The Control System for a New Proton Extraction Probe at TRIUMF

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Abstract

A motor control system was designed for the new Beamline 2A Proton Beam Extraction Probe of the 500 MeV Cyclotron at TRIUMF. The probe uses four motors for positioning the extraction foil within the vacuum tank. The mechanics of the probe use a pantograph for lowering the extraction foil into the beam plane, which affects the radial position of the foil. An automatic correction of this shift was crucial to proper foil positioning.

Requirements of the system included accurate positioning, integration into the existing control system, and the potential to replace existing systems in use at a future date.

1 History

Existing extraction probes in the TRIUMF cyclotron use a hardware based stepping motor control system. This system uses full step activation of the motors and does not employ acceleration. The lack of acceleration in the motor drive can lead to slipping of the motor during motion. Each motor axis requires a shaft encoder to ensure proper movement.

Interlocking of each probe axis is controlled by relay boxes wired to produce logic statements.

The equipment was designed and built at TRIUMF and has worked fairly well for the last 20 years. Many of the components are now obsolete and much of the equipment is difficult to support.

2 Recent developments

Newer motor systems have used various computer systems and a variety of control and drive modules. These include:

- a CAMAC based general purpose single board computer designed and built by TRIUMF running motor control software in ROM. This system integrates easily into the existing control system, and is used for many small motorized systems. The interface between the autonomous motor system and the control system is with a shared CAMAC memory module.
- commercial motor control systems using stepper and DC motors. Some of these interface using RS-232C, others are adapted to interface to the existing control system.

These newer systems use acceleration in their motion algorithms to reduce the possibility of slippage. Most of these systems do not use encoders to read back position. They run *open loop* with a possible secondary position readback using a potentiometer. There is a high level of confidence in the motor operation, reducing the need and cost of a *closed loop* control system.

3 Hardware overview

The control system computer is VME based using a Motorola MVME162-023 Single Board Computer. This computer has several useful features including:

VME Interface Provides system controller functions for the VME enclosure and access to VME modules.

SCSI Interface Used to communicate with a local CAMAC Crate.

Flash Memory Used to store the operating system kernel in compressed form along with boot and decompressor modules. The kernel is decompressed from here into the main memory during the boot process.

Battery backed SRAM Used to simulate a disk drive to store application and database files. This allows easy changes to the application by copying the new object files from the development system. Several boot scripts are stored here to change how the system starts up during development.

Ethernet Interface Used for communication with the diagnostic program to build and modify the database and control motors during testing.

Motor control is handled by an Oregon Micro Systems VME58-8 Stepping Motor Controller module. This VME module has a versatile internal language for controlling single and multiple axis motions. Different acceleration and deceleration profiles are available.

A Jorway 73A SCSI to CAMAC Crate Controller is used to access a local CAMAC Crate. The Crate holds a shared memory module used by other motor systems and the Central Control System as a communication port. There are also digital input and output modules in the CAMAC Crate used for position encoder inputs and general purpose input/output bits. A library of routines was written to allow ESONE CAMAC calls to be made with the SCSI interface on the Motorola computer.

4 Software overview

During development of the system, it was decided to make the device database for the system expandable. This would allow future additions to the system (See section 7). The database describes all parameters for each device, including motor parameters, storage locations, interlocks and dependencies.

4.1 Real time control

The control program runs under WindRiver VxWorks 5.2, a real-time kernel. The control program runs autonomously, and does not use any display functions of its own. The program is written in the C language. Tasks are created to:

- monitor requests for motion via the shared memory in CAMAC. Each new motor command is acknowledged and processed by the system.
- monitor motor positions and limit switches. This data is written into the shared memory in locations defined by the device database.
- monitor input bits and control output bits.
- provide server services to the diagnostic program.

There are several different devices defined for use in the system. These include:

Stepping motors controlled by the VME58-8.
Digital inputs and outputs from auxillary bits on the VME58-8
Digital inputs and outputs from bits in VME modules
Digital inputs and outputs from bits in CAMAC modules
Digital values from CAMAC input gates
Counters for monitoring extraction foil positions
Links to join one device to another for complex behavior

4.2 Diagnostic display

The diagnostic display is an X/Motif application running under UNIX. The program communicates with the real time server via Remote Procedure Calls using the Ethernet interface on the Motorola computer. The program has a client application which requests regular updates of system status from the server routine.

The diagnostic program uses a series of dialog boxes for editing device parameters, interlocks and dependencies. Other dialogs are used for control and monitoring of each type of device in the system.

4.3 Interlocks and dependencies

Interlocking is crucial for safe operation of the BL2A Probe, and data entry and modification were carefully addressed to reduce errors. The Interlocks are implemented as a series of AND statements ORed together. This format causes duplication of information, since the entries are not simplified, but also allows concise descriptions. The underlying structure allows a variable length interlock statement for each device, both in the ANDed members and the ORed statements.

