SLAC-PUB-2626
October 1980
(I)

A MODULAR STAND-ALONE MONITOR AND CONTROL SYSTEM (SAMAC)*

J. Kieffer
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

Abstract

Large high energy physics experiments require constant monitoring and control of the numerous components of the particle detector apparatus. This paper describes a basic hardware configuration which has been designed to satisfy the monitoring and control requirements of the many different experimental setups. The system is designed to operate in the stand-alone mode, and may be interfaced to a host computer via CAMAC. The entire system is modular so that it can be easily tailored to an individual experiment. The items monitored and/or controlled may include gas pressures, temperatures, magnetic fields, high and low voltages, and system status or safety information.

Introduction

The monitoring and control of detector operating parameters are often crucial to a physics experiment. These 'environmental' parameters may include low and high voltages, pressures, temperatures, and magnetic fields. Often the actual values must be recorded along with the experimental data for use in the final analysis of an experiment. These environmental parameters change, or require changing, at relatively slow rates when compared to particle data rates. Slow and thus relatively inexpensive hardware may be used for monitor and control. Often the main data acquisition computer is not available when the physical detector environment requires supervision. Therefore a separate system supervisor is needed. A Stand-Alone Monitor and Control system (SAMAC) satisfies these requirements.

In the typical high energy physics experiment the detector is a large system, both in physical size and in terms of the amount of equipment required. The electronics instrumentation equipment may be divided into two general catagories, the data acquisition instrumentation and the detector environment instrumentation. Although the dividing line is often not clear, this paper defines data acquisition instrumentation as that which acquires the data for each physics event. These would be items such as ADCs, counter 'hit' registers, TDCs, event trigger information, etc.

The detector environment instrumentation is defined as that equipment necessary for physics data acquisition, but not necessarily part of an individual data acquisition cycle. One example is that of a Proportional Wire Chamber (PWC) enclosed in a magnet, with a photo-multiplier hodoscope or a trigger detector. Such a system could be required to perform the following operations:

(a) Monitor and record the PWC gas temperature, pressure, and flow-rate.
(b) Set the magnetic field to the desired flux value, monitor that field for deviations, and maintain that value. Also, monitor the temperatures at various points on the field coil, as necessary to keep coolant flow and coil resistance information available for possible future fault/problem diagnosis.
(c) In conjunction with test pulsers, calibrate (plateau) the photo-multiplier tube high-voltages; then set and monitor those voltages as required. Monitor tube currents if desired.
(d) Set and monitor the high-voltages and currents for the PWC. Monitor the status of the PWC HV power supplies to warn of data acquisition with tripped supplies following chamber overcurrent as may be caused by arcing or broken wires.
(e) Monitor the experimental beam status and reduce or shut-down selected high-voltage systems during beam-fill (injection and storage of the beam on circulating or storage-ring machines) as necessary to protect the detectors.
(f) Monitor the many low-voltage power supplies typically required by modern experiments. This may include four voltages per NIM bin, four or six voltages per CAMAC crate, and one or more voltages for each detector preamplifier system. Often there are over 100 individual power supply voltages which must be at the correct value for the physics data to be accurate.
(g) In addition, it is sometimes desirable to allow the operating system to have some control over external 'hard' interlock chains. This control is limited to three modes only. These are:
    (1) shut-down a system at any time;
    (2) generate an 'inhibit' to allow external (computer) control without requiring a manual restart procedure; and
    (3) allow computer control of a system that has a 'permit' pending, i.e., an otherwise complete interlock chain.

    Note that provision to bypass (override) part of a primary interlock system is not included, and is not designed into SLAC systems.

Commercial equipment is available (with the possible exception of a software operating system) to perform almost all of the required functions. It may be cost-effective to consider implementation of such a system (for example, a CAMAC system with a resident microprocessor) for a single small system. For a large system and especially for several such systems, SLAC has determined that such an approach is not cost effective.

