COMPUTER CONTROL FOR THE MILAN K800 CYCLOTRON RF SYSTEM

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ABSTRACT

The operation of the RF system for the Milan Superconducting Cyclotron is controlled by means of a computer driven electronics. Its main feature consists of an extensive use of microcontroller based boards as near as possible to the equipments to be controlled. These boards are connected between them and to a master element, a Multibus I CPU, using a high speed SDLC-like bus (Bitbus). The whole system is able to operate either from the main consolle of the accelerator or from a local console for stand alone and maintenance use. In this paper the control system design is presented together with a discussion of the experience gained during its use.

INTRODUCTION

The Milan Superconducting Cyclotron RF System has been successfully tested since 1985 [1,2]. A NIM modules based control electronics has been designed and used during the power tests, which took place until April 1986 [2]. All the settings were manually done via potentiometers, placed on the control electronics rack, and all the cavity parameters were measured directly reading instruments placed close to the RF system prototype. Push buttons on the control logic board were used to start and stop the cavity, while a provisional microcomputer system, based on the 8085AH microprocessor, was used to set the positions of the trimming capacitor, to read its position and to set the transmission of the DACs placed on the alarm board.

As a consequence of the delay [3] in the construction and testing of other machine parts, we decided to directly implement a complete computer control for the RF system, in spite of duplicating the existing control electronics, based on NIM modules and having a philosophy close to the one followed for the power tests.

Two different requirements must be fulfilled by a control architecture for an RF system : to perform dynamic regulation on amplitude and phase loops [4] and to allow setting and data monitoring on the main components. We have decided to follow two different approaches for these items, taking into account the response time required for proper operation and the easier way to implement the control. In particular, control loops have been handled in a pure analog way either because the parameters to be controlled are typical analog quantities, such as amplitude or phase modulation, or because the response speed needed (for protections) is too fast for a computer system (such as the control of sparks in the RF cavity).

A multicomputer based station has been dedicated to perform data acquisition from sensors, convert measurements to engineering units for data base updating and monitoring and coordinate the activities of the whole RF system. According to the general architecture of the computer control for the cyclotron [5,6], the RF control station has been designed as a Multibus I [7] based card-cage which acts as a master of a low-level field bus (Bitbus). The master station is connected to the control local area network, so that it can exchange data with the other stations and with the main consolle.

Due to the complexity of the RF system, which initially may require a lot of time to acquire a detailed knowledge of the best settings, the possibility of independent operation of the station has been greatly enhanced. So, beside the control elements, local operation facilities have been added. In particular, RF equipments directly incorporate microcontroller based boards, taking advantage of this flexible and low-cost alternative to centralized structures. The block diagram of the computer control for the RF system is shown in fig. 1.

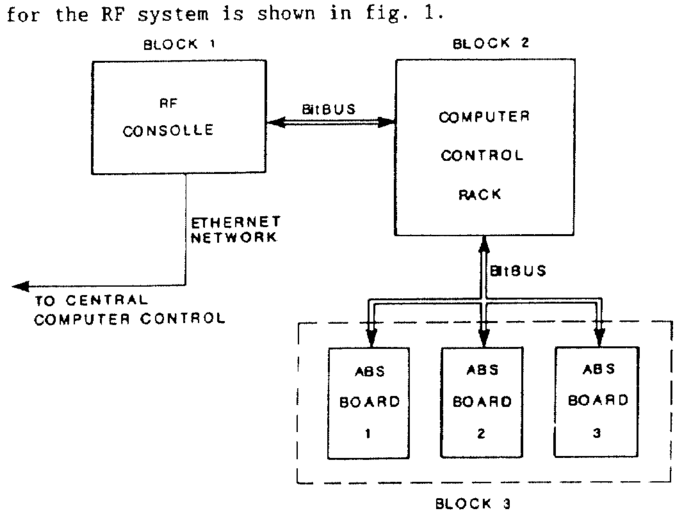

Fig. 1 - Block diagram of the RF control system.

There are 3 main blocks:

a)The consolle, designed for the interaction between the RF system and the operator, and for the connections between RF peripheral station and the central computer control.

b)The Computer rack, that contains all the RF system control units (control electronics, BBC power amplifier, sliding short).

c)The AM Loop block, with 3 Bitbus standard intelligent boards (having both analog and digital input/output), designed for the RF dee voltage management and monitoring.

