CAMAC CONTROLS APPLICATIONS AT TRIUMF

H. Dollard, D.R. Heywood and D.E. Marquardt
TRIUMF, Vancouver 8, B.C., Canada

D.P. Gurd
University of Alberta, Edmonton, Alta., Canada

R.R. Johnson
University of British Columbia, Vancouver 8, B.C., Canada

ABSTRACT

Using CAMAC as a design reference standard modules have been used as signal multiplexer interfaces resulting in cabling reduction and system cost reduction. Prototype CAMAC modules are used to control the central region cyclotron. The console for this cyclotron is operated on an interrupt basis. The console interrupts are enqueued presenting 2 LAM points to the cyclotron 6 CAMAC crate control system. Enqueuing prior to entry into CAMAC can also be done with systems economies.

1. INTRODUCTION

Standard CAMAC modules are used to advantage when signal multiplexers are placed in remote site locations. Other commercial modules are used to interface high accuracy power supplies and temporary control stations. These applications are discussed in Section 2. Section 3 presents details of the central region cyclotron control system and console. Section 4 describes data enqueuing as a system cost economy for local control consoles.

2. STANDARD CAMAC APPLICATIONS TO LOGGING AND CONTROL

CAMAC modules are used as a means of efficiently placing data multiplexers in remote areas. Local control of cyclotron subsystems are also based on CAMAC principles.

The basic building block for all TRIUMF analogue measurements is a 65 channel FET Multiplexer (MUX).[1] Three types of MUXes are used, ±5 V/12 bit (high level), ±50 mV/12 bit, and ±100 mV/8 bit (low levels) multiplexers stationed in remote locations. The central region cyclotron, the magnet/vacuum area, and the ion source area have central analogue-to-digital (ADC) boxes[1] capable of processing 1024 channels of data. This ADC is interfaced to the CAMAC system. Table I summarizes the CAMAC instruction sequence for this interface. When a collection of analogue signals can be assembled in a location removed from the area ADC, a multiplexer is stationed at that location. A CAMAC parallel output driver[2] addresses the multiplexer and the switched analogue data is digitized by a CAMAC ADC.[3] The three equipment configuration CAMAC sequences are summarized in Table I. The cost savings is considerable when small groups of analogue signals are incorporated into the CAMAC framework. A CAMAC ADC costs less than $750 while an equivalent stand-alone ADC system costs more than $3000. Over the 64-channel limitation of this approach the savings per channel is greater than $30.

Table I. CAMAC sequences for multiplexed analogue to digital converters

Application	CAMAC + Data	Description
Analogics MUX A/D	F(16) + channel address	Sends channel to MUX, starts conversion.
	F(1) + data return	Returns digitized data, preceded by LAM for low level.
Remote Multiplexing	F(16) + channel address	Sends channel to remote MUX.
	F(16) + box address	Selects input channel in ADC chassis, starts conversion.
	F(1) + data return	Returns digitized data, preceded by LAM for low level.
CAMAC ADC	F(16) + channel address	Sends channel to MUX, delays, starts conversion.
	F(1) + data return	Returns digitized data, preceded by LAM for low level.

Most reference voltages at TRIUMF are generated by CAMAC digital-to-analogue converters (DACs). These TRIUMF designed DACs have a 1:1023 resolution. Some applications such as the main magnet power supply, combination magnet power supply, and RF voltage must be controlled to higher resolution. A DAC capable of delivering the required resolution is installed at the power supply. It is set with a standard CAMAC 24-bit input gate/output driver.[4] The input portion of the module is used to echo digital data sent to the DAC.

Temporary local control stations are quickly interfaced through CAMAC. Shaft encoders connected to incremental encoder modules,[5] and 24-bit input/output drivers[4] wired to thumbwheel switches and LED numeric displays, offer the local users a means of dialing an adjacent power supply reference and monitoring a corresponding voltage. The local control station is scanned on a 50 msec basis, and control changes are made with that period. Since this configuration is not interrupt driven its usefulness is limited. Extensive use burdens the central computer with data that is not changing.

3. CENTRAL REGION CYCLOTRON CONTROL

The TRIUMF central region cyclotron (CRC) control system is based on prototype CAMAC modules. Over 64 power supply references and 200 high-speed multiplexed analogue voltage channels are serviced using a six-crate CAMAC system.

Two guidelines were used to develop and install the central region cyclotron control console. The first was to use existing electronics. The second was to install a flexible interrupt-driven system. CAMAC was chosen as the reference design. Since the central region cyclotron uses a single CAMAC branch, the LAM structure must service cyclotron modules (e.g. low-level conversion finished) as well as the console interrupts. An interrupt enqueuing circuit processes console interrupts prior to activating a LAM.

The console front panel is conventional. Shaft encoders are used to set references. Illuminated push-buttons are used for digital control. Beside each shaft encoder and digital control panel a thumbwheel selects address assignments. Up to three four-digit numeric displays showing analogue and reference data readbacks are also assigned by the thumbwheels. A total of 28 interrupt sources from the console thumbwheels, shaft encoders, and digital control switches are multiplexed onto two CAMAC LAM points. Whenever any thumbwheel, shaft encoder, or push-button on the console is moved, it becomes an independent interrupt source. Encoding each source in a hardwired priority stack reduces the LAM requirements to one digital control LAM and one reference setting LAM. A stack pointer gates addressing data onto a CAMAC input register. Upon receiving a reference setting LAM the CAMAC input register is read. It contains the console station number and type of interrupt from the station (e.g. shaft encoder change or thumbwheel change). A digital control LAM is followed by reading an input register containing the console station number, type of interrupt, thumbwheel number, and digital control data.

