Introduction to Assembly Language

COE 205

Computer Organization and Assembly Language

Computer Engineering Department

King Fahd University of Petroleum and Minerals

Presentation Outline

- Basic Elements of Assembly Language
- Flat Memory Program Template
- Example: Adding and Subtracting Integers
- Assembling, Linking, and Debugging Programs
- Defining Data
- Defining Symbolic Constants
- Data-Related Operators and Directives

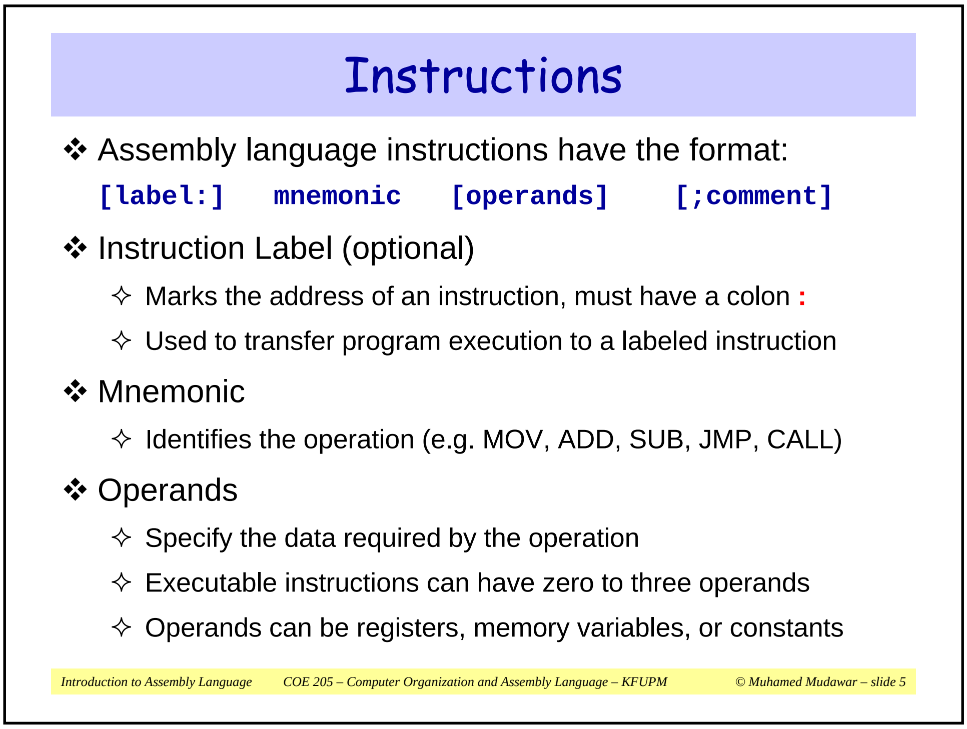
Constants

- ❖ Integer Constants
  - ✧ Examples: –10, 42d, 10001101b, 0FF3Ah, 777o
  - ✧ Radix: b = binary, d = decimal, h = hexadecimal, and o = octal
  - ✧ If no radix is given, the integer constant is decimal
  - ✧ A hexadecimal beginning with a letter must have a leading 0
- ❖ Character and String Constants
  - ✧ Enclose character or string in single or double quotes
  - ✧ Examples: 'A', "d", 'ABC', "ABC", '4096'
  - ✧ Embedded quotes: "single quote ' inside", 'double quote " inside'
  - ✧ Each ASCII character occupies a single byte

Assembly Language Statements

- ❖ Three types of statements in assembly language
  - ✧ Typically, one statement should appear on a line

1. Executable Instructions
   - ✧ Generate machine code for the processor to execute at runtime
   - ✧ Instructions tell the processor what to do
2. Assembler Directives
   - ✧ Provide information to the assembler while translating a program
   - ✧ Used to define data, select memory model, etc.
   - ✧ Non-executable: directives are not part of instruction set
3. Macros
   - ✧ Shorthand notation for a group of statements
   - ✧ Sequence of instructions, directives, or other macros

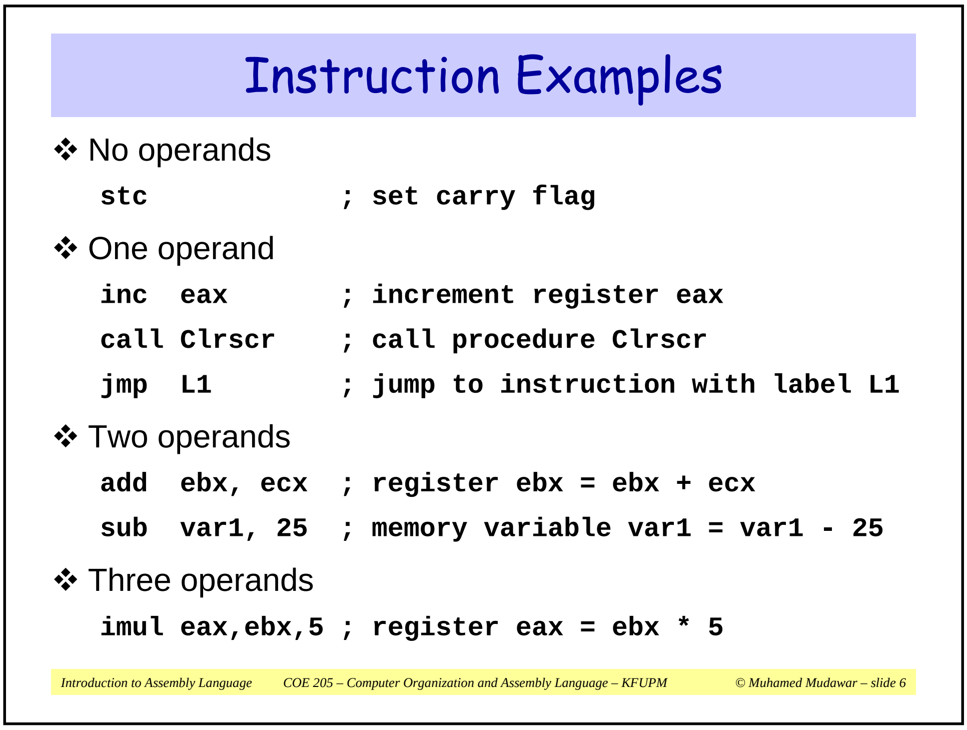


Instructions

- Assembly language instructions have the format:

```
[label:]   mnemonic   [operands]    [;comment]
```

- Instruction Label (optional)
  - Marks the address of an instruction, must have a colon **:**
  - Used to transfer program execution to a labeled instruction
- Mnemonic
  - Identifies the operation (e.g. MOV, ADD, SUB, JMP, CALL)
- Operands
  - Specify the data required by the operation
  - Executable instructions can have zero to three operands
  - Operands can be registers, memory variables, or constants



Instruction Examples

- No operands

```
stc             ; set carry flag
```

- One operand

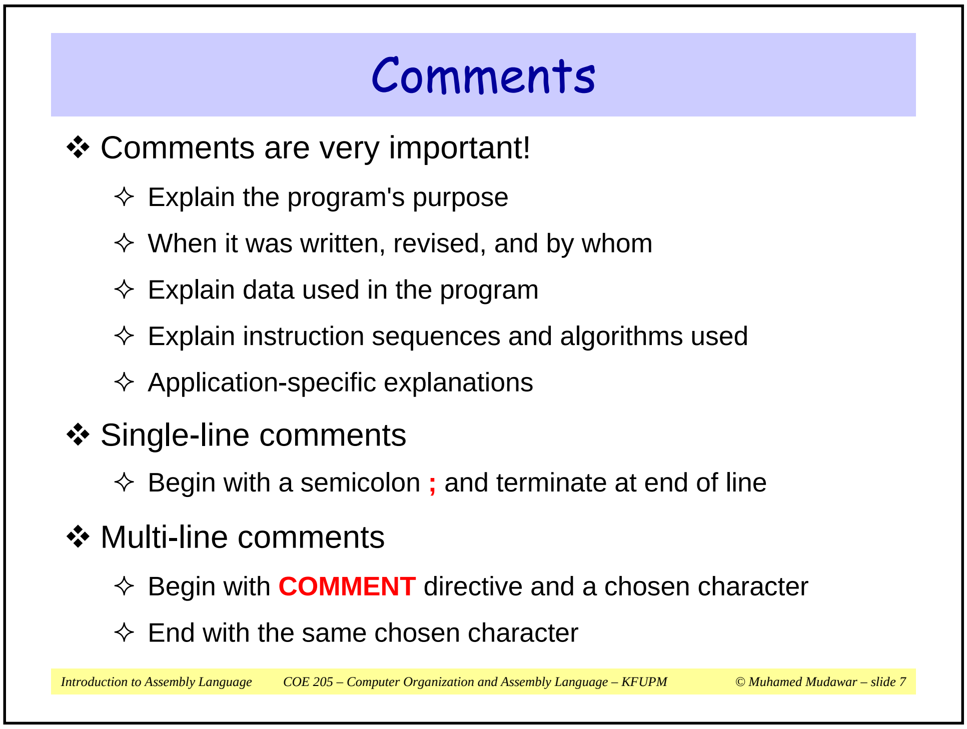
```
inc  eax        ; increment register eax
call Clrscr     ; call procedure Clrscr
jmp  L1         ; jump to instruction with label L1
```

- Two operands

```
add  ebx, ecx  ; register ebx = ebx + ecx
sub  var1, 25  ; memory variable var1 = var1 - 25
```

