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The gateway Calibration Unit for the KM3NeT Telescope

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ABSTRACT: The KM3NeT Collaboration is currently deploying the first Detection Units of a neutrino observatory in the Mediterranean Sea, which, once completed, will be equipped with thousands of so-called Digital Optical Modules. In addition to the Detection Units KM3NeT has designed an independent Calibration Unit, housing a set of calibration instruments, including e.g. an acoustic beacon and a laser beacon. The Calibration Unit and the embedded software developed to operate it are presented here.

KEYWORDS: Neutrino telescope, Calibration, Instrumentation.

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1 Introduction

The KM3NeT collaboration[1] is constructing a neutrino telescope distributed throughout the Mediterranean Sea with two main objectives: the detection of cosmic neutrinos and the determination of the neutrino mass hierarchy. This detector will consist of blocks, called **Building Blocks (BBs)**, of 115 lines called **Detection Units (DUs)**. Each DU will be made up of 18 optical modules, called **Digital optical Modules (DOMs)**[2]. The **DOMs** of the **DUs** are kept vertical and aligned by a system of buoys. The functionalities of the **DOMs** are controlled by specific hardware, the so-called **Central Logic Board (CLB)**[3]. The KM3NeT telescope will be installed in two sites: the Italian site, located about 100 km from Capo Passero, called **Astroparticle Research with Cosmics Abyss (ARCA)** which will be mainly dedicated to the detection of cosmic neutrinos, and the French site, located about 40 km from Toulon, called **Oscillation Research with Cosmics Abyss (ORCA)**, which main objective is to study the neutrino oscillations and to determine the neutrino mass hierarchy. The performance of KM3NeT relies on making precise measurements of the energy and time arrival of the events, for which it is necessary to achieve good temporal accuracy. In this regard, it is important to take into account the effect produced by the optical properties of water, as well as the sea currents. These parameters can be monitored by devices installed within the **DOMs** and in the Bases of special **DUs**, the so-called **Calibration Units (CUs)** which will be distributed throughout the telescope. The **CU** is powered by the **DU** through an interlink cable of 50 m and is composed of the so-called **Calibration Base (CB)** and the so-called **Instrumentation Unit (IU)**. Figure 1 shows an overview of some **DUs** of the **ORCA** telescope with the **CU** and the interconnections between **CU** and the Base of the **DU**.

2 Calibration Base

The **CB** is a **DU** Base module equipped with the following devices:

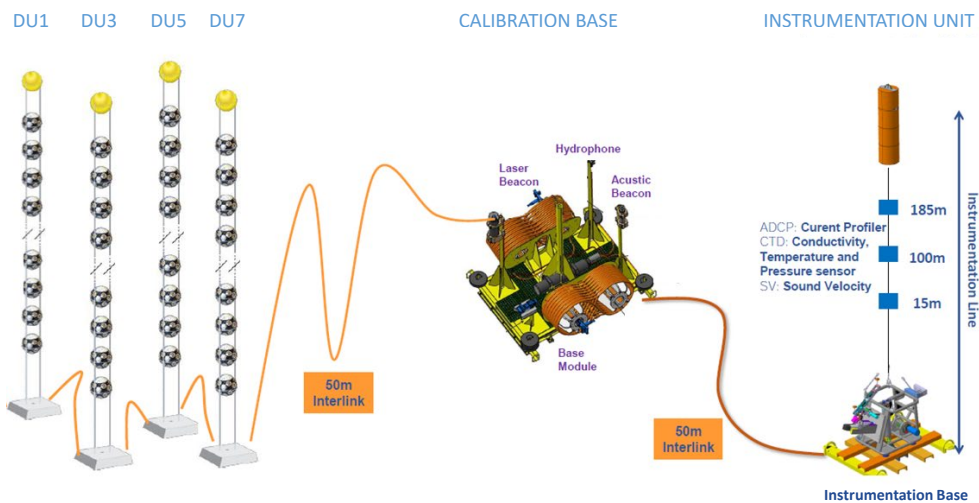


Figure 1. Overview of some DUs and a CU. CU is powered by an interlink cable connected to the DU. The CB and IU subsystems are shown.

- A Laser Beacon used for time calibration and to measure optical properties of the sea water. The Laser emits at 532 nm and is able to emit trains of pulses of high power with a maximum frequency of 4 kHz.
- An acoustic emitter to determine the DOMs positions in the sea water.
- A hydrophone which provides the position of the CB in the seafloor

Moreover the CB also contains the same electronic and optical devices included in a DU Base: two Erbium Doped Fiber Amplifiers (EDFAs) and a CLB to control all the devices.

