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NBS/LANL Racetrack Microtron Control System*

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Abstract

The distributed intelligence control system for the NBS/LANL racetrack microtron (RTM) is now nearing completion, with all major subsystems implemented and tested, thus providing some operating experience with most of the control system innovations. These include a triple hierarchy of microprocessor-based control elements, consisting of a primary control station and multiple secondary and tertiary control stations; light-link coupling to a tertiary station which operates at a 100 kV potential; a common database shared by separate microprocessors for handling hardware control and operator interactions; and joy stick control of the entire system. A unique secondary station interpreter program was used to great advantage for testing and checkout of various control and monitoring subsystems. The hardware design of the control system is based on Multibus I crates containing commercial Multibus I boards and a few custom designed boards. The primary-secondary data link is a high speed, bidirectional, full-duplex, 8-bit, "byte" parallel link designed for this application. This link permits very fast updating of the monitored data (>5 per second) and timely response to operator control inputs at the primary station.

General Configuration

Figure 1 shows the control system configuration. The basic structure is a triple hierarchy system: a central control point, the primary station, is linked to three secondary stations, which in turn are linked to four tertiary stations. The accelerator devices under control of the system, which are not shown in Fig. 1, are connected to appropriate I/O boards in the secondary and tertiary control stations. All major control elements are now operational. Secondary stations provide local control of a subset of the accelerator parameters by means of a control panel. As stand-alone control elements, they have been used to commission subsystems of the RTM.

Tertiary stations are used either to distribute the processing requirements of a secondary station with a large number of controlled/monitored devices, such as the RTM secondary and its magnet tertiaries, or to provide control and monitoring functions in a hostile environment, such as the injector tertiary which operates at 100 kilovolts.

The requirements for the RTM control system remain essentially as they were set forth in reference 1. One exception is an increase in the maximum number of database entries per secondary station from 250 to the

