

COMPUTER CONTROL SYSTEM OF PHOTON FACTORY STORAGE RING

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INTRODUCTION

The electron storage ring at KEK Photon Factory (PF) has been successfully operated at an energy of 2.5 GeV. We have constructed a computer network system which is expected to offer a unified way of machine control and a powerful tool for analyzing machine characteristics. Our goal is highly automated control by a few, ideally one, operator and to realize complete reproducibility of machine conditions. These are essential to provide a stable synchrotron radiation constantly for experiments.

Thus, the network system which connects distributed control computers is strongly required to operate the machine as a total system.

This paper will describe the outline of hardware and software of the control system with the computer network.

SYSTEM OVERVIEW

The layout of the control computer system is shown in Fig. 1. The control system consists of 7 control stations which are connected to each other through one exchange station, so each station can communicate with any other station. (Only exception is RF station, it cannot access this network because of its different operating system. The reason is explained later.)

Usually, each control station performs almost independently its own tasks, control/monitoring of the magnet system, the RF equipment, the vacuum system, the safety interlocks, operators console and beam monitoring system, etc. When a station needs to send/receive some data to/from other station, they can achieve it using program-to-program communication facility supported by the network system.

Both vacuum and beam monitoring stations leave a part of their work to micro-computer (PANAFACOM C-180, NEC PC9800) which sends/receives data to/from the host computer through RS-232C link.

The medium-size computer (FACOM M-200) with 6 MB

of memory is also linked to the network through a front-end processor (FACOM U-400) to log and analyze operation data or do some simulation on orbit analysis. The computer is shared by TSS for batch users and experiment users.

CONTROL STATION

Hardware Configuration

A typical hardware configuration of the control station is shown in Fig. 2.

Almost all objectives of controlling or monitoring are driven through CAMAC interfaced modules such as input/output register, control register, ADC, DAC and multiplexer, etc.. For some GPIB-interfaced devices such as digital multi-meter and coaxial relay etc. are also driven through CAMAC using GPIB-CAMAC conversion module.

The processing power is supplied by a 16-bit mini-computer (AICOM C-6) with 1 MB of memory. The CAMAC branch driver was specially developed for the computer. The computer has also serial I/O ports to drive some devices which have a I/O interface to the RS-232C link (graphic displays, microcomputers etc.). It is equipped with hard disks with capacity of 40 MB and a line printer. Furthermore, a magnetic tape unit is also installed to some stations for system maintenance. The local console is used only for system set-up or maintenance, so the operator usually interacts with touch panels or other console desk devices through CAMAC interfaces.

The communication with other control station is achieved by network interface modules of CAMAC as described in section 4 in detail.

Software Structure

Figure 3 shows a schematic view of the memory assignment of the control station computer.

