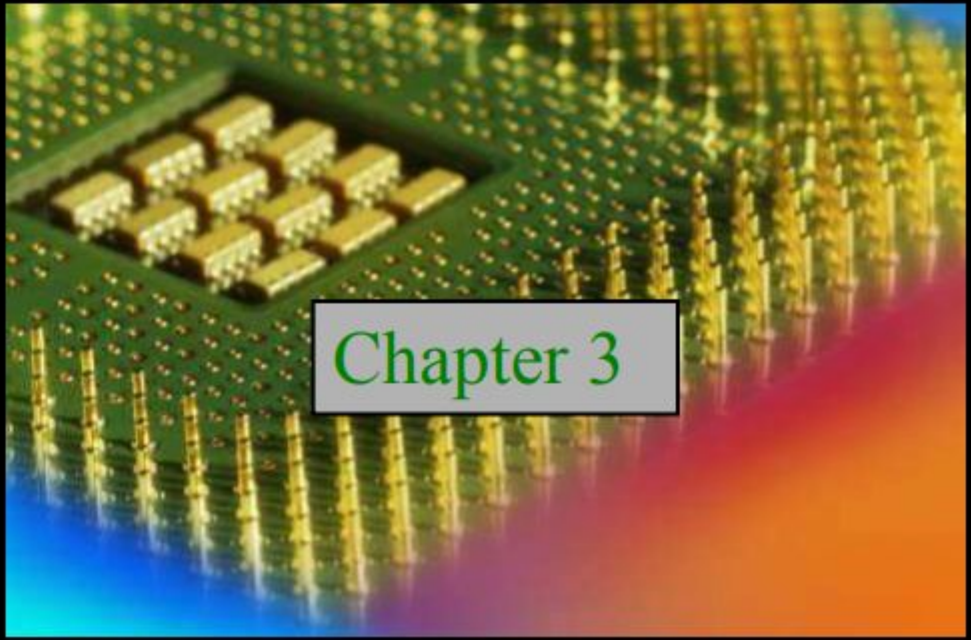
Digital Fundamentals

Tenth Edition

Floyd



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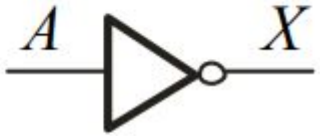
Summary

The Inverter



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 $X = \overline{A}$.

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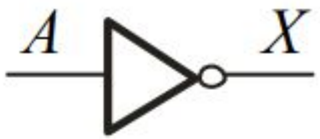
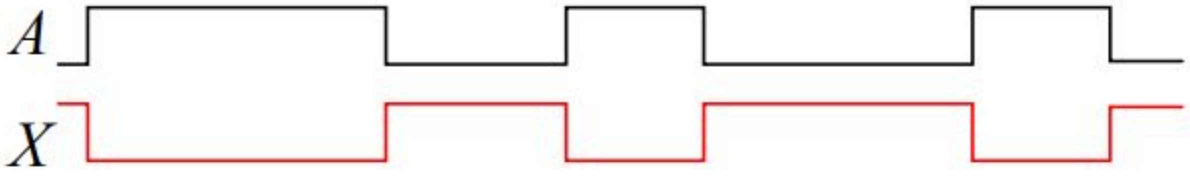
Summary

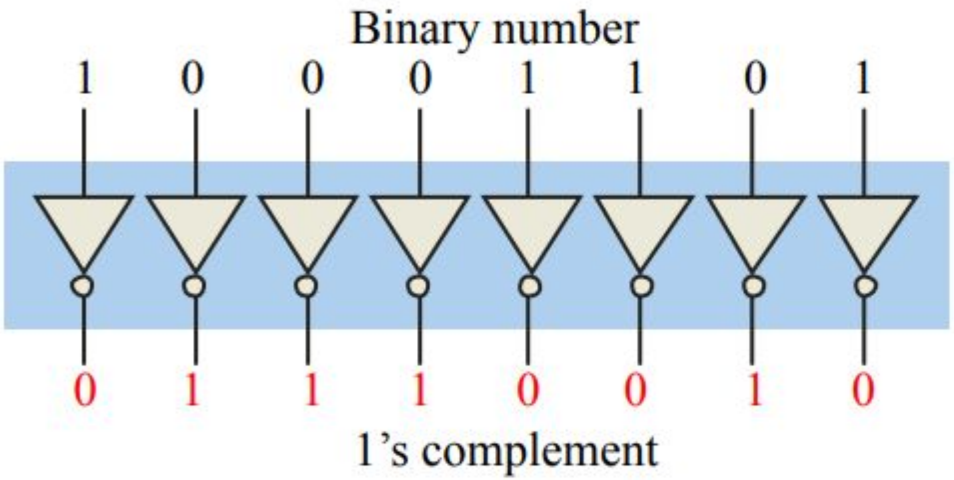
The Inverter



Example waveforms:



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



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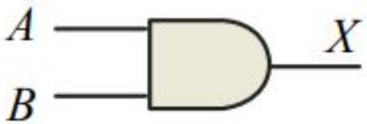
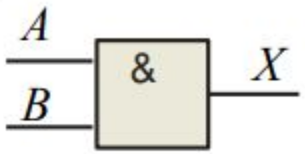
Summary

The 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 $X = AB$.

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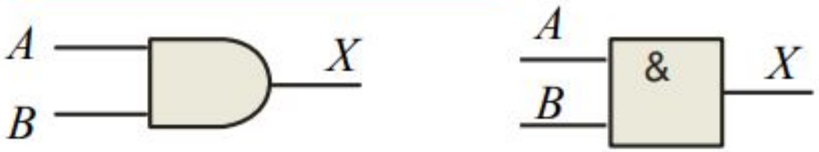
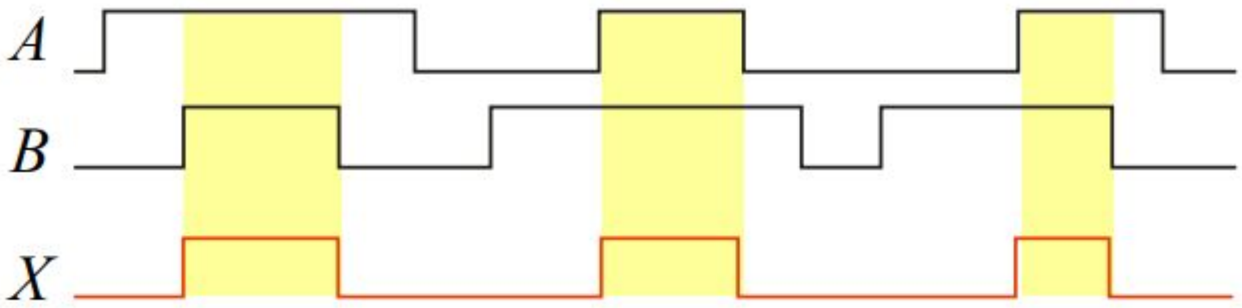
Summary

The 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

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EXAMPLE 3–5

For the 3-input AND gate in Figure 3–13, determine the output waveform in relation to the inputs.

