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LOW COST CAMAC CONTROL SYSTEMS USED FOR AUXILIARY CONTROLS IN THE CERN PS COMPLEX

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Low cost CAMAC control systems using Macintosh computers, type L2 serial crate controllers and 68000-based auxiliary crate controllers have been developed and used at the CERN PS Division for the stand-alone control of autonomous equipment and for auxiliary control of accelerator equipment. One important characteristic of these systems is the fact that they interconnect inexpensive micro-computers with the control system interfaces: the crate controllers, using minimal hardware addition (about $50 per processor) and that they do not require any modification of the components. This paper describes the systems involved and the field of application of each configuration. Details are also given on the different choices implied with their benefits and limitations.

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Abstract

Low cost CAMAC control systems using Macintosh[1] computers, type L2 serial crate controllers and 68000-based auxiliary crate controllers have been developed and used at the CERN PS division for the stand-alone control of autonomous equipment and for auxiliary control of accelerator equipment. One important characteristic of these systems is the fact that they interconnect inexpensive micro-computers with the control system interfaces: the crate controllers, using minimal hardware addition (about $50 per processor) and that they do not require any modification of the components. This paper describes the systems involved and the field of application of each configuration. Details are also given on the different choices implied with their benefits and limitations.

Introduction

During the early phase of the LEP Preinjector control system design (1984), it has been decided to use Macintosh computers in order to provide a versatile and user-friendly stand-alone CAMAC control facility for commissioning and test purposes in place of previous old-fashioned and expensive configurations. The Macintosh computer was very attractive because of its low price and of its high-level user interface. This facility has been in operation at the PS division since 1985. The original system has then been extended in order to operate also as an auxiliary control facility integrated into the PS control system.

The first part is a short overview of the PS control system in order to describe the context into which these facilities are used and to define the terms mentioned in the following. In the next two parts, the systems used for stand-alone and auxiliary control are described and analysed.

PS Control System Overview

Architecture

For the most recently installed equipment, the architecture of the control system consists of three layers: console computers, front-end computers (referred to as FEC) and optional 68000 based CAMAC auxiliary crate controllers (referred to as SMACC) with all the equipment being interfaced to CAMAC.

The console computers and the FECs are Norsk Data minis interconnected with a dedicated star network manufactured by TITN.

The CAMAC crates are connected to the FECs via 2.5 Mbit/s CAMAC serial highways. Via Serial CAMAC, a FEC has direct memory access to the SMACCs belonging to the serial loops it controls and can issue/receive interrupts to/from them. The SMACC holds also a pair of serial ports which may be used for asynchronous or synchronous communications.

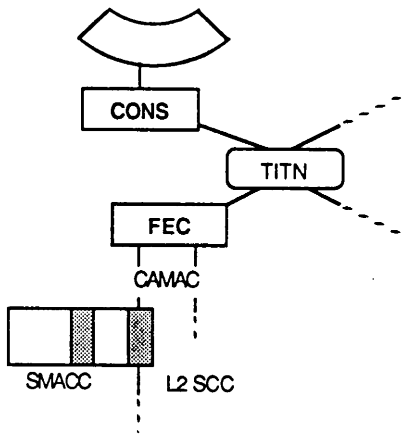

Fig 1 - Control System Architecture

Communications

Dedicated protocols : remote procedure calls (referred to as RPC) and synchronous data transfer protocols are implemented on the two main communication channels: TITN between consoles and FECs, and Serial CAMAC between FECs and SMACCs.

In addition, a datagram service (network layer) is implemented on these networks in order to provide an homogeneous layer on top on the different communication channels, and a RPC server communicating via datagram service is implemented in the SMACC. This, for instance, provides direct access to equipment controlled by a SMACC from a console.

One of the serial ports of the SMACC is reserved for the connection of a terminal or of a Macintosh which, in this case, operates as a terminal and a mass storage unit.

The Appletalk[2] network may also be used to interconnect SMACCs and Macintoshes for local control purposes. When connected, the Appletalk network occupies the second serial port of the SMACC.

Software Environment

The operating systems are: Syntran III on the Norsk Data computers and RMS (Motorola's Real-time Multitasking Software) on the SMACC. The software developments are done either on a Nord-500 system or on a VAX-8530 running UNIX[3] for 68000 cross-software.

The control software consists of (1) modules having well-defined interface loaded as parts of a general module either in the FECs or in the SMACCs (more often), (2) of interaction programs executed in the consoles and (3) of process programs executed in the FECs or in the SMACCs.

Nodal, the CERN-SPS interpreter, is available on every system and may be used as a RMS command interpreter on the SMACC. Nodal is used for interaction programs in the consoles and for test or initialisation programs on each system.

Stand-alone Control Systems

For the stand-alone control of CAMAC interfaced equipment which is not connected to the PS control system, two low-cost systems based on the Macintosh computer are used.

