

# Representing Negative Numbers in Binary

(“Two’s complement”)

<u>8</u>	<u>4</u>	<u>2</u>	<u>1</u>
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0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
...				...

Sgn    4    2    1

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0    1    0    1    5

1    1    0    1    -5

If 8 bits, then  
-5 = 10000101

-    4    2    1

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

0  
1  
2  
3  
4  
5  
6  
7

<u>-</u>	<u>4</u>	<u>2</u>	<u>1</u>
1	1	1	1
1	1	1	0
1	1	0	1
1	1	0	0
1	0	1	1
1	0	1	0
1	0	0	1
1	0	0	0
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1

-7  
-6  
-5  
-4  
-3  
-2  
-1  
-0  
0  
1  
2  
3  
4  
5  
6  
7

<u>-</u>	<u>4</u>	<u>2</u>	<u>1</u>
1	1	1	1
1	1	1	0
1	1	0	1
1	1	0	0
1	0	1	1
1	0	1	0
1	0	0	1
1	0	0	0
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1

-7  
-6  
-5  
-4  
-3  
-2  
-1  
-0  
0  
1  
2  
3  
4  
5  
6  
7



<u>-</u>	<u>4</u>	<u>2</u>	<u>1</u>
1	1	1	1
1	1	1	0
1	1	0	1
1	1	0	0
1	0	1	1
1	0	1	0
1	0	0	1
1	0	0	0
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1

-7  
-6  
-5  
-4  
-3  
-2  
-1  
-0  
0  
1  
2  
3  
4  
5  
6  
7

	5	0101
<u>+</u>	<u>(-5)</u>	<u>+ 1101</u>
	2	10010

  

	6	0110
<u>+</u>	<u>(-2)</u>	<u>+ 1010</u>

**Let's try something else ... a different encoding.**



# One's Complement

<u>-</u>	<u>4</u>	<u>2</u>	<u>1</u>	
1	0	0	0	-7
1	0	0	1	-6
1	0	1	0	-5
1	0	1	1	-4
1	1	0	0	-3
1	1	0	1	-2
1	1	1	0	-1
1	1	1	1	-0
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7

From 3, how do we get -3?

# One's Complement

<u>-</u>	<u>4</u>	<u>2</u>	<u>1</u>
1	0	0	0
1	0	0	1
1	0	1	0
1	0	1	1
1	1	0	0
1	1	0	1
1	1	1	0
1	1	1	1
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1

- 7
- 6
- 5
- 4
- 3
- 2
- 1
- 0
- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7

From 3, how do we get -3?

5

+

(-5)

-0

0101

+

1010

11111

5

+

(-3)

1

0101

+

1100

10001

6

+

(-2)

# One's Complement

-	4	2	1	
1	0	0	0	-7
1	0	0	1	-6
1	0	1	0	-5
1	0	1	1	-4
1	1	0	0	-3
1	1	0	1	-2
1	1	1	0	-1
1	1	1	1	-0
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7

# Two's Complement

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

$$\begin{array}{r}
 5 \\
 + \quad (-5) \\
 \hline
 \end{array}
 \xrightarrow[\text{Then add 1.}]{\text{Invert the digits.}}
 \begin{array}{r}
 0101 \\
 + \quad 1011 \\
 \hline
 10000
 \end{array}$$

$$\begin{array}{r}
 6 \\
 + \quad (-2) \\
 \hline
 \end{array}$$

## Two's Complement

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

# Two's Complement

*How do you represent -3?*

$$-8 + 4 + 1 = 3$$

$$-8 \times 1 + 4 \times 1 + 2 \times 0 + 1 \times 1 = 3$$

<u>-8</u>	4	2	1	
1	0	0	0	-8
1	0	0	1	-7
1	0	1	0	-6
1	0	1	1	-5
1	1	0	0	-4
1	1	0	1	-3
1	1	1	0	-2
1	1	1	1	-1
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7