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CMS Tracker Optical Control Link Specification

Part 5: Back-end Opto-transceiver Module

Version 2.1, 12th January 2004.

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 total 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.

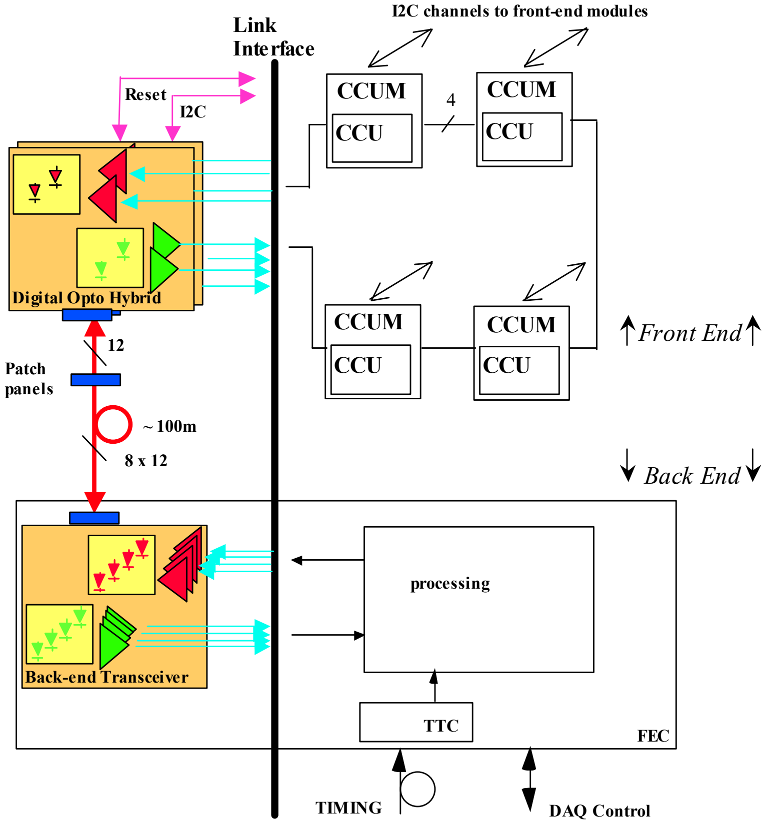

Fig. 1.1. Tracker control ring with optical link highlighted on the left.

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

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/

1.3. Document history

Rev. 1.0, 22/10/02	Draft (KG)
Rev. 1.1, 17/12/02	Changed Rx saturation spec to -4dBm (KG)
Rev. 1.2, 21/1/03	Minor changes to input signal voltage ranges (KG)
Rev. 1.3, 7/3/03	Added 1kΩ external termination of output (KG). Added comment regarding 7dB max variation of OMA input to receiver channels (KG)
Rev. 1.4, 25/3/03	Modified 7dB comment back to 5dB (FV)
Rev. 1.5, 9/4/03	Modified points and figures related to external output termination (KG)
Rev. 2.0, 12/11/03	Included NGK implementation and minor changes to input voltage. Manufacturer tests added.
Rev. 2.1, 12/1/04	Remaining TBDs resolved.

1.4. Contacts

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2. Technical requirement, part 5: back-end opto-transceiver module

2.1. Description

At the back-end of the digital control links 4+4 way transceiver modules, each having a 12-way MPO optical interface, will be mounted on the Front-end Controller (FEC) cards.

