EEE251

Logic Design and Circuits

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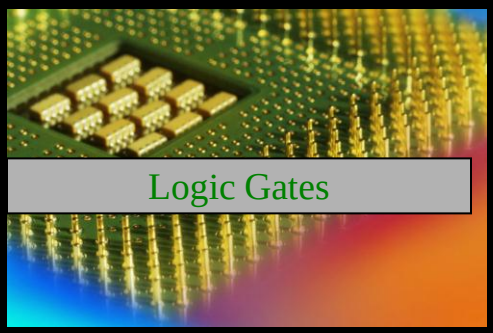


October 16, 2012

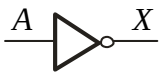
Introduction

- The simplest and basic element of logic circuits are logic gates.
- An electronic element, which uses value (valtage) of logic variables as inputs and operates these inputs according to logic equivalent, is named as logic gate.
- Basically there are 5 different logic gates. They are minimum integral parts of all kind electronic equipments.
- As logic gates build up Flip-Flop, registers, counters, etc., resistance, diode, transistor, FET, MOSFET, etc. build up logic gates.

Introduction

- AND, OR, NOT, NAND and NOR are commonly used and these are named as **'basic logic gates'**.
- **'Logic Circuits'** is built up using logic gates.
- Logic circuits are also named as hardware.
- Hardware term is generally used to represent electronic, magnetic and machanical circuits or units.

The Inverter (Not Gate)

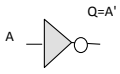


The inverter performs the Boolean **NOT** operation. When the input is LOW, the output is HIGH; when the input is HIGH, the output is LOW.

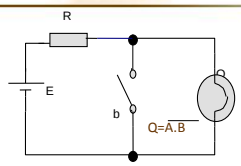
Input	Output
A	*X*
LOW (0)	HIGH (1)
HIGH (1)	LOW(0)

The **NOT** operation (complement) is shown with an overbar. Thus, the Boolean expression for an inverter is $X = \overline{A}$.

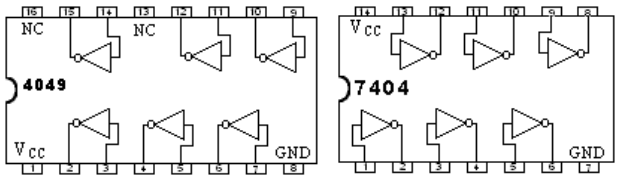
The Inverter (Not Gate)



A	Q
0	1
1	0



NOT gate symbol, truth table, electrical equivalent

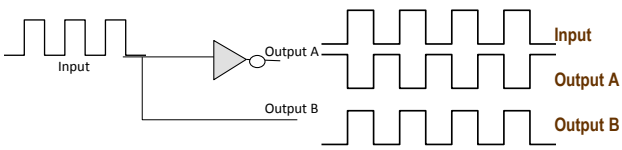


IC structure of NOT gates

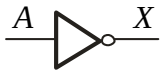
The Inverter (Not Gate)

Example : Design a logic circuit produce two different signal using NOT gate.

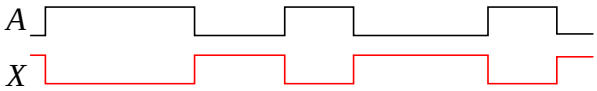
- Square signal is applied to NOT gate as shown in the following.



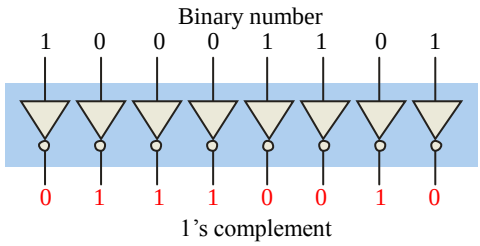
The Inverter (Not Gate)



Example waveforms:

