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# Laboratori Nazionali di Frascati

LNF90/033(NT)
4 Maggio 1990

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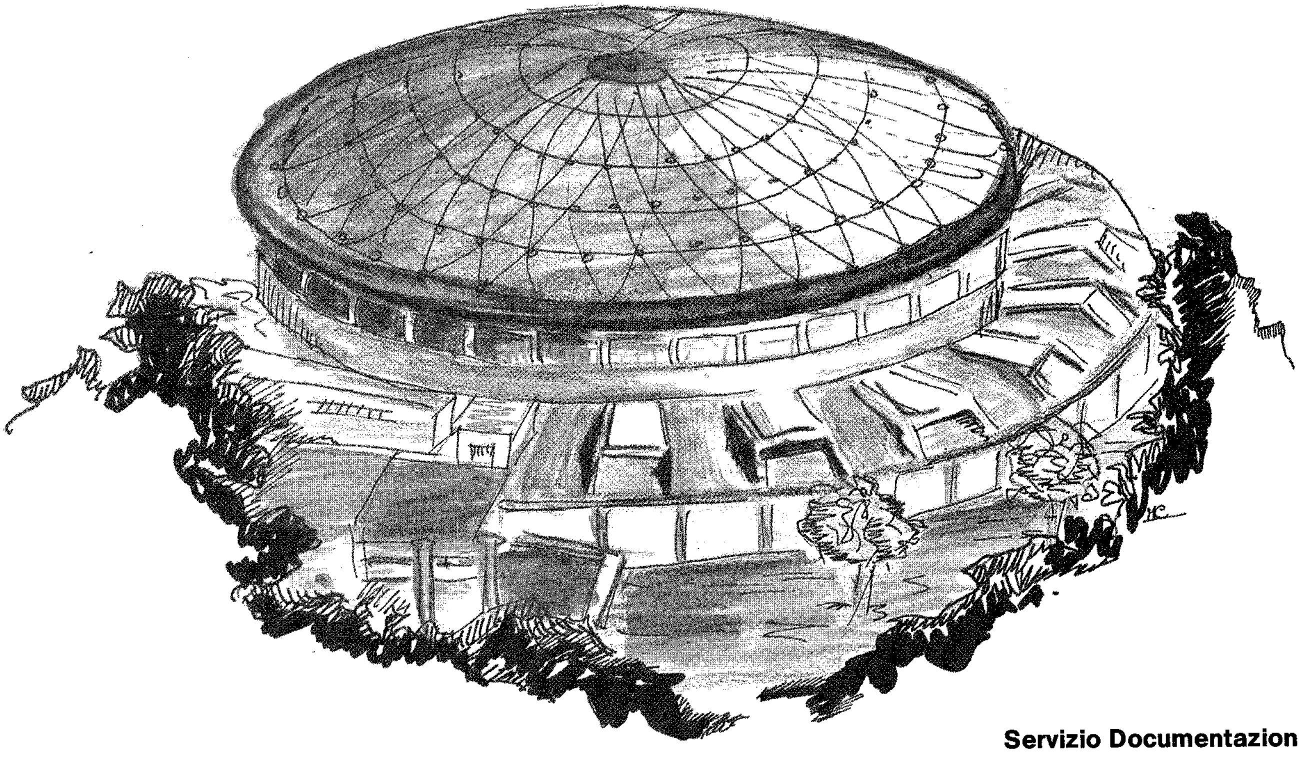

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# AUTOMATIC CONTROL AND MONITORING OF A SET OF STEERING COILS FOR THE LNF LINAC

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## ABSTRACT

We have applied a reduced version of the control system designed for the new accelerator LISA to the control of a set of 30 steering coils of the ADONE LINAC.

The system is built on two levels of processors tied together by a very fast bus: the first level uses a Macintosh IIx to implement the human interface, while the second level realizes the hardware interface and control through a CPU and peripheral equipment mounted in a VME crate.

Hypercard has been used for the human interface, implementing a set of XCMD's and XFCN's (external commands and functions) .

