IEEE Transactions on Nuclear Science, Vol.NS-22, No.3, June 1975

A FULLY CAMAC INTERFACED COMPUTER CONTROL SYSTEM FOR THE VICKSI-ACCELERATORS

W. Busse, H. Kluge
Hahn-Meitner-Institut für Kernforschung Berlin GmbH
Bereich Kern- und Strahlenphysik
Berlin, Germany

Summary

The computer control system for the VICKSI-project uses CAMAC modules as the unique interface. A single loop CAMAC-Serial-Highway will control all the equipment associated with the accelerators and the beam paths. The components of the main-control-console as well as general maintenance-equipment are interfaced to the computer via a Parallel-CAMAC-Highway. No further submultiplexing is done. Special attention was given to the choice and specification of CAMAC-Modules in order to reduce the number of different types and to standardize the ports to the equipment under control. The impact on hardware (cabling, maintenance, error detection) and software design will be reviewed. The software itself is based on the use of a real-time executive in conjunction with an interpreter and a data base allowing a comprehensive addressing scheme and simple system tasks.

Introduction

The accelerator project VICKSI[1] at the Hahn-Meitner-Institute in Berlin combines the existing 7-MV Van-de-Graaff with a new isochronous split pole cyclotron to serve as a heavy-ion accelerator-system. The beam matching path[2] between the two accelerators will include a stripper and two bunchers to adapt the Van-de-Graaff beam to the requirements of the cyclotron injection. After extraction from the cyclotron the ion beam may be sent along the postaccelerator transport system[3] to about 12 different target areas. The present state of the project is presented in a separate contribution[4] to this conference.

The value of computer control for the VICKSI accelerators was recognized in an early state of detailed planning since the number of controls was exceeding the amount which could be easily operated manually. Preference was given to a fully computer assisted control system to be introduced from the start, resulting in the following design decisions:

1. There should be one control room for the accelerators and the beam transport system.
2. The main control console should allow independent operation for at least two operators.
3. It should be possible to have remote or mobile consoles for special diagnostic purposes wherever the control system can be accessed.
4. All accelerator and beam line components should be designed or revised to be compatible with computer control. Additional local control panels should be the exception. Equipment associated with experiments should be supported by other computers.
5. The interlocks within all safety systems should be hard-wired and only feed status information to the control system.

Prior to our final decision with regard to the control system configuration we have studied existing control systems in other laboratories in Europe and the United States. We tried to extract positive and efficient development for introduction into our system after duly reducing size and facilities to our requirements.

In the following we shall report on some features which were given special attention in the design phase.

Design Objectives

Starting from the decision to take computer control into account from the very beginning no manual back-up was foreseen for times where one of the major components of the control could fail. In order not to degrade the system performance various conditions had to be imposed on the design.

With regard to the hardware set-up flexibility and reliability as well as easy maintenance were the major goals. Comprehensive and most flexible interaction were required for accelerator operation where the human element plays a considerable role. The software support should be powerful yet not impose any restrictions on the use of system resources.

Therefore it was decided to consider right from the beginning all the hardware implications necessary to feed into the system any information which is available on the hardware status (analog and digital) as well as those necessary to control whatever takes part in the acceleration and beamtransport process.

On the other hand the software development was to be put forward in several stages ranging from simple "direct" control via knob-to-device or display-to-device assignments up to sophisticate control operations including start-up according to preset tables and closed loop control in the long run. These problems have of course been investigated by many accelerator laboratories. In most cases a more or less singular solution has been provided, however, we could take over many of their ideas and many recommendations arising from their experience, especially with regard to the concept of man-machine interaction. After all our design will be closest to the CERN Lab II solution[5,6].

Normal operation will be extensively supported by standard routines which can be called by "push-button interactions" including easy assignment of knobs and quick response of the system. More sophisticated investigations will be allowed by the use of an interpreter with the power of BASIC or FOCAL but especially adapted to the needs of accelerator control like NODAL which is used at CERN Lab II.

System Configuration

A schematic view of the VICKSI computer control system is given in Fig. 1. A PDP-11/40 computer is used in the system with a Parallel-CAMAC-Highway [7] to provide the interface to the operator's Main Console, to a system maintenance area and to a CAMAC-Serial-Highway[8] driver.

All the accelerator and beam line components will be controlled via the single loop CAMAC Serial Highway System. As the equipment under control is distributed almost equally along the beam transport path the Serial Highway will be of about 300 m of total length. It will interface 35 crates with about 550 module-ports.

