Microprocessor and Assembly Language

Processor Status and Flag Register

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References

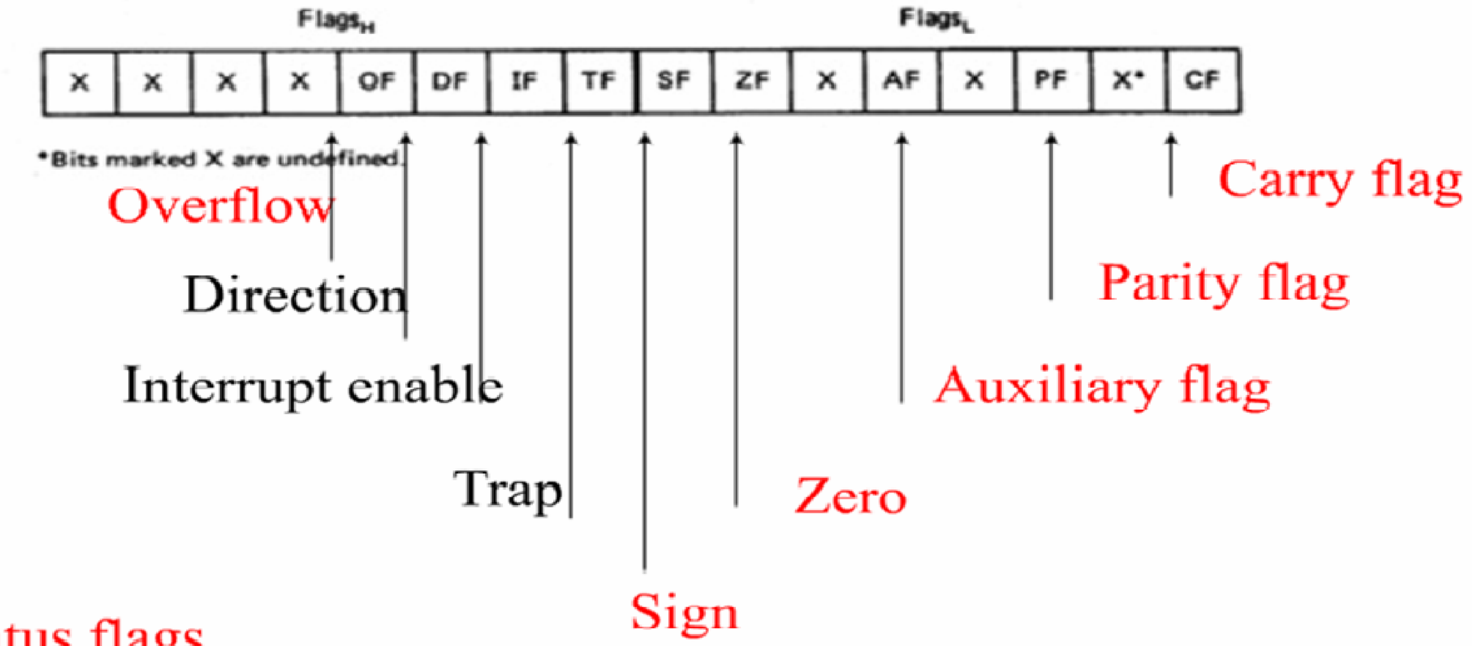
[1] ***Chapter 5*** Yutha Yu and Charles Marut, “Assembly Language Programming and Organization of the IBM PC", McGraw-Hill International Edition, 1992.

Overview

- ✓ Nine individual bits called as flag are used to represent the 8086 processor state.
- ✓ Flags are placed in FLAG Register.
- ✓ Two types of flags:
  - **Status Flags:** Reflects the result of computation. Located in bits: 0, 2, 4, 6, 7 and 11.
  - **Control Flags:** Used to enable/disable certain operations of the processor. Located in bits 8, 9 and 10.

The FLAG Register

Flags



Flags$_H$ Flags$_L$

X	X	X	X	OF	DF	IF	TF	SF	ZF	X	AF	X	PF	X*	CF

*Bits marked X are undefined.

Overflow

Direction

Interrupt enable

Trap

Sign

Zero

Auxiliary flag

Parity flag

Carry flag

6 are status flags

3 are control flag

The Status FLAG

There are 6 status flags in 8086 processor.

- ✓ Carry Flag (CF)
- ✓ Parity Flag (PF)
- ✓ Auxiliary Carry Flag (AF)
- ✓ Zero Flag (ZF)
- ✓ Sign Flag (SF)
- ✓ Overflow Flag (OF)

Carry Flag:

- ✓ The Carry Flag is set to 1 when there is a carry out from MSB on addition or there is a borrow into the MSB on subtraction.
- ✓ Also affected by shift and rotate instructions.
- ✓ Examples:
  - ✓ 0FFh + 11h = 110h (If a register can store only 1 byte, then where to store the carry generated by MSB?)
  - ✓ 0001b – 1000 0010b = 11111111b (How processor would know a borrow is required to perform subtraction?)

