EE-2003
Computer Organization & Assembly Language

Shoaib Rauf

Chapter No: 06

CONDITIONAL PROCESSING

BIT-WISE OPERATIONS

Status Flags (Revision)

- The Zero flag is set when the result of an operation equals zero.
- The Carry flag is set when an instruction generates a result that is too large (or too small) for the destination operand.
- The Sign flag is set if the destination operand is negative, and it is clear if the destination operand is positive.
- The Overflow flag is set when an instruction generates an invalid signed result.
- The Parity flag is set when an instruction generates an even number of 1 bits in the low byte of the destination operand.
- The Auxiliary Carry flag is set when an operation produces a carry out from bit 3 to bit 4.

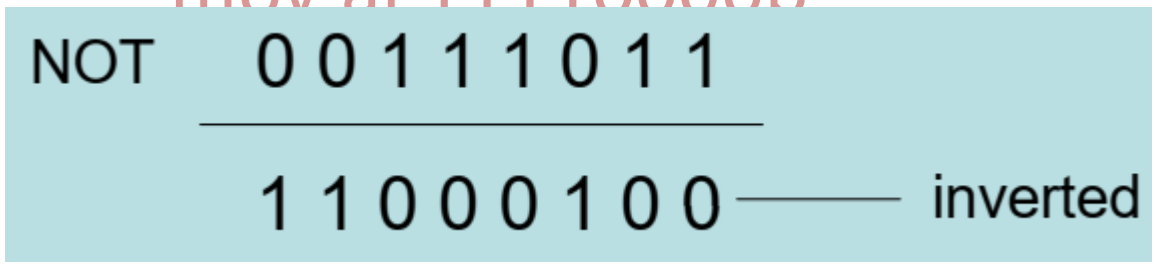
NOT Instruction

- Performs a bitwise Boolean **NOT** operation on a single destination operand
- Syntax: (no flag affected)

  NOT destination

- Example:

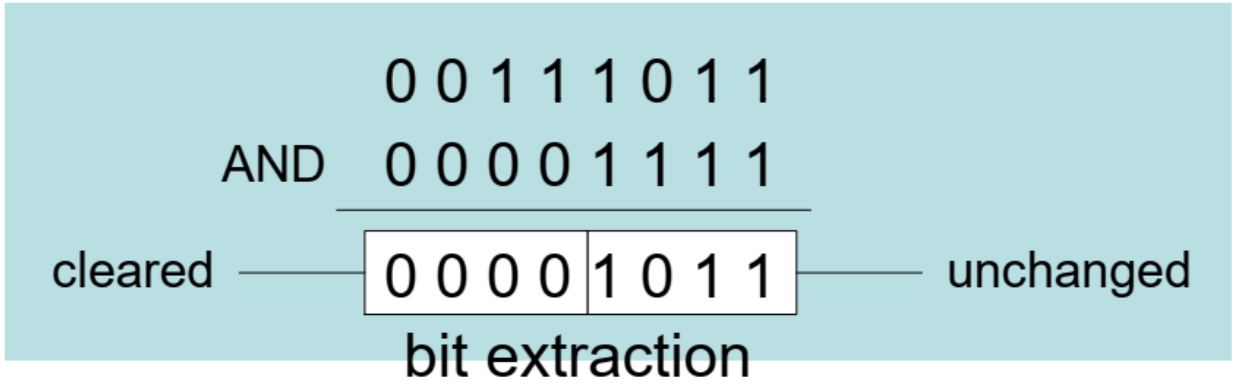
  mov al 11110000b



AND Instruction

- Performs a bitwise Boolean **AND** operation between each pair of matching bits in two operands
- AND instruction always clears Overflow and Carry flag. Also can modify Sign, Zero, and Parity in a way that is consistent with the value assigned to the destination operand.
- Syntax: AND destination, source
- Example:

```
mov
and
```

