THE COMPUTER CONTROL SYSTEM FOR THE SPS

J.T. Hyman

CERN Lab II, Geneva, Switzerland

Summary

The aim in the design of the control system for the SPS has been to give the operators and machine physicists an integrated system capable of providing sophisticated control facilities but yet retaining simplicity of use for normal operations.

Twenty four minicomputers are used in the system with CAMAC input/output and a fast multiplex system to provide the interface to the SPS equipment. The inter-computer communication is over serial data links through a store and forward message transfer system.

The software is based on the use of an interpreter in conjunction with a small real-time executive. A comprehensive addressing scheme, with segmented data tables is used in preference to a large monolithic structure.

Introduction

Two factors influenced the design of the computer control system, namely, the physical size of the machine - with the large number of pieces of equipment to be controlled and the determination to liberate the power of modern computers from the past software barrier at the user level. Figure 1 shows the phsysical layout of the site and gives an idea of the distributed nature of the control system.

Experience elsewhere had demonstrated that the use of Interpretive software (where source statements are interpreted directly at run-time and not pre-compiled or assembled) would do much to provide the flexibility needed for the commissioning, machine development and operational phases of the machine[1]. By careful consideration of all the steps involved in the software,it has been possible to provide an extremely powerful but easy to learn and use control language - NODAL, which retains good real-time response through the use of assembly language programs for critical operations.

In all, 24 modern 16 bit computers (NORD-10 manufactured by Norsk Data Elektronikk, Oslo) are distributed around the site. Each is connected via a fast serial data link to a packet switching message transfer system employing a further NORD-10 computer. Some of the computers perform specific functions while others provide general control and surveillance facilities. A simplified diagram of the system is shown in figure 2 and the functions listed in Table 1. The hardware and the software have been developed very much in parallel to the benefit of both the two disciplines and the rate at which implementation has been possible.

Table 1

Computer	Core(k)	Drum(k)	Other Periphs.	Function
GP1 - 6	16	64	TTY, VDU	General Acqisition and control in BA's
Extraction North/West	24	128	TTY, VDU PT-R/P MT cassette	Control of Extraction systems
Power Supply	24	128	TTY, VDU PT-R/P MT cassette	Control of Power Supply & Function Generators
Radio Frequency	24	128	TTY, VDU PT-R/P MT cassette	RF system
Beam Line North/West BA80/WRB2 Injection	16	-	TTY	Control of Primary Beams
BA81	16	64	TTY, VDU	Control of North Expt. Area. User Interface
CPS	16	-	-	Interface to CPS
Console	24	-	-	Console and Operator Interface
Display	16	-	Special Character Controllers Printer	Display Generation
Alarm	16	256	-	Analysis of Alarms
Service	64	2 x 512	2 X Discs TTY, VDU PT-R/P Printer M. Tape	Number Crunching Program Development
Library	16	2 x 512	2 X Discs	System Library Data Bank

Hardware

Several features of the NORD-10 make the computer particularly suitable for the SPS application[2].

i) fast microprogram including all operator communications and floating point operations

ii) availability in a range of sizes from 8K up to 64K words of core store

iii) separate internal and fully buffered external input/output busses - the latter with full interrupt facilities

iv) full set of operating registers for each of the 16 hardware interrupt levels - context switching in 1.5 μs.

v) the ability to have a large number (512 theoretically!) of true cycle-stealing DMA channels (1 M word/second interleaved throughput)

vi) good well proved software (compatible with the earlier NORD-1)

These computers are interfaced to the SPS equipment in the manner shown in figure 3. The primary interface is provided by CAMAC using a crate controller interface developed by CERN in collaboration with the computer manufacturers[3]. The controller provides direct vector addressing of interrupts, DMA (with an additional module) and an Autonomous Function Control (allowing traffic on the CAMAC crate dataway independent of the computer). Some SPS equipment is controlled and read directly by the CAMAC, notably the fast beam monitors. All interrupts from the SPS equipment pass via the CAMAC system. Both commercially available CAMAC modules and specially designed ones are used.

