2

Notice that in LOW range there doesn't 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, however, it acts like a resistor when it ought to be acting as an open.

8-7. ZENER DIODES

Regular diodes conduct when forward biased only. When reverse biased, they act as opens unless so much voltage is applied that they break down and can no longer prevent current flow.

Some diodes are made to work when reverse biased, but under carefully controlled conditions. Zeners are special diodes that are designed to do their work when reverse biased. When forward biased, 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 rated zener voltage, at which time they begin to conduct current. Even if the reverse voltage is increased, the voltage across the zener remains constant. It is this feature of zeners that allows them to be used as voltage regulators. Because they conduct in both directions, we can expect to see two knees on the Tracker display, one at 0.6V and the other at the zener voltage of the diode being tested.

8-8. Exercise 4 - Zener Diodes

Setup:

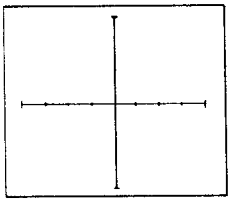
1. Set range to MED 2.

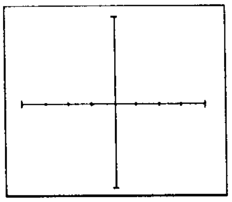
2. Set frequency to 50/60Hz.

Do the following:

1. Place your probe on the test point next to D2, then D3. Record the signatures below.

Zener diode signatures





D2 D3

Since each horizontal division in MED 2 range = 5V, you can estimate that this is a 9V Zener. The signature at D3 is the signature of two zeners in series. The zener voltage (V_Z) of this circuit is the combined V_Z of each of the separate diodes. You should be able to estimate the V_Z of this diode circuit at approximately 18V.

*8-9. Questions

1. How could you determine the anode of a diode if the cathode mark were missing? ________________________________

2. Looking at a unknown zener diode in the LOW range it is noted that the device avalanches or breaks down at two horizontal divisions. What is the approximate voltage of this zener?__________

3. If the knee of a diode junction is rounded instead of square, what would this indicate? ________________________________

4. What signature would you expect to see if you probed across two diodes in series with the cathodes connected using LOW range?

____

5. What signature would you expect to see if the cathodes on the above diodes were facing the same direction? ____________________

Points [ ]/5

Total Points [ ]/5. It is suggested that you review the section if you didn't score at least 4 of the possible points.

8-10. REVIEW

- Diodes conduct current in one direction (forward biased) and not the other. This is displayed on the Tracker as the "knee" effect.
- 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.
- Zener diodes are special diodes that conduct when reverse biased at a specific voltage.

8-11. APPLYING WHAT WE HAVE LEARNED

- Diode damage or degradation can appear as a loss of sharpness or rounding in the "knee". See Appendix A.
- While faulty diodes do display resistive current and voltage legs, they are usually nonlinear or curved.
- The polarity of a diode can be determined by the orientation of the display with a known diode.
- The Tracker can be used to identify an unknown zener. If the zener is damaged, locate a good one, possibly on another board or in the same circuit and use the Tracker to approximate the voltage.
- Look for the zener effect when checking voltage regulators such as the 7805. This can help determine an unknown or faulty device.
- The Tracker can be used to test and determine the pin connections on a bridge rectifier, AC, + and -.

NOTES:

SECTION 9
TESTING TRANSISTORS

9-1. INTRODUCTION

A bipolar junction 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. Figures 9-1 and 9-2 show the relationship between type of material and circuit symbol for a PNP and an NPN transistors.

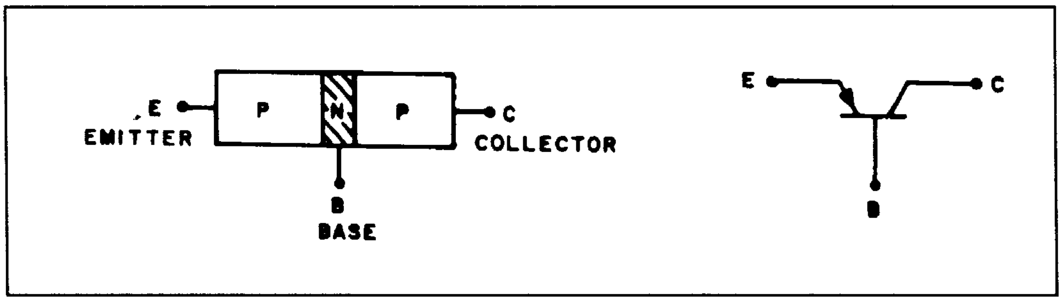


Figure 9-1. PNP Transistor and Circuit Symbol.

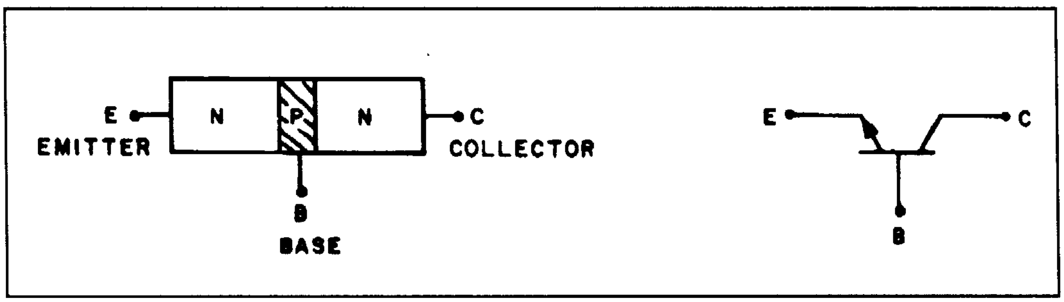


Figure 9-2. NPN Transistor and Circuit Symbol.

9-2. TRANSISTOR SIGNATURES

In order to better understand the signatures that transistors create on the Tracker, we can model these devices in terms of equivalent diode circuits. These can be seen in Figures 9-3 and 9-4. These figures show that the collector-base junction looks to the Tracker as a diode, and the emitter-base junction looks to the Tracker as a zener diode. Because we have already seen the signatures of these two types of junctions when we tested diodes, they should be familiar to you.

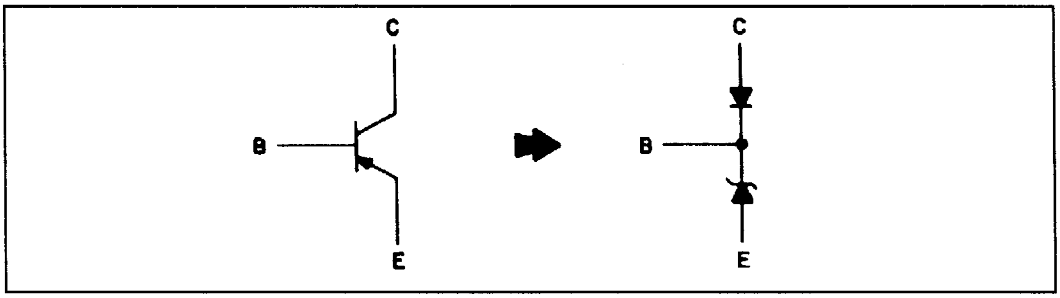


Figure 9-3. PNP Transistor Diode Model.

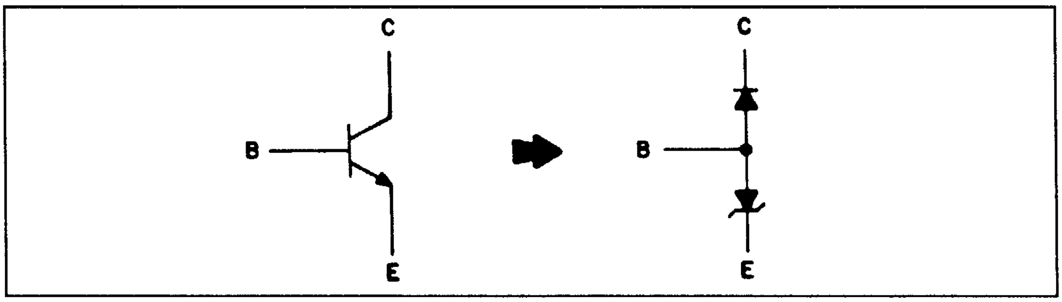


Figure 9-4. NPN Transistor Diode Model.

9-3. Exercise 1 - Base-Collector Transistor Signatures

Setup:

1. Set the range to MED 2.

2. Set the frequency to 50/60Hz.

3. Plug the black micro probe into the COM jack.

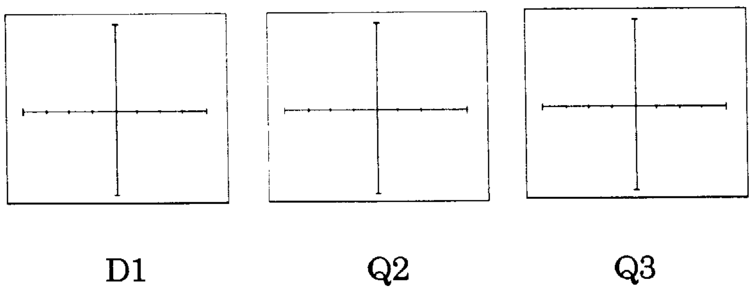
Do the following:

1. Put the red probe on the anode of D1 and the black probe on its cathode. Record the signature below.

2. Put the red probe on the collector of Q2 and the black probe on its base. Record the signature below.

3. Put the red probe on the collector of Q3 and the black probe on its base. Record the signature below.

Base-Collector Transistor Signatures



Notice that the collector-base signature of a PNP transistor is identical to the signature of a forward-biased diode. The collector-base signature of an NPN transistor, which has opposite polarity from an PNP, looks like 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 Base-Emitter circuits.

9-4. Exercise 2 - Base-Emitter Transistor Signatures

Setup:

1. Set the range to MED 2.

2. Set the frequency to 50/60Hz.

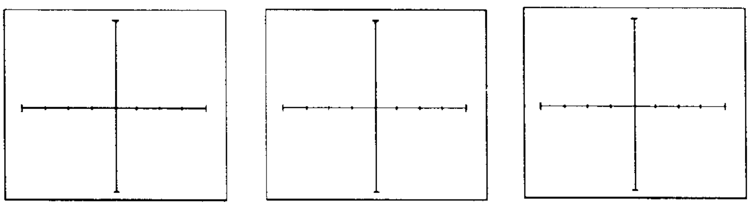
Do the following:

1. Put the red probe on the anode of D2 and the black probe on its cathode. Record the signatures below.

2. Place the red probe on the emitter of Q2 (PNP) and the black probe on its base. Record its signature below.

3. Place the red probe on the emitter of Q3 (NPN) and the black probe on its base. Record its signature below.

Base-Emitter Transistor Signatures



D2   Q2 PNP   Q3 NPN

We can see that the emitter-base signature of the PNP transistor is identical with the signature of the zener diode, and that the emitter-base signature of an NPN transistor is identical but opposite in polarity to the zener.

9-5. Exercise 3 - Collector-Emitter Transistor Signatures

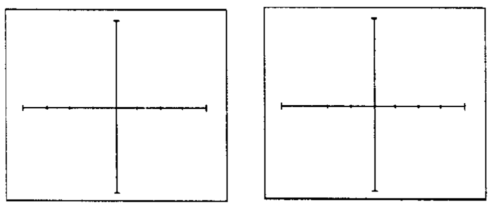
Setup:

1. Set the range to MED 2.
2. Set the frequency to 50/60Hz.

Do the following:

1. Place the red probe on the collector of Q2 (PNP) and the black probe on its emitter. Record its signature below.
2. Place the red probe on the collector of Q3 (NPN) and the black probe on its emitter. Record its signature below.

Predicted Collector-Emitter Signatures



Q2 PNP   Q3 NPN

You can see that the collector-emitter signature of a PNP transistor looks like a forward biased diode with the knee at approximately 15V. The collector-emitter signature of an NPN transistor looks like a reverse biased diode with the knee at approximately -15V.

All bipolar junction transistors have essentially the same signatures. Q4 is a PNP power transistor. Probe it to verify that the signatures are similar.

9-6. Exercise 4 - Another Transistor Signature

Setup:

1. Follow the procedure of exercises 1 through 3.
2. Probe transistor Q1 in this exercise.

Do the following:

1. Display the base-collector junction signature. Verify that it is similar to the collector-base signature you found in exercise 1.
2. Repeat for the base-emitter junction signature.
3. Repeat for the collector-emitter junction signature.

9-7. IDENTIFYING UNKNOWN TRANSISTORS

Sometimes, we need to identify unknown transistors. We may need to replace one in a circuit for which we don't have a schematic. The Tracker makes that 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. Rather than describing the procedure in detail, we'll let you try it out.

*9-8. Exercise 5 - Identifying Unknown Transistors

Setup:

1. Set the range to MED 2.
2. Set the frequency to 50/60Hz.

Unknown transistor Q5

Do the following:

1. Probe pin 1 with the red probe and pin 2 with the black probe.
2. Identify the signature. This looks like a collector-base signature. What you don't know yet is which pin is the collector and which is the base.
3. Probe pin 3 with the red probe and pin 2 with the black probe.

4. Identify the signature. This looks like a collector-emitter signature.

5. Now that you know that pin 2 of the unknown transistor is the collector. Place the black probe on this pin and move the red lead from the base to the emitter. Do the same with the two known transistors.

6. Use the same procedure for unknown transistors below.

Answer the following questions:

1. Unknown transistor Q5

   Is this an NPN or a PNP? _________

   Which lead is the Emitter____, Base____, Collector____

2. Unknown transistor Q6

   Is this an NPN or a PNP? _________

   Which lead is the Emitter___, Base___, Collector___

3. Unknown transistor Q7

   Is this an NPN or a PNP? _________

   Which lead is the Emitter____, Base____, Collector____

4. Unknown transistor Q8

   Is this an NPN or a PNP?_________

   Which lead is the Emitter____, Base____, Collector____

5. What did you notice that was unusual about Q8?_________________

   Did you suspect that this was a Darlington transistor?_________
   (See Figure 9-5)

6. What is different about Q1? ____________________

____

7. Can you explain why Q7 has the unusual leg pattern? ____________________

____

Points [ ]/19

Total Points [ ]/19. It is suggested that you review the section again if you didn't score at least 15 of the possible 19 points.

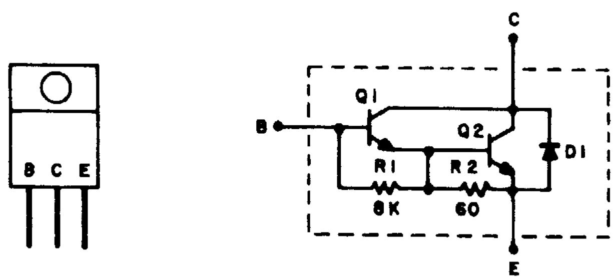


Figure 9-5. Diagram of a Darlington Transistor.

9-9. USING THE PULSE GENERATOR TO TEST TRANSISTOR OPERATION

Figure 9-6 shows the test circuit for an NPN transistor using the pulse generator to drive the base. The constant current signature produced is like that produced by a transistor curve tracer except that only one curve is shown instead of a family of curves. This technique can be useful for functionally testing and matching transistor gain.

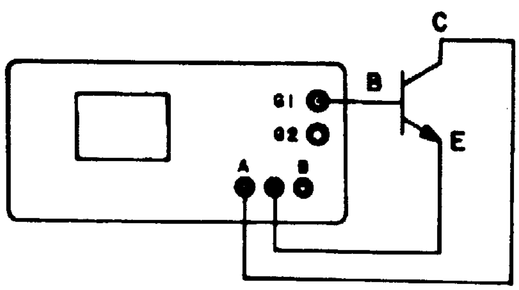


Figure 9-6. NPN Test Circuit.

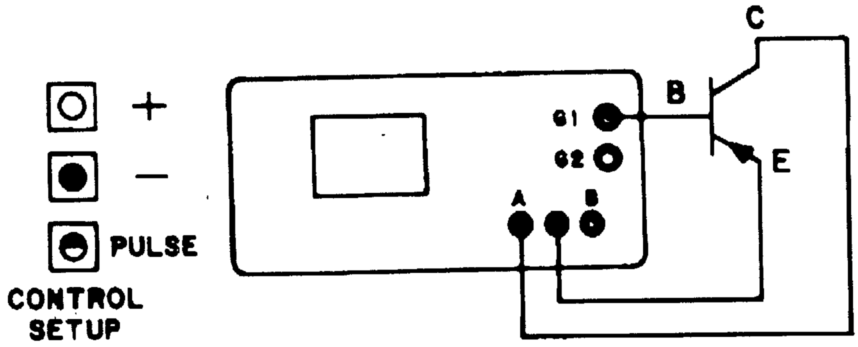


Figure 9-7a. PNP Test Circuit.

Figure 9-7a shows the test setup for a PNP transistor. As for the NPN transistor, this signature will be the result of the collector-base junction of the transistor.

9-10. Exercise 6 - Displaying Gain

Setup:

1. Set up the test circuit pictured in Figure 9-7 using Q2 on the test board.
2. Set the frequency to 50/60 Hz.
3. Set the range to MED 1.

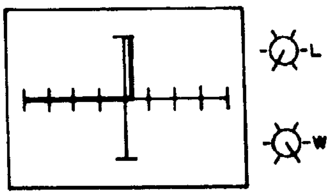


Figure 9-7b.

Do the following:

1. Adjust the LEVEL and WIDTH control to duplicate the signatures in Figure 9-7b, c, d.

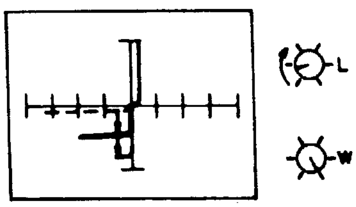


Figure 9-7c.

2. Do the same procedure with Q4.

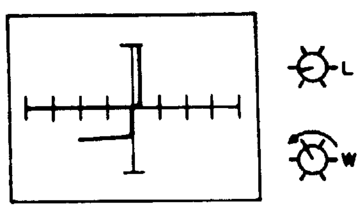


Figure 9-7d.

