ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

CMS Tracker Optical Readout Link Specification

Part 2.2: Laser Transmitter

Version 3.2, 27 April 2001

CERN EP/CME

1. Introduction

1.1. General system description

This specification defines the design requirements for the analogue optical link to be used in the readout system of the tracker sub-detector of the CMS detector [1.1] at the CERN [1.2] Large Hadron Collider (LHC). The tracker sensing elements are silicon microstrip detectors. The approximate total number of detector channels is 10 millions, to be multiplexed and read-out by approximately 40000 optical links (plus spares). A thorough description of the CMS tracker is found in [1.3].

The CMS tracker optical readout link is embedded into the data acquisition chain shown in Fig. 1.1. It starts at the electro-optic opto- hybrid interface and ends at the opto-electric receiver module interface. Specifications for the Front End Driver board (FED), MUX and APV front-end chips can be found in: [1.4] and [1.5]

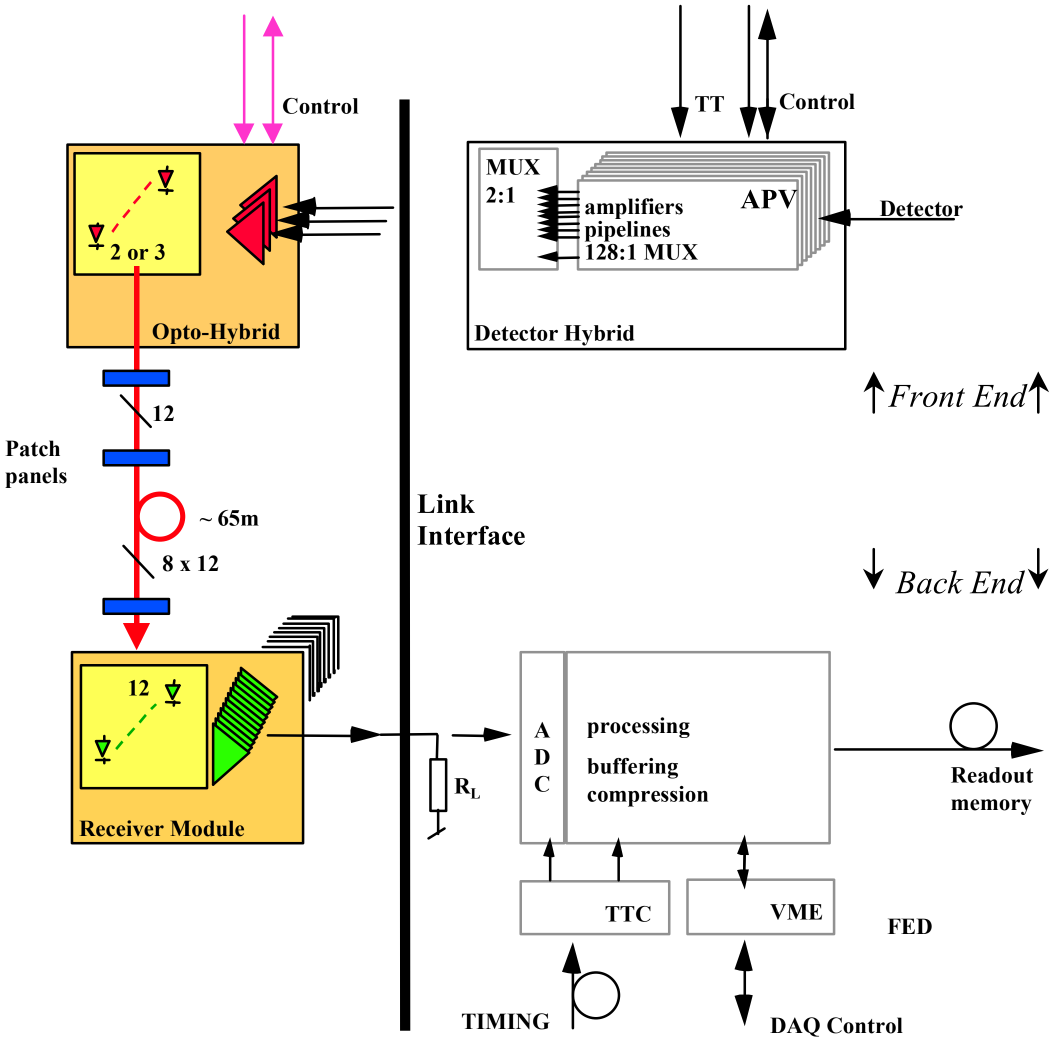


Fig. 1.1. Tracker readout chain with optical link highlighted on the left.

