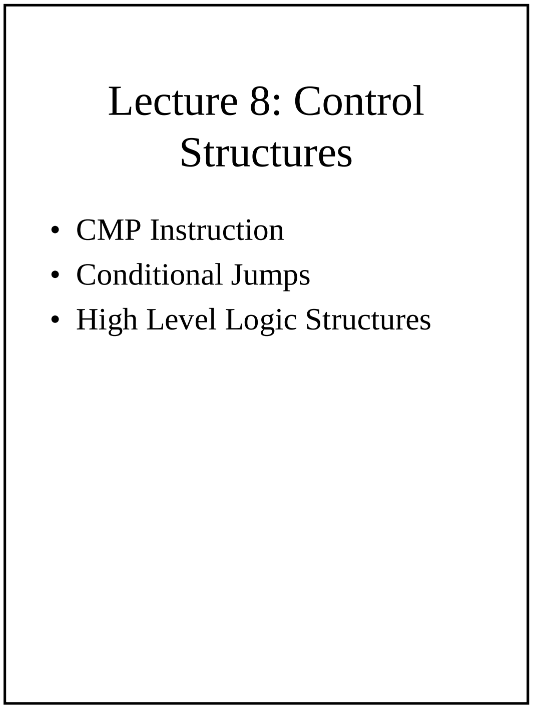
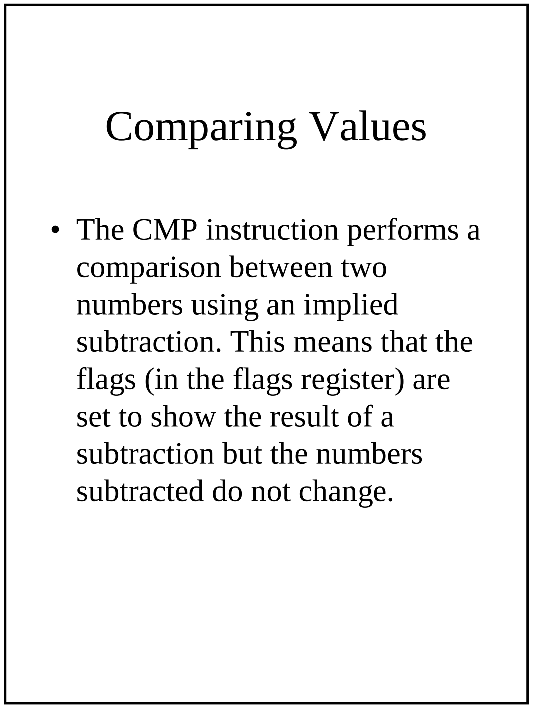


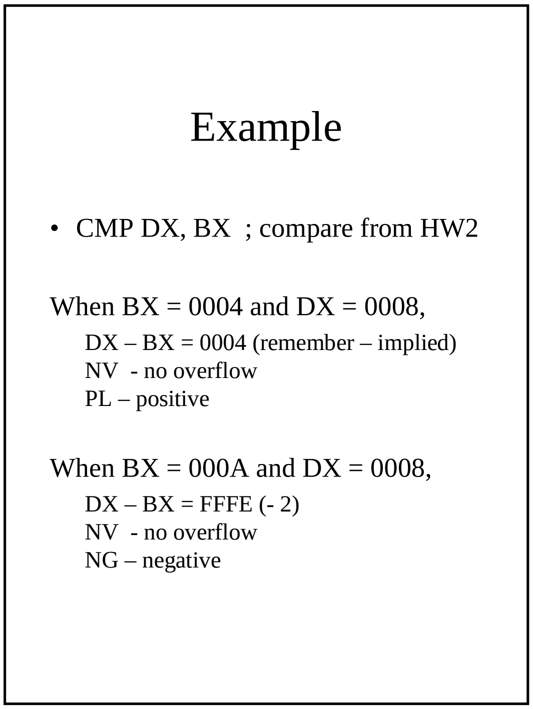
Lecture 8: Control Structures

- CMP Instruction
- Conditional Jumps
- High Level Logic Structures



Comparing Values

- The CMP instruction performs a comparison between two numbers using an implied subtraction. This means that the flags (in the flags register) are set to show the result of a subtraction but the numbers subtracted do not change.



Example

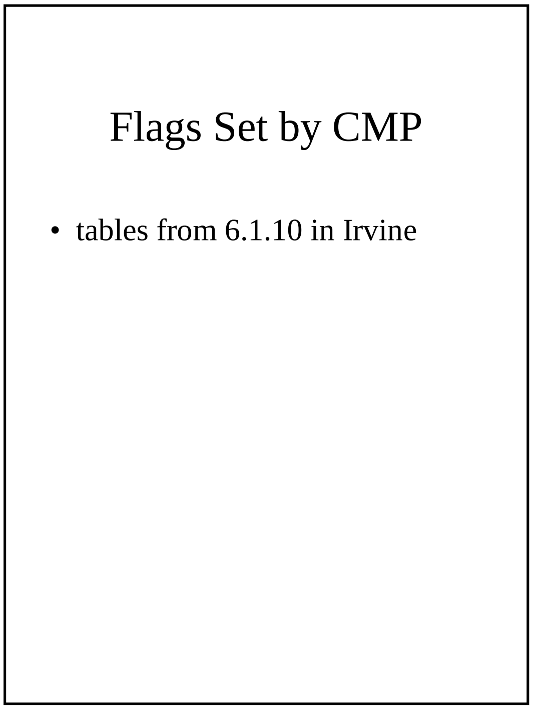
- CMP DX, BX ; compare from HW2

When BX = 0004 and DX = 0008,

DX – BX = 0004 (remember – implied)
NV - no overflow
PL – positive

When BX = 000A and DX = 0008,

DX – BX = FFFE (- 2)
NV - no overflow
NG – negative



Flags Set by CMP

- tables from 6.1.10 in Irvine

CMP Examples

- AX = 10, BX = -12 (decimal)
- CMP AX, BX

  AX – BX = +22

  PL (positive), CY (carry), NV (no overflow), NZ (not zero)
- CMP BX, AX

  BX – AX = -22

  NG (negative), NC (no carry), NV (no overflow), NZ (not zero)
- CMP AX, AX

  AX – AX = 0

  PL (positive), NC (no carry), NV (no overflow), ZR (zero)

What can we compare?

