Data Sheet

Cable testing with TDRs & Digital Bridges

This data sheet applies to the **E2550**, **E2570** and **E2770** Cable Fault Locators and the **E2501** Blocking Filter.

RS stock no.	Item
287-4443	E2770 Long range TDR with memory
375-0102	E2550 TDR
375-0118	E2501 Mains blocking filter accessory
375-0124	E2570 Combined TDR & Bridge

Principle of operation TDRs

A test pulse, transmitted down a faulty cable, is reflected by a fault such as an open or short circuit. The time between the test pulse being transmitted and the reflected pulse being received at the instrument is proportional to the distance to the fault, and by lining up the reflected pulse with a cursor, this time may be determined. The speed at which the TDR pulse will travel along any cable depends upon the cable dielectric and therefore to convert the cursor position from time into distance it is necessary for the user to know the speed at which the pulse will travel along the cable under test and adjust the TDR accordingly. This speed is a ratio of the speed of light through a vacuum relative to its speed through another dielectric and is know as the velocity factor.

The **E2550** and **E2570** TDRs can read in either feet or metres however the **E2770** can be adjusted to show the distance to the cursor in feet, metres or nano-seconds.

Applications E2550/E2570/E2770/E2501

The TDRs are designed for use on de-energised circuits however if the blocking filter **E2501** is used they may be connected to cables energised up to 230v. The instruments incorporate safety terminals and are double insulated for operator safety, however only the **E2770** has IP54 rating.

TDRs can be used on most types of cable from telecommunications cables to power distribution cables, they are suitable for accurately measuring the length of cables and locating a variety of cable conditions such as; open and short circuits; sheath faults; crosses; resistive joints or splices; splits and re-splits; water ingress; bridge taps and load coils.

The ability to accurately locate a fault along a length of cable can save a great deal of expense. For instance, when underground cables develop faults the more accurately the fault is located the cheaper the excavation to effect a repair will be; or for cables that are high up the access equipment can be placed correctly the first time; or for signal cables that pass through a number of junction boxes, locating the faulty box first time saves money. TDRs are also able to determine the remaining length of cable on drums, facilitating stock taking or allowing part used drums to be used with confidence.

The **E2770** has 15 memory locations which can be used to store waveforms from cables which have been connected to the TDR. These waveforms may be stored for future analysis or be downloaded to the Metrace Software package. The most useful feature of the memory facility, however, is that it can be used to simplify the fault finding and diagnostic procedure.

Mains blocking filters

The **E2550**, **E2570** and **E2770** may be fitted with an **E2501** mains blocking filter which is available as an accessory.

Mains blocking filters enable the TDRs to be used on cables carrying mains voltages, without first isolating them. The blocking filter allows the short pulses of a TDR to pass through them, whilst stopping mains voltages and transients from reaching the instrument and damaging its circuitry.

The availability of blocking filters greatly widens the range of low voltage electrical distribution applications to which the TDR can be applied.

Measurement techniques

Velocity factor

The velocity factor differs for various types of cable, some typical values for commonly used cable dielectrics are shown below.

Velocity factors for commonly used cable types

Dielectric type	Typical velocity factor
Oil filled paper	0.50 to 0.56
Cross linked poly.	0.52 to 0.58
Jelly filled poly.	0.64
Polyethylene	0.67
PTFE	0.71
Paper	0.72 to 0.88
Foam poly.	0.82
Air	0.94 to 0.98

The **E2550** and **E2570** TDRs may be set by the operator to any velocity factor between 0.01 and 0.99 in steps of 0.01. The **E2770** velocity factor may be set between 0.300 and 0.999 in 0.001 steps.

Cables with unknown velocity factor

If the velocity factor of a cable is not known, it can be determined from a known length of the same type of cable.

First, the TDR cursor should be positioned at the start of the pulse corresponding to the end of the known cable length. The velocity factor may then be varied until the distance to the cursor shown on the TDR agrees with the known cable length.

Line 1/Line 2 comparisons

The **E2770** has two pairs of inputs this allows them to be used to compare two similar cables. For instance, a faulty pair could be connected to the Line 1 input and a known good pair to the Line 2 input, if dual trace mode is selected the TDR would display two traces or if differential trace mode is selected only the difference between the good and faulty pair would be shown, this eliminates all the common features of the cable from the display as well as the waveform due to the connection.

