The Binary

A lecture in 11 parts

Part 0

Logic Gates

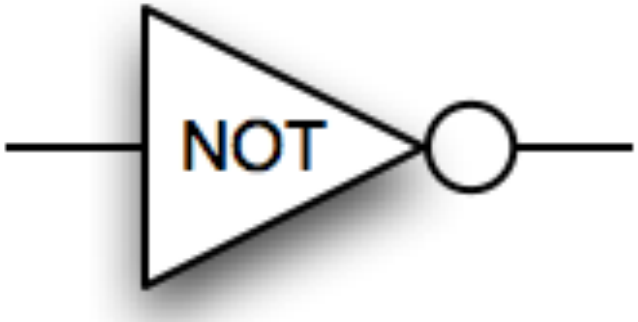
Inside a computer there is only ZUUUL

Actually there is only **high voltage** or **low voltage.** Trying to deal with voltages in between just introduces error.

Traditionally **high** voltage is associated with **1** and **True.**

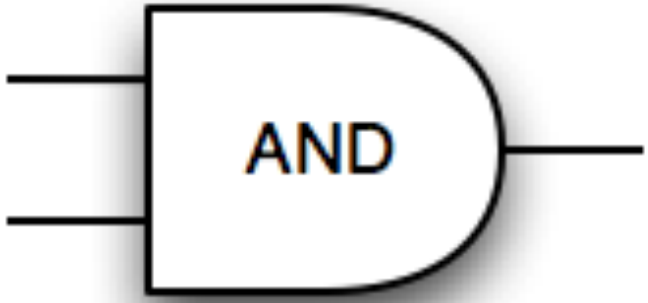
Traditionally **low** voltage is associated with **0** and **False.**

Ways of combining True and False



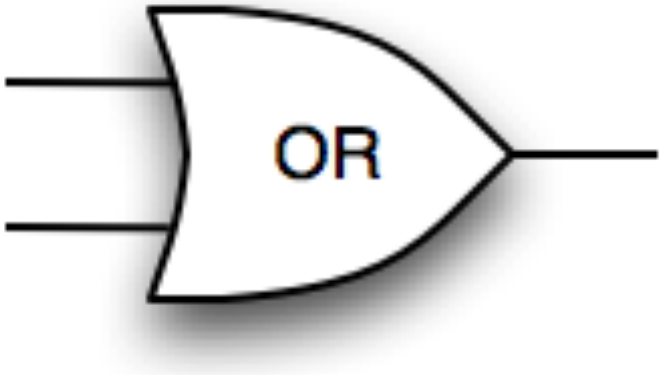
Input	Output
0	1
1	0

Ways of combining True and False



Input 1	Input 2	Output
0	0	0
0	1	0
1	0	0
1	1	1

Ways of combining True and False

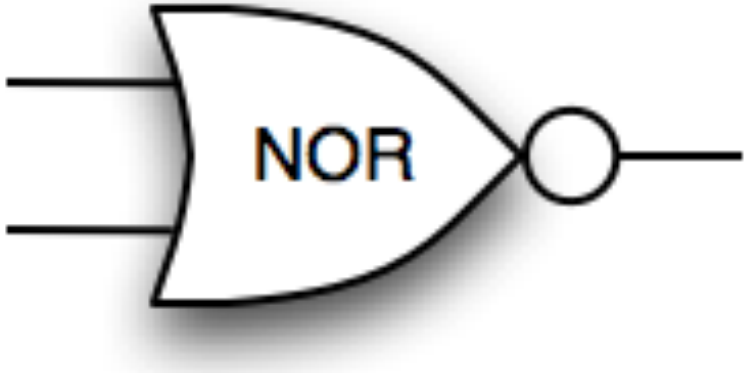


Input 1	Input 2	Output
0	0	0
0	1	1
1	0	1
1	1	1

Ways of combining True and False

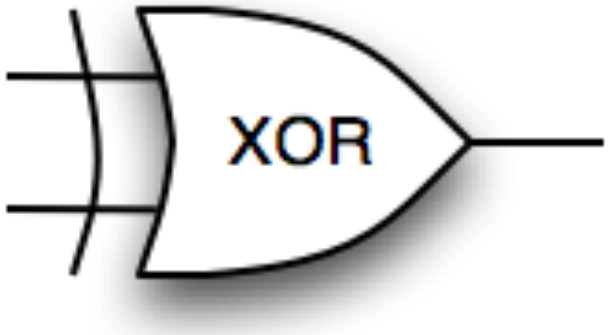
Input 1	Input 2	Output
0	0	1
0	1	1
1	0	1
1	1	0

