Characterization of the Trigger Data Serializer ASIC Prototype for the ATLAS Forward Muon Detector Upgrade

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Introduction: ATLAS muon NSW upgrade

Trigger Data Serializer (TDS) ASIC requirement and design

Characterization of the first prototype

Summary and Outlook
Introduction: ATLAS muon NSW upgrade

- **ATLAS New Small Wheel (NSW) Upgrade**: Replace the innermost station of the muon spectrometer in the forward region to prepare for high luminosity runs after LHC phase-I upgrade.

- **Main objectives:**
  - Remove “fakes” to keep Level-1 low $p_T$ ($\sim 25$ GeV) muon trigger un-prescaled.
  - Maintain good muon $p_T$ resolution ($\sim 10\% @ 1$ TeV) under high radiation background
NSW structure: two multilayers. Each consists 8 layers of Micromesh Gaseous Structure detector + 8 layers of Small-strip Thin Gap Chamber (sTGC).

Multilayer cross-section

sTGC detector layout

sTGC trigger scheme

Impossible to readout ~280k strips every bunch crossing (25 ns)

sTGC LV-1 trigger progresses in two steps:

- Make pad coincidences from two quadruplets to form trigger roads
- Send out charge information only from strips covered by the trigger road
**Trigger Data Serializer (TDS) ASIC design**

- TDS is responsible to prepare trigger data from both strips and pads, perform strip-pad matching, with additional tasks to serialize and transmit data off detector.

### Requirements and challenges:

- **Two modes:** strip and pad mode to transfer hit and charge information.
- **Large number of input (128 per chip) w. programmable delay (pad-mode only).**
- **Fast output data rate:** 4.8 Gbps.
- **Low latency** (~100 ns) and low power consumption (< 8 mW/channel).
- **Radiation hard** (complying with ATLAS policy).
Trigger Data Serializer (TDS) ASIC design

- From design to silicon die

- Fabricated with IBM 8RF-DM 323, 130 nm CMOS, 1.5 V
Characterization of first prototype

- Silicon dies directly wire bonded to printed circuit board

Bonded chip on PCB

- Silicon dies directly wire bonded to printed circuit board

TDS silicon die

Bonding pads

Bonding wires

FPGA Evl. Board
Characterization of first prototype: Serializer (SER)

- SER tested with embedded PRBS-31 generator @ 4.8 Gbps: Bit error rate < 10^{-15}, eye diagram total jitter @ 10^{-12} BER: 46 ps (22% UI).
- Embedded frame builder tested.
Characterization of first prototype: VMM interface

- Trigger match bypassed. 6-bit charge data provided from embedded source or externally.
- Pre-assigned BCID, pad trigger information (pad phi and band ID) given from external configuration port.
- Result: charge de-serialized correctly
Emulated pad trigger from FPGA transfers 32bits/25 ns (predefined BCID, pad band ID and phi ID).

Predefined strip charge data successfully flow through the entire logic chain. Pad-trigger interface behaves as expected.
Characterization of first prototype: Pad-mode operation

- TDS provided with 10 ns pulses representing sTGC pad hits
- Hit information transmitted through TDS are resolved correctly
First prototype of the Trigger Data Serializer (TDS) developed for the ATLAS NSW sTGC trigger system is a success.

Trigger data processing logic is validated. Serializer has good performance to meet trigger data transfer requirement.

TDS silicon dies will be packaged and tested in the following step.

Under the way towards second prototype.

Thanks!

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Backup

• Serializer modified from CERN GBT design. Major changes implemented:
  - Load parallel bits with faster clock to reduce latency (40MHz → 160MHz)
  - Change metallization to have co-production with other ATLAS NSW ASIC
  - Pad-mode sends out only hit (yes/no) information
Pad-TDS block diagram
Pad trigger interface
sTGC trigger: strip logic: one layer of one 1/16th

Choose the band of strips under the tower

Selected band:
One 120-bit word per BC: BCID, bandID, φ-ID, strip charges
⇒ 4.8 Gb/sec

in USA15

centroid finder and track extrapolator

8 layers

candidates from MM
to sector logic up to 8 candidates per BC

in USA15

centroid finders 3 (for 8 layers)

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Kintex-7 FPGA

12.5 GHz Oscilloscope

Logic Analyzer

Emulated Pad Trigger

TDS

TDS Serializer

Output