CONTROL SYSTEM OF THE RIKEN RING CYCLOTRON

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The RIKEN ring cyclotron system is controlled by means of three mini computers, which are linked with one another through optical fiber loops. A CAMAC serial crate network and a GP-IB are used for the control of accelerator devices. Two types of intelligent modules are used; One is a CAMAC module and the other is a terminal module for high speed local control of the accelerator devices. The operating system of the control computer is a combination of a real time and a UNIX system. Application programs are written in FORTRAN 77 language. Most operations are performed with touch pannels.

Introduction

The RIKEN ring cyclotron facility(RRC) consists of two injectors(a heavy-ion linac and an AVF cyclotron) and a ring cyclotron. The construction of the ring cyclotron was completed[1]. The first beam was extracted on December 16, 1986. This system is controlled by three mini computers; The first one is for data base and program development, the second for the control of injector linac(RILAC), and the third for the control of the ring cyclotron and AVF cyclotron. These computers are linked with one another.

The parameter values are transferred between the accelerator devices and computers through a CAMAC serial network. Two types of intelligent modules are used for high speed local control of the accelerator devices[2].

Computer System

Figure 1 shows the block diagram of control system. Three computers are of the same type, a 32-bit industrial computer MELCOM 350-60/500(M-60) of Mitsubishi Electric Corp.. The execution speed is about 3.7 MIPS. The characteristics of this computer are shown in Table 1. These computers are linked by using glass optical fiber cables (MDWS-60 data way). The network is a duplex system. Even in a failure of one line or failure/power-off of any one computer, the link can be retained automatically by adopting a loop back method. The transmission rate of MDWS-60 is 15.36 Mbps.

This computer system has other two types of networks; One is an Ethernet and the other is a UNIX network(uucp). Programs and data transfer and local diagnostics are performed by using these networks.

The computer #1 stores the field mapping data of sector magnets and transport magnets. At a request from any control computer (computer #2 or #3), the computer #1 performs time consuming tasks such as orbit calculations and transport calculations using these mapping data and the results are sent back to the control computer. The computer #1 is equipped with a CAMAC SHD and can be used as a back-up computer for the control computer. The computer #1 is also linked to the central computer of our institute (FACOM M-780) in order to process jobs in which larger memory and higher computation speed are necessary.

