

THE CONTROL SYSTEM OF THE CERN NEW LINAC

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Summary

When in operation the New Linac will be the source of protons for the whole PS - SPS - ISR complex. This places a high responsibility on the Linac to keep going. For this reason two computers are used for the Linac control system, interfaced to the process over CAMAC, configured in such a way that each computer has direct access to the CAMAC system. Therefore, should the main computer go down, the front end computer continues with the basic facilities available at its consoles. Should the front end computer go down, the main computer takes over the functions of the front end computer.

The control system is designed in such a way as to minimize the knowledge of programming and computers required by the normal users of the system. The consoles use touch panels for parameter, program and option selections and are interfaced over parallel CAMAC to the computers, whereas the process itself is interfaced over bit serial CAMAC. In the case of the ion source, the CAMAC Serial Highway crosses the 750 kV with the help of optical data links.

Introduction

At the end of 1973 approval was given to the proposal to rebuild the CERN 50 MeV PS Linac ^{1,2}. The ideas in the field of accelerator control have changed considerably over the last twenty years since the beginning of the construction of our first Linac. Obviously, the new control system should be designed around a computer and furthermore, under influence from the general trend at CERN and other laboratories, we decided to use CAMAC for the interface equipment. Serial CAMAC entered a decisive phase at the time our project started, and it seemed a reasonable risk to try it out on our project in view of the many new features it offered, such as freedom in the distance between computer and CAMAC crate, simple interface for galvanic separation between CAMAC crates, cheaper transmission cable for the branch.

The following figures should give an idea of the scope of our project :

- The New Linac should be able to produce a 50 MeV proton beam pulse of about 150 mA, 200 μ s wide, every 500 ms.

- There are approximately 400 control parameters, of which 200 might need to be changed on a pulse to pulse basis.
- There are 1300 data words which could be acquired from the process.
- There are 1600 status acquisition bits that might be read.
- There are about 500 status command bits (on-off commands).

Computer back-up scheme

At present, the old Linac is available around 99% of scheduled time. After the usual period of initial problems, we must strive to reach similar figures for the New Linac. Since we rely on a computer to keep the New Linac going we have for reliability reasons used two computers in back-up scheme, a DEC PDP 11/45 known as the main computer (MAC) and a DEC PDP 11/40 which is the front end computer (FEC). The FEC contains all the necessary software to drive the Linac independently of the MAC. The FEC is synchronized to the main Linac timing ³ and carries out certain well-defined operations. The FEC is transparent to an applications programmer. All requests to interact with the Linac process are handled by this computer.

The MAC, however, operates asynchronously with the Linac timing and is the application programmer's machine. This computer will do all beam transport calculations and emittance measurements or whatever the user cares to work on. Therefore, should the main computer go down, the front end computer continues with the basic control facilities allowed at its console, the so-called Midiconsole. Should the front end computer go down, the main computer takes over the functions of the front end computer which then takes priority over other MAC activities. Obviously, this causes a slow-down of service to other MAC users.

The Computer CAMAC Layout

Each computer has an SAIP ICP-11B CAMAC interface unit which allows both computers to use CAMAC. The CAMAC branches from each computer are mixed

