The Processor Status and the FLAGS Register

Course Code: COE 3205

Course Title: Computer Organization & Architecture

Dept. of Computer Science
Faculty of Science and Technology

Lecturer No:	**06**	**Week No:**	**06**	**Semester:**	**Fall 21-22**
Lecturer:	*Dr. Md. Sohidul Islam* *sohidul@aiub.edu*				

Lecture Outline

1. **Overview**
2. **Learning Objective**
3. **The FLAGS Register**
4. **The Status Flags**
5. **Overflow**
6. **How Instructions Affect the Flags**
7. **DEBUG Program**

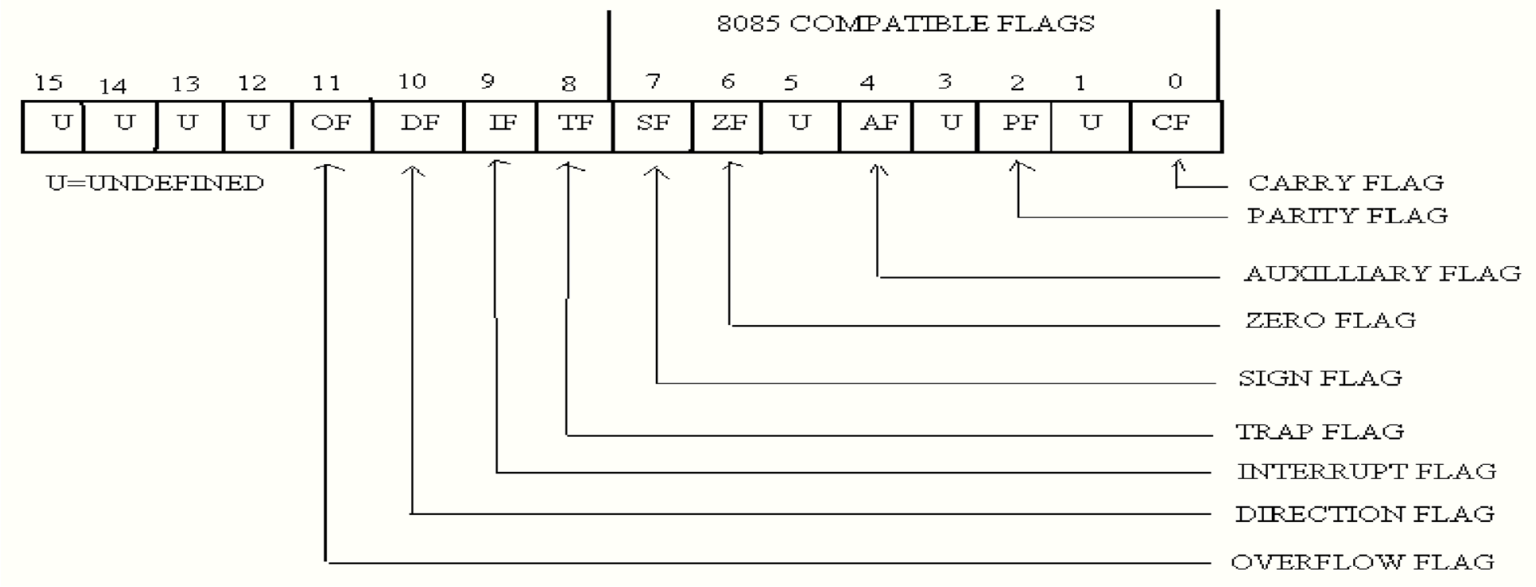
Overview

- **Computer's decision making ability makes it unique than other devices.**
- **The CPU circuits perform decision making based on the processor's current state.**
- **The 8086 processor's state is represented with nine individual bits or flags.**
- **The 8086 takes decision based on the flags value.**
- **The flags are placed in the FLAGS register.**
- **Status flags: Reflects the result of computation.**
- **Control flags: used to enable or disable certain operations of processor**

Learning Objective

- **How flags are effected by the machine instructions.**
- **DOS program DEBUG**
- **Display registers, flags and memory locations using DEBUG.**

The FLAGS Register



Status Flags: bit **0, 2, 4, 6, 7** and **11**

Control Flags: bit **8, 9** and **10**

*** **bit 1,3,5,12,13,14,15** has **no significance**

The Status Flags (1/2)

Flags	Descriptions
Carry Flag	• CF=1 If there is a carry out from the most significant bit (MSB) on addition. • CF=1 If there is a borrow into the most significant bit MSB on subtraction. • Otherwise CF=0
Parity Flag	• Even Parity:PF=1, if low byte of a result has even number of one bits [e.g. 1111000011] • Odd Parity: PF=0, if low byte of a result has an odd number of one bits [e.g. 1111000111] • e.g FFFF is odd parity and FFFE is even parity
Auxiliary carry Flag	• AF=1, if there is a carry out from bit 3 on addition or • AF=1, if there is a borrow from bit 3 on subtraction.

The Status Flags (2/2)

Zero Flag	• ZF=1 for a zero result. e.g. for AX-AX= Zero, thus, ZF=1 • ZF=0 for a non-zero result
Sign Flag	• SF=1 if MSB of a result is 1. that is the result is negative • SF=0 if the MSB is zero
Overflow Flag	• OF=1 if signed overflow occurred otherwise it is 0 (Zero)

Overflow

- The range of numbers can be represented is limited!
  - Range of **signed** numbers can be represented in 16-bit word is **-32768 to 32767**
  - For 8 bit byte it is **-128 to 127**
  - For unsigned number, the range for **word is 0 to 65535.**
  - For byte it is 0 to 255

- If an Operations falls **outside these range**, overflow occurs and truncated result that is saved and will be incorrect.

