

# HIMALAYAN MAKERS GUILD

## ACTIVITY 10 – TRANSISTOR CONTROLLED NIGHT-LIGHT

### LEARNING OUTCOMES

Students will **build a night-light circuit using a transistor**. This activity should take **~1 hour** to complete.

### OUTLINE

1. 5m Review of the night-light circuit
2. 10m Transistors
3. 5m Adding a transistor to the night-light
4. 30m Building the circuit
5. 5m Reflection

This lesson plan assumes free access to a black-and-white printer, a classroom with a whiteboard, blackboard, or chart-paper. This activity does not require regular access to electricity.

### MATERIALS AND COSTS PER STUDENT

Item	Qty.	Cost per Student <sup>1</sup>	Expendable <sup>2</sup>	Supplier
LED Assorted 3mm 5mm	1	0.02	y	<a href="#">AliExpress</a>
Resistors Assorted 2100pcs	3	0.02	y	<a href="#">AliExpress</a>
9V Battery Snap	1	0.16		<a href="#">AliExpress</a>
Jumper cables MM 10cm	6	0.12	y	<a href="#">AliExpress</a>
Light Sensitive Resistor (LSR)	1	0.05		<a href="#">AliExpress</a>
Breadboard 400 point	1	1.49		<a href="#">AliExpress</a>
Breadboard Power Supply	1	0.75		<a href="#">AliExpress</a>
BJT NPN PN2222	1	0.10		<a href="#">AliExpress</a>
9V Ni-Mh 450mAh	1	5.17		<a href="#">AliExpress</a>
<b>Total Cost per Student</b>		<b>\$7.88 CAD</b>		

1. Currency is CAD, 2017-06-10. Assuming one set of parts per student. ↩
2. Likely to be broken or lost during the activity. ↩

Note that the LED used here is a white LED (turns on at 2.8V).

If running the activity in a room with daylight, I recommend using a 22k ohm resistor in the voltage divider. If running the activity in a fluorescent lit room, use a 220k ohm resistor in the voltage divider. This will also depend on your light sensitive resistor (LSR). The one used in this activity behaves as follows:

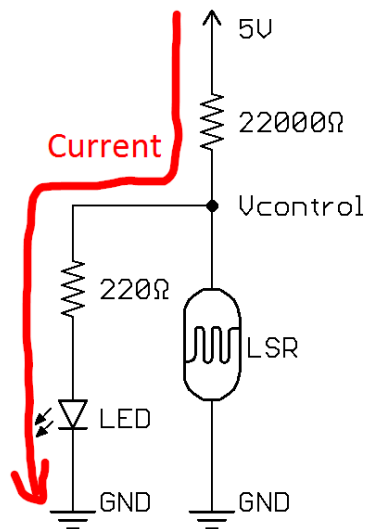
- In daylight: 2.2k ohms, 20k ohms when covered with a finger
- At dusk: 10k ohms, 40k ohms when covered with a finger
- Fluorescent lighting: 11k ohms, >50k ohms when covered with a finger

## LESSON

Before class: connect each of the power supplies to a breadboard; snap the battery snaps onto the 9V batteries; print student handouts. All images shown below are intended to be drawn on the board for the students during the lesson.

### 1. REVIEW OF THE NIGHT-LIGHT CIRCUIT

- Last week we used a Light Sensitive Resistor (LSR) in a voltage divider to control an LED.

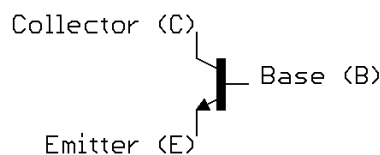


- There was an issue with this circuit though, what was the problem? A: the light was dim, because current must flow through the large resistor in the voltage divider.

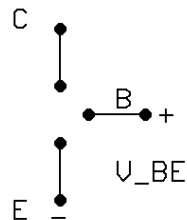
### 2. TRANSISTORS

- We usually just connect the LED and 220 ohm resistor to 5V, so we get full brightness, and control it using a button.
- What if we had a switch that, instead of pressing it with our finger, we could control it with the voltage from the voltage divider?