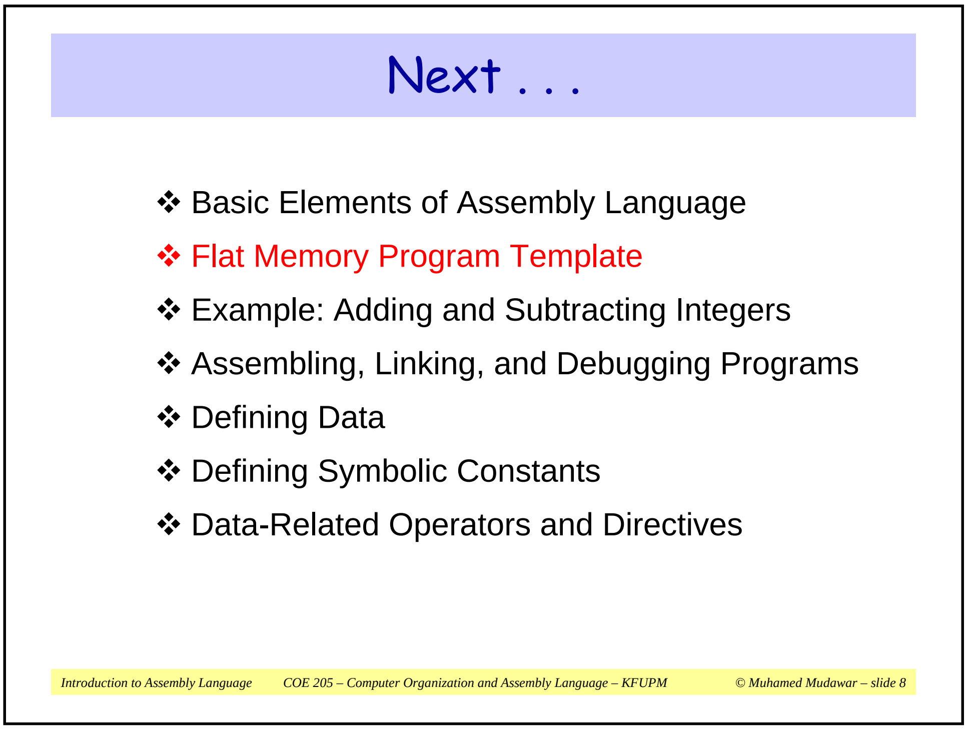
- Three operands

```
imul eax,ebx,5 ; register eax = ebx * 5
```



Comments

- ❖ Comments are very important!
  - ✧ Explain the program's purpose
  - ✧ When it was written, revised, and by whom
  - ✧ Explain data used in the program
  - ✧ Explain instruction sequences and algorithms used
  - ✧ Application-specific explanations
- ❖ Single-line comments
  - ✧ Begin with a semicolon **;** and terminate at end of line
- ❖ Multi-line comments
  - ✧ Begin with **COMMENT** directive and a chosen character
  - ✧ End with the same chosen character



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- ❖ Example: Adding and Subtracting Integers
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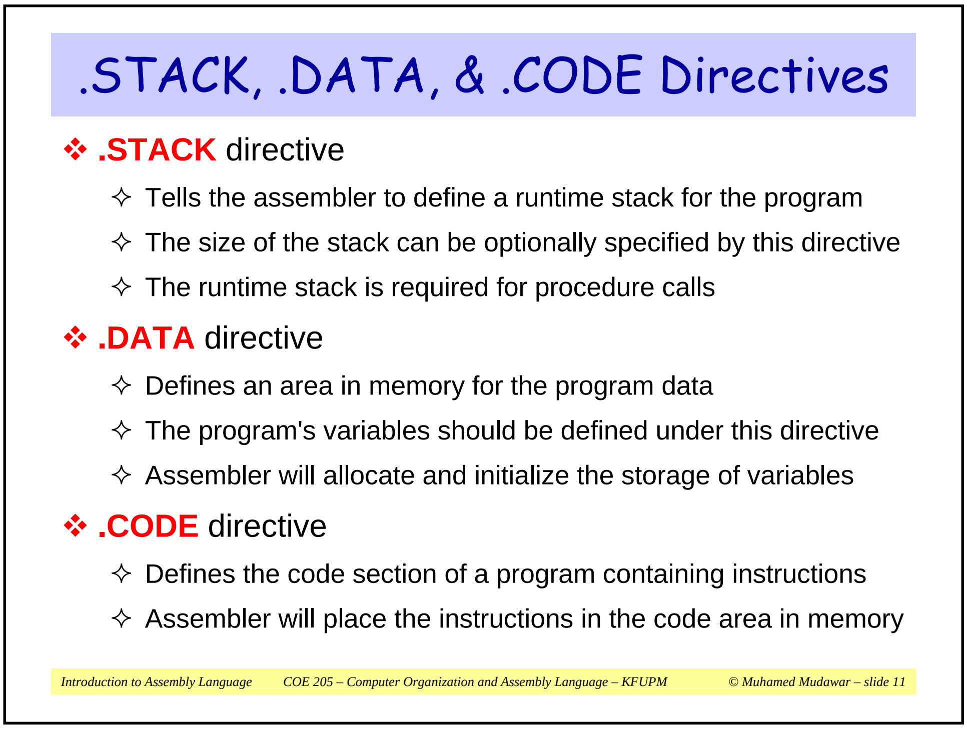
- ❖ Defining Symbolic Constants
- ❖ Data-Related Operators and Directives

Flat Memory Program Template

```
TITLE Flat Memory Program Template   (Template.asm)

; Program Description:
; Author:                      Creation Date:
; Modified by:                 Modification Date:

.686
.MODEL FLAT, STDCALL
.STACK

INCLUDE Irvine32.inc
.DATA
    ; (insert variables here)
.CODE
main PROC
    ; (insert executable instructions here)
    exit
main ENDP
    ; (insert additional procedures here)
END main
```

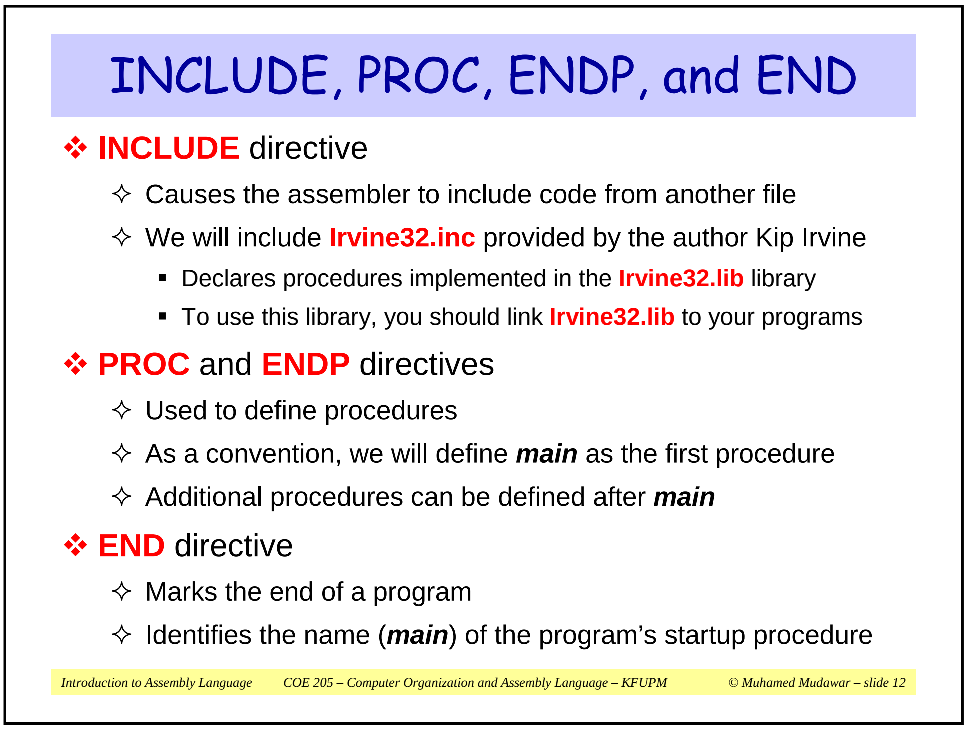
TITLE and .MODEL Directives

- **TITLE** line (optional)
  - Contains a brief heading of the program and the disk file name
- **.MODEL** directive
  - Specifies the memory configuration
  - For our purposes, the **FLAT** memory model will be used
    - Linear 32-bit address space (no segmentation)
  - **STDCALL** directive tells the assembler to use …
    - Standard conventions for names and procedure calls
- **.686** processor directive
  - Used **before** the **.MODEL** directive
  - Program can use instructions of Pentium P6 architecture
  - At least the **.386** directive should be used with the **FLAT** model



.STACK, .DATA, & .CODE Directives

- **.STACK** directive
  - Tells the assembler to define a runtime stack for the program
  - The size of the stack can be optionally specified by this directive
  - The runtime stack is required for procedure calls
- **.DATA** directive
  - Defines an area in memory for the program data
  - The program's variables should be defined under this directive
  - Assembler will allocate and initialize the storage of variables
- **.CODE** directive
  - Defines the code section of a program containing instructions
  - Assembler will place the instructions in the code area in memory



INCLUDE, PROC, ENDP, and END

- **INCLUDE** directive
  - Causes the assembler to include code from another file
  - We will include **Irvine32.inc** provided by the author Kip Irvine
    - Declares procedures implemented in the **Irvine32.lib** library
    - To use this library, you should link **Irvine32.lib** to your programs
- **PROC** and **ENDP** directives
  - Used to define procedures
  - As a convention, we will define ***main*** as the first procedure
  - Additional procedures can be defined after ***main***
- **END** directive
  - Marks the end of a program
  - Identifies the name (***main***) of the program's startup procedure

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Adding and Subtracting Integers

```
TITLE Add and Subtract           (AddSub.asm)
; This program adds and subtracts 32-bit integers.
.686
.MODEL FLAT, STDCALL
.STACK
INCLUDE Irvine32.inc

.CODE
main PROC
   mov eax,10000h             ; EAX = 10000h
   add eax,40000h             ; EAX = 50000h
   sub eax,20000h             ; EAX = 30000h
   call DumpRegs              ; display registers
   exit
main ENDP
END main
```

