DVT Solutions, LLC
Giga Probes

DVT40-1MM Advanced Failure and Impedance Analysis

True Differential and Single-Ended TDR Probe System

Utilizing TDR and Differential Probes to Locate Open/Shorts in Differential Traces

Prior to using a TDR's measurements to detect an open, short, or to determine if the trace has a 50- or 100-ohm matched impedance, individuals who are not familiar with TDR usage must comprehend how the TDR waveform signature is depicted on the TDR plot. These waveform signatures delineate the visual representation of how an open, short, and matched load manifest on the TDR plot.

The TDR instrument, in its default Time Domain measurement mode, is employed to identify open/short failures or impedance issues. It presents raw measurements without any waveform processing applied, displaying Voltage on the X-axis and Time on the Y-axis, as illustrated in Figure 1. If the voltage waveforms are converted an impedance (Zline) measurement scaling, then the Time Domain measurement for an open/short or impedance looks very different as shown in Figure 2. Prior to employing TDR for interconnect fault detection or impedance analysis, understanding this information will prove beneficial in accurately interpreting the TDR signature responses.

Figure 1

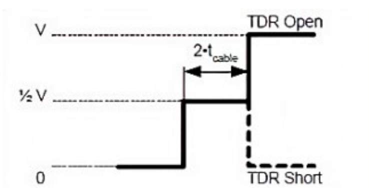
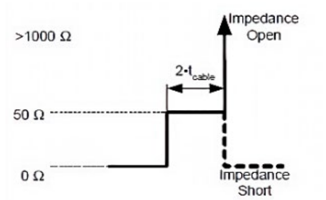
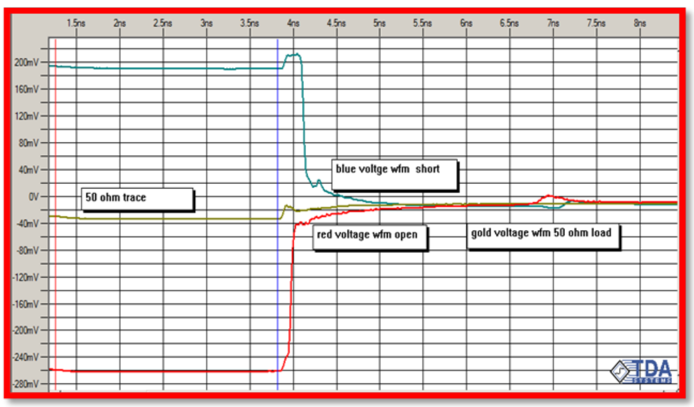
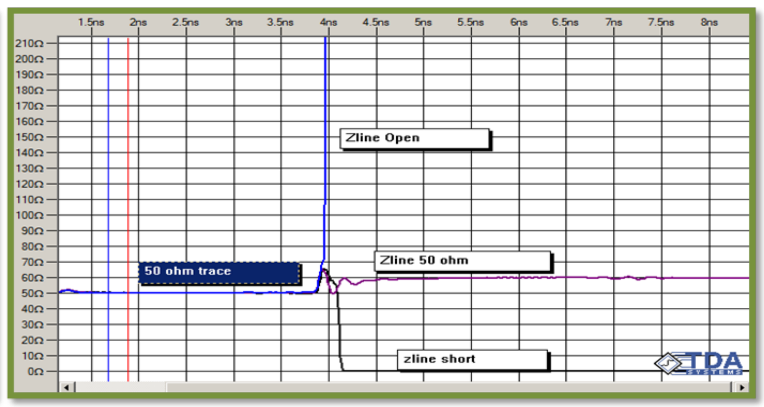


Figure 2







Unveiling the Internal Architecture of Differential Probes

Measurements without a Physical Ground Connection

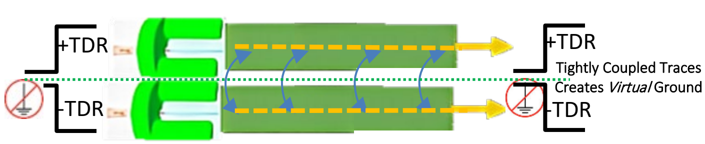


Figure 3
True Differential Probe Architecture Diagram

Figure 4
DVT40 Failure Analysis/Impedance/40 GHz S-parameters
Datasheet link

Understanding how open failures in differential traces can be found using a differential probe without a ground (Figure 4) involves examining the mechanism used to create the virtual ground. In this context, the +/- TDR pulses emitted by the instrument are deliberately set 180° out of phase. This intentional phase difference generates a virtual ground by using the difference between two TDR signals that are 180° apart. The virtual ground effectively manifests as the midpoint between these two signals, serving as a reference point for each signal pin as shown in Figure 3.

