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MICROPROCESSORS HELP IN CONTROL AND BEAM OBSERVATION AT THE CERN PS BOOSTER

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Summary and Introduction

Many applications requiring either the transfer of large amounts of data for simple processing or the repetition of real time calibration of equipment are not easily or rapidly implemented with the present PS computer system, without restricting other uses of the computer The availability of MOS microprocessors now allows local data processing in the equipment, supplying final results to the central computer system.

The microprocessors (μP) and their peripheral circuits are housed in CAMAC modules to be compatible with the equipments now built in CAMAC technology. The μP module acts as an auxiliary CAMAC controller. The CAMAC crate is linked to the central computer system through a conventional crate controller*.

In one application a microprocessor is used to reduce the amount of data to be collected by the central computer system from some 7000 words to 60 thus enabling the continuous monitoring of the shunt current of 60 pulsed magnet power supplies. Consequently a standard computer program dealing with only one parameter per power supply can be used for pulsed power supplies as well.

In another application a calibration and linearization system is being designed to improve the operational characteristics (pulse-to-pulse intensity modulation[1], wide range) of the existing hardware used for the acquisition of the beam intensity in the PSB injection line.This technique will eliminate the need for a complex calibration programme and will allow the extension of the general display facilities within the present computer system.

PSB multipole varilog

Varilog for pulsed power supplies

The pulse-to-pulse stability of DC power supplies is monitored by a program called VARILOG which compares the actual value of the shunt current to a reference value stored in the computer. Pulsed power supplies cannot be monitored through a single amplitude measurement at a fixed time within the machine cycle. To cope with this difficulty the use of a microprocessor has been proposed in the new PSB multipoles[2,3,4] power supply control system to measure the shape of the function produced by each of the 60 power supplies. In this application it is known that a simple area measurement will give a good approximation of the function, but requires the acquisition of some 7680 values (128 samples/power supply) each Booster cycle.

With a serial crate system, each acquisition takes approximately 50 μsec, and therefore the total transmission time would be nearly 400 msec, which represents a large part of the Booster cycle. By introducing a microcomputer facility locally, in the CAMAC crate responsible for monitoring the power supplies, it is possible to perform all the necessary calculations to obtain the areas and then only transmit 60 values.

This microcomputer facility is in the form of CODOC 1 [4] and its interface to CAMAC, which acts as an auxiliary controller. Such an 'intelligent' auxiliary controller in the CAMAC crate also allows us to perform equipment status monitoring and provide this information as data to be acquired by the central computer.

Hardware implementation

A block diagram of the monitoring system is shown in Fig. 1 and consists of three multiplexers, an A/D converter, and the auxiliary controller is to set the multiplexers to the required address and read the digitized data from the A/D converter. This is repeated 128 times for each power supply during the Booster cycle, commencing at STBI (STart Booster Injection)and finishing before EBC (End of Booster Cycle). See Timing system for the PSB[5].

The equipment to monitor these supplies is in two CAMAC crates at diametrically opposite sides of the Booster ring, with each crate controlling 30 supplies. The multiplexer and A/D converter with memory are also used by another acquisition system once per cycle so that the auxiliary controller must be informed when the equipment is not available (by a BUSY signal). Further, the CAMAC crate is also used ∿ 30 times/cycle for the transmission of the digital scale factor to the D/A driving the power supplies. The microcomputer must therefore be interrupted if it is in the process of using the dataway when the controller also requires its use. These two interrupts are the only change in context of the task required during its otherwise simple operation.

To control the multiplexer and A/D converter[6], a daisy-chain connection of the equipment is required, such that on writing (F(16)A(Ø)) an address to an MPX (or an increment function F(25)A(0)), the A/D converter will also be triggered. The hardware internal to the A/D copes with the necessary set-up time of the MPX address before triggering the conversion. Also, in this configuration, when writing to one multiplexer the others are automatically cleared, and incrementing one multiplexer until overflow occurs will cause the next MPX in the chain to be incremented. Thus by only controlling the first multiplexer, the analogue signals on all the multiplexers can be accessed. The only time the other two multiplexers need to be accessed directly, in the multipole varilog, by the auxiliary controller, is after an interrupt by either CAMAC or the BUSY signal.

Software implementation

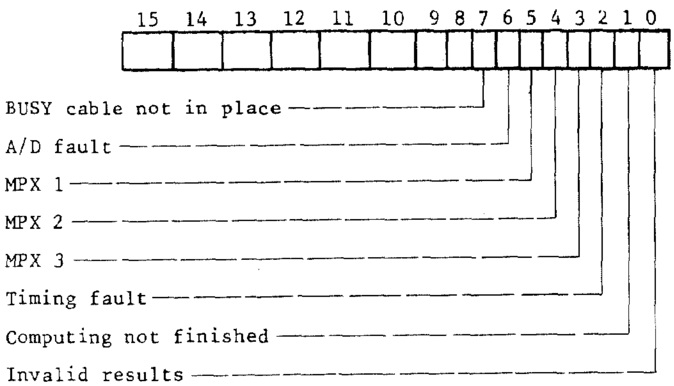
The software to perform this varilog resides in PROM memory on the CODOC 1 module and is written in the ASSEMBLER language of the INTEL 8080 microprocessor. The development of this program was performed on the INTELLEC 8/MOD 80 MCS, PDP 11/45 [7] development system which was acquired by the Booster group for this purpose.

