The TOTEM Roman Pot Motherboard

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Abstract

The TOTEM Roman Pot Motherboard (RPMB) is the interface between the hybrids with silicon detectors and front end chips in the Roman Pots, and the outside world. The RPMB is glued in the vacuum flange which separates the vacuum chamber containing the detector hybrids, and forms the feed through between vacuum and atmosphere. The hybrids have a flexible part with on-board connector for connection to the motherboard. The motherboard is equipped with connectors to the detector hybrids from one side and front panel with connectors to the patch panel form the other side.

The RPMB needs to provide power and control, clock and trigger information to the 10 hybrids. It acquires tracking and triggers data from the hybrids, performs data conversion from electrical to optical format and transfers the data to the next level of the system [1]. It also collects information like temperature, pressure and radiation dose inside the pot. This paper presents the TOTEM RPMB in detail.

I. Introduction

TOTEM (Total Cross Section, Elastic Scattering and Diffraction Dissociation Measurements) [2] is an experiment dedicated to the measurement of total cross section, elastic scattering and diffractive processes at the LHC. The full TOTEM detector consists of Roman Pot Stations (RPS), Cathode Strip Chambers T1 (CSC) and Gas Electron Multipliers T2 (GEM). The T1 and T2 detectors are located on each side of the CMS interaction point in the very forward region, but still within the CMS cavern. Two Roman Pot stations are foreseen on each side of the interaction point at 220 m and 150 m. Each Roman Pot station consists of two groups of three Roman Pots separated by a few meters to obtain a sufficiently large lever arm to establish co-linearity with the LHC beam for the tracks prior to generating a level one trigger for the corresponding event. Each Roman Pot contains 10 silicon strip detectors with 512 strips read out by 4 VFAT2 readout chips [3].

II. General design specifications

Apart from the electrical functionality described in detail below, the design of the RPMB was constrained by the mechanics and by radiation tolerance.

The RPMB has to fit in the Roman Pot mechanics, connect to 10 hybrids in a secondary vacuum (the primary vacuum is that of the machine within the beam pipe, the primary and secondary vacuum are separated by a window of about 100 micron thick), and feed through about 800 signals to and from the outside world. The connections to the outside are naturally on the end opposite to the hybrids. The maximum width of the feed through for these 800 signals is about 12 cm and together with the other size limitations this results in a very challenging layout with 16 layers for the RPMB.

The RPMB is also subject to radiation, imposing radiation tolerance for all components. In particular all on-board integrated circuits are full-custom circuits designed in 0.25 micron CMOS technology with special techniques to increase the radiation tolerance [4][5].

Safety regulations imposed also fabrication of the board with halogen free material.

Figure 1: RPMB Photo - top and bottom side

Figure 1 shows the pictures of both sides of the completed board without mezzanine cards mounted. A front panel (at the right of the picture) with connectors for low and high voltage, control, data and trigger bits transfer is used to facilitate the connection to the central patch panel of the RP stations. The narrow part on the left with the connectors for the hybrids is the part placed inside the pot. The feed through (area glued in the flange) is the large copper stripe on the narrow part.

III. TOTEM ROMAN POT MOTHERBOARD

The TOTEM RPMB functional block diagram is shown in Figure 2. The blocks are described in detail below.

