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CONTROLLING THE LEP PRE-INJECTOR INSTRUMENTATION:

SOFTWARE ARCHITECTURE, IMPLEMENTATION AND EXPERIENCE

Cl.H. Sicard

Abstract

The beam diagnostic instrumenation for the LEP pre-injector comprises magnetic pick-ups, current monitors, wire beam scanners, sem-grids and synchrotron radiation light detectors. These devices are controlled through a two-level architecture made of local CAMAC-based microprocessors and central mini-computers. The general facilities offered are parallel local and central control, real-time video displays, a uniform high-level interface to control and acquisition data, and a fast protocol for transferring acquisition data to the central consoles.

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CONTROLLING THE LEP PREINJECTOR INSTRUMENTATION:
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The beam diagnostic instrumentation for the LEP pre-injector comprises magnetic pick-ups, current monitors, wire beam-scanners, sem-grids and synchrotron radiation light detectors. These devices are controlled through a two-level architecture made of local CAMAC-based microprocessors and central mini-computers. The general facilities offered are parallel local and central control, real-time video displays, a uniform high-level interface to control and acquisition data, and a fast protocol for transferring acquisition data to the central consoles.

Introduction

The LEP preinjector (LPI) controls have been planned as an integral part of the CERN PS control system, already handling a group of about 8 accelerators from a central control room. For LPI, a new Camac-based auxiliary controller, called SMACC, has been developed. This is a M68000-based microprocessor, running Motorola's real- time kernel system RMS68k. The increase in memory size (up to 760Kbytes) and in computing power was the occasion for a deep change in the overlaying application program architecture.

This paper discusses how this change has been applied, taking as an example the different instrumentation systems used in LPI.

THE LPI INSTRUMENTATION SYSTEMS

Figure 1 shows the disposal of the instrumentation along the LPI Linacs (LIL) and the electron-positron accumulator (EPA).

Not mentioned are the scintillator screens and slits, which are only interfaced with the control system via an in/out or position indication, neither measurement devices such as vacuum pressure, RF frequency and Klystron water cooling systems, which have no real-time constraints.

Timing and sequencing

The Linac can produce beam at a maximum 100Hz rate, while EPA accumulates and stacks beam for one or more 1.2 second Basic Periods.

The LIL instruments receive the LIL beam production pulse train, while devices used for EPA in storage mode receive the fixed 100Hz pulse train for basic acquisition triggering. In addition, the EPA RF train is used to select a particular bunch in the accumulator. A sequencing device, called TSU (Telegram Slave Unit), broadcasts every Basic Period a 256-bit telegram, which is stored in each SMACC and provides information on the beam destination, type of particle, etc... for the current and next cycle.

Magnetic Pick-Ups (UMA) equip the Linacs (15 units), the EPA ring (19 units), and the transfer lines (2 for injection, 6 for ejection). They provide transverse (horizontal ΔH + vertical ΔV) position and intensity (Σ) signals; the SMACC software computes actual position information taking in account magnetic and mechanical offsets (measured off-line), and amplifier offsets measured with no beam. Calibration generators allow correction for gain dispersion in the amplifiers, and non-linearities detected by precise bench measurements are compensated as follows:

$$H_c = H + \varepsilon|V|\,H + \partial\, V^3$$

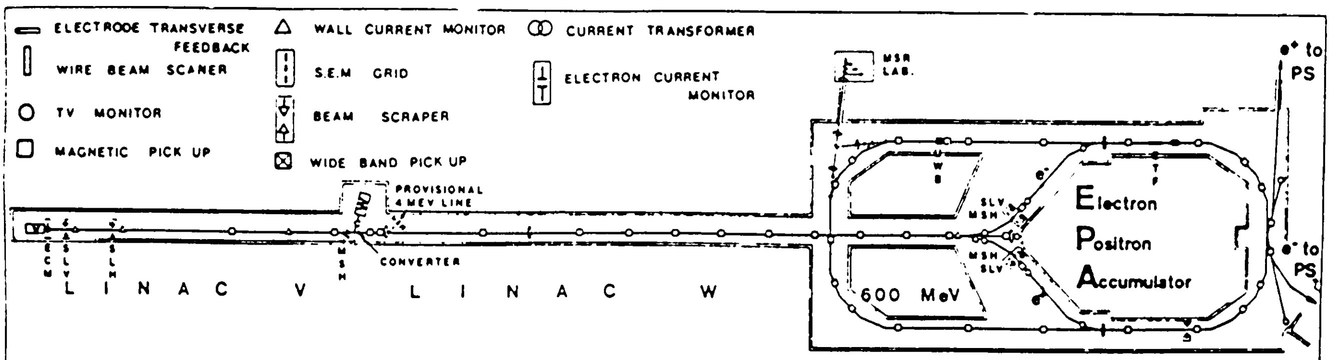
When better precision is desired, the software averages up to 100 measurements done every 10 milliseconds on the same bunch.

Statistics for one pick-up (standard deviation) can be done in order to estimate the actual accuracy.

