AACS3064
Computer Systems Architecture

Chapter 8: Assembly Language Fundamental II

Chapter Overview

1) Arithmetic
   - Multiplication & Division
   - Shifting
2) Multiple Initializers
3) Direct-Offset Operands
4) Data related operators & Directives
   - (DUP, OFFSET, TYPE, LENGTHOF, ALIGN, SIZEOF)
5) Indirect Operands
6) Unconditional Jump and Loop

1.Arithmetic

1.Arithmetic

MUL **instruction**

- Performs multiplication on <u>unsigned data</u>.
- Affect the carry and overflow flags.

- Format:

```
MUL   register / memory
```

1.Arithmetic (Continued)

MUL instruction

- Byte times byte (8-bit)

Before :

After:

AH (.....)	AL (Multiplicand)
AX (Product)	

1.Arithmetic (Continued)

MUL instruction

- Word times word (16-bit)

Before :	DX (Ignored)	AX (Multiplicand)
After:	DX (High product)	AX (Low product)

1.Arithmetic (Continued)

MUL instruction

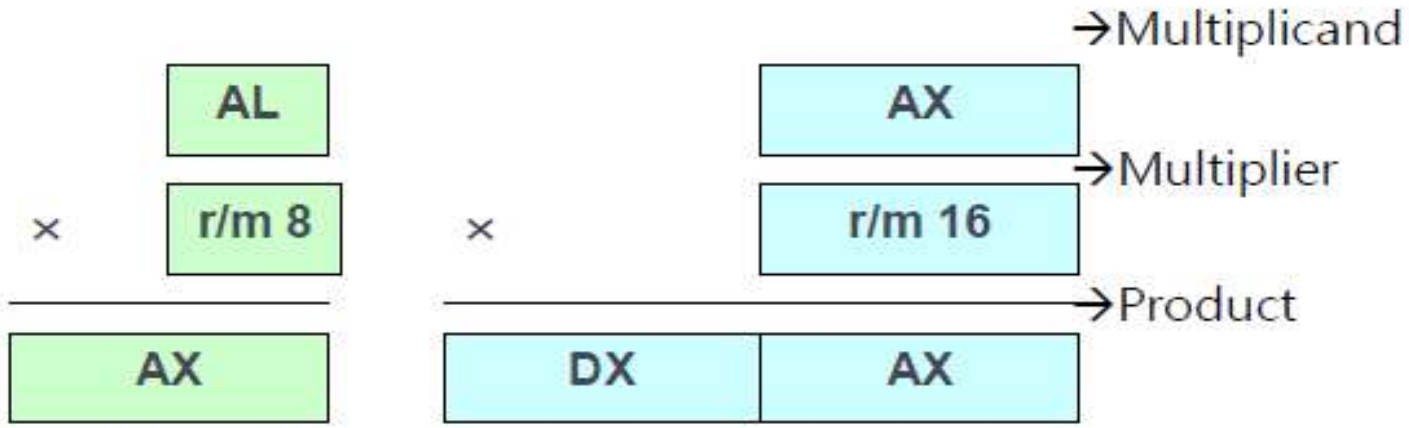
- When the multiplier is in register, the size of the register determines the type of operation :

Instruction	*Multiplier*	*Multiplicand*	*Product*
MUL CL	Byte	AL	AX
MUL BX	Word	AX	DX:AX

1.Arithmetic (Continued)

MUL instruction

- Note that the product is stored in a register (or group of registers) twice the size of the operands.



1.Arithmetic (Continued)

MUL instruction

E.g.

```
.DATA
        var1            DB      80H
        var2            DB      40H
        word1           DW      8000H
        word2           DW      2000H
.CODE
        MOV     AL, var1                ; byte x byte
        MUL     var2

        MOV     AX, word1               ; word x word
        MUL     word2

        MOV     AL, var1                ; byte x word
        SUB     AH, AH
        MUL     word1
```

1.Arithmetic (Continued)

DIV **instruction**

- Performs division on **unsigned data**.
- Format:

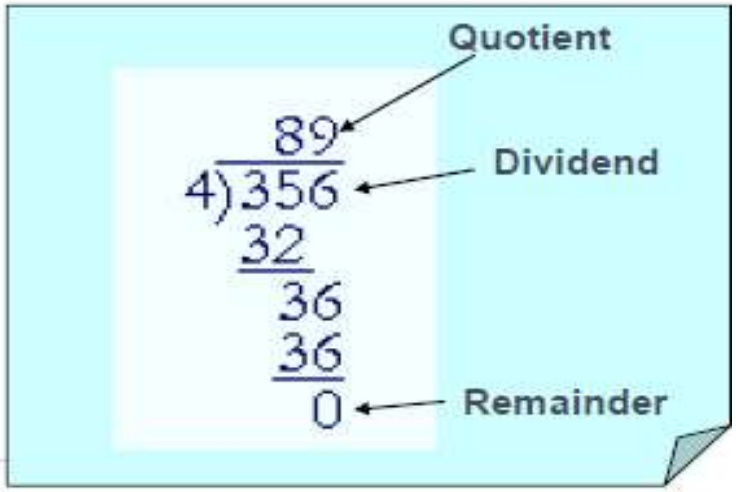
```
DIV   register / memory
```

1.Arithmetic (Continued)

DIV **instruction**

- Byte into word (8-bit divisor)

Before :	AX (Dividend)	
After:	AH (Remainder)	AL (Quotient)

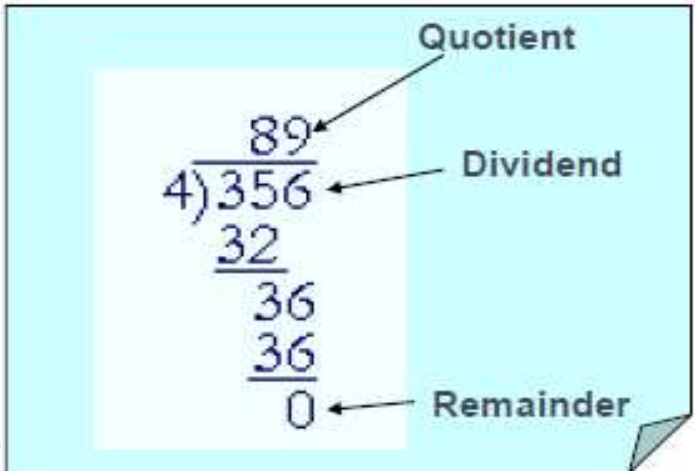


1.Arithmetic (Continued)

DIV **instruction**

- Word into doubleword (16-bit divisor)

Before :	DX (High Dividend)	AX (Low dividend)
After:	DX (Remainder)	AX (Quotient)



1.Arithmetic (Continued)