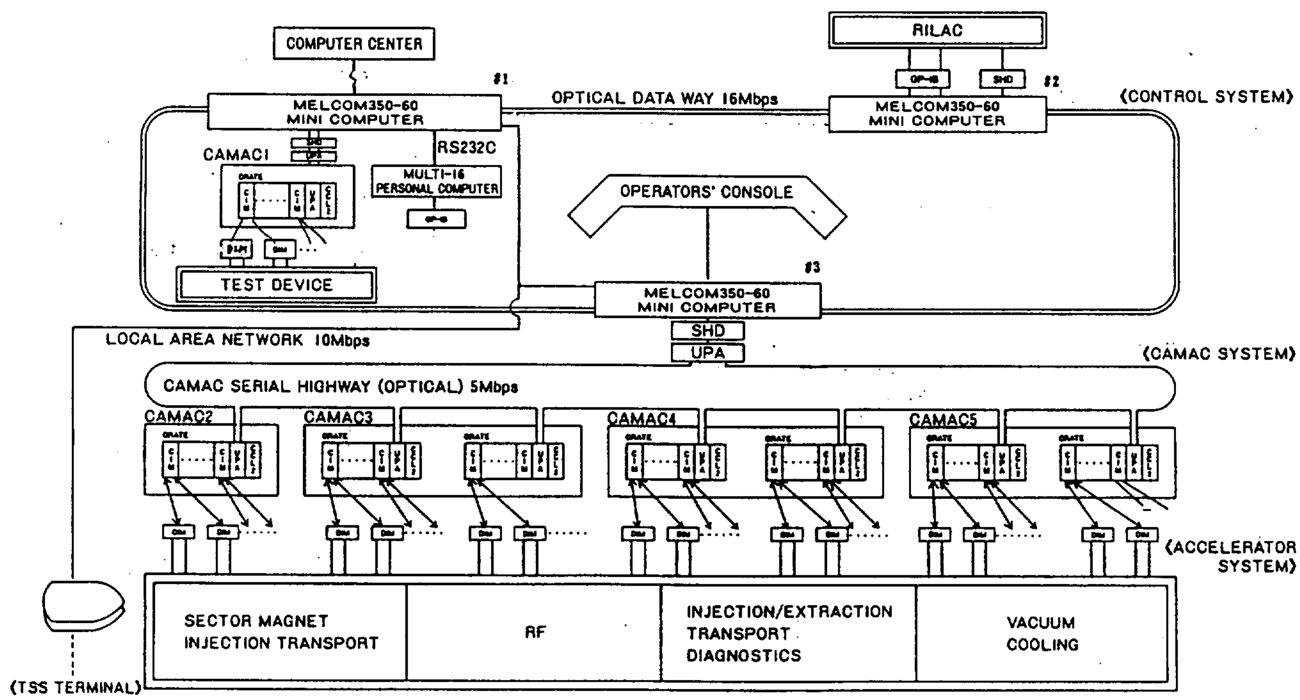

Fig. 1. Block diagrams of control system.

Table 1 Characteristics of MELCOM 350-60/500

CPU	ECL LSI	
memory	64 Kbit LSI with ECC	
word length	32 bit	
max. memory	16 MB	
max. address	16 MB	
cycle time	250 ns/8 byte	
cache memory	160 KB	
register	24 (32 bit)	
instruction	450	
pipeline	5 steps	
MIPS	3.7	
computation time	ADD	0.095 µs
	FADD	0.3 µs
	FMULT	0.5 µs
	SIN(x)	5 µs
interrupt	8 levels	
network	15.36 Mbps	
CAMAC SHD	5 Mbps	
GP-IB	250 KBps	

The computer #2 controls the RILAC through GP-IB using optical fiber links[3].

The computer #3 controls the ring cyclotron and AVF cyclotron through a CAMAC bit serial loop. The console devices such as touch panels and color displays are linked with the computer #3 without a CAMAC system. This computer is also linked with a computer MX-3000 of MITSUBISHI of radiation safety control system[4]. For radiation safety, MX-3000 has the highest priority in accelerator operation. Before starting operation, an operator should ask MX-3000 for the permission. If any erratic conditions occur in the safety system during operation, MX-3000 send back a beam-stop command.

The computer #1 and #3 are installed in the control room of the ring cyclotron and the computer #2 is in the control room of the RILAC.

Interface System

Six CAMAC crates are distributed in four power supply rooms of the ring cyclotron. One is installed within an operator's console. Because of a long distance (90 m max.) between these rooms and the control computer, these CAMAC crates are linked by a bit serial loop of optical fiber cables; the transmission rate is 5 Mbps. A disadvantage of this optical loop is that it has no bypass function when any crate is powered off.

Two types of intelligent modules are used for the interface between controlled devices and the CAMAC system. Each integrates a micro processor Intel 8031 (11.0592 MHz), 8 KB EPROM, and 8 KB RAM. CIM is a CAMAC module and DIM is a terminal module for each controlled device and installed close to the devices. Twelve DIM's can be linked with one CIM. CIM executes message transfer between the control computer and DIM. Information is transferred between CIM and DIM through plastic optical fiber cables. The maximum length of this cable is limited to 30 m. DIM executes local sequence control, local surveyllance, function generation, and testing, thus reducing the load of the control computer. DIM has several digital input/output (DI/DO) ports and sixteen analog input (AI) ports. There are two types of ports depending on the usage. The DI/DO ports of DIM for power supply are of a 12 V opto-coupled type. Figure 2 shows the block diagram of power supply control[5]. DIM for beam diagnostics has TTL level DI/DO ports in order to carry on such high speed exchange of data as that from a beam profile monitor or an emmitance measuring system. For control of main differential probes, a dedicated micro processor is linked with DIM. Figure 3 shows electronics for the beam diagnostic eqipment[6]. For these diagnostics circuit the DI/DO ports are used as the data/control bus lines. It takes about 0.6 seconds to transfer the 1.4 KB data of a three wires beam profile monitor to the control computer.

