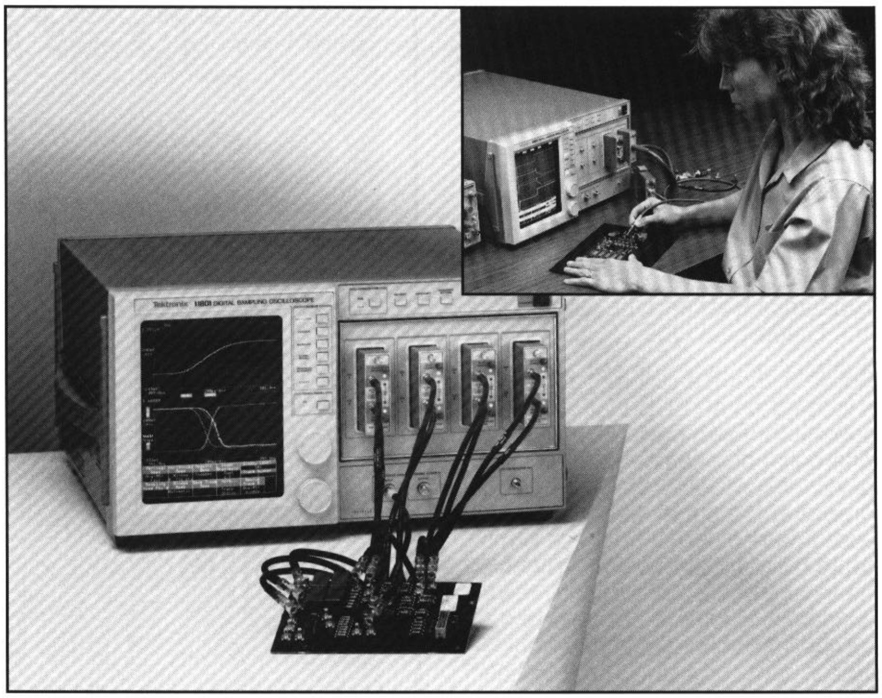
CHARACTERIZATON OF A DIFFERENTIAL LINE USING THE 11800-SERIES OSCILLOSCOPE DIFFERENTIAL TDR CAPABILITIES

The 11800-Series Oscilloscopes and the SD-24 TDR/Sampling Heads offer unique differential TDR capabilities that are very beneficial to designers and troubleshooters of differential transmission lines on etched circuit boards (ECBs) and other media. With the 11800-Series Oscilloscope's ability to display both the individual positive-going and negative-going TDR waveforms of a differential line, you can view the reflection characteristics and directly measure the impedance of each conductor of the differential line.

The 11800-Series Oscilloscopes display the impedance of each conductor in ohms in the Cursors major menu. This feature is unique to the 11800-Series Oscilloscopes and is invaluable to engineers and technicians that design and troubleshoot differential systems.

In addition to measuring the impedance of each conductor, the 11800-Series Oscilloscope can display the imbalance that often exists between conductors of a differential line. The simultaneous display of the reflection characteristics of both conductors of a differential line allows you to see the imbalance between these conductors.

If balance between two conductors of a differential line is not maintained, timing errors can occur in the system. For example, a logic gate that uses a differential clock signal may trigger incorrectly if the two differential steps do not arrive at the gate inputs simultaneously. Because differential lines are primarily for preserving the signal quality, it is important to optimize the balance between the two conductors that conduct the differential signal. Optimizing this balance is therefore an important design factor; however the balance cannot always be maintained when laying out a densely populated ECB (that is, an ECB with numerous mounted components). Factors such as bends in the line, IC pins, jumpers, the width of the conductors, and shunt stubs all affect a differential line residing on an ECB.



Displaying the reflection characteristics of the individual TDR waveforms, along with the difference TDR waveform (the difference between the individual TDR waveforms), reveals much more about a differential system than the difference TDR waveform alone. For example, the individual TDR waveforms will show you which conductor (or that both conductors) of a differential line causes a particular aberration to appear on a differential signal. The difference waveform by itself does not convey this information.

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Figure 1 illustrates three different cases where the imbalance between the individual TDR waveforms (M1 and M2) produce exactly the same aberration on the difference waveform (M1-M2). Because one or both of the conductors could cause such an aberration, the advantage of seeing both of the individual TDR waveforms is that, with a single measurement, a designer or troubleshooter can locate exactly where a problem exists.

