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COMPUTER CONTROL AT THE KVI CYCLOTRON

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ABSTRACT. - Computer control is being introduced at the KVI cyclotron for the following purposes: i) control of new additions to the accelerator installation, ii) increase of the number of observables for the operator, iii) beam diagnostics and iv) beam optimization.

The new system will eventually control all accelerator components from one single desk. Control of experimental set-ups will, at least initially, not be foreseen. The system is based on a PDP-11/34 computer, the RSX-11M operating system and CAMAC. A CAMAC Serial Highway with a total length of 300 m links remote CAMAC crates to the computer. The control software includes a disk resident database describing all accelerator components in terms relevant for control purposes. Independent control tasks service the touch screens, TV displays and knobs.

Since many existing devices widely varying in properties have to be controlled, an efficient, flexible and standardized interface has been designed for connecting these to CAMAC.

Microprocessors are used for controlling autonomous subsystems, such as beam profile monitors, in order to reduce the load on the central computer.

INTRODUCTION. - The main components of the KVI cyclotron facility are a K=160 cyclotron, 10 beam lines and a Q3D magnetic spectrograph. The facility has been in regular operation for nearly 10 years, during which time many extensions and improvements to the installation have been made. At present, two external ion source set-ups are being contructed together with an axial injection system. Since the basic design of the accelerator dates from the early sixties, the controls are nearly entirely hard-wired. Although they operate satisfactorily from the viewpoint of dependability, they are, by their nature, inflexible and constrained.

It is therefore not surprising that during the past operational period of the cyclotron demands frequently arose which could not be satisfied by the present control system.

These demands can roughly be sorted into four categories:

i) Control of new components. Problems here typically arise from lack of physical space in the control desk or lack of multiplexer channels.

ii) Operator help. Typical examples are: beam alignment, harmonic coil setting or simply more data taking, e.g. on beam position.

iii) Beam diagnostics. Examples: Beam centring in the central region of the cyclotron, beam profile scans, R.F. phase measurements.

iv) Beam optimization, e.g. adjustment of the RF phase history of the beam during acceleration.

In 1978 the decision was made to introduce a dedicated computer into the cyclotron controls, primarily for beam diagnostics and optimization. When, shortly afterwards, funding for the axial injection system was obtained, we decided to emphasize computer control in view of the very significant number of new components which could not be controlled from the old desk anyway.

BASIC REQUIREMENTS AND CONSTRAINTS. - Although initially the new control system will mainly be used for controlling the components of the new low energy beam lines and the axial injection system, it should take over all existing controls eventually. Therefore it is required that existing components, which have no provisions for computer control, should be easily interfaced to the new control system. Additionally, expansion should be possible in view of possible later extensions to the facility.

Furthermore it was decided to replace the existing controls gradually, in order to minimize cyclotron down time.

Since the manpower available for implementing the new control system is very limited, its complexity should be minimized and standardization of components and procedures is mandatory. This has led to the following design decisions.

a) CAMAC has been chosen as the standard for computer interfacing. Also, local standards have been set up for connecting equipment to CAMAC modules. These standards refer to signal levels, cable and connector usage and lay-out, local controls and to the number and purpose of data lines.

b) For the basic organization of the control system few new concepts should be introduced. Rather, the examples set elsewhere [1) 2) 3)] should be followed as much as allowed by differences in accelerators, computer hardware, local ergonomic preferences and the need for continuity with the old control system.

c) Detailed control of more or less autonomous subsystems is to be relegated to dedicated microprocessors, thereby decreasing the load on the central control computer. Examples: beam profile monitors, emittance measurements.

d) The existing subsystems which provide safety interlocks, local and remote control and data transmission facilities will continue to be used for controlling the beam line components. A microprocessor will be used to connect these systems to the control computer.

For off-line testing and back-up purposes it was decided that - as a rule - all equipment should also have local controls.

No safety interlocks should be implemented by the control system, nor should it be part of closed loops essential for normal stable operation of the accelerator.

CONTROL SYSTEM HARDWARE. - The computer system consists of a PDP-11/34 with 124K words memory, floating point processor, 3 RL01 cartridge disk drives, a RX02 dual floppy disk drive, one console terminal, up to 8 other terminals and a CA11FP CAMAC interface. A simple data link to the VAX computer obviates the need for a line printer.

The CA11FP directly interfaces a single CAMAC crate to the computer. This crate is used for the modules needed to drive the control desk, it also houses the driver module for the CAMAC Serial Highway.

The Serial Highway is used to connect crates at remote locations, such as the ion source room on top of the cyclotron vault. Its round trip length is approximately 300 m and it is operated in bit serial mode at a bit rate of 5 Mbit/s. Six stations are located on the Serial Highway. Initially they contain one CAMAC crate each.

