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THE ISABELLE HALF-CELL CONTROL SYSTEM*

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SUMMARY

The primary function of the ISABELLE half-cell control system is to monitor and control the magnet power supplies of the half-cell. In addition, the control system must be flexible enough that it can be expanded to become involved in additional areas such as vacuum and magnetic measurements. A control system based upon AGS control standards, but modified into a development tool for research and electrical engineering support has been constructed. Special attention was given to the inherent differences between controlling an ISABELLE and a conventional fast cycling accelerator. The use of FORTRAN and BASIC networks, and microprocessors is reviewed insofar as they pertain to this system. Some general opinions on model control systems, based upon our experience, will be presented.

The half-cell is a full-scale model of an actual half-cell of the machine lattice of ISABELLE. A half-cell is composed of two dipole magnets and a quadrupole magnet. There are also multipole correction windings in the magnets for working line control. The primary function of the half-cell control system is to monitor and control the power supplies for these magnets.[1] However, there are other services which the control system provides in addition. This article will review the development of the half-cell control system, emphasizing why certain decisions were reached. These were the managerial and technical criteria that most influenced the design.

In October of 1975, a target date of January 1977 was set for the completion of a computer control system capable of controlling the power supplies of the half-cell. The system was to allow convenient interactions between researchers and the system under test. The control system was not to be a prototype of the ISABELLE control system. A rough upper limit on the cost of the computer itself, and peripherals was 40 K$. The initial personnel to be directly involved had much of their computer experience with DEC equipment.

The above-mentioned criteria led to the decisions to buy a DEC minicomputer and to build a process I/O system based upon an existing AGS design. Initially, the computer supported in-house program development using either FORTRAN or BASIC under RT-11, a foreground/background monitor available from DEC. As the system has developed, a multi-user need has arisen. The ISABELLE Electrical Engineering Group has a requirement for computer support in both the development and production of control system components and power supplies. In addition, the ISABELLE Vacuum Group has an experimental facility in need of computer monitoring and control. The process I/O system has been expanded to satisfy these needs. The multi-user software package is DEC's Multi-user BASIC, which allows three users to work on the host computer simultaneously. Multi-user BASIC will in theory support up to eight users, but we find that with our memory configuration (28 K words - the maximum supported by RT-11), three users is the useful limit.

Our original motive for using multi-user BASIC was to permit several simultaneous users under RT-11. However, it quickly became evident that with only two assembly language subroutines, a Datacon driver and an elapsed time clock, it was possible to perform highly efficient (in terms of man-hours) equipment testing. Further, despite some format limitations, BASIC serves as a fully satisfactory control language. Ease of use by the casual and, even more important, the intermittent programmer, is one of the factors contributing to the success of our system.

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The system is built around a DEC PDP-11/10 and associated peripherals (Fig. 1). The manufacturer's equipment was supplemented with only two special devices: a Datacon central (computer interface) and an Event interface.

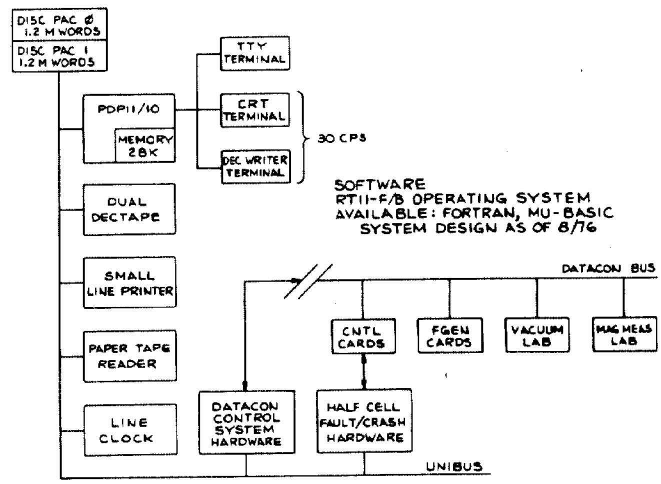

Fig. 1. ISABELLE Half-Cell Computer System Block Diagram.

Serial transmission of commands and data has been in use at the AGS since 1970.[2] Datacon is a fixed format, transformer isolated, phase encoded, alternate duplex control scheme especially designed for accelerator control activities.[3,4] The design has aged well and offers a cost effective solution to many control and data acquisition problems. Since Datacon is a polling scheme, provision was made in the control system for an Event interface,[5] which furnishes 16 channels of vectored priority driven program interrupt for use in real-time data acquisition, status, and command applications. Datacon is insensitive to computer type and has been used successfully with PDP-8, PDP-10 and PDP-11 computers. The hardware realization for the PDP-11/10 is a single wire-wrap card plus several DEC M-series modules located in a BB11 system unit (a similar realization is employed for the Event interface). Using a single coaxial wire and having a range (without repeaters) in excess of 700 meters, Datacon allows control of the half-cell (located on the old Cosmotron target floor) from the former Cosmotron control room (Fig. 2). Adding a sense of realism to the model, this scheme provides a simulation of remote control problems which will be encountered in ISABELLE.

Just as an effort was made to avoid the design and construction of much special purpose computer interface hardware, a considerable effort was made to live within the limits of commercially available software. The model has ten power supplies. The nature of a cryogenic ISABELLE requires the generation of many real-time magnet correction and control functions, these would ordinarily require a high speed, closely synchronized flow of data. Supervisory control via a set of self-contained function generators achieves the desired performance while allowing continued use of the standard Mu-BASIC/RT-11 operating system.