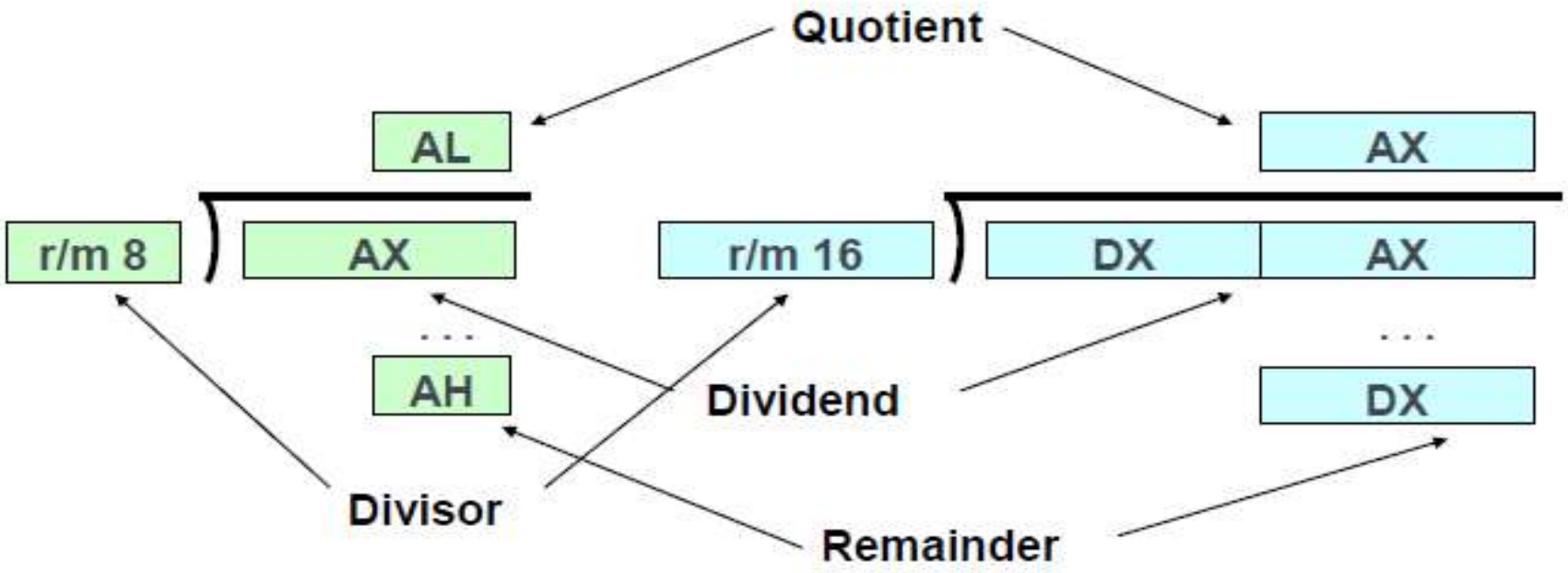
DIV **instruction**

- When the divisor is in register, the size of the register determines the type of operation :

Instruction	*Divisor*	*Dividend*	*Quotient*	*Remainder*
DIV CL	Byte	AX	AL	AH
MUL BX	Word	DX:AX	AX	DX

1.Arithmetic (Continued)

DIV instruction



1.Arithmetic (Continued)

DIV instruction

E.g.

```
.CODE
        ; doubleword / word
        MOV     DX, 0
        MOV     AX, 8003H
        MOV     CX, 100H
        DIV     CX
```

AX =

DX =

1.Arithmetic (Continued)

DIV **instruction**

E.g.

```
.DATA
        var1            DB      80H
        var2            DB      16H
        word1           DW      2000H
        word2           DW      0010H
        word3           DW      1000H
.CODE
        MOV     AX, word1               ; word / byte
        DIV     var1
        MOV     AL, var1                ; byte / byte
        SUB     AH, AH
        DIV     var2
        MOV     DX, word2               ; doubleword / word
        MOV     AX, word3
        DIV     word1
```

1.Arithmetic (Continued)

CBW instruction

- E.g.
  - Assume AL = 60H

```
CBW              ; Extend AL sign into AH
ADD     AX, 20H    ; Add to AX
```

  - AX =

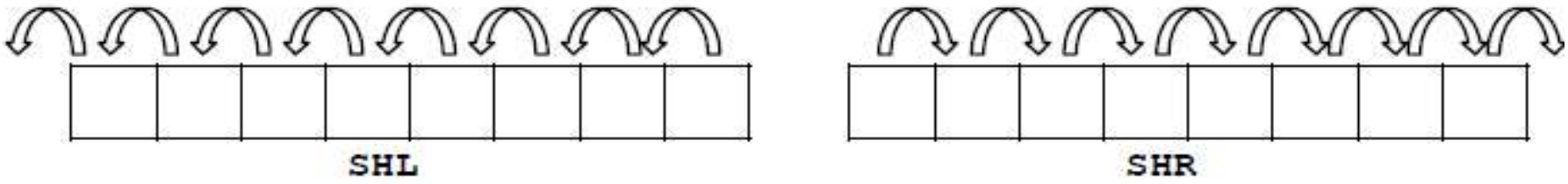
1.Arithmetic (Continued)

Shifting **instruction**

- SHL (Shift Left) : shift the bits to the left.
- SHR (Shift Right) : shift the bits to the right.

- Format:

```
SHL   destination, 1/CL
SHR   destination, 1/CL
```



1.Arithmetic (Continued)

Shifting **instruction**

- E.g.
- A bit that is shifted off enters the carry flag.

```
SHR     AL, 1
```

Before	0000 0100B
After	0000 0010B

- A 0 is shifted into the msb position.

1.Arithmetic (Continued)

Shifting **instruction**

- E.g.

```
MOV   CL, 03
MOV   AL, 10110111B
SHR   AL, 01              ; AL =
SHR   AL, CL              ; AL =
```

1.Arithmetic (Continued)

Shifting **instruction**

- E.g.
- A bit that is shifted off enters the carry flag.

```
SHL     AL, 1
```

Before	0000 0100B
After	0000 1000B

- A 0 is shifted into the rightmost bit position.