The different elements of the RF computer control architecture are discussed in the following.

THE CONTROL STATION

The main control station consists of commercially available Multibus I boards.

The central intelligence is provided by: one INTEL iSBC 286/12 with 1 megabyte on-board memory, one 80286 8 MHz microprocessor, one 80287 mathematics coprocessor, one parallel I/O port configured as a Centronics-compatible parallel printer interface and two programmable RS-232C serial communication ports.

The interface to the Ethernet network is an INTEL iSBC 186/51 board.

Network services are managed by application programs (burned on EPROMs) conforming to the ISO-OSI protocol up to the transport layer.

Upper levels have been implemented by us, with a particular care to obtain fast transmission rate, reliable data transfer and high flexibility in network configuration.

The interface to the equipment bus chosen, Bitbus, is accomplished by an INTEL iSBX-344 board.

We have chosen to not implement a redundant, fault tolerant, architecture at the main CPU level, but rather to distribute intelligence where it is needed, giving the capability to independently drive and maintain each equipment. Troubles in the master CPU, or in a single microcontroller board, do not affect the security of the whole system.

The benefits of such a distributed design may be so summarized:

- It allows to convert to digital signals every analog parameter, as near as possible to the transducer, thus avoiding to transmit at long distances analog low-level values.
- Specializing hardware and software for very specific tasks, a higher modularity and easier enhancements can be achieved.
- Extensive use of cheap microcontrollers doesn't not affect in a sensible way the overall cost of the project.

Once accepted these concepts, the next step consists in finding a good connection method, as traditional ones (like RS232-C, or current loop, or IEEE488) do not provide sufficient performance or are not adequate for long distances. So that we have decided to adopt the standard Bitbus interconnection, which is a serial bus optimized for high speed transmission of short messages.

The main features of the Bitbus interconnection are the following:

- Electrical standard: RS485.
- Cable: at the moment two wires twisted pairs, in a near future optical fibers.
- Mechanical form factor: single-height Eurocard.
- Transfer rate: up to 2.4 Mbaud.
- The serial bus supports up to 250 nodes.
- Communication protocol is standard firware based.

Bitbus is a hierarchical system with a master an a number of slaves. In our system we have used standard INTEL boards for digital and low resolution analog I/O and a 16 bit A/D and D/A board (developed in our laboratory) for high resolution. The digital boards (iRCB 44/10) support each one 24 software programmable parallel I/O lines (allowing expansion capability up to 48), 64 kbytes of code memory, 64 kbytes of data memory and two interrupt lines. Each iRCB 44/10 unit controls a set of control electronics boards. A proper designed Interface circuit is used to increase the control capability of a single iRCB 44/10 unit, i.e. a single board can control three equivalent circuits (one for each cavity) which do not work together, or a complex chain of devices.

The iRCB 44/10-Interface connection is shown in fig. 2.

The RF main parameters are monitorized via 2 iRCB 44/20 boards, which are a fully programmable analog I/O subsystems on a single-Eurocard form-factor bord, having 12 bit analog resolution, 20 kHz acquisition rate, 16 single ended or 8 differential input channels and two output channels.

For the AM control loops, high resolution boards are needed. So that we have integrated in the electronics 3 Bitbus boards (ABS) with a precision 16-bit DAC (the Hybrid System DAC9377) and a 16 bit ADC (HS9516).

