

Differential Impedance Measurement with Time Domain Reflectometry

Application Note 1382-5

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Who Should Read This Application Note?

This application note is written for hardware designers of high-speed digital systems, including high speed backplanes (Teradyne, etc.), high speed interconnects (Molex, Amp, etc.) or laser modulator drive circuitry (Nortel, Lucent, JDS Uniphase, etc).

Introduction

Differential-impedance circuit boards are becoming more common as low-voltage differential signaling (LVDS) devices proliferate. Yet there is much confusion in the industry about what differential impedance means, how to design for it, and how to leverage its benefits for noise rejection. Knowing the general features of

differential-impedance transmission lines and how they can be characterized with traditional TDR instruments can help in the design and testing of high-speed digital systems.

Although differential pairs have been used for high-speed interconnects since the early 1960s, it is only in the last few years that the introduction of LVDS technology has accelerated their use. Differential pairs have proliferated into almost every high-speed application. In addition to their use in many common board-level buses such as SCSI, Rambus® RDRAMs™ and InfiniBand, they are used in virtually all high-speed serial links. However, even with this widespread use, the properties of differential pairs are often poorly understood or misunderstood.



Differential Varieties

A differential pair is simply two transmission lines that are coupled in some way. There are a number of ways of distinguishing the various types of coupled transmission lines, based on their modal properties. The lines can be strongly or weakly coupled. A pair of lines is balanced when the signal paths have the same electrical properties as the return paths. Twisted pairs are balanced lines, while microstrip pairs are unbalanced.

When the two lines have the same cross-sectional geometry, they are called symmetric and have a simplified electrical description. Finally, when the dielectric is homogeneous (all field lines see exactly the same dielectric constant), each of the two modes will propagate at the same speed. This is the case for stripline pairs.

In addition to the intrinsic fundamental electrical properties of the interconnects themselves, the nature of the signals on the pair of lines can be described in terms of the voltage patterns imposed. When the signal on one line is independent of the signal on an adjacent line, the transmission lines are not really being used as part of a differential pair; each line is being used as a single-ended line.

When the lines are differentially driven but there is no dc connection to ground, the external plane acts as a virtual ground. Its voltage reference is capacitively tied to the midpoint of the two voltages on the signal lines. Alternatively, the plane can be dc connected to ground, as is commonly implemented in high-speed differential signaling.

Differential vs. Single-Ended

To understand what makes a differential pair different from a single-ended transmission line, it is useful to consider a coplanar microstrip with a floating plane below it. In this configuration, the coplanar traces compose a balanced single-ended transmission line, with one trace the signal path and the other the return path. The impedance of this line depends on the line parameters of the capacitance and loop inductance per length of the coplanar pair.

If a floating metal plane is brought underneath this coplanar pair, the impedance of the lines will be changed. How this third conductor influences the single-ended impedance is the basis of understanding what differential impedance really means. A time domain reflectometer (TDR) can be used as a tool to measure the impedance of the lines as the plane is moved into their proximity.

The equipment used for these examples is an Agilent 86100 Infiniium DCA oscilloscope main-frame with an Agilent 54754A differential TDR plug-in module. This module can be operated as a single- or a dual-channel TDR, with the step waveforms from each channel adjusted for differential drive or common drive. The addition of an Agilent 83484A 2-channel, 50-GHz module, allows for measurements to be taken on the waveforms that appear at the far end of the transmission line pair. This plug-in displays what the actual signal of a differential receiver would detect after the transmission through the pair can be emulated.

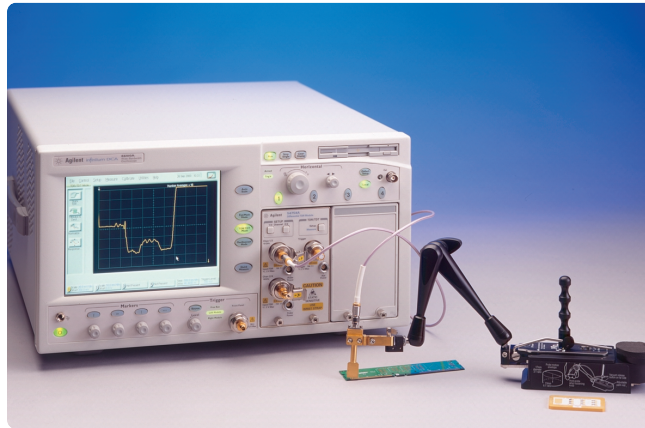


Figure 1. Probing physical layer with N1020A TDR probe kit.

One channel of the differential TDR (DTDR) plug-in can be used to perform conventional TDR analysis. A 35 ps, fast-edge step signal is generated and launched through a 50 Ω source impedance to the device under test (DUT). The voltage launched into the internal 50 Ω transmission line connecting from the internal source to the SMA connector on the front panel is measured with a very fast sampling scope and displayed. Reflected voltages (from impedance discontinuities, for example), are displayed as increasing voltages (for higher impedances) or decreasing voltages (for lower impedances). In this way, the TDR can act as a very fast, time-domain impedance analyzer. The reflected voltage is a direct measure of the impedance of the DUT.

Using this setup, the measured TDR response from three different microstrip interconnects is displayed in the TDR plot in figure 2. In the top trace, the line width is equal to the dielectric thickness, and the impedance is about 70 Ω . In the middle trace, the line width is twice the dielectric thickness. Since there is almost no reflected voltage, the impedance is measured as just slightly less than 50 Ω . In the bottom trace, the fabricated line width is eight times the dielectric thickness. This is a very wide line and the measured impedance is very low, less than 20 Ω .

