Gates

Instructor: Dmitri A. Gusev

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CSC 120.02: Introduction to Computer Science

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Basic Definitions

A *gate* is a device that accepts one or more input electrical signals, and produces a single output electrical signal.

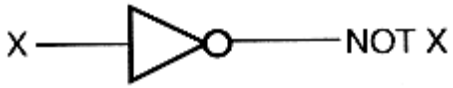
A *circuit* is a combination of gates.

Boolean algebra is an algebra in which variables and functions take on one of two values, 0 (“false”) or 1 (“true”).

A *logic diagram* is a graphical representation of a circuit, where each type of gate is represented by a specific graphical symbol.

A *truth table* is a table showing all possible input values and the associated output values.

NOT Gate



X	NOT X
0	1
1	0

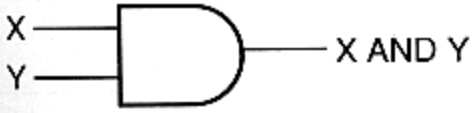
A triangle with an *inversion bubble*.

! is the corresponding Java *unary operator* inverting the value of a boolean variable.

```
boolean x=false, y; // boolean is a primitive data type.
y=!x; // Assignment statement:
        // The value of y becomes true.
```

Boolean expression: Y = X’

AND Gate



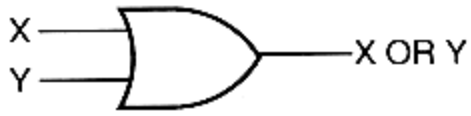
X	Y	X AND Y
0	0	0
0	1	0
1	0	0
1	1	1

Boolean expression:
$A = X \cdot Y$

&& is the corresponding Java *binary operator*. In Java, it is called Conditional-AND, because the second operand is evaluated only if needed there.

```
int a=3, b=3; // int is another primitive data type
if ((a==b)&&(b==3)) // == means “equal to”, also binary
   System.out.println(“a and b are equal to 3.”);
```

OR Gate



X	Y	X OR Y
0	0	0
0	1	1
1	0	1
1	1	1

Boolean expression: A = X + Y

|| is the corresponding Java binary operator. In Java, it is called Conditional-OR, because the second operand is evaluated only if needed.

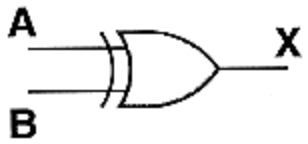
```
boolean x=false, y=true;
if (x || y)
   System.out.println("At least one is enough!");
```

XOR Gate

Boolean Expression

$X = A \oplus B$

Logic Diagram Symbol



Truth Table

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

Exclusive OR. Java has no such operator for variables of type boolean, but it offers *bitwise exclusive OR,* **^**.

```
int x = 0xAA; // Hexadecimal values are
int y = 0xD4;  // preceded by “0x” in Java!
System.out.println(x ^ y); // Prints 126 (decimal)
```

More Bitwise Operators in Java

~ inverts a bit pattern; i.e., it's a bitwise NOT;

& denotes a bitwise AND operation;

| is the bitwise OR operator.

The int data type is a 32-bit signed two's complement integer. It has a minimum value of -2,147,483,648 and a maximum value of 2,147,483,647 (inclusive).

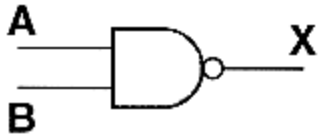
```
int x = 0xAA; // 10101010 in Base 2
int y = 0xD4; // 11010100 in Base 2
System.out.println(~x); // Prints -171 (decimal)
System.out.println(x&y); // Prints 128 (decimal)
System.out.println(x|y); // Prints 254 (decimal)
```

NAND Gate

Boolean Expression

$X = (A \cdot B)'$

Logic Diagram Symbol



Truth Table

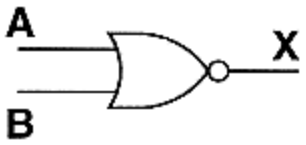
A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

NOR Gate

Boolean Expression

$X = (A + B)'$

Logic Diagram Symbol



Truth Table

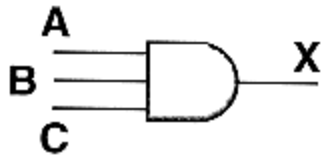
A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

Three-Input AND Gate

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

Constructing Gates

Gates can be constructed using transistors (Section 4.3). You're not responsible for this section.