A LOW COST MODULAR CONTROL AND INSTRUMENTATION SYSTEM FOR ACCELERATORS

M.R. Shubaly, J.G. Plato and R.W. Davis
Atomic Energy of Canada Limited, Research Company
Chalk River Nuclear Laboratories
Chalk River, Ontario, Canada K0J 1J0

Summary

A modular control and instrumentation system, being developed for the RFQ1 accelerator and for ion beam test facilities, is based on an intelligent crate and interchangeable plug-in modules for specific applications. The 8085-based microcomputer used in the system can access up to 256 K of memory, has up to 64 levels of vectored interrupts and time of day, and supports terminals, printers, floppy discs and digital cassette drives. This computer is linked to a bus in the front of the crate which carries not only the usual address, data, and control signals, but also interrupt lines and interrupt chip control lines. This bus is designed for easy interfacing. Plug-in modules connect to the bus, and to monitored equipment via a separate connector leading to a terminal strip on the rear of the crate. These modules monitor absolute and differential temperature, flow-rate, voltages and currents and switch settings. A permanently installed module provides ac power switching, an RS232 serial link and full duplex fibre optic serial links for connection to a central computer. Software for the crate provides for task scheduling, data storage and limit tests, communication to higher levels of the control system and field configuration of the crate.

Introduction

In planning an upgrade to the control and data acquisition systems on our ion source development facilities, and the design of the system for the RFQ1 accelerator[1] we had three options. We could modify some of the signal conditioning hardware that we had and use commercially available A/D boards in a standard chassis; we could purchase a CAMAC-based system; or we could design our own hardware. The problems with the first approach were - a) all corrections for sensor non-linearities were in hardware and calibration was very tedious, b) the equipment was not modular so a failure meant that the whole chassis had to be removed for repairs, and c) we would require a lot of shielded cabling between hardware and computer. This cabling would provide a route for high-voltage transients to enter the computer. A CAMAC-based system would be extremely expensive and modules were not available to interface to some of our transducers. Before embarking on our own design effort, we listed what we felt were desirable features. The system must interface directly to the experiment, performing all required signal conditioning, digitizing, sensor correction and linearization in one chassis to reduce inter-system wiring and noise pickup. This implies use of a small microprocessor in the chassis. Any signals out of the chassis to the rest of the control and data acquisition system would go via fibre-optic serial links. If measured parameters exceeded defined limits, this level must open the interlock chain, as was done by the original hardware. All connections to the modules should be in the rear and it should not be necessary to disconnect wires to change modules. Furthermore, the computer bus used must be simple, to ease design of modules, but must carry all signals required, especially those for cascading interrupts. The Process Control and Instrumentation (PCI) system described in this paper fulfills these requirements. A maximum of 216 sensor inputs can be accommodated by a PCI crate. This represents a relatively small basic processing load so additional functions such as conversions to engineering units and simple control loops can also be implemented.

PCI Crate Description

The PCI crate uses a double-height (6U), full depth Europac chassis. A switching power supply providing +8V/15A, +15V/3.5A, -15V/3.5A, +24V/3.5A is mounted on the outside of a hinged panel at the upper rear of the crate. On board regulation is used to help reduce noise problems. Below this are typically six terminal board connectors, each with twenty-six screw terminals. These are used to connect the sensors or controller devices to the modules via a ribbon cable going to connectors along the bottom half of the partition dividing the front and back of the crate.

The crate microcomputer fits in the upper rear of the chassis. The CPU board uses an 8085 microprocessor, an Intel 8259A programmable interrupt controller, an OKI MSM 5832 clock-calendar integrated circuit and associated circuitry. Bank switching is used to permit up to 256 K of memory to be addressed. Memory boards each hold up to 32 K of mixed RAM, EPROM or EEPROM in 2 K blocks which can be separately disabled to provide windows for memory-mapped devices in the system. Other boards that can be used for special applications support floppy discs, RS232 links, digital-cassettes and Centronics printers. Up to six boards can be installed on a mother board which connects, via buffers, to the PCI bus board located in the upper half of the front section of the crate. This bus is designed for easy interfacing to simplify design of the plug-in modules. Table 1 lists the signals on this bus. Timing and polarity of control signals are consistent with present interface circuits and all signals required for vectored interrupt handling are on a single bus connector.

Table 1

PCI Bus Signals

Power:	+8V, ±15 V, GND
Data:	8 bidirectional lines D0 to D7
Address:	20 lines A0 to A19 (1 Mbyte)
Interrupt:	8 interrupt IR0 to IR7 (to master PIC on CPU board) 3 address lines for up to eight slave 8259A PIC's 1 interrupt acknowledge 1 non-maskable interrupt
Bus Control:	1 address latch enable 1 each memory read, memory write 1 each I/O port in, out 1 ready/wait line
Miscellaneous:	1 reset 1 system clock 6 multi-master control lines (reserved but not presently implemented) 1 PCI/crate-micro buffer control

The final component of the crate is a narrow module that plugs into the front of the crate and provides active bus termination, two full-duplex fibre-optic serial links (19.2 k baud) and an RS232 port, ac fail and power supply dropout protection and push-buttons to access the vectored interrupts on the 8085 microprocessor. Figure 1 gives an overview of the crate.

