Topic 6
Lecture 6a
Conditional Processing

CSCI 150

Assembly Language / Machine Architecture

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Chapter Overview

- **Boolean and Comparison Instructions**
- Conditional Jumps
- Conditional Loop Instructions
- Conditional Structures
- Application: Finite-State Machines
- Conditional Control Flow Directives

Boolean and Comparison Instructions

- CPU Status Flags
- AND Instruction
- OR Instruction
- XOR Instruction
- NOT Instruction
- Applications
- TEST Instruction
- CMP Instruction

Status Flags – Review (1 of 2)

- 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.

Status Flags – Review (2 of 2)

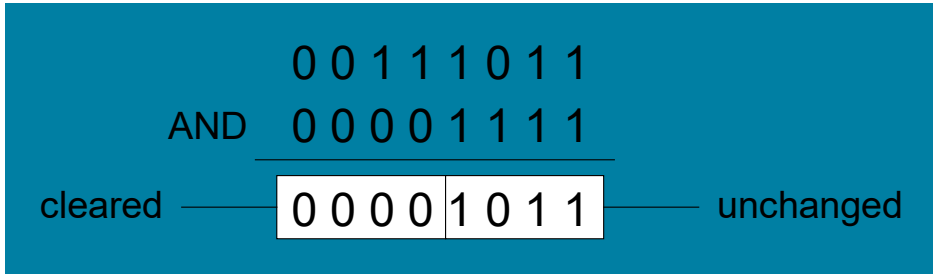
- The Overflow flag is set when an instruction generates an invalid signed result (bit 7 carry is XORed with bit 6 Carry).
- The Parity flag is set when an instruction generates an even number of 1 bits in the low byte of the destination operand.
- The Auxiliary Carry flag is set when an operation produces a carry out from bit 3 to bit 4

AND Instruction

- Performs a Boolean AND operation between each pair of matching bits in two operands
- Syntax:

  AND destination, source

  (same operand types as MOV)



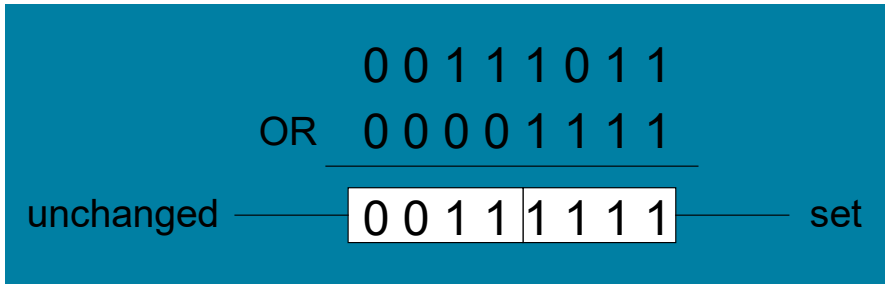
AND

x	y	x ∧ y
0	0	0
0	1	0
1	0	0
1	1	1

OR Instruction

- Performs a Boolean OR operation between each pair of matching bits in two operands
- Syntax:

  OR destination, source



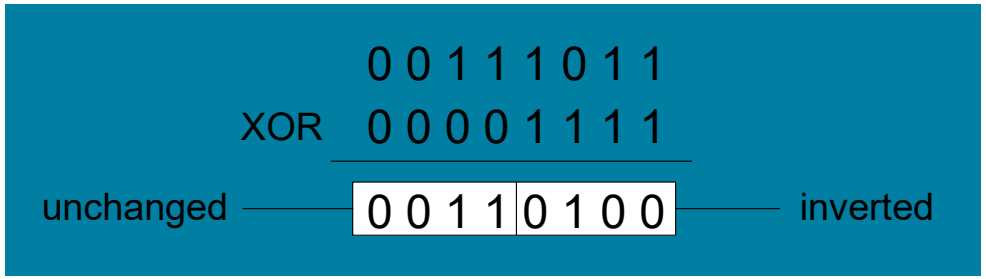
OR

x	y	x ∨ y
0	0	0
0	1	1
1	0	1
1	1	1

XOR Instruction

- Performs a Boolean exclusive-OR operation between each pair of matching bits in two operands
- Syntax:

  XOR destination, source



XOR

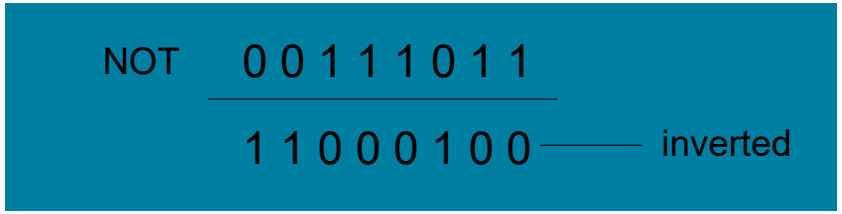
x	y	x ⊕ y
0	0	0
0	1	1
1	0	1
1	1	0

XOR is a useful way to toggle (invert) the bits in an operand.

