OPERATION CONTROL SYSTEM OF THE PHOTON FACTORY STORAGE RING

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ABSTRACT

The KEK Photon Factory Storage Ring (2.5 GeV) began its operation by utilizing manual switches and potentiometers to control the equipment in MAR 1982. The Storage Ring came into a new era since the remote control system was completed in JAN 1983 and enabled any operation to be made from the control room.

There are various functions furnished by this control system such as operation of machine, environment protection, personal security, collection of machine status etc. Notable features of this system are the flexibility and programmability to meet system expansion or change of operational modes.

SYSTEM OUTLINE

The control system is organized by three-layer hierarchy consisting of INTERFACE, INTERLOCK and COMPUTER layers (Fig. 1). There are several tens of input and output signals from and to the machine components, radiation monitor, personal protection and interlocked doors.

The INTERFACE layer deals with all the signals converted from or to a standard form that can be processed by a programmable hard-wired interlock subsystem.

The INTERLOCK layer controls all the fundamental sequences of machine operation. It is constructed of NAND/NOR DTL gates.

The COMPUTER layer receives machine status signals via a CAMAC system for the operator's information and logging purposes.

INTERFACE LAYER

The Storage Ring is composed of many components which transmit signals in various forms such as switch closures, analog levels, etc. The INTERFACE layer processes 56 signals to standard formats or conversely send back 7 control signals to the equipment with suitable signal level and formats.

Two types of modules, TRANSMITTER and RECEIVER were designed for constructing the INTERFACE layer. A TRANSMITTER module (TX) converts its input signal from the equipment to the standard signal and then transmits as the status to the interlock subsystem. Conversely, a RECEIVER module (RX) receives commands from the interlock subsystem and relays them to the destination components.

These modules have manual override key-switches on their front panels for maintenance or troubleshooting. The keys are normally unlocked and have no effect on the status or command. For maintenance or emergency recovery, one can stop sending status signals to the interlock subsystem or inhibit any command to the component by locking keys. With a locked key, the interface module goes into INHIBIT state which will be transmitted to the INTERLOCK layer as well as to the mini-computer, and displayed on the operator's console.

The standard signal is specified to be balanced voltage output to a twisted pair and connected to an isolated load to prevent ground loop current. A logical "1" outputs 12 V to a twisted pair, and a logical "0" presents a high impedance state. Figure 2 shows a typical circuit made up of an optically isolated load and a HYB-80, which is a hybrid module developed by the Storage Ring Control Group. The same standard signal is used for a CAMAC in/out register.

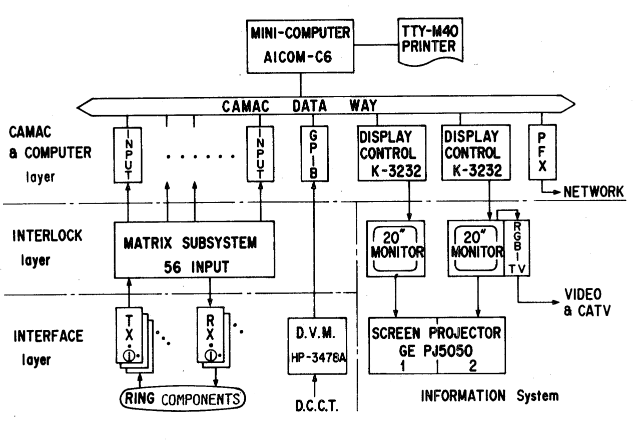

Fig. 1 Block diagram of Storage Ring operation control system.

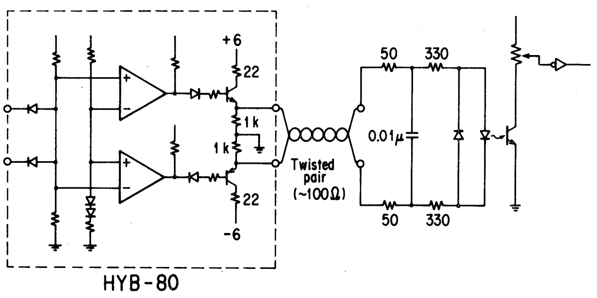

Fig. 2 A typical standard signal circuit.