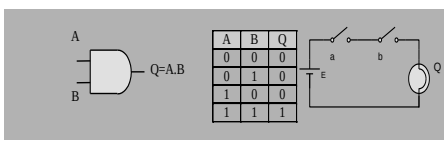


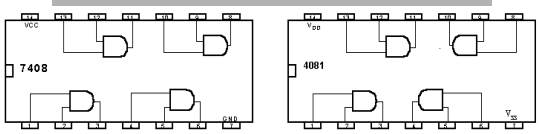
A group of inverters can be used to form the 1's complement of a binary number:



AND Operation and AND Gate

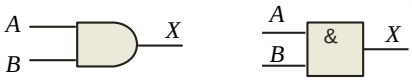
- Multiplication operation of AND gate is shown with '.' or '*'. Operation of AND gate is defined as Q=A*B.
- In AND operation, if one of inputs is '0', output becomes '0'. When all inputs are '1', then output becomes '1'.
- This is valid for AND gates with 3 inputs. The output of AND gate with 3 inputs is represented as Q = A*B*C, for AND gate with 4 inputs the output is shown as Q = A*B*C*D.





The positions of AND gates in IC

AND Operation and AND Gate

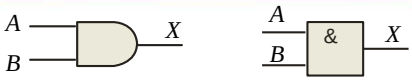


The **AND gate** produces a HIGH output when all inputs are HIGH; otherwise, the output is LOW. For a 2-input gate, the truth table is

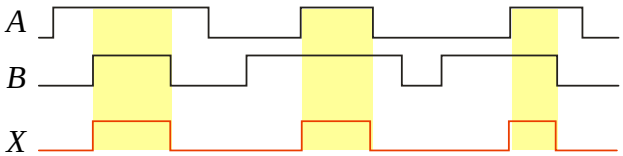
Inputs		Output
A	*B*	*X*
0	0	0
0	1	0
1	0	0
1	1	1

The **AND** operation is usually shown with a dot between the variables but it may be implied (no dot). Thus, the AND operation is written as $X = A \cdot B$ or $X = AB$.

AND Operation and AND Gate



Example waveforms:



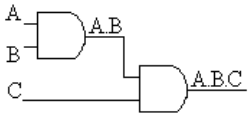
The AND operation is used in computer programming as a selective mask. If you want to retain certain bits of a binary number but reset the other bits to 0, you could set a mask with 1's in the position of the retained bits.

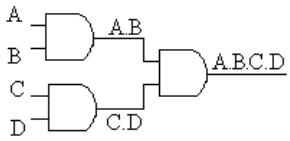
Example

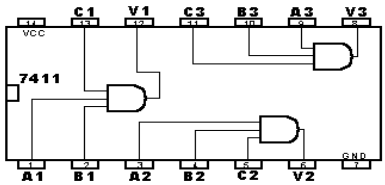
If the binary number 10100011 is ANDed with the mask 00001111, what is the result? 00000011

AND Operation and AND Gate

Example: Create AND gate with 3 inputs and 4 inputs.



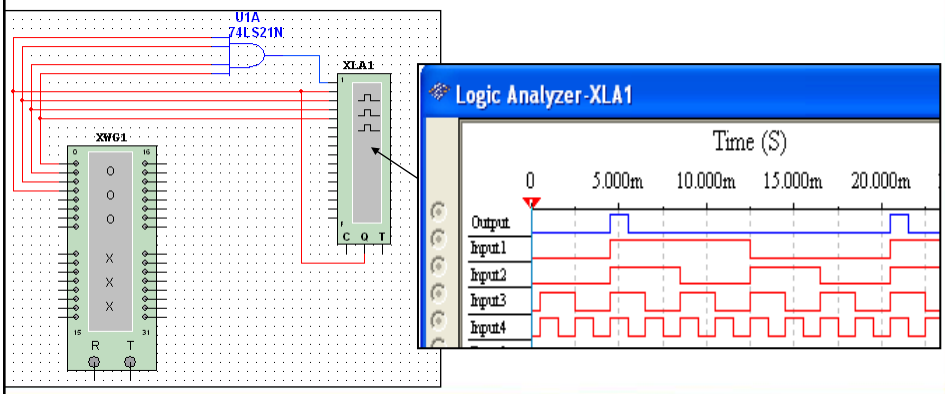




AND Operation and AND Gate

Example A Multisim circuit is shown. XWG1 is a word generator set in the count down mode. XLA1 is a logic analyzer with the output of the AND gate connected to first (upper) line of the analyzer. What signal do you expect to on this line?

