The Interface and Control System of the Upgraded HVOpto/HVRemote Card of the *TileCal*

C. Rato[a], J. Sabino[a], L. Gurriana[b], L. Seabra[b], A. Gomes[ab], G. Evans[ac], J. Soares Augusto[ad], A. Maio[ab]
[a]Faculdade de Ciências da Universidade de Lisboa, Portugal
[b]LIP, Portugal
[c]BioISI, Universidade de Lisboa, Portugal
[d]Inesc-ID, Portugal

***Abstract*—To comply with the increase in luminosity of the LHC (Large Hadron Collider) in the next decades, the electronics of the ATLAS (A Toroidal LHC Apparatus) experiment is being upgraded. Included in the upgrade is the interfacing and control electronics system of the *HVOpto/HVRemote* cards in the *TileCal* (Tile Calorimeter) detector, which provides high voltages to about 10^4 photomultipliers (PMTs). This paper presents the new interfacing architecture for the system and details the design of a prototype control board (*HVRemote-Ctrl*) used for test and validation. The tests evaluate the system multiplexing capabilities needed to monitor all the *TileCal* PMTs in real time.**

Keywords: Instrumentation for High-Energy Physics, Electronic Control, Ethernet/SPI Interfacing.

I. Introduction

An electronic system currently being upgraded at the ATLAS experiment is the one in charge of the control and distribution of high-voltage (HV) to the approximately 10^4 PMTs of the *TileCal* detector. Its core comprises two cards [1]: the *HVOpto* and the *HVMicro*. In the current ATLAS setup, this system is located inside the detector, so it works under high doses of radiation. Current *TileCal* HV (High Voltage) electronics is in operation for more than 10 years and is aging despite its design took into account radiation hardness. Another severe constraint is the difficulty in maintaining and replacing faulty *HVOpto* or *HVMicro* cards: it is never possible when the LHC is running and is only possible when the LHC stops at least a few months.

To alleviate these constraints, one of the proposed upgrade options [2][3] moves the *TileCal*'s *HVOpto* electronic control system from the detector, for a location in the USA15 room which is a low radiation environment far away (100 m) from the detector. This will improve the lifetime of the system and provides for immediate maintenance and replacement. On the other hand, the power supplies of the *HVRemote*[1] board will now be linked through a bunch of 100 m cables, what worsens its stability and noise levels. Since the current electronic design is about 20 years old, some components in the *HVOpto*, such as the ADCs and DACs, have to be replaced.

[1]To keep things clear, we call to the "old" HV system, now in operation, the *HVOpto*, and we call to the upgraded system the *HVRemote*.

The *HVRemote* board has some caveats, noticeably the fact that very high voltages (in the -800 to -1000 V range), low level analog signals, several digital control lines and a low speed processor share the board. So, the overall noise in the board which is highly shaped by components' and traces' layout, shielding and cabling is significant and difficult to predict.

In this paper it is described the upgrade of the control system of the HV cards for the *HVRemote* version. There is a concurrent effort at the *TileCal*'s community [4] that keeps the HV electronics in the detector.

II. The *HVRemote* Control System

A. The HVOpto Control Path and Hardware

The architecture of the upgraded system is shown in fig. 1. The control master is a PC/workstation configured as a node of the DCS (Detector Control System) of ATLAS. The DCS commands to, and the data read from the *HVRemote* boards flow through a tree of Ethernet links, joining the PC and 256 boards, each of these managing 24 PMT channels.

The control software consists in DCS (high-level commands), C++ and Python programs, running in the PC, which use the DCS API, and C programs running in the *Tibbo* EM1206 modules (described below). These modules, one attached to each *HVRemote* board, are used to read commands from the Ethernet channel, convert them into raw digital signals and send them to *HVRemote*'s digital control circuits through a SPI (Serial Peripheral Interface) link. It also manages the reverse data flow (from the *HVRemote* to the upstream DCS computers.)

B. The HVRemote-Ctrl Testing Card

To evaluate the supervising and control system of the *HVRemote*, it was built a test card, the *HVRemote-Ctrl* (figs. 2 and 3), which has the same control components of the *HVRemote*, but without the front-end electronics of the 24 PMTs. This provides means to test the digital control hardware and the *Tibbo* module, and to assess the transfer speeds. The *HVRemote-Ctrl* is being assembled and tests will start soon.

A DC/DC converter MAX3002 is used to couple the 3.3 V signals from *Tibbo* to 5 V in the CMOS (Complementary Metal-Oxide Semiconductor) hardware. The test card has a

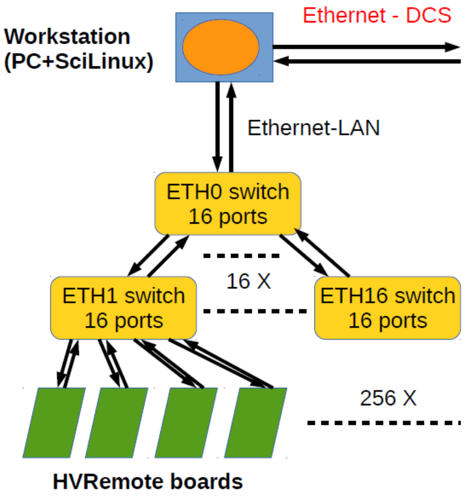

Fig. 1. Architecture of the *HVRemote* control tree.

