

DEVICE CONTROLS OF RCNP RING CYCLOTRON

T. Yamazaki, A. Ando, K. Hosono, T. Itahashi, I. Katayama, M. Kibayashi, S. Kinjo, M. Kondo,
I. Miura, K. Nagayama, T. Noro, T. Saito, A. Shimizu, M. Uraki and H. Ogata

Research Center for Nuclear Physics, Osaka University
Mihogaoka, Ibaraki, Osaka 567, Japan

and

M. Maruyama and S. Yamada

Accelerator Business Center, Technological Department, Sumitomo Heavy Industries, Ltd.
Soubiraki, Niihama, Ehime 792, Japan

Abstract

A distributed computer control system of the RCNP ring cyclotron has been designed and is at the stage of construction. To control devices the Universal Device Controller module and a software for the micro-controller in UDC have been developed. The control system will be assembled in 1990.

Introduction

The RCNP ring cyclotron is now under construction. For the control system of the ring cyclotron, a hierarchical computer system is adopted.¹⁾ The computers used are a microVAX 3500, a microVAX II and three RT VAX systems, and they are connected through a computer network Ethernet. Computers to control experimental apparatuses will be connected to this network in order to perform fine tunings of some magnet parameters in beam transport lines according to experimental conditions in future.

Fig. 1 shows the schematic diagram of control system. The first layer of the network consists of a main computer, and performs man-machine interface and file management. The second layer consists of four sub-computers, and controls subsystem such as magnets, RF systems, beam transport lines, vacuum systems and cooling systems. The third layer consists of the Universal Device Controllers, and controls each device such as power supply and driving motor system.

The basic design of the control system was done in 1987. 2) The detailed design on utilization of the Universal Device Controller and device interlock has been almost completed. To measure the magnetic field of the sector magnets of the ring cyclotron, some power supplies of the main magnet and the trim coils have been already used with the Universal Device Controllers in local mode.

Communication between Group Control Computers and Device Controllers

To control power supplies and motor driven devices, a device controller is used in each device. These device controllers are linked to a subcomputer through optical fiber cables, and constitute a distributed control network.

A signal-multiplexed communication system named a message tree has been developed for the control of accelerators, and is shown in Fig. 2. The message tree is made of an interface board installed in the group control computer named a Message Tree Communicator (MTC), a branch device of the communication signal named a Message Tree Brancher (MTB) and a controller installed within many devices named a Universal Device Controller (UDC). Each UDC is connected to the MTB in a tree configuration.

Message Tree Communicator (MTC)

Fig. 3 shows an MTC board. The MTC is connected to the bus of a host computer. The MTC receives an order message from the host computer, and sends it to the designated UDC. The MTC receives a status message from UDC through MTB, and sends it to the host computer.

The MTC includes an 8344 micro-controller, two 8k byte ROMs, six 1k byte dual-port RAMs, CSR (Control Status Register) bus interface, interrupt lines and serial communication interfaces.

The internal RAM region of the 8344 micro-controller consists of working region and buffers for serial communications. Programs for the 8344 micro-controller are stored in the ROM region. They are a communication software between UDC and MTC and a communication software between MTC. External RAM region is divided into three regions; RAM1 region, RAM2 region and a work region. The RAM1 region is a region used by micro-controller and host computer. The host computer writes data into RAM1 region. The micro-controller reads the data and sends them to UDC through the serial communication interface. The RAM2 region is also a region used by host computer and micro-controller. Micro-controller stores the data received from UDC, and host computer reads the data later. The work area is used by micro-controller as a database to manage the status of UDCs. The CSR is used for the handshake between micro-controller and host computer.

The message tree uses SDLC (Synchronous Data Link Control) as the data transmission protocol. The message tree has multi-point duplex constitution. The MTC is the primary station and the UDCs are the secondary stations.

Message Tree Brancher (MTB)

The Message Tree Brancher (MTB) is a signal distributor, and connects the MTC and up to 50 UDCs. The MTB receives data from the MTC, and distributes them to all UDCs connected to the MTB. Responses from UDCs are received by the MTC through the MTB, and are written into the dual-port memory RAM1 of the MTC.

