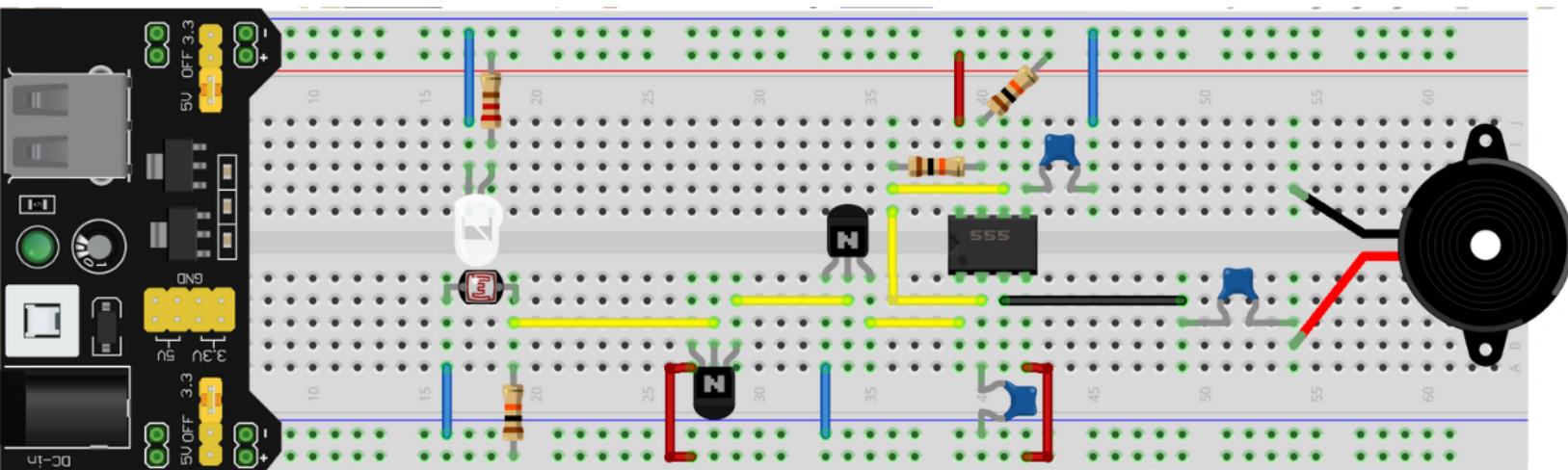


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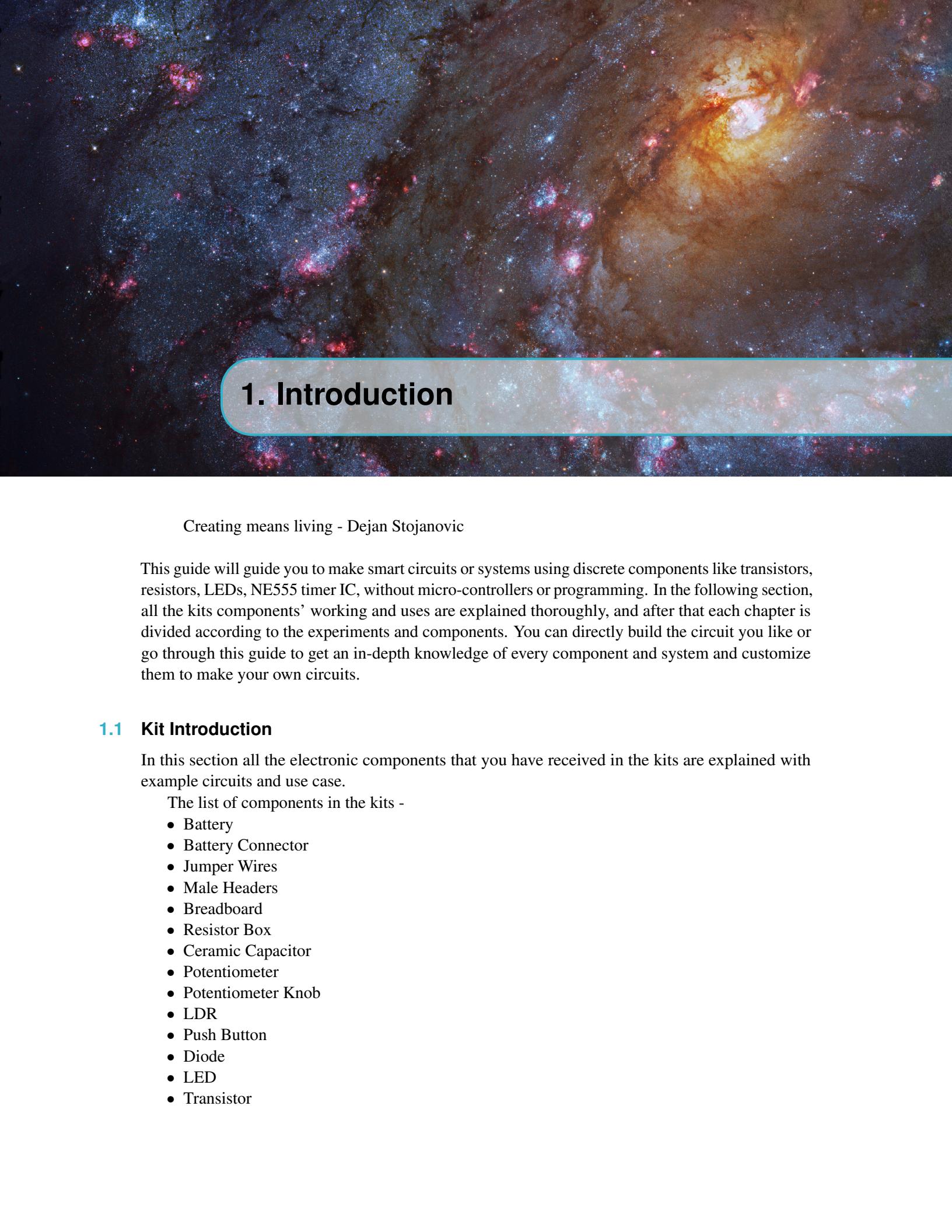
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1. Introduction

Creating means living - Dejan Stojanovic

This guide will guide you to make smart circuits or systems using discrete components like transistors, resistors, LEDs, NE555 timer IC, without micro-controllers or programming. In the following section, all the kits components' working and uses are explained thoroughly, and after that each chapter is divided according to the experiments and components. You can directly build the circuit you like or go through this guide to get an in-depth knowledge of every component and system and customize them to make your own circuits.

1.1 Kit Introduction

In this section all the electronic components that you have received in the kits are explained with example circuits and use case.

The list of components in the kits -

- Battery
- Battery Connector
- Jumper Wires
- Male Headers
- Breadboard
- Resistor Box
- Ceramic Capacitor
- Potentiometer
- Potentiometer Knob
- LDR
- Push Button
- Diode
- LED
- Transistor

- Power Supply Module
- Buzzer
- NE555 IC
- Toy Motor
- Toy Fan

1.2 Components' Introduction

1.2.1 Battery

2. Fun with LEDs

2.1 Overview

In this section you'll learn about Light Emitting Diodes (LED) and how to turn it on using different methods.

2.2 Component Introduction

Before diving into making circuits, we will first learn about the components that we are going to use and how to select the right component.

2.2.1 Resistors

Resistor is a passive electric component that resists the flow of current through it. They are used in almost all electrical and electronic circuits and systems. The resistance of a resistor is measured in ohms (Ω). An ohm is the resistance that occurs when one ampere (A) of current flows through a resistor with potential (or voltage) drop of one volt (V) across its terminal.



Figure 2.1: Resistor Symbol

Ohm's Law

Ohm's law states that the current through a resistor is directly proportional to the voltage applied across it.

$$I \propto V$$
$$\Rightarrow R = \frac{V}{I} (\Omega)$$

2.2.2 Light Emitting Diode

Light emitting diodes (LEDs) are semiconductor devices that emit lights of different wavelength depending on the substrate semiconductor material used when an electric current is applied. The color of light emitted depends on the amount of energy required by the electrons to cross the band gap of the semiconductor. Since, LEDs are basically a PN junction diode, they allow current flow only in one direction.



Figure 2.2: LED Symbol

Determining the pins of the LED

There are multiple ways to determine the anode and cathode of an LED:

1. Looking at the LED pins (or legs). The longer leg is anode and the shorter cathode. But sometimes the legs could be trimmed, therefore, you can use this method for new LEDs only.
2. Locate a flat edge on the LED. The pin close to flat edge is cathode.
3. By looking inside the LED, the bigger conductor (flag shaped) is the cathode.
4. By using multi-meter in continuity mode, only in one direction the LED will turn on (or the resistance in one direction will be smaller than in the other).

2.2.3 Breadboard

A breadboard is a rectangular plastic board with a bunch of tiny holes in it. There's strip of metal inside the plastic. Most through hole components have pin spacing of 2.54mm, therefore, the holes have the same spacing between them. You can easily insert electrical components in these holes. There is also a deep groove in the middle, indicating the break in the connection. Some breadboard have two strips of holes (also called rails) along the long edges of the breadboard. They are used for power rails, with strip of metal inside.

A breadboard is used to prototype an electronic circuit. The connection on breadboard are not permanent and can be removed easily. This makes breadboard great for beginners who are new to electronics but the connections are not as reliable as soldered connections.

2.2.4 Breadboard Power Supply

A power supply is a hardware component that provides electricity to power devices like computer, fridge, lights and much more. The breadboard power supply of type linear DC to DC. A linear power supply has two major components, a linear regulator and filtering capacitors.

The breadboard power supply can provide constant 3.3V or 5V and is compatible with the breadboard power rails, i.e., you can directly plug in on top of the breadboard to have voltage across the power rails. The input voltage or power can be provided through the DC barrel jack (for 6-12V) or through the USB connector (5V).

Calculating power dissipation

To calculate the power dissipation across the voltage regulator, we need to determine the output current. For linear regulator the input and output current remains same and the power difference is dissipated through the voltage regulator.

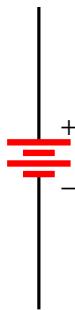


Figure 2.3: Battery Symbol

Example: We need 200mA current at 3.3V output, and the input power supply is of 9V. Then,

$$P_{out} = 3.3V \times 0.2A = 0.66W$$

$$P_{in} = 9V \times 0.2A = 1.8W$$

$$P_{reg} = P_{in} - P_{out}$$

$$= 1.8 - 0.66$$

$$= 1.14W$$

$$\eta = \frac{P_{out}}{P_{in}} \times 100$$

$$= 36.67\%$$

2.2.5 Push Button

Push button is used to control or provide input to the circuit. It is normally open and only when you press it the current will flow through it. And when released, the current will stop flowing. Push button have mechanical contacts, so when you press or release it, it doesn't instantaneously make or release contact. It bounces back and forth before making a firm connection.



Figure 2.4: Push Button Symbol

2.2.6 Potentiometer

A potentiometer (pot) is a variable resistor and comes in different packages, size and values. They generally have 3 terminals. And the resistance between the outer most terminals is equal to the maximum resistance of the potentiometer and the resistance between middle and any outer pin can vary from 0 to the total resistance of potentiometer.



