

The Carry Flag

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1 Based on

2 The Carry flag

- TOC: Carry flag
- Examples of signed and unsigned integer arithmetic
- The Carry flag in unsigned and signed computations
- Rules for the carry flag
- Method for computing the carry flag
- More examples of the carry flag

- The CARRY flag and OVERFLOW flag in binary arithmetic
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[https://teaching.idallen.com/dat2343/10f/notes/
040_overflow.ttx](https://teaching.idallen.com/dat2343/10f/notes/040_overflow.ttx)

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Compiling 32-bit program on 64-bit gcc

- `gcc -v`
- `gcc -m32 t.c`
- `sudo apt-get install gcc-multilib`
- `sudo apt-get install g++-multilib`
- `gcc-multilib`
- `g++-multilib`
- `gcc -m32`
- `objdump -m i386`

- Examples of signed and unsigned integer arithmetic
- Carry flag in unsigned and signed computations
- Rules for the carry flag
- Method for computing the carry flag
- More examples of the carry flag

TOC: Examples of signed and unsigned integer arithmetic

- Examples of interpreting **signed** and **unsigned** numbers
- Examples of **signed** and **unsigned** integer arithmetic
- 2's complements
- **Unsigned** subtraction
- **Signed** subtraction
- Interpreting the result as a **signed** or an **unsigned** integer
- Summary of **signed** and **unsigned** subtractions
- Examples of **unsigned** integer overflows
- Examples of **signed** integer overflows

Examples of **signed** and **unsigned** integer arithmetic

- subtracting **0x0000618D** from **0x0000195D**

unsigned subtraction	0x0000195D - 0x0000618D	= 0xFFFFB7D0
	6493 - 24973	4294967296 - 18480
		= 4294948816
	subtraction by hand	borrow (CF=1)
		$2^{32} = 16^8 = 4294967296$

signed subtraction	0x0000195D + (-0x0000618D)	= -0x00004830
	0x0000195D + 0xFFFF9E73	= 0xFFFFB7D0
	6493 - 24973	-18480
	the <i>transformed addition</i> using	Cn=0 → CF=1
	the 2's complement of <u>subtrahend</u>	CF = !Cn for subtraction

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

2's complement of the subtrahend 0x0000618D

- the 2's complement of 0x0000618D \rightarrow 0xFFFF9E73 ($= -24973_{10}$)

	F	F	F	F	9	E	7	3	
0xFFFF9E73	0x1111_1111_1111_1111_1001_1110_0111_0011								
0x0000618C	0x0000_0000_0000_0000_0110_0001_1000_1100								(1's complement)
0x0000618D	0x0000_0000_0000_0000_0110_0001_1000_1101								(2's complement)
	0	0	0	0	6	1	8	D	

- the 2's complement of 0xFFFF9E73 \rightarrow 0x0000618D ($= +24973_{10}$)

	0	0	0	0	6	1	8	D	
0x0000618D	0x0000_0000_0000_0000_0110_0001_1000_1101								
0xFFFF8E72	0x1111_1111_1111_1111_1001_1110_0111_0010								(1's complement)
0xFFFF8E73	0x1111_1111_1111_1111_1001_1110_0111_0011								(2's complement)
	F	F	F	F	9	E	7	3	

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Interpreting 0xFFFF9E73 (1)

- interpreting 0x0xFFFF9E73
 - as an **unsigned** Number : $+0xFFFF9E73 (= +4294942323_{10})$

F	F	F	F	9	E	7	3
15	15	15	15	9	14	7	3
16^7	16^6	16^5	16^4	16^3	16^2	16^1	16^0

- as a **signed** number : $-0x0000618D (= -24973_{10})$

0	0	0	0	6	1	8	D
0	0	0	0	6	1	8	13
16^7	16^6	16^5	16^4	16^3	16^2	16^1	16^0

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Interpreting 0xFFFF9E73 (2)

- interpreting 0xFFFF9E73

as an **unsigned** number +0xFFFF9E73 +4294942323₁₀

as a **signed** number -0x0000618D -24973₁₀

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Unsigned subtraction 0x0000195D - 0x0000618D (1)

