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The Central Logic Board for the KM3NeT detector: Design and production

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ABSTRACT

The KM3NeT deep sea neutrino observatory will include a very large number of multi-Photomultiplier (PMT) optical modules (DOM) to detect the Cherenkov light generated by secondary particles produced in neutrino interactions. The Central Logic Board (CLB) has been developed to acquire timing and amplitude information from the PMT signals, implementing time-to-digital conversion (TDC) with time over threshold (TOT) technique. The board is also used to configure all the DOM subsystems, to assist in the DOM position and orientation, calibration and to monitor temperature and humidity in the DOM itself. All the collected data are transmitted to shore using a wide-bandwidth optical network. Moreover, through the optical network, all the DOMs are kept synchronized in time within 1 ns precision using the White Rabbit (WR) Precision Time Protocol (PTP) over an Ethernet connection. A large Field Programmable Gate Array (FPGA) has been adopted to implement all the specifications witht the requested performances. The CLB will be also used in the base container of the detection unit (DU) to set-up and monitor all the requested functionalities: in this scenario a dedicated firmware and software will be deployed on board. The design has been started in early 2013 and several prototypes have been developed. After deep test carried on in different EU laboratories, the final mass production batch of 600 boards has been ordered and built: all the CLB are now ready for integration in the DOMs and base containers. The first two KM3NeT DU will be deployed in summer 2015 and all other units are in advanced stage of integration.

1. Introduction

The KM3NeT collaboration is designing and building a very large scale (km^3 size) deep-sea neutrino telescope to be deployed and operated in the Mediterranean Sea. Neutrino-induced charged particles are detected by measuring their Cherenkov light in sea-water, using photomultiplier tubes (PMTs) inside transparent and pressure resistant spherical enclosures. We have successfully developed an optical sensor, the Digital Optical Module (DOM), by placing 31 3-in. PMTs in a 17-in. glass sphere along with the readout electronics. Thousands of these modules will instrument the sea volume and they will be connected to the shore through electro-optical cables up to 100 km length.

2. The digital optical module

The DOM [1], in Fig. 1, is composed of two glass hemispheres. It houses 31 3-in. PMTs and all the related electronics needed to manage them:

- PMT base board with high voltage bias generator, signal pre-amplifier and discriminator.
- Octopus boards used to collect signals from PMT bases, configure them and feed the Central Logic Board.
- Central Logic Board (CLB) used to control the DOM and to handle the communication with the shore station [2].
- Power Board (underneath the CLB) used to efficiently generate all the needed low voltage power rails [3].

3. The central logic board

The CLB (shown in Fig. 2) main components are the following:

- Xilinx Kintex-7 FPGA (XC7K160TBG676) is the core of the board, used to measure the arrival time and the pulse width of the 31 PMT discriminated signals with 1 ns resolution.
- Tunable oscillators (20 MHz and 25 MHz base frequencies) for White Rabbit PTP core.
- 512 Mbit Quad SPI Flash Eprom.
- PMT interface (31 x) through Octopus boards connectors.
- SFP laser module housing with heatsink.

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0168-9002/

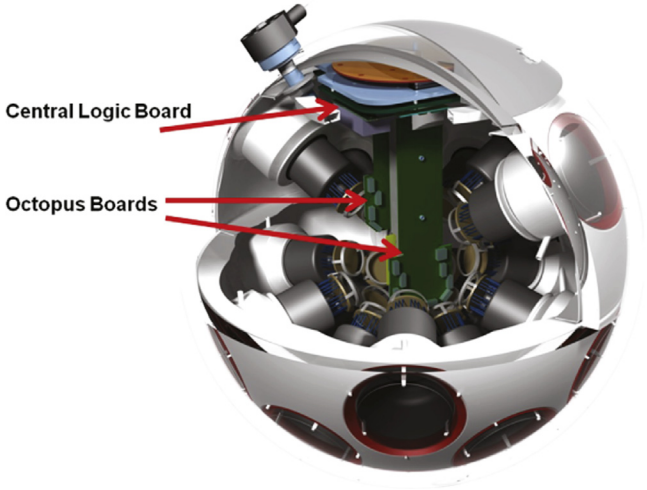

Fig. 1. An exploded drawing of the DOM.