Figure 2.5: Potentiometer Symbol

2.2.7 Circuit

A circuit is a closed loop that provides path for current to flow. Circuit must have a path that start and end at the same component, or in other words must form a loop. Electronic circuits operate at low voltages.

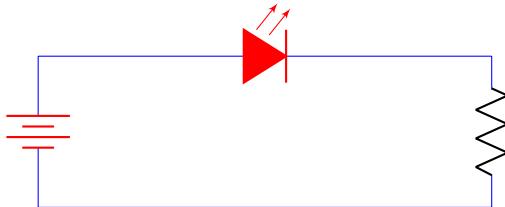


Figure 2.6: Simple Circuit

A circuit has broadly the following components -

- Power source/supply
- Load (Light, led, motor etc)
- Pathwire (conductive path providing current flow)

Apart from these, a circuit can have more complex design.

2.3 Lesson 1: Lighting up an LED

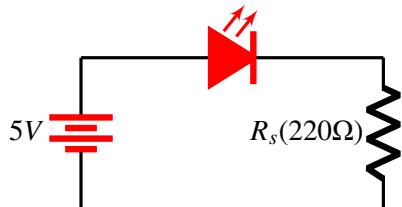
2.3.1 Objective

In this activity you'll learn how to turn on an LED

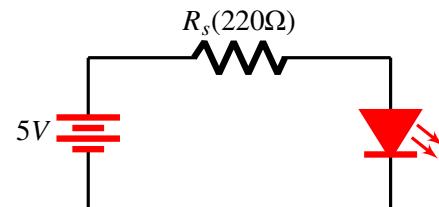
2.3.2 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 5mm Red LED × 1
6. 220Ω resistor × 1
7. Male to Male Jumper Wires × 2

2.3.3 Circuit



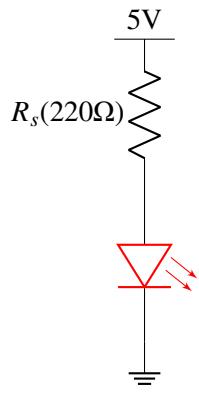
(a) Circuit A



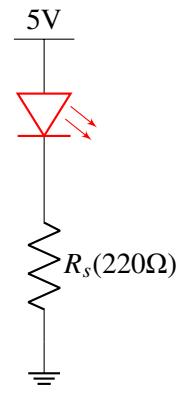
(b) Circuit B

Figure 2.7: Simple LED Circuits

Throughout this guide we'll be using these symbols for power supply.



(a) Circuit A



(b) Circuit B

Figure 2.8: Simplified LED Circuits

2.3.4 Circuit Explanation

If we look at the graphs in the datasheet of RED led[Sem13], the forward current through the led (I_F) is typically in between 10 mA to 20 mA and the voltage drop (V_F) across it is 2 V. If we directly

connect the LED across 5 V supply it will burn out due to excessive power. Therefore, we need a resistor in series with the LED to drop the voltage. This resistor is referred as the current-limiting resistor. If you look at the figure 2.7 both the circuits A & B are same because in series circuits the current remains same across all the components.

To calculate the series resistance (R_S) we'll use Ohm's law: We'll take the average value for I_F

$$V = I \times R$$

$$\begin{aligned} R_S &= \frac{V_{5V} - V_F}{I_F} \\ &= \frac{5V - 2V}{15mA} \\ &= \frac{3 \times 1000}{15} \\ R_S &= 200\Omega \end{aligned}$$

Since, in the kit a 220Ω is available, we will use that. If we calculate the current using a 220Ω resistor, it will $3 \div 220 = 0.0136A = 13.6mA$ which is in the range provided by the datasheet.

2.3.5 Circuit Picture

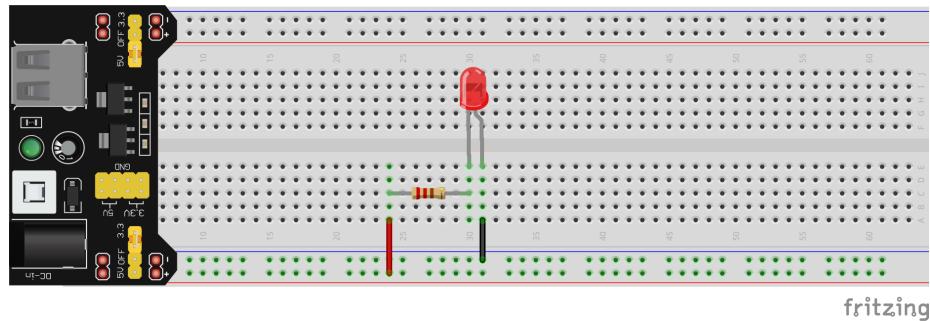


Figure 2.9: Simple Circuit on Breadboard

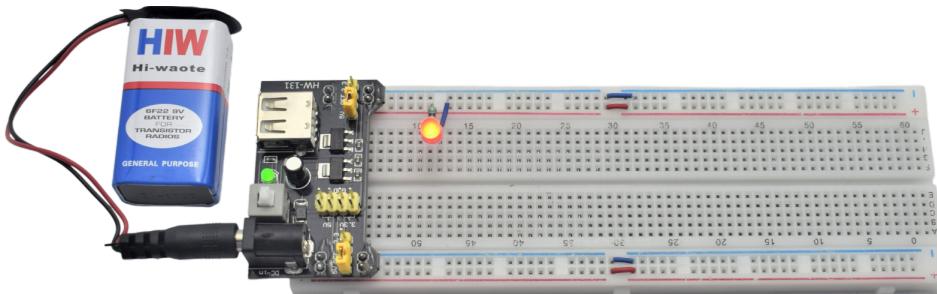


Figure 2.10: Simple Circuit on Breadboard

2.4 Lesson 2: Lighting up an LED by pressing a Switch

2.4.1 Objective

In this activity we'll turn on the led using a push button.

2.4.2 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 5mm Red LED × 1
6. 220Ω resistor × 1
7. Male to Male Jumper Wires × 2
8. Push Button × 1

2.4.3 Circuit

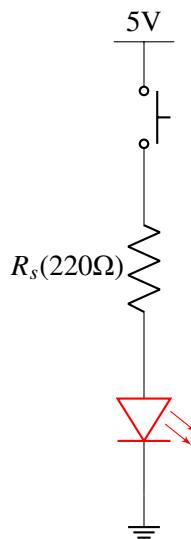


Figure 2.11: Push Button Circuit

2.4.4 Circuit Explanation

This circuit is similar to the one we made previously, except for the fact that we have a push button in series. The button is normally open, meaning no current flows through the circuit (no complete loop or path) and when we press the button the path is complete and LED will turn on.

2.4.5 Circuit Photo

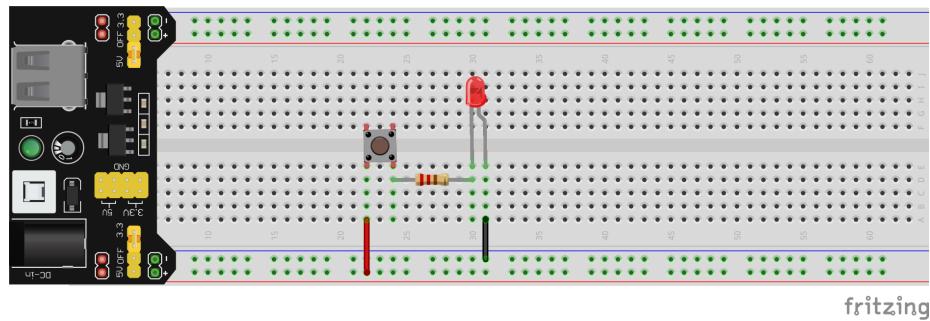


Figure 2.12: Circuit Schematic

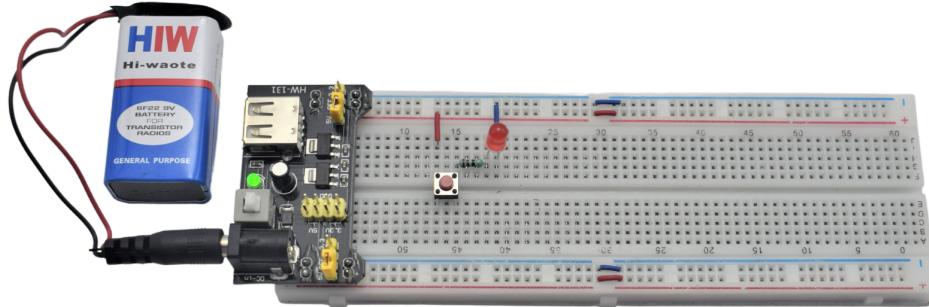


Figure 2.13: LED Off, Switch Open

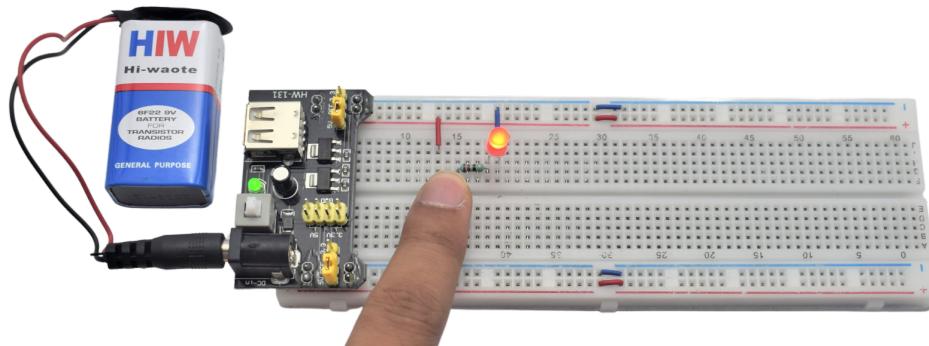


Figure 2.14: LED On, Switch Closed/Pressed

2.5 Lesson 3: Controlling LED brightness using a Potentiometer

2.5.1 Objective

In this activity, we'll control the LED brightness/intensity with help on a potentiometer.

2.5.2 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 5mm Red LED × 1
6. 220Ω resistor × 1
7. Male to Male Jumper Wires × 2
8. Potentiometer × 1

2.5.3 Circuit

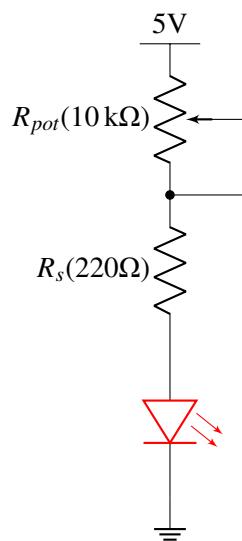


Figure 2.15: Potentiometer LED Circuit

2.5.4 Circuit Explanation

When the potentiometer resistance R_{pot} is 0Ω , the LED will be in series with R_s and glow. As we'll increase the resistance of potentiometer the effective series resistance will increase $R_t = R_s + R_{pot}$. With increase in the series resistance, the current through the circuit will decrease according to the Ohm's law ($I \propto \frac{1}{R}$) changing the intensity of the LED.