RTM CONTROL SYSTEM CONFIGURATION

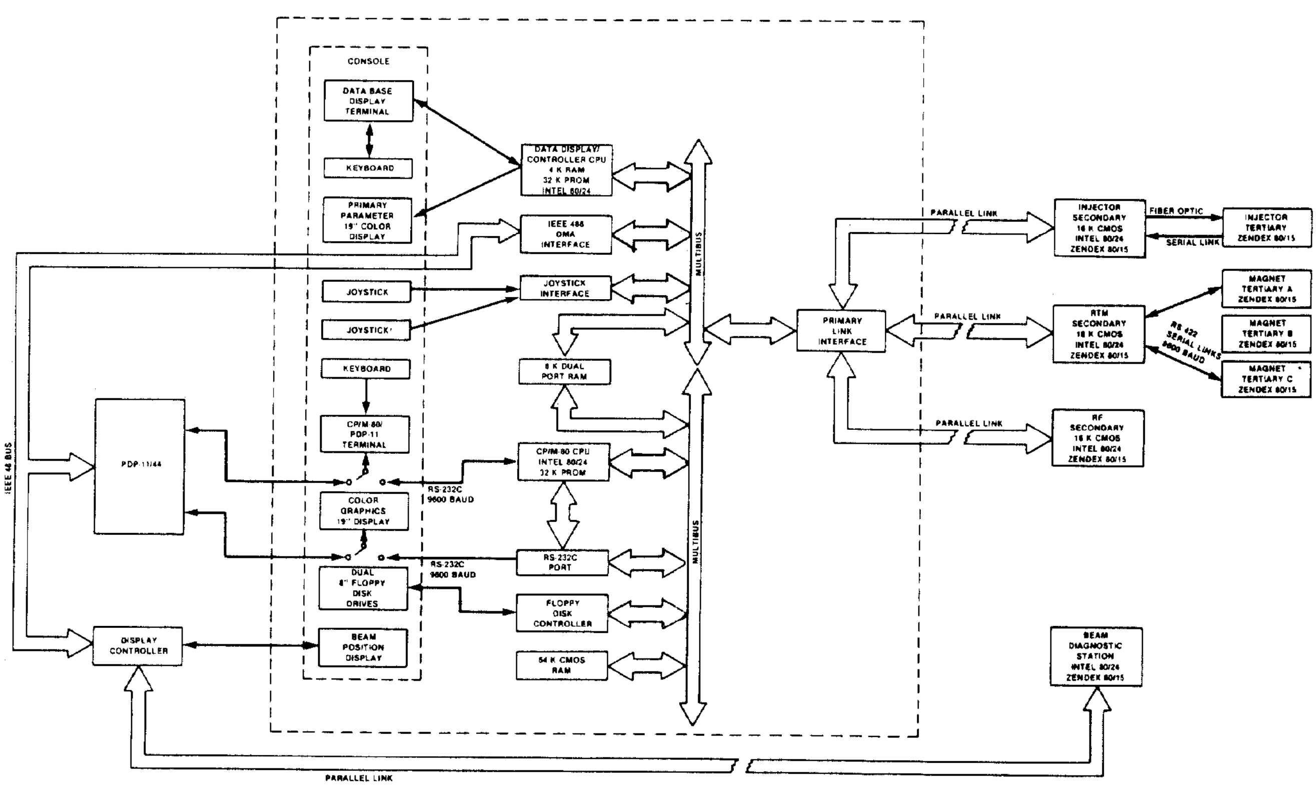

Figure 1. Block diagram of RTM control system showing configuration of primary station and its interconnections to the other control subsystems.

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present maximum 340 or 680 respectively, using either 16 kbyte or 32 kbyte of random access read/write (RAM) memory for the shared data-base.

Secondary Stations

The secondary stations are the heart of the RTM control system. All basic system control and monitoring functions can be performed, for a subset of accelerator devices, at the appropriate secondary station control panel. The secondary station design is based on a Multibus I crate containing two 8085 processor boards, a shared RAM memory board, and other peripheral boards, such as, analog-to-digital converter "ADC", digital-to-analog "DAC" boards, and binary I/O boards. Each secondary station is also equipped with a 30 line by 80 character alphanumeric video display, a keyboard, and a control panel. The video display and control panel are shown in Figure 2. The latter consists of two infinite-turn control knobs, four pushbuttons for mode selection, and four push buttons to select parameter display units. One knob positions the cursor on the data-base display to select a parameter for control. The second knob adjusts the value of the data-base parameter selected by the current cursor position.

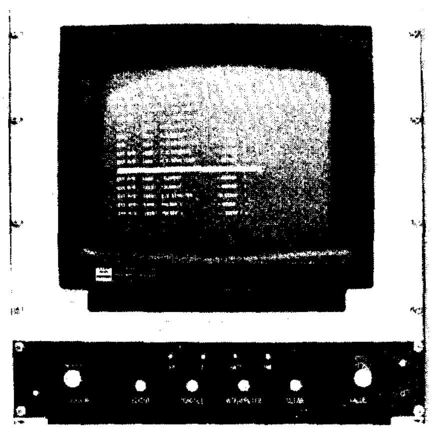

Figure 2. Secondary station display and control panel

Any of four modes can be selected: (1) Console mode; (2) Edit mode; (3) Interpreter mode; or (4) Clear screen mode. The console mode allows local control from the secondary station control panel. In this mode, as shown in Fig 2, the CRT displays the database entries of devices connected to the secondary station. The clear screen mode simply blanks the video display and is used when operating from the primary station. In the edit mode, the secondary station cursor knob and keyboard are used to expand or modify the database. The interpreter mode permits the operator to exercise and log accelerator control system parameters using loops, delays, branch instructions, and other higher level instruction sequences.

One of the two 8085 single board computers (SBC), an Intel 80/24 SBC, handles all traffic with either the primary station or the control panel, as well as the keyboard and video display. The second, a Zendex 80/15 SBC, handles all traffic for the controlled and monitored devices and with the tertiary stations. In addition, the 80/24 SBC supports the editor and interpreter functions.

The two processors share a common 16 kbyte (expandable to 32 kbyte) CMOS RAM memory. This memory contains the database, consisting of parameters for all devices controlled or monitored by the secondary station. Each database entry includes the channel number, device type, status, link channel number, 16-bit data field, calibration factors, and tolerance limit fields (beyond which the data will be displayed as out of tolerance). The link channel number permits the control and monitor channels of a device to be linked together, so that monitor channels will accept and execute commands by redirecting these commands to the linked control channel. Communications between the two processors is initiated when the requesting processor sets a service request bit in the status byte for the device for which service is required.

The interpreter provides the operator with a powerful debugging tool to use for initial system testing, characterization, and subsequent maintenance as well as closed-loop control testing. It permits conditional or absolute looping, conditional or absolute branching, assignments, and delays, together with the ability to read or write data to selected devices defined in the database.