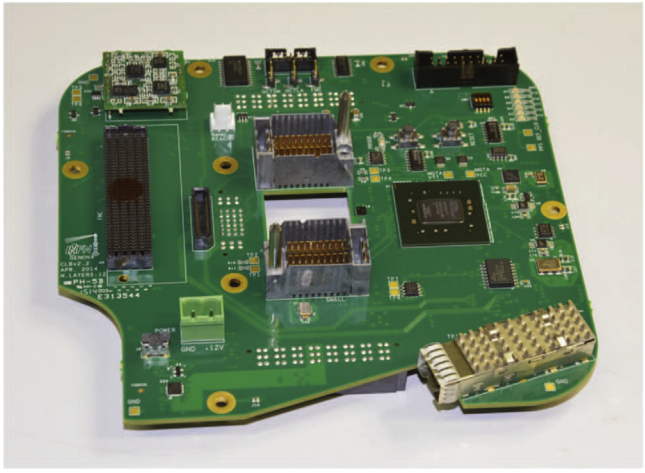

Fig. 2. One of the first Central Logic Board prototypes.

- Temperature & Humidity sensor.
- Compass & Tilt meter.
- NanoBeacon (calibration LED Flasher) Interface [4].
- Acoustic AES interfaces for Hydrophone and Piezoelectric acoustic sensors.
- Expansion industry standard FMC High Pin Count connector.
- Debugging: Serial to USB converters, Standard Header 20 pin connector, High density connector for batch production testing, Dip-Switches & LEDS.

CLB power consumption: <4.5 W Total DOM power consumption will be about 7.5 W.

In the FPGA two microprocessor systems based on LM32 soft processor are implemented:

- White Rabbit Precision Time Protocol engine: implement 1 ns time synchronization and transfer data to shore station [5].
- Configuration and slow control: handles all the devices inside the DOM, manage housekeeping data and implement debug ports.

4. Building all the parts

The first batch of 8 prototypes has been built by mid December 2013 and tested in the first months of 2014. WR PTP has been tested with 200 Mbit/s Ethernet traffic originated in the CLB and connected to a dedicated switch together other data generators. Some marginal modifications drove us to build few additional prototypes before preparing the tender procedure. Tender for 600 pieces was assigned in July 2014 to an Italian company (EES SpA). All the pieces were built by end of December 2014. The testing procedure was based on

- Burn-in.
- Jtag test (slow speed).
- Functional test (full speed).

The CLB will be used also as DU Base Container controller placed on the sea floor. All the 31 needed CLB have been shipped to the integration site. More than 200 CLBs equipped with the dedicated power boards have been delivered for integration in the DOMs. The 1st DU equipped with 18 DOMs was successfully built in December 2014.

All DOMs are in advanced integration phase.

5. Conclusion

All the parts needed to build the Detection Units have been fabricated in the expected time. The production yield is very high: $>99\%$. The burn in test did not kill any board: this means that parts choice have been carried on very carefully and that the assembly process is well under control.

Reliability analysis has been performed showing a failure rate of less than 4% in 10 years which is acceptable for the needs of KM3NeT collaboration.

The first two Detection Units will be deployed underwater during summer 2015 one in the French site close to Toulon and the other in the Itlian site in Sicily.

Acknowledgements

Three European institutions are actively working on the design: INFN (Italy), IFIC (Spain), NIKHEF (Netherlands). All involved people worked (and still working) very hard to maintain the tight schedule imposed by the collaboration board.

References

[1] D. Real, Digital optical module read-out electronics system of the KM3NeT neutrino telescope, In: Proceedings TIPP2014.
[2] P. Musico, The central logic board for the optical module of the KM3NeT detector, In: Proceedings TIPP2014.
[3] K. Manolopoulos, Design and development of the power supply board within the digital optical module in KM3NeT, In: Proceedings TIPP2014.
[4] D. Calvo, Nanobeacon and laser beacon: KM3NeT time calibration devices, In: Proceedings TIPP2014.
[5] M. Mendez, KM3NeT on-shore station and broadcast customization of white-rabbit switches towards optimizing communication resources for shared control link, In: Proceedings TIPP2014.