Macintrotte

The first system, "Macintrotte", consists of a Macintosh (Macintosh Plus actually) controlling a standard CAMAC serial highway operated in bit-serial mode at 250 Kbits/s. The CAMAC interface box is a very simple circuit, costing about $50 to produce, which plugs into one serial port of the Macintosh and requires no modification of the computer. Using this interface, the Macintosh can control up to 62 CAMAC crates through type L2 Serial Crate Controllers.

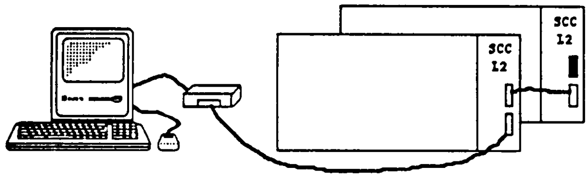

Fig 2 - Macintrotte

The programming language of the Macintrotte is an extended version of Nodal which integrates most of the Macintosh high-level user-interface: pull-down menus, dialog-boxes and graphics for example. The programs are written on the Macintosh and have direct control of the CAMAC equipment.

This system is used in three situations: (1) as an autonomous control system for instrumentation, (2) as a preliminary control system if the main control system is not available and (3) for test programs used either in labs or on on-line equipment by disconnecting them from the main control system.

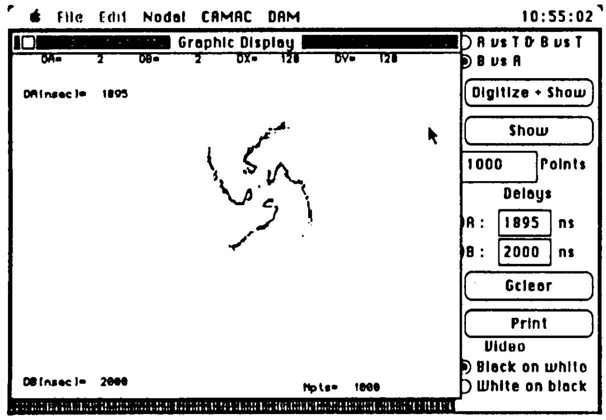

Fig 3 - Sample: Dynamic Aperture Measurement

An important decision was to adapt, by special system software (i.e. serial CAMAC driver with language interfaces), the existing communication facilities of the PC to our existing communication channels using minimal hardware additions. Alternatives to that approach are, (1) at one end, to use dedicated crate controllers (RS232 for instance) which can be controlled directly without any software addition, even by Basic programs or (2) at the other end, to add in each PC system special hardware interface connected to the PC bus(es) as plug-in or extension card. The first alternative is less costly in terms of software development, but the main drawback is that the crate controllers must be chosen according to the PC capacities. In addition, in case of an asynchronous link, the performances are poor. The other alternative, which is also used at CERN in some experiments for controlling CAMAC equipment with a Macintosh, provides much better performances but increases the cost of each PC unit and also leads to the use of a dedicated type of crate controller.

Compared to the first alternative, our system does not provide any simple way to control CAMAC equipment from Basic and compared to the second one, the performance stays low : 13ms for a Nodal CAMAC function execution, 6ms/16bits-word (166 Word/s) for data transfer. Optimisation could probably not reduce that time under 1ms (1 KWord/s).

In the PS control system, however, there are about 200 serial crate controllers of type L2. Therefore, in terms of price, it has been very important to use the same kind of controllers in autonomous systems as in the main control. As a result, a plain Macintosh with the CAMAC interface box may be used as a transportable test unit to be connected to any crate of on-line equipment by just by-passing the crate in the loop and plugging the Macintosh cable in the crate controller. Moreover, the Macintosh may be used remotely by connecting it to installed current-loop serial highways via U-port adapters (set to 250 Kbits/s).

A third alternative is to interface the crate controllers with the Macintosh by means of a more elaborate device in order to increase the performances. But the cost (development and production) can be considered disproportionate with the price, performances and life-time of a PC like the Macintosh Plus. This may, however, be a valid approach when using a more sophisticated computer as a Macintosh II, for instance.

MacinSMACC

The second system, "MacinSMACC", is an enhanced version of the previous one incorporating a SMACC in the CAMAC crate(s) in order to increase the performance of the system. The Macintosh has then two functions: (1) SMACC software development and loading via serial CAMAC and asynchronous serial communication through the SMACC terminal line and (2) interaction program execution communicating with the SMACC's programs via serial CAMAC or Appletalk. Serial CAMAC and terminal line communications use the same Macintosh port, they are therefore mutually exclusive.