Universal Device Controller (UDC)

For the easiness of maintenance of the control components interfaces to devices are standardized. For these purposes a Universal Device Controller (UDC) has been developed. Fig. 4 shows a UDC board.

In the power supplies of magnet coils of the ring cyclotron and the beam transport lines and high voltage devices such as the electro-

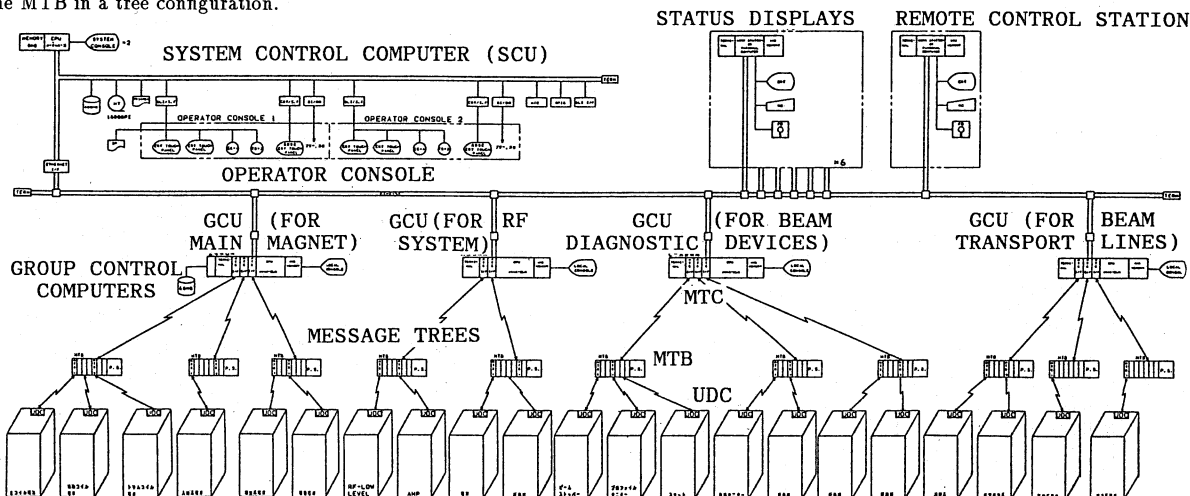


Fig. 1 Control system of RCNP ring cyclotron

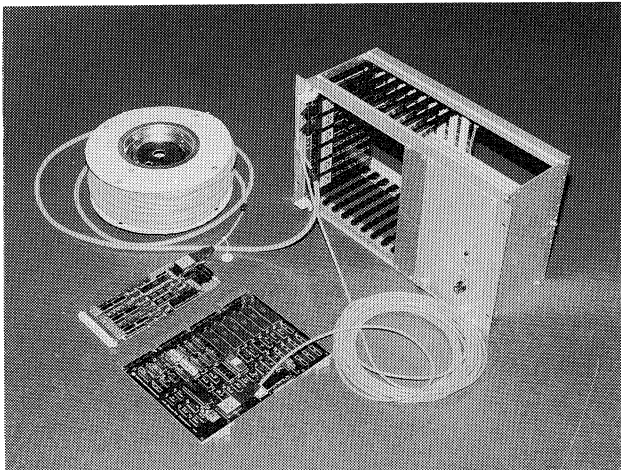


Fig. 2 A signal-multiplex communication system. Message Tree Communicator, Message Tree Brancher and Universal Device Controller.

static channels and the RF system of the ring cyclotron, main functions of the UDCs for the power supplies are periodic operation data acquisitions, sequence controls within the power supplies, interlock checks of the power supplies, polarity change, slow up and slow down controls based on UDC software and preset values, stability checks, local panel handling, and the communication with the group control computer.