Balancing for single lines

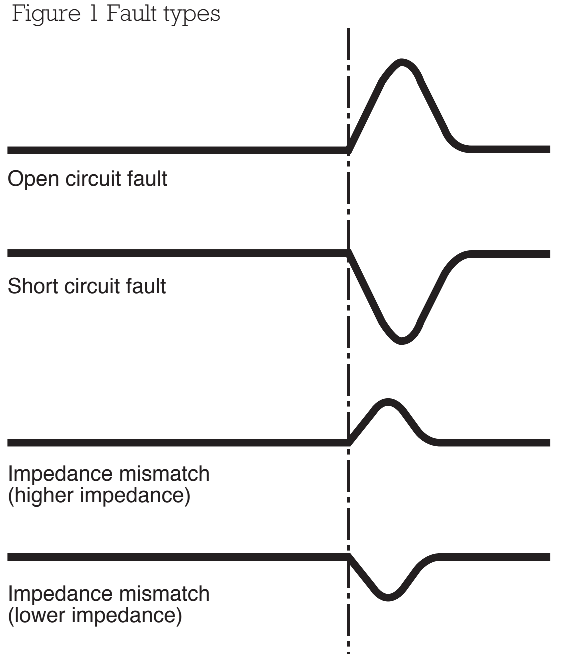
In order to detect and locate short range faults (within 10 metres) the output of the tester must be balanced to the cable under test in order to minimise the waveform caused by the connection to the cable. On cables with only two conductors this can be achieved by use of the balance control knob on the **E2550** and **E2770** TDRs

Balance can also be achieved on the **E2770** by connecting a good pair to Line 2 whilst the faulty pair is connected to Line 1.

Interpretation of display traces

The reflection of the test pulse is shown as a disturbance to the trace on the LCD of the TDR. The nature of this disturbance indicates the type of fault. The distance to the fault is determined by moving the cursor to the start of the disturbance, a digital value on the LCD then shows the distance represented by that cursor position.

Figure 1 Fault types



An open circuit such as the end of a length of cable or a break in cable, will show as a large positive wave. A short circuit will show as a large negative wave. Impedance mismatches caused by bad junctions, connections to a different type of cable, cable degradation or spur circuits will show as smaller deviations to the trace on the display.

For accurate measurement of the distance to a fault the cursor must be placed at the start of the wave form, the 'breakpoint'.

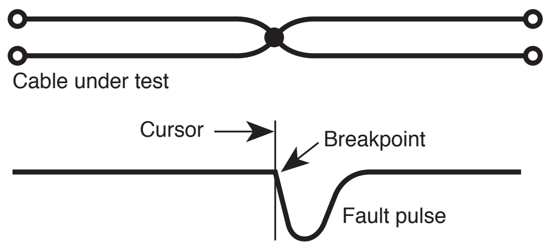
Fault analysis

Described here are characteristic displays for common cable faults, bearing in mind that a given cable/pair may have more than one type of fault. On occasions, a close fault may hide a distant fault, therefore, always locate and correct the closest fault then test again to check for other faults that may be present.

Short circuit faults

1. **Metallic shorts:** This type of fault is caused by metallic contact between two conductors as shown in Figure 2. This produces a strong downward pulse that is easily seen. To detect distant faults the gain may need to be adjusted.

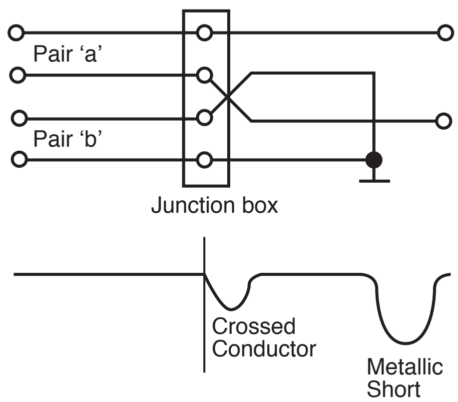
Figure 2 Metallic short circuit



2. **Crosses:** These occur when conductors in multi-pair cables are connected wrongly at a junction, conductors from pair 'a' become crossed over with conductors for pair 'b' as shown in Figure 3. Crosses will appear as a downward pulse but not as distinctive as a metallic short. Though crosses can be located by a TDR when connected to just one pair, the fault will stand out more clearly if the TDR is connected across both pairs containing the crossed conductors.

