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MAN 129–9803

# TONEOHM 950 OPERATOR MANUAL

# TONEOHM 950 MULTILAYER SHORTS LOCATOR OPERATOR MANUAL

## POLAR INSTRUMENTS LTD. HARDWARE WARRANTY

1. Product Warranty. Product hardware is warranted to be free from defects in material and workmanship during the Warranty Period (as defined below). Product hardware is warranted to conform substantially to Polar's then current (as of the date of Polar's product shipment) published user documentation during the Warranty Period. The Warranty Period is twelve (12) months. Product support beyond these periods may be available at additional cost – consult Polar for details.

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**EUROPEAN COMMUNITY DIRECTIVE CONFORMANCE STATEMENT**

This product conforms to all applicable EC Council Directives, including:

> EC Council Directive 89/336/EEC on the approximation of the laws of the Member States relating to electromagnetic compatibility.
>
> EC Council Directive 73/23/EEC on the harmonisation of the laws of the Member States relating to electrical equipment designed for use within certain voltage limits.

A declaration of conformity with the requirements of these Directives has been signed by:

> POLAR INSTRUMENTS (UK) LTD
> 11 College Place
> London Road
> Southampton
> England
> SO1 2FE

Harmonised standards applied in order to verify compliance with these Directives:

> EN 50081-1:1992
> EN 50082-1:1992
> EN 61010-1:1993

# SAFETY

## WARNING

The LIVE and NEUTRAL lines on this unit are BOTH fused.

This unit contains no user-serviceable parts. When the unit is connected to its supply, the opening of covers or removal of panels is likely to expose dangerous voltages. To maintain operator safety, do not operate the unit unless the enclosure is complete and securely assembled.

## GROUNDING

This unit must be earthed (grounded); do not operate the instrument with the safety earth disconnected. Ensure the instrument is connected to an outlet with an effective protective conductor terminal (earth). Do not negate this protective action by using an extension cord without a protective conductor.

*Note: This instrument is fitted with 3-wire grounding type plug designed to fit only into a grounding type power outlet. If a special local plug must be fitted to the power cord ensure this operation is performed by a skilled electronics technician and that the protective ground connection is maintained. The plug that is cut off from the power cord must be safely disposed of.*

Power cord color codes are as follows:

**Europe**

| | |
|---|---|
| brown | live |
| blue | neutral |
| green/yellow | earth (ground) |

**United States**

| | |
|---|---|
| black | live |
| white | neutral |
| green | ground |

# POWER SUPPLY

Check that the indicated line voltage setting corresponds with the local mains power supply. See the rear panel for line voltage settings.

*To change the line voltage settings refer the instrument to a skilled electronics technician. Instructions for changing the line voltage settings are contained in the TONEOHM 950 Service Manual published by Polar Instruments.*

# TONEOHM 950 OPERATION

> *This manual contains instructions and warnings which must be observed by the user to ensure safe operation. Operating this instrument in ways other than detailed in this manual may impair the protection provided by the instrument and may result in the instrument becoming unsafe. Retain these instructions for later use.*

The TONEOHM 950 is designed for use indoors in an electrical workshop environment at a stable work station comprising a bench or similar work surface.

Use only the accessories (e.g. test probes and clips) provided by Polar Instruments.

The TONEOHM 950 must be maintained and repaired by a skilled electronics technician in accordance with the manufacturer's instructions.

If it is likely that the protection has been impaired the instrument must be made inoperative, secured against unintended operation and referred to qualified service personnel. Protection may be impaired if, for example, the instrument:

- Shows signs of physical damage
- Fails to operate normally when the operating instructions are followed
- Has been stored for prolonged periods under unfavourable conditions
- Has been subjected to excessive transport stresses
- Has been exposed to rain or water or been subject to liquid spills

# CAUTION

**Electrical Isolation**

Disconnect the board under test from the local mains supply (including ground) when using Track Resistance, Plane Shorts and Trace ranges.

# SPECIFICATIONS

**Track Resistance**

| | |
|---|---|
| RANGES | [Ω], 200mΩ, 2Ω, 200Ω, 20KΩ. Instruments with serial numbers below 005975 have a 2KΩ range instead of 200Ω. |
| ACCURACY | +/-6% in 200mΩ<br>+/-5% in 2Ω<br>+/-4% in 200Ω<br>+/-5% in 20KΩ |
| [Ω] RANGE | High sensitivity, uncalibrated.<br>Approximately 40mΩ full scale. |
| PROBE VOLTAGE | 60mV maximum. |
| INDICATION | Tone and meter in all ranges. |
| PROBE PROTECTION | Protected to +/- 30V. |

**Track Current**

| | |
|---|---|
| RANGES | 200mA, 2A, TRACE. |
| ACCURACY | +/-15% in 200mA, 2A for track resistance between 25mΩ and 500mΩ.<br>Reading proportional to current when UNCALIBRATED LED is lit.<br><br>UNCALIBRATED LED lit during ranging.<br><br>Reading in TRACE is proportional to detected magnetic field strength. |
| TRACE SENSITIVITY | Capable of detecting current flow with 200Ω resistance across Drive Source. |
| PROBE VOLTAGE | 600mV maximum in 200mA, 2A.<br>Not applicable in TRACE. |
| INJECTION CURRENT | 250mA maximum.<br>Not applicable in TRACE. |
| INDICATION | Tone and meter in all ranges. |
| PROBE PROTECTION | Protected to +/- 30V in 200mA, 2A.<br>Not applicable in TRACE. |

**Track Voltage**

| | |
|---|---|
| RANGES | 2mV, 20mV, 20V. |
| ACCURACY | +/-4%, +/-15µV. |
| INPUT RESISTANCE | 120Ω in 2mV, 20mV.<br>1MΩ in 20V. |
| INDICATION | Meter in all ranges. Tone in 2mV, 20mV. |
| PROBE PROTECTION | Protected to +/- 30V |

**Plane Shorts**

| | |
|---|---|
| INDICATION | Tone, uncalibrated meter and fault direction arrows. |
| SENSITIVITY | Adjustable for differing plane resistance. Capable of detecting shorts up to 20Ω. |

**Plane Stimulus**

| | |
|---|---|
| OUTPUT VOLTAGE | 550mV maximum. Active only when PLANE SHORTS is ACTIVE and outputs are connected to a plane. |
| OUTPUT CURRENT | 700mA RMS maximum. |
| PROTECTION | Each output separately fused. |

**Drive Source**

| | |
|---|---|
| OUTPUT VOLTAGE | 0 to 550mV, adjustable.<br>AC in TRACE, DC in all other ranges. |
| PROTECTION | Protected to +/- 30V. |

## ENVIRONMENTAL OPERATING CONDITIONS

The instrument is designed for indoor use only under the following environmental conditions:

| | |
|---|---|
| Altitude | Up to 2000m |
| Temperature | +5°C to +40°C ambient |
| Relative humidity | RH 80% maximum at 31°C — derate linearly to 50% at 40°C |
| Mains borne transients | As defined by Installation Category II (Overvoltage Category II) in IEC664 |
| Pollution Degree | 2 (IEC664) |

***Power Requirements***

230V ± 10%, 115V ± 10% or 100V ± 10% at 50/60Hz, 25VA.

***Physical characteristics (excluding accessories)***

Dimensions 305mm (12 in.) wide.
150mm (5.9 in.) high.
275mm (10.8 in.) deep.

Weight 3.5 kg.

Flammability Enclosure to UL94 V-0.

## SYMBOLS

⚠ CAUTION To prevent damage to this product and to ensure its safe use observe the specifications given in this manual when connecting to terminals marked with this symbol.

# ACCESSORIES

***Standard Accessories***

| | |
|---|---|
| Needle Probes | ACC152 |
| 950 Plane Probe/Clip assembly | ACC113 |
| 950 Current Trace Probe assembly | ACC114 |
| 950 Stimulus Lead (Set of 4) | ACC134 |
| Lightweight Headphones | EPM115 |

***Optional Accessories***

| | |
|---|---|
| Bare-board Stimulus Lead set (0.025") | ACC121/XG25 |
| Bare-board Stimulus Lead set (0.031") | ACC121/XG31 |
| Bare-board Stimulus Lead set (0.040") | ACC121/XG40 |
| Bare-board Lead set (universal) | ACC154 |
| Service Manual | MAN130 |

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# SECTION 1 INTRODUCTION

## INTRODUCTION

Short circuits and loading problems are a common cause of faults in both Manufacturing and Service.

