Assembly Language for x86 Processors

- Arrray; Data-related Operators and Directives

a collection of data that has the same type

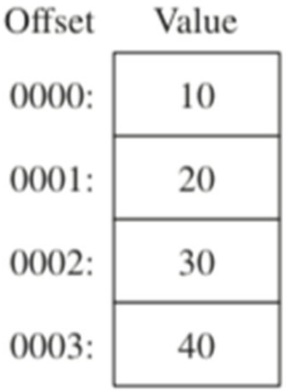
Outline

- Defining Arrays
- Data related directives
- Addressing

Defining Arrays

- Arrays use multiple initializers:

```
list1 BYTE 10,20,30,40

list2 BYTE 10,20,30,40

      BYTE 50,60,70,80

      BYTE 81,82,83,84

list3 BYTE ?,32,41h,00100010b

list4 BYTE 0Ah,20h,‘A’,22h

myList WORD  1,2,3,4,5 ; array of words
val4 SDWORD -3,-2,-1,0,1   ; signed array
```



Offset	Value
0000:	10
0001:	20
0002:	30
0003:	40

Using the DUP Operator

- Use DUP to allocate (create space for) an array or string.
- Syntax:
  - counter DUP (argument)
- Counter and argument must be constants or constant expressions

```
var1 BYTE 20 DUP(0)           ; 20 bytes, all equal to zero
var2 BYTE 20 DUP(?)           ; 20 bytes, uninitialized
var3 BYTE 4 DUP("STACK")      ; 20 bytes: "STACKSTACKSTACKSTACK"
var4 BYTE 10,3 DUP(0),20      ; 5 bytes
```

Defining Strings

- A string is implemented as an array of characters
  - For convenience, it is usually enclosed in quotation marks
  - It is often null-terminated
- Examples:

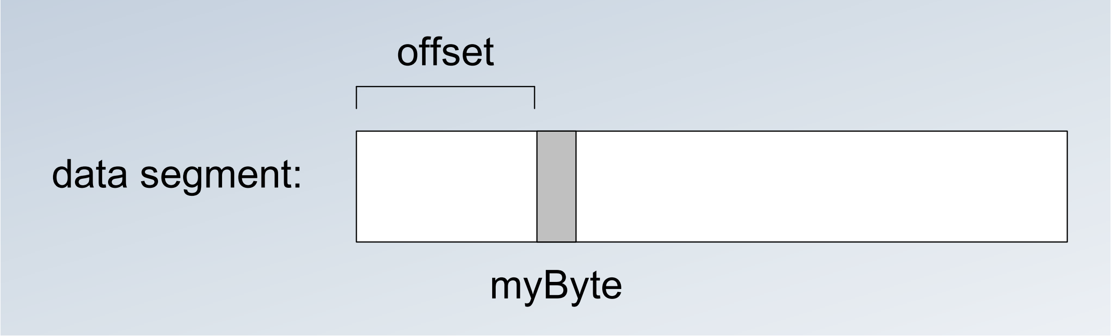
```
str1 BYTE "Enter your name",0
str2 BYTE 'Error: halting program',0
str3 BYTE 'A','E','I','O','U'
greeting  BYTE "Welcome to the Encryption Demo program "
          BYTE "created by Kip Irvine.",0
```

DATA-RELATED OPERATORS AND DIRECTIVES

- OFFSET Operator
- TYPE Operator
- LENGTHOF Operator
- SIZEOF Operator

OFFSET Operator

- OFFSET returns the distance in bytes, of a label from the beginning of its enclosing segment
- The value returned by OFFSET is a pointer.



```
// C++ version:

char array[1000];
char * p = array;
```

```
; Assembly language:

.data
array BYTE 1000 DUP(?)
.code
mov esi,OFFSET array
```

Examples

- Let's assume that the data segment begins at 00404000h:

```
.data
bVal BYTE ?
wVal WORD ?
dVal DWORD ?
dVal2 DWORD ?
.code
mov esi,OFFSET bVal
                           ; ESI = 00404000
mov esi,OFFSET wVal
                           ; ESI = 00404001
mov esi,OFFSET dVal
                           ; ESI = 00404003
mov esi,OFFSET dVal2
                           ; ESI = 00404007
```

