User Guide

Toneohm 950A

MULTI-LAYER SHORTS LOCATOR

Polar Instruments Ltd

Polar Instruments Ltd.
Garenne Park
St. Sampson
Guernsey
Channel Islands
GY2 4AF
ENGLAND
email: polarcare@polarinstruments.com
https://www.polarinstruments.com

MAN 209–2411

Toneohm 950A User Guide

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.

2. Warranty Claims. Polar shall incur no liability under this warranty if the end user fails to provide Polar with notice of the alleged defect during the applicable Warranty Period and within seven (7) days of delivery to end user or, if the defect would not have been reasonably apparent on inspection, within seven (7) days of its discovery by end user. After receiving such notice, Polar will notify the purchaser of its designation of one of the following problem resolution methods:

   Return to Factory: The allegedly defective goods must be returned to Polar within seven days of Polar's notice and in accordance with Polar's instructions advised at the time.

   Other: Polar will use commercially reasonable efforts to repair, correct or work around the problem by means of telephone support or other means reasonably determined by Polar.

   Polar shall incur no liability under this warranty if Polar's tests disclose that the alleged defect is due to causes not within Polar's reasonable control, including alteration or abuse of the goods. Under the *Return to Factory* alternative, if a Product is determined not to be defective or to have a defect due to causes not within Polar's reasonable control, Polar reserves the right to apply a processing charge.

3. Damage in Transit. End user must notify Polar and the carrier of any claim for damage in transit within two (2) days of receipt of the damaged merchandise. Failure to do so may result in the carrier and/or Polar refusing to accept liability in which case end user must pay the purchase price as if the hardware had been delivered without damage.

4. Polar's Liability Polar's liability, and end user's sole and exclusive remedy, shall be limited to the express remedies set forth in this Polar Hardware Warranty.

COPYRIGHT

Due care was exercised in the preparation of this document. Polar Instruments Ltd. shall not be liable for errors contained herein or for incidental or consequential damages in connection with furnishing, performance, or use of this material.

Polar Instruments Ltd makes no warranties, either expressed or implied, with respect to the product described in this manual, its quality, performance, merchantability, or fitness for any particular purpose.

DISCLAIMER

1. Disclaimer of Warranties

POLAR MAKES NO OTHER WARRANTIES, EXPRESS, IMPLIED OR STATUTORY, REGARDING PRODUCTS. ALL OTHER WARRANTIES AS TO THE QUALITY, CONDITION, MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT ARE EXPRESSLY DISCLAIMED.

2. Limitation of Liability.

POLAR SHALL NOT BE RESPONSIBLE FOR DIRECT DAMAGES IN EXCESS OF THE PURCHASE PRICE PAID BY THE END USER OR FOR ANY SPECIAL, CONSEQUENTIAL, INCIDENTAL, OR PUNITIVE DAMAGE, INCLUDING, BUT NOT LIMITED TO, LOSS OF PROFITS OR DAMAGES TO BUSINESS OR BUSINESS RELATIONS, WHETHER OR NOT ADVISED IN ADVANCE OF THE POSSIBILITY OF SUCH DAMAGES, THE FOREGOING LIMITATIONS SHALL APPLY, NOTWITHSTANDING THE FAILURE OF ANY EXCLUSIVE REMEDIES.

DECLARATIONS

EUROPEAN COMMUNITY DIRECTIVE CONFORMANCE STATEMENT

Product: Toneohm 950A

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

EC Council Directive **2014/30/EU** (commonly referred to as “the EMC Directive”) on the approximation of the laws of the Member States relating to electromagnetic compatibility.

EC Council Directive **2014/35/EU** (commonly referred to as the LVD Directive”) on the harmonisation of the laws of the Member States relating to electrical equipment designed for use within certain voltage limits.

EC Council Directive **EC 1907/2006** as amended by **2015/863/EU** (commonly referred to as “the RoHS 3 Directive”) on the Registration, Evaluation, Authorisation and Restriction of Chemicals (**REACH**) as regards skin corrosion/irritation, serious eye damage/eye irritation and acute toxicity

EC Council Directive **2012/19/EU** (commonly referred to as “the WEEE Directive”) on waste electrical and electronic equipment.

Standards applied in order to verify compliance:

EN55011:2016+A1:2017+A2:2021

EN IEC 61000-3-2:2019+A1:2021+A2:2024

EN 61000-3-3:2013+A2:2021

EN IEC 61326-1:2021

EN61010-1:2010+A1:2019

The CE-mark was first applied to this product in 2024.

The manufacturer of this product takes full responsibility for this declaration of conformity:

Polar Instruments Ltd

Garenne Park

St Sampsons

Guernsey

GY2 4AF

Signed for Polar Instruments Ltd:

Nigel A. Mann (Director)

This declaration issued 28/08/2024

SAFETY

WARNING

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

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.

Return to factory repair service

This unit contains no user-serviceable parts. Polar Instruments provides a Return-to-Factory repair service for a malfunctioning instrument – contact your local Polar office

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

The Toneohm 950A is fitted with a universal power supply – the power source input range is within AC 90 – 250 volt, 50 / 60 Hz

Toneohm 950A 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.*

Operating environment

The Toneohm 950A 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 950A 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 **Ohms** (track resistance), **Plane** (plane shorts) and **Trace** ranges.

