Report from sub-group C, Optical Link Evaluation Criteria and Test Procedures

Joint ATLAS/CMS NOTE 2007/002

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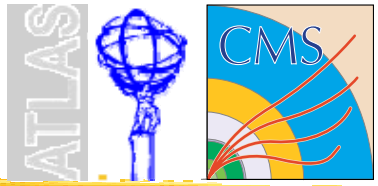
Table of Contents

Introduction

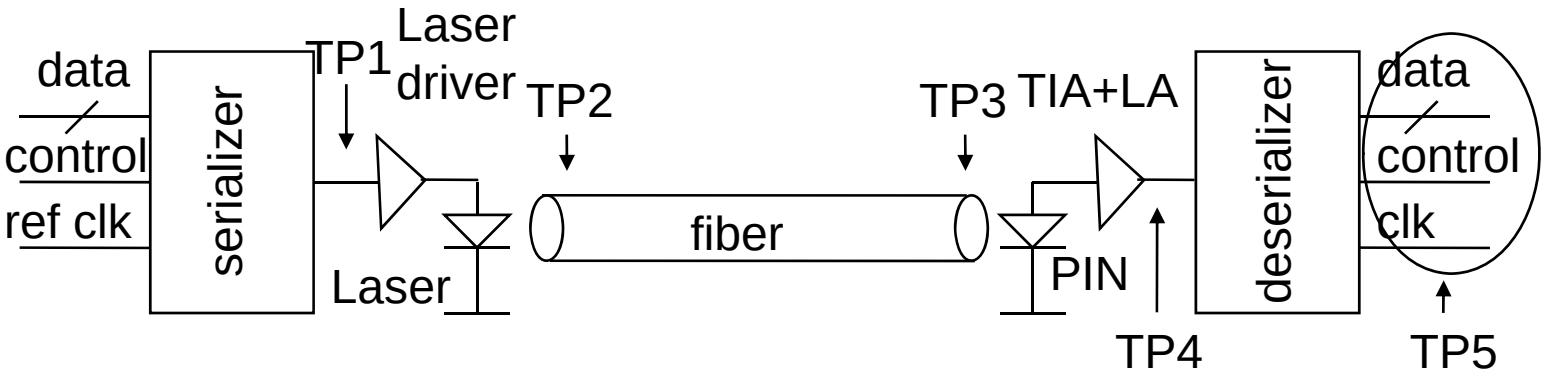


- This document proposes the evaluation criteria and test procedures for optical data links that are developed to read out the detector front-end electronics in ATLAS and CMS for the LHC upgrade (SLHC). These optical links need to be radiation resistant to the requirement of the detectors' operational lifetime in the SLHC. The goal of this document is to develop standardized test procedures and evaluation criteria for future designs and tests to follow, and to make our testing work for optical link R&D projects simpler and more effective.

- A short history:

  The discussions of a standardized testing procedure and evaluation criteria started shortly after the joint working group was formed. Past experiences in ATLAS and CMS show that we need to put more thinking into tests at the beginning of the R&D projects. In these tests, there are many things we did before in each individual institutes can now be put in a joint common project for the SLHC. After the ATLAS CMS joint workshop on common electronics projects in March this year at CERN, serious efforts in the joint optoelectronics working group were spent to create a standardized testing procedure and evaluation criteria for optical link development work. This document is the result of these efforts.