INTERLOCK LAYER

The INTERLOCK layer is composed of matrix modules and connected to the Main Console Switch Panel (MCSP) for operator's command input (Fig. 3). All Storage Ring operation modes can be entered on operator's request via the MCSP only if safety conditions for the mode are satisfied. If any condition is not satisfied, this subsystem warns the operator with both MCSP display and audible alarm. The MAIN MATRIX module (PF410) encodes 8 different conditions from 64 status inputs by a pin programing matrix. The CHANNEL CONTROL module (PF412) concerns the light source channels. It permits channels to open, confirms if all channels are closed or detects unusual state of channels. The PF304 matrix module includes an 8 × 16 pin programing matrix, an 8 NAND/NOR change-over switch, two 8-input buffers and two 8-output buffers in a double widths NIM case. This matrix module is used as not only for normal NAND/NOR gates but also for FLIP-FLOPs by the aid of module interconnection. The safety condition for each operational mode is encoded from the status of components by the pin programing matrices, and the control signal is created with those module wiring. All the circuit time constants was chosen to be from a few micro-seconds to a few milli-seconds to filter out noise and relay chatter.

Figure 4 shows the diagram of operational modes and states. There are four modes: SHUTDOWN, LINAC ONLY, INJECTION and STORAGE. Each operational mode has one to three states and is represented graphically by a large circle. All permissible transitions are allowed by hard-wired logic and represented by arrows between states. Each transition labelled with a tag in the diagram is brought about by operator's action on the MCSP. In operation, the interlock subsystem waits until all conditions described below the the tag of the

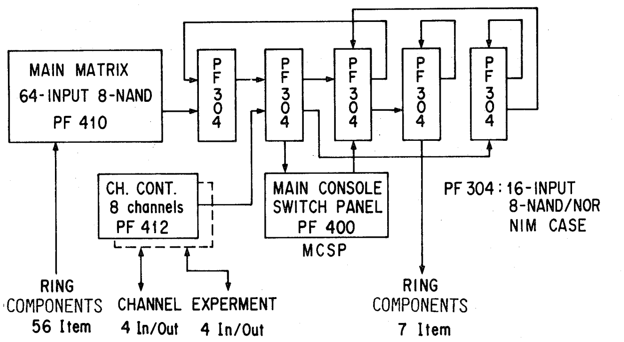

Fig. 3 Schematic drawing of the interlock subsystem. Main MATRIX and PF304 are built with pin programing matrices.

chosen transition are satisfied, then it automatically controls the various components described below the horizontal bar.

The MCSP is shown in the lower half of Fig. 5. It indicates the present state with an LED light and informs abnormal condition in the same state with a blinking LED and audible alarm signal. The operator can tell which transition between states is on by seeing both lighting LED of the starting state and a blinking LED of the ending state.

COMPUTER AND INFORMATION SYSTEM

The Storage Ring operation can be made safely within the two layers described above. However, it is necessary to install a computer to process status displaying, trouble hunting, information displaying and system logging.

The 16 bits mini-computer (AICOM-C6) consists of 1 Mb memory, 40 Mb storage disk, TTY model/40 printer, console terminal and CAMAC branch driver.

The surveillance program of about 2000 lines is written in PFO-BASIC language, which is developed for the Storage Ring control on the computer.

There are two kinds of displaying media. Two 20" color monitors are installed in the console desk for displaying the ring status and information. There are two 1.92 m × 1.44 m large screen projectors on the wall of the control room (Fig. 6). They accept RGB signals or NTSC encoded signals and display the same contents as the monitors. They convenience the people working around the control room for they can be easily seen from any place.

