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OUTLINE OF THE CONTROL SYSTEM FOR THE MILAN SUPERCONDUCTING CYCLOTRON

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Abstract. - The preliminary design of a high-speed control system for the Milan superconducting cyclotron is presented. Some characteristics of the architecture based on an intensive use of microcomputers connected by means of an optical bus,are discussed.

1. Introduction

Since a few years it is widely recognized that computer control systems are a very powerful,and indeed indispensable tool for modern particle accelerators.

This is even more true for heavy ions machines where practically infinite beams,and infinite energies, have to be tuned.

Experience also shows that computer control design should start as early as possible during the machine construction, and that the control architecture should be modular,in order to be flexible and adaptable to future,unexpected needs.

This is the basic philosophy we are following for the Milan superconducting project.

Use of CAMAC for the control of accelerating machines has, since long, solved the problem of modularity for the hardware components.Today's available technology also makes possible a totally distributed microcomputer architecture,which can reach the same goal for the software as well, simplifying programming and improving system performances.

2. Design concepts

The experience of most control systems already operating for cyclotrons and other accelerating machines,[1),2)] shows that software design is becoming predominant both in terms of costs and man-hours, especially for a centralized control configuration.

On the other hand, microprocessors technology has reached such a development stage,that now it is easy to find computer boards, competitive with minicomputers for speed and memory size,and besides cheaper and more oriented toward particular control applications.

These elements prompted us to investigate new solutions in the design of our control system,according to the following assumptions :

- the commercial availability of a large number of inexpensive microcomputer boards,gives the opportunity to implement a system with real parallel processing capabilities; this goal can be achieved by distributing processors in peripheral stations programmed to execute particular tasks,and dividing processing from communication functions by means of very fast input-output processors.

- optical fibers are becoming more and more reliable for several applications in short and long range transmissions. High bandwith and noise immunity are advantages that make them attractive for control systems; furthermore the recent availability of passive optical couplers opens up new interesting ways for the design of a local tranmission network.

- use of compatible hardware is a well-grounded requirement for machine control designers; we have chosen the Multibus industry standard, which is supported by over fifty boards manufacturers. [3)]

- for complex calculations, mass storage management, and control of the console,through which the operators have access to the machine parameters,a minicomputer is well-suited. It will be connected to every special purpose microcomputers through an optical link, and will gather all the peripheral databases in his own memory. In such a way, a software image of the cyclotron will be directly readable through the console.

3. The system lay-out

A schematic view of the computer control architecture is given in fig.(1). It has a star-type topology in which intelligence is distributed within seven peripheral stations(P.C.S.), and a PDP 11/44 minicomputer. Each P.C.S. will perform the control of a functional partition of the cyclotron equipment, while the PDP 11 will be interfaced with standard peripherals as cartridge disk systems,magtapes and terminals and with the operators' console in the control room.

Each station will be connected with each other and with the PDP 11 by means of a serial optical bus, able to allow transmission rates over 20 Mbits/S.

The key of the optical network is the implementation of a passive optical coupler. The latter makes it possible to avoid a centralized active controller for data traffic regulation that could be a possible bottleneck for the system, increasing in such a way the overall reliability.

The implementation of an independent safety system looks absolutely necessary for a computer controlled machine; for this reason some critical parameters will be also under the control of a second circuit.

On the basis of several industrial applications we shall use a programmable controller working in parallel with the main control system.

Designed to perform logic decisions, it is able to operate in a hostile environment, has a quite simple ladder diagram language and a powerful internal diagnostic.

In case of emergency it will act with the highest priority taking the machine to a security level ; in such a case it will send a number of diagnostic informations to the main control system through an RS232-C serial link.

