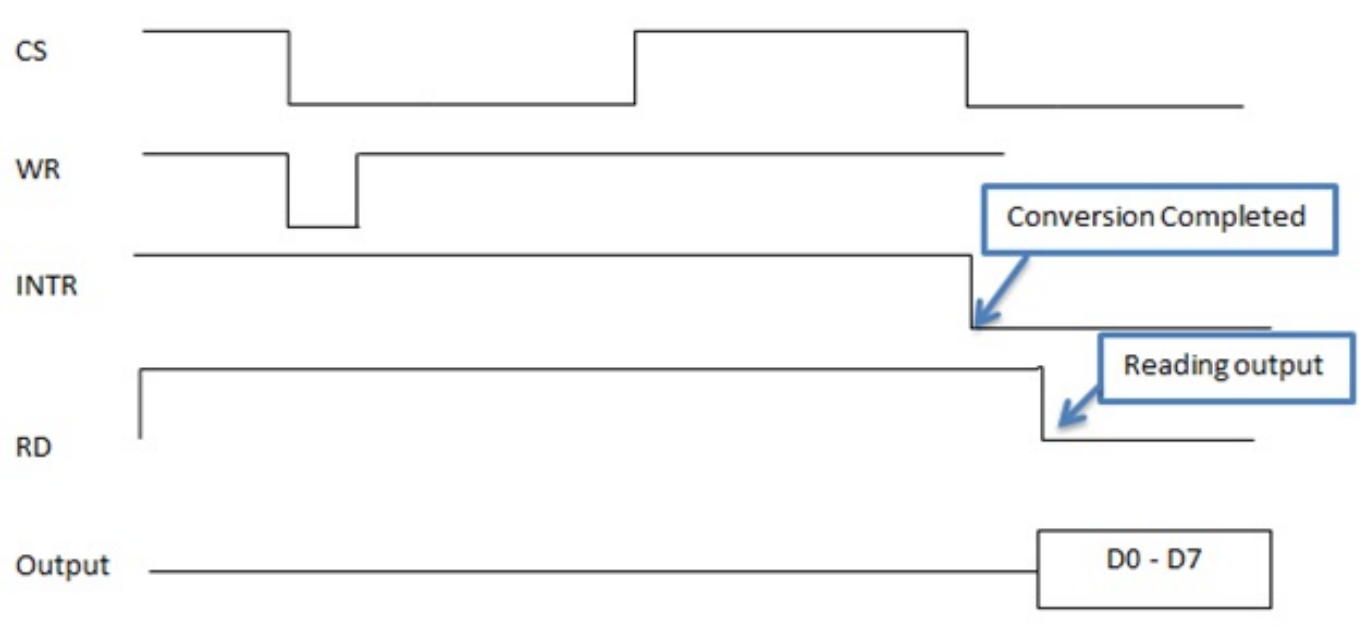
Timing Diagram

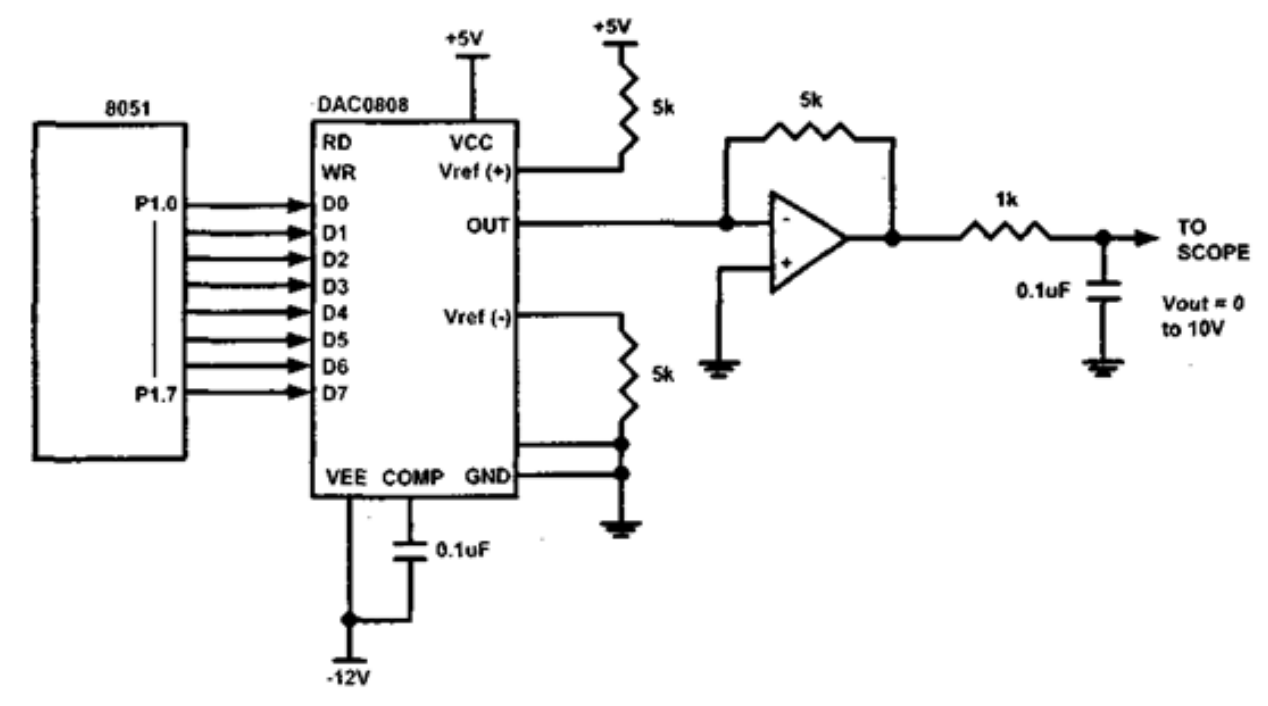


Digital to Analog Conversion (DAC)

- Converts digital pulses to analog signals
- Resolution of a DAC is a function of number of binary inputs
- In DAC0808, binary numbers at D0-D7 inputs are converted to reference current I_{ref}

$$I_{out} = I_{ref} \left(\frac{D7}{2} + \frac{D6}{4} + \frac{D5}{8} + \frac{D4}{16} + \frac{D3}{32} + \frac{D2}{64} + \frac{D1}{128} + \frac{D0}{256} \right)$$

Interfacing DAC0808 with 8051



Converting I_{out} to voltage in DAC0808

- Ideally we connect the output pin I_{out} to a resistor, convert this current to voltage
- This can cause inaccuracy since the input resistance of the load where it is connected will also affect the output voltage.
- I_{ref} current output is isolated by connecting it to an op-amp such as the 741 with R_f = 5K ohms for the feedback resistor.

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Generation of Stair-Step Ramp

```
        CLR   A
AGAIN:  MOV   P1,A          ;send data to DAC
        INC   A             ;count from 0 to FFH
        ACALL DELAY         ;let DAC recover
        SJMP  AGAIN
```

Generating a Sine Wave

- We first need a table whose values represent the magnitude of the sine of angles between 0 and 360 degrees
- The values for the sine function vary from -1.0 to +1.0 for 0- to 360-degree angles
- The table values are integer numbers representing the voltage magnitude for the sine of theta
- This method ensures that only integer numbers are output to the DAC by the 8051 microcontroller
- Full-scale output of the DAC is achieved when all the data inputs of the DAC are high. Therefore, to achieve the full-scale 10 V output, we use the following equation

$$V_{out} = 5\ V + (5 \times \sin \theta)$$

NPTEL

Angle vs. Voltage Magnitude for Sine Wave

Angle	Sine	Voltage out	DAC count
0	0	5	128
30	0.5	7.5	192
60	0.866	9.33	238
90	1.0	10	255
120	0.866	9.33	238
150	0.5	7.5	192
180	0	5	128
210	-0.5	2.5	64
240	-0.866	0.669	17
270	-1.0	0	0
300	-0.866	0.669	17
330	-0.5	2.5	64
360	0	5	128

- To find the value sent to the DAC for various angles, we simply multiply the V_{out} voltage by 25.60 because there are 256 steps and full-scale V_{out} is 10 volts. Therefore, 256 steps /10 V = 25.6 steps per volt.

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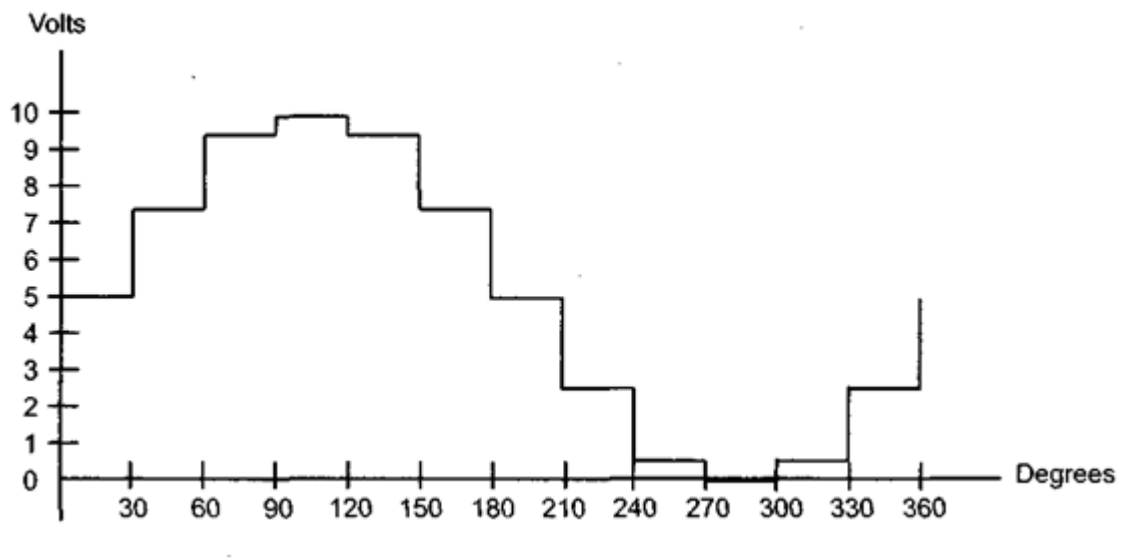
8051 Program

```
AGAIN:      MOV DPTR,#TABLE
            MOV R2,#COUNT
BACK:       CLR A
            MOVC A,@A+DPTR
            MOV P1,A
            INC DPTR
            DJNZ R2,BACK
            SJMP AGAIN
            ORG 300
TABLE:      DB 128,192,238,255,238,192
            DB 128,64,17,0,17,64,128
```

Waveform


Volts
10
9
8
7
6
5
4
3
2
1
0
30
60
90
120
150
180
210
240
270
300
330
360
Degrees

LCD Interfacing

Advantages over LED

1. Declining prices
2. Ability to display numbers, characters and graphics
3. Refreshing controller is part of LCD
4. Ease of programming

NPTEL

LCD Pins

Pin No:	Name	Function
1	VSS	This pin must be connected to the ground
2	VCC	Positive supply voltage pin (5V DC)
3	VEE	Contrast adjustment
4	RS	Register selection
5	R/W	Read or write
6	E	Enable
7	DB0	Data
8	DB1	Data
9	DB2	Data
10	DB3	Data
11	DB4	Data
12	DB5	Data
13	DB6	Data
14	DB7	Data
15	LED+	Back light LED+
16	LED-	Back light LED-

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RS – Register Select

- RS = 0 → instruction command code register selected
- RS = 1 → Data register selected to send data to be displayed
- E : Enable LCD to latch data presented to data pins
- R/W : 1 for reading, 0 for writing

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LCD Commands

Command	Function
0F	LCD ON, Cursor ON, Cursor blinking ON
01	Clear screen
02	Return home
04	Decrement cursor
06	Increment cursor
0E	Display ON ,Cursor blinking OFF
80	Force cursor to the beginning of 1st line
C0	Force cursor to the beginning of 2nd line
38	Use 2 lines and 5×7 matrix
83	Cursor line 1 position 3
3C	Activate second line
08	Display OFF, Cursor OFF
C1	Jump to second line, position1
OC	Display ON, Cursor OFF
C1	Jump to second line, position1
C2	Jump to second line, position2

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LCD initialization

- Send 38H to the 8 bit data line for initialization
- Send 0FH for making LCD ON, cursor ON and cursor blinking ON.
- Send 06H for incrementing cursor position.
- Send 01H for clearing the display and return the cursor.

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Sending data to LCD

- Make R/W low.
- Make RS=0 if data byte is a command and make RS=1 if the data byte is a data to be displayed.
- Place data byte on the data register.
- Pulse E from high to low.
- Repeat above steps for sending another data.

