A PROTOTYPE OF THE

LHCB MUON DETECTOR CONTROL SYSTEM

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ABSTRACT

The LHCb Muon Detector System [1, 2] will be equipped with about 1400 high efficiency chambers (Multi-Wire Proportional Chambers and Triple-GEM detectors) which will host a total of approximately 120000 physical channels. The Muon Detector System will have to be controlled in its entirety: gas, readout electronics, environmental parameters (temperature and pressure), Low (LV) and High Voltage (HV) power supplies. This document presents an outline of the Control System and some recent improvements regarding mainly circuitry and the Supervisory Control and Data Acquisition (SCADA) software tool in use, PVSS. An overview of the design principles of the FSM-based structure for the foreseen device units is also given.

INTRODUCTION

Transfer of control related data and instructions is carried out utilizing CANopen between a host PC and control modules, and with an I^2C-like protocol based on LVDS for the connections with FE boards (FEB). A distributed PC network runs the supervision program and allows download of start-up settings and procedures, as well as upload of data logs. A custom VME 6U module [3] (Service Board, SB) has been developed to manage the FE System; it relies on Embedded Local Monitor Boards (ELMBs) [4], allowing FE circuitry monitoring and control by means of customized firmware developed for their main building block: a microcontroller (Atmel ATMega128); an ELMB features also a CANBus controller to implement the CANopen protocol. An SB is provided with a flash-memory based radiation tolerant Actel FPGA, used mainly to generate test and synchronization pulses sent to FE boards.

MWPCs will be supplied with 2 or 4 HV channels (depending on their position in the Muon Detector), while the Triple-GEM detectors will need 4 HV channels each. Therefore there will be more than 4000 HV channels. The management, control and monitoring of such a high number of HV channels is being developed in the Control System framework.

The Low Voltage power distribution is based upon Wiener (Maraton) supplies. LV Drivers are also present in the JCOP framework and their parameters and procedures must be defined. For the Gas management the Muon Control System will be able to monitor only data provided by CERN infrastructure management while for environmental parameters control, sensors must be implemented because FEE and chambers are sensitive to temperature and pressure.

This document will be focused mainly on FEE and HV control.

FRONT-END ELECTRONICS CONTROL

The Muon Control System will handle and monitor the whole of FEBs, performing calibration and test routines for every channel. It can be divided into 3 parts, depending on their location (Figure 1). The first environment, the cavern, is located 100 meters underground; for safety reasons access will not be permitted during data acquisition, due to high radiation levels in proximity of the beam pipe. Consequently, operation of electronic equipment must be unaffected by radiation induced failures. The circuitry inside the detector must be radiation hard, being able to cope with higher levels of radiation, whereas devices in the vicinity of the detector have to be radiation tolerant, in other words they have to withstand lower levels of ionizing particles. There must be a provision to remotely reset and re-program all devices, thus ensuring single event upset (SEU) recovery and power cycling of selected parts of the Experiment Control System (ECS), in order to prevent data acquisition stoppages otherwise needed to perform on-site maintenance. The control terminals will reside in the control room, on the ground level, where operators will be able to monitor the entire system. Such

workstations should be simple to utilize and their user interface should be intuitive enough to allow usage by non-specialist personnel. Local stations will be situated in the counting room, on the same level of the cavern; system control and monitoring will operate in the same way as in the control room. In the counting room a C-based alternative tool will be available as well, for debugging purposes and as a fallback option in case of a failure of the main control system.
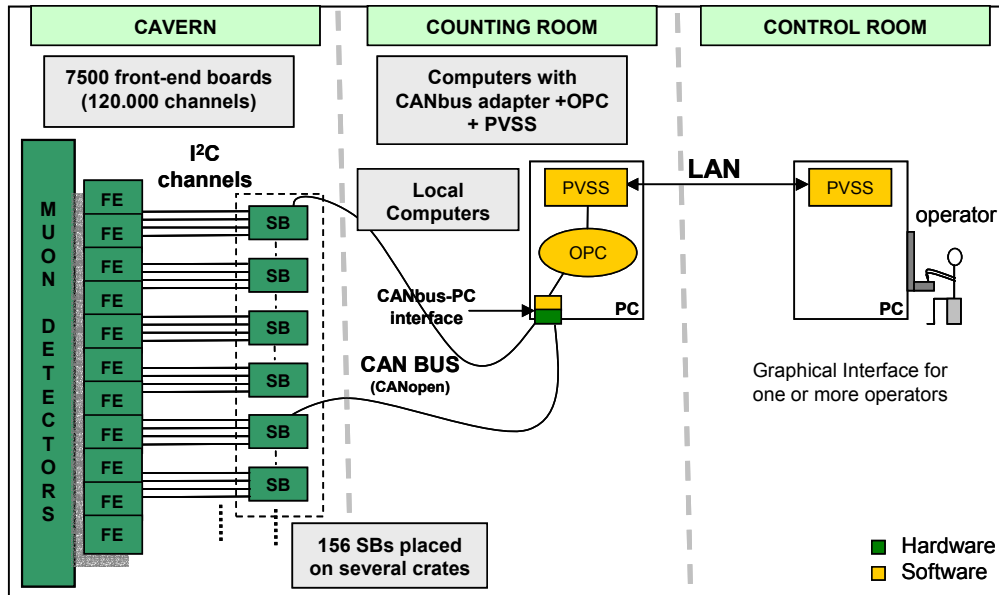

