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Controlled Impedance Test System

Operator Manual

CITS800s (32-bit)

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Instrument	CITS800s

Serial Number	
Software version	
Name	
Company	
Job Title	
Address	
Post/ZIP Code	
Country	
Telephone	
Fax	
E-mail	

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CITS800s OPERATOR MANUAL

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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

   TDR Head warranty
   This product is an extremely sensitive measuring instrument. To prevent damage it is essential to observe static precautions at all times. The TDR head will be damaged if any voltage (e.g. from static) is applied to the probes.
   The warranty period for the TDR head is six (6) months or until one failure, whichever occurs sooner. Reliability statistics indicate that if the TDR head is damaged, it is likely to have arisen from misuse (e.g. static damage or similar) and as these circumstances are outside Polar Instruments' control, any further failures will not be covered by warranty.

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.
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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.

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DECLARATIONS

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
20 Picton House
Hussar Court
Waterlooville
Hampshire
England PO7 7SQ

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

EN 61326:1997

EN 61010-1:2001

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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

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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 CITS Service Manual published by Polar Instruments.

CITS 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 unit is designed for use indoors in an electrical workshop environment at a stable workstation comprising a bench or similar work surface. Use only the accessories (e.g. test probes and cables) provided by Polar Instruments. The unit 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

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CAUTION

Electrical Isolation

Always disconnect the board under test from the local mains supply (including ground) before using this instrument. The CITS applies test voltages to the item under test. Make sure that the item under test is isolated from all other sources of electrical power. External power could damage the tester.

Static Sensitive Devices

This unit contains Static Sensitive Devices. Observe static precautions at all times.

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SPECIFICATIONS

Test parameters

Controlled Impedance Measurement Range	20 – 150Ω (single-ended) 40 - 200Ω (differential)
Measurement Accuracy (single-ended) *Calibrated against traceable airline standards at 28Ω, 50Ω, 75Ω and 100Ω*	1.5% at 28Ω 1% at 50Ω 1.25% at 75Ω 1.5% at 100Ω
Measurement Accuracy (differential, typical) *Typical values for even mode Z_{oe}< 100Ω.* *For 100Ω< Z_{oe}< 150Ω add 1%.* *For 150Ω< Z_{oe}< 180Ω add 1.5%.*	2.5% at 56Ω 2% at 100Ω 2.5% at 150Ω 3% at 200Ω
Impedance Tolerance Range	0.1% – 99.99%
Vertical Display Ranges (Ω)	1, 2, 5, 10, 20, 50Ω/division
Vertical Display Ranges (mRho)	10, 20, 50, 100, 200, 500 mRho/division
Horizontal Display Ranges	Automatically set by software
Testable Trace Lengths Optimum Minimum (using non-matched probe) Minimum (using matched probe) Maximum	 0.09 meters 0.09 meters 0.04 meters 15 meters
Horizontal Distance Units	Inches, feet, meters, millimeters
Horizontal Time Units	Nanoseconds, picoseconds
Test Method	Time Domain Reflectometer (TDR measurement using PC software control)
Reflected Pulse Risetime	≤ 200ps
System Bandwidth	1.75 GHz (derived from maximum risetime)
Output Impedance	50Ω (± 2%)
Pulse Amplitude	Nominal 300mV into 50Ω load
Calibration Method	Ratiometric measurement to calibrated precision internal 50Ω reference
Series Loss Compensation	0 – 5Ω/inch
Vp Compensation	0.33 – 0.99
Relay Life	2×10^6 operations/channel (typical)

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Channels	CITS800s2	2
	CITS800s4	4
	CITS800s8	8

ENVIRONMENTAL OPERATING CONDITIONS

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

Altitude	Up to 2000m
Temperature	+10°C to +30°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 IEC60364–4–443
Pollution Degree	2

Power Requirements

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

Physical characteristics (excluding accessories)

Temperature	
Operating	10°C to 30°C
Storage	0°C to +50°C
Dimensions	
	446 mm (17.6 in.) wide
	132 mm (5.2 in.) high
	300 mm (11.81 in.) deep
Weight	6.9kg (15.2 lb.)

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SYMBOLS

 CAUTION No external voltage should be applied to these terminals. Read Section 2 — INSTALLATION for information on how to use these connectors

 CAUTION Static sensitive devices — observe static precautions. A wrist strap is provided with the CITS (connect the wrist strap to the socket on the CITS front panel).

Note: The CITS contains static sensitive devices — observe static precautions at all times.

PERSONAL COMPUTER REQUIREMENTS

Computer	IBM PC AT or compatible
Processor	Pentium 100 or better
Operating system	Microsoft Windows 95, Windows 98
	Windows NT, Windows 2000
System memory required	16MB Windows 95, Windows 98
	32 MB Windows NT, Windows 2000
Hard disk space required	2MB (min.)
Video standard	SVGA (800 x 600 min.)
Diskette drive	3½" High density – 1.44Mbyte
CDROM	
Mouse	Microsoft compatible
Printer port	1 x parallel printer port
Communication ports	1 available serial communication port required

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ACCESSORIES

Standard Accessories

Probe Cable	WMA326
IP-50 Microstrip Probe (50Ω)	
IPD-100 Differential Probe (100Ω)	
Sample Test Coupon	MPCD1325
Operator manual	MAN174
RS-232 interface cable	ACC142
Foot Switch	ACC124
Antistatic wristband	ACC175
Wrist band ground cord	ACC185
50 ohm reference impedance	ACC254
Torque wrench	ACC313
Manufacturing data files diskette	FSW148
Software disk	FSW163
SMA Adaptor	MQX428
Software Key (Parallel Port)	DGL130
Software Key (USB Port)	DGL131

Optional Accessories

Instrument carrying case	ACC125
Coupon Holder	ACC153
CITS Service Manual	MAN143
Barcode Reader	ACC186
IP-28 Microstrip Probe (28Ω)	
IP-60 Microstrip Probe (60Ω)	
IP-65 Microstrip Probe (65Ω)	
IP-75 Microstrip Probe (75Ω)	
IP-100 Microstrip Probe (100Ω)	
IP-50V Variable-pitch Microstrip Probe (50Ω)	
Datalog Report Generator	ACC230
CITS Verification Kit	ACC229
Si6000 (Full version)	
28Ω Reference airline	ACC232
50Ω Reference airline	ACC233
75Ω Reference airline	ACC234
100Ω Reference airline	ACC235
150Ω Verification resistor box (“a” models only)	ACC347

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GUIDE TO THE MANUAL

INTRODUCTION	An overview of the Polar CITS800s. A description of the principles of operation and explanation of basic TDR principles and controlled impedance.
INSTALLATION/SET UP	Connecting the instrument to a power supply, installation of software and preparation for use. Specifying the PC communication ports, calibration type and passwords.
GETTING STARTED	Introduction to basic CITS operation using the supplied sample Test Coupons.
OPERATION	Operation of the CITS800s. Information about the different ways in which the facilities of the CITS800s can be used and how to test boards.
THE TEST FILE EDITOR	Description of test parameters — creating, writing and saving test files.
MAINTENANCE	Details of maintenance and cleaning procedures.
APPENDIX A	Notes on Characteristic Impedance.
APPENDIX B	Notes on static sensitive devices and preventing damage to the CITS.

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OPERATING THE CITS800s

The CITS software is designed for use within the Microsoft Windows environment. Familiarity with the Microsoft Windows 95, Windows 98 or Windows NT/2000 environments is assumed.

For information on Microsoft Windows operation consult the Microsoft Windows User Guide.

CITS800s functions are controlled by selecting the associated commands from pull-down menus or clicking the "short-cut" buttons with the mouse.

Selecting commands

Using the keyboard:

Activate the CITS menu bar by pressing the Alt key on the keyboard.

Press the underlined letter in the menu name to display the menu command list.

Press the underlined letter in the command name.

Using the mouse:

To display a command list, point to the menu name and click the left mouse button.

Point to the command name and click the left mouse button.

Selecting a command name which is followed by ellipses (...) displays a dialog box containing options which qualify the command.

Clicking the **OK** button corresponds to pressing the <CR> or <Enter> key on the keyboard.

Clicking the **Cancel** button corresponds to pressing the <Esc> key on the keyboard.

On-line help

The CITS software incorporates comprehensive on-line operating information. The Help command offers a rapid and convenient way to find information, such as how to perform tasks. Press the <F1> key to access the Help file.

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SECTION 1 — INTRODUCTION

CONTROLLED IMPEDANCE TESTING

1-1 The CITS system

The CITS800s Controlled Impedance Test System is designed to provide low cost automated measurements of the characteristic impedance of printed circuit boards and test coupons. The CITS system is shown in the diagram below. *It should only be used on unpowered pcb samples in accordance with the instructions in this manual.*

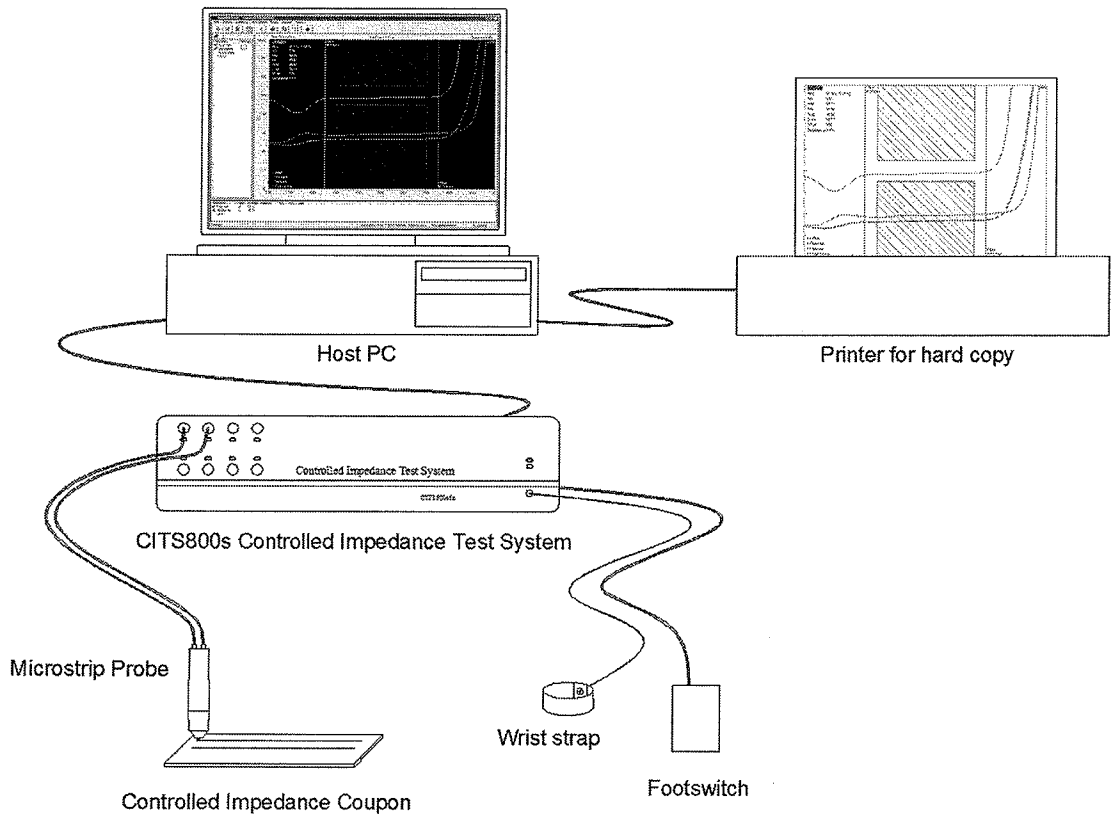


Figure 1-1 The CITS Controlled Impedance Test System

The Polar Instruments Controlled Impedance Test System comprises a measurement system controlled by software running

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within the Microsoft Windows environment on an IBM PC compatible computer.

The CITS800s is designed to facilitate rapid and convenient testing of single-ended and differential controlled impedance printed circuit board traces and test coupons.

Connection between the CITS and boards under test is achieved using Polar supplied probe cables and Microstrip probes.

The CITS software is written to run within the Microsoft Windows environment, so test result waveforms may be printed out using the currently installed printer.

The CITS system may be controlled from the PC keyboard or by simple point-and-click operations with a Microsoft-compatible mouse. Use of a mouse is recommended for maximum ease of use.

A plug-in foot-switch is included with the CITS to allow the operator to perform hands-off testing.

1-2 Test files

All the information necessary for performing a controlled impedance measurement on a circuit board is stored in a *test file*. An operator only needs to select the appropriate test file from a list and the system is ready for testing.

Test files are easily created and modified using the integrated test file editor — most files will be created with just a few key strokes and mouse clicks.

Test files provide a convenient method for automated testing of boards with a number of different controlled impedance traces.

1-3 Data analysis

Test results are displayed as a graph of impedance against distance along a PCB track and a PASS or FAIL result is reported according to whether or not the trace remains within tolerance over the full length of the tested region. The average, standard deviation, minimum and maximum impedance values over the tested region are displayed on screen along with the waveform. Odd and even mode impedances are included in differential tests.

All test results are displayed on the PC screen in waveform and statistical form for rapid analysis. Waveforms may also be stored to disk for later inspection.

Test data may be logged for subsequent statistical analysis. The stored data may be printed out or imported into a spreadsheet or the Datalog Report Generator (Optional Accessory).

The CITS also generates data in delimited format (suitable for importing into a spreadsheet or database) for statistical process control (SPC) analysis.

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1-4 CITS features

The CITS system is designed to make the complex process of impedance testing as simple as possible. The CITS800s includes the following features:

User interface

Microsoft Windows 95, 98 or Windows NT/2000 environment

Mouse driven user interface for ease of use

Comprehensive on-line help

Board testing

Two channels (CITS800s), four channels (CITS800s4) or eight channels (CITS800s8)

Test method supports measurement of unbalanced lines

Imbalance between lines measured and logged in differential tests

Warning when imbalance exceeds operator-specified level

Wide range of Polar Instruments manufactured Microstrip probes for easy connection to the board under test

Automatic instrument set up

Integrated test file editing

Group testing for verification of impedance spread

Data logging

Rapid data logging of test results

Statistical analysis for process control

Disk storage of test results

Hard copy of test & stored results

Display

Linear display of impedance against distance (in inches or metric measurements) or time

Impedance display in Ohms or mRho

Differential impedance measurements incorporate optional on-screen single-ended and even mode impedance waveforms for engineering analysis

On-screen cursors for easy distance measurement

On-screen display of waveform statistical analysis

Simple Pass/Fail PCB track test results displayed in waveform window

Waveform overlay for rapid comparison of results

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Status Outputs

The CITS includes opto-isolated, open-collector Status Outputs (located on the rear of the CITS) to provide a hardware indication of the PASS/FAIL results of a test. See Appendix C for connector details.

Statistical Process Control

The CITS provides the facility to log continuously all data to an external file. The file is in delimited text format so can be easily imported into and edited by a spreadsheet or database and includes fields which can be used by statistical process control systems.

1-5 Characteristic impedance

As the speed of electronic devices increases the electrical properties of the circuits carrying signals between them become more important.

At the high frequencies and clock rates of modern digital circuitry, cables and PCB tracks cannot be regarded as simple connections but should be considered as transmission lines.

In the case of PCB tracks the series resistance and parallel conductance of the transmission lines are largely negligible. The most significant circuit parameters governing performance are the distributed series inductance and parallel capacitance of the conductors.

These parameters give rise to the characteristic impedance Z_o.

$$Z_o = \sqrt{\frac{L}{C}}$$

where L is in henrys per unit length, C is in farads per unit length and Z_o is in ohms.

Consider an electrical signal travelling through a conductor such as a PCB track.

When the signal encounters a change of impedance (Z_o) arising from a change in material or geometry, part of the signal will be reflected and part transmitted.

These reflections are likely to cause aberrations on the signal which may degrade circuit performance.

To optimise performance of high speed circuits it is desirable to match the input and output impedances of devices with the characteristic impedance of the interconnections.

See Appendix A for a more detailed discussion of characteristic impedance.

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1-6 TDR fundamentals

The CITS800s Controlled Impedance Test System makes measurements using *Time Domain Reflectometry* (TDR).

Time Domain Reflectometry

A Time Domain Reflectometer is a special kind of oscilloscope.

A “normal” oscilloscope measures changes in voltage over a period of time and displays this as a graph. A TDR performs a similar function but incorporates additional circuitry to output a voltage and monitor changes in that voltage level over a period of time.

Time domain reflectometry is similar in principle to radar or sonar in that a signal is transmitted and the reflections or echoes of that signal are monitored. In the case of TDR the signal is a voltage transmitted along a cable or PCB track.

Reflections of the signal occur when there is a change in the characteristic impedance of the conductor. The time taken for the reflections to return to the TDR can be used to measure the distance to any change in impedance.

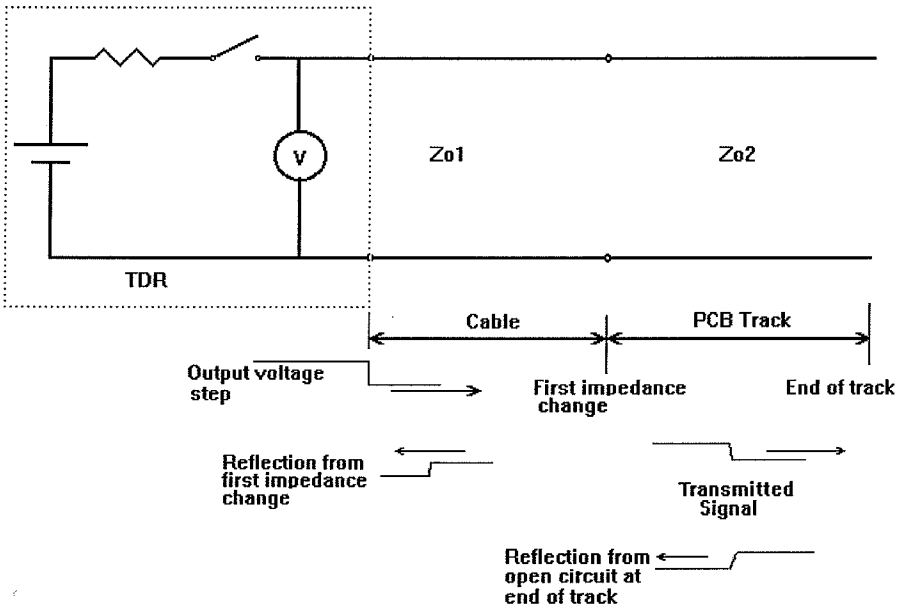


Figure 1-2 Simplified TDR-cable system equivalent circuit

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The diagram below shows a typical TDR waveform.

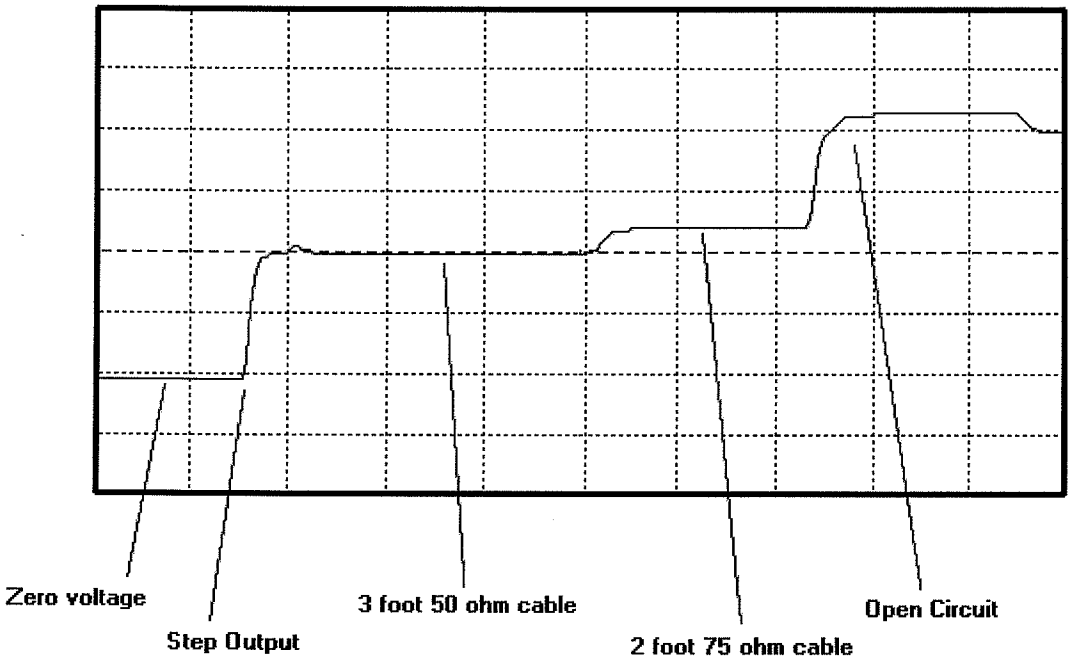


Figure 1-3 TDR trace showing voltage steps at impedance discontinuities

As a step wave propagates down a cable any increase in characteristic impedance causes a reflected voltage which adds to the initial step.

This is shown, for example, in the previous diagram by the step up from the 50Ω to 75Ω cable.

A decrease in impedance would cause a reflection in the opposite sense which would show as a downward step in the TDR trace. As long as the characteristic impedance remains constant the trace remains level.

An open circuit at the end of the cable reflects 100% of the voltage in a large upward step.

If the end of the cable were to be short circuited a 100% reflection in the opposite direction would occur, returning the trace to the zero voltage level.

1-7 CITS measurements

The CITS displays a graph of the characteristic impedance of a specified length of PCB trace.

This is achieved by calculating the impedance along the length of the cable or PCB based on the size of the reflections measured using time domain reflectometry.

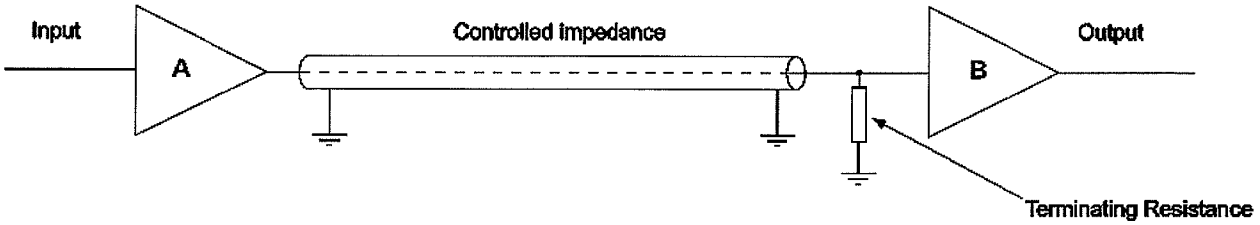
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Single ended impedance testing

Normal controlled impedance structures comprise a single signal conductor and a ground plane or planes. Impedance measurements made between the signal and ground are sometimes referred to as *single-ended*.

