The GBT Bi-directional Link and Data System

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A Versatile Bi-Directional Link System

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Outline

- Links in HEP
  - Is a different approach viable?
  - A Versatile Bi-Directional Link System
  - The concept
  - GBT ASIC
  - Link configuration
  - Bandwidth
  - Handling SFU
  - The GBT as a "Communications Controller"
  - Prototypes
  - Summary

Links in HEP

- Data transmission roles in HEP
- Data Acquisition (DAQ)
- Timing, Trigger (TT)
- Experiment Control (EC)
- LHC Emu
- A different architecture for each function
- A dedicated physical support for each architecture
- Experiments share a common development:
  - TTC system
  - DCS
  - But a lot of effort went into developing several similar systems for each of the four LHC experiments

Future HEP Links

- Can we develop a one-size-fit-all solution?
- Some support hardware?
- Some link architecture?
- As a "universal" link requires:
  - The experiments to agree on a common interface
  - A well-defined set of specifications (requirements):
    - TTC
    - TT
    - DCS
    - ASIC
    - OPTOELECTRONICS
  - The system has to be Versatile:
    - TT has to accommodate several topologies
    - But the physical support can be "shared"
    - Some electronics (ASIC)
    - A limited set of optoelectronic "flavours"
    - Same WOS

Versatile Bi-Directional Link System

- The objective is to build a system based on a single ASIC which can provide a complete link solution for:
  - Timing
  - Trigger
  - Experiment Control
  - Data Transmission
- What's the target?
- Implement versatile link topologies
  - Higher bandwidth:
    - Data, Timing, Trigger and Experiment Control
  - Bi-directional links
  - Some, Timing, Trigger and Experiment Control
- Robust handling of irradiation effects
- Versatility
- Common development
  - Better use of names/economical resources

Transceiver Module

Multi-protocol ASIC

Scalable

Configurable to multiple optical network (layer drivers)

QSF

GTS

This is a simple TLA containing the ASIC, optoelectronic components and optical and electrical connections.

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GBT

- Such a Versatile system response:
  - Multi-protocol Transceivers
  - 3-to-1
  - 2-to-1
  - N-to-1

- Operation modes:
  - Trigger
    - TTC function
  - Link
    - General purpose
    - Simplex/Duplex

- Data transmission mode:
  - Continuous
    - Data is continuously transmitted
  - Packet
    - Data is transmitted in bursts of packets

GBT Operation Modes

- Continuous mode (think about a traditional optical link)
  - Each link is 100% occupied by a single transmitter.
  - The transmitter/receiver pairs are fully synchronous.
  - This is the case for:
    - A trigger source sending data to several trigger destinations
    - Synchronous point-to-point optical link

- Packet mode (think about a backbone bus)
  - Common Transmission medium is shared:
    - A transmitter can only send data if there is no receiver
  - Several devices can share the same medium and thus communicate with
    the same destination without collisions
  - This is the case for:
    - Trigger return link (Bus)
    - Asynchronous point-to-point data link

Link Configuration 1: Broadcast Network

- Down-path: Passive Optical Tree
  - Current TTC system architecture
  - One source to N destinations
  - For large N, an optical power source is required
  - Operation mode: continuous

Link Configuration 2: Broadcast Network with O/E/O Repetitions

- Down-path: Passive/Active Tree
  - Passive power splitting with electrical regeneration
  - One source to N destinations
  - Optical or electrical 3-to-1
  - Redundant optical power at each transmitter
  - Operation mode: continuous
  - Moderate increase in latency: one-to-one

Link Configuration 3: Point-to-Point

- Up/Down-path: Optical
  - Full bandwidth available for
    - data transmission
  - Simplex/Duplex operation
  - Operation mode: continuous
  - DAQ Link
    - Counting beam

Link Configuration 4: Bidirectional One-to-N / N-to-One

- Down-links: Passive Optical Tree
  - Passive optical tree in both directions
  - Down-link: 1-to-N
  - Up-link: 1-to-1
  - For moderate power optical source
  - Operation mode:
    - Down-link: continuous
    - Up-link: packet
    - Up-link under control of the master transmitter

