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APPLICATIONS AND DEVELOPMENT OF CAMAC IN NORTH AMERICA IN 1975

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Summary

CAMAC is now a well established instrumentation system in North America. Research organizations outside of the National Laboratories and industrial users are finding that this modular instrumentation system for data handling is indeed a very practical and cost effective approach to Computer Aided Measurement And Control. Accordingly, this paper reviews applications of new developments in CAMAC during the past year and considers its future in view of related technological developments.

Two items are of major importance; both in immediate application and in long-range CAMAC planning. One of these is the new specification for CAMAC Serial System Organization (ESONE/SH/01 and TID-26488), and the other is the rapid introduction of single-chip microprocessors by several commercial integrated circuit manufacturers. Developments, underway and planned, for the use of these two new tools within the CAMAC environment bring one to a firm realization that they each complement and supplement the CAMAC systems of today. Any system for which CAMAC is considered a practical implementation, and which can benefit from the utilization of either the serial highway or the distributed intelligence concept will find these tools to be helpful as new configurations are designed. In fact, many stand-alone systems which previously might not have been attractive in this configuration are now good candidates for implementation in CAMAC.

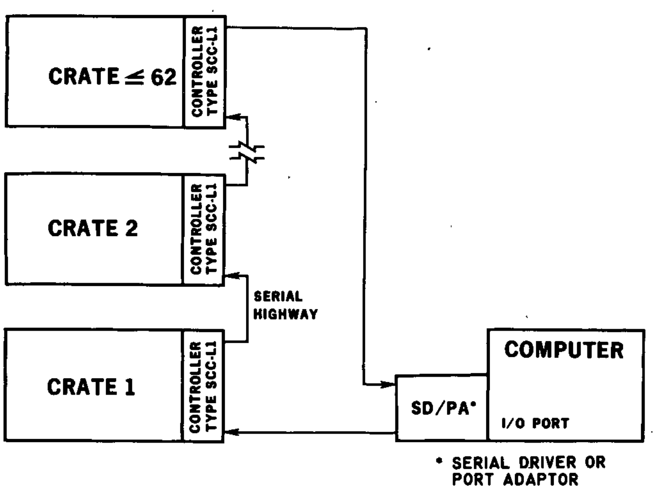

Fig. 1. Basic CAMAC Serial System Organization

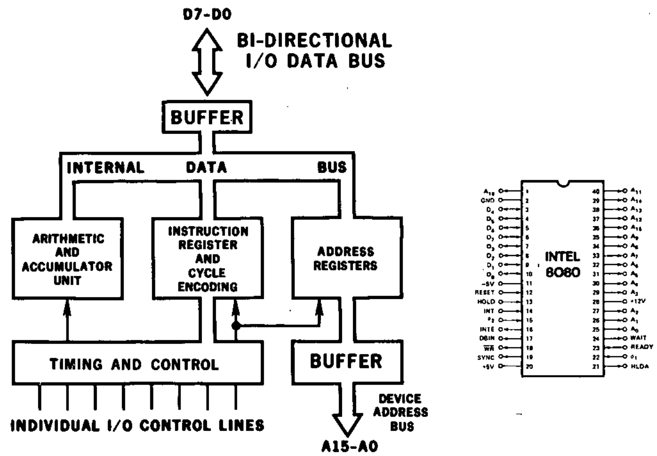

Fig. 2. Simplified Block Diagram And Chip Diagram For The INTEL 8080 Microprocessor

Technological advancements in memory devices and in hybrid integrated circuits have resulted in significantly improved data throughput capabilities for CAMAC systems. Single-width and double-width modules can now: 1) accept up to 128 channels of input data for time digitization and/or address encoding, 2) provide input buffering to accommodate fast event rates, and 3) store up to 32 events for subsequent readout via the dataway.

Current Developments

Serial Highway vs Parallel Highway Systems

The obvious need for some commonality among serial highway systems is evident in that Fermilab[1], LAMPF[2], and TRIUMPF[3] had each developed versions of a serial system for their own control applications before the CAMAC Serial System Organization was written. It is not surprising then, to find that commercial companies were developing serial drivers and serial crate controllers in parallel with the drafting of this specification.