The single-ended transmission line is probably the commonest way to connect two devices. In this case a single conductor connects the source of one device to the load of another device.

The circuit below is an example of a single-ended transmission line.



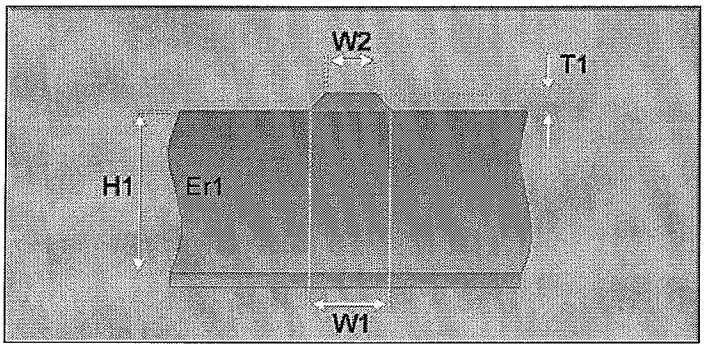
The reference (ground) plane provides the signal return path. This is an example of an unbalanced line. The signal and return lines differ in geometry — the cross-section of the signal conductor is different from that of the return ground plane conductor.

The impedance of a PCB trace will be determined by its inductive and capacitive reactance, resistance and conductance. These will be a function of the physical dimensions of the trace (e.g. trace width and thickness) and the dielectric constant of the PCB substrate material and dielectric thickness. PCB impedances will typically range from 25 to 120 ohms.

Single-ended transmission lines on PCBs

In practice, a single-ended PCB transmission line typically consists of a line conductor trace, one or more reference planes and a dielectric substrate comprising one or more layers of dielectric material. Two configurations are commonly used, *microstrip* and *stripline*.

Surface Microstrip



Surface microstrip with single dielectric below the trace

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The simplest configuration, the surface (or *exposed*) microstrip, shown in the previous diagram, consists of a signal line, the top and sides exposed to air, on the surface of a board of dielectric constant Er and referenced to a power or ground plane. Surface microstrip can be implemented by etching one surface of double-sided PCB material. The diagram illustrates the typical layout of the surface microstrip structure (using a single dielectric layer) and shows the characteristic microstrip impedance attributes:

the microstrip impedance references a single plane

the impedance trace is often on an outer layer.

The trace and plane(s) form the controlled impedance. The PCB will frequently be multi-layer in fabrication and the controlled impedance can be constructed in several ways. However, whichever method is used the value of the impedance will be determined by its physical construction and electrical characteristics of the dielectric material:

The width W1, W2 and thickness T1 of the signal trace

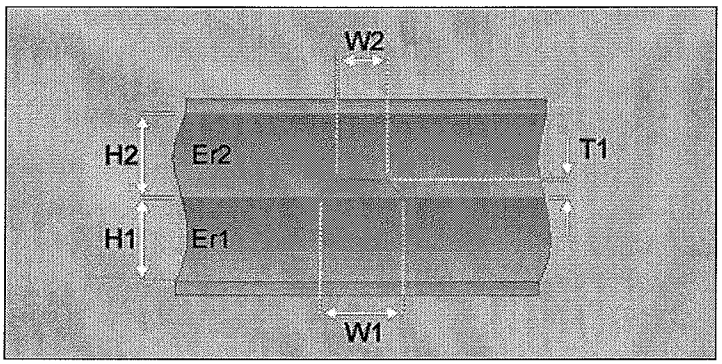
The height H1 of core or pre-preg material either side of the trace

The configuration of trace and planes

The dielectric constant Er1 of the core and pre-preg material

Offset stripline

The stripline (shown in profile below) typically consists of a line conductor trace sandwiched between two reference planes and a dielectric material (shown as two layers).



Offset stripline with one layer of dielectric above and below the trace

In this configuration the signal trace is sandwiched between two planes and may or may not be equally spaced between the two planes. This construction is often referred to as Dual Stripline.

A second mirror trace will be positioned down from the top ground plane. These two signal layers will be routed orthogonally (crossing at right angles so as to minimise the crossing area).

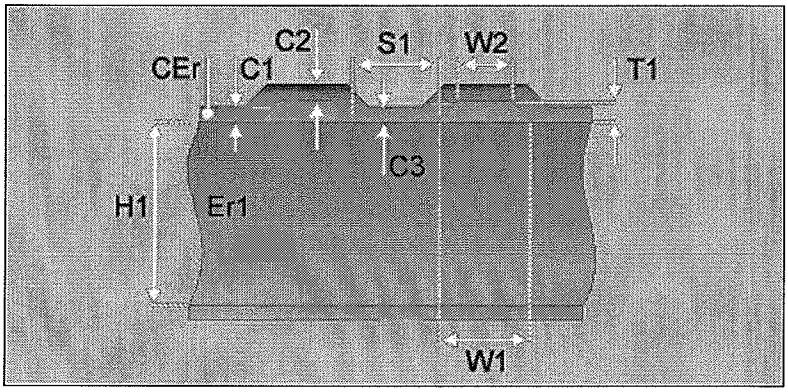
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The transmission line, i.e. the trace and planes, form the controlled impedance. The value of the impedance will be determined by its physical construction and electrical characteristics of the dielectric material:

- The width and thickness of the signal trace
- The dielectric constant and height of the core or pre-preg material either side of the trace
- The configuration of trace and planes

Electromagnetic waves in a vacuum travel at the speed of light. The propagation velocity in a material is primarily dependent on the Er of the material and is roughly inversely proportional to the square root of the dielectric constant of the material. Assuming a value of about 4 for dielectric constant for G-10 or FR-4 (the actual value will depend on frequency and the glass to resin ratio) the propagation velocity will approximate to half the speed of light.

Coated microstrip



Edge-coupled coated microstrip with single dielectric below the trace

As in the case of the Surface Microstrip this construction is simple to fabricate, but the extra process of adding solder mask coating can cause impedance variations. The operator must specify the thickness of the coating outside, above and between the traces to allow for variations in the board fabricating process.

This construction is particularly sensitive to solder mask flooding with LPI (Liquid Photo Imagable) solder mask. This causes the dielectric constant in the edge coupling region to vary, depending on flood depth.

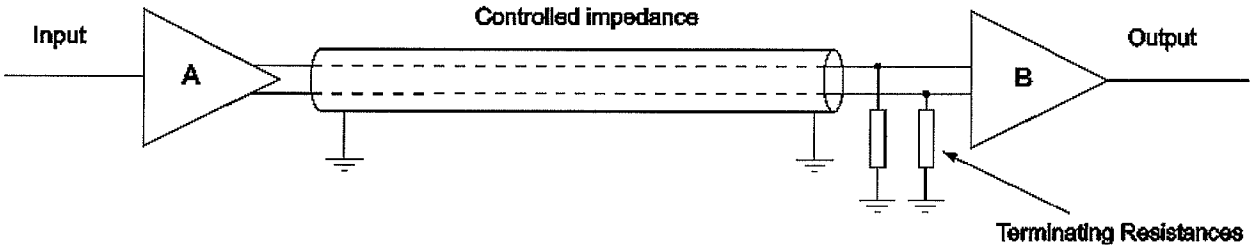
Differential impedance testing

A more complex type of controlled impedance structure is that of a differential pair of signal conductors. The lines are driven as a pair with one line transmitting a signal waveform of the opposite polarity to the other. At the receiving end one signal is subtracted from the other so noise induced in both lines is cancelled out. This method is commonly employed to achieve high noise immunity in high speed digital and analog systems.

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The characteristic impedance of a differential pair is affected not only by the impedance of each line of the pair to ground but also by the interaction of the signal lines with each other.

The differential configuration (often referred to as a balanced line) is used when better noise immunity and improved timing are required. In differential mode the signal and its logical complement are applied to the load.

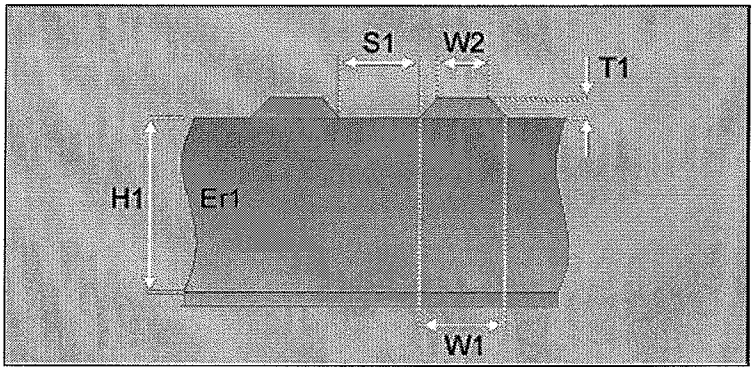


The balanced line thus has two signal conductors and an associated reference plane or planes as in the equivalent single-ended (unbalanced) case. Fields generated in the balanced line will tend to cancel each other, so EMI and RFI will be lower than with the unbalanced line. External noise will be "common-moded out" as it will be equally sensed by both signal lines.

Differential transmission lines on PCBs

A typical differential configuration, the edge-coupled surface microstrip is shown below.

Edge-coupled surface microstrip



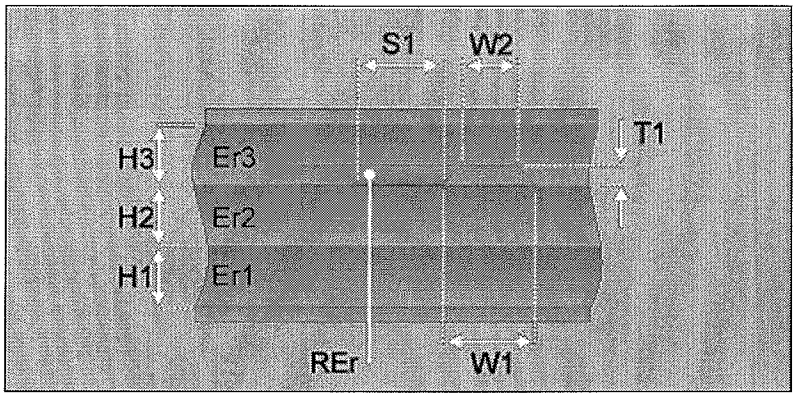
Edge-coupled surface microstrip with one layer below the traces

In this construction the gap S1 between the traces defines the coupling factor and hence the differential impedance. The etch factor, plating density and undercut will make this construction simple to manufacture, but with a wider tolerance due to the extra processing required on external layers.

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The stripline construction is also used in differential pair configurations. A typical construction, the edge-coupled offset stripline is shown below

Edge-coupled offset stripline



Edge-coupled offset stripline with one dielectric layer above the traces and two below

The reduced processing of internal layers makes this construction easier to fabricate with more consistent results than the equivalent surface trace structure. During the manufacturing process resin will be forced in between the traces resulting in a resin-rich region (shown as Rer in the model) between the two traces. This region will consist of a dielectric with Er different from the rest of the structure.

The Differential Test

Controlled impedance structures often comprise a single signal conductor and a ground plane or reference plane. Impedance measurements made between the signal and ground are then sometimes referred to as *single-ended*.

Where higher performance (e.g. greater noise immunity and better EMC performance) is required a more complex type of controlled impedance structure is employed — that of a *differential pair* of signal conductors. The signal lines are driven as a pair with one line transmitting a waveform of opposite polarity to the other.

At the receiving end one signal is subtracted from the other so any noise induced in both lines is cancelled out. This is a technique commonly used to increase noise immunity (and reduce signal skew in bus circuitry) in high speed digital and analog systems.

The characteristic impedance of a differential pair, therefore, is affected not only by the impedance of each line of the pair to ground but also by the interaction of the signal lines with each other.

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Test coupons

The impedance of a PCB trace depends on a number of factors, including the dimensions of the trace (i.e. trace width and thickness) and the thickness and dielectric constant of the laminate and pre-preg material. It's common practice for board manufacturers to check controlled impedance build integrity initially by building engineering lots to verify copper weight, line widths and dielectric thickness and constant before beginning volume production. Even in production manufacturers perform 100% controlled impedance testing on controlled impedance boards.

However, it is not uncommon for the actual PCB traces to be inaccessible for testing. In addition, traces may be too short for accurate measurement and will probably include branches and vias which would also make exact impedance measurements difficult. Adding extra pads and vias for test purposes would almost certainly adversely affect the performance of a controlled impedance trace as well as occupying valuable board space. PCB testing is therefore normally performed, not on the PCB itself, but on one or two test coupons integrated into the PCB panel. The coupon will be of the same layer and trace construction as the main PCB and will include traces with precisely the same impedance as those on the PCB, so testing the coupon will give a high degree of confidence that the board impedances will be correct.

The CITS800s is supplied with a sample coupon, typical of those used in manufacturing, with the associated test files so that users may familiarise themselves with the operation of the instrument.

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SECTION 2 — INSTALLATION AND SET UP

SETTING UP THE CITS SYSTEM

Siting the CITS800s

The CITS800s should be installed indoors on a stable, level bench or workstation in an environment as described in the SPECIFICATIONS section.

The host PC should be sited adjacent to the CITS and its monitor and keyboard positioned at suitable heights for the operator.

When assigning a work area for the testing of pcbs and positioning equipment, consideration should be given to the probe cables and how they flex. See Figure 1-1 for typical workstation layout.

System requirements

The CITS software is designed to run on a personal computer meeting the following specifications:

Computer	IBM PC AT or compatible	
Processor	Pentium 100 or better	
Operating system	Microsoft Windows 95, 98	
	Microsoft Windows NT/2000	
System memory required	Windows 95, 98	16MB
	Windows NT/2000	32MB
Hard disk space required	2MB	
Video standard	SVGA (800 x 600 minimum)	
CDROM drive		
Diskette drive	3½" High density 1.44MB	
Mouse	Microsoft compatible	
Printer port	1 x parallel printer port	
Serial Communication ports	1 x available serial communication port required	

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2-1 Unpacking

The instrument is shipped in a sturdy transit pack. Open the pack carefully and remove the instrument and its accessories. If the instrument is damaged in any way contact the local distributor or supplier.

Retain the pack for possible future use.

Note: Always obtain a Return Number before returning an instrument to Polar Instruments.

The package should contain:

CITS800sa/CITS800s4a/CITS800s8a

50Ω Probe cables (x2)

IP50 Microstrip probe

IPD100 Differential Probe

Sample test coupons

Power cord

RS 232 interface cable

Foot switch

Accessory pouch

Operator manual

Program installation diskette

Anti-static wrist band and cord

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 Controls and connectors

SMA connectors

The Front Panel SMA connectors should be connected to Polar Instruments microstrip probes only.

Caution: Tighten with care. Use a torque wrench set to 5 lbf inches ±0.3 lbf inches (0.565 Nm ±0.034Nm).

RS232 interface to the PC

To maintain compliance with EMC specification use only Polar cables .

Foot switch

Connect only to a Polar footswitch. This connector may be left disconnected if not required.

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Status

Connections to the 9-pin D Status output are to be made as instructed by trained and qualified technicians in accordance with the information in the Service Manual. See Appendix C for Status connection details.

Wrist strap/Ground

The wrist strap socket provides a connection to the machine's enclosure; it is connected directly to the protective conductor of the supply cord. This connector should only be used for antistatic wrist straps.

Connecting to a power supply

WARNING! Do not locate the instrument in such a way as to prevent access to the power switch.

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 CITS Service Manual.

Note: If a special local plug must be fitted to the power cord ensure this operation be 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

Connect the power cord to the instrument and to the power source.

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2-3 Installing the CITS software

Installing the program

Close all other programs.

Insert the CITS800s Software CDROM in the drive and follow the install wizard instructions on screen.

If the install program does not run when the CDROM is inserted:

Click the **Start** button — choose **Settings**.

Choose **Control Panel**

Double Click the **Add/Remove Programs** icon.

On the **Install/Uninstall** tab click the **Install** button.

When **Setup.exe** appears in the Command line box click Finish.

Follow the instructions on screen.

Choosing the install folder

The CITS Installation program proposes the destination location — the drive and folder of the hard disk onto which the CITS program is to be installed (by default **C:\Program Files\Polar\CITS800s**).

Press <**Continue**> to accept the proposed destination drive and folder or type the name of an alternative drive and folder.

To choose an existing drive and folder (directory) press the Choose Directory button — the Choose Directory dialog box is displayed.

Navigate to the destination directory from the Choose Directory box and press **OK**

Press <**Continue**>.

The Installation program will prompt for a name for the CITS program group. The CITS program icons will be created in the specified program group.

Press <**Enter**> to accept the proposed name, or type in a different name in the name box or select an existing group (press the drop-down list box arrow to display the current group list).

The installation program will create the CITS directory and file structure, copy the CITS files onto the hard disk and create a program group and the CITS program item.



The CITS program icon

Hint: The CITS program may be started each time Windows is started — hold the <**Ctrl**> key depressed and drag the CITS icon with the mouse to copy it to the **Startup** group.

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2-4 Connecting the computer to the CITS

CITS commands and data are transferred between the CITS and the host computer via a serial communication (RS 232) link using the supplied cable.

Ensure the host computer and the CITS are both powered down before connecting cables.

Connecting the CITS to the communication port

Connect the cable between the host computer's serial port and the connector on the rear of the CITS. Ensure the connections are secure. If a serial mouse is connected to the PC, the mouse will normally be connected to the host computer's serial port COM1 or COM2 — connect the CITS serial cable to an available port, using a 9 to 25-pin adaptor if necessary. (Note: if a 9 to 25-pin adaptor is used all 9 pins must be wired).

Connecting the CITS peripherals

Plug the Foot Switch D connector into its socket on the rear of the CITS. Plug in the 4mm anti-static wrist strap.

Connect the Barcode Reader (if used) between the keyboard and the computer — unplug the keyboard from the computer, plug the Barcode Reader into the keyboard socket on the computer and plug the keyboard into the Barcode Reader.

Connecting the cables

The CITS is calibrated before shipment using cables labelled with the channel number and instrument serial number. If a cable is replaced the instrument should be re-calibrated and the cable relabelled with the channel number and the instrument serial number.

For single-ended testing connect a probe cable to its corresponding SMA front panel connector of the CITS and connect the Microstrip probe to the probe cable.

The CITS channels are arrange in pairs for differential testing; connect the differential probe (e.g. the IPD100 probe) to Channels 1 and 2 or 3 and 4 or 5 and 6 or 7 and 8 SMA connectors using the supplied cables.

Power up the CITS and the host computer. The green BUSY LED should light for approximately 5 seconds and then turn off, indicating that the system is operating normally.

If applicable, connect a 9-pin D connector to the **Status** output. Connection details and a description of the function of each pin for the Status output are contained in Appendix C.

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2-5 Running the program



The CITS program icon

To start the program, double click the CITS icon with the mouse or highlight the icon and press <**Enter**>.

After a few seconds the main CITS display will appear.

Note: If the program is being run for the first time, the system Configuration dialog box is displayed.

Options can be changed at any time during normal operation by choosing **Config** from the Utilities menu.

The CITS installation program will select COM2 by default (the mouse on most systems is connected to COM1). Choose the port appropriate to your system.

The **Config** dialog box allow the user to specify the host computer's Serial Communications Port to be used when transferring commands and data – select the appropriate port and press **OK** to confirm.

2-6 System configuration

The system configuration (**Config**) dialog allows the operator to specify the CITS operating environment.

From the **Options** menu select **Config...** to display the **Config** dialog box. Select the **General** tab:

To exit any of the **System Configuration** menus without recording any changes press <**Esc**> or click the **Cancel** button.

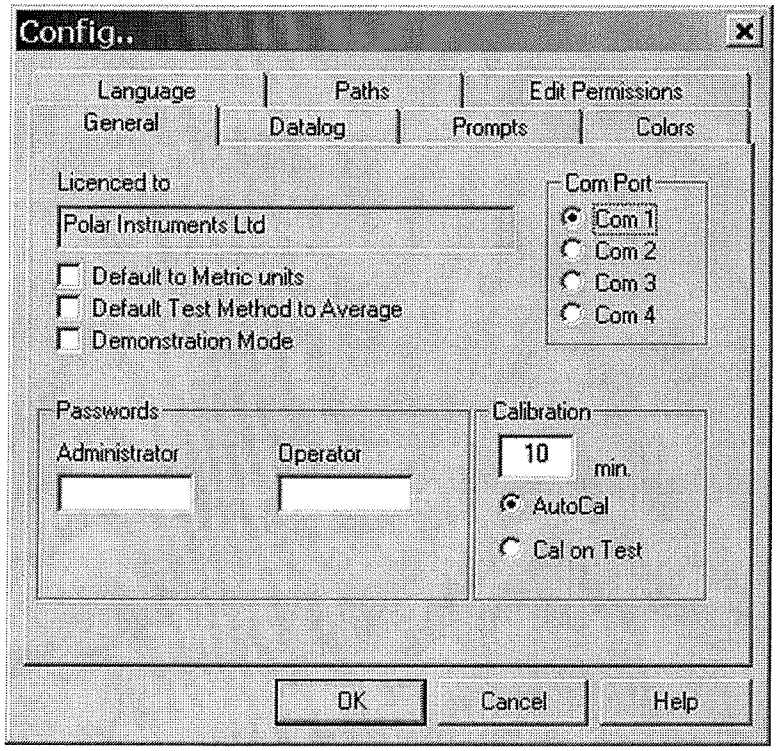


Figure 2-2 The System Configuration menu

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General options

Metric Defaults

The CITS is able to generate distances in English or metric measurement units. When this box is checked the Defaults button in the Test Setup Editor is made to generate distances in metric units.

Demonstration Mode

Demonstration mode is provided to allow the CITS program to be operated without an instrument connected. In this mode when the Test function is selected the CITS allows the operator to select a stored waveform for display.

Specifying the serial communications port

Commands and data are transferred over the RS232 serial communications link via one of the host computer's serial communications ports.

Choosing a communication port

The **Com Port** field allows the serial communications port through which the PC communicates with the CITS to be specified or changed.

Typically, if a serial mouse is in use, it will be connected to serial communications port COM 1. The CITS must therefore be connected to a different port (usually COM2).

The system displays the current communication port; specify a new communication port if necessary — the system will enable the selected port.

Other serial communication parameters are set automatically by the CITS system.