Specifications

Track Resistance

Ranges	40mΩ, 200mΩ, 2Ω, 200Ω, 2KΩ, 20KΩ.
Accuracy	± 20% of FSD in 40mΩ, ±6%, ±5% of FSD in 200mΩ, ±5%, ± 1% of FSD in 2Ω το 20KΩ
Probe voltage	260mV maximum.
Indication	DVM and Bar-graph in all ranges. Tone in 40mΩ, 200mΩ, 2Ω, 20Ω, 200Ω
Probe protection	Momentary contact up to 30V

Track Voltage

Ranges	2mV, 20mV, 200mV, 2V, 20V.
Accuracy	±5%, ±20μV.
Input resistance	120Ω in 2mV, 20mV. 1MΩ in 200mV, 2V, 20V.
Indication	DVM and bar-graph in all ranges. Tone in 2mV, 20mV, 200mV, 2v
Probe protection	Momentary contact up to 30V

Plane Shorts

Indication	Tone, uncalibrated DVM and bar-graph, 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 in **Plane** mode
Output current	500mA RMS maximum.
Protection	Each output separately fused (5A Fast)

Drive Source

Output voltage	0 to 500mV, adjustable. 0 to 100mA peak into a short circuit. 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
Mains supply fluctuations	Up to 10% of nominal voltage
Pollution Degree	2

Power Requirements

90 to 264V AC, 47 to 63Hz, 0.49A max, 20VA.

Physical characteristics (excluding accessories)

Dimensions	275mm (11 in.) wide.
	160mm (6.3in.) high.
	110mm (4.4 in.) deep.
Weight	2.7 kg.

Guide to the Manual

Introduction	Introducing Polar Instruments Toneohm 950A	
Getting started with the Toneohm 950A	Toneohm 950A operating modes	
Using Toneohm 950A	Using the Toneohm 950A's operating functions:	
	Ohms – Track Resistance	Using the Toneohm's milli-ohmmeter for locating low resistance shorts.
	Plane – Plane Shorts	Use the Toneohm's Vector Plane Stimulus on multilayer boards to locate shorts between a track and plane or between two planes.
	Trace – Current Trace	Non-contact current tracing where access to tracks or components is difficult.
	Volts/mVolts – Track Voltage	Digital Voltmeter – enables current flow to be traced by measuring the voltage drop caused by the current flowing in a track. Use when tracing loading faults on very low resistance tracks.

Contents

Introduction to the Toneohm 950A

Multi-Layer Shorts Locator

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 950A operating modes

The Toneohm 950 Multi-Layer Shorts Locator has multiple operating modes to enable the user physically to locate any type of short circuit without lifting components, cutting tracks, or otherwise damaging the board under test:

Ohms – Track Resistance	Milli-ohmmeter for locating low resistance shorts.
Trace – Current Tracer	Non-contact current tracing where access to tracks or components is difficult.
Volts/mVolts – Track Voltage	Digital Voltmeter – 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 – Plane Shorts	Used on multilayer boards to locate shorts between a track and plane or between two planes.

Installing Toneohm 950A

Unpacking

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

The Toneohm 950A carton should contain the following:

Toneohm 950A

ACC455 Needle probes

ACC456 Current Trace Probe / Drive Source lead assembly

ACC457 Plane Probe / Clip assembly

ACC134 Set of four Plane Stimulus leads

EPM115 Headphones

Power cord to suit location

Retain the packaging for possible future use.

NOTE: If the Toneohm 950A has been shipped or stored in a cold environment, allow the instrument to reach the temperature of its new location before applying power.

Connecting the Toneohm 950A to a power supply

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.

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

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

Plug the other end into a wall outlet.

Connectors and probes

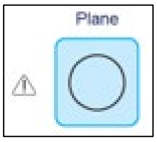
Toneohm 950A probes

The instrument is supplied with sets of probes to support the operating functions. Each probe fits into a unique socket on the front panel.

Probe color coding

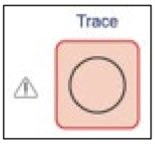
Probes are color coded to match the probe connection color as shown in the connectors below.

Plane probe



The Plane probe and Clip are used in the Plane 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.

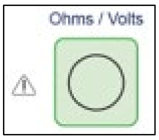
Current Trace probe and Drive Source leads



The magnetic Current Trace probe is used to detect currents flowing through tracks, components, etc. without making physical contact. The probe is tuned to the frequency of the AC current supplied by the Trace Drive Source when Trace is selected. The Trace/Drive Source leads (a pair of red and black clips) are used to inject the current into the board.

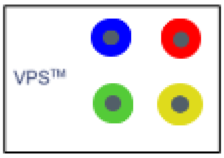
When the Volts/mVolts ranges are selected the Drive Source output is a DC voltage (red clip positive) which can be used to stimulate the board under test.

Ohms/Volts needle probes



The Ohms/Volts needle probes are used in the Ohms and Volts ranges. Red (positive) and black (negative) markings on the probes indicate direction of current flow in Volts.

Plane Stimulus leads

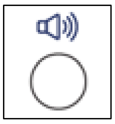


Four test clips (color-keyed) used in the Plane range to stimulate the shorted plane.

The colored sockets shown left indicate the relative plane connections on the board under test:

- blue lead to the top left corner of the plane
- red lead to top right
- green lead to bottom left
- 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.

Controls

Mode/Range/Sensitivity function selector

Mode/Range/Sensitivity function selector

Press repeatedly to cycle through / activate:

- Modes – then rotate to select the mode
- Ranges – (if available in the selected mode) then rotate to select the range – see *Ranges*
- Sensitivity – (if available in the selected mode) then rotate to change sensitivity/drive source voltage

Volume/Mute

The Volume/Mute control

- Adjusts the volume of the speaker or headphone output. Press to mute/unmute.

