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UPPSC – Polytechnic Lecturer

Electronics Engineering

Uttar Pradesh Public Service Commission (UPPSC)

Volume - 4

Microprocessor

SIERRA INNOVATIONS

INDEX

1 CHAPTER

Microprocessor and Microcontroller

THEORY

1. INTRODUCTION OF MICROPROCESSOR

Microprocessor is one of the most important components of a digital computer. It can be viewed as a programmable logic device that can be used to control processes or to turn on/off devices. Simultaneously, it can be viewed as a data processing unit or a computing unit of a computer.

1.1 DEFINITION

Microprocessor is the controlling unit or CPU of a micro-computer, fabricated on a very small chip capable of performing ALU operations and communicating with the external devices connected to it.

or

A microprocessor is a programmable integrated device that has computing and decision making capability similar to that of the Central Processing Unit (CPU) of a computer.

2. MICROPROCESSOR AS A CPU (MPU)

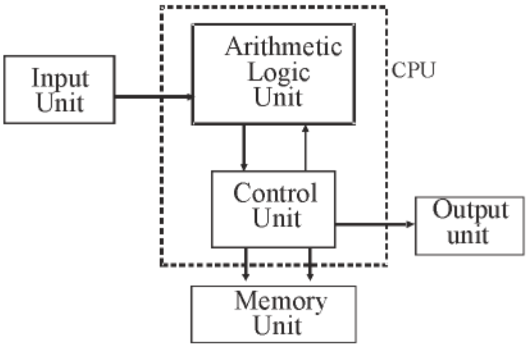
Generally, a basic computer has the four components/units :

(1) Input Unit

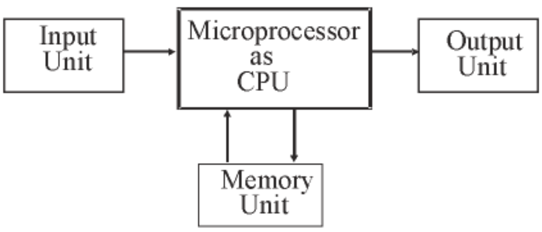
(2) Output Unit

(3) Memory Unit

(4) Central Processing Unit



Basic Block Diagram of Computer

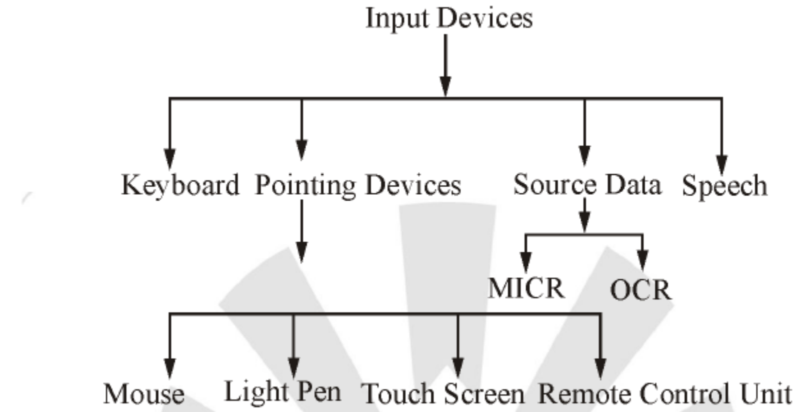


Block Diagram of microprocessor as a CPU or a Micro Computer

2.1 INPUT UNIT :

The input unit consists of the devices which accept the data and instructions from the user and communicates it to the CPU.

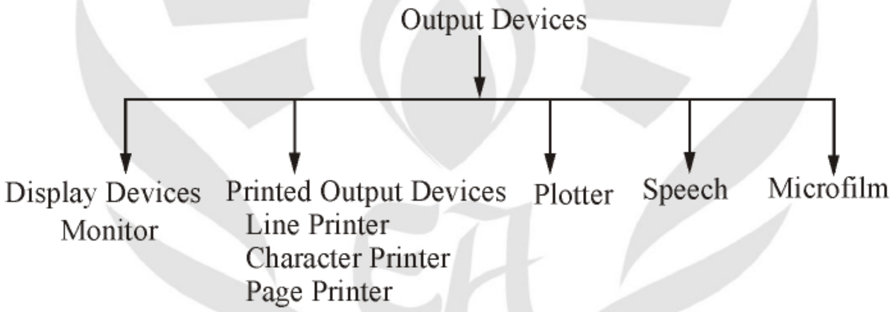
Various input devices are : Keyboard, mouse, Joystick, trackball etc.



2.2 OUTPUT UNIT :

It provides the result of the various operations performed by the CPU to the user.

Various output devices are : Printer, Monitor, Loudspeaker etc.



2.3 CENTRAL PROCESSING UNIT (CPU) :

It fetches the instruction and data from the peripheral devices and performs all the arithmetic operations, takes logical decision and control the operations of all other units.

CPU is considered to be heart and nerve centre of computer

Sub blocks of the central processing unit are :

(a) Arithmetic & Logic Unit (ALU)

(b) Timing & Control Unit (CU)

(c) Registers

2.4 ARITHMETIC AND LOGIC UNIT (ALU) :

This unit performs all the logical and arithmetic operations.

Various arithmetic operations are : additions, subtraction, increment and decrement etc.

Various Logical operation are : AND, OR, NOT, XOR, etc.

2.5 TIMING AND CONTROL UNIT (CU) :

This unit controls the entire operations being performed by the system. It controls the operation of ALU, input/output devices and memory unit. This unit interprets the instructions and generates various timing and control signals.

