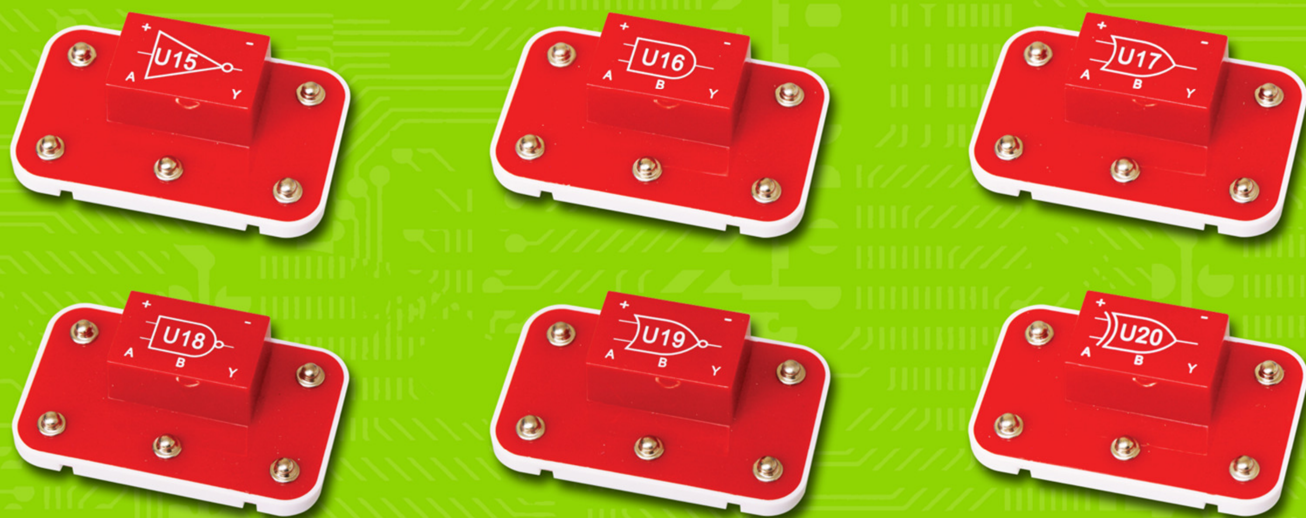
SNAP CIRCUITS®

Understanding Logic Gates

Model DLG-100

SNAP CIRCUITS®



ELENCO®

Patents: 7,144,255; 7,273,377; & other patents

Parts List

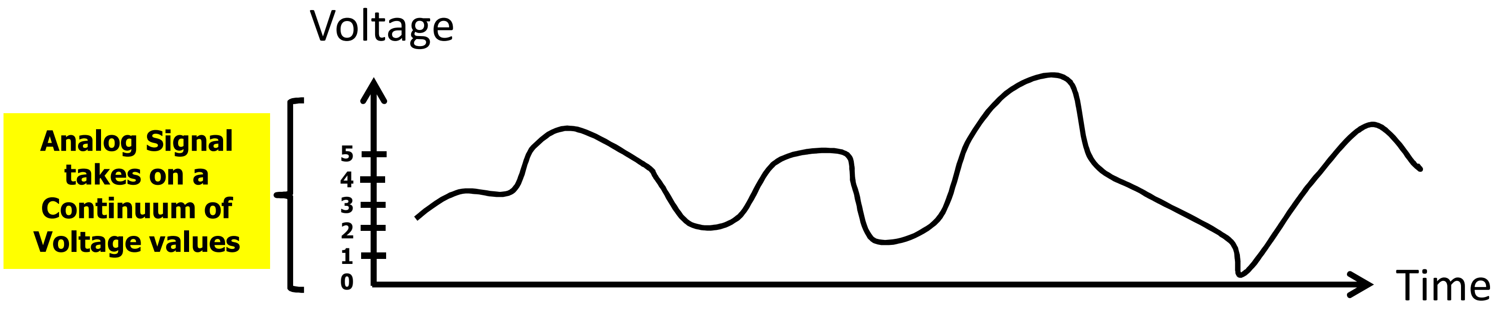
ID	Part Name	Part Number	QTY
2	2-snap	6SC02	2
3	3-snap	6SC03	1
5	5-snap	6SC05	2
B1	Battery holder (dual AA)	6SCB1	1
	Mini base grid	6SCBGM	1
D1	LED red	6SCD1	1
D2	LED green	6SCD2	2
	Jumper wire black	6SCJ1	1
	Jumper wire red	6SCJ2	1
S1	Slide switch	6SCS1	1
U15	Gate	6SCU15	1
U16	Gate	6SCU16	1
U17	Gate	6SCU17	1
U18	Gate	6SCU18	1
U19	Gate	6SCU19	1
U20	Gate	6SCU20	1

