

Introduction

- A microprocessor is a programmable circuit that supports the execution of a set of instructions called an Instruction Set.
- Each instruction in the instruction set is represented by a predefined unique sequence of bits and is called OP CODE.
- The data required for the execution of the operation i.e. operands are also expressed in bits and is also in binary form and follows the opcode.
- Thus, microprocessor instructions consist of opcode and operand bytes.
- A microprocessor can execute one instruction at a time. Hence, a task to be executed by the microprocessor is expressed in terms of a sequence of instructions called a 'program'.

- Thus a microprocessor is a digital circuit that accepts instructions or data expressed only in terms of 1s and 0s.
Thus when entering instructions into a microprocessor they are entered byte by byte.
- Thus a microprocessor program is a sequence of bytes expressed in hexadecimal system.
These programs, expressed in terms of hexadecimal bytes are called "machine-language programs".
- Thus, the type of circuits, systems and machines which are able to remember the sequence of instructions, the operands related to each instruction, can execute them and finally store the result of complete execution are called "programmable circuits or machines".

These are available in the form of crude microprocessor based systems or advanced personal computers, laptops, notebooks, mobile etc.

→ Intel Corporation is one of the pioneers in the microprocessor industry from its infant stage.

1971 — 4 bit microprocessor - 4004 -
thousand transistors

1972 — 8 bit microprocessor - 8008
(these were not successful)

1974 — 8 bit microprocessor - 8080
(not fully functional)

1974 — 8 bit microprocessor - 8085
(fully functional
complete CPU),

→ 8085 CPU is most popular among all 8 bit CPUs

- on chip clock generator
- optimum set of registers
- a reasonably powerful ALU

Limitations

- limited memory addressing capacity
- slow speed of execution
- limited number of general purpose registers
- non availability of complex instruction and addressing modes.

→ 8086 — 16 bit CPU - from Intel.

- set of 16 general purpose registers
- supports 16 bit ALU
- rich instruction set
- segmented memory addressing scheme
(The introduction of a set of segment registers for addressing segmented memory was a major step in the evolution of later microprocessors)

Limitations:

- No memory management / protection capability (which is considered an important feature)

- IBM PC development in July 1981
- IBM PC-XT in 1983, with 10MB hard disk, double side double density floppy disk drive, keyboard, monitor, asynchronous communication adapter. (These used MS-DOS from Microsoft)
- 80286 advanced version of 8086 had memory management abilities.
- 80386 - 32 bit CPU from Intel.
80386 along with 80387 math coprocessor provided a high speed environment for graphical applications. Windows 95 was being used.
- 80486 similar as 80386 with an integrated math coprocessor.
Speed of graphics applications enhanced threefold.
A 5-stage instruction pipelining was used.
Concept of set-associative memory mapping and data cache were introduced.

- later the trend was to design CPUs that could support more and more complex instructions at the assembly language level.
- CISC designer worked on this idea. Their efforts led to the development of first virtually 64 bit processor - Pentium I. P-I supported SIMD, SIMD popularly used for multimedia application.
- Variations of P-I, P-II, P-III, P-IV, Pentium MMX came which had features like superscalar execution, multimedia extension, streaming SIMD extension and RISC features.
- Now, multicore processor architectures are coming with higher processing capability and higher degrees of parallelism.

Digital Computer:

A digital computer is a multipurpose, programmable machine that reads binary instructions from its memory, accepts binary data as input and processes data according to those instructions and provides result as output.

- A set of instruction written for the computer to perform a task is called a program
- A group of programs is called software.
- The physical components of the computer are called hardware.

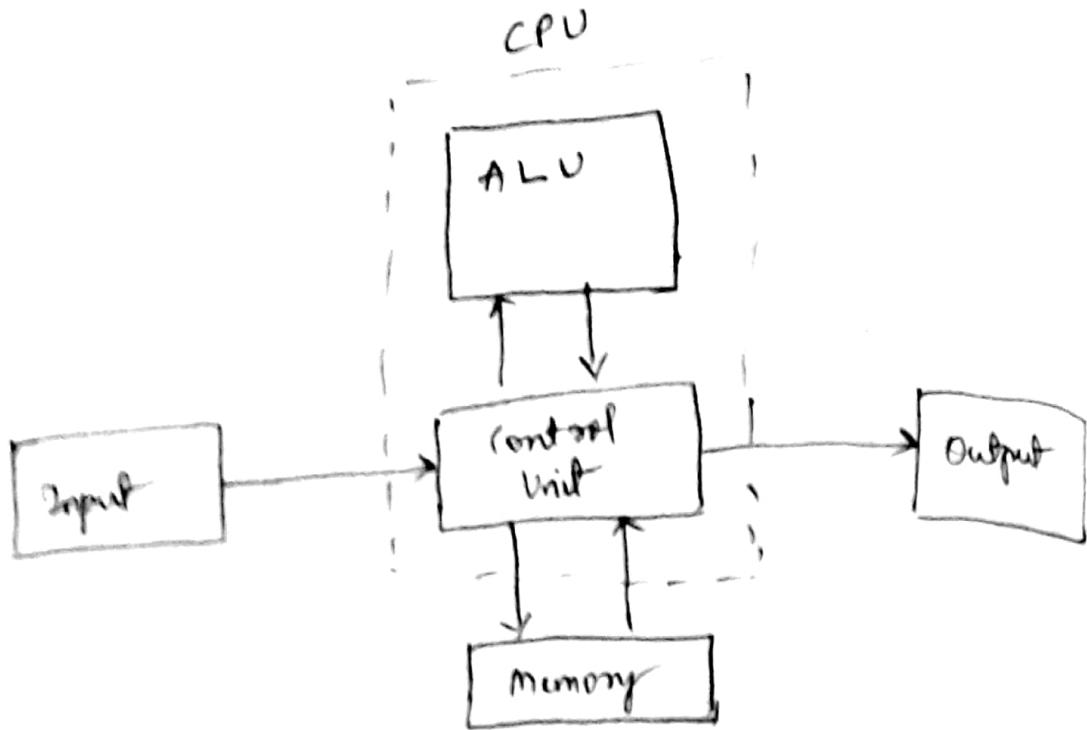


fig. Traditional block diagram of Computer

Computer Technology

- ICs appeared in the end of 1950's following the invention of Transistor. In an IC, an entire circuit consisting of several transistors, diodes and resistors is contained in a single chip.
- In 1960's logic gates appeared in the form of 7400 series of ICs.

