Technologies and Choices for the SLHC EMU/Trigger Upgrade

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• Notes from the CMS SLHC Calorimeter Trigger Upgrade Workshop, Madison, November 29, 2007
  - Advanced Telecommunication Architecture (ATCA)
  - MicroTCA Architecture
  - Custom MicroTCA backplane and processing board

• Serial Transmission Technologies for the SLHC Upgrade
  - Texas Instruments TLK family of SERDES
  - Xilinx Virtex-5 RocketIO
  - Parallel Optical links
Reports from Erik Hazen (Boston U), Costas Foudas (Imperial College) and Matt Stattler (LANL) are of special interest. They propose a 3 year program to build, test and evaluate new hardware based on general purpose MicroTCA processing card and custom active backplane.

- It aims to be used as a standard platform for all L1 algorithms at SLHC.
  - It will have the capability to process data from all CMS detectors participating in the first level trigger decision (muon and silicon trackers, calorimeters, ...).

- It will have the potential of replacing the \(~10^2\) different devices which constitute the current CMS L1-trigger.
• Gigabit serial connections, no parallel buses
• Redundancy (power supply, control, serial links)
ATCA Backplane – Dual Star

- 1.2” (30.48 mm) space between slots
- 322 x 280 mm boards
- Up to 200W per module, 3kW per crate
- Tyco/Erni ZD connectors (up to 5Gbps)
ATCA Module

- Front Access Door
  - 90mm Optical Cabling/Air Plenum
- Up to 4 standard PMCs
- 322.25 mm (12.697"")
- Front Board (8U x 280 mm) (140 in²)
  - 1.2” pitch
- Zone 2:
  - Keying/alignment
  - Synch. Clocks
  - Update Channels
  - Fabric Interface
  - Base Interface
- Zone 1:
  - Power
  - Management
- Rear panel I/O Interconnect
- Zone 3
- Rear Transition Module (8U x 70 mm x 1.2” (35 in³)
- 75mm Metallic Cabling/Air Plenum

Dimensions:
- Front Access Door: 25 mm
- Rear Access Door: 25 mm
**MicroTCA Modules/Connectors**

**Figure 2 AdvancedMC Module configuration examples**

<table>
<thead>
<tr>
<th></th>
<th>Compact-Size (3HP)</th>
<th>Mid-Size (4HP)</th>
<th>Full-Size (6HP)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single modules</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>Dimensions</td>
<td>73.8x13.88x181.5mm</td>
<td>73.8x18.96x181.5mm</td>
<td>73.8x28.95x181.5mm</td>
</tr>
<tr>
<td><strong>Double modules</strong></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td>Dimensions</td>
<td>146.8x13.88x181.5mm</td>
<td>148.8x18.96x181.5mm</td>
<td>149.8x28.95x181.5mm</td>
</tr>
</tbody>
</table>

- **MicroTCA is based on Advanced Mezzanine Card (AMC) Standard used in ATCA**
- **170-pin card edge connector**
Schroff MicroTCA Backplane

Power Module

2 MicroTCA Carrier Hubs (MCH)

Power Module

4 full-size slots

4 Single/Double Compact Slots

4 full-size slots
MicroTCA Crates

- Elma
- Emerson Network Power (former Motorola Embedded Computing Division)
Specifications

• ATCA 3.0 Short Form Specification is available for free from http://www.picmg.org/pdf/PICMG_3_0_Shortform.pdf

• MicroTCA Short Form Specification is available for free from http://www.picmg.org/pdf/MicroTCA_Short_Form_Sept_2006.pdf (overview; not intended for design)

• Full ATCA and MicroTCA Specifications are available for purchase from http://www.picmg.org/v2internal/specorderformsec.htm ($400 for non-PICMG Members and $195 for Members)
• Available 1st half of 2008
GCT Upgrade Hardware(II)

Custom Backplane block diagram

Mindspeed M21161 144x144 crosspoint

Mesh control 12 serial links

Control FPGA For Misc Backplane Functions

Ethernet from each uTCA slot

Ethernet Switch

nxp LPC23xx uController

Uplink

Ref Clock Distribution Tree
MicroTCA in the EMU System?

