DESIGN OF A MICROPROCESSOR-BASED MODULE FOR MAGNET CONTROL

F.Aghion and A.Mainoli
University of Milan and Istituto Nazionale di Fisica Nucleare,Milan,Italy

Summary

Design principles of a computerized module for the current control in the superconducting coils of a heavy ions Cyclotron magnet are described.
Operating as an integral part of the superconducting coils power supplies,the micro-module is able to perform a number of control actions,function generation,sequencing,local dignostics and communication with the control system in form of messages. Some topics concerning the quench detection system and the trim coils power supplies controllers are also discussed.

Introduction

The computer control for the Superconducting Cyclotron,which is currently under construction at the Departmemt of Physics of the University of Milan,[1] has been designed as a network of powerful microprocessor-based control stations each one performing the real-time control of a section of the accelerator equipment.

In this paper a comprehensive description of the first fully designed module will be presented.

It has been designed to perform the magnet operation, i.e. the control of the currents in the superconducting coils and in the trim coils. As exaustively described in other papers,[2,3] 28 power supplies housed in five cabinets deliver currents between 400A and 500A for the trim coils with voltages ranging from 36V to 48V. Currents up to 2000A (20V),in the main coils,are generated by two power supplies in the same cabinet,designed and built in the house.

In order to provide superconducting coils protection fast safety switches activated by a quench detection system can be opened so to obtain magnet discharge on a couple of 40MJoule dump resistors.

Design concepts

Use of microprocessors integrated into the equipment that has to be controlled,is now an attractive solution[4].In fact in addition to the advantages deriving from their capability of performing specialized tasks like sequencing, closed loop controls, data acquisition and surveillance, the following aspects should be enphasized :

- interaction with the control system can be done at a higher level in the form of significant messages
- dynamically changing values and informations describing the status of an equipment can be updated on the operator console or in the host computer in an asynchronous way i.e. on the initiative of the equipment itself, only in case of significant changes,thus reducing the load on the communication network
- background diagnostic program can be running in the equipment giving useful informations in case of failure of some component
- test programs can be down-loaded from the host for maintenance or software modifications.

For the Milan Cyclotron magnet operation, these concepts have been largely used. An architecture with a two level hierarchy has been adopted; i.e. every trim coils power supplies controller "talks", via a serial channel (RS-232C) with the main module housed in the superconducting coils power supplies cabinet. This latter has the direct access to a high speed bus that will link together all the control stations,the host computer and the operator console. (fig.1)

A design requirement has been to provide a local operation on every power supply. Thanks to the ASCII-based protocol of the trim coils p.s. controllers a simple interfacing of a terminal on the serial line gives the capability of operating on the equipment with manual commands. For the main coils a home made local controller has been implemented.

The control station

The heart of each control station is an Intel cardcage (fig.2), containing eight (expansible to twelve) standard (Multibus) IEEE 796 boards.

This choice gives, in our opinion, the chance to take full advantage now,of the availability of an impressive number of commercial boards on the market, and in the future,of next generation boards for which upgrading will be possible with a minimum effort.

The module has been configured in such a way to perform the following distinct functions :

- fast communication : an intelligent controller provides the hardware and software interface to a high speed (10 Mbits/s) Ethernet network, which will link via an optical bus with a star topology up to sixteen control station.[2]
- slow communication : five serial lines (RS-232C) connect the main module to as many local controllers housed in each trim coils power supplies cabinet. An auxiliary serial channel is available to be connected to a small console for local tests and maintenance.
- processing : powerful,sixteen bits, CPU boards have been selected (SBC 86/14) for closed loop controls, magnet ramping, data acquisition and processing from the quench detection system and driving the analog and digital input output boards.

