**History of Microprocessor**

It is year 1969, and a team of Japanese engineers from the BUSICOM company arrives to United States with a request that a few integrated circuits for calculators be made using their projects. The proposition was made to INTEL, and Marcian Hoff was responsible for the project. Since he was the one who has had experience in working with a computer (PC) PDP8, it occurred to him to suggest a fundamentally different solution instead of the suggested construction. This solution presumed that the function of the integrated circuit is determined by a program stored in it. That meant that configuration would be simpler, but that it would require far more memory than the project that was proposed by Japanese engineers would require. After a while, though Japanese engineers tried finding an easier solution, Marcian's idea won, and the first microprocessor was born. In transforming an idea into a ready made product , Frederico Faggin was a major help to INTEL. He transferred to INTEL, and in only 9 months had succeeded in making a product from its first conception. INTEL obtained the rights to sell this integral block in 1971. First, they bought the license from the BUSICOM company who had no idea what treasure they had. During that year, there appeared on the market a microprocessor called 4004. That was the first 4-bit microprocessor with the speed of 6 000 operations per second. Not long after that, American company CTC requested from INTEL and Texas Instruments to make an 8-bit microprocessor for use in terminals. Even though CTC gave up this idea in the end, Intel and Texas Instruments kept working on the microprocessor and in April of 1972, first 8-bit microprocessor appears on the market under a name 8008. It could address 16Kb of memory, and it had 45 instructions and the speed of 300 000 operations per second. That microprocessor was the predecessor of all today's microprocessors. Intel kept their developments up in April of 1974, and they put on the market the 8-bit processor under a name 8080 which could address 64Kb of memory, and which had 75 instructions, and the price began at $360.

In another American company Motorola, they realized quickly what was happening, so they put out on the market an 8-bit microprocessor 6800. Chief constructor was Chuck Peddle, and along with the processor itself, Motorola was the first company to make other peripherals such as 6820 and 6850. At that time many companies recognized greater importance of microprocessors and began their own developments. Chuck Peddle leaves Motorola to join MOS Technology and keeps working intensively on developing microprocessors.

At the WESCON exhibit in United States in 1975, a critical event took place in the history of microprocessors. The MOS Technology announced it was marketing microprocessors 6501 and 6502 at $25 each, which buyers could purchase immediately. This was so sensational that many thought it was some kind of a scam, considering that competitors were selling 8080 and 6800 at $179 each. As an answer to its competitor, both Intel and Motorola lower their prices on the first day of the exhibit down to $69.95 per microprocessor. Motorola quickly brings suit against MOS Technology and Chuck Peddle for copying the protected 6800. MOS Technology stops making 6501, but keeps producing 6502. The 6502 is a 8-bit microprocessor with 56 instructions and a capability of directly addressing 64Kb of memory. Due to low cost , 6502 becomes very popular, so it is installed into computers such as: KIM-1, Apple I, Apple II, Atari, Comodore, Acorn, Oric, Galeb, Orao, Ultra, and many others. Soon appear several makers of 6502 (Rockwell, Sznertek, GTE, NCR, Ricoh, and Comodore takes over MOS Technology) which was at the time of its prosperity sold at a rate of 15 million processors a year! Others were not giving up though. Frederico Faggin leaves Intel, and starts his own Zilog Inc.

In 1976 Zilog announces the Z80. During the making of this microprocessor, Faggin makes a pivotal decision. Knowing that a great deal of programs have been already developed for 8080, Faggin realizes that many will stay faithful to that microprocessor because of great expenditure which redoing of all of the programs would result in. Thus he decides that a new processor must be compatible with 8080, or that it must be capable of performing all of the programs which had already been written for 8080. Beside these characteristics, many new ones have been added, so that Z80 was a very powerful microprocessor in its time. It could address directly 64 Kb of memory, it had 176 instructions, a large number of registers, a built in option for refreshing the dynamic RAM memory, single-supply, greater speed of work etc. Z80 was a great success and everybody converted from 8080 to Z80. It can be said that Z80 was without a doubt commercially most successful 8-bit microprocessor of that time. Besides Zilog, other new manufacturers like Mostek, NEC, SHARP, and SGS also appear. Z80 was the heart of many computers like Spectrum, Partner, TRS703, Z-3 and Galaxy here at home.

In 1976, Intel comes up with an improved version of 8-bit microprocessor named 8085. However, Z80 was so much better that Intel soon lost the battle. Even though a few more processors appeared on the market (6809, 2650, SC/MP etc.), everything was actually already decided. There weren't any more great improvements to make manufacturers convert to something new, so 6502 and Z80 along with 6800 remained as main representatives of the 8-bit microprocessors of that time.

The history of the μP development is very interesting. The first μP was introduced in 1971 by Intel Corporation. This was the Intel 4004, a processor on a single chip. It had the capability of performing simple arithmetic and logical operations. E.g. Addition, subtraction, comparison, logical AND and OR. It also had a control unit which could perform various control functions like fetching an instruction from the memory, decoding it and generating control pulses to execute it. It was a 4 bit μP operating on 4 bits of data at a time. The processor was the central component in the chip set, which was called the MCS-4. The other components in the set were a 4001 ROM, 4002 ROM and a 4003 shift register. Shortly after the 4004 appeared in the commercial market place, there is other general purpose μP were introduced. These devices were the Rockwell International 4 bit PPS-4, the Intel 8 bit 8008 and the National Semiconductor 16 bit IMP-16. Other companies had also contributed in the development of μP.

The first 8 bit μP, which would perform arithmetic and logic operations on 8 bit words, was introduced in 1973, by Intel. This was 8008 that was followed by an improved version- the 8080 from the same company. The μPs introduced between 1971and 1972 were the first generator systems. They were designed using the PMOS technology. This technology provided low cost, slow speed and low output currents and was compatible with TTL.

