100BASE-TX Ethernet Cable Test

Test Solution Overview

Using the E5071C ENA Option TDR

Last Update: 2015/04/08 (YS)
Reference Documents

Specifications

IEEE Std 802.3™-2008
Fiber Distributed Interface
-Token Ring Twisted Pair
Physical Layer Medium Dependent

Test Procedure

Test Suite for Ethernet
University of New Hampshire
InterOperability Laboratory (UNH-IOL)
Ethernet Logo Certification Program

<table>
<thead>
<tr>
<th>Standard</th>
<th>Standard Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB-IF</td>
<td>USB-IF</td>
</tr>
<tr>
<td>PCI-SIG</td>
<td>PCI-SIG</td>
</tr>
<tr>
<td>SATA-IO</td>
<td>SATA-IO</td>
</tr>
<tr>
<td>Ethernet</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Logo certification program is not available for Ethernet (100BASE-TX / 1000BASE-T).

- PHY tests performed in accordance to test procedure issued by University of New Hampshire InterOperability Laboratory (UNH-IOL).
- Self-compliance
Keysight Digital Standards Program

• Our solutions are driven and supported by Keysight experts involved in international standards committees:
  • Joint Electronic Devices Engineering Council (JEDEC)
  • PCI Special Interest Group (PCI-SIG®)
  • Video Electronics Standards Association (VESA)
  • Serial ATA International Organization (SATA-IO)
  • USB-Implementers Forum (USB-IF)
  • Mobile Industry Processor Interface (MIPI) Alliance
  • And many others…

• We’re active in standards meetings, workshops, plugfests, and seminars.
• We get involved so you benefit with the right solutions when you need them.
### Ethernet Data Rate and Distance

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Distance</th>
<th>Media</th>
<th>Method</th>
<th>Encoding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mbps</td>
<td>100m</td>
<td>Twisted pair</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>10 Mbps</td>
<td>100m</td>
<td>1550nm optical</td>
<td>2 pair parallel</td>
<td>4B5B, 8B10B</td>
</tr>
<tr>
<td>100 Mbps</td>
<td>100m</td>
<td>1310nm optical</td>
<td>4 pair parallel</td>
<td>64B6B</td>
</tr>
<tr>
<td>1 Gbps</td>
<td>100m</td>
<td>850nm optical</td>
<td>4 pair parallel</td>
<td>SONET</td>
</tr>
<tr>
<td>1000 Mbps</td>
<td>1 km</td>
<td>Cat5e</td>
<td>4 pair parallel</td>
<td>SONET</td>
</tr>
<tr>
<td>10 Gbps</td>
<td>1 km</td>
<td>shielded cable</td>
<td>4 pair parallel</td>
<td>SONET</td>
</tr>
<tr>
<td>10km</td>
<td>1 km</td>
<td>195m (max) coaxial</td>
<td>4 pair parallel</td>
<td>SONET</td>
</tr>
<tr>
<td>100km</td>
<td>1 km</td>
<td>500m (max) coaxial</td>
<td>4 pair parallel</td>
<td>SONET</td>
</tr>
<tr>
<td>1000BASE-LX</td>
<td>5 km</td>
<td>3600m (max) coaxial</td>
<td>4 pair parallel</td>
<td>SONET</td>
</tr>
</tbody>
</table>

**10BASE-T**: 100m, Cat5

**100BASE-TX**: 100m, Cat5, Fast Ethernet

**1000BASE-T**: 100m, Cat5e, Gigabit Ethernet

**10G BASE-T**: 100m, Cat6a

**10G BASE-KR**: 1m, Backplane

**10G BASE-SR**: 300m, MMF

**10G BASE-LR**: 10 km, SMF

**10G BASE-ER**: 40 km, SMF

**10G BASE-ER**: 40 km, SMF

**1000BASE-LX**: 5 km, SMF

**1000BASE-SX**: 550m, MMF

**10G BASE-ER**: 40 km, SMF

**10G BASE-ER**: 40 km, SMF

**10G BASE-ER**: 40 km, SMF

**10G BASE-ER**: 40 km, SMF
100BASE-TX Ethernet Overview

- **Data rate:** 100 Mbps
- **Tx** and **Rx** are independent and use 1 twisted pair each. The remaining 2 pairs are not used.
- **4B5B** MAC frame encoding… convert 4 bit pattern into 5 bit pattern to limit length of consecutive 1s, or 0s to within 4 bits (x1.25)
- **MLT-3** (Multi Level Transmission - 3) modulation used to reduce the signal frequency… No change for a “0”, change level sequentially for a “1”
- **Highest frequency component** is 31.25MHz. **Cat 5** (max 100MHz) cable or better is required.
100BASE-TX Ethernet Cable Test

Measurement Parameters

<table>
<thead>
<tr>
<th>Specification</th>
<th>Test Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Std 802.3™-2008</td>
<td>[25.4.7.2.1] Insertion loss</td>
</tr>
<tr>
<td></td>
<td>[25.4.7.2.2] Differential characteristic impedance</td>
</tr>
<tr>
<td></td>
<td>[25.4.7.2.3] Return loss</td>
</tr>
<tr>
<td></td>
<td>[25.4.7.2.4] Differential near-end crosstalk (NEXT)</td>
</tr>
</tbody>
</table>
100BASE-TX Ethernet Cable Test Solution