These faults may range from a low resistance short, such as a solder bridge, to a defective component loading down a bus line in a microprocessor system.

Different methods are required to locate different types of short.

### *TONEOHM 950 operating modes*

The TONEOHM 950 has five operating modes to enable the user to physically locate any type of short circuit without lifting components, cutting tracks or otherwise damaging the board under test:

| | |
|---|---|
| Track Resistance | Milliohmmeter for locating low resistance shorts. |
| Track Current | Measures current flowing in a track without breaking the circuit. Used for stuck bus or device loading problems. |
| Current Tracer | Non-contact current tracing where access to tracks or components is difficult. |
| Track Voltage | Enables current flow to be traced by measuring the voltage drop caused by the current flowing in a track. Used when tracing loading faults on very low resistance tracks. |
| Plane Shorts | Used on multilayer boards to locate shorts between a track and plane, or between two planes. |

# SECTION 2 – INSTALLATION AND SET UP

## PREPARATION FOR USE

### *2.1 Unpacking*

The instrument is shipped in a sturdy transit pack. Open the pack carefully and remove the instrument and its accessories.

The TONEOHM 950 carton should contain the following:

TONEOHM 950
Needle probes
Current Trace Probe / Drive Source lead assembly
Plane Probe / Clip assembly
Set of four Plane Stimulus leads
Headphones
Operator manual
Power cord

Retain the packaging for possible future use.

NOTE: If the instrument has been shipped or stored in a cold environment, allow the instrument to reach the temperature of its new location before applying power.

### *2.2 Connecting the TONEOHM 950 to a power supply*

**Refer to the voltage label on the rear panel of the instrument and make sure that the marked rating is suitable for the local mains power supply.**

If the rating on the label is not suitable for the local power supply refer the instrument to a skilled electronics technician. Instructions for changing the line voltage settings are contained in the TONEOHM 950 Service Manual.

*Note: If a special local plug must be fitted to the power cord ensure this operation is performed by a skilled electronics technician and that the protective ground connection is maintained. The plug that is cut off from the power cord must be safely disposed of.*

Power cord colour codes are as follows:

**Europe**

| | |
|---|---|
| BROWN | LIVE |
| BLUE | NEUTRAL |
| GREEN/YELLOW | EARTH (GROUND) |

**United States**

| | |
|---|---|
| BLACK | LIVE |
| WHITE | NEUTRAL |
| GREEN | GROUND |

Check that the TONEOHM 950 mains switch (on the rear panel) is OFF.

Plug the power cable into the receptacle on the rear panel of the TONEOHM 950.

Plug the other end into a wall outlet.

### *2.3 Self test*

When the instrument is switched on it performs a self test. During the self test the front panel LEDs are lit in sequence. Do not operate front panel controls during the self test. If the test passes the instrument is left in the 20V range.

# SECTION 3 – DESCRIPTION

### *3.1 Connectors and probes*

The instrument is supplied with three sets of probes. Each probe fits into a unique socket on the front panel. A LED adjacent to each socket indicates which probe to use in the selected range.

**Plane Probe**

The blue Plane Probe and Clip are used in the PLANE SHORTS range. The Clip is attached to the shorted track, and the Probe used to sense the response on the plane being stimulated by the Plane Stimulus.

**Current Trace Probe and Drive Source leads**

The magnetic Current Trace Probe is used to detect currents flowing through tracks, components, etc. without making physical contact. The Probe must be used in conjunction with the Drive Source output, as it is tuned to the frequency of the AC current supplied by the Drive Source when TRACE is selected.

The Drive Source leads (a pair of red and black clips) are used to inject the current into the board.

When Track Voltage, 200mA or 2A ranges are selected the Drive Source output is a DC voltage (red clip positive) which can be used to stimulate the board under test.

**Needle Probes**

The Needle Probes are used in all ranges except TRACE and PLANE SHORTS. The red (positive) and black (negative) markings on the probes indicate direction of current flow in Track Current or Track Voltage.

**Plane Stimulus leads**

Four test clips (colour-keyed) used in the PLANE SHORTS range to stimulate the shorted plane. The blue lead is connected to the Top Left corner of the plane, red lead to Top Right, green lead to Bottom Left, and yellow lead to Bottom Right.

**Headphone socket**

When the headphones are connected to this socket the internal speaker is switched off. Use only 3.5mm stereo jack plugs in this socket. A stereo to mono adapter is required for use with an earpiece.

### *3.2 Indicators*

**Liquid crystal display**

The liquid crystal display (LCD) gives an indication of the parameter being measured in the units appropriate to the selected range.

When TRACE, PLANE SHORTS or [Ω] is selected, the display is uncalibrated but proportional to the reading at the probes.

The display is also uncalibrated if the UNCALIBRATED LED is lit.

**Plane Shorts direction arrows**

Four LED indicators under the LCD display indicate the direction in which the Plane Probe should be moved to locate the fault. The indicators operate as follows:

| Probe Unconnected | Probe Distant | Close to Fault |
|---|---|---|
| All LEDs off | Direction LED on | All LEDs on |

**Uncalibrated LED**

Lit in the 200mA and 2A ranges during ranging or when the Needle Probes are too close together for an accurate measurement of the current to be displayed.

**Probes Reversed LED**

Lit when the Needle Probes are connected to a negative voltage or current.

**Drive Source LED**

Lit when the Drive Source leads are connected correctly and a current greater than 4mA (approximately) is flowing from the Drive Source.

### *3.3 Controls*

**Volume**

Adjusts the volume of the speaker or Headphone output.

**Drive Source**

Adjusts the amplitude of the Drive Source output (0-550mV approximately). The DRIVE SOURCE LED lights when Drive Source current is flowing.

Adjusts sensitivity in PLANE SHORTS to accommodate different plane resistances.

### *3.4 Ranges*

**Track Resistance**

There are five resistance ranges.

A low resistance generates a high tone, and a high resistance generates a low tone. On the 200 mΩ range resistances below 15 mΩ generate a steady warble.

Use the 200 mΩ and [Ω] ranges for locating low resistance shorts. These ranges are sensitive enough for measuring track resistance. [Ω] is approximately five times more sensitive than 200 mΩ.

Use the 2 Ω, 200 Ω and 20 KΩ ranges for general purpose resistance measurement.

To protect PCB components, the maximum voltage at the probe tips on these ranges is 60mV.

**Track Current**

There are three current ranges.

In the 200mA and 2A ranges the Needle Probes are used to make a *non-invasive* measurement of the current flowing in a track, i.e. without breaking the circuit. This may be used to trace currents or locate loading faults. A positive current will produce a reading on the display and a tone. A negative current produces a zero display, no tone and the PROBES REVERSED LED will be lit.

TRACE uses the *non-contact* Current Trace Probe to detect the magnetic field intensity of current flowing from the Drive Source. The reading on the LCD display is proportional to the intensity of the field and therefore to the magnitude of the current. A tone is produced whose frequency is proportional to the displayed amplitude (low magnetic field intensity causes low frequency tone).

# SECTION 4 – OPERATION

## LOCATING FAULTS WITH THE TONEOHM 950

### *4.1 Range selection*

Different types of short circuit and loading fault require different location techniques. It is often possible to find the fault in more than one way, but the following approach is recommended. In some cases a combination of techniques may be required.

When selecting the range to use, consider the following questions:

- Is the fault a low resistance short (i.e. less than 200 mΩ)?
- Is the fault *static* or *dynamic*, i.e. is the fault always present (static) or only present when the board is powered (dynamic)?

Track Resistance is applicable to locating static, low resistance shorts on single or two-sided boards.

If the fault is dynamic then use either Track Current or Track Voltage. Using Track Current provides a direct display of the current flowing in a track, but on very low resistance (wide) tracks it may be necessary to use Track Voltage.

- Are the tracks or cables associated with the short accessible?

If access is difficult (e.g. a wire harness or densely packed memory bank) the Current Trace Probe is useful, as it can detect current without making contact.

- Does the short involve a plane in a multi-layer board?

If the short involves a plane, then the PLANE SHORTS range is the optimum range to use. However, if the fault is dynamic it will be necessary to use either Track Current or Track Voltage.