The multi-task real time operating system was de-

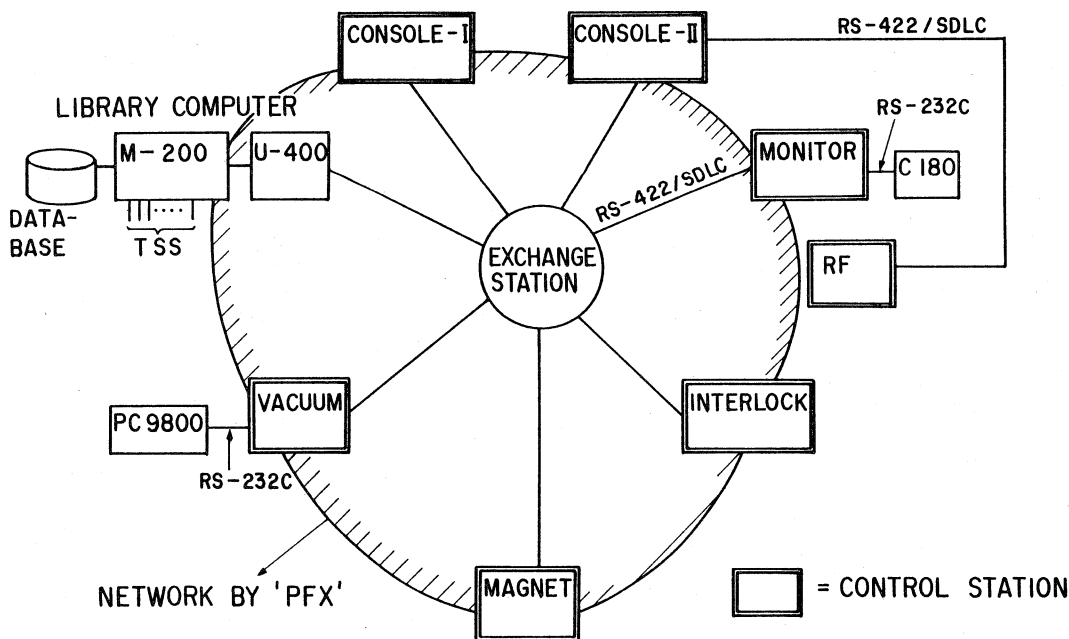


Fig. 1 Layout of the computer control system of Photon Factory storage ring.

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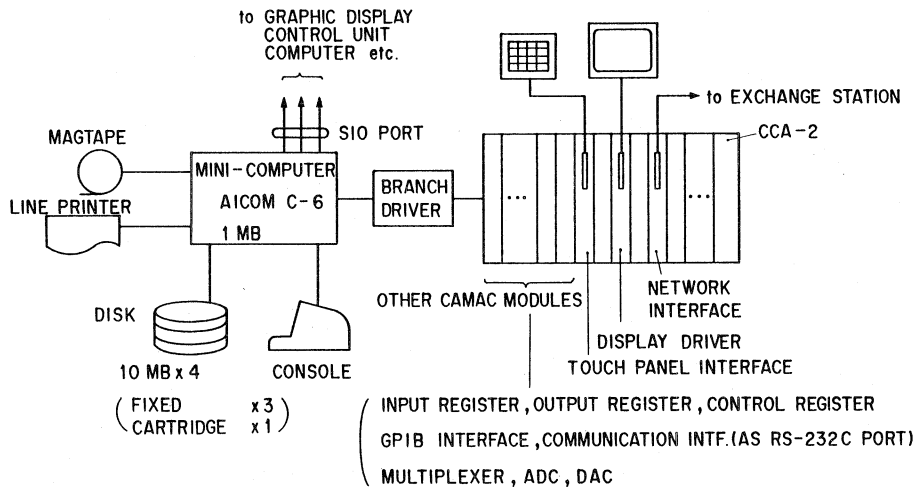


Fig. 2 Typical configuration of a control station.

veloped and installed to perform both local data processing and network processing simultaneously.

An interactive language, 'PF-BASIC' (Photon Factory Basic) was specially prepared as a common language for the control program code. This has all features of standard BASIC with some extended functions and commands such as matrix calculation, virtual memory access, synchronized data communication with other computers and various interrupt handling (LAM of CAMAC, clock, network action) etc. The PF-BASIC interpreter code is made to re-entrant because it may be used by two or more programs at the same time.

A users space of main memory is divided into two areas, one for 'local space' and the other for 'remote space'. A boundary of two spaces is changeable and set at system boot-strapping. A single job is run in the local space by operators commands from the system console and one or more jobs are able to be executed in the remote space by an action from other computers through the network.

Two spaces are fully independent to each other, so there remains possibility that two or more programs access one CAMAC module at the same time. The system software module, 'CXC' (CAMAC exclusive controls) avoids this situation by keeping a management table of CAMAC, and all users program must access CAMAC only through CXC.

Some extended features like block transfer of memory, string functions and generalized treatment of some CAMAC modules (input/output register, multiplexer, GPIB interface,...etc.) are provided in a form of BASIC-callable subroutines for users convenience.