3 Instrumentation Unit

The IU is composed of two subsystems: the Instrumentation Base (IB) and the Instrumentation Line (IL). The IB is a Titanium container with an Inductive Modem inside. The power is provided by the CB but IU also includes a power system based on internal batteries. The IL is composed of several instrumentation devices placed at different depths depending whether it is ORCA or ARCA. The IL is composed of:

- A CDT (Conductivity, Temperature, Depth) probe intended to measure water properties such as salinity and temperature which influence the sound velocity in the sea water.
- A sound velocimeter to measure the time of flight of the acoustic signals.
- An Acoustic Doppler Current Profiler (ADCP) hydro-acoustic instrument used to measure the speed and current flow of water over a specified depth range.

4 Firmware and software

The **CLB** is the main electronic element of KM3NeT. It is a multi-layer electronic board which controls the operation of the **DOM**, including the acquisition, synchronization, instrumentation, communication interfaces and devices of the **CU**. The **CLB** is also used in the Bases of both the **DU** and **CU**. The control of all the components of the electronic board has been implemented on a **Field-Programmable Gate Array (FPGA)** Kintex-7 from Xilinx Inc company. The **FPGA** is in charge of carrying out the acquisition and digitization of the optical and acoustic events, which are digitized with a timestamp provided by the **White Rabbit (WR)**[4] synchronization protocol, a protocol that allows all KM3NeT nodes to be synchronized with a precision of 1 ns. The **FPGA** has two embedded microprocessors developed by the Lattice Semiconductor Corporation company, to control the synchronization protocol and to manage the rest of the functions: acquisition, instrumentation, connections, communication and the control of the **CU** and **DU** devices.

4.1 Firmware

The **CLB** firmware is based on Lattice Mico LM32 embedded microprocessors, an open source firmware microprocessor from Lattice. One of them is entirely dedicated to the **WR** protocol, while the other one runs the embedded software to control the acquisition, instrumentation, and Bases devices[5]. All the sensors and instrumentation devices placed on the **CLB** are controlled by the **FPGA** through four **Inter-Integrated Circuit (I2C)** communication buses. For the instruments of the **DU** and **CU** the serial **Recommended Standard 232 (RS-232)** protocol is used. Seven serial interfaces are needed to control the **CU**. All the **CU** devices are connected to an expansion **FPGA Mezzanine Card (FMC)** board plugged on the **CLB**.

4.2 Software

The control of the **DOM** is achieved through robust embedded software running in the Lattice Mico LM32 microprocessor. No operating system is used in order to reduce power consumption. The software has been structured in three layers, named Common, Platform and Application. The Common layer contains the common functions, macros and standard libraries used throughout the software. The Platform layer includes the start-up code and drivers to control the connected hardware, the network protocol and the system services. Finally the Application layer includes the high level functionalities to monitor and configure the hardware. It contains the specific code for detectors, peripherals and slow control. The implementation for all the drivers within both **CB** and **IU**, as well as its slow control are coded in the Application layer. Figure 2 shows the layers and structure of the embedded software for the **CU**. The embedded software is able to execute and manage remote communication and commands from the on-shore station. A Java Graphical User Interface has been developed for this purpose.

5 Conclusions

Several **CUs** will be placed in the KM3NeT neutrino telescope. The purpose of these special units is to measure the physical properties of the surroundings of the detector. All the **CU** functionalities are controlled by a **CLB** inside the **CB**. The drivers for **CU**, **CB** and **IU**, have been implemented

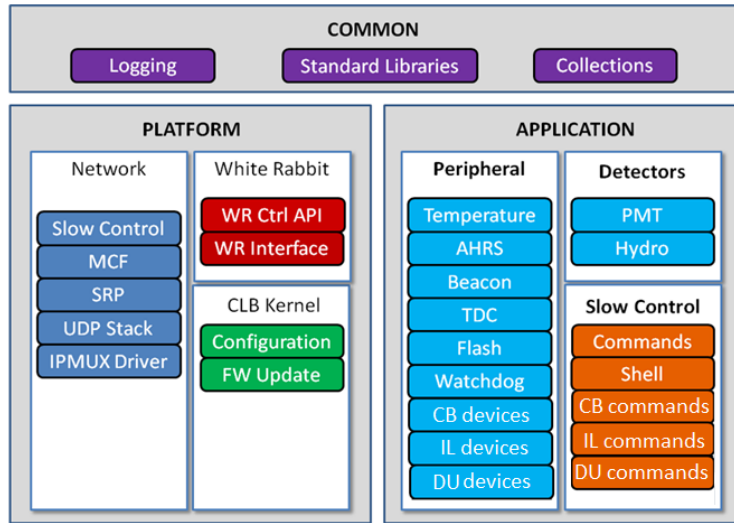


Figure 2. Representation of the layers and structure of the CU embedded software implemented in the LM32 microprocessor.

in the embedded software running in the LM32. A Java Graphical User Interface has also been developed to manage the CU functionalities remotely from the on-shore station.

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