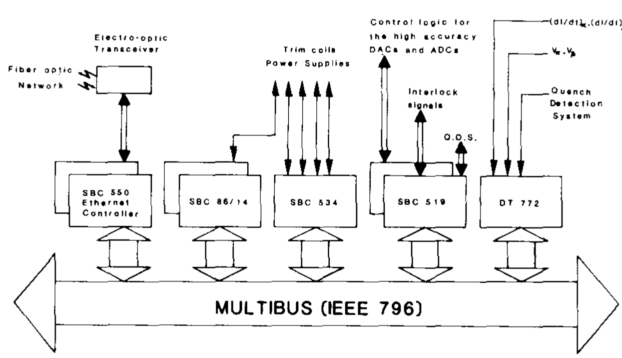

Fig.1 - The internal configuration of the boards in the main module

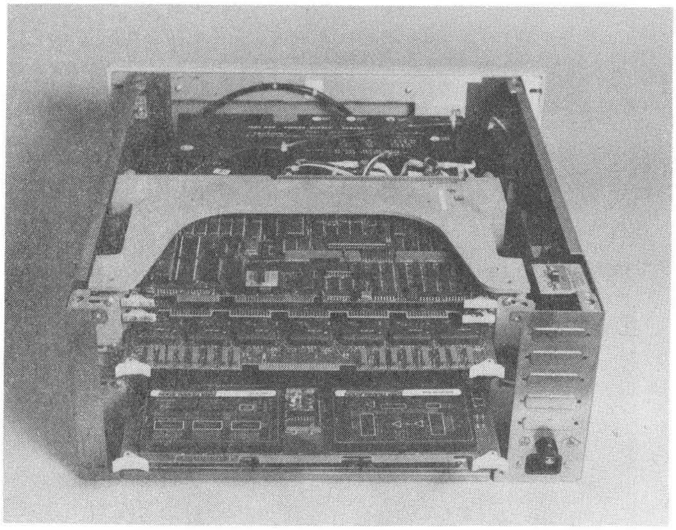

Fig.2 - The main module of the control station

Up to now no operating system is running on the CPU boards, having found easier to increase the number of the boards for specialized tasks. Neithertheless we are investigating on the advantages deriving from the use of compact executives or real-time silicon software components.

Superconducting coils current regulation

The achievement of a magnetic field stability better than 2 in 10^5, depends on the current stability in addition to the stability in the cryostat and the mechanical stability.

A simplified schematic for the currents control is shown in fig.3.

- two high precision current transducers (Holec - Zero Flux Current Transformers) supply a voltage value (0-10 volts) proportional to the current flowing in the coils (0-2000A).These output signals are used as a feedback in the control loop and digitally converted.

Such measuring devices have an intrinsic output noise of about 100μV in the full range. Thus a Butterworth low pass filter has been added to improve current control, and accuracy in the analog to digital conversion.

Values for dI/dt in the two coils are also supplied by the D.C.C.T. and acquired by the control station.

- reference current values are supplied by means of a couple of high accuracy 18 bits digital to analog converter (DAC 1138K) driven by the main module.

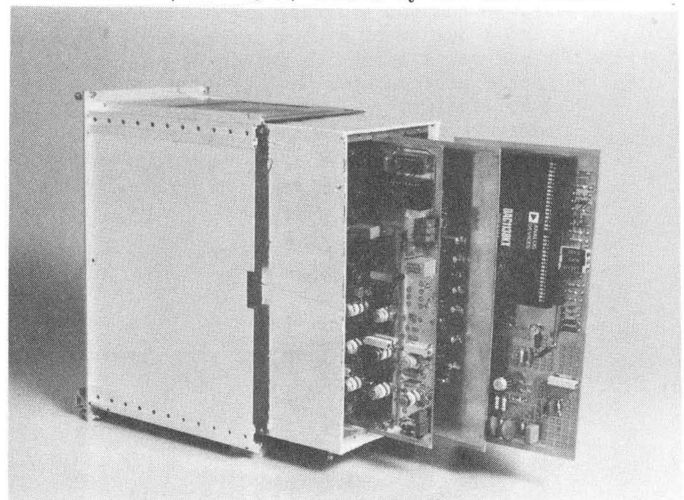

Fig.4 - The ADC and DAC boards housed in a temperature controlled module

- a couple of accurate 16 bits binary ADC based on a C.E.R.N. design(5), supply on demand to the microcomputer the actual current value in the coils.

