## Basics of Computing – Chapter 1.1-1.3 Data Manipulation and Storage Media

Cory L. Strope



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### Boolean Symbol System

#### Circuits

Data Storage

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O's and 1's Binary **number system** vs. Boolean **symbol system** 

Binary:

- Operations: +,  $\times$ , /, –
- ▶ {0, 1, 10, 11, 100, 101, ...}

Boolean:

- Operations: AND, OR, XOR, NOT, ...
- $\{0,1\}$  or  $\{true, false\}$  or  $\{on, off\}$

#### Boolean Circuitry

### Boolean Logic Binary Nature

Boolean logic is binary in nature, thus there are two values for:

- Any given condition
- Any answer based on the condition

For example, is the weather pleasant?

- Three conditions: Wind, warmth, and rain.
- ▶ These values can be set to either true (1), or false (0).

Today: warm = false, wind = false, rain = true. Weather pleasant? False

Allowing degrees of warmth, wind, and rain would require levels of each condition.

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#### Boolean Circuitry

### Boolean Logic Gate

The circuitry to carry out boolean logic are called logical gates.

- Designed to accept a small number of conditions
- Conditions expressed as true or false

Consider logic gates with only two inputs. For a given gate, there will be particular response if:

- 1. Both inputs are false,
- 2. Only the first input is false,
- 3. Only the first input is true, and
- 4. Both inputs are true.

To show the output of a gate for each pair of inputs, we build truth tables.

#### Boolean Circuitry

### Truth Tables

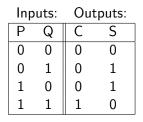
Truth tables compute functional values of logical expressions w.r.t. all possible combinations their logical variables may take.

Column headings on a truth table show:

- 1. Inputs (variables)
- 2. Expression result, based on variables and operators

Row headings show:

- 1. All possible T/F assignment to variables
- 2. Result of T/F assignment to Expression



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### Boolean Logic Operations and Circuitry

- Input: 2 bits
- Number of operations for 2-bit input operations: 2<sup>4</sup> = 16
- Given the following setup for a truth table:

Ρ	Q	P op Q
0	0	<i>X</i> <sub>1</sub>
0	1	<i>X</i> <sub>2</sub>
1	0	<i>X</i> <sub>3</sub>
1	1	$X_4$

where result  $X_i \in \{0,1\}$ .

# 16 combinations possible using the given setup:

$X_1 X_2 X_3 X_4$	Description	Gate Name?
0000	Inputs ignored	False
0001	P and Q true	AND
0010	Only Q true	Q AND NOT P
0011	Q true	Q
0100	Only P true	P AND NOT Q
0101	P true	Р
0110	Only P or Q true	XOR
0111	P or Q true OR	
1000	P and Q false NOR	
1001	P = Q NXOR	
1010	P false NOT P	
1011	Not only P true P implies Q	
1100	Q false NOT Q	
1101	Not only Q true	Q implies P
1110	P or Q false NAND	
1111	Inputs ignored	True

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Boolean Operations: NOT, AND, OR, XOR

**Boolean Logic** Operations

Out of the 16 possible gates, we will study only four:

- Three basic gates:
  - 1. NOT
  - 2. AND
  - 3. OR
- Combinations of these gates construct our other common gate:
  - 1. XOR

Boolean Symbol System

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Boolean Operations: NOT, AND, OR, XOR

Boolean Operations NOT – (NOT P, NOT Q)

The simplest boolean operation is **NOT**.

Takes 1 input and inverts it.

NOT 
$$0 = 1$$

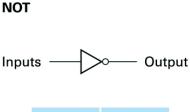
NOT 1 = 0

Ρ	Q	NOT P	NOT Q
0	0	1	1
0	1	1	0
1	0	0	1
1	1	0	0

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Boolean Operations: NOT, AND, OR, XOR		

## Boolean Gates



Inputs	Output	
0	1	
1	0	

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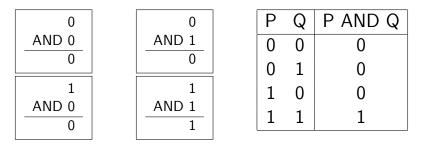
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Boolean Operations: NOT, AND, OR, XOR

# Boolean Operations

Boolean AND works similar to binary multiplication.

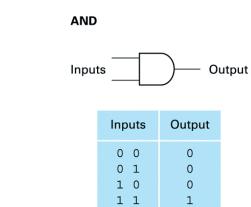
Takes 2 inputs, P and Q.