2.2. Block diagram

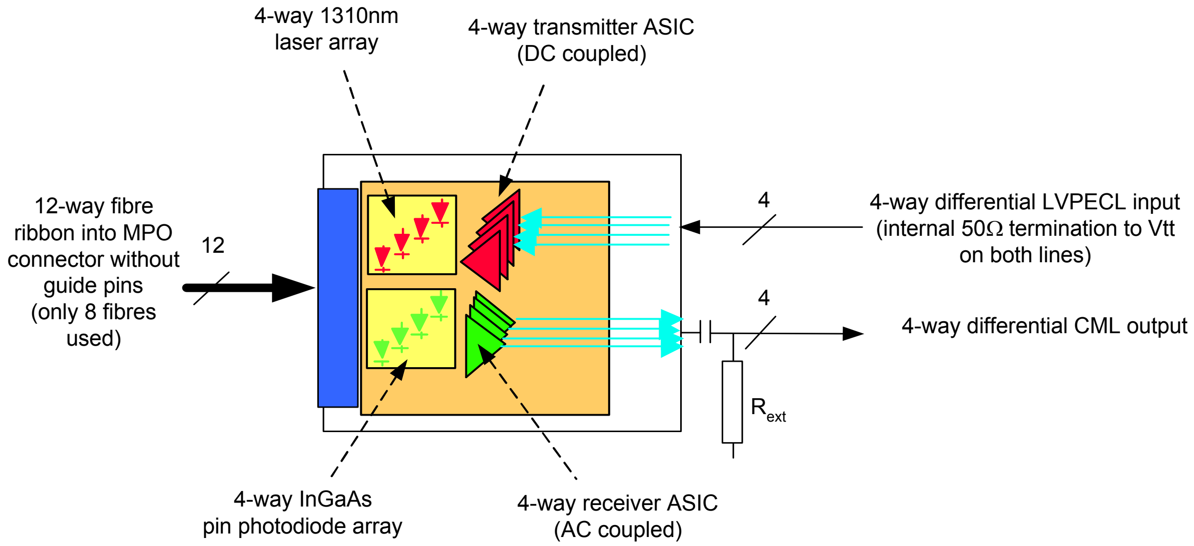


Fig. 2.1. Backend transceiver block diagram

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

#	Operational specifications	min	typ	max	unit	note
5.1	Bit Rate	2		80	Mb/s	Balanced code
5.2	Bit error rate			10^{-12}		Under condition that uniformity of optical signal amplitudes into all four receiver channels is ≤5dB.
5.3	Skew			1	ns	Between any 2 fibres coming from the same module, see glossary 3.1
5.4	Jitter			0.25	ns	rms, see glossary 3.2
5.5	Operation rate		4000		hrs/year	Total lifetime 10 years
	specs 5.6 to 5.10					reserved for future use

#	Physical specifications	min	typ	max	unit	note
5.11	Number of Tx channels	4				Fibre channel assignment, see Table 2.7.3
5.12	Number of Rx channels	4				Fibre channel assignment, see Table 2.7.3
5.13	Module size	33.3 x 24.9 x 9.5			mm	According to NGK design, see Figure 2.7.1
5.14	Module type	surface mount component				Solder reflowable.
	specs 5.15 to 5.20					reserved for future use

#	electrical specifications	min	typ	max	unit	note
5.21	Differential input voltage	±400	±600		mV	LVPECL
5.22	Input impedance		100		Ω	Both inputs terminated internally with 50Ω to V_{tt}
5.23	Differential output voltage	±600			mV	CML, amplitude depends upon external termination, see glossary 3.3.
5.24	Output impedance		100		Ω	Both outputs terminated internally with 100Ω to V_{cc}
5.25	Power supply	3.1	3.3	3.5	V	
5.26	Power dissipation			2	W	Tx and Rx channels
	specs 5.27 to 5.30					reserved for future use

#	optical specifications	min	typ	max	unit	note
5.31	Wavelength	1260	1310	1360	nm	Over temperature range
5.32	Average launch power	-13		-3	dBm	Over temperature range
5.33	Optical modulation amplitude	-12		-3	dBm	Over temperature range
5.34	Rx sensitivity			-20	dBm	Over temperature range
5.35	Rx saturation	-4			dBm	Maximum average input power.
5.36	Optical connector	MPO				Angle-polished single-mode, without guide pins
	specs 5.37 to 5.50					reserved for future use

2.4. Operating environment

#	environmental specifications	min	typ	max	unit	note
5.51	Operating temperature	0		70	°C	
5.51	Operating humidity			60	% RH	
5.52	Storage temperature	-20		70	°C	
5.53	Reflow Temperature			260	°C	30 seconds, 3 cycles
	Specs 5.54 to 5.60					reserved for future use

#	safety specifications		note
5.61	Optical	laser class 1	IEC 825-1
5.62	Fire	CERN standards for underground equipment	CERN IS23 and IS41, see reference [2.2].
	specs 5.63 to 5.69		reserved for future use

2.5. Other characteristics

- electrical interface:

Surface mount leadframe, to be soldered on FEC board.
External termination resistors on output lines.

- optical interface:

MPO-12 connector receptacle, angle polished single-mode without guide pins.

