

CONTROLS FOR THE ANTIPROTON ACCUMULATOR

D. Blechschmidt, B. Carpenter, A. Daneels, T. Dorenbos, H. Kugler,  
T. Pettersson, J-P. Riunaud, G. Shering, A. van der Schueren

CERN, 1211 Geneva 23, Switzerland

The Antiproton Accumulator (AA) is a technically advanced, complicated and unusual facility. Its controls had to be built in a short time by a very small permanent staff calling on part-time resources from other parts of CERN. As the AA will eventually be integrated into the PS accelerator complex, its process interface, process computer, systems software and lower level applications software have been made to the new PS standards. For the efficiency of commissioning and first operation the present versions of high level application programs have been written in NODAL by the equipments specialists using a programming philosophy and a new "Touch Terminal" from the SPS. In addition, two desk top computers with a separate GPIB are used for the stochastic cooling system. The paper outlines the pragmatic approach in composing the controls for a complicated machine using the procedures and components available at CERN. The experience gained after an early and successful start-up is reported.

Introduction

The AA will eventually be an operational facility in the CPS accelerator complex, operated from the CPS Main Control Room. Therefore, its CAMAC interface, process computer, systems software and low level application software were implemented according to the new CPS controls standards. Since, however, the AA controls had to be built by a small permanent staff in a short time, a pragmatic approach was adopted wherever this was feasible. In particular, the specific interface had to match with process equipment designed by the various Divisions at CERN where it was usually conceived according to local philosophy. Nevertheless, the interface was built from existing designs with a minimum of modifications and a high degree of uniformity. This was achieved as a global effort calling on part-time help from various groups all over CERN.

Another important feature in this context was the new "Touch Terminal", developed at the SPS. Its choice fits conveniently the philosophy for high level application programs which were written in NODAL by the individual equipment engineers. This pragmatic and flexible approach in the composition of the controls of such an unusual and complex machine was a necessary condition for the early and successful start-up of the AA, the first machine using principles and components of the new CPS controls system.

Process Computer and Basic Software

The computer system handling the controls of the Antiproton Accumulator is based on the standard CPS computer configuration, NORD-10S, with 256 kilobytes of main memory and 10 megabytes of disc memory. The hardware interfacing is via serial CAMAC. The operating system used is the manufacturer's standard virtual operating system.

To cope with the requirements of real time control in such a specialized environment a certain number of operating system facilities have been added but without endangering migration to future releases of the operating system. This is a necessity if the cost

of system software maintenance is to be kept within reasonable limits.

All user programs are written in the interpretative language NODAL, pioneered at the SPS. This language offers easy-to-use syntax and structure at a time penalty which is of limited importance in this application. To access the actual process hardware all user programs call Equipment Modules<sup>4</sup>.

The computer is installed in the computer room of the new CPS Control System, and is fully integrated in a general back-up scheme. Thus, although several computer hardware faults have occurred during the early runs, none of them have caused excessive loss of machine time. A no-break power supply has now been installed to protect the computer and the central CAMAC installation.

The computer system is presently used in a stand-alone mode, using three touch terminals<sup>3</sup>. Eventually, it will be integrated into the CPS Control System, using standard network software and hardware.

Standard Interface

About 900 process variables are accessible. The necessary hardware consists of 18 CAMAC crates, about 430 CAMAC or CAMAC related modules. Their variety is less than 20 with only 5 different types of modules covering over 70% of the total. The length of the serial highway is about 1 km. At present two loops are installed. One of the loops is used for the process whereas the other serves for laboratory tests. As major constraint the short time of realization, only 2 years from lay-out to commissioning in July 1980, had to be considered.

The interface is structured in the way that the systems are controlled by sets of CPS standard interface modules<sup>5</sup>. The serial CAMAC loop allows for full crate decoupling and a high degree of autonomy of systems. A loop-collapse and bypass facility provides an easy and fast system diagnosis, and allows for graceful degradation in certain cases.

The distribution of the machine programme information and the acquisition of analog signals of large bandwidth (DC to 25 MHz) is superposed on the structure outlined above. The Program Line Sequencer broadcasts all relevant information about CPS machine cycles<sup>2</sup>. This together with pulses for synchronization are fed through the free channels of the video cable transmitting the Serial Highway information. Thus all relevant CPS machine information is available wherever the Serial Highway arrives. When control is transferred to the CPS control room, about 100 analog signals will also be transferred using the CPS standard Signal Observation System. Higher frequency signals will be converted by transient recorders before transfer.