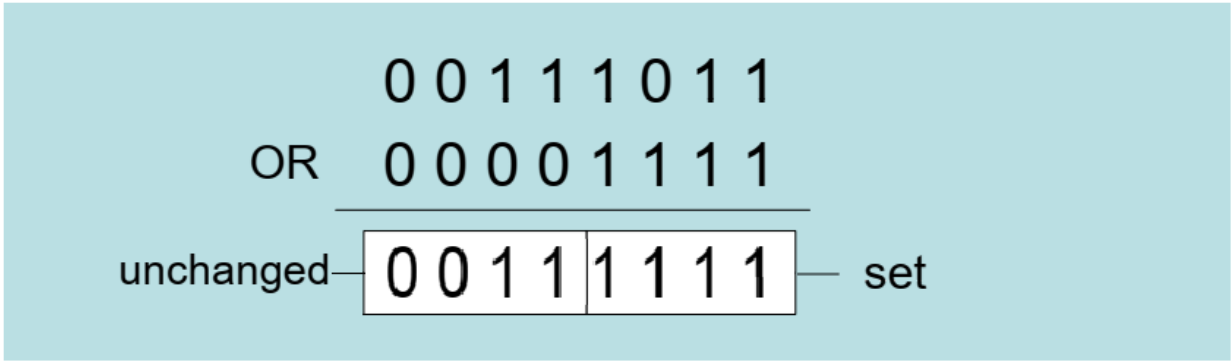


OR Instruction

- Performs a bitwise Boolean **OR** operation between each pair of matching bits in two operands
- Syntax: Clears Overflow, Cary . Modifies Sign, Zero, and Parity in a way that is consistent with the value assigned to the destination operand
- Syntax: OR destination, source
- Example:

mc

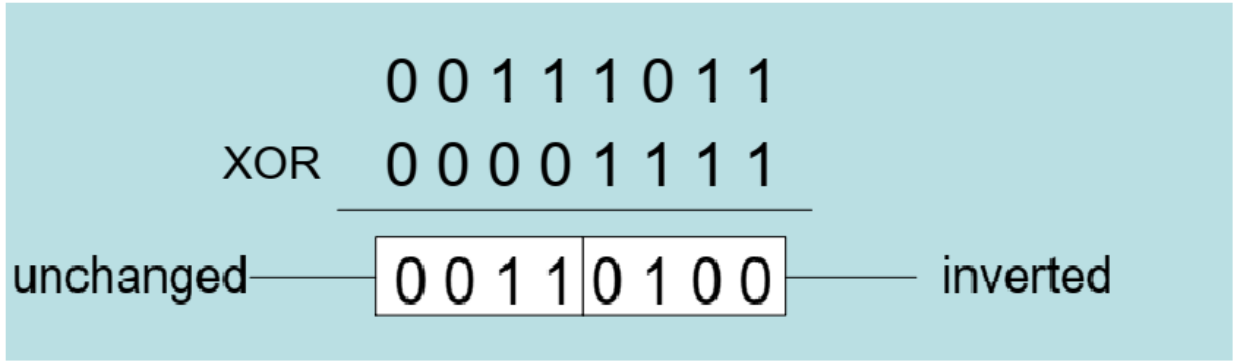
or



XOR Instruction

- Performs a bitwise Boolean X**OR** operation between each pair of matching bits in two operands
- The XOR instruction always clears the Overflow and Carry flags.
- Syntax: XOR destination, source
- Example:

```
mov al, 00111011b
xor al, 00001111b
```



XOR is a useful way to invert the bits in a operand and data encryption

APPLICATIONS

- Convert the character in AL to upper case
- **Solution:** Use the AND instruction to clear bit 5

```
mov     al , 'a'                ; AL = 01100001b
and     al , 11011111b          ; AL = 01000001b
```

- Convert a binary decimal byte into its equivalent ASCII decimal digit
- **Solution:** Use the OR instruction to set bits 4 and 5

```
mov     al , 6                  ; AL = 00000110b
or              al , 00110000b          ; AL = 00110110b
```

- Jump to a label if an integer is even
- **Solution:** AND the lowest bit with a 1, If the result is Zero, the number was even

```
mov     ax , wordVal
and     ax , 1                  ; low bit set?
jz      EvenValue               ; jump if Zero flag
```