Perhaps even more to the point of the commercial interest has been the encouragement from the industrial process control market. The Aluminum Company of America (ALCOA) conducted a thorough analysis of their process control systems[4,5], and has decided in favor of a 23-crate CAMAC-based serial system for use in their Warrick, Indiana aluminum smelting plant.

What are the factors that make a serial highway system attractive for data acquisition and process control applications? Does this mean that parallel highway systems are no longer in vogue? To answer these questions, let us examine several features that are often required of programmed control and data acquisition systems being constructed today.

1. Information transmission over long distances. The parallel highway can normally operate over distances up to 25 meters.[6] The serial highway is limited only when the time delay of the transmission loop exceeds the time that can be allowed by maximum data rate considerations.

2. Transmission in electrically noisy environments. Error detection and response are part of the specified serial system protocol, whereas similar protection in parallel branch systems is dependent upon user developed techniques.

3. Transmission over commercially available channels employing MODEMS or RS-232-C[b] links.

4. Transmission with unique cabling systems which require strict electrical or mechanical isolation.

5. Large systems with greater than 7-crate capacity. The serial system can accommodate up to 62 crates.

6. System control via the bit serial port of a computer. This may be accomplished easier with the serial system.

Serial highway systems are obviously well suited for the above set of requirements. Where speed is a critical factor, however, the parallel highway has the advantage. Twenty-four bit word transfers can be handled by the parallel branch highway at a maximum word rate of 500-800 KHz; whereas, an optimum serial highway can handle a maximum 24-bit word rate of about 35 KHz. Thus, there is a basic factor of at least 14:1 reduction in speed with the serial highway system. Transmission distance and equipment factors may slow the serial highway system even more; these same factors, however, may prohibit parallel branch operation completely. In summary, the parallel highway is the choice where high data rate transfer is necessary; the serial highway is the choice where long distances are involved or where bit serial transmission is required.

Costs of Functionally Comparable Bit Serial Highway and Parallel Highway Systems

When the selection of either a serial system or a parallel system is not dictated by technical factors which exclude the other from consideration, cost may become the major criterion. Based upon manufacturer's price lists, the following diagrams and graph compare costs of highway drivers, crate controllers, and cabling for several such systems. Except for the estimated cost of the minimum serial port adaptor, the costs indicated are for items that are readily available. Some may minimally meet the capabilities of the devices specified, and are selected for that very reason on the premise that additional features either would confuse the comparison, or would cost the same in either system.