Time-Dependent Impedance

The time-dependent impedance of the DUT can be extracted directly from the measured voltage. The Agilent 86100 mainframe can perform this analysis automatically, displaying not only the measured voltage but also the extracted impedance. The calculated impedances of the three microstrip transmission lines are displayed in figure 2.

One interesting observation is that each line has the same physical length of nine inches, yet their electrical lengths are different. The highest impedance line has the shortest electrical length, due to the lower effective dielectric constant of the narrow microstrip line. The narrowest line has more fringe fields in air, contributing to a lower effective dielectric constant and hence shorter round-trip time delay. The widest line has the lowest impedance and least amount of field lines in air, resulting in higher effective dielectric constant and longest round-trip time delay.

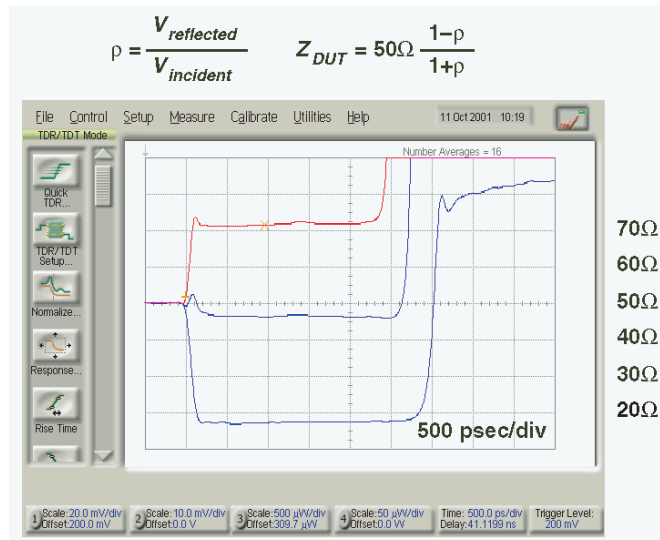


Figure 2. The impedance of microstrip transmission lines of different widths.

Measuring Differential Pairs

The use of a second TDR channel allows analysis of the properties of differential transmission line pairs. The simplest way of thinking about differential impedance is to consider a coplanar transmission line composed of two traces on an FR4 substrate. With no metal plane beneath them, they represent a simple coplanar transmission line. The impedance of this transmission line depends on the line parameters of the capacitance and loop inductance per length. What will happen to the impedance a signal sees if the coplanar pair passes over a floating metal plane?

To explore this scenario, a simple test board was built with a coplanar pair of traces mounted to an FR4 substrate. For the first four inches, there is no plane on the backside of the board. For the second four inches, there is a continuous plane. The front end of the coplanar pair has an SMA connector that is interfaced to the TDR through a 50Ω coax cable. The TDR can drive a signal into the coplanar pair, with one trace acting as the signal and the other trace acting as the return path. Since this is a balanced pair, it doesn't matter which line is which. The TDR allows direct measurement of the impedance the signal sees in propagating down the line (figure 3).

In the first four inches, the impedance is rather high, about 150Ω. This is due to the relatively large separation of the traces, with higher inductance per length and lower capacitance per length than is typical of microstrips.

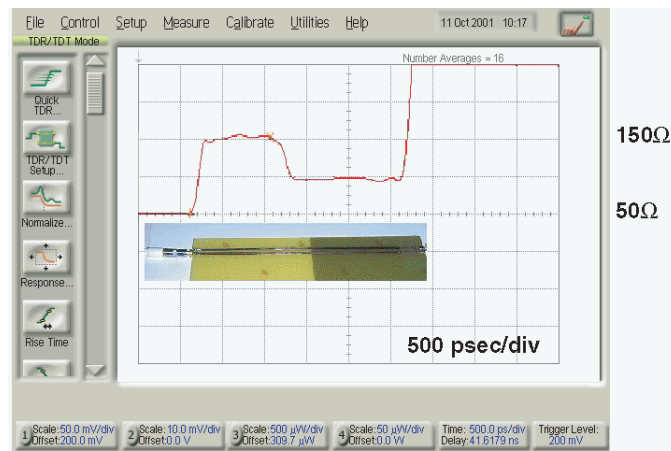


Figure 3. The TDR allows direct measurement of the impedance the signal sees in propagating down the line.

In the second half of the trace, where the plane extends beneath the traces, the impedance the signal sees is dramatically reduced to about 100Ω. This drop in impedance is due to the change in the line parameters caused by the proximity of the plane below. The total capacitance between the two lines is dominated by the series combination of the coupling capacitance from one line to the plane and the capacitance of the plane up to the second line. This series capacitance is much larger than the direct line-to-line capacitance. In addition, the loop inductance is reduced due to the induced eddy currents generated in the plane by the signal edge propagating down the transmission line. This combination of factors results in a reduction of the impedance to only 100Ω.

Even though there is no direct electrical connection between the two coplanar lines and the plane below, the electromagnetic coupling has a significant impact on the impedance a signal sees moving down the coplanar lines. It is not a coincidence that the geometry of the second half corresponds to two single-ended lines, each with a single-ended characteristic impedance of 50Ω.

This experiment leads to the simplest possible description of differential impedance. When the two coplanar lines were driven as a single-ended transmission line, the signal was the voltage difference between the two lines. The impedance the signal saw was 150Ω where there was no plane and 100Ω where there was a plane. In the region where there is a plane below, the transmission lines look like two coupled microstrip lines (a differential pair).

Differential Driving

Driving the two transmission lines by single-ended signals that are exactly out of phase is called differential driving. As the signals propagate down the differential pair, there is a voltage pattern between each signal line and the reference plane below. In addition, there is a signal between the two signal lines. This is called the difference signal or differential signal. If the differential pair is driven symmetrically, the differential signal voltage is twice the single-ended signal voltage.

