Ethernet SFF-8431 SFP+ SFF-8635 QSFP+ Compliance and Debug Testing

Tektronix Innovation Forum
Leading Solutions for Today, Tomorrow and Beyond
Agenda

- QSFP+ SFP+
  - Technology Overview
  - Testing challenges
    - Performing TWDPe Measurements

- Solution for Debug & Compliance Testing
  - SFP-TX – Automation
  - SFP-WDP – TWDPe Measurements

- SFP+/QSFP+ Fixture
  - Overview of HCB and MCB fixtures

- Features and Benefits
QSFP+ SFP+ Technology and Related Testing Challenges
10Gigabit Ethernet Interface Evolution

**MSA Form Factors**
- XENPAK Transceiver
- X2 Transceiver
- XFP Transceiver
- SFP+ Transceiver
- SFP+ direct attach
- QSFP

**10GBE Standards**
- IEEE 802.3ae SR/LR/ER/LX4
- IEEE 802.3ak CX4
- IEEE 802.3an 10GBASE-T LRM
- IEEE 802.3aq SFF-8431 SFP+

**Timeline**
- 2002: IEEE 802.3ae SR/LR/ER/LX4
- 2004: IEEE 802.3ak CX4
- 2006: IEEE 802.3an 10GBASE-T LRM
- 2008: IEEE 802.3aq SFF-8431 SFP+
- 2010: Next Big Thing SFF-8431 SFP+, QSFP+

Source: Ethernet Alliance
SFF-8431 SFP+/SFF-8635 QSFP+ Technology overview

- SFP+ is a next-generation hot-pluggable, small footprint, serial-to-serial multi-rate optical transceiver for 8.5GbE to 11.1GbE Datacom and Storage Area Networks (SAN) applications.
- SFF-8635 QSFP+ 10 Gb/s 4X Pluggable Transceiver Solution (QSFP10)
- SFP+ technology moved the clock and data recovery units out of the module and onto the line card – Reducing size drastically
- As a result, the modules are smaller, consume less power, allow increased port density, and are less expensive compared to XFP.
- High density capable Up to 48 ports in a rack
- Low power per port - Host Port power < 1 W and Low Latency
SFP+ Test Challenges

- **Test Time**
  - 48 Port Devices
  - Multiple test points and repetition in setup

- **Debug vs. Compliance**
  - When and how to make the shift with port replication in the process
  - Difficult to detect low amplitude impact on eye pattern performance

- **Connectivity**
  - Smaller package with difficulty to access test points

- **Ambiguous Test Specification**
  - Primary instrument defined for eye pattern measurements is equivalent-time oscilloscope so redefinition needed for real-time oscilloscope

- **Test Pattern Setup**
  - PRBS31 pattern is treated as an arbitrary waveform
TWDPc Measurement Definitions

- **TWDPc**
  - **Transmitter Waveform Dispersion Penalty for Copper**
  - *Defined as a measure of the deterministic dispersion penalty due to a particular transmitter with reference to the emulated multi-mode fibers and a well-characterized receiver.*
  - The fiber optics concept has been extended to quantify channel performance of high speed copper links “10GSFP+Cu”
  - Critical for performance
  - Requires a special algorithm
  - ClariPhy has IP rights for this algorithm

- **Test Specification Requirements for TWDPc**
  - 7 measurement samples per unit interval
  - Causes worst-case 0.24 dB TWDPc over 30 measurements
SFP-TX Host Transmitter Measurements

- 15 Defined Measurements for Host Tx Compliance

<table>
<thead>
<tr>
<th>SL No.</th>
<th>Measurements</th>
<th>Signal Type Recommended</th>
<th>Limit</th>
<th>Min</th>
<th>Target</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Transmitter output electrical Specifications:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>Single Ended Output Voltage Range</td>
<td>PRBS31</td>
<td>-0.3</td>
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<td>4</td>
<td></td>
<td>V</td>
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<tr>
<td>2</td>
<td>Output AC Common Mode voltage (RMS)</td>
<td>PRBS31</td>
<td>15</td>
<td>mV(RMS)</td>
<td></td>
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<tr>
<td>Host Transmitter Jitter and Eye Mask specifications</td>
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<tr>
<td>3</td>
<td>Crosstalk source rise/fall time (20%-80%) (Tr, Tf)</td>
<td>8180</td>
<td>34</td>
<td>ps</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td>Crosstalk source amplitude (p-p differential)</td>
<td>8180</td>
<td>1000</td>
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<td>6</td>
<td>Total Jitter (p-p) (Tj)</td>
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<td>7</td>
<td>Data Dependent Jitter (p-p) (DDJ)</td>
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<td>Ul(p-p)</td>
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<td>8</td>
<td>Data Dependent Pulse Width Shrinkage (p-p) (DDPWS)</td>
<td>PRBS9</td>
<td>0.055</td>
<td>Ul(p-p)</td>
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<td>9</td>
<td>Uncorrelated Jitter (RMS) (UJ)</td>
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<td>10</td>
<td>Transmitter Qsq</td>
<td>8180</td>
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<tr>
<td>11</td>
<td>Eye mask hit ratio(Mask hit ratio of 5x10-5)</td>
<td>PRBS31</td>
<td>X1=0.12Ul, X2=0.33Ul, Y1=95mV, Y2=350mV</td>
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<td>Host Transmitter output specifications for Cu (SFP+ host supporting direct)</td>
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<td>Output AC Common Mode Voltage</td>
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<td>mV(RMS)</td>
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<td>15</td>
<td>Host Output TWDPc</td>
<td>PRBS9</td>
<td>10.7</td>
<td>dBe</td>
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SFP-TX Module Transmitter Measurements

