CSC 3210

Computer Organization and Programming

Chapter 4: Data Transfers, Addressing, and Arithmetic

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Outline

- **Data Transfer Instructions**
- Addition and Subtraction
- Data-Related Operators and Directives
- Indirect Addressing
- JMP and LOOP Instructions

Data Transfer Instructions

- Operand Types
- Instruction Operand Notation
- Direct Memory Operands
- MOV Instruction
- Zero & Sign Extension
- XCHG Instruction
- Direct-Offset Instructions

Data Transfer Instructions: Operand Types

- **Immediate** – a constant integer (8, 16, or 32 bits)
  - value is **encoded** within the instruction
- **Register** – the name of a register
  - register name is **converted** to a number and **encoded** within the instruction
- **Memory** – reference to a location in memory
  - memory address is **encoded** within the instruction, or a register holds the address of a memory location

Listing File

```
00000000   .data
00000000 00000000  sum DWORD 0
00000000   .code
00000000   main proc
00000000   B8 00000008       mov eax, 8
00000005   83 C0 04          add  eax, 4
00000008   A3 00000000 R     mov sum, eax
```

Data Transfer Instructions: Instruction Operand Notation

Operand	Description
reg8	8-bit general-purpose register: AH, AL, BH, BL, CH, CL, DH, DL
reg16	16-bit general-purpose register: AX, BX, CX, DX, SI, DI, SP, BP
reg32	32-bit general-purpose register: EAX, EBX, ECX, EDX, ESI, EDI, ESP, EBP
reg	Any general-purpose register
sreg	16-bit segment register: CS, DS, SS, ES, FS, GS
imm	8-, 16-, or 32-bit immediate value
imm8	8-bit immediate byte value
imm16	16-bit immediate word value
imm32	32-bit immediate doubleword value
reg/mem8	8-bit operand, which can be an 8-bit general register or memory byte
reg/mem16	16-bit operand, which can be a 16-bit general register or memory word
reg/mem32	32-bit operand, which can be a 32-bit general register or memory doubleword
mem	An 8-, 16-, or 32-bit memory operand

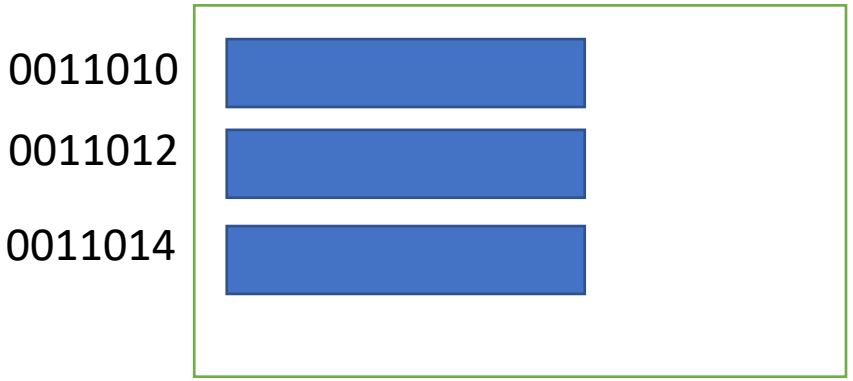
MOV **reg,reg**
MOV **mem,reg**
MOV **reg,mem**
MOV **mem,imm**
MOV **reg,imm**

```
MOVZX   reg32,reg/mem8
MOVZX   reg32,reg/mem16
MOVZX   reg16,reg/mem8
```

