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PHILOSOPHY OF A COMPUTER-AUTOMATED COUNTING SYSTEM

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Abstract

The LAMPF Nuclear Chemistry computer system is designed to provide both real-time control of data acquisition and facilities for data processing for a large variety of users. It is a PDP-11/34 connected to a parallel CAMAC branch highway as well as a large variety of peripherals. The philosophy for the design of this system will be discussed, and will cover such points as use of the computer for control only versus direct data acquisition by the computer, why a CAMAC system was chosen, and the advantages and disadvantages of this system. Also to be discussed will be future expansion of the system and what might be done differently if the system were redesigned.

The Nuclear Chemistry Laboratory

The Los Alamos Clinton P. Anderson Meson Physics Facility (LAMPF) is a medium energy, 800-MeV, proton linear accelerator¹. Nuclear chemistry experiments may be conducted at LAMPF using either the direct proton beam or any of the secondary beams of muons, pions, or neutrons. The targets irradiated in any of these beams may be transported to the Nuclear Chemistry Laboratory (NCL) manually, or via a pneumatic transfer system, where they are analyzed.

The NCL consists of four chemistry laboratories, five counting rooms, and office space for staff and visiting scientists (see Figure 1). The basement area can also be used for counting equipment. The types of equipment used for data acquisition include α and β proportional counters, low-background β proportional counters, α spectrometers, positron annihilation counters, β - γ coincidence counters, NaI(Tl) and Ge(Li) γ -ray spectrometers, and a large Ge(Li) anti-Compton spectrometer. These various counters are connected to a large number of scaler-timers and multichannel analyzers (MCAs) to collect the data.

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The NCL Data Acquisition System

The NCL Data Acquisition System (DAS) is a Digital PDP-11/34 (Figure 2) with a floating point processor, 128k words of memory, two magnetic tapes, two DEC tapes, three removable disk cartridge drives of 1.2M words each, a paper tape reader punch, one removable disk pack drive of 20M words, a 500 lpm printer/plotter, two storage display consoles which are also connected to the printer/plotter for hard

Figure 1. A plan view of the Nuclear Chemistry Laboratory at LAMPF.

copy output, three CRT control consoles, and a DEC-writer system control console. The system also has a special purpose computer, a Microprogrammed Branch Driver (MBD)², to interface the PDP-11/34 to the CAMAC Branch Highway.

The CAMAC Branch Highway³ contains all the connections to the various counting systems. The scaler-timers are connected in parallel with the scaler-timers on the non-spectrometer counters and the MCA interfaces are connected to a variety of multichannel analyzers to provide direct computer readout and control. The dual-parameter data acquisition system is a special design using a DEC LSI-11 computer as a base and can communicate with the PDP-11/34 through the branch highway. In addition to these data acquisition units, the CAMAC system also has an interface to the Julian clock providing time-of year information throughout the counting rooms and chemistry laboratories. Also interfaced to the computer through CAMAC is an IBM 020 or 029 keypunch which operates as an output device.

The computer is used to control the counting rooms through the CAMAC Branch Highway and to collect data from nuclear chemistry experiments. These experiments are all off-line experiments of counting induced radioactivity. The PDP-11/34 is also used for data analysis although its main function is data acquisition and control.

Experimenter Interaction

The basic operation of the PDP-11/34 is controlled through Digital's RSX-11D operating system, a multi-user, multiprogrammed system. The data-acquisition system consists primarily of special purpose software with some use of a collection of programs called "Q", a general data acquisition system developed at LAMPF for use in the on-line experimental nuclear physics program⁴.

The experimenter interacts with the control computer via a CRT console and a CAMAC crate in each counting room (Figure 3). Through the CRT console, the experimenter can initialize the data-acquisition programs to be used and can enter additional information about the samples being counted. They are also used to monitor progress of the experiments.

In addition to data acquisition modules, each CAMAC crate contains an Event Trigger module⁵. One function of this module is experimenter-generated LAMs. These LAMs can be used by data-acquisition programs to interactively change operating parameters.

Philosophy of Design

In 1973 when the design was begun, it was known what types of counting equipment were to be supported, since this counting system is a small version of one already existing in the nuclear

Figure 2. The NCL Data Acquisition Computer System.

Figure 3. The CAMAC Branch Highway of the NCL DAS. The CRT in each counting room is used to communicate with the computer.

chemistry group. Many scalers and timers are needed for the α and β proportional counters, the β - γ coincidence counter, and the positron annihilation counters. Also, a number of MCAs are needed for the various spectrometers.

One way to provide these functions is by direct connection of the signals to be scaled and the analog-to-digital converters (ADCs) for the spectrometers to Unibus interfaces. The computer would then have to respond to each event from each counter and ADC as well as keep an elapsed time clock for each input. This obviously would easily overload the computer and therefore not be feasible.

By providing scalers, timers and multichannel analyzers as units separate from the computer, most of the direct data acquisition load would be taken off the main computer. The computer would only need to set the various counters to the desired count length and then read out the data when the counters were done counting. The internal bookkeeping would be greatly simplified and more counters could be supported.

Selection of CAMAC

With the decision made to interface external collection units to the computer, the next step was to find the best way to do it. Several manufacturers of nuclear counting equipment had pro-

prietary busses to connect their modules together and to a printer or teletype. These busses are rather slow and have limited capability for computer contact of the counting modules.

Connecting these modules directly to the computer bus itself is another possibility. However, due to the large number of modules involved and the fact that they are in four counting laboratories several Unibus repeaters would be needed. Also, a large number of non-counting peripherals are already heavily loading the bus. Therefore, this option is unuseable.

