

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
 - The GBT ASIC
 - Link configurations
 - Bandwidth
 - Handling SEUs
- The GBT as a "Communications Controller"
- Prototypes
- Summary

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Links in HEP

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

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Future HEP Links

- Can we develop a one-size fit-all solution?
 - Same support hardware?
 - Same link architecture?
- An "universal" link requires:
 - The experiments to agree on a common interface!
 - A well defined set of specifications (requirements):
 - DAQ
 - TT
 - EC
 - ASIC
 - OPTOELECTRONICS
- The system has to be Versatile:
 - It has to accommodate several topologies
 - But the physical support can be "shared"
 - Same electronics (ASIC)
 - A limited set of optoelectronics 'flavours'
 - Same MCM

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Versatile Bi-Directional Link System

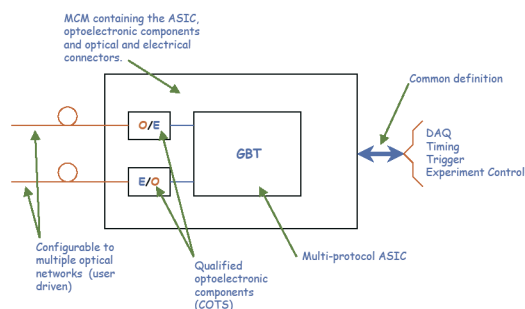
- The objective is to build a system based on a single ASIC which can provide a complete link solution for:
 - Timing
 - Trigger
 - Experiment Control
 - Data Transmission
- What's the target:
 - Implement versatile link topologies
 - Higher bandwidth
 - Data, Timing, Trigger and Experiment Control
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

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Transceiver Module



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- Such a Versatile system requires:
 - Multi-protocol transceiver:
 - 1-to-1
 - 1-to-N
 - N-to-1
- Operation modes:
 - Trigger:
 - TTC functions
 - Link
 - General purpose
 - Simplex/Duplex
- Data transmission modes:
 - Continuous
 - Data is continuously transmitted
 - Packet
 - Data is transmitted in bursts of packets

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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 data link
- Packet mode (think about a backplane bus):
 - Common Transmission medium is shared:
 - A transmitter can only send data upon the request of a master transmitter
 - 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

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Link Configuration 1: Broadcast Network

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

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

- Down-path: Passive/Active Tree
 - Passive power splitting with electrical regeneration
 - One source to N destinations
 - Optical or electrical: 1-to-16
 - Moderate optical power at each transmitter
 - Operation mode: continuous
 - Moderate increase in latency: o/e-r-e/o

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Link Configuration 3: Point-to-Point

- Up/Down-paths: Optical
 - Full bandwidth available for data transmission
 - Simplex/Duplex operation
 - Operation mode: continuous

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

- Down/up-links: Passive Optical Trees
 - Passive optical tree in both directions
 - Down-link: 1-to-16
 - Fan-In-Out: 16-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
 - Still not decided!
 - Numbers below assume $f_{SLHC} = M \times f_{LHC}$ (not necessarily true)
- Transmission data rates must be multiples of the (S)LHC bunch crossing frequency:
 - Trigger system remains synchronous with the accelerator cycles
 - Fixed latency communication channels
- 130 nm CMOS technology:
 - Raw 3.2 Gbit/s OK, (~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 nm CMOS technology:
 - Raw 6.4 Gbit/s OK, (~10 Gbit/s maybe feasible)
 - Transmission of 128-bits properly encoded at 40 MHz (the LHC rate)
 - ... or 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)

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Line Codes and Error Correction

- High SEU rates are expected for SLHC
- SEU errors at the optical receiver (PIN-Preamp) will be detected as corrupted data bits
- Traditional Error Coding 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):
 - 64-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.
 - Line rate $\rightarrow 40 \text{ MHz} \times 88\text{-bit} = 3.52 \text{ Mbit/s}$
 - 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: $64/88 = 72.7\%$

(Further details were given by Giulia Papotti this morning)