After 1973, the second generation μPs such as Motorola 6800 and 6809, Intel 8085 and Zilog Z80 evolved. These μPs were fabricated using NMOS technology. The NMOS process offered faster speed and higher density than PMOS and was TTL compatible. The distinction between the 1st & 2nd generation devices was primarily the use of new a semiconductor technology to fabricate the chips.

This new technology resulted in a significant increase in instruction execution speed & higher chip densities. After 1978, the 3rd generation microprocessors were introduced. Typical μPs are Intel 8086/80186/80286 and Motorola 68000/68010. These μPs were designed using HMOS technology.

HMOS provides the following advantages over NMOS.

1) Speed power produced (SSP) of HMOS is 4 times better than that of NMOS. That is for NMOS, SSP is 4 picojoules (PJ) and for HMOS, SSP is 1 picojoules (PJ).

Speed power product = speed \* power

= nanoseconds \* mill watt

= picojoules

2) Circuit densities provided by HMOS are approximately twice those of NMOS. That is for NMOS. It is 4128 μm2/gate and for HMOS it is 1052.5 μm2/gate, where 1 μm = 10-6 meter.

Later, Intel initialized the HMOS technology to fabricate the 8085A. Thus, Intel offers a high speed version of the 8085A called 8085AH.

The third generation introduced in 1978 is typically separated by the Intel 8086 iAPX 8086 iAPX 80186, iAPX 80286 Zilog 78000, and the Motorola 68000 which are 16- bit s with minicomputer like performances. One of the most popular 16 bit μP has been introduced by Intel, which is 8088. The 8088 has the same introduction set as the 8088. However, it has only an 8 bit data bus.

The 8088 is the μP used in the IBM PC and its clones.A precursor to these microprocessors was the 16-bit Texas instruments 9900 microprocessor introduced in 1976. The latest microprocessor has the word length of 32-bit. Example of 32-bit microprocessors is Intel iAPX 80386, iAPX 432, Motorola MC68020, National semiconductor NS 32032. The characteristic for few microprocessors introduced by Intel are given in the Table. This shows that power of microprocessors has increased tremendously with advancement in integrated circuit technology & microprocessor systems architecture.

Very large & cute integration, VLSI allow extremely complex system consisting of as many as a million of transistors on a single chip to be realized.

In 1980, the fourth generation μps were evolved. Intel introduced the first commercial 32 bit microprocessor, Intel 432. This μP was discontinued by Intel due to some problem. Since 1985, more

32bit μPs have been introduced. These include the Motorola MC 68020/68030/68040 and Intel 80386/80486. These processors are fabricated using the low power version of HMOS technology called HCMOS, and they include an on-chip RAM called the cache memory to speed up program execution.

**Table evaluation of major characteristics.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **4004** | **8008** | **8085A** | **8086** | **80386** |
| **Data** | 71 | 71 | 77 | 78 | 85 |
| **Lass** | 4-bit | 8 | 8 | 16 | 32 |
| **Technology** | PMOS | PMOS | NMOS | HMOS | CHMOS |
| **Record size data** | 4/8 | 8/8 | 8/8 | 16/16 | 32/32 |
| **Address capacity** | 4K | 16K | 64K | 1M | 4G |
| **Clock kHz/phase** | 740/2 | 800/2 | 6250/2 | 8000/2 | 16000/2 |
| **Add time** | 10.8 μs | 20 μs | 1.3 μs | 0.375 μs | 0.125 μs |
| **Internal reg. al/gp** | 1/16 | 1/6 | 1/6 | 1/8 | 1/8 |
| **Tale size** | 3\*12 | 7\*14 | RWM | RWM | RWM |
| **Records/bits** | 150-40.5\* | -9.5v | +5v | +5v | +5v |
| **Voltages** | 16 pin | 18 pin | 40 pin | 40 pin | 132 pin |
| **Package size introduction** | 45 | 48 | 74 | 133 | 135 |
| **Transition** | 2300 | 2000 | 6200 | 29000 | 275000 |
| **Chip size (mil)** | 117\*159 | 125\*170 | 164\*222 | 225\*230 | 390\*390 |
| **Manufactures** | Intel | Intel | Intel | Intel | Intel |

The performance offered by a32 bit μP is more comparable to that of super computers such as VAX 11. Recently, Intel and Motorola introduced a 32 bit RISC (Reduced Instruction Set Computer) μP (Intel 80960 and Motorola 88100) with a simplified instruction set. The trend in μPs is not toward introduction of 64 bit μPs. Extensive research is being carried out for implementation of more on chip functions and for improvement of the speed of the memory and I/O devices; i.e. microcontrollers.

**Introduction to Microprocessor System**

**The Microprocessor System**

A *microprocessor* is an IC (integrated circuit) that contains most of the digital logic required to implement a computer except for memory and I/O (input/ output) devices. This course describes how to interface a microprocessor to memory and I/O devices to make a *microcomputer*. Memory and I/O devices usually can’t be connected directly to the microprocessor. The logic circuits required to interface the microprocessor and other chips is often called *glue logic*. This additional logic can vary from none in the case of *microcontrollers* (microprocessors that contain on-chip memory and I/O devices) to “intelligent” peripheral interfaces that are as complex as the microprocessor itself. A large part of this course is devoted to the design of such circuits. The next section lists some common functions required to interface the microprocessor and its peripheral chips. These are the circuits that we will study in this course.

Microprocessors are regarded as one of the most important devices in our everyday machines called computers. Before we start, we need to understand what exactly microprocessors are and their appropriate implementations. Microprocessoris an electronic circuit that functions as the central processing unit (CPU) of a computer, providing computational control. Microprocessors are also used in other advanced electronic systems, such as computer printers, automobiles, and jet airliners. Typical microprocessors incorporate arithmetic and logic functional units as well as the associated control logic, instruction processing circuitry, and a portion of the memory hierarchy. Portions of the interface logic for the input/output (I/O) and memory subsystems may also be infused, allowing cheaper overall systems. While many microprocessors and single chip designs, some high-performance designs rely on a few chips to provide multiple functional units and relatively large caches.

