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A CAMAC-BASED INTELLIGENT SUBSYSTEM FOR ATLAS
EXAMPLE APPLICATION: CRYOGENIC MONITORING AND CONTROL

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Abstract

A subunit of the CAMAC accelerator control system of ATLAS for monitoring and, eventually, controlling the cryogenic refrigeration and distribution facility is under development. This development is the first application of a philosophy of distributed intelligence which will be applied throughout the ATLAS control system. The control concept is that of an intelligent subunit of the existing ATLAS CAMAC control highway. A single board computer resides in an auxiliary crate controller which allows access to all devices within the crate. The local SBC can communicate to the host over the CAMAC highway via a protocol involving the use of memory in the SBC which can be accessed from the host in a DMA mode. This provides a mechanism for global communications, such as for alarm conditions, as well as allowing the cryogenic system to respond to the demands of the accelerator system.

Introduction

ATLAS [1], the Argonne Tandem-Linac Accelerator System, is a major expansion of an existing heavy-ion accelerator facility which consists of an electrostatic Van de Graaff tandem accelerator and a prototype superconducting linear booster accelerator. The superconducting linac control system is a CAMAC-based system with an enhanced Digital Equipment PDP 11/34 computer as the central control computer. The CAMAC system is configured as a byte-serial multi-crate highway interfaced to the central computer via a serial highway driver residing in a unibus memory-mapped crate.

The ATLAS project places a significantly increased load on the accelerator control system. This effect occurs both due to the increased number of devices which must be monitored and controlled but also because the much more complex accelerator system requires more computing support in order to allow the staff, which has not increased in size significantly, to efficiently operate the facility.

The ATLAS facility contains a number of complex subsystems which can significantly benefit from increased automation and computer control. Subsystems such as ion sources, cryogenic distribution system, a superconducting dipole switching magnet, and subsections of the superconducting linac are examples of complex subsystems which require or can dramatically benefit from close supervision and control through a computer system. We report in this paper the first application of a philosophy of expansion using single board computers in specific CAMAC crates to achieve distributed intelligence in the ATLAS control system.

System Design Considerations

There are many possible approaches which may be used to achieve such a goal and the proper choice is often strongly influenced not only by local personal biases but the environment, both hardware and software, which presently exists.

The following points were requirements which the enhanced system has been designed to satisfy:

1. We felt that the major investment in hardware and software which had already gone into making our facility one of the most automated heavy-ion facilities existing could not be abandoned. Therefore, the constraint of building on the existing system was a requirement.

2. The load on the central computer due to simple monitoring tasks should be minimized in order to free that computer for more complex tasks such as program development, high level calculations, data management, and human interfacing.

3. The congestion on the serial highway should be kept as low as possible to allow for future activities.

4. The reliability of the monitoring and control of the subsystems mentioned before should be high. This requirement essentially rules out the use of the central computer since its reliability is compromised by the higher failure rate of disc drives, line printers, terminals and other peripherals, not to mention system crashes that occur during such activities as program development.

5. The operation of the these major subsystems locally should not be dependent on the operation of the overall CAMAC highway or the central control computer.

The solution which has been adopted at ATLAS is to add local intelligence in any CAMAC crate which contains the interfacing hardware for a particular subsystem. Such a configuration is shown in Figure 1.

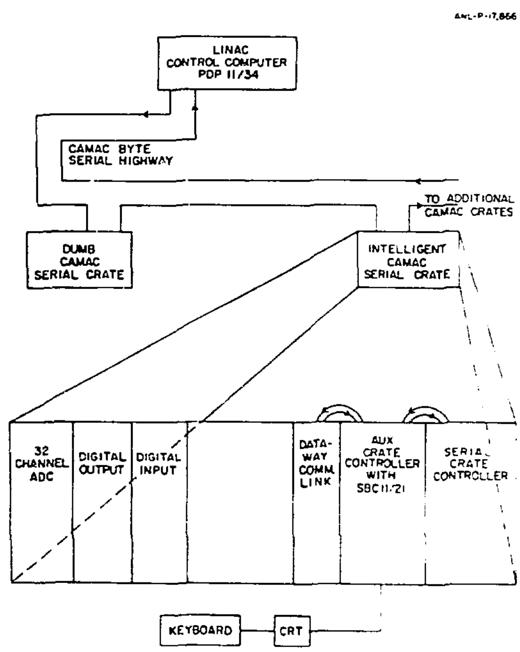

Fig. 1. Hardware configuration for remote intelligence applications in ATLAS control system.

The local microprocessor is interfaced into the desired CAMAC crate through the use of the auxiliary crate controller protocol. Many of the functions of the remote processor require no interface to the central computer. Communication with the central computer is through the CAMAC highway using a CAMAC-DMA mode into the micro-processor's memory. This mechanism allows the use of LAM's as interrupts for both CPU's as well as allowing essentially transparent polling of system status for data logging in the control room, direct communication to the operator from a remote site (home), and central data base updates. By maintaining all systems as integral parts of the serial highway, it is possible to develop more complex, seldom used routines which use various hardware components of the subsystem in a way that is often transparent to the local microprocessor. An example of this last feature is the measurement of the Q of a resonator using the cryogenic thermometry which is actually part of a microprocessor subsystem.

All choices have disadvantages. The disadvantages of this approach include:

1. The elaborate libraries of control functions which have been developed for our RSX-based system cannot be used in the microprocessor environment we have chosen. Therefore program development has been slower than might have been otherwise possible.

