LED Night Light - Manual

EXPLORATION DAY

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Overview

A **LED night light** is a small, low-power lighting device that uses light-emitting diodes (LEDs) to provide gentle illumination during the night. It is commonly used in bedrooms, hallways, or bathrooms to improve visibility without disturbing sleep.

The LED night light operates automatically based on the surrounding light conditions. During the day, or when the environment is bright, the photoresistor (light-dependent resistor) senses the light and decreases its resistance, causing the voltage at its output to drop. As a result, insufficient current flows through the LED, keeping it turned off. When the environment becomes darker, the photoresistor's resistance increases, raising the voltage across the LED circuit. This allows current to flow through the resistor and the LED, turning the light on automatically.

Figure 1: Plug-In LED night light.

Main Features

- **Energy-efficient:** Uses less than 1 W of power.
- **Long-lasting:** LEDs can last over 25,000 hours.
- **Cool to the touch:** Minimal heat generation, safe for continuous use.
- **Compact:** Often plug directly into wall outlets or powered via USB.

Beyond their simplicity, LED night lights demonstrate key electrical and electronic engineering concepts such as voltage division, current limitation using resistors, and automatic light control with photoresistors. Their compact and reliable design makes them an excellent example of how everyday devices combine circuit fundamentals with real-world functionality. By understanding their internal operation, students can connect theory with practical application, reinforcing knowledge about semiconductors, sensors, and energy conversion.

How It Works

1. **Power Supply:** Usually 120V AC (wall outlet) or 5V DC (battery).
   - When 120V AC is used, typically the voltage is reduced to 5V using a small AC-to-DC converter (like we have in our cell phone chargers).
2. **Light Emission:** A resistor is connected in series with the LED to limit the current. When the LED is forward biased (watch out! LEDs have polarity!) current flows through the LED, producing light.

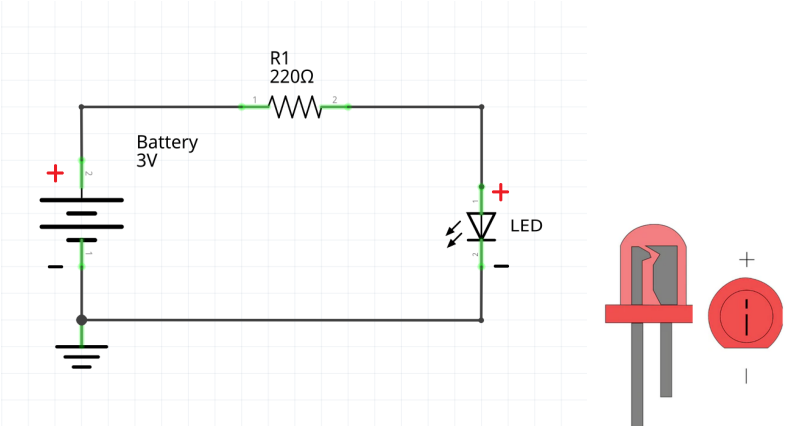


Figure 2: Simple Basic LED Circuit.

3. **Voltage Divider and Light Sensor Control**

   To automate the night light so it only turns on in darkness, a photoresistor (also called a Light Dependent Resistor(LDR)) is used as part of a **voltage divider** circuit. The voltage divider consists of two resistors in series, one fixed resistor (R_2) and one PhotoResistor ($R_{photoresistor}$), Figure 3. The output voltage at the midpoint (the node between the two resistors) depends on the resistance ratio, Equation 1.

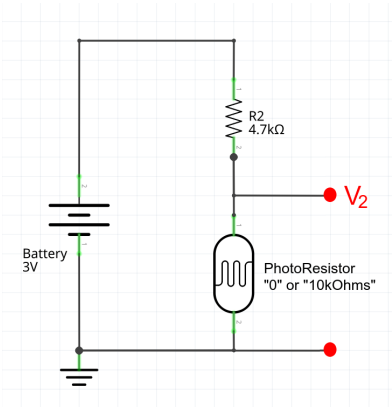


Figure 3: Voltage divider circuit using a photoresistor.

$$V_2 = \left(\frac{R_{photoresistor}}{R_{photoresistor} + R_2} \right) V_{battery} \tag{1}$$

4. **Circuit Design**

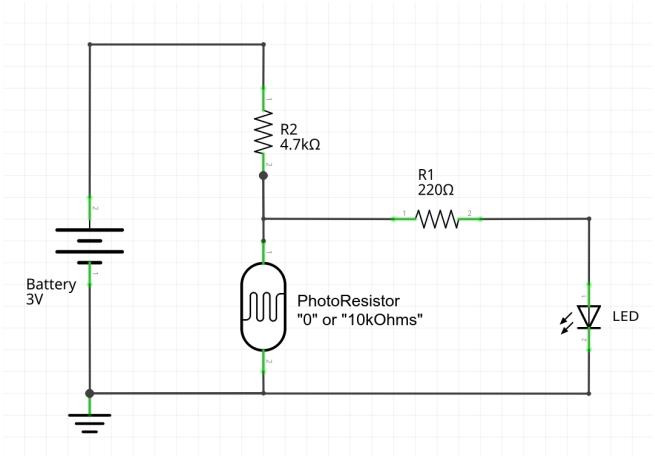


Figure 4: Battery-powered LED Night Light, Cicuit Desing.

- **Operation principle:**
  - In bright light, the PhotoResistor is low, so the voltage drop in the PhotoResistor is small. The LED receives little or no voltage — it stays off.
  - In darkness, the PhotoResistor increases dramatically. This raises V_{out} the voltage drop in the PhotoResistor, enabling voltage to reach the LED and series resistor, allowing current to flow and the LED to illuminate.