2.5.5 Circuit Picture

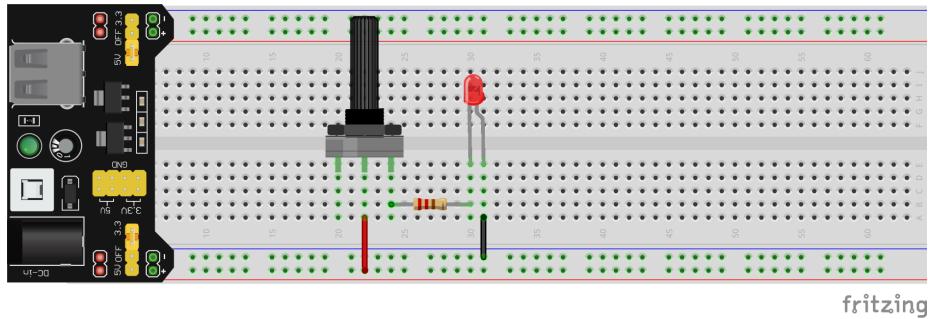
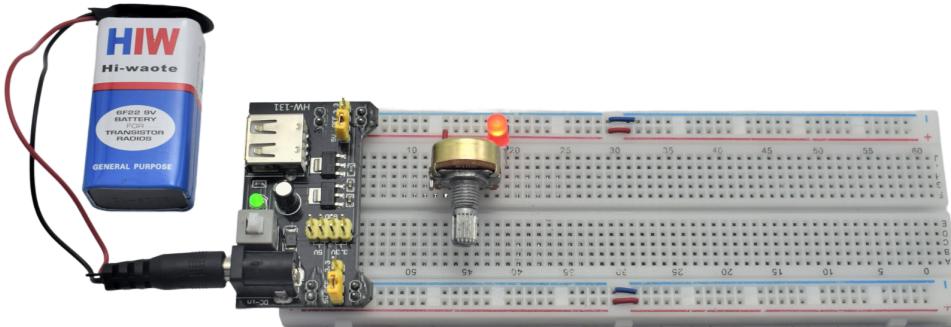
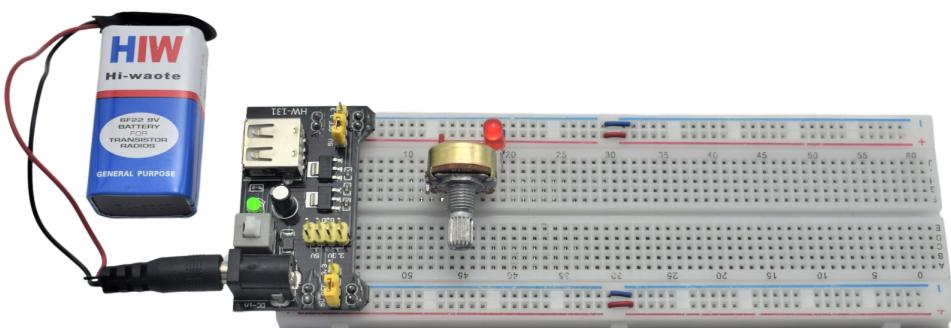


Figure 2.16: Circuit Schematic

Figure 2.17: Max Intensity, $R_{pot} = 0$ Figure 2.18: Min Intensity, $R_{pot} = 10k\Omega$

2.6 DIY: Activities

- Calculate series resistance for RED led using 3.3V power supply



3. Transistors

3.1 Overview

In this section you'll learn about Light Emitting Diodes (LED) and how to turn it on using different methods.

3.2 Component Introduction

In this chapter we will be using transistor to make electronic circuits. There are different types of transistors available but we will be using bipolar junction transistor (BJTs) only. BJTs are the most common transistor type used among the hobbyists and DIYers.

3.2.1 BJT

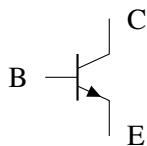
A transistor is a semiconductor device with 3 terminals or regions. The interface between each of the regions forms a p-n junction, it likes two diodes together. There are two types of BJTs - NPN, when a p-type semiconductor is in-between two n-type. PNP, when a n-type semiconductor is in-between two p-type. Transistors are used to amplify or switch electronic signals and electrical power. Each of the terminals or regions are named -

- Collector: The largest semiconductor region of the transistor.
- Emitter: The second largest semiconductor region of the transistor.
- Base: Middle region of the transistor. This serves as a gatekeeper that determines the amount of current that can flow through emitter-collector regions.

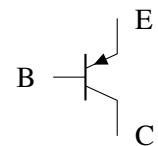
Operation Modes for Transistor

There are 4 modes in which a transistor works -

1. **Cut-off** In cut-off mode no current flows through the transistor. The transistor acts like an open circuit.
2. **Saturation** In saturation mode the transistor allows current to flow freely and acts like an short-circuit.



(a) NPN



(b) PNP

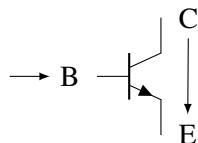
Figure 3.1: Transistor Symbol

3. **Active** In active mode the amount of current flowing through the collector-emitter region is proportional to the current flowing through base.
4. **Reverse-Active** It is similar to active mode, but the direction of current is reversed. The transistors are not meant to operate in Reverse-Active mode.

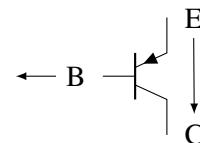
If we make sure that the transistor operates in only cut-off or saturation region, then it can act like a switch turning current flow ON or OFF by controlling the base voltage. In this guide most of the circuits will use transistor in Saturation & cut-off mode.

In NPN transistor, the base voltage should be higher than the emitter voltage by threshold voltage V_{th} , defined in the datasheet of the transistor. Generally it is near about 0.7 V.

For PNP, the base voltage should be lower than the emitter voltage by V_{th} .



(a) NPN



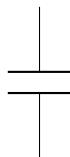
(b) PNP

Figure 3.2: Direction of Conventional current in BJTs

For both the transistors, $I_E = I_C + I_B$

3.2.2 Capacitor

Capacitor is a pretty simple electronic device. It consists of two conductive plates separated by an insulated medium called dielectric. Capacitors when powered are able to store energy in the form of electric field between the two plates. With different types of dielectric, there are different types of capacitors and have different qualities and uses. Capacitors can be polarized when dielectric used is polarized and favours electric field in one direction. The value of capacitor is measured in Farads



(a) Non Polarized



(b) Polazired

Figure 3.3: Capacitor Symbol

(F), and one farad is a very big value. *The capacitance of earth is 710 μ F.*

Capacitors or Caps are used in many ways and can be found in almost every electronic circuits. On Polar capacitors the exact values are written on the body, for ceramic capacitor the value is written with 2 significant digits and 1 multiplier, for example capacitance of a ceramic capacitor with 105 written on it is, $10 \times 10^4 \text{ pF} = 1 \times 10^5 \times 1 \times 10^{-12} \text{ F} = 1 \times 10^{-7} \text{ F} = 0.1 \mu\text{F}$

3.2.3 LDR

Light Dependent Resistor(LDR) or photocell or photoresistor is a semiconductor device which exhibits a very special property, it acts like a resistor but the value of resistance depends on the amount of light falling on it.

In bright light, the LDR resistance will be in the range of 0.01-10k Ω and in darkness it's resistance will be in the range of 100-1000k Ω .

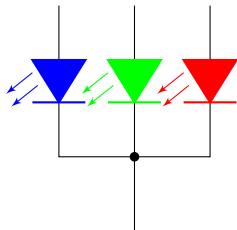


Figure 3.4: LDR Symbol

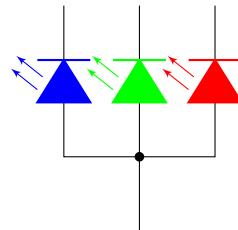
3.2.4 RGB LED

RGB LED is a combination of all three LEDs (RED, GREEN, BLUE) in one single package. You can produce different colors using RGB LEDs by configuring the intensity of each LED.

There are two kinds of RGB LED, one shares the cathode pin and the other shares the anode pin.



(a) Common Anode



(b) Common Cathode

Figure 3.5: RGB LED Symbol

3.3 Lesson 4: Astable Multivibrator

3.3.1 Objective

In this activity, we will make an astable multivibrator using BJTs and flash two LEDs.

3.3.2 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. Red LED × 2
6. 220Ω × 2
7. $100\text{k}\Omega$ × 2
8. 2N2222 NPN Transistor × 2
9. $10\mu\text{F}$ × 2
10. Male-Male jumper wire × 6

3.3.3 Circuit

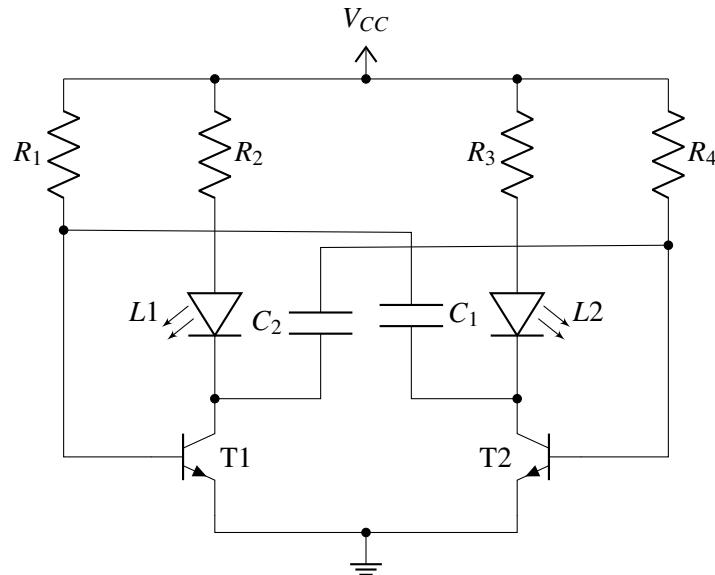


Figure 3.6: Astable Multivibrator

3.3.4 Circuit Explanation

Let's assume that T_1 has just turned off and T_2 has just turned on which means C_2 is fully charged and C_1 is discharged. Since, T_1 is in cut-off mode, the collector $T_{1,C}$ will rise to V_{cc} potential and the potential across the C_2 capacitor will be $V_{cc} - V_{th}$, where V_{th} is the threshold voltage of transistors.

T_2 is fully on, the capacitor C_1 will start charging through resistor R_1 and the LED_1 will be turned on. When the plate of C_1 connected to base of T_1 rises to potential V_{th} it will pull T_1

into conduction and then saturation mode. When the transistor T_1 is in saturation mode it will immediately pull the capacitor C_1 to ground, this rapid change in voltage at the plate of capacitor C_1 connected to $T_1.C$ causes an equal and instantaneous fall in voltage at the plate connected to base of T_2 , turning it hard off. Now T_1 is On turning LED_1 on and T_2 is off and the same cycle repeats again, C_2 starts charging turning T_2 on and C_1 turning T_1 off.