Ways of combining True and False



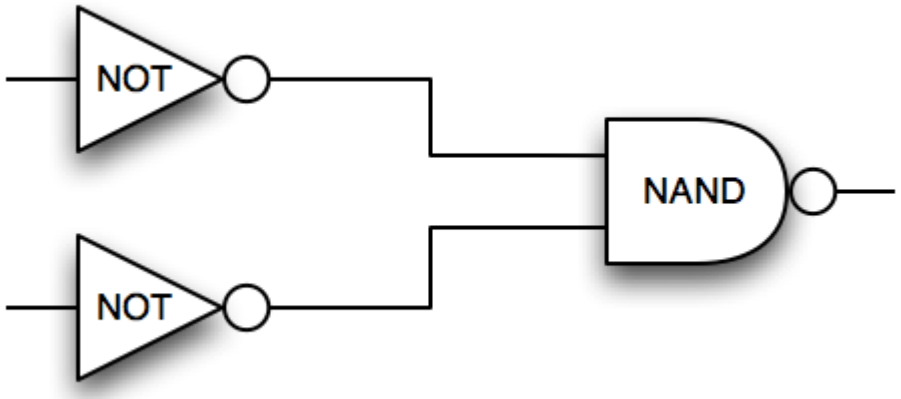
Input 1	Input 2	Output
0	0	1
0	1	0
1	0	0
1	1	0

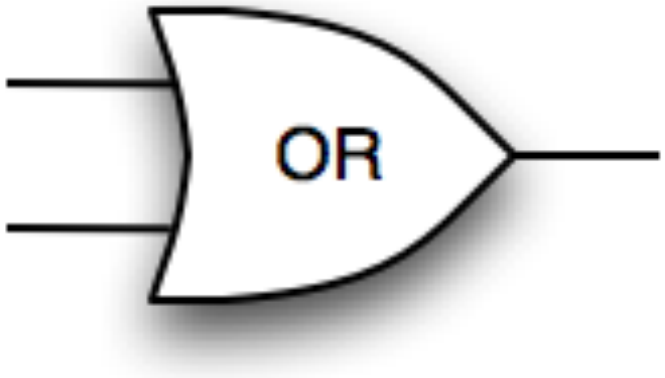
Ways of combining True and False



Input 1	Input 2	Output
0	0	0
0	1	1
1	0	1
1	1	0

You can build logic gates out of other logic gates.





Part 1

Numbers

How do computers represent numbers?

low is **0**

high is **1**

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Great that's two numbers. What about all the rest of the numbers?

How do humans represent numbers?

0 1 2 3 4 5 6 7 8 9

Further numbers we have to represent by **place value**

We have **ten** possible digits and so each time you go left by one digit the value of that digit multiplies by **ten**

456

4*10*10 + 5*10 + 6

$4*10^2 + 5*10^1 + 6*10^0$

How do computers represent numbers?

low is **0**

high is **1**

Great that's two numbers. What about all the rest of the numbers.

Computers represent numbers the same way, except only **two** possible **bits** instead of ten possible digits.

10101

$1*2^4 + 0*2^3 + 1*2^2 + 0*2^1 + 1*2^0$

21

We just converted binary to decimal

10101

$1*2^4 + 0*2^3 + 1*2^2 + 0*2^1 + 1*2^0$

21

Binary is base 2

Decimal is base 10

Convert binary to decimal	Convert decimal to binary
1101	10
0010	16
1111	0
0101	4

Converting binary to hexadecimal

Binary is base 2

Decimal is base 10

Hexadecimal (hex for short) is base 16

When we run out of numbers (0123456789) we use letters. So the possible hex digits are:

0 1 2 3 4 5 6 7 8 9 A B C D E F

Converting binary to hexadecimal

Every group of 4 bits is a hex digit

10110110
1011 0110
B 6

Converting back to decimal:
11*16 + 6
182

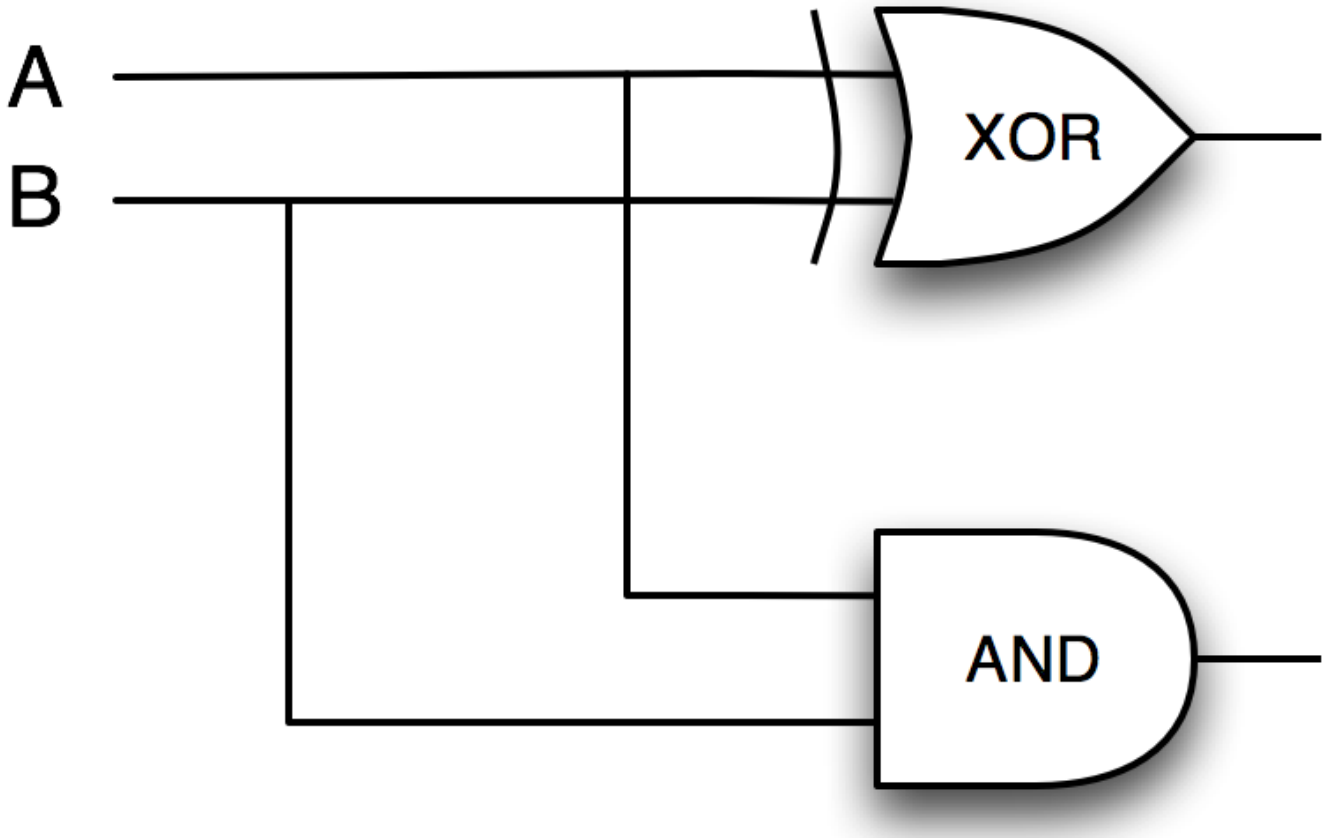
Part 10

Adding up numbers

Adding one-bit numbers

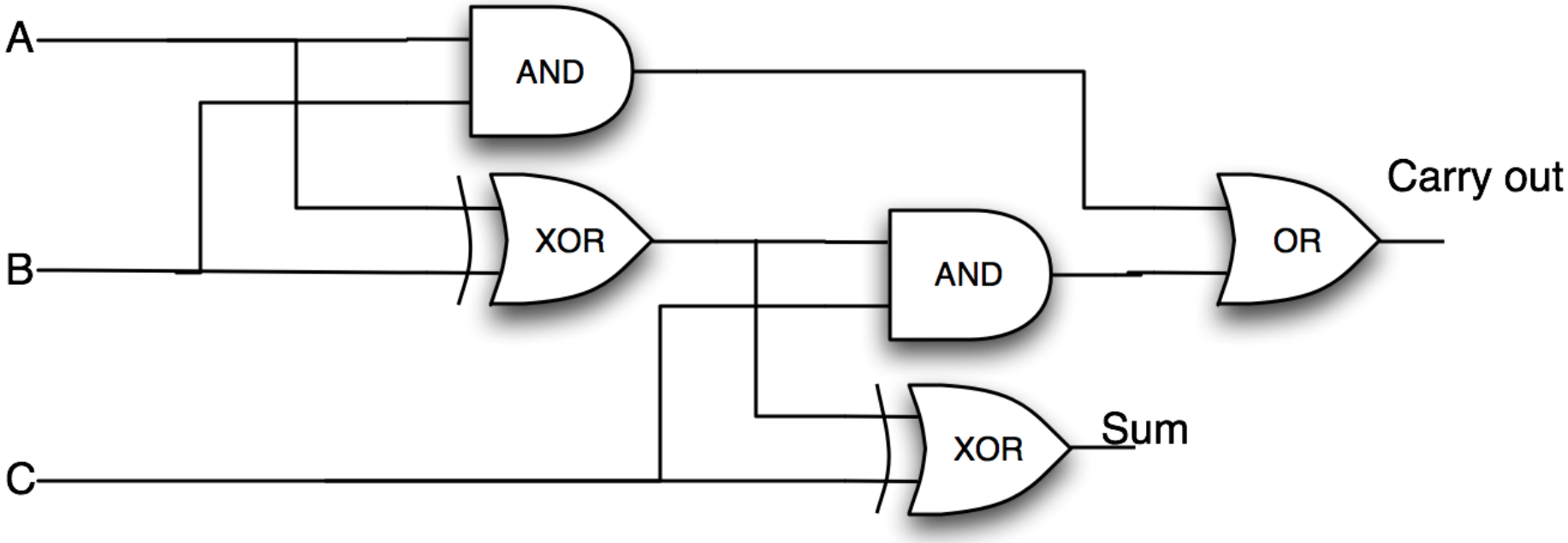
A	B	Twos	Ones
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Half adder



Adding one-bit numbers, continued

- What if someone carried a number into your column



Adding multi-bit numbers