2.6 REGISTERS :

A register is a very small amount of very fast memory that is built into the CPU in order to store the current data and instructions which are being executed by the CPU.

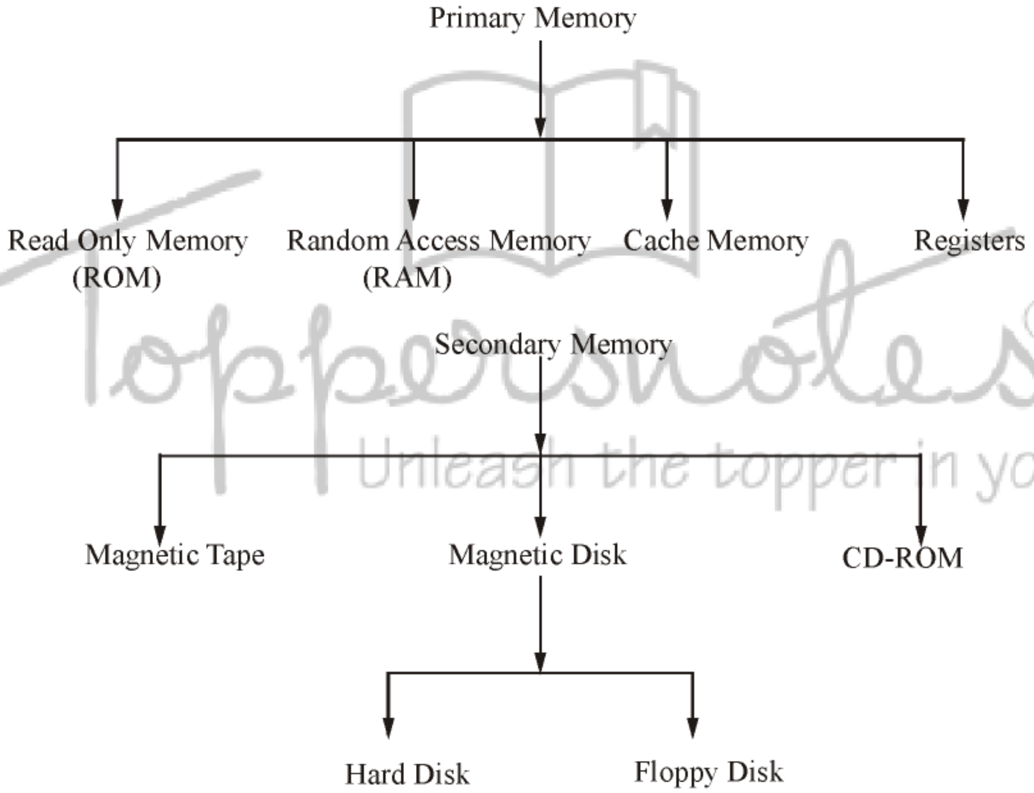
2.7 MEMORY UNIT :

(1) It stores the program statement and the data i.e., the information supplied from the input unit and also stores the final output.

(2) Through a bi-directional bus, it is connected to the CPU,

(3) CPU processes the information as taken from the memory and performs the operations in the ALU section.

Results are either transferred to the output unit or stored in the memory for later use by CPU



3. MICRO-COMPUTER

(1) The microprocessor, embedded in a larger system, can be a stand alone unit controlling processes, or at can function as the CPU of a computer called microcomputer.

(2) The block diagram of the microcomputer is similar to the computer except that the central processing unit of the micro computer is contained in a single IC called microprocessor.

(3) A microprocessor is a LSI (Large Scale Integration) IC that does almost all the functions of CPU.

The basic function of microprocessor is :

(1) To fetch the instructions stored in the main memory

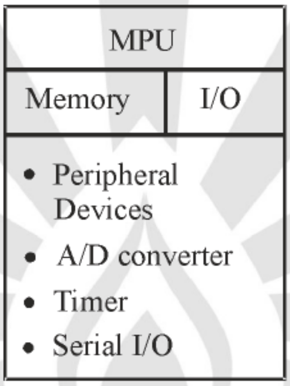
(2) Identify the operations and the devices involved in it.

(3) Generate control signals to determine when a given action is to take place.

(4) A desktop computer, laptop, notebook, palmtop, etc., contain one microprocessor to act as a CPU and hence they come under the category of micro computer.

4. MICROCONTROLLER

A highly integrated chip that contains all the components such as CPU, RAM. Some form of ROM, input-output ports, A/D converter and timers is called Microcontroller or microcontroller unit (MCU).



5. MICROPROCESSOR CHARACTERISTICS

5.1 INSTRUCTION SET :

(1) A Microprocessor communicates and operates in the binary format 0 and 1 called bits.

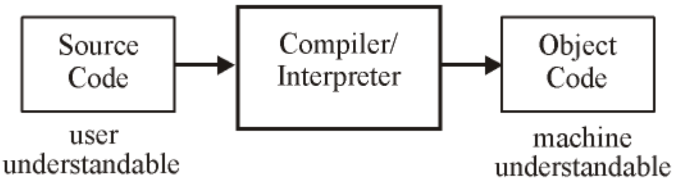
(2) Each microprocessor has a fixed set of instructions in the form of binary pattern called a machine language (platform dependent or machine specific language or low level language)

(3) It is difficult for humans to communicate in the language of 0s and 1s, hence, binary instructions are given abbreviated names, called mnemonics, which form assembly language (platform dependent or machine specific language or low level language)

(4) Assembler is a software. If translation task is performed manually, it is known as hand assembly.