APPLICATIONS

- Jump to a label if the value in AL is not zero
- **Solution:** OR the byte with itself, then use the JNZ (jump if not zero) instruction

```
or      al , al
jnz     IsNotZero          ; jump if not zero
```

Non-Destructive Instructions

TEST INSTRUCTION

- Performs a nondestructive AND operation between each pair of matching bits in two operands
- No operands are modified, but the flags are affected
- The TEST instruction always clears the Overflow and Carry flags
- Example: jump to a label if either **bit 0** or **bit 1** in AL is set

```
test    al, 00000011b
jnz     ValueFound
```

- Example: jump to a label if neither **bit 0** nor **bit 1** in AL is set

```
test    al, 00000011b
jz              ValueNotFound
```

CMP Instruction

- Compares the destination operand to the source operand
  - Nondestructive subtraction of source from destination (destination operand is not changed)
- Syntax:

```
CMP destination, source
```

- Example: destination == source

```
mov al , 5
cmp al , 5                    ; Zero flag set
```

- Example: destination < source

```
mov al , 4
cmp al , 5                    ; Carry flag set
```

The comparisons shown so far were unsigned

- Example: destination > source

```
mov al , 6
cmp al , 5                    ; ZF = 0, CF = 0
```

CMP Instruction

- The comparisons shown here are performed with signed integers
- Example: destination > source

```
mov al , 5
cmp al , -2                    ; Sign flag == Overflow flag
```

- Example: destination < source

```
mov al , -1
cmp al , 5                     ; Sign flag != Overflow flag
```

Conditions and Output

Unsigned	ZF	CF
destination < source	0	1
destination > source	0	0
destination = source	1	0

Signed	FLAGS
destination < source	SF != OF
destination > source	SF == OF
destination = source	ZF = 1

Setting and Clearing Individual Flags

```
and     al , 0          ; set Zero
or      al , 1          ; clear Zero
or      al , 80h        ; set Sign
and     al , 7Fh        ; clear Sign
stc                     ; set Carry
clc                     ; clear Carry

mov     al , 7Fh
inc     al              ;set Overflow
or      eax , 0         ;clear Overflow
```

BT (Bit Test) Instruction

- Copies n^{th} bit from an operand into the Carry flag
- Syntax:

```
BT reg/mem16 , reg16/reg32/imm
BT reg/mem32 , reg16/reg32/imm
```

- Example: jump to label L1 if bit 9 is set in the AX register

```
bt AX , 9                    ; CF = bit 9
jc L1                        ; jump if Carry
```

- There are three more BT instructions:
  - BTC bitBase, n ; bit test and complement
  - BTR bitBase, n ; bit test and reset (clear)
  - BTS bitBase, n ; bit test and set

CONDITIONAL JUMPS

CONDITIONAL STRUCTURES

- There are no high-level logic structures such as if-then-else, in the IA-32 instruction set
  - But, you can use combinations of comparisons and jumps to implement any logic structure
- First, an operation such as CMP, AND or SUB is executed to modified the CPU flags
- Second, a conditional jump instruction tests the flags and changes the execution flow accordingly
- Example:

```
cmp eax,0
and dl,10110000b
jz L1              ; jump if ZF = 1
jnz L2             ; jump if ZF = 0
  . .
 ….
L1:
L2:
```

JCOND INSTRUCTIONS

- A conditional jump instruction branches to a label when specific register or flag conditions are met

  Jcond Destination

- Four groups: (some are the same)
  - based on specific flag values
  - based on equality between operands
  - based on comparisons of unsigned operands
  - based on comparisons of signed operands

JUMPS BASED ON SPECIFIC FLAGS

Flag	Instruction	Description	Flag Status
ZERO	JZ	Jump if zero	ZF = 1
	JNZ	Jump if not zero	ZF = 0
CARRY	JC	Jump if carry	CF = 1
	JNC	Jump if not carry	CF = 0
Over-Flow	JO	Jump if overflow	OF = 1
	JNO	Jump if not overflow	OF = 0
SIGN	JS	Jump if sign	SF = 1
	JNS	Jump if not sign	SF = 0
PARITY	JP	Jump if parity (even)	PF = 1
	JNP	Jump if not parity (odd)	PF = 0

