AUXILIARY/MASTER MICROPROCESSOR CAMAC CRATE CONTROLLER APPLICATIONS

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Summary

The need for further sophistication of an already complex serial CAMAC control system at Fermilab lead to the development of an Auxiliary/Master CAMAC Crate Controller.[1] The controller contains a Motorola 6800 microprocessor, 2K bytes of RAM and 8K bytes of PROM memory. Bussed dataway lines are time shared with CAMAC signals to provide memory expansion and direct addressing of peripheral devices without the need of external cabling. The Auxiliary/Master Crate Controller (A/MCC) can function as either a Master, i.e., stand alone, crate controller or as an Auxiliary controller to Fermilab's Serial Crate Controller (SCC). Two modules, one single and one double-width, make up an A/MCC. The double-width module contains the necessary crate controller hardware, i.e., read/write registers, station number registers, dataway cycle timing generator, etc. in addition to hardware providing input and output block transfer capabilities through the SCC. When the A/MCC is used as an auxiliary controller, the single-width module contains the microprocessor, RAM, PROM, MPU clock, and the timing and logic circuitry required for interleaving A/MCC and SCC dataway cycles as well as extending memory via dataway lines. When the A/MCC is functioning as a master crate controller, the first single-width module or one with DMA cycle-stealing transfer capabilities may be used. The module, in this latter case, need not and thus does not have dataway cycle interleaving capabilities.

The microprocessor has one nonmaskable and one maskable vectored interrupt. The maskable interrupt has eight sublevels of vectored interrupts for ease of interrupt prioritizing and servicing. A 60Hz real time clock is provided, if used, on one of the sublevels of maskable interrupts. Four front panel and eight jumperable LAM signal interrupt inputs are provided. The SCC communicates with the A/MCC via the F, A, and W lines and the nonmaskable interrupt.

Time sharing the dataway between SCC programmed and block transfer generated dataway cycles and A/MCC operations still allows a 99% microprocessor CPU busy time.

Since the conception of the A/MCC, there has been an increasing number of control system-related projects proposed which would not have been possible or would have been very difficult to implement without such a device. The first such application now in use at Fermilab is a stand-alone control system for a mass spectrometer experiment in the Main Ring Internal Target Area. This application in addition to other proposed A/MCC applications, both stand-alone and auxiliary, will be discussed in the following paragraphs.

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Master Crate Controller Applications

The A/MCC can reside in any group of three slots while functioning as a master or stand-alone controller. Access to station number (N) lines and LAM lines is made via a rear connector and harness from the A/MCC double-width module to the control station of a crate. In this operating mode, the A/MCC functions independently, i.e., without an additional computer and branch or serial driver.

Mass Spectrometer Experiment

Many experiments at Fermilab require some level of intelligence in the hardware used for controlling and monitoring of experimental devices and data. For the sophistification required in some experiments a mini or a medium-sized computer would be unfeasible. A microprocessor-controlled CAMAC crate controller is ideal for these cases. A mass spectrometer experiment to study proton on proton elastic scattering is now becoming operational in the Internal Target Area of the Main Accelerator at Fermilab. The experiment is being controlled and monitored solely by an Auxiliary/Master Microprocessor Crate Controller-based CAMAC system. A sketch of the associated hardware is shown in Fig. 1. Currently the A/MCC program which controls the experiment is 4K bytes in length. Its interface to a user is via a CRT interactive terminal. A CRT "page" from the system program is shown in Fig. 2. Some of the features on this page are listed below:

1. Device digital status monitoring.
2. Device digital control (eg. on, off, reset controls for power supplies).
3. Device analog control (via typed-in settings or knob controls).
4. Device analog readbacks (includes a binary to decimal conversion routine with scale factors.
5. System diagnostic routines including a basic test CAMAC subprogram and memory read/write capabilities via the CRT terminal.