As mentioned previously, the task is to acquire 128 samples from the power supplies during each Booster cycle, calculate the area, and supply these results as integer values (range 0-32768) to be acquired by the central computer. A status word will also be generated by the program, which will give the validity of the results and the status of the equipment controlled by the

* A custom designed crate controller is installed at present, a serial controller will be implemented later.

task.

There are seven possible errors that may occur during the operation of this varilog program, and this information will be placed in a status word to be acquired by the central computer along with the results. The definitions of the status words and the errors are:



If the cable for the BUSY signal is not in place, the program will not commence and this error bit (7) will be set. A timing fault will occur if the program is interrupted too many times during one Booster cycle, as the rate at which the power supplies are sampled will be too unevenly spaced leading to unpredictable results. The 'Computing not finished' error bit is set at the beginning of the program and is only reset when the results are available to be acquired by the central computer. Finally, the 'Invalid result' bit is of course just the OR of all other bits (the A/D and MPX faults are not yet implemented).

To acquire the results from CODOC 1 in a single step mode, the following sequence of operations must be performed by the central computer:

i) Perform the CAMAC command N(9)A(3)F(16) with data = $FBFF_{16}$ (hexadecimal): this operation puts the microprocessor in the HALT mode and loads the DMA address register with 0400_{16}; it also reads the first result into the CAMAC READ register in CODOC 1.

ii) Do the CAMAC command N(9)A(1)F(0) (read result) 31 times to read the 30 results and the status word.

iii) The final command is to remove the hold signal from the microprocessor; CAMAC function is N(9)A(2)F(16) and data = 0.

Present state of realization

A complete microprocessor set has been made and debugged in one CAMAC crate measuring and monitoring 30 power supplies. The second crate will receive the same facilities soon.

Calibration of injection current transformers

Problem to be solved

The second application of a μP differs from the first: its purpose is to improve an existing measurement system. The injection current transformer system (ITR) is used to measure the number of protons injected into each of the PSB's 4 rings and by comparison with measurements upstream of the distributor the injection efficiency is calculated. The measurement range is from 2×10^{11} to 2.5×10^{13} protons per ring and the desired accuracy is $\pm 1 \times 10^{10}$ protons $\pm$ 0.5%. The original equipment was made with 4 ranges and an automatic calibration procedure was incorporated to be executed by the central computer. With the introduction of Intensity Modulation certain inadequacies became apparent and proposals were made to overcome the difficulties. The favoured solution incorporates a μP to treat the measurement and calibration data.

To eliminate the problems of range switching, but still maintain the accuracy, regular calibration is being introduced. In essence the analogue system remains unchanged except for increasing the dynamic range of the integrator. Offset and non-linearity errors are minimized by selecting 2 calibration pulse values, one each side of the measurement and treating the calibration and measurement data in the μP. The calibration pulse generator is the principal source of error but this can be kept very small. In addition to calculating the number of protons, the μP can be used for calculating the injection efficiency, piloting a local display, and equipment monitoring.

The μP will be an INTEL 8080 housed in a CAMAC module. An 'Interface Unit' will be used to link the μP with the measurement equipment and data exchanges between the interface and μP will be via the Dataway. All the CAMAC norms will be respected enabling the remaining space to be used for other CAMAC functions. Data transmission from the measurement system to the Interface will consist of 16 bits, 12 measurement 3 for identification and 1 for the sieve.

Proposed system

A block diagram of the proposed system is shown in Fig. 2.

The analogue signals from the transformers will be transmitted and amplified by the existing equipment, but the integrators and sample-and-hold circuits will be improved to allow better resolution. The data stored in the eight sample-and-hold units will be switched into the ADC through an 8 to 1 FET multiplexer. With a 5 volt full scale range for 2.5×10^{13} protons, the MSB of the 12 bit convertor will correspond to 1.28×10^{13} protons, and the LSB to 6.25×10^{9} protons.

By means of the local selection switch measured values of the number of protons, or the efficiency or the calibration pulse may be displayed. Even when no beam is available the calibration pulses may be selected manually. These features will help fault detection and off-line checking of the equipment.