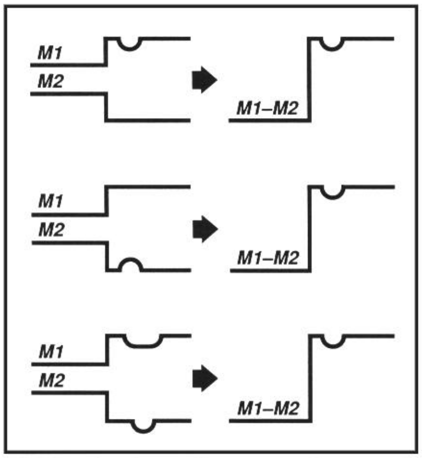

Figure 1. Three Separate Cases of Imbalance Between the Conductors of a Differential Line

Figure 2 shows a differential line that is located on an ECB that is unpopulated. Each conductor of the differential pair has several pin launches for ICs, as well as a series jumper and a shunt stub. During the board design, not all of these items could be placed symmetrically on the board; which is frequently the situation when there are a large number of components and conductor paths crowded into a limited amount of board space.

Figure 3 shows an 11800-Series Oscilloscope display of a differential TDR measurement performed on the conductors shown in Figure 2. M1 is the positive TDR waveform and M2 is the negative TDR waveform. To allow you to easily compare M1 and M2, M2 is inverted and is shown as -M2. M1-M2 is the difference waveform. Because rho scaling assumes a unity amplitude of the incident TDR waveform, the mathematical combination of M1-M2 is rescaled (for the waveforms in Figure 2, the rho scaling reduces the amplitude of the difference waveform by a factor of two). Note that the net effect of this scaling is that the M1-M2 waveform appears as the average of the M1 and -M2 waveforms.

The individual M1 and -M2 waveforms in Figure 3 reveal many unsymmetrical features of the differential line shown in Figure 2. The following is a list of the most significant features:

- At approximately 4.6 divisions from the left edge of the screen, the M1 waveform shows a drop in impedance. This is the result of the capacitive loading of the shunt stub on the channel M1 conductor (for a normal TDR display, excess shunt capacitive loading causes a negative-going reflection). This shunt stub causes a deeper and wider capacitive-aberration than does the shunt stub on the channel M2 conductor. This is consistent with the relative lengths of the shunt stubs shown in Figure 2. Cursor 1 and Cursor 2 in Figure 3 show that the unequal lengths of the shunt stubs cause a difference of nearly 460 mρ between the M1 and -M2 waveforms.