Example of Console Output

Procedure **DumpRegs** is defined in **Irvine32.lib** library

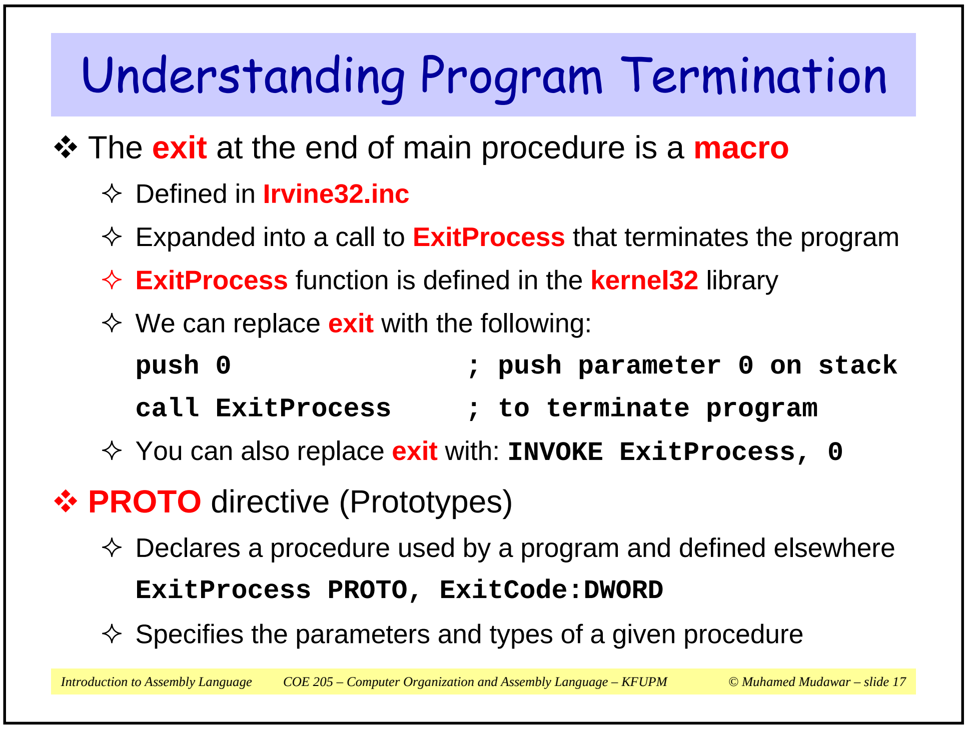
It produces the following console output,

showing registers and flags:

```
EAX=00030000  EBX=7FFDF000  ECX=00000101  EDX=FFFFFFFF
ESI=00000000  EDI=00000000  EBP=0012FFF0  ESP=0012FFC4
EIP=00401024  EFL=00000206  CF=0  SF=0  ZF=0  OF=0
```

Suggested Coding Standards

- Some approaches to capitalization
  - Capitalize nothing
  - Capitalize everything
  - Capitalize all reserved words, mnemonics and register names
  - Capitalize only directives and operators
  - MASM is NOT case sensitive: does not matter what case is used
- Other suggestions
  - Use meaningful identifier names
  - Use blank lines between procedures
  - Use indentation and spacing to align instructions and comments
    - Use tabs to indent instructions, but do not indent labels
    - Align the comments that appear after the instructions



Understanding Program Termination

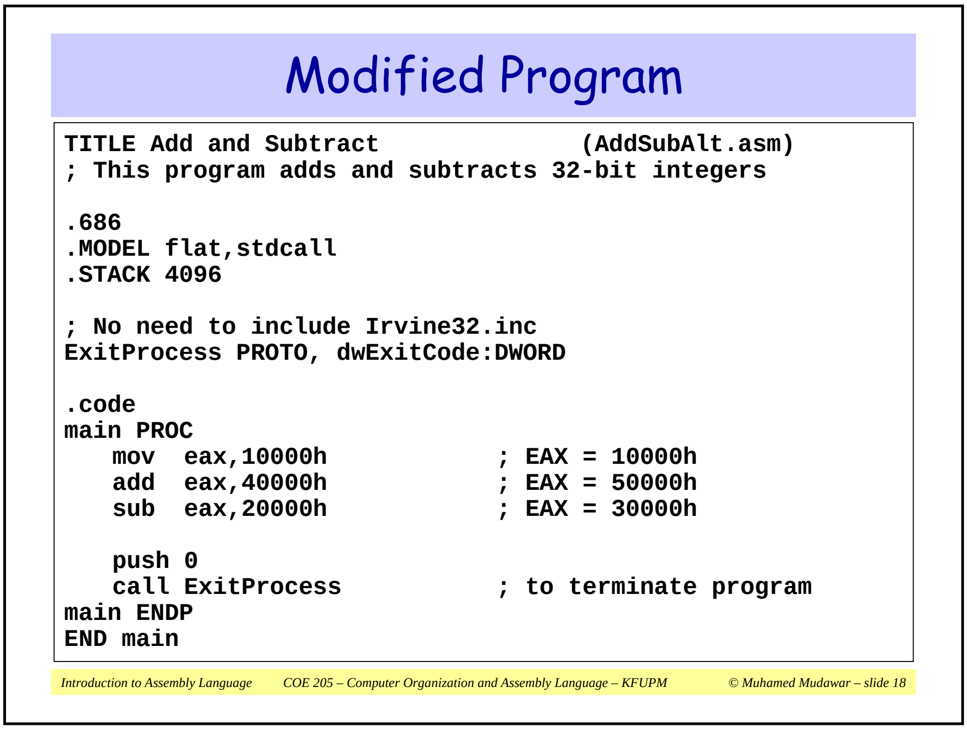
- The **exit** at the end of main procedure is a **macro**
  - Defined in **Irvine32.inc**
  - Expanded into a call to **ExitProcess** that terminates the program
  - **ExitProcess** function is defined in the **kernel32** library
  - We can replace **exit** with the following:

```
push 0                ; push parameter 0 on stack
call ExitProcess      ; to terminate program
```

  - You can also replace **exit** with: `INVOKE ExitProcess, 0`
- **PROTO** directive (Prototypes)
  - Declares a procedure used by a program and defined elsewhere

```
ExitProcess PROTO, ExitCode:DWORD
```

  - Specifies the parameters and types of a given procedure



Modified Program

```
TITLE Add and Subtract                  (AddSubAlt.asm)
; This program adds and subtracts 32-bit integers

.686
.MODEL flat,stdcall
.STACK 4096

; No need to include Irvine32.inc
ExitProcess PROTO, dwExitCode:DWORD

.code
main PROC
    mov  eax,10000h             ; EAX = 10000h
    add  eax,40000h             ; EAX = 50000h
    sub  eax,20000h             ; EAX = 30000h

    push 0
    call ExitProcess            ; to terminate program
main ENDP
END main
```

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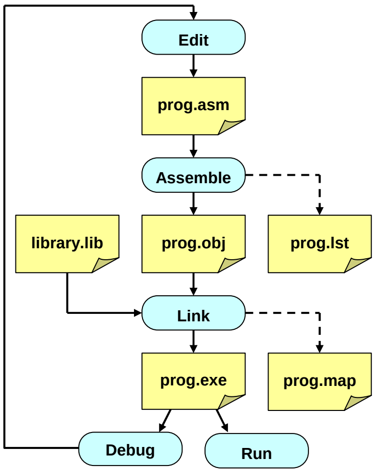
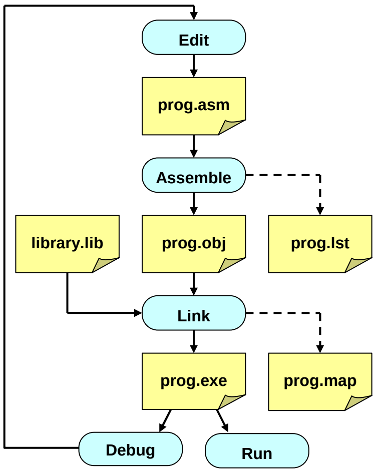
Assemble-Link-Debug Cycle

- ❖ Editor
  - ✧ Write new (**.asm**) programs
  - ✧ Make changes to existing ones
- ❖ Assembler: **ML.exe** program
  - ✧ Translate (**.asm**) file into object (**.obj**) file in machine language
  - ✧ Can produce a listing (**.lst**) file that shows the work of assembler
- ❖ Linker: **LINK32.exe** program
  - ✧ Combine object (**.obj**) files with link library (**.lib**) files
  - ✧ Produce executable (**.exe**) file
  - ✧ Can produce optional (**.map**) file



Assemble-Link-Debug Cycle - cont'd

- ❖ **MAKE32.bat**
  - ✧ Batch command file
  - ✧ Assemble and link in one step
- ❖ Debugger: **WINDBG.exe**
  - ✧ Trace program execution
    - Either step-by-step, or
    - Use breakpoints
  - ✧ View
    - Source (**.asm**) code
    - Registers
    - Memory by name & by address
    - Modify register & memory content
  - ✧ Discover errors and go back to the editor to fix the program bugs



Listing File

- ❖ Use it to see how your program is assembled
- ❖ Contains
  - ✧ Source code
  - ✧ Object code
  - ✧ Relative addresses
  - ✧ Segment names
  - ✧ Symbols
    - Variables
    - Procedures
    - Constants

Object & source code in a listing file

```
00000000                     .code
00000000                     main PROC
00000000  B8 00060000            mov eax, 60000h
00000005  05 00080000            add eax, 80000h
0000000A  2D 00020000            sub eax, 20000h

0000000F  6A 00                  push 0
00000011  E8 00000000 E          call ExitProcess
00000016                     main ENDP
                             END main
```

Relative Addresses

object code (hexadecimal)

source code

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Intrinsic Data Types

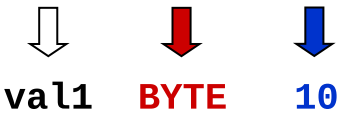
- ❖ BYTE, SBYTE
  - ✧ 8-bit unsigned integer
  - ✧ 8-bit signed integer
- ❖ WORD, SWORD
  - ✧ 16-bit unsigned integer
  - ✧ 16-bit signed integer
- ❖ DWORD, SDWORD
  - ✧ 32-bit unsigned integer
  - ✧ 32-bit signed integer
- ❖ QWORD, TBYTE
  - ✧ 64-bit integer
  - ✧ 80-bit integer

- ❖ REAL4
  - ✧ IEEE single-precision float
  - ✧ Occupies 4 bytes
- ❖ REAL8
  - ✧ IEEE double-precision
  - ✧ Occupies 8 bytes
- ❖ REAL10
  - ✧ IEEE extended-precision
  - ✧ Occupies 10 bytes

Data Definition Statement

- ❖ Sets aside storage in memory for a variable
- ❖ May optionally assign a name (label) to the data
- ❖ Syntax:

[*name*] *directive* *initializer* [, *initializer*] . . .



