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Railway Recruitment Board

Junior Engineer Examination

Electronics Engineering

Microprocessors and Microcontroller

Well Illustrated **Theory** *with*

Solved Examples and **Practice Questions**

Microprocessors and Microcontroller

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Chapter 1

Introduction to 8085 Microprocessor

1.1 Introduction

The most important technological invention of modern times is the "microprocessor". A microprocessor is a multiple purpose programmable clock driven, register based electronic device that reads binary instructions from memory, accepts binary data as input and processing this data according to the instructions written in the memory. The microprocessor is capable of performing computing functions and making decisions to change the sequence of program execution. The microprocessor can be embedded in a larger system, and can function as the CPU of a computer called a microcomputer.

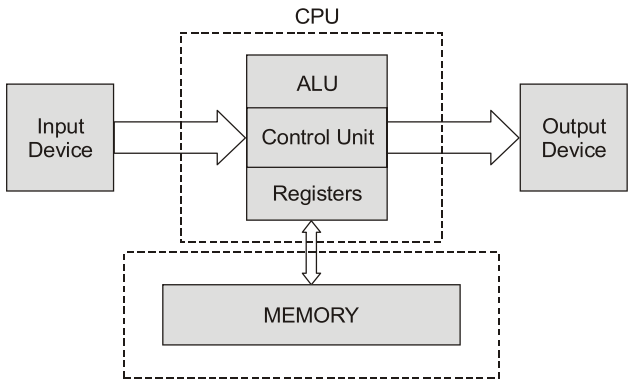


Figure-1.1 : *Block diagram of microcomputer*

The Figure 1.1 shows the basic block diagram of a microcomputer which processes binary data and traditionally represented by four blocks i.e. CPU, memory, input device and output device.

Here, input device is a device that transfers information from outside world to the computer for example: Key board, mouse, webcam, microphone, scanner, electronic white boards, etc. The output device transfers information from computer to the outside world like monitor, printers (all types), speakers, headphones, projector, plotter, Braille embosser, LCD projection panel, computer output microfilm (COM) etc. Memory is an electronic medium that stores binary information.

Central Processing Unit (CPU) is the heart of computer systems. The microprocessors in any microcomputer act as a CPU. The CPU can be made up with ALU + CU + Registers, where ALU is the group of circuits that perform arithmetic and logical operations. Control Unit (CU) is a group of circuits that provide timings and signals to all the operations in the computer and controls the data flow.

Microcontroller is a programmable device that includes microprocessor, memory and I/O signal lines on a single chip, fabricated using VLSI technology. Microcontrollers are also known as single chip microcomputers. They are mostly used to perform dedicated functions such as automatic control of equipment, machines and process in industries and consumer appliances.

System Bus

A bus is a group of wires/lines used to transfer data (bits) between components inside a computer or between computers. In most simple form, they are communication path used to carry the signals between microprocessor and peripherals.

The system bus of a microprocessor is of three types:

1. **Address Bus**
   - It is a group of lines that are used to send a memory address or a device address from the Microprocessor Unit (MPU) to the memory or the peripheral.
   - The address bus is always uni-directional i.e address always goes out of the microprocessor.
   - If the number of address lines is 'n' for a MPU then its addressing capacity is 2^n.
2. **Data Bus**
   - It is group of lines used to transfer data between the microprocessor and peripherals and/or memory.
   - Data bus is always bi-directional.
3. **Control Bus**
   - Control bus provides signals to control the flow of data.

DO YOU KNOW:

The internal architecture of the microprocessor unit depends on the data bus width, which is equal to the bit-capacity of the microprocessor.