To ease the understanding and use of this document, a brief explanation of the CMS tracker sub-detector data flow is given below. A more detailed description of the CMS tracker readout chain can be found for instance in [1.6].
Signals from all sensor channels are sampled and stored every 25ns in the APV front-end chip analogue memory. In the event of a Level 1 trigger occurrence (TT), the analogue samples corresponding to the time slice of interest in the memory are processed, time multiplexed and transferred in packet form from the detector hybrids to the opto-transmitter hybrids via short lengths of flexible cable tape (0 to 30 cm typ.). They are then sent via optical fibres to the receivers situated at the link back-end, where they are converted back to electrical. A to D conversion, processing and buffering take place on the Front End Driver (FED) boards before the data packets are sent out to the readout memory and computer farms.

1.2. Document structure and convention

The optical link specification is broken down into eight independent parts, each describing and specifying a different level or function in the system:

Part 1. System

Part 2. Analogue Opto- Hybrid
- 2.1 Laser Driver
- 2.2 Laser Transmitter
  - 2.2.1 Terminated Pigtail
    - 2.2.1.1 Buffered Fibre
- 2.3 Analogue Opto-Hybrid Substrate

Part 3. Terminated Fibre Ribbon
- 3.1 Ruggedized Ribbon

Part 4. Terminated Multi-Ribbon Cable
- 4.1 Dense Multi-Ribbon Cable

Part 5. Analogue Opto-Receiver Module
- 5.1 Analogue Receiving Amplifier

Part 6. Distributed Patch Panel
- 6.1 MU-SR Adaptor

Part 7. In Line Patch Panel
- 7.1 Connector shell

Part 8. Backend Patch Panel
- 8.1 Connector shell

Each part has the following structure:

1. Introduction
   - 1.1. System description
   - 1.2. Document structure
   - 1.3. Related WWW sites
   - 1.4. Contact
   - 1.5. Document history
2. Technical requirement
   - 2.1. description
   - 2.2. block diagram
   - 2.3. specification
   - 2.4. operating environment
   - 2.5. other characteristics
   - 2.6. testing
   - 2.7. option (when required)
3. Glossary
4. References

Due to the preliminary nature of this document, the specification section (section 2.3) of each system part is labelled "target specifications". CERN should be consulted before any hard- or software relying on these characteristics is being designed. Target specifications will eventually evolve into full specifications once the system definition is mature. Still to be determined parameters are labelled TBD.

1.3. Related WWW sites

- CERN laboratory: http://www.cern.ch/Public/
- CMS project: http://cmsinfo.cern.ch/Welcome.html
- CMS Tracker Technical Design Report: http://cmsdoc.cern.ch/ftp/TDR/TRACKER/tracker.html
- CMS Tracker Electronic System: http://pcvlsi5.cern.ch:80/CMSTControl/
- CMS Tracker Optical Links: http://cms-tk-opto.web.cern.ch/
- FED developments: http://hepwww.rl.ac.uk/cms_fed/
- APV and MUX developments: http://www.te.rl.ac.uk/med/

1.4. Contact

All questions regarding this document should be addressed to:

F. Vasey
EP Division
CERN
CH-1211 Geneva 23

Fax: +41 22 767 2800
Phone +41 22 767 3885
E-mail francois.vasey@cern.ch

1.5. Document history

Rev. 0.4, 02/08/96	Draft
Rev. 1.0, 04/09/97	Major rework, single document covering all system parts
Rev. 2.0, 05/06/98	Rework, document distributed
Rev. 3.0, 06/04/00	Document (Rev2.3) split into independent parts.
Rev. 3.1, 18/08/00	Connector type specified, test requirements specified, Integral Linearity Deviation re-specified, Spec 2.2.4 added
Rev. 3.2, 27/04/01	Document in conformity with Invitation to Tender

2. Technical requirement, part 2.2: Laser Transmitter

2.1. Description

The laser transmitter converts into optical signals the electrical signals generated by the laser drivers (2.1). It consists of an edge emitting MQW semiconductor laser diode emitting light into a single-mode optical fibre exiting the package in pigtail form. The fibre connection linking the laser transmitter optical output to the distributed patch panel (6) is specified in (2.2.1).

About 50000 laser transmitter channels will be required for the CMS tracker detector readout links.