TYPE Operator

- The TYPE operator returns the size (in bytes) of a single element of a data declaration.

```
.data
var1 BYTE ?
var2 WORD ?
var3 DWORD ?
var4 QWORD ?

.code
mov eax,TYPE var1          ; 1
mov eax,TYPE var2          ; 2
mov eax,TYPE var3          ; 4
mov eax,TYPE var4          ; 8
```

LENGTHOF Operator

- The `LENGTHOF` operator counts the number of elements in a single data declaration.

```
.data                                        LENGTHOF
byte1  BYTE 10,20,30                           ; 3
array1 WORD 30 DUP(?),0,0                      ; 32
array2 WORD 5 DUP(3 DUP(?))                    ; 15
array3 DWORD 1,2,3,4                           ; 4
digitStr BYTE "12345678",0                     ; 9

.code
mov ecx,LENGTHOF array1                        ; 32
```

SIZEOF Operator

- The SIZEOF operator returns a value that is equivalent to multiplying `LENGTHOF` by `TYPE`.

```
.data                                          SIZEOF
byte1   BYTE 10,20,30                           ; 3
array1 WORD 30 DUP(?),0,0                       ; 64
array2 WORD 5 DUP(3 DUP(?))                     ; 30
array3 DWORD 1,2,3,4                            ; 16
digitStr BYTE "12345678",0                      ; 9

.code
mov ecx, SIZEOF array1                          ; 64
```

Spanning Multiple Lines

- A data declaration can span multiple lines if each line (except the last) ends with a comma.
- The LENGTHOF and SIZEOF operators include all lines belonging to the declaration:

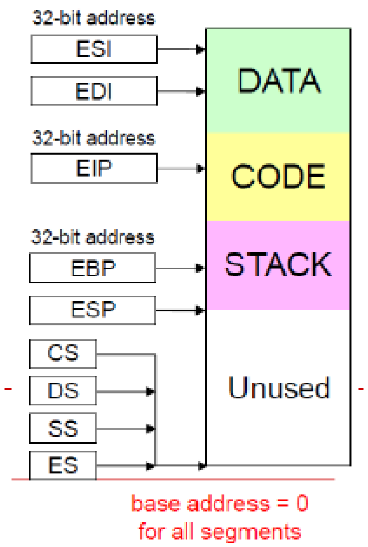
```
.data
array WORD 10,20,
           30,40,
           50,60

.code
mov eax,LENGTHOF array           ; 6
mov ebx,SIZEOF array             ; 12
```

ADDRESSING MODES

Review:

Ch-4 MARIE

Jump X:	PC <-- X	
JnS X:	M[X] <-- PC ;	PC <-- X+1
JumpI X:	PC <-- M[X]	