Outline

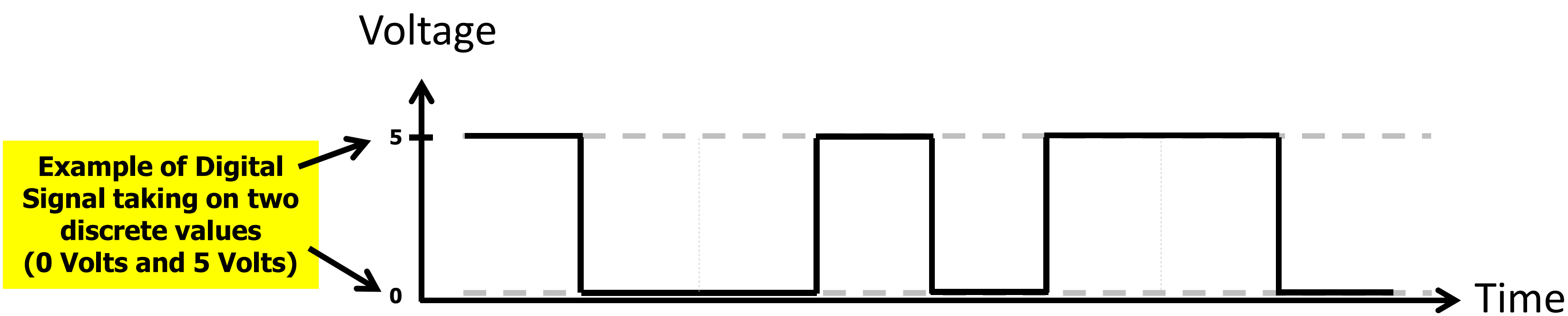
1. Digital Signals
2. NOT Gate (Inverter)
3. AND Gate
4. OR Gate
5. NAND Gate
6. NOR Gate
7. Exclusive OR Gate

Analog vs. Digital Waveforms

- **Analog Waveform – can take on any voltage value**



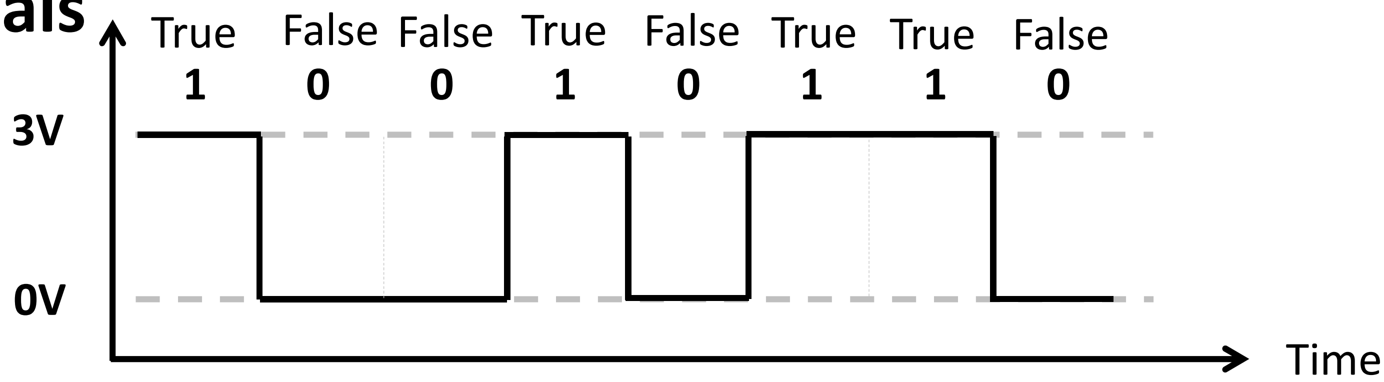
- **Digital Waveform – takes on discrete voltage values**



Analog signals can take on a continuum of values while digital signals take on only discrete values