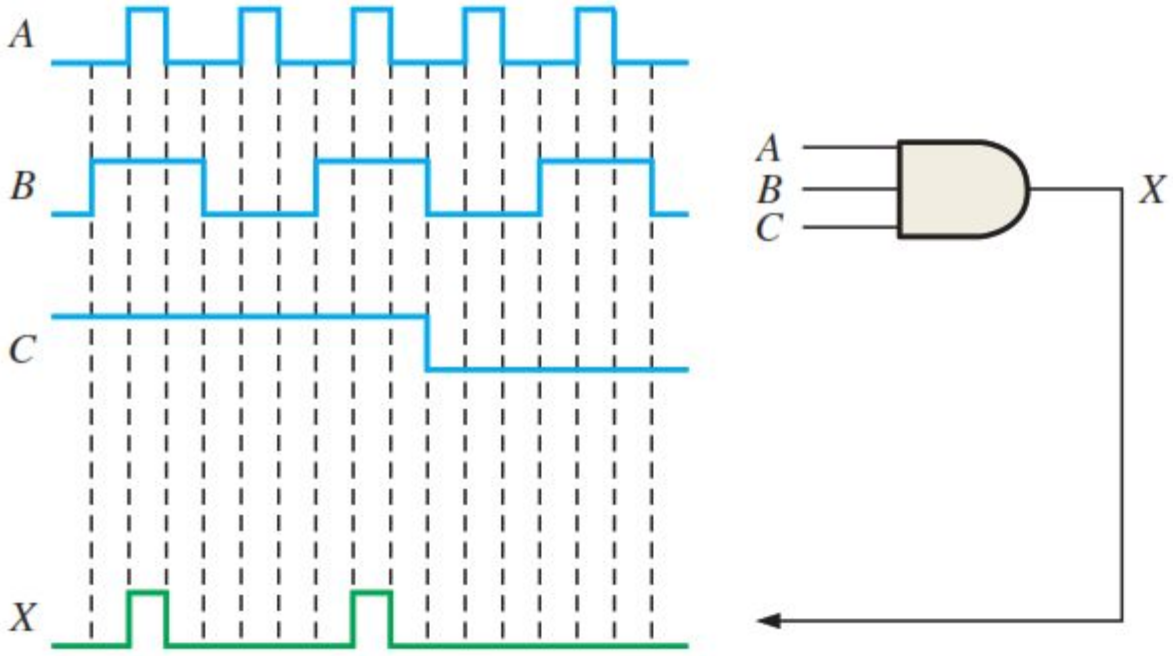


FIGURE 3–13

Solution

The output waveform X of the 3-input AND gate is HIGH only when all three input waveforms A, B, and C are HIGH.

Application

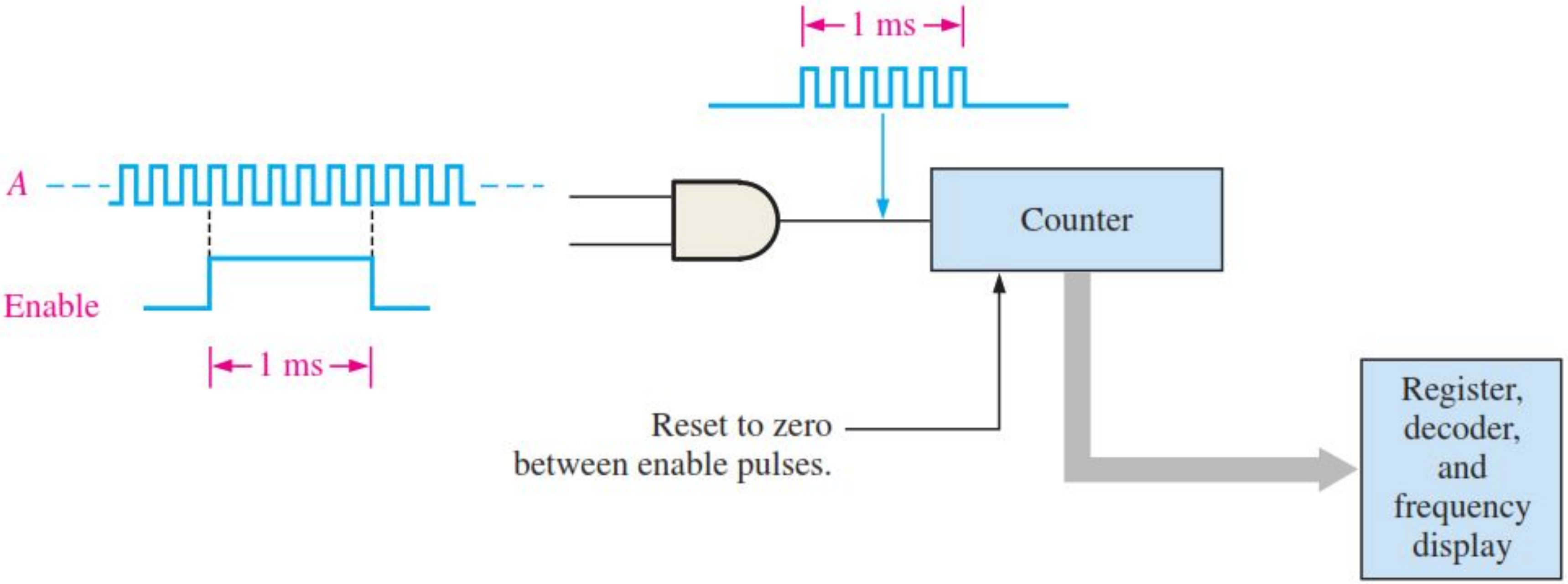
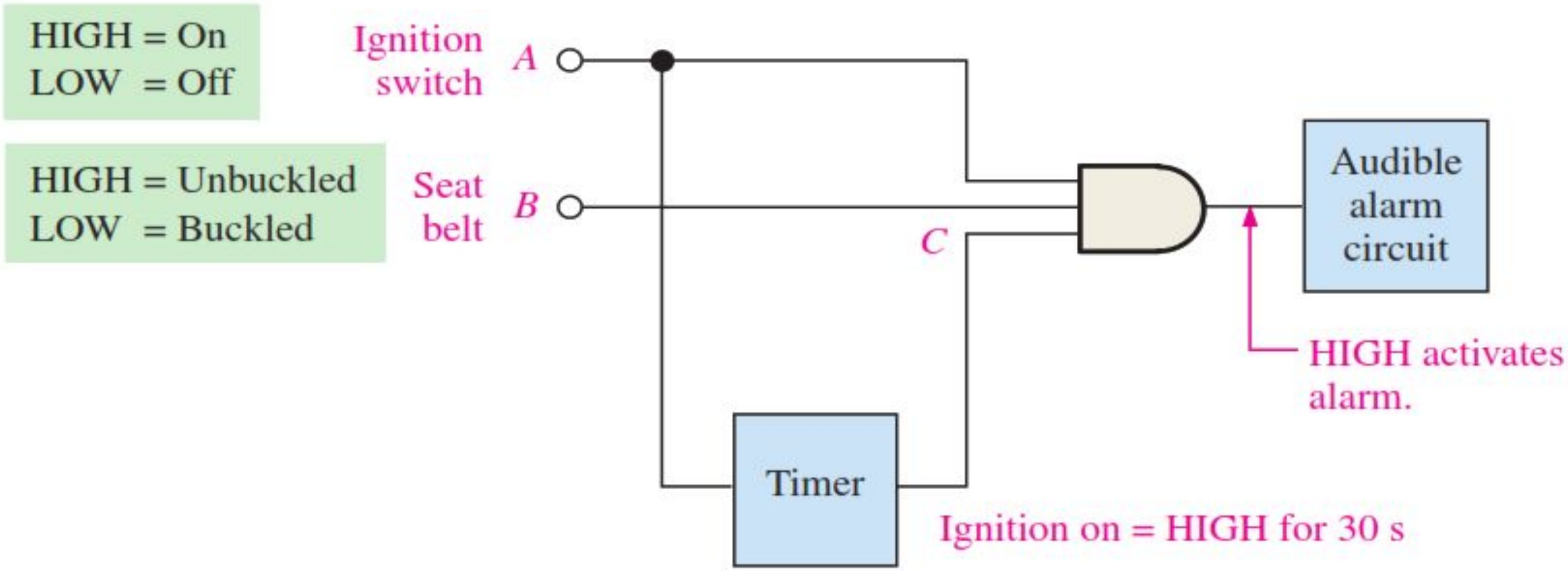