1.2 History of Microprocessors

A brief review of certain microprocessors were given in the Table 1.1. Intel introduced its first 4-bit PMOS microprocessor 4004 in the year 1971. It has 16 pins, 640-bytes of memory addressing capability and 10 address lines. After this enhanced version of 4004, a 4-bit, Intel 4040 was developed. In 1972, Intel introduced its first 8-bit processor Intel 8008, which also uses PMOS technology. The PMOS technology processors were slow and not compatible with TTL logic. These microprocessors could not survive as general purpose microprocessor due to design limitations. In 1974, Intel introduced its more powerful and faster 8 bit NMOS microprocessor Intel 8080. These processors were faster and compatible with TTL logic. Intel 8085 followed 8080 microprocessor. The main limitations of 8 bit microprocessors tempted the designers to go for more powerful processors in terms of advanced architecture, more processing capability, larger memory addressing capability and more powerful instruction set. The Intel 8086 was the result, launched in 1978 . The technology used was HMOS, high speed and high performance MOS technology.

Microprocessor	Word length	Memory capacity
Intel 4004 (PMOS)	4-bit	640 B
Intel 8008	8-bit	16 kB
Intel 8080 (NMOS)	8-bit	64 kB
Intel 8085 (NMOS)	8-bit	64 kB
Intel 8086 (HMOS)	16-bit	1 MB
Intel 8088	8/16-bit	1 MB
Intel 80186	16-bit	1 MB
Intel 80286	16-bit	16 MB real, 4 GB virtual
Intel 80386	32-bit	4 GB real, 4 GB virtual
Intel 80486	32-bit	4 GB real, 64 TB virtual
Pentium-II	64-bit	64 GB real
Z-80	8-bit	64 kB
Z-800	8-bit	500 kB

Table 1.1 : *A brief review of various microprocessors*

NOTE:

Most of the general purpose microprocessors used in the modern world computers are the family of 8086.

1.3 Computer Language

- Scale of integration:
  - **SSI (Small Scale Integration):** The term refers to the technology used to fabricate discrete logic gates on a chip.
  - **MSI (Medium Scale Integration):** The process of designing few tens of gates on a single chip.
  - **LSI (Large Scale Integration):** The process of designing hundreds of gates on a single chip similarly terms VLSI (very large scale integration), ULSI (ultra large scale integration) are used to indicate the scale of integration.
- **Digital computer:** A programmable machine that processes binary data. It is traditionally represented by five components: CPU, ALU, CU, memory, input and output.
- **Instruction:** a command in binary that is recognized and executed by the computer in order to accomplish a task. Some instructions are designed with one word, and some require multiple words.
- **Mnemonic:** a combination of letters to suggest the operation of an instruction.
- **Program:** a set of instructions written in a specific sequence for the computer to accomplish a given task.
- **Machine Language:** the binary medium of communication with a computer through a designed set of instructions specific to each computer.
- **Assembly Language:** a medium of communication with a computer in which programs are written in mnemonics. An assembly language is specific to a given computer.
- **Low-Level Language:** a medium of communication that is machine-dependent or specific to a given computer. The machine and the assembly languages of a computer are considered low-level languages. Programs written in these languages are not transferrable to different types of machines.
- **High-Level Language:** a medium of communication that is independent of a given computer. Programs are written in English-like words, and they can be executed on a machine using a written translator (a compiler or an interpreter).
- **Compiler:** a program that translates English-like words of a high-level language into the machine language of a computer. A compiler reads a given program, called a source code, in its entirety, and then translates the program into the machine language which is called an object code. (Ex. *C*, *C*++)
- **Interpreter:** a program that translates the English-like statements of a high-level language into the machine language of a computer. An interpreter translates one statement at a time from a source code to an object code. (Ex. BASIC)
- **Assembler:** a computer program that translates an assembly language program from mnemonics to the binary machine code of a computer and these machine codes are called object programme .
  Difference between compiler and interpreter: Interpreter reads one line at a time, converts it into object code, executes and then reads next line. Whereas compiler reads whole program at a time and convert it into the object code and then execute.
- **Bit:** a binary digit, 0 or 1.
- **Byte:** a group of eight bits.
- **Nibble:** a group of four bits.
- **Word:** a group of byte the computer recognizes and processes at a time.

Example - 1.1 Machine instructions are written using which of the following?