When combined with other integrated circuits that provide storage for data and programs, often on a single semiconductor base to form a chip, the microprocessor becomes the heart of a small computer, or microcomputer. Microprocessors are classified by the semiconductor technology of their design (TTL, transistor-transistor logic; CMOS, complementary-metal-oxide semiconductor; or ECL, emitter-coupled logic), by the width of the data format (4-bit, 8-bit, 16-bit, 32-bit, or 64-bit) they process; and by their instruction set (CISC, complex-instruction-set computer, or RISC, reduce destruction- set computer; see RISC processor). TTL technology is most commonly used, while CMOS is favored for portable computers and other battery-powered devices because of its low power consumption. ECL is used where the need for its greater speed offsets the fact that it consumes the most power. Four-bit devices, while inexpensive, are good only for simple control applications; in general, the wider the data format, the faster and more expensive the device. CISC processors, which have 70 to several hundred instructions, are easier to program than RISC processors, but are slower and more expensive. Microprocessors have been described in many different ways. They have been compared with the brain and the heart of humans. Their operation has been likened to a switched board, and to the nervous system in an animal. They have often been called microcomputers. The original purpose of the microprocessor was to control memory. That is what they were originally designed to do, and that is what they do today. Specifically, a microprocessor is *“a component that implements memory****.”***

A microprocessor can do any information-processing task that can beexpressed, precisely, as a plan. It is totally uncommitted as to what its planwill be. It is a truly general-purpose information-processing device. Theplan, which it is to execute—which will, in other words, control itsoperation—is stored electronically. This is the principle of “stored programcontrol”. Without a program the microprocessor can do nothing. With one,it can do anything. Furthermore, microprocessors can only performinformation-processing tasks. To take action on the outside world, or toreceive signals from it, a connection must be provided between the microprocessor’s representation of information (as digital electronic signals)and the real world representation.

Developed during the 1970s, the microprocessor became most visible as the central processor of the personal computer. Microprocessors also play supporting roles within larger computers as smart controllers for graphics displays, storage devices, and high-speed printers. However, the vast majority of microprocessors are used to control everything from consumer appliances to smart weapons. The microprocessor has made possible the inexpensive hand-held electronic calculator, the digital wristwatch, and the electronic game. Microprocessors are used to control consumer electronic devices, such as the programmable microwave oven and videocassette recorder; to regulate gasoline consumption and antilock brakes in automobiles; to monitor alarm systems; and to operate automatic tracking and targeting systems in aircraft, tanks, and missiles and to control radar arrays that track and identify aircraft, among other defense applications.

A digital computer is an electronic machine capable of quickly performing a wide variety of tasks. They can be used to compile, correlate, sort, merge and store data as well as perform calculations. A digital computer is different from a general purpose calculator in that it is capable of operating according to the instructions that are stored within the computer whereas a calculator must be given instructions on a step by step basis. By the definition a programmable calculator is a computer. Historically, digital computers have been categorized according to the size using the words large, medium, minicomputer and microcomputer. In the early years of development, the emphasis was on large and more powerful computers. Large and medium sized computers were designed to store complex scientific and engineering problems. These computers were accessible and affordable only to large corporations, big universities and government agencies. In the 1960s’ computers were accessible & affordable only to large corporations, big universities & government agencies, In late 1960s, minicomputers were available for use in a office, small collage, medium size business organization, small factory etc. As the technology has advanced from SSI to VLSI & SLSI (very large scale integration & super large scale integration) the face of the computer has changed. It has now become possible to build the control processing unit (CPU) with its related timing functions on a single chip known as microprocessor. A microprocessor combined with memory and input/output devices forms a microcomputer. As for as the computing power is concerned the 32- bit microcomputers are as powerful as traditional mainframe computers.

The microcomputer is making an impact on every activity of mankind. It is being used in almost all control applications. For example analytical and scientific instruments, data communication, character recognition, musical instruments, household items, defence equipments, medical equipments etc.

Computers communicate and operate in binary numbers 0 and 1 also known as bits. It is the abbreviation for the term binary digit. The bit size of a microprocessor refers to the number of bit which can be processed simultaneously by the arithmetic circuit of the microprocessor. A number of bits taken as a group are this manner is called word. For example, the first commercial microprocessor the Intel 4004 which was introduced in 1971 is a 4-bit machine and is said to process a 4-bit word. A 4-bit word is commonly known as nibble and an 8-bit word is commonly known as byte. Intel 8085 is an 8-bit microprocessor. It should be noted that a processor can perform calculations involving more than its bit size but takes more time to complete the operation. The short word length requires few circuitry and interconnection in the CPU.

**Microcomputers:**

In a very general a microcomputer is best regard as a system incorporating a CPU and assisted hardware whose purpose is to manipulate data in same fashion. This is exactly what any digital circuit designed using SSI’s and MSI’s will also do therefore, microcomputer should be regard as a general purpose logic device. In contrast to standard SSI’s and MSI’s where the manufacturer decides what the device will do, with microcomputer it is the user who decides what the device should do by asking it to execute a proper set of instructions. A microcomputer, from this point of view is merely an assembly of devices whose sole task is to ensure that the instruction desire are indeed carried out properly and to allow the microprocessor to communicate with the real world, i.e. the user environment. The power of the microcomputer lies in the fact that if the application change, the same system can still used by appropriately modifying the instruction to be executed and if necessary some changes in the hardware. In contrast, a digit circuit designed using SSI’s and MSI’s for same application will need to be completely redesigned if the application changes significantly.

The objective of a microcomputer is to manipulate data in a certain fashion specified by the system designer. A typical microcomputer achieves their objective by getting its CPO (μp) to execute a number of instructions in the proper sequence. This sequence of instruction comprises the program that is executed by the micro computer.