- 0x0000195D - 0x0000618D : unsigned subtraction

subtraction by hand

```

          0  0  0  0  1  9  5  D
0x0000195D  0x0000_0000_0000_0000_0001_1001_0101_1101
- 0x0000618D  0x0000_0000_0000_0000_0110_0001_1000_1101
-----
0          0  0  0  0  6  1  8  D
-----
0xFFFFB7D0  1 0x1111_1111_1111_1111_1011_0111_1101_0000 (hand subtraction)
1          F  F  F  F  B  7  D  0
.
V borrow (CF=1) : unsigned integer overflow
```

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Unsigned subtraction $0x0000195D - 0x0000618D$ (2)

- $0x0000195D - 0x0000618D$: unsigned subtraction
subtraction by hand
 - A borrow is indicated by the carry flag (CF=1)
 - whenever an unsigned integer overflow happened
 - $A - B$, when $A < B$, for non-negative integers A, B

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Signed subtraction $0x0000195D + (-0x0000618D)$ (1)

- $0x0000195D + (-0x0000618D)$: signed subtraction

the *transformed addition* using the 2's complement of subtrahend

		0	0	0	0	1	9	5	D	
0x0000195D		0x0000_0000_0000_0000_0001_1001_0101_1101								(+0x0000195D)
+ 0xFFFF9E73		0x1111_1111_1111_1111_1001_1110_0111_0011								(-0x0000618D)
		F	F	F	F	9	E	7	3	

0xFFFFB7D0	0	0x1111_1111_1111_1111_1011_0111_1101_0000								(hand addition)
	0	F	F	F	F	B	7	D	0	
-0x00004830	.	0x0000_0000_0000_0000_0100_1000_0011_0000								(2's complement)
	.	0	0	0	0	4	8	3	0	
	V	no carry in the transformed addition (Cn=0) --> (CF=1)								

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Signed subtraction $0x0000195D + (-0x0000618D)$ (2)

- $0x0000195D + (-0x0000618D)$: signed subtraction
the *transformed addition* using the 2's complement of subtrahend
 - signed integer overflow is indicated by the **overflow** flag (OF)
 - the **carry** flag is set by the **inverted** carry of a transformed addition

ADD	SUB
$CF = c_n$	$CF = \overline{c_n}$

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Interpreting the result 0xFFFFB7D0

- subtracting 0x0000618D from 0x0000195D
the results of **unsigned** and **signed** subtractions have
the same bit pattern 0xFFFFB7D0

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

2's complement of the result 0xFFFFB7D0

- the 2's complement of 0xFFFFB7D0 : 0x00004830 (= +18480₁₀)

	F	F	F	F	B	7	D	0
0xFFFFB7D0	0x1111_1111_1111_1111_1011_0111_1101_0000							
0x0000482F	0x0000_0000_0000_0000_0100_1000_0010_1111							(1's complement)
0x00004830	0x0000_0000_0000_0000_0100_1000_0011_0000							(2's complement)
	0	0	0	0	4	8	3	0

- the 2's complement of 0x00004830 : 0xFFFFB7D0 (= -18480₁₀)

	0	0	0	0	4	8	3	0
0x00004830	0x0000_0000_0000_0000_0100_1000_0011_0000							
0xFFFFB7CF	0x1111_1111_1111_1111_1011_0111_1100_1111							(1's complement)
0xFFFFB7D0	0x1111_1111_1111_1111_1011_0111_1101_0000							(2's complement)
	F	F	F	F	B	7	D	0

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Interpreting 0xFFFFB7D0 (1)

- interpreting 0x0xFFFFB7D0
 - as an **unsigned** Number : +0xFFFFB7D0 (= +4294948816₁₀)

F	F	F	F	B	7	D	0
15	15	15	15	11	7	13	0
16 ⁷	16 ⁶	16 ⁵	16 ⁴	16 ³	16 ²	16 ¹	16 ⁰

- as a **signed** number : -0x00004830 (= -18480₁₀)