Regarding the selection of standard CAMAC modules, it is necessary to choose between two types of modules [4], which may respectively be characterized as 'function' or 'equipment' oriented. A function oriented module performs a single type of input or output. Examples: 24 bit input module, 16 channel ADC module. An equipment oriented module is designed to interface a specific type of equipment. Example: power supply controller module, containing a DAC, input bits for status readout, output bits for status control and an ADC.

When building a new installation, equipment type modules may be preferred, since the specifications of the equipment and the modules may be matched. Cabling between module and equipment is then very simple. We, however, are confronted with great variability, even in components as easily specifiable as power supplies. In this case the flexibility that results from combining in- and outputs from function oriented modules on an 'as needed' basis is advantageous. We have decided, therefore, to standardize on modules of this type. It was found that nearly all equipment could be interfaced using only four different modules, i.e.: 24-bit input, 16-bit output, 16-channel ADC (12 bit) and 16-channel DAC (12 bit).

For each piece of equipment to be controlled, bits and analog channels are taken as required. This makes the use of distribution panels for the logical signals unavoidable. Also, level conversion is necessary since relay contacts are generally used for control.

This approach is very efficient in the sense that nearly all bits available in the CAMAC modules may be utilised and that no more bits are routed away than are needed in each case. However, more than one cable is needed for connecting each piece of equipment and the distribution process tends to be labour intensive, time and space consuming, inflexible and difficult to trace and to document.

Fig.1 schematically illustrates our solution to the distribution problem, which does not suffer from these defects. Starting at the CAMAC crate, the input and output bits from the CAMAC modules are connected to patch panels, where they are given individual wire terminations. From these, connections are made to similar bur smaller patch panels, each of which is cabled to a standard interface unit. These units perform signal level conversion and are cabled to the equipment to be controlled. Since the most common piece of equipment is the power supply, a standard power supply interface has been designed.

The following features contribute to easy signal distribution: i) For all wire terminations, types employing the insulation displacement technique are used. This results in very fast wiring when compared to soldering or wirewrap connections. ii) Only two different types of fixed length cables with connectors on both ends are needed for all connections within one Serial Highway station. iii) Printed circuit boards (of only four different types) are used for the other connections and for level conversion.

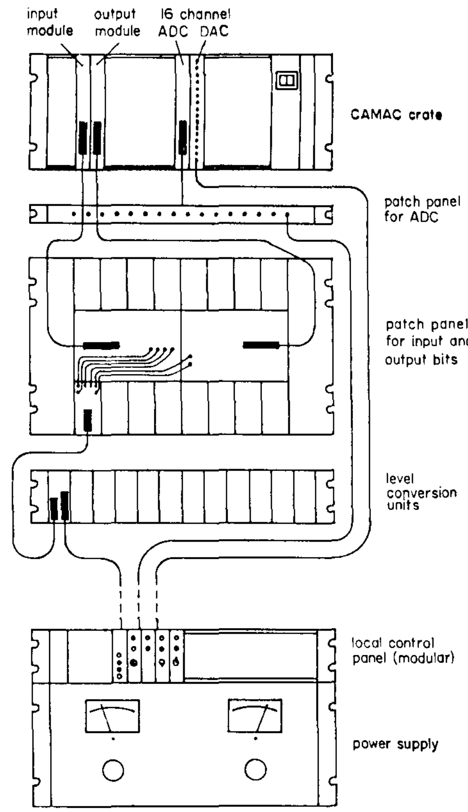

Fig. 1 : Distribution of data lines between CAMAC modules and equipment, e.g. a power supply. Equipment specific wiring is confined to the patch panels, all other connections are made through standardized cables.

CONTROL DESK. - Since the existing control desk is both mechanically and ergonomically unsuited, is already overcrowded and moreover will remain operational for some time, a new control desk was designed for housing the new control elements. Fig.2 gives an artists impression; the real desk, although delivered, was not fit for being portraited. The desk is designed to be used by one operator, although two persons can sit and work at it.

The following control elements are provided: two sets of four turning knobs, each knob may be assigned to any variable suited for such control. To each set of knobs a TV display is assigned on which the names and control values of the variables currently being controlled are displayed.

The desk contains two touch panel displays, used by the operator to perform knob assignments, switching operations etc.

There is one large colour display screen which is used for status display of a number of operator selected variables. The values may be displayed numerically or as horizontal bar graphs. For displaying 'once only' information, e.g. the beam schedule or hot news for operators, there is a separate 'scratch' display. Four TV monitors are to be multiplexed to TV cameras, e.g. for looking at viewing targets.