Jumps Based on Equality

Instruction	Description
JE	Jump if equal (left OP = right OP)
JNE	Jump if not equal (left OP ≠ right OP)
JCXZ	Jump if CX = 0
JECXZ	Jump if ECX = 0

JUMPS BASED ON UN-SIGNED COMPARISON

Condition	Instruction	Description
$>$	JA	Jump if above $(left\ OP > right\ OP)$
	JNA	Jump if not above $(left\ OP \leq right\ OP)$
$\geqq$	JAE	Jump if above and equal $(left\ OP \geq\ right\ OP)$
	JNAE	Jump if not above and equal $(left\ OP < right\ OP)$
$<$	JB	Jump if below $(left\ OP < right\ OP)$
	JNB	Jump if not below $(left\ OP \geq right\ OP)$
$\leqq$	JBE	Jump if below and equal $(left\ OP \leq right\ OP)$
	JNBE	Jump if not below and equal $(left\ OP > right\ OP)$

JUMPS BASED ON SIGNED COMPARISON

Condition	Instruction	Description
$>$	JG	Jump if greater $(left\ OP > right\ OP)$
	JNG	Jump if not greater $(left\ OP \leq right\ OP)$
$\geq$	JGE	Jump if greater and equal $(left\ OP \geq\ right\ OP)$
	JNGE	Jump if not greater and equal $(left\ OP < right\ OP)$
$<$	JL	Jump if less than $(left\ OP < right\ OP)$
	JNL	Jump if not less than $(left\ OP \geq right\ OP)$
$\leq$	JLE	Jump if less than and equal $(left\ OP \leq right\ OP)$
	JNLE	Jump if not less than and equal $(left\ OP > right\ OP)$

EXAMPLES

Example 1:

```
mov  edx,0A523h
cmp  edx,0A523h
jne  L5                    ; jump not taken
je   L1                    ; jump is taken
```

Example 2:

```
mov  bx,1234h
sub  bx,1234h
jne  L5                   ; jump not taken
je   L1                   ; jump is taken
```

Example 3:

```
mov    cx,0FFFFh
inc    cx
jcxz   L2                  ; jump is taken
```

Example 4:

```
xor    ecx,ecx
jecxz  L2                  ; jump is taken
```

EXAMPLES (Signed CMP)

Example 1

```
mov    edx,-1
cmp    edx,0
jnl    L5                    ; jump not taken (-1 >= 0 is false)
jnle   L5                    ; jump not taken (-1 > 0 is false)
jl     L1                    ; jump is taken (-1 < 0 is true)
```

Example 2

```
mov    bx,+32
cmp    bx,-35
jng    L5                   ; jump not taken (+32 <= -35 is false)
jnge   L5                   ; jump not taken (+32 < -35 is false)
jge    L1                   ; jump is taken (+32 >= -35 is true)
```

Example 3

```
mov  ecx,0
cmp  ecx,0
jg   L5                     ; jump not taken (0 > 0 is false)
jnl  L1                     ; jump is taken (0 >= 0 is true)
```

Example 4

```
mov  ecx,0
cmp  ecx,0
jl   L5                     ; jump not taken (0 < 0 is false)
jng  L1                     ; jump is taken (0 <= 0 is true)
```

EXAMPLES

- Compare unsigned AX to BX, and copy the larger of the two into a variable named Large
- **Solution:**

```
        mov     Large , bx
        cmp     ax , bx
        jna     Next
        mov     Large , ax
    Next:
```

- Compare signed AX to BX, and copy the smaller of the two into a variable named small
- **Solution:**

```
        mov     small , ax
        cmp     bx , ax
        jnl     Next
        mov     small , bx
    Next:
```