Table 4-1 indicates the suggested range for locating different types of short circuit.

| Type of fault | Range | Section |
|---|---|---|
| Shorts below 200 mΩ | [Ω], 200 mΩ | 4.2 |
| Multi-layer shorts (static) | PLANE SHORTS | 4.3 |
| Multi-layer shorts (dynamic) | 200mA | 4.4 |
| Excessive Vcc loads | 200mA | 4.4 |
| Stuck Bus line (static) | TRACE, 200mA | 4.5, 4.4 |
| Stuck Bus line (dynamic) | 200mA | 4.4 |
| Backplanes/wiring harnesses | TRACE | 4.5 |
| Open Circuit Capacitor | TRACE | 4.5 |

Table 4-1 Range selection

### *4.2 (Low resistance) shorts*

> *NOTE: Disconnect power from the board under test before using any of the resistance ranges.*

*Low resistance shorts* are shorts having a resistance under 200 mΩ, caused typically by a solder or land bridge. They often occur between adjacent tracks or solder joints on a PCB. Resistance measurements, using the 200 mΩ range, should isolate the fault to within a few millimetres.

In situations where tracks are thick, more sensitivity and resolution can be gained using the [Ω] range.

As the 950 uses DC for resistance measurement, capacitors do not affect its accuracy. The open circuit probe tip voltage is limited to a maximum of 60mV to prevent any damage to sensitive components.

To obtain the best results and minimise damage to the track, hold the probes at right angles to the PCB and apply sufficient pressure to pierce flux and solder resist. Probe the track at different points rather than scraping the probe along its length.

It is not unusual for a fault to be located between two parallel tracks where there is no visual sign of a short, even using an eyeglass. This often happens if the board is covered with solder resist, masking a hairline whisker short. Use a suitable tool to cut between the tracks through the solder resist and the short. **Considerable care is needed when using cutting tools in this type of operation. Eye protection should be worn**. An open circuit reading confirms that the fault has been cleared.

With a densely populated board, where very little track is exposed, the milliohm technique may be difficult to use. In this case see Section 4.5 — *CURRENT TRACING (NON-CONTACT).*

*Example – Low Resistance Short*

Refer to Figure 4-1 — there is a short circuit between the output of U1 and the input of U2. Board power is disconnected.

- Place the Needle Probes at A and E. The resistance of the tracks via the short gives a reading and a tone.
- Moving the probe from A to B gives a lower reading and a *higher tone*. This indicates that the probe has moved *closer* to the short.

- Moving the probe from B to C gives a higher reading and a *lower tone*, indicating that the probe has *moved beyond* the fault.
- This implies that the fault is between B and C.
- Now move the other probe from E to give the lowest reading and the highest frequency tone. When the reading is below about 15 mΩ, the probes should be within a few millimetres of the short and the tone changes to a warble.

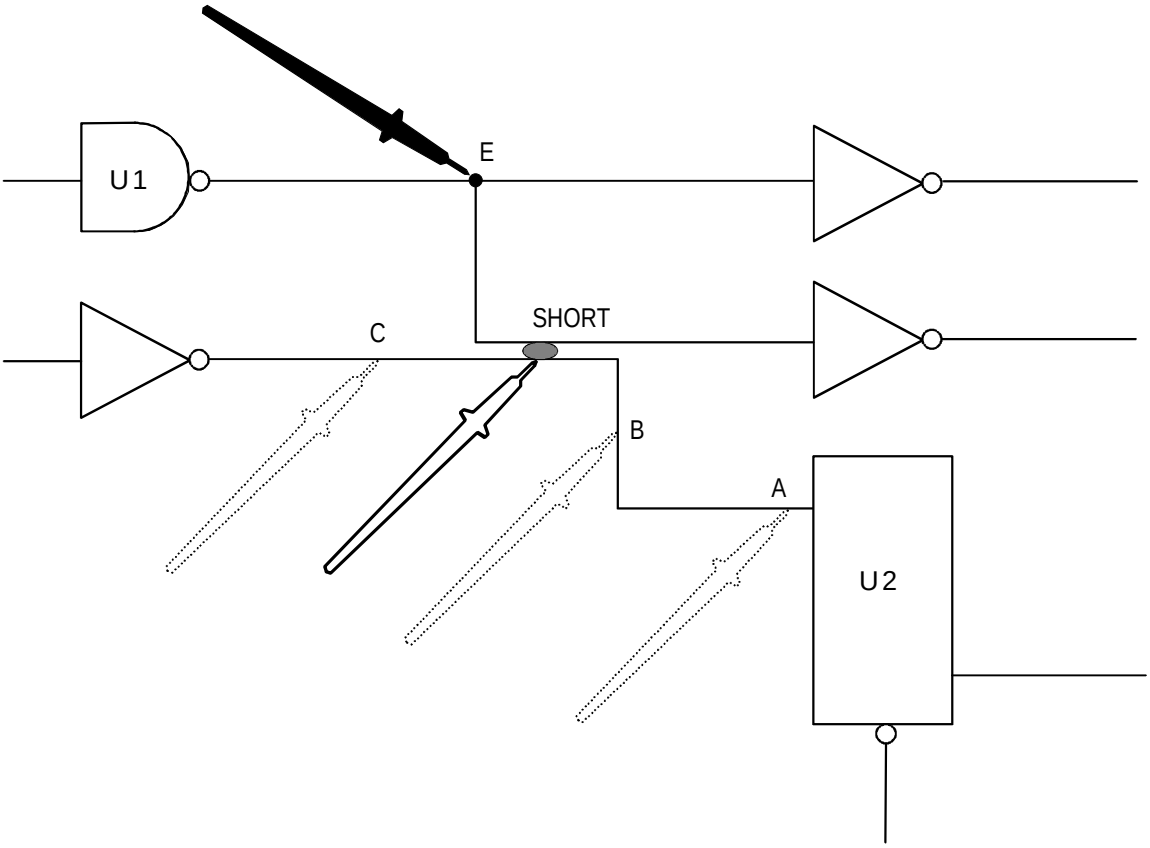



Figure 4-1 Low Resistance Short

### *4.3 Plane Shorts*

> *CAUTION: Disconnect power from the board under test before using PLANE SHORTS.*

*NOTE: The Plane Stimulus outputs should only be connected to a PCB plane. Do not connect to PCB tracks.*

This range is effective in physically locating shorts between a track and a plane, or between two planes. Single and multiple shorts each require a different method of location. The two methods are described in this section.

### Causes of Shorts on Multi-layer Boards

Polar Instruments has evaluated many defective multi-layer boards (both bare and assembled) from a range of manufacturers and found that the cause of most of these faults are the same as on single or double-sided boards (e.g. solder bridges, bent component leads etc.) Where the short occurs internally this is usually associated with a via hole. *Thus it is usually possible to locate the short to a point that is accessible from the surface of the board*.

### Connection

Connect the four Plane Stimulus leads to the corners of the shorted plane as shown in Figure 4-2.

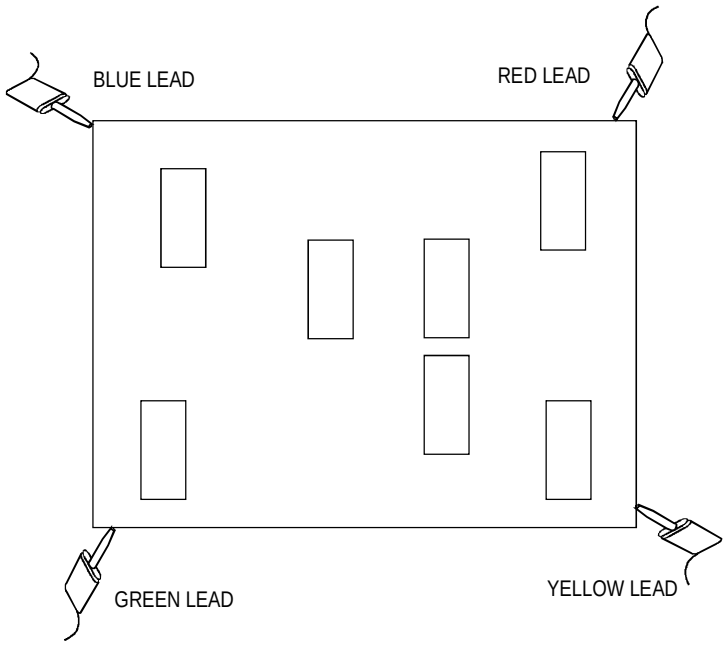



Figure 4-2 Plane Stimulus Connection

The positions of the Stimulus sockets on the front panel correspond to their positions on the board under test (e.g. blue in Top Left corner, red in Top Right corner, etc.).