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Calibration

To ensure continued accuracy and consistency of measurements the CITS800s incorporates internal references for self-calibration purposes.

The **System** option allows the operator to control when the CITS performs a self-calibration.

Two modes of **Calibration** are available:

Autocal

In Autocal mode the CITS self-calibrates automatically at a given interval in time. This may be specified from 1 to 60 minutes (the default is 20 minutes). This is the normal mode of operation.

Cal On Test

In Cal on Test mode the CITS self-calibrates before every test.

System security

The CITS incorporates two levels of security, **Administrator** and **Operator**. The **Passwords** options enable the Administrator to specify password protection for critical system and test file information. The system administrator is able to control operator access to each field in the Test Setup Editor via the Test Permissions page

Specifying a password

Specifying a password is optional; if an **Administrator** password is specified, unauthorised users will be prevented from modifying the system configuration, editing test files (files containing test parameters) or deleting logged records. If a password is set it will be requested before these operations are permitted.

If an **Operator** password is set it will be required if an operator attempts to alter test parameters . All system changes will require the Administrator password.

To specify a password, activate the **Password** box and type the password — up to 8 characters may be used. For security, characters typed will be displayed as asterisks. If no password is required leave the field blank.

Confirmation

If a password is entered the CITS displays a confirmation box. Re-type the password in the confirmation box to verify the original.

Activate on Exit

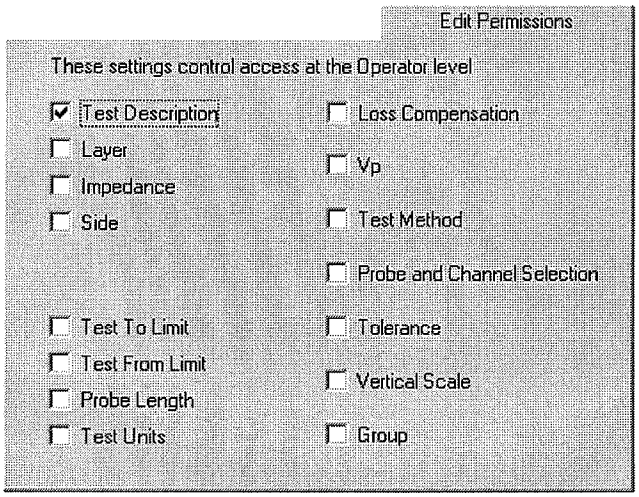
If a password has been specified, exiting this screen with this box checked enables password protection immediately; otherwise the password protection is not enabled until the software is next run.

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Controlling test file editing permissions

With an Administrator password specified the CITS800s will require the Administrator password to access the Test File Editor to alter test parameters for a test or group of tests.

If an operator password has been specified the Administrator is able to grant controlled operator access to the Test File Editor. Use the **Edit Permissions** page to control which test parameter fields, if any, may be modified by the operator.



Click each checkbox to enable the associated field as required.

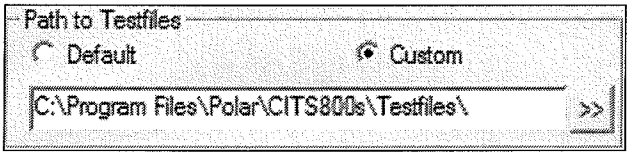
When the operator attempts to modify test parameters the system will request a password. Supplying the Administrator password will open the Test Setup Editor with full access to all test parameters, if the Operator password is entered the Test Setup Editor opens with only the parameters checked in the Edit Permisions page enabled. Press **OK** to confirm and close the dialog.

Logging off the current user

To switch between Administrator and Operator (without exiting the program) choose the **Utilities|Revoke Current Permissions** command. At the next attempt to modify test parameters the system will request a password. Enter the Administrator or Operator password as required.

Setting the path to Testfiles options

Click the **Paths** tab to specify the location for test parameter files.





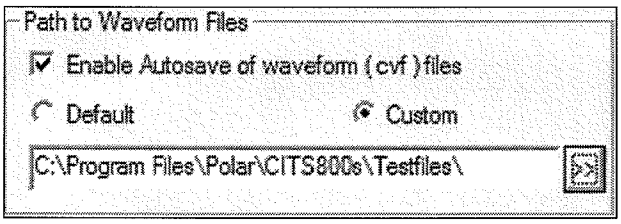
Select Testfile Target Folder...button

Test files are stored by default in the C\Program Files\Polar\CITS800s\TestFiles folder; to choose another folder click the **Custom** option button and use the **Select Testfile Target folder...**button to navigate to the desired folder.

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Setting the path to Waveform files options

Click the **Enable Autosave of waveform (.cvf) files** check box to allow waveform files to be saved automatically at the datalog point. During the datalogging process waveform files are saved and named using the board serial number and test name.



Waveform files are stored by default in the C:\Program Files\Polar\CITS800s\Waveforms folder; to choose another folder click the **Custom** option button and navigate to the desired folder.

Setting the Datalog options

The **Datalog** dialog allows the operator to specify datalogging options. The user can

- Specify an identifying name for the test station.
- Choose between date formats.
- Specify user fields to provide additional board information (e.g. batch ID, process, etc.). The user fields can be completed during the datalog process.
- Specify optional checking of serial numbers for duplicates during datalogging
- Change the destination folder for logged data.

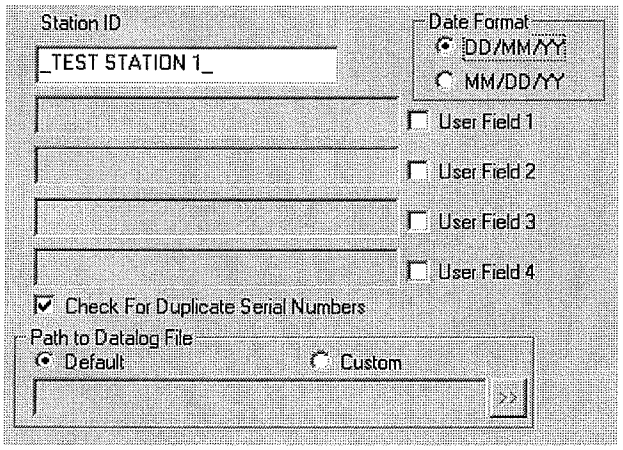


Figure 2-3 The Datalog dialog tab

Specifying a Station ID

Click into the Station ID field and type the name of the test station. This is used when multiple CITS stations are datalogging to a common log file

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Defining additional user fields

Extra fields may be added to the datalog to include additional information such as batch ID, process information, etc.

Click into each user field check box to activate the field, then type the name of the field into the associated text box.

Specifying the date format

The CITS datalogging can record the date in one of two formats. Choose DD/MM/YY or MM/DD/YY to specify English or U.S. format.

Checking for duplicate serial numbers

If this option is set, the CITS will alert the operator if two identical serial numbers are entered during datalogging.

Specifying the Datalog folder

Datalog files are located by default in the C:\Program Files\Polar\CITS800s\Testfiles folder (assuming a default installation). To specify a different folder click the **Custom** option button.

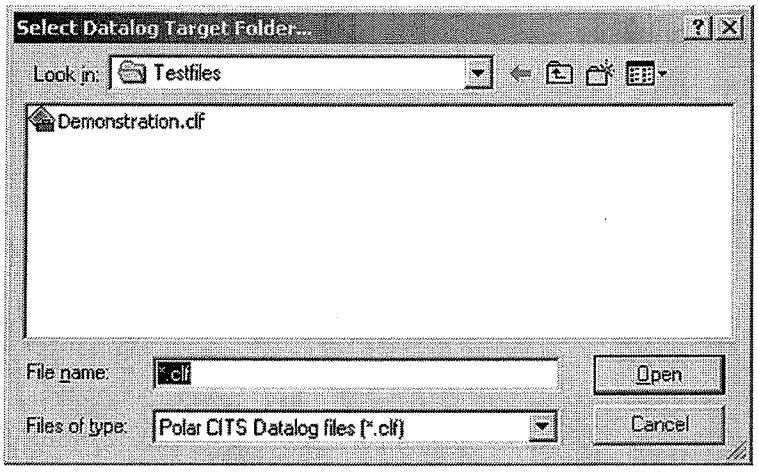


Figure 2-4 Select Datalog folder dialog box

Navigate to the data logging folder and press **Open**.

Note: if necessary, create the folder by right clicking a blank area within the **Select Datalog Target Directory...** dialog box and choosing **New** then **Folder** from the shortcut menus.

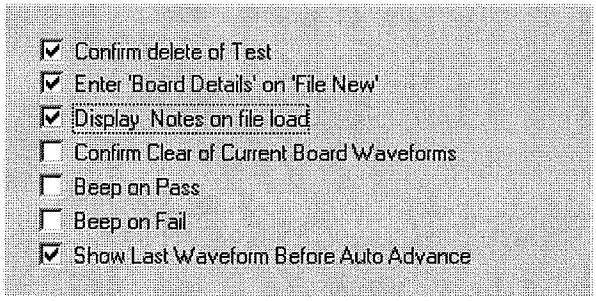
See the Windows User Guide for details.

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Changing the system prompts

The CITS incorporates facilities automatically to display confirmation or information dialog boxes as test files are created, loaded or deleted. Click on the Prompts tab to specify the system prompt options:

- Show the Board Notes (a text box containing notes, instructions, etc. for a board under test) as a test file is loaded
- Display a Confirm Delete message to prevent accidental deletion of a test file
- Automatically display the Board Details dialog box each time a new test file is generated
- Sound an audible warning when a board passes or fails the test process
- During datalogging tests may be cycled through in sequence automatically (if **Auto Advance** from the **Datalog** menu is selected). The operator can specify a brief view of each waveform as the CITS advances through the tests.



Click the associated check box to select each option.

Changing the CITS display colors

Click the Colors tab to change the colors of objects (waveforms, cursors, graticules, axes, etc.) in the display window. Click on the object name then click the Edit button to display the color palette.

If necessary click Define Custom Colors to choose from a wider range of available colors (the actual range will depend on the graphics card installed on the machine).

Click **Reset** to set colors to their default values.

Hardware Activation

The CITS800s requires a hardware activation key. Plug the supplied key into its port then start the CITS800s program.

Supply the company name; this name will appear on results printouts. The CITS800s will record the installation date and issue warning messages as the recalibration date approaches. The hardware key is locked to the machine.

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SECTION 3 — GETTING STARTED

FIRST TIME CITS OPERATION

IMPORTANT The CITS is an extremely sensitive measuring instrument. To prevent damage to the CITS, observe static precautions at all times. See Appendix B for information

*Note: These operating instructions assume that the installation procedure has been successfully completed and the hardware has been activated (see **Hardware Activation**) and the key present.*

This section discusses the basic operation of the CITS program using the sample test coupons included with the CITS. First time operators are encouraged to work through this section using the coupons and test files provided to verify the correct operation of the CITS and quickly gain familiarity with the impedance testing procedure.

Power up the CITS800s and PC, and press the **Start** button and choose **Programs**, then **CITS800s** and click the CITS800s program (or double-click the CITS icon on the desktop) to start the CITS program. The CITS main screen is shown in Figure 3-1.

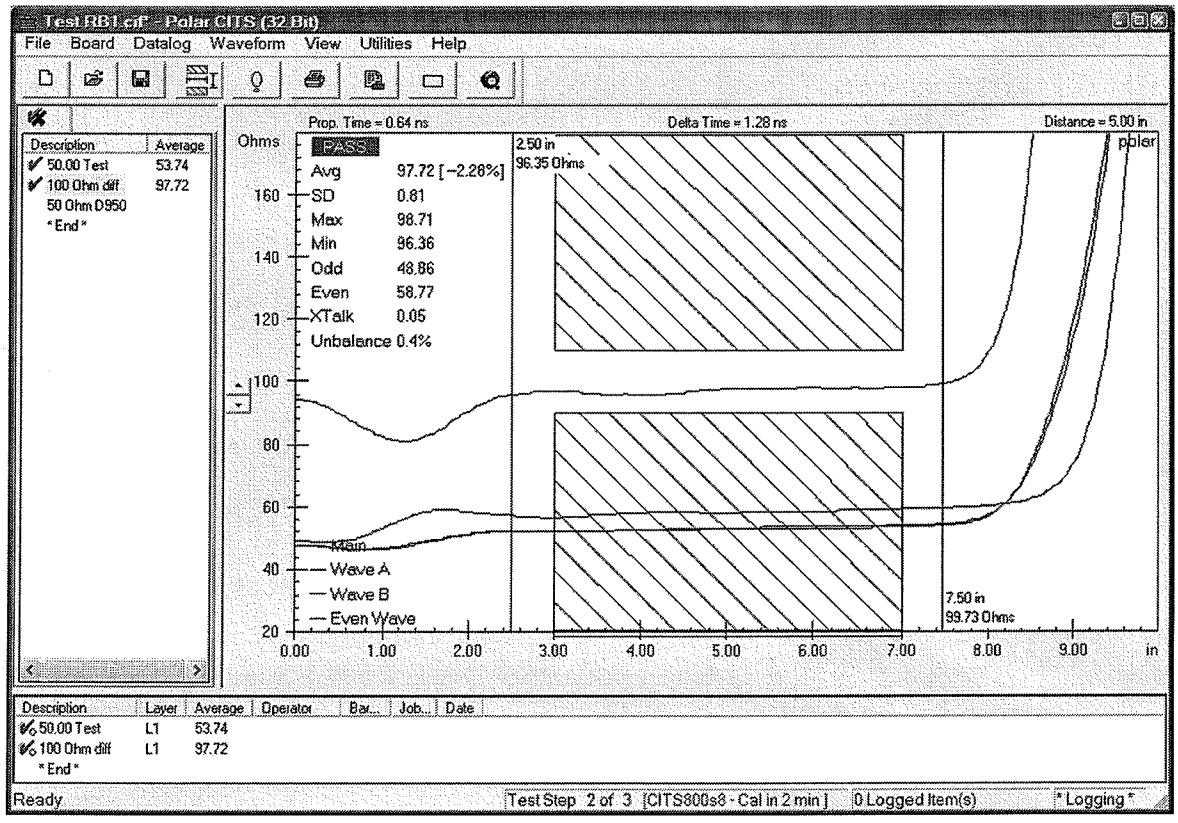


Figure 3-1 The CITS main screen

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Note: the colours of the screen displays may be changed at the option of the user — the screen views used in this manual may differ slightly from the system in use.

The CITS screen

The CITS screen window is split into three window panes and comprises six sections:

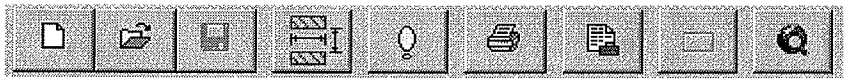
- The Test List window pane which lists the tests within the active test file.
- The Waveform Display window pane which displays the impedance waveform and test results.
- The Datalog Results window pane which displays logged test results (e.g. for a batch of boards using the active test file).
- The menu bar containing the CITS commands
- The tool bar which provides short cut access to the most commonly uses commands.
- The status bar which displays descriptions of the tool bar buttons as the mouse is moved over each button and test and datalogging information.

The CITS window may be increased or decreased in size by dragging the window borders with the mouse.

If necessary press the Maximise button to increase the display size to full screen.

The CITS main tool bar

The CITS main toolbar (described in detail in the next section) contains buttons that provide quick mouse access to the most frequently used CITS commands:



(In this section we use only the **File Open** and **Execute Test** buttons.)

 The **File Open** button display the **Open** dialog box and allows the user to choose a test file. Each test file contains one or more tests for the board under test.

 The **Execute Test** button performs a test using the selected test list item.

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3-1 Testing the sample coupons

When testing wear a wrist strap connected to a suitable earth point. A wrist strap is provided with the CITS (connect the wrist strap to the Wrist Strap stud on the CITS front panel).

The CITS800s includes a sample coupon to allow users to familiarise themselves with the operation of the instrument. The coupon includes three single-ended PCB traces of nominal impedance, 50Ω, 75Ω and 100Ω and one differential trace of 100Ω nominal impedance.

The CITS software includes a test file incorporating the 50Ω, 75Ω and 100Ω tests associated with the coupon.

Note: the sample coupon includes impedances of nominal value only and should not be used for calibration purposes.

To test any PCB trace it is necessary to select the correct test file for the board trace under test. This file includes the nominal trace impedance to be tested for, the test tolerance and the distance over which to test.

In this section we will test the sample coupon supplied with the CITS800s.

Selecting a test file



*The file **Open...** button*

From the **File** menu select **Open...** or press the **Open...** button on the tool bar with the mouse — the **Open** dialog box appears with the test files listed. See Figure 3-2.

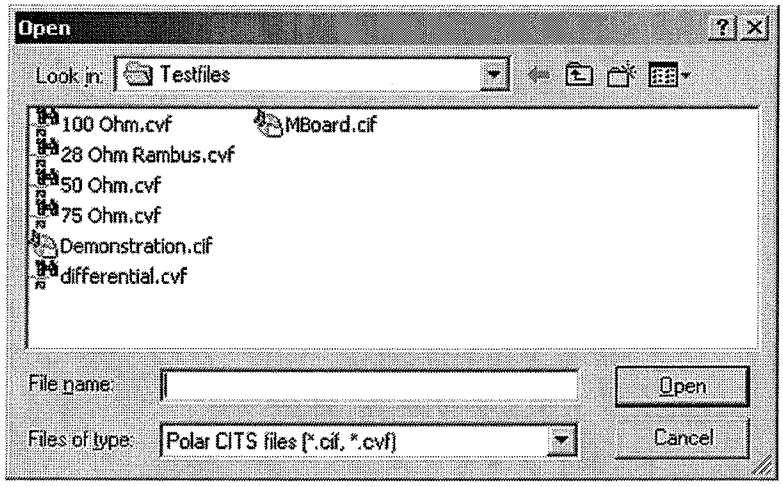


Figure 3-2 The Open Test File dialog

The Demonstration file contains the tests associated with the sample coupon. In this example we test the coupon's 50Ω trace using the 50 Ohm Test in the Demonstration file.

Select the Demonstration file by either clicking the mouse on its name in the file list window or stepping the selection down to it with the cursor direction keys. Click on **OK** to select the file.

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The CITS loads the selected test file and displays the list of trace tests for the coupon in the Test List window pane.

The CITS provides the option of selecting test files from the list using the mouse or keyboard arrow keys or using the CITS foot pedal to advance through the list and perform each test in the sequence without the use of mouse or keyboard. If a barcode reader is used this is entered at the start of a cycle.

Click on the 50 Ohm Test — the Waveform Display pane reflects the impedance and distance scales for the test and a cross hatched area indicating the region over which impedance will be tested. The impedance scale indicates the nominal impedance and acceptable impedance range.

Click on the 75 Ohm and 100 Ohm tests and note the changes in the Waveform display window.

For the test shown in Figure 3-3 the nominal impedance has been specified in the test file as 50Ω ±10% so the acceptable range of impedance values is from 45 – 55Ω. The test is performed over a 6" length of coupon trace (from 3" to 7").

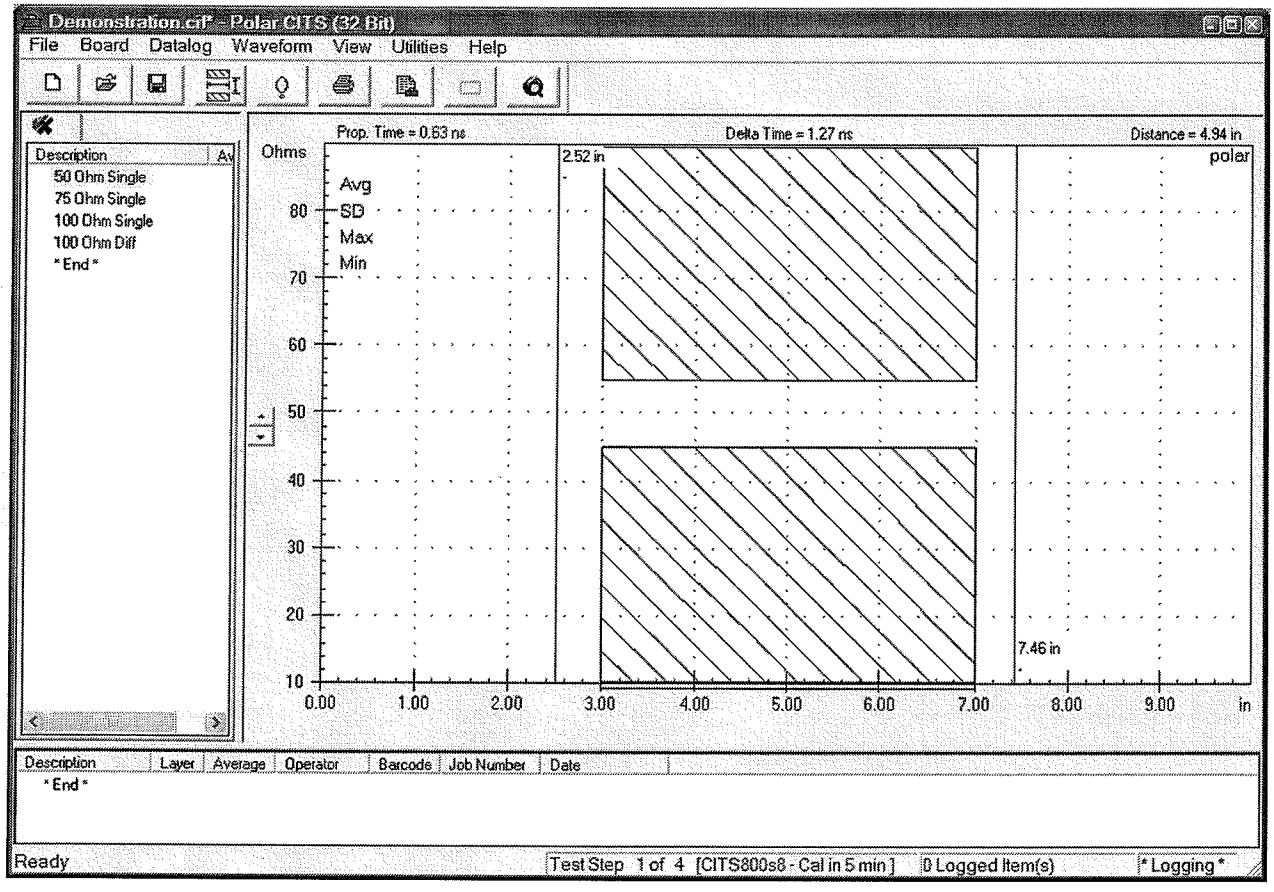


Figure 3-3 The CITS Test Window with the Demonstration file loaded (50 Ohm test selected)

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Performing the single-ended tests

Note: *When executing the test ensure the Microstrip probe signal pin is connected to the signal pad and the probe ground pin to coupon ground pad. Typically, ground connections have square pads to distinguish them from signal pads.*

Note: it is important to use high quality test connections (e.g. Polar microstrip probes) to minimise aberrations.

