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FAST SYNCHRONOUS BEAM PROPERTY MODULATION USING A LARGE DISTRIBUTED MICROPROCESSOR SYSTEM

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Summary

One of the design objectives of the new CPS controls system is to permit changing the setting conditions from one machine cycle to the next in order to serve different users with different beam properties. Cycles may be as short as 650 ms and for the PS Booster (PSB) about 1000 parameters may have to be refreshed each cycle. This task is handled by 20 microprocessor-based Auxiliary CAMAC Crate Controllers (ACC).[1] This layout offers three major possibilities:

(i) fast and reliable parameter refreshment in each cycle;
(ii) the microprocessors constitute a distributed database, which allows autonomous execution of complicated tasks triggered by simple commands from the process computer;
(iii) the microprocessors allow complete decoupling between the severe process real-time constraints and human interaction: asynchronous operator commands are executed in a precise synchronous way with the process.

Introduction

The realization presented has been developed within the framework of the new CERN PS control system.[2,3] This system will permit the control of the PS Booster, the PS, the Antiproton Accumulator, and the Linac complex, as well as the injection and ejection beam lines concerned, all from one single control room.

The ongoing control improvement program is meant to alleviate operational and maintenance problems and to make expansion and growth of the accelerator complex possible in a straightforward and convenient manner.

The layout and the topology of the computer system is based on a ND-10/100 minicomputer network[3] and a serial CAMAC interface. Fig. 1 shows how the PSB front-end computer communicates with the process.

At the time of writing, in addition to the whole computer network, the CAMAC interface, the consoles, and the application programs frame, the first package of this project has been implemented; it concerns the PSB with its injection, ejection and measurement lines. The control of the accelerator, i.e. the acquisition and the control comprises about 1000 parameters, whose working values have to be adjusted separately from one of the five operator consoles.

Up to eight different beams for different users may be programmed in a sequence, called supercycle, and the operation mode is called pulse-to-pulse modulation (PPM).

As a consequence, eight different setting values must be foreseen for each parameter. For that, two mechanisms have been developed. The first one grants refreshing of all values set for each cycle in the supercycle; the second one allows the operators to adjust parameters only for one selected cycle without interfering with the other cycles.

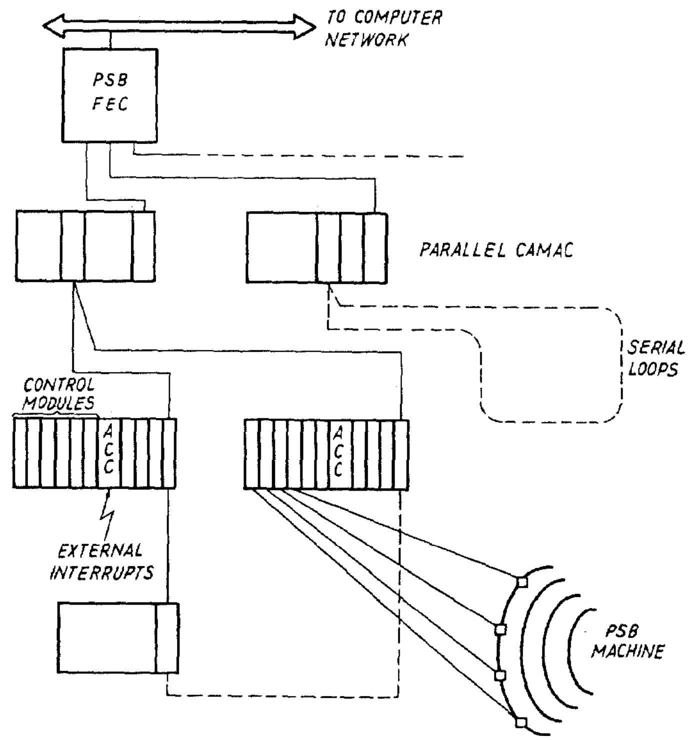

Fig. 1 INTERFACE BETWEEN COMPUTER AND ACCELERATOR

Real-time and System Constraints

The Real-time Constraints

A possible sequence of machine cycles within a supercycle is shown in Fig. 2.