The only apparent remaining choice is the CAMAC Branch Highway. The units used in a CAMAC system are modular and therefore very portable, similar to existing NIM units. Since there are many standard, off-the-shelf units, they provide great flexibility in how to configure and reconfigure a system. This system is also easily expandable.

With these advantages come several disadvantages. Although many of the units we needed were standard NIM designs, no equivalent CAMAC modules existed. As a result, most of our CAMAC modules, all those shown in Figure 2, were custom designed.

Associated with this are the problems of having them repaired since they were the only ones of their kind in the world. Repairs are performed by a laboratory in-house electronics maintenance group with some consultation with the manufacturer. Since other people have the similar needs for their counting systems, some of these CAMAC modules are now available commercially, and thus more support and documentation is available when problems occur.

An obvious second problem is software. Since the CAMAC modules are custom designed, the software must be also be custom designed. A large amount of effort by LAMPF programmers has gone into the data acquisition package called "Q"⁵. This set of programs provides the user a very powerful tool with which to control his CAMAC system. Its primary disadvantage is that it is a single user system. Since we have to provide counting facilities for several users at a time, we must use a subset of "Q". This subset is slow, one CAMAC command at a time, and is not interrupt driven. As a result, reading out a multichannel analyzer takes a few minutes instead of a few seconds.

Peripherals

The original proposal for this data acquisition system included a PDP 11/40 with 88k words of memory, one LA30 Console, two Tektronix 4010 graphic terminals, one RK05 disk drive, two DEC-tape drives, a paper tape reader/punch and two IBM 729 7-track magnetic tape drives. This configuration was based on one proposed for LAMPF data

acquisition systems⁶. Very rapidly the need for the three CRT consoles and the two additional RK05 disk drives appeared and they were purchased. The DEC tapes and paper tape system were purchased since they were the then available system software distribution media and also the only means for intercomputer software distribution.

As use of this system increased, the need for a printer/plotter and the full 128k-words of memory developed. With these items added to the system, the use and useability of the system further increased. Now two of the RK05s were needed just for operating system and locally written data acquisition programs. This left only one disk drive to be shared by all user for their programs and data. Also, much of the data came from off-line MCAs via 7-track 556 bpi magnetic tape. With the low data density on the tapes and the unreliability of the old tape drives, it was apparent that changes had to be made. As a result, the magnetic tape drives on the DAS and the off-line MCA tape drives are being converted to 9-track. Also a 20M-word disk drive was purchased.

As a result, this system has a large variety of peripherals, perhaps too many for good system reliability. The DEC tapes currently are rarely used. For several years, the paper tape hardware was rarely used. However, because of the PDP-11/03 connection through CAMAC, it is again being used for high speed reading of diagnostics for the PDP-11/03. With the addition of the large disk system to the DAS, the use of the RK05s, has greatly decreased, but they are still used for data storage for individual experimenters and program and data transfers between computers. So, although use of many of the peripherals has decreased, they are still occasionally needed.

During this period, we also had problems due to the inability to add a floating point processor to the PDP-11/40. In particular, we could not easily do double precision (32-bit) integer operations, and floating point operations were done in software which is considerably slower than hardware. Since another group within the laboratory was interested in trading PDP-11/34s to get PDP-11/40s, we traded and immediately added a floating point processor to the new central processor.

Future Expansions

In each counting room is a CAMAC crate and an alphanumeric CRT. This works out fine for controlling the counting. However, these terminals have no graphic capabilities. Therefore, it is planned to add a graphic terminal to each of the counting rooms in addition to the equipment already there. This will allow the experimenter to analyze his data as soon as it is read out rather than wait until after the experiment is over or run back and forth between the graphic terminals in the computer room and the rooms where his counting is being done.

Since several of our MCAs are very old, they have no computer control capability. They are being replaced with modern, microprocessor based MCAs that can be completely controlled by the central computer. This will provide greater versatility for the experimenters.

With all this new hardware, the software will also have to be improved. "Q" will have to be modified to provide at least a pseudo multiuser capability. This increase in the speed of reading out the MCAs is rapidly becoming necessary.

What Would We Do If...

All this leads to what would we do differently if one could start over. This question is difficult to answer because of the rapid development of electronics in the six years since this system was initially proposed. Time has shown that many of the decisions made were correct. The biggest problem was the lack of sufficient manpower when the system was first installed. As a result, much of the current effort is catching up with users needs and desires and getting the best utilization of the various counters.

A second area of improvement would be the PDP 11/03 based, dual-parameter data acquisition system⁷. It uses a specially designed interface to provide control signals and route the ADC data either to a PDP-11/03 or directly through CAMAC to the central computer. Due to the complexity of the unit and the difficulty in developing a system that works both with the strobed CAMAC system and the interrupt driven PDP-11/03, this system could be better implemented with CAMAC ADCs and a computer in an auxiliary crate controller. Both the hardware and software would be much simpler.

It should be mentioned that such hardware was not commercially available when 11/03 system was designed and built. Our experience has shown that unless adequate support is available in-house one should try to meet one's requirements through the use of commercial equipment when at all possible.

Summary

The LAMPF Nuclear Chemistry computer system is designed to provide both real-time control of data acquisition and data analysis for a large variety of users. The system is a PDP-11/34 connected to a parallel CAMAC Branch Highway as well as a variety of peripherals. The CAMAC system was chosen for the data acquisition because of its standardization, flexibility, modularity and its commercial availability. The CAMAC system provides a means of connecting a large variety of units to a central computer without loading down the computer and its bus. As this system has evolved both in software and hardware, more experimenters have made use of it. In turn, this has required adding

more software and hardware. Eventually, the data acquisition will push the data analysis to larger and faster computers and may even require another replacement of the central processor with a more powerful and faster model.

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