0	0	0	0	4	8	3	0
0	0	0	0	4	8	3	0
16 ⁷	16 ⁶	16 ⁵	16 ⁴	16 ³	16 ²	16 ¹	16 ⁰

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Interpreting 0xFFFFB7D0 (2)

- interpreting 0xFFFFB7D0

as an **unsigned** number +0xFFFFB7D0 +4294948816₁₀

as a **signed** number -0x00004830 -18480₁₀

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Summary of signed and unsigned subtractions (1)

- subtracting $0x0000618D$ from $0x0000195D$
 - $0x0000195D - 0x0000618D$: unsigned integer subtraction
hand subtraction
 - $0x0000195D + (-0x0000618D)$: signed integer subtraction
the *transformed addition* using the 2's complement of the subtrahend
 - the same result : $0xFFFFB7D0$ (the same bit pattern)
 - interpreting as a unsigned integer 4294948816_{10}
 $0xFFFFB7D0$ with a borrow (CF=1)
 - interpreting as a signed integer -18480_{10}
 $-0x00004830$ (meaningless CF=1)

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Summary of **signed** and **unsigned** subtractions (2)

unsigned subtraction $0x0000195D - 0x0000618D$ $0xFFFFB7D0$
4294948816₁₀
subtraction by hand with CF=1

signed subtraction $0x0000195D + (-0x0000618D)$ $-0x00004830$
-18480₁₀
the *transformed addition* using
the 2's complement of subtrahend

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Carry Flag (CF) and **unsigned** integer overflows

- $0x0000195D - 0x0000618D$: **unsigned** subtraction
 - there is an **unsigned** integer overflow
so the **carry** flag will be set ($CF=1$) to indicate a **borrow**
 - $A - B$, when $A < B$, for non-negative integers A, B
(unsigned integers can't be negative),

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Overflow Flag (OF) and signed integer overflows

- $0x0000195D + (-0x0000618D)$: signed subtraction
 - there is no signed integer overflow
the overflow flag won't be set (OF=0)
 - signed overflow occurs , in the transformed addition,
 - two *positive* numbers are added and
the result is a *negative*, ($P + P \rightarrow N$), or
 - two *negative* numbers are added and
the result is a *positive*, ($N + N \rightarrow P$)

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

TOC Carry flag in unsigned and signed computations

- 2's complement numbers : 4-bit
- Addend and augend in a n -bit addition
- Full adder operation in each bit position
- Internal and external carry bits
- Addition and Subtraction
- Using the Carry Flag as a borrow

2's complement numbers : 4-bit

0111	(+7)	1000	(-8)
0110	(+6)	1001	(-7)
0101	(+5)	1010	(-6)
0100	(+4)	1011	(-5)
0011	(+3)	1100	(-4)
0010	(+2)	1101	(-3)
0001	(+1)	1110	(-2)
0000	(0)	1111	(-1)

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Addend and augend in a n -bit addition

n	bits	addended	A	$\{ a_{n-1}, a_{n-2}, \dots, a_1, a_0 \}$
n	bits	augend	B	$\{ b_{n-1}, b_{n-2}, \dots, b_1, b_0 \}$
$(n+1)$	bits	carry bits	C	$\{ c_n, c_{n-1}, c_{n-2}, \dots, c_1, c_0 \}$
n	bits	sum bits	S	$\{ s_{n-1}, s_{n-2}, \dots, s_1, s_0 \}$

external carry bits : c_n carry out, c_0 carry in

$$\begin{array}{cccccc} a_{n-1} & a_{n-2} & \cdots & a_1 & a_0 & \\ b_{n-1} & b_{n-2} & \cdots & b_1 & b_0 & \\ \hline & & & & c_0 & \\ c_n & s_{n-1} & s_{n-2} & \cdots & s_1 & s_0 \end{array}$$