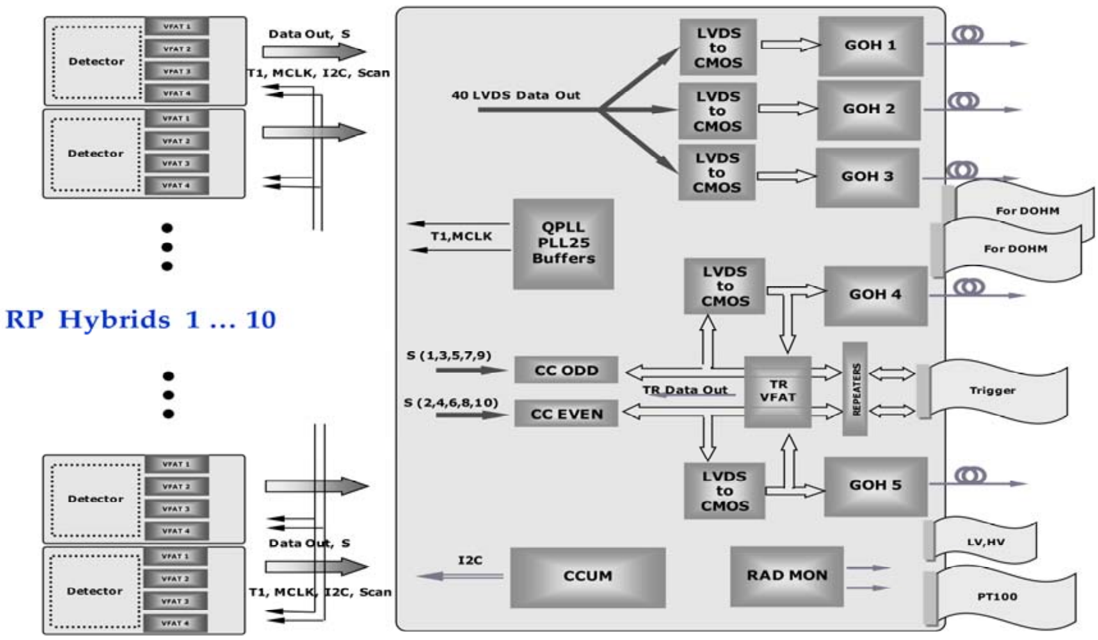

Figure 2: RPMB Functional Block Diagram

A. Power Distribution

The RPMB needs to receive low voltage power at 2.5 V for its own operation, and for the operation of the hybrids. The power on the hybrids has been carefully separated between analog and digital blocks, both powered at 2.5 V.

The silicon detectors need to be biased up to 500 V after irradiation. The RPMB receives this high voltage supply and distributes it to the detector hybrids. The supply is separate for all detectors; grouping is done in the counting room. This allows isolating defective detectors from the rest if needed.

B. The slow control

The slow control system has been copied from the CMS tracker and ECAL detectors [6]. A FEC-CCS board in the counting room sends and receives optical control data, on the detector side a Digital Opto-Hybrid Module (DOHM) converts this data back to electrical form and interfaces with the RPMB via two 20pins 3M high speed connectors placed on the front panel. A Communication and Control Unit mezzanine (CCUM) on the RPMB (see Figure 3) decodes this information and provides 16 I^2C interface channels and one 8 bit parallel control port for use on the RPMB. All integrated circuits including the VFAT2 are controlled using these I^2C interfaces.

In addition to the slow control information transmitted over I^2C, several sensors mounted on the RPMB or on the hybrids provide additional information like temperature, pressure and radiation dose.

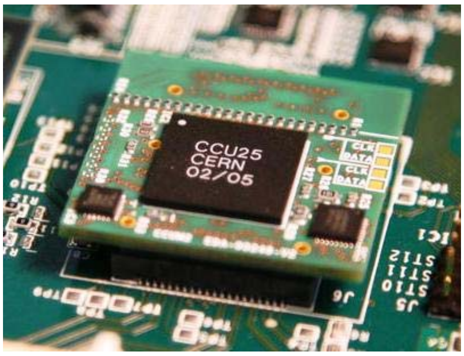

Figure 3: CCUM Mezzanine photo

PT100/1000 sensors are used for temperature, and a piezoelectric pressure sensor measures the pressure inside the pot to verify the pressure remains close 0 (a secondary vacuum has to be maintained in the Roman Pot).

A special small carrier card (RADMON) [7] is used for radiation monitoring on the RPMB. This carrier is made of a thin (~500 m) double-sided PCB. It can host up to 5 *p-i-n* diodes and five RadFETs mounted inside a proper package. It also includes a temperature sensor (10k NTC). This total of 11 devices can be read out via a 12-way flat cable: 11 for sensor signals and a common Return Line (RL) connection. A photo of the carrier is shown on Figure 4.

was designed to carry one Coincidence Chip and two 130 pins input/output connectors. Figure 5 shows a photo of the CC mezzanine.

