MASTER

TITLE: PHILOSOPHY OF A COMPUTER-AUTOMATED COUNTING SYSTEM

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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 accelerator. 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 $\alpha$ and $\beta$ proportional counters, low-background $\beta$ proportional counters, $\alpha$ spectrometers, positron annihilation counters, $\beta$-y coincidence counters, NaI(Tl) and Ge(Li) $\gamma$-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 (MCA) 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), to interface the PDP-11/34 to
the CAMAC Branch Highway.

The CAMAC Branch Highway contains all the
connections to the various counting systems. The
counter-timers are connected in parallel with the
counter-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 acquis-
tion 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 025 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 con-
trolled 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 LANL for use in the on-line
experimental nuclear physics program.

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 infor-
mation 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 module. One
function of this module is experimenter-generated
LAMs. These LAMs can be used by data-acquisition
programs to interactively change operating para-
meters.

**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

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**Figure 2. The NCL Data Acquisition Computer System.**
chemistry group. Many scalers and timers are needed for the \( \alpha \) and \( \beta \) proportional counters, the \( \beta-\gamma \) 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 proprietary 'buses 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 unusable.

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 also be custom designed. A large amount of effort by LAMPF programmers has gone into the data acquisition package called "Q". 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 198k 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 systems. 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 usability of the system further in-
creased. Now two of the RK05s were needed just for
operating system and locally written data acquisi-
tion 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, 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 opera-
tions, and floating point operations were done in
software which is considerably slower than hardware.
Since another group within the laboratory was inter-
ested in trading PDP-11/34S to get PDP-11/40S, we
loaded and immediately added a floating point pro-
cessor to the new central processor.

Future Expansions

In each counting room is a CAMAC crate and an
alphanumeric CRT. This works out fine for con-
trolling 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. "0" 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 diffi-
cult 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
system. It uses a specially designed interface to
provide control signals and route the ADC data
either to a PDP-11/03 or directly though 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-1/34 con-
ected 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 com-
puter 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.

References