A microcomputer which does nothing other than manipulate data present within itself, Will not be of much use to anybody. In order to do something meaningful, data being manipulated should depend on same fashion on input provided to the microprocessor would be completely senseless unless the results of these manipulations affects things outside the μc itself. A μc should on its input, the which in same way, depends on its input, the way input and output are related is decided by the program that gets executed.

Therefore, a μc is an assembly of devices including a CPU, which manipulate data depending on one or more inputs and according to a program, in order to generate one or more output.

There are several standards for logic ‘1’ and logic ‘0’.

A) TTL logic 0V-0.8 V → logic ‘0’

2.4 V-5.2V → logic ‘1’

B) 20 mA current loop Zero current → logic ‘0’

20 mA current → logic ‘1’

C) RS-232 C +3V to +15V → logic ‘0’

-5V to +15V → logic ‘1’

For microprocessor and most of its peripherals, TTL logic levels are used. 20 mA current loops are used for TTY and RS-232 C is used for serial data communication.

**Microcontrollers**

A μP does not have enough memory for program and data storage, neither does it has any input and output devices. Thus when a μP is used to design a system, several other chips are also used to make up a complete system. For many applications, these extra chips imply additional cost and increased size of the product. For example, when used inside a toy, a designer would like to minimize the size and cost of the electronic equipment inside the toy.

Therefore, in such applications a microcontroller is used more often than a microprocessor.

A microcontroller is a chip consisting of a microprocessor, memory and an input/output device. There is 4 bit as well as 32 bit microcontrollers.

**COMPUTER MEMORY:**

Because the microprocessor alone cannot accommodate the large amount of memory required to store program instructions and data, such as the text in a word-processing program, transistors can be used as memory elements in combination with the microprocessor. Separate integrated circuits, called random-access memory (RAM) chips, which contain large numbers of transistors, are used in conjunction with the microprocessor to provide the needed memory. There are different kinds of random-access memory. Static RAM (SRAM) holds information as long as power is turned on and is usually used as cache memory because it operates very quickly.

Another type of memory, dynamic RAM (DRAM), is slower than SRAM and must be periodically refreshed with electricity or the information it holds is lost. DRAM is more economical than SRAM and serves as the main memory element in most computers**.**

**MICROPROCESSOR DESIGN AND ARCHITECTURE:**

Microprocessors are fabricated using techniques similar to those used for other integrated circuits, such as memory chips. Microprocessors generally have a more complex structure than do other chips, and their manufacture requires extremely precise techniques. The first step in producing a microprocessor is the creation of an ultra pure silicon substrate,

a silicon slice in the shape of a round wafer that is polished to a mirror-like smoothness. At present, the largest wafers used in industry are 300 mm (12 in) in diameter**.**

Economical manufacturing of microprocessors requires mass production. Several hundred *dies,* or circuit patterns, are created on the surface of a silicon wafer simultaneously. Microprocessors are constructed by a process of deposition and removal of conducting, insulating, and semi conducting materials one thin layer at a time until, after hundreds of separate steps, a complex sandwich is constructed that contains all the interconnected circuitry of the microprocessor. Only the outer surface of the silicon wafer, a layer about 10 microns (about 0.01 mm/0.0004 in) thick, or about one tenth the thickness of a human hair—is used for the electronic circuit. The processing steps include substrate creation, oxidation, lithography, etching, ion implantation, and film deposition.

In the oxidation step, an electrically no conducting layer, called a dielectric, is placed between each conductive layer on the wafer. The most important type of dielectric is silicon dioxide, which is “grown” by exposing the silicon wafer to oxygen in a furnace at about 1000°C (about 1800°F).

The oxygen combines with the silicon to form a thin layer of oxide about 75 angstroms deep (an angstrom is one ten-billionth of a meter). Nearly every layer that is deposited on the wafer must be patterned accurately into the shape of the transistors and other electronic elements. Usually this is done in a process known as photolithography, which is analogous to transforming the wafer into a piece of photographic film and projecting a picture of the circuit on it. A coating on the surface of the wafer, called the photo resist or resist, changes when exposed to light, making it easy to dissolve in a developing solution. These patterns are as small as 0.13 microns in size.

Because the shortest wavelength of visible light is about 0.5 microns, short wavelength ultraviolet light must be used to resolve the tiny details of the patterns. After photolithography, the wafer is etched—that is, the resist is removed from the wafer either by chemicals, in a process known as wet etching, or by exposure to a corrosive gas, in a special vacuum chamber

In the next step of the process, ion implantation, also called doping, impurities such as boron and phosphorus are introduced into the silicon to alter its conductivity. This is accomplished by ionizing the boron or phosphorus atoms and propelling them at the wafer with an ion implanter at very high energies. The ions become embedded in the surface of the wafer.

The thin layers used to build up a microprocessor are referred to as films. In the final step of the process, the films are deposited using sputterers in which thin films are grown in a plasma; by means of evaporation, whereby the material is melted and then evaporated coating the wafer; or by means of chemical-vapor deposition, whereby the material condenses from a gas at low or atmospheric pressure. In each case, the film must be of high purity and its thickness must be controlled within a small fraction of a micron.

Microprocessor features are so small and precise that a single speck of dust can destroy an entire die. The rooms used for microprocessor creation are called clean rooms because the air in them is extremely well filtered and virtually free of dust. The purest of today's clean rooms are referred to, as class 1, indicating that there is no more than one speck of dust per cubic foot of air**.**

A basic difference between a microprocessor and other logic chips is the functional flexibility afforded by the microprocessor’s programmable nature. Its instruction set comprises the group of available low-level operations. Each instruction has a specific binary pattern, or operation code.

This operation code specifies the operation as well as the location of the operands. A programmer uses sequences of these low-level instructions to create a desired higher-level function. Therefore the personality of a microprocessor-based system can be readily modified without the hardware modifications usually associated with non-programmable logic systems.