The present control system uses many stepping motors and AC motors for the position controls. One UDC controls up to four stepping motors or AC motors, and main functions of the UDCs for the driving systems are drive controls of motors, periodic position data acquisitions using driven pulses for stepping motors and using potentiometers for AC motors, stability checks for AC motors, driving speed changes if necessary for the beam diagnostic devices, local panel handling including position displays and limit switch status displays, and the communication with the group control computer.

For the beam diagnostic devices both the position controls and the beam current measurements are necessary. In case of beam slits in the ring cyclotron and beam transport lines the position settings and the beam current measurements are generally separated functions. Therefore two independent UDCs perform each function. In case of beam profile monitors the beam currents must be measured as a function of monitor positions, and single UDC performs both functions. In case of some beam probes such as the main probe to measure the beam current in the ring cyclotron, there are two modes for the probe controls. The one is an automatic measurement mode, and the beam current is measured as a function of monitor position with constant velocity under software control. For this purpose single UDC performs both functions. The other is a manual measurement mode, and the beam current is measured at fixed position after an operator set the probe position manually. For the acquisitions of beam

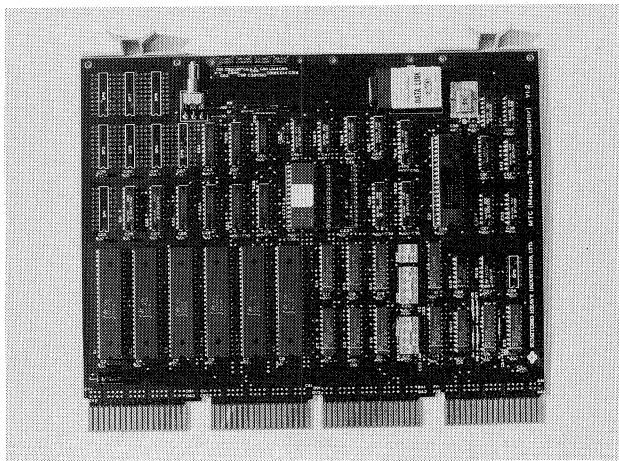


Fig. 3 Message Tree Communicator board

current values each UDC controls four multiplexers having eight channels, and the gain changes of beam current amplifiers. The UDCs also have functions of local panel handling and the communication with the group control computer.

The interfaces and software designs of the UDCs for the vacuum systems and the cooling systems are now in progress. The UDCs for the vacuum system have some limited functions from periodic vacuum data acquisitions, sequence controls of vacuum pumps and vacuum valves, interlock checks in the vacuum systems, local panel handling and the communication with the group control computer. The UDCs for the cooling system have some limited functions from periodic temperature and interlock data acquisitions, local panel handling and the communication with the group control computer.

Hardware of UDC

Functions

The UDC contains an eight-bit microcomputer chip 8344, 16k byte ROM, 8k byte SRAM and related interface chips. For the interfaces to devices, 32-bit digital inputs (DI) and 32-bit digital outputs (DO) are prepared. Moreover 16-bit bidirectional process input-outputs (PIO) can be used as inputs or outputs. For the extensions of input-output devices the UDC has a connector of an Intel iSBX bus, and it is possible to connect iSBX modules boards such as ADC, DAC and GPIB. In the present control system this extension connector is not used except vacuum system. The ADC is connected to DI ports, and the DAC is connected to DO ports of the UDC. The GPIB devices don't use the UDC, and they are connected to the host computer directly. The UDC has a serial communication interface with an optical link connector and a local-panel interface. All input-output signals except signals for the local panels are isolated by using optical couplers.

Memories

The memories of the UDC is used as UDC44, USER1, USER2, USER3 and USER4 regions. The UDC44 is a compact monitor program suitable to the device control. The UDC44 monitor is stored in the ROM region, and uses both internal RAM region of the microcontroller 8344 and external SRAM region. The USER1 region occupies two bytes of the internal RAM, and both byte access and bit access are possible for this region. In case of bit access region, user can treat 16 flags. The USER2 region occupies 16 bytes of the internal RAM, the byte access is possible for this region. The USER3 region is prepared in external ROM, and it is possible for the user programs and data region of fixed values. The USER4 region is prepared in external SRAM, and it is possible as work area and program area.