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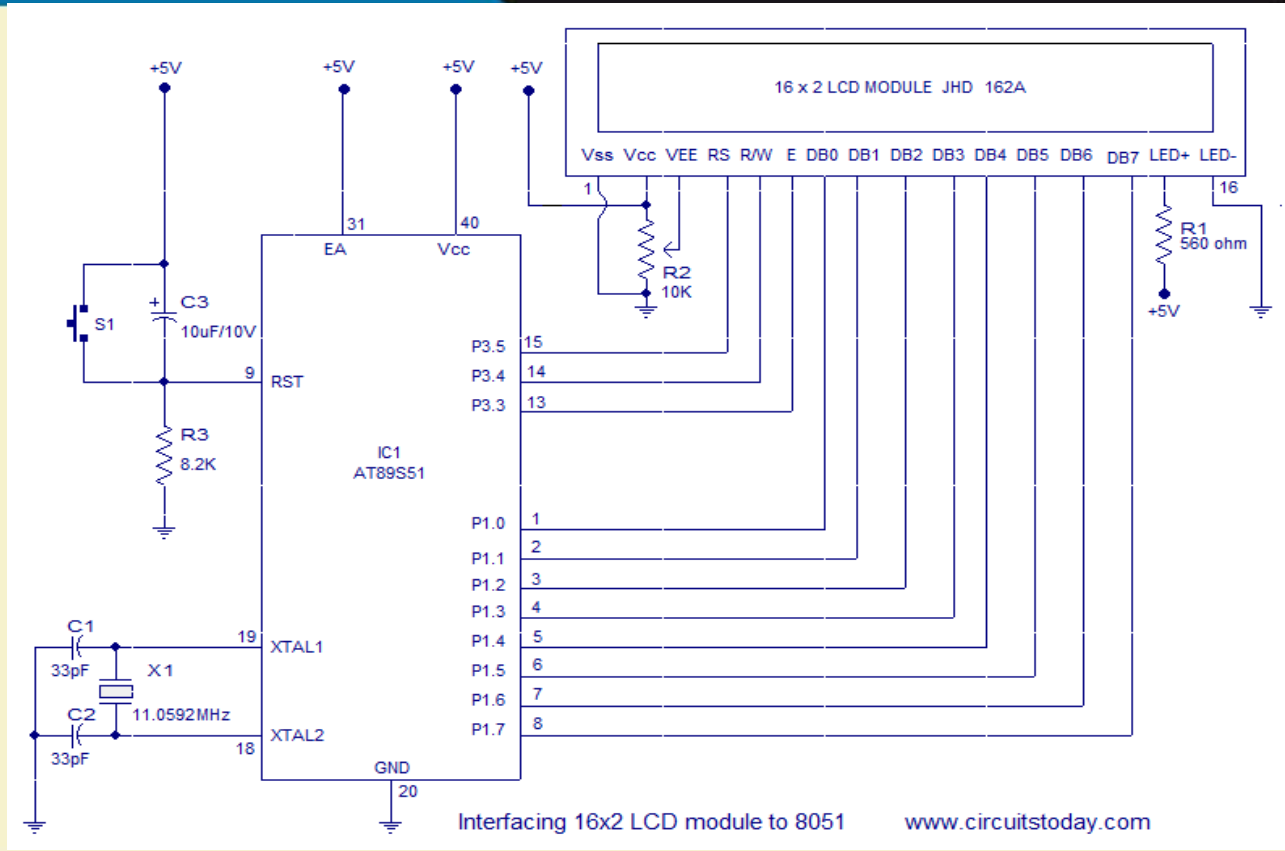
Interfacing



Program

```
MOV A,#38H    // Use 2 lines and 5x7 matrix
ACALL CMND
MOV A,#0FH    // LCD ON, cursor ON, cursor blinking ON
ACALL CMND
MOV A,#01H    //Clear screen
ACALL CMND
MOV A,#06H    //Increment cursor
ACALL CMND
MOV A,#82H    //Cursor line one , position 2
ACALL CMND
MOV A,#3CH    //Activate second line
```

NPTEL

```
ACALL CMND
MOV A,#49D
ACALL DISP
MOV A,#54D
ACALL DISP
MOV A,#88D
ACALL DISP
MOV A,#50D
ACALL DISP
MOV A,#32D
ACALL DISP
```

NPTEL

```
MOV A,#76D
ACALL DISP
MOV A,#67D
ACALL DISP
MOV A,#68D
ACALL DISP
MOV A,#0C1H //Jump to second line, position 1
ACALL CMND
MOV A,#67D
ACALL DISP
MOV A,#73D
```

NPTEL

```
ACALL DISP
MOV A,#82D
ACALL DISP
MOV A,#67D
ACALL DISP
MOV A,#85D
ACALL DISP
MOV A,#73D
ACALL DISP
MOV A,#84D
ACALL DISP
```

NPTEL

```
        MOV A,#83D
        ACALL DISP
        MOV A,#84D
        ACALL DISP
        MOV A,#79D
        ACALL DISP
        MOV A,#68D
        ACALL DISP
        MOV A,#65D
        ACALL DISP
        MOV A,#89D
        ACALL DISP
HERE: SJMP HERE
```

NPTEL

```
CMND:   MOV P1,A
        CLR P3.5
        CLR P3.4
        SETB P3.3
        CLR P3.3
        ACALL DELY
        RET
DISP:MOV P1,A
        SETB P3.5
        CLR P3.4
        SETB P3.3
        CLR P3.3
        ACALL DELY
        RET
DELY:   CLR P3.3
        CLR P3.5
        RET
```

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8086 Microprocessor

Santanu Chattopadhyay
Electronics and Electrical Communication Engineering

NPTEL

Overview

First 16-bit processor released by INTEL in the year 1978

Originally HMOS, now manufactured using HMOS III technique

Approximately 29, 000 transistors, 40 pin DIP, 5V supply

Does not have internal clock; external asymmetric clock source with 33% duty cycle

20-bit address to access memory ⇒ can address up to 2^{20} = 1 megabytes of memory space.

Addressable memory space is organized in to two banks of 512 kb each; Even (or lower) bank and Odd (or higher) bank. Address line A_0 is used to select even bank and control signal $\overline{BHE}$ is used to access odd bank

Uses a separate 16 bit address for I/O mapped devices ⇒ can generate 2^{16} = 64 k addresses.

Operates in two modes: minimum mode and maximum mode, decided by the signal at MN and $\overline{MX}$ pins.

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Pins and signals

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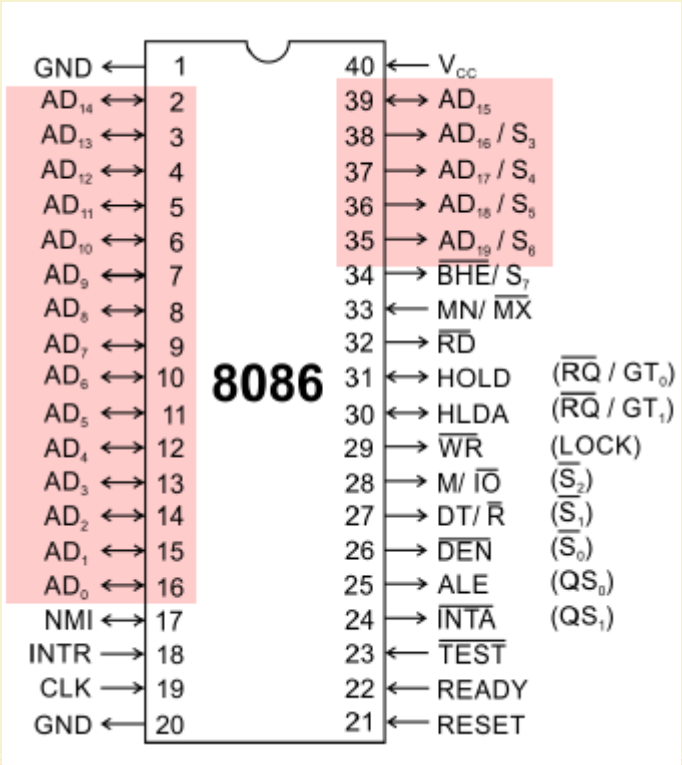
Pins and Signals



AD_0-AD_{15} (Bidirectional)

Address / Data bus

Low order address bus; these are multiplexed with data.

When AD lines are used to transmit memory address the symbol A is used instead of AD, for example A_0-A_{15}.

When data are transmitted over AD lines the symbol D is used in place of AD, for example D_0-D_7, D_8-D_{15} or D_0-D_{15}.

A_{16}/S_3, A_{17}/S_4, A_{18}/S_5, A_{19}/S_6

High order address bus. These are multiplexed with status signals

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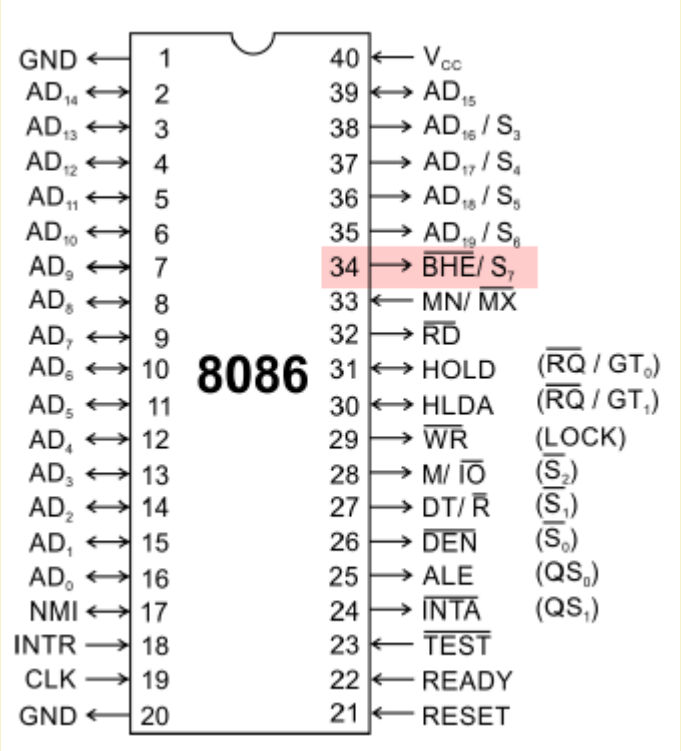

BHE (Active Low) / S_7 (Output)

Bus High Enable / Status

It is used to enable data onto the most significant half of data bus, D_8-D_{15}. 8-bit device connected to upper half of the data bus use BHE (Active Low) signal. It is multiplexed with status signal S_7.

MN / MX

MINIMUM / MAXIMUM

This pin signal indicates what mode the processor is to operate in.

RD (Read) (Active Low)

The signal is used for read operation.
It is an output signal.
It is active when low.

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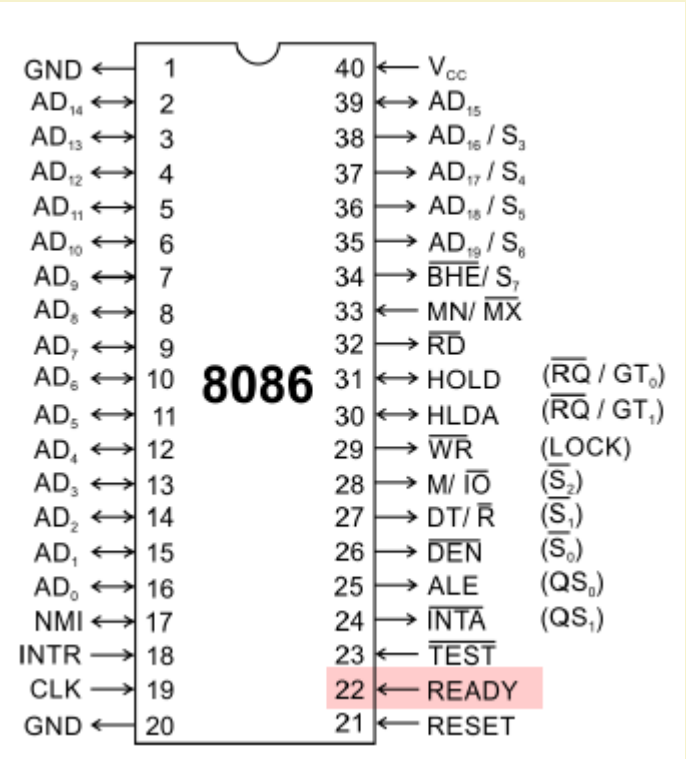

TEST

$\overline{\text{TEST}}$ input is tested by the 'WAIT' instruction.