- exchange of test and traceability documentation:

Excel file on CD-ROM or sent by e-mail.

- shipping and storage requirements:

Shipping in 8-module trays, storage according to best practice.

- TRx module mounting and handling requirements:

Hermetically sealed modules.
Modules to be handled with standard ESD precautions.
Soldering conditions: Max. 260ºC during 30s 3 times

- TRx cooling recommendations:

Forced air cooling, 3m/s.

- labelling:

Human readable S/N on lid. Should also include laser safety Class 1 label.

2.6. Testing (Preliminary)

#	Specification to be tested	Manufacturer Testing	CERN	
			Pre-production Qualification	Lot Acceptance
5.1	Bit Rate	100% [1,2]	◆	◆
5.2	Bit error rate	[3]	◆	
5.3	Skew	[3]	◆	◆
5.4	Jitter	100% [1,2]	◆	◆
5.5	Operation rate	[3]		
5.11	Number of Tx channels	100% [1]	◆	◆
5.12	Number of Rx channels	100% [2]	◆	◆
5.13	Module size	5% sampling	◆	◆
5.21	Differential input voltage	[3]	◆	◆
5.22	Input impedance	[3]	◆	
5.23	Differential output voltage	100% [2]	◆	◆
5.24	Output impedance	[3]		
5.25	Power supply	[3]	◆	
5.26	Power dissipation	100% [1,2]	◆	◆
5.31	Wavelength	100% [4]	◆	◆
5.32	Average launch power	100% [1]	◆	◆
5.33	Signal modulation	100% [1]	◆	◆
5.34	Rx sensitivity	100% [2]	◆	◆
5.35	Rx saturation	5% sampling [2]	◆	◆
5.36	Optical connector	[3]	◆	◆
5.51	Operating temperature	100% [1,2]	◆	
5.52	Operating humidity	[3]		
5.53	Storage temperature	[3]		
5.54	Reflow Temperature	[3]	◆	
5.61	Optical safety class	[3]		
5.62	Fire hazard	[3]		

[1] Each channel of Tx side is checked with a digital input signal of 80Mbps at 70C.
[2] Each channel of Rx side is driven by a single-channel laser source using an 80Mbps input signal at 70C. No optical signals go to the other channels.
[3] Guaranteed by design.
[4] Final inspection at vendor.