Note: *(1) Compiler reads whole program at once from source code and produces object code that is executed by processor.*

(2) Interpreter. Reads instruction at a time from source code and produces its object code that is executed by processor before reading next instruction from source code.



- **Faster Execution :**

Machine Language > Assembly Language > High Level Language

- **Memory :**

Machine Language < Assembly Language < High Level Language

(Require Large memory to store)

- **Debugging :**

Machine Language < Assembly Language < High Level Language

(Debugging or trouble shooting is faster i.e., to find error)

5.2 BAND WIDTH :

(1) Gordon Moore, cofounder of Intel corporation, predicted that the number of transistors per integrated circuit would double every 18 months i.e., Moore's law.

(2) Currently, processors are designed with 15 million transistors, that can address one Terabyte (1×10^{12}) of memory and can operate at 400 MHz to 1.5 GHz frequency.

5.3 CLOCK SPEED :

(1) The clock speed determines how many operations per second the processor can perform.

(2) Every computer contains an internal clock that regulates the rate at which instructions are executed and synchronizes the various computer components.

(3) Expressed in megahertz (MHz) or gigahertz (GHz), faster the clock, more instructions CPU execute per second.

(4) Microprocessor of personal computer have clock speeds of anywhere from 300 MHz to over 3.8 GHz.

5.4 WORD LENGTH :

(1) It depends upon the width of internal data bus, registers, ALU etc.

(2) Word length is defined as the number of bits the microprocessor recognizes and processes at a time.

6. CISC AND RISC

CISC :- CISC stands for complex instruction set architecture. The CISC approach attempts to minimize the number of instructions per program, instead of number of cycle per instruction.

RISC :- RISC stands for reduced instruction set architecture. The RISC approach attempts to reduce the cycle per instructions per program.

6.1 COMPARISON BETWEEN RISC AND CISC :

Parameter	RISC	CISC
Design	Simple	Complex
Design time	Short	Long
Speed	High	Low
Price	Cheap	Costly
	Single length instruction	Variable length instruction
	Simple operation	Complex operation
	Number of instruction is more	Number of instruction is less
	Tablet, Smartphone etc use RISC	Computer uses CISC

7. WORKING OF MICROPROCESSOR :

(1) The instructions are stored sequentially in the memory.

(2) The microprocessor fetches the first instruction from its memory sheet, decodes it and executes that instruction.

(3) The sequence of fetch, decode and execute is continued until the microprocessor comes across an instruction to stop.

(4) During the entire process, the microprocessor uses the system bus to fetch the binary instruction and data from the memory.

(5) Uses register from teh register section to store data temporarily and performs the computing function in the ALU section.

(6) Using same bus lines, it sends out the result in binary format to the seven segment LED display.

8. MICROPROCESSOR APPLICATIONS

The applications of microprocessors are given below:

(1) Toys Robots, remote-controlled cars, and hand games.

(2) Simple Applications Microwave oven, telephone diallers, smart thermostats, shortwave scanners, and TV remote controls.

(3) Complex Intelligent Product Controllers VCR control and programming, security systems, and lighting system controllers

(4) Computer Peripherals Video Display, higher-speed printers, modems, plotters, and communication controllers.

(5) Industrial Controllers Robotics, processing control, sequence control, and machine tool control.

(6) Instruments Logic analyses, communication analyzers, disk drive testers, digital oscilloscopes, and smart voltmeters.

(7) Communications Data, voice, mobile, electronic switching, and routing.

(8) Automatic Test Equipment Automatic test equipment at all levels from development, fabrication, component testing assemble, PCB, module and system testing.

(9) Electrical Power System Date acquisition, logging, protection, metering, control and processing, automatic control of generators voltage and fuel control of furnaces in a power plant.

(10) Industrial Process Control Instrumentation, monitoring and control, data acquisition, logging and processing.

(11) Household Appliances Cooking ovens, and washing machines.

(12) Medical Electronics Quick patient check up, diagnosis, blood analysis, ECG, etc.

(13) Database Management Word processing, database management and storing information.

❍❍❍

2 CHAPTER

Microprocessor 8085

THEORY

1. INTRODUCTION TO 8085 MICROPROCESSOR

(1) 8085 A is commonly known as 8085 microprocessor.

(2) It is based on **NMOS** technology.

(3) It is **8-bit** microprocessor.

(4) Bit of microprocessor $\rightarrow$ size of ALU (accumulator) is known as bit of microprocessor.

(5) No. of data bits execute in one machine cycle is known as bit of microprocessor.

8 bit	=	Byte
4 bit	=	nibble
2 bit	=	Dit/Dite
210	=	Kilo
220	=	Mega
230	=	Giga

2^{40}	=	Tera
2^{50}	=	Peta
2^{60}	=	Exa
2^{70}	=	Zetta
2^{80}	=	Yotta

Microprocessor	Bit of Microprocessor	Technology
4004	4 bit	PMOS
8008	8 bit	NMOS
8080	8 bit	NMOS
8085	8 bit	NMOS
8085	16 bit	HMOS H- High density channel
8088	8/16 bit	HMOS

(6) 8088-externally 8 bit but internally 16 bit microprocessor.

80186	16 bit	CMOS / Bi CMOS
80286	16 bit	
80386	32 bit	
80486	32 bit	

Pentium	32/64 bit	Bi CMOS
Pentium Pro	32/64 bit	
P – II	64 bit	
P – III	64 bit	
P – IV	64 bit	

(7) 8085 is the advanced version of 8080 microprocessor.