The System Components

The major SAMAC components are: (1) The system supervisor, which is a microprocessor system including a microprocessor chassis and a console terminal (the human interface); (2) a CAMAC system; (3) the monitor chassis system; (4) sensors and transducers (the experimental interface); and (5) the operating system, which is the software necessary to run the SAMAC hardware.

These five components combine to form a stand-alone system designed to monitor and control the general environmental system of many of the major detectors in use at SLAC. The hardware and software have been designed to allow convenient tailoring to match the individual requirements of each specific detector environmental system. The block drawing of a typical stand-alone system is shown in Fig. 1. An expanded system which includes communication links to an experimental data acquisition computer and to the SLAC main computation system (the 'TRIPLEX'), and also allows control of the monitor and control system by the data acquisition computer, is shown in Fig. 2. This system loads the operating program (software) from either of the computers with mass storage devices attached.

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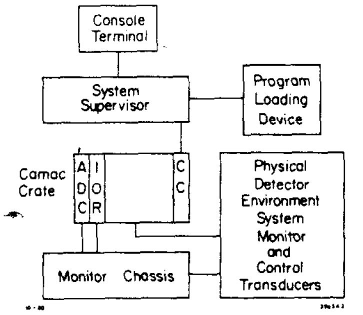
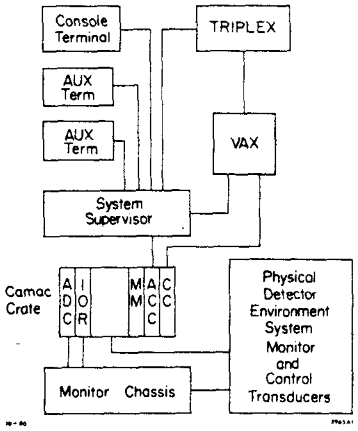
* Work supported by the Department of Energy, contract DE-AC03-76SF00515.

(Contributed paper to the 1980 Nuclear Science and Nuclear Power Systems Symposium, Orlando, Florida, November 5-7, 1980.)



ADC = System Analog-to-Digital Convertor Module
IOR = System 16-Bit Input/Output Register Module
CC = Slot 25 Crate Controller

Fig. 1. A typical stand-alone system.



TRIPLEX = Main SLAC Computer System
VAX = Experimental Data Computer
ADC = System Analog-to-Digital Convertor Module
IOR = System 16-Bit Input.Output Register Module
MM = 4K-Word RAM Module
ACC = Auxiliary Crate Controller
CC = Slot 25 Crate Controller

Fig. 2. An expanded monitor and control system.

The System Supervisor

The system supervisor consists of a processor chassis, microprocessor and interface cards, and peripheral components. The chassis (described in more detail below) is a SLAC-designed enclosure which includes a commercial card-cage and power supply. The microprocessor subsystem consists of the Digital Equipment Corporation LSI-11/2 (KD11-HA), and RAM, PROM, ASCII interface, etc., boards manufactured by DEC and others. This system was chosen because of the wide use and available hardware and software support, both in general and especially at SLAC.

Peripherals that are required include a console terminal and an LSI-11 Q-Bus to CAMAC interface. A dual floppy-disk system is usually included for program loading and storage. These are all commercial units. A complete description of the system including configuration details, is contained in Ref. 1.

The System Supervisor Chassis

The SLAC-designed microprocessor enclosure is an 8-3/4 inch high (5-U) by 19 inch wide rack-mount chassis with slides. This enclosure is commonly refered to as the "MK II Chassis" (Fig. 3). The card-cage is a commercial 8-high, quad-wide, 16-slot backplane assembly.(1) A high efficiency, switching power supply with 25 amp capability at +5 volts and with ±12 volt power, will easily operate a broad range of microprocessor and peripheral cards. Either of two commercial power supplies may be installed.(2) A pair of 100 CFM fans provide the necessary air flow for the cards and power supply. Four printed circuit boards are used for system control and basic ASCII-port interfacing. The chassis top cover is designed to mount in the rack rather than on the chassis. Thus the unit is enclosed when in the rack, but when slid forward for access it is immediately exposed without having to remove the cover.

