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Laboratoire Européen pour la Physique des Particules
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4-Channel Prototype Analogue Optical Data Link

Reference Manual

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1. Introduction

This manual describes the operation and performance of 4-channel prototype analogue optical data links developed for the readout of the CMS tracker. This Section introduces the CMS tracker optical link concept. In Section 2 a description of all the delivered link components is given. Section 3 gives the link operation and eye safety instructions. The link performance is detailed in section 4. The references are located in Section 5.

Optical links are being developed for the Large Hadron Collider experiments at CERN. For the central tracker of the Compact Muon Solenoid (CMS) experiment over 50000, 100m long, analog links are required to read out data[3] (Ref[1]). The prototype analogue link described here consists of a monolithic quad laser driver ASIC followed by a hybrid assembly of four InGaAsP/InP edge-emitting laser diodes transmitting at ~1310nm over a distance of approximately 100m of single-mode fiber through two optical connections based on angle-polished MPO-connectors. The receivers are four InGaAs/InP pin photodiodes followed by 2-stage transimpedance amplifiers. The delivered links are close in performance to the final CMS tracker links, however with only two breakpoints instead of the foreseen three breakpoints necessary in the CMS experiment. A gain of about 2 is achieved, converting a ±400mV differential input into a 1.6V single ended output swing.

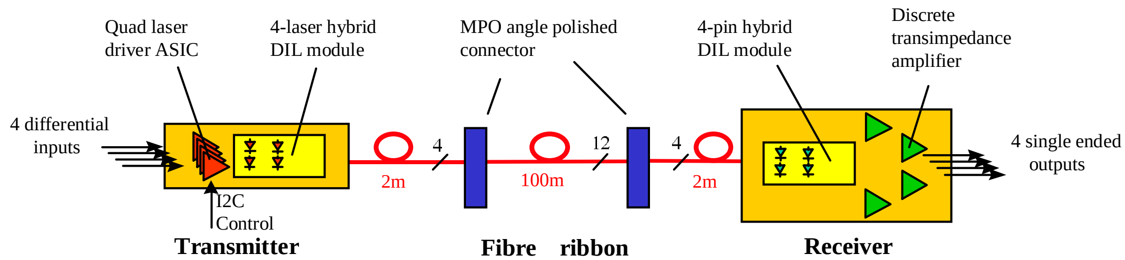

Fig 1: 4-channel optical link prototype.

2. Prototype Link Components

The delivered 4-way link consists of one 4-way laser module, one 4-way pin module, one 4-channel transmitter card, one 4-channel receiver card, one motherboard for up to four Tx/Rx-cards respectively, one 100m long single-mode fiber ribbon with spool, two adaptors for MPO connectors. Cables for signal injection can be included as an option (50Ω coaxial 10ns with SCI-LEMO connectors). A listing of delivered components can be found in Attachment B.1.

2.1 LASER MODULE

The laser module is housed in a 4-way hybrid, ceramic 14-pin DIL-package manufactured by Italtel. The individual lasers are InGaAsP/InP edge-emitters transmitting at ~1310nm and are produced by NEC. Each individual laser is pigtailed with single-mode fiber and the four fibers are bundled and connectorized with an Europtics 4-way angle-polished MPO-T male connector. Electrical and optical characteristics for the delivered laser modules are given in Attachment B.2. The laser module serial number is given as **4T-XXX-XXX** and is engraved on the bottom of the module.

[3] Full link documentation with all developments can be found on the WWW at URL : http://www.cern.ch/CERN/Divisions/ECP/CME/OpticalLinks/.