- register to register:
  - CMP AX, BX
- register to memory:
  - CMP AX, mval
- register to immediate:
  - CMP AX, 42
- memory to register:
  - CMP mval, AX
- memory to immediate (!)
  - CMP mval, 42

What can't we compare?

- You can not compare memory to memory!!!
- One value will need to be copied into a register prior to the CMP instruction.

Why is this Useful?

- CMP is generally followed by a conditional jump statement to create an If statement:

```
CMP dest, src  ;sets flags
Jxxx  label     ;jumps based on flags
```

Conditional Jumps

- Conditional jumps are used to jump to another location based on the settings in the flags register.
- The numbers you are comparing can represent signed or unsigned values. Different flags will be checked depending on which interpretation you are using.
- How does the CPU know how you are interpreting the numbers?
  - It knows by your choice of jump instruction!

General Comparison Jumps

- Irvine, Ch 6, table 4
- These are the same for signed and unsigned

Unsigned Comparison Jumps

- Irvine, Ch 6, table 5
- Unsigned jumps refer to “above and “below”

Signed Comparison Jumps

- Irvine, Ch 6, Table 6
- Signed jumps refer to “greater” and “less”

Signed vs. Unsigned

```
     .data
total dw 0FFFFh
; jump if total < 10 (signed)
   CMP       total, 10
   JL  less10      ;jump total < 10
   …
less10:
```

FFFFh = -1, so code will jump to less10 since –1 < 10.

```
;jump if total < 10 (unsigned)
   CMP total, 10
   JB     less10       ; jump total < 10
   ….
less10:
```

This code will not jump to less10 because FFFFh unsigned = 65535 > 10.

How does assembler know if FFFFh is –1 or 65,535? You tell it by your choice of jump instruction!

Using Conditional Jumps

- As shown earlier, the relation expressed by the jump instruction refers to the two operands from a previous CMP.
- Conditional jumps are *usually* used directly after a CMP.
- Why usually? Well, you could use a jump based on the result of an arithmetic operation.

Example

```
CMP DX, BX  ; compare from HW2
JGE   add_lup  ; jump to top of loop
```

When BX = 0004 and DX = 0008,

DX – BX = 0004 (remember – implied)
NV - no overflow (0)
PL – positive (0)
overflow matches sign – jumps back to top of loop: DX >= BX

When BX = 000A and DX = 0008,

DX – BX = FFFE (- 2)
NV - no overflow (0)
NG – negative (1)
overflow <> sign – does not jump:
DX < BX

High Level Logic Structures

- So what are some of the control structures in high level programming languages?
  - if
  - do-while
  - repeat-until
  - case
  - …..
- These can be implemented in assembly using CMP and conditional Jump

If Statement

```
if (op1 = op2) then
     <statement1>
     <statement2>
end if
```

In assembler (still pseudo-code!):

```
     cmp op1, op2
     jne   false
     <statement1>
     <statement2>
false: <rest of program>
```

If Statement Example

```
   .data
op1    db     10
op2    db     –12
op3    db     ?

   .code
       mov   al, op1         ;why?
       cmp   al, op2         ; op1 = op2?
       jne   noteq           ;  if no, jump
       mov   bl, op2         ;statement 1
       mov   op3, bl         ;statement 2
noteq: add   al, op2
```

If-then-Else

```
if (temp > max) then
      max = temp
else
      max = max + 1
endif
```

In Assembly:

```
     mov   ax, temp
     mov   bx, max
     cmp   ax, bx          ;compare temp to max
                           ;"if"
     jle    els            ;jump if temp <= max
     mov   max, ax         ;temp > max "then"
     jmp   done            ;unconditional jump
els: inc   bx              ; temp <= max "else"
     mov max, bx
done:
```

Compound If Using OR

- Examples from Irvine, 6.4.2

Compound IF Using AND

- more examples from Irvine 6.4.2

Another example (this time: unsigned)

```
if ((ax < 10) and (bx < 10)) then
    assign 1 to CX register
else
    assign 0 to CX register
end if
```

In assembly:

```
     cmp  ax, 10
     jae  els    ;jump ax >= 10
     cmp  bx, 10 ; ax < 10
     jae  els    ;jump bx >= 10
     mov  cx, 1  ;ax < 10 and bx < 10
     jmp  done
els: mov  cx, 0  ;ax >= 10 or bx >=10
done:
```

With AND – negate the conditions you test for!

Do-While

```
do
  ax = ax + 1
  cx = ax
while ((ax < bx) AND (cx == dx))
```

In assembly:

```
top:  inc  ax      ;ax = ax + 1
      mov  cx, ax  ;cx = ax
      cmp  ax, bx
      jae  done    ;ax >=bx done
      cmp  cx, dx
      jne  done    ;cx <> dx:done
      jmp  top
done:
```

The condition that brings you back to the top is (AX < BX) AND (CX == DX).

You want to exit from the loop when AX >= BX or CX <> DX)

Case Statement

Examples in Irvine, 6.4.5