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 2.1: Laser Driver

Version 4.0, 25 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]

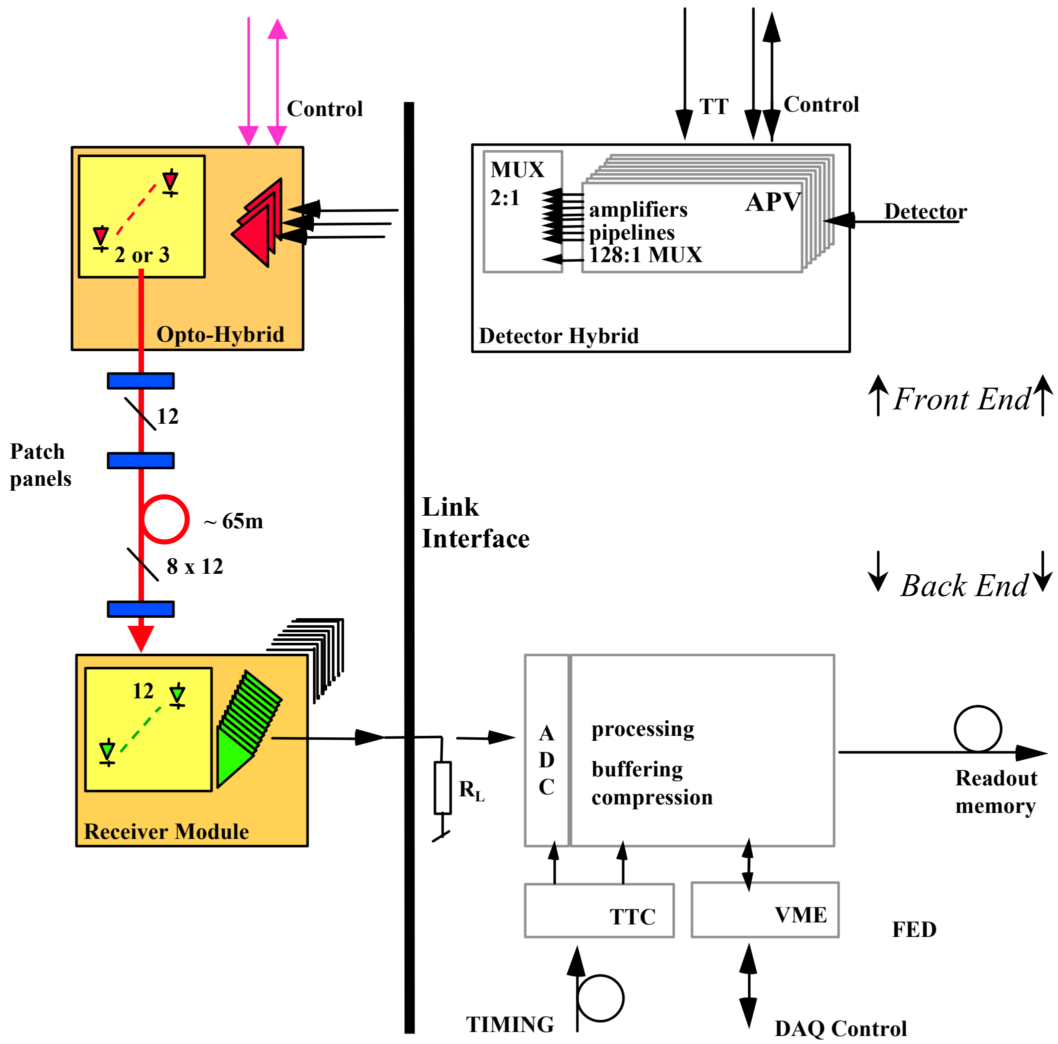


Fig. 1.1. Tracker readout chain with optical link highlighted on the left.

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

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. 3.2, 15/08/00 Introduction and Glossary added. Testing section added. Spec 2.1.7 made min
Rev. 4.0, 25/04/01 New chip design, current source option removed (2.1.30), quiescent output current decreased to 0 (2.1.34), channel count decreased to 3 (2.1.1)

2. Technical requirement, part 2.1: laser driver

2.1. Description

The laser driver converts a differential input voltage into a single ended output current superimposed on a presettable constant pre-bias. 3 channels can be individually addressed via an I2C interface, allowing channel masking and pre-bias control. Input voltage levels are comparable to digital LVDS standard, but the driver is optimised for analogue operation.
About 19000 3-way laser drivers will be required for the CMS tracker detector readout links.