Local Panel Interface

The UDC has a local panel interface for a keyboard and LED displays. The programmable keyboard/display controller i8279 is used in this interface.

Software of UDC

The UDC is one component of a distributed control network, the message tree. The UDC must execute many tasks such as device controls, communications with the MTC, and interfaces with the local operator in real time.

For these purpose real-time multitask monitor UDC44 has been developed. Programs to control individual devices can be described by PL/M language. The UDC44 monitor can execute task controls and input-output managements by issuing system calls. The UDC44

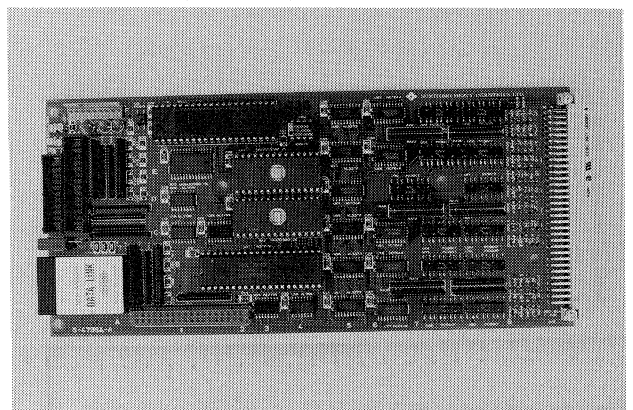


Fig. 4 Universal Device Controller board

monitor is constituted by kernel, BIOS and SIU handler. The BIOS (Basic Input-Output System) manages communication registers and input-output ports. The SIU handler (Supervisory-Information-Unnumbered frame handler) manages data communication of the message tree, and starts by receiving data.

Communication Register (CRG)

The UDC has a memory region of 128 bytes called Communication Register (CRG) on the inner RAM. These CRG data are copied to the memory of host computer. The contents of CRG are necessary informations to control and manage the devices, that is, commands, data and status. Each byte and bit of the CRG is determined uniquely for each UDC.

By introducing the concept of CRG an application program of a UDC is connected to an application program of a host computer by CRG, SIU handler in UDC, Message Tree Brancher (MTB), SIU handler and two-port RAM in MTC, and MTC handler and CRG image in host computer. A local panel handler (Local Input-Output Handler, LIO) in UDC is also specific to each device like application program.

UDC44 Kernel

The UDC44 monitor can manage up to eight tasks including SIU handler. The number of priority level of tasks on UDC44 monitor is eight that is equal to the number of tasks, and the priority of the SIU handler is fixed to the second level. The status of tasks in UDC is entry, ready, wait or run status. A created task is in entry state. The starting period and the starting address are registered at this time. This task moves to ready state in each registered period. After other task having higher priority in run state moves to entry state, the task having the highest priority in ready state moves to run state. The task in run state occupies the processor. When a task having higher priority moves to ready state, the task having lower priority in run state moves to ready state. The task in run state can move to wait state, and after preset waiting time this task moves from wait state to ready state. The task in run state can also move to entry state.

UDC44 BIOS

The UDC44 BIOS manages Communication Register (CRG) and input-output port. A task in UDC executes specific job respectively. However, the contents of the tasks can be classified to the following two functions. The first function is inputs from CRG, processings and outputs to CRG or output ports. The second function is inputs from input ports, processings and outputs to CRG or output ports. In order to inhibit an interruption by higher priority tasks during an access by lower priority tasks to CRG and input-output ports, application programs must use the system calls for the managements of CRG and input-output ports.

UDC44 SIU Handler

The SIU Handler (Handler for Supervisory, Information and Unnumbered frames) manages the communications in the message tree.

The message tree constitutes a multipoint semiduplex configuration. The Message Tree Communicator (MTC) is the primary station and Universal Device Controllers (UDC) are the secondary stations. The primary station (MTC) always sends a command to the secondary stations (UDC), and then the secondary stations send responses to the primary station. The transmission protocol of the message tree is synchronous data link control (SDLC).

