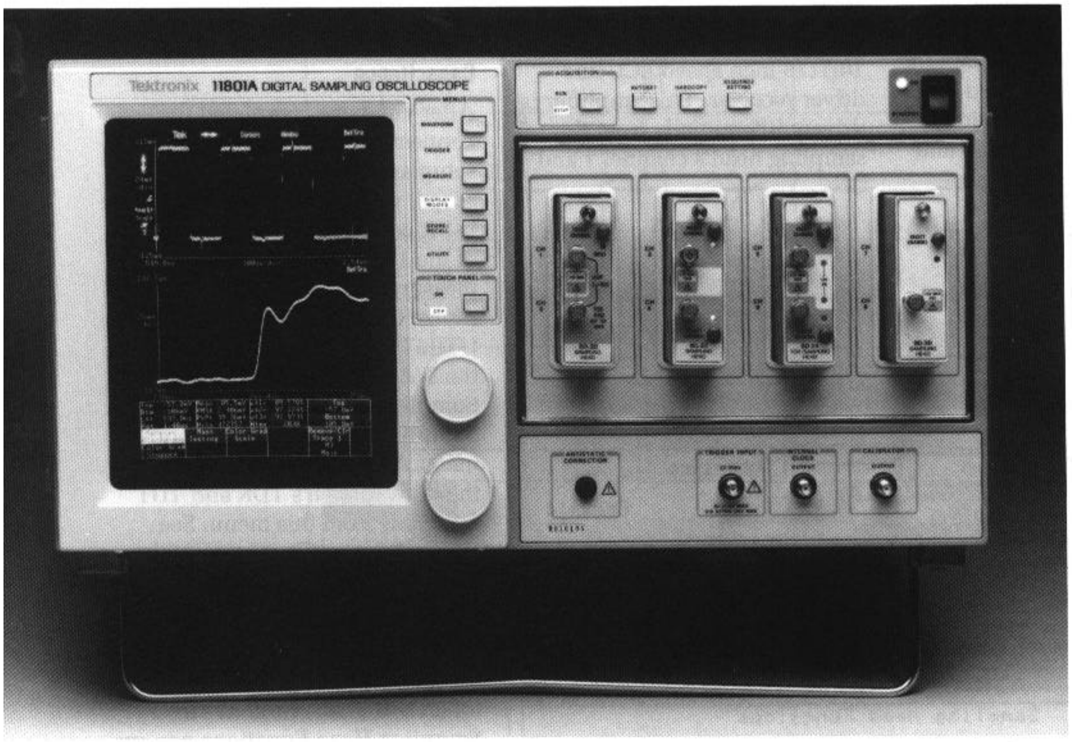
Tektronix

Application Note

Characterizing a Differential Amplifier Using the 11800 Series



Time-domain reflectometry (TDR) measurements are made with the same method that a radar system ranges and identifies an unknown jet in the sky or a ship in the ocean. Both systems send out a signal to an object (or component) and the signal that is reflected back from that object provides the trained eye with valuable information. Radar scopes relate how far an object is from your location and certain characteristics of this object (for example, velocity, direction, and size). And, these characteristics often provide enough information so an experienced person can identify the object exactly.

A TDR waveform provides similar information. A step pulse is applied to a component (or a network of components) in an electrical system, and the reflections are analyzed. The TDR waveform will contain reflections at the point(s) where the incident waveform encountered an impedance difference in the circuit path. These reflections indicate, for instance, the electrical distance from the acquisition point of the TDR system to a component in the network, a short circuit, an open circuit, or a crimp in a cable.

Furthermore, the magnitude, polarity, and geometry of the reflections indicate some of the characteristics of the impedance change (such as the value of resistance, capacitance, or inductance).

If the transmitted waveform, and not the TDR waveform and its reflections, is the waveform you are attempting to analyze, then you should perform time-domain transmission (TDT) measurements. TDT looks at the transmitted output of the incident TDR step on a second acquisition channel.

The following example demonstrates how easily and efficiently you can perform TDR and TDT measurements using an 11800 Series Digital Sampling Oscilloscope (with its differential TDR/TDT capabilities), the SD-24 TDR/Sampling Head, and a differential amplifier. Differential TDR measurements involve propagating two TDR steps of opposite polarity to the system under test.

