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Quench Data Acquisition and Slow Control for the Superconducting Magnet of the COMPASS Experiment

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ABSTRACT

The COMPASS experiment at CERN will use a new large acceptance superconducting magnet. A quench acquisition system and a slow control system for field rotation have been developed. In terms of hardware, the acquisition system is done with an off-the-shelf modern VME64x solution, whereas the slow control system re-uses a 12 year old VME configuration coming from the former SMC experiment. The software is based on EPICS with a dedicated development concerning quench acquisition (32 analog and 64 binary inputs permanently sampled at 5kHz in a circular buffer of 100sec duration) and field rotation (complex procedure involving the smooth correlated modification of 34 field values). Standard EPICS supervision applications and a dedicated tool for visualization of quench data run on a Linux PC. This system will be commissioned during the second half of 2005 and then, installed on the experiment at CERN.

INTRODUCTION

The COMPASS experiment (Common Muon and Proton Apparatus for Structure and Spectroscopy) runs at CERN using a 160Gev beam from the SPS accelerator. Its goal is the study of the nucleon spin structure with the interaction of a polarized muon beam with a polarized deuton target. A new large acceptance magnet for polarization has been built by Oxford Instruments and will be installed on the experiment at the end of 2005. It is composed of:

- A superconducting solenoid which provides a high longitudinal field with a very good homogeneity.
- A superconducting dipole which is used to achieve reversal of the spin direction by field rotation.
- A set of 16 trim coils is also used to make local magnetic field corrections.

Saclay is in charge of:

- The instrumentation of this magnet system.
- The quench detection electronics for the solenoid.
- The quench acquisition system.
- The slow control system used for field rotation.

The computer system is composed of a redHat Linux PC and two VME crates. The VME systems use vxWorks. One VME achieves acquisition for the quench protection system and the other one controls the magnet power supplies. The organization of the software tasks follows a standard scheme: the VME systems manage acquisition and control and all the aspects related to real-time, whereas the PC is used for supervision, data storage and visualization. The only exception concerns the field rotation sequencing which is done on the Linux PC with a set of Perl scripts. The EPICS control software is used for slow control, low frequency acquisition and supervision of the system. Specific software loosely coupled with EPICS is used for fast acquisition of the quench events. On the PC side, a software designed with the IDL graphical package is used to display quench data.

QUENCH DAC SYSTEM

An unexpected loss of superconductivity caused by a rapid increase of the resistivity of the coils is called a “quench”. This can cause damage to the magnets (dipole and solenoid). To avoid such damage, a sophisticated hard-wired quench detection system is used: the Magnet Safety System (MSS).

This system is based on the following principle:

- a high voltage isolated analogue front end compares the voltages across the layers of the coils to a given threshold (a differential comparison between the layers is made),
- the result of the comparison is analysed by a digital treatment unit taking into account other digital information coming from the command control of the experiment and the cryogenics system,
- in case of a quench, the digital treatment unit stirs the safety elements of the dipole and solenoid electrical circuits.

The redundancy of the measurements and of the digital treatment enables the reliability of the MSS.

To be able to analyse “a posteriori” what happens during a quench event, a fast data acquisition system acquires:

- the analogue voltages across the layers,
- the digital data coming from the outputs of the analogue front end,
- the digital data coming from the digital treatment unit.

The data are memorized a given time before and after the detected event and their analysis will allow the understanding of the quench, its origin, its propagation etc...

The requirements for the acquisition system were the following:

- 16 bit acquisition of 40 analog parameters with a frequency up to 10 kHz,
- acquisition of 64 digital inputs with a frequency up to 10 kHz,
- acquisition over a time span of 60 seconds (30 seconds before the quench, 30 seconds after the quench).

The DAC system is built with a VME64x industrial solution from Hytec Electronics Ltd. The analog acquisition is done with an Industry Pack (IP) carrier VME module able to accommodate 4 IP modules and 8 channels 16bit simultaneous ADC with transient recorder memory IP modules. The IP in-board memory enables 1 second storage of the 16 channels at 1 kHz. The digital acquisition is done with a 64 bit digital input/output module with a memory allowing tracing of changes through time. Following the VME64x specifications, these modules support hot-swap and geographical addressing. The rear I/O connectivity of VME64x is also provided by Hytec with analog and digital transition modules (see figure 1). Finally, the modules are fully software configurable. This set of features greatly helps for installation, setup and maintenance of the system. The CPU is a PPC MVME2434 with 256MB of memory from Motorola.

