KEYNOTE SESSION

EMERGING ROLE AND IMPACT OF THE MICROPROCESSOR

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To understand the role and impact that microprocessors will have on the electronics industry, it is pertinent to recall the first important meeting on LSI, held at the International Solid-State Circuits Conference just a decade ago here in Philadelphia. A central issue of LSI was then, and has continued to be, the question of standard versus custom LSI components. A great deal of effort was expended in the past ten years toward development of a capability such that end users' low-volume custom LSI logic designs could be fabricated with quick response and at low cost. The concept extended to the idea that with powerful design automation software, customers could literally design their own custom LSI requirements from terminals connected into semiconductor companies' computers.[1] Consistent with this capability was the idea that the semiconductor industry would consolidate into four or five major companies who would provide both custom and standard products to a much larger applications-oriented industry (Figure 1).[1,2] This development was supported by the large semiconductor companies working with computer manufacturers.

During the same period, on another front, the calculator industry was providing the semiconductor industry a market for high-volume logic parts. This culminated in Feb. 1971 when the complete logic for a four-function calculator was integrated on a single chip of silicon by Mostek Corporation. This chip, while it was a custom

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[1] P. E. Haggerty, "Integrated Electronics--A Perspective," Proceedings of the IEEE, Vol. 52, No. 12, December 1964, pp. 1400-1405.

[2] R. L. Petritz, "Technological Foundations and Future Directions of Large-Scale Integrated Electronics," Proceedings--Fall Joint Computer Conference, 1966, pp. 65-87.

design, was manufactured in such high volume that it soon became a standard product. The desire of the calculator industry to provide more powerful functions, such as scientific functions, gave impetus to the development by Intel of the first microprocessor chip, the 4-bit 4004 in Nov. 1971. It is an interesting historical note that the same Japanese calculator company, Busicom, worked both with Mostek on the four-function calculator, and with Intel, on the scientific calculator program.

In the case of the scientific calculator, Busicom wanted a family of products to meet various market requirements. To custom design such a family was seen to be a difficult and not necessarily cost effective approach. M. E. Hoff, Jr., a young engineer at Intel, proposed an elegant solution to this problem. And that was that instead of customizing a series of chips, Intel would design a powerful CPU (central processing unit) chip which would interact with two memory chips, one ROM and one RAM, to form a stored program microcomputer system. A specific scientific calculator would be implemented by a stored program, which would be fixed on a ROM chip. Thus, suddenly the job of customizing became, instead of designing a complex logic chip, that of writing a specific software program for the application, and storing it on a custom ROM chip. This important development also made it possible for the semiconductor industry to concentrate its efforts on what is has historically done best, namely produce standard parts in high volume. At the same time it enabled the user industry to focus its design talents not on complicated custom logic systems, but rather on solving problems through the use of stored program computers. The principal design task then became one of writing an applications program which would be stored in ROM.

In this paper we review briefly the current status of microprocessor development; and then discuss the role and impact of the microprocessor on the following five subjects:

Semiconductor Industry

End-user Industry

Engineering Profession

Structure of the Electronics Industry

Pervasiveness of Electronics.

A microprocessor is a program-controlled LSI component which performs operations on data according to a (changeable) series of instructions (the program). Operations include:

Input and output of data

Arithmetic or logic operations on data

Data-controlled decision functions.

The microprocessor is the control element (or central processing unit) of a system which is called a microcomputer. A microcomputer is a computer system utilizing:

Microprocessor for the CPU

Program memory (usually ROM)

Data storage (usually RAM)

I/O circuitry

Clock generators.

Microprocessors are available today in both MOS and bipolar technologies with word lengths of 4, 8, 12, and 16 bits, and also bit-slice approaches. The Intel 8080 is illustrative of the power available today on a single chip.

- 8 bit word length
- 70 instructions
- Vectored interrupt
- 2 μsec instruction cycle
- 512 I/O parts addressable
- Stack operations
- 65K directly addressable memory
- 8 registers and 4 flags
- Binary and decimal arithmetic
- Direct memory address (DMA)
- Powerful supporting chip family (ROMs, RAMs, I/Os).

Software support includes:

- Assembler
- PLM Compiler
- Text Editor
- Simulator
- Debugger
- Utilities

An outline of the role and impact of microprocessors follows.

Semiconductor Industry:

1. The basic building blocks for electronic systems will be

   Microprocessors

   ROMs

   RAMs

   Specialized I/O Devices

   Microcomputers.