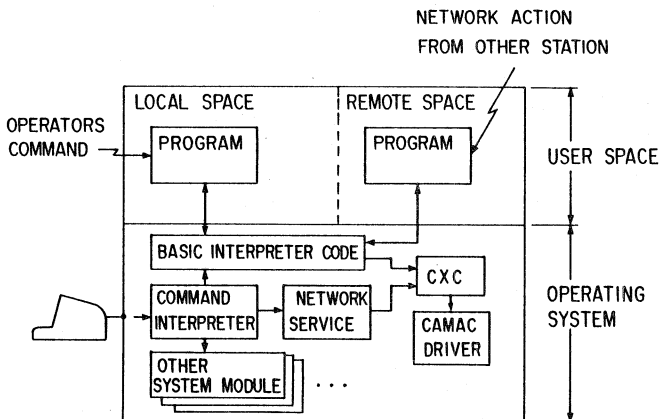


Fig. 3 A schematic view of memory assignment of a control station.

NETWORK SYSTEM

Hardware of Network

The intercommunication between computers is performed using network interface modules of CAMAC which are specially developed for the PF network system.

The interface consists of two modules. One is a fundamental module which processes CAMAC functions (as shown in Table 1) and controls interface unit. The other is a line control module which handles signals on a physical link. Various types of link, SDLC, RS-232C and parallel I/O etc., can be supported only by replacing the line control module without any change of other hardware/software environment. Two modules are connected by 60-wire flat cable.

Table 1

CAMAC functions of network interface module

F	A	Function	Q-Response
0	0	Read Received Data	Receive
1	0	Read Received Data Length	1
1	1	Read Status	1
1	15	Read Module ID Code	1
8	0	Test LAM	LAM
16	0	Write Transmitting Data	Transmit
17	0	Write Transmitting Data Length	1
17	1	Write Control Word	1
17	13	Write LAM Mask	1
22	14	Selective Clear of LAM	1

LAM source = Line error, Transmit error, Receive error, Transmit done, Receive done

The interface has two buffers of 2 kB each for both data to be transmitted and those received.

The possible errors of transmitted data are checked by means of CRC, check-sum and parity bit, so the interface requests re-transmission of data when it detects errors.

The PF network system uses SDLC protocol on RS-422 as a physical link, and the line speed can be chosen from 62.5 k ~ 1 Mbps which is selectable by 4-bit DIP switch in the line control module.

Software of Network

The software of the network system has a three-layered structure as shown in Fig. 4.

The lower layer called 'DLC' (Data Link Control) manages a link between physical nodes.

The 'PC' (Path Control) is the middle layer and controls logical communication paths in order that PF network allows multiple communications simultaneously

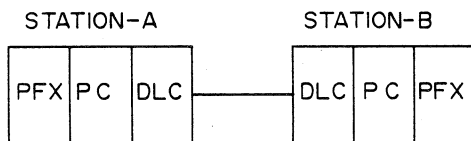


Fig. 4 Three-layered structure of the network software. DLC = Data Link Control, PC = Path Control, PFX = Photon Factory Executive.

on a single physical link. The upper layer called 'PFX' (Photon Factory Executive) defines the protocol of the actual communication. Each layer is absolutely independent to its upper-side layer.

The message format is shown in Fig. 5. The message packet has three types of header corresponding to the software structure mentioned above. The 'DLC' header includes receiver/transmitter address, packet control word and transmitters terminal name. The 'PC' header contains informations on an identity of a communication and a message order number. The 'PFX' header keeps informations on length and content of text.

A text has variable size up to 2 kB and its content will be command, data, response or command completion code.

A fundamental features provided by PFX are as follows; file transfer, program-to-program data transfer and submitting program to other stations. These are supported by both operators command and BASIC statement. (A program-to-program data transfer is realized only by BASIC.)

