

THE COMPUTER-CONTROL-SYSTEM OF THE HEIDELBERG POSTACCELERATOR<sup>+</sup>

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Abstract

The 3MV section of the Heidelberg postaccelerator is operated under full computer control. A PDP 11/34 equipped with a JY 411-CAMAC interface services the operator's console via a parallel branch as well as the accelerator components via an extended serial highway. All parameters are controlled from the console by use of touchpanels and digital knobs. The basic software consists of a core resident data base and three control tasks which are functionally completely equivalent to a conventional console. Numerous other tasks are running under the operating system RSX11M for more complex operations and special control processes.

Introduction

The first postaccelerator<sup>1</sup> behind a tandem-van-de-Graaff accelerator consisting of independently phased RF-Resonators<sup>2</sup> is now in routine operation since more than one year. This accelerator which is fully operated by a CAMAC-based computer-control-system is used to boost the heavy ion energies from the 13 MV tandem by additional 3.3 MV of effective accelerating voltage in CW-mode and almost 6 MV in the pulsed mode.

The postaccelerator system consists of - at present - 12 room-temperature spiral-loaded RF-cavities as accelerating or bunching elements, each of them powered by a commercial 20 kW FM broadcast transmitter. For beam handling there are 8 dipole magnets, 26 quadrupoles, and a considerable number of beam diagnostic elements, like faraday-cups, viewers, beam scanners, an emittance measurement device, and an extended vacuum system, allowing to feed the post-accelerated beam back to the existing experimental area of the tandem. Though the postaccelerator in its present form is already in use for nuclear physics experiments this system represents only about one third of the complete postaccelerator which is scheduled for operation about end of 1979.

Basic Concept of the Control System

The use of independently phased resonators for an acceleration of a large variety of different ion species delivered by the electrostatic tandem injector demands for an efficient computer assistance of the operator. A computer program to calculate all settings for RF-amplitudes, -phases, quadrupole-gradients and dipole fields which depend strongly on the injection parameters, was mandatory. Control of all parameters directly by a computer maintaining the accessibility for manual interaction was highly desirable.

As only very limited time was available for the development of the control system the concept was based on the following general guidelines in order to limit the complexity of the overall system:

- a) all remote control of the postaccelerator should be performed only via the computer. As no hardwired back-up system for control was to be installed this decision enormously simplified the wiring as well as the logics of the programming, but demanded for a reliable and comfortable interface between the operator and the accelerator hardware.
- b) The computer control system should not be used for closed-loop regulation of parameters or for operating safety interlocks. Every critical device should have its own hardware regulation system keeping track of the values set by the computer

and should be protected by its own hardware interlocks which can react even in the case of a computer failure. Similarly the computer should not have to synchronize with the accelerator to acquire time dependent parameters. All rapidly varying parameters e.g. in the pulsed operation mode have to be latched to be read at any time. By these provisions timing problems were greatly alleviated.

- c) The control system should reflect the modularity and expandability, which are the key features of the accelerator itself. Thus, the inclusion of additional parameters, controls or functions as well as the expansion of the overall system by a factor of three should be easily possible without major modifications to the existing system.
- d) As already most of the RF-regulation electronics had to be designed and built in house the control-system had to be based on standard, commercially available products to a widest possible extent. CAMAC at present is the most commonly accepted standard for control applications offering the widest choice of general purpose as well as highly specialized modules, and a variety of interfaces for different types of computers. Thus, the CAMAC standard was adopted for the control system of the Heidelberg postaccelerator.

The Control Hardware

The hardware of the accelerator control is schematically indicated in fig. 1. The system is controlled by a dedicated PDP 11/34 minicomputer equipped with 128k of memory, a floating point

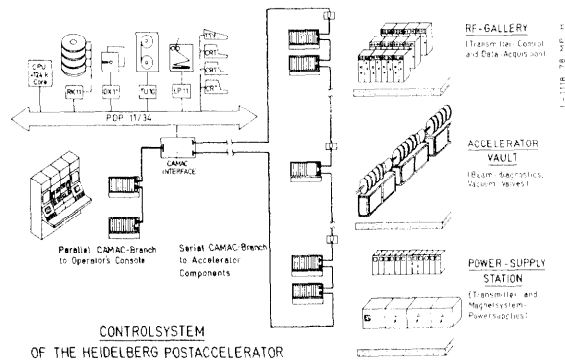


Fig. 1 Schematic diagram of the Heidelberg post-accelerator control system

processor and standard peripherals facilitating the development of the software.

All accelerator components and the operator's console are accessed via a single JY 411-CAMAC interface, which directly can drive a parallel CAMAC branch as well as a serial highway. Both branches are completely compatible with respect to software as they use the same control registers, and all features like direct memory access from CAMAC into the memory or vice versa are implemented for both branches. The highspeed parallel branch which is limited in length to 15 m and in the number of crates to 7 is used for servicing the operator's console where various display units need to be updated rapidly. Though refresh rates between 10 Hz and 1 Hz depending on the type of unit have proven to

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be sufficient much care was taken to minimize the response to an operator's intervention. The serial highway which can accommodate up to 63 crates runs as a large loop of about 300 m total length from the computer through three storeys of a remote part of the building. Only one cable consisting of 9 twisted pairs of wires necessary for a byte parallel serial highway interconnects the different hardware components of the acceleration and essentially is the only link for communication between the operator and the post-accelerator. The loop operated at a clock rate of 2.5 MHz is equipped with U-port adaptors for refreshing the signals and for galvanically isolating different sections of the loop, thus avoiding ground loop problems and difficulties due to differences in the ground potential.