- Connect the colours as shown to ensure the LED Direction Arrows indicate the correct direction. Connect as close as possible to the corners of the plane.
- If the short is between two planes, select either plane but ensure the leads are all connected to the *same* plane. This plane is referred to as the *stimulated plane*.
- If there are via holes closer to the corners of the plane than component leads, then solder a short length of tinned copper wire to the holes and connect the Stimulus leads to those wires.
- Connect the Plane Clip to the other side of the short. If the fault is a plane to plane short, connect the Clip to the *other* plane (referred to as the *un-stimulated plane*). The Clip can be connected to any point on the track or plane.
- Press PLANE SHORTS, which will light the STANDBY LED. In Standby the display reads "1---".
- Check the Plane Stimulus leads are connected correctly, then press PLANE SHORTS again. This will turn on the Plane Stimulus and light the ACTIVE LED.

- If the warning bell sounds and the 950 returns to STANDBY, check that all the Plane Stimulus leads are connected to the same plane. To protect components the maximum voltage appearing on the stimulus outputs is 500mV, and disconnecting any one of them will automatically turn the stimulus off and return to STANDBY.

**Sensitivity Adjustment**

The Drive Source control adjusts the sensitivity of the system. It is usually possible to use maximum sensitivity (i.e. with the control set fully clockwise) but if the plane's internal resistance is high it will be necessary to reduce the sensitivity to avoid over-ranging near the edges of the board (which would prevent a meter reading or Direction Arrow from being displayed):

- Set the Drive Source control fully clockwise (maximum sensitivity).
- Connect the Plane Probe to a point on the stimulated plane *near the board centre,* e.g. an IC ground pin if the ground plane is being stimulated.
- If no tone is produced, turn the Drive Source control anti-clockwise (to reduce the sensitivity) until a tone is heard.

Once the general area of the short has been determined, the resolution of the system can be increased (if necessary) in one of the following ways:

- If the sensitivity is not already set to maximum, it is possible to increase the sensitivity once the Plane Probe has been moved closer to the short (by turning the Drive Source control clockwise).
- Moving the Plane Stimulus leads in from the edges of the board will stimulate a smaller area of the plane and hence increase the resolution within this area.

Note that increasing the resolution is usually only required when locating a high resistance short.

**Operation (Single Short)**

Use the Plane Probe to probe points on *the same plane as the Plane Stimulus*. These points will usually be accessible at power supply connections to ICs or decoupling capacitors.

*Do not touch the probe tip when probing, as this will interfere with the measurement being made.*

The four Direction Arrows under the display indicate the direction in which to move the Probe towards the short. This is accompanied by a tone which rises in frequency and a meter reading which decreases as the fault is approached. The Direction Arrows can be used to determine the *approximate* location of the short (within 40-50mm). Close to the short all four arrows will light, and the tone or meter readings must be used to perform the final location.

The highest tone and therefore the lowest meter reading indicate that the probe is within a few millimetres of the short.

As it is not possible to probe all of a plane from the board surface, it is possible that the fault may be on or near an adjacent component or via (see Example #2 below). In these cases visual inspection of the immediate area where the highest tone occurs may be necessary. If there is no apparent fault, refer to "Multiple Shorts" later in this section.

Note that probing *any* point on the side of the short connected to the Plane Clip (i.e. the un-stimulated plane, if the short is between two planes) will result in a high tone, low meter reading and all arrows lit.

If a reading greater than 3.0 is displayed this indicates there may be multiple shorts. (Refer to *Multiple Shorts* later in this section.)

*Example #1*

Consider a board on which the +5V plane is shorted to the 0V (ground) plane.

- Connect the Plane Stimulus leads to the corners of the ground plane, and the Plane Clip to any point connected to the +5V plane.
- Use the Plane Probe to probe the ground plane (at IC pins or decoupling capacitors). The arrows will lead the user to 40-50mm of the short.
- Use the tone and meter reading to locate the short precisely.

Care should be taken when probing decoupling capacitors to note that the lead being probed is connected to the stimulated plane, as on some boards the +5V and ground may not be consistently connected to the same side of these components.

*Example #2*

If a reading less than 5.0 cannot be obtained when probing the stimulated plane, this suggests that the short is not exactly at the probed point, but some distance from it.

Consider a board where there is a short between the Vcc and ground planes, and assume that the short actually occurs at the Vcc pin of an IC.

If the ground plane is stimulated, then the user will never probe the precise point where the short occurs, so the lowest reading will be obtained when the probe is at a point on the ground plane that is close to the Vcc pin of the IC. If this situation is suspected, try stimulating the Vcc plane instead of the ground plane.

*High Resistance Shorts*

When the resistance of the short is greater than 20–30 Ω then the TONEOHM 950 will not be able to resolve its position as precisely as for a "hard short".

Resolution can be improved by moving the positions of the Drive Stimulus leads to reduce the area of the plane being stimulated.

- Start with the leads attached as normal at the corners of the board.
- Probe the stimulated plane as normal to determine the approximate area of the short (i.e. where the readings are lowest).
- Then move the Plane Stimulus leads in from the corners of the board to stimulate a smaller area of the plane. This will increase the resolution of the reading in the display.
- This process can be repeated if necessary, each time reducing the area of the plane that is stimulated and hence increasing the resolution within that area.

*Multiple Shorts*

If there are multiple shorts between planes, the Direction Arrows will not lead the operator to the short(s) and a different probing technique must be used as described in this section.

- To determine if multiple plane shorts are present, probe various points on the *un-stimulated* plane. Usually a reading of no more than 3.0 will be displayed. If some readings are 5.0 or more, this suggests there may be multiple shorts between the planes.
- To locate the multiple shorts, continue to probe the *un-stimulated* plane (*ignoring the direction arrows*) until the *highest* reading is displayed; one of the shorts will be in this area.
- Repeat this process until one short remains, then use the method for locating a single short to locate the final short.

In the event of this being unsuccessful TRACE may be used to locate the shorts individually. (See Section 4.5 — *CURRENT TRACING (NON-CONTACT)*)

*Segmented Planes*

On some very complex boards, the plane in a layer may be broken into segments making it more difficult to locate the short circuit.

In this situation it is necessary to study the PCB artwork and *treat each segment separately* as an individual plane.

If the arrows direct the user to one of the borders of the stimulated area, it may be assumed that the fault lies outside the area being probed. In this case move the stimulus probes to the plane segment adjacent to the indicated border, and repeat the search.

*Non-Rectangular Boards*

Where the shape of the board is not rectangular it may be difficult to determine the true "corners" of the plane. In this situation try using four points furthest apart on the board.

Alternatively, divide the board into rectangular sections and treat each section separately. If the arrows direct the user to the edge of a rectangle and the fault is not evident at this location, stimulate the area adjacent to that edge.

### *4.4 Track current measurement*

The 200mA and 2A ranges are used to measure the current flowing in a PCB track without needing to cut the track, lift components or break the circuit in any way.

- Either power the board from its own supply, or disconnect external power and connect the TONEOHM 950's Drive Source between the shorted nodes. Use of the Drive Source is recommended, as its output voltage is limited and its amplitude can be adjusted using the Drive Source control.
- Use the Needle Probes to measure the current flowing in a track (see Fig 4-3). The probes should be kept a few millimetres apart to ensure a valid reading. If the probes are too close the UNCALIBRATED LED will light.

Note:

- When the probes are first connected to the track the UNCALIBRATED LED will briefly light while the instrument auto-ranges.
- Unlike a conventional ammeter where errors are minimum at FSD the current injection technique used on the 950 results in lower errors at LOWER readings.

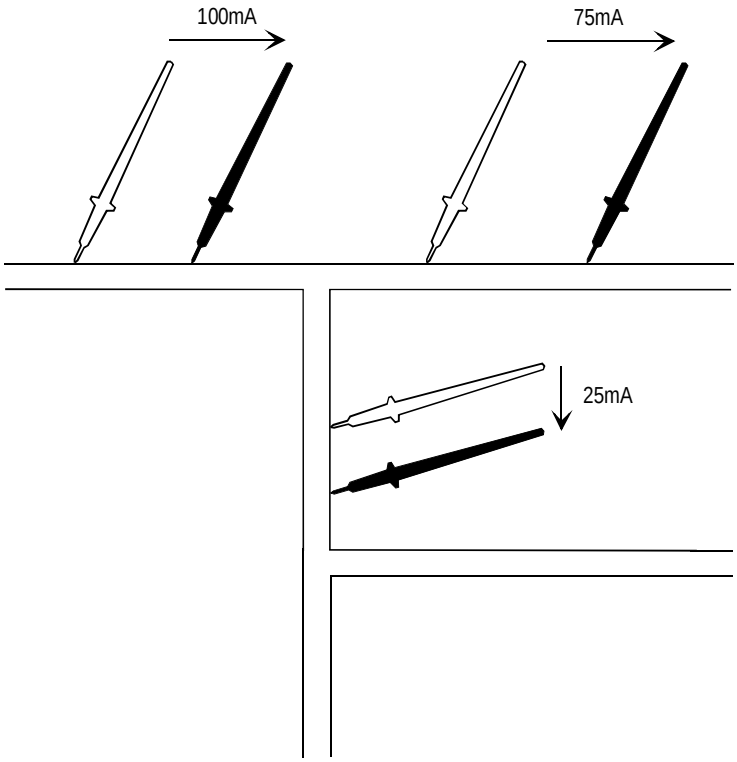



Figure 4-3 Track Current Measurement

The 950 determines the current by measuring the voltage drop along the track, so for a measurement to be meaningful do not probe a track at a branch (see Figure 4-4).