Operator's Consoles

There will be one Main Control Console set up in the Main Control Room. For general service in any area we will foresee the possibility to connect mobile consoles to the control system. In general any readable information may be accessed from any console, simultaneous control of a device will, however, be excluded.

Main Control Console. The Main Control Console will basically contain three general purpose bays designed for independent system operation. The additional bays will be more or less dedicated to specific system tasks.

One of the general purpose bays will be set up for general graphics as well as system access via the inter-

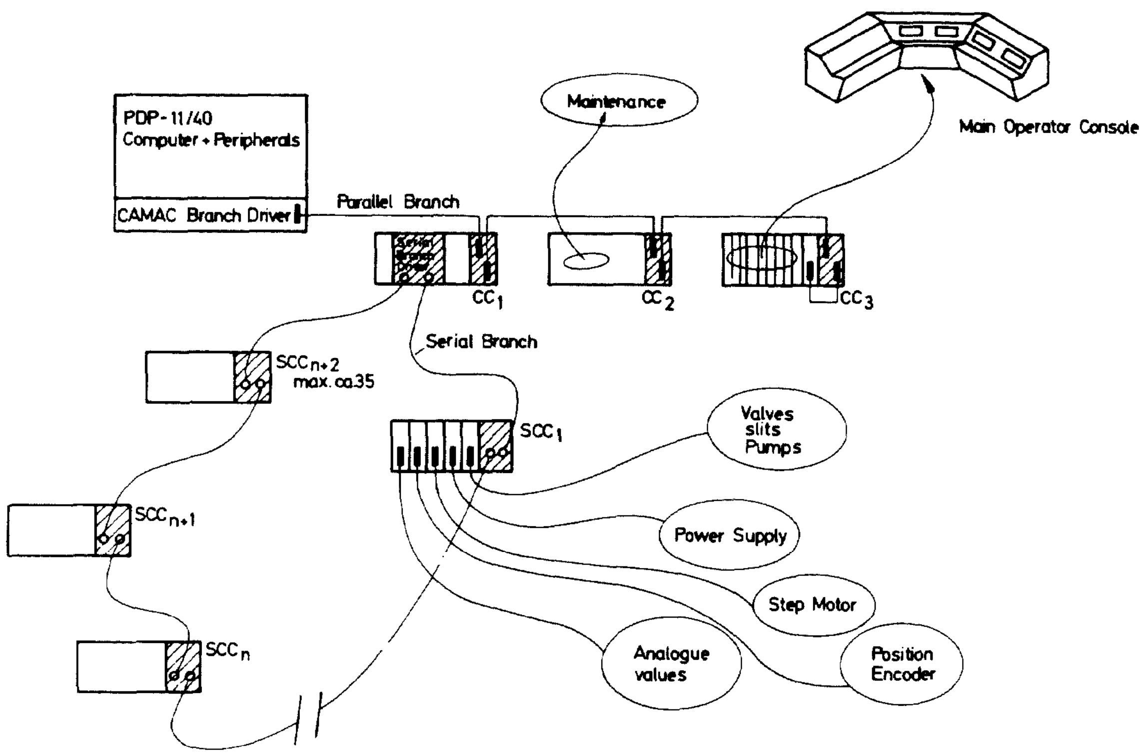

Fig. 1 Schematic View of the VICKSI Control System

preter. The two other bays will be equipped identically. Each of them will consist of

- a large colour TV-screen for any general purpose display including coarse graphics
- one or two knobs for device-control
- touch panels[6] consisting of a BW-TV monitor under a transparent screen with 16 touch-sensitive areas for program requests, program-option selection, device-to-knob assignments or device-to-display assignments.

The additional bays will be dedicated to

- permanent displays of information on critical subsystems including a touch-panel and a knob for quick access to the critical control variables
- beam observation equipment again including a touch-panel for parameter assignment.

Mobile consoles. No special design has been made so far. Our first approach will be alphanumeric display terminals which can be connected to the CAMAC system in any place near a CAMAC crate. Interaction with the system will be done by the use of the interpreter or maintenance programs if this applies.