9-11. 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 silicone 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 signatures resemble the diode signatures previously examined. They have polarity and may exhibit the zener effect.

9-12. APPLYING WHAT WE HAVE LEARNED

- Transistors will display the same type of faulty signature as diodes, rounded "knee" and nonlinear or resistive current and voltage legs. (See Appendix A.)

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

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

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

- The Tracker 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.

SECTION 10
TESTING THE OPERATION OF SWITCHING DEVICES

10-1. INTRODUCTION

Switches are electrical devices that either stop or allow current to flow in a circuit. They are either on or off. In the world of electronics, we often speak of "switching" as a basic function, one which can be performed by a variety of devices. All these devices are similar in that they are either on or off. They are different because each uses a different kind of stimulus to turn them on or off.

Switching devices come in all types and sizes. There are simple mechanical switches, relays, optical switches, and many kinds of semiconductor switches. Because there are so many kinds of switching devices, there is no single testing procedure that will test them all completely. What we can do with the Tracker, however, is to ignore the differences and concentrate on what all these devices have in common: the switching function itself. In this section, we will develop a strategy that focuses on testing 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.

10-2. MECHANICAL SWITCHES

A mechanical switch has two states: it is either open or closed. When open, no current can flow; when closed, it acts like a short between its poles. Because they are typically mechanically actuated, we can test the switching function with the Tracker. Unlike the DVM that samples and gives a measurement, the Tracker displays real time activity as it happens. If a switch has noisy, resistive or intermittent contacts the Tracker display will reflect it.

10-3. Exercise 1 - Basic Mechanical Switch

Setup:

1. Set the range to MED 2.

2. Set the frequency to 50/60Hz

Do the following:

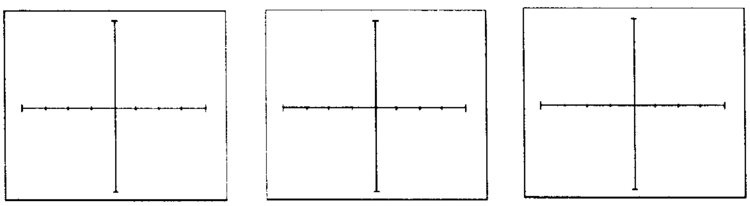
1. Put your red probe on the test point by the switch S1 and black probe to common.

2. Push and release the switch and observe what happens on the display. Record that in the space below marked MED 2.

3. Change the range first to MED 1. Record what you see below.

4. Change the range to LOW and repeat. Record what you see below.

Basic Mechanical Switch Signatures



MED 2 MED 1 LOW

Notice that as you switch from MED 2 range to MED 1 and then to LOW, the signature slants away from the vertical. This is similar to the signature of a diode with internal resistance, and has the same causes.

- The switch has some resistance.

- As the test voltages decreases, the voltage of each voltage division becomes smaller so the effects of a small voltage drop across the switch resistance becomes more pronounced.

10-4. OPTICAL SWITCHES (PHOTOTRANSISTORS)

A phototransistor 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.

10-5. Exercise 2 - Optical Switch (Light Activated Transistor)

Setup:

1. Set the Range to MED1.

2. Connect the black COM lead to the Emitter.

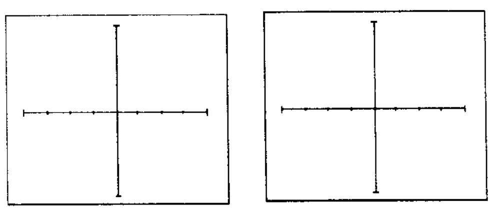
3. Put the red lead on the collector of Q1.

Do the following:

1. Draw the collector-emitter signature in the display box labelled "No Light".

2. Shine a bright light on the phototransistor's photo cell. Draw the signature below in the display box labelled "With Light".

Phototransistor Signatures



No Light With Light

Notice that the phototransistor acts as a diode in reverse breakdown mode when not activated by light, and as a short when activated by a strong light.

- The optocoupler consists of a light emitting diode and a phototransistor. They are electrically isolated. When the diode in the above exercise is powered by the pulse generator it radiates light. This light falls on the phototransistor emitter-collector junction (exercise 3) and turns the device on.

10-6. USING THE TRACKER 2000 PULSE GENERATOR

Many switching devices are voltage controlled. Some, like relays, respond to a changing voltage to turn the switch on and off. Others, like semiconductor switches respond to a voltage above a certain level, to activate the switching function. All these devices can be tested dynamically with the Tracker's Pulse Generator function. By applying the correct signal to the control input of a switching device while the test leads are connected across the switch terminals, we will be able to see the device turning on and off.

10-7. Exercise 3 - Optical Switch (optocoupler)

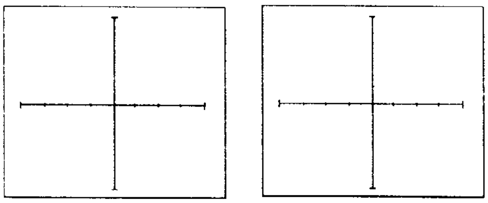
Setup:

1. Set the Range to MED 1.
2. Connect the pulse generator (G1) to the diode on SW3 (pin 1).
3. Put your red probe on the test point (pin 4).

Do the following:

1. Set the pulse generator controls to DC, +, and the LEVEL counterclockwise.
2. Observe and draw the signature.
3. Observe and draw the signature when the LEVEL is turned totally clockwise.

Optocoupler Signatures



CCW CW

10-8. REED RELAYS

A relay is a switch activated by an inductor. We can test the inductor part of the relay by observing its signature. Using the Tracker's pulse generator, we can activate the inductor and test the switching function directly. We will do both in the following two exercises.

10-9. Exercise 4 - Reed Relay Inductor Test

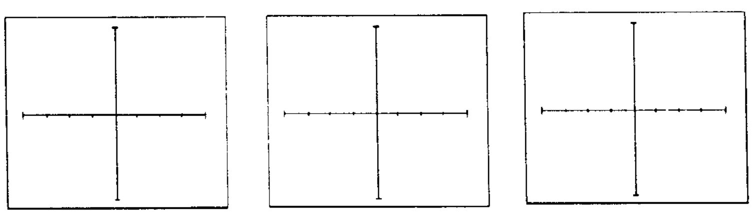
Setup:

1. Set the range to LOW.
2. Set the frequency to 2000Hz.
3. Connect the COM jack to ground.
4. Put your red probe on the coil test point (pin 6).

Do the following:

1. Observe the signature. Record it below.
2. Change to MED 1 then to MED 2 range. Observe and record.

Reed Relay Inductor Signatures



LOW MED 1 MED 2

Notice the characteristic inductive oval in the two lowest ranges, and the ringing sound as the switch is vibrated by the inductive action.

10-10. Exercise 5 - Using the Pulse Generator to Test a Reed Relay

Setup:

1. Connect Tracker output G1 to the coil test point (pin 6).
2. Put your red probe on the switch test point (pin 8).

Do the following:

1. Activate the "+" button and be sure the PULSE/DC light is steady.
2. Turn the LEVEL control back and forth and watch the relay turn on and off.
3. Keep changing the LEVEL until you are satisfied you understand how the relay works and how to test it with the Tracker 2000.
4. If the reed relay dose not activate, connect both G1 and G2 to the coil terminal. This will increase the current available to the device. This method also works well for large SCR's.

10-11. SEMICONDUCTOR SWITCHES

Transistors and other three-leaded semiconductor devices are usually controlled by a voltage at one of the leads. Current will flow between the collector and emitter of an NPN transistor when the base is more positive than the emitter. Current flow between drain and source in Field Effect Transistors is controlled by a voltage at the gate. Although these transistors can be used as switches, they can also be used as amplifiers and may need to be tested accordingly. (See Section 9-9).

There are, however, some semiconductor devices that are always used as switches. We will learn how to dynamically test two of these: SCRs and triacs.

10-12. 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 is at the same voltage level as the cathode, the SCR acts as an open. When the gate is made more positive than the cathode, positive current flows between the anode and the cathode.

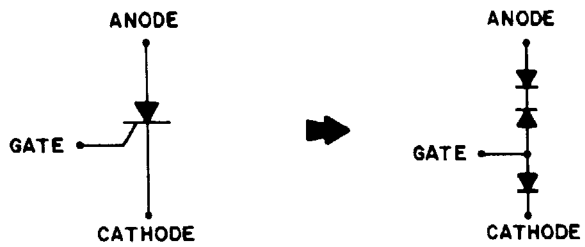


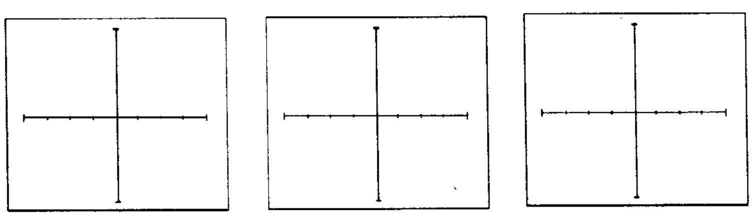
Figure 10-1. Silicon Controlled Rectifier.

*10-13. Exercise 6 - Silicon Controlled Rectifiers (SCR'S)

Draw below the signatures you would expect if you probed:

1. Red on gate and black on anode.
2. Red on gate and black on cathode.
3. Red on anode and black on cathode.

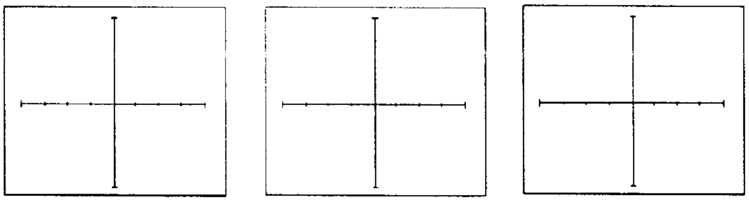
Silicon Controlled Rectifier Predicted Signatures



Gate-Anode Gate-Cathode Anode-Cathode

Now verify your predictions by probing with the Tracker. Use the LOW range for this.

Silicon Controlled Rectifier Observed Signatures



Gate-Anode Gate-Cathode Anode-Cathode

Give yourself a score for how well you did. One point for each correct signature.

Points [ ]/3

10-14. Exercise 7 - Dynamic Testing of an SCR

Connect the SCR to the Tracker as illustrated below:

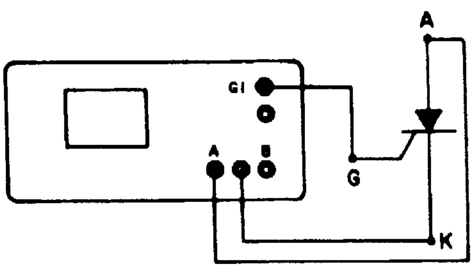


Figure 10-2. SCR Test Circuit Using Pulse Generator

Set the range to LOW. By turning the LEVEL knob you can see the SCR turn on and off as you raise and lower the voltage at the gate.

10-15. Triacs

SCRs are designed to conduct current in one direction only. When turned on, their signature looks like the signature of a diode. There are times, however, when we want to permit current to flow in both directions. The Triac is a device designed to switch an AC current with either positive or negative gate current pulses. It is tested with the Tracker by connecting it as illustrated below.

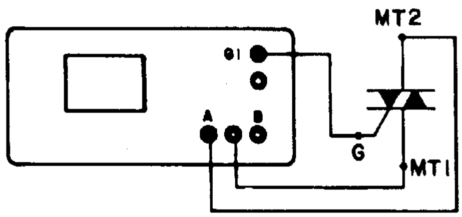


Figure 10-3. Triac Test Circuit Using Pulse Generator

10-16. Exercise 8 - Dynamic Testing of Triacs

Setup:

1. Use the MED 1 range.

2. Set the LEVEL knob full counterclockwise.

Do the following:

1. Start turning the LEVEL knob clockwise.

2. Observe the triac begin to conduct first in a forward direction and then in a reverse direction. You will see that the triac can be turned on by pulses of either polarity.

*10-17. Questions

1. What signature would you expect to see with the Tracker in LOW range looking across a closed mechanical switch?________________

____

2. What two devices would you expect to see in the optocoupler? ______

____

3. Which junction of the phototransistor is affected by light, the base-emitter, the base-collector, or the emitter-collector? _________

4. When you turn on an SCR, how many junctions do you see on the Tracker (cathode to anode)? ________________________________

5. When you turn on a triac, how many junctions do you see on the Tracker (MT1 to MT2)? ________________________________

6. What would cause the contacts of a reed relay to exhibit an angular signature in LOW range when the relay is energized? ___________

____

7. Why should the pulse generator be in positive and negative pulse mode when testing a triac? ________________________________

Points [ ]/7

Total Points [ ]/10. It is suggested that you review the section again if you didn't score at least 7 of the possible 10 points.

10-18. REVIEW

- While a switch in its simplest form is an open or short it can exhibit noise, bounce, resistance and intermittent contact. To test this type of device you need a real time test instrument.

- Solid state optical devices are silicon junctions that can be effected by light. Usually a collector-emitter combination.

- When the silicon junction is activated by a light emitting diode it becomes an optocoupler. These are commonly used as circuit isolators.

- Reed relays can be tested for proper operation with a Tracker.

- SCRs and triacs are solid state switches that are turned on by a gate. SCRs conduct current in one direction while triacs conduct current in both directions.

10-19. APPLYING WHAT WE HAVE LEARNED

- The Tracker 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 broken display. Switch bounce will display multiple closures. Resistive contacts will display a resistive signature in low range.

- The Tracker can also dynamically test optocouplers. These devices are very common in isolation circuits. Their performance can slowly deteriorate making them intermittent and difficult to detect. The Tracker will detect very small defects in the transmitting diode and the emitter-collector receiving junction.

- The SCR and triac can also be a problem to troubleshoot. They may be used to control large currents. Their use makes these devices high fatality components, susceptible to degradation. The Tracker will display these faults.

NOTES:

SECTION 11
TESTING DIGITAL DEVICES

11-1. INTRODUCTION

One of the strongest trends in electronics today is the push toward making everything smaller. Digital logic circuits, for example, were once built out of discrete transistors. Now, they are made as complete circuits on a chip. This trend will only intensify in the future so it is important to understand how the Tracker responds to this kind of circuitry.

11-2. WHY INTEGRATED CIRCUITS FAIL

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

1. EOS	Electrical over stress. The IC's electrical specifications have been exceeded. This can cause shorts and opens.
2. ESD	Electrostatic discharge. Repeated exposure causes resistance to build in the device junctions. The range of resistance varies from 5k to 25k with a typical value of 20k. ESD will cause resistance, opens and shorts.
3. Dendrites	Hair like particles that grow between conductors on a substrate causing shorts.
4. Ionic Contamination	Contamination introduced at the time of manufacture that develops into leakage between substrate channels. This causes 5k to 25k of resistance.
5. Purple Plague	Interaction between gold and aluminum. Junctions become very brittle and will cause opens.
6. Corrosion or Metalization	Aluminum metalization can cause electromigration, pinholes, corrosion and resistance. This will create opens and resistance.

11-3. DIGITAL INTEGRATED CIRCUIT SIGNATURES

Digital integrated circuit chips are made from semiconductor transistors on a common substrate. Because they are semiconductors, their signatures are variations on basic diode and transistor signatures. Many logic chips contain multiple circuits on one chip. These chips, although they may have many pins, often have only a few different signatures. [This can make troubleshooting easier by giving us an easy-to-find signature to use as a comparison. We will see how to do this below.]

U13 is a 74LS245 Octal Transceiver or bidirectional bus buffer. Examine the circuit drawing for this chip below. You will see that there are really only four different kinds of circuits on the chip.

- Pins 2 through 9 and 11 through 18 are all the same. Each is connected to both an input and an output of a buffer.
- Pins 1 and 19, although they have different names, are both enables and are inputs to AND gates.
- Pin 10 is Ground.
- Pin 20 is V_{CC}.

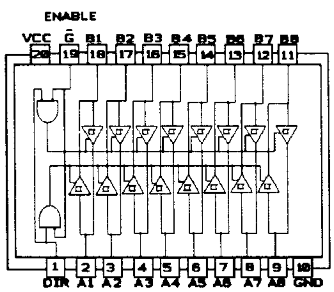


Figure 11-1. 74LS245 Circuit Diagram.

Each type of circuit will generate a typical signature. Because there are only four types of circuits on the chip, it will only have four signatures.

11-4. Exercise 1 - Finding the Signatures of a Logic Chip

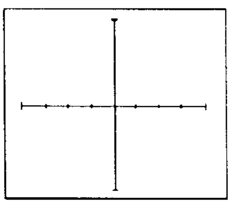
Setup:

1. Set the range to MED 2.
2. Set the frequency to 50/60Hz.
3. Connect the COM lead to Pin 10 on U13.
4. Verify all switches are off on the test board.

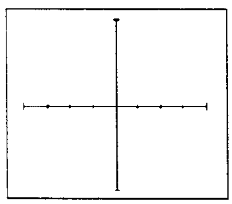
Do the following:

1. Probe in turn, pins 2 through 9 and 11 though 18 on U13. Because they are all connected to the same kind of circuit, they all give the same signature. Draw this signature below.
2. Probe pins 1 and 19. These are also both connected to the same kind of circuit and have the same signature. Draw this signature below.
3. Probe pin 20 in LOW range, the V_{cc} pin. Draw this signature below.

