LOGIC GATES - INTRODUCTION

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Overview & Introduction

- Digital Design underpins the creation of the myriad of imaginative digital devices that surround us…
  - Computers
  - Calculators
  - Phones
  - Digital watches
  - Microwave ovens
  - Robots…

Really…

Everything

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Digital Design

- Organizing an arrays of simple switches into a discrete system that performs transformations on two-level (Binary) information in a meaningful and predictable way

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What You Will Know…

- Prior Knowledge
  - Binary Numbers
    - How to count in binary
    - How to Add in Binary
    - How to Multiply in Binary
- What You Will Know & Be Able To Do
  - Explain the difference between AND, OR, NOT logic gates
  - Read and fill out a Truth Table
  - Convert a Logical Expression in to Gate Diagram
  - Convert a Logical Expression in to a Truth Table

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New Words…

- Binary
- Logical Expression
- Truth Table

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Review Binary Numbers

- Take 10 minutes and review binary numbers
  - Binary Number Systems
  - Binary Digits

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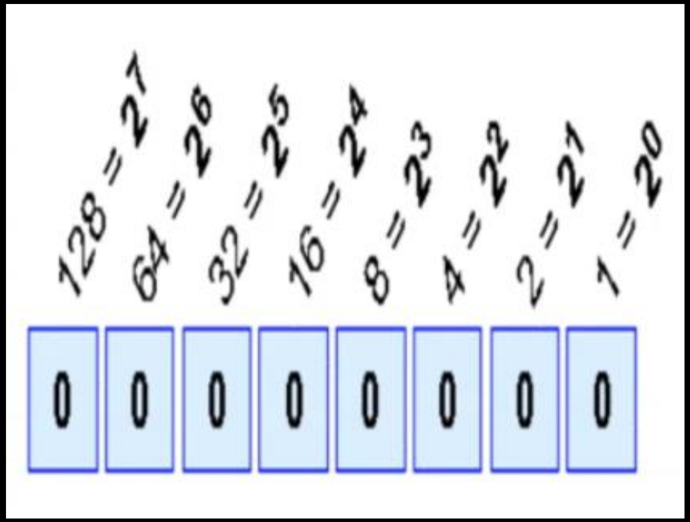
How to Convert from Binary or Decimal

Computer Humor

- Binary is as easy as 01, 10, 11



Place Values

Convert the Following Binary Numbers:

0011 = ? **1x2 + 1x1 = 3**

1011 = ? **1x8 + 0x4 + 1x2 + 1x1 = 11**

10101 = ? **1x16 + 0x8 + 1x4 + 0x2 + 1x1 = 21**

110011 = ? **1x32 + 1x16 + 0x8 + 0x4 + 1x2 + 1x1 = 51**

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Binary Quiz

- https://docs.google.com/forms/d/e/1FAIpQLSc82cMmtQFs0CJ7IW1a_sVz7N6eGZl64MbAlJmrdc6ZndfYPw/viewform?usp=sf_link

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ADDING AND MULTIPLYING BINARY NUMBERS

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ADDING BINARY NUMBERS

Rule 1 → 0 + 0 = 0
Rule 2 → 0 + 1 = 1
Rule 3 → 1 + 0 = 1

} Just like decimal addition

Rule 4 → 1 + 1 = 10 ← Surprise!

```
   110
+  101
------
  1011
```

Since 0 + 1 =1

Since 1 + 0 = 1

Since 1 + 1 = 10

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https://www.quickanddirtytips.com/education/math/how-to-add-binary-numbers?page=1

MULTIPLYING BINARY NUMBERS

```
      110
*     101
---------
    1 1 0
  0 0 0 0
1 1 0 0 0
---------
    11110
```

Rule 1 → 0 * 0 = 0
Rule 2 → 0 * 1 = 0
Rule 3 → 1 * 0 = 0
Rule 4 → 1 * 1 = 1

} Just like decimal multiplication

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ADDING AND MULTIPYING IN BINARY

- Adding Binary Numbers
  - Adding in binary | Applying mathematical reasoning
- Multiplying Binary Numbers
  - Multiplying in binary | Applying mathematical reasoning

