**Chapter 6**

**Microprocessors**

*Lesson 6.1:* Introduction to Microprocessors

*Lesson 6.2:* ALU and Control

*Lesson 6.3:* Microprocessor: Past, Present and Future

*Lesson 6.4:* Parallel Processing

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***Lesson 6.1***

***Introduction to Microprocessors***

**6.1.0 Objectives**

*On completion of this lesson you will know:*

* *Functions of a microprocessor*
* *Organization of a microprocessor*
* *Components of a microprocessor*

**6.1.1 Microprocessor**

Microprocessor is a silicon chip that contains a central processing unit (CPU). In a personal computer (PC), the terms microprocessor and CPU are used interchangeably. At the heart of all personal computers and most workstations sits a microprocessor. Microprocessors also control the logic of almost all digital devices, from clock radios to fuel-injection systems for automobiles.

Three basic characteristics microprocessors:

* Instruction set: Set of instructions that the microprocessor can execute.
* Bandwidth: Number of bits processed in a single instruction.
* Clock speed: Given in megahertz (MHz), the clock speed determines how many instructions a microprocessor can execute per second.

The higher the value of bandwidth and clock speed, the more powerful is the CPU. For example, a 32-bit microprocessor that runs at 50MHz is more powerful than a 16-bit microprocessor that runs at 25MHz.

In addition to bandwidth and clock speed, microprocessors are classified as either RISC (reduced instruction set computer) or CISC (complex instruction set computer).

**6.1.2 Instruction Execution**

A microprocessor is a small chip that carries all the roles of a CPU. It is a device that allows a computer to work. The first ever microprocessor was introduced by Intel Company of USA in 1971. The processor is called Intel4004 and it carried out most simple operations related to mathematics. Figure 6.1.1 shows basic principle for execution of an instruction by a typical CPU



Figure: 6.1.1: Instruction execution

* A microprocessor first fetches an instruction from the main memory.
* The instruction is then decoded to determine what action is required to be done.
* Based on instruction the processor fetches, if required, data from the main memory or I/O module.
* The instruction is then executed which may require performing arithmetic or logical operation on data.
* In addition to instruction execution, a CPU also supervises and controls I/O devices. If there is any request from I/O devices, called interrupt, the CPU suspends execution of the current program and transfers control to an interrupt handling program.
* Finally, the results of an execution may require transfer of data to memory or I/O module.

**6.1.3 Internal Organization of a Microprocessor**

Figure 6.1.2 shows a block representation of a typical microprocessor with its major components. The major components are

* Arithmetic/logic unit (ALU), and
* Control unit (CU)

The ALU performs the actual computation or processing of data. The CU controls the movements of data and instructions into and out of the CPU. It also controls the operation of the ALU. In addition, the figure shows registers, the data transfer and logic control paths. The internal CPU bus is needed to transfer data between the various register and the ALU. The ALU operates only on data in the CPU registers. The registers in the CPU serve two major functions:

* ***User-visible Registers:*** These registers enable the programs to minimize main memory references by optimizing use of registers.
* ***Control and Status Registers***: These are used to control the operations of the CPU and to control the execution of programs.

**6.1.4 User-Visible Registers**

These are characterized in the following categories:

* General Purpose Registers
* Data Registers
* Address Registers
* Condition Code Registers

General purpose registers can be assigned by the programmer for a variety of functions. It can contain the operand for any opcode. For example, when a program is interrupted its state, i.e., the value of the registers such as the program counter, instruction register or memory address register - may be saved into the general purpose registers for when the program is to restart again.



Figure 6.1.2: Block representation of a typical microprocessor

General-purpose registers can be used for addressing functions. In other cases, there is a partial or clean separation between data registers and address registers. Data registers may be used only to hold data and cannot be employed in the calculation of an operand address. Address registers may be somewhat general purpose or they may be devoted to a particular addressing mode. Some examples are

* ***Segment Pointers***: A segment pointer holds the address of the base of memory segment. There may be multiple registers. For example, one for the operating system and one for the current process.
* ***Index Registers***: These are used for indexed addressing and may be auto-indexed.
* ***Stack Registers***: Typically the stack is in memory and there is a dedicated register that points to the top of the stack. This allows push, pop and other stack instructions.

A final category of registers, which is at least partially visible to the user, holds condition codes or flags. Condition codes are bits set by the CPU as the result of operations. For example, an arithmetic operation may produce a positive, negative or zero results or an overflow. In addition to the result, it may subsequently be tested as part of a conditional branch operation.