- 10 Defined Measurements for Tx Module Compliance

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SFP-TX & SFP-WDP – SFP+/QSFP+
Automation and Debug Solution
SFP-TX – SFP+/QSFP+ Compliance and Debug Solution

- Automated Tests
  - One-button selection of critical Host & Module Tests reduces testing time

- Integrated Debugging
  - Popular DPOJET-based interface enables deeper debug of timing root cause analysis without moving to a different instrument/measurement setup

- Integrated support for TWDPc measurements
  - Rely on off-the-shelf products to perform this complex measurement rather than developing custom lab setup reducing testing time and complexity

- Documentation/Reporting
  - Real-time waveform capture and pre-recorded waveform support provides ability to share waveform details with other labs, vendors and customers across multiple locations
Operates on Tektronix DPO/DSA70000C/D Series Oscilloscopes

Automate setup & quickly generate reports

Meets Compliance needs of SFF-8431/SFF-8635

User defined mode supports PRBS7, PRBS11, PRBS15, PRBS20 & PRBS23 in addition to patterns supported in Compliance mode including PRBS9, PRBS31 and 8180.
Tektronix SFP-TX – Debug Part

- Operates on Tektronix DPO/DSA70000C/D Series Oscilloscopes
- DPOJET(DJA) Standard Specific Drop down menu item
- Meets Compliance needs of SFF-8431/SFF-8635
- Signal patterns supported include - 8180, PRBS9 & PRBS31
Tektronix SFP-WDP Option – TWDPC Measurement

- Operates on Tektronix DPO/DSA70000C/D Series Oscilloscopes
- Perform Transmitter Waveform Dispersion Penalty measurement with simple setup and test execution
- Ideal for high sample rate acquisition
  - 100GS/sec setting available on DPO/DSA70000C/D
Tektronix application supports multiple data rates including 9.95328 Gbps, 10.3125 Gbps, 10.51875 Gbps and 11.10 Gbps.
Tektronix SFP-TX Option – J2 & J9 Support

- SFP-TX allows users to enter BER value of in the range of BER $e^{-2}$ to $-18$, providing them the flexibility to calculate Total Jitter at various BER values.
- J2 & J9 measurements are part of other 10G standards like 40GBASE-CR4 and XLPPI.
Reporting and Documentation

- Summary-reporting capability in .mht (HTML) format with pass/fail status
- Detailed report includes
  - Measurement results:
    - Test configuration details, waveform plots, and margin analysis
  - Test Setup details:
    - Calibration status, oscilloscope model, probe model, software version, date, execution time etc.
- Flexible report configuration provides options like auto increment, appending etc.
QSFP+ SFP+ Fixture
Connectivity for SFP+/QSFP+

- Connectivity Challenges:
  - Fixture required in SFF-8431/SFF-8635 spec is difficult to source
  - Low amplitude signaling so DC offset must be carefully removed
  - Fixture/DUT connections can be difficult to lock/unlock

- Tektronix family of SFP+/QSFP+ Fixtures

<table>
<thead>
<tr>
<th>Transmitter Test Recommended Accessories – Probes &amp; Fixtures</th>
</tr>
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<tbody>
<tr>
<td>Probing</td>
</tr>
<tr>
<td>SMA Cables</td>
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<tr>
<td>Fixturing</td>
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<tr>
<td>TF-SFP-TPA-HCB-P</td>
</tr>
<tr>
<td>TF-SFP-TPA-MCB-R</td>
</tr>
<tr>
<td>TF-SFP-TPA-PR</td>
</tr>
<tr>
<td>TF-SFP-TPA-HCB-PK</td>
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<tr>
<td>TF-SFP-TPA-MCB-RK</td>
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<tr>
<td>TF-SFP-TPA-PRK</td>
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<tr>
<td>TF-QSFP-TPA-HCB-P</td>
</tr>
<tr>
<td>TF-QSFP-TPA-MCB-R</td>
</tr>
<tr>
<td>TF-QSFP-TPA-PR</td>
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<tr>
<td>TF-DC-BLOCK-KIT</td>
</tr>
</tbody>
</table>
Two variants of the fixture board are available:

- SFP+ HCB Plug Kit with DC Blocks & Termination
- SFP+ HCB Plug Kit without DC Blocks & Termination
Test Fixture – SFP+ Module Compliance Board (MCB)

- Two variants of the MCB fixture board are available
  - SFP+ MCB Kit with DC Blocks & Termination
  - SFP+ MCB Kit without DC Blocks & Termination.
Test Fixture – QSFP+ Host Compliance Board (HCB)

- QSFP+ HCB Test Adapter
- DC Block Kit (Quantity 4) – Available as separate part number
Figure 2. The QSFP+ MCB Test Adapter tests to the requirements of the Module Compliance Board (Receptacle)

(Note: Coaxial cables shown are illustrated shorter than those used in the test adapter.)
Mapping Technology to Oscilloscope Bandwidth Requirements

- SFF-8431/SFF-8635 SFP+ provides 10.3125 Gb/second connections with the minimum rise time requirement of 34 psec
- DPO/DSA/MSO71604C/D 16GHz Oscilloscope (24.5 psec Rt)
- DPO/DSA/MSO72004C/D 20GHz Oscilloscope (18psec Rt)
  - >16GHz Oscilloscope will meet rise time requirements of SFF-8431/SFF-8635 SFP+ signal
- Option SFP-WDP requires 100GS/sec Sample Rate

<table>
<thead>
<tr>
<th>Oscilloscope</th>
<th>Software</th>
<th>Fixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPO/DSA/MSO16-33 GHz scope*</td>
<td>SFP-TX, SFP-WDP &amp; DJA</td>
<td>HCB and MCB</td>
</tr>
</tbody>
</table>

*SFP-WDP requires "C" & "D" series scopes with BW greater than equal to 16GHz
## Tektronix SFP-TX/QSFP+ - Features & Benefits

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developed on Platform of choice for Debug and Compliance</td>
<td>Tektronix SFP+ QSFP+ Tx is developed on a Real Time Oscilloscope platform, which is the platform of choice for engineers working on designing their products around SFF-8431 &amp; SFF-8635 technology.</td>
</tr>
<tr>
<td>Seamless movement from Compliance to Debug Environment</td>
<td>Customers can seamlessly move from compliance to debug environment and use world-class debug tool from Tektronix i.e. DPOJET.</td>
</tr>
<tr>
<td>Integrated TWDPc measurement</td>
<td>SFF-8431 SFP+ TWDPc based Matlab code has been integrated into SFP-WDP option to make sure Engineers can use this measurement in the automated setup</td>
</tr>
<tr>
<td>Reduces Testing Time</td>
<td>Tektronix Automated QSFP+/SFP+ Compliance and Debug solution meets compliance needs of SFF-8431 &amp; SFF-8635 specifications. Users can save up to 80% on testing time as compared to manual testing.</td>
</tr>
<tr>
<td>“One Stop Shop” - Test Fixture Availability</td>
<td>Engineers working on QSFP+/SFP+ can turn to Tektronix for their complete PHY testing solution needs including fixtures and don’t have to design their own fixtures</td>
</tr>
<tr>
<td>MOI and Debug Feature</td>
<td>DPOJET setup files for N1N0, PRBS11 and PRBS31 patterns are provided with the SFP-TX which help set scope and load measurements in DPOJET. This helps reduce debug time and set the scope for debug environment.</td>
</tr>
</tbody>
</table>
SFP-TX Demonstration
Host Transmitter Test Setup

SFP+ Setup Configuration Diagram
Tektronix Ethernet Solution – Information

- Tektronix has strong portfolio of products and solution in Ethernet Space – RT Scope, Sampling scope, BERTScope and Optametra products
- TDSET3 – Available since 2003 with, ET3 is widely used solution across industry
- XGbT – 10GBASE-T Compliance solution is the only “One Box” solution available in the market
- SFP-TX & SFP-WDP provides comprehensive solution for SFP+ & QSFP+, Tektronix is first to market
- 10GBASE-KR - 802.3ap™-2007 – We now have a Compliance, Debug and Decode Solution
- FC-16G – Fiber Channel 16G Compliance and Debug solution available on RT Scopes
- 802.3az – Energy Efficient Ethernet – Tektronix was the first T&M company to develop a solution in this space
- 10GBASE-KR and SFP+ RX MOI are available on BERT Scope
Backup
Advantages of SFP+

- SFP+ has encapsulation more compact shape dimension which better than the X2 and XFP (the same size as SFP)
- The production cost is lower than XFP, X2, XENPAK.
- The different between SFP+ and SFP
  - SFP and SFP+ have the same appearance and same size
  - SFP protocol specification: IEEE802.3, SFF-8472
- The different between SFP+ and XFP
  - The SFP+ and XFP are both 10G optical modules, and can connect other types of 10G modules
  - SFP+ is smaller than XFP
  - Because of the smaller volume, SFP+ transfer signal modulation function, serial / deserializer, the MAC, clock and data recovery (CDR) and electronic dispersion from module to the card