(a) Bits 0 and 1 only
(b) Digits 0 and 9 only
(c) Digits 0 and 9 and the capital alphabets *A* to *Z* only
(d) Digits 0 to 9, the capital alphabets *A* to *Z* and certain special characters

Solution : (a)

Machine instructions are written using bits 0 and 1 only.

Example - 1.2 Output of the assembler in machine code is referred to as

(a) Object program
(b) Source program
(c) Macroinstruction
(d) Symbolic addressing

Solution : (a)

Output of the assembler in machine code is referred to as object program.

Example - 1.3 Which one of the following statements is correct?

A micro-controller differs from a microprocessor it has
(a) Both on-chip memory and on-chip ports
(b) Only on-chip memory but not on-chip ports
(c) Only on-chip ports but not on-chip memory
(d) Neither on-chip memory nor on-chip ports

Solution : (a)

A micro-controller differs from a microprocessor in that has both on-chip memory and on-chip ports.

Example - 1.4 Assertion (A): Many programmers prefer assembly level programming to machine language programming.

Reason (R): It is possible to efficiently utilize the hardware of the computer in machine language programming.
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not a correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

Solution : (b)

Many programmers prefer assembly level programing to machine language programming because assembly language is simple and easily understandable. So assertion is true. Also it is possible to efficiently utilize the hardware of the computer in machine language programming because the machine language is directly understood by microprocessor.

Application of Microprocessors

A few more applications of microprocessors are mentioned below:

- A microprocessor based stepping motor controller used for controlling several stepping motors in a pulsed Laser system. The motors are used to precisely align a set of mirrors used in this system.
- There are several other motor control applications reported in the literature, Lin (1977) describes one approach to motor speed control using an SCR chopper.

- A microprocessor controlled Railways Signalling Inter lock was developed to exhibit the applications of microprocessors in signalling. The system mirrors train positions in different blocks on a section and sends speed codes to each block. The speed codes are displayed and used by train drivers to control the speed.
- A patient surveillance system was designed using distributed processing.
- Microprocessors have been used in a variety of automation applications. Control of tester for surveillance checking the electronic functioning capability of a target detecting device (Frantz, 1977) is one of these. A microprocessor based blood gas analyzer has been developed by Margalith et al. (1977).

1.4 Microprocessor Architecture

The process of data manipulation and communication is determined by the logic design of microprocessor, called the "Architecture". There are two types of architecture depending upon storage of program and data in memory:

- Von Neumann architecture of computers
- Harvard architecture of computers

Von Neumann Architecture

The idea of basic organization of a digital computer containing a CPU, a main memory, input and output device and secondary storage devices was given by John von Neumann in 1945. He introduced the "stored – program concept"-where the programs and data are stored in the same high speed memory unit. In Von Neumann architecture there is a program counter and instructions are executed in sequential manner. The MPU fetches one instruction of the program and executes it, then it goes to the next instruction. The speed of computer is limited by the speed at which the MPU can fetch the instructions and data from the memory and process them. Digital computers based on this principle are called control-flow or control driven computers.

Examples: Intel 8085 and Intel 8086

Harvard Architecture

The enhanced version of Von Neumann architecture is the Harvard architecture. It contains separate instruction memory and data memory. The instruction memory and data memory in Harvard architecture have separate data path , that eliminated the speed limitation of single bus architecture in a Von Neumann processor.

Examples: TMS 32010, Intel 8051, Intel's Pentium. etc.

1.5 The 8085 Microprocessor Pins and Signals

The 8085A (8085) is an 8-bit microprocessor. The device has 40 pins, requires a +5 V single power supply, and can operate with a 3 MHz single-phase clock frequency. The 8085 is an advance version of 8080A. Its instruction set is compatible with that of the 8080A, it means that 8085A instruction set includes all the instruction of 8080A with some additional instructions.

Figure 1.2 (a) and (b) shows the 8085 pinout and simplified pinout of 8085 respectively.