If the UNCALIBRATED LED lights, there is insufficient current and/or track resistance for the instrument to make a valid measurement, although the reading will still be proportional to the current. Either increase the distance between the probes or use Track Voltage.

Positive current flowing through the track provides a tone and meter indication of the current flow. Negative current will produce a zero reading, no tone and the PROBES REVERSED LED will light.

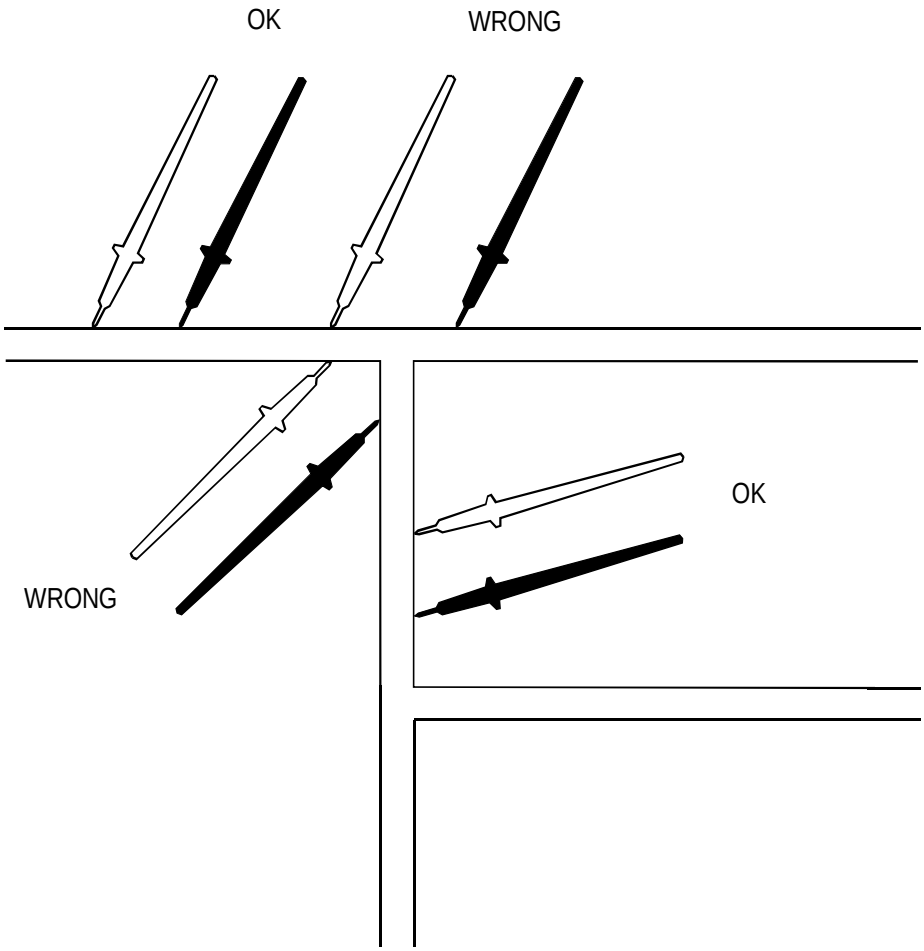



Figure 4-4 Track Current Probing

**Excessive Vcc Loads**

A common problem is a power supply rail being held low by a faulty device drawing excessive current. This is not a low resistance short (less than 200 mΩ) or the rail would read 0V and the shorts location procedure (Section 4.2) could be used.

The fault may be caused by a component going low resistance, producing a permanent low resistance between Vcc and ground. This is an example of a static fault, which remains when power is removed from the board under test.

Another common component failure is an IC that draws excessive current, causing the Vcc rail to be held low when the board is powered. When the board is un-powered, the Vcc to ground resistance is normal. This is an example of a dynamic fault.

If the fault is static it is recommended that the Drive Source is connected between the faulty nodes to supply the current. Its output of 550mV will not damage devices or turn on silicon junctions, making tracing of the current flow easier. As the output is DC, decoupling capacitors do not affect operation. *Disconnect power from the board under test if the Drive Source is used*.

For a dynamic fault it will be necessary to power the board. In this case the current flow that is traced will be a combination of the "normal" load to devices connected to the supply and the excess current due to the fault.

As the tone frequency is proportional to the voltage measured, it is usually sufficient to follow the tone change rather than check readings. If the measured current is negative the tone is turned off and the PROBES REVERSED LED is lit.

*Example – Excessive Vcc Load*

Consider the board shown in Figure 4-5 where the Vcc supply is being loaded. Assume the fault is static.

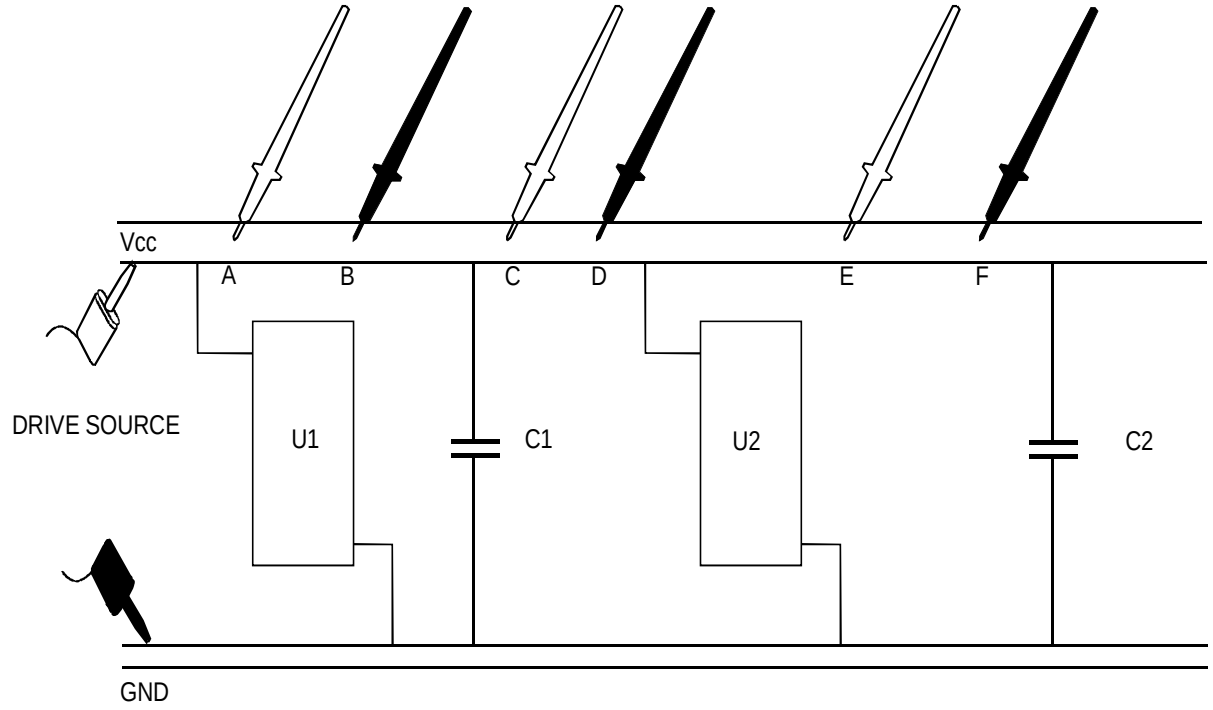



Figure 4-5 Excessive Vcc Load

- Connect the Drive Source leads across the Vcc and ground connections of the PCB.
- Press 200mA and set the Drive Source control to maximum.
- The path of the Drive Source current can now be followed to locate the faulty device.
- Using the Needle Probes, measure the current through the track AB at approximately 90mA.
- Measure the current through CD at approximately 90mA, i.e. approximately the same.
- Then measure the current through EF at approximately 5mA. This suggests that 85mA is flowing into U2, and that this is the device loading down the supply.

