Muxes

Bit and Beyond

Digital Information

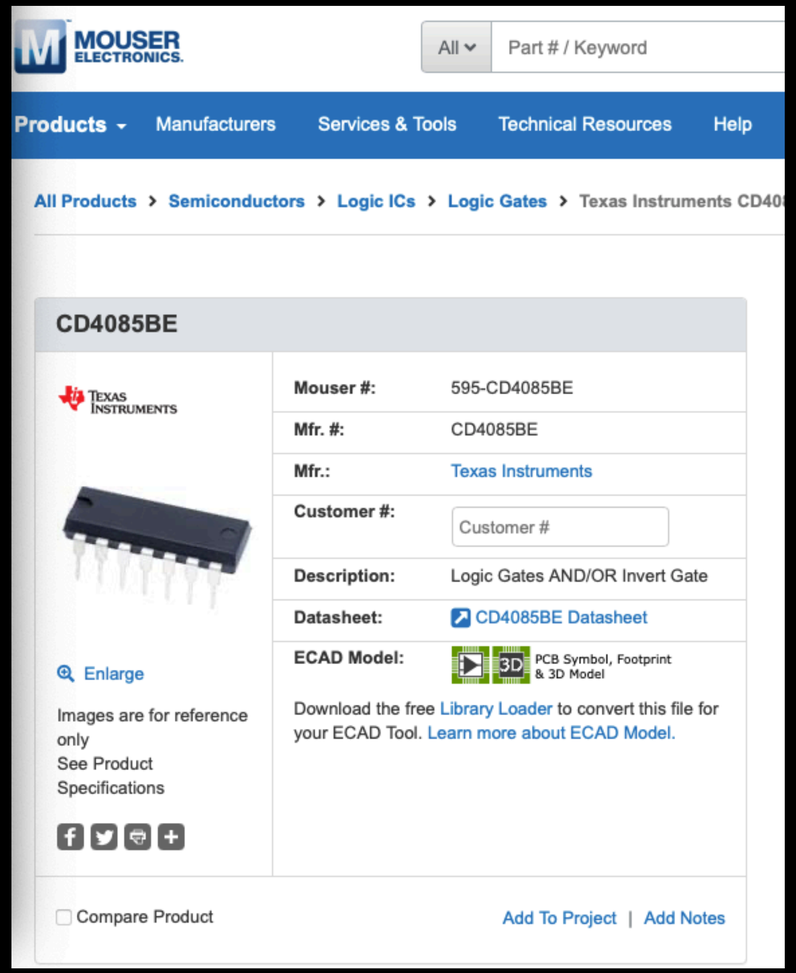
Daniel G. Graham

Goals