The difference signal is the same signal as if the two coplanar traces are driven as a single-ended line, as in the previous example. In this case, the impedance the signal saw was 100Ω in the region where there was a plane underneath. If the two microstrips were driven differentially, the difference signal would also see an impedance of 100Ω . The impedance the difference signal sees is called the difference impedance or differential impedance.

Differential impedance is really the impedance seen by the difference signal that is driven between the two signal lines in the differential pair. The impedance the

difference signal sees is the ratio of the signal voltage (difference voltage) to the current in the line. The difference voltage is twice the voltage of the edges driven into each line. The current into each line is related to the impedance of each individual line in the pair. There is an additional current between the signal lines that is due to the coupling between the traces themselves. This is generally a small amount, but cannot be neglected.

In this simple perspective, differential impedance is the impedance the difference signal sees when opposite-polarity edges are launched in a differential pair of transmission lines. And, as illustrated before, this is also the impedance a signal would see if it were launched between the two signal lines, keeping the external plane as a floating plane.

To quantify the concepts of differential impedance, it is important to introduce the formalism of describing the nature of the coupling between transmission lines. This allows any arbitrary pair of coupled lines to be analyzed with the same methods.

Impedance Matrix

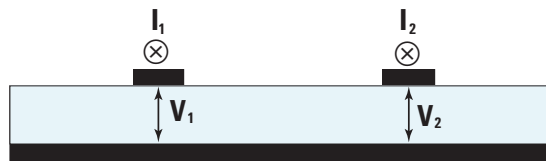
If there were no coupling between transmission lines, the impedance of a line, as defined by the ratio of the voltage across the paths and the current through them, would depend only on the line parameters of that one line. However, as soon as coupling is introduced, the voltage on one line may be affected by the current in an adjacent line. To include these effects, the concept of impedance or characteristic impedance must be expanded to allow for one trace interacting with another. This is handled by expanding the impedance into an impedance matrix (figure 4).

Any two transmission lines, each with a signal path and a return path, can be modeled using an impedance matrix. The diagonal elements are the impedances of each line when there is no current in the adjacent line. This is sometimes called self-impedance. The off-diagonal elements represent the amount of voltage noise induced on the adjacent trace when current flows on the active line. If there were little or no coupling, the off-diagonal impedance would be near zero.

As the coupling between the lines increases, the off-diagonal terms will increase. If the microstrip traces are moved closer together, the diagonal impedance (self-impedance) will not change very much, but the off-diagonal

elements will increase. Alternatively, if the plane is lowered, the diagonal elements will increase and the off-diagonal elements will increase. When the off-diagonal impedance elements are a large fraction of the diagonal elements, the lines are very strongly coupled.

The definition of the characteristic impedance matrix between any two transmission lines does not in any way depend on their size, shape, material composition, or the signals imposed. Of course, the values of the matrix elements themselves strongly depend on the geometry and material properties. The matrix is symmetric for identical transmission lines, so they are often called symmetric lines.



$$V_1 = Z_{11} I_1 + Z_{12} I_2$$

$$V_2 = Z_{22} I_2 + Z_{21} I_1$$

Example:

Characteristic Impedance Matrix (Ω):

	1	2
1	49.6	6.4
2	6.4	49.6

Figure 4. The characteristic impedance matrix of a coupled differential pair.

Modes

Any arbitrary voltage pattern may be imposed on a pair of transmission lines. However, certain patterns have special properties in that they will propagate down the line undistorted. These patterns are called modes. When the dielectric is inhomogeneous and the conductors are identical, the mode patterns that propagate undistorted are the same voltage patterns as when the pair is driven differentially, with opposite edges; or driven in common, with the same voltage edge polarity. These two modes have the special names of odd and even modes (figure 5).

When the impedance matrix is symmetric, the odd mode is excited when the pair is driven with a differential signal. The even mode is excited when the pair is driven with a common signal. These modes are intrinsic features of the transmission lines, and depend on their precise geometry and material properties. The voltages imposed on the lines depend on how the drivers are configured.

Based on the definition of the impedance matrix, and the definition of odd and even modes, the impedance of each mode can be calculated. The odd-mode impedance is the impedance a driver would see, looking into one of the lines, when the pair of lines is driven in the odd mode, or with a differential signal. Likewise, the even-mode impedance is the impedance a driver would see, look-

ing into one of the lines, when the pair of lines is driven in the even mode, or by a common signal.

Even and Odd Modes

If there were no coupling, both the odd- and even-mode impedances would be equal, and equal to the impedance of just one isolated line, as expected. However, with coupling, there are additional current paths between the signal lines in odd mode, and the odd-mode impedance decreases. Some current flows not only from the first signal line to the return path, but through to the second signal line and then into the return path. This increased current through the coupling path with increasing coupling results in a decrease in the odd-mode impedance of one line.

The even mode is also affected by coupling. When two signal traces are driven with a common signal, there is no voltage difference between them. There is thus no coupled current between the signal lines and the even-mode impedance is higher than the odd-mode impedance.

From this analysis, it is clear that when there is coupling between transmission lines, as in a differential pair, referring to the “impedance” of one line is meaningless. The impedance varies depending on how the adjacent line is driven. When both lines are driven in common, the impedance of one line is the even-mode impedance. When both lines are driven differentially, the impedance of one line is the odd-mode impedance.

