1.1 Number systems

Signed integers using two's complement

How can we represent a negative number?

From the previous video, we know the smallest number you can represent in binary is 0.

If we are using 8 bits:

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0	0	0	0	0	0	0	0	**= 0**

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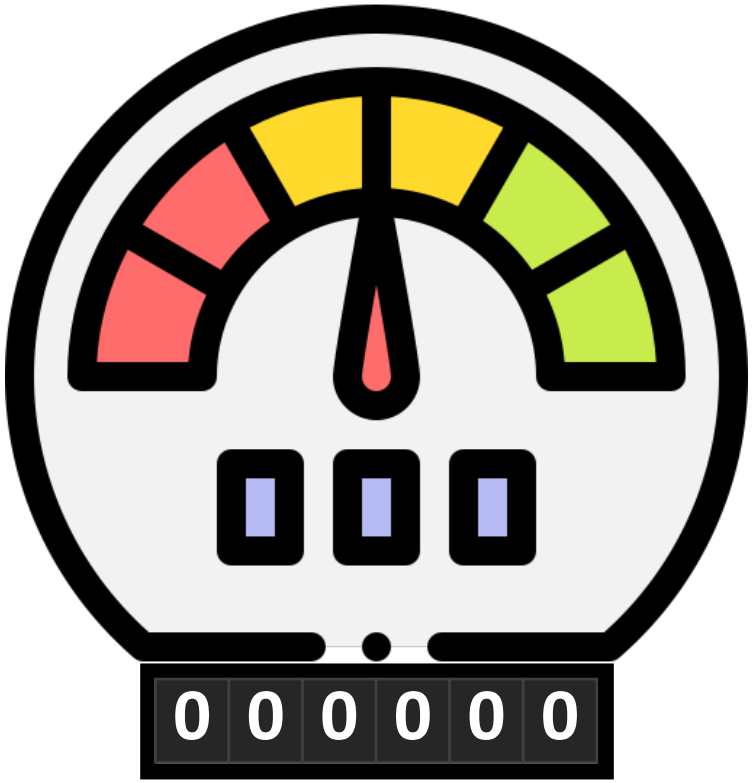
So, if adding 1s increases the number's value, how can we represent negative numbers like -10?

Think about a car's milometer



A car leaves the factory with all digits set to 0.

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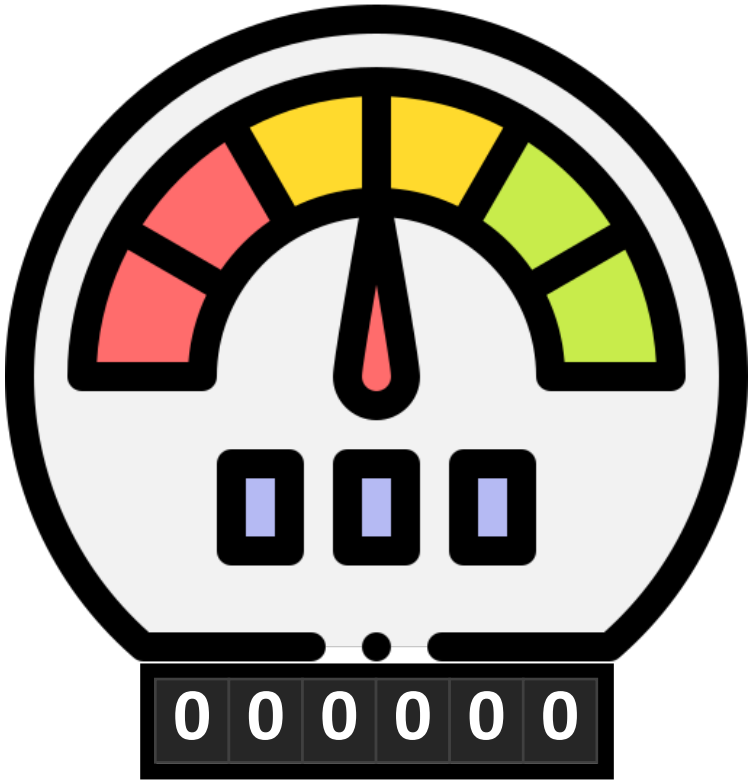

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If we drive the car for one mile, we end up with 000001 on the meter.