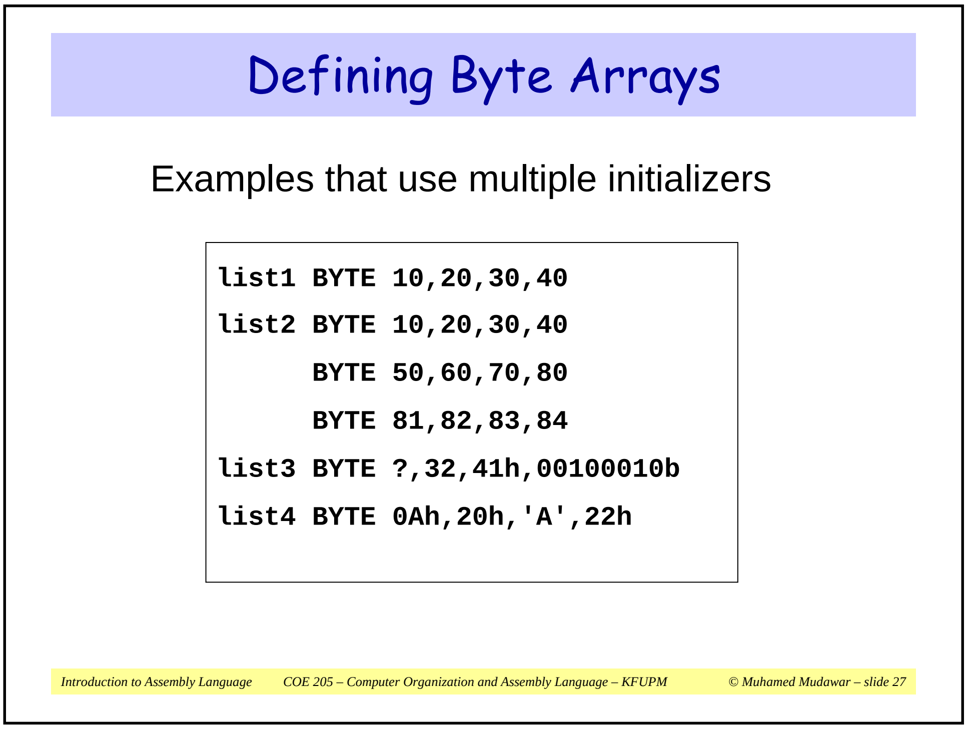
- ❖ All initializers become binary data in memory

Defining BYTE and SBYTE Data

Each of the following defines a single byte of storage:

```
value1 BYTE 'A'             ; character constant
value2 BYTE 0               ; smallest unsigned byte
value3 BYTE 255             ; largest unsigned byte
value4 SBYTE -128           ; smallest signed byte
value5 SBYTE +127           ; largest signed byte
value6 BYTE ?               ; uninitialized byte
```

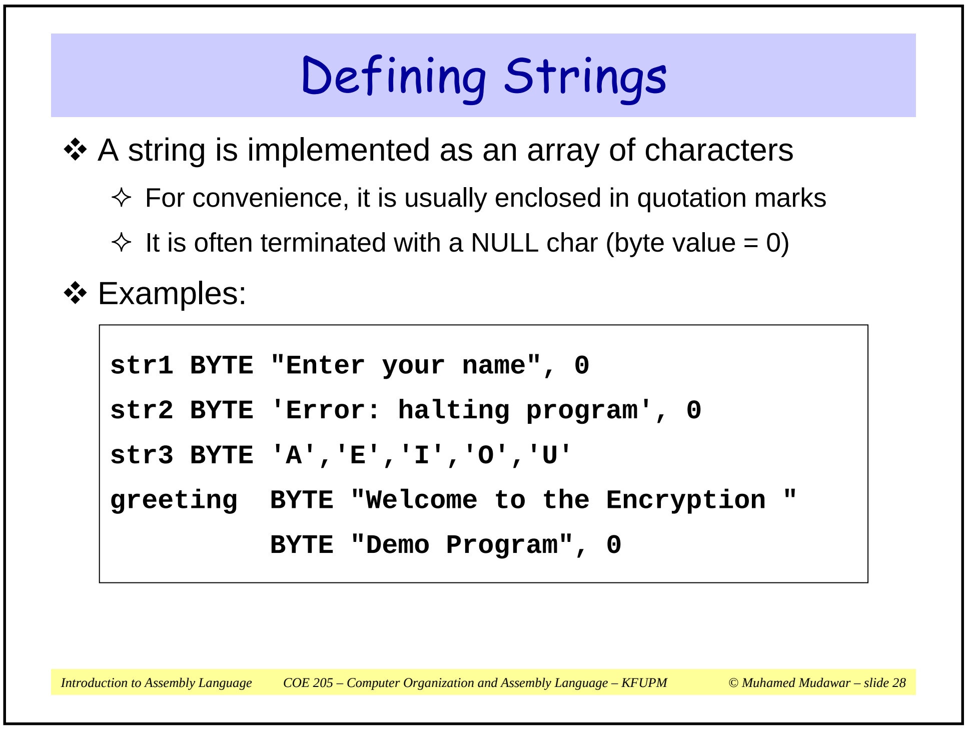
- MASM does not prevent you from initializing a BYTE with a negative value, but it's considered poor style.
- If you declare a SBYTE variable, the Microsoft debugger will automatically display its value in decimal with a leading sign.



Defining Byte Arrays

Examples that use multiple initializers

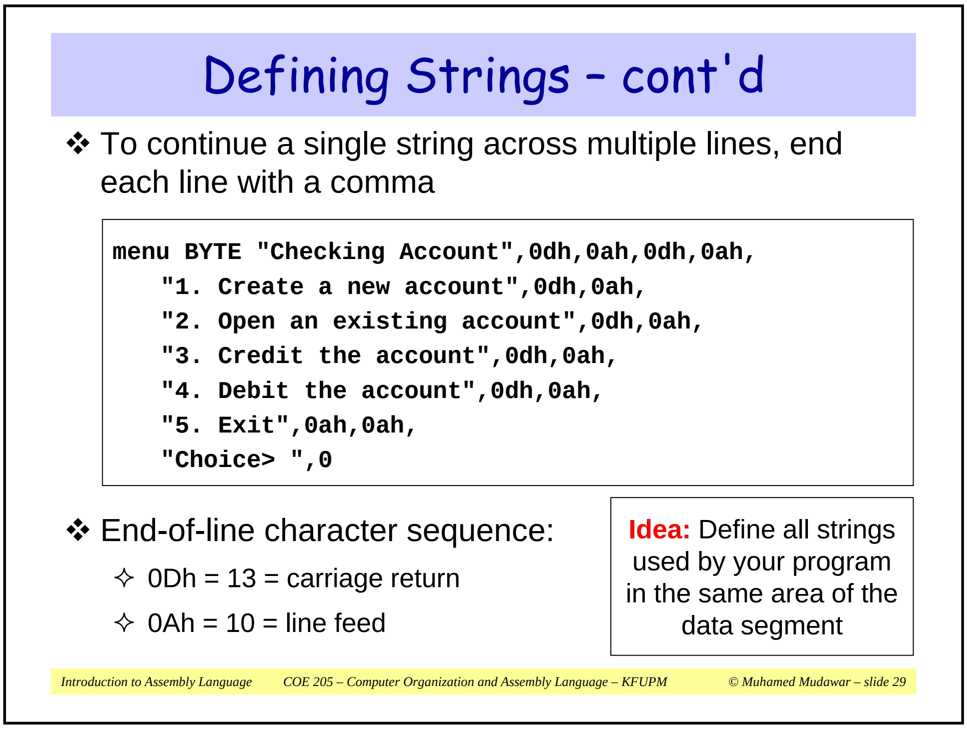
```
list1 BYTE 10,20,30,40
list2 BYTE 10,20,30,40
      BYTE 50,60,70,80
      BYTE 81,82,83,84
list3 BYTE ?,32,41h,00100010b
list4 BYTE 0Ah,20h,'A',22h
```



Defining Strings

- A string is implemented as an array of characters
  - For convenience, it is usually enclosed in quotation marks
  - It is often terminated with a NULL char (byte value = 0)
- 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 "
          BYTE "Demo Program", 0
```



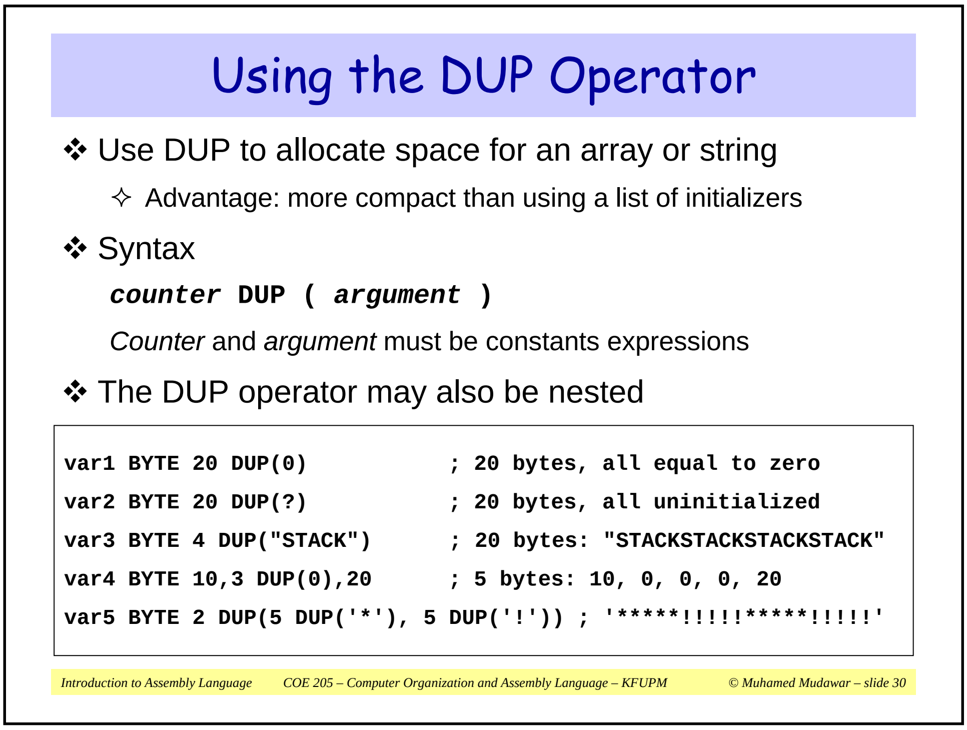
Defining Strings - cont'd

- To continue a single string across multiple lines, end each line with a comma

