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CONTROLS FOR THE LEP PREINJECTOR

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Abstract

The paper describes the controls for the LEP Preinjector, as relevant to its specific needs and as an evolutionary, backward compatible step starting from the present controls of the PS accelerator complex.

Introduction

The LEP preinjector[1] consists of (i) the LEP Injector Linac (LIL), a 200 MeV high current electron linac, followed in tandem by a 600 MeV e^-/e^+ linac injecting at the rate of 100 pulse/sec into (ii) an Electron Positron Accumulator (EPA), which in turn ejects its beams to the CPS after accumulation of ~1 sec for e^- and ~10 sec for e^+. Different filling and ejection schemes are foreseen and great flexibility is desired for commissioning. Some measure of stand-alone capability is required for certain equipment groups like Modulator/Klystrons, since controls will only stepwise become available.

The controls for the preinjector will be an extension of the existing PS Controls System but allowing for pecularities of the LPI. The stand-alone capability results in an extra hierarchical level, the microcomputer-based Auxiliary Crate Controller (SMACC) in the CAMAC interface. Additional systems software and adapted applications software structures are then necessary. Some improvements to the latter, relating to reliability, exploitability and productivity, as suggested by four years of operational experience, will be included. Powerful and user-friendly local interaction for servicing at several levels will also be provided.

Following the new principles being developed for the controls of the Main Ring LEP has been considered, but it would have been a complete breach with the present and delivery could not have met the LPI construction schedule. LPI has a very strong operational binding with the PS accelerator complex and it is thus wiser to go for a more evolutionary and backwards compatible extension of the present.

The Existing PS Controls

The PS accelerator complex,[2] with the 25GeV CPS as turn-table, produces beams of different particles (p, $\bar{p}$, e^-, e^+, ions....) of different characteristics for different destinations. It does so in interlaced cycles as short as 1.2 sec, in a periodic sequence called supercycle. Over one thousand control values and hundreds of displayed acquisitions are therefore refreshed each cycle, a feature called Pulse-to-pulse Modulation (PPM).[3]

About twenty Norsk Data minicomputers, ND-10 and ND-100, are linked by a star-topology packet switching network (Fig. 1). At the upper level, there are the console computers, each driving one general purpose console. At the lower side, the process computers interface to the process through CAMAC. Microprocessor-based Auxiliary Crate Controllers in almost every CAMAC crate do the cycle-to-cycle refreshing of the working registers and buffer the fast data bursts from beam measuring equipment. In principle, each minicomputer handles one complete accelerator process, like Booster, Antiproton Accumulator, etc.

The detailed control data and the acquisition tables for each cycle in the supercycle are resident in

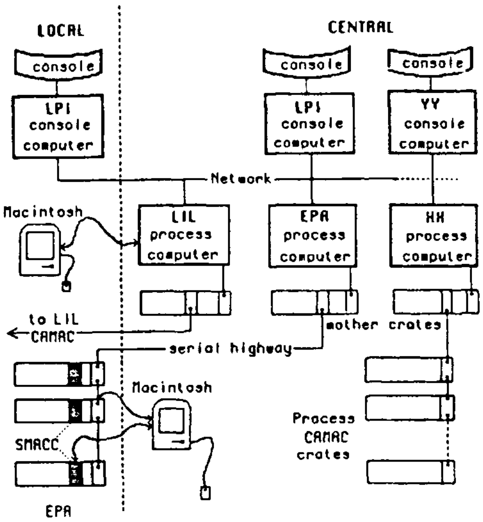


Fig. 1 PS Controls Topology

the Auxiliary Crate Controllers in CAMAC. They may be changed individually or loaded from archives. The cycle-to-cycle coordination of which data to present to the process next and where to store relevant acquisitions, is done by a computer-assisted system called Program Lines Sequencer (PLS)[2,4] which distributes relevant messages to the interface in each cycle. The PLS also allows interactive composition of supercycles on the consoles, thus giving the flexibility required for the ever-changing physics programmes.

Each general purpose console[5] may control and display data from any system in any process, but only for one chosen type of cycle in the supercycle. Two consoles may thus work on one and the same system on different types of cycle. Each has thus the impression of working alone on a machine with one type of cycle and beam (Virtual Accelerator), while actually sharing the same process hardware with another console. The console hardware and software feature a great capacity for concurrent display and interaction. In additon to data handled via the computer network, there is a computer-switched analog signal multiplexer network. This allows selecting analog signals from any part of the processfor display on the console. A similar system allows oscilloscope display of video signals, e.g. from cameras viewing scintillating screens or from drivers in the CAMAC, generating real-time displays.

The main pieces of systems software[6] are the manufacturer's real-time operating system SINTRAN III in the minicomputers, a simple monitor in the Auxiliary Crate Controllers, the package switching system between minicomputers and a simple transfer protocol between process minis and the Auxiliary Crate Controllers. Languages used are P+, a CERN made language[7] somewhere between Pascal and Ada (for most applications), a CERN-made interpreter NODAL (for trouble shooting, interacting and simple programs) and the manufacturer's structured assembler NPL (for systems work and highly time-critical applications).

