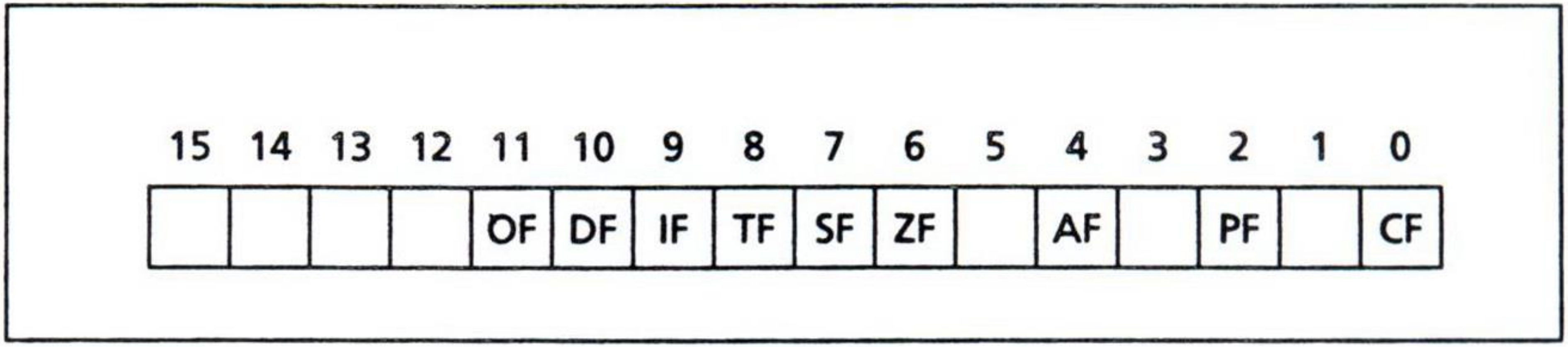
CHAPTER 5

THE PROCESSOR STATUS AND FLAG REGISTERS

Outline

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

The FLAGS Register



15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
				OF	DF	IF	TF	SF	ZF		AF		PF		CF

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 0001 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
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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.