An RTF FORTRAN program running under MacSys takes care of the lower levels.

The system is installed and operational.

## CONTROL SYSTEM PHILOSOPHY

The beam steering in the ADONE LINAC is performed by a set of 30 coils, originally controlled by a bank of manual potentiometers. This setup was a source of problems, not only because of the lack of stability, but also because the transition between two different states of the machine (typically electron or positron injection) was slow and cumbersome.

We have therefore implemented an automatic system capable of continuous closed loop control against slow drifts and of fast transitions between different states, using the general structure designed for the control system of the new LISA accelerator[1,2].

The LISA control system has been designed for high flexibility and easy access to all information about the status of the system under control. Strong accent has been placed on a powerful and friendly human interface [3].

To obtain all of these goals we have separated the different tasks (human interface, control supervision and hardware interface) among separate processors.

This in turn has been made possible by the use of very fast buses to communicate between the different levels [4].

The high transfer speed makes it possible to have a single central memory, lying in a VME crate and adjourned by the second level processor, presenting at every moment the status of the system to the consoles [5,6].

## LINAC STEERING IMPLEMENTATION: HARDWARE

In the present application the original three level structure has been reduced to two levels, where the second level (supervisory) and the third level (hardware interface) have been implemented in the same VME processor (see Fig. 1). This has been made possible by the limited dimensions and by the uniformity of the system.

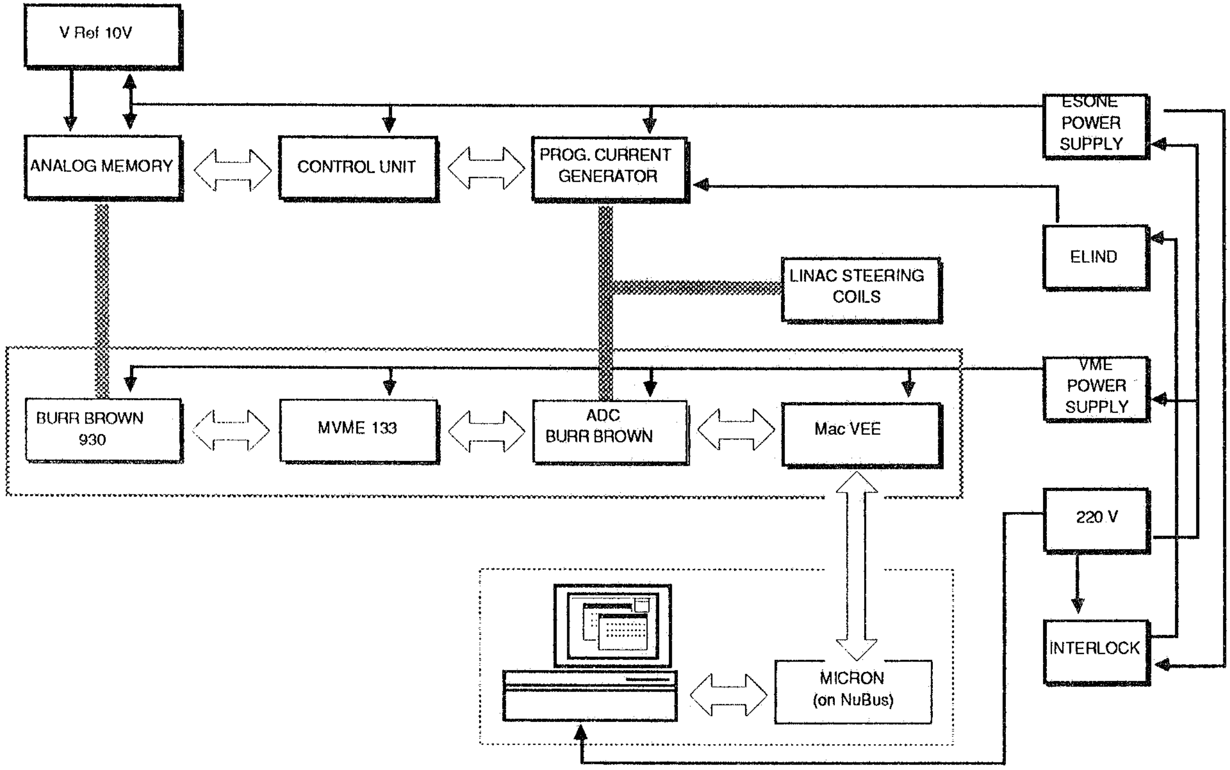


**FIG. 1** - Control system schematic.

The first level is the console level realized using a Macintosh IIx personal computer.

