Gates and Circuits

(Part A)

By

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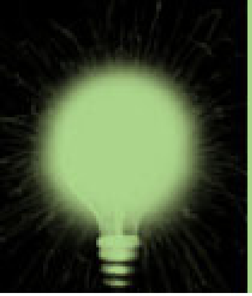
Goals

- Identify the basic gates and describe the behavior of each
- Describe how gates are implemented using transistors
- Combine basic gates into circuits

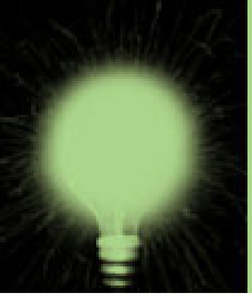


Computers and Electricity

- A **gate** is a device that performs a basic operation on electrical signals
- Gates are combined into **circuits** to perform more complicated tasks

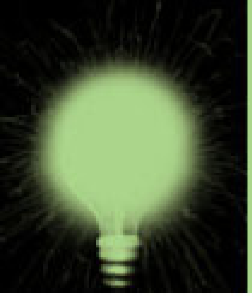
Computers and Electricity

- There are three different, but equally powerful, notational methods for describing the behavior of gates and circuits
  - Boolean expressions
  - logic diagrams
  - truth tables



Computers and Electricity

- **Boolean algebra**: expressions in this algebraic notation are an elegant and powerful way to demonstrate the activity of electrical circuits



Computers and Electricity

- **Logic diagram:** a graphical representation of a circuit
  - Each type of gate is represented by a specific graphical symbol
- **Truth table:** defines the function of a gate by listing all possible input combinations that the gate could encounter, and the corresponding output

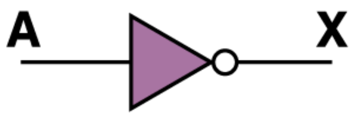
NOT Gate

- A NOT gate accepts one input value and produces one output value

Boolean Expression

X = A'

Logic Diagram Symbol



Truth Table

A	X
0	1
1	0

Figure 4.1 **Various representations of a NOT gate**

NOT Gate

- By definition, if the input value for a NOT gate is 0, the output value is 1, and if the input value is 1, the output is 0
- A NOT gate is sometimes referred to as an *inverter* because it inverts the input value

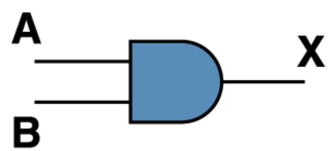
AND Gate

- An AND gate accepts two input signals
- If the two input values for an AND gate are both 1, the output is 1; otherwise, the output is 0

Boolean Expression

$$X = A \cdot B$$

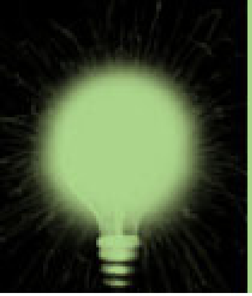
Logic Diagram Symbol



Truth Table

A	B	X
0	0	0
0	1	0
1	0	0
1	1	1

Various representations of an AND gate



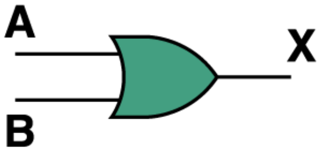
OR Gate

- If the two input values are both 0, the output value is 0; otherwise, the output is 1

Boolean Expression

$$X = A + B$$

Logic Diagram Symbol



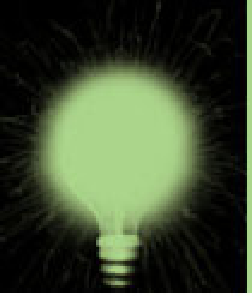
Truth Table

A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

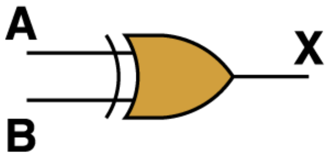
Various representations of a OR gate

XOR Gate

- XOR, or *exclusive* OR, gate
  - An XOR gate produces 0 if its two inputs are the same, and a 1 otherwise
  - Note the difference between the XOR gate and the OR gate; they differ only in one input situation
  - When both input signals are 1, the OR gate produces a 1 and the XOR produces a 0