- With logic gate ICs we were able to build bigger digital systems.
- Technology of integrating the circuits of a logic gate on a single chip is known as small scale integration (SSI)
- With technology advancement, more than hundred gates were fabricated in a single chip. This was known as Medium Scale Integration (MSI)
- Within few years, it was possible to fabricate more than thousand gates in a single chip. This was the era of large scale integration (LSI)
- Now we are in the era of very large scale integration (VLSI) and ultra large scale integration (ULSI) which involves many millions of gates in a single chip.

→ With advancement of integration technology, it became possible to build the whole CPU and its related timing function on a single chip. This came known as microprocessor and a computer built with microprocessor known as micro computer came into picture.

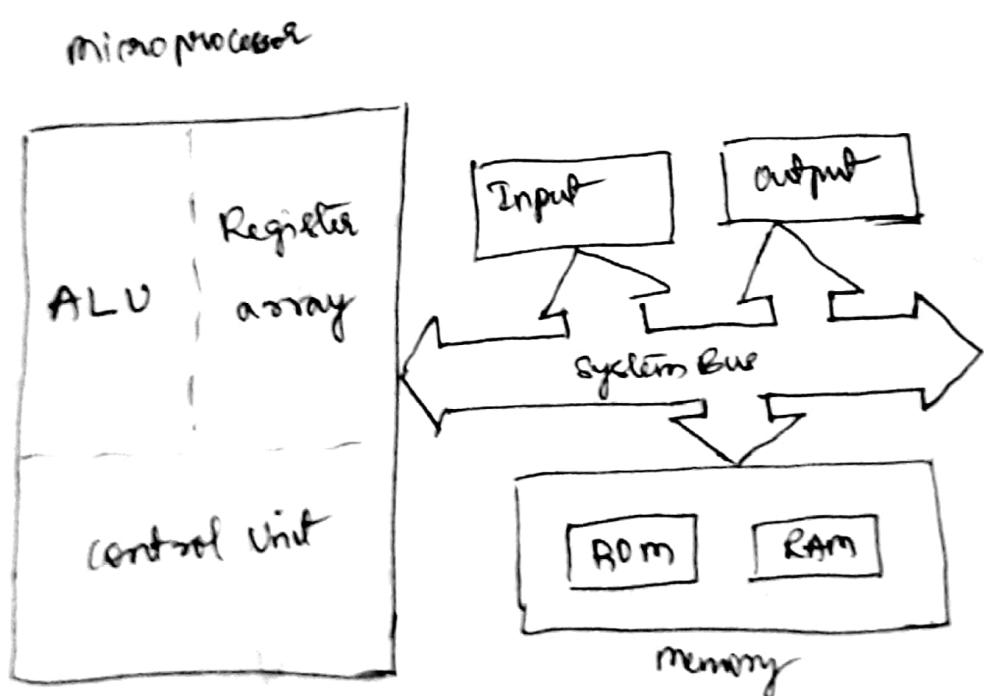


Fig. Block diagram of a micro computer

Examples of micro processor :

→ Initial micro processor

Intel 8080A, 8085, Zilog Z80,
Motorola 6800, 6809, MOS Technology 6500 series.

→ Advanced micro processor

You name them.

Examples of micro computer :

→ Initial micro computer

Intel SIK-85, → based on 8085
Motorola MEK-6800-D2 → based on 6800
Rockwell AIM 65 → based on 6502 micro processor

→ Advanced micro computer:

You name them.

Microprocessor architecture and its operations
(general description) (specific to 8085 and 8086
is discussed later)

- The microprocessor is a programmable logic device, designed with registers, flipflops and timing elements.
- Every microprocessor has its unique set of instructions, designed internally, to manipulate data and communicate with peripherals.
- The process of data manipulation and communication is determined by the logic design of the microprocessor called the architecture.

functions of a microprocessor:

functions performed by the microprocessor
can be classified in three general categories

1. microprocessor initiated operations

2. Internal data operations

3. Peripheral (or externally) initiated operations

D Microprocessor - Initiated Operations and 8085/8080A

Bus Organization:

→ The MPU performs primarily four operations:

1. Memory Read : Reads data from memory
2. Memory Write : Writes data into memory
3. I/O Read : Accepts data from input device
4. I/O Write : Sends data to output device.

→ The above operations are part of communication between MPU and peripheral devices (memory also)

→ This communication involves three steps

Step 1: Identify the peripheral or the memory location with its address

Step 2: Transfer data.

Step 3: Provide timing and synchronization signals.

