

# Princeton University

## COS 217: Introduction to Programming Systems

### IA-32 Condition Codes

#### Condition Codes

Bits in the EFLAGS register

```
cmpl src, dest
```

Performs the subtraction  $dest - src$ , and sets the condition codes depending upon the difference:

| Condition Code     | Set to 1 when:   |
|--------------------|--|
| ZF (zero flag)     | Mathematically: The difference was 0.<br>Physically: All bits of the difference were 0.  |
| SF (sign flag)     | Mathematically: The difference was negative.<br>Physically: The most significant bit of the difference was 1.  |
| CF (carry flag)    | Mathematically: The difference was incorrect when we view the operands and difference as <b>unsigned</b> integers.<br>Physically: A borrow occurred into the most significant bit.   |
| OF (overflow flag) | Mathematically: The difference was incorrect when we view the operands and difference as <b>signed</b> integers.<br>Physically: The borrow into the most significant bit differed from the borrow out of the most significant bit. |

#### Conditional Control Transfer Instructions (Used After Comparing Unsigned Numbers)

| Instruction                                | Jump if and only if: |
|--|----------------------|
| <code>je</code> (jump iff equal)           | ZF                   |
| <code>jne</code> (jump iff not equal)      | $\sim$ ZF            |
| <code>jb</code> (jump iff below)           | CF                   |
| <code>jae</code> (jump iff above or equal) | $\sim$ CF            |
| <code>jbe</code> (jump iff below or equal) | CF   ZF              |
| <code>ja</code> (jump iff above)           | $\sim$ (CF   ZF)     |

Examples (assuming a 5-bit computer for simplicity):

| Comparison | Subtraction   | Resulting Condition Codes            | Execution of <code>jb</code> |
|------------|---|--------------------------------------|------------------------------|
| 12 and 6   | $\begin{array}{r} 01100 \quad 12 \\ -00110 \quad -6 \\ \hline 00110 \quad 6 \end{array}$  | CF = 0 (unsigned diff was correct)   | CF == 0<br>So don't jump     |
| 6 and 12   | $\begin{array}{r} 00110 \quad 6 \\ -01100 \quad -12 \\ \hline 11010 \quad 26 \end{array}$ | CF = 1 (unsigned diff was incorrect) | CF == 1<br>So jump           |

## Conditional Control Transfer Instructions (Used After Comparing Signed Numbers)

| Instruction                          | Jump if and only if: |
|--------------------------------------|----------------------|
| je (jump iff equal)                  | ZF                   |
| jne (jump iff not equal)             | ~ZF                  |
| jl (jump iff less than)              | SF ^ OF              |
| jge (jump iff greater than or equal) | ~(SF ^ OF)           |
| jle (jump iff less than or equal)    | (SF ^ OF)   ZF       |
| jg (jump iff greater than)           | ~((SF ^ OF)   ZF)    |

### Examples (assuming a 5-bit computer for simplicity):

| Comparison | Subtraction   | Resulting Condition Codes  | Execution of jl                 |
|------------|---|--|---------------------------------|
| 12 and 6   | <pre> 01100  12 -00110  -6 ----- 00110   6           </pre> | SF = 0 (diff was positive)<br>OF = 0 (signed diff was correct)   | (SF ^ OF) == 0<br>So don't jump |
| -6 and -12 | <pre> 11010  -6 -10100 -12 ----- 00110   6           </pre> | SF = 0 (diff was positive)<br>OF = 0 (signed diff was correct)   | (SF ^ OF) == 0<br>So don't jump |
| 6 and 12   | <pre> 00110   6 -01100 -12 ----- 11010  -6           </pre> | SF = 1 (diff was negative)<br>OF = 0 (signed diff was correct)   | (SF ^ OF) == 1<br>So jump       |
| -12 and -6 | <pre> 10100 -12 -11010 -6 ----- 11010  -6           </pre>  | SF = 1 (diff was negative)<br>OF = 0 (signed diff was correct)   | (SF ^ OF) == 1<br>So jump       |
| -12 and 6  | <pre> 10100 -12 -00110  -6 ----- 01110  14           </pre> | SF = 0 (diff was positive)<br>OF = 1 (signed diff was incorrect) | (SF ^ OF) == 1<br>So jump       |
| -6 and 12  | <pre> 11010  -6 -01100 -12 ----- 01110  14           </pre> | SF = 0 (diff was positive)<br>OF = 1 (signed diff was incorrect) | (SF ^ OF) == 1<br>So jump       |
| 6 and -12  | <pre> 00110   6 -10100 -12 ----- 10010 -14           </pre> | SF = 1 (diff was negative)<br>OF = 1 (signed diff was incorrect) | (SF ^ OF) == 0<br>So don't jump |
| 12 and -6  | <pre> 01100  12 -11010 -6 ----- 10010 -14           </pre>  | SF = 1 (diff was negative)<br>OF = 1 (signed diff was incorrect) | (SF ^ OF) == 0<br>So don't jump |

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