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A Facility For EDUCATION IN REAL-TIME COMPUTING

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OBJECTIVES

IN THE FALL OF 1968 it was decided to establish a facility for graduate and undergraduate education in real-time computing at the College of Engineering of The University of Oklahoma. This facility was to provide i) on-line data acquisition and processing capabilities for the undergraduate engineering laboratories; ii) "hands-on" experience in operation of real-time computers; iii) experience in hardware and software design for graduate and advanced undergraduate students; and iv) a facility for the rapid synthesis and check-out of complex digital logic circuits.

CONSTRAINTS

THE ENTIRE SYSTEM had to be purchased with $35,000 available as a one-shot investment from College of Engineering funds, plus whatever funding could be obtained from outside agencies. After the initial purchase, only limited funds—around $500 per year—would be available for system operation and maintenance. Thus, the computer system would have to be **reliable** and **easily maintainable** with local faculty and student effort. Also, since only a limited number of peripheral interfaces could be purchased, the system had to be **easy to interface**; then the bare-bones peripheral equipment could be purchased and interfaces built as student projects. Finally, the system had to have adequate **core memory** to support a minimal two-user **time-shared** monitor for on-line use in undergraduate laboratories.

EQUIPMENT

CONSIDERING THE ECONOMIC and performance constraints, we decided to purchase a Digital Equipment Corporation PDP-9/L computer with a basis cycle time of 1.5μsec, 8K of 18-bit word memory, and ASR-33 teletype input/output. In addition we bought as factory-installed options a 12-bit analog-to-digital (A/D) converter, capable of multiplexing up to 64 channels of analog data with 4 channels implemented, since we considered our experience to that point inadequate to construct these interfaces locally.

Through an NSF Instructional Scientific Equipment Grant[1] we obtained $17,500 to obtain additional peripheral equipment, including:

i) A DEC Multiple Teletype Interface with KSR-33 teletype;

A real time computing facility based on a PDP-9/L computer was established at Oklahoma for online laboratory data acquisition and processing and for experience in real-time hardware and software design.

ii) A Remex 300 char/sec paper tape reader;
iii) A Tektronix 611 storage display unit;
iv) A GDI 200 card/sec reader;
v) A NCR 30 char/sec thermal printer;
vi) A removable-media disk storage unit;
vii) A tape cassette drive;

plus sufficient hardware to interface these devices to the PDP-9/L, as well as to construct a logic patchboard system for the rapid synthesis and testing of digital circuits.

In addition, Fisher Governor Co. of Marshalltown, Iowa supplied equipment to convert a level-control experiment in the Chemical Engineering Laboratories to electronic control, in order to facilitate experiments in computer control.

EXPERIENCE WITH THE SYSTEM

THE SYSTEM WAS installed in September 1969; it was fully operational in two days despite a blow received in shipping which left a memory stack lying on the floor of the shipping crate with two broken wires. In the first two months of operation, timing difficulties developed which necessitated the replacement of the ASR-33 teletype; since then, however, no problems have arisen which could not be solved with local maintenance effort.

We soon found that software development was severely hindered by the necessity of loading lengthy system programs through the 10 character/sec. Teletype paper tape reader; to load the assembler, for instance, took about 20 minutes. To remedy this, author Vargo designed an **ad hoc** interface for the Remex 300 cps reader. This interface was somewhat unreliable, and the difficulty was traced to the circuits used to convert from the PDP-9/L's discrete-component logic levels (0 and —3 volts) to the TTL integrated-circuit levels (0 and +3 volts) used in the interface. This was remedied by using more reliable level-conversion circuits (designed by a student.[2])

USE IN COURSE WORK

THE SYSTEM HAS BEEN USED in undergraduate course work primarily for i) rapid data acquisition and processing, using FOCAL (DEC's Formula Calculator) language, to improve experimental turnaround time; and ii) to provide "hands-on" experience in hardware and software design.

In the first category, fast statistical analysis of data has been performed for experiments in resistor statistics; first- and second-order thermocouple dynamics; and transient response of a proportional level-control system. On-line data acquisition and analysis has been performed to determine the natural frequency and damping coefficient of a spring-mass-dashpot system. Both the thermocouple and level-control experiments will be adapted to on-line data acquisition as interfacing equipment becomes available.