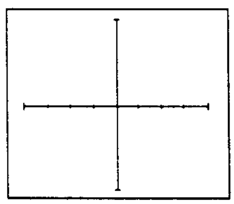
74LS245 Signatures with Ground as Tracker Common



Buffer pins



Enable pins

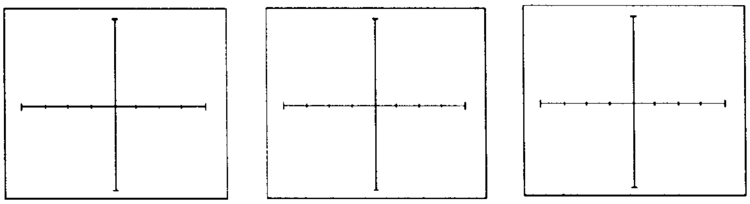


Power pin

11-5. Exercise 2 - Testing TTL Circuits with Reference to V_{CC}

One feature of TTL circuits is that testing can be done with reference to Ground as we just did, or to Power. Try that now by repeating the tests you made above but this time connect the COM lead of the Tracker to pin 20 of U13. Draw the signatures below.

74LS245 Signatures with V_{CC} as Tracker Common



Buffer pins Enable pins Ground pin

11-6. SIGNATURES OF DIFFERENT TTL CHIP FAMILIES

TTL is considered to be one of the main logic chip families. Unfortunately, there is not just one type of TTL circuit. Although the logic function is the same, there are differences in the circuitry of each type. These differences are reflected in the signatures that you will see on the Tracker display.

There are two hex inverters on the test board, U10 is a 7404 and U9 is a 74LS04. From the logic diagram below, you can see that they have the same logic functions and pin arrangements. The difference is that the LS04 uses Schottky transistors for increased switching speed and is designed for reduced power consumption. Notice that there are only four types of circuit connections and therefore only four signatures on this chip: inverter inputs and inverter outputs plus the usual power and ground.

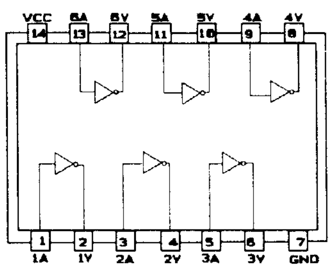


Figure 11-2. 7404 and 74LS04 Diagram.

11-7. Exercise 3 - Comparing Two TTL Hex Inverters

Setup:

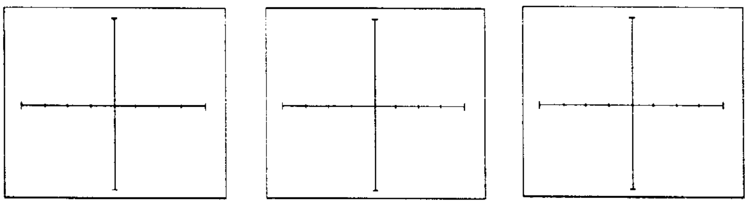
1. Set the range to MED 2.
2. Set the frequency to 50/60Hz.
3. Connect the COM lead to a ground point on the board.

U10 7404 Hex Inverter

Do the following:

1. Probe U10 pins 1, 2 and 14.
2. Draw the signatures below.

7404 Hex Inverter Signatures



Pin 1 Input | Pin 2 Output | Pin 14 Power

3. Change range to AUTO with HIGH LOCKOUT.
4. Probe U10 pins 1, 2 and 14 again and observe the effects of the different ranges on the signatures.

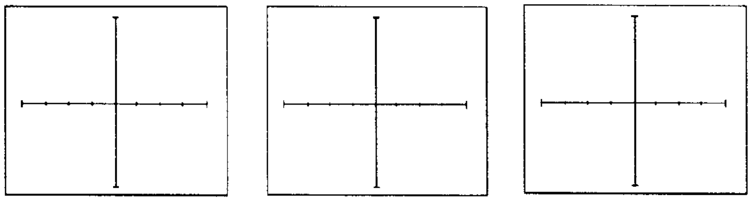
U9 74LS04 Hex Inverter

Do the following:

1. Probe U9 pins 1, 2 and 14.

2. Draw the signatures below.

74LS04 Hex Inverter Signatures



Pin 1 Input | Pin 2 Output | Pin 14 Power

3. Change range to AUTO with HIGH LOCKOUT.

4. Probe U10 pins 1, 2 and 14 again and observe the effects of the different ranges on the signatures.

11-8. CMOS LOGIC CIRCUITS

CMOS circuits are constructed differently than TTL circuits. The inputs to CMOS transistors are capacitive and, therefore, open circuits. No power supply current is needed except during input logic changes. As a result, one common application of CMOS is when power requirements are critical. Portable laptop computers are one example of such an application.

To compare CMOS and TTL signatures, we will use two hex inverters. U11 is a 74LS14 Schmidt Trigger Hex Inverter. U12 is a 74HC14, a comparable CMOS device. Both have the same pin configurations, and both have only four signatures.

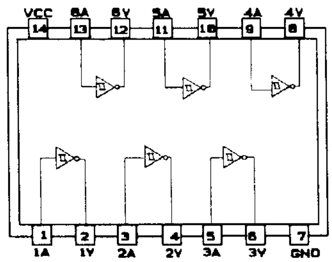


Figure 11-3. 74LS14 and 74HC14 Circuit Diagram.

11-9. Exercise 4 - Comparing TTL and CMOS Logic Circuits

Setup:

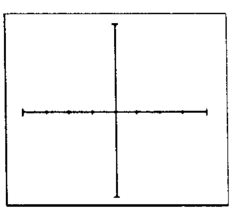
1. Set the range to MED 1.
2. Set the frequency to 50/60Hz.
3. Connect the COM lead to a ground point on the board.

U11 74LS14 TTL Hex Inverter

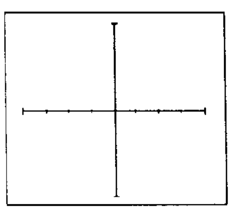
Do the following:

1. Probe U11 pins 1, 2 and 14.
2. Draw the signatures below.

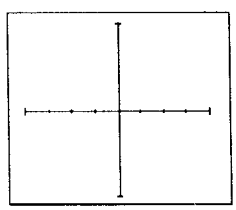
74LS14 TTL Hex Inverter Signatures



Pin 1
Input



Pin 2
Output



Pin 14
Power

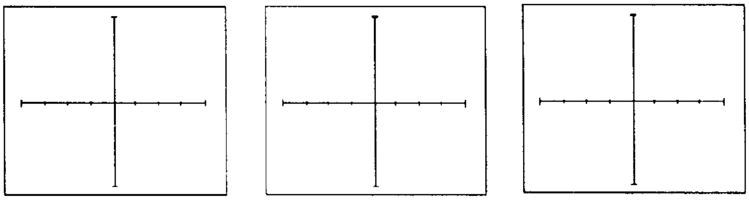
U12 74HC14 CMOS Hex Inverter

Do the following:

1. Probe U12 pins 1, 2 and 14.

2. Draw the signatures below.

74HC14 CMOS Hex Inverter Signatures



Pin 1 Input | Pin 2 Output | Pin 14 Power

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

11-10. TROUBLESHOOTING DIGITAL LOGIC DEVICES

So far, in this section, we have seen signatures of TTL, Schottky TTL and CMOS logic circuits. To make matters even more complicated, we have seen the signatures of inverter inputs, inverter outputs, power inputs, and the inputs to an AND gate, all of which have different signatures. Fortunately, you don't have to remember all of these signatures. The Tracker has a feature that makes it relatively easy to identify faulty circuits: Comparison Testing.

Remember that each of the chips that we have so far examined have only four signatures. For example, U10, the 7404 has inverter inputs, inverter outputs, plus power and ground. The two hex inverters have inputs and outputs plus power and ground. We can use this feature to develop a model for troubleshooting digital logic chips.

*11-11. Exercise 5 - Finding Comparison Pins

Setup:

1. Set the range to MED 2.
2. Set frequency to 50/60Hz.
3. Connect the COM lead to a ground point on the board.
4. Connect the black probe into the yellow "B" jack.

Do the following:

1. Push the "A CHANNEL" button. Place the red probe on pin 1 of U10. Observe the signature. This is the signature of an input pin.
2. Push the "B CHANNEL" button. Place the black probe on pin 2 of U10. Observe the signature. This is the signature of an output pin.
3. Push the "ALT CHANNEL" button. Keep the black probe on pin 2 of U10 and place the red probe on pin 1. Adjust the RATE until it feels comfortable watching the Channel A and Channel B signatures alternate on the display.
4. Keep the red probe on pin 1, an input pin. Probe all the other pins with the black probe until you have identified all the pins that have signatures that are the same as pin 1. Write the pin numbers below:
   U10 input pin numbers____________________________________
5. Move the red probe to pin 2, an output pin. Probe all the other pins with the black probe until you have identified all the pins that have signatures that are the same as pin 2. Write the pin numbers below:
   U10 output pin numbers___________________________________
6. If you want more practice, try the above sequence using the other ranges.

Give yourself one point for each correct pin in exercise 4 and 5.

Points [ ] / 12

*11-12. Exercise 6 - Testing Digital Logic Chips 1

Setup:

1. Set the range to MED 2.
2. Set the frequency to 50/60Hz.
3. Connect the COM lead to a ground point on the board.
4. Set CHANNEL to ALT.
5. Set Fault Switch #4 to its fault position.

Do the following:

1. Place the red probe on U10 pin 1.
2. Keep the red probe in place while using the black probe to test all the U10 pins that have the same signature as pin 1.
3. Move the red probe to U10 pin 2. Use the black probe to test the all the U10 pins that have the same signature as pin 2.
4. Identify the fault.

   The fault is on pin______.

5. How did the fault change the signature? ______________________

   ____

6. How do you interpret this change? ___________________________

   ____

7. Repeat steps 1 through 4 using the other ranges.
8. Give yourself one point for each correct answer above.

Points [ ]/3

*11-13. Exercise 7 - Testing Digital Logic Chips 2

Setup:

1. Set the range to MED 2.
2. Set frequency to 400Hz.
3. Connect the COM lead to a ground point on the board.
4. Set Fault Switch #5 to its fault position.

Do the following:

1. Place the red probe on U4 pin 2.
2. Keep the red probe in place while using the black probe to test all the U4 pins that have the same signature as pin 2.
3. Identify the fault.

   The fault is on pin____.

4. How did the fault change the signature? ________________________

   ____

5. How do you interpret this change? ____________________________

   ____

6. Repeat steps 1 through 4 using the other ranges.
7. Give yourself one point for each correct answer.

Points [ ] / 3

Total Points [ ] / 18. It is suggested that you review the section if you didn't score at least 14 of the possible 18 points.

11-14. REVIEW

- Integrated circuits are small complex devices that are built using basic electronic components.
- The IC signatures resemble zener diodes that were previously looked at in section 7.
- There are numerous causes for IC failures, but the end result is a change in the IC's ability to handle current. This will be displayed on the Tracker 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 types of signatures.
- To simplify the large number of signature variations, the Tracker has the comparatrace feature. This switches the A and B channel to allow comparison of two individual signatures.

11-15. APPLYING WHAT WE HAVE LEARNED

- Testing for faulty IC's is one of the more common uses for the Tracker. A technician can compare IC's in circuit or out.
- Using the Huntron Switcher 410 allows fast direct comparison of an IC, pin for pin. This device is available from Huntron as an accessory to the Tracker.
- The most commonly used range for viewing TTL signatures is MED 2. The reason for this can be seen by looking at the resistive range of the faults listed in the front of this section. If a fault is not identified in the MED 2 range then try LOW and MED 1.
- The most common range for MOS circuits is MED 1.

SECTION 12
TESTING MORE COMPLEX CIRCUITS

12-1. INTRODUCTION

In this chapter we will develop our troubleshooting skills on more difficult circuits. In the last chapter, you used the comparison method to test digital logic chips. In this chapter, we will extend this idea to three new kinds of circuits: microprocessor bus circuits, analog circuits, and circuit cards with edge connectors.

The basic principle of comparison is simple. All we need is a second good signature that we can compare to the signature on the Circuit Under Test. This second signature can be on the same chip, as we have seen with many digital logic chips. It can also be on another good board. The Tracker 2000 is designed to make it easy to compare two signatures. We'll see how it works in the exercises below.

12-2. MICROPROCESSOR CIRCUITS

Microprocessor circuits are characterized by shared signal lines called buses that route signals throughout the system. There are typically three buses: the address bus contains signals that originate at the microprocessor and are used to select some specific memory or I/O location with which the microprocessor wants to exchange data. The data bus is a set of signal lines over which the data is transferred. The control bus is a set of signal lines which are used individually to coordinate system activity with the microprocessor's bus cycle. A key fact about these buses is that they act as signal highways to which many devices are connected. Some of these devices, like latches and buffers, isolate the different parts of the system and synchronize their activity with the microprocessor chip. Other devices, such as memory chips and I/O circuits, are connected in parallel with each other; their activity is synchronized to the microprocessor by the address and control lines.

Because there are often many devices connected in parallel, troubleshooting microprocessor circuits can be difficult. It requires a three step process of fault isolation. These steps are:

1. Using some test procedure to isolate the fault to a particular circuit.

2. Using the Tracker to isolate the fault to a particular signal line.

3. Using the Tracker to find the particular chip that is faulty.

12-3. Isolating a Problem to a Particular Circuit

This is where your troubleshooting skills come into play. Depending on your knowledge of the system and the resources available, this can be done in a variety of ways. Specialized test equipment can sometimes be helpful. Test programs are sometimes available or can be developed. Often, just knowledge of how the system is supposed to operate is all that is required to successfully isolate the problem sufficiently.

12-4. Isolating the Problem to a Particular Signal Line

Here is where we can use comparison testing for fault isolation. The chips on microprocessor buses, like those of the digital chips we worked with in the previous chapter, tend to only have a few distinct signatures. This makes it possible to use an internal comparison to find a faulty signal line. We'll start by examining the signatures of a microprocessor chip, and then do some troubleshooting.

U1 is a Z80 microprocessor chip. Here is a diagram of its pin configuration:

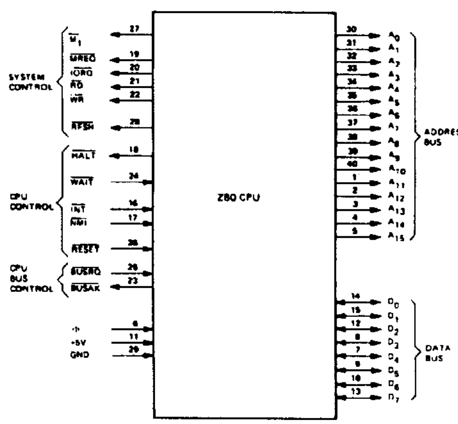


Figure 12-1. Z80 Microprocessor Pin Configuration.

On our test board, four address lines are connected as a bus to U2, a static RAM chip; U3, an EPROM chip; and to U4, the 74LS245 Octal Bus Transceiver you met in the previous chapter. All the other pins, except for power and ground are open. We'll start by learning what the signatures of a microprocessor look like.

12-5. Exercise 1 - Finding the Signatures of a Microprocessor.

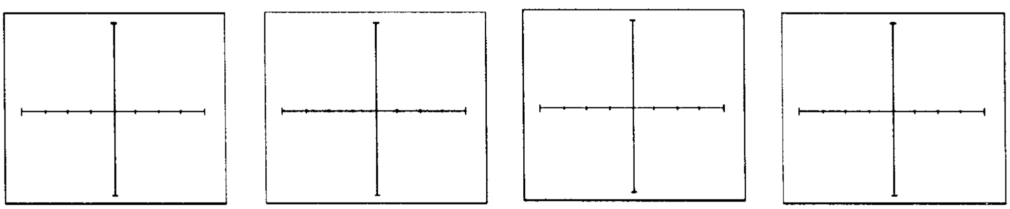
Setup:

1. Set the range to MED 2.
2. Set the frequency to 50/60Hz.
3. Connect the COM lead to a ground point on the board.

Do the following:

1. Using the red test lead, probe each of the Z80 pins. You will see four different signatures.
2. Draw these signatures below. You will have to change the range to distinguish the power pin from the ground pin.

Microprocessor Signatures



Bus lines   NC pins   Power pin   Ground

12-6. Isolating the Fault to the Signal Level

To find the faulty signal line we have to do an internal comparison just like we did in the last chapter.

12-7. Exercise 2 - Troubleshooting to the Signal Level

Setup:

1. Set the range to MED 2.
2. Set the frequency to 50/60Hz.
3. Connect the COM lead to a ground point on the board.

Do the following:

1. Set fault switch 1 to its fault position.
2. Push the ALT CHANNEL button.
3. Place the red test lead on U1 pin 1 and hold it there.
4. Use the black test lead to test all the pins on the Z80 chip that have the same signature.
5. Place the red test lead on U1 pin 37 and hold it there.
6. Use the black test lead to test all the pins on the Z80 chip that have this signature.

*12-8. Questions

When you have found the fault, answer the following questions.

1. What is the name of the faulty signal line (use the chip diagram to help you answer this)? ______________________________
2. What other chips and pins is this signal line connected to?

   U2, pin______________________________

   U3, pin______________________________

   U4, pin______________________________

Points [ ]/4

12-9. Isolating the Problem to a Particular Chip

The fact that the faulty signal line is connected to many chips makes it hard to know which chip is the problem. Fortunately, faulty chips generally have problems that affect more than one pin. By using the following procedure, we can often find which chip is faulty.

12-10. Exercise 3 - Troubleshooting to the Chip Level

Setup:

1. Set the range to MED 2.
2. Set the frequency to 50/60Hz.
3. Connect the COM lead to the Chip Enable of U4: pin 19.

Do the following:

1. Probe the four connected bus lines of U1, U2 and U3. Verify that the problem is only on the signal line you identified in Exercise 2.
2. Probe the other pins of U1. Verify that none of them shows the fault.
3. Probe the other pins of U4. Identify the other pins that share the same fault as pin 15.

Note:

This is only a simulation. Faulty signatures may not be as consistent in your circuits.

12-11. OP AMPS AND OTHER LINEAR CIRCUITS

Op amp circuits present another troubleshooting challenge. Each pin creates a different signature on the Tracker. This signature is the result of the internal architecture of the chip, and the circuit elements to which it is connected.

Op amps are best tested using the comparison method. In this case, a bad board is compared to a known good board. Using the alternate channel method, it is possible to quickly find the defective circuit component.

