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ABSTRACT

Drawn from a survey of engineering departments known to be teaching microprocessor courses, this paper shows that the adoption of microprocessors by Electrical Engineering Departments has been rapid compared with their adoption of minicomputers. The types of courses that are being taught can be categorized as: surveys of microprocessors, intensive study of one microcomputer, inclusion of microprocessors in a general course, project courses, and specific applications courses. (MLH)

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MICROPROCESSORS IN U. S. ELECTRICAL ENGINEERING DEPARTMENTS, 1974-1975

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ABSTRACT

This paper presents information on the types of microprocessors and microprocessor courses characteristic of U. S. Electrical Engineering departments in the 1974-1975 academic year. Much of the paper is drawn from a survey of departments known to be teaching microprocessor courses.

The paper shows that the adoption of microprocessors by Electrical Engineering departments has been rapid compared with their adoption of minicomputers. Predictably, Intel eight-bit microprocessors predominate. Departments use a variety of hardware and software support systems with software written within the department prevalent. The types of courses taught can be categorized as: 1) surveys of microprocessors, 2) intensive study of one microcomputer, 3) inclusion of microprocessors in a general course, 4) project course, and 5) specific applications course.

INTRODUCTION

The growth of microprocessors in U. S. Electrical Engineering departments has been extremely rapid, paralleling the rapid growth of sales and applications of microprocessors in industry. As is generally known, Intel alone sold more microprocessors last year than all computer firms sold computers of minicomputer size and up. One of the best measures of the involvement of Electrical Engineering departments with microprocessors is their use in courses. Starting with a dribble of courses two or three years ago, largely taught by industrial personnel from the semiconductor houses, the number of schools teaching courses based on microprocessors has grown to an estimated 20 in 1973-74 and an estimated 40 or more in 1974-75.[1] As shown in this paper, some of these schools are teaching two or more courses based entirely on microprocessors and three or more that are at least partially based on microprocessors. This rate of adoption is considerably ahead of the rate of adoption of minicomputers in Electrical Engineering departments.[2]

This paper attempts to survey the types of microprocessors and the types of microprocessor-based courses in Electrical Engineering departments in 1974-75 with some projections for 1975-76. It is based in part on a survey of Electrical Engineering departments. Those departments surveyed had responded to a survey previously conducted by the Education Committee of the IEEE Computer Society with a statement that they were teaching about micro-

processors or had microprocessors in their departments. A short letter inquiring about their use of microprocessors was sent to approximately 30 such departments. Replies--usually course outlines with a letter of explanation--were received from the 11 schools listed in Appendix A. All statistics and course outlines presented in this paper are drawn from these schools. However, the author has drawn freely from conversations with faculty from a wide variety of schools and visits to some other departments to supplement and flesh out the detailed information and to draw conclusions. The author gratefully acknowledges help from the responding schools and from many others.

EQUIPMENT

An important consideration is the types of microprocessors which Electrical Engineering departments have obtained or are considering. The Intel eight-bit microprocessors are clearly dominating the market to date, both in the schools surveyed and in other schools known to the author. Departments that purchased their microprocessors relatively early usually obtained the Intel 8008; departments that obtained them within the last year usually have the Intel 8080. Departments that are considering microprocessors now are about as likely to want the Motorola MC 6800 as the Intel 8080. The microprocessors reported by the surveyed departments are summarized in Table I; some depart-

ments reported two or more microprocessors and some reported none. A few departments reported that they were given microprocessors or lent them, usually by local industry. Substantial discounts are known to be available from some semiconductor houses. Both factors have probably facilitated the rapid acquiring of microprocessors; their very low cost relative to the cost of early minicomputers has helped even more in these days of low department equipment budgets.

Table I

Microprocessors in Surveyed Departments

In House 1974-1975		Expected for 1975-1976	
Intel 8008	4	Intel 8080	2
Intel 8080	5	Motorola MC 6800	2
Intel 4040			
Motorola MC6800	1		
RCA COSMAC	1		

Some departments reported more than one microprocessor.

Hardware and software support for microcomputer systems are important in determining the sophistication and flexibility of a system. Most departments that used the Intel 8008 or 8080 used a commercial hardware support system, such as the Intellec 8/80 or the Altair 8800, a new, low-cost system. Hardware

support for other microprocessors tended to be constructed within the department, possibly reflecting the fewer alternative commercial systems available for other microprocessors. Prototyping hardware systems reported by the surveyed departments are shown in Table II.

Table II

Prototyping Hardware in Surveyed Departments

Altair 8800	2
Control Logic LDS System (8008)	1
Intellec 8/80	2
Homemade	3

Information on software development systems is more difficult to categorize. Departments make good use of cross-assemblers, most of which assemble programs on other computers either in the department or in the university rather than on commercial time-sharing services. Presumably most of these cross-assemblers were written either by faculty or by students for projects. Cross-assemblers for the Intel 8008 or 8080 were reported for the PDP-8 (3), and PDP-10, IBM 370, and Varian 620L-100 (each 1). Some departments also reported substantial use of PL/M for the Intel microprocessors, using compilers on several larger computers. Other departments simply reported use of the manufacturer's software without supplying details.