Parity Flag:

- ✓ PE (Even Parity): If the low byte of a result has an even number of one bits. For Even parity, PF =1
- ✓ PO (Odd Parity): If the low byte of a result has odd number of one bits. For Odd parity, PF = 0
- ✓ Examples:

  ✓1000 0001b – 1000 0010b = 11111111b (Number of one’s in result = 8, so PF = 1)

Auxiliary Carry Flag:

- ✓ The Auxiliary Carry Flag is set to 1 if there is a carry out from bit 3 on addition, or a borrow into bit 3 on subtraction.
- ✓ Used in Binary Coded Decimal (BCD) Operations.
- ✓ Examples:
  - ✓1000 0001b – 0000 0010b = 01111111b (Borrow from bit 4 to bit 3)

The Status FLAG

Zero Flag:

- Zero Flag is set when the result is zero.
- Zero Flag is unset when result is non zero.
- Examples:
  - ✓0FFh – 0FFh = 00h

Sign Flag:

- ✓ Set when MSB of a result is 1; it means the result is negative (signed interpretation)
- ✓ Unset when MSB is 0 i.e. result is positive.
- ✓ Examples:
  - ✓0FFh – 0FFh = 00h (MSB = 0, SF = 0)

The Status FLAG

Overflow Flag:

- ✓ Set if signed overflow occurred, otherwise it is 0.

Overflow:

- ✓ Range of numbers that can be represented in a computer is limited.
- ✓ If the result of an operation falls outside the defined range, Overflow occurs and the truncated result will be incorrect.
- ✓ Four possible outcomes of an arithmetic operation:
  - ✓No Overflow
  - ✓Only Signed Overflow
  - ✓Only Unsigned Overflow
  - ✓Both Signed and Unsigned Overflow

Example of Unsigned Overflow Only:

- ✓ AX = FFFFh, BX = 0001h
- ✓ ADD AX, BX
- ✓ Result: AX = 0000h but the correct answer is 10000h
- ✓ But FFFFh = -1 and 0001h= 1, -1+1 = 0 so the stored answer is correct if consider signs as well. Therefore, no sign verflow occurred.

Example of Signed Overflow Only:

- ✓ AX = 7FFFh, BX = 7FFFh
- ✓ ADD AX, BX
- ✓ Result: AX = FFFEh (correct unsigned result, so unsigned overflow)
- ✓ 7FFFh = 32767,
- ✓ 32767 + 32767 = 65534, which is out of ranged for signed numbers, also FFFE = -2 so signed overflow occurred.

The Status FLAG

How the Processor Indicates Overflow:

- The Processor sets:
  - ✓Overflow Flag = 1 for Signed Overflow
  - ✓Carry Flag = 1 for Unsigned Overflow

The Status FLAG

How the Processor determines that the overflow occurred?:

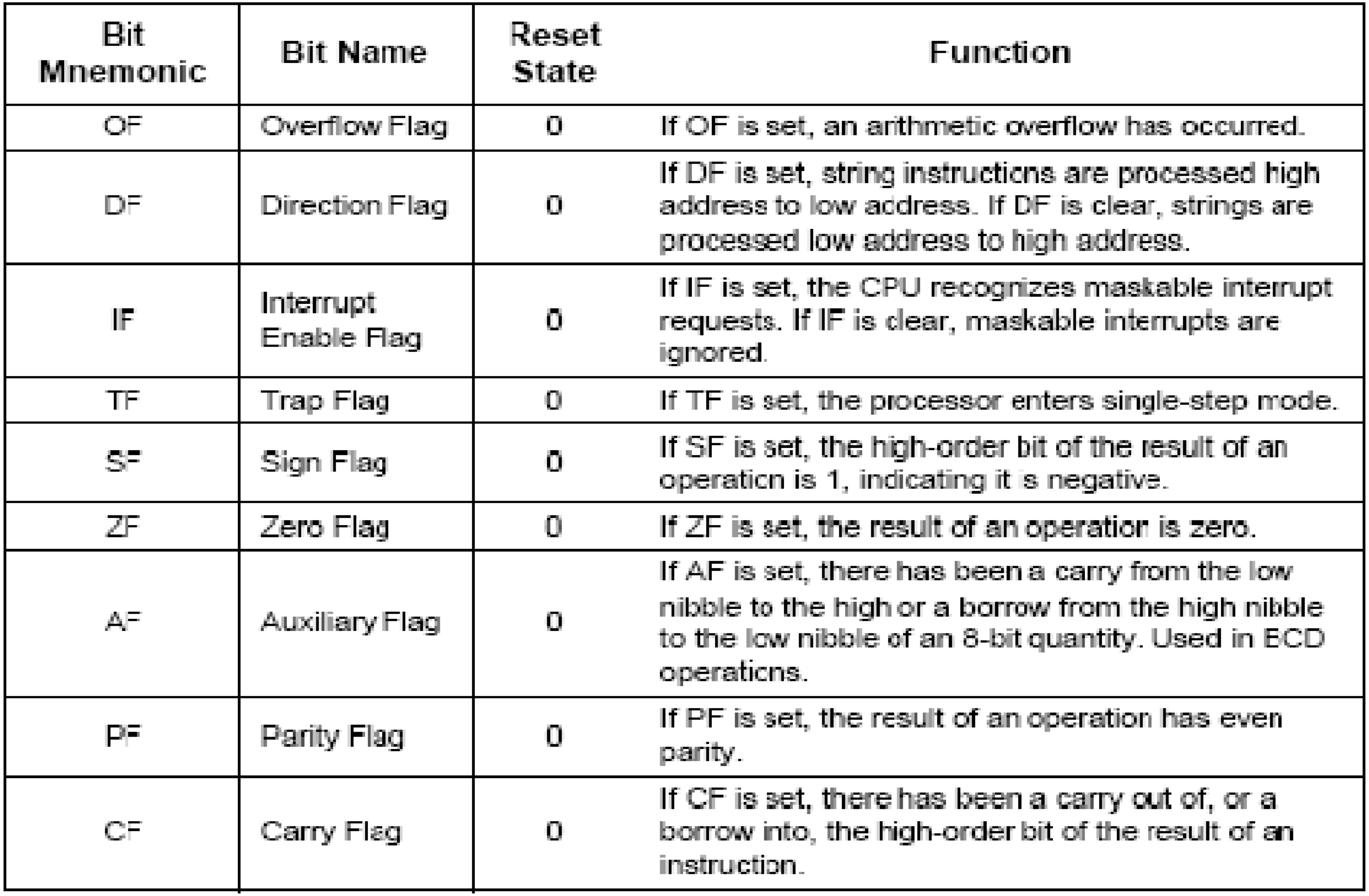
Unsigned Overflow:

- ✓ Addition: Carry out from MSB
- ✓ The correct Answer is largest than the biggest unsigned number FFFFh for a word and FFh for a byte.
- ✓ Subtraction: Borrow into MSB

- ■ **Signed Overflow:**
- ✓ Addition: Same sign but sum has a different sign (e.g.: when you add two positive numbers and answer is negative)
- ✓ Subtraction: If result has different sign than expected

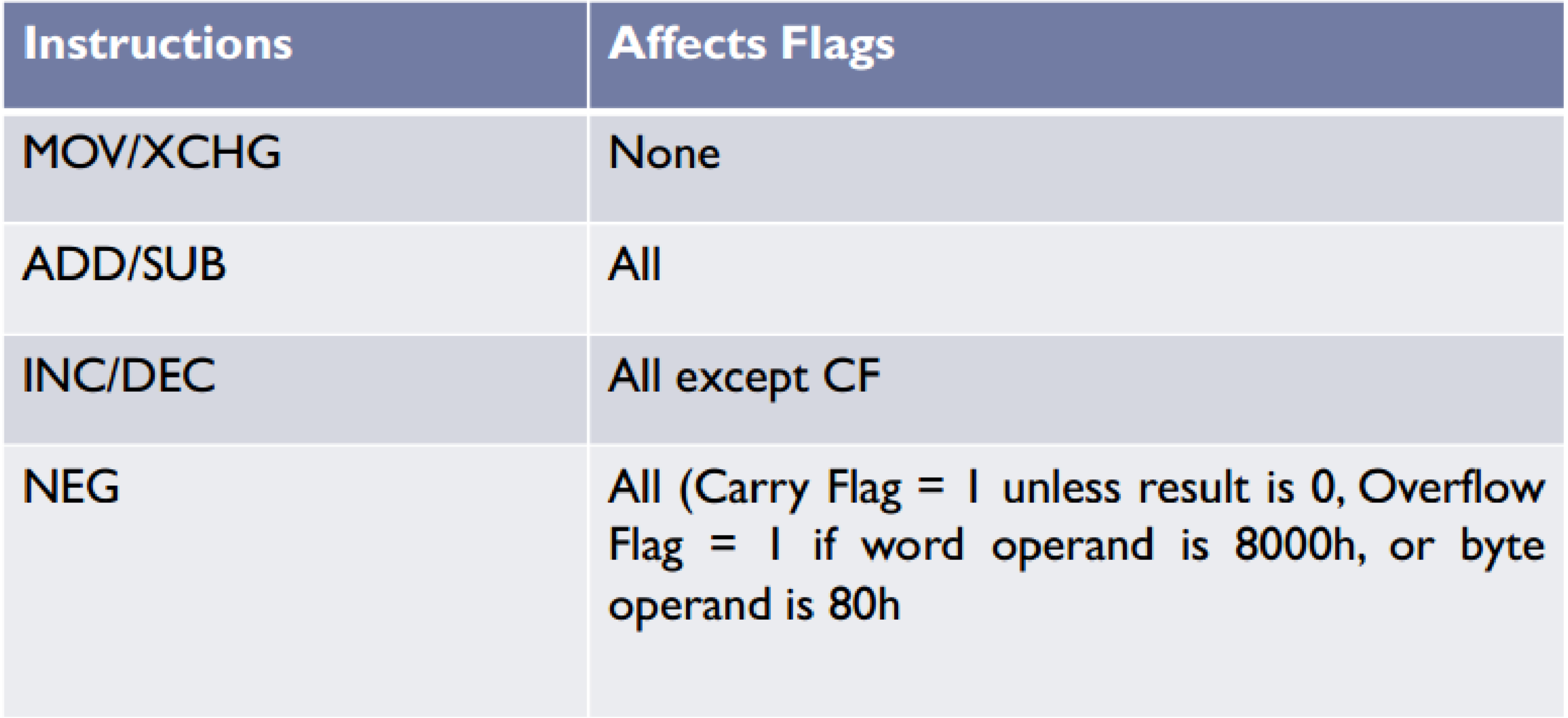
N.B.: In Addition/Subtraction of two numbers with different signs, overflow is impossible . E.g.: A + (-B) = A – B

