

Chapter-4

Microprocessor System

A microcomputer consists of a set of components or modules of three basic types CPU memory and I/O units which communicate with each other.

PIN Configuration of 8085

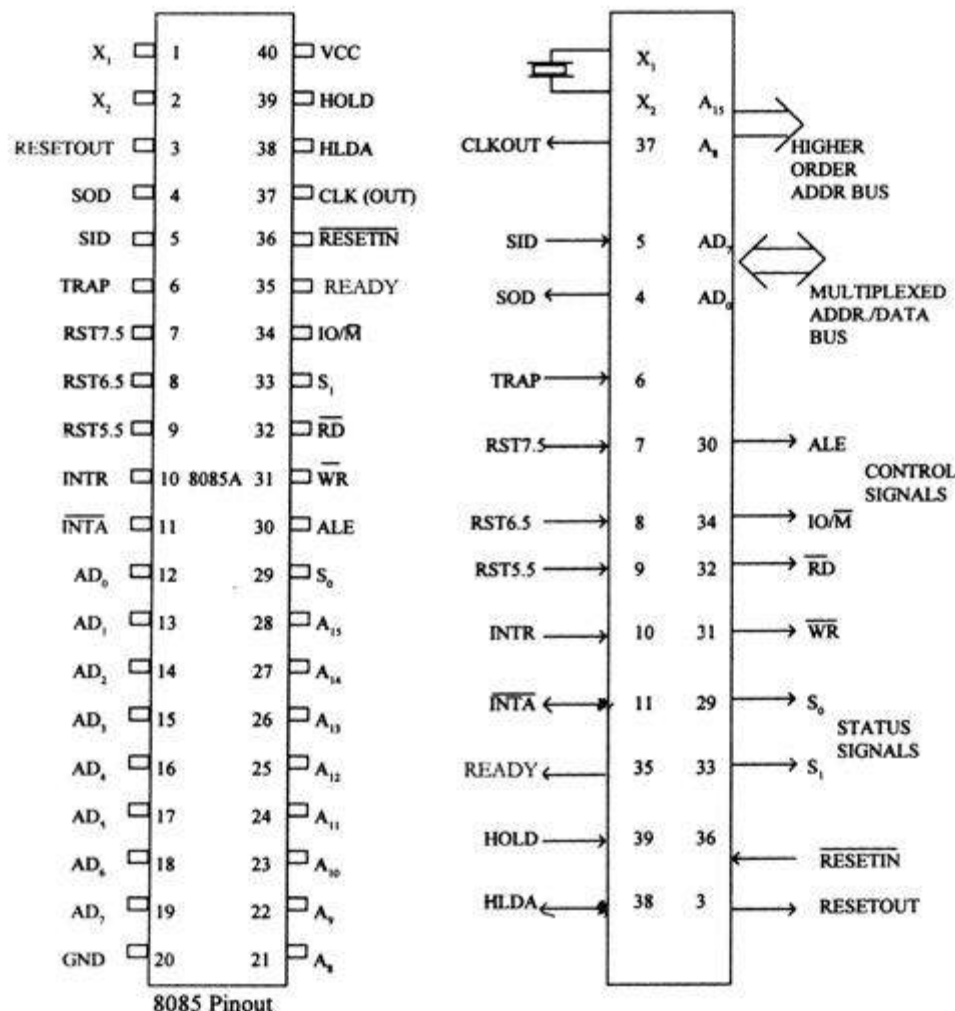


Fig (a) - Pin Diagram of 8085 & Fig(b) - logical schematic of Pin diagram

- The microprocessor is a clock-driven semiconductor device consisting of electronic logic circuits manufactured by using either a large-scale integration (LSI) or very-large-scale integration (VLSI) technique.
- The microprocessor is capable of performing various computing functions and making decisions to change the sequence of program execution.
- In large computers, a CPU implemented on one or more circuit boards performs these computing functions.

- The microprocessor is in many ways similar to the CPU, but includes the logic circuitry, including the control unit, on one chip.
- The microprocessor can be divided into three segments for the sake clarity, arithmetic/logic unit (ALU), register array, and control unit.
- 8085 is a 40 pin IC, DIP package. The signals from the pins can be grouped as follows

1. Power supply and clock signals
2. Address bus
3. Data bus
4. Control and status signals
5. Interrupts and externally initiated signals
6. Serial I/O ports

1. Power supply and Clock frequency signals:

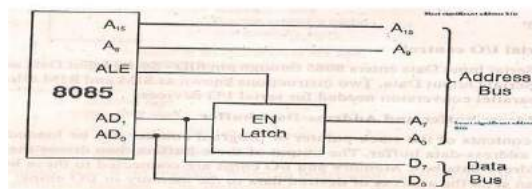
- Vcc + 5 volt power supply
- Vss Ground
- X1, X2 : Crystal or R/C network or LC network connections to set the frequency of internal clock generator.
- The frequency is internally divided by two. Since the basic operating timing frequency is 3 MHz, a 6 MHz crystal is connected externally.
- CLK (output)-Clock Output is used as the system clock for peripheral and devices interfaced with the microprocessor.

2. Address Bus:

- A8 - A15
- It carries the most significant 8 bits of the memory address or the 8 bits of the I/O address.

3. Multiplexed Address / Data Bus:

- AD0 - AD7
- These multiplexed set of lines used to carry the lower order 8 bit address as well as data bus.
- During the opcode fetch operation, in the first clock cycle, the lines deliver the lower order address A0 - A7.
- In the subsequent IO / memory, read / write clock cycle the lines are used as data bus.
- The CPU may read or write out data through these lines.



4. Control and Status signals:

These signals include two control signals (RD & WR) three status signals (IO/M, S1 and S0) to identify the nature of the operation and one special signal (ALE) to indicate the beginning of the operations.

- ALE (output) - Address Latch Enable.
 - This signal helps to capture the lower order address presented on the multiplexed address / data bus. When it is the pulse, 8085 begins an operation. It generates $AD_0 - AD_7$ as the separate set of address lines $A_0 - A_7$.
- RD (active low) - Read memory or IO device.
 - This indicates that the selected memory location or I/O device is to be read and that the data bus is ready for accepting data from the memory or I/O device.
- WR (active low) - Write memory or IO device.
 - This indicates that the data on the data bus is to be written into the selected memory location or I/O device.
- IO/M (output) - Select memory or an IO device.
 - This status signal indicates that the read / write operation relates to whether the memory or I/O device.
 - It goes high to indicate an I/O operation.
 - It goes low for memory operations.

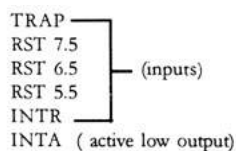
5. Status Signals:

It is used to know the type of current operation of the microprocessor.

IO/M (Active Low)	S1	S0	Data Bus Status (Output)
0	0	0	Halt
0	0	1	Memory WRITE
0	1	0	Memory READ
1	0	1	IO WRITE
1	1	0	IO READ
0	1	1	Opcode fetch
1	1	1	Interrupt acknowledge

6. Interrupts and Externally initiated operations:

- They are the signals initiated by an external device to request the microprocessor to do a particular task or work.
- There are five hardware interrupts called,



- On receipt of an interrupt, the microprocessor acknowledges the interrupt by the active low INTA (Interrupt Acknowledge) signal.

Hold (Input)

- This indicates peripheral controller requesting the bus.

HLDA (Output)

- This indicates the acknowledgement for the Hold request.

READY (Input)

- It is used to delay the microprocessor read and write cycles until a slow responding peripheral is ready to send or accept data.
- Memory and I/O devices will have slower response compared to microprocessors.
- Before completing the present job such a slow peripheral may not be able to handle further data or control signal from CPU.
- The processor sets the READY signal after completing the present job to access the data.
- The microprocessor enters into WAIT state while the READY pin is disabled.

Reset In (input, active low)

- This signal is used to reset the microprocessor.
- The program counter inside the microprocessor is set to zero.
- The buses are tri-stated.

Reset Out (Output)

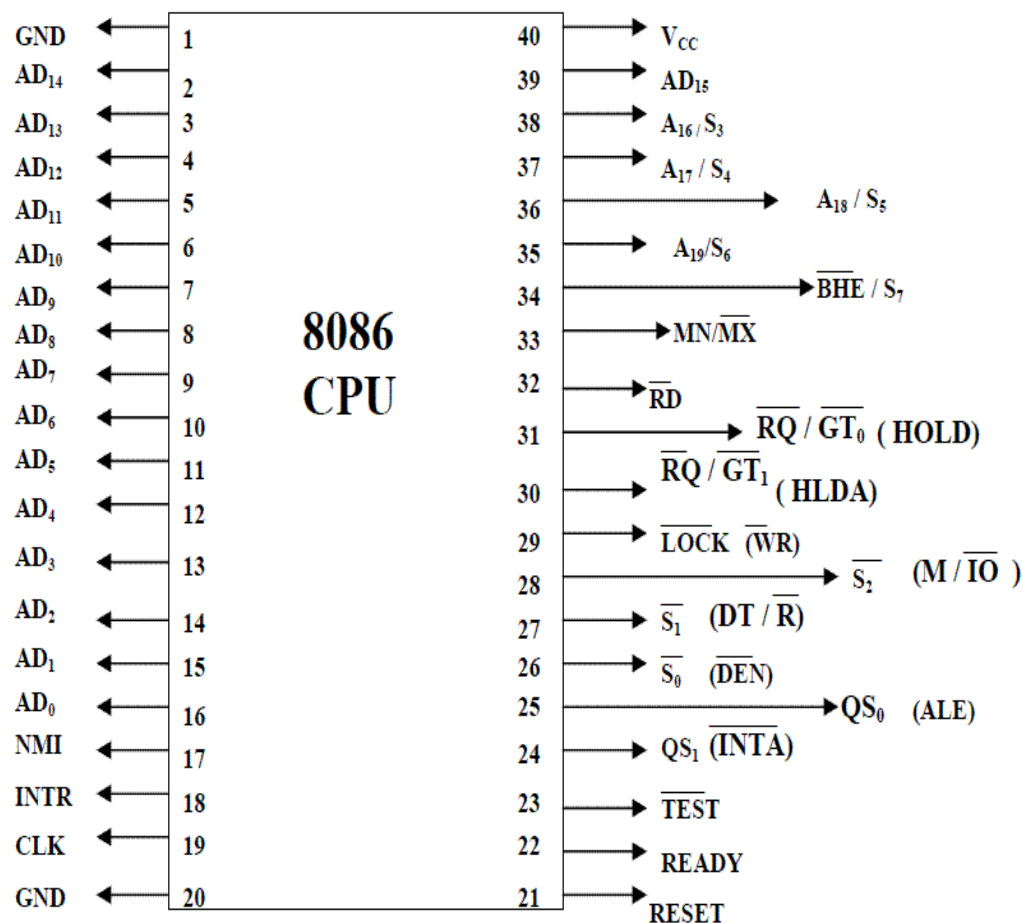
- It indicates CPU is being reset.
- Used to reset all the connected devices when the microprocessor is reset.

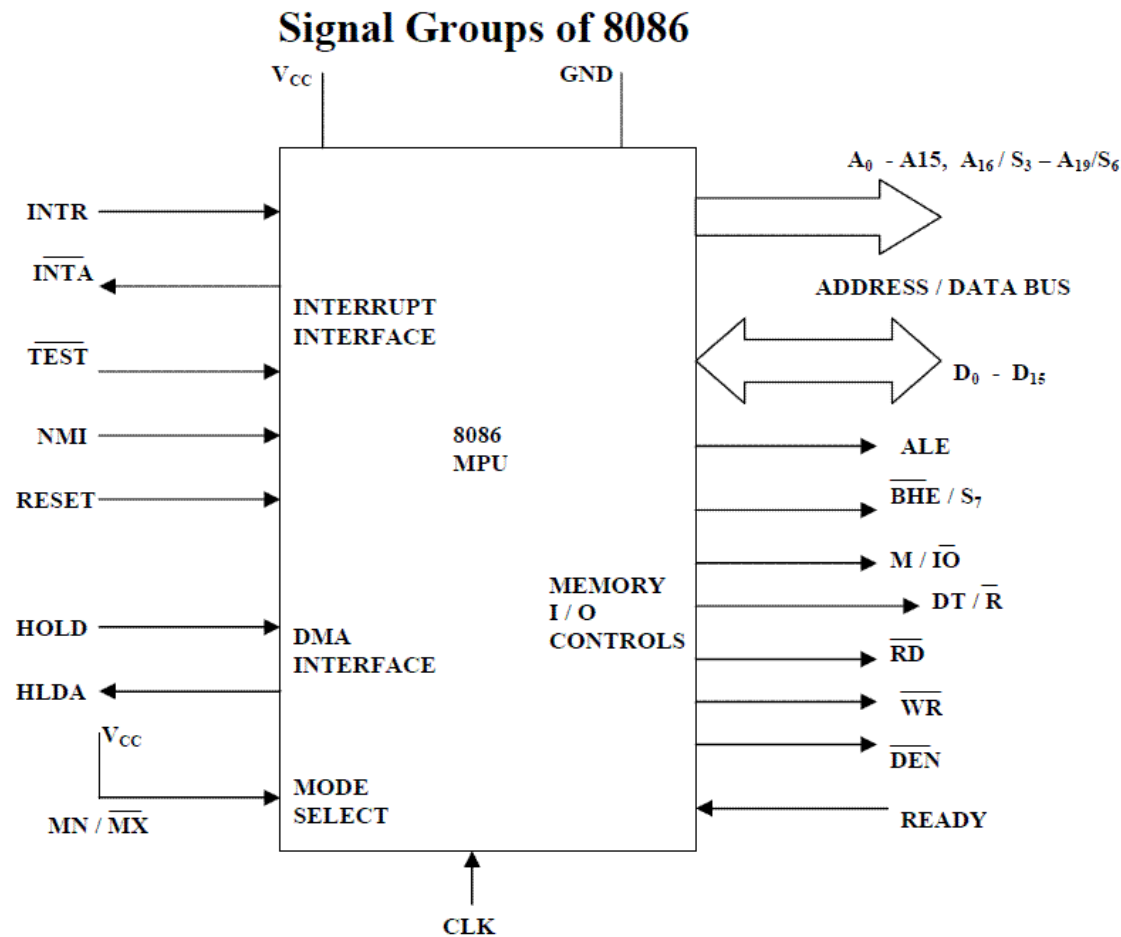
7. Single Bit Serial I/O ports:

- SID (input) - Serial input data line
- SOD (output) - Serial output data line
- These signals are used for serial communication.

Pin Configuration of 8086

Pin Diagram of 8086





- The Microprocessor 8086 is a 16-bit CPU available in different clock rates and packaged in a 40 pin Cerdip or plastic package.
- The 8086 operates in single processor or multiprocessor configuration to achieve high performance. The pins serve a particular function in minimum mode (single processor mode) and other function in maximum mode configuration (multiprocessor mode).
- The 8086 signals can be categorized in three groups.
 - The first are the signal having common functions in minimum as well as maximum mode.
 - The second are the signals which have special functions for minimum mode
 - The third are the signals having special functions for maximum mode.

The following signal descriptions are common for both modes.

- **AD15-AD0** : These are the time multiplexed memory I/O address and data lines.
- **A19/S6,A18/S5,A17/S4,A16/S3** : These are the time multiplexed address and status lines. The address bits are separated from the status bit using latches controlled by the ALE signal.
- **BHE/S7** : The bus high enable is used to indicate the transfer of data over the higher order (D15-D8) data bus.
- **RD – Read** : This signal on low indicates the peripheral that the processor is performing memory or I/O read operation.
- **READY** : This is the acknowledgement from the slow device or memory that they have completed the data transfer.
- **INTR-Interrupt Request** : This is to determine the availability of the request from external devices. If any interrupt request is pending, the processor enters the interrupt acknowledge cycle.
- **TEST** : This input is examined by a ‘WAIT’ instruction. If the TEST pin goes low, execution will continue, else the processor remains in an idle state.
- **CLK- Clock Input** : The clock input provides the basic timing for processor operation and bus control activity.

The following pin functions are for the minimum mode operation of 8086.

- **M/IO – Memory/IO** : When it is low, it indicates the CPU is having an I/O operation, and when it is high, it indicates that the CPU is having a memory operation.
- **INTA – Interrupt Acknowledge**: This signal is used for interrupt acknowledge i.e. when it goes low; the processor has accepted the interrupt.
- **ALE – Address Latch Enable**: This output signal indicates the availability of the valid address on the address/data lines.
- **DT/R – Data Transmit/Receive**: This output is used to decide the direction of data flow through the trans-receivers (bidirectional buffers). When the processor sends out data, this signal is high and when the processor is receiving data, this signal is low.
- **DEN – Data Enable**: This signal indicates the availability of valid data over the address/data lines. It is used to enable the trans-receivers (bidirectional buffers) to separate the data from the multiplexed address/data signal.
- **HOLD, HLDA- Acknowledge**: When the HOLD line goes high, it indicates to the processor that another master is requesting the bus access. The processor, after receiving the HOLD request, issues the hold acknowledge signal on.