A typical microprocessor chip set includes an instruction control unit, one or more functional units, a set of register, and one or more caches. Conceptually, the instruction control unit fetches an instruction from main memory, interprets the operation code, and then dispatches the instruction to a functional unite. The functional unit may again interpret the operation code, read the required operands from the register or memory perform the specified operation and store the result in either the register set or memory.

Then the process repeats, with the instruction control unite fetching the next instruction. A powerful aspect of programmability arises from the ability to specify which instruction will be executed next; selection is often based on the outcome of a test involving computed results.

For performance reasons, implementations commonly segment the instruction processing into stages and allow multiple instructions to overlap, each executing in a different pipeline stage. High-end designs dispatch multiple instructions each processor cycle. Since main memory access times are relatively slow, smaller, faster memory units are frequently employed to cache recently used portions of main memory, creating a memory hierarchy.

These caches are typically an order of magnitude faster than main memory. Separate caches may be used for instruction and data, or a unified cache may hold both. Multiple levels of cache are how a popular solution to the performance problems created by the increasing gap between processor and memory speeds.

**CLASSIFICATION OF MICROPROCESSORS:**

Several functional classifications can be used to classify microprocessors. The different types of microprocessors used most frequently are as follows:

**INTEL MICROPROCESSORS:**

**4004 (1970)**

Intel's Ted Hoff and Federico Faggin designed and implemented (respectively) the first general-purpose microprocessor. The 4004 processor, used in a hand-held calculator built by Busicom of Japan, was part of a four chip set called the 4000 Family:

**4001 - 2,048-bit ROM memory**

**4002 - 320-bit RAM memory**

**4003 - 10-bit I/O shift register**

**4004 - 4-bit central processor**

**8008 (1972)**

The 8008 increased the 4004's word length from four to eight bits, and doubled the volume of information that could be processed. It was still an invention in search of a market however, as the technology world was just beginning to view the microprocessor as a solution to many needs.

**8080 (1974)**

The 8080 were 20 times as fast as the 4004 and contained twice as many transistors.

This 8-bit chip represented a technological milestone as engineers recognized its value and used it in a wide variety of products. It was perhaps most notable as the processor in the first kit computer, the Altair, which ignited the personal computing phenomenon.

**8088 (1979)**

Created as a cheaper version of Intel's 8086, the 8088 was a 16-bit processor with an 8-bit external bus. This chip became the most ubiquitous in the computer industry when IBM chose it for its first PC. The success of the IBM PC and its clones gave Intel a dominant position in the semiconductor industry.

**80286 (1982)**

With 16 MB of addressable memory and 1 GB of virtual memory, this 16-bit chip is referred to as the first "modern" microprocessor. Many novices were introduced to desktop computing with a "286 machine" and it became the dominant chip of its time. It contained 130,000 transistors and packed serious compute power (12 MHz) into a tiny footprint.

**80386 (1985), 80486 (1989)**

The price/performance curve continued its steep climb with the 386 and later the 486 --32-bit processors that brought real computing to the masses. The 386, which became the best-selling microprocessor in history, featured 275,000 transistors; the 486 had more than a million.

**Pentium¨ (1993)**

Adding systems-level characteristics to enormous raw compute power, the Pentium supports demanding I/O, graphics and communication sin tensive applications with more than 3 million transistors.

**Pentium¨ Pro (1995)**

The newest Pentium has dynamic instruction execution and other performance-enhancing features such as a large L2 cache in the chip package, in addition to its more than 5.5 million transistors.

**Pentium¨ II (1997)**

The 7.5 million-transistor Pentium II processor incorporates Intel MMXTM technology, which is designed specifically to process video, audio and graphics data efficiently.

**Pentium II Xeon (1998)**

The Pentium II Xeon processors are designed to meet the performance requirements of mid-range and higher servers and workstations. Consistent with Intel's strategy to deliver unique processor products targeted for specific markets segments, the Pentium II Xeon processors feature technical innovations specifically designed for workstations and servers that utilize demanding business applications such as Internet services, corporate data warehousing, digital content creation, and electronic and mechanical design automation. Systems based on the processor can be configured to scale to four or eight processors and beyond.

**Celeron (1999)**

Continuing Intel's strategy of developing processors for specific market segments, the Intel Celeron processor is designed for the value PC market segment. It provides consumers great performance at an exceptional value, and it delivers excellent performance for uses such as gaming and educational software.

**Pentium III (1999)**

The Pentium III processor features 70 new instructions. It was designed to significantly enhance Internet experiences, allowing users to do such things as browse through realistic online museums and stores and download high-quality video. The processor incorporates 9.5 million transistors, and was introduced using 0.25-micron technology.

**Pentium III Xeon (1999)**

The Pentium III Xeon processor extends Intel's offerings to the workstation and server market segments, providing additional performance for e-Commerce applications and advanced business computing. The processors incorporate the Pentium III processor's 70 SIMD instructions, which enhance multimedia and streaming video applications. The Pentium III Xeon processor's advance cache technology speeds information from the system bus to the processor, significantly boosting performance. It is designed for systems with multiprocessor configurations**.**

**4-BIT MICROPROCESSORS:**

Historically, the 4-bit microprocessor was the first general purpose microprocessor introduced on the market. The basic design of the early microprocessors was derived from that of the desk calculator. The Intel 4004, a 4-bit design, was the grandfather of microprocessors. Introduced in late 1971, the 4004 was originally designed for a Japanese manufacturer as the processing element of a desk calculator; it was not designed as a general-purpose computer. The shortcomings of the 4004 were recognized as soon as it was introduced. But it was the first general purpose computing device on a chip to be placed on the market. Many of the chips introduced at about the same time by other companies were, in fact, mere calculator chips. Some of them were even serial-by-bit devices, which performed calculations a single bit at a time. The Intel 4004 chip took the integrated circuit down one step further by placing all the parts that made a computer think (i.e. central processing unit, memory, input and output controls) on one small chip. Programming intelligence into inanimate objects had now become possible**.**