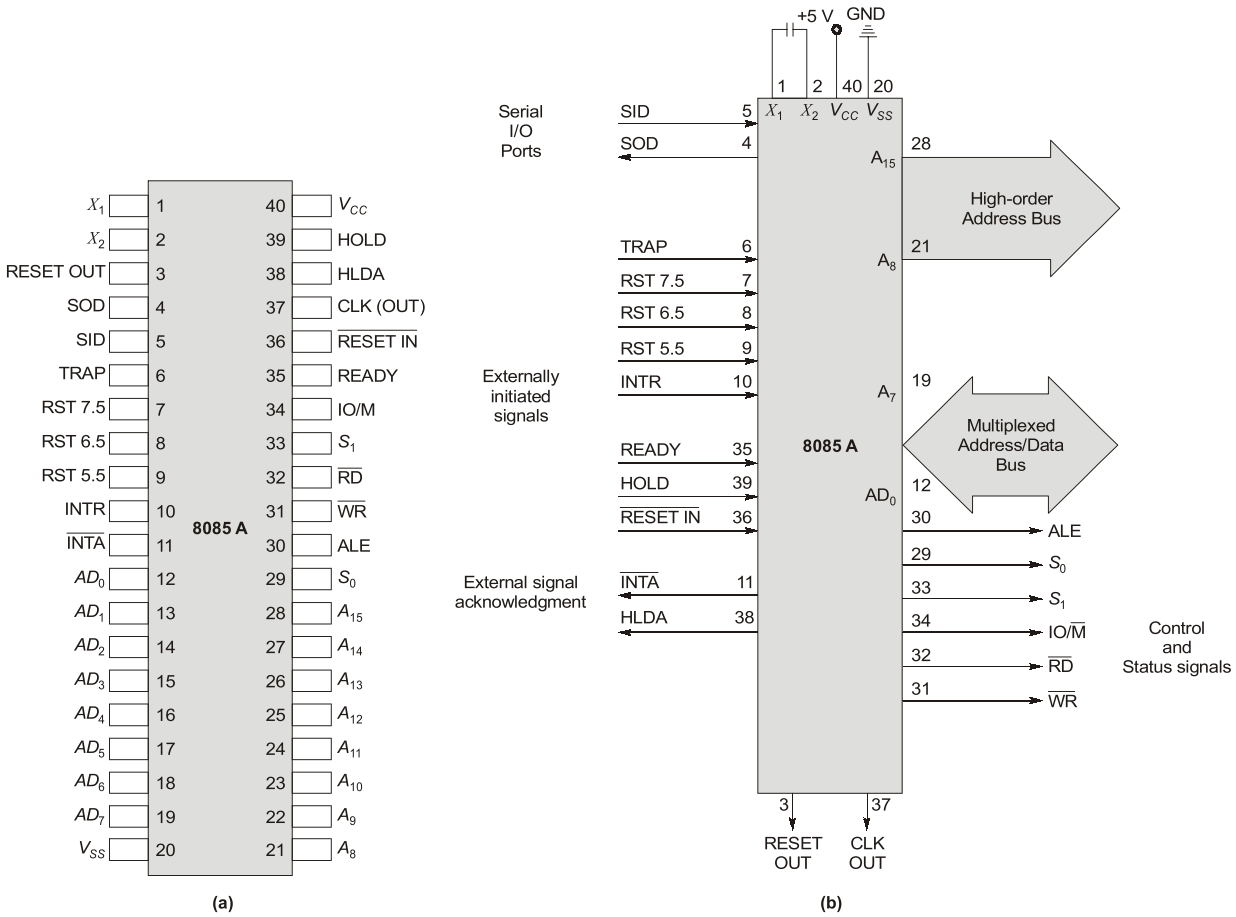


Figure-1.2 : **8085 Pinout**

Key Points of Microprocessors 8085

- It is manufactured using NMOS technology.
- It is upward compatible with 8080A.
- It is a 40 pin DIP (Dual in line Package) chip.
- It is a 8-bit processor.
- It has total 16 address lines with addressing capacity of 64 KB.
- It has 8 data bus lines which is the bit capacity of the microprocessor.
- Internal architecture of the 8085 depends on the bit capacity.
- Serial data transfer facility is provided by 8085 MPU.
- Low order address bus (AD_0 – AD_7) is multiplexed with data bus.
- High order address bus is not multiplexed with any other lines.
- Advantage of multiplexing lower order address with data lines is that the number of pins are reduced.
- To de-multiplex address from data ALE (Address Latch Enable) signal is used.
  ALE = 1, Address transfer to bus.
  ALE = 0, Data transfer to bus.
- Disadvantage of multiplexing is that speed will be reduced.
- It has on chip clock generation facility.
- It requires +5 V power supply for its operation.

- Only one ground pin is present.
- There are five hardware interrupts available for 8085.
- The crystal frequency of processor is 6 MHz and the clock frequency is 3.07 MHz (~3 MHz), which is approximately half the crystal frequency.
- The word length or bit capacity is 8.
- 8085 has 74 basic instructions with 246 opcodes.

Signals of 8085 Microprocessors

According to the above figure all the signals can be classified into six groups:

1. Address Bus signals
2. Data Bus signals
3. Control and Status signals
4. Power supply and frequency signals
5. Serial I/O ports
6. Externally initiated signals

Address Bus/Data Bus Signals

Address Bus Signals:

- Control pins: Pin 21 to 28.
- It is 16 bits in length.
- It is unidirectional bus.
