Processor Status and the FLAGS Register

Module 5

CS 272

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FLAGS Register

- Individual bits control the action or represent the status of the processor
  - Control flags (TF, IF, DF)
    - Determine how the processor responds to certain situations
  - Status flags (CF, PF, AF, ZF, SF, OF)
    - Set to represent the result of certain operations
    - Used to control conditional jump instructions
  - EFLAGS and RFLAGS are the 32- and 64-bit extensions of the FLAGS register

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FLAG Register Bits

Bit	Name	Symbol
0	Carry flag	`cf`
2	Parity flag	`pf`
4	Auxiliary carry flag	`af`
6	Zero flag	`zf`
7	Sign flag	`sf`
8	Trace flag	`tf`
9	Interrupt flag	`if`
10	Direction flag	`df`
11	Overflow flag	`of`

Control Flags

- DF - Direction flag
  - STD: direction = down
  - CLD: direction = up
- IF - Interrupt enable
  - STI: enable external interrupts
  - CLI: disable maskable external interrupts
- TF - Trace flag
  - Interrupt 1 after executing instruction, if set

Status Flags (Overview)

- Carry
  - carry or borrow at MSB in add or subtract
  - last bit shifted out
- Parity
  - low byte of result has even parity
- Auxiliary
  - carry or borrow at bit 3

- Zero
  - result is 0
- Sign
  - result is negative
- Overflow
  - signed overflow occurred during add or subtract

The Carry Flag (CF)

- CF = 1 if there is a carry out from the msb (most significant bit) on addition, or there is a borrow into the msb on subtraction
- CF = 0 otherwise
- CF is also affected by shift and rotate instructions

The Parity Flag (PF)

- PF = 1 if the low byte of a result has an even number of one bits (even parity)
- PF = 0 otherwise (odd parity)

The Auxiliary Carry Flag (AF)

- AF = 1 if there is a carry out from bit 3 on addition, or there is a borrow into the bit 3 on subtraction
- AF = 0 otherwise
- AF is used in binary-coded decimal (BCD) operations

The Zero Flag (ZF)

- ZF = 1 for a zero result
- ZF = 0 for a non-zero result

The Sign Flag (SF)

- SF = 1 if the msb of a result is 1; it means the result is negative if you are giving a signed interpretation
- SF = 0 if the msb is 0

The Overflow Flag (OF)

- OF = 1 if signed overflow occurred
- OF = 0 otherwise

(Signed) Overflow

- Can only occur when adding numbers of the same sign (subtracting with different signs)
- Detected when carry into MSB is not equal to carry out of MSB
  - Easily detected because this implies the result has a different sign than the sign of the operands
- Programs can ignore the Flags!

Signed Overflow Example

```
  10010110              00110110
+ 10100011            + 01100011
  00111001              10011001
```

Carry in = 0, Carry out = 1   *Carry in = 1, Carry out = 0*
Neg+Neg=Pos   *Pos+Pos=Neg*
Signed overflow occurred   *Signed overflow occurred*
OF = 1 (set)   *OF = 1 (set)*

Examples of No Signed Overflow

```
  10010110              10010110
+ 01100011            + 11110011
  11111001              10001001
```

Carry in = 0, Carry out = 0   *Carry in = 1, Carry out = 1*
Neg+Pos=Neg   *Neg+Neg=Neg*
No Signed overflow   *No Signed overflow*
* occurred*   * occurred*
OF = 0 (clear)   *OF = 0 (clear)*

Unsigned Overflow

- The carry flag is used to indicate if an unsigned operation overflowed

```
  10010110
+ 11110011
  10001001
```

- The processor only adds or subtracts - it doesn't make any difference if the data is signed or unsigned!

Carry out = 1
Unsigned overflow occurred
CF = 1 (set)

Instructions and Flags

- MOV and XCHG - no flags are changed
- ADD and SUB - all flags affected
- INC and DEC - all except CF
- NEG - all flags affected
  - CF=0 only if value is 0
  - OF=1 only if value is -MAXINT
    - 80h (8-bit), 8000h (16-bit), 80000000h (32-bit)