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INTRO TO LOGIC GATES

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Binary Logic

- Deals with binary variables that take 2 discrete values (0 and 1), and with logic operations
- Three basic logic operations:
  - AND, OR, NOT
- Binary/logic variables are typically represented as letters: A,B,C,…,X,Y,Z

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Basic Logic Operators

- AND
- OR
- NOT

Binary (AND, OR)

Unary (NOT)

- F(a,b) = a•b,   F is 1 if and only if a=b=1
- G(a,b) = a+b, G is 1 if either a=1 or b=1
- H(a) = a’,   H is 1 if a=0

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Binary Logic Function

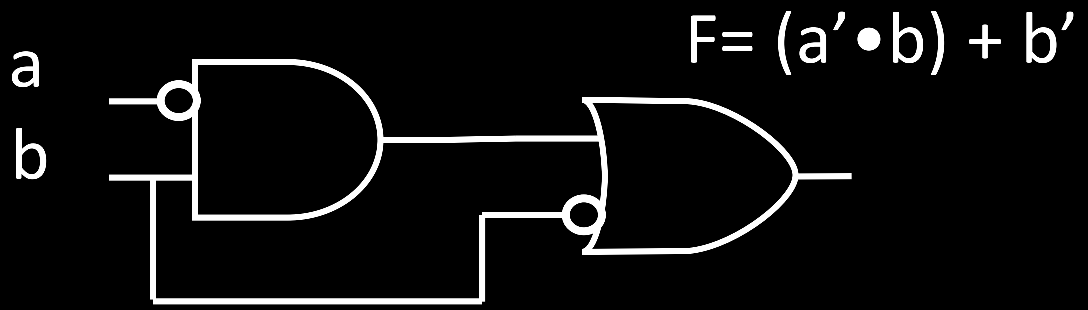
F(var) = expression

This is a set of Binary variables
Defines the set of "Inputs"

Operators (+, •, ')
Variables
Constants (0, 1)
Groupings (parenthesis)

Ex: F(a,b) = (a'•b) + b'

F(a,b,c) = a•((b+c')+(b'+c))



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Basic AND & OR Logic Operators

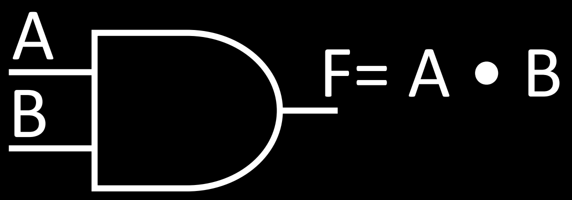
1-bit logic AND resembles binary multiplication:

$0 \bullet 0 = 0$

$0 \bullet 1 = 0$

$1 \bullet 0 = 0$

$1 \bullet 1 = 1$



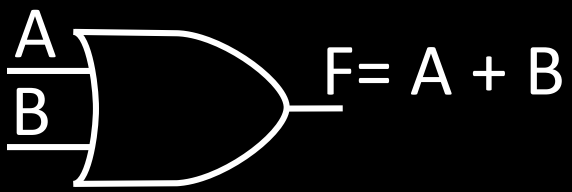
1-bit logic OR resembles binary addition, except for one operation:

$0 + 0 = 0$

$0 + 1 = 1$

$1 + 0 = 1$

$1 + 1 = 1$ $(\neq 10_2)$



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Combinational Logic Gates

- Outputs depend directly on their inputs
- Outputs are generated asynchronously and instantaneous*
- Do not require a clock or other synchronous signals
- Let's call them "Logic Gates"

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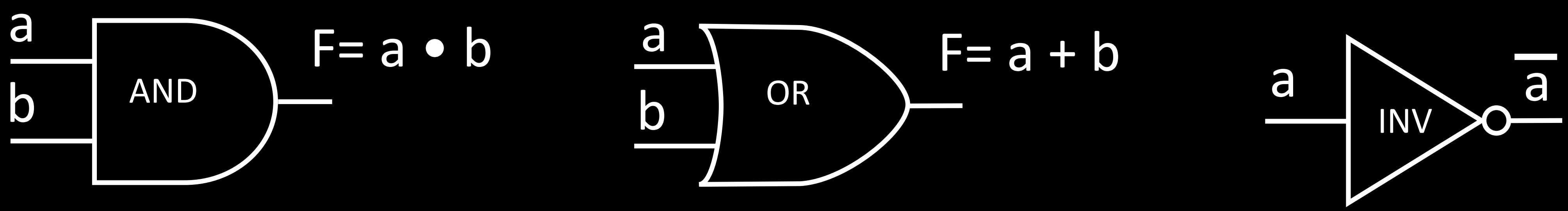
Logic Gates

