8086 Hardware Specifications

Dept. of Computer Science and Engineering
BRAC University
CSE 341 Team

Lecture References:

- **Book:**

 - *Microprocessors and Interfacing: Programming and Hardware,*

    Author: Douglas V. Hall

  - *The 8086/8088 Family: Design, Programming, And Interfacing,*

    Author: John Uffenbeck.
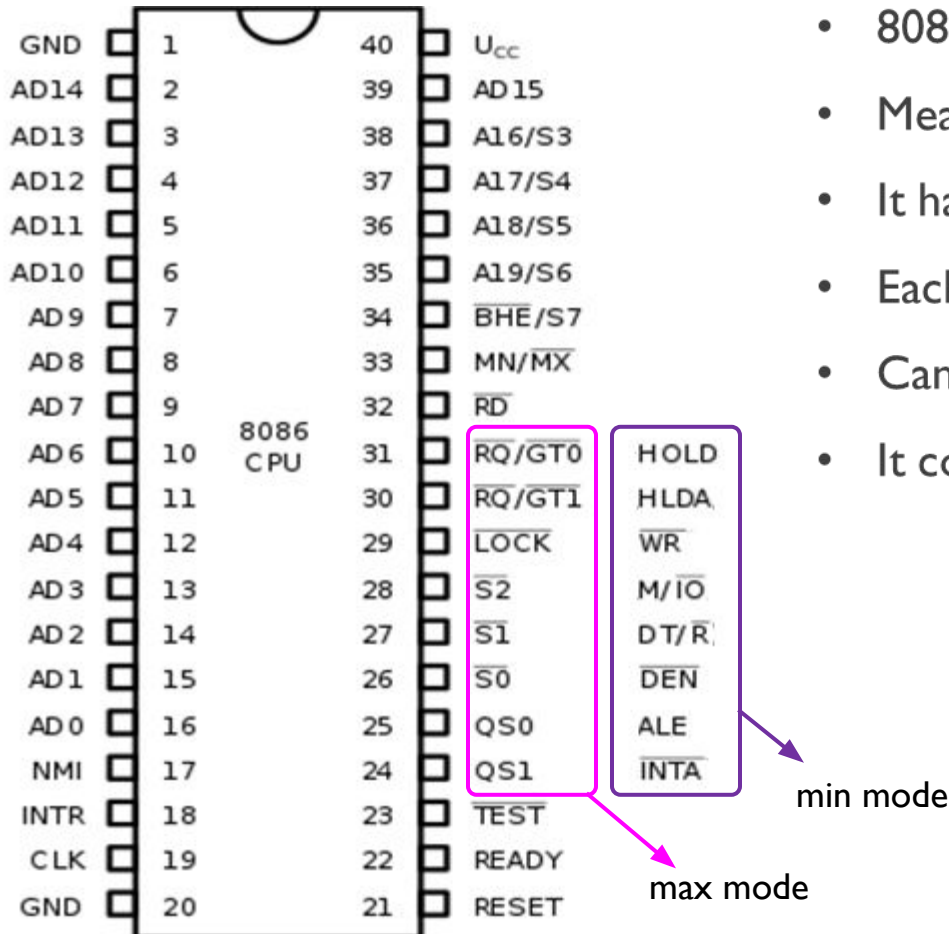
8086 Pin Specification

- is a 40-pin DIPs; **Dual in-line package**

- DIP refers to a rectangular housing with two parallel rows of electrical connection pins.

- DIPs have a notch on one end to show its correct orientation.

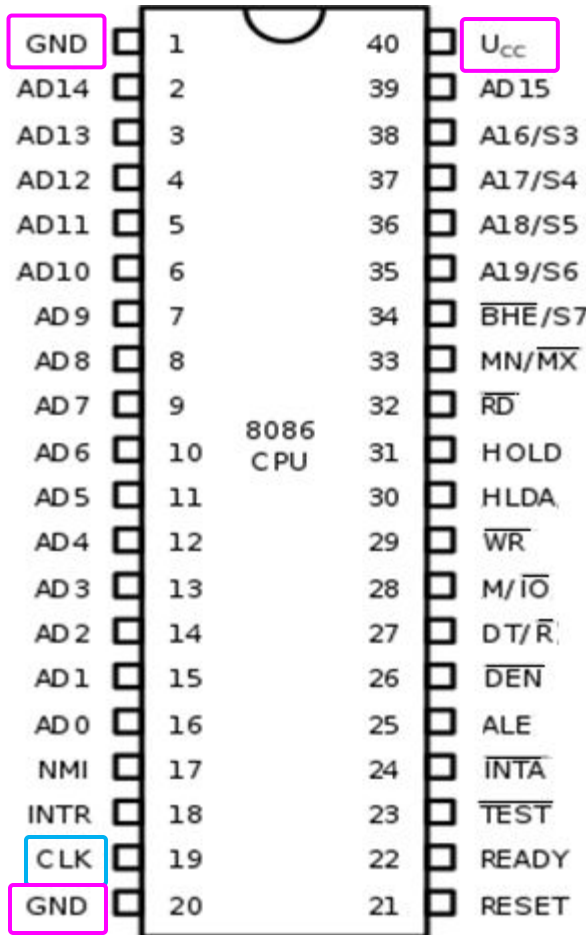- The pins are then numbered as shown in the figure below.
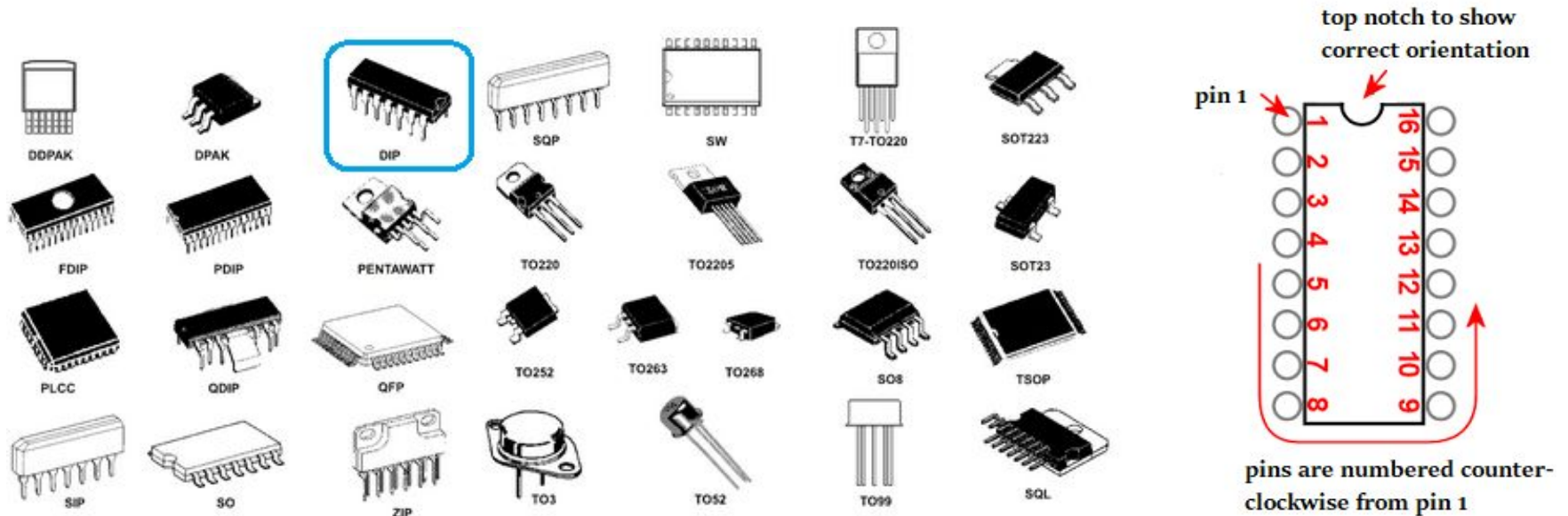
8086 Pin Diagram

Recap

- 8086 is a 16-bit microprocessor.

- Meaning it has 16 data lines/bus.

- It has 20 address lines/bus.

- Each memory location holds only 1 byte

- Can address 2^{20} different memory locations

- It could address up to 1MB of memory.

8086 Pin Specification

|				
GND	1		40	U_cc
AD14	2		39	AD15
AD13	3		38	A16/S3
AD12	4		37	A17/S4
AD11	5		36	A18/S5
AD10	6		35	A19/S6
AD 9	7		34	$\overline{BHE}$/S7
AD 8	8		33	MN/$\overline{MX}$
AD 7	9	8086	32	$\overline{RD}$
AD 6	10	CPU	31	HOLD
AD 5	11		30	HLDA
AD 4	12		29	$\overline{WR}$
AD 3	13		28	M/$\overline{IO}$
AD 2	14		27	DT/$\overline{R}$
AD 1	15		26	$\overline{DEN}$
AD 0	16		25	ALE
NMI	17		24	$\overline{INTA}$
INTR	18		23	$\overline{TEST}$
CLK	19		22	READY
GND	20		21	RESET

