Opto Working Group - Mini Workshop

21.3.2014

VTRx and VTTx pre-production status and plans

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Introduction

- VTRx/VTTx project has *almost* reached the production phase
- Easy-to-use test tools are required
- Not only to measure but also to
  - qualify devices
  - store data
  - analyse data
  - read out later on

<table>
<thead>
<tr>
<th></th>
<th>VTRx SM</th>
<th>VTRx MM</th>
<th>VTTx MM</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHCb</td>
<td>2900</td>
<td>7000</td>
<td></td>
</tr>
<tr>
<td>CMS</td>
<td>200</td>
<td>400</td>
<td>2000</td>
</tr>
<tr>
<td>ATLAS</td>
<td></td>
<td>800</td>
<td>600</td>
</tr>
<tr>
<td>ALICE</td>
<td>3550</td>
<td>3200</td>
<td></td>
</tr>
<tr>
<td>BE-BI</td>
<td>1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>1200+</strong></td>
<td><strong>7650+</strong></td>
<td><strong>12800+</strong></td>
</tr>
</tbody>
</table>
Production Tests

• During earlier phases of the Versatile Link project extensive prototyping and environmental testing has been carried out (radiation, magnetic field, temperature…)

• Individual components and the full assembly has been qualified

• The purpose of the production tests is to guarantee the functionality of every single device before the delivery

• In lab environment but as complete as possible with the given time constrains
Specifications

- Versatile Link components are specified in great detail
  - Specifications are based on commercial standards (Fiber Channel and IEEE), which are modified to fit our special requirements (data rate, radiation, magnetic field, size...)
  - Stored in EDMS

- For production testing (100% of devices) the main parameters are selected:
Parameters: transmitter side

Transmitter specifications at 4.8 Gbps

<table>
<thead>
<tr>
<th>Specification</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold EEL/VCSEL</td>
<td>10</td>
<td>2</td>
<td>mA</td>
</tr>
<tr>
<td>Slope Eff. EEL/VCSEL</td>
<td>0.034</td>
<td>0.06</td>
<td>W/A</td>
</tr>
<tr>
<td>OMA</td>
<td>300</td>
<td></td>
<td>uW</td>
</tr>
<tr>
<td>Extinction Ratio</td>
<td>3</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Eye Opening</td>
<td>60</td>
<td></td>
<td>%OMA</td>
</tr>
<tr>
<td>Rise/Fall Time</td>
<td>70</td>
<td></td>
<td>ps</td>
</tr>
<tr>
<td>Total Jitter</td>
<td>52</td>
<td></td>
<td>ps</td>
</tr>
<tr>
<td>Deterministic Jitter</td>
<td>25</td>
<td></td>
<td>ps</td>
</tr>
</tbody>
</table>

1. Tx: LI measurement (power meter)

2. Tx: Eye diagram measurement (scope)
Parameters: receiver side

<table>
<thead>
<tr>
<th>Specification</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity SM/MM</td>
<td>29/49</td>
<td></td>
<td>uW</td>
</tr>
<tr>
<td>Diff. Output Voltage</td>
<td>200</td>
<td>600</td>
<td>uW</td>
</tr>
<tr>
<td>Rise/Fall Time</td>
<td>50</td>
<td></td>
<td>ps</td>
</tr>
<tr>
<td>Total Jitter</td>
<td>71</td>
<td></td>
<td>ps</td>
</tr>
<tr>
<td>Deterministic Jitter</td>
<td>29</td>
<td></td>
<td>ps</td>
</tr>
</tbody>
</table>

3. Rx: BER measurement (BER tester)

4. Rx: Eye diagram measurement (scope)
Traceability & data storage

- In addition to just carrying out the measurements, the results must be identified and stored for later use
  - IDs (barcodes)
  - Database
  - Read out and analysis tools
Test Setup
Test Setup

- The first setup version consists of only commercial lab instruments.
Test Setup: Control Software