U7 and U8 are 741 Op Amps. They are both configured as inverting amplifiers as in the schematic below.

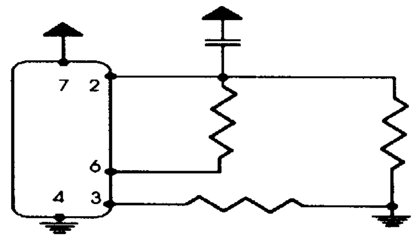


Figure 12-2. U7 and U8 Schematic Diagram.

U7 is the good Op Amp that we will use for comparison testing in the troubleshooting exercise. First, we'll find the signatures of this Op Amp circuit. Then, we'll do some troubleshooting.

12-12. Exercise 4 - Op Amp Signatures

Setup:

1. Set the range to MED 1.

2. Set the frequency to 50/60Hz.

3. Connect the COM lead to a ground point on the board.

Do the following:

1. Probe each of the U7 Op Amp pins with the red test lead.

2. Observe that the signatures of each pin is different.

12-13. Exercise 5 - Troubleshooting Op Amp Circuits

Setup:

1. Set the range to MED 1.

2. Set the frequency to 50/60Hz.

3. Connect the COM lead to a ground point on the board.

Do the following:

1. Push the ALT CHANNEL button so both the A and B test leads are active.

2. Set fault switch 7 to its on position.

3. Put the black test lead on pin 1 of U8 and the red test lead on pin 1 of U7. Observe the signatures on the Tracker display. They should be almost identical.

4. Move to pin 2 of both chips and compare the signatures. Continue until you find the fault.

*12-14. Questions

1. Which pin is faulty?_____

2. How is the bad signature different from the good signature?_______

____

Points [ ] / 2

12-15. USING CARD EDGE CONNECTORS FOR TROUBLESHOOTING

This is our last troubleshooting topic, but it is an important one. If the circuit at fault is on a plug-in circuit card, the edge connector can be used to speed troubleshooting. We'll see an example of the technique in the next exercises.

12-16. Exercise 6 - Troubleshooting from the Card Edge

Setup:

1. Set the range to MED 1.

2. Set the frequency to 50/60Hz.

3. Connect the COM lead to a ground point on the board.

Do the following:

1. Use the red test lead to probe P1 pins 10 through 15. Notice that they are similar.

2. Set fault switch 3 to the on position.

3. Probe P1 pins 10 through 15. You should have no trouble finding the faulty pin.

This procedure works well if you have a good board to compare the faulty card with. If you set the Channel selection to ALT, you can place one test lead on the good card pin and the other test lead on the same pin on the known bad card. By moving them both together, you can speedily find the fault. From there, it is just a matter of following it to the faulty chip.

*12-17. TROUBLESHOOTING EXERCISES

Here are some troubleshooting exercises for you to try on your own.

1. Put switch 2 in its fault position. This creates a fault at U12. Use the comparison testing facility of the Tracker to find it.

   Which pin had the fault?________________________________

   What kind of problem is it?______________________________

   Which range worked best for finding this fault?_______________

2. Put switch 6 in its fault position. This creates a fault at U5. Use the comparison testing facility of the Tracker to find it.

   Which pin had the fault?____

   What kind of problem is it?______________________________

   Which range worked best for finding this fault?________________

3. Put switch 8 in its fault position. This creates a fault at U7. Use the comparison testing facility of the Tracker to find it.

   Which pin had the fault? ____

   What kind of problem is it? ______________________________

   Which range worked best for finding this fault? ________________

Points [ ]/9

Total points [ ]/15. It is suggested that you review the chapter if you didn't score at least 12 of the possible 15 points.

12-18. REVIEW

- Comparison testing is a powerful troubleshooting technique. With it we can use identical chips or even pins on the same chip to help us find faults without having to memorize every possible signature.
- The complex signatures viewed while troubleshooting a board are actually composites of all the primary components we have previously looked at.
- Edge connector testing is a quick way to locate catastrophic failures caused by the board interface.
- The Tracker can test microprocessors, RAM, EPROM and analog circuitry without causing damage to the circuitry. See Appendix D.

12-19. APPLYING WHAT WE HAVE LEARNED

- Each address line in a processor circuit should exhibit the same signature. This is also true for the data lines. Comparing one to another will identify any bus lines connected to defective components.

- When doing comparison testing on a whole board, view edge connectors first, and then ICs. Mark the questionable components in some fashion and review these after going over the whole board. This reduces the number of questionable signatures and allows you to select the most different.

- When using the above technique, watch for patterns. For example, one obvious "different signature" shows up on numerous chips when testing a whole board. One chip has three bad signatures besides the one appearing all over the board. The other chips only exhibit one or no bad signatures. Which chip do you think is bad? The pattern points to the one chip with multiple bad signatures.

Good Luck!

APPENDIX A
Good and Bad Signatures

The following signatures are from actual good and faulty electronic components. These were generated on a Huntron Tracker Model 5100DS at a frequency of 200 Hz. The "good signature" is above the "bad signature". The signatures were arranged so that the differences can be easily seen.

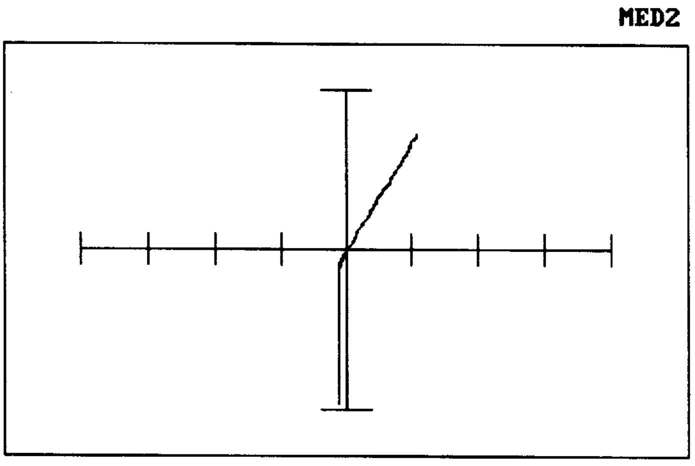


Figure A-1. Good Bus Signature with 10k Pull-up Resistor.

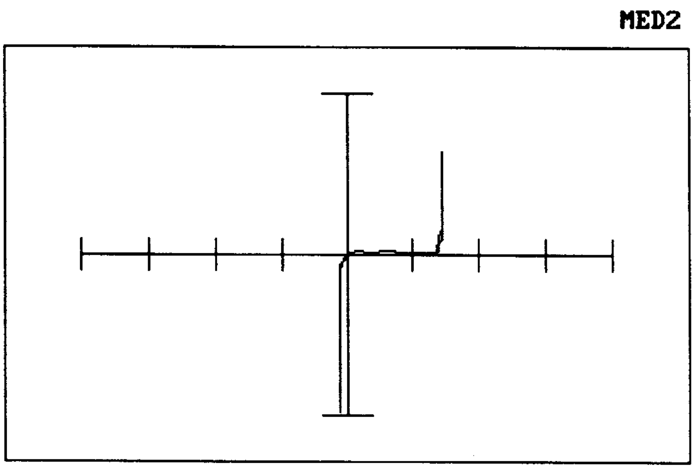


Figure A-2. Bad Bus Signature with an Open 10k Resistor.

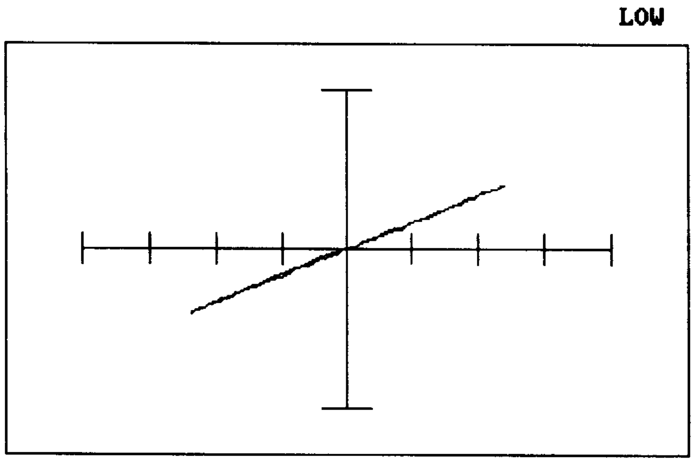


Figure A-3. Good Potentiometer.

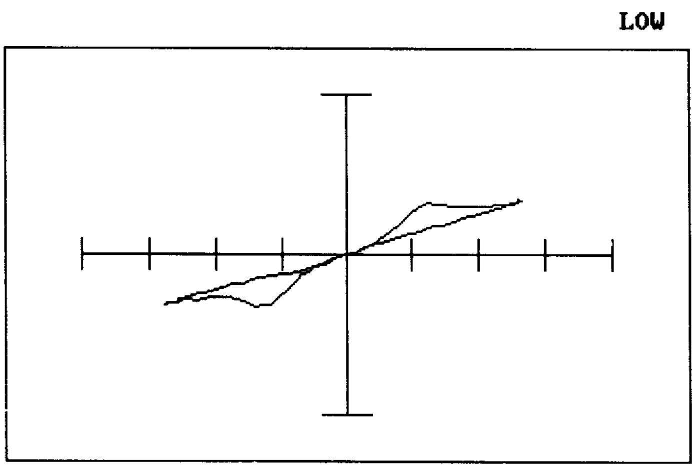


Figure A-4. Bad Potentiometer, Noisy.

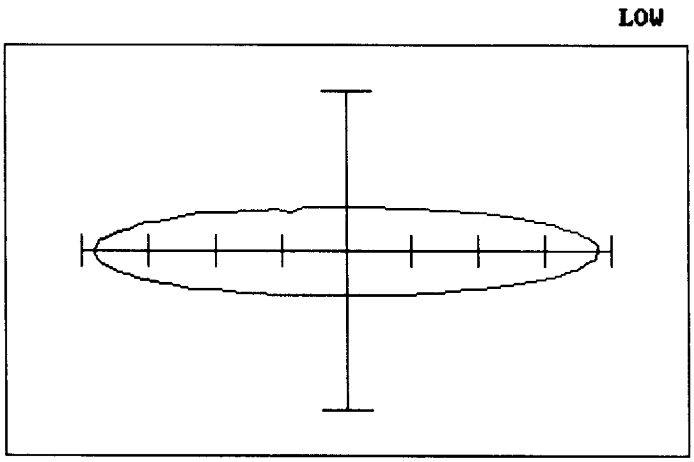


Figure A-5. Good 4.7μF Capacitor.

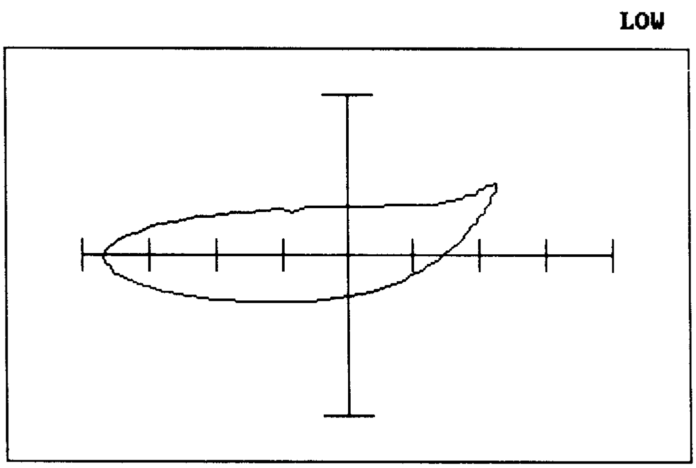


Figure A-6. Bad 4.7μF Capacitor, Electrolytic Abnormality.

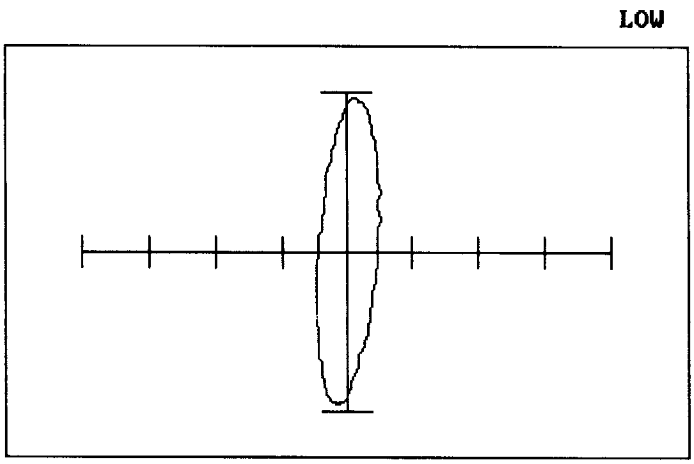


Figure A-7. Good 68µF Capacitor.

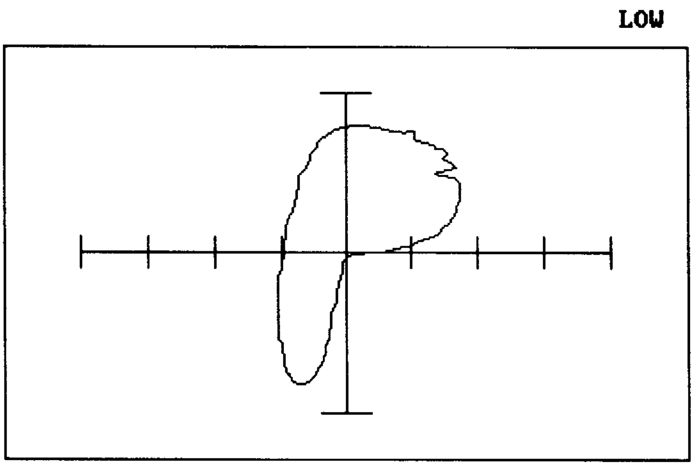


Figure A-8. Bad 68µF Capacitor, Breakdown with Current.

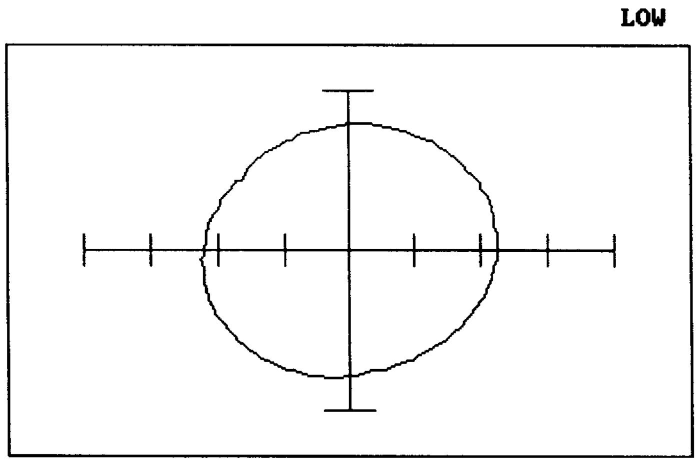


Figure A-9. Good 22μF Capacitor.

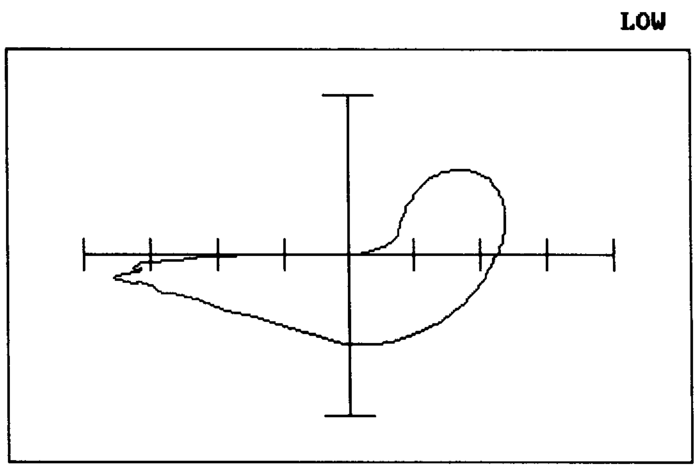


Figure A-10. Bad 22μF Capacitor.

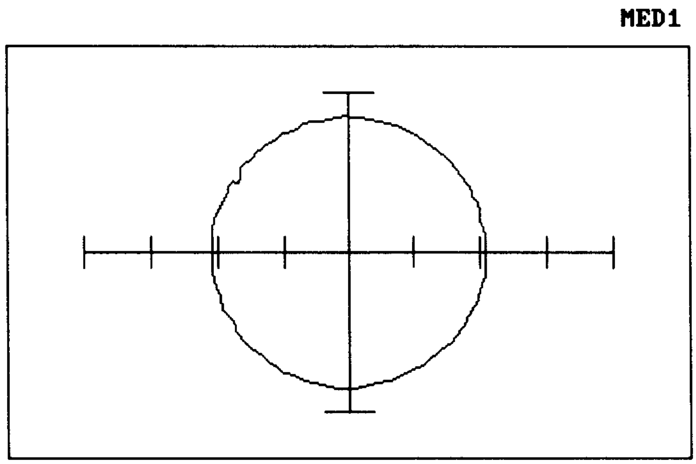


Figure A-11. Good 1μF Capacitor.

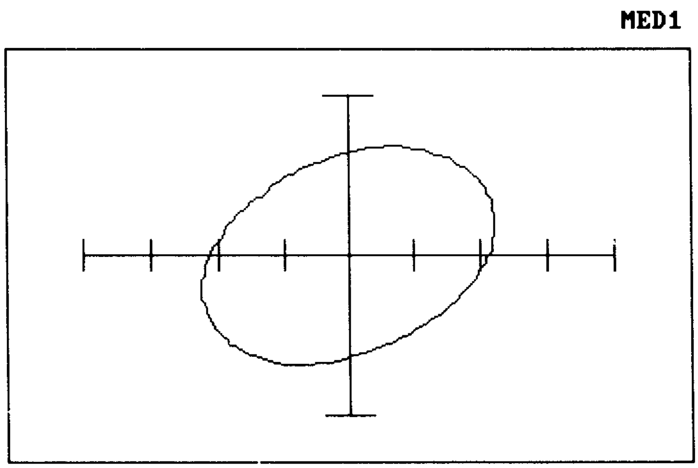


Figure A-12. Bad 1μF Capacitor, Leakage.