Choose the **Datalog** menu and ensure the **Autolog** command is off (un-ticked).



*The CITS **Test** button*

To test the coupon, connect the microstrip probe across the 50Ω test impedance and press the foot switch or click the **Test** button. Take care not to touch the track on the coupon during testing.

The system will set up the instrument for testing and then graph the impedance of the 50Ω trace.

The CITS displays the trace's impedance against the test program limits. See Figure 3-4.

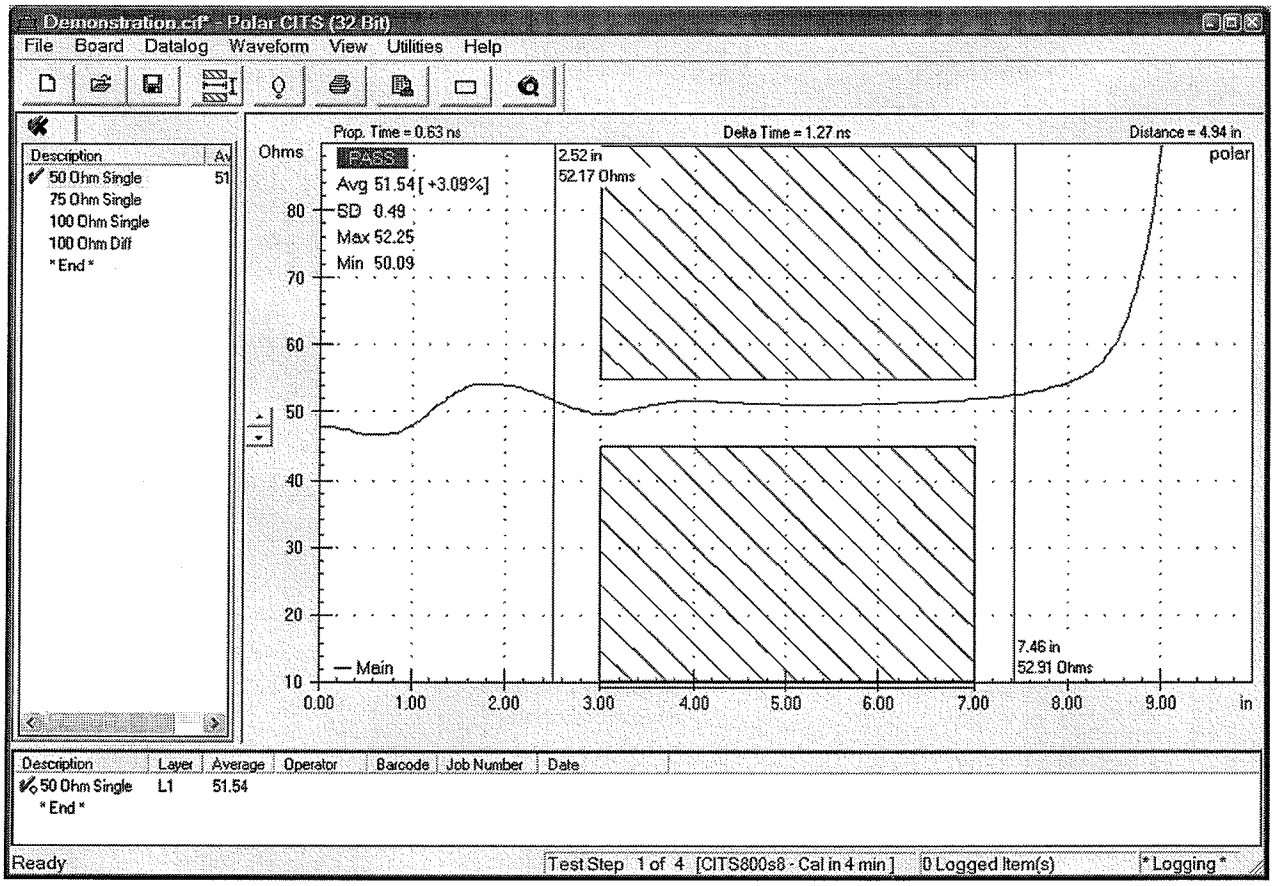


Figure 3-4 Graph of 50Ω impedance within limits

If the waveform remains between the crosshatched area over the whole of the tested region the CITS records a **PASS**.

If necessary, use the up and down arrows to move the display vertically to view portions of the trace .

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Displaying the impedance statistics

The CITS displays the PASS/FAIL result for the test and displays the impedance statistics over the tested area:

- average impedance
- standard deviation
- minimum impedance
- maximum impedance

The tested area is usually the flattest portion of the coupon waveform and is usually referred to as the *undisturbed interval* (ignore test connection aberrations and open circuit termination effects). Values are presented in the associated boxes on screen along with the impedance waveform. If the displayed waveform extends into the crosshatched area the CITS records a **FAIL**.

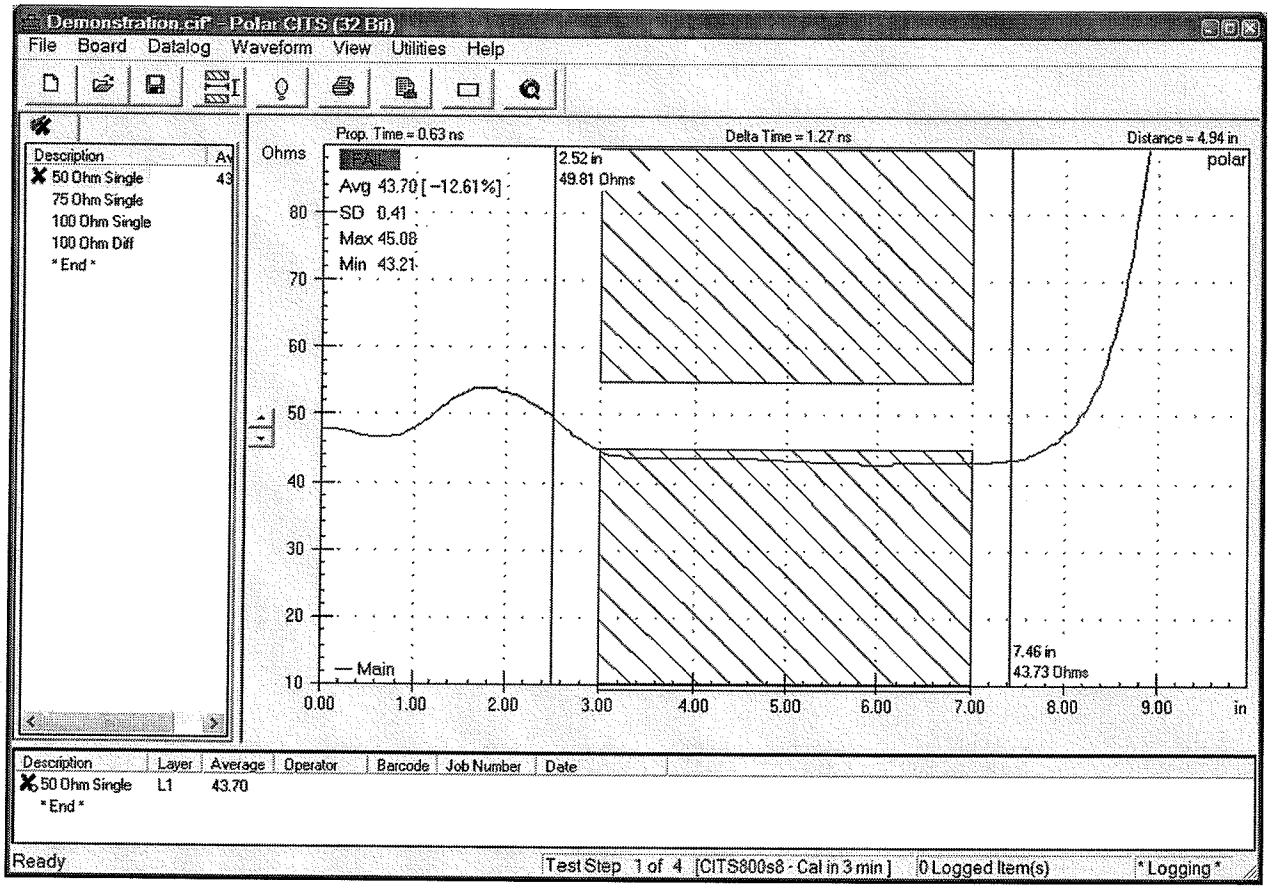


Figure 3-5 Graph of 50Ω impedance outside 10% limits

(If the CITS records a **FAIL** on the coupon, check for correct probe/coupon polarity and good contact between the microstrip probe and the trace on the coupon and try again.)

Repeat the procedure for the 75Ω and 100Ω nominal impedance traces on the sample coupon using the 75 Ohm Test and 100 Ohm Test respectively.

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As each test is completed a tick or cross is displayed alongside each test in the Test List window pane to indicate a PASS or FAIL result for the trace along with the Average value of impedance for each test. Test results for all tests performed on the coupon are recorded in the Datalog window pane. A small yellow circle alongside each result indicates that the logged results have not been saved to disk.

The Status Bar indicates which test is currently displayed and the time to the next automatic calibration.

The CITS foot switch can be used to advance through the list and perform each test in the sequence without the use of the mouse or keyboard. Test results (PASS/FAIL) are displayed next to each test file as testing progresses. When all three test are complete, step through and review each test result (waveform and statistical results) by clicking the test name in the Test List window pane.

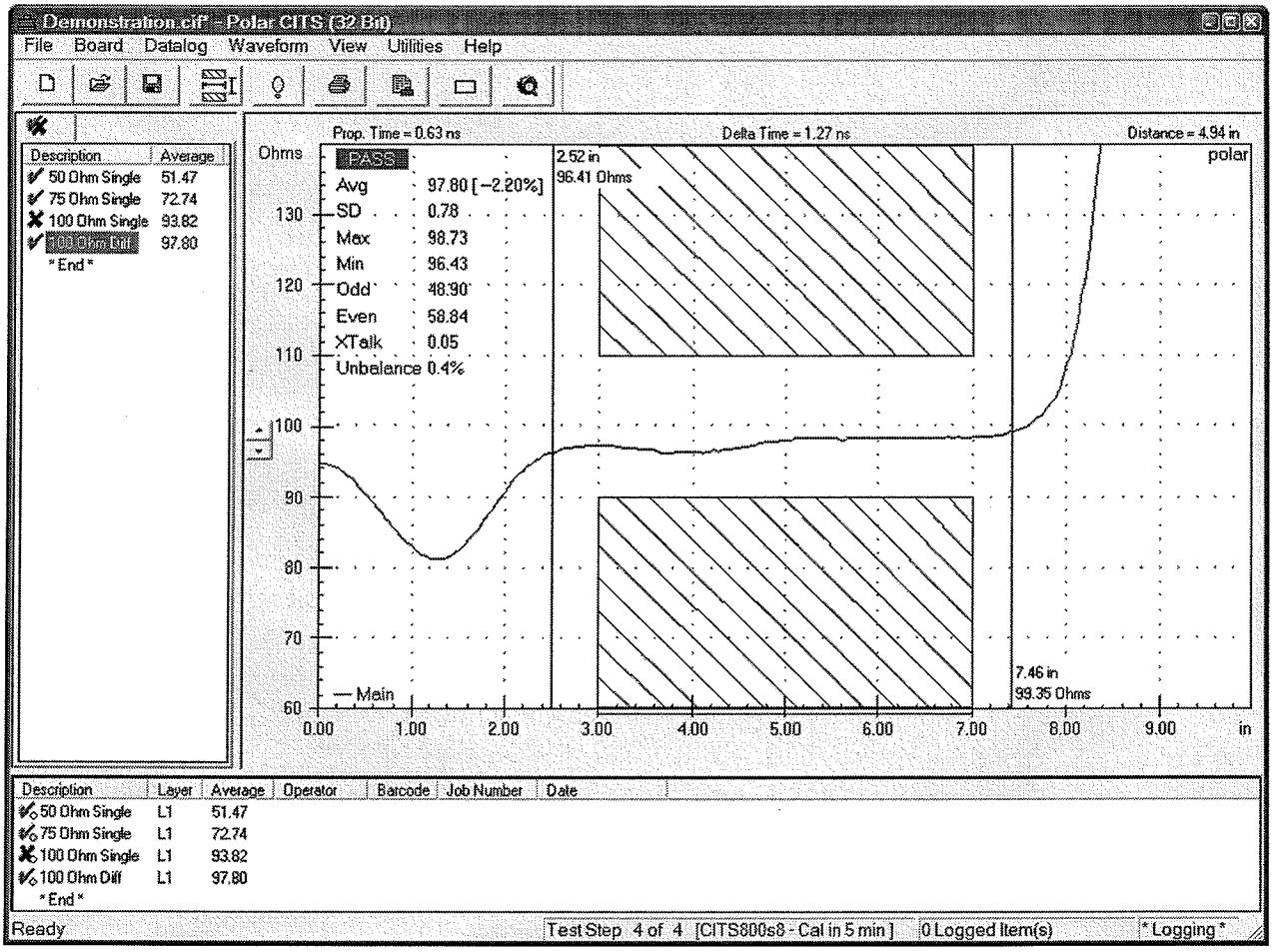


Fig 3-6 Completed set of Coupon Test results

Using the measurement cursors

The CITS800s incorporates on-screen measurement cursors to display absolute values of propagation delay times, distance and impedance along the displayed waveform. Use the cursors for critical time measurements — click onto each cursor and drag it with the mouse to the point of interest on the waveform. Each

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cursor displays the distance along the trace and impedance at the point where the cursor crosses the waveform.

The distance between the cursors, i.e. propagation delay time, delta time and distance between the cursors are displayed above the Waveform Display window pane. Delta time (or real time) is the "out and back" time of the TDR signal. Propagation time, the "out only" time is calculated as half that value.

Testing the Differential coupon

The sample coupon includes a 100Ω differential pair.

Connect the IPD100 Differential Probe to the Channels 1 and 2 SMA connectors on the CITS front panel.

Select the Differential 100Ω Ohm Diff Test. Locate the IPD100 Probe across the 100Ω impedance and press the Test button.

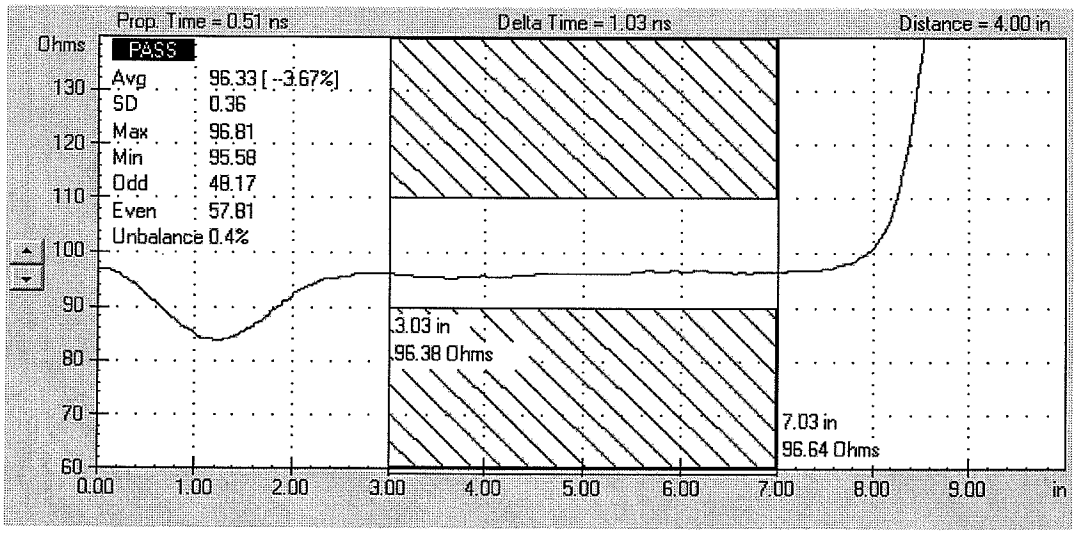


Figure 3-7 Differential Coupon Test PASS result

The differential pair returns results as for the single-ended case but also includes values for Odd and Even mode impedance and unbalance between the lines.

Odd mode impedance is defined as the impedance of either of the conductors in a differential pair when both drives are driven differentially (i.e. with signals of equal and opposite polarity), so odd mode impedance is equal to half the value for differential impedance in a balanced system.

Even mode impedance is the impedance of either of the conductors in a differential pair when both drives are driven in common mode (i.e. with identical signals of the same polarity).

3-2 Exiting the program

Select **Exit** from the **File** menu or press **Alt+F4** to leave the program and return to the Windows Program Manager.

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SECTION 4 — SYSTEM OPERATION

USING THE CITS

IMPORTANT The CITS is an extremely sensitive measuring instrument. To prevent damage to the CITS observe static precautions at all times. See Appendix B for information

STARTING THE CITS

*Note: These operating instructions assume that the installation procedure has been successfully completed and the hardware has been activated (see **Hardware Activation**) and the key present.*

Double clicking the CITS icon starts the CITS program. When the CITS program runs, the main CITS screen is displayed loaded with the last test file used. Figure 4-1 shows the CITS main screen:

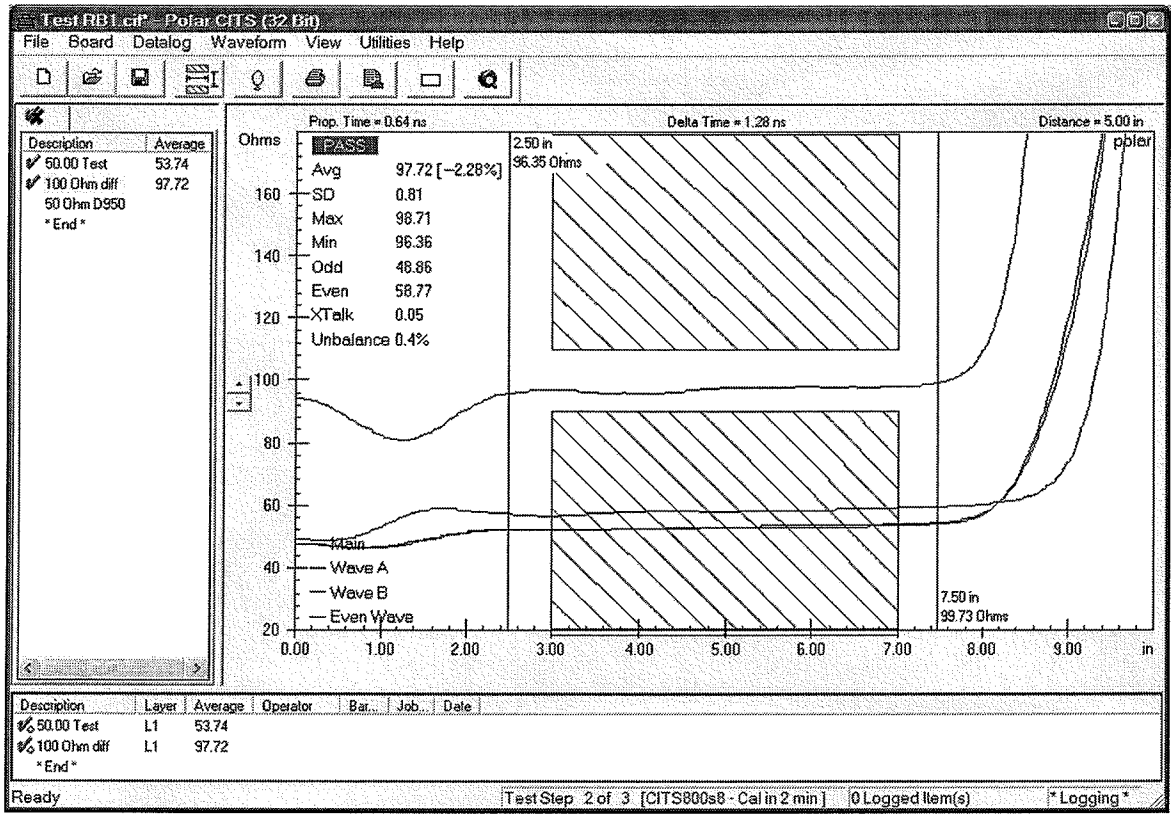


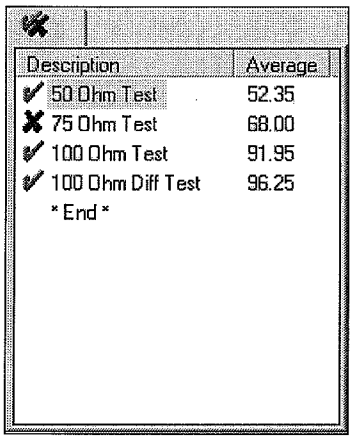
Figure 4-1 The CITS main screen

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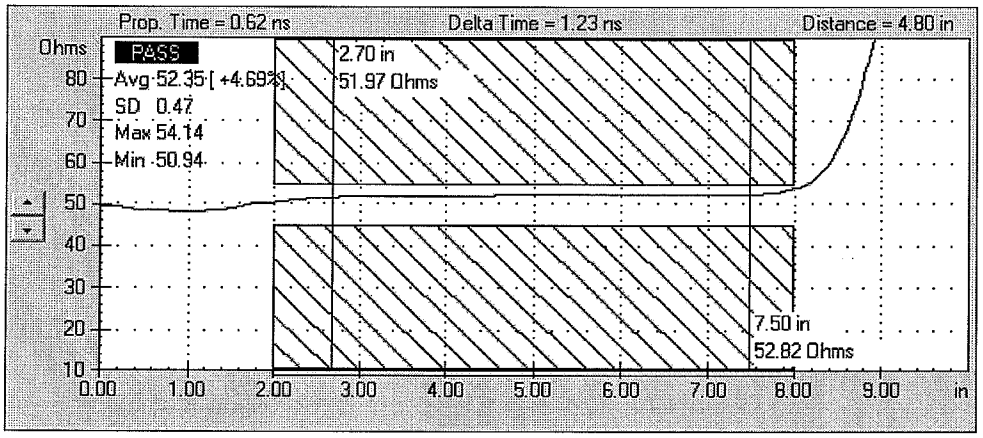
4-1 The CITS screen

The CITS800s window is split into three main areas:

The Test List window pane containing each named tests within the currently selected test file.



