TWO CASE STUDIES FOR DEPLOYMENT OF PC TECHNOLOGY IN INSTRUMENTATION FOR NUCLEAR AND NEUTRON PHYSICS EXPERIMENTS

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Abstract

In our lab, PC technology is used for a couple of years in developments for experiment control and data acquisition where less mainstream equipment (embedded, realtime, VAX) was dominating before.

In neutron scattering experiments, spectrometer control and detector readout are done by CompactPCI systems, partly using custom peripherals. In particle physics data acquisition, passive backplane systems, tailored to our needs, are used.

Experiences gathered in these two application fields, and future directions and expectations will be presented.

1 INTRODUCTION, HISTORY

Two major areas of activity in our research facility ("Research Center Juelich") are nuclear and particle physics in the mid-energy range and neutron scattering. For the former, a 2.5 GeV proton synchrotron was constructed in the early nineties; as neutron source a reactor is used (which is some decades older). The "Central Laboratory for Electronics" (ZEL) has been developing control and data acquisition systems for both classes of experiments from their respective beginnings.

Particle physics and neutron scattering experiments have some parts in common – both need detectors to be read out delivering positional, timing and energy information, and both have slow control components which need to be set up for the measurement runs.

So it is natural to use a common set of equipment and tools to solve the instrumentation and data acquisition needs of these two research fields, besides the fact that it is desirable for an effectice exploitation of limited manpower ressources.

After the times went by when the VAX was ubiquitous, our lab preferrably used Motorola (m68k) based VME processors running the realtime operating system OS-9 (Microware) where intelligence was needed in the frontend. In nuclear physics data acquisition, most of the digitizing modules were CAMAC modules. To read these out with low latency, an intelligent CAMAC controller was developped together with the Swiss company CES (VCC2117), equipped with a Motorola 68030 processor and also running OS-9. VME and CAMAC parts were coupled by the VICbus, a parallel cable bus. The data were written directly from a VME processor to a streaming tape (EXABYTE). Slow control and monitoring was done through a 10Mb/s ethernet connection.

Neutron scattering experiments typically have more extensive and more safety sensitive slow control tasks. This lead to use of industrial control components as SIEMENS S5 PLCs and SMP16 modules. These were coupled to the VME computer by PROFIBUS (layer 2 protocol). The VME-PROFIBUS and PROFIBUS-SMP16 interfaces were developped in our lab. Serial (RS232) and GPIB devices, inevitable in neutron scattering, were connected directly to the processor unit (ELTEC) or to piggyback modules, respectively.

2 PROBLEMS WITH LEGACY EQUIPMENT AND GOALS OF PC TECHNOLOGY DEPLOYMENT

While a 40 MHz MC68040 processor was of impressive preformance at the time of its introduction, and better than what most people had on their desks, this relation changed dramatically in the following years. Clocking rates of desktop processors were cranked up to formerly unbelievable heights; the embedded world had no chance to keep up. PCB design and manufacturing became increasingly complex, so that an own development of a modern CPU subsystem for an embedded controller got out of reach. Also, faster versions of local area (ethernet) and storage subsystem (SCSI) connections became common in general computing. Especially in nuclear physics data acquisition, where data throughput can never be enough, users expected performance figures not much below of what one can get for little money from a PC retailer.

Spare part acquirement and repair got difficult. Even minor components like batteries backing the realtime clock or the GPIB piggyback mentioned above were almost impossible to obtain.

The OS-9 operating system was also found to be difficult to handle by many users, and the pool of potential developers is limited. Since we didn't make use of its hard real-time features, these inconveniences and the price tag were hard to justify.

The VICbus occasionally was the cause of reliability problems due to sensitive cable connectors (2 x 64 pins). Fast ethernet was effectively of compatable performance, and with gigabit ethernet on the horizon there was a replacement strategy.

The world of industrial automation had changed as well in that time: The SIEMENS S5 series of PLCs was replaced by the S7, and the PROFIBUS DP profile became popular.