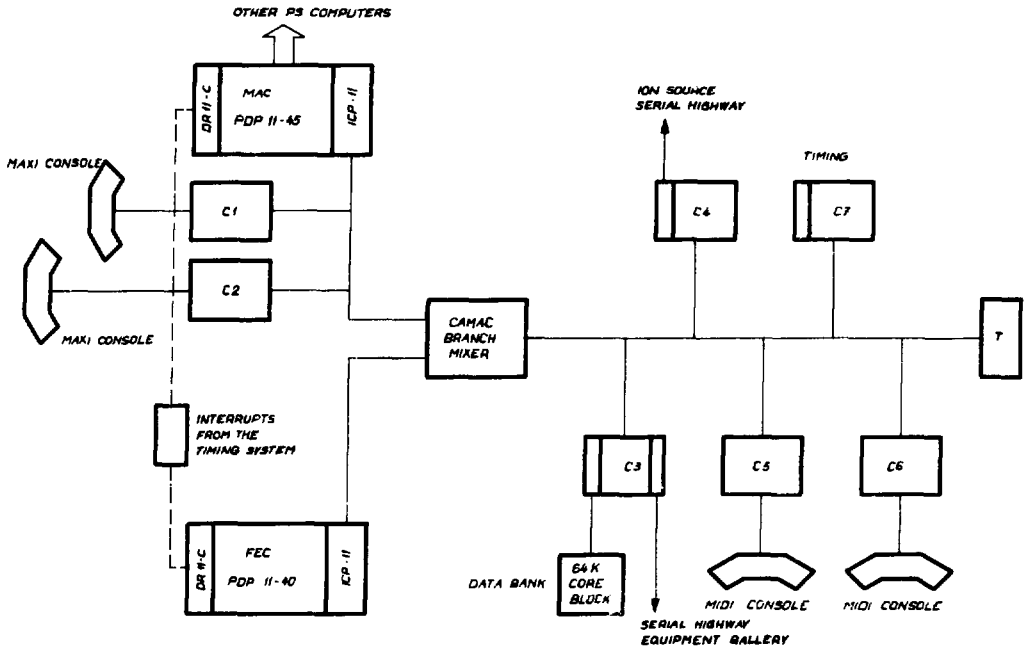


FIG. 1: COMPUTER - CAMAC LAYOUT

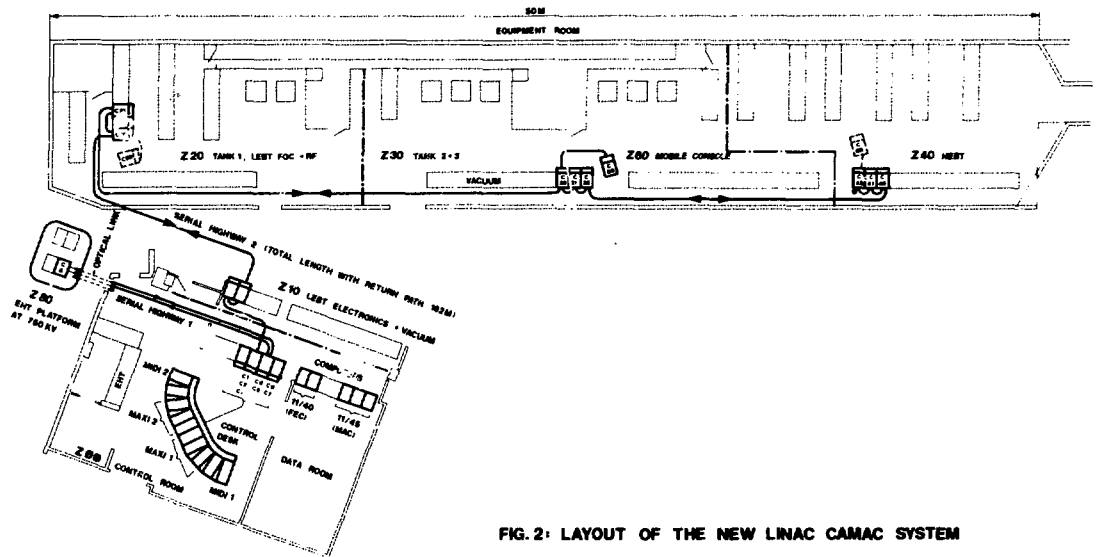


FIG. 2: LAYOUT OF THE NEW LINAC CAMAC SYSTEM

together in a branch mixer unit ⁴ which allows either computer to use CAMAC crates on the common branch. (Fig. 1) One of the crates on the common CAMAC branch contains a special CAMAC module which is interfaced to a 64 kwd block of core memory ⁵. This memory contains all the specifications of all the parameters known to the Data Base management program, and is known as the Data Bank. As both the Data Bank and the CAMAC crates which are linked to the process are on the CAMAC branch common to both computers, then it can be clearly seen that if one computer goes down the other still has access to the Data Bank and the process, and vice versa.

Process Requests

Requests to the Linac process may come from either the MAC computer or from within the FEC itself. The principal source of requests from each computer is as follows :

MAC (11/45)

- Application programs (emittance and energy spread measurements, beam transport calculations, etc.)
- Requests from the outside world which have arrived via the data communication system.

FEC (11/40)

- Midiconsoles (two in the control room, one mobile in the equipment gallery)
- Closed-loop control programs
- Watch-dog and supervisory programs
- Other programs which must be in the FEC

Requests to interact with the Linac process thus arise from a multi user, two computer system, and are all transferred to the FEC to be processed.

Pulse Requests

The New Linac will be required to produce three types of beam which will be sent to one of six destinations, and any of these conditions may be specified in a user request. These pulse types and beam destinations occur at different times in the Linac super cycle. Therefore, a means of synchronising these requests with the process and returning relevant information to the requestors in either computer is required.

The type and destination of a given beam pulse are specified by the main PS timing to which, in fact, the Linac is a slave. The work of setting up the necessary conditions in the Linac hardware to produce a given pulse type and to steer it to a given destination is carried out by the front end computer (FEC). After a given beam pulse has occurred, the FEC changes the necessary parameters in preparation for the next beam pulse and destination, regardless of whether or not there are user requests to the process.

