The Flags Register

Basic Assembly

Assembly language programming
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Objectives

- We will learn about the **Flags** register.
- We will learn about some specific flags inside the flags register:
  - The **Zero** flag.
  - The **Sign** flag.
  - The **Carry** flag.
  - The **Overflow** flag.
- In the future we will use the values of those flags to make branches and decisions in our code.

The Flags Register

- A 32-bit register inside the x86 processor.
  - Has 64 bit extension for long-mode.
  - There is no usual direct access to this register.
- Every bit in this register is “a flag”:
  - It means that it represents True or False.
- Contains bits with values that reflect on the result of the last calculation.
  - Has the last calculation resulted in zero?
  - Has the last calculation resulted in a negative number?
  - Has the last calculation resulted in a number that doesn’t fit into a 32 bit register?
- Contains other system related bits.

The Flags register (Cont.)

Bit number	Short name	Description
0	CF	Carry flag
1	1	Reserved
2	PF	Parity flag
3	0	Reserved
4	AF	Auxiliary Carry flag
5	0	Reserved
6	ZF	Zero flag
7	SF	Sign flag
8	TF	Trap flag
9	IF	Interrupt enable flag
10	DF	Direction Flag
11	OF	Overflow flag
More bits …		

The Flags register (Cont.)

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0	**CF**	**Carry flag**
1	1	Reserved
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6	**ZF**	**Zero flag**
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8	TF	Trap flag
9	IF	Interrupt enable flag
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11	**OF**	**Overflow flag**
More bits …		

Changes in the Flags register

- Every instruction can have certain effects on some bits of the flags register.
  - There are some general rules of thumb regarding how each flag is changed by different instructions.
  - With some experience, you will be able to get a feeling of how the flags are going to change.
- The Flags Register is like the “mood” of the processor.
  - It changes when things happen.

The Zero Flag (ZF)

- The zero flag is set (to 1) whenever the last calculation had the result of zero.
- It will be cleared (to 0) whenever the last calculation had a nonzero result.
- Example:

```
mov       eax,3h
mov       ecx,3h
sub       eax,ecx
```

- Right after the execution of the sub instruction, the zero flag will be set to 1.
- In this example, right after the execution of the add instrucion, the zero flag will be cleared to 0.

```
mov       eax,3h
mov       ecx,3h
add       eax,ecx
```

The Sign flag (SF)

- The sign equals the most significant bit of the last result.
  - 0 if the result is positive in the two’s complement representation.
  - 1 if the result is negative in the two’s compliment representation.
- Examples:

```
mov edx,0
dec edx

; edx == 0xffffffff
; Sign flag is 1
```

```
mov edx,0
inc edx

; edx == 1
; Sign flag is 0
```

The Carry flag (CF)

- The carry flag "understands" unsigned addition and subtraction.
- The carry flag is set if the addition of two numbers causes a carry out of the most significant bits (Leftmost bits).
- Example:

```
mov eax,0ffffffffh
add eax,1

; eax == 0
; Carry flag is set.
```

	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
+	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- Tells you that the result you got adding two unsigned numbers, is wrong.

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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- Tells you that the result you got adding two unsigned numbers, is wrong.

The Carry flag (Cont.)

- The carry flag is also set if the subtraction of two numbers requires a borrow into the most significant bits.
- Example:

```
mov ecx,0
mov edx,11b
sub ecx,edx

; ecx == 0xfffffffd
; Carry flag is 1.
```

	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1

The Carry flag (Cont.)

- The carry flag is also set if the subtraction of two numbers requires a borrow into the most significant bits.
- Example:

```
mov ecx,0
mov edx,11b
sub ecx,edx

; ecx == 0xfffffffd
; Carry flag is 1.
```

	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1

The Carry flag (Examples)

- Otherwise, the carry flag is cleared (0).
- Examples:

```
mov eax,f0h
mov ecx,35h
add eax,ecx

; eax == 0x125
; Carry flag is 0.
```

```
mov eax,f0h
mov ecx,35h
add al,cl

; al == 0x25
; Carry flag is 1.
```

```
mov eax,f0h
mov ecx,35h
sub eax,ecx

; eax == 0xbb
; Carry flag is 0.
```

```
mov eax,f0h
mov ecx,35h
sub cl,al

; cl == 0x45
; Carry flag is 1.
```

The Overflow flag (OF)

- The overflow flag “understands” signed addition and subtraction.
  - According to the two’s complement representation.
- Addition:
  - Set if the addition of two positive numbers has a negative result.
  - Set if the addition of two negative numbers has positive result.
- Subtraction:
  - Set if “positive – negative” has a negative result.
  - Set if “negative – positive” has a positive result.
- Tells you if something went wrong with your signed arithmetic calculation.

The Overflow flag (Cont.)

- How does it work?
  - The processor looks on the msb of the two operands and the msb of the result.
    - The msb (Most significant bit) is the sign of the number.
  - If the result of the addition/subtraction has a “reasonable” sign, the overflow flag is cleared. If not, it is set.
- “positive + negative” can never set the overflow flag.
  - Because there is no reasonable prediction. The result could be both positive or negative.
  - Same for “positive – positive”, “negative – negative”.