The second level is the control level and consists of a single VME crate containing:

1) Processor: Motorola MVME133 using a 68020 CPU.
2) ADC to read the current in the steering coils (Burr Brown MPV901P).
3) Parallel I/O to interface the VME with an existent DAC (Burr Brown MPV930).

4) MacVee interface from the Macintosh to the VME.

The system does not use a VME DAC, but interfaces to an existing DAC system mounted on the "ADONE BUS" [7,8]. The interface is realized simulating the bus protocol in software through a digital I/O board.

## SOFTWARE: HUMAN INTERFACE

The first level software has been implemented using Hypercard. This system, supplied by Apple with all Macintosh systems, allows to build very easily a typical Macintosh interface structure, with buttons, fields, and graphics. A very simple programming language permits to develop general programs, while it is possible to attach pieces of code written in other languages through the use of XCMD's and XFCN's, (external commands and functions) which can be recalled directly by name [9].

The interface with the second level has been realized using two different mechanisms:

i) direct memory access to update the screen data, using the VME memory which is continuously updated by the second level.

ii) message exchange with the second level CPU through two mailboxes:

a) Commands from the console to the control processor to activate an action.

b) Warning or Error messages from the control processor to the console.

A set of three XCMD's and three XFCN's implemented in "C" handles this task; the syntax is as follows:

| | |
|---|---|
| - put PEEK(address, size) into int | for 1,2,4 byte read |
| - put PEEKFL(address,prec) into val | for floating point values |
| - put PEEKMESSAGE(address) into str | for string messages |

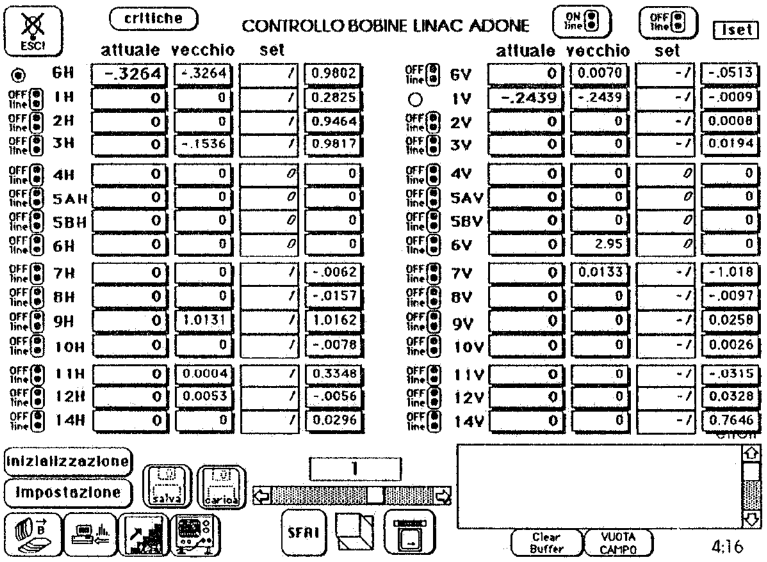
| | |
|---|---|
| - POKE address, value,size | for 1,2,4 byte read |
| - POKEFL address,value | for floating point values |
| - POKEMESSAGE address | for string messages |

where:

- *address* is the physical address in the VME memory.
- *size* is the size of the transfer (1for bytes, 2 for words and 4 for longwords).
- *prec* is the number of digits following the decimal point.

The user interface is made up of a central data acquisition card, four initialization cards and four graphic routine cards.