- It is divided into two parts namely,
  Lower order address bus (AD_0 - AD_7) → also called "Line number".
  Higher order address bus (A_8 - A_{15}) → also called "Page Number".

Multiplexed Address/Data Bus Signals:

- Control pins: Pin 12 to 19.
- Its length is in 8-bit.
- It is a bidirectional bus.
- It is multiplexed with lower order address bus with lines (AD_0 - AD_7).
- To reducing the number of pins in microprocessor, databus is "Time Division Multiplexed" with address bus.

Control and Status Signals

Microprocessor 8085 has two control signals $\overline{RD}$ and $\overline{WR}$, three status signals IO/$\overline{M}$, S_1 and S_0 and one special purpose signal ALE.

- Control pins: pin31 and pin32
- Control signals: $\overline{WR}$ and $\overline{RD}$
- Status pins: pin34, pin33 and pin29
- Status signals: IO/$\overline{M}$, S_1 and S_0

$\overline{RD}$ (Read): It is an active low signal. When the signal is low on this pin, the microprocessor performs memory reading or I/O reading operation.

$\overline{WR}$ (Write): It is an active low signal. When the signal is low on this pin, the microprocessor performs memory writing or I/O writing operation.

IO/$\overline{M}$:

- This is the status signal used to differentiate between I/O and memory operations.
- When it is **HIGH** → an I/O operation performed.
- When it is **LOW** → a memory operation performed.

IO/$\overline{M}$	$\overline{RD}$	$\overline{WR}$	Description
0	0	1	Memory Read ($\overline{MEMR}$)
0	1	0	Memory Write ($\overline{MEMW}$)
1	0	1	IO Read ($\overline{IOR}$)
1	1	0	IO Write ($\overline{IOW}$)

Table-1.2 : ***Memory or IO operations based on Control Signals***

S_1 and S_0: These two status signals, similar to IO/$\overline{M}$, which can identify various operations based on the combinations of S_1 and S_0.