CLK, input

- provides basic timing to control processor operation

- frequencies of different versions are 5, 8 or 10 MHz

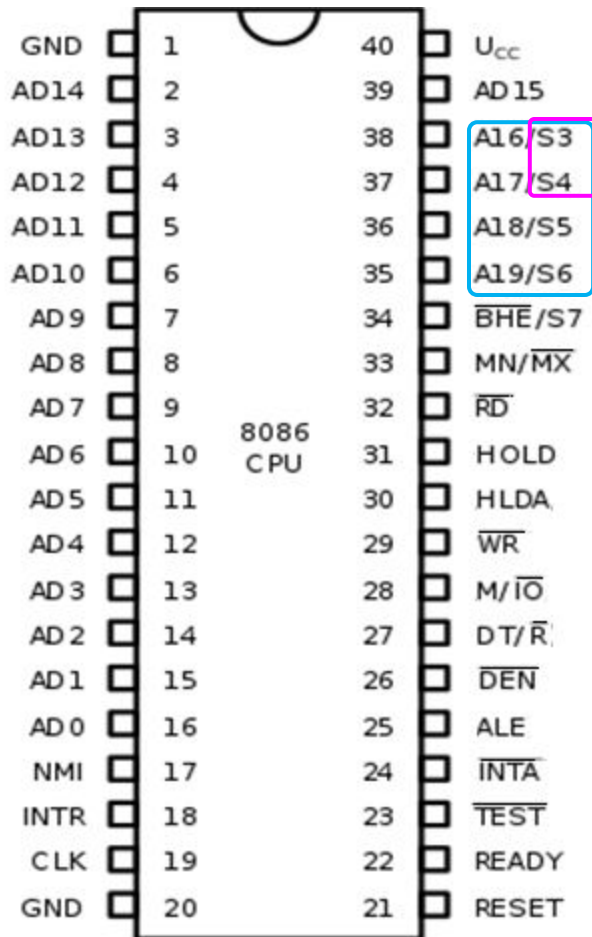- asymmetric with a 33% duty cycle
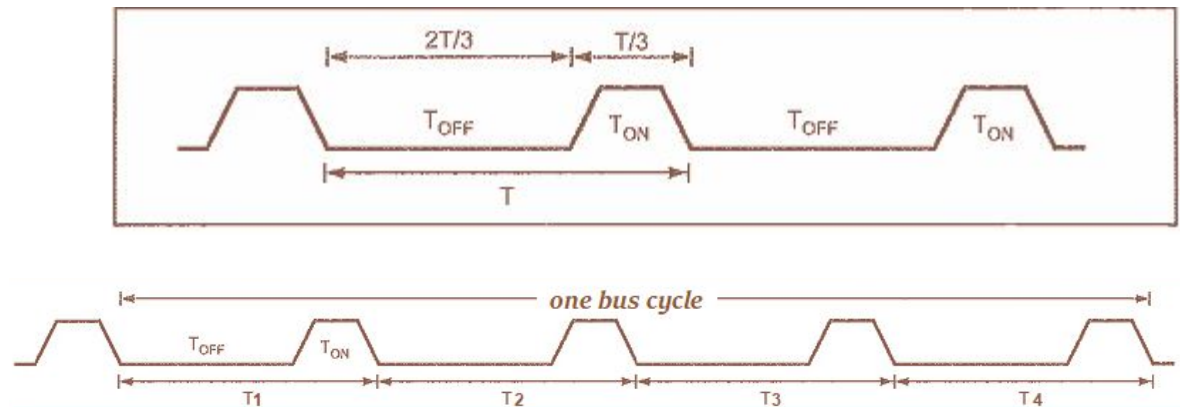
8086 Pin Specification
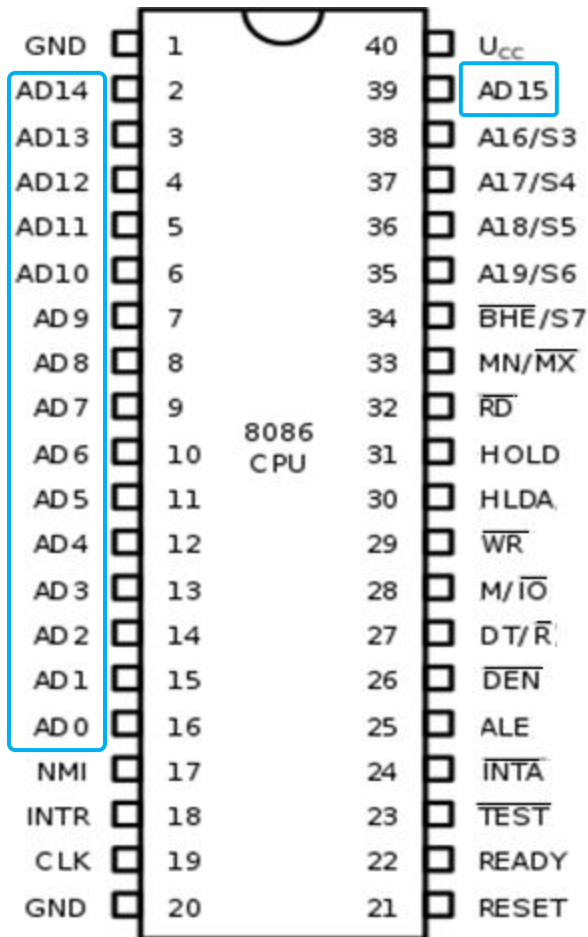
$AD_0 - AD_{15}, \boldsymbol{bi-directional}$

- lines are multiplexed bidirectional address/data bus.

- During T_1, they carry 16-bit address.

- In remaining clock cycles $T_2, T_3 \ and \ T_4$, 16-bit data.

- $AD_0 - AD_7$ carry lower order data byte

- $AD_8 - AD_{15}$ carry higher order data byte
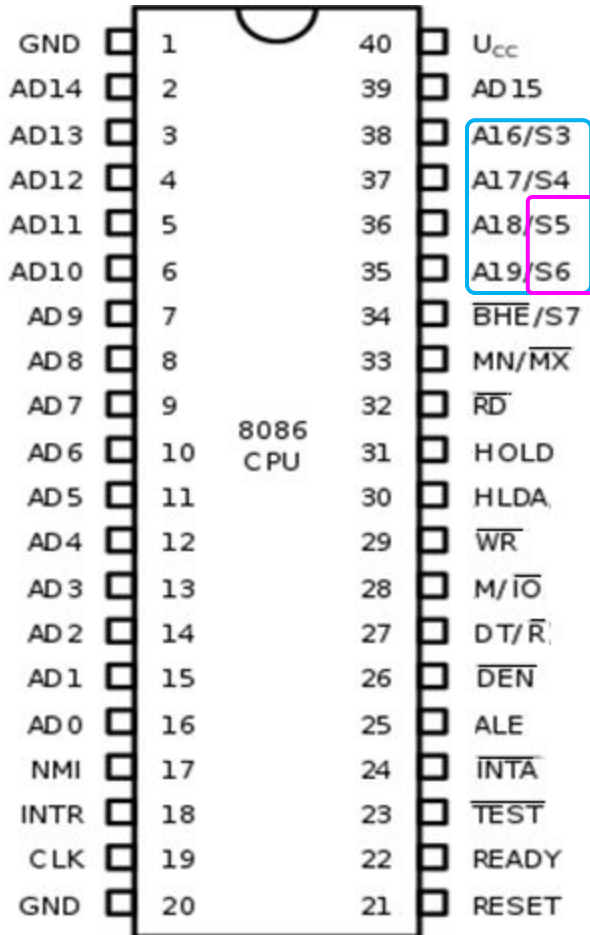
8086 Pin Specification

GND	1	40	U_{CC}
AD14	2	39	AD15
AD13	3	38	A16/S3
AD12	4	37	A17/S4
AD11	5	36	A18/S5
AD10	6	35	A19/S6
AD9	7	34	$\overline{BHE}$/S7
AD8	8	33	MN/$\overline{MX}$
AD7	9	32	$\overline{RD}$
AD6	10	31	HOLD
AD5	11	30	HLDA
AD4	12	29	$\overline{WR}$
AD3	13	28	M/$\overline{IO}$
AD2	14	27	DT/$\overline{R}$
AD1	15	26	$\overline{DEN}$
AD0	16	25	ALE
NMI	17	24	$\overline{INTA}$
INTR	18	23	$\overline{TEST}$
CLK	19	22	READY
GND	20	21	RESET

8086 CPU

$A_{19}/S_6, A_{18}/S_5, A_{17}/S_4, A_{16}/S_3, \textbf{output}$

- lines are multiplexed address and status bus.
- During T_1, they carry the highest order 4-bit address.
- During T_2, T_3 and T_4, status signals.
- S_3 and S_4, segment identifiers as in table below

S4	S3	Function
0	0	Extra segment access
0	1	Stack segment access
1	0	Code segment access
1	1	Data segment access

8086 Pin Specification

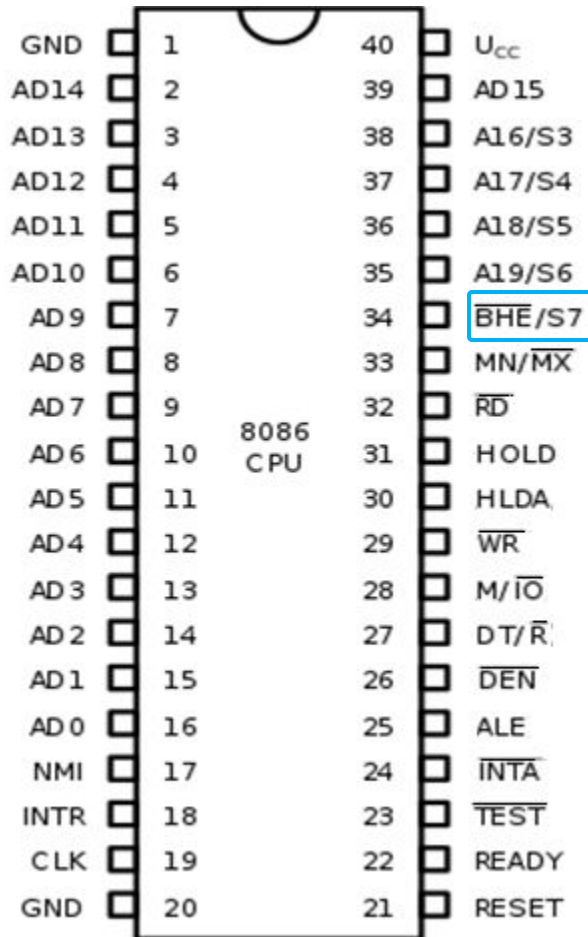|				
GND	1		40	U$_{CC}$
AD14	2		39	AD15
AD13	3		38	A16/S3
AD12	4		37	A17/S4
AD11	5		36	A18/S5
AD10	6		35	A19/S6
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AD8	8		33	MN/$\overline{MX}$
AD7	9	8086	32	$\overline{RD}$
AD6	10	CPU	31	HOLD
AD5	11		30	HLDA
AD4	12		29	$\overline{WR}$
AD3	13		28	M/$\overline{IO}$
AD2	14		27	DT/$\overline{R}$
AD1	15		26	$\overline{DEN}$
AD0	16		25	ALE
NMI	17		24	$\overline{INTA}$
INTR	18		23	$\overline{TEST}$
CLK	19		22	READY
GND	20		21	RESET

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

S_5 : Indicates if interrupt is enabled or disabled.

- If S_5 =1 , then the IF = 1, so the interrupt is enabled.

- If S_5 =0 , then the IF = 0, so the interrupt is disabled.

