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 5: Analogue Opto-Receiver Module

Preliminary **Version 1.1, 30 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]

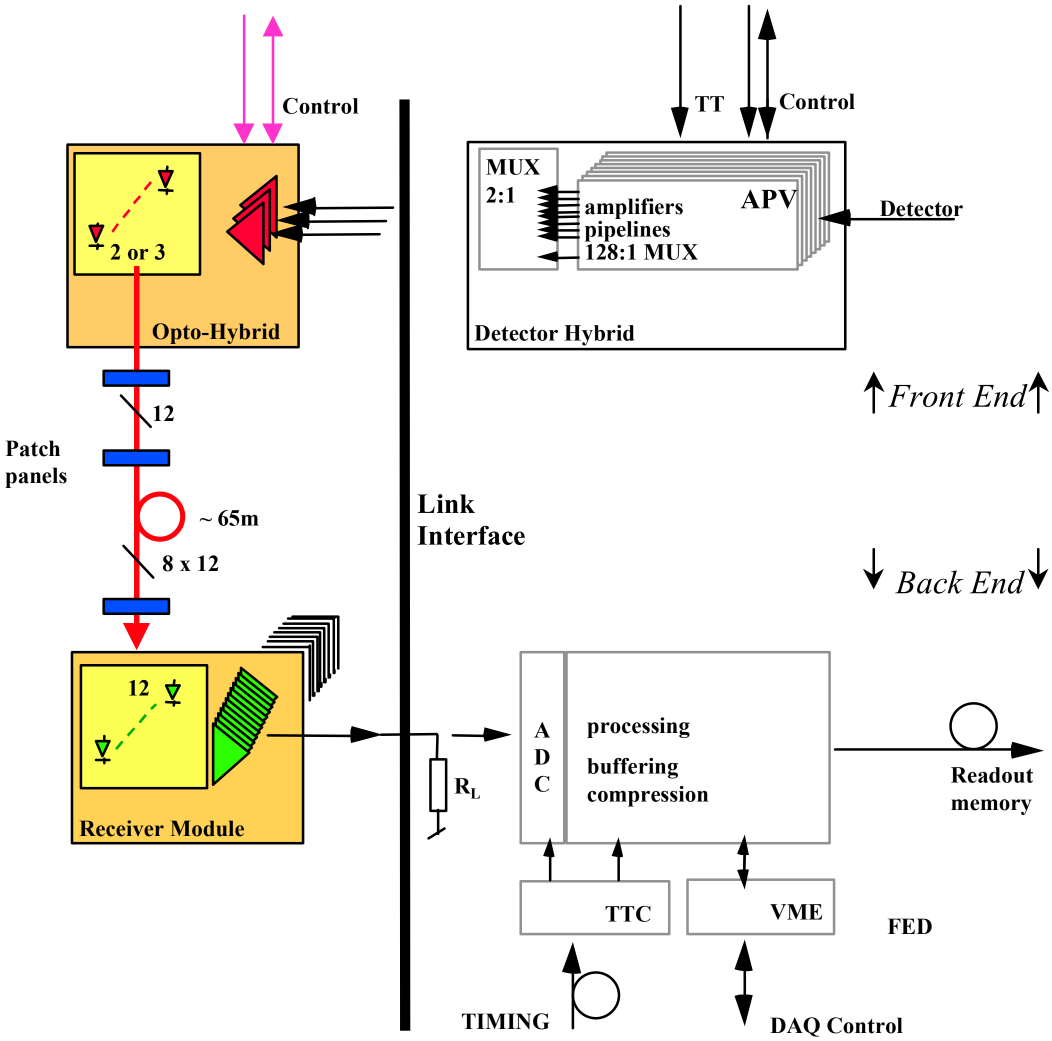


Fig. 1.1. Tracker readout chain with optical link highlighted on the left.

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. 1.1, 30/04/01 based on market survey document

2. Technical requirement, part 5: Analogue Opto-Receiver Module

2.1. Description

The 12-channel analogue opto-receiver module consists of a sealed package housing a 12-channel pin-photodiode array bonded to a 12-channel current amplifier array. The amplifier chip, to be designed and supplied by a CERN appointed supplier, is described in part 5.1. The optical interface to the module is via a 12-channel connector, based on a MT-ferrule. This connector is part of the package (receptacle). The electrical connections to the module are achieved with a surface mount leadframe.
About 4500 12-channela analogue opto-receiver modules will be required for the CMS tracker detector readout links.

2.2. Block Diagram

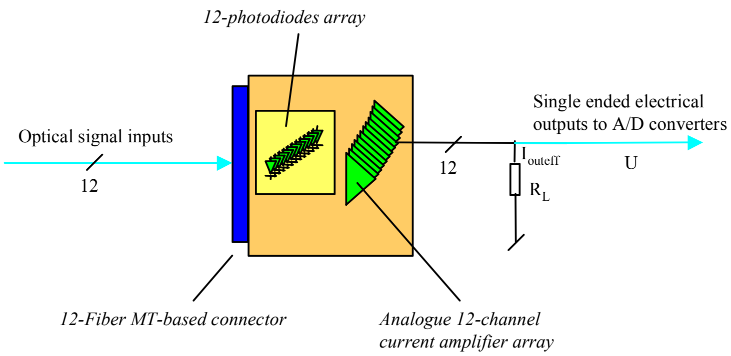


Fig. 1.1. Analogue receiver block diagram

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

Note: the Analogue Receiving Amplifier ASIC is specified separately in the technical requirement part 5.1.

