KEK POSITRON GENERATOR CONTROL SYSTEM DESIGN

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ABSTRACT

The control system of the KEK positron generator was designed to be composed of a multi-microprocessor controlled CAMAC system, local controllers built in terminal equipments, fiber optics communication circuits and a local operator's console simplified by introducing five sets of personal computers.

INTRODUCTION

The general principle for the KEK positron generator control system construction is the same as that for the Photon Factory (PF) 2.5 GeV electron linac: Autonomous operation capability of every terminal equipment (klystron modulators, magnet power supplies, etc.), a completely hard-wired logic safety interlock system, system construction with easily replaceable modules and real-time remote control through computerized communication system with noise-free fiber optics.

The positron generator (an electron linac) is to be controlled by a newly designed multi-microprocessor CAMAC complex system which forms one of subcontrol stations of the PF linac. The positron generator is required to be operable independently of the PF linac; it is matter of course that the new subsystem is designed to be also operable from the PF linac main operator's console. All functions of the positron generator operation are concentrated in a subcontrol room with an area of 4.8×8 m^2 situated at the south end of the positron generator building.

The basic design of the communication system for the positron generator control is the same as that for the PF linac; however a subcontrol station for the positron generator is designed to be fairly different from the PF linac system as a result of recent technical innovations for microelectronics.

The PF linac control system[1] has six subcontrol stations placed at intervals of 80 m along the linac. Every subcontrol station consists of a minicomputer with a general-purpose operating system, a CAMAC crate and subcontrol panels with voltage and current meters, status indicating lamps, switches, etc. connected to various terminal equipments by hard-wiring. In contrast with this system, the positron generator subcontrol station is composed of a multi-microprocessor controlled CAMAC system and a local operator's console with five graphic display terminals. This subsystem has no 'central processor' like a minicomputer in the PF linac; that is a completely distributed processing system with many single-task-executing microprocessors. An outstanding feature of a multi-processor system, where every processor executes only one task, is simpleness of the software; any complicated multitasking operating system can be excluded. Figure 1 shows a simplified block diagram of the positron generator control system.

COMMUNICATION SYSTEM

Communications between the subcontrol station and terminal equipments are made in the same way as the PF linac communication system. Two kinds of bit serial communication loops are used: One is 'LOOP-II' with a 500 kbps synchronous transmission mode based on the High-level Data Link Control procedure (HDLC), and the other is 'LOOP-III' with a 48 kbps asynchronous transmission mode based on the Basic Mode procedure where a transparent mode protocol is adopted to transmit binary data.