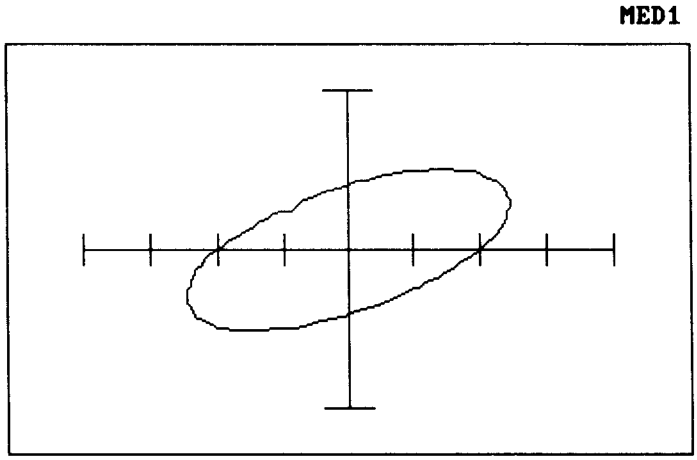


Figure A-13. Bad 1µF Capacitor.

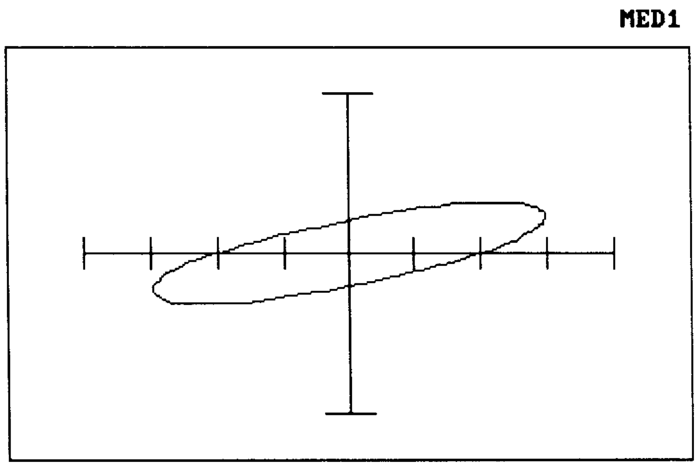


Figure A-14. Bad 1µF Capacitor.

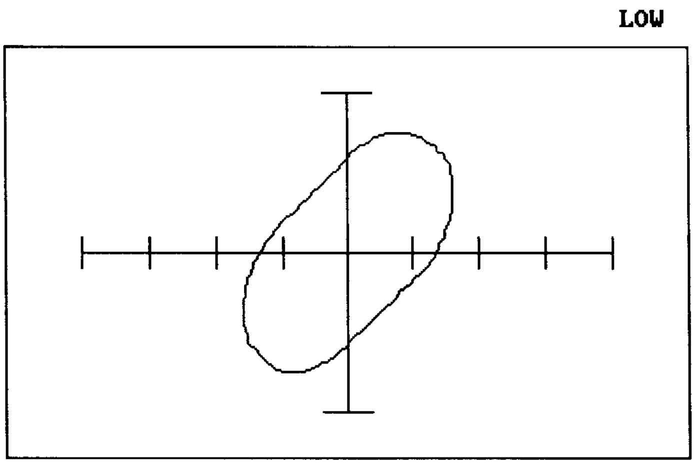


Figure A-15. Good 9.5mH Coil.

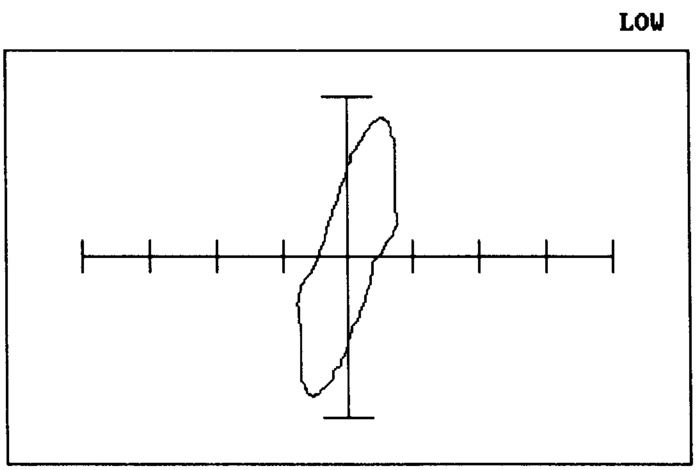


Figure A-16. Bad 9.5mH Coil, Damaged Core.

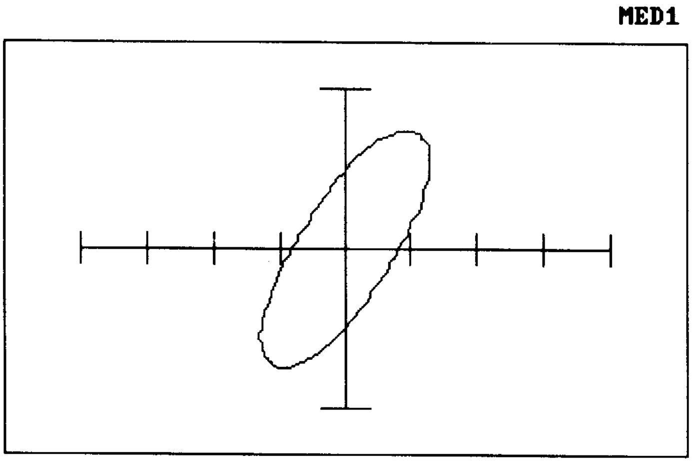


Figure A-17. Good 243mH Inductor.

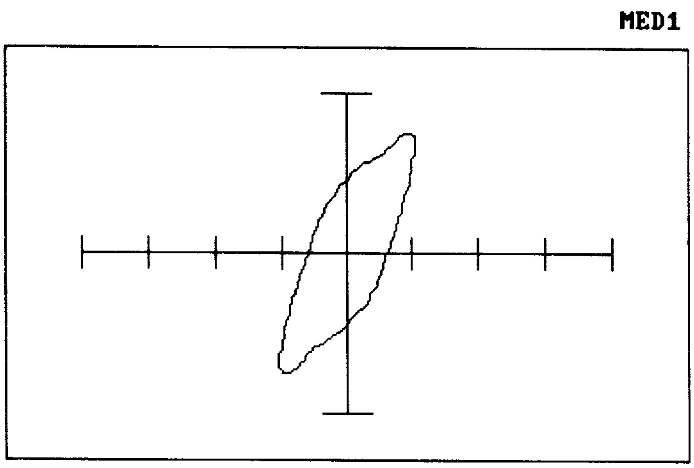


Figure A-18. Bad 243mH Inductor, Shorted Windings.

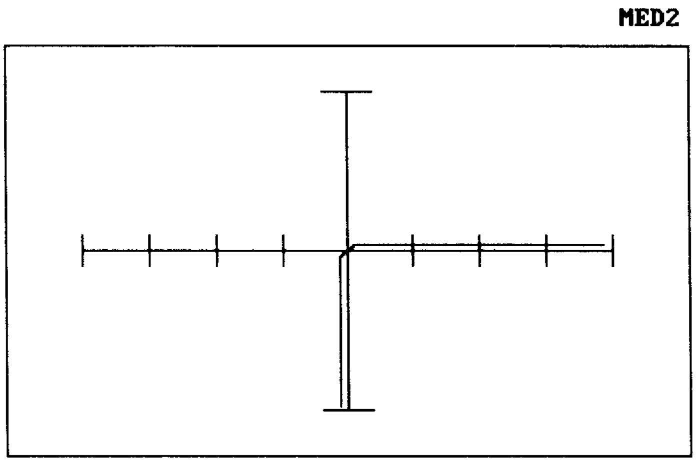


Figure A-19. Good Diode.

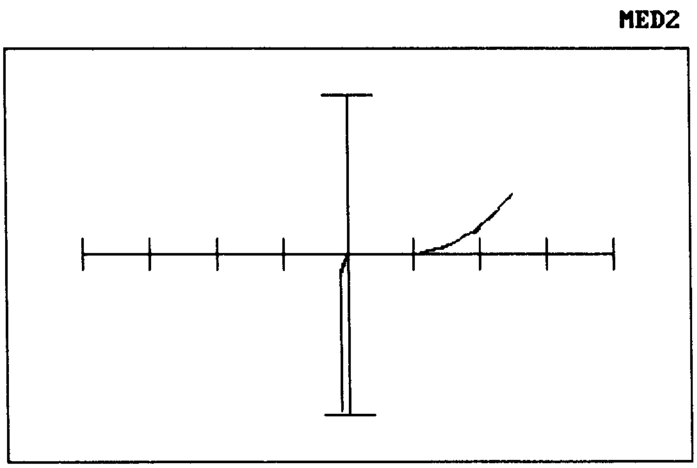


Figure A-20. Bad Diode, Leakage in the Reverse Bias Region.

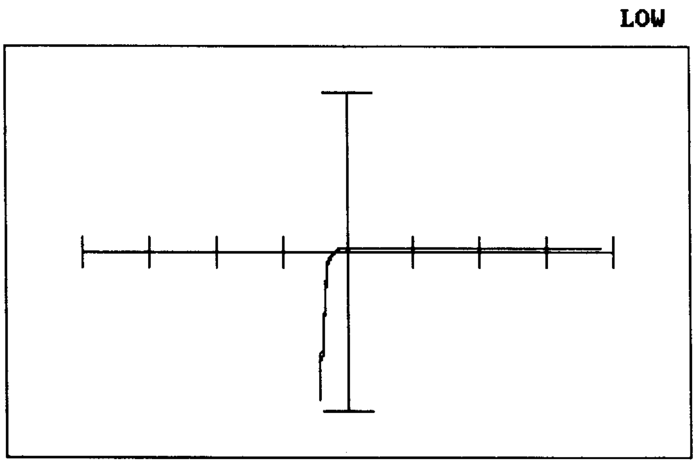


Figure A-21. Good Diode.

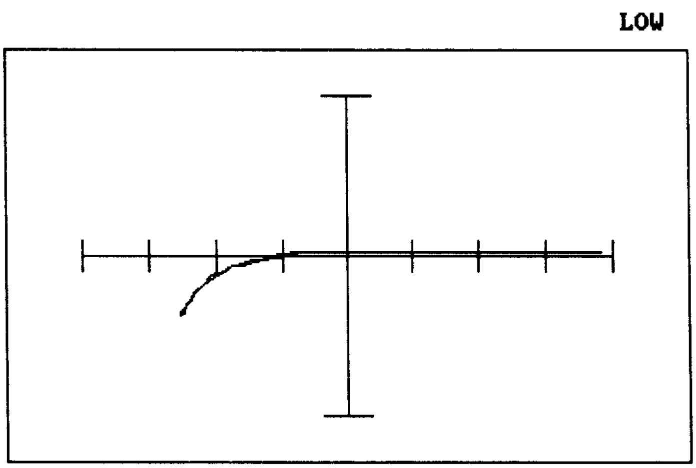


Figure A-22. Bad Diode, Leakage in the Forward Bias Region.

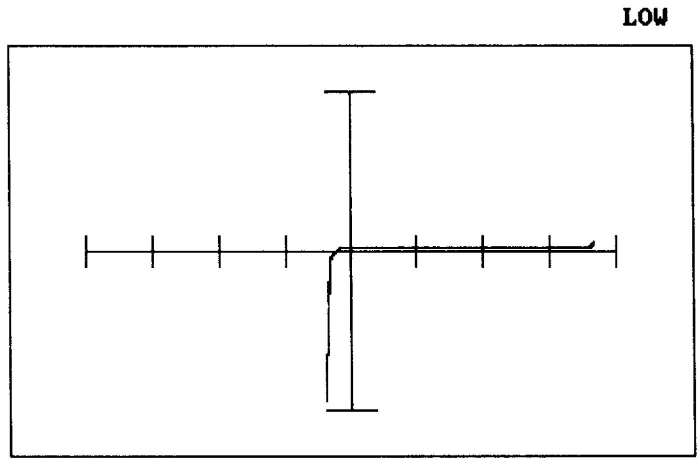


Figure A-23. Good Zener Diode.

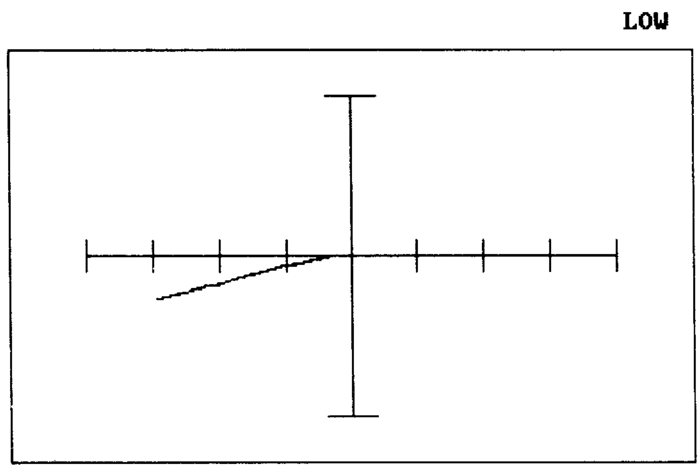


Figure A-24. Bad Zener Diode, Leakage.

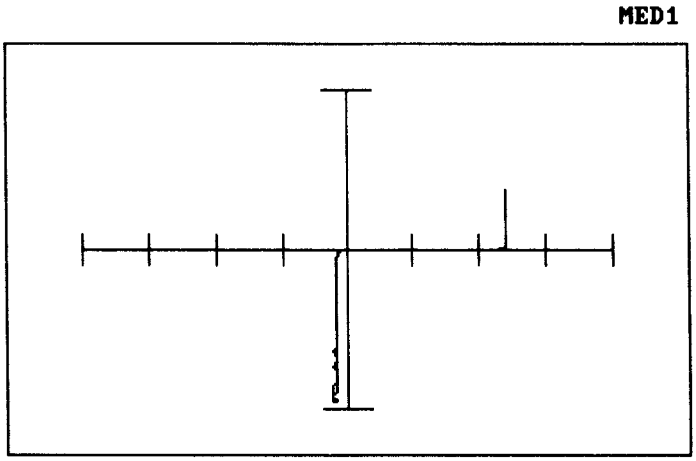


Figure A-25. Good Zener Diode.

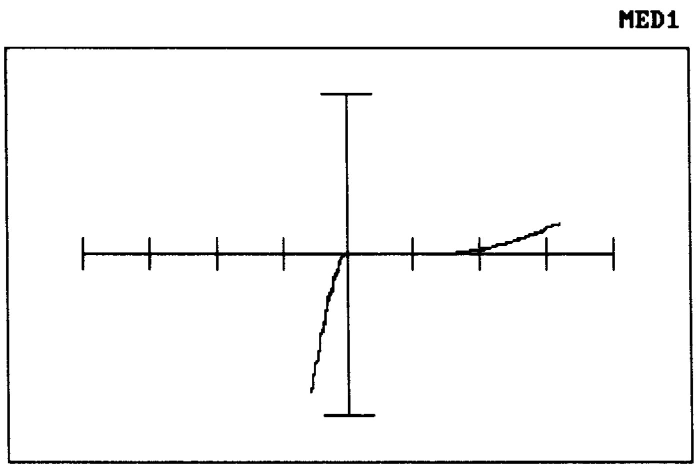


Figure A-26. Bad Zener Diode.

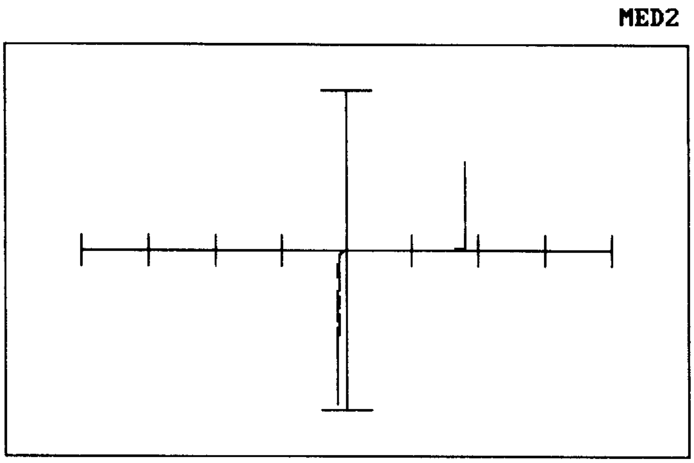


Figure A-27. Good Zener Diode.

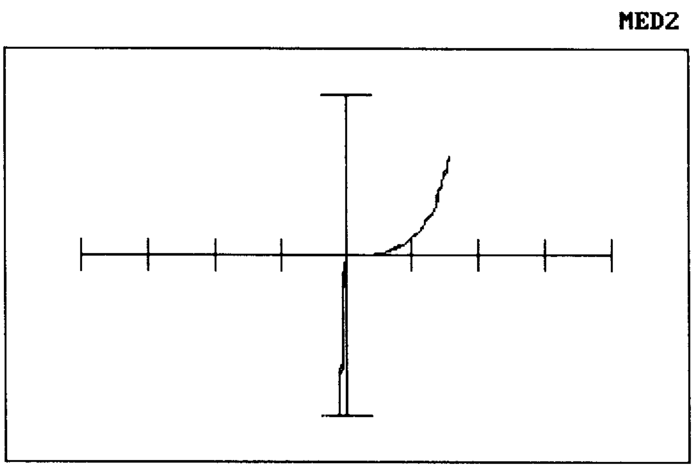


Figure A-28. Bad Zener Diode.