Interface Equipment ⁶

CAMAC

The layout of the New Linac CAMAC system is shown on Fig. 2. Parallel CAMAC is used for interfacing the control desk and for lodging the drivers of the two serial highways. One highway crosses, with the help of two optical data links, the 750 kV of the preinjector for controlling a CAMAC crate on the ion source electronic platform ⁷. The second highway, having a length of 162m including return path, links ten CAMAC crates in four clusters, distributed so as to minimize interface to equipment cable lengths. Both highways operate at a bit rate of 2.5 Mbits/sec in the serial bit mode. This mode offers the simplest solution for providing galvanic isolation between crates, e.g., the 750 kV interface. Byte serial CAMAC offers at first sight an order of magnitude of improvement in speed over pure bit serial CAMAC. However, one should remember that each serial crate controller can introduce a delay of 1.5 clock pulses, to which should be added a delay of one clock pulse in the U-port adapter. (The latter provides, by biphasic modulation, a transformer compatible signal to the serial highway and provides also bypass and loop collapse facilities.) These delays are not so important in a bit serial system but degrades the advantages to be gained from the byte serial scheme, particularly in a loop with many crates ⁸.

Use of NIM Crates for Analogue Equipment

The Linac is basically a single shot machine where most of the phenomena occur in a few hundred microseconds. Analogue memories, i.e., sample and holds, must therefore extensively be used before multiplexing the information to an A/D converter. All this equipment is fairly voluminous. The space in a CAMAC crate is fairly expensive due to the complicated highway and we therefore felt, like many others, the need of another level of equipment between the CAMAC and the process. The NIM crate offers the advantage of a well-known standard and competition between many makers. By putting the high density digital equipment in CAMAC and most of the voluminous analogue equipment in NIM crates, we feel that we have arrived at a more economical solution with the advantage also of a more robust interface towards our clients. As a result we use a total of 19 CAMAC crates and 52 NIM crates.

The Main Console ⁶

The shape of the main console has, with small modifications, been copied from the CERN SPS design ⁹. Each half of the console (Fig. 3) contains, with minor exceptions, the same equipment for reasons of back-up and access. The two outer bays of each half console, the so-called Midiconsole and the Analogue Console, are interfaced to the front end computer, whereas the three central bays, the Maxiconsole, are interfaced to the main computer. Credit card readers are used for operator identification ¹⁰ and the SPS touch panel ¹¹ for selection purposes.

The Midiconsole

Parameters can be selected with the touch panel and sequentially "hooked" to four computerized knobs. To each of the four knobs corresponds a vertical field on a colour TV monitor. In such a field appears the label of the "button" on the touch panel when the parameter is "hooked" to a knob, as well as information read from the description of the parameter in the Data Bank, such as mnemonic name, status and reference values for acquisition and command. Also, on each pulse, appears the actual acquisition and command values in engineering units of the selected parameters. The Midiconsole permits an operator without previous computer experience, after a minimum of training, to select parameters and adjust these in a very similar manner to the old classical "one parameter - one knob" control system.

The Analogue Console 12

The Analogue Console consists of two 10 MHz double beam scopes and a touch panel for parameter selection. Commands for connection or disconnection of a parameter to one of the four analogue buses go over CAMAC.

The Maxiconsole

The Maxiconsole permits selection of measurement programs and options within programs with the help of touch panels. Individual or sets of parameters can be controlled by computerized knobs and ad hoc programs can be created using an interpreter language at a video terminal on the Maxiconsole. A Tektronic 611 storage scope is used for graphical output.

Control System Software 13

The Data Base

The control system software has been designed in such a way as to minimize the knowledge of computers, system software and hardware interfaces required by a normal user of the system, who is primarily concerned with the performance of the Linac itself. This has been accomplished by aggregating all of the information about the hardware and its CAMAC interfaces into a Data Base. Each piece of physical equipment is given a Name, which is a mnemonic of the position and function of the equipment, and is entered into the Data Base together with all the relevant specifications of that equipment. This includes information on the type and address of the CAMAC modules used for control and acquisition of the equipment, the maximum and minimum allowed values, reference values and control protection masks. 40 such specifications are required to describe a parameter fully. Once this information has been entered into the Data Base, however, the user need only concern himself with the Name given to that parameter. Moreover, the Data Base

Management program will allow the user to group, at random, any number of Names into a Named Set. For example, he may group all of the quadrupoles in Tank 1 into a Set which he calls, say, TIQUAD. Any action he carries out using this Name will be interpreted by the control system software as actions on the components making up that Set.