FIGURE 3–16 An AND gate performing an enable/inhibit function for a frequency counter.

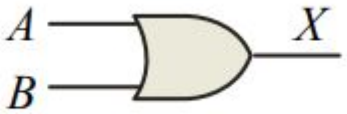
A Seat Belt Alarm System

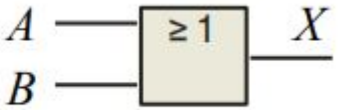
In Figure 3–17, an AND gate is used in a simple automobile seat belt alarm system to detect when the ignition switch is on *and* the seat belt is unbuckled. If the ignition switch is on, a HIGH is produced on input *A* of the AND gate. If the seat belt is not properly buckled, a HIGH is produced on input *B* of the AND gate. Also, when the ignition switch is turned on, a timer is started that produces a HIGH on input *C* for 30 s. If all three conditions exist—that is, if the ignition is on *and* the seat belt is unbuckled *and* the timer is running—the output of the AND gate is HIGH, and an audible alarm is energized to remind the driver.



Summary

The 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 $X = A + B$.

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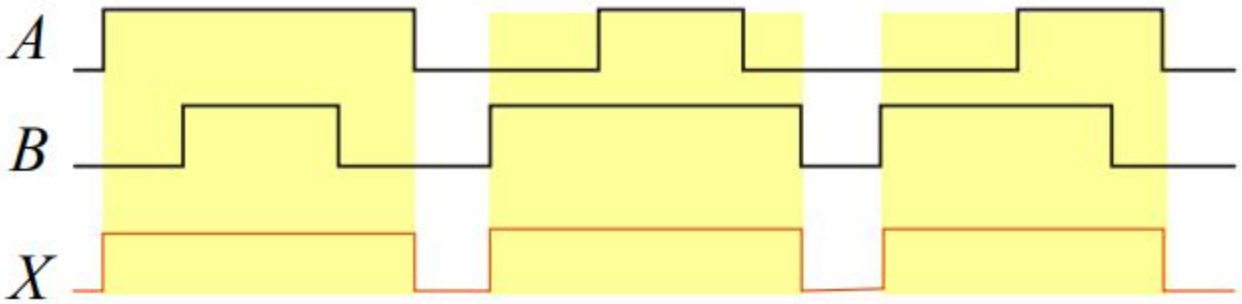
Summary

The 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.

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EXAMPLE 3–9

For the 3-input OR gate in Figure 3–23, determine the output waveform in proper time relation to the inputs.

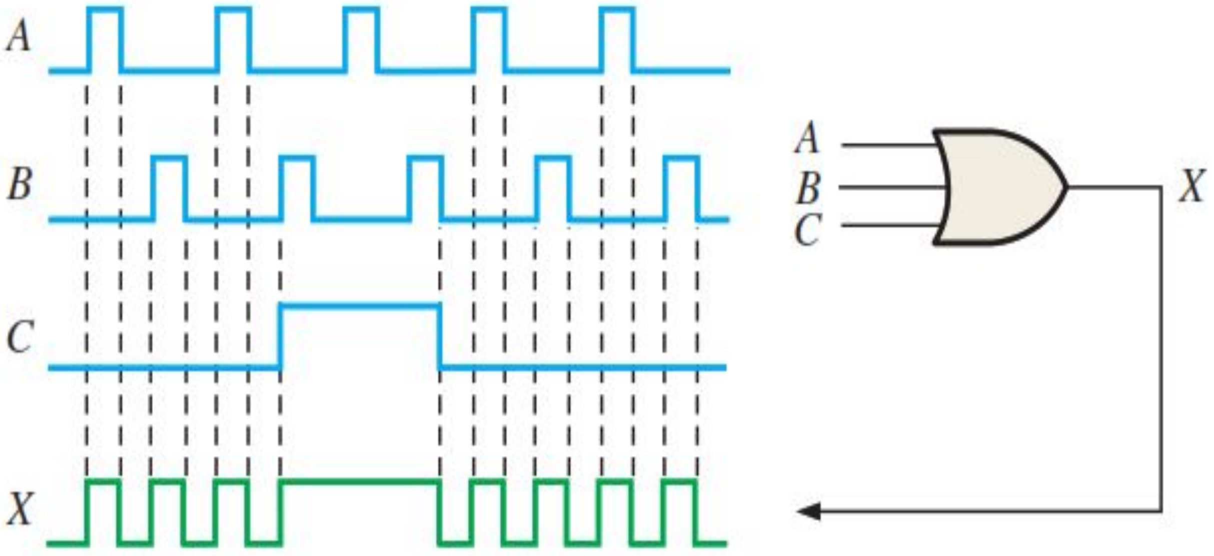
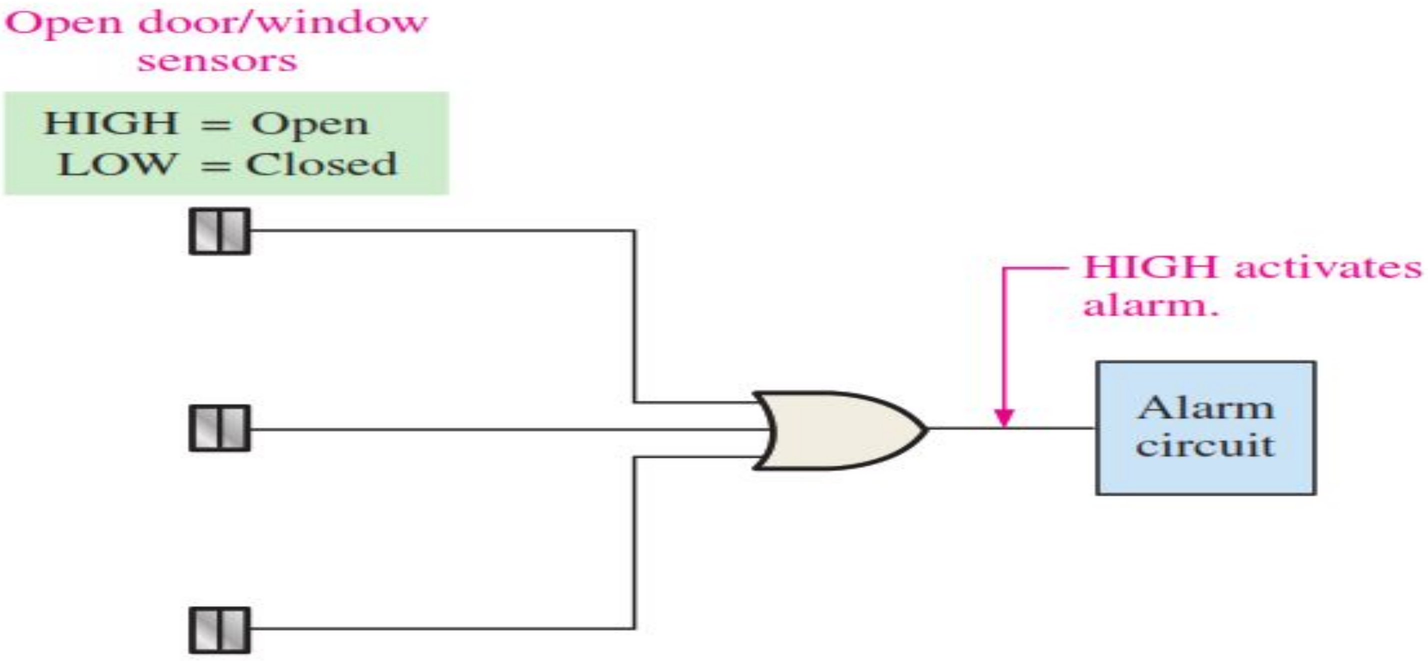