One terminal is mounted in the desk, it is not needed for normal cyclotron operation but will be used for testing purposes and for I/O by application tasks.

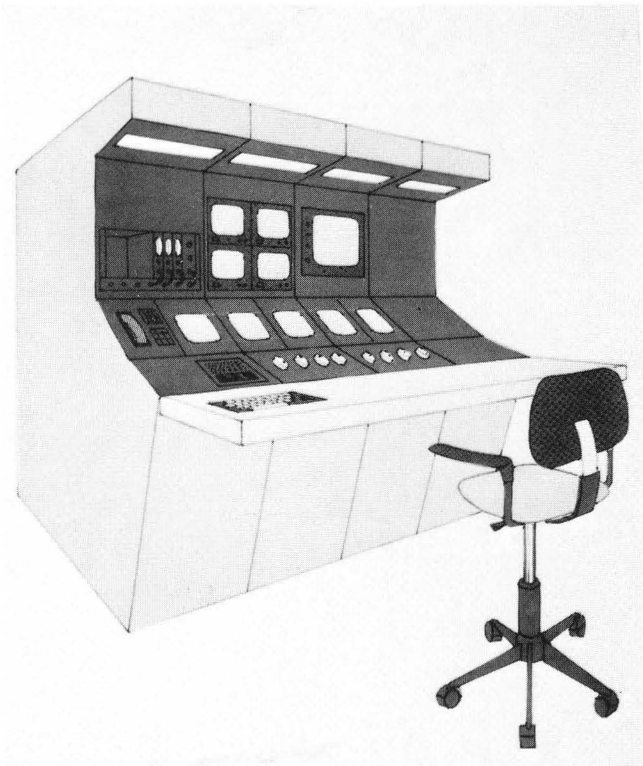

Fig. 2 : The new control desk.

CONTROL SYSTEM SOFTWARE. - The database is one of the most central components of the control software. Its elements describe separately controllable or readable entities. There is no need for such an element to have a one to one correspondence with a piece of hardware. It is possible e.g. to have a database entry for the beam optical magnification in a section of beam line. The elements are referenced by name, the naming convention has been adopted from ref. 2.

Since many variables may be switched to local control, the database elements are not used as an up-to-date image of the accelerator status. Data acquisition is, therefore, only done when the information is actually requested. However, data describing the most recent (remote) control action are stored in the varable's database element.

Since only a limited number of variables can be accessed simultaneously from the control desk and since the replacement of these variables by others does not occur at high frequency even on beam startup, we decided to make the database disk resident but to place the index to the database and the database elements referring to the variables currently being controlled in a memory resident common block. In other control systems the database is entirely located in main memory [3] or in a special CAMAC accessible memory block [1) 2)]. Contrary to these examples we preferred the advantages of simplicity and cost to speed. Because of the modularity of the software several ways of increasing the database speed are possible, if the need should arrive.

The control desk is serviced by a number of tasks, each dedicated to a single purpose. These tasks execute in parallel and communicate by sending and receiving messages and via database elements. The most central of these tasks is the one which services the touch panels, since it controls the execution of the other tasks to a large extent.

There are two boundary conditions other than those imposed by design objectives which have had a large influence on the software: the size of the virtual address space of 32K words and the maximum memory size of 124K words, both imposed by the 16/18 bit word length of the PDP-11/34. These restrictions have influenced the software design, most notably that of the database, and virtually preclude the use of a high level structured programming language for the system software. Most of the code, therefore, has been written in assembler language without the advantages of readability, structure and portability of such languages as Pascal or Fortran 77.

Fortran has been used, however, for tasks that are not frequently used and for application like programs.

Contrary to many examples, we have no plans for incorporating an interpreter based language into the control system. We feel that Fortran callable CAMAC service routines provide sufficient capabilities for application programs while a too great profusion ad hoc programs referencing CAMAC may be avoided.

REALIZATION. - At the time of writing the control system is being built. The CAMAC Serial Highway has been installed and a sufficient number of crates and modules is available for interfacing the components of the axial injection system. Prototypes of the interface electronics have been tested and series production has started. The control desk has been delivered and is being fitted with TV monitors etc.

The software design has progressed to the stage of testing control tasks. The database design has been completed and the database service routines are operational.

A microprocessor controlled set of stepmotor driven beam scanners is operational and is in its turn controlled from the PDP-11. It delivers the beam charge profile and the position of its centre of gravity with respect to the beam line axis to the operator [5)].

From an operational point of view we expect that near the end of 1981 the first power supplies will be controlled from the new desk. A year later all components of the axial injection system should be (computer) controllable. One year later again we expect to be thinking about removing the old control desk.

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