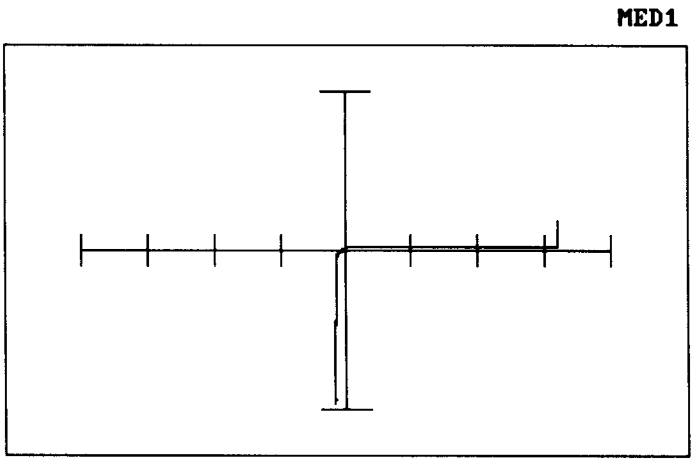


Figure A-29. Good Base-Emitter Junction of a TIP50.

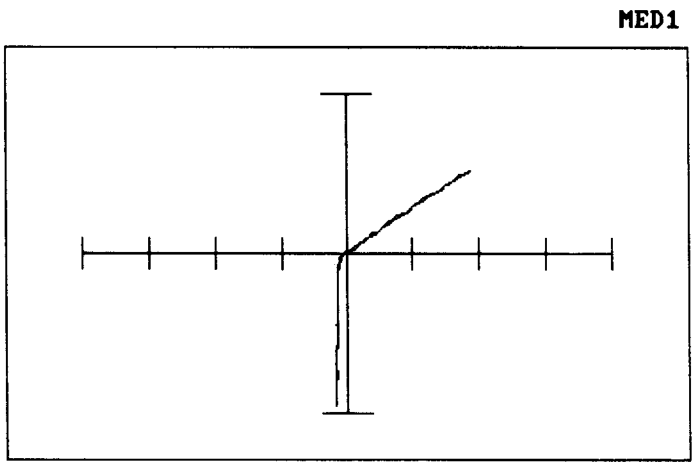


Figure A-30. Bad Base-Emitter Junction of a TIP50.

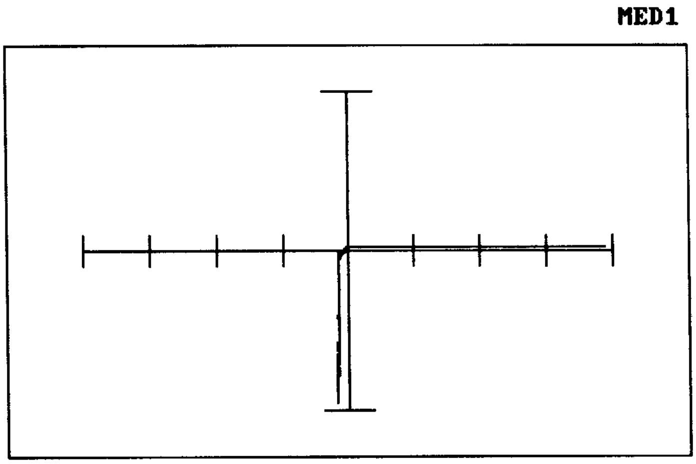


Figure A-31. Good Base-Collector Junction of a TIP50.

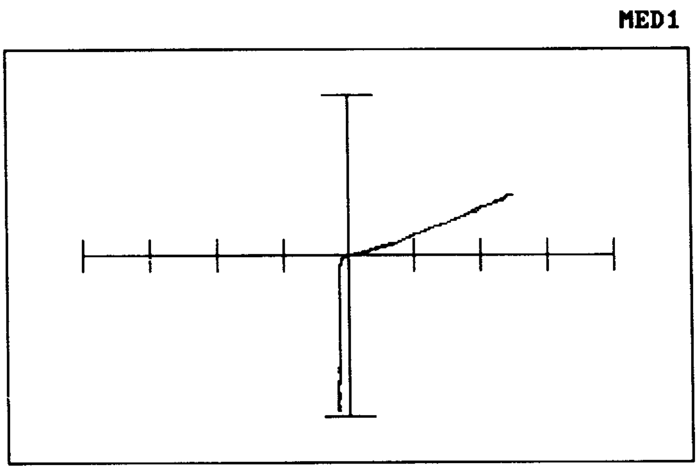


Figure A-32. Bad Base-Collector Junction of a TIP50.

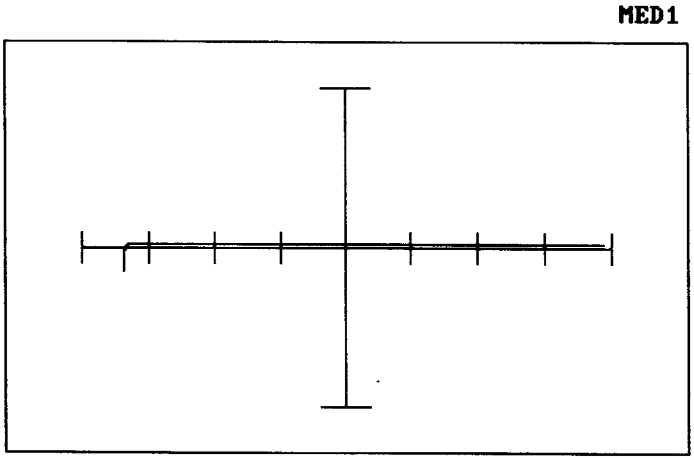


Figure A-33. Good Emitter-Collector Junction of a TIP50.

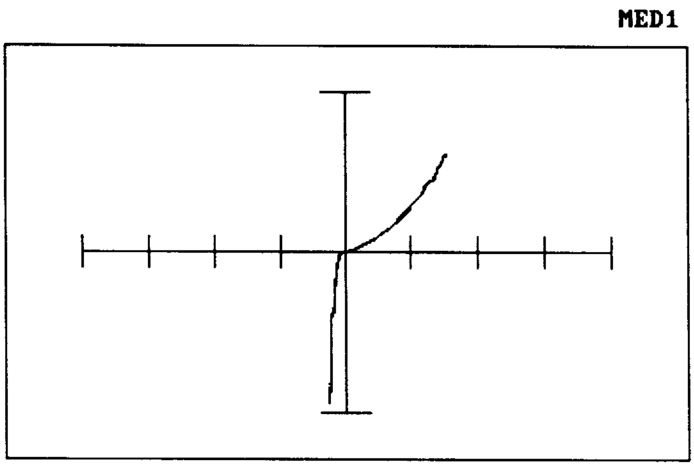


Figure A-34. Bad Emitter-Collector Junction of a TIP50.

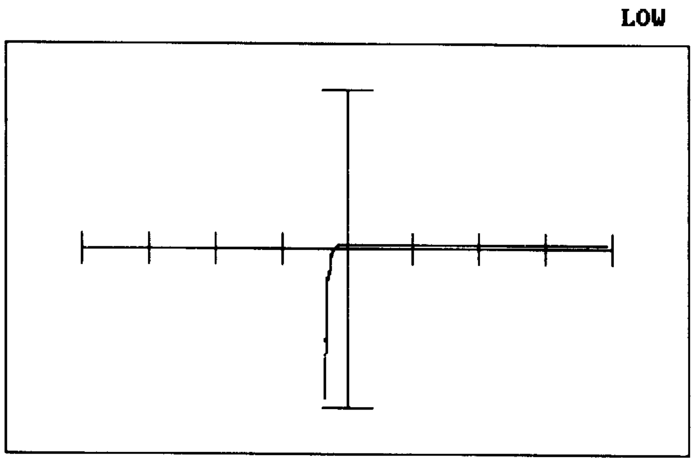


Figure A-35. Good Base-Emitter Junction of a 2N3055.

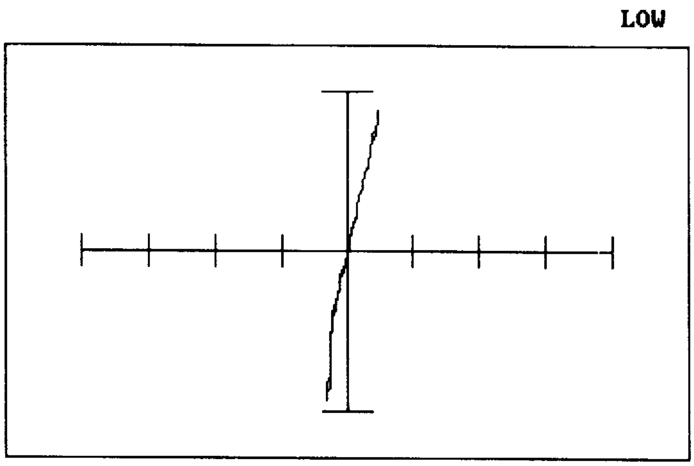


Figure A-36. Bad Base-Emitter Junction of a 2N3055.

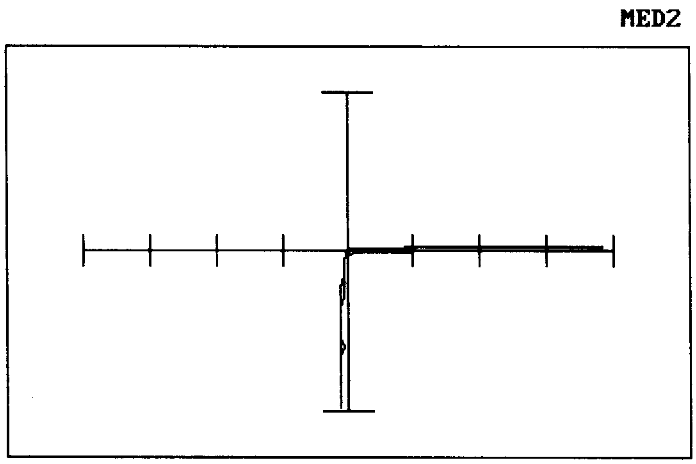


Figure A-37. Good Base-Collector Junction of a 2N3055.

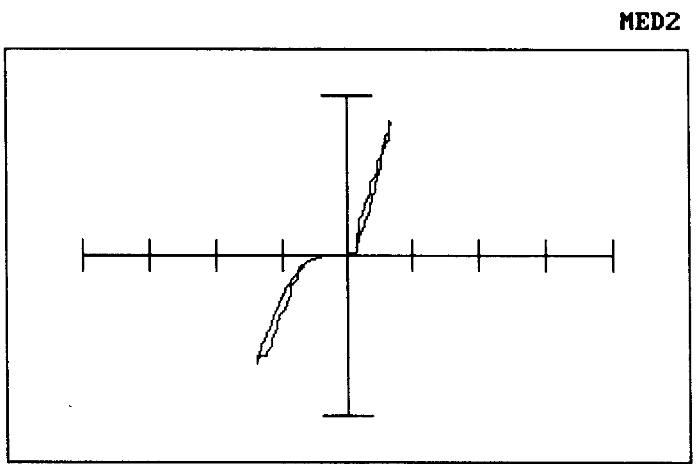


Figure A-38. Bad Base-Collector Junction of a 2N3055.

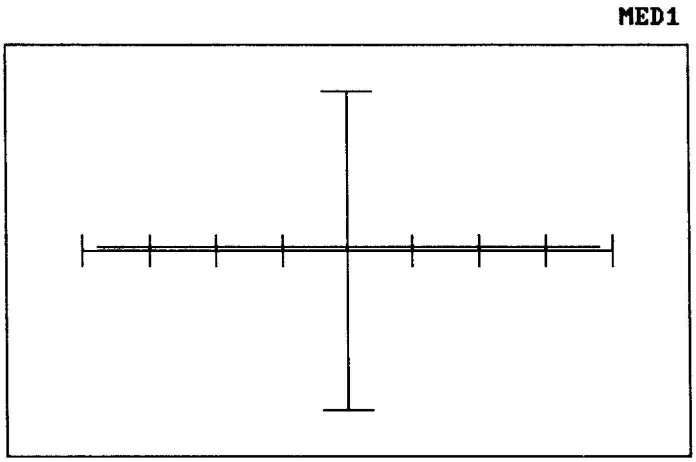


Figure A-39. Good Emitter-Collector Junction of a 2N3055.

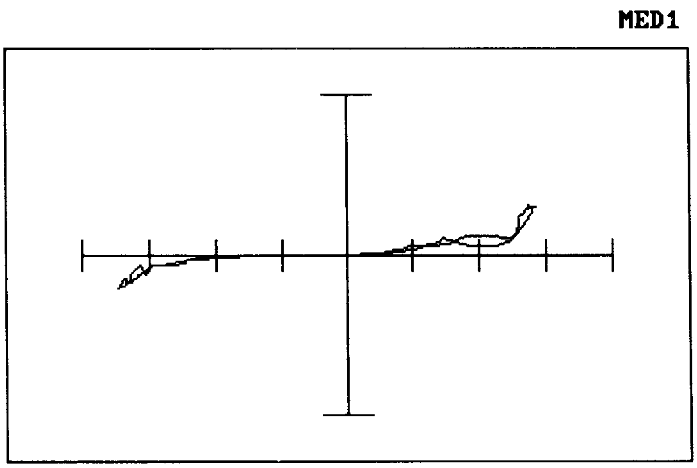


Figure A-40. Bad Emitter-Collector Junction of a 2N3055.

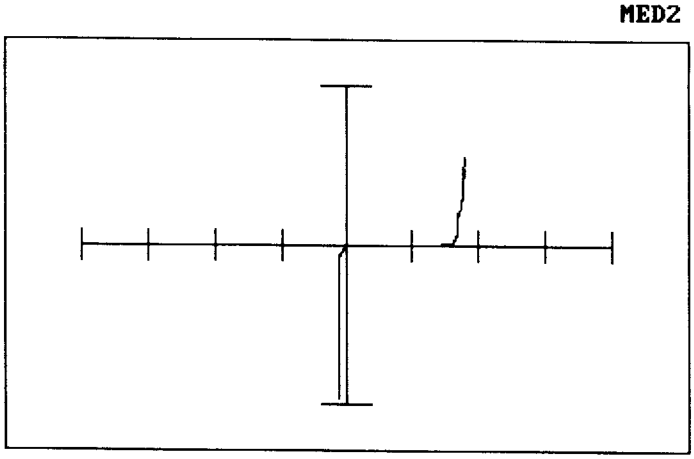


Figure A-41. Good 7400, Pin 10.

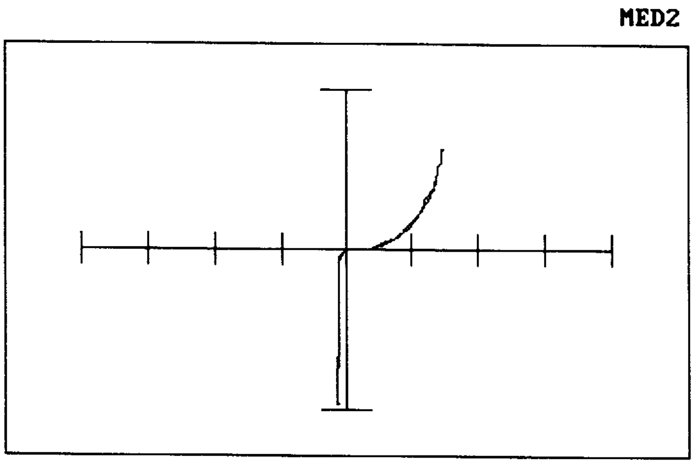


Figure A-42. Bad 7400, Pin 10.

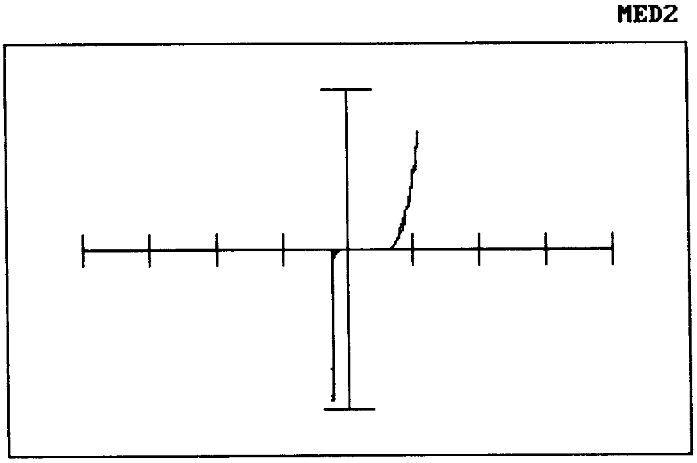


Figure A-43. Good CD4011, Pin 4.

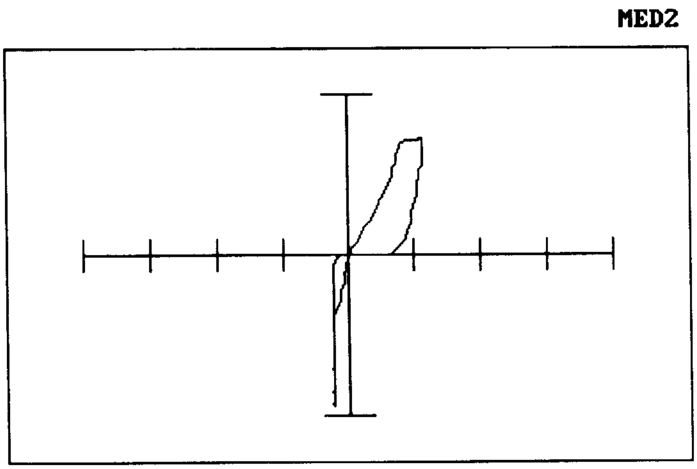


Figure A-44. Bad CD4011, Pin 4.

APPENDIX B
Answers

Below are the answers for the questions in the previous text.

5-6.

1a. A linear straight line.

1b. Voltage and current through a pure resistance is linear.

2a. The angle of slope becomes more horizontal.

2b. The more resistance, the less current.

