THE USE OF CAMAC WITH SMALL COMPUTERS IN THE TRIUMF CONTROL SYSTEM

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Abstract

The TRIUMF control system uses several small computers rather than one larger one. This provides a great deal of flexibility, allowing tasks to be partitioned in hardware rather than by a complex operating system. This flexibility was especially convenient during the developmental stages of TRIUMF. The multi-mini approach also improves mean time to repair by introducing at the computer level a modularity consistent with the CAMAC philosophy. All control system computers are to be interfaced simultaneously to a single CAMAC system of 35 crates on seven branches. Other computers, belonging to separate systems, communicate with the control system via parallel CAMAC-to-CAMAC links. Modularity at both the computer and controller levels, combined with CAMAC multisourcing, has allowed the introduction of considerable redundancy, thereby increasing overall system reliability.

1. Introduction

The TRIUMF control system bears only a slight resemblance to that proposed in early design studies.[1,2] It has evolved from earlier concepts as a result of a continuing search for solutions to immediate problems, better understanding of long-term requirements, and the availability of new products.

That such an evolution has been possible with no major upheavals or large unplanned expenditures is a direct result of flexibility derived from two design decisions taken at the outset, namely:

1) the use of several small computers ('multi-minis') rather than one larger one, and
2) the choice of CAMAC as an interface medium.

Controversial at the time, the use of CAMAC requires little defence today. For a large system CAMAC is not more expensive than other possible choices. Multiple sources of supply, reduced cabling costs and less computer interfacing all result in savings. Moreover, many expensive manhours of specification and design time are saved by using a well defined external standard to avert potential arguments.

The use of several small computers is consistent with the CAMAC spirit of modularity. Several tasks must be carried out in any cyclotron laboratory during both the developmental and the operational phases. These include both hardware and software development and debugging as well as the obvious operational tasks of logging and scanning, analysis and display, communications and control. All of these can be performed in a single computer with an elaborate operating system, but TRIUMF has chosen to allocate these tasks to six separate computers, each operating with the system and language best suited to its current application. During the development of TRIUMF these six machines moved between rooms and buildings, even between cities, satisfying the needs of the moment. At present, three computers programmed in Assembler and operating under a small, stand-alone real time executive are active in the control system; one, programmed in BASIC and in communication with the control system, is used for internal and external beam diagnostics and display; one is used with a disc operating system for program development; and the last is used for hardware, including computer hardware, development and repair.

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The flexibility of such an arrangement is apparent, as is the immediate availability of spares for failed computer components in the control system proper. In addition, three times as many computer cycles/second are available in the control system, and expansion is trivial.

2. Multisourcing

TRIUMF has realized maximum benefit from the 'multi-mini' CAMAC approach by interfacing more than one computer to a single CAMAC system. This technique is called 'multisourcing'. It has provided elegant solutions to more than one problem, and has allowed the system to evolve dramatically, but not traumatically. The original concept did not envisage multisourcing, the present system configuration makes moderate use of multisourcing (Fig. 1a), and developments planned for the near future will consolidate all aspects of controls into a single CAMAC system (Fig. 1b).

Several advantages of the fully multisourced configuration are immediately apparent, notably complete freedom in task allocation, increased use of the CAMAC system (more cycles/second), a saving in CAMAC system modules and crates, far less dependence on inter-processor communications, and the possibility of on-line debugging. Moreover, the system can easily be expanded with the addition of new computers of any type, programmed in any language.

The fully multisourced system is achieved by extending the Elliott 'Executive Crate' dataway into a second crate, making room for up to 7 sources driving 7 branches (Fig. 2). Sources or source interfaces are housed in one crate and branch drivers in the second. Modules in these crates are all commercially available.[3] Sources may be computers, or any other devices capable of initiating CAMAC cycles. The 'executive controller' arbitrates between sources requesting system access, giving control to waiting sources according to a hardware-defined priority scheme, and locking out all others while a CAMAC cycle is in progress.

A typical CAMAC cycle time is between 1 and 5 μsec, depending upon the length of the branch. Most CAMAC transfers are performed under programmed

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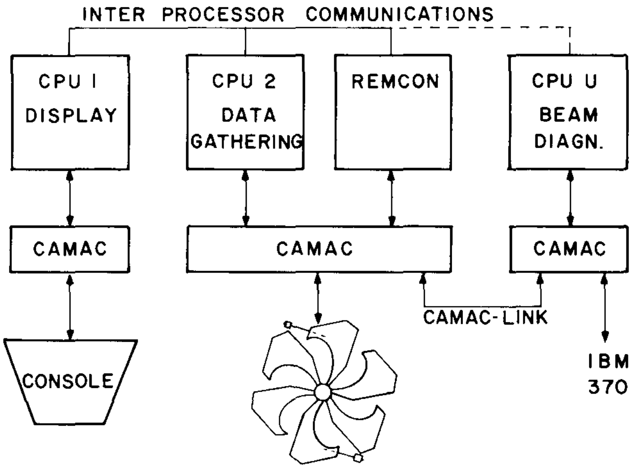

Fig. 1a. Present system configuration.