- Build and adding machine

Goals

Gates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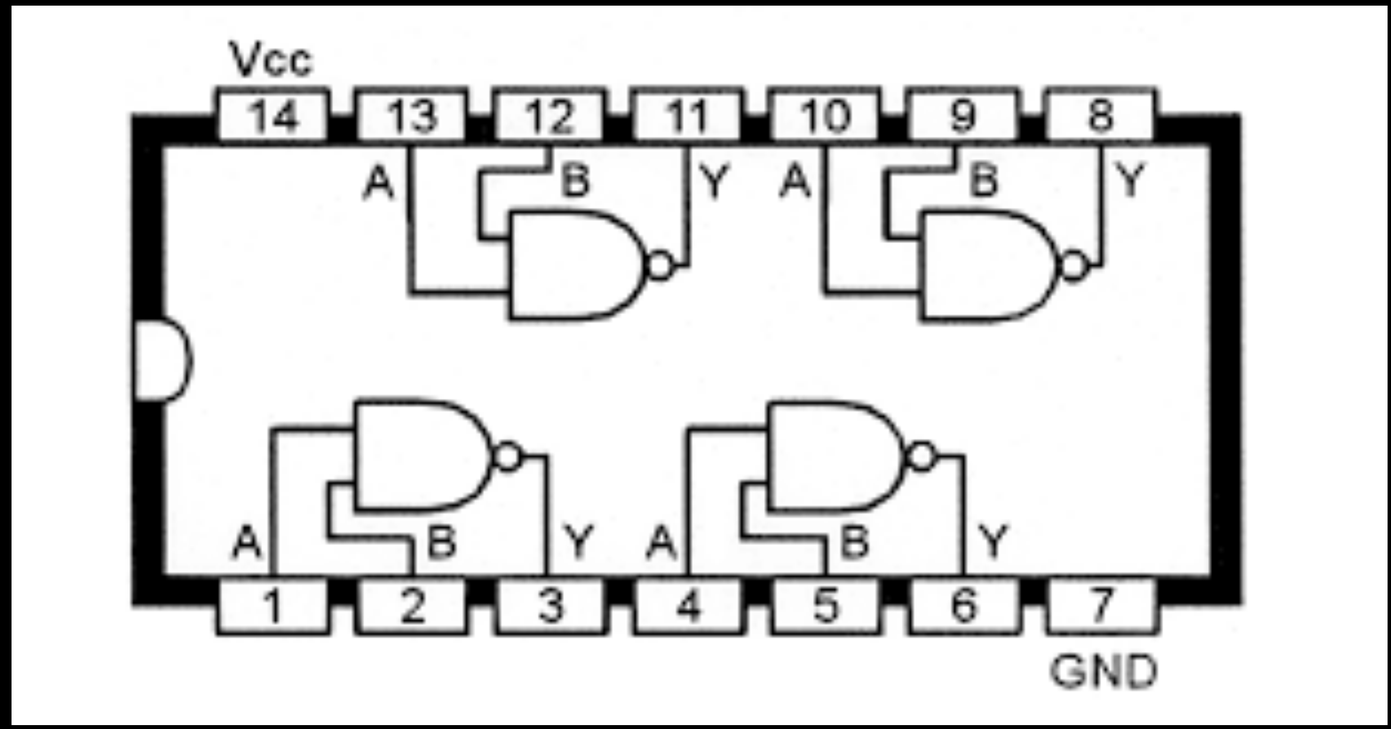
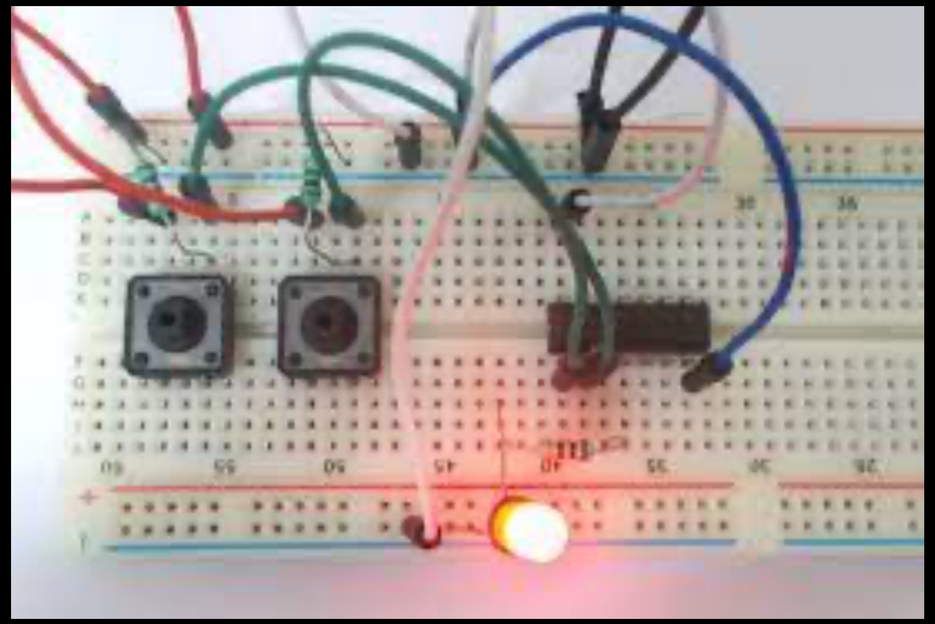
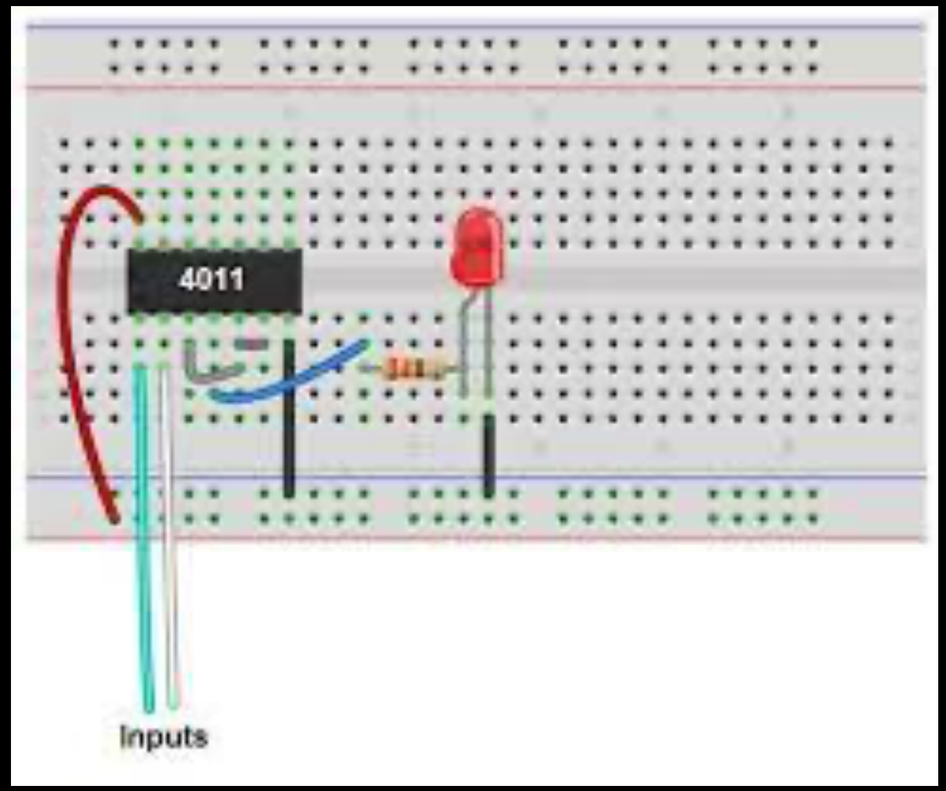