We had originally planned to run a cable between the computer on the second floor of the Engineering Center, and the Chemical Engineering Laboratories in the sub-basement, to provide both Teletype and analog communication for a number of experiments. However, it soon became apparent that demand for on-line computing would develop at several scattered locations about the campus. We decided to solve the access problem through the design and construction, as a student project, of a Remote Analog Terminal (RAT) which would allow A/D and D/A conversion data to be sent through acoustic couplers over telephone lines simultaneously with Teletype data. The only interface necessary on the computer end will then be the already-existing multiple teletype interface. In the meantime, analog and Teletype cabling is provided to an adjacent second-floor laboratory.

The FOCAL interpreter was found to be too slow to give accurate results on the spring-mass-dashpot system, even with a natural frequency of about 1 sec. This can be traced directly to its use of double-precision floating-poing arithmetic with software multiply and divide, and to its use of symbol-table scanning every time a variable reference is encountered. We plan to avoid these difficulties by implementing single-word floating-point arithmetic, which will be within the accuracy of experimental data, in the BASIC interpreter which will be part of our on-line time-sharing software.

STUDENT PROJECTS

THREE M.S.-LEVEL DESIGN projects have been completed, two involving interface hardware design for the storage display unit[3] and card reader,[2] and one involving software design of the time-sharing monitor[4]. Current work in progress involves hardware design and construction of the RAT, and software design of the BASIC time-shared interpreter. In the Fall work will begin on interfaces for the NCR thermal printer and removable-media disk, and on operating-system software for the disk.

Undergraduate class projects have included software for paper-tape editing, card-to-tape conversion, and relocatable assembly; and hardware for drive and interface circuits for a salvaged Teletype 60 cps paper tape punch, as well as preliminary work on the RAT. In our experience, satisfactory completion of such projects requires more time than students can devote to a single class project. Additional time may be provided for interested students to complete their projects through independent-study or senior-thesis courses.

CONCLUSIONS

WE BELIEVE THAT this facility is making a substantial contribution to the education of engineers at the University of Oklahoma: First, through providing a flexible and innovative approach to undergraduate experimentation; and second, by providing graduate and advanced undergraduate students experience in designing hardware and software for on-line computing within both economic and time constraints.

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At the University of Florida

A REAL TIME COMPUTER CONTROL FACILITY

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IN 1968 THE CHEMICAL ENGINEERING Department at the University of Florida considered various alternatives by which it could introduce computer control into its undergraduate laboratories. The option available ranged over rather large systems at $150,000 or more to a relatively inexpensive remote terminal system in the under $20,000 range.

The choice ultimately made was for the remote terminal (See Figure 1), an IBM 1070 terminal, principally for its low cost. We also determined that, by designing our own interface equipment, we could have equipment which would generally satisfy our laboratory requirements. One of these requirements was that the total equipment cost no more than $30,000 as that amount was available. If the equipment were more expensive, outside financing would be needed with all its inherent delays.

We also desired to have an easily programmable system which would not first require significant software development on our part. The terminal would tie directly to a large scale scientific computer, an IBM 360/65, and could be operated by FORTRAN calls. With not too extensive a software system design, it was apparent that we could have a very easily programmed system. The power of the scientific computer would also permit complex control and/or analysis algorithms to be tried. We would obviously need the cooperation of the computing center for the quick computer response necessary for control. The programs we would write would use little actual time, but, when the process required attention,

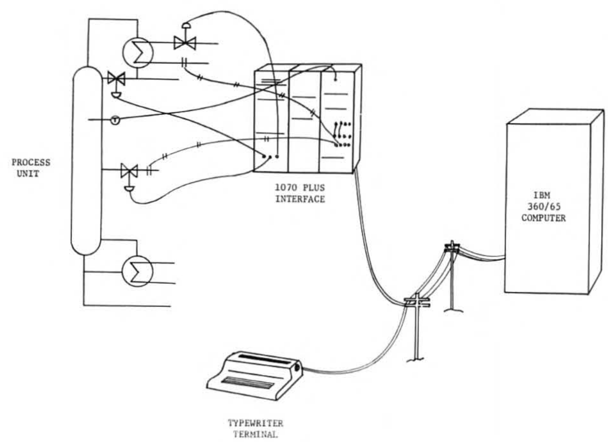

Fig. 1. — Chemical Engineering Remote Computer Control System.