The Waveform Display window pane which displays the impedance waveform and statistical results for the selected test.



The Datalog Results window pane which displays the logged results for one or more boards using the current test file.

Description	Z Nominal	Average	Max Z	Min Z	Differential	Even Mode	Unbalance
50 Ohm Test	50.00	52.35	54.14	50.94			
75 Ohm Test	75.00	68.00	68.81	65.99			
100 Ohm Test	100.00	91.95	92.93	90.38			
100 Ohm Diff Test	100.00	96.25	97.05	95.21	Yes	57.55	0.80%
* End *							

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The CITS800s includes two control sections:

The menu bar containing the CITS commands

The tool bar which provides short cut access to the most commonly uses commands.

The status bar displays descriptions of the tool bar buttons as the mouse is moved over each button and test and datalogging and calibration information.

The CITS window may be increased or decreased in size by dragging the window borders with the mouse.

The main screen window can be maximised to full screen view if desired — click the **Maximise** button (or double-click the CITS800s Title Bar or press **Alt+Spacebar** then **X** on the keyboard).

4-2 The CITS menu bar

All CITS commands are available from pull-down menus; commands can be accessed via the keyboard or mouse (see OPERATING THE CITS800s).

The File menu

The **File** menu provides the commands for working with test files — the user is able to:

Create new test files

Open and save existing files

Choose and set up printers for hard copy

Preview and print the displayed waveform, datalog results or test file list

Exit from the CITS800s program

When the **File** menu appears the last five test files opened are listed in reverse order.

The Board menu

The Board menu contains the commands to insert new tests and modify existing board test parameters within the current test file. Typically each board will have an associated test file containing all the tests for the controlled impedance traces on the board. Each board test file will include board setup information (e.g. customer name, board type and part number) along with notes for the board (comments, special instructions, etc.)

For convenience the Board menu includes the **Setup Wizard...** command which will guide the user through the steps required to create a test for a board trace.

Use the **Waveform** commands to store waveforms as reference for future tests.

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The **Snap Test Limits to Cursor** command allows the user to change the distance over which the trace is tested to the distance indicated by the cursor positions.

Individual trace tests may be designated as members of a named group and tested for impedance spread across the group.

Board notes will be displayed at test time.

The Datalog menu

The **Datalog** menu allows the user to control the CITS800s datalogging facilities. Datalogging enables test data to be automatically logged to a text file for archiving and subsequent analysis. The log file can be printed out or imported into a spreadsheet for analysis or the optional Datalog Report Generator.

If the **Enable Autosave of waveform (.cvf) files** check box (see the **Config|Paths** options) has been checked waveform files will be saved automatically at the datalog point.

During the datalogging process waveform files will be saved and named using the board serial number and test name (e.g SN123_Test50Ohm.cvf).

Automatic data logging can be toggled on or off via the **Autolog** command. **Autolog** is ON by default and its status is saved between sessions.

Tests may be cycled through in sequence automatically or manually selected. If **Auto Advance** is selected the CITS steps through the test list from the top depending on the Auto Advance option specified (**Off**, **On Pass**, **After Test**).

If the **Show Last Waveform Before Auto Advance** option has been set (see the Config|Prompts dialog in the Utilities menu) the test waveform is displayed briefly before **Auto Advance** moves to the next test.

The **Datalog Report Generator** command starts the optional Datalog Report Generator.

The **Reload Datalog File** command allows CITS users logging data to a common datalog file on a network server to refresh the local copy of the datalog file with the updated data from the server.

The Waveform menu

The **Waveform** menu allows the operator to:

Save the current waveform as the reference waveform for a test file — this reference waveform is then displayed in green (default color) whenever the test file is selected. Reference waveforms are retained even when the screen is cleared.

Reference waveforms will be removed from the test file when the associated test parameters are changed.

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Overlay multiple waveforms — allowing comparison of a sequence of test results.

Record (save) the current waveform to disk for later viewing.

View recorded waveforms.

In differential tests, view the single ended and even-mode impedance waveforms for engineering analysis.

In differential tests, assign the measurement cursors to the differential, single ended or even mode waveforms.

The View menu

The View menu allows the user to control the display of CITS800s screen items (readout, cursors, graticule, toolbar, etc.)

This menu also allows the user to select for display statistical information in the Test List and Datalog window panes.

The Utilities menu

Users can change operating conditions during normal CITS operation via the **Utilities** menu.

Config…

Use the **Config** command to change System Configuration options (see SYSTEM CONFIGURATION for more details).

Import…

Use the **Import** command to open CITS test files produced using earlier versions of the product.

Diagnostics…

The **Diagnostics** command allows users to verify the calibration of the CITS and to re-calibrate the instrument

Learn Cable Length…

Use the **Learn Cable Length** command to ascertain the actual length of the cable attached to each channel and apply correction factor.

The Help menu

The Help menu includes concise explanations and instructions for every CITS operation — press the F1 function key to access the on-line help from anywhere in the program.

Select **Help Topics** for help in operating the CITS800s.

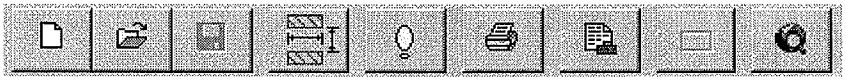
Select **About** for system information (firmware versions, etc.)

If a modem is installed in the host computer and an Internet connection is available, select **Visit www.polarinstruments.com** to access the Polar Instruments web site for product and application information.

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4-3 The CITS main tool bar

The CITS main toolbar contains buttons that provide quick mouse access to some of the most frequently used CITS commands:





Press the **File New** button to create a new test file.



File Open... — press this button to display the **Select Test File** dialog box and choose a test file. Each test file contains one or more tests for the board under test.



File Save — save the current test file.



Board Edit — starts the Test File Editor



Execute Test — perform a test using the selected test file.



Print waveform — send current waveform to printer for hard copy.



Datalog Report Generator — start the (optional) Datalog Report Generator.



Clear Screen — clears the waveform display window.



Visit Polar Website — Access the Polar Instruments Internet Web site for updates and application information.

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4-4 The Waveform Display window pane

When a test is executed the CITS displays the resulting impedance waveform along with the test limits (the hatched area), and the results of the test in the Waveform Display window pane.

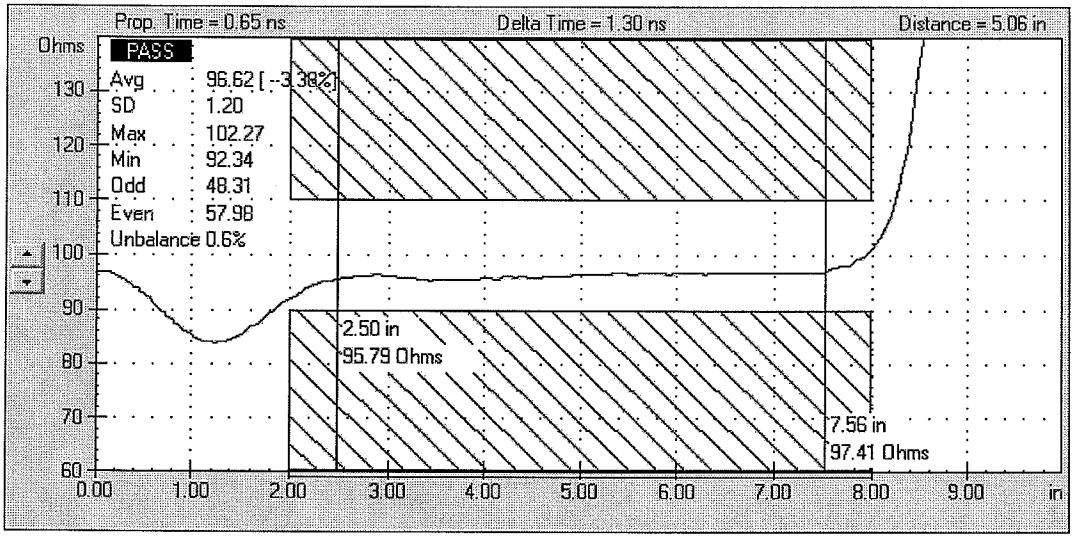


Fig 4-2 Waveform Display window pane

The PASS/FAIL result and the statistical data for the tested region of the displayed waveform (i.e. between the two hatched areas) is included in the statistics/results area — the upper left corner of the Waveform Display window pane. The tested region is commonly referred to as the *undisturbed interval* (or flattest portion) of the waveform and delimited by the width of the test limits (the crosshatched areas — shown in blue by default).

On completion of a test the resulting test waveform is displayed, a PASS or FAIL is reported and displayed statistical data is updated.

For single ended measurements four values are displayed:

- Average impedance
- Standard deviation
- Minimum impedance
- Maximum impedance

Note: If the test limits are correctly set the average impedance is the measured characteristic impedance for the trace under test.

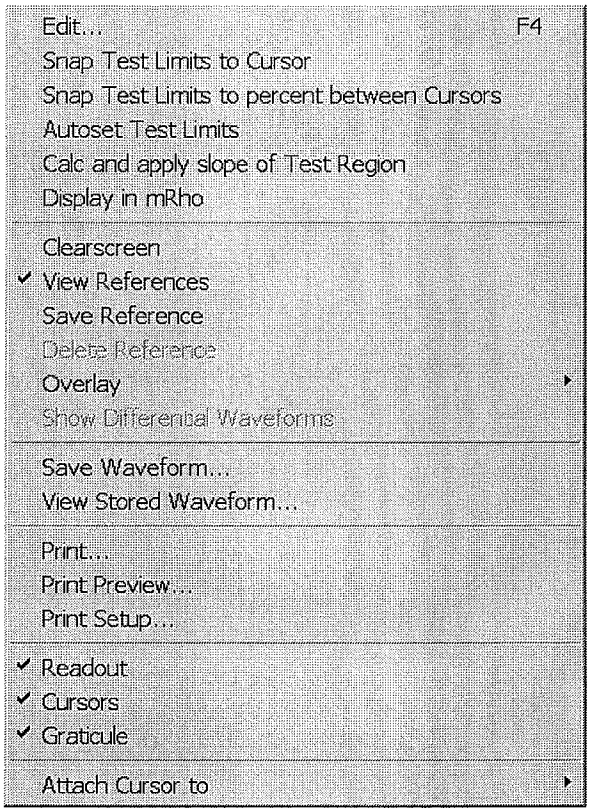
When differential impedance measurements are specified in the test (i.e. when testing a differential pair of traces) additional values are displayed:

- Odd mode impedance
- Even mode impedance
- Unbalance (shown as a percentage) between the lines

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The Waveform Display shortcut menu

Right-clicking into the Waveform Display window pane displays the Waveform Display shortcut menu:

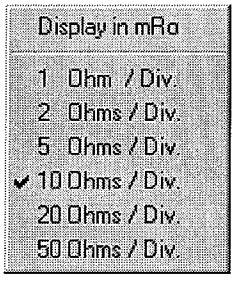


The shortcut menu contains the most commonly used functions for waveform display.

Vertical and horizontal axes

The vertical axis is graduated in Ohms/div by default. The vertical deflection factors (Ohms/div) for each test are derived from the settings in the test file (see Section 5 — EDITING TEST FILES).

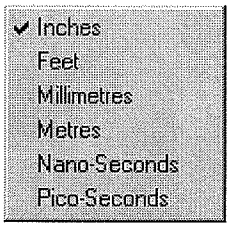
The deflection factor can be changed on screen by right-clicking the mouse on the vertical scale and selecting a new deflection factor from the short cut menu:



The vertical axis can be graduated in mRho. Select **Display in mRho** from the shortcut or the **View** menu. The CITS converts the current Ohms/div setting to mRho.

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The horizontal axis is graduated in units of distance or time. When measuring distance (i.e. along the controlled impedance trace) the units of measurement can be selected by right clicking the horizontal scale:



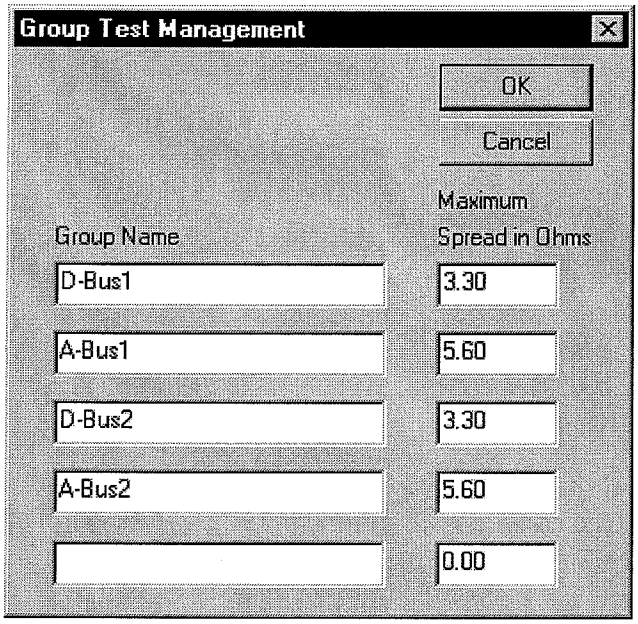
Horizontal units are graduated in inches, feet, millimetres, metres, nanoseconds or picoseconds.

Changing the vertical and horizontal deflection factors via the shortcut menus method will not invalidate the results of a test.

Group testing

Individual trace tests may be designated as members of a named group and tested for impedance spread across the group.

From the **Board** menu choose the **Edit Groups...** command — the **Group Test Management** dialog is displayed.



Enter a group name and maximum impedance spread for each group for each group; up to five groups may be specified. Use the Test List Editor to designate a test as a member of a group; see *EDITING TEST FILES*.

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4-5 The Test List

The Test List is displayed in the Test List window pane.

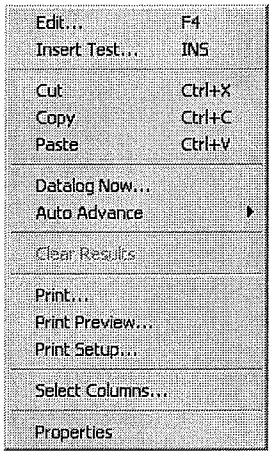
The List contains one or more columns, or *fields*, displaying information (for example, the description, test parameters or test results, if any) for each test in the active test file. Descriptive and parameter information is derived from the entries and settings in the Test Setup Editor window. By default the Description (i.e. the test name) and the Average impedance result are displayed.

Test results include a PASS/FAIL result along with statistical information for the test. The Description field displays the PASS result (green tick) or FAIL (red cross) for both absolute and group spread values as shown in the table below

Pass/Fail Indication	Impedance Value	Group Spread Test
✓✓	PASS	PASS
✓×	PASS	FAIL
×✓	FAIL	PASS
××	FAIL	FAIL

Adding columns to the Test List

To add fields to the Test List right click into the Test List window pane — the Test List short cut menu is displayed:



Choose the **Select Columns...** command to display the Select Test List Display Columns dialog box.

The Select Test List Display Columns dialog box comprises two list boxes — the box on the left lists the fields which are still available for inclusion in the Test List pane, the box on the right lists the currently displayed fields

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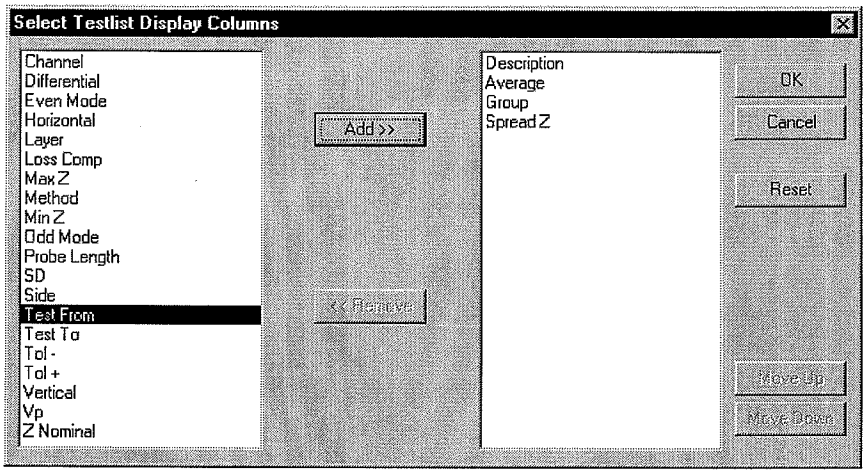


Fig 4-3 Adding and removing fields with the Select Testlist Display Columns dialog box

To add a column, select the field from the list of available fields and click the Add button; to remove a column, select the field from the list of displayed fields and click the Remove button.

To select a group of adjacent fields drag the mouse over the range of fields; to select non-adjacent fields, hold the Ctrl key down while clicking on the fields of interest — press OK to confirm the selection.

Pressing the Reset button restores the displayed fields to the default Description and Average fields.

4-6 The Datalog

Test results are recorded in the Datalog window pane.

Description	Layer	Average	Date	Time
100 Ohm Test	1	95.39		
75 Ohm Test	2	76.48		
50 Ohm Test	1	49.37		
* End *				

With a test file loaded, as the first test is executed the test list is added to the Datalog window. As each test is executed its results are displayed in columns in the Datalog.

By default the Description, Layer, Average, Date and Time columns are selected for display.

To display other result fields right click into the Datalog window pane and choose **Select Columns** — the Select Datalog Display Columns window is displayed:

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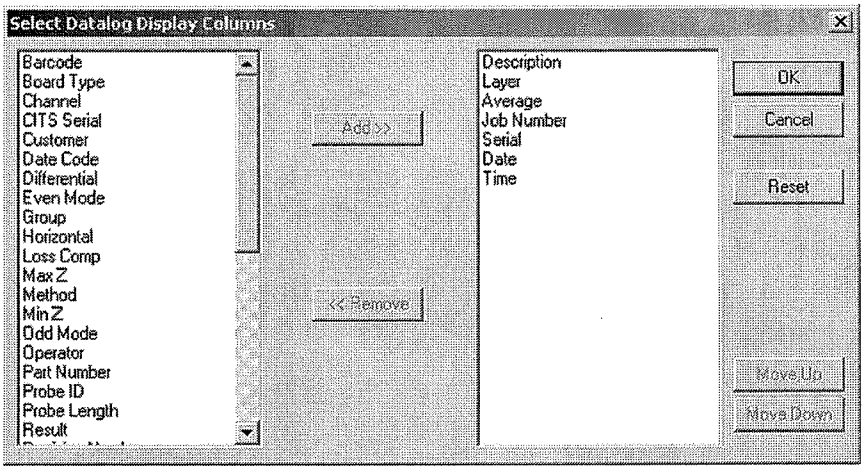


Fig 4-4 Adding and removing fields with the Select Datalog Display Columns dialog box

Click on the field of interest in the list of available fields and press Add to include a new column to the Datalog window pane.

If logging is turned off, each time a test is repeated the test results overwrite previous data. A yellow circle alongside each test result signifies that the results have not been logged. Datalogging is discussed in Section 4-9 – LOGGING TEST DATA

4-7 The Status bar

The CITS status bar displays activity and status information and messages to assist the user during CITS operation.

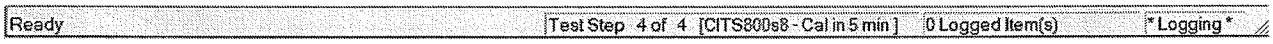


Figure 4-5 The CITS status bar

The status bar comprises three sections:

Current activity — the CITS reports its current activity, Ready... (awaiting instructions), Calibrating..., Setting up..., Testing..., etc. When the mouse is moved over a Toolbar button this portion of the Status Bar is used to display a brief description of the button function.

Calibration mode — indicates progress of testing and the currently selected Calibration mode (Autocal — timed calibration or Cal on Test — calibration before each test is executed).

Datalogging information — the number of logged items, updated as each batch of tests is completed for a board.

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4-8 Testing printed circuit boards

The procedure for testing printed circuit boards is similar to that described for the sample test coupon in the previous section:

Prior to testing boads ensure appropriate anti-static measures are observed.

Select a test file if one exists (or create a new file and insert tests for each controlled impedance on the board. Each test will include a complete set of test parameters for the trace under test — see Section 5 — Editing Test Files).

Select the test to be executed (usually the first test in the list).

Connect the tip of the Microstrip probe to the board terminals or connections (be careful to maintain correct polarity of signal and ground connections).

Execute the tests via the **Board** menu or click the **Test** button (see note below).

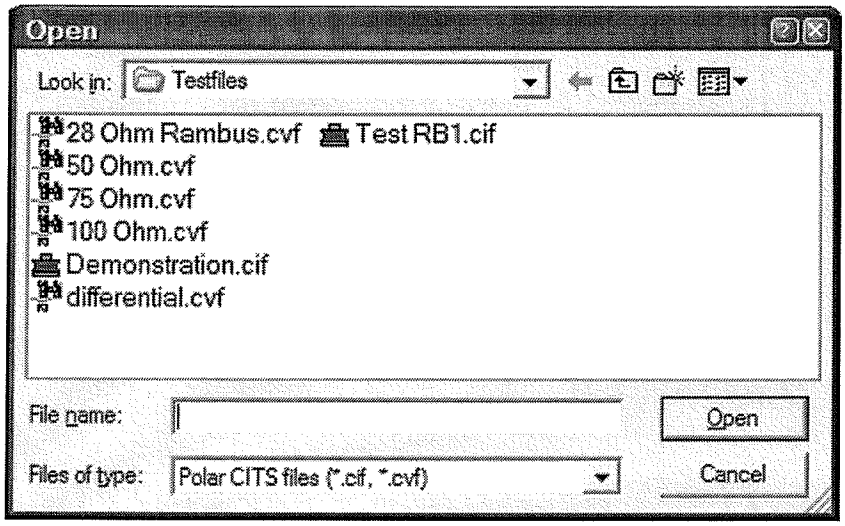
If datalogging has been turned on, when all tests for the board are completed supply board details for data logging in the Datalog Board Information dialog box.

Note: For convenience, users are recommended to use the Foot Switch to operate the CITS in a "hands-free" mode. Using the Foot Switch allows the operator to use both hands to hold the probe in proper contact with, and support, the board under test).

Selecting a test file

Prior to testing a board or batch of boards a test file containing tests associated with the board type must be selected (or created if none exists). See Section 5 — Test Setup Editor for details of creating, modifying and saving test files.