8086 will enter a wait state after execution of the WAIT instruction and will resume execution only when the $\overline{\text{TEST}}$ is made low by an active hardware.

READY

This is used to synchronize an external activity to the processor. It is the acknowledgement from the slower device or memory that they have completed the data transfer.

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RESET (Input)

Causes the processor to immediately terminate its present activity.
The signal must be active HIGH for at least four clock cycles.

CLK

The clock input provides the basic timing for processor operation and bus control activity. Its an asymmetric square wave with 33% duty cycle.

INTR Interrupt Request

This is a triggered input. This is sampled during the last clock cycles of each instruction to determine the availability of the request. If any interrupt request is pending, the processor enters the interrupt acknowledge cycle.

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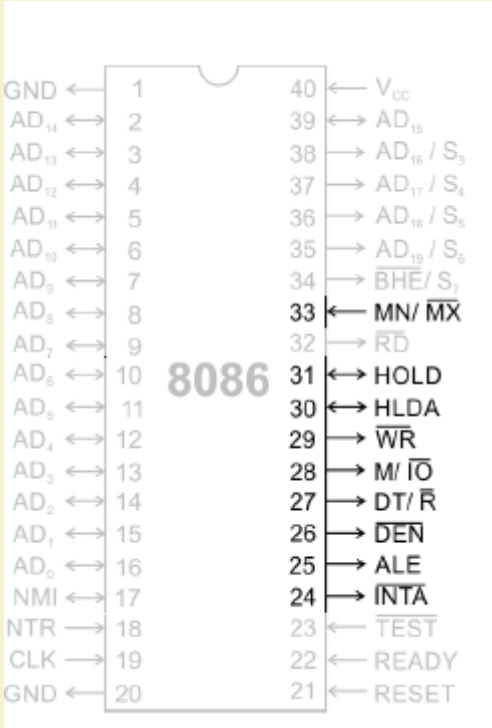
Min/ Max Pin



The 8086 microprocessor can work in two modes of operations : Minimum mode and Maximum mode.

In the minimum mode of operation the microprocessor do not associate with any co-processors and can not be used for multiprocessor systems.

In the maximum mode the 8086 can work in multi-processor or co-processor configuration.

Minimum or maximum mode operations are decided by the pin MN/ MX(Active low).

When this pin is high 8086 operates in minimum mode otherwise it operates in Maximum mode.

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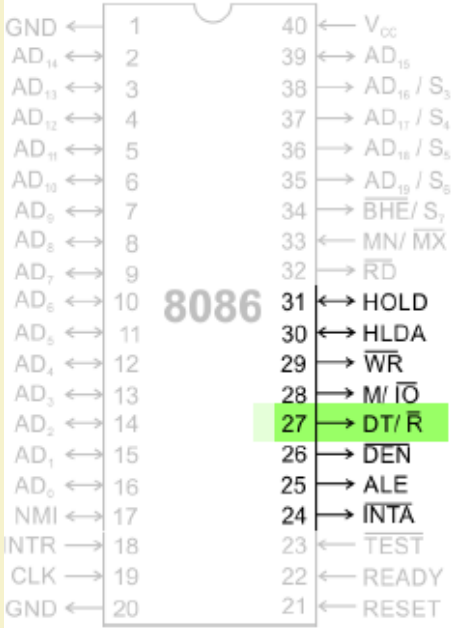
Minimum mode signals



Pins 24 -31

For minimum mode operation, the MN/ $\overline{MX}$ is tied to VCC (logic high)

8086 itself generates all the bus control signals

DT/$\overline{R}$ — (Data Transmit/ Receive) Output signal from the processor to control the direction of data flow through the data transceivers

$\overline{DEN}$ — (Data Enable) Output signal from the processor used as out put enable for the transceivers

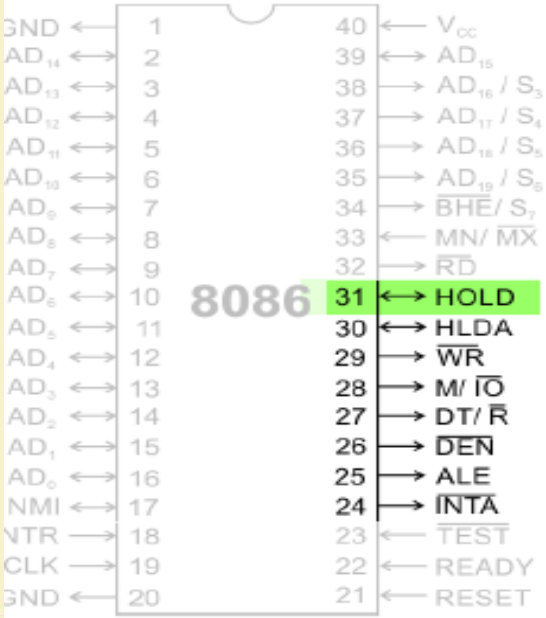
ALE — (Address Latch Enable) Used to demultiplex the address and data lines using external latches

M/$\overline{IO}$ — Used to differentiate memory access and I/O access. For memory reference instructions, it is high. For IN and OUT instructions, it is low.

$\overline{WR}$ — Write control signal; asserted low Whenever processor writes data to memory or I/O port

$\overline{INTA}$ — (Interrupt Acknowledge) When the interrupt request is accepted by the processor, the output is low on this line.

Minimum mode signals



Pins 24 -31

For minimum mode operation, the MN/ $\overline{MX}$ is tied to VCC (logic high)

8086 itself generates all the bus control signals

HOLD — **Input signal to the processor form the bus masters as a request to grant the control of the bus.**

Usually used by the DMA controller to get the control of the bus.

HLDA — **(Hold Acknowledge) Acknowledge signal by the processor to the bus master requesting the control of the bus through HOLD.**

The acknowledge is asserted high, when the processor accepts HOLD.

Maximum mode signals

During maximum mode operation, the MN / $\overline{MX}$ is grounded (logic low)

$\overline{S_0}, \overline{S_1}, \overline{S_2}$

Status signals; used by the 8086 bus controller to generate bus timing and control signals. These are decoded as shown.

Status Signal			Machine Cycle
$\overline{S}_2$	$\overline{S}_1$	$\overline{S}_0$	
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/Inactive

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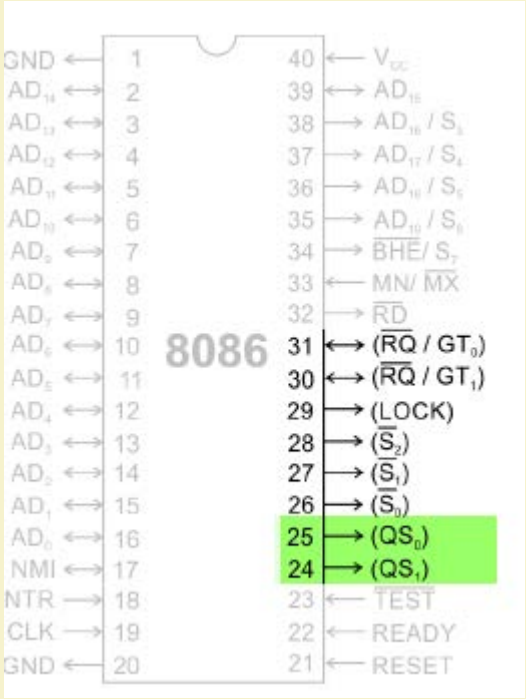
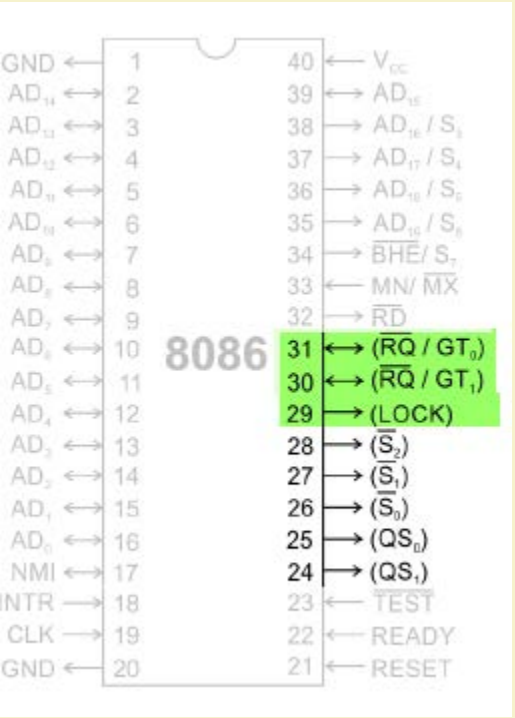
Maximum mode signals



$\overline{QS_0}$, $\overline{QS_1}$	(**Queue Status**) The processor provides the status of queue in these lines. The queue status can be used by external device to track the internal status of the queue in 8086. The output on QS_0 and QS_1 can be interpreted as shown in the table.

Queue status		Queue operation
QS_1	QS_0	
0	0	No operation
0	1	First byte of an opcode from queue
1	0	Empty the queue
1	1	Subsequent byte from queue

Maximum mode signals



$\overline{RQ}/\ \overline{GT_0}$, $\overline{RQ}/\ \overline{GT_1}$	(Bus Request/ Bus Grant) These requests are used by other local bus masters to force the processor to release the local bus at the end of the processor's current bus cycle. These pins are bidirectional. The request on $\overline{GT_0}$ will have higher priority than $\overline{GT_1}$
$\overline{LOCK}$	An output signal activated by the LOCK prefix instruction. Remains active until the completion of the instruction prefixed by LOCK. The 8086 output low on the $\overline{LOCK}$ pin while executing an instruction prefixed by LOCK to prevent other bus masters from gaining control of the system bus.

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Architecture

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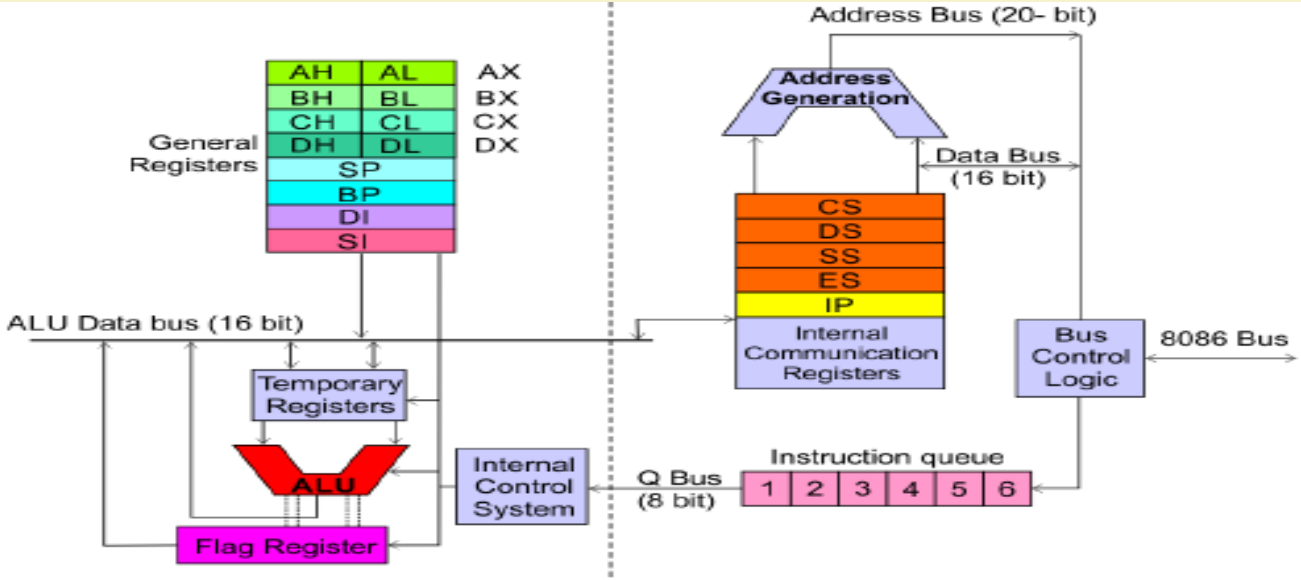
Architecture



Execution Unit (EU)