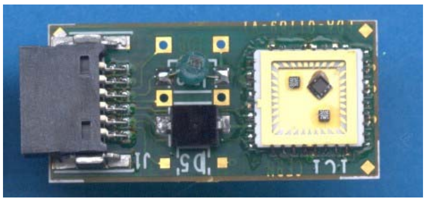

Figure 4: RADMON carrier photo

C. Clock and Fast Commands

The FEC-CCS card receives clock and fast commands in the counting room and includes these with the slow control data for transmission to the detector using the same channel as the slow control. On the RPMB the clock and fast command signals are reconstructed by the PLL25 chip. The QPLL, a quartz based PLL, is used to further reduce the clock jitter necessary for serialization and optical transmission of data. The clock and fast command tree has been designed to minimize timing spread over all components on the RPMB.

D. Tracking Data transmission

The data sent by the VFAT2 front end chips upon a level 1 trigger signal is converted from LVDS to CMOS on the RPMB and then presented to the gigabit optical hybrids GOH modules, which serialize and convert the electrical data to optical for transmission to the Data Acquisition (DAQ) system in the counting room. Three GOH modules are used to send data from 40 VFAT2 chips.

E. Trigger Data generation and Transmission

Each VFAT2 front end chip has 8 trigger outputs of which 4 are used in the Roman Pots. Every hybrid therefore generates 16 trigger outputs, and 5 hybrids have the same orientation of the silicon strips (U coordinate), and the 5 others have strips oriented at 90 degrees (V coordinate). The trigger signals are put into coincidence in two separate Coincidence Chips (CC), one for the U and one for the V coordinate. The CC chips are mounted on the RPMB as mezzanine cards (CC mezzanine), one mezzanine per CC. The CC provides 16 outputs (so the number of trigger signals is reduced from 2x80 to 2x16), and these signals have to be transmitted to the counting room.

For these coincidences a full custom chip rather than using a Field Programmable Gate Array was developed for two reasons:

- the latency constraints on the generation of the trigger bits especially from the Roman Pots are very severe: after subtraction of cable delays only about 8-10 bunch crossings are left for the generation of the trigger signals to be provided to CMS from the signals generated by the Roman Pot. A full custom chip with dedicated logic can implement the required coincidence in one clock;

- the CC needs to be placed on the RPMB or at least near the detectors and is therefore subject to radiation. Special design techniques were used to make the CC much more robust against radiation both with regard to total dose and single event effects than a standard FPGA. The CC mezzanine

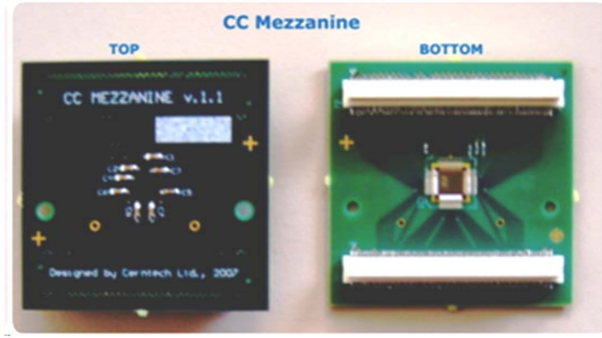

Figure 5: CC Mezzanine photo

To transmit trigger bits to the counting room two ways have been selected: optical fibers are used for the 150m RP stations and in TOTEM standalone runs also for the 220m stations. The runs with CMS on the other hand are subject to CMS's limited trigger latency time, imposing trigger bit transmission with LVDS signals through fast electrical cables, because the serialization and deserialization and optical transmission in the fiber (~5 ns/m) take too much time. The electrical transmission over such a long distance requires care to preserve signal integrity. This can only be achieved by restoring the LVDS signals to full levels at regular intervals over the transmission distance. A special integrated circuit was designed for this purpose: the LVDS repeater chip can treat 16 LVDS channels in parallel and was designed in special layout to guarantee radiation tolerance. This chip will be mounted on a small repeater board. At regular intervals of about 70m a repeater station is introduced which consists of 12 repeater boards (one for every cable carrying 16 LVDS signals).