S_6 : Indicates if **8086** is the bus master or not

- If S_6 = 0 , **8086** is the bus master
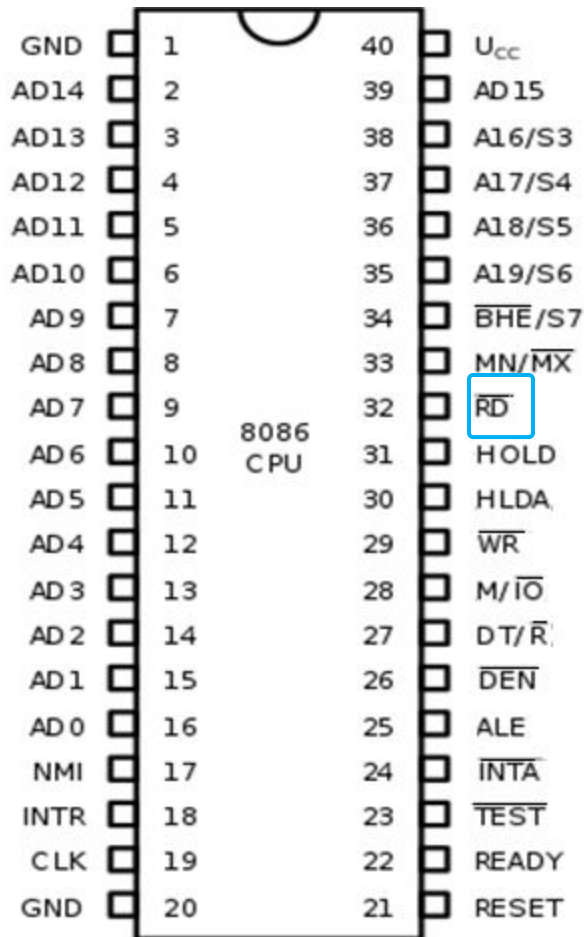
- If S_6 = 1 , **8086** is not the bus master

8086 Pin Specification

GND	1	40	U$_{cc}$
AD14	2	39	AD15
AD13	3	38	A16/S3
AD12	4	37	A17/S4
AD11	5	36	A18/S5
AD10	6	35	A19/S6
AD9	7	34	$\overline{BHE}$/S7
AD8	8	33	MN/$\overline{MX}$
AD7	9	32	$\overline{RD}$
AD6	10	31	HOLD
AD5	11	30	HLDA
AD4	12	29	$\overline{WR}$
AD3	13	28	M/$\overline{IO}$
AD2	14	27	DT/$\overline{R}$
AD1	15	26	$\overline{DEN}$
AD0	16	25	ALE
NMI	17	24	$\overline{INTA}$
INTR	18	23	$\overline{TEST}$
CLK	19	22	READY
GND	20	21	RESET

8086 CPU

$$\overline{BHE}/S_7, \textbf{\textit{output}}$$

- Bus High Enable

- $\overline{BHE}$ is active low

- To indicate the transfer of data over $AD_8 - AD_{15}$

- Related to memory bank

- Selects odd/high memory bank when $\overline{BHE}$ is 0
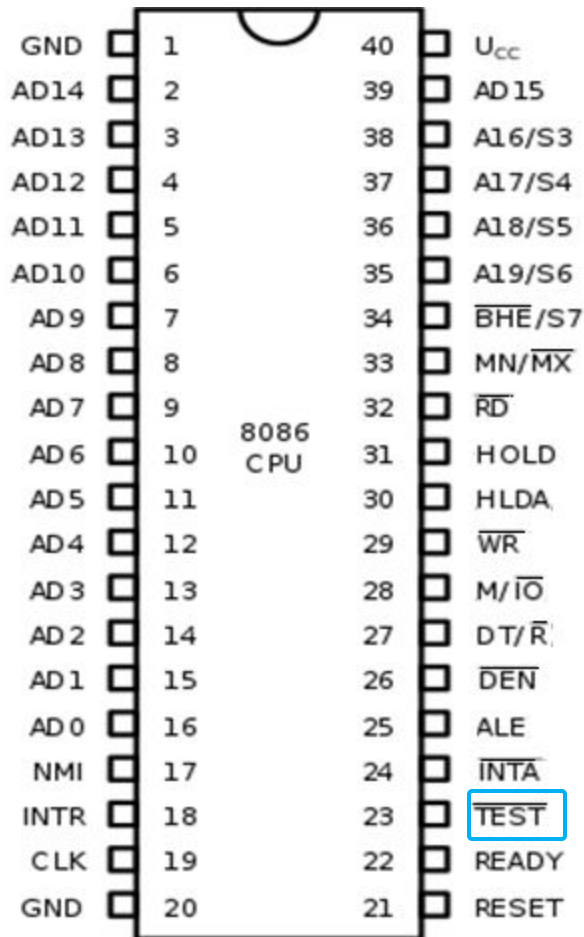
- S_7 : Reserved for further development

8086 Pin Specification

GND	1		40	U$_{CC}$
AD14	2		39	AD15
AD13	3		38	A16/S3
AD12	4		37	A17/S4
AD11	5		36	A18/S5
AD10	6		35	A19/S6
AD9	7		34	$\overline{BHE}$/S7
AD8	8		33	MN/$\overline{MX}$
AD7	9	8086	32	$\overline{RD}$
AD6	10	CPU	31	HOLD
AD5	11		30	HLDA
AD4	12		29	$\overline{WR}$
AD3	13		28	M/$\overline{IO}$
AD2	14		27	DT/$\overline{R}$
AD1	15		26	$\overline{DEN}$
AD0	16		25	ALE
NMI	17		24	$\overline{INTA}$
INTR	18		23	$\overline{TEST}$
CLK	19		22	READY
GND	20		21	RESET

$\overline{RD}, \boldsymbol{output}$

- is active low

- Indicates read operation when low

- Processor reading from memory or I/O device

- Is low during $T_2, T_3 \ and \ T_w$ states of the read cycle

8086 Pin Specification

```
         ┌──────┴──────┐
GND   □ 1              40 □  U_CC
AD14  □ 2              39 □  AD15
AD13  □ 3              38 □  A16/S3
AD12  □ 4              37 □  A17/S4
AD11  □ 5              36 □  A18/S5
AD10  □ 6              35 □  A19/S6
AD9   □ 7              34 □  BHE/S7
AD8   □ 8              33 □  MN/MX
AD7   □ 9    8086      32 □  RD
AD6   □ 10   CPU       31 □  HOLD
AD5   □ 11            30 □  HLDA
AD4   □ 12            29 □  WR
AD3   □ 13            28 □  M/IO
AD2   □ 14            27 □  DT/R
AD1   □ 15            26 □  DEN
AD0   □ 16            25 □  ALE
NMI   □ 17            24 □  INTA
INTR  □ 18            23 □  TEST
CLK   □ 19            22 □  READY
GND   □ 20            21 □  RESET
         └─────────────┘
```

$$\overline{TEST}, input$$

- Is examined by the WAIT instruction.

- If this pin is Low, execution continues.

- Else the processor waits in an idle state.

8086 Pin Specification
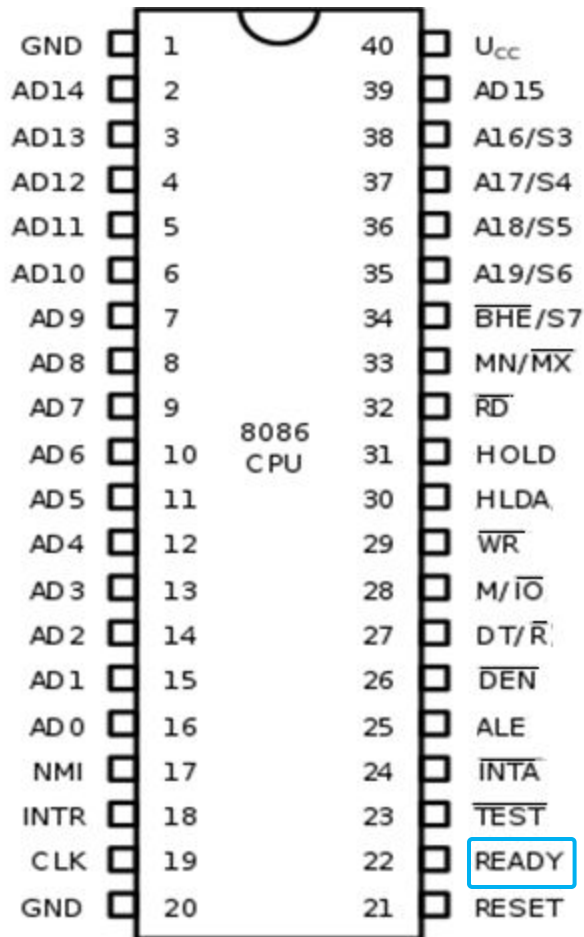
READY, input

- acknowledgement from a slow I/O device or memory

- To indicate ready/completion of data transfer

- When low, microprocessor enters wait state, T_W.

8086 Pin Specification

GND	1		40	U_cc
AD14	2		39	AD15
AD13	3		38	A16/S3
AD12	4		37	A17/S4
AD11	5		36	A18/S5
AD10	6		35	A19/S6
AD9	7		34	$\overline{BHE}$/S7
AD8	8		33	MN/$\overline{MX}$
AD7	9	8086 CPU	32	$\overline{RD}$
AD6	10		31	HOLD
AD5	11		30	HLDA
AD4	12		29	$\overline{WR}$
AD3	13		28	M/$\overline{IO}$
AD2	14		27	DT/$\overline{R}$
AD1	15		26	$\overline{DEN}$
AD0	16		25	ALE
NMI	17		24	$\overline{INTA}$
INTR	18		23	$\overline{TEST}$
CLK	19		22	READY
GND	20		21	RESET
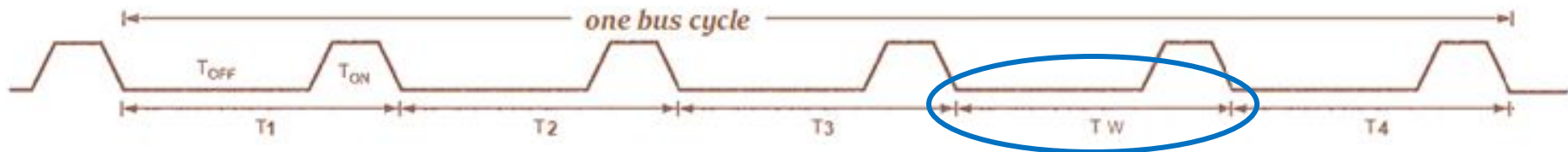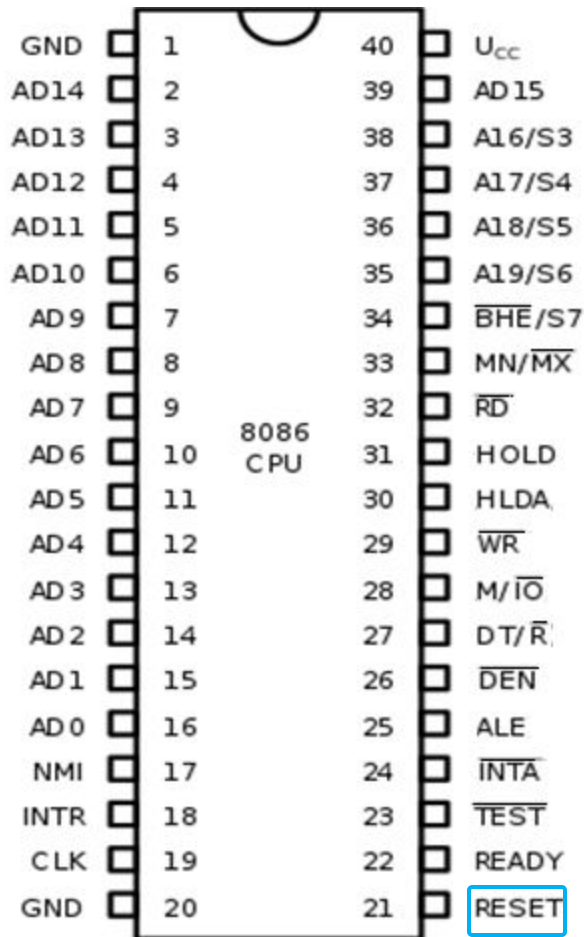
RESET, input

- To reset the system reset.