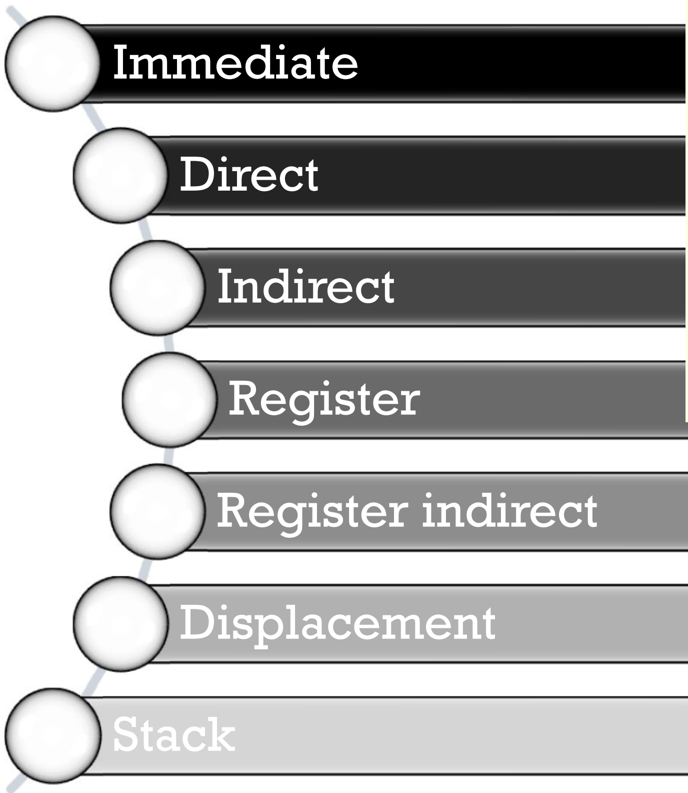
Ch-5 ISA

Immediate:	#	operand is the **value**
Direct:	X	operand is the address
Indirect:	M[X]	operand is the address of the address
Register:	R1	register is the address
Reg. Indir:	M[R1]	register data is the address
Indexed:	X+Roi	register is the index/offset to the address in the operand X
Base:	Rb+D	register is the base address and the operand D is the displacement

Addressing Modes

- The address field or fields in a typical instruction format are relatively small → various modes of addressing

Ch 5.4



Immediate

Direct

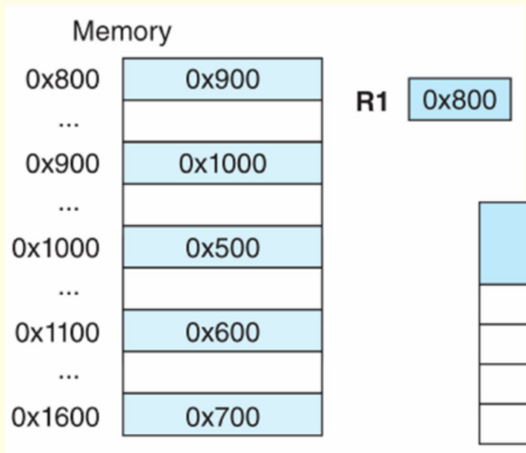
Indirect

Register

Register indirect

Displacement

Stack



LOAD 800

Mode	Value Loaded into AC
Immediate	0x800
Direct	0x900
Indirect	0x1000
Indexed	0x700

R1 is the index register

Direct Memory Operands

- A direct memory operand is a named reference (variable) to storage in memory
- The variable is automatically dereferenced by the assembler
  - After dereferencing, its value can be obtained

```
.data
var1 BYTE 010h
.code
mov al, var1                ; After moving, AL = 010h
mov al,[var1]               ; After moving, AL = 010h
```

alternate format

Direct-Offset Operands

Direct-Immediate offset

- A constant offset is added to a data label to produce an effective address (EA).
  - The offset are 0, 1, 2, …..
- The address is dereferenced to get the value inside its memory location.

```
.data
arrayB BYTE 010h,020h,030h,040h
.code
mov al,arrayB+1                 ; AL = 020h
mov al,[arrayB+1]               ; alternative notation
```

Q : Why doesn't arrayB+1 produce 11h?

