Microprocessor Based Systems

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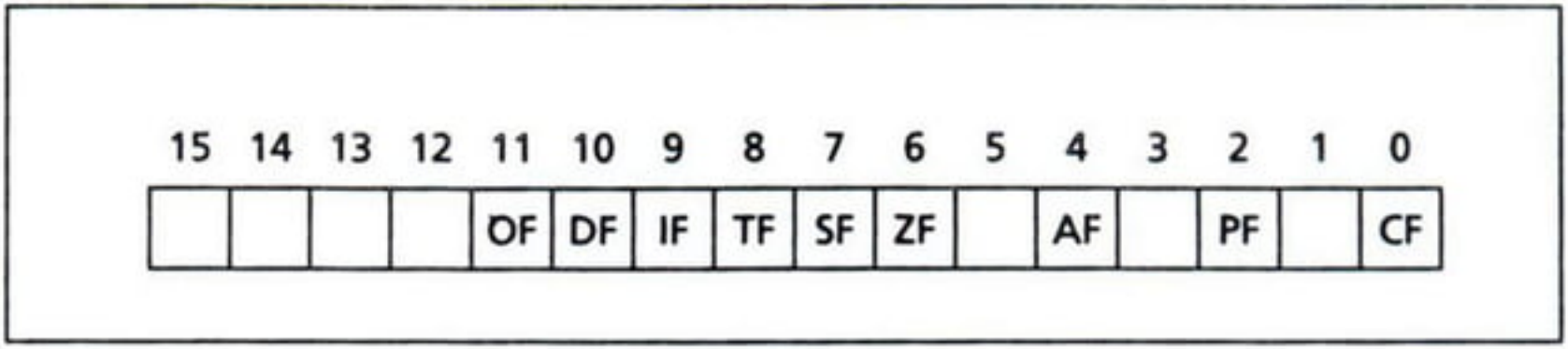
CHAPTER 5

THE PROCESSOR STATUS AND FLAG REGISTERS

Outline

- The FLAG Register
- Overflow
- How Instruction Affect the Flags
- DEBUG

The FLAGS Register



The Status Flags

- The processor uses the status flags to reflect the result of an operation.
- Bits 0, 2, 4 ,6, 7, 11
- If SUB AX, AX is executed, the zero flag becomes 1, thereby indicating that a zero result was produced.

Carry Flag (CF)

- CF = 1 if there is a carry out of msb on addition, or there is a borrow into msb on subtraction; otherwise, CF = 0.

Parity Flag (PF)

- PF = 1 if the low byte of a result has an even number of one bits (even parity).
- PF = 0 if the low byte has odd parity.
- If the result of a word addition is FFFEh, then the low byte contains 7 one bits, so PF = 0.

Auxiliary Carry Flag (AF)

- AF = 1 if there is a carry out from bit 3 on addition, or a borrow into bit 3 on subtraction.

Zero Flag (ZF)

- ZF = 1 for a zero result.
- ZF = 0 for a nonzero result.

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.

Overflow Flag (OF)

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

Unsigned Overflow: ADD AX, BX

Unsigned Interpretation

1111 1111 1111 1111	65535	AX = FFFFh
+ 0000 0000 0000 0001	1	BX = 0001h
1 0000 0000 0000 0000	0	AX = 0000h

Signed Interpretation

1111 1111 1111 1111	-1	AX = FFFFh
+ 0000 0000 0000 0000	1	BX = 0001h
1 0000 0000 0000 0000	0	AX = 0000h

Signed Overflow: ADD AX, BX

Unsigned Interpretation

0111 1111 1111 1111	32767	AX = 7FFFh
+ 0111 1111 1111 1111	32767	BX = 7FFFh
1111 1111 1111 1110	65534	AX = FFFEh

Signed Interpretation

0111 1111 1111 1111	32767	AX = 7FFFh
+ 0111 1111 1111 1111	32767	BX = 7FFFh
1111 1111 1111 1110	-2	AX = FFFEh

How the Processor Determines that Unsigned Overflow Occurred

- CF = 1
- Addition
  - The correct answer is larger than the biggest unsigned number (FFFFh and FFh).
- Subtraction
  - The correct answer is smaller than 0.
  - There is a borrow into the msb.