We can think of this as +1 mile.

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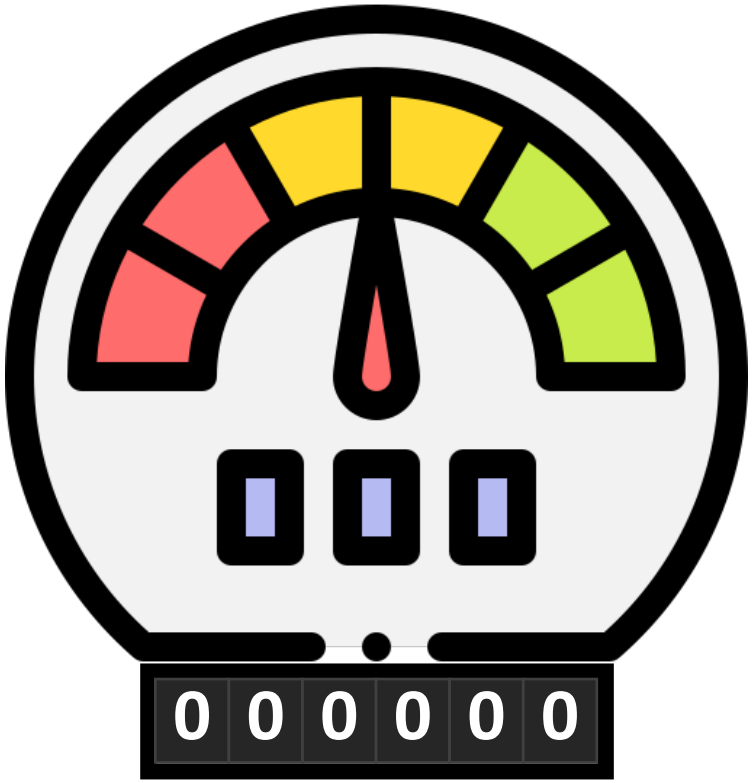

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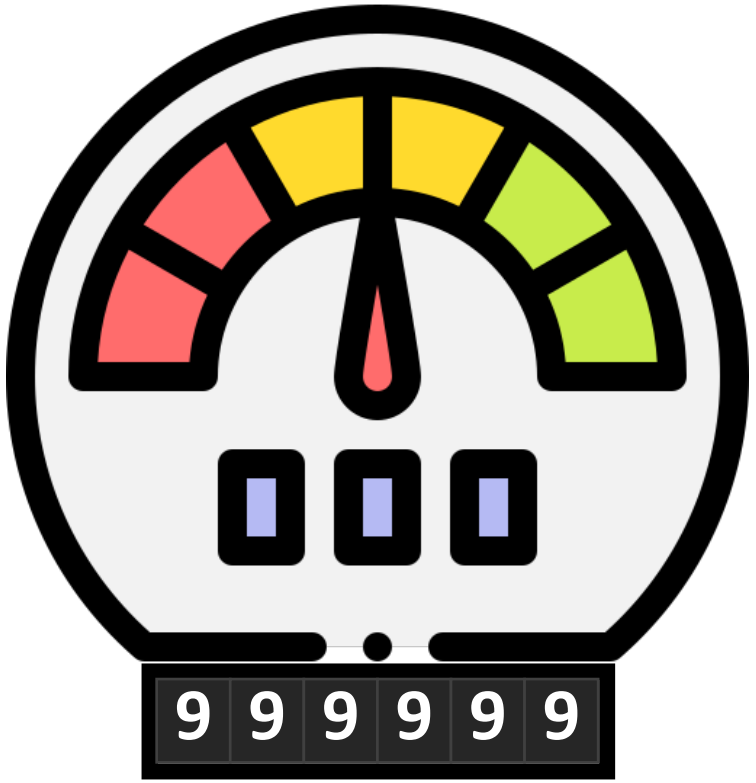

Imagine if we could turn the meter back one mile to 999999.

We can think of this as -1 mile.

Computers can use a similar concept.