Data Transfer Instructions

- Register to Register

- Register to Memory , Vice versa



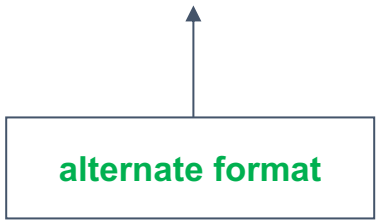
How to see variables in VS

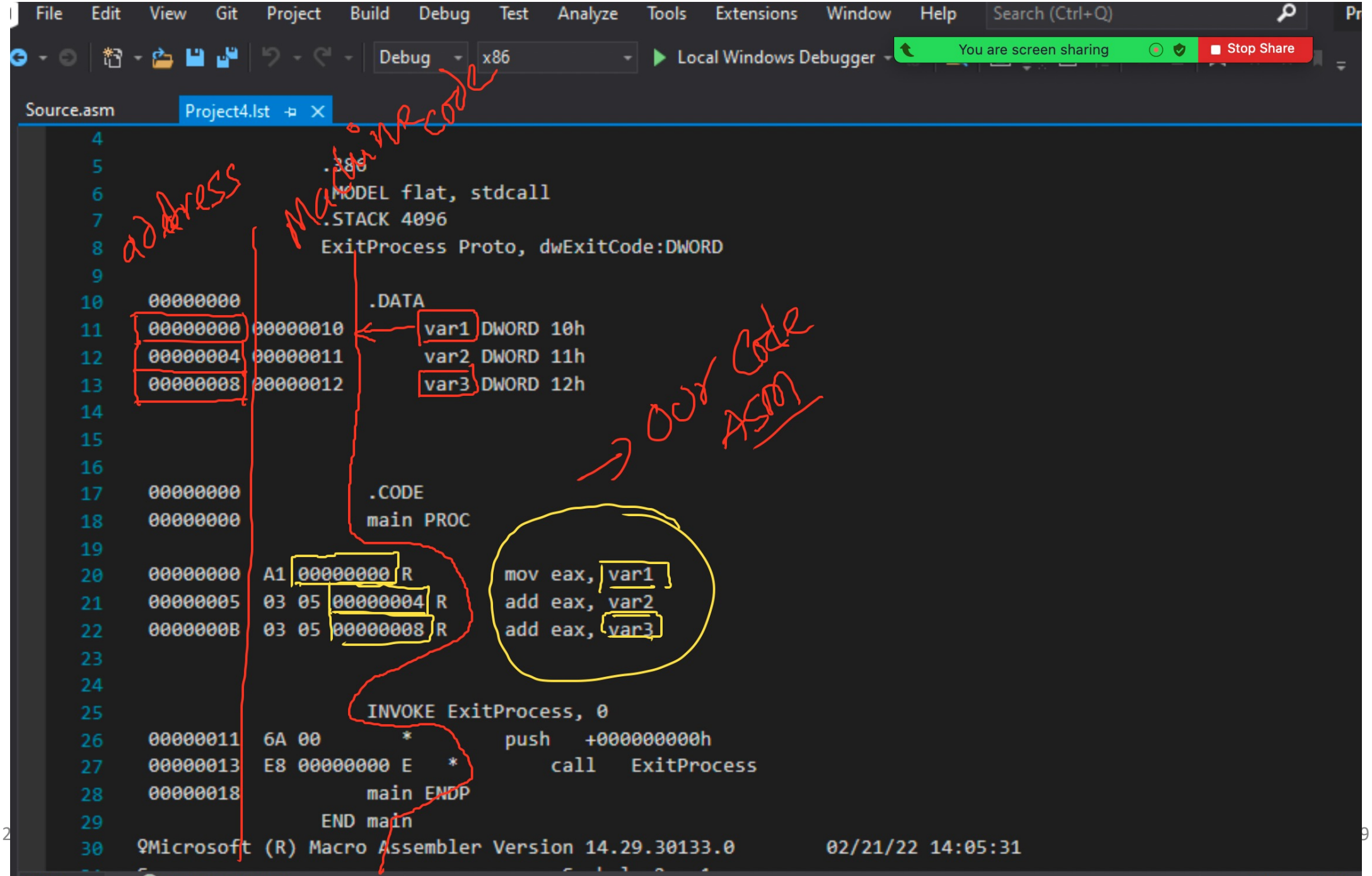
Data Transfer Instructions: Direct Memory Operands

- A **direct memory operand** is a named reference to storage in memory

```
.data
var1 BYTE 10h
.code
mov al,var1     ; AL = 10h
```

```
mov al,[var1] ; AL = 10h
```




File Edit View Git Project Build Debug Test Analyze Tools Extensions Window Help
Search (Ctrl+Q)
Debug
x86
Local Windows Debugger
You are screen sharing
Stop Share
Source.asm
Project4.lst
address
Machine code
our code
ASM
.386
.MODEL flat, stdcall
.STACK 4096
ExitProcess Proto, dwExitCode:DWORD
00000000 .DATA
00000000 00000010 var1 DWORD 10h
00000004 00000011 var2 DWORD 11h
00000008 00000012 var3 DWORD 12h
00000000 .CODE
00000000 main PROC
00000000 A1 00000000 R mov eax, var1
00000005 03 05 00000004 R add eax, var2
0000000B 03 05 00000008 R add eax, var3
INVOKE ExitProcess, 0
00000011 6A 00 * push +000000000h
00000013 E8 00000000 E * call ExitProcess
00000018 main ENDP
END main
Microsoft (R) Macro Assembler Version 14.29.30133.0 02/21/22 14:05:31