In the past, differential measurement results were obtained by one of two methods: (1) using a single-ended TDR system, where you must subtract the two single-ended TDR signals to obtain differential results, or (2) using proprietary push-pull generators. The former method can only be used with balanced, linear systems; the latter method has not been available outside of Tektronix.

The SD-24 TDR/Sampling Head generates synchronized, differential TDR steps on two separate channels. The amplitude of these steps can be adjusted to adapt the SD-24 TDR/Sampling Head to a wide spectrum of applications. These individual TDR steps and the resulting reflections are displayed on the 11801A oscilloscope screen. And, the differential output can be displayed as the difference between the two corresponding TDT waveforms. This allows you to view the differential results along with the individual incident TDR signals.

Setup

The amplifier under test is a 10H116 high speed ECL line driver-receiver. This amplifier is driven differentially from the sampling head's channel 1 and channel 2 connectors. A separate sampling head provides the channel 3 and channel 4 connectors that acquire the output TDT waveform.

Setup and bias the amplifier as shown in Figure 1. It is beneficial (although not necessary) that the two input coaxial cables and the two output coaxial cables be equivalent in length.

Calculating the Differential Input Capacitance

After you have completed the connections in the preceding setup and power on the oscilloscope, you are ready to begin using some of the vast capabilities of the 11800 Series TDR/TDT measurement system. First, **Initialize** the oscilloscope from the UTILITY menu, and then press the WAVEFORM button. Touch **Sampling Head Fnc's** to view the **Sampling Head Functions** pop-up menu. You can control most of the oscilloscope's TDR and TDT functions from this menu. See Figure 2 for an illustration of the **Sampling Head Functions** pop-up menu.

To apply differential TDR steps to the amplifier's inputs, simply touch **Diff TDR Preset** in the **Sampling Head Functions** pop-up menu. This activates a positive-going step on the channel 1 connector and a negative-going step on the channel 2 connector. Set the oscilloscope's **Main Size** to 2 ns/div, and check that the two differential TDR steps are symmetrical to each other. If the two waveforms are not exactly symmetrical, then the two differential waveforms are slightly out-of-phase. Touch **TDR Head Δ Delay** in the **Sampling Head Functions** pop-up menu, and then adjust one of the control knobs to optimize the symmetry between the two TDR waveforms.

This calibration procedure ensures that the positive-going and negative-going steps arrive at the amplifier simultaneously. Figure 3 illustrates the two incident TDR waveforms.

The information contained in either of the incident TDR waveforms is sufficient to calculate the

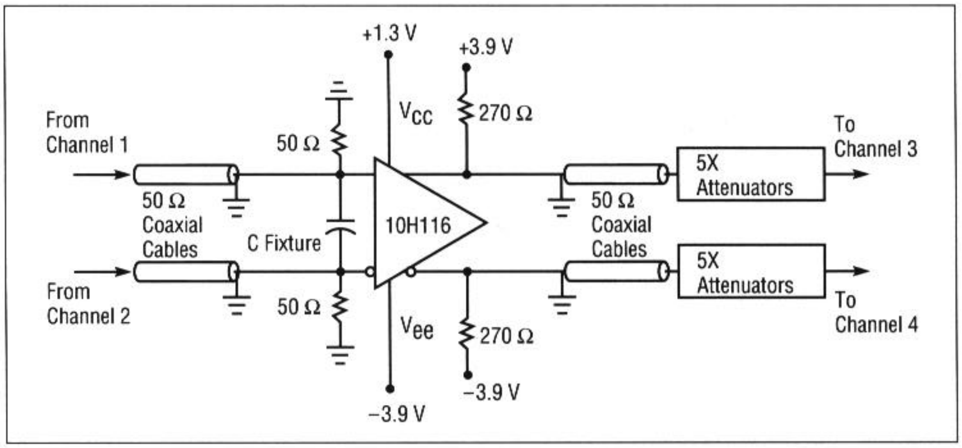


Figure 1. ECL Line Driver/Receiver Circuit Diagram.