Tertiary Stations

Each tertiary station is built around a single 80/15 SBC in a Multibus I crate. The stations are linked to a secondary station using a full duplex, asynchronous, serial link operating at 9600 baud. For the three magnet tertiaries the RS422 protocol is used. To satisfy the voltage isolation requirements of the injector tertiary, a bidirectional fiber optic link is used. Each secondary station is capable of supporting three tertiary stations, with provision for expansion to seven.

Each magnet tertiary can support a maximum of 16 commercial Multibus, 8-channel DAC boards and 4 Multibus, 32-channel differential-input ADC boards. Both boards have 12 bits of resolution and may be configured for either unipolar or bipolar signals. In addition to the DAC and ADC boards the injector tertiary contains a custom fiberoptic link board. Tertiary stations also have a watchdog timer board that monitors the operation of the CPU and resets the CPU if it fails.

Primary Station

A block diagram of the primary station is included in Fig. 1. The top and front views of the primary station in Figure 3 show the positions of the major components. The processor is a 4-slot Multibus I crate containing an Intel 80/24 SBC, a commercial dual-port 8 kbyte RAM memory board, and custom dual joystick interface and 4-port, bidirectional, byte-parallel link boards. Peripherals attached to the processor include a color alphanumeric video display, dual 2-axis joysticks with dual position trigger and three thumb operated push buttons, a 30 line by 80 character alphanumeric video display, keyboard, and 8085 processor based CP/M subsystem.

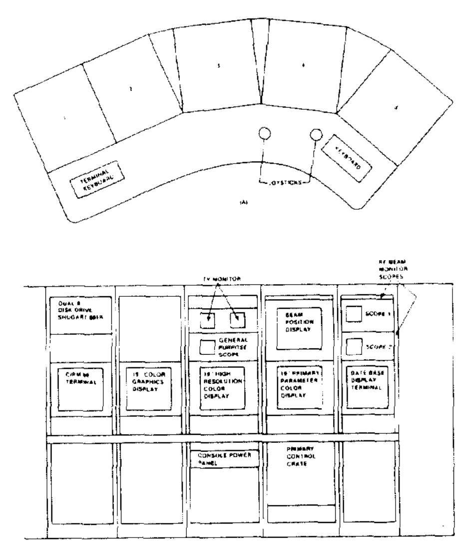

Figure 3. Layout of the primary station as viewed from the top(a) and front(b).

The primary station acts as a central communications and display processor. Operator inputs are accepted from either the joystick controls or the keyboard and the corresponding commands are directed either to the appropriate video display through an RS232-C serial link or to a secondary station through the byte parallel link. The color parameter display has four display fields. The largest field contains up to 15 database parameters, known as a data block, for which control inputs will be accepted from the joystick whose cursor is positioned on the parameter entry. The other three fields are: a warnings field, which displays the channel number and title of any device whose data lie outside predefined upper and lower tolerance limits; a fault field, which displays the title of any device failure producing a machine trip; and a single line command field, which echos all keyboard entries. Both the warning and fault fields can display, respectively, 27 and 49 entries, queueing additional entries for display when the current entries are cleared. The other video display is used to show either the block display list or a window containing 30 consecutive entries from the full database list.

The operation of the primary station can best be understood by considering the interactions between the various control inputs available to the operator and their effect on the primary station displays and controlled or monitored system devices. The principle operator control input devices are the two 2-axis joysticks with dual position triggers and three thumb-operated push buttons. At present only one axis of each joystick is implemented, the sideways motion not being used. The three thumb-operated buttons are located on the top of each joystick, with functions implemented for the three buttons on the righthand, "major", joystick only. On this joystick, the center button is used for cursor control and toggles the cursor between the color parameter display and the database display. The left pushbutton is used to assign/deassign a device channel on the color parameter display. The righthand "red" button is used to toggle the data-base display between displaying the database listing or a listing of the saved blocks. Since the buttons on the left, or "minor" joystick, are not used, its cursor always remains on the color parameter display. The cursors corresponding to the major and minor joysticks are distinguished from each other by color.

The keyboard may also be used to perform most of the same control functions as the joysticks. Several other functions can only be executed by keyboard command. For example, the keyboard must be used for editing of database parameters at the primary station.