Vcc
14
13
12
11
10
9
8
A
B
Y
A
B
Y
A
B
Y
A
B
Y
1
2
3
4
5
6
7
GND

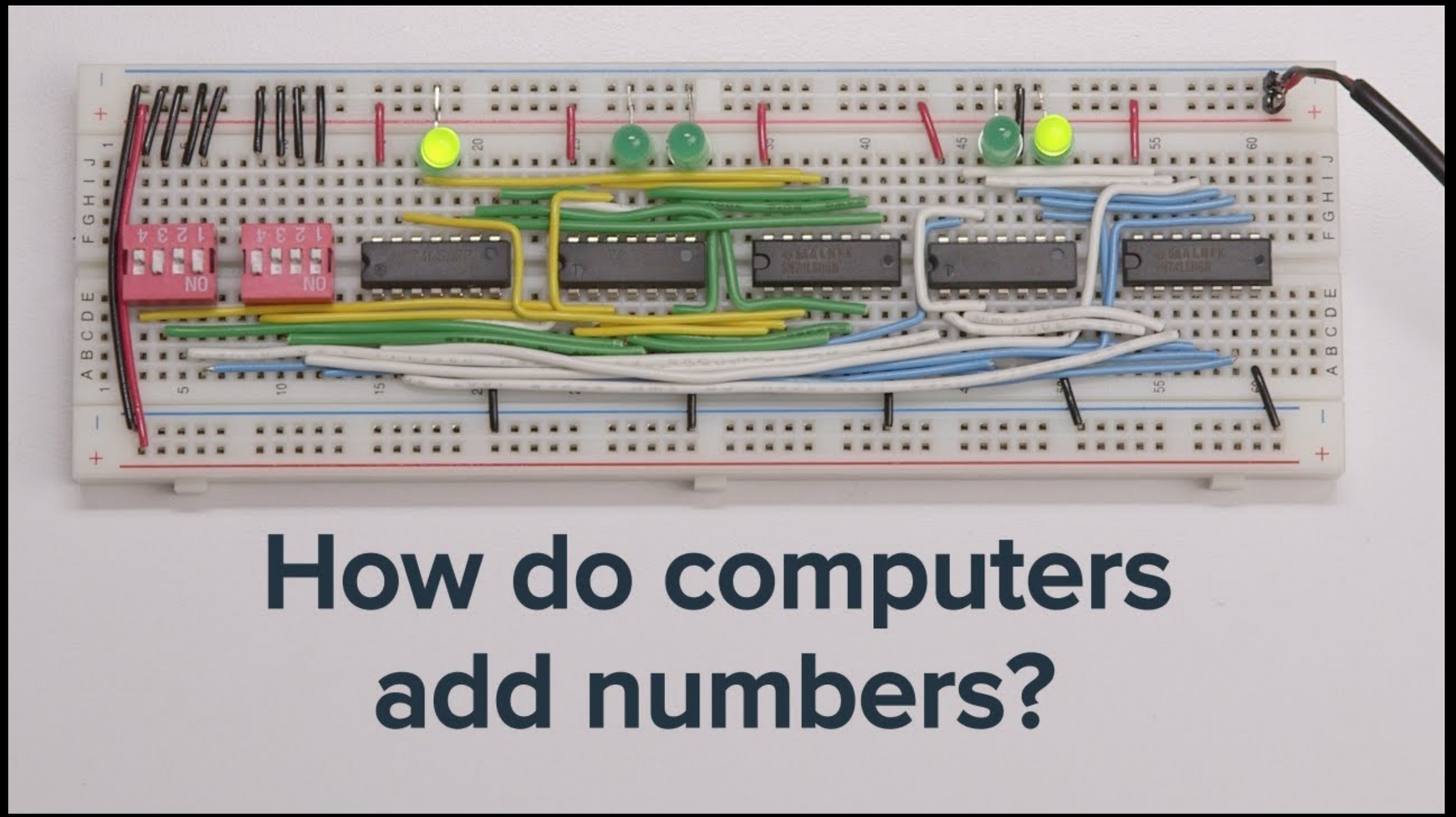
Gates on a bread board





Goals

- Build and adding machine



Problem

We need to be able to represent numbers in binary

Skills

By end of this lecture

- Convert Binary to Base 10
  - 110101
- Add in binary
-

```
  1011
+ 1001
------
```

- Convert Hex decimal to base 10
  - 0xd02
- Add hexicamal numbers
-

```
  d0b2
+ 300f
------
```

- Represent Negative Numbers in binary

Place-value numbers

Base-10 “Decimal”

- 314109

10^5	10^4	10^3	10^2	10^1	10^0
3	1	4	1	0	9

$3 \times 10^5 + 1 \times 10^4 + 4 \times 10^3 + 1 \times 10^2 + 9 \times 100 = 314109$

Place-value numbers

Base-2 “binary”

- 110101

2^5	2^4	2^3	2^2	2^1	2^0
1	1	0	1	0	1

$2^5 + 2^4 + 0 \times 2^3 + 2^2 + 0 \times 2^1 + 2^0 = 53$

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	*64*	*32*	*16*	*8*	*4*	*2*	*1*