FIGURE 3–23

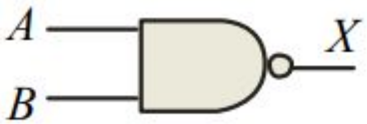
Application

A simplified portion of an intrusion detection and alarm system is shown in Figure 3–25. This system could be used for one room in a home—a room with two windows and a door. The sensors are magnetic switches that produce a HIGH output when open and a LOW output when closed. As long as the windows and the door are secured, the switches are closed and all three of the OR gate inputs are LOW. When one of the windows or the door is opened, a HIGH is produced on that input to the OR gate and the gate output goes HIGH. It then activates and latches an alarm circuit to warn of the intrusion.



Summary

The 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, $X = \overline{AB}$.)

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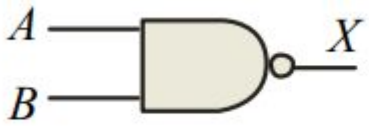
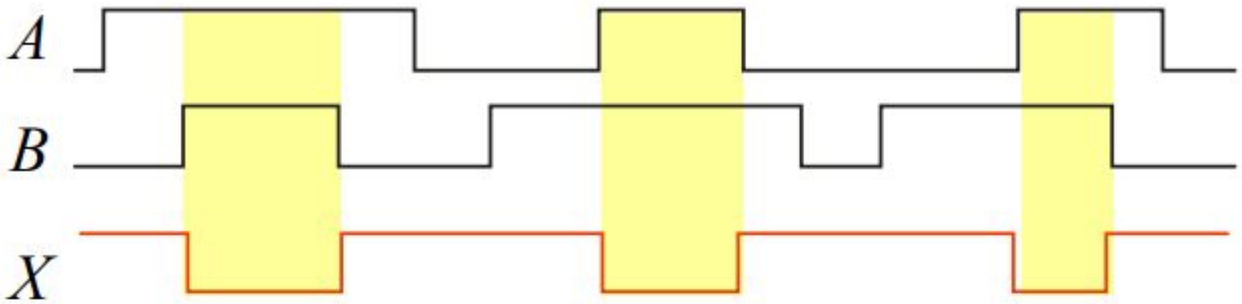
Summary

The NAND Gate

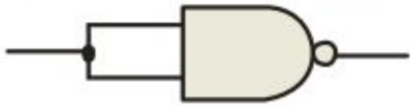


Example waveforms:



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?



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EXAMPLE 3–11

Show the output waveform for the 3-input NAND gate in Figure 3–29 with its proper time relationship to the inputs.

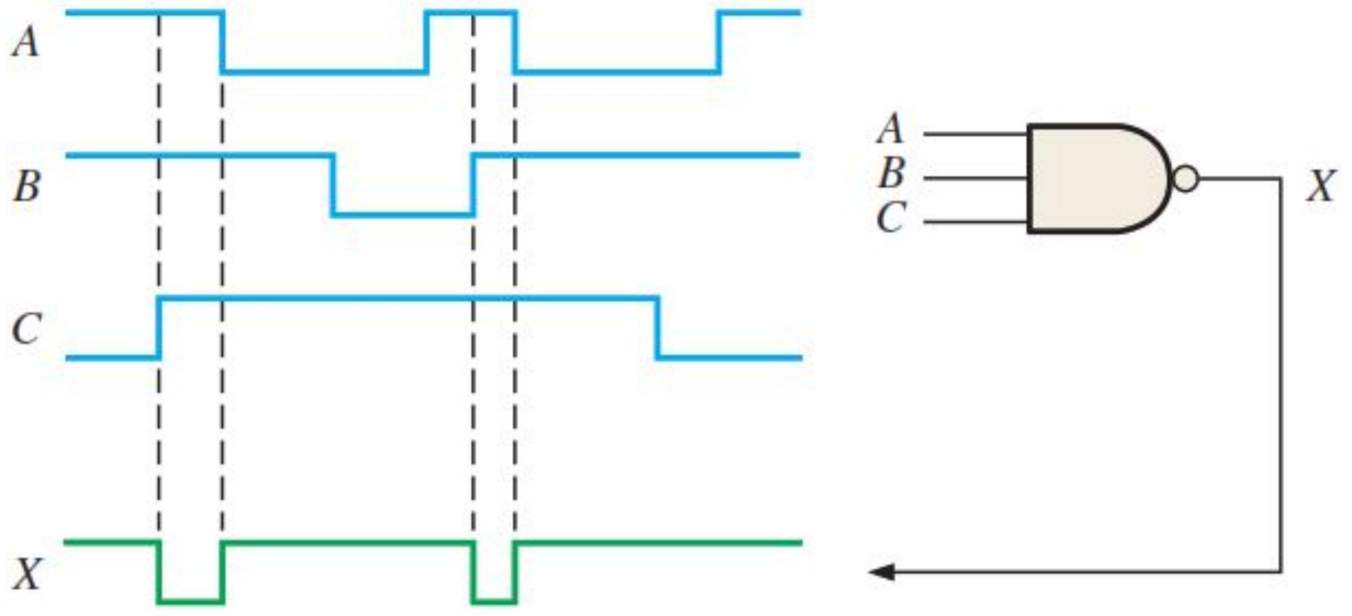
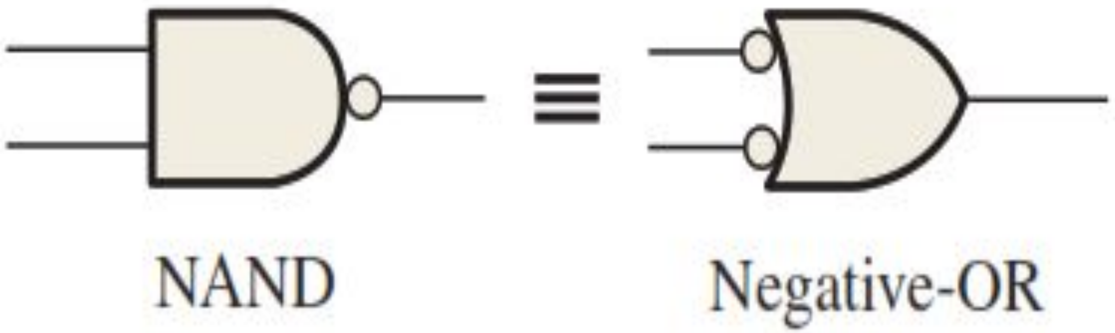