EXAMPLES

- Find the first even number in an array of unsigned Integers
- **Solution:**

```
.date
intArray DWORD 7, 9, 3, 4, 6, 1
.code
...
    mov ebx, OFFSET intArray
    mov ecx, LENGTHOF intArray
L1:         test DWORD PTR [ebx], 1
            jz found
            add ebx, 4
            loop L1
...
Found:
```

Conditional Structures

IF STATEMENTS

- If Condition th Then Else

Condition

JNE esle

Then

JMP endif

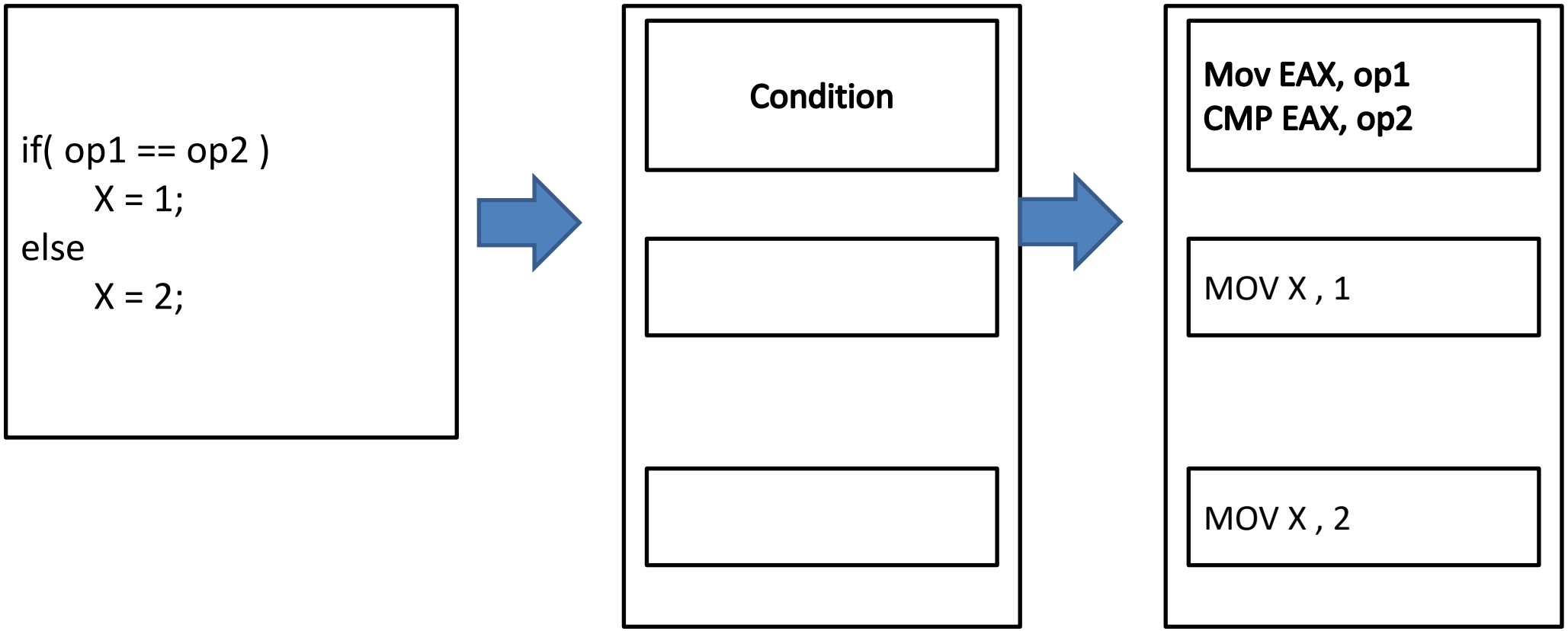
else:

Else

endif:

BLOCK-STRUCTURED IF STATEMENTS

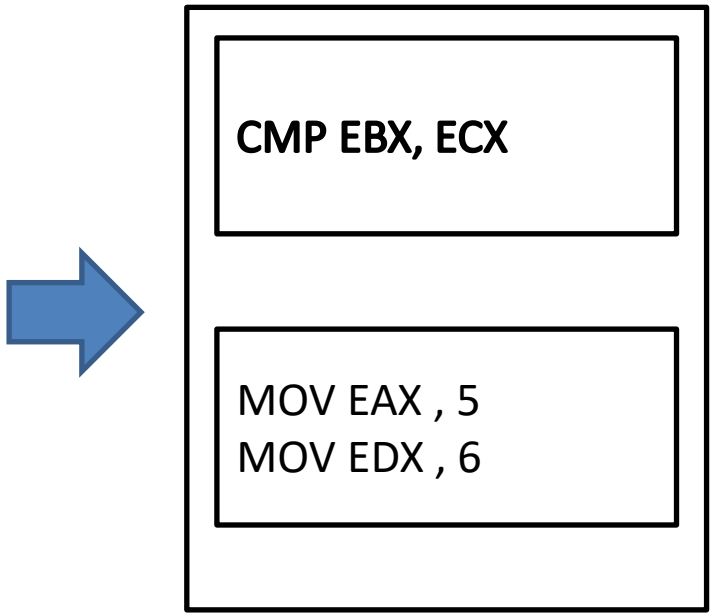
- Assembly language programmers can easily translate logical statements written in C++ into assembly language. For example



EXERCISE

- Implement the following pseudocode in assembly language, all values are unsigned:

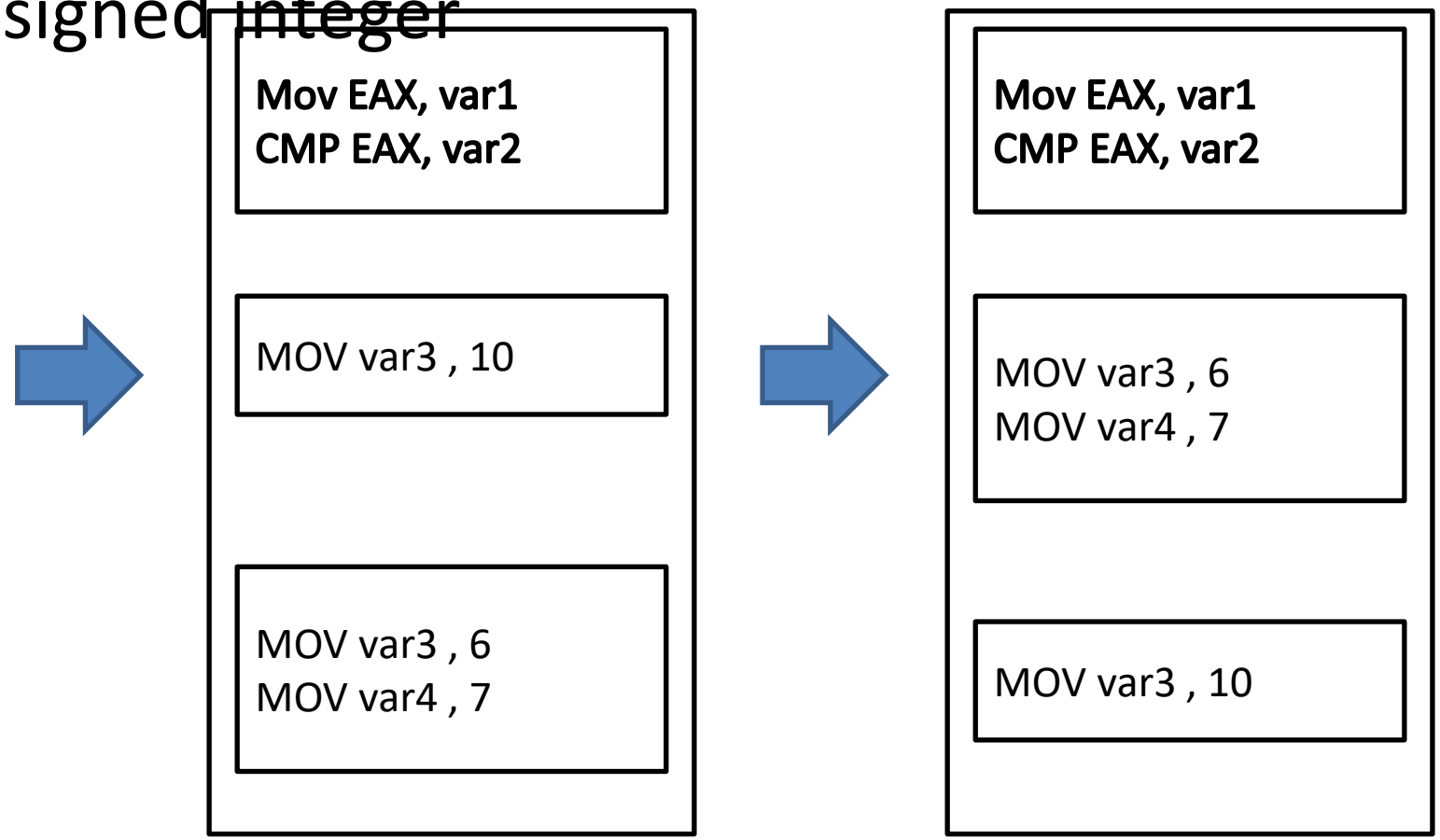
```
if( ebx <= ecx )
{
        eax = 5;
        edx = 6;
}
```