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Full adder operation in each bit position

full adder operation in the i^{th} bit position

$$\{c_{i+1}, s_i\} = a_i + b_i + c_i$$

$$\begin{array}{r} a_i \\ b_i \\ c_i \\ \hline c_{i+1} \quad s_i \end{array}$$

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Internal and external carry bits

external carries c_n output, c_0 input
 internal carries $\{c_{n-1}, c_{n-2}, \dots, c_2, c_1\}$ output / input
 sum bits $\{s_{n-1}, s_{n-2}, \dots, s_1, s_0\}$ output

	a_{n-1}	a_{n-2}	\dots	a_1	a_0
	b_{n-1}	b_{n-2}	\dots	b_1	b_0
c_n	c_{n-1}	c_{n-2}	\dots	c_1	c_0
	s_{n-1}	s_{n-2}	\dots	s_1	s_0

	a_{n-1}	a_{n-2}	\dots	a_1	a_0
	b_{n-1}	b_{n-2}	\dots	b_1	b_0
					c_0
c_n	s_{n-1}	s_{n-2}	\dots	s_1	s_0

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Addition and Subtraction

- addition

$$\{c_n, S\} = A + B = A + B + 0$$

	a_{n-1}	a_{n-2}	⋯	a_1	a_0
	b_{n-1}	b_{n-2}	⋯	b_1	b_0
	c_{n-1}	c_{n-2}	⋯	c_1	0
c_n	s_{n-1}	s_{n-2}	⋯	s_1	s_0

- subtraction - transformed addition

$$\{c_n, S\} = A - B = A + \overline{B} + 1$$

	a_{n-1}	a_{n-2}	⋯	a_1	a_0
	b_{n-1}	b_{n-2}	⋯	b_1	b_0
	c_{n-1}	c_{n-2}	⋯	c_1	1
c_n	s_{n-1}	s_{n-2}	⋯	s_1	s_0

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Using the Carry Flag as a borrow (1)

- a **borrow** (CF=1) occurs in the **subtraction** $A - B$ when b is larger than a ($A < B$) as unsigned numbers
- Computer hardware can detect a **borrow** (CF=1) in **subtraction** by looking at whether a carry out (Cn) occurred in the transformed addition

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Using the Carry flag as a borrow (2)

- a **borrow** ($CF=1$) occurs in the **subtraction** $A - B$ ($A < B$) as unsigned numbers
- a carry out (C_n) in the transformed addition
 - If there is no **carry** ($C_n=0$) then there is a **borrow** ($CF=1$)
 - If there is a **carry** ($C_n=1$) then there is no **borrow** ($CF=0$)
 - **$CF = !C_n$**

<https://stackoverflow.com/questions/47333458/assembly-x86-64-setting-carry-flag-f>

Using the Carry Flag as a borrow (3)

- the same *addition* and *subtraction* instructions are used for both **unsigned** and **signed** integer arithmetic.
 - no special *addition* and *subtraction* instructions for **unsigned** and **signed** integer arithmetic
- the only difference is
 - which flags you *test* afterwards and
 - how you *interpret* the result

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TOC Rules for the carry flag

- 2's complement numbers : 4-bit
- The 1st rule for setting the carry flag
- The 2nd rule for setting the carry flag
- Cases for clearing the carry flag
- Computing CF in unsigned additions and subtractions

2's complement numbers : 4-bit

0111	(+7)	1000	(-8)
0110	(+6)	1001	(-7)
0101	(+5)	1010	(-6)
0100	(+4)	1011	(-5)
0011	(+3)	1100	(-4)
0010	(+2)	1101	(-3)
0001	(+1)	1110	(-2)
0000	(0)	1111	(-1)

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

The 1st rule for setting the carry flag

- 1 **CF = 1 : carry in unsigned addition**
 - the **carry flag** is set if the **addition** of two **unsigned** numbers causes a **carry** out of the most significant bits added.
 - **unsigned integer overflow** in **unsigned addition**
 - *hand addition rule*

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

The 2nd rule for setting the carry flag

- ② **CF = 1 : borrow in unsigned subtraction**
 - the **carry flag** is also set if the **subtraction** of two **unsigned** numbers requires a **borrow** into the most significant bits subtracted.
 - unsigned integer overflow in unsigned subtraction**
 - hand subtraction rule*