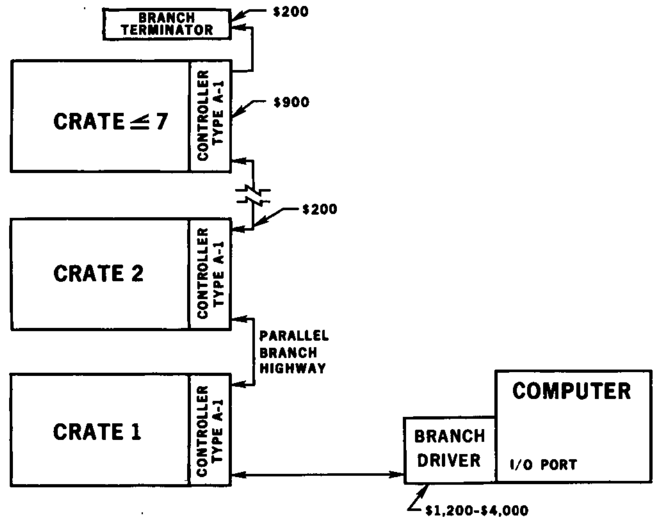

Fig. 3. Highway Costs - Parallel System With Type A-1 Controller

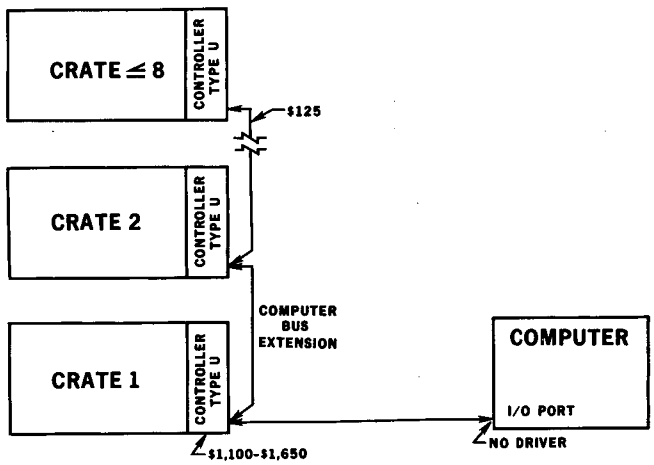

Fig. 4. Highway Costs - Parallel System With Type U Controller

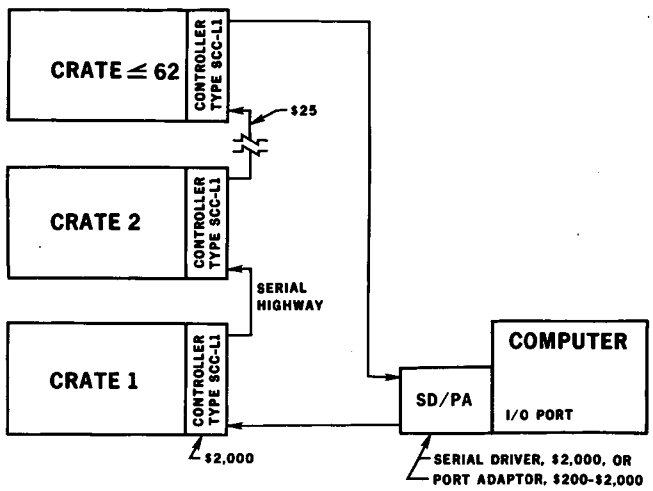

Fig. 5. Highway Costs - Serial System With Type SCC-L1 Controller

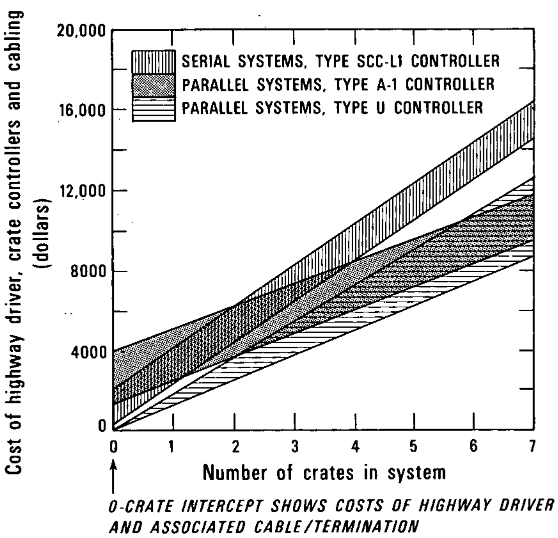

Fig. 6. Highway Costs Of Comparable Parallel Highway And Serial Highway Systems

Specific Installations

An Extended Branch Serial Driver (EBSD) has been developed[7] at the Fermi National Accelerator Laboratory in order to take advantage of the features of the standard serial highway system while retaining the investment and advantages of the installed parallel branch highway system in extensive use at that facility. The EBSD allows the use of serial highway loops within the configuration of the CAMAC-based standard on-line computing system at FERMILAB, called the BISON network[8].