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**Data Rate and User Bandwidth**

- Data rate and word size will depend on the SLHC frequency.
- Not yet decided.
- Numbers below assume f_data = M x f_clock (not necessarily true).
- Transmission data rates must be multiples of the (5)SLHC bunch crossing frequency.
- A trigger system remains synchronized with the accelerator cycle.
- Fixed latency communication channels.
- 130 mm CMOS technology:
  - 2x 2.2 Gbit/s OC (-5 Gbit/s maybe feasible).
  - Transmission of 88 bits encoded at 40 MHz (the LHC rate).
  - Effective data bandwidth of 2.56 Gbit/s (for 3.2 Gbit/s raw).
- 90 mm CMOS technology:
  - New 6.4 Gbit/s OC (-10 Gbit/s maybe feasible).
  - Transmission of 128 bits properly encoded at 40 MHz (the LHC rate).
  - Transmission of 64 bits encoded at 80 MHz (the SLHC rate).
  - Effective data bandwidth of 5.12 Gbit/s (for 6.4 Gbit/s raw).

**Line Codes and Error Correction**

- High SEU rates are expected for SLHC.
- SEU errors at the optical receiver (PSN-Preamp) will be detected as corrupted data bits.
- Error correction followed by Line Coding will not work.
- The order of operations must be reversed.
- To deal with higher SEU rates in SLHC, the following scheme is proposed (illustrative example only):
  - 8-bit data is first scrambled for DC balance.
  - The scrambled data is Reed-Solomon encoded 16-bit FEC field.
  - An 8-bit redundant header is added to form a frame.
  - This results in an 88-bit frame.
  - A line rate of 40 MHz (=88 bit/1.25 MHz).
- To minimize the dead-time due to a loss of synchronization, the scrambler is designed as self-synchronizing.
- One LHC clock cycle is enough to synchronize the scrambler.
- The efficiency of the line encoding is 64/88 = 0.727.

(Further details were given by Guido Papek, this morning.)

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**The GBT as a TTC and Communications Controller**

- Ethernet PHY
- Ethernet Master (1---vclone) (+)
- Ethernet Slave (4---vclone) (+)
- CTP Master (2---vclone) (+)
- CTP Slave (2---vclone) (+)
- Parallel port (54---96bit (+)
- Memory bus (16-bit, 16-bit)
- Phase programmable delays (+)
- Trigger simulator (4---vclone) (+)
- Commercial serial bus?
- Event Counter
- Burst Counter
- Receiver control
- Link Flow control
- Transmitter control
- IP Slave
- JTAG Port

**GBT Block Diagram**

- Configuration Generator
- Link Flow Generator
- Transmitter Interface
- JTAG Interface
- Event Counter
- Burst Counter
- Receiver Control
- Link Flow Control
- Transmitter Control
- IP Slave
- JTAG Port

**Prototypes**

- Three GBT building blocks were prototyped in 130 nm CMOS:
  - Laser driver (Gianni Zizza, INP-Paris) (presented this morning).
  - Encoder / decoder (Guido Papek, CERN).
  - Limiting Amplifier (Paulo Moreira, CERN).

**Limiting Amplifier**

- Specifications:
  - Data rate: 3.4 Gbit/s (Nyquist) 6.8 Gbit/s (even) 13.6 Gbit/s (odd)
  - Bandwidth: 2.53 GHz
  - Equivalent input noise: 1 mV
  - Maximum output signal (differentiated): 10 mV
  - Maximum output signal (differentiated): 600 mV
Summary

- We propose a Versatile Link solution for:
  - Timing Trigger Links
  - Data Acquisition Links
  - Experiment Control Links

- The system allows flexible link topologies:
  - Bi-directional
  - Uni-directional
  - Point-to-Point
  - Point-to-Multipoint

- Specifications and Interfaces are still evolving for which we need the feedback of the potential users

- Some universal building blocks have already been prototyped:
  - Laser driver
  - Encoder/Deserializer, Line code and FEC
  - Limiting Amplifier

- The Versatile Bi-Directional Link project has been proposed by the Microelectronics group as a CERN common development.