Data Transfer Instructions: Direct Memory Operands

- The **named reference (label)** is automatically dereferenced by the **assembler**

```
.data
var1 BYTE 10h
```

  - Suppose **var1** were located at offset 10400h.
  - The following instruction copies its **value** into the AL register:

```
mov al, var1
```

    - It would be **assembled** into the following machine instruction:

```
A0 00010400
```

Data Transfer Instructions: Direct Memory Operands

- The **named reference (label)** is automatically dereferenced by the **assembler**

A0 00010400

Listing File

- The **first byte** in the machine instruction is the **opcode**.
- The **remaining part** is the **32-bit hexadecimal address of var1**.

```
00000000   .data

00000000 00000000  sum DWORD 0

00000000   .code

00000000   main proc
00000000   B8 00000008       mov eax, 8
00000005   83 C0 04          add  eax, 4
00000008   A3 00000000 R     mov sum, eax
```

Data Transfer Instructions: MOV Instruction

- Move from **source** to **destination**.
- **Syntax:**

  MOV *destination*, *source*

- MOV instruction **formats**:

  MOV **reg,reg**
  MOV **mem,reg**
  MOV **reg,mem**
  MOV **mem,imm**
  MOV **reg,imm**

  - Both operands must be the same size.
  - Atleast one of the operand is a register
  - The (IP, EIP, or RIP) cannot be a destination operand.

Ex:

```
.data
count BYTE 100
wVal  WORD 2
.code
    mov bl,count
    mov ax,wVal
    mov count,al

    mov al,wVal
    mov ax,count
    mov eax,count
```

Data Transfer Instructions: MOV Instruction

- Explain why each of the following MOV statements are invalid:

```
.data
bVal  BYTE   100
bVal2 BYTE   ?
wVal  WORD   2
dVal  DWORD  5

.code
```

`mov ds,45`	immediate move to DS not permitted
`mov eax,wVal`	size mismatch
`mov eip,dVal`	EIP cannot be the destination
`mov 25,bVal`	immediate value cannot be destination
`mov bVal2,bVal`	memory-to-memory move not permitted

- Both operands must be the same size.
- Both operands cannot be memory operands.
- The (IP, EIP, or RIP) cannot be a destination operand.

Data Transfer Instructions: MOV Instruction

- **Memory to Memory (problem):**
  - A single MOV instruction cannot be used to move data directly from one memory location to another.
  - Instead, you must move
    - the source operand's value to a register
    - before assigning its value to a memory operand:

Ex:

```
.data
var1 WORD ?
var2 WORD ?
.code
mov ax,var1
mov var2,ax
```

Data Transfer Instructions: MOV Instruction

- Overlapping Values
  - The same 32-bit register **can be modified** using differently sized data.
    - When oneWord is moved to AX, it **overwrites** the existing value of AL.
    - When oneDword is moved to EAX, it **overwrites** AX.
    - When 0 is moved to AX, it **overwrites** the lower half of EAX.

```
.data
oneWord WORD 1234h
oneDword DWORD 12345678h
```

```
.code
mov eax, 0
mov ax, oneWord          ; EAX = 00001234h
mov eax, oneDword        ; EAX = 12345678h
mov ax, 0                ; EAX = 12340000h
```

windows10_fall21 [Running]

File Edit View Git Project Build Debug Test Analyze Tools Extensions W

You are screen sharing | Stop Share

Project4

Debug x86 Continue Live Share

Process: [0x25C4] Project4.exe Lifecycle Events Thread: [0x1968] Main Thread Stack Frame: main

Source.asm | Project4.lst

```
2   .MODEL flat, stdcall
3   .STACK 4096
4   ExitProcess Proto, dwExitCode:DWORD
5
6   .DATA
7    var1 DWORD 10h
8    var2 DWORD 11h
9
10
11
12
13  .CODE
14  main PROC
15      mov dx, 1122h
16      movzx eax, dx
17
18
19      INVOKE ExitProcess, 0  ≤1ms elapsed
20  main ENDP
```

