LNF-95/001

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Nuclear Instruments & Methods In Physics Research A 352, 455-457, (1994)

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North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

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DANTE (DAΦNE new tools environment) is the control system for the DAΦNE Φ-factory under construction at the Frascati National Laboratories of the Italian Institute for Nuclear Physics (INFN).

The main design goal has been to keep the software simple and easy to debug. Commercial components have been used whenever possible, with a preference for widely diffused and well established products, as opposed to"standards". Macintosh computers are used throughout the system and LabVIEW has been chosen as development environment. We strongly oppose the "start from scratch" philosophy.

1. DAΦNE

The DAΦNE accelerator complex [1] consists of a two ring colliding beam Φ-Factory with a 510 MeV e^+/e^- injector and of a commercial LINAC operating at the same energy.

The project was approved by the INFN Board of Directors in June 1990. The complex is scheduled to become operational in mid 1996.

From the point of view of the peripheral hardware, the accelerator complex consists of about 1000 devices, which will be controlled by 5 consoles and about 60 CPUs.

2. System structure

Fig. 1 shows the general architecture of the control system. Three levels are defined:

PARADISE (parallel display environment) is the operator interface level. Several consoles, all equivalent, communicate with the rest of the system through high speed DMA buses and fiber optic links.

PURGATORY (primary unit for readout and gating of real time yonder) is the second level of the system. It contains a single CPU (CARON) that receives commands from the consoles, checks them for integrity and forwards them to the appropriate peripheral CPUs. CARON also checks through a polling mechanism the status of these CPUs, relaying to the consoles error and warning messages.

HELL (hardware environment at low level) is the third level of the system and consists of many (about 60) VME crates distributed around the machines. Each crate is equipped with at least one CPU (DEVIL) which reads the status and values of a set of elements, checking for any abnormal status and generating appropriate error messages. These CPUs contain memories that together form the database of the whole system. A record corresponds to each element and it is updated by the DEVIL whenever a significant change in the parameters is detected, thus avoiding sending useless information to the central processor. These memories can be accessed directly from the consoles, through a series of interfaces.

This organization makes readout and command delivery completely asynchronous, with considerable advantages, both for data traffic and for simplicity. The consoles always have at their disposal the updated status of the machine, without having to issue read commands. In fact, the "READ" command does not exist in our system. The access is very fast, since it is entirely a hardware memory access. A 4 byte transfer takes, in the worst case, less than 15 μs.

Several innovative features have been inserted in the design to improve reliability and to ease the debugging phase:

- all the messages of the system are controlled by a single CPU, CARON, in the purgatory
- the real time data base is not duplicated anywhere to avoid incoherence problems,
- point-to-point links have replaced the use of a network, to make the system modular and easy to expand,
- we do not use interrupts, and replace them with polling mechanisms. This dramatically reduces the time for debugging and maintenance of the system,
- many simple CPUs are used for high computing power and ease of programming.

The system configuration has been changed in the last two months to eliminate memory redundancy and