The main acquisition card (see Fig.2) shows a number of data on the status of the system, and many buttons and controls to change settings.



| | attuale | vecchio | set | |
|---|---|---|---|---|
| ● 6H | -.3264 | -.3264 | / | 0.9802 |
| 1H | 0 | 0 | / | 0.2825 |
| 2H | 0 | 0 | / | 0.9464 |
| 3H | 0 | -.1536 | / | 0.9817 |
| 4H | 0 | 0 | 0 | 0 |
| 5AH | 0 | 0 | 0 | 0 |
| 5BH | 0 | 0 | 0 | 0 |
| 6H | 0 | 0 | 0 | 0 |
| 7H | 0 | 0 | / | -.0062 |
| 8H | 0 | 0 | / | -.0157 |
| 9H | 0 | 1.0131 | / | 1.0162 |
| 10H | 0 | 0 | / | -.0078 |
| 11H | 0 | 0.0004 | / | 0.3348 |
| 12H | 0 | 0.0053 | / | -.0056 |
| 14H | 0 | 0 | / | 0.0296 |

| | attuale | vecchio | set | |
|---|---|---|---|---|
| 6V | 0 | 0.0070 | -/ | -.0513 |
| ○ 1V | -.2439 | -.2439 | -/ | -.0009 |
| 2V | 0 | 0 | -/ | 0.0008 |
| 3V | 0 | 0 | -/ | 0.0194 |
| 4V | 0 | 0 | 0 | 0 |
| 5AV | 0 | 0 | 0 | 0 |
| 5BV | 0 | 0 | 0 | 0 |
| 6V | 0 | 2.95 | 0 | 0 |
| 7V | 0 | 0.0133 | -/ | -1.018 |
| 8V | 0 | 0 | -/ | -.0097 |
| 9V | 0 | 0 | -/ | 0.0258 |
| 10V | 0 | 0 | -/ | 0.0026 |
| 11V | 0 | 0 | -/ | -.0315 |
| 12V | 0 | 0 | -/ | 0.0328 |
| 14V | 0 | 0 | -/ | 0.7646 |

1

FIG. 2 - Layout of control card.

For every one of the 30 coils the following data are shown:

- Name;
- A button showing through icons, color and highlight the status of the coil (online-offline, OK, Warning, Error, Busy) and allowing to apply control;
- Present current value;
- Current value when the coil was last selected for control;
- Set current value, which is the value loaded from a data file (which in this case is a Hypercard stack);
- Actual value sent to the DAC. This field can be hidden by a button (ISET) to simplify the screen appearance.

Furthermore, several buttons allow to save and load a configuration to/from a data stack, to perform initialization tasks, and to activate graphycal routines.

Error messages are displayed in one corner of the card in a scrollable field: two buttons allow to clear the field and to clear directly the second level mailbox.

The control structure is implemented through a set of buttons and fields to be as flexible as possible: five different methods are available to change a coil current, once a particular coil has been selected by a mouse click on the corresponding status button:

1) The requested current value can be introduced in the lower central field, and then sent to the coil by a click on the lower "pushbutton".

2) A continuous sequence of increasing or decreasing values can be sent holding down the extreme arrows of the scroll bar.

3) The same operation can be performed using the right and left arrow keys of the keyboard; this capability can be disabled for safety reasons by the button under the scroll bar. This method of operation was specifically suggested by the operation crew.

4) The same, but with a much higher step value, can be accomplished by holding down the mouse button inside the scroll bar (standard Macintosh interface)

5) The "thumb" of the scroll bar can be dragged to the desired value.

An "UNDO" button (SFAI) allows to restore the selected coil to the current setting which was current when the coil was last selected.

This structure will be adopted in the LISA control system.

Several fields double as buttons: a mouse click on the Current fields sends the value it contains into the control field.