Solution The output (line 1) will be HIGH only when all of the inputs are HIGH.



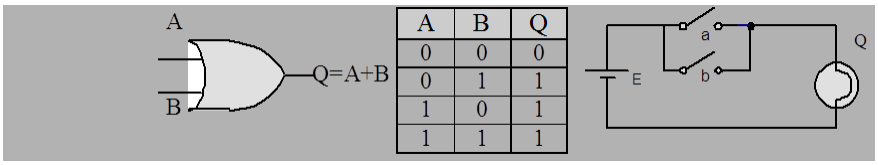
OR Operation and OR Gate

The **OR gate** produces a HIGH output if any input is HIGH; if all inputs are LOW, the output is LOW. For a 2-input gate, the truth table is

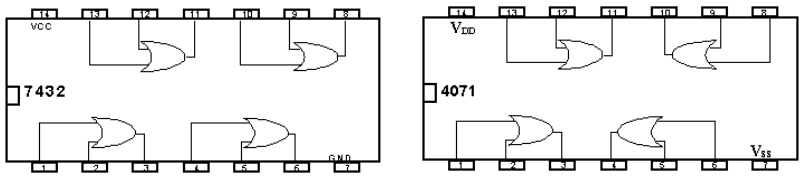
Inputs		Output
A	*B*	*X*
0	0	0
0	1	1
1	0	1
1	1	1

The **OR** operation is shown with a plus sign (+) between the variables. Thus, the OR operation is written as $X = A + B$.

OR Operation and OR Gate



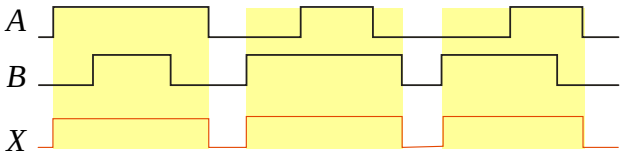
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1



Internal structure of OR IC

OR Operation and OR Gate

Example waveforms:



The OR operation can be used in computer programming to set certain bits of a binary number to 1.

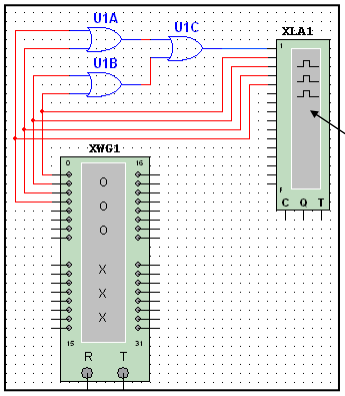
Example ASCII letters have a 1 in the bit 5 position for lower case letters and a 0 in this position for capitals. (Bit positions are numbered from right to left starting with 0.) What will be the result if you OR an ASCII letter with the 8-bit mask 00100000?

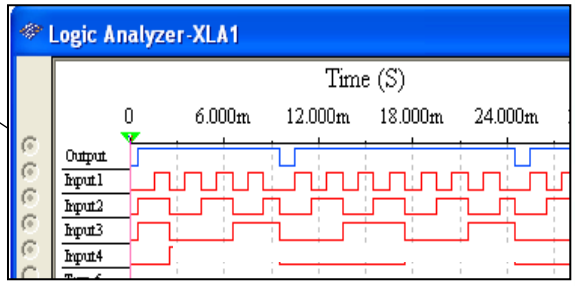
Solution The resulting letter will be lower case.

OR Operation and OR Gate

Example A Multisim circuit is shown. XWG1 is a word generator set to count down. XLA1 is a logic analyzer with the output connected to first (top) line of the analyzer. The three 2-input OR gates act as a single 4-input gate. What signal do you expect on the output line?

Solution The output (line 1) will be HIGH if any input is HIGH; otherwise it will be LOW.