Overflow

Possible Overflows

- If we perform an arithmetic operation such as addition, there are four possible consequences:
  - **No overflow**
  - **Signed overflow only**
  - **Unsigned overflows only**
  - **Both signed and unsigned overflows**

Overflow

Example: Unsigned but not Signed Overflow

AX , FFFFh = 1111111111111111 [-1]
BX , 0001h = 0000000000000001 [+1]
==========
ADD AX,BX 1 0000 0000 0000 0000

- For an unsigned interpretation, the correct answer is 10000h or 65536.but this is out of range and 1 is carried out of **msb** and finally AX= 0000h[WRONG!] thus **UNSIGNED overflow occurred.**

- However, for a signed number the answer is correct FFFFh+0001h or -1+1=0. So **no signed overflow occurred.**

Overflow

Example: Signed but not Unsigned Overflow

AX 7FFFh = 0111111111111111
BX 7FFFh = 0111111111111111
==========
ADD AX,BX 1111111111111110 [FFFEh = -2]

- For singed and unsigned interpretation, 7FFFh= 32767 thus 7FFFh+7FFFh= 32767+32767 = 65534 [out of range for signed numbers!]. **So signed overflow occurred.**

- However, an **unsigned** interpretation the answer is correct FFFEh or 65534

Overflow

Processor Overflow Indication

- **OF = 1** for a **signed** overflow
- **CF = 1** for **unsigned** overflow

Unsigned Overflow:

- **On addition:** the unsigned overflow occurs when there is a carry out of the MSB.
  Meaning the correct answer is bigger than largest unsigned number i.e. FFFFh or FFh
- **On Subtraction:** If there is a borrow into the MSB
  Meaning the correct answer is Smaller than 0.

Overflow

Signed Overflow:

- **On addition:** On addition with the numbers with the same sign, signed overflow occurs while **SUM** has different sign.
  However, overflow is impossible in addition of numbers with different sign.

- **On subtraction:** Subtraction of numbers with different signs is like adding numbers of the same sign. Signed overflow occurs if the result has different sign than expected.

Overflow

Overflow Summary on Addition:

- Note that the overflow bit was set whenever we had a carry from bit 6 to bit 7, but no carry from bit 7 to C.
- It was also set when we had a carry from bit 7 to C, but no carry from bit 6 to bit 7.
- Upshot: The overflow bit is the EXCLUSIVE-OR of a carry from bit 6 to bit 7 and a carry from bit 7 to C.

How Instructions Affect the Flags

	Flag affected				
Instruction	*Z-flag*	*C-flag*	*S-flag*	*O-flag*	*A-flag*
ADD	Yes	Yes	Yes	Yes	Yes
ADC	Yes	Yes	Yes	Yes	Yes
SUB	Yes	Yes	Yes	Yes	Yes
SBB	Yes	Yes	Yes	Yes	Yes
INC	Yes	No	Yes	Yes	Yes
DEC	Yes	No	Yes	Yes	Yes
NEG	Yes	Yes	Yes	Yes	Yes
CMP	Yes	Yes	Yes	Yes	Yes
MUL	No	Yes	No	Yes	No
IMUL	No	Yes	No	Yes	No
DIV	No	No	No	No	No
IDIV	No	No	No	No	No
CBW	No	No	No	No	No
CWD	No	No	No	No	No

How Instructions Affect the Flags

Examples

1. ADD AX,BX , WHERE AX CONTAINS FFFFH AND BX CONTAINS FFFFH.

➢

```
    FFFFh
+   FFFFh
=========
   1FFFEh
```

The result stored in AX is FFFEh = 1111 1111 1111 1110

- **SF = 1, because msb is 1**
- **PF = 0, because there are 7 of 1 bits in the low byte of the result**
- **ZF = 0, because the result is non zero**
- **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)**

How Instructions Affect the Flags

Examples

2. ADD AL, BL ,WHERE AL CONTAINS 80H AND BL CONTAINS 80H.

➢
```
    80h
+   80h
==========
  1 00h
```

The result stored in AL is 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 the addition**
- **OF = 1 because the numbers being added are both negative, but the result is 0(as a binary addition, there is no carry out into the msb but there is a carry out.)**

How Instructions Affect the Flags

Examples

3. NEG AX, WHERE AX CONTAINS 8000H.

➢

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

The result is stored in AX is 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.**

How Instructions Affect the Flags

Task : Solve the Following and Show the Effects on Flag Registers

- **SUB AX,BX , WHERE AX CONTAINS 8000H AND BX CONTAINS 0001H.**
- **INC AL, WHERE AL CONTAINS FFH.**
- **MOV AX, -5 .**

DEBUGING Program

- Debug is used to step through a program, display and change the registers and memory.
- It is possible to enter assembly code directly. DEBUG then converts it to machine code and stores it in memory.

DEBUGING Program

Program 1: Checking Flags

```
.MODEL    SMALL
.STACK          100H
.DATA
.CODE
        MAIN PROC
        MOV AX,4000H     ;AX=4000h
        ADD AX,AX                       ;AX=8000h
        SUB AX,0FFFFH      ;AX=8001h

        NEG AX              ;AX=7FFFh

        INC AX              ;AX=8000h

        MOV AH,4CH

        INT 21H

                MAIN ENDP

END MAIN
```

DEBUGING Program

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	El (enable interrupts)	DI (Disable interrupt)

Books

- Assembly Language Programing and Organization of the IBM PC

Ytha Yu
Charles Marut

References

- Flag Register Details
  - https://www.youtube.com/watch?v=-LXc6IvtsfI
  - https://www.youtube.com/watch?v=vkpGK5bZbSY&list=RDCMUCCU6xxwO9uJuFieylWL2lSA&start_radio=1&t=27

- Carry and Overflow Details
  - https://www.youtube.com/watch?v=9cXe_T99nL4