The applications software[8] must cater for high concurrency and it must have flexibility for reconfiguration. A strongly modular system (Fig. 2) in hierarchical layers matches the interaction at the consoles

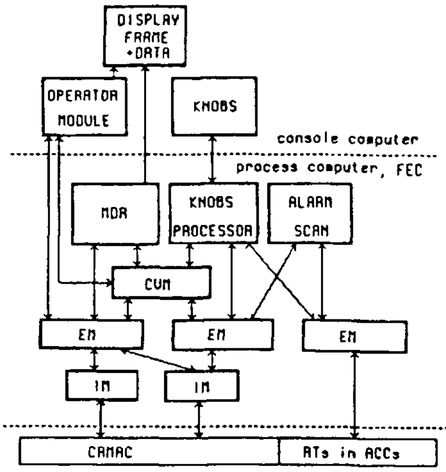


Fig. 2 AP Layout Old

to the hardware interface in the process computers. The Real-time Tasks (RT) in the ACCs refresh the working parameters and place measurement data in their reserved tables. In the process computers, the Interface Modules (IM) hide percularities of CAMAC modules. Above these, the Equipment Modules (EM) allow controlling or acquiring parameters or arrays by programmer-friendly calls; they also contain max/min values and a parameter reservation mechanism. Again above the EMs, the Composite Variable Modules (CVM), with the same calling interface as the EMs, allow controlling abstract machine variables by accessing in their turn a collection of process variables in EMs. The Operator Modules (OM) contain the higher control algorithm, while the Main Interactive Program (MIP) sests up the interaction. For repetitive displays, the Main Display Routine (MDR) compacts acquired data from the activated devices and sends them to the consoles via the so-called Pipe, a simplified fast transmission protocol, bypassing the normal structures. In the console computer these data are then reallocated to their relative displays.

LPI Controls Pecularities

The filling cycles of EPA are synchronised in the supercycle of the PS accelerator complex, many equipment have somewhat different settings for e^- and e^+ and, in part, different equipment is required for e^- and e^+ (e.g. LIL V, transfer lines,...). There is thus a Filling-to-Filling Modulation (FFM), similar to PPM in the PS, the EPA filling cycle taking the place of the PS magnet cycle. The coordination must then also come from the PLS in some form, e.g. by a separate LPI telegramme. This allows homogeneous central programming of filling cycles as a part of the PS supercycle. For both e^- and e^+ filling cycles, different filling and ejection schemes are possible. This is analogous to PS and can thus be included in the telegramme. For LPI, too, the consoles must work on one chosen filling type (either e^- or e^+), excluding information on the other one, so as not to confuse the operator.

Analogous to the PS, the detailed control values for each filling cycle of EPA will be in tables, resident in the Auxiliary Crate Controllers, the PLS telegramme message indicating which set is to be sent to the process. This is also the case for the sequence of microstates, making up the details of each filling cycle, generated locally in the LPI timing system.

The short pulse interval (10 ms) of LIL makes it necessary to load coherent sets of data - for change of mode - in corresponding time windows. This means that, in many cases, the sum of times for context switching on interrupt and for loading of the data must be less than 10ms, with adequate margin.

Some equipment like the electron guns and modulator/klystron groups may not be stopped pulsing, lest they lose their thermal equilibrium hence stability. Yet it must be possible to inhibit their action on the beam, individually or in combinations, both systematically for changing between e^- and e^+ modes and at choice for machine development. The inhibit (DUMMY mode, normal = PROD mode) is then achieved by time shifting their triggers so that they pulse between the passage of beam bunches. This may be superimposed on any other mode.

Since placing the 12 ns long LIL bunches into the 19 MHz EPA radio frequency buckets requires nanosecond precision, a number of equipment need timing of nanosecond resolution and stability.

LPI Controls Hardware Layout

Two console computers and two process computers (one for LIL and EPA each) will be added to the central message handling computer (Fig. 1). Three of these will be located centrally, with most other ones. A number of CAMAC loops run from there to the interface clustering points in LPI.

A console with its computer will be located in the main equipment building of LIL, for commissioning and machine development. It is identical with the ones in the Main Control Room hence fully software compatible and with analog signal and video multiplexing facilities. There will be hard copy devices next to it.

The key new feature is the Auxiliary CAMAC Crate Controller (SMACC),[9] based on the Motorola MC68000 microprocessor, a two slot CAMAC module featuring 24 bit linear address space and 16 bit data width. A typical configuration has 128KByte EPROM and 256KByte RAM, but it may be reconfigured using a combination of 8KByte RAM chips and 8, 16 or 32KByte EPROM chips, within the 48 foreseen chip locations. There are two front-panel ports, one RS-232C/20mA current loop, the other RS-232C/RS422 for communication.