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Cases for clearing the carry flag (1)

- Otherwise, the **carry flag** is turned off (zero).
 - all three interpretations have the same CF=1, the same S=0000

unsigned addition		signed addition		signed subtraction
0111 (7)		0111 (+7)		0111 (+7)
+1001 +(9)		+1001 +(-7)		-0111 -(+7)
-----		-----		-----
10000 (16)		10000 (0)		10000 (0)
CF=1		Cn=1 -> CF=1		Cn=1 -> CF=1
CF means 16		CF meaningless		CF meaningless
S = 0000		S = 0000		S = 0000
* think hand		* think Cn of the corresponding addition		
addition		CF <- Cn		

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Cases for clearing the carry flag (2)

- Otherwise, the **carry flag** is turned off (zero).
 - all three interpretations have the same CF=0, the same S=1111

unsigned addition		signed addition		signed subtraction
0111 (7)		0111 (+7)		0111 (+7)
+1001 +(- 9)		+1001 +(-7)		-0111 -(+7)
-----		-----		-----
10000 (16)		10000 (0)		10000 (0)
CF=1		Cn=1 -> CF=1		Cn=1 -> CF=1
CF means 16		CF meaningless		CF meaningless
S = 0000		S = 0000		S = 0000
* think hand		* think Cn of the corresponding addition		
addition		CF <- Cn		

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Computing CF in unsigned additions and subtractions

- Computing CF in an **unsigned** addition
 - do the **signed** addition
 - C_n is the carry out
 - $CF \leftarrow C_n$
- Computing CF in an **unsigned** subtraction
 - do the transformed **signed** addition
 - do the **signed** addition
 - C_n is the carry out
 - $CF \leftarrow !C_n$

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TOC: Method for computing the carry flag

- Carry flag computation

Carry flag computation (1)

ADD (addition)	SUB (subtraction)
$CF = c_n$	$CF = \overline{c_n}$
normal carry of a 2's complement addition	inverted carry of a transformed addition
$A + B = A + B + 0$	$A - B = A + \overline{B} + 1$
$\{c_n, s_{n-1}\}$ $= a_{n-1} + b_{n-1} + c_{n-1}$	$\{c_n, s_{n-1}\}$ $= a_{n-1} + \overline{b_{n-1}} + c_{n-1}$

https://www.csie.ntu.edu.tw/~cyy/courses/assembly/12fall/lectures/handouts/lec14_1

Carry flag computation (2)

- In **unsigned** arithmetic,
 - the **carry flag** is used to detect *overflow*
 - the **carry flag** is used to extend *n-bit* result into *(n+1)-bit* result
 - for **addition**, the **carry flag** is a **carry out**
 - for **subtraction**, the **carry flag** is a **borrow in**
- In **signed** arithmetic,
 - the **carry flag** is useless
 - the **carry flag** neither detects overflow nor extends n-bit result

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Carry flag computation (3)

- In **unsigned** arithmetic,

Addition	CF = 1 means carry out	when Cn = 1
Subtraction	CF = 1 means borrow in	when Cn = 0

- **CF** - Carry Flag in x86
- **Cn** - the normal carry out
 - the carry out of a 2's complement addition for **ADD**
 - the carry out of a *transformed* addition for **SUB**
- In **signed** arithmetic,
 - the **carry** flag is useless

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TOC: More examples of the carry flag

- Summary I
- Summary II
- Cases for setting the carry flag
- Cases for clearing the carry flag