3a. The straight line signature becomes more vertical.

3b. The more voltage applied the more current will flow.

5-12.

1. Zero ohms resistance, maximum current flow

5-13.

1. Maximum resistance, no current flow

6-4.

1. The ellipse becomes thinner, more vertical.

2. More capacitance means more current flow. See Figure 6-9.

6-7.

1. The ellipse becomes thinner, more vertical.

2. More capacitive reactance means more current flow. See Figure 6-9.

6-8.

1. The ellipse becomes thinner, more vertical.

6-11.

1. The ellipse becomes diagonal and thinner.

2. The circuit represents resistance in parallel and the resistor shunts some of the current.

6-12.

1. The ellipse becomes more vertical.

2. As you increase frequency the current will increase.

7-4.

1. The signature becomes rounder.

2. Increasing the frequency increases the inductive reactance. See Figure 7-5.

3. The reed relay

8-9.

1. Using the red and black micro probes, if the signature current leg is upward the black is on the cathode and the red is on the anode or compare to a known diode.

2. 5 volts

3. Leakage

4. Straight open horizontal signature

5. Normal diode signature with a higher forward voltage drop.

9-8.

1. NPN, emitter 3, base 1, collector 2

2. PNP, emitter 3, base 2, collector 1

3. NPN, emitter 3, base 1, collector 2

4. NPN, emitter 1, base 3, collector 2

5. The emitter collector signature is a PNP type junction. See Figure 9-5.
6. Q1 is a photo transistor and the signatures are light sensitive.
7. This is a Japanese transistor.

10-17.

1. Vertical straight line, short
2. Transistor, triac or photoresistor and an LED
3. The emitter collector junction
4. One
5. Two
6. Dirty or resistive contacts
7. The triac is an AC device. You need to activate both junctions for AC current to flow.

11-11

4. Pins 1, 3, 5, 9, 11, and 13
5. Pins 2, 4, 6, 8, 10, and 12

11-12

4. Pin 11
5. The horizontal portion became angular.
6. Leakage

11-13

3. Pin 6
4. The horizontal portion became capacitive, the forward current leg noisy.
5. Leakage, most likely to 5 volts

12-8.

1. Pin 34, Address line 4

2. U2-6, U3-6, and U4-15

12-10.

3. 11, 12, 13, 14

12-14.

1. Pin 3

2. The bad signature has capacitance or leakage.

12-17.

1. Pin 12, resistive short, Med 2

2. Pin 3, output, resistive leakage to gnd

3. Pin 1, leaky junction, low

APPENDIX C
ASA GLOSSARY

ANALOG SIGNATURE ANALYSIS

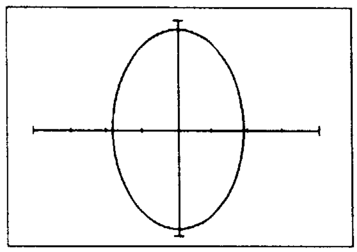
ASA is an unique, "power off" troubleshooting technique. It uses sine wave (AC) stimulus to display the current vs. voltage characteristic of a device on a CRT. Also referred to as VI testing.

BACK

The portion of the chair pattern rising upwards from the seat. This represents reverse current in a zener diode. See CHAIR PATTERN.

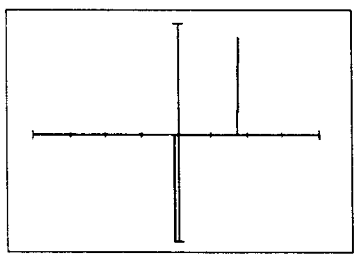
CAPACITIVE

A signature or portion of a signature that is round or elliptical caused by the voltage and current being out of phase.



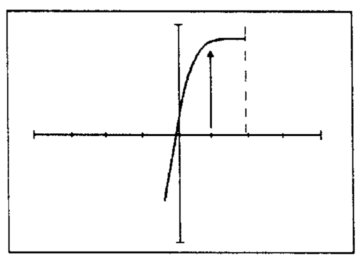
CHAIR PATTERN

The pattern common to IC's and zener diodes that resembles a CHAIR. The lower vertical part is the leg, the horizontal part is the seat and the upper vertical part is the back.



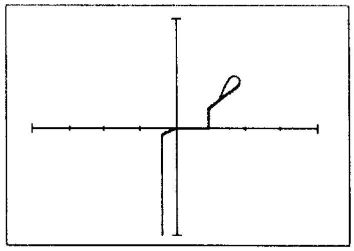
CHARGING EFFECT

A condition where the seat moves up and stabilizes over a short period of time.



COMPOSITE SIGNATURE

A signature composed of resistive, capacitive, inductive, and or diode characteristics.

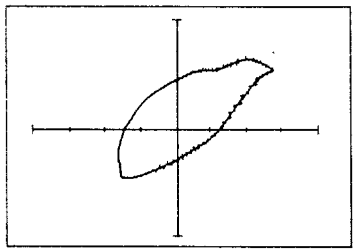


CURRENT

The vertical component of a signature. See CHAIR. Shorting the probes causes maximum current to flow, a vertical line.

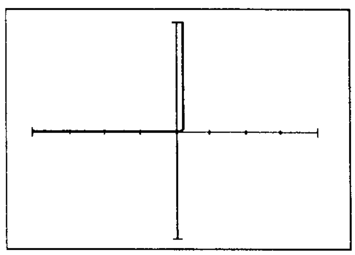
DEGENERATION

The effect of time or stress on a component, causing a change in its ideal signature. A fault common to capacitors and solid-state junctions. The diagram shows a capacitor exhibiting noise, loss of capacitance and resistance.



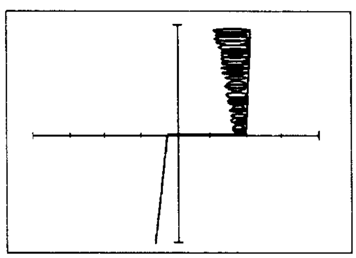
DIODE PATTERN

A pattern common to diodes or single junction devices. See POLARITY.

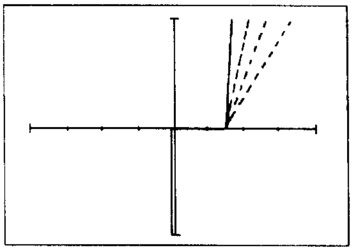


FLAGGING

Oscillations in the signature, usually located on the back of a chair pattern.

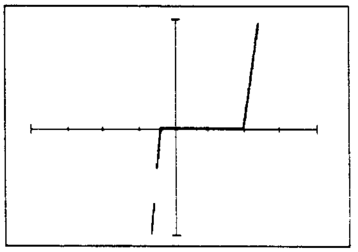


FLUTTER



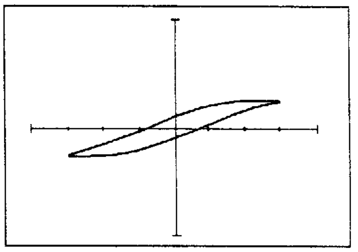
A signature or part of the signature oscillates in an erratic or consistent manner. Common in capacitors and solid state junctions. The diagram shows a chair pattern with the back fluttering.

GAP



A missing section of a signature.

INDUCTIVE

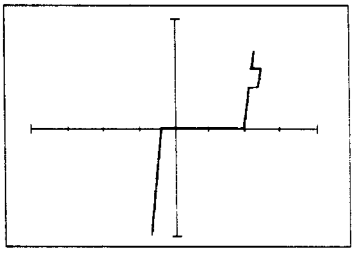


The inductive signature resembles the capacitive, being round or elliptical. Unlike the capacitive signature the inductive signature may have distortions.

LEG

The vertical portion of a chair pattern extending downward from the seat. See CHAIR.

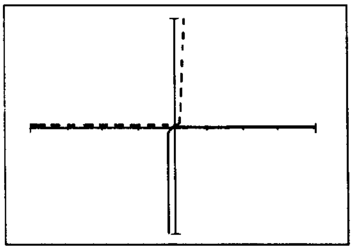
OFFSET



A sharp change in the voltage characteristics of a current leg or back.

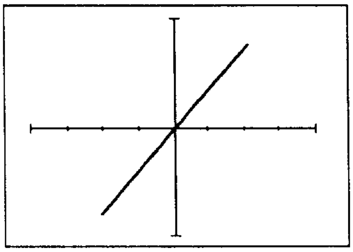
POLARITY

By reversing the probes on a component the display will be reversed. Note the diode in the diagram.



RESISTIVE

A linear response characterized by the angular trace.

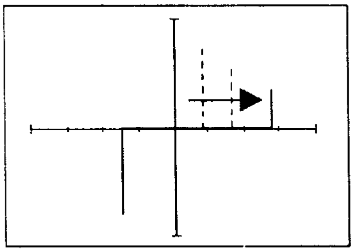


SEAT

The horizontal portion of a chair signature. See CHAIR.

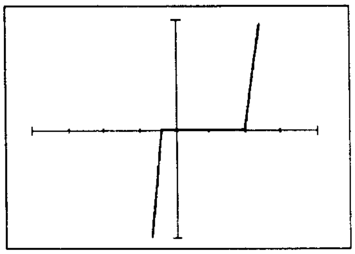
SETTLING EFFECT

A condition where the back of a chair pattern will stabilize over a short period of time.

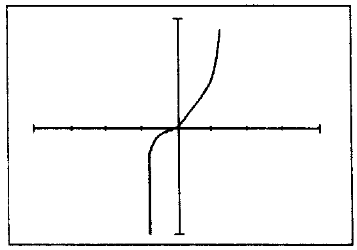


SHARP CORNER

The sharp angle where a device conducts current.



SOFT CORNER



A curve rather than an angle where a device conducts current and voltage. On some devices this is an indication of leakage.

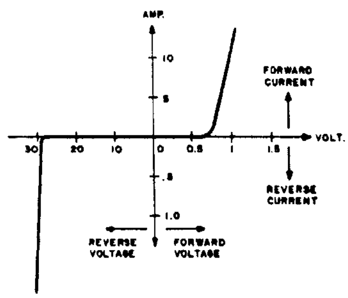
VOLTAGE

The horizontal portion of a signature. An open circuit, a horizontal line, represents maximum voltage.

VI

V = Voltage and I = Current, another name for ASA testing.

ZENER PATTERN



A pattern similar to a chair pattern, although in the opposite polarity. Corners indicate actual operating voltages.

NOTES:

APPENDIX D

HUNTRON TRACKER CMOS TEST

MTL Microtesting Limited
Alton, Hampshire, England

REQUIREMENT

It was required to ascertain whether normal usage of various types of Huntron Tracker instruments on any, or all, of their ranges could cause damage or catastrophic failure of normal CMOS devices.

Equipment used

Five Huntron Trackers were used to conduct five tests simultaneously. All had been checked as conforming to manufacturers' standards prior to the test. Types were as follows:

Qty 1 Huntron Tracker Type HTR-1005-BD
Qty 3 Huntron Tracker Type HTR-1005-B1
Qty 1 Huntron Tracker Type HTR-1005-B1S

The Compar-a-trace model was used in the Tracker mode (mode switch in "up" position) except during the actual Compar-a-trace test.

60 CMOS devices were obtained from three manufacturers as shown below. All were brand new devices and were delivered in protective packing. Half of the devices were retained as reference devices and were kept in protective conductive foam except when removed for data-logging at the beginning and end of the test. Each device was numbered and retained the same number throughout the test.

Device No.	Manufacturer	Type No.	Type	Used for
1	Motorola	MC14071BC	Quadruple 2-input OR Gate	Test
2	Motorola	MC14071BC	Quadruple 2-input OR Gate	Test
3	Motorola	MC14071BC	Quadruple 2-input OR Gate	Test
4	Motorola	MC14071BC	Quadruple 2-input OR Gate	Test
5	Motorola	MC14071BC	Quadruple 2-input OR Gate	Test
6	Motorola	MC14071BC	Quadruple 2-input OR Gate	Reference
7	Motorola	MC14071BC	Quadruple 2-input OR Gate	Reference
8	Motorola	MC14071BC	Quadruple 2-input OR Gate	Reference
9	Motorola	MC14071BC	Quadruple 2-input OR Gate	Reference
10	Motorola	MC14071BC	Quadruple 2-input OR Gate	Reference
11	Motorola	MC14081BC	Quadruple 2-input AND Gate	Test
12	Motorola	MC14081BC	Quadruple 2-input AND Gate	Test
13	Motorola	MC14081BC	Quadruple 2-input AND Gate	Test
14	Motorola	MC14081BC	Quadruple 2-input AND Gate	Test
15	Motorola	MC14081BC	Quadruple 2-input AND Gate	Test

Device No.	Manufacturer	Type No.	Type	Used for
16	Motorola	MC14081BC	Quadruple 2-input AND Gate	Reference
17	Motorola	MC14081BC	Quadruple 2-input AND Gate	Reference
18	Motorola	MC14081BC	Quadruple 2-input AND Gate	Reference
19	Motorola	MC14081BC	Quadruple 2-input AND Gate	Reference
20	Motorola	MC14081BC	Quadruple 2-input AND Gate	Reference
21	N.S.C.	MC14071BCN	Quadruple 2-input OR Gate	Test
22	N.S.C.	MC14071BCN	Quadruple 2-input OR Gate	Test
23	N.S.C.	MC14071BCN	Quadruple 2-input OR Gate	Test
24	N.S.C.	MC14071BCN	Quadruple 2-input OR Gate	Test
25	N.S.C.	MC14071BCN	Quadruple 2-input OR Gate	Test
26	N.S.C.	MC14071BCN	Quadruple 2-input OR Gate	Reference
27	N.S.C.	MC14071BCN	Quadruple 2-input OR Gate	Reference
28	N.S.C.	MC14071BCN	Quadruple 2-input OR Gate	Reference
29	N.S.C.	MC14071BCN	Quadruple 2-input OR Gate	Reference
30	N.S.C.	MC14071BCN	Quadruple 2-input OR Gate	Reference
31	N.S.C.	MC14081BCN	Quadruple 2-input AND Gate	Test
32	N.S.C.	MC14081BCN	Quadruple 2-input AND Gate	Test
33	N.S.C.	MC14081BCN	Quadruple 2-input AND Gate	Test
34	N.S.C.	MC14081BCN	Quadruple 2-input AND Gate	Test
35	N.S.C.	MC14081BCN	Quadruple 2-input AND Gate	Test
36	N.S.C.	MC14081BCN	Quadruple 2-input AND Gate	Reference
37	N.S.C.	MC14081BCN	Quadruple 2-input AND Gate	Reference
38	N.S.C.	MC14081BCN	Quadruple 2-input AND Gate	Reference
39	N.S.C.	MC14081BCN	Quadruple 2-input AND Gate	Reference
40	N.S.C.	MC14081BCN	Quadruple 2-input AND Gate	Reference
41	R.C.A.	MC14071BE	Quadruple 2-input OR Gate	Test
42	R.C.A.	MC14071BE	Quadruple 2-input OR Gate	Test
43	R.C.A.	MC14071BE	Quadruple 2-input OR Gate	Test
44	R.C.A.	MC14071BE	Quadruple 2-input OR Gate	Test
45	R.C.A.	MC14071BE	Quadruple 2-input OR Gate	Test
46	R.C.A.	MC14071BE	Quadruple 2-input OR Gate	Reference
47	R.C.A.	MC14071BE	Quadruple 2-input OR Gate	Reference
48	R.C.A.	MC14071BE	Quadruple 2-input OR Gate	Reference
49	R.C.A.	MC14071BE	Quadruple 2-input OR Gate	Reference
50	R.C.A.	MC14071BE	Quadruple 2-input OR Gate	Reference
51	R.C.A.	MC14081BE	Quadruple 2-input AND Gate	Test
52	R.C.A.	MC14081BE	Quadruple 2-input AND Gate	Test
53	R.C.A.	MC14081BE	Quadruple 2-input AND Gate	Test
54	R.C.A.	MC14081BE	Quadruple 2-input AND Gate	Test
55	R.C.A.	MC14081BE	Quadruple 2-input AND Gate	Test

Device No.	Manufacturer	Type No.	Type	Used for
56	R.C.A.	MC14081BE	Quadruple 2-input AND Gate	Test
57	R.C.A.	MC14081BE	Quadruple 2-input AND Gate	Test
58	R.C.A.	MC14081BE	Quadruple 2-input AND Gate	Test
59	R.C.A.	MC14081BE	Quadruple 2-input AND Gate	Test
60	R.C.A.	MC14081BE	Quadruple 2-input AND Gate	Test

A test jig was constructed using Vero-Board and high quality gold flashed 14-pin DIL sockets. Each socket was isolated from all others by track cutting in order to avoid any effects of circulating earth currents due to variations in the output levels of the various Huntron Test units. As each device contained four identical gates only one gate per device (pins 1, 2, and 3) was checked on each device, although data logging checked all gates.

PROTECTION

All devices were kept in conductive foam except when actually being tested. Devices were only handled when a wrist earth strap (connected to the Test House Silent Earth) was being worn. The bench on which the tests were carried out was surfaced with a conductive mat also connected to the Silent Earth.

TEST SYSTEM

The five Huntron Trackers were connected to the five test sockets with the Huntron black socket connected to pin 7 which was made a common earthpoint for all untested gates, and an earthpoint for the unconnected inputs in the tested gate. The Huntron's were left connected for a period of one hour, and then switched off and the devices changed. The first check was carried out on the Huntron low range with connections to pin 1 and pin 7 with pin 2 earthed. Pin 3 was left open circuit. After all test devices had been checked on pin 1, the Huntrons were then connected to pin 2 and pin 7 with pin 1 earthed and pin 3 open circuit. The final check per device was with the Huntrons connected to pin 3 with pins 1 and 2 earthed.

