Control System Prototype for the ISAC Radioactive Beam Facility

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Abstract

The ISAC ion source test stand at TRIUMF was used to implement a prototype control system in preparation for the ISAC radioactive beam facility, which is currently under construction. The test stand consists of an ion source, an electrostatic beam line with an analyzing magnet, and various beam diagnostic equipment. The control system (approximately 300 control channels) was implemented using the EPICS toolkit. It integrates three systems: an industrial PLC for vacuum and ion source control, a set of distributed power supply controllers on a CAN-bus networks for beam control, and the beam diagnostics systems which was implemented in CAMAC for cost and historical reasons. Experience with EPICS, necessary extensions and integration issues will be discussed.

1 Introduction

ISAC is a new radioactive beam facility presently under construction at TRIUMF. Protons from the TRIUMF 500Mev cyclotron will strike one of two hot underground targets. The resulting beams of short lived radioactive isotopes are analysed in a mass separator and transported to either low energy experiments or to an RFQ / Drift-Tube-Linac accelerator. After acceleration, these beams of short lived isotopes are used for nuclear reaction studies, in particular in the field of nuclear astrophysics. In order to test and characterize different types of target-ion-sources before use in ISAC, an ion source test facility was constructed.

The ISAC machine is only loosely coupled to the existing TRIUMF accelerator. It was therefore possible to consider a non-evolutionary, new approach for the control system design. The ion source test stand seemed to present an ideal opportunity to build a prototype control sytem in order to validate an EPICS based concept. Joining the EPICS collaboration promised to reduce in-house development and reduce overall system costs.

2 System overview

The test facility consists of the ion source at 60 kV potential, an electrostatic beam line with six quadrupoles, two sextupoles, two octupoles and several steering elements, an analyzing magnet, and various beam diagnostic equipment such as faraday cups, wire scanners, and emittance measurement stations. This translates into a control system with approximately 300 hardware I/O channels, roughly 10% the expected size of the initial ISAC control system.

The decision to design this prototype control system based on EPICS was made easier by the fact that most of the necessary infrastructure was already in place so that no major start-up costs were incurred. For a number of years the vxWorks kernel [1] and 680x0 based CPUs have been used at TRIUMF by the data acquisition group and for embedded systems development in our group. Also available were two Sun SPARCstations.

3 Hardware implementation

The control system for the test facility consists of one EPICS input/output controller (IOC), using a VME crate with a Motorola MVME162 CPU. This IOC controls three sub-systems, which are implemented with different I/O hardware:

- ion source, vacuum system and services
- beam optics
- beam diagnostics

3.1 Vacuum system

The vacuum system and the services (such as water, air, etc.) are controlled by a commercial PLC system in order to provide high up-time and use the advantages of ladder logic programming. The ion source was included with this sub-system because of the interlock requirements and cost considerations. We chose the new Quantum PLC line from Modicon with a model 160 CPU which is VME based and allowed easy integration with EPICS. For this sub-system, EPICS acts in a supervisory function only.

3.2 Beam optics

From a technical point of view, the PLC approach could also have been used to control the beam optics system, but this would not have been cost-competitive for ISAC where several hundred electrostatic and magnetic power supplies have to be controlled. Instead, we developed intelligent" power supply controller modules, which are connected directly to the power supplies' remote control connectors. These controllers communicate with EPICS via CAN-bus, using a TIP810 industry pack [2] on the MVME162. With this approach analogue signals are digitised right at their sources and cabling and documentation costs are drastically reduced. The power supply controller design is discussed in detail in a separate contribution to this conference [3].

3.3 Beam diagnostics

The beam diagnostic sub-system was implemented in CAMAC. This decision was driven by time and cost considerations because TRIUMF has a large base of available CAMAC modules. Some diagnostic elements, such as the TRIUMF emittance rigs were only available packaged in CAMAC. For the ISAC facility, this sub-system will be migrated into VME to allow for tight integration with the front-end CPUs.

A block diagram of the control system hardware is shown in Figure 1.