```
menu BYTE "Checking Account",0dh,0ah,0dh,0ah,
    "1. Create a new account",0dh,0ah,
    "2. Open an existing account",0dh,0ah,
    "3. Credit the account",0dh,0ah,
    "4. Debit the account",0dh,0ah,
    "5. Exit",0ah,0ah,
    "Choice> ",0
```

- End-of-line character sequence:
  - 0Dh = 13 = carriage return
  - 0Ah = 10 = line feed

Idea: Define all strings used by your program in the same area of the data segment



Using the DUP Operator

- Use DUP to allocate space for an array or string
  - Advantage: more compact than using a list of initializers
- Syntax

  ***counter* DUP (*argument*)**

  Counter and *argument* must be constants expressions
- The DUP operator may also be nested

```
var1 BYTE 20 DUP(0)            ; 20 bytes, all equal to zero
var2 BYTE 20 DUP(?)            ; 20 bytes, all uninitialized
var3 BYTE 4 DUP("STACK")       ; 20 bytes: "STACKSTACKSTACKSTACK"
var4 BYTE 10,3 DUP(0),20       ; 5 bytes: 10, 0, 0, 0, 20
var5 BYTE 2 DUP(5 DUP('*'), 5 DUP('!')) ; '*****!!!!!*****!!!!!'
```

Defining 16-bit and 32-bit Data

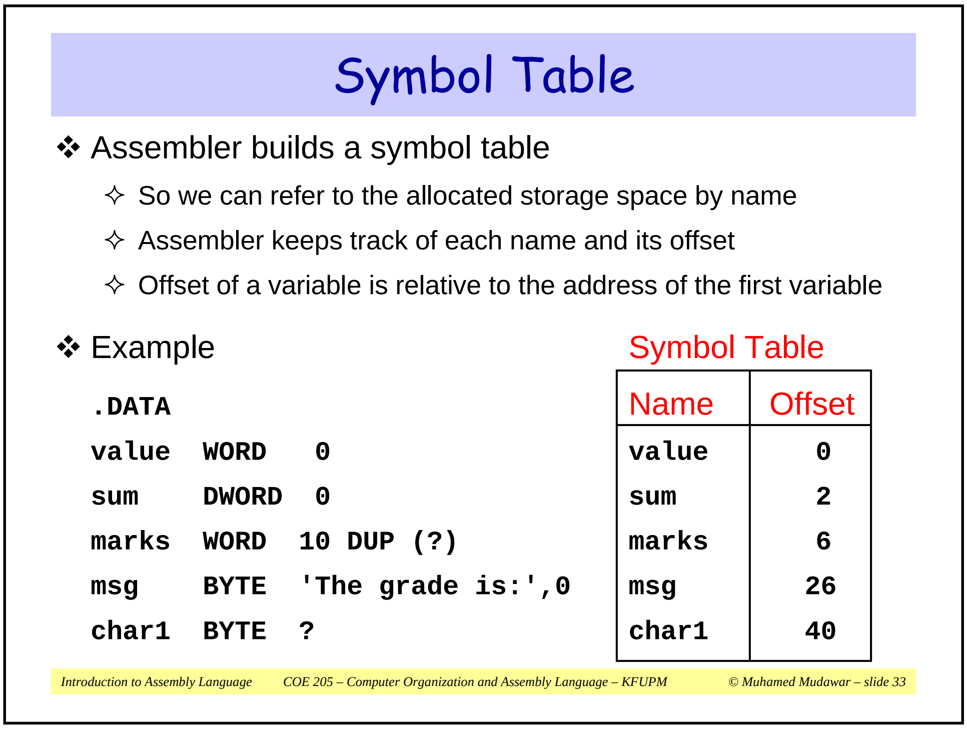
- Define storage for 16-bit and 32-bit integers
  - Signed and Unsigned
  - Single or multiple initial values

```
word1  WORD   65535        ; largest unsigned 16-bit value
word2  SWORD  –32768       ; smallest signed 16-bit value
word3  WORD   "AB"         ; two characters fit in a WORD
array1 WORD   1,2,3,4,5    ; array of 5 unsigned words
array2 SWORD  5 DUP(?)     ; array of 5 signed words
dword1 DWORD  0ffffffffh   ; largest unsigned 32-bit value
dword2 SDWORD –2147483648  ; smallest signed 32-bit value
array3 DWORD  20 DUP(?)  ; 20 unsigned double words
array4 SDWORD –3,–2,–1,0,1 ; 5 signed double words
```

QWORD, TBYTE, and REAL Data

- QWORD and TBYTE
  - Define storage for 64-bit and 80-bit integers
  - Signed and Unsigned
- REAL4, REAL8, and REAL10
  - Defining storage for 32-bit, 64-bit, and 80-bit floating-point data

```
quad1 QWORD  1234567812345678h
val1  TBYTE  1000000000123456789Ah
rVal1 REAL4  -2.1
rVal2 REAL8  3.2E-260
rVal3 REAL10 4.6E+4096
array REAL4  20 DUP(0.0)
```



Symbol Table

❖ Assembler builds a symbol table

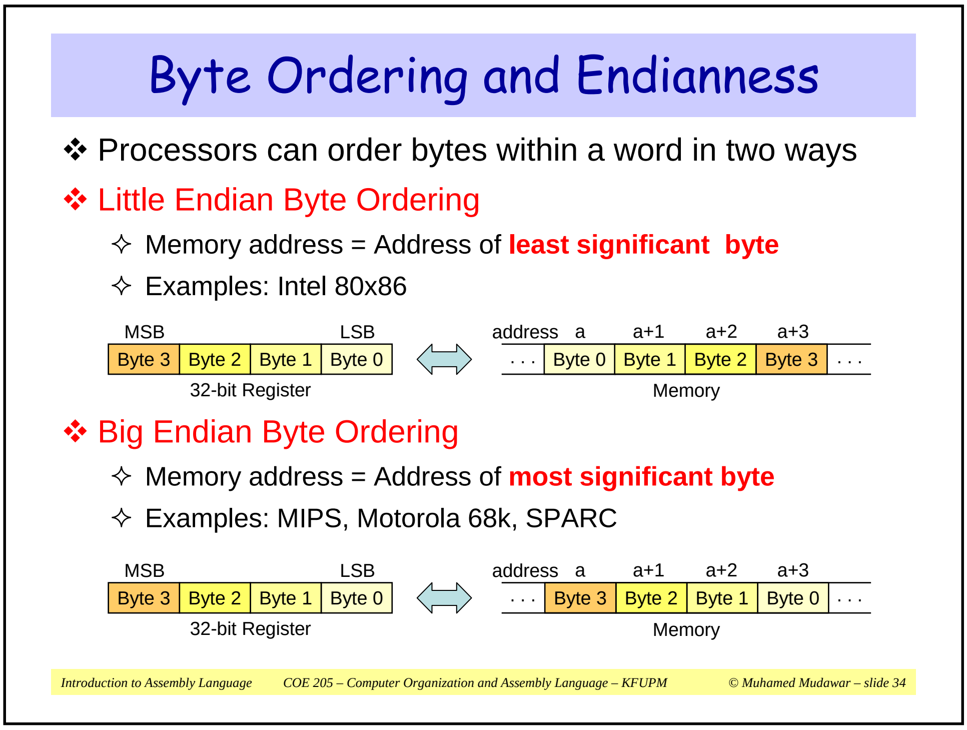
- ✧ So we can refer to the allocated storage space by name
- ✧ Assembler keeps track of each name and its offset
- ✧ Offset of a variable is relative to the address of the first variable

❖ Example