Condition code bits are collected into one or more registers. Usually, they form part of a control register. Generally, machine instructions allow these bits to be read, but they cannot be altered by the programmer.

**6.1.5 Control and Status Registers**

A variety of CPU registers control the operation of the CPU. Most of these are not visible to the user. A reasonably complete list of register types with brief description are presented here. The following four registers are essential for instruction execution:

* Program Counter (PrC) : It contains the address of an instruction to be fetched.
* Instruction Register (IR): It contains the instruction most recently fetched.
* Memory Address Register (MAR): It contains the address of a location in memory.
* Memory Buffer Register (MBR): It contains a word of data to be written to memory or the word most recently read.

The program counter (PrC) contains an instruction address in microcomputer memory. Typically the PrC is updated by the CPU after each instruction fetch and thus it always points to the next instruction to be executed. A branch or skip instruction modify the contents for the PrC. The fetched instruction is loaded into an instruction register, where the opcode is analyzed. Data are exchanged with memory using the MAR an MBR. In a bus-organized system the MAR connects directly to the address bus, and the MBR connects directly to the data bus. User-visible registers, in turn, exchange data with the MBR.

The four registers mentioned above are used for the movement of data between the CPU and memory. Within the CPU, data must be presented to the ALU for processing. The ALU may have direct access to the MBR and user visible registers. Alternatively, there may be additional buffer registers at the boundary to the ALU; these registers serve as input and output registers for the ALU and exchange data with the MBR and user-visible registers.

All CPUs include a register or a set of registers, often called the program status word (PSW), which contains status information. The PSW typically contains codes plus other status information. Common field or flags include the following.

* Sign flag / Negative flag: It indicates that the result of a mathematical operation is negative. In some processors, the N and S flags are distinct with different meanings and usage: One indicates whether the last result was negative whereas the other indicates whether a subtraction or addition has taken place.
* Zero flag: It indicates that the result of arithmetic or logical operation was zero.
* Carry flag: It enables numbers larger than a single word to be added/subtracted by carrying a binary digit from a less significant word to the least significant bit of a more significant word as needed. It is also used to extend bit shifts and rotates in a similar manner on many processors.
* Overflow flag: It indicates that the signed result of an operation is too large to fit in the register width using twos complement representation.
* Interrupt Enable/Disable: It is used to enable or disable interrupts.
* Parity flag: It indicates whether the number of set bits of the last result is odd or even.
* Supervisor: It indicates whether the CPU is executing in supervisor or user mode. Certain privileged instructions can be executed and certain areas of memory can be accessed only in supervisor mode.

In addition to the PSW, there may be a pointer to a block of memory containing additional status information. In machines using vectored interrupts, an interrupt vector register may be provided. If a stack is used to implement certain functions, i.e., subroutine call, then a system stack pointer is needed. A page table pointer is used with a virtual memory system. Finally registers may be used in control of I/O operations.

A modern microprocessor may also have the following components:

* ***Integer unit (iu)*:** It handles the integer operation efficiently.
* ***Floating point unit (fpu)*:** It handles the floating point operations.
* ***Memory management unit (mmu)*:** It handles run-time memory management problems to enhance performance.
* ***Data cache and instruction cache*:** Data cache and instruction cache are also called built-in-cache. These are fast primary memory.

It is also noted that currently some microprocessor may have a special component for a specific purpose, for instance multimedia. Some processors may also have more than one ALU to enhance performance. Finally it is essential to say that the components of a microprocessor may change or new components may be incorporated in future.

**6.1.6 Key points**

* Microprocessor is a silicon chip that contains a CPU.
* At the heart of all personal computers and most workstations sits a microprocessor.
* Microprocessors also control the logic of almost all digital devices, from clock radios to fuel-injection systems for automobiles.
* Three basic characteristics of microprocessors are instruction sets, bandwidth and clock speed.
* The major components of microprocessors are: an arithmetic/logic unit (ALU) and control unit (CU).
* Registers in the CPU are User-visible Registers and Control and Status Registers
* User-visible Registers enable the programs to minimize main memory references by optimizing use of registers
* Control and Status Registers are used to control the operations of the CPU and to control the execution of programs.
* A segment pointer holds the address of the base of memory segment.
* Index Registers are used for indexed addressing and may be auto-indexed.
* The stack is in memory and there is a dedicated register that points to the top of the stack. This allows push, pop and other stack instructions.
* Program Counter (PC) contains the address of an instruction to be fetched.
* Instruction Register (IR) contains the instruction most recently fetched.
* Memory Address Register (MAR) contains the address of a location in memory.
* Memory Buffer Register (MBR) contains data to be written to memory or the data most recently read.
* Sign flag / Negative flag: indicates that the result of a mathematical operation is negative.
* Zero flag indicates that the result of arithmetic or logical operation (or, sometimes, a load) is zero.
* Overflow flag indicates that the signed result of an operation is too large to fit in the register width.