Select the **File** menu and the **Open...** command — the CITS displays the **Open** dialog:



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Figure 4-6 Selecting a test file

The **Open** dialog opens with the list of files (identified by the **.cif** extension) in the current folder displayed. (Test files may also be selected from the recently used file list from the **File** menu.)

If necessary navigate to the folder containing the test file. Select the board test file by clicking the file name with the mouse (or press the <**Tab**> key to move into the file list field and use the cursor keys to highlight the test file) — in this case we test the single-ended coupon with the Coupon Test file — press **OK** to load the file, then click on the 100 Ohm test.

The CITS displays the name of the selected file in the Title Bar and the 100 Ohm Test 's impedance and distance scales and test limits in the Waveform Display window pane.

From the **Datalog** menu click on **Autolog** to turn automatic data logging on and select **Auto Advance** and choose **After Test** to step through the tests automatically and log results to the log file.

Select the test to be run and run the test.

The **Auto Advance** function controls how tests in the test file are sequenced. Autoloading is controlled using the options in the **Auto Advance** sub-menu — **Off, On Pass, After Test**. If **Auto Advance** is turned **Off** the CITS will not automatically sequence through the tests. Steps in the sequence must be manually selected then run. If **Auto Advance** is set to **After Test** the CITS will automatically sequence through the tests, regardless of test PASS/FAIL results. When **Auto Advance** is set to **On Pass** the next test file in the sequence is automatically loaded if the test records a PASS.

To advance to the next test in the list manually, use the mouse or the arrow keys on the keyboard.

Executing the Test

Most board testing will be performed with Microstrip probes. Using Microstrip probes will minimise measurement errors due to mismatch between the impedance of the measurement system (50Ω) and the track under test.

Keep to a minimum the number of changes in impedance between the CITS and the PCB track. The CITS output impedance is rated at 50Ω so as far as possible use cabling and connectors from the CITS with 50Ω characteristic impedance.

For more information and hints on testing PCBs and test coupons see the notes at the end of this section.

Locate the Microstrip Probe in position on the circuit board under test (or coupon). Connect the signal pin to the signal trace pad and the ground pin to the ground plane (reference plane) pad.

Hint: On test coupons the signal and ground pads can be identified by shape (signal pins pads are commonly round in shape, ground pins square).

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Select the **Test** function from the Board menu (or click the mouse on the **Test** button or use the Foot Switch for hands-off operation).

When the test screen is displayed the limits of tolerance defined in the test for the tested portion of the track will be indicated by the cross-hatched areas (at installation the CITS test window is set to its default — red cross-hatched areas on a black background — see the **Utilities** menu for information on changing screen colors).

During a board test the system checks that the displayed impedance waveform falls within the limits defined in the test file.

Select the 100 Ohm Test and test the 100Ω impedance trace; the results are displayed on screen and added to the log and the CITS selects the next test in the list. Test each of the traces on the coupon.

As each group of tests is completed (i.e. when the whole board has been tested) the Board Information box is displayed so that board information may added to the test results and logged.

Data in the log may be processed by the optional Datalog Report Generator.

Deleting test results

From the **Board** menu select the **Clear All Waveforms** command to clear all test data from the current set of results.

Caution: Selecting **Clear All Waveforms** *will clear all result entries from the Test List window pane and all unlogged data from the Datalog window pane but will not remove logged data.*

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4-9 Logging Test Data

The **Datalog** function allows the operator to test and record the results of a series of tests on a board or batch of boards. The CITS creates a log file (a text file containing test data) for archiving and subsequent analysis.

The log file is stored in delimited form (using the | character as the delimiter between fields). This format will be found suitable for import into most spreadsheet or database programs — and can be printed out for hard copy.

Polar Instruments supply a Datalog Report Generator accessory to automatically process this data for use in statistical process control. To enable logging select the **Datalog** menu and ensure **Autolog** is turned on.

Test the board using the associated test file; when the test is complete, the **Datalog - Board Information** dialog box is displayed — Figure 4-7. (For details of creating user-defined fields, e.g. Batch, Process, etc., see SYSTEM CONFIGURATION.) Enter the details for the board under test — serial number, date code and operator name, etc. and press **OK**.

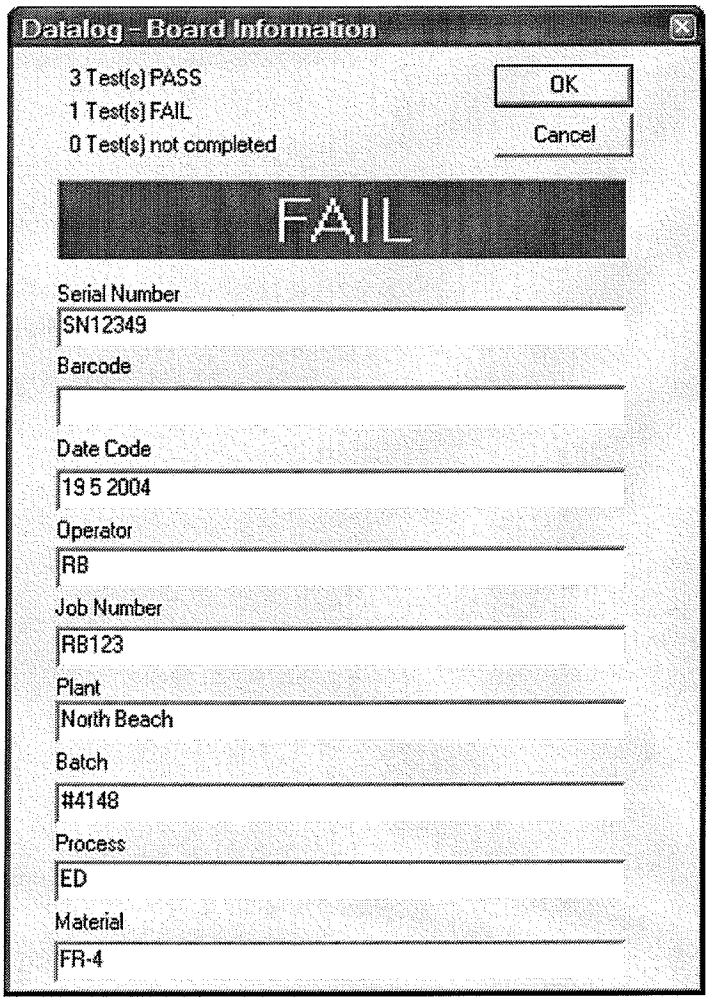


Figure 4-7 Datalog information dialog box

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If the **Enable Autosave of waveform (.cvf) files** check box (see the **Config|Paths** options) has been checked waveform files will be saved automatically at the datalog point.

During the datalogging process waveform files will be saved and named using the board serial number and test name (e.g SN123_Test50Ohm.cvf).

The Data Log window

The Data Log window displays all logged entries in the log file.

Test results are stored sequentially as records in the log file. If necessary, use the scroll bar to scroll through the list when inspecting records in the log. Each entry comprises a subset of the logged data — board details, test name, trace layer, the result of each test, average impedance and test date and time are included by default. Columns for Maximum impedance, Minimum impedance and Standard Deviation have been added to the Datalog window pane.

Description	Layer	Average	Date	Time	Max Z	Min Z	SD
✔ 100 Ohm Test	1	95.11	03/11/99	1038	99.24	93.55	0.99
✔ 75 Ohm Test	2	76.39	03/11/99	1038	78.91	74.93	1.14
✔ 50 Ohm Test	1	48.89	03/11/99	1038	50.44	46.25	0.90
✔ 100 Ohm Test	1	95.05	03/11/99	1055	98.89	93.81	0.82
✔ 75 Ohm Test	2	76.29	03/11/99	1055	78.91	74.87	1.15
✔ 50 Ohm Test	1	49.23	03/11/99	1055	50.68	46.40	0.90
* End *							

Figure 4-8 Datalog window pane with logged data

To include other information such statistical data, test parameters right click into the Datalog window pane and choose Select Columns

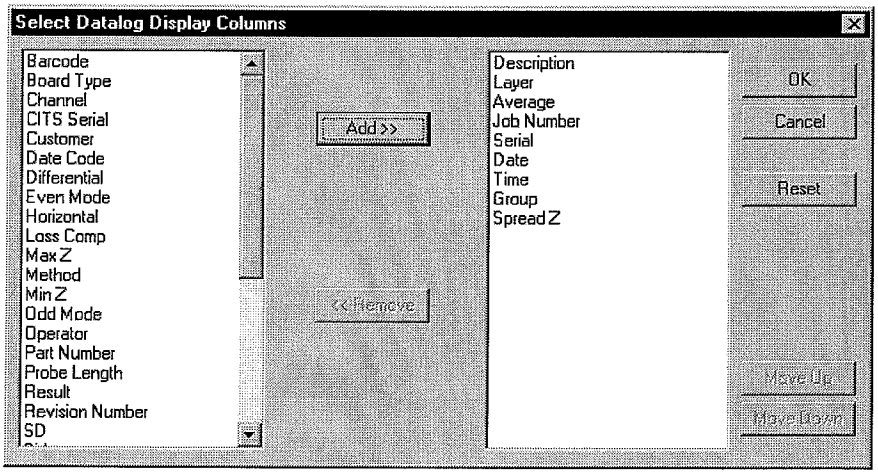


Figure 4-9 Select Datalog display columns window

Choose the fields containing the statistical data or test parameters and click **Add** then **OK** — the new fields will be added to the log window.

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Deleting records

To delete a single record from the log file, scroll through the list of entries, select the record with the mouse or the keyboard cursor keys and press the **Delete** button — all the tests for the board will be deleted.

Note: The record will be permanently deleted.

Editing records

Each line of logged data (a small yellow circle is shown against data not yet logged) can be edited if necessary (e.g. to correct for the results of spurious readings, intermittent connections, etc.) with the **Edit Line** command. The **Edit Line** command is "greyed out" for data not yet logged.

Right click onto the line to be modified and choose **Edit Line** to display the **Edit Datalog Line** dialog box.

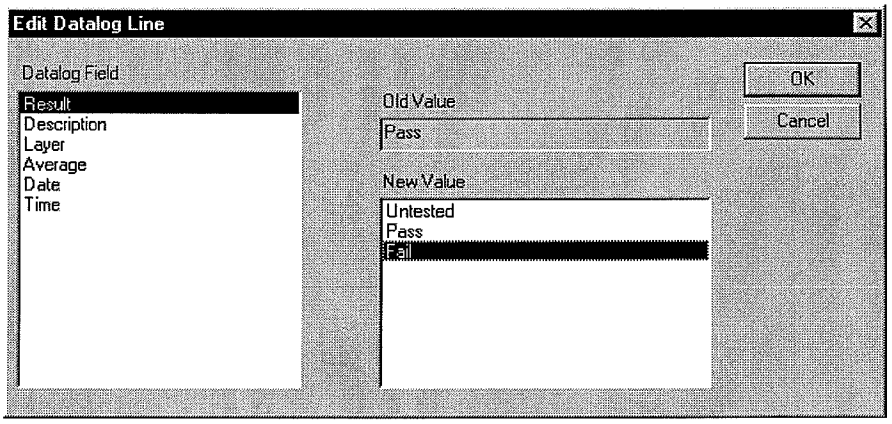


Figure 4-10 Edit Datalog Line dialog box

The Datalog field box lists the columns (fields) displayed in the Datalog window.

Choose the Field to be edited

Select a value from the New Value list or type a new value in the New Value box to replace the entry in the Old Value text box.

Press OK to confirm the new value.

Printing logged data

To print the complete datalog right click into the Datalog window pane and choose the **Print** command from the short cut menu. To print only selected lines use the left mouse button + Shift or Control to select the lines required.

4-10 Using Delta Time Cursors

Propagation delay times may be measured by positioning the cursors at the beginning and end of the test specimen.

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To enable the cursors select **Cursors** from the **View** menu or from the Waveform Display short cut menu.

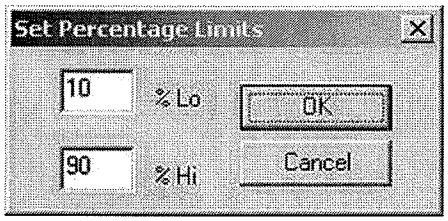
To position a cursor click the left mouse button on the cursor (the mouse pointer changes to a double headed arrow); drag the cursor onto the required location on the waveform. Release the mouse button.

The screen displays the distance and impedance where each cursor crosses the impedance waveform.

Use the **Snap Test Limit to Cursor** command to reassign the **Test From:** and **Test To:** distances to the cursor positions.

Snapping test limits to Percent between cursors

Use the **Snap Test Limits to Percent between Cursors** command to change the horizontal **Test From** and **Test To** limits to percentage values of the current lower and upper cursor time positions. Use Set Percentage Limits dialog box to specify the **Test From** and **Test To** limits



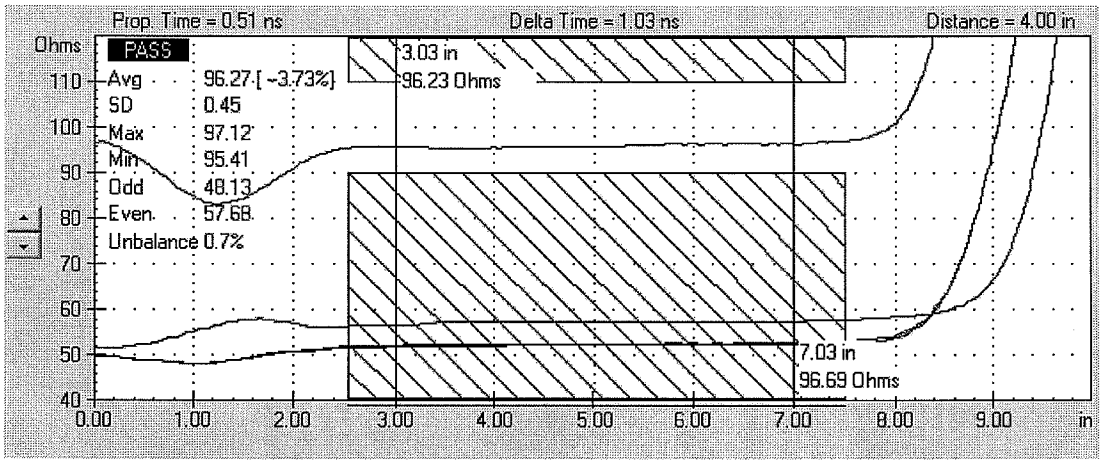
For example, if the cursors are set to test from 1 to 4 inches (i.e. a 3 inch test range) using the above values will change the lower limit to 1.3 inches (1+0.3) and 3.7 inches (4–0.3).

4-11 Viewing differential waveforms

Normally only the differential impedance waveform is displayed. During differential testing, however, the CITS records the differential impedance of the pair of traces, the single-ended impedance of each line to ground and the differential even mode impedance of the pair. Results for odd and even mode impedance along with unbalance between the lines are logged and displayed on screen. The results displayed by the CITS take into account the effect of unbalanced lines.

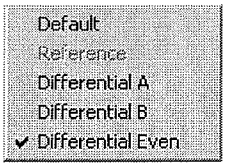
To view the single-ended and even mode waveforms (e.g. for engineering analysis) select **Show Differential Waveforms** (right-click the waveform window to display the short cut menu).

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Offset the display vertically using the up and down arrows to display all waveforms. The display above shows the 100Ω differential impedance waveform along with the two single-ended waveforms (approximately 50Ω) and the even mode waveform (approximately 58 Ω).

The cursors can be used to display values along each of the four waveforms. Select the **Attach Cursor To** command and from the sub-menu choose the waveform to be measured.



Calculating waveform slope

Series resistance will appear as a ramp in the waveform with impedance increasing linearly with distance. Series resistance simply adds to the characteristic impedance over the length of the waveform. (See the section **Test Editor|Loss Compensation** for a brief discussion of loss compensation.) Series loss can be compensated for by adjusting the slope of the waveform by a specified number of ohms/horizontal unit. This cancels out the series resistance leaving the true characteristic impedance displayed.

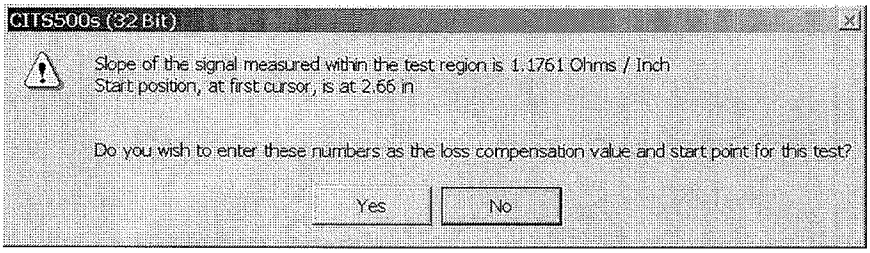
Applying loss compensation

Caution! Applying loss compensation may invalidate results. *A sloping waveform may be attributable to a number of causes. Consult the board design authority before applying loss compensation.*

Use the **Calc and apply slope of Test Region** command to calculate the slope of the test waveform.

Right-click the waveform display window and choose the **Calc and apply slope of Test Region** command: the CITS800s displays the slope of the waveform within the test region along with the horizontal position (i.e. the distance) of the first cursor.

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To apply loss compensation locate the first cursor at the horizontal distance loss compensation should begin. Click **Yes** to apply the values for loss compensation and start point, click **No** to leave the data unmodified.

The waveform is shown in bold from the first cursor position and a small triangle is added at the beginning of the compensated portion of the waveform. To remove the compensation start the Test Setup Editor (right click the waveform or the test name in the test list and choose Edit...) and reset the Loss Compensation setting to Default.

4-12 Printing waveforms, datalog or test results

Select the **Print** function from the **File** menu.

The Print dialog box includes the Select Printout group of options — choose Waveform, Datalog or Test List for printout. Use the text box to add comments to the printout. See Figure 4-10.

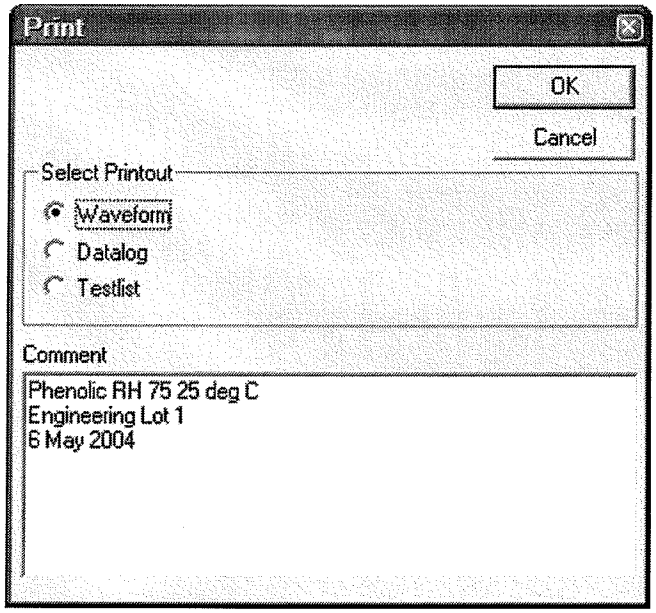


Figure 4-11 Print dialog box

Select **OK** to proceed with printing.

4-13 Saving and viewing waveforms

The **Save Waveform** function allows the operator to store individual test waveforms on disk. Test waveforms are stored as files with the **.cvf** file extension. With the waveform displayed in

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the Waveform Display window pane select **Save Waveform** from the **Waveform** menu —the system will display the **Enter Waveform Filename** dialog box.

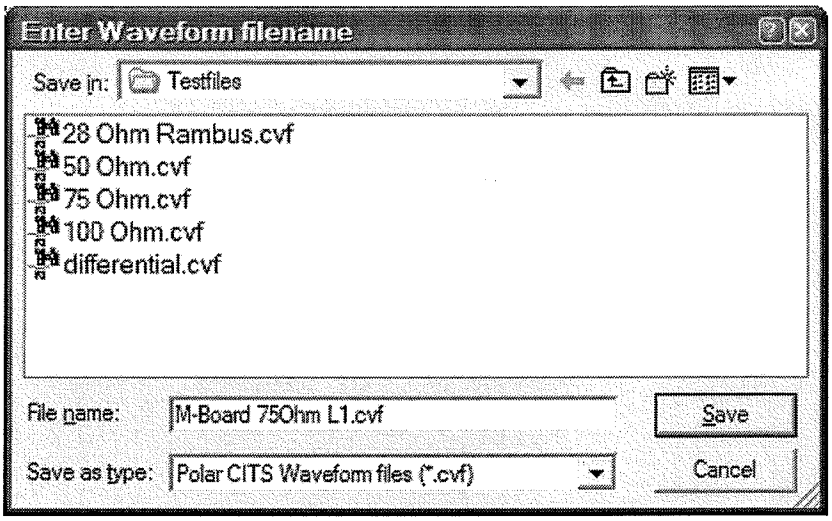


Figure 4-12 Save waveform dialog box

Choose a name for the waveform and press **Open** — the CITS displays a Notes text box; add comments (board serial number, date code, the operator's name, etc.) and press **OK**.

To overwrite a previously stored waveform select the name of an existing waveform file from the list and press **OK**.

Viewing recorded waveforms

Waveforms stored on disk with the **Save Waveform** function may be retrieved and printed with the **View Stored Waveform** menu command.

Select **View Stored Waveform** from the **Waveform** menu — a list of previously recorded waveforms is displayed. Use the cursor keys or the mouse to highlight and select a file from the list and press **OK**. The CITS displays the stored waveform and associated statistics with the CitsView program.

Further waveforms may be inspected using **Open** on the **File** menu and results may be printed out using the **Print** command as described earlier. To return to normal operation select **Exit** from the **File** Menu.

The CitsView waveform viewer

The CitsView program allows the user to display waveforms saved with the **Save Waveform** command. CitsView can display and print saved waveforms and comments and the test parameters specified for each saved waveform. Using CitsView the Waveform Display can be maximised to full screen.