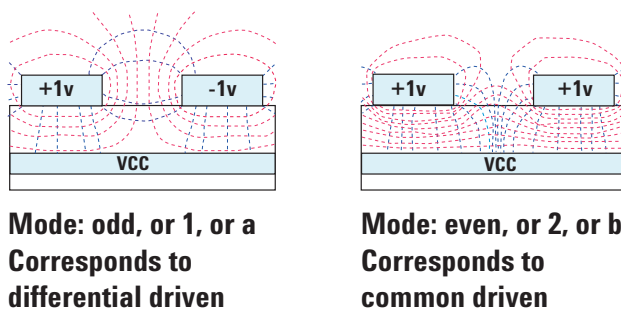


Figure 5. The even and odd modes.

Measuring Odd- and Even-Mode Impedances

To measure the odd- and even-mode impedances requires applying simultaneous signals to each of the two lines. This requires using a dual-channel TDR that can be configured for differential drive and common drive. With this instrument, the even- and odd-mode impedances can be measured and the characteristic impedance matrix elements extracted.

In figure 6, the TDR response of one trace of a closely-coupled differential pair of microstrips is measured. The other trace is driven by channel 2 of the Agilent 54754 differential TDR module. The TDR response has been converted from a voltage

scale directly into an impedance scale to facilitate direct readout of impedance.

When channel 2 is driven in phase with channel 1, the differential pair is driven with a common signal. The impedance measured by the TDR for one of the microstrip traces is the even-mode impedance of that line and is about 52Ω. Merely by changing the signal on the second trace to out of phase, thereby driving the pair with a differential signal, the impedance of the line under test decreases. The odd-mode impedance is about 45Ω. Finally, when the second channel is turned off, and the voltage on line 2 is zero, the impedance of line 1 is measured

as the self-impedance, which is the diagonal matrix element, about 48.5Ω. Using the measurements of the odd- and even-mode impedances, the off-diagonal impedance matrix elements can be extracted, as shown in figure 6.

When the differential pair is driven differentially by the DTDR module, the impedance measured by each channel is the odd-mode impedance of each line. These can both be displayed directly on the screen. For symmetric lines, the odd-mode impedance of each line is nominally the same, but in the real world there are always some asymmetries. These show up as slightly different odd-mode impedances for line 1 and line 2.

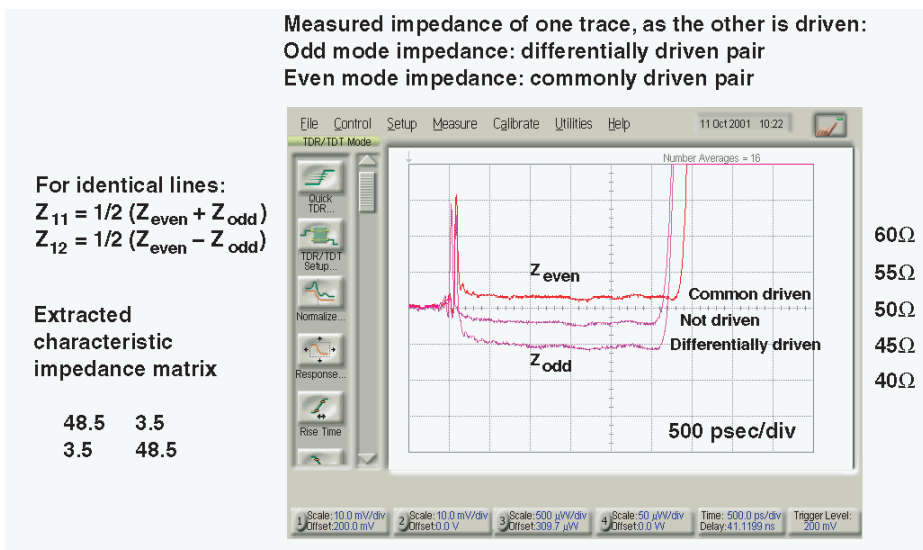


Figure 6. Measuring odd and even impedance of tightly coupled lines.

Measuring Odd- and Even-Mode Impedances (continued)

In figure 7, one of two microstrip lines has an odd-mode impedance of 46Ω and the other has one of 47Ω . There is some variation across the length of the trace due to line-width variations in the tape used to fabricate the trace. When the two traces have different odd-mode impedances, the differential impedance is just the sum of the two different odd-mode impedances. After all, the difference signal sees the series combination of the impedances of each line to the plane below.

The differential impedance can be displayed directly on the screen as the sum of the two odd-mode impedances. In this example, it is about 93Ω , with some variation across the length.

Differential TDR is useful for measuring the odd- and even-mode impedances of a coupled pair of transmission lines, enabling calculation of its characteristic impedance matrix elements and thus the differential impedance. With coupled transmission lines, the impedance of one line depends on how the adjacent line is driven.

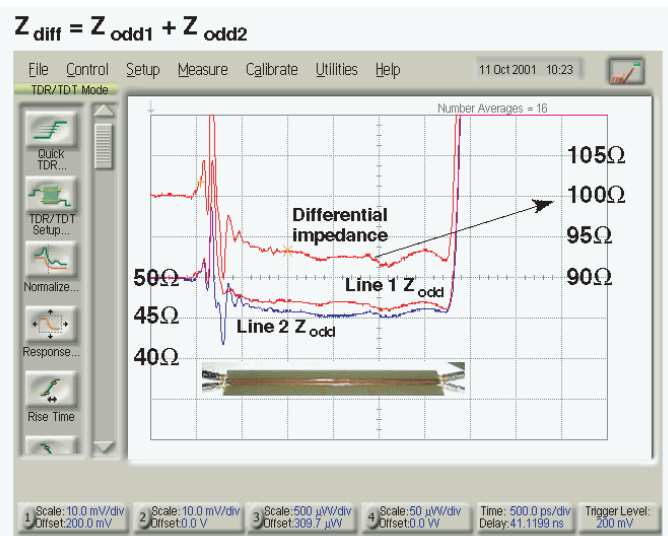


Figure 7. Direct measurement of differential impedance.