Example Circuits

Breadboard

The **breadboard** is a simple and reusable platform for prototyping and testing electronic circuits without soldering. It provides a flexible and reliable environment for assembling components such as resistors, LEDs, sensors, and integrated circuits using jumper wires (see Figure 5). As an essential educational and development tool, it helps students understand circuit design concepts before transitioning to permanent soldered PCBs.

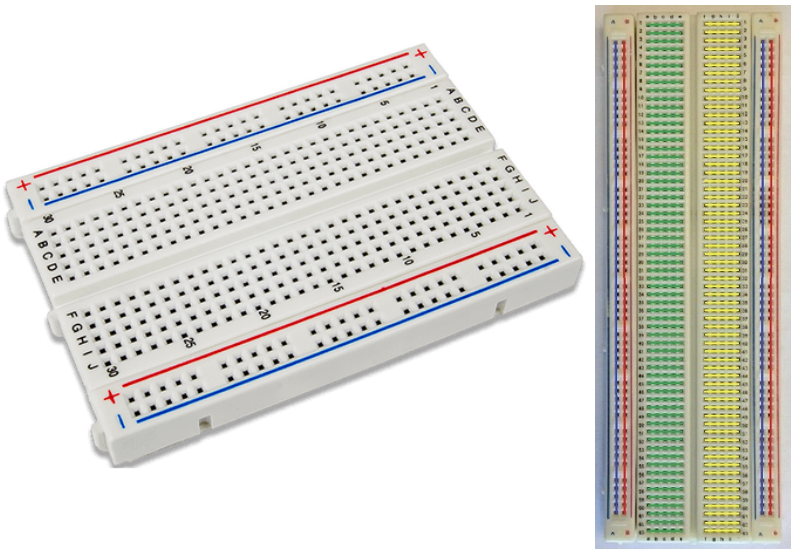


Figure 5: Breadboard.

Structure and Layout

A breadboard is made of rows and columns of small holes (*tie points*) with metal clips underneath that form electrical connections. It has two main regions:

1. **Terminal strips (main area):** The central region where the components are inserted. Each horizontal row (*green* and *yellow* lines) of five holes is electrically connected, forming a common node. The middle gap, or *trench*, isolates the left and right halves.

2. **Bus strips (power rails):** Vertical columns, typically marked with *red* (for $+V$) and *blue* (for GND), distribute power and ground along the length of the board. All holes aligned vertically within the same colored rail are internally connected, forming a continuous electrical node.

When you insert an LED and a resistor into connected rows, the current can flow through the internal metal strips rather than the plastic body. This design makes it simple to build and modify circuits without permanent connections.

Battery-powered Night Light in the breadboard

Components:

- Breadboard (B07LFD4LT6)
- Battery holder (1528-2707-ND)
- AA batteries
- 220Ω resistor, for current limiting (CFS1/4CT52R221J)
  Color: Red – Red – Brown – [Gold or Silver]
- 4.7kΩ resistor, for the voltage divider (CF1/4CT52R472J)
  Color: Yellow – Violet – Red – [Gold or Silver]
- LED (754-1733-ND)
- Photoresistor (PDV-P8103-ND)
- Jumper (BC-32626)

LED circuit

An LED circuit can be assembled using a resistor and a battery as the power source, Figure 6.
Steps:

1. **Place the 220Ω resistor:** Insert one end of the resistor into a row on the terminal strip and the other end into a different row that will connect to the LED. The resistor limits the current through the LED, preventing damage.
2. **Insert the LED:** LEDs have two terminals: the **anode** (positive) and the **cathode** (negative). The cathode can be identified by the **flat edge on the LED casing**. Place the LED so that the rounded side (positive) is connected to the row with the free end of the resistor.
3. **Complete the circuit:** Connect the positive terminal of the battery to the resistor, and use a jumper wire to link the LED's cathode (flat edge) row to the GND power rail. When powered, current flows from the positive rail, through the resistor and LED, to ground, causing the LED to emit light.

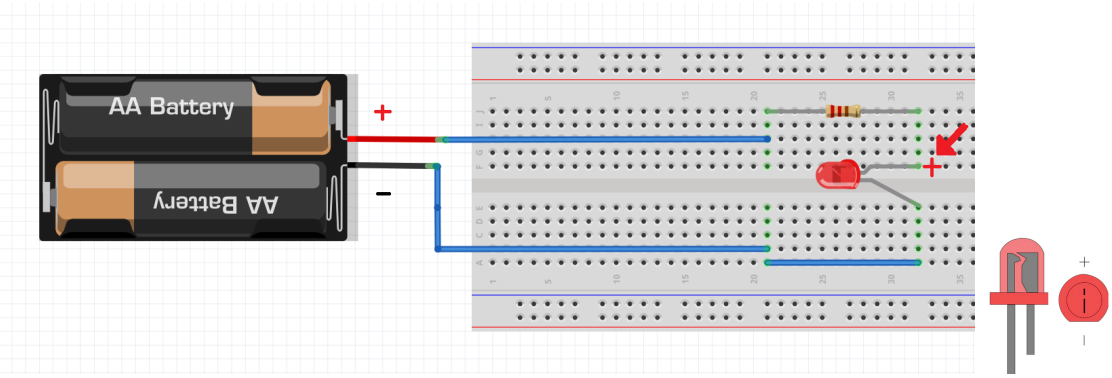


Figure 6: Breadboard Circuit, LED.

Battery-powered LED Night Light

By modifying the previously assembled LED circuit, the Battery-Powered LED Night Light can be constructed, as shown in Figure 7.