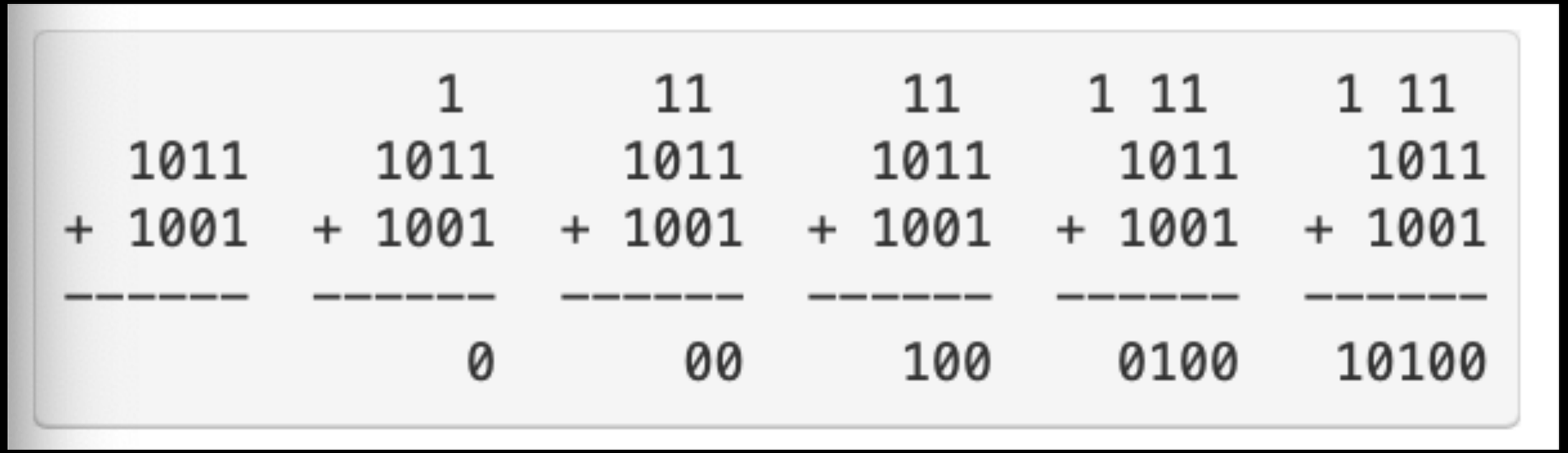
Skill Check

- What is the decimal value of the following binary number

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	*64*	*32*	*16*	*8*	*4*	*2*	*1*
1	0	1	1	0	0	0	1

Math in Binary

It is possible to add, subtract and divide in binary



Place-value numbers

Base-2 “binary”

- $d02_{16}$ 0x0d02

16^2	16^1	16^0
d	0	2

$$d \times 16^2 + 0 \times 16^1 + 2 \times 16^0 = 3330$$

Hexadecimal digits are taken from the set of nibbles

d	0	2
1101	0000	0010

Bytes or Octets {00, 01, 02, … fd, fe, ff}.

Binary	Decimal	Hex
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

Hexadecimal

Skill Check

- What is 0xBAD in decimal and binary

Binary	Decimal	Hex
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

Math with Hexidecimal

add, subtract, divide and multiple

```
          1       1       1   1  1    1  1
  d0b2    d0b2    d0b2    d0b2    d0b2    d0b2
+ 300f  + 300f  + 300f  + 300f  + 300f  + 300f
------  ------  ------  ------  ------  ------
             1      c1     0c1    00c1   100c1
```

Binary	Decimal	Hex
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

Skill Check

Hexidecimal.

- What is 0xbad + 0xb0b

Binary	Decimal	Hex
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

Base-2 logs and exponents

Value	base-10	Short form	Pronounced
2^{10}	1024	Ki	Kilo
2^{20}	1,048,576	Mi	Mega
2^{30}	1,073,741,824	Gi	Giga
2^{40}	1,099,511,627,776	Ti	Tera
2^{50}	1,125,899,906,842,624	Pi	Peta
2^{60}	1,152,921,504,606,846,976	Ei	Exa

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

Value	Split	Written
2^{27}	$2^7\ 2^{20}$	128M
2^3	$2^3\ 2^0$	8
2^{39}	$2^9\ 2^{30}$	512G

$\lg(64G) = \lg(2^6\ 2^{30}) = \lg(2^{36}) = 36$

Value	base-10	Short form	Pronounced
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2^{20}	1,048,576	Mi	Mega
2^{30}	1,073,741,824	Gi	Giga
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2^{40}	1,099,511,627,776	Ti	Tera
2^{50}	1,125,899,906,842,624	Pi	Peta
2^{60}	1,152,921,504,606,846,976	Ei	Exa

Exercise — Fill in the rest of

Exponent	Written As
17	128K
3	
38	
11	
	256M
	16G
	32

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

Value	Split	Written
2^{27}	$2^7\ 2^{20}$	128M
2^3	$2^3\ 2^0$	8
2^{39}	$2^9\ 2^{30}$	512G