**6.1.7 Practice Set**

**Multiple Choice Questions**

1. Microprocessor is the CPU of the

(a) microcomputer (b) supercomputer (c) mainframe computer (d) none of these

1. Major components of microprocessors are

(a) ALU, CU and I/O devices

(b) ALU and CU

(c) ALU and I/O device

(d) None of these

1. Data register is a

(a) user-visible register (b) control register (c) status register (d) None of these.

1. IR stands for
2. internal register
3. individual register
4. instruction register
5. none

**Review Questions**

1. What is a microprocessor?
2. Distinguish between CPU and microprocessor.
3. What are the factions of registers?
4. What are the types of user-visible registers?
5. What are the controls and status registers?
6. What is the function of program counter?

**Analytical Questions**

1. Describe the execution of an instruction by a microprocessor with the help of a flowchart.
2. Draw the internal structure of a microprocessor and list its components.
3. Briefly describe the register sets of a microprocessor.

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***Lesson 6.2***

***ALU and Control***

**6.2.0 Objectives**

*On completion of this lesson you will know:*

* *Arithmetic logic unit*
* *Operation of the control unit*
* *Difference between hardwired control and micro programmed control*

**6.2.1 Arithmetic Logic Unit**

Arithmetic logic unit (ALU) is the data processing unit of the microprocessor. Figure 6.2.1 shows the block diagram of an ALU. Functions of the ALU are:

* Arithmetic calculations like addition, subtraction, multiplication and division.
* Logical operations like OR, AND, NOR etc.
* Decision making

ALU is the computer’s calculator. A few current processors use multiple ALUs to attain high processing speeds. However, most microprocessors have a single ALU.

Arithmetic operation includes addition, subtraction, multiplication and division. The data operated on can be stored in various forms: the binary, BCD, EBCDIC and ASCII representations.

The ALU makes use of temporary storage areas referred to as resisters. Data to be arithmetically manipulated are copied from memory and placed in registers for processing. Upon completion of the arithmetic operation, the result can be transferred from the accumulator to memory. ALU uses one or more adders as shown in Figure 6.2.1 to add, subtract, multiply or divide the binary digit.



***Figure 6.2.1: Block diagram of an ALU and its relation to control and memory units.***

Decision making is the ability to compare two numbers to determine, if the first number is smaller than, equal to, or greater than the second number and to take approximate action based on the results of the comparison. For example, if the question is : the ALU would determine answer as being either true or false depending on the value of . It is also possible to test a condition during the processing of an application and to alter the sequence of the instructions accordingly.

The various electronic circuits used in the execution of data processing instructions by a processor are usually merged into the ALU. The complexity of an ALU is determined by the manner in which its arithmetic instructions are realized. Simple ALUs for fixed point operations can be constructed around the circuits developed for multiplication and division. More expensive data processing and control logic is necessary to implement floating point arithmetic in hardware. Some microprocessor families having fixed-point ALUs employ special-purpose units called arithmetic coprocessor to perform floating point and other complex numerical functions.

**6.2.2 Control Unit**

The control unit performs the computer’s traffic control. It coordinates and controls operations of the CPU. It does this like the human brain coordinates and controls the activities of the human body. The control unit does not process input and output or store data; rather it initiates and controls these operations. The control unit also communicates with input devices to begin the transfer of data or instructions into memory and with output devices to begin the transfer of results from memory.

Data transfer involves the moving of data or instructions from one location to another. When an item of data is stored in a given location, it replaces the previous contents of the location. But when an item of data is moved from one location to another, the data item is not physically removed from its initial location; actually the data item is copied to the new location. When the computer executes a program contained in primary memory, the control unit obtains the instructions in the sequence in which they are executed, interprets the instructions, and issues control signals to execute them. To accomplish this, the control unit must communicate with ALU and primary storage.

The control unit generally performs all or most of the following functions for execution of instructions:

* Determines the instruction to be executed.
* Determines the operations to be performed.
* Determines when data are needed and where they are stored.
* Determines where results, if any, are to be stored.
* Determines where the next instruction is located.
* Causes the instruction to be executed.
* Transfers control to the next instruction.