   There will be more 'clutter' on the trace when a TDR is connected between pairs than when it is connected across a single pair. This is because the capacitance between conductors in different pairs varies more than it does within a single pair.

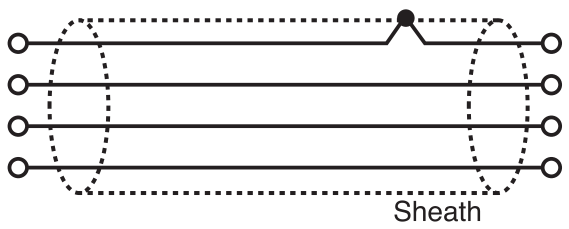
Figure 3 Crossed conductors



3. **Short to sheath:** Where sheath can refer to conductive foil for screening purposes on coax through to wire armour on electrical distribution cables. This type of fault occurs when any line conductor within a cable has metallic contact with the conductive sheath surrounding the cable conductors.

   To locate short to sheath faults, connect the TDR between the sheath and the suspect conductor(s), after disconnecting both the sheath and the faulty conductor at the point of test. The fault pulse will be similar to that seen with a metallic short.

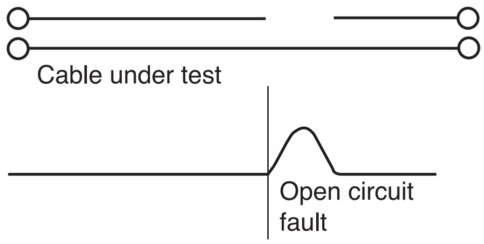
Figure 4 Short to sheath



Open circuit faults

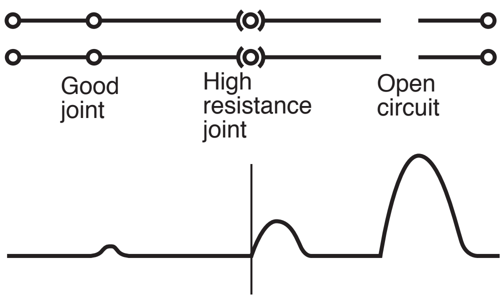
1. **Open or disconnection fault:** This occurs when either one leg or both conductors are severed (Figure 5).

Figure 5 Open circuit



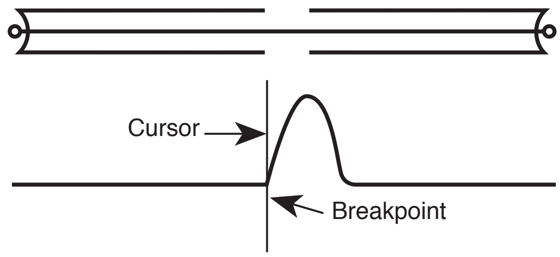
2. **Resistive joints or splices:** These faults are due to poor joints or connections between legs of a cable run, producing high resistance contacts which appear as partial open circuits on the TDR trace. Due to the sensitivity of the TDRs, and the variation of cable capacitance at the joint, even good joints may show on the screen. In general the worse (more resistive) the joint is the larger the fault pulse.

Figure 6 Resistive joint faults



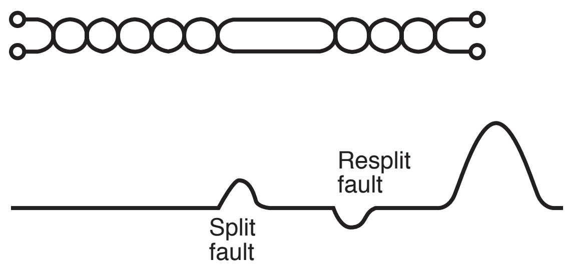
3. **Open sheath:** This type of fault occurs when there is a break in the metallic sheath of the cable. Connect the TDR between the sheath and as many conductors in the cable as possible (to reduce the amount of clutter on the trace). Depending upon the degree of separation at the break in the sheath, disturbance in the trace will vary from a slight resistive joint to a full open circuit.