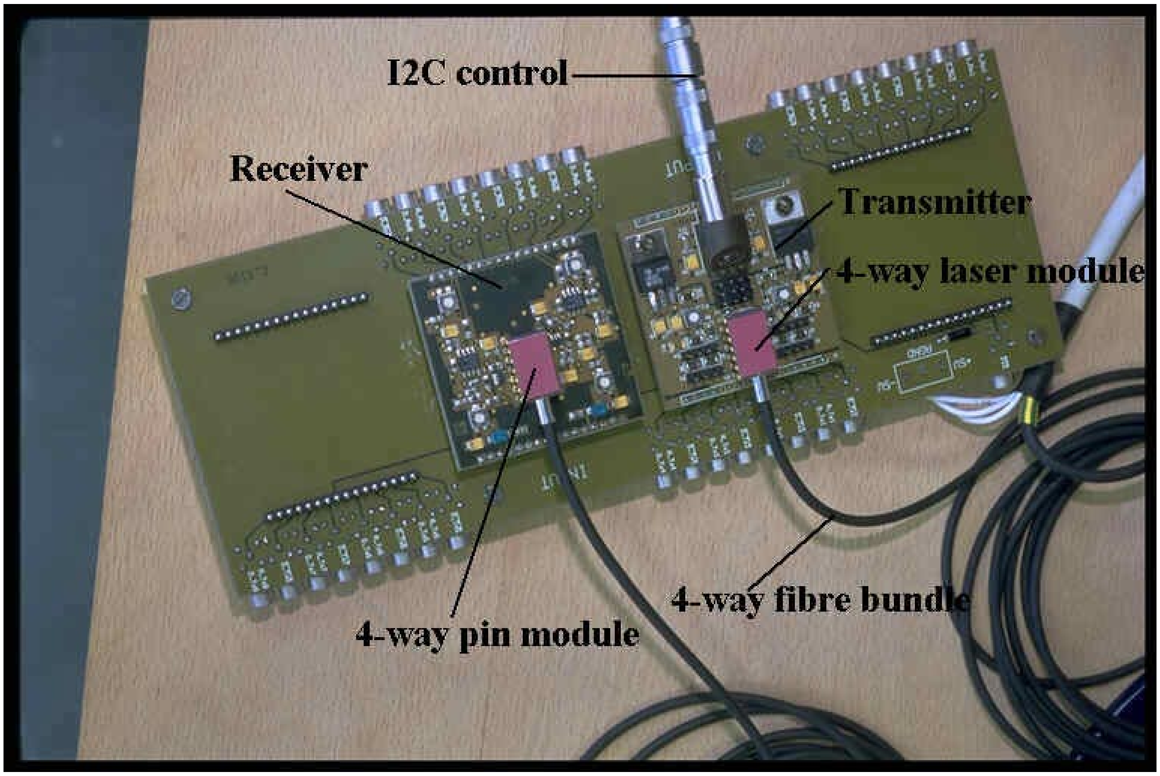

Fig 2: Prototype 4-way analogue optical link.

2.2 PIN MODULE

The PIN module is housed in a 4-way hybrid ceramic 14-pin DIL-package manufactured by Italtel *of exactly the same type as the laser module*. The individual PINs are InGaAs devices and are produced by Epitaxx. Each individual PIN is pigtailed with single-mode fiber and the four fibers are bundled and connectorized with an Europtics 4-way angle-polished MPO-T male connector. Electrical and optical characteristics for delivered PIN modules are given in Attachment B.3. The PIN module serial number is given as **4R-XXX-XXX** and is engraved on the bottom of the module.

2.3 TRANSMITTER CARD A_TX_4CH

The 4-channel transmitter card is a custom daughter-card developed by CERN and holds a 4-way laser driver with I2C-control of the laser bias. The card allows for simultaneous operation of up to four lasers through four differential SCI-connector interfaces (eight SCI-connectors in total). The laser driver has differential inputs terminated with 100Ω. To ease the interface with standard instrumentation (single ended signals referenced to ground) the transmitter card is configured as shown on Fig. 3(b). It can easily be re-configured as in Fig. 3(a). The layout of the transmitter card is described in Attachments B.4, B.5 and Ref. [2] and the laser driver operation and characteristics is described in Ref. [3].

