Date:

COAL

Computer Organization and Assembly Language

Assembly Language

Phases
- → Fetch
- → Decode
- → Execution
- → Write/Back

Processor → 1 kh_z
1000 cycles s^{-1}
1 instruction ⟶ 4 cycles

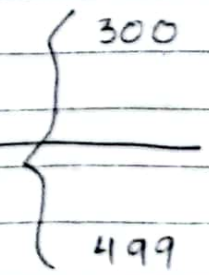
1 sec → 250 instructions

Processor designed on 1 Mhz
1 see → 250 × 1600
= 250000 instructions per second

PC (Program Counter) ← Register

At time T which instructions is executed

We have to check the value of PC at that specific time T.



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Data

- unsigned
  - Range
  - $0 \rightarrow 2^n - 1$
- signed
  - Range
  - $-2^{n-1} \rightarrow 2^{n-1} - 1$

For 8 bit register

$0 \rightarrow 2^8 - 1$ $\quad -2^{8-1} \rightarrow 2^{8-1} - 1$

$0 \rightarrow 255$ $\quad -128 \rightarrow 127$

8 Registers are the combination of 8 Flip Flops

Number Systems

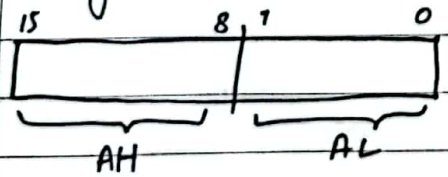
- Binary
- Decimal
- Hexadecimal
- Conversions
- Counting

Registers

Data Registers / General Purpose Registers

- AX (Accumulator Reg)
- BX (Base Reg)
- CX (Count Reg)
- DX (Data Reg)

They all are 16-bit registers



MOV AX, BX

↓

It copies BX to AX value

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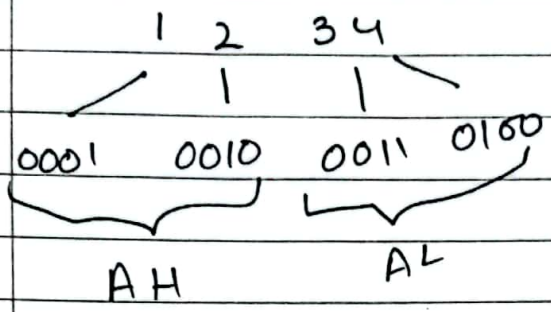
MOV AX, 1234



Lecture #2:

Data Registers:

Segment Registers:

16-bit
- DS → Data segment Reg
- CS → Code " "
- SS → stack " "
- ES → Extra " "

Index and Pointer Register

16-bit
- SI → Source Index Reg
- DI → Destination index Reg
- IP → Instruction Pointer Reg
- SP → Stack Pointer Reg
- BP → Base Pointer Reg

To access a location in memory either for reading or writing a segment and index Register is required.

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Offset Address stores in Index ~~Pointer~~ Register

DS → SI, DI
CS → IP
Stack Reg → SP, BP

For 16 MBytes register, size of address will be 2^{16} = 16 bytes.

$2^4 = 16$

Address will be of 4

For 1K bytes = 1024 byte

$2^{10} = 1024$

$64K = 64 \times 1024$
$= 2^6 \times 2^{10}$
$= 2^{16}$

$1K = 2^{10}$
$1M = 2^{20}$
$1G = 2^{30}$

For 16 MB $= 16 \times 1024 \times 1024$
$= 2^4 \times 2^{10} \times 2^{10}$
$= 2^{24}$

Address of very 1st location is all zeroes
" " " last " is all ones.

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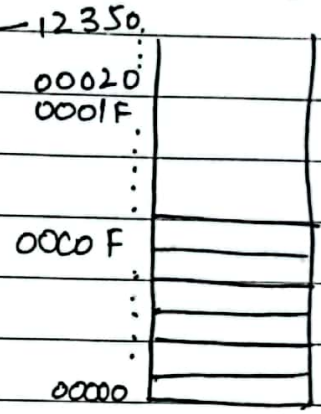
For 1MB
$= 2^{20}$
20 bits
in hexa decimal
20/4 = 5 bits

lower 4 bits of binary or 1 bit in hexa decimal should be zero. So, that memory segment can start.

After every 10 hex or 16 decimal our segment can be start.