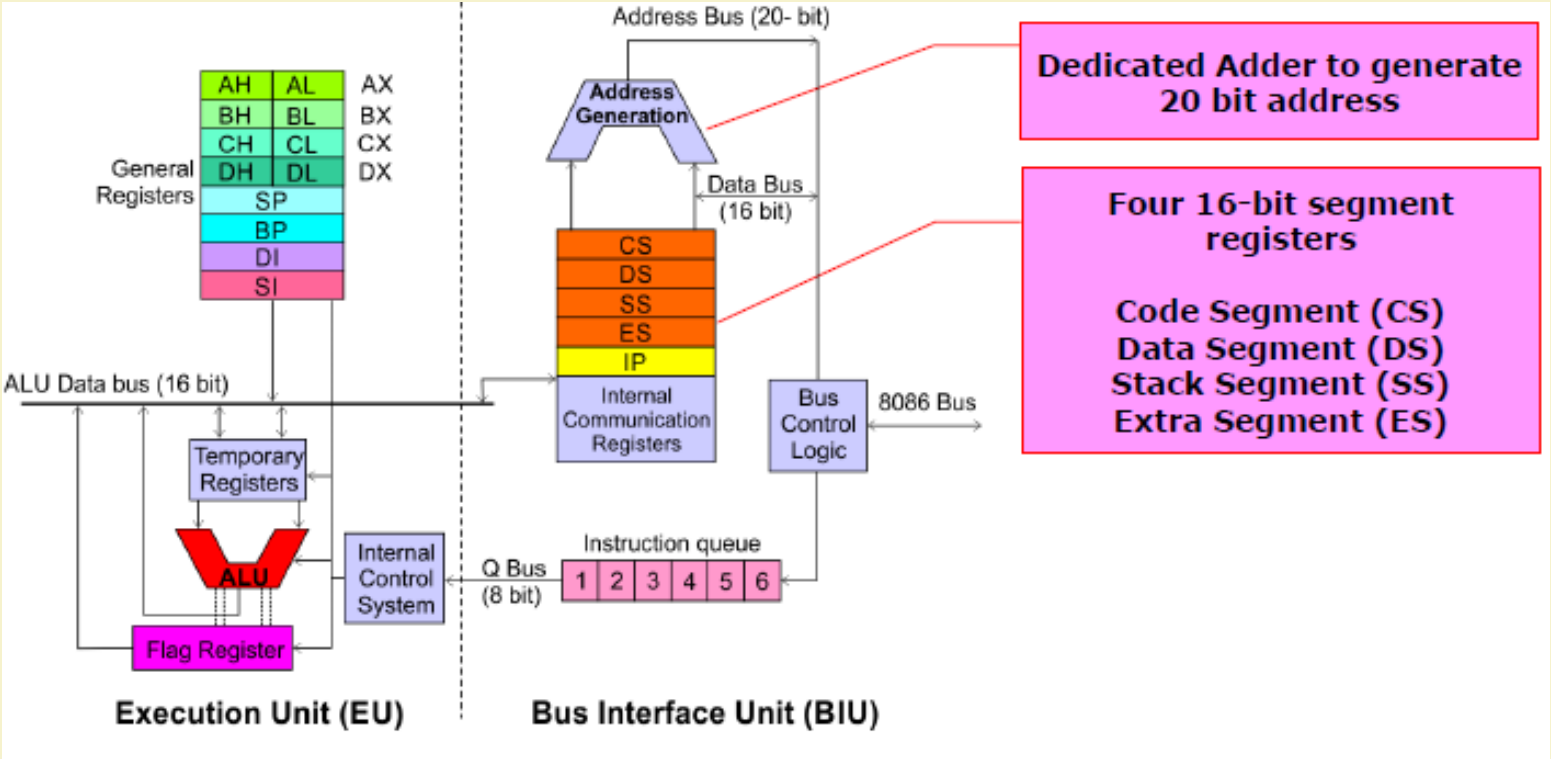
EU executes instructions that have already been fetched by the BIU.

BIU and EU functions separately.

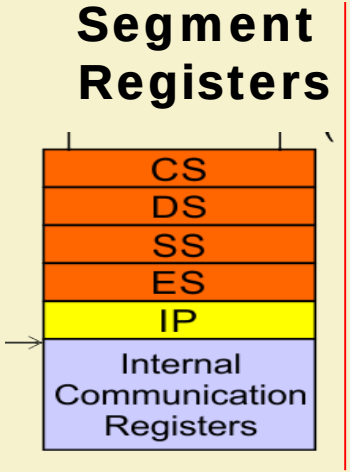
Bus Interface Unit (BIU)

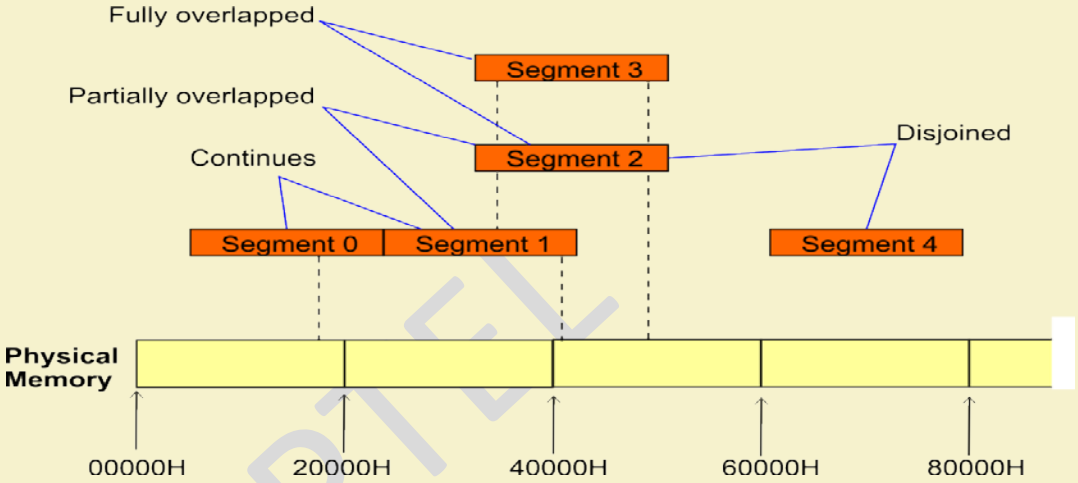
BIU fetches instructions, reads data from memory and I/O ports, writes data to memory and I/ O ports.

Bus Interface Unit (BIU)



Bus Interface Unit (BIU)

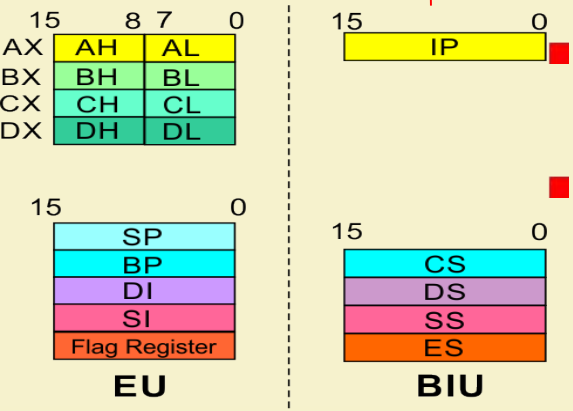




- 8086's 1-megabyte memory is divided into segments of up to 64K bytes each.
- The 8086 can directly address four segments (256 K bytes within the 1 M byte of memory) at a particular time.
- Programs obtain access to code and data in the segments by changing the segment register content to point to the desired segments.

Bus Interface Unit (BIU)

Segment Registers



Code Segment Register

- 16-bit
- CS contains the base or start of the current code segment; IP contains the distance or offset from this address to the next instruction byte to be fetched.
- BIU computes the 20-bit physical address by logically shifting the contents of CS 4-bits to the left and then adding the 16-bit contents of IP.
- That is, all instructions of a program are relative to the contents of the CS register multiplied by 16 and then offset is added provided by the IP.

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Bus Interface Unit (BIU)

Segment Registers

Data Segment Register

- 16-bit
- Points to the current data segment; operands for most instructions are fetched from this segment.
- The 16-bit contents of the Source Index (SI) or Destination Index (DI) or a 16-bit displacement are used as offset for computing the 20-bit physical address.

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Bus Interface Unit (BIU)

Segment Registers

Stack Segment Register

- 16-bit
- Points to the current stack.
- The 20-bit physical stack address is calculated from the Stack Segment (SS) and the Stack Pointer (SP) for stack instructions such as PUSH and POP.
- In based addressing mode, the 20-bit physical stack address is calculated from the Stack segment (SS) and the Base Pointer (BP).

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Segment Registers

Extra Segment Register

- 16-bit
- Points to the extra segment in which data (in excess of 64K pointed to by the DS) is stored.
- String instructions use the ES and DI to determine the 20-bit physical address for the destination.

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Bus Interface Unit (BIU)

Segment Registers

Instruction Pointer

- 16-bit
- Always points to the next instruction to be executed within the currently executing code segment.
- So, this register contains the 16-bit offset address pointing to the next instruction code within the 64Kb of the code segment area.
- Its content is automatically incremented as the execution of the next instruction takes place.

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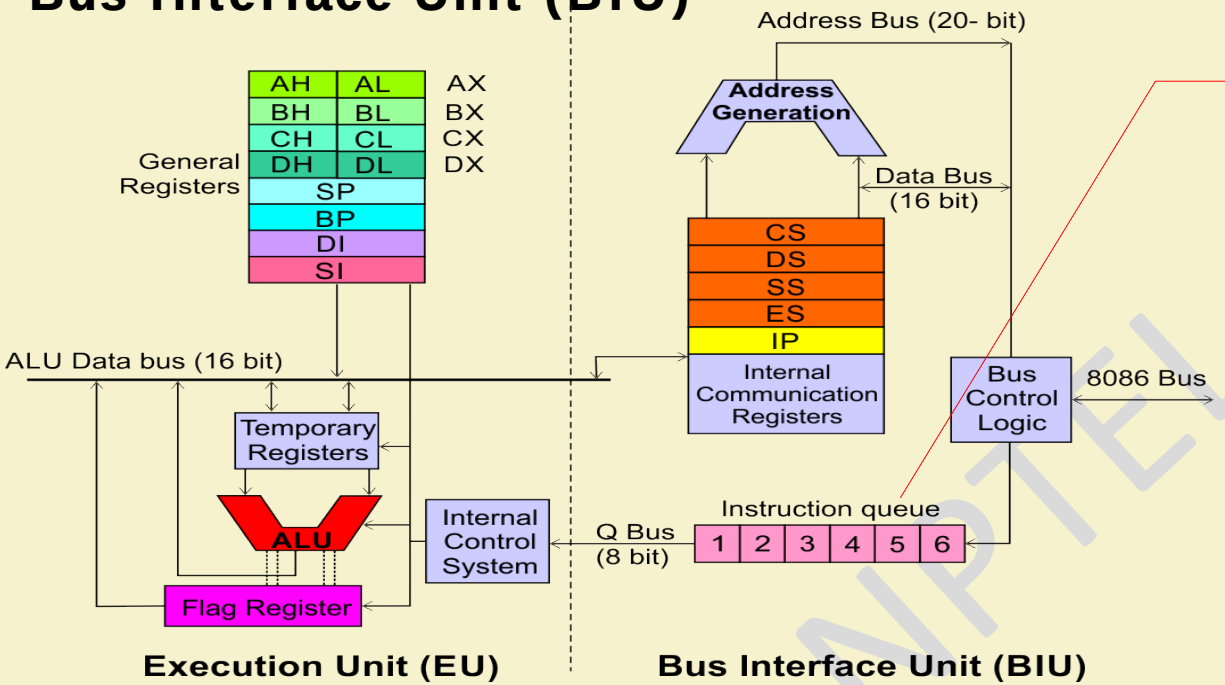
Bus Interface Unit (BIU)



Instruction queue

- A group of First-In-First-Out (FIFO) in which up to 6 bytes of instruction code are pre fetched from the memory ahead of time.
- This is done in order to speed up the execution by overlapping instruction fetch with execution.
- This mechanism is known as pipelining.

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Execution Unit (EU)

EU decodes and executes instructions.

A decoder in the EU control system translates instructions.

