J. Fryklund†
W. Loveland†

Use of a Time-sharing Computer in Nuclear Chemistry*

Abstract: The Oregon State University computer-analyzer system couples the advantages of on-line data acquisition and analysis with the low cost of a time-sharing computer. The system operates in two modes. In Mode A, a 4096-channel analyzer serves as a data acquisition and buffer storage device with the contents of the analyzer memory being transmitted via telephone lines to the Oregon State University computer for analysis. In Mode B, the correlated outputs of *N* analog-to-digital converters (corresponding to an *N*-parameter event) are transmitted to the computer in real time for storage and analysis. Additional information, programming and computations may be entered at any time from a remote terminal console. The results of the data analysis can be returned immediately to the remote terminal console or to any regular computer output device. This system has the advantages of being able to utilize the full facilities of a large computer, its FORTRAN compiler, etc., for on-line data acquisition and analysis while avoiding the responsibilities of hardware maintenance and systems programming for the nuclear chemists.

Introduction

Nuclear chemistry consists of the study by chemists of the structure and dynamics of nuclei. Experimentally, such studies involve the detection of one or more emitted radiations from a radioactive nucleus, the energy and direction of an emitted particle, et cetera. Frequently, one desires to measure several such radiations and particles emitted during a single nuclear reaction or decay. Each such radiation detected is called a "parameter" and the detection of several radiations from a given event is called an "*N*-parameter" event. Typically, the detected radiation produces analog signals at the output of radiation detectors and these analog signals are then amplified, shaped, digitized and recorded. The recording of these signals and their subsequent analysis in terms of physically meaningful quantities is the subject of this discussion.

In particular, we wish to describe the method chosen by the computer center and Nuclear Chemistry groups at Oregon State University to achieve the capability for on-line data acquisition and analysis. We will also show why we believe the method chosen may offer certain advantages over more conventional techniques of on-line data acquisition.

Basic problem

Our basic problem was one of wanting to achieve the capability for on-line data acquisition and analysis (especially in the *N*-parameter mode) for nuclear chemistry experiments. In solving this problem, we had certain restrictions imposed on any potential solution. First, little or no nuclear chemistry effort could be made in the area of systems maintenance and programming. In other words, we did not want any scientist to withdraw from scientific work for any period of time to devote his attentions primarily to computer programming. Secondly, the solution had to be economical in terms of the usual financial and manpower constraints that face a university.

The equipment available to us at Oregon State University in solving this problem was a commercial pulse height analyzer with 12-bit analog-to-digital converters (ADC's) and a 4096-word memory. Also, our University has a time-sharing computer system with the variety of input/output devices and data paths (channels) shown in Fig. 1. One of the input/output channels communicates with a small peripheral computer (an 8K PDP-8). This peripheral computer is a message switching system for the central computer. In this message switching role, the peripheral computer collects data from, and disseminates data to, remote devices for the central computer. Data transfers between the central computer and the peripheral computer are blocked while transfers between the peripheral computer and remote devices are usually bit-serial via the multiplexor.

The system

The solution we found to our basic problem is shown schematically in Fig. 2. In order to understand how this system works, let us consider some typical nuclear chemistry data acquisition and analysis situations. The first

† The authors are at Oregon State University, Corvallis, Oregon.
* Work supported in part by the National Aeronautics and Space Administration under (Grant SC-NGR-38-002-020) and by the U. S. Atomic Energy Commission.

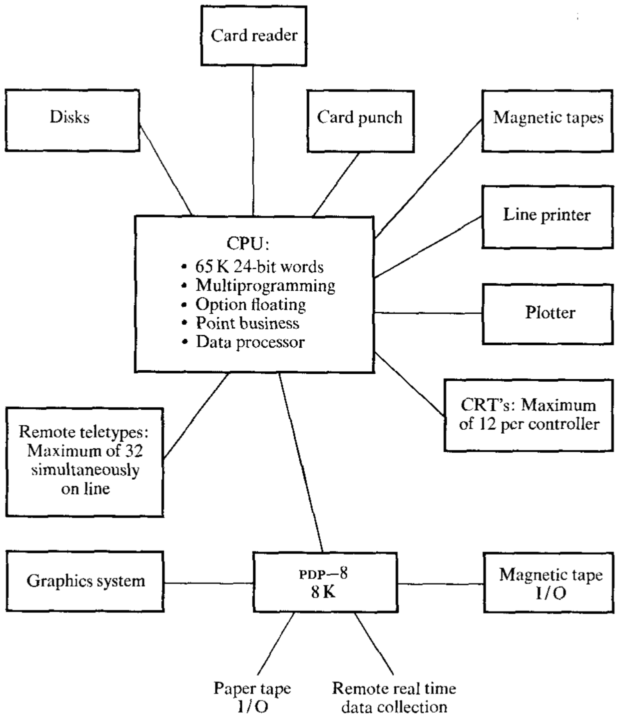

Figure 1 Schematic diagram of the Oregon State University time-sharing computer indicating various input-output devices.

situation involves the collection of data in single-parameter or low-resolution, two-parameter experiments. Such applications are found in activation analysis, and γ-ray spectroscopy. We call this situation "Mode A" analysis. The steps in the system operation (Fig. 2) in Mode A are:

1) Incoming analog signals from radiation detectors are digitized by either one or two ADC's and stored in the 4096-word analyzer memory. Data collection rates are limited by the ADC speed (50 MHz).