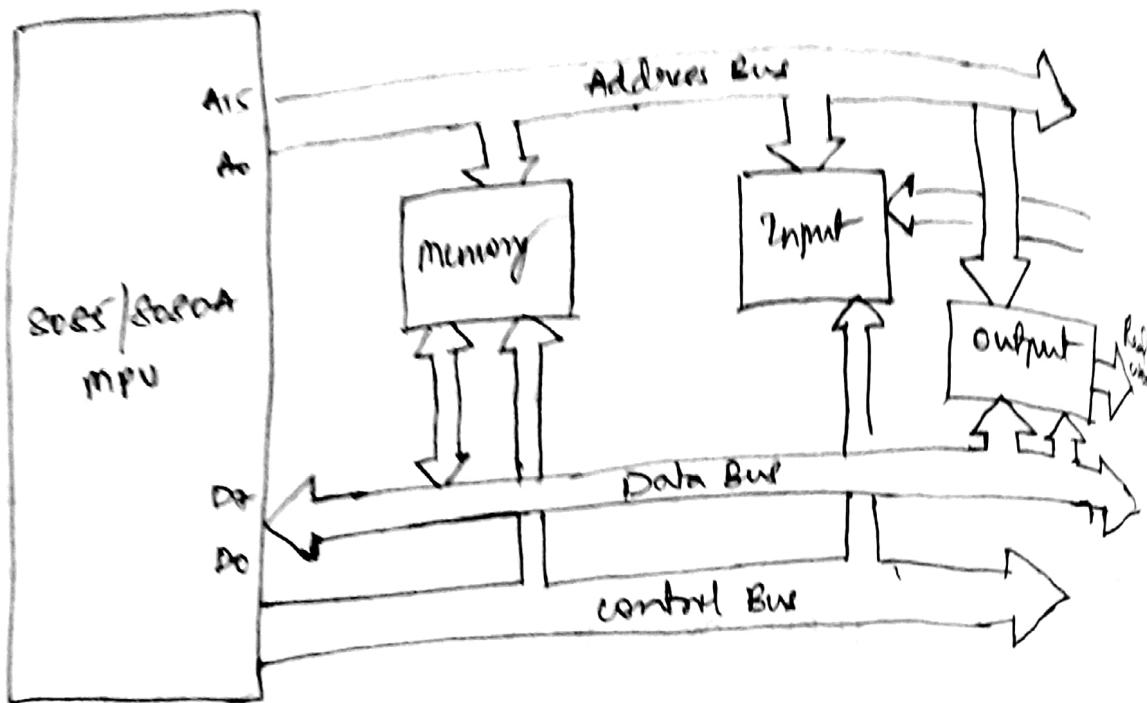


fig. The 8085/ 8080 A Bus Structure

→ Address bus is 16 lines ($A_0 - A_{15}$). It is unidirectional; bits flow in one direction — from MPU to peripherals.
 The MPU uses the address bus ($A_0 - A_{15}$) to identify the peripheral.
 ∵ Each peripheral is identified by a 16 bit address.

8085/8080A with 16 address lines is capable of addressing $2^{16} = 65536$ memory locations ($2^{16} = 2^6 \cdot 2^{10} = 64\text{K}$ memory location).
 ∵ most 8 bit microprocessors may have a maximum of 64K memory.

most single board microcomputers have less than 2K memory.

→ Data Bus is a group of eight lines used for data flow. These lines are bidirectional - data flow in both directions between MPV and its peripherals.

8 bits ($D_0 - D_7$) \Rightarrow MPV will be able to manipulate 8 bit data ranging from 0000 0000 (00) to 1111 1111 (FF) i.e. $2^8 = 256$ numbers. The largest number that can appear on the data bus is 1111 1111 (FF) which is (255)₁₀.

Data bus influences the microprocessor architecture. It determines the ~~register size~~ word length and the register size of the microcomputer.

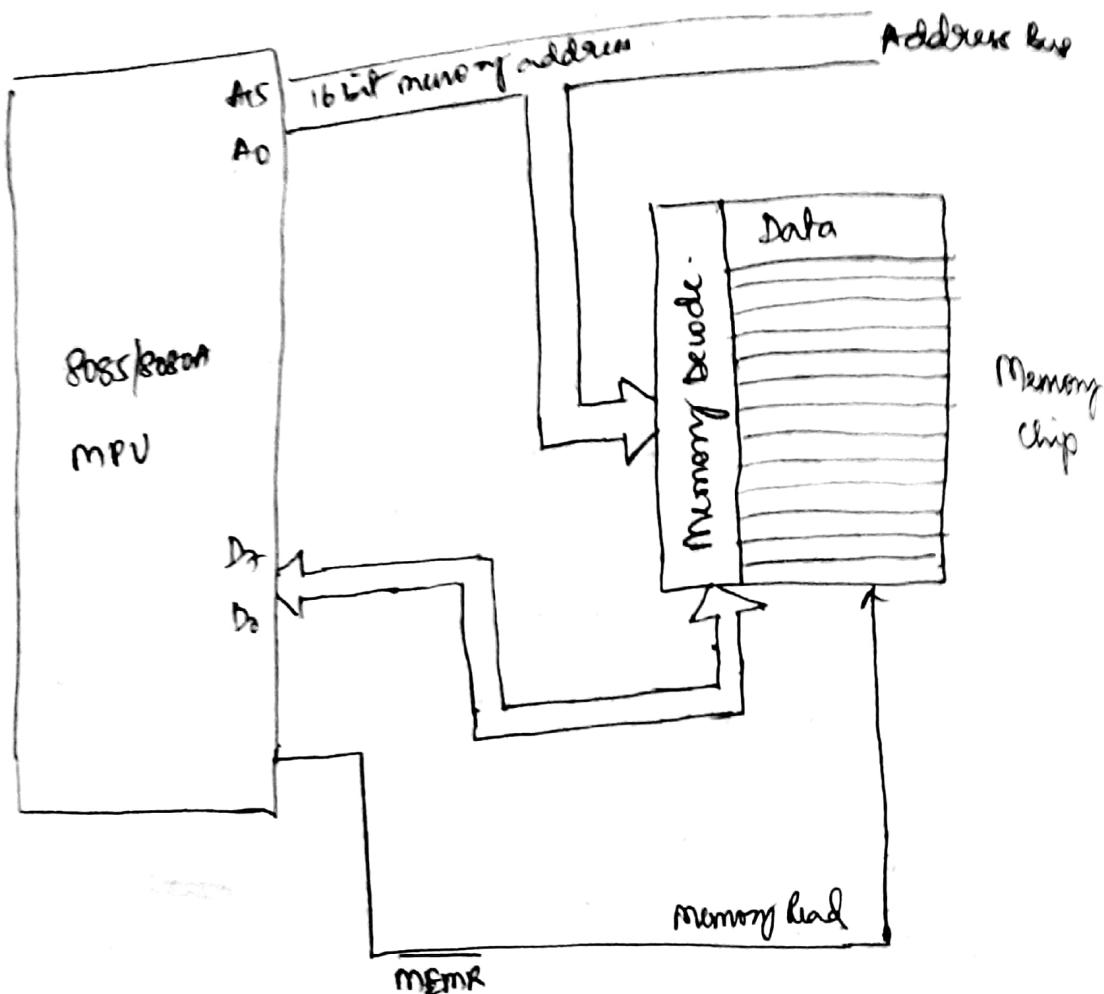
8085/8080A \rightarrow 8-bit microprocessor