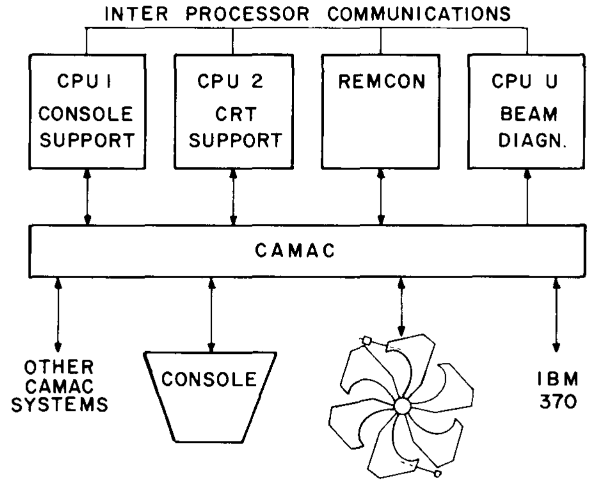

Fig. 1b. Fully multisourced system configuration.

Input/Output, and require about 50 μsec of software support per cycle. There is therefore no risk of overloading the CAMAC system, nor any need to take care in priority allocation. The system has been tested with three computer sources operating simultaneously, and even an autonomous test controller[4] requesting cycles at 100 kHz is transparent to those sources. We therefore foresee no problems in expanding to the larger system planned.

Two problems inherent to multisourcing have required solutions, however. Where a single operation requires more than one CAMAC cycle to complete—for example, selecting a channel and then reading an ADC —two sources can interfere with one another. In our system this problem is most severe, and potentially hazardous, in addressing the ion sources across the CAMAC serial light link,[5] which requires a series of CAMAC cycles. The simple solution has been to have, for each such device, a flag in the CAMAC system which must be tested and set before beginning the corresponding operation. This works well at the price of adding two CAMAC cycle times (∿100 μsec) to each of these already lengthy operations.

A second, more difficult, problem concerns the servicing of interrupts. In our present system a CAMAC demand is received by all sources, and each must initiate a CAMAC cycle (BG) to identify the originating module. Software then determines which computer will service the demand, and the others must wait until it is cleared. Though inelegant, this works satisfactorily except when one computer has been stopped. The solution to be implemented at

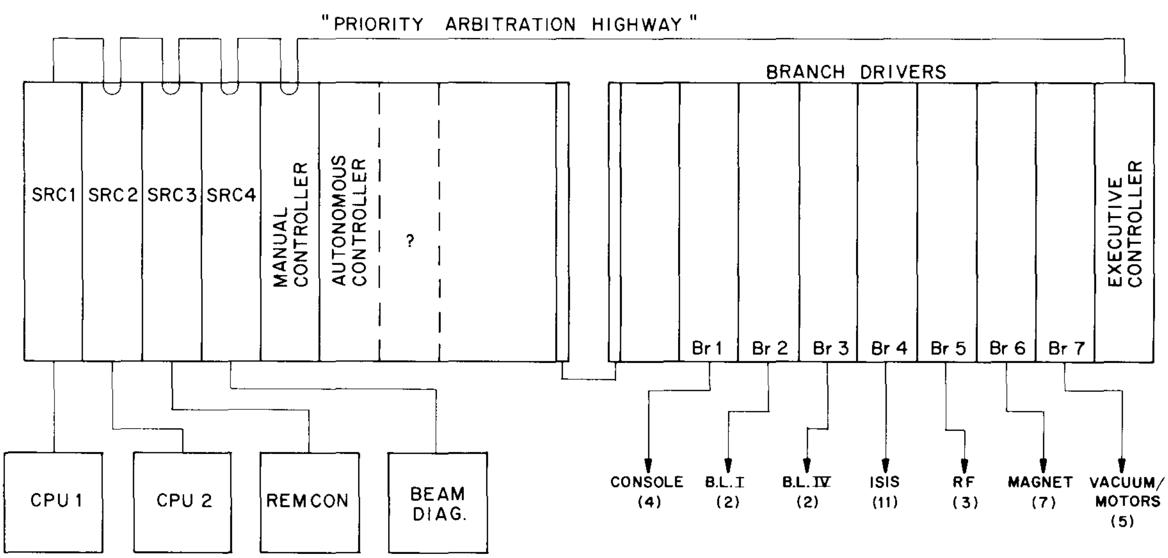

Fig. 2. System crate configuration. (The numbers in brackets indicate the number of crates currently on each branch.)