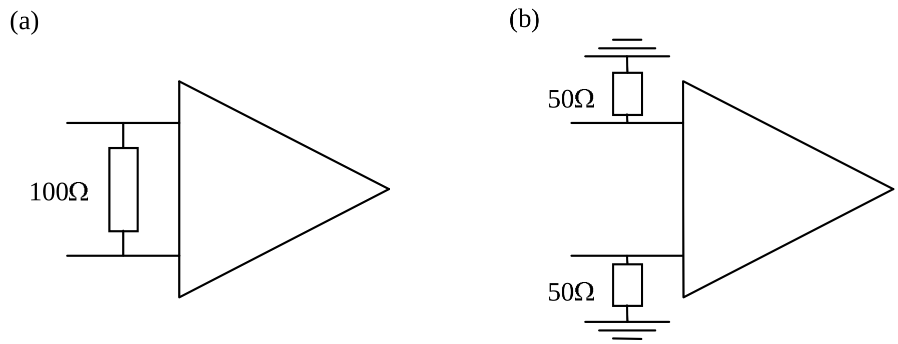

Fig. 3: Driver input configuration.

2.4 RECEIVER CARD A_RX_4CH

The 4-channel receiver card is a custom daughter-card developed by CERN and holds four individual 15kΩ transimpedance amplifiers. A 50Ω series output resistor is mounted for optimal dynamic performance. The transmitter card is equipped with four potentiometers to adjust the output voltage offset for each of the four receiver channels between ±1.75 Volts. The layout of the receiver card is described in Attachments B.6, B.7 and in Ref. [4] which also gives typical receiver performance data.

2.5 MOTHERBOARD

The motherboard is custom developed by CERN. To provide the power for the transmitter and receiver cards the mother board should be connected to a regulated power supply set at +/5 Volts. The motherboard holds female LEMO connectors for analog signal extraction. The layout for the motherboard is provided as Attachment B.8. Each board can hold up to four 4-channel analog or digital Tx or Rx cards.

2.6 OPTICAL FIBER RIBBON

The 100 meter long 12-way ribbonized single-mode optical fiber is manufactured by Sumitomo Cable Ltd. and is of standard telecom grade. The ribbon is connectorized with 12-way MPO-U female connectors. They interface with the 4-way MPO-T angle-polished connectors of the 4-way laser and PIN modules through the centre four channels of the 12-way ribbon. Even though only four channels are used in these prototypes, the ribbon used in the final CMS system will be based on a modularity of 12 channels.

2.7 MPO-TO-MPO ADAPTORS

Two MPO adaptors provided by Europtics allow for mating of the angle-polished MPO male and female connectors of the laser/PIN module and optical fiber ribbon. The adaptors provide keying to aid proper mounting and are marked accordingly. Caution: When de-mating the MPO connections, care should be taken not to loose the precision alignment pins.

2.5 COAXIAL CABLE (OPTIONAL)

Two 50Ω, 10ns, coaxial cables with SCI-LEMO connectors are used to inject the signal to the laser driver through either of the four differential SCI connectors provided on the transmitter card.

3. Link operation instructions

3.1 EYE SAFETY AND HANDLING OF OPTICAL AND ELECTRO-OPTICAL COMPONENTS

The delivered laser modules are of class 3A and can deliver more than 10mW of optical power. *Therefore never expose the naked eye to direct laser light.*

Optical connectors should always be cleaned with designated optical lens cleaning paper or cloth and liquid (isopropyl alcohol). The guiding pins of the male MPO connectors are removable which eases cleaning but repeated removal and insertion of the guiding pins might damage the connector.

All electronic and electro-optical components are sensitive to electrostatic damage when handled and use of grounded wrist-bracelets is strongly recommended.

3.2 MOUNTING AND CONNECTING THE LINK

Power supply cables should be connected on the bottom side of the motherboard as shown in Attachment B.8. The link is delivered with the transmitter card and the receiver card already mounted on the motherboard. The laser module should be mounted with the fiber facing the opposite way as the I2C connection on the transmitter card as shown in Attachment A.4. The PIN module should be mounted with the fiber facing the opposite direction as the marking "c-s" on the receiver card or as shown in Attachment B.6. Thus the optical fiber will protrude from the motherboard in the same direction for both the transmitter and the receiver.