2. These building blocks will be manufactured as high-volume standard parts, with low-volume custom parts becoming a small part of the industry's production.

3. Both logic and memory chip complexity will continue to increase rapidly; but overall package number, and consequently dollar volume, will increase relatively slowly.

4. An electrically reprogrammable ROM will be developed which will allow the user to program his microprocessor independent of the semiconductor manufacturer.

5. Standardization of microprocessors and related hardware will not occur by decree, but by usage.

6. Standardization of software will occur at high level languages, allowing freedom for continued architecture innovation at the component level.

7. Innovations in design and process technology will continue to be made.

End-user Industry:

1. Microprocessors will impact the entire controller-computer industry, shown in Fig. 2.

2. A large percentage of controllers, normally implemented with hard-wired logic,will be implemented with microprocessors.

3. Mini and macro computers will undergo another round of cost reduction by use of bit-slice microprocessors.
4. True distributed computing power will become a reality.
5. Many new applications will become cost effective.

Engineering Profession:

1. Digital designers will learn to program and implement systems around stored program microcomputers rather than hard-wired MSI logic or custom LSI.
2. Linear designers will learn digital techniques by learning to program microprocessors. Their skill and understanding of sensors and I/O devices will make them valuable microprocessor applications engineers.
3. Programmers without formal engineering training will be valuable members of the design team.
4. Management will support training programs for both their digital and linear engineers to become microprocessor applications engineers.
5. Engineers will find programming relatively easy to learn and use because of its logical sequential nature.
6. Job opportunities will expand for engineers because of the growth and dispersion that will occur in the electronics industry, as discussed below.

Structure of the Electronics Industry:

1. The electronics industry will continue to develop along the directions shown in Fig. 1, with value added being related principally to materials technology and software technology, with mechanical technology becoming less important.

2. Semiconductor technology will become widely disseminated throughout two major groups: component suppliers and systems houses. Semiconductor manufacturing operations will become commonplace.

3. The economies of high-volume production of standard parts will make it unfeasible for more than two or three independent companies to manufacture the same product line, resulting in the semiconductor components industry fragmenting into many companies, each of which is relatively specialized along a specific product line.

4. Systems houses, with internal (captive) semiconductor operations, will have technology agreements with several specialized semiconductor houses. In time, the systems houses will produce a major portion of their requirements.

5. The applications-oriented industry will be much larger and broader than the components industry, and many companies not previously skilled in electronics will begin to use electronics for the solution of their customer requirements.

6. Because of their specialization, most semiconductor manufacturers will not successfully vertically integrate upward.

7. However, the systems producer, with market control of large segments will stabilize enough conditions to successfully vertically integrate downward.

Pervasiveness of Electronics:

Microprocessors will contribute significantly toward overcoming the four limitations[1] of electronics:

1. The limitation of cost
2. The limitation of reliability
3. The limitation of complexity
4. The limitation imposed by the specialized character of and relative sophistication of the science, engineering and art of electronics.