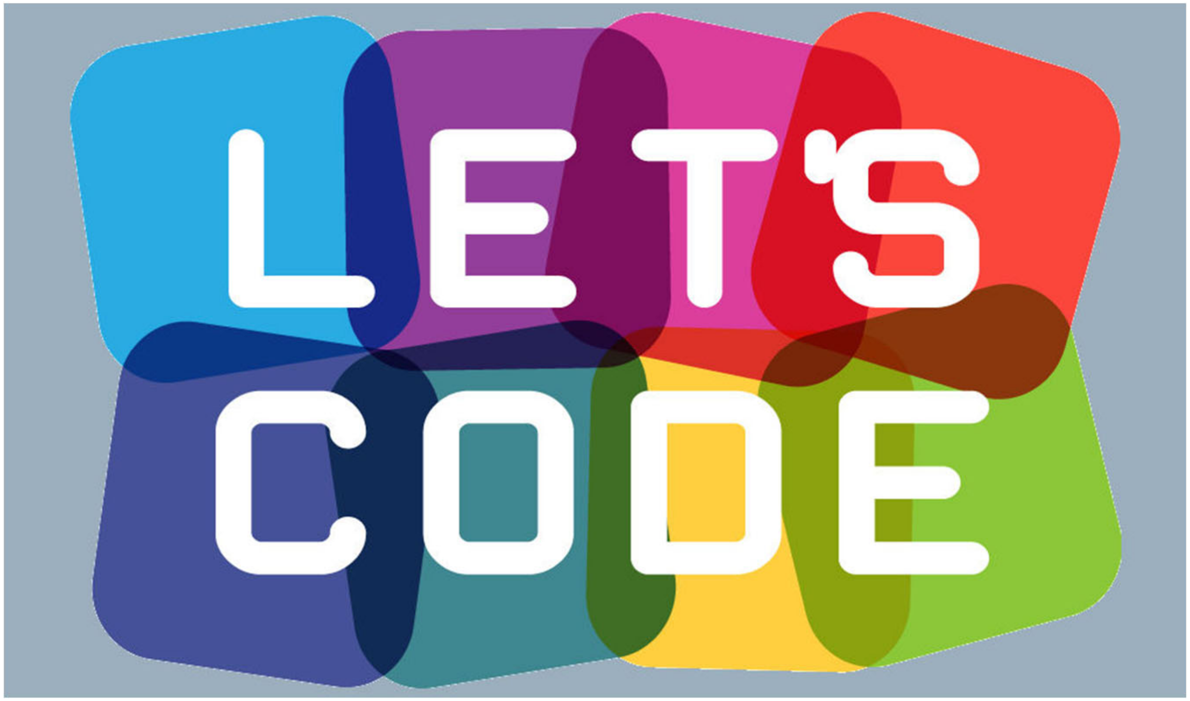
Your turn . . .

```
.data
arrayW  WORD 01000h,02000h,03000h
arrayD  DWORD 1,2,3,4
.code
mov ax, arrayW                  ;
mov ax,[arrayW+2]               ;
mov ax,[arrayW+4]               ;
mov eax,[arrayD+4]              ; EAX = 00000002h
```

What will happen when they run?

Write a program that sums the elements of a WORD array that is initialized with 080h,066h,0A5h

Use base addressing



Write a program that sums the elements of a ~~WORD~~ array
that is initialized with 080h,066h,0A5h