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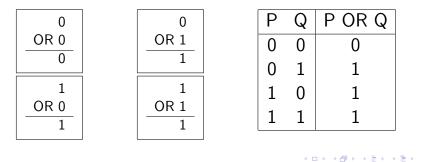
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Boolean Operations: NOT, AND, OR, XOR

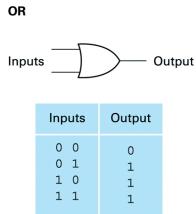
# Boolean Operations

Boolean OR works similar to binary addition.

Takes 2 inputs, P and Q.



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Boolean Operations: NOT, AND, OR, XOR		
Boolean Gates		



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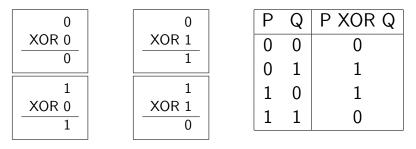
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Boolean Operations: NOT, AND, OR, XOR

# Boolean Operations

Boolean XOR = 
$$\begin{cases} | \text{ input } 1' \text{s even } | & \text{output } 0 \\ | \text{ input } 1' \text{s odd } | & \text{output } 1 \end{cases}$$

► Takes 2 inputs, P and Q.



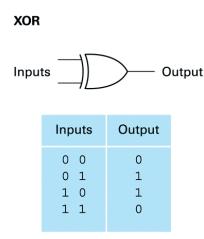
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Boolean Operations: NOT, AND, OR, XOR

## Boolean Gates



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### Boolean Symbol System

#### Circuits

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Creating a Circuit

## Creating a Circuit

Ρ	Q	P XOR Q
0	0	0
0	1	1
1	0	1
1	1	0

As it was previously mentioned, the XOR gate can be produced by the three basic gates

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- AND
- ► OR

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NOT

Boolean Symbol System

#### Creating a Circuit

## Creating a Circuit Steps

Ρ	Q	P XOR Q
0	0	0
0	1	1
1	0	1
1	1	0

- 1. Highlight the rows in which a 1 shows up in the output.
- 2. For each row, use AND and NOT gates to make the inputs equal 1.

 $r_{01}$  (NOT P AND Q)  $r_{10}$  (P AND NOT Q)

- 3. If there is more than 1 row highlighted, connect gates with OR
  - (NOT P AND Q) OR (P AND NOT Q)

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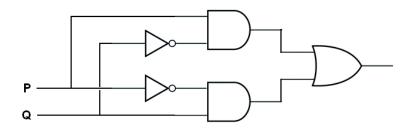
4. Draw circuit (on board)

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Creating a Circuit

### Creating a Circuit XOR using AND's and NOT's



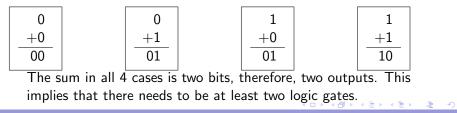
Boolean Symbol System

**Boolean Addition** 

## Boolean Addition

Addition can be performed using the general equation:

P and Q are the inputs, C is the **carry** bit, and S is the **sum** bit. To add two bits, we need to match all four cases of addition:

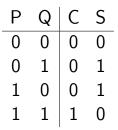


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Boolean Addition

### Boolean Addition Circuit Creation

To create a circuit with more than one output, create a circuit for each output.



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Boolean Addition

## Boolean Addition

Highlight the rows with 1's in the output. Note that each output (S and C) is treated independently of the other!



Boolean Symbol System

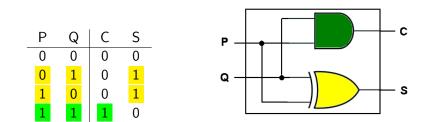
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**Boolean Addition** 

## Boolean Addition



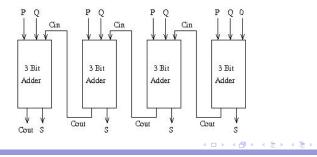
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#### Boolean Addition

### Boolean Addition Three-bit Adder

The two-bit adder is restricted to adding bit-strings of length 1 only.

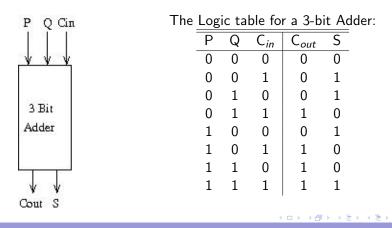
Multi-column addition is preferable. For this, we need an adder that can propagate carry bits:



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#### Boolean Addition

### Boolean Addition Three-bit Adder



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Boolean Symbol System

#### Boolean Addition

## Boolean Addition

3-bit Adder:								
Ρ	Q	Cin	Cout	S				
0	0	0	0	0				
0	0	1	0	1				
0	1	0	0	1				
0	1	1	1	0				
1	0	0	0	1				
1	0	1	1	0				
1	1	0	1	0				
1	1	1	1	1				

C<sub>out</sub>:

S:

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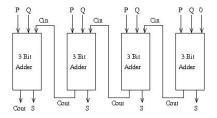
- Occurs when either P & Q, P & C<sub>in</sub>, or Q & C<sub>in</sub> are 1.
- Bullet point above: 3 &'s, 1 or!
- True when an odd number of inputs are 1.
- Suggests we need only to compute the sum, as in the two-bit adder
  - ▶ 3-bit XOR: (P XOR Q) XOR C<sub>in</sub>

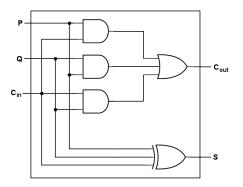
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#### **Boolean Addition**

## Boolean Addition





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#### Flip-Flops

### Flip-Flops

In previous digital computations, the inputs were given to a gate, and stage-by-stage, the output of each gate is found by a lookup in it's logic table, until the end of the computation is reached, and the output is determined.

More difficult (though important) computations require *feedback* from outputs into earlier inputs. One example of such a gate is the **flip-flop**.

### Definition

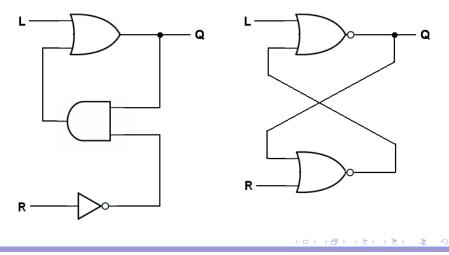
A flip-flop is a circuit that produces an output value of 0 or 1, which remains constant until a temporary pulse from another circuit causes it to shift to the other value.

Boolean Symbol System

Circuits

#### Flip-Flops

Flip-Flops Like a Light Switch



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#### Flip-Flops

Flip-Flops Why?

Once set, flip-flops will maintain it's current state (output value). Other circuits can change the state of the flip-flop by sending a **pulse** (1-bit) to the inputs of the flip-flop.

- To store information, many flip-flops can be constructed on a computer chip.

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Boolean Symbol System

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## Storage Devices in Computer Systems

Storing "stuff" brings up many issues, depending on what it is:

- ▶ How much storage do we need?
- How do we get our stuff?
- How fast can we get our stuff?
- How much are we willing to spend on our storage materials?
- How do we organize our stored stuff?
- How long will the items last?

We can answer these questions for many things:

- Food,
- papers (like old homework),
- etc.

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### Storage Devices in Computer Systems Bits and Bytes

- ► How much storage do we need? Size
- How do we get our stuff? Access Method
- How fast can we get our stuff? Access Speed
- How much are we willing to spend on our storage materials? Cost
- How do we organize our stored stuff? Organization and Structure
- ► How long will the items last? Life-time of stored elements.

It is important to understand the impact of each of these questions when working with computers.

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- We want to find the phone number of someone fast
- Assume phone book is not in alphabetical order
  - Sequentially search entry-by-entry.

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Very slow. Sequential.

<sup>&</sup>lt;sup>a</sup>http://www.lynnlake.ca

### Storage Devices in Computer Systems Paper Clipped Numbers



- We keep the business cards of numbers we use frequently in our wallet.
  - Look at the cards on a regular basis.
  - Faster and easier than the phonebook.
  - Wallet is small.

Circuits

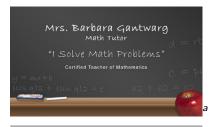
Still flip through the cards.

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Faster than phone book, but still slow. Sequential or Random?

<sup>a</sup>http://www.sfcwebdesign.com

#### Storage Devices in Computer Systems Number that is Found, taken from paper clip.



<sup>a</sup>http://www.toadwebsites.com

- Making calls, take a couple of cards out.
  - Find correct number on business card (Fax, office, home, ...)
  - Business card is very small.
  - Easier to find number.

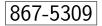
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Limitations?

Fast. Random

#### Storage Devices in Computer Systems Written Number



- Found the number, write it down
  - Very fast.
  - Cannot write more than one number.
  - After phone call, what happens to number?

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Very Fast. Random.

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# Comparisons of Storage Options

	Speed	Size	Volatility	Access
				Method
Phone Book	Very Slow	Very Large	Very Low	Sequential
Paper Clip	Slow	Large	Low	Random
Biz. Card	Fast	Small	High	Random
Whiteboard	Very Fast	Very Small	Very high	Random

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#### Storage Devices in Computer Systems From Slowest to Fastest

- ▶ Mass Storage: Hard Drive, CD, DVD, Tape backup
- Main Memory
- Cache
- Registers

Circuits 000 0000000 000

## Storage Devices in Computer Systems Main Memory

Memory is stored in units called cells.

- Each cell is 1 byte.
- each cell has a "name", or address.
  - Similar to house address
- Main Memory is usually called Random Access Memory (RAM)
  - We can access any cell directly, without scanning other cells.