When employing the probe with an analog TDR, the out-of-phase nature of the differential TDR pulses plays a crucial role in generating a virtual ground. This occurs through the two tightly coupled signal conductors in the differential probe cable, establishing a reference point for the signals.
When using the probe with a Vector Network Analyzer (VNA), a differential probe model is developed by making open, short and in situ measurements to the bandwidth of the probe. The three measurements are used by Ataitec ISD software to create a probe de-embedding file that accounts for differential signal-signal crosstalk. The VNA utilizes this probe model to de-embed the probe from its measurement and sets the measurement reference to the probe tips. The probe model contributes to the establishment of a virtual ground reference for differential time domain measurements. This innovative approach allows for the identification of open failures in differential traces even in the absence of a physical ground connection.

Comparative TDR (Time Domain Reflectometry) Failure Analysis Method

Identifying Open/Short Failures in Single-Ended and Differential Traces

The Comparative TDR Failure Analysis method is an advanced technique designed to identify open or short failures in wide-pitch single-ended and differential traces on a Printed Circuit Board (PCB). Utilizing a Time Domain Reflectometry (TDR) probe and instrument. The process involves comparing TDR waveforms obtained from a faulty PCB trace with those acquired from a known, properly functioning PCB—referred to as the golden reference board. It is crucial that both boards share the same revision number for the process to be effective.

The primary objective is to pinpoint any deviations or anomalies in the TDR waveforms of the malfunctioning PCB trace when compared to the golden reference board. Notably, while this method has demonstrated success in locating failures in single-ended traces using a single-ended probe with a ground reference, a true differential probe is necessary for effectively identifying opens in differential traces due to the absence of a ground probe reference for the signal pins.

Over 90% of PCB designs feature differential traces without a ground reference. In such cases, the most effective tool for identifying open or short failures is a true differential probe, as illustrated in Figures 3 & 4. The illustration shows how a differential probe creates its own virtual ground. This allows the same comparison method used for single-ended traces to be applied for locating failures in differential traces. The following steps outline how to utilize a true differential probe to identify open or short trace failures in differential traces without a ground or in most two adjacent traces.

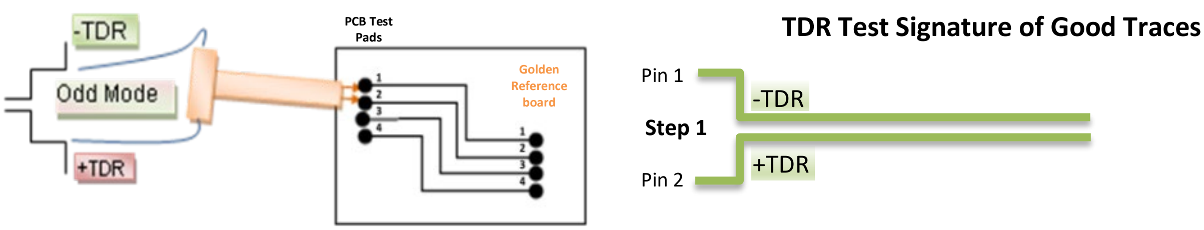
1. Waveform Comparison: Use the TDR probe to capture waveform responses from both the failing device board and the known golden reference board. This involves sending a TDR pulse signal into the traces and analyzing the reflected signals.
2. Golden Reference Board: The waveform obtained from the traces of the known good board serves as a reference or baseline, representing the expected behavior of properly functioning traces.
3. Failing Device Board and Anomaly Detection: Compare the waveform measurement from the malfunctioning device to the golden reference waveform measurements. Discrepancies or anomalies in the waveform indicate potential issues, such as open failures in the PCB traces.
4. Overcoming Hardware Limitation: The Comparative TDR method is valuable in overcoming hardware limitations. It offers a quick and straightforward approach for identifying the likely location of the failure without relying on detailed trace layout, circuit information, or specialized device expertise.
5. Challenges: One challenge with the Comparative TDR method is the difficulty in precisely differentiating the region of potential failure within the device. Factors such as the speed of the TDR rise time or multi-path reflection can limit the resolution of failure detection.

In summary, the Comparative TDR method, coupled with a TDR probe and a true differential probe like the DVT40, is a robust diagnostic technique for locating open/short failures in wide pitch PCB traces. This step-by-step process offers a comprehensive guide for efficiently identifying opens in differential traces without a ground reference, using an instrument with superior specifications for accurate and repeatable measurements.

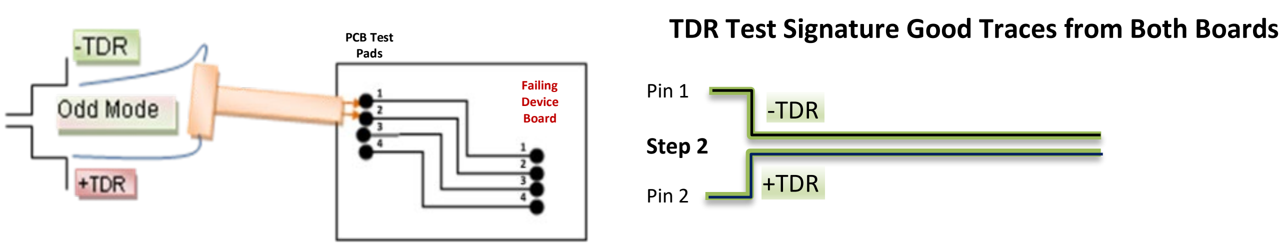
Utilizing Comparative Analysis for Open Trace Failure Identification
in Differential Traces Without Ground in PCBs

Below is a simple example that describes how we can use the comparative analysis TDR technique to locate an open failure in a differential trace by utilizing a differential probe's virtual ground coupling. The coupling or crosstalk will give us a ground reference to locate an open trace failure without the need for a physical ground. This is a step-by-step procedure that you can use to locate an open trace in a differential trace with the DVT40 probe.