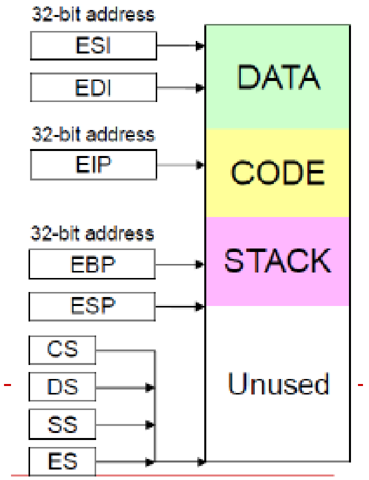
BYTE

Use base addressing

Solution(s)

```
.data
myBytes BYTE 080h,066h,0A5h
```

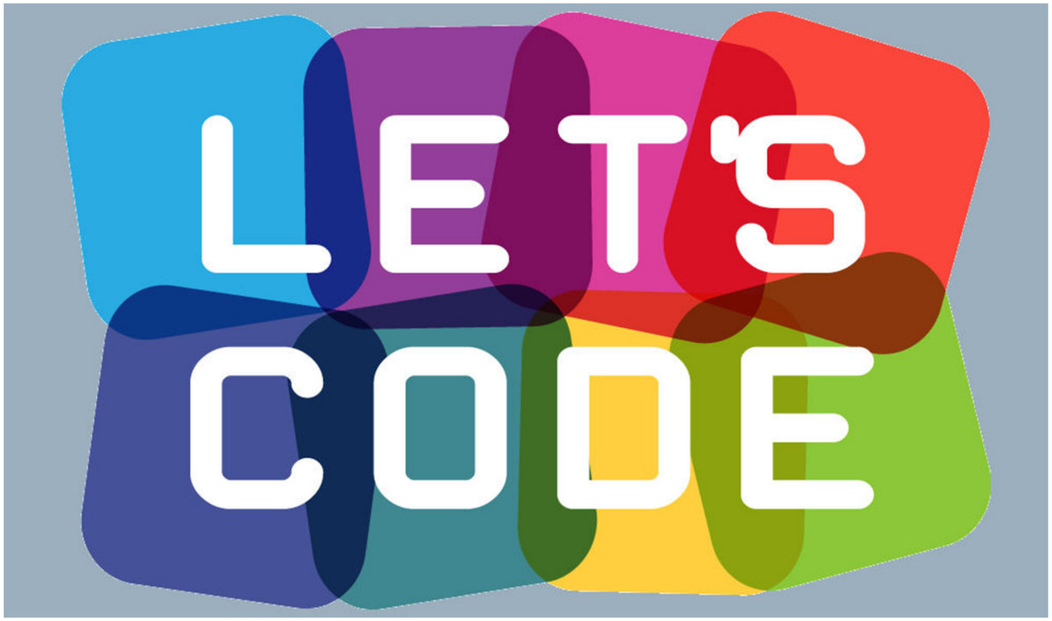
```
mov al, myBytes         ;al=080h
add al,[myBytes+1]      ;al=0E6h
add al,[myBytes+2]      ;al=018bh
```



base address = 0
for all segments

Any other possibilities?

Write a program that rearranges the values of three double-word values in an array initialized with 1,2,3 as: 3, 1, 2.



DWs 1,2,3 array order to 3,1,2

Solution

- **Step1:** copy the 1st element into EAX and exchange it with the element in the 2nd position.
- **Step 2:** Exchange EAX with the 3rd element and copy the element in EAX to the first array position.

```
.data
    arrayD DWORD 1,2,3
.code
        mov eax,arrayD
        xchg eax,[arrayD+4]
        xchg eax,[arrayD+8]
        mov  arrayD,eax
```

Your turn...

- Show the value of the destination operand after each of the following instructions executes:

```
.data
myByte BYTE 0FFh, 0
.code
    mov al,myByte
    mov ah,[myByte+1]
    dec ah
    inc al
    dec ax
```

Your turn...

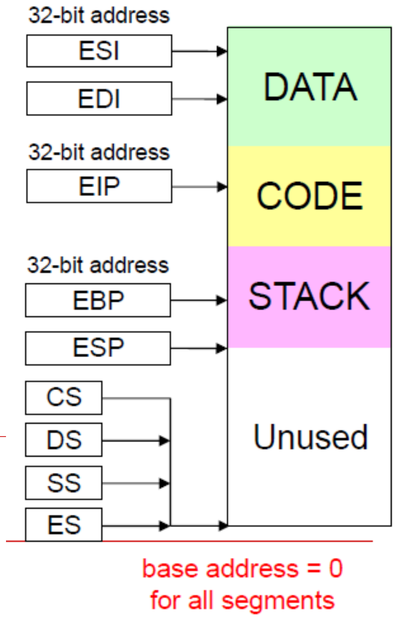
- Show the value of the destination operand after each of the following instructions executes:

```
.data
myByte BYTE 0FFh, 0
.code
   mov al,myByte
   mov ah,[myByte+1]
   dec ah
   inc al
   dec ax
                      ; AL =   FFh
                      ; AH =   00h
                      ; AH =   FFh
                      ; AL =   00h
                      ; AX =   FEFF
```