2.2. Block Diagram

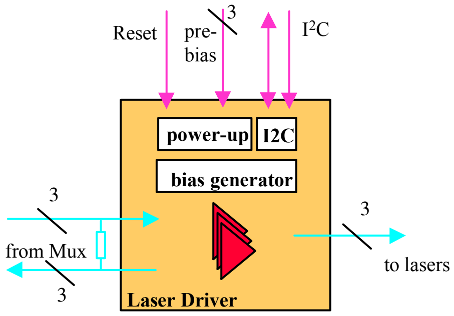


Fig. 2.1. Laser driver block diagram

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

#	operational specifications	min	typ	max	unit	note
2.1.1	Number of channels	3				individually maskable
2.1.2	Integral linearity deviation			0.5	%	in any 100mV and 200mV window within operating input range see glossary 3.2
				1	%	in any 400mV window within operating input range see glossary 3.2
2.1.3	Bandwidth	100			MHz	DC coupled
2.1.4	Settling time to ±1%			10	ns	see glossary 3.3
2.1.5	Skew			0.5	ns	see glossary 3.4
2.1.6	Jitter			0.1	ns	rms, see glossary 3.5
2.1.7	Crosstalk	-60			dB	see glossary 3.6
	specs 2.1.8 to 2.1.20					unused

#	electrical specifications	min	typ	max	unit	note
2.1.21	Input voltage range	-0.5		+0.5	V	differential
2.1.22	Max. operating* input voltage range	-0.3		+0.3	V	differential
2.1.23	Input impedance	100		5	kΩ pF	see 2.4 for specified external input termination
2.1.24	Equivalent input noise			0.8	mV	Rms in 150MHz bandwidth
2.1.25	Common mode range at input	±250			mV	Referred to (Vdd-Vss)/2
2.1.26	Input common mode rejection ratio	40			dB	At 1MHz, in ±250mV input common mode range, Referred to (Vdd-Vss)/2
2.1.27	Power supply rejection ratio	30			dB	At 1MHz, for any pre-bias value between zero and half maximum. see glossary 3.8
2.1.28	Output voltage	Vss +0.5		Vdd -0.5	V	Single ended ESD protected outputs
2.1.29	Transconductance	4	5	6	µA/mV	Individually pre-settable for each channel via I2C
		6	7.5	9		
		8	10	12		
		10	12.5	15		
2.1.30	Current generator type	Current sink				
2.1.31	Output current range	45	55	65	mA	at maximum pre-bias, 0V input
2.1.32	Quiescent operating point	user adjustable via IIC interface, 7bits pre-bias resolution (X_1 to X_7) X_1 to X_7 =0≡channel masked				defined at 0V differential input
2.1.33	Quiescent operating point resolution (X_1=LSB)	0.35	0.43	0.51	mA	Any LSB step (X_1) over 7 bit range (see also 2.1.32)
2.1.34	Minimal quiescent output current (X_1=1, X_2 to X_7 =0)	0.35	0.43	0.51	mA	0V input
2.1.35	Hardware Reset	Active low				
2.1.36	Quiescent operating point after reset	Preset via 3 hardwired input bits X_7 X_6 X_5, corresponding to the 3 MSbs of the 7bit pre-bias register. The 4LSbs are reset.				Common to all channels. Internal pull-down resistors. X=0≡pad left open, X=1≡pad externally hardwired to Vdd.
2.1.37	Power supply	2.25	2.5	2.7	V	Vdd-Vss
2.1.38	Power dissipation		30		mW	per optical channel at min pre-bias
			200		mW	per optical channel at max pre-bias
	specs 2.1.39 to 2.1.40					unused

* The operating range is defined as the range where linearity can be guaranteed (see also glossary 3.2)

2.4. Operating environment

#	environmental specifications	min	typ	max	unit	note
2.1.61	Magnetic field			4	T	parallel to particle beam axis
2.1.62	Hadronic fluence			3e14	$1/cm^2$	Integrated over lifetime[1], 90% charged particles, 10% neutrons, see ref. [2.1]
2.1.63	Gamma radiation dose			1.5e5	Gy (Si)	see ref. [2.1]
2.1.64	Temperature	-20		70	°C	Operation and Storage
2.1.65	Operating humidity	Dry lab environment during testing and dry Nitrogen flow during operation.				
	Specs 2.1.66 to 2.1.80					unused

[1]Foreseen operating lifetime: nominal 10 years.

2.5. Other characteristics

- electrical interface

Soldered (possibly bonded) connections to opto-hybrid.
External 100 Ω termination resistor on differential input lines.

