CHAPTER # 05

COMPUTER ARCHITECTURE

COMPUTER ORGANIZATION:

Computer organization is concerned with the way the hardware components operate and the way. They are connected together to form the computer system. The various components are assumed to be in place and the task is to investigate the organizational structure to verify that the computer parts operate as intended.

COMPUTER DESIGN:

Computer design is concerned with the hardware design of the computer. Once the computer specifications are formulated, it is the task of the designer to develop hardware for the system.
Computer design is concerned with the determination of what hardware should be used and how the parts should be connected. This aspect of computer hardware is sometimes referred to as computer implementation.

COMPUTER ARCHITECTURE:

Computer architecture is concerned with the structure and behavior of the computer as seen by the user. It includes the information formats the instruction set, and techniques for addressing memory. The architectural design of a computer sustem is concerned with the specifications of the various functional modules, such as processor and memories, and structuring them together into a computer system.

COMPONENTS OF A DIGITAL COMPUTER:

A digital computer can be broadly classified as a collection of four basic units.
1. Input Unit
2. Output Unit
3. Central Processing Unit (CPU)
4. Memory Unit

Input Unit:

The input unit provides an interface between the users and the machine for inputting data and instructions etc. One of the most common examples is the keyboard.

Output Unit:

Like the input unit, the output unit also provides an interface between the user and the machine. A common example is the monitor of a personal computer.

Central Processing Unit (CPU):

The Central Processing Unit is the brain of the computer system. It has two principal sections; an arithmetic/logic unit and a control unit. It also contains several register and a network of buses connecting various components.

Memory Unit:

Memory also called main memory, RAM Primary or Internal Storage. It holds programs and data passed to the computer system for processing, intermediate processing results and output ready for transmission to a secondary storage or output device.

MEMORY LOCATIONS:

The memory unit may be considered as made of small compartments, usually called cells or memory locations.

ADDRESS:

A memory location can hold a data or an instruction. Each of these locations is assigned a particular number called its address.

COMPUTER REGISTERS:

A register is a temporary storage device which holds data (or an instruction) as long as it is being manipulated. Each register within the CPU performs a specific role.

Registers also differ from memory in that they are not addressed as a memory location.

Registers are used in many different ways in a computer may hold data being processed, an instruction being executed, a memory or I/O address to be accessed, or even special binary codes used for some other purpose, such as codes that keep track of the status of the computer.

GENERAL PURPOSE REGISTERS:

The General-Purpose Registers may be used for temporarily storing data. General-Purpose Registers are also known as programmable registers as they may be programmed by the user with the help of instructions.

ACCUMULATOR (AC)

The Status Register also called Flag Register, holds 1-bit flag to indicate certain conditions that arise during arithmetic and logical operations. The important conditions shown by flag or status registers are:

Carry	Indicates whether there is overflow or not.
Zero	Indicates whether the result is zero or non-zero.
Sign	Indicates whether the result is plus or minus.
Parity	Indicates whether the result contains odd number of 1st or even number of 1s

MEMORY BUFFER REGISTER (MBR):

This register is also known as the Memory Data Register (MDR). It is used to hold a word that is being stored to or retired from the memory location currently addressed by the Memory Address Register.

MEMORY ADDRESS REGISTER (MAR):

This register holds the address of a memory location of the word to be written from or read into the MBR.

INSTRUCTION REGISTER (IR):

This is very important register. It holds the actual instruction being excuted currently by the computer.

PROGRAM COUNTER (PC):

This is a register which deals with the order for execution of instructions. This acts like a pointer which indicates the subsequent memory location where instruction is stored. After one instruction is executed, the Program Counter gets incremented by one to indicate the location of the next instruction in the serial order.

STACK POINTER (SP):

Stack may be defined as a set of memory locations and the Stock Pointer may be defined as the indicator to these memory locations. Stack memory location are used by a microprocessor for storing data temporarily for execution of a program.

MINIMUM NUMBER OF REGISTERS REQUIRED BY A COMPUTER:

For the basic computer we shall consider the following registers:

1. One register for holding data called Memory Buffer Register (MBR).
2. One register for storing instruction called Instruction Register. (IR).
3. A register for holding the address of memory word called Memory Address Register (MAR).
4. A register for holding temporary data generated during processing. This register is named s Temporary Register (TR).
5. A processor Register also called Accumulator (AC) is required for doing operations on data.

This Process Register holds data on which addition, subtraction, multiplication, shift and logical operations are to be carried out.

6. A register that will act as a counter and will act as a counter and will hold the address of next instruction. Such a register is named as Program Counter. (PC).
7. Register for inputting and outputting data. Input Register (INPR) will hold data obtained from user through inputting and outputting data. Input Register (INPR) will hold data that need to be sent to output devices like monitor, printer etc.