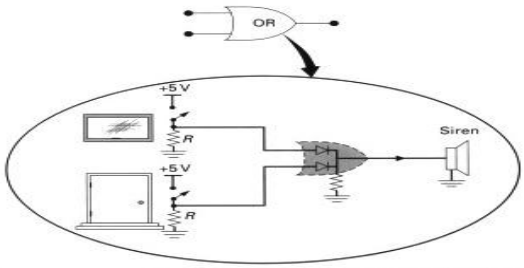




OR Operation and OR Gate

Example : Consider a room with a door and a window. Desing an alarm system with OR gate that runs when the door or the window are close at one time.

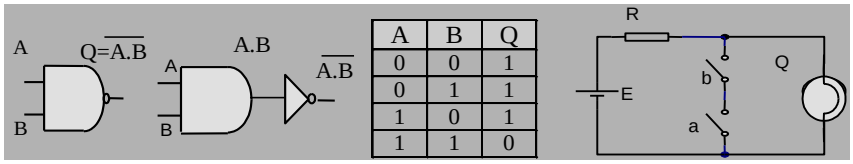
- The switches of door and window are connected to inputs of OR gate and the output is connected to a siren. When one of switches is closed, the output becomes ‘1’, so siren runs.



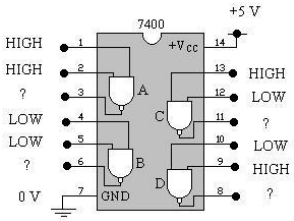
NAND Gate

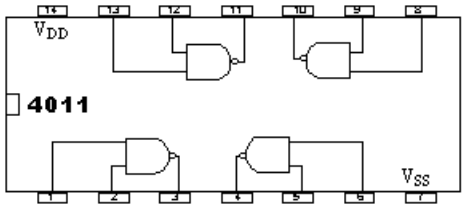
- NAND gate is cerated with AND gate and NOT gate
- IN NAND gate, if one of inputs is ‘0’ output become ‘1’. The output becomes ‘0’ only when both inputs are ‘1’.
- Output function is defined as Q=(A.B)’
- According to this function, truth table is written as reverse of AND gate.

NAND Gate



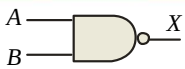
A	B	Q
0	0	1
0	1	1
1	0	1
1	1	0

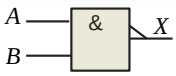




NAND IC structure

NAND Gate





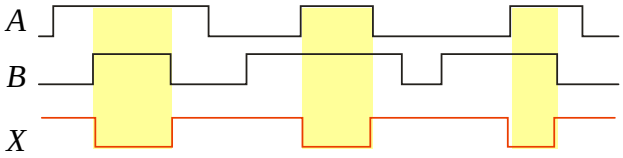
The **NAND gate** produces a LOW output when all inputs are HIGH; otherwise, the output is HIGH. For a 2-input gate, the truth table is

Inputs		Output
A	*B*	*X*
0	0	1
0	1	1
1	0	1
1	1	0

The **NAND** operation is shown with a dot between the variables and an overbar covering them. Thus, the NAND operation is written as $X = \overline{A \cdot B}$ (Alternatively, $X = \overline{AB}$.)

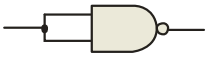
NAND Gate

Example waveforms:



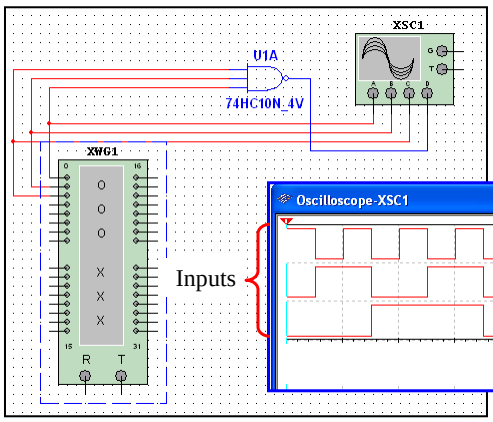
The NAND gate is particularly useful because it is a "universal" gate – all other basic gates can be constructed from NAND gates.