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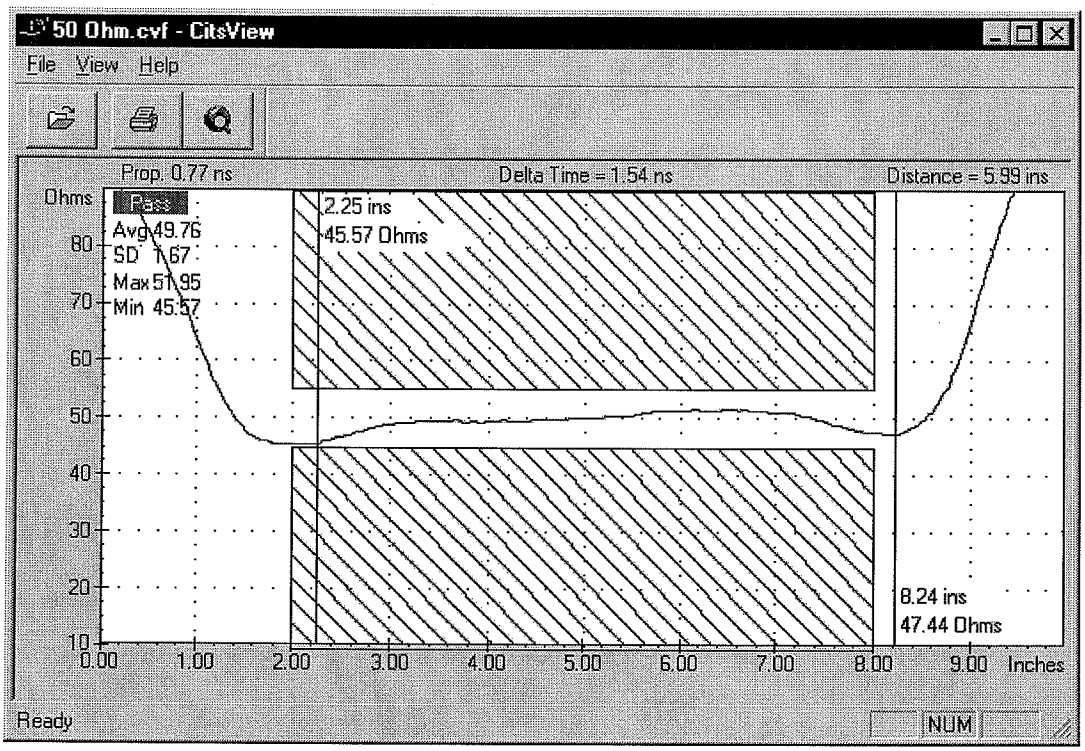
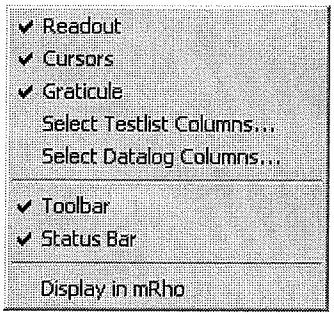


Figure 4-13 CitsView waveform viewer

The items displayed in the Waveform Display window pane can be controlled via the View menu (or the Waveform Display short cut menu)



Select items for display (readout, cursors, etc.) as necessary.

The Stored Waveform tool bar

The CitsView Toolbar includes buttons for the most commonly used functions.

 Press the Open button to view other stored waveforms.

 Press the Print button to print out the displayed waveform.

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 **Visit Polar Website** — Access the Polar Instruments Internet Web site for updates and application information.

The Stored Waveform Status bar

The Stored Waveform Status Bar is similar in function to the CITS800s Status Bar. Brief functional descriptions of each command or button are displayed in the left of the Status Bar as the mouse is paused over an item. The right of the Status Bar displays the state of the Caps Lock, Num Lock and Scroll Lock keys.

4-14 Reference Waveforms

The CITS incorporates the facility to store a reference waveform as part of the definition for a test — the reference waveform is displayed, e.g. as an example of a good trace, when the test is selected. Reference waveforms can saved for each test in a file.

Setting a Reference Waveform

With a good waveform displayed, to save the current waveform as the reference waveform for a test use the **Save Reference** command from the **Waveform** menu. The waveform is then displayed whenever the test is selected. To make this change permanent save the test file and reference to disk using the **Save** command from the **File** menu.

Viewing a Reference Waveform

To view the current reference waveforms for the tests use the **View References** command from the **Waveform** menu.

Saving all waveforms as references

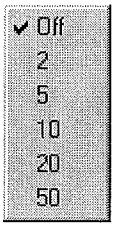
To save the waveforms associated with every test in the in the Test List (e.g. to store the results for a known good board) select the **Save all Waveforms as References** command.

4-15 Overlaying waveforms

The **Overlay** command from the **Waveforms** menu allows waveforms from a series of test operations to be superimposed, or overlaid.

The **Overlay** option displays a sub-menu from which the user specifies the number of waveforms to be superimposed — 2, 5, 10, 20 or 50.

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With the **Overlay** option selected, the waveform window is not cleared between board tests. The results of the last 2, 5, 10, 20 or 50 tests will appear superimposed until **Overlay** is deselected (set to **Off**) — when the maximum number of overlays is reached the oldest test result will be discarded first. See Figure 4-13.

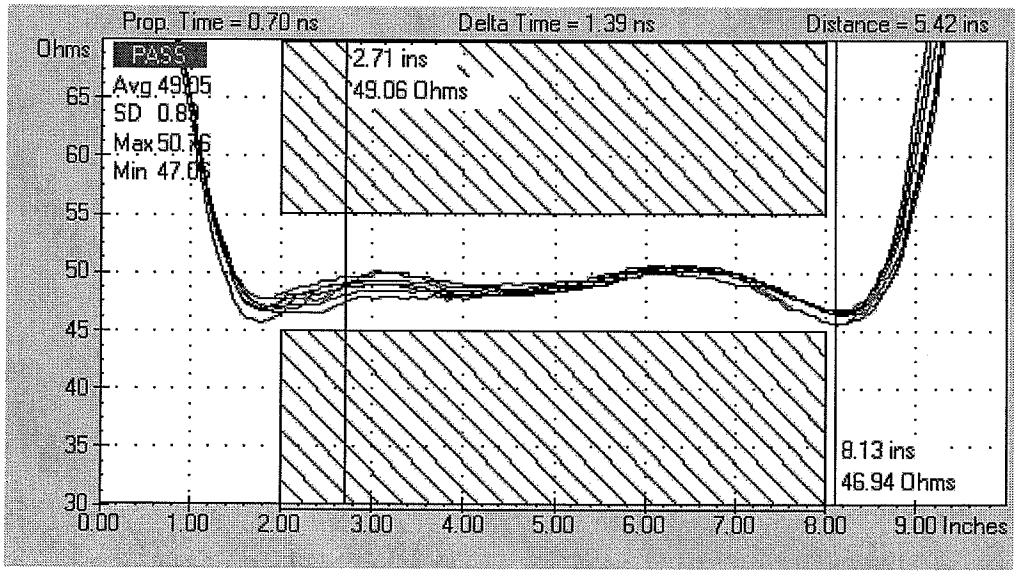


Figure 4-14 Waveforms superimposed in **Overlay** mode

Test the board or batch of boards as described earlier — the test waveforms from each test operation will be overlaid on the previous waveforms until **Overlay** is switched off.

Note: the PASS/FAIL result and information appearing in the Statistics area **ONLY** refer to the most recent test. The Statistics area does not accumulate data.

Turn **Overlay** off the to clear the overlaid waveforms.

Note that the last test result is not cleared — if necessary use **Clear Results** to clear the screen.

4-16 Exiting the CITS program

Select **Exit** from the **File** menu to leave the CITS program.

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4-17 Notes on testing printed circuit boards

Board testing should normally be carried out using the Polar Instruments Microstrip probes. These probes are designed to minimise measurement errors caused by mismatch between the impedance of the measurement system (50Ω) and the PCB under test.

Operation is possible however using direct connections to a board.

Note the following observations when not using the Microstrip probes.

Keeping impedance changes to a minimum

When setting up PCBs for test, the most accurate results will be achieved by keeping to a minimum the number of changes in impedance between the CITS and the PCB track.

The CITS output impedance is rated at 50Ω so as far as possible use cabling and connectors from the CITS to the PCB track with 50Ω characteristic impedance.

Use a probe which minimises the impedance discontinuity at the interface to the PCB.

Using high quality cabling.

Always use high quality low loss cable. Low quality cable may show series resistance, dielectric losses and radiated losses. Series resistance will be displayed as a gradual increase in characteristic impedance along the cable.

Inexpensive cables also tend to have greater impedance variations over their length and at the connectors at each end.

Precision cables (50Ω ±1Ω) are provided with the CITS. Note: the CITS is calibrated before shipment using the cable labelled with the instrument serial number. Use this cable on the MAIN input for optimum system accuracy.

When replacing instrument cables it is important to check (and adjust if necessary) the CITS' Cable Length calibration and impedance measurement accuracy.

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SECTION 5 — EDITING TEST FILES

TEST PARAMETER FILES

EDITING TEST FILES

Each board type to be tested is tested in accordance with one or more tests each of which includes a set of test parameters. Typically the set of tests for one board type will be stored in a single test file. For example, the coupon test files contained the tests for the sample coupons supplied with the CITS800s. The diagram below illustrates the test parameters specified in a test.

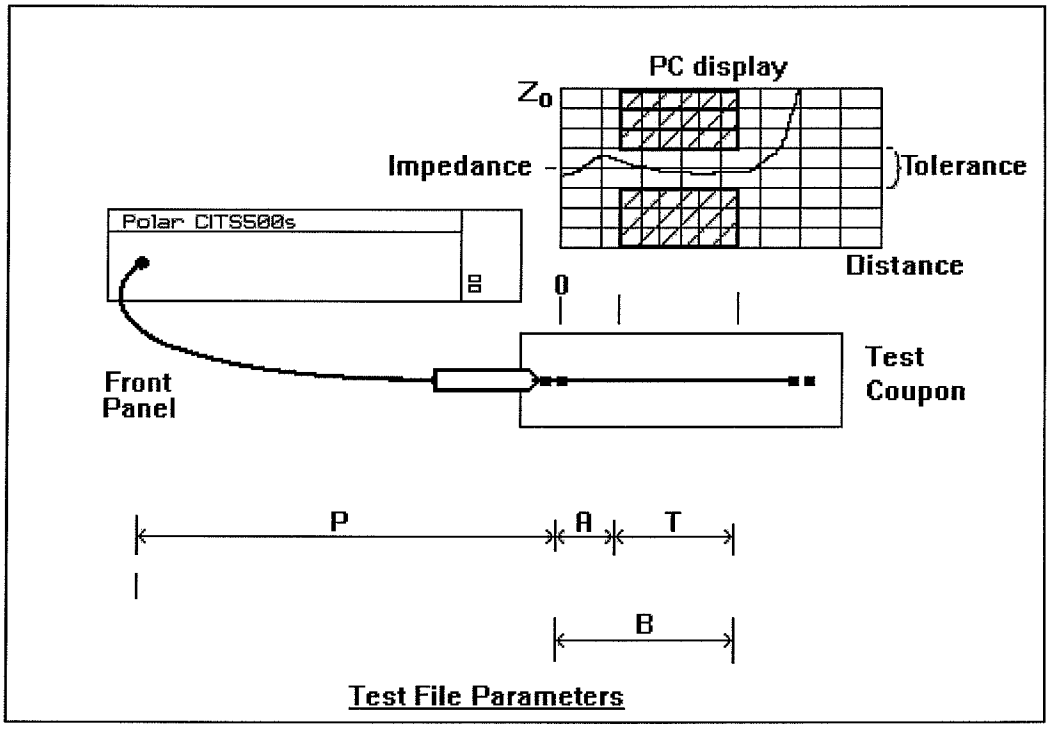


Figure 5-1 Test parameters defined in a test

In Figure 5-1 letters P, A, B, T signify the test parameters listed below:

P	=	Probe Length
A	=	Test From
B	=	Test To
T	=	Tested region (B – A)

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5-1 The Test Setup Editor

Test parameters for boards under test may be defined or modified using the integrated **Test Setup Editor**. See Figure 5-1.

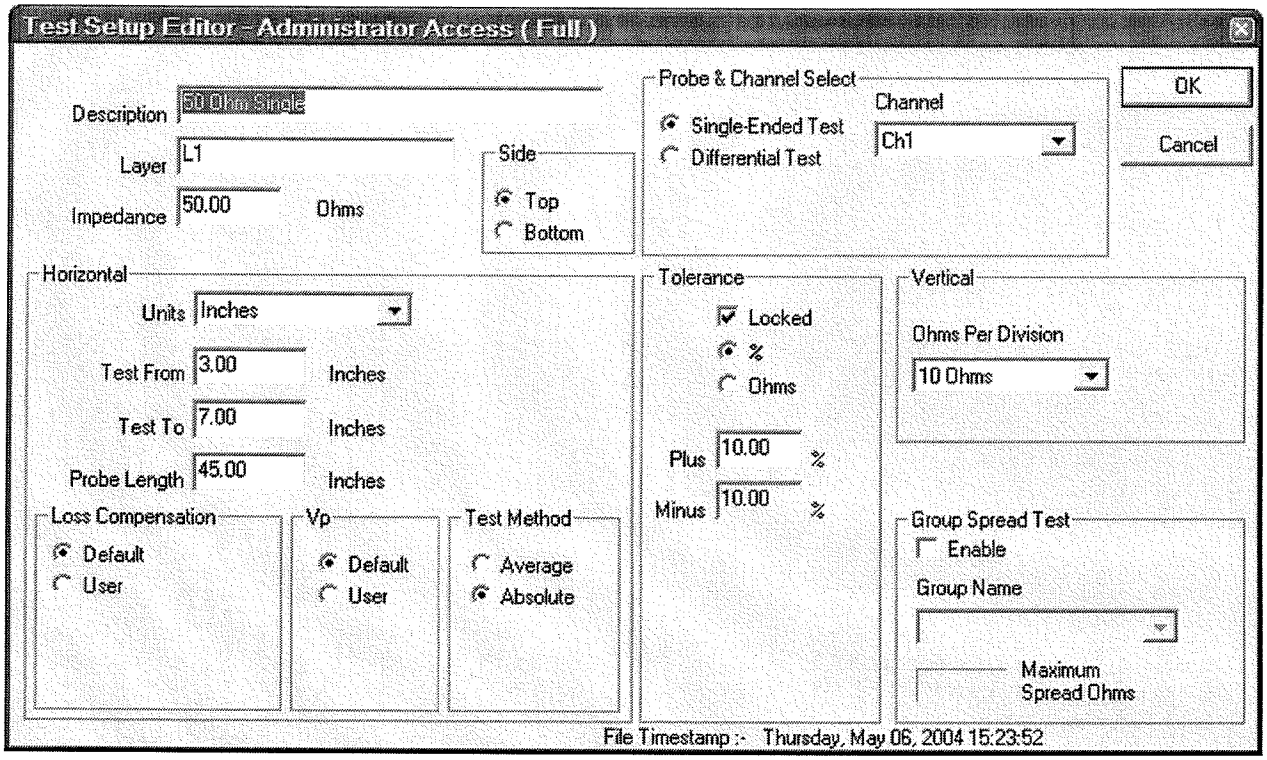


Figure 5-2 The Test Setup Editor

5-2 Creating and modifying test files

Creating a new test file

To create a new test file choose the **New** command from the **File** menu. This will create a new test file called **Untitled** and display the **Edit Board Details** dialog box. This dialog will be displayed each time a new batch of tests (i.e. a new board type) is created.

Enter the details for the board under test, Customer, Board Type, Part Number and Revision Number and Press **OK**.

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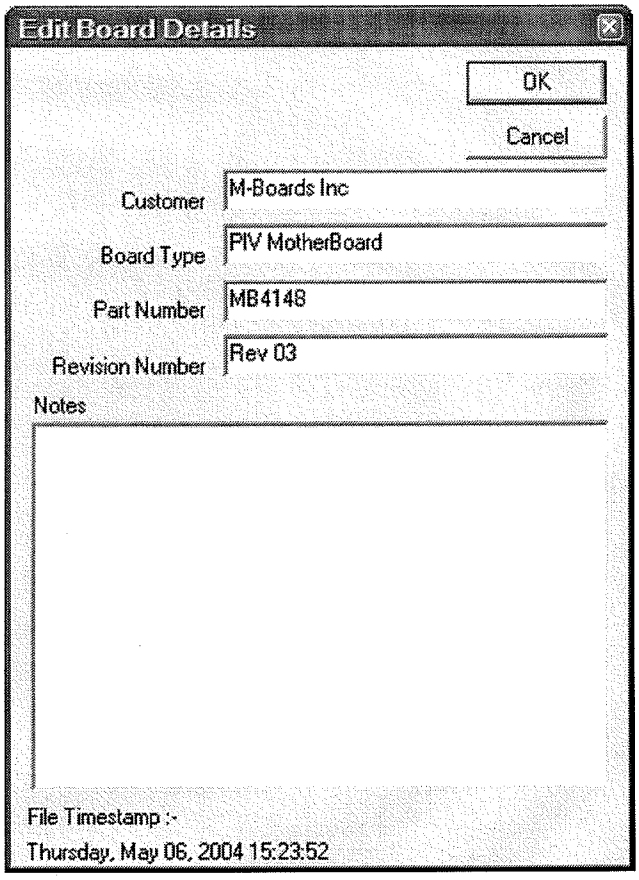


Figure 5-3 Edit Board Details dialog box

The CITS800s creates the new (empty) file. Tests are added to the file via the Insert command.

Inserting tests

Select the Insert command from the Board menu (or press the Insert key) — the Test Setup Editor is displayed:

Each parameter is defined and displayed in a *parameter field*. To create or edit a test, modify the test parameters as required and then use the **OK** button to confirm the field edits.

The fields are described in the following sections.

5-3 Board test parameters

Entries in the fields contained in the Test Setup Editor will be available for display in the Test List and Datalog and printed out with the test results.

Description

Enter the test type into the **Description** field (e.g. D-1, 50 Ohm Trace, etc). The Description is included as part of the data for a board.

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Layer

Use the **Layer** field to indicate the trace layer (e.g. L1).

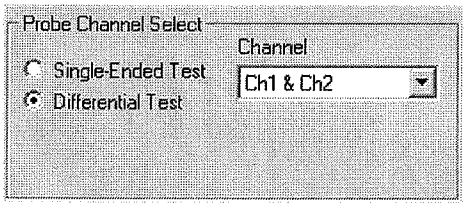
Impedance

Use the **Impedance** field to define the nominal impedance in ohms of the PCB track under test.

This field must contain a number of up to 4 significant digits in the range 10.10 – 200 Ohms.

Probe Channel Select

Use the **Probe Channel Select** function to specify the CITS channel or channels to be used for the test.



Specify any of the four channels for single-ended tests. For differential tests use Channels 1 and 2, Channels 3 and 4, Channels 5 and 6 or Channels 7 and 8.

Single-Ended Test

To perform a single-ended test click the **Single-Ended Test** option button and click the channel number check box.

The CITS is calibrated before shipment using cables labelled with the channel number and instrument serial number. For single-ended testing, connect a probe cable to its corresponding CITS channel and connect the Microstrip probe to the probe cable.

Note: To preserve signal integrity, it is strongly recommended that the cables supplied with the instrument and labelled with the instrument serial number and channel number be used.

Differential Test

To perform a differential test, click the **Differential Test** check box.

In order to perform differential measurements the CITS800s uses Channels 1 and 2, Channels 3 and 4, Channels 5 and 6 and Channels 7 and 8 as differential channels. Differential testing is performed using the IPD100 Differential Probe. For differential testing, connect the differential probe to Channels 1 and 2, Channels 3 and 4, Channels 5 and 6, or Channels 7 and 8 using the supplied cables.

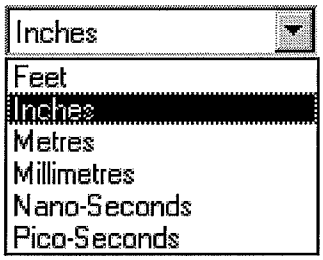
Use the Channel combo box to specify the CITS channel pair.

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Note: It is critical for a differential test that the probe cabling for both channels is of matched impedance and length.

Horizontal Units

The horizontal axis on the Waveform Display screen can display either distance along the trace under test or "real (i.e. out and back) time". Click on the drop down list box arrow to display the units available:



The **Units** field specifies the units (Feet, Inches, Millimeters, Meters, Nano-Seconds and Pico-Seconds) which will be used for the Test From, Test To and Probe Length fields. It defines the units used to specify all the distance or time parameters and those used on the horizontal axis of the displayed waveform.

Note: If time units are selected the Waveform Display window displays "real time", i.e. the "out and back" time for the TDR pulse.

Test from

This parameter, along with the **Test to** parameter enables the user to specify the length of trace or propagation time to be tested. This allows the user to avoid testing for controlled impedance in an area where the displayed waveform may be ringing (e.g. where a sharp change of impedance occurs in the test system connection).

The **Test from** parameter specifies the distance or time from the start of the display to the *start* of the length or time over which impedance is to be tested (see Figure 5-1).

It defines the *start* of the tested area within the display window

Test from may be set in the range:

Distance

0 to 600 inches

0 to 50 feet

0 to 15.24 meters

0 to 15240mm.

Time

154.04nS

154040pS

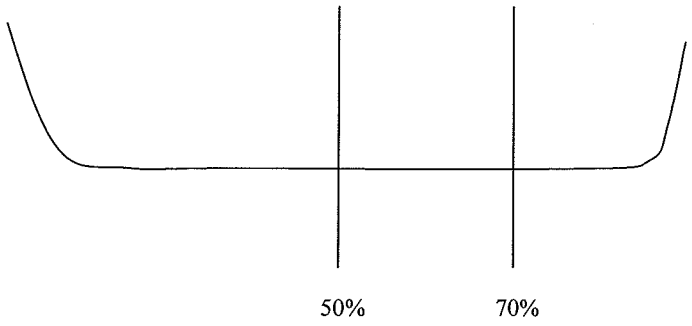
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Test to

The **Test to** parameter specifies the distance or time from the start of the display to the *end* of the length or time over which impedance is to be tested (see Figure 5-1). It defines the end of the tested area within the display window.

It is important to set **Test From** and **Test To** to define part of the undisturbed interval in the display.

Typically this will correspond to a region as shown below.



Test to may be set in the range:

Distance

0 to 600 inches

0 to 50 feet

0 to 15.24 meters

0 to 15240mm.

Time

154.04nS

154040pS

Note that **Test to** must be greater than **Test from**.

Probe length

The **Probe length** field specifies the distance or time from the CITS front panel connector to the beginning of the displayed graph on the PC (see Figure 5-1).

If the supplied cable and a Microstrip probe are used **Probe Length** can be left at its default value (45 inches, 11.55 nS).

If a different connection method is used **Probe Length** can be used to define the starting point of the display (i.e. the left edge of the screen) in terms of the distance or time from the CITS front panel. For example, if 37 inches is specified the display will show a graph of impedance starting 37 inches from the CITS front panel connector.