Selected LCTs to TF

Serialized LCTs from TMB

Muon Port Card processing logic
Present Design (both Trigger and DAQ):
• FTRJ8519 + TLK2501
  - 16 bit @ 80MHz = 1.6Gbps with 8B/10B encoding

Upgrade options:
• 1-channel SFP transceiver + Texas Instruments TLK family
  - 16 or 18 bit parallel interface
  - up to 156MHz reference clock frequency
  - 8B/10B or start/stop encoding
• 1-channel SFP transceiver + MGT (Xilinx V5)
• 4-channel parallel optical transmitter/receiver + MGT (Xilinx V5)
  - QSFP
  - POP4
• 12-channel parallel optical transmitter/receiver + MGT (Xilinx V5)
  - SNAP12
## Texas Instruments TLK Family

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Parallel Bus, bit</th>
<th>Serial Interface</th>
<th>Bit Rate, Gbps</th>
<th>Reference Clock Frequency, MHz</th>
<th>Encoding Method</th>
<th>Embedded PRBS generator</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLK1501</td>
<td>16</td>
<td>CML*</td>
<td>0.6-1.5</td>
<td>30-75</td>
<td>8B/10B</td>
<td>2⁷-1</td>
</tr>
<tr>
<td>TLK2501</td>
<td>16</td>
<td>CML*</td>
<td>1.5-2.5</td>
<td>75-125</td>
<td>8B/10B</td>
<td>2⁷-1</td>
</tr>
<tr>
<td>TLK3101</td>
<td>16</td>
<td>VML*</td>
<td>2.5-3.125</td>
<td>125-156.25</td>
<td>8B/10B</td>
<td>2⁷-1</td>
</tr>
<tr>
<td>TLK1521</td>
<td>18</td>
<td>VML*</td>
<td>0.5-1.3</td>
<td>25-65</td>
<td>Start/Stop</td>
<td>None</td>
</tr>
<tr>
<td>TLK2521</td>
<td>18</td>
<td>VML*</td>
<td>1.0-2.5</td>
<td>50-125</td>
<td>Start/Stop</td>
<td>None</td>
</tr>
<tr>
<td>TLK2701</td>
<td>16</td>
<td>CML*</td>
<td>1.6-2.7</td>
<td>80-135</td>
<td>8B/10B</td>
<td>2⁷-1</td>
</tr>
<tr>
<td>TLK2711</td>
<td>16</td>
<td>VML*</td>
<td>1.6-2.7</td>
<td>80-135</td>
<td>8B/10B</td>
<td>2⁷-1</td>
</tr>
</tbody>
</table>

* CML – Current Mode Logic, VML – Voltage Mode Logic, for more details see TI Application Report SLLA120 available at [http://focus.ti.com/lit/an/slla120/slla120.pdf](http://focus.ti.com/lit/an/slla120/slla120.pdf)

- Pin compatible general purpose SERDES devices
- Minor differences in serial and control interfaces
- Same PCB layout for all devices
- Single +2.5V power supply
- 64-pin VQFP package with thermal pad for better cooling and grounding
- Low power consumption (250…450mW typical)
- Low cost parts ($10..$25) available from several distributors
## Texas Instruments TLK Family

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Parallel Bus, bit</th>
<th>Serial Interface</th>
<th>Bit Rate, Gbps</th>
<th>Reference Clock Frequency, MHz</th>
<th>Encoding Method</th>
<th>Embedded PRBS generator</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLK4015</td>
<td>4x16</td>
<td>CML*</td>
<td>0.6-1.5</td>
<td>30-75</td>
<td>8B/10B</td>
<td>$2^7-1$</td>
</tr>
<tr>
<td>TLK4120</td>
<td>4x18</td>
<td>VML*</td>
<td>0.5-1.3</td>
<td>25-65</td>
<td>Start/Stop</td>
<td>None</td>
</tr>
<tr>
<td>TLK4250</td>
<td>4x18</td>
<td>VML*</td>
<td>1.0-2.5</td>
<td>50-125</td>
<td>Start/Stop</td>
<td>None</td>
</tr>
</tbody>
</table>

- Pin compatible general purpose SERDES devices
- Minor differences in serial and control interfaces
- Same PCB layout for all devices
- Single +2.5V power supply
- 19x19 mm 289 BGA package
- Low cost parts ($30..35) available from several distributors
## Xilinx Virtex 5 LX/LXT Family