Digital Signals

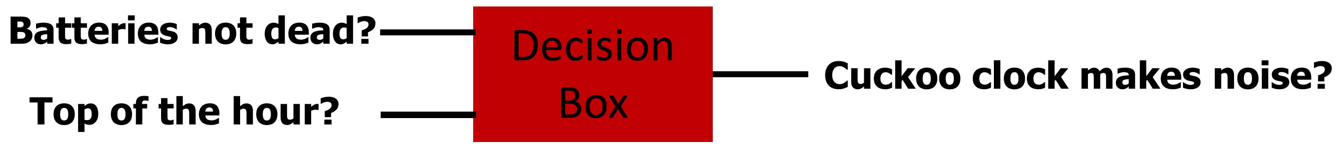
- **Digital waveforms can be used to represent digital signals (e.g. 0 or 1, true or false), for example**
  - 0 (false) – represented by 0 Volts
  - 1 (true) – represented by a small voltage, e.g. 3 Volts
- **Example of Digital Waveform representing digital signals**



Digital signals are represented by a "high" state (1) or "true" state consisting of a small voltage (e.g. 3V) and "low" state (0) or "false" state consisting of 0 Volts

Logic Problem Statements

- Logic problems have outcomes (or outputs) that depend on events (or inputs).
- For example
  - The cuckoo clock makes noise if the batteries are not dead AND it's the top of the hour.
  - In this example, the output is "the cuckoo clock making noise" and the inputs are "the batteries are not dead" and "it's the top of the hour".

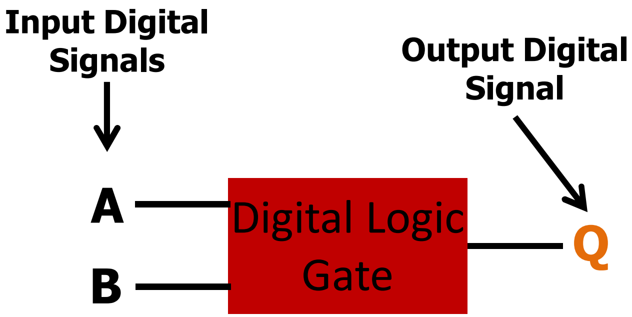


  - Note that in this example, the output is true (cuckoo clock makes noise) if and only if both inputs are true (batteries are not dead AND it's the top of the hour).
  - You will see that this decision box can be represented by digital logic using an AND gate, with the inputs and output being represented by digital signals.

You can think of digital logic gates as decision boxes that solve logic problems

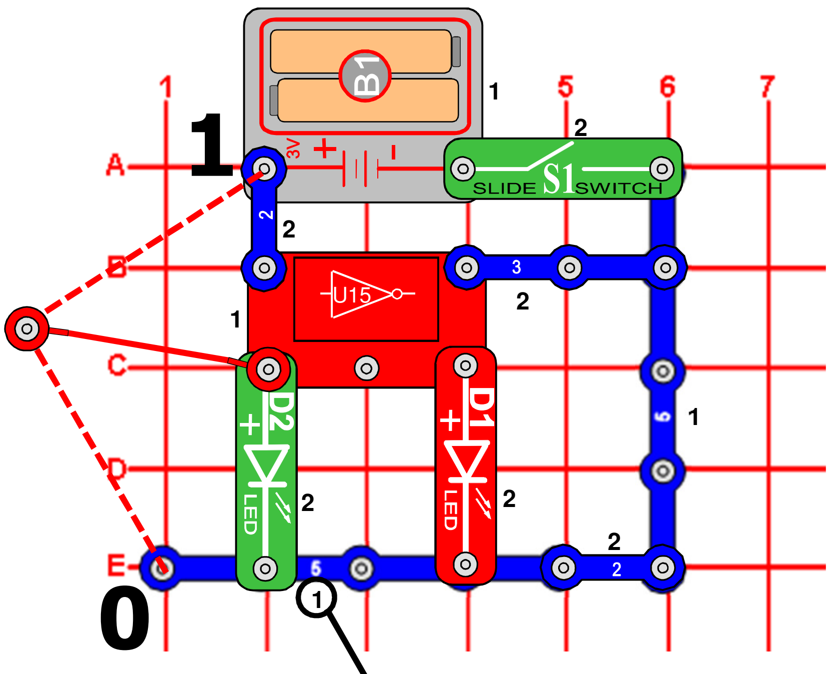
Logic Gates

- A digital logic gate is an Integrated Circuit (IC) device that makes logical decisions based on various combinations of digital signals presented to it's inputs.
- Digital logic gates can have more than one input signal, but generally have a single output signal, just like the decision box on the previous slide.
- In the following slides, the input digital signals will be represented by A and/or B and the output digital signal will be represented by Q.
- The next six slides will demonstrate how the output digital signal is determined by the input digital signals for various different digital logic gates (NOT gate, AND gate, OR gate, NAND gate, NOR gate, XOR gate).



