

Programmable Interfacing Devices

General-Purpose Programmable Peripheral Devices

- PPI – Programmable Peripheral Interface
- It is an I/O port chip used for interfacing I/O devices with microprocessor.
- Very commonly used programmable devices from Intel family are:
 - The 8255A peripheral interface.
 - The 8254 Interval Timer.
 - The 8294A Interrupt Controller.
 - The 8237 DMA controller.

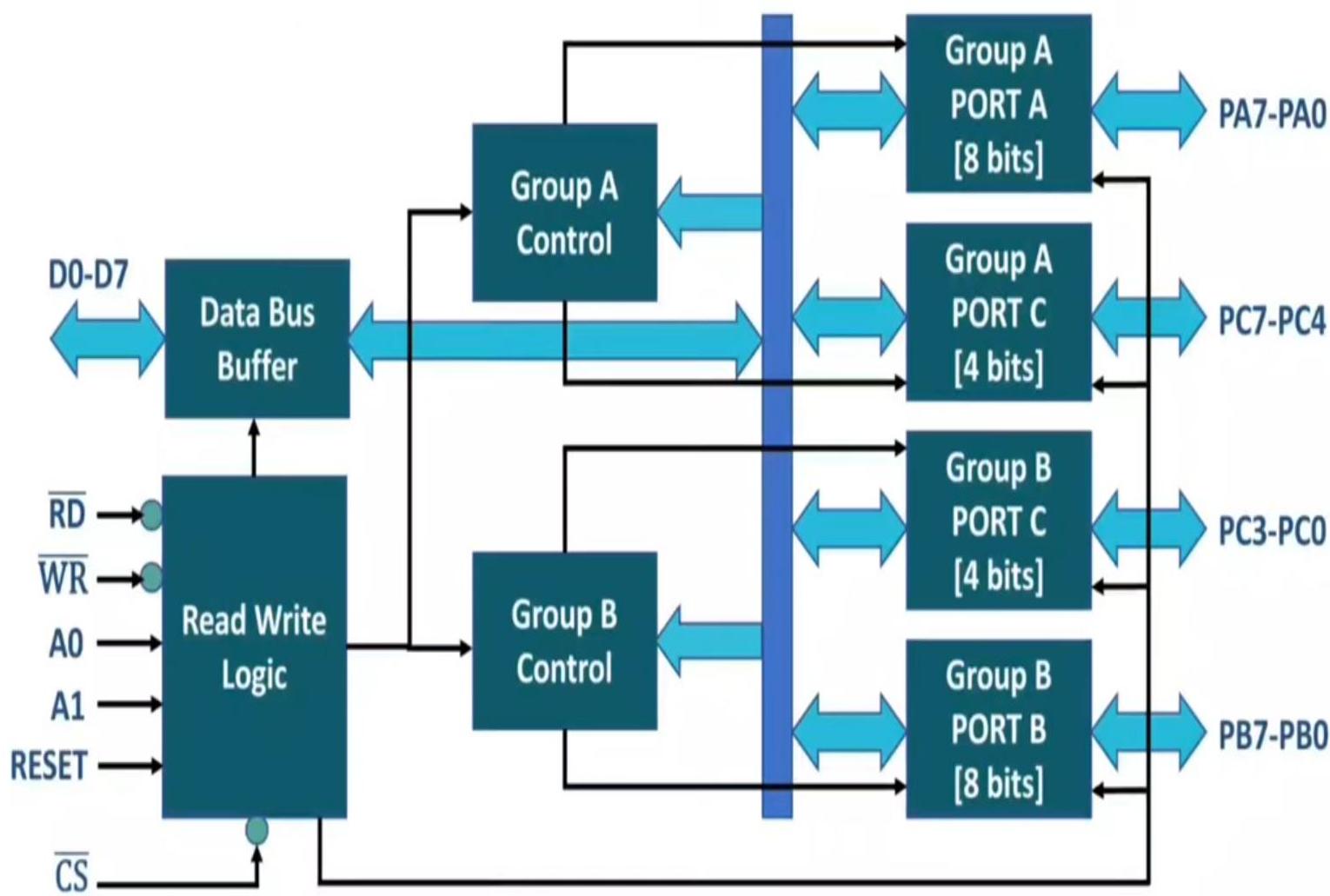
8255 Programmable Peripheral Interface

❖ Features of 8255 Programmable Peripheral Interface

- 8255 is designed to work with various microprocessors like 8085, 8086 etc.
- 8255 is designed to increase capacity of Input Output Interface.
- 8255 has three 8bits bidirectional IO ports.
- 8255 has three IO modes of transfer data:
 - Simple IO mode
 - Handshake IO mode
 - Bidirectional handshake IO mode
- 8255 has BSR mode to alter individual bits of port C.

8255A Programmable Peripheral Interface

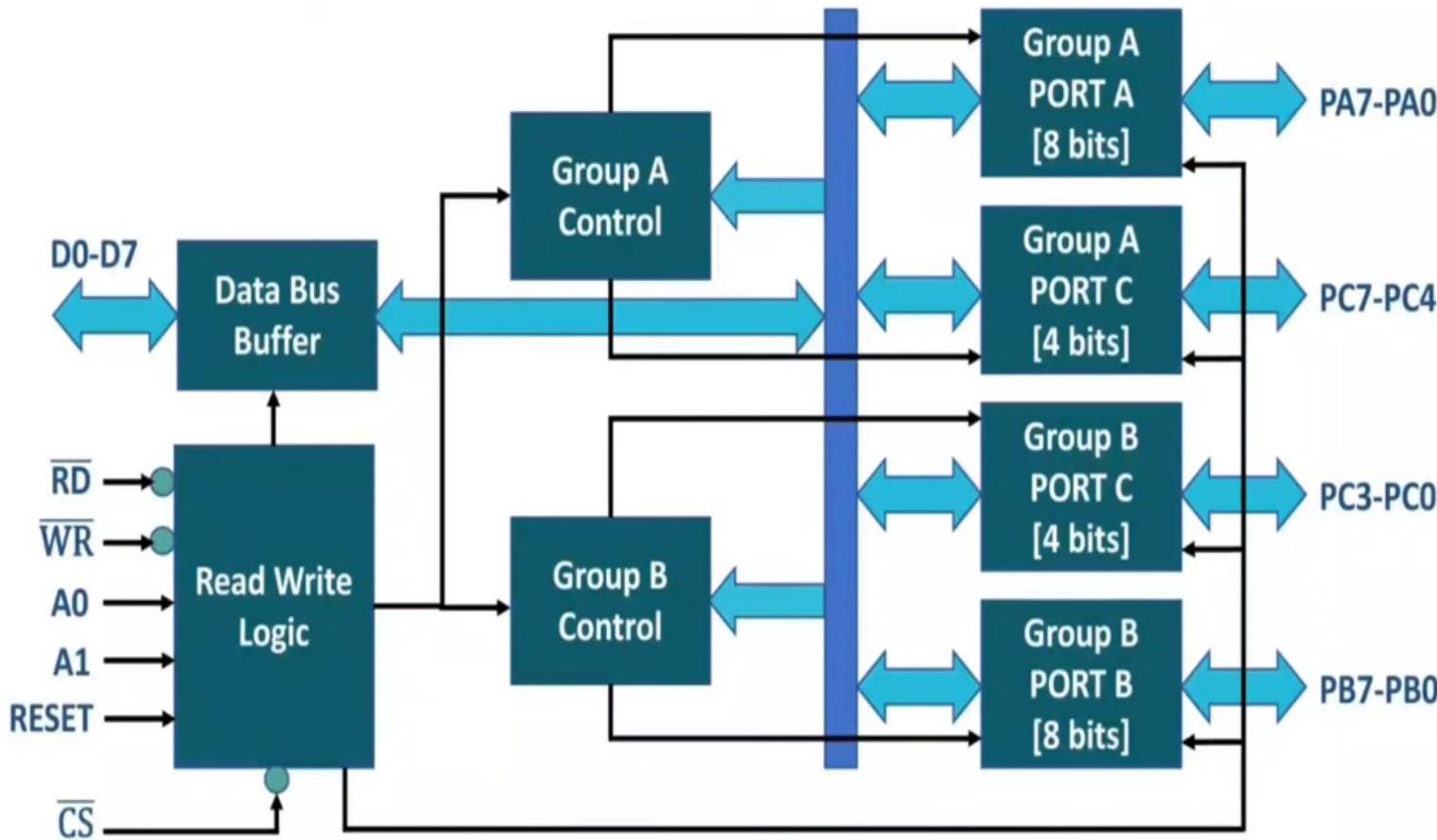
- The 8255A is a general purpose programmable I/O device designed to transfer the data from I/O to interrupt I/O under certain conditions as required. It can be used with almost any microprocessor.
- It consists of three 8-bit bidirectional I/O ports (24 I/O lines) which can be configured as per the requirement.



❖ Data Bus Buffer

- ❑ It has bidirectional data bus D0 – D7.
- ❑ D0 – D7 is interfaced with system data bus of Microprocessor.

Read Write Control Logic of 8255

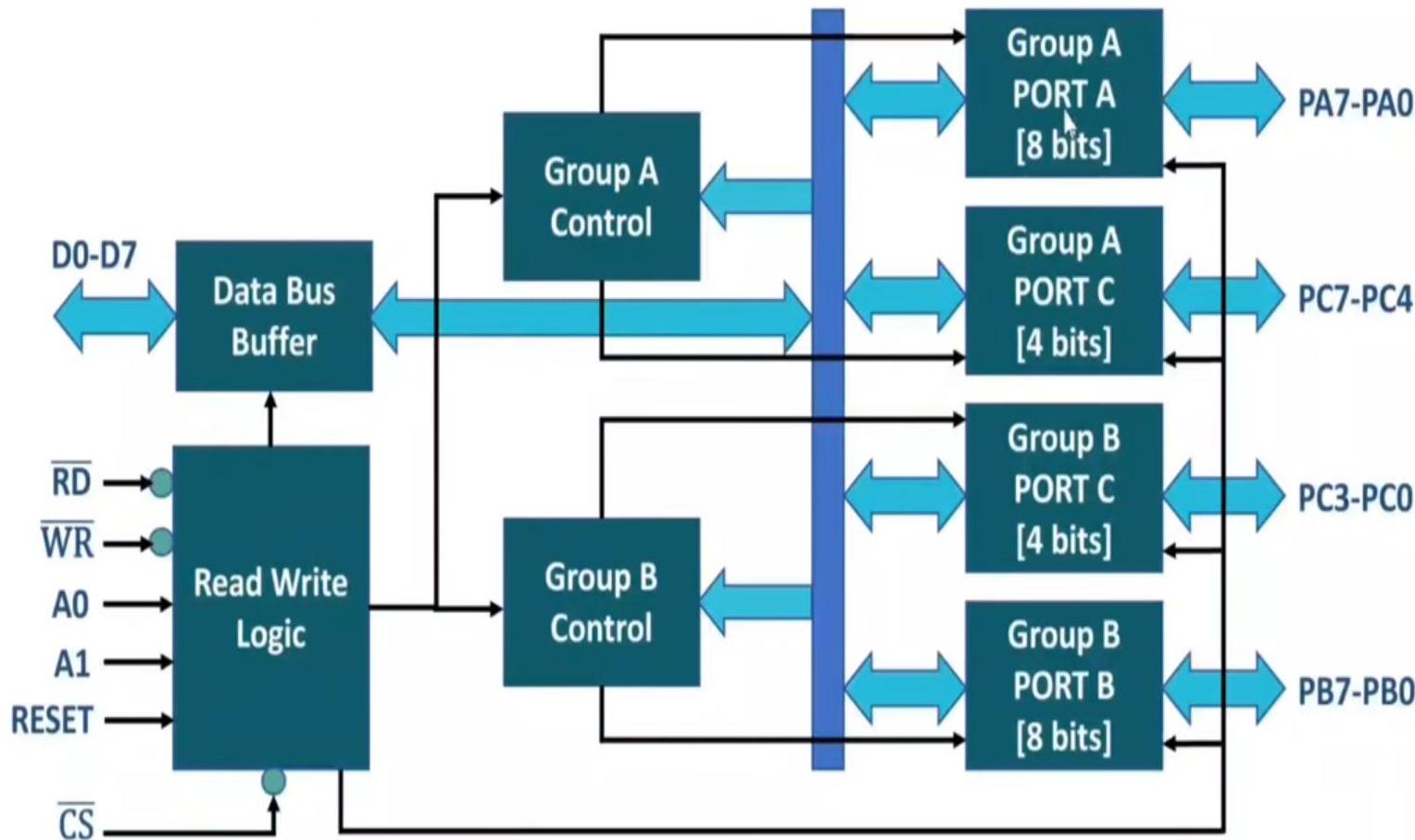


❖ Read Write Control Logic

- ❑ 8255 read and write data as per control signals \overline{RD} and \overline{WR} connected with microprocessor.
- ❑ RESET will reset 8255.
- ❑ A1 and A0 used to select port and control word.
- ❑ \overline{CS} is used to select chip of 8255.

\overline{CS}	A1	A0	Selected	Sample Address
0	0	0	Port A	80H [1000 0000]
0	0	1	Port B	81H [1000 0001]
0	1	0	Port C	82H [1000 0010]
0	1	1	Control Register	83H [1000 0011]
1	X	X	8255 is not selected	

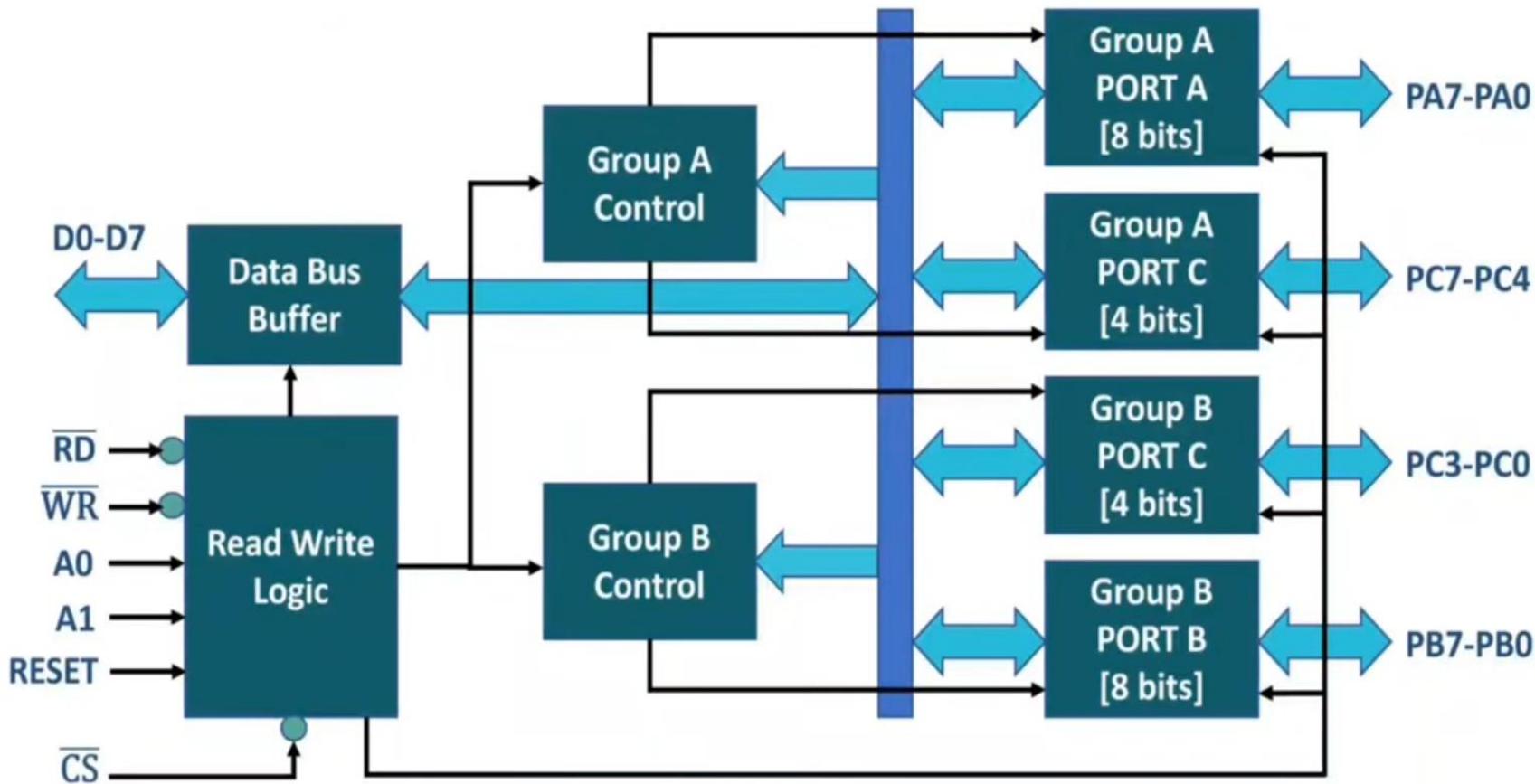
Group A & Group B Control of 8255



❖ Group A and Group B Control

- ❑ Group A control is used to control PORT A [PA7 – PA0] and UPPER PORT C [PC7 – PC4].
- ❑ Group B control is used to control PORT B [PB7 – PB0] and LOWER PORT C [PC3 – PC0].
- ❑ It takes control signals from control word and forwards it on respective ports.

Ports of 8255



❖ PORT A, PORT B and PORT C

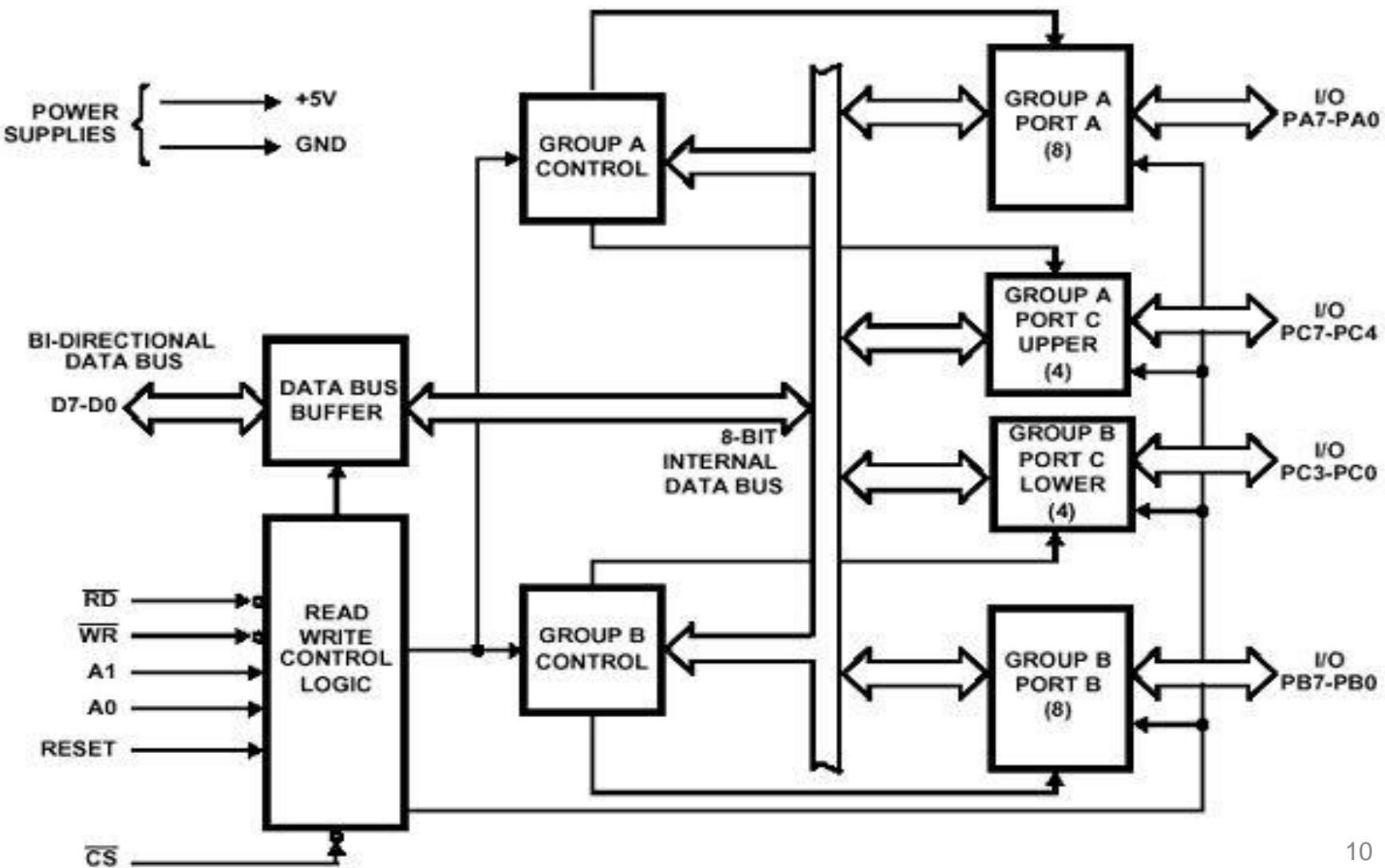
These are 8 bits IO ports and works as follows:

Port	MODE 0	MODE 1	MODE 2	BSR MODE
PORT A	YES	YES	YES	NO
PORT B	YES	YES	NO	NO
PORT C	YES	NO [HS]	NO [NS]	YES

Ports of 8255A

- 8255A has three ports, i.e., PORT A, PORT B, and PORT C.
 - **Port A** contains one 8-bit output latch/buffer and one 8-bit input buffer.
 - **Port B** is similar to PORT A.
 - **Port C** can be split into two parts, i.e. PORT C lower (PC0-PC3) and PORT C upper (PC7-PC4) by the control word.
- These three ports are further divided into two groups, i.e. Group A includes PORT A and upper PORT C. Group B includes PORT B and lower PORT C. These two groups can be programmed in three different modes, i.e. the first mode is named as mode 0, the second mode is named as Mode 1 and the third mode is named as Mode 2.

Block diagram of 8255



Different Mode of Operation of 8255

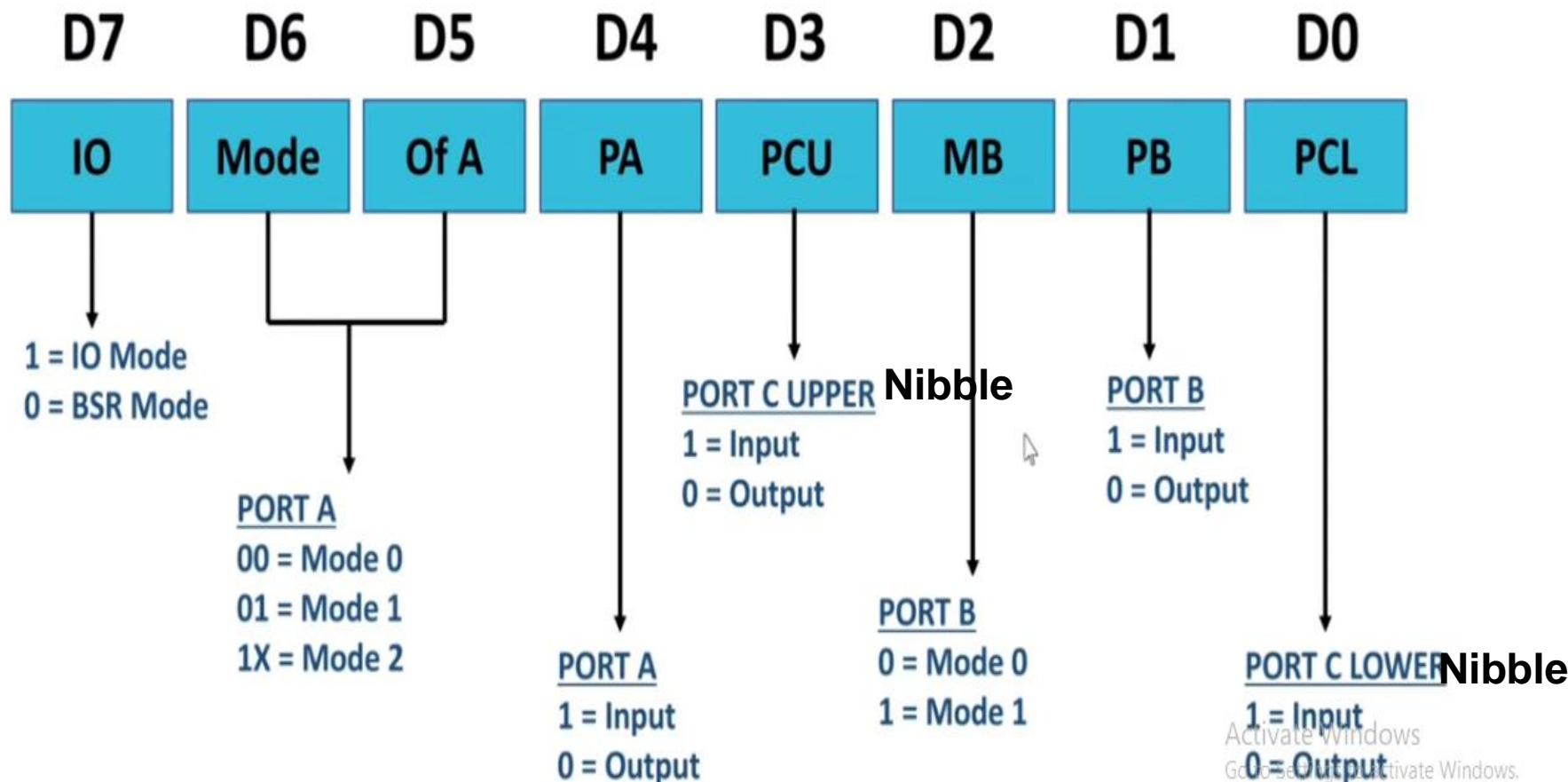
8255A has three different operating modes –

- **Mode 0** – In this mode, Port A and B is used as two 8-bit ports and Port C as two 4-bit ports. Each port can be programmed in either input mode or output mode where outputs are latched and inputs are not latched. Ports do not have interrupt capability.
- **Mode 1** – In this mode, Port A and B is used as 8-bit I/O ports. They can be configured as either input or output ports. Each port uses three lines from port C as **handshake** signals. Inputs and outputs are latched.
- **Mode 2** – In this mode, Port A can be configured as the bidirectional port and Port B either in Mode 0 or Mode 1. Port A uses five signals from Port C as **handshake** signals for data transfer. The remaining three signals from Port C can be used either as simple I/O or as handshake for port B.

Control Word and Modes of 8255

❖ Control Word

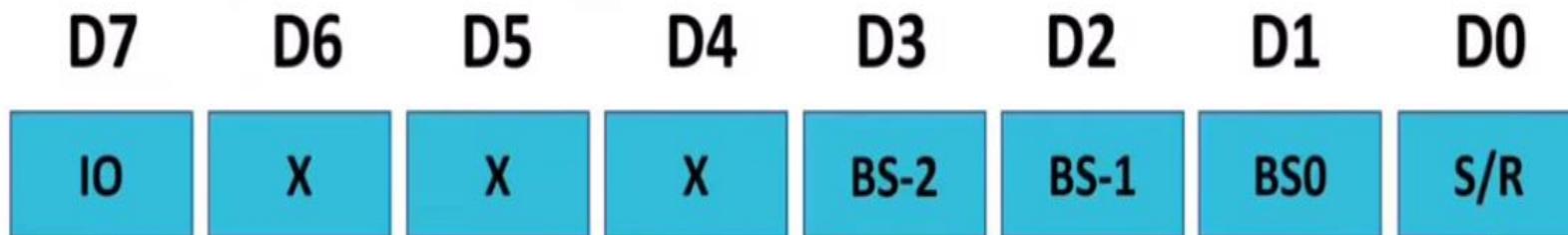
- 8255 has 8 bits of control word. It defines working of IO ports A, B and C.



Control Word and Modes of 8255

❖ BSR [Bit Set Reset] Mode of 8255

- BSR Mode only works with PORT C.



1 = IO Mode
0 = BSR Mode

BIT Select			Bit
0	0	0	PC0
0	0	1	PC1
0	1	0	PC2
0	1	1	PC3
1	0	0	PC4
1	0	1	PC5
1	1	0	PC6
1	1	1	PC7

1 = Set bit of Port C
0 = Reset bit of Port C

D1, D2, D3 Is used
to select individual
terminal of port-C

If the Terminal
(PC0-PC7)
values is 0/1 is
selected by D0

Activate Windows
Go to Settings to activate Windows.



Control Word and Modes of 8255

❖ Modes of 8255

- ❑ There are three 8 bits IO ports and works as follows:

Port	MODE 0	MODE 1	MODE 2	BSR MODE
PORT A	YES	YES	YES	NO
PORT B	YES	YES	NO	NO
PORT C	YES	NO [HS]	NO [HS]	YES

- ❑ Here, Mode 0 is simple IO mode.

- Output are latched and Input are not latched.
- Port Do not have Interrupt handling capacity.

- ❑ Here, Mode 1 is IO mode with handshake.

- Here each port uses three lines from port C as Handshake signals.
- Here, Input and Output are latched.
- Interrupt handling is supported.

- ❑ Here, Mode 2 is Bidirectional IO mode with handshake.

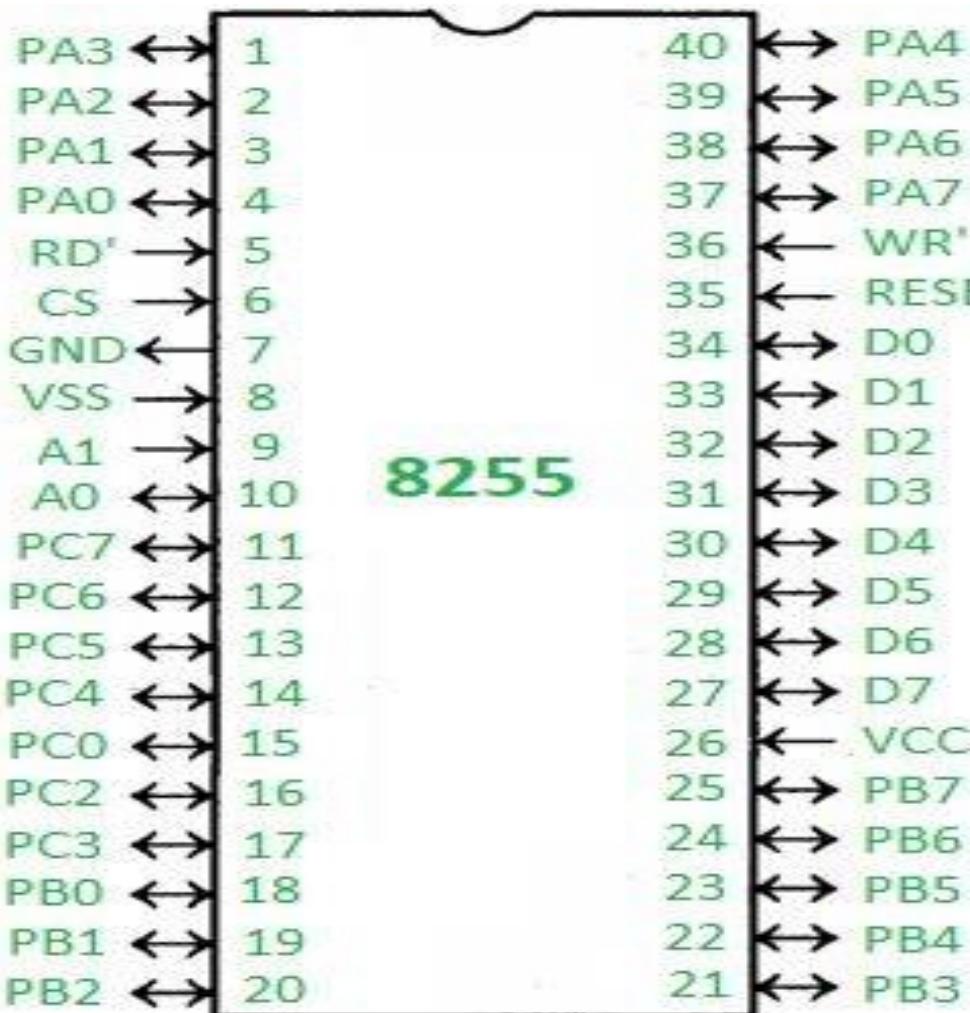
- Here port A uses five lines from port C as Handshake signals.
- Interrupt handling is supported.

→ Works in handshaking mode

Activate Windows
Go to Settings to activate Windows.



Pin Diagram of 8255



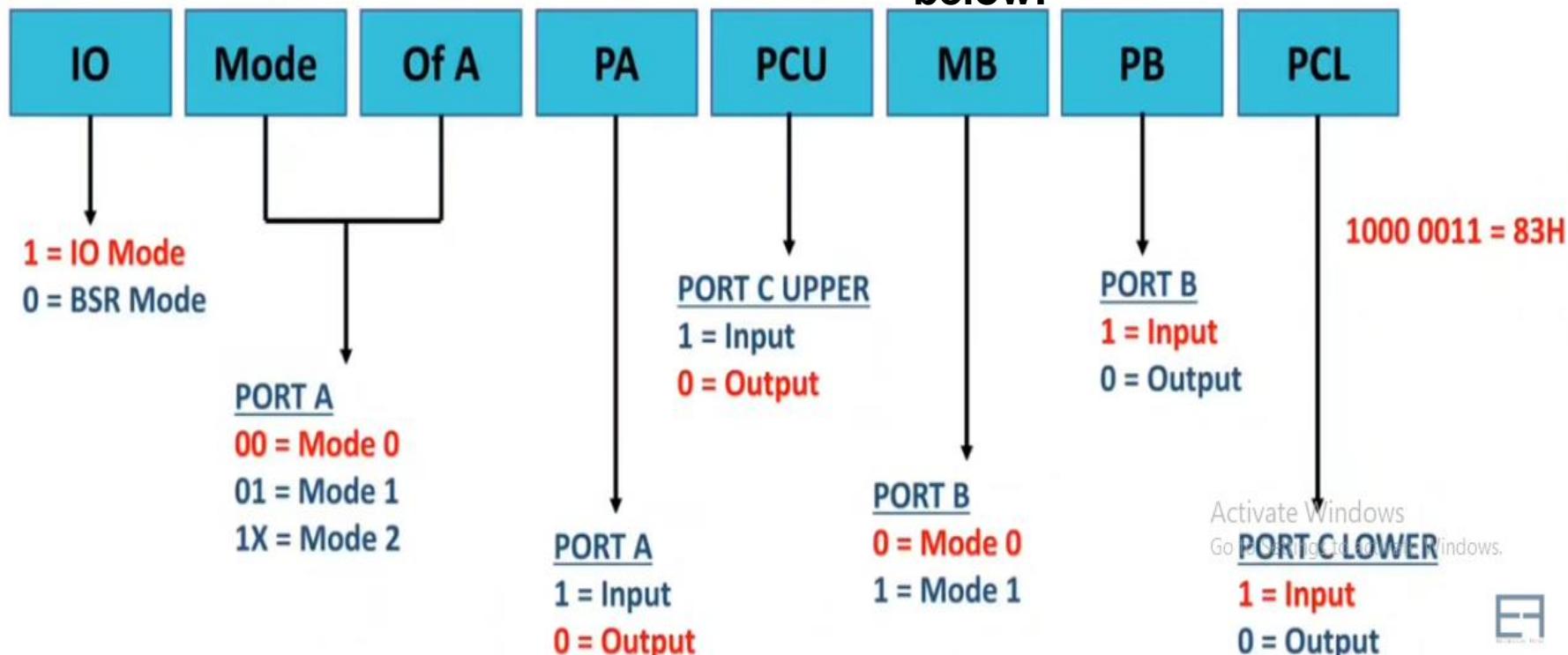
- PA0 – PA7 – Pins of port A
- PB0 – PB7 – Pins of port B
- PC0 – PC7 – Pins of port C
- D0 – D7 – Data pins for the transfer of data
- RESET – Reset input
- RD' – Read input
- WR' – Write input
- CS' – Chip select
- A1 and A0 – Address pins

Problem

Programming of 8255

- Identify the port Address, Identify the Mode 0 control word to configure port A & Upper port C as output port and port B & Lower port C as Input port. Write a program to read DIP from Input and display it with LED on Output.

Control word for the problem below:

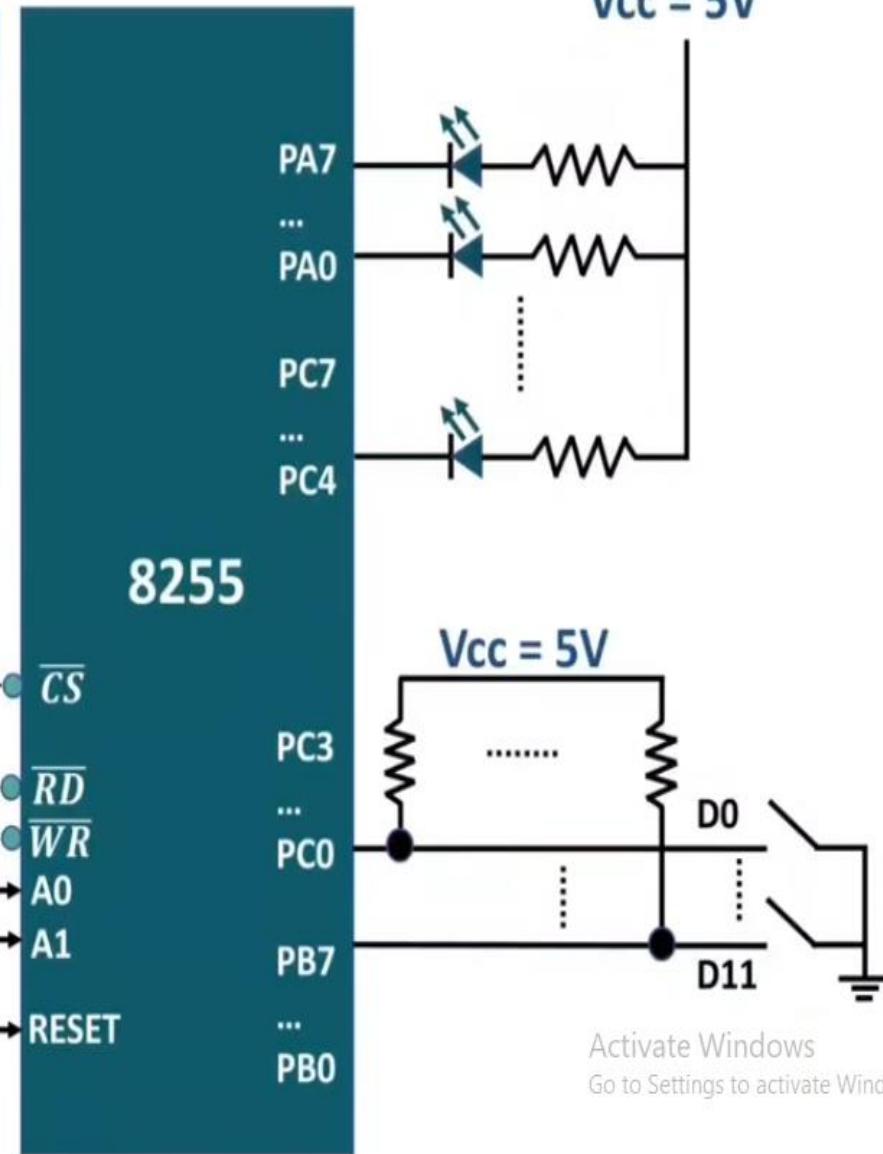
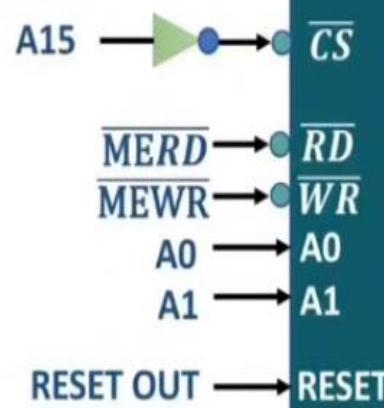


Interfacing, and Addressing Details

A15	A1	A0	Selected	Sample Address
1	0	0	Port A	8000H [1000 0000]
1	0	1	Port B	8001H [1000 0001]
1	1	0	Port C	8002H [1000 0010]
1	1	1	Control Register	8003H [1000 0011]
0	X	X	8255 is not selected	

XX:

- MVI A,83H
- STA 8003H
- LDA 8001H
- STA 8000H
- LDA 8002H
- ANI 0FH
- RLC
- RLC
- RLC
- RLC
- STA 8002H
- JMP XX

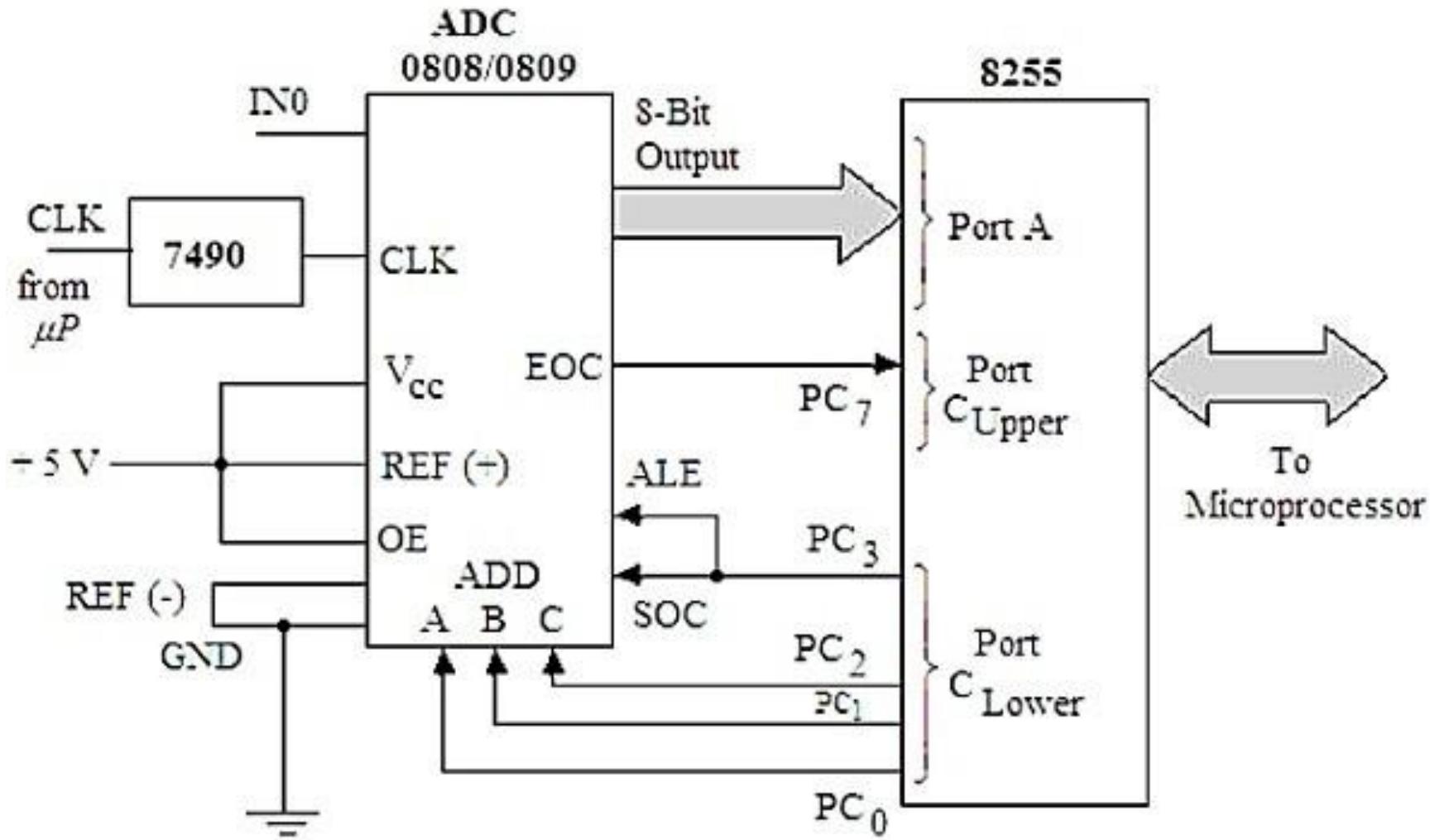


MVI=Move immediately ANI=Immediate addressing RLC=Rotate Left through Carry (Convert lower to upper nibble)

Interfacing A/D converter using 8255

- To interface the ADC with 8085, we need 8255 Programmable Peripheral Interface chip with it.
- The Port A of 8255 chip is used as the input port. The PC_7 pin of Port C_{upper} is connected to the End of Conversion (EOC) Pin of the analog to digital converter. This port is also used as input port. The C_{lower} port is used as output port. The PC_{2-0} lines are connected to three address pins of this chip to select input channels. The PC_3 pin is connected to the Start of Conversion (SOC) pin and ALE pin of ADC 0808/0809.

Interfacing A/D converter using 8255 (Cont.)



8253/54 Programmable Interval Timer

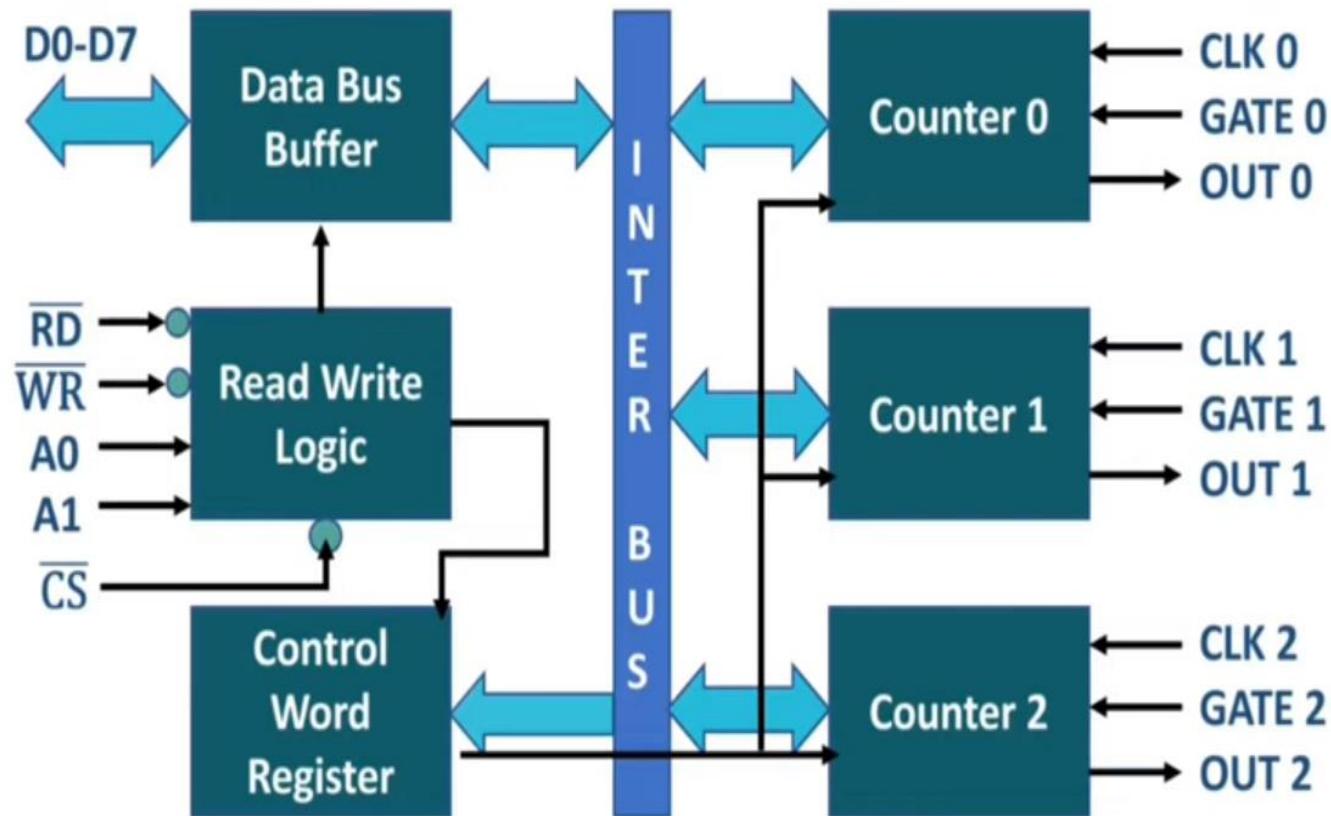
❖ Features of 8253/54 Programmable Interval Timer

- 8254 is designed to work with various microprocessors like 8085, 8086 etc.
- 8254 is used as Timer to generate Hardware Delay.
- 8254 can be used as real time clock or as square wave generator.
- Hardware delay is more useful than software delay as microprocessor is not actively involved in generating delay. So when delay is produced by 8254 at that time microprocessor is free to execute other programs.
- 8254 has three independent 16 bits Down counters.
- These counters can take count in BCD or in Binary.
- Once counters finishes count [required delay], 8254 interrupts Microprocessor.

8253 Programmable Interval Timer

- The Intel 8253 is Programmable Interval Timers (PTIs) designed for microprocessors to perform timing and counting functions using three 16-bit registers.
- Each counter has 2 input pins, i.e. Clock & Gate, and 1 pin for “OUT” output.
- To operate a counter, a 16-bit count is loaded in its register.
- On command, it begins to decrement the count until it reaches 0, then it generates a pulse that can be used to interrupt the CPU.

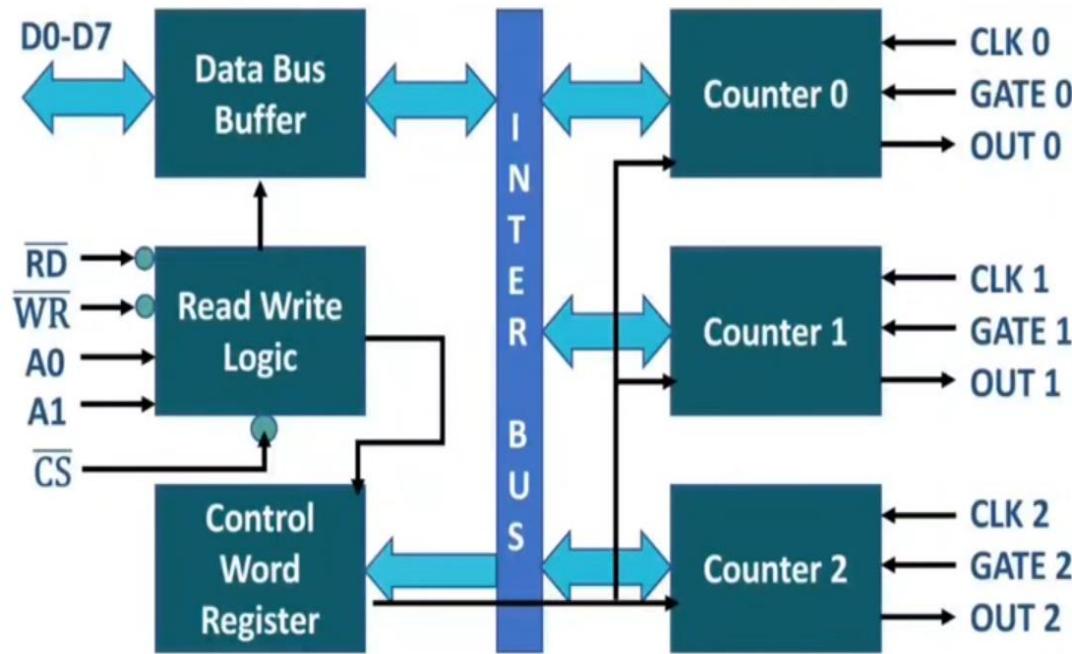
Block Diagram of 8253/54 Programmable Interval Timer



❖ Data Bus Buffer

- ❑ It has bidirectional data bus D0 – D7.
- ❑ D0 – D7 is interfaced with system data bus of Microprocessor.

Read Write logic for 8254



❖ Read Write Logic

- ❑ \overline{RD} and \overline{WR} is used to read write on D0 – D7.
- ❑ A1 and A0 lines are used to select counter and control word.
- ❑ \overline{CS} will select chip of 8254.

\overline{CS}	A1	A0	Selected	Sample Address
0	0	0	Counter 0	80H [1000 0000]
0	0	1	Counter 1	81H [1000 0001]
0	1	0	Counter 2	82H [1000 0010]
0	1	1	Control Word	83H [1000 0011]
1	X	X	8254 is not selected	

Control Word and Modes of 8254



Select Counter [SC1 – SC0]

Read Write [RW1 – RW0]

Mode selection [M2, M1 & M0]

SC1	SC0	Selected	RW1	RW0	Operation	Mode Select	Bit
0	0	Counter 0	0	0	Counter Latch command	0	0
0	1	Counter 1	0	1	R/W Least Byte significant Only	0	0
1	0	Counter 2	1	0	R/W Most Byte significant Only	X	1
1	1	Read Back Command	1	1	R/W least Byte significant 1 st then most significant Byte.	X	1
						1	0
						1	0

Select Counter [SC1 – SC0]

BCD	Selected
0	Binary Counter 16 bits
1	BCD Counter of 4 Decades

Modes of 8253/54 Programmable Interval Timer

❖ Modes of 8253/54 is selected by Control word with M0, M1 & M2 bits.

- ❑ There are six modes & three counters with 8254.
- ❑ All modes works with clock input.
- ❑ First we need to load value of count in 8254 by 8085.
- ❑ After every clock count works in auto decrement mode.

Mode selection [M2, M1 & M0]

Mode Select			Bit	Name of Mode
0	0	0	Mode 0	Interrupt on terminal count
0	0	1	Mode 1	Monostable Multivibrator
X	1	0	Mode 2	Rate Generator
X	1	1	Mode 3	Square Wave Generator
1	0	0	Mode 4	Software Trigger Strobe
1	0	1	Mode 5	Hardware Trigger Strobe

All MODES of 8254

	CLK	WR	GATE	OUT		
MODE 0 – Interrupt on Terminal Count		N=4	Load Count			
				4 3 2 1 0	During Count Out is Low	GATE Pin is high so Count is enabled
						On Terminal count OUT pin goes high
MODE 1 – Mono Stable Multivibrator			Rising Edge on GATE enabled Count		During Count Out is Low	On Terminal count
			OUT is high for LC		4 3 2 1 0	OUT pin goes high
MODE 2 – Rate Generator			GATE Pin is high so Count is enabled			On clock number 1, OUT goes low.
			OUT	4 3 2 1 0/4 3 2 1 0/4 3 2 1 0/4		
MODE 3 – Square wave Generator			GATE Pin is high so Count is enabled			On Terminal count OUT pin changes.
			OUT	4 2 0/4 2 0/4 2 0/4 2 0/4 2 0/4 2 0/4		
MODE 4 – Software Triggered Strobe			GATE Pin is high so Count is enabled			On Terminal count OUT pin
			OUT	4 3 2 1 0		goes low for one cycle
MODE 5 – Hardware Triggered Strobe			Rising Edge on GATE enabled Count			On Terminal count OUT pin goes low for one cycle
			OUT	4 3 2 1 0		E

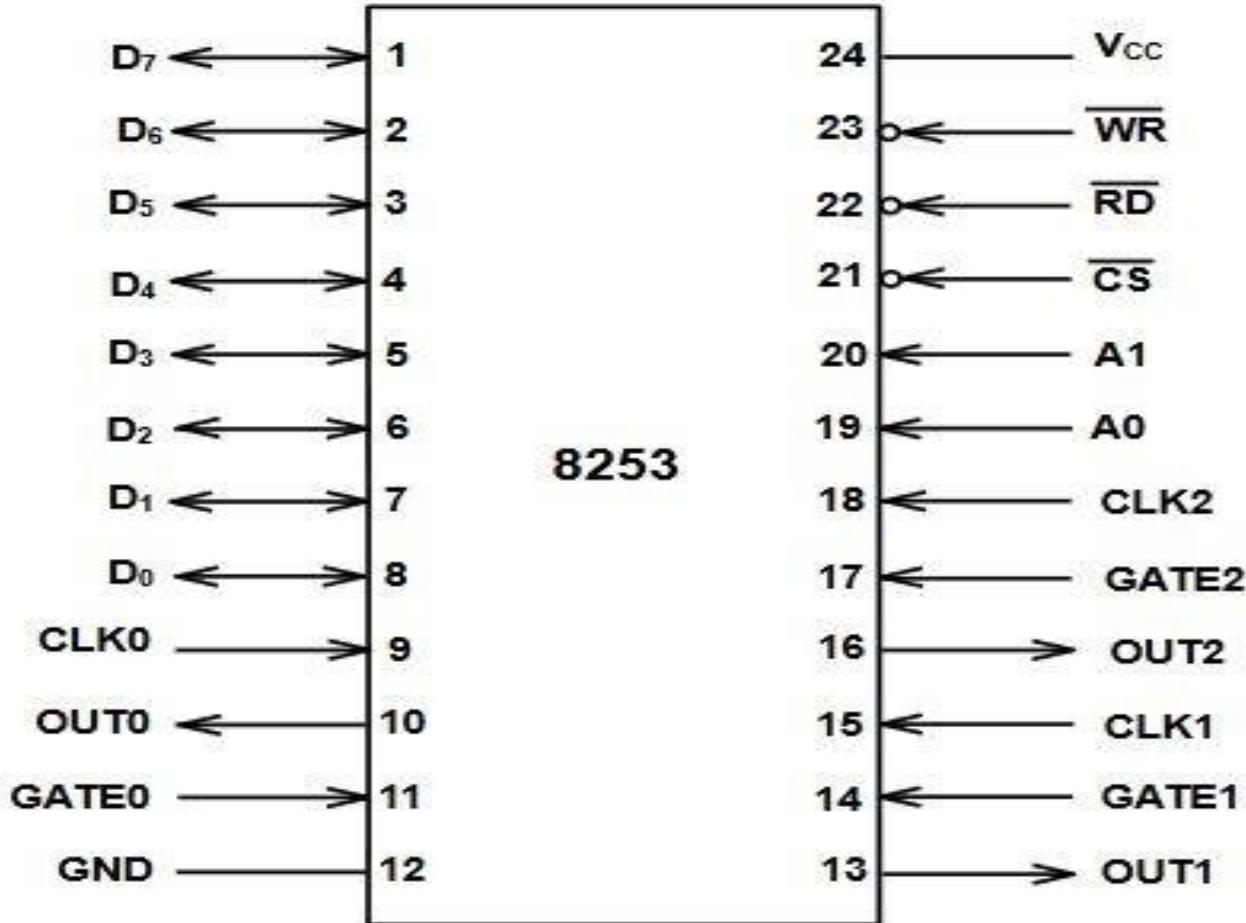


Fig.10.1 Pin Configuration of Intel 8253

8259 Programmable Interrupt Controller

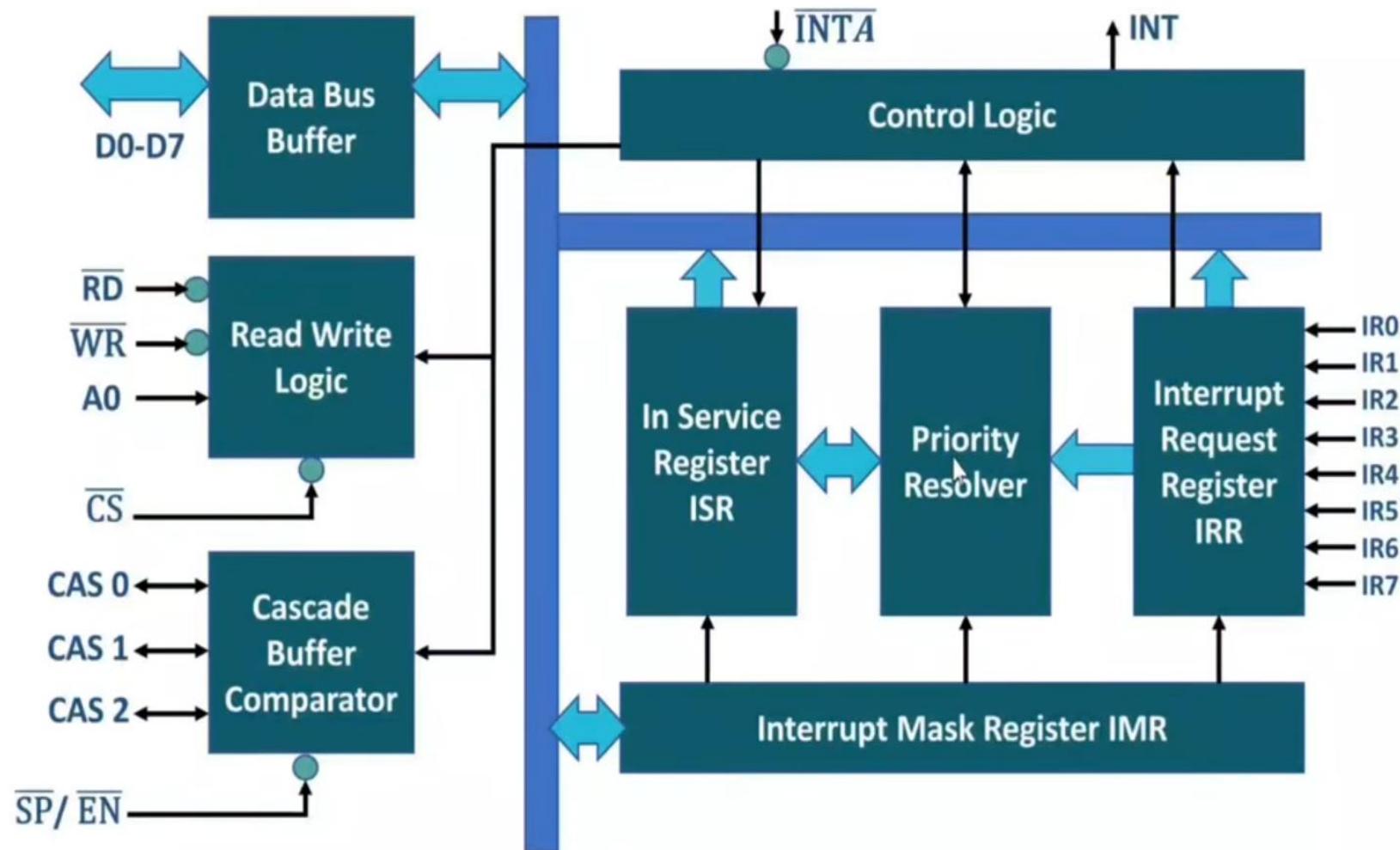
❖ Features of 8259 Programmable Interrupt Controller

- 8259 is designed to work with various microprocessors like 8085, 8086 etc.
- 8259 is designed to increase capacity of interrupts.
- 8259 can handle 8 interrupts with single IC.
- A cascade connection of 8259 can handle 64 interrupts.
 - One Master 8259 can works with eight Slave 8259, so total capacity will be 64.
- 8259 has flexible interrupt priority structure.
- Using 8259, we can mask interrupt as well.
- The vector address of 8259 is programmable.
- Status of interrupt can be observed by microprocessor :
 - Pending status
 - In service status
 - Masked status

8259 Programmable Interrupt Controller

- The 8259A is a programmable interrupt controller specially designed to work with Intel microprocessor 8080, 8085A, 8086, 8088.

Block diagram of 8259



❖ Interrupt Request Register - IRR

- ❑ Here, we have 8 interrupt lines **IR7 – IR0**.
- ❑ IRR is Eight bits register, each bit stores individual interrupt.
- ❑ When interrupt occurs on any lines, corresponding bit will get set to One.

Block diagram of 8259

❖ In Service Register - ISR

- It is 8 bits register.
- It stores the data of currently served interrupt.



❖ Interrupt Mask Register - IMR

- It is 8 bits register.
- It stores the masking pattern of 8259.
- Each bits holds masking of individual interrupt.



❖ Priority Resolver

- It examines IRR, ISR and IMR. Based on that determines which interrupt has maximum priority and should be sent to microprocessor.



❖ Control Logic

- It has INT pin connected with INTR of microprocessor to send interrupt request.
- It has INTA pin connected with INTA of microprocessor to receive acknowledgment.
- It is also used to control remaining blocks.



Block diagram of 8259

❖ Data Bus Buffer

- ❑ It has bidirectional data bus D0 – D7.
- ❑ D0 – D7 is interfaced with system data bus of Microprocessor.

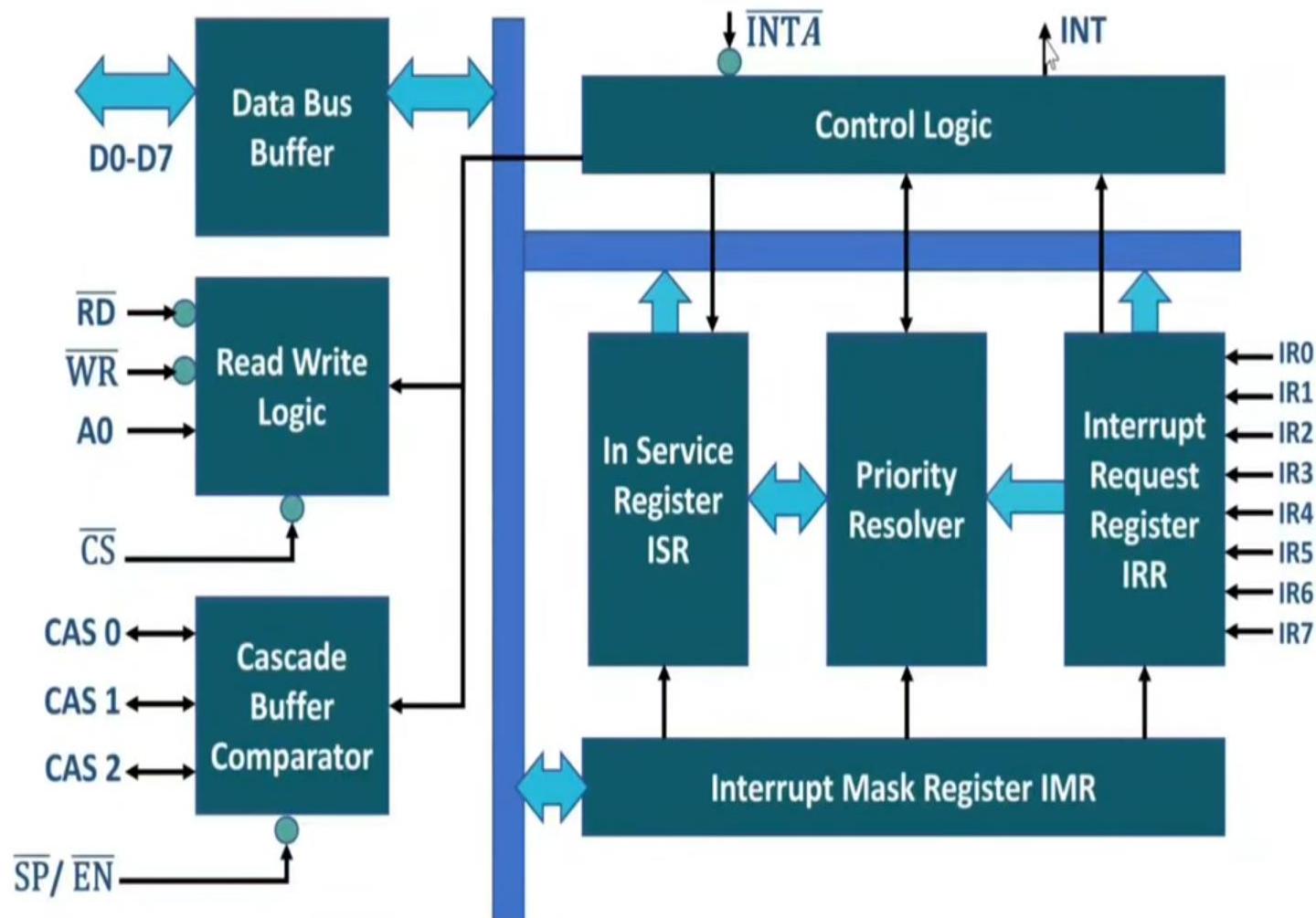
❖ Read Write Logic

- ❑ It is used to take read, write, A0 and Chip select.
- ❑ It also holds Initialization Command Words (ICW) and Operational Command Words (OCW).

❖ Cascade Buffer Comparator

- ❑ It is used in cascade mode operation.
- ❑ It is used for Master Slave Interrupt control from multiple 8259.
- ❑ $\overline{SP/EN}$ – It is Slave Program/ Master Enable line. In buffer Mode, it function as enable line and In non buffer mode it functions as SP enable line.

Working of 8259 PPI



1. INTR of 8085 must be enabled with EI Instruction.
2. 8259 is initialized by necessary commands. [ICW]
3. Once 8259 is initialized, if multiple interrupts comes then corresponding bit of IRR is set to one.
4. Priority resolver checks IRR, IMR & ISR. Based on that, it will decide highest priority and then it gives signal to Microprocessor 8085 at INTR.

Working of 8259 PPI

5. The Microprocessor completes current instruction, after that it give acknowledgement to 8259 on $\overline{\text{INTA}}$.
6. On receiving $\overline{\text{INTA}}$ from Microprocessor, ISR will set corresponding bit to one in ISR to indicate service to this interrupt is started and the bit in IRR is reset to indicate request is accepted. Now 8259 can give opcode of CALL instruction to Microprocessor.

E

7. The microprocessor decodes the CALL instruction and sends two more $\overline{\text{INTA}}$ to 8259.
8. In response to $\overline{\text{INTA}}$ signals, 8059 sends address of interrupt service routine. So it completes three bytes CALL instruction.
9. Now Microprocessor perform Interrupt Service Routine by pushing content of PC on stack.
10. At the end of interrupt, Microprocessor will send EOI command to 8259, that makes corresponding bit 0 in ISR of 8259.



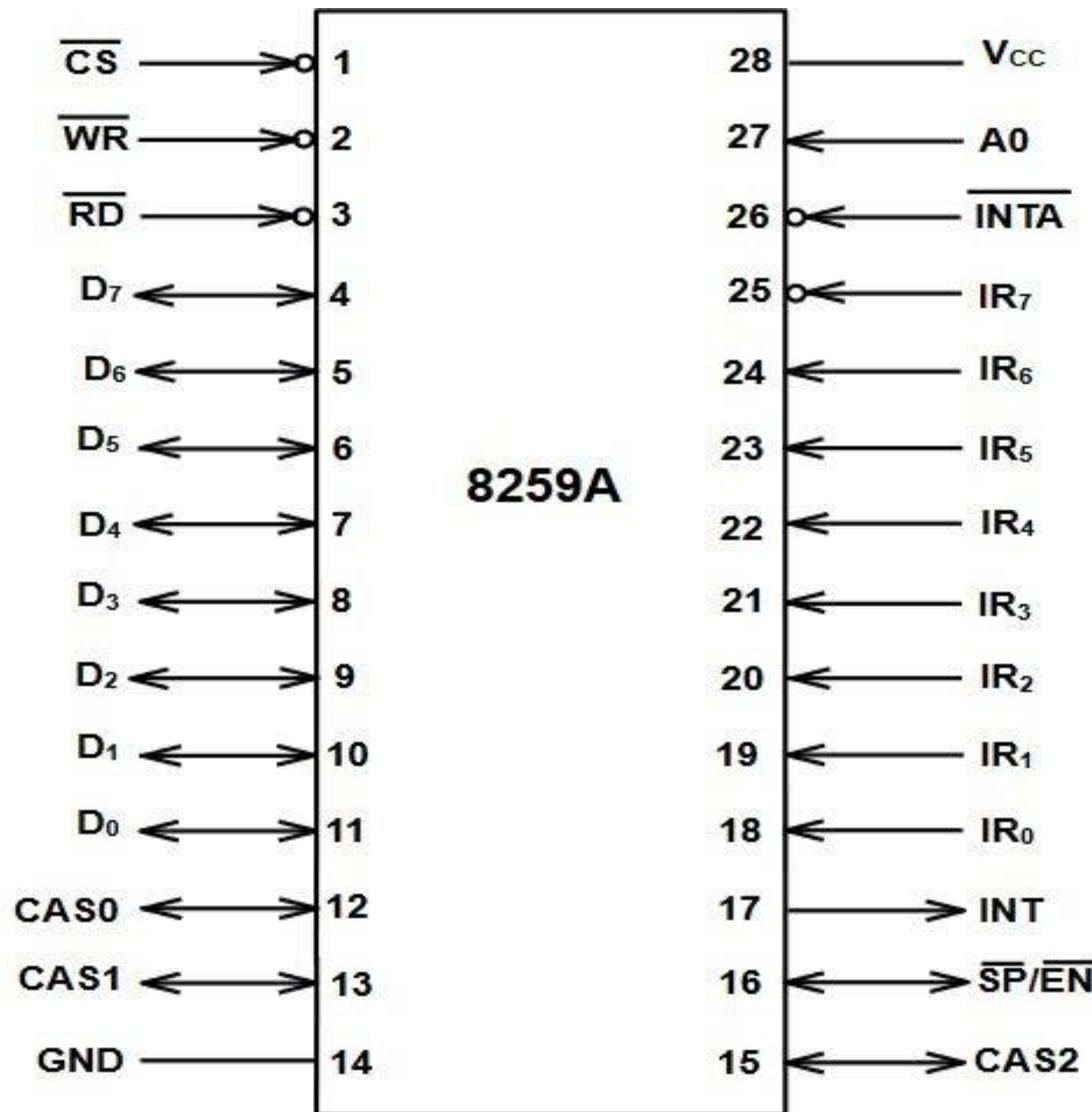


Fig.11.2 Pin Configuration of Intel 8259A

Modes of 8259A PIC

- Fully Nested mode
- Special Fully Nested mode
- Nonspecific Rotating
- Specific Rotating
- Special Mask
- Polling
- Fixed priority mode

- Fully nested mode:
 - This is a general purpose mode where all IR's are arranged in highest to lowest.
 - IR0 highest and IR7 lowest.
- Special Fully Nested Mode:
 - Used in more complicated systems.
 - Similar to, normal nested mode.
 - When an interrupt request from a certain slave is in service, this slave can further send requests to the master.
 - The master interrupts the CPU only.
- Automatic Rotation Mode:
 - In this mode a device after being serviced receives the lowest priority.

- Specific Rotation Mode:
 - In this user can select any IR for lowest priority thus fixing all priorities.
- Special Mask Mode
 - When a mask bit is set in OCW, it inhibits further interrupts at that level and enables interrupt from other levels, which are not mastered.
- Poll command
 - The INT output is neglected, though it functions normally by not connecting INT output or by masking INT input of the microprocessor.
 - This mode is entered by setting p=1 in OCW3.
 - A poll command may give more than 64 priority levels.

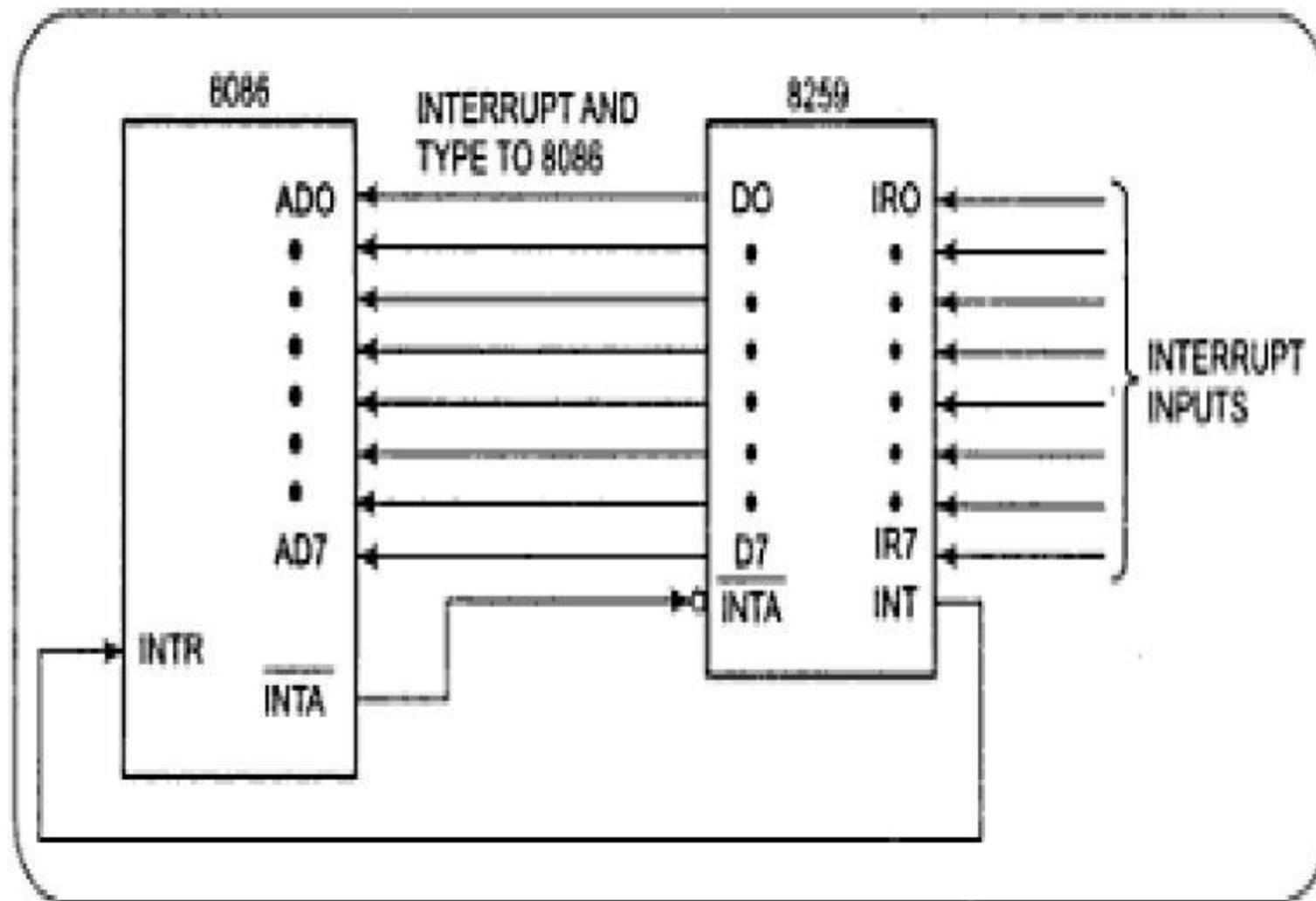
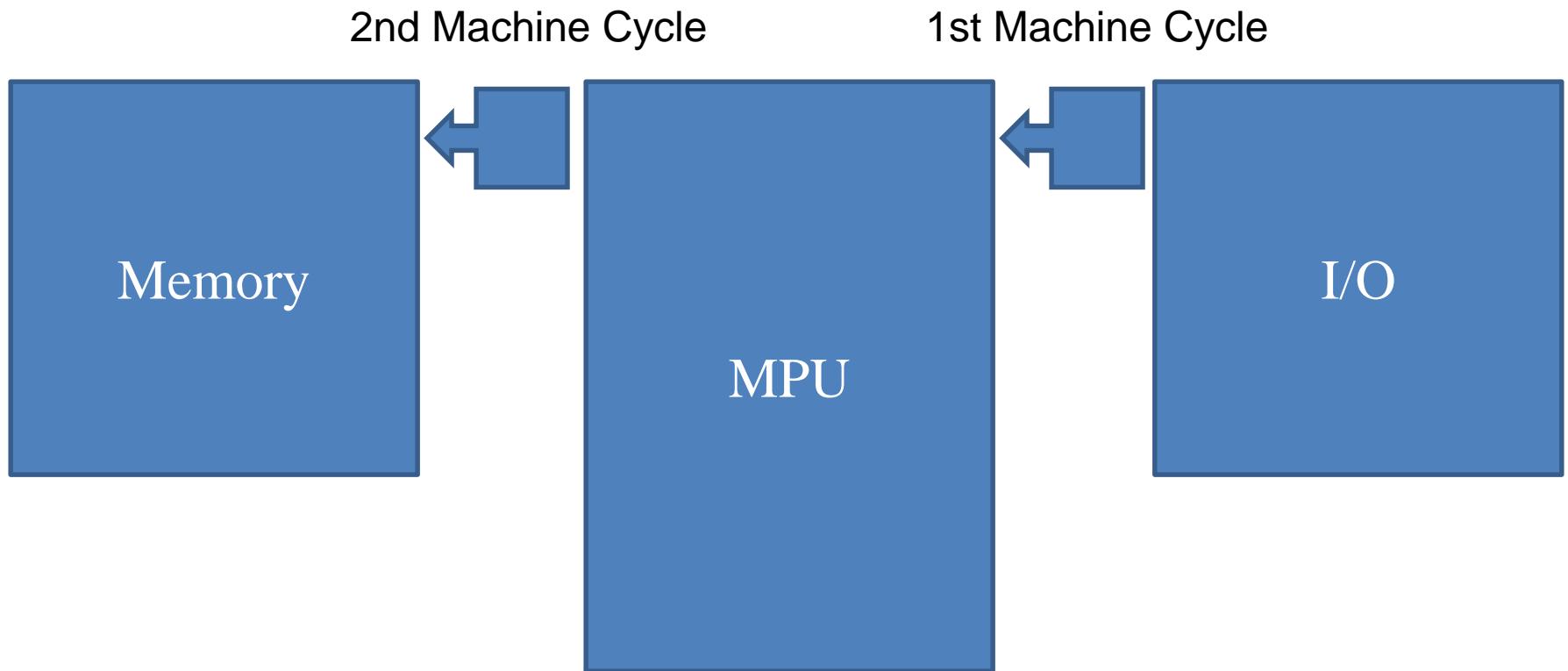


Fig:- Interface 8259 PIC with 8086 Microprocessor

8257 DMA Controller



In typical process data transfer rate slow down. DMA's roles is to bypass the microprocessor so that faster data exchanges happens between Memory and I/O

Basics 8257 DMA Controller

- DMA stands for Direct Memory Access. It is designed by Intel to transfer data at the fastest rate. It allows the device to transfer the data directly to/from memory without any interference of the CPU.
- Using a DMA controller, the device requests the CPU to hold its data, address and control bus, so the device is free to transfer data directly to/from the memory. The DMA data transfer is initiated only after receiving HLDA signal from the CPU.

8257 Direct Memory Access

❖ Basics of 8257 Direct Memory Access

- 8257 is used to for high speed data transfer in between in IO devices and memory.
- Using Microprocessor data transfer is slow, as microprocessor have to execute instructions and it have to check interrupt as well.
- Using 8257, MPU releases the control of the buses to the DMA.
- Here, Data transfer between memory and IO is been done by bypassing MPU.
- To take control of Address and Data bus from MPU, it has HOLD and HLDA control terminals which are used by DMA.

HLD & HLDA of 8257

❖ HOLD and HLDA

□ HOLD :

- This is active high signal input MPU.
- It gives request to MPU for address and data bus control.
- After receiving HOLD signal, MPU relinquishes the buses in following machine cycle.
- All buses are tri stated and HLDA sent out by MPU.
- MPU regains the control of buses after HOLD goes low.

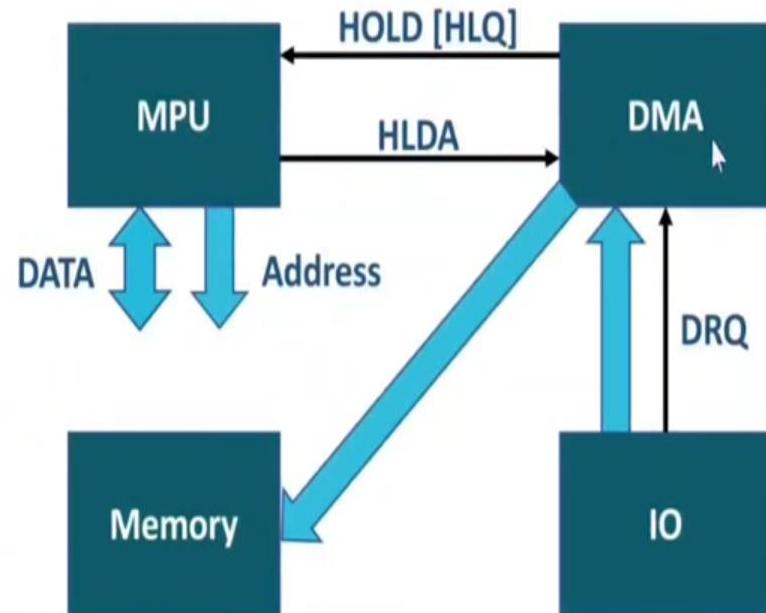
□ HLDA :

- This is active high signal indicating that the MPU is relinquishing control of buses.

Working of 8257

❖ Working of DMA

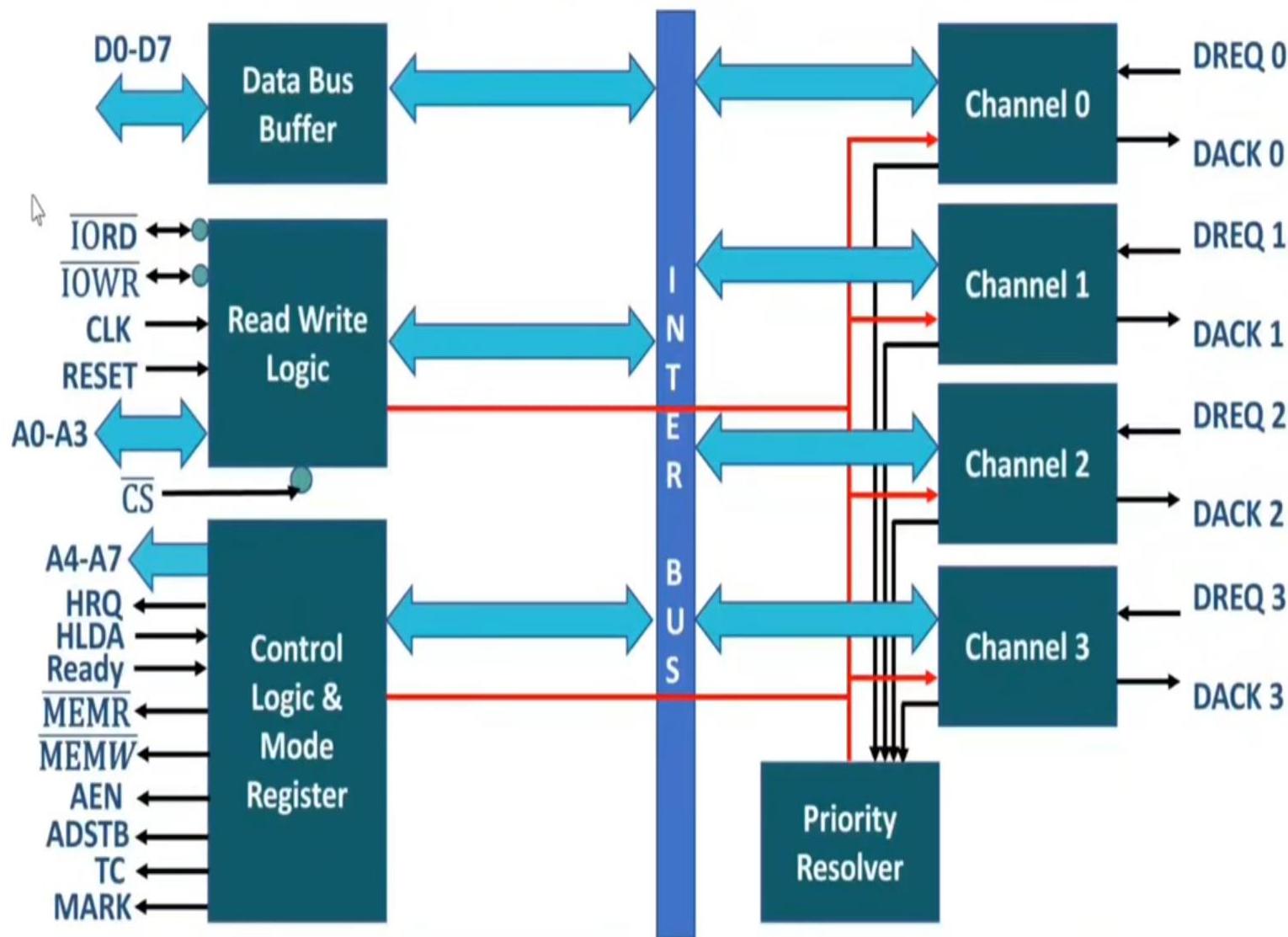
- ❑ If IO wants to send data to memory, then it will send request to DMA. [DRQ]
- ❑ To take control of system buses, DMA will send HOLD signal to MPU.
- ❑ To give control of address and data, MPU will give HLDA [HOLD Acknowledge]. Which indicates that now DMA is master of Buses. So now buses will be managed by DMA for memory and IO.
- ❑ Now data transfer can happen without involvement of MPU. Here now MPU don't need to execute instructions, so data exchange will be faster.
- ❑ Once HOLD signals goes low, MPU will take control of system buses and then MPU becomes master.



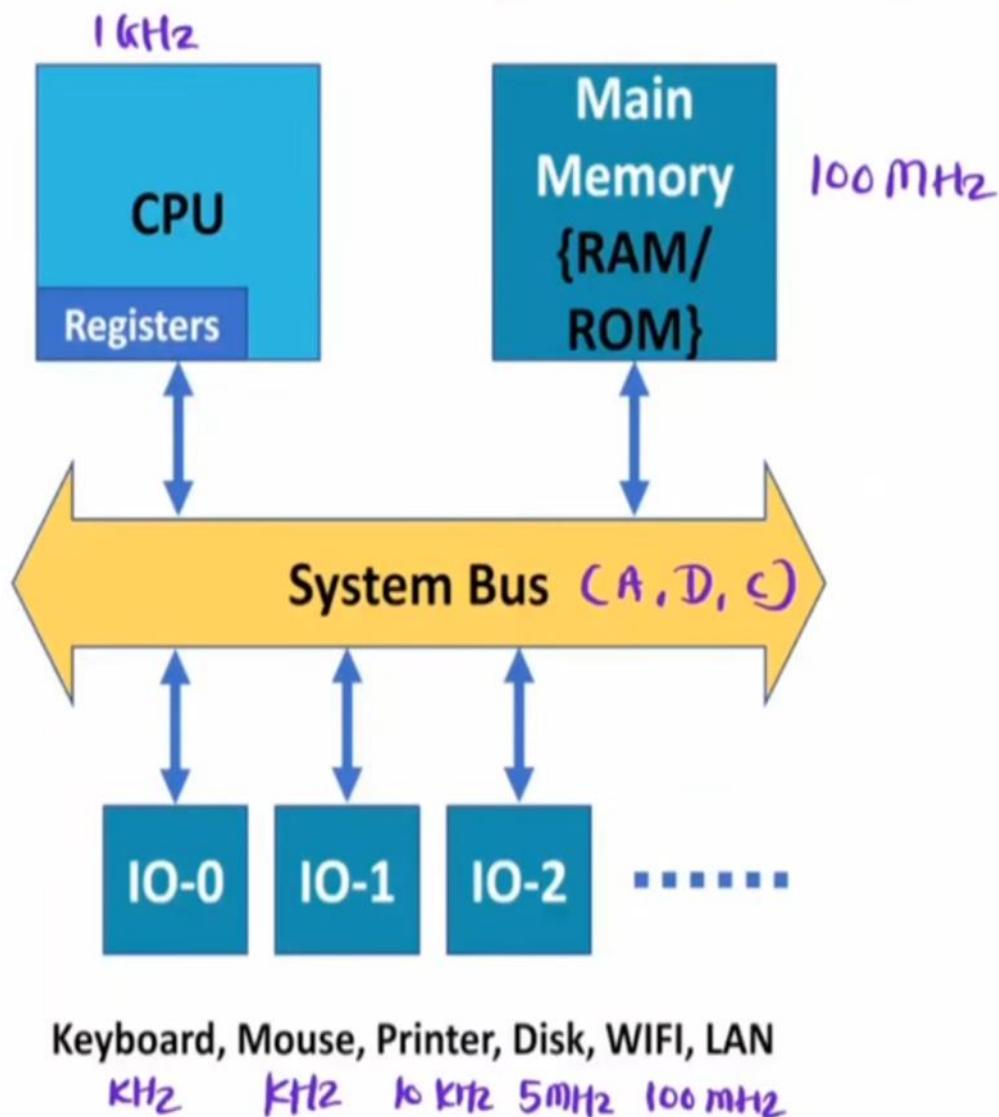
Features of 8257

- It has four channels which can be used over four I/O devices.
- Each channel has 16-bit address and 14-bit counter.
- Each channel can transfer data up to 64kb.
- Each channel can be programmed independently.
- Each channel can perform read transfer, write transfer and verify transfer operations.
- It generates MARK signal to the peripheral device that 128 bytes have been transferred.
- It requires a single phase clock.
- Its frequency ranges from 250Hz to 3MHz.
- It operates in 2 modes, i.e., **Master mode** and **Slave mode**.

Block Diagram of 8257



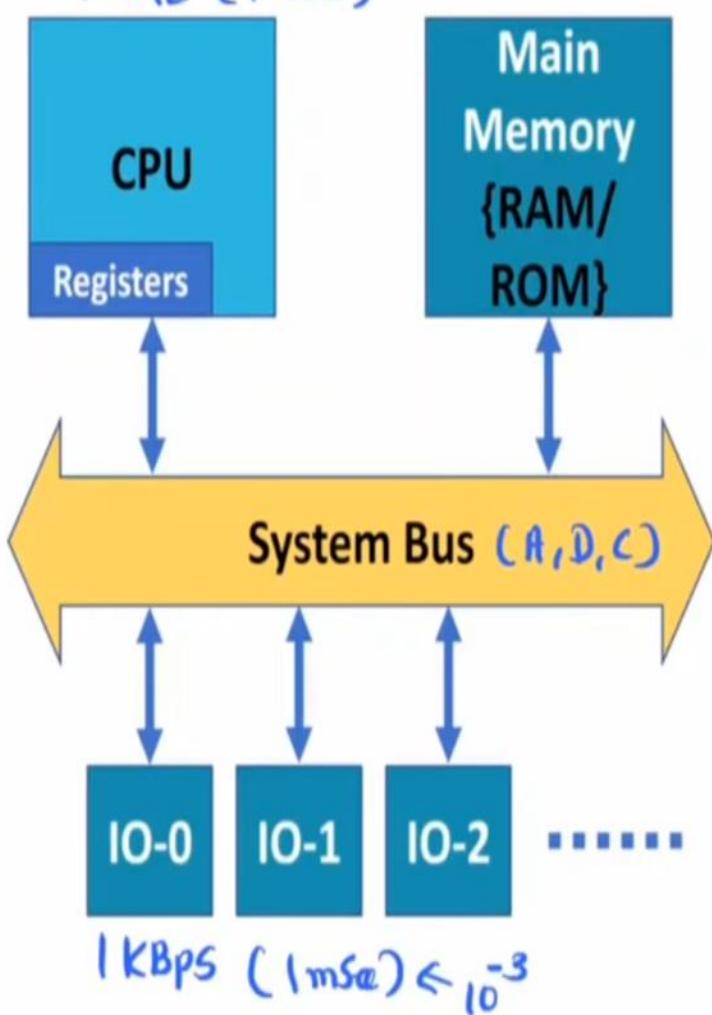
Input Output Organization



- ❖ IO Transfer Modes:
 1. Programmed IO
 2. Interrupt Driven IO
 3. DMA



Programmed IO



❖ Program execution:

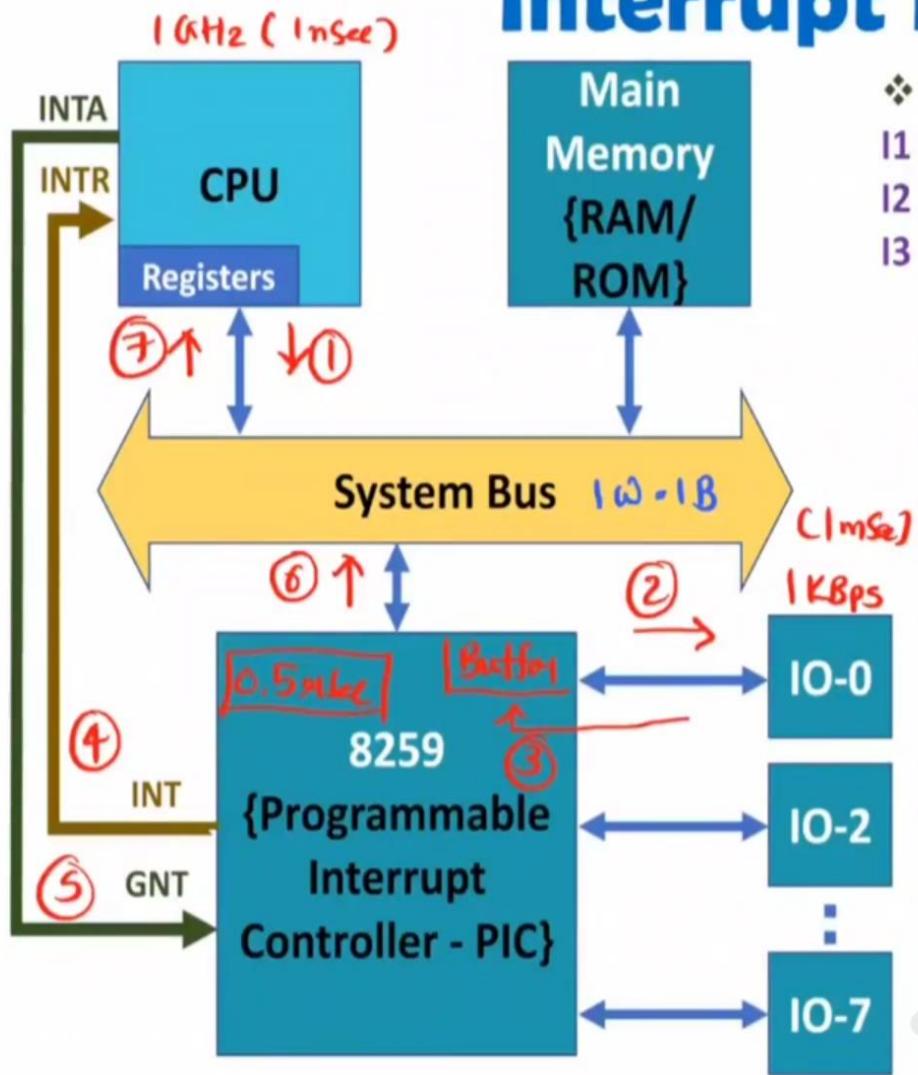
I1 ...
I2 LDA IO-0
I3 ...

❖ Disadvantage:

1. CPU will have more wait time.
2. This type of IO configuration makes performance of CPU Slower

Keyboard, Mouse, Printer, Disk, WIFI, LAN

Interrupt Driven IO



❖ Program execution:

I1 ...
I2 LDA IO-0
I3 ...

❖ Another Program:

I1 ...
I2 ...
I3 ...

❖ Advantage:

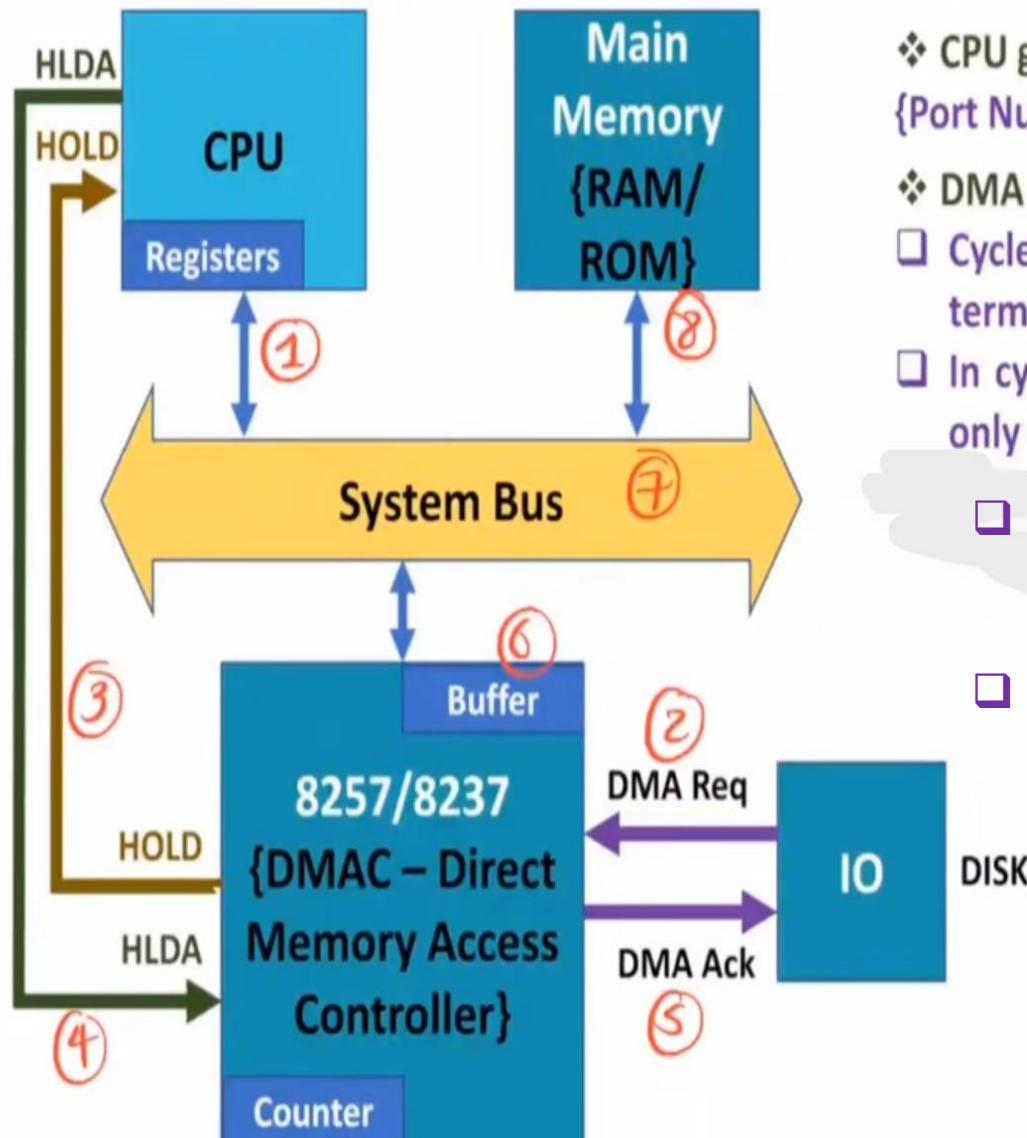
- CPU will have less block time compared to Programmed IO.

❖ Disadvantage:

- For data transfer in between IO and Memory CPU stays busy.

Keyboard,
Mouse,
Printer,
Disk, (1MB)
WIFI,
LAN

DMA – Direct Memory Access



- ❖ CPU gives IO command at start.
{Port Number, Memory Address, Count, Control Signal}
- ❖ DMA Modes {It depends on size of buffer}
 - ❑ Cycle stealing: in this mode, DMA sends data in terms of byte by byte or word by word.
 - ❑ In cycle stealing, DMAC waits till buffer is full then only for one cycle only. it takes control of system.
- ❑ Burst / Batch Mode: In this mode DMA sends data in bulk. Here size of buffer is large
- ❑ * In Burst mode once DMAC buffer is full, it takes control of system bus for data transfer.

What is DMA in Cycle-Stealing Mode?

- DMA allows an I/O device to transfer data directly to or from main memory **without CPU intervention**.
- In **cycle-stealing mode**, the DMA controller "steals" memory cycles to transfer data, temporarily **blocking the CPU** from accessing the memory.

We are calculating how much of the CPU time is spent in a blocked state (i.e., when the CPU cannot access the memory due to DMA operations). The calculation involves:

1. Buffer Time (T_{fill}):

- The time it takes for the I/O device to generate enough data to fill a buffer for a DMA transfer.
- Formula:

$$T_{\text{fill}} = \frac{\text{Buffer Size}}{\text{Data Rate}}$$

2. Transfer Time (T_{transfer}):

- The time it takes the DMA controller to transfer the buffer's data to memory.
- This transfer blocks the CPU because memory cycles are used for DMA instead of the CPU.

3. Cycle Time (T_{cycle}):

- The total time for a single cycle includes:
 - Time to fill the buffer (T_{fill}).
 - Time for the DMA to transfer the buffer to memory (T_{transfer}).

4. Percentage of Time CPU is Blocked:

- The ratio of blocked time (DMA transfer time) to the total cycle time.
- Formula:

$$\text{Blocked Percentage} = \frac{T_{\text{transfer}}}{T_{\text{cycle}}} \times 100$$

Examples on DMA: Consider a 1MBPS IO device interfacing with CPU using DMA in cycle stealing mode. Whenever 32bytes are present in the buffer, it is transferred to the main memory. Main memory cycle time is 60micro second. Percentage of time CPU is in BLOCKED state during the DMA operation is.....

Solution:

One cycle time, $T_{cycle} = 10^{-6}$ sec =
1 micro sec

To fill the buffer time takes is, $T_{prep} = 32 * 1$ cycle time period = 32 micro sec

Transfer (Buffer to MM) Time,

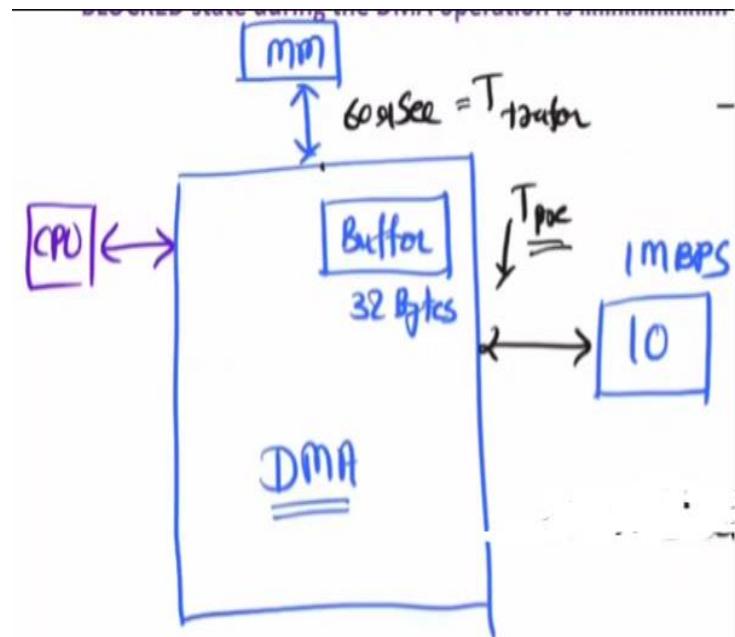
$T_{transfer} = 60$ micro sec

Percentage (%) Block = $(T_{transfer} /$

$T_{transfer} + T_{prep}) * 100\%$

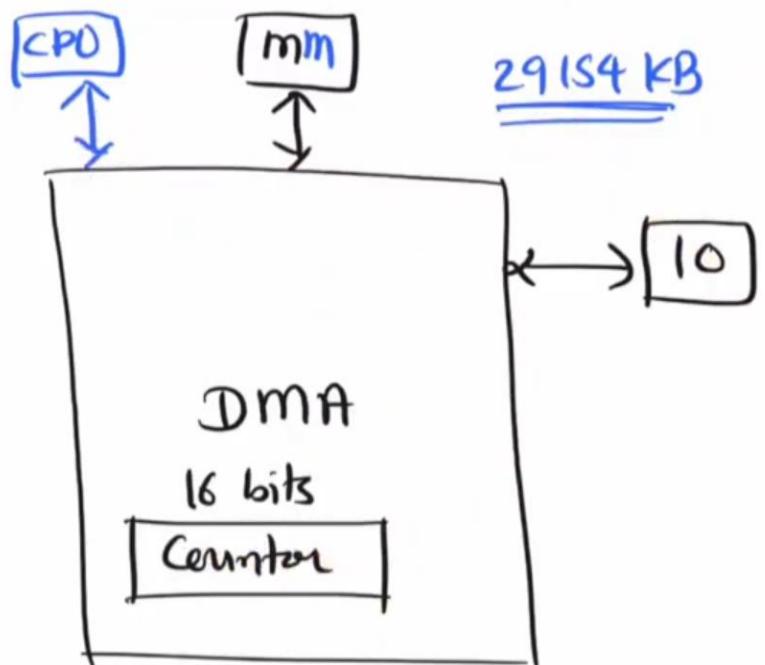
$$= (60 / 60+32) 100\%$$

$$= 65.21 \%$$



Examples on DMA 2:

- The size of the data count register of a DMA controller is 16 bits. The processor needs to transfer a file of 29154 KB from disk to main memory. Here memory is byte addressable. The minimum number of times the DMA controller needs to get control of the system bus from the processor to transfer the file from the disk to main memory is



→ In One go data transfer
= 2^{16} B
= 64 KB

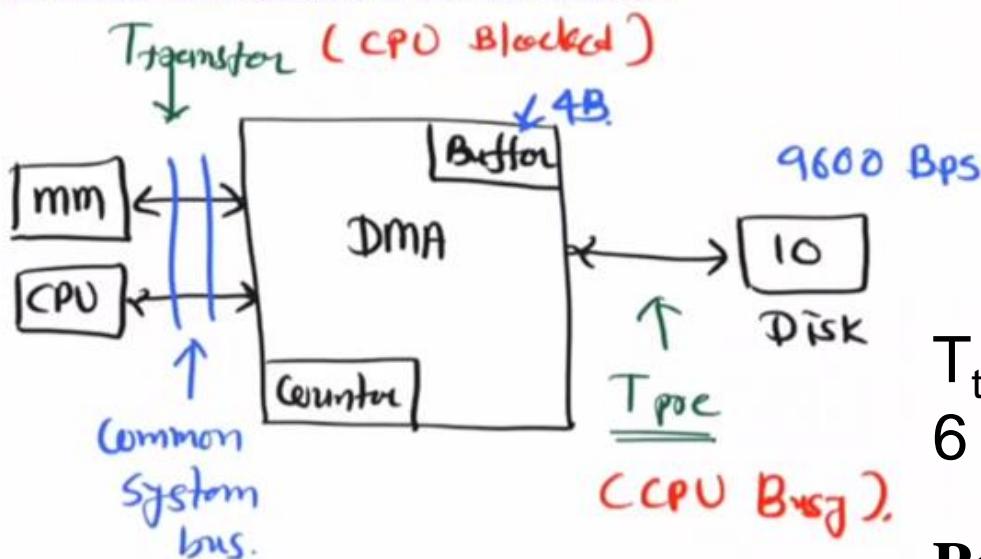
→ $= \frac{29154}{64} = 455.5 = 456$

Examples on DMA 3:

Examples on DMA

- A DMA controller transfers 32 bit words to memory using cycle stealing. The words are assembled from a device that transmits characters at a rate of 9600 characters per second. Assume one character is encoded using 1 byte. The CPU is fetching and executing instructions at an average rate of two million instructions per second. By how much % with the CPU be slowed down because of the DMA transfer?

- 0.6%
- 0.12%
- 1.2%
- 2.5%



$$\begin{aligned} \Rightarrow T_{prep} &= \frac{4B}{9600 \text{ Bps}} \\ &= 4.166 \times 10^{-4} \text{ sec} \end{aligned}$$

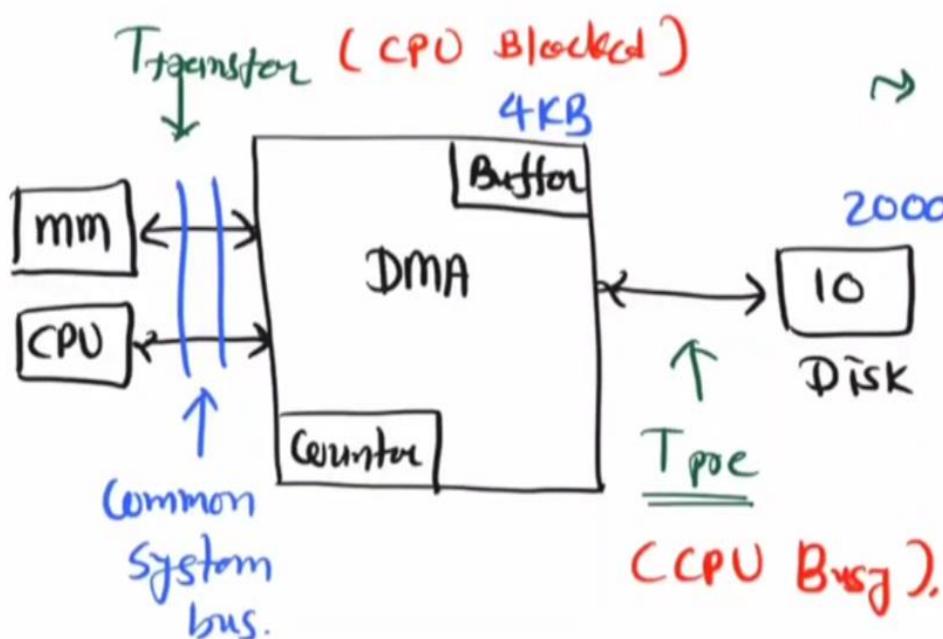
~

$$T_{transfer} = 1/2 \times 10^6 = .5 \times 10^{-6} \text{ sec}$$

$$\begin{aligned} \text{Percentage (\%)} \text{ Block} &= \\ (T_{transfer} / T_{transfer} + T_{prep}) * 100\% &= 0.12\% \text{ (Ans)} \end{aligned}$$

Examples on DMA 4:

- ❖ A hard disk is connected to a 50 MHz processor through a DMA controller. Assume that the initial set up of DMA transfer takes 1000 clock cycles for the processor. The hard disk has a transfer rate of 2000 KBPS and average block transferred is 4KB. What fraction of the processor time is consumed by the disk, if the disk is actively transferring 100% of the time.



$$\rightarrow T_{proc} = \frac{4KB}{2000 KBPS} = 2 \times 10^{-3} \text{ sec}$$

$$\begin{aligned} \rightarrow T_{transistor} &= 1000 t_{cyc} \\ &= 1000 \times \frac{1}{50 \times 10^6} \\ &= 20 \times 10^{-6} \text{ sec} \end{aligned}$$

$$\begin{aligned} \rightarrow \% \text{ Block of CPU} &= \frac{T_{transistor}}{T_{transistor} + T_{proc}} \times 100 \\ &= 1\% \text{ (Ans)} \end{aligned}$$