S_1	S_0	Microprocessor Operation
0	0	Halt (no operation)
0	1	Write operation
1	0	Read operation
1	1	Opcode fetch (Reading instruction)

Table-1.3 : ***Processor operation based on status pins S_1 and S_0***

Machine Cycle	Status			Control signals
	IO/$\overline{M}$	S_1	S_0	
Opcode Fetch	0	1	1	$\overline{RD}$ = 0
Memory Read	0	1	0	$\overline{RD}$ = 0
Memory Write	0	0	1	$\overline{WR}$ = 0
I/O Read	1	1	0	$\overline{RD}$ = 0
I/O Write	1	0	1	$\overline{WR}$ = 0
Interrupt Acknowledge	1	1	1	$\overline{INTA}$ = 0
Halt	X	0	0	

Table-1.4

ALE (Address Latch Enable): It is a special signal used to demultiplex the address bus and data bus. This is a positive going pulse generated every time the processor begins an operation (machine cycle) to latch the low-order address from the multiplexed bus and generate a separate set of eight address lines

Example - 1.5 If the status of the control lines S_1 and S_0 is LOW, then 8085 microprocessor is performing:

(a) Reset operation
(b) HOLD operation
(c) Halt operation
(d) Interrupt acknowledge

Solution : (c)

Power Supply and Frequency Signals

- Power supply: pin 40 (V_{CC})
- Frequency signals: pins 1 and 2 (X_1 and X_2)
- Ground: pin 20 (V_{ss})
- V_{CC}: Microprocessor unit is energized by a single battery supply of +5 V given through pin 40
- V_{ss}: Ground reference
- X_1 and X_2: A crystal (or *RC*, *LC* network) is connected at these two pins. The frequency is internally divided by two; therefore, to operate a system at 3 MHz, the crystal should have a frequency of 6 MHz.

Serial I/O Ports

- It is used to provide serial interface between microprocessor and other devices like as PEN drive etc.
- It contains two signals to implement the serial transmission.
  1. **SID (Serial Input Data) :** This pin is used for receiving the data into microprocessor serially. The data is read into D_7 bit of accumulator.
  2. **SOD (Serial Output Data) :** This pin is used for sending the data from the microprocessor serially. The data is sent from D_7 bit of accumulator to the peripheral.

Externally Initiated Signals

These are the signals that are generated outside and are received by the processor. These are:

1. Hardware interrupts
2. READY
3. $\overline{\text{RESET IN}}$
4. HOLD and HLDA

1. Hardware Interrupts

The 8085 microprocessor has 5 interrupt signals that can be used to interrupt a programme execution.

- It is also used to accept external interrupts to provide acknowledgment (ACK) to the external device.

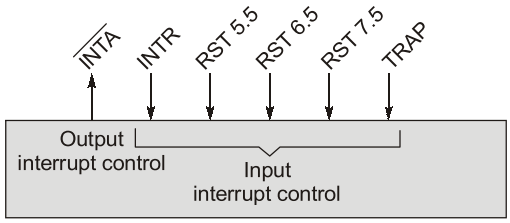


Figure-1.3

- Here TRAP, RST-7.5, RST-6.5, RST-5.5, INTR are called Hardware interrupts.

TRAP:

- It has highest priority.
- It is the only non-maskable interrupt.
- It is a vectored interrupt.
- Also called RST-4.5.
- This is both edge and level triggered signal.
- Its vector address = $(0024)_H$

NOTE:

Trick : Since it is a RST - 4.5.

So, $4.5 \times 8 = 36 \xrightarrow{\text{Heaxadecimal}} (24)_H \text{ » } (0024)_H$

RST-7.5:

- It has 2nd highest priority.
- It is a maskable interrupt.
- It is a vectored interrupt.
- It is edge triggered only.
- Its vectored address = $(003C)_H$

RST-6.5:

- It has 3rd highest priority.
- It is a maskable interrupt.
- It is a vectored interrupt.
- It is a level triggered.
- It vectored address = $(0034)_H$

RST-5.5:

- It has 4th highest priority.
- It is a maskable interrupt.
- It is a vectored interrupt.
- It is a level triggered.
- Its vectored address = $(002C)_H$

INTR:

- It is abbreviated as interrupt request.
- It is used as general purpose interrupt.
- It has least or 5th priority.
- It is a non-vectored interrupt.
- Address is provided by user of external device.
- It is a level triggered signal.