Figure 7 Open sheath fault



4. **Splits and re-splits**: Splits can occur in twisted pair cable where a pair becomes un-twisted, causing a change in the cable capacitance. The disturbance in the trace caused by a split will be similar to that of a moderately resistive joint. Re-splits occur where a split pair of conductors are twisted together again, causing the cable capacitance to return to normal. This gives a downward pulse smaller than that of a metallic short.

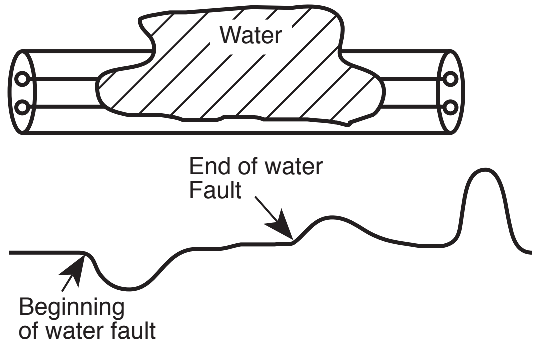
Figure 8 Split and resplit fault



5. **Water:** This type of fault is caused by water contaminating the insulation medium, due to moisture ingress through a damaged sheath. This produces a short-type fault pulse where the water begins, followed by a small open-type pulse where it ends. In some cases, where the moisture increases or decreases very gradually with distance, these pulses broaden out into a gentle swell or dip in the horizontal line. Old cables that are thoroughly wet from end to end may not show an easily recognisable water display, because there is no well defined beginning or end to the water. In very few cases will the fault pulse be as sharp as the displays for shorts and opens. Water in jelly-filled cable may produce only a very small echo due to the restricted area of water.

   Always measure the extent of water entry to the cable from both ends. The presence of water changes the velocity factor of the cable. Therefore, if you read distance through the wet section, you may not get an accurate measurement.

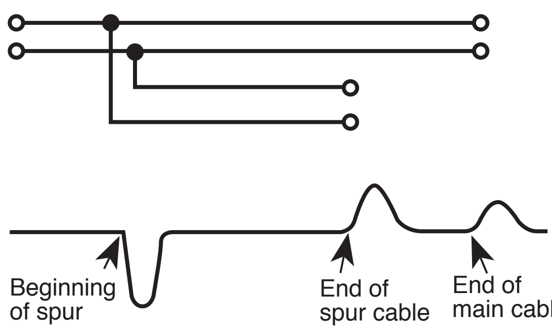
Figure 9 Water fault



Miscellaneous faults

1. **Spur circuits:** Where another cable is joined to the main cable, at the branch or spur, the TDR will display a negative going pulse. This is due to a relatively large increase in capacitance at the junction. If the cable has a large number of branch connections, the waveform on the TDR display will be difficult to evaluate without local knowledge of the cable network. For fault finding on such circuits, a comparison against a TDR trace taken prior to the fault can greatly simplify the task.

Figure 10 Spur or branch circuits



2. **Reactive components:** Circuits may in some circumstances have reactive components added to cable runs (to improve power factor or transmission characteristics for instance). Reliable measurements and diagnosis of faults will often require removal of such reactive components prior to use of the TDR.

Product specifications

The Metrohm E2550 and E2570

Have measuring ranges of 10, 30, 100, 300, 1000, 3000 metres

The output impedance of the E2550 can be adjusted to 25, 50, 75, and 100Ω. This facility allows the user to match the instrument to twisted pair, coax and power cable and provides enhanced short range performance. The E2570 has the output impedance fixed at 100Ω.

The E2550 and E2570 both have a 128 3 64 pixel graphic LCD displays which show a trace of the reflected pulse, the velocity factor, range, output impedance and gain settings, along with the cursor and associated distance in feet or metres.

To further simplify use the E2550 and E2570 have 4 variable gain (amplification) setting pre-set for each range.

The Metrohm E2710 and E2750

The E2770 is more sophisticated and offers ranges of 200, 400, 1000, 2000, 4000, 8000, and 16000m respectively. It has two switchable balanced outputs of 120Ω and also has an integral balance control for use when only one output can be connected.

The 256 3 128 pixel graphic LCD display on the **E2770** has three selectable displays.

1 The screen show two traces, that in the top half of the display represents the whole of the range selected and the lower half represents the area around the cursor magnified ten times.