```
.DATA
value   WORD    0
sum     DWORD   0
marks   WORD   10 DUP (?)
msg     BYTE   'The grade is:',0
char1   BYTE   ?
```

Symbol Table

Name	Offset
value	0
sum	2
marks	6
msg	26
char1	40



Byte Ordering and Endianness

❖ Processors can order bytes within a word in two ways

❖ Little Endian Byte Ordering

- ✧ Memory address = Address of **least significant byte**
- ✧ Examples: Intel 80x86

MSB			LSB
Byte 3	Byte 2	Byte 1	Byte 0

32-bit Register

address	a	a+1	a+2	a+3	
. . .	Byte 0	Byte 1	Byte 2	Byte 3	. . .

Memory

❖ Big Endian Byte Ordering

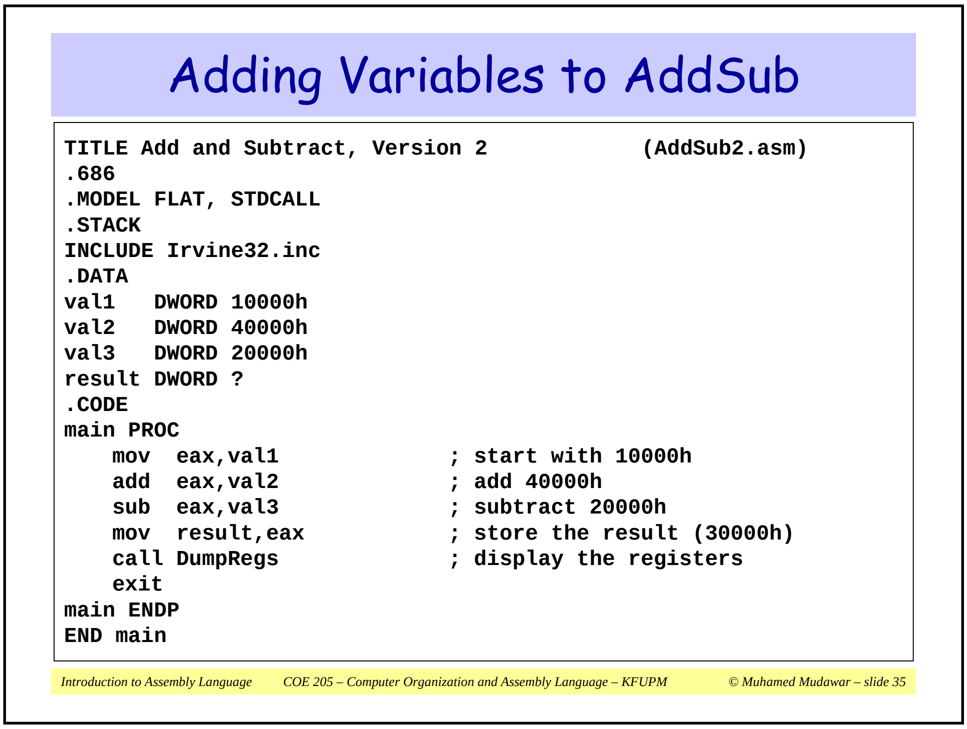
- ✧ Memory address = Address of **most significant byte**
- ✧ Examples: MIPS, Motorola 68k, SPARC

MSB			LSB
Byte 3	Byte 2	Byte 1	Byte 0

32-bit Register

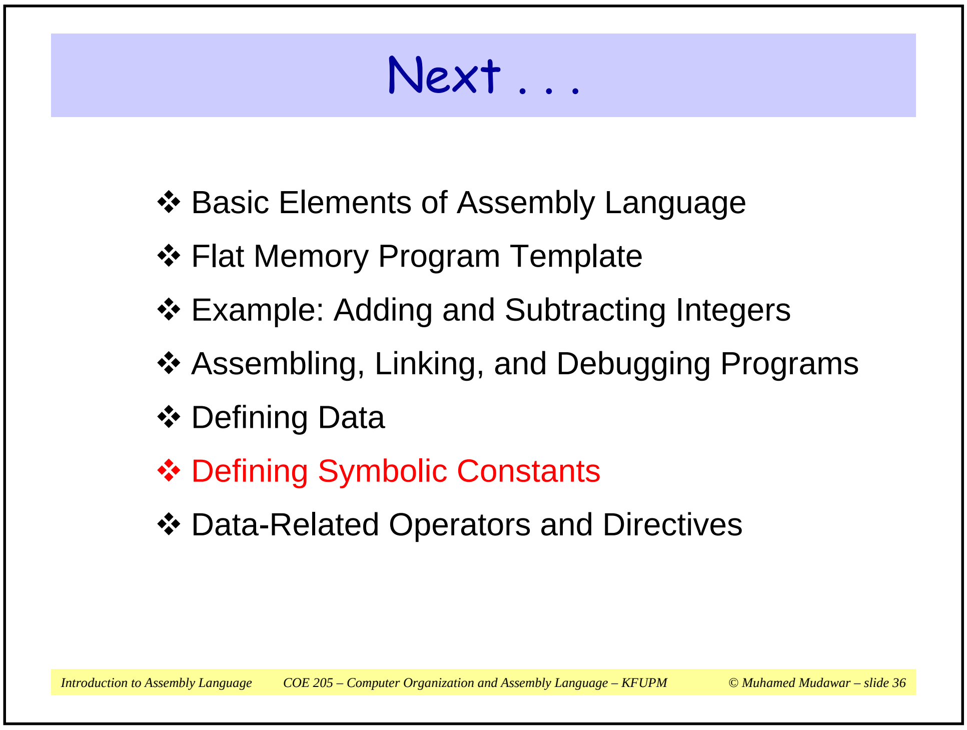
address	a	a+1	a+2	a+3	
. . .	Byte 3	Byte 2	Byte 1	Byte 0	. . .

Memory



Adding Variables to AddSub

```
TITLE Add and Subtract, Version 2            (AddSub2.asm)
.686
.MODEL FLAT, STDCALL
.STACK
INCLUDE Irvine32.inc
.DATA
val1   DWORD 10000h
val2   DWORD 40000h
val3   DWORD 20000h
result DWORD ?
.CODE
main PROC
    mov  eax,val1              ; start with 10000h
    add  eax,val2              ; add 40000h
    sub  eax,val3              ; subtract 20000h
    mov  result,eax            ; store the result (30000h)
    call DumpRegs              ; display the registers
    exit
main ENDP
END main
```



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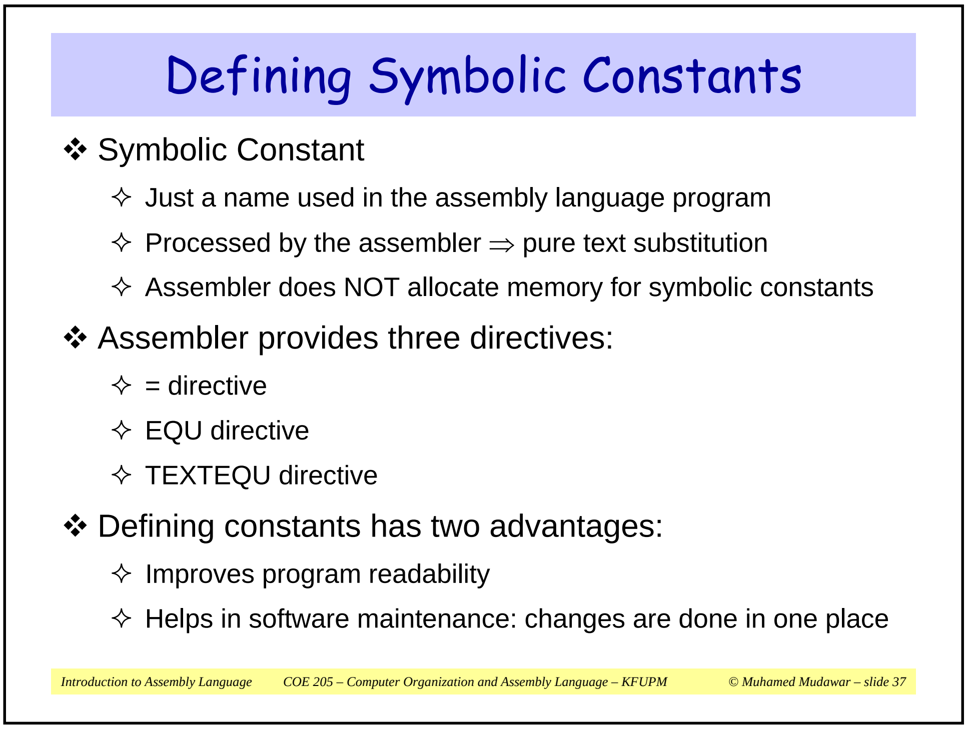
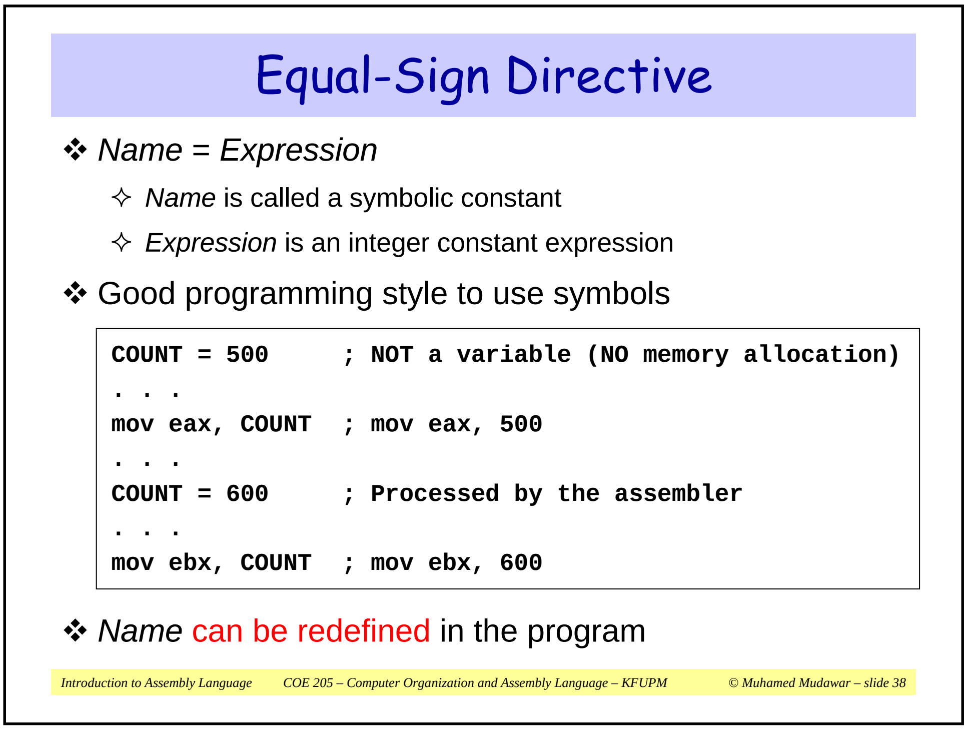


Defining Symbolic Constants

- Symbolic Constant
  - Just a name used in the assembly language program
  - Processed by the assembler ⇒ pure text substitution
  - Assembler does NOT allocate memory for symbolic constants
- Assembler provides three directives:
  - = directive
  - EQU directive
  - TEXTEQU directive
- Defining constants has two advantages:
  - Improves program readability
  - Helps in software maintenance: changes are done in one place

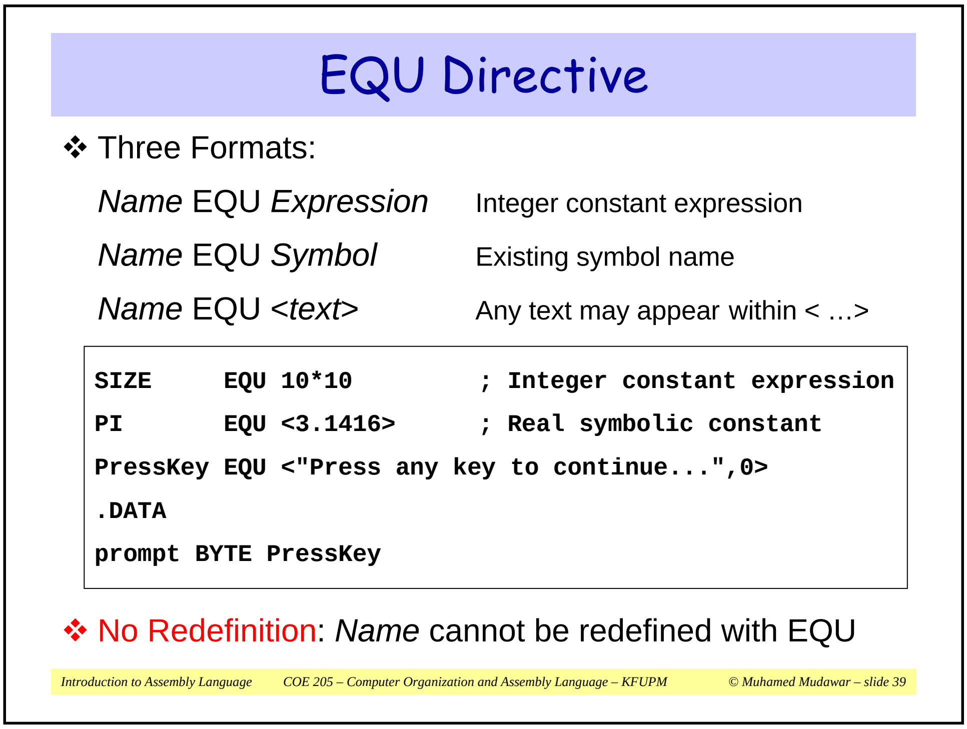


Equal-Sign Directive

- *Name* = *Expression*
  - *Name* is called a symbolic constant
  - *Expression* is an integer constant expression
- Good programming style to use symbols

