THE CONTROL SYSTEM FOR THE TITAN EXPERIMENT AT ISAC

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Abstract

The TITAN experiment at the ISAC radioactive beam facility consists of an RF cooler system, a Magnetic Penning Trap (MPET), and an Electron Beam Ion Trap (EBIT). These three systems may run together or independently. This paper describes the EPICS-based TITAN control system, which was modeled after the ISAC control system in order to facilitate integration. Both software and hardware configurations will be described, with emphasis on pulsed diagnostics and the pulse distribution system for synchronizing the traps in different operation modes.

INTRODUCTION

TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN) facility is a series of multiple ion traps connected to the ISAC radioactive beam [1]. Figure 1 shows a photograph of the TITAN platform. The combination of different ion traps coupled with the most intense radioactive beam of very exotic nuclei makes TITAN unique in the world. TITAN's physics emphasis is on testing the standard model and nuclear astrophysics by determining precise mass measurements. ISAC's continuous radioactive beam is cooled and bunched utilizing a gas-filled Radio Frequency Quadrupole (RFQ) Paul Trap. The ions may be injected into an Electron Beam Ion Trap (EBIT) where charge breeding takes place. The extracted beam is sent through additional separation stages to the Penning trap where the mass is determined. A penning trap provides a well controlled environment using a combination of magnetic (4 Tesla) and electrical fields in a high vacuum to trap the ions. A small controllable alternating electric field is applied to the trapped ion causing the ion to act as though it was in a cyclotron. The frequency at which this occurs is inversely proportional to the mass. Frequency measurement is capable of the highest precision.

The control and synchronization of the traps required special care due to the pulsed nature of this system. In addition beam diagnostics of a pulsed system was new to TRIUMF.

STANDARD EPICS CONTROLS

Similar to other semi-permanent installations at ISAC, the control system for the TITAN experiment was implemented by the ISAC controls group. Although the system is operated by the experimenters, it is tightly integrated with the ISAC control system. The implementation follows the ISAC standards:

- Beam diagnostics devices are controlled via VME modules in order to maintain tight coupling with the IOC CPU. Most VME I/O modules are TRIUMF designed.
- Beam optics devices are equipped with intelligent local controllers, which are supervised by the input/output computers (IOCs). These controllers are distributed on CANbus networks.
- Vacuum devices are controlled by Modicon Quantum series programmable logic controllers (PLC)s, which are peer nodes on the controls Ethernet. Functionally they rank below the EPICS IOCs and are supervised by those IOCs using the Modbus protocol on TCP/IP.

The ISAC control system software is based on the EPICS toolkit and is described in detail in [2] [3],

While the control system provides the beam transport and infrastructure control, a majority of the trap functions are controlled by the experiment's data acquisition systems.

SPECIAL REQUIREMENTS

RFQ beam cooler and buncher

The RFQ beam cooler and buncher [4] consists of a MOSFET driven square wave RFQ capable of 1MHz with a peak to peak voltage of 400V [5]. The voltage is controlled using TRIUMF standard CANbus power supply controllers, but the frequency is controlled with a custom built VME module. The ions are trapped by a longitudinal electric field profile, which is generated by 24 DC electrodes. The electrode voltages are provided by three eight channel +/- 40VDC VME modules along with two high voltage (+/-500VDC) modules. Another VME module [6] provides the drive signals to fast Behlke HV switches, which open the trap field profile for the extraction. It also provides the timing trigger pulses for a multi-channel plate detector as well as the triggering of the laser for spectroscopy.

The RFQ beam cooler is biased at 30 kV with respect to ground and requires the associated VME controls to be located at the same potential. In order to make the setup less spark-sensitive, a VME-to-VME bridge solution is currently being evaluated, which would allow locating the VME CPU at ground potential.

Figure 1: Picture of the TITAN platform. In the foreground one can see the vertical transfer beam line and the HV cage surrounding the RFQ cooler, in the background the circular shape of the MPET superconducting magnet. EBIT is behind the racks perpendicular to RFQ-MPET beamline.

MPET

The Mass Penning Trap (MPET) functions are controlled using the Maximum Integration Data Acquisition System (MIDAS) [7]. MIDAS uses EPICS Channel Access to set up the beam-line elements between the RFQ and MPET and a TRIUMF Pulse Programmer (PPG). This VME module is used to control the operation sequence for the various measurement cycles. For the first MPET measurements the MPET PPG was also used to trigger the extraction of the RFQ cooler.

EBIT

The EBIT (Electron Beam Ion Trap) was built at the Max Plank Institute in Heidelberg and uses Labview for control. The intention is to upgrade the control system to a combination of MIDAS and EPICS in the near future. A transfer beam-line has been added since the EBIT's arrival at TRIUMF. The optics elements of this beam-line are controlled by the TITAN/ISAC control system.

The beam optics controls for the EBIT experiment presented a new challenge in EPICS database design in ISAC. The beam-line design includes two Sikler lenses, comprised of 6 electrostatic elements each. Operation of the Sikler lenses requires simultaneous adjustment of four elements in combinations of differing polarities and magnitudes. The control algorithm was straightforward enough to implement using EPICS database design. However, the customary use of a single Capfast symbol to encapsulate the complete functionality of such a device proved to be too unwieldy. No previous devices encountered in the ISAC control system had been found to approach this limit: a credit to the application of Capfast within the EPICS toolkit.