Dual-channel TDR can be used to analyze features and real-world effects of high-speed differential transmission lines under a variety of conditions such as a gap in the return path. Dual-channel TDR can be hooked up in a variety of ways to maximize the amount of information obtained

about a differential-pair transmission line. When the second channel is just used for input, it can measure either the transmitted response of a single line, as in conventional time domain transmission (TDT), or the response of an adjacent quiet trace due to crosstalk.

Simultaneous Measurements

In TDT, the first channel generates the exciting source into one end of the transmission line and the second TDR channel is the receiver at the other end. In this way, the TDR and TDT response of the device under test (DUT) can be measured simultaneously. The TDR response gives information about the impedance of the DUT, and the TDT gives information about the signal propagation time, signal quality, and rise-time degradation. In this mode, the TDT is emulating what a receiver might see at the far end (figure 8).

One limitation of TDR/TDT is that the source and receiver have impedances of 50Ω . This may not match the impedance of the actual end-use application. However, many of the commonly encountered signal-integrity effects can

be illustrated with this 50Ω impedance, and these measurements can be used to create or verify interconnect models, which can then be used in simulations with real device models as the sources and loads.

The configuration of dual-channel TDR can also be used to measure crosstalk between two adjacent traces. The first TDR channel can be used to generate the exciting waveform for the active line. The voltage induced on the quiet line is then measured with the second channel by alternately connecting one end and then the other to this second channel. During this procedure, the unattached ends of the two transmission lines should be terminated in 50Ω to keep the loads the same as when the cables are attached.

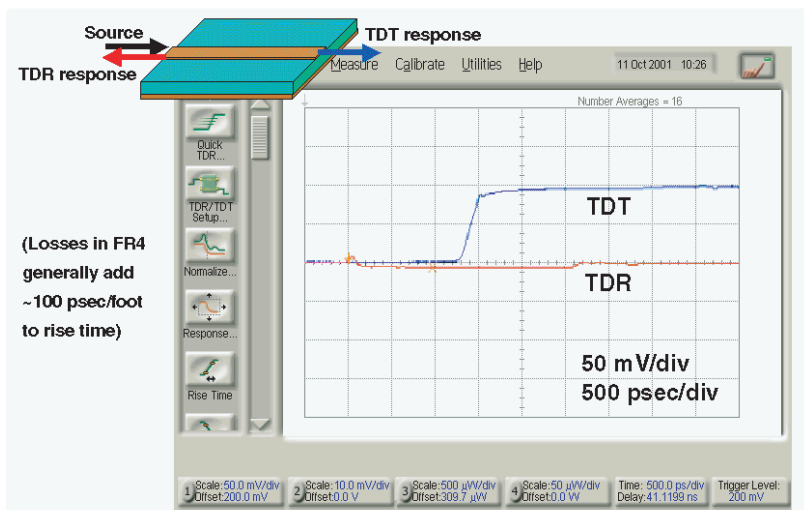


Figure 8. A dual-channel TDR can provide both the TDR and TDT response.

Crosstalk

In the example displayed in figure 9, the near-end crosstalk (NEXT) and far-end crosstalk (FEXT) of two closely spaced microstrip lines are measured. The line width is 2xh and the space is equal to the line width. The saturated NEXT is about 7 mV, which is 3.5 percent. The FEXT shows a peak of 63 mV, strongly dependent on the rise time and coupled length.

A dual-channel TDR module allows the measurement of the impedance characteristics of any coupled differential pair. With the addition of an Agilent 83484A 2-channel, 50-GHz plug-in module, the signals propagated to the end of the differential pair can be measured. This emulates what the actual far-end receivers might see, given the caveat of 50Ω termination.

In the example shown in figure 10, the signal at the far end when the pairs are driven differentially is measured. In the upper left screen shot, the TDR response without the DUT connected is shown. This highlights that one channel is driving a signal of 0 to 400 mV, while the other channel is driving a signal of 0 to -400 mV. What gets launched into a 50Ω load is 0 to 200 mV in channel 1 and 0 to -200 mV in channel 2.

At the far end of the roughly 50Ω differential pair, the two channels of the Agilent 83484A measure the received voltage into a 50Ω load. This shows the roughly 100 ps rise time from propagating down eight inches of FR4. The

individual channels are displayed as directly measured. In addition, the common signal (being the average of these two) and the differential signal can be automatically displayed. All received signals are displayed on the same

scale. When driven differentially, very little common signal is created by the transmission down the pair. When the pair is driven with a well balanced differential signal, the common signal is virtually nonexistent.

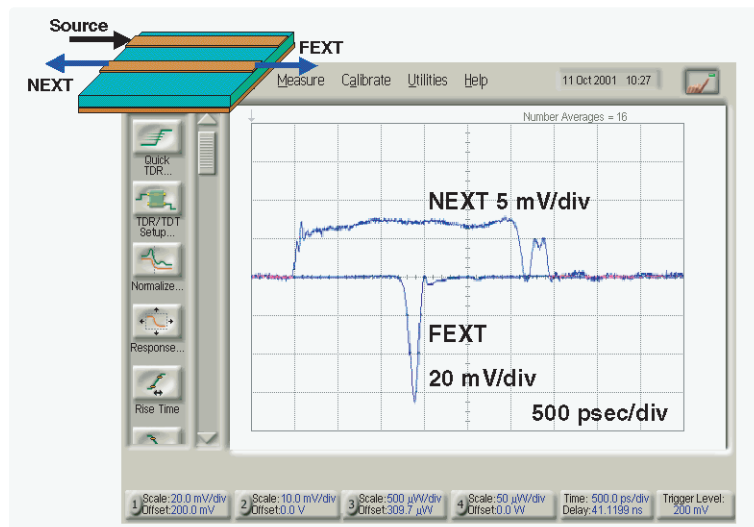


Figure 9. Using a dual-channel TDR to measure the near-end crosstalk (NEXT) and far-end crosstalk (FEXT).

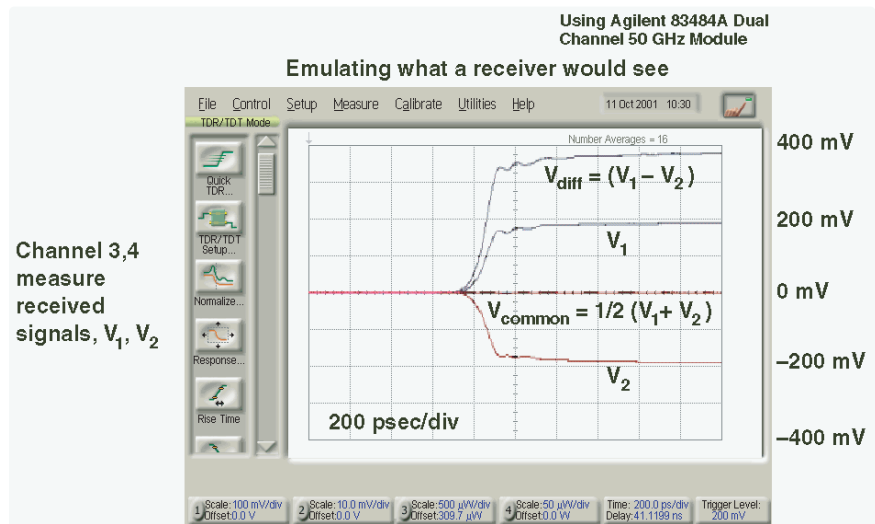


Figure 10. Measuring the impedance characteristics of a coupled differential pair.

Skewed Differential Signals

A common problem with differential drivers for differential-pair lines is skew between the two channels. This arises due to driver mismatch, different rise and fall times, different interconnect delays due to routing differences, or different loads on the two lines of the differential pair. Any signal imbalance at the receivers will create a common signal.

A variable skew can be introduced between the two driven TDR step generators, emulating what would happen if there were a skew in the drivers. In the example shown in figure 11, the common signal increases steadily as the skew increases from zero to 100 ps, comparable to the rise time. If the skew is longer than 100 ps, the common signal at the receiver is basically constant. This suggests that to minimize the common signal, the skew should be kept to just a small fraction of the rise time.

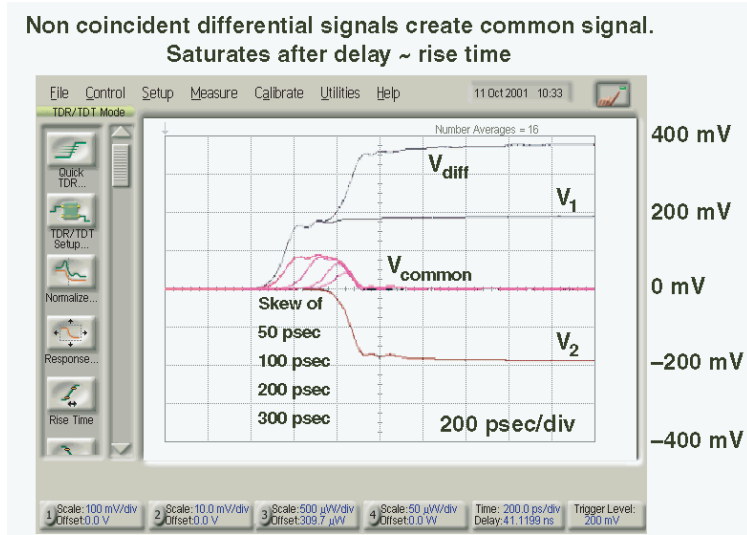


Figure 11. Emulation of a skewed differential pair by introducing a skew between the two TDR step generators.

Full Characterization

The full characterization of the performance of a differentially driven differential pair includes the TDR response of each channel, which relates to the odd-mode impedance of each line, and the received signals of the two channels at the far end, combined as the differential and common signals. In the example shown in figure 12, the measured response of a uniform differential pair is shown, illustrating all six measurements. In this example, the common signal is very small because the differential drivers are well balanced.

This response should be compared to the behavior of the same pair when one line is driven single ended while the other line is held low, as shown in figure 13. In this case, TDR channel 2 is measuring the NEXT and the channel 4 receiver is measuring the FEXT. When a signal is launched into only one line of a symmetric pair of lines, there are equal parts odd-mode and even-mode signal created. These propagate down the line and are received at the end, where they are calculated from the voltages in the two receiver channels and displayed as the differential signal and common signal. The differential signal, corresponding to the odd mode, arrives at the receiver before the common signal, corresponding to the even mode.

This is a direct measure of the difference in velocity of the odd and even modes. The odd mode, having more fringe fields in the air, has a lower effective dielectric constant and hence higher propagation speed. The even mode has more fields in the dielectric and a

higher effective dielectric constant, and takes longer to reach the receiver. From this measurement, the connection between crosstalk and modes is also apparent. The common-mode signal is delayed due to the FEXT.