Ranges

Track Resistance

Resistance ranges:
~40 mΩ, 200 mΩ, 2 Ω, 20 Ω, 200 Ω, 2 KΩ and 20 KΩ

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 2 Ω ranges for locating low resistance shorts. These ranges are sensitive enough for measuring track resistance. 200 mΩ is approximately five times more sensitive than 2 Ω.

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

To protect PCB components, the maximum voltage at the probe tips on these ranges is 260mV.

Track Voltage

Voltage measurement ranges:
2 mV, 20 mV, 200 mV, 2V and 20 V

The voltage measurement ranges enable current flow to be traced by measuring the voltage drop caused by the current flowing in a track. Voltage measurement will be found useful, for example, when tracing loading faults on very low resistance tracks.

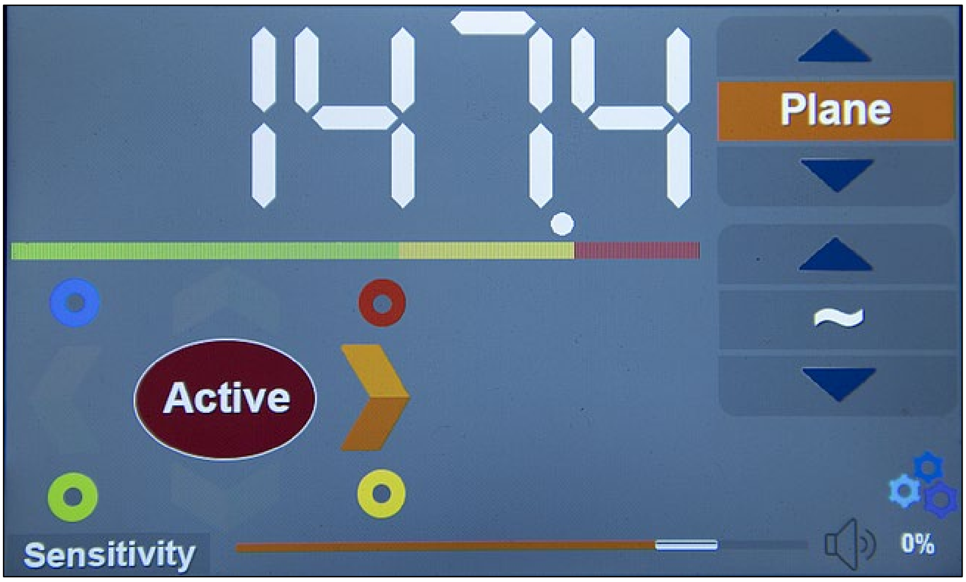
Trace

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 screen 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).

Sensitivity may be adjusted via the Sensitivity control.

Toneohm 950A display

The Toneohm 950A display is a touch display module.



The touch display module – shown above in Plane mode – allows for touch control of modes, Volts/mVolts and resistance ranges and drive source and also gives an indication of the parameter being measured in the units appropriate to the selected range. Touch the arrows to change Mode and Range and touch and drag the bar to change sensitivity/Drive source.

When Trace or Plane is selected, the displayed values are uncalibrated but proportional to the reading at the probes.

Plane Shorts Active / direction arrows

The 950A indicates **Active** to signify the four plane drives are correctly connected to the plane.

Missing or wrongly connected leads will be indicated by **Missing Plane Drive**.

Four on-screen arrows indicate the direction in which the Plane Probe should be moved to locate the fault.

The arrow indicators operate as in the table below:

Probe Unconnected	Probe Distant	Close to Fault
All arrows off	Direction arrow on	All arrows on

Getting started with the Toneohm 950A

Online tutorial guides

Polar's web site provides online downloadable quick start videos and version specific user guides to familiarize users with the operation and features of the product.

Video

Locating ground plane shorts – getting started with the Toneohm_950

Application Notes

Toneohm 950 helps you find Power to Ground shorts

Application Note AP201

Finding power to ground plane shorts

Application Note AP202 describes how Polar's Toneohm 950A's vector plane stimulus (VPS) helps find ground plane shorts (PowerPoint presentation)

Download the latest version of the Toneohm User Guide

Self-test

When the instrument is switched on it performs a self-test. During the self-test, the front panel screen is exercised in sequence. Do not operate front panel controls during the self-test. If the test passes, the instrument is left in the last operating mode used

Using the Toneohm 950A Shorts Locator

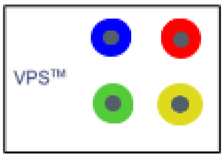
The Toneohm 950A Front Panel

The Toneohm 950A front panel comprises:

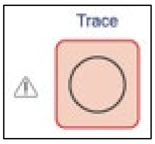
Display screen

Mode/Range/Sensitivity function selector (Press knob) and range or sensitivity by rotation once selected.

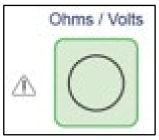
Volume(Rotate)/mute control (Press)



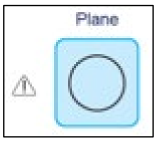
VPS drive connectors



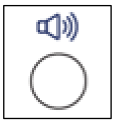
Current Trace probe connector



Ohms/Volts needle probes connector



Plane probe connector



3.5mm headphone/speaker socket – when the headphones are connected to this socket the internal speaker is switched off.