⟶ Backward compatible ⟵ Upward compatibility

Instruction set ≡ Instruction set of 8080 + RIM + SIM

RIM - Read interrupt mask.

SIM - Set interrupt mask.

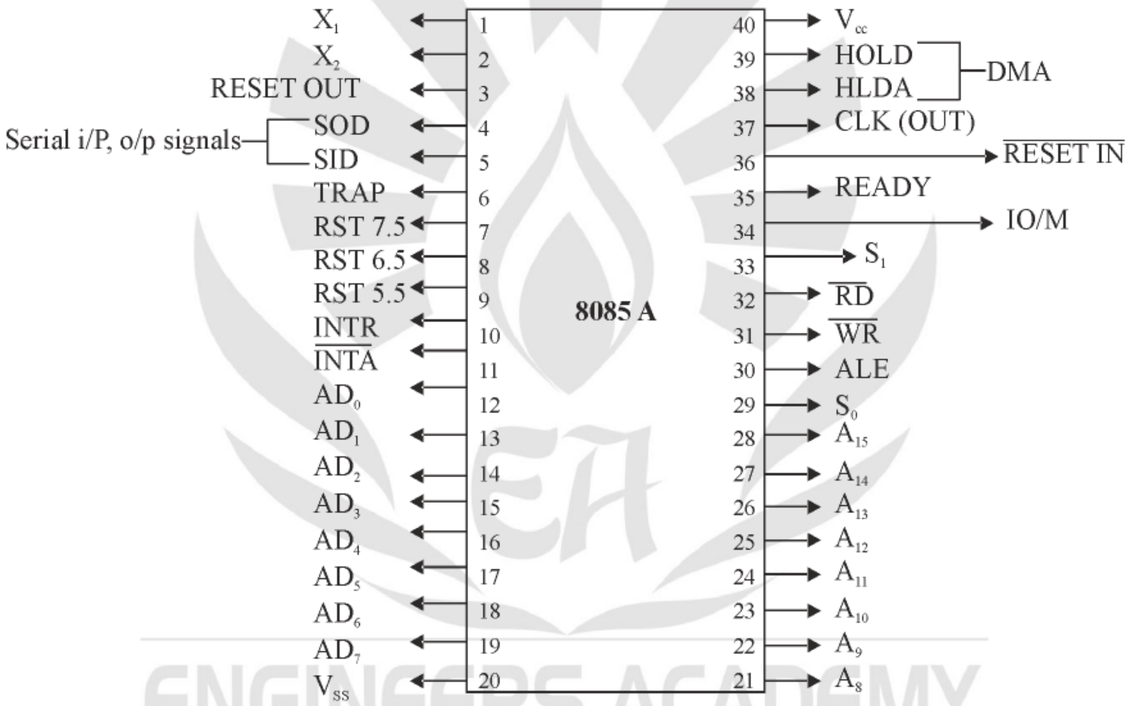
(8) Vcc = + 5V

Operating frequency = 3 MHz = f_{Op}

speed α operating frequency

$$\text{speed} \propto \frac{1}{\text{total time}} \propto \frac{1}{4T} \propto \frac{1}{4/f} \propto f_{Op}$$

2. PIN DIAGRAM OF 8085



3. MEMORY

(1) Program, data and stack memories occupy the same memory space. The total addressable memory size is 64 KB.

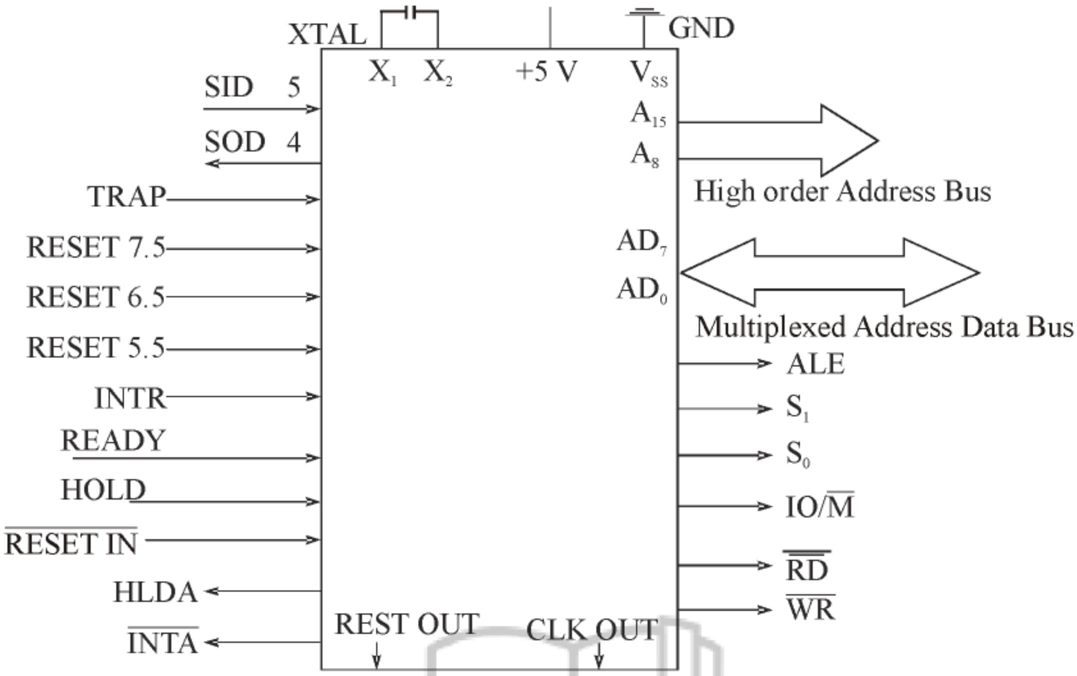
(2) Program memory: program can be located anywhere in memory. Jump, branch and call instructions use 16-bit addresses, i.e. they can be used to jump/branch anywhere within 64 KB. All jump/branch instructions use absolute addressing.

