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CMS Tracker Optical Control Link Specification

Part 2.3: PIN Photodiode

Preliminary **Version 1.2, 8th April, 2003.**

CERN EP/CME

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1. Introduction

1.1. General system description

This specification defines the design requirements for the digital optical link to be used in the control system of the various sub-detectors of the CMS detector [1.1] at the CERN [1.2] Large Hadron Collider (LHC). The system architecture is based on the token ring concept, with mixed optical and copper sections [1.3]. The system was originally developed for the Tracker subdetector [1.4], where the total number of redundant control rings is 320, corresponding to 2560 optical link channels. In the other subsystems, namely ECAL, preshower and pixels, the combined number of digital links required is expected to be a similar to that for the Tracker.

The CMS optical control link is embedded into the control ring, as shown in Fig 1.1 taking the Tracker system as an example. The optical link is highlighted on the left of the figure, starting and ending at the backend transceiver module which is mounted on the Front End Controller board (FEC). Specifications for the FEC, and communication control unit (CCU) ASICs can be found in [1.5] and [1.6] respectively.

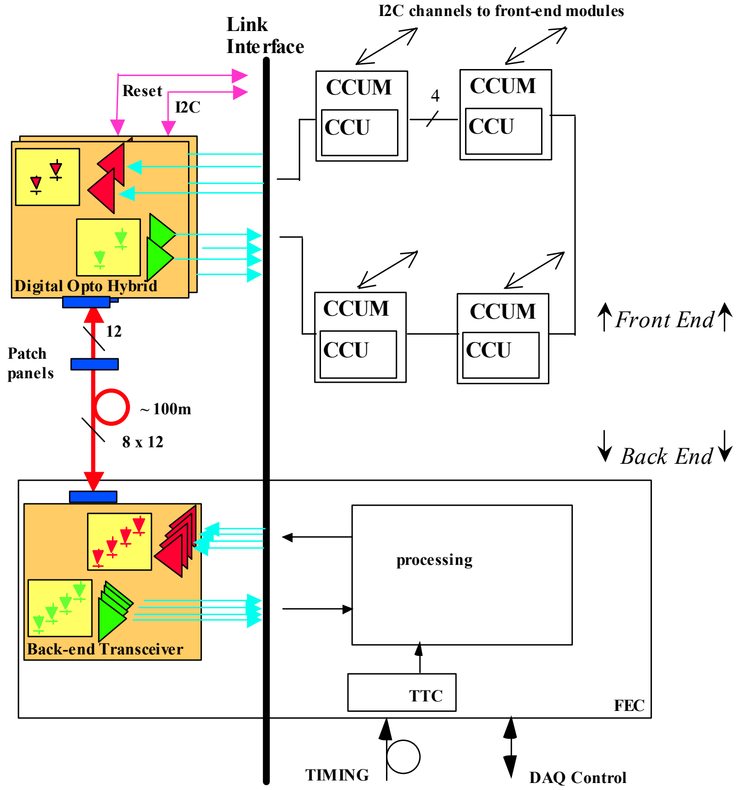

Fig. 1.1. Tracker control ring with optical link highlighted on the left.

The communication architecture proposed to control the embedded electronics is based on two layers. A more detailed description can be found for instance in [1.3]. The first layer (called the Ring) connects the FEC to the CCU modules (CCUMs) as well as connecting between CCUMs on the same ring. The protocol on this first layer is message-based and is implemented in a way similar to LAN networks. Four lines are required to transmit data (40Mb/s) and system clock (40MHz) with redundancy. Optical links are used to transmit data between the back-end (FEC) and the front-end digital optohybrid (DOH). The data is then communicated between CCUMs via electrical interconnections. The second layer of communication, between the CCUMs and the front-end chips, is entirely electrical and is based on the I^2C standard protocol.

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. Digital Opto-Hybrid
- 2.1 Laser Driver ASIC
- 2.2 Laser Transmitter
  - 2.2.1 Terminated Pigtail
    - 2.2.1.1 Buffered Fibre
- 2.3 PIN Photodiode
- 2.4 Digital Receiver ASIC
- 2.5 Digital Optohybrid Substrate

Part 3. Terminated Fibre Ribbon
- 3.1 Ruggedized Ribbon Harness
  - 3.1.1 Ruggedized Ribbon

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

Part 5. Back-End Opto-Transceiver Module

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

Part 7. In Line Patch Panel
- 7.1 MFS Adaptor

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. implementation

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 hardware or software relying on these characteristics is being designed. Target specifications will eventually evolve into full specifications once the system definition is mature. Parameters still to be determined 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://cmstrackercontrol.web.cern.ch/CMSTrackerControl/docmain.htm
- CMS Tracker Optical Links: http://cms-tk-opto.web.cern.ch/
- FED developments: http://www.te.rl.ac.uk/esdg/cms_fed_pmc/index.html
- APV and MUX developments: http://www.te.rl.ac.uk/med/