Figure 1: LHCb muon FEE control overview.

FEBs are directly connected to chambers while FE control boards are installed in equipment crates and racks, in the cavern; both are exposed to radioactivity, to different levels. For this reason the Muon Group developed two radiation hard ASICs (FEB chips) and the Roma I group developed two CANbus based boards using radiation tolerant components. Those cards are the Service Board (SB) and the Pulse Distribution Module (PDM), which will be described in the following. The control scheme is based on several electronic sub-units, using a combination of SBs and PDMs (for a total of roughly 160 boards), installed in crates equipped with a customized backplane interconnect.

CANbus access via PC is made possible using a commercial PCI card with 4 CAN channels available manufactured by Kvaser AB (Sweden) (the ECS Group has recently decided to replace it with an USB attached adapter capable of performing the same tasks). The control system will make use of approximately 2000 I^2C-like links to access all the FEBs. An SB can handle up to 12 I^2C-like channels, each of them being able to manage up to 8 FEBs (though it could look after up to 16 I^2C slaves) and to span a maximum cable length of 10 meters. Considering that an I^2C channel must not connect FEBs belonging to more than one chamber, which in turn can use a couple of I^2C channels, the estimated total number of SBs required in the system is of 156.

SCADA Implementation

The SCADA system [5] is being tooled with features which permit management of FE functionalities by means of read-out channels calibration, auto-injection testing, chamber noise analysis [6], adjustment of FE parameters, on-line monitoring and initialization, diagnostic procedures, archiving and alarm handling. During data acquisition the system will be capable of making decisions, correcting failures without human intervention, reporting changes and logging actions taken.

Each FEB contains 93 registers: as a consequence in total there will be approximately 700000 byte wide registers in the LHCb Muon System which will need to be accessed by the SCADA system. For this reason a server-client model communication system known as OPC [7] (OLE for Process Control) is being used. It provides data-transfer facilities between CAN devices and high-level software. The SCADA system in use (PVSS II) has been chosen by the CERN JCOP Group as a general solution for all LHC experiments. It is well adapted to large controlling systems, allowing manipulation of a high number of devices and registers by means of data acquisition, alarm handling,

communication protocols, graphic user interfaces, etc. Data manipulation is carried out by means of PVSS data-point elements which represent individual system registers. Each entry requires implementation of a unique OPC item and PVSS data-point. A specific procedure has been developed in order to generate automatically every OPC item and data-point. Such a method performs, at experiment initialization, detection of the ELMBs and FEBs connected to the system and subsequently creation of all the structures needed to manage them via PVSS.

