CONTROL SYSTEM OF THE RIKEN RING CYCLOTRON

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The RIKEN ring cyclotron (separated-sector cyclotron) facility consists of two injectors, HI linac-AVF cyclotron and a separated-sector cyclotron. This system is controlled by means of three mini-computers, which are linked with one another through an optical fiber loop. A CAMAC serial crate network and a GP-IB are used for the control of accelerator devices. Two types of intelligent modules have been developed; one is a CAMAC module and the other is a terminal module for high speed local control of the accelerator devices. The operating system OS60/UMX is a combination of a real time and a UNIX system. Application programs are written in FORTRAN 77 language.

Introduction

The RIKEN ring cyclotron facility consists of two injectors, an HI linac*-AVF cyclotron and a separated-sector cyclotron[1]. The above three accelerators are composed of many kinds of subsystems, such as beam injection/extraction, vacuum, radio frequency, sector magnets, beam transport, and cooling water systems. In order to obtain a desired beam (particle and energy) and to transport it to a proper experimental area in a short time, the control system has to perform complicated and fast control of these subsystems taking into account the interrelation among them. The aim of the control system is to obtain a good quality beam quickly by controlling the above subsystems accurately.

The two injectors are also operated independently of the ring cyclotron, and for the diagnostics, they must be operated independently. Taking into account of these operational forms, we have introduced a distributed control system by using a network of several high speed mini-computers.

For the interface system to the accelerator devices, a CAMAC system is widely used because many kinds of standard and reliable modules are comercially available. However, these modules are usually of a unit function, so that several modules must be connected to a single controlled device. Consequently a great number of modules and crates are necessary, and this increases the hardware cost. To reduce this cost, we have developed intelligent interface modules using micro processor from following reasons:

(1) The accelerator devices are usually of slow response;

(2) High speed micro processors are available at low cost.

The number of necessary CAMAC crates is reduced to 7, which is far less than the first estimate of about 40 using standard modules. Furthermore these intelligent module can execute a local control and reduce the load of mini-computers.

High level language, a convenient text editor, and a powerful debugging tool are necessary to increase the efficiency of program development and maintenance.

*RILAC

The characteristics of the SSC control system are as follows:

(1) A computer network consisting of distributed mini-computers is adopted;

(2) CAMAC crates are linked by a serial highway through optical fiber cables;

(3) Micro processors are used for the interface between CAMAC and controlled devices;

(4) Analog signals are digitized as many as posible and sent to the control room;

(5) Application programs are written in FORTRAN 77 language;

(6) Operating system is a combination of a real time and a UNIX system.

One of the three computers was already installed in August, 1984, and has been used for the program, data base development, and the field measurement of the four sector magnets. This computer was installed in the SSC vault which is not a due site. Although the enviroment is not good in room temperature and humidity, there have no hardware error during 9 months.

Computer System

Three mini-computers are linked by using optical fiber cables. Figure 1 shows the network system. The computers are of the same type, a new 32-bit industrial computer MELCOM 350-60/500 of Mitsubishi Electric Corp.(M-60). The characteristics of the computer are listed in Table 1, where SHD is a bit serial highway driver and ECC is an error check/correction. An intelligent system console includes two flexible disk drives. Many of the system subroutines required for a real time operation have been converted to firmwares which allow faster program execution. The time critical part of the operating system and the application program can be made resident on the cache memory. Table 2 lists the configurations of the computers.

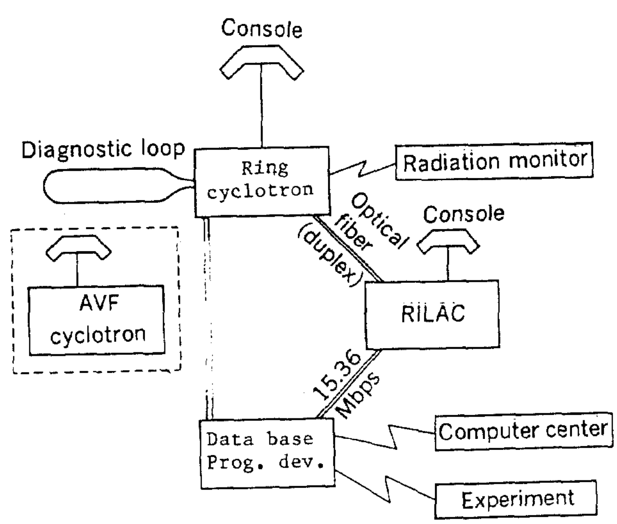

Fig. 1. Computer network.