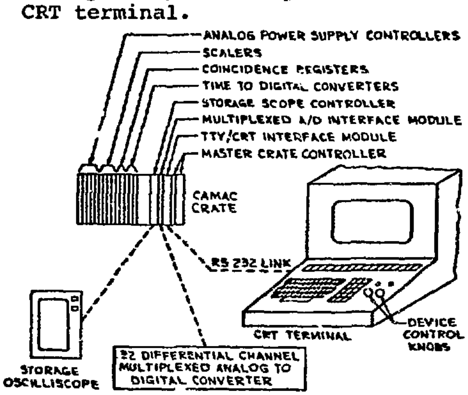

FIGURE 1

MASTER CRATE CONTROLLER APPLICATION CONTROL SYSTEM FOR INTERNAL TARGET AREA MASS SPECTROMETER EXPERIMENT

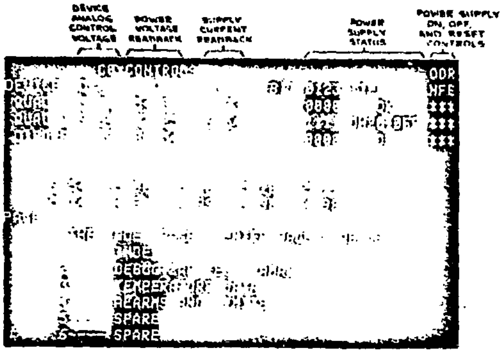

FIGURE 2

MASS SPECTROMETER EXPERIMENT CONTROL SYSTEM CRT TERMINAL PAGE

Additional features expanding the program to greater than 8K bytes in length will include an alarms and limits subprogram, a linearizing routine for nonlinear temperature data, a storage scope driver, scaler handler, and expansion to an additional but remote CRT terminal.

It would not have been practical to include such specialized software in one of the computers controlling the much larger Main Accelerator control system. These computers are located more than one mile from the mass spectrometer experiment. The demands on CPU and serial transmission time would have exceeded the capabilities of the system.

Using the A/MCC to control this experiment has resulted in a fairly sophisticated control system for a relatively small cost. The costs were too prohibitive to use a minicomputer-based control system.

<u>Hydrogen Target Control And Monitoring</u>

Three identical but essentially independent serial CAMAC control systems[2,3] control the three experimental areas at Fermilab. The Cryogenic Group has the responsibility of controlling and monitoring over thirty Hydrogen targets throughout the Meson, Neutrino, and Proton experimental areas. Because of the potential danger of liquid Hydrogen, this group is located at a remote area approximately three miles from the experimental areas and thus does not have easy access to consoles in each of those areas. Another problem is that each system computer has access only to the Hydrogen targets in that area. For example, Hydrogen targets in the Proton and Neutrino areas can not be controlled or monitored by a console in the Meson area. To provide the required twenty-four hour seven days a week monitoring of these targets by the Cryogenic Group, the system as shown in Fig. 3 has been proposed.

Serial system software allows the use of experimenter's computers to control and monitor devices via two bidirectional memory modules, one in an experimenter's CAMAC crate and one in a control system crate. As shown in Fig. 3, a CAMAC crate containing an A/MCC operating as a stand-alone or master crate controller is used to control three memory modules. Each module is linked via a similar module in a serial system crate to one of the three experimental area computers. Thus, a link to Hydrogen target information in all three areas is established by defining the three pairs of memory modules as experimenter interfaces. The "intelligent" crate, via dedicated phone lines and two communications interface modules, provides a link to a console for the Cryogenic Group. Note that a second crate with an A/MCC is required to complete the system. This second A/MCC is used only to intercept transmissions from the first A/MCC or the console and retransmit the data to the other device. The software in the first A/MCC is more complicated. It must accept requests from the console and determine which experimental area computer should receive the request and retransmit the request accordingly. Return information from the computer must then be retransmitted to the console.

Another function of the first A/MCC program is to gather data from all three experimental areas, restructure it and retransmit it to the console so that information from all three areas can be monitored simultaneously.