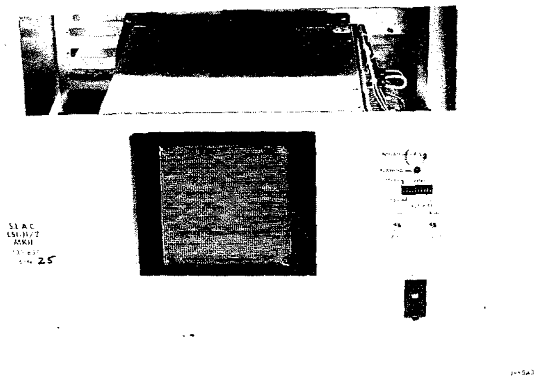


Fig. 3. MK II Chassis, front view with cover.

The four chassis PC boards are:

(1) The front panel board (Fig. 4) which mounts all displays and control switches except the main AC power circuit breaker.

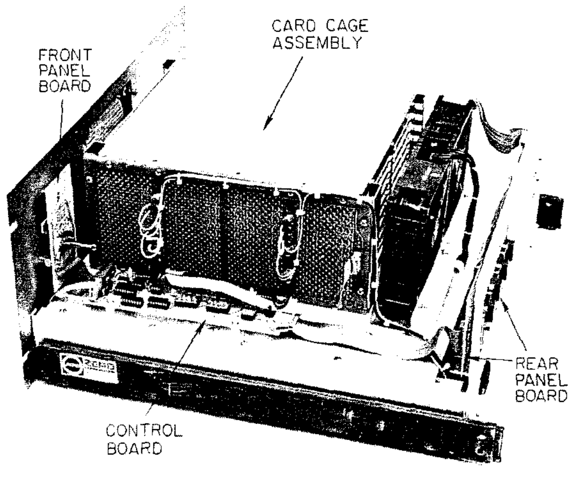


Fig. 4. MK II Chassis, side view.

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(1) Manufactured by Netcom.

(2) Manufactured by Sierracin/Power or Gould.

(2) The system control board (Fig. 4) includes the switch debounce circuits, display drivers, ASCII-port activity monitors, power on/fail monitor circuits, line-time-clock control circuits, and four switch-selected baud-rate generators for the basic system ASCII-ports.

(3) An ASCII-port interface board (the back panel board) which converts from flat ribbon cable to standard 25-pin male D-connectors (Figs. 4 and 5). This board also includes four position-dependent 14-pin headers. By positioning each header in either of two directions, each output connector is configurable either as a data-terminal-equipment device or data-communications-equipment device. By locating each header in either of two sockets, each connector may be configured as either RS-232/423 compatible or RS/422 compatible. This card also contains the line-taps used by the port activity monitor circuits.

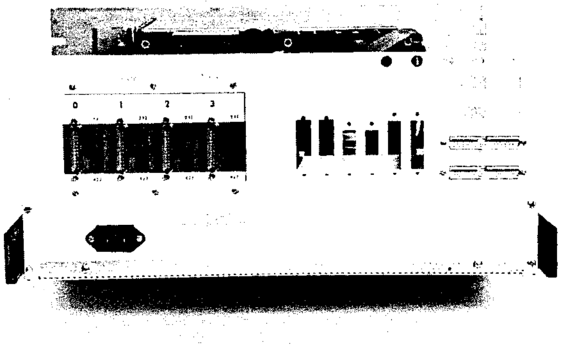

Fig. 5. MK II Chassis, rear view. Note rear panel board mounting and interface cut-outs.

(4) The line-time-clock generator board: Although the board contains minimal circuitry (only an opto-isolator and TTL-driver), it does derive the line clock from 120 VAC power. For safety reasons this board is located in the screen covered area on the bottom of the chassis, along with all other AC circuitry. Thus no hazardous voltages are exposed, even during normal maintenance procedures (Fig. 6).