**6.2.3 Machine Cycle:**

The activities of the control unit include thousands of individual steps, each of which takes place in a fixed interval of time. These intervals are controlled by an internal electronic clock that emits millions of regular electronic pulses every second. Clock speed are generally measured in gigahertz (GHz). In general, operations within the CPU of the computer take place in terms of a fixed number of clock pulses. This number determines the machine cycle for the computer. During a machine cycle, the computer can perform one machine operation. The number of machine operations required to execute a single instruction vary from instruction to instruction. Execution of instructions takes place under the direct supervision of the control unit.

**Instruction Format:**

Program instructions stored in memory must be in a machine-readable form. In general, these instructions consist of two distinct parts:

* An operation code, and
* One or more operands

The operation code (Opcode) tells the machine what task is to be performed; the operands specify what are to be used to perform the task. Examples of operands are:

* Address of a data item or an instruction in primary memory
* Address of a data item or a program outside the CPU on a secondary memory.
* Address of an input or an output unit.
* Address of a register or special-purpose temporary memory area.

For example, the instruction

MOV 8000 9000

contains the operation code MOV and the operands 8000 and 9000. This could mean that the machine is to move the contents of storage location 8000 to storage location 9000. In addition to the address of an item of data in primary storage, an operand can be used to indicate the address of a register, the address of data stored in secondary storage, or even the address of an input or output device.

**6.2.4 Instruction Execution Cycle**

Each computer's CPU can have different cycles based on different instruction sets, but will be similar to the following cycle (Figure 6.2.2):

**Step 1: Fetch the instruction**

The next instruction is fetched from the memory address that is currently stored in the Program Counter (PrC), and stored in the Instruction register (IR). At the end of the fetch operation, the PrC points to the next instruction that will be read at the next cycle.

**Step 2: Decode the instruction**

The decoder interprets the instruction. During this cycle the instruction inside the IR gets decoded.

**Step 3: Execute the instruction**

The control unit passes the decoded information as a sequence of control signals to the relevant function units of the CPU to perform the actions required by the instruction such as reading values from registers, passing them to the ALU to perform mathematical or logic functions on them, and writing the result back to a register. If the ALU is involved, it sends a condition signal back to the control unit.

**Step 4: Execute:** Actually process the command or instruction.

**Step 5: Store the results**

The result generated by the operation is stored in the main memory, or sent to an output device. Based on the condition of any feedback from the ALU, PrC may be updated to a different address from which the next instruction will be fetched.

The cycle is then repeated.

For example, to add the numbers 5 and 6 and show the answer on the screen requires the following steps given in Table 6.2.1:

Table 6.2.1: Instruction execution cycle for ‘5+ 6’ and display answer on screen

|  |  |
| --- | --- |
| **No of**  **Cycle** | **Distinct steps** |
| 1 | Fetch instruction: "Get number at address 123456" |
| 2 | Decode instruction. |
| 3 | Execute: ALU finds the number. *(which happens to be 5)* |
| 4 | Store: The number 5 is stored in a temporary spot in Main Memory. |
| 5 -8 | Repeat steps for another number (= 6) |
| 9 | Fetch instruction: "Add those two numbers" |
| 10 | Decode instruction. |
| 11 | Execute: ALU adds the numbers. |
| 12 | Store: The answer is stored in a temporary spot. |
| 13 | Fetch instruction: "Display answer on screen." |
| 14 | Decode instruction. |
| 15 | Execute: Display answer on screen. |

**6.2.5 Key points**

* Arithmetic logic unit (ALU) is the data processing unit of the microprocessor.
* Arithmetic operation includes addition, subtraction, multiplication and division. The data operated on can be stored in various forms: the binary, BCD, EBCDIC and ASCII representations.
* The ALU makes use of temporary storage areas referred to as resisters.
* The control unit performs the computer’s traffic control. It coordinates and controls operations of the CPU.
* The control unit does not process input and output or store data; rather it initiates and controls these operations.
* The activities of the control unit are composed of thousands of individual steps, each of which takes place in a fixed interval of time.
* Program instructions stored in memory must be in a machine-readable form. These instructions consist of two distinct parts: An operation code, and one or more operands.
* Each computer's CPU can have different cycles based on different instruction sets, but will be similar to the following cycle: fetch the instruction, decode the instruction, read the effective address, execute the instruction, store the results

**6.2.6 Practice Set:**

**Multiple Choice Questions**

1. The functional units of a microprocessor are
2. ALU and memory
3. ALU and control unit
4. Control unit and register
5. None of above
6. Main function of the control unit is
7. To control the computer traffic
8. To perform arithmetic operation
9. To store information
10. None of above

3. The control unit does not process \_\_\_\_\_\_\_\_\_\_\_\_\_.

1. input
2. output
3. store data
4. All

**Review Questions**

1. What is an ALU?
2. What are the main fictional units of an ALU.
3. Briefly write the functions of an ALU.
4. What is meant by an operand?
5. What is the purpose of an accumulator?