A terminal connection is provided in all racks containing CAMAC crates in order to permit tests close to the equipment.

So far, the system has been operational for 3500 hours. Its MTBF was greater than 350 hours, corresponding to > 15 years for an individual module. This high performance at start-up prevented tedious and lengthy debugging phases due to intricate coupling of malfunctioning of hardware, software and equipment. Fatal errors destroying the beam have not yet been experienced. Finally, the short repair time of typically some 15 min. should be mentioned; for the first run this results in less than a percent of machine operation time with reduced control power. This is mainly due to very comprehensive on-line and off-line diagnostic facilities.

### Specific Interface

The AA process equipment has been designed and built at various other Divisions of CERN. In many cases it could not directly be linked to the standard CAMAC interface, so it has been necessary to add some specific interface modules.

A "Status-Command Unit" was developed for control of the vacuum system. It translates standard logic levels into relay contact closures. For standardisation purposes this module has been further developed to cope with a wider range of systems and to show all control and status bits on a display at its front panel. This provision has been very useful for the diagnosis of problems arising from particular parts of the control chain as a whole.

A similar module was developed also handling analog controls, with a linear LED to indicate the analog potentials transmitted and received. These two versions of the Status-Command Unit are globally used as the standard modules of the specific interfaces of AA.

Mechanical movements in the AA, such as beam scrapers or timing of delay and filter lines for the stochastic cooling system, are carried out by stepping motors. The motor drive electronics have been taken over from the PS Linac, with some modification.

The motor is driven until its acquired position corresponds with the position requested by the computer (local closed loop control). A keyword is used to prevent inadvertent operation, which in the case of the scrapers could destroy the stack of antiprotons. The motor drive also provides detailed information on abnormal conditions, such as open cables, etc.

Another module has been designed and built for the AA Specific Interface to minimise the risk of an accidental destruction of the antiproton beam due to transmission or operator errors. This keyword module will be used to protect sector valves, TV screens and eventually the r.f. cavity.

### Terminals

As the AA is a complex machine, many of the features of a full control system are required, which include multiple access points, display and touch panel facilities and also sophisticated application programs. The solution found for the intermediate phase of commissioning and initial operation from the local control room was to use

three of the "Touch Terminals" developed for the SPS control room. These provide graphics and touch panel facilities but make minimal demands on the system software of the process computer. A dedicated video monitor displays active alarms generated by the background scanning programs.

On the touch terminal, a raster scan TV screen displays monochrome graphics on a 384 x 288 matrix. A touch panel and screen provide up to 16 computer written "buttons" with legends of up to 30 characters under each button. In addition a pair of digit selection switches and displays are available.

The displays and touch panel facilities are CAMAC based units widely used at the SPS and elsewhere. In the Touch Terminal configuration they are packaged into a compact mini-crate with a microprocessor controller. The hardware link to the computer is the same 2400 baud serial current loop as used for the standard video display unit (VDU). The Touch Terminal is simply put in series between the VDU and the computer, no extra hardware is required. The microprocessor controller is programmed to be transparent to the terminal driver software in the process computer. It passes characters on to the VDU except for certain "escape sequences" which it can detect, and other sequences which it can insert. These are chosen so that simple functions such as LEGEND, BUTTON, BUTS, MOVE, VECT, SOLID, etc. can be provided to allow a powerful and easy to use dialogue.

### Application Software

The application software is built in layers of modules reflecting the structure of the process hardware and its operational use.

Interface Modules, at the lowest level, are tailored to the hardware interface, i.e. the various CAMAC modules to which they communicate through the CAMAC driver. Basically, they are procedures which convert standard control functions (read, write, initialisation, etc.) into a sequence of CAMAC calls as requested for a particular CAMAC module.

The medium layer consists of Equipment Modules reflecting the various equipment such as power supplies, timing units, beam transformers etc. in the standard interface. Equipment modules are essentially procedures operating on a data base which describes all process variables belonging to a particular category. These procedures are function-oriented, i.e. they ensure serial execution of a control function on an array of equipment of the same type. An additional entry makes them visible to NODAL as system variables.

At the user end, the high level layer is a set of NODAL programs organised in a tree-structure which performs all process control activities and also serves for the operator-terminal dialogue. This last layer will eventually be redefined once the AA operational procedures are frozen and its controls merged with the CPS controls complex.

The 12 Interface Modules and 36 Equipment Modules have been provided on an industrial basis by the PS Controls Group according to AA requirements; they are coded in low level language within appropriate software templates, hence to a high degree of uniformity according to the new CPS control system standards.