2) At the completion of the measurement, the nuclear chemist via the Remote Terminal Console enters the following information:

a) File identification—a string of alphanumeric characters.
b) Any processing of the data he wants prior to disk storage. Here he may call programs, write them, enter other input data, etc.

3) The nuclear chemist activates the Start button on the control console. A 24-bit word is entered into the data register containing the Start code, ADC selector information and file identification information.

This information is then shifted out of the data buffer, 6 bits at a time to the parallel-to-serial (P/S) shift register (SEND module), and then this information is shifted out one bit at a time to the data set. Each 6-bit data group is preceded by a start bit and followed by a parity bit and at least two mark bits. The START STOP codes are transmitted in even parity while all other information is transmitted in odd parity.

Data are then sent approximately one mile across the Oregon State University campus to the computer center where the whole procedure is reversed by a RECEIVE module and entered into the peripheral computer via a multiplexor.

The purpose of the multiplexor is to service real-time data interrupts from several sources (a maximum of 256) concurrently. Thus we have designed a system capable of servicing data collection interrupts from:

a) Nuclear chemists at the radiation center;
b) an oceanography buoy at sea transmitting data via radio telemetry to shore (to be implemented in June, 1969); and
c) a student across the state at another school doing his homework at a remote console.

The peripheral computer responds to this initial transmission with a 6-bit READY code. This READY code is transmitted to the analyzer terminal RECEIVE module where it is decoded and then the READY status indicator on the control console is set. Then the TIMING CONTROL module synchronizes the analyzer readout, serial-to-parallel (S/P), and parallel-to-serial (P/S) converters, and data set and initiates data transmission.

During data transmission, data are read out of the analyzer memory (using a standard peripheral output cable) in the form of 24-bit words into the data buffer. (The peripheral computer distinguishes between START and STOP commands and data by means of the parity bits—commands are in even parity while data are transmitted in odd parity.)

The 24-bit data word (in 6-bit groups) is then transmitted to the peripheral computer much as the initial command word was. Parity is generated at the analyzer terminal and continually monitored at the computer terminal. Whenever a parity error is detected at the computer terminal the data item is flagged with a parity error bit and stored along with the other data. Also, the computer transmits a parity error code to the analyzer terminal where it is decoded and the parity error indicator is set.

In general, the nuclear chemist is informed of the status of the data acquisition and analysis by indicator lamps on the control console and by messages on the remote terminal console.

After 256 24-bit data words have been accumulated in the peripheral computer memory, the peripheral computer initiates a block output to the central computer and the data are transferred to the central computer at about 10^6 bits per second for intermediate processing and storage on disk files. (Concurrently, the central computer may be servicing several other programs via its multiprogramming

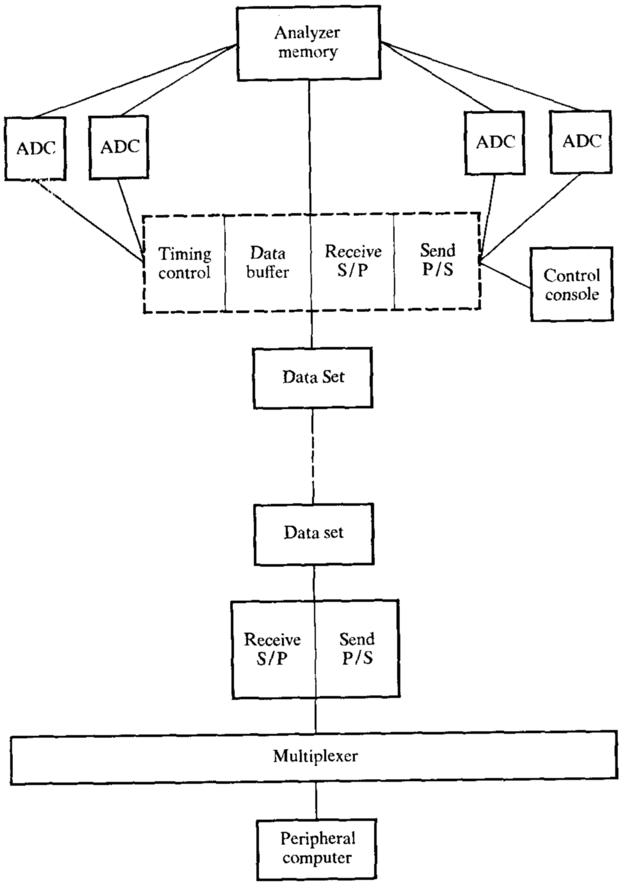

Figure 2 Schematic diagram of the Oregon State University computer-analyzer system for on-line data acquisition and analysis.

capability.) This procedure is repeated for the duration of the data.