Steps

1. **Remove the battery cables:** Unplug the positive and negative wires that connect the battery holder to the LED circuit (Figure 6).
2. **Place the photoresistor:** Insert one end of the photoresistor into the terminal strip where the resistor was previously connected to the positive battery terminal. Connect the other end of the photoresistor to the same rail where the jumper wire was connected to the negative battery terminal.
3. **Place the 4.7 kΩ resistor:** Insert one end of the resistor into a row on the terminal strip where the 220 Ω resistor and photoresistor terminals are located. Connect the other end to a separate, unconnected terminal row.
4. **Reconnect the battery cables:** Connect the positive terminal of the battery to the rail where the free end of the 4.7 kΩ resistor is located. Connect the negative terminal of the battery to the rail where the jumper wire and the photoresistor are connected.
5. **Test the circuit:** Power the circuit by reconnecting the battery. Cover the photoresistor or reduce the ambient light to observe the LED turning on. Gradually increase the light exposure to verify that the LED turns off when sufficient light is detected.

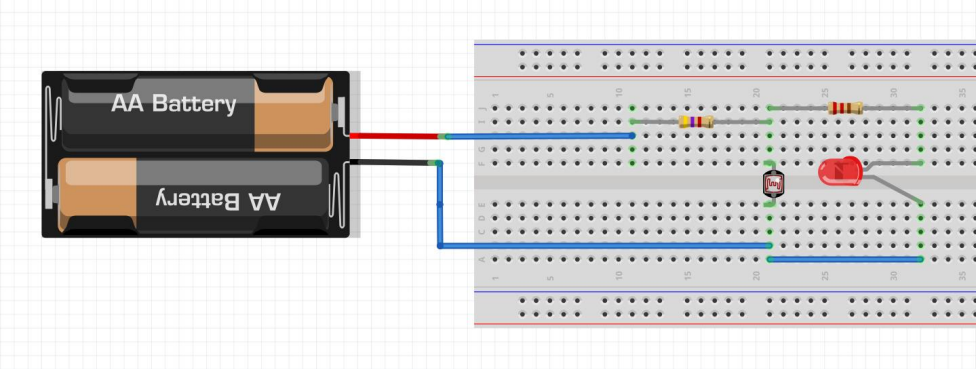


Figure 7: Breadboard, Battery-powered LED Night Light Circuit

PCB (printed circuit board)

A **Printed Circuit Board (PCB)** is a rigid structure that provides both mechanical support and electrical connections for electronic components. These copper traces form predefined paths that replace the need for manual wiring, ensuring a compact and organized circuit layout. Components like resistors, LEDs, and integrated circuits are soldered to the PCB, creating strong and reliable electrical and mechanical connections. Most people are already familiar with PCBs, as they are the typically green boards found inside nearly all electronic devices, from computers and mobile phones to household appliances and automotive systems, Figure 8.

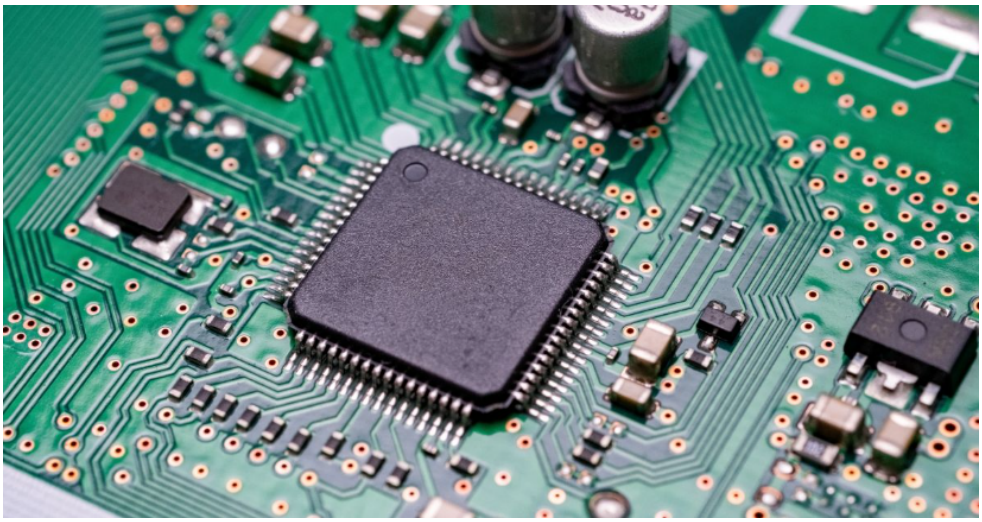


Figure 8: PCB (printed circuit board), Example.