- And terminates the current activity.

- Must be active for at least four clock cycles

8086 Pin Specification
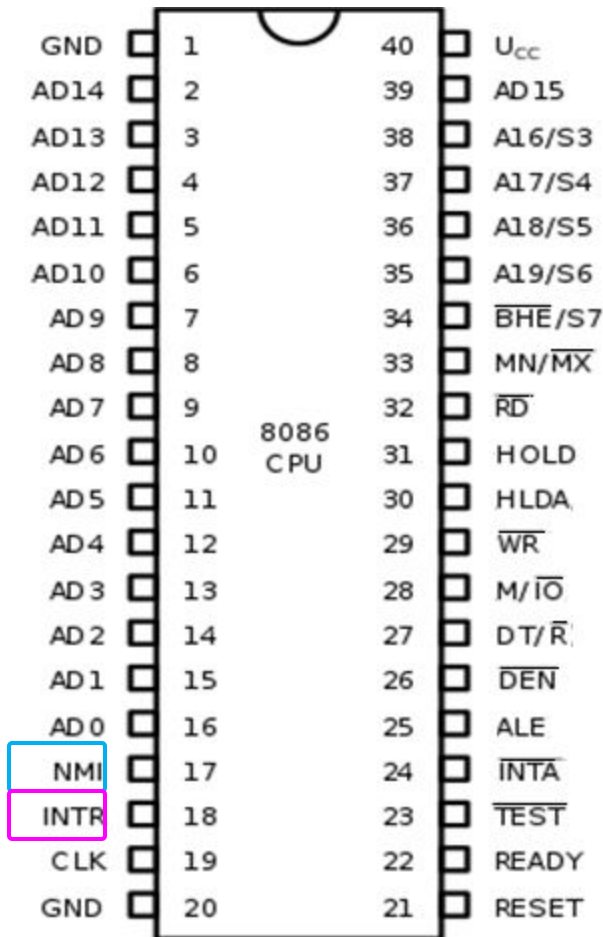
INTR, input

- Interrupt request

- Used to request a hardware interrupt.

- Can be masked.

NMI, input

- Non-maskable interrupt signal.

- Causes a type-2 interrupt.

- Initiates the interrupt at the end of the current instruction.

8086 Pin Specification

GND	1		40	U_{CC}
AD14	2		39	AD15
AD13	3		38	A16/S3
AD12	4		37	A17/S4
AD11	5		36	A18/S5
AD10	6		35	A19/S6
AD9	7		34	$\overline{BHE}$/S7
AD8	8		33	MN/$\overline{MX}$
AD7	9		32	$\overline{RD}$
AD6	10	8086 CPU	31	$\overline{RQ}/\overline{GT0}$ / HOLD
AD5	11		30	$\overline{RQ}/\overline{GT1}$ / HLDA
AD4	12		29	LOCK / $\overline{WR}$
AD3	13		28	S2 / M/$\overline{IO}$
AD2	14		27	$\overline{S1}$ / DT/$\overline{R}$
AD1	15		26	$\overline{S0}$ / $\overline{DEN}$
AD0	16		25	QS0 / ALE
NMI	17		24	QS1 / $\overline{INTA}$
INTR	18		23	$\overline{TEST}$
CLK	19		22	READY
GND	20		21	RESET

min mode

max mode
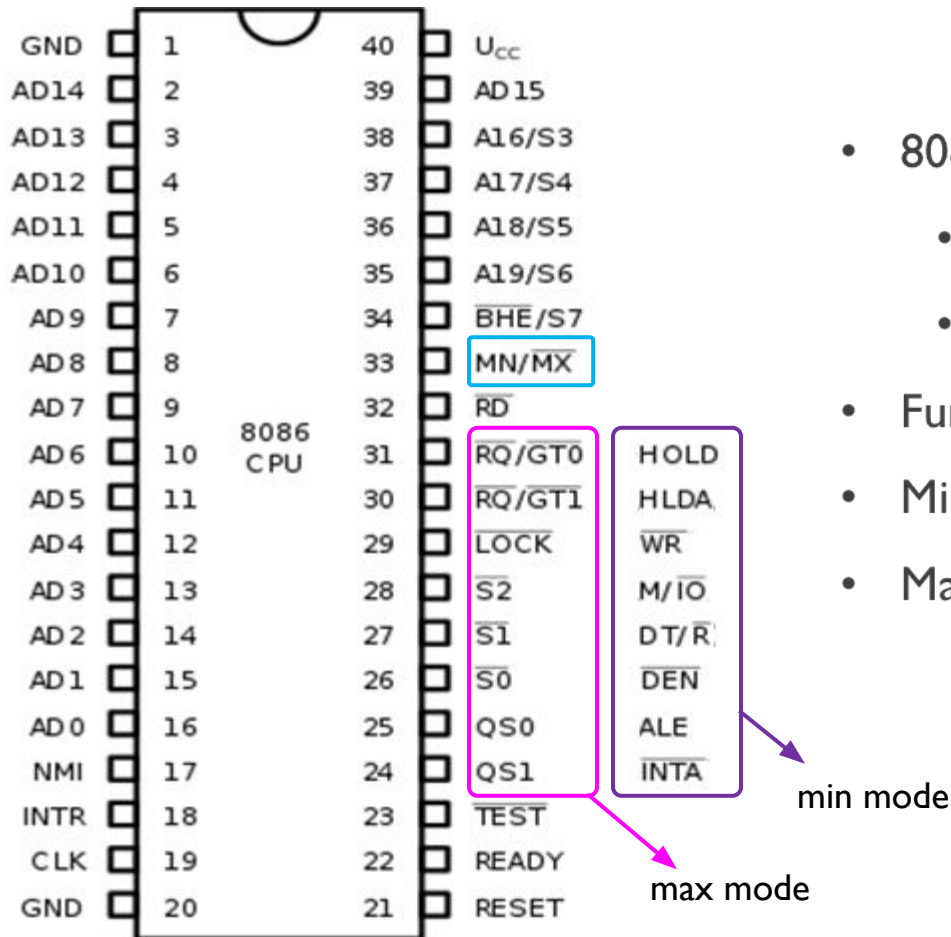
$MN/\overline{MX}, input$

- 8086 works in two modes:
    - Minimum Mode if high
    - Maximum Mode if low

- Functions of pins 24-31 depend on the mode

- Minimum Mode - single processor

- Maximum Mode - multi processor

Minimum Mode Pin Specification

GND	1	40	U$_{CC}$
AD14	2	39	AD15
AD13	3	38	A16/S3
AD12	4	37	A17/S4
AD11	5	36	A18/S5
AD10	6	35	A19/S6
AD9	7	34	$\overline{BHE}$/S7
AD8	8	33	MN/$\overline{MX}$
AD7	9	32	$\overline{RD}$
AD6	10	31	HOLD
AD5	11	30	HLDA
AD4	12	29	$\overline{WR}$
AD3	13	28	M/$\overline{IO}$
AD2	14	27	DT/$\overline{R}$
AD1	15	26	$\overline{DEN}$
AD0	16	25	ALE
NMI	17	24	$\overline{INTA}$
INTR	18	23	$\overline{TEST}$
CLK	19	22	READY
GND	20	21	RESET

8086 CPU
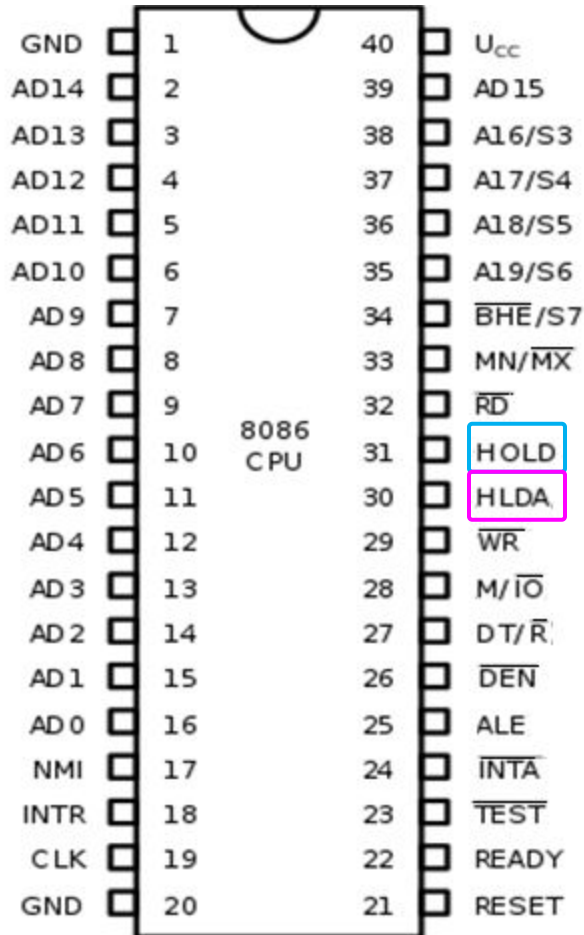
HOLD, *input*

- To request for bus by another device.

- It is an active HIGH signal.

HLDA, *output*

- Hold Acknowledgment.

- When acknowledged, it relinquish the bus to the requesting device

Minimum Mode Pin Specification
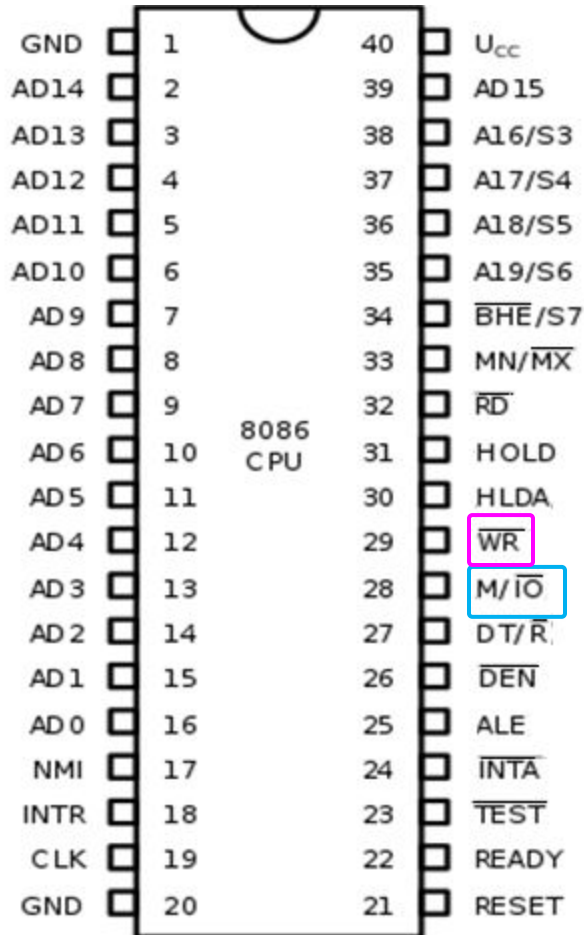
$\overline{WR}, \boldsymbol{output}$

- Active low write signal.