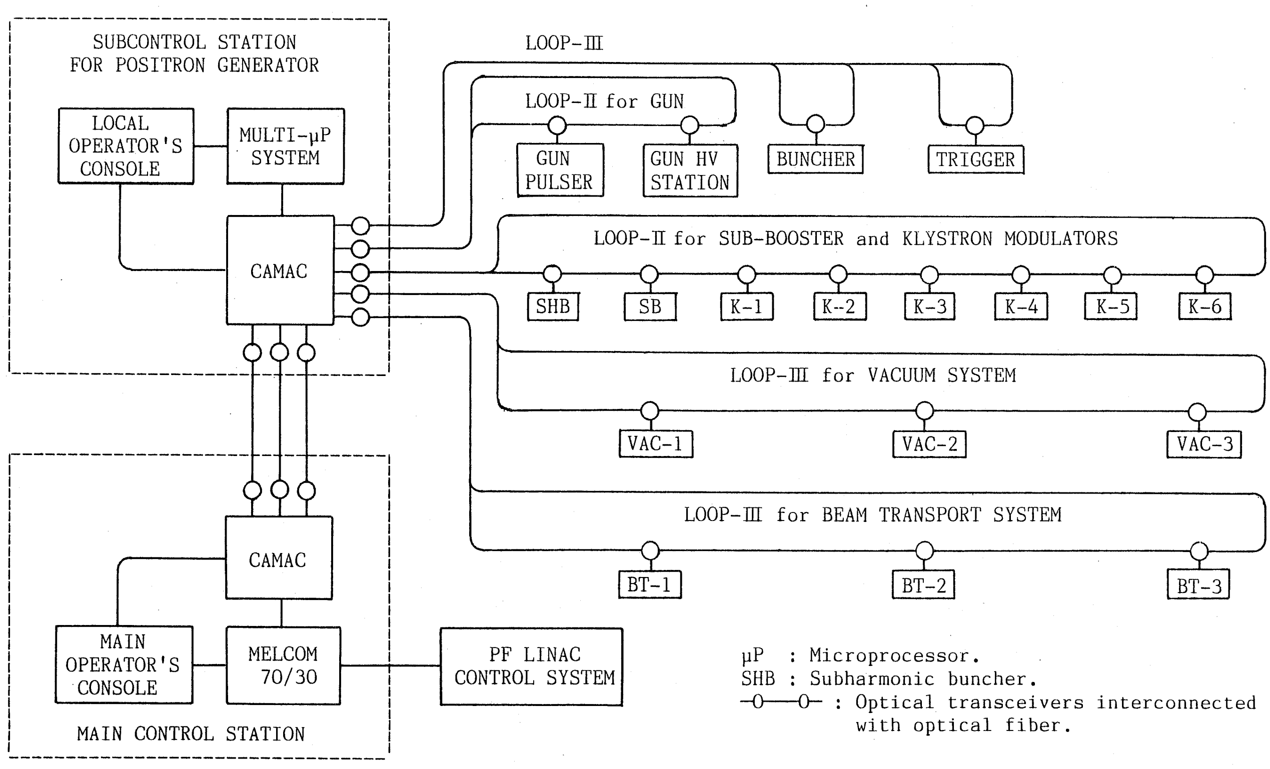

Fig. 1 Positron generator control system block diagram.

The communication control unit (CCU) utilized in the subcontrol station is a microprocessor-controlled CAMAC module developed for the PF linac control. The same type modules for the LOOP-II are used for communications between the main control station and subcontrol station; the firmware built in the module is modified so as to support a secondary station function.

Control system operation experience of the PF linac has demonstrated that fiber optics is much effective to avoid electronic circuit malfunction in very noisy environment. The positron generator control system follows the same way as the fiber optics communication system of the PF linac; the optical transceiver is modified only a little.

MULTI-MICROPROCESSOR CAMAC SYSTEM

According to operation experience of the PF linac control system, a commercially available general-purpose multi-tasking minicomputer used in the PF linac subcontrol system is unsatisfactory as the followings:

-- Heavy overhead of the large operating system is the main reason for reducing an effective signalling rate of real-time data transfer between the main operator's console and terminal equipments via the minicomputers. This weakens 'real-time feel' for operators.

-- A large general-purpose operating system is a black box for computer users. This makes it difficult to modify the operating system even for a little improvement.

Great progress in the microprocessor production technology has made it possible to overcome easily these difficulties. A solution to them is a multi-microprocessor system in which each microprocessor executes only one task. Every task is always in the running state; this much improves throughput of the system. No complicated large operating system is needed for the target system. The software becomes very simple and is easily made; no skillful programing technique is needed. In contrast with this multi-microprocessor system, several tasks run essentially in series in a multi-tasking single processor system which reduces system throughput.

The multiple single-tasking-microprocessor system can be formed with two architectural method: One is a CAMAC system with multiple auxiliary crate controllers[2], and the other is several single-board-computers (SBC) interconnected with a common microprocessor bus. The latter is called multi-SBC system.

The CAMAC dataway is not suitable for random access to common memory with large space through which processors interchange information each other; therefore the multi-microprocessor system is not constructed only with CAMAC auxiliary controllers each of which has only one microprocessor.

On the contrary, it is also an idea to construct the whole system only with SBC family boards; it seems rather preferable as compared with a complex system including CAMAC, because the bus conversion between SBC and CAMAC reduces throughput of the control system. The present multi-microprocessor CAMAC system is, however, a compromize between a simple multi-SBC system and a CAMAC system with single-microprocessor auxiliary controllers, since most of the CAMAC modules required for the present system construction have already been developed for the PF linac.

Figure 2 shows a block diagram of the system adopted for the subcontrol station. Table 1 lists CAMAC modules contained in two crates. Some of them are described below.

Auxiliary crate controller This single width module was originally designed for a 6800 type 8-bit microprocessor; it is, however, applicable to other type microprocessors by making adequate bus buffer circuits. In the present system, this auxiliary controller is also applied to a 68000 microprocessor system. Buffered bus lines of the microprocessor are extended directly to the auxiliary controller. This controller has also a 24-bit LAM mask register and a direct memory access (DMA) control line.