2. Each subsystem is essentially limited to one CAMAC crate. This disadvantage can be overcome with the use of a local branch highway and is being done in our ion source subsystem, but it is not possible for a microprocessor to access another crate on the main accelerator CAMAC serial highway except through an elaborate communication scheme involving the central computer.

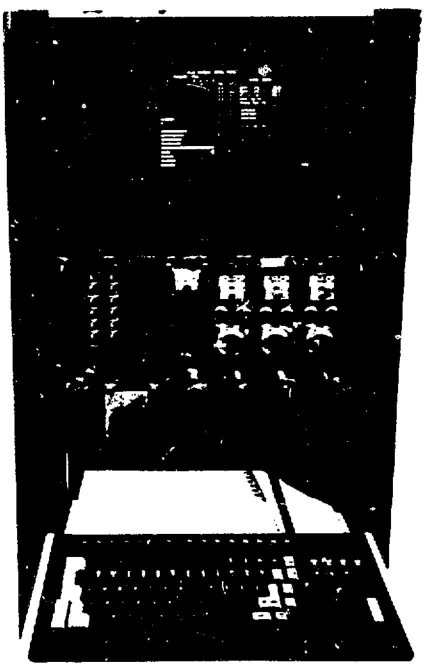

Fig. 2. Terminal interface for ATLAS cryogenic monitoring and control subsystem.

Hardware and Software Implementation

The microprocessor chosen for implementing this concept was the Digital Equipment SBC 11/21 (Falcon) single board computer. The Falcon is easily configurable in a number of memory modes. This allows development and debugging using RAM memory which can later be converted into PROM memory allowing complete stand-alone operation independent of the rest of the control system. The Falcon resides in and is interfaced into the CAMAC crate through a Kinetics System 3921 crate controller operating in the auxiliary mode. The CAMAC-DMA unit is a Kinetics System 3825 Dataway Communications Link. This system is installed in a CAMAC crate which is a part of the accelerator control system serial highway.

The software development environment selected is Pascal with parallel features similar to Modula. This software runs under the RT-11 operating system and has features quite similar to DEC's Micropower Pascal. The software runs in the Falcon with no operating system and, in the final version, will execute immediately upon bootup.

During the development period, which we are still in, the executable code is compiled and linked on the program development computer system and then downline loaded into the SBC 11/21 using the features available in the ODT PROM on the 11/21. The debugging cycle can actually include execution of the code on the development computer under RT-11 prior to testing in the target system. This feature is accomplished via switches in the compile and link cycles.

The Cryogenic Monitoring and Control System

The cryogenic monitoring and control system is the first application of the design philosophy described above. The implementation of this system has allowed us to break the task into three phases which will be

Fig. 3. ATLAS cryogenic monitoring and control CAMAC crate showing auxiliary crate controller housing single board computer.

described below. Phase I is essentially complete and Phase II is in the early stages of development.

The ATLAS cryogenic system [2] consists of two separate liquid helium refrigerators (an additional one is planned), an elaborate liquid helium distribution system with a total length of nearly 200 feet, two large helium dewars, and an associated liquid nitrogen distribution system. This system provides the necessary cooling for ATLAS which consists of 47 superconducting resonators, 22 superconducting solenoids, and a superconducting beam switching dipole magnet. The total number of parameters which should be monitored in the system is more than seventy. These parameters are temperatures, pressures, flow rates, liquid levels, compressor operation, and some miscellaneous information. Presently the system operates in an intensive manual mode. The only automatic feature is the control of heaters, located in the main dewar reservoirs, based on either liquid level, pressure, or flow rate. Unfortunately the complexity of the system causes this simple regulation to be an inadequate control under varying load conditions of the accelerator, thereby requiring intensive human interaction for most situations.

The Phase I control system development goals were to implement a stand-alone monitoring system for the ATLAS cryogenic system. The parameters to be interfaced and the basic software required are now in place and have been functioning for three months. A local terminal is provided which provides graphical and textual display of system temperatures, pressures, and liquid levels. The terminal keyboard is used to provide input of allowed ranges, to activate limit checks on desired parameters, and control the displayed information. The terminal is interfaced through one of the two serial ports available on the Falcon. The terminal interface is shown in Figure 2 and the CAMAC crate housing the micro-processor is shown in Figure 3. The system is presently running from RAM memory but it will be converted soon to PROM memory configuration for the program and RAM for the data regions only.

The goal for Phase II is to provide communication back to the central control computer to allow data logging, global alarm condition broadcasting, and remote site communication. This phase of development will employ the dataway communications link, a CAMAC-DMA device which allows DMA access to the memory of the local microprocessor in order to communicate and to retrieve data concerning the subsystem parameters. For data logging functions, the central computer can extract information from the microprocessor memory without the need for any communication software interface. Similarly, for error condition reporting the microprocessor can interrupt the central CPU by setting a LAM in the CAMAC crate and loading the error information into a predefined region of memory. Therefore in Phase II communication the problems of asynchronous communication can be avoided. The need for such communication will surface later in the Phase III period when actual automatic control is attempted and the need for remote operator input may become desirable. Phase II implementation should occur during the next six months.

The third phase will be to implement certain control features on the cryogenic system. A more elaborate heater control allowing regulation based on a number of parameters and some additional control of specific valves and loading of compressors may also be included. The details of this effort will require intensive implementation and testing cycles which await the full implementation of Phases I and II.

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References

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