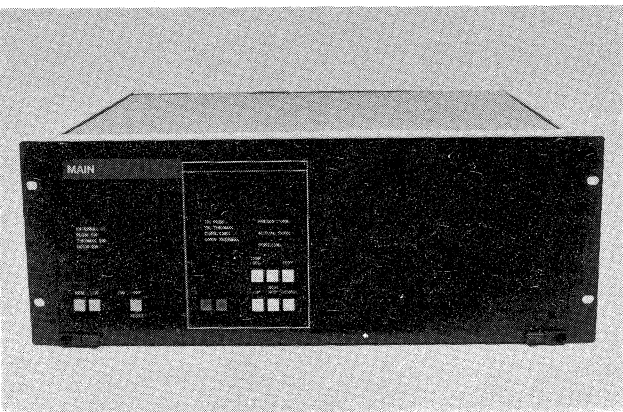


Fig. 5 Control unit for the main coil power supply

The frames of SDLC used in the message tree are classified to the information frame, the supervisory frame and the unnumbered frame. The information frame is used to send and receive informations including commands, responses, CRG data and other data accompanying starting address. The supervisory frame is used for RR (Receive Ready) and RNR (Receive Not Ready) commands. The unnumbered frame is used for DISC (Disconnect), SNRM (Set Normal Response Mode), UA (Unnumbered Acknowledgement) and FRMR (Frame Reject) commands.

Control Unit and Local Panel

The Universal Device Controller, interface boards, interlock relay boards and local panels are installed in a control unit. This control unit is installed in cabinet of a power supply or a control module of driving motors. To avoid the radiation damage of the Universal Device Controller boards, the control unit is usually installed far from the cyclotron vault and beam transport lines.

Fig. 5 shows a control unit for a power supply. This control unit contains a common local panel and only one individual panel. Some power supply such as quadrupole magnet power supply can control many magnet currents, and many control units are installed in the cabinet of the power supply. The first control unit can install common local panel, up to three individual local panels and up to three Universal Device Controllers. The second and subsequent control units have no common local panel, and can install up to four individual local panels and up to four Universal Device Controllers.

The control programs constitute setting value output task, sequence control task and man-machine interface task. These tasks execute parameter changes for the setting values of power supply, alarm display, status and data display of communication registers (CRG) and input-output ports, the monitoring of stability of power supplies and device interlocks.

Interlock System

In order to minimize the device damages in case of emergency, reliability and speed are required for the actions of the device interlocks. For this purpose the present control system can be designed with the double structure interlock system consisting of both hardware and software interlocks. The device interlocks generally consist of internal interlocks managed by the conditions within the device itself and external interlocks determined by external conditions. For the internal interlocks the UDC acquires corresponding status informations periodically. The external hardware interlock system consists of relay circuits. They cover important items which directly connect to the damage of devices or necessary items on the local operation. In case of external software interlock system the group control computer, that takes charge of each UDC, acquires the interlock data at an interval of about 100ms periodically and performs the interlock checks. When the group control computer finds a fault status for a device, corresponding fault sequence program including the software interlock management starts.

Some examples of the software interlocks are stabilities of the output currents of the magnet power supplies, stabilities of the output voltages of the electrostatic channels power supplies at injection and extraction systems, stabilities of the cavity voltages of the RF systems, and beam current values which exceed the predetermined threshold values. Many software interlock items are used as a closing condition of the beam stoppers in the injection beam line before the entrance of the ring cyclotron.

Conclusion

The message tree including the Message Tree Communicator, the Message Tree Brancher and the Universal Device Controller has been developed. Simultaneous controls of many devices have been realized with the distributed control functions to the Universal Device Controllers. The formats of the communication registers in the Universal Device Controllers have been almost determined. The design of the interlock systems is now in progress. The control system is at the stage of construction, and will be completed in 1990.

References

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- 2) T. Yamazaki, et al., Design of Control System for RCNP Ring Cyclotron, Proc. Sixth Symp. on Accelerator Science and Technology, Tokyo, 1987, pp.251-252.