In order to avoid affecting the resolution because of the temperature sensitiveness of critical components,

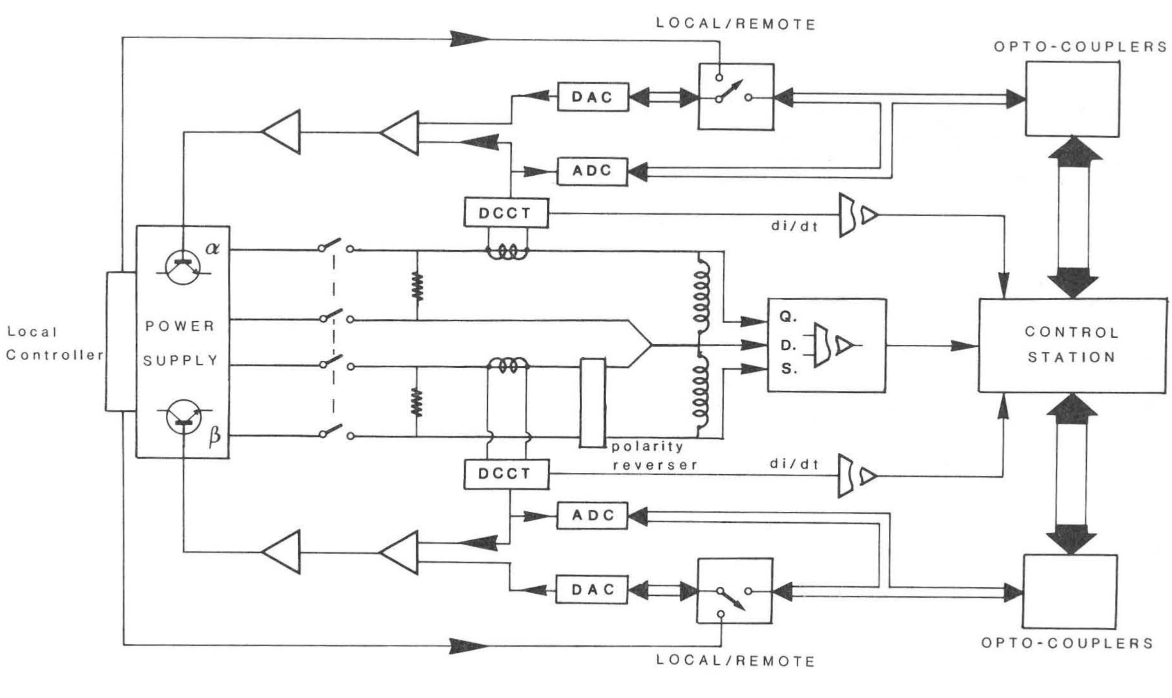

Fig.3 - Simplified schematic of the main coils current control

the ADC and DAC boards are housed in a temperature controlled (0.1°C) module. (fig.4)

- isolation between each power supply and the micro-module is a mandatory requirement; a number of interface boards with fast opto-couplers (fig.5) has been designed for the digital signals from and to the ADC and DAC modules. On board diagnostic, based on a parity check technique, has been implemented to detect a failure in the optical components. On line switching to redundant circuits allows to mantain full operation and an alarm message gives information that a logic board must be substituted.
- On/off commands and starting sequences are both provided and a number of status informations are sensed by the control station ,the main ones being :
  - local/remote status
  - β coil polarity
  - currents or voltages limits exceeded
  - excessive temperature in the p.s. boards
  - primary power status
  - interlocks