Cell 0	01011011	
Cell 1	01001111	
Cell 2	01100111	
Cell 3	00000010	
Cell 4	01101011	
Cell 5	10001101	
Cell 6	00110010	
Cell 7	10111011	
:		
Cell n	11011011	

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Circuits 000 0000000 000

## Storage Devices in Computer Systems Main Memory

- There are two operations in memory:
  - Read
  - Write
- ▶ Read(Cell 5) → 10001101
- Write(0000000, Cell 5) replaces the contents of Cell 5 with 00000000.

Cell 0	01011011	
Cell 1	01001111	
Cell 2	01100111	
Cell 3	00000010	
Cell 4	01101011	
Cell 5	10001101	
Cell 6	00110010	
Cell 7	10111011	
:	:	
Cell n	11011011	

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#### Storage Devices in Computer Systems Main Memory – Pro's

Main memory plays a vital role in any computer

- All read and write operations go through the Main memory
- Main memory is faster than the Hard drive

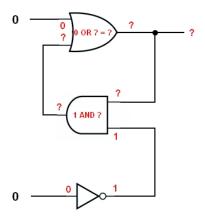
Boolean Symbol System

Circuits 000 00000000

## Storage Devices in Computer Systems Main Memory – Cons

Main memory, cache, and registers all work using electrical pulses. As in flip-flops, before any pulses **there is no state** 

- Without electricity, a flip-flop loses it's state.
- Shutting down a computer resets the state of memory, cache, and registers!



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### Storage Devices in Computer Systems Mass Storage

- Magnetic Systems
  - Disk
  - Tape
- Optical Systems
  - CD
  - DVD

## Storage Devices in Computer Systems Mass Storage

Pros:

- Can hold huge amounts of data
- Do not lose data when the power is off

Cons:

- Very slow
- Some mass storage devices are *sequential*.
  - You cannot directly access the data you need. For example, tape drives.

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#### Storage Devices in Computer Systems Mass Storage vs. Main Memory

	Speed	Size	Volatility	Access
				Method
Mass Storage	Slow	Huge	Very Low	Sequential
				<i>or</i> Random
Main Memory	Fast	Small	High	Random
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## Definition

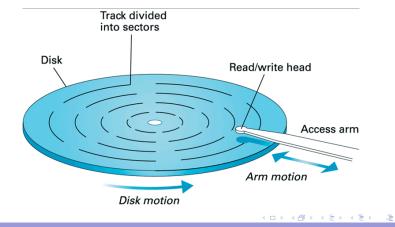
On-line means the device or information is connected and readily available to the machine without human intervention.

#### Definition

Off-line means that human intervention is required before the device or information can be accessed by the machine.

#### Mass Storage Magnetic Disk Drives

A good example of a magnetic disk drive is the floppy disk drive:



#### Mass Storage Hard Disk Drives – Time

$$Disk Speed = \begin{cases} Access Time = \begin{cases} Seek Time \\ Latency Time \end{cases}$$
Transfer Time

Seek time: The time required to move the read/write heads from one track to another.

Rotation (Latency) time: **Half** the time required for the disk to make a complete rotation.

Transfer time: The rate at which data can be transferred to or from the disk.

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#### Mass Storage Hard Disk Drives – Time

Example: What is the average access time of a hard disk that spins at 75 revolutions per second<sup>5</sup> with a seek time of 15 milliseconds?

1. Calculate the rotation time: (one half of the rotation time)

$$0.5 imes rac{1 ext{ second}}{75 ext{ revolutions}} = rac{1}{150}$$

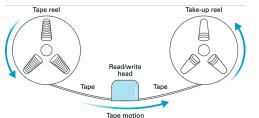
2. Add rotation time and seek time:

$$0.00667 + 0.015 = 0.02167 \ s = 21.67 \ ms.$$

<sup>5</sup>75 revolutions per second is the same as 4500 revolutions per minute. 4500 RPM is the slowest hard drive speed for commonly sold disks.

### Mass Storage Tape drive

To access data from a tape drive, the tape is mounted in a device called a tape drive that can read, write, and rewind the tape.





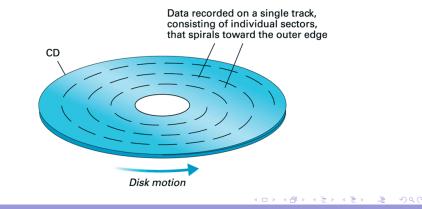
Pros: Low cost, High capacity.

Cons: Extremely slow, so often done overnight.

Magnetic tapes are still used as a popular off-line data storage for archival purposes.

## Optical Storage Compact Disk (CD)

CDs store information on a single track that spirals around the CD, from inside to out.



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# Questions over Chapters 1.1-1.3?