FIGURE 3–29

Negative-OR Equivalent Operation of a NAND Gate

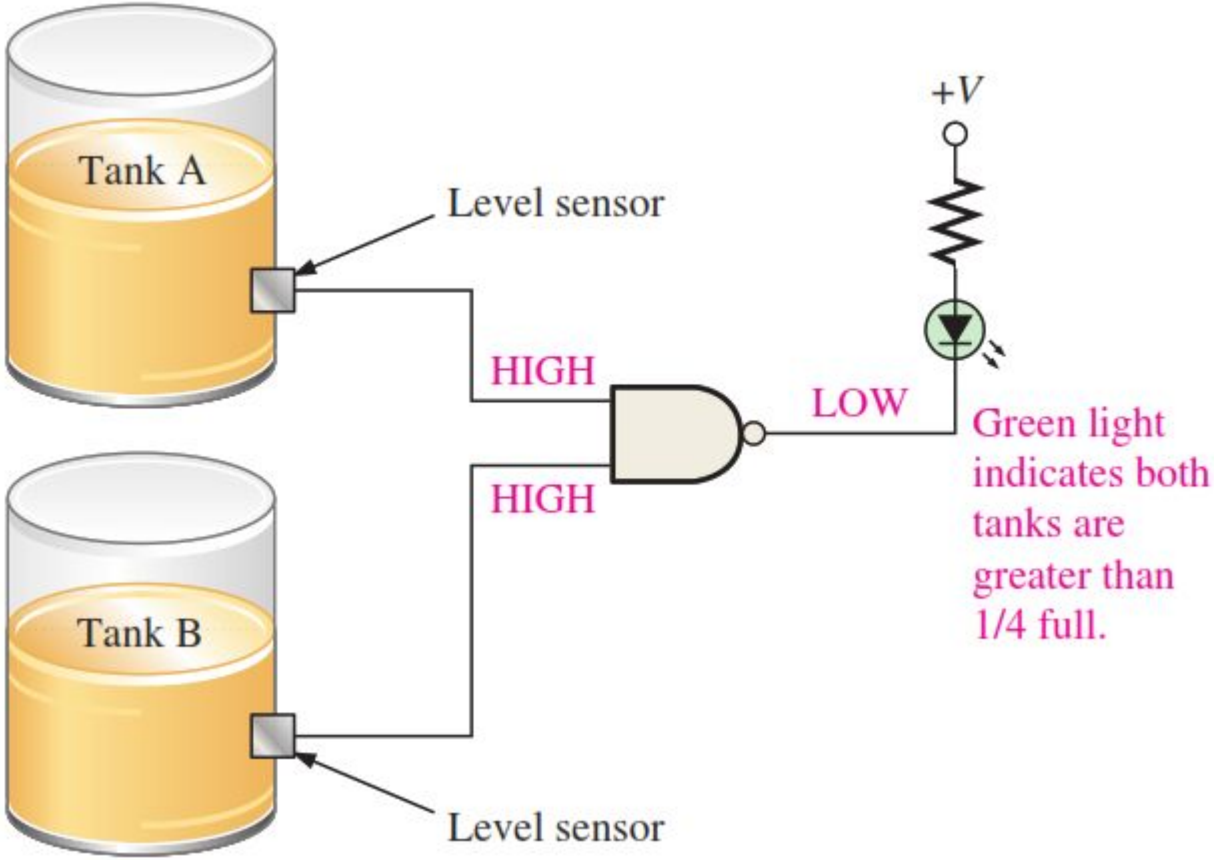
For a 2-input NAND gate performing a negative-OR operation, output *X* is HIGH when either input *A* or input *B* is LOW, or when both *A* and *B* are LOW.