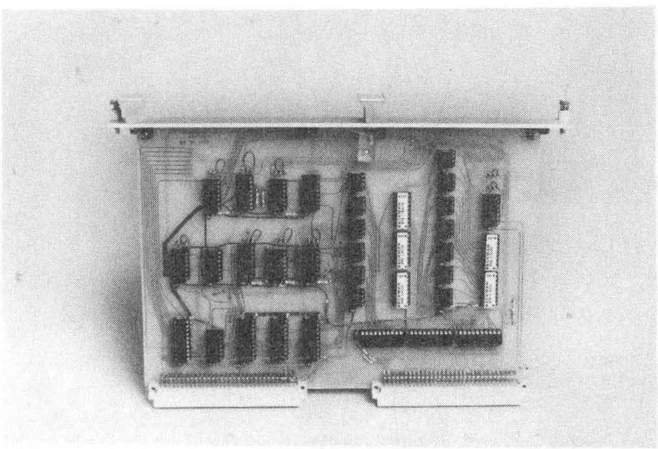

Fig.5 - The opto-isolated interface board

- a local operation on the main power supplies has been a requirement for tests and maintenance; thus a local processor has been implemented with the capability of programming the DACs and setting currents with a choice of five different rates.(fig.6)

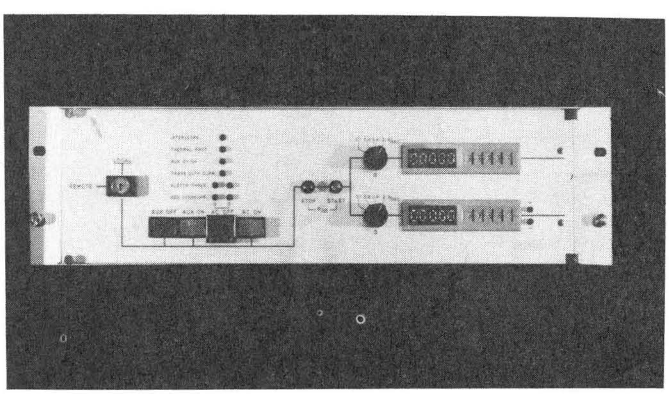

Fig.6 - The local controller for the main coils p.s.

Trim coils power supplies controllers

Requirements for current stability and for measurements accuracy (better than 1 in 10^3) in these equipments are typical of industrial process control systems. Thus a well tailored solution has been to distribute in each cabinet containing six power supplies an intelligent process to computer interface (μMAC4000) with the capability of supplying programmable voltage references for the d.c. currents p.s., reading currents,voltages and alarms and performing start-up and shut-down sequences.

Distinctive features of such a controller are galvanic isolation for all the I/O, to eliminate ground loops (± 1000V), and protect against transients and common mode voltage problems,battery back-up and local programmability. Interfacing with the main module is carried out by means of a serial link. The whole system has been organized in a point to point polling configuration in which communication is performed via standard ASCII commands.

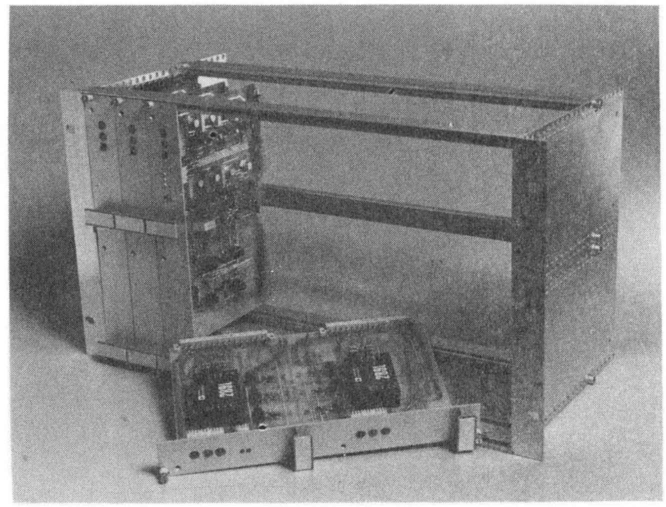

Fig.7 - Analog circuits for the quench detection

The quench detection system

To guarantee supronducting coils protection, a reliable control is necessary to detect if some winding has gone normal. Circuits designed to measure voltages across symmetrical pancake windings (fig.7) supply amplified values to a microcomputer that, using a comparing technique has the capability to detect a quench and initiate a fast discharge of the magnetic energy of the coils. A redundant circuit has been added to take the place of the computer in case of failure.

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