



### Overview:

In this lesson, students will learn how to use a digital output pin on the breadboard connector of the TI-Innovator™ Hub. Students will learn what an electrical circuit is and how to represent that circuit with a schematic diagram. Students are also introduced to the resistor value color code table.

### Goals:

1. Build an electrical circuit with a Red LED and 100 Ohm resistor on a breadboard and connect it to the TI-Innovator Hub.
2. Author a TI-Basic program on a TI-84 Plus CE calculator that will control the digital output on BB1 of the TI-Innovator Hub to repeatedly turn the Red LED on and off.
3. Interpret and trace the flow of current in a circuit.
4. Draw and interpret a schematic diagram of a circuit.
5. Read the resistance color code of a resistor.

### Background:

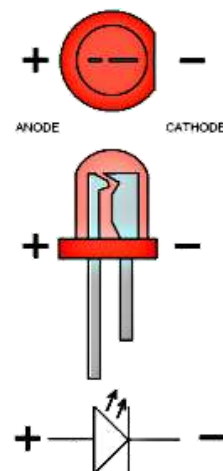
An electrical circuit contains materials called conductors that allow electrons to flow through the circuit when the electrons are pushed by voltage. These conductive materials are built into parts such as wires, resistors and breadboards.

The electrons flow through a circuit, starting at negative (-) and ending at positive (+). A power source is needed to push the electrons through the circuit, usually; this push comes from a battery or a power source like the TI-Innovator Hub. A digital output pin on the TI-Innovator Hub is an electrical output connection that exists in one of two states: on or off. In the on state, which is represented by the number one (1), the pin is held at 3.3 volts. In the off state, which is represented as a zero (0), the pin is held at 0 volts.

The circuit you will build turns on a small light called an LED. An LED is a Light Emitting Diode, and it makes light as electrons are pushed through a special material called a semiconductor. The energy from the motion of the moving electron is converted into light. An LED has polarity. One lead is positive (+) and is referred to as the anode, and the other lead is negative (-) and is referred to as the cathode. Refer to the LED diagram on the right to distinguish between the anode and cathode leads.

It is a good practice to use a current-limiting resistor in an LED circuit. This resistor prevents too much current from flowing through the device and breaking (burning) the LED. Typically, the current-limiting resistor is placed in series with the cathode (-) lead.

Resistors vary in the amount of resistance to the flow of current. There are four colored bands marked on a resistor. The first and second band colors represent the first and second digits in the resistance value. The third colored band represents the factor the first two numbers are multiplied by to equal the resistor value. The fourth band is the manufactured tolerance and is not important in this lesson. The chart on the right can be used to determine the resistance value of resistors.



Color	Number	Multiplier
Black	0	1 or ( $10^0$ )
Brown	1	10 or ( $10^1$ )
Red	2	100 or ( $10^2$ )
Orange	3	1000 or ( $10^3$ )
Yellow	4	10000 or ( $10^4$ )
Green	5	100000 or ( $10^5$ )
Blue	6	1000000 ( $10^6$ )
Violet	7	10000000 or ( $10^7$ )
Gray	8	100000000 or ( $10^8$ )
White	9	1000000000 or ( $10^9$ )



### Practice:

#### Example:



For the 100 Ohm ( $\Omega$ ) resistor in this activity, the first and second colored bands are brown (1) and black (0), and the third band is brown  $10^1(10)$ . So the calculation would be:

$$10 \times 10 = 100$$

### Practice:



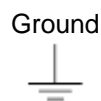
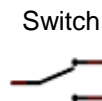
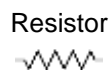
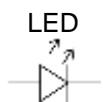
Find the value of the resistor on the left. The first color is brown; the second is black; and the third is yellow.

**Answer:**  $10 \times 10000 = 100,000$  or 100k ohm

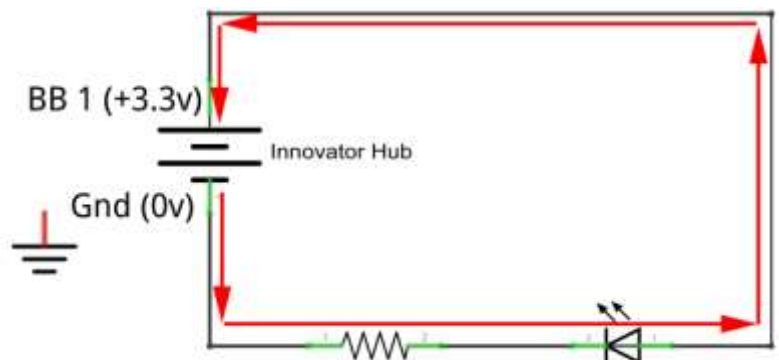
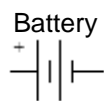
### Schematic Diagrams:

Below and to the right is the schematic diagram for this activity. Work with students to follow the flow of current through the diagram from the breadboard ground pin, through the current-limiting resistor, then through the LED, and finally back to the BB1 pin on the breadboard connector.

Some schematic symbols:



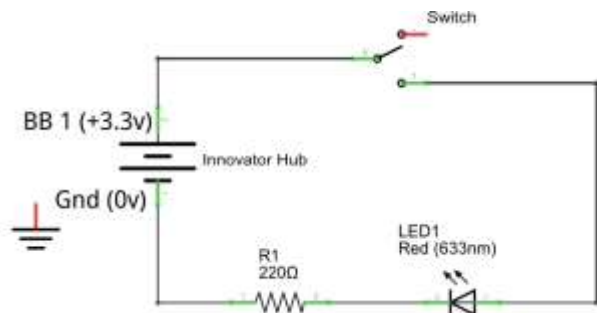
TI-Innovator Hub



BB1 is a digital output pin on the TI-Innovator Hub and Gnd is the ground on the TI-Innovator Hub.