Mode/function control

Press the Mode control successively to activate the Mode function/Range/Sensitivity as shown below;

Mode/function – press successively to activate:

- Mode/Function
- Range
- Sensitivity

The activated function is highlighted

Mode/Function highlighted

Rotate to select:

- Ohms
- Trace
- Plane
- Volts

Range highlighted

Ohms – Rotate to select:

- ~40 mΩ
- 200mΩ
- 2Ω
- 20Ω
- 200Ω
- 2KΩ
- 20KΩ

Volts/mVolts – Rotate to select:

- 2mV
- 20mV
- 200mV
- 2V
- 20V

Sensitivity highlighted

Rotate to:

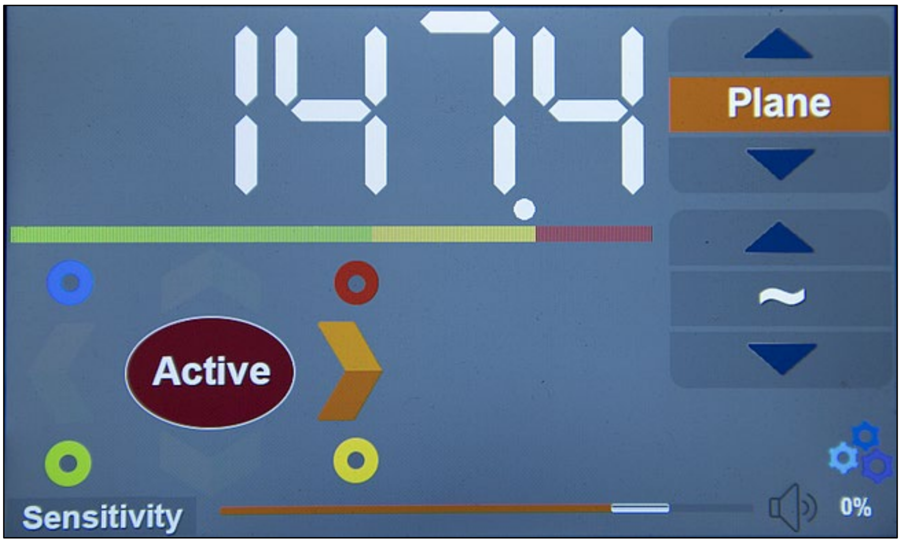
- In Trace mode – adjust Drive Source
- In Plane mode – adjust Sensitivity
- In Volts mode – adjust Drive Source

See *Sensitivity Adjustment* below

Press to mute/unmute or Rotate to:

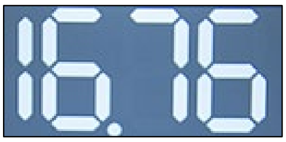
- Adjust Speaker / Headphone volume

The Toneohm 950A screen



The Toneohm 950A screen (shown in Plane mode above) reflects:

- The mode selected: Ohms, Volts, Trace or Plane



- The numerical reading associated with the mode (Volts, Ohms in their respective ranges, unitless values in Trace and Plane modes) This numeric value is also represented by a bar graph.

- The resistance range (FSD) in Ohms mode

- Voltage range (FSD) in Volts/mVolts mode

- Direction arrows in Plane mode to guide the user to the plane short

- Sensitivity shows the level of the drive source in Volts or Trace mode or Sensitivity in Plane mode

- Speaker/ headphone volume 0-100% and mute status

- Readings out of Range

- Plane Drive Active

- Missing plane drive in Plane mode – check all plane drive leads for secure / correct connection – see *Connectors and probes – Plane Stimulus Leads*

Locating faults with the Toneohm 950A

Mode / 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 mode / 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?)

Low resistance shorts

Static
For static shorts – the **Ohms** (track resistance) function is applicable to locating static, low resistance shorts on single or two-sided boards.

Dynamic
If the fault is dynamic then use **Volts/mVolts** (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 **Trace** mode and 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** (plane shorts) function is the optimum mode to use. However, if the fault is dynamic, it will be necessary to use the **mVolts/Volts** (track voltage) function. The table below indicates the suggested range for locating different types of short circuit.

Type of fault	Mode/Range
Shorts below 200 mΩ	Ohms – 2Ω, 200 mΩ
Multi-layer shorts (static)	Plane (plane shorts)

Stuck Bus line (static)	Trace
Backplanes/wiring harnesses	Trace
Open Circuit Capacitor	Trace

Mode / Range selection

Ohms – 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 **Ohms**, 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 ~40 mΩ range. Note that the ~40 mΩ range is subject to probe contact resistance variation.

As the 950A uses DC for resistance measurement, capacitors do not affect its accuracy. The open circuit probe tip voltage is limited to a maximum of 260mV 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.

