CUSTOM ELECTRONIC MODULES FOR THE TRIUMF/ISAC CONTROL SYSTEM

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ABSTRACT

The TRIUMF/ISAC Control system utilizes EPICS based on VME hardware with CANbus as the fieldbus. The Electronics Development group at TRIUMF/ISAC has previously developed VME modules [1] for the ISAC facility. This success led to development of several purpose built modules. Specifically for TITAN (TRIUMF's Ion Trap for Atomic and Nuclear science) five VME modules were developed: a frequency generator for the RFQ cooler with an output in the range of 200kHz to 1.2MHz 1Vp-p sine wave, a gate trigger module to generate timing pulses for injection and extraction of the ion beam, a 6-channel high voltage module to provide the extraction voltages adjustable from 0-2000V, an 8-channel +/-40V power supply used in setting the trap DC levels, and an 8-channel 12 or 16 bit scanning ADC with a single 16bit DAC. For ISAC four CANbus modules were developed to complement the existing power supply controllers [2] and allow control and monitoring of devices not currently connected to the control system. These include magnetic field measurement with a Hall probe, water flow measurement and interlock, and laser devices and power supplies requiring RS-232 or IEEE-488. A Stepper motor controller was also developed.

INTRODUCTION

Interfacing devices to an accelerator control system involves balancing the needs between competing approaches of "buy off the shelf" and "design in-house".

If available, commercial modules are often expensive and offer additional features that are usually not required. These extra features complicate the controls software, which makes system integration difficult. At TRIUMF's ISAC radioactive beam facility, input/output (I/O) hardware for controlling beam optics and beam diagnostics devices were designed in-house [1,2]. With experience and infrastructure in place, the Electronics Development group felt confident designing several new specific purpose modules.

Purpose built electronics provides many advantages over generic commercial modules:

- the users receive electronics designed specifically for their requirements
- significantly reduced cost (which is partially due to the fact that engineering cost is provided as a TRIUMF service to users)
- compact design, which makes optimal use of scarce space especially on high voltage platforms
- local expertise provides for fast repair and the ability to modify existing hardware for future applications

This paper discusses two areas of development: VME based modules targeted specifically for use in TRIUMF's Ion Trap for Atomic and Nuclear Science (TITAN) and CANbus based modules for more general use throughout ISAC.

VME HARDWARE FOR TITAN

Requirements

The TITAN facility consists of a gas-filled linear Radio Frequency Quadrupole (RFQ) Paul trap, which provides beam to either a charge-breeding Electron Beam Ion Trap (EBIT) or a Penning trap for precise mass measurements [3]. The TITAN project's RFQ device will be used to cool and bunch a 60keV ion beam taken from the ISAC radioactive beam facility. This section describes work on this RF cooler portion of TITAN.

The RF cooler is driven by a 600V 3MHz square wave driver [4]. This driver requires a reference frequency, which is dependent on the ions to be trapped. The driver also requires that the power supply voltage be adjusted dependent on the RFQ frequency. A trap is created by breaking the RFQ into segments; each having a different DC voltage applied creating a longitudinal electrostatic potential profile, which is added to the RF field.

The RF cooler functions in two modes, a forward extraction mode, in which the cooled bunch is extracted downstream, or a reverse extraction mode where the cooled bunch is extracted back upstream. These two modes require several sequentially timed triggers. In the primary forward extraction mode, ions are trapped for a period of time (~100 msec) then the bunch is ejected downstream (~15 µsec). After the ejection, the ion bunch is slowed to the transport potential. In the reverse extraction mode, two additional events are required. Before the bunch is ejected, the deceleration electrodes at the front of the cooler must be disabled and the deflector plates energized to bend the bunch.

At present, the TITAN RF cooler is operating in a test stand using forward extraction only. The RFQ and the entire EPICS IOC system is biased up to 60 kV. This simplifies connection to the devices of the cooler system.

In order to satisfy the listed requirements, the following VME modules were developed:

- Frequency Generator
- Gate Trigger Module
- 6 Channel High Voltage Power Supply
- 8 Channel Low Voltage Power Supply
- 8-Channel ADC

Frequency Generator

The Frequency Generator uses an existing module designed for use in a different experiment [5]. The original design generated a complex modulated swept signal. By modifying the firmware this module is able to provide single fixed frequencies. The module generates a RFQ frequency (f_{RFQ}) between 200kHz and 1.2MHz and an associated Power Supply Driver frequency (f_{PSD}) based on the formula $f_{PSD} = (0.21249 \times f_{RFQ}) + 59871$ Hz (see [4]). Only two of the four outputs of the original module are used for TITAN. The maximum output levels are ±0.5 volts into 50 ohms. The signals are synthesized digitally using an Analog Devices AD9857 Direct-Digital-Synthesizer. An external signal-squaring module generated the required TTL pulses from the module's sinusoidal output. The VME form factor is 6U, single-width.

Gate Trigger Module

The Gate Trigger Module provides sequenced outputs for the TITAN RFQ extraction timing. The cycle can be started with a pulse into either of the trigger inputs or with an internal oscillator. For the case of a forward extraction, the ejection pulse width can be adjusted from 30 nanoseconds up to 164 microseconds, with a repetition rate from 1 to 127 Hz. The beam energy conversion pulse can be delayed from 30 nanoseconds to 164 microseconds and the width varied from 30 nanoseconds to 164 microseconds. The VME form factor is 6U, single-width.