- Writes data to memory or output device depending on $M/\overline{IO}$ signal.

$M/\overline{IO}, \boldsymbol{output}$

- Differentiates memory access from I/O access.

- When high, memory is accessed.

- When low, I/O devices are accessed.

Minimum Mode Pin Specification
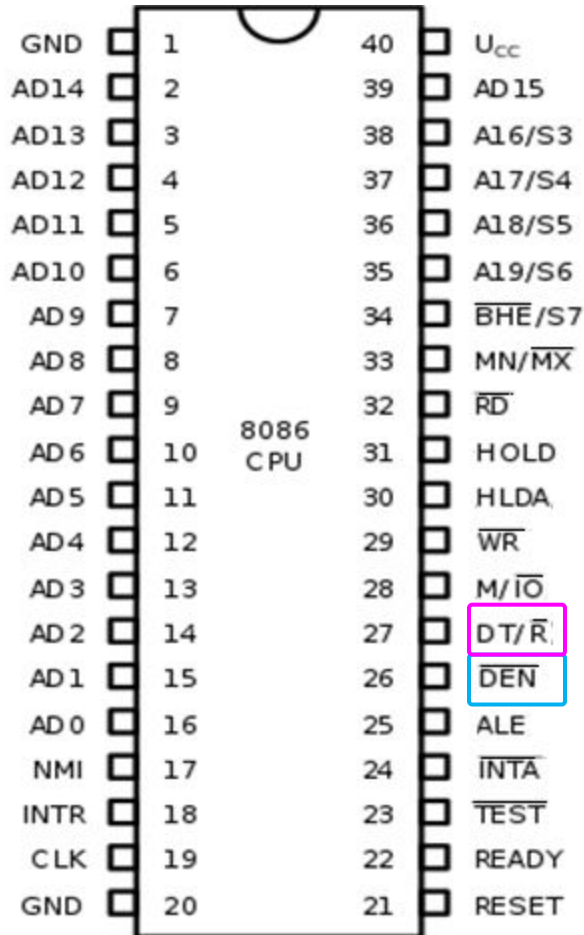
$DT/\bar{R}, \boldsymbol{output}$

- Data Transmit/Receive signal.

- indicates the direction of flow *through the transceiver.*

- When high, data is transmitted out i.e. written to.

- When low, data is received in i.e. read in.

$\overline{DEN}, \boldsymbol{output}$

- Data Enable signal.

- Used to enable a transceiver connected to the µP

Minimum Mode Pin Specification
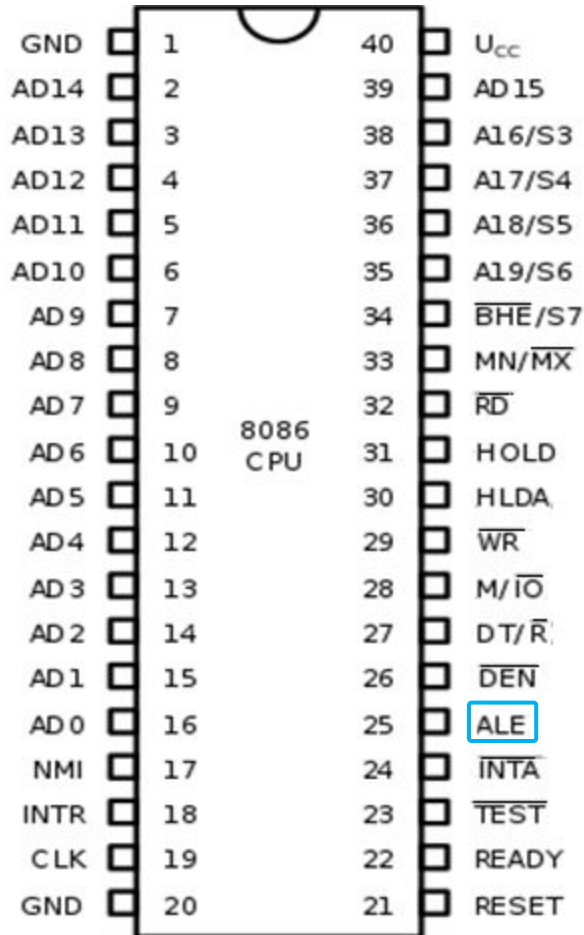
$ALE, \textbf{output}$

- Address Latch Enable

- indicates an address is available on bus $AD_0 - AD_{15}$.

- active high during T_1 state

Minimum Mode Pin Specification
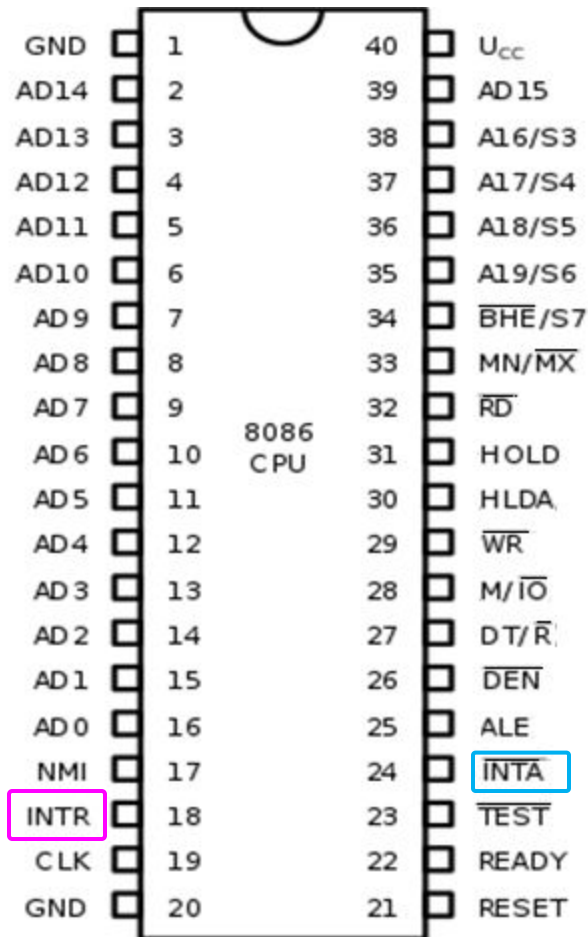
$$\overline{INTA}, \textbf{\textit{output}}$$

- An active low signal.

- An interrupt acknowledge signal.

- When microprocessor receives an INTR signal, it acknowledges the interrupt by generating this signal

- When low it indicates an interrupt is being serviced.

8086 Maximum Mode Pins

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Maximum Mode Pin Specification

```
GND    1        40   Ucc
AD14   2        39   AD15
AD13   3        38   A16/S3
AD12   4        37   A17/S4
AD11   5        36   A18/S5
AD10   6        35   A19/S6
AD 9   7        34   BHE/S7
AD 8   8        33   MN/MX
AD 7   9        32   RD
AD 6   10  8086 31   RQ/GT0
AD 5   11  CPU  30   RQ/GT1
AD 4   12       29   LOCK
AD 3   13       28   S2
AD 2   14       27   S1
AD 1   15       26   S0
AD 0   16       25   QS0
NMI    17       24   QS1
INTR   18       23   TEST
CLK    19       22   READY
GND    20       21   RESET
```
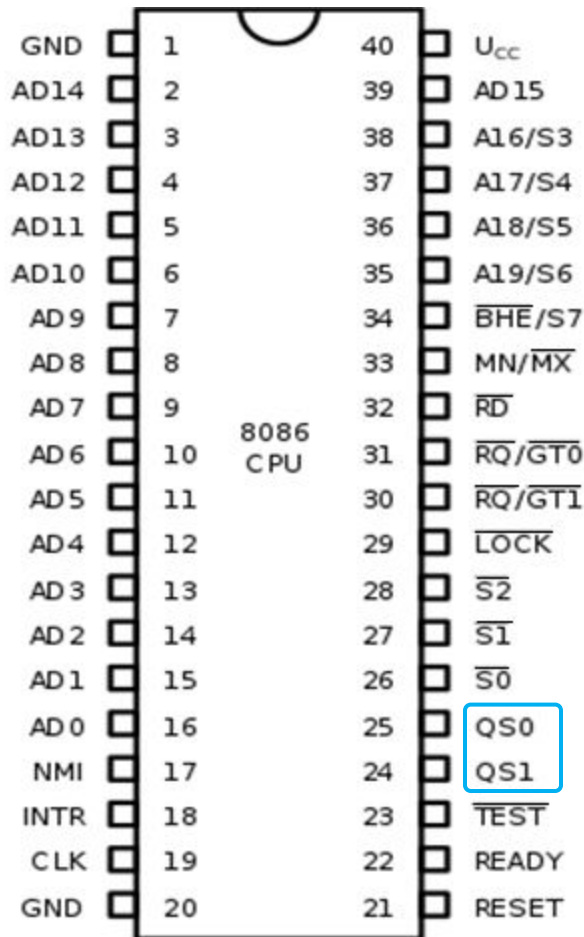
$QS_0 \text{ and } QS_1, \textbf{output}$

- Instruction queue status.

- Instruction queue is 6 bytes long

$Qs1$	$Qs0$	*Function*
0	*0*	*No Operation. During the last clock cycle, nothing was taken from the queue.*
0	*1*	*First Byte. The byte taken from the queue was the first byte of the instruction.*
1	*0*	*Queue Empty. The queue has been reinitialized as a result of the execution of a transfer instruction.*
1	*1*	*Fetch subsequent byteSubsequent Byte. The byte taken from the queue was a subsequent byte of the instruction.*

Maximum Mode Pin Specification

$$\overline{S_0}, \overline{S_1}, \overline{S_2}, \textbf{\textit{output}}$$
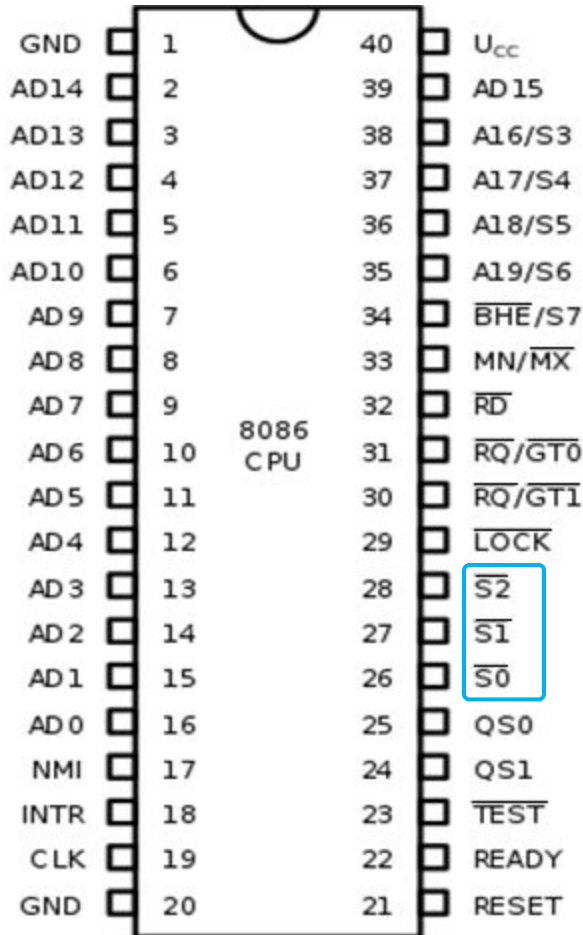
- Status Signals.