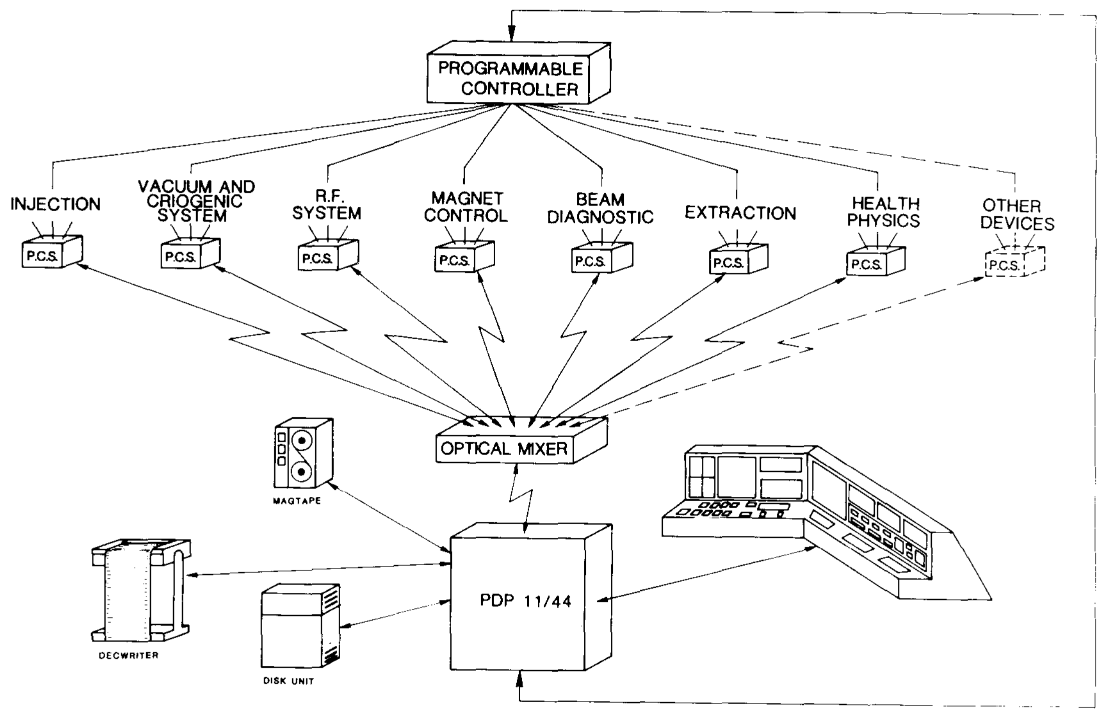

Fig. 1 - A schematic view of the control architecture

3.1. The optical bus.

Use of fiber optic links, is an already proved technique for local distributed microprocessor networks operating in laboratories and industrial environments.

On the contrary, the design of a real optical bus - i.e. a system in which there is no change from optical to electrical communication or vice versa - must deal with the problem of finding the appropriate network configuration depending on the given application and on the available optical components (transmission medium and couplers).

Choice is restricted between two main topologies, the first one based on a ring-type and the second on a star-type configuration; hybrid solutions of the two previous topologies may be also taken into account for some applications.

At present the following reasons lead us to believe that a star-type configuration is the most suited for a particle accelerators control systems :

- when peripheral stations exceed the number of ten, a pure ring network becomes impracticable, because, as tapped elements have access to the main information channel via T couplers, power losses, mainly due to the couplers, increase linearly.

- the dynamic range required for the detectors in a star-type configuration is some orders of magnitude smaller than the range required for a ring network; this means an easier design of the detection unit.

- better reliability is obtained, since a broken fiber does not stop the whole flow of informations but only a part.

- even if the ring configuration has a minimum cable cost, distances covered in a cyclotron control system are not so long as to make a serious difference in fibers costs, compared with a star topology.

The key element of the network is the star coupler (fig.2); it is a passive optical element designed to distribute optical power from one excited input fiber to each of the output fibers.

Several techniques for star couplers design are described in the literature,[4)] but the most promising one seems the coupling of a planar glass chip, whose thickness equals the fibers core diameter, with n ($4 \leqslant n \leqslant 16$) input and m (typically m=n) output adjacent fibers.

Some of these optical elements are already commercially available, but, as several fiber optic manufacturers are developing such a new component, we will wait till the end of the year for a final choice.

3.2. The peripheral control stations

The peripheral control stations are the distributed intelligencies directly interfaced to the accelera-

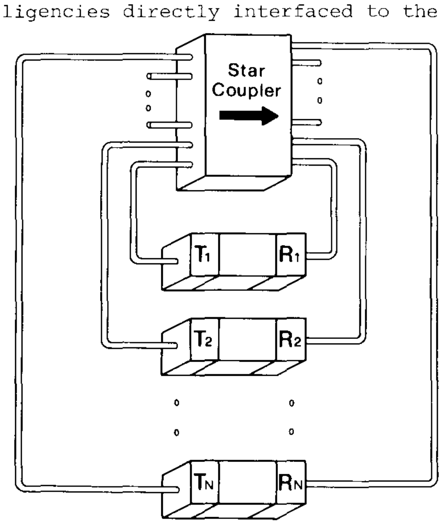

Fig. 2 - The optical star coupler with MxN ports.