Four buttons allow to access graphical routine cards:

1) time diagram of the current value of a selected coil (see Fig. 4);

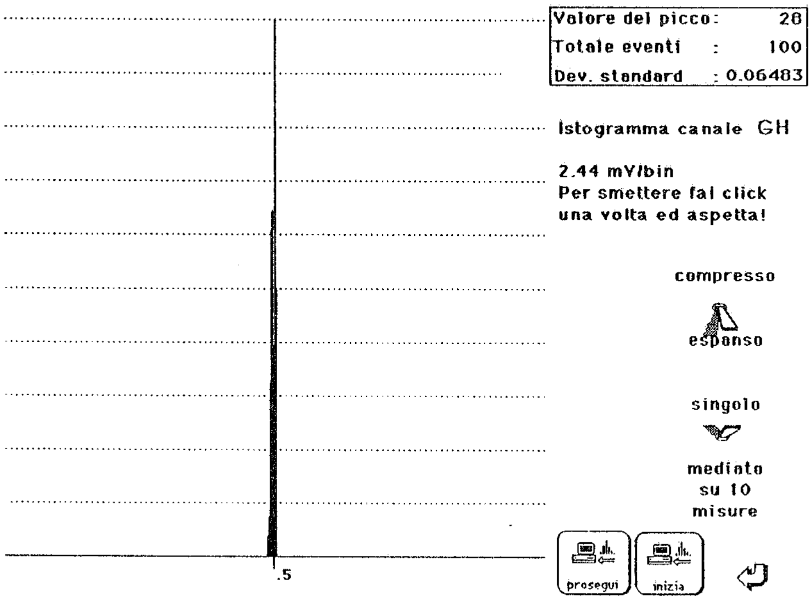
2) histogram of the current values in the coil (see Fig. 3);

3) ramp calibration (performed on line through a series of steps) (see Fig. 5);

4) space diagram of the current in the coils (see Fig. 6);

A set of initialization cards (see Fig. 7) allows to:

- Load the second level CPU software;
- Set maximum and minimum values, sensitivity and time delays for all of the channels or for a set of them;
- Start and stop the automatic closed loop control for selected channels;
- Start and stop control on selected channels.



Valore del picco: 28
Totale eventi : 100
Dev. standard : 0.06483

Istogramma canale GH

2.44 mV/bin
Per smettere fai click una volta ed aspetta!

FIG. 3 - Hystogram card.