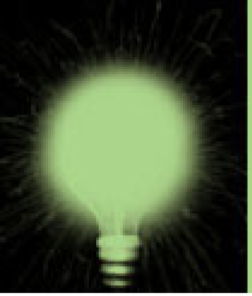
XOR Gate

Boolean Expression	Logic Diagram Symbol
$X = A \oplus B$	

Truth Table

A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

Various representations of an XOR gate



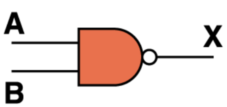
NAND and NOR Gates

- The NAND and NOR gates are essentially the opposite of the AND and OR gates, respectively

Boolean Expression

$X = (A \cdot B)'$

Logic Diagram Symbol



Truth Table

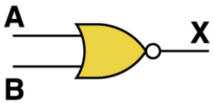
A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

Various representations of a NAND gate

Boolean Expression

$X = (A + B)'$

Logic Diagram Symbol



Truth Table

A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

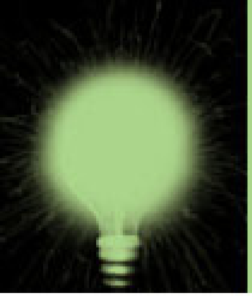
Various representations of a NOR gate

Review of Gate Processing

- A NOT gate inverts its single input value
- An AND gate produces 1 if both input values are 1
- An OR gate produces 1 if one or the other or both input values are 1

Review of Gate Processing (cont.)

- An XOR gate produces 1 if one or the other (but not both) input values are 1
- A NAND gate produces the opposite results of an AND gate
- A NOR gate produces the opposite results of an OR gate



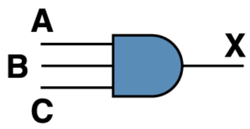
Gates with More Inputs

- Gates can be designed to accept three or more input values
- A three-input AND gate, for example, produces an output of 1 only if all input values are 1

Boolean Expression

$X = A \cdot B \cdot C$

Logic Diagram Symbol



Truth Table

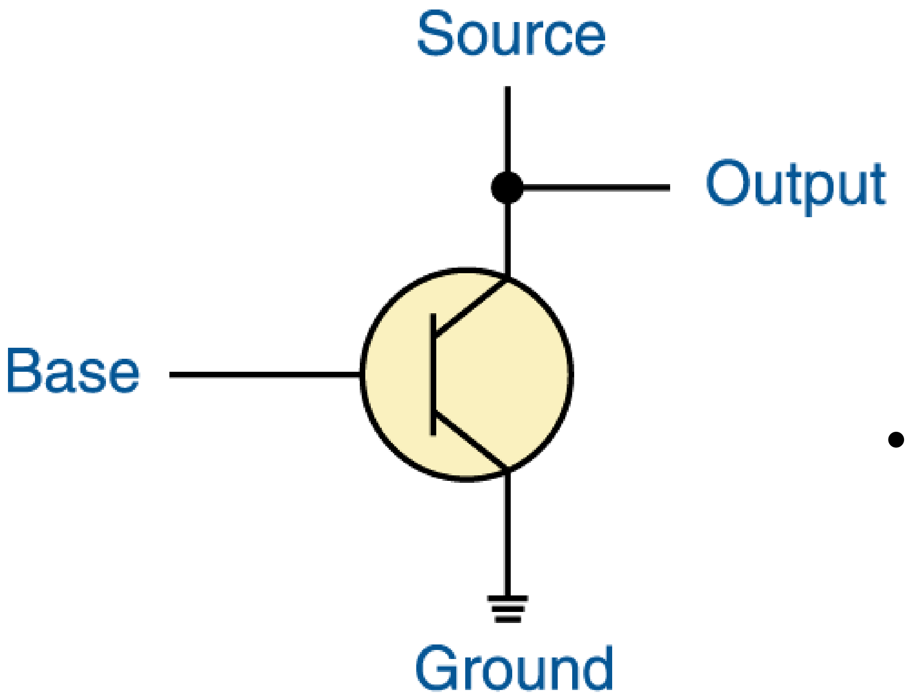
A	B	C	X
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