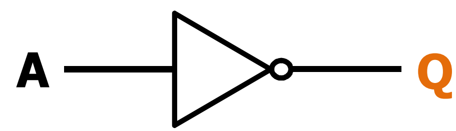
Almost all modern electronics such as computers and cellphones use digital logic circuitry

NOT Gate (Inverter)



Place parts labeled 1 on the grid first and parts labeled 2 on second

This circuit demonstrates how the NOT Gate (U15) works. Connect one end of the red jumper wire to the A input on U15 and the loose end to either low voltage (denoted as a "0") or high voltage (denoted as a "1"). If input A is low (0, green LED off), then the Q output on U15 will be high (1), and the red LED (D1) will be on.



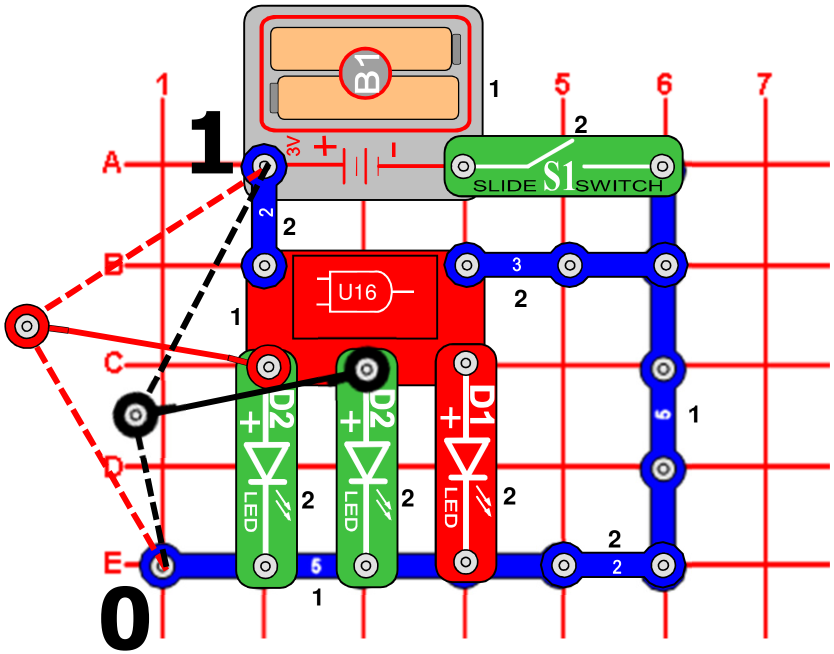
The inversion of a state is often represented with a bar over the variable, so $Q = \overline{A}$.

Input (A)	Output (Q)
0	1
1	0

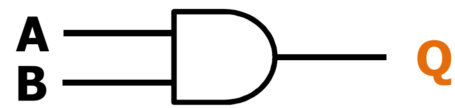
Note: High electric currents can damage LEDs, so normally resistors are placed in series with LEDs to protect them. Resistors aren't needed with your Snap Circuits® D1 & D2 LEDs, because they already have internal resistors to protect them from incorrect wiring. External resistors would be needed with the LEDs if you were using your logic gates (U15-U20) to control other logic gates along with the LEDs, because the low resistance of the LED and its protection resistor could disrupt the operation of the logic gates being controlled.

NOT gates are used in digital logic circuits to "invert a voltage level". A high voltage level (1) into the NOT gate becomes a low voltage level (0) at the output and vice versa.

AND Gate



This circuit demonstrates how the AND Gate (U16) works. Connect one end of the red and black jumper wires to the A & B inputs on U16 and the loose ends to either low voltage (denoted as a "0") or high voltage (denoted as a "1"). If, and only if, both input A AND input B are high (both 1s, both gree LEDs on), then the Q output on U16 will be high (1), and the red LED (D1) will be on.