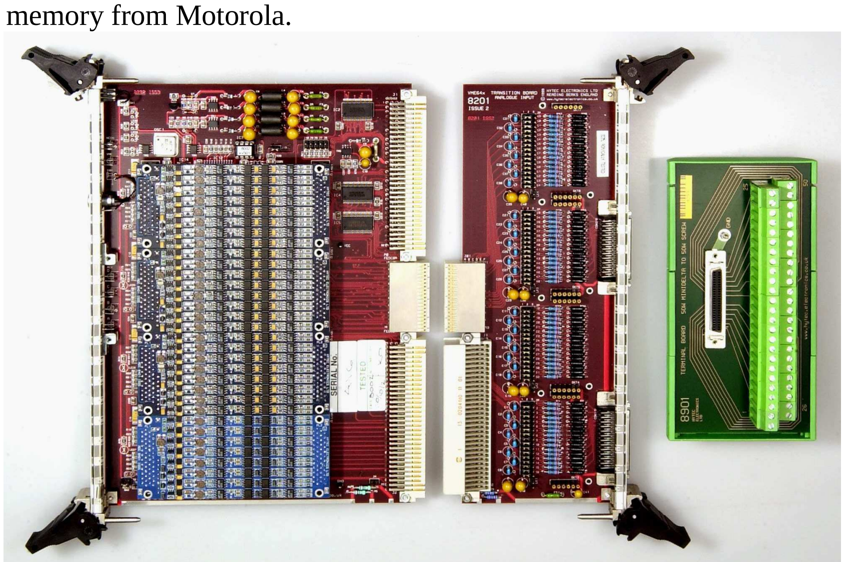
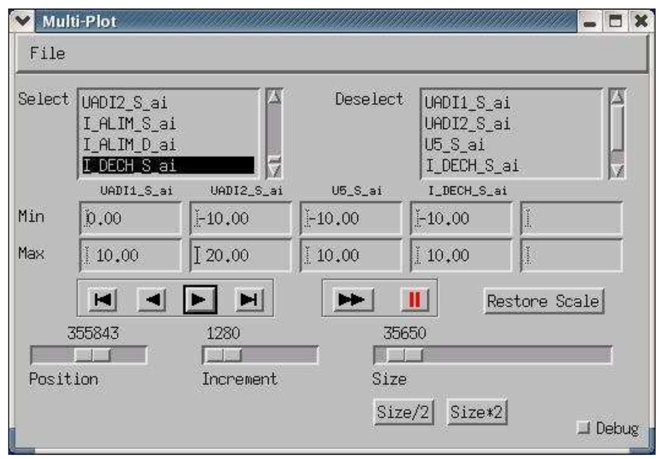


Figure 1:VME64x IP carrier with ADC IP modules, transition board, connector

The choice of this solution was also influenced by the availability of an EPICS software support for these modules. This point is of great importance because all the previously mentioned features (hot-swap, geographical addressing, software configuration, transition modules detection, IP management) increase dramatically the software complexity. The standard EPICS software support enables the monitoring of the parameters up to 10Hz which is enough for the standard supervision tasks (displays, archiving, alarm handling). The 10 kHz acquisition software was developed in our laboratory. It uses the in-board memory of the modules to store the acquisitions temporarily. A high priority task transfers the data from the IP modules to the CPU memory. The transfer delay from the IP memory to the CPU memory is of the order of 1µsec /Byte. This is a potential limitation of the number of channels for a given frequency, but not in our case with 40 Channels at 10 kHz.

A quench event triggers a digital input which raised an interrupt of the VME CPU. Then, a 30 second countdown is started. Finally, all the raw data are sent to the PC via NFS. The conversion in physical units is done off-line, when needed. A visualization interactive tool based on the IDL package from RSI was developed to display the data (see figure 2). Later, this tool was adapted to visualize the data coming from the standard EPICS archiver.