110 % No issues found Ln: 19 Ch: 1 TABS CRLF

Registers

```
EAX = 00001122 EBX = 0099E000
ECX = 00371005 EDX = 00371122
ESI = 00371005 EDI = 00371005
EIP = 00371017 ESP = 00AFFBA4
EBP = 00AFFBB0 EFL = 00000246
```

110 %

AX

8bit 8bit 8bit 8bit

AH AL

DX

8bit 8bit 8bit 8bit

11 22

EAX

32 bit

4 byte

EDX

32 bit

4 bytes

Watch 1

Search (Ctrl+E) Search Depth: 3

Name	Value	Type
var1	0x00000010	unsigned long
var2	0x00000011	unsigned long
Add item to watch		

Call Stack

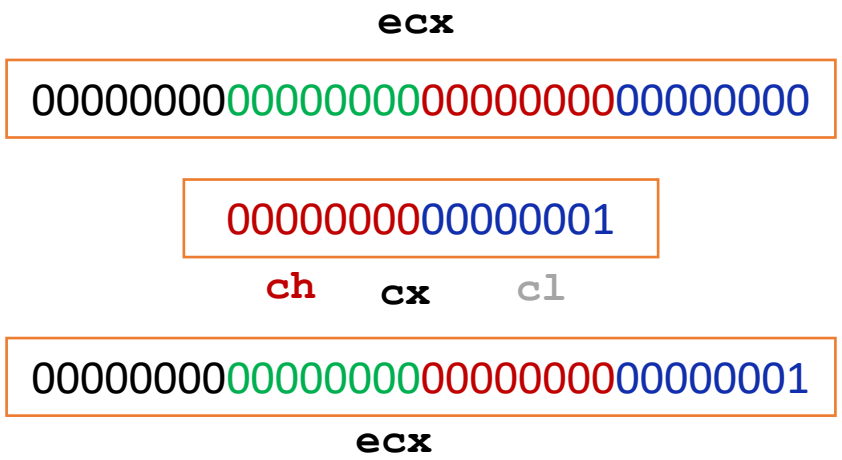
Name	Lang
Project4.exe!main() Line 19	Un...
[External Code]	
ntdll.dll![Frames below may be incorrect and/or missing, no symbols loaded for ntdll.dll]	Un...

Solution Explorer

Data Transfer Instructions: Zero & Sign Extension

- **Sign extension problem**:
  - MOV cannot directly copy data from a **smaller** operand to a **larger** one
  - **Workarounds**:
    - Suppose **count** (**unsigned**, **16 bits**) must be moved to **ECX** (32 bits).
    - **Trick**: Set **ECX** to **zero** and move **count** to **CX**:

```
.data
count WORD 1
.code
mov ecx,0
mov cx,count
```



  - What happens if we try the same approach with a signed integer equal to -16?

Data Transfer Instructions: Zero & Sign Extension

- **Sign extension problem:**
  - What happens if we try the same approach with a signed integer equal to -16?

```
.data
signedVal SWORD -16              ; FFF0h (-16)
.code
mov ecx,0
mov cx,signedVal                 ; ECX = 0000FFF0h (+65,520)
```

-16 ⟶ Hex.

Decimal

16 ⇒ 10000

8 bit ⇒ 00010000

2's complement: 1111

11101111

+1

11110000

F 0

0000 0000 00010000

1111

2's complement:

1111 1111 1110 1111

+1

1 11111111 11110000

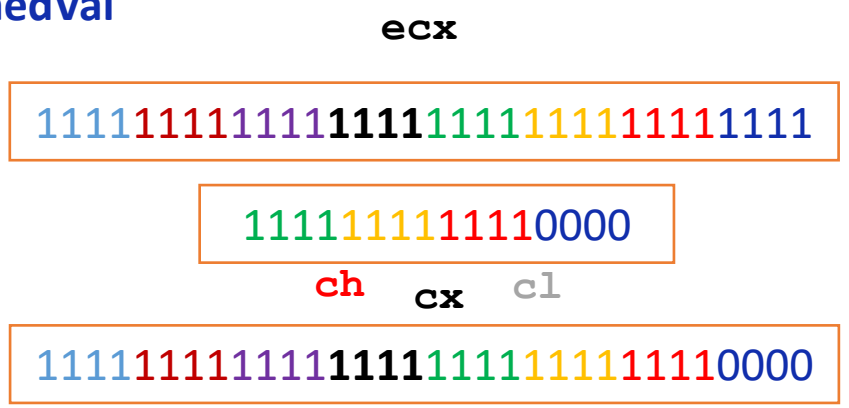
Data Transfer Instructions: Zero & Sign Extension