SSDI 0168-9002(94)00034-5

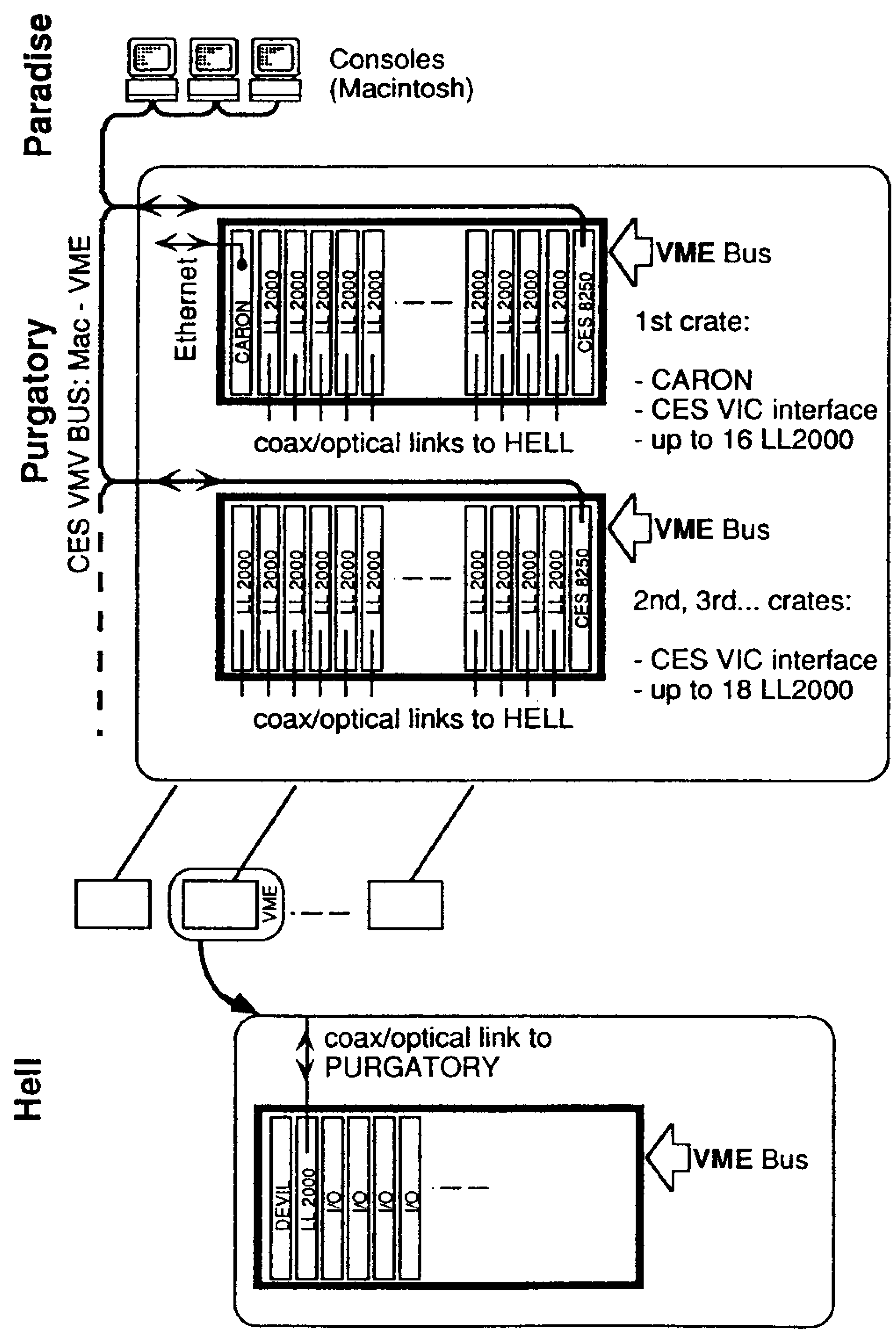

Fig. 1. Control system schematic diagram.

to make it possible to use commercial products for the communication links.

3. Bus system

The consoles (Macintosh Quadra) communicate with the second level through a CES VIC bus interface (CES 7212–8250). This interface allows access to 256 memory windows, 1 MByte each. Access to the third level is accomplished through a LEXTEL LL2000 interface. This VME single width module is based on the AMD Taxi chips and it implements a serial communication at 125 Mbit/s. The physical medium can be coaxial cable for short distances or optical fibers for longer distances up to 2 km. Memory is mapped directly from one crate to another, with a longword access time of 5 μs. Since a VME crate only carries 19 slots, 4 crates will be necessary to access all HELL from the consoles. Access to these crates is obtained through a single VIC bus that also connects the consoles together.

The consoles read the machine status directly from the third level CPUs, through a global map, available at the second level.

Commands are sent from the consoles to CARON via the VIC interface. CARON, in turn, forwards them to the DEVILs via the VIC and the LL2000 interfaces.

Thus all system communications go through a system of memory addresses associated with mailboxes and with the records of the elements. The final configuration map has already been defined.

4. System software

Software is the problem. This has been true for some time and is becoming very obvious now.

We chose not a language, but a development environment. LabVIEW offers a multitasking system with a graphical language and many routines appropriate for our environment. The fact that its development took about 100 man years should be an indication of the complexity of a modern software environment. C and FORTRAN plug-ins are available for particular tasks. In particular, the development of the operator interface is enormously eased by the use of preprogrammed and customizable knobs, buttons, histograms, etc.

The Macintosh computers offer a very good human interface, an excellent network system and a lot of good software which has been thoroughly debugged by an enormous body of customers. Software quality is to us more important than MIPS. If more computing power is needed, it is definitely cheaper to use several CPUs.

We originally chose Macintoshes and LabVIEW for the consoles, and then decided that the cost and worry of hardware development was a good price to pay for the uniformity of the software environment. Therefore we developed an interface between a Macintosh LC III and VME, adding 4 Mbytes of memory and VSB access, plus the possibility of an ETHERNET interface. The resulting DEVIL, now built commercially, is a double width VME module with an embedded Macintosh logic board, unmodified, running a LabVIEW application.

We now have the same environment for all levels of the control system, with obvious advantages.

5. Secondary buses

VME was originally chosen for the peripheral bus. This standard is by now well established and very many boards are available commercially. Moreover, several firms have started implementing VME carrier boards capable of carrying up to four piggy back I/O boards of different kinds, chosen by the user. This is a great help in increasing the versatility of the bus.

On the other hand, commercial instruments, power supplies, vacuum pumps, etc. tend to be sold with embedded computer interfaces, typically RS/232, RS/485, IEEE488 and recently ETHERNET. The use of these well known interfaces reduces drastically the amount of cabling necessary in a system, and virtually adds a fourth level of intelligence to the architecture. A good example is power supplies with RS/485 addressable serial interfaces which are also capable of generating a controllable ramp. We have revised our original I/O design to include these interfaces, with considerable savings in terms of complication and cabling.

6. Status

A prototype of the system has been implemented and installed using the beta version of LabVIEW 3. All the communication structure has been tested and we are now optimizing the software for speed and efficiency. We have started developing the control system interfaces to the separate pieces of equipment, in collaboration with the designers. Several prototypes of the control system are being installed in different laboratories to create the "expert" windows.

In the meantime, work is proceeding on the implementation of the "Physics" programs, which will be implemented in FORTRAN by the machine physicists and integrated into the LabVIEW structure with the help of the control group.

Acknowledgements

We would like to thank the Accelerator Group of the LNF for continuing discussions and encouragement.

References

[1] G. Vignola et al., talk presented at the San Francisco Particle Accelerator Conference, May 1993.