Text 2
"Electronics and microelectronics"

The intensive effort of electronics to increase the reliability and performance of its products while reducing their size and cost has led to the results that hardly anyone would have dared to predict.

The evolution of electronic technology is sometimes called a revolution. What we have seen has been a steady quantitative evolution: smaller and smaller electronic components performing increasingly complex electronic functions at ever higher speeds. And yet there has been a true revolution: a quantitative change in technology has given rise to qualitative change in human capabilities.

It all began with the development of the transistor.

Prior to the invention of the transistor in 1947 its function in an electronic circuit could be performed only by a vacuum tube. Tubes came in so many shapes and sixes and performed so many functions that in 1947 it seemed audacious to think that the transistor would be able to compete except in limited applications.

The first transistors had no striking advantage in size over the smaller tubes and they were more costly. The one great advantage the transistor had over the best vacuum tubes was exceedingly low power consumption. Besides they promised greater reliability and longer life. However, it took years to demonstrate other transistor advantages.

With the invention of the transistor all essential circuit functions could be carried out inside solid bodies. The goal of creating electronic circuits with entirely solid-state components had finally been realized.

Early transistors, which were often described as being a size if a pea, were actually enormous on the scale at which electronic events take place, and therefore they were very slow. They could respond at a rate of a few million times a second; this was fast enough to serve in radio and hearing-aid circuits but far below the speed needed for high-speed computers or for microwave communication systems.

It was, in fact, the effort to reduce the size of transistors so that they could operate at higher speed that gave rise to the whole technology of microelectronics.

A microelectronics technology has shrunk transistors and other circuit elements to dimensions almost invisible to unaided eye.

The point of this extraordinary miniaturization is not so much to make circuits small per se as to make circuits that are rugged, long-lasting, low in cost and capable of performing electronic functions at extremely high speeds. It is known that the speed of response depends primarily on the size of transistor: the smaller the transistor, the faster it is.

The second performance benefit resulting from microelectronics stems directly from the reduction of distances between circuit components. If a circuit is to operate a few billion times a second the conductors that tie the circuit together must be measured in fractions of an inch. The microelectronics technology makes close coupling attainable.

It may be helpful if we say a few words about four of the principal devices found in electronic circuits: resistor, capacitors, diodes and transistor. Each device has a particular role in controlling the flow of the electrons so that the completed circuit performs some desired function.

During the past decade the performance of electronic systems increased manifold by the use of ever larger numbers of components and they continue to evolve. Modern scientific and business computers, for example, contain 109 elements; electronic switching systems contain more than a million components.

The tyranny of numbers - the problem of handling many discrete electronic devices - began to concern the scientists as early as 1950. The overall reliability of the electronic system is universally related to the number of individual components.

A more serious shortcoming was that it was once the universal practice to manufacture each of the components separately and then assemble the complete device by wiring the components together with metallic conductors. It was no good: the more components and interactions, the less reliable the system.

The development of rockets and space vehicles provided the final impetus to study the problem. However, many attempts were largely unsuccessful.

What ultimately provided the solution was the semiconductor integrated circuit, the concept of which has begun to take shape a few years after the invention of the transistor. Roughly between 1960 and 1963 a new circuit technology became a reality. It was microelectronics development that solved the problem.

The advent of microelectronic circuits has not, for the most part, changed the nature of the basic functional units: microelectronic devices are also made up of transistors, resistors, capacitors, and similar components. The major difference is that all these elements and their interconnections are now fabricated on single substrate in single series of operations.

Several key developments were required before the exciting potential of integrated circuits could be realized.

The development of microelectronics depended on the invention of techniques for making the various functional units on or in a crystal of semiconductor materials. In particular, a growing number of functions have been given over the circuit elements that perform best: transistors. Several kinds of microelectronic transistors have been developed, and for each of them families of associated circuit elements and circuit patterns have evolved.

It was the bipolar transistor that was invented in 1948 by John Bardeen, Walter H. Brattain and William Shockley of the Bell Telephone Laboratories. In bipolar transistors charge carries of both polarities are involved in their operation. They are also known as junction transistors. The npn and pnp transistors make up the class of devices called junction transistors.

A second kind of transistor was actually conceived almost 25 years before the bipolar devices, but its fabrication in quantity did not become practical until the early 1960's. This is the field-effect transistor. The one that is common in microelectronics is the metal-oxide-semiconductor field-effect transistor. The term refers to the three materials employed in its construction and is abbreviated MOSFET.

The two basic types of transistor, bipolar and MOSFET, divide microelectronic circuits into two large families. Today the greatest density of circuit elements per chip can be achieved with the newer MOSFET technology.

An individual integrated circuit (IC) on a chip now can embrace more electronic elements than most complex piece of electronic equipment that could be built in 1950.

In the first 15 years since the inception of integrated circuits, the number of transistors that could be placed on a single chip (with tolerable yield) has doubled every year. The 1980 state of art is about 70K density per chip. Nowadays we can put a million transistors on a single chip.

The first generation of commercially produced microelectronic devices is now referred to as small-scale integrated circuits (SSI). They included a few gates. The circuitry defining a logic array had to be provided by external conductors.

Devices with more that about 10 gates on a chip but fewer than about 200 are medium-scale integrated circuits (MSI). The upper boundary of medium-scale integrated circuits technology is marked by chips that contain a complete arithmetic and logic unit. This unit accepts as inputs two operands and can perform any one of a dozen or so operations on them. The operations include additions, subtraction, comparison, logical "and" and "or" and shifting one bit to the left or right.

A large-scale integrated circuit (LSI) contains tens of thousands of elements, yet each element is so small that the complete circuit is typically less than a quarter of an inch on a side.