#	operational specifications	min	typ	max	unit	note
5. 1	Number of channels	12				
5.2	Number of electrical pins	40	50			12 single ended outputs
5.3	Integral linearity deviation			0.5	%	in any 29µW and 57µW window within operating input range
				1	%	in any 114µW window within operating input range
5.4	Bandwidth		100		MHz	DC coupled, see also max load spec 5.26
5.5	Settling time to ±1%			15	ns	
5.6	Skew			1.5	ns	
5.7	Jitter			0.5	ns	rms
5.8	Crosstalk		-60		dB	See glossary, section 3.6
5.9	Responsivity	27	34	42	A/W	Current sourced into R_L
	specs 5.10 to 5.20					reserved for future use

#	electrical specifications	min	typ	max	unit	note
5. 21	Photocurrent input range **Iph**	0		300	µA	
	Effective input current **Ipheff**	Ipheff = Iph – Iphoff				Iphoff user adjustable from –200 to 175µA with 4bits (X_1 X_2 X_3 X_4), 25µA resolution
5.22	Output current range **Iout**	0		13	mA	Within output voltage range.
	Effective output current **Iouteff**	Iouteff=Iout+Ioutoff				Ioutoff user adjustable from 2.5 to 10mA with 2bits (X_5 X_6), 2.5mA resolution
5.23	Control inputs X_1 X_2 X_3 X_4 X_5 X_6	CMOS compatible, active high				Internal pull up resistors TBD
5.24	Output voltage range	0.4		3	V	ESD protected outputs
5.25	Load Resistance $\mathbf{R_L}$	50	100	200	Ω	
5.26	Output loading		1.6	2.5	ns	$\tau = C_L * R_L$
5.27	Equivalent input noise		50		nW	Rms in 100MHz bandwidth @ Pin = 100µW
5.28	Power supply	4.5	5	5.5	V	Vcc - Vee
5.29	Power dissipation			3	W	12 Channels, X_5,X_6 on, to be minimized
				2.5	W	12 Channels, X_5,X_6 off, to be minimized
5.30	Output track capacitance			4	pF	
5.31	Pin diode rise/fall time			2	ns	Into 50 Ω load
5.32	Pin diode capacitance	0.6	0.8	1.0	pF	Including connection to Rx ASIC
5.33	Pin diode dark current		0.05	1	nA	
5.34	Pin diode absolute maximum photo current			3	mA	
5.35	Pin diode absolute maximum forward current			10	mA	
5.36	Pin diode absolute maximum reverse voltage			25	V	
	specs 5.37 to 5.40					reserved for future use

#	Optical specifications	min	typ	max	unit	note
5.41	Wavelength		1310		nm	
5.42	Optical input range	0		300	µW	Per channel
5.43	Absolute maximum optical input power			3	mW	Per channel
5.44	Pin diode responsivity	0.7	0.85	1	A/W	Light into MT-interface
5.45	Module optical return loss	40			dB	
	specs 5.46 to 5.60					reserved for future use

2.4. Operating environment

#	environmental specifications	min	typ	max	unit	note
5.61	Storage temperature	-20		70	°C	
5.62	Operating ASIC junction temperature	+20		130	°C	
5.63	Operating humidity			60%	RH	13 °C dew point
	Specs 5.64 to 5.80					reserved for future use

#	safety specifications		note
5.81	Material composition	Halogen-free material	CERN IS41, see reference [2.2]
	Specs 5.82 to 5.99		reserved for future use

2.5. Other Characteristics

- electrical interface

Surface mount leadframe, soldered on printed circuit board
External 50 to 200 Ω termination resistors on output lines.

- package

package must be sealed, hermeticity requirement to be determined

- Test Documentation and traceability: TBD

- Shipping and storage requirements: TBD

2.6. Testing

#	Specification to be tested	Manufacturer		CERN	
		Product qualification	Lot validation (before delivery	Product qualification	Lot acceptance
5. 1	Number of channels	♦	♦	♦	♦
5.2	Number of electrical pins	♦	♦	♦	♦
5.3	Integral linearity deviation			♦	♦
5.4	Bandwidth		♦ [1]	♦	♦ [1]
5.5	Settling time to ±1%			♦	
5.6	Skew			♦	
5.7	Jitter			♦	
5.8	Crosstalk			♦	
5.9	Responsivity			♦	♦
5. 21	Photocurrent input range **Iph**			♦	♦
	Effective input current **Ipheff**	♦	♦	♦	♦
5.22	Output current range **Iout**			♦	♦