Indirect Operands

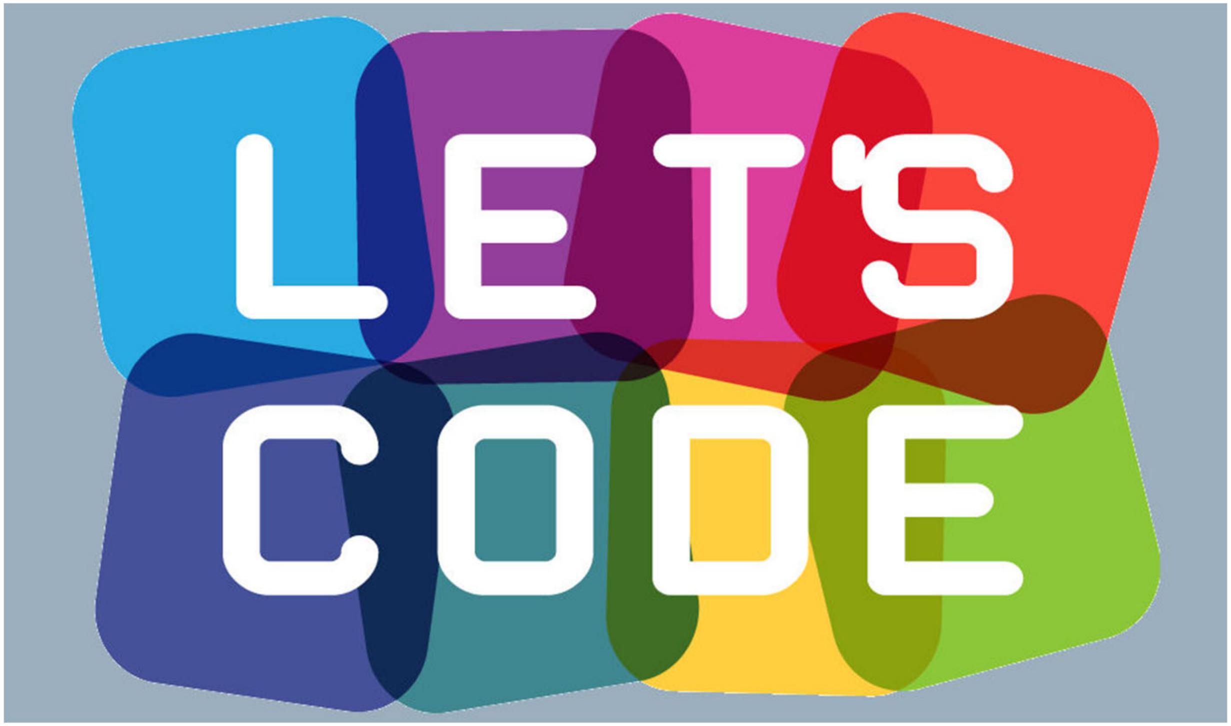
- An indirect operand holds the address of a variable, usually an array or string.
- It can be dereferenced by the assembler (just like a pointer).

```
.data
val1 BYTE 010h,020h,030h
.code
mov esi,OFFSET val1
mov al,[esi]                    ; dereference ESI (AL = 10h)

inc esi
mov al,[esi]
                                ; AL = 020h
inc esi
mov al,[esi]
                                ; AL = 030h
```



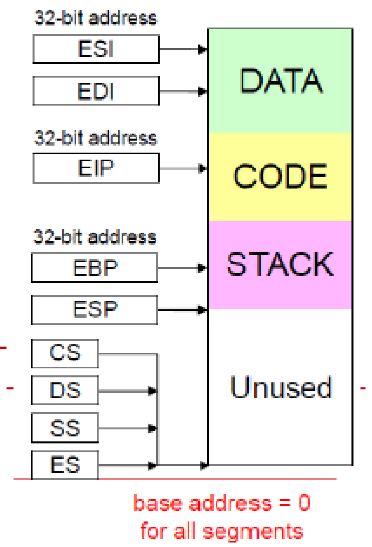
Write a program that sums the elements of a WORD array that is initialized with 01000h,02000h,03000h

Use indirect addressing



Write a program that sums the elements of a WORD array that is initialized with 01000h,02000h,03000h

Use indirect addressing



Solution

```
.data
    arrayW WORD 01000h,02000h,03000h
.code
    mov esi,OFFSET arrayW
    mov ax,[esi]
    add esi,2                    ; or: add esi,TYPE arrayW
    add ax,[esi]
    add esi,2
    add ax,[esi]                 ; AX = sum of the array
```

The register in brackets must be incremented by a value that matches the array type