Interface connection to most LSI-11 series cards is made using flat ribbon cable. For ease of interconnection the back panel has provisions for mounting bulkhead transition connectors for flat cables (Figs. 5 and 7). To allow for the occasional odd cable the chassis back panel has been designed so that there is a one-inch opening at the top when the chassis is installed with the cover. Additional cables may then be brought out of the enclosure over the top edge of the back panel.

The chassis has been designed to allow rapid maintenance. The four system boards are mounted using quick-release, snap-in standoffs. Board connectors are either flat cable connectors, or screw lugs on the line-clock generator board and power supply. Most maintenance may be rapidly performed in the field with a small stock of systems and microprocessor boards, which keeps systems down-time to a minimum.

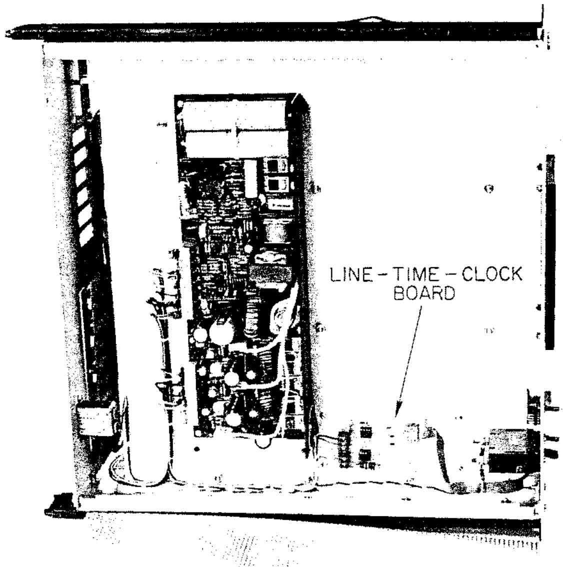

Fig. 6. MK II Chassis, bottom view.

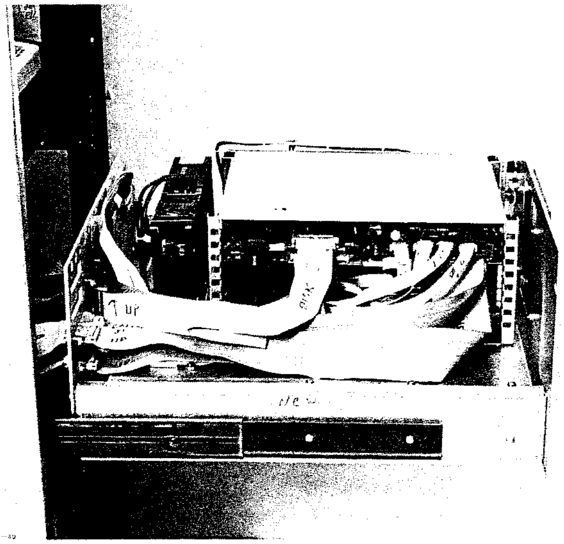

Fig. 7. MK II Chassis, cabled and installed.

The CAMAC Subsystem

A commercially available CAMAC crate controller interface is used between the system supervisor and the CAMAC subsystem. In addition to a CAMAC crate and the above interface, the two components required for any system operating with a monitor chassis are an analog-to-digital converter module and a 16-bit digital I/O register module.(3)

Additional CAMAC modules are often used, especially as control modules. Additional modules can be selected to tailor the system for specific detectors.

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(3) SLAC systems use the following units: (1) crate controllers manufactured by Standard Engineering, either a CC-LSI-11 slot 25 controller, or a CC-LSI-11A auxiliary bus controller; (2) a KineticSystems 3553-Z1C is used as the 12-bit ADC module, configured for 0 to +10.24, differential input, with programmable gains of 1, 10 and 100; and (3) a KineticSystems 3061-E1B is used as the 16-bit digital I/O module, with CAMAC LAM capability and handshaking to the external device (the Monitor Chassis).