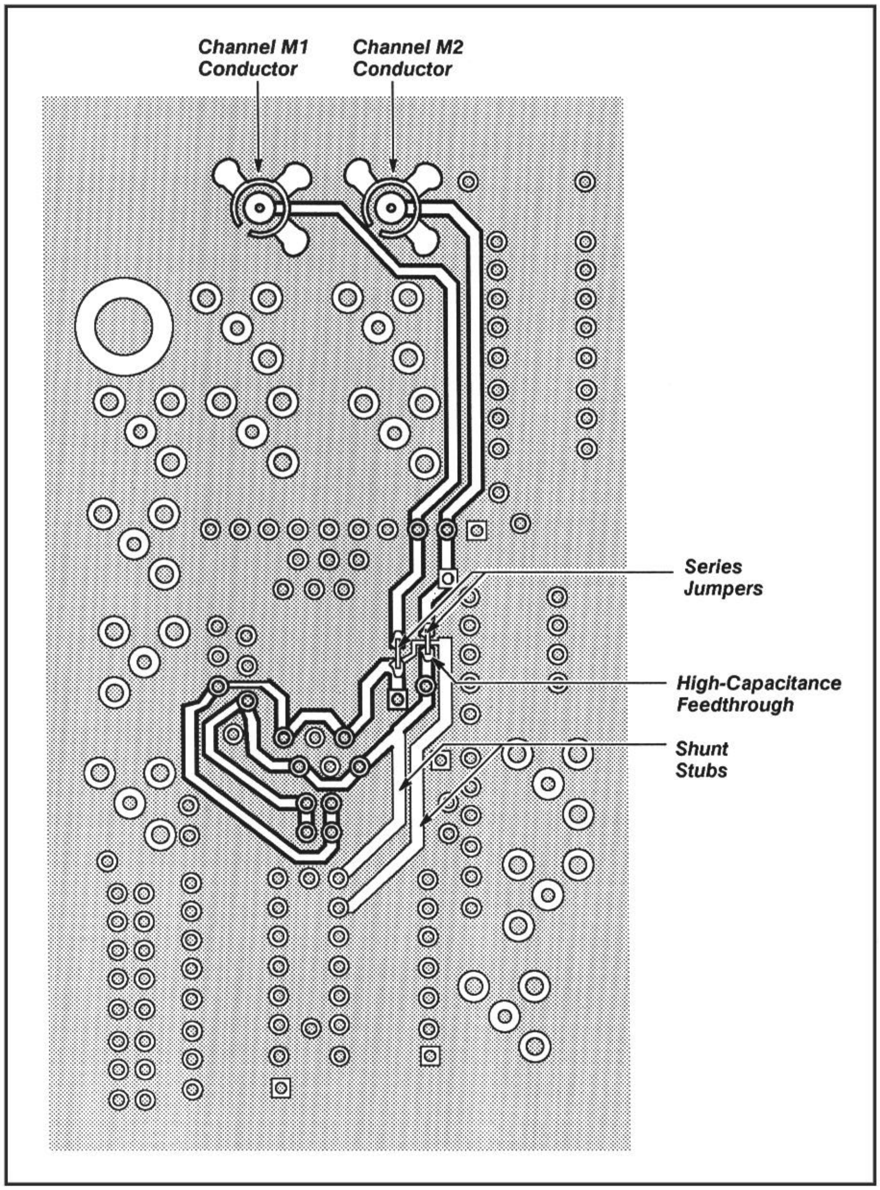

Figure 2. A Differential Line on an ECB

- The two different slopes in the M1 waveform impedance drop are due to the fact that the shunt stub has two different widths. The thinner portion of the shunt stub is less of a capacitive load to the differential line than is the wider section of the stub; which accounts for why the impedance drop at the beginning of the shunt stub is more gradual.
- At approximately 4.6 divisions from the left edge of the screen, the -M2 waveform temporarily dips. This dip is due to a high capacitance feedthrough hole on the channel M2 conductor where the series jumper is installed. The loading effect of this feedthrough hole temporarily causes a larger aberration than does the shunt stub on the channel M1 conductor.
- Both waveforms (M1 and -M2) eventually show inductive aberrations beyond eight divisions from the left edge of the screen (for a normal TDR display, excess series inductance causes a positive-going reflection). However, at ten divisions from the left edge of the screen, the -M2 waveform is greater than the M1 waveform by more than 400 mρ.