1.8, 256G, 2K, 28, 34, 5↩

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2^{20}	1,048,576	Mi	Mega
2^{30}	1,073,741,824	Gi	Giga
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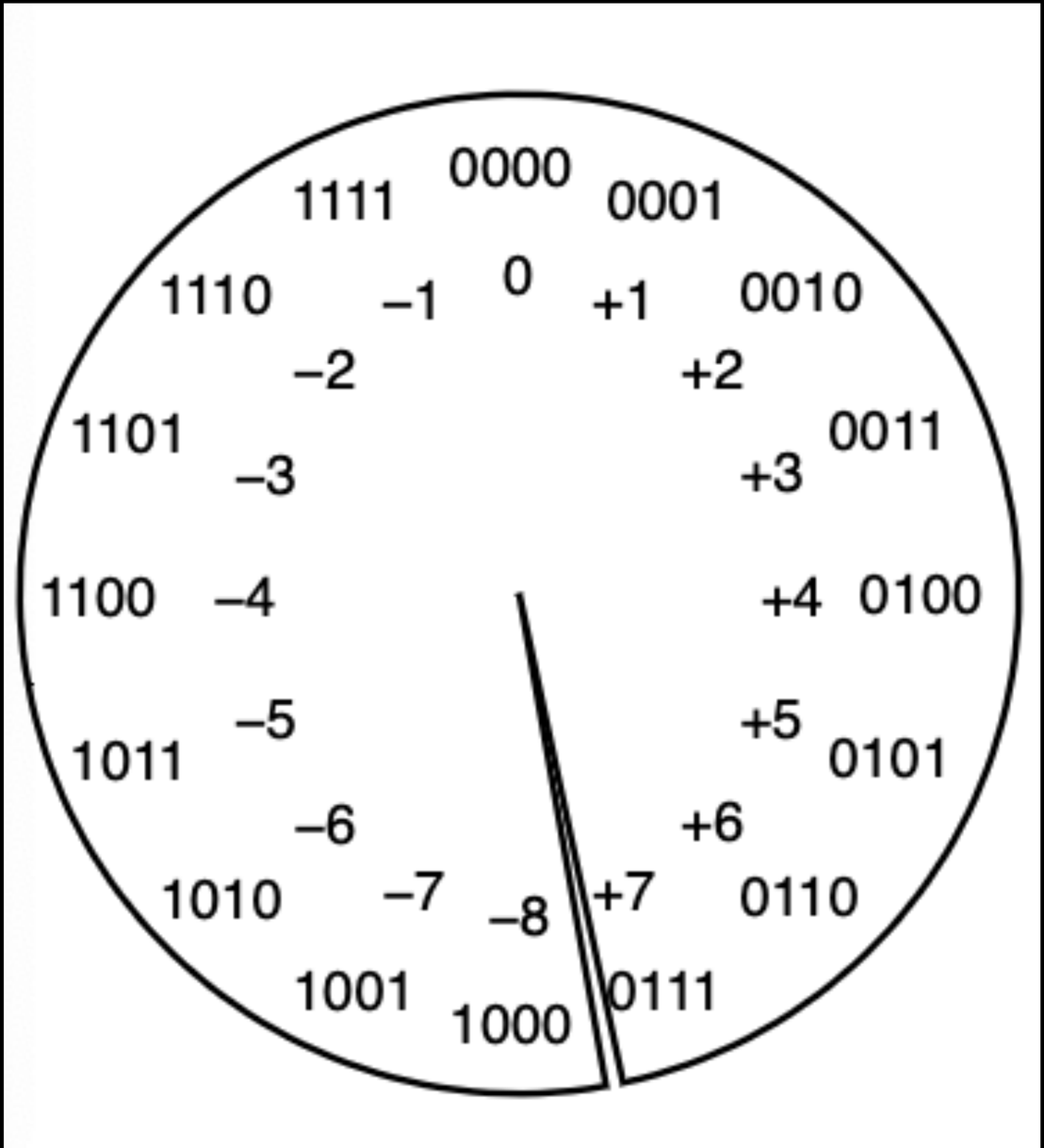
Value	Split	Written
2^{27}	$2^7\ 2^{20}$	128M
2^3	$2^3\ 2^0$	8
2^{39}	$2^9\ 2^{30}$	512G