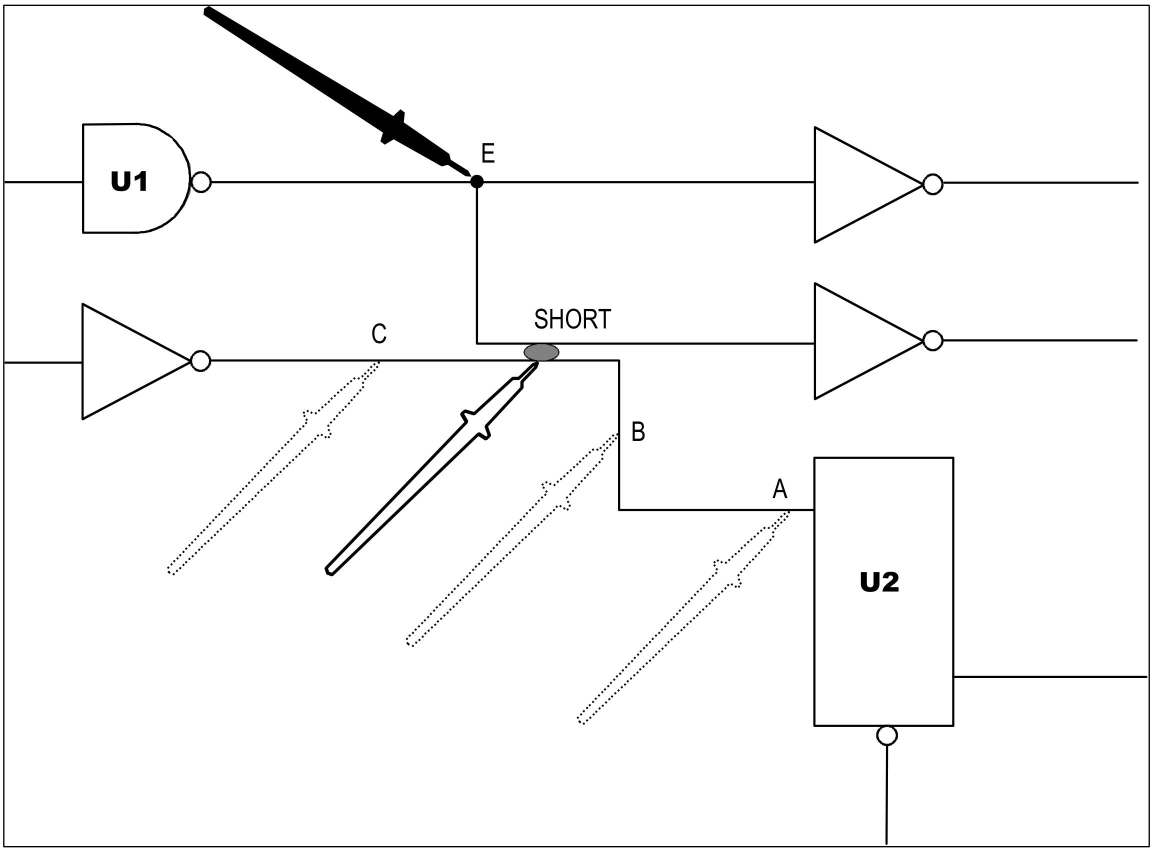
It is not unusual for a fault to be located between two parallel tracks where there is no visual sign of a short, even using an eyeglass. This often happens if the board is covered with solder resist, masking a hairline whisker short. Use a suitable tool to cut between the tracks through the solder resist 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 Trace — *Current Tracing (Non-Contact).*

Example – Low Resistance Short

Refer to the Figure below – Low Resistance Short – 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.



Low Resistance Short

Plane – locating plane shorts

> CAUTION: Disconnect power from the board under test before using Plane
>
> NOTE: The Plane Stimulus outputs should only be connected to a PCB plane – do not connect to PCB tracks

The Plane range is effective in physically locating shorts between a track and a plane, or between two planes.

The Plane screen comprises:

- The (unitless) numerical reading associated with the Plane mode
- The Active indicator to signify the four plane drives are correctly connected to the plane.
- VPS drive connector indicators – corresponding to the four color-keyed test clips used to stimulate the shorted plane.
- Four on-screen arrows indicate the direction in which the Plane Probe should be moved to locate the fault.

The arrow indicators operate as in the table below:

Probe Unconnected	Probe Distant	Close to Fault
All arrows off	Direction arrow on	All arrows on

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

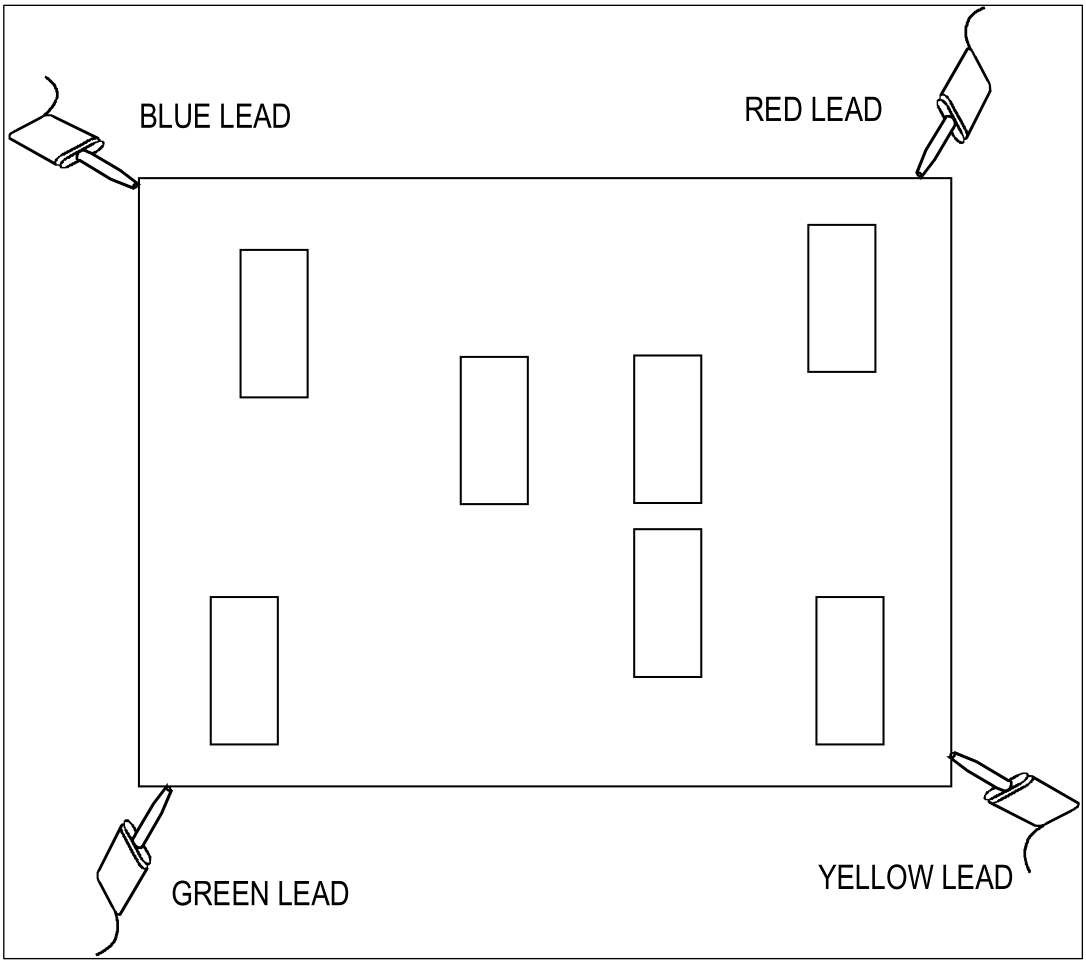
Polar Instruments has evaluated many defective multi-layer boards (both bare and assembled) from a range of manufacturers and found that the cause of most of these faults are the same as on single or double-sided boards (e.g. solder bridges, bent component leads, etc.)