2 The screen shows one trace that represents the whole of the range selected.

3 The screen shows the area around the cursor magnified ten times, note the distance to the cursor is a constant on all screens.

Accurate alignment of the cursor is achieved by coarse and fine cursor control of buttons.

Separate gain controls are provided enabling greater amplification to be selected to aid distant fault location.

In addition to the greater range the **E2770** also has memory features. This allows any one of 15 memory traces to be compared with the cable under test or another memory. Comparison can be achieved in either 'dual waveform mode' or 'differential mode'. (See Figures 11, 12, and 13,). Traces stored in memory can be saved on a PC, equipped with the Metrace Windows™ based software. This software, in addition to enabling a library of cable traces to be stored on the PC, will allow the user to examine and compare the traces stored on the PC in exactly the same manner as they may be compared on the TDR.

For complex cable traces the extra facilities of the **E2750** greatly simplify the fault finding task.

Figure 11 Use of single waveform mode

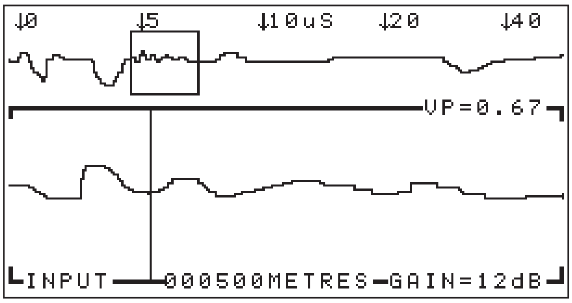
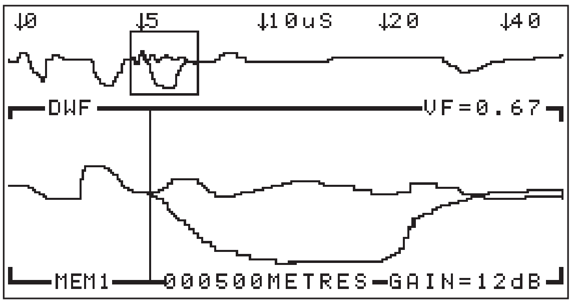


Figure 12 Use of dual waveform



TDRs are excellent fault location tools however they have a weakness which is that the technology is not suited to finding high resistance contacts (metallic shorts) or high resistance earth faults, in multi T jointed circuits where access is confined to only one end of the circuit, (low voltage power systems are a good example) they are the only method that can be used however for the telecommunications engineer where the systems are discreet cables and both ends of the system are available another method of fault location may be used, one that is superb at location high resistance contacts and earths, this method is the bridge.

The E2570 is in fact a multi function instrument and one of its functions is as a digital bridge fault locator. The unit when switched on displays a start menu which allows the user to select the mode in which the instrument is to be used, these are Bridge, TDR, Voltmeter.

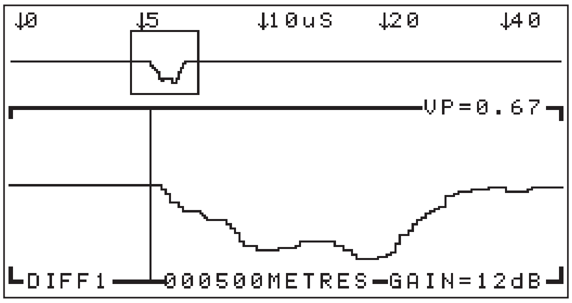
Insulation: This test measures the resistance of any selected conductor relative to another and displays the result in Megohms.

Loop: This measurement requires the operator to join the two conductors to be measured at the end of the cable remote from the tester once the function has been selected the instrument will present the operator with a series of prompts which include cable temperature and gauge until finally the instrument presents the operator with the loop resistance in ohms and the distance around the loop in feet or metres.

Fault: If one leg of a twisted pair comms cable is in contact with earth or a conductor from another pair in the same cable this function will determine the distance to the contact in ohms, feet or metres, the operator merely has to loop the good leg to the faulty leg at the remote end connect the instrument to the good leg and the two legs in contact and proceed. The instrument will present the operator with a series of prompts including temperature and wire gauge until finally the operator is presented with the resistance in ohms or the distance in metres or feet from the instrument to the fault.

Voltmeter: This function measures dc voltage and indicates polarity.