Thus, we will need all these registers to hold data temporarily as well as we will need memory unit and control unit.

SIZES OF CPU REGISTERS:

Since Accumulator (AC), Memory Buffer Register (MBR), Instruction Register (IR) and Temporary Register (TR) holds data, these registers should be of 16 pits because each word consists of 16 bits.

Memory Address Register (MAR) and Program counter (PC) store addresses of memory words. Therefore, MAR and PC registers are of 12 bits each because we need to store 4096 addressed and this is possible with a 12-bit register, as $2^{12} = 4096$. Thus, 12 bits would from 4096 different combinations.

INPR and OUTR (Input & Output Registers) are taken to be of 8 bits each. They are supposed to transfer 8 bits at a time to the memory or to other registers or to output devices. This is because of the fact that if we have 16-bit word, we would move it in two parts of 8 bits each. The transfer of bits is done using one byte (or 8 bits) at a time through the bus which connects different parts in a motherboard, The rest of the 8 bits would follow.

BUSES:

In a microcomputer, the input/output devices and memories are connected to the microprocessor by means of wires called Buses. There are three types of buses called.

1. Address bus.
2. Data bus
3. Control bus

Address Bus:

The address bus is used by the microprocessor to transmit the address of the memory location which it wants to access for reading of writing purposes. An address bus is unidirectional i.e. electrical signals are transmitted in one direction only from microprocessor to other devices by this bus.

Data Bus:

The data bus is used to transmit data from the memory to microprocessor and vice versa. It may be used to transmit data to other devices such as output units. The data bus is bi-directional because data has to pass from microprocessor to memory as well as from memory to the microprocessor.

Control Bus:

The Control bus supervises the reading or writing of data. It transmits signals to all the devices at the proper time. In fact, it informs the microprocessor that a particular unit has completed its job.

Instructions:

An instruction is an order for the computer to perform a certain specified operation.
Before a computer is able to execute an instruction, it must be stored in the main memory of the computer.
An instruction is stored in the computer main memory as a certain specified number of bits.

Fields:

If an instruction has n-bits then these bit positions are divided into two or more sections called Fields.

TYPES OF FIELDS:

Opcode:

Opcode (pronounced as oup code), that specifies the operation to be performed. The Opcode may instruct the computer to add two number or compare two numbers or it may direct the computer to stop the execution of the program.

Address Field:

The remaining part of the instruction is called the Address Field. It may be divided into one or more parts, each part containing address of a particular memory location where data for the instruction could be found.

TYPE OF INSTRUCTIONS:

1. Operation Code, abbreviated to Opcode.
2. Address or Addresses of one or more memory locations.

Operation Code:

The operation code of an instruction consists of a group of bits that define certain arithmetic or some other operations, such as addition subtraction, multiplication, division, shifting or complementation. The number of bits required for an operation code depends upon the total number of operations to be performed to be performed by the computer. If the operation code has n bits then the computer is capable of performing 2" distinct operations E.g.: if 16 distinct operations are to be performed by a computer then the Opcode must have at least 4 bits as $2^4 = 16$. The least number of bits needed for the Opcode is 4.
An operations code is a part of an instruction stored in a memory location in the computer memory.

Address:

The operation code of an instruction specifies the operation to be performed. Since the operation is to be performed on data or on a set of data, the instruction must also tell where the data is stored.
The data may be stored in a register or in a memory location.

The data on which the operation to be performed is called an Operand. An instruction must specify the operation to be performed along with the address or addresses of the operands or registers where the result of an operation is to be stored.

Instruction Formats:

An instruction format defines the layout of bits of an instruction in terms of its constituent parts.

Types of Instruction Formats:

The types of commonly used instructions are:

1. Three-Address Instruction.
2. Two-Address Instruction.
3. One-Address Instruction.
4. Zero-Address Instruction.

STACK ORGANIZED CPU:

A tack can be considered as a storage method in which the items are stored in consecutive memory locations and the last element stored is the first element retrieved.

Stack may be finite number of registers bundled together or stack can also be a part of memory unit.

STACK POINTER:

An address register is associated with stacks. The address register called Stack Pointer contains the address of the recently stored element. Stack pointer always points to the topmost element in the stack.

How Push and Pop functions are performed n Stack?

1. „Push" is the term used for inserting an element into a stack and is done by incrementing the Stack Pointer.
2. „Pop" is the term used for removing an element from a stock and is done by decrementing the Stack Pointer.

Polish Notation:

Polish notation, named after the Polish mathematician Jan Lukasiewics, refers to the notation in which the operator symbol is placed before its two operands. This notation is also called prefix notation. For example:

+AB –CD *EF /GH

The fundamental advantage of polish notation is that one never needs parentheses when writing expressions.