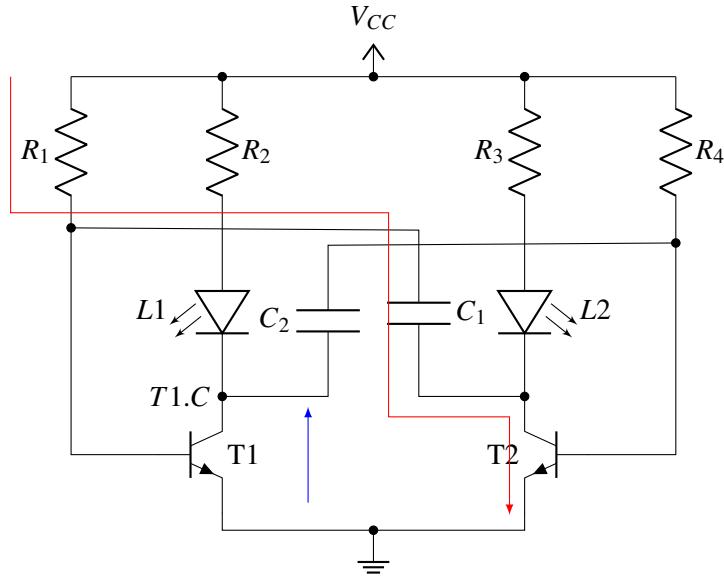


Figure 3.7: T1 off, T2 on

The time period or frequency of oscillation for astable multivibrator can be calculated using the below equations -

$$t_1 = 0.693 \times R_1 \times C_1$$

$$t_2 = 0.693 \times R_4 \times C_2$$

where, t_1 & t_2 are charging and discharging time period for the capacitors.

For symmetrical astable multivibrator $R_1 = R_2$ and $C_1 = C_2$.

The total time period is -

$$T = t_1 + t_2$$

$$T = 0.693RC + 0.693RC$$

$$T = 1.386RC$$

In our circuit we will use $R_2 = R_3 = 220\Omega$, $R_1 = R_4 = 100k\Omega$ and $C_1 = C_2 = 10\mu F$.

By changing the values of series RC we have change the time period of oscillation.

3.3.5 Circuit Picture

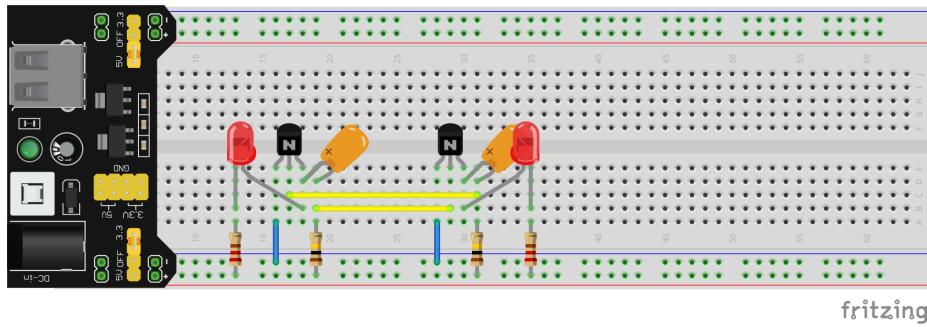


Figure 3.8: Circuit Schematic

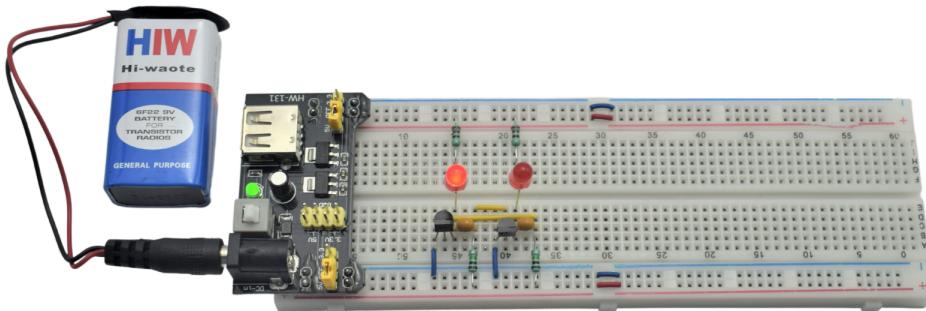


Figure 3.9: Astable Multivibrator on Breadboard

3.4 Lesson 5: Transistor as Touch Sensor

3.4.1 Objective

In this activity we will build a very basic touch sensor using transistors.

3.4.2 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. Red LED × 1
6. 220Ω × 1
7. $10k\Omega$ × 1
8. 2N2222 NPN Transistor × 2
9. Male pin header × 2
10. Male-Male jumper wire × 5

3.4.3 Circuit

3.4.4 Circuit Explanation

By default both the transistors are turned off. When you touch the male pin headers connected between VCC and the base of T1, your body acts like a resistor between them, allowing a very small

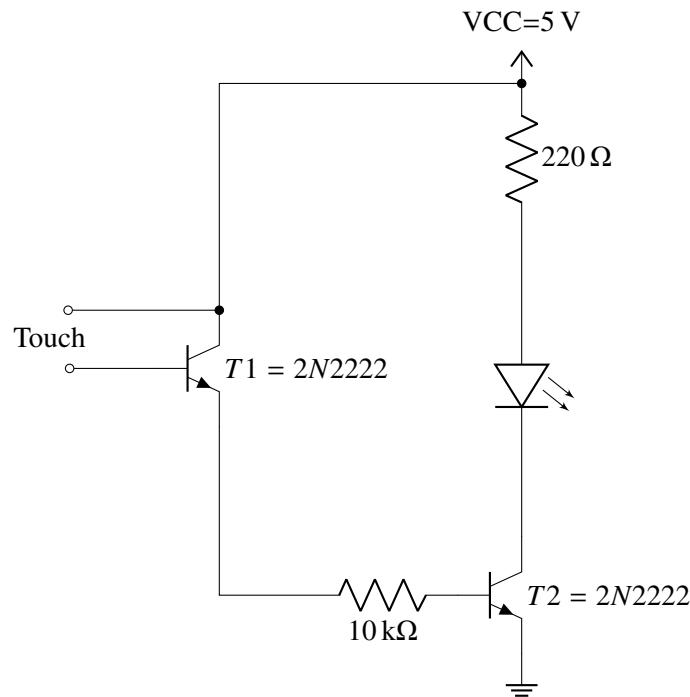


Figure 3.10: Transistors as Touch Sensor

current(I_{B1}) to pass through the base of $T1$. This current is not sufficient to push $T1$ into saturation.

Therefore, we have connected the base of $T2$ to the emitter of $T1$ and the base current(I_{B2}) for $T2$ is approximately equal to the collector current(I_{C1}) of $T1$, which is $\beta \times I_{B1}$. This current is sufficient to pull the $T2$ transistor into saturation mode and the LED turn on.

3.4.5 Circuit Picture

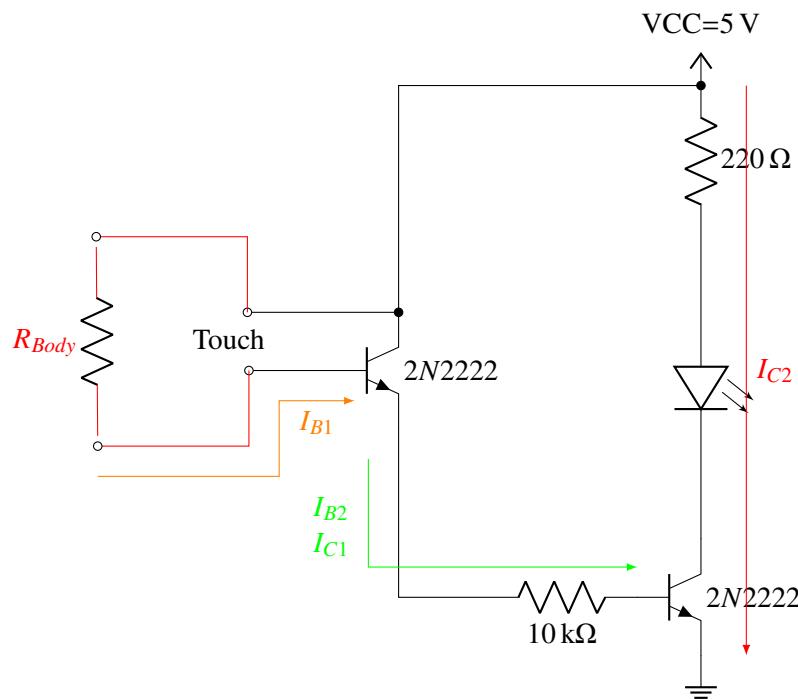


Figure 3.11: Touch Sensor Working

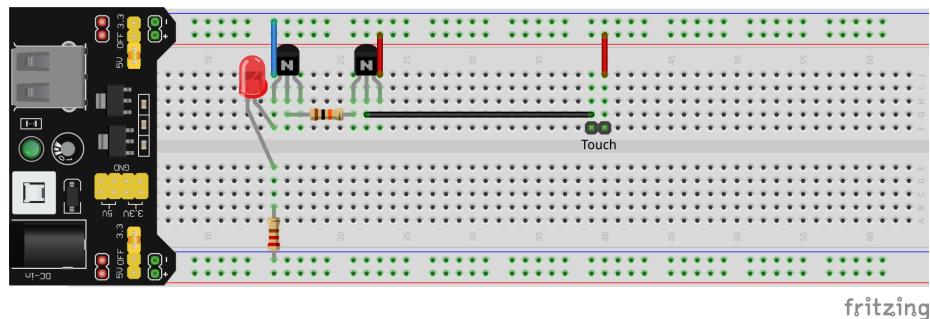


Figure 3.12: Circuit Schematic

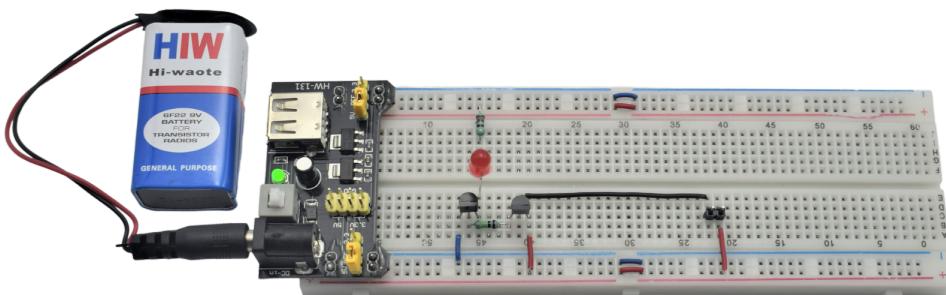


Figure 3.13: Touch Switch on Breadboard

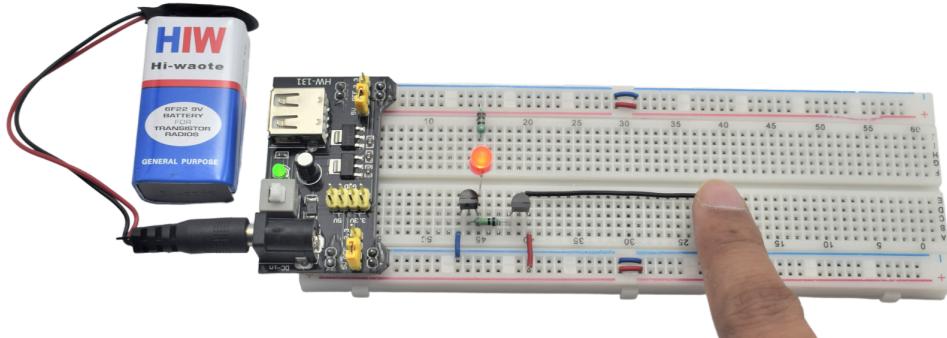


Figure 3.14: Touch Switch on Breadboard - LED glows on touching the pin headers

3.5 Lesson 6: Flip Flop

3.5.1 Objective

In this activity we'll use transistors and push buttons to make a flip flop circuit.