Testing and debugging of the more complex EPICS databases for the Sikler lenses was made easier by the use of the sch2edl tool. Sch2edl allows the EPICS database and the interactions between records to be easily observed and design changes to be made online interactively. More details on sch2edl can be found elsewhere in these proceedings [8].

Emittance scans

Standard TRIUMF Allison-type electric sweep emittance scanners [9] consist of a motor driven slit (controlled by a VME OMS58 motor controller module) followed by deflector plates (driven by a DAC on a TRIUMF VADC module [6]) the beam continues through a second parallel fixed slit where it is read by a faraday cup . This has worked well at TRIUMF for DC beams, even for radioactive beams in the nanoAmp regime, due to the development of a VME based current ADC (VQSX) [10]. Pulsed beams of radioactive ions, however, require a different approach. The charge deposited on a standard faraday cup is too small to be read accurately using the VQSX. Therefore the faraday cup has been replaced with a Multi-channel plate (MCP) detector. The MCP signal is processed by a TRIUMF designed integrator module. The module contains an analogue integrator, ADC, DAC and digital I/O signals controlled by an FPGA. On occurrence of a trigger the baseline corrected value of the integrated current is latched in the DAC and sent to the VME system together with a Data Ready signal making the data available to the control system. The trigger can be provided by an external timing system (time delayed from the RFQ extraction) or internally generated from the digitized integrator signal by a constant fraction discriminator. The digital processing is done in the FPGA which controls the integrator, ADC, DAC and the Data Ready signal. After a fixed interval the integrator and DAC are reset and ready for the next trigger.

The scan sequence is started by an operator or user from an EDM screen. An EPICS subroutine record moves the entrance slit to the starting position, voltage is applied to the deflector plates and the measurement cycle begins. A task to determine when the integrator has data ready is spawned. Once the data ready signal is detected the ADC is read and the voltage on the deflector plates is incremented. The entrance slit is repositioned on completion when the field scan is complete. This process continues until the entrance slit has been moved across the beam. Data is collected in an array and saved in a file at the end of the scan. The results are displayed on the EDM screen using a Matlab application [11]. An example of bad beam emittance is shown in figure 2.

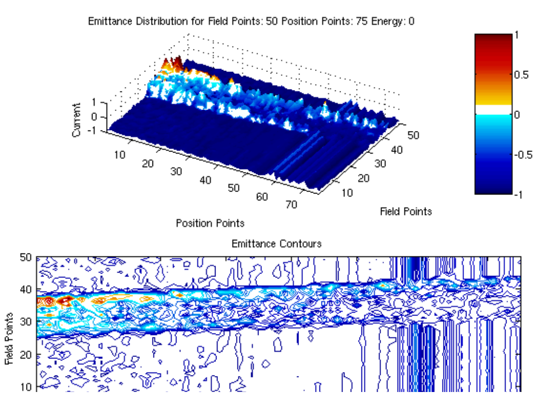

Figure 2: An example of the displayed pulsed beam emittance scan

Synchronization of beam transfer

Since each of the three traps can function independently, a separate timing sequencer module is used for each trap. A custom module was developed for the RFQ because it required being located at high voltage potential. The MPET and EBIT use a PPG. When all three traps come online a master timing trigger module will be used to coordinate the beam transfer between the traps.

STATUS

Reverse extraction from the RFQ cooler using TRIUMF's offline ion source was successfully demonstrated in December 2006.

TITAN's first experiment used the RFQ cooler to trap, cool and extract the Li ions directly to the penning trap. During this experiment the masses of ^{6}Li and ^{7}Li (both stable) as well as ^{8}Li and ^{9}Li were determined with high precision (dm/m~ 10^{-7}). The determination of the ^{11}Li (8 ms half-life) mass is scheduled for the next on-line run, starting December 14, 2007.

REFERENCES

[1] www.triumf.ca/titan

[2] R. Keitel, et al., 'Design and Commissioning of the ISAC Control System at TRIUMF', ICALEPCS99, Trieste, October 1999, p. 674

[3] R. Keitel, et al., 'Status Update on the ISAC Control System', ICALEPCS01, San Jose

[4] M. Smith et al, "First tests of the TITAN digital RFQ beam cooler and buncher" Hyperfine Interactions, November 2006, p.171-180

[5] M. Barnes et al., "A high frequency MOSFET driver for the TITAN facility at TRIUMF" International Pulsed Power Conference, Monterey, 2005 www.triumf.ca/publications/pub/arch05/pp-05-21.pdf

[6] D. Dale et al., "Custom electronic modules for the ISAC control system" ICALEPCS, October 2005, Geneva, p.171-180

[7] midas.psi.ch

[8] R. Nussbaumer, "Live Capfast Schematics in the ISAC Control System", these proceedings

[9] P. W. Allison, D. B. Holtkamp and J. D. Sherman, IEEE Trans. Nucl. Sci. **NS-30**, 2204 (1983)

[10] D. Bishop et al, "Custom VME Modules for TRIUMF/ISAC Beam Diagnostics" ICALEPCS99, Trieste, October 1999,

[11] E. Tikhomolov, "Processing and Visualization of Epics Data with Matlab Applications", these proceedings