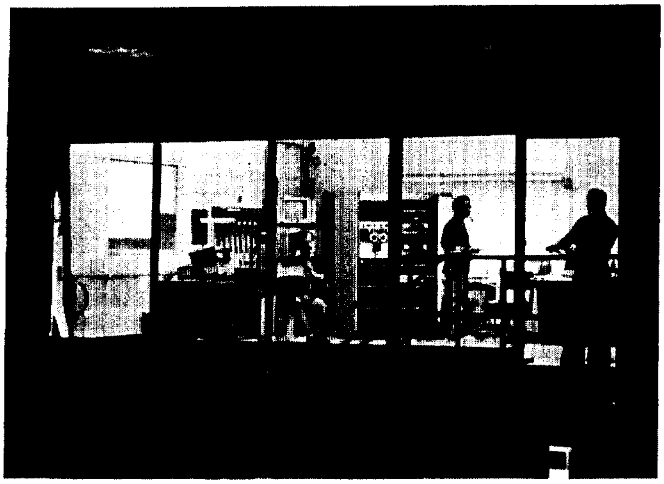

Fig. 2. ISABELLE Half-Cell Control Room.

The function generators are of two types.[6,7] Most are random access with 2048 sixteen bit words of MOS memory, while the main dipole current is controlled by a Break point/Rate device capable of 64 segments. All units are capable of operating independently of the computer, once loaded; other features include full, interleaved access to the function generator's memory and a direct computer control mode.

Another set of boards dedicated to command/status and interlock states completes the application oriented devices.[8,9] In addition, a Datacon Crate Controller,[10] similar in concept to a CAMAC Crate Controller, provides a TTL compatible semiserial internal bus structure.

In order to avoid problems in interfacing various control system areas, it was decided that before any design work was started a standards document[11] should be written. One of the first problems encountered was how to interface digital circuits, analog circuits, and the outside world without ground loops and noise pickup. The solution was to completely separate the analog and digital circuitry and to isolate all lines coming from the outside world using opto-isolators. The standards document specified several circuits to drive these devices. The isolation is to be on the receive end of a line and the transmit end has to supply the drive current. All fault lines that entered the system have to drive current into an opto-isolator in a no fault condition to fail safe the control system. If a line is broken or left unconnected, the system would therefore show a fault condition. All command lines entering the system have to drive current into an isolator, when a command is issued. Thus, if a line is broken or left unconnected the system would not see an erroneous command. Two different isolators were specified so that we could economically span our need for high speed fast switching devices and those used only for level detection.

The standards document specifies connectors, pin assignments, and color coding. Connectors were selected that would reduce as much as possible the time and skill needed for construction.

Due to the thorough planning behind the standards document, no serious interfacing problems occurred.

Since we were limited both in time and manpower the best way to design the half-cell power supply controls was to use TTL circuitry, with which we were all familiar. We chose to use wire wrap assembly because there was a small number of cards of each design. There was a usable wire wrap collage board available in-house and there were local automated wire wrap services available.

Some problems were encountered using TTL that probably would not have been problems at all with another approach. As the card that controls the power supply (i.e. standby, on, crash, etc.) was designed to run the supply in a certain sequence. During development it was discovered that sequencing had to be altered under certain conditions. It was not difficult to incorporate changes to meet these requirements in TTL. However, the circuit rapidly became complex, since a change in one section ultimately had an effect on some other section. An alternate technique would be to use a prom to do the sequencing. Any variation in the sequencing can then be changed in software leaving the hardware unchanged. We are also going to investigate using microprocessor technology in this application.

Each power supply can be operated by the PDP-11/10 computer or by its manual control panel. The panels for all the supplies are grouped together in a control console. Since each supply has its own panel and requires a 38 conductor cable, this is expensive and time consuming to build. The cost would be prohibitive in a machine the size of ISABELLE. Therefore, the next generation manual panel will probably be a microprocessor based device that uses the process I/O communications lines to control all the supplies from a single device situated locally.

Although not required for a half-cell model, we expect to shortly implement a small network using the PDP-11/10 as a host computer and several LSI-11 computers as remote stations. This system is expected to operate under a standard DEC software product known as REMOTE 11, a subset of DECNET. The goal here is to study the properties of computer networks, something required by the size of ISABELLE. Simultaneously, the network will expand the capability of our control installation to a point wherein sophisticated control of additional devices such as a cryogenic refrigerator and beam vacuum facilities may be undertaken.

Microprocessors were not used originally because we considered their use a development, rather than a design, project. The physics research aspects of the half-cell are of greater initial importance than a control system design study. Thus, it was our intention to defer development work until a later period. As a consequence, all design, while employing sophisticated digital techniques, are not microprocessor based. Our conclusions may be stated as follows: It is possible to rapidly design and construct a high performance, cost effective system without microprocessors. However, in a second generation of equipment, we would use them primarily because of the ease of effecting design changes necessitated by an expanded understanding of overall mission requirements.

In conclusion, we are pleased to state that the control system for the ISABELLE half-cell model was completed on schedule and within original budget estimates. We believe it provides the necessary flexibility and power to fully satisfy its mission, but expect and desire considerable feedback from noncomputer specialists when physics oriented testing begins in the near future.

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