CAMAC Interface

The main operations within the hardware system will be

- monitoring of status information of all process components within the accelerator system (e.g. status of power supplies and valves, slit position, interlock status)
- reading of analogue values (e.g. magnetic fields, current and voltage of power supplies or beam optics equipment, vacuum, beam currents)
- control of peripheral devices (e.g. switching power of devices, setting of devices, positioning of slits)

As far as monitoring of status information is concerned it was decided not to use the interrupt facility (DEMAND or LAM) to induce computer reaction on status change. The main argument against interrupt handling in this part of our application was the fact that mechanical displacements are involved in various control-actions. These actions may possibly not come to their correct stop thus refraining from interrupting the system. Instead of superimposing a timer-check within the operating software we have chosen a polling procedure. Thus DEMAND-handling within the Serial CAMAC loop will only be used with a small number of special devices such as the mobile consoles.

CAMAC Modules

When analyzing the control ports between CAMAC interfaces and external devices one comes down to the following list of necessary data:

- On/Off control (e.g. switching of mains power, opening or closing valves etc.)
- 16 bit data out (e.g. setting of power supplies)
- 16 bit data in (e.g. status information)
- analogue data in (e.g. beam currents, vacuum measurement)

From these requirements it follows that the major part of operations can be induced by a small set of CAMAC functions F:

- F(0) for data transfer to the computer (e.g. read status)
- F(16) for data transfers to a module (e.g. setting of power supplies)
- F(25) for pulse output (e.g. power switching, opening/closing of valves)
- F(27) to test the external device.

The use of the latter function was introduced to simplify status monitoring. The bit tested by F(27) should be "True" for the "normal operating condition" of the external device combining all status bits which define this condition. By introducing this bit for every external device status-word reading and analyzing is only required during set-up and run-down. When a device has been set up to its "normal operational status" the status-word will only be acquired if the test by F(27) is negative.

However, when checking the market of CAMAC modules currently offered, you seldom find those which combine these requirements in such a way that one external device can be completely controlled by one module. If one would use those currently offered one would end up with several modules where each would perform one of the required tasks (On/Off or Data In or Data Out etc.).In addition this would imply the use of several cables to control one device or splitting of cables if facilities of one module are to be used in different devices. In addition, different manufacturers of the same type of modules use different combinations of CAMAC subaddresses and functions (A·F) to perform a more or less equal set of operations. If follows directly that the impact on hardware and software is enormous.

To simplify hardware interfacing and to reduce software complexity it was decided to run a tendering on new modules specified in such a way that each type of accelerator system device can be completely controlled by one module. Thus interconnection of such a device to the control system can be achieved by one cable, which can be a standard cable throughout the system, and through one specific CAMAC address (C,N).

Table 1 presents the modules which have been specified and which will be used to run the system. In general no other modules are necessary for interfacing with the exception of a few non-standard devices.

Hardware Reliability

The CAMAC-Serial-Highway is carried over a rather long distance interfacing devices in different areas and with different ground potentials. The system is no longer operational if power fails in one of these areas and noise can generally affect the performance of the system. Therefore it is expected that all crates can be bypassed, that all clusters of crates are completely insulated and that High-Level-Logic signal standards, relais or optocouplers are used at the ports between CAMAC modules and peripheral devices.

Test and Maintenance Equipment

In order to avoid later tedious error searches we are prepared to do program controlled module testing at the moment when the modules arrive. A special module testbox has been developed for this purpose. The same device can be used later if error detection or maintenance has to be run on a particular device.

The same philosophy applies to cable testing and module simulation.

The module simulators which substitute a specific module are used to test the external equipment before it is branched to the control system or, particularly to do manual local control on a device if this has to be done for maintenance reasons.