(3) Data memory : The processor always uses 16-bit addresses so that data can be placed anywhere.

(4) Stack memory : It is limited only by the size of memory. Stack grows downward.

(5) First 64 bytes in a zero memory page should be reserved for vectors used by RST instructions.

4. SIGNAL GROUPS OF 8085



5. INTERRUPTS

(1) The processor has 5 interrupts. They are presented below in the order of their priority (from lowest to highest):

(2) **INTR** is maskable 8080 A compatible interrupt. When the interrupt occurs the processor fetches from the bus one instruction, usually one of these instructions:

(3) One of the 8 RST instructions (RST_0 - RST_7). The processor saves current program counter into stack and branches to memory location N * 8 (where N is a 3-bit number from 0 to 7 supplied with the RST instruction).

(4) **CALL** instruction (3 byte instruction). The processor calls the subroutine, address of which is specified in the second and third bytes of the instruction).

(5) **RST5.5** is a maskable interrupt. When this interrupt is received the processor saves the contents of the PC register into stack and branches to 2CH (hexadecimal) address.

(6) **RST 6.5** is a maskable interrupt. When this interrupt is received the processor saves the contents of the PC register into stack and branches to 34H (hexadecimal) address.

(7) **RST 7.5** is a maskable interrupt. When this interrupt is received the processor saves the contents of the PC register into stack and branches to 3CH (hexadecimal) address.

(8) **TRAP** is a non-maskable interrupt. When this interrupt is received the processor saves the contents of the PC register into stack and branches to 24H (hexadecimal) address.

(9) All maskable interrupts can be enabled or disabled using EI and DI instructions. RST 5.5, RST 6.5 and RST 7.5 interrupts can be enabled or disabled individually using SIM instruction.

6. RESET SIGNALS

6.1 RESET IN:

When this signal goes low, the program counter (PC) is set to zero, microprocessor is reset and resets the interrupt enable and HLDA flip-flops.

(a) The data and address buses and the control lines are 3-stated during RESET and because of asynchronous nature of RESET, the processor internal registers and flags may be altered by RESET with unpredictable results.

(b) RESET IN is a Schmitt-triggered input, allowing connection to an R-C network for power-on RESET delay.

(c) Upon power-up, RESET IN must remain low for at least 10 ms after minimum V_{CC} has been reached.

(d) For proper reset operation after the power-up duration, RESET IN should be kept low a minimum of three clock periods.

(e) The CPU is held in the reset condition as long as RESET IN is applied. Typical Power-on RESET RC values $R_1 = 75k\Omega$, $C_1 = 1\mu F$.

6.2 RESET OUT:

This signal indicates that microprocessor is being reset. This signal can be used to reset other devices. The signal is synchronized to the processor clock and lasts an integral number of clock periods.

7. SERIAL COMMUNICATION SIGNAL

7.1 SID- SERIAL INPUT DATA LINE:

The data on this line is loaded into accumulator bit 7 whenever a RIM instruction is executed.

7.2 SOD-SERIAL OUTPUT DATA LINE:

The SIM instruction loads the value of bit 7 of the accumulator into SOD latch if bit 6 (SOE) of the accumulator is 1.

8. DMA SIGNALS

8.1 HOLD:

Indicates that another master is requesting the use of the address and data buses. The CPU, upon receiving the hold request, will relinquish the use of the bus as soon as the completion of the current bus transfer.

(a) Internal processing can continue. The processor can regain the bus only after the HOLD is removed.

(b) When the HOLD is acknowledged, the Address, Data RD, WR and Input output /Memory ($IO/\overline{M}$) lines are 3-stated

8.2 HLDA: Hold Acknowledge:

Indicates that the CPU has received the HOLD request and that it will relinquish the bus in the next clock cycle.

HLDA goes low after the Hold request is removed. The CPU takes the bus one half-clock cycle after HLDA goes low.

8.3 READY:

This signal Synchronizes the fast CPU and the slow memory, peripherals.

(a) If READY is high during a read or write cycle, it indicates that the memory or peripheral is ready to send or receive data.

(b) If READY is high during a read or write cycle, it indicates that the memory or peripheral is ready to send or receive data.

(c) If READY is low, the CPU will wait an integral number of clock cycle for READY to go high before completing the read or write cycle.

9. REGISTERS

(1) Accumulator or A register is an 8-bit register used for arithmetic, logic, input-output and load/store operations.

(2) Flag Register has five 1-bit flags.