Since for the RF system high speed control is necessary, programmable controllers (PC) are introduced. DIM's are linked with these PC's. The status are read from the memory of PC's. A vacuum control system also uses PC. Vacuum gauges and the temperatures of cryo-pumps are read directly by DIM's. It takes about 2.6 seconds to read 40 vacuum gauges. A residual gas analyzer (QMA) is controlled by a dedicated micro computer and the data are transferred directly to the control computer through an optical RS232C line. For a cooling system, DIM only reads the status.

The total numbers of CIM and DIM are 30 and 170, respectively. Additionally two crates and ten DIM's will be installed for the control of the AVF cyclotron and for the control of devices of the extention of beam transport line.

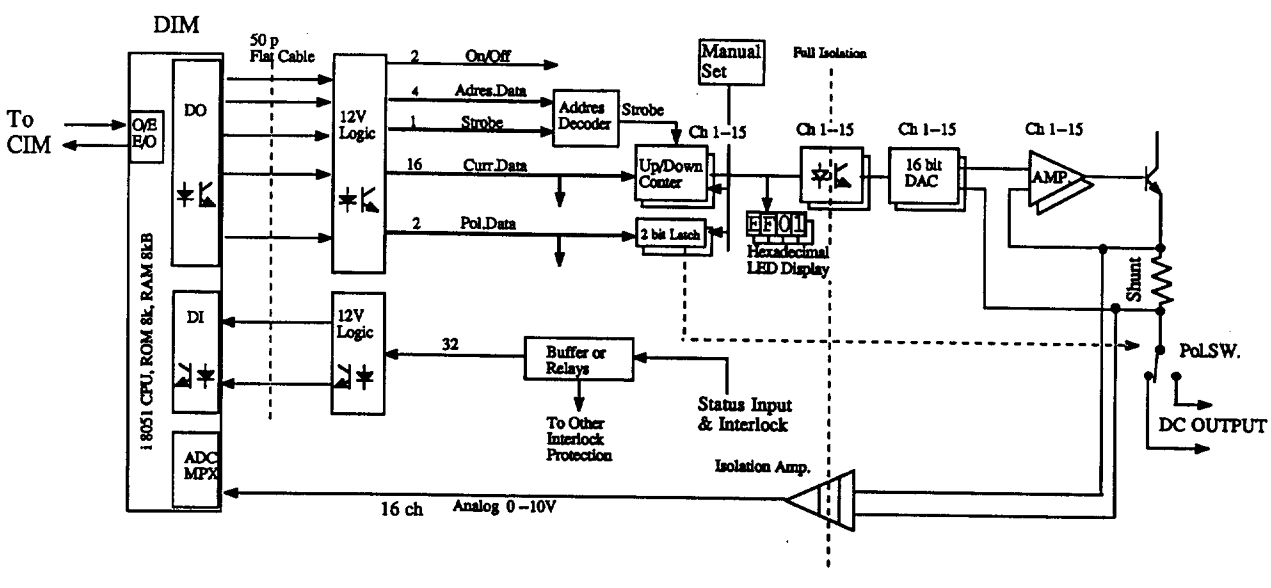

Fig. 2. Block diagram of power supply control.

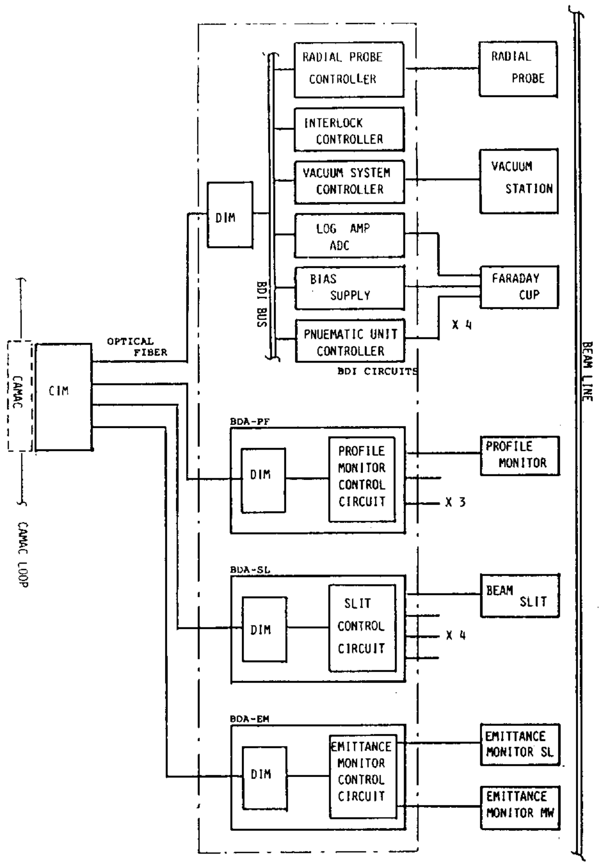

Fig. 3. Block diagram of the circuits for the beam diagnostic system.