How the Processor Determines that Signed Overflow Occurred

- OF = 1
  - There is a carry into the msb but no carry out.
  - There is a carry out but no carry in.
- Addition
  - The sum has a different sign.
- Subtraction
  - The result has a different sign than expected.
  - A – (–B) = A + B
  - –A – B = –A + –B
- Addition of Numbers with Different Signs
  - Overflow is impossible.
  - A + (– B) = A – B

How Instructions Affect the Flags

Instruction	**Affects Flags**
MOV/XCHG	none
ADD/SUB	all
INC/DEC	all except CF
NEG	all (CF = 1 unless result is 0, OF = 1 if word operand is 8000h, or byte operand is 80h)

ADD AX, BX where AX contains FFFFh and BX contains FFFFh.

FFFFh	1111 1111 1111 1111		
+ FFFFh	+ 1111 1111 1111 1111		
1 FFFEh	1 1111 1111 1111 1110	AX = FFFEh	

SF = 1 because the msb is 1.

PF = 0 because there are 7 (odd number) of 1 bits in the low byte of the result.

ZF = 0 because the result is nonzero.

CF = 1 because there is a carry out of the msb on addition.

OF = 0 because the sign of the stored result is the same as that of the numbers being added (as a binary addition, there is a carry into the msb and also a carry out).

ADD AL, BL where AL contains 80h and BL contains 80h.

80h	1000 0000
+ 80h	+ 1000 0000
1 00h	1 0000 0000

AL = 00h

SF = 0 because the msb is 0.
PF = 1 because all the bits in the result are 0.
ZF = 1 because the result is 0.
CF = 1 because there is a carry out of the msb on addition.
OF = 1 because the numbers being added are both negative, but the result is 0 (as a binary addition, there is no carry into the msb but there is a carry out).

SUB AX, BX where AX contains 8000h and BX contains 0001h.

8000h	1000 0000 0000 0000
− 0001h	− 0000 0000 0000 0001
7FFFh	0111 1111 1111 1111 AX = 7FFFh

SF = 0 because the msb is 0.

PF = 1 because there are 8 (even number) one bits in the low byte of the result.

ZF = 0 because the result is nonzero.

CF = 0 because a smaller unsigned number is being subtracted from a larger one.

OF = 1 because in a signed sense we are subtracting a positive number from a negative one, which is like adding two negatives but the result is positive (the wrong sign).

INC AL where AL contains FFh.

FFh	1111 1111	
+ 1h	+ 0000 0001	
1 00h	1 0000 0000	AL = 00h

SF = 0, PF = 1, ZF = 1.

CF is unaffected by INC.

If CF = 0 before the execution of the instruction, CF will still be 0 afterward.

OF = 0 because numbers of unlike sign are being added (there is a carry into the msb and also a carry out).

MOV AX, -5

AX = FFFBh

None of the flags are affected by MOV.

NEG AX where AX contains 8000h.

8000h	= 1000 0000 0000 0000	
one's complement	= 0111 1111 1111 1111	
	+1	
	= 1000 0000 0000 0000	= 8000h

SF = 1, PF = 1, ZF = 0.

CF = 1 because for NEG CF is always 1 unless the result is 0.

OF = 1 because the result is 8000h; when a number is negated, we would expect a sign change, but because 8000h is its own two's complement, there is no sign change.

DEBUG

- **R** display registers
- **T** trace an instruction
- **G** execute a program
- **Q** quit

DEBUG Flag Symbols

Status Flag	Set (1) Symbol	Clear (0) Symbol
CF	CY (carry)	NC (no carry)
PF	PE (even parity)	PO (odd parity)
AF	AC (auxiliary carry)	NA (no auxiliary carry)
ZF	ZR (zero)	NZ (nonzero)
SF	NG (negative)	PL (plus)
OF	OV (overflow)	NV (no overflow)
Control Flag		
DF	DN (down)	UP (up)
IF	EI (enable interrupts)	DI (disable interrupt)