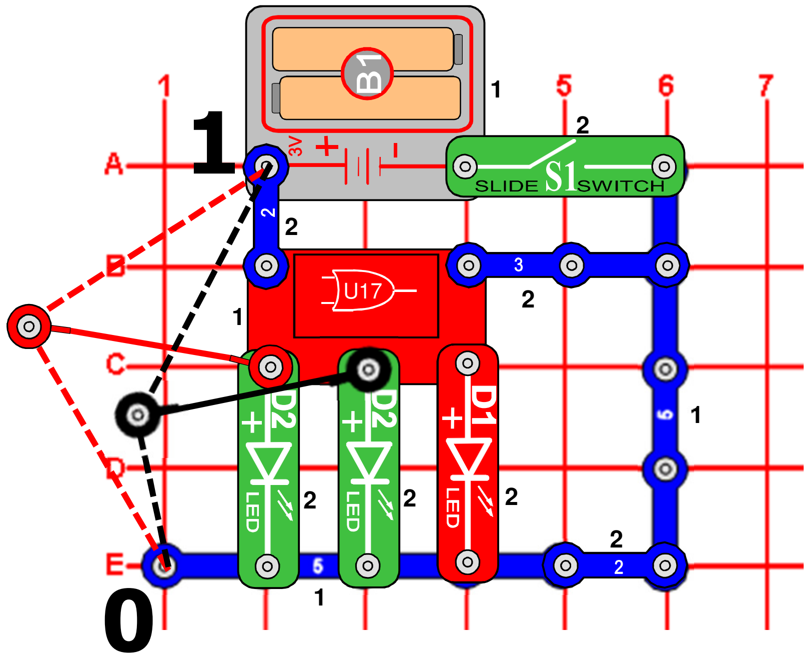


The output of an AND gate is often represented as the product of the inputs, so **Q = AB**.

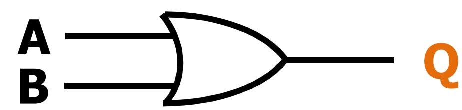
Input (A)	Input (B)	Output (Q)
0	0	0
0	1	0
1	0	0
1	1	1

AND gates are used in digital logic circuits to perform a logical multiply. When one of the inputs is low (0), the output is low (i.e. multiply by 0). The output will only be high (1) when both inputs are high.

OR Gate



This circuit demonstrates how the OR Gate (U17) works. Connect one end of the red and black jumper wires to the A & B inputs on U17 and the loose ends to either low voltage (denoted as a "0") or high voltage (denoted as a "1"). If either input A **OR** input B are high (1, either green LED is on), then the Q output on U17 will be high (1), and the red LED (D1) will be on.

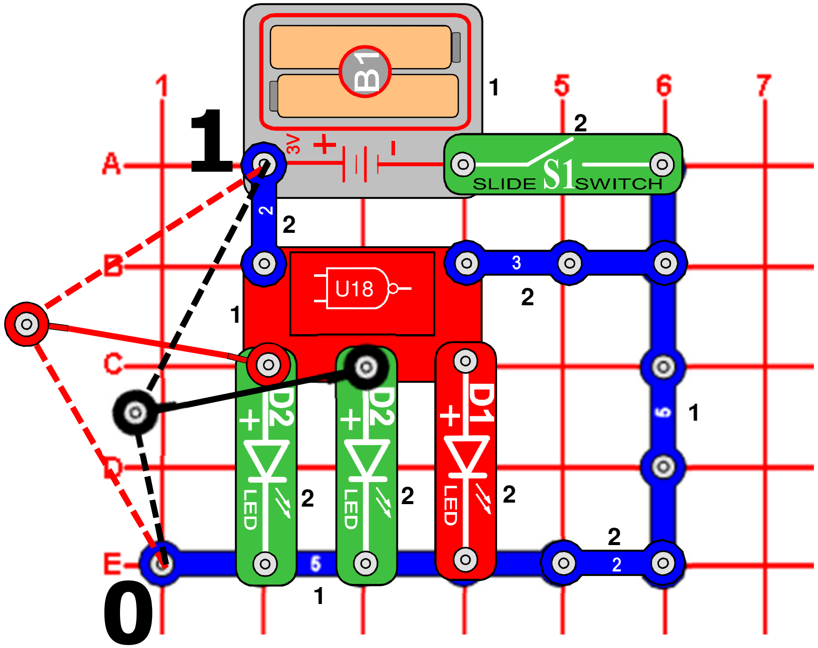


The output of an OR gate is often represented as the sum of the inputs, so **Q = A+B**.