The control system at its present stage of development, makes possible to read and write all FE registers using PVSS. Each FE channel has its own threshold, scaler, mask, pattern and timing (delay and shaper) registers. PVSS is able to set all of them automatically when necessary and to monitor ELMBs and FEBs operation. Figure 2 shows the main panel (left) from which every FE and microcontroller unit (ELMB) can be supervised and accessed.
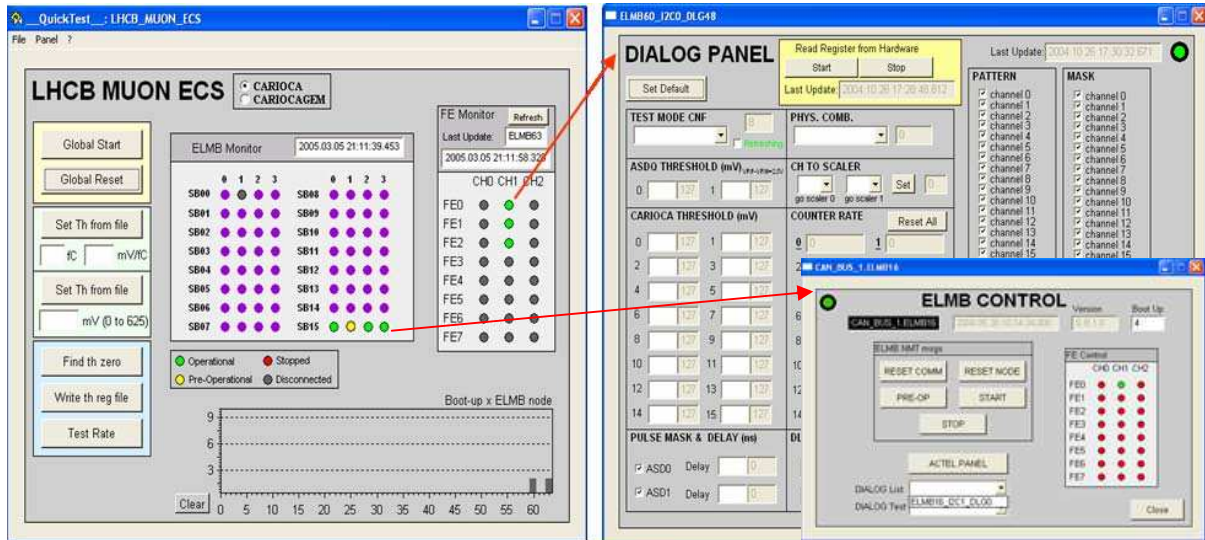

Figure 2: PVSS based panels to supervise the FE and control electronics (clicking on a specific 'led' it is possible to call individual (addressed) FEB and ELMB panels).

Features developed to control the FEE are summarized below:

- Automatic on site front-end calibration*
- Front-end board presence monitoring
- Test of all FE channels using ASD chip auto-injection
- ELMB CANopen state and operation control
- ELMB reset monitoring
- Masking out of noisy and broken channels
- Automatic threshold adjustment in fC or mV for all channels
- Reset of control and front-end electronics
- Use of database with threshold values
  * routine implemented in C (the other features make part of PVSS program)

C-based Program

As mentioned before, a C-based program is being implemented to be used as a debugging instrument for those subsystems of the FEE monitored by their local computers (in the counting room). Such a program is also being used as a development platform for the control, calibration and test procedures for the FE system. Many of the routines written in this program are planned to be included to PVSS system after a verification period, taking into account suggestions from institutes in the LHCb Muon group (CERN, Frascati, Cagliari, Potenza and Roma), which should be the final users of such a system.

The main features of the C code are: Control of MWPC and GEM electronics, access to FE registers and ELMBs, Front End boards offset calibration and threshold adjustment, using mVolts, fCoulombs, or a noise rate analysis.
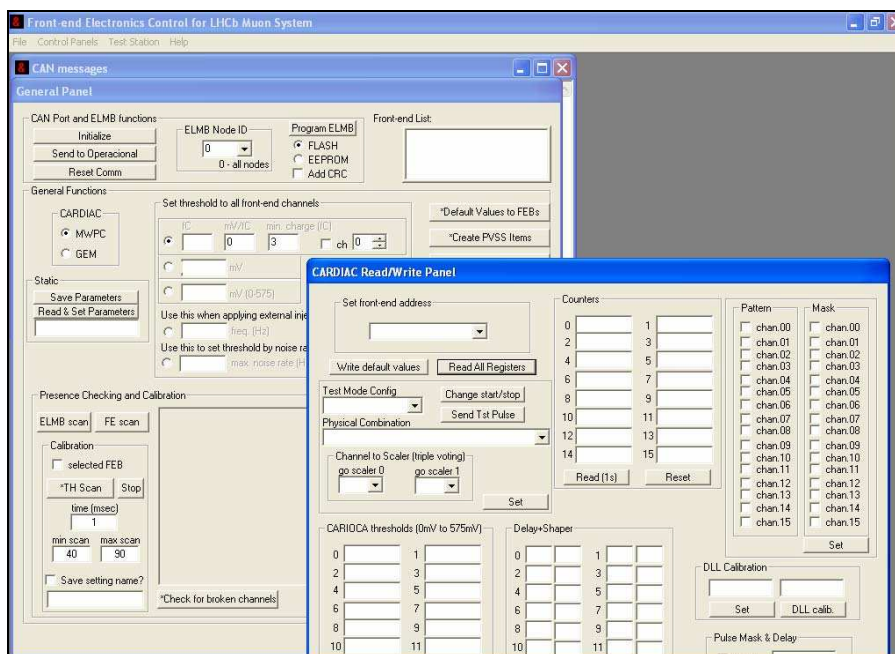
Figure 3: C-based program window.

