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Résumé. — Un groupe de scientifiques de Yale et de IBM a mis au point un système souple d'acquisition de données utilisant un calculateur IBM 360/44 qui fonctionne maintenant en *production*. L'acquisition des données se fait à travers un interface comprenant des convertisseurs analogiques digitaux et des registres moniteurs permettant à l'expérimentateur de définir jusqu'à 16 événements distincts. Le système moniteur permet le traitement des événements par langage Fortran. Le dialogue entre expérimentateur et calculateur s'effectue au moyen d'une unité de visualisation 1024-1024 points CRT et d'un pupitre à clefs. Le contrôle et le monitorage de l'instrumentation ainsi que les conditions de fonctionnement de l'accélérateur peuvent être effectués à partir du calculateur. Un superviseur de multiprogrammation permet l'exécution simultanée de plusieurs travaux indépendants avec possibilité de traitement des données pendant leur acquisition.

Abstract. — A collaborating group of Yale and IBM scientists have developed a versatile data acquisition system, based on an IBM System/360 Model 44 Computer, which is now in routine use. Data acquisition is performed via an interface which features modular and digitally compatible ADCs, scalers and monitor registers, and which allows the experimenter to define up to sixteen independent events. The software system makes possible the processing of all incoming events by Fortran programs. Communication between the experimenter and computer is carried out by means of a display terminal which includes a 1024-1024 random point plotting CRT with a built-in characteric generator, and a function keyboard. Facilities are also included for control and monitoring of the experiment hardware and accelerator conditions. A multiprogramming supervisor enables several independent jobs to be run simultaneously, with inter-job communication facilities to enable analysis of data to be carried out concurrently with its acquisition.

A collaborating group of Yale and IBM scientists have developed a versatile data acquisition system, based on an IBM System/360 Model 44 Computer which is now in routine use at the Wright Nuclear Structure Laboratory, at Yale University which houses the world's first Emperor tandem Van de Graaff accelerator. Components of the system, other than the computer itself, include a data acquisition interface system including a set of modular and digitally compatible ADCs, scalers and monitor registers, a CRT display and function keyboard, a digital control system for controlling and monitoring experimental equipment, a data acquisition program package including a real time monitor and library of subroutines which enable data acquisition programs to be written in Fortran augmented by special statements for specifying nuclear data acquisition processes, and a multiprogramming supervisor which enables subdivision of a data acquisition program into a number of tasks processed in parallel, along with one or more unrelated background users.

The 360/44 is equiped with 131,072 bytes of 1 μs memory, high speed (250 ns) general registers, floating point hardware, eight external interrupt lines, and fetch and store memory protection. Three data channels are attached. One low speed (200,000 bytes/s) multiplexor channel services two single disk storage drives, Calcomp graph plotter, card reader/punch, line printer and console typewriter. One high speed (400,000 bytes/s) multiplexor channel services two 120,000 bytes/s tape drives and an 1827 data control unit which drives the display, function keyboard, and apparatus monitoring and control equipment. Another high speed multiplexor channel services the nuclear data acquisition interface itself through a 2701 data adapter.

The nuclear data acquisition interface system, fabricated by IBM Research, allows the experimenter to define, through insertion of diode pins in a convenient plugboard, up to sixteen types of events. The occurrence of an event is signalled by a pulse from a source determined by the experiment (coincidence circuit, beam integrator overflow, or other source). When such an event occurs, the instruments associated with it by means of the configuration plugboard are read into the memory preceded by an identification word which contains the event number and any desired information manually established for the experiment in a group of code switches.

The scalers are 15 bits, 25 MHz scalers which may be operated either as scalers or as 25 MHz timers, utilizing an internal time base oscillator common to all ADCs and scalers. The standard Yale-IBM ADCs are 1024 channel, 25 MHz ramp-type converters with 1 % differential and 1 % integral linearity and are constructed entirely in state of the art computer hardware. The monitor registers are general purpose 15 bits input registers which may be set either electrically or through front panel push-buttons. These monitor registers are used, for example, to interface Yale-built 4096 channel successive approximation ADCs which utilize the Gatti averaging principle, and which are based on a recent design of Goulding at Berkeley.

The display system features a 1024 $\times$ 1024 point plotting oscilloscope whose data are stored in the main memory and passed to the display repetitively, through the data channel. It is usually operated in multiplex mode, at a speed of 200,000 bytes per second (100,000 points per second in raster mode; 50,000 in random mode) although it is capable of running at twice this speed in the channel's burst mode. The function keyboard is a general purpose keyboard each of whose keys may be associated with a system or user-supplied (in Fortran) program stored in the disk file. Pressing a key generates an external interrupt and transmits a 16 bits word to the computer which is used to determine which program is to be fetched and executed. The function of the individual keys is, of course, controlled by the data acquisition software in use; normally, in changing between completely different types of experiments as, for example, between those involving determination of an excitation function through systematic variation of the accelerator beam energy and those involving determination of correlation functions using the laboratories on-line precision goniometer, a 9 megabits disk file containing the appropriate software is replaced in the central processor and a corresponding mask, which redefines the push-button function is placed over the keyboard.