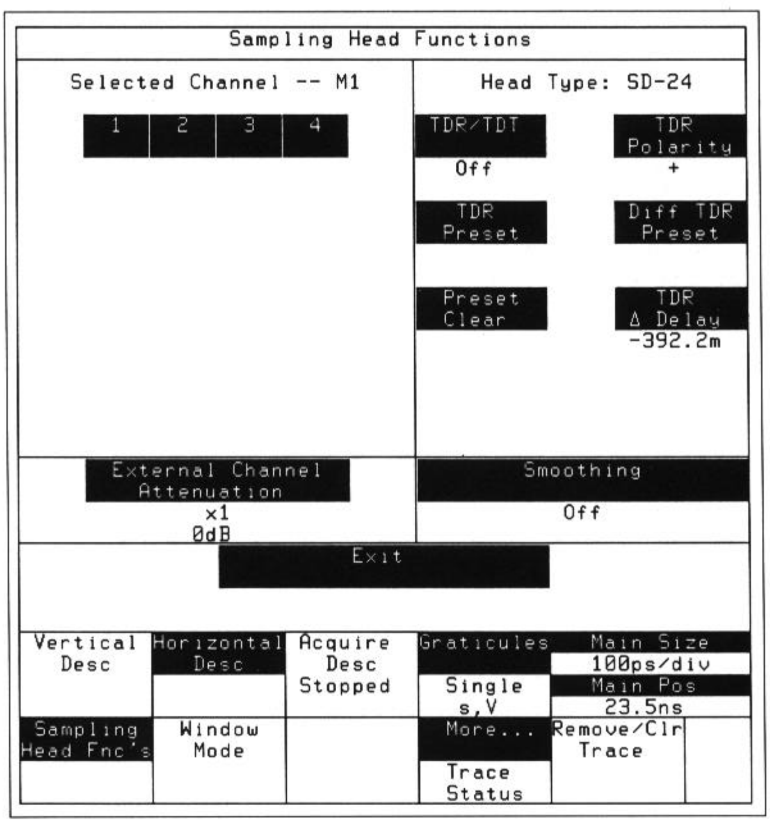


Figure 2. The 11801A oscilloscope's Sampling Head Functions pop-up menu.