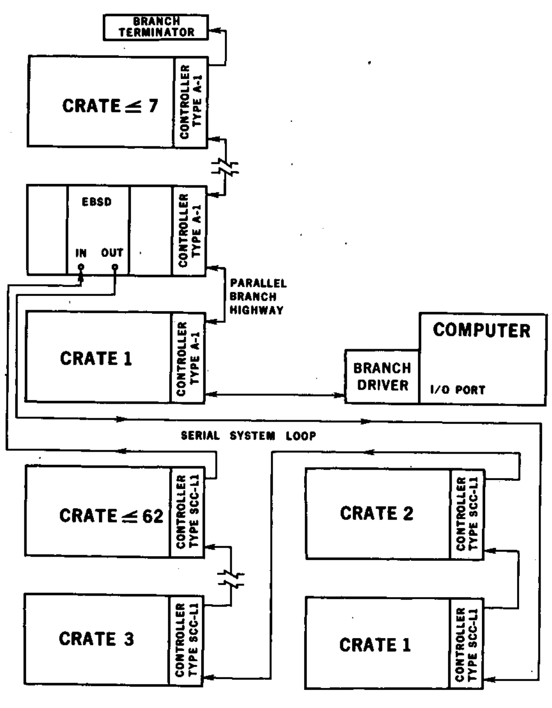

Fig. 7. FERMILAB, Extended Branch Serial Driver (EBSD) System

The EBSD is a sophisticated serial driver that can be used in either bit-serial or byte-serial modes at a clock rate up to 5 MHz. The driver incorporates first-in-first-out (FIFO) memory to enhance the efficiency of communication with the parallel branch system driving the host crate. Four modes of operation with increasing degrees of autonomy are possible. Mode A is basically a programmed data transfer/control mode; however automatic address increment registers can be used. Modes B, C, and D are FIFO-buffered transfer modes with varying degrees of handling scan addresses and command messages within the EBSD.

At Atlantic Richfield Hanford Company, Richland, Washington, two analytical laboratories, physically separated by 2 kilometers are joined together via a data communications link utilizing the CAMAC serial highway[9]. This link will be used both for communication between computers and for automatic analytical instrument control.

An interesting feature of this system is the unique application of the serial system "U" ports[(c)] to drive IR laser diode transmitter/receiver modules over the 2 Km link. By means of this laser link, the serial highway is able to operate reliably at bit rates up to 1 MHz. Except for the adaptor from "D" port[(c)] to "U" port, this system was assembled completely from commercially available modular units.

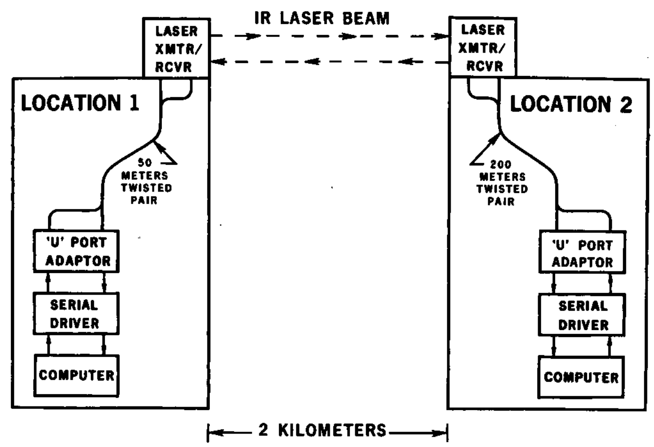

Fig. 8. ATLANTIC RICHFIELD HANFORD LABORATORIES, Serial System With IR Laser Link

The ALCOA Aluminum Smelting Plant at Warrick, Indiana, is installing a prototype 23-crate serial system which will control 45 furnaces. The serial system provides reliable transmission in a hostile electrical noise environment; this is assured by means of the error check routine specified by the Serial System Organization. Both crate bypass and loop collapse features are incorporated to preserve the integrity of the system should there be failures at individual stations. These features also facilitate system trouble-shooting.