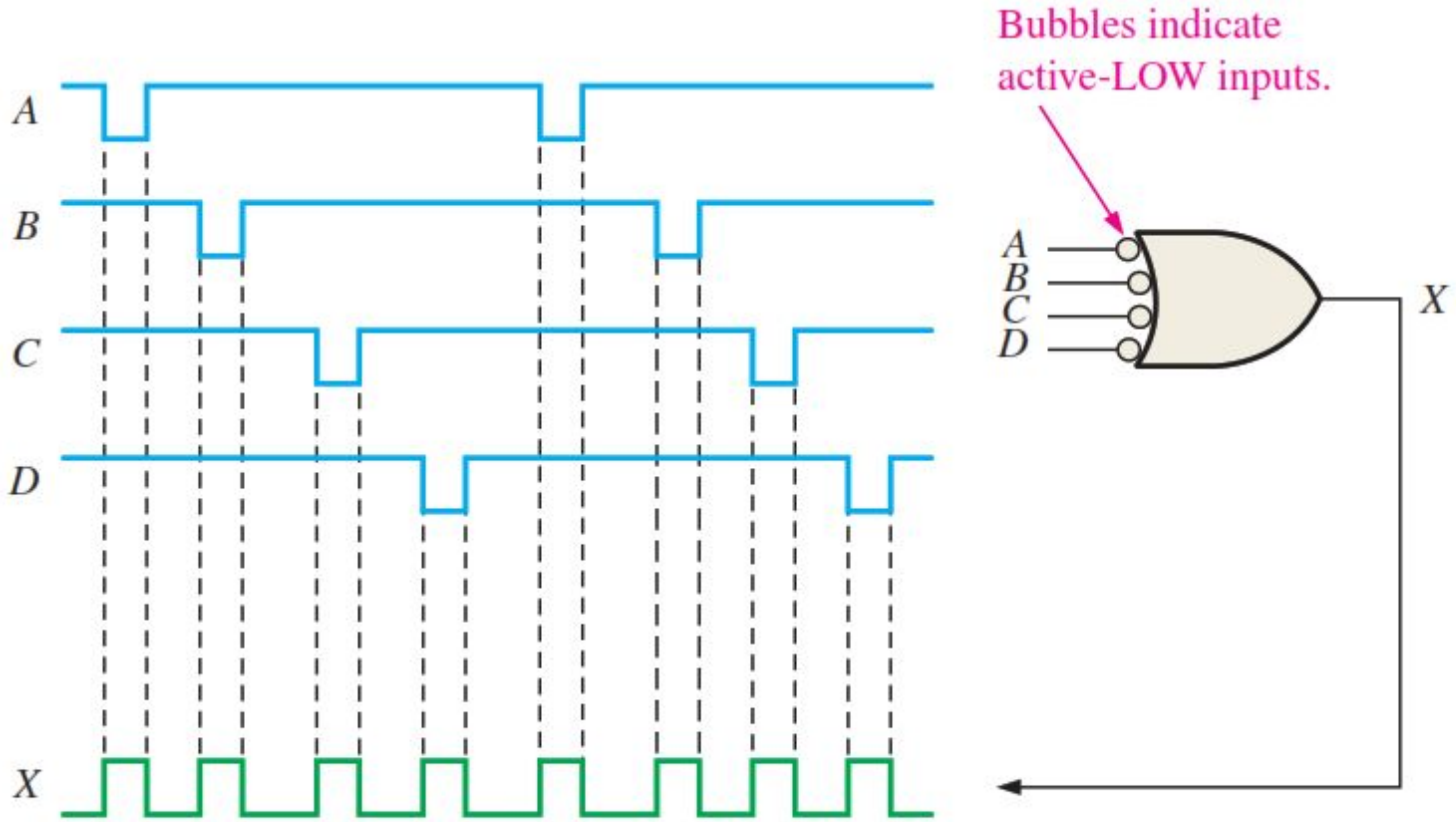
EXAMPLE 3–12

Two tanks store certain liquid chemicals that are required in a manufacturing process. Each tank has a sensor that detects when the chemical level drops to 25% of full. The sensors produce a HIGH level of 5 V when the tanks are more than one-quarter full. When the volume of chemical in a tank drops to one-quarter full, the sensor puts out a LOW level of 0 V.

It is required that a single green light-emitting diode (LED) on an indicator panel show when both tanks are more than one-quarter full. Show how a NAND gate can be used to implement this function.

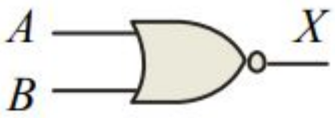

Tank A
Level sensor
HIGH
HIGH
Tank B
Level sensor
+V
LOW
Green light indicates both tanks are greater than 1/4 full.

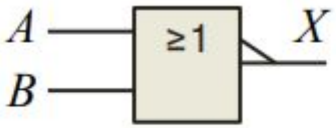
For the 4-input NAND gate in Figure 3–33, operating as a negative-OR gate, determine the output with respect to the inputs.



Summary

The 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 $X = \overline{A + B}$.

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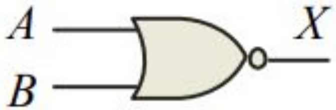
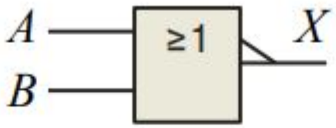
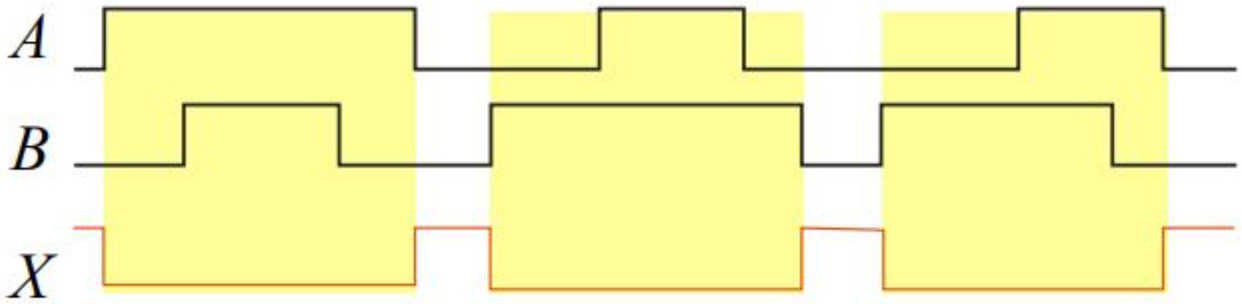
Summary

The NOR Gate



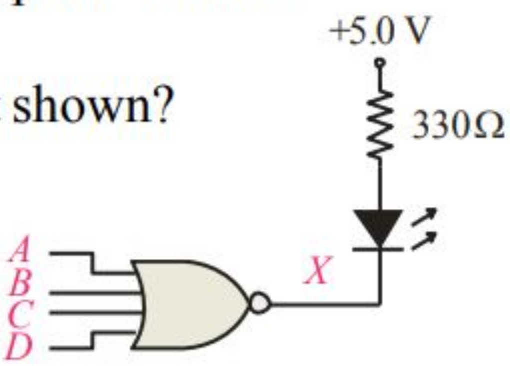


Example waveforms:



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.