the time of the proposed system configuration is the inclusion of an 'interrupt vector generator'[3] with each source which, acting as an independent source, will automatically initiate the BG cycle, and then interrupt the associated computer only if enabled to do so for that demand—i.e. only the interested computer will be interrupted. TRIUMF now possesses the modules required to implement this solution, but they have not as yet been tested.

3. Applications

Several features of the TRIUMF control system make use of the ideas discussed above, and can be used to illustrate their application.

3.1 REMCON

During the early stages of TRIUMF, one computer was set aside to control and monitor developing systems, while software development proceeded independently toward support of the main control console. A general purpose remote console, illustrated in Fig. 3, was designed to allow local control, through the CAMAC interface, of these first systems. The program which supported these remote consoles came to be known as REMCON. It grew with the systems it supported, its simple, table-driven structure permitting easy addition of new devices as required.

The implementation of multisourcing, along with the realization that REMCON could serve as a back-up to the main system, suggested its inclusion in the final system. One of the 'remote consoles' has been located in the central control room and serves as an extension to the main control desk. The program has been fully integrated into the system, affording the following advantages:

1) It can monitor and control *all* cyclotron devices, including many not available at the main console. For this reason it serves as a full back-up to the main console in case of failure. The availability of two completely independent control programs also permits real time changes to be made to one or the other without affecting cyclotron operation.

2) It monitors the CAMAC (DAC) set points of all remotely-controlled devices, information that is available nowhere else. Set points are often useful for diagnostic purposes, and our experience has been that they are more useful for reproducing cyclotron conditions than are the analogue readbacks.

3) Remote consoles can be placed in a 'diagnostic' mode, returning unconverted data for display. This is useful in detecting program errors or digital errors in the CAMAC system, as well as for calibrating analogue-to-digital converters.

4) The simple tabular structure of the program often means that support for a new device can be added in real time with a program 'patch' long before it can be added to the more complex main program. The tabular structure, of course, is a direct reflection of the identical treatment of all devices on the remote consoles themselves.

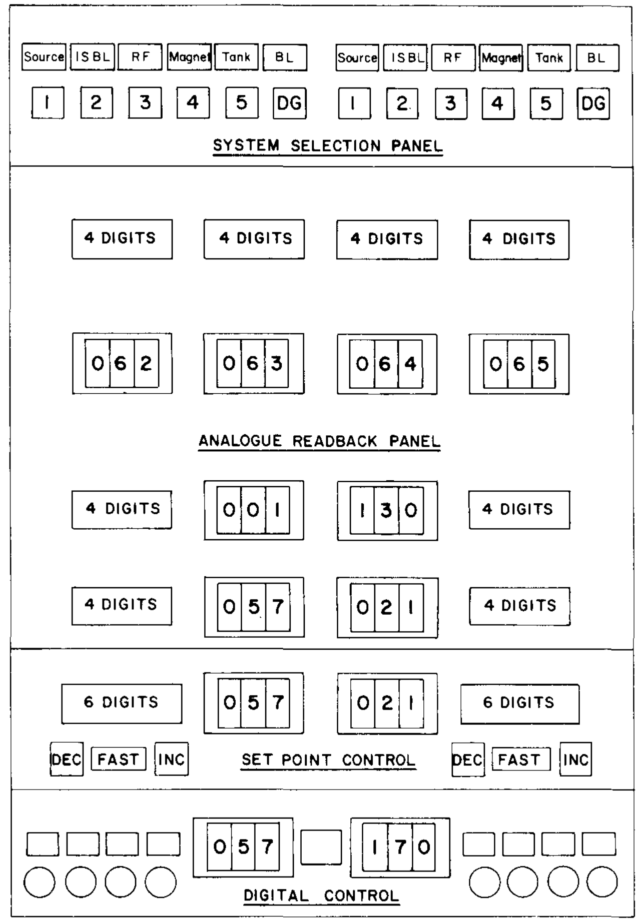

Fig. 3. Fully assignable remote console.

For these reasons and others, REMCON has become an essential and permanent component of the TRIUMF control system, preferred by some of the operations staff to the main console where a choice exists.