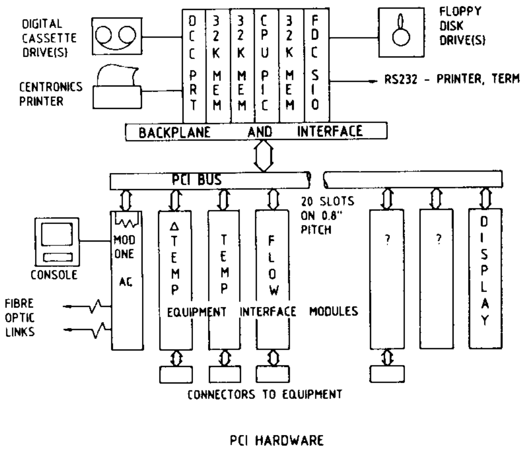

Fig. 1 PCI hardware configuration.

Equipment Interface Modules

These modules are designed to interface directly to specific sensors, equipment or controllers. The top connector on the module connects to the PCI bus, the bottom connector goes, via a ribbon cable, to a terminal strip on the back of the crate where equipment connections can be made. Thus, faulty modules can be easily and rapidly replaced from the front of the crate without having to disconnect wires.

General purpose modules currently under development are:

(a) Absolute Temperature

- 13 channels per module, AD590 sensors
- 8 bit resolution ±1/2°C
- 2 point fit calibration in software

(b) Differential Temperature

- 6 pairs per module, AD590 sensors
- 0.05°C resolution, $\Delta T = 50°C$
- 3 point fit calibration (wide range) or 2 point (narrow range)

(c) Coolant Flow

- 6 channels per module
- for paddle-wheel type flowmeters (low pulse rate)
- uses 8253 counter-timer chip to reduce processor load
- average to reduce effect of fluctuation
- 1% full-scale accuracy (limited by paddle wheel)

(d) Stepper Motor Driver

- 4 phase drive to external power amplifier package, opto-isolated
- controls two motors using CY512 stepper controller chips
- easy control of acceleration rate, maximum speed
- incremental encoder feedback, limit switches

Other modules will be developed as required. Future modules include a display/keypad module for a completely stand-alone package, a master controller for a multi-channel fibre-optic link[1], a module for rf phase and amplitude signals and an x-ray monitor. Also under development is a module to interface to operators - a programmable knob and display unit.

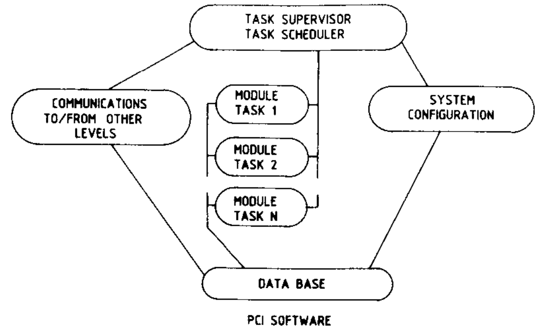

Fig. 2 PCI software overview.

Software

Software for the PCI system is divided into four sections - task supervisor, communications, module tasks and configuration (see Fig. 2). The configuration task is menu driven and allows a user to define, via a terminal plugged into the crate or a link to another computer, the modules in the crate, their addresses, calibration factors, limits, etc. This sets up a data base for the task scheduler which runs module control tasks consecutively passing required data to the tasks. For example, if there were three temperature modules and one flow module in a crate, the temperature task would be called three times, each time with different device addresses and pointers to data areas and the flow task would be called once. The scheduler also includes a number of generally usable routines (i.e., mathematical, unit conversion, etc.) which can be called by any task. The scheduler is responsible for transmitting updated data to upper layers of the control system. The module tasks control the functioning of specific modules: initiating measurements, scanning sensors, applying corrections and storing data in tables or carrying out control functions. The communication software is used to handle messages to and from upper layers in the control system. It is fully interrupt driven in both send and receive so it can operate in parallel with the other tasks.

Review and Costs

This paper has described a simple, modular and intelligent control and instrumentation system to act as the first level between an accelerator and the remainder of a computerized control and data acquisition system. The direct connection to the equipment minimizes interconnections and noise pickup. An intelligent system eases calibration, permits limit tests and the use of fibre-optic serial links for reliable, noise-free data transfer. The simple bus structure eases design of the equipment interface modules.

Costs for the system are very low. Prices quoted are in Canadian dollars and include all materials and labour, but not development costs. A complete chassis with power supply costs $1200, the microcomputer costs $1000 and modules are about $300 each. Thus a fully loaded crate, with six equipment interface modules and a display module, costs under $5000.

References

1. M.R. Shubaly et al., "RFQ1, A 600 keV, 75 mA CW Proton Accelerator", IEEE Trans. Nucl. Sci., NS-30 (2), 1428 (1983).
2. M.R. Shubaly and J.G. Plato, "A Multi-Channel Fibre-Optic Link for Analog Telemetry", IEEE Trans. Nucl. Sci., NS-30 (4), 2296 (1983).