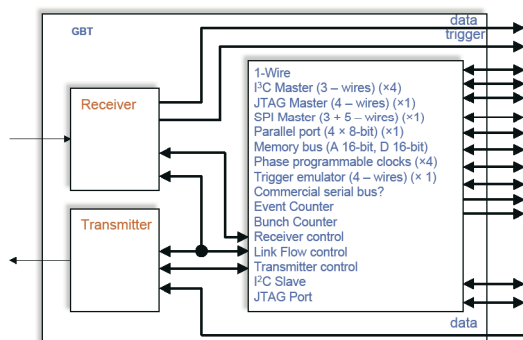


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The GBT as a TTC and Communications Controller

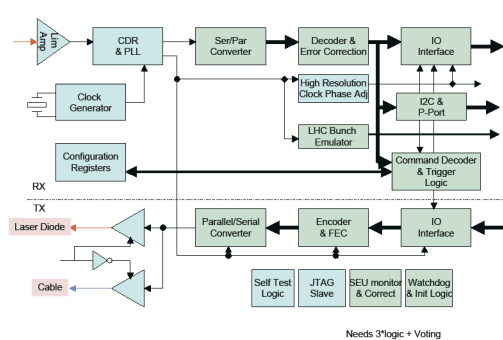


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GBT Block Diagram



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Prototypes

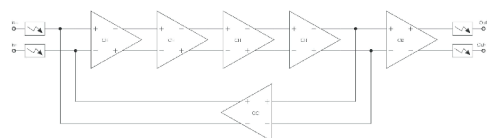
- Three GBT building blocks were prototyped in 130 nm CMOS:
 - Laser driver (Gianni Mazza, INFN Torino)
 - Encoder / decoder (Giulia Papotti, CERN) (Presented this morning)
 - Limiting Amplifier (Paulo Moreira, CERN)

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Limiting Amplifier

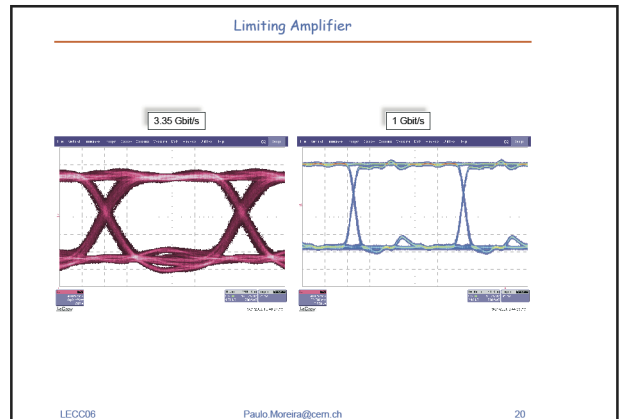
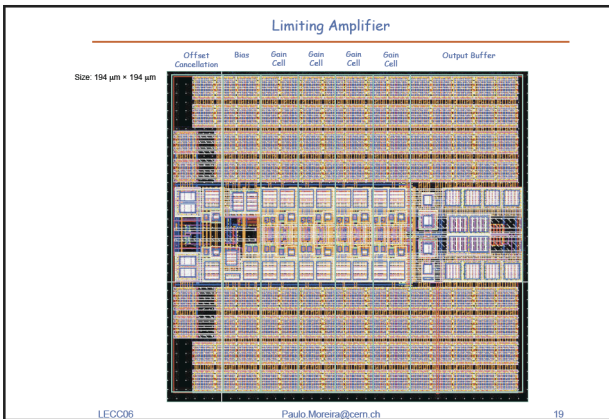


- Specifications:
- Data rate: 3.60 Gbit/s
 - Gain: > 55 dB
 - Bandwidth > 2.52 GHz
 - Equivalent input noise: < 1 mV
 - Minimum input signal (differential): 10 mV
 - Maximum input signal (differential): 600 mV

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- Summary
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- 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/decoder: Line code and FEC
 - Limiting amplifier
 - The Versatile Bi-Directional Link project has been proposed by the Microelectronics group as a CERN common development.
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