Segment NO → stored in DS
But DS is 16 bit and segment NO is 20 bits
so we ignore last 4 bits

= P

SA x 10h + 0A = Phy

16
9 10
12 11 h
B

110
100

16 | 16
1 - 0

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Label opcode operand

```
MOV  al, bl   ✓
Mov  bl, 20   ✓
Mov  20, bl   X
Mov  bl, [SI] ✓
MOV  bl, SI   X
```

DS = 1234
SI = 0200

```
MOV bL, 0
MOV al, [SI]
Add bL, al
INC SI;  SI = 0201
MOV al, [SI]
Add bL, al
INC SI
```

JUMP

Unconditional	Conditional
	JZ → Jump if zero flag set
	JNZ → " " reset
JA	above
AE	
B	Below
BE	
JG	
JGE	

zero Flag → set → when result is zero

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JZ again

Jump if zero flag is set

```
MOV SI, 0200
MOV CX, 8
MOV bl, 0
again: MOV al, [SI]
       Add bl, al
       INC SI
       JMP again
```

```
MOV SI, 0200
MOV CX, 8
; MOV bl, 0
again: Add bl, [SI]
       INC SI
       DEC CX
       JNZ again
```

Jump

- unconditional: JMP
- conditional: JZ, JNZ, JC, JNC, JA, JAE, JB, JBE, JG, JGE

```
MOV AX, 1234
MOV DS, AX
```

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We can't move data from memory to memory because of size
If al is destination than 8 bits will transfer or if ax is used than 16 bits will transfer

- Similarly in Add, Sub operations both operands cannot be memory address
  Add [SI], [DI] X
  Add [SI], al ✓

```
.model small
.stack 100h
.code
. main Proc
    MOV AX, @data
    MOV DS, AX
    MOV DX, offset string1
    MOV AH, 09
    INT 21h
    MOV AH, 4ch
    INT 21 H
main endp
```

use to terminate the program

```
.data
string1 db 'Good $'
end main
```

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(Label) : opcode operands ; comment
destination, source

* In debugers — no label and comments

MOV al, bl — size should be same

MOV bl, [SI] — pointer

DS = 1234
SI = 0200
↳ it points to data in bytes store at that location

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```
.model small
.stack 100h
.code
 main Proc
    MOV  Ax, @data
    MOV  DS, AX
    MOV  DX, offset string1
    MOV  AH, 09
    INT  21H
    MOV  AH, 4ch
    INT  21H
 main endp
.data
 string1 db 'Good $'
end main
```

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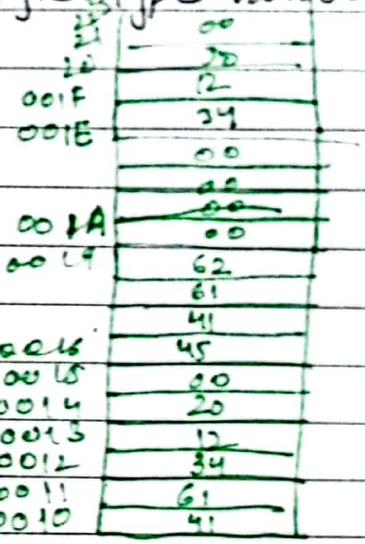
Starting offset of string should be in DX.

If you want to print string in next line then we 10,13 before string.
0Ah,0Dh

db (define byte) declare byte type variable
2 bytes — dw (define word)
dd (double word)
dq (quad word)



long 8
int 4
short 2

```
.data
num1  db  41h
num2  db  61h
num3  dw  1234h
num4  dw  20h
array1 db  45h, 41h, 61h, 62h
array2 db  4 dup(00)
array3 dw  1234h, 50h, 200h
```

↓

6 memory locations will be allocated for array 3.

string1 db 'Good Morning'

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LOGIC INSTRUCTIONS

Arithmetic operations change the whole number completely

Example

```
  ① 1111 1111
+           1
-----------------
  0000 00 00
```

If we want to change a specific bit, we use logic instructions

AND → used to RESET certain bits keeping remaining bits unchanged.

Example: Let BL = 0100 0111 → Want to RESET bit 2

```
  1111 1011
    ↓    ↓
    F    B  → logical operand
```

Keep the bit zero in logical operand that you want to reset and remaining bits will be 1.

AND BL, 0FBh

```
  0100 0111
  1111 1011
-----------------
BL = 0100 0011
```

If logical operand is 0F0h than which bits of BL will be changed

As the logical operand is 1111 0000 so first four bits will be changed.

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Take a lower case character from user and change it in upper case using logic instruction.

Observe the bit pattern of both cases. Only 5th bit is changed

a = 0 1 1 0 0 0 0 1
A = 0 1 0 0 0 0 0 1

b = 0 1 1 0 0 0 1 0
B = 0 1 0 0 0 0 1 0