All other equipment is connected via a secondary interface in the form of a General Purpose Multiplexer, designed by CERN, and controlled itself by four CAMAC modules as shown in figure 3[4]. A basic concept of the multiplexer is that of having one module to provide all of the setting and monitoring facilities necessary for the full control of the piece of equipment connected. By careful choice of the number of different on/off controls, digital acquisition words, analogue acquisition channels and status check bits for each module design, the number of different types has been kept below 20. The modules use photo-coupler or reed-relay outputs to eliminate unwanted earth loops. As distinct from the CAMAC system, where the plug-in module address is associated with its position in the crate, the multiplex modules carry their own local (i.e. within a crate) address decoders. Serial transmission at a rate of approximately 1 M Baud over twisted pairs is used between the MPX Control Units and the remote stations. The distribution of general timing signals (derived from SPS Event + N ms delay) is also conveniently performed through the G.P. MPX[5].

The only control circuits between the various buildings, apart from those required for synchronisation between the SPS and its injector (the CERN PS) and those for the power supply, are provided by the Data Links and Message Transfer System. To provide adequate security in the transmission both cross parity checks within each word and longitudinal parity (checksum) techniques are employed. The data link for each computer uses two quads (a video pair + an audio pair in each direction) of a 6 quad or pod cable (of the type used for domestic television distribution). Data is carried in serial form over the video pairs, leaving and entering the computers via DMA. There is a handshake for each block of data together with other control information over the audio pairs using PI/O computer entry and interrupts. Facilities are provided in the system, using the hardware operator communication of the NORD-10 micro processor, to bootstrap the remote computers from the central library system.

In addition to the hardware described above, the operator interface in the Main Control Room uses some special devices. The operator interface is described in a separate paper presented at the Conference[6].

Software

Very great store was placed on the availability of good basic software when the choice of computer was being made. Specific requirements for the system were stated as:-

1) A sophisticated monitor supporting assemblers, interactive editor, linker etc.

2) A small real-time executive capable of accepting input for scheduling tasks from programs running under its control.

These two requirements are satisfied by the NORD-10 software in the form of TSS - a multi-user time sharing system and the SINTRAN II real-time executive, which is capable of working with a drum system or in a core-only environment. All of the relevant SINTRAN commands are available from NODAL so that program scheduling can be carried out on-line.

NODAL itself has been developed at CERN and has a powerful set of commands[7]. These can be used either:-

a) Immediately -

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SET MBV(2) = 154
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which will set the current in Vertical Bending Magnet 2 to 154 amps.

b) Programmed -

```
1.1 FOR INJPHS = 5,15;DO 2
1.2 END

2.1 TYPE INJPHS
2.2 TYPE BCT(4)!
```

which will type the reading of Beam Current Transformer 4 over a range of INJection PHase. Comprehensive mathematical functions are available and special commands exist which allow one computer to send a NODAL program to another computer and for this latter to send back the results of running the program received.

In the examples, MBV, INJPHS and BCT are the names of system variables and are used by NODAL to find entry into the appropriate Equipment Subroutines. These subroutines are written in assembly language and each contains its own data table (with entries for property of interest i.e. nominal value, current value, status etc). One equipment subroutine can be used for all equipment of the same type. By avoiding a large monolithic data base, it is possible to add new equipment to the system with the minimum of trouble and without changing what already exists and is proved.

Considerable thought has been given to the detailed way in which access is achieved to the required piece of equipment. An equipment numbering scheme has been developed where information redundant to later addressing operations is replaced successively by further data. This scheme has made possible full unambiguous addressing of all equipment throughout the SPS within the 16 bits available. Data table accesses are reduced to simple indexed operations[8]. The equipment subroutine approach and the addressing scheme are shown in outline in figure 4.

To provide the necessary program priority, two main task buffers are provided in the NODAL-SINTRAN SYSTEM. The lowest level buffer is provided for interactive use while the second is for system programs. A third small high priority buffer is provided for immediate commands passed down the data links. In addition to programs written in NODAL, assembly language programs can be run directly under SINTRAN with, in computers with drums, swapping of core-loads.