3.5.2 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. Red LED × 2
6. 1 kΩ × 2
7. 100 kΩ × 2
8. 2N2222 NPN Transistor × 2
9. 10-XX Push Buttons × 2
10. Male-Male jumper wire × 8

3.5.3 Circuit

3.5.4 Circuit Explanation

Let's assume that L_1 is on, which means there is a very small amount of current flowing through the L_2 to the base of transistor T_1 . The current flowing through L_1 will prefer to go through the transistor T_1 because this path offers the least resistance.

Now, when we press the button B_1 the current going to the base of T_1 will now directly go to the ground, switching T_1 off. And there will be a small current going through the led L_1 to the base of transistor T_2 , pushing it into saturation. And when we leave the button B_1 the current through L_2 will go through T_2 only, as it will offer a path with least resistance.

3.5.5 Circuit Picture

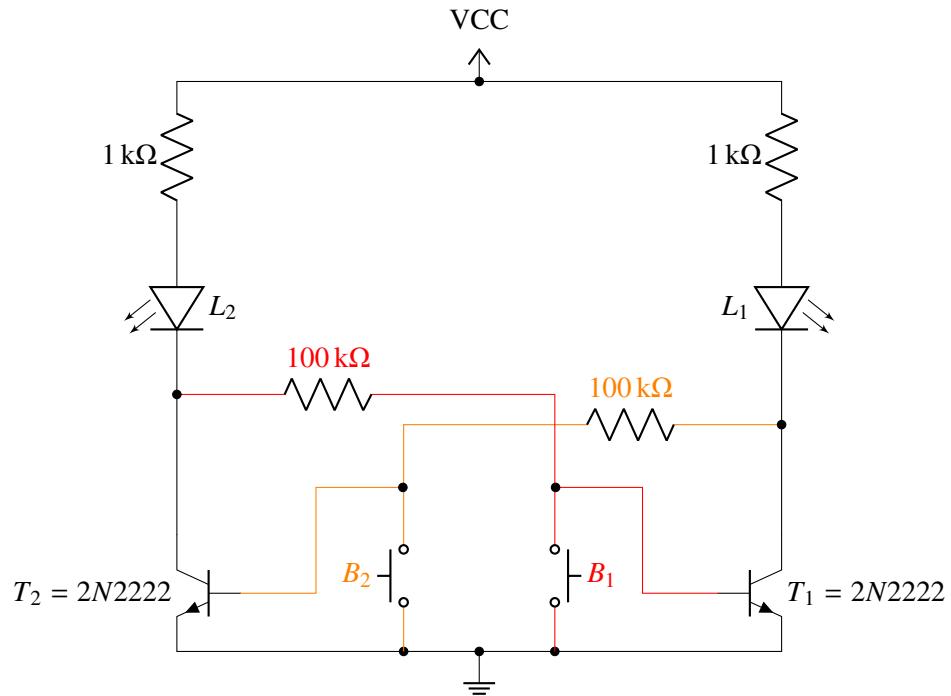


Figure 3.15: Flip Flop

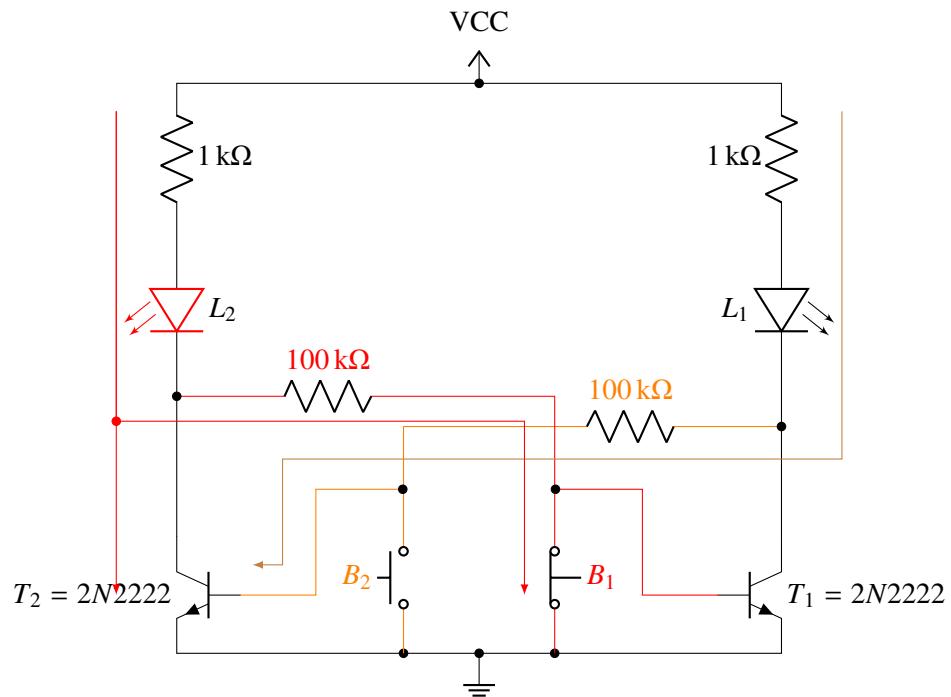


Figure 3.16: Flip Flop Working

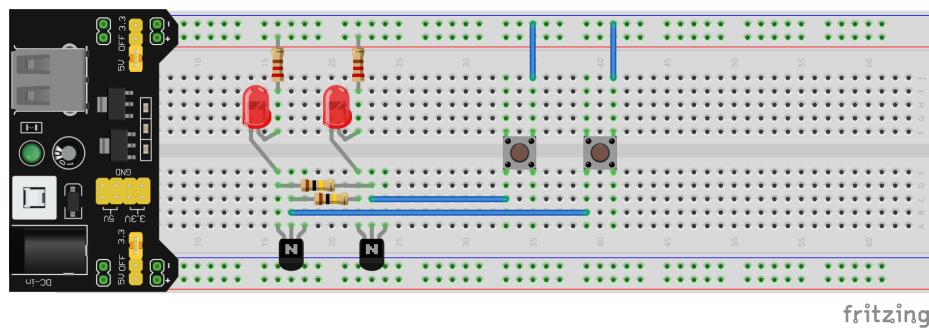


Figure 3.17: Circuit Schematic

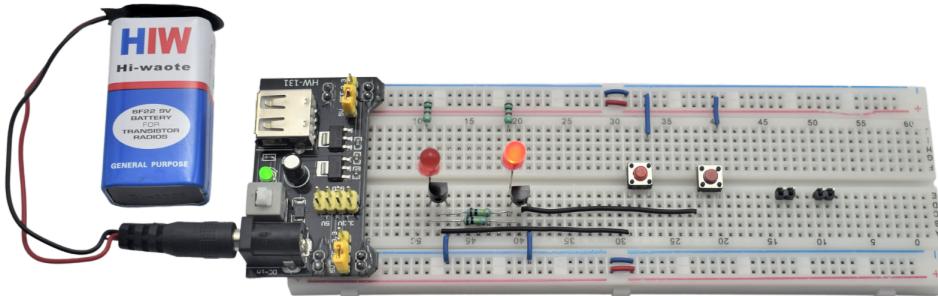


Figure 3.18: Flip/Flop using BJTs on Breadboard

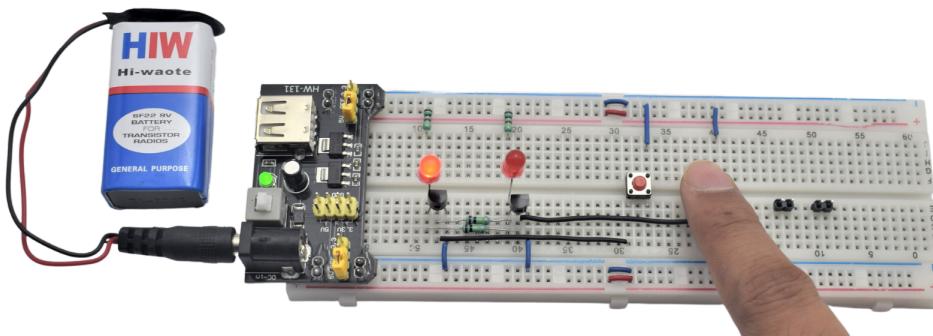


Figure 3.19: Flip/Flop using BJTs on Breadboard

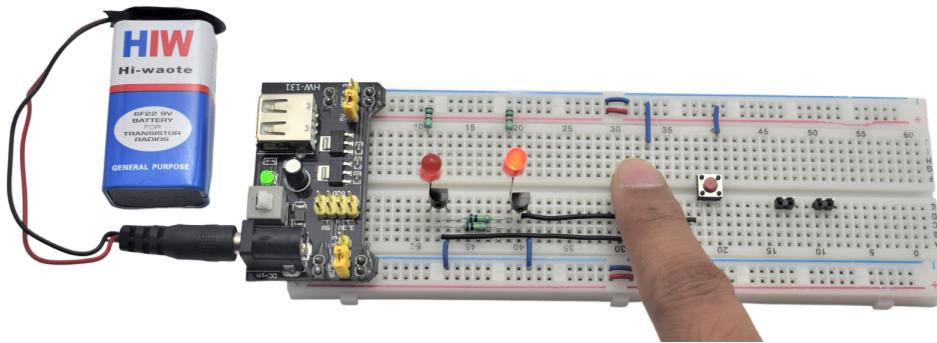


Figure 3.20: Flip/Flop using BJTs on Breadboard

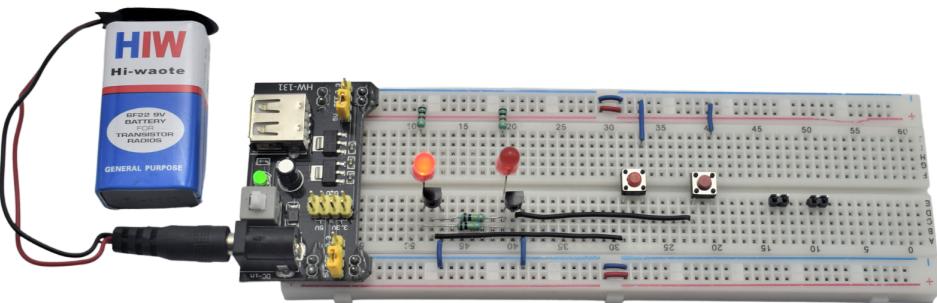


Figure 3.21: Flip/Flop using BJTs on Breadboard

3.6 Lesson 7: On/Off Touch using Transistors

3.6.1 Objective

In this activity we will make an on off touch switch using transistors, which will remember its state.

