Functional Super Read Out Driver Demonstrator for the Phase II Upgrade of the Atlas Tile Calorimeter

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On behalf of the ATLAS Tile Calorimeter System

Outline

- Introduction
- Phase II Upgrade
- Optical Link Card development (OLC)
- Optical Multiplexer Board (OMB)
- sROD demonstrator tests
- sROD demo board
- Conclusions

Introduction

- ATLAS Hadronic Tile Calorimeter at LHC (CERN)

- Materials:

- Iron as passive material
- Plastic scintillating plates

- Structure:

- One central barrel
- Two extended barrels

- Energy deposited in cells of barrels generates light

- Front-end electronics digitizes signals @ 25ns
 - Located at the outermost section of the Calorimeter
 - Send digital samples with optical fibers to the back-ends electronics
- Back-end electronics receives digitized information
 - Main component is the ReadOut Driver (ROD)
 - » 9U VME format
 - » SFP optical connectors
 - » 2 PU equipped with TMS320C64 DSPs
 - » Data format
 - » Management
 - » Transmission

ATLAS Experiment

TileCal detector

Read Out Driver board

Level I trigger

Phase II Upgrade

- LHC increases luminosity in a factor of 10
 - Increase of data rate between front-end and back-end electronics
 - Digital trigger to be implemented
 - Higher resolution needed
 - Radiation tolerance must be increased
 - Highly reliable data transmission protocols must be deployed
 - GigaBit Transceiver protocol
 - Redesign of the front-end and back-end electronics
- New proposed back-end electronics implies
 - Increased data bandwidth
 - SNAP12 optical connectors
 - FPGA with embbebed SerDes
 - Increase in processing requirements
 - High performance FPGA with DSP blocks

Atlas trigger system

SNAP12 optical connectors

Optical Link Card

● Description

■ Specifications

- ROD double PU Board format (4.72 in x 6.85 in)
- 12 input channels up to 75 Gbps
- 12 output channels up to 75 Gbps

■ Technical details

- Altera Stratix II GX EP2SGX60E FPGA
 - 1152 pins
 - 12 high speed transceivers @ 6.375Gbps
 - 534 I/Os
- 2 SNAP12 connectors (12 fibers @ 6.25Gbps)
- 1 SFP connector (1 input @ 1Gbps, 1 output @ 1Gbps)
- 12 copper layers
 - 6 layers - 0.6 mils thick for signals
 - 6 layers - 1.2 mils thick for planes
- Different thickness of dielectric: 2.5, 4 and 6 mils
 - Need high capacitance between planes but sufficient thickness for striplines
- Over 2000 routes: 5 mils width
- Over 2400 vias: 10 mils

Optical Link Card

- Tests developed

- Test 1: Measurement of latency and maximum data bandwidth
 - Raw data: 32 bit counter
 - No protocol
 - 6.25 Gbps per fiber
 - Latency of 108ns - 17 clock cycles
 - Total measured bandwidth of 75 Gbps
 - Power consumption 11.71 W
- Test 2: 1 link GBT
 - 1 link GBT protocol
 - Receiver and transmitter located in different GX transceiver block
 - 48 hours without errors
 - BER of $3.61 \cdot 10^{-15}$ for a confidence of 95%
 - Total bandwidth of 4.8 Gbps
 - Power consumption 7.128 W
- Test 3: 12 link GBT
 - 12 link GBT protocol
 - Receiver and transmitter located in different GX transceiver block
 - Internal FIFO compensation needed
 - BER of $6.05 \cdot 10^{-16}$ for a confidence of 95%
 - Total bandwidth of 57.6 Gbps
 - Power consumption 14.025 W

Optical Link Card

BER confidence level

Optical Multiplexer Board

- Add redundancy to data transmission
 - Two optical fibers
 - Same data from front-end electronics
- Specifications
 - 9U format board
 - 16 input channels up to 10.24 Gbps
 - 8 output channels up to 5.12 Gbps
- Technical details
 - 8 Altera Cyclone I EP1C12 FPGA
 - CRC checking
 - Link control
 - 1 Altera ACEX EP1K100
 - VME interface
 - 1 TTCrx chip
 - 12 SFP optical connectors
 - 8 TX channels @640Mbps (HDMP-1032)
 - 16 RX channels@640Mbps (HDMP-1034)
 - 10 copper layers
 - More than 1200 components
- Tests
 - 2100 hours
 - BER better than 10^{-13} for a confidence level of 95%

Optical Multiplexer Board

OMB Tests

sROD demonstrator tests

- Functional sROD Demonstrator
 - OLC plugged on an OMB
 - Optical Link Card
 - Function
 - Send event data with GBT protocol @4.8Gbps
 - » Emulating Front-End electronics
 - Receive sent data and decode it @4.8Gbps
 - » Emulating Back-End electronics
 - Used devices
 - Altera Stratix II GX FPGA
 - SNAP12 optical connectors
 - » 1 TX channel @ 4.8Gbps
 - » 1 RX channel @ 4.8Gbps
 - Optical Multiplexer Board
 - Function
 - Receive event data through PU connectors
 - Send event data to ROD @640Mbps
 - Used devices
 - Altera Cyclone I FPGA
 - SFP optical connector
 - » 1 TX @640Mbps

OLC plugged on an OMB

sROD demonstrator tests

- Block diagram

- Front-end emulation

- Event data from ROM (OLC)
 - Stored in Stratix II GX
 - 1 TX GBT link @4.8Gbps (OLC)
 - TX SNAP12 optical connector

- Back-end emulation

- 1 RX GBT link @4.8Gbps (OLC)
 - RX SNAP12 optical connector
 - CRC data check (OMB)
 - 1 G-link @640Mbps (OMB)
 - Send event data to ROD
 - 1 TX SFP optical connector

sROD demonstrator tests

sROD demonstrator testbench

sROD demo board

- Next step for the Upgrade phase II
- Aim of the sROD demo board
 - Read-Out of a complete super-drawer (Upgrade architecture)
 - Transmit trigger data to the L1Calo
 - Send data at L1 trigger rate to the ROS
- Physical features:
 - ATCA format
 - Ethernet interface
 - Remote configuration
 - Remote process monitoring

sROD demo board block diagram

Conclusions

- Developed an evaluation board for test SNAP12 connectors
 - Optical Link Card
- A super Read Out Driver demonstrator has been presented
 - OLC plugged on an OMB
 - Transmission data rate @ 4.8Gbps
 - Reception data rate @ 4.8Gbps
- Basis for a new project: sROD demo board
 - Read-out a whole module (super-drawer)
 - 4 RX SNAP12
 - 2 TX SNAP12

Thank you