A "U" port adaptor in which signal and clock are combined through bi-phase modulation, allows the use of a single coaxial cable. Low noise pickup and high bandpass signal characteristics are features of this system. Although the plant is approximately

300 meters long and the total serial loop about 1 Km, 1 MHz bit rates are made possible by keeping cable lengths moderate and regenerating the signals more often. If all furnace control stations were connected consecutively as the network extends down the length of the plant, a loop return cable of 300 meters would be necessary, and the signal would be deteriorated accordingly. By connecting to alternate crates on the way up the line, and to the adjacent alternate set of crates on the return loop, the length of the individual coaxial lines is kept below about 45 meters.

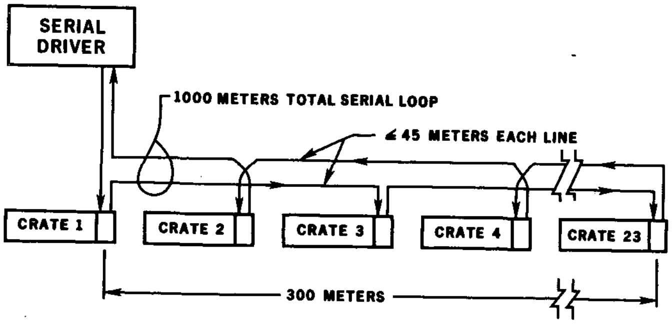

Fig. 9. Block Diagram of Technique Used By ALCOA To Keep Coaxial Lines Short

Both the Atlantic Richfield Hanford Laboratories and the ALCOA installations described above use a serial branch driver that operates from a parallel-driven host crate in a manner like that of the FERMILAB Extended Branch Serial Driver (EBSD). A commercially available serial driver of this type, and a serial crate controller of the SCC-L1 type are shown below.

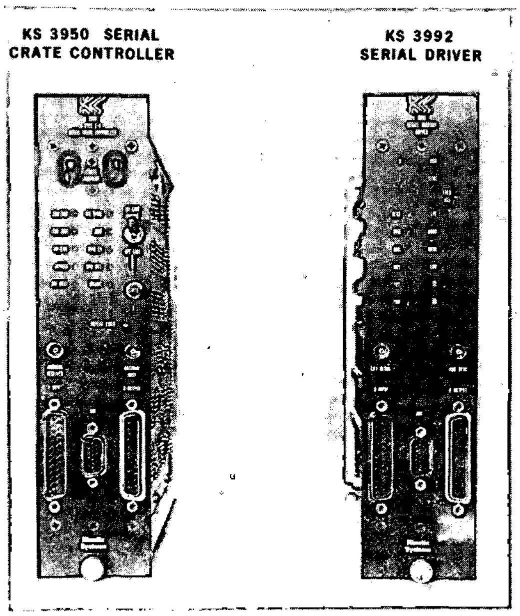

Fig. 10. KINETIC SYSTEMS CORP., Serial Crate Controller Type SCC-L1, And Serial Driver

Distributed Intelligence CAMAC Systems Incorporating Microprocessors

An excellent treatise on the potential for distributed intelligence, or local processor control, in CAMAC systems has been presented by F. Iselin, et al, at the CERN laboratory[10]. The local control can be introduced at several levels: at the module, at the crate controller, at the branch driver, or at the computer interface. A microprogrammable branch driver has been developed at LAMPF more than two years ago[11]. Currently, interest and development in North America are centering on the intelligent module and the intelligent crate controller.