The following pin functions are applicable for maximum mode operation of 8086.

- **S2, S1, S0 – Status Lines:** These are the status lines which reflect the type of operation, being carried out by the processor.

S2	S1	S0	Indication
0	0	0	Interrupt Acknowledge
0	0	1	Read I/O port
0	1	0	Write I/O port
0	1	1	Halt
1	0	0	Code Access
1	0	1	Read Memory
1	1	0	Write Memory
1	1	1	Passive

- **LOCK :** This output pin indicates that other system bus master will be prevented from gaining the system bus, while the LOCK signal is low.
- **RQ/GT0, RQ/GT1 – Request/Grant :** These pins are used by the other local bus master in maximum mode, to force the processor to release the local bus at the end of the processor current bus cycle.

BUS STRUCTURE:

A microcomputer consists of a set of components or modules of three basic types CPU memory and I/O units which communicate with each other. A bus is a communication pathway between two or more such components. A bus actually consists of multiple communication pathway or lines. Each line is capable of transmitting signals representing binary 1 and 0. Several lines of the bus can be used to transmit binary data simultaneously. The bus that connects major microcomputer components such as CPU, memory or I/O is called the system bus. System bus consists of number of separate lines. Each line assigned a particular function. Fundamentally in any system bus the lines can be classified into three group buses.

1. Data Bus:

Data bus provides the path for monitoring data between the system modules. The bus has various numbers of separate lines like 8, 16, 32, or 64. Which referred as the width of data bus .These number represents the no. of bits they can carry because each carry 1 bit.

2. Address Bus:

Each Lines of address bus are used to designate the source or destination of the data on data bus. For example, if the CPU requires reading a word (8, 16, 32) bits of data from memory, it puts the address of desired word on address bus. The address bus is also used to address I/O ports. Bus width determines the total memory the up can handle.

3. Control Bus:

The control bus is a group of lines used to control the access to control signals and the use of the data and address bus. The control signals transmit both command and timing information between the system modules. The timing signals indicate the validity of data and address information, where as command signals specify operations to be performed. Some of the control signals are:

Memory Write ($\overline{\text{MEMW}}$): It causes data on the bus to be loaded in to the address location.

Memory Read (MEMR): It causes data from the addressed location to be placed on the data bus.

I/O Write ($\overline{\text{IOW}}$): It causes the data on the bus to be output to the addressed I/O port.

I/O Read (IOR): It causes the data from the addressed I/O port to be placed on the bus.

Transfer Acknowledge: This signal indicates that data have been accepted from or placed on the bus.

Bus Request: It is used to indicate that a module wants to gain control of the bus.

Bus Grant: It indicates that a requesting module has been granted for the control of bus.

Interrupt Request: It indicates that an interrupt has been pending.

Interrupt Acknowledge: it indicates that the pending interrupt has been recognized.

Bus Types

1. Synchronous Bus:

In a synchronous bus, The Occurrence of the events on the bus is determined by a clock . The clock transmits a regular sequence of 0's & 1's of equal duration. All the events start at beginning of the clock cycle.

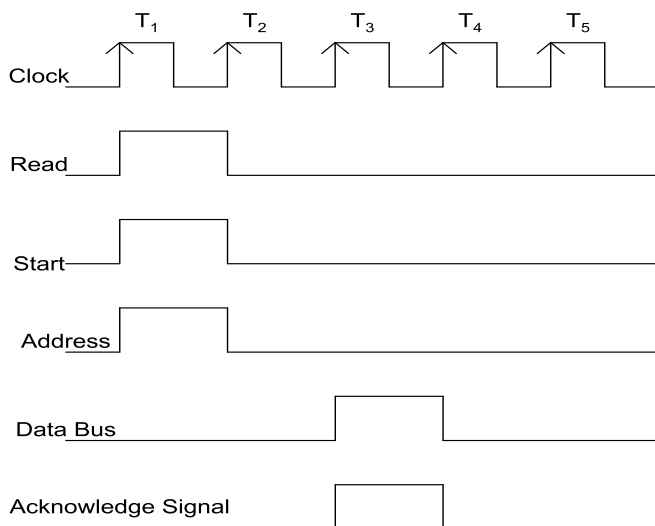


Fig: Synchronous Read Operation

- Here the CPU issues a START signal to indicate the presence of address and control information on the bus.

- Then it issues the memory read signal and places the memory address on the address bus.
 - The addressed memory module recognizes the address and after a delay of one clock cycle it places the data and acknowledgment signal on the buses.
- In synchronous bus, all devices are tied to a fixed rate, and hence the system can not take advantage of device performance but it is easy to implement.

2. Asynchronous Bus:

In an asynchronous bus, the timing is maintained in such way that occurrence of one event on the bus follows and depends on the occurrence of previous event.

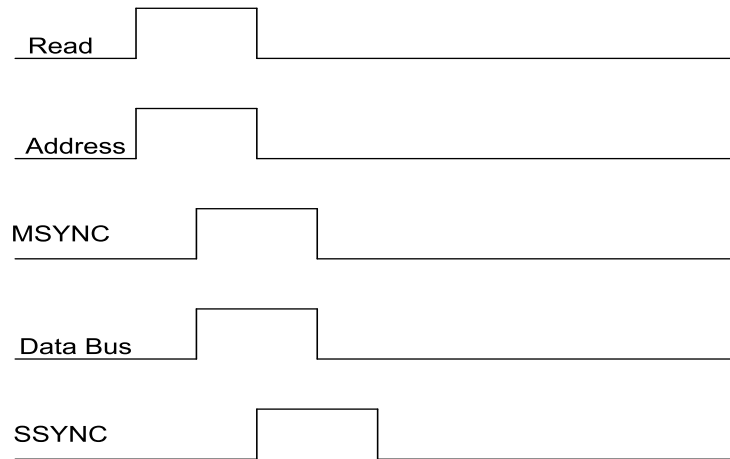


Fig: Asynchronous Read Operation

- Here the CPU places Memory Read (Control) and address signals on the bus.
- Then it issues master synchronous signal (MSYNC) to indicate the presence of valid address and control signals on the bus.
- The addressed memory module responds with the data and the slave synchronous signal (SSYNC)

Machine cycles and bus timing diagrams:

Operation of a microprocessor can be classified in to following four groups according to their nature.

- Op- Code fetch
- Memory Read /Write
- I/O Read/ Write
- Request acknowledgement

Here Op-Code fetch is an internal operation and other three are external operations.

During three operations, microprocessor generates and receives different signals. These all operations are terms as machine cycle.

- Clock Cycle (T state): It is defined as one subdivision of the operation performed in one clock period.
- Machine Cycle: It is defined as the time required to complete one operation of accessing memory, I/O, or acknowledging an external request. This cycle may consist of three to six T-states.

- **Instruction Cycle:** It is defined as the time required completing the execution of an instruction. The 8085 instruction cycle consists of one to six machine cycles or one to six operations.

Op-Code fetch Machine Cycle

The first operation in any instruction is Op-Code fetch, The microprocessor needs to get(fetch) this machine code from the memory register where it is stored before the microprocessor can begin to execute the instruction.

Let's consider the instruction MOV C, A stored at memory location 2005H. The Op-Code for the instruction is 4FH and Op-Code fetch cycle is of 4 clock cycles.

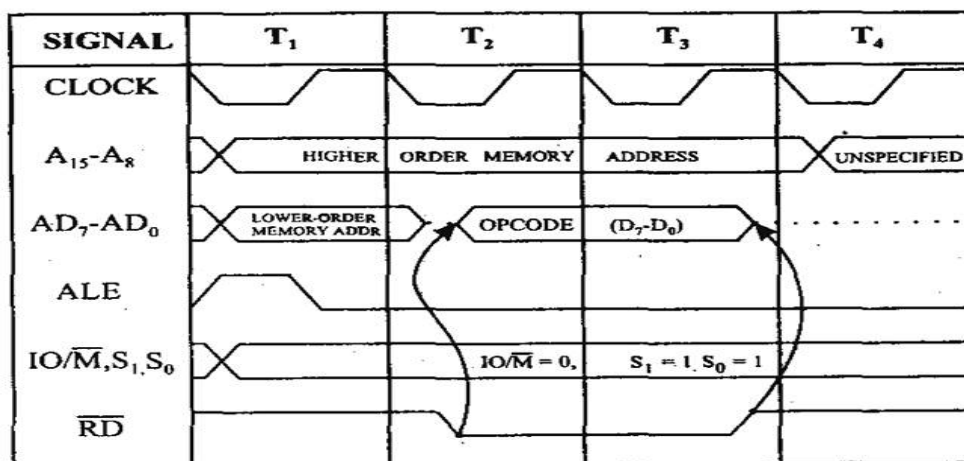


Fig - Timing Diagram for Opcode Fetch Machine Cycle

Step1: Microprocessor places the 16 bit memory address from Program Counter on the address bus. At T₁, high order address (20) is placed at A₈-A₁₅ and lower order address (05) is placed at AD₀- AD₇ ALE signal goes high. IO/ \overline{M} goes low and both S₀ and S₁ goes high for Op-Code fetch.

Step 2: The control unit sends the control signal \overline{RD} to enable the memory chip and active during T₂ and T₃.

Step 3: The byte from the memory location is placed on the data bus .that is 4f into D₀-D₇ and \overline{RD} goes high impedance.

Step4: The instruction 4FH is decoded and content of accumulator will be copied into register C during clock cycle T₄.

Memory Read Cycle:

Let's consider the instruction MVI A, 32 H stored at memory location 2000H.

2000	3EH	MVI	A,	32	H
2001	32H				

Here two machine cycles are presented, first is Op-Code fetch which consists of 4 clock cycles and second is memory read consist of 4 clock cycle.

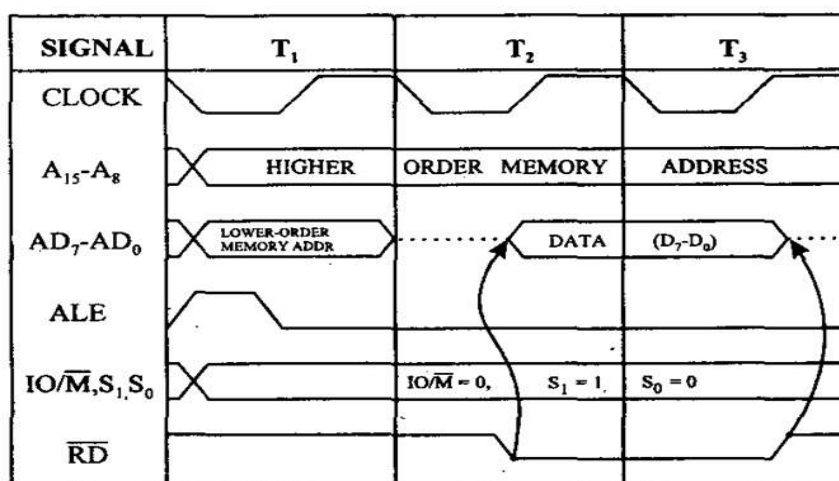


Fig - Timing Diagram for Memory Read Machine Cycle

Step 1 : First machine cycle (Op-Code fetch) is identical for timing diagram of Op-Code fetch cycle.

Step 2: After completion of Op-Code fetch cycle, 8085 places the address 2001 on the address bus and increments PC to 2002H. ALE is asserted high IO/ \overline{M} = 0, S₁ = 1, S₀ = 0 for memory read cycle. When RD = 0, memory places the data byte 32H on the data bus.

Memory Write Machine:

- The memory write machine cycle is executed by the processor to write a data byte in a memory location.

- The processor takes, 3T states to execute this machine cycle.

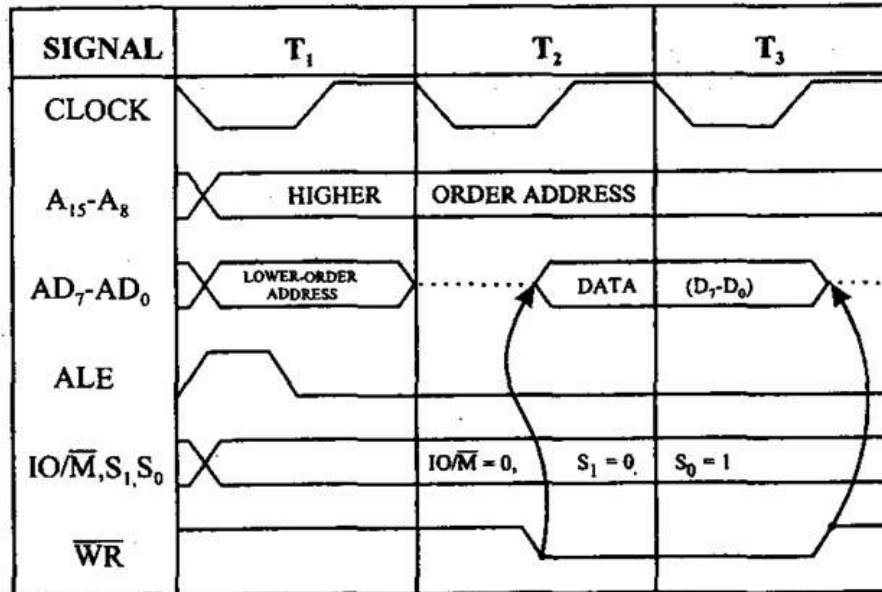


Fig - Timing Diagram for Memory Write Machine Cycle

I/O Read Cycle:

- The I/O Read cycle is executed by the processor to read a data byte from I/O port or from the peripheral, which is I/O, mapped in the system.
- The processor takes 3T states to execute this machine cycle.
- The IN instruction uses this machine cycle during the execution.

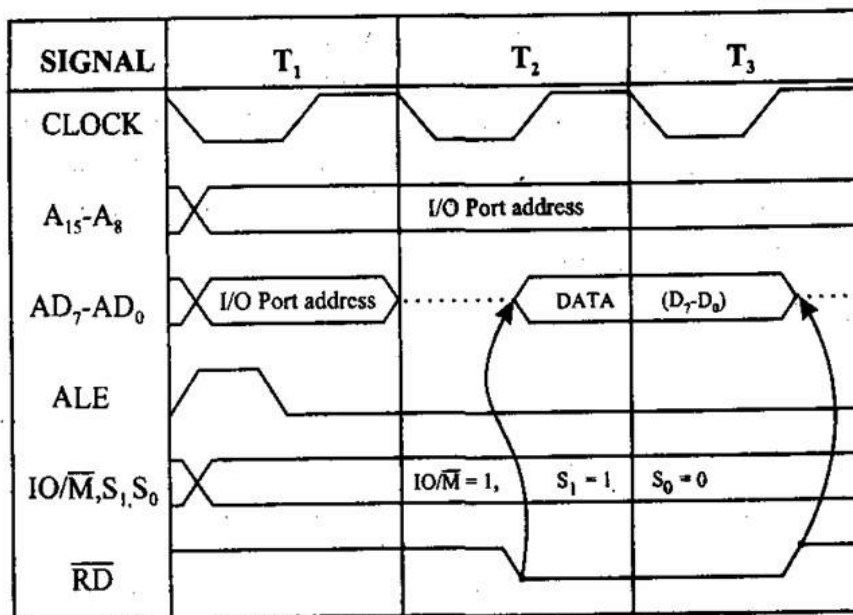


Fig - Timing Diagram for I/O Read Machine Cycle

I/O Write Cycle:

Let's consider the instruction OUT 01H stored at memory location 2050H.

2050	D3	OUT 01H
2051	01	

Op-Code Fetch Cycle 4T

Memory read Cycle 3T

I/O Write Cycle 3T

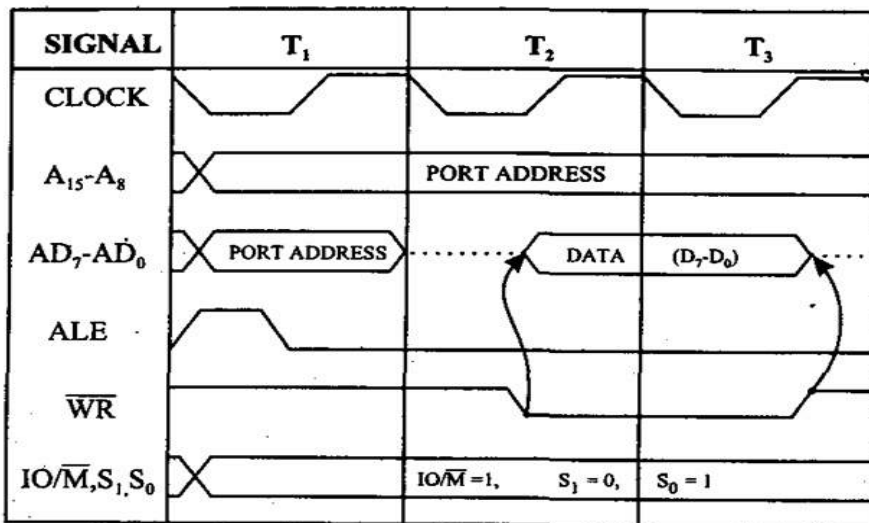


Fig - Timing Diagram for I/O Write Machine Cycle

Step 1: In Machine Cycle M_1 , the microprocessor sends \overline{RD} control signal which is combined with IO/\overline{M} to generate the \overline{MEMR} signal and processor fetches instruction code D3 using the data bus.

Step 2: In 2nd Machine Cycle M_2 , the 8085 microprocessor places the next address 2051 on the address bus and gets the device address 01H via data bus.

Step 3: In machine Cycle M_3 , the 8085 places device address 01H on low order as well as high order address bus. IO/\overline{M} goes high for IO and accumulator content are placed on Data bus which are to be written into the selected output port.

Timing diagram for STA 526AH

- STA means Store Accumulator -The contents of the accumulator is stored in the specified address(526A).
- The opcode of the STA instruction is said to be 32H. It is fetched from the memory 41FFH(see fig). - *OF machine cycle*
- Then the lower order memory address is read(6A). - *Memory Read Machine Cycle*
- Read the higher order memory address (52).- *Memory Read Machine Cycle*
- The combination of both the addresses are considered and the content from accumulator is written in 526A. - *Memory Write Machine Cycle*
- Assume the memory address for the instruction and let the content of accumulator is C7H. So, C7H from accumulator is now stored in 526A.

Address	Mnemonics	Op code
41FF	STA 526AH	32H
4200		6AH
4201		52H

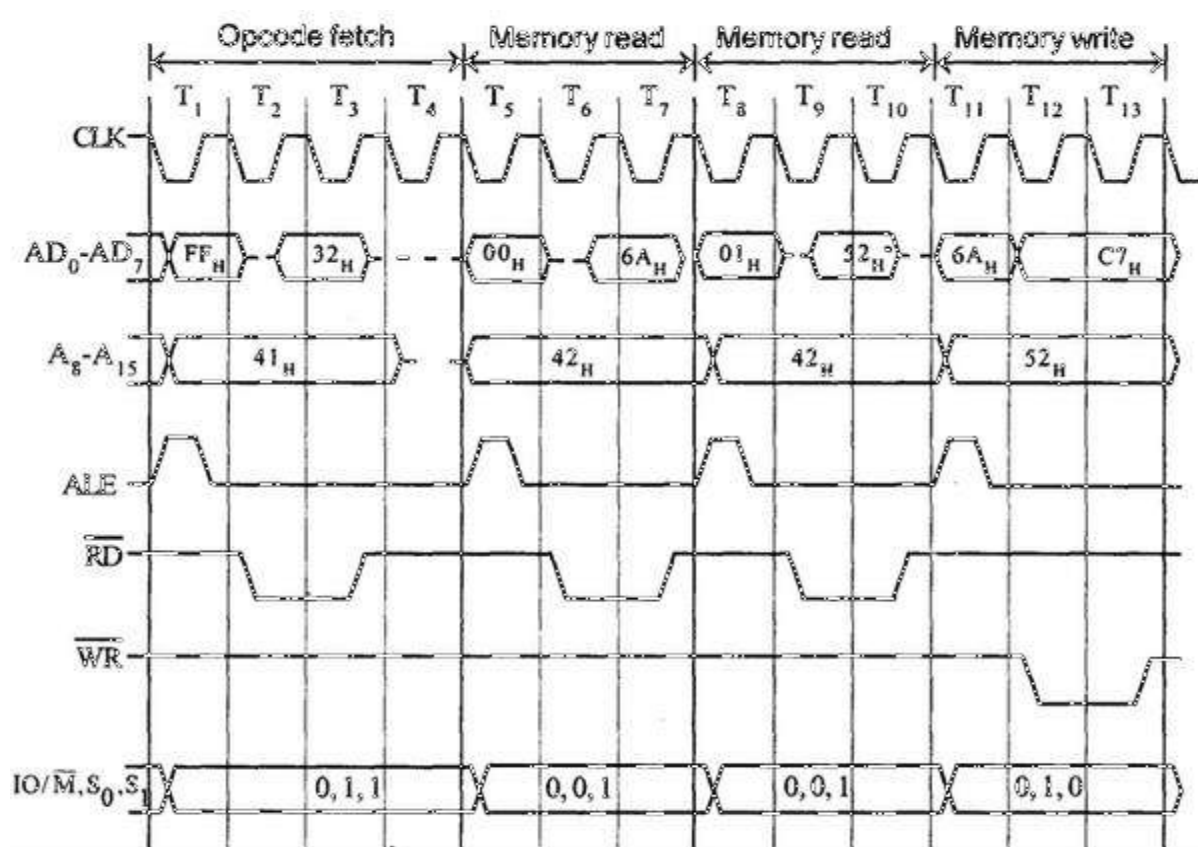


Fig. Timing diagram for STA 526AH

Timing diagram for IN C0H.

- Fetching the Opcode DBH from the memory 4125H.
- Read the port address C0H from 4126H.
- Read the content of port C0H and send it to the accumulator.
- Let the content of port is 5EH.

Address	Mnemonics	Op code
4125	IN C0H	DBH
4126		C0H

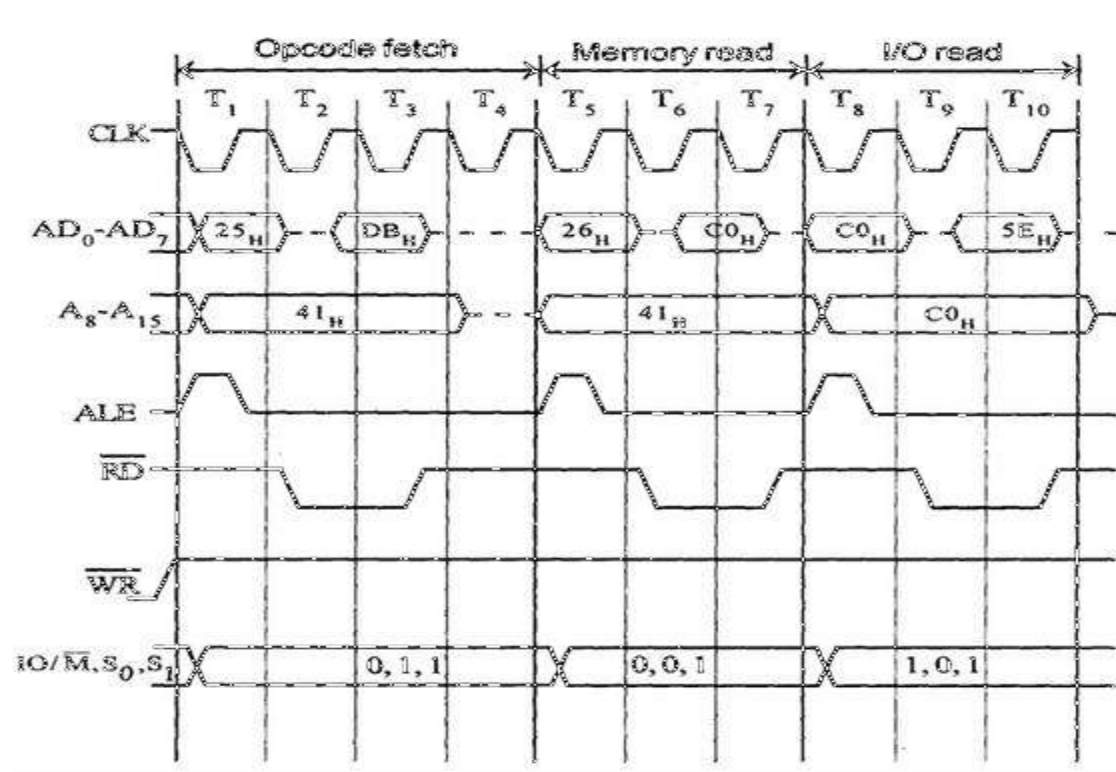
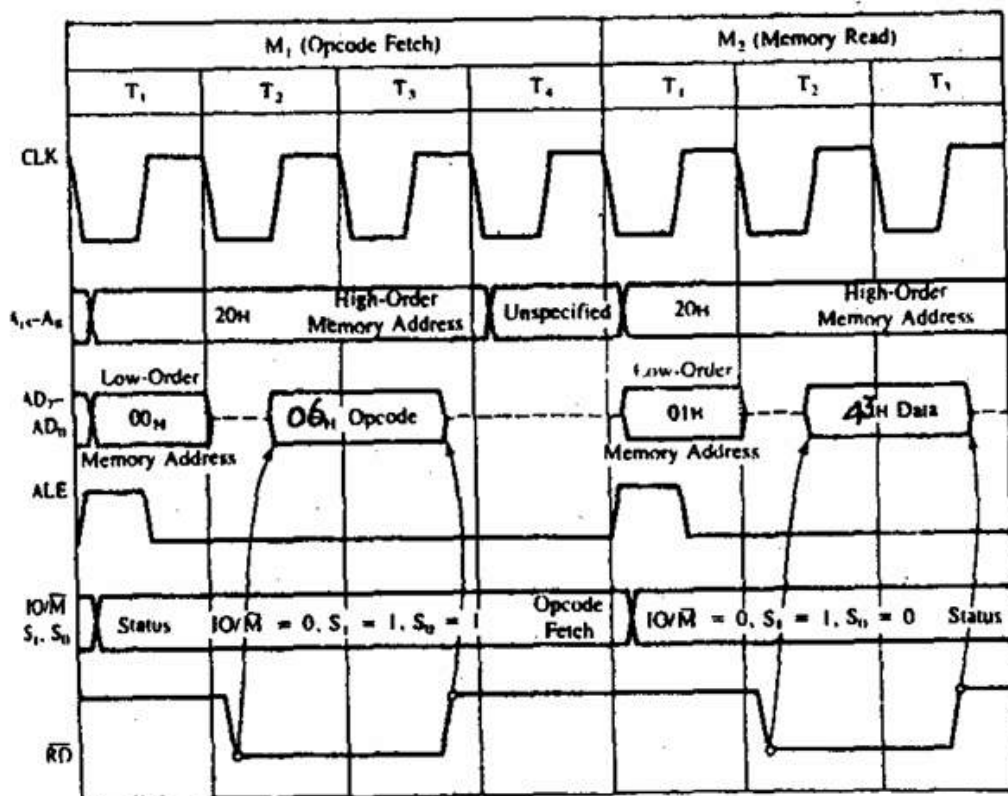


Fig. Timing diagram for IN C0H.

Timing diagram for MVI B, 43H.



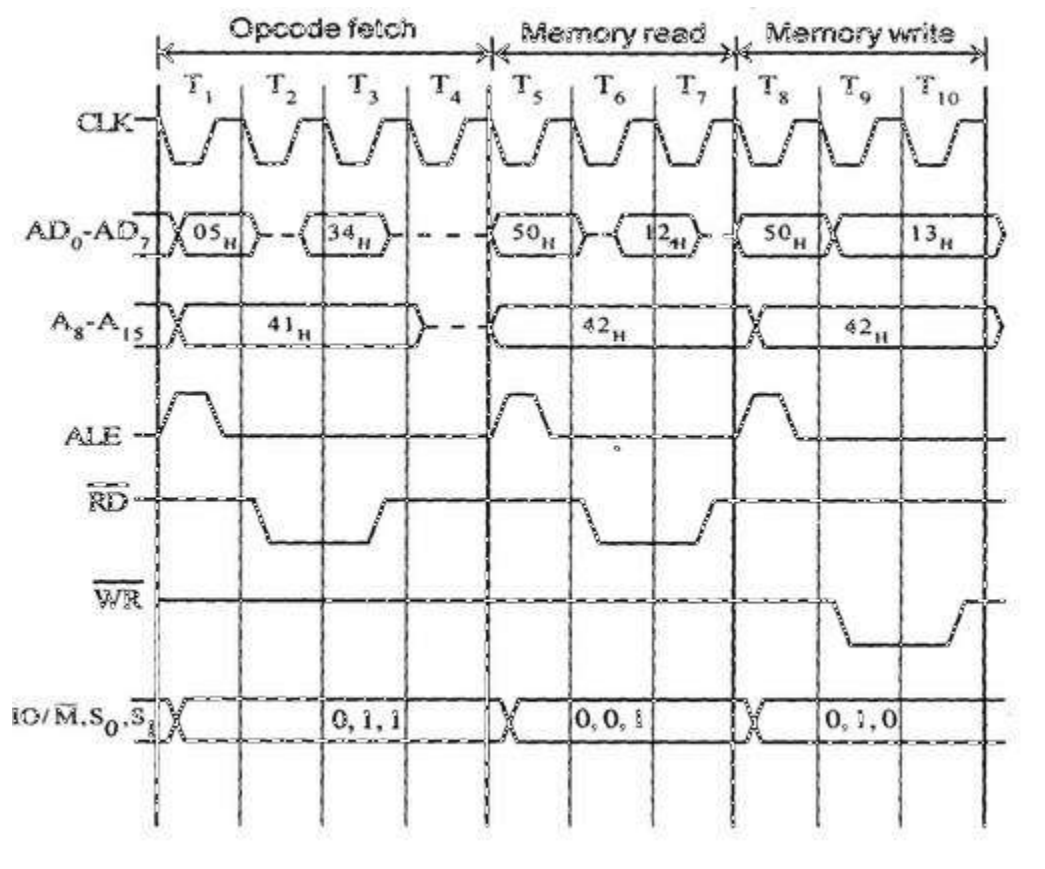
- Fetching the Opcode 06H from the memory 2000H. (OF machine cycle)
- Read (move) the data 43H from memory 2001H. (memory read)

Address	Mnemonics	Op code
2000	MVI B, 43H	06H
2001		43H

Timing diagram for INR M

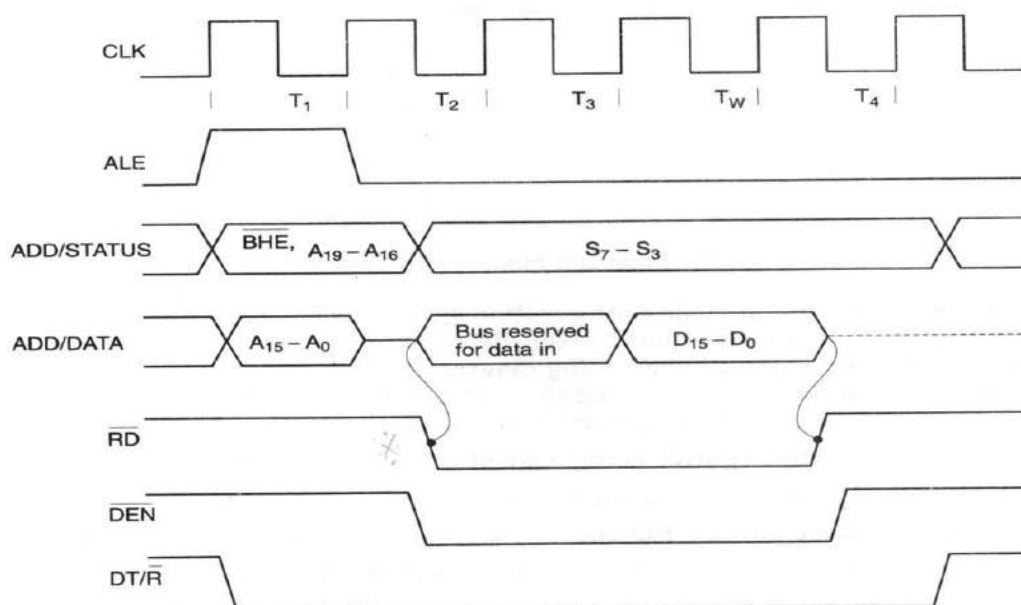
- Fetching the Opcode 34H from the memory 4105H. (OF cycle)
- Let the memory address (M) be 4250H. (MR cycle -To read Memory address and data)
- Let the content of that memory is 12H.
- Increment the memory content from 12H to 13H. (MW machine cycle)

Address	Mnemonics	Opcode
4105	INR M	34 _H



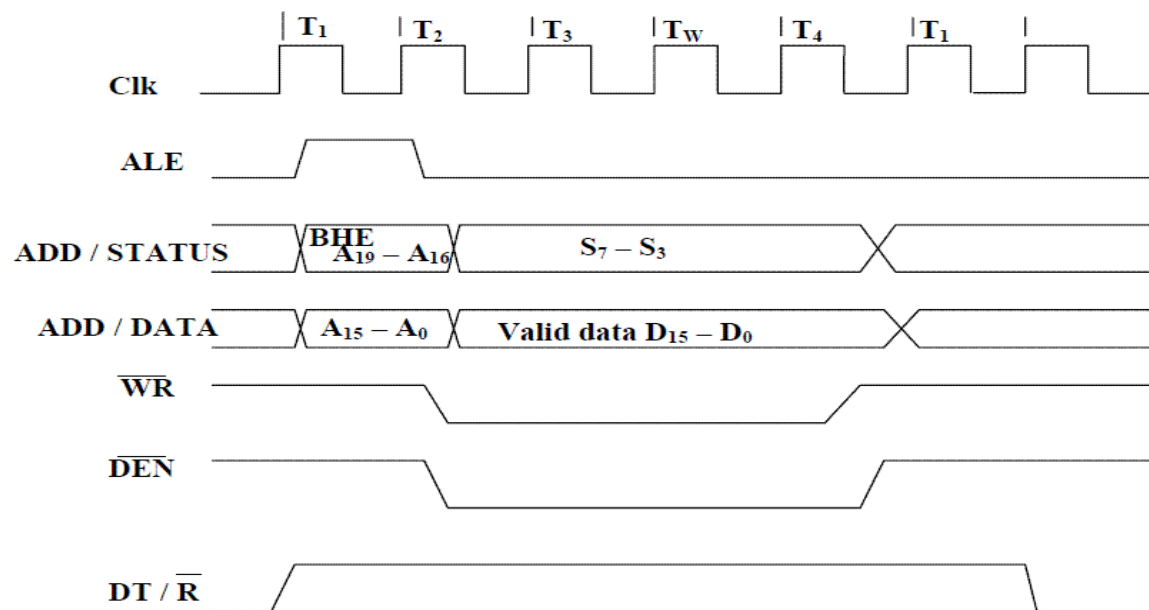
Read and write bus timing of 8086 microprocessor

- The working of the minimum mode configuration system can be better described in terms of the timing diagrams rather than qualitatively describing the operations.
- The op-code fetch and read cycles are similar. Hence the timing diagram can be categorized in two parts, the first is the timing diagram for read cycle and the second is the timing diagram for write cycle.
- The read cycle begins in T₁ with the assertion of address latch enable (ALE) signal and also M / IO signal. During the negative going edge of this signal, the valid address is latched on the local bus.
- The BHE and A₀ signals address low, high or both bytes. From T₁ to T₄, the M/I/O signal indicates a memory or I/O operation.
- At T₂, the address is removed from the local bus and is sent to the output. The bus is then tri-stated. The read (\overline{RD}) control signal is also activated in T₂.
- The read (\overline{RD}) signal causes the address device to enable its data bus drivers. After \overline{RD} goes low, the valid data is available on the data bus.
- The addressed device will drive the READY line high. When the processor returns the read signal to high level, the addressed device will again tristate its bus drivers.



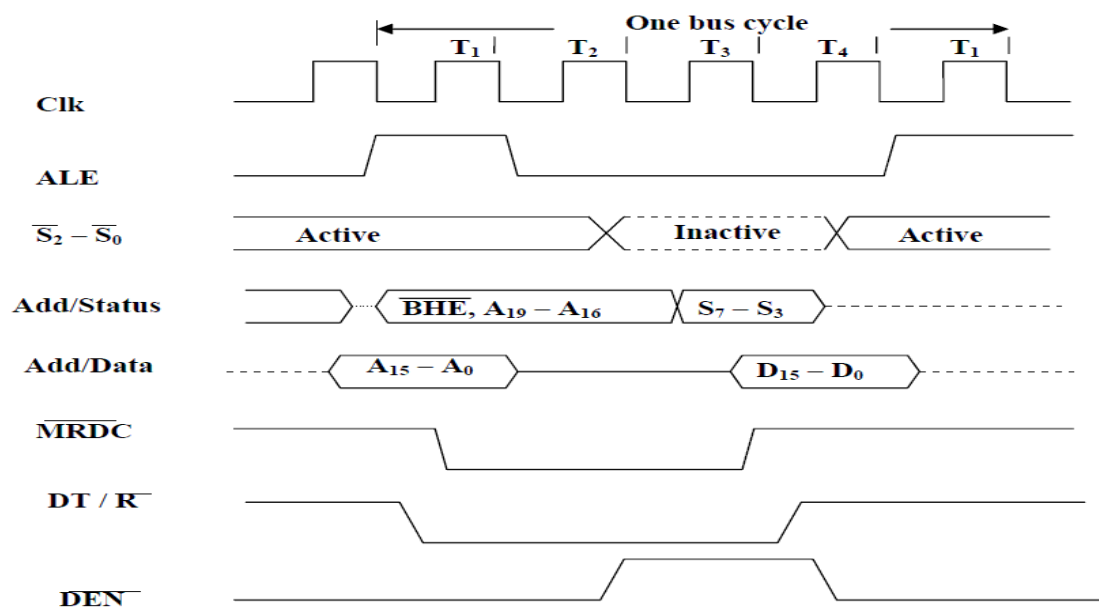
Write cycle timing diagram for minimum mode operation

- A write cycle also begins with the assertion of ALE and the emission of the address. The M/I/O signal is again asserted to indicate a memory or I/O operation. In T_2 , after sending the address in T_1 , the processor sends the data to be written to the addressed location.
- The data remains on the bus until middle of T_4 state. The \overline{WR} becomes active at the beginning of T_2 (unlike \overline{RD} is somewhat delayed in T_2 to provide time for floating).
- The BHE and A_0 signals are used to select the proper byte or bytes of memory or I/O word to be read or write.
- The M/I/O, \overline{RD} and \overline{WR} signals indicate the type of data transfer as specified in table below.



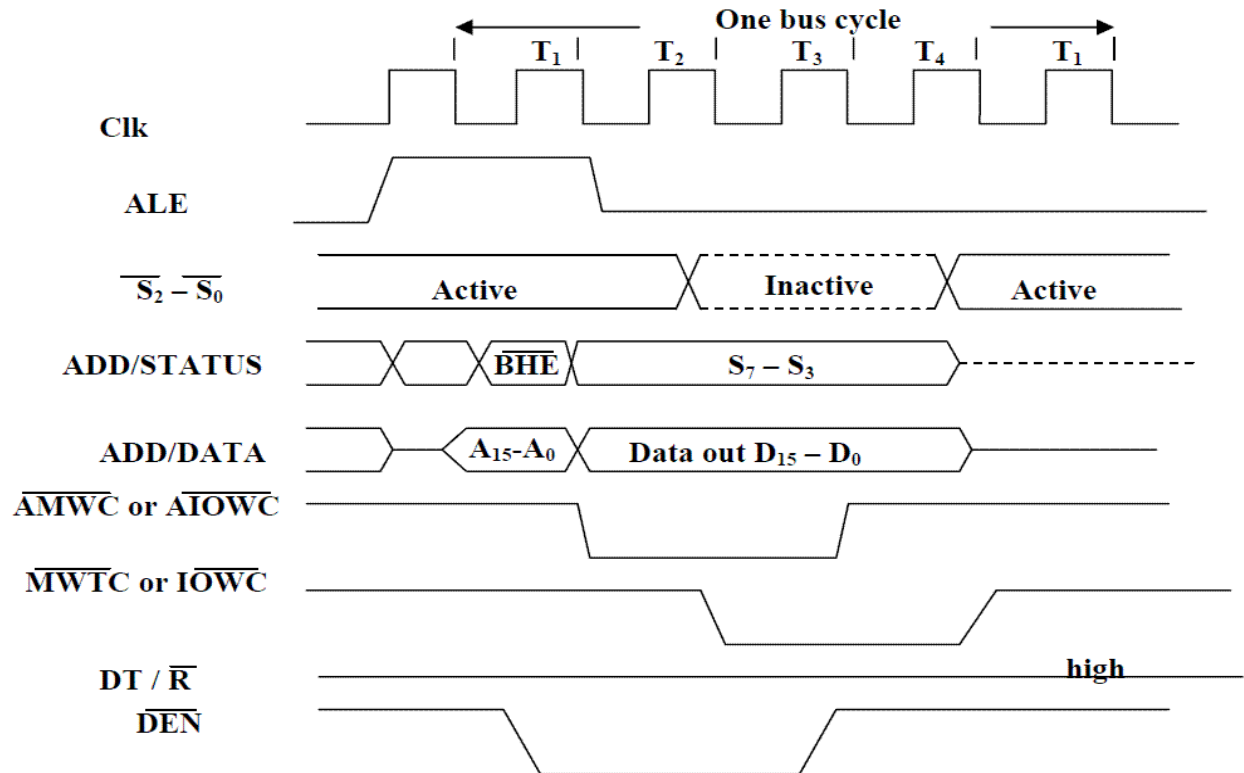
Write Cycle Timing Diagram for Minimum Mode

Memory Read Timing Diagram in Maximum Mode of 8086



Memory Read Timing in Maximum Mode

Memory Write Timing in Maximum mode of 8086



Memory Write Timing in Maximum mode.

Memory devices:

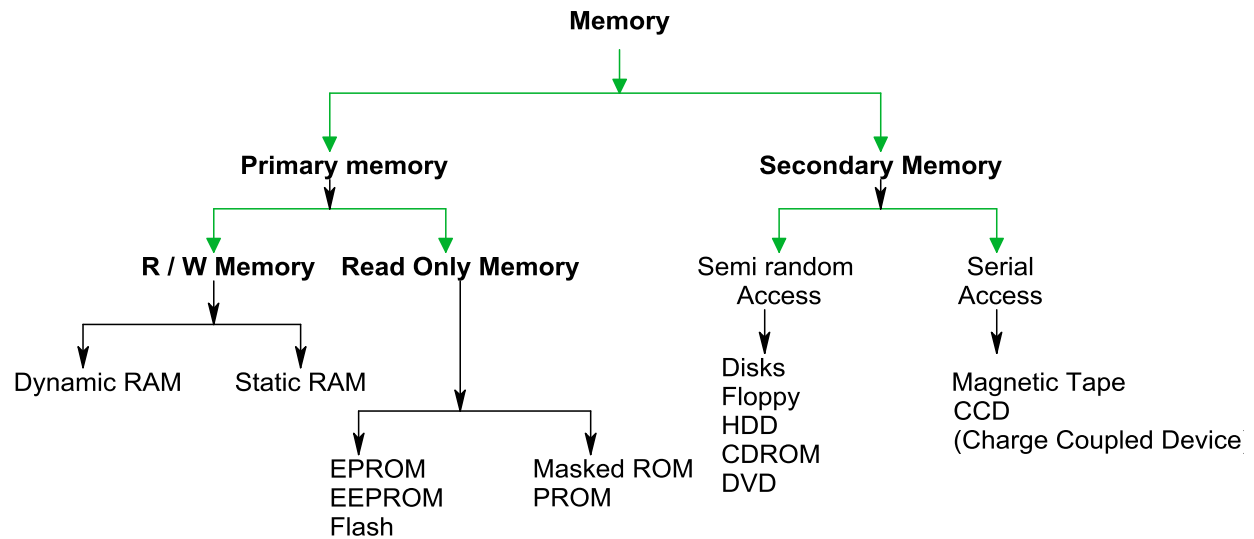


Fig: Classification of memory system

Memory is an essential component of the microcomputer system. It is used to store both instructions and data. It is used to store both instructions and data. Memory is made up of registers and the number of bits stored in a register is called memory word. Memory word is identified by an address. If microprocessor uses 16 bit address, then there will be maximum of $2^{16} = 65536$ memory addresses ranging from 0000H to FFFFH.

There are various types of memory which can be classified into two main groups i.e. Primary memory and Secondary memory.

1. Primary Memory:

It is the memory used by microprocessor to execute programs. The microprocessor can access only those items that are stored in this memory. Hence, all data and program must be within primary memory prior to its execution. Primary memory is much larger than processor memory that is included in the microprocessor chip.

Primary memory is divided into two groups.

i. R/W Memory (RAM)

Microprocessor can read from and write into this memory. This memory is used for information that are likely to be altered such as writing program or receiving data. This memory is volatile i.e. the content will be lost if the power is turned off and commonly known as RAM, RAM are basically of two types.

A. Static RAM (SRAM)

This memory is made up of flip flops and it stores bit as voltage. A single flip flop stores binary data either 1 or 0. Each flip flop is called storage cell. Each cell requires six transistors. Therefore, the memory chip has low density but high speed. This memory is more expensive and consumes more power.

B. Dynamic RAM (DRAM)

This memory is made up of MOS transistor gates and it stores the bit as charge. The advantage of DRAM is it has high density, low power consumption and cheaper than SRAM. But the bit information leaks therefore needs to be rewritten again every few milliseconds. It is called refreshing the memory and requires extra circuitry to do this. It is slower than SRAM.

Read Only Memory (ROM):

ROM contains a permanent pattern of data that cannot be changed. It is non volatile that is no power source is required to maintain the bit values in memory. ROM are basically of 5 types.

- A. Masked ROM: A bit pattern is permanently recorded by the manufacturer during production.
- B. Programmable ROM: In this ROM, a bit pattern may be written into only once and the writing process is performed electrically. That may be performed by a supplier or customer.
- C. Erasable PROM (EPROM):

This memory stores a bit in the form of charge by using EPROM programmer which applies high voltage to charge the gate. Information can be erased by exposing ultra

violet radiation. It is reusable. The disadvantages are : (i) it must be taken out off circuit to erase it (ii). The entire chip must be erased (iii) the erasing process takes 15 to 20 minutes.

D. Electrically Erasable PROM(EEPROM):

It is functionally same as EPROM except that information can be altered by using electrical signal at the register level rather than erasing all the information. It is expensive compared to EPROM and flash and can be erased in 10 ms.

E. Flash Memory:

It is variation of EPROM. The difference is that EPROM can be erased in register level but flash memory must be erased in register level but flash memory must be erased in its entirety or at block level.

2. Secondary memory

The devices that provide backup storage are called secondary memory. It includes serial access type such as magnetic disks and random access type such as magnetic disks. It is nonvolatile memory.

Performance of memory:

1. Access time (t_a):

Read access time: It is the average time required to read the unit of information from memory.

Write access time: It is the average time required to write the unit of information on memory.

$$\text{Access rate } (r_a) = 1/t_a$$

2. Cycle time (t_c):

It is the average time that lapses between two successive read operation .

$$\text{Cycle rate } (r_c) = \text{bandwidth} = 1/t_c$$

Access modes of memory:

1. Random access: In random access mode, the t_a is independent of the location from which the data is accessed like MOS memory.
2. Sequential access: In that mode, the t_a is dependent of the location from which the data is accessed like magnetic type.
3. Semi random-access: the semi random access combines these two. for eg. In magnetic disk, any track can be accessed at random. But the access within the track must be in serial fashion.

The Memory Hierarchy

- Capacity, cost and speed of different types of memory play a vital role while designing a memory system for computers.
- If the memory has larger capacity, more application will get space to run smoothly.
- It's better to have fastest memory as far as possible to achieve a greater performance. Moreover for the practical system, the cost should be reasonable.
- There is a tradeoff between these three characteristics cost, capacity and access time. One cannot achieve all these quantities in same memory module because

- If capacity increases, access time increases (slower) and due to which cost per bit decreases.
- If access time decreases (faster), capacity decreases and due to which cost per bit increases.
- The designer tries to increase capacity because cost per bit decreases and the more application program can be accommodated. But at the same time, access time increases and hence decreases the performance.

So the best idea will be to use memory hierarchy.

- Memory Hierarchy is to obtain the highest possible access speed while minimizing the total cost of the memory system.
- Not all accumulated information is needed by the CPU at the same time.
- Therefore, it is more economical to use low-cost storage devices to serve as a backup for storing the information that is not currently used by CPU
- The memory unit that directly communicate with CPU is called the *main memory*
- Devices that provide backup storage are called *auxiliary memory*
- The memory hierarchy system consists of all storage devices employed in a computer system from the slow by high-capacity auxiliary memory to a relatively faster main memory, to an even smaller and faster cache memory
- The main memory occupies a central position by being able to communicate directly with the CPU and with auxiliary memory devices through an I/O processor
- A special very-high-speed memory called **cache** is used to increase the speed of processing by making current programs and data available to the CPU at a rapid rate
- CPU logic is usually faster than main memory access time, with the result that processing speed is limited primarily by the speed of main memory
- The cache is used for storing segments of programs currently being executed in the CPU and temporary data frequently needed in the present calculations
- The memory hierarchy system consists of all storage devices employed in a computer system from slow but high capacity auxiliary memory to a relatively faster cache memory accessible to high speed processing logic. The figure below illustrates memory hierarchy.

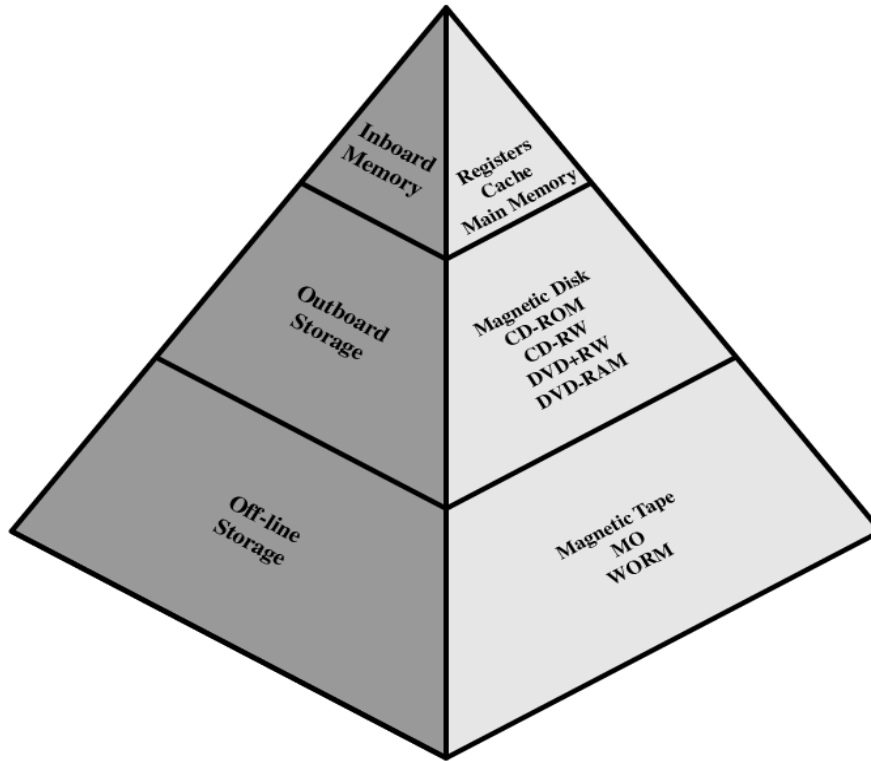


Fig: Memory Hierarchy

- As we go down in the hierarchy
 - Cost per bit decreases
 - Capacity of memory increases
 - Access time increases
 - Frequency of access of memory by processor also decreases.

Hierarchy List

- Registers
- L1 Cache
- L2 Cache
- Main memory
- Disk cache
- Disk
- Optical
- Tape

Address decoding:

Microprocessor is connected with memory and I/O devices via common address and data bus. Only one device can send data at a time and other devices can only receive that data. If more than one device sends data at the same time, the data gets garbled. In order to avoid this situation, ensuring that the proper device gets addressed at proper time, the technique called address decoding is used.

In address decoding method, all devices like memory blocks, I/O units etc. are assigned with a specific address. The address of the device is determined from the way in which the address lines are used to derive a special device selection signal k/a chip select (CS). If the microprocessor has to write or to read from a device, the CS signal to that block should be enabled and the address decoding circuit must ensure that CS signal to other devices are not activated.

Depending upon the no. of address lines used to generate chip select signal for the device, the address decoding is classified as:

1. I/O mapped I/O

In this method, a device is identified with an 8 bit address and operated by I/O related functions IN and OUT for that IO/M =1. Since only 8bit address is used, at most 256 bytes can be identified uniquely. Generally low order address bits A_0-A_7 are used and upper bits A_8-A_{15} are considered don't care. Usually I/O mapped I/O is used to map devices like 8255A, 8251A etc.

2. Memory mapped I/O

In this method, a device is identified with 16 bit address and enabled memory related functions such as STA, LDA for which IO/M =0, here chip select signal of each device is derived from 16 bit address lines thus total addressing capability is 64K bytes. Usually memory mapped I/O is used to map memories like RAM, ROM etc.

Depending on the address that are allocated to the device the address decoding are categorized in the following two groups.

1. Unique Address Decoding:

If all the address lines on that mapping mode are used for address decoding then that decoding is called unique address decoding. It means all 8-lines in I/O mapped I/O and all 16 lines in memory mapped I/O are used to derive \overline{CS} signal. It is expensive and complicated but fault proof in all cases.

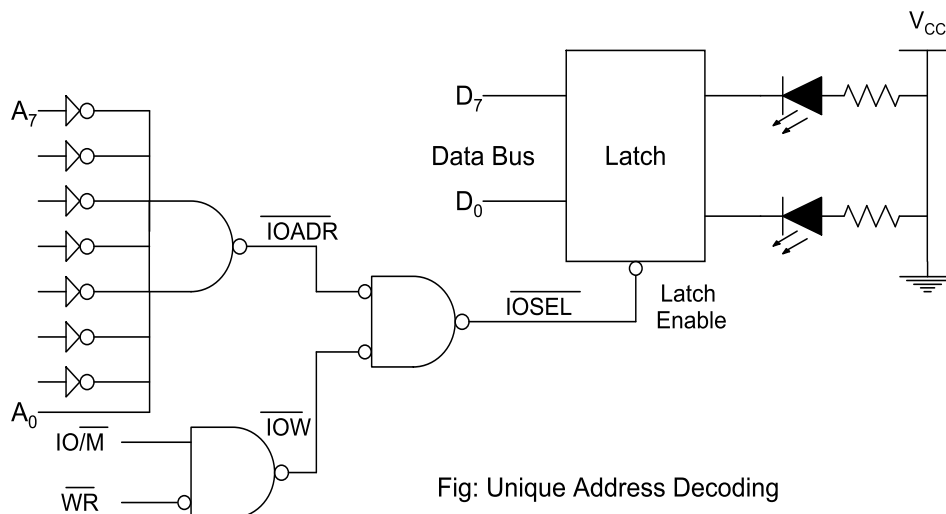


Fig: Unique Address Decoding

- If A_0 is high and A_1 - A_7 are low and if \overline{IOW} becomes low, the latch gets enabled.
- The data to the LED can be transferred in only one case and hence the device has unique address of 01H.

Eight I/P switch interfacing at 53H. (01010011)

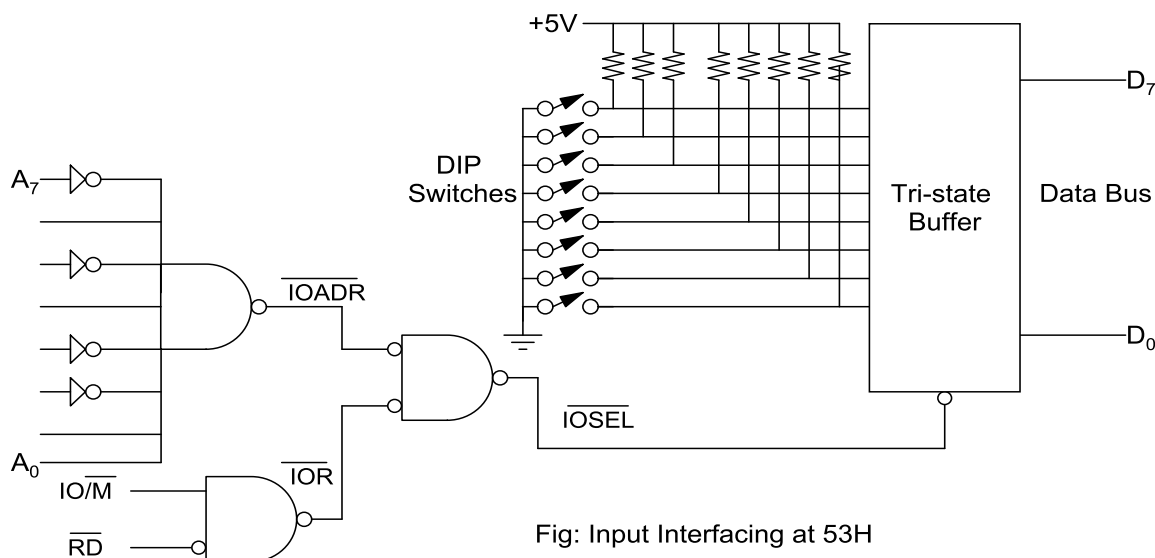


Fig: Input Interfacing at 53H

Non Unique Address decoding:

If all the address lines available on that mode are not used in address decoding then that decoding is called non unique address decoding. Though it is cheaper there may be a chance of address conflict.

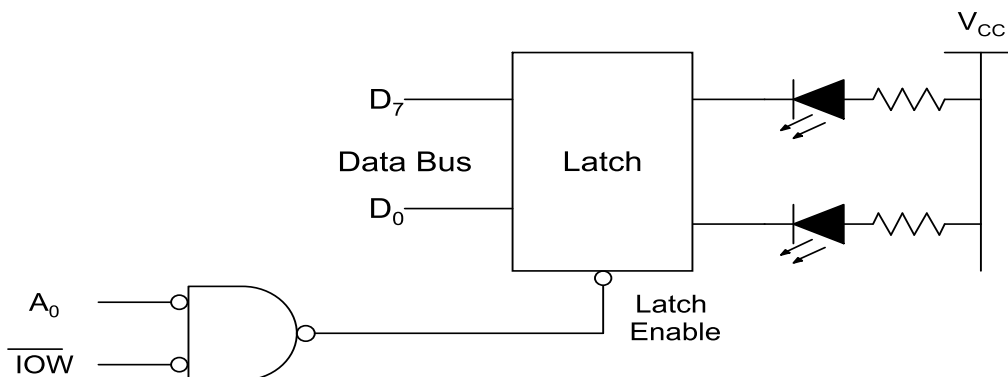


Fig: Non unique Address Decoding

- If A₀ is low and \overline{IOW} is low. Then latch gets enabled.
- Here A₁-A₇ is neglected that is any even address can enable the latch.

Q) Design an address decoding circuit for two RAM chips each of 256 bytes at address 5300H.

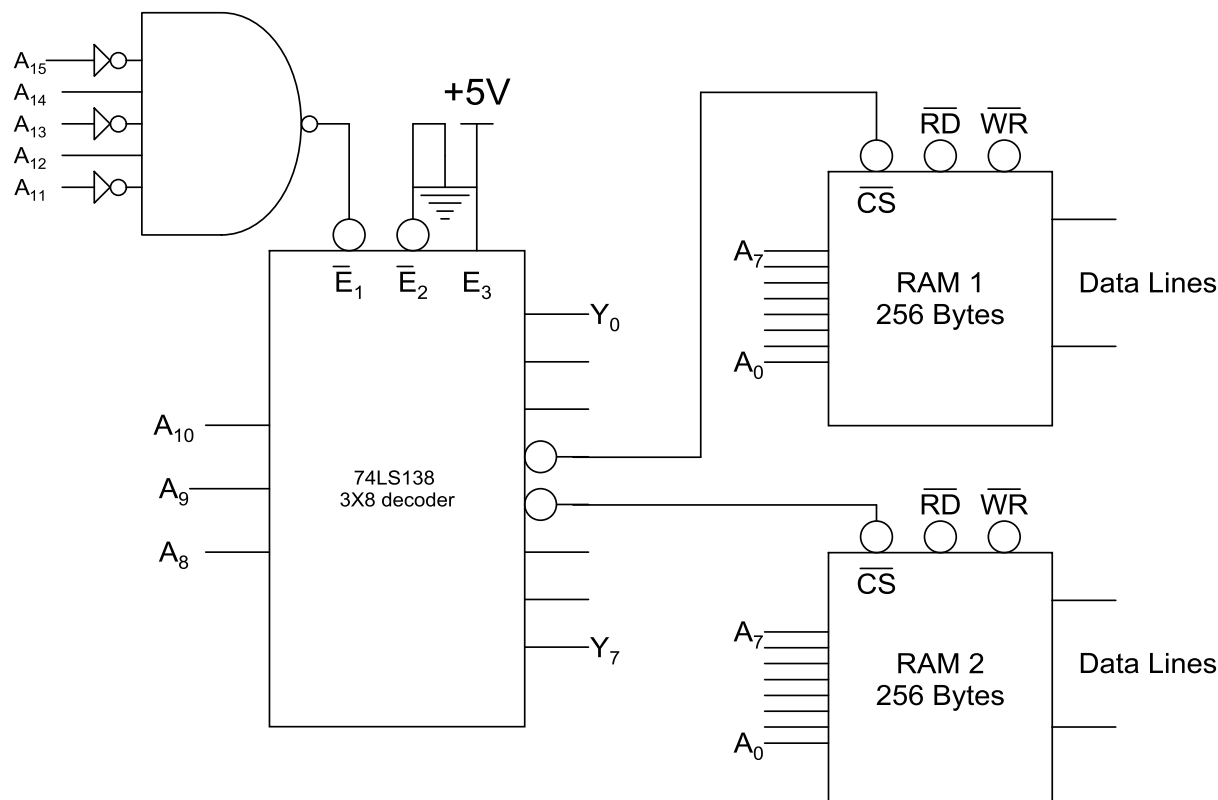
- 256 bytes requires 8 address lines.

$$2^x = 256, x = 8$$

So to address one of 256 bytes in each RAM requires 8 address lines A₀-A₇

Block		Address	A ₁₅	A ₁₄	A ₁₃	A ₁₂	A ₁₁	A ₁₀	A ₉	A ₈	A ₇	A ₆	A ₅	A ₄	A ₃	A ₂	A ₁	A ₀
1	Start	5300H	0	1	0	1	0	0	1	1	0	0	0	0	0	0	0	0
	End	53FFH	0	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1
2	Start	5400H	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
	End	54FFH	0	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1

Address Decoding Circuit:



Q. Draw a circuit diagram to interface two 256 Byte memory chips at address starting at 2050H and 3050H.

Q. Two 4 KB ROM at starting address 0000H

4 KB = $4 \times 1\text{KB} = 2^2 \times 2^{10} = 2^{12}$ therefore we need 12 address lines

Address Decoding with 8086 Microprocessor

The 8086 microprocessor provides a 20 bit memory address that allows up to 1 MB main memory. Out of these several address lines are unused, but these extra lines determine the range of addresses the memory interface occupies. Address decoder circuit determines these extra address lines and enables the memory for a specific range of addresses. Depending up on number of lines used for decoder, we get

Full Decoding (Absolute Decoding): All the unused lines (zero lines) are used.

Partial Decoding (Linear Decoding): All the unused lines (zero lines) are not used.

Block Decoding: Same as full decoding except that in this case blocks of memory is enabled using the unused lines.

Important Points to be considered for Memory Interfacing

- After reset CS contains FFFFH and IP contains 0000H. Therefore, the physical address is FFFF0H. Here instruction execution starts from FFFF0H which is normally a jump from some other location where a longer program resides. This program always resides in a ROM. For example, we want to interface 4 chips of 2K memory that means 8K bytes of

memory requires 13 address lines A_0 to A_{12} . So, 8K means 01FFFH bytes, therefore EPROM address starts from FFFFFH – 01FFFH = FE000H.

- Since ROMs and EPROMs are read-only devices, A_0 and BHE' are not required to be part of the chip enable/select decoding. The 8086 address lines must be connected to the ROM/EPROM chip starting with A_1 and higher to all the address lines of the ROM/EPROM chips. The 8086 unused address lines can be used as chip enable/select decoding.
- Since static RAMs are read/write memories, both A_0 and BHE' must be included in the chip select/enable decoding of the devices and write timing must be considered in the compatibility analysis.

EPROM Interfacing with 8086

Whenever the 8086 CPU is reset, its value is set to FFFFH and IP value is set to 0000H that corresponds to physical address FFFF0H which is always a part of ROM. This means FFFF0H to FFFFFH should be always included in the ROM.

Let us take an example to address 16 KB of EPROM to 8086 microprocessor, 16 KB means 3FFFH bytes. Hence the EPROM memory should start from FFFFFH – 03FFFH = FC000H. To address 16 KB, we require 14 address lines. Of the 16 KB, 8 KB will be at even addresses and 8 KB will be at odd addresses. Hence, we use 2 EPROM chips, each of 8 KB capacity one for storing bytes at even address and another for storing bytes for odd address.

	A_{19}	A_{18}	A_{17}	A_{16}	A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0
Start:	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
End:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Used for Chip Select						Address within the 16KB													

The EPROM address ranges from FC000H to FFFFFH

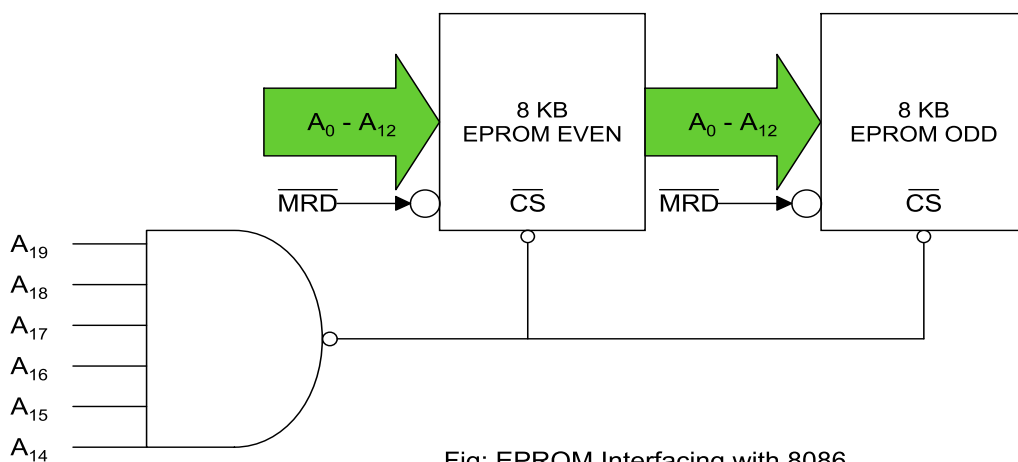


Fig: EPROM Interfacing with 8086

A_0 and BHE' is not used for interfacing of EPROM. Both the 8 KB EPROM chips are selected whenever any address in the range FC000H – FFFFFH comes on the address bus.

Static RAM Interfacing with 8086

The general procedure of static memory interfacing with 8086 is briefly described as follows.

- Arrange the available memory chips so as to obtain 16 bits data bus with the upper 8 bit bank is called “Odd address memory bank” and the lower 8 bit bank is called “Even address memory bank”.
- Connect available memory address lines of memory chips with those of the microprocessor and also connect the memory RD' and WR' inputs to the corresponding processor control signals. Connect the 16 bit data bus of the memory bank was that of microprocessor 8086.
- The remaining address lines of the microprocessor, BHE' and A_0 are used for loading the required chip select signals for the odd and even memory banks. The CS' of the memory is derived from the O/P of the decoding.

Let us take an example to address 16 KB of RAM to 8086 microprocessor. We will split 16 KB into two blocks each of 8 KB one of even addressed and another of odd addressed. Depending upon the bit on A_0 , either the even or odd bank will be selected. If $A_0 = 0$, the even bank is selected. Now the BHE' signal will be 0 whenever a byte or a word is being accessed at odd address. Also for an even addressed word, both the banks will have to be enabled at the same time. Hence, A_0 has to be given to CS' of even bank and BHE' has to be given to CS' of odd bank.

- If only A_0 is low, memory location from even bank is accessed.
- If only BHE' is low, memory location from odd bank is accessed.
- If both are low, 2 memory locations are accessed from each bank.

To address 16 KB, we require 14 address lines. Of the 16 KB, 8 KB will be at even addresses and 8 KB will be at odd addresses. Hence, we use 2 RAM chips, each of 8 KB capacity one for storing bytes at even address and another for storing bytes for odd address. We will start the RAM address from 80000H.

	A_{19}	A_{18}	A_{17}	A_{16}	A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0
Start:	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
End:	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Block A																				
Start:	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
End:	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Block B																				

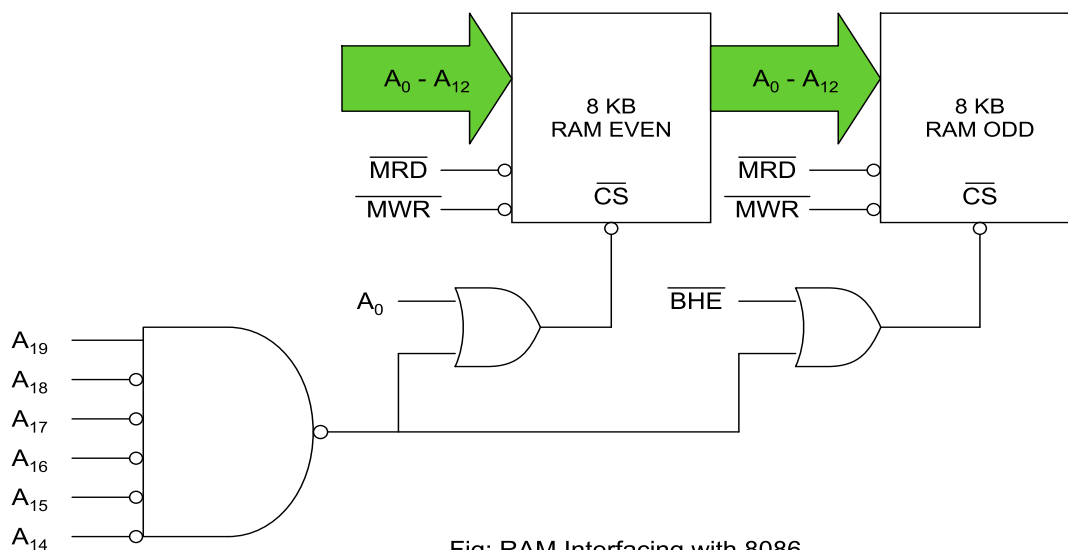


Fig: RAM Interfacing with 8086

As a good and efficient interfacing practice, the address map of the system should be continuous as far as possible i.e. there should be no windows and no feedback space should be allowed. A memory location should have a single address corresponding to it i.e. absolute decoding should be preferred.

Q) Interface two 4K X 8 EPROMs and two 4K X 8 RAM chips with 8086, select suitable maps.

We know that, after reset, the IP and CS are initiated to from address FFFF0H. Hence this address must lie in the EPROM. The address of RAM may be selected anywhere in the 1MB space of 8086, but we will select the RAM address such that the address map of the system is continuous as shown in table below.

Address	A ₁₉	A ₁₈	A ₁₇	A ₁₆	A ₁₅	A ₁₄	A ₁₃	A ₁₂	A ₁₁	A ₁₀	A ₉	A ₈	A ₇	A ₆	A ₅	A ₄	A ₃	A ₂	A ₁	A ₀
FFFFFH	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	EPROM 8K X 8																			
FE000H	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
FDFFFH	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
	RAM 8K X 8																			
FC000H	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total 8K of EPROM need 13 address lines A_0 - A_{13} (Since $2^{13} = 8K$). Address lines A_{13} - A_{19} are used for decoding to generate the chip select. The BHE' signal goes low when a transfer is at odd address or higher byte of data is to be accessed, let us assume that the latched address, BHE' and de-multiplexed data lines are readily available for interfacing.

The two 4K X 8 chips of RAM and EPROM are arranged in parallel to obtain 16-bit data bus width. If A_0 is 0 i.e. the address is even and is in RAM, then the lower RAM chip is selected

indicating 8-bit transfer at even address. If A_0 is 1 i.e. the address is odd and is in RAM, the BHE' goes low, the upper RAM chip is selected further indicating that the 8 bit transfer is at an odd address. If the selected addresses are in ROM, the respective ROM chips are selected. If at a time A_0 and BHE' both are zero, both the RAM or ROM chips are selected i.e. the data transfer is of 16 bits. The selection of chips takes place as shown in table below.

Decoder I/P Address / BHE'	A_2	A_1	A_0	Selection / Comment
	A_{13}	A_0	BHE'	
Word transfer on D_0-D_{15}	0	0	0	Even and Odd address in RAM
Byte transfer on D_0-D_7	0	0	1	Only even address in RAM
Byte transfer on D_8-D_{15}	0	1	0	Only odd address in RAM
Word transfer on D_0-D_{15}	1	0	0	Even and Odd address in ROM
Byte transfer on D_0-D_7	1	0	1	Only even address in ROM
Byte transfer on D_8-D_{15}	1	1	0	Only odd address in ROM

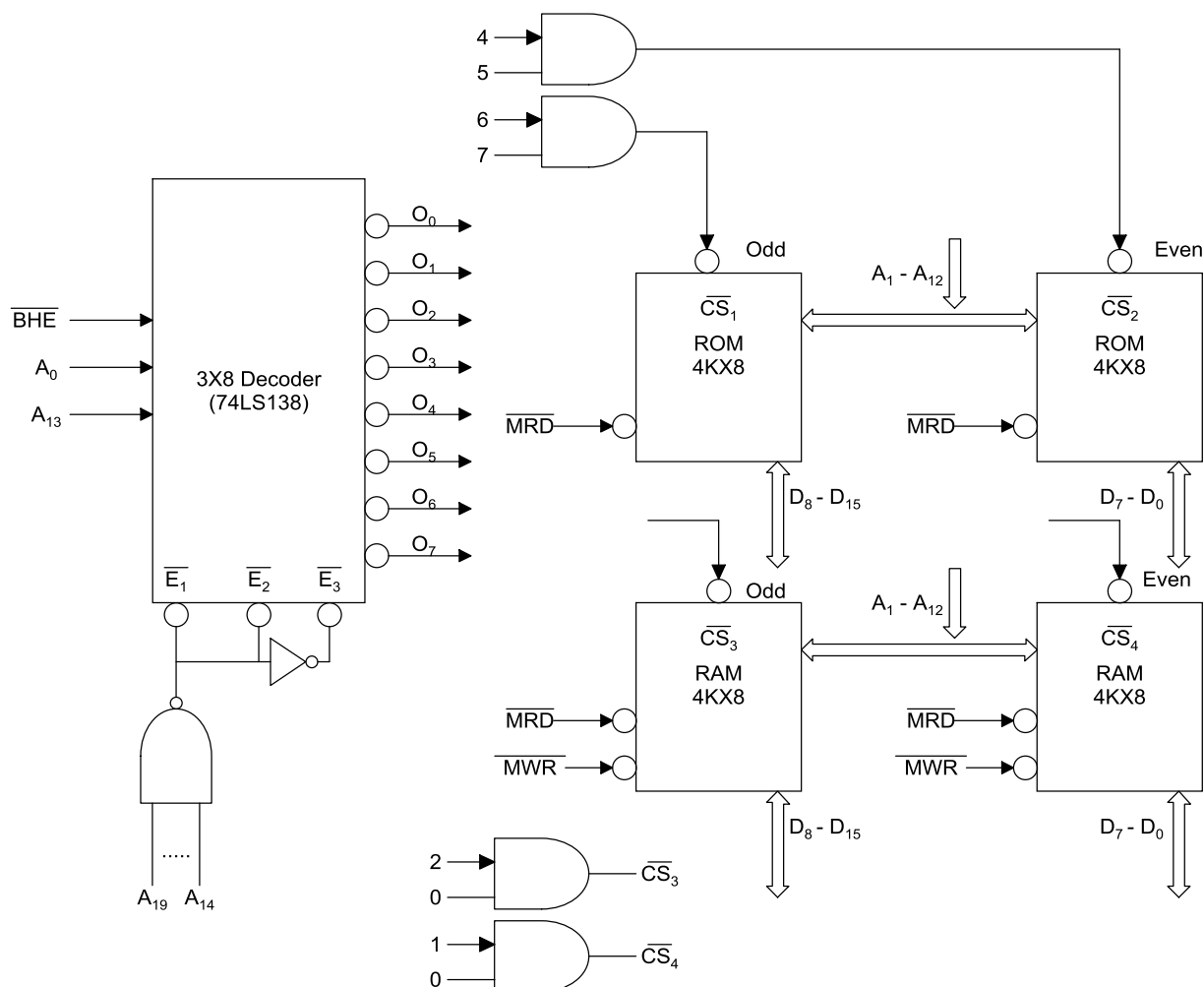


Fig: 8086 Interfacing Circuit

Input/ Output Devices

Input / Output devices are the means through which the microcomputer unit communicates with the outside world. The link between the I/O devices and the microprocessor is maintained by a circuitry known as I/O module. This circuitry includes the specific interfaces needed for I/O devices as well as control functions that implement the I/O transfers within the computer. I/O devices usually are appeared as passive devices which take action only when instructed to do. The CPU monitors the status of the I/O devices and selects them according to availability and need.

- ✓ Consider the keyboard as input device and the steps when the key is pressed are
 - Microprocessor detects the key change in status of keyboard i.e. the key is pressed.
 - It receives the encoded information corresponding to pressed key.
 - It checks the validity of required signal.
- ✓ Consider the printer as output device

- Here microprocessor checks ideal condition of printer, if ideal then sends the data to be printed and required command for that.

For interfacing of typical microprocessor to I/O devices such as keyboard, CRT, printer etc. All need I/O interface circuits which are of mainly two types.

1. Serial Interface

- Data are transferred serially one bit at a time starting from Least Significant bit.
- Slow due to single communication link but inexpensive to implement.
- It uses clock to separate consecutive bits.
- Its function is to deal with the data on the bus in the parallel mode and communicate with the connected device in serial mode.
- Its data bus has n data lines, the serial I/O interface accepts n bit of data simultaneously from the bus and n bits are sent one at a time thus requiring n time slots.
- Not suitable for fast operation needed microprocessor.

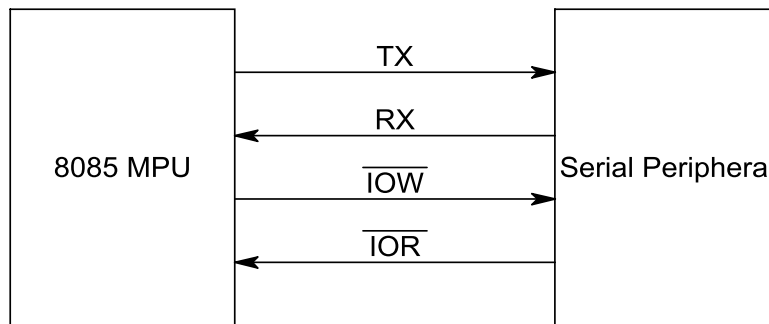


Fig: Serial Interface between microprocessor and I/O device.

2. Parallel Interface

- The device which can handle data at higher speed cannot support with serial interface.
- N bits of data are handled simultaneously by the bus and the links to the device directly.
- Achieves faster communication but becomes expensive due to need of multiple wires.

Synchronizing the computer with peripherals:

The information exchanged between a microprocessor and an I/O interface circuit consists of input or output data and control information. The status information enable the microprocessor monitor the device and when it is ready then send or receive data. Control information is the command by microprocessor to cause I/O device to take some action. If the device operates at different speeds, then microprocessor can be used to select a particular speed of operation of the device. The techniques used to transfer data between different speed devices and computer is called synchronizing. Different techniques under synchronizing are:

1) Simple I/O

For simple I/O, the buffer switch and latch switches i. e. LED are always connected to the input and output ports. The devices are always ready to send or receive data.

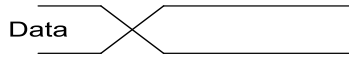


Fig: Simple I/O

Here cross line indicate the time for new valid data.

2) Wait Interface(Simple strobe I/O)

In this technique, MP need to wait until the device is ready for the operation.

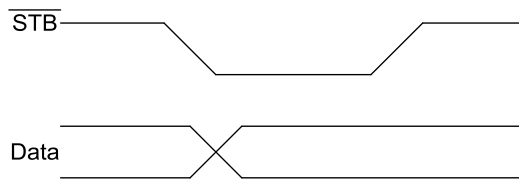


Fig: Simple Strobe I/O

Consider a simple keyboard consisting of 8 switches connected to a MP through a parallel interface CKT (Tri-state buffer). The switch is of dip switches. In order to use this keyboard as an input device the MP should be able to detect that a key has been activated. This can be done by observing that all the bits are in required order. The processor should repeatedly read the state of input port until it finds the right order of bits i.e. at least 1 bit of 8 bits should be 0.

Consider the tri-state A/D converter

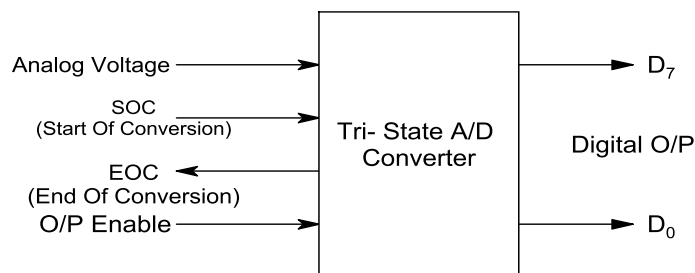


Fig: Tri-State A/D Converter

- Used to convert analog to digital data which can be read by I/O unit of MP
- When SOC appears 1, I/O unit should ready for reading binary data/digital data.
- When EOC's status is 1, then I/O unit should stop to read data.
- Strobe signal indicates the time at which data is being activated to transmit.

3) Single Handshaking:

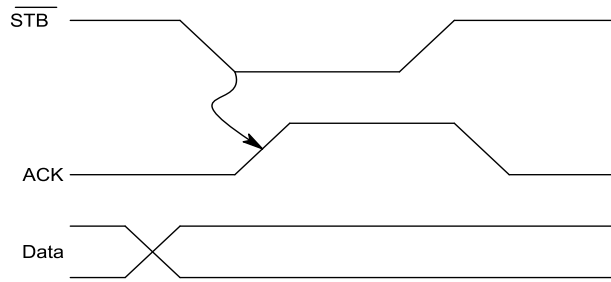


Fig: Single Handshaking

- The peripheral outputs some data and send \overline{STB} signal to MP. “here is the data for you.”
- MP detects asserted \overline{STB} signal, reads the data and sends an acknowledge signal (ACK) to indicate data has been read and peripheral can send next data. “I got that one, send me another.”
- MP sends or receives data when peripheral is ready.

4) Double Handshaking

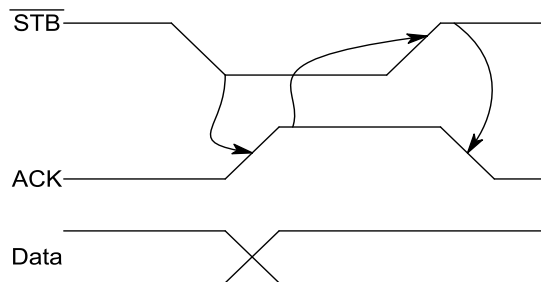


Fig: Double Handshaking

- The peripheral asserts its \overline{STB} line low to ask MP “Are you ready?”
- The MP raises its ACK line high to say “I am ready”.
- Peripheral then sends data and raises its \overline{STB} line low to say “Here is some valid data for you.”
- MP then reads the data and drops its ACK line to say, “I have the data, thank you, and I await your request to send the next byte of data.”

Programmable Peripheral Interface (PPI) - 8255A:

- The INTEL 8255 is a device used to parallel data transfer between processor and slow peripheral devices like ADC, DAC, keyboard, 7-segment display, LCD, etc.
- The 8255 has three ports: Port-A, Port-B and Port-C.
- Port-A can be programmed to work in any one of the three operating modes mode-0, mode-1 and mode-2 as input or output port.
- Port-B can be programmed to work either in mode-0 or mode-1 as input or output port.

- Port-C (8-pins) has different assignments depending on the mode of port-A and port-B.
- If port-A and B are programmed in mode-0, then the port-C can perform any one of the following functions.
 - As 8-bit parallel port in mode-0 for input or output.
 - As two numbers of 4-bit parallel ports in mode-0 for input or output.
 - The individual pins of port-C can be set or reset for various control applications.
- If port-A is programmed in mode-1/mode-2 and port-B is programmed in mode-1 then some of the pins of port-C are used for handshake signals and the remaining pins can be used as input/ output lines or individually set/reset for control application.

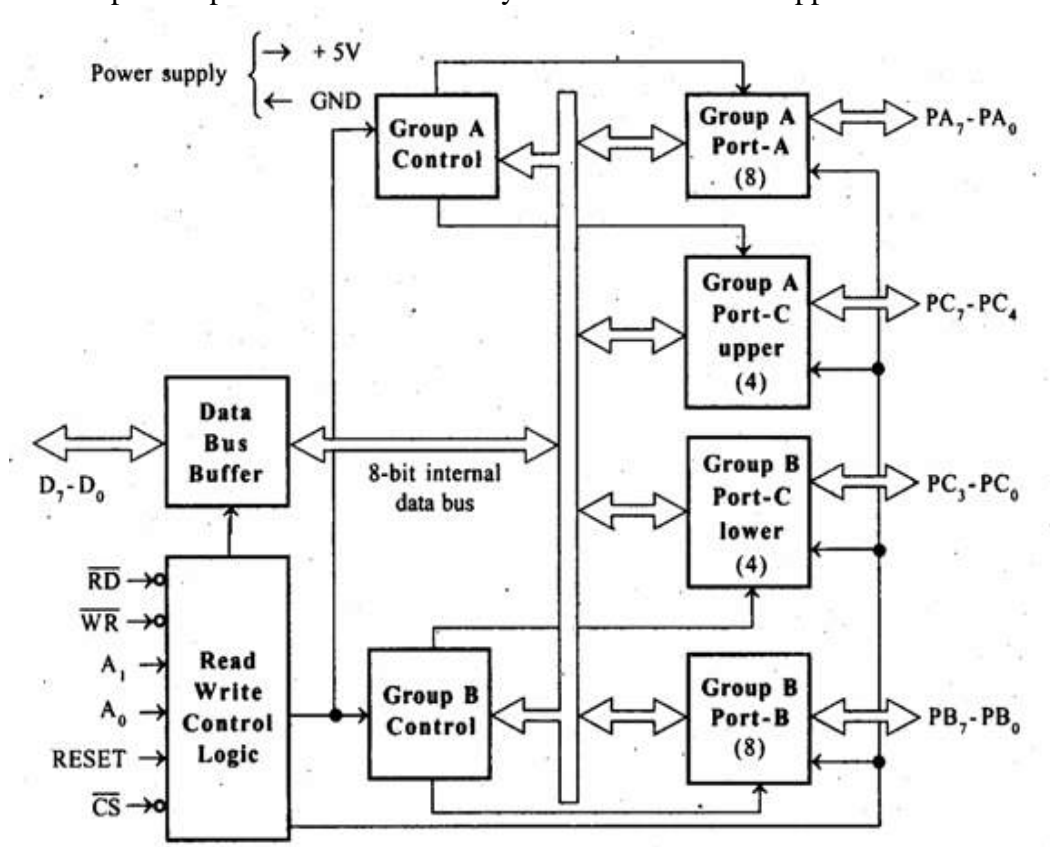


Fig2: Internal Block Diagram of 8255

Key Features of Mode-0, Mode-1 and Mode-2

- Mode 0: Ports A and B operate as either inputs or outputs and Port C is divided into two 4-bit groups either of which can be operated as inputs or outputs*
- Mode 1: Same as Mode 0 but Port C is used for handshaking and control*
- Mode 2: Port A is bidirectional (both input and output) and Port C is used for handshaking. Port B is not used.*

The read/write control logic requires six control signals. These signals are given below.

1. RD (low): This control signal enables the read operation. When this signal is low, the microprocessor reads data from a selected I/O port of the 8255A.
2. WR (low): This control signal enables the write operation. When this signal goes low, the microprocessor writes into a selected I/O port or the control register.

3. RESET: This is an active high signal. It clears the control register and set all ports in the input mode.
4. CS (low), A0 and A1: These are device select signals. They are,

Internal Devices	A ₁	A ₀
Port A	0	0
Port B	0	1
Port C	1	0
Control Register	1	1

Serial Interface /Serial data transmission:

Serial I/O transfer is more common than the parallel I/O. The two major forms of serial data transmission are:

1) Synchronous serial data transmission:

- Data is transmitted or received based on a clock signal i. e. synchronously.
- The transmitting device sends a data bit at each clock pulse.
- Usually one or more SYNC characters are used to indicate the start of each synchronous data stream.
- SYNC characters for each frame of data.
- Transmitting device sends data continuously to the receiving device. If the data is not ready to be transmitted, the transmitter will send SYNC character until the data is available.
- The receiving device waits for data, when it finds the SYNC characters then starts interpreting the data.

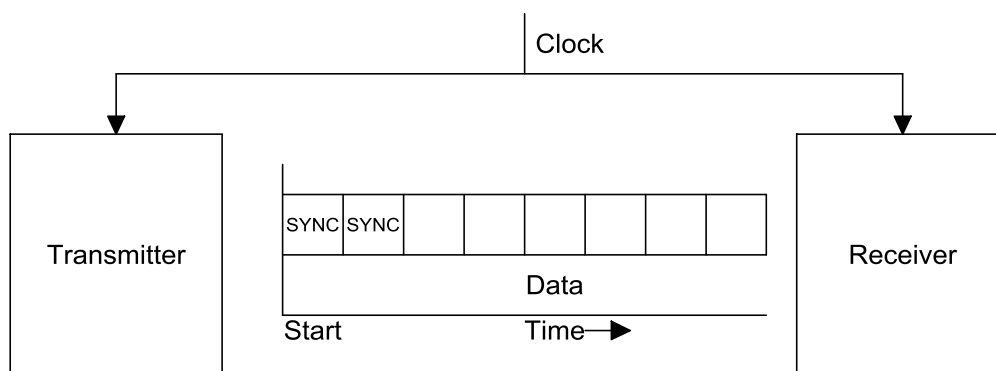


Fig: Synchronous Serial Transmission Format

2) Asynchronous serial data Transmission:

- The receiving device does not need to be synchronized with the transmitting device.
- Transmitting device send data units when it is ready to send data.

- Each data unit must contain start and stop bits for indicating beginning and the end of data unit. And also one parity bit to identify odd or even parity data.
- For e.g. To send ASCII character (7 bit)
- We need:
 - 1 start bit: beginning of data
 - 1 stop bit: End of data
 - 1 Parity bit: even or odd parity
 - 7 or 8 bit character: actual data transferred

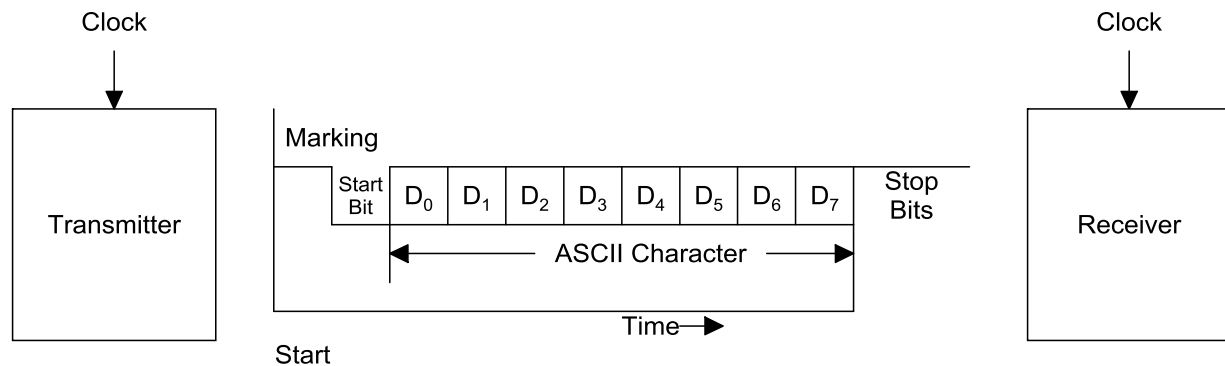


Fig: Asynchronous Serial Transmission Format

Synchronous vs. Asynchronous Data Transmission

Asynchronous Communication

- Simple interface (limited data rate, typically < 64 kbps)
- Used for connecting: Printer, Terminal, Modem, home connections to the Internet
- No clock sent (Tx & Rx have own clocks)
- Requires start and stop bits which provides byte timing and increases overhead
- Parity often used to validate correct reception.
- Independent transmit & receive clocks

Synchronous Communication

- Clock sent with data (more configuration options).
- Synchronised transmit & receive clocks.
- More complex interface (high data rates supported up to ~ 10 Gbps)
- Used for: Connections between computer and telephony networks.

Universal Synchronous Asynchronous Receiver Transmitter (USART) – 8251A

- The 8251A is a programmable serial communication interface chip designed for synchronous and asynchronous serial data communication.
- It supports the serial transmission of data.

The functional block diagram of 8251A consists five sections. They are:

- Read/Write control logic
- Transmitter

- Receiver
- Data bus buffer
- Modem control.

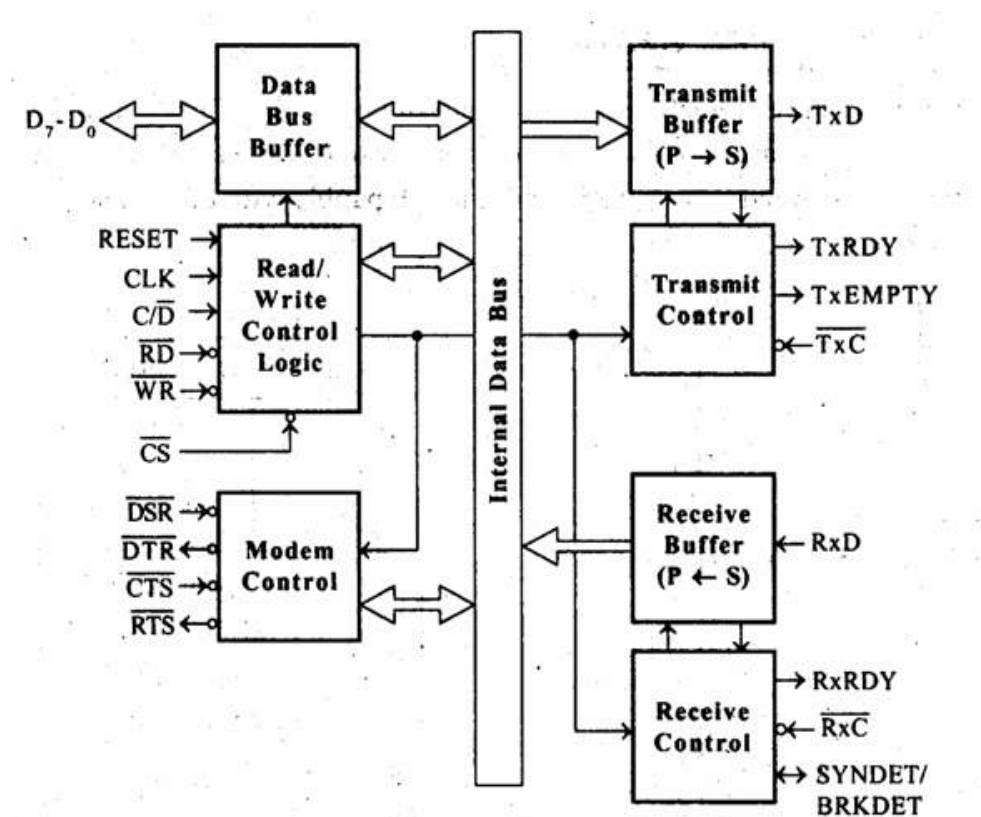


Fig: Functional block diagram of 8251A-USART

Read/Write control logic:

- The Read/Write Control logic interfaces the 8251A with CPU, determines the functions of the 8251A according to the control word written into its control register.
- It monitors the data flow.
- This section has three registers and they are control register, status register and data buffer.
- The active low signals RD, WR, CS and C/D(Low) are used for read/write operations with these three registers.
- When C/D(low) is high, the control register is selected for writing control word or reading status word.
- When C/D(low) is low, the data buffer is selected for read/write operation.
- When the reset is high, it forces 8251A into the idle mode.
- The clock input is necessary for 8251A for communication with CPU and this clock does not control either the serial transmission or the reception rate.

Transmitter section:

- The transmitter section accepts parallel data from CPU and converts them into serial data.

- The transmitter section is double buffered, i.e., it has a buffer register to hold an 8-bit parallel data and another register called output register to convert the parallel data into serial bits.
- When output register is empty, the data is transferred from buffer to output register. Now the processor can again load another data in buffer register.
- If buffer register is empty, then TxRDY is goes to high.
- If output register is empty then TxEMPTY goes to high.
- The clock signal, TxC (low) controls the rate at which the bits are transmitted by the USART.
- The clock frequency can be 1,16 or 64 times the baud rate.

Receiver Section:

- The receiver section accepts serial data and convert them into parallel data.
- The receiver section is double buffered, i.e., it has an input register to receive serial data and convert to parallel, and a buffer register to hold the parallel data.
- When the RxD line goes low, the control logic assumes it as a START bit, waits for half a bit time and samples the line again.
- If the line is still low, then the input register accepts the following bits, forms a character and loads it into the buffer register.
- The CPU reads the parallel data from the buffer register.
- When the input register loads a parallel data to buffer register, the RxRDY line goes high.
- The clock signal RxC (low) controls the rate at which bits are received by the USART.
- During asynchronous mode, the signal SYNDET/BRKDET will indicate the break in the data transmission.
- During synchronous mode, the signal SYNDET/BRKDET will indicate the reception of synchronous character.

MODEM Control:

- The MODEM control unit allows to interface a MODEM to 8251A and to establish data communication through MODEM over telephone lines.
- This unit takes care of handshake signals for MODEM interface.

Baud rate /Bit rate

The difference between Bit and Baud rate is complicated and intertwining. Both are dependent and inter-related.

Bit Rate is how many data bits are transmitted per second.

A baud Rate is the number of times per second a signal in a communications channel changes. Bit rates measure the number of data bits (that is 0's and 1's) transmitted in one second in a communication channel. A figure of 2400 bits per second means 2400 zeros or ones can be transmitted in one second, hence the abbreviation "bps." Individual characters (for example letters or numbers) that are also referred to as bytes are composed of several bits.

A baud rate is the number of times a signal in a communications channel changes state or varies. For example, a 2400 baud rate means that the channel can change states up to 2400 times per

second. The term “change state” means that it can change from 0 to 1 or from 1 to 0 up to X (in this case, 2400) times per second. It also refers to the actual state of the connection, such as voltage, frequency, or phase level).

The main difference between the two is that one change of state can transmit one bit, or slightly more or less than one bit, that depends on the modulation technique used. So the bit rate (bps) and baud rate (baud per second) have this connection:

$$\begin{aligned} \text{If signal is changing every } 10/3 \text{ ns then,} \\ \text{Baud rate} &= 1/10/3\text{ns} = 3/10 \times 10^9 = 3 \times 10^8 \\ &= 300 \text{ mbd} \end{aligned}$$

Note:

- If 1 frame of data is coded with 1 bit then band rate and bit rate are same.
- Sometimes frame of data are coded with two or three bits then baud rate and bit rate are not same.

RS -232

- Serial transmission of data is used as an efficient means for transmitting digital information across long distances, the existing communication lines usually the telephone lines can be used to transfer information which saves a lot of hardware.
- RS-232C is an interface developed to standardize the interface between data terminal equipment (DTE) and data communication equipment (DCE) employing serial binary data exchange. Modem and other devices used to send serial data are called data communication equipment (DCE). The computers or terminals that are sending or receiving the data are called data terminal.
- Equipment (DTE) RS- 232C is the interface standard developed by electronic industries Association (EIA) in response to the need for the signal and handshake standards between the DTE and DCE.
- It uses 25 pins (DB – 25P) or 9 Pins (DE – 9P) standard where 9 pin standard does not use all signals i. e. data, control, timing and ground.
- It describes the voltage levels, impedance levels, rise and fall times, maximum bit rate and maximum capacitance for all signal lines.
- It also specifies that DTE connector should be male and DCE connector should be female.
- It can send 20kBd for a distance of 50 ft.
- The voltage level for RS-232 are:
 - A logic high or 1 , 3V to -15V
 - A logic low or 0, +3v to +15v
 Normally $\pm 12\text{V}$ voltage levels are used

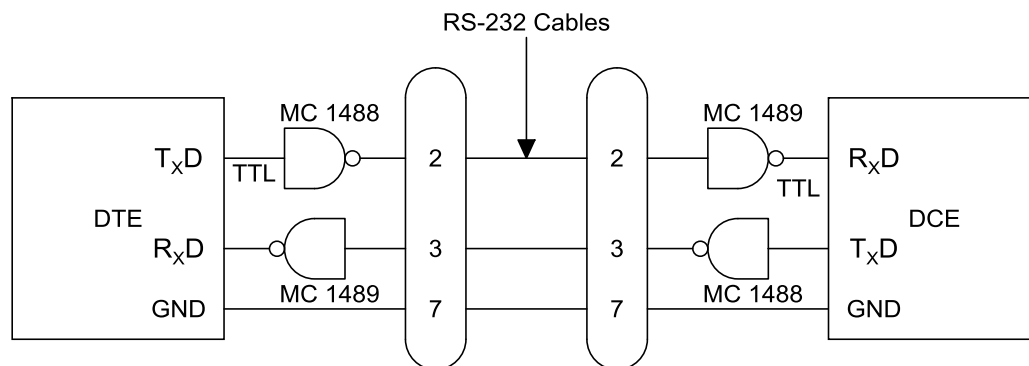


Fig: Connection of DTE and DCE through RS-232C Interface

- Mc1488 converts logic 1 to -9V
Logic 0 to +9v
- Mc1485 converts RS – 232 to TTL
- Signal levels of RS-232 are not compatible with that of the DTE and DCE which are TTL signals for that line driver such as M 1488 and line receiver MC1485 are used.
- RS- 232 signals used in handshaking:

<u>Flow</u>	<u>DE-9P</u>	<u>DB-25P</u>	<u>Signal</u>	<u>Description</u>
DTE to DCE	3	2	TxD	Transmitted data
DCE to DTE	2	3	RxD	Received data
DTE to DCE	7	4	\overline{RTS}	Request to send
DCE to DTE	8	5	\overline{CTS}	Clear to send
DCE to DTE	6	6	\overline{DSR}	Data set ready
Common ref	5	7	GND	Signal ground
DCE to DTE	1	8	\overline{DCD}	Data carrier detect
DTE to DCE	4	20	\overline{DTR}	Data terminal ready

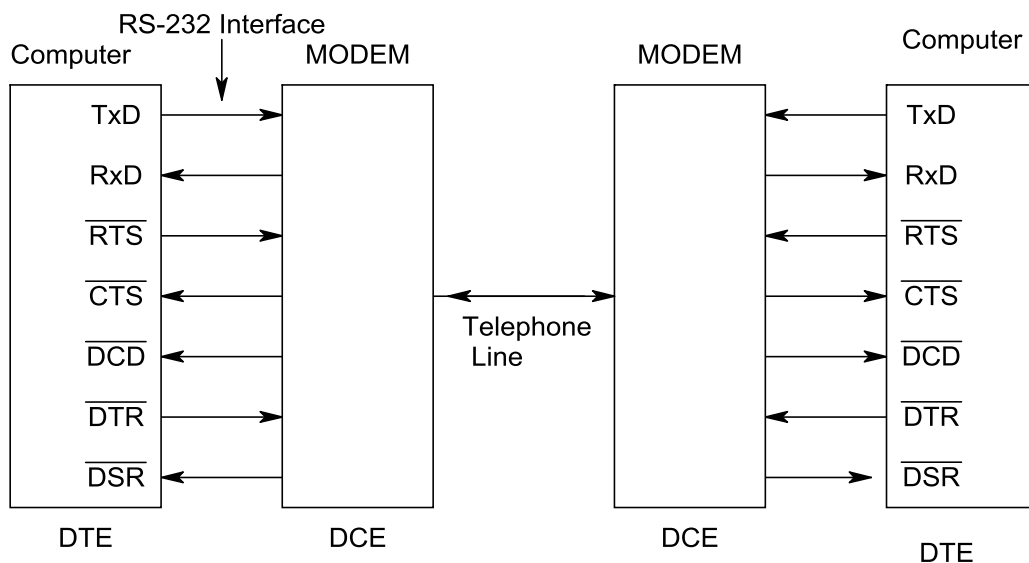


Fig: Digital Data transmission using MODEM and Telephone Line

- DTE asserts $\overline{\text{DTR}}$ to tell the modem it is ready.
- Then DCE asserts $\overline{\text{DSR}}$ signal to the terminal and dials up.
- DTE asserts $\overline{\text{RTS}}$ signal to the modem.
- Modem then asserts $\overline{\text{DCD}}$ signal to indicate that it has established connection with the computer.
- DCE asserts $\overline{\text{CTS}}$ signals, then DTE sends serial data.
- When sending completed, DTE asserts $\overline{\text{RTS}}$ high, this causes modem to unassert its $\overline{\text{CTS}}$ signal and stop transmitting similar handshake taken between DCE and DTE other side.
- To communicate from serial port of a computer to serial port of another computer without modem, null-modem is used.

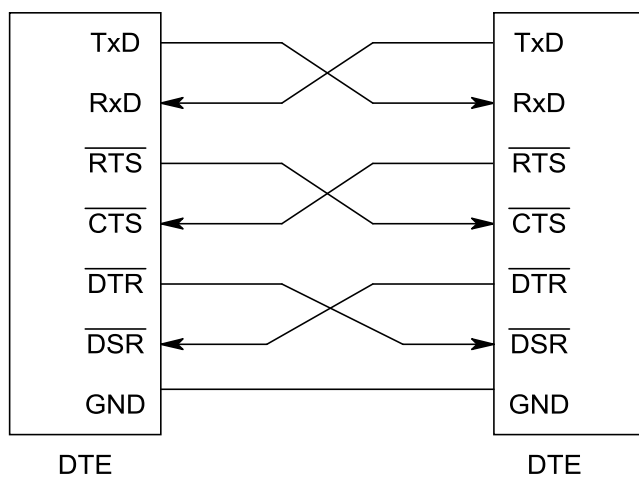


Fig: Null MODEM Connection for RS-232 Terminals

RS 423A and R5422A serial standards**RS 423A**

- A major problem with Rs 232C is that it can only transmit data reliably for about 50 ft at its maximum rate of 20Kbd. If longer lines are used the transmission rate has to be drastically reduced due to open signal lines with a common signal ground.
- Another EIA standard which is improvement over RS-232C is RS-423A.
- This standard specifies a low impedance single ended signal which can be sent over 50Ω coaxial cable and partially terminated at the receiving end to prevent reflection.
- Voltage levels
 - o High 4 -6V negative
 - o Low 4-6V positive
- Transmission rate 100 Kbd over 40 ft
 1 Kbd over 4000 ft

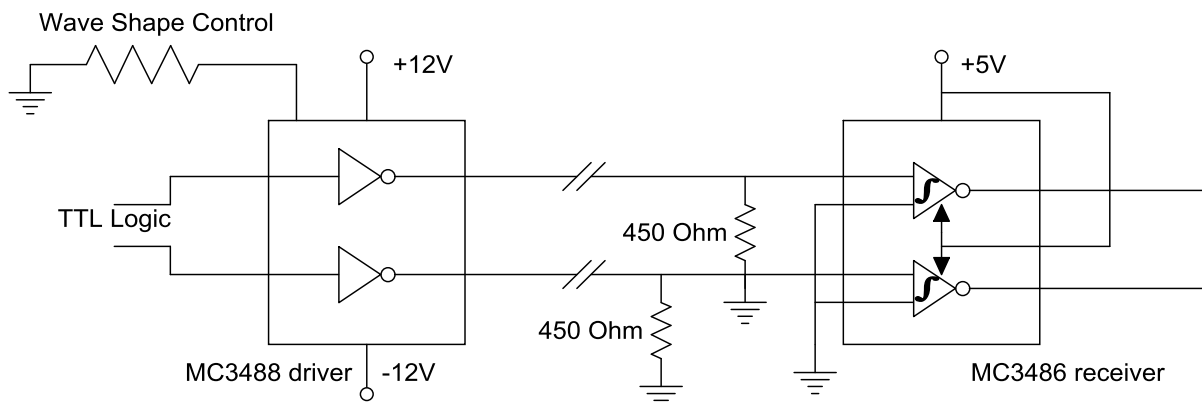


Fig: MC3488 driver and MC3489 receiver used for RS-423A Interface

RS 422A

- A newer standard for serial data transfer.
- It specifies that can signal will be send differentially over two adjacent wires in a ribbon cable or a twisted pair of wires uses differential amplifier to reject noise.

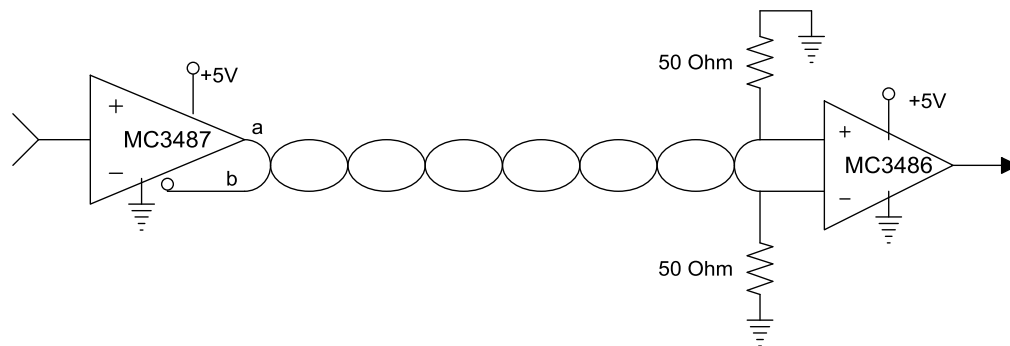


Fig: MC3487 driver and MC3486 receiver used for RS-422A Interface

- Voltage level logic high making a line more positive.

- Logic low making a line lines must.
- The voltage difference between the two lines must be greater than 0.4V but less than 12V.
- The mc3487 driver provides a differential voltage of about 2V.
- The center or common mode voltage on the lines must be between -7v and +7v
- Transmission rate is 10000 KBd for 40 FT
- 100 KBD for 4000 ft.
- The high data transfer is because of differential line functions as a fully terminated transmission line.
- Mc 3486 receiver only responds to the differential voltage eliminating noise.

Introduction to Direct Memory Access (DMA) & DMA Controllers

During any given bus cycle, one of the system components connected to the system bus is given control of the bus. This component is said to be the master during that cycle and the component it is communicating with is said to be the slave. The CPU with its bus control logic is normally the master, but other specially designed components can gain control of the bus by sending a bus request to the CPU. After the current bus cycle is completed the CPU will return a bus grant signal and the component sending the request will become the master.

Taking control of the bus for a bus cycle is called **cycle stealing**. Just like the bus control logic, a master must be capable of placing addresses on the address bus and directing the bus activity during a bus cycle. The components capable of becoming masters are processors (and their bus control logic) and DMA controllers. Sometimes a DMA controller is associated with a single interface, but they are often designed to accommodate more than one interface.

This is a process where data is transferred between two peripherals directly without the involvement of the microprocessor. This process employs the HOLD pin on the microprocessor. The external DMA controller sends a signal on the HOLD pin to the microprocessor. The microprocessor completes the current operation and sends a signal on HLDA and stops using the buses. Once the DMA controller is done, it turns off the HOLD signal and the microprocessor takes back control of the buses.

Basic DMA operation

- The direct memory access (DMA) technique provides direct access to the memory while the microprocessor is temporarily disabled.
- A DMA controller temporarily borrows the address bus, data bus, and control bus from the microprocessor and transfers the data bytes directly between an I/O port and a series of memory locations.
- The DMA transfer is also used to do high-speed memory-to memory transfers.
- Two control signals are used to request and acknowledge a DMA transfer in the microprocessor-based system.
- The HOLD signal is a bus request signal which asks the microprocessor to release control of the buses after the current bus cycle.

- The HLDA signal is a bus grant signal which indicates that the microprocessor has indeed released control of its buses by placing the buses at their high-impedance states.
- The HOLD input has a higher priority than the INTR or NMI interrupt inputs.

DMA Data Transfer scheme

- Data transfer from I/O device to memory or vice-versa is controlled by a DMA controller.
- This scheme is employed when large amount of data is to be transferred.
- The DMA requests the control of buses through the HOLD signal and the MPU acknowledges the request through HLDA signal and releases the control of buses to DMA.
- It's a faster scheme and hence used for high speed printers.

Block (Burst) mode of data transfer

In this scheme the I/O device withdraws the DMA request only after all the data bytes have been transferred.

Cycle stealing technique

In this scheme the bytes are divided into several parts and after transferring every part the control of buses is given back to MPU and later stolen back when MPU does not need it.

PROGRAMMABLE DMA CONTROLLER - INTEL 8257

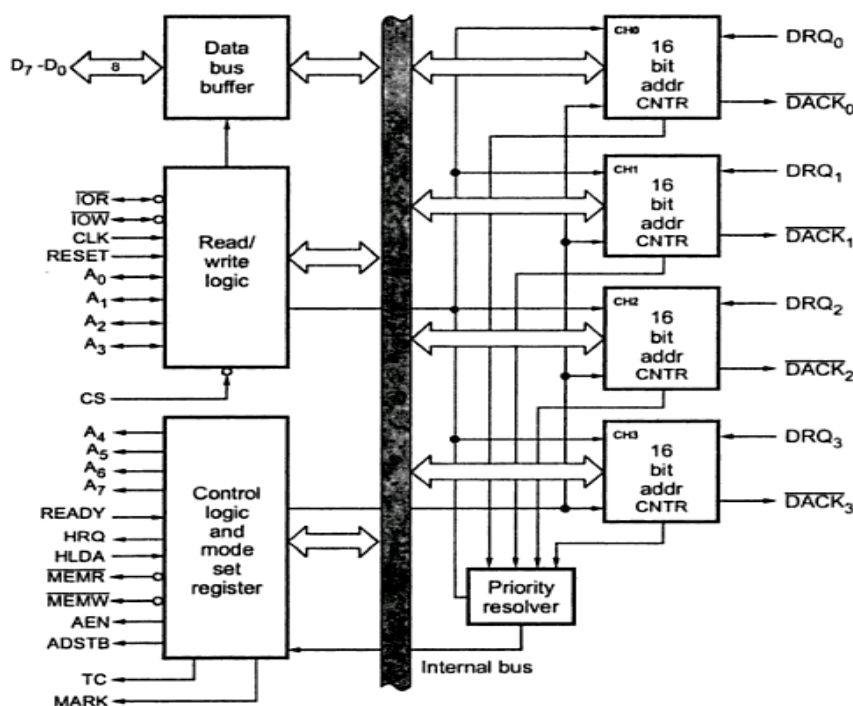


Fig: Functional block diagram of DMA Controller

It is a device to transfer the data directly between IO device and memory without through the CPU. So it performs a high-speed data transfer between memory and I/O device.

The features of 8257 is,

- The 8257 has four channels and so it can be used to provide DMA to four I/O devices.
- Each channel can be independently programmable to transfer up to 64kb of data by DMA.
- Each channel can be independently perform read transfer, write transfer and verify transfer.

The functional blocks of 8257 as shown in the above figure are data bus buffer, read/write logic, control logic, priority resolver and four numbers of DMA channels.

Operation of 8257 DMA Controller

- Each channel of 8257 has two programmable 16-bit registers named as address register and count register.
- Address register is used to store the starting address of memory location for DMA data transfer.
- The address in the address register is automatically incremented after every read/write/verify transfer.
- The count register is used to count the number of byte or word transferred by DMA.
- In read transfer the data is transferred from memory to I/O device.
- In write transfer the data is transferred from I/O device to memory.
- Verification operations generate the DMA addresses without generating the DMA memory and I/O control signals.
- The 8257 has two eight bit registers called mode set register and status register.