Status Displaying

All conditions of the ring equipment connected into the INTERLOCK layer can be read at any time by the mini-computer via CAMAC modules. The surveillance program maps binary data to proper signal names such as OPEN/CLOSE, ACTIVE/NOT-READY and INHIBIT related to all components. The program prepares display frames for interlock safety conditions and logging summary. There are 11 different display frames: 10 for the states, and one for logging summary. When the operator triggers the MCSP, the program changes the display frame automatically. It takes a few tens of seconds in the worst case to change from one frame to the other mainly due to the overhead of the present operating system as well as the language itself.

Trouble Hunting

When any trouble should happen, the computer makes it easy to locate it and saves a lot time (It would be quite time-consuming work without any computer if one tries to do it by going directly to the INTERFACE layer). The program is always surveying all the status and comparing the current status with the previous one. When any changes found there, it will turn green letters into flashing red ones to inform where the trouble occurred.

Information Displaying

The information frame which is composed by the program contains beam current value, beam current vs. time in a graph form, beam lifetime, and status of the light source channels being used (Fig. 7). The frame starts at the latest injection from the LINAC, and it will be renewed at the start of the next injection.

The frame is also converted to composite video signals to be distributed to other places e.g. experimental area, LINAC control, CATV etc.

System logging

System logging is also included in this program. The logged items are as follows:

1. Date and time of START or STOP of state.
2. Duration of state.
3. Duration of channel opening.

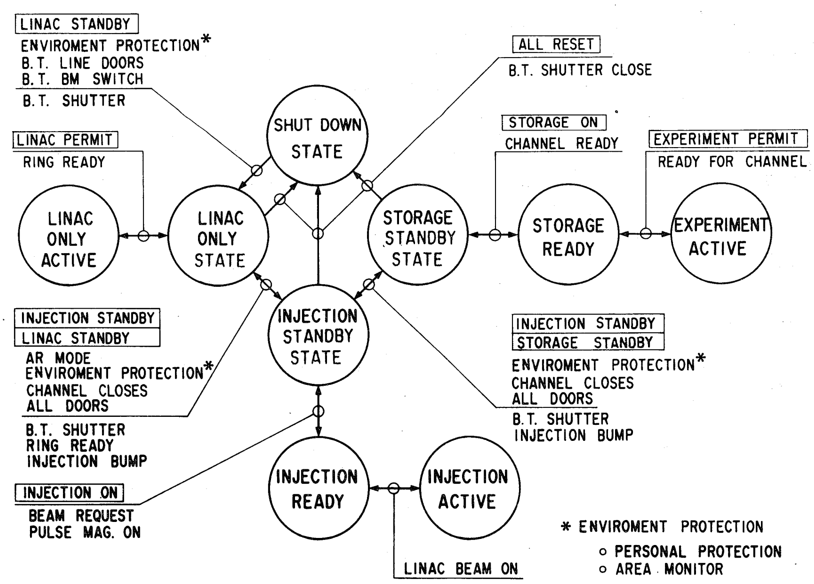

Fig. 4 Operation mode and state diagram. Refer to the main text for details.

Fig. 5 20" color monitor and MCSP on the console desk.

4. Integral beam intensity between injections.
5. Summary of the week's operation.

Figure 8 shows a sample printout of state transition and Fig. 9 shows a summary of week's operation.

SUMMARY

There have been no trouble in the INTERFACE and INTERLOCK layers up to now, but the mini-computer failed at a rate of once in 2-3 months by unknown reason in either hardware or system software. Even then the Storage Ring operation was continued safely without the mini-computer, but the system logging was lost.

In this year, a few changes of the matrix system were necessary because of new legal classification of doors, and an additional state for collaboration use of the LINAC by the TRISTAN Accumulator Ring. They were carried out simply by relocating matrix pins and modifying the software .

System testing and debugging are in progress to send all status via PFX network[1] to the library computer (FACOM M-200) which acquires data into the data base system.