EXERCISE

- Implement the following pseudocode in assembly language, all values are 32-bit signed integer

```
if( va1 <= var2 )
        var3 = 10;
else
{
        var3 = 6;
        var4 = 7;
}
```

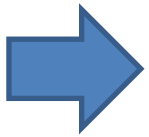


COMPOUND EXPRESSION WITH AND

- When implementing the logical AND operator, consider that HLLs use short-circuit evaluation
- In the following example, if the first expression is false, the second expression is skipped

```
if(al > bl && bl > cl)
        X = 1;
```

```
    cmp al,bl ;1st expression
    ja L1
    jmp next
L1:
    cmp bl,cl ;2nd expression
    ja L2
    jmp next
```

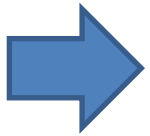


```
cmp al,bl ;1st expression
jbe next
cmp bl,cl ;2nd expression
jbe next
mov X,1
```

COMPOUND EXPRESSION WITH OR

- In the following example, if the first expression is true, the second expression is skipped

```
if(al > bl || bl > cl)
        X = 1;
```



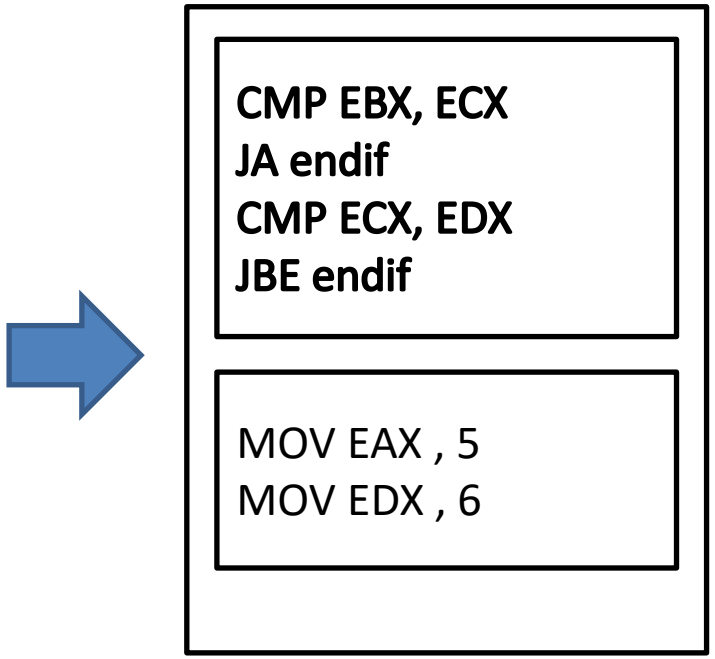
```
    cmp al,bl ;1st expression
    jbe L1
    jmp L2
L1:
    cmp bl,cl ;2nd expression
    jbe next
L2: ; both are true
    mov X,1    ; set X to 1
next:
```

```
    cmp al,bl ;1st expression
    ja L1
    cmp bl,cl ;2nd expression
    jbe next
L1:
    mov X,1    ; set X to 1
next:
```

