

Suez University Faculty of Petroleum and Mining Engineering BSE225, Spring Term 16-17



Binary Logic

Lecture 4 – Monday March 13, 2017

1

- Boolean Logic
- Boolean Algebra
- Binary Variables
- Binary Operators
 - Logical AND
 - Logical OR
 - Logical Negation
- Boolean Expressions
- Logic Gates
- Logic Circuits
- Summary

• <u>Boolean Logic</u>

- Boolean Algebra
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Boolean Logic

- Boolean logic is a branch of mathematics that deals with rules for manipulating two logical values **true** and **false**.
- It was named after George Boole.



George Boole (1815-1864) British mathematician and philosopher

- Boolean logic is simply a way of comparing individual bits.
- Why is Boolean logic so relevant to computers?



- Straightforward mapping to binary digits!
- Binary digit values can be thought of as: ON/OFF, High/Low, Yes/No, 1/O

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Boolean Algebra

• An algebra in which elements have one of two values and the algebraic operations defined on the set are logical OR, a type of addition, and logical AND, a type of multiplication.



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Binary Variables

- Binary variables take on one of two values, true or false.
- Variable identifiers: A, B, C, X, Y,



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Binary Operators

- Logical AND
- Logical OR
- Logical Negation (NOT).

- AND is denoted by a dot (·)
- Consider two logic variables A and B and the result is C.
- C is true if and only if A is true AND B is true



In order for current to flow, both switches must be closed

$$C = A.B$$

Truth '	Table
---------	-------

Inputs		Output
A	В	C=A.B
0	0	0
0	1	0
1	0	0
1	1	1



If both the Person Sensor **AND** the Alarm Switch are on then the Burglar Alarm is activated



• (A AND B) yields true only if both A and B are true.

Example: Adult blood pressure is considered normal at 120/80 where the first number is the systolic pressure and the second is the diastolic pressure.

- A = True if Systolic Pressure = 120
- B = True if Diastolic Pressure = 80
- $C = True \implies$ Blood pressure is normal

C = A.B

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Diastolic Pressure

• Example-2: Google Search



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- OR is denoted by a plus (+)
- Consider two logic variables A and B and the result is C.
- C is true if A is true OR B is true



Inputs		Output	
А	В	C = A + B	
0	0	0	
0	1	1	
1	0	1	
1	1	1	

ON/OFF

Front Doorbell Switch



ON/OFF





If either the Front Doorbell Switch **OR** the Back Doorbell Switch is pressed then the Doorbell rings



• (A OR B) yields true only if either A or B, or both are true.

Example: Adult blood pressure is considered normal at 120/80 where the first number is the systolic pressure and the second is the diastolic pressure.

- A = True if Systolic Pressure \neq 120
- B = True if Diastolic Pressure $\neq 80$
- $C = True \implies Blood pressure is abnormal$

C = A + B

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Diastolic Pressure

• Example-2: Google Search



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Binary Operators: Logical Negation

- NOT is denoted by a bar (⁻) over, a single quote mark
 (') after, or ~ before the variable.
- Consider a logic variable A and the result is C.
- C is true if A is false and vice versa.

•
$$C = A$$
 or $C = A'$ or $C = \sim A$





Binary Operators: Logical Negation

Temperature detector (Above 20°C) ON/OFF

If the temperature is above 20°C then the Central Heating is switched off.

If the temperature is below 20°C then the Central Heating is switched on



Binary Operators: Logical Negation

- Inverts its operand.
- Example: Adult blood pressure is considered normal at 120/80 where the first number is the systolic pressure and the second is the diastolic pressure.
 - A = True if Systolic Pressure = 120
 - $\overline{A} = False \implies Systolic Pressure \neq 120$
 - B = True if Diastolic Pressure = 80
 - $B = False \implies Diastolic Pressure \neq 80$





Systolic Pressure



Diastolic Pressure

Logic Gates: NOT Gate • Street Light ON/OFF Switch Street Light Light sensor (LDR) ON/OFF Bright=1, Dark=0 Switch **Street light** LDR Dark On On **Bright** On On Off Dark On **Bright** Off Off

Logic Gates

• Fire alarm security system



Exercise: The system shown is not functioning well. Suggest a modification in order to make the system works.

