© 1973 IEEE. Personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution to servers or lists, or to reuse any copyrighted component of this work in other works must be obtained from the IEEE.

A MODULAR CONTROL SYSTEM UTILIZING CAMAC HARDWARE FOR INTERFACING REMOTE COMPONENTS AT NAL

W. H. DeLuca, A. J. Maier, J. E. Michelsen and C. A. Swoboda
National Accelerator Laboratory*
Batavia, Illinois

Introduction

The diversification and physical remoteness of components constituting the NAL proton beam switchyard and site-wide fire detection systems necessitated the use of mini-computers to centralize monitoring and control. Devices are interfaced to the computers by series connected local controllers. The local controllers utilize a standard CAMAC crate with a simplified dataway to achieve economic modular construction. Serial data transfers are used between controllers for reliable operation in a high noise environment. Bulk data transfers to the Switchyard System Computer are implemented on a special high speed serial link which operates independent of, but initiated by, the local controllers. A special Minicontroller module with an emergency back-up power source is used to monitor NAL fire detection systems. These Mini's are continuously scanned and tested by the Fire System Computer which presents status and alarms on strategically located terminals.

8 GeV Transfer/Switchyard Control System

The 8 GeV Transfer and Switchyard Control System utilizes a MAC-16 Control Computer in conjunction with series connected Device Controllers located throughout the galleries and service buildings housing beam transfer equipment. Due to the distances between controllers, as far as 2000 feet, a serial data transfer system is employed. Only two cables are needed to link any controller to the computer. A serial system also provides additional noise immunity since a series of events must occur, uninterrupted, for the integrity of the communication to be confirmed and utilized. In general, the MAC-16 communicates with a local Transmitter/Receiver in parallel via its PDC buss. The transmitter and receiver appear as a single device to the computer and utilize standard I/O instructions to initiate a serial data transfer to or from a Device Controller. Once a transfer is initiated, a serial data word, consisting of ten address bits, two function bits, and 16 data bits, is transmitted, at a 1 MHz bit rate, to all controllers via a single cable. Each Controller regenerates and transfers the word to the next controller. The addressed controller returns the data portion of the word to the receiver for both read and write functions via a second cable. Upon receipt of this returned data or expiration of the transmitter watch dog timer, an interrupt is given to the computer. The computer then checks the status of the transmission and processes the returned data. Data transfers may be executed at a maximum word rate of 20 KHz.

To facilitate block transfers of data from devices to the computer, a third cable is used called the Multiplexed Data Channel (MDC) Link. This link is similar to the data return line mentioned above except it inputs through a special receiver to the computer's MDC. The execution of a data transfer on this link is initiated by a command function on the standard data link. The MDC receiver, upon receipt of a 16 bit data word, will send a service request to the MDC which idles the CPU between instructions, initiates a read cycle, and stores the word in memory. The operating program automatically resumes execution after each request is serviced. Upon receipt of the prescribed number of data words in memory, the computer is automatically interrupted to process the data. This link allows data to be transferred from devices into memory at a 40 KHz word rate independent of programmed instructions, thus allowing the normal operating program and serial data link to function uninterrupted. Figure 1 is a block diagram of the 8 GeV/Switchyard Control System.

A Device Controller consists of a standard CAMAC crate with a simplified dataway, and five single width computer link interface modules. The CAMAC crate is utilized to take advantage of its availability and modular structure while the replacement of the multilayer mother board dataway yields a cost savings of 30%. The serial data word format provides a system capacity of 64 controllers. Each controller can interface up to 16 device modules to the computer and, in addition, generate six programmed timing signals and four general purpose D/A converter outputs.[1] Each device module, using the four function codes, can send or receive 32 bits of data. There are several standard control modules available for interfacing devices. Associated with each controller is a programmable 64 channel, 12 bit, analog to digital converter. There are several modes of operation available, one of which is a sequential conversion of a prescribed number of analog input channels with the digital data being transferred to the computer via the MDC link. Figure 2 is a photograph showing a Device Controller station.

The MAC-16 computer is linked to the NAL Central Control Computer to enable operator communication and control from the Main Control Room.[2,3] The Central System uses various application programs to provide the user with device status displays and control functions, graphics, and analog control of devices.[4] Status displays provide a full line of text for each status point and allow status control that is simple yet versatile. Analog displays provide a full line of descriptive text for each signal, and display the value in selectable units. Analog control is accomplished by moving the display cursor under the line describing a particular device and turning a console knob. Communication between the Central Computer and the MAC-16 is in terms of an Analog or Digital Index, to specify a device, and data. The Central Computer is not bothered with the idiosyncrasies of devices; this is a

* Operated by Universities Research Assoc. Inc. under contract with the U. S. Atomic Energy Commission.

function of the MAC-16.