Function of Each of the Status Flags



Bit Mnemonic	Bit Name	Reset State	Function
OF	Overflow Flag	0	If OF is set, an arithmetic overflow has occurred.
DF	Direction Flag	0	If DF is set, string instructions are processed high address to low address. If DF is clear, strings are processed low address to high address.
IF	Interrupt Enable Flag	0	If IF is set, the CPU recognizes maskable interrupt requests. If IF is clear, maskable interrupts are ignored.
TF	Trap Flag	0	If TF is set, the processor enters single-step mode.
SF	Sign Flag	0	If SF is set, the high-order bit of the result of an operation is 1, indicating it is negative.
ZF	Zero Flag	0	If ZF is set, the result of an operation is zero.
AF	Auxiliary Flag	0	If AF is set, there has been a carry from the low nibble to the high or a borrow from the high nibble to the low nibble of an 8-bit quantity. Used in BCD operations.
PF	Parity Flag	0	If PF is set, the result of an operation has even parity.
CF	Carry Flag	0	If CF is set, there has been a carry out of, or a borrow into, the high-order bit of the result of an instruction.

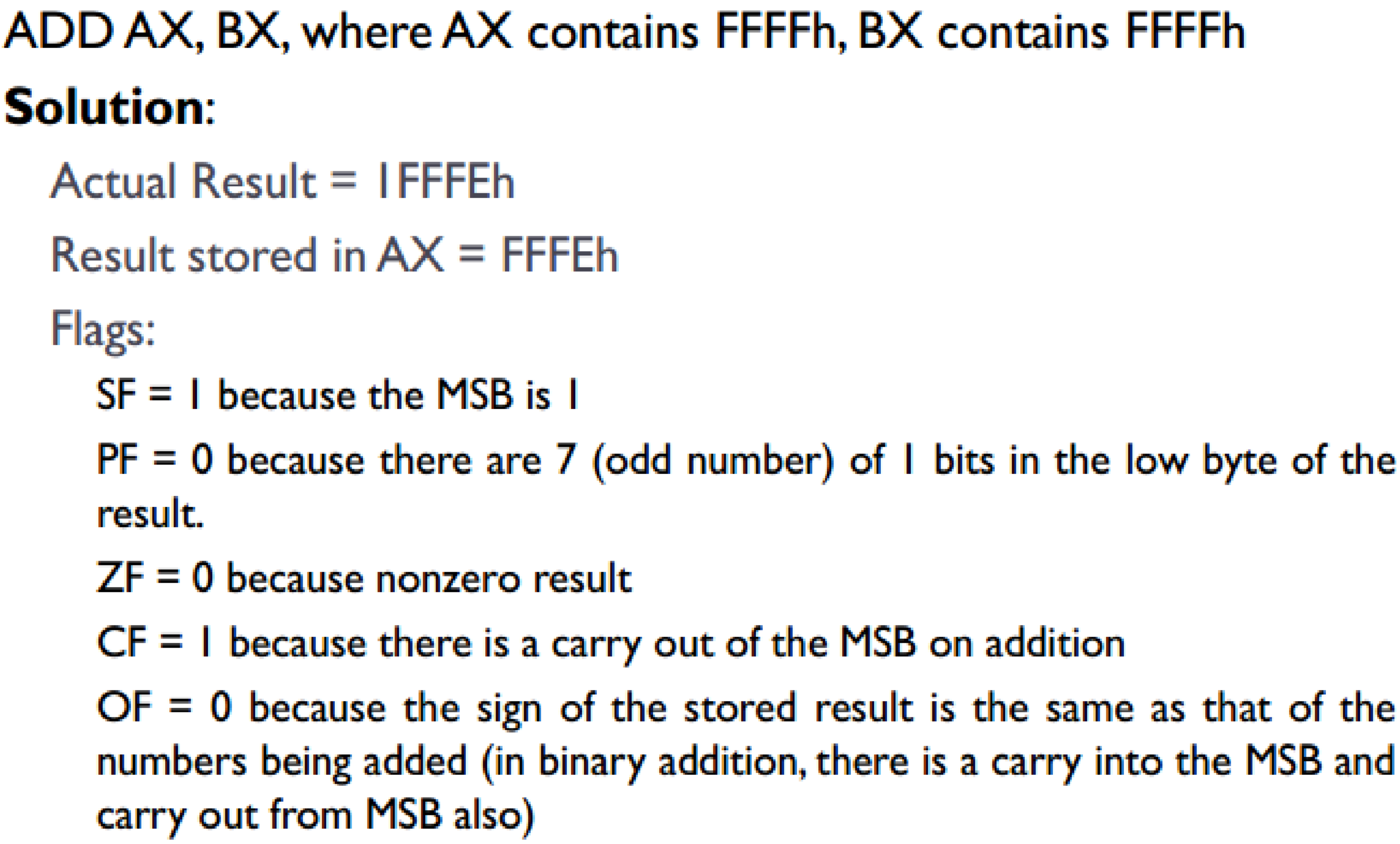
How Instruction Affects the Flags?