The exchange station simply distributes packets according to its physical node address, and all protocol processing of the networks must be done by each control station. This would be rather heavy load for a control computer sometimes. Furthermore, multi-task operating system, which is installed to realize the network, pays cost of large system overhead. For RF control station, this turned out to be an unendurable demerit because it lowers the speed of CAMAC accessing. So it uses ordinary single-task disk operating system which is unable to support the network by PFX. However, a data transfer from RF station to other control station is realized using the same network interface module and special protocol even in a restricted form.

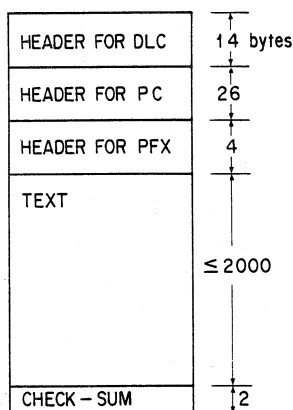


Fig. 5 Format of a message packet.

OPERATION DATA ACQUISITION

Continuous acquisition of data on the machine parameters is very useful for a trouble-shooting or a analysis of machine characteristics.

Operation data of each control station are gathered to the library computer through the network system. These data have a variety in their quantities,

format and sampling rate. However, these must be treated in a unified way to provide easy and speedy access tools for database users.

To realize this request, we adopted 'multi-levelled file architecture' as shown in Fig. 6. (A part of this work is still in preparation.)

Transferred data are added to 'temporary dataset (TDS)' group as one member of them. Every control station has its own TDS. The length and format of data are different for each control station, but each data should have a common heading which contains informations on time/date and beam current at the time when these data were taken. After pre-processing like deletion of unnecessary record, condensation and time-sorting, the data in TDS are stored to 'Reserved dataset (RDS)', so TDS is ready for next data. RDS is unique for a system and dumped to 'Archived dataset (ADS)' on a magnetic tape when it is full.

All these processes are performed by logged data processing utilities referencing a logged data management table (LDMT) which keeps all records on this procedure.

Users can search and access any data of a certain period of time using time/date and beam current as indexes. They can save a copy of extracted data in their own work file or use interactive data processing service (IDPS) which makes time-dependence plot of any data or correlational plot of two or more quantities etc. from a TSS terminal.

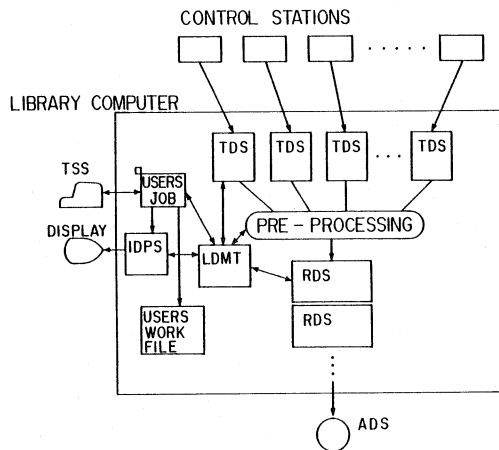


Fig. 6 Block diagram of the operation data acquisition. TDS = Temporary Dataset, RDS = Reserved Dataset, ADS = Archived Dataset, LDMT = Logged Data Management Table, IDPS = Interactive Data Processing Service.

CONCLUSION

The computer control system of Photon Factory storage ring has been constructed and operated. Mini-computers which are distributed along various machine devices achieved control and monitoring tasks with fairly satisfaction. The network system of the computers has been developed and almost all designed features are realized. However, it became rather heavy load to support this network system for mini-computers with sizable operating system. Consequently this turned out to be slowness of a network operation or other I/O service. At some control stations, tasks to be processed are already beyond their processing power.

To improve this situation, installation of more powerful processors, 32-bit super mini-computers, with high-speed network system is scheduled. Design of an architecture of new system is proceeding, and it will be some 'computer complex' bound closely by a network.

The authors would like to thank Professor K. Huke for his valuable advice and encouragement for this work.