Since the trigger signals are sent every clock cycle some time reference has to be included in the trigger data stream to facilitate recovering the correspondence between the event and the transmitted bits. This is done from the fast command bunch crossing 0 (BC0) by the VFAT trigger mezzanine (Figure 6). The VFAT on board decodes the BC0 signal and provides this to some circuitry which actually disables the GOH's data valid signal upon reception of the BC0 signal for the duration of one clock cycle. This can be recognized in the counting room, and provides the time reference.

Figure 6: Trigger VFAT Mezzanine

In addition the VFAT trigger mezzanine records the trigger bits and merges them upon a level one trigger with the tracking data, so that the trigger bits which lead to a triggered event are recorded with the tracking data from that event.

Figure 7 shows a block diagram of the trigger generation and transmission block on the RPMB.

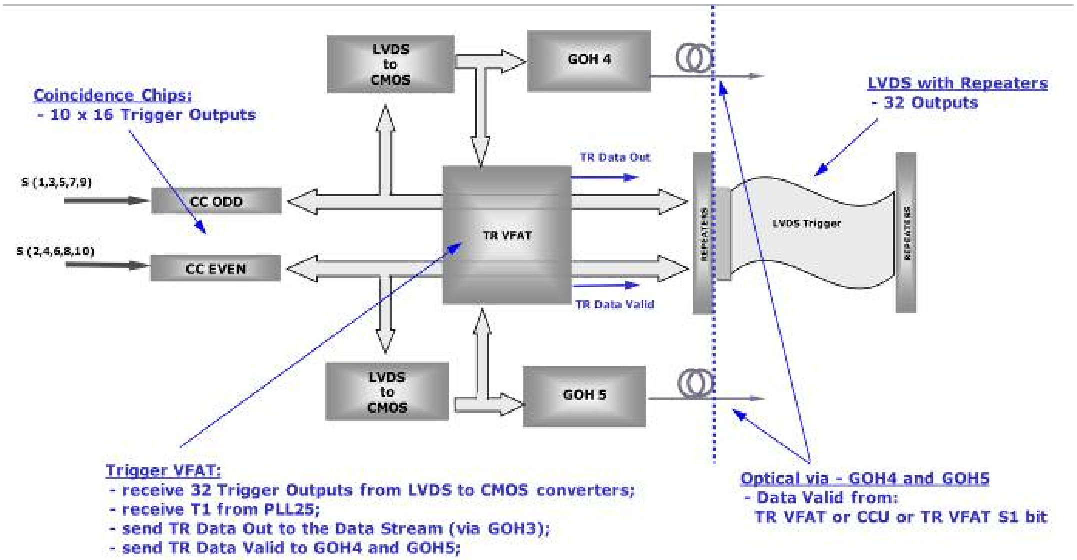

Figure 7: Trigger Generation and Transmission Block

IV. Summary

The TOTEM RPMB is a complex system which forms the interface between the silicon detector hybrids and the outside world. It provides the feed through between vacuum and atmosphere for about 800 connections. It has to fit in a relative small space and is subject to radiation. All integrated circuits on board were full custom designed for radiation tolerance. Special precautions were taken for power, clock and data distribution and transmission. The use of mezzanines allowed testing at several stages.

In total 24 Roman Pots (and RPMB) are foreseen for the TOTEM experiment. Currently 2 are installed, one on each side of the experiment at 220 m (sectors 4-5 and 5-6). The others will be installed over the next several months.

V. Acknowledgments

The authors would like to thank Norbert Lopez and Pascal Vulliez from CERN TS-DEM group for their hard work on the layout of the RPMB. The PH-DT group was responsible for the mechanical integration of the electronics with detectors in the Roman Pot.

VI. References

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