$\overline{\text{INTA}}$:

- It is abbreviated as interrupt acknowledge.
- It is an output signal.

REMEMBER:

In priority order, interrupts are as, TRAP > RST-7.5 > RST-6.5 > RST-5.5 > INTR

2. READY

- It is used to interface the slow peripheral devices (memory or I/O devices) to the microprocessor.
- In other words, we can say, it is used to delay the microprocessor read or write cycles until a slow responding peripheral is ready to send or accept data.
- When READY signal goes LOW, the microprocessor waits for an integral number of clock cycles until it goes HIGH.

3. RESET

$\overline{\text{RESET IN}}$:

This is an active low signal, when the pin 36 goes low the signal gets activated and program counter is initiated with 0000H, address and data buses are tri-stated, all the registers are cleared, interrupt system is disabled and Microprocessor 8085 unit is reset.

When $\overline{\text{RESET IN}}$ signal is active some of the actions performed by 8085 is

- PC contents become 0000H
- IR [Instruction Register] contents become 00H
- All interrupts, except TRAP, are disabled by resetting IE flip-flop
- RST 7.5, RST 6.5 and RST 5.5 interrupts are masked
- RST 7.5 flip-flop will be reset to 0
- Address and data buses are tri-stated
- Resets the interrupt enable and HLDA flip-flops
- Resets the internal registers

RESET OUT:

- It indicates that the MPU (Microprocessor Unit) is being reset.
- This signal can be used to reset the other peripheral devices.

4. HOLD and HLDA

- These signals are used for peripheral such as DMA (Direct Memory Access) operations.
- To perform "DMA" operations external device requires address and data buses but normally they are under the control of microprocessor.

  For this reason, an external devices will generate "HOLD" signal to microprocessor then after receiving HOLD signal microprocessor firstly complete the current operation (MC) and then release the address data buses to external devices by using a "HLDA" signal (Hold acknowledge).

Example - 1.6 Some of the pins of an 8085 CPU and their functions are listed below. Identify the correct answer that matches the pins to their respective functions:

P. RST 7.5	1. Selects IO or memory
Q. HOLD	2. Demultiplexes the address and data bus
R. $IO/\overline{M}$	3. Is a vectored interrupt
S. ALE	4. Facilitates direct memory access
	5. Is a clock
	6. Selects BCD mode of operation

(a) P-3, Q-2, R-1, S-4 (b) P-4, Q-1, R-5, S-3
(c) P-3, Q-4, R-1, S-2 (d) P-2, Q-3, R-6, S-1

Solution: **(c)**

P. RST 7.5 is a vectored interrupt.

Q. HOLD signal facilitates the direct memory access.

R. $IO/\overline{M}$ signal selects I/O or memory.

S. ALE signal demultiplexes the address and data bus.

Example - 1.7 The number of output pins of a 8085 microprocessor are

(a) 40 (b) 27
(c) 21 (d) 19

Solution : (b)

In 8085 there are 40 pins out of which 27 pins are output pins, 21 pins are input pins and 8 pins ($AD_0 - AD_7$) are shared between output and input signals.

Example - 1.8 Which one of the following statements is correct?

The ALE line of Intel 8085 microprocessor is used to
(a) latch the output of an I/O instruction into an external latch
(b) deactivate the chip-select signal from memory devices
(c) latch the 8-bits of address lines $AD_7 - AD_0$ into an external latch
(d) find the interrupt enable status of the TRAP interrupt

Solution : (c)

The ALE signal of Intel 8085 microprocessor is used to latch the 8-bits of address lines $AD_7 - AD_0$ into an external latch.

Example - 1.9 Which signal of 8085 microprocessor is used to insert wait states?

(a) READY (b) ALE
(c) HOLD (d) INTR

Answer : (a)

1.6 Internal Architecture of 8085 MPU

The Figure 1.4 shows Internal Architecture of Intel 8085 Microprocessor. Functionally the architecture is divided into following blocks.