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 below – Plane Stimulus Connection.



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.) and to the blue, red, green and yellow annular ring indicators on the display screen.

- Connect the colored leads 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.
- Enter Plane mode
- Check the Plane Stimulus leads are connected correctly,
- If the warning beep sounds and the 950A returns to Missing Plane Drive, 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 550mV, and disconnecting any one of them will automatically turn the stimulus off and return to Missing Plane Drive.

Sensitivity Adjustment

The Sensitivity / 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 Sensitivity / Drive Source
- 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, 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 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.

Avoid touching the probe tip when probing, as this will interfere with the measurement being made.

The four Direction Arrows in 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.

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/contact pad 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 950A 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. If some readings are high, 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 *Trace – 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.

Trace – Current Tracing (non-contact)

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

Locating faults using Trace

Trace mode 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, for example, a track running under an IC or in the middle layer of a multi-layer PCB.

Trace Drive Source
When using Trace, the current must be supplied by the Trace Drive Source leads.

The Trace/Drive Source leads (a pair of red and black clips) are used to inject the current into the board. The Trace Drive Source drives an AC current and the resulting magnetic field is detected using the Current Trace Probe.

The maximum voltage generated by the Trace Drive Source is 500mV, which will not damage devices or turn on silicon junctions. Its amplitude can be adjusted using the Sensitivity control.

The peak current supplied is approximately 100mA

Current Trace Probe
Trace uses the *non-contact* Current Trace Probe to detect the magnetic field intensity of current flowing from the Trace

Drive Source. The reading on the screen is proportional to the intensity of the field and therefore to the magnitude of the current. The magnetic Current Trace Probe is used to detect currents flowing through tracks, components, etc. without making physical contact. The probe is tuned to the frequency of the AC current supplied by the Trace Drive Source when Trace is selected.

The sensitivity of the Current Trace Probe depends on the orientation of its tip.

Rotate the probe for maximum sensitivity. This can be observed by the display reading and tone frequency increasing.

Connection and Sensitivity Adjustment

Connect the Trace Drive Source leads across the shorted tracks and set the Trace Drive Source / Sensitivity to maximum. 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.

To alter the distance over which the probe detects current, adjust the Sensitivity.

Trace 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.

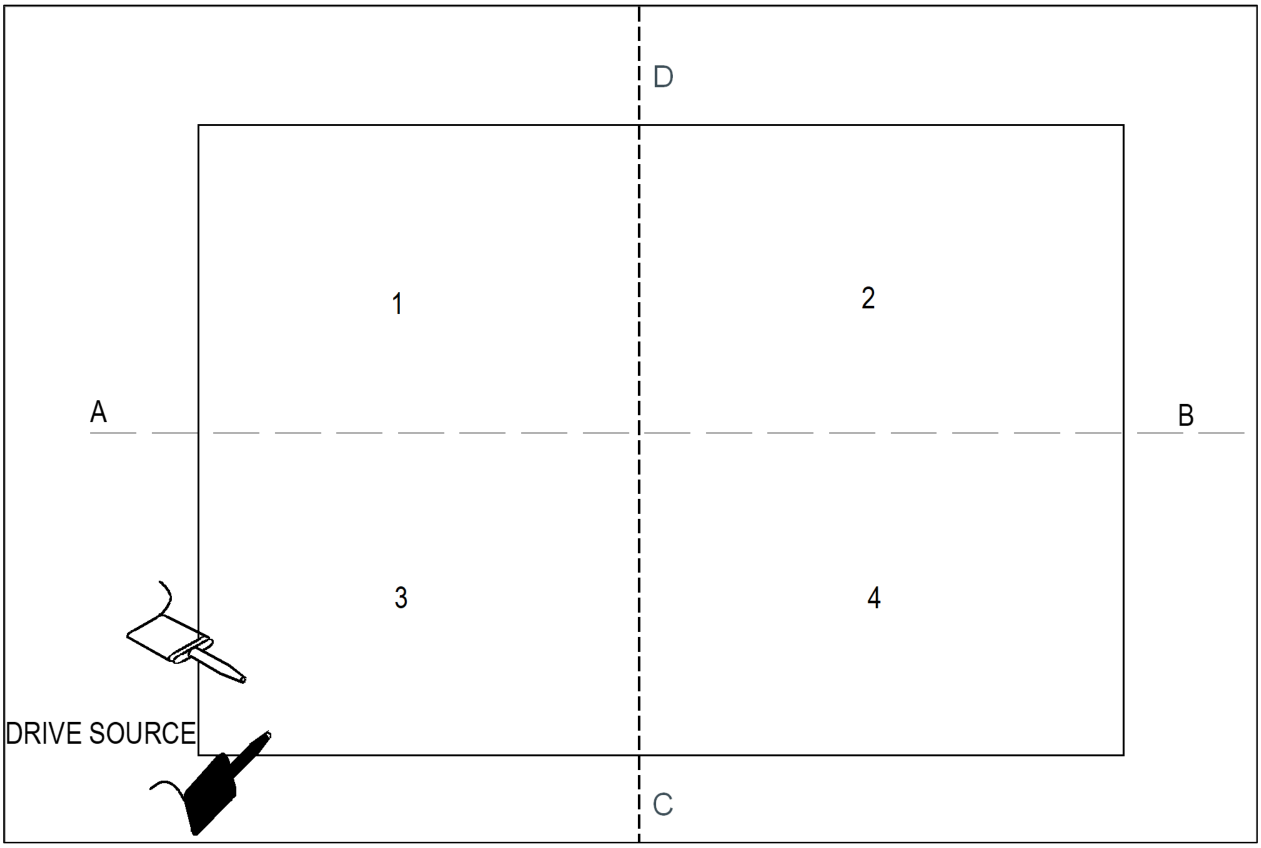
When using the Current Trace Probe take care not to detect the magnetic field from the Drive Source leads draped over the PCB.