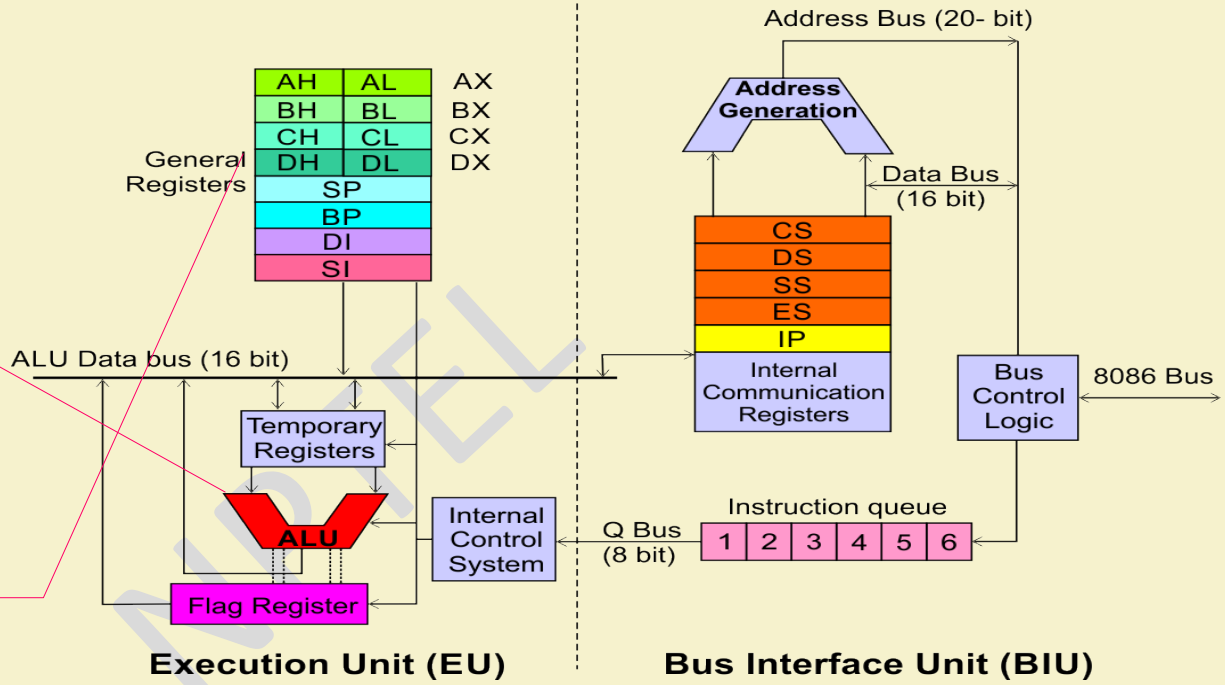
16-bit ALU for performing arithmetic and logic operation

Four general purpose registers(AX, BX, CX, DX);

Pointer registers (Stack Pointer, Base Pointer);

and

Index registers (Source Index, Destination Index) each of 16-bits



Some of the 16 bit registers can be used as two 8 bit registers as : AX, BX, CX, DX

Accumulator Register (AX)

- Consists of two 8-bit registers AL and AH, which can be combined together and used as a 16-bit register AX.
- AL in this case contains the low order byte of the word, and AH contains the high-order byte.
- The I/O instructions use the AX or AL for inputting / outputting 16 or 8 bit data to or from an I/O port.
- Multiplication and Division instructions also use the AX or AL.

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Base Register (BX)

- Consists of two 8-bit registers BL and BH, which can be combined together and used as a 16-bit register BX.
- BL in this case contains the low-order byte of the word, and BH contains the high-order byte.
- This is the only general purpose register whose contents can be used for addressing the 8086 memory.
- All memory references utilizing this register content for addressing use DS as the default segment register.

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EU Registers

Counter Register (CX)

- Consists of two 8-bit registers CL and CH, which can be combined together and used as a 16-bit register CX.
- When combined, CL register contains the low order byte of the word, and CH contains the high-order byte.
- Instructions such as SHIFT, ROTATE and LOOP use the contents of CX as a counter.

Example:

The instruction LOOP START automatically decrements CX by 1 without affecting flags and will check if [CX] = 0.

If it is zero, 8086 executes the next instruction; otherwise the 8086 branches to the label START.

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EU Registers

Data Register (DX)

- Consists of two 8-bit registers DL and DH, which can be combined together and used as a 16-bit register DX.
- When combined, DL register contains the low order byte of the word, and DH contains the high-order byte.
- Used to hold the high 16-bit result (data) in 16 X 16 multiplication or the high 16-bit dividend (data) before a 32 ÷ 16 division and the 16-bit reminder after division.

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Stack Pointer (SP) and Base Pointer (BP)

- SP and BP are used to access data in the stack segment.
- SP is used as an offset from the current SS during execution of instructions that involve the stack segment in the external memory.
- SP contents are automatically updated (incremented/ decremented) due to execution of a POP or PUSH instruction.
- BP contains an offset address in the current SS, which is used by instructions utilizing the based addressing mode.

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EU Registers

Source Index (SI) and Destination Index (DI)

- Used in indexed addressing.
- Instructions that process data strings use the SI and DI registers together with DS and ES respectively in order to distinguish between the source and destination addresses.

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Flag Register

Auxiliary Carry Flag

This is set, if there is a carry from the lowest nibble, i.e, bit three during addition, or borrow for the lowest nibble, i.e, bit three, during subtraction.

Carry Flag

This flag is set, when there is a carry out of MSB in case of addition or a borrow in case of subtraction.

Sign Flag

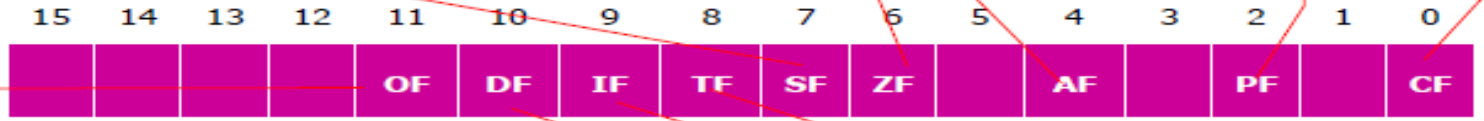
This flag is set, when the result of any computation is negative

Zero Flag

This flag is set, if the result of the computation or comparison performed by an instruction is zero

Parity Flag

This flag is set to 1, if the lower byte of the result contains even number of 1's ; for odd number of 1's set to zero.



Over flow Flag

This flag is set, if an overflow occurs, i.e, if the result of a signed operation is large enough to accommodate in a destination register. The result is of more than 7-bits in size in case of 8-bit signed operation and more than 15-bits in size in case of 16-bit sign operations, then the overflow will be set.

Tarp Flag

If this flag is set, the processor enters the single step execution mode by generating internal interrupts after the execution of each instruction

Direction Flag

This is used by string manipulation instructions. If this flag bit is '0', the string is processed beginning from the lowest address to the highest address, i.e., auto incrementing mode. Otherwise, the string is processed from the highest address towards the lowest address, i.e., auto incrementing mode.

Interrupt Flag

Causes the 8086 to recognize external mask interrupts; clearing IF disables these interrupts.

8086 registers categorized into 4 groups

Sl.No.	Type	Register width	Name of register
1	General purpose register	16 bit	AX, BX, CX, DX
		8 bit	AL, AH, BL, BH, CL, CH, DL, DH
2	Pointer register	16 bit	SP, BP
3	Index register	16 bit	SI, DI
4	Instruction Pointer	16 bit	IP
5	Segment register	16 bit	CS, DS, SS, ES
6	Flag (PSW)	16 bit	Flag register

Registers and Special Functions

Register	Name of the Register	Special Function
AX	16-bit Accumulator	Stores the 16-bit results of arithmetic and logic operations
AL	8-bit Accumulator	Stores the 8-bit results of arithmetic and logic operations
BX	Base register	Used to hold base value in base addressing mode to access memory data
CX	Count Register	Used to hold the count value in SHIFT, ROTATE and LOOP instructions
DX	Data Register	Used to hold data for multiplication and division operations
SP	Stack Pointer	Used to hold the offset address of top stack memory
BP	Base Pointer	Used to hold the base value in base addressing using SS register to access data from stack memory
SI	Source Index	Used to hold index value of source operand (data) for string instructions
DI	Data Index	Used to hold the index value of destination operand (data) for string operations

Addressing Modes

- **Every instruction of a program has to operate on a data.**
- **The different ways in which a source operand is denoted in an instruction are known as addressing modes.**

1. Register Addressing 2. Immediate Addressing	Group I : Addressing modes for register and immediate data
3. Direct Addressing 4. Register Indirect Addressing 5. Based Addressing 6. Indexed Addressing 7. Based Index Addressing 8. String Addressing	Group II : Addressing modes for memory data
9. Direct I/O port Addressing 10. Indirect I/O port Addressing	Group III : Addressing modes for I/O ports
11. Relative Addressing	Group IV : Relative Addressing mode
12. Implied Addressing	Group V : Implied Addressing mode

Register Addressing Modes

The instruction will specify the name of the register which holds the data to be operated by the instruction.

Example:

MOV CL, DH

The content of 8-bit register DH is moved to another 8-bit register CL

(CL) ← (DH)

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Immediate Addressing

In immediate addressing mode, an 8-bit or 16-bit data is specified as part of the instruction

Example:

MOV DL, 08H

The 8-bit data (08_H) given in the instruction is moved to DL

(DL) ← 08_H

MOV AX, 0A9FH

The 16-bit data ($0A9F_H$) given in the instruction is moved to AX register

(AX) ← $0A9F_H$

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Addressing Modes : Memory Access

- 20 Address lines ⇒ 8086 can address up to 2^{20} = 1M bytes of memory
- However, the largest register is only 16 bits
- Physical Address will have to be calculated
  Physical Address : Actual address of a byte in memory. i.e. the value which goes out onto the address bus.
- Memory Address represented in the form –
  Seg : Offset (Eg - 89AB:F012)
- Each time the processor wants to access memory, it takes the contents of a segment register, shifts it one hexadecimal place to the left (same as multiplying by 16_{10}), then add the required offset to form the 20- bit address

```
89AB : F012  →  89AB →   89AB0  (Paragraph to byte → 89AB x 10 = 89AB0)
                F012 →    0F012  (Offset is already in byte unit)
                      + --------
                          98AC2  (The absolute address)
```

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Direct Addressing

Here, the effective address of the memory location at which the data operand is stored is given in the instruction.

The effective address is just a 16-bit number written directly in the instruction.

Example:

```
MOV  BX, [1354H]
MOV  BL, [0400H]
```

The square brackets around the 1354_H denotes the contents of the memory location. When executed, this instruction will copy the contents of the memory location into BX register.

This addressing mode is called direct because the displacement of the operand from the segment base is specified directly in the instruction.

NPTEL

Register Indirect Addressing

In Register indirect addressing, name of the register which holds the effective address (EA) will be specified in the instruction.

Registers used to hold EA are any of the following registers: BX, BP, DI and SI.

Content of the DS register is used for base address calculation.

Example: MOV CX, [BX]

Operations:

EA = (BX)

BA = (DS) x 16_{10}

MA = BA + EA

(CX) ← (MA) or,

(CL) ← (MA)

(CH) ← (MA +1)

Note : Register/ memory enclosed in brackets refer to content of register/ memory

NPTEL

Based Addressing

In Based Addressing, BX or BP is used to hold the base value for effective address and a signed 8-bit or unsigned 16-bit displacement will be specified in the instruction.

In case of 8-bit displacement, it is sign extended to 16-bit before adding to the base value.

When BX holds the base value of EA, 20-bit physical address is calculated from BX and DS.

When BP holds the base value of EA, BP and SS is used.

Example:

MOV AX, [BX + 08H]

Operations:

$0008_H \leftarrow 08_H$ **(Sign extended)**

$EA = (BX) + 0008_H$

$BA = (DS) \times 16_{10}$

$MA = BA + EA$

$(AX) \leftarrow (MA)$ **or,**

$(AL) \leftarrow (MA)$, $(AH) \leftarrow (MA + 1)$

NPTEL

Indexed Addressing

SI or DI register is used to hold an index value for memory data and a signed 8-bit or unsigned 16-bit displacement will be specified in the instruction.

Displacement is added to the index value in SI or DI register to obtain the EA.

In case of 8-bit displacement, it is sign extended to 16-bit before adding to the base value.

Example:

MOV CX, [SI + 0A2H]

Operations:

$FFA2_H \leftarrow A2_H$ **(Sign extended)**

$EA = (SI) + FFA2_H$

$BA = (DS) \times 16_{10}$

$MA = BA + EA$

$(CX) \leftarrow (MA)$ **or,**

$(CL) \leftarrow (MA)$

$(CH) \leftarrow (MA + 1)$

NPTEL

Based Indexed Addressing

In Based Index Addressing, the effective address is computed from the sum of a base register (BX or BP), an index register (SI or DI) and a displacement.

Example:

MOV DX, [BX + SI + 0AH]

Operations:

$000A_H \leftarrow 0A_H$ **(Sign extended)**

$EA = (BX) + (SI) + 000A_H$

$BA = (DS) \times 16_{10}$

$MA = BA + EA$

$(DX) \leftarrow (MA)$ **or,**

$(DL) \leftarrow (MA), (DH) \leftarrow (MA + 1)$

NPTEL

String Addressing

Employed in string operations to operate on string data.

The effective address (EA) of source data is stored in SI register and the EA of destination is stored in DI register.