Diagnostic Network

Diagnostics of controlled devices is carried out conveniently by verifying the response of the devices. For this local diagnostics, an local area network (Ethernet) with a transmission rate of 10 Mbps is adopted. Four interface terminals (TIA) are prepared: Two are placed close to computer #1 and #3, and the other two are closely to the CAMAC stations. Diagnosis is carried out by plugging a TSS terminal unit into a port of a nearest TIA. These ports are also used for displaying machine status in an operator's room or counting rooms by selecting a desired part of the machine on a keyboard. Since this network links two computers (computer #1 and #3), an operator is accessible to each computer.

Console

Figure 4 shows the operator's console, which consists of three parts (center, left, and right parts). The left and right parts are made equivalent to each other for convenience of diagnostics of accelerators. At least two operators can access the accelerator system independently. The central part is prepared for the devices such as ITV's, scopes, and error message output CRT. The console devices are linked directly with the computer #3 without CAMAC interface. Because of an industrial computer, there are many convenient and powerful man-machine interface devices and softwares.

The CRT's from #1 to #7 are the model VT241 of DEC with a touch pannel(TP) on the screens. The CRT #8 is also VT241 but without a touch pannel. The CRT's from #9 to #14 are 19" color graphic CRT's. All the keyboards are hiden within the console box. However, the keyboards of CRT's #1 and #7 can be pulled out for the use of program debugging. Almost all man-machine interactions are performed by the TP's and the informations are displayed on the 19" CRT's. Only three hard wired push buttons are used for accelerator control: One is an emergency stop, and the other two are the open/close of beam shutters at the exit of RILAC

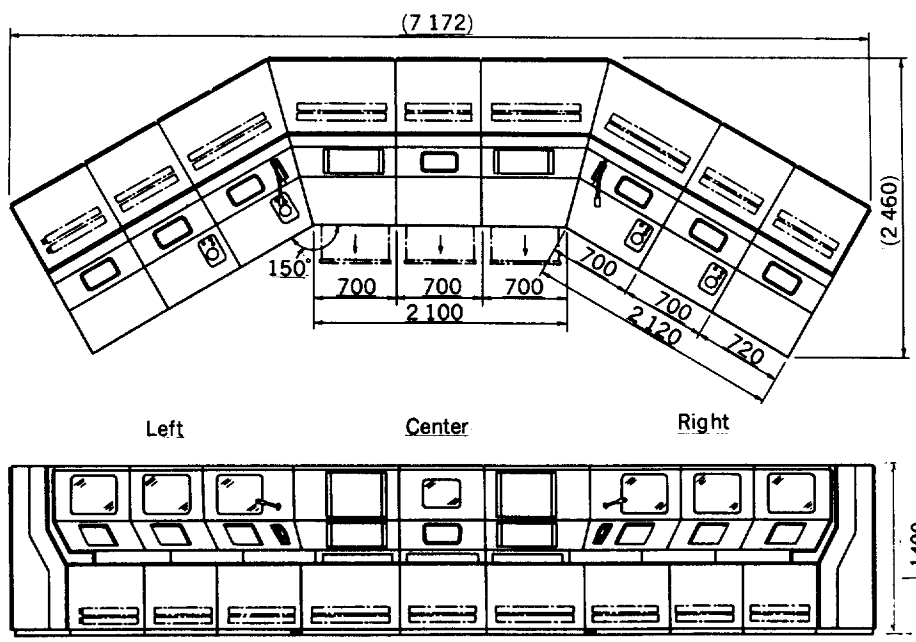

Fig. 4. Operater's console.

and AVF cyclotron. These beam shutter are also controlled by a computer.