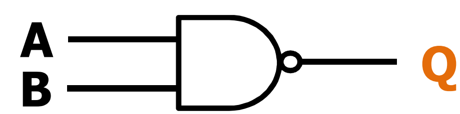
Input (A)	Input (B)	Output (Q)
0	0	0
0	1	1
1	0	1
1	1	1

OR gates are used in digital logic circuits to perform a logical add. When one of the inputs is high (1), the output is high. The output will only be low (0) when both inputs are low.

NAND Gate



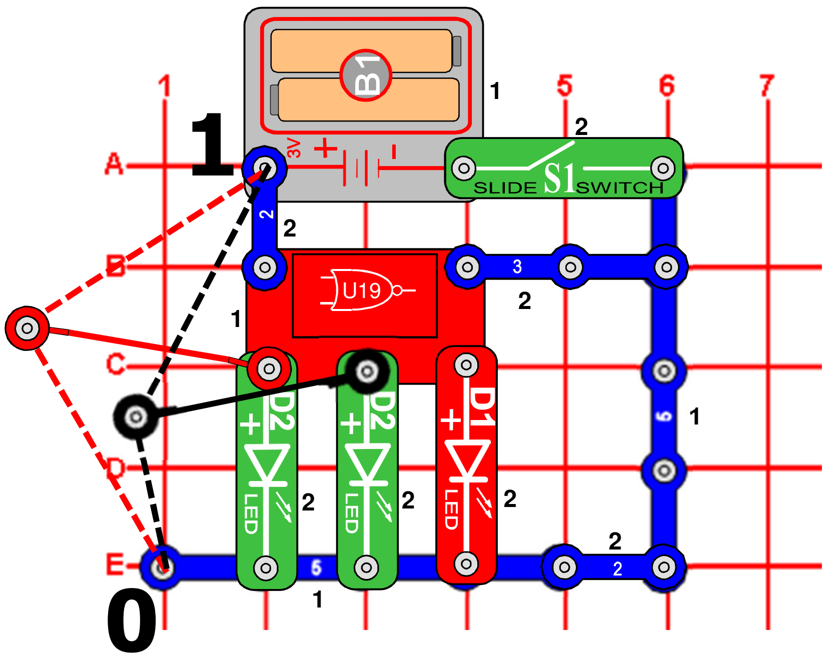
This circuit demonstrates how the NAND Gate (U18) works. Connect one end of the red and black jumper wires to the A & B inputs on U18 and the loose ends to either low voltage (denoted as a "0") or high voltage (denoted as a "1"). If either input A OR input B are low (0, either green LED is off), then the Q output on U18 will be high (1), and the red LED (D1) will be on. The output logic is exactly the opposite of the AND gate, hence this gate is called the NOT AND or NAND Gate



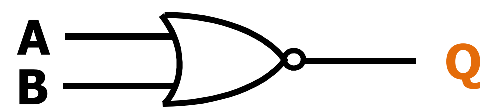
Input (A)	Input (B)	Output (Q)
0	0	1
0	1	1
1	0	1
1	1	0

NAND gates are used in digital logic circuits to perform an inverted logical multiply. When one of the inputs is low (0), the output is high. The output will only be low (0) when both inputs are high.