HIGH-VOLTAGE SYSTEM

In the Control System framework a series of tools for High Voltage management is being developed. The main purpose is the tuning and monitoring of a vast amount of HV channels (about 4000) needed to supply the whole Muon Detector.

Communication with the HV system is currently implemented by means of an OPC server running on the HV crate. Fig. 4 shows an example of a control panel for a HV module with 12 channels.

Channel	OnOff	Status	VSet (V)	Vmon (V)	ISet (uA)	Imon (uA)
Chan000	Off	Off	0	0	0.002000000094	0.00200000
Chan001	On	On	1000	1000.25	0.002000000094	0.00400000
Chan002	On	On	1000	1000.25	0.002000000094	0.00400000
Chan003	On	On	1000	1000.25	0.002000000094	0.00400000
Chan004	On	On	0	0	0	0
Chan005	On	On	0.25	0.25	0.002000000094	0.00200000
Chan006	On	On	0	0	0	0
Chan007	On	On	0	0	0.002000000094	0.00200000
Chan008	On	On	0	0	0	0
Chan009	On	On	0	0	0.002000000094	0.00200000
Chan010	On	On	0	0	0.004000000189	0.00400000
Chan011	On	On	0.25	0.25	0.25	0

start conditioning   close

Figure 4: Control panel for a HV 12 channels module.

Routines for the ramp-up, ramp-down and data taking phases have been implemented and are currently being validated on real chambers.

The high levels of performance required and the high particle flux foreseen in the Muon System suggest leaving all chambers set to the same gain value, in the middle of the efficiency plateau. Moreover, detector gain depends on gas temperature and pressure. ECS will provide equalization and gain stabilization by means of tuning high voltage supplies according to changes of the environmental parameters.

FSM STRUCTURE

As the Control System grows up, a more complex structure becomes necessary to normalize communication between the different Control and Device Units and to perform a distributed supervision of the whole apparatus. A Guide for FSM (Finite State Machine) implementation to manage the equipment has been prepared [8].

An aspect peculiar to the LHCb Muon System is that FEE, more than only being monitored, should also be configured by the Control System. Such a path should be transparent for those who operate such devices from the DAQ tree. In order to put in practice such a structure it is necessary to implement a 'virtual' path between FEE System and FE electronics, as shown in Fig. 5 while the real commands and states path is exerted via the SB System.
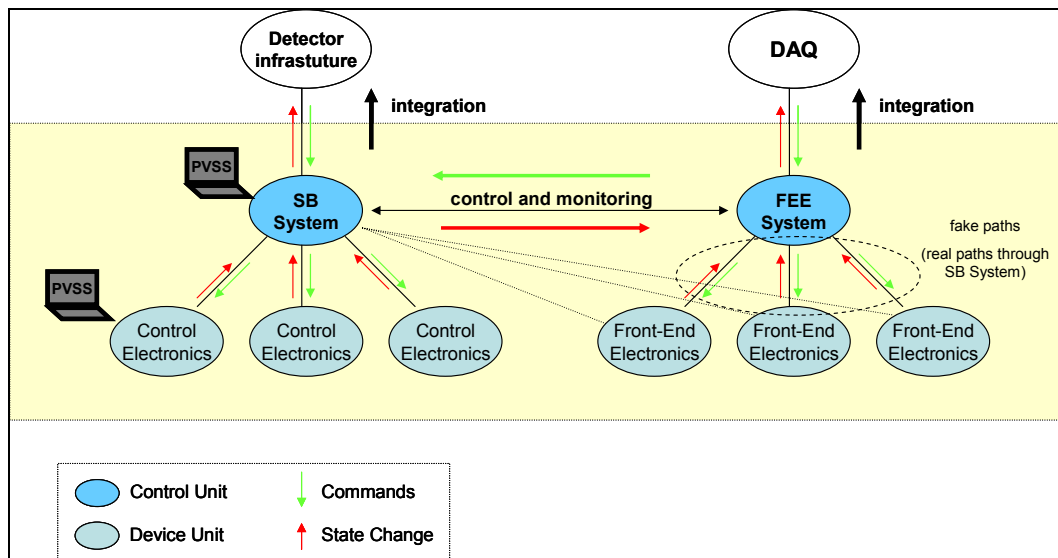

Figure 5: Control and Device Units scheme.