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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	4 GB	
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 us
	FADD	0.3 us
	FMULT	0.5 us
	SIN(x)	5 us
interrupt	8 levels	
network	15.36 Mbps	
CAMAC SHD	5 Mbps	
GP-IB	250 KBps	

Table 2 Configurations of computers

Computer 1 (ring cyclotron)	
memeory	4 MB
fixed disk	202 MB
CAMAC SHD	1
GP-IB	2
console devices	
Computer 2 (data base)	
memory	4 MB
fixed disk	70 MB x 2
magnetic tape	2 (1600/800 bpi)
line printer	1 (390 lpm)
TSS terminal	4
plotter	1 (10 pen)
communication port	11
20" graphic display	1 (7 color)
hard copy	1
CAMAC SHD	1
Computer 3 (RILAC)	
memory	3 MB
fixed disk	202 MB
magnetic tape	1 (1600/800 bpi)
line printer	1 (390 lpm)
plotter	1 (10 pen)
20" graphic display	1 (7 color)
hard copy	1
20" character display	1 (7 color)
GP-IB	2

The network is a duplex system with optical fiber cables. Even in the failure of one line or failure/power-off of any one computer, the computer link can be retained automatically by adopting a loop back method. The transmission rate is 15.36 Mbps. The computer 1 and 3 are used for the control of accelerator devices (the control computers). The computer 2 is used to store the data base of these devices (data base computer). The computers 1 and 2 are installed in the control room of SSC and the computer 3 is in the control room of the RILAC.

The computer 1 controls the ring cyclotron through the CAMAC bit serial loop. The console devices (such as touch panels, color displays, and shaft encoders) installed in the control desk are linked to the computer 1 without a CAMAC system. The control desk consists of three parts (center, left, and right parts), and the left and right parts are made equivalent to each other for the convenience of diagnostics of accelerators. At least two operators can access the accelerator system independently. The console devices linked to the computer 1 are installed in these areas. The minimum time of data refresh on a CRT is 280 ms, which is determined by the digital displays in automobiles. The center part is prepared for the devices such as ITV's and scopes which are not linked to the computer.

The computer 2 is used to store the data base of the whole control system into large disk files. Most of the data are initial values, logging data and device name/link tables. The current status and values of controlled devices are stored locally in the memory of the micro computers mentioned later. The source programs are also stored in a disk file. The machine codes of the control programs are stored in the disk files of control computers (computer 1 and 3). The control computers pick up the necessary data or ask for remote batch jobs to this computer(computer 2). This computer is also equipped with a CAMAC SHD and can be used as a back-up computer for the control computers. This computer is linked to the central computer of our institute (FACOM M-380).

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

The first computer system (the computer 2 of Table 2) installed in August, 1984, is used for program development, data base establishment, and the field measurement of the four sector magnets. On the first stage of the field measurement, a DEC LSI-11/02 computer is used for interfacing GP-IB devices such as a DVM and a scanner, because a GP-IB interface has not yet been installed. The obtained data are transferred to the M-60 computer via a serial link.

The computer 3 and GP-IB interface will be installed in October, 1985, and the computer 1 and operator console in May, 1986.

Interface System

The CAMAC and the GP-IB interface system are shown in Fig. 2. Seven CAMAC crates are distributed in four power supply rooms. Because of the long (90 m max.) distance of these rooms from the control computer, these CAMAC crates are connected by a bit serial CAMAC loop of optical fiber cables; the transmission rate is 5 Mbps.

Two types of module which include a micro processor are developed for the interface between controlled devices and the CAMAC system. One is a CAMAC module which has 12 pairs of serial I/O ports and the other is an interface module to each controlled device and installed close by the device. The former module, named a CIM (Communication Interface Module), executes the message transfer between the M-60 computer and the later module, a DIM (Device Interface Module). The DIM executes a local sequence control, local surveillance, function generation, and testing, thus reducing the load of the control computer. The micro processor is the Intel 8031 having an integrated serial communication channel. The clock cycle is 11.0592 MHz. RAM and EPROM of 8 KB are included. Information is transferred serially between these two modules through a pair of plastic optical fiber cables at a transmission rate of 172.8 Kbps. Five CIM's and fifteen DIM's were fabricated in October, 1984. The details of these modules are given elsewhere[3].