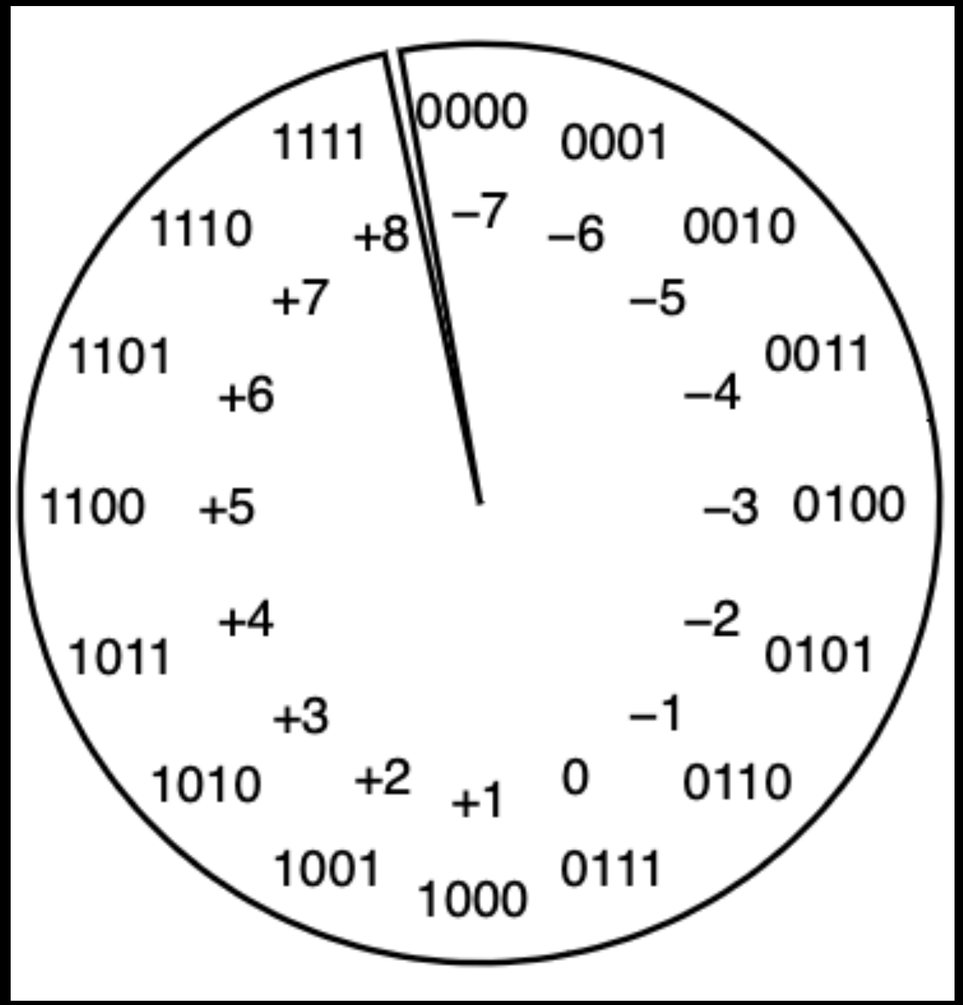
What about negative numbers

Two’s Complement, Biased, Sign Bit

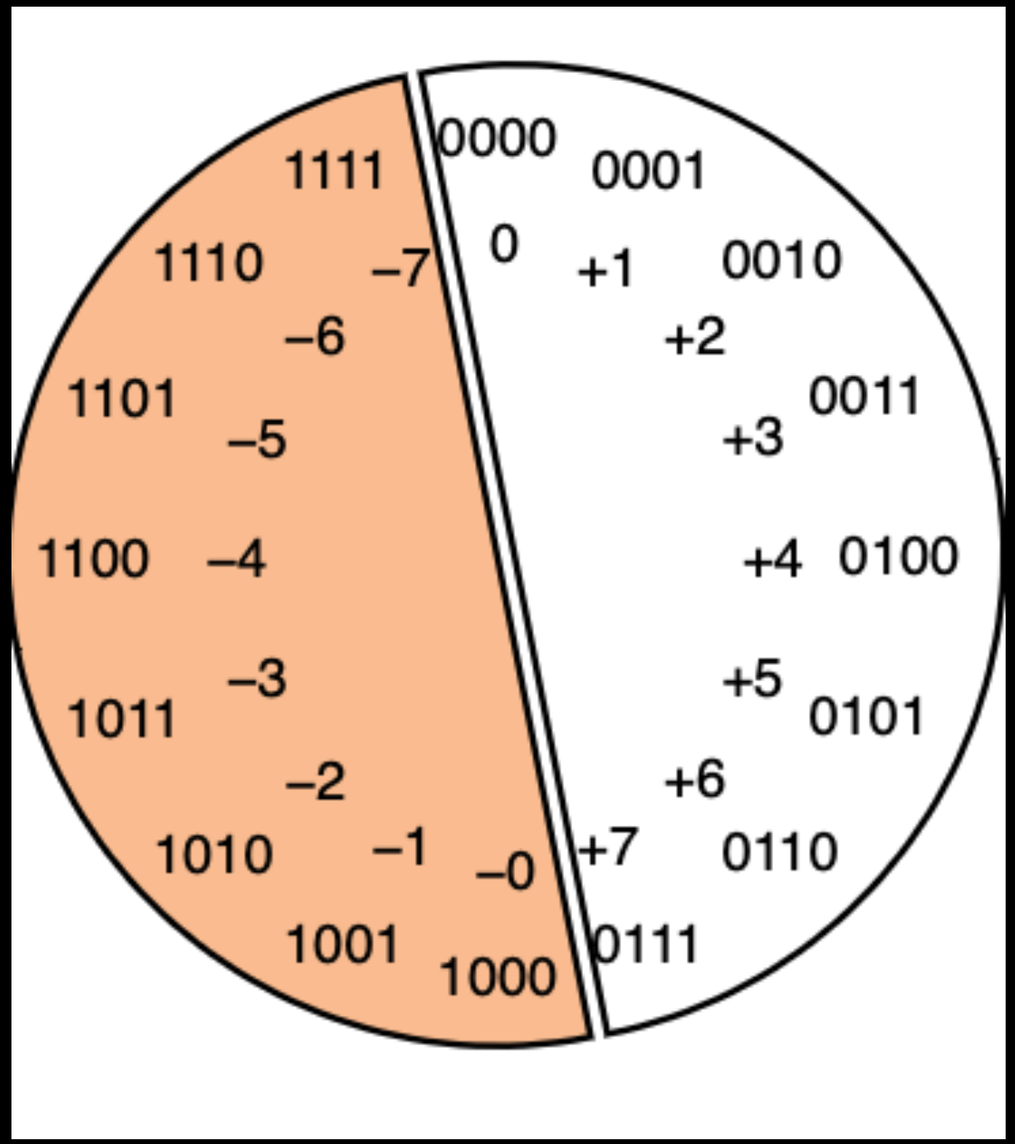
Two’s Complement



Biased


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

Sign bit


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

Exercise — Fill in the rest of the following table. Assume you are using 6-bit numbers. Answers are in footnotes.

Decimal	Two's-C	Biassed
5	000101	100100
–5	111011	011010
11	[6]	[7]
–1	[8]	[9]
[10]	110011	[11]
[12]	011111	[13]
[14]	[15]	101111
[16]	[17]	010000

Exercise — Fill in the rest of the following table. Assume you are using 6-bit numbers. Answers are in footnotes.

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5	000101	100100
–5	111011	011010
11	[6]	[7]
–1	[8]	[9]
[10]	110011	[11]
[12]	011111	[13]
[14]	[15]	101111
[16]	[17]	010000

1. 001011↩
2. 101010↩
3. 111111↩
4. 011110↩
5. –13↩
6. 010010↩
7. 31↩
8. 111110↩
9. 16↩
10. 010000↩
11. –15↩
12. 110001↩