*Example – Multiple Current Paths*

Often on power supply rails, there can be several paths from the Drive Source to the low resistance fault. As the current is not confined to one track, some interpretation is required.

Figure 4-6 shows the Drive Source current taking two paths to the faulty device which is drawing approximately 120mA from the supply.

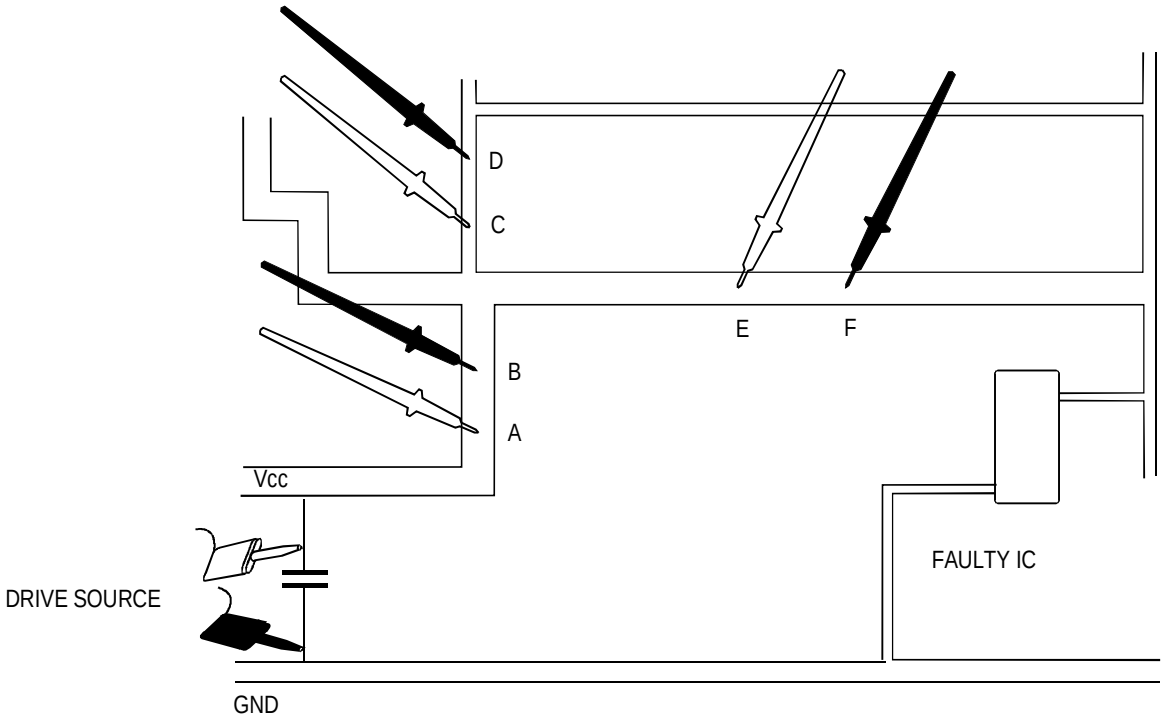



Figure 4-6 Multiple Current Paths

- Reading AB is 120mA.
- Reading CD is 10mA.
- Reading EF is 110mA.

In general it is better to follow the larger current path.

### *4.5 Current Tracing (non-contact)*

> *NOTE: Disconnect power from the board under test before using TRACE.*

#### *Locating faults using TRACE*

This method is effective in the following situations:

- Densely populated double sided PCBs.
- Environmentally coated PCBs.
- Cable looms with internal shorts.
- Shorts on multi-layer boards where the short is on an inner layer.

Use TRACE to detect the current flowing in tracks which cannot be probed using the Needle Probes, e.g. a track running under an IC or in the middle layer of a multi-layer PCB. When using TRACE the current must be supplied by the Drive Source leads.

The Drive Source drives a current and the resulting magnetic field is detected using the Current Trace Probe.

The maximum voltage generated by the Drive Source is 550mV, which will not damage devices or turn on silicon junctions. Its amplitude can be adjusted using the Drive Source control.

The sensitivity of the Current Trace Probe depends on the orientation of its tip. Minimum sensitivity occurs when the black lines on the probe tip are either side of the PCB track carrying the current.

Turning the probe through 90°, so that the black lines are directly over the PCB track, gives maximum sensitivity. This can be observed by the display reading and tone frequency increasing.

#### Connection and Sensitivity Adjustment

Connect the Drive Source leads across the shorted tracks and turn the Drive Source control fully clockwise. The most effective way to use TRACE is to connect leads 10–20mm apart on the board under test. Unless there is a good reason, do not put the leads at opposite corners of the board.

The DRIVE SOURCE LED indicates flow of Drive Source current. If the LED does not light, either the leads are connected incorrectly, or there may be insufficient current flowing for the Current Trace Probe to detect the resulting field.

- Hold the Current Trace Probe near one of the Drive Source leads. As the probe approaches the lead, the LCD reading and the tone frequency should increase.
- Position the probe for a maximum reading against one of the Drive Source leads.
- Adjust the DRIVE SOURCE control to give a reading of 100 to 130. If the reading is less than 100, leave the control at maximum (this occurs with high resistance shorts, i.e. above 150 Ω).
- To alter the distance over which the probe detects current, adjust the DRIVE SOURCE control.

**Operation**

Unlike the milliohm ranges, when using TRACE the probe does not gradually *approach* the fault, giving a highest tone when it is reached. Instead the probe shows the *path of the current*. Since the reading and tone are proportional to the detected field, it is evident when the probe is moving away from the current carrying track.

When using the Trace Probe take care not to detect the magnetic field from the Drive Source leads draped over the PCB.

When using TRACE, the following should be considered as a primary objective:

> Find a position where the Drive Source leads can be clipped on the board under test, such that the Trace Probe detects no field outside a 15 to 20mm square adjacent to the leads. This will mean that the fault must be within that square.

Trying to locate the fault without moving the Drive Source leads is usually unsuccessful without some familiarity with the PCB layout. A recommended approach is to move the injection points of the Drive Source around the board to determine in which regions there is current flowing.

The board is first divided into four sectors (see Figure 4-7).