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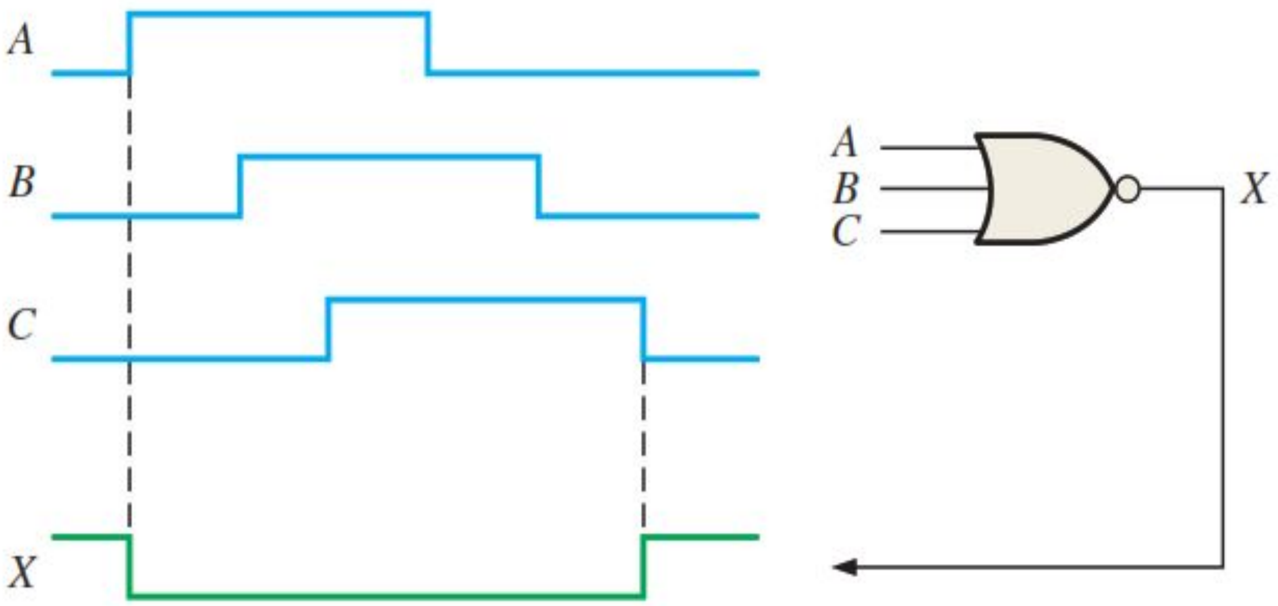
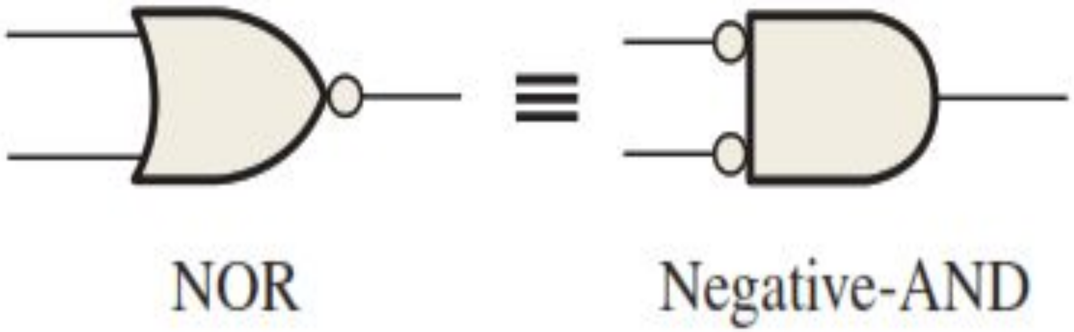
EXAMPLE 3–16

Show the output waveform for the 3-input NOR gate in Figure 3–37 with the proper time relation to the inputs.



Negative-AND Equivalent Operation of the NOR Gate

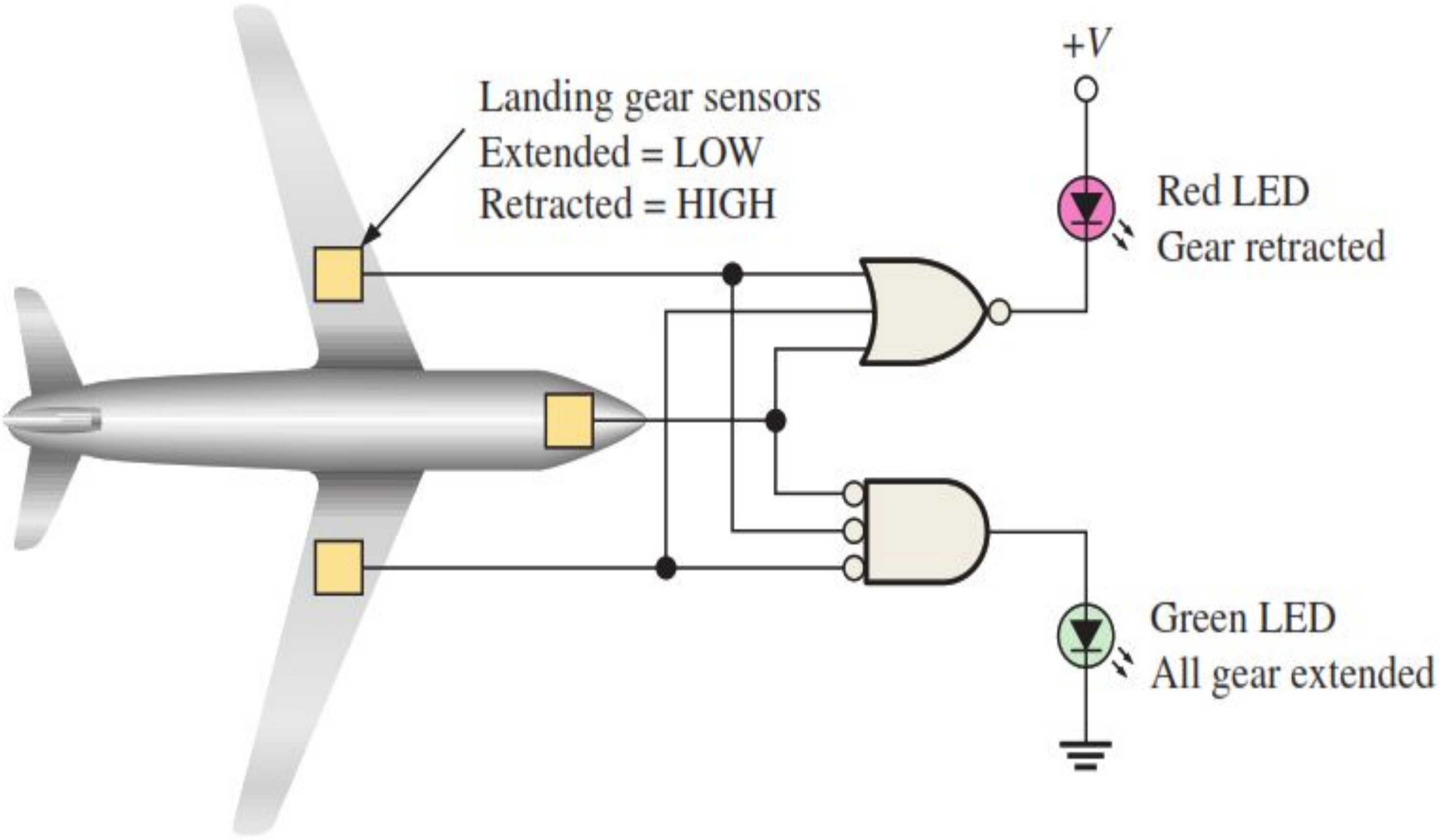
For a 2-input NOR gate performing a negative-AND operation, output *X* is HIGH only when both inputs *A* and *B* are LOW.