Shaft encoders are serviced with CAMAC 16-bit input/output registers. Numeric displays are serviced with CAMAC 16-bit output drivers.[2] Thumbwheel interrupts are hardwire delayed, allowing for an operator address searching time of 100 msec. Shaft encoder interrupts from a single encoder are limited to one per 50 msec while the encoder is being turned.

Fig. 1 presents a schematic plan of the console and console interface.

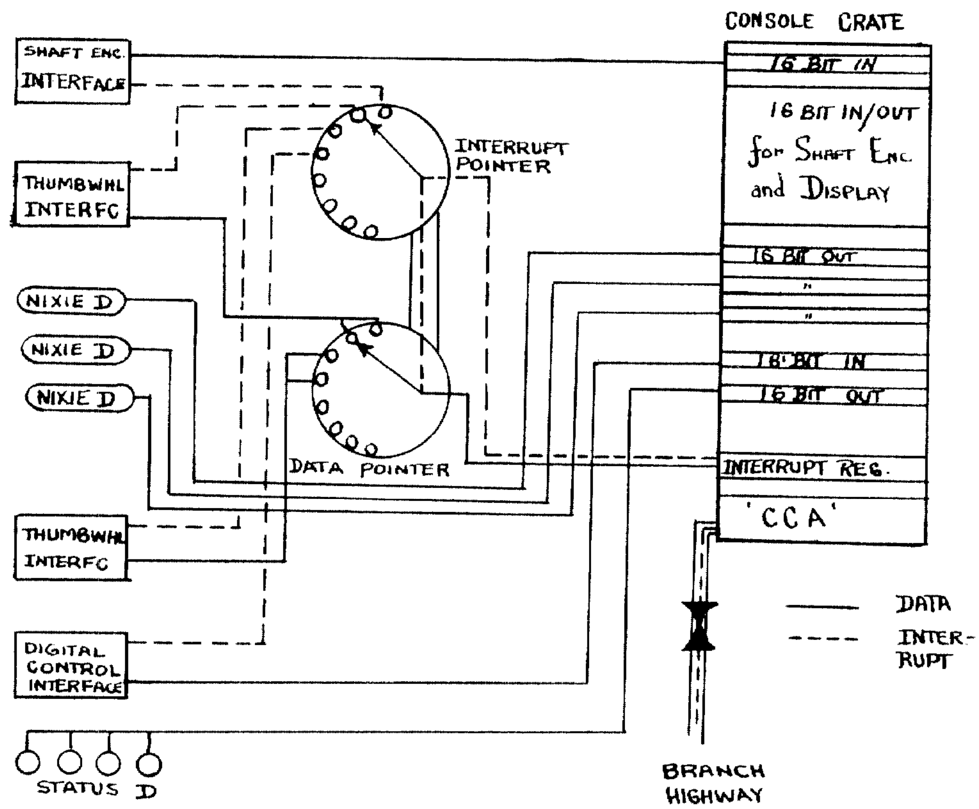

Fig. 1. Basic CRC panel features with CAMAC interface. Stack pointer hardware is used to reduce number of CAMAC cycles required for interrupt service.

The program servicing the console interrupts performs the console request (e.g. set a DAC) immediately and updates the related displays. However, console numeric display, CRT display updating, and data logging on cassette tape or teletype are placed in a task queue by ansynchronous interval timers. These tasks are then scheduled for execution according to a predefined priority scheme. Scheduling is accomplished by a 374 word executive, NATS.[6] Console displays are routinely updated three times per second. Displays associated with references being changed are updated more rapidly--10 times per second. The CRT display is updated at a rate specified by the operator using the teletype. Conversion to engineering units (e.g. kV or μA) is provided on the CRT display and data logging.

Worst case tests of the system, where simultaneous operation of all shaft encoders, thumbwheels, displays, and cassette tapes by two engineers and their children, were made. The program, occupying 8K of core, coped with the full load of interrupts. The flexibility of this interface was demonstrated after the initial commissioning period of the console. Manual and automatic control modes of operation were required for a stepping motor/probe drive unit in the central region cyclotron. A digital control console station handled the application with no modification. Necessary distinctions between the probe-digital console station and the conventional digital console station were made in the control program.

4. INTERRUPT ENQUEUING MODULES

The use of devoted CAMAC modules for numeric displays and for multiple shaft encoder interfaces does not offer the least expensive solution. A means of economy is now being developed with the CAMAC reference. Local control requirements of the TRIUMF ion source and injection beam line specify a console arrangement similar to the central region cyclotron console. Data enqueuing prior to entry into CAMAC similar to the CRC console digital control is used. A single CAMAC encoder-data register passes parallel data to as many as 16 independent locations. A four-bit device code identifier with strobe allows data to travel to and from the register on two buses connecting all 16 locations. The hardwire interrupt stack of the CRC with an associated data stack is accessible in a single CAMAC cycle. As a result, fewer CAMAC crate positions are necessary, and the overall cost of the local control console is reduced while still adhering to the CAMAC terms of reference.

5. CONCLUSION

Standard CAMAC modules can be used with many channel multiplexer units to multiplex analogue signals, reducing cabling. Small groups of analogue signals can be multiplexed onto a CAMAC ADC at a significant cost savings. The central region cyclotron console has been a test-bed for prototype control modules. Interrupt enqueuing from console devices prior to CAMAC has resulted in an acceptable interrupt handling. The enqueuing concepts are being extended to data display for local control.

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