Segment register for calculating base address of source data is DS and that of the destination data is ES

Example: MOVS BYTE

Operations:

Calculation of source memory location:

EA = (SI) BA = (DS) x 16_{10} MA = BA + EA

Calculation of destination memory location:

EA_E = (DI) BA_E = (ES) x 16_{10} MA_E = BA_E + EA_E

(MAE) ← (MA)

If DF = 1, then (SI) ← (SI) – 1 and (DI) = (DI) - 1

If DF = 0, then (SI) ← (SI) +1 and (DI) = (DI) + 1

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I/O Port Addressing

These addressing modes are used to access data from standard I/O mapped devices or ports.

In direct port addressing mode, an 8-bit port address is directly specified in the instruction.

Example: IN AL, [09H]
Operations: $PORT_{addr} = 09_H$
(AL) ← (PORT) Content of port with address 09_H is moved to AL register

In indirect port addressing mode, the instruction will specify the name of the register which holds the port address. In 8086, the 16-bit port address is stored in the DX register.

Example: OUT [DX], AX
Operations: $PORT_{addr}$ = (DX)
(PORT) ← (AX)

Content of AX is moved to port whose address is specified by DX register.

NPTEL

Relative Addressing

In this addressing mode, the effective address of a program instruction is specified relative to Instruction Pointer (IP) by an 8-bit signed displacement.

Example: **JZ 0AH**

Operations:

$000A_H \leftarrow 0A_H$ **(sign extend)**

If ZF = 1, then

$EA = (IP) + 000A_H$
$BA = (CS) \times 16_{10}$
$MA = BA + EA$

If ZF = 1, then the program control jumps to new address calculated above.

If ZF = 0, then next instruction of the program is executed.

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Implied Addressing

Instructions using this mode have no operands. The instruction itself will specify the data to be operated by the instruction.

Example: CLC

This clears the carry flag to zero.

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INSTRUCTION SET

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Instruction Set

8086 supports 6 types of instructions.

1. **Data Transfer Instructions**
2. **Arithmetic Instructions**
3. **Logical Instructions**
4. **String manipulation Instructions**
5. **Process Control Instructions**
6. **Control Transfer Instructions**

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Data Transfer Instructions

Instructions that are used to transfer data/ address in to registers, memory locations and I/O ports.

Generally involve two operands: Source operand and Destination operand of the same size.

Source: Register or a memory location or an immediate data
Destination : Register or a memory location.

The size should be a either a byte or a word.

A 8-bit data can only be moved to 8-bit register/ memory and a 16-bit data can be moved to 16-bit register/ memory.

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Data Transfer Instructions

Mnemonics: MOV, XCHG, PUSH, POP, IN, OUT …

MOV reg2/ mem, reg1/ mem	
MOV reg2, reg1	(reg2) ← (reg1)
MOV mem, reg1	(mem) ← (reg1)
MOV reg2, mem	(reg2) ← (mem)
MOV reg/ mem, data	
MOV reg, data	(reg) ← data
MOV mem, data	(mem) ← data
XCHG reg2/ mem, reg1	
XCHG reg2, reg1	(reg2) ↔ (reg1)
XCHG mem, reg1	(mem) ↔ (reg1)

Data Transfer Instructions

Mnemonics: MOV, XCHG, PUSH, POP, IN, OUT …

PUSH reg16/ mem	
PUSH reg16	(SP) ← (SP) – 2 MA_S = (SS) x 16_{10} + SP (MA_S ; MA_S + 1) ← (reg16)
PUSH mem	(SP) ← (SP) – 2 MA_S = (SS) x 16_{10} + SP (MA_S ; MA_S + 1) ← (mem)
POP reg16/ mem	
POP reg16	MA_S = (SS) x 16_{10} + SP (reg16) ← (MA_S ; MA_S + 1) (SP) ← (SP) + 2
POP mem	MA_S = (SS) x 16_{10} + SP (mem) ← (MA_S ; MA_S + 1) (SP) ← (SP) + 2

Data Transfer Instructions

Mnemonics: MOV, XCHG, PUSH, POP, IN, OUT …

IN A, [DX]	
IN AL, [DX]	$PORT_{addr}$ = (DX) (AL) ← (PORT)
IN AX, [DX]	$PORT_{addr}$ = (DX) (AX) ← (PORT)
IN A, addr8	
IN AL, addr8	(AL) ← (addr8)
IN AX, addr8	(AX) ← (addr8)

OUT [DX], A	
OUT [DX], AL	$PORT_{addr}$ = (DX) (PORT) ← (AL)
OUT [DX], AX	$PORT_{addr}$ = (DX) (PORT) ← (AX)
OUT addr8, A	
OUT addr8, AL	(addr8) ← (AL)
OUT addr8, AX	(addr8) ← (AX)

Arithmetic Instructions

Mnemonics: ADD, ADC, SUB, SBB, INC, DEC, MUL, DIV, CMP…

ADD reg2/ mem, reg1/mem	

ADD reg2, reg1
ADD reg2, mem
ADD mem, reg1
	(reg2) ← (reg1) + (reg2)
	(reg2) ← (reg2) + (mem)
	(mem) ← (mem)+(reg1)

ADD reg/mem, data	
ADD reg, data ADD mem, data	(reg) ← (reg)+ data (mem) ← (mem)+data
ADD A, data	
ADD AL, data8 ADD AX, data16	(AL) ← (AL) + data8 (AX) ← (AX) +data16

Arithmetic Instructions

Mnemonics: ADD, ADC, SUB, SBB, INC, DEC, MUL, DIV, CMP…

ADC reg2/ mem, reg1/mem	
ADC reg2, reg1	(reg2) ← (reg1) + (reg2)+CF
ADC reg2, mem	(reg2) ← (reg2) + (mem)+CF
ADC mem, reg1	(mem) ← (mem)+(reg1)+CF
ADC reg/mem, data	
ADC reg, data	(reg) ← (reg)+ data+CF
ADC mem, data	(mem) ← (mem)+data+CF
ADDC A, data	
ADD AL, data8	(AL) ← (AL) + data8+CF
ADD AX, data16	(AX) ← (AX) +data16+CF

Arithmetic Instructions

Mnemonics: ADD, ADC, SUB, SBB, INC, DEC, MUL, DIV, CMP…

SUB reg2/ mem, reg1/mem	
SUB reg2, reg1	(reg2) ← (reg1) - (reg2)
SUB reg2, mem	(reg2) ← (reg2) - (mem)
SUB mem, reg1	(mem) ← (mem) - (reg1)
SUB reg/mem, data	
SUB reg, data	(reg) ← (reg) - data
SUB mem, data	(mem) ← (mem) - data
SUB A, data	
SUB AL, data8	(AL) ← (AL) - data8
SUB AX, data16	(AX) ← (AX) - data16

Arithmetic Instructions

Mnemonics: ADD, ADC, SUB, SBB, INC, DEC, MUL, DIV, CMP…

SBB reg2/ mem, reg1/mem	
SBB reg2, reg1	(reg2) ← (reg1) - (reg2) - CF
SBB reg2, mem	(reg2) ← (reg2) - (mem)- CF
SBB mem, reg1	(mem) ← (mem) - (reg1) –CF
SBB reg/mem, data	
SBB reg, data	(reg) ← (reg) – data - CF
SBB mem, data	(mem) ← (mem) - data - CF
SBB A, data	
SBB AL, data8	(AL) ← (AL) - data8 - CF
SBB AX, data16	(AX) ← (AX) - data16 - CF

Arithmetic Instructions

Mnemonics: ADD, ADC, SUB, SBB, INC, DEC, MUL, DIV, CMP…

INC reg/ mem	
INC reg8	(reg8) ← (reg8) + 1
INC reg16	(reg16) ← (reg16) + 1
INC mem	(mem) ← (mem) + 1
DEC reg/ mem	
DEC reg8	(reg8) ← (reg8) - 1
DEC reg16	(reg16) ← (reg16) - 1
DEC mem	(mem) ← (mem) - 1

Arithmetic Instructions

Mnemonics: ADD, ADC, SUB, SBB, INC, DEC, MUL, DIV, CMP…

MUL reg/ mem	
MUL reg	For byte : (AX) ← (AL) x (reg8) For word : (DX)(AX) ← (AX) x (reg16)
MUL mem	For byte : (AX) ← (AL) x (mem8) For word : (DX)(AX) ← (AX) x (mem16)
IMUL reg/ mem	
IMUL reg	For byte : (AX) ← (AL) x (reg8) For word : (DX)(AX) ← (AX) x (reg16)
IMUL mem	For byte : (AX) ← (AX) x (mem8) For word : (DX)(AX) ← (AX) x (mem16)

Arithmetic Instructions

Mnemonics: ADD, ADC, SUB, SBB, INC, DEC, MUL, DIV, CMP…

DIV reg/ mem	
DIV reg	For 16-bit :- 8-bit : (AL) ← (AX) :- (reg8) Quotient (AH) ← (AX) MOD(reg8) Remainder For 32-bit :- 16-bit : (AX) ← (DX)(AX) :- (reg16) Quotient (DX) ← (DX)(AX) MOD(reg16) Remainder
DIV mem	For 16-bit :- 8-bit : (AL) ← (AX) :- (mem8) Quotient (AH) ← (AX) MOD(mem8) Remainder For 32-bit :- 16-bit : (AX) ← (DX)(AX) :- (mem16) Quotient (DX) ← (DX)(AX) MOD(mem16) Remainder

Arithmetic Instructions

Mnemonics: ADD, ADC, SUB, SBB, INC, DEC, MUL, DIV, CMP…

IDIV reg/ mem	
IDIV reg	For 16-bit :- 8-bit : (AL) ← (AX) :- (reg8) Quotient (AH) ← (AX) MOD(reg8) Remainder For 32-bit :- 16-bit : (AX) ← (DX)(AX) :- (reg16) Quotient (DX) ← (DX)(AX) MOD(reg16) Remainder
IDIV mem	For 16-bit :- 8-bit : (AL) ← (AX) :- (mem8) Quotient (AH) ← (AX) MOD(mem8) Remainder For 32-bit :- 16-bit : (AX) ← (DX)(AX) :- (mem16) Quotient (DX) ← (DX)(AX) MOD(mem16) Remainder

Arithmetic Instructions

Mnemonics: ADD, ADC, SUB, SBB, INC, DEC, MUL, DIV, CMP…

CMP reg2/mem, reg1/ mem	

CMP reg2, reg1	Modify flags ← (reg2) – (reg1)
	If (reg2) > (reg1) then CF=0, ZF=0, SF=0
	If (reg2) < (reg1) then CF=1, ZF=0, SF=1
	If (reg2) = (reg1) then CF=0, ZF=1, SF=0

CMP reg2, mem	Modify flags ← (reg2) – (mem)
	If (reg2) > (mem) then CF=0, ZF=0, SF=0
	If (reg2) < (mem) then CF=1, ZF=0, SF=1
	If (reg2) = (mem) then CF=0, ZF=1, SF=0

CMP mem, reg1	Modify flags ← (mem) – (reg1)
	If (mem) > (reg1) then CF=0, ZF=0, SF=0
	If (mem) < (reg1) then CF=1, ZF=0, SF=1
	If (mem) = (reg1) then CF=0, ZF=1, SF=0

Arithmetic Instructions

Mnemonics: ADD, ADC, SUB, SBB, INC, DEC, MUL, DIV, CMP…

CMP reg/mem, data	

CMP reg, data	Modify flags ← (reg) – (data)
	
	If (reg) > data then CF=0, ZF=0, SF=0
	If (reg) < data then CF=1, ZF=0, SF=1
	If (reg) = data then CF=0, ZF=1, SF=0

CMP mem, data	Modify flags ← (mem) – (mem)
	
	If (mem) > data then CF=0, ZF=0, SF=0
	If (mem) < data then CF=1, ZF=0, SF=1
	If (mem) = data then CF=0, ZF=1, SF=0

Arithmetic Instructions

Mnemonics: ADD, ADC, SUB, SBB, INC, DEC, MUL, DIV, CMP…

CMP A, data	
CMP AL, data8	**Modify flags ← (AL) – data8** **If (AL) > data8 then CF=0, ZF=0, SF=0** **If (AL) < data8 then CF=1, ZF=0, SF=1** **If (AL) = data8 then CF=0, ZF=1, SF=0**
CMP AX, data16	**Modify flags ← (AX) – data16** **If (AX) > data16 then CF=0, ZF=0, SF=0** **If (mem) < data16 then CF=1, ZF=0, SF=1** **If (mem) = data16 then CF=0, ZF=1, SF=0**

Logical Instructions

Mnemonics: AND, OR, XOR, TEST, SHR, SHL, RCR, RCL …

AND A, data AND AL, data8	(AL) ← (AL) & data8
AND AX, data16	(AX) ← (AX) & data16
AND reg/mem, data AND reg, data	(reg) ← (reg) & data
AND mem, data	(mem) ← (mem) & data

Logical Instructions

Mnemonics: AND, OR, XOR, TEST, SHR, SHL, RCR, RCL …

OR reg2/mem, reg1/mem OR reg2, reg1	(reg2) ← (reg2) | (reg1)
OR reg2, mem	(reg2) ← (reg2) | (mem)
OR mem, reg1	(mem) ← (mem) | (reg1)

OR reg/mem, data OR reg, data	(reg) ← (reg) | data
OR mem, data	(mem) ← (mem) | data

OR A, data OR AL, data8	(AL) ← (AL) | data8
OR AX, data16	(AX) ← (AX) | data16

String Manipulation Instructions

- String : Sequence of bytes or words
- 8086 instruction set includes instruction for string movement, comparison, scan, load and store.
- REP instruction prefix : used to repeat execution of string instructions
- String instructions end with S or SB or SW. S represents string, SB string byte and SW string word.
- Offset or effective address of the source operand is stored in SI register and that of the destination operand is stored in DI register.
- Depending on the status of DF, SI and DI registers are automatically updated.
- DF = 0 ⇒ SI and DI are incremented by 1 for byte and 2 for word.
- DF = 1 ⇒ SI and DI are decremented by 1 for byte and 2 for word.