1.4. Document history

Rev. 1.0, 22/10/02	Draft (KG)
Rev. 1.1, 7/3/03	Fixed pigtail lengths. Add comment to minimize magnetic parts without compromising reliability. (KG)
Rev. 1.2, 8/4/03	Relaxed pigtail length tolerance. (KG)

1.5. Contacts

All questions regarding this document should be addressed to:

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2. Technical requirement, part 2.3: p-i-n photodiode

2.1. Description

Two identical pin photodiodes are mounted on each front-end digital optohybrid (DOH). The photodiodes receive clock and data signals sent from the FEC to the front-end electronics modules. The signals are detected and amplified by the receiver ASIC (RX40)[1.7]. It is estimated that around 3300 PIN photodiodes (including spares) are required to equip the various subdetector control systems within CMS.
The photodiode receivers are based on a planar InGaAs/InP pin structure, with the p-side (front) illuminated.
The photodiodes are mounted in a compact, single-channel package, complete with fibre pigtail terminated with an MU-connector. The use of magnetic materials in the package must be minimized. The photodiode package is mounted such that the fibre pigtail is oriented parallel to the plane of the digital optohybrid. The pigtail lengths will vary according to the position of the photodiode in the final system.
The photodiodes are sufficiently radiation resistant for operation inside the CMS Tracker. The fibre pigtails and MU-connector are pre-validated for radiation resistance and are supplied by CERN to the photodiode manufacturer.

2.2. Block diagram

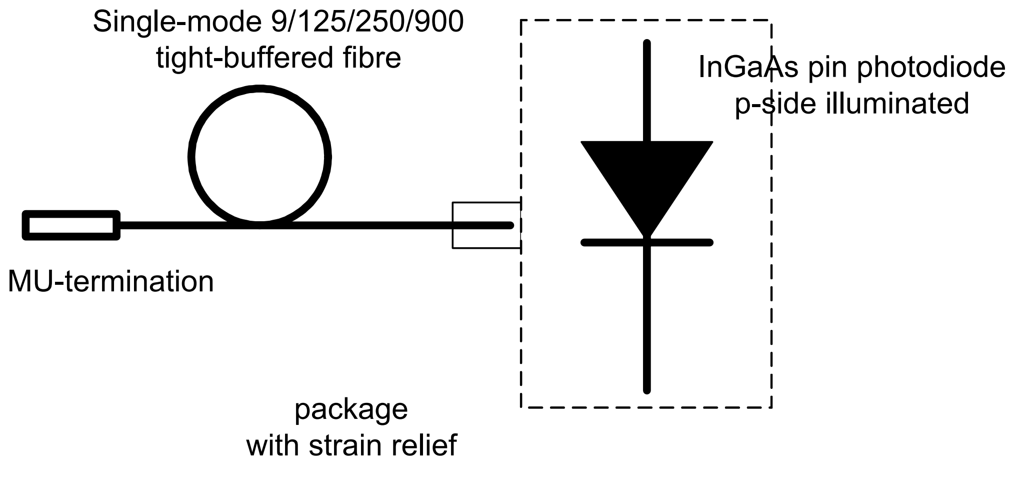

Fig. 2.1. Photodiode block diagram representation

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

#	operational specifications	min	typ	max	unit	note
2.3.1	Number of channels		1			Single-channel components
2.3.2	Active material structure	InGaAs on InP p-i-n				P-side illuminated
2.3.3	Tensile load on connector side of pigtail or package			7	N	During installation
				3	N	During operation
2.3.4	Target package size	10x4x3			mm	max. lengths in each dimension including ferrule and lead-frame
2.3.5	Package type	Wire bond or solder attach				Ferrule parallel to plane of digital optohybrid
2.3.6	Operation rate		4000		hrs/year	Failure rate <<1000FIT[1]
	specs 2.3.7 to 2.3.20					reserved for future use

#	electrical specifications	min	typ	max	unit	note
2.3.21	Dark current			1	nA	at –5V, start of life
2.3.22	Capacitance			1.0	pF	At –2V, 100KHz, start of life
2.3.23	Bandwidth	100			MHz	
2.3.24	Reverse bias voltage		2.5	20	V	Over lifetime[1].
2.3.25	Maximum forward current	2			mA	TBD
	specs 2.3.26 to 2.3.30					Reserved for future use

#	optical specifications	min	typ	max	unit	note
2.3.31	Wavelength	1260	1310	1360	nm	
2.3.32	Input power range	-30		3	dBm	
2.3.33	Responsivity	0.75			A/W	Based on external quantum efficiency. Start of life
2.3.34	*Fibre type*	*Single-mode 900µm tight-buffered fibre*				*To be supplied by CERN*
2.3.35	*Connector type*	*MU*				*To be supplied by CERN*
2.3.36	Pigtail length, L_p	0.56		0.60	m	2 different lengths, short: 0.56m and long: 2.00m. Tolerance on lengths will be +40mm, -0mm
		2.00		2.04		
	specs 2.3.37 to 2.3.40					reserved for future use

[1] Foreseen operating lifetime: nominal 10 years.