8086/Zilog Z8000/Motorola 6800 \rightarrow 16 data lines
 \rightarrow 16 bit microprocessor.

→ Control Bus consists of various single lines that carry synchronization signals. The MPV uses these lines to provide timing signals.

The MPV generates specific signals for every operation such as memory read or write to perform. These signals help the MPV to identify the device to communicate with.

Ex:- Memory Read operation



To read an instruction from memory

- MPV places 16 bit address on the address bus
- The address on the bus is decoded by an external logic circuit (Memory decoder) and the memory location identified.
- MPV sends an memory read signals as the control signal.
- This control signal activates the memory chip and the 8 bit data as specified by the 16 bit address is placed on the data bus and brought to the MPV.

② Internal Data Operations and 8085/8080A Registers

The internal architecture of 8085/8080A micro processor determines how and what operations can be performed with data.

These operations are

1. Store 8 bit data
2. perform arithmetic and logic operations
3. Test for conditions.
4. Sequence the execution of instructions
5. Store data temporarily during execution in the defined RAM location called stack.

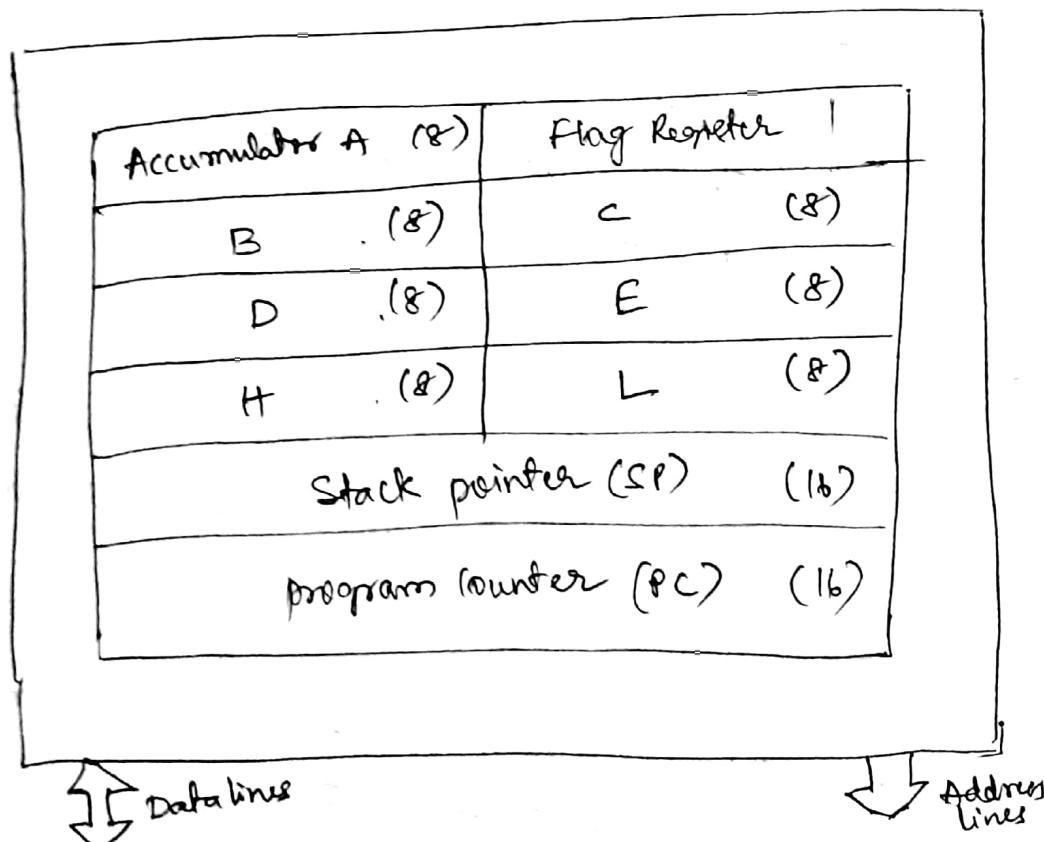


fig. 8085/8080A programmable Registers

→ Registers

6 general purpose registers B, C, D, E, H, L.

These registers are programmable means that programmer can use these registers to load or transfer data from registers by using instruction, ex:- There can be an instruction like MOV B, C to transfer data from register C to register B.

These can be combined as register pairs to perform 16 bit operations.

- BC, DE, HL - to perform 16 bit operations.

→ Accumulator

- One Accumulator A (8 bit).

- used to store 8 bit data and perform ALU operations.

→ The result of an operation is stored in Accumulator.