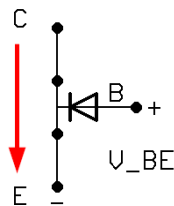
- This voltage-controlled switch is called a transistor.
- Today we are going to look at a common type of transistor called an NPN Bipolar Junction Transistor (BJT)
- *Note: Two common kinds of transistors are BJTs and FETs. This activity uses the NPN Bipolar Junction Transistor (BJT). Be aware that there are also PNP BJTs that behave differently.*
- *Note: For more advanced students, it is helpful to look at the datasheet for the NPN transistor (in our case the PN2222A) and highlight important points: the pin-out on page 1 and the threshold voltage  $V_{BE(sat)}$  on page 2.*
- How many pins do you think the BJT has? A: The transistor has 3 pins. Just like a button, there are two pins that become connected when the BJT is on. There is also 3rd pin that controls whether current will flow between the two pins.



- The pins are called the Collector (C), Base (B), and Emitter (E).
- Current flows from C to E, and is controlled by the voltage between B and E ( $V_{BE}$ )
- Similarly to how we needed 3V to turn on the LED, the BJT turns on when  $V_{BE}$  is greater than 0.6V
- When  $V_{BE}$  is less than 0.6V, the BJT is like an open switch



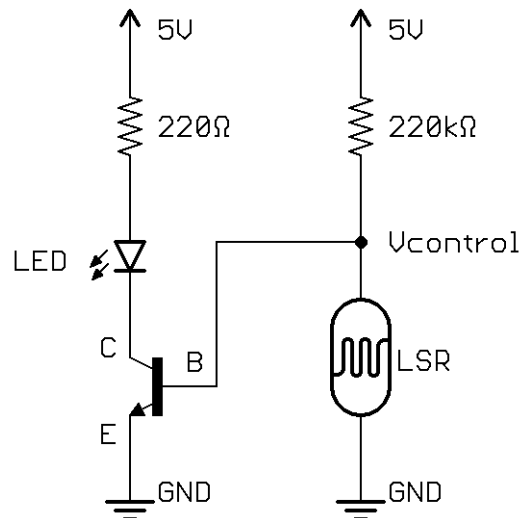
- When  $V_{BE}$  is greater than 0.6V, the BJT is like a closed switch and current can flow from C to E. There is also some current that flows from B to E, and the  $V_{BE}$  will stay quite constant (around 0.7V), so here we can represent it as a diode.



- Just like with an LED, the BJT can be damaged by too much current going from B to E, so we need to make sure we have a resistor attached to B

### 3. ADDING A TRANSISTOR TO THE NIGHT-LIGHT

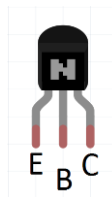
- We will place the BJT so that E is connected to ground, and C is connected to the negative pin of the LED. This way, we only need to get B up to 0.6V to turn on the light.



- We connect B to Vcontrol on the divider, so that the LSR controls the BJT
- Before, we wanted Vcontrol to get up to 3V to turn on the LED. Now we only need 0.6V. To do this, should we make the top resistance bigger or smaller? A: Bigger, to lower Vcontrol. Change the resistor on the drawing from 22k ohms to 220k ohms

### 4. BUILDING THE CIRCUIT

- In real-life, the BJT we are using looks like this:



- When looking at the flat side, the pins are arranged E, B, C.
- If your circuit is working, but the light isn't bright, the BJT may be backwards (current flowing from E to C)!

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### FREQUENTLY ASKED QUESTIONS

- It's working, but the LED doesn't look that bright. A: make sure that the BJT is in the right orientation, with the Emitter connected to ground.

- The student thinks the circuit isn't working because the light isn't turning on. A: clarify that in a bright room, we want the light off. To imitate being in a dark room, the student should cover the LSR with their finger, and the LED should turn on.
- The student connects all of the components in series. A: have them try drawing the circuit diagram of the circuit they've built, and compare it to the night-light circuit.
- Circuit looks good, but it's still not working. A: Check LED polarity (long leg should be connected towards the positive voltage, short leg towards ground); check that the power supply isn't on the board backwards (+ from the power supply is connected to the + column on the breadboard).

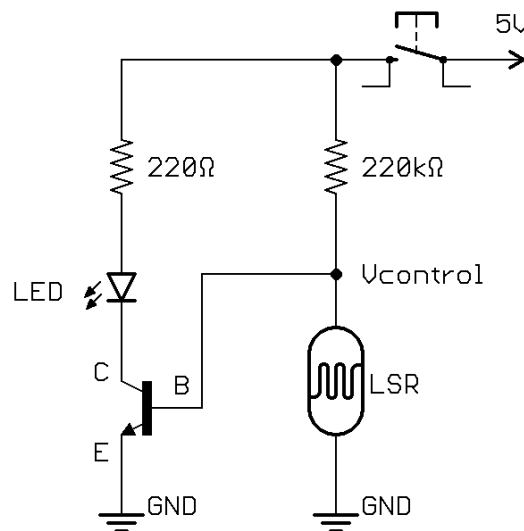
## 5. REFLECTION

- This circuit has two advantages over our circuit that didn't use the BJT.
- First, current only flows through 220 ohm resistor so we get full LED brightness.
- What do you think the second advantage is? It has to do with the big resistor we are now using in the voltage divider. A: when the LED is off, our stand-by current is much lower (1/10th), so our battery will last longer!