- **Sign extension problem:**

```
.data
signedVal SWORD -16             ; FFF0h (-16)
.code
mov ecx,0
mov cx,signedVal                ; ECX = 0000FFF0h (+65,520)
```

  - If we had filled **ECX** first with FFFFFFFFh and then copied **signedVal** to **CX**:

```
mov  ecx,FFFFFFFFh
mov  cx,signedVal          ; ECX = FFFFFFF0h (-16)
```



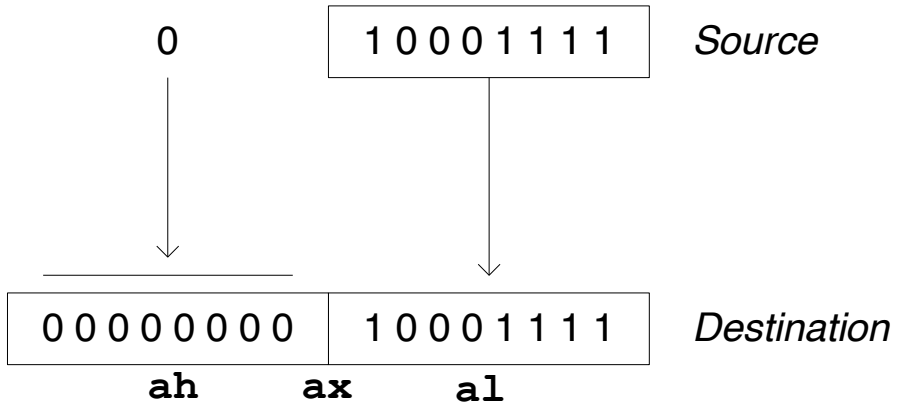
- **MOVZX** and **MOVSX** instructions to deal with both unsigned and signed integers.

Data Transfer Instructions: Zero Extension (MOVZX)

- The MOVZX instruction
- When you copy a smaller value into a larger destination,
  - the MOVZX instruction fills (extends) **the upper half** of the destination with **zeros**.

```
mov bl,10001111b
movzx ax,bl      ; zero-extension
```

```
MOVZX   reg32,reg/mem8
MOVZX   reg32,reg/mem16
MOVZX   reg16,reg/mem8
```



The destination must be a register.

Attendance!

Data Transfer Instructions: Zero Extension (MOVZX)

The following examples use registers for all operands, showing all the size variations:

```
mov    bx,0A69Bh
movzx  eax,bx                  ; EAX = 0000A69Bh
movzx  edx,bl                  ; EDX = 0000009Bh
movzx  cx,bl                   ; CX  = 009Bh
```

The following examples use memory operands for the source and produce the same results:

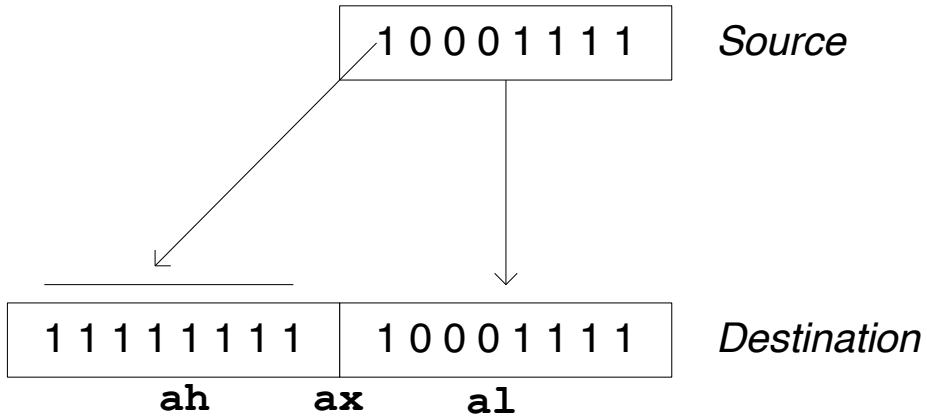
```
.data
byte1  BYTE 9Bh
word1  WORD 0A69Bh
.code
movzx  eax,word1               ; EAX = 0000A69Bh
movzx  edx,byte1               ; EDX = 0000009Bh
movzx  cx,byte1                ; CX  = 009Bh
```