All devices (both reference and test) were data-logged on Imperial Technology IT200 equipment prior to the start of the tests. The test devices were then data-logged again after pin 1 tests were completed and again after the pin 2 tests. The final data-logging was completed when all tests on pins 1, 2, and 3 were complete with the Huntrons switched to the low range

All test devices were then tested in a similar way using the Huntrons on medium range, except that the test devices were not data-logged after pins 1 and 2 were completed. Data-logging did take place when tests on pin 3 were complete. Devices were then tested using the high range with data-logging again taking place on completion of tests on pin 3. In order to check the effect (if any) on the Huntron Compar-a-trace action on the CMOS devices a sample device of each manufacturer was subject to ten minutes Compar-a-trace action on the low range (2.53V) output at approx .9Hz cycle rate (Nos. 2, 22, 42; and 12, 32, 52). The six devices (3 x 4071 and 3 x 4081) were then data-logged.

In order to ascertain whether leads connecting the Huntrons to the devices under test could act as antennae in the region of weak fields of electro-magnetic radiation, thus causing damage to the devices, the five Huntrons were left connected to five test devices (2 x Motorola-No 1, a 4071 and No 11, a 4081; 2 x NSC-No 21, a 4071, and No 31, a 4081; and 1 x RCA-No 41, a 4071).

The devices under test were then subjected to radiation from a battery driven, all solid-state frequency modulation type transmitter operating on 145MHz. The PA input power was approximately 2 watts and the antenna was a 1/4 whip vertical located approximately 19" (1/4) from the center of the interconnecting wiring. Modulation was NOT applied but the carrier was switched at irregular intervals. Induction was evident by "jumping" of the Huntron traces, except on the type HTR-1005-BE. RF was radiated for approximately 15 minutes. The devices were then data-logged. All sixty off devices were then loaded onto static burn-in boards with input and output pins terminated to Vcc by 47K pull-up resistors and then loaded into a Ceetel burn-in chamber at 125 degrees Celsius. After 48 hours at 125 degrees Celsius the devices were removed from the oven and all devices data-logged. The devices were then re-loaded into the burn-in chamber for a further 120 hours burn-in at 125 degrees Celsius. The devices were then finally data-logged to determine the long-term effect (if any) of the Huntron Trackers.

ROTATIONAL TESTING

In order to ensure that any variations in output levels of the three types of Huntron Instruments used did not affect part of the test series devices only, devices under test were "rotated" around the test instruments as shown in the table below. The figures shown represent the Test Number followed by the Section Number, i.e. 9/2 = Test No. 9, the 2nd Part.

HUNTRON INSTRUMENTS

Device No.	1	2	3	4	5
1	1/1	3/1	5/1	9/1	7/1
2	7/2	1/2	3/2	5/2	9/2
3	9/2	7/2	1/3	3/2	5/2
4	5/3	9/3	7/3	1/3	3/3
5	3/3	5/3	9/3	7/3	1/3
11	2/1	4/1	6/1	10/1	8/1
12	8/2	2/2	4/2	6/2	10/2
13	10/2	8/1	2/2	4/2	6/2
14	6/3	10/3	8/1	2/3	4/3
15	4/3	6/3	10/3	8/3	2/3
21	7/1	1/1	3/1	5/1	9/1
22	9/2	7/2	1/2	3/2	5/2
23	5/2	9/1	7/2	1/2	3/2
24	3/2	5/2	9/2	7/2	1/2
25	1/3	3/3	5/3	9/3	7/3
31	8/1	2/1	4/1	6/1	10/1
32	10/1	8/1	2/1	4/1	6/1
33	6/2	10/2	8/1	2/2	4/2
34	4/2	6/2	8/2	10/2	2/2
35	2/3	4/3	6/3	10/3	8/3

Device No.	HUNTRON INSTRUMENTS				
41	5/1	9/1	7/1	1/1	3/1
42	3/1	5/1	9/1	7/1	1/1
43	1/2	3/2	5/1	9/2	7/2
44	7/3	1/3	3/3	5/3	9/3
45	9/3	7/3	1/3	3/3	5/3
51	6/1	10/1	8/1	2/1	4/1
52	4/1	6/1	10/1	8/1	2/1
53	2/2	4/2	6/1	10/2	8/2
54	8/3	2/3	4/3	6/3	10/3
55	10/3	8/3	2/3	4/3	6/3

RESULTS SUMMARY

1. Motorola devices appeared to be more sensitive on the input pins when subject to the Tracker tests.

2. No change in functionality of DC parameters were exhibited on any device subjected to stimulus from the Huntron on all ranges prior to burn-in at 125 degrees Celsius.

3. Device No. 1 (Motorola 14071) failed supply current after 48 hours burn-in. Device No. 3 (Motorola 14071) failed supply current and functionality in gate No. 4 (pins 11, 12 and 13) after 48 hours burn-in.

4. Device No. 1 failed supply current and functionality in gate No. 4 (pins 11, 12 and 13) after 168 hours burn-in. Device No. 17 (Motorola 14081 Reference device) failed supply current after 168 hours burn-in.

CONCLUSIONS

Although three devices failed during static burn-in it is felt that the failures cannot be attributed to any harmful effects due to stimulus from the Huntron Trackers as the failure modes were totally independent of pins 1, 2 and 3 which were pin stimulated by the Trackers. Furthermore, one of the devices which failed during burn-in was a Reference device which was not connected to the Tracker in any form.

It should be noted that the burn-in condition which was applied to the devices was very extreme (viz., 125 degrees) for plastic encapsulated devices and that the incident of failure is unlikely to be related to the test performed by the Huntron Tracker.

NOTES:

APPENDIX E

HUNTRON TRACKER TTL AND CMOS TESTS

Component Concepts
Everett, WA 98201

OBJECT: To determine the effect of the testing signals from a Huntron Tracker in-circuit component tester on performance of CMOS and TTL integrated circuits.

COMPONENT TESTED: Motorola MC 14011 and TI 74LS11

(1) Burn-in (100%) 180 pieces at 125 degrees Celsius = 48 hours

(2) Electrical (100%) to obtain 150 units to be labeled as follows:

Label 25 units as HH1, HH2, HH3......................................HH25
Label 25 units as HM1, HM2, HM3....................................HM25
Label 25 units as HL1, HL2, HL3...HL25
Label 25 units as VH1, VH2, VH3.......................................VH25
Label 25 units as VM1, VM2, VM3.......................................VM25
Label 25 units as VL1, VL2, VL3..VL25

(3) Electrical (100%) in the following sequence:

(a)	HH1, HH2................................HH25
(b)	HM1, HM2................................HM25
(c)	HL1, HL2.................................HL25
(d)	VH1, VH2.................................VH25
(e)	VM1, VM2.................................VM25
(f)	VL1, VL2.................................VL25

For DC Parametrics and function per the manufacturers specifications. T_A = 25 degrees Celsius. They are to be tested on HP5054 digital IC tester. All parameters datalogged. Propagation delay tested per specification for pass/fail only.

(4) Connect Huntron Tracker to sequencer (sequencer is a piece of equipment supplied by Huntron Instruments, Inc. which applies testing signals from the Tracker and tester to device under test) to each piece of equipment and turn on power.

(5) (a) Set Tracker range to HIGH.

(b) Set Tester range to HIGH.

(c) Insert HH1 in zero-insertion force socket marked "Huntron Tracker" located on top of sequencer.

(d) Activate "start" button on sequencer. The red LED will come on when sequencing is completed (it takes about 90 seconds).

(e) Remove devices under test.

(f) Repeat steps (c), (d), (e), (f), for HH2, HH3,...,HH25.

(6) Set Tracker and tester range to medium and repeat steps (c), (d), (e), (f), for HM1, HM2,...,HM25 and VM1, VM2,...,VM25.

(7) Set Tracker and tester range to low and repeat steps (c), (d), (e), (f), for HL1, HL2,...,HL25 and VL1, VL2,..., VL25.

(8) Electrical test (100%) in the following sequences:

HH1, HH2.................................HH25
HM1, HM2.................................HM25
HL1, HL2.................................HL25
VH1, VH2.................................VH25
VM1, VM2.................................VM25
VL1, VL2.................................VL25

For DC parametrics and function per the manufacturer's specifications T_A = 25 degrees Celsius. Propagation delay tested per specification for pass/fail only. All parameters datalogged on the HP5054 digital tester.

TEST REPORT

Component Concepts, Inc., an independent test lab for active electronic components, performed testing on the effect of part exposure to the Huntron "Tracker". The Huntron "Tracker" is an in-circuit stand-alone component tester. Two types of parts were tested and pertinent data recorded prior to test with the "Tracker". The parts were then tested and data logged after the "Tracker" test. The two sets of data, pre- and post-, were then compared for any possible effect that the "Tracker" might have upon the parts. Seventy-five pieces of 74LS11's and seventy-five of 4011's were tested. All parts passed after testing with the Huntron. The datalogged parameters were input and operating current, and output voltage. No discernible effects were observed upon analysis of the pre- and post- data logs.

The exact test flow is as follows:

1. All parts before testing were subjected to 48 hours burn-in at 125 degrees Celsius.
2. 74LS11 and 4011 tested for pass/fail operation at 125 Celsius.
3. 75 of each part tested for propagation delay, pass/fail.
4. Parts datalogged for specific parameters.
5. Parts subjected to test by the Huntron instrument.
6. Propagation delay tested.
7. Post-test datalog performed, some parameters recorded.
8. Datalogs analyzed to determine any effects of the Huntron "Tracker" upon parts.

TEST DISCUSSION

The testing procedures used can only validate the externally measurable parameters of the part and its function. The internal functioning of the part can be assumed to follow with the externally measurable parameters.

The lot of parts received from Huntron were uniform in date code and manufacture. All parts were 100% functional after a static burn-in of 48 hours. The TTl and CMOS parts were tested on a Hewlett Packard 5045 IC Tester (Ser.# 1712A00222). The data was recorded on a companion HP9825 Calculator. Huntron provided a "Tracker" and "Sequencing Unit". The Huntron "Tracker" (Ser.# 21F01001), was connected to the sequence unit which, according to Huntron, automatically connected the leads of the part to the tester one lead at a time. The actual functioning of the sequencer and the two test units are not the responsibility of Component Concepts other than the following of instructions provided by Huntron for proper operation. After burn-in the parts were tested pass/fail for propagation delay in a bench set-up using a pulse generator and a 100MHz HP oscilloscope. The parts were also datalogged. They were then tested on the sequencer with the two testers attached. After being tested with the sequencer the parts were again tested for propagation delay and datalogged. At all times attention was paid to static ESD precautions.

TEST RESULTS

At pre-test, after burn-in, all parts were functional for DC and AC parameters, seventy-five parts were data-logged from each part type, 74LS11 and 4011BC. A comparison of data after testing showed no significant change in either input current or output voltage under load. The data printed out by the HP9825 Calculator was reduced to a more readable format which clearly shows the value recorded before and after the differences between the two values. The majority of differences between values are within the accuracy limits of the HP5045 Tester. Points where there are differences greater than that value are not significant in number to produce any possible negative conclusions on tester interaction with the tested parts. Based on the collected data, the Huntron "Tracker" had no discernable impact on the parts tested.

NOTES:

APPENDIX F
USING THE SHORTRACK

The Huntron SHORTRACK Model 90 is a short locating accessory for the Tracker line of Analog Signature Analysis (ASA) instruments. A Tracker can detect that there is a low impedance fault on a certain node of a PCB but it cannot always locate where the fault is. The SHORTRACK is designed to pick up and give an indication of the current flowing through the fault so that it can be followed and located. The SHORTRACK can be used with the LOW range of any Tracker.

An inductive probe is used to trace current flow in the PCB.

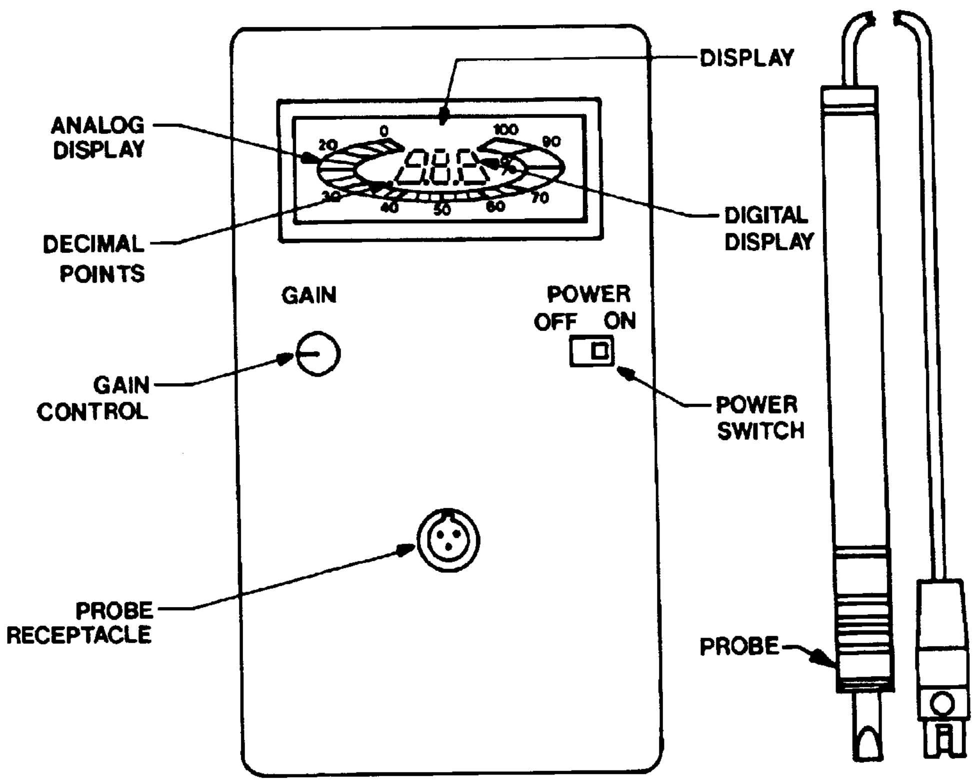


Figure F-1. Huntron ShorTrack.

1. Select the LOW range on the Tracker, at 50/60 Hz.
2. Connect the COM lead to the COM terminal on the Training Board. Connect the red A channel probe to the ST1 terminal.
3. Turn the power on and hold the instrument in tour left hand so that you can adjust the GAIN control with your thumb.
4. Hold the current probe in your right hand and place it over the maximum current point (see figure below). This is a trace on the PCB that has all the Tracker current flowing through it.

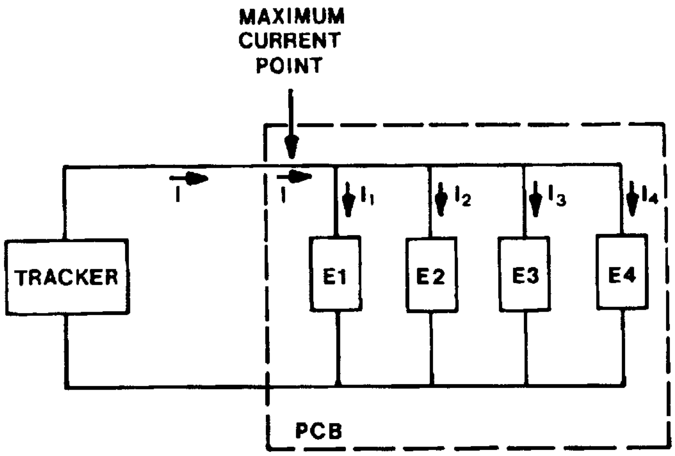


Figure F-2. Circuit current paths.

5. Align the probe for best sensitivity by orienting the wide part of the tip perpendicular to the PCB trace (see figure below).

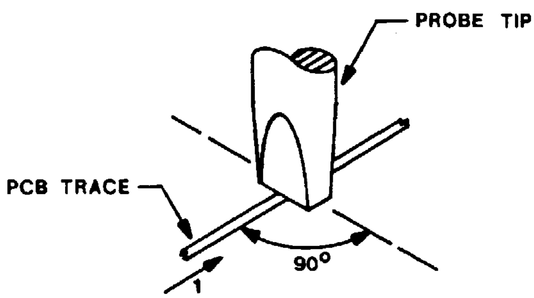


Figure F-3. ShorTrack probe tip alignment.

Also keep the probe body perpendicular to the PCB as shown in the following figure.

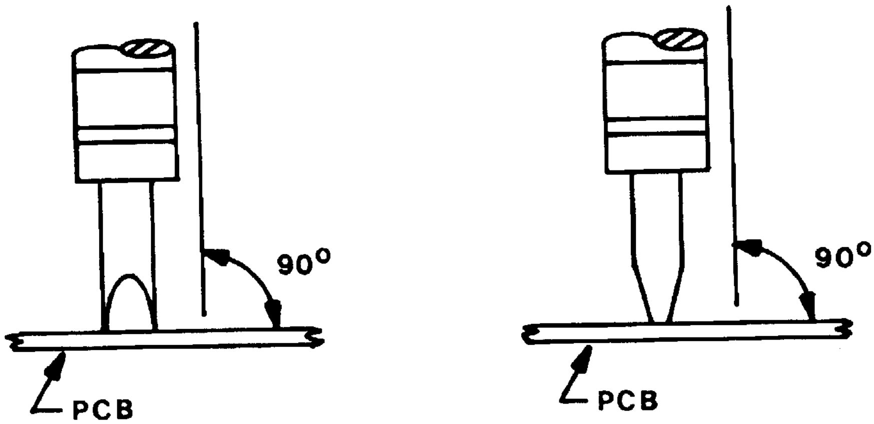


Figure F-4. ShorTrack probe body alignment.

6. While holding the probe steady, adjust the GAIN control until the display reads 100%. ST1 is shorted to COM. Follow the ST1 current path until the short is located.

   ST2 is shorted to VCC, can you find the short between ST2 and VCC?

The SHORTRACK will give an approximate indication of the relative amount of current (with respect to 100%) that is flowing in any trace that the probe is placed on. As you move the probe along the trace, the reading will drop to zero when you pass the short or the current branches off into another trace. If there is no other physical branch where the reading goes to zero, inspect that location for the fault that is causing the short.

Notes: