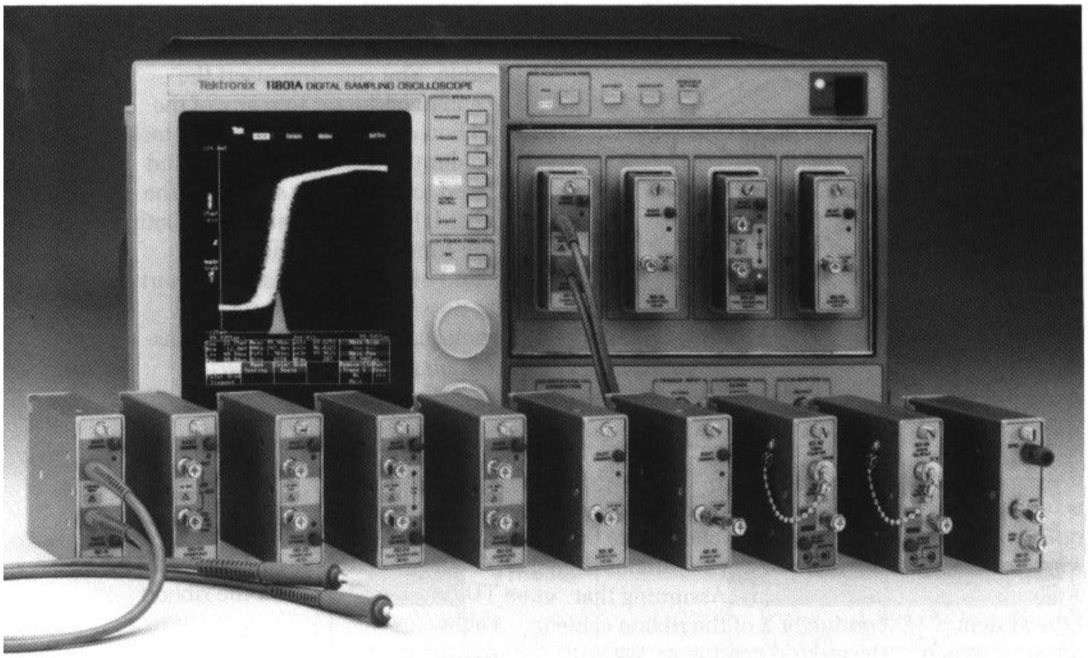
Tektronix

Application Note

Crosstalk Characterization of a Ribbon Cable Using the 11800 Series



The Tektronix 11800 Series Digital Sampling Oscilloscopes are specifically designed to meet the demands of engineers who use TDR and TDT measurements to troubleshoot and design state-of-the-art circuits. The 11800 Series oscilloscopes, together with the Tektronix SD-24 TDR/Sampling Head, provides a system that can perform simple TDR measurements as well as complex, differential, multi-channel TDR and TDT measurement.

The 11800 Series oscilloscopes provide a minimum of four TDR/TDT channels. When integrated with four SM-11 Multi-Channel Units you have 136 possible TDR/TDT channels. In a high-speed IC tester, this large number of TDR channels assist in precisely deskewing signal lines.

A high throughput TDR system can handle this task in seconds.

The 11800 Series oscilloscopes also provide the capability to store and sum the TDR signals on various channels. This feature is highlighted in the following example of a typical TDR/TDT application.

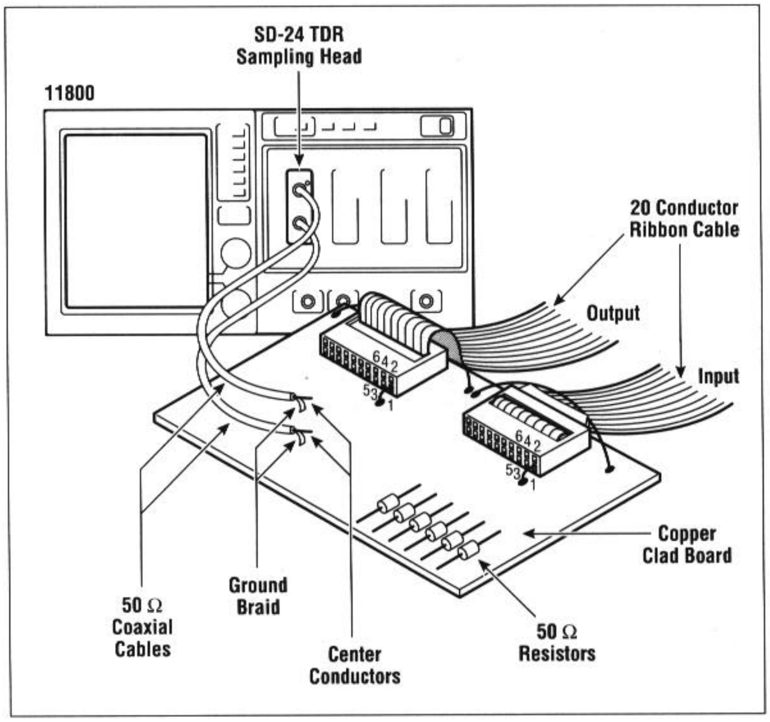


Figure 1. Setup for Performing Impedance and Crosstalk Measurements.

Introduction

Time Domain Reflectometry (TDR) and Time Domain Transmission (TDT) are vital to engineers who must troubleshoot complex circuits at the system level and component level. When a TDR measurement is performed, a step pulse is applied to a component, or a network of components, and then the signal that is reflected back from that component or component network is analyzed. This reflected signal provides precise information as to how that component affects and reacts to the applied input. TDT measurements are performed in the same way, except that the signal transmitted through the component is analyzed on a second acquisition channel.

The SD-24 TDR/Sampling Head provides a built-in step generator that has a rise time of typically less than 20 ps. This fast rise time provides more accurate information about the circuit or component under test, and is critical when testing systems that typically use signals with rise times of less than 1 ns (such as ECL or GaAs logic systems).

Characterizing a Ribbon Cable

The following examples involve a 20-conductor ribbon cable that connects two synchronous digital circuit boards. Assuming that conductor 1 of the ribbon cable is the ground conductor, we will designate conductor 2 as the clock signal conductor. The clock is the most critical signal in the ribbon cable because any variation of the clock signal can result in data being strobed incorrectly into latches.

Two parameters that affect the clock signal are the impedance of the ribbon cable and the crosstalk that is induced from neighboring conductors. This application note provides an easy way to measure these parameters using a Tektronix 11800 Series oscilloscope and an SD-24 TDR/Sampling Head.

Setup

Fasten the connectors on both ends of the ribbon cable to a piece of copper-clad board. (You can either glue the connectors to the board or solder a wire across each connector.) Orient each connector so that the conductors inside the ribbon cables are parallel to the board. Insert a pin into socket number 1 of each connector and solder the pins to the board. (Ensure that the ground pins are as short as possible.)

Connect two 50 Ω coaxial cables to the sampling head inputs. Strip the insulation from the unconnected ends of the cables so that the center conductor and the ground braid of the cable are accessible.

Gather the ground braid of each cable. You can now insert the center conductor into any of the ribbon cable's connectors and tack solder the coaxial cable's ground braid to the copper surface of the board. It is important to keep both the conductor and the ground braid of the coaxial cable as short as possible (no longer than 0.2 inches). See Figure 1 for an illustration of this setup.

Caution: *Do not allow the center conductor to touch any object that may hold a static charge. The sampling head is very susceptible to electrostatic discharge.*

You are now prepared to make TDR measurements on the ribbon cable.

Impedance

Connect the sampling head's channel 1 coaxial cable to socket number 1 on the input connector of the ribbon cable. Connect the sampling head's channel 2 coaxial cable to socket number 1 of the output connector of the ribbon cable. Press the WAVEFORM button on the 11801A oscilloscope, and then touch **Sampling Head Fnc's** in the WAVEFORM major menu.

To apply the sampling head's TDR step to the input of the ribbon cable, touch **TDR Preset** in the **Sampling Head Functions** pop-up menu; which will automatically switch the channel 1 step generator on, and display the incident TDR step on the screen.

Set the oscilloscope's **Main Size** to 500 ps/div and then press the sampling head's channel 2 SELECT CHANNEL button to view the ribbon cable's output step (that is, the TDT waveform). Figure 2 shows the TDR waveform (top) and the TDT waveform (bottom).

