Solving Cable Faults Challenges with TI Ethernet PHYs

Anmol Ramraika, Geet Modi

ABSTRACT

This application report outlines how Time Domain Reflectometry helps solve various kinds of cable fault challenges of Ethernet-based communication systems. The application report describes how to use the TDR feature of the DP8325I to implement the cable diagnostics feature in the system.

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Trademarks

1 Time Domain Reflectometry

1.1 TDR

TDR only works for twisted pair connections. TDR involves sending a pulse on TX and RX pair and observing results on either pair. By measuring voltage amplitude, polarity, and the time interval, the PHY can determine the nature and position of the fault. The DP83825I TDR generator sends pulse on the TX and RX channel, then monitors both channels to observe reflections. It sends a pulse one channel at a time, and if reflections are observed on the other channel, then the PHY TDR realizes that the wires have been crossed. The DP83825I can detect one peak for each transmit and receive channel. TDR can be used for the following:

- Cable open
- Cable short
- TX/RX pair cross-wired
- Impedance discontinuity

TDR can only be used when the link is down.

1.2 Example Connections

The following sections are example connections where TDR can be used.

1.2.1 Open Circuit Cable

Open cable is easy to diagnose since it generates a strong reflection. No reflection is observed on the other channel. The reflection due to the open circuit is in-phase with the transmitted pulse (positive polarity). Any kind of inductive impedance discontinuity generates in-phase reflection and the amplitude depends on the amount of impedance discontinuity.

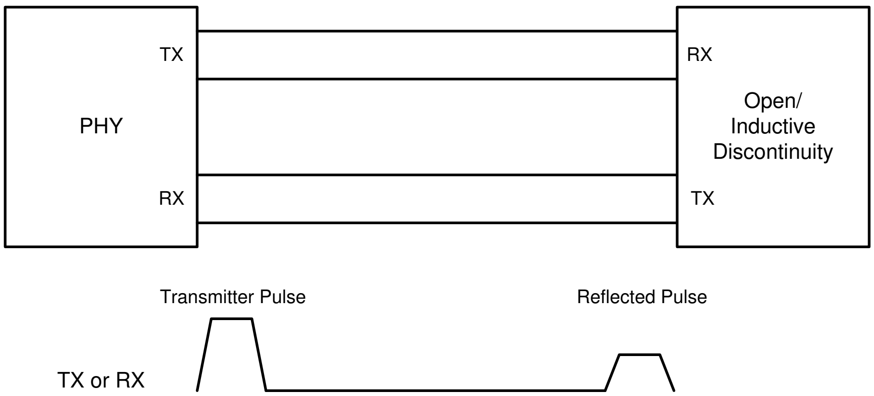

Figure 1. Open Circuit Cable

1.2.2 Short Circuit Cable

Short-circuited cables also generate a strong reflection, but this reflection is out-of-phase with the original pulse (negative polarity). Any kind of capacitive impedance discontinuity generates out-of-phase reflection. The amplitude depends on the amount of impedance discontinuity.

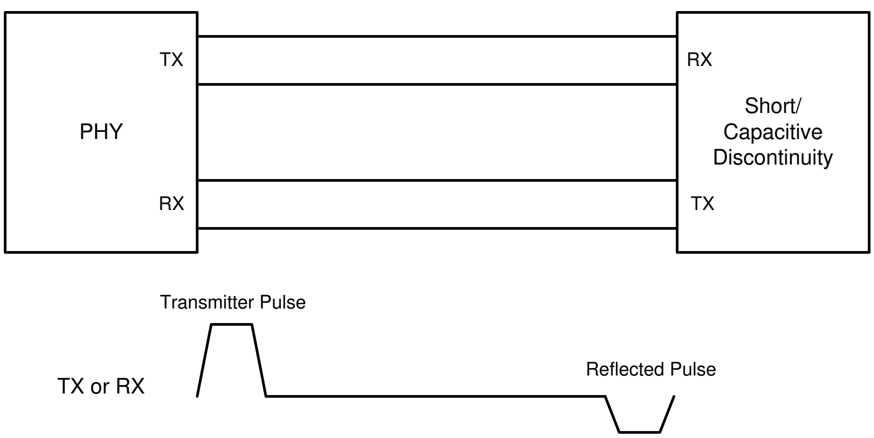

Figure 2. Short Circuit Cable

1.2.3 Cross-Wired Cable

Due to incorrect cable or connector assembly, a single wire from TX or RX differential pair is routed to the opposite channel. This results in an unexpected return pulse on the channel not being tested. For example, if the transmit channel is being tested in a cross-wired cable, then an unexpected return pulse is observed on the receive channel. To check for this, the PHY observes both the channels even if it sends a pulse on one channel at a time. In addition, to return pulse on the other channel, there can be a return pulse on the channel under test.