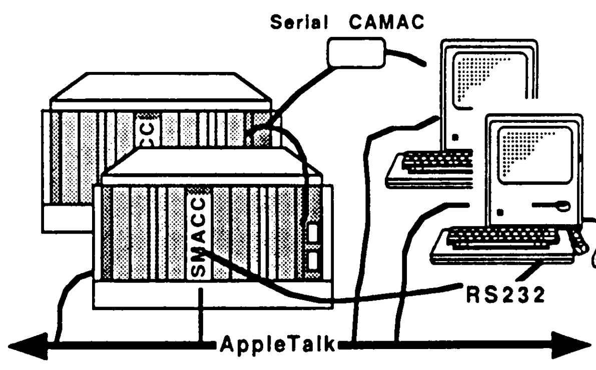

Fig 4 - MacinSMACC

Being the CAMAC loop controller, the Macintosh may be used to down-load the SMACC static memory with two kinds of code: compiled functions callable from programs or through RPC and programs executed as RMS tasks, being either compiled programs or Nodal programs. When switched to the terminal port of the SMACC, the Macintosh may also be used to load, in volatile memory, Nodal programs and data as well as compiled functions callable by a Nodal program.

In our current system, most of the software development is executed on a VAX 8530 but the tools used to compile and link a Pascal program may be transported to the Macintosh if such a support were not available.

In addition, because of a (fortunate) compatibility between the code format produced by the native tools of the Macintosh and the one produced by the CERN tools, these native tools may be used to generate code for the SMACC either to be linked with code generated by the CERN's compilers or to be loaded autonomously. This facility has been used when developing communication software to be implemented on the two targets. For this purpose, a translator between the format of the two linkers has been developed.

The static part of the SMACC's RAM is preserved from power shut-down and therefore, once it is loaded, the SMACC's system may start-up again without further intervention. A user-coded Nodal program is executed at the system start-up to do the user's specific initialization.

The second use of the Macintosh is, as in the previous configuration, the execution of the interaction programs, integrating a high-level user interface. But in this case, the Macintosh not only controls equipment directly (through the serial CAMAC) but also communicates with programs in the SMACC via CAMAC DMA or calls compiled procedures through RPC.

This system is especially effective for stand-alone measurement units or equivalent which need a higher speed in data-treatment than the Macintrotte system may deliver. The increase in performance is however limited by (1) the Nodal interpreter speed, (2) the data rate of the communication channels and (3) by the SMACC hardware (plain 68000, 8MHz, no co-processor). On the other hand, when such a system needs to be connected to the central control system, one just needs to replace the Macintosh connection by the FEC loop. The interface to the SMACC's software (serial CAMAC DMA and RPC) stays identical but all the interaction programs which intensively use the Macintosh user-interface may not be transported on a FEC.

The main drawback of the system, in its current version, is the complexity of Pascal code development and loading for non-experts, it requires the use of a Unix VAX and involves slow communication media: Kermit from VAX to Macintosh over a 4,8 KBauds terminal line, then serial CAMAC from Macintosh to SMACC. This may be improved by transporting of the development tools on the Macintosh as mentioned before, but this would require several months of development.

Some remarks can be made on the integration of Appletalk into these systems, of which, at present, only the "Link Access Protocol" is used. This protocol seems to be a good solution for systems whose architectures are close to the Macintosh one: 68000 + Serial communication controller with SDLC and FM0 facilities + RS422 interface. Once the software has been transported on the target machine, a very inexpensive network may be installed which performance matches well the hardware characteristics. This network is available on each Macintosh system and there exist some simple tools for network analysis. The main restriction is that the upper layers of the Appletalk protocols (network, transport ...) are not standard and their transport to a new system is not an easy task. Alternatives are to use a portable implementation of a network/transport protocol on top of Appletalk or to integrate commercials TCP/IP to Appletalk gateways. In the current implementation (still experimental) a dedicated segmentation / reassembly protocol is used between the Appletalk link layer and the RPC protocol which integrates some of the transport layer facilities. Another problem that was met in a real-time context (in terms of milli-seconds), when the communication controller has no DMA, is that the size of the frames must be kept small and this may deteriorate the performances of the CSMA/CA network. At last, the number of nodes is limited to 32 and, except if using recent optic fiber adapters, the total bus length is limited to 300 m.

Auxiliary Control Systems

Current Configurations

For auxiliary controls of equipment connected to the main control system, MacinSMACC systems may also be used. In this case, the master of the CAMAC loop is the FEC and therefore, the Macintosh may only be connected to the terminal port of one SMACC or via an Appletalk network to the other serial ports of a few SMACCs.