```
      7 6 5 4 3 2 1 0
b:    0 1 1 0 0 0 1 0
DF:   1 1 0 1 1 1 1 1
      ---------------
B:    0 1 0 0 0 0 1 0
```

AND AL, DFh

Take character from user if it is in lower case convert it into upper case otherwise display it as it is →

```
MOV AH, 01
INT 21H
AND AL, DFh
MOV DL, AL
MOV AH, 02
INT 21H
```

∴ OR → used to set specific bit

The bit you want to set is 1 and remaining will be zero

Upper case to lower case → OR used

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XOR → compliment / toggle

Keep the bit → 1 you want to toggle and remaining bits will be 0

XOR AL, 02H →

```
  0 0 1 0   0 0 0 1
  0 0 0 0   0 0 1 0
-------------------
  0 0 1 0   0 0 1 1
```

Change the case of character → XOR used

Convert the case of string

```
Main Proc
    MOV AX, @data
    MOV DS, AX
    MOV SI, offset string
    MOV CX, 5
    MOV al, 20H
again: XOR [SI], al
    INC SI
    INC al
    DEC CX
    JNZ again

    MOV Ah, 09
    INT 21h
```

```
.data
string db "Hello $"
```

```
MOV bl, [SI]
XOR bl, 20H
MOV [SI], bl
```

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```
main Proc
    MOV  AX, @ data
    MOV  DS, AX
    MOV  DX, offset string
    MOV  AH, 09
    INT  21 H
    MOV. CX, 5
    MOV  SI, offset string
again: MOV  bl, [SI]
    XOR  bl, 20H
    MOV  [SI], bl
    INC  SI
    DEC  CX
    JNZ  again

    MOV  DX, offset string
    MOV  AH, 09
    INT  21h
    MOV  AH, 4ch
    INT  21h
' main endp
.data
    string db "Hello $"
```

0000 0001

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1 2 4 A
0001 0010 0100 1010

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→ Compare instruction works like subtract instruction
→ Flags update on the basis of result.

```
CMP AL, BL
JE  GO
=
=
=
=
SUB AL, BL
JMP exit
```
→ if AL ≠ BL

```
GO:  ==
     ==
exit: ==
```
→ if AL = BL

JE
JNE

unsigned:
- JB
- JBE
- JA
- JAE

treat as signed:
- JG
- JGE
- JLE
- JL

Label should be used before second block and unconditional jump is used at the end of first block.

FF as signed
↓
−1 as signed

```
11111111   −1
00000000
      +1
00000001  → +1
```
so

9

```
CMP al, '9' 39h
JBE Num
```

JMP exit

Num:

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Shift Instructions

- unsigned
  - Logic Shift
    - Left → SHL
    - Right → SHR
- signed
  - Arithmetic Shift
    - Left → SAL
    - Right → SAR

SHR BL, 1

1 0 0 1 0 0 1 0 → goes to carry flag

↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ → Right shift

0 1 0 0 1 0 0 1

↓

vacated bit is filled with zero

MOV cl, 3

SHL BX, cl

0 0 1 E

\+ 1

0 0 1 F

1

0 0 2 0

16 | 16

1 - 0

2 | 41

2 | 20 - 1

2 | 10 - 0

2 | 5 - 0

2 | 2 - 1

1 - 0

001

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Rotate Instructions

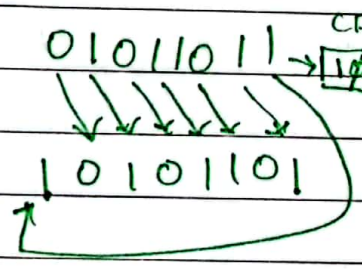
Rotate without carry

- Right → ROR
- Left → ROL

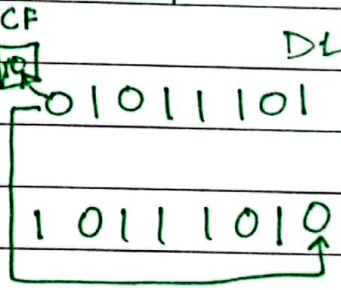
Rotate with carry

- Right → RCR
- Left → RCL

ROR AL, 1



ROL AL, 1

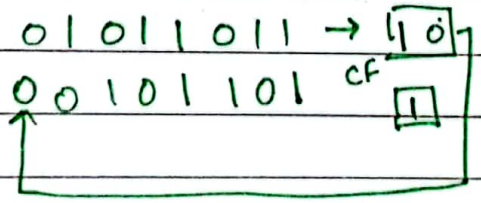


0000 0001 · 1

DL = 1 AND DL, 01

ADD DL, 30h

RCR AL, 1 · CF



ROR, ROL → Same bit goes to carry flag and vacated place

RCR, RCL → Bit goes to carry flag and carry flag bit move to the vacated place.