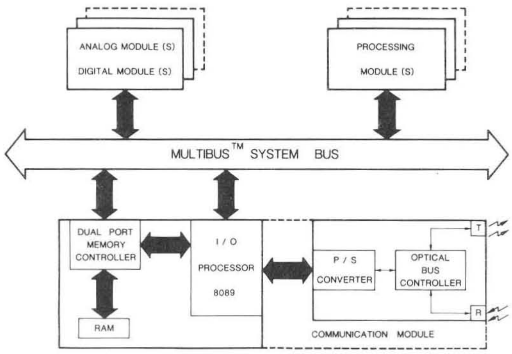

Fig. 3 - The internal partition of a P.C.S.

tor equipment.

Each P.C.S.,designed to operate in a stand-alone configuration,makes use of plug-in boards accordingly to the IEEE 796 Standard (Multibus) and is housed in a iCS80 industrial chassis available from Intel Corporation (fig.4).

The minimum lay-out consists of a four-slot Multibus card-cage, expandable for housing up to twelve boards.

Stations are divided in three sections connected through the Multibus and organized to provide the following functions :

- communication
- processing
- input/output and A/D or D/A conversion

3.2.1. Communication board.This board,the same for every P.C.S., is based on the 8089 I/O Processor (fig.3); it will perform high-speed block data transfer from and to the network,through two independent channels each of which combines attributes of a CPU with those of a flexible DMA controller.

A dual-port controller provides access from any other Multibus master to an on-board RAM used as the active database for each P.C.S.

A high-speed parallel to serial converter and the electro-optical interfaces connect the I/O Processor to the serial optical bus.

3.2.2. Processing boards. The SBC 86/05 sixteen bits microcomputer has been chosen as the standard processing

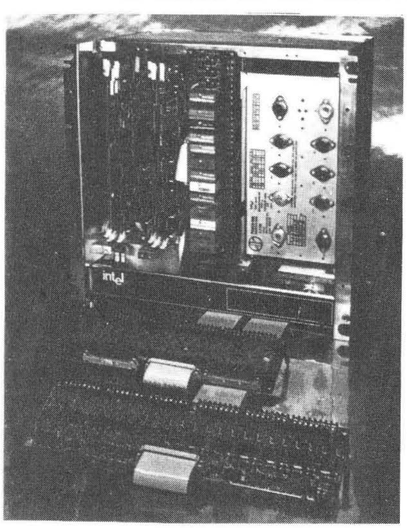

Fig. 4 - The iCS80 chassis with the signal conditioning termination panels.

unit.Nethertheless,Multibus allows the implementation of different kind of processors (8 or 16 bits), on the condition that IEEE 796 specifications are observed on the board interface.

3.2.3. Analog and digital boards. These boards are directly connected to the machine components; they are almost always commercially available except some special conversion boards that will be developed in our lab.

3.3. Communication problems.

Due to the refractive characteristics of fibers, we must deal with a propagation delay on the line of about 5 ns/m;this means that,for a 20 Mbit/s transmission rate, a station could have already sent 10 bits on the bus, before another station at a distance of a hundred meters has a bus-busy acknowledgement.

This physical problem causes data collisions on the bus. Solutions for collision detection and retry strategies are well-known in the literature; we plan to adopt a model quite similar to the one described in the ETHERNET specifications.

For the very first tests,a simple polling solution with a centralized time-base will be used.

3.4. Software.

As every P.C.S. has a stand-alone computing capability,programming will be more flexible,allowing the choice of different languages.

At present we believe that PASCAL,being well-suited for control routines,will be the most frequently used language.

For the man-machine software interface we will take into account the positive experience of several already operating control systems,implementing an interpretative language.

Such an interpreter will be also an important facility for device testing and maintenance routines.

4. Schedule

At present we are still in a stage in which thinking about solutions,writing specifications and testing hardware components are the biggest efforts.

Our first goals are to have the optical bus system operating before next summer and the hardware for some P.C.S. assembled and tested during next year.

Adopting the same philosophy of the main control system,we are designing a P.C.S. for the magnetic field apparatus.It will be ready next summer,planning to start measurements in the beginning of 1983.

5. Acknowledgements.

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6. References.

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