DISTRIBUTED DATA PROCESSING IN THE MICROCOMPUTERS BASED CONTROL SYSTEM

B.B.Dilmukhamedov, A.P.Elin, E.N.Kallistratov, V.V.Komarov, A.A.Matjushin,
A.K.Pudovkin, N.N.Trofimov, Yu.S.Chernousko
Institute for High Energy Physics, Serpukhov, USSR

Abstract: The paper describes the organisation and structure of the IHEP beam ejection control system. The system constitutes a node of local computer network interconnecting 8 microcomputers "Electronica 60" and a minicomputer SM-4. The overall control task is functionally distributed among processors, with micros performing low level equipment-oriented control functions. The application programs written in FORTRAN run in the mini.

The distributed processing in the system is based on the "virtual device" concept. The device consists of the data table and real time routine activated by the process interrupts and maintaining permanent correspondance between the table contents and current process variable values. Network software provides uniform access to all device data tables, thus forming the system wide distributed data base. Application programs in the system have no direct access to the interface hardware. They perform process-oriented I/O via the data base by reading or writting the data tables items.

The IHEP proton synchrotron beam ejection system /1/ is in use since 1972 and all the time has been involved in numerous experimental activities. During the past 15 years current control needs formed a complex of miscellaneous control tools and measurement devices - "manual", as well as working on line with minicomputers /2,3,4/. Many of them are well suited for their purposes, but permanent increase of the equipment complexity and tightening of the beam quality requirements necessitated their integration into the overall control system.

The control system has the primary function of continual monitoring all the vital parameters of the beam ejection system, informing an operator of current process status and signalling them of any parameters that are out of the preset tolerance. The system generated some control signals, particularly in the circuits, where closed loop digital control may be especially effective. Nevertheless, the comprehensive computer control and automation were not goals of the system design. The existing manual control facilities were neither replaced nor bypassed where it gained no significant benefits.

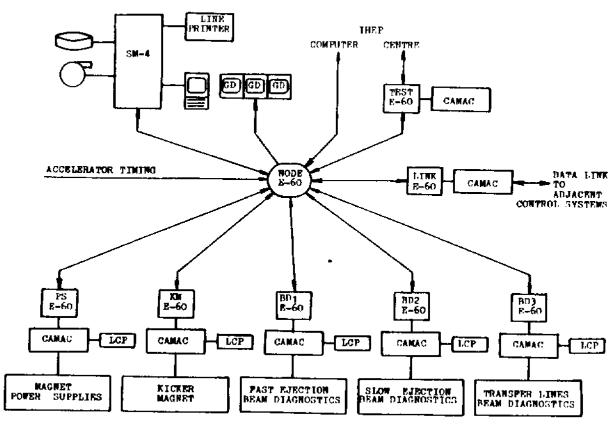

Figure 1. The beam ejection control system layout.

The control system has a star topology with central (node) microcomputer "Electronica-60" (E-60) and 8 peripheral computers: seven micros E-60 and a minicomputer SM-4 (fig.1). Peripheral computers are connected to the node by "point-to-point" duplex serial data links. The data transfer is asynchronous, byte oriented with hardware handshake. The maximum hardware data transfer rate is 1 MBaud. The data line control level protocol operates with formatted blocks of data, up to 1 kbyte long, accompanied by the control code. The data link handling is based on the programmed I/O and involves no DMA transfers. The data block transfer speed is near 5 kbytes/sec or 180 ms per block of maximum size.

Encoded timing signals are distributed from the node together with the data links by separate line of the same cable. The signals are used for synchronisation of the control tasks with the real time of the accelerator complex.

The next higher level of the network protocol deals with messages. The message consists of the header and text. The header includes the source and destination addresses and message type identifier. The network implements logical message addressing. Using the routing table, node computer performs logical to physical address transformation and routes the messages to the destination line specified by the physical address. The data flow control is based on the hardware level handshake and involves no intermediate message buffering in the node. Two classes of the network users are defined in the system: application tasks (AT) and the virtual devices (VD).

The virtual device is the principal concept of the distributed processing in the system. The VD's correspond to some units or functionally closed parts of the beam ejection equipment. VD includes the data table (DT) and real time routine (RT) maintaining permanent correspondence between the table contents and current process variable values.

Each row of the data table describes an elementary piece of the equipment within the VD, e.g. a pick-up electrode in the multichannel beam track monitor or single magnet power supply in the group, supporting beam transfer channel. Row elements of the equipment are pooled in a VD on the ground of functional similarity and identity of their parametric description. In a simple case the data table may consist of a single row. Columns of the data table correspond to the parameters of the equipment. All items within each column are of the same format, dimension and physical (or "technical") sense.