Data Transfer Instructions: **Sign Extension (MOVSX)**

- The MOVSX instruction
- It fills the upper half of the destination with a copy of the source operand's sign bit.

```
MOVSX  reg32,reg/mem8
MOVSX  reg32,reg/mem16
MOVSX  reg16,reg/mem8
```

```
mov bl,10001111b
movsx ax,bl      ; sign extension
```



The destination must be a register.

Data Transfer Instructions: **Sign Extension (MOVSX)**

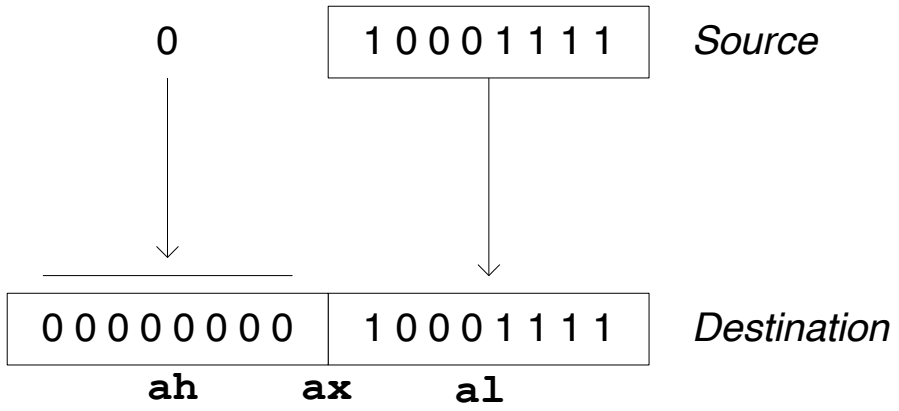
- In the following example,
  - the hexadecimal value moved to BX is A69B,
  - so the leading "A" digit tells us that the highest bit is set.

```
mov     bx, A69Bh
movsx eax,bx            ; EAX = FFFFA69Bh
movsx edx,bl            ; EDX = FFFFFF9Bh
movsx cx,bl             ; CX = FF9Bh
```

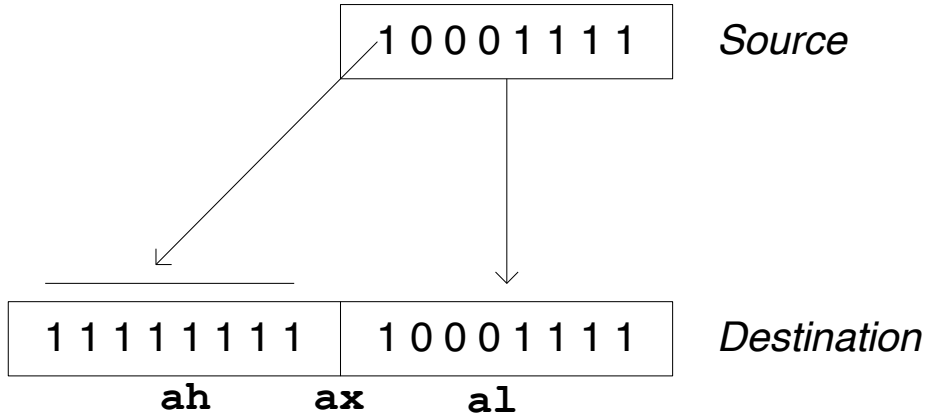
Data Transfer Instructions: Zero & Sign Extension