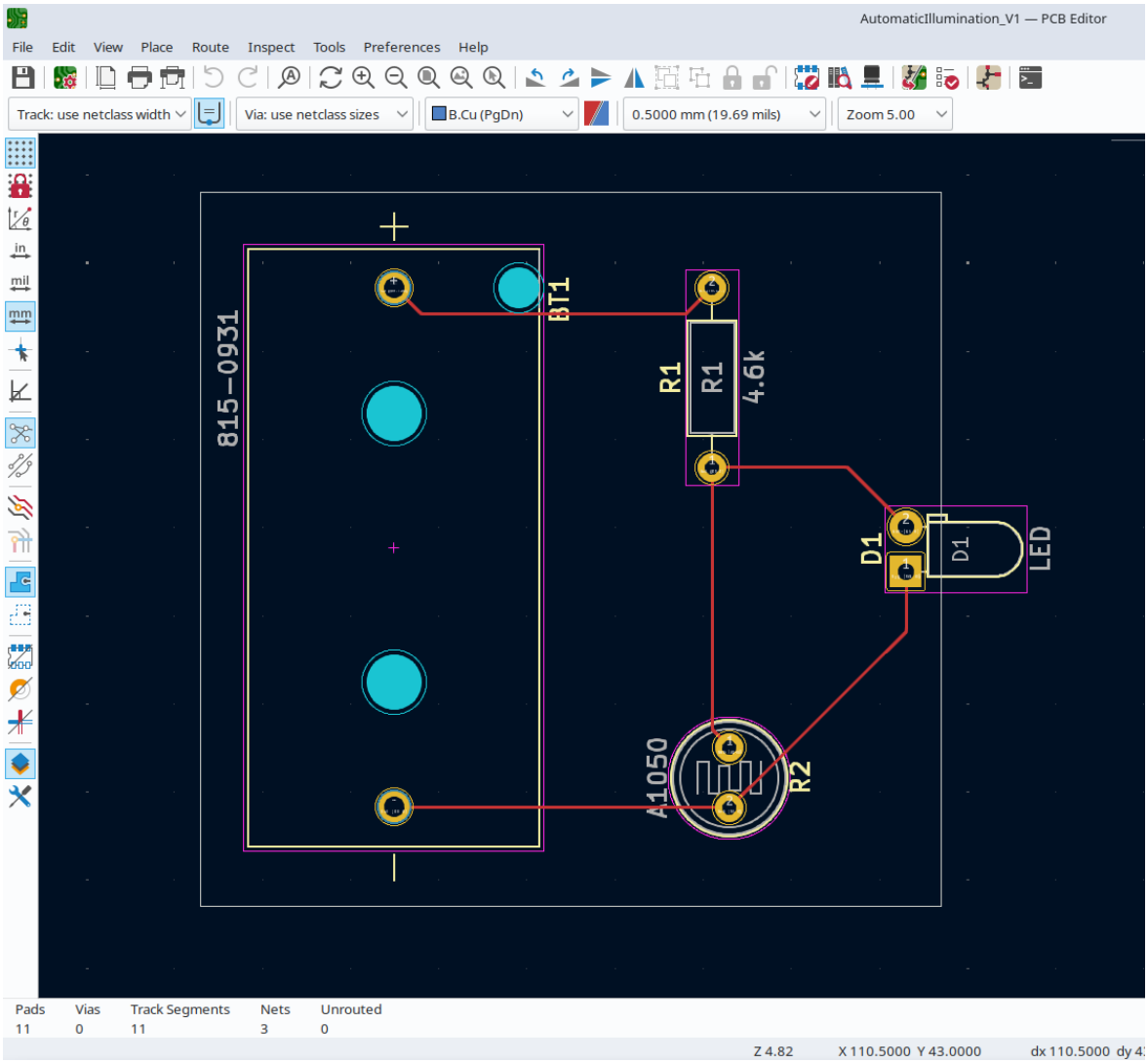
Compared to a breadboard prototype, a PCB offers several advantages: it provides higher reliability, reduced electrical noise, and improved long-term durability. It also enables mass production and miniaturization, since all connections are fixed in place and optimized for performance. In the context of this project, the LED night light circuit was first built and tested on a breadboard for experimentation and debugging, and later transferred to a PCB design for a more permanent and professional implementation.

Educational Project: Battery-powered LED Night Light

As part of the my classes in the CU Boulder / CMU Partnership Program, students were challenged to design and build a **Battery-Powered LED Night Light** circuit. This activity aimed to combine theoretical knowledge with practical circuit design skills, providing students with hands-on experience in electronics assembly and testing.

The project also served a special purpose beyond the classroom. Students designed the LED night light as a **souvenir for future students**, especially high school visitors interested in engineering. Students first built and tested the circuit on a breadboard, then transferred it to a printed circuit board (PCB) for a permanent and professional version—promoting technical learning, creativity, and teamwork within the CU Boulder / CMU Partnership Program.

The schematic diagram of the **Battery-Powered LED Night Light** is shown in Figure . It illustrates the electrical connections between the main components: a photoresistor (LDR), a fixed resistor, an LED, and the battery supply.



From the schematic diagram, a **PCB** version of the LED night light was developed. An additional challenge was introduced: students would assemble the circuit **without using soldering equipment**, relying only on a small plier. To make this possible, the PCB layout was carefully designed with **extra holes** that allowed components to be securely connected and mechanically fixed to the board by bending their leads. This creative approach ensured that students could build a functional circuit using minimal tools, while still learning about PCB design, assembly, and component placement. The final PCB layout is shown in Figure 9.

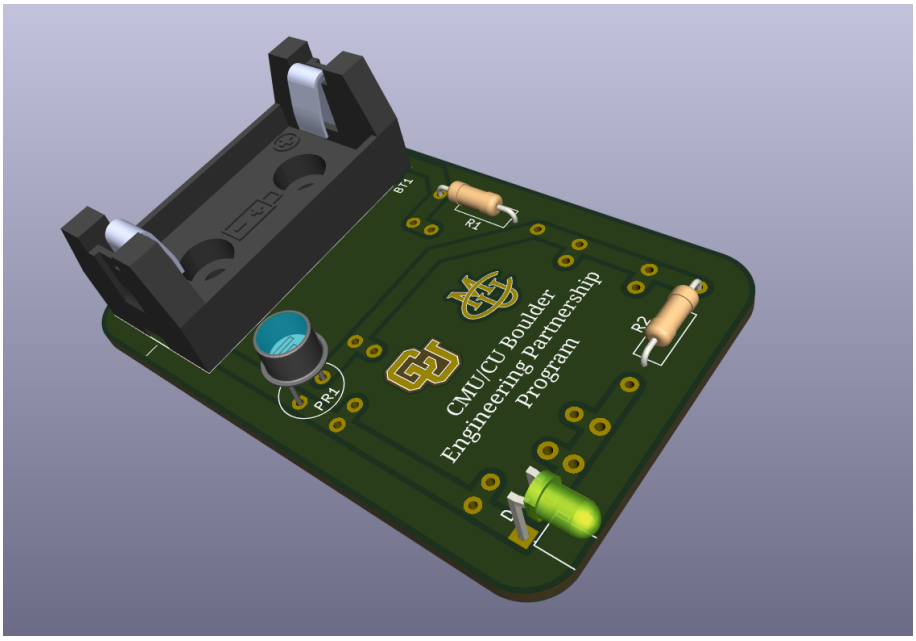


Figure 9: PCB, Battery-powered LED Night Light

Tutorial of How to Assemble the PCB

To assemble the **LED Night Light PCB**, students should carefully follow the steps below. This process was designed so that the circuit can be fully assembled using only a small plier, with no soldering required.