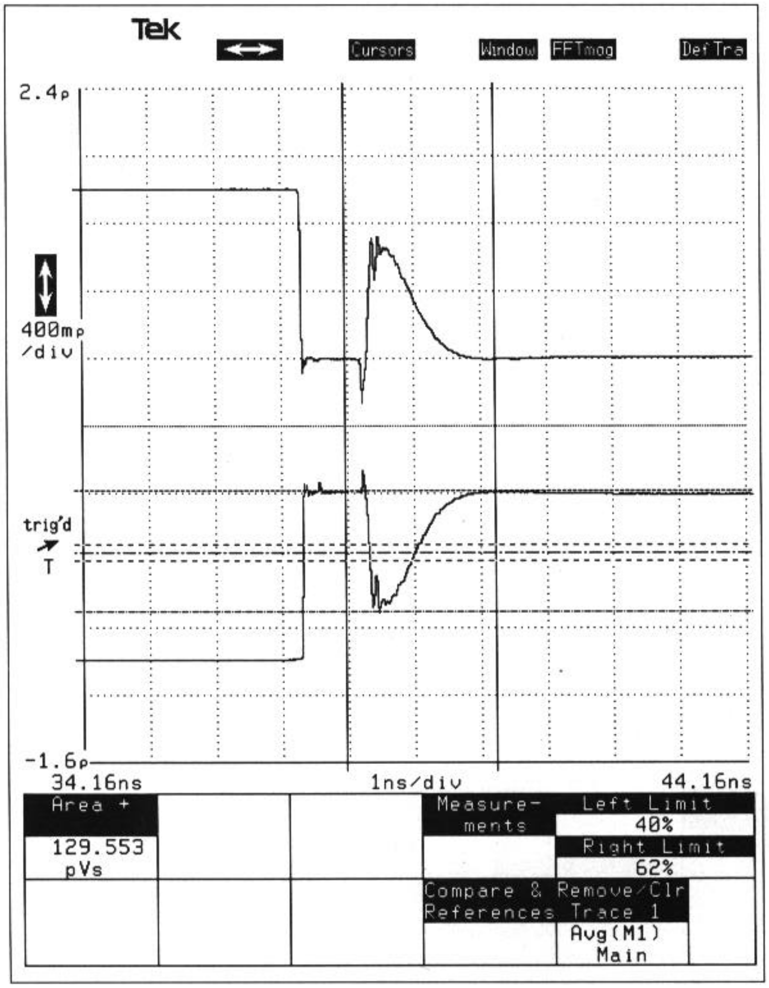


Figure 3. Differential TDR Steps Generated by the SD-24 TDR Sampling Head.

odd-mode input capacitance of the amplifier. The powerful measurement system of the 11801A instrument makes this very straightforward and accurate. For any shunt capacitance to ground in a single ended transmission line, the amount of capacitance is simply:

$$C_{sin} = 2 * A_{ref}/(Z_o * V_o)$$

where

A_{ref} = Area under reflected TDR signature attributed to capacitance (units will be in volt-seconds)

Z_o = Transmission line impedance

V_o = Incident TDR system amplitude

The line-to-line differential capacitance is then exactly half the odd-mode capacitance, due to the effective series connection of the single-ended odd-mode capacitances:

$$C_{dif} = C_{sin}/2 = A_{ref}/(Z_o * V_o)$$

To calculate this capacitance, use the Area+ measurement to determine the area of the reflected waveform from the input.

$$Z_o = 50\ \Omega$$

$$V_o = 250\ \text{mV}$$

The area under the reflected TDR signature in Figure 3 is:

$$A_{ref} = 1.295 * 10^{-10}\ \text{v-s}$$

This makes the differential input capacitance equal to:

$$C_{dif} = A_{ref}/(Z_o * V_o) =$$

$$(1.295 * 10^{-10}\ \text{v-s})/(50 * 0.25) = 10.4\ \text{pF}$$

Characterizing the Amplifier

In order to view the characteristics of a differential amplifier (in this case the line driver-receiver), the magnitude of the incident TDR steps must be set to enable linear operation of the amplifier. A 50 mV differential step will ensure that the amplifier is operating linearly. A 50 mV differential step requires that the channel 1 TDR step is +25 mV and the channel 2 TDR step is –25 mV. Since the SD-24 TDR/Sampling Head initially outputs 250 mV TDR steps, you must significantly reduce the amplitude of these signals.

To do this, put 10X pads and inside DC blocks on the TDR signals used to drive the amplifier. The DC blocks ensure a nominal zero level drive signal.

To view the total differential input step to the amplifier, that is, the mathematical difference between the individual TDR steps, it is necessary to view loop through input signals. The differential input signal amplitude is about 50 mV pp. Touch **Def Tra** at the top of the oscilloscope screen, and define the mathematical waveform **Avg(M1-M2)**. To minimize possibly having a cluttered and confusing display, remove the two individual TDR steps from the screen.

Touch Sampling Head Functions, External Channel Attenuation, 8.3X

To view the TDT output waveform of the amplifier, touch **Def Tra**, and define the mathematical waveform **Avg(M3-M4)**. This mathematical operation combines the two differential TDT outputs of the amplifier.

Figure 4 illustrates the differential TDR input that is applied to the amplifier and the resulting TDT output.

The Tektronix 11800 Series oscilloscopes coupled with the Tektronix SD-24 TDR/Sampling Head simplifies and accelerates the process of performing differential TDR and TDT measurements. With these instruments, you can view differential results directly on the display in a matter of seconds.