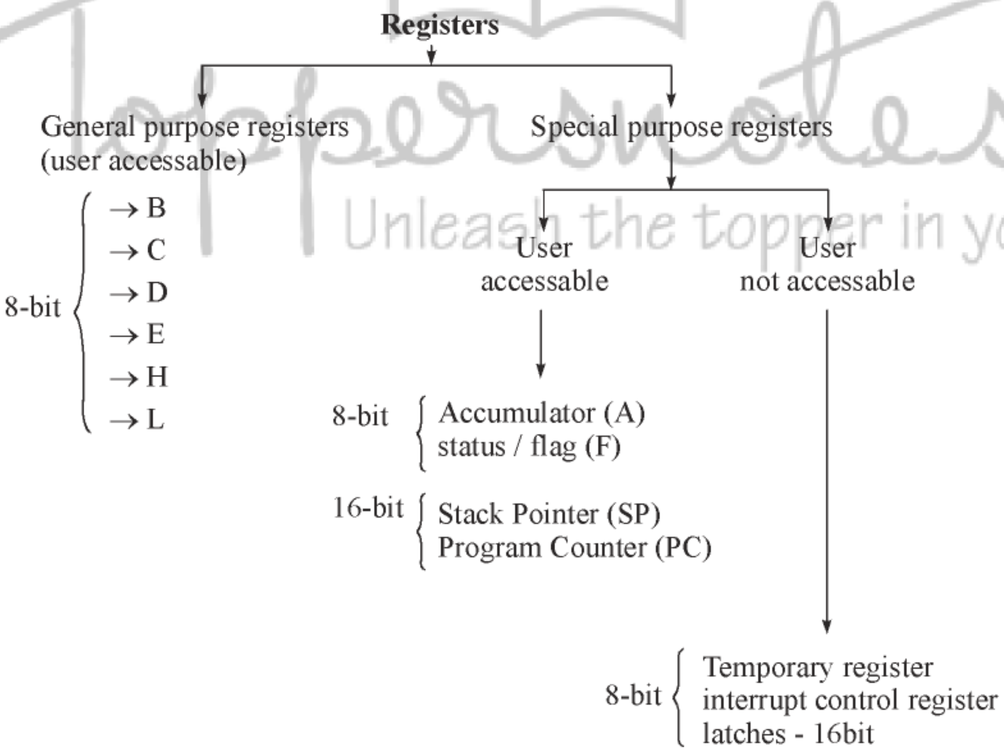
(a) **Sign**-set if the most significant bit of the result is set.

(b) **Zero**-set if the result is zero.

(c) **Auxiliary carry**-set if there was a carry out from bit 3 to bit 4 of the result.

(d) **Parity** - set if the parity (the number of set bits in the result) is even.

(e) **Carry**-set if there was a carry during addition, or borrow during subtraction/comparison/rotation.



10. GENERAL REGISTERS

(1) 8-bit B and 8-bit C registers can be used as one 16-bit BC register pair. When used as a pair the C register contains low-order byte. Some instructions may use BC register as a data pointer.

(2) 8-bit D and 8-bit E register can be used as one 16-bit DE register pair. When used as a pair the E register contains low-order byte. Some instructions may use DE register as a data pointer.

(3) 8-bit H and 8-bit L registers can be used as one 16-bit HL register pair. When used as a pair the L register contains low-order byte. HL register usually contains a data pointer used to reference memory addresses.

(4) Stack pointer is a 16 bit register. This register is always decremented/incremented by 2 during push and pop.

(5) Program counter is a 16-bit register.

11. INSTRUCTION SET

8085 instruction set consists of the following instructions:

(1) Data moving instructions.

(2) Arithmetic- add, subtract, increment and decrement.

(3) Logic - AND, OR, XOR and rotate.

(4) Control transfer-conditional, unconditional, call subroutine, return from subroutine and restarts.

(5) Input/Output instructions.

(6) Other-setting/ clearing flag bits, enabling/disabling interrupts, stack operations etc.

12. ADDRESSING MODE

(1) Register-references the data in a register or a register pair.

(2) Register indirect - instruction specifies register pair containing address, where the data is located.

(3) Direct, Immediate-8 or 16-bit data.

13. CONTROL AND STATUS SIGNALS

Microprocessor 8085 has 2 control signals RD and WR , three status signals (IO/M, S_o and S_1) and one special purpose signal (ALE)

13.1. ALE (ADDRESS LATCH ENABLE):

It is positive going pulse generated every time when the microprocessor begins with an operation of reading or writing the data on memory or IO devices. When the signal on this pin is high the lower order address bus carries the lower order address and when the signal is low the lower order address bus carries the 8 bit data. The signal is primarily used to latch the low-order address from the multiplexed bus and generate a separate set of address lines, A_7 -A_0.

13.2. RD (READ):

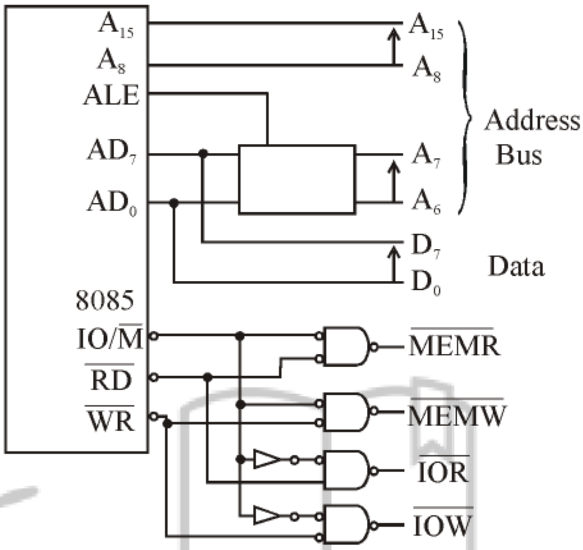
It is active low signal. When signal on this pin is low the reading operation is performed with memory or I/O device.