Requirements for both time and frequency domain measurements

**Frequency Domain**
- Insertion Loss (Sdd21)
- Return Loss (Sdd11)
- Crosstalk (NEXT)

**Time Domain**
- Characteristic Impedance (TDR)

**Traditional Solution**
- Vector Network Analyzer (VNA)
- TDR Scope

**New Solution**
- ALL parameters can be measured with ENA Option TDR
  - One-box solution

**100BASE-TX CabCon**
Test Solution Overview
100BASE-TX Ethernet Cable Test Solution

Typical Configuration

- **ENA Mainframe**
  - E5071C-440/445: 4-port, 9 kHz/100 kHz to 4.5 GHz
  - E5071C-460/465: 4-port, 9 kHz/100 kHz to 6.5 GHz
  - E5071C-480/485: 4-port, 9 kHz/100 kHz to 8.5 GHz
  - E5071C-4D5: 4-port, 300 kHz to 14 GHz
  - E5071C-4K5: 4-port, 300 kHz to 20 GHz
- **Enhanced Time Domain Analysis Option (E5071C-TDR)**
- **ECal Module (N4431B/N4433A)**

(*) The list above includes the major equipment required. Please contact our sales representative for configuration details.

- **Method of Implementation (MOI) document and instrument setup files available for free download on Keysight.com**

Test Fixtures

**Keysight P/N: N5392-66402 (2/ea)**

Test Fixture for Ethernet Application.
100BASE-TX Ethernet Cable Test
Measurement Parameters
IEEE Standard 802.3™-2008

25.4.7.2.1 Insertion Loss

- Frequency response of the differential signal that propagates through the cable.
- Direct measure of the signal reaching the receiver.
- Provides a measure for the highest useable bandwidth.
IEEE Standard 802.3™-2008
25.4.7.2.2 Differential characteristic impedance

• Noise is generated at the receiver due to impedance mismatch and multiple reflections. The impedance profile provides an indication of the multiple reflection noise.
• Most commonly measured parameter, but is an indirect measure of the signal reaching the receiver.

The nominal differential characteristic impedance of each link segment, which includes cable cords and connecting hardware, is 100 Ω for all frequencies between 1 MHz and 100 MHz.
25.4.7.2.3 Return loss

- Ratio of reflected voltage to incident voltage. Key parameter when evaluating impedance mismatch.
- When impedance match is poor, transmission signal quality is degraded due to multiple-reflection effects, leading to increase in bit error rate.
IEEE Standard 802.3™-2008
25.4.7.2.4 Differential near-end crosstalk (NEXT)

• Measure of the coupling between the differential pairs.
### ENA Option TDR Certified Method of Implementation (MOI)
Available for free download at [www.keysight.com/find/ena-tdr_compliance](http://www.keysight.com/find/ena-tdr_compliance)

<table>
<thead>
<tr>
<th><strong>Cable / Connector</strong></th>
<th><strong>Tx/Rx Impedance (Hot TDR)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• USB</td>
<td>• HDMI</td>
</tr>
<tr>
<td>• HDMI</td>
<td>• SATA</td>
</tr>
<tr>
<td>• SATA</td>
<td>• MIPI</td>
</tr>
<tr>
<td>• DisplayPort</td>
<td>• 10GBASE-KR/40GBASE-KR</td>
</tr>
<tr>
<td>• 100BASE-TX</td>
<td>• MHL</td>
</tr>
<tr>
<td>• 10GBASE-T</td>
<td>• Thunderbolt</td>
</tr>
<tr>
<td>• 10GBASE-KR/40GBASE-KR</td>
<td>• SD Card (UHS-II)</td>
</tr>
<tr>
<td>• MHL</td>
<td>• Cfast</td>
</tr>
<tr>
<td>• PCIe</td>
<td></td>
</tr>
<tr>
<td>• BroadR-Reach</td>
<td></td>
</tr>
</tbody>
</table>
Certified Test Centers using ENA Option TDR

ENA Option TDR is used world wide by certified test centers of USB, HDMI, DisplayPort, MHL, Thunderbolt and SATA.
100BASE-TX Ethernet Cable Test Solution

Summary

ENA Option TDR Cable Test Solution

• **One-box solution** which provides complete characterization of high speed digital interconnects (time domain, frequency domain, eye diagram)

• Similar look-and-feel to traditional TDR scopes, providing **simple and intuitive operation** even for users unfamiliar to VNAs and S-parameters

• Adopted by test labs worldwide
What is ENA Option TDR?

The ENA Option TDR is an application software embedded on the ENA, which provides an one-box solution for high speed serial interconnect analysis.

3 Breakthroughs
for Signal Integrity Design and Verification

- Simple and Intuitive Operation
- Fast and Accurate Measurements
- High ESD Robustness
What is ENA Option TDR?

[Video] Changing the world of Time Domain Reflectometry (TDR) Measurements

https://www.youtube.com/watch?v=uBHXkzk4lzk
Additional Resources

ENA Option TDR Reference Material  www.keysight.com/find/ena-tdr
• Technical Overview (5990-5237EN)
• Application Notes
  • Correlation between TDR oscilloscope and VNA generated time domain waveform (5990-5238EN)
  • Comparison of Measurement Performance between Vector Network Analyzer and TDR Oscilloscope (5990-5446EN)
  • Effective Hot TDR Measurements of Active Devices Using ENA Option TDR (5990-9676EN)
  • Measurement Uncertainty of VNA Based TDR/TDT Measurement (5990-8406EN)
  • Accuracy Verification of Agilent’s ENA Option TDR Time Domain Measurement using a NIST Traceable Standard (5990-5728EN)

Method of Implementation (MOI) for High Speed Digital Standards  www.keysight.com/find/ena-tdr_compliance