→ Flags

ALU includes five flipflops that set or reset according to data conditions in accumulator and other registers.

CY → CY=1 when sum in the accumulator (carry) is larger than 8 bits.

$Z \rightarrow Z=1$ when the arithmetic operation results in zero.
(zero)

The flags are
 $Z, CY, \text{Sign}^{(S)}, \text{Parity}^{(P)}, \text{Auxiliary carry}^{(AC)}$.

These flags are stored in an 8-bit register so that the programmer can examine these flags by accessing the register through an instruction. The term PSW (Program Status Word) refers to the accumulator and the flag register.

These flags are important in decision making process of microprocessor
Ex:- JC → this instruction is implemented to change the sequence of a program when $CY=1$.

→ Program Counter (PC)

This deals with sequencing the execution of instructions. This register is a memory pointer. The function of PC is to point to the memory address from which the next byte of instruction is to be fetched.

→ Stack pointer (SP):
Also a 16-bit register to point to memory location. The beginning of stack is defined by loading a 16-bit address in SP.

③ Peripheral or Externally Initiated Operation

External device (or signals) can initiate following operations, for which individual pins on the microprocessor chip are assigned.

1. Reset : When reset is activated, all internal operations are suspended and the PC is cleared (\oplus hold $0000H$). The program execution can again begin at zero memory address.

2. Interrupt :

The microprocessor can be interrupted from the normal execution of instructions and asked to execute some other instruction called service routine. The microprocessor resumes its operation after completing the service routine.

3. Ready : AD₀/SOA has a pin called READY. If $READY = 0$, the microprocessor enters into a wait state. This is mainly used for synchronizing with slower peripherals.

4. Hold : When HOLD signal is activated, the microprocessor leaves control of buses and allows the external peripheral to access them. Ex:- HOLD is used in DMA data transfer.

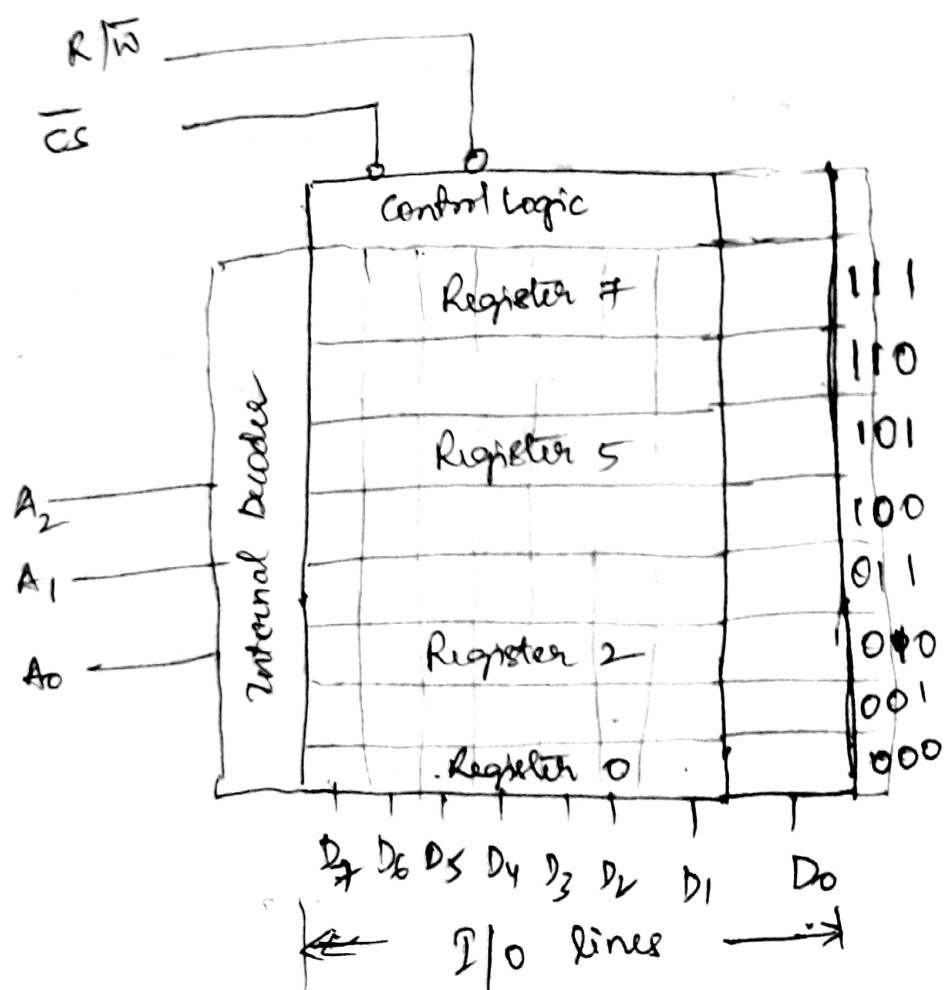
Memory

- Broadly two types of memory: RAM, ROM.
- The RAM memory is made of registers and each register has a group of flip flops that store bits of information.
The no. of bits stored in a register is called a memory word;
memory devices (chips) are available in various word sizes.
The MPV can read from and write into this memory.
- The ROM stores information permanently in the form of diodes; a group of diodes can be viewed as a register.
The MPV can only read information from the ROM; it cannot write into this memory.
- In a memory chip, all registers are arranged in a sequence and identified by binary numbers called memory addresses.

Memory Organization (RAM):

- For an 8 bit microprocessor, memory is required to store eight bits of information as a group.
- To communicate with memory, the MPU should be able to
 1. Select the chip
 2. Identify the register
 3. Read from or write into register

Ex:- A memory chip with eight registers



\overline{CS} → to select the chip

R/W → to control data flow

$D_0 - D_7$ → 8 I/O lines.