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Probe length may be set in the range:

Distance

0 to 600 inches

0 to 50 feet

0 to 15.24 meters

0 to 15240mm.

Time

154.04nS

154040pS

Loss Compensation

Caution! Applying loss compensation may invalidate results. *A sloping waveform may be attributable to a number of causes. Consult the board design authority before applying loss compensation.*

Applying loss compensation for series loss

The Loss Compensation field may be used to compensate for series loss in the track being tested.

Any series resistance will appear as a ramp in the waveform with impedance increasing linearly with distance. Series resistance simply adds to the characteristic impedance over the length of the waveform.

This phenomena is caused by the DC resistance of the track combined with high frequency skin effects reducing the effective cross-sectional area of the track.

Series loss can be compensated for by adjusting the slope of the waveform by a specified number of ohms/horizontal unit. This cancels out the series resistance leaving the true characteristic impedance displayed.

Note: Series loss may be distinguished from the case of a slightly tapered track by testing from both ends of the trace. In the case of series loss the impedance waveform will appear to have the same rising slope when tested from both ends.

For normal use it is suggested that loss compensation should be *left in the default state — disabled*. In some instances, however, where long conductors or those with small cross sectional area are being tested enabling loss compensation may prove useful.

Select **User** to display the Series Loss text box then type in the desired value.

See SPECIFICATIONS for the range of acceptable values.

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Velocity of Propagation (Vp)

The Velocity of Propagation (Vp) is the speed at which electrical signals propagate along a cable or printed circuit board trace. Vp is given as a percentage of the speed of light, c.

The speed of the signal depends on the dielectric of the medium in which it travels. For simplicity of operation the CITS program assumes that all cables and PCB tracks have a velocity of propagation of 66% the speed of light. The CITS calculates displayed distance or time from time based on a default Vp of 0.66. This value will be found valid for typical coaxial cables and circuit board traces.

This will, however, result in some apparent errors in the indicated distances and times in systems which have significantly different velocities of propagation. For example, airlines, which have a very high velocity of propagation (98–99% the speed of light), will appear shorter than their true physical length if both are measured with the default Vp. Since the purpose of the CITS is to measure impedance, for most applications the linear accuracy of the horizontal scales will probably not be critical.

If desired, the Vp used for display of test waveforms can be adjusted for the display window. If Vp is correctly adjusted then the displayed electrical length of any tested specimen will match its physical length. This adjustment is applied to all of the displayed waveform.

For most applications leave the **Vp** setting at **Default**.

Selecting the **User** option displays a text box containing the current value of Vp. With the text box displayed use the left and right arrow keys or the mouse to locate the cursor and type in the desired value.

Ohms/div

The vertical axis on the PC screen is scaled in ohms per vertical division. The scale may be set to one of the pre-defined values **1**, **2**, **5**, **10**, **20** or **50** ohms/div.

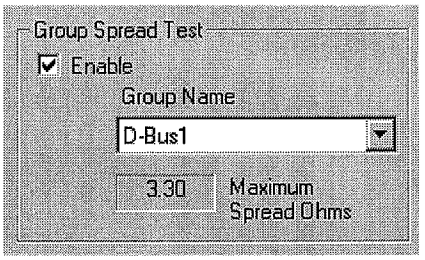
Click the dropdown list box arrow to select the vertical scale value.

Choose the scale factor which gives optimum display — lower values display the waveform in greater detail.

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Group Spread Test

The test may be designated as part of a test group defined by the **Board|Edit Groups...** command.



To assign the test to a group click the **Enable** check box and select the group from the **Group Name** combo box.

Test Method

When this parameter is set to **Absolute** the CITS will record a FAIL if the trace waveform is out of tolerance (i.e. touches the crosshatch area of the test limits) *at any point* over the tested area.

Selecting **Average** will cause the test to fail only if the *average impedance* value (top left of screen statistics box) is out of tolerance.

When **Average** is selected the test limits (50Ω nominal impedance, ±10% between 2 inches and 8 inches) are displayed as shown in the diagram below:

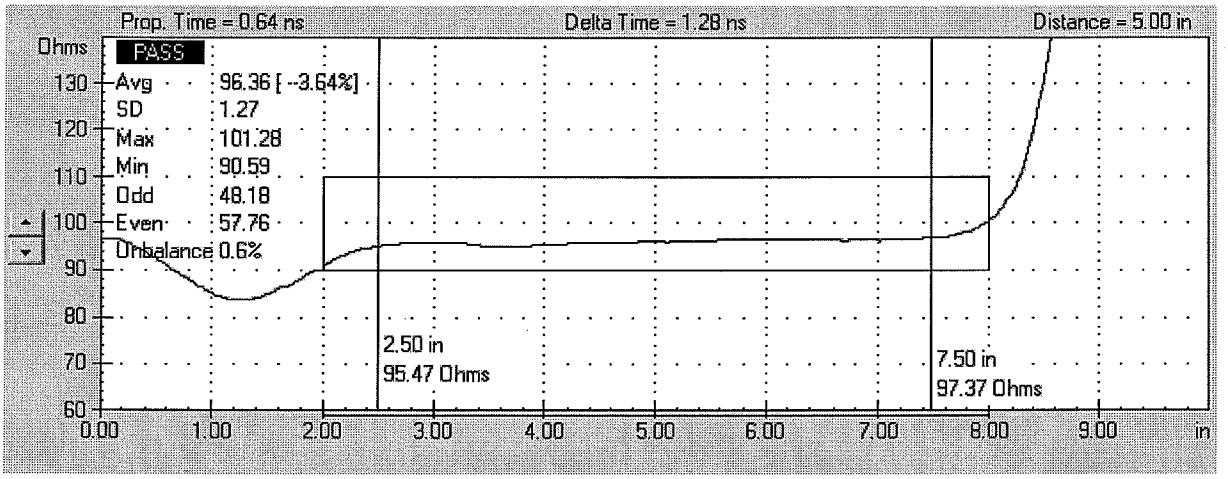


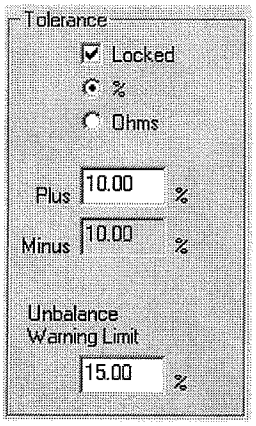
Figure 5-5 Average Test Method display window

This method is used most often when large numbers of via holes are disturbing the PCB trace impedance waveform. Typical examples are backplane traces.

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Tolerance

This parameter defines the tolerance about the nominal impedance to which the track will be tested.



Plus and Minus tolerances may be locked; i.e. have the same value, or unlocked, where each value is set independently. Click the Locked check box to lock or unlock the tolerance.

The tolerance must be set to a value in the range 0.10% to 99.99% in 0.01% steps. Alternatively it may be set directly in Ohms. Click the % or Ohms option buttons to select.

Setting the Unbalance Warning Limit

During differential testing the CITS checks the single-ended impedance of both signal lines. The CITS logs the percentage difference between lines and issues a warning if the unbalance exceeds the threshold set in the **Unbalance Warning Limit** field. Use the **Unbalance Warning Limit** field to set the limit as required.

Press **OK** to confirm the test parameters and close the Test Setup Editor.

5-4 Saving the test file

Press the Save button to save the file

When all tests for the board under test have been specified press the **Save** button, or use the **Save** or **Save As** commands from the **File** menu, to store the file as a new test file. The system will display the **Save As** dialog box to request the new file name.

Naming test files

Names assigned to test files must conform to the Microsoft Windows conventions for file names. File names must be unique and may contain up to 255 characters. The following characters may be used in file names:

Letters A to Z and a to z

Numbers 0 to 9

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and the following special characters:

- ! $ % ^ & ( ) @ ~ # { } ` ' _

Operating system reserved characters such as backslashes (\ ), question marks (?) and asterisks (*) and are not permitted in file names. For more information on file naming conventions, consult the Windows 95/NT operating system user guides.

It is recommended that users employ systematic test naming schemes in which tests are assigned descriptive names

Saving test files under new names

To save a file under a new name select the existing file using the **Open** command from the **File** menu, choose the **Save As** command and name the new file (if necessary edit the file).

5-5 Using existing files as templates

An alternative method of creating a new test file is to open an existing test file, save it under a new name and then edit it. If this is a new test file, select a suitable existing file and edit the parameters for each test as required.

5-6 Printing test files

To obtain hard copy of test files (e.g. for reference or customer conformance reports) right click the Test File window pane (or select the **Print** command from the File menu (or press Ctrl-P).

The Print function will print to the default Windows printer.

Click the Print Preview command to inspect the printout prior to printing.

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MAINTENANCE AND FAULT FINDING

Cable Replacement

Whenever cables are replaced on a system the user should use the Calibration function to calibrate the CITS/cable system.

CITS Verification and Calibration

The CITS800s includes facilities to verify the accuracy of the CITS800s system (i.e. the instrument and probe cable without the probe) and if necessary calibrate the system against impedance standards (e.g. airlines or similar).

If the CITS is to be used for measurements of low impedances (e.g. 28Ω) it is recommended that the system accuracy is verified daily.

Note: It is important to ensure that when the system is verified or calibrated the probe cable attached is the cable used for testing boards.

Verification

- Select the Diagnostics command from the Utilities menu
- Connect the working probe cable, without the probe, to the MAIN SMA front panel connector.
- Press the Learn Cable Length button. The CITS will determine the length of the cable, and display the time difference from the nominal length. If necessary press Apply Correction to adjust the system calibration.
- Choose the impedance to be verified and connect a suitable impedance reference to the probe cable. *Verifying differential accuracy will require a pair of references.* See section on Differential Calibration.
- Press the associated impedance button and enter its exact impedance.
- Note the error in the CITS800s reading.
- Repeat for the other impedances.
- If necessary perform the Calibration described in the next section.
- Press OK to exit.

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Calibration

Caution: Incorrect use of Calibration mode may invalidate the CITS800s calibration

Calibration should only be carried out against NIST/NPL traceable impedance standards (e.g. airlines or similar).

- Select the Diagnostics command from the Utilities menu
- Double click the right mouse button on the CITS800s icon to enable Calibration mode.
- Press the Learn Cable Length button. The CITS will determine the length of the cable, and display the time difference from the nominal length. If necessary press Apply Correction to adjust the system calibration.
- Connect the probe cable to the reference impedance. *Calibrating differential accuracy will require a pair of references.* See section on Differential Calibration.
- Choose the impedance to be calibrated and press the associated button. If necessary press Apply Correction to adjust the system calibration.
- Repeat as necessary for other calibration points.
- Press OK to exit.

Differential Calibration

Differential calibration or verification will require a pair of reference impedances. Calibration at 100Ω (differential) will require a pair of 50Ω airlines, 150Ω (differential) will require a pair of 75Ω airlines etc.

Impedance References for Calibration

Calibration should only be carried out using references that have been made traceable to NIST/NPL.

The reference impedances used to verify or calibrate may be either airlines or measured semi-rigid cables.

A Verification Kit is available (Polar Instruments part number ACC229) containing a range of semi-rigid cables which have been measured against traceable standards, making them suitable for verification and calibration of the CITS.

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CITS800s Servicing

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

IMPORTANT The CITS is an extremely sensitive measuring instrument. To prevent damage to the CITS observe static precautions at all times. See Appendix B for information

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

Microstrip probes

If a different pitch between the ground and signal pins on the Microstrip probes is required this may be adjusted with the aid of a soldering iron. (In the event of damage or loss to the spring loaded pins, replacements are obtainable from I.D.I or their local agents. The order code is SS 75E 4.9 G)

Cleaning

Clean the CITS800s 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.

Technical Support

For technical support contact your local Polar Instruments distributor or Polar Instruments. See front cover for email address and fax numbers.

Consumable parts

Cables and probes should be replaced every two years or when showing signs of significant wear.

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Fault diagnosis

The following symptoms may be investigated by the user. More serious faults should be referred to qualified personnel.

Symptom	Test
Communication Error reported by the host computer	Check CITS power is switched on. Check CITS green BUSY LED is lit for a few seconds on power up then extinguished. If the green LED stays lit, the CITS is faulty; refer to the supplier or agent Check the connection of CITS to the PC. Check that the cable used is the cable supplied with the CITS. Check that the COM port connected to the CITS matches that selected via the System Configuration screen. Check for no Communication port conflicts
Foot switch not working	Check that the RS232 cable in use is the cable supplied. Ensure that if a 9–25 way RS232 adaptor is used all 9 signal lines are connected. Check that the Foot switch is plugged in.
Printer fails to work	Check the printer is switched on. Check connection of the PC to the printer. Print a window test page for the printer.

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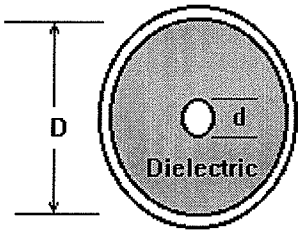
APPENDIX A

CHARACTERISTIC IMPEDANCE

CHARACTERISTIC IMPEDANCE OF CONDUCTORS

The characteristic impedance of a conductor is a function of the dimensions of the conductor, its surrounding environment and the dielectric constant E_r of the insulating material.

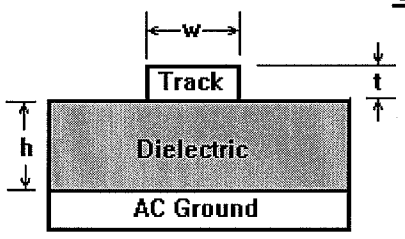
The diagram below includes equations for calculating the characteristic impedance of coaxial cable, microstrip and stripline.



a. Coaxial Cable

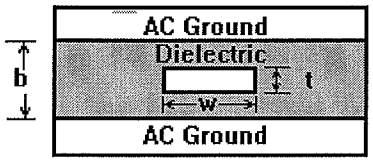
$$Z_o = \frac{138}{\sqrt{\epsilon_r}} \log_{10} \frac{D}{d}$$

b. Microstrip



$$Z_o = \left[\frac{87}{\sqrt{Er + 1.41}}\right] \ln \left[\frac{5.98h}{0.8w + t}\right]$$

c. Stripline



$$Z_o = \left[\frac{60}{\sqrt{Er}}\right] \ln \left[\frac{4b}{0.67\pi\,(0.8w+t)}\right]$$

where $w/(b-t)<0.35$ and $t/b<0.25$

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Figure A-1 Typical conductors and associated impedance equations

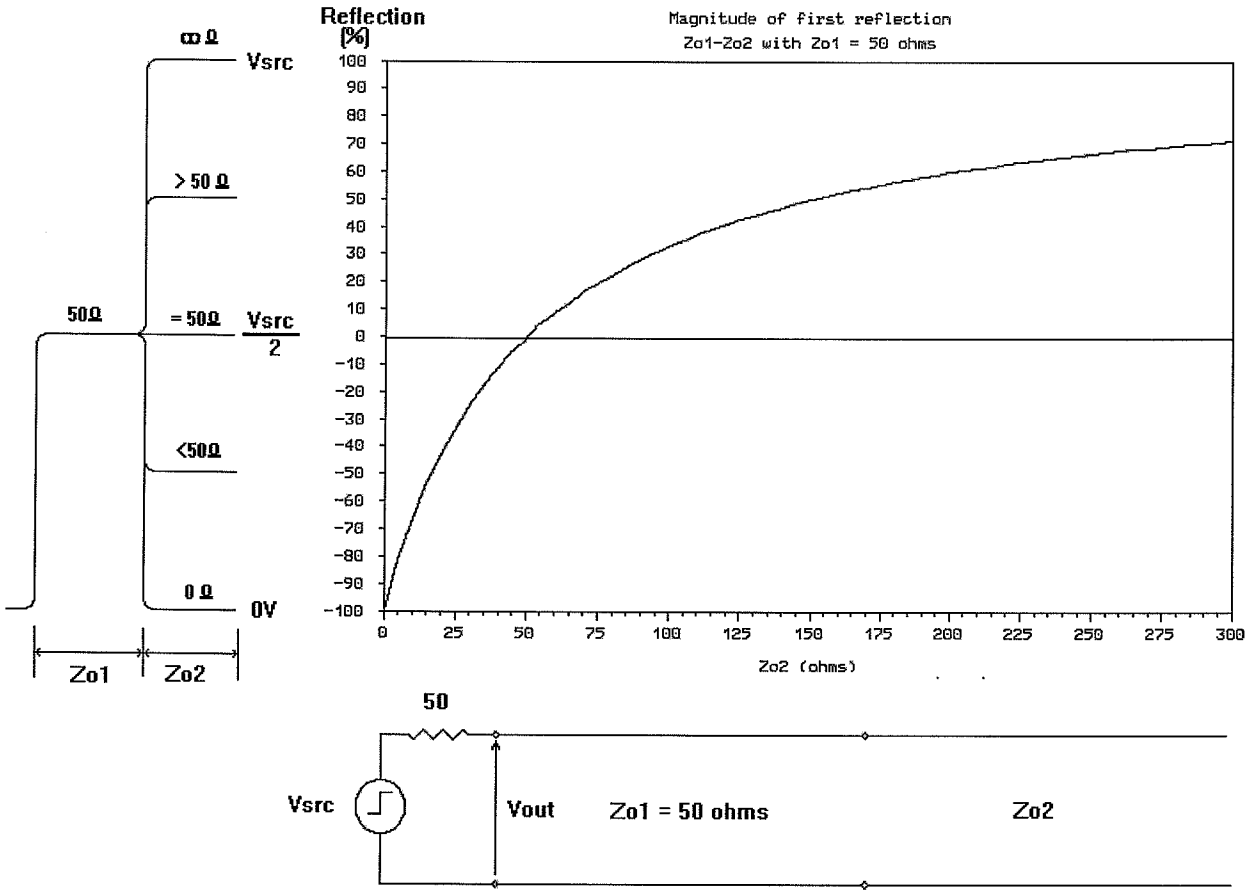


Figure A-2 Reflection magnitude v discontinuity impedance for a 50Ω Z_o, step output TDR

Determination of characteristic impedance

The CITS displays a graph of the characteristic impedance of a specified length of PCB trace. This is achieved by calculating the impedance along the length of the cable or PCB based on the size of the reflections measured using time domain reflectometry.

The above graph shows the size of reflection from an impedance discontinuity encountered by the out-going pulse of a 50Ω, step output TDR such as the CITS.

The CITS software translates the magnitude of voltage reflections measured by the TDR into a linear plot of impedance against distance. Note that the size of the reflection is not linearly related to the impedance discontinuity. As the impedance gets larger the slope of the curve is reduced so that at high impedances a large change in impedance will only cause a small change in reflection. Consequently the accuracy of measurements of high impedances is reduced.

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APPENDIX B

ELECTROSTATIC DISCHARGE

PROTECTING THE CITS FROM ELECTROSTATIC DISCHARGE

> *Caution: The probe/input circuitry of the CITS includes sensitive components that are susceptible to damage from electrostatic discharge — precautions must be taken to avoid static discharge into the probe.*

Many of the components in modern instruments like the CITS employ internal construction which may be damaged by electrostatic discharge (ESD). Such components are often referred to as *static sensitive*.

Damage caused by electrostatic discharge may be severe enough to result in the complete and instant failure of a component. Often, however, components are not destroyed but merely degraded and failure occurs in later use.

Some devices are sensitive enough to be damaged or degraded by electrostatic discharge of only several tens of volts, voltages not uncommon at a typical unprotected work station.

Everyday activities such as applying tape from a dispenser, walking across nylon carpets or separating plastic transparency films can generate charges of several thousand volts.

Sources of static electricity

There are two sources of static electricity most likely to be encountered by the technician:

People (especially when wearing clothes made from synthetic fibre)

Packaging materials such polythene (e.g. bags or tubes), polystyrene containers or padding (e.g. chipples, etc.) and adhesive tape used to seal containers

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Static free workstations

Static sensitive components, including completed circuit boards, should only be used (i.e. inserted or replaced) at a static free work station. The static free work station will typically include anti-static bench mats, floor mats and wrist straps and should be kept free from materials which could generate or store a static charge.

Working with the CITS

When using the CITS observe the same procedures as when handling static sensitive components:

Use the CITS at an approved anti-static work station.

Wear a wrist strap connected to a suitable earth point. A wrist strap is provided with the CITS (connect the wrist strap to the stud on the CITS front panel).

Other protective clothing, such as conducting heel straps and metallised coats can be worn if available.

Keep materials which may produce static electricity away from the work station.

Treated completed circuit boards as static sensitive components.

Avoid dragging the CITS probes across work surfaces.

Do not point the probe tip at surfaces that may have a static charge, e.g. monitor screens

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APPENDIX C

STATUS OUTPUT CONNECTOR DETAILS

Pin	Name	Description (all outputs are open-collector)
1	Pass	On if test passes
2	/Pass	Off if test passes
3	Fail	On if test fails
4	/Fail	Off if test fails
5	Testing	On during testing
6	/Testing	Off during testing
7	Strobe	Turns On to strobe Pass and Fail outputs
8	/Strobe	Turns Off to strobe Pass and Fail outputs
9	Common	Common line for all outputs

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APPENDIX D

CONTROLLED IMPEDANCE APPLICATION NOTES

Polar Instruments produces a series of Applications Notes to assist customers with Controlled Impedance testing applications. The following introductory application notes are currently available.

Introduction to controlled impedance

LIT145	Introduction to controlled impedance PCBs — a helpful document for those new to controlled impedance
AP138	Microsoft PowerPoint presentation introducing controlled impedance (no electronics knowledge required)
AP166	How is a PCB made, and what affects impedance? PowerPoint Presentation
AP118	Frequently Asked Questions on Controlled Impedance
AP120	Introduction to Controlled Impedance
AP121	Transmission Line Configurations
AP122	Microstrip Transmission Line Structures
AP123	Single-ended Stripline Structures
AP124	Testing with Test Coupons
AP125	Calculating differential and coplanar impedance on FR4
AP127	Measuring short traces
AP128	Choosing the best probe for your application
AP129	Characterising your process
AP130	Sources of impedance measurement error
AP131	Paper – Calculation of PCB track impedance
AP139	How measured impedance may vary from field solver calculations when using woven glass reinforced laminates
AP141	Setting up impedance test TDR limits
AP143	Unbalanced Tracks and Differential Impedance
AP150	Top 12 reasons for specifying DC track resistance.

Other, more advanced, topics are covered on the Polar Instruments web site by application notes and white papers. Application Notes are added on a frequent basis; contact your Polar representative or check the Polar Instruments web site **www.polarinstruments.com** for the latest notes.

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