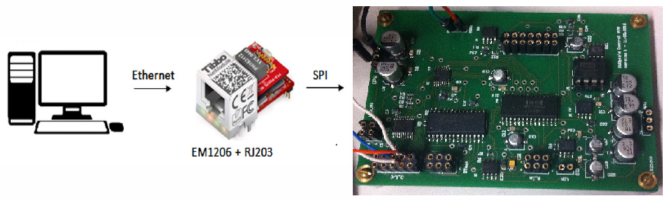

Fig. 2. Protocols in the *HVRemote* system. *HVRemote-Ctrl* at right.

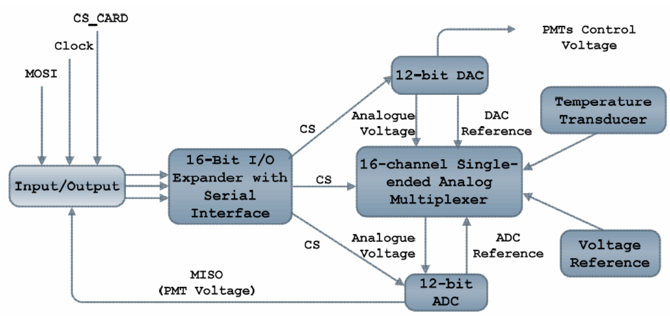

Fig. 3. Block diagram of the *HVRemote-Ctrl* card.

16-bit port expander with SPI (MCP23S17), a 12-bit DAC (DAC7568), a 16-bit analog multiplexer (MPC506), an instrumentation amplifier (INA128), a 12-bit ADC (TLV2541), a temperature sensor (TMP17) and a voltage reference (AD589). These are the same components (in less quantity) and architecture of the *HVRemote* full card.

C. Evaluation of the Tibbo EM1206 module

To evaluate the interfacing solution, it was used a *Tibbo* EM1206-EV evaluation board. *Tibbo* supplies an integrated development system for the board, which includes C libraries for sockets programming and SSH communications, two important libraries for our work. *Tibbo* also supplies a standalone tool, the *IO Ninja*, which allows testing the Ethernet communication between the board and the PC.

The *Tibbo* module can be programmed either in C or in BASIC. A raw Ethernet client using sockets was developed in C and deployed in the module. It succeeded in communicating with an Ethernet master in the PC, programmed in Python, and with the *IO Ninja* also working as an Ethernet/sockets master.

The programs (or scripts) used in these preliminary tests followed closely the reference implementations suggested by the board vendors.

III. Results and Conclusion

The development of the *HVRemote* continues, guided by knowledge gained from evaluating the *HVRemote-Ctrl* card. The following tasks have been completed:

- Development of the *HVRemote-Ctrl* card to evaluate the digital control and supervising system. The component assembly in the prototype (fig. 2) is undergoing.
- Development, in Python, of a panel to manage the *HVRemote-Ctrl* card.
- Evaluation of the *Tibbo* EMS1206 module as a suitable Ethernet controller for the *HVRemote* board.
- Evaluation of the *Tibbo* EMS1206 module as SPI master, using Arduinos configured as SPI slaves (fig. 4).

The speeds measured in both Ethernet and SPI communications with the *Tibbo* module are suitable to monitor in real time all 256 *HVRemote* boards and 10^4 PMTs in the *TileCal*.

In the next months the prototype of a full *HVRemote* card will be assembled and several pieces of software to be used in the system will be developed. Hopefully, the new *HVRemote* control system will comply with the requirements needed to cope with the escalade in *TileCal* data flow triggered by the increase in luminosity of the LHC.

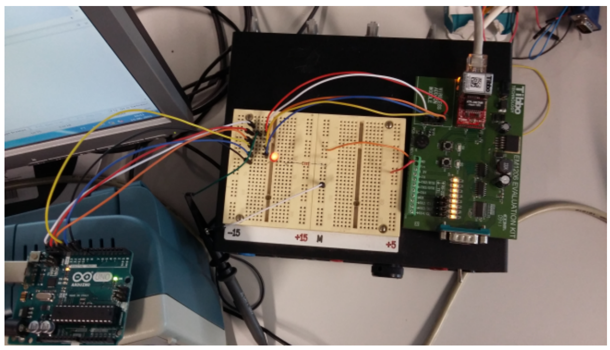

Fig. 4. Tests of *Tibbo*-Arduino communication through the SPI interface.

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