- Logic gates are abstractions of electronic circuit components that operate on one or more input signals to produce an output signal



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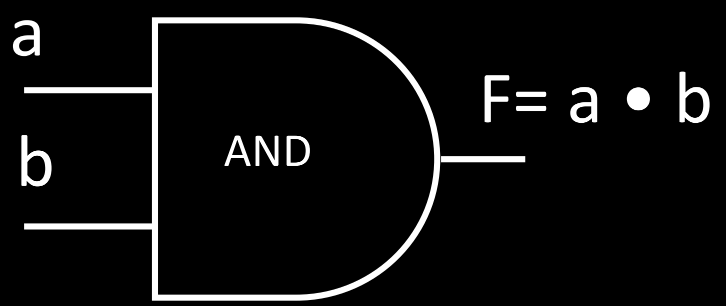
AND GATE



- This AND gate has two inputs and an output
- Output is zero unless both Inputs are 1's

2-Input AND

A	B	F=A•B
0	0	0
0	1	0
1	0	0
1	1	1

The AND operation is mathematically defined as the product of two Boolean values

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

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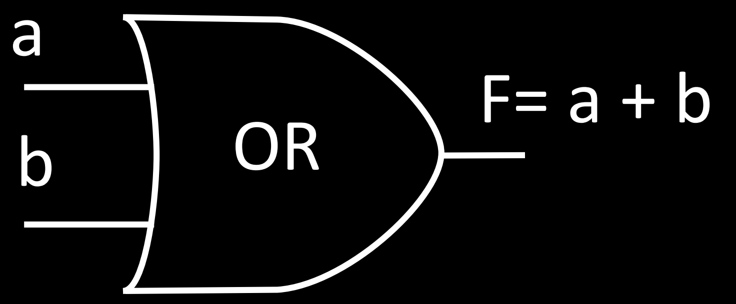
OR GATE



- This OR gate has two inputs and an output
- Output is 1 if any of the Inputs are 1's

The OR operation is mathematically defined as the summation of two Boolean values

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

2-Input OR

A	B	F=A+B
0	0	0
0	1	1
1	0	1
1	1	1

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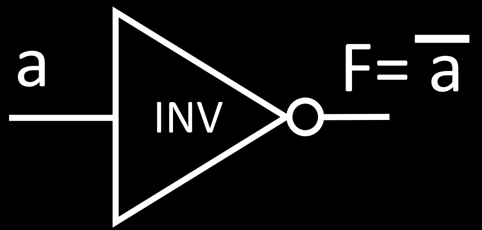
NOT (Inverter) Gate



- This NOT gate has one input and one output
- This is an “inverter” function
- Output is 1 if the Input is 0, and 0 if the Input is 1

(Inverter)
NOT

a	$F=\overline{a}$
0	1
1	0

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

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Truth Tables for Logic Operators

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

2-Input AND

A	B	F=A•B
0	0	0
0	1	0
1	0	0
1	1	1

2-Input OR

A	B	F=A+B
0	0	0
0	1	1
1	0	1
1	1	1

NOT

A	F=A'
0	1
1	0

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Truth Tables – Check for Understanding

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

2-Input AND

A	B	F=A•B
0	0	
0	1	
1	0	
1	1	

2-Input OR

A	B	F=A+B
0	0	
0	1	
1	0	
1	1	

NOT

A	F=A'
0	
1	

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TRUTH TABLES – CHECK FOR UNDERSTANDING

Q: Let a function F() depend on n variables.
How many rows are there in the truth table of F(a,b) = (a+b)?

What about F(a,b,c) = (a+b+c)?
What about F(a,b,c,d) = (a+b+c+d)?