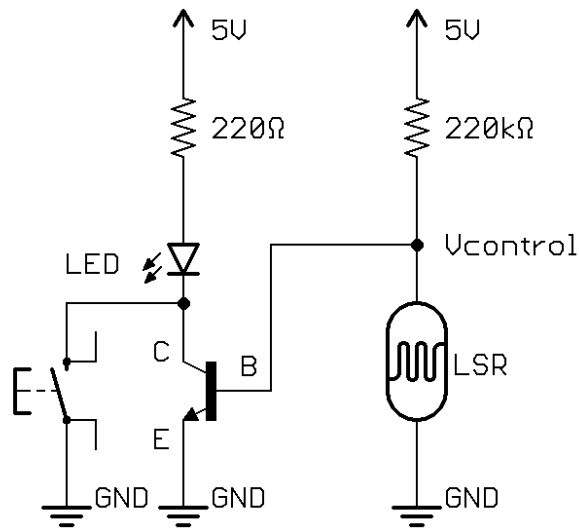
## CHALLENGE AND EXPLORE

Evaluate the students' understanding of the learning objective by asking them to try the following:

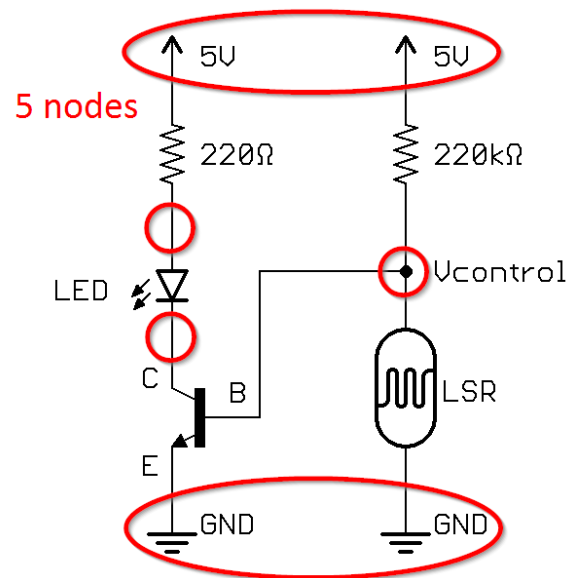
- Add a button so that the button must be pressed for the night-light to work.
  - Skill: Building breadboard circuits



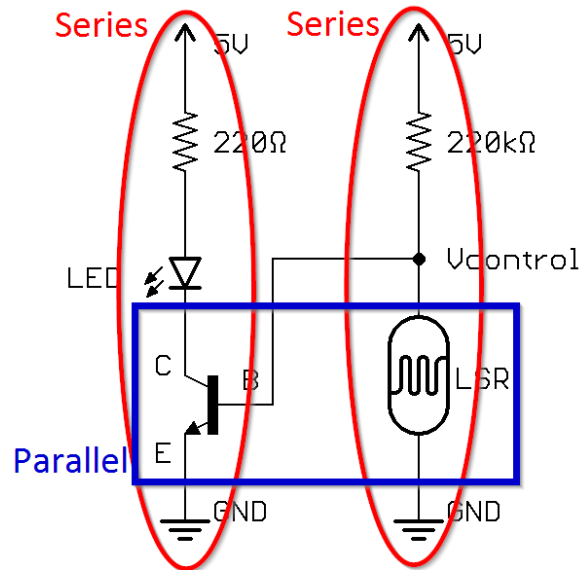
- Add a button so that the night light works as usual, but if the button is pressed the LED turns on.
  - Skill: Building breadboard circuits



- How many nodes are in the circuit? A: 5.
  - Skill: Reading and drawing circuit diagrams



- Which parts are in parallel/series?
  - Skill: Define parallel and series connections
  - Skill: Reading and drawing circuit diagrams



Further reading: <https://learn.sparkfun.com/tutorials/transistors>