Two's complement

1	1	1	1	1	1	0	1	=	**-3**
1	1	1	1	1	1	1	0	=	**-2**
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	1	=	**1**
0	0	0	0	0	0	1	0	=	**2**
0	0	0	0	0	0	1	1	=	**3**

Two's complement

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1	1	1	1	1	1	1	0	=	**-2**
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	1	=	**1**
0	0	0	0	0	0	1	0	=	**2**
0	0	0	0	0	0	1	1	=	**3**

When using the two's complement method of representing binary numbers, you will notice that:

- All positive numbers **always** start with a **zero**.

Two's complement

1	1	1	1	1	1	0	1	=	-3
1	1	1	1	1	1	1	0	=	-2
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	1	=	1
0	0	0	0	0	0	1	0	=	2
0	0	0	0	0	0	1	1	=	3

When using the two's complement method of representing binary numbers, you will notice that:

- All positive numbers **always** start with a **zero**.
- All negative numbers **always** start with a **one**.

Two's complement

Notice that the left-hand bit – known as **the most significant bit (MSB)** – is now representing a negative value.

-128	64	32	16	8	4	2	1

Two's complement

Let's start by representing **positive** 117 (+117):

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Two's complement

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0							

Two's complement

Let's start by representing **positive** 117 (+117):

-128	64	32	16	8	4	2	1
0	1	1	1	0	1	0	1
	64 +	32 +	16		+ 4		+ 1

= +117

Two's complement

Now let's try representing **negative** 117 (-117):

-128	64	32	16	8	4	2	1	
0	1	1	1	0	1	0	1	**= +117**

Two's complement

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-128	64	32	16	8	4	2	1	
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1								

Two's complement

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-128	64	32	16	8	4	2	1	
0	1	1	1	0	1	0	1	**= +117**
1	0	0	0	1	0	1	1	
-128				+ 8				

= -120

Two's complement

Now let's try representing **negative** 117 (-117):

-128	64	32	16	8	4	2	1	
0	1	1	1	0	1	0	1	**= +117**
1	0	0	0	1	0	1	1	
-128				+ 8		+ 2		
						= -118		

Two's complement

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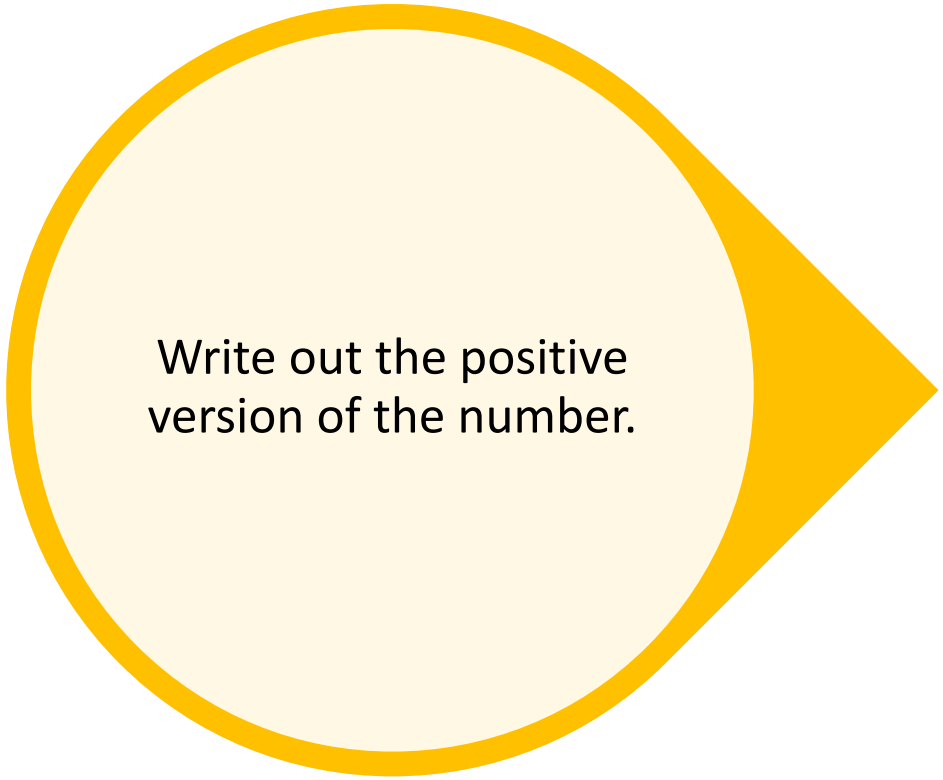
-128				+ 8		+ 2	+ 1	**= -117**