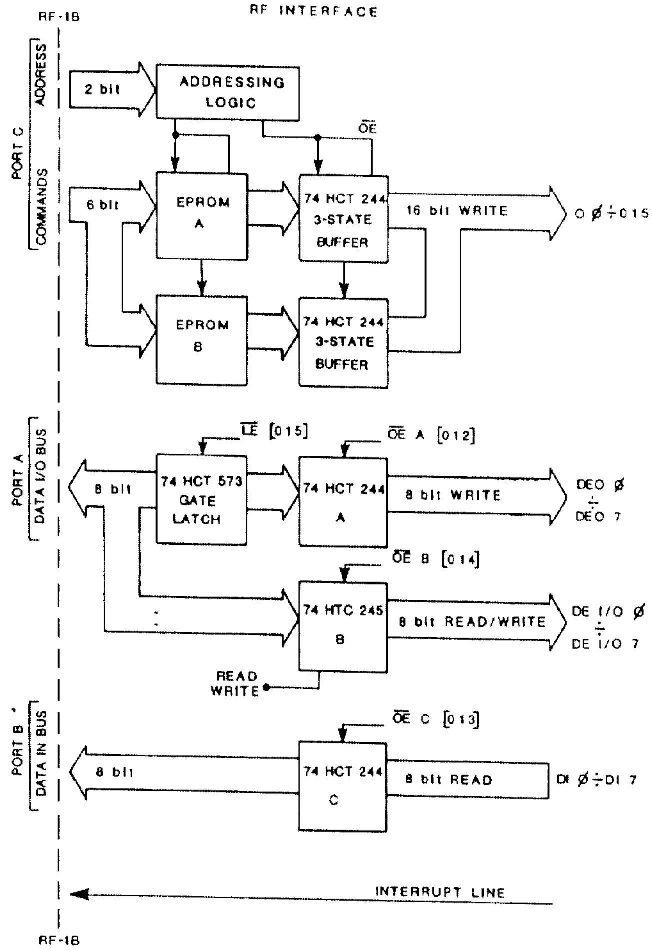

Fig. 2 - iRCB 44/10 - Interface connection.

Although the response time is not a critical parameters, performance evaluations of the Bitbus network have been carried out. The experimental results are shown in fig. 3.

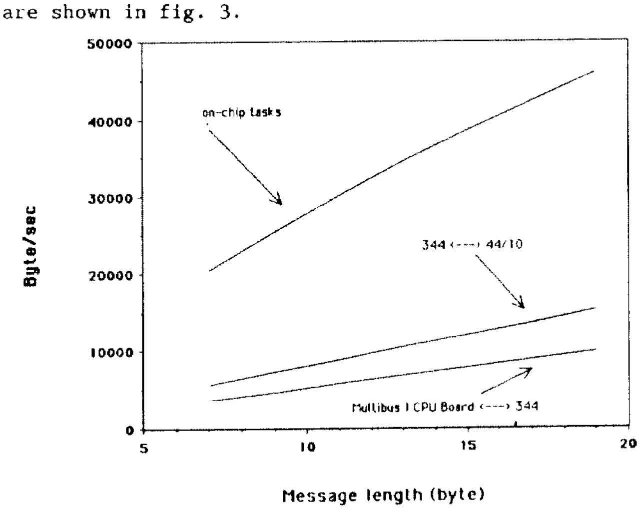

Fig. 3 - Performance evaluations of the Bitbus network.

Throughput between the nodes is excellent, well behind the design requirements, while a bottleneck has been verified on the interface to the CPU board, due to the poor characteristics of the communication FIFO.

A detailed list of the RF parameters controlled by the computer system is shown in table 1.

IDCM module	Control Electronics Block	Controlled Parameters
IRCB 44/10	Delay lines	Phase shifts
IRCB 44/10	BBC Amplifiers	Settings
		Power On/Off
		Status
IRCB 44/20	BBC Amplifiers	Instrumentation readings
IRCB 44/10	Control interlock	RF system status checks
IRCB 44/10	Sliding shorts	Movement and positions readings
IRCB 44/10	Turn On	System On/Off
IRCB 44/10	Alarm boards	System security
IRCB 44/10	Phase loops	Loops insertion
		Loops gain
IRCB 44/10	Trimming capacitors and couplers	Movement
IRCB 44/20	Trimming capacitors and couplers	Position readings
IRCB 44/10	RF multiplexers	Instruments selection
ABS Board	Amplitude loop	Loops Insertion
		Loops Gain
		Dee voltages settings and acquisitions

Table 1 - Parameters controlled by the RF computer system.

THE LOCAL CONSOLLE

Local operation of the RF system, for test and maintenance, is provided by a local consolle, designed as a subset of the main consolle of the accelerator. The RF consolle, under construction, is shown in the picture of fig. 4.