Two schemes will be used for surveillance of the SPS. The first of these will be the normal periodic scan which will be implemented as time initiated tasks (either NODAL or assembly language) under SINTRAN. The second will use a special DMA scan facility built into the G.P. MPX. This latter scan will soak up any idle time the computers have. Any errors discovered from either of the scans - or from program errors detected by the NODAL interpreter will be noted in an Error "Bucket". This will be sent to the Alarm computer once per machine cycle (or when full).

The Message Transfer System software is designed to be completely transparent to the users and to allow any computer to communicate with any other[9]. Messages will be divided into 64 word blocks to facilitate coupling to the overall and local filing schemes. Each block will be preceded by a 4 word leader as shown below.

Source Computer	Destination
Priority	Word count
Directive *	
Program Name	

* Directive gives information to destination computer as to type of message.

The whole MTS works on a store and forward principle and will look to each satellite computer rather like a mag-tape unit (with about the same data rate). The MTS software will run under SINTRAN and programs will be available for traffic analysis.

The software for the operator interface has been designed in such a way that the maximum use is made of the NODAL-SINTRAN system used in the remote satellite computers. The "drivers" required for the special interface hardware are implemented as either NODAL functions or as CALLS to assembly language subroutines.

References

1. K9 Computer Software System - P. Adams RHEL/R240 Rutherford Laboratory, Chilton, Didcot, England.

2. NORD-10 Reference Manual - A/S Norsk Data Elektronikk, Oslo.

3. A multicontroller Approach to CAMAC for the SPS Control System - M. Collins, R. Rausch CERN report Lab II-CO/73-1

4. G.P. MPX Equipment for Analogue and Digital Acquisition and Digital Command for the SPS Computer Control System - R. Rausch, J.M. Sainson, R. Wilhelm CERN report Lab II-CO/73-2

5. The SPS Timing System - C.G. Beetham, R. Rausch CERN report Lab II-CO/Int/CC/74-2

6. The Operator Interface of the 300 GeV Accelerator - F. Beck, This Conference Publication No. 7-14.

7. Preliminary Programming Information for the SPS Control System - J.T. Hyman, G. Shering CERN report Lab II-CO/Int/CC/73-5

8. System Variables - M.C. Crowley-Milling CERN report Lab II-CO/Int/OO/73-8

9. Technical Specification for the Data Links and Message Transfer System for the SPS (Amendment) CERN Lab II-CO/SPEC/73-18