You weren't put on Earth to be remembered.
You were put here to prepare for eternity.

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Multiple Rotation

Ax: 4 3 A 7

Ax: 0100 0011 1010 0111

ROL Ax, 4

0011 1010 0111 0100

ROL Ax, 8 A743 ↓ 3 A74

ROL Ax, 12 7 4 3 A

```
CMP DL, 0
JE zero
CMP DL, 1
JE ONE
```

zero: ——

JMP exit

ONE:

CMP DL, 9
JBE bb

aa: Add DL, 37h
MOV AH, 02
INT 21H

bb: Add DL, 30h
MOV AH, 02
INT 21H

aa:
0 — 30h
1 — 31h
2 — 32h
|
9 — 39h
Add 30h

CMP DL, 9
JBE aa
A — 41h
|
F — 46H
Add 37

41
− A
37h

10
A 41

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```
main Proc
    Mov  Ax, @data
    Mov  DS, Ax
    MOV  Dx , offset string1
    Call display
    Mov Dx, offset string2.
    Call display
```

```
display Proc
MOV AH, 09
INT 21H
RET
display endp
```

```
.data
string1  db 'Good Morning $"
string2  db 'Hope you will be fine $'.
```

When call instruction is executed IP update and sp is decremented by 2.

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0000
-1

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```
HEX proc
MOV CL, 4
ROL DL, CL
MOV BL, DL
AND BL, 0Fh
CMP BL, '9'
```

SP = 0100

```
0100  MOV  AX, 1234
0103  MOV  BX, 5678
0106  PUSH AX → SP = 00FE
0107  PUSH BX → SP = 00FC
0108  ADD  AX, 10   //
0109  ADD  BX, 10   //
010A  POP  BX → SP = 00FE
010B  POP  AX → SP = 0100
010C
```

→ If we PUSH in procedure then before RET POP all the values that you PUSH

SP se value → IP

Take a number in main make 2 proc (A HEX and binary)

Make a single function that prints HEX on first call and binary on 2nd call.

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Program to display Number in HEX.

```
MOV  BX, 12A4h
MOV  CX, 4
again : ROL  BX, 4
   MOV DL, BL
   AND DL, 0Fh
   CMP DL, 09
   JBE aa
   ADD DL, 37H
   MOV AH, 02
   INT 21H
   JMP exit
aa:  Add DL, 30H
   MOV AH, 02
   INT 21H
exit . DEC CX
   JNZ again
```

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```
.model small
.stack 100h
.code
main PROC
        MOV BX, 1234h
        MOV CX, 4
again:  MOV DL, 13
        AND DL, 0Fh

        Same code
exit:   ROR BX, 4
        DEC CX
        JNZ again
```

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reverse

Program to display binary using rotate

```
MOV BX, 124AH
MOV CX, 16
again: MOV DL, BL
       AND DL, 01H
       CMP DL, 09
       JBE, aa
       Add  DL, 37H
       MOV  AH, 02
       INT  21H
       JMP  exit
aa:    ADD  DL, 30H
       MOV  AH, 02
       INT  21H
exit:  ROR  BX, 1
       DEC  CX
       JNZ  again
```

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one by one Store in BX

Binary Input → ~~Binary~~ Output

```
MOV BX,00H
MOV CX,16
again:MOV AH,01
INT 21H
SUB AL,30H
SHL BX,1
OR BL,AL

DEC CX
JNZ again
```

B=A
MOV AX,A
MOV B,AX

1. Input Binary → Output ✓
   ↓
   BX
2. Input Binary → output HEX ✓
3. HEX → BINARY ✓
4. HEX → HEX ✓

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Book

→ 4.9

4.12

lower case → upper case sub 20h

Q3, Q4, Q6, Q7(A,B), Q8, Q9

Pg 93, 94 (6,2)

Example 6.5

JG == JNLE

LEA = Load Effective Address

Don't use LEA