```
COUNT = 500     ; NOT a variable (NO memory allocation)
. . .
mov eax, COUNT  ; mov eax, 500
. . .
COUNT = 600     ; Processed by the assembler
. . .
mov ebx, COUNT  ; mov ebx, 600
```

- *Name* can be redefined in the program



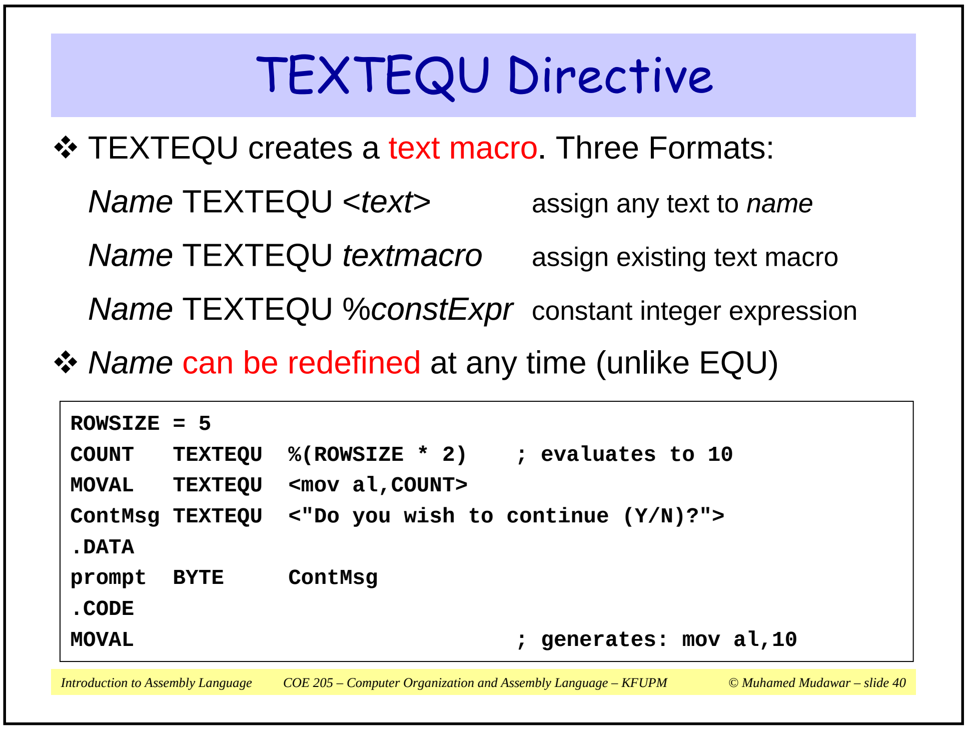
EQU Directive

❖ Three Formats:

Name EQU *Expression*	Integer constant expression
Name EQU *Symbol*	Existing symbol name
Name EQU <*text*>	Any text may appear within < …>

```
SIZE     EQU 10*10         ; Integer constant expression
PI       EQU <3.1416>      ; Real symbolic constant
PressKey EQU <"Press any key to continue...",0>
.DATA
prompt  BYTE PressKey
```

❖ No Redefinition: *Name* cannot be redefined with EQU



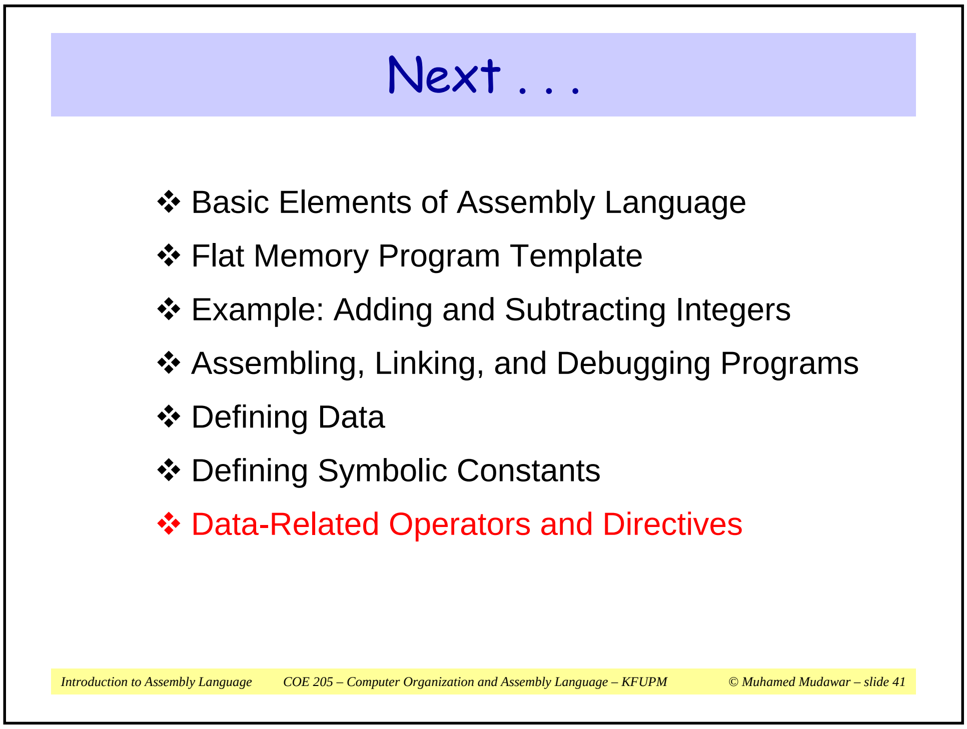
TEXTEQU Directive

❖ TEXTEQU creates a text macro. Three Formats:

Name TEXTEQU <*text*>	assign any text to *name*
Name TEXTEQU *textmacro*	assign existing text macro
Name TEXTEQU %*constExpr*	constant integer expression

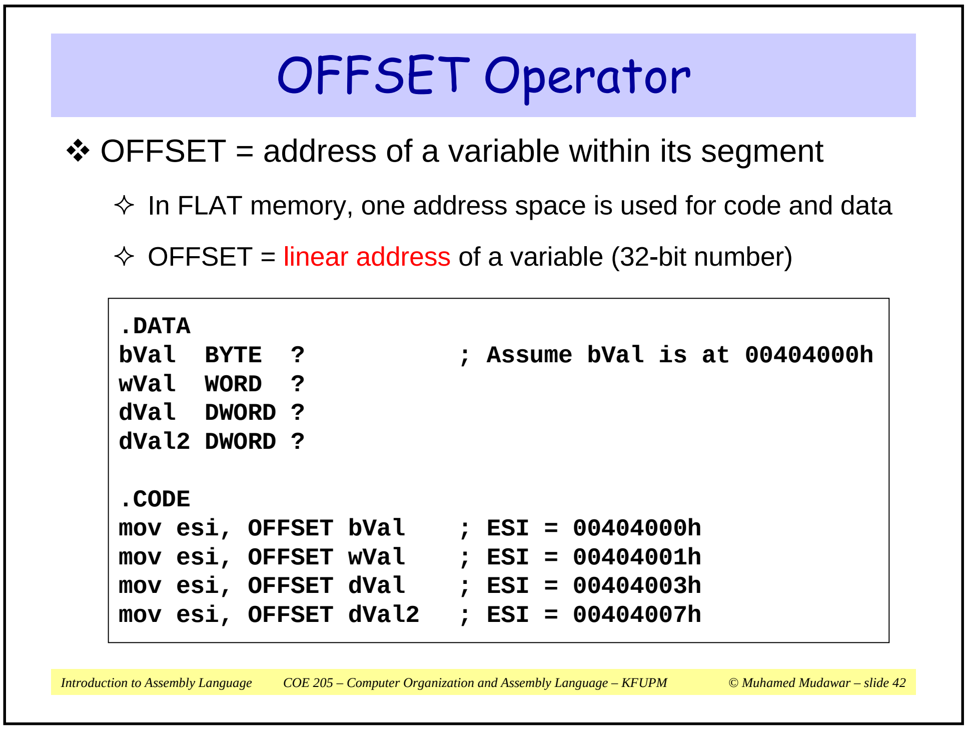
❖ *Name* can be redefined at any time (unlike EQU)

```
ROWSIZE = 5
COUNT   TEXTEQU  %(ROWSIZE * 2)    ; evaluates to 10
MOVAL   TEXTEQU  <mov al,COUNT>
ContMsg TEXTEQU  <"Do you wish to continue (Y/N)?">
.DATA
prompt  BYTE     ContMsg
.CODE
MOVAL                              ; generates: mov al,10
```



Next . . .

- Basic Elements of Assembly Language
- Flat Memory Program Template
- Example: Adding and Subtracting Integers
- Assembling, Linking, and Debugging Programs
- Defining Data
- Defining Symbolic Constants
- Data-Related Operators and Directives



OFFSET Operator

- OFFSET = address of a variable within its segment
  - In FLAT memory, one address space is used for code and data
  - OFFSET = linear address of a variable (32-bit number)

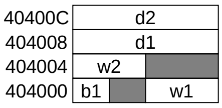
```
.DATA
bVal  BYTE  ?           ; Assume bVal is at 00404000h
wVal  WORD  ?
dVal  DWORD ?
dVal2 DWORD ?