How to easily turn a positive number into its two's complement negative version



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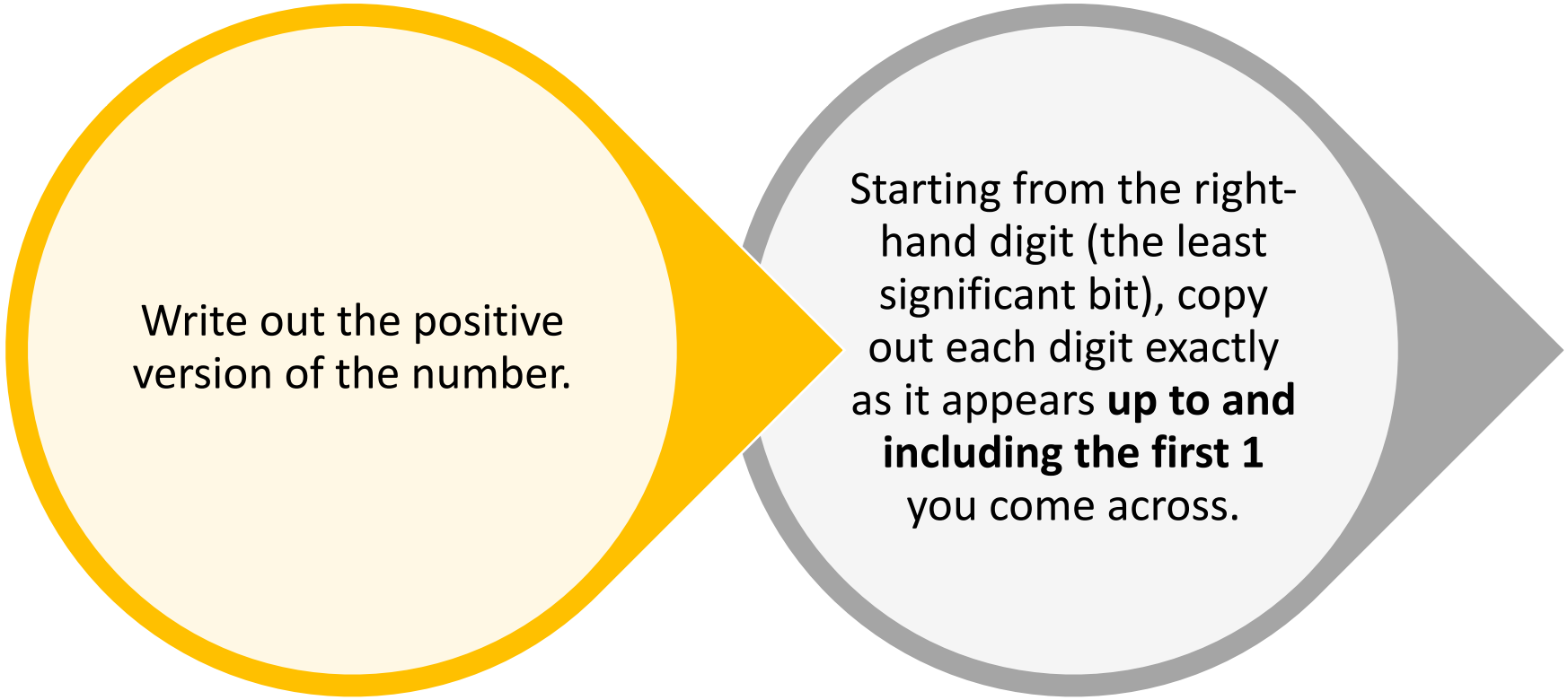

How to easily turn a positive number into its two's complement negative version

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Let's convert the number +12 into -12.

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How to easily turn a positive number into its two's complement negative version

Let's convert the number +12 into -12.

-128	64	32	16	8	4	2	1
0	0	0	0	1	1	0	0

1. Write out the positive version of the number.
2. Starting from the right-hand digit (the least significant bit), copy out each digit exactly as it appears **up to and including the first 1** you come across.
3. From the next digit onwards, **swap every 1 for a 0** and **swap every 0 for a 1**.

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1.1 Number systems | Logical binary shifts