2.2. Block diagram

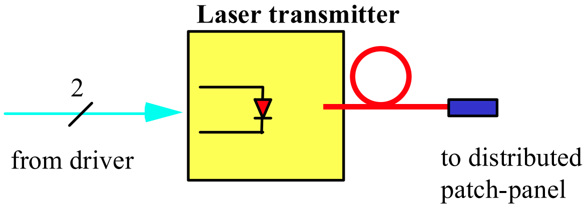


Fig. 2.1. Laser transmitter block diagram

2.3. Target Specifications (@25°C unless otherwise noted)

Note: the laser pigtail is specified separately in the technical requirement part 2.2.1

#	operational specifications	min	typ	max	unit	note
2.2.1	Number of channels		1			
2.2.2	Integral linearity deviation			1	%	in any 1.5mA and 3mA window in a 9mA input range above Ith+0.5mA, see glossary 3.2
				2	%	in any 6mA window in a 9mA input range above Ith+0.5mA, see glossary 3.2
2.2.3	Tensile load on connector side of pigtail			7	N	installation
				3	N	operation
2.2.4	Tensile load on submount side of pigtail			3	N	Installation TBD
				1	N	Operation TBD
2.2.5	Pigtail length Lp	0.3		3	m	To be defined at time of quarterly batch request. Lp is distributed in typ. 10 to max. 15 standard lengths, with tolerance: +20mm, –0mm
2.2.6	Target size	5x5x2			mm	LxWxH
	specs 2.2.7 to 2.2.20					unused

#	electrical specifications	min	typ	max	unit	note
2.2.21	Max. input current	60	100		mA	
2.2.22	Threshold current			12	mA	at start of life

2.2.23	Forward voltage		1.2	1.75	V	at start of life, at 60 mA
2.2.24	Reverse voltage	2			V	
2.2.25	Rise / fall time			1	ns	
	specs 2.2.26 to 2.2.40					unused

#	optical specifications	min	typ	max	unit	note
2.2.41	Wavelength	1285	1310	1335	nm	
2.2.42	Fibre output power	1.3	1.6	1.9	mW	at start of life, at Ith+40mA drive current
2.2.43	Slope efficiency	0.032	0.04	0.048	mW/mA	at start of life
2.2.44	RIN		-130		dB/Hz	200µW output power, 10MHz
	specs 2.2.45 to 2.2.60					unused

2.4. Operating environment

#	environmental specifications	min	typ	max	unit	note
2.2.61	Magnetic field			4	T	parallel to any axis
2.2.62	Hadronic fluence[1]			3e14	1/cm^2	Integrated over lifetime [2] 90% charged particles 10% neutrons
2.2.63	Gamma radiation dose[1]			1.5e5	Gy(Si)	Integrated over lifetime [2]
2.2.64	Temperature	-20	-10	70	°C	Operation and storage
2.2.65	Operating humidity	dry Nitrogen flow				
	specs 2.2.66 to 2.2.80					unused

[1]The component resistance to radiation will be verified under the sole responsibility of CERN.
[2]Foreseen operating lifetime: nominal 10 years.

#	safety specifications		note
2.2.81	Optical	laser class 3A	IEC 60825-1 1998-01 IEC 60825-1 amendment 2 2001-01
2.2.82	Material composition	Halogen-free, flame retardant material	CERN IS41, see reference [2.2].
	specs 2.2.83 to 2.2.99		unused

2.5. Other Characteristics

- <u>electrical interface</u>

Bonded connections to laser driver on opto-hybrid (laser anode, laser cathode).

- optical interface (see 2.2.1 for pigtail specification)

Fibre type Single mode, 9/125/250/900µm, tight buffered jacket (TBD)
Fibre length 0.3m to 3m (TBD, dependent on hybrid geometrical position)

Length tolerance +20mm –0mm
Connector type MU

- <u>package</u>

housing non-metallic, to be glued on transmitter hybrid
fibre strain relief 250µm primary coating attached to housing. 900µm buffer either attached to housing, or to start ≤3.5mm after submount edge (TBD).
labeling on connector