The high level application programs have been written in NODAL by the AA process equipment specialists. For convenience, all programs dedicated to the machine operations are organised in a tree structure. All commands are entered via the touch terminal; logging and display are done via the TV screens and a line printer. Apart from some further conventions concerning program naming and preferential format, use of the touch screen, warnings and hardware error display, no particular standardizations have been imposed for the sake of flexibility.

All programs attached to this tree are nested to not more than five levels deep, but are organised in non-hierarchical sequence, each program calling any other one for execution by the function NEXT or also the one by which it was called itself by BACK.

The tree branches map the twelve basic AA systems such as timing or stochastic cooling; three additional buttons call the following program packages

- "controls" to read, change or restore Equipment Module data bases, in particular CAMAC module hardware addresses, to initialise the hardware and also for CAMAC error recovery and diagnostics.

- "alarms", consisting of a series of scheduled surveillance programs for particular equipment and running in background NODAL. Such alarm conditions are displayed on a dedicated display in a standardized format.

- "operations" for an easy and quick access to particular machine operations, thus avoiding deep probing into branch programs, such as for beam dumping, switching all interlocked magnets on or preparing for a particular mode of AA operation.

#### Timing

All timing pulses for the AA are produced by preset counters in the standard interface. For coarse timing, these counters are synchronised with the PS by a 1 kHz pulse train. For users requiring particle synchronised timing the modules are running on the RF train of the PS of several MHz depending on the PS harmonic number. A software controlled simulator in the AA can replace all these timing signals from the PS at the desirable repetition rate for equipment test purposes. Low precision timing is distributed together with the CAMAC Serial Highway on a 6-quad cable, the "umbilical cord", and repeated in a "timing distributor receiver" in each rack containing a CAMAC crate.

The coarse timing counters are triggered by a "forewarning" pulse which arrives 300 ms before p-extraction from the PS and 2 s before  $\bar{p}$ -extraction from the AA, whereas the modules for precise timing are started by a pulse synchronised with the p-bunches in the PS for p-extraction or with the  $\bar{p}$ -bunches in the AA for  $\bar{p}$ -extraction, at 100  $\mu$ s before either event. As all the counters

are entirely controlled by software, they can also be triggered asynchronously from an application program.

Two signals "p request" for extraction of protons from the PS (corresponding to AA injection timing) and " $\bar{p}$  ready" for extraction of antiprotons from the AA (corresponding to AA ejection timing) inform the CPS about the operating conditions desired by AA. They are logic levels which can be activated continuously or on a single shot basis. Both signals are also used to gate the "fore-warning" to equipment to be triggered on purpose only, such as kickers, shutters, r.f. function generators, etc. The synchronisation procedure of the AA with the CPS and SPS is described elsewhere<sup>6</sup>.

#### Control Room

The local control room (ACR) is situated on ground level and immediately attached to the AA hall for rapid access to the machine. This proximity also favours observation of analogue signals at high frequencies, with cable lengths between 50 and 150 m.

The radiation level in the machine hall being expected to be sufficiently low, the ACR is separated only by a thin wall that provides no shielding. Large windows to overlook the AA could therefore be permitted. Public relations greatly profit from this unusual facility and occasional doubts on the status of equipment can be settled with the help of binoculars.

For low level electronics and instrumentation there are 29 racks (23 of standard height, 6 lower ones). Computer peripherals are simply mounted on tables in the centre of the room.

The stochastic cooling instrumentation forms an independent subsystem based on the use of two desk-top computers and the GPIB. This instrument cluster is being connected to the CAMAC system for remote access.

#### Acknowledgements

The authors wish to acknowledge the contributions made by many of their colleagues in the PS, ISR and SPS Divisions of CERN.

#### References

1. G. Baribaud et al., CERN-PS/CO/Note 79-16, paper presented at the 1979 Particle Acc. Conf., San Francisco.
2. J. Boillot, G. Daems, CERN-PS/OP/CO/79-39 (1979).
3. G. Shering, CERN-PS/AA/Note 80-10 (1980).
4. G.P. Benincasa et al., paper presented at the 2nd IFAC/IFIP Symposium, Software for Computer Control (SOCOCO), Prague (1979).
5. S. Battisti, H. Kugler (editors) CERN-PS/CCI/Note 77-31 (1977).
6. G. Beetham et al., CERN-PS/DL/Note 80-3 (1980).