The MAC-16 computer monitors device status, executes new status commands and generates fault condition alarms. Analog data is gathered via the MDC and made available to the Central System once each main ring cycle. Critical analog signals are periodically monitored and alarms are generated if the readings exceed a specified tolerance. Many power supplies in the Switchyard area require programmable real time analog control signals. These signals are computer generated by fitting a curve to a set of 32 points specified by the operator. Points on the resultant curve are sent to the power supply in real time, one every 16.7 msec. The computer can generate three independent curves, each being defined by a set of 32 points, and a maximum of 20 devices may be controlled with each curve. The MAC-16 can monitor any analog signal in the system at a 300 Hz data rate for plotting real time graphs thru the Central System. The MAC-16 also provides on-line graphics of beam data from Segmented Wire Ion Chamber (SWIC) beam monitors.[5]

Fire Alarm Monitor/Supervisory System

The NAL Fire Alarm Monitor and Supervisory System became operational in November of 1972. In this system, a MAC-16 computer and three remote hard copy terminals are used to control, monitor, and report the status of the commercial fire detection systems throughout the NAL site. Minicontrollers are used for connecting all the relay contact alarm points to the Fire Alarm System. Each Minicontroller has a capacity of sixteen points with provision for remotely testing the operation of each point. The Minicontrollers are interconnected with two coaxial cables, one for data from the computer and one for data to the computer. In general, the computer-to-Minicontroller operation is identical to that described for the 8 GeV/Switchyard Control System except there is no MDC link. Data is serially transferred at a 250 KHz bit rate and at a 5 KHz maximum word rate.

To facilitate the control and monitoring of utilities (such as power demand, water flow, etc.), the serial data word format conforms to that of the 8 GeV/Switchyard Control System. This permits the use of that system's Device Controllers (in this system called Maxicontrollers) and that system's standard set of device modules. These Maxicontrollers are always connected downstream from Minicontrollers so that their operation cannot affect the performance of the fire alarm monitoring.

The Minicontroller is a small self-contained wall mounted unit placed in or near the area being monitored and connected directly, thru conduit, to the local fire alarm system. Power is supplied from a standard power distribution system as well as an emergency backup battery source. A Minicontroller uses two function codes for reading and testing its 16 status input points. A total of 11 bits are available for addressing. Figure 3 is a photograph of a Minicontroller.

The computer interrogates every monitoring point at least once per second. Any change in status which remains stable for one second is reported on selected terminals. On all alarms, the appropriate audio and visual indicators at each terminal are activated. When the terminal operator acknowledges the condition, the computer turns off the audible alarm at that terminal and records the time when the acknowledge occurred. If another unusual condition occurs, the alarm is activated again. Indicator lights continue to flash until all conditions are normal. At least once every ten seconds, the computer tests all bits of all Minicontrollers to check that they are functioning properly. In addition, the operator at each terminal may explicitly test any status point without affecting the other terminals. A report of abnormal conditions is printed at each terminal every four hours or at a given terminal upon demand. If any part of the data link fails, a subset of all the terminals is notified of the failure.

When an alarm is to be reported, an intrinsically meaningful text message describing the alarm point is constructed from three dictionaries supplying general-description words, names of buildings, and fire zone codes. The exact time and date are included on all messages to provide a hard-copy permanent record of system operation. A sample print-out of a fire being detected and then extinguished in the utility enclosure area of the Linear Accelerator is given in Figure 4. The first line registers the zone trip at the utility enclosure, indicating where and what the abnormal condition is. The second line registers the break in the summation chain at the Linear Accelerator, indicating the presence of at least one alarm. The third line is printed when the terminal operator acknowledges the condition. The fourth and fifth lines are printed when the fire detector indicates that the condition has returned to normal.

Reliability of a fire alarm system is clearly of utmost importance. Attention was accordingly given to selection of hardware components for high reliability. However, equipment will fail, but a goal was achieved that is essentially equivalent to fail-safe operation. That is that no system component can fail unnoticed. Individual bit signals are continuously tested; failures are reported on the system's terminals to the accompaniment of alarms and flashing lights. Any failure of the serial transmission system will similarly be reported. The terminals themselves are continuously tested and any failure is reported to all other terminals. Finally, each terminal alarm panel has a watchdog timer which will trigger the terminal's computer alarm and indicator light if the computer fails.

Acknowledgments

The efforts of many people were necessary in the completion of these systems. In particular, the authors would like to acknowledge the work of Alan Jones on the development of new interface modules and maintenance in the 8 GeV/Switchyard System and Richard Mahler for his assistance and efforts in the design, development and installation of the Fire Alarm Monitor/Supervisory System.