- <u>Test Documentation and traceability</u>: TBD

- <u>Shipping and storage requirements</u>: TBD

2.6. Testing

#	Specification to be tested	Manufacturer		CERN		
		Product Qualification	Lot validation (before delivery)	Advance Sample Validation	Pre-production Qualification	Lot Accept-ance
2.2.1	Number of channels	♦	♦	♦	♦	♦
2.2.2	Integral linearity deviation	♦			♦	♦
2.2.3	Tensile load on connector side of pigtail	♦	♦		♦	
2.2.4	Tensile load on submount side of pigtail	♦	♦		♦	
2.2.5	Pigtail length Lp	♦	♦		♦	♦
2.2.6	Target size	♦	♦		♦	♦
2.2.21	Max. input current	♦	♦		♦	♦
2.2.22	Threshold current	♦	♦		♦	♦
2.2.23	Forward voltage	♦	♦		♦	♦
2.2.24	Reverse voltage	♦	♦			
2.2.25	Rise / fall time	♦	♦		♦	♦
2.2.41	Wavelength	♦	♦		♦	
2.2.42	Fibre output power	♦	♦		♦	♦
2.2.43	Slope efficiency	♦	♦		♦	♦
2.2.44	RIN	♦	♦		♦	
2.2.61	Magnetic field				♦	
2.2.62	Hadronic fluence[1]			♦	♦	
2.2.63	Gamma radiation dose[1]			♦	♦	
2.2.64	Temperature	♦				
2.2.65	Operating humidity	♦				
2.2.81	Optical safety					
2.2.82	Material composition	♦				

3. Glossary

This glossary is common to all parts of both the control link and the readout link specification. Some definitions may thus not be relevant to the part under consideration.

3.1. Signal to noise ratio

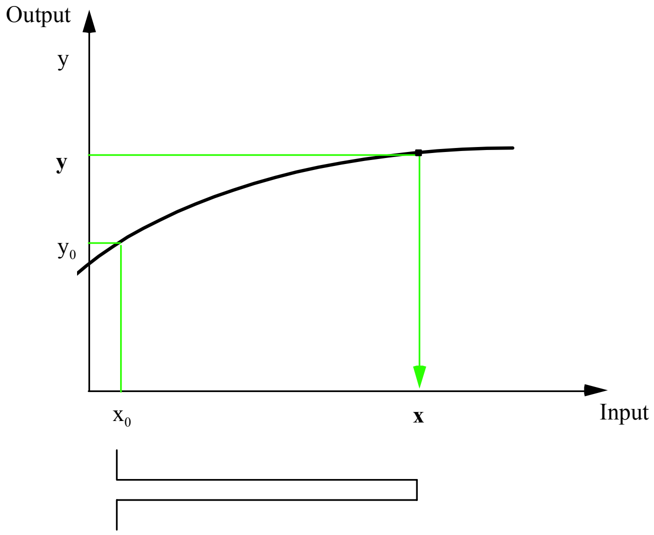


Fig. 3.1. Signal to noise ratio

The signal is defined as $\Delta y = y - y_0$, where y_0 is the system quiescent working point.
The rms noise y_{rms} is defined as the noise spectral density integrated over the full optical link bandwidth.

The signal to noise ratio (SNR) is defined as:

$$SNR = 20 Log \frac{Signal}{rmsNoise} = 20 Log \frac{|\Delta y|}{y_{rms}}$$

The peak signal Δy_{peak} is the largest amplitude which can be handled by the optical link in its linear operating range. The peak signal to noise ratio (PSNR) is defined as:

$$PSNR = 20 Log \frac{|\Delta y_{peak}|}{y_{rms}}$$

3.2. Integral Non-Linearity

The integral non-linearity INL is defined as the full-scale-normalized error one makes when, for a given link output signal y, the link input signal is assumed to be the linearized value x_L instead of the real value x.

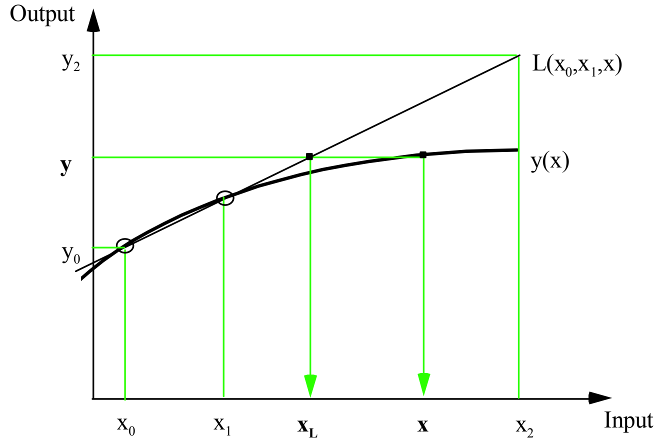


Fig. 3.2. Integral non-linearity

The linear regression is calculated by fitting the transfer characteristic in a linear operation window $]x_0, x_1]$ (alternatively $]y_0, y_1]$ in the output range) .