Module Type	I/O-Signals per Port	Number of Ports	Application
PSC: Power Supply Controller	Out: 1 Analogue Reference Voltage unipolar: 0 .... +5 V bipolar: -5 V ... +5 V controlled by 2's complement number 4 Pulses via Relays for ON/OFF control etc. In : 8 Bit Status Information 1 Bit Test External Status Module: Single Width/1 Port	120	Control by Reference Voltage with a Resolution and Stability of 2.5×10^{-4}, e.g. Power Supplies of Quadrupoles
SMC: Stepping Motor Controller	Out: 4 Phase Control of Stepping Motors, number of steps controlled by 2's complement number In : 3 Bit Status Information 1 Bit Test External Status Module: Single Width/1 Port	70	Control of 4-Phase Stepping Motors, switch capacity of 2A/24 Volts, alternative use of External or CAMAC power.
SPO: Status Input Register and Pulse Putput	Out: 8 Pulses via Relays In :16 Bit Data- or Status Input 1 Bit Test External Status Module: Single Width/2 Ports	140	Pumps, Valves, Faraday Cups, Slits, Beam Stoppers
EIR: Eucoder Input Register	In : Gray coded number of the CERN/MPS-LINAC absolute multiturn position encoder Module: Single width/2 Ports	60	Especially used with CERN type encoders for position reading of slits, Beam monitor probes etc.
IGOR: Input Gate/Output Register	Out: 16 Bit Data 4 Pulses via Transistor Drivers In : 16 Bit Data- or Status Information 1 Bit Text External Status Handshake : Independent for output and input Module: Double width/2 ports (Both ports are adressed via the same Station Number)	140	- Control of Dipoles via 2 ports - Control of Trim Coils and Degausser Coils via 1 port - Control of any other device that cannot be interfaced by PSC, SMC, SPO, e.g. Digital Multimeters, Frequency Synthesizers etc.
Analogue Measurement Relay-Multiplexer BORER Type 1701 H	In : 15 Analogue Signals Out: 1 Analogue Signal Controls Bus for chains of up to 20 Multiplexers	40	Multiplexing of up to 300 Analogue Signals to be acquired via ADC, Digital Multimeter or Oscilloscope
AD-Converter BORER Type 12414	In : 1 Analogue Signal Control Bus for Multiplex-ADC-Int.Control	6	Acquisition of Analogue Value by Dual-Slope Integration, input completely floating

Tab. 1: List of CAMAC Modules which were specified for common applications within the VICKSI control system

Software Aspects

As stated above the software for the control-system will be developped in several steps. To start with we have decided to rely only on resources which have proven to be operational.

- The software is based on the RSX-11D operating system, a multitask system available for the PDP-11
- FIV is used as high level language for all standard routines, system tasks or application programs.
- MACRO-11 is used as assembler for time critical routines or handlers, however, this should be the exception. The intention to use a high level assembler (PL-11, CERN-DD) had to be given up because it was not available in due time.
- An interpreter is used for device test and maintenance routines, for machine physics, and any problem which cannot be handled by an existing standard routine. It will be most useful during the construction and running-in period.
- All the devices will be known to the system on the basis of a device description table which will be part of a data-base.

Similar to other control systems[9] a data base will be the central part for any operation. It is designed to be the image of the process in the computer so that all programs can operate in up-to-date initial conditions. It will allow a central management facility of the control hardware and provide standard control facilities for all application programs by the use of symbolic device names where the actual hardware implications are transparent to these programs. Finally it allows to prevent conflicting control in a multiuser environment and will ensure a rapid recovery from mains failure, computer crashes etc.

Concluding Remarks

As stated earlier, the control system for the VICKSI project is under construction. The necessary hardware has been delivered to about 90 % including the CAMAC-Serial-Highway System. The hardware is presently under test and first parts have been commissioned to the groups setting up the external devices. During all this time the use of an interpreter has proven a powerful help.

We are grateful for many discussions we had with colleagues from HMI and other laboratories. We are especially indebted to the members of the HMI-Electronics and Data-Division who take a substantial part in the hardware design and the interpreter implementation.

References

1) VICKSI-Proposal, HMI-Report B-118 (1972)
2) G. Hinderer et al., The Beam-Matching System between Pre- and Main-Accelerator for the Van de Graaff-Cyclotron-Combination VICKSI, Contribution J-17 to this conference
3) F. Hinterberger, Das Strahlführungssystem für VICKSI, HMI-B 135 (1973)
4) W. Busse et al., Status of the VICKSI Heavy Ion Accelerator, Contribution J-6 to this conference
5) J. T. Hyman, The Computer Control System for the SPS, 9. International Conf. on High Energy Accelerators (1974)
6) F. Beck, The Operator Interface of the 300 GeV Accelerator, 9. International Conf. on High Energy Acc. (1974)
7) CAMAC - A Modular Instrumentation System, EUR 4100 (1972)
CAMAC - Organisation of Multicrate Systems, EUR 4600 (1972)
8) CAMAC Serial System Organisation, ESONE/SH/01 (1973) and ESONE/SH/02 (1974)
9) A. Daneels, A Data Bank for On-Line Process Control, CERN-Note SI/Int. DL/72-3 (1972) and CERN-Note MPS/CCI 74-5 (1974)