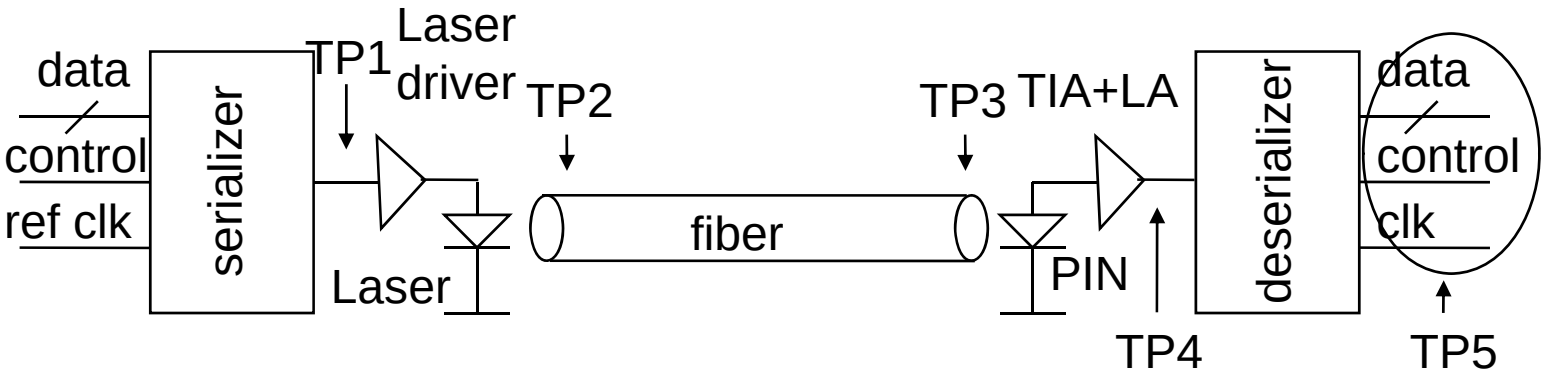
The laboratory tests .1/3.



At the link system level:

- The input and output (parallel) data timing diagram with respect to the reference (input case) or recovered (output case) clock.
- The range of data transmission rate and associated reference clock frequency.
- System latency (excluding fiber propagation delay).
- Eye diagrams at TP1, TP2, TP3 and TP4 and the eye mask tests at TP2, TP3 and TP4. Electrical signals at TP1 and TP4 (usually LVDS) need to be checked against their design specifications. From the eye diagram the following information needs to be extracted: the rise and fall times (20%-80%) of the signal waveform, the jitter in the serial bit stream triggered with the reference (frame) clock, the optical power levels (high, low and average) at TP2 and TP3.

The laboratory tests .2/3.



At the link system level:

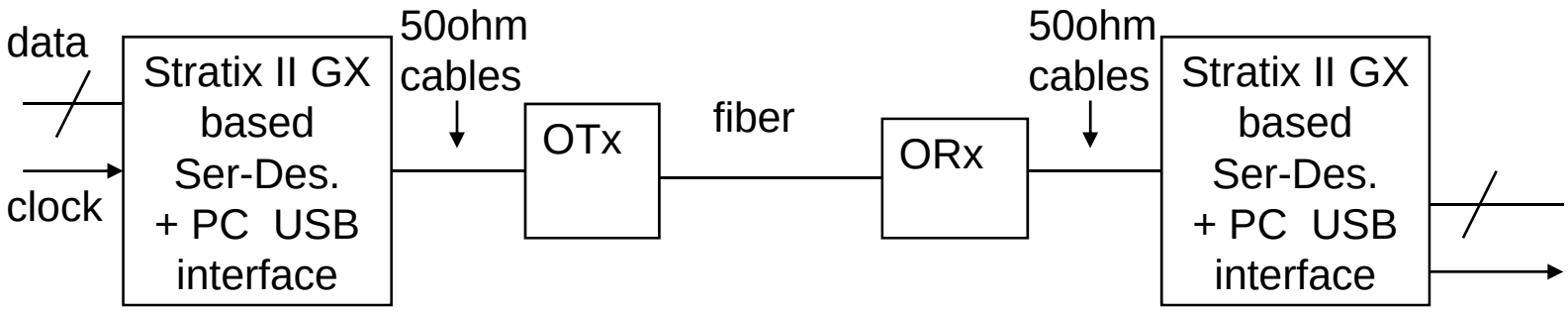
5. The BER as a function of the input optical power to ORx.
6. The maximum transmission range (the length of the fiber) at the specified bit error rate (BER) or mask margin over a certain type of fiber at the specified data rate.
7. The reference clock jitter tolerance as a function of the bit error rate (BER).
8. Other general system parameters: power supply voltages and consumption of each component, optical power margins and a powering up/reset scheme.
9. The measurement of the system should cover a range of operational conditions such as temperature, humidity, vibration, magnetic field, if applicable.