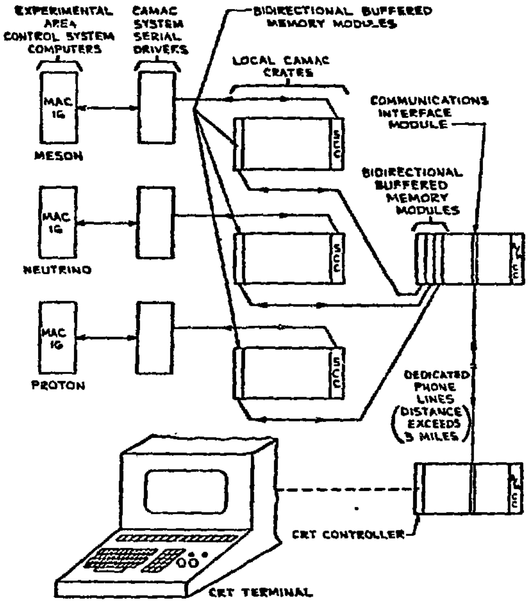

FIGURE 3

MASTER CRATE CONTROLLER APPLICATION REMOTE HYDROGEN TARGET CONTROL AND MONITORING SYSTEM

<u>Stand-Alone CAMAC Test Station</u>

The testing of complicated CAMAC modules sometimes requires a sequence of CAMAC commands perhaps separated by specific times to the module(s) under test. An example of such a module at Fermilab is a Segmented Wire Ionization Chamber FET Scanner Controller. The testing of this module requires an initial command defining the length and type of wire chamber scan followed by a set sequence of input commands. To check that analog input data is being sampled, digitized, and read correctly, some form of stored display or hard-copy printout of the data is required. For such a module, simple manual crate controllers are too cumbersome to use. A test station using an A/MCC in a "master" mode provides an inexpensive method for testing both complicated and simple modules.

Control System For The Neutrino Focussing Horn

The method used to control a magnetic focussing horn in the Neutrino experimental area used to maximize the neutrino flux from secondary particles, is being studied. If a microprocessor A/MCC-based system is chosen, the system would consist of several CAMAC crates of hardware, each controlled with a Master Crate, Controller, and one or more linked to the areas serial CAMAC control system.

Auxiliary Crate Controller Applications

At Fermilab, two bidirectional buffered memory modules, one in an experimenter's CAMAC crate, and one in a control system crate are used to link experimenters' computers to devices and data throughout the accelerator. By placing an A/MCC in a control system crate along with a SCC and, via software, making the A/MCC simulate a memory module, an endless list of intelligent data handling applications are possible. Some future implementations of the above are described below.

System Console Expansion

Each of the three experimental area control systems at Fermilab can simultaneously service up to sixteen user consoles[2]. Core and CPU time restraints in the system computer make it difficult to increase this number or make consoles function differently from one another for special applications. The main control room of a particular area requires expanded capabilities over what is provided at a general user console. By using the block transfer capabilities[3] of the serial system, data from any group of remote devices may be block-transferred to an Auxiliary Crate Controller (ACC). The ACC is programmed to respond identically like a bidirectional buffered memory module and thus simulate an experimenter's computer interface. The data gathered by the ACC can then be processed and displayed on a terminal much like a normal console. Unlike a normal console this data can be checked for limits and tolerances and thus create operator alarms. In essence these "satellite" computers can increase the capabilities of the serial system substantially with a negligible increases in system computer memory and CPU time requirements.

Experimenter's Console Graphics Processor

The serial CAMAC system in a experimental area interfaces to a MAC 16 minicomputer. As mentioned previously this computer simultaneously services sixteen experimenter's consoles. The console driver routines in this computer are programmed to service many of the general requirements of users. For specific user applications another computer can be accessed by the consoles. One use of this computer is to provide graphics data to a storage oscilloscope. The system operation is shown in Fig. 4 and is described below. An Auxiliary Crate Controller (ACC) resides in the experimenter's CAMAC crate. By simulating a bidirectional buffered memory module it can request a particular application program residing in the PDP 11/45 computer. This program could be to generate a plot of a device's magnet current verses voltage. The request is transmitted via the MAC 16 to the PDP 11. The PDP 11 then requests timed readings of the device current and voltage via the MAC 16 and normal serial link. The PDP 11 then begins transmitting plot data to a memory module. The MAC 16 then initiates a crate-to-crate block transfer from the memory module thru a block transfer controller to the ACC. The ACC receives the data, processes it, and then transmits the processed data to the storage oscilloscope via a CAMAC module.