Question How would you connect a 2-input NAND gate to form a basic inverter?



NAND Gate

Example A Multisim circuit is shown. XWG1 is a word generator set in the count up mode. A four-channel oscilloscope monitors the inputs and output. What output signal do you expect to see?

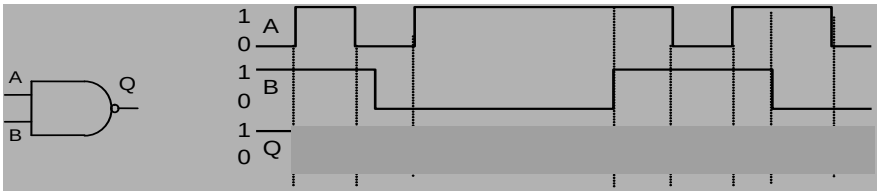


Solution

The output (channel D) will be LOW only when all of the inputs are HIGH.

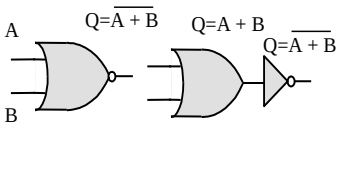
NAND Gate

Example : Apply A and B inputs to NAND gate.

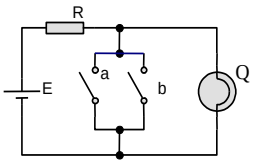


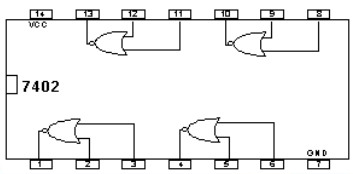
NOR Gate

- NOR gate is created with OR and NOT gates, operates the reverse of OR gate.
- Its symbol and truth table are shown in the following. And its function can be defined as Q=(A+B)'.



A	B	Q
0	0	1
0	1	0
1	0	0
1	1	0





NOR Gate

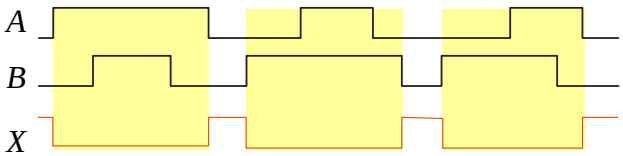
The **NOR gate** produces a LOW output if any input is HIGH; if all inputs are HIGH, the output is LOW. For a 2-input gate, the truth table is

Inputs		Output
A	*B*	*X*
0	0	1
0	1	0
1	0	0
1	1	0

The **NOR** operation is shown with a plus sign (+) between the variables and an overbar covering them. Thus, the NOR operation is written as $X = \overline{A + B}$.

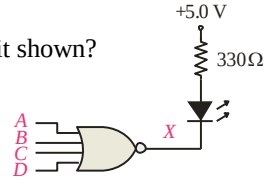
NOR Gate

Example waveforms:



The NOR operation will produce a LOW if any input is HIGH.

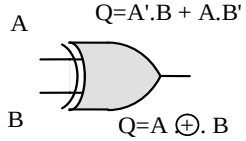
Example When is the LED is ON for the circuit shown?



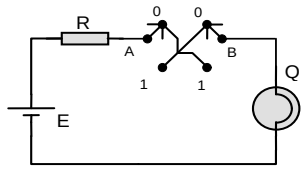
Solution The LED will be on when any of the four inputs are HIGH.

XOR Gate

- There are two inputs and one output in'XOR'.
- Its symbol, logic function, truth table and electrical equivalent are shwon in the following.

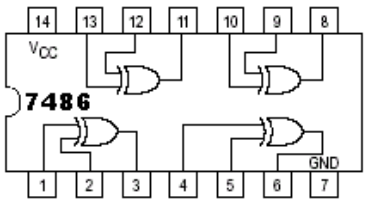


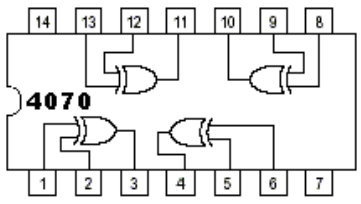
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	0



XOR Gate

- Its function can be written as Q=A⊕B or Q=AB'+A'B
- XOR gate can be also defined as '**differences gate**'.