COURSES

Courses reported by the responding departments can be classified as:

1) Survey of microprocessors
2) Intensive study of one microcomputer
3) Inclusion of microprocessors in a general course
4) Project course
5) Specific applications course

Survey of microprocessors

Of these, the survey of microprocessors course predominates both in the responding departments and in other departments with which the author is familiar. It is perhaps the easiest course to teach and can readily be taught without microcomputers in house; several responding departments did just that. The first microprocessor courses taught tended to be either a general survey or a survey with some concentration on one or two microprocessors with which the instructor was especially familiar; many courses taught by engineers from the semiconductor houses follow the second format. These courses are easy to teach without a text and are usually supplemented by reprints of papers from technical journals or trade magazines. Typical outlines for such courses are those shown for Iowa State University and the University of South Carolina. The course at Iowa State is followed by a second course on microcomputer system design.

EE437X: INTRODUCTION TO MICROCOMPUTERS (Iowa State University)

A. OVERVIEW

B. SURVEY OF MEMORIES AND ORGANIZATIONS

C. PLAs AND MICROPROGRAMMING

D. DETAILED SURVEY OF:

INTEL 4004, 4040, 8008, 8080, 3002

MOTOROLA 6700, 6800, 6900

NATIONAL IMP 4, IMP 8, IMP 16, PACE

ROCKWELL PPS 8

FAIRCHILD F8

MOSTEK 5065

TI SBP0400

E. DETAILED MICROCOMPUTER CIRCUIT DESIGN

F. TYPICAL APPLICATIONS OF MICROCOMPUTERS

ENGR 765: MICROPROCESSOR APPLICATIONS (U. of South Carolina)

I. COMPUTERS, MICROPROCESSORS, AND MICROCOMPUTERS

II. MICROPROCESSOR ARCHITECTURE FEATURES

A. Addressing modes
B. Interrupts
C. Internal registers
D. Microprogramming
E. Direct memory access
F. Cycle time
G. Subroutine calls
H. Arithmetic capability
I. Word size
J. TTL compatability
K. Clock(s)
L. Power supplies
M. Support components
N. Packaging
O. The instruction set

III. SOFTWARE FEATURES

A. Resident editor
B. Resident/cross assembler
C. Higher language programming
D. Simulators
E. Relocatable binary code
F. Cross page boundaries

IV. THE MICROPROCESSORS

A. Intel 8008
B. Intel 4004/4040
C. Intel 8080
D. Motorola 6800
E. National Semiconductor μP Family
F. Intersil
G. RCA
H. MOSTEK
I. The bipolars

IVB. (THE MICROCOMPUTERS)

V. THE INSTRUCTION SET

VI. MACHINE-CODE PROGRAMMING

ENGR 765: MICROPROCESSOR APPLICATIONS (U. of South Carolina) cont'd:

VII. THE ASSEMBLER

VIII. ASSEMBLER-LANGUAGE PROGRAMMING

IX. INTERFACE PROBLEMS

A. Serial/asychronous devices/UART's
B. Analog/digital converters
C. I/O ports

X. TIME-SHARE APPLICATIONS

TEXT: Microcomputer Design, Martin Research

Intensive study of one microcomputer

Courses that concentrate on one microcomputer are intended to develop students' skills at writing programs and developing systems based on one microprocessor in the belief that hands-on experience with one microcomputer is more valuable than casual knowledge of several. Such a course necessitates an in-house microcomputer system with a variety of software and hardware development aids. A typical outline is that of a course at Stanford University.

Inclusion of microprocessors in a general course

A growing use of microprocessor material is its incorporation in a more general course, usually a computer architecture course. This can be done at any level from an introductory computer engineering course at the freshman or sophomore level to an advanced graduate architecture course. It is especially valuable in introductory courses for students who will not take other computer engineering courses. Because of the increasing use of microprocessor systems to replace hard-wired logic in many electronics systems, the inclusion of microprocessors in electronics courses as well as computer engineering courses is increasingly likely. Course outlines from the University of South Carolina and Princeton University (introductory courses) and the University of New Hampshire (a more advanced course) illustrate the possibilities.

EE390 (section 76): SPECIAL STUDIES IN ELECTRICAL ENGINEERING (Stanford University)

Microprocessor Applications. Lab course on microprocessor programming and applications. Hands-on experience using an Intel MCS-8 microcomputer. Students at first will familiarize themselves with the necessary supporting software; a high-level language (PL/M) compiler and a simulator. These are running on the IMSS PDP-10 and are available to students via time-sharing terminals. After the programs are debugged using the simulator, the programs will then be loaded and the final system debugged on the MCS-8. At this time, students will have added their own I/O to the system. The first phase of the course can be taken as EE390 (sec. 76) for one credit. In the following quarter, the student would implement and complete an individual project under EE391 (sec. 76), credit and hours to be arranged. Prerequisite: knowledge of a high-level language (Algol or Fortran) plus some familiarity with digital ICs. Consent of instructor required.