Before any control operations can be executed from the primary station, the channels corresponding to the devices to be controlled and/or monitored must first be assigned to the color parameter control display. Assigning channels to this display can be done by placing the major cursor on the database display, using the cursor control button, and scrolling through the data base to the desired channel. Once the cursor is located on the desired channel, pressing the assign/deassign button transfers the data-base parameter line to the parameter control display. Alternatively, the "ASSIGN (channel #)" keyboard command may be used. To deassign a channel, the cursor is positioned on the selected channel on the parameter control display and the assign/deassign button pressed. No corresponding keyboard deassign command exists.

Once assigned to the control display, the data values of the device may be changed by positioning the cursor on the device channel, depressing the joystick trigger to its first position to lock the cursor in position, and then to its second position which allows the forward/backward movement of the joystick to change the device's data value. If the selected channel is a binary device, depressing the joystick trigger to its second position toggles the device binary value between 0 and 1. By keyboard command, the data value of a device is changed by entering "(channel #)=n", where n is the new data value.

The operator may wish to save a particular arrangement or grouping of channels on the parameter control display for future use. This can be done by typing "BLOCK SAVE (filename)" from the keyboard. Filename is a one to six letter designation under which the operator wishes this particular block, grouping of channels, to be stored. To recall a previously made block assignment, the operator types "BLOCK RECALL (filename)" from the keyboard. The array of device channels contained in the block filename will be transferred to the primary control display and replace the existing contents of the control field on the display. Block recalls can also be made using the major joystick controls. This is done by positioning the cursor on the database display, using the rightmost button to toggle the display to its block list mode, positioning the cursor on the desired block name, and pressing the assign/deassign button.

Other Subsystems

Also shown in Fig. 1 are three subsystems that are separate from the main triple hierarchy. These are the wire scanner display and control subsystem, the CP/M subsystem, and the DEC PDP 11/44 minicomputer. The wire scanner subsystem is used to acquire and control beam profile information from multiple, high resolution wire scanners located at various positions along the RTM beamline[2]. The graphics display processor, used to display wire scanner data, is linked to the primary station through a high speed (500 kbytes per second) IEEE-488 bus. DMA IEEE-488 interface boards are used in both systems. This interface will permit the exchange of status, data, and commands between the two systems as well as the PDP 11/44 attached to the same bus.

The PDP 11/44 minicomputer will be used to provide offline and realtime control parameter calculations, issue stored or calculated control inputs, and provide other higher level system support functions, e.g., uploading and downloading snapshots of the control system database parameters. Use of this minicomputer is expected to achieve semiautomatic or fully automatic control of the accelerator.

The CP/M subsystem was developed at LANL to test the software necessary to implement some of the higher level functions to be provided by the linked minicomputer. It will be retained in the final system for the purpose of providing functional backup for the minicomputer. Unlike the other subsystems, the CP/M subsystem is linked to the primary station processor through a shared dual-ported RAM memory board. At present, code has been tested for the CP/M subsystem to:

1) save and restore on floppy disk the entire data-base contents of any one or all of the secondary stations;
2) save and restore groups of data blocks from the primary parameter display todisk;
3) read or write any specified system database parameter;
4) acquire and plot any specified data-base parameter as a function of any other parameter, or as a function of time, on a 19-inch 1024 by 1024 color graphics display.

Conclusions

Operation of the control system to date, which includes several years of operation with some of the secondary and tertiary stations, has shown that the system meets all of the initial design specifications with remarkably high reliability. Based on this experience, we expect a very low machine downtime due to control system failures.

Minor changes to the database element format have made it easier to to incorporate additional device driver routines in the system software. Despite some reservations expressed in our earlier paper[1] regarding the applicability of control system design to more general applications, we now feel confident that this system could prove useful in other control applications.

As with any design of this type there are some things one would do differently if starting over again. However, the decisions made in designing the system have proven to be quite sound considering that the overall design philosophy and major component selections were made over five years ago. Present plans include adding a color graphics touch-screen device as an alternate control input device. This should make it easier to train new accelerator operators. Also, for this and other system additions or upgrades, we plan to use one of the new Eurocard-based bus designs, such as VMEbus for the processor bus. The pin and socket DIN connectors used in these new bus designs are considered to be more reliable than the card edge connectors used in present Multibus I systems.

References

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[2] R. I. Cutler, et al., IEEE Trans. on Nucl. Sci. NS-30, No. 4, 2213 (1983).