2.7. Implementation - NGK 4-way TRx module

2.7.1. package

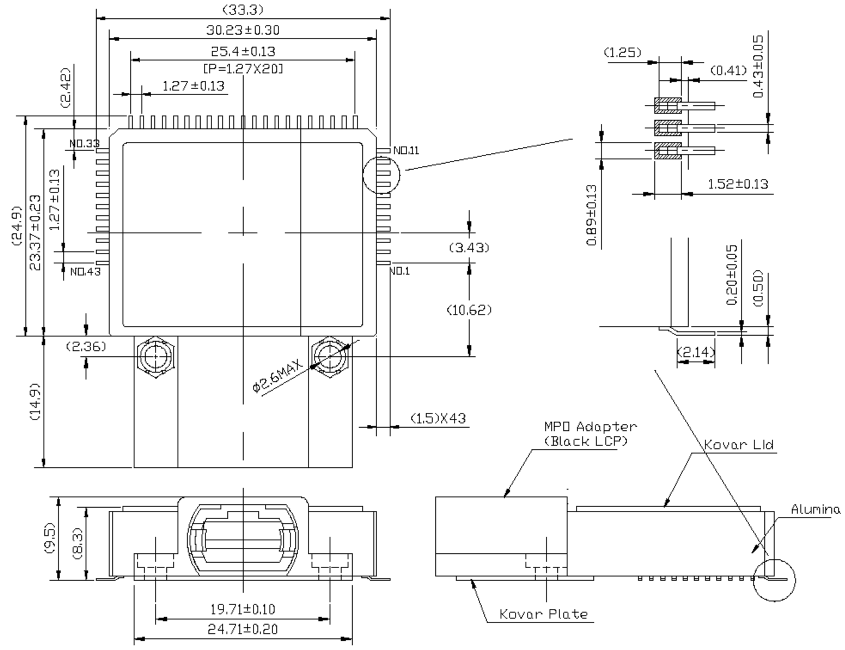


Fig. 2.7.1: NGK design specification for TRx package

2.7.2. pin assignments

Pin #	Name	Logic Level	Description	Pin #	Name	Logic Level	Description
1	V_{CC1}	–	Tx Power Supply (Vcc)	23	GND	–	Rx Ground
2	V_{CC2}			24	DO3P	–	Data output 3 non-inverted
3	V_{TT}		Termination Voltage	25	DO3N	–	Data output 3 inverted
4	N/C		Left Open	26	GND	–	Rx Ground
5	V_{CT}	LVTTL in	Laser Enable/Disable	27	DO2P	–	Data output 2 non-inverted
6	GND	–	Tx Ground	28	DO2N	–	Data output 2 inverted
7	DI0N	–	Data input 0 inverted	29	GND	–	Rx Ground
8	DI0P	–	Data input 0 non-inverted	30	DO1P	–	Data output 1 non-inverted
9	N/C	–	Left Open	31	DO1N	–	Data output 1 inverted
10	GND	–	Tx Ground	32	GND	–	Rx Ground
11	GND	–	Tx Ground	33	GND	–	Rx Ground
12	GND	–	Tx Ground	34	GND	–	Rx Ground
13	DI1N	–	Data input 1 inverted	35	N/C	–	Left Open
14	DI1P	–	Data input 1 non-inverted	36	DO0P	–	Data output 0 non-inverted
15	GND	–	Tx Ground	37	DO0N	–	Data output 0 inverted
16	DI2N	–	Data input 2 inverted	38	GND	–	Rx Ground
17	DI2P	–	Data input 2 non-inverted	39	LOS	LVTTL out	Los of signal
18	GND	–	Tx Ground	40	N/C	–	Left Open
19	DI3N	–	Data input 3 inverted	41	V_{CC1}		Rx Power Supply (V_{CC})
20	DI3P	–	Data input 3 non-inverted	42	V_{CC2}		
21	GND	–	Tx Ground	43	V_{CC1}		
22	N/C	–	Left Open				

Table 2.7.2: NGK TRx pin assignments

2.7.3. Optical fibre channel assignment

Taken from system specification, CMS-TK-ES-0018

Channel	Assignment
1	CK (from FEC to CCUM ring A)
2	DA (from FEC to CCUM ring A)
3	CK (from FEC to CCUM ring B)
4	DA (from FEC to CCUM ring B)
5	Dark
6	Dark
7	Dark
8	Dark
9	DA (from CCUM ring B to FEC)
10	CK (from CCUM ring B to FEC)
11	DA (from CCUM ring A to FEC)
12	CK (from CCUM ring A to FEC)

Table 2.7.3: Fibre ribbon channel assignment.

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:

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

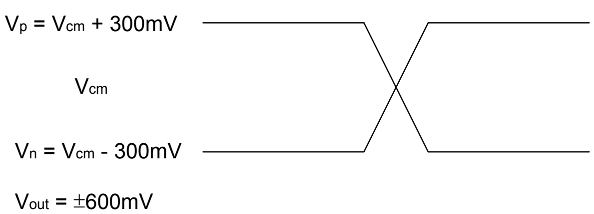
3.2. Jitter

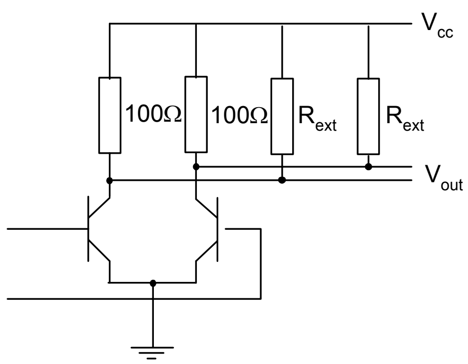
The rms jitter is defined as the rms deviation of the time t_{50} required for a step response signal to reach 50% of its end value:

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

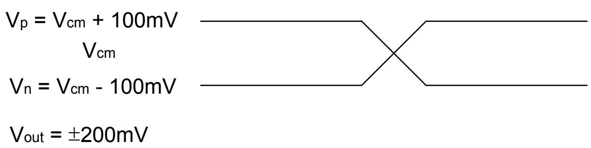
3.3. Output signal amplitude, specified minimum levels

(a) Without external output termination $R_{ext} = \infty$





(b) With R_{ext} = 50Ω external output termination (for module testing)



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

[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