- indicate operation done by the microprocessor

- Related to memory and I/O access control signals.

S2	S1	S0	*Function*
0	*0*	*0*	*Interrupt acknowledgement*
0	*0*	*1*	*Read data from I/O port*
0	*1*	*0*	*Write data from I/O port*
0	*1*	*1*	*Halt*
1	*0*	*0*	*Opcode fetch*
1	*0*	*1*	*Memory read*
1	*1*	*0*	*Memory write*
1	*1*	*1*	*Passive state*

Maximum Mode Pin Specification
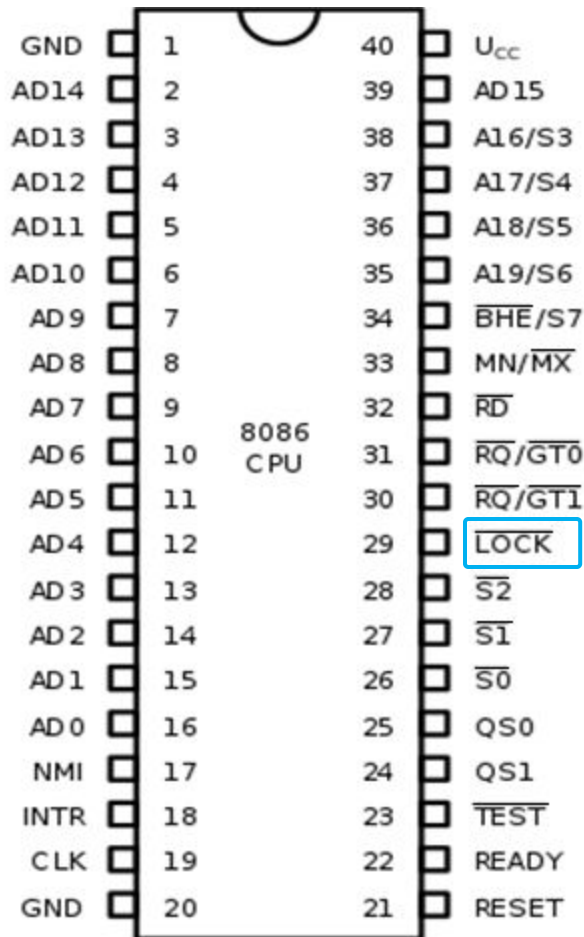
$\overline{LOCK}, \boldsymbol{output}$

- When low, all interrupts are masked

- Indicates to other processors to not request for system bus.

- No HOLD request is granted.

- No bus is relinquished to the other processors

Maximum Mode Pin Specification
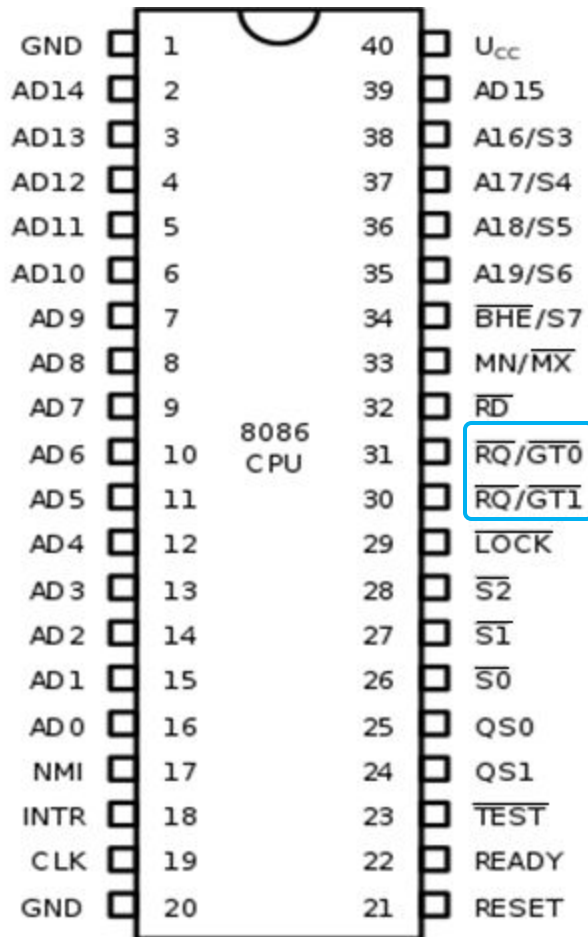
$$\overline{RQ/GT_0} \text{ and } \overline{RQ/GT_1}, bi-directional$$

- Request/Grant pins.

- Other processors request the CPU through these for system bus.

- CPU sends acknowledge signal on the same lines.

- $\overline{RQ/GT_0}$ has higher priority than $\overline{RQ/GT_1}$.

QUIZ

1) Assuming you want to type a secret message using a keypad connected to an **8086** microprocessor, deduce the values of the following pins during that time. Justify your anwers too.

   a) $\overline{RD}$ e.g. mention if low (0) / high (1) and why.

   b) $\overline{WR}$

   c) $M/\overline{IO}$

2) Do you think there may be other pins involved? If so, justify your answer.

8086 Clocks & Timing Diagrams

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Microprocessor Operation
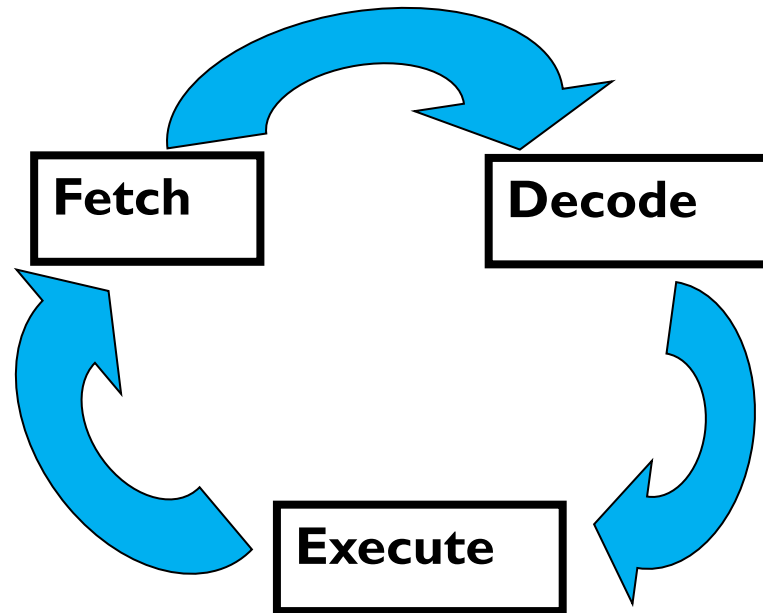
- An instruction e.g. MOV [7531h], AX ; SUB CH, [0ABCh] etc

- The time a μP requires to complete **fetch-(decode)-execute** operation of a single instruction is known as *Instruction*

Cycle

Microprocessor Operation

☐ ***Instruction Cycle*** consists of one or more ***Machine Cycles***

☐ A basic µP operation such as reading/writing a byte from or to memory or I/O port is called a ***Machine/Bus cycle***

one bus cycle

T_{OFF} T_{ON}

T1   T2   T3   T4

T_1 T_2 T_3 T_4 T_1 T_2 T_3

Machine Cycle (FC)   Machine Cycle (EC)

Instruction Cycle (IC) = Fetch cycle (FC) + Execute Cycle (EC)
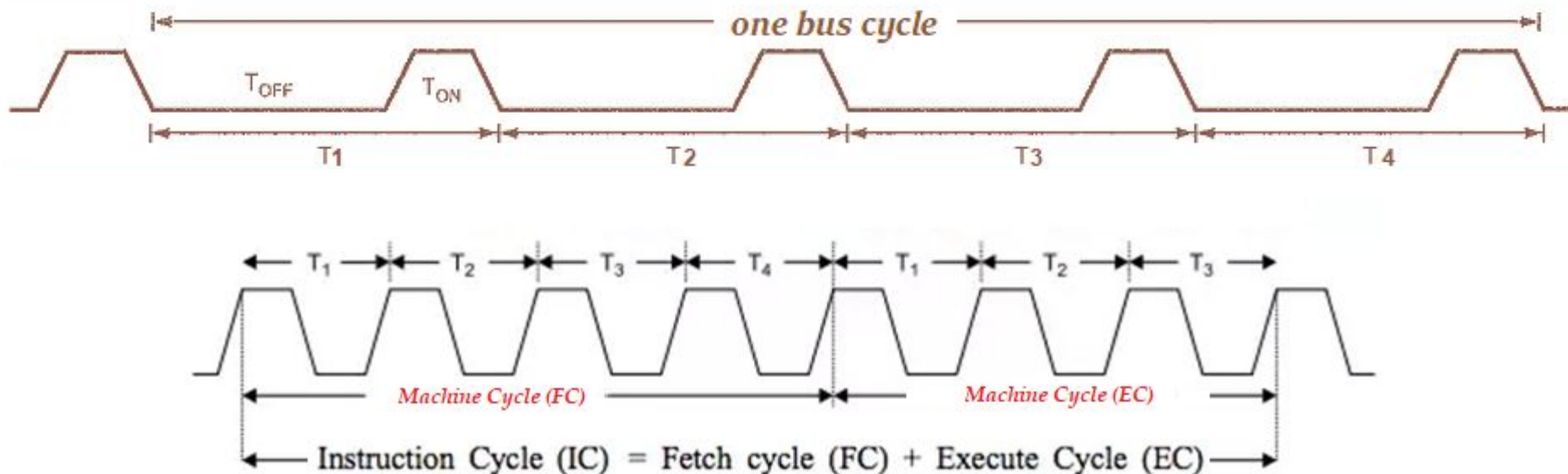
Microprocessor Operation

☐ A **Machine (bus) cycle** consists of at least **four** clock cycles, called **T** states.