The registers are arranged sequentially and numbered 000_2 to 111_2 . These numbers are the addresses used to identifying each register as a memory location.

To identify each register, one MPU would require three address lines to place eight different addresses from 000_2 to 111_2 .

→ 8085/8080A MPU with 16 address lines is capable of identifying or addressing 65536 (64K) such memory registers or locations.

→ The size of this chip can be specified as 8 byte or 8×8 bit or 64 bit.

→ A memory chip with 256 registers with 4 I/O lines can be specified as 256×4 bit or 1024 bit.

For an 8-bit microprocessor, two such memory chip (256×4) would be necessary to form 8 bit memory word size, resulting in 256 bytes of memory.

- To read from or write to memory location, the micro processor places the address 101 on address bus. The decoder decodes the address and identifies the register.
- The control signal R/ \bar{W} enables the I/O lines and the data byte is either read from or stored in the memory location.
- The \bar{CS} (chip select) line is necessary to select one particular memory chip among several memory chips in a system.

Memory map:

Memory map is defined as the assignment of addresses to memory registers in various chips in a system.

→ In 8085/8080A microprocessor, the entire memory map can range from 0000H to FFFFH ($2^{16} = 65,536$)

$$65536 = 256 \times 256$$

first 256 → 00 - FF
second 256 → 00 - FF

Therefore, we can divide the total 65536 memory locations into

256 pages where in each page will be having 256 memory locations.

Low order hex digits can be used to refer to one of the 256 memory locations in a page.

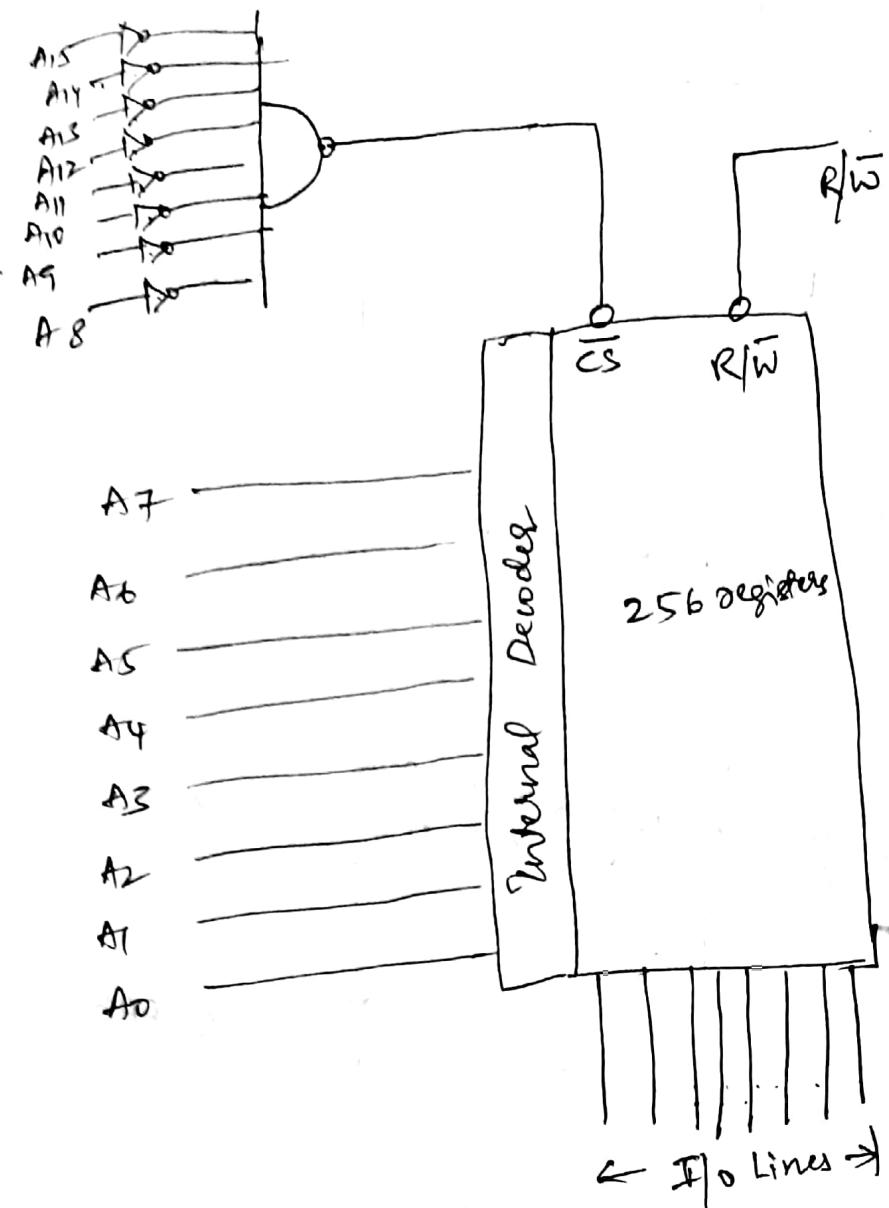
Higher order hex digits can be used to refer to one of the 256 pages.

Ex:- The memory address $020Fh$
low order digit $\rightarrow 0Fh \rightarrow 15$ memory location
high order digit $\rightarrow 02h \rightarrow$ page 2
 \therefore the address $020Fh$ refers to ~~15~~
memory location whose address is $0F (15_{10})$
in page 2.

Ex:- If the memory address is $07FFh$
represent the memory address location
on page 7 of the memory
chip.

Ex:- If the address is $1064h$
it represents $64h (100_{10})$ memory location
in page $10h (16_{10})$ of memory.

Ex : Illustration of memory map of a chip with 256 bytes of memory interfaced with a microprocessor with 16 address lines.