	Effective output current **Iouteff**	♦	♦	♦	♦
5.23	Control inputs X_1 X_2 X_3 X_4 X_5 X_6	♦	♦	♦	♦
5.24	Output voltage range			♦	
5.25	Load Resistance $\mathbf{R_L}$			♦	
5.26	Output loading			♦	
5.27	Equivalent input noise			♦	
5.28	Power supply		♦	♦	
5.29	Power dissipation	♦	♦	♦	
5.30	Output track capacitance	♦		♦	
5.31	Pin diode rise/fall time	♦			
5.32	Pin diode capacitance	♦		♦	
5.33	Pin diode dark current	♦		♦	
5.34	Pin diode absolute maximum photo current	♦		♦	
5.35	Pin diode absolute maximum forward current	♦		♦	
5.36	Pin diode absolute maximum reverse voltage	♦			
5.41	Wavelength	♦		♦	
5.42	Optical input range			♦	
5.43	Absolute maximum optical input power	♦			
5.44	Pin diode responsivity	♦			
5.45	Module optical return loss	♦	♦	♦	♦
5.61	Storage temperature	♦			
5.62	Operating ASIC junction temperature				
5.63	Operating humidity	♦			
5.81	Material composition	♦			

[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

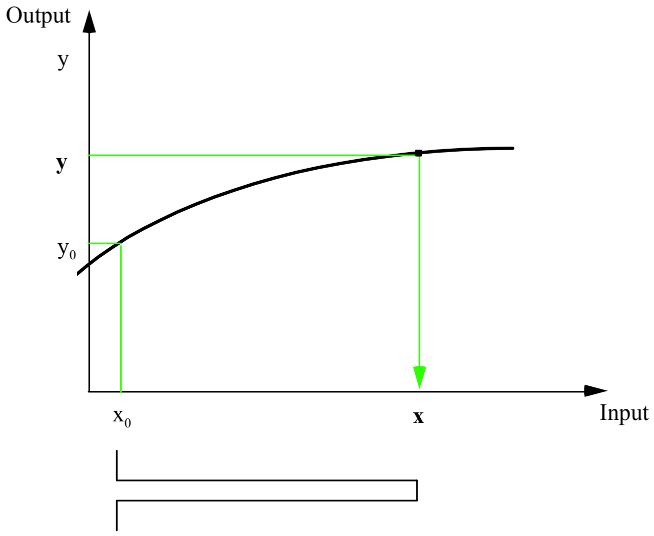


Fig. 3.1. Signal to noise ratio

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:

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

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:

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

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.

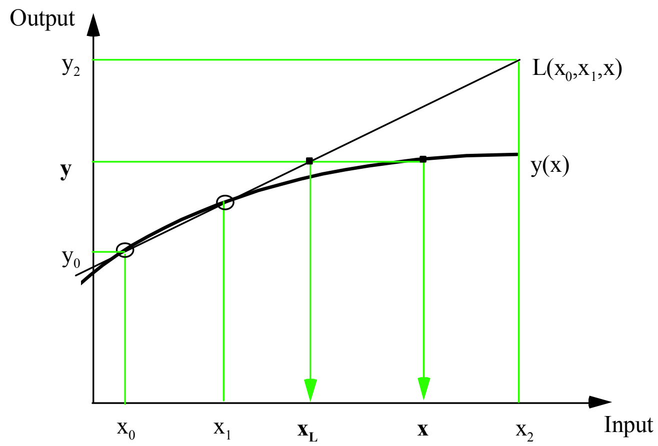


Fig. 3.2. Integral non-linearity

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:

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

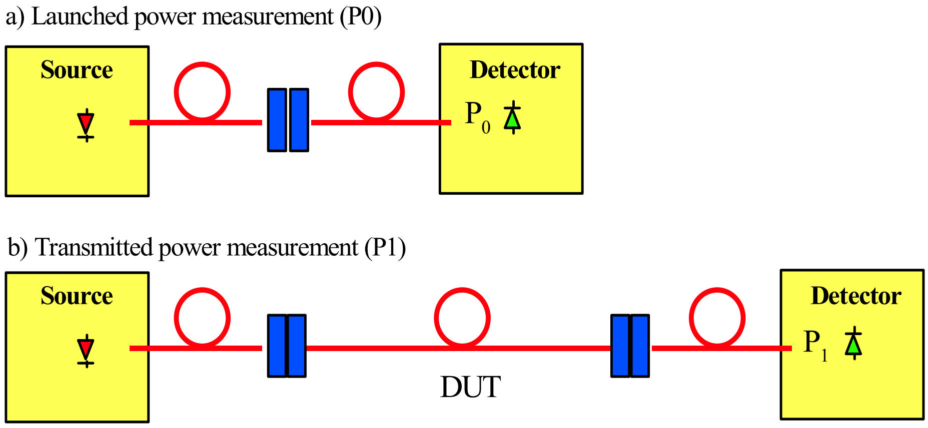
3.6. Crosstalk

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.



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

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