☐ One cycle of a clock is called a **State**

☐ Each read or write operation takes 1 bus cycle.
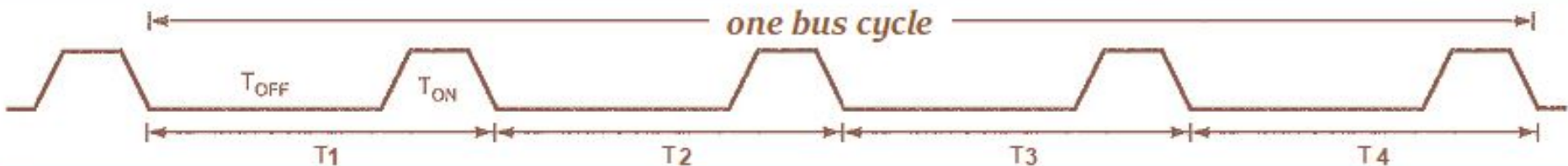
Clock Generation

□ Clock generator circuit is **8284A** and connected to **pin 19** (**CLK**) of 8086.
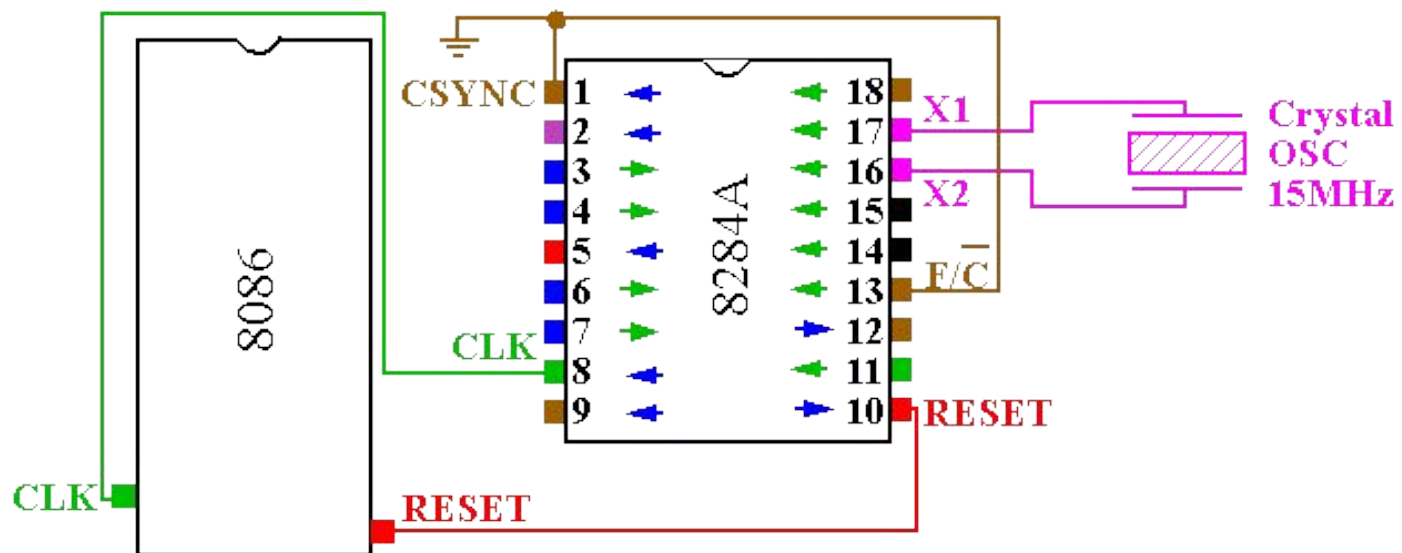
System Clock Concept

- **8086** is found to operate in between 5 to 10 Mhz.

- An **8086** running at 5MHz, its clock pulses will be of 200ns and it would take 800ns for a complete bus cycle.

T_{off} T_{on}

33% Duty Cycle

400 ns

One bus cycle

T1   T2   T3   T4

System clock
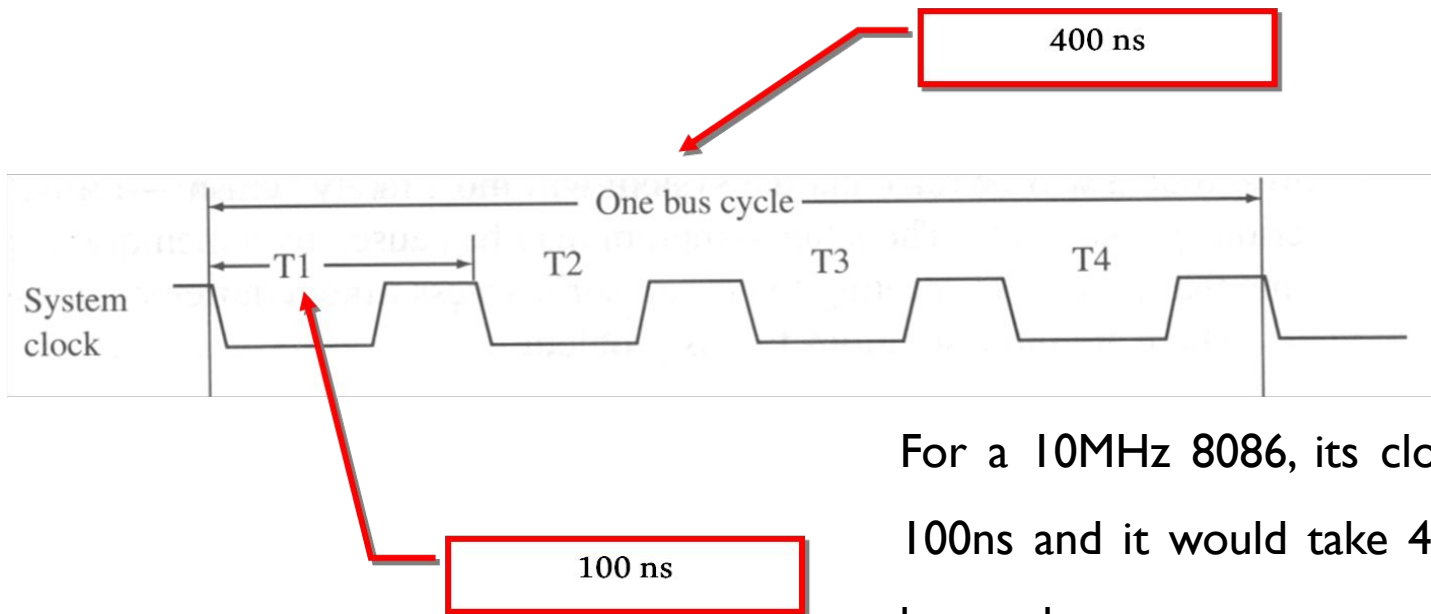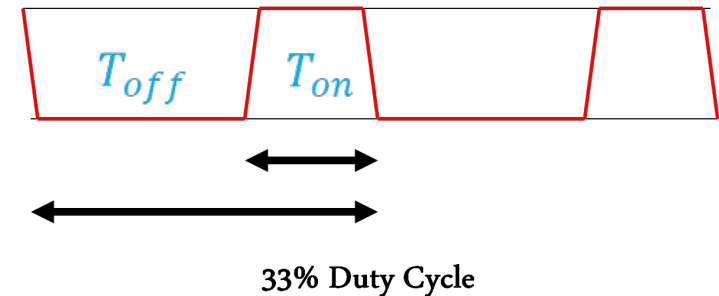
100 ns

For a 10MHz 8086, its clock pulses will be of 100ns and it would take 400ns for a complete bus cycle.

Clock States - Why are there T states?

- In 8086, address and data lines are multiplexed to reduce number of pins e.g. AD_{0-15} else 32 pins would have been needed instead of 16

- The μp needs time to change the signals during each bus cycle.

- Memory devices need time to interpret the address value and then **read/write** the data (*access time*)

- A specific defined action occurs during each T state (**T_1 - T_4**)

  - **T_1** : Address is output

  - **T_2** : Bus cycle type (Mem/IO, read/write)

  - **T_3**: Data is supplied / Data is received

  - **T_4** : Data latched by CPU, control signals removed

READ BUS Timing (Complete BUS Cycle)

T_1: Address is output
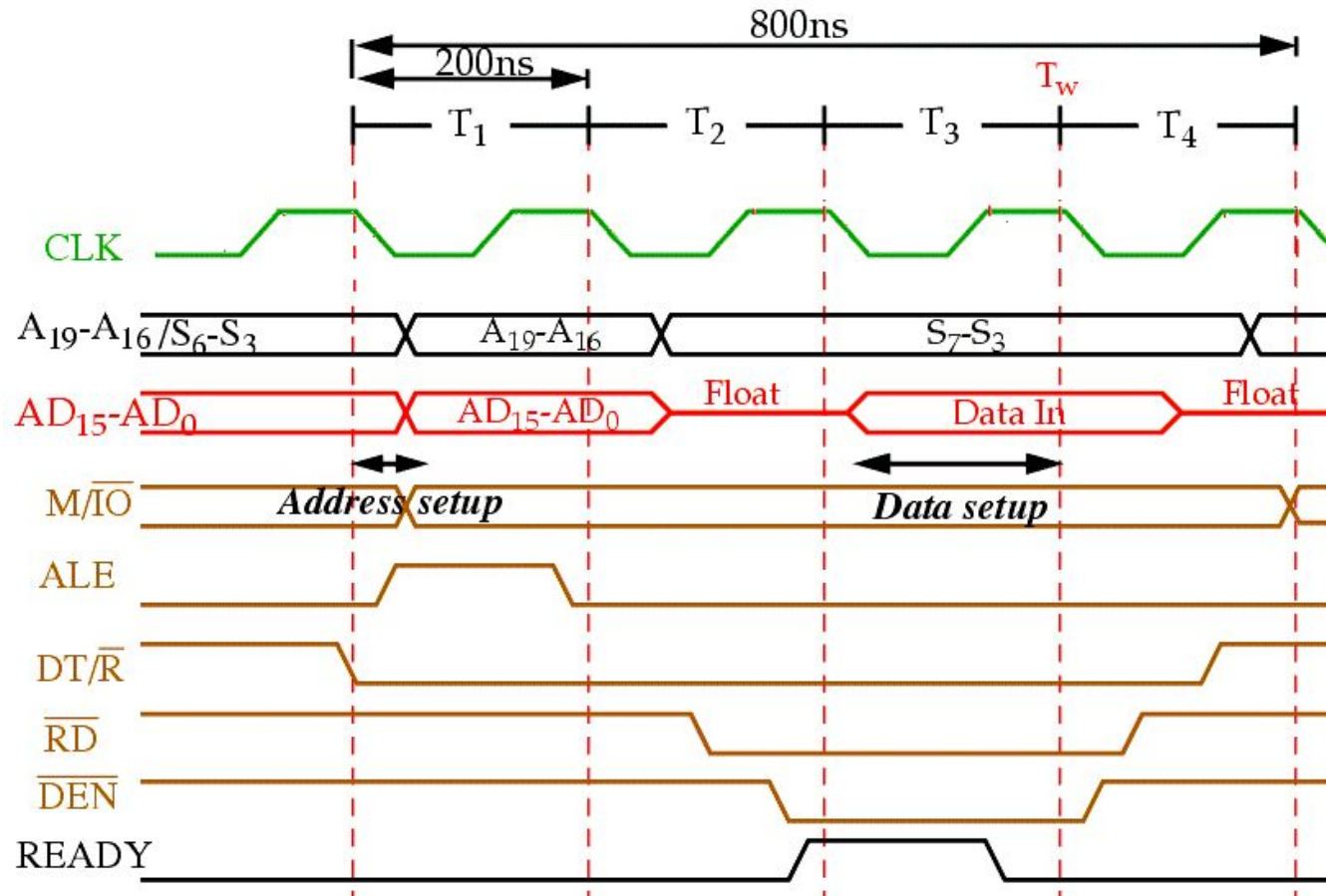
Address of memory is sent out by 8086 via address bus
Used Control signals: ALE, DT/R', M/IO' shows some output