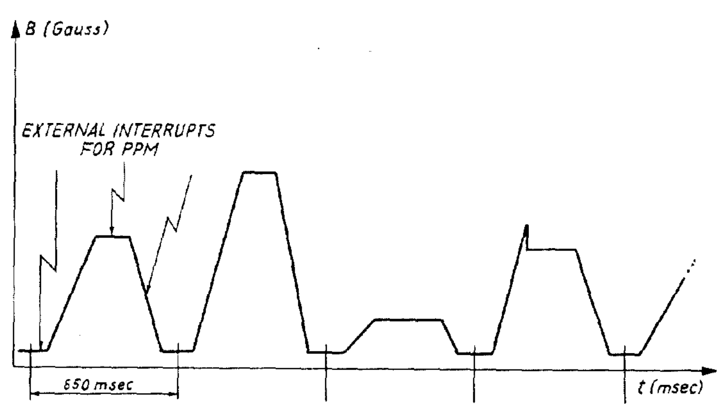

Fig. 2 EXAMPLE OF ACCELERATOR CYCLES

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A cycle can be as short as 650 ms and up to a few seconds. In general the control action required to set the accelerator parameters to their working values, consists in sending a certain number of data per parameter to the specific equipment. In most of the cases this action must take place before the start of the cycle concerned: this will permit the correct setting at the moment when the proton beam arrives. But a certain number of problems exist:

- Some injection and ejection magnetic elements are of the capacity discharge type: the capacitors require up to 600 ms to reach their full charging value. In case of short cycles (650 ms) this implies that the control system must refresh the setting values for the next cycle inside time windows as short as 30 - 50 ms. Moreover, this action must be executed twice, once per cycle for injection, and once for ejection parameters.
- Synchronization (Timings) must also be modulated by reloading preset-counters: this will guarantee the correct trigger for equipment in the different cycles. The variety of hardware used and the different operating modes group these triggers into three sets that must be reloaded at three separate instants of the same cycle.
- The transmission speed through the CAMAC serial loop is about 200 μs per word. The total transmission time for the PSB parameters would take an important fraction of the cycle period and this would dangerously interfere with other data transfers (acquisition) during the same cycle.
- As already mentioned, certain control actions have to be executed inside time windows as short as 30 ms. In case of heavy system use, the process computer could not always guarantee the appropriate execution in time of any control action, driven by interrupts.

System Constraints

The lowest level of application software[4] in the process minicomputer is represented by equipment modules (EMs).

These EMs provide a fast, safe and standard interface to application programs (APs) and contain a database, describing all process variables and data on equipment characteristics, like hardware addresses, acquired values and status information, control values sent. Because of PPM, these values are present nine times, one value for each possible cycle, giving roughly a total of 100 words/parameter. Therefore the whole database (∿ 100 K) is too big for the memory of the front-end computer, and the access to that data would be too slow if put onto a magnetic disc.

The Solution Adopted

The constraints mentioned in the former chapter have been overcome by putting an ACC in nearly each crate and the RT-task into the ACCs.

Consideration of size (∿ 100 K) and data management demanded a distribution of that database amongst the ACCs memories. Only a stub is kept in the memory of the process computer, containing mainly pointers to different ACCs.

Normally a function performed by an EM is quite simple, e.g. it switches on - via CAMAC commands - a certain element, at the time when the AP asks for it, i.e. as soon as the command is transferred via the network. But there are certain functions which have to be performed at a fixed time in the cycle, or functions to be performed on a large array of elements during the same cycle. These functions are favourite candidates for an RT-task running in the ACCs, and only started by the EM. The first are called PPM functions, the latter global functions.

The PPM Functions

The PPM tasks in the ACC set process variables at the precise moment required, to different values from one pulse to the next.

Since these tasks share the database with the EM, they fully benefit from its availability within the ACC. In addition to being controlled through the ACC, all process variables are also acquired at every pulse and their values are stored until the next supercycle. All data relative to a particular pulse are now available for the EM to be read asynchronously at any time.

Now an ACC controls only a much smaller set of parameters and can access CAMAC directly within 10 μs/word. Different ACCs may be driven by different interrupts, depending on the parameters they control.

The Global Functions

Global control functions operating as a single-shot activity on a set of process variables are of the type: "save current control values onto a buffer", or "restore them from the buffer", or "put all equipment in stand-by mode", etc. They are initiated via the EM in the process computer. Usually, there is one ACC per crate, but more than one EM can work together with one ACC. In addition, one EM usually works together with many ACCs in different crates (Fig. 3).

Four different types of RT-tasks may run in a given ACC: Acquisition, Control, Global and special applications. They are all interrupt-driven and communicate with the data tables, which are also accessed by the EM in a completely asynchronous fashion.

Each task recognizes the type of machine cycle by reading an encoded pulse train from a general cycle distribution system, called PLS (Program Lines Sequencer).[5]

Whenever a global function is started in the EM, it sends out to all ACCs concerned the so-called ACC-Information-Block (AIB). These AIBs contain all the necessary information for the RT-tasks in the ACC (what kind of function, which elements concerned, which pulse number, etc.). As soon as the RT-task detects a newly sent AIB, it executes at the next interrupt the necessary data exchange in the database and/or sends data to the CAMAC.

Special Cases

The control software for the PPM consists of a structured assembly of a dozen basic modules that, differently composed in each microprocessor, permit to cover all the PSB equipment. This is mainly due to the standardization of the hardware.