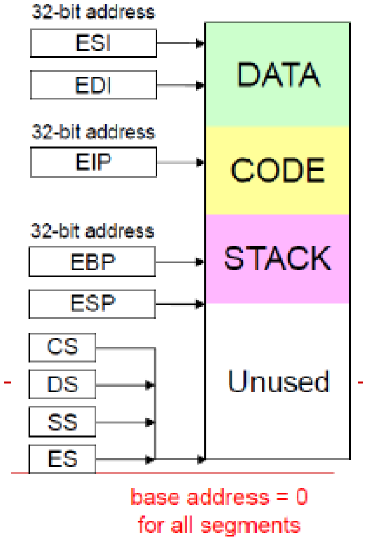
Indexed Operands

- An indexed operand adds a constant to a register to generate an effective address.
- There are two notational forms:

  `[label + reg]`

  `label[reg]`

- example



```
.data
arrayW WORD 01000h,02000h,03000h
.code
    mov esi,0
    mov ax,[arrayW + esi]           ; AX = 1000h
    mov ax, arrayW[esi]             ; alternate format
    add esi,2
    add ax,[arrayW + esi]
    etc.
```

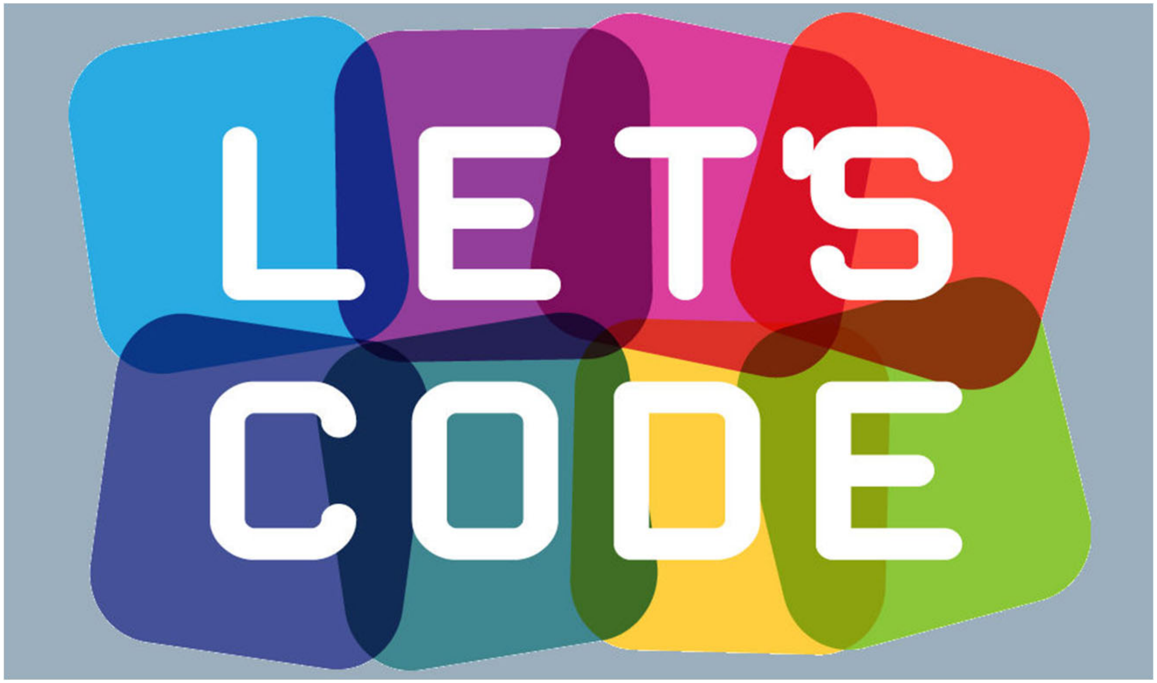
Index Scaling

- You can scale an indirect or indexed operand to the offset of an array element.
  - This is done by multiplying the index by the array's TYPE:

```
.data
arrayB BYTE  0,1,2,3,4,5
arrayW WORD  0,1,2,3,4,5
arrayD DWORD 0,1,2,3,4,5
.code
mov esi,4                             ; 5th element
mov al,arrayB[esi*TYPE arrayB]        ; 04
mov bx,arrayW[esi*TYPE arrayW]        ; 0004
mov edx,arrayD[esi*TYPE arrayD]   ; 00000004
```