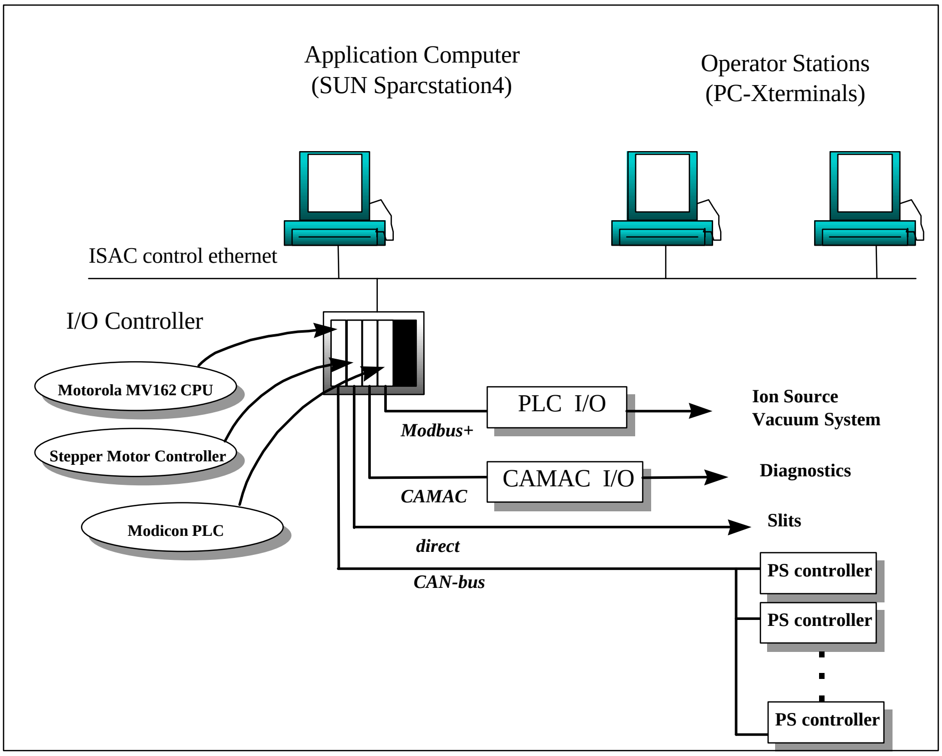

Figure 1: Block Diagram of the ISAC Test Stand Control System

4 Software implementation

The software effort for producing this control system fell into three broad categories:

- using EPICS tools to configure the IOC function block data base, operator interface screens, etc. This part did not involve any conventional code development.
- writing C code
  - to integrating the Modicon PLC system into EPICS
  - for the CAN-bus controller embedded program
  - to adapt the EPICS CAMAC system for TRIUMF
  - for special devices
- programming the PLC in ladder logic.

4. 1 EPICS tools

Up to now, only a few of the many available EPICS tools have been used extensively. We selected edd/dm over medm for building the operator interface because of the higher performance.

As the primary tool for building EPICS databases we selected the CAPFAST schematic drawing package [4]. In addition to the possibility of graphically visualising the IOC code functionality we were attracted by the support for multi-level schematic hierarchies which we implemented in the form

Sub-system >> device >> component >> EPICS primitives.

Each schematic drawing is represented at the next higher level by a corresponding symbol. Device functionality is constructed from reusable components wherever possible. To define device specific operating parameters, hardware type, etc. macro substitution is used at the device symbol level.

4.2 Code development

One of the attractive features of EPICS is the reduction of conventional code development during the building of a control system. Only 2200 lines of C code and 160 lines of assembler code needed to be written for the following areas:

4.2.1 Modicon PLC integration

The Modicon 160 Quantum PLC is a VME master module which has ladder logic instructions to copy data to and from the MVME162 dual port VME memory. In order to make these data available to EPICS, simple device and driver support software layers were written.

4.2.2 CAN-bus controller embedded code

Integration of the CAN-bus power supply controllers into EPICS was straightforward as device and driver support for CAN-bus and the TIP810 industry pack were available from the collaboration [5]. A simple application layer protocol for peer to peer interaction between EPICS and the controllers was implemented. The code for the embedded microprocessor on the power supply controllers was developed in C with minor assembler portions. This is described in more detail in ref. [3].

4.2.3 CAMAC driver adaptation

The existing EPICS drivers for the HYTEC 2992 serial branch driver were modified to support the JORWAY 73 SCSI crate controller which was used in this system. This was done by replacing the hardware dependent inline code with calls to the SCSI driver.

4.2.4 Special devices

A few devices of the test stand needed faster controls than provided by the standard EPICS scan classes. Fast read-out loops were implemented to acquire data from free-running beam profile wire scanners at 3 kSamples/sec as well as fast drive loops for the emittance measurement stations. For this, EPICS subroutine records were written using the vxWorks auxiliary system clock.

4.3 PLC programming

The PLC was programmed in ladder logic, using Modicon's MODSOFT programming tool. For ease of program state visualisation in on-line mode, the program was implemented as a linear ladder and no subroutine programming was used. A simple hand-shake and watchdog protocol was implemented to ensure safe startup and synchronisation between the PLC and EPICS. The PLC program can be switched between simulation mode and run mode by the supervisory system. This is achieved by using intermediate variables instead of hardware input or output values in the ladder logic. In run mode, the hardware I/O space is mapped to these variables before executing one ladder scan cycle. In simulation mode, this hardware mapping is replaced by the execution of a simulation code segment, which mimics real device behaviour..

5 Conclusion

The experience with EPICS in this prototype system was very positive. Starting from zero EPICS knowledge, the ISAC test stand control system was delivered within eight months using 1.5 person-equivalents for the EPICS part. One additional person worked on the hardware installation and PLC programming. With these limited resources we were able to provide a reliable and easily understood control system and operator interface. EPICS combines flexibility due to extensibility at all levels with a wide base of expertise available from members of the collaboration throughout the world. We were also able to integrate existing control software from other sources using subroutine records. Data gathered by epics was made available in file format to analysis software written by operators and physicists at TRIUMF.

Acknowledgements

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References

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