So our goals and motivations are obvious: We wanted to take part of modern developments, the performance advantage and cost benefits of mass market desktop computing. This also promises to broaden the base of potential developers, and hopefully lowers the expenses for diagnosis tools, spare parts, connectors etc.

3 SPECIFICS OF NUCLEAR AND PARTICLE PHYSICS

As already mentioned, performance is a major selling point for nuclear physics data acquisition systems. There is a relatively large number of detector channels (some thousands are common) which should be read out on every event indicated by the trigger logics. Due to the stochastical nature of particle reactions, any performance improvement which leads to a decrease of system dead time increases the number of events which can be recorded in a time unit, thus in turn lowers the total measurement time necessary for a given statistical accuracy.

Detector readout is done in parallel – there is one CPU for each detector subsystem. An average experiment uses about 10 frontend processors, so the price per CPU starts to matter.

We have decided to use passive backplane systems (PICMG standard) for these experiments. CPU boards are relatively cheap, so it is affordable to replace them by faster ones as they become available.

The need for fast network connections and SCSI adapters can be easily satisfied because the peripheral connectors are PCI as used in desktop computers.

A drawback is that cooling is worse than with a slot arrangement as with VME or CompactPCI. For that reason, and for more efficient use of vertical rack space, we have constructed a special dual-system enclosure which fits our needs.

4 SPECIFICS OF NEUTRON SCATTERING

Neutron scattering experiments are usually less CPU and data transfer performance demanding. There is typically a single detector array where all space, timing and energy information arrive, so that histogramming can take place in the frontend. Data transfer is only necessary at the end of a measurement run (occasional monitoring left aside).

A spectrometer is an expensive device often consisting of numerous mechanical axes which must be controlled, and moved during a measurement following a sequence given by the user. Here reliability and safety is most important. Such a device often lives for tens of years with only little modification. Thus guarantees for maintainance and delivery of spare parts are highly desirable.

For the control components, in particular the safety sensible parts, we use industrial control components from the SIEMENS S7 series and matching decentral peripherals (digital and analog I/O, motor controllers) of the ET200 family, connected to PROFIBUS DP. [1]

The freely programmable frontend CPUs control this subsystem at a high level (in terms of functionality) through another PROFIBUS-DP connection.

For these tasks, one or two CPU modules are sufficient. For sake of reliability and robustness, we use CompactPCI systems here. We don't expect the CPUs to be replaced often, so the additional cost is considered well justified.

The PROFIBUS interface in CompactPCI formfactor was developped in our lab. It was decided to use the Linux operating system, and there was no solution commercially available at that time. Serial lines and GPIB interfaces are easily available, especially since CompactPCI got some popularity in industrial control applications.

5 CONCLUSIONS

The switch to PC technology made it possible to ramp up performance of data acquision systems quickly as new and faster processors arrive. This lead to customer satisfaction. (maybe also to some lazyness because it is easier to plug in a new CPU module than to fix flaws in the algorithm...) Reliability didn't turn out to be a problem. This can be attributed to the diskless approach which eliminates the most common source of catastrophic system failures, and to careful selection of components like power supplies. Occasionally we are experiencing interoperability problems between backplanes and modules which cause that certain peripherals just don't work in certain slots. We assume electrical problems on the PCI bus.

CompactPCI systems, while at the upper end of PC compatible equipment, is still less expensive than VME. For that reason, and because we didn´t make use of the advantages of VME anyway (large slot count, multiprocessing), the choice of CompactPCI for neutron scattering is reasonable. Further, it gives users a more familiar environment. In our case, the CompactPCI systems are equipped with hard disks, which is more or less caused by the fact that we wanted to use a standard Linux distribution as operating system. The possible negative impact on reliability is mitigated by the fact that critical control functions are delegated to a PLC.

6 REFERENCES

[1] M.Drochner at al., Application of Industrial Standard Process Control Equipment in Neutron Scattering Experiments, IEEE Trans. Nucl. Sci., vol. 47, pp. 214-218, 2000