In a few cases it has been necessary to develop special software to cope with non-standard hardware, or to fulfil particular operational requirements.

In the first case (e.g. 96 multipole correction lenses) special interface routines are interposed between the hardware and the standard software: their goal is to translate standard control commands for non-standard hardware. Usually they handle bit patterns, they simulate CAMAC transactions or they establish software links between the hardware and higher level software.

In the second category are included all those parameters that must be controlled or acquired many times per cycle (e.g. certain radio frequency parameters and instrumentation). In such cases the software is interrupt-driven and completely separate from the PPM. The only common part is the data table to which both refer to avoid the dangerous duplication of information.

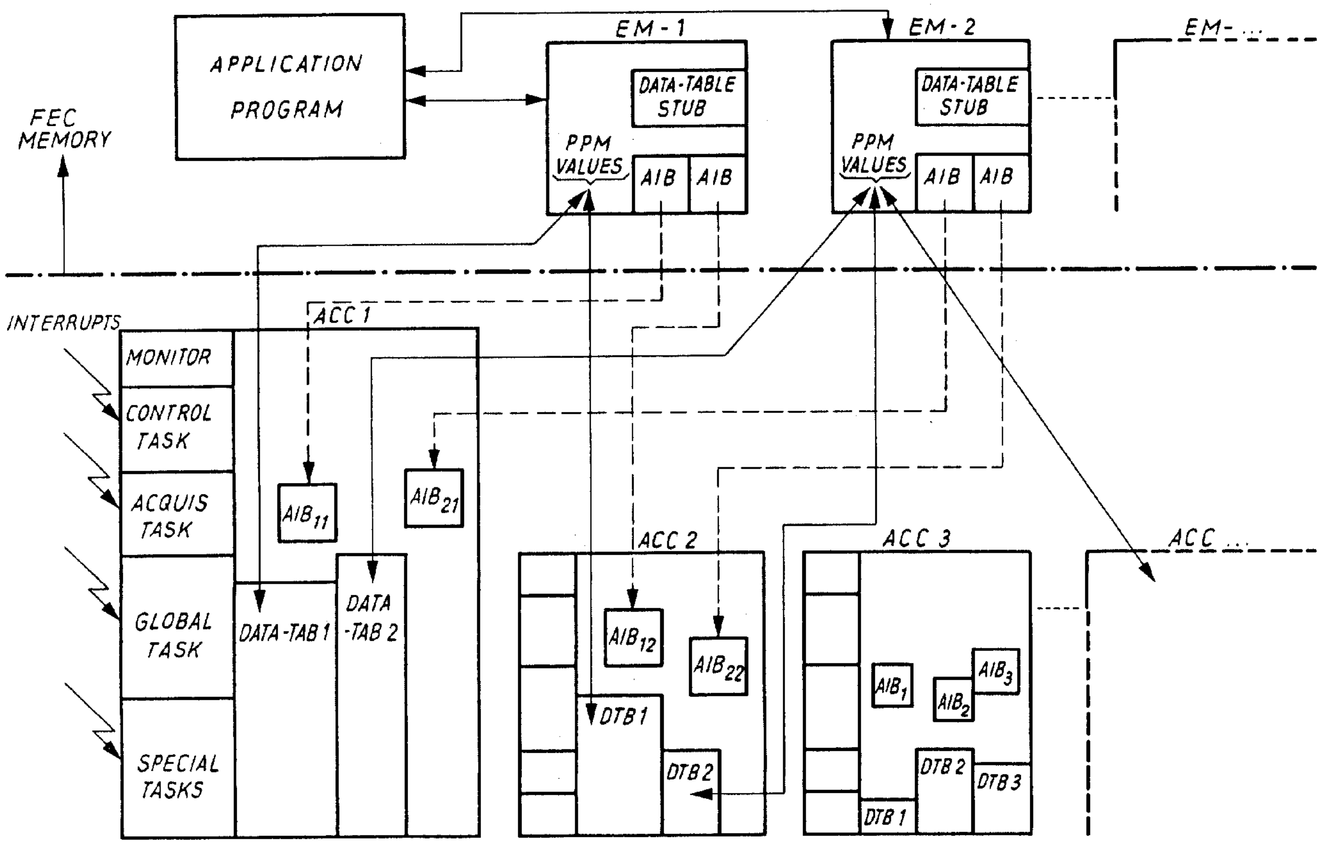

Fig. 3 COMMUNICATION BETWEEN EQUIPMENT MODULES AND RT-TASKS IN ACC s

Conclusion

The system described has been operational for four months, giving only minor problems; these problems are related to the difficulties in separating and identifying very rare hardware and software faults. But the graceful degradation of the system under such circumstances usually prevents the operators from losing the accelerated beam. The satisfying experience with the present system allows an extension to other subsystems of the accelerator complex.

Acknowledgement

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