Summary I

unsigned add/sub			signed addition			signed subtraction			CF	OF
1101	(13)		1101	(-3)		1101	(-3)			
+1110	+(14)	ADD	+1110	+(-2)	ADD	-0010	-(-2)			
-----	-----		-----	-----		-----	-----			
11011	(11)	(+16)	11011	(-5)		11011	(-5)		1	0
0011	(3)		0011	(+3)		0011	(+3)			
-1110	-(14)	SUB	+0010	+(+2)		-1110	-(-2)	SUB		
-----	-----		-----	-----		-----	-----			
10101	(5)	(-16)	00101	(+5)		00101	(+5)		1	0
0011	(3)		0011	(+3)		0011	(+3)			
+0010	+(2)	ADD	+0010	+(+2)	ADD	-1110	-(-2)			
-----	-----		-----	-----		-----	-----			
00101	(5)	(+ 0)	00101	(+5)		00101	(+5)		0	0
1101	(13)		1101	(-3)		1101	(-3)			
-0010	-(2)	SUB	+1110	+(-2)		-0010	-(-2)	SUB		
-----	-----		-----	-----		-----	-----			
11011	(11)	(-16)	11011	(-5)		11011	(-5)		0	0

Summary II

unsigned add/sub			signed addition			signed subtraction			CF	OF
1011	(11)		1011	(-5)		1011	(-5)			
+1100	+(12)	ADD	+1100	+(-4)	ADD	-0100	-(+4)			
-----	-----		-----	-----		-----	-----			
10111	(7) (+16)		10111	(+7)		10111	(+7)		1	1
0101	(5)		0101	(+5)		0101	(+5)			
-1100	-(12)	SUB	+0100	+(+4)		-1100	-(-4)	SUB		
-----	-----		-----	-----		-----	-----			
11001	(9) (-16)		01001	(-7)		01001	(-7)		1	1
0101	(5)		0101	(+5)		0101	(+5)			
+0100	+(4)	ADD	+0100	+(+4)	ADD	-1100	-(-4)			
-----	-----		-----	-----		-----	-----			
01001	(9) (+ 0)		01001	(-7)		01001	(-7)		0	1
1011	(11)		1011	(-5)		1011	(-5)			
-0100	-(4)	SUB	+1100	+(-4)		-0100	-(+4)	SUB		
-----	-----		-----	-----		-----	-----			
00111	(7) (0)		10111	(+7)		10111	(+7)		0	1

Cases for setting the carry flag (1) CF=1, OF=0

- unsigned integer overflow (CF=1 means +16)

* unsigned addition		* signed addition		signed subtraction
1101 (13)		1101 (-3)		1101 (-3)
+1110 +(14) ADD		+1110 +(-2) ADD		-0010 -(+2)
-----		-----		-----
11011 (11) (+16)		11011 (-5)		11011 (-5)
CF=1		Cn=1 -> CF=1		Cn=1 -> CF=1
CF means 16		CF meaningless		CF meaningless
S = 0000		S = 0000		S = 0000
* think hand		* think Cn of the corresponding addition		
addition		CF <- Cn (for unsigned addition)		

* CF=1, S=1011, OF=0 for all three interpretations

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Cases for setting the carry flag (2) CF=1, OF=0

- unsigned integer overflow (CF=1 means -16)

* unsigned subtraction		signed addition		* signed subtraction
0011 (3)		0011 (+3)		0011 (+3)
-1110 -(14) SUB		+0010 +(2)		-1110 -(-2) SUB
-----		-----		-----
10101 (5) (-16)		00101 (+5)		00101 (+5)
CF=1		Cn=0 -> CF=1		Cn=0 -> CF=1
CF means -16		CF meaningless		CF meaningless
S = 0101		S = 0101		S = 0101
-----		-----		-----
* think hand subtraction		* think Cn of the transformed addition		
		CF <- !Cn (for unsigned subtraction)		
-----		-----		-----

* CF=1, S=0101, OF=0 for all three interpretations

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Cases for setting the carry flag (3) CF=1, OF=1

- unsigned integer overflow (CF=1 means +16)

* unsigned addition		* signed addition		signed subtraction
1011 (11)		1011 (-5)		1011 (-5)
+1100 +(12) ADD		+1100 +(-4) ADD		-0100 -(+4)
-----		-----		-----
10111 (7) (+16)		10111 (+7)		10111 (+7)
CF=1		Cn=1 -> CF=1		Cn=1 -> CF=1
CF means +16		CF meaningless		CF meaningless
S = 0111		S = 0111		S = 0111
* think hand		* think Cn of the corresponding addition		
addition		CF <- Cn (for unsigned addition)		