The laboratory tests .3/3.

At component or subassembly level

1. The serializer reference clock jitter transfer function.
2. The latency introduced at each component (serializer, OTx, etc) level.
3. The serial bit stream jitter measurements at TP1, TP2, TP3 and TP4, hence to learn the jitter contribution from the OTx and the ORx and the signal dispersion introduced by the fiber.
4. The optical power output of the OTx.
5. The optical power attenuation of the fiber.
6. The sensitivity of the ORx (for example at BER of 10^{-12}), hence the optical power budget is measured.

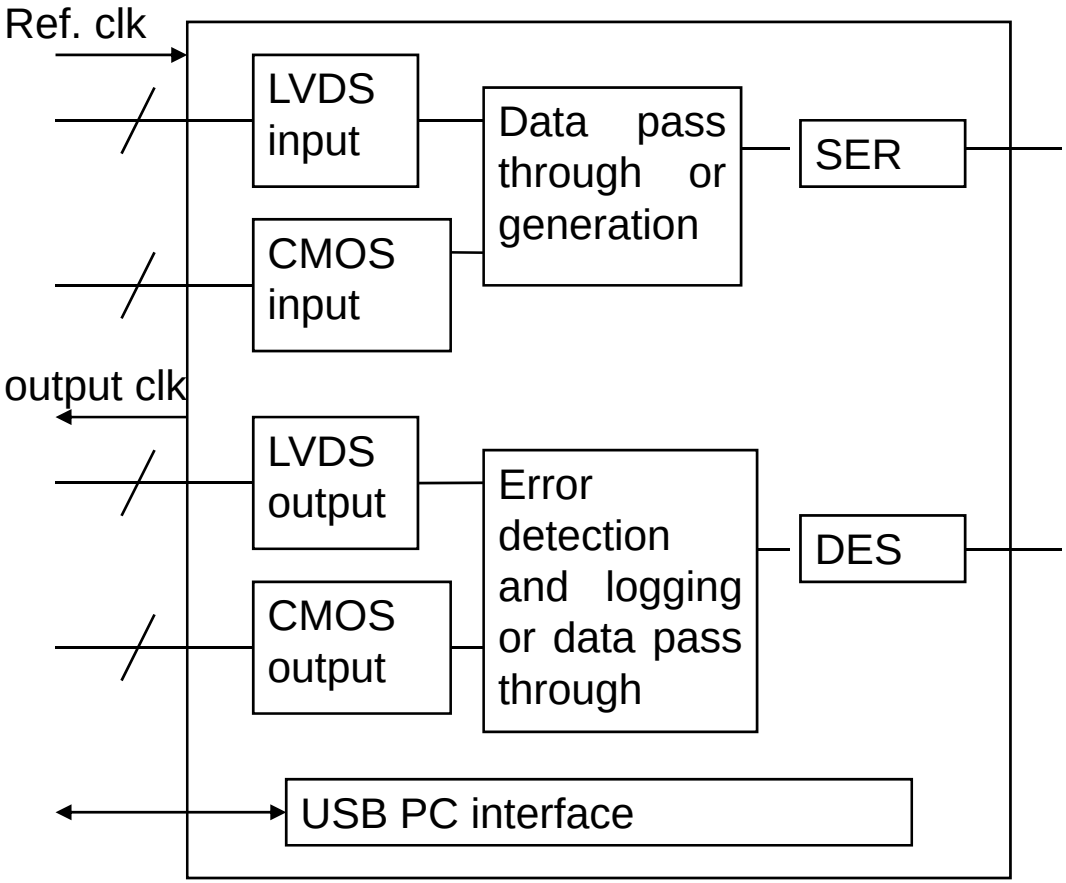
The reference optical link and a standardized test setup .1/3.