Related Problem

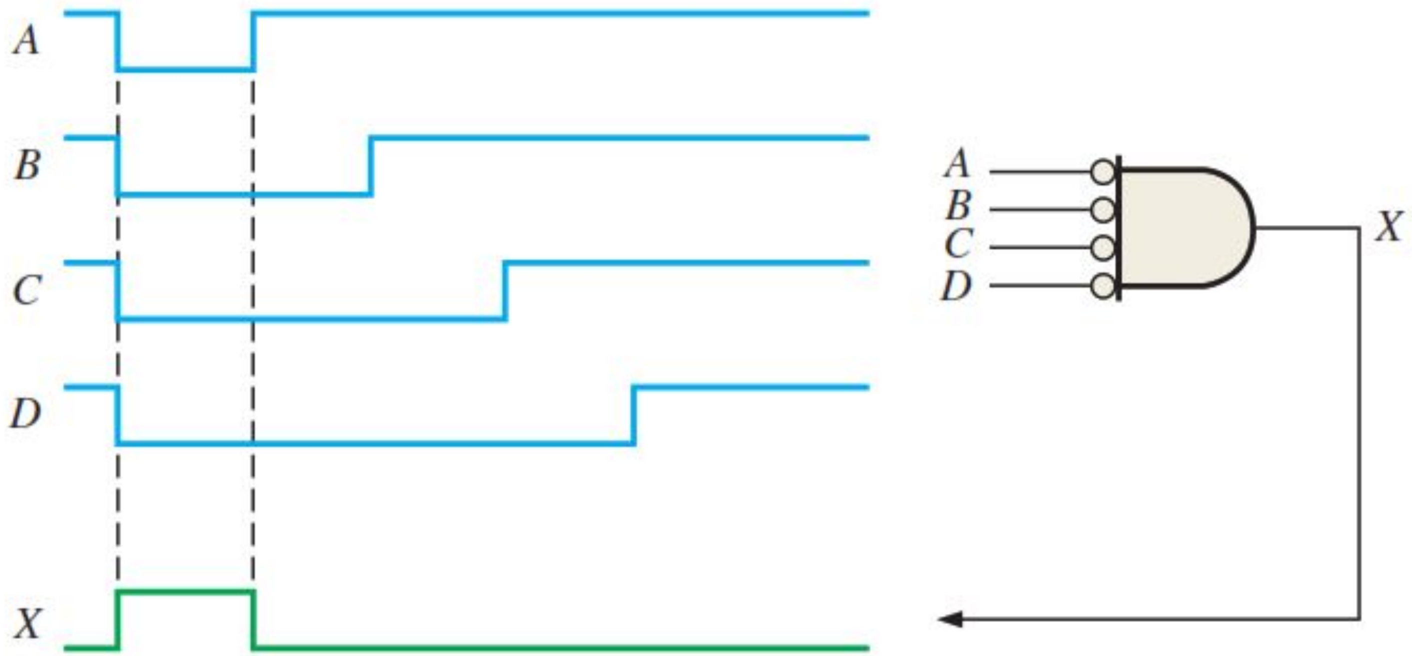
A device is needed to indicate when one or two HIGH levels occur on its inputs and to produce a LOW output as an indication. Specify the device.

As part of an aircraft's functional monitoring system, a circuit is required to indicate the status of the landing gears prior to landing. A green LED display turns on if all three gears are properly extended when the "gear down" switch has been activated in preparation for landing. A red LED display turns on if any of the gears fail to extend properly prior to landing. When a landing gear is extended, its sensor produces a LOW voltage. When a landing gear is retracted, its sensor produces a HIGH voltage. Implement a circuit to meet this requirement.


+V
Landing gear sensors
Extended = LOW
Retracted = HIGH
Red LED
Gear retracted
Green LED
All gear extended

EXAMPLE 3–19

For the 4-input NOR gate operating as a negative-AND in Figure 3–41, determine the output relative to the inputs.



Summary

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

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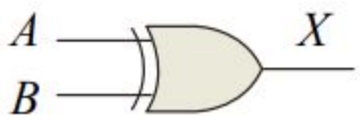
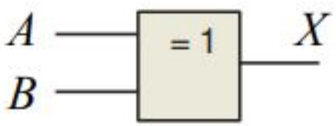
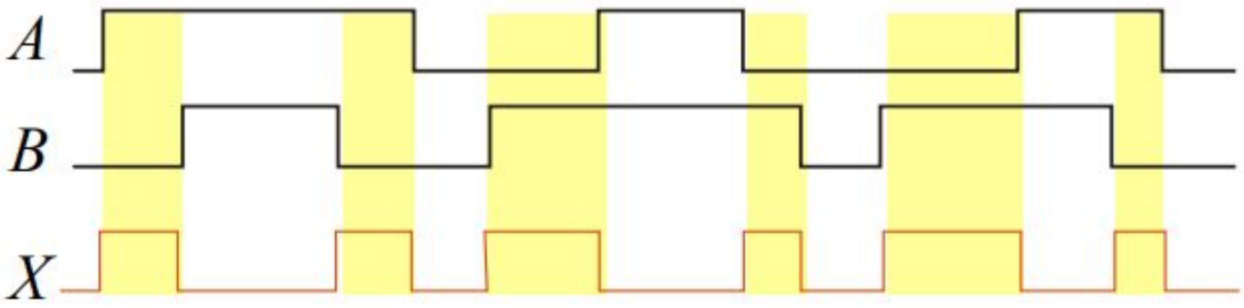
Summary

The 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.

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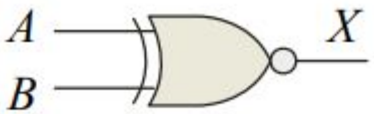
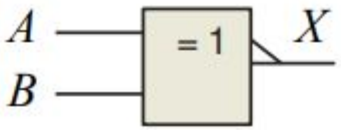
Summary

The 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 $X = A \odot B$.

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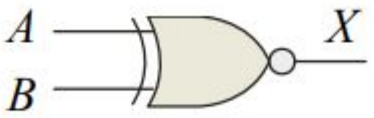
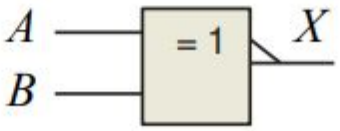
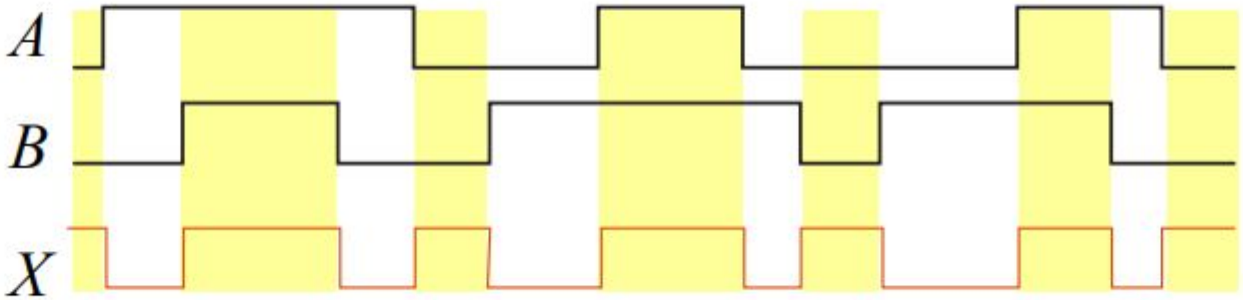
Summary

The XNOR 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.

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