1. ALU (Arithmetic and Logical Unit)
   - Accumulator
   - Temporary register
   - Arithmetic and logical circuit
   - Flags
2. Register array
3. Timing and control units
4. Instruction register and decoder
5. Interrupt control

Example - 1.17 What is the vectored address of interrupt RST5?

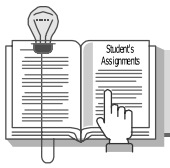
(a) 0040 H
(b) 0028 H
(c) 0005 H
(d) 0008 H

Solution : (b)

Vectored address for RST $n = n \times 8$

Here, $n = 5$

$5 \times 8 = (40)_{10} = (28)_{16} \Rightarrow$ 0028 H



Student's Assignments

Q.1 In 8085 microprocessor unit scratch pad memory comprises of
(a) *B*, *C*, *D*, *E*, *H* and *L* Registers
(b) *W*, *Z*, *B*, *C*, *D*, *E*, *H* and *L* Registers
(c) *W*, *Z*, *B*, *C*, *D* and *E* Registers
(d) *W*, *Z*, *B*, *C*, *D*, *E*, *H*, *L* and status Registers

Q.2 An interrupt in which the external device supplies its address as well as the interrupt request is known as
(a) vectored interrupt
(b) maskable interrupt
(c) polled interrupt
(d) non-maskable interrupt

Q.3 **Assertion (A):** The data bus and address bus of 8085 microprocessor are multiplexed.
Reason (R): Multiplexing reduces number of pins.
(a) Both A and R are correct and R is correct explanation of A.
(b) Both A and R are correct but R is not correct explanation of A.
(c) Only A is correct.
(d) Only R is correct.

Q.4. **P :** Program counter is the register which stores the address of the next instruction to be executed.
Q : Stack pointer stores the address of the top of the stack.
Out of these two statements, which statement/s is/are true?
(a) Only P (b) Only Q
(c) Both P and Q (d) None of them

Q.5 How many instructions does microprocessor 8085 has
(a) 255 (b) 256
(c) 246 (d) 250

Q.6 How many nibbles are there in 1 kbyte data?
(a) 500 (b) 1024
(c) 2048 (d) none of these

Q.7 Match **List-I (Interrupt)** with **List-II (Property):**

List-I	List-II
P. RST 7.5	1. Non-maskable
Q. RST 6.5	2. Edge sensitive
R. INTR	3. Level sensitive
S. TRAP	4. Non-vectored

Codes:

	P	Q	R	S
(a)	1	3	4	2
(b)	2	4	3	1
(c)	1	4	3	2
(d)	2	3	4	1

Q.8 For fetch machine cycle the status signal S_1 and S_0 are respectively
(a) 0 and 0 (b) 0 and 1
(c) 1 and 0 (d) 1 and 1

Q.9 In INTEL 8085, while executing a program non maskable interrupt occurs. The data present on data line is
(a) 00 H (b) 24 H
(c) 36 H (d) can't be predicted

Q.10 Consider the table given below.

IO/$\overline{M}$	S_1	S_0	Machine cycle
0	1	1	*X*
1	0	1	*Y*
1	1	1	*Z*

Here S_0, S_1 are status signals.
X, *Y*, *Z* are respectively.

(a) Interrupt acknowledgment, I/O read, opcode fetch.
(b) Interrupt acknowledgment, I/O write, opcode fetch.
(c) Opcode fetch, I/O read, Interrupt acknowledgment.
(d) Opcode fetch, I/O write, Interrupt acknowledgment.

Q.11 A stack is
(a) an 8-bit register in the microprocessor
(b) an 16-bit register in the microprocessor
(c) a set of memory location in R/W memory reserved for storing information temporarily during the execution of a program.
(d) A 16-bit memory address stored in the program counter

STUDENT'S ASSIGNMENTS ANSWER KEY

1. (a) **2.** (c) **3.** (a) **4.** (c) **5.** (c)
6. (c) **7.** (d) **8.** (d) **9.** (b) **10.** (d)
11. (c)

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