.CODE
mov esi, OFFSET bVal    ; ESI = 00404000h
mov esi, OFFSET wVal    ; ESI = 00404001h
mov esi, OFFSET dVal    ; ESI = 00404003h
mov esi, OFFSET dVal2   ; ESI = 00404007h
```

ALIGN Directive

- ❖ ALIGN directive aligns a variable in memory
- ❖ Syntax: ALIGN *bound*
  - ✧ Where *bound* can be 1, 2, 4, or 16
- ❖ Address of a variable should be a multiple of *bound*
- ❖ Assembler inserts empty bytes to enforce alignment

```
.DATA          ; Assume that
b1 BYTE   ?    ; Address of b1 = 00404000h
ALIGN 2        ; Skip one byte
w1 WORD   ?    ; Address of w1 = 00404002h
w2 WORD   ?    ; Address of w2 = 00404004h
ALIGN 4        ; Skip two bytes
d1 DWORD ?     ; Address of d1 = 00404008h
d2 DWORD ?     ; Address of d2 = 0040400Ch
```



40400C	d2		
404008	d1		
404004	w2	▨	
404000	b1	▨	w1

TYPE Operator

- ❖ TYPE operator
  - ✧ 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    ; eax = 1
mov eax, TYPE var2    ; eax = 2
mov eax, TYPE var3    ; eax = 4
mov eax, TYPE var4    ; eax = 8
```

LENGTHOF Operator

- ❖ LENGTHOF operator
  - ✧ Counts the number of elements in a single data declaration

```
.DATA
array1    WORD    30 DUP(?),0,0
array2    WORD    5 DUP(3 DUP(?))
array3    DWORD   1,2,3,4
digitStr  BYTE   "12345678",0

.code
mov ecx, LENGTHOF array1         ; ecx = 32
mov ecx, LENGTHOF array2         ; ecx = 15
mov ecx, LENGTHOF array3         ; ecx = 4
mov ecx, LENGTHOF digitStr       ; ecx = 9
```

SIZEOF Operator

- ❖ SIZEOF operator
  - ✧ Counts the number of bytes in a data declaration
  - ✧ Equivalent to multiplying LENGTHOF by TYPE

```
.DATA
array1     WORD    30 DUP(?),0,0
array2     WORD    5 DUP(3 DUP(?))
array3     DWORD   1,2,3,4
digitStr   BYTE   "12345678",0

.CODE
mov ecx, SIZEOF array1           ; ecx = 64
mov ecx, SIZEOF array2           ; ecx = 30
mov ecx, SIZEOF array3           ; ecx = 16
mov ecx, SIZEOF digitStr         ; ecx = 9
```

Multiple Line Declarations

A data declaration spans 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
```

In the following example, array identifies the first line WORD declaration only

Compare the values returned by LENGTHOF and SIZEOF here to those on the left

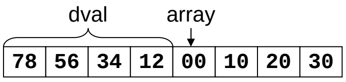
```
.DATA
array  WORD 10,20
       WORD 30,40
       WORD 50,60

.CODE
mov eax, LENGTHOF array ; 2
mov ebx, SIZEOF array   ; 4
```

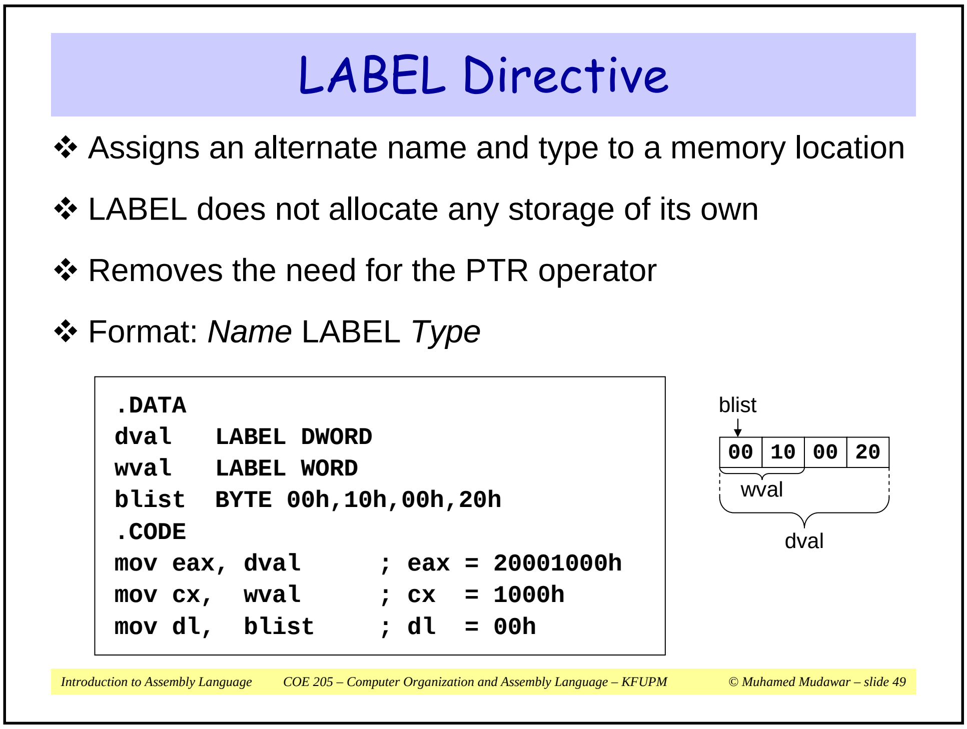
PTR Operator

- ❖ PTR Provides the flexibility to access part of a variable
- ❖ Can also be used to combine elements of a smaller type
- ❖ Syntax: *Type* PTR (Overrides default type of a variable)

```
.DATA
dval   DWORD 12345678h
array BYTE   00h,10h,20h,30h
```



```
.CODE
mov al,  dval            ; error – why?
mov al,  BYTE PTR dval   ; al = 78h
mov ax,  dval            ; error – why?
mov ax,  WORD PTR dval   ; ax = 5678h
mov eax, array           ; error – why?
mov eax, DWORD PTR array ; eax = 30201000h
```

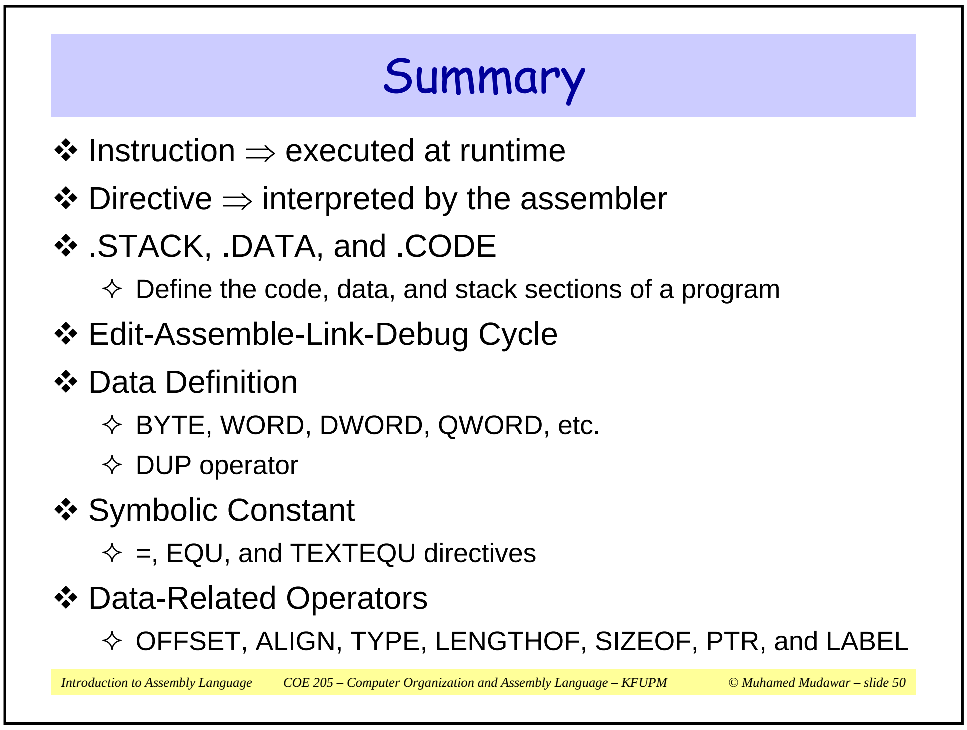


LABEL Directive

- ❖ Assigns an alternate name and type to a memory location
- ❖ LABEL does not allocate any storage of its own
- ❖ Removes the need for the PTR operator
- ❖ Format: *Name* LABEL *Type*

```
.DATA
dval   LABEL DWORD
wval   LABEL WORD
blist  BYTE 00h,10h,00h,20h
.CODE
mov eax, dval      ; eax = 20001000h
mov cx,  wval      ; cx  = 1000h
mov dl,  blist     ; dl  = 00h
```

blist
00
10
00
20
wval
dval



Summary

- ❖ Instruction ⇒ executed at runtime
- ❖ Directive ⇒ interpreted by the assembler
- ❖ .STACK, .DATA, and .CODE
  - ✧ Define the code, data, and stack sections of a program
- ❖ Edit-Assemble-Link-Debug Cycle
- ❖ Data Definition
  - ✧ BYTE, WORD, DWORD, QWORD, etc.
  - ✧ DUP operator
- ❖ Symbolic Constant
  - ✧ =, EQU, and TEXTEQU directives
- ❖ Data-Related Operators
  - ✧ OFFSET, ALIGN, TYPE, LENGTHOF, SIZEOF, PTR, and LABEL