The male MPO connectors on the pigtail of the laser and PIN modules can be directly connected (after cleaning as described in section 3.1) to the respective female connectors of the optical fiber ribbon by way of the two provided MPO-adaptors. The connectors are angle-polished and therefore the adaptors provide keying to aid proper mating.

3.3 POWER SUPPLY

The power supply for the motherboard should give ±5 Volts. The drive voltage for the transmitter and receiver cards is supplied through the motherboard as indicated in Attachment B.8. The transmitter card is equipped with potentiometers to adjust the voltage for the laser driver which runs on ±2 Volts. The driver voltage (±2V) has been adjusted on delivery and *an erroneous setting may damage the laser driver.*

3.4 SIGNAL INJECTION/EXTRACTION AND LASER BIASING

The laser bias currents are set via the I2C-interface by the laser driver and a detailed description of the bias-current programming register is given in Ref. [3]. Differential or single-ended signals should be fed to the link through the male SCI connectors provided with the polarity indicated in Attachment B.4. The full input range of the laser driver is ±800mVdifferential, but linearity is only specified in a ±400mV range. The output signal is extracted from the female LEMO-connectors on the motherboard marked A_Rx-1, A_Rx-2, …, A_Rx-8 depending on the channel used. When using long cables a 50Ω termination is recommended.

4. Link performance

The analogue performance, including static, noise and time characteristics, has been measured and evaluated for the delivered link. Full documentation on the evaluation procedure can be found in Ref. [5] with background material in Ref. [6]. Example performance data for the delivered devices and other component types can be found in Ref. [7].

4.1 LINK EVALUATION

A schematic of the experimental setup used to evaluate the optical link is shown in Fig. 4. The objective of this measurement is to characterize the static and noise performance of the system. A computer running labview software controls an arbitrary waveform generator (AWG) and an oscilloscope via GPIB. The AWG generates about 100 static levels that are fed sequentially to the system input as a ramp, plus synchronization signals for the measuring instruments. A high resolution (12bit) analog to digital converter (ADC), housed in a VME-crate, is used to evaluate the deviation from linearity of the system to better than 1% and a large bandwidth (300MHz) oscilloscope is utilized to measure the noise into the system bandwidth (Ref. [6]). For each static measurement point the average of the output voltage is measured by the 12-bit ADC, and the standard deviation of the link output voltage is measured by the oscilloscope.