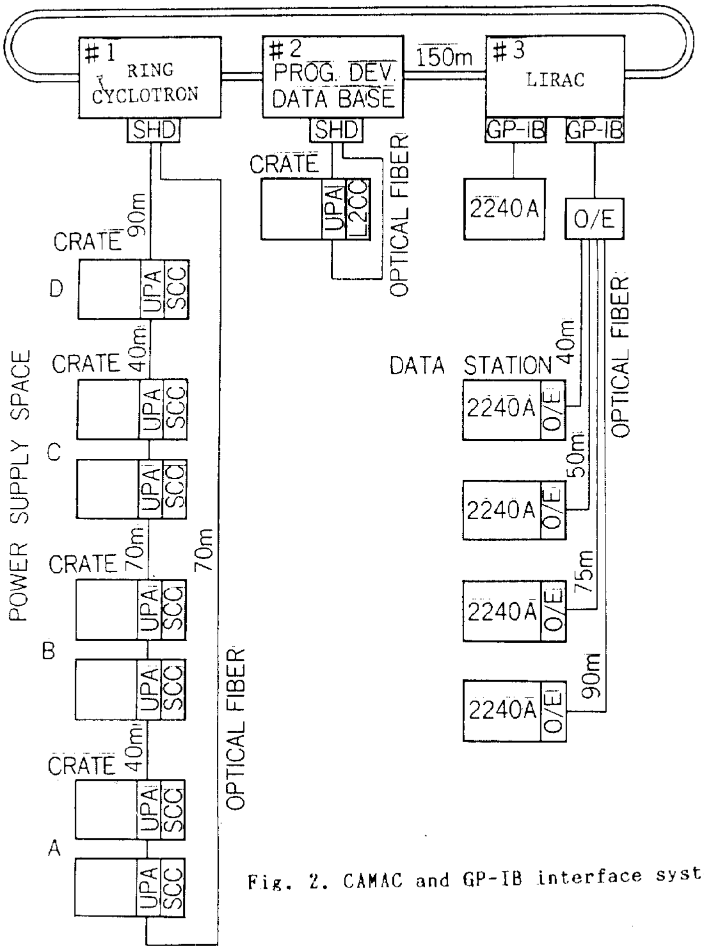

Fig. 2. CAMAC and GP-IB interface system.

Diagnostic Network

For the local diagnostics, it is convenient to use movable consoles[4]; however, we make another decision in order to reduce the cost and to have more flexibility. A simple network is adopted and only the ports for a CRT display are prepared at given places. In making diagnosis, the CRT display unit is carried to and plugged at a nearest port. These ports are also used for the display of machine operations at the operator room or the counting rooms by selecting a desired part of the machine at a keyboard.

Analog System

Analog signals are digitized as many as possible and sent to the control room through the CAMAC loop. It is often necessary to observe wave forms of the signals from some beam detectors such as coaxial Faraday cups and phase probes. For these signals a sampling method is adopted and the band width is reduced. The results are sent to an A/D converter by coaxial cables and stored in a display memory, the contents of which are displayed on the scopes on the control desk and also read into the control computer through the GP-IB for numerical analysis.

Software

The operating system OS60/UMX is a combination of a real time and a UNIX system. Figure 3 shows the configuration of operating system. It consists of a kernel, OS60, and UNIX parts. The programs are first developed and tested in the UNIX system and finally transferred to the disk area of the OS60 system which can be started (FORKed) on a real time. The source programs are developed by a screen editor (vi) of the UNIX system.

The application programs are written in FORTRAN 77 language which includes real time functions. A FORTRAN 77 debugger is prepared for the interactive debugging of the programs. Many software packages for a graphic display, a network, and a data base are prepared. CAMAC subroutines are developed following the IEEE standard[5]. Besides these standard subroutines, four subroutines are developed in order to utilize the real time functions of the OS60 system. In the first version, the execution time of the subroutines is rather slow; for example, the subroutine CFSA takes about 5 ms. One half of this time is the OS overhead and other half is that of the micro processor in the SHD. The execution time for data transfer between the M-60 computer and the DIM through CIM is 20-30 ms, which include waiting time of the ready or LAM status of the CIM. We are now investigating the software system for CAMAC, CIM, and DIM to find the possibility of reducing the execution time.

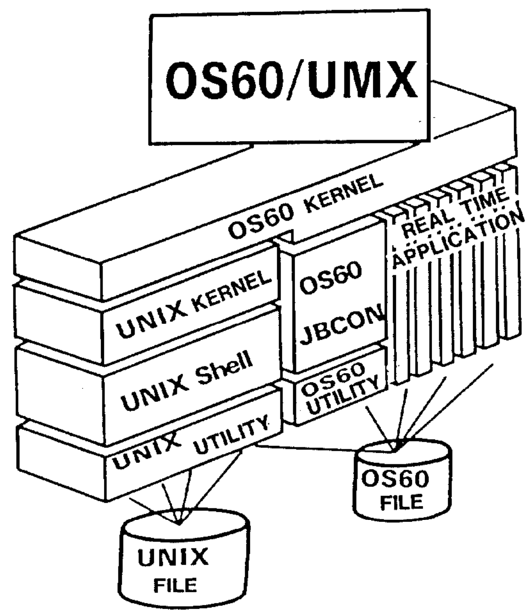

Fig. 3. Configuration of operating system.

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