The 4004 was the world's first universal microprocessor. In the late 1960s, many scientists had discussed the possibility of a computer on a chip, but nearly everyone felt that integrated circuit technology was not yet ready to support such a chip. Intel's Ted Hoff felt differently; he was the first person to recognize that the new silicon-gated MOS technology might make a single-chip CPU (central processing unit) possible**.**

Hoff and the Intel team developed such architecture with just over 2,300 transistors in an area of only 3 by 4 millimeters. With its 4-bit CPU, command register, decoder, decoding control, control monitoring of machine commands and interim register, the 4004 was one heck of a little invention. Today's 64-bit microprocessors are still based on similar designs, and the microprocessor is still the most complex mass-produced product ever with more than 5.5 million transistors performing hundreds of millions of calculations each second - numbers that are sure to be outdated fast**.**

Within a short period of time, the 4004 became obsolete and was replaced by the 4040. Then, the powerful 8-bit microprocessors were introduced at a price that was only slightly higher than the price of the 4040. Although 4-bit microprocessors played an important role in the early years of the microcomputer revolution, today they are technically obsolete. Because of their extremely low cost, however, they still offer an attractive alternative to low-end- 8-bit microprocessors. In fact, several 4-bit chips continue to be among the best sellers of all microprocessors: prime examples are the ***National Semiconductor COP400 and the NEC uPD75XX series.***

**8-BIT MICROPROCESSORS:**

Today, 8-bit microprocessors coexist with 16-bit microprocessors as the design standard. Although 16-bit chips provide higher performance computationally, 8-bit designs have more than adequate power for many applications—plus the advantage of lower cost. As originally design, most 16-bit microprocessors were limited to packages with a maximum of 40 to 48 pins. This was not due to physical, but rather to economic, constraints: industrial tester of the time was generally limited to 40-pin DIPs. The ancestor of today’s 8-bit microprocessors was the Intel 8008, introduced in 1972-1973. The 8008 was not intended to be a general-purpose microprocessor. IT was to be a CRT display controller for Data point. Taking into account all of its design inadequacies and its limited performance, the 8008 was an overwhelming success.

**INTEL (8-BIT MICROPROCESSORS) :**

The 8080, designed as a successor to Intel’s 8008, was the first powerful microprocessor introduced on the market. Several other microprocessors of similar performance were introduced on the market within a year after the 8080 appeared, and several additional powerful designs were introduced later. Technically, however, the 8080 long remained the most powerful product on the market. Furthermore, Intel was the first company to invest in the development of support chips and software for its products. This ensured the continued success of the 8080 because its performance was then sufficient for many applications. The early 8080 competitors were introduced with at least a nine-month delay and failed to dislodge it. The 8080 is still sold today thought. It has been largely eclipsed by successor products—most notably the 8085 microprocessor. Today, the 8085 accounts for roughly one of every four 8-bit microprocessors sold.

**MOTORALA (8-BIT MICROPROCESSORS):**

The 6800 was introduced by Motorola as a direct competitor to the 8080. The design of the 6800 was obviously inspired by the 8008 and the then prevalent minicomputer philosophy. The 6800 has essentially the same internal architecture as the 8080, though there are some differences at the register level. The internal architecture of the 6800 is equipped with tow accumulators. The 6800 has a special indeed register (IX) that facilitates access to tables stored in the memory. The 8080 does not have an indeed register but is equipped with register pairs than can be used to provide a similar facility. The 6800 instructions reflect the fact that it was introduced after the 8080. They tend to be somewhat more complex but generally similar to those of the 8080. Depending on the function used in the comparison, either of the two microprocessors can be said to be marginally faster.

The most significant different in performance is achieved not by comparing a standard 8080 to a standard 6800—their performance is essentially similar—but by considering a faster version of either the 8080 or the 6800. The 8080 is available in three versions, the standard 8080A with a 2MHZ clock, the 8080A-2, and the 8080A-1 with a 3MHZ clock. The 6800 is also available in two versions. The standard 6800 use a 1MHZ clock. However, the clock rates do not mean that the standard 6800 is twice as fast as the standard 8080A. The clock simply supplies the pulses needed by the internal micro program of the control unit. In the average, the 8080 uses simpler microinstructions and requires twice as many microinstructions as the 6800. It therefore uses a faster clock. The overall performances of the 8080 and the 6800 are similar. A typical instruction is executed in two microseconds on either microcomputer.

In the 1990s the number of transistors on microprocessors continued to double nearly every 18 months. The rate of change followed an early prediction made by American semiconductor pioneer Gordon Moore. In 1965 Moore predicted that the number of transistors on a computer chip would double every year, a prediction that has come to be known as Moore's Law. In the mid-1990s chips included the Intel Pentium Pro, containing 5.5 million transistors; the UItra Sparc-II, by Sun Microsystems, containing 5.4 million transistors; the PowerPC620, developed jointly by Apple, IBM, and Motorola, containing 7 million transistors; and the Digital Equipment Corporation's Alpha 21164A, containing 9.3 million transistors. By the end of the decade microprocessors contained many millions of transistors, transferred 64 bits of data at once, and performed billions of instructions per second.

**MICROPROCESSOR APPLICATIONS:**

When microprocessors appeared, they were first used in computer systems for a negative reason. In the early 1970’s there were few support chips and microprocessors were programmed to perform functions that are now done by a wide variety of hardware chips. For this reason assembling a complete microprocessor-based system required both hardware and software expertise. Only five years later in 1976 companies realized that microprocessors could be used to build inexpensive personal computers. It then took several more years to manufacture computers that were adequate for business and professional purposes. Yet the technology had been there all along. (Naturally with time costs have diminished and integrated circuits have been improved). Many of the early microprocessor applications found markets by accident rather than by design. New product development had generally been a direct result of the dissemination of technical information. In the early 1970s the necessary combination of hardware and software expertise was rarely found outside the computer manufacturing industry. This was not perceived as a problem, because when microprocessors were introduced, the computer establishment saw them only as low-cost processors for simple control applications. In fact, the first 8-bit microprocessor, the Intel 8008, was designed for direct control of a CRT display. Microprocessors are now used for controlling virtually every computer peripheral that does not require bipolar speeds. Initially, such applications were limited by the relatively low speed of early microprocessors. But now, with the faster microprocessors coupled with specialized peripheral controller chips, such as CRT and floppy disk controllers, it is possible to control fast devices such as CRT’s and disks.