6 Channel High Voltage Power Supply

The High Voltage Power Supply module provides the trap and ejection voltages for the last three segments of the RF cooler. The module also supplies voltage to the exit steering plates. Plug-in commercial [6] HV supply sub-modules provide six channels of variable output voltage. The voltage range and polarity for each channel depends on the installed sub-module. The sub-module ranges of 500, 1000, 1500 volts and 2000 V with current capability of up to 1mA are available. Each channel can be controlled and monitored from the VME interface or the front panel. The VME form factor is 6U, double-width.

8 Channel Low Voltage Power Supply

The Low Voltage Power Supply module supplies DC voltages to the 21 centre segments of the RF cooler. Each of the eight channels provides a variable voltage with a range of +/-40 V, although higher voltages can be configured by changing output sub-modules. An external +/-48 V power supply must be provided. The 16-bit output voltage is achieved by the use of high voltage operational amplifiers. Each channel has both 16-bit voltage and current read-back. The VME form factor is 6U, single-width. Three modules are used in TITAN.

8-Channel ADC

The ADC module provides auto-scanning 12 or 16 bit (via a component change) differential analogue input. Each channel is digitized into a separate 4K acquisition buffer up to a maximum conversion rate of 40 kHz. Conversion rates are individually configurable for all channels. Analogue inputs are connected via the front panel with BNC Twinax connectors.

In addition, a 16-bit +/-10V DAC is provided. This DAC is configured manually via the front panel to monitor either one of the eight ADC channels. A seven-segment display indicates the source of the DAC output.

Each ADC channels has eight selectable gain ranges:

- Gain 1 +/-10V
- Gain 10 +/-1V
- Gain 100 +/-100mV
- Gain 1000 +/-10mV

The VME form factor is 6U, single width.

CANBUS HARDWARE FOR ISAC

HallProbe Controller

The Hall Probe controller module is intended as an inexpensive readout device for commercial Hall Sensors. It monitors magnetic fields in beamline dipole magnets and aids operators in beamline tuning. Hall sensor excitation and signal conditioning functions are incorporated into the module, which digitizes the conditioned field value. The result, converted to engineering units, is reported through a CANbus link to the EPICS control system. The control system selects field ranges and displays module status.

Water flow Controller

The eight-channel water flow controller was designed to replace an existing TRIUMF module which suffered from CPU-resets during Ion Source sparking. The module counts pulses from Proteus water [7] flow paddle wheels, converts the flow rate into engineering units (litres/min) and reports the rates to an EPICS IOC via CANbus. It also provides low flow trip contact closures. The module uses a microprocessor to calculate flows and handle CANbus communications, but uses a Complex Programmable Logic Device (CPLD) for the critical interlock function eliminating the susceptibility to sparking.

RS-232/GPIB/IEEE-488 Controller

Although the ISAC controls group discourages the use of devices with RS-232 or IEEE-488 control, there is increasing demand from experiments and facility engineers to provide this type of control. The new Charge State Booster requires a very stable high voltage power supply. The manufacturer, FUG [8], would not guarantee the stability using an external reference with an analogue controller. Instead, they recommended using their RS-232 interface with an internal 16-bit DAC. Since all of the power supplies in ISAC are controlled by microprocessors boards distributed on CANbus loops [2], it was decided to design an RS-232 device controller with a CANbus communication interface. The firmware is written such that the new FUG RS-232 power supply looks exactly like a power supply with analogue control. An IEEE-488 interface is included for future use.

For more complex clusters of IEEE-488 devices, a solution exists with a commercially available PC-104-based IEEE-488 module [9].

Stepper Motor Controller

Currently, stepper motor systems for slits and linear profile monitors (LPM) at ISAC are controlled using an Oregon Micro Systems VME-58 module [10] and a commercial translator module. In the existing installations, close proximity of several motors justified the use of the VME-58 system. For ISAC II there will be single motor installations separated by a greater distance. Therefore, a stepper motor controller was designed for integration via CANbus. For position read-back it supports both an analogue potentiometer as well as an absolute or incremental optical encoder. Two-phase motors up to five amps are supported.

SOFTWARE

During the process of selecting commercially available IO modules, it is customary to base that decision not only on functionality but also on the availability of a suitable driver from the manufacturer or science community. If not available, writing such drivers can be quite complex in order to support the generally richer feature-set of the commercial equipment.

With in-house designs, we were able to standardize on register sets and thus greatly simplify the process of driver design. We have developed vxWorks 5.5 device drivers for all modules with device support for EPICS Revisions 3.13.xx and 3.14.xx. For all modules, we maintain the strict EPICS layering, separating device support and driver support. This hides hardware details from EPICS or any other high level application and simplifies the process of testing and debugging new modules

CONCLUSION

Experience at ISAC has shown that special purpose I/O hardware modules can be designed, built and integrated rapidly by standardizing on components and by utilizing a common register model. Using Altera CPLDs and C language for processor-based applications has allowed for “cut and paste” implementation of new modules. This has resulted in modules performing optimally for the targeted applications at attractive cost for the users.

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