Control Units (CU) are defined by the ECS Group in order to standardize FSM states and commands while Device Units (DU) should be defined by their own developers. A first approach to the definition of states and commands for the Device Units is presented in the following sub-items.

Between the CUs and DUs summarized above extra CU and Logical Units (LU) ought to be inserted. The FEE system tree could be made up by the following layers (from FEE System to FEBs): Stations (M1 to M5), Regions (R1 to R4), Chambers and finally FEBs while the SB Structure could be organized by Stations (M1 to M5), Crates, SBs and ELMBs (4 units per SB).

The states for FEE and SB System DUs are:

- NOT READY
- READY
- RUNNING
- ERROR
- UNKNOWN (in case of communication lost)
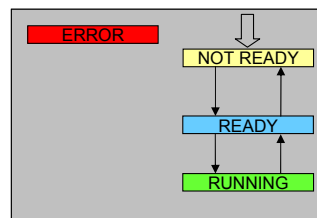
In general, the NOT READY state means that the system cannot reach the RUNNING state but it can receive specific commands to configure electronics. It is the default state when the system is initialized. READY indicates that the system has been configured and can receive the start command to transition to the acquisition state (RUNNING state). When in RUNNING state, units can receive only a stop command in order to come back to the READY state. ERROR indicates that one or a group of electronics nodes is not responding and UNKNOWN communication failure. A recovery command from this state is foreseen.

State	Meaning
NOT READY	Node not configured for acquisition but it can receive commands
READY	Device can accept a start command (RUNNING)
RUNNING	Device in use (acquisition has begun) and monitoring routines should take place
ERROR	At least one or a group of devices not responding
UNKNOWN	Lost communication

Device Units Commands for the Front-End Electronics

Command	Source state	Target state	Actions
Start	READY	RUNNING	Set FEE parameters
Stop	RUNNING	READY	Leave RUNNING state
Configure FEE	READY NOT READY	READY	FEE Calibration (threshold scan and noise analysis)
Test FEE	NOT READY	NOT READY	Test FEBs functionalities
Reset FEE	READY NOT READY	NOT READY	Reset FEBs
Recover	UNKNOWN	NOT READY	Reset Communication

All those commands take actually the SB System path but this is transparent for the DAQ users.

Device Units Commands for the FEE Control Electronics

Command	Source state	Target state	Actions
Start*	READY	RUNNING	Set FEE parameters and start monitoring procedures
Stop*	RUNNING	READY	Leave RUNNING state
Test CS Electronics	NOT READY	NOT READY	Test CAN nodes and SB components
Reset Control Electronics	READY NOT READY	NOT READY	Reset CAN nodes
Recover	UNKNOWN	NOT READY	Reset Communication
Configure FEE**	READY NOT READY	READY	FEE Calibration (threshold scan and noise analysis)
Test FEE**	NOT READY	NOT READY	Test FEBs functionalities.
Reset FEE**	READY NOT READY	NOT READY	Reset FEBs

* Start and Stop commands always come from the DAQ tree.   ** Mirrored commands from FEE tree (actual path).

REFERENCES

[1]   LHCb Collaboration, "The LHCb Muon system TDR", CERN/LHCC 2001-010.

[2]   LHCb Collaboration, "Second Addendum to the Muon System Technical Design Report", CERN/LHCC 2005-012.

[3]   Bocci, V et al, Service Board – Datasheet v1.0 . INFN sezione di Roma I, Italy, 2005.

[4]   Hallgren, B et al, "The Embedded Local Monitor Board (ELMB) in the LHC Front-end I/O Control System", CERN, Geneva, Switzerland.

[5]   Anelli, M et al, "Test of a MWPC for the LHCb Muon System at the Gamma Irradiation Facility at CERN", CERN/LHCb 2005-003.

[6]   Bocci, V et al, "Diagnostics of the Muon System Front-end Electronics during the LHCb Experiment", LECC-2005, Heidelberg, Germany.

[7]   Filimonov, V.M, "Description of the CANopen OPC server", CERN, Geneva, Switzerland.

[8]   Duval, P, "Guide for ECS FSM design in LHCb detectors", CERN/LHCb EDMS 655828.