READ BUS Timing (Complete BUS Cycle)

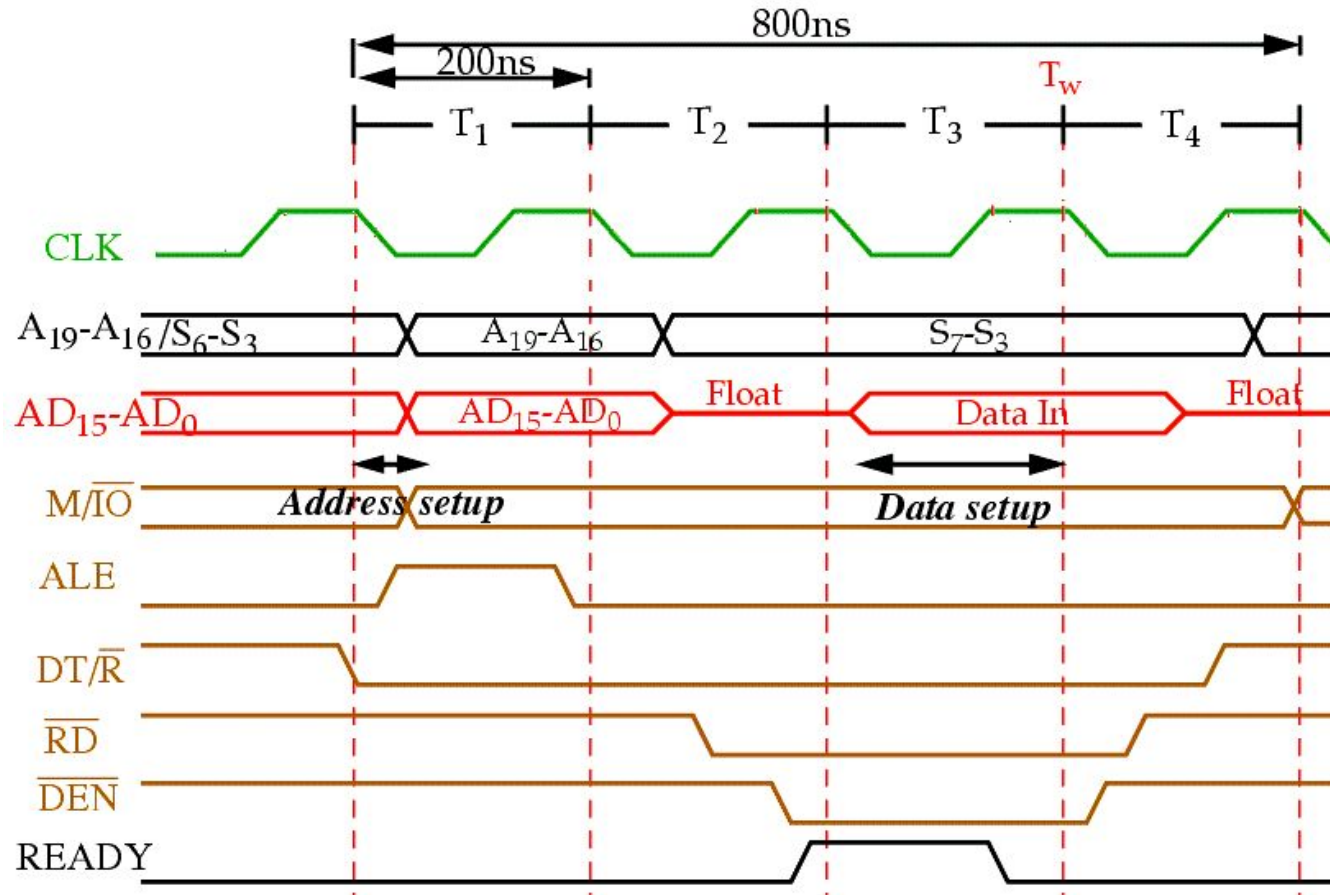8086 issues either RD' or WR' and DEN'

In case of WRITE (WR) operation, data to be written appear on data bus
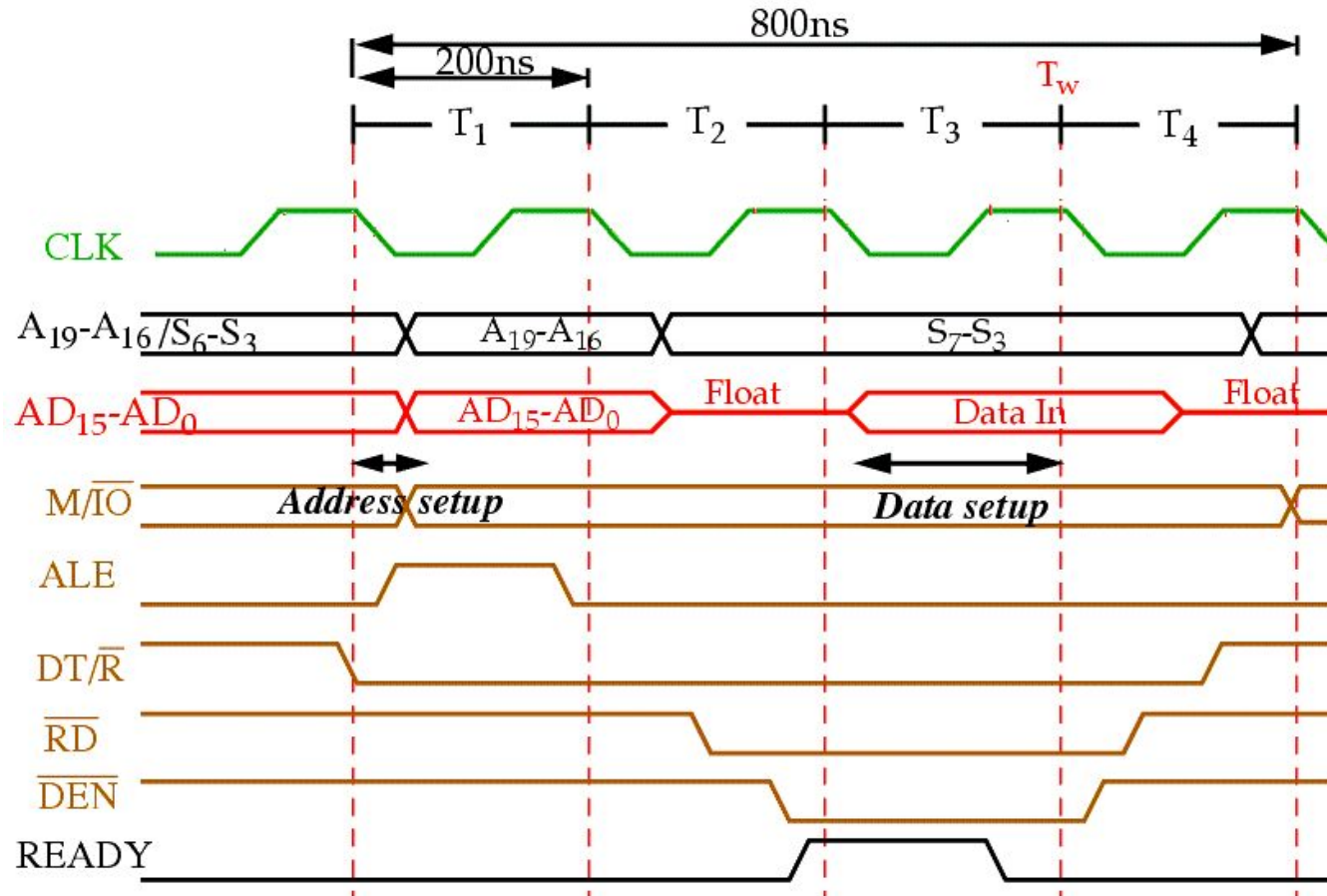
READ BUS Timing (Complete BUS Cycle)

READY is sampled at the end of T2

If READY is low, T3 becomes a wait state (Tw), means no operation (NOP).

In READ bus cycle data bus is sampled at end of T3

READ BUS Timing (Complete BUS Cycle)

T_4: Data latched by µP, control signals removed

All bus signals deactivated in preparation for next bus cycle
µP sampled data bus for data that read from M or I/O

Clock States

- A specific, defined action occurs during each T states $(T_1 - T_4)$

- **T_1**: Address is output

  - Address of memory is sent out by 8086 via address bus

  - Used Control signals: ALE, DT/R', M/IO' shows some output

- **T_2**: Bus cycle type (MEMORY/IO, READ/WRITE)

  - 8086 issues either RD' or WR' and DEN'

  - In case of **WRITE (WR)** operation, data to be written appear on data bus

Clock States

- **T_3**: Data is supplied

  - READY is sampled at the end of T_2

    - If READY is low, T_3 becomes a wait state (T_w), means no operation (NOP).

    - In **READ** bus cycle data bus is sampled at end of T_3

- **T_4**: Data latched by µP, control signals removed

    - All bus signals deactivated in preparation for next bus cycle

    - µP sampled data bus for data that read from M or I/O

    - At trailing edge of WR', transfer data to M or I/O

8086 Ready pin

- The READY input is controlled to insert "Wait states" into the timing of the microprocessor for slower memory and I/O components..

- If the READY pin is at a logic 0 level, the micro-processor enters into wait states and remains idle.

- When it is high (logic 1), it indicates that the device is ready to transfer data.

- A wait state is a situation in which a computer processor is waiting for the completion of some event before resuming activity.

- A program or process in a wait state is inactive for the duration of the wait state.

Ready pin and Wait state

- When a computer processor works at a faster clock speed than the random access memory (RAM) that sends it instructions, it is set to go into a wait state for one or more clock cycles so that it is synchronized with RAM speed. In general, the more time a processor spends in wait states, the slower the performance of that processor.

- Wait states are a pure waste for a processor's performance. Modern designs try to eliminate or hide them using a variety of techniques: CPU caches, instruction pipelines, instruction prefetch, simultaneous multithreading and others.

Thank You

Questions are welcome in the discussion class