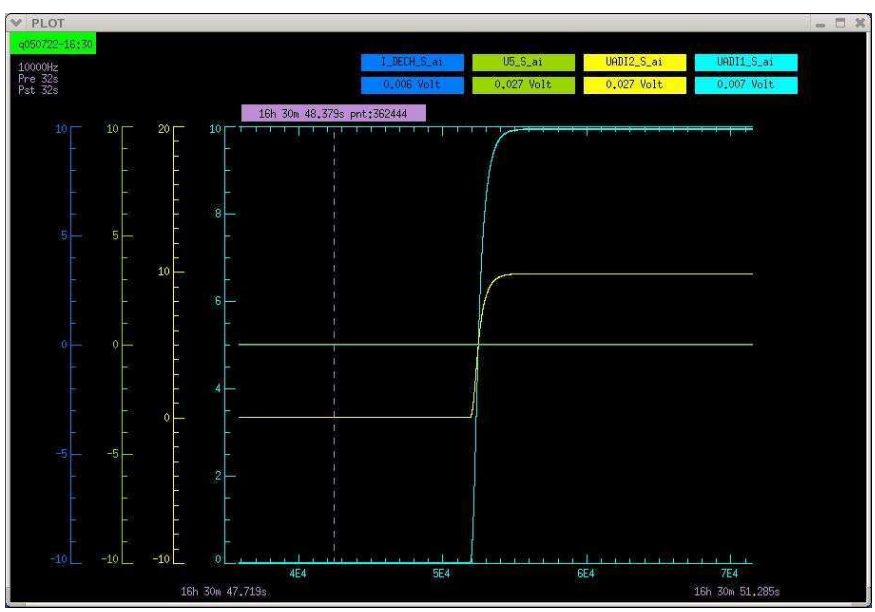


Figure 2: Quench data visualization

FIELD ROTATION SLOW CONTROL SYSTEM

Unlike the DAC system, this VME is based on a very conventional hardware layout. The crate and modules (analog and digital I/Os from ADAS Company) used previously for the SMC experiment, are re-used. SMC is the former nucleon spin experiment for which a similar system for rotation field was developed 12 years ago [1]. This is a good demonstration of the impressive life-span of such solutions, compared to PC-based solutions. The only change for hardware, concerns the CPU which is now a Motorola MVME167 we had previously used for another experiment. The software is redesigned and is based now on EPICS. In particular, the dialog with the solenoid power supply is handled by the EPICS stream device [2] which isolates the bus type to the device protocol handling. The EPICS drivers for the ADAS boards were already developed 10 years ago for the DESY TTF project.

The sequencing of the field rotation procedure is a complex and critical operation. It lasts more than 30 minutes and a failure of this procedure will cause the interruption of the experiment for several hours. For flexibility reasons, a set of Perl scripts is in charge of the operation sequencing. Adjustments and tuning of this procedure are expected during the first runs at CERN. So it will be much more convenient to modify such scripts rather than using the more complicated remote vxWorks software development cycle (such vxWorks development environment is not available locally on the experiment). Critical magnet stepping is done locally on the VME with a suitable arrangement of EPICS records. For each power supply the following records are used:

- an analog output record configured in incremental mode is used to send the value to the power supply
- a calculation record is used to trigger periodically at 1Hertz the increments of the analog output record
- an analog output record is used to set the ramping speed.

The communication between the Perl scripts and the VME is done through the EPICS Channel Access protocol.

This scheme is adopted for the 18 power supplies of the magnet system. It reduces dramatically the complexity and volume of the software.

RESULTS AND FUTURE WORK

All the different elements are now operational. It took some time to have the acquisition system running (bugs in the firmware of the IP modules, availability of functions in the low level software, correct setup of the external clock). Now the system is working correctly. It shows a very interesting price/performance ratio and it can be upgraded nicely, thanks to the modularity of the solution. The slow control system is ready. The use of the EPICS stream device avoids unnecessary software development for the main magnet power supply interfacing. During the second half of 2005, the system will be commissioned with the magnet and, finally, installed at CERN at the end of 2005. This integration is still to be done.

ACKNOWLEDGMENTS

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