**Analytical Question**

1. Describe machine cycle with suitable diagram.
2. Describe the steps performed during the instruction cycle.
3. Write an essay on functional units of an ALU.

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***Lesson 6.3***

***Microprocessor: Past, Present and Future***

**6.3.0 Objectives**

*On completion of this lesson you will know:*

* *Classification of microprocessor*
* *Comparison between CISC and RISC*
* *Generations of Microprocessors*
* *Microprocessor’s specifications*

**6.3.1 Classification Based On Characteristics**

Based on characteristics, the microprocessors are classified into three categories. These are as follows:

* RISC processors
* CISC processors
* Special processors

**RISC Processor**

RISC is an acronym for reduced instruction set computer. The concept of RISC processor involves an attempt to reduce execution time by simplifying the instruction set of the computer. The major characteristics of a RISC processor are:

* Relatively few instructions
* Relatively few addressing modes
* Memory access limited to load and store instruction.
* All operations done within the registers of the CPU
* Fixed-length, uniform, easily decoded instruction format.
* Single-cycle instruction execution.
* Hardwired rather than micro-programmed control.

Some architectural features of RISC processors are

* Relatively large number of registers in the processing unit.
* Use of overlapped register windows to speed up procedure, call and return.
* Efficient instruction pipeline.
* Compiler support for efficient translation of high level language programs into machine language programs.

Well known RISC families include DEC Alpha, AMD 29k, ARC, ARM, Atmel AVR, MIPS, PA-RISC, Power (including PowerPC), SuperH, and SPARC.

**CISC Processor**

CISC is an acronym for complex instruction set computer. Major characteristic of the CISC processors are:

* Large number of instructions
* Some instructions that perform specialized tasks
* Variety of addressing modes
* Variable length instruction formats
* Instructions that manipulate control
* Several cycles may be required to execute one instruction.

Examples of CISC instruction set architectures are PDP-11, VAX, Motorola 68k, and x86. For many years, Intel is the only major supplier of x86 processors with few authorized and controlled alternate sources. Today a large number of companies offer compatible processor with no assistance from Inter. They are:

* Advanced Micro Device (AMD) processors
* Cyrix processors
* Texas Instrument (TI) processors
* NexGen processors.

All CISC microprocessor that run PC software were derived from the early Intel 8086 or x86 architectures. Today Intel controls the development of CISC microprocessor and other industries produce the Intel compatible processors.

Intel presented a new processor in 1993 called Pentium. With this processor, Intel opened a new era of technology. New features are added to the processor and as a result new highly developed processors come out.

Table 5.3.1 shows difference between CISC and RISC

***Table 5.3.1: CISC versus RISC***

|  |  |  |
| --- | --- | --- |
|  | CISC | RISC |
| Emphasis on | Hardware | Software |
| Includes | Multi-clock, Complex instructions | Single clock, Reduced instructions only |
| Load and Store | Memory to memory load & store incorporated in instructions | Register to register load & store are independent instructions. |
| Code size | Small code sizes, high cycles per second | Low cycles per second, large code sizes |
| Memory | Transistors used for storing complex instructions | Spends more transistors on memory registers. |

**Special Processors**

There are several other processors, which are used for special purposes. Some of these processors are briefly discussed below

**Coprocessor:** A coprocessor is a microprocessor used to supplement the functions of the CPU. Operations performed by the coprocessor may be floating point arithmetic, graphics, signal processing, string processing, or encryption. Since the coprocessors are designed for a special purpose, these can accelerate system performance. Coprocessors allow a line of computers to be customized, so that customers who do not need the extra performance need not pay for it. The most well known coprocessor is the math-coprocessor.

Until the introduction of the 486DX microprocessor, the math-coprocessor was a separate chip. But 486DX and Pentium microprocessors have the math-coprocessor integrated on the same chip with the microprocessor. Table 5.3.1 shows different types of Intel math-coprocessors.