1.Arithmetic (Continued)

Shifting **instruction**

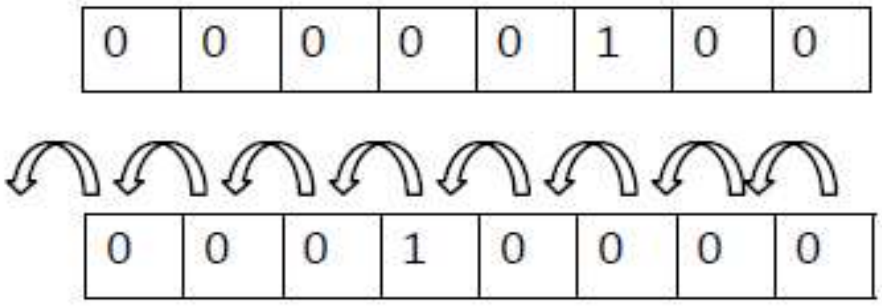
- E.g.

```
MOV   CL, 03
MOV   AL, 10110111B
SHL   AL, 01              ; AL =
SHL   AL, CL              ; AL =
```

1.Arithmetic (Continued)

Shifting **instruction**

- To multiply or divide by a power of two.
  - A left shift will multiply 2^n.
  - A right shift will divide by 2^n.
  - where n is the number of bits to shift.



AL = 4

SHL 2 bit
AL = 4 x 2^2 = 16

2. Multiple Initializers

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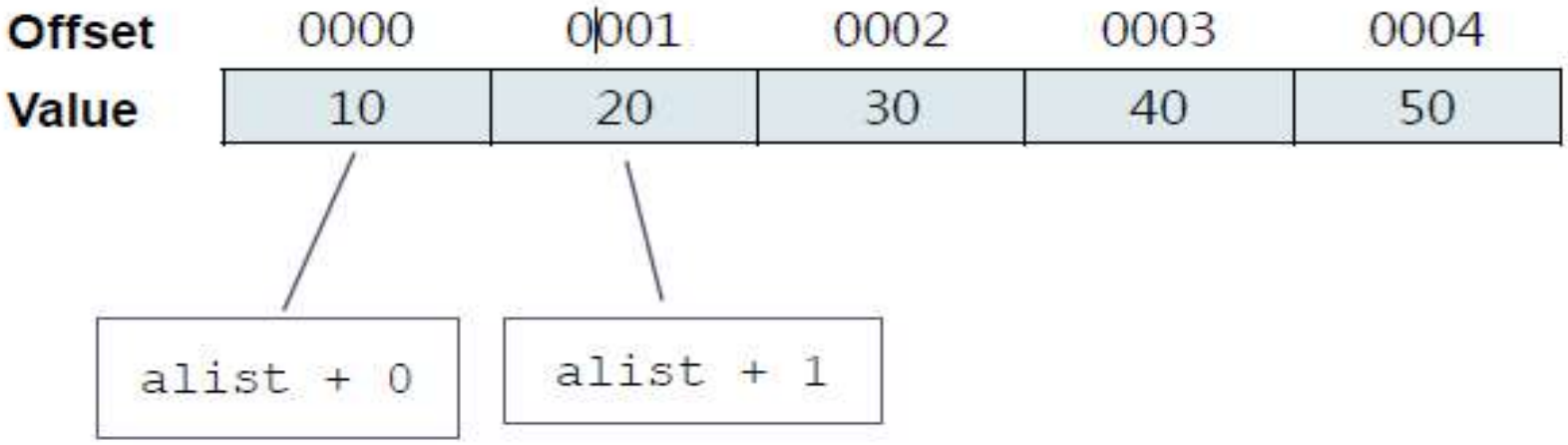
Multiple Initializers

- If a definition has multiple initializers, the label is the offset for the first data item

```
alist    DB      10, 20, 30, 40, 50
```



3. Direct-Offset Operands

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Direct-Offset Operands

- Add a displacement to the name of a variable, creating a direct-offset operand.
- Enable access to memory locations that may not have explicit labels.

```
.DATA
     arrayB     DB    10H, 20H, 30H, 40H, 50H
.CODE
     MOV  AL, arrayB              ; AL =
     MOV  AL, [arrayB + 1]        ; AL =
     MOV  AL, [arrayB + 2]        ; AL =
```