2.4. Operating environment

#	environmental specifications	min	typ	max	unit	note
2.3.41	Magnetic field resistance	4			T	parallel to particle beam axis
2.3.42	Hadronic fluence[1]			3e14	$1/cm^2$	Integrated over lifetime[2], 90% charged particles, 10% neutrons, see ref [2.1]
2.3.43	Gamma dose[1]			1.5e5	Gy(Si)	Integrated over lifetime[2], see ref [2.1]
2.3.44	Temperature	-20		70	°C	Operation and Storage
2.3.45	Operating humidity	Dry lab environment during testing				Dry nitrogen flow during operation in Tracker.
2.3.46	Operation rate		4000		hours/year	
	Specs 2.3.47 to 2.3.80					reserved for future use

#	safety specifications		note
2.3.81	Fire	CERN standards for underground equipment	CERN IS23 and IS41, see reference [2.2].
	specs 2.3.82 to 2.3.99		reserved for future use

[1] Qualification of the parts for radiation resistance is the sole responsibility of CERN. No radiation testing is required of the manufacturer.
[2] Foreseen operating lifetime: nominal 10 years.

2.5. Other characteristics

- electrical interface

2-pin lead-frame. Soldered or wire-bonded onto digital opto-hybrid.

- optical interface

Fibre type: single-mode (9/125/250/900µm) tight buffered acryllate fibre.

Fibre length: Two different lengths

Short: 0.56m
Long: 2.00m
tolerances of +40mm and –0mm

Connector type: MU
Connectorized MU-MU Jumpers to be supplied by CERN.

- packaging

Housing: Ceramic with lead-frame + ferrule.
Use of magnetic parts should be minimized, without compromising reliability of component.

Fibre strain relief: 900µm buffer attached to ferrule (TBD).
Fibre to emerge parallel to optohybrid.

- Radiation-hardness

Testing: Radiation hardness testing will be the made by CERN according to specified procedures.

Advance validation: In advance of production, samples from candidate wafers will be validated for sufficient radiation hardness. Photodiode receivers will only be accepted from validated wafers.

- Traceability

Labelling: QR code (supplied by CERN) attached near MU connector.
Manufacturer will be required to use QR code in test data reports.
For the photodiodes to be used inside CMS, no other labels should be attached.

Advance validation: Devices must be traceable to a wafer already validated for sufficient radiation hardness.

- Test documentation

Electronic format. Details TBD

- Shipping, storage and handling requirements

TBD

2.6. Testing (preliminary)

#	Specifications to be tested	Manufacturer		CERN	
		Product Qualification	Lot Test Data	Pre-production qualification	Lot acceptance
2.3.1	Number of channels			◆	◆
2.3.3	Tensile load			◆	
2.3.7	Operation rate				
2.3.21	Dark Current			◆	◆
2.3.22	Capacitance			◆	
2.3.23	Bandwidth (risetime)			◆	◆
2.3.24	Reverse bias voltage			◆	
2.3.25	Max forward current			◆	
2.3.31	Wavelength			◆	◆
2.3.32	Input power range			◆	◆
2.3.33	Responsivity			◆	◆
2.3.34	*Fibre type*			◆	◆
2.3.35	*Connector type*			◆	◆
2.3.36	Pigtail length			◆	◆
2.3.41	Magnetic field resistance			◆	
2.3.42	Hadron radiation resistance			◆[1]	
2.3.43	Gamma radiation resistance			◆[1]	
2.3.44	Operating temperature				
2.3.45	Operating humidity				
	Other tests			TBD	TBD

Details of the above test procedures are available upon request.

2.7. Implementation

TBD

[1] Advance validation test.

3. Glossary

3.1. 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:

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

3.2. 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:

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

4. References

[1.1] http://cmsinfo.cern.ch/cmsinfo/Welcome.html
[1.2] http://www.cern.ch/
[1.3] A. Marchioro, " Specifications for the Control Electronics of the CMS Inner Tracker", Draft V2, CERN
[1.4] The tracker project, technical design report, CERN/LHCC 98-6, CMS TDR 5
[1.5] A. Marchioro, "FEC specification", Draft, CERN
[1.6] A. Marchioro, "CCU specification", Draft, CERN
[1.7] F. Faccio et al., "RX40. An 80Mbit/s optical receiver ASIC for the CMS digital optical link. Reference and Technical Manual." 2001.

[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