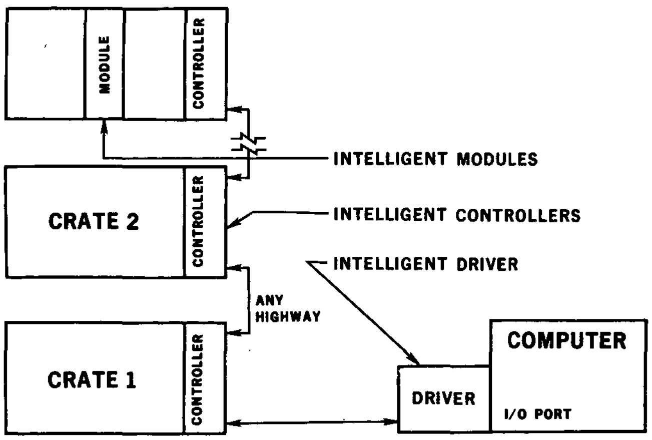

Fig. 11. Distributed Intelligence (Local Control) In CAMAC Systems

The Extended Branch Serial Driver described earlier is a significant application of intelligence in a module. In mode A, the address increment algorithms and decision logic are invoked or removed under program control of the host CAMAC system. In mode B, the limits of internal algorithms are set by the host system. In mode C, the entire command instruction set, (and data, if a write instruction is involved) is transferred into the FIFO memory at maximum host-system speeds. The command is executed at serial system speeds, and the responses are transferred back to the host-system when the EBSD "notifies" the host that it has completed its list of instructions.

Intelligent crate controllers are receiving a great deal of attention; both as stand-alone devices and as components of larger CAMAC systems. For example in recent developments we have noted that J. Bobbitt at the Fermilab has designed an autonomous crate controller around the Intel 8080 μ-processor[18]. This device is designed primarily as a stand-alone process controller. The 16-bit "external memory bus" of the 8080 module allows multiple crates (via a type "U" data bus), additional memory, and special devices (such as memory-driven displays) to be controlled externally from the crate in which the controller resides.

Standard Engineering Corp., Fremont, California, has announced preliminary specifications for a microprocessor CAMAC controller for general purpose use[12]. A significant feature of this controller is that it will be designed to be used autonomously in either the control stations (usually 24 and 25) of a CAMAC crate, or in a normal station as a second, auxiliary controller. When used as an auxiliary controller, direct dataway drive and response to N & L lines will be gated off within the module. These data will then be communicated via a rear-panel connector to the master controller located in the usual control stations in the crate. When used as an auxiliary controller this device assumes a second priority relative to the master controller. Priority resolution will require some modifications to existing type A-1 and type U controllers. Priority control will also be maintained via rear panel connectors.

At the Lawrence Berkeley Laboratory we see an immediate use for such a controller as a display driver for existing "blind" binary scalers. Such a device could be used autonomously to monitor count rates during setup time of an experiment. When experimental data are actually being gathered, this device, occupying a normal station, could autonomously provide visual data from the scalers. The value of such operation is that CPU time from the system computer may be relegated entirely to the control and data acquisition aspects of the experiment. These latter functions would be effected via the master controller located in the normal control position in the crate.

Large Throughput CAMAC modules

T. Nunamaker, Enrico Fermi Institute at the University of Chicago, has designed two single-width modules to interface between spark and proportional chamber readout electronics and the CAMAC dataway. The early module can handle signals from 8,000 wires, and a later module has been expanded to handle 64,000 wires. Addresses of "hit" wires are encoded into 16-bit words by the chamber readout electronics, and are transferred to the module in a serial transfer that keeps pace with the maximum speed of the dataway.

LeCroy Research Systems, Corp. (LRS), of West Nyack, New York, has offered a 96-channel drift chamber digitizer and a 128-channel multiwire proportional chamber encoder; each in double-width modules. Both of these devices provide input buffer registers to facilitate high event rates, and FIFO memories of 32-word X 16-bit capacity to store multiple events for subsequent readout via the CAMAC dataway.

Awareness of CAMAC Systems Capability

Because of the effectiveness that the CAMAC instrumentation standard has achieved in the National Laboratories in North America, new developments will occur within these establishments as a matter of course. New developments in the industrial/commercial digital data market, where the benefits of standardization are not yet so well understood nor accepted (especially by the producers), may require considerable improvement in the awareness of the users who stand to benefit from this user-developed system.

Through the efforts of the CAMAC Industry Applications Group (CIAG), which is an independent organization of industrial users of digital data monitor/control systems, under the chairmanship of Dale Zobrist of ALCOA, user awareness outside of the nuclear research community is picking up rapidly.

As a part of the IEEE Continuing Education Program, several one-day short courses have been presented on CAMAC. The most recent presentations at Nashua, New Hampshire; New York City; and FERMILAB during the week of April 6-12, 1975 included a section on the use of microprocessors.