***Table: 5.3.1: Math coprocessor***

|  |  |
| --- | --- |
| **Math coprocessor** | **Used with** |
| 8087 | 8086/8088 |
| 80287 | 80286 |
| 80387 | 80386 |

Cyrix and Weitekare also math coprocessor available in market.

**Input/output Processor:** One of the most important types of processors is I/O processors. An I/O processor has a local memory of its own right. With this architecture, a large set of I/O devices can be controlled, with minimal CPU involvement. A common use for such architecture has been to control communication with interactive terminals. I/O processors are used in the following fashion:

* The CPU executes a series of data-transfer instructions that send a set of input operands and command information to registers in the I/O processor.
* The I/O processor decodes and executes the command received from the CPU generating results that is placed in registers accessible to the CPU.
* The CPU determines that the I/O processor has completed its task either by checking its status or else by receiving an interrupt signal from the I/O processor.
* The CPU then obtains the results from the I/O processor by executing more data transfer instructions.

Common examples of I/O processors are:

* DMA (Direct Memory Access) controller
* Keyboard/mouse controller
* Graphic display controller
* SCSI port controller, etc.

**Transputer:** The transputer, is the name deriving from transistor and computer, was the first general purpose microprocessor designed specifically to be used in parallel computing systems. The goal was to produce a family of chips ranging in power and cost that could be wired together to form a complete parallel computer. The name was selected to indicate the role the individual transputers would play: numbers of them would be used as basic building blocks, just as transistors had earlier. The transputer family consists of several types of VLSI devices including the 16-bit T212, the 32-bit T425 and the floating point T800, T805 and T9000 processors.

**Digital signal processor (DSP):** A digital signal processor (DSP) is is incredibly fast and powerful microprocessor. It is unique because it processes data in real time. This real-time capability makes a DSP perfect for applications where we won't tolerate any delays.

The main applications of DSP are audio signal processing, audio compression, digital image processing, video compression, speech processing, speech recognition, digital communications, RADAR, SONAR,. Specific examples are speech compression and transmission in digital mobile phones, room correction of sound in hi-fi and sound reinforcement applications, weather forecasting, economic forecasting, seismic data processing, analysis and control of industrial processes, medical imaging such as CAT scans and MRI, etc.

**6.3.2 Generations of Microprocessors**

A major technological development characterizes each generation of computer that fundamentally changed the way computers operate, resulting in increasingly smaller, cheaper, powerful, more efficient and reliable devices.

**First Generation (1G) Microprocessors:** The 1G of microprocessors were developed between 1971-1973. They used monolithic integrated circuit (IC) and P-MOS technology. This technology has slow speed, not supported with TTL. Due to the lack of pins, signals have to be multiplexed. Intel 4004 and Intel4040 are the example of 1G of microprocessors.

**Second Generation (2G) Microprocessors:** The 2G of microprocessors were introduced between 1973-1978. They were designed using N-MOS technology and had faster speed and higher density packaging than P-MOS technology. It had more powerful instruction set, ability to handle large memory space and had better interrupt handling capability. Intel   
8080 and Intel 8085 are the example of 2G of microprocessors.

**Third Generation (3G) Microprocessors:** The 3G of microprocessors were introduced between 1978-1980. They were basically 16 bit processor and were made by using H-MOS technology. It had flexible input-output port addresses. 8-bit-8086, 16 bit- 80286, 80386 and 80486 are the example of 3G of microprocessors.

**Fourth Generation (4G) Microprocessors:** The 4G of microprocessors were introduced between 1980-1990. It had 2 kb main memory, 16 Mb physical memory, 1 Tb virtual memory for enhancing speed. Celeron and further invented processor are the example of 4G of microprocessors. Intel 486 series processors are the example of 4G of microprocessors. Celeron are the example of 4G of microprocessors.

**Fifth Generation (5G) Microprocessors:** The 5G of microprocessors were released in 1992. Instead of calling Intel 586, they were known as Pentium. They were implemented first Complex Instruction Set Computer (CISC) superscalar technology.

**Sixth Generation (6G) Microprocessors:** The 6G of microprocessors were released in 1995. The 686 processor family began with the Pentium Pro. The new features of 6G Microprocessors are: dividing CISC instructions into RISC instructions (microinstructions), executing them multiple execution units, and advanced branch prediction. Pentium II was introduced in 1997 with clock up to 300MHz. It contained MMX instruction set and level 2 cache outside the CPU. Pentium III was introduced in 1999. It was Enhanced and faster version of Pentium II. It used Single instruction Multiple Data (SIMD). It provided many floating-point versions of the MMX instructions and more.