- package

ASAT 32L LPCC 5x5mm (32 pins), possibly bare die

- Test Documentation and traceability
- Shipping and storage requirements

2.6. Testing

#	Specification to be tested	CERN	
		ASIC qualif.	All devices
2.1.1	Number of channels	♦	♦
2.1.2	Integral linearity deviation	♦	
2.1.3	Bandwidth[1]	♦	♦
2.1.4	Settling time to ±1%		
2.1.5	Skew	♦	
2.1.6	Jitter	♦	
2.1.7	Crosstalk	♦	
2.1.21	Input voltage range	♦	♦
2.1.22	Max. operating* input voltage range	♦	♦
2.1.23	Input impedance	♦	
2.1.24	Equivalent input noise	♦	
2.1.25	Common mode range at input	♦	
2.1.26	Input common mode rejection ratio	♦	
2.1.27	Power supply rejection ratio	♦	
2.1.28	Output voltage	♦	♦
2.1.29	Transconductance	♦	♦
2.1.30	Current generator type	♦	
2.1.31	Output current range	♦	♦
2.1.32	Quiescent operating point	♦	♦
2.1.33	Quiescent operating point resolution (X_1=LSB)	♦	♦
2.1.34	Minimal quiescent output current (X_1=1, X_2 to X_7=0)	♦	♦
2.1.35	Hardware Reset	♦	♦
2.1.36	Quiescent operating point after reset	♦	♦
2.1.37	Power supply	♦	
2.1.38	Power dissipation	♦	♦
2.1.61	Magnetic field	♦	
2.1.62	Hadronic fluence	♦	
2.1.63	Gamma radiation dose	♦	
2.1.64	Temperature	♦	
2.1.65	Operating humidity		

[1]rise time and fall time measurement

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

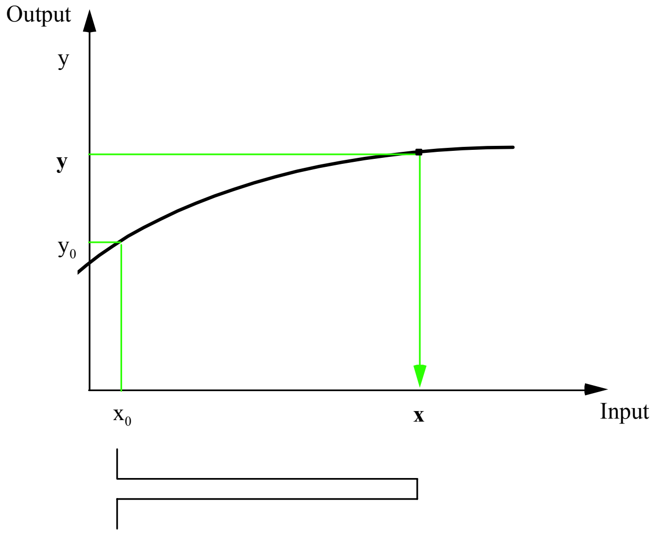


Fig. 3.1. Signal to noise ratio

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.

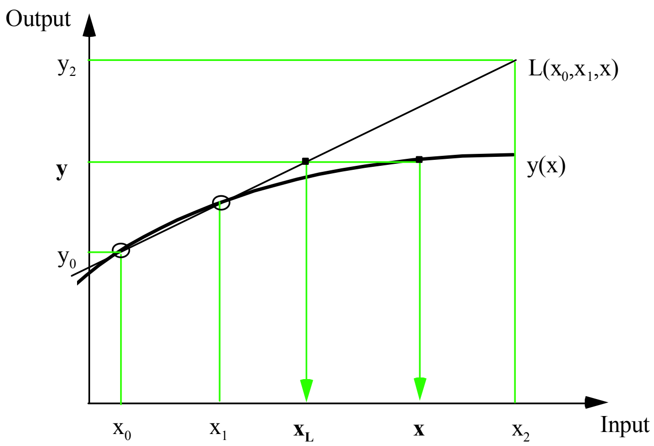


Fig. 3.2. Integral non-linearity

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

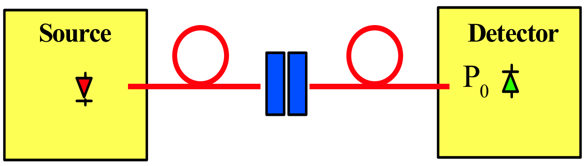
The crosstalk between two channels i and j is defined as the relative feedthrough from channel i to channel j at sampling time t_s=20ns when an ideal step signal is injected into channel i at t=0s.

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

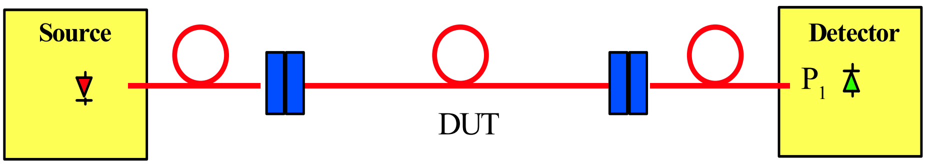
3.7. Insertion loss

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: $IL = 10\text{Log}\frac{P_0}{P_1}$

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 .

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

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/documents/Sandro/Ccu260598.pdf

[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