ACKNOWLEDGEMENT

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REFERENCE

1. C.O. Pak et al., "Computer Control System of Photon Factory Storage Ring", presented at this conference.

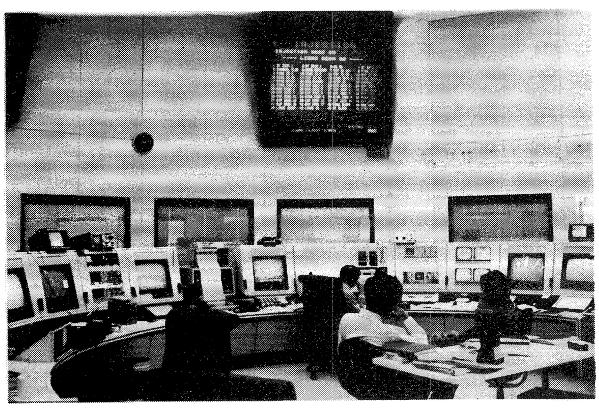

Fig. 6 The Photon Factory Storage Ring control room.

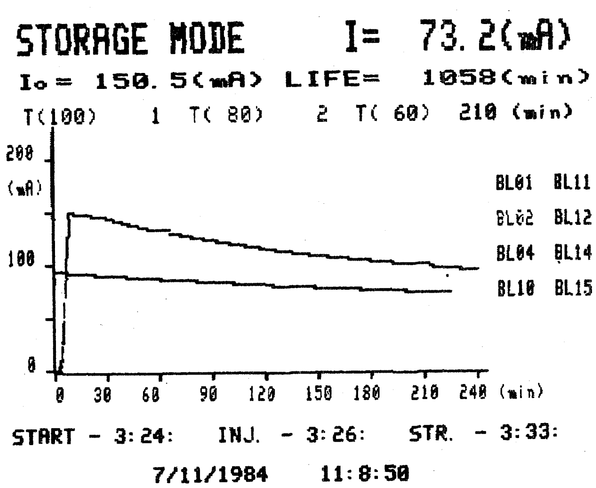

Fig. 7 A typical information frame.