- **IGOR** (a scientific data analysis software, numerical computing environment and programming language)
- Controls all instruments
- Reads and writes to a database
- Shows the results and notifies the user
Device Configuration Info:
- Device ID: 455
- Device Type: VTRx
- TOSA Mfr: JD SU
- Laser Driver: GBL Dv4
- ROSA Mfr: Hamamatsu
- PCB Type: VTRx v3
- Wavelength [nm]: 1550
- TOSA Model: PL-FLD-03-S4...
- ROSA Model: G12072-1909
- Latch Type: v3_2013

Channel 1 LI measurement:
- Optical power [dBm] vs. Bias Current [mA]

Channel 2 SCAN measurement:
- Plot showing time vs. opening

Channel 1 EYE measurement:
- EYE diagram showing data

Channel 2 BER measurement:
- BER vs. OMA [dB]

LI Characteristics:
- I_bias Max [mA]: 12
- I_bias Step [mA]: 1

EYE Diagram Characteristics:
- I_bias [mA]: 6
- I_mod [mA]: 16

Receiver Characteristics:
- Reference Tx: TRX100GVP 2010
- SN: EM0921-00127

Getting parameters:
- No input eye parameters measured. Default values of kBERT source are used.
- TOTAL JITTER DOES NOT MEET THE SPECIFICATION: 55 ps (limit 52 ps)

- Measuring Rx SCAN
- Eye scan at level of 20% measured
- Eye scan at level of 50% measured
- Eye scan at level of 80% measured

- Measuring BER
- Data Rate: 4.30 Gbps
- Target BER: 1.0e-10
- Confidence level: 99 %
- 6 data points recorded in 54 seconds
Test Setup: Communication with the database

- Reads from the database:
  - All the components and their manufacturers (TOSAs, ROSAs, laser drivers…)

- Writes to the database:
  - Device configuration and used instruments
  - Measurement settings: bias/modulation currents, data rates…
  - Raw data and extracted parameters
Database

• MySQL database on the servers of CERN’s *Database On Demand* service
  • database engine updates, access to backup and recovery services etc.

• Our responsibilities: configuration, maintenance and administration
Database includes

- Configuration
  - Types and manufacturers (TOSAs, ROSAs, drivers…)

- Test results
  - Measurement data
  - Raw data

- Location log
  - to keep track on the device locations

- Repair history
Database website: cern.ch/optodb

Test Result Search

Device Type: VTRx  Device ID: 801  Submit Query  Generate eye diagrams (takes approx. 20 seconds)

Device Location Log (Restricted access: only for Opto Team members)

Device Configuration:

<table>
<thead>
<tr>
<th>Device ID</th>
<th>Channel</th>
<th>OSA Model</th>
<th>Laser Driver</th>
<th>PCB type</th>
<th>Latch Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>801</td>
<td>1</td>
<td>Mitsubishi FU-466RLD-6M2</td>
<td>OBL Dv4.1</td>
<td>VTRx SM (green)</td>
<td>SM3dProto</td>
</tr>
<tr>
<td>801</td>
<td>2</td>
<td>Hamamatsu G12072-1908</td>
<td>-</td>
<td>VTRx SM (green)</td>
<td>SM3dProto</td>
</tr>
</tbody>
</table>

LI characteristics:

<table>
<thead>
<tr>
<th>Device ID</th>
<th>Channel</th>
<th>Threshold Current [mA]</th>
<th>Slope Efficiency [WA]</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>801</td>
<td>1</td>
<td>6.4</td>
<td>0.02</td>
<td>23 October 2013</td>
</tr>
</tbody>
</table>

EYE characteristics at 4.8 Gbps using current settings: bias = 24 mA and modulation = 24 mA

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>801</td>
<td>1</td>
<td>304</td>
<td>90</td>
<td>394</td>
<td>78</td>
<td>6.4</td>
<td>40</td>
<td>70</td>
<td>33</td>
<td>10</td>
<td>-17.1</td>
<td>23 October 2013</td>
</tr>
</tbody>
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Rx characteristics at 4.8 Gbps:

<table>
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<tr>
<th></th>
<th></th>
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<tr>
<td>801</td>
<td>2</td>
<td>342</td>
<td>46</td>
<td>45</td>
<td>22</td>
<td>13</td>
<td>-17.1</td>
<td>23 October 2013</td>
</tr>
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Note: The eye diagram presentation slightly filters out jitter and amplitude noise. However, the shape of the eye is presented correctly.
Results (so far)
VTTx’s: The first batch

• 650 VTTx’s with a commercial laser driver and a VCSEL laser for CMS oSLB (a part of the calorimeter trigger upgrade)

• Assembly done by four different companies

• Components selected by CERN and sent to the assembly houses. Assembled PCB’s back to CERN.

• “Finishing touches” and latch assembly by us
VTTx’s: The first batch

- Devices tested with the setup:

<table>
<thead>
<tr>
<th>Assembled by</th>
<th>Tested</th>
<th>Failed</th>
<th>Failure %</th>
<th>Fixed</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CERN</td>
<td>410</td>
<td>36</td>
<td>9%</td>
<td>24</td>
<td>Bad quality assembly</td>
</tr>
<tr>
<td>Hapro</td>
<td>100</td>
<td>2</td>
<td>2%</td>
<td>2</td>
<td>Both TOSA problems</td>
</tr>
<tr>
<td>AWS</td>
<td>90</td>
<td>11</td>
<td>12%</td>
<td>9</td>
<td>Bad quality assembly</td>
</tr>
<tr>
<td>Norcott</td>
<td>50</td>
<td>25</td>
<td>50%</td>
<td>24</td>
<td>TOSA solder pads</td>
</tr>
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- Realistic speed for latch assembly and testing: 100/day
VTTx’s: The first batch - static parameters
VTTx’s: The first batch - static parameters

Examples of min and max slope efficiencies (both still meet our specs!)
VTTx’s: The first batch - dynamic parameters
VTTx’s: The first batch - dynamic parameters

Examples of min and max OMA
VTTx’s: The first batch - dynamic parameters

Examples of min and max jitter
Lessons learnt during the first test run

- Significant differences between assembly houses:
  - CERN and AWS: unacceptable failure rate
  - Hapro shows that the assembly can be done right!

- Specs are always met, provided the device works in the first place
  - Performance variations in the TOSAs and drivers are small enough

- Most of the problems due to bad component assembly
  - we have found and fixed tens of bad solder joints and broken components

- In the future PCB’s must be well finished to avoid problems in latch assembly!
The next step
The next step

- Replace J-BERT with kBERT
  - we don't want to keep J-BERT occupied for an extended period of time
  - kBERT is a FPGA-based BER tester
  - in our setup it replaces pattern generator, I2C interfaces, BER tester, receiver eye measurement
  - external PLL board delivers the clock for both kBERT and scope
The next step

• All receiver side measurements with kBERT
• Sensitivity -> BER
• No more Rx eye diagram -> Rx eye scan

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<td></td>
</tr>
<tr>
<td>Horizontal opening</td>
<td>TBC</td>
<td></td>
<td>ps</td>
</tr>
<tr>
<td>“Rise time”</td>
<td>TBC</td>
<td></td>
<td>ps</td>
</tr>
<tr>
<td>“Fall time”</td>
<td>TBC</td>
<td></td>
<td>ps</td>
</tr>
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</table>
Eye scan

Rx eye diagram:

Rx eye scan:
Barcode IDs

- DataMatrix 2D codes
- Due to lack of space on the PCB we are forced to put 2D codes on latches
  - transparent plastic > contrast issues
  - DPM (direct part marking) readers
- Goal:
  - read the barcode from the device
  - place the device on the test board and plug in the optical fibre
  - press play on the test GUI
  - repeat 25728 times
Summary

- Production test procedure has been realised including:
  - test setup
  - control software
  - database
  - basic analysis and read-out tools
- It has been used with individual devices and a bigger batch
- Even though the setup is ready for “plug and play” operation changes and optimisation are done all the time