A	B	F=A+B
0	0	0
0	1	1
1	0	1
1	1	1

A: 2^n rows, since there are 2^n possible binary patterns / combinations for the *n* variables

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LAB TIME - HTTPS://LOGIC.LY/DEMO/

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Check out this Logic Link

- Learning about Logic Gates and Circuits
  - https://logic.ly/lessons/

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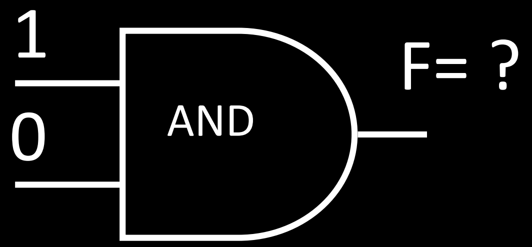
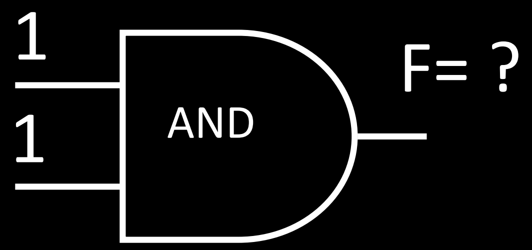
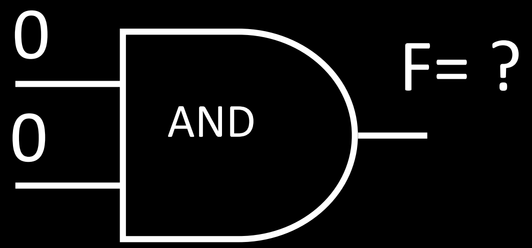
Logic Gates – Check for Understanding

- What are the outputs for each of these gates with the specified inputs values?







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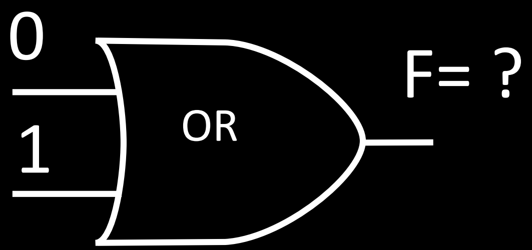
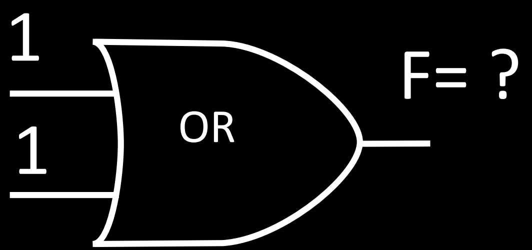
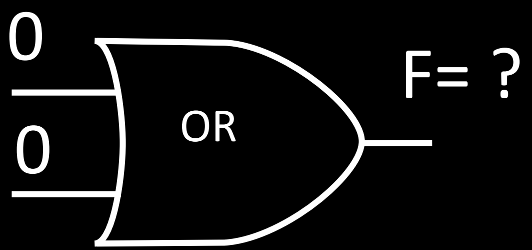
LOGIC GATES – CHECK FOR UNDERSTANDING

- What are the outputs for each of these gates with the specified inputs values?







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XOR, NAND, NOR GATES

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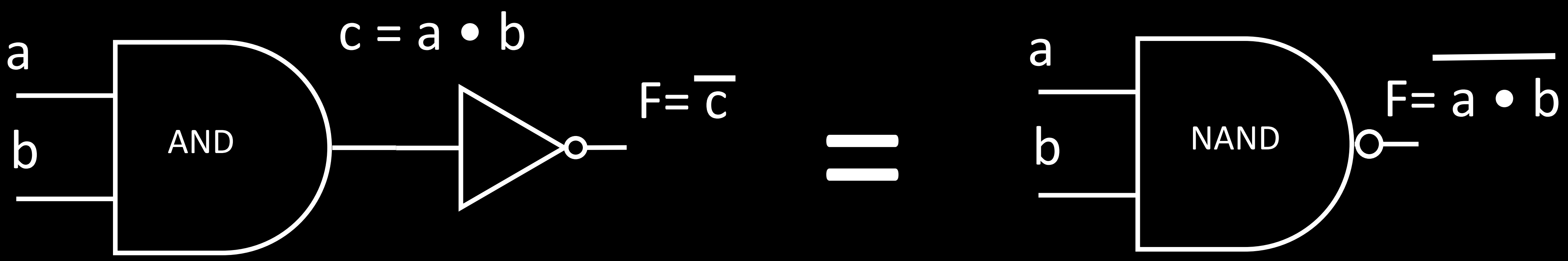
AND GATE + INVERTER