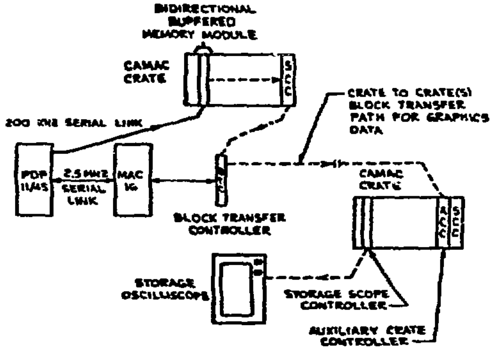

FIGURE 4

AUXILIARY CRATE CONTROLLER APPLICATION
EXPERIMENTER'S CONSOLE GRAPHICS SYSTEM
SIMPLIFIED BLOCK DIAGRAM

Additional Auxiliary Crate Controller Applications

Two applications for the microprocessor Auxiliary Crate Controller (ACC) have been proposed for use in the Booster pre-accelerator. The first involves pulsing 96 DC correction element magnets during the high field portion of the Booster acceleration cycle to compensate for nonlinearities in the main magnet at high currents. The acceleration cycle is roughly 33 milliseconds. During the last several milliseconds a specific current waveform must be loaded into each of the 96 magnets. Timing and waveform information is loaded into each of six Auxiliary Crate Controllers whose crates contain 24 quad correction element power supply controller modules. As shown in Fig. 5, a compensating waveform is added to each element to produce the desired compensating field. This is accomplished by programming the ACC's to, at specified times, read digital to analog settings, readjust the settings and at the end of the correcting cycle reset the elements back to their normal settings.

The second application uses an ACC to read and digitize, at specific times, an analog error signal from the low-level RF system. This digitized signal can then be processed by the ACC to "close the loop" on the low-level RF acceleration system. The open loop system operates by having the serial CAMAC system computer load times and settings into a large remote CAMAC memory module. An analog RF acceleration curve is generated from the memory module. With the digitized error signal the ACC "reprograms" this memory module minimizing the error signal and thus "closing the loop" on the low-level RF system.

Because of the CPU and serial link transmission time limitations in the Booster serial CAMAC control system, neither of these applications would have been possible without the use of an intelligent crate controller.

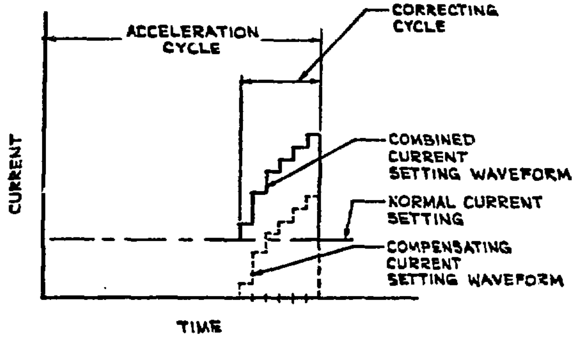

FIGURE 5

AUXILIARY CONTROLLER APPLICATION COMPENSATING SYSTEM FOR MAGNET NONLINEARITIES

Conclusions

Applications which would not have been possible with Fermilab's serial CAMAC control systems because of CPU and serial transmission time constraints are now being implemented by using the Auxiliary/Master CAMAC Crate Controller.

The main trade offs in systems requiring "local' intelligence is whether that intelligence should be incorporated into the modules (eg. intelligent storage scope controllers) or in an auxiliary crate controller. Discussions have led to the conclusion that whenever communication to or from several modules in a crate or to several crates is required auxiliary or master crate controllers should be used. In other cases intelligent modules should be developed.

Acknowledgments

I would like to express my appreciation for the valuable assistance given me in the development of the Auxiliary/Master CAMAC Crate Controller by R. Hance, J. Snow, and A. Maier. Special credit should be given to A. Maier for the outstanding operating system he developed for the Mass Spectrometer Experiment.

References

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