- MOVZX vs. MOVSX

MOVZX



MOVSX



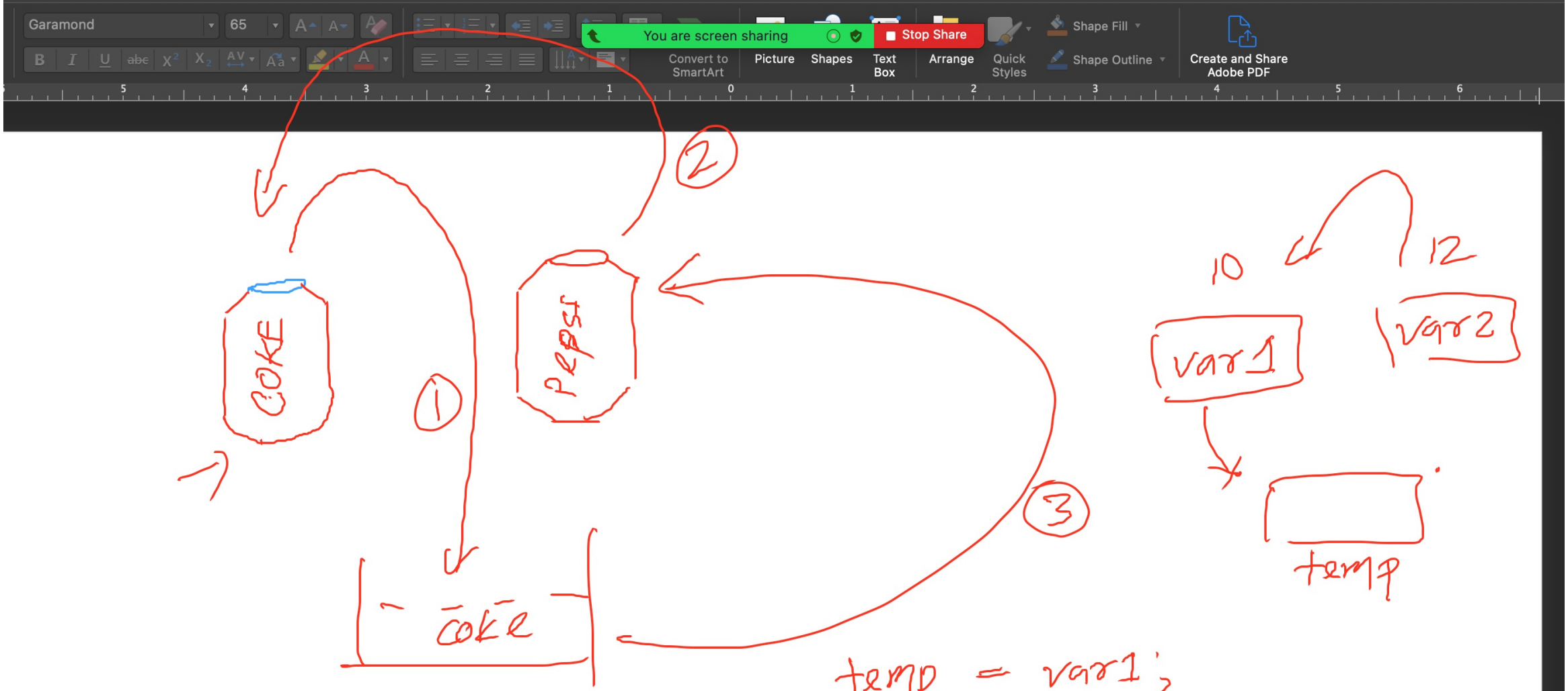
Data Transfer Instructions: XCHG Instruction

- **XCHG** **exchanges** the values of two operands.
  - **At least one operand must be a register**.
  - No **immediate** operands are permitted.

```
XCHG  reg,reg
XCHG  reg,mem
XCHG  mem,reg
```

```
xchg ah,al          ; exchange 8-bit regs
xchg ax,bx          ; exchange 16-bit regs
xchg eax,ebx        ; exchange 32-bit regs
xchg var1,bx ; exchange 16-bit mem op with BX
```

```
xchg var1,var2      ; error: two memory operands
```


Garamond
65
You are screen sharing
Stop Share
Convert to SmartArt
Picture
Shapes
Text Box
Arrange
Quick Styles
Shape Fill
Shape Outline
Create and Share Adobe PDF
COKE
Pepsi
1
2
3
Coke
10
12
var1
var2
temp
temp = var1;
var1 = var2;
var2 = temp;

windows10_fall21 [Running]

