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ELMB++

A Proposal for the Successor of the Embedded Local Monitoring Board

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Abstract

The Embedded Local Monitoring Board (ELMB) is a plug-on board used in LHC detectors for front-end control and monitoring tasks. It communicates using the CAN field bus protocol and provides analog read-out, digital input/outputs and a serial interface to the hardware it is connected to. The ELMB has been designed to be insensitive to strong magnetic fields and to be radiation tolerant within the environment of the LHC experiments during the initial phase of LHC running. However, for subsequent phases of LHC upgrades, additional design requirements for the ELMB functionality arise, such as increased radiation tolerance, and extension of the connectivity to field bus and input/output channels. Further, the readout software interface is currently based on OPC DA which is foreseen to be succeeded by the platform-independent software interface OPC Unified Architecture (OPC-UA). This poster describes the current version of the ELMB and the ideas and constraints for its upgrade – the ELMB++.

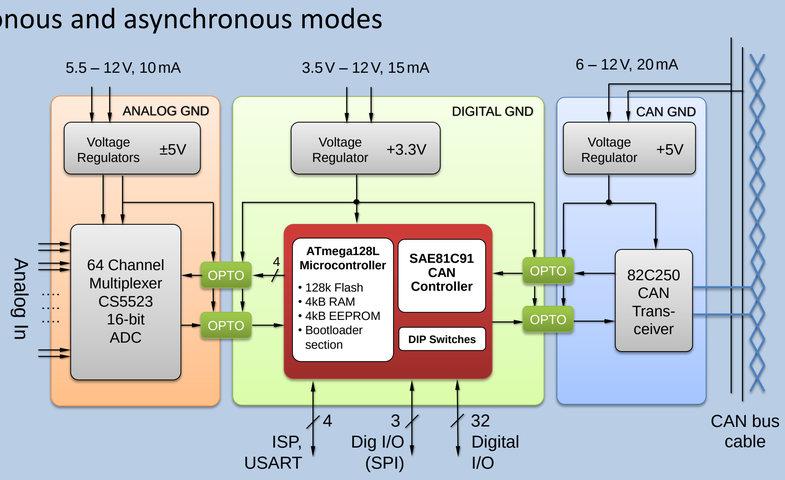
The ELMB – Description and Usage

The Embedded Local Monitoring Board (ELMB)

Hardware:
- ATMEL ATmega128 **microcontroller** (8 bits, 4 MHz)
- **CAN controller** for communication over field-bus (CANopen)
- 64 analog input channels read out by a 16-bit Analog to Digital Converter (**ADC**)
- 32 digital Inputs/Outputs (I/O)
- Serial Peripheral Interface (**SPI**) to control external components (also used on-board to communicate with the CAN controller)

Software:
- A boot loader allows to perform **remote upgrades** of the firmware
- A general purpose **CANopen I/O application** which manages all kinds of I/O available on the ELMB in synchronous and asynchronous modes

Top view of an ELMB



Simplified block diagram of the ELMB

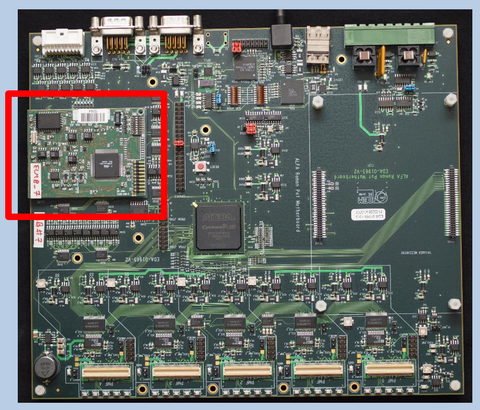
Tolerance to environment:
- **Radiation tolerance**: Qualified up to a dose of 1Gray/year and a fluence of particles of 10^{12} n/cm^2 (1MeV equivalent Neutrons)
- **Insensitive to magnetic field** (exposed to a strength up to 1.4 T with no influence)

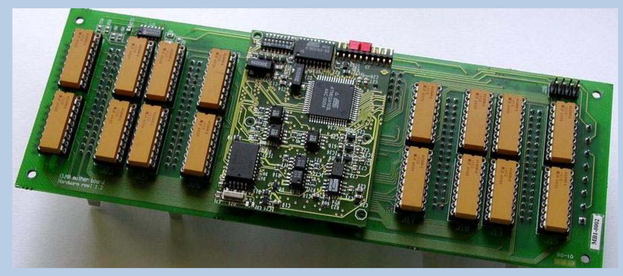
A. Barriuso Poy et al., JINST 3:P05006,2008.