13.3. WR (WRITE)*:*

It is active low signal. When the signal on the pin is low the write operation is performed with memory or I/O devices.

13.4. IO / M:

When signal on this pin is high the reading and writing operation is performed with I/O devices and when it is low the reading and writing operation is performed with memory.



8085 Demultiplexed Address and Data Bus with control signals

13.5. S_0 AND S_1:

These are the status signals of 8085 which indicates the status of operation being performed by microprocessor.

Note:- *No. of control signals = 2 (*$\overline{RD}$ *and* $\overline{WR}$*). No. of status signals = 3 (IO/M ,* S_0 *&* S_1 *)*

Operation	IO/$\overline{M}$	S_1	S_2	Control Signal
Op code fetch	0	1	1	$\overline{RD}$ = 0
Memory read	0	1	0	$\overline{RD}$ = 0
Memory write	0	0	1	$\overline{WR}$ = 0
IO Read	1	1	0	$\overline{RD}$ = 0
IO Write	1	0	1	$\overline{WR}$ = 0
Interrupt Acknowledge	1	1	1	$\overline{INTA}$ = 0
Halt	Z	0	0	$\overline{RD}$ = Z
Hold	Z	X	X	$\overline{WR}$ = Z
Reset	Z	X	X	$\overline{INTA}$ = 1

Note: *Z = Tristate or high impedance state*

X = Unspecified

Tri-state logic devices have three states: logic 1, logic 0, and high impedance.

14. POWER SUPPLY AND CLOCK SIGNAL

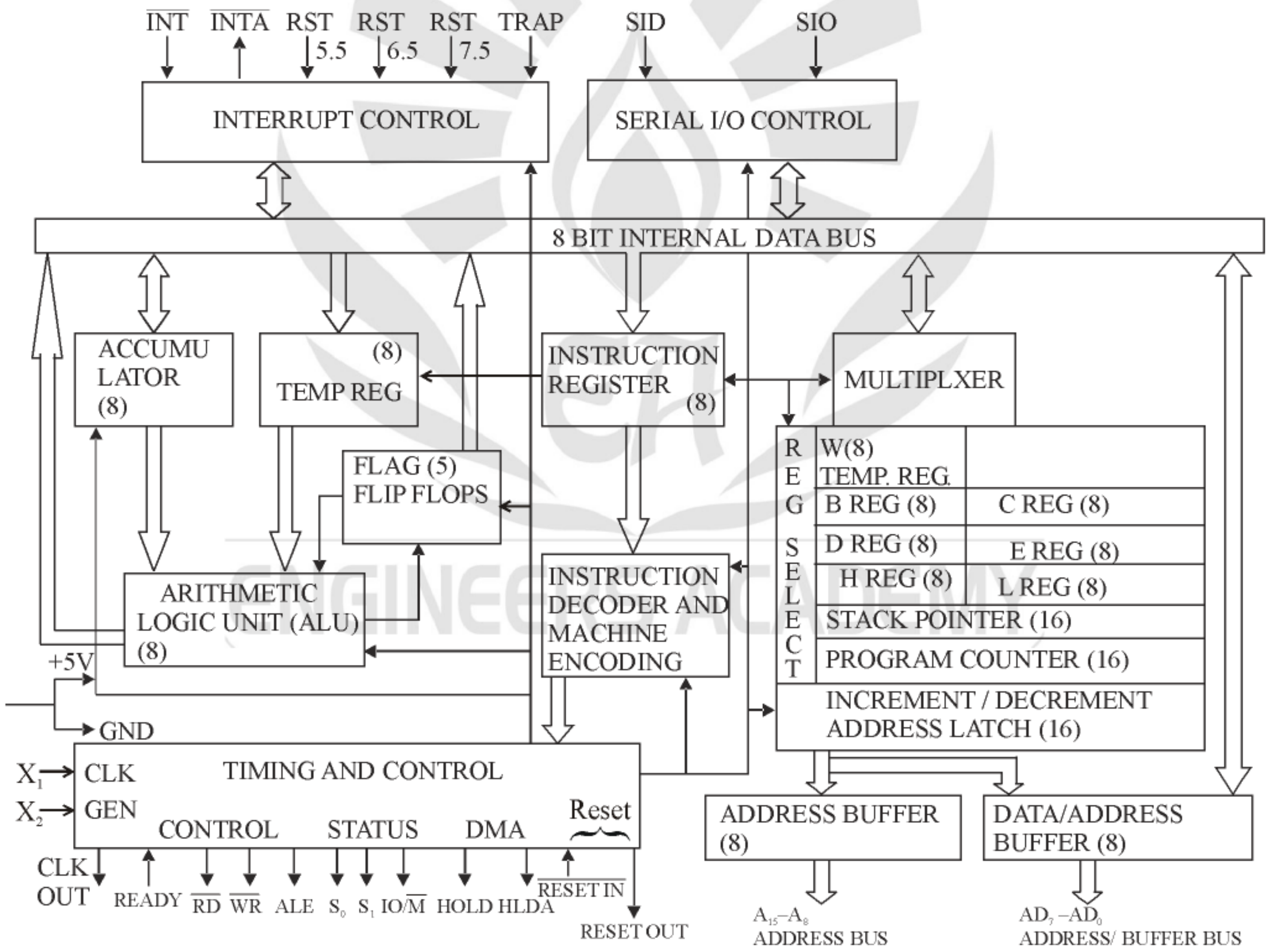
(1) V_{CC} : A power supply of+5 V.