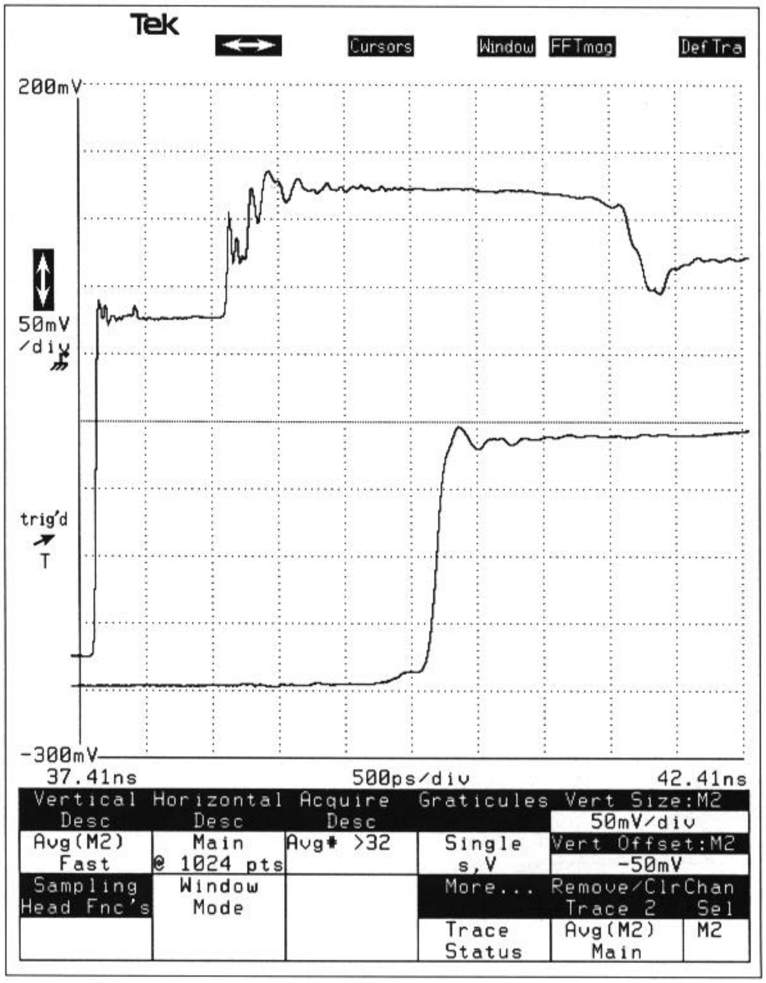


Figure 2. TDR and TDT Waveforms of a 20-Conductor Ribbon Cable.

Looking from left to right on the oscilloscope screen, the TDR waveform (channel 1) represents three things:

- the incident step leaving the sampling head (the first step)
- the incident step entering the ribbon cables connector (the second step)
- the difference in impedance between the 50 Ω coaxial cable and the ribbon cable

The impedance difference is shown as an increase in the amplitude of the TDR step once it is reflected from the ribbon cable transition. The 11800 Series oscilloscopes provide a simple and direct method of measuring the impedance of the ribbon cable.

First, verify that the waveform is vertically scaled in units of rho (ρ) (when initialized, the oscilloscope is set to volts scaling). You can set the vertical scaling to rho in the **Graticule** pop-up menu (that is touch **Graticules** in the WAVEFORM major menu, and then set **Y units** to **Rho**). Incidentally, rho is the traditional unit for TDR and is based on a normalized unity amplitude of the incident step. For convenience, the oscilloscope displays results in terms of rho or millivolts.

Next, touch **Cursors** at the top of the display. Select **Horizontal Bars** in the **Cursor Type** pop-up menu, and position **Cursor 1** (top cursor) to the average amplitude of the TDR waveform after it has entered the ribbon cable. Now, you can read the impedance (in ohms) directly from the oscilloscope display. It appears just in front of the **ρ1** reading at the bottom of the display.

The propagation delay of the ribbon cable can also be measured with the cursors. Set the **Main Size** and **Main Pos** so that the TDR waveform shows two positive-going steps: one located where the incident TDR signal reflects from the ribbon cable interface, and one where the TDR step reflects from the open circuit at the output end of the ribbon cable. Touch **Cursors**, and then select **Paired Dots**. Two cursor "dots" should now appear on the TDR waveform. Position the **Cursor 2** on the right-most step (the open circuit at the end of the ribbon cable) and **Cursor 1** on the left-most step (the ribbon cable interface). The **Δt/2** reading shown is the time it takes the TDR step to travel the distance of the cable.

Crosstalk

To measure the full effect of crosstalk on the clock conductor you must measure the contribution of each wire in the ribbon cable. Since you are using conductor 2 as the clock line, you can expect conductor 3 to contribute the most crosstalk; with the contribution of the other conductors decreasing as the distance from conductor 2 increases.

Apply the incident TDR step to conductor 3 of the input connector to measure the crosstalk induced from this wire. Measure the induced crosstalk of conductor 2 on the sampling head's channel 2 input.