Structure of XOR IC

XOR Gate

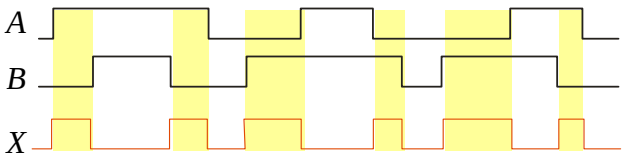
The **XOR gate** produces a HIGH output only when both inputs are at opposite logic levels. The truth table is

Inputs		Output
A	*B*	*X*
0	0	0
0	1	1
1	0	1
1	1	0

The **XOR** operation is written as $X = \bar{A}B + A\bar{B}$. Alternatively, it can be written with a circled plus sign between the variables as $X = A \oplus B$.

XOR Gate

Example waveforms:



Notice that the XOR gate will produce a HIGH only when exactly one input is HIGH.

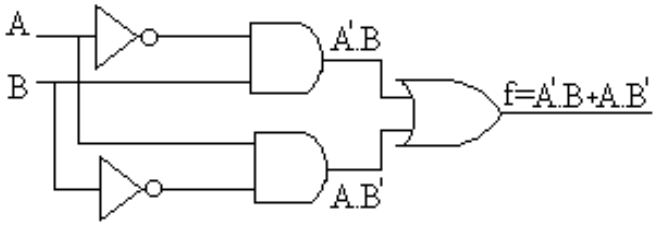
Question If the *A* and *B* waveforms are both inverted for the above waveforms, how is the output affected?

There is no change in the output.

XOR Gate

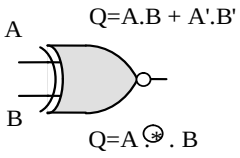
Example : Design an XOR gate using AND, OR and NOT gates

- Considering the function of XOR gate as $f=A.B^{'} + A^{'}.B$ Logic circuit is drawn in the following.

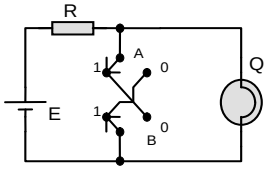


XNOR Gate

- In XNOR gate with 2 inputs and one output, when inputs are same output becomes '1', when inputs are different output becomes '0'.
- XNOR gate is also defined as '**eqivalent gate**'.

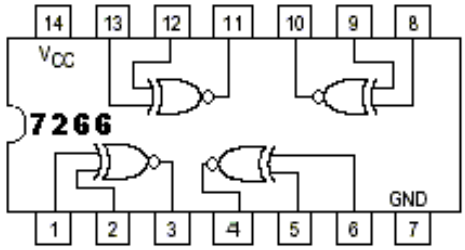


A	B	Q
0	0	1
0	1	0
1	0	0
1	1	1



XNOR Gate

- The output function of EXNOR gate is written as;
- Q= A⊗B or Q=AB+A'B'



The structure of EXNOR gate IC

XNOR Gate

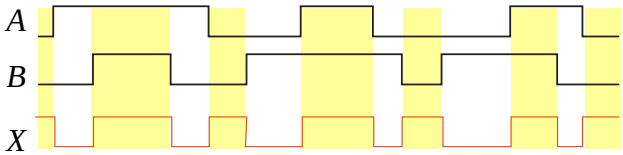
The **XNOR gate** produces a HIGH output only when both inputs are at the same logic level. The truth table is

Inputs		Output
A	*B*	*X*
0	0	1
0	1	0
1	0	0
1	1	1

The **XNOR** operation shown as $X = \overline{A}\,\overline{B} + AB$. Alternatively, the XNOR operation can be shown with a circled dot between the variables. Thus, it can be shown as $X = A \odot B$.

EXNOR Gate

Example waveforms:



Notice that the XNOR gate will produce a HIGH when both inputs are the same. This makes it useful for comparison functions.