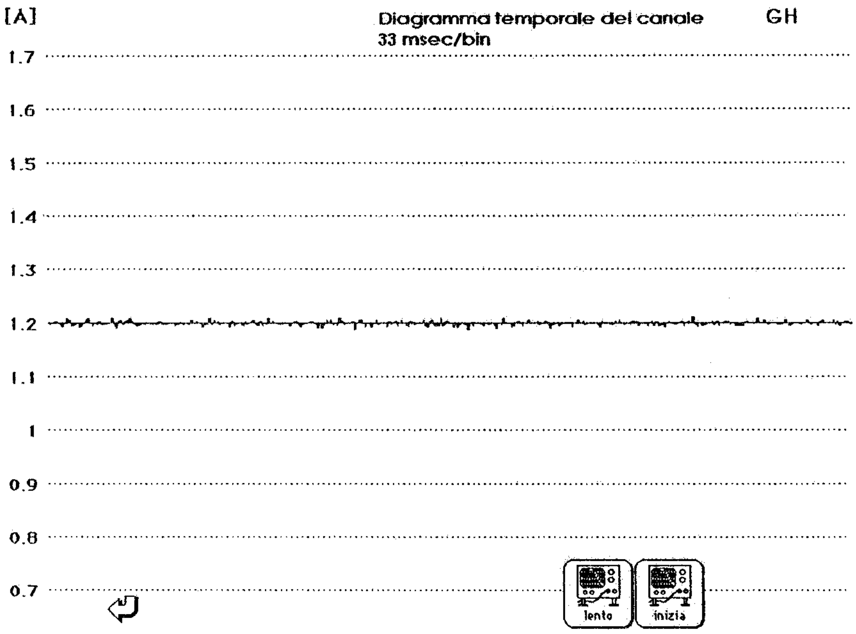


**FIG. 4** - Time development card.

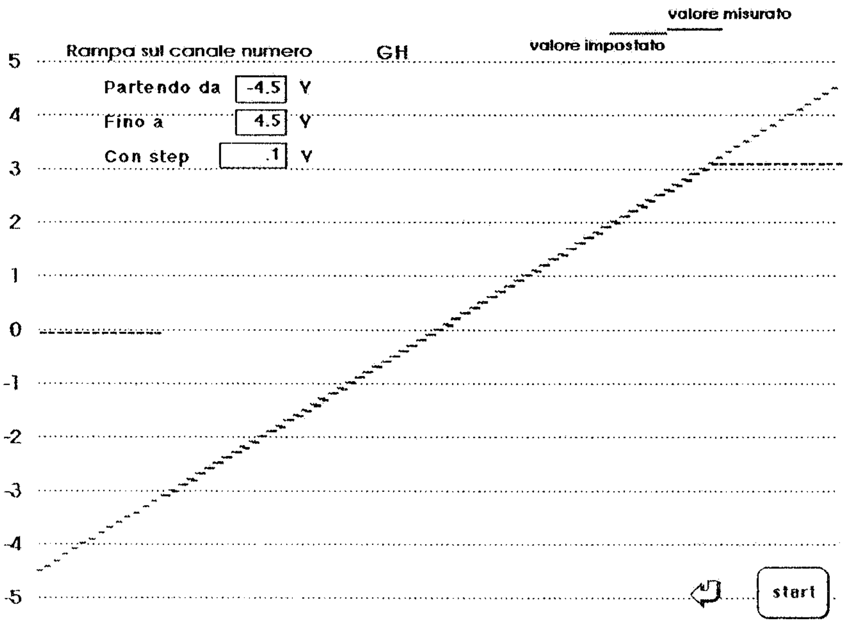

Rampa sul canale numero GH
Partendo da -4.5 V
Fino a 4.5 V
Con step .1 V

**FIG. 5** - Ramp calibration card.

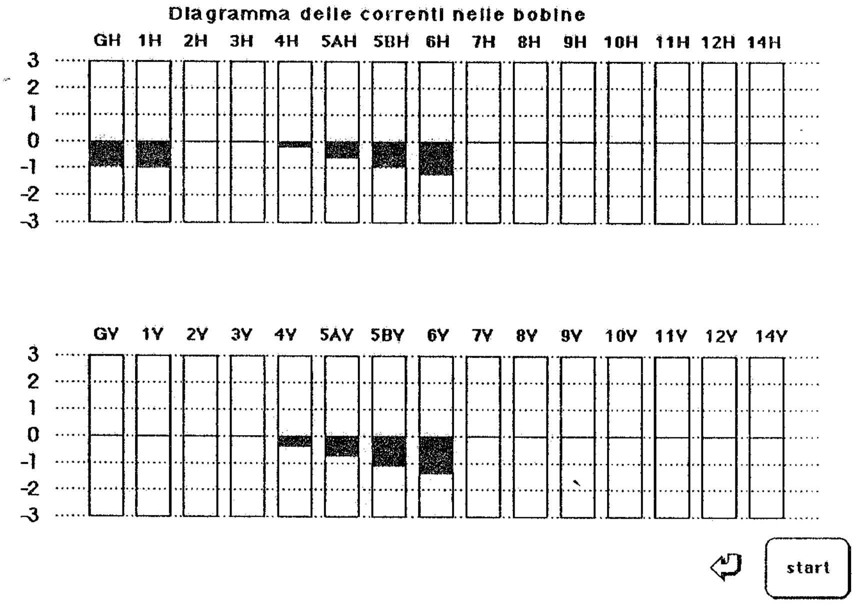
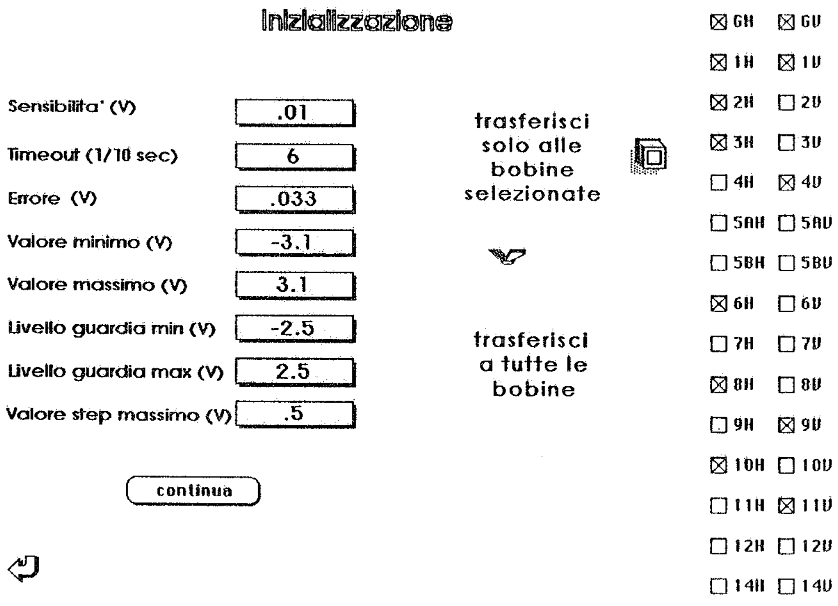