Various representations of a three-input AND gate

Constructing Gates

- A **transistor** is a device that acts, depending on the voltage level of an input signal, either as a wire that conducts electricity or as a resistor that blocks the flow of electricity
  - A transistor has no moving parts, yet acts like a switch
  - It is made of a **semiconductor** material, which is neither a particularly good conductor of electricity, such as copper, nor a particularly good insulator, such as rubber

Constructing Gates

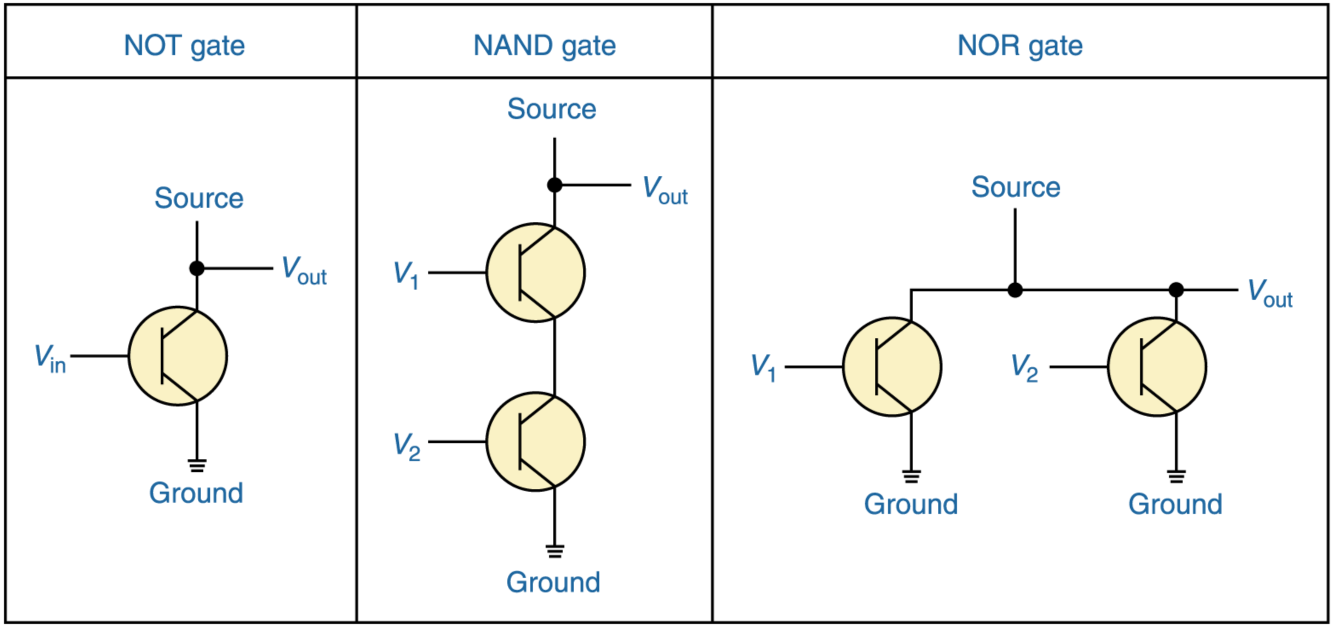


The connections of a transistor

- A transistor has three terminals
  - A source
  - A base
  - An emitter, typically connected to a ground wire
- If the electrical signal is grounded, it is allowed to flow through an alternative route to the ground (literally) where it can do no harm

Constructing Gates

- It turns out that, because the way a transistor works, the easiest gates to create are the NOT, NAND, and NOR gates



Constructing gates using transistors