80Mbit/s Digital Optical Links for Control, Timing and Trigger of the CMS Tracker

Part I. System Overview
Part II. Prototype Testing

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Tracker Optical Links

Analogue Readout
40000 links @ 40MS/s

Digital Control
2300 links @ 40MHz

Front-End

Back-End

10. September 2002
Digital Optical Control System
## Tracker Requirements

<table>
<thead>
<tr>
<th>Item</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength (nm)</td>
<td></td>
<td>1310 nm</td>
<td></td>
<td>To share analogue readout link components</td>
</tr>
<tr>
<td>Speed (Mbit/s)</td>
<td>2</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bit-error-rate</td>
<td></td>
<td>$10^{-12}$</td>
<td>$10^{-9}$</td>
<td></td>
</tr>
<tr>
<td>Jitter (ns)</td>
<td></td>
<td>0.5</td>
<td></td>
<td>rms</td>
</tr>
<tr>
<td>Skew (ns)</td>
<td></td>
<td>2</td>
<td></td>
<td>Fibres to or from same optohybrid</td>
</tr>
</tbody>
</table>

- **Tracker environment**
  - $T \sim -10^\circ C$
  - $B = 4T$
  - $150kGy \& 3 \times 10^{14} \pi/cm^2$ radiation dose
  - 10 years min. lifetime
Final p-i-n diodes and back-end Transceiver still to be procured
Prototype Testing

- DOH (3/5 Parts)
  - ASIC made at CERN
  - Dimensions:
    - Footprint: 35x25mm
    - Height: 5mm

- TRx (5/10 Parts)
  - Commercial 4 way 2.5 Gbit/s Transceiver from NGK Optobahn

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Digital optohybrid</th>
<th>NGK Transceiver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Power</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Saturation</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Reset</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Minimum Data Rate</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Measurement setup DOH

- BERT
- Reference Optohybrid
- I2C
- Optohybrid under test
- Optical attenuators

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Digital Optical Control System
TRx test setup
**Tx Characteristics**

![Graph showing average launched power vs. signal amplitude for DOH and TRx.]

- **DOH:**
  - Average launched power: -6.7 dBm
  - Signal Amplitude: -8.5 dBm

- **TRx:**
  - Typical eye-pattern from TRx
  - Signal Amplitude: -8.5 dBm
  - Average launched power: -6.7 dBm
Rx Sensitivity & Saturation

Example of bit-error-rate versus average launched power
Rx characteristics

- **DOH**
  - RX40 Specs
  - Sensitivity ~ -20 dBm
  - Saturation ~ -3 dBm

- **TRx spec**:
  - Sensitivity ~ -18 dBm
  - Saturation ~ -5 dBm
Full link

- Full link made with DOH, TRX, 100m cable + 3 ‘patch-panels’

- Optical power margins measured in each channel
  - optical attenuation increased to point where errors occur or link fails
    - From DOH to TRx
    - Clock: ~17.5dB
    - Data: ~17.5dB
    - From TRx to DOH
    - Clock: ~9.5dB
    - Data: ~10dB

- Two Links tested with attenuation for 15 hours without any errors BER < 3* 10^{-13}
Summary

- 80Mbit/s digital links developed at CERN for CMS Tracker control
  - will also be used by ECAL, Preshower and Pixels

- Philosophy has been to (re)use analogue link components

- Extensive testing of the prototype DOH and NGK-TRx
  - Devices work well and compatible with intended link system
  - Testing procedures in place for production

- Full prototype link with DOH, TRX and realistic cabling tested
  - operates with a large safety margin
  - BER < 10^{-12}

- The remaining specs and interfaces to be frozen end of 2002, procurement of devices to start in 2003
• More information on the Digital Optical Links:

http://cern.ch/cms-opto