Note: In order to achieve the most accurate results, it is recommended that all conductors, excluding the conductor that is transmitting the TDR step, be terminated as they would be in the actual application; typically with 50 Ω. To accomplish this, insert 50 Ω resistors into the connector sockets and then solder the other ends to the copper-clad board.

Use the STORE/RECALL menu structure to store and then recall the resulting crosstalk waveform. Repeat this procedure for the remaining conductors.

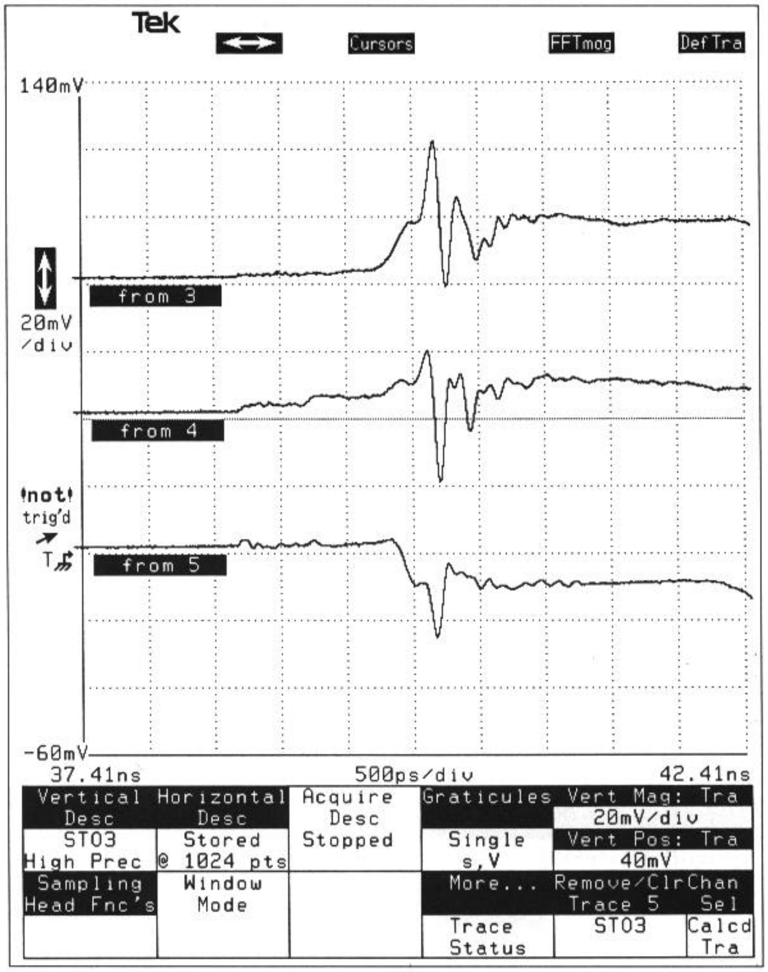


Figure 3. Crosstalk from Conductors 3, 4, 5, and 6.

Figure 3 shows the results of measuring the crosstalk that is induced from conductors 3, 4, and 5. Each of the four waveforms shown in Figure 3 have two stages of crosstalk. The first stage is the fast, high amplitude portion of the crosstalk. This stage is the result of the shared ground in the ribbon cable to the copper board interconnect. The second stage is the slow, lower amplitude portion of the cross-talk. This stage is the result of the proximity of the wires in the cable itself. Note that this figure illustrates and validates the relationship assumed earlier; the amplitude of the crosstalk decreases as the distance from the clock conductor increases. Since the cable is essentially a linear system, the 11800 Series oscilloscopes can sum the individual crosstalk waveforms to characterize the total induced crosstalk on conductor 2.

One factor to keep in mind when interpreting the results of this test is that the crosstalk shown in Figure 3 is induced by an extremely fast pulse. Even GaAs logic is unable to equal the sampling head TDR pulse's 17.5 ps rise time. Slower signals will induce less crosstalk, but how much less? The oscilloscope provides a **Filter** function that allows you to quickly view and measure this crosstalk that would be induced by a slower incident step. When you create a waveform using the **Filter** function, you specify risetime as a parameter. The oscilloscope automatically computes a live (that is, continuously updated) waveform that would result from an incident step with the risetime you specified. You can also use the waveform math functions to subtract any aberrations caused by imperfect cables and connectors, or other effects that would distort the TDR response.

The 11800 Series Digital Sampling Oscilloscopes, combined with the SD-24 TDR/Sampling Head provides a highly efficient and unique TDR measurement system. This application note was intended only as introduction to the potential of the features and applications available using the 11800 Series oscilloscopes.

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