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 – 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 Board Sectoring graphic below.)



Board Sectoring

* Connect the Drive Source Leads 10-20mm apart near one corner of the board (Sector 3 in the Board Sectoring graphic above.)
* 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 (for example, 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.

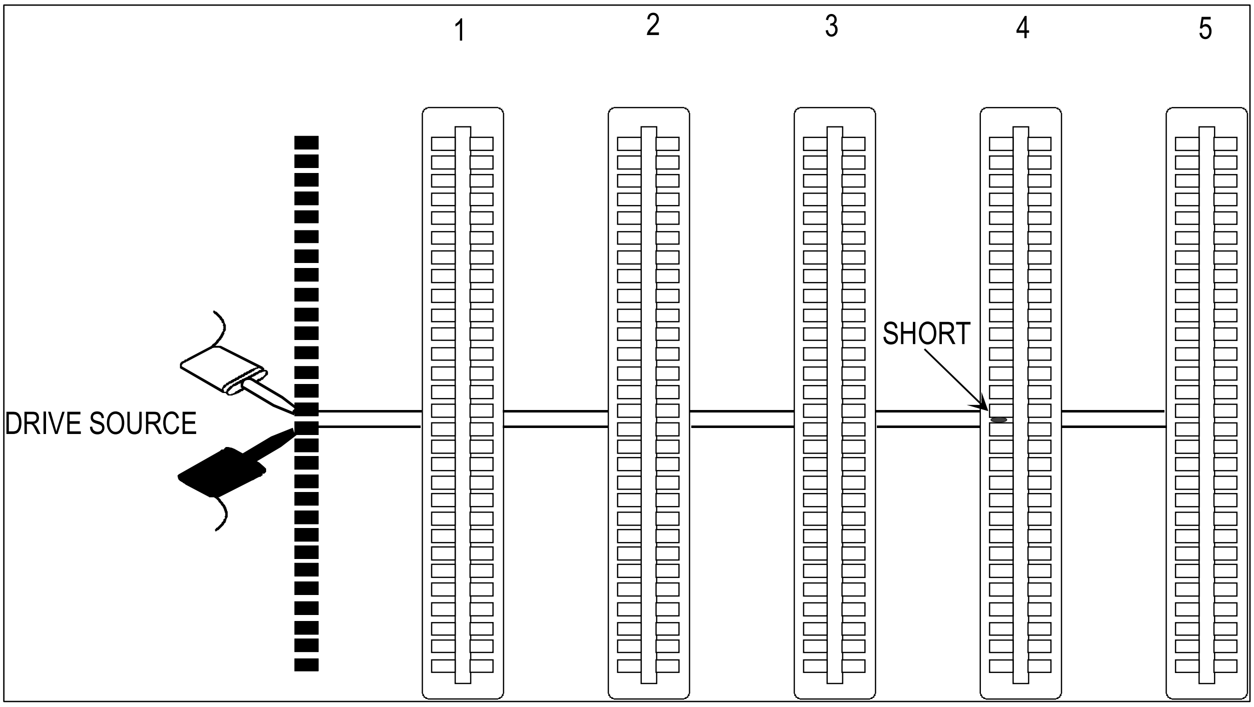
Bus lines have little or no capacitance so when one device is known to be holding the bus down, current tracing is often the quickest way to isolate the fault.

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 output (Sensitivity) so that the Trace Probe responds within 10mm of one of the Drive Source leads.
* Pass the Probe over each suspect IC, probing each IC pin in turn.
* 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 below