The Data Base is maintained as a file on disk, but this is not the operational Data Base. The throughput possible with a disk-based Data Base in the Linac cycle time of 500 msec is not very great; therefore a core-based Data Base is used, interfaced to the common CAMAC branch, and therefore quickly accessible by either computer using DMA (Direct Memory Access) transfers. The disk-based Data Base is copied into the core block before the start of the machine run.

T. User Interface to the Linac Process

The two computers used both run under the DEC operating system RSX11-M. This operating system uses a standard software interface to interact with any peripheral equipment, such as disks and line printers, which is called a QIO directive. This directive is used to queue up a request for input or output to a special piece of software, a Device Handler, which services the given peripheral. This philosophy has been adopted as the interface to the Linac process. A special Device Handler has been made, called the Name Handler, which carries out the desired action, such as control or acquisition, on a list of Data Base Names.

The user interface is therefore very well defined; the user issues a QIO directive to the Name Handler giving the addresses of a list of Names and a list of data together with a function code indicating the action to be carried out. He need not know the details about the Names, the control system software or the hardware interfaces; he just issues the QIO request and waits for the action to be performed.

The Processing of a User Request

The Name Handler receives the user issued QIO request, examines and verifies each Name in the user Name list, converting each Name to a pointer which is the record number of the Name in the Data Base. A message is then sent to the FEC computer consisting of the Data Base record numbers and data values corresponding to the user request. The FEC receives this request and inserts it into a queue for the specified Linac pulse or destination type.

It is the job of a program in the FEC, called the Central Request Processor, CREP, to treat requests entered into the request queues. It does this by treating each variable making up a request. It uses the Data Base record number to read in all the specifications of that parameter from the Data Base core block into computer memory. Using these specifications CREP builds up commands, called CAMAC cells, suited for the particular CAMAC module that is the interface to the equipment. In so doing, it performs certain checks on the internal consistency of that

Data Base record, and on the permissibility of the desired user action. The CAMAC cells produced by this processing are put into a queue to be sent out to CAMAC when the requested pulse or destination type next occurs. The Data Base record is then written back into the Data Base core Block. This procedure is followed for every component of the user request.

When the given beam pulse or destination type timing occurs the CAMAC cells queued up for it are sent out to the real CAMAC modules. This is done at high speed taking 30 μ s and 100 μ s for CAMAC cells for the parallel and serial highways respectively. CREP then checks that each CAMAC module responded as expected, noting any faults, and sends a reply message back to the MAC computer. This message is received by the Name Handler which then notifies the user about the status of his QIO request and passes any acquired data into his buffer. The user program then continues.

The total load (T) on the computer system produced by a user program QIO request containing n Names has been measured and may be expressed as

$$T = 2.4 + 2n \text{ msec}$$

This load is reduced if Sets are used as the Name Handler need only verify the Set Name, instead of a list of Names.

The Present Situation (August 1976)

Both computers are installed and running with the CAMAC Branch Mixer on the parallel branch. The two serial highways have been completed and tested. All CAMAC modules and corresponding analogue equipment for the Low Energy Beam Transport, LEBT, have been installed and tested as well as the Main Console and most parts of a Maxiconsole.

A good demonstration of the ease of using the Midiconsole were the first adjustments of the ion source by the preinjector technicians. A series of emittance measurements have been performed at 750 keV using the facilities of the Midiconsole and the Maxiconsole. These measurements were a good test of how easily an application program can address the system software with only a list of parameter names and data buffers.

The serial CAMAC has fulfilled all our requirements, and we are convinced that it was the right choice for our application.

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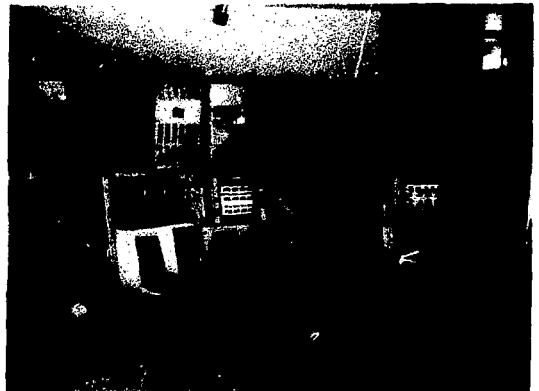


Fig. 3 Photo of the right half of the Main console. The three nearest bays represent the Maxiconsole, interfaced to the Main computer. Thereafter follows the Analogue Console and the Midiconsole, both interfaced to the Front End Computer.