INL is defined as the error one makes when approximating x by x_L, normalised by the full-scale signal:

$$INL = \frac{x - x_L}{x_2 - x_0}$$

3.3. Settling time

The settling time is defined as the time required for a step response signal to settle to ±1% of its end value.

3.4. Skew

The skew is determined by measuring, for two channels, the average time $\overline{t_{50}}$ required for a step response signal to reach 50% of its end value. The skew between channels i and j is defined as:

$$t_{skew} = \overline{t_{50,\,j}} - \overline{t_{50,i}}$$

3.5. Jitter

The rms jitter is defined as the rms deviation of the time t_{50} required for a step response signal to reach 50% of its end value:

$$t_{jitter} = \sqrt{(t_{50} - \overline{t_{50}})^2}$$

3.6. Crosstalk

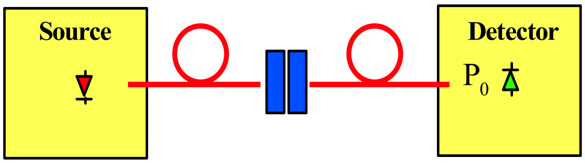
The crosstalk between two channels i and j is defined as the relative feedthrough from channel i to channel j at sampling time t_s=20ns when an ideal step signal is injected into channel i at t=0s.

$$\text{Crosstalk} = 20\,\text{Log}\left|\frac{\text{Out}_j}{\text{Out}_i}\right|_{t_s=20\,\text{ns}}$$

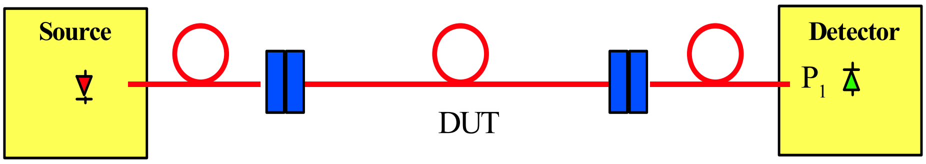
3.7. Insertion loss

The insertion loss (IL) is defined as the Log of the ratio of optical powers measured before (P0) and after (P1) insertion of the device under test (DUT). In case the DUT is a single connector, optical power (P0 and P1) is measured with a large area detector in a receptacle.

a) Launched power measurement (P0)



b) Transmitted power measurement (P1)



c) Insertion loss: $\text{IL} = 10\text{Log}\dfrac{P_0}{P_1}$

3.8. Power supply rejection ratio

The power supply rejection ratio (PSRR) is defined as the amplitude of a sinusoidal disturbance Δd injected into the power supply rail and causing a ripple Δy on the output of the device under test, divided by the input signal Δx which would cause an identical ripple Δy .

$$PSRR = 20Log\frac{\Delta d}{\Delta x}$$

4. References

[1.1] http://cmsinfo.cern.ch/cmsinfo/Welcome.html
[1.2] http://www.cern.ch/
[1.3] The tracker project, technical design report, CERN/LHCC 98-6, CMS TDR 5
[1.4] R. Halsall, "FED specifications", Draft, RAL, http://hepwww.rl.ac.uk/cms_fed/
[1.5] M. French, "APV specifications", Draft, RAL, http://www.te.rl.ac.uk/med/
[1.6] G. Hall, "Analogue optical data transfer for the CMS tracker", Nuclear Instruments and Methods in Physics Research A, Vol. 386, pp. 138-42, 1997, http://pcvlsi5.cern.ch:80/CMSTControl/documents/Geoff/Readout_summary.pdf
[1.7] A. Marchioro, " Specifications for the Control Electronics of the CMS Inner Tracker", Draft V2, CERN, http://pcvlsi5.cern.ch:80/CMSTControl/manuals.htm
[1.8] A. Marchioro, "FEC specification", Draft, CERN
[1.9] A. Marchioro, "CCU specification", Draft, CERN, http://pcvlsi5.cern.ch:80/CMSTControl/manuals.htm
[2.1] M. Huhtinen, "Studies of neutron moderator configurations around the CMS inner tracker and Ecal", CERN CMS TN/96-057, 1996.
[2.2] http://www.cern.ch/CERN/Divisions/TIS/safdoc/instr_en.html