File Edit View Git Project Build Debug Test Analyze Tools Extensions W

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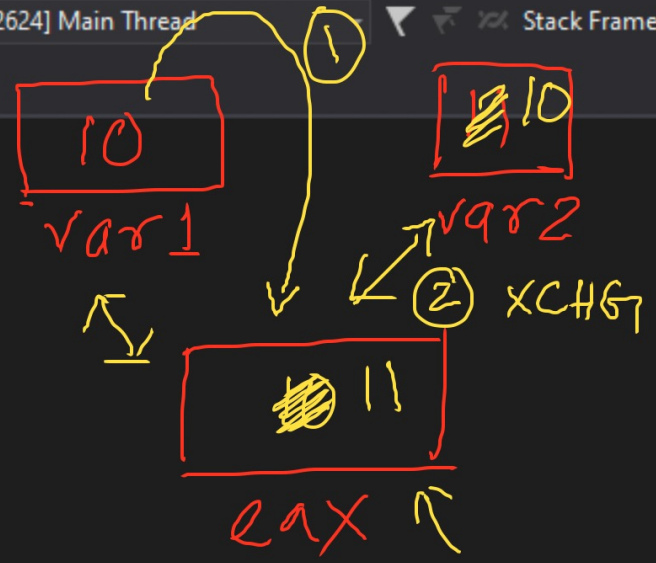
Project4

Debug | x86 | Continue | Live Sha

Process: [0x28E4] Project4.exe | Lifecycle Events | Thread: [0x2624] Main Thread | Stack Frame: main

urce.asm | Project4.lst

```
2   .MODEL flat, stdcall
3   .STACK 4096
4   ExitProcess Proto, dwExitCode:DWORD
5
6   .DATA
7    var1 DWORD 10h
8    var2 DWORD 11h
9
10
11
12
13  .CODE
14  main PROC
15      mov eax, var1
16      xchg eax, var2
17      mov var1, eax
18
19
20      INVOKE ExitProcess, 0  ≤1ms elapsed
```



Registers

```
EAX = 00000011 EBX = 0075E000
ECX = 00281005 EDX = 00281005
ESI = 00281005 EDI = 00281005
EIP = 00281020 ESP = 0097F92C
EBP = 0097F938 EFL = 00000246
```

0 % | No issues found | Ln: 20 | Ch: 1 | TABS | CRLF | 110 %

atch 1

arch (Ctrl+E) | Search Depth: 3

Name	Value	Type
var1	0x00000011	unsigned long
var2	0x00000010	unsigned long
Add item to watch		

Call Stack

Name
Project4.exe!main() Line 20
[External Code]
ntdll.dll![Frames below may be incorrect and/or missing, no symbols loaded for ntdll.dll]

Data Transfer Instructions: **XCHG Instruction**

- **XCHG** **exchanges** the values of two operands.
  - **At least one operand must be a register**.
  - No **immediate** operands are permitted.

```
XCHG  reg,reg
XCHG  reg,mem
XCHG  mem,reg
```

```
.data
var1 WORD 1000h
var2 WORD 2000h
.code
mov ax,val1
xchg ax,val2
mov val1,ax
```

Data Transfer Instructions: **Direct-Offset Operands**

- A constant offset is added to a data label to produce an **effective address** (EA).
- The address is dereferenced to get the **value inside its memory location**.

```
.data
arrayB BYTE 10h,20h,30h,40h
.code
mov al,arrayB                    ; AL = 10h
mov al,arrayB+1                  ; AL = 20h

  mov al,[arrayB+1]        ; alternative notation
```

Why doesn't arrayB+1 produce 11h?

Data Transfer Instructions: **Direct-Offset Operands**

```
.data
arrayW  WORD 1000h,2000h,3000h
arrayD  DWORD 1,2,3,4
.code
mov ax, [arrayW+2]              ; AX = 2000h
mov ax, [arrayW+4]              ; AX = 3000h
mov eax,[arrayD+4]              ; EAX = 00000002h
```

Will the following statements assemble?

```
mov ax,[arrayW-2]          ; ??
mov eax,[arrayD+16]        ; ??
```

Data Transfer Instructions: **Direct-Offset Operands**

```
.data
arrayW  WORD 1000h,2000h,3000h
arrayD  DWORD 1,2,3,4
.code
mov ax, [arrayD+0]              ; AX = 2000h
mov ax, [arrayD+4]              ; AX = 3000h
mov eax,[arrayD+8]              ; EAX = 00000002h
```

Will the following statements assemble?

```
mov ax,[arrayW-2]          ; ??
mov eax,[arrayD+16]        ; ??
```