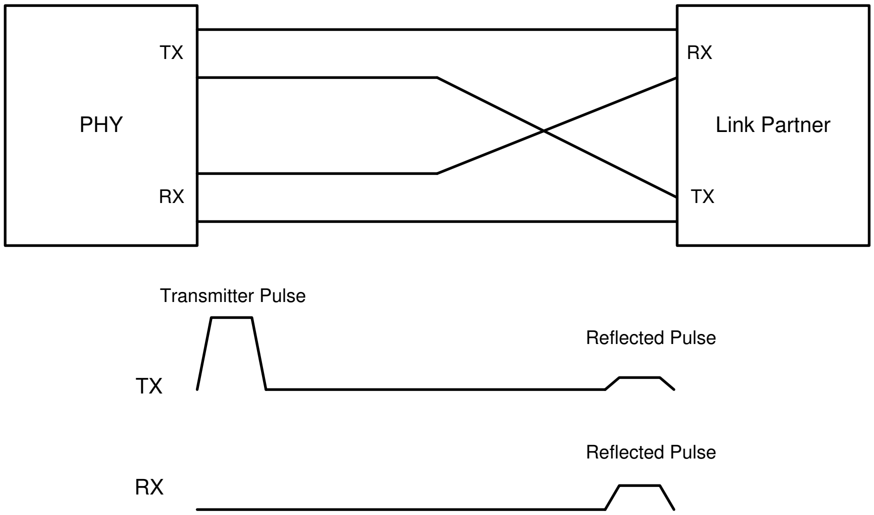

Figure 3. Cross-Wired Cable

2 DP83825I TDR Configuration

The DP83825I can support 150 meter and above cable reach. Long cable reach causes the transmitted signal to face higher attenuation with cable length, so the gain and other settings need to be tweaked with cable length to achieve reliable fault detection using TDR. The cable is assumed to be divided into the following five segments:

- Segment 1: 0 m to 10 m
- Segment 2: 10 m to 20 m
- Segment 3: 20 m to 40 m
- Segment 4: 40 m to 80 m
- Segment 5: 80 m to 190 m

Based on the length of cable in the use case, TDR can be run for relevant cable segments.

Each cable segment can have four combinations of transmit and receive since it can have two channels, meaning four iterations of TDR for each segment. For each such iteration of TDR, location, amplitude, and sign of peak (if reported) must be stored until all cable segments are covered.

For each segment, software configures the PHY with register settings given in the following table. The TDR process for that segment must be started by writing Register 0x001E bit 15.

REGISTER	SEGMENT 1	SEGMENT 2	SEGMENT 3	SEGMENT 4	SEGMENT 5
0x456[10:9]	0x3	0x3	0x3	0x3	0x3
0x411[4:0]	0x13	0x13	0x15	0x16	0x16
0x416[7:4]	0xA	0xA	0xA	0xA	0x9
0x190[12:0]	0x1C12	0x1C22	0x1E32	0x1E42	0x1E52
0x173	0x0D07	0x0D14	0x0D14	0x343B	0x8F6F
0x175	0x1004	0x1004	0x1004	0x1008	0x100B
0x178[2:0]	0x2	0x2	0x2	0x2	0x6

For every segment, four combinations of transmit and receive can be configured by the following:

- Transmit on A, Receive on A: 0x170[14:13] = 2’b10
- Transmit on A, Receive on B: 0x170[14:13] = 2’b00
- Transmit on B, Receive on A: 0x170[14:13] = 2’b01
- Transmit on B, Receive on B: 0x170[14:13] = 2’b11

3 Fault Location and Type

For each iteration, software needs to wait until Register 0x001E Bit 1 is set, indicating TDR is completed.

If TDR Register 0x001E Bit 0 is set, it means this iteration of TDR has failed if there is noise on the line, the link already being established, and so forth.

If this bit is not set, TDR is successfully completed. If Register 0x0185 Bit [6:0] shows a non-zero value, it means a peak was reported for this TDR iteration. Once a peak is reported, software can store peak location (0x0180[7:0]) and peak sign (0x018A[11]).

Similarly, this process has to be repeated for four transmit/receive channel combinations and for all cable segments.

If TDR is run for all cable segments, software may have to store information of maximum 20 peaks.

If no peaks are reported across all iterations, no fault has been reported by the TDR mechanism. If at least one peak is reported, the cable has fault and software discards all peaks reported in higher cable segments. Use the following table to identify the fault type using peak information from the peak observed in lowest cable segment.

FAULT TYPE	Tx = A, Rx = A		TX = A, Rx = B		TX = B, Rx = A		Tx = B, Rx = B	
	PEAK	SIGN	PEAK	SIGN	PEAK	SIGN	PEAK	SIGN
Both open	Yes	1'b0	No	-	No	-	Yes	1'b0
Both short to VDD/GND/Between P–N	Yes	1'b1	No	-	No	-	Yes	1'b1
Cross Short	Yes	1'b0	Yes	1'b1	Yes	1'b1	Yes	1'b1

The location of this fault can be calculated by using the peak location value from Register 0x180[7:0] for the first encountered peak using following:

1. Convert 0x180[7:0] to decimal value (DV).
2. Round off (DV-7) / 1.3 to the nearest integer and call it PL.

PL is location of peak in meters.

4 Summary

This application report explains the basics of TDR and how to use the TDR functionality of the DP83825I Industrial Ethernet PHY.

5 References

• Texas Instruments, *DP83825I Low Power 10/100 Mbps Ethernet Physical Layer Transceiver Data Sheet*

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (November 2019) to A Revision	Page
• Edited application report for clarity	1
• Fixed the formatting of table 1 and table 2	1

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