In this example, the differential and common signals are displayed using the Math function of the Agilent 86100A mainframe, so that the TDR response can be switched between single output and dual output.

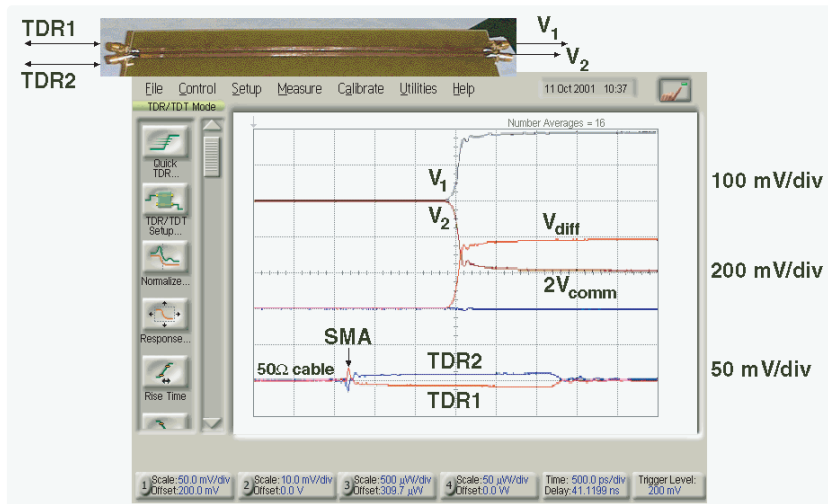


Figure 12. The measured response of a well balanced signal shows a very small common signal.

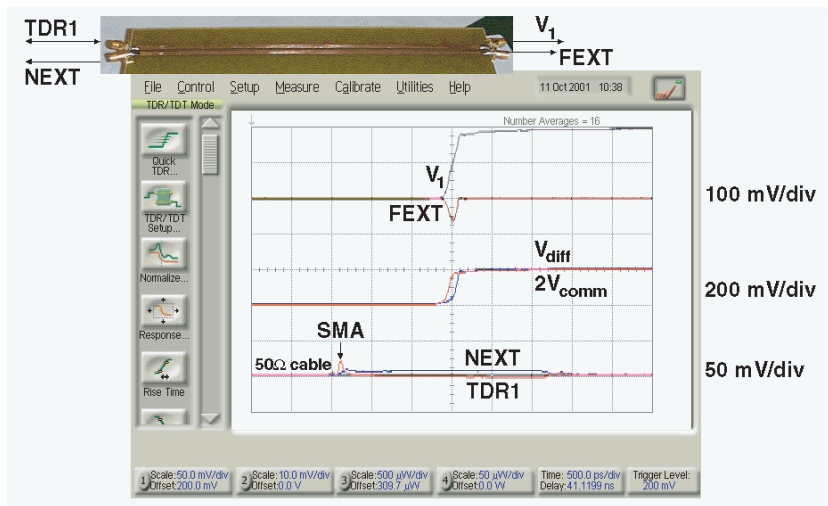


Figure 13. The same pair from figure 6 when one line is driven single ended.

Signals Crossing a Gap

With this perspective, the response of a differential pair that crosses a gap in the return path can be examined. The traces are about eight inches long with a 50Ω load, and with weak coupling between them. The gap in the return path is about one inch wide. The time delay across this gap is comparable to the rise time of about 100 ps. As before, the response at the near end and far end of each line can be measured when one line is driven single ended and also when both lines are driven differentially, as shown in figure 14.

As expected, the TDR response of channel 1 shows the uniform transmission line until the gap is reached. Electrically, the gap looks like a large inductive discontinuity and the reflection is a large positive value. The second TDR channel is measuring the reflected NEXT noise. Initially there is the saturated near-end noise, until the gap is reached. The mutual inductance between the two traces in the vicinity of the gap is almost as large as the self-inductance that causes the reflection of channel 1. This results in induced noise generated in trace 2 that is almost as large as the reflected signal in trace 1.

The inductively generated noise in trace 2 propagates down the trace 2 transmission line in both directions, and appears at the far end as much-enhanced far-end noise. From the time constant of roughly 400 ps, the inductance of the discontinuity can be extracted as roughly 40 nH. This corresponds to the self-inductance of the perimeter of the current path around the gap, which is about $3\frac{1}{2}$ inches, or roughly 15 nH/in.

The enhanced crosstalk, both near and far, between the two

adjacent traces, due to high mutual inductance of the return paths around the gap, is a primary reason to carefully route return paths over continuous planes and avoid crossing gaps. Also, the common and differential signals are greatly distorted compared to if there were no gap in the return path. This sort of discontinuity would cause major problems for most single-ended-driven transmission lines, and is another reason why design rules recommend routing adjacent traces over continuous return paths.

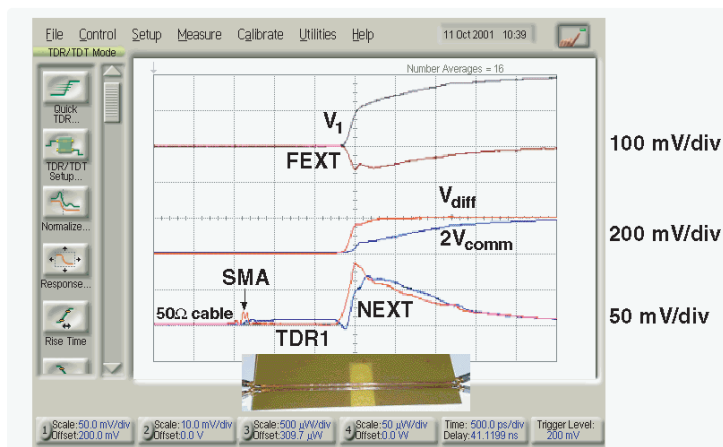


Figure 14. The response of a differential pair that crosses a gap in the return path when driven single ended.