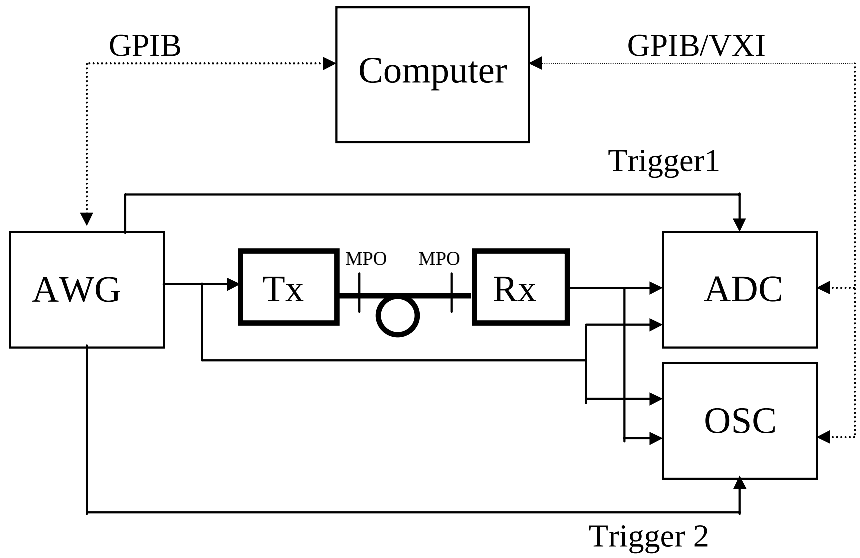

Fig. 4: Experimental setup for link and device performance tests

The laser pre-bias is selected via the I2C bus. The laser and PIN module pigtails are connected to the 100m long single mode fiber ribbon via MPO connectors. The lasers have a typical efficiency of 0.06W/A and the driver transconductance is about 6.29 mS (Ref. [3]). On the receiver side the PIN-diodes have an average responsivity of 0.93A/W and the amplifiers have a transimpedance of 15kΩ. All system outputs are terminated with 50Ω.

The link pulse response is characterized with a pulse generator feeding a square pulse to the link and the output voltage is measured with a 300MHz oscilloscope. All measurements were performed at 25 ± 1 ^{o}C.

4.2 LINK TRANSFER CHARACTERISTIC

The link transfer characteristics are shown in Appendix A.1 for all four channels. The measured output voltage is shown as a function of the input voltage. The kink at about -0.4V is related to the laser threshold and the curvature in the upper part of the transfer functions is due to the laser driver reaching saturation. The link gain of each channel is indicated in the legend (50Ω-terminated outputs). It should be noted that the link gain may vary depending on the quality of the optical connection, therefore the measured gain may differ between measurements if the MPO-connectors are remated. It should further be noted that the laser thresholds depend on the laser junction temperature and thus on the ambient temperature, laser warm-up time and duty cycle. In Appendix A.1 the I2C-bias setting are also displayed.

4.3 RMS-NOISE

The Link Root-Mean-Square (RMS) noise is shown in Appendix A.2. The sudden rise in noise at about -0.4V is related to the laser threshold. The actual RMS-noise measured depends on the quality of the optical connection and may vary slightly between measurements if connectors have been re-mated. The link noise may also depend to some extent on the laser junction temperature and thus on the ambient temperature, laser warm-up time and duty cycle. The receiver RMS noise below threshold is typically 1.3 - 1.4 mV.

4.4 PULSE RESPONSE

The link pulse response is shown in Appendix A.3, together with the rise-time for each individual optical channel.

5. References

[1] F. Vasey, C. Aguilar, C. Azevedo, V. Arbet-Engels, G. Cervelli, K. Gill, R. Grabit, F. Jensen, C. Mommaert, P. Moreira and G. Stefanini, ‘A 4-channel analogue optical link for the CMS-Tracker”, Proceedings from the 4th Workshop on electronics for LHC Experiments, Rome, pp. 344-348, 1998.

[2] R. Grabit, "Analogue Optical Link Laser Diode Transmitter A_Tx_4Ch", 1998. Available from the Author (CERN).

[3] P. Moreira and A Marchioro, "Linear Laser Driver IC–Reference and Technical Manual", 1997. Available from the authors and at URL: http://www.cern.ch/CERN/Divisions/ECP/CME/OpticalLinks/

[4] R. Grabit, "Analogue Optical Link Photo Diode Receiver A_Rx_4Ch", 1998. Available from the Author (CERN).

[5] F. Jensen, C.S. Azevedo, G. Cervelli, K.A. Gill, R. Grabit, and F. Vasey, CMS technical note (in preparation).

[6] G. Cervelli, V. Arbet-Engels, K. Gill, R. Grabit, C. Mommaert, G. Stefanini, F. Vasey, "A method for the static characterisation of the CMS tracker analogue optical links", Technical note, CMS Note 043, 1998.

[7] F. Jensen, C. Aguilar, V.P. Arbet-Engels, C.S. Azevedo, G. Cervelli, K.A. Gill, R. Grabit, C. Mommaert and F. Vasey, "Characterisation of laser diodes for analog parallel optical links", proceedings of SPIE Vol. 3626, pp. 202-208, 1999.