- This NAND gate has two inputs and an output
- Output is 1 unless both Inputs are 1's, then it's 0

2-Input NAND

A	B	$F=\overline{A \bullet B}$
0	0	1
0	1	1
1	0	1
1	1	0



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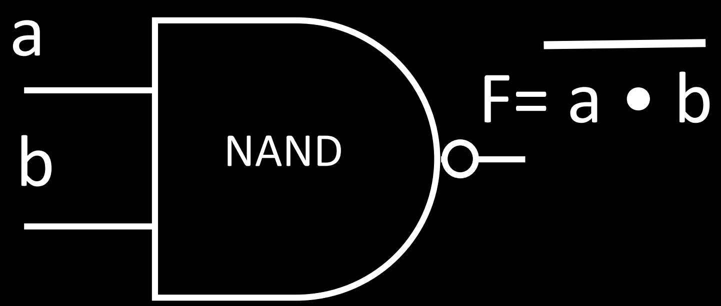
NAND GATE



- This NAND gate has two inputs and an output
- Output is 1 unless both Inputs are 1’s, then it’s 0

The NAND operation is mathematically defined as the product of two Boolean values

2-Input NAND

A	B	$F=\overline{A \bullet B}$
0	0	1
0	1	1
1	0	1
1	1	0

Truth table: tabular form that <u>uniquely</u> represents the relationship between the input variables of a function and its output

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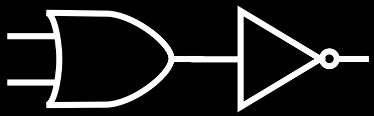
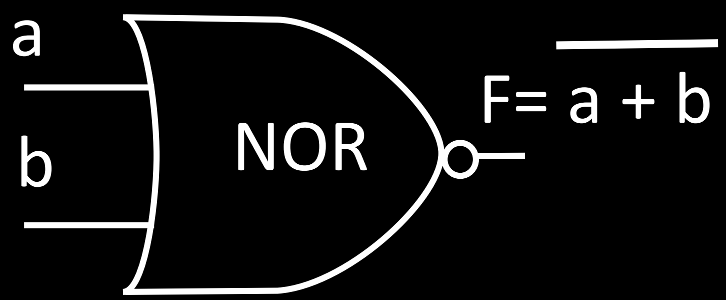
NOR GATE





- This NOR gate has two inputs and an output
- Output is 0 if any of the Inputs are 1's

The NOR operation is mathematically defined as the summation of two Boolean values

2-Input NOR

A	B	$F=\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

Truth table: tabular form that <u>uniquely</u> represents the relationship between the input variables of a function and its output

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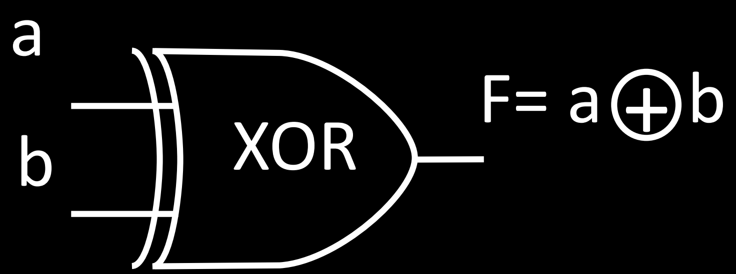
XOR GATE



- This XOR gate has two inputs and an output
- Output is 1 if the Inputs are different

The XOR operation is mathematically defined as the summation of two Boolean values if they are different

2-Input XOR

A	B	F=A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

Truth table: tabular form that <u>uniquely</u> represents the relationship between the input variables of a function and its output

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- Power Point Logic Gates Symbols – Oliver Mannay
- Slide Share Logic Gates
- PPT from Michigan Tech EE 4271

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