Differential Signals Crossing a Gap

However, when both lines are driven with a differential signal between the pair of traces, the reflected noise from each line is in the opposite direction and the resulting reflection is reduced considerably (figure 15).

Likewise, since the gap offers a nearly balanced discontinuity to each of the two signal lines, the effect on the common signal is almost negligible. This illustrates a chief advantage of transmitting signals on differential pairs—differential signals are much more robust to imperfections in the propagation paths that are common to both lines. The effects on each line are better balanced, with less common-signal noise generated, as the lines are routed closer to each other and the coupling is larger.

Another way to look at the gap in the return path is in terms of what impedance the differential signal sees. This can be measured directly with the differential TDR (DTDR) module. The differential pair is driven differentially, and the DTDR measures the odd-mode impedance of each line. Their sum is the differential impedance.

Before and after the gap, the differential impedance is about 97Ω . In the region of the gap, the differential impedance is about 150Ω . This corresponds to the impedance that was measured for two coplanar transmission lines

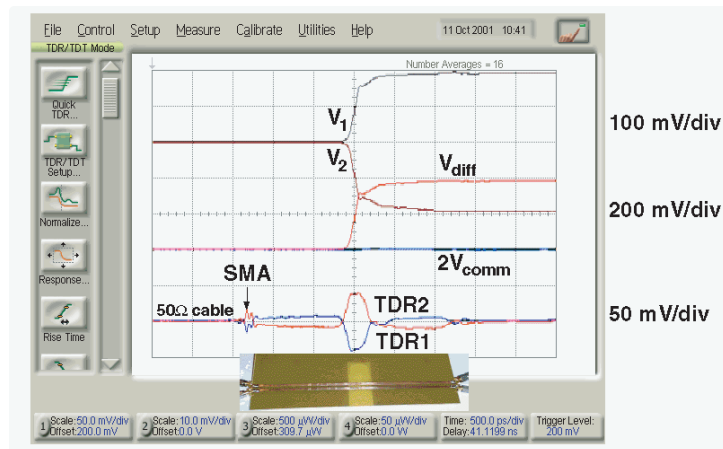


Figure 15. The response of the differential pair from figure 8 driven differentially, showing the robustness of differential signals to imperfections in the propagation path.

with no conducting plane beneath them, which is exactly what the region of the gap appears as. The gap acts as a high-impedance region for the differential signal, which will create a reflection. However, if the lines are terminated at both ends, this reflection might not cause signal-integrity problems.

These examples show that if signals must cross gaps in the return path, routing the signals as differential signals on closely coupled differential pairs is the way to do

it. This method may result in some increase in the differential impedance, but there is very little distortion of the differential signal and very little common voltage created.

DTDR and a dual-channel amplifier module provide full characterization of differential pairs of transmission lines, enabling engineers to better determine how their designs are working at the electrical level and suggesting ideas for how to improve them.

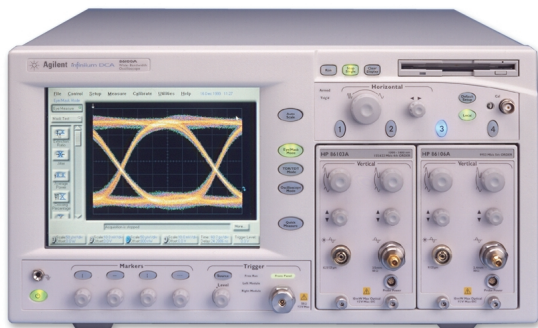
Ease Dual-Channel TDR Measurements

As differential signals become a more important part of high-speed systems, it is essential that you have the tools to properly design and verify the impedance of differential signal paths. Using multiple-channel time domain reflectometry (TDR) simplifies the process as you can make simultaneous measurements and then use math functions to present the data in the engineering units you need.

The Agilent 86100 Infiniium DCA oscilloscope provides a 50 GHz bandwidth and plug-in modules that ease the task of characterizing a differential-pair transmission line. Additional modules specifically for the 86100 are being created, but the new oscilloscope can still use modules from the Agilent 83480A digital communications analyzer and the Agilent 54750A high-bandwidth digitizing oscilloscope.

When used with the Agilent 54754A plug-in module, the 86100 oscilloscope becomes a differential time-domain reflectometer. The module has two independent step generators that can be synchronized, and the response from each channel is measured independently of the other channel. To further ease your measurements, the instrument has the ability to convert the voltage measured into an impedance scale. This allows you to directly read the impedance on the display.

The Agilent 83484A module is also used to provide multiple 50 GHz inputs. Each module has two 50 GHz electrical channels and one trigger input port. This allows measurements of the waveforms that appear at the far end of the transmission-line pair, thereby emulating the actual signal a differential receiver would detect after transmission through the pair.



When used with the Agilent 54754A plug-in module, the 86100 Infiniium DCA oscilloscope becomes a differential time-domain reflectometer.

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Related Literature

Publication Title	Publication Type	Publication Number
<i>Test Tools for InfiniBand</i>	Color brochure	5988-2424EN
<i>Infiniium DCA: Agilent 86100 Wide Bandwidth Oscilloscope</i>	Color brochure	5988-3666EN
<i>Infiniium DCA: Agilent 86100 Wide Bandwidth Oscilloscope</i>	Technical specs	5968-8546E
<i>40 Gb/s and Return-to-Zero Measurements Using the Agilent 86100 Infiniium DCA</i>	Product note	5988-2039EN

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