Write a program that sums the elements of a WORD array that is initialized with 100h,200h,300h,400h

Use index addressing



Write a program that sums the elements of a WORD array that is initialized with 100h,200h,300h,400h

Use index addressing

Solution

- □ calculate the sum of an array of 16-bit integers using LOOP

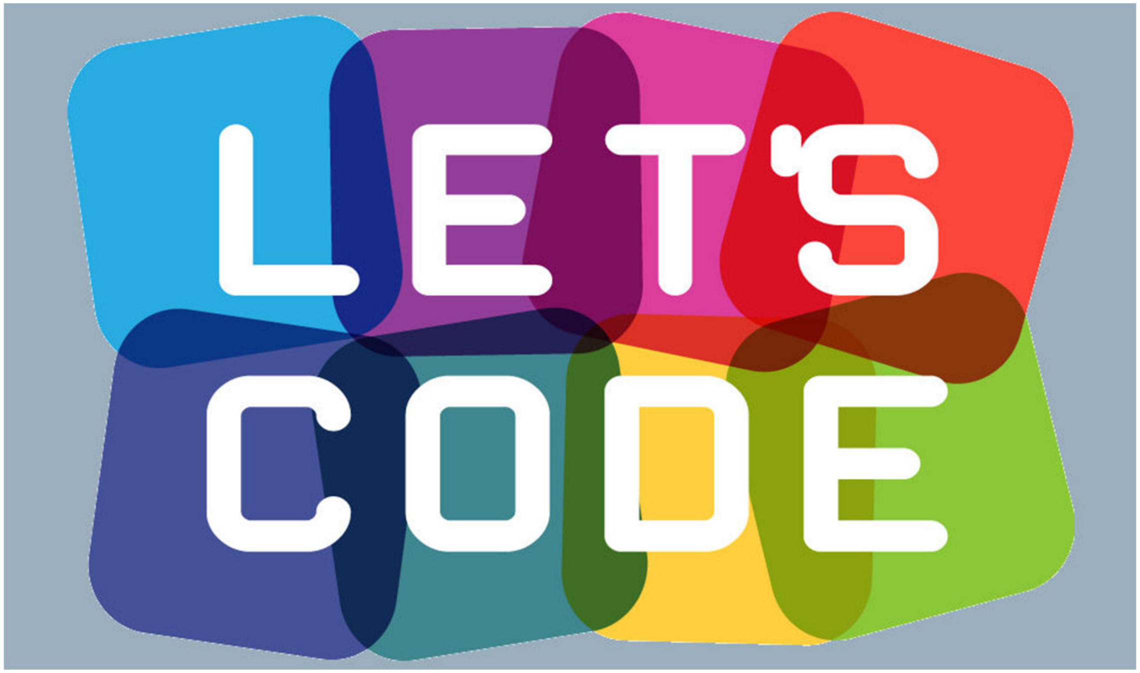
```
.data
intarray WORD 100h,200h,300h,400h
.code
    mov edi,OFFSET intarray       ; address of intarray
    mov ecx,LENGTHOF intarray     ; loop counter
    mov ax,0                      ; zero the accumulator
L1:
    add ax,[edi]                  ; add an integer
    add edi,TYPE intarray         ; point to next integer
    loop L1                       ; repeat until ECX = 0
```

Your turn . . .

- What changes would you make to the program on the previous slide if you were summing a *double-word* array?

Write Assembly code to copy a string from source to target

Use index addressing



copy a string using index addressing

Solution

good use of SIZEOF

```
.data
source  BYTE  "This is the source string",0
target  BYTE  SIZEOF source DUP(0)

.code
    mov  esi,0                     ; index register
    mov  ecx,SIZEOF source         ; loop counter
L1:
    mov  al,source[esi]            ; get char from source
    mov  target[esi],al            ; store it in the target
    inc  esi                       ; move to next character
    loop L1                        ; repeat for entire string
```

Your turn . . .

- Rewrite the program shown in the previous slide, using indirect addressing rather than indexed addressing.

laborious!

right?