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String Manipulation Instructions

Mnemonics: REP, MOVS, CMPS, SCAS, LODS, STOS

REP REPZ/ REPE (Repeat CMPS or SCAS until ZF = 0)	While CX ≠ 0 and ZF = 1, repeat execution of string instruction and (CX) ← (CX) – 1
REPNZ/ REPNE (Repeat CMPS or SCAS until ZF = 1)	While CX ≠ 0 and ZF = 0, repeat execution of string instruction and (CX) ← (CX) - 1

String Manipulation Instructions

Mnemonics: REP, MOVS, CMPS, SCAS, LODS, STOS

MOVS	
MOVSB	MA = (DS) x 16_{10} + (SI) MA_E = (ES) x 16_{10} + (DI) (MA_E) ← (MA) If DF = 0, then (DI) ← (DI) + 1; (SI) ← (SI) + 1 If DF = 1, then (DI) ← (DI) - 1; (SI) ← (SI) - 1
MOVSW	MA = (DS) x 16_{10} + (SI) MA_E = (ES) x 16_{10} + (DI) (MA_E ; MA_E + 1) ← (MA; MA + 1) If DF = 0, then (DI) ← (DI) + 2; (SI) ← (SI) + 2 If DF = 1, then (DI) ← (DI) - 2; (SI) ← (SI) - 2

String Manipulation Instructions

Mnemonics: REP, MOVS, CMPS, SCAS, LODS, STOS

Compare two string byte or string word

CMPS **CMPSB** **CMPSW**	 **MA = (DS) x 16_{10} + (SI)** **MA_E = (ES) x 16_{10} + (DI)** **Modify flags ← (MA) - (MA_E)** **If (MA) > (MA_E), then CF = 0; ZF = 0; SF = 0** **If (MA) < (MA_E), then CF = 1; ZF = 0; SF = 1** **If (MA) = (MA_E), then CF = 0; ZF = 1; SF = 0** **<u>For byte operation</u>** **If DF = 0, then (DI) ← (DI) + 1; (SI) ← (SI) + 1** **If DF = 1, then (DI) ← (DI) - 1; (SI) ← (SI) - 1** **<u>For word operation</u>** **If DF = 0, then (DI) ← (DI) + 2; (SI) ← (SI) + 2** **If DF = 1, then (DI) ← (DI) - 2; (SI) ← (SI) - 2**

String Manipulation Instructions

Mnemonics: REP, MOVS, CMPS, SCAS, LODS, STOS

Scan (compare) a string byte or word with accumulator

SCAS	

SCASB	$MA_E = (ES) \times 16_{10} + (DI)$
	Modify flags ← (AL) - (MA_E)
	If (AL) > (MA_E), then CF = 0; ZF = 0; SF = 0
	If (AL) < (MA_E), then CF = 1; ZF = 0; SF = 1
	If (AL) = (MA_E), then CF = 0; ZF = 1; SF = 0
	
	If DF = 0, then (DI) ← (DI) + 1
	If DF = 1, then (DI) ← (DI) – 1

SCASW	$MA_E = (ES) \times 16_{10} + (DI)$
	Modify flags ← (AL) - (MA_E)
	If (AX) > $(MA_E ; MA_E + 1)$, then CF = 0; ZF = 0; SF = 0
	If (AX) < $(MA_E ; MA_E + 1)$, then CF = 1; ZF = 0; SF = 1
	If (AX) = $(MA_E ; MA_E + 1)$, then CF = 0; ZF = 1; SF = 0
	
	If DF = 0, then (DI) ← (DI) + 2
	If DF = 1, then (DI) ← (DI) – 2

String Manipulation Instructions

Mnemonics: REP, MOVS, CMPS, SCAS, LODS, STOS

Load string byte in to AL or string word in to AX

LODS	
LODSB	MA = (DS) x 16_{10} + (SI) (AL) ← (MA) If DF = 0, then (SI) ← (SI) + 1 If DF = 1, then (SI) ← (SI) – 1
LODSW	MA = (DS) x 16_{10} + (SI) (AX) ← (MA ; MA + 1) If DF = 0, then (SI) ← (SI) + 2 If DF = 1, then (SI) ← (SI) – 2

String Manipulation Instructions

Mnemonics: REP, MOVS, CMPS, SCAS, LODS, STOS

Store byte from AL or word from AX in to string

STOS	
STOSB	$MA_E = (ES) \times 16_{10} + (DI)$ $(MA_E) \leftarrow (AL)$ If DF = 0, then (DI) ← (DI) + 1 If DF = 1, then (DI) ← (DI) – 1
STOSW	$MA_E = (ES) \times 16_{10} + (DI)$ $(MA_E ; MA_E + 1) \leftarrow (AX)$ If DF = 0, then (DI) ← (DI) + 2 If DF = 1, then (DI) ← (DI) – 2

Processor Control Instructions

Mnemonics	Explanation
STC	Set CF ← 1
CLC	Clear CF ← 0
CMC	Complement carry CF ← CF/
STD	Set direction flag DF ← 1
CLD	Clear direction flag DF ← 0
STI	Set interrupt enable flag IF ← 1
CLI	Clear interrupt enable flag IF ← 0
NOP	No operation
HLT	Halt after interrupt is set
WAIT	Wait for TEST pin active
ESC opcode mem/ reg	Used to pass instruction to a coprocessor which shares the address and data bus with the 8086
LOCK	Lock bus during next instruction

Control Transfer Instructions

- Transfer the control to a specific destination or target instruction
- Do not affect flags

❑ 8086 Unconditional transfers

Mnemonics	Explanation
CALL reg/ mem/ disp16	Call subroutine
RET	Return from subroutine
JMP reg/ mem/ disp8/ disp16	Unconditional jump

Control Transfer Instructions

- 8086 signed conditional branch instructions
- 8086 unsigned conditional branch instructions

- Checks flags
- If conditions are true, the program control is transferred to the new memory location in the same segment by modifying the content of IP

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Control Transfer Instructions

- 8086 signed conditional branch instructions

Name	Alternate name
JE disp8 Jump if equal	JZ disp8 Jump if result is 0
JNE disp8 Jump if not equal	JNZ disp8 Jump if not zero
JG disp8 Jump if greater	JNLE disp8 Jump if not less or equal
JGE disp8 Jump if greater than or equal	JNL disp8 Jump if not less
JL disp8 Jump if less than	JNGE disp8 Jump if not greater than or equal
JLE disp8 Jump if less than or equal	JNG disp8 Jump if not greater

- 8086 unsigned conditional branch instructions

Name	Alternate name
JE disp8 Jump if equal	JZ disp8 Jump if result is 0
JNE disp8 Jump if not equal	JNZ disp8 Jump if not zero
JA disp8 Jump if above	JNBE disp8 Jump if not below or equal
JAE disp8 Jump if above or equal	JNB disp8 Jump if not below
JB disp8 Jump if below	JNAE disp8 Jump if not above or equal
JBE disp8 Jump if below or equal	JNA disp8 Jump if not above

Control Transfer Instructions

- 8086 conditional branch instructions affecting individual flags

Mnemonics	Explanation
JC disp8	Jump if CF = 1
JNC disp8	Jump if CF = 0
JP disp8	Jump if PF = 1
JNP disp8	Jump if PF = 0
JO disp8	Jump if OF = 1
JNO disp8	Jump if OF = 0
JS disp8	Jump if SF = 1
JNS disp8	Jump if SF = 0
JZ disp8	Jump if result is zero, i.e, Z = 1
JNZ disp8	Jump if result is not zero, i.e, Z = 1

Memory mapping vs. I/O mapping

Memory mapping	I/O mapping
20 bit address are provided for I/O devices	8-bit or 16-bit addresses are provided for I/O devices
The I/O ports or peripherals can be treated like memory locations and so all instructions related to memory can be used for data transmission between I/O device and processor	Only IN and OUT instructions can be used for data transfer between I/O device and processor
Data can be moved from any register to ports and vice versa	Data transfer takes place only between accumulator and ports
When memory mapping is used for I/O devices, full memory address space cannot be used for addressing memory. ⇒ Useful only for small systems where memory requirement is less	Full memory space can be used for addressing memory. ⇒ Suitable for systems which require large memory capacity
For accessing the memory mapped devices, the processor executes memory read or write cycle. ⇒ M / $\overline{IO}$ is asserted high	For accessing the I/O mapped devices, the processor executes I/O read or write cycle. ⇒ M / $\overline{IO}$ is asserted low

8086 and 8088 comparison

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8086 and 8088 comparison

8086	8088
Similar EU and Instruction set ; dissimilar BIU	
16-bit Data bus lines obtained by demultiplexing $AD_0 - AD_{15}$	8-bit Data bus lines obtained by demultiplexing $AD_0 - AD_7$
20-bit address bus	8-bit address bus
Two banks of memory each of 512 kb	Single memory bank
6-bit instruction queue	4-bit instruction queue
Clock speeds: 5 / 8 / 10 MHz	5 / 8 MHz
In MIN mode, pin 28 is assigned the signal M / $\overline{IO}$	In MIN mode, pin 28 is assigned the signal IO / $\overline{M}$
To access higher byte, $\overline{BHE}$ signal is used	No such signal required, since the data width is only 1-byte

8087 Coprocessor

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Co-processor – Intel 8087

Multiprocessor system

- A microprocessor system comprising of two or more processors
- Distributed processing: Entire task is divided in to subtasks

Advantages

- Better system throughput by having more than one processor
- Each processor have a local bus to access local memory or I/O devices so that a greater degree of parallel processing can be achieved
- System structure is more flexible.
  One can easily add or remove modules to change the system configuration without affecting the other modules in the system

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Co-processor – Intel 8087

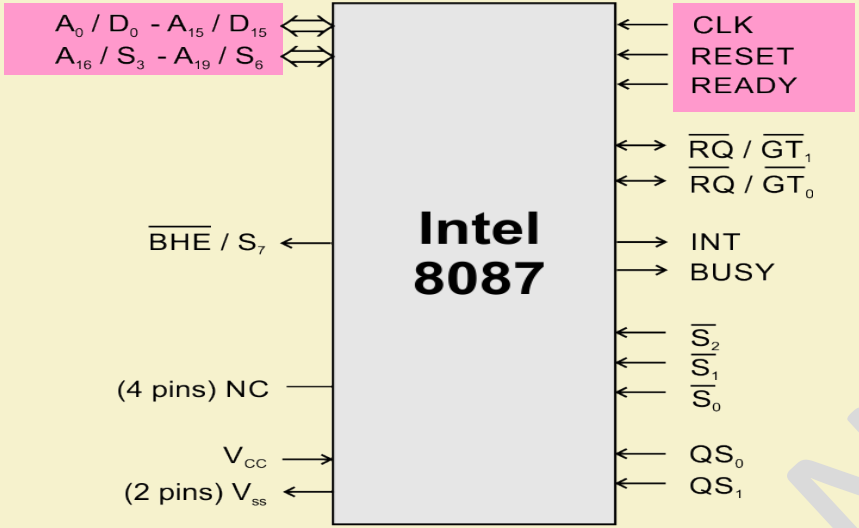
8087 coprocessor

- Specially designed to take care of mathematical calculations involving integer and floating point data
- "Math coprocessor" or "Numeric Data Processor (NDP)"
- Works in parallel with a 8086 in the maximum mode