3.2 CAMAC as a Data Base

In the present TRIUMF control system configuration (Fig. 1a) one computer spends much of its time updating a core buffer with current cyclotron data, and passing this buffer to the other. This table resides in both computers and is referenced by several tasks for various purposes. In other comparable systems similar data buffers are placed on a mutually accessible disc file, and referred to as a 'data base'.

There is no need to send the same data to REMCON, however, for it has direct access to all the data in the cyclotron CAMAC system. In a very real sense CAMAC is a common data base to REMCON and CPU2, and will be the common data base to all computers when the system is reconfigured as in Fig. 1b. There is then no need to update all data base parameters in case they should be needed—each task can acquire data as required.

Some parameters are not always immediately available in the CAMAC system because they are multiplexed. In the TRIUMF system this applies particularly to the positions of all the diagnostic probes and extraction foils which are stored in computer memory only. The data base will be completed when such information can be stored in 128-word randomly addressable CAMAC memory modules, currently under design. These modules will be available for installation this fall.

In association with the CAMAC memory mentioned above, an autonomous scanner is being developed. This module will scan a sequence of 128 channels on our multiplexed ADC system, storing the results in the CAMAC memory. It will be used for low level (50 mV) and therefore slowly converted signals. Data will be available in one CAMAC cycle time (50 μsec) rather than one conversion time (10 msec), and without the problems associated with multisourcing the ADC.

3.3 Inter-Computer Communications

Multisourcing provides a simple means of inter-computer communications—all computers interfaced to the same system may communicate via modules in the system. The 'device busy module' described above is a trivial example; more complex messages could be passed via a CAMAC memory.

In addition to those computers interfaced directly to the main CAMAC system, there are other computers that require access to the data base. We have modified a commercial CAMAC output register/input gate for 24-bit parallel communications between two CAMAC, and hence computer, systems. Communication is at the CAMAC crate level, using a simple protocol, and speeds are software limited. This device is now in routine use for passing data from the control system to another Nova programmed in BASIC for analysis. The same technique can be used for communication between experimental users, all of whom have CAMAC systems, or between these users and the control system.

Where distance is a factor, a serial communication system could be based upon a standard CAMAC teletype driver. We have not as yet attempted this for CAMAC-CAMAC communications, although we intend to do so. We have, however, implemented a 3 km communications link with the University of British Columbia Computing Centre using a CAMAC teletype driver modified to operate at 9600 baud. Such a system will allow large beam analysis programs to be run using real time cyclotron parameters, and eventually even to return suggested new set points to the control system. It should be noted that one such driver installed in the multisourced CAMAC system will provide a link to the IBM 370 for four or more computers. Provided demand can be satisfied, the cost saving would be considerable.

4. Operating Experience

In spite of early attempts to make it otherwise, TRIUMF cannot operate without the computer-based control system, which has been required to support cyclotron operation since October 1974. Cyclotron performance records show that during this period failed control system components have accounted for about 20 h, or <2% of cyclotron down time.

There have been two computer failures in this period. The first (predictably on a Sunday afternoon) stopped operations for about two hours while members of the controls group were called in and a failed memory board was replaced. The second was a defective computer power supply which also took about two hours to replace, but at a time when the cyclotron was not operating.

The most frequent failure in the overall system has been of CAMAC power supplies, which typically take about one hour to replace. Five have failed during the last nine months, although only two of these failures affected cyclotron operation. The other failure-prone device has been multiplexer cards in our analogue-to-digital conversion system. These failures have generally been considered as an annoyance only, and repair (board replacement) has awaited a scheduled maintenance period. A new multiplexer card has been designed, and the frequency of this type of failure has decreased almost to zero in recent months. Finally, individual CAMAC modules occasionally fail. In some cases, these failures affect operations not at all; at other times operation must be halted until the module can be replaced. These failures are routinely diagnosed and repaired by the operations staff.

The controls programs are under constant revision, and each revision seems to contribute a new idiosyncrasy or fault. Although most of these are only annoying, the programs do suffer total failures with an average frequency of perhaps once per day. Program reload procedures are easy and quick (requiring less than one minute) and can be performed by the operations staff, so these failures, while embarrassing to the programmers, do not seriously affect operations. The best performance record to date for the program has been 10 days of full operation without a reload.

5. Conclusion

As the TRIUMF cyclotron approaches its design specifications, an expanded and more active computer participation in cyclotron operations is to be expected. Improved beam diagnostics, more inter-system communications, increased use of higher level languages, and some loop closure will all be necessary. The multi-mini CAMAC system now in use has proven adaptability, and should be able to support these and all other proposals now under consideration.

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