### Practice:

Using the example above, have students draw the same schematic but include a switch that will turn the LED on or off. Have the students trace the current flow through the schematic as well as label each component (resistor, battery, LED, and switch).





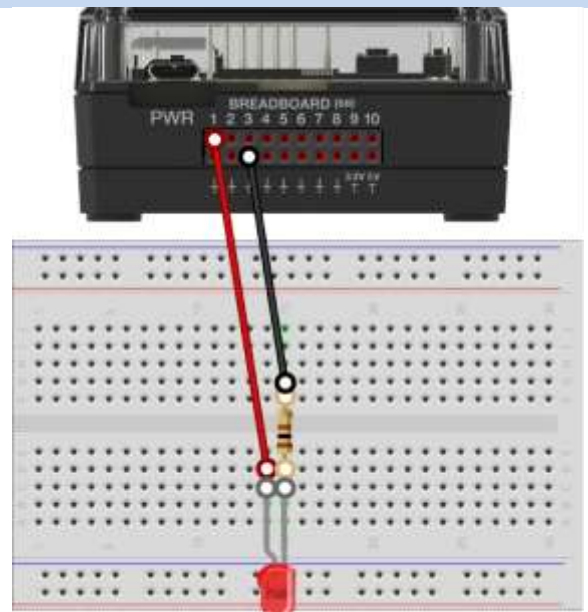
### Materials and Tools:

- TI-84 Plus CE
- TI-Innovator™ Hub with USB Cable
- TI-Innovator Breadboard Pack:
  - Breadboard
  - Male to Male jumper Cables
  - Red LED
  - Resistor 100 Ohm (brown, black, brown)

### Build the Hardware:

Assemble the circuit in the diagram by following these steps:

1. Insert a Red LED into the breadboard as shown on right.
  - Be sure each leg is in its own column so that the two legs are not electrically connected.
2. Use a red Male to Male Jumper Cable to connect the anode (+) leg of the Red LED to BB1 on the breadboard connector of the TI-Innovator Hub.
3. Place the 100 Ohm resistor into the same column as the cathode (-) of the Red LED.
4. Bend the 100 Ohm resistor so that it bridges the gap in the breadboard, and insert the opposite lead of the 100 Ohm resistor into any hole in the upper half of the breadboard.
  - Remember, the upper half and lower half of the breadboard are separated by the gap and are **not** electrically connected.
5. Insert a black Male to Male Jumper Cable into any hole in the same row as the lead of the 100 Ohm resistor. Connect the opposite end of the black Male to Male Jumper Cable into any ground pin on the breadboard connector of the TI-Innovator Hub.
6. Trace the flow of current through the circuit to ensure it is complete.
7. Plug the B end of the unit-to-unit USB cable into the TI-Innovator Hub and then the A end into the handheld device.



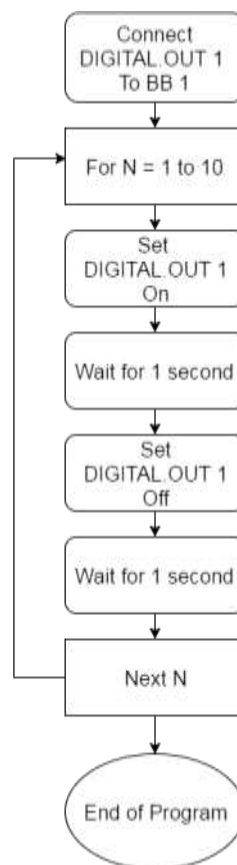
**Teacher Tip:** It is important to demonstrate to students how to be methodical when checking for hardware and software errors. Show them how to trace the current through the circuit and the requirement for a complete circuit from source to ground. A common problem is a reversed polarity on the Red LED or an incomplete circuit through the resistor.

**Write the Software for the TI-84 Plus CE:**

**Task:** Write a TI-BASIC program on the TI 84 Plus CE that will blink a red LED connected to pin 1 on the breadboard connector of the TI-Innovator Hub ten times with a 1 second pause between on and off.

**Code for the TI-84 Plus CE:**

```
Send("CONNECT LED 1 TO BB 1")
For(N,1,10)
Send("SET LED 1 ON")
Wait 1
Send("SET LED 1 OFF")
Wait 1
End
```

**Extra for Experts:**

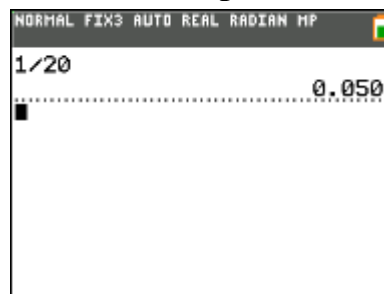
Periodic phenomenon can be described by frequency; that is, how many times the event happens per second. Alternatively, the phenomenon can also be described by period; that is, how long the event lasts. The unit for frequency is in honor of Heinrich Hertz, the discoverer of electromagnetic waves. The unit Hertz (Hz) is the number of cycles per second of a periodic phenomenon such as a wave or a rotating wheel.

Frequency (f) is measured in unit of Hz.

Period (T) is measured in units of seconds.

Calculate the period (T) of a frequency (f) of 20 Hz on your calculator. Try a few more for practice.

$$f = \frac{1}{T}$$



- a) 5 Hz

**Answer:**  $1/5 = .2$  sec

- b) 10 Hz

**Answer:**  $1/10 = .1$  sec

- c) 75 Hz

**Answer:**  $1/75 = .0133$  sec

- d) 4,000,000 Hz

**Answer:**  $1/4,000,000 = .00000025$  sec