With microprocessors, we have now entered the era of *distributed systems*. In distributed systems, intercommunication between a number ofprocessors is reduced to a minimum because they do not interact in real-timebut exchange data words or block. Each processor is then a direct processcontroller that completely controls a process. Such network may involvemultiple microprocessors. Traditionally, a multiprocessor system is one inwhich several processors interact with each other in real-time for controlpurposes. Most systems involving networks of microprocessors do not interact so closely and therefore do not qualify as ***“multi microprocessor*** ***systems.”***

The widespread use of microprocessors to replace random logic has dramatically increased since the early 1980’s. Microprocessors afford a flexibility not available in conventional “hardwired” circuitry. Design and production costs of a single high-volume system can be amortized by using different programs to tailor the system to meet the diverse needs of several specific applications. Incorporating last-minute design changes is normally quicker and easier in software that in hardware. Finally, many inexpensive microprocessors are now capable of speeds that are more than adequate for many products**.**

Microprocessors are utilized in computer systems ranging from notebooks computers to small personal computers to supercomputer-class workstations. Programs include word processing, electronic mail, spreadsheets, animation, graphics, and database processing. Owing to their low cost and flexibility, microprocessors appear in many everyday household products, such as microwave ovens, handheld electronic games, washing machines, programmable videocassette recorders (VCRs), and programmable thermostats. Newer cars incorporate microprocessor26 controlled ignition and emission systems to improve engine operation, increasing fuel economy while reducing pollution**.**

With the continuing progress of LSI technology, most microprocessor systems actually use multiple processors distributed over several chips.

Processors can often be found in the peripheral chips of the system, i.e., the PIO, the UART, or other system chips. This makes the programming tasks more difficult than with traditional systems; however, it does result in standardized systems, all of the traditional chips that were merely interface devices in the past are now fully programmable. Programmed instructions are sent to these devices by the microprocessor. These processors, residing in peripheral devices, should be considered as slaves.

**FUTURE TRENDS:**

Cheaper systems will result from greater integration of support circuitry within the microprocessor chip. The trend of incorporating larger portions of the computer system may advance to placing multiple microprocessors on a single chip. Additional processing capacity will support abstractions, such as productivity-motivated object-oriented programming, while maintaining acceptable response times. Higher degrees of system integration and additional performance on a chip will open new arena for microprocessor use, as well as new products, including speech and pen-based character recognition systems, virtual reality, simulations of other architectures, compression, and enhanced graphics.

In 2000-chip manufacturer Advanced Micro Devices debuted a 1 GHz microprocessor, the fastest microprocessor ever mass-produced for personal computers. The high-speed processor contains approximately million transistors**.**

**RECENTLY LAUNCHED MICROPROCESSORS:**

*Intel’s Pentium-4 processor:*

The Pentium-4 is fabricated in Intel's 0.18-micron CMOS process. Its die size is 217 mm2, power consumption is 50W. The Pentium 4 is available in 1.4GHz and 1.5Hz bins. At 1.5GHz the microprocessor delivers 535 SPECint2000 and 558 SPECfp2000 of performance. Currently it is the second-performing general-purpose microprocessor. The world champion is Compaq/Digital Alpha 21264B CPU delivering 544 SPECint2000 and 658 SPECfp2000 at 833 MHz. The previous Intel chip, Pentium-III "Coppermine", had 442 SPECint2000 and 335 SPECfp2000 results at 1GHz. Pentium-4 is the first completely new x86-processor design from Intel since the Pentium PRO processor, with its P6 micro-architecture, was introduced in 1995. Pentium-4' micro-architecture is known as Net Burst. It has many interesting features. Compared to the Intel Pentium-III processor, Intel's Net Burst micro-architecture doubles the pipeline depth to 20 stages. In addition to the L1 8 KB data cache, the Pentium 4 processor includes an

Execution Trace Cache that stores up to 12 K decoded micro-ops in the order of program execution. The on-die 256KB L2-cache is non-blocking, 8- way set associative. It employs 256-bit interface that delivers data transfer rate of 48 GB/s at 1.5 GHz. The Pentium 4 processor expands the floating point registers to a full 128-bit and adds an additional register for data movement. Pentium-4' Net Burst micro-architecture introduces Internet Streaming SIMD Extensions 2 (SSE2). This extends the SIMD capabilities that MMX technology and SSE technology delivered by adding 144 new instructions. These instructions include 128-bit SIMD integer arithmetic and 128-bit SIMD double-precision floating-point operations. Pentium 4 processor's 400 MHz (100 MHz "quad pumped") system bus provides up to 3.2 GB/s of bandwidth. The bus is fed by dual PC800 Rambus channel. This compares to 1.06 GB/s delivered on the Pentium-III processor's 133-MHz system bus.

Two Arithmetic Logic Units (ALUs) on the Pentium 4 processor are clocked at twice the core processor frequency. This allows basic integer instructions such as Add, Subtract, Logical AND, Logical OR, etc. to execute in a half clock cycle. The integer register file runs also runs at the double frequency. Interesting is that this method was firstly introduced by Elbrus team in their E2K processor design. The E2K design was described in Microprocessor Report article by Keith Diefendorff in Feb 1999.