At the start of operation, a menu display is shown on one of seven TP's, and on that the assignments of the roll to other TP's are determined. Figure 5 shows the menu display on TP. Figure 6 is an example of TP display for the control of power supplies. In this case, maximum four power supplies are controlled on the same screen. Assignment to other power supplies are selected by pushing the upper right four buttons. There is an exit area in any control screen. When this area is selected, the menu of Fig. 5 is displayed on the same screen.

Since these VT241 CRT's are linked with the computer by 9600 bps RS232C lines and are operated in ReGIS mode, the response is not so quick, compared to a CAMAC module TP.

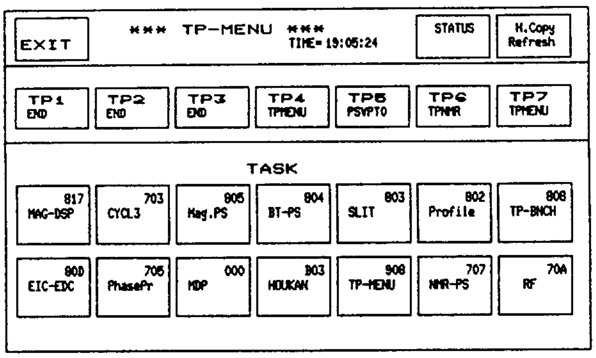

Fig. 5. Menu display on TP screen.

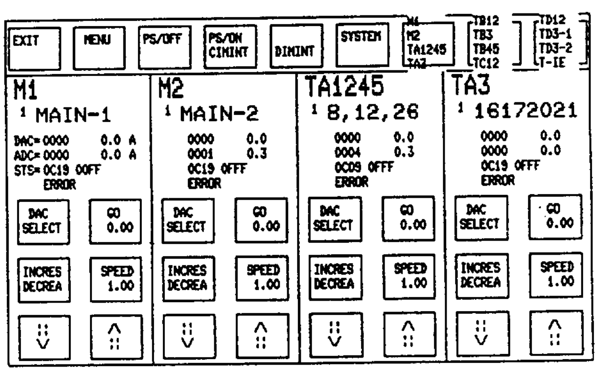

Fig. 6. Power supply control screen.

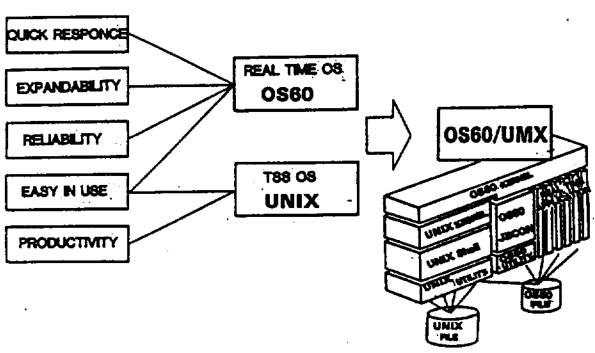

Fig. 7. Configuration of OS60/UMX oprationg system

Software

The operating system OS60/UMX is a combination of real time and UNIX systems. Figure 7 shows the configuration of operating system. The application programs are first developed and tested in the UNIX system and later executed in the real time OS to get high-speed response. The application programs are written in FORTRAN 77 language. These programs are composed of several tens of thousands of lines. The data base about accelerator devices are almost completed. The required memory is about 20 KB. They are first created in disk files and at IPL time are loaded into a common memory area. In our computer, different tasks occupy independent logical memory spaces in order to avoid addressing overlaps. These tasks exchange information through the common area to which other computers are also accessible through the MDWS-60 data way.

Many kind of programs are developed for the man-machine interface with TP's. We can use TP conveniently and flexibly and layout various types and colors of push buttons on it. The programs for DIM of the power supply are extensively improved to carry out high speed execution[2]. Since the programs of CIM/DIM are written in an assembler language, it is a little inconvenient for the maintenance. We are going to use high level language.

As a next step we are going to control the injector RILAC at the operator's console of the ring cyclotron by the computer #3 through MDWS-60 data way and computer #2. The first reason is in the simplification of accelerator operation: Both accelerators can be operated at one console. The second, which is most important, is the establishment of closed loop control system: The ion source of the RILAC can be adjusted automatically by monitoring the beam current at an experimental position.

References

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