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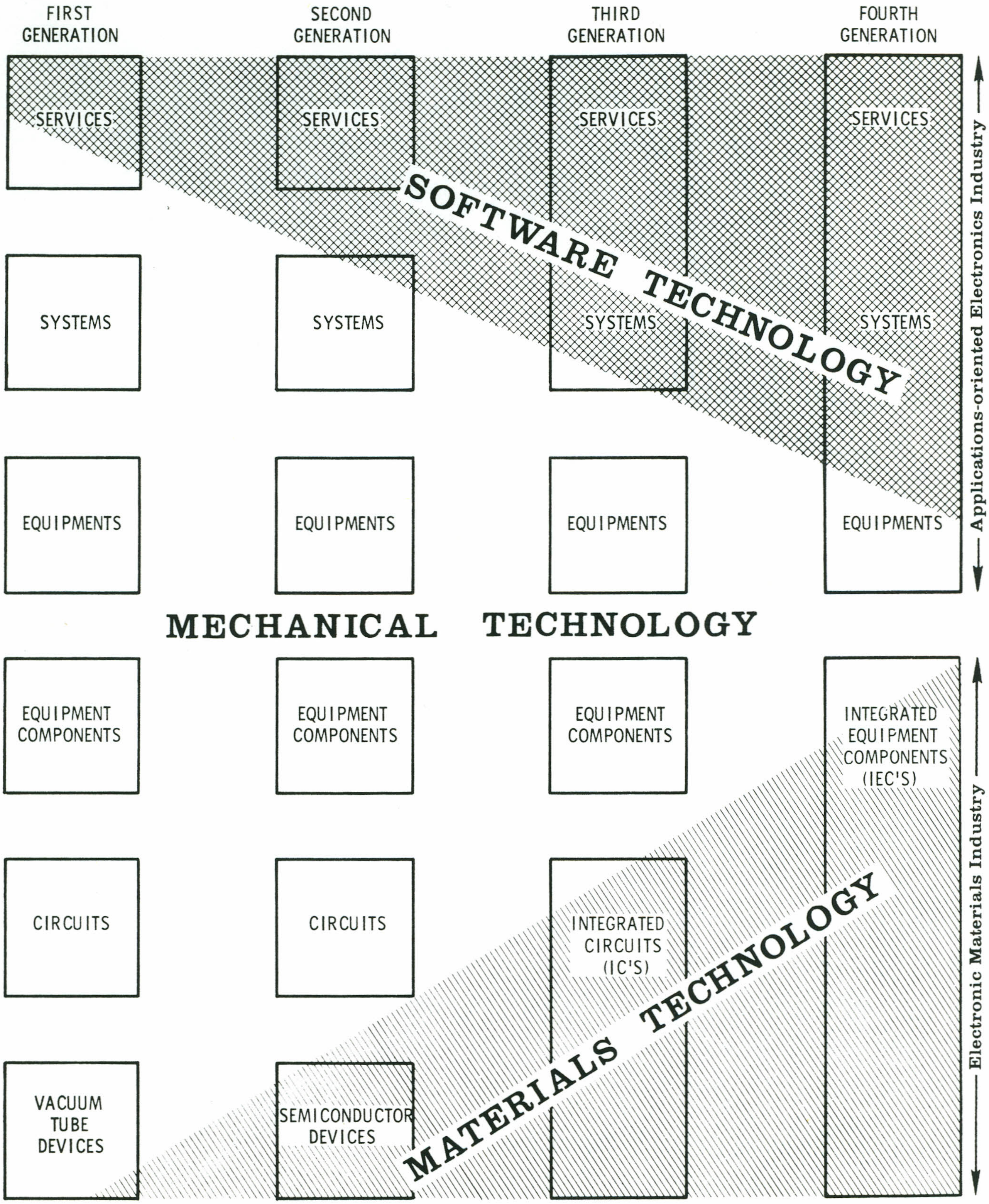
[1] P. E. Haggerty, op. cit.

The fourth limitation, that of "sophistication" has been the most difficult one to overcome, and it is here that the microprocessor will have its greatest impact. This is because the microprocessor reduces the application of electronics essentially to that of writing a computer program, and the average person can be educated to program a computer. Programming will be taught in school as the application side of modern mathematics. Hardware will be available in the form of hand-held microcomputers selling for less than $100. Software programs, assemblers and higher level languages, are already available. With literally everyone being familiar with and able to use microcomputers there can be no real limitations on the pervasiveness of electronics in our society.



Structure of the Electronics Industry

CHARACTERISTICS OF THE CONTROLLER-COMPUTER INDUSTRY

WORD LENGTH	1	2	4	8	16	32	64
COMPLEXITY	HARD-WIRED LOGIC	PROGRAMMED LOGIC ARRAY	CALCULATOR	MICRO-PROCESSOR	MINI-COMPUTER		LARGE COMPUTER
APPLICATION		CONTROL			DEDICATED COMPUTATION	LOW COST GENERAL DATA-PROCESSING	HIGH-PERFORMANCE GENERAL DATA-PROCESSING
COST	UNDER $100		$1,000			$10,000	$100,000 AND UP
PROGRAM	READ ONLY						RELOADABLE
MEMORY SIZE	VERY SMALL 0-4 WORDS	SMALL 2-10 WORDS		MEDIUM 10-1,000 WORDS	LARGE 1,000-1 MILLION		VERY LARGE MORE THAN 1 MILLION
SPEED CONSTRAINTS	REAL TIME	SLOW			MEDIUM		THROUGHPUT-ORIENTED
INPUT-OUTPUT	INTEGRATED	FEW SIMPLE DEVICES			SOME COMPLEX DEVICES		ROOMFUL OF EQUIPMENT
DESIGN	LOGIC	LOGIC + MICROPROGRAM			MICROPROGRAM MACROPROGRAM		MACROPROGRAM HIGH-LEVEL LANGUAGE SOFTWARE SYSTEM
MFG. VOLUME	LARGE						SMALL