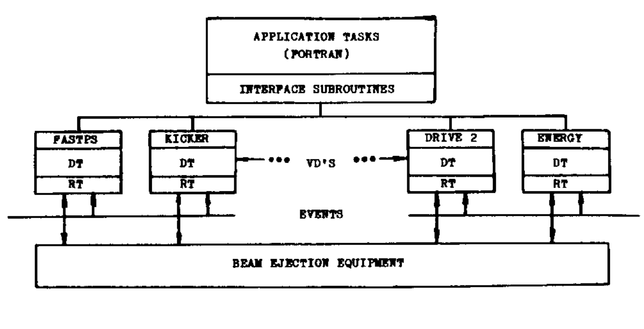

Figure 2. The logical structure of the control system.

The data table structure is defined strictly and uniform for all VD's in the system. The whole set of the data tables forms the system-wide working data base (fig.2). The application tasks in the system have no direct access to the interface hardware. All process oriented I/O is done via the working data base.

Five types of the network messages support application tasks access to the distributed data base:

RR - request to read data from the table;
WR - write request (includes data to be written);
RD - read request acknowledge (includes data requested);
AK - write request acknowledge;
ER - negative RR or WR acknowledge (includes identifier of the error found out in the request message processing).

The normal DT-access sequence includes two message transfers, e.g. RR-RD for reading. The data unit of the access is a DT column. The data tables are accessible by the columns only and only one column may be read or written per request.

The measured access times are (in ms):

TR = 12 + 0.32 * N for reading and
TW = 14 + 0.52 * N for writing,

where N is the number of data bytes read or written.

The figures are gives for FORTRAN AT's executed in the SM-4 under the OS-RV operating system. Typical DT access time is somewhere within 80...100 ms. A somewhat slower write access (as compared with the reading) is explained by the additional time required for write data validity check prior to its actual writing in the DT.

From the 'bottom" DT's are directly accessible to the real time routines. The real time routines are periodically activated by the timing interrupts, normally associated with some "reference" events in the beam ejection system operation. Those are, for example, start of the accelerator cycle, fast ejection, start and end of the slow beam extraction,etc. Encoded events are distributed over all the control system computers. The VD generation procedure includes its connection to this or that reference event. A VD may be connected to more than one event.

The RT functions are defined strictly and limited to:

1) input/output, test and calibration of the I/O channels;
2) conversion from physical to hardware units and vice versa;
3) "within the limits'' control of analog inputs and digital surveillance for status inputs;
4) "templates" - based fault diagnostics: sorting results of (3) above with the "templates" of fault patterns typical for the given device;
5) statistics accumulation in the form of histograms of cycle to cycle parameters distribution.The histogram window, bin size and accumulation time are set by the application task.

"Warning" or "alarm" indicators are set as result of (3) and (4) above. The indicators are part of the VD data structure and may be polled by the application task responsible for alarm processing.

The current system configuration includes 56 VD's, these implementing 194 channels of the "within the limits" control, 104 surveillance channels, 14 channels of the templates-based diagnostics and 119 channels of the histogram statistics. The total size of the VD's data tables in the system is 29 kbytes.

Physically VD's reside in the microcomputers (PS, KM, BD1, BD2, BD3, LINK, see fig.1) in such a way, that each of the micros forms a functionally closed and relatively autonomous subsystem. The most important of them are five "technological" subsystems;

PS - control of the beam ejection and beam transport channels magnet power supplies;
KM - kicker magnet control;
BD1 - fast ejection beam diagnostics;
BD2 - slow ejection beam diagnostics;
BD3 - transfer channels beam diagnostics.

The autonomy of the subsystems is supported by the local control panels (LCP). The LCP consists of small graphics display and 16 button programmed functional keyboard. With LCP an operator can look through the data tables and change, if necessary, some device parameters.

The LINK subsystem performs the data interchange with adjacent control systems: those of the ring accelerator and secondary beam transfer channels/5/.

The microcomputers software has been designed at the mainframes of the IHEP computer center and debugged at the special test and debugging microcomputer (TEST, fig.1). It is written completely in PL-11 language /6/ and includes about 30000 lines of the source text. Executable files of the debugged microcomputer programs are sent from mainframes down to the SM-4 disk memory. In normal operation, the SM-4 is the bootstrap source for microcomputer, having no local program loading devices.

All application tasks are written in FORTRAN and executed in the SM-4 under the OS-RV operating system. A set of FORTRAN callable subroutines has been designed to simplify application task interfacing to the distributed data base and support graphics display output.

The control system, as described, has worked successfully in 8 physics runs of the accelerator.Main efforts at present are put in application software design and development, which is done mainly by direct users of the system: specialists of the Beam Ejection Operations Service.

References

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