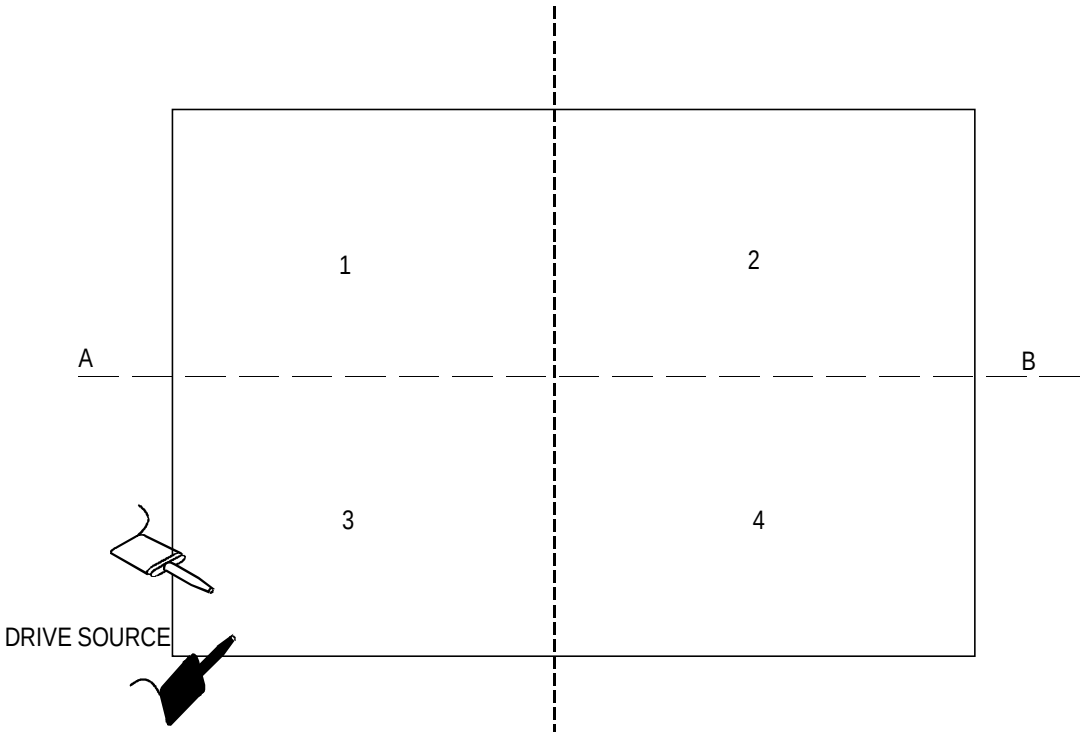



Figure 4-7 Board Sectoring

- Connect the Drive Source Leads 10-20mm apart near one corner of the board (Sector 3 in the illustration).
- Run the Trace Probe along the lines AB, then CD to determine if current is flowing out of Sector 3 into the other sectors. If current is detected along these lines then it is flowing into another sector. If so, alter the position of the Drive Source leads to a different sector and repeat.
- Continue to move the Drive Source until no current is flowing out of the sector where the Drive Source is connected. The position of the short is now somewhere within that sector.
- Repeat the above process *within* that sector until the fault is isolated to within a 20mm square. Use of the circuit diagram, combined with knowledge of the current path can often identify a likely place for a short (eg two adjacent IC pins).

**Bus Faults (Stuck Nodes)**

Where a static fault exists between two points that have no parallel capacitors, TRACE can be used to locate the fault.

TRACE is usually unsuitable for locating Vcc loading faults, as power supplies are likely to have high value electrolytic capacitors connected. These will produce misleading results because the capacitors will conduct AC current from the Drive Source.

Bus lines have little or no capacitance so when one device is known to be holding the bus down, current tracing is often the quickest way to isolate the fault.

The sectoring technique described previously is effective in most cases. However, it may be that the fault is already known to be in one of five or six memory ICs, in which case there is a quicker method:

- Connect the Drive Source leads across the faulty lines.
- Adjust the Drive Source control so that the Trace Probe responds within 10mm of one of the Drive Source leads.
- Pass the Probe over each suspect IC, with the thickest sides of the probe tip parallel to the IC pin sides.
- The defective IC will be conducting Drive Source current through its substrate, which will be detected by the probe.

**Edge Connectors**

Shorts between two pins of a row of edge connectors can be detected by connecting the Drive Source as shown in Figure 4-8.

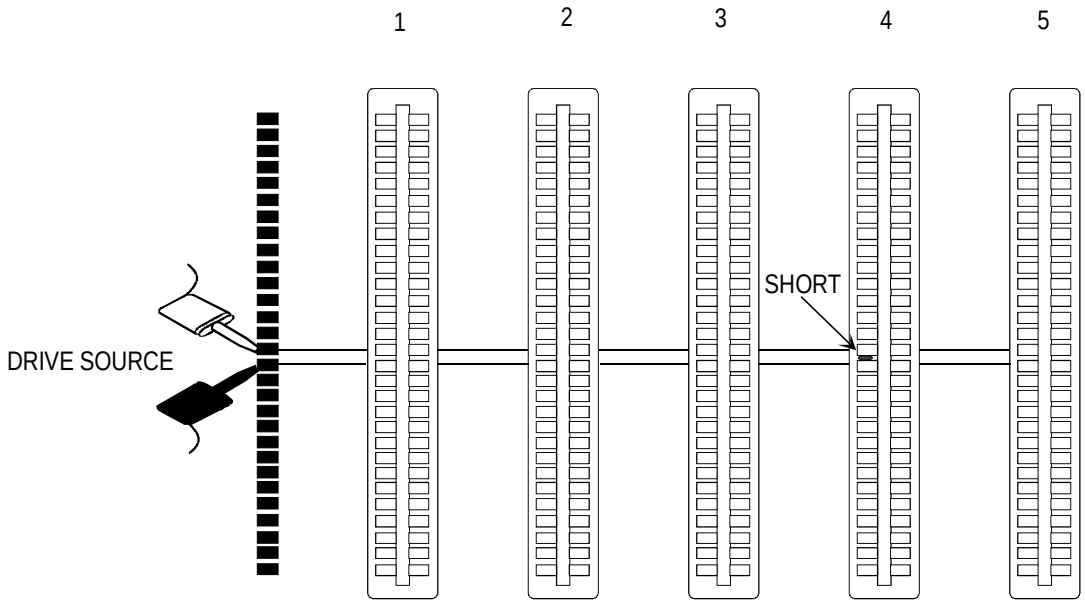



Figure 4-8 Edge Connector Shorts

Adjust the Drive Source control to give a reading with the Current Trace Probe at edge connector height.

- Move the Probe down the gap between each connector in turn, starting nearest to the Drive Source leads.
- As the Probe is moved between connectors 1 and 2, 2 and 3, 3 and 4, a tone is generated. However, when the Probe is moved between connectors 4 and 5 there is no tone, showing that no current is reaching connector 5. This indicates that the short is on connector 4.

Note that if the short was on the edge connector nearest to the Drive Source leads, no tone would be generated when the Probe moved between connectors 1 and 2.

**Faulty Decoupling Capacitors**

In certain situations TRACE can help to identify an open circuit decoupling capacitor.
Figure 4-9 provides an example.

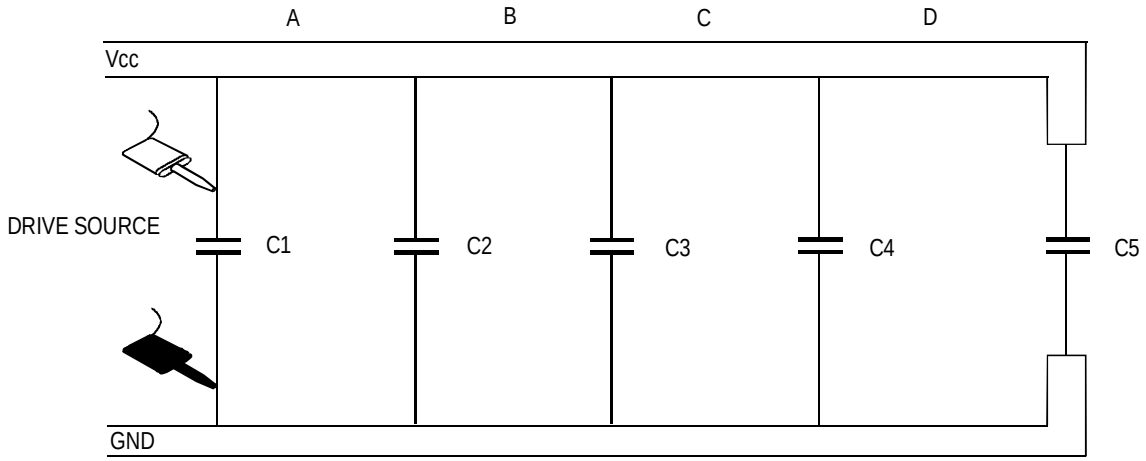



Figure 4-9 Isolation of Open Circuit Decoupling Capacitor

As the Drive Source is AC in TRACE, each capacitor conducts some current.

The Trace Probe can be used to identify the current flow. The display reading and tone give an indication of its relative magnitude.

The reading at A would be the highest (the sum of four capacitor currents). The readings at B, C and D would progressively diminish. The reading at D would be the lowest (only C5's current).

If C3 were open circuit, the readings at B and C would be equal. This method is most suitable for capacitors in the range 0.1uF to 1.0uF.

### *4.6 Track voltage measurement*

The 20mV and 2mV ranges provide a method for tracing the flow of a DC current through a PCB track. This provides an alternative to using the 200mA or 2A Track Current ranges, and is particularly applicable where the tracks are very thick (i.e. very low resistance)

If the fault is static it is recommended that the Drive Source is connected between the faulty nodes to supply the current. Its output of 550mV will not damage devices or turn on silicon junctions, making tracing of the current flow easier. As the output is DC, decoupling capacitors do not affect operation. *Disconnect power from the board under test if the Drive Source is used*.

For a dynamic fault it will be necessary to power the board. In this case the current flow that is traced will be a combination of the "normal" load to devices connected to the supply and the excess current due to the fault.

It is then possible to trace the current flow through the track and its branches by measuring the voltage drop along the track due to the current flowing in it.