3.6.2 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. Red LED × 1
6. 220Ω × 1
7. $10k\Omega$ × 1
8. $100k\Omega$ × 1
9. 2N2222 NPN Transistor × 3
10. 2N2907 PNP Trsnsistor × 1
11. Male pin headers × 4
12. Male-Male jumper wire × 13

3.6.3 Circuit

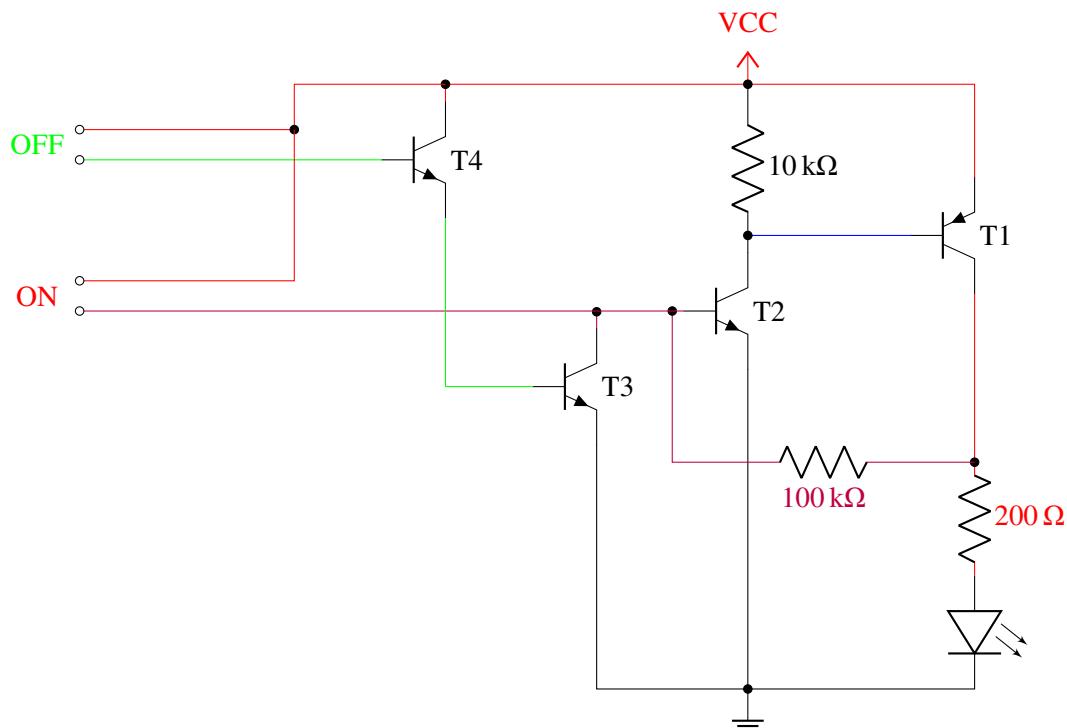


Figure 3.22: On/Off Touch Switch using Transistors

3.6.4 Circuit Explanation

When we touch the pin headers marked *on*, we introduce our body resistance between VCC and base of transistor $T2$, turning it on. When $T2$ is turned on, it pulls the base of transistor $T1$ to ground, pushing it to saturation mode. A small part of the current flowing through the collector of $T1$ goes to the base of $T2$ through feedback resistor. Now, when we remove our body resistance from the circuit the current through feedback keeps $T2$ on, which make sure the $T1$ is on and the led is glowing.

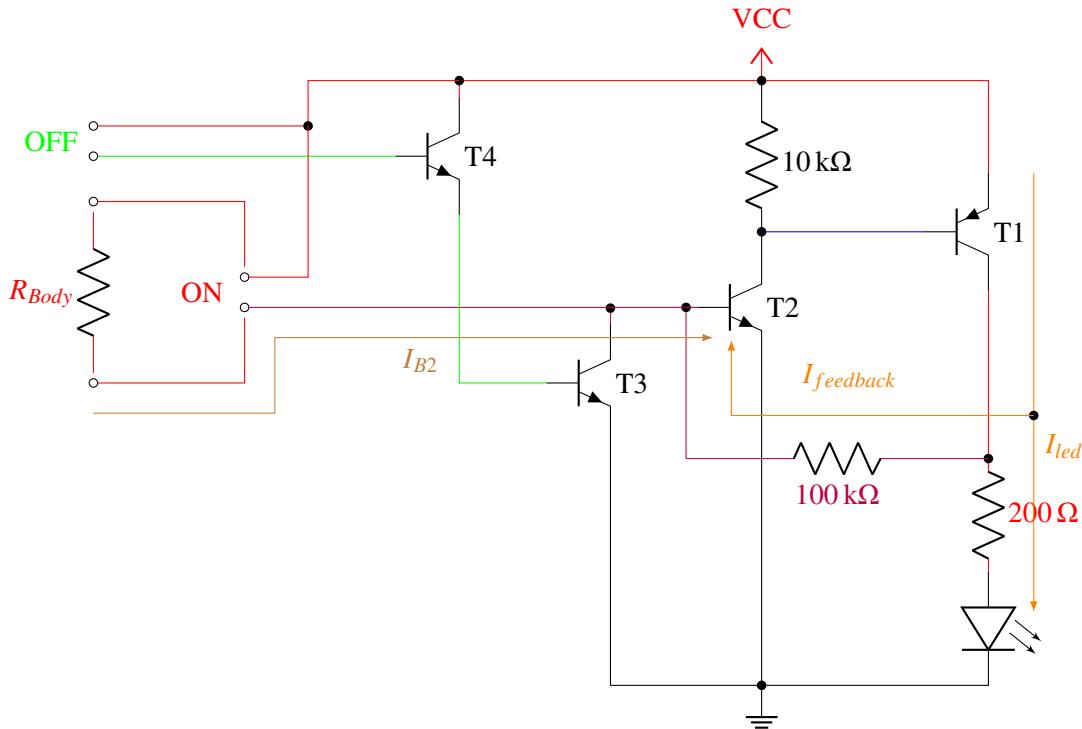


Figure 3.23: Touch Switch using Transistors - On State

Now, when we touch the pin header marked *off*, we introduce our body resistance in between the VCC and the base of $T4$, turning it on. The $T4$ collector current goes to the base of $T3$, turning it on. There are two things that causes the led to turn off, base of $T2$ is pulled to ground, and the feedback current keeping it on goes to ground via $T3$. It means $T2$ is switched off, and when $T2$ is off the base of $T1$ is pulled high, turning it hard off.

3.6.5 Circuit Picture

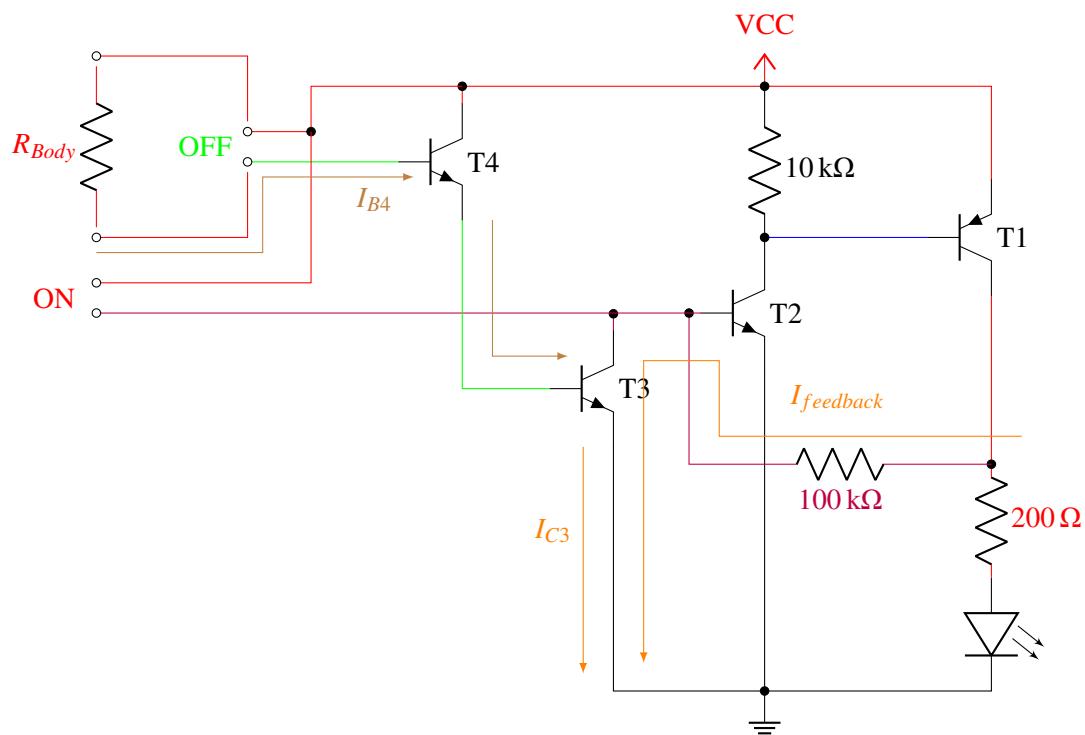


Figure 3.24: Touch Switch using Transistors - Off State

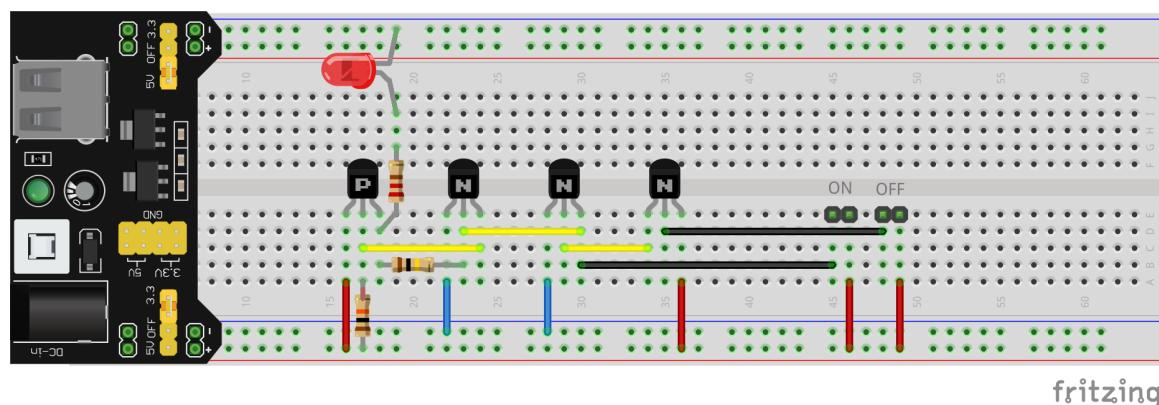


Figure 3.25: On/Off touch switch using BJTs on Breadboard

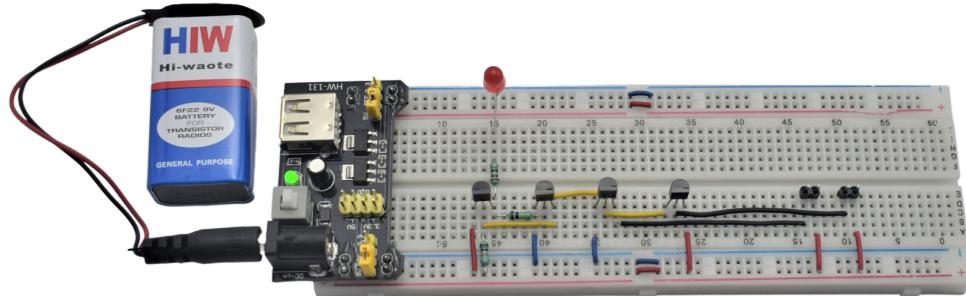


Figure 3.26: On/Off Touch Switch:

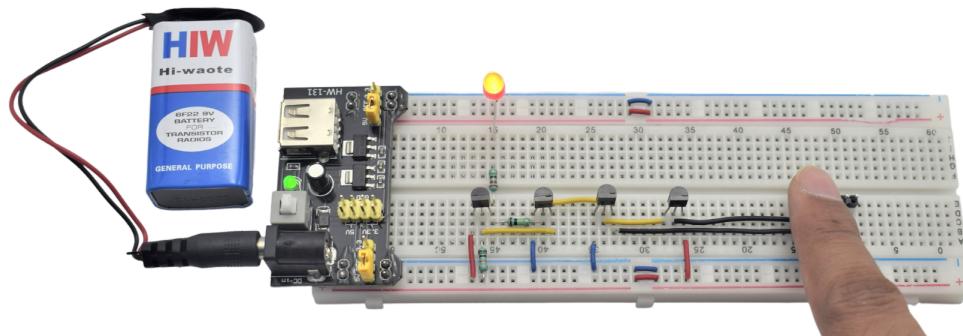


Figure 3.27: On/Off Touch Switch:

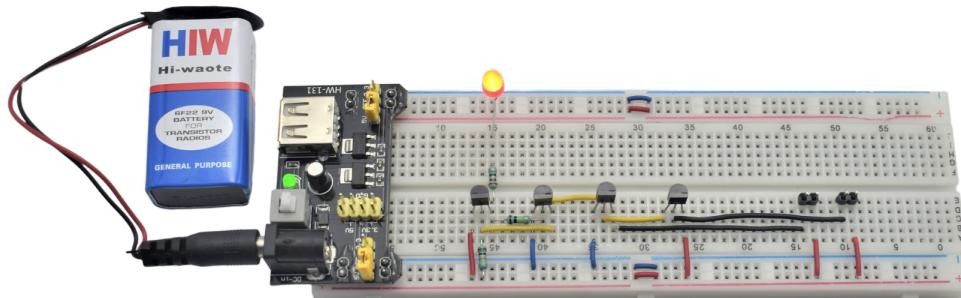


Figure 3.28: On/Off Touch Switch:

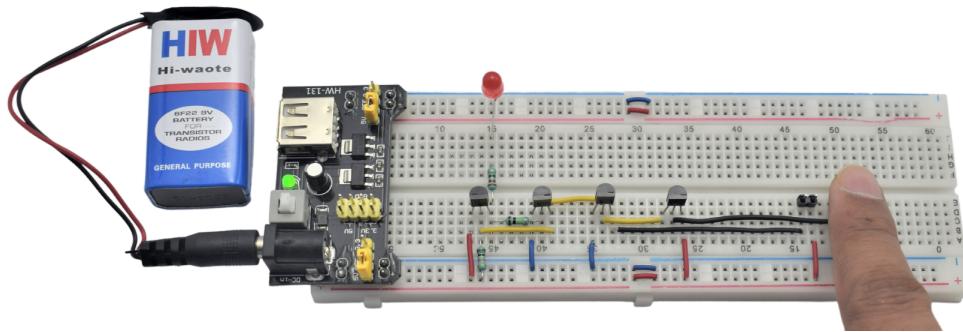


Figure 3.29: On/Off Touch Switch:

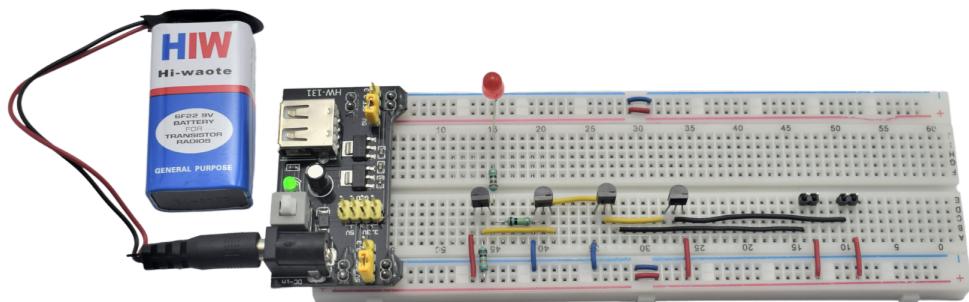


Figure 3.30: On/Off Touch Switch:

3.7 Lesson 8: Toggle Switch using Transistors

3.7.1 Objective

In this activity we will make an toggle switch which toggles the output state using push button and transistors.

3.7.2 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. Red LED × 1
6. 100 nF × 1
7. 220Ω × 1
8. $10k\Omega$ × 1
9. $100k\Omega$ × 2
10. $1M\Omega$ × 2
11. 2N2222 NPN Transistor × 2
12. 2N2907 PNP Trsnsistor × 1
13. 10-XX Push Button × 1
14. Male-Male jumper wire × 10

3.7.3 Circuit

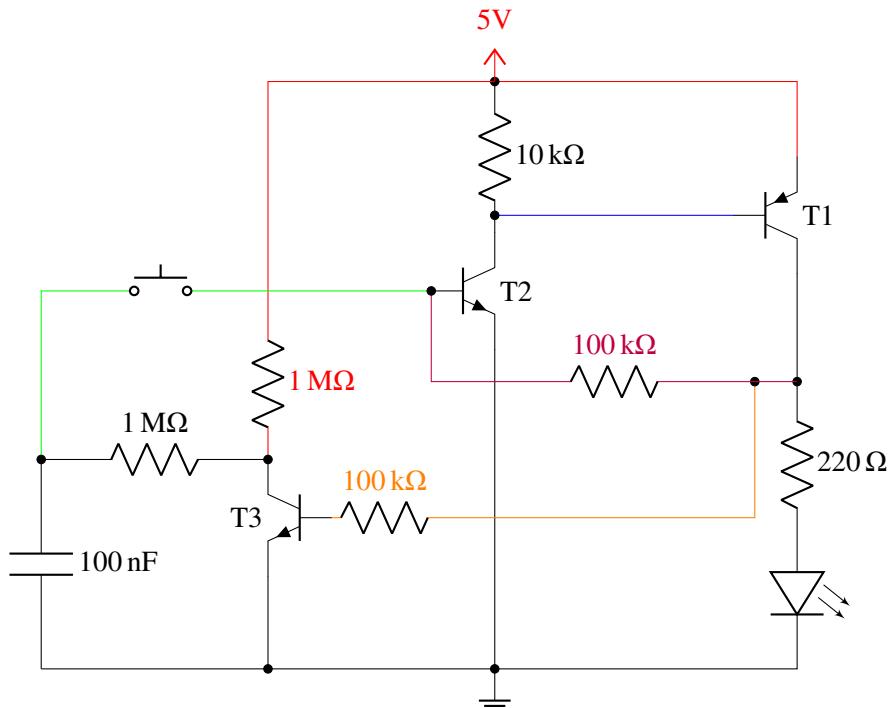


Figure 3.31: Toggle Switch using Transistors

3.7.4 Circuit Explanation

Let us assume that initially all the transistors are off along with the led. In this case, the capacitor gets charged via the two $1M\Omega$ resistors. And no current is flowing through any transistor.

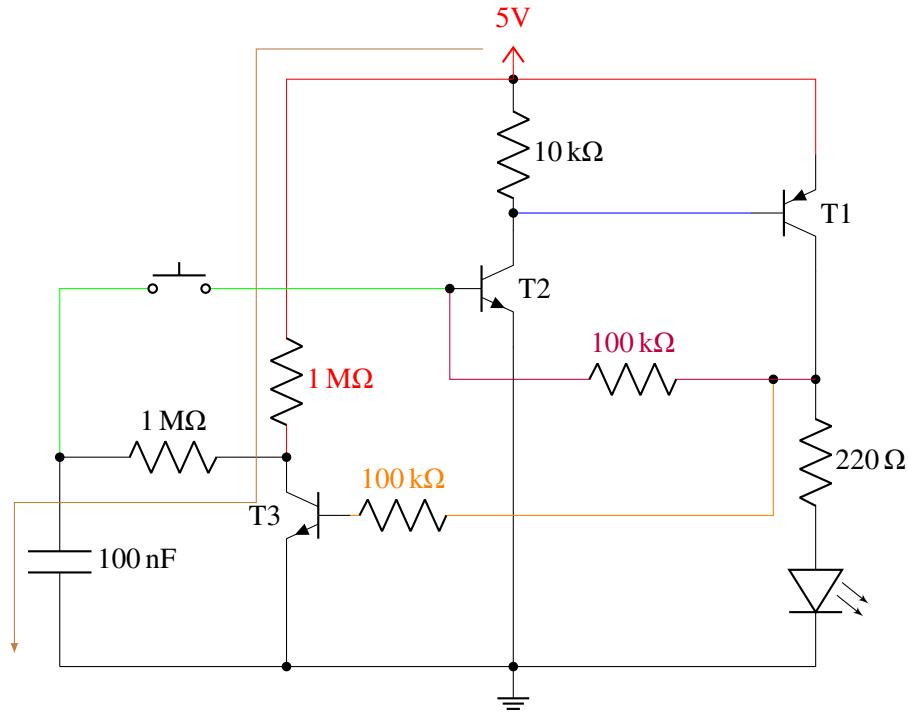


Figure 3.32: Toggle Switch using Transistor - Idle

When we press the switch, the capacitor's +ve plate is connected to the base of the transistor T_2 , and therefore a base current starts flowing, turning T_2 on. With T_2 on the base of transistor T_1 is pulled to ground, turning it on and the led on. There is also a feedback current flowing back to base of T_2 and T_3 .

On leaving the switch, the feedback current keeps the T_2 on which keeps T_1 on. Also, this feedback current turns on the T_3 which discharges the capacitor through it. At this stage all the transistors are on, led is on and the capacitor is completely discharged.

Now, when we again press the switch, the feedback current going to base of T_2 , goes to ground via the capacitor, which is discharged and therefore provides little to no resistance. This turns off the T_2 , and the base of T_1 is pulled back to V_{CC} , causing it to turn off. Now the led is off and all the transistors are not conducting, which is idle state.

