© 1969 IEEE. Personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution to servers or lists, or to reuse any copyrighted component of this work in other works must be obtained from the IEEE.

COMPUTER CONTROL FOR THE MARYLAND CYCLOTRON*

J. Etter, K. Jenkins, D. Nelson

University of Maryland, College Park, Maryland

Abstract

The isochronous cyclotron at the University of Maryland has been designed to allow computer control of all machine operations in a manner which permits unique operational flexibility. Digital control lines, 16 bits wide, run from various devices in the laboratory to a central multiplexer unit. From there, they are routed to either the operator's console or to a computer data bus. The data bus is attached to a small control computer which will be interfaced to an on-line IBM 360/44, and it will be capable of reading and setting machine controls as well as communicating with the machine operator. The software of the control computer will consist of a highly simplified time sharing system which will coordinate the execution of several independent software modules called 'tasks'. Each task will pertain to a particular control function, and the operating system will 'time share' among several tasks, allowing them to run concurrently. It is intended that this system will greatly simplify normal operations, allowing the operator greater freedom from menial chores.

The early decision to use overall computer control of the cyclotron, beam transport, and data-taking system allowed each component of the cyclotron to be designed and built directly for computer control. To this end, all power supplies requiring adjustment for different modes of operation or trimming use as an internal reference a D/A converter of from one decade (main RF anode power supply) to six decades (energy analyzing magnets). Each D/A converter has internal memory requiring +24 volts at 50 mA to turn on each bit and zero volts at 50 ohm impedance to turn off each bit. Remote manual control is by means of a digiswitch of appropriate decades using a complimentary BCD code that connects each line to either 24 volts or zero. When the digiswitch is disconnected, the D/A converter will remain as last set and will maintain a +12 volt signal on each 'on' bit and zero volts for each 'off' bit.

All tuning or device positioning motors use stepping motors. Tuning motors used in servo loops, such as the RF frequency tuning drives, use an integrator on the error signal converting to either positive or negative pulses to step the motor. Geared to each motor is a potentiometer, which presents an analog voltage that is compared to a voltage from a BCD controlled reference voltage. Thus the error driving signal can be an internally generated tune sensing voltage or an external digital reference voltage. All positioning motors are driven by one of four preset indexers. Each motor can be disconnected from the preset indexer and reconnected later without losing position, because the indexers are adjusted so that the minimum increment is four steps, leaving the motor always in the same electrical phase. Thus 96 motors can be adjusted from the same indexers, any four at a time. Motors are adjusted incrementally in digitally controlled steps.

All other devices on the cyclotron are simply 'on-off' type controls operating from the same 24 volt dc control voltage. The controls on the control console are either digiswitches, on-off switches, or push buttons arranged in a control logic so that once the controls are set the operation will remain as set whenever the controls are disconnected.

The digital control lines and desirable 'on-off' controls are routed through a common unit called the 'multiplexer'. The multiplexer connects individual control lines in sets of 16 from each controllable device to the control console controls (digiswitches) or to the common 16 line computer data bus. Associated with each digiswitch or set of controls is a remote-local toggle switch. In the local switch position, the multiplexer connects the device to the control console. In the remote switch position, an external control signal can connect each device, one at a time, to the computer data bus.

Multiplexer

The multiplexer consists of a transistorized device selector and a relay calling card for each 16 lines of controllable devices. The device selector connects the 16 read and write lines, one at a time, to two 16 lines buses as commanded by eight control and sense lines from the computer I/O and changes the signal level for relay control. The device selector signals the calling cards to connect one or more devices to the two 16 line buses (but not more than one to each bus) and tests the 16 line bus for low impedance. If the remote-local switch on the console is in remote, the calling card can connect the device to the bus. If the R/L switch is in local, the calling card is locked out, and the device selector will see an open circuit and signal the computer that the device is not controllable.

The calling cards contain eight 4PST reed relays mounted on a plug-in card with 16 cards to a bin and eight bins arranged in pairs. Normally, two calling cards are connected one to each 16 line bus; thus two devices up to 7,999 plus polarity or one device up to 799,999 plus polarity can be controlled at one time. The calling card is constructed with a plug at both ends; 22 contacts plug into the bin which contains the 16 line bus and the relay control lines. The other (outside) end has a 35 connector cable plug. Each device is connected to its digiswitch by means of an 18 conductor cable which is currently uncut. As each device is put into computer operation, it is necessary only to cut the cable now running through the multiplexer cabinet and install the plug. If the calling card must be removed for

repair, a simple shorting card can be slipped into the plug, and the device is back in local operation.

Computer

The computer is an Interdata Model 3 with a 16 read and 16 write line I/O equipped with an ASR-33 Teletypewriter, display panel, 60 cps clock and is capable of controlling 253 additional I/O's. The multiplexer is only one I/O; another will be used on our Kennedy Tape Recorder, and still another will be used to interface with our IBM/360/44.

Devices

The devices currently digitized include 23 cyclotron power supplies, nine RF units including frequency setting, five ion source regulating units, four deflector power supplies, three six-decade analyzing magnet power supplies, and four stepping motor drive units capable of driving 96 different motors. The quadrapole power supplies, which were delivered with potentiometer control, have not as yet been converted; all other controls excepting for a few manual override controls have been digitized.

In addition to the external devices, there is a DVM used directly by the computer to read any analog signals up to 256 in number. The DVM and its reed relay matrix are treated as a device. All devices appear to the computer as a 16 line unit or units which knows each only as an address; thus any device can be added to the system, including a control box that can display a digital readout of an analog signal and a display of the control setting. Then, with a selector digiswitch for the address and a plus-minus generator for controlling, any other device can be controlled remotely through the computer.

Software

The software of the accelerator computer consists of a variable number of tasks which are executed under the supervision of a simplified time sharing monitor. Each task pertains to a specific control function and may be written in the form of an independent, stand-alone program. The monitor carries out all I/O requests and provides a time sharing environment allowing any number of tasks to run concurrently. The basic components of the monitor are the time schedular and the device schedular.

Time Schedular

The time schedular is responsible for scheduling computer CPU time slices among all active tasks. The time slice allotted for each task is a dynamic variable normally about 100 ms. It should be noted that tasks normally run in a background environment and hence have a response time on the order of tenths of seconds. Control functions requiring a faster response time can be easily incorporated into a foreground environment which operates via a priority interrupt.

Device Schedular

The device schedular carries out all I/O operations requested by the tasks. It maintains queues of current and pending requests and schedules foreground and background control among the device routines. I/O operations are overlapped, with computation and operations for different devices run in parallel; whereas operations for the same device run sequentially, allowing a high degree of I/O efficiency.

The monitor occupies only 2,500 bytes of storage on an 8192 byte computer. As designed, the software is machine independent and may be written for a variety of small computers.

Conclusion

The system approach, making all elements of both hardware and software device independent, allows maximum versatility in adding to or changing the operation.

*Work performed under the auspices of the United States Atomic Energy Commission.