***Elbrus E2K***

Russian company Elbrus International has disclosed the technical details of its revolutionary new microprocessor E2K. The microprocessor will function 3 to 5 times more quickly than Intel Merced while still running all legacy MS DOS and Windows software. Fabricated in a 0.18-micron process, the chip would run at 1.2GHz and deliver 135 SPECint95 and 350 SPECfp95, yet require only 35 Watts of power and occupy 126 mm2 of silicon. By contrast, Intel's forthcoming processor, which will be manufactured in the same process, would operate at 800MHz, occupy 300 mm2, consume 60 Watts, and score only 45 SPECint95 and 70 SPECfp95.

30 Elbrus technology does not infringe on any Western intellectual property and it is protected by 70 US patent applications.

The technology underlying the E2k delivers computing performance that exceeds all other existing and planned processors, including Digital/Compaq Alpha. This extraordinary performance results from an incredibly efficient architecture design that has been continually refined by the Elbrus team. Over the decades, it turns out, it was often far ahead of Western rivals, introducing cutting-edge techniques such as super scalar design, shared-memory multiprocessing and explicitly parallel instruction computing (EPIC) before similar products or even papers on the subjects were available here.

The Elbrus team, led by a supercomputer architect Boris Babaian (another transcription -- Babayan), has worked together for nearly 40 years, mostly for the former Soviet Union's and Russia's defense establishment. Since 1992 the team works in tight cooperation with Sun Microsystems. The same team has taken a great part in developing Sun UltraSPARC processor,

Sun Ultra SPARC compilers, and Sun Solaris operating system. The E2K project is a commercial version of the design has already been used in the Russian Space Mission Control and the Russian Missile Defense System.

The previous chip was manufactured in February 1998 in 0.5-micron process.

Intel announced new brand name for its Merced IA-64 microprocessor - *Itanium*. So, new HP/Intel microprocessor family has rather long list of brand names, code names, etc: Itanium, Merced, McKinley, Madison, Deerfild, IA-64, EPIC, P7, Play Doh, Super-Parallel Processor Architecture (SP-PA), Wide-Word. Itanium is sampling now.

Experimental systems with Itanium samples inside were demonstrated at last Intel Developer Forum. Nevertheless still it is not known about future Itanium performance as well as other metrics.

**Common Support Circuits**

**Clocks and Reset Circuits**

Microprocessors use a fixed frequency clock to synchronize the operation of their internal logic. This clock signal is usually generated by a quartz-crystal controlled oscillator.

The processor must be initialized to a known state when power is first applied or when the system “crashes.” Most microprocessors require external circuits to detect the power-on condition or external resets.

**Buffers**

In larger systems the microprocessor must be connected to more chips than the microprocessor chip’s electrical specifications allow. ICs called *buffers*, *bus* *drivers* or *transceivers* are used between the microprocessor and the other chips.

**Latches**

Some microprocessors reduce the number of pins required on the chip by using the same pin for two purposes, such as using the same pins first as part of the address bus and then as part of the data bus. An external chip (a latch) is required to temporarily hold the address bus value.

**Address Decoders**

Since microprocessors can usually address more memory than an individual memory chips contains, there has to be external logic to select the appropriate memory chip for a given address. This function is called address decoding.

**Wait State Generators**

The access-, hold-, and setup-times of memory and I/O devices often exceed the values provided by the microprocessor’s read and write cycles. Circuits are used to force the processor to “wait” one or more clock cycles to extend the durations of read or write cycles.

**Interrupt Controllers**

I/O devices that require immediate attention can interrupt a program’s normal execution by asserting an *interrupt* signal to the microprocessor. When a system has several sources of interrupts it is useful to be able to distinguish between them and to ensure that higher-priority interrupts are recognized first.

**Timers and Counters**

It’s often useful for programs to be able to measure elapsed time so they can compute the time of day and measure intervals between events. Timers are counters driven from a clock and whose value can be read by the CPU. Timers are often used to generate periodic interrupts to allow an operating system to switch between tasks.

**I/O Interfaces**

I/O interfaces are used to read and write data to storage and I/O devices such as keyboards, printers, disk drives, etc. *Serial* interfaces transfer one bit at a time while *parallel* interfaces transfer several (typically 8) bits at a time. A typical serial interface is the “RS-232” serial interface. Typical parallel interfaces include the “Centronics” (printer), IDE, SCSI and GPIB interfaces.

**DMA Controllers and Bus Arbitration**

DMA (Direct Memory Access) allows peripherals to directly read or write memory or other peripherals on the system bus independently of the CPU. Special logic is required to ensure that only one device at time tries to use the bus.

**DRAM Refresh**

Dynamic RAM (a type of Random-Access Memory) stores data as electric charge in a capacitor.

DRAM requires that every memory cell’s content be “refreshed” periodically by recharging the capacitor. Circuits are required to ensure that the DRAM contents are periodically refreshed.

**Cache Memory**

Many modern microprocessors require faster access to memory than is possible with inexpensive memory devices. Fast auxiliary memories called cache memories are used to store the contents of frequently used memory locations and thus improve the overall performance of the system.

Exercise: A PC is composed of a motherboard containing the microprocessor and two plug-in PCB (printed circuit board) cards, one a memory card and the other a high-performance I/O card. Which of the above circuits would we likely find on each of the three boards?

**Buses**

A *bus* is a group of related signals. Most microprocessor systems include several buses: The signals appearing on the pins on the microprocessor chip are called the *processor bus*. Many microcomputers allow peripherals and memory to be placed on physically separate PC cards which plug into connectors on a “motherboard” or “backplane.” The signals on these connectors are called the *system bus*. Examples of system buses include the ISA, VME, and PCI buses.

Peripherals (such as modems or disk drives) are connected to the computer using different connectors. The signals on these connectors are called the *peripheral bus*. Some common peripheral buses include the RS-232 serial interface and the SCSI (Small Computer Systems Interface) bus. These buses are often further divided into smaller buses. For example, the pins on the microprocessor and system bus can be grouped into a data bus, an address bus, a control bus, and a utility bus. A large part of this course is devoted to the study of typical processor, system and peripheral buses.