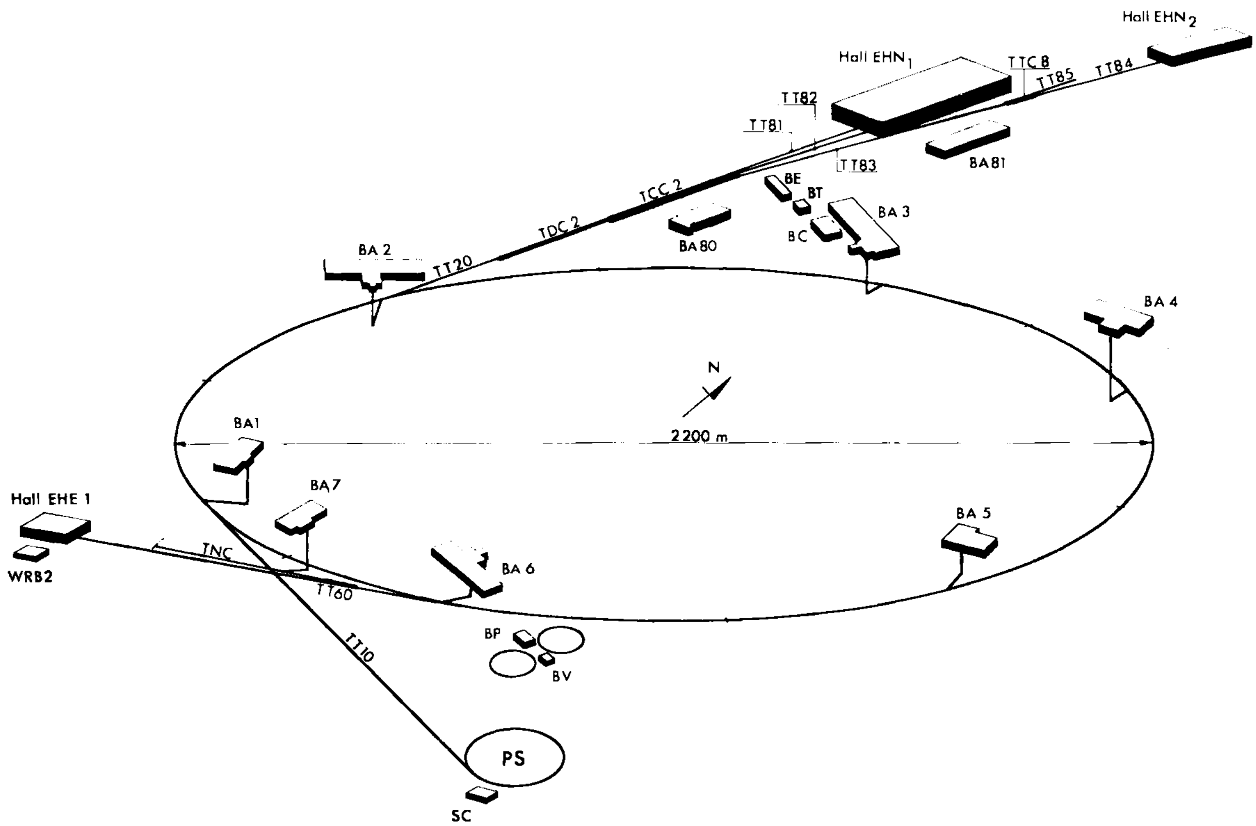

FIG. 1 SPS SITE LAYOUT

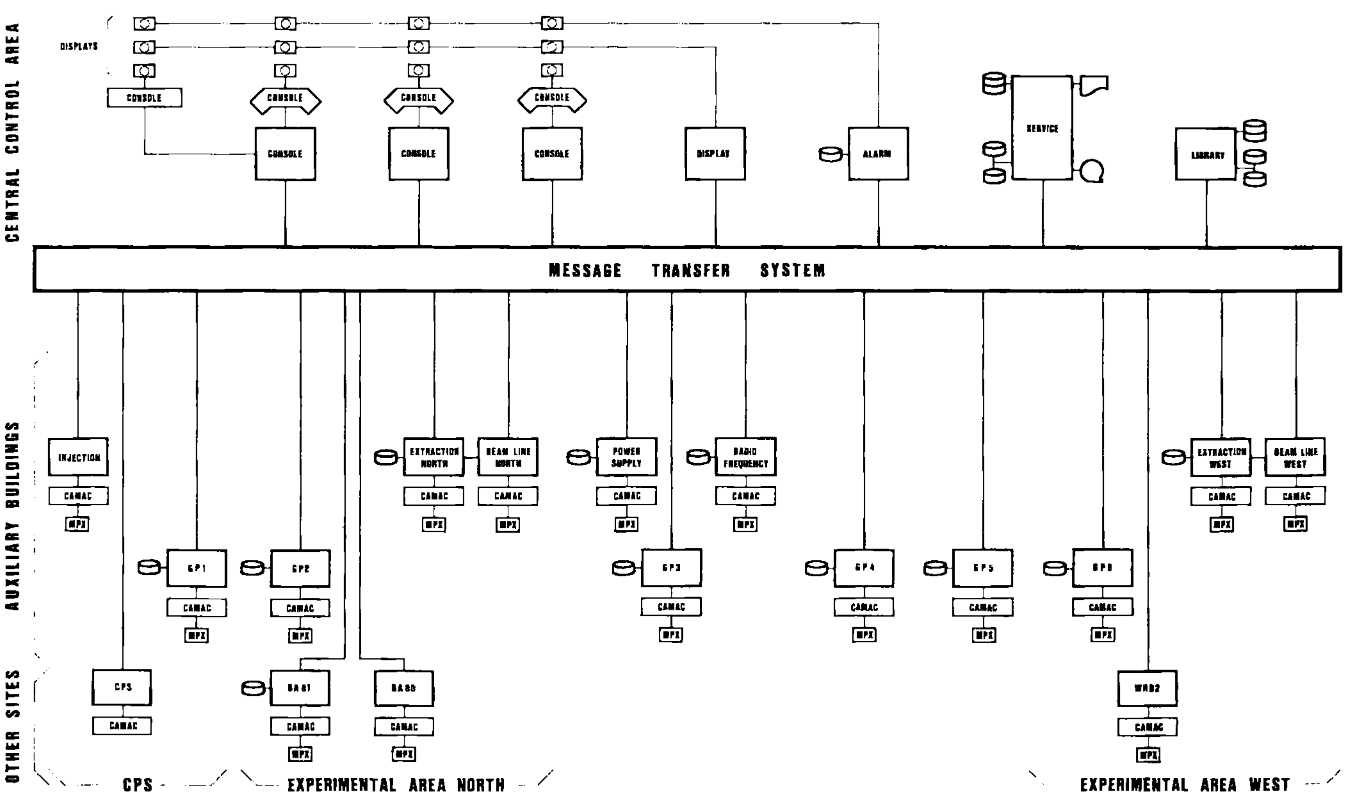