Interrupt request register CAMAC module By setting a bit in this register, one processor can request another processor to read information written in memory of a RAM module. The request signal is outputted to a LEMO-type connector on the front panel, and then it is inputted to an auxiliary controller front panel connector. Four auxiliary controllers can be served by one interrupt request register module.

The multi-SBC system is constructed with commercially available single board computers and some circuit boards designed in the laboratory. The SBC boards are H680SBC series family boards made by Hitachi, Ltd. The principal features are as follows:

SBC Four boards with 16-bit microprocessor 68000 are used; each of them executes one of the following tasks: system monitor, traffic control of communication, terminal surveillance and graphic display control. An on-board I/O port is utilized to receive an interrupt signal issued by another SBC through an interrupt request register board.

Common memory This is a 512 kByte board composed of 18 packages of 256 kbit dynamic RAM.

Interrupt request register board An interrupt signal from an SBC to another SBC within the multi-SBC system is relayed through this board.

Two sets of single 8-bit 6800 SBC's are connected to auxiliary controllers in order to read panel switches and to handle UP/DOWN signals for magnet current change, rf phase adjustment, etc. The UP/DOWN signal is generated by rotating manually a rotary encoder on the local console or transmitted from the main operator's console through a LOOP-III communication line.

New system programs for 16-bit microprocessors are developed on the target system using SUPER-PL/H (a PL/I like language) and FORTRAN-77 compilers[3]; these run on the CP/M-68K operating system[4]. The real-time program can be executed independently of CP/M-68K. Most pro-

Table 1

List of CAMAC modules contained in two crates used in the subcontrol station.

Module name	Width/module	Number of modules	Remarks
Crate controller in minimum configuration	2	2	Defined in ref. 2
Auxiliary controller	1	2	Defined in ref. 2
Interrupt request register	1	2	Interrupt request between auxiliary controllers
RAM (Rundom Access Memory)	1	2	2 kW/block × 4 blocks
CCU (LOOP-II)	2	5	500 kbps synchronous communication control unit
CCU (LOOP-III)	2	5	48 kbps synchronous communication control unit
Rotary encoder input	1	2	Count pulses from a rotary encoder and generate LAM
Output register	1	3	Coaxial switching, beam monitor control
Dataway display	1	2	For debugging and maintenance.