Edge Connector Shorts

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

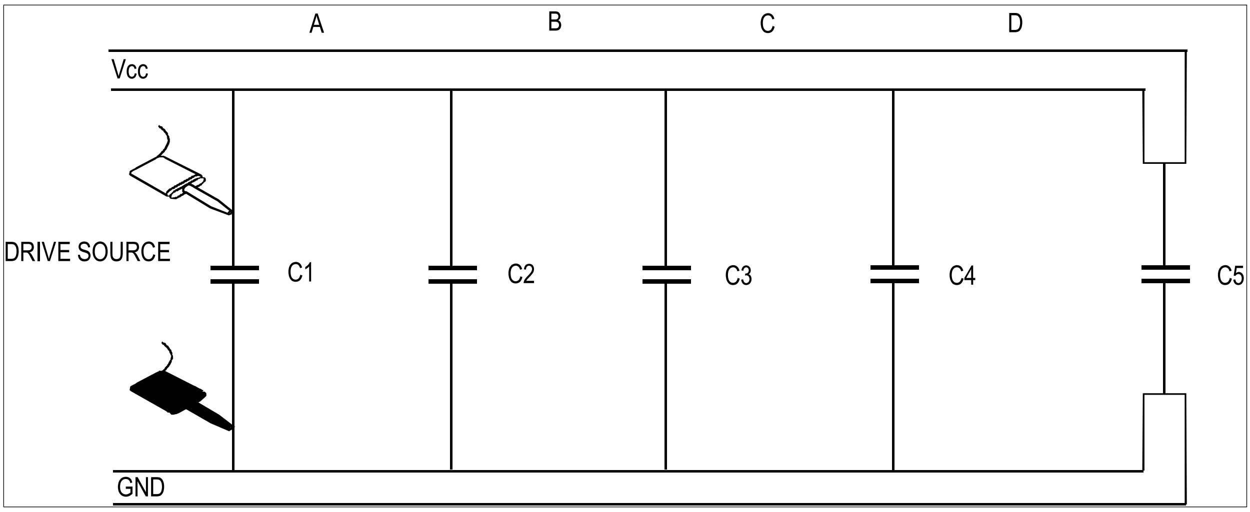
* Move the Probe down the gap between each connector in turn, starting nearest to the Drive Source leads.
* As the Probe is moved between connectors 1 and 2, 2 and 3, 3 and 4, a tone is generated. However, when the Probe is moved between connectors 4 and 5 there is no tone, showing that no current is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

The graphic below provides an example.



Isolation of Open Circuit Decoupling Capacitor

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

The Current 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.

Volts/mVolts – track voltage measurement

The Volts/mVolts mode and associated voltage ranges provide a method for tracing the flow of a DC current through a PCB track.

This is particularly applicable where the tracks are very thick (i.e. very low resistance.)

If the fault is static, it is recommended that the Trace Drive Source is connected between the faulty nodes to supply the current. Its output of 500mV 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, 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 below.

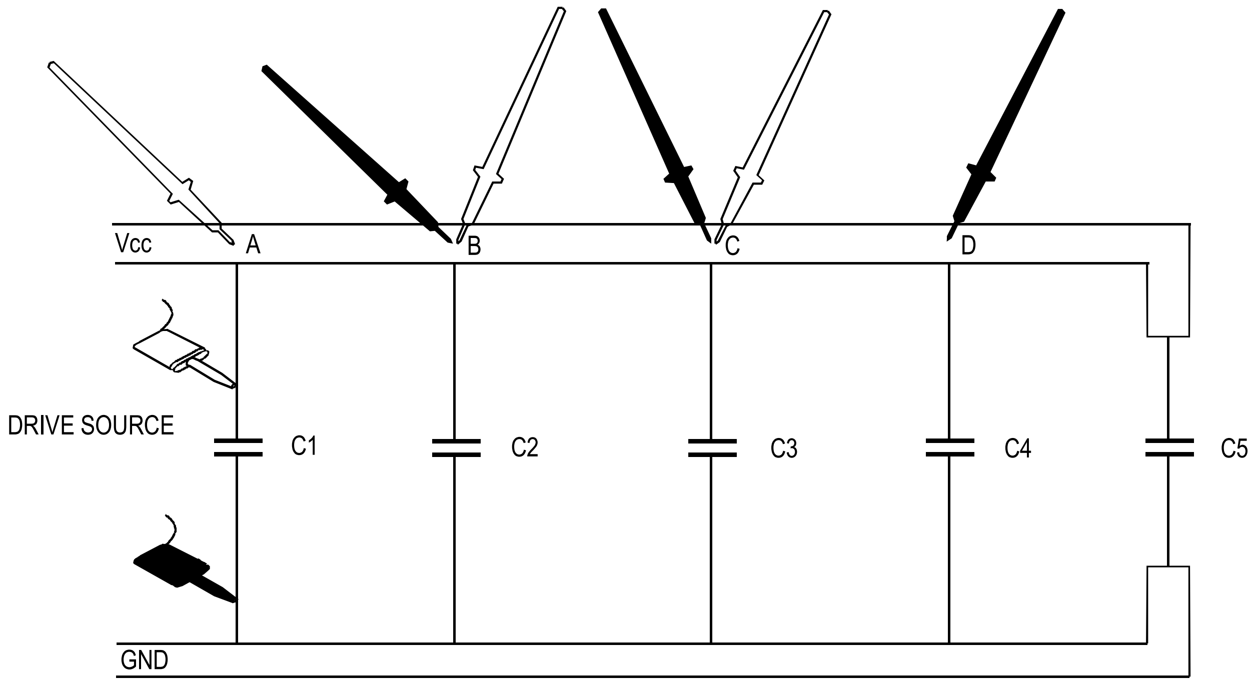
As the tone is proportional to the voltage measured, it is usually sufficient to follow the tone change rather than check readings.

NOTE: Do not place too much reliance 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 950A does not produce a tone for readings below about 50µV.

Example – Excessive Vcc Loads

See Trace section for a preferred method of tracing current. However, if the PCB tracks are very thick (i.e. very low resistance) then use the following method.

Consider the board shown below where the Vcc supply is being loaded. Assume the fault is static.



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

Application Note: Questions about Plane – plane shorts

For full details on using the Plane range refer to
Plane – locating plane shorts

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 *Operation (Single Short)* 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 Toneohm 950A 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.

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.