Question If the *A* waveform is inverted but *B* remains the same, how is the output affected?

The output will be inverted.

Selected Key Terms

Inverter	A logic circuit that inverts or complements its inputs.
Truth table	A table showing the inputs and corresponding output(s) of a logic circuit.
Timing diagram	A diagram of waveforms showing the proper time relationship of all of the waveforms.
Boolean algebra	The mathematics of logic circuits.
AND gate	A logic gate that produces a HIGH output only when all of its inputs are HIGH.

Selected Key Terms

OR gate	A logic gate that produces a HIGH output when one or more inputs are HIGH.
NAND gate	A logic gate that produces a LOW output only when all of its inputs are HIGH.
NOR gate	A logic gate that produces a LOW output when one or more inputs are HIGH.
Exclusive-OR gate	A logic gate that produces a HIGH output only when its two inputs are at opposite levels.
Exclusive-NOR gate	A logic gate that produces a LOW output only when its two inputs are at opposite levels.

Quiz

1. The truth table for a 2-input AND gate is

a.

Inputs		Output
A	*B*	*X*
0	0	0
0	1	1
1	0	1
1	1	0

b.

Inputs		Output
A	*B*	*X*
0	0	1
0	1	0
1	0	0
1	1	0

(c.)

Inputs		Output
A	*B*	*X*
0	0	0
0	1	0
1	0	0
1	1	1

d.

Inputs		Output
A	*B*	*X*
0	0	0
0	1	1
1	0	1
1	1	1

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Quiz

2. The truth table for a 2-input NOR gate is

a.

Inputs		Output
A	*B*	*X*
0	0	0
0	1	1
1	0	1
1	1	0

b.

Inputs		Output
A	*B*	*X*
0	0	1
0	1	0
1	0	0
1	1	0

c.

Inputs		Output
A	*B*	*X*
0	0	0
0	1	0
1	0	0
1	1	1

d.

Inputs		Output
A	*B*	*X*
0	0	0
0	1	1
1	0	1
1	1	1

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Quiz

3. The truth table for a 2-input XOR gate is

a.

Inputs		Output
A	*B*	*X*
0	0	0
0	1	1
1	0	1
1	1	0

b.

Inputs		Output
A	*B*	*X*
0	0	1
0	1	0
1	0	0
1	1	0

c.

Inputs		Output
A	*B*	*X*
0	0	0
0	1	0
1	0	0
1	1	1

d.

Inputs		Output
A	*B*	*X*
0	0	0
0	1	1
1	0	1
1	1	1

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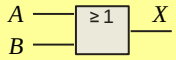
Quiz

4. The symbol 

is for a(n)

a. OR gate

b. AND gate

c. NOR gate

d. XOR gate

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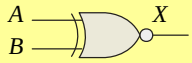
Quiz

5. The symbol 

is for a(n)

a. OR gate

b. AND gate

c. NOR gate

d. XOR gate

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Quiz

6. A logic gate that produces a HIGH output only when all of its inputs are HIGH is a(n)

a. OR gate

b. AND gate

c. NOR gate

d. NAND gate

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Quiz

7. The expression $X = A \oplus B$ means

a. *A* OR *B*

b. *A* AND *B*

c. *A* XOR *B*

d. *A* XNOR *B*

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Quiz

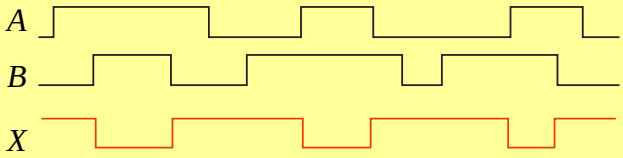
8. A 2-input gate produces the output shown. (*X* represents the output.) This is a(n)

a. OR gate

b. AND gate

c. NOR gate

d. NAND gate



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Quiz

9. A 2-input gate produces a HIGH output only when the inputs agree. This type of gate is a(n)

a. OR gate

b. AND gate

c. NOR gate

d. XNOR gate

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