NOT Instruction

- Performs a Boolean NOT operation on a single destination operand
- Syntax:

  NOT destination



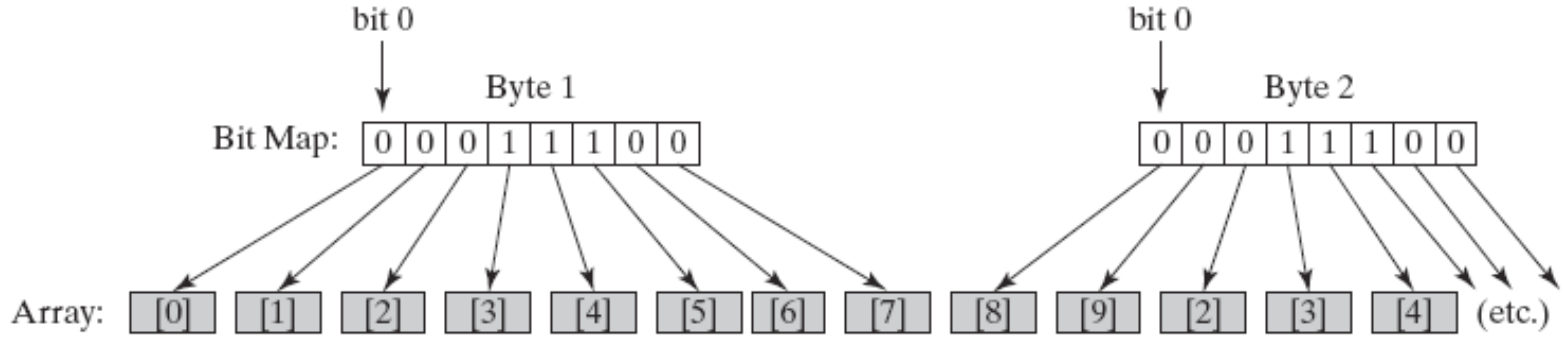
NOT

X	¬X
F	T
T	F

Bit-Mapped Sets

- Binary bits indicate set membership
- Efficient use of storage
- Also known as *bit vectors*

FIGURE 6–1 Mapping Binary Bits to an Array.



Bit-Mapped Set Operations

- Set Complement

```
mov eax, SetX
not eax
```

- Set Intersection

```
mov eax, setX
and eax, setY
```

- Set Union

```
mov eax, setX
or   eax, setY
```

Applications (1 of 4)

- Task: 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
```

Applications (2 of 4)

- Task: 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
```

The ASCII digit '6' = 00110110b

Applications (3 of 4)

- Task: 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 set
```

JZ (jump if Zero) is covered in Section 6.3.

Your turn: Write code that jumps to a label if an integer is negative.

Application (4 of 5)

- Task: 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
```

ORing any number with itself does not change its value.

TEST Instruction (1 of 2)

- Performs a nondestructive AND operation between each pair of matching bits in two operands
- No operands are modified, but the Zero flag is affected.
- Example: jump to a label if either bit 0 or bit 1 in AL is set.

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

TEST Instruction (2 of 2)

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

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

CMP Instruction (1 of 3)

- 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
```

CMP Instruction (2 of 3)

- Example: destination > source

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

(both the Zero and Carry flags are clear)

CMP Instruction (3 of 3)

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
```

Boolean Instructions in 64-Bit Mode

- 64-bit boolean instructions, for the most part, work the same as 32-bit instructions
- If the source operand is a constant whose size is less than 32 bits and the destination is the lower part of a 64-bit register or memory operand, all bits in the destination operand are affected
- When the source is a 32-bit constant or register, only the lower 32 bits of the destination operand are affected

What's Next (1 of 5)

- Boolean and Comparison Instructions
- **Conditional Jumps**
- Conditional Loop Instructions
- Conditional Structures
- Application: Finite-State Machines
- Conditional Control Flow Directives

