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A Front-end ASIC for the readout of the PMT in the KM3NeT Detector.

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A number of possible techniques exists for detecting high energy neutrinos from space. The most widely exploited method is the detection of neutrinos in large volumes of water or ice, using the Cherenkov light from the muons and hadrons produced by neutrino interactions with matter around the detector. A photon sensor (photo multiplier tube aka PMT) is housed in a glass sphere (aka Optical Module) to detect single photons from the Cherenkov light. A new String structure approach for the readout of the OMs with multi-PMTs has been proposed for the KM3NeT[1] project. Stringent power budgeting, area constraints and cost command us to design a custom front-end ASIC for the PMT. The circuit amplifies the PMT signal and discriminates against a threshold level and delivers the information via LVDS signals. These LVDS signals carry highly accurate information on the Time of arrival (< 2ns) of photons . The length of the LVDS signals or Time over Threshold (ToT) gives information on the number of incident photons. A PROM block provides unique identification to the chip. The chip communicates with the data acquisition electronics via an I2C bus. The data is transmitted real-time to shore via fiber optics, where Time-stamping is done.

Summary

Neutrino Detection Principle
Only one feasible solution is currently known to realise neutrino telescopes beyond a target size of some 10 megatons for neutrinos of energies beyond about 100 GeV: Use the Cherenkov light emitted by secondary charged particles created through a neutrino interaction in an optically transparent medium, such as water or ice. The detection of the Cherenkov light must proceed on a single-photon level, where a precise measurement of place and time of arrival of the photons associated to a neutrino event is the basis for identifying neutrino reactions and reconstructing the neutrino direction and energy. This basic principle is adopted for the KM3NeT neutrino telescope; the target material will be the water in the Mediterranean deep sea.
The neutrino telescope is composed of a number of vertical structures (the "Detection Units"), which are anchored to the sea bed and usually kept vertical by one or several buoys at their top. Each detection unit carries photo-sensors and possibly further devices for calibration and environmental measurements on "Storeys", i.e. mechanical structures supporting the necessary sensors, interfaces to supply and data lines and electronic components where applicable. The basic photo-sensor unit is an "Optical Module (OM)" housing one or several photomultiplier tubes, their high-voltage bases and their interfaces to an acquisition system of the nanosecond-precision data. In each detection unit, the data and power flow proceed vertically and is connected via the anchor to a deep-sea "Cable Network". This network typically contains one or more junction boxes and one or several electro-optical cables to shore, through which the OM data are transferred to shore. It also provides power and slow-control communication to the detector. The KM3NeT research infrastructure will be de-signed to survive a time of at least a decade in the deep sea, under high pressure and in the chemically aggressive salt water environment.
String structure: The storeys in this solution are very compact without specific electronics containers. The full structure is placed in a ready-to-deploy container. The full detection unit is "rolled up" inside the container. At deployment it can be winched to the seabed or left to freefall, after which it is positioned with a submersible. The unit is unfolded on the seabed by raising the container while leaving the anchor on the seabed. Global constraints for electronics is specified in the table below:

Time resolution (for a single photon, photomul-tiplier + electronics) < 2 ns
Position resolution < 40 cm
Charge dynamic range ≈100/25 ns
Two-hit time separation <25 ns
Coincidence acceptance >50 %
False coincidences Dominated by random coincidences from marine background photons
Dark noise rate <20% of the 40K rate
Failure rate of optical modules <10% over 10 years without major maintenance

A pre-amplifier boosts the input signal from a PMT and a comparator discriminates against a pre-determined threshold level. The ToT is determined by how long the signal is above the threshold value. The data is finally transmitted in the form of LVDS signals. LVDS seems the obvious choice for high speed transmission and low

power dissipation. The functionality of the chip also include two 8-bit DACs: 1. to control the threshold level of the comparator 2. To control the reference voltage of the High Voltage generation part. A standard library Operation Amplifier component is included for the control of HV feedback.
An I2C slave configuration is implemented to communicate with the subsequent electronics. A 20 bit (which could potentially identify a million PMTs)one-time programmable memory is integrated to uniquely identify each chip.
The present ASIC is designed in 0.35u CMOS technology and consumes <20 mW power and 1.6mm x 1.8mm of board space.

References :
[1] http://www.km3net.org
[2] http://www.km3net.org/CDR/CDR-KM3NeT.pdf
[3]L.Caponetto et. al. "Smart Analogue Sampler for the Optical Module of a Cherenkov Neutrino Detector" , TWEPP 2009.

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