A light pen system is provided for convenient and rapid communication with the computer and for use in data analysis generally. Text of all software in the computer can be displayed and modified on demand without recompiling. A high resolution slave display is equiped with automatic camera facilities to permit hard copy recording of any desired display. This copy may readily be of direct publication quality.

Apparatus control operations are carried out by means of a digital comparator developed at Yale. This may be used to control any operation which may be expressed as adjustment of a parameter toward a target value or destination. For example, to change a detector angle on the goniometer, the computer loads the new angle into a destination register and starts the drive motor in the correct direction. The digital comparator continuously compares the actual instantaneous angle (read on a shaft encoder) with the destination. When near equality is achieved, the comparator slows the motor to prevent overshoot and when final equality is achieved it stops the motor and generates an external interrupt. To this point, the computer is free to engage in other work. When the comparator interrupt is received, the computer reads the shaft encoder to confirm that the correct destination was reached. A precisely similar operation results in change of the proton resonance frequency, hence beam energy output, of the accelerator analyzing magnet. All devices to be monitored or controlled are connected to the computer through a pair of registers on the 1827 data control unit, using multiplexers built at Yale. Devices connected, or planned to be connected in the near future include pulse height stabilizers, the nuclear magnetic resonance magnetometer, focussing and beam handling magnets, beam current integrators, generating voltmeters, the precision goniometer and charged particle scattering chambers. Interfacing between the laboratory equipment and the data acquisition system is accomplished through extensive use of a very inexpensive 1024 channel ADC developed by Gingell at Yale.

The basis of the data acquisition program package is a real time monitor which handles operations on the data acquisition interface, display, and event log tape. The experimenter defines real time processes with a program written in Fortran supplemented by special statements. These statements form part of a new data acquisition language which is interpreted, by a new system precompiler which has been written at Yale, in standard Fortran statements interpretable by the standard System 360 compiler. The user supplies a separate block of statements to process each of the event types which he expects; these event routines are called by the monitor whenever the corresponding events occur, and in the same random order in which the events occur in real time. In these routines he may specify pulse height analysis, digital gating, peak fitting, angle change, energy change or any other process he can program. Special statements define analyzers, digital gates, scalers and physical equipment in the laboratory and specify the corresponding operations on these entities. If the user wishes to log his events' on magnetic tape for later replay, he requests this with a control card; no reprogramming is necessary on his part. Analyzers may have either 32 bits per channel, or 16 bits with an overflow table being kept on the disk. In either case, all references to analyzer channels always retrieve the correct number of counts, reference to the disk being made automatically when needed. For the initial period of operation, this system has run as a standard batch job under the IBM-supplied programming system for the 360/44.

A new multiprogramming system, written especially for this nuclear data system, is now in the final stages of testing. Its purpose is twofold : First, by enabling the program for an experiment to be written as a series of parallel multiprogrammed tasks, it makes possible considerable analysis of data while they are being accumulated, thus improving the quality of the results and minimizing the need for repeat experiments. Indeed, this on-line narrowing or closing of the gap between the experimentally measured parameters and those of final nuclear significance is one of the most important aspects of the system. The improvement in the quality of nuclear data and in the effectiveness of utilization of the time and effort of the user, is impressive. Second, multiprogramming makes the access computing power (both time and memory) usually available during an on-line experiment, available to independent users in the laboratory. The system is structured as a multilevel priority system, with priorities assigned on a first-come, first-served basis. In a single-experiment environment, this is adequate to insure that the experimenter (who has actual control over the computer) can arrange his programs to achieve his purpose and makes whatever computing power he does not require available to others who automatically have lower priority.

Dynamic storage allocation enables efficient use to be made of storage resources at all times. A global symbol system handles analyzers and other data which must be available to several users at one time. Physical users (corresponding to actual people) are memory-protected (by hardware) against each other's errors; they also use physically distinct terminal and display facilities. A physical user may be divided into several logical users, which perform individual tasks in parallel. The logical user is the basic unit of priority assignment. All logical users belonging to the same physical user have the same memory protection key (i.e. are not protected against each other), in order to enable rapid communication among them. A typical experiment program might be divided into four logical users, listed in priority order : data collector and logger, event routines, function keyboard and display, and spectrum analysis and output.

The over-riding consideration in the design of this nuclear data acquisition system has been to maximize the flexibility and ease of utilization by nuclear physicists and to minimize the amount of computer expertise required in their part. To that end, for example, extensive efforts has been devoted to writing the new nuclear data acquisition language and the system precompiler; the reward is that individual data acquisition programs for entirely new experiments may be written in a matter of hours. Similarly extensive effort devoted to the design and fabrication of the front-end interface pays very handsome dividends in the ease with which experimental configurations may be assembled. The system is a dynamic one in that under a continuing joint study agreement between Yale and IBM modifications and improvements will be incorporated as they become available or as continuing experience with the system suggests. One specific addition in the near future will be small additional computer which will act as a buffer during multichannel spectrum accumulation and as a control for an automatic photographic plate scanning system for use with the laboratory multigap magnetic spectrograph.

Experience to data with this Yale-IBM system has been highly satisfactory; similar systems are installed, or under installation in a number of laboratories throughout the world.

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