ENGR 524: ORGANIZATION AND DESIGN OF DIGITAL SYSTEMS
(U. of South Carolina)

TEXTS: 1) Digital Networks and Computer Systems, Booth

2) Introduction to Programming, Staff Digital Equipment Corp.

I. INTRODUCTION TO THE COMPUTER

A. Computer organization
B. The instruction cycle
C. Machine-language programs
D. Assembler programs
E. Assembler-language programs

II. DESIGN OF DIGITAL SYSTEMS/THE CONTROLLER

A. Register-level operations and notation
B. Control of information processing tasks
C. The classes of controllers
D. The autonomous controller
E. The status-input controller
F. The instruction-controlled controller

III. STORED INFORMATION PROCESSORS AND COMPUTERS

A. Major units of the computer
B. The memory
C. The central processing unit (CPU)
D. The input/output (I/O) unit
E. The control unit
F. Instruction word formats

IV. SEDCOM

A. Basic organization
B. The SEDCOM instruction cycle
C. The memory reference instructions
D. The operate instructions
E. I/O instructions

ENGR 524: ORGANIZATION AND DESIGN OF DIGITAL SYSTEMS (U. of South Carolina) cont'd:

V. MACHINE-LANGUAGE PROGRAMS

A. Basic programming concepts
B. Pointers and counters
C. Loops
D. Subroutines
E. I/O programming
F. Numerical calculations
G. Symbolic calculations

VI. ASSEMBLER-LANGUAGE PROGRAMS

A. Introduction to the assembler
B. Assembler syntax
C. Structure of a simple assembler program
D. Additional assembler concepts
E. PAL - 8 examples

VII. THE MICROPROCESSOR

A. Definition of microcomputer and microprocessor
B. Structure of an example microprocessor
C. A microprocessor assembler
D. Program examples

EE317: COMPUTER STRUCTURE (Princeton University)

An introduction to the structure, organization, and operation of computers and other digital information handling systems. Topics include basic system requirements, hardware building blocks, analysis and design of logic circuits, memory structure and memory hierarchy, control design and microprogrammed control, and the organization of typical computers. Three lectures, one laboratory.

EE712: LOGICAL DESIGN OF DIGITAL COMPUTERS
(U. of New Hampshire)

Is primarily an introduction to computer architecture through analysis of machine language instruction sets and internal data flow and timing. Selected maxi, midi, mini, and micro computers are analyzed to varying degrees. Approximately two weeks are spent on microprocessors, with emphasis on the Intel MCS 8 and MCS 4 systems. Our MCS 8 has been slaved to our PDP-8L, providing a prototyping arrangement superior but similar to the Intellec 8. Our system allows program loading and dumping, internal register and stack loading and dumping, single step, run, breaking on preselected addresses, etc. We use an MCS 4 program analyzer for prototyping that system. We presently have cross-assemblers for both microcomputers on our PDP-8L and are developing cross-assemblers on our Varian 620L-100. We have also developed a hardware-software package for programming PROMS under control of our Varian system.

Project courses

Although only one project course was described in the survey responses (see the Stanford University course outline), project courses using microprocessors are known to be common. Presumably much of the special software developed for departmental microprocessors was done by students for project credit. Project courses are an excellent way to develop students' skills and initiative while at the same time obtaining hardware or software for a system. In addition to the one project course reported, the author also was sent a copy of a paper on the design and construction of a small computer system based on the Intel 8080 written by three undergraduate students at Vanderbilt University, which may have resulted from a project course.[3]

Specific applications course

As microprocessors become more standard parts of the electronics arsenal, courses that use microprocessors to implement a particular application can be expected to become more common. The only such course reported in the survey was a course that may be taught at Yale University in 1975-1976. This course is intended to be a senior-year signal processing laboratory. The microprocessor (probably the Intel 8080) will be used as a vehicle for the student's exploration of encoding, decoding, and digital filtering techniques.

REFERENCES

1. M. E. Sloan et al., "Computer Science and Computer Engineering 1974-1975," in preparation.

2. M. E. Sloan, C. L. Coates, and E. J. McCluskey, "COSINE Survey of Electrical Engineering Departments, Fall 1972," Computer, June 1973, 30-39.

3. M. J. Adkins, M. V. Johnston, and T. C. Slattery, "Design and Construction of a Small General Purpose Computer System Utilizing the Intel 8080 Microprocessor," submitted for presentation at Region 3, IEEE 1975 Regional Competition.

APPENDIX A

Schools Reporting

Georgia Institute of Technology

Iowa State U.

Kansas State U.

Michigan Technological U.

U. of New Hampshire

Princeton U.

U. of South Carolina

Stanford U.

Vanderbilt U.

Wright State U.

Yale U.