EXERCISE

- Implement the following pseudocode in assembly language, all values are unsigned:

```
if( ebx <= ecx && ecx > edx)
{
        eax = 5;
        edx = 6;
}
```



WHILE LOOP

- A WHILE loop is really an IF statement followed by the body of the loop followed by an unconditional jump to the top of the loop
- Consider the following example

```
while( eax < ebx)
        eax = eax + 1;
```

```
CMP EAX, EBX
JAE _endwhile

Jmp _while
_endwhile:
```

WHILE LOOP

- A WHILE loop is really an IF statement followed by the body of the loop followed by an unconditional jump to the top of the loop
- Consider the following example

```
while( eax < ebx)
        eax = eax + 1;
```

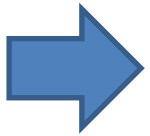
```
CMP EAX, EBX
JAE _endwhile

Jmp _while
_endwhile:
```

EXERCISE

- Implement the following loop, using unsigned 32-bit integer

```
while( ebx <= val1)
{
        eax++;
        if (ebx == ecx)
                X=2;
        else
                X=3;
}
```



```
CMP EbX, val1
JA _endwhile

INC EAX
CMP EBX, ECX
JNE else
MOV X, 2
Jmp _while
else:
MOV X, 3

Jmp _while
_endwhile:
```

Do Loop

- A DO loop is really an IF statement, here the body of the loop followed by an IF statement to unconditional jump
- Consider the following example

```
Do
{
        eax = eax + 1;
}while( eax < ebx)
```

```
Inc EAX

CMP EAX, EBX
JAE _enddo

Jmp _do
_enddo:
```

LOOPZ AND LOOPE INSTRUCTION

- **Syntax:**

  LOOPE destination

  LOOPZ destination

- **Logic:**
  - ECX ← ECX – 1
  - if ECX != 0 and ZF=1, jump to destination
- The destination label must be between -128 and +127 bytes from the location of the following instruction
- Useful when scanning an array for the first element that meets some condition

LOOPNZ AND LOOPNE INSTRUCTION

- **Syntax:**

  LOOPNE destination

  LOOPNZ destination

- **Logic:**
  - ECX ← ECX – 1
  - if ECX != 0 and ZF=0, jump to destination
- The destination label must be between -128 and +127 bytes from the location of the following instruction
- Useful when scanning an array for the first element that meets some condition

EXAMPLES

- The following code finds the first positive value in an array:
- **Solution:**

```
.data
    array SWORD -3,-6,-1,-10,10,30,40,4
    sentinel SWORD 0
.code
mov esi , OFFSET array
mov ecx , LENGTHOF array
next:
    test WORD PTR [esi] , 8000h                ; test sign bit
    pushfd                                     ; push flags on stack
    add esi , TYPE array
    popfd                                      ; pop flags from stack
loopnz next                                    ; continue loop
jnz quit                                                ; none found
sub esi,TYPE array                             ; ESI points to value
quit:
```

EXAMPLES

- Locate the first nonzero value in the array. If none is found, let ESI point to the sentinel value
- **Solution:**

```
.data
    array SWORD 50 DUP (?)
    sentinel SWORD 0
.code
mov esi , OFFSET array
mov ecx , LENGTHOF array
next:
    cmp WORD PTR [esi] , 0          ; check for zero
    pushfd                          ; push flags on stack
    add esi , TYPE array
    popfd                           ; pop flags from stack
loopnz next                         ; continue loop
jnz quit                                    ; none found
sub esi,TYPE array                  ; ESI points to value
quit:
```