PHOTON FACTORY RING STATUS LOG DATE= 84/07/11 PAGE= 7

MSG.ID	MODE	NAME	TIME	ON.TIME(MIN)	GO.TIME(MIN)	I(MA)	I*H (AH)
55	2	INJECTION MODE ON	02:04:26				
56	2	INJECTION MODE START	02:08:50				
57	2	INJECTION MODE STOP	02:18:39		9.82	126.97	
58	2	INJECTION MODE START	02:32:41				
59	2	INJECTION MODE STOP	02:39:18		6.62	149.14	
60	2	INJECTION MODE OFF	02:40:52	36.43			
61	3	STORAGE MODE ON	02:40:52				
62	3	STORAGE MODE OFF	02:43:02	2.17		125.88	0.03
63	2	INJECTION MODE ON	02:43:02				
64	2	INJECTION MODE START	02:44:42				
65	2	INJECTION MODE STOP	02:46:17		1.58	148.59	
66	2	INJECTION MODE OFF	02:46:29	3.45			
67	3	STORAGE MODE ON	02:46:29				
68	3	STORAGE MODE OFF	02:48:48	2.32		116.70	0.01
69	2	INJECTION MODE ON	02:48:49				
70	2	INJECTION MODE START	02:50:13				
71	2	INJECTION MODE STOP	02:51:01		0.80	119.52	
72	2	INJECTION MODE OFF	02:51:44	2.93			
73	3	STORAGE MODE ON	02:51:44				
74	3	STORAGE MODE START	02:52:40				
75	3	STORAGE MODE STOP	03:24:49		32.15	0.00	
76	3	STORAGE MODE OFF	03:24:49	33.08		0.00	0.06
77	2	INJECTION MODE ON	03:24:49				
78	2	INJECTION MODE START	03:27:22				
79	2	INJECTION MODE STOP	03:33:16		5.90	140.90	
80	2	INJECTION MODE OFF	03:33:35	8.77			
81	3	STORAGE MODE ON	03:33:35				
82	3	STORAGE MODE START	03:57:06				
83	4	EXPERIMENT MODE START	03:57:53				
84	4	BL10 OPEN	03:58:38			143.65	
85	4	BL04 OPEN	03:58:46			147.58	
86	4	BL11 OPEN	03:59:07			143.41	
87	4	BL15 OPEN	04:00:09			142.87	
88	4	BL14 OPEN	04:01:11			142.35	
89	4	BL12 OPEN	04:04:04			140.96	
90	4	BL01 OPEN	09:02:08			83.72	
91	4	BL01 CLOSE	11:29:57		147.82	71.73	
92	4	EXPERIMENT MODE STOP	11:31:20		453.45		
93	3	BL10 CLOSE	11:31:23		452.75	71.65	
94	3	BL11 CLOSE	11:31:26		452.32	71.65	
95	3	BL12 CLOSE	11:31:28		447.40	71.65	
96	3	BL15 CLOSE	11:31:30		451.35	71.65	
97	3	BL04 CLOSE	11:31:32		452.77	71.65	
98	3	BL14 CLOSE	11:31:34		450.38	71.65	
99	3	STORAGE MODE STOP	11:33:57		456.95	0.00	
100	3	STORAGE MODE OFF	11:33:57	480.37		0.00	3.80
101	2	INJECTION MODE ON	11:33:57				
102	2	INJECTION MODE OFF	11:36:23	2.43			
103	3	STORAGE MODE ON	11:37:51				
104	3	STORAGE MODE OFF	11:37:55	0.07		-0.05	0.00
105	1	LINAC MODE ON	11:38:21				
106	1	LINAC MODE STOP	11:39:40		1345.52		
107	2	INJECTION MODE ON	11:40:00				
108	2	INJECTION MODE START	11:44:49				
109	2	INJECTION MODE STOP	11:54:27		9.63	133.25	

Fig. 8 A typical system logging printout.

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*   PHOTON FACTORY STORAGE RING WEEKLY REPORT    *
*                                                *
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OPERATIONS SUMMARY  FROM   07/10/1984    TO   07/14/1984
                           08:54:37           09:16:30

      ******************    PF    ******************

TOTAL OPERATION TIME:     5765.62 (MIN)      96.09 (HOUR)

MODE                    ON TIME                  GO TIME

LINAC            261.13 (MIN)    4.53%  1551.62 (MIN)   26.91%
INJECTION        770.78 (MIN)   13.37%   226.48 (MIN)    3.93%
STORAGE         4733.70 (MIN)   82.10%  4382.14 (MIN)   76.00%

(EXPERIMENT                             4094.07 (MIN)   71.01%)

      ******************   RING   ******************

RING OPERATION TIME:      5504.48 (MIN)      91.74 (HOUR)

MODE                    ON TIME                  GO TIME

INJECTION        770.78 (MIN)   14.00%   226.48 (MIN)    4.11%
STORAGE         4733.70 (MIN)   86.00%  4382.14 (MIN)   79.61%

(EXPERIMENT                             4094.07 (MIN)   74.38%)

      ******************  CHANNEL  ******************

BL10            3876.98 (MIN)   94.70%
BL11            4071.75 (MIN)   99.45%
BL12            4021.03 (MIN)   98.22%
BL15            4043.60 (MIN)   98.77%
BL01            2657.82 (MIN)   64.92%
BL02               0.00 (MIN)    0.00%
BL04            4042.83 (MIN)   98.75%
BL14            2196.10 (MIN)   53.64%

      ******************   BEAM   ******************

THE NUMBER OF INJECTION =          34(TIMES)
TOTAL ACCUMLATE CURRENT =          8.58(AH)
MAXIMAM STORAGE CURRENT =        160.65(MA)
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Fig. 9 A typical summary of the week's operation.