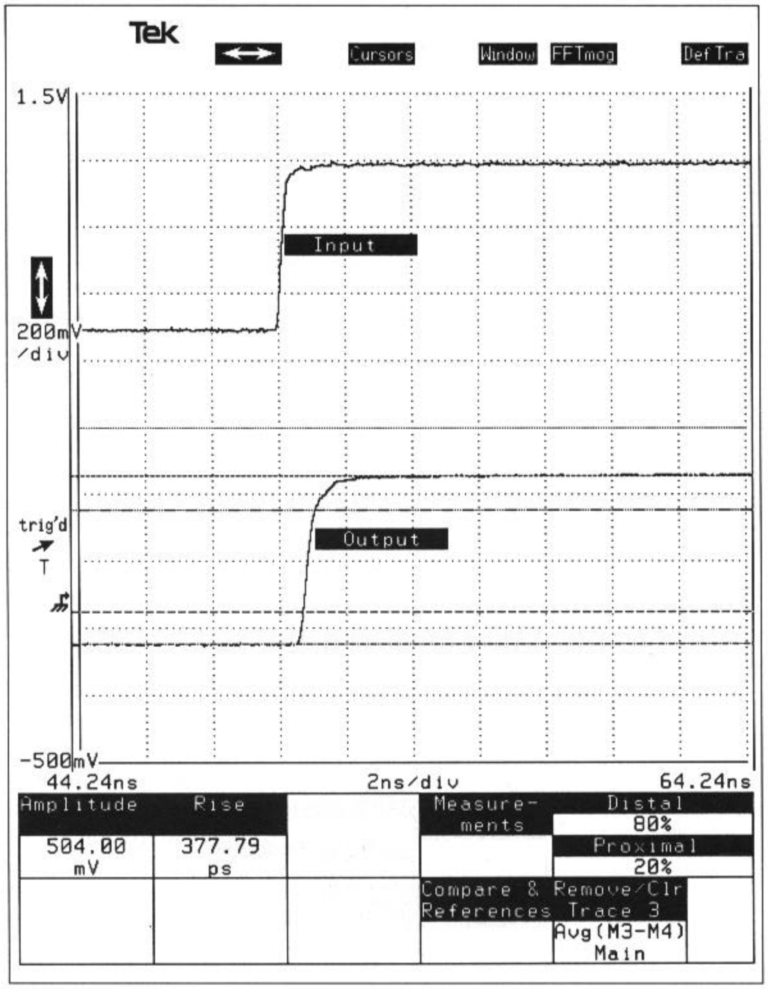


Figure 4. Differential TDR Input Waveform (top) and the TDT Output Waveform (bottom).

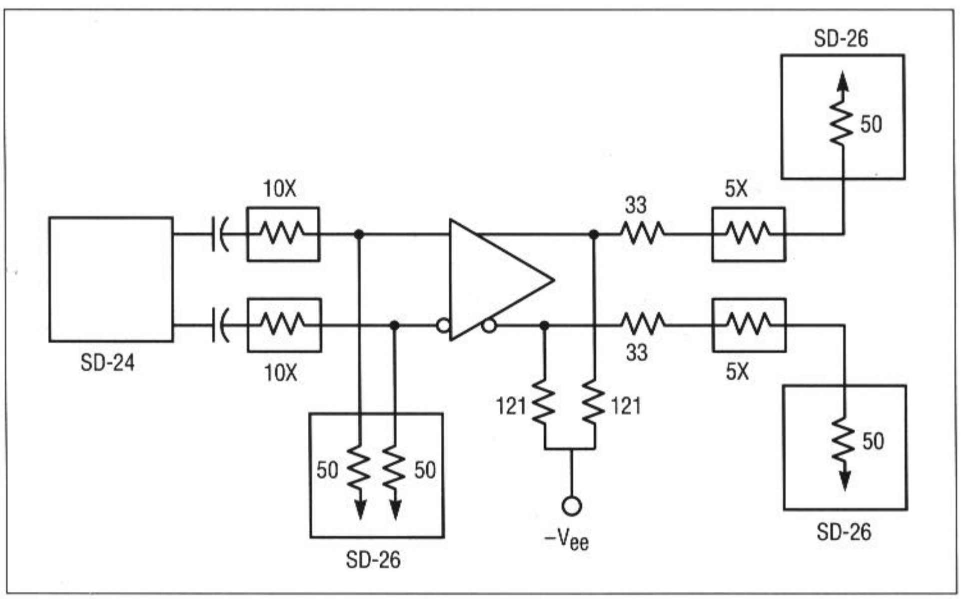


Figure 5. Test setup used for waveform in Figure 4.

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