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Boolean Expressions

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Boolean Expressions

• Basic operations:

C = A.B is read "C is equal to A and B."

z = x + y is read "z is equal to x OR y."

 $D = \overline{A}$ is read "D is equal to NOT A."

• Using the basic operations, we can form more complex expressions:

$$Z = (A.B + C) + X.Y$$

- If A=True, B=False, C=True, X=True, Y=False.
- Z=(True.False+True)+False.False

=(False+True)+False=True+False=True

Boolean Expressions

• Example

Assuming that x=-10, y=50, and z=60 determine the value of the following Boolean expression:

(0<x<50)AND(50<y<100)OR([y-x]=z)

 $(0 < x < 50) \Rightarrow (0 < [-10] < 50) \Rightarrow FALSE$

 $(50 < y < 100) \Rightarrow (50 < 50 < 100) \Rightarrow FALSE$

```
([50-(-10)]=60) \Rightarrow (60=60) \Rightarrow TRUE
```

FALSE AND FALSE \Rightarrow FALSE

```
FALSE OR TRUE \Rightarrow TRUE
```

Boolean Expressions: Operator Precedence

- NOT has the highest precedence, followed by AND, and then OR.
- All higher-precedence operators are evaluated before any lower-precedence operators.
- Operators at the same precedence are evaluated left-toright.



Boolean Expressions: Operator Precedence

• Parentheses can be used to override operator precedence.



Boolean Expressions: Truth Table

• A truth table represents all possible values of an expression given the possible values of its inputs.

• How do we build a truth table?

- Step 1: Create columns for all variables
- Step 2: Determine the number of rows needed (how many rows should appear?) \Rightarrow For n inputs, # of rows is 2^n .
- Step 3: Define all possible values for the inputs starting from all 0's to all 1's, e.g. for 3 input variables from 000 to 111
- Step 4: Find the value of the expression for each input value and fill in the table.

Boolean Expressions: Truth Table

- Example: Boolean expression F = X + Y.Z
- Inputs: X, Y, Z
- Outputs: F
- # of inputs=n=3
- # of columns=#of inputs + #of outputs=4
- # of rows=2ⁿ=2³=8

Inputs			Output
Х	Y	Ζ	F
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

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Logic Gates

- A logic gates is an electronic device that operates on a collection of binary inputs to produce a binary output.
- The three basic logic gates are: AND gate, OR gate, NOT gate.



Logic Gates: AND Gate

• AND (product) of two inputs.



AND gate

Inputs		Output
А	В	A.B
0	0	0
0	1	0
1	0	0
1	1	1

Logic Gates: OR Gate

• OR (sum) of two inputs.



OR gate

Inputs		Output	
А	В	A+B	
0	0	0	
0	1	1	
1	0	1	
1	1	1	

Logic Gates: NOT Gate

• NOT (complement) of one input.

NOT gate

Input	Output
А	Ā
0	1
1	0

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Logic Circuits

• Summary

Logic Circuits

Χ

Ζ

• A circuit is a collection of logic gates that implements one or more Boolean expressions.

F

Example-1: Boolean expression $\mathbf{F} = \mathbf{X} + \mathbf{Y}.\mathbf{Z}$

Inputs: X, Y, Z

Outputs: F

Logic Circuit



	Inputs	Output	
X	Y	Ζ	F
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

Y

Logic Circuits



Logic Circuit - Half Adder

Logic Circuits

Example-3: Determine the Boolean expression of the following circuit and construct the corresponding truth table considering that a and b are the input signals.



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• <u>Summary</u>

Summary

- Boolean Algebra is a mathematical tool used in the analysis and design of digital circuits.
- OR, AND, NOT: basic Boolean operations.
- OR: HIGH output when any input is HIGH.
- AND: HIGH output only when all inputs are HIGH.
- NOT: output is the opposite logic level as the input.
- The order of evaluation in Boolean Expressions is: Parentheses, NOT, AND, OR.
- A logic gates is an electronic device that operates on a collection of binary inputs to produce a binary output.