4) Data transmission is terminated by activating the Stop button. The peripheral computer checks for a STOP code and responds to this code by transmitting the last data block to the central computer and by transmitting an END code to the analyzer terminal.

The total time for a 4096-word memory dump is ~90 seconds. The rate-determining step is the slow speed (1800 bps) of the telephone lines connecting the terminal at the Radiation Center to the computer center. The disk files on which the Mode A data are stored are then accessible for time-sharing processing at any time so long as the user does not command the system to purge the data file.

The second mode of data collection is called "Mode B." It consists of the collection of N-parameter data at high resolution. This is very useful in studies of nuclear fission or other complex nuclear phenomena where the energies of two or more particles from a given reaction must be measured. The steps in the system operation in Mode B are:

1) The nuclear chemist enters file identification, number of parameters of a nuclear event, and any processing procedures and data via the control console, and the remote terminal console.

2) The nuclear chemist then activates the Start button and a primary initialization is accomplished (similar to Mode A). The main difference between Modes A and B at this point is that the two Start codes call in different sets of software in the time-sharing computer to service the two types of data.

3) Data collection begins:

a) An event consisting of N analog signals appears at N ADC's simultaneously, and each signal is digitized. (The analyzer memory now monitors any combination of two ADC's.) The ADC gates are "frozen."
b) A correlated address N-tuple is then strobed out of the ADC address registers into the data buffer in the form of 12-bit words per ADC and sent to the computer as in Mode A.
c) After strobing out all the appropriate address registers, the ADC gates are "unfrozen" and the system is ready for another event.

4) Item 3) is repeated until data transmission is terminated by actuating the Stop button.

In Mode B operation, the actual data collection rate rather than just the memory dump time is controlled by the transmission speed of the telephone lines linking the nuclear chemists with the computer. For two-parameter events, the data collection rates are ~75 events per second, and for four-parameter events ~38 events per second, which for the heavily used 4-parameter mode results in no significant loss of events.

Evaluation of the system

The weakest point of this system is the low data collection rate in Mode B operation, N-parameter analysis. However, this is a temporary problem for we now believe that a high speed (~10^6 bps) data line could be strung between the Radiation Center and the computer center at a cost approximating one year's rental of the telephone lines.

One strong point of this system is its low cost. A second strong point is the ease of programming; no large amount of special systems programming was necessary. We were able to use the conventional library of time-sharing software furnished by the Oregon State University Computer Center. Unlike many systems using small computers for data collection, we have the advantage of being able to use a big-machine FORTRAN compiler and a large (64K) memory. The features of conversational computer languages are also available to us for use in data analysis.

The over-all advantages of on-line processing of data cannot be overemphasized, especially in nuclear chemistry. To describe the many different present and future applications of this system in the OSU nuclear chemistry program would be prohibitively difficult. However, a few typical examples should indicate some of the advantages of this system. Our laboratory engages in forensic activation analysis: identification of the origin of objects for use in criminal and civil legal proceedings. We are also part of the Project Apollo Lunar Sample Return program, where we are charged with responsibility for using activation analysis to determine the composition of the lunar samples our astronauts return. Both these programs employ the Mode A analysis feature of our system and the ability of knowing the elemental composition of a sample within minutes (rather than days or weeks) after the start of the analysis has obvious advantages.

We are also studying fission prompt γ-ray angular correlation patterns. Here we record in a 4-parameter analysis (Mode B): the γ-ray energy, the time of flight of the γ-ray and the two fission fragment energies. This simultaneous recording of four parameters was not even possible with our commercial pulse height analyzer. To obtain this feature on a commercial analyzer would incur at least twice the cost of our present system. Secondly in the commercially available, traditional methods of data analysis, data are stored on magnetic tape and the transformation of the experimental data into physically meaningful quantities usually takes place days or months after the experiment. With on-line processing, the physically meaningful information is available during the experiment and can thus guide the nuclear chemist in the course of his experiment. Interesting effects, such as a mass dependence of the correlation patterns, can be checked; mistakes costing tens of hours of expensive reactor time are avoided by having the experimental results available during the experiment. As the complexity of nuclear chemistry increases, on-line data acquisition becomes essential. We think that the Oregon State University system represents an economical, powerful method of achieving such capability.

Acknowledgments

We would like to thank Professor R. A. Schmitt for his general support of this project and R. A. Davis for initial participation in this work. One of us (WL) would like to acknowledge the hospitality of the Argonne National Laboratory, where this paper was partially written.

Received July 12, 1968