Remember that the displayed value and tone correspond to the *voltage* being measured along the track. This voltage is proportional to the current flowing, but will also vary with the distance between the probes and the resistance of the track (e.g. a current flowing through a thin track will develop a larger voltage drop than the same current flowing through a thick track). When comparing the current flow through tracks, the distance between the probes should be kept approximately the same and the method of probing shown in Figure 4-4 used.

As the tone is proportional to the voltage measured, it is usually sufficient to follow the tone change rather than check readings. If the measured voltage is negative, a warble is generated as a warning of reversed polarity.

NOTE: Do not rely too much on voltage readings, or differences between readings, of less than 15µV. Readings as small as these can be caused by thermoelectric voltages instead of PCB track currents. For this reason the TONEOHM 950 does not produce a tone for readings below about 50µV.

*Example – Excessive Vcc Loads*

See Section 4.5 for a preferred method of tracing current. However, if the PCB tracks are very thick (i.e. very low resistance) then the following method is applicable.

Consider the board shown in Figure 4-10 where the Vcc supply is being loaded.
Assume the fault is static.

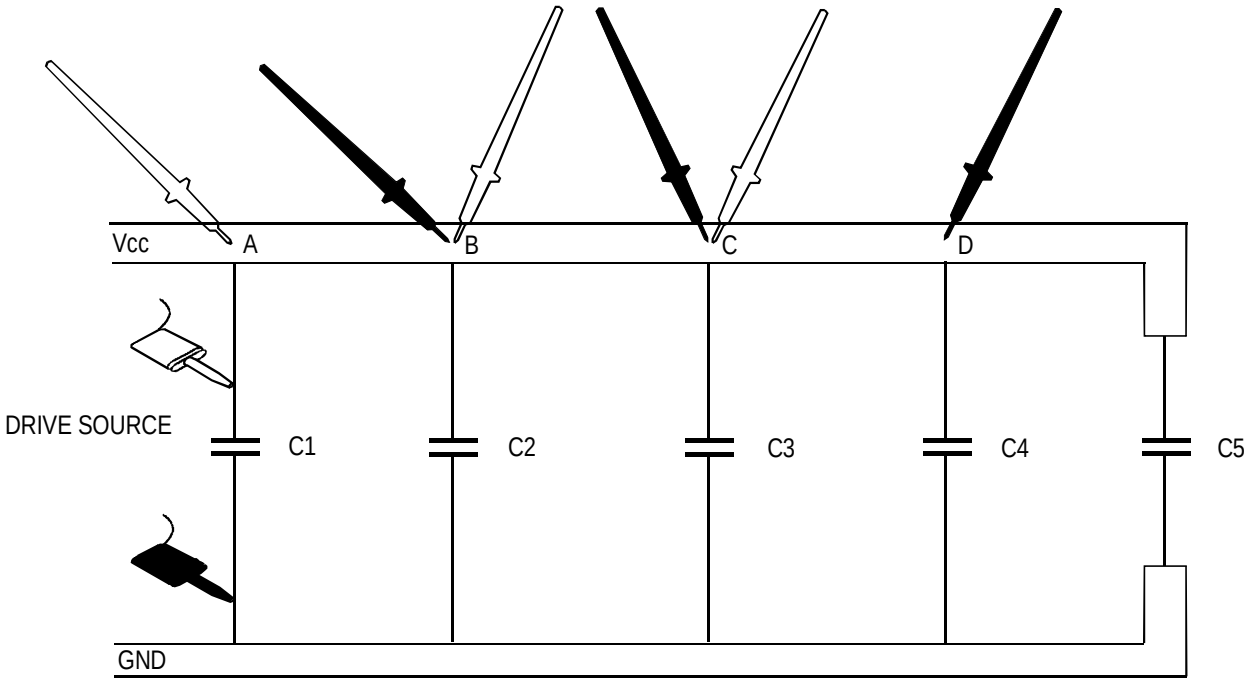



Figure 4-10 Use of Track Voltage Measurement

- Connect the Drive Source leads across the Vcc and ground connections of the board.
- Press 2mV and set the DRIVE SOURCE control to maximum.
- The path of the Drive Source current can now be followed to locate the faulty device.
- Using the Needle Probes, measure the voltage between A and B. The reading is 1.257mV indicating high current flow.
- Measure the voltage between B and C. The reading is 1.118mV suggesting approximately the same current flow.
- Measure the voltage between C and D. The reading is 0.018mV i.e. a low current, suggesting that C3 has gone low resistance.
- Note that if the Drive Source leads had been connected across C3, all voltage measurements would be zero. If this happens, the solution would be to move one of the leads, e.g. to C2, giving a PCB track drop leading to C3.

# SECTION 5 – MAINTENANCE AND CLEANING

**WARNING This instrument should only be serviced by a qualified electronics technician.**

Refer all servicing to qualified service personnel. Polar Instruments publishes a TONEOHM 950 Service Manual to assist the service technician.

### *5.1 Calibration requirements*

To maintain the calibration of the instrument it is recommended that its Calibration/Adjustment Procedure is carried out at intervals not exceeding 12 months.

### *5.2 Plane Stimulus Protection Fuses*

Each of the four Plane Stimulus outputs are individually protected by an internal fuse. If an output is connected to a powered board the fuse opens to minimise damage to the instrument.

Refer all servicing to qualified service personnel.

### *5.3 Cleaning*

Clean the instrument with a cloth lightly moistened with water with a small amount of mild detergent. Alternatively, a cloth lightly moistened with alcohol (ethanol or methylated spirit) or isopropyl alcohol (IPA) may be used.

*Do not spray cleaners directly onto the instrument.*

### *5.4 Technical Support*

For technical support contact your local Polar Instruments distributor or Polar Instruments.

# SECTION 6 – APPLICATION NOTE

## QUESTION ABOUT PLANE SHORTS

For full details on using the PLANE SHORTS range refer to Section 4.3.

*Even if I can find the location of a short on a multi-layer board, will I be able to repair it?*

Most shorts on multi-layer boards have similar causes to those on single or double-sided boards — solder bridges, track bridges, bent components, etc. These usually occur on the surface of the board and can be rectified as normal.

*The displayed reading is different when the same point is probed several times.*

Check that you are not touching the probe tip as this will interfere with the measurement.

*When I move a probe 10mm away from the short the reading is lower than another point that is closer to it!*

This is caused by variations in the physical shape and resistance characteristics of the plane. Once you are close to the short, probe all appropriate points in the area and look for the lowest reading.

*I cannot obtain a reading less than 10.0.*

The actual short may be some distance from the points being probed. Example #2 in Section 4.3 describes a situation where the short occurs at the Vcc pin of an integrated circuit, but the user is stimulating (and therefore probing) the ground plane. If you are unable to obtain under 10.0 it may be necessary to remove components around the area of the lowest reading to locate the short. *Visually inspect the area* as a *hard short* is usually caused by a solder or track bridge, or bent component lead.

*What is a "hard short"?*

A hard short is one whose resistance is under 200mΩ, typically caused by a solder or track bridge or bent component lead. If the short resistance exceeds 1Ω, it is probable that a defective component is the cause of the fault.

*What if the short resistance is greater than 30Ω?*

If the resistance of the short is high, the resolution of the 950 is reduced. Moving the Plane Stimulus leads to stimulate a smaller area of the board will help compensate for this. This may be repeated as necessary.

*What are the symptoms of multiple shorts?*

If the results of probing the stimulated plane are inconclusive, try probing the *un-stimulated* plane. If varying readings greater than 5.0 are obtained, this suggests that there are multiple shorts between the planes.

*How do I find multiple shorts?*

These shorts are more difficult to locate since the Direction Arrows cannot be used. The technique reverses the method used to find a single short — in this situation the user probes the *un-stimulated* plane and looks for the *highest* reading in the display. Since the Arrows cannot be used it will be necessary to probe the plane randomly until an area is found where the readings are higher than surrounding points on the plane. Then probe all the points in that area to find the highest reading.

*What if the results are still inconclusive after testing for multiple shorts?*

This may indicate that there are multiple catastrophic device failures on the board causing multiple high resistance paths between the planes. To troubleshoot in this situation it will be more effective to use an instrument such as the T3000 Fault Locator to test components on the board and replace them as necessary.

*The Direction Arrows point in different directions when points that are close to each other are probed.*

This indicates that the probe is close to the short. Ignore the Arrows and use the probe to find the lowest displayed reading.

*Two of the Direction Arrows are lit at the same time.*

This also indicates that the probe is close to the short. Ignore the Arrows and use the probe to find the lowest displayed reading.

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