FIG. 2 SPS CONTROL COMPUTERS

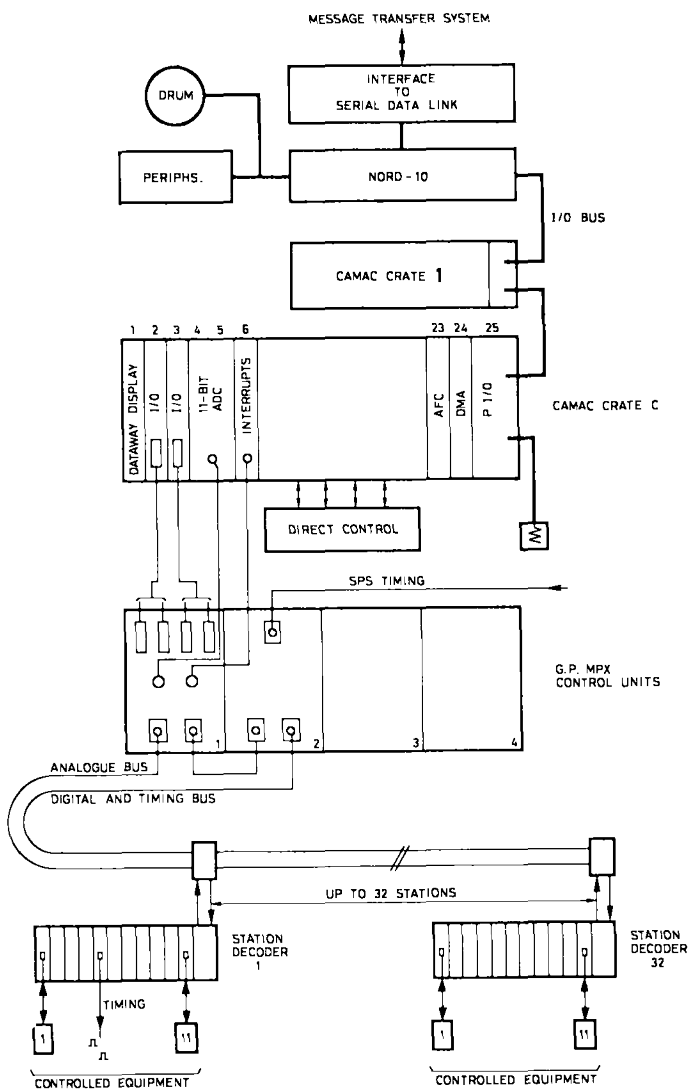

FIG. 3 COMPUTER / SPS