Instructions	Affects Flags
MOV/XCHG	None
ADD/SUB	All
INC/DEC	All except CF
NEG	All (Carry Flag = 1 unless result is 0, Overflow Flag = 1 if word operand is 8000h, or byte operand is 80h

How Instruction Affects the Flags?

Example 5.1



ADD AX, BX, where AX contains FFFFh, BX contains FFFFh

Solution:

Actual Result = 1FFFEh

Result stored in AX = FFFEh

Flags:

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.

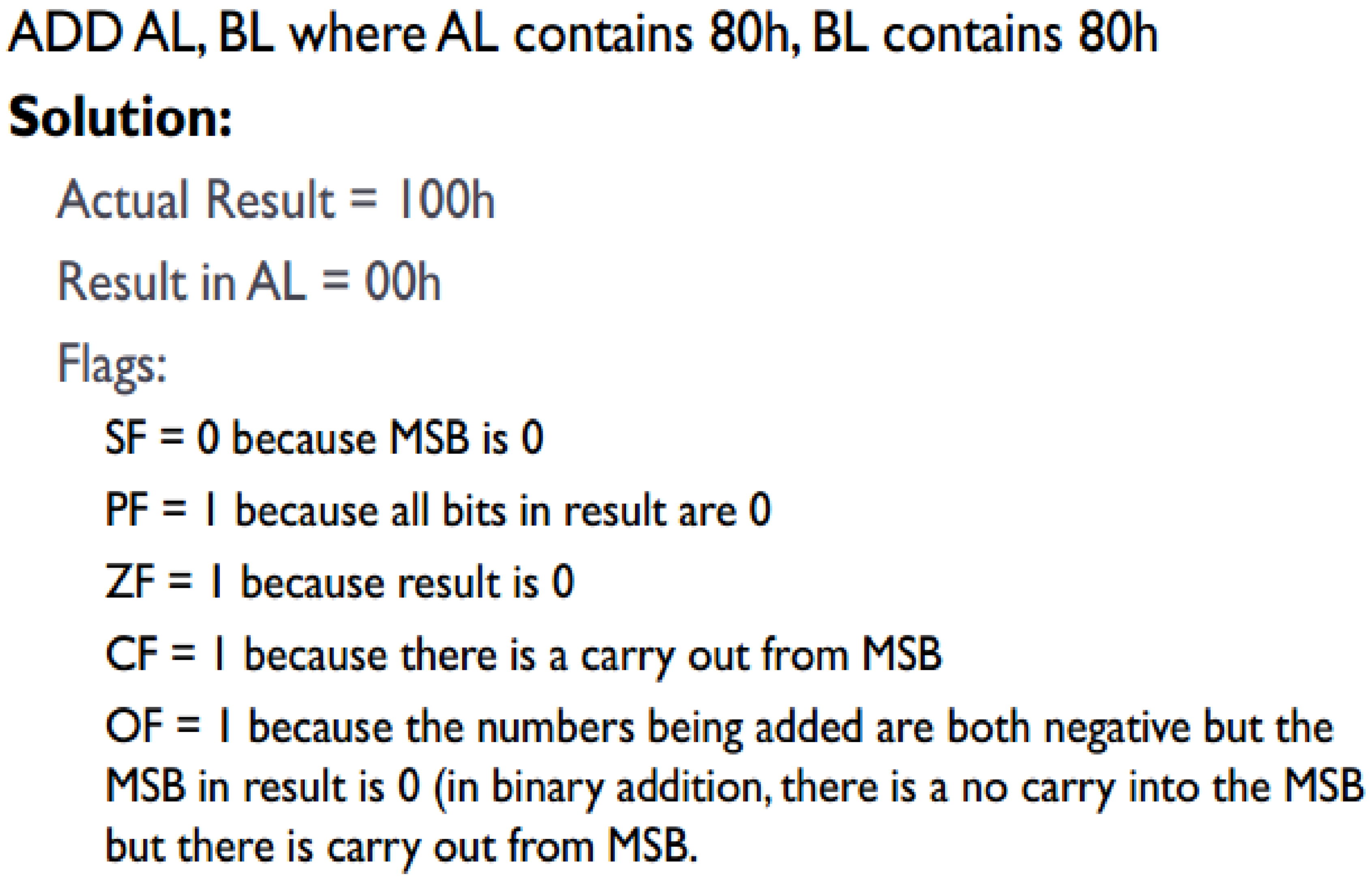
ZF = 0 because nonzero result

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 (in binary addition, there is a carry into the MSB and carry out from MSB also)

How Instruction Affects the Flags?