FIG. 6 - Space diagram card.



Sensibilita' (V) .01
Timeout (1/10 sec) 6
Errore (V) .033
Valore minimo (V) -3.1
Valore massimo (V) 3.1
Livello guardia min (V) -2.5
Livello guardia max (V) 2.5
Valore step massimo (V) .5

☒ GH ☒ GV
☒ 1H ☒ 1V
☒ 2H ☐ 2V
☒ 3H ☐ 3V
☐ 4H ☒ 4V
☐ 5AH ☐ 5AV
☐ 5BH ☐ 5BV
☒ 6H ☐ 6V
☐ 7H ☐ 7V
☒ 8H ☐ 8V
☐ 9H ☒ 9V
☒ 10H ☐ 10V
☐ 11H ☒ 11V
☐ 12H ☐ 12V
☐ 14H ☐ 14V

FIG. 7 - Initialization card.

## SOFTWARE: CONTROL

The second level (and the third, in the LISA scheme) are performed in the VME crate. This level performs the following tasks:

a) Measures the current values of the 30 coils and updates the central memory which is asynchronously read by the console.

b) Receives and decodes command messages originated by the console, and executes them. Possible messages are:

i) ON LINE - Starts and stop control of one element
ii) SET - Initiates a movement and brings the element on line if it was not initialized
iii) LOOP - Initiates or stops automatic closed loop control on one element
iiii) HIST - Performs one thousand readings on one element and stores the results into a memory buffer

c) Controls that there is no drift and that an executing command has terminated successfully; otherwise sends error messages.

d) Sends, when necessary, error messages to the console through a mailbox.

e) Checks the front panel RS232 serial line for input (debugging only).

These five tasks cannot be performed serially, since the execution of a command can last quite a long time. In particular, a large movement is performed in small steps chosen by the operator. Therefore a continuous program loop runs through the first four items, servicing one command at a time, and exiting to control during busy periods. A priority system prevents any attempt to perform contemporarily several queued commands to the same element.

To permit such a scheme, a memory structure has been implemented consisting of one record per element, containing all the relevant information about the status of the element.

The system adjusts automatically the calibration constants. Every time a movement has been performed, the slope of the resulting displacement is measured, and the next movement will use the average of the last five slope measurements to find the best possible prediction of the correct setting.

## CONCLUSIONS

The system has been installed and tested on the ADONE Linac.

It must be stressed that, apart from the reduction in the hardware, an effort has been made during the implementation to keep in mind the future needs of the more complex LISA control system. No shortcuts have been taken to simplify the system, trying to make this work directly portable to our next installations.

## AKNOWLEDGEMENTS

We are very grateful to the ADONE staff for continuing support and encouragement. The help of the operation crew while structuring and debugging the human interface section has been invaluable.

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