→ To select the memory chip address lines

A₈ - A₁₅ should be at logic 0.

No other logic levels on lines A₁₅ - A₈

can select the chip.

→ Once the chip is selected, the address lines $A_7 - A_0$ can assume any combination from 00h to FFh and identify one of the 256 memory locations through its decoder.

→ $R/W = 1 \rightarrow$ Read operation
 $R/W = 0 \rightarrow$ Write operation.

∴ the memory address of the chip will range from 0000h to 0FFh. as given below

$A_7 A_6 A_5 A_4 A_3 A_2 A_1 A_0$	$0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0$	$= 0000H$
$A_7 A_6 A_5 A_4 A_3 A_2 A_1 A_0$	$1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1$	$= 0FFH$

If $A_{15} - A_0$ are some thing like below

$A_{15} A_{14} A_{13} A_{12} A_{11} A_{10} A_9 A_8$	$1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0$	$A_7 A_6 A_5 A_4 A_3 A_2 A_1 A_0$	$0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0$
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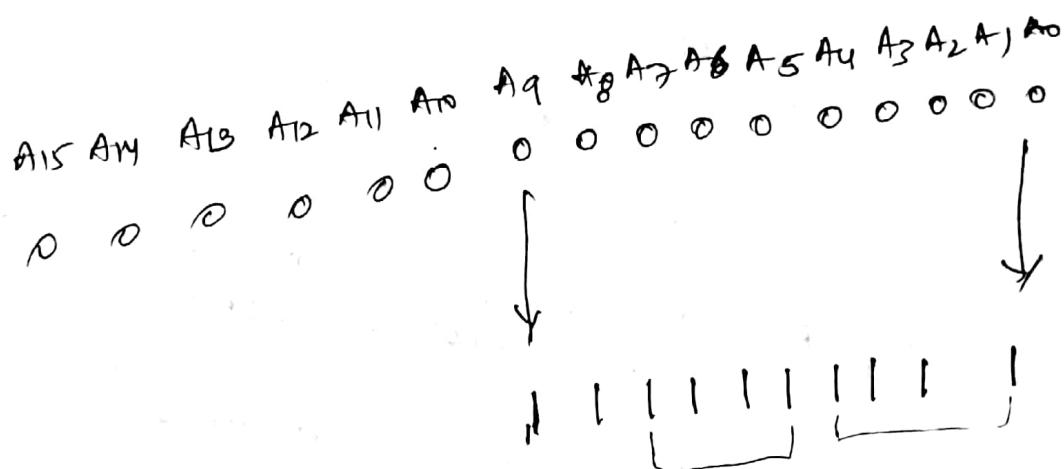
1111111

they can address memory locations from 8000H to 80FFH

Ex: Explain the memory map of 1K (1024×8) memory using a micro processor with 16 address lines.

$1K \Rightarrow 2^{10} \Rightarrow 10$ address lines.

∴ to access 1024 memory locations
10 address lines ($A_9 - A_0$) can be used
Remaining address lines ($A_{15} - A_9$) can be used
for chip selection.



∴ This memory map will be able to address / access the locations

$0000h$ to $0fffh$ (1024 memory locations)

from

00 00 } page 0 with 256 locations
00 FF }

01 00 } page 1 with 256 locations
01 FF }

02 00 } page 2 with 256 locations
02 FF }

03 00 } page 3 with 256 location.
03 FF }

The memory map can therefore be viewed as four pages ; ^{as} in reality all the registers are on one chip -

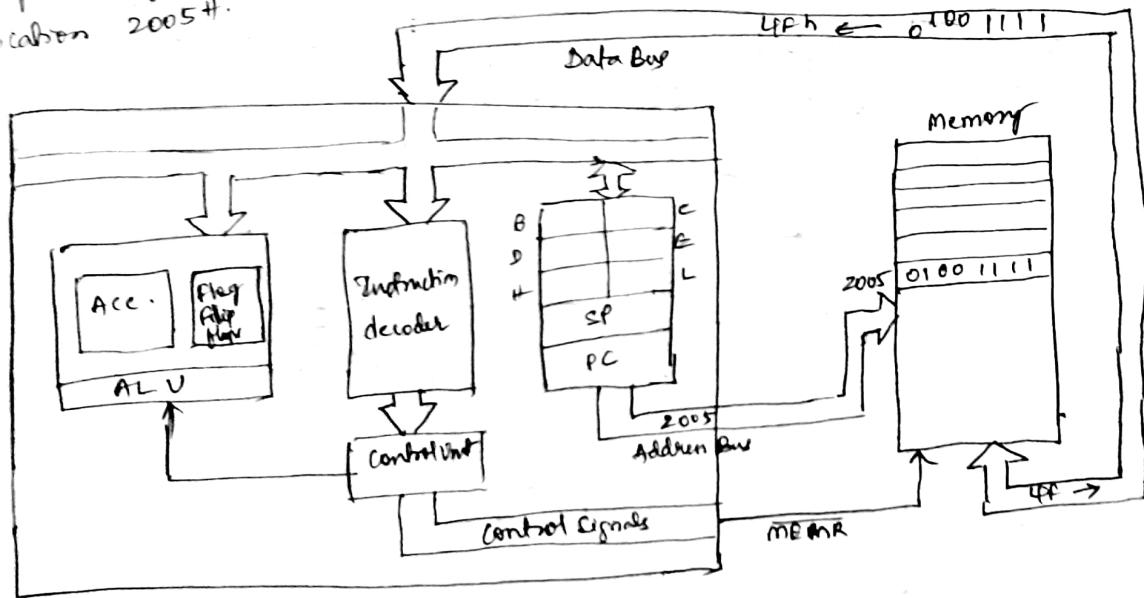
Note : If $A_{15} = 1$, the memory map will range from 8000h to 83FFh.