Systems that desire optimum communication with the ata acquisition computer will require that both the ystem supervisor and the data acquisition computer ave access to the CAMAC System Crate, each through its wn crate controller. To provide communication, a K × 24-bit-word Random Access Memory module is installed n the System Crate so that data may be passed in both irections using CAMAC accesses. This requires the ddition of one auxiliary-bus crate controller, as well s the RAM module.(4)

The Monitor Chassis Subsystem

The monitor chassis consists of one or more hassis, each with a I/O board, power supply card, hassis control card, and a collection of up to 16 ata-cards. The Data-cards perform the monitor and ontrol interfacing to the detector subsystems.

The monitor chassis subsystem has been designed s a much slower yet cost-effective analog of the eneral CAMAC concept for use where speed and massive ata transfers are not required. By using inexpensive lastic-body I/O connectors (interfaced as part of the ackplane), 'hardware-less' card construction, and CMOS ntegrated circuits to reduce power supply and cooling equirements, the chassis costs have been kept low. he general design goal that signal latching only be one where needed, and that prior data is not latched or readout except when that latch is otherwise re-uired for system operation, has also kept costs down. n a monitor and control system where each output ommand should cause a desired response, monitoring the esponse should be a sufficient check on the operation f the control system. If the response is invalid, aintenance is required, regardless of the cause of the nvlaid response. Also, in these (detector) types of ystems, improper operation usually implies or requires subsystem shutdown, regardless of the specific cause.

A cost analysis is given in Ref. 2. In general, he combination of a CAMAC System Crate and the ex-andable Monitor Chassis front end is a very cost-ffective approach.

Monitor Chassis Description

Each Monitor Chassis consists of a card-cage and ackplane assembly. The unit is 10.5 inches (6U) high, 5 inches deep, and mounts in a standard 19 inch rack Fig. 8). The backplane contains 19 card-edge connec-ors and 128 rear-mounted, 5-pin, data I/O connectors Fig. 9). When viewed from the front, the 19 slots ave the following functions:

a) The left-hand slot is for a power supply card. There are two standard power supplies available. Both provide ±15 volts of regulated DC for system power, and ±10 volts DC each at a maximum of 20 milliamps for reference power. Card SA-135-615-10 provides for system power of ±750 milliamps (Fig. 8), and card SA-135-675-11 provides for system power of ±2.5 amps (Fig. 10b).

b) The next 16 slots are for Data I/O cards (some examples are shown in Fig. 10c-f). These 16 slots correspond to Data-card addresses 0 through 15, from the left. The connector for the card-edge Data-cards is a 43-pair, 0.156 centers (Viking 2VH43/1DD12, or equal) connector. When viewed from the front, the left column of pins on each connector is used for I/O data to the rear panel structure; the right column pins, with four exceptions, are bused across for analog and digital data and control, and for card power. The four excepted pins, F, H, J and K, are binary-coded 0 through 15 for the 16 connectors P2 through P17. This hard-wired code is compared with the Card-Address data to select a single card for any given Data-card command.

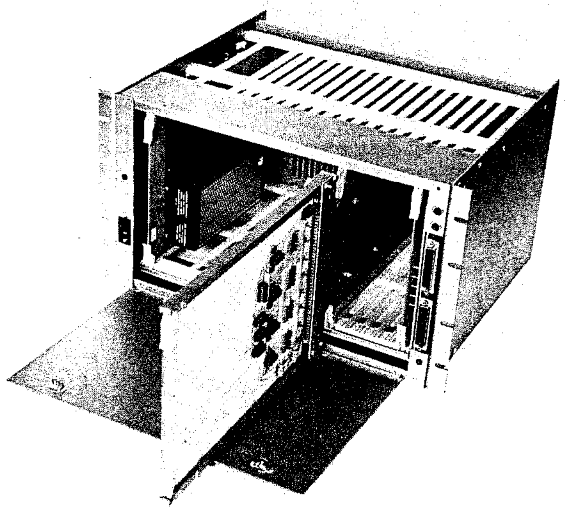

Fig. 8. Monitor Chassis front view, with extender card installed.