For access and control of the accelerator hardware a compromise between comfort and costs had to be found. As most of the possible hardware faults would need a local intervention by a service technician for detailed diagnosis and repair the computer control is limited to those parameters which are essential for the normal operation of the system.

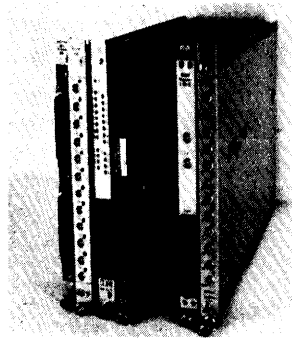


Fig. 2  
Camac modules used for basic control functions (from left to right: 32 channel ADC (LRS), 12-channel DAC (NE), transmitter control module (WES), power supply controller (KSC), relay multiplexer (Wenzel), RF-multiplexer (SEN).

Basically, four standard types of highly integrated CAMAC modules (fig. 2) are used throughout the accelerator, keeping the number of crates down to a minimum. Readout of analog values is achieved by an ADC module with 32 independent differential input channels which are scanned continuously by the module itself. Half of such a module is required to readout all relevant analog parameters of one 20 kW RF-generator. Setting of analog values by the computer e.g. resonator phases or amplitudes is performed by 12-channel DAC-modules which can service four transmitters simultaneously. The third unit in fig. 2 is a specially designed transmitter control module which combines 24 relay contacts and 24 status flags for a completely remote operation of one 20 kW RF-station modified accordingly. One fourth type of module is used for the control of one magnet power supply each. In addition to these four basic modules there are two relay multiplexers, which are used to select analog or RF-signals which the operator can inspect on an oscilloscope at the console for diagnostic purposes.

Though these modules are quite different in function they all meet one common criterion which has proven to be essential for easy software development: to perform a specific operation the computer needs to know and execute only one single CAMAC command and not a series of consecutive steps. Thus, all units can be handled formally identically and no special device drivers are necessary.

#### Software Organisation

The PDP 11/34 is operated fully under control of the multitasking operating system RSX 11M. The control software is largely subdivided into different smaller programs which are responsible for specific operations and can be run independently from each other in

parallel. By this scheme the software development and maintenance was greatly facilitated. Tasks which have to perform larger numerical calculations are written in Fortran, whereas the control software is written in assembler language.

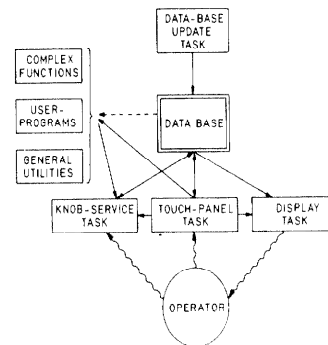


Fig. 3  
Structure of the control software

Fig. 3 shows the structure of the basic software. The main effort was invested into the scheme of a data base which contains all information on the accelerator components, e.g. CAMAC addresses and commands, actual values, calibration factors and the names of the parameters. This data base is stored in the memory. Using a memory-resident data base guarantees fast access and fast response, but has been possible only by taking full advantage from the modularity of the hardware itself. Wherever possible the same set of tables is used to describe different units of the same type. Thus the size of the data base could be kept below 9 k of words of memory and certainly will not exceed 16 k for the accelerator in its final size.

All tasks can access the CAMAC hardware only by using the information stored in the central data base. After changes or additions to the hardware in most cases just the data base needs to be updated. Without further programming the basic control routines then will have access to the newly installed components.

Three primary control routines are provided which together with their related hardware components at the console are completely equivalent to a conventional operator's console and enable the operator to perform all necessary operations manually. These are i) a display-routine, to inspect all required parameters on a TV-screen in a numerical or quasi-analog form ii) a knob service routine to change or optimize settings of parameters manually by turning some control knobs and iii) a touch panel service routine as the central program.

By touch panel interaction, the operator has full access to the data base. At maximum four logically consecutive steps are required to uniquely specify a parameter, which afterwards by touch panel command can be included in the display table or can be connected to one of four control knobs. Simple functions like switching operations are directly performed via the touch panel. For illustration fig.4 shows the sequence of touchpanel images the operator has to work through in order to observe the phase of a certain resonator. For convenience, there are preformatted pages of parameter sets which can be called for display as shown in fig. 5 containing the most important parameters of one resonator.

Without noticeable difference the operator can perform more complex operations like the startup sequence for one RF-generator or even the whole accelerator. For such purposes there now exist a large number of different tasks, which can be started via the touch-panel and which communicate with each other under control of the operating system.