Example 5.2



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

Solution:

Actual Result = 100h

Result in AL = 00h

Flags:

SF = 0 because MSB is 0

PF = 1 because all bits in result are 0

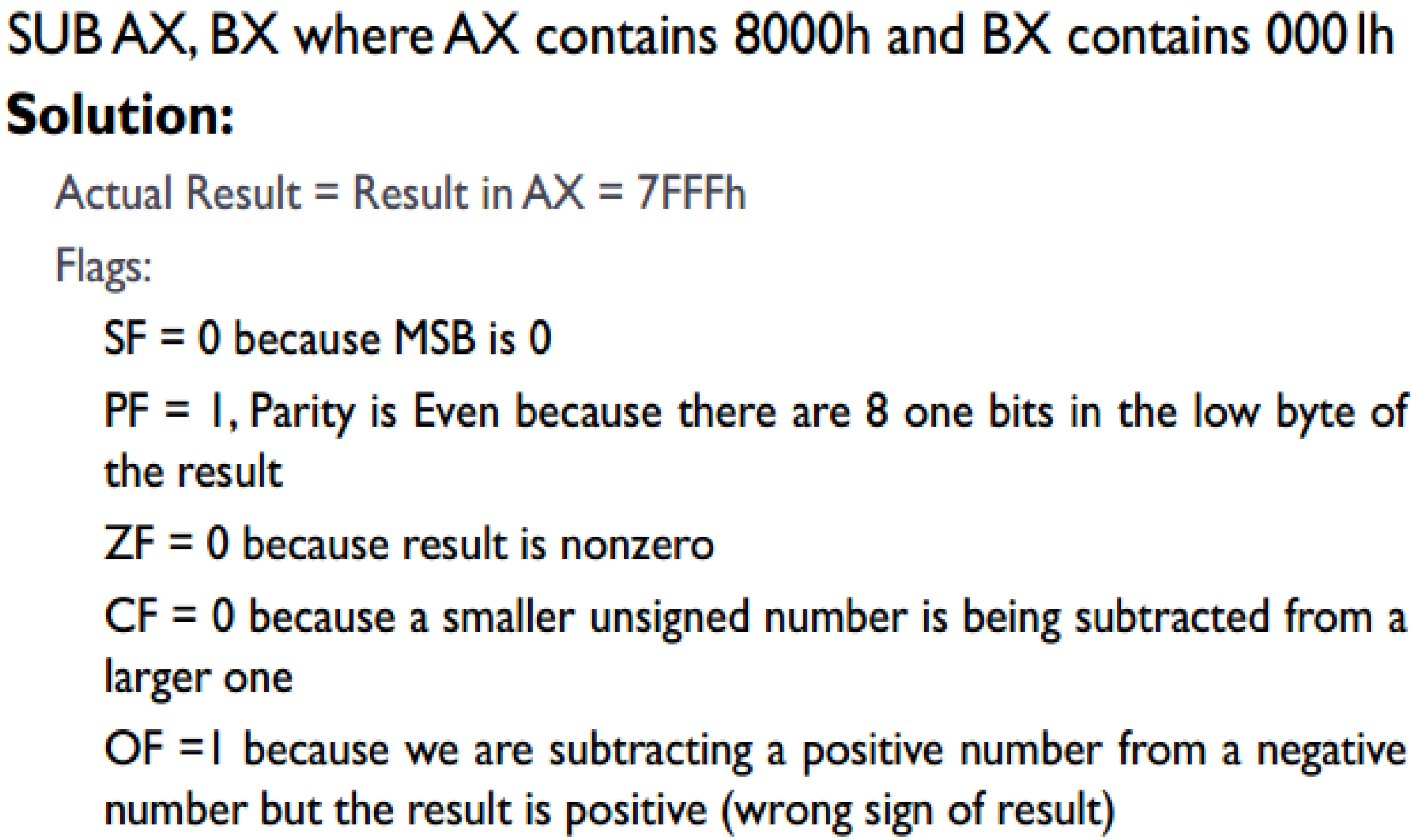
ZF = 1 because result is 0

CF = 1 because there is a carry out from MSB

OF = 1 because the numbers being added are both negative but the MSB in result is 0 (in binary addition, there is a no carry into the MSB but there is carry out from MSB.

How Instruction Affects the Flags?