The Overflow flag (Example)

```
mov al,7fh
mov cl,1h
add al,cl

; al == 0x80
; Overflow flag
; is set.
```

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mov cl,1h
add al,cl

; al == 0x80
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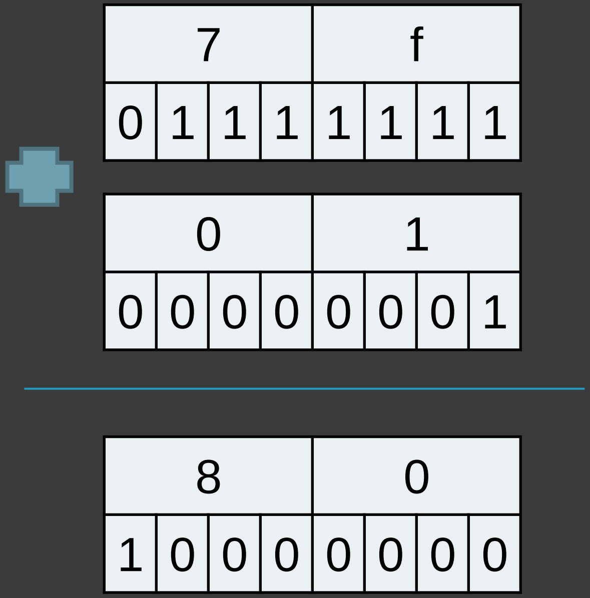
```



7				f			
0	1	1	1	1	1	1	1

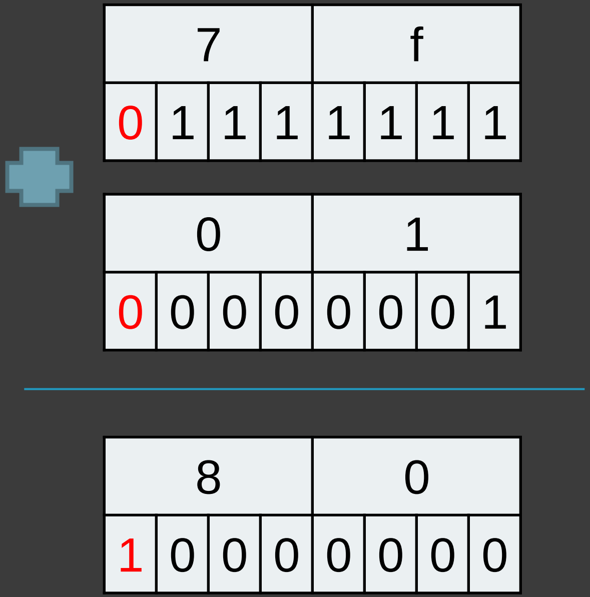
0				1			
0	0	0	0	0	0	0	1

8				0			
1	0	0	0	0	0	0	0

The Overflow flag (Example)

```
mov al,7fh
mov cl,1h
add al,cl

; al == 0x80
; Overflow flag
; is set.
```



7				f			
0	1	1	1	1	1	1	1

+

0				1			
0	0	0	0	0	0	0	1

8				0			
1	0	0	0	0	0	0	0

The Overflow flag (Example)

```
mov al,7fh
mov cl,1h
add al,cl

; al == 0x80
; Overflow flag
; is set.
```

7				f			
0	1	1	1	1	1	1	1

+

0				1			
0	0	0	0	0	0	0	1

8				0			
1	0	0	0	0	0	0	0

- “Positive + Positive = Negative”
  - Wrong singed result → Overflow flag is set.

The Overflow flag (Cont.)

- More examples:

```
mov eax,7fffffffh
mov edx,1h
add eax,edx

; eax == 0x80000000
; Overflow flag is set.
```

```
mov dx,6342h
mov cx,2000h
add cx,dx

; cx == 0x8342
; Overflow flag is set.
```

```
mov eax,7fffffffh
mov edx,1h
sub eax,edx

; eax == 0x7ffffffe
; Overflow flag is cleared.
```

```
mov esi,0ffffffffh
mov edi,0ffffffffh
add esi,edi

; esi == 0xfffffffe
; Overflow flag is cleared.
```

Overflow and Carry flags

- Both of the flags will change in every arithmetic operation.
  - The processor doesn’t care about your interpretation of the bits.
  - It is your responsibility as a programmer to look at the relevant flags.
- Which flag to look at?
  - Depending on how you interpret your numbers.
  - If you work with unsigned numbers, you only care about the **carry** flag.
  - If you work with signed numbers, you only care about the **overflow** flag.

Overflow, Carry Comparison

Code	Carry flag	Overflow flag
mov eax,0x0 sub eax,1		
mov dl,0x7f add dl,0x1		
mov ax,0x5 mov si,0x4 add si,ax		
mov cl,0x80 mov dl,0x80 add cl,dl		

Overflow, Carry Comparison

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mov eax,0x0 sub eax,1 **; eax == 0xffffffff**	1	0
mov dl,0x7f add dl,0x1		
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Overflow, Carry Comparison

Code	Carry flag	Overflow flag
mov eax,0x0 sub eax,1 ; **eax == 0xffffffff**	1	0
mov dl,0x7f add dl,0x1 ; **dl == 0x80**	0	1
mov ax,0x5 mov si,0x4 add si,ax ; **si == 0x9**	0	0
mov cl,0x80 mov dl,0x80 add cl,dl		

Overflow, Carry Comparison

Code	Carry flag	Overflow flag
mov eax,0x0 sub eax,1 **; eax == 0xffffffff**	1	0
mov dl,0x7f add dl,0x1 **; dl == 0x80**	0	1
mov ax,0x5 mov si,0x4 add si,ax **; si == 0x9**	0	0
mov cl,0x80 mov dl,0x80 add cl,dl **; cl == 0x0**	1	1

Summary

- The **Zero flag** is 1 iff the last result was zero.
- The **Sign flag** is 1 iff the last result was negative.
- The **Carry flag** is 1 iff the result (considering unsigned numbers) is wrong.
- The **Overflow flag** is 1 iff the result (Considering signed numbers) is wrong.