(2) V_{SS} : Ground reference.

(3) X_1 and X_2: A crystal oscillator is connected between X, and X_2. The frequency of crystal oscillator is divided by 2 internally therefore for 3 MHz operation a crystal of 6MHz should be used.

(4) CLK (OUT): The signal on this pin can be used as the system clock for the peripherals to synchronize their operation with the microprocessor.

15. BLOCK DIAGRAM OF 8085



16. FLAG REGISTERS

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
S	Z		AC		P		CY

17. GENERAL PURPOSE REGISTERS

INDIVIDUAL	B	C	D	E	H	L
COMBINATION	B & C		D & E		H & L	

18. ARCHITECTURE OF 8085 CONSISTS OF FOLLOWING COMPONENTS,

(1) Arithmetic and Logic Unit (ALU): ALU consists of

- (a) Accumulator
- (b) Temporary register
- (c) Arithmetic & Logical Circuit
- (d) Flags

(2) Register Array

(3) Timing and Control Unit.

(4) Instruction Register and Instruction Decoder.

(5) Interrupt Controller.

(6) Serial I/O Ports.

18.1 ARITHMETIC AND LOGIC UNIT (ALU)

This unit includes the accumulator, the temporary register, the arithmetic and logic circuits, and five flags.

(a) Accumulator

It is an 8 bit programmable register of 8085. All the arithmetic and logical operations are performed with the contents of accumulator and the results are stored in accumulator only.

(b) Temporary Register

It is an 8 bit non-programmable register used to store 8 bit data temporarily during an arithmetic or logical operation. This register is not accessible to the programmer.

(c) Arithmetic and Logic Circuit

This unit performs all the arithmetic and logical operations on the data coming from accumulator and temporary register.

18.2 FLAGS

8085 has five flags which reflect the status of arithmetic and logical operations performed on the content of accumulator with some exceptions.

The different flags are as follows:

(i) Sign Flag (S)

This flag is used for operation on signed numbers. It is set when the result of an arithmetic operation is a negative number. The flag is affected by D_7 bit of result (usually in accumulator). The Sign Flag is set when D_7 bit is' 1' and reset when D_7 bit is '0'. The flag is affected by D_7 bit even if operation is on unsigned number but it is irrelevant for operation on unsigned numbers.

(ii) Zero Flag (Z)

This flag is set when the result of an arithmetic or logical operation is zero. This flag is affected by results in accumulator as well as in the other registers.

(iii) Carry Flag (CY)

Carry flag is set when carry is generated during an arithmetic operation. It works as a borrow flag during subtraction.

(iv) Auxiliary Carry (AC)

This flag is set when a carry is generated during the addition of D_3 bits of two numbers and passed to D_4 bit. Auxiliary carry is not available to the programmer for change of sequence of program with jump instruction rather it is used by microprocessor internally during a BCD operation.

(v) Parity Flag (P)

Parity flag is set when the result of an arithmetic or logical operation has even parity and it is reset if result carries odd parity. ***Locations of different flags in flag register :***

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
S	Z		AC		P		CY

Flag Register

***Note** : The values of D_1, D_3, and D_5 bits should be taken as '0' in programs while using PSW instruction.*

18.3 REGISTER ARRAY

Microprocessor 8085 consists of six general purpose 8 bit programmable registers called , B, C, D,E, H and L. These registers can be used in pairs as BC, DE and HL for 16 bit operations. There are two 8 bit non-programmable temporary registers called W and Z. This register pair is used to store the 16 bit data / address temporarily during the execution of some instructions. W and Z are not accessible to the programmer. There are 2 special purpose 16 bit programmable registers called stack pointer (SP) and program counter (PC).

***(i) Program Counter(PC)**:*

The program counter is used to store the 16 bit address of the next byte to be fetched from the memory or address of next instruction to be executed. It is incremented automatically after the fetching each byte from the memory.

(ii) Stack Pointer(SP):

The SP is a 16 bit programmable register which is used to store the address of top of the stack. The stack is the group of memory locations used to store the data temporarily during execution of a program. Stack pointer is decremented by two after execution of each PUSH instruction and incremented by two after execution of each POP instruction. The stack pointer is initiated by the programmer using instruction LXI SP, 16 bit address.

18.4 TIMING AND CONTROL UNIT

This unit synchronizes all operations of microprocessor with clock and generates control signals necessary for communication between the microprocessor and peripherals.

18.5 INSTRUCTION REGISTER AND INSTRUCTION DECODER

(i) Instruction Register:

This is an 8 bit non-programmable register used to store an 8 bit instruction code when Opcode is fetched from the memory.

(ii) Instruction Decoder:

The instruction decoder decodes the instruction codes and establishes the sequence of events to follow. Both instruction register and decoder are part of ALU.

18.6 INTERRUPT CONTROLLER

This unit accepts the different interrupts and generates the interrupt acknowledgment if required.

18.7 SERIAL I/O PORTS

This unit communicates the data serially between microprocessor and peripherals.

19. SUMMARY OF 8085 MICROPROCESSOR

Parameters	8085
Power supply	+5 V
Functional microprocessor	One 8085 IC with latch and gates
Clock pulse	One φ
Clock frequency	3 MHz
Address bus	16-bit address lines lower-order address bus is multiplexed with data bus
Data bus	8-bit data lines
Interrupt	Five lines
Extra features	Serial I/O lines
Statue	The lines S_0, S_1 and IO/M
Instruction set	74 instructions

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