Example 5.3



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

Solution:

Actual Result = Result in AX = 7FFFh

Flags:

SF = 0 because MSB is 0

PF = 1, Parity is Even because there are 8 one bits in the low byte of the result

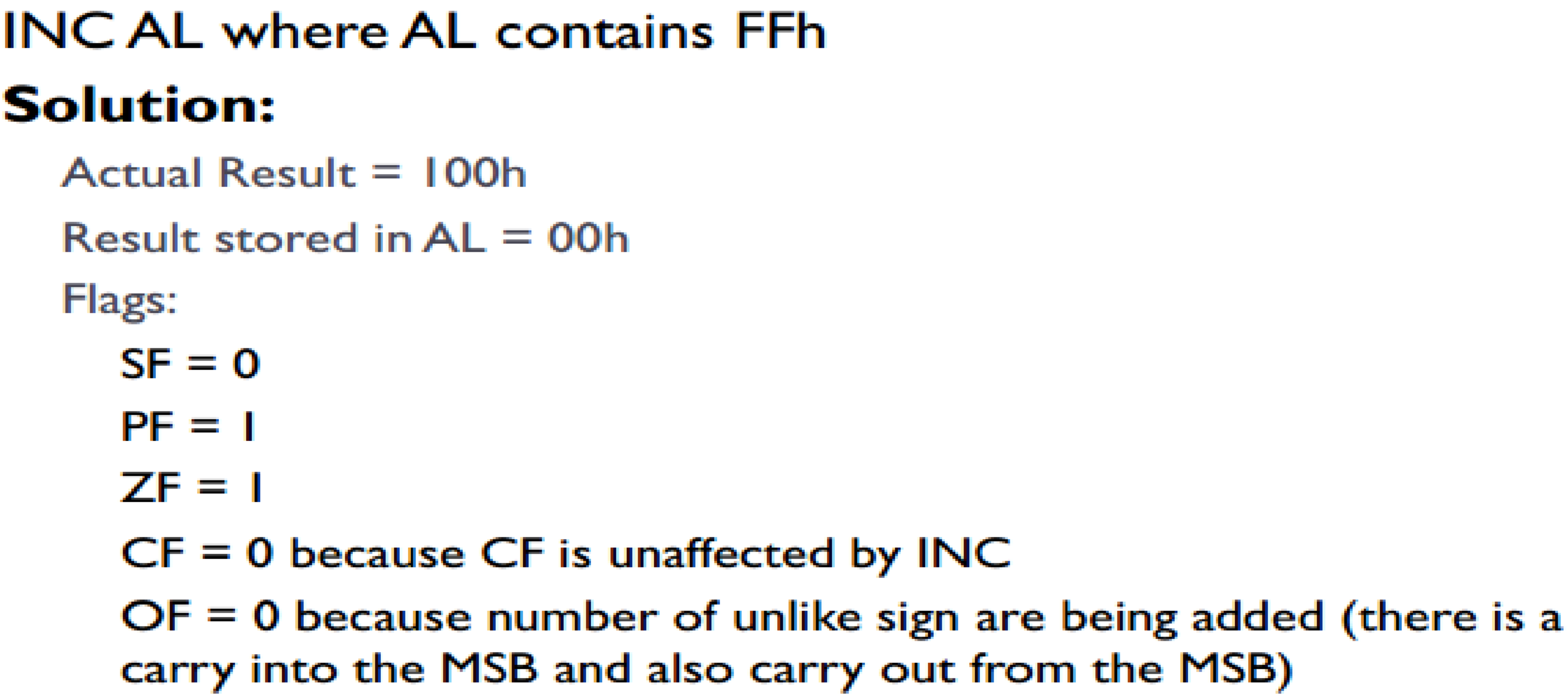
ZF = 0 because result is nonzero

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

OF =1 because we are subtracting a positive number from a negative number but the result is positive (wrong sign of result)

How Instruction Affects the Flags?

Example 5.4



INC AL where AL contains FFh

Solution:

Actual Result = 100h

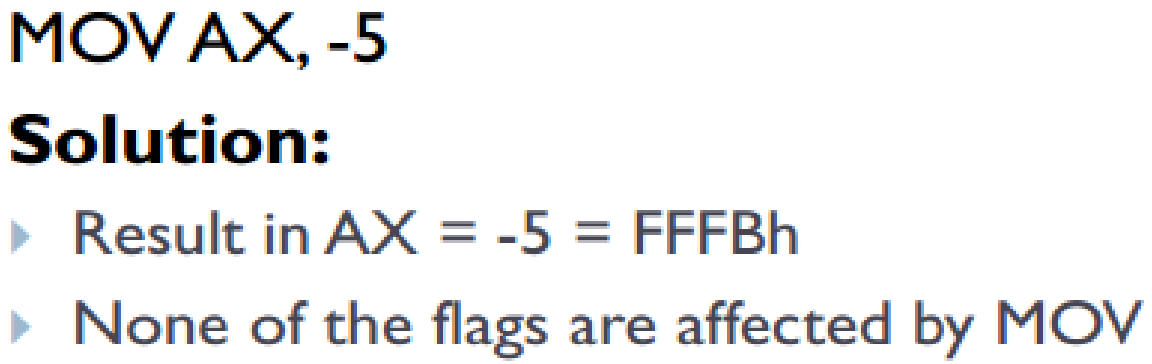
Result stored in AL = 00h

Flags:

- SF = 0
- PF = 1
- ZF = 1
- CF = 0 because CF is unaffected by INC
- OF = 0 because number of unlike sign are being added (there is a carry into the MSB and also carry out from the MSB)

How Instruction Affects the Flags?