Features

1) Can operate on data of the integer, decimal and real types with lengths ranging from 2 to 10 bytes
2) Instruction set involves square root, exponential, tangent etc. in addition to addition, subtraction, multiplication and division.
3) High performance numeric data processor ⇒ it can multiply two 64-bit real numbers in about 27μs and calculate square root in about 36 μs
4) Follows IEEE floating point standard
5) It is multi bus compatible

Co-processor – Intel 8087



- 16 multiplexed address / data pins and 4 multiplexed address / status pins
- Hence it can have 16-bit external data bus and 20-bit external address bus like 8086
- Processor clock, ready and reset signals are applied as clock, ready and reset signals for coprocessor

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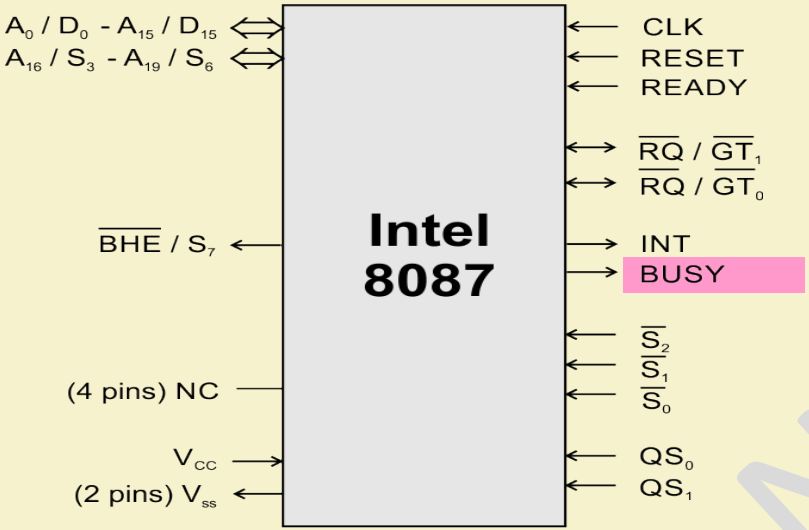
Co-processor – Intel 8087



BUSY

- **BUSY signal from 8087 is connected to the $\overline{TEST}$ input of 8086**
- **If the 8086 needs the result of some computation that the 8087 is doing before it can execute the next instruction in the program, a user can tell 8086 with a WAIT instruction to keep looking at its $\overline{TEST}$ pin until it finds the pin low**
- **A low on the BUSY output indicates that the 8087 has completed the computation**

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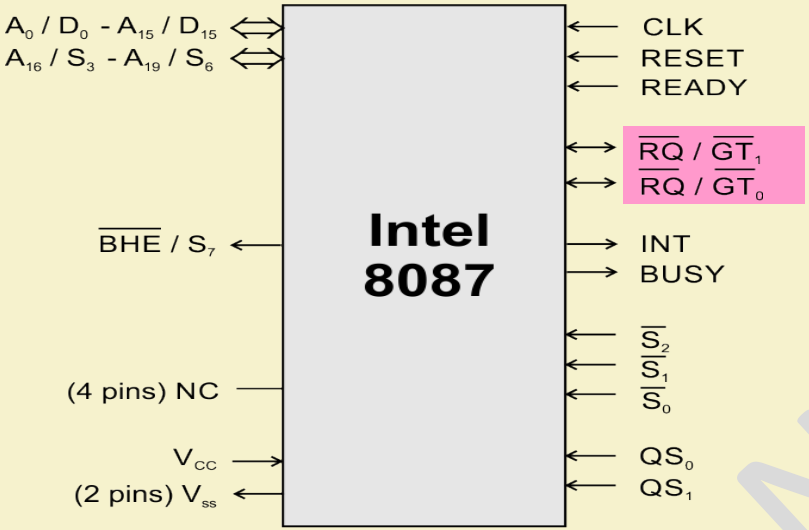
Co-processor – Intel 8087



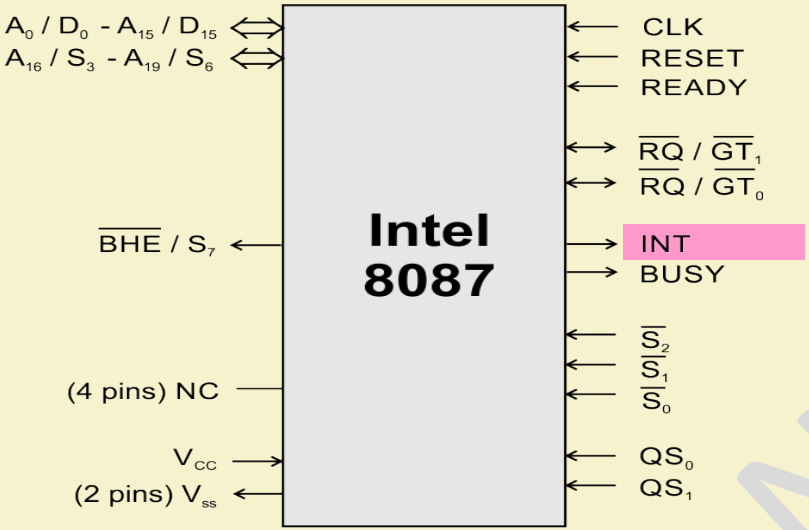
$\overline{RQ}$ / $\overline{GT_0}$

- The request / grant signal from the 8087 is usually connected to the request / grant ($\overline{RQ}$ / $\overline{GT_0}$ or $\overline{RQ}$ / $\overline{GT_1}$) pin of the 8086

- The request / grant signal from the 8087 is usually connected to the request / grant pin of the independent processor such as 8089

$\overline{RQ}$ / $\overline{GT_1}$

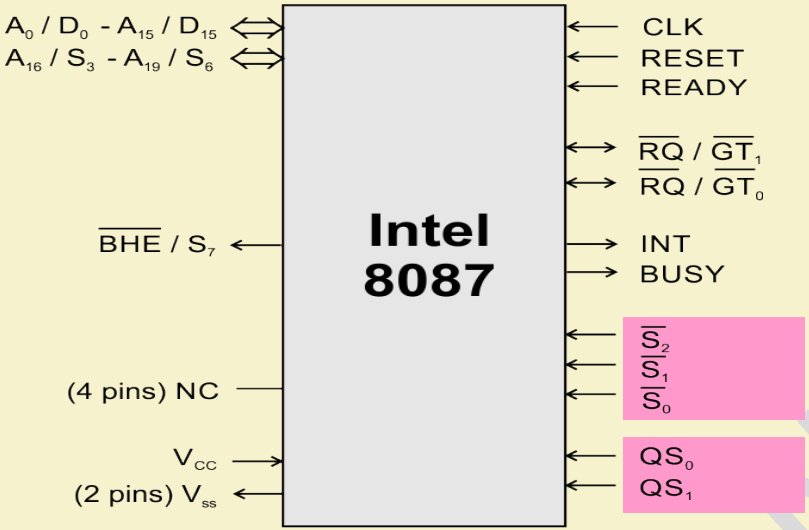
Co-processor – Intel 8087



INT

- **The interrupt pin is connected to the interrupt management logic.**
- **The 8087 can interrupt the 8086 through this interrupt management logic at the time error condition exists**

Co-processor – Intel 8087



$\overline{S}_0$- $\overline{S}_2$

$\overline{S}_2$	$\overline{S}_1$	$\overline{S}_0$	Status
1	0	0	Unused
1	0	1	Read memory
1	1	0	Write memory
1	1	1	Passive

$QS_0 – QS_1$

QS_0	QS_1	Status
0	0	No operation
0	1	First byte of opcode from queue
1	0	Queue empty
1	1	Subsequent byte of opcode from queue

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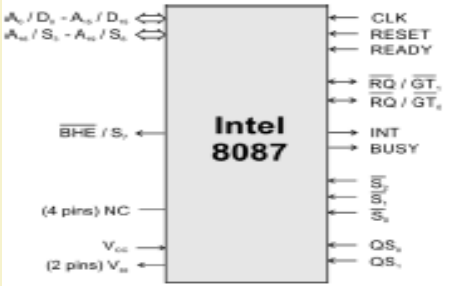
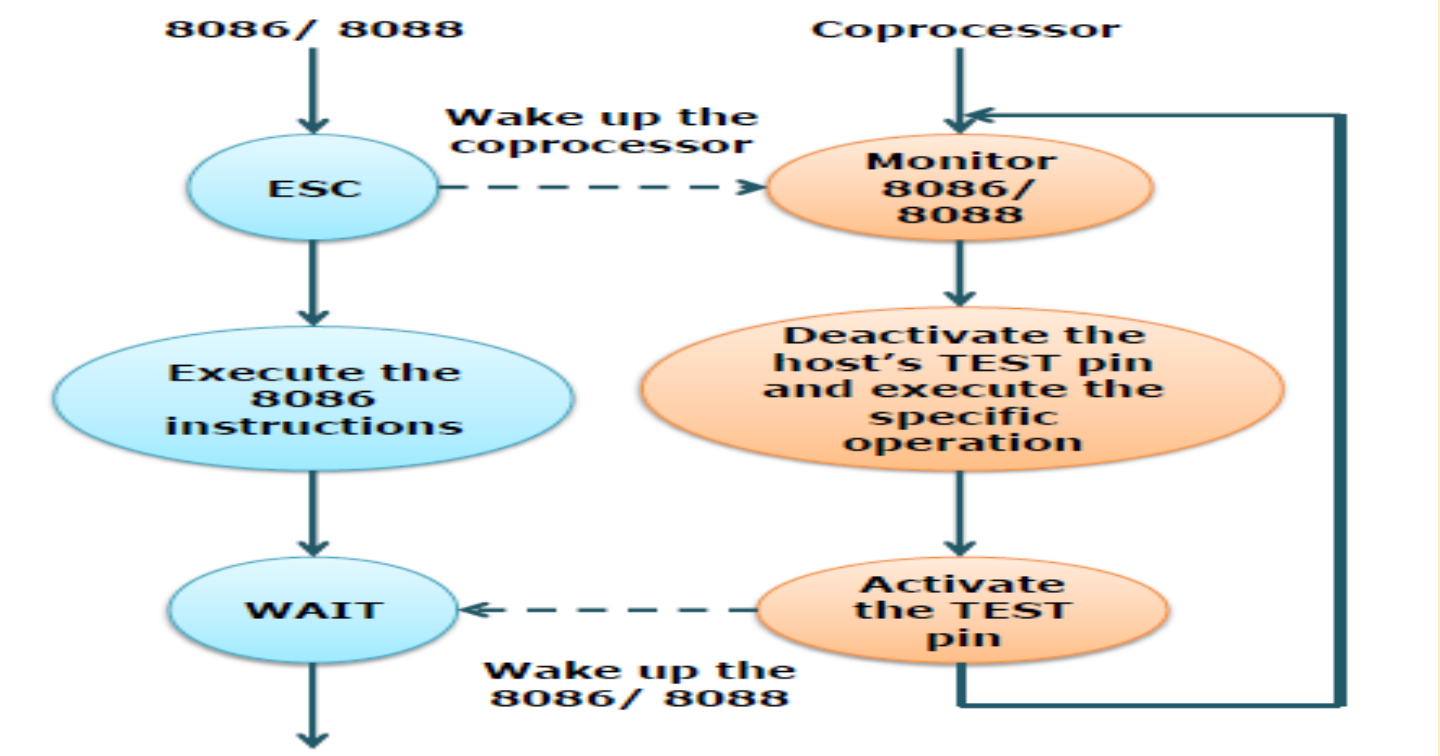
Co-processor – Intel 8087

- 8087 instructions are inserted in the 8086 program

- 8086 and 8087 reads instruction bytes and puts them in the respective queues
- NOP
- 8087 instructions have 11011 as the MSB of their first code byte

- 8087 keeps track for ESC instruction by monitoring $\overline{S_2}$ - $\overline{S_0}$ and $AD_0 - AD_{15}$ of 8086.
- Also keeps track of $QS_0 - QS_1$.
- Q status 00; does nothing
- Q status 01; 8087 compares the five MSB bits with 11011
- If there is a match, then the ESC instruction is fetched and executed by 8087
- If there is error during decoding an ESC instruction, 8087 sends an interrupt request



- Memory read/ write
- Additional words : $\overline{RQ}$ - $\overline{GT_0}$
- 8087 BUSY pin high
- $\overline{TEST}$
- WAIT

Co-processor – Intel 8087