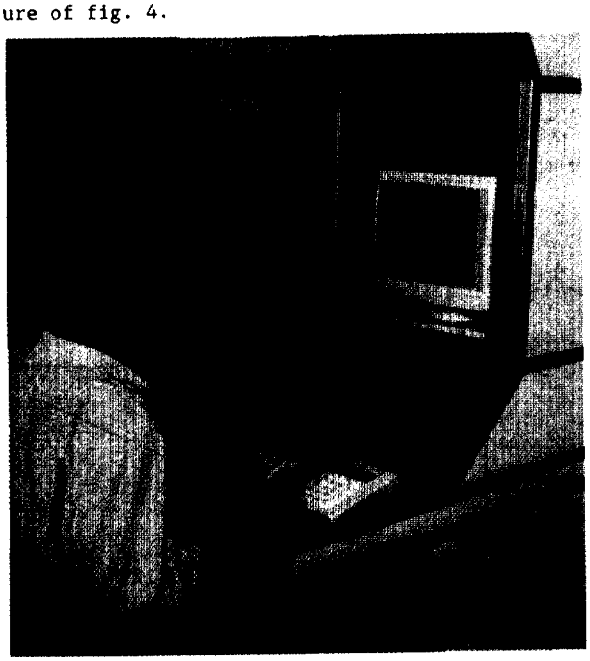

Fig. 4. - RF consolle.

This choice allows to use elements already developed and extensively tested, both for the hardware and for the software. A MATROX SX-900 intelligent graphic board provides graphics generation, with 640 K 480 resolution and up to 16 colors, by means of a graphic coprocessor (NEC 7220) and an on board 80286 microprocessor. A MATROX MSBC-QV3 controller drives two alphanumeric monochrome monitors. The board supports up to four independent displays and all the video attributes are user programmable via an on board CRT controller. The standard display format which has been used is 40 characters for 24 lines. Operator inputs are handled by a touch panel and 4 operator interaction modules, based on the 8044 microcontroller and interconnected on Bitbus. The main CPU for such a consolle may be an 80286 based board.

A cost and performance evaluation has shown that it would be possible to collapse the control station and the local consolle on the same Multibus I card-cage. A schematic lay-out of the whole computer control for the RF system is shown in fig. 5.

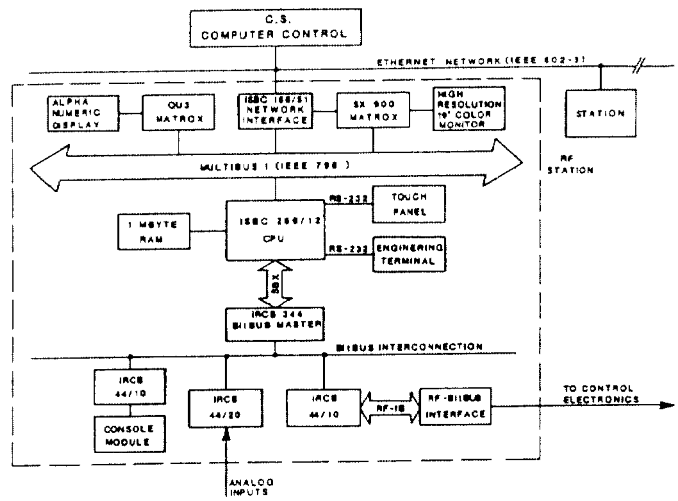

Fig. 5 - RF System computer control block diagram.

SOFTWARE

A real time, event driven, operating system (iRMX 86) has been adopted to coordinate the resources in the control station. The choice to use an operating system simplifies the development of the programs and allows to deal on applications and not on system management.

Particular care has been devoted in the integration of the local consolle in the control station. From the point of view of applied software, the tasks which drive the consolle elements (both for output and input), are on a "virtual" machine which may be the local or the main consolle. In this way local or remote operations would not require different handling routines, and the integration of the station in the Cyclotron control system is immediate.

REFERENCES

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6 - F. Aghion et al., The Operator Interface in the Control System for the Milan Superconducting Cyclotron, Proc. XI Int. Conf. on Cyclotr., Tokyo 86, Ionics Pub., pag. 432.
7 - Multibus and Bitbus are trademarks of INTEL Corporation.