Example 5.5



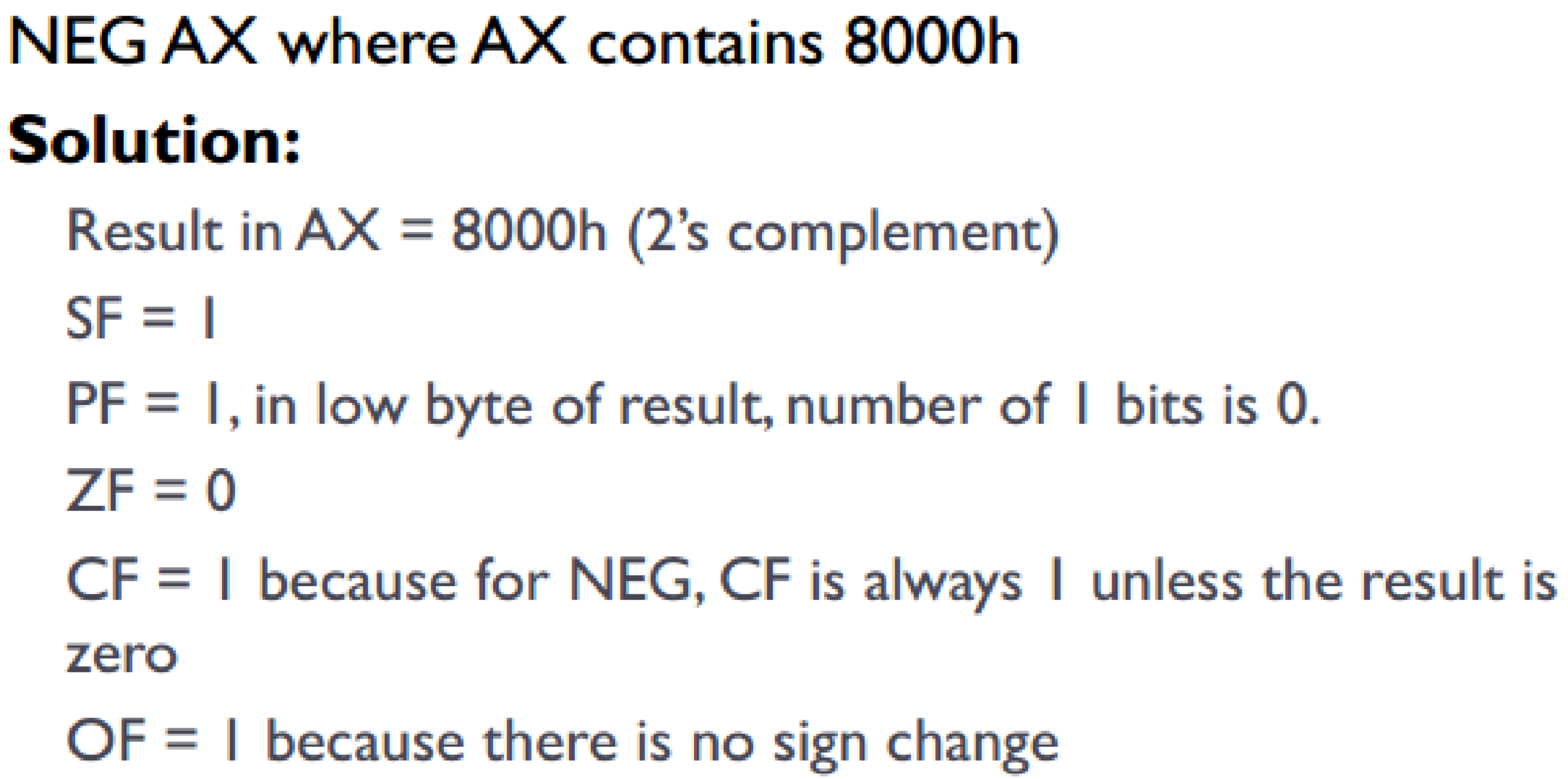
MOV AX, -5

Solution:

- Result in AX = -5 = FFFBh
- None of the flags are affected by MOV

How Instruction Affects the Flags?

Example 5.6



NEG AX where AX contains 8000h

Solution:

Result in AX = 8000h (2's complement)

SF = 1

PF = 1, in low byte of result, number of 1 bits is 0.

ZF = 0

CF = 1 because for NEG, CF is always 1 unless the result is zero

OF = 1 because there is no sign change

The Status FLAG

There are 3 control flags in 8086 processor.

- ✓ Trap Flag
- ✓ Interrupt Flag
- ✓ Direction Flag

The Status FLAG

Direction Flag: Controls the assumed direction used by string processing instructions. 1=Up, 0=Down.

Interrupt Flag: Enable/Disable external interrupt.

Trap Flag: Determines whether or not CPU will be halted after each instruction.