Note : The discussion of memory map is equally applicable to read only memory (ROM).

Note :

Memory and Instruction fetch

Illustration of data flow and the sequence of events when the instruction code 0100 1111 (4Fh) is stored in memory at location 2005h.

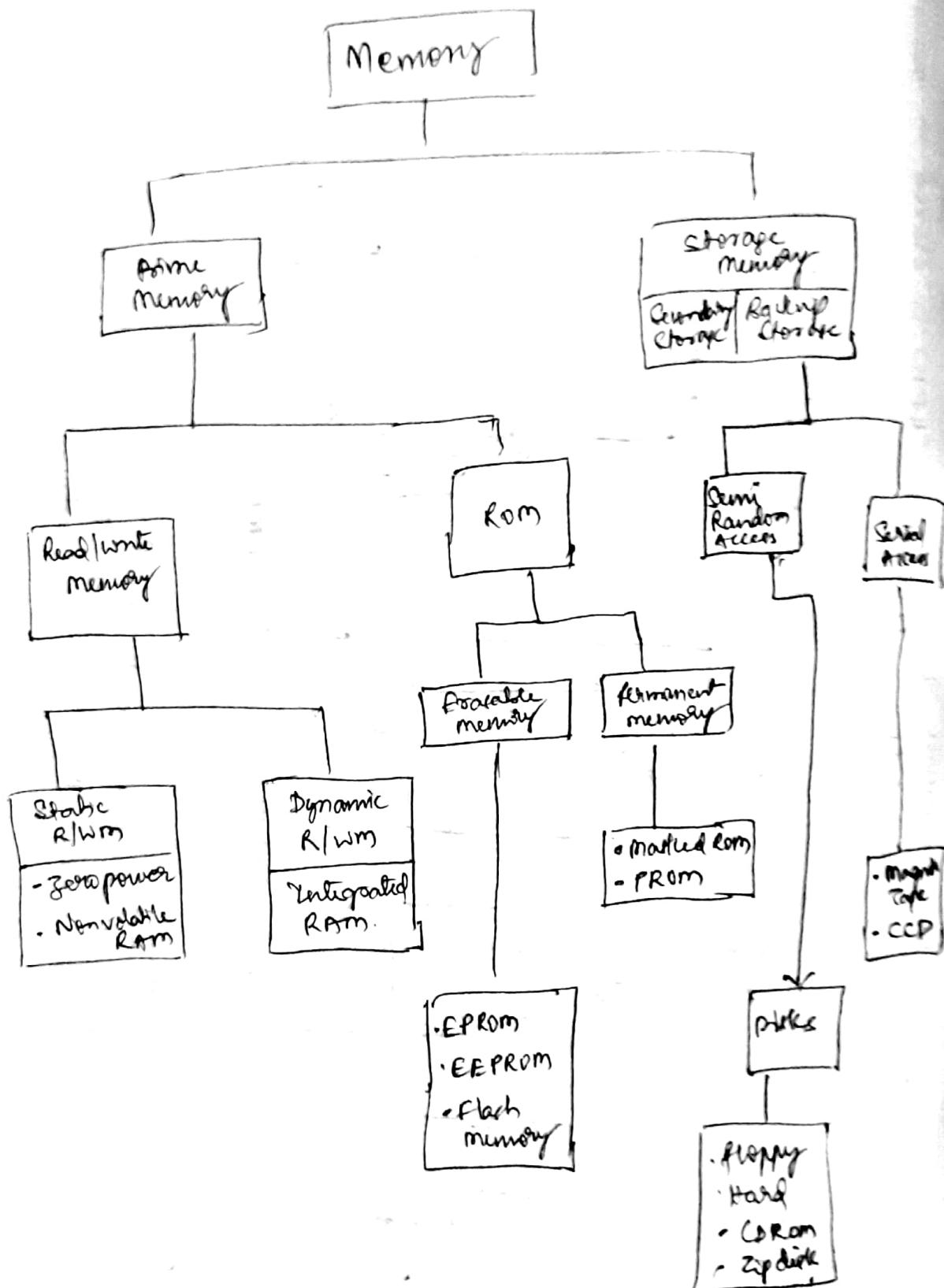


8085/8086
microprocessor

Steps:

- ① PC places 16 bit address 2005 on address bus.
- ② Control unit sends MEMR to enable the memory chip.
- ③ The instruction (4F) from memory is placed on data bus.
- ④ It is then decoded and executed by ALU.

Memory classification:



Input / Output (I/O)

There are two methods, by which the MPU identifies and communicates with I/O devices.

① Peripheral (or direct) I/O

② Memory-mapped I/O.

The methods differ in the no. of address lines used in identifying the I/O device, the type of control lines used to enable the device and the instructions used for data transfer.

Peripheral (or direct) I/O:

In peripheral or direct I/O (also known as Accumulator I/O) two instructions IN and OUT are used for data transfer.

The MPU uses & address lines to send address of an I/O device. Therefore, we can access 256 input devices and 256 output devices.

The input and output devices are differentiated by the control signals I/O Read (\overline{IOR}) or I/O Write (\overline{IOW}).

I/O addresses range from 00h to FFh.

∴ I/O addresses are also known as I/O device addresses or I/O port numbers.

Steps :

1. The MPV places the 8 bit device address on the address bus, which is decoded by the external code logic
2. The MPV sends a control signal (ZIO Read or ZIO write) and enables the ZIO device.
3. Data is placed on the data bus for transfer.

Memory mapped I/O :

- The MPV uses 16 address lines to identify the I/O device.
- The MPV then uses the \overline{MEMR} or \overline{MEMW} control signals
- The memory map 64K is shared between memory and I/O devices.
- The MPV views the I/O devices as if they were memory locations.