3. Direct-Offset Operands

Direct-Offset Operands

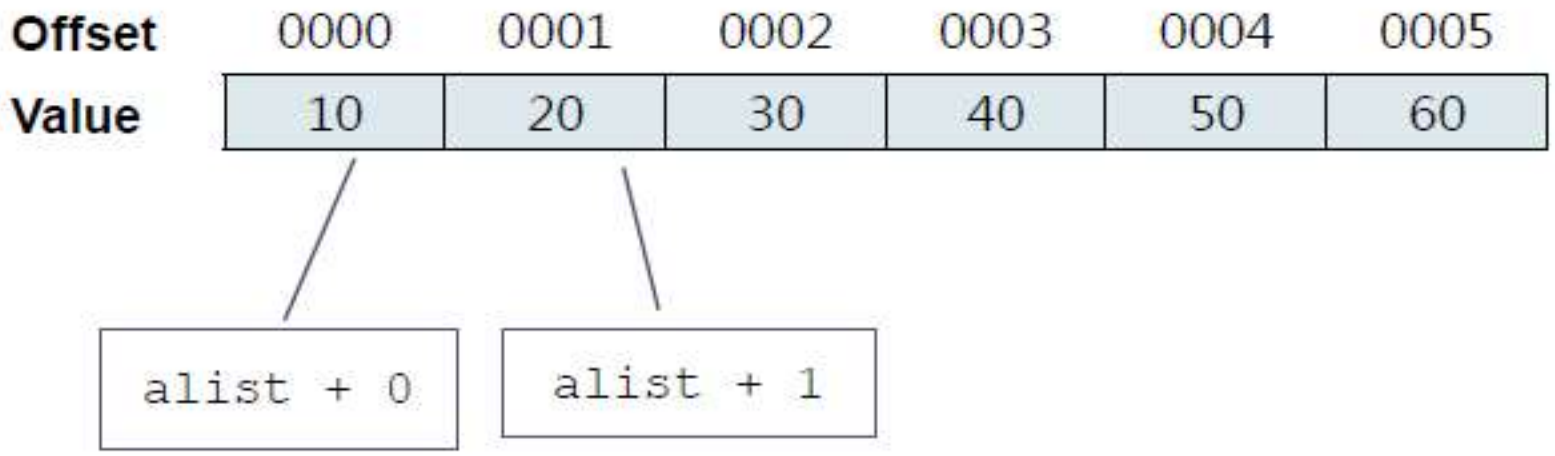
- Add a displacement to the name of a variable, creating a direct-offset operand.
- Enable access to memory locations that may not have explicit labels.

```
.DATA
     arrayB     DB    10H, 20H, 30H, 40H, 50H
.CODE
     MOV  AL, arrayB              ; AL =
     MOV  AL, [arrayB + 1]        ; AL =
     MOV  AL, [arrayB + 2]        ; AL =
```

3. Direct-Offset Operands (Continued)

Multiple Initializers

```
alist    DB      10, 20, 30,
         DB      40, 50, 60
```



3. Direct-Offset Operands (Continued)

Multiple Initializers

- Different initializers can use different radixes

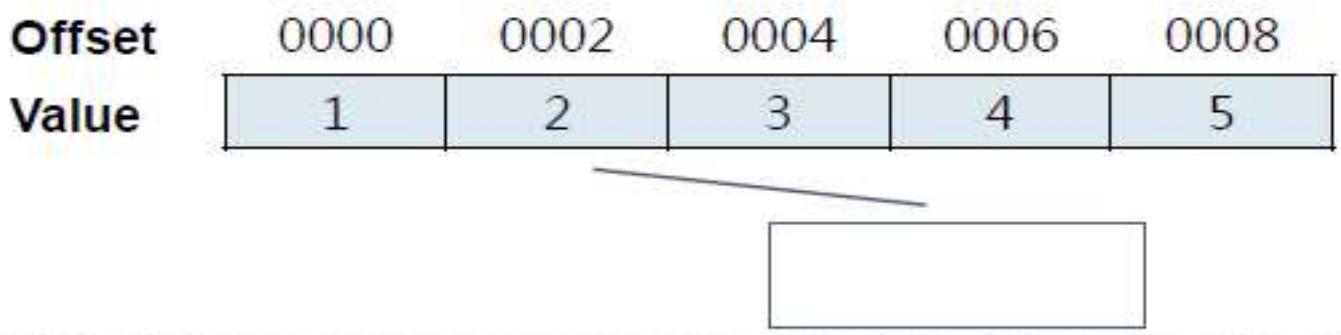
```
alist   DB      10, 25, 41H, 00100010B
blist   DB      0BH, 'A', 60
```