Current Usage in LHC experiments

Some numbers:
- Designed at CERN. First developments in 1998 – **Final version in 2001**: *http://cdsweb.cern.ch/record/690030/files/daq-2003-053.pdf*
- A total of about **10 000 ELMB** boards are currently used in LHC experiments
- More than 5000 ELMBs are used in the ATLAS experiment
- The ELMB is a small-sized **plug-on board** (50x67 mm)

Integration in the experiments:
- The ELMBs are integrated as **front-end devices of the Detector Control Systems** (DCS) of the experiments – on-detector, in the ATLAS cavern and counting rooms
- It can be used on its **dedicated multi-purpose motherboard** which provides connectivity to the ELMB inputs/outputs, power is provided directly via the CAN bus (6-12V)
- It is fully integrated in **sub-detector motherboards** for:
  - Readout of local parameters
  - Detector front-end configuration
  - Digital input / output usage
  - Powering by host board
- Many sub-detectors customized the ELMB firmware for their highly specialized tasks





Left : ATLAS sub-detector motherboard with on-board ELMB for front-end electronics configuration, voltages, currents and temperatures monitoring, and local reset of the motherboard
Top: ELMB mounted on its dedicated motherboard for general purpose usage

ELMB++ – Definition and First Ideas

ELMB++ - An Upgrade of the ELMB

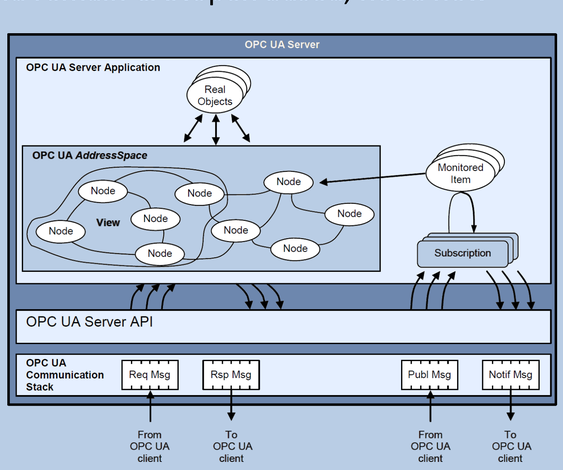
Motivation:
- The ELMB has been designed to comply with the requirements of the first phase of the exploitation of the LHC with luminosities of up to 10^{34} cm^{-2}s^{-1}
- The LHC upgrade motivates a re-design of the ELMB:
  - The environmental constraints will change
  - The scope of usage might be enlarged
  - New technologies can be considered

Work Areas:
- **Design and production** of new board which will meet the new requirements
- **Review of** the technological choices for the **connectivity and readout chain**

Evolution of the Readout Chain

Standard Controls-PC Hardware Interface:
- **Modernize** standard controls **back-end interface hardware** (currently PCI based hardware is obsolete)
- **Back-end interface driver software** should remain CANopen based, need new driver for standard Ethernet extension

Controls Software Interface:
- Controls software interface for ELMB communication currently based on **OPC DA** (Data Access) **Servers** using Microsoft technology DCOM
- ➲ Replacement with new industry standard **OPC Unified Architecture**,
  - Platform independent
  - Embedding into devices possible
  - Enables use of high-level structured data
  - Secure data transfer



OPC UA server communication diagram,
from OPC Unified Architecture Specification Part 1, Release 1.01, 2009

Requirements and Constraints of ELMB++ Design

The requirements for the ELMB++ are still largely under discussion. The key aspects are listed in the following:

Environmental constraints:
- Luminosity of the future LHC phases is increased:
  - Peak luminosity of up to 10^{35} cm^{-2}s^{-1}
  - Integrated luminosity per year will be up to a factor ~10 higher than for initial phase
  - Expected radiation levels for potential ELMB++ locations are still being estimated – use factor of 10 increase for radiation dose and neutron fluence as upper limit
- ➲ ELMB++ **radiation tolerance** improvements over the ELMB:
  - Replacement of the microcontroller by RH-FPGA / RH-ASIC controller
  - Downgrade the ADC to 12 or 14 bits
  - Flash memory might have to be replaced by rad-hard solution for booting
  - Opto-couplers, I/O peripherals need special attention
- **Immunity to strong magnetic fields** (up to 1.5T) remains a necessity

Additional features which are considered:
- Keep **CAN interface** (might be embedded in the new microcontroller)
- Add an alternative communication interface based on field-bus **Ethernet**, but must overcome magnetic field intolerance of standard components
- Embed a **DAC** on-board
- Implementation of additional serial interface protocol like **I^{2}C** (e.g. for Pixel upgrade)

User requirements:
- The ELMB++ must be **pin-to-pin compatible** with the current version (many motherboards won't be exchanged for the LHC upgrade
- **Space constraints**: The board dimensions can not be increased as it has to fit at current ELMB locations in the detectors
- Keep possibility of ELMB++ **powering through field-bus** cable
- LHC controls department is interested in an ELMB++ for replacing currently used PLCs in high radiation environment ➲ additional constraints

Outlook

The ELMB++ project – aiming to provide the LHC experiments with a local monitoring board which will comply with the requirements of the LHC upgrade – has been initiated. The improvement of the board's radiation hardness is the main challenge and is believed to be possible to achieve with reasonable effort for most of the electronic components. Nevertheless, a significant development effort will be required to provide radiation tolerant non-volatile (flash) memory and opto-couplers. Additional features of the ELMB++ – such as additional connectivity, native support for the I^{2}C protocol and on-board DAC conversion – are considered while keeping form-factor constraints and pin-to-pin compatibility with the existing ELMB as required by most of the potential users. The development of an optional Ethernet interface is envisaged, requiring a new solution for the coupling line transformer which is insensitive to strong magnetic fields and the development of a dedicated communication driver. The project is foreseen to be a collaborative effort of CERN and all interested institutes.