REVERSE POLISH NOTATION:

Reverse polish notation refers to the analogous notation in which the operator symbol is placed after its two operands. This notation is also called postfix notation. For example:

AB+ CD– EF* GH/

Any mathematical expression can be evaluated using stacks as follows:

1. First convert the arithmetic expression into equivalent reverse polish notation (postfix notation).
2. Push the operands into stack in the order in which they appear.
3. Use the two topmost operations for evaluation.
4. The stack is popped and the result of the operation is again pushed into the stack.
5. Finally, only the result of the operation is left on stack top.

Internal Working of CPU:

The Central Processing Unit (CPU) is the heart of the computer. It is this unit that accepts data and instructions, processes the data according to the instructions and delivers the output to the output unit. This unit also controls and coordinates the activities of all other unit.

The processing required for a single instruction is called on instruction cycle.

1. Fetch cycle
2. Execute cycle

Fetch Cycle:

The fetch cycle is that duration of time in which as instruction stored in the memory is brought to an appropriate register, all this happening under the commands from control unit of the CPU. The process of bringing an instruction from memory to a register is called a Fetch cycle and has to be completed in a specified of time.

Fetching Of An Instruction:

The instructions and data are stored in computer memory as computer as computer words, each word being 16-bit long. These instructions and data are stored in memory in binary coded forms (i.e. in terms of 0s and 1s) and the two are indistinguishable from each other. It is the responsibility of the programmer to keep the track of the instructions and data. Bu fetching of an instruction, we mean transferring an instruction from a memory location to the Instruction Register (IR). This instruction register holds an instruction temporarily only for the time when the instruction and data are being interpreted or decoded. The instruction from a memory location is transferred to Instruction Register via another register called Memory Buffer Register (MBR).

All the instructions and data from memory pass through Memory Buffer Register on their way to other units. The other register used in a fetching operation and Program Counter (PC) and Memory Address Register (MAR). Thus, the registers needed in instruction fetching operations are:

1. Instruction Register (IR)
2. Memory Buffer Register (MBR)
3. Program Address Register (MAR)

The operation of fetching of an instruction from the main memory to the instruction register is performed under the control of the control unit. The dotten lines show the signals form the control unit.

Fetching Operation:

Let us consider a small computer program stored in the main memory in the locations from 0000 to 0008. The first instruction to be fetched is in the location 0000. To start with the Program Counter is set to 0000. Under the signals from control unit this address 0000 is passed to Memory Address Register (MAR) and PC itself gets incremented by 1 and now it holds the address 0001 which is the address of the next instruction. Again the control unit issues commands to MAR to pass on this address to the main memory and under the directions of the control unit the instruction stored at address 0000 in the memory is passed to the Memory buffer Register (MBR). This instruction is held in MBR temporarily and is passed to current Instruction Register under the commands from control unit. Once this is done, the above process is repeated to fetch the next instruction.

Execution of An instruction:

The execution of an instruction by the computer means completion of the work by the computer as specified by the instruction. The fetch cycle brings the instruction to the Instruction Register, which holds this instruction temporarily as long as it is being interpreted (decoded) and executed.

For the computer having word size of say 16-bit, the instruction held in IR has two parts, namely

1. A 4-bit operation code,
2. A 12-bit address of operand.

The operation code is transferred to the control unit. This control unit sends Opcode to decoder where it is decoded. After decoding the Opcode, the control unit issues commands in the form of control signals to various other units such as arithmetic/ logic unit to perform the necessary operations. The address of a partuclar memory location. This address is transmitted to Memory Address Register (MAR) which transmits it to the main memory. Under the directions of the control unit, the operand stored in that particular memory location is transmitted to the Memory Buffer Register, from where is that particular memory location is transmitted to the Memory Buffer Register, from where it is transmitted to the ALU. The most important register of the ALU is Accumulator where all the arithmetic is performed. This operand (data) is passed to the Accumulator in ALU where the necessary arithmetic, as directed by the control unit, is performed and the result of the operation is held in the Accumulator for onward transmission to the main memory.

Steps in Execution of an Instruction:

The instruction stored in the current instruction register is executed in the following steps:

1. The operation code of the instruction is transmitted to the control unit. The control unit decodes this operation code and issues commands to various other hardware units.
2. The address part of the instruction is transferred to a decoder. The decoder interrupts it and communicates this address to the Memory Address Register, which transmits this address to the main memory. In fact, this is the memory address of the operand.
3. Under the instructions from the control unit the operand stored in this memory location is transferred to Memory Buffer Register.
4. Memory Buffer Register transfers the operand to the arithmetic/ logic unit, where the necessary operation is performed on the operands in the Accumulator, one operand already being stored in the accumulator. The result of the operand remains in the accumulator.

This completes the execution cycle.