3. Direct-Offset Operands (Continued)

Defining Data – (16-bit)

```
value1   DW   65535      ; unsigned word
value2   DW   -32768     ; signed word
```

```
myList   DW   1, 2, 3, 4, 5
```



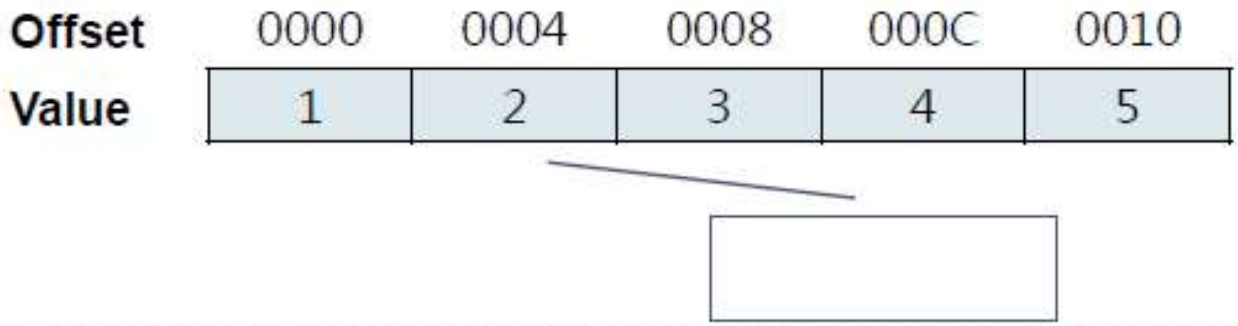
3. Direct-Offset Operands (Continued)

Defining Data – (32-bit)

```
value1   DD   12345678H          ; unsigned doubleword
value2   DD   -21474836648       ; signed doubleword
```

- E.g.

```
myList   DD    1, 2, 3, 4, 5
```



4. Data related operators & Directives

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DUP **Operator**

- Allocates storage for multiple data items, using a constant expression as a counter.
- It is useful when allocating space for a string or array, and can be used with initialized or uninitialized data.

```
array1 DB 20 DUP(0)       ; 20 bytes with zero  array2 DB
20 DUP(?)                 ; 20 bytes uninitialized
array3 DB 2 DUP("STACK")        ; "STACKSTACK"
array4 DB 5, 4, 3 DUP (2, 3 DUP(0), 1)
```

4. Data related operators & Directives (Continued)

OFFSET Operator

- The offset operator returns the number of bytes between the label and the beginning of its segment.
- It produce a 16-bit immediate value. Therefore, the destination must be a 16-bit operand.

```
.DATA
     bListDB   10H, 20H, 30H, 40H
     wList DW  1000H, 2000H, 3000H
.CODE
     MOV  DI, OFFSET bList          ; DI = 0000
     MOV  BX, OFFSET bList + 1      ; BX = 0001
     MOV  SI, OFFSET wList + 2      ; SI = 0008
```

4. Data related operators & Directives (Continued)

LENGTHOF **Operator**

- Counts the number of elements in an array, defined by the values appearing on the same line as its label.

```
.DATA
      byte1       DB     10, 20, 30          ; LENGTHOF =
      array1      DW     30 DUP(?), 0, 0     ; LENGTHOF =
      array2      DW     5 DUP(3 DUP(?))     ; LENGTHOF =
      array3      DW     1, 2, 3, 4          ; LENGTHOF =
      digitStr    DB     "12345678$"         ; LENGTHOF =
```