* CF=1, S=0111, OF=1 for all three interpretations

Cases for setting the carry flag (4) CF=1, OF=1

- unsigned integer overflow (CF=1 means -16)

* unsigned subtraction		signed addition		* signed subtraction
0101 (5)		0101 (+5)		0101 (+5)
-1100 -(12) SUB		+0100 +(4)		-1100 -(-4) SUB
-----		-----		-----
11001 (9) (-16)		01001 (-7)		01001 (-7)
CF=1		Cn=0 -> CF=1		Cn=0 -> CF=1
CF means -16		CF meaningless		CF meaningless
S = 1001		S = 1001		S = 1001
* think hand subtraction		* think Cn of the transformed addition		CF <- !Cn (for unsigned subtraction)

* CF=1, S=1001, OF=1 for all three interpretations

Cases for clearing the carry flag (1) CF=0, OF=0

- no unsigned integer overflow (CF=0)

* unsigned addition		* signed addition	signed subtraction
0011 (3) +0010 +(2) ADD ----- 00101 (5) (+ 0)		0011 (+3) +0010 +(2) ADD ----- 00101 (+5)	0011 (+3) -1110 -(-2) ----- 00101 (+5)
CF=0		Cn=0 -> CF=0	Cn=0 -> CF=0
CF means 0 S = 0101		CF meaningless S = 0101	CF meaningless S = 0101
* think hand addition		* think Cn of the corresponding addition CF <- Cn (for unsigned addition)	

* CF=0, S=0101, OF=0 for all three interpretations

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Cases for clearing the carry flag (2) CF=0, OF=0

- no unsigned integer overflow (CF=0)

* unsigned addition	* signed addition	signed subtraction
1101 (13)	1101 (-3)	1101 (-3)
-0010 -(2) SUB	+1110 +(-2)	-0010 -(+2) SUB
-----	-----	-----
11011 (11) (-16)	11011 (-5)	11011 (-5)
CF=0	Cn=0 -> CF=0	Cn=0 -> CF=0
CF means 0	CF meaningless	CF meaningless
S = 1011	S = 1011	S = 1011
-----	-----	-----
* think hand subtraction	* think Cn of the corresponding addition	
	CF <- Cn (for unsigned addition)	

* CF=0, S=1011, OF=0 for all three interpretations

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt

Cases for clearing the carry flag (3) CF=0, OF=1

- no unsigned integer overflow (CF=0)

* unsigned addition		* signed addition	signed subtraction
0101 (5)		0101 (+5)	0101 (+5)
+0100 +(4) ADD		+0100 +(+4) ADD	-1100 -(-4)
-----		-----	-----
01001 (9) (+ 0)		01001 (-7)	01001 (-7)
CF=0		Cn=0 -> CF=0	Cn=0 -> CF=0
CF means +0		CF meaningless	CF meaningless
S = 1001		S = 1001	S = 1001
* think hand		* think Cn of the corresponding addition	
addition		CF <- Cn (for unsigned addition)	

* CF=0, S=1001, OF=1 for all three interpretations

Cases for clearing the carry flag (4) CF=0, OF=1

- no unsigned integer overflow (CF=0)

* unsigned subtraction		signed addition		* signed subtraction
1011 (11)		1011 (-5)		1011 (-5)
-0100 -(4) SUB		+1100 +(-4)		-0100 -(+4) SUB
-----		-----		-----
00111 (7) (0)		10111 (+7)		10111 (+7)
CF=0		Cn=1 -> CF=0		Cn=1 -> CF=0
CF means 0		CF meaningless		CF meaningless
S = 0111		S = 0111		S = 0111
* think hand subtraction		* think Cn of the transformed addition		CF <- !Cn (for unsigned subtraction)

* CF=0, S=0111, OF=1 for all three interpretations

http://teaching.idallen.com/dat2343/10f/notes/040_overflow.txt