<table>
<thead>
<tr>
<th>Virtex-5 LX/LXT FPGA</th>
<th>Number of 3.2Gbps * RocketIO MGT</th>
<th>Maximum Number of User IO **</th>
<th>Cost, $ (speed grade -1, December 2007)</th>
<th>Cost, $ (speed grade -2, December 2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30/30T</td>
<td>None/8</td>
<td>400/360</td>
<td>250-288/334</td>
<td>312-360/418</td>
</tr>
<tr>
<td>50/50T</td>
<td>None/12</td>
<td>560/480</td>
<td>394-520/530-583</td>
<td>492-650/663-729</td>
</tr>
<tr>
<td>85/85T</td>
<td>None/12</td>
<td>560/480</td>
<td>928-1,066/941</td>
<td>1,160-1,334/1,176</td>
</tr>
<tr>
<td>110/110T</td>
<td>None/16</td>
<td>800/680</td>
<td>1,375-1,513/1,824-2,006</td>
<td>1,719-1,891/2,280-2,508</td>
</tr>
<tr>
<td>220/220T</td>
<td>None/16</td>
<td>800/680</td>
<td>3,625/4,206</td>
<td>4,531/5,257</td>
</tr>
<tr>
<td>330/330T</td>
<td>None/24</td>
<td>1200/960</td>
<td>8,731/13,179</td>
<td>10,914/16,474</td>
</tr>
</tbody>
</table>

* Recently upgraded to 3.75Gbps for speed grade –2 and –3 devices. Reference clock frequency from 60MHz to 350MHz for all speed grades.

** Up to 1.25Gbps on all available LVDS pairs (User IO)
4-Channel QSFP Parallel Links

  - specification at: http://www.reflexphotonics.com/PDFs/QSFP_Specification_Revision_1_0.pdf
- Pluggable transceiver with 4 independent full duplex channels
  - Zarlink, Emcore, Reflex Photonics…
- 30% larger than the SFP package
- 38-contact right angle connector
- 2/4/5Gbps per channel
- 3.3V power
- Reflex Photonics QS-X04-C0051
  - 1W max
  - no heat sink requirement
  - $375 per module, 6-8 weeks delivery

Supported link length for fiber types:

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>Modal BW</th>
<th>2 Gb/s (m)</th>
<th>4 Gb/s (m)</th>
<th>5 Gb/s (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OM1 - MM 62.5 MHz-km</td>
<td>150 m</td>
<td>70 m</td>
<td>65 m</td>
<td></td>
</tr>
<tr>
<td>OM2 - MM 50/125 500 MHz-km</td>
<td>300 m</td>
<td>150 m</td>
<td>125 m</td>
<td></td>
</tr>
<tr>
<td>OM3 - MM 50/125 1500 MHz-km</td>
<td>500 m</td>
<td>270 m</td>
<td>200 m</td>
<td></td>
</tr>
</tbody>
</table>
8-Channel POP4 Parallel Links

- “POP4” Multisource Agreement
  - spec at:  http://www.popoptics.org
- 8-channel optical transceiver
  (4 receivers + 4 transmitters)
  - Avago Technology HFBR-7924/7934
  - Optoic Technology PL-2500SX-1X4
- Up to 2.7Gbps/3.125Gbps per channel
- Up to 150/300 m on 50/125um MMF
- 3.3V power
  - 1W typ, 1.4W max
- Up to 16 modules on 9U VME board
- $500-$700 per module

- 16 mm high with heat sink
  - does not fit single-width VME card
- 13 mm high without heat sink

10 x 10 ball array
1.27 mm pitch

18 mm
13 mm

10 x 10 ball array
1.27 mm pitch
12-Channel Parallel Optical Links

- SNAP12 Multisource Agreement
  - [http://www.zarlink.com/assets/SNAP12-MSA.pdf](http://www.zarlink.com/assets/SNAP12-MSA.pdf)
- 12-channel optical transmitter/receiver
  - Picolight, OptolC, Emcore, Reflex Photonics…
- 2.5/2.7/3.3Gbps per channel
- 100..500 m link distance on 50/125um MMF
- 3.3V power
- Reflex Photonics SN-T12(R12)-P00501
  - 1.1W typ, 1.5W max power consumption
  - no heat sink requirement
  - $550 (T12), $525 (R12)
  - 4..6 weeks delivery

10 x 10 ball array
1.27 mm pitch
Conclusion

• GCT MicroTCA designs might be useful for the EMU/Trigger upgrade
  - mezzanine board
  - need better understanding of data volumes
  - hard to evaluate within present EMU/Trigger architecture

• 4-channel parallel optical links coupled with the RocketIO Multigigabit Transceivers is a good choice for the SLHC CSC TF
  - space saving
  - faster than present links