Conditional Jumps

- Jumps Based On . . .
  - Specific flags
  - Equality
  - Unsigned comparisons
  - Signed Comparisons
- Applications
- Encrypting a String
- Bit Test (BT) Instruction

J*cond* Instruction

- A conditional jump instruction branches to a label when specific register or flag conditions are met
- Specific jumps:
  - JB, JC - jump to a label if the Carry flag is set
  - JE, JZ - jump to a label if the Zero flag is set
  - JS - jump to a label if the Sign flag is set
  - JNE, JNZ - jump to a label if the Zero flag is clear
  - JECXZ - jump to a label if ECX = 0

J*cond* Ranges

- Prior to the 386:
  - jump must be within –128 to +127 bytes from current location counter
- x86 processors:
  - 32-bit offset permits jump anywhere in memory

Jumps Based on Specific Flags

Mnemonic	Description	Flags
JZ	Jump if zero	ZF = 1
JNZ	Jump if not zero	ZF = 0
JC	Jump if carry	CF = 1
JNC	Jump if not carry	CF = 0
JO	Jump if overflow	OF = 1
JNO	Jump if not overflow	OF = 0
JS	Jump if signed	SF = 1
JNS	Jump if not signed	SF = 0
JP	Jump if parity (even)	PF = 1
JNP	Jump if not parity (odd)	PF = 0

Jumps Based on Equality

Mnemonic	Description
JE	Jump if equal (*leftOp* = *rightOp*)
JNE	Jump if not equal (*leftOp* ≠ *rightOp*)
JCXZ	Jump if CX = 0
JECXZ	Jump if ECX = 0

Jumps Based on Unsigned Comparisons

Mnemonic	Description
JA	Jump if above (if *leftOp* > *rightOp*)
JNBE	Jump if not below or equal (same as JA)
JAE	Jump if above or equal (if *leftOp* >= *rightOp*)
JNB	Jump if not below (same as JAE)
JB	Jump if below (if *leftOp* < *rightOp*)
JNAE	Jump if not above or equal (same as JB)
JBE	Jump if below or equal (if *leftOp* <= *rightOp*)
JNA	Jump if not above (same as JBE)

Jumps Based on Signed Comparisons

Mnemonic	Description
JG	Jump if greater (if *leftOp* > *rightOp*)
JNLE	Jump if not less than or equal (same as JG)
JGE	Jump if greater than or equal (if *leftOp* >= *rightOp*)
JNL	Jump if not less (same as JGE)
JL	Jump if less (if *leftOp* < *rightOp*)
JNGE	Jump if not greater than or equal (same as JL)
JLE	Jump if less than or equal (if *leftOp* <= *rightOp*)
JNG	Jump if not greater (same as JLE)

Applications (1 of 4)

- Task: Jump to a label if unsigned EAX is greater than EBX
- Solution: Use CMP, followed by JA

```
cmp eax, ebx
ja  Larger
```

- Task: Jump to a label if signed EAX is greater than EBX
- Solution: Use CMP, followed by JG

```
cmp eax, ebx
jg  Greater
```

Applications (2 of 4)

- Jump to label L1 if unsigned EAX is less than or equal to Val1

```
cmp eax, [Val1]
jbe L1                    ; below or equal
```

- Jump to label L1 if signed EAX is less than or equal to Val1

```
cmp eax, [Val1]
jle L1
```

Applications (3 of 4)

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

```
        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

```
        mov [Small], ax
        cmp bx, ax
        jnl Next
        mov [Small], bx
Next:
```

Applications (4 of 4)

- Jump to label L1 if the memory word pointed to by ESI equals Zero

```
cmp WORD [esi], 0
je  L1
```

- Jump to label L2 if the doubleword in memory pointed to by EDI is even

```
test DWORD [edi],1
jz   L2
```

Applications

- Task: Jump to label L1 if bits 0, 1, and 3 in AL are all set.
- Solution: Clear all bits except bits 0, 1,and 3. Then compare the result with 00001011 binary.

```
and al, 00001011b       ; clear unwanted bits
cmp al, 00001011b       ; check remaining bits
je  L1                  ; all set? jump to L1
```

BT (Bit Test) Instruction

- Copies bit *n* from an operand into the Carry flag
- Syntax: BT *bitBase*, n
  - bitBase may *be r/m16* or *r/m32*
  - n may be *r16*, *r32*, or *imm8*
- 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
```

54 6F 20 42 65 20 43 6F 6E 74 69 6E 75 65 64