Intensity measurements from the UMAs and wall-current monitors provide an accurate estimate of beam transmission along the Linacs and EPA injection lines.

Beam Current Transformer and Integrated UMAs

A ring transformer, together with a selected number of UMA intensity signals integrated along a full EPA cycle, are triggered at specific instants (end of accumulation, before and after ejection). They provide beam statistics information, and a display of every cycle in the supercycle (Vistar).



-FIG1-

Wire Beam Scanners(WBS)

Two perpendicular wires move back and forth across the beam, providing horizontal and vertical beam profile information (1 point for every beam crossing). The wire speed is not directly controllable, as the controlling stepping motor follows fixed acceleration/ maximum speed characteristics. The movement can be either continuous, (valid for beam repetition rates higher than 10Hz), or step-by-step (for low rates).

Secondary Emission Monitor grids (MSH)

They are used for beam profile and energy measurements in LILV and EPA injection lines. The grid plane can be tilted with respect to the beam, thus varying the projected width between 2 monitor bands from 1 to 2mm. The SMACC collects up to 100 measurements and averages them; the Console program computes a spline interpolation of the beam profile The energy dispersion measurement is done with a dipole magnet associated to each grid.

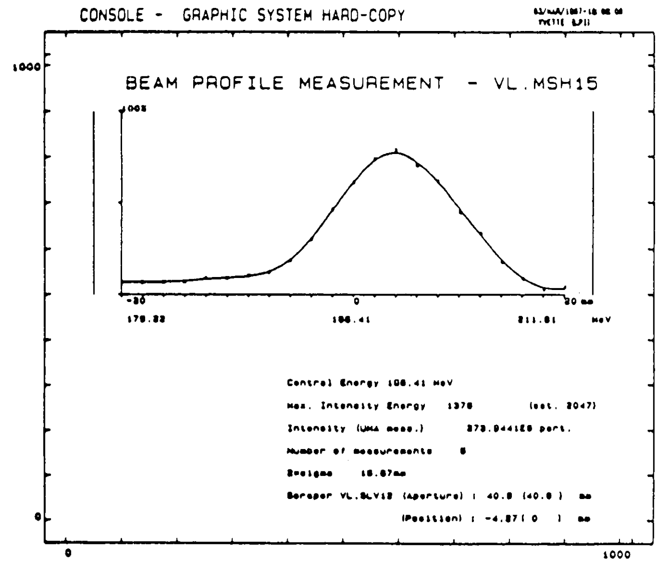


Fig 2 - SEMgrid beam profile

Synchrotron Radiation Monitor (MSR) can select visible synchrotron light from 4 different points in a quadrant of EPA, according to the choice of particle (e+/e-) and of energy dispersion (dispersion-free or not). The light is sent via an optical transport to 32 photodiodes; a HP 9920 microcomputer treats the data and sends the main beam transverse characteristics - vertical and horizontal emittances, form of profile, damping times - to the control system via a GPIB CAMAC interface.

SOFTWARE ARCHITECTURE

In the previous software architecture, the communication between Front-end mini-computers (FECs) and the Camac-based micros (ACCs) was done through the sharing of the ACC memory, the address and structure of which had to be described properly in both FEC-based interface software (Equipment-Modules), and in the ACC real-time tasks. The main reason for this protocol was the serial Camac link used as interconnection, which is a pure master-slave command bus, without any higher level of communication protocol.

The introduction of SMACC opened several new lines: the improved power and memory allow to use Remote-procedure-call and process-to-process communication protocols, and to move at the SMACC level the whole layer of Equipment-Module software. This has the advantage of providing a clean application-level interface (in the form of fixed-form procedure calls) between the two processors, of allowing full local control through local workstations, and of generating local video displays which can be broadcasted in a fast way without overloading the software communication link. All SMACC code is to be written in a high-level language, including Interrupt-service routines (ISRs), with the exception of small interface routines to RMS68k or to Camac.

Application-level Protocols

The Serial Camac link from the SMACC to the higher level is planned to be replaced in the near future by a more standard inter-processor network, providing commercial high-level software facilities, such as Ethernet with TCP/IP. For easy transition to such a link, the application-level protocols for FEC-SMACC communication have been redesigned as follows:

-A Remote-procedure-call protocol is used for the 'casual' equipment-module calls sent by one-shot application programs, or interpreter commands typed in by operators.

-The performance of remote-procedure calls on Serial Camac is not very high, due to the dissymetric nature of the link, and in addition some applications use inter-task communication between FEC and SMACC. A Datagram service is thus made available for this purpose.

-The highest percentage of traffic on the FEC-SMACC link is due to the flow of acquisition data from the process up to the main consoles. For this reason, a special protocol has been developed, called 'Data grabbing', which is described in more detail below.