The program to calibrate the transformers and calculate the injection efficiency will be written in INTEL 8080 assembler language, using the μP development system described in Ref. 7. The total time required to perform this data processing will be in the region of 200 msec, the majority of the time being taken by the floating point calculations. Sufficient time is, however, left for the μP to update the local display and for the central computer to acquire the results.

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4. For details, see CERN Internal Notes PS/BR by P. Horne.
5. G. Gelato, Private communication.
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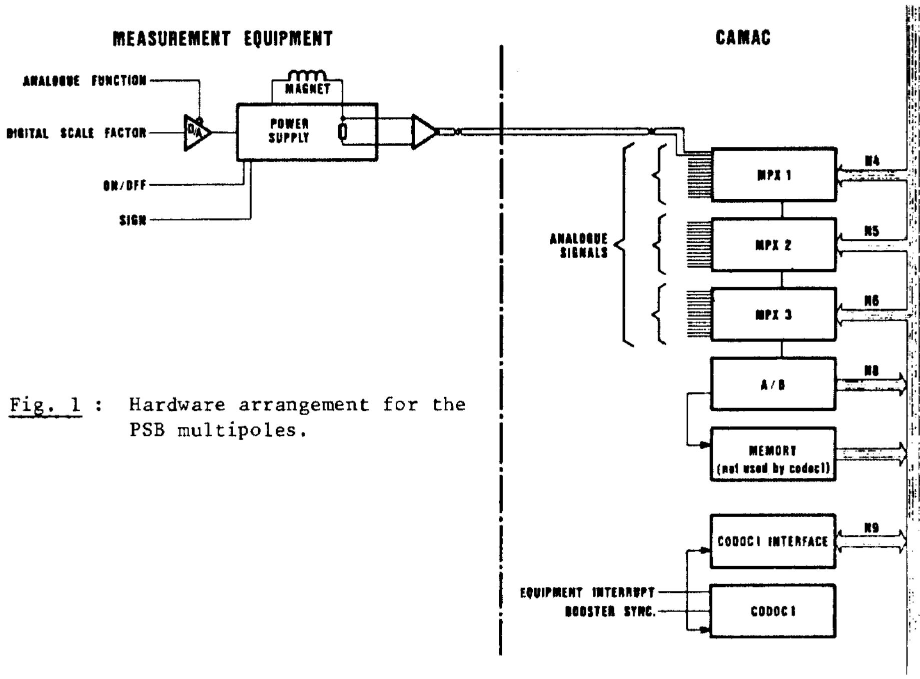

Fig. 1 : Hardware arrangement for the PSB multipoles.

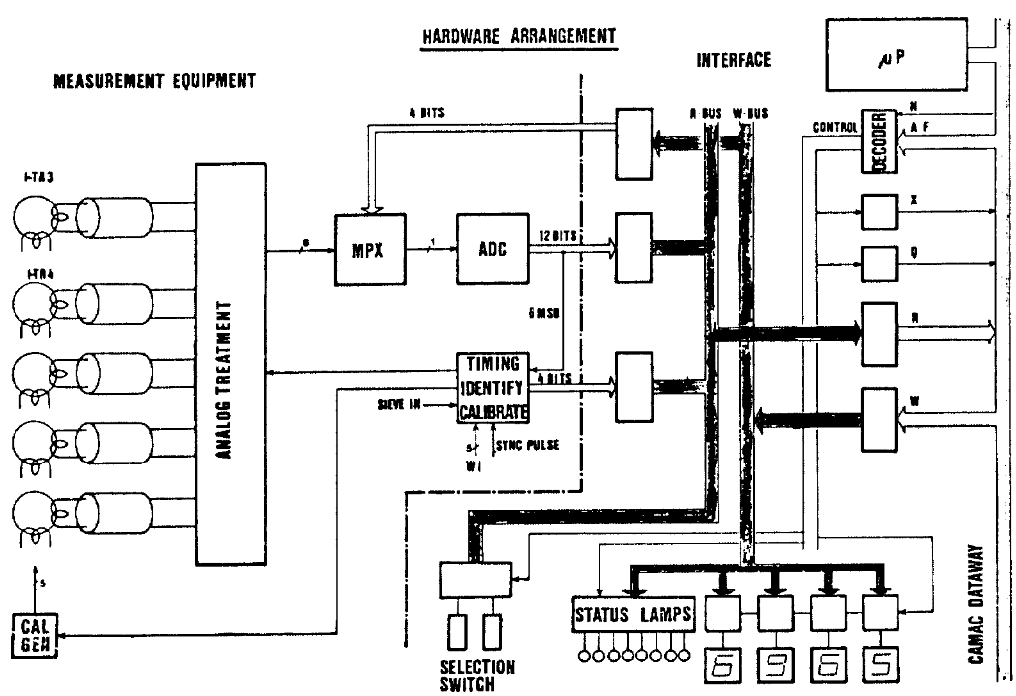

Fig. 2 : Hardware arrangement for the injection current transformers.