4. Data related operators & Directives (Continued)

LENGTHOF **Operator**

- Counts the number of elements in an array, defined by the values appearing on the same line as its label.

```
.DATA
      byte1       DB     10, 20, 30          ; LENGTHOF =
      array1      DW     30 DUP(?), 0, 0     ; LENGTHOF =
      array2      DW     5 DUP(3 DUP(?))     ; LENGTHOF =
      array3      DW     1, 2, 3, 4          ; LENGTHOF =
      digitStr    DB     "12345678$"         ; LENGTHOF =
```

4. Data related operators & Directives (Continued)

ALIGN **Operator**

- Aligns a variable on a byte, word, doubleword, or paragraph boundary.

```
bVal        BYTE   ?              ; 00404000
ALIGN       2
wVal        WORD   ?              ;
bVal2       BYTE   ?              ;
ALIGN       4
dVal        DWORD  ?              ;
dVal2       DWORD  ?              ;
```

4. Data related operators & Directives (Continued)

ALIGN **Operator**

- Aligns a variable on a byte, word, doubleword, or paragraph boundary.

```
bVal        BYTE   ?              ; 00404000
ALIGN       2
wVal        WORD   ?              ;
bVal2       BYTE   ?              ;
ALIGN       4
dVal        DWORD  ?              ;
dVal2       DWORD  ?              ;
```

4. Data related operators & Directives (Continued)

SIZEOF **Operator**

- Returns the number of bytes an array takes up.
- It is equivalent to multiplying LENGTHOF by TYPE.

```
.DATA
     intArray  DW    32 DUP(0)
.CODE
     MOV  AX, SIZEOF intArray ; AX = 64
```

5. Indirect Operands

5. Indirect Operands

Indirect Operand

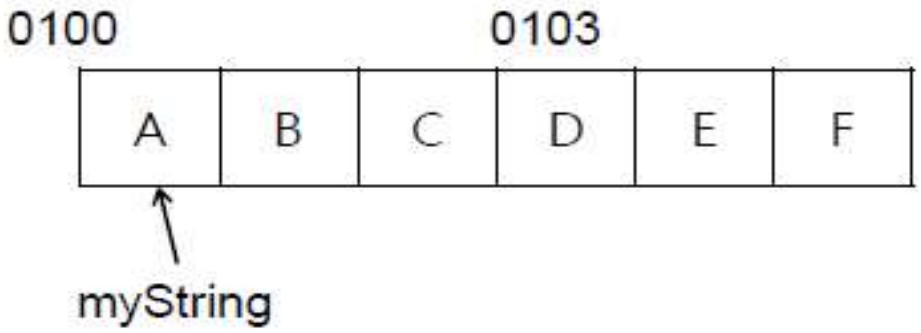
- An indirect operand is a register containing the offset for data in the memory location.
- If the register is used as an indirect operand, it may only be SI, DI, BX, or BP. Avoid BP unless you are using it to index into the stack.

```
.DATA
     byteVal    DB    10h
.CODE
     MOV   SI, OFFSET byteVal
     MOV   AL, [SI]                ; AL = 10h
```

5. Indirect Operands (Continued)

Indirect Operand

```
.DATA
      myString DB "ABCDEF"
.CODE
      MOV    BX, OFFSET myString      ; BX = 0100
      ADD    BX, 3                    ; BX = 0103
      MOV    DL, [BX]                 ; DL = 'D'
```



5. Indirect Operands (Continued)

Indirect Operand – Array of 8-bit

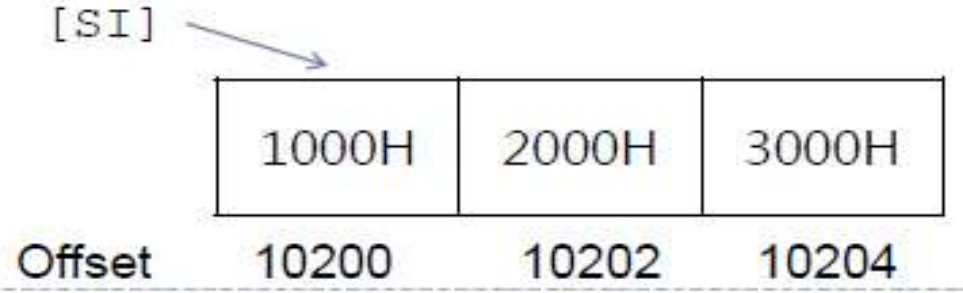
- Useful in manipulating arrays.

```
.DATA
      arrayA       DB     10H, 20H, 30H
.CODE
      MOV    SI, OFFSET arrayA
      MOV    AL, [SI]              ; AL = 10H
      INC    SI
      MOV    AL, [SI]              ; AL = 20H
      INC    SI
      MOV    AL, [SI]              ; AL = 30H
      INC    SI
```