Figure 13 **Use of difference mode**



Specifications

	E2550	E2570	E2770
Electrical			
Ranges	Nominal: 10, 30, 100, 300, 1000, 3000 and Auto range		200, 400, 1000, 2000, 4000, 8000, 16000m at VF = 0.67
Accuracy	± 1% of range		±0.1% of reading
Resolution	1% of range		0.05% of range using zoom
Gain	Variable 4 steps per range		Variable 0 to 90dB in 6dB steps
Velocity factor	Variable 0.01 to 0.99 in 0.01 steps		Variable 0.300 to 0.999 in 0.001 steps
Pulse amplitude	5V peak to peak into open circuit		14V peak to peak into open circuit
Output Impedance	25, 50, 75 and 100Ω	100Ω	Balanced 120Ω
Pulse width	Automatically varied for range selected		20 to 16000nS selectable with range
Update rate	1Hz		1Hz
Power down	Automatic after 5 min with no key press		Automatic after 5 min with no key press
Batteries	Six AA size,MnAlk or NiCad cells		Six, C-size, NiMH cells
Nominal battery	9V - MnAlk		7.2V - NiMH
Voltage	7.2V - NiCad		
Battery low	6.5V nominal		6.5V nominal
Battery consumption without backlight	80mA nominal		100mA at 1Hz update rate
Safety	Complies in general with IEC 1010		Complies in general with IEC 1010
Mechanical			
Case dimensions	190mm long 90mm wide 54mm deep		300mm long 180mm wide 70mm deep
Case material	ABS and polycarbonate		ABS and polycarbonate
Connectors	Two 4mm safety terminals		Four 4mm safety terminals
Bump	To IEC 69-2-29		To 68-2-29
Free fall	To IEC 1010		To IEC 1010
Vibration	To IEC 68-2-6		To IEC 1010
Impact	To IEC 1010		To IEC 1010
Weight (less carry case)	0.6kg (with batteries)		1.5kg (with batteries)
Lead	2 metres		2 metres
Display	128 × 64 graphics LCD		256 × 128 graphics LCD
Environmental			
Operational temp. range	-15°C to +50°C		-15°C to +50°C
Storage temp. range	-20°C to +70°C		-20°C to +60°C
Cold temperature	To IEC 68-2-1		To IEC 68-2-1
Dry heat	To IEC 68-2-2		To IEC 68-2-2
Damp heat	To IEC 68-2-3		To IEC 68-2-3

E 2570 Bridge Specification

Bridge range	0 to 2000Ω equivalent to 15.2 km of 0.4mm copper
Bridge line voltage	100V DC nom at 100micro Amps nom
Bridge insulation range	0 to 200 MΩ
Bridge insulation accuracy	± 2% of reading ± 1 digit
Bridge fault range	0 to 5 MΩ (5 to 20 MΩ with reduced accuracy)
	50 volt battery contact faults.
Bridge accuracy at 20 deg C	
Insulation	± 2% of reading ± 1 digit
Loop	± 0.2% of reading ± 1 digit
Fault <1 MΩ	± 0.2% of reading ± 1 digit
Fault <5 MΩ	± 0.2% of reading ± 3 digit
Fault <20 MΩ	± 0.2% of reading ± 6 digit
Withstands ringing tone	300 V DC or 240 VA
Voltmeter range	-250 to +250 V DC
Voltmeter accuracy	1% of range ±1 digit at 1 volt resolution

Specification for E2501 Blocking filter
(optional accessory for E2550 and E2770)

Cable voltage	Max. 300V 50/60 Hz,
	Probe to Earth / Max. 450V, 50/60 Hz, Probe to Probe
Probe voltage rating	1000V, 50/60 Hz
Fuse rating	0.5A, F, 660V
Installation (IEC 1010)	Category III
Size	80mm x 40mm x 20mm (excluding lead and probes)
Material	ABS
Operating temperature	-15 to +50°C
Storage temperature	-20 to +70°C
Pollution (IEC 1010)	Category II
Max. relative humidity	93% at 45°C
Altitude	Up to 2000 metres

Except where otherwise stated, this specification applies at an ambient temperature of 20°C.

RS Components, PO Box 99, Corby, Northants, NN17 9RS
An Electrocomponents Company
Telephone: 01536 201234