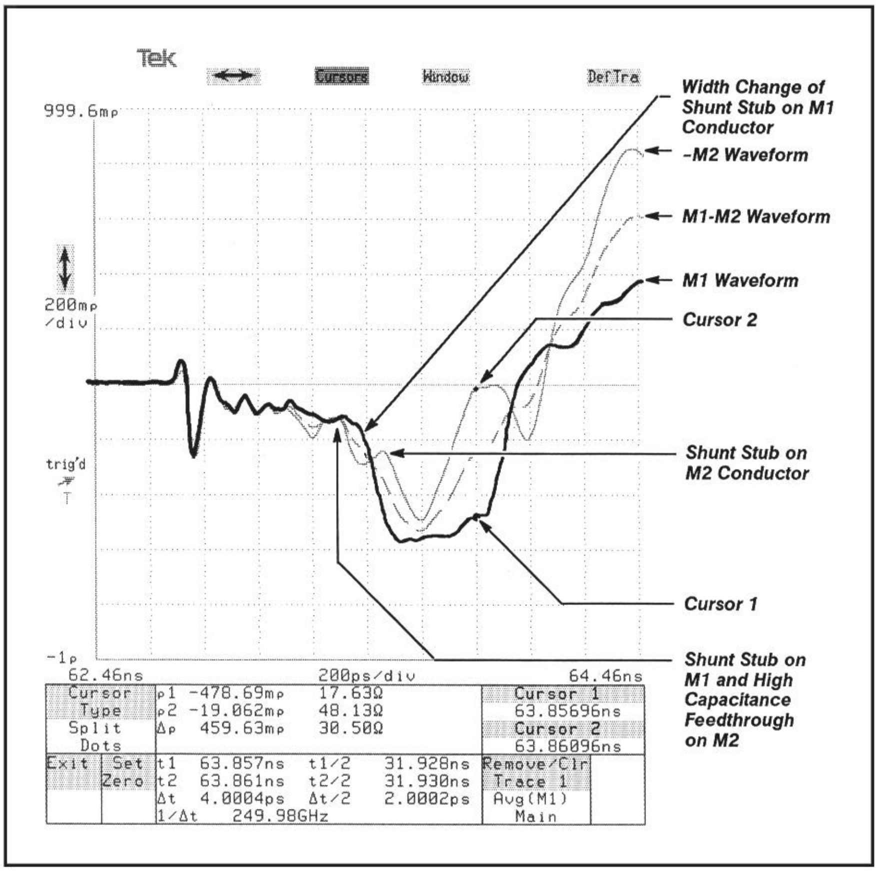

Figure 3. 11800-Series Oscilloscope Differential TDR Display of the Differential Line (from Figure 2)

Note that the M1-M2 waveform alone reveals very little about the unsymmetrical features of the differential line. As a matter of fact, many features are nearly hidden because of the inherent advantage of aberration reduction that differential lines provide to a designer. Yet, the M1-M2 waveform is the only "live" display (that is, immediate and continually updated display) that a single-ended TDR system provides.

The 11800-Series Oscilloscopes show you a live display of the individual M1 and -M2 waveforms and the M1-M2 waveform. This is very important for locating the causes of aberrations. Typically, a troubleshooter will slide a capacitive load down one of the conductors until the reflection caused by this capacitive load matches the location of the aberration displayed. Also, moving this load from one conductor to the other often reveals whether the problem is confined to one conductor, or shared by both. This technique was employed to locate all of the features listed previously.

With the information obtained from the individual TDR waveform components of a differential system, you can immediately begin to troubleshoot the differential line. And this troubleshooting becomes even more intuitive because the problem areas on a live waveform are obvious and easy to locate. Without this information, the problems in the differential line may not surface until the board is fully populated and failing to perform properly; and even at this point you may still find it difficult to locate the source of the problem. Obviously, if you are using a single-ended TDR measurement system that doesn't provide all of the essential information about the differential line, you can waste time and money.

The combination of the 11800-Series Oscilloscope and the SD-24 TDR/Sampling Head is ideal for providing all of the information you need to characterize differential lines. The unique capabilities provided by this system make it an excellent design and troubleshooting tool.

For further information, contact:

U.S.A., Asia, Australia, Central & South America, Japan
Tektronix, Inc.
P.O. Box 1700
Beaverton, Oregon 97075
Phone: (800) 835-9433
TWX: (910) 467-8708
TLX: 151754
FAX: (503) 641-7245

Canada
Tektronix Canada, Inc.
50 Alliance Blvd.
P.O. Box 6500
Barrie, Ontario L4M 4V3
Phone: (705) 737-2700
Telex: 06875672 TEKTRONIX BAR
FAX: (705) 737-5588

Federal Republic of Germany
Tektronix GmbH
P.O. Box 101544
D-5000 Cologne 1
Germany
Phone: 49 (221) 77220
Telex: (841) 8885417 ATEK D
FAX: 49 (221) 7722-362

France and Africa
Tektronix S.A.
Z.I. Courtaboeuf, Av. du Canada
BP. 13
91941 Les Ulis Cedex
France
Phone: 33 (169) 86 81 81
Telex: (842) 690332 TEKOR A
FAX: 33 (169) 07 09 37

North Europe Area
Tektronix Europe B.V.
P.O. Box 406
2130 AK Hoofddorp
The Netherlands
Phone: 31 (2503) 65265
Telex: (844) 74876 TEKE NL
FAX: 31 (2503) 30424

South Europe Area, Eastern Europe and Middle East
Tektronix Espanola, S.A.
Calle Condesa de Venadito, 1-5°
28027 Madrid
Spain
Phone: 34 (1) 404-1011
Telex: (831) 46014 TKME E
FAX: 34 (1) 404-0997

United Kingdom
Tektronix U.K. Limited
Fourth Avenue
Globe Park
Marlow
Bucks SL7 1YD
Phone: 44 (6284) 6000
Telex: (851) 847277, 847378
FAX: 44 (6284) 74799

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