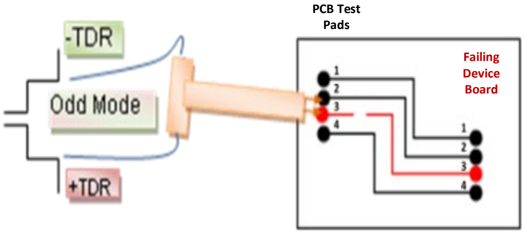
Step 1: On Golden Reference Board (GRB) - Measure and display individual Time Domain Reflectometry (TDR) pulses from Pin 1 with a -TDR pulse and Pin 2 with a +TDR pulse. Capture and store the TDR measurements on the instrument screen. This will establish a distinctive TDR signature for the two traces. Importantly, the traces under consideration need not conform to a differential controlled impedance set, enhancing the versatility of this technique for locating opens in both differential and non-coupled traces. By recording and storing the TDR signatures from the Golden Reference Board, a foundation is created for effective comparative analysis against measurements from the same pins on the Failure Device Board, which can facilitate the identification and diagnosis of potential open trace failures in subsequent measurements when compared to the established reference.



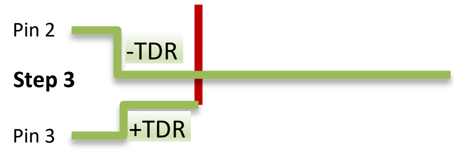
Step 2: On Failing Device Board (FDB) - Acquire data from the Failing Device Board by measuring the individual +TDR pulses from Pin 1 and the -TDR pulse from Pin 2. Subsequently, overlay all four measurements on the Time Domain Reflectometry (TDR) screen in a manner represented in the given configuration. It is important to ensure that all four traces overlay each other so that the resulting trace will blend into one trace, acknowledging the possibility of a slight horizontal time skew offset if associated probing data or memory I/O interfaces, which is deemed normal. If any of the four traces do not correlate, potential issues should be investigated, such as: (1) the two Printed Circuit Board (PCB) revisions are not the same or (2) the probes were misaligned in one set of test pads. Once correlation is achieved, this step confirms that Pin 1 and Pin 2 from both the failing device board and the Golden Reference Board (GRB) correlate appropriately, indicating that we can use the -TDR measurement going forward as a virtual ground reference for the +TDR pulse measurement.



Step 3: On Failing Device Board (FDB) - Place the -TDR probe on pin 2 and + TDR probe on pin 3. The TDR pulses will propagate down the two traces until the coupling or the Virtual ground between the two traces ends due to in this case an open in the trace 3. You could probe pins 3 and 4 and the open in pin 3 will still show an open as coupling goes both ways. To verify that you found the open trace, probe pin 2 and 3 on the Golden reference board and overlap the two traces. Pin 3 on the Failing Device Board will not corollate with pin 3 on the Golden Device Board. If you did not locate the open on pin 3 you could move the probe down the trace sets until a trace on the +TDR probe shows an anomaly that can be verified by the traces on the Golden Device Board.



TDR Test Signature of Open and Good Traces



Conclusion: By correlating the -TDR and +TDR measurements on both Pin 1 and Pin 2 from the Failing Device Board (FDB) and the Golden Reference Board (GRB). The successful correlation affirms that both boards share the same Printed Circuit Board (PCB) revision and that the probed -TDR traces on Pins 2 do not exhibit an open or short failures.

Subsequently, turn off the waveform display but not the TDR signal from the -TDR channel, focusing solely on the +TDR trace that will be associated with the trace suspected to have an open failure. This deliberate sequence of actions streamlines the diagnostic process, allowing for a clear and efficient examination of the targeted trace while ensuring the integrity of the measurements and the consistency between the boards' revisions.

Part numbers and datasheets for TDR True Differential and Single-Ended TDR Probe System

Part Number	Link to datasheet
VT40-1MM two probe kit	*View Datasheet*
DVT-FP250 probe positioner	*View Datasheet*
DVT-CS-1 Camera Positioner	*View Datasheet*
Optional PCB fixtures	
DVT-PHA01 Adjustable Test Fixture (requires 4 DVT-SM PCB Holders)	*View Datasheet*
DVT-SM Holder Test Fixtures (suggested 4-6)	*View Datasheet*

Please contact your sales representative or DVT Solutions if you have any questions or would like a quote for a DVT40-1MM Advanced Failure and Impedance Analysis probe system.