**Seventh Generation (7G) Microprocessors:** The 7G of microprocessors (Pentium 4) were released in 2000 with clock up to 1.3GHz. The new features of are: It introduced new sets of SSE instructions: SSE2 and SSE3, L1 cache of 8 to 16kB and L2 cache up to 1MB, simulating two processors in the system (virtual processor).

**Eighth Generation (8G) Microprocessors:** The 8G microprocessors were 64bit processors released in 2001 by Intel – Itanium. In 2002 they released Itanium 2. In 2004 Intel released versions of Pentium 4 that have 64bit instructions. The new features of Itanium and Itanium 2: dedicated to use in advanced servers and workstations, first processors with all 3 levels of cache integrated, more than 592 millions of transistors and 9MB of L3 cache integrated.

As the Intel’s processors based on NetBurst core (Dual core processors) reached the barrier of 4GHz, they realized that the power consumption and the amount of heat produced were too high.

Intel Core Duo released at the beginning of 2006 is 32-bit processor with dual core. It has 2MB L2 cache shared between two cores and contains arbiter that controls access to system bus and cache. Intel was announcing that future versions will have option of switching off one of the cores to save power. The first Intel processor used in Apple computers Dual core processors. Core 2 Duo was released in the middle of 2006. Basically it is the 64bit version of Core Duo and outperformed the Pentium processor family. Core2 Quard was released in 2007. It is designed to handle massive compute and visualization workloads enabled by powerful multi-core technology. Providing the bandwidth you need for multi-threaded application.

**Ninth Generation (9G) Microprocessors:** Nehalem is named for is the 9G of Intel Core. It is a flexible processor as it has been designed for Server, workstation, high end desktop PC, notebook PC, and slim notebook PC devices. The processor blends performance and efficiency by intelligent handling of multiple threads, better shared cache between cores and dynamically altering the power consumption in performance requirements decrease. The new features are: It includes L3 Cache memory, microprocessor is 64 bit, DDR3 memory support, micro architecture enhancements, dynamic power management, and it supports 2,4 or 8 cores. Intel Core i7 is the first Processors based on the Intel Nehalem architecture, and it launched in the second half of 2008. Core i7 and Core i3 are 64 bit microprocessors launched in 2009 and 2010 respectively.

**6.3.3 Microprocessor Specifications**

There are several attributes of a microprocessor which determine its power and capabilities:

* Width of external data bus in bits.
* Width of address bus in bits.
* Width of internal data bus in bits.
* Cache Memory.
* Clock Speed in Megahertz (MHz)
* MIPS (Million Instructions per Second)
* Power Consumption (Watts)

The details of these attributes are given below:

**Data bus:** The earliest microprocessors could handle data only in bytes (8 bits). As the width of the data bus increases, the width of the data bus determines how much information can be moved in or out of the processor in one operation. It also determines the number and length of instructions which can be used.

**Address bus:** The width of the address bus determines how much memory can be addressed. **Internal data bus:** The width of the internal data bus and the storage registers may differ from the external data bus.

**Cache Memory:** Cache memory is much faster, but more expensive, so it is used in small quantities as a temporary storage location for data on the microprocessor. It is operated by a cache controller which attempts to identify which data or instructions will be needed next and load them into the cache so that the processor will not have to stand idle while waiting for data to be retrieved from RAM. The higher is the size of cache memory, the better is the performance of a microcomputer.

**Clock Speed:** An oscillator, in the motherboard, generates a series of electrical pulses which the computer uses to synchronize the operations of its many components. The speed of the processor is often a multiple of the external bus speed: for example a 500 MHz chip installed on a 100MHz mainboard will operate at 5x the bus speed.

**MIPS:** The clock speed does not relate directly to the speed at which the CPU processes instructions. Early microprocessors required as many as 10 clock cycles to complete a single instruction. Modern microprocessors with 'superscalar" architecture has dual or multiple 'pipelines' so that more than one instruction can be executed at once. Therefore, a more accurate measure of processor speed is Millions of Instructions per Second (MIPS), although the number of actual instructions processed rarely reaches the theoretical maximum.

**Power consumption:** Power consumption is an often unnoticed measure of microprocessor performance. Much of the power consumed is given off as heat, which must be dissipated, or it will cause malfunctions. Low power consumption is also a critical factor in extending the life of batteries in notebook computers.