Future Outlook

The question has been raised whether the IEEE standard 488/81, Standard Digital Interface For Programmable Instruments And Related Systems Components (often referred to as the H-P bus or the ASCII bus), will hamper the future development of CAMAC. The consensus from a number of systems designers is that it will not. There is clearly a continuing need for a standard which includes modular mechanical packaging as well as signal levels and transmission protocol. CAMAC, through its parallel branch and serial highway systems continues to meet that need. It will not soon be displaced by a standard that is lacking in mechanical specification. To be sure, new instruments will be manufactured to IEEE 488/81 specification, and engineers will design systems to that standard for various reasons; but the cost effectiveness and freedom from single source of supply that CAMAC has demonstrated in the nuclear and industrial process control markets in the past two years has set an irreversible trend.

This is not to say that IEEE 488/81 is not here to stay. Some CAMAC users will find themselves adapting to the ASCII bus, and will benefit from the features it presents. D. Machen at LAMPF has already designed and constructed a CAMAC module that uses an 8080 microprocessor algorithm to convert to the ASCII bus protocol[13]. The Systems Compatibility Subgroup of the NIM/CAMAC Dataway Working Group is also considering a CAMAC interface to the ASCII bus; they will carefully consider the work already performed at LAMPF.

Plans for an interesting medical development come from Vanderbilt Hospital in Nashville, Tennessee. J. Erickson is planning autonomous one-crate systems with floppy discs that can be transported to the patient's room for data collection and then returned to the large computer for analysis[14].

Dale Zobrist at ALCOA sees the use of intelligent controllers with pre-programmed control algorithms which are connected via a serial highway system to a central computer for monitor and control of various parameters[5].

The Hydro Quebec company of Ontario, Canada is seriously considering CAMAC for the power control grid for the province of Quebec[15]. The planned network will be comprised of 350 remote monitor/control stations, eight regional dispatch centers, and the central control facility. Hydro Quebec engineers have completed a 2-year study of the project and have established the feasibility of a serial CAMAC system from technical considerations. They find the modularity of the CAMAC system particularly attractive in that it allows flexibility for changeover as the system grows with time.

As reported earlier, CAMAC is being considered by NASA for use in the Space Shuttle program[16,17]. It is interesting that even in this unique application, studies of two planned experiments show a dramatic cost effectiveness for CAMAC, one-fifth to one-tenth the cost of instrumenting these experiments by the more traditional customized packaging. Low power components and special radiative cooling hardware will have to be employed because of the loss of convection cooling in the evacuated environment. During FY 76 selected modules will be fabricated and tested to verify the conclusions of the studies.

Conclusion

Clearly, the dynamic growth for CAMAC in North America in the immediate future is in serial systems and in stand-alone systems, each using micro-processors. Serial systems employing distributed intelligence have boundless potential for data acquisition and control. Developments in this area, as described in this paper, are already underway. For the time being, we have found that the bit serial mode is receiving more serious consideration and design than is the byte serial mode, though the Serial Highway Organization allows both.

Stand-alone single-crate systems incorporating intelligent, autonomous, crate controllers have the potential for bringing standardization and flexibility for change or growth to even the smallest of control or monitor applications. Imagine the possibilities for environmental monitoring alone!

High speed parallel systems will grow mainly in the sophistication of the modules used for data acquisition. More controllers of the intelligent variety will be developed to minimize the number of tasks required of the CPU.

Notes

(a) The word "serial" in this paper, when used without prefix, is to be considered bit-serial. Wherever byte-serial is discussed, it will be explicitly so prefixed.

(b) Electronic Industries Association (EIA) standard RS-232-C, Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange.

(c) "U" ports are Undefined ports in the CAMAC Serial System Organization (ESONE/SH/01 and TID-26844); in contrast to "D" ports which are Defined ports. A commonly used "U" port may be in accordance with the RS-232-C specification noted in (b) above.

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