NOR Gate



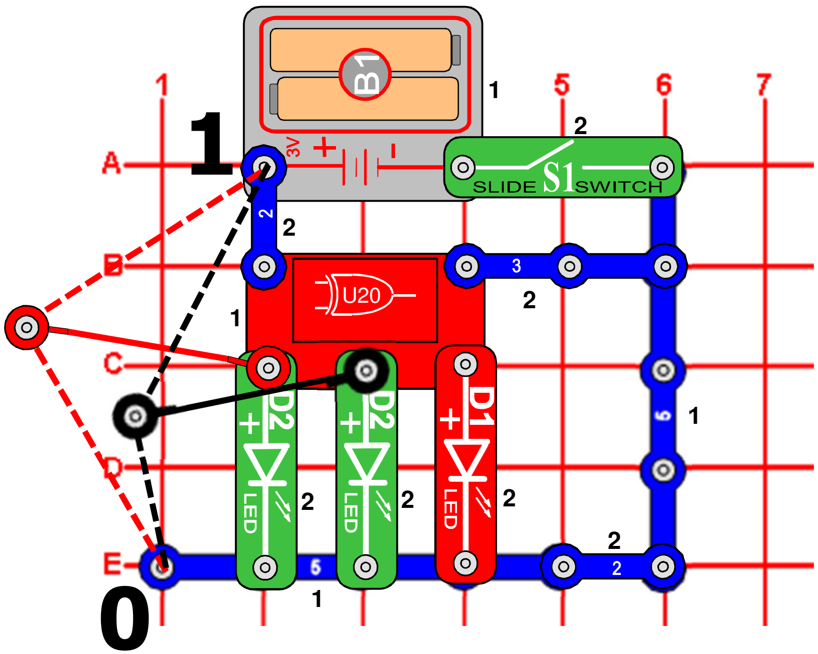
This circuit demonstrates how the NOR Gate (U19) works. Connect one end of the red and black jumper wires to the A & B inputs on U19 and the loose ends to either low voltage (denoted as a “0”) or high voltage (denoted as a “1”). If, and only if, both input A AND input B are low (0, both green LEDs are off), then the Q output on U19 will be high (1), and the red LED (D1) will be on. The output logic is exactly the opposite of the OR gate, hence this gate is called the NOT OR or NOR Gate



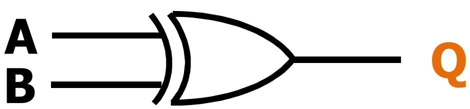
Input (A)	Input (B)	Output (Q)
0	0	1
0	1	0
1	0	0
1	1	0

NOR gates are used in digital logic circuits to perform an inverted logical add. When one of the inputs is high (1), the output is low. The output will only be high (1) when both inputs are low.

Exclusive OR (XOR) Gate



This circuit demonstrates how the Exclusive OR (XOR) Gate (U20) works. Connect one end of the red and black jumper wires to the A & B inputs on U20 and the loose ends to either low voltage (denoted as a "0") or high voltage (denoted as a "1"). If input A and input B are exclusive (i.e. different, one green LED is on and the other green LED is off), then the Y output on U20 will be high (1), and the red LED (D1) will be on.



Input (A)	Input (B)	Output (Q)
0	0	0
0	1	1
1	0	1
1	1	0

XOR gates are used in digital logic circuits to perform a comparison. When the inputs are mutually exclusive (i.e. different), then the output is high (1). When the inputs are the same, then the output is low (0).

Quiz

1. **The output will be LOW (0) for any case when one or more input is LOW (0) for a(n):**
   a) OR gate
   b) NAND gate
   c) AND gate
   d) XOR gate

2. **The output of a NOR gate is HIGH (1) if:**
   a) All inputs are HIGH (1)
   b) Any input is HIGH (1)
   c) Any Input is LOW (0)
   d) All inputs are LOW (0)

3. **Which of the following is true about a 2-input NAND gate:**
   a) If one of the inputs is HIGH (1), then the output is always the same as the opposite of the other input
   b) There are 8 possible input combinations
   c) The output is LOW (1) if any input is HIGH (1)
   d) If one of the inputs is LOW (0), then the output is always the same as the other input

Quiz Answers

1. **The output will be LOW (0) for any case when one or more input is LOW (0) for a(n):**
   a) OR gate
   b) NAND gate
   c) AND gate
   d) XOR gate

2. **The output of a NOR gate is HIGH (1) if:**
   a) All inputs are HIGH (1)
   b) Any input is HIGH (1)
   c) Any Input is LOW (0)
   d) All inputs are LOW (0)

3. **Which of the following is true about a 2-input NAND gate:**
   a) If one of the inputs is HIGH (1), then the output is always the opposite of the other input
   b) There are 8 possible input combinations
   c) The output is LOW (1) if any input is HIGH (1)
   d) If one of the inputs is LOW (0), then the output is always the same as the other input

ELENCO®

150 Carpenter Avenue

Wheeling, IL 60090

(847) 541-3800

Website: www.elenco.com

e-mail: elenco@elenco.com