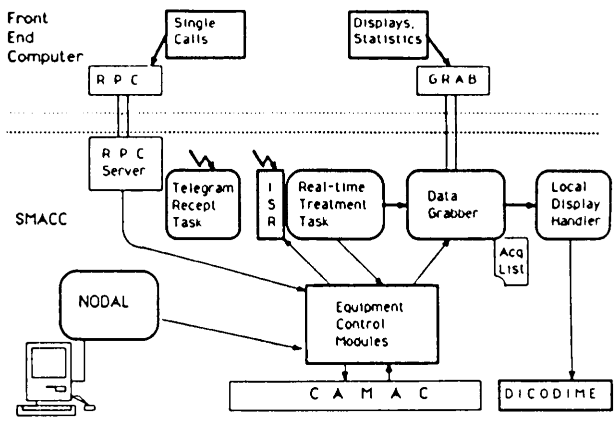


Fig.3 Typical SMACC Task Layout

The Data-Grabbing Protocol

The purpose of this protocol is to reduce to a minimum the overhead of transmitting messages from SMACCs to the upper level which concern the regular acquisition of data, by minimising the number of such messages exchanged. In the PS Control system, a concept of 'virtual accelerator' has been defined, allowing any machine to provide beam of different characteristics to the final destination. In normal operation, each main console is hooked to one virtual accelerator, sending and requesting data for the machine cycles devoted to this destination. This concept is integrated in the Data grabbing protocol, via an assignment of an 'User control block' to each requesting console or data-collection program. The basic functions offered are the creation,reading or deletion of acquisition request-lists. At creation, a request-list is defined as a sequence of elementary acquisition descriptions, which are split in the different SMACCs. Every machine cycle, each SMACC forwards a single composite message of all acquisitions currently requested, in the form of a linked list, from which an user can extract any given request-list.

Local Video Displays

As mentioned previously, several subsystems generate a video display through a Camac module (DicoDime), which can appear on a local TV monitor and be broadcasted, via the PS video multiplexer system, to any console. A simple editor for such displays has been provided on MacIntosh, emulating the DicoDime screen and allowing to entirely define simple displays, from the raw acquisition, through a range of predefined treatments (fixed scaling, bit selecting..), to the final display format (float,integer,variable texts). A data-driven SMACC task uses this information to update the displays at the desired rate - usually every LPI basic period (1.2 second).

The display device is also used for error messages by the SMACC tasks.

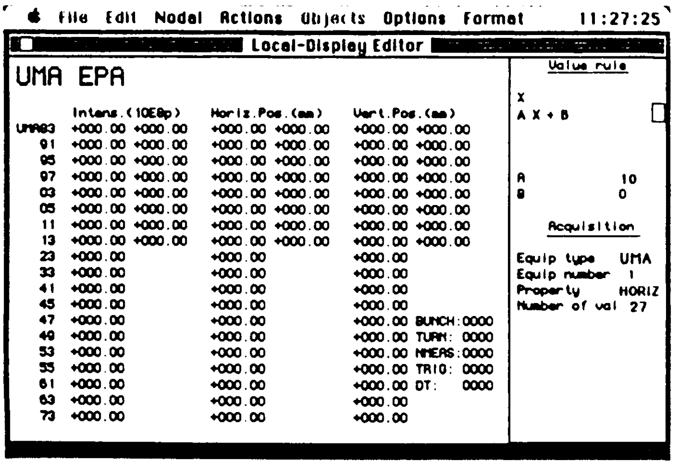


Fig.4 - Example of local Display Edition

Auxiliary Control Workstations

Experience with the previous system showed a lack of local access facilities, particularly when the accelerator was in a shut-down period, the front-end computers being often subject to maintenance or software upgrades - the same period being also the best for instrumentation specialists to work on their equipment.

The Apple Macintosh, used as SMACC terminal with mass-storage and also a resident Nodal interpreter- called MacinSMACC [3]-, has shown to be an appropriate and low-cost solution for the setting-up phase of new systems by the programmers.

Some effort must still be invested to show the benefits of using such tools by the controls exploitation team for diagnostic purposes, or by equipment specialists for improvement studies (long term statistics,..).

Implementation aspects

Instrumentation systems for new machines can never be fully specified before a first experimental period, which can last several months. The previous ACCs suffered of a lack of prototyping tools for this purpose, being only programmable in assembler, and needing to change both ACC code and FEC Equipment-module code whenever the data structures changed.

For the SMACC, a Nodal interpreter language was provided from the beginning, with a full command interface with the operating system RMS68k. This has been a powerful aid to build prototypes of instrument systems, together with local workstations mentioned above. However, the effort needed to provide a complete and fast cross-software production chain for compiled languages (C and Pascal) from a Vax-8530 running Ultrix[1], via the Norsk-Data network, was under-estimated, and the current state is still not very satisfactory. In addition, the use of remote cross-software development systems results in an increased complexity of the production task, which is not easy to learn by 'casual' programmers: knowledge of multiple operating systems and of network communications cannot be entirely hidden to them.

We believe that the main improvement can come from a maximum of testing and software quality control on the development machine, and for this reason are improving the test environment for software modules and RMS68K tasks in this context.

[1] Ultrix is a trademark of Digital Equipment Corp.

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