EQUIPMENT INTERFACE

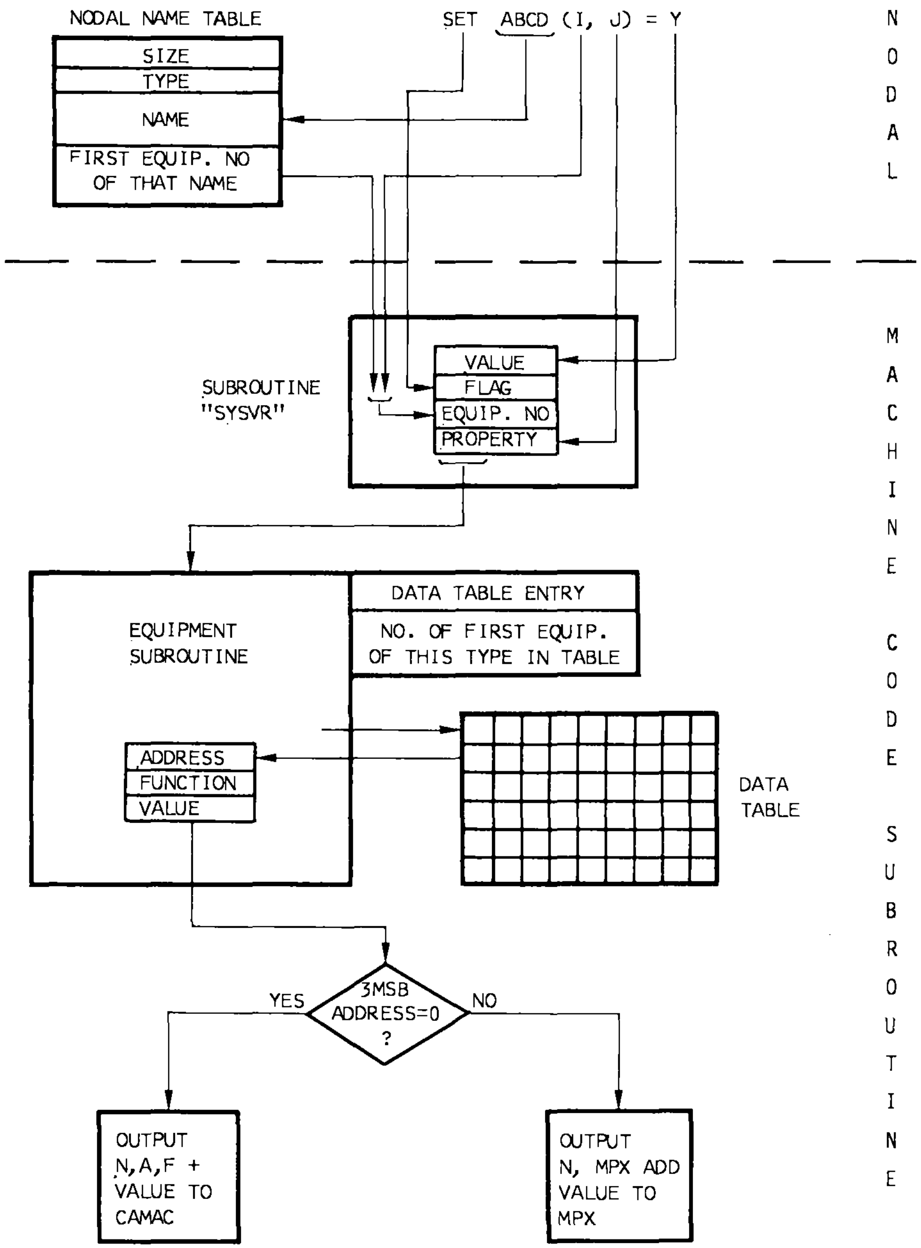

FIG. 4 EQUIPMENT SUBROUTINE APPROACH