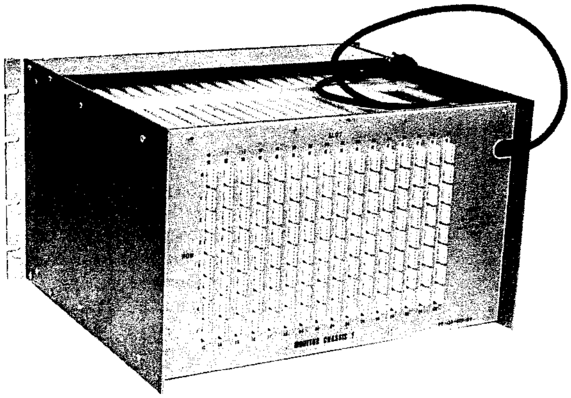

Fig. 9. Monitor Chassis rear view, showing the Data I/O connectors.

(c) The next slot on the right is designed for the control card ONLY (Fig. 10a). The edge connector and spacing is the same as used on the Data I/O cards. This allows the use of one type of extender card for the system (Fig. 8). The control card is the basic interface to the system CAMAC modules. The card also has provisions for polarity reversal of the analog signal to the ADC module, the setting of a variable "system reference voltage," and the monitoring of all the system voltages. It also contains the logic necessary to cause LAM generation by the CAMAC I/O module (when valid and enabled).

(d) The right-hand slot contains a permanently mounted card with only one active component, an LED. This card is used to bring the necessary backplane signals to the right front of the chassis, where they interconnect to the system digital and analog

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) A KineticSystems 3821-K1A will operate as the RAM module with the SLAC developed software.

cables. This method of interconnection was selected to remove the requirement for extensive hand-wiring in the construction of the chassis. The two LEMO connectors for the analog signal are wired as bridging connectors. Two 50-pin connectors are used for all external digital signals. The male connector is the control connector and the female is used for system expansion.

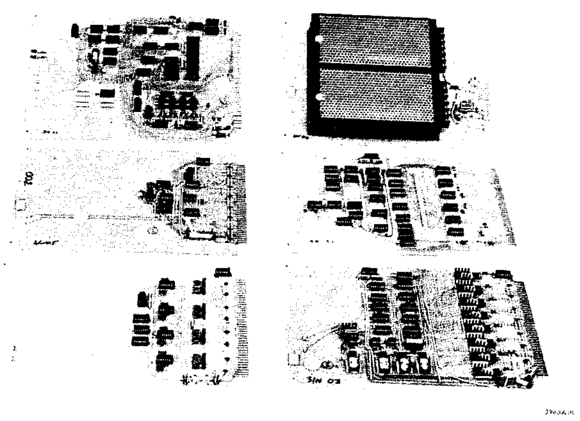

Fig. 10. Monitor Chassis Cards. From the top, left to right: (a) chassis control; (b) dual 2.5 amp power supply; (c) 16-channel temperature sensor; (d) 32-channel switch/open-collector status monitor; (e) 32-channel 40-volt monitor; and (f) 8-channel Hall-effect device power and monitor.

Sensors and Transducers

Although some items are of general use, the selection of these devices is usually very detector dependent, and is done as part of detector system design. A few examples of devices used are: (1) Hall-effect sensors, F. W. Bell BH700; (2) Temperature sensors, analog Devices AD590; and (3) Pressure transducers, Cognition AP3705.

System Software - The Operating System

A general purpose operating system has been described in a previous publication (Ref. 3). Written in PL-11, the system software provides all of the general control and access functions needed for both the CAMAC and Monitor Chassis subsystems. A full description of the operating system is contained the reference.

Summary and Conclusions

I have described a monitor and control system which is in operation in several experimental installations at SLAC. All basic design goals have been met. Experiment changes have occurred which have required system modification and expansion. The changed requirements were easily met by the addition of Data-cards and sensors. The ability to exchange cards without removing system wiring has been found to be a major asset in the maintenance of these systems. Some additional SLAC experiments presently being developed will include the SAMAC systems.

Acknowledgements

The contributions and support of R. S. Larsen, C. A. Logg, L. Paffrath and especially W. Harless, all of SLAC, have been invaluable, both to this paper and the two technical notes referenced.

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