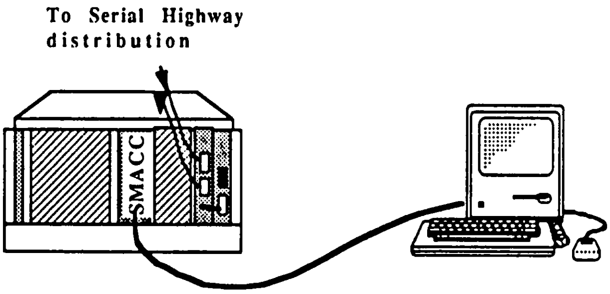

Fig 5 - Auxiliary Control

This configuration is used on most of the CAMAC crates where software is being installed, in order to test recently installed software or to load and execute temporary tasks as Nodal programs. No Appletalk network is in operation, SMACCs and Macintoshes are linked by serial links and switch boxes. In these configurations, the Macintosh is used as a data editor and as an intelligent terminal with mass storage (and an optional printer).

For these applications, the Macintosh is a low-cost alternative to provide the CAMAC CPU with a terminal and a mass-storage device for initialisation and tests purposes. These systems, when connected to operational equipment, are mainly used during the set-up phase of the process and may then be disconnected during normal operation.

As an example, this configuration is used for the set-up of the local displays of the LEP Pre-injector. The local displays of the machine parameters are generated by the SMACCs controlling the instrumentation by means of CAMAC display controllers (CERN-SPS DICO-DIME). The Macintosh is used to edit off-line, by means of a graphic editor, the layout of these displays. These layouts are either loaded in the SMACC's static memory or, when modifications are made, dynamically loaded from the Macintosh at the SMACC's startup [5].

In our system, graphics are employed on the Macintosh by means of an emulator of the display controllers we use in the CAMAC crates, but the Macintosh can also be used to emulate some commercial B/W graphic terminal.

Future Developments

The main direction of future developments is to provide some local interaction facilities which integrate a user-friendly control environment for the end-user and easy extension facilities for the control engineer. This should be done by means of Macintoshes (because we have some of them, now) connected via Appletalk to the control system.

A first prototype, ControlTalk, [6] has been realized which proposes an object-oriented control environment both for the configuration of the system and for its operation. A second prototype, which use the object-oriented programming facilities of MacApp, is being developed and should be tested with the LEP Preinjector instrumentation.

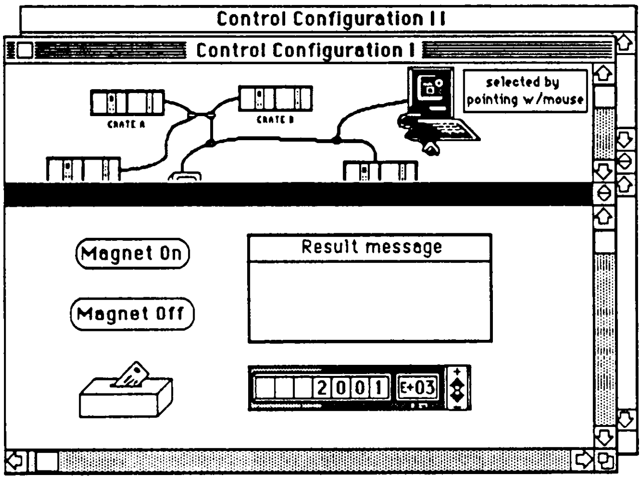

Fig 6 - ControlTalk Prototype

In that sense, the Macintosh - Appletalk - SMACC architecture is also an inexpensive operational workbench to prototype new concepts especially in the area of high-level user interface in order to use workstations in place of consoles.

Conclusion

The main assets of the systems described above are:

- They integrate "inexpensive workstations" into a pre-defined control environment which, in the case of the PS complex, is represented by CAMAC crates with type L2 crate controllers.

- The basic product is used without any modification or addition, which simplifies the repartition and maintenance, at the institute level.

- The systems integrate a high-level user interface for user-friendly operation by non specialists.

- The hardware interface necessary at each connection point is very inexpensive, which is especially important in the case of a large control system.

- The good software development facilities of the micro may be used to compensate the poor (or none) native facilities of the CPUs used as crate controllers. This requires, at least, that the same processor is present in the two units.

The most important restrictions which can be pointed out are:

- In the absence of standards both for the Operating Systems and for communication protocols, a lot of effort has to be put into the development or integration of communication software.

- The simplicity of the hardware interface limits the performances of the data exchanges.

- The hardware used for the CPUs (PC and crate controllers) implies also some limits on the overall performances.

These systems are however very helpful in the field of equipment commissioning and on-line tests as well as for autonomous instrumentation systems. They have been intensively used for the commissioning of the LEP Preinjector [7] and are also more and more used to replace old-fashioned lab's computers.

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[7] F. Di Maio, W. Heinze and F. Perriollat, "Experience with the Use of Macintrotte for Commissioning Process Equipment of the LEP Pre-injector", CERN/PS/87-27 (CO), presented at the 1987 Particle Accelerator Conference, Washington, D.C., March 16-19, 1987.

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[1] Macintosh is a trademark of Apple Computer
[2] Appletalk is a trademark of Apple Computer
[3] UNIX is a trademark of Bell Laboratories