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TITLE: A GENERAL DISTRIBUTED CONTROL SYSTEM FOR FUSION EXPERIMENTS

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A General Distributed Control System for Fusion Experiments

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A general control system using distributed LSI-11 microprocessors is being developed. Common software resides in each LSI-11 and is tailored to an application by control specifications downloaded from a host computer. The microprocessors, their control interfaces, and the micro-to-host communications are CAMAC based. The host computer also supports an operator interface, coordination of multiple microprocessors, and utilities to create and maintain the control specifications. Typical applications include monitoring safety interlocks as well as controlling vacuum systems, high voltage charging systems, and diagnostics.

I. INTRODUCTION

Over the past ten years a number of computer control systems have been developed for magnetic confinement experiments at Los Alamos. Each new application has required an increase in control system size, function, and complexity. The result is a collection of software and hardware systems with little in common. While each supports the tasks for which it was designed, none have the generality to be useful in the future.

We are now developing a general computer control system which satisfies a wide range of experiment control needs. We intend to use this single package for all future control applications, from prototype experiments and sub-system development installations to major research facilities. The use of a standardized system will improve efficiency in troubleshooting and maintenance, expansion, and user training.

Common software is downloaded from a host computer to distributed microprocessors. The program reads configuration, control logic, and sequence information from the host computer or from a local console. Smaller applications may be fully supported by a single microprocessor;

larger ones can be divided into independent sub-systems, each with its own processor, coordinated by the host computer.

II. HARDWARE

All hardware is housed in CAMAC¹ crates. The microprocessor is an LSI-11/23 or 11/73 with 256-Kbyte memory, an auxiliary CAMAC crate controller, and a CAMAC-to-LSI bus communications interface. Because all software loading, configuration, and message passing is handled through CAMAC from a host computer, no mass storage is necessary on the microprocessor. This configuration allows placement in severe environments where dust or electrical noise might otherwise be a problem.

Four classes of physical control signals are implemented with commercially available CAMAC modules. Digital inputs provide switch contact monitoring, typically used for safety interlocks and valve position indicators. Digital outputs allow on/off control for devices such as power supplies, pumps, relays, and valves. Voltage-controlled devices, such as ramped power supplies, are supported by analog output channels. Analog input channels provide voltage

monitoring; typically they are used to measure capacitor bank voltages and vacuum system pressures.

A locally-built watchdog timer module provides fail-safe protection. The program loads this module with a timeout period equal to the monitoring cycle time, then keeps it alive by resetting it each cycle. Should the processor fail to cycle on time for any reason, the module drops its optical output signal. Any controlled systems relying on constant computer control can use this signal to achieve a fail-safe state when indicated.

An interface system provides optical isolation for each control signal². The host communicates with the microprocessor system over a CAMAC serial branch highway implemented with fiber optics. This isolation assures protection of both the control hardware and the host computer from electrically noisy environments and allows for flexibility and convenience in locating the package.

III. SOFTWARE

A. General

Software for the microprocessor is developed on a dedicated LSI-11/73 system running Digital Equipment Corporation's MicroPower/Pascal-RT. This product provides the Pascal language with extensions for real-time multi-process support, and produces a runtime file designed for downloading to target microprocessors. This image file is transferred to the host computer where it can then be distributed to microprocessors anywhere on its CAMAC branches.

Once downloaded and running, the program receives information about the system it is to control in messages from the host computer or from an optional local keyboard. Each message is a request for a single control system action of one of the following types: local hardware description, control and sequence logic building, status requests, signal state setting, and sequence execution. A reply message is returned to the sender in response to each request.

Because the local console implements the full command message set, it is possible to use the system in a stand-alone mode, once program downloading is complete. Any command messages which would normally be sent by the host computer can be given manually. Sub-system control is not

necessarily interrupted by downtime on the host computer.

B. Structures

In addition to the four physical signal classes controlled by the microprocessor, a number of internal structures are provided for timing, sequence programming, and logical control.

Ramps may be defined for the control of analog output channels. A ramp is specified with initial and final values and a time over which the signal is to be incremented or decremented. Commands are provided to start, hold, or turn off a ramp. A typical use is linear control of high voltage power supplies in bank charging applications.

For each analog input channel the user may define parameters for limit monitoring. Both upper and lower limits are provided. They may be constant or they may increment or decrement, much like a ramp, to follow changing signal levels. They are accessed as Boolean values which reflect whether or not a channel is within its limits.

A set of 64 internal digital channels, or software switches, is available. Software

switches are Boolean constructs which may be used as both inputs and outputs.

For timing functions a set of 32 timers is available. A reset and a start channel for each timer may be set with standard commands. Timers are defined by two periodic time parameters, a transition count, and a first transition state. A timer is initially false. When started it assumes the first transition state then alternates states for the respective intervals until the transition count is satisfied. The final state is retained until reset.

C. Sequences and Ladders

These structures along with the physical control signals interact through two higher level constructs, the sequence and the ladder. These features provide a combination of programmed events with actions based on the results of constant monitoring and evaluation.

A sequence is a stored list of commands to be executed on request. Sequence commands set and test signal states, execute delays, and initiate and abort other sequences. Conditional branching within a sequence is supported. Up to

32 sequences may be defined, and up to 8 may run concurrently with certain restrictions.

Each sequence has an assigned priority; only the highest priority receives service from the CPU. The CPU is surrendered to a lower priority sequence only on encountering a wait or stop command. In practice, most sequences spend the majority of their running time in waits for certain conditions or events, and this scheduling method is satisfactory. Requests to run sequences are queued by priority until fewer than eight sequences are active.

While sequences allow for easy programming of events, they do not satisfy the need for actions based on asynchronous events, such as changes in safety interlock monitors. Constant monitoring with control actions dependent on evaluation of input states is accomplished with the ladder.

The ladder consists of rungs defined by command messages received from the host or local keyboard. Each rung controls a system output from the set of digital outputs, timer resets and starts, sequence initiation, and software switches. The input portion of a rung consists of logical tests of system inputs linked with Boolean terminology. Possible inputs are digital

inputs, software switches, analog inputs, timers, and limit evaluations. Rung outputs are updated whenever a change in a component input is detected.

Consider a capacitor bank charging system whose programmed actions are defined in a sequence. We want the bank to begin to charge when all safety interlocks are closed and an operator's switch is depressed. The ladder rung is defined such that its output initiates the sequence when the logical AND of each interlock signal with that from the switch is true. Other rungs might monitor conditions indicative of proper charging and initiate abort sequences as necessary.

Concurrent ladder monitoring and execution of one or more sequences provides a powerful and versatile system for control. Conditions detected by ladder scans can initiate sequences of events. Sequences can enable and disable individual rungs as needed, and can set software switches which may be monitored by rungs.

D. Host Computer Software

Software for the host computer is responsible for creating and maintaining control

specifications, providing a high level operator interface to the microprocessors, and coordinating multiple microprocessors with each other and with a diagnostics data acquisition system. At this level control channels are assigned symbolic names for use in constructing sequences and the ladder.

IV. SUMMARY

This control system offers general features which can be applied to any number of fusion experiment control needs. Its modular and compact design, optical isolation features, and variety of software structures make it useful in both stand-alone and integrated systems.

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