1. **Identify the components:**
   - Battery-powered LED Night Light PCB (Figure 9).
   - Plier (Mini Needle Nose Pliers 5")
   - 1/2 AA Size LS batteries (ER14250)
   - 220Ω resistor, for current limiting (CFS1/4CT52R221J)
     Color: Red – Red – Brown – [Gold or Silver]
   - 4.7kΩ resistor, for the voltage divider (CF1/4CT52R472J)
     Color: Yellow – Violet – Red – [Gold or Silver]
   - Red LED (754-1733-ND)
2. **Insert the resistors, photoresistor and LED:** Place the resistors into their corresponding holes on the PCB according to the color codes and the schematic. Slightly bend the resistor leads on the back side of the board to hold them in place.
3. **Insert the LED:** Place the LED into its corresponding holes on the PCB according to the color codes and the schematic.

   Slightly bend the leads on the back side of the board to hold them in place. * Remember, the LED has polarity. The flat edge indicates the **cathode (negative)**, while the rounded side corresponds to the **anode (positive)**.

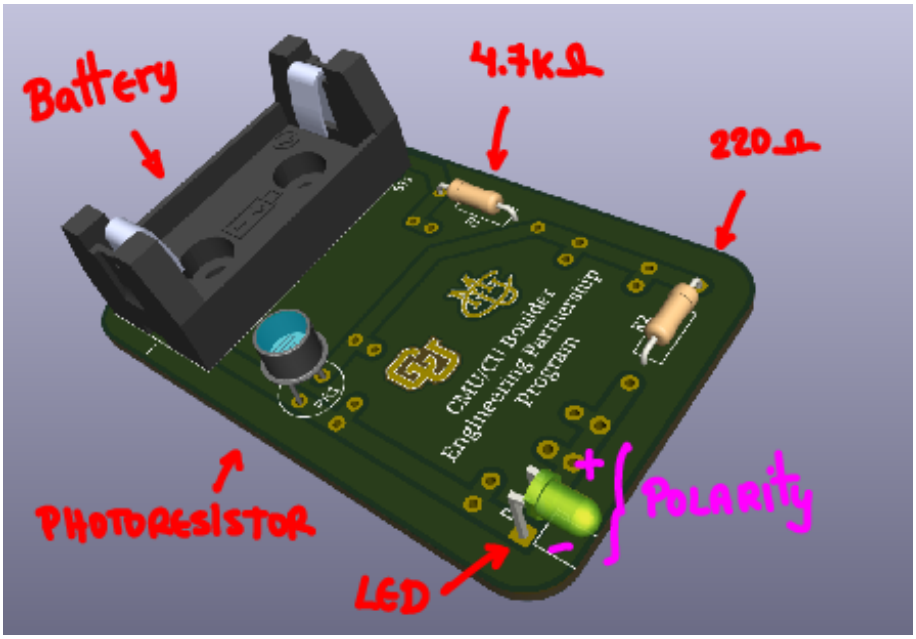


Figure 10: PCB placement, Battery-powered LED Night Light

4. **Connect the battery:** Insert the battery into the designated battery holder, matching positive ($+V$) and ground ($-V$) symbols.

5. **Test the circuit:** Cover the photoresistor or reduce the ambient light to observe the LED turning on. Gradually increase the light exposure to verify that the LED turns off when sufficient light is detected.

Figures 11-17 show step by step how to assemble the components:

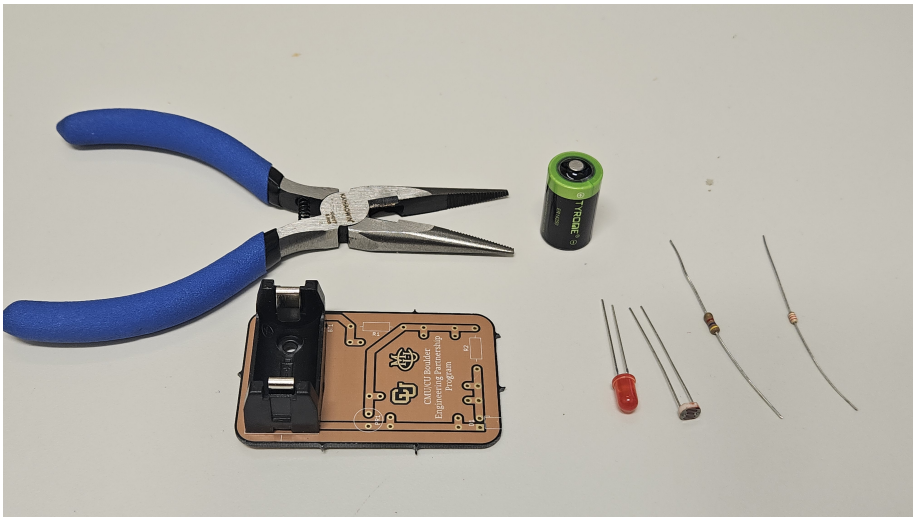


Figure 11: Battery-powered LED Night Light, components

Place 4.7kΩ resistor

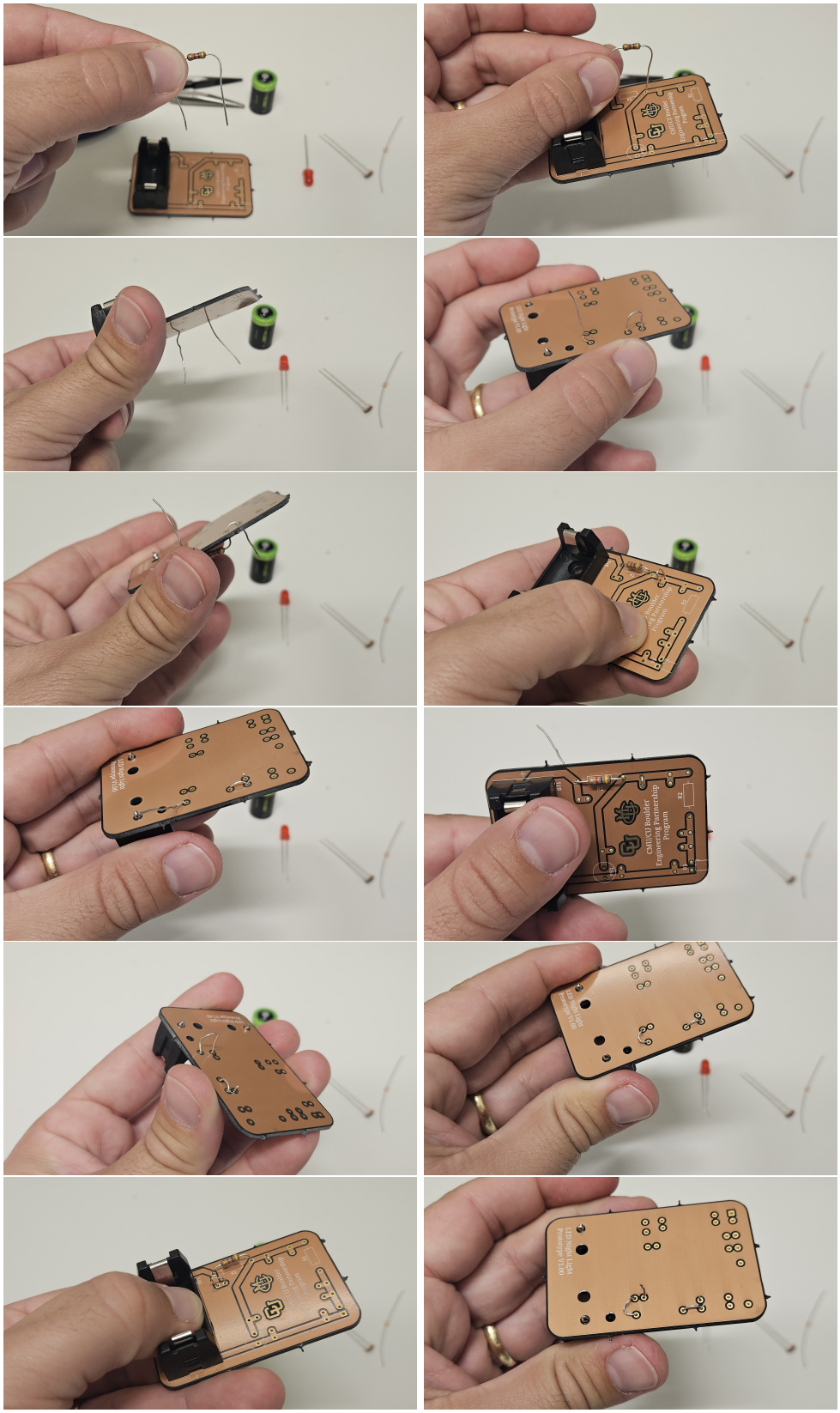


Figure 12: Step by Step. Place 4.7kΩ resistor

Place 220Ω resistor

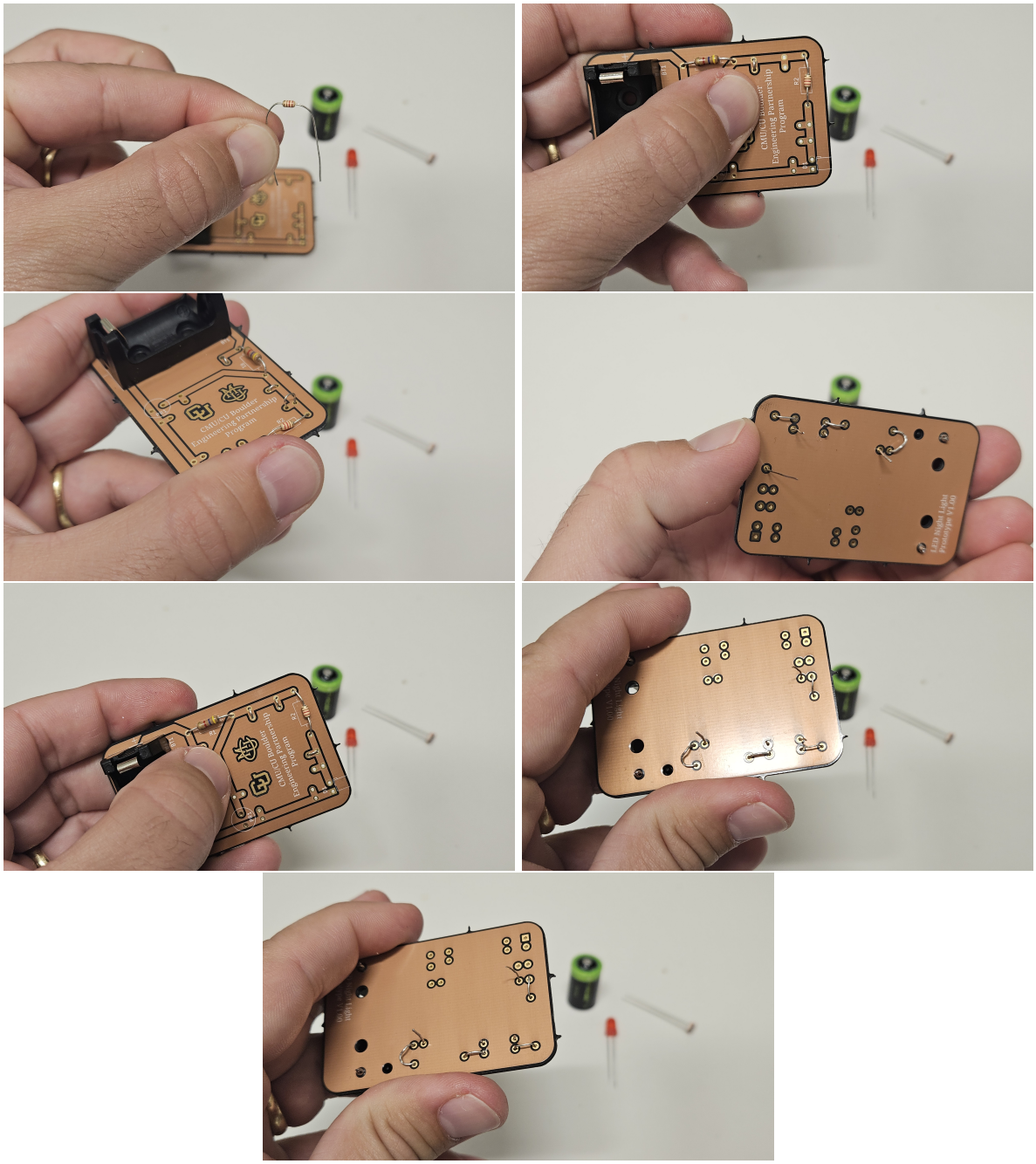


Figure 13: Step by Step. Place 220Ω resistor

Place Photoresistor

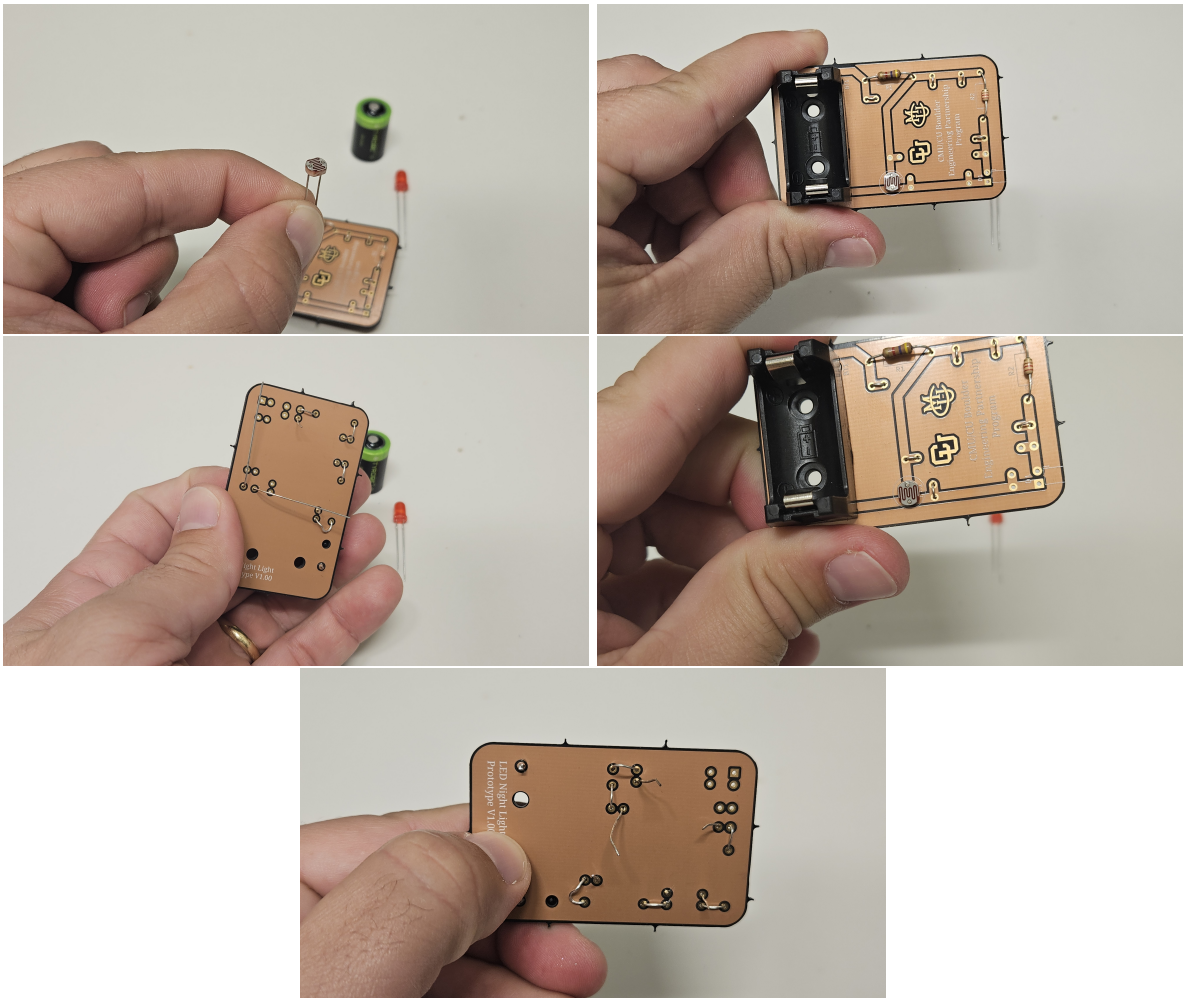


Figure 14: Step by Step. Place Photoresistor

Place LED

Figure 15: Step by Step. Place LED

Place Battery

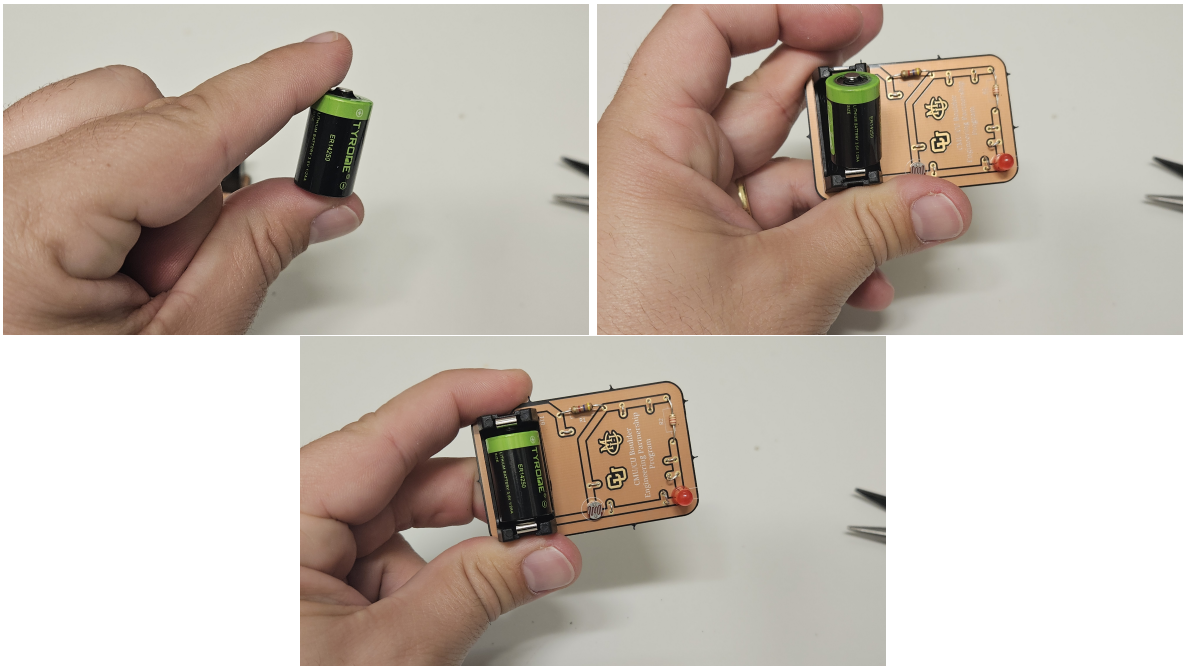


Figure 16: Step by Step. Place Battery

Testing

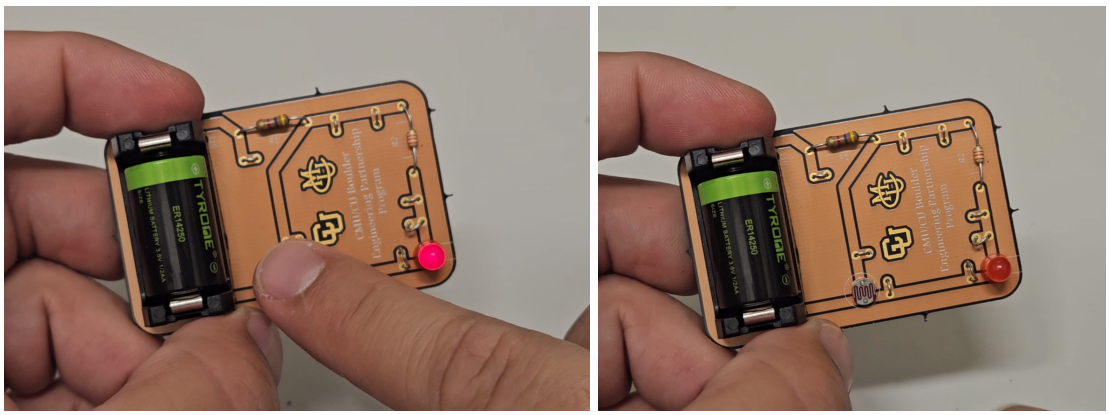


Figure 17: Step by Step. Testing

Disclaimer and Safety Notice

This activity is intended solely for educational purposes to promote hands-on learning in electronics. Follow all assembly instructions carefully, and handle tools and components responsibly. The plier used for bending and inserting components has sharp edges—use it with caution. This is not a toy, but an educational electronic device that must be used in a safe environment. Keep the circuit and components away from heat sources, moisture, and small children. The author and the CU Boulder/CMU Partnership Program are not responsible for any injury, damage, or malfunction resulting from misuse or improper handling of the materials provided.

This project encourages creativity and experimentation; however, safety remains the top priority. Always make sure that all connections are correct before powering the circuit, and avoid touching conductive parts while the battery is connected. Any modification of the original design should be done under supervision or after consulting an instructor. It is also strongly recommended to wear protective glasses during assembly to prevent injury from component leads or tool slips. Please note that safety glasses will not be provided as part of the activity. By participating in this activity, users acknowledge that they are responsible for their own safety and agree to use the materials only for instructional and non-commercial purposes.

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