References

1. C. A. Swoboda, et al, 1973 Particle Accelerator Conference, Session H (March, 1973)

2. R. E. Daniels, 1973 Particle Accelerator Conference, Session H, (March, 1973)

3. S. R. Smith, et al, 1973 Particle Accelerator Conference, Session H (March, 1973)

4. R. W. Goodwin, Proceedings of the 1970 Proton Linear Accelerator Conference, p. 371 (1970)

5. F. Hornstra and J. R. Simanton, Nuclear Instruments and Methods 11 p. 4062 (1960)

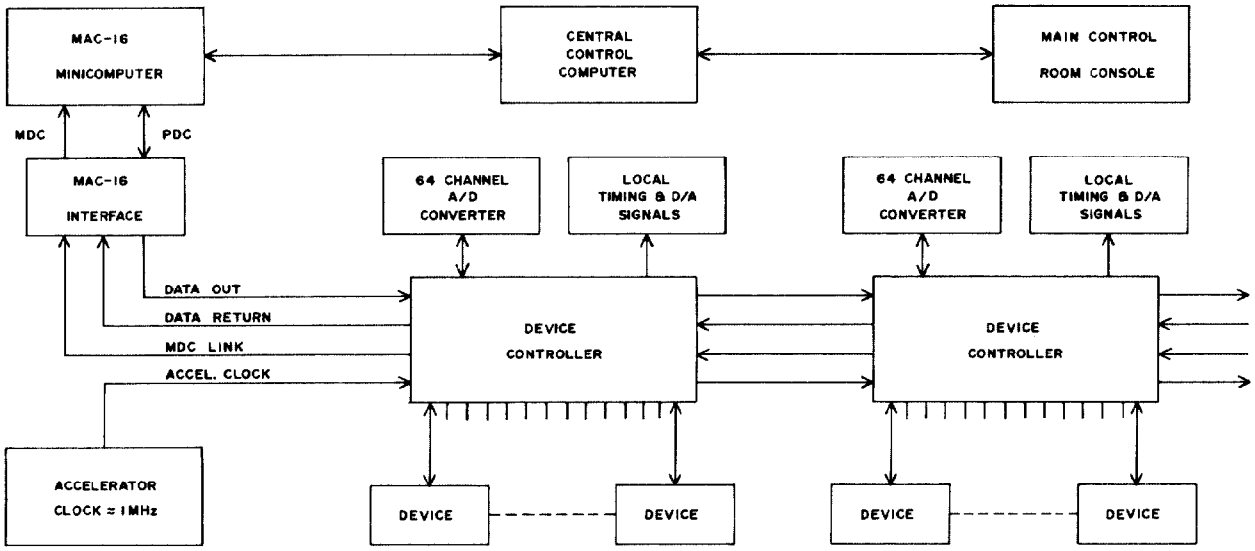


Figure 1 8 GeV/Switchyard Control System

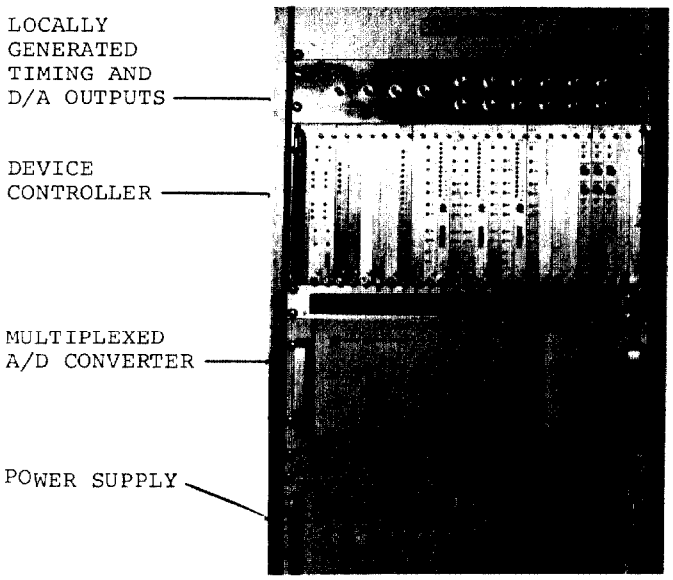


Figure 2 Device Controller Station

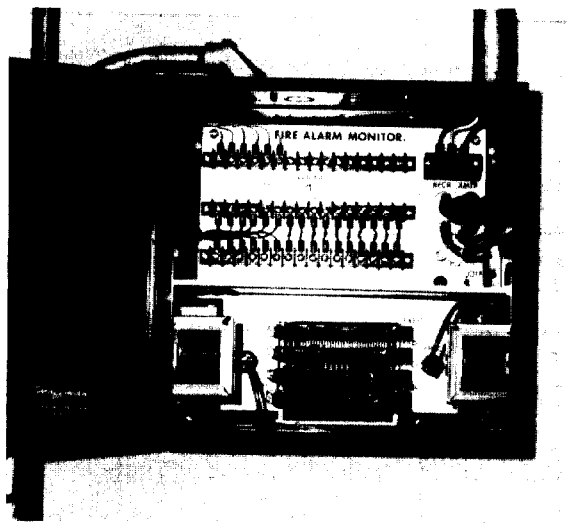


Figure 3 Minicontroller

13:12:04:23	02/10/73	ALARM	FIRE-D	LNAC	02	UTILTY ENCL
13:12:04:23	02/10/73	ALARM	ALARM	LNAC		LINEAR ACCEL
13:12:40:07	02/10/73	FIRE ACKNOWLEDGE				
13:25:04:45	02/10/73	NOW NORMAL	FIRE-D	LNAC	02	UTILTY ENCL
13:28:04:45	02/10/73	NOW NORMAL	ALARM	LNAC	02	LINEAR ACCEL

Figure 4 Fire Alarm System Terminal Message