5. Indirect Operands (Continued)

Indirect Operand – Array of 16-bit

```
.DATA
      arrayB       DW    1000H, 2000H, 3000H
.CODE
      MOV    SI, OFFSET arrayB
      MOV    AX, [SI]                    ; AL = 1000H
      ADD    SI, 2
      MOV    AX, [SI]                    ; AL = 2000H
      ADD    SI, 2
      MOV    AX, [SI]                    ; AL = 3000H
      ADD    SI, 2
```



5. Indirect Operands (Continued)

LEA **instruction**

- Stands for "Load Effective Address" .
- Initializes a register with an offset address.

```
.DATA
      dataTable    DB     25    DUP   (?)              value1
      DB     ?
.CODE
      LEA BX, dataTable ; equivalent to
                        ; MOV BX, OFFSET dataTable
      MOV    BYTEFLD, [BX]
```

6. Unconditional Jump and Loop

6. Unconditional Jump and Loop

JMP **instruction**

- unconditional jump :
  - transfers control under all circumstances.
- Allows transfer of control to the target address (any instruction that has a label).
- Format :

```
JMP   short / near / far address
```

6. Unconditional Jump and Loop (Continued)

JMP **instruction**

- Format

Distance	Short	Near	Far
Instructions	-128 to 127 Same segment	-32,768 to 32, 767 Same segment	Another segment
JMP	Yes	Yes	Yes
Jnnn	Yes	80386 / 486	No
LOOP	yes	No	No

6. Unconditional Jump and Loop (Continued)

JMP **instruction**

- Instruction Labels
  - The JMP, and LOOP instructions require an operand that refers to the label of an instruction.

- E.g.

```
            JMP   A90
            ...
A90:        MOV   AH, 00
            ...
```

6. Unconditional Jump and Loop (Continued)

JMP **instruction**

- Backward jump

```
A50:
        ...
        JMP   A50
```

- Forward jump

```
        JMP   A90
        ...
A90:
```

6. Unconditional Jump and Loop (Continued)

LOOP **instruction**

- Repeats a block of statements a specific number.
- **CX** is automatically used as a counter and is decremented each time the loop repeats.
- Format :

```
LOOP shortAddress
```

- Execution Steps :

```
CX --
If (CX != 0)
   jump to the target address.
```

6. Unconditional Jump and Loop (Continued)

LOOP **instruction**

- E.g.

Calculates the sum of the integers 1+2+3+4+5.

```
        MOV   AX, 00H     ; AX = 0
        MOV   CX, 05      ; CX = 5

L1:
        INC   AX          ; Add 1 to AX
        LOOP  L1
```

6. Unconditional Jump and Loop (Continued)

LOOP **instruction**

- E.g.

```
        MOV AX,00
        MOV BX,00
        MOV CX,8   ;Initialize for 8 loops

A20:
        INC AX
        ADD BX,AX

        LOOP A20          ;Decrement CX
                          ;Repeat if nonzero
```

6. Unconditional Jump and Loop (Continued)

Nested LOOP

- When creating a loop inside another loop, special consideration must be given to the outer loop counter in CX.

```
.DATA
      count DW    ?
.CODE
      MOV   CX, 100
L1:
      MOV   count, CX    ; save outer loop count
      MOV   CX, 20       ; set inner loop count
L2:
      …
      LOOP  L2           ; repeat the inner loop
      MOV   CX, count    ; restore outer loop count
      LOOP  L1           ; repeat outer loop
```

6. Unconditional Jump and Loop (Continued)

Summing an integer Array

- E.g. calculates the sum of an array of 8-bit integers.

```
.DATA
      arrayNum     DB     10H, 20H, 30H, 40H
.CODE
      MOV    DI, OFFSET    arrayNum     ; address
      MOV    CX, LENGTHOF arrayNum     ; loop counter
      MOV    AX, 0         ; zero the accumulator
L1 :
      ADD    AL, [DI]              ; add an integer
      INC    DI                    ; point to next
      LOOP   L1
```

Chapter Review

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