The LPI timing system derives a few key synchronisation pulses from the PS timing. Locked to these, all LPI timing pulses are generated locally by preset-counters from pulse trains of 100 Hz (LIL repetition rate), of 1kHz (coarse timing) and of19 MHz (EPA RF),in several cases followed by computer settable cable delays for nanosecond resolution (synchronisation of guns, Lips phase inversions, inflector and ejector magnets). The microstate generator for the filling cycles, injection and ejection schemes, choses between pre-fabricated micro sequences according to the PLS telegramme. Some other equipment responds directly to the PLS telegramme. There is a gate matrix allowing to chose any combination between the DUMMY/PROD and the e^-/e^+ alternatives for certain equipment.

Systems Software

Using a powerful microcomputer, the SMACC, implies a significant increase in the complexity and facilitities of the controls system. The SMACC will act more like a multitasking minicomputer, unlike the present ACCs which run only interrupt driven dedicated routines. In order to reap full benefits of the decision yet limit the inherent risks, a substantial addition of systems software facilities[10] is necessary for applications running, applications development and for protection. Thus a full operating system's kernel must be installed in the SMACC, instead of the simple monitor sufficing in the existing ACC; more communications facilities between FECs and SMACCs must be provided; high level language must be used for applications, and a local interaction package must be available.

The manufacturers operating system, RMS68K, with Nodal as command language, has been taken, giving the full set of its directives in all SMACCs yet allowing some tayloring for major classes. Dynamic task loading will be provided later on. The RMS68K interrupt service, working at high priority, allows starting the interrupt routines in less than 100 microseconds. These routines then do PPM-like I/O to CAMAC, as required for LPI. For dedicated applications like the microstate generator of the LPI timing system, a bare SMACC without operating system may be used for speed.

For communications, the long-term goal is a uniform set of communications services to applications and terminals, both in the SMACCs and process computers. This will be done by providing (i) in a first phase, a uniform set of reasonably efficient communication services between each host and its SMACCs and (ii) later on, the same set between any processors in the system, albeit with lower efficiency. The latter will follow ISO/OSI principles and, if possible, use the Norsk Data medium independent network architecture COSMOS. The urgent level-2 primitives are, first, the PUTBL/GETBL facility, which writes/reads 16 bit words to/from a SMACC memory zone from/to the given user program buffer and, second, a Datagramme service on which the Nodal IMEX/EXEC mechanism and the P^+ Remote Procedure Call are built.

A full NODAl interpreter with with command functions for RMS68K will be installed on each SMACC. A P^+ (version B) compiler, generating MC68K assembler code, will be available on the Program Development Computer as well as a run time library on the SMACC. There will be the interactive symbolic debugger MONICA.

Applications Software

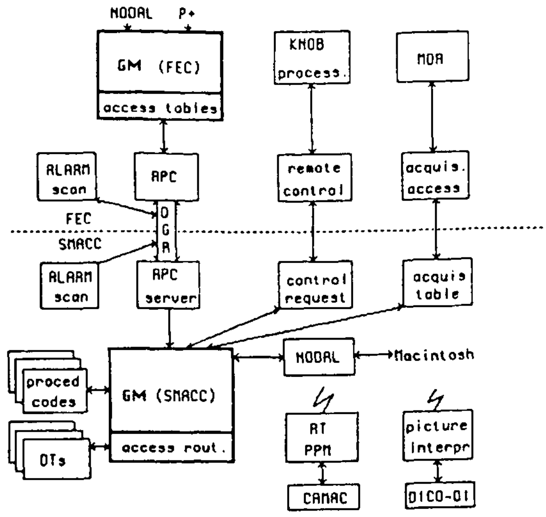
The requirement for stand-alone capability of certain equipment groups requires a further decentralisation of the Applications into the SMACC. One main adaptation is that the Equipment Modules must now be in the SMACCs. At the same time they must be accessible at the FEC level by the same calling sequence. A further aim (yielding more transparency and applications productivity) is the separation in the EMs of (i) calling interface and general facilities, (ii) specific code and (iii) data tables. The first, now called General Module (GM) is made reentrant. The GM is repeated in the FEC and accesses its SAMCC version through RPC. From the CVM level upwards things remain much as they are now in FEC and CONsole computers (Fig. 3).

Interrupt driven real-time tasks (RT) will, like for PPM, do the FFM data refreshing and buffering of fast data bursts from beam instrumentation. Dedicated routines will send data to the picture generator(s) in that CAMAC crate, for real-time display(s). These may also be displayed at the consoles through the video multiplexing network.

For repetitive displays, a new MDR now accesses the GM in the SMACC through acquisition lists. The KNOB processor accesses the same GM through control request lists.

The alarms scan routine in the process mini will be seconded by satellite routines, in the SMACCs which, upon interrogation through DATAGRAM, return a list of faults with equipment identity. The periodic CAMAC survey remains in the FECs.

A user-friendly access to the SMACC has been developed through the Macintosh personal computer, used as an intelligent terminal and a file server. By a SMACC resident NODAL, the GM but also other levels of the applications software can be accessed by Macintosh. The same is also possible by remote EXEC from the FEC or by double EXEC from the main operator consoles.



AP Layout New

A number of editors are being added and a central data base will be the unique updated source for the project, in particular for generating various real-time data bases.

Acknowledgments

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