**6.3.4 Parallel Processing:**

Parallel processing means the simultaneous use of more than one CPU to execute a program. Ideally, parallel processing makes a program run faster because there are more engines (CPUs) running it. In practice, it is often difficult to divide a program in such a way that separate CPUs can execute different portions without interfering with each other.

Most computers have just one CPU, but some models have several. There are even computers with thousands of CPUs. With single-CPU computers, it is possible to perform parallel processing by connecting the computers in a network. However, this type of parallel processing requires very sophisticated software called distributed processing software.

Note that parallel processing differs from multitasking, in which a single CPU executes several programs at once. Parallel processing is also called parallel computing.

**6.3.5 Key points**

* RISC is an acronym for reduced instruction set computer. The concept of RISC processor involves an attempt to reduce execution time by simplifying the instruction set of the computer.
* Well known RISC families include DEC Alpha, AMD 29k, ARC, ARM, Atmel AVR, MIPS, PA-RISC, Power (including PowerPC), SuperH, and SPARC.
* CISC is an acronym for complex instruction set computer. Large number of instructions, some instructions that perform specialized tasks, variety of addressing modes are the features of CISC.
* Examples of CISC instruction set architectures are PDP-11, VAX, Motorola 68k, and x86.
* Coprocessor performs floating point arithmetic, graphics, signal processing, string processing, or encryption operation.
* The transputer was the first general purpose microprocessor designed specifically to be used in parallel computing systems.
* A digital signal processor (DSP) is a type of microprocessor is incredibly fast and powerful.
* The 1G of microprocessors used monolithic IC and P-MOS technology.
* The 2G of microprocessors were designed using N-MOS technology and had faster speed and higher density packaging than P-MOS technology.
* The 3G of microprocessors were basically 16 bit processor and were made by using H-MOS technology.
* The 4G of microprocessors were introduced between 1980-1990. It had 2 kb main memory, 16 Mb physical memory, 1 Tb virtual memory for enhancing speed.
* The 5G of microprocessors were released in 1992. Instead of calling Intel 586, they were known as Pentium.
* The 6G of microprocessors were released in 1995. The 686 processor family began with the Pentium Pro.
* The 7G of microprocessors (Pentium 4) were released in 2000 with clock up to 1.3GHz.
* The new features of 8G microprocessors are dedicated to use in advanced servers and workstations. Such microprocessors include L3 cache.
* Nehalem is named for is the 9G of Intel Core. It is a flexible processor as it has been designed for Server, workstation, high end desktop PC, notebook PC, and slim notebook PC devices.
* The width of the address bus determines how much memory can be addressed.
* The width of the internal data bus and the storage registers may differ from the external data bus.
* As processor speeds increased, the speed of main memory (RAM) could not keep up.
* An oscillator mounted on the motherboard generates a series of electrical pulses which the computer uses to synchronize the operations of its many components.
* Parallel processing means the simultaneous use of more than one CPU to execute a program.
* parallel processing makes a program run faster because there are more engines (CPUs) running it
* Parallel processing differs from multitasking, in which a single CPU executes several programs at once. Parallel processing is also called parallel computing.

**6.3.6 Practice Set**

**Multiple Choice Questions**

1. RISC processor involves an attempt to \_\_\_\_\_\_\_\_\_\_.
2. increase execution time
3. reduce execution time
4. keep same execution time
5. None
6. Which one is not the feature of CISC?
7. Emphasis on hardware
8. Small code size.
9. Multiclock, complex instruction.
10. Emphasis on software
11. DSP is a type of microprocessor which is \_\_\_\_\_\_\_\_\_\_.
12. fast
13. powerful
14. fast and powerful
15. process non-real time data
16. Core i7 and Core i3 are \_\_\_\_\_\_\_\_\_\_ microprocessors.
17. 6G
18. 7G
19. 9G
20. none
21. Pipeline architecture belongs to \_\_\_\_\_\_\_\_\_\_ type.
22. SISD
23. SIMD
24. MISD
25. MIMD

**Question for Short Answers**

1. What is the basis for the rapid developments of microprocessor technology?
2. What are the different categories of processors based on generations?
3. Classify the microprocessor based on characteristics.
4. Distinguish between CISC and RISC processors.
5. What is transputer?
6. What is coprocessor?
7. What is parallel processing?

**Analytical Questions**

1. Describe the microprocessors of different generations.
2. What is the RISC and CISC controversy? Distinguish between CISC and RISC processors.
3. Briefly describe the classification of microprocessors based on characteristics