3.7.5 Circuit Picture

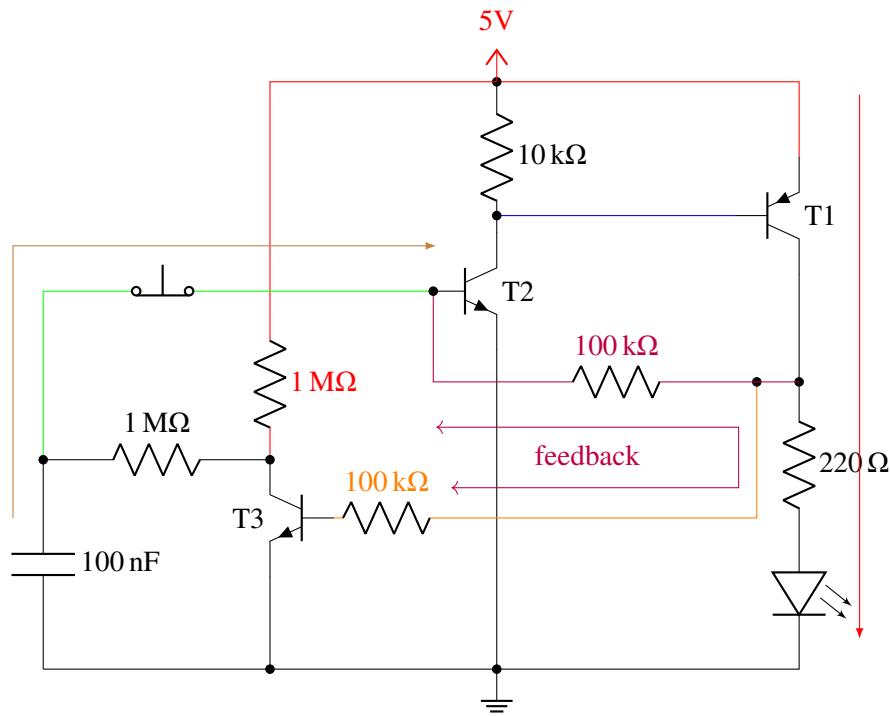


Figure 3.33: Toggle Switch using Transistor - On

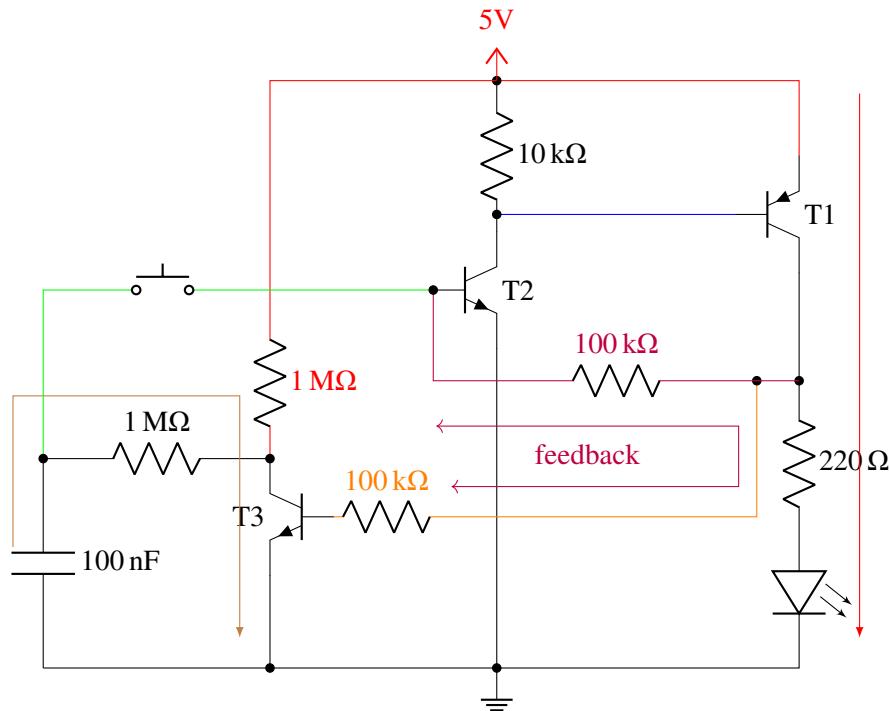


Figure 3.34: Toggle Switch using Transistor - Idle On

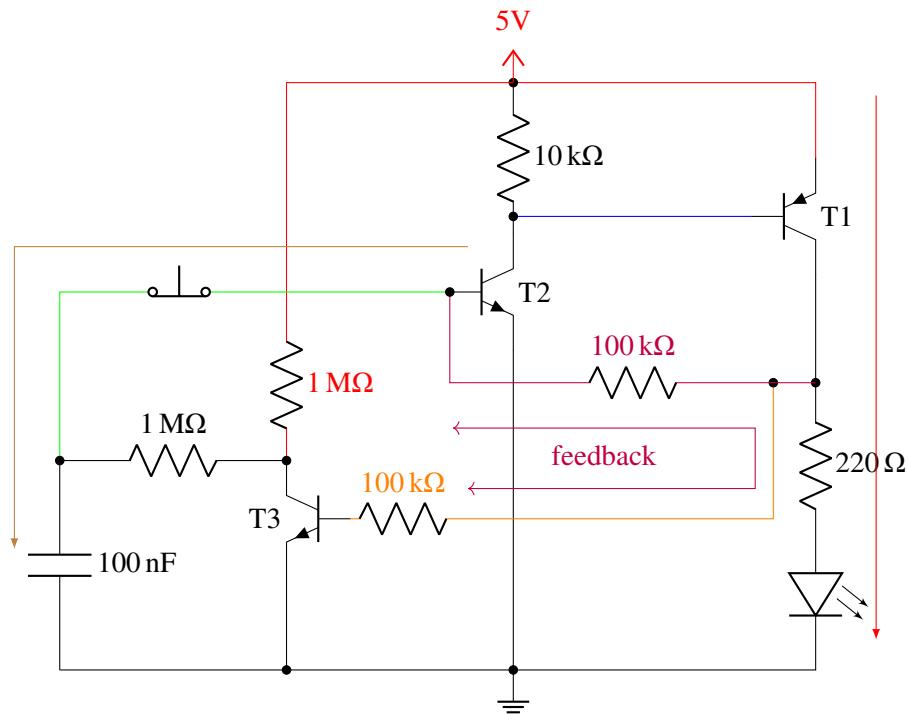


Figure 3.35: Toggle Switch using Transistor - Off

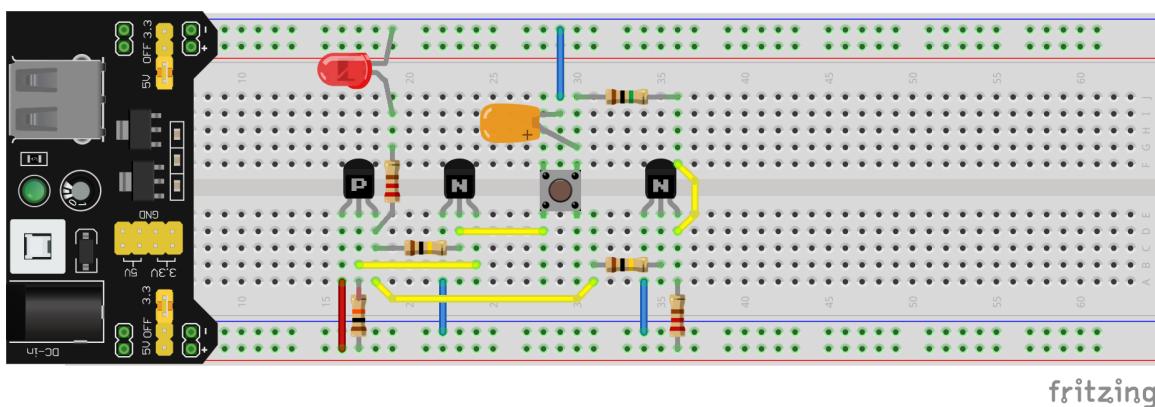


Figure 3.36: Toggle Switch using BJTs on Breadboard

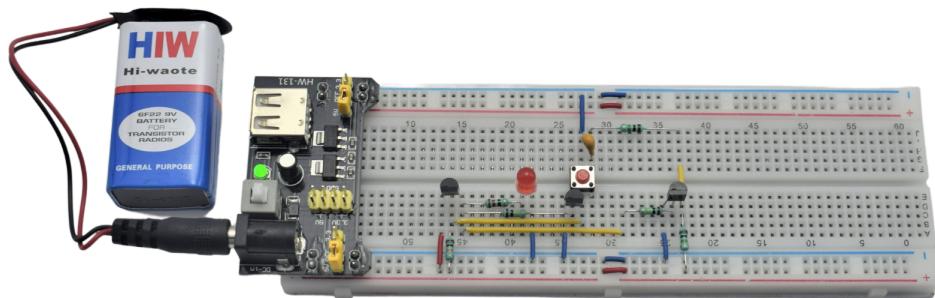


Figure 3.37: Toggle Switch: Off State

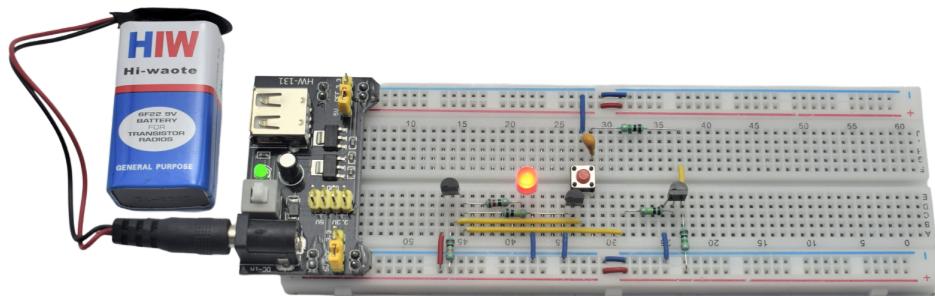


Figure 3.38: Toggle Switch: On State

3.8 Lesson 9: Two Color LED Flasher using Transistors

3.8.1 Objective

In this activity we will use the astable multivibrator to flash a rgb led.

3.8.2 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. RGB LED (Common Cathode) × 1
6. 220Ω × 2
7. $100\text{k}\Omega$ × 2
8. 2N2222 NPN Transistor × 2
9. $10\mu\text{F}$ × 2
10. Male-Male jumper wire × 5

3.8.3 Circuit

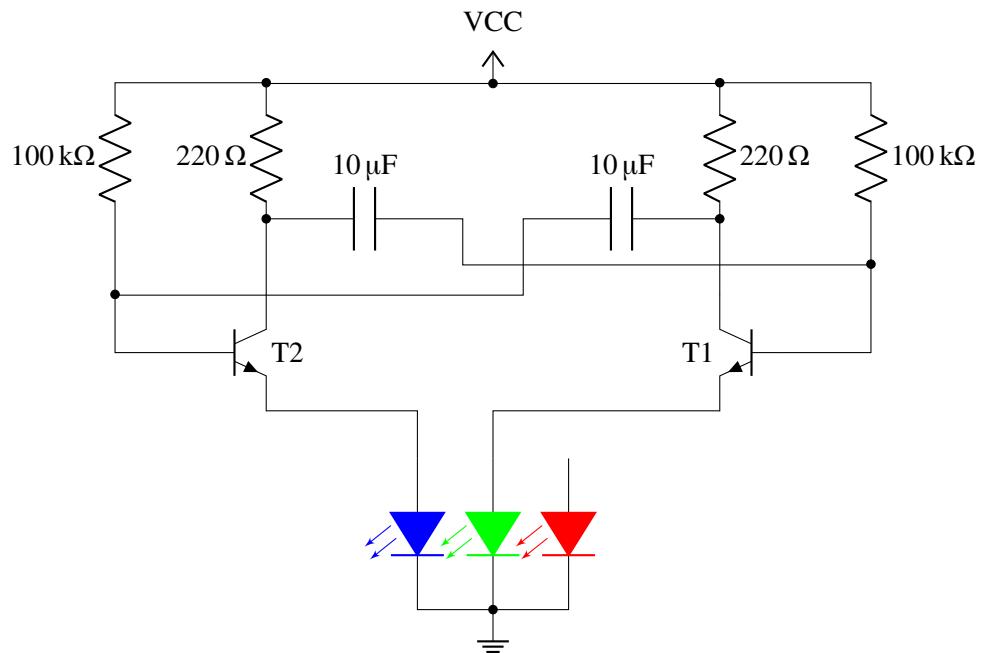


Figure 3