- Reference optical link:
  - Three boards:
    - the FPGA board: data generation, error detection (BERT), ser-des, PC interface (USB).
    - The OTx board: laser driver, laser.
    - The ORx board: PIN diode, trans-impedance-amplifier, limiting amplifier.

The reference optical link and a standardized test setup .2/3.

❖ Function blocks inside the FPGA:

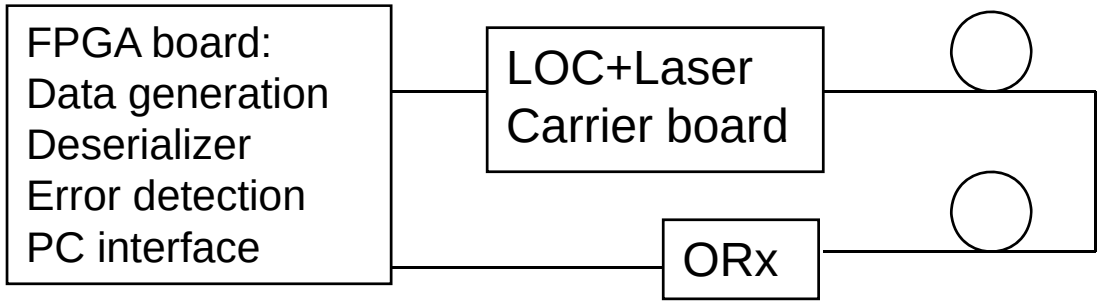


Error detection scheme:

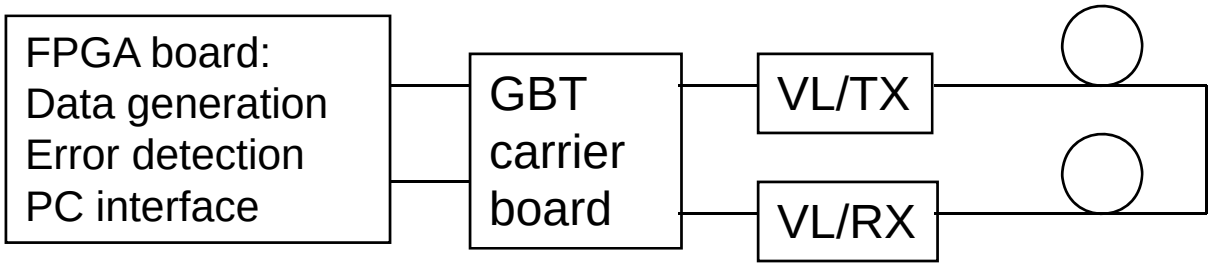
1. With frame locked.
   a) Single bit flip. Time stamp, flipped bit location and flip type (1 to 0 or 0 to 1)
   b) Multiple bit flips. Time stamp and number of flips.
2. Frame loss error. Defined as bit flips in two+ consecutive words. Record the length of frame loss.

Examples of using the reference link .3/3.

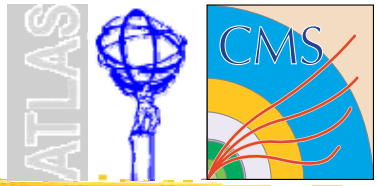
- As a reference to a custom link at system or component evaluation level.
- Constructing optical links with custom components for in-lab and irradiation tests.
  - Test the LOC:



  - Test the GBT and/or Versatile Link (VL):



Summary



Test procedures and evaluation criteria for radiation resistant optical links for the SLHC upgrade are discussed. The in-lab functional tests are described in this document, while the irradiation evaluation and tests are discussed in the subgroup B report. A specially designed reference optical link is proposed to benchmark the developed links, to standardize their testing, and to simplify the test preparations. Based on this reference link, standardized test systems can be constructed for component and subassembly tests.