Figure 1 shows the dialog box used to describe the interlocks for the radial motor.

Dependencies describe positional interference information between different motors. There are devices in the cyclotron vacuum vessel that can collide with each other. Instead of describing these motions using interlocks, which are one sided, dependencies describe the interaction zone between two devices, and can prevent motion if a device is in a danger zone for another device's movement. See Figure 2.

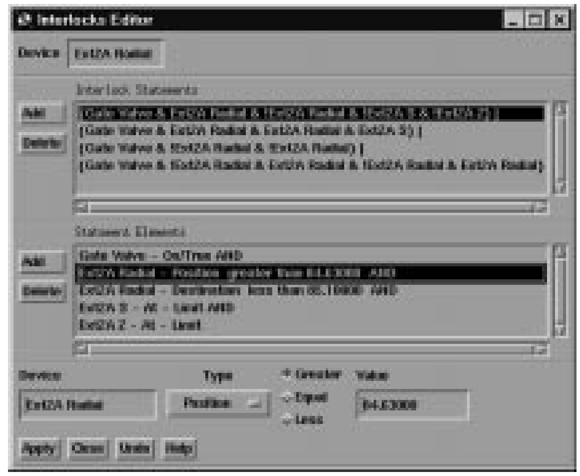

Figure. 1. Interlock Editor Dialog Box

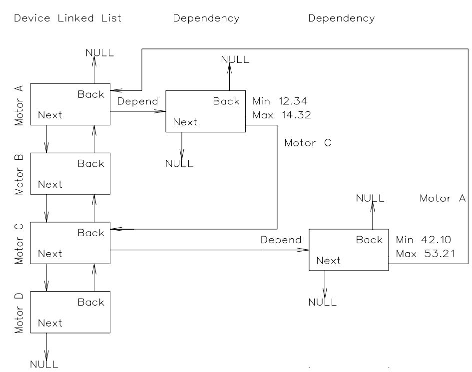

Figure. 2. Dependency Relationship

4.4 Outputs

To simplify the implementation, interlocks are also used to describe the equations determining the state of output bits. Bits are set true or false based on a regular evaluation of the interlock statements associated with that bit, and the new value is written either to auxiliary bits on the VME58 motor board or to CAMAC modules.

5 Integration

There is no direct access to the Motorola computer by the Central Control System (CCS). Communication is via a shared CAMAC memory module. Most newer motor systems at TRIUMF use a standard format for command and data transfer, and this format was kept for consistency. Position and status are written by the motor system into locations in the memory to provide updated information to the CCS.

6 CCS XTPage

The operator interface is provided by the CCS which consists of a mixture of DEC VAXes and Alphas running OpenVMS. It is an X/Motif based program called XTPAGE. The data is constantly updated and the command request monitored by the local processor. A location in the shared memory is used as a watchdog counter. If it stops counting, the operator will be notified by messages.

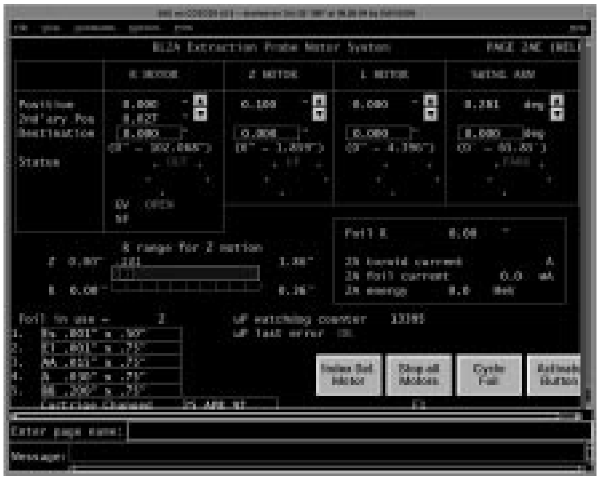

Figure. 3. XTPage Display

The XTPAGE shows all relevant data for the Probe Motor System. The update rate is once a second. A slider is used to show the coupling effect of the R and Z motors. It is our experience that limiting the variety of colors on the page helps operators to assimilate the information. Black is used for background color to reduce glare for the operator's comfort. Five foreground colors are used for different purposes: Coral for headings, Off-White for general text, Red for alarm states, Green for normal states and Blue for the currently active state.

A pull-down menu is used for sending commands via the CAMAC memory to the local processor. After a command is sent, further checking is done to test for the command accept/reject code. Error codes for a rejected command are displayed on the page. Buttons are used to facilitate the most frequently used commands. To prevent executing a command by mistake, an activate button is implemented. Commands will only be sent if the activate button has been pushed.

7 Future plans

Future plans for this system include the replacement of many of the older motor controllers running extraction and monitor probes in the cyclotron. Many motors can be accomodated by the software, and a variety of different drive systems can be supported while keeping the same interface to the Central Control System.

Replacement of relay logic will improve reliability and addition of motor acceleration will improve performance.