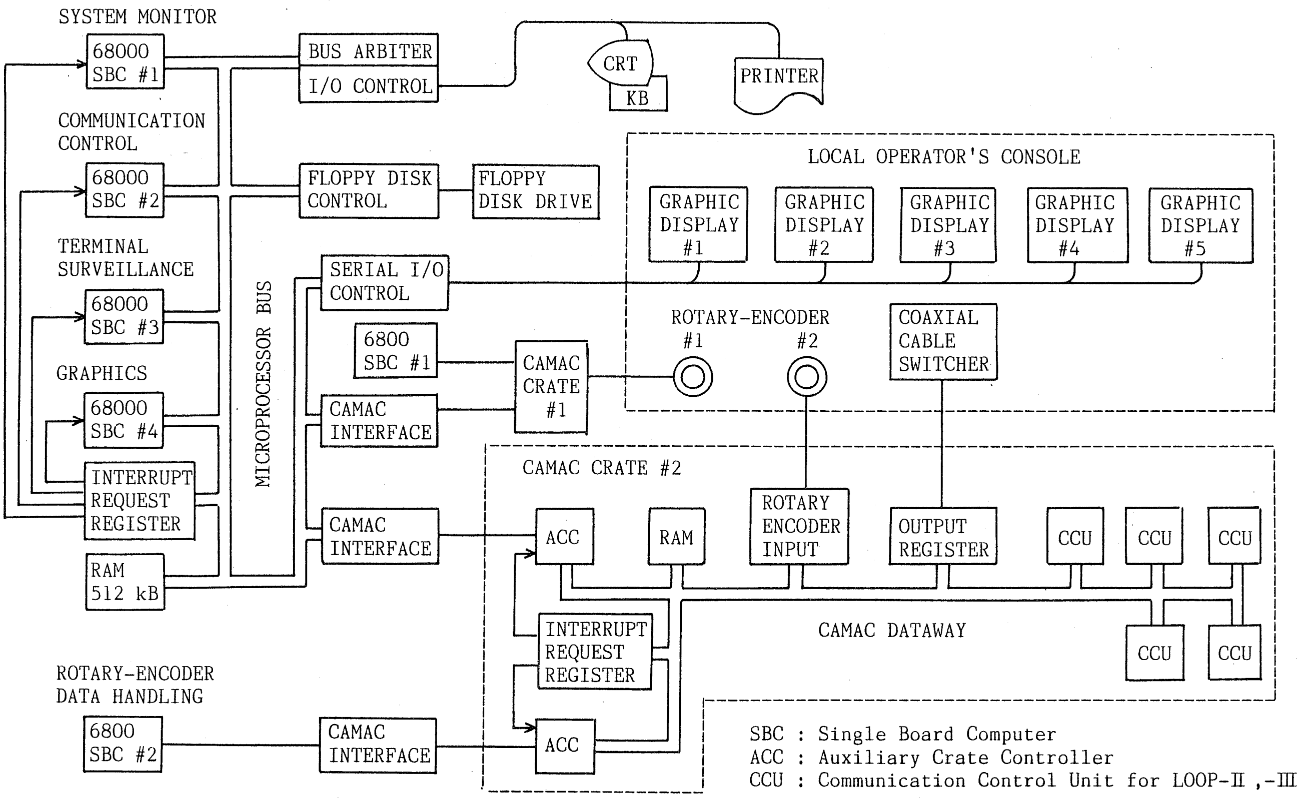

Fig. 2 Block diagram of the multi-microprocessor-CAMAC system for the positron generator.

grams are written in S-PL/H, and some programs are copied from the PF linac control program for minicomputers written in FORTRAN-77. Load modules are written in UV-EPROM's (Ultra-Violet-Erasable Programable Read Only Memory) and mounted on SBC boards. Exclusive usage control of resources can easily be made by 'TEST AND SET' instruction of the 68000 microprocessor.

For system debugging, a test program can be loaded from a floppy disk into common memory on which the program is executed.

Programs for 8 bit SBC's are written in an assembly language and PL/H.

LOCAL OPERATOR'S CONSOLE

The local operator's console in the positron generator subcontrol station is composed of five sets of graphic displays with light pens, two rotary encoders, a few hard-wired switches, etc. as follows.

Graphic Display Current mass production of personal computers enables to construct a high-performance and low-cost graphic display system. A low-end personal computer applicable to the linac control can be purchased at a considerably low price as compared with an advanced graphic display for CAD and CAM. The drawing speed in the personal computer is tolerable except for a few applications like a beam current display in real time. Pictures for every kind of terminal equipments are programed in every personal computer in a BASIC language, and displayed on a CRT screen by executing the BASIC interpreter. This outstandingly facilitates ease of programing. In the local operator's console for the positron generator, five sets of personal computers FM-11 with light pens are used to present information and to input control commands. Pictures are displayed on 14" color CRT's with the resolution of 640 × 400 dots. Four sets of them are built in the operator's console cabinets, and one set with a 10 MB hard disk unit is used on a working desk for program development and terminal equipment test. The message interchange between the subcontrol processor and those personal computers are performed in a hand-shake mode through 4800 bps asynchronous communication lines.

Rotary Encoders Beam focusing and steering magnet current and rf phase in accelerator guides can be controlled by rotary encoders on the operator's console. Number of pulses corresponding to rotation angle is counted by a CAMAC rotary encoder input module and transmitted to selected terminal equipments every 100 ms, if number of counts is not zero.

TV Monitors Four 9" black/white TV monitors are installed in the console cabinets to observe beam profile on alumina screens and to display other pictures. Twenty sets of TV cameras can be switched by the subcontrol processor through a CAMAC output register.

Switch Panel A few hard-wired switches are used for safety interlock and the gun control to keep high reliability.

SUMMARY

Positron generator operation with graphic displays, light pens and rotary encoders is acceptable for the operators who have been experienced in operation of such a system in the PF linac. Personal computers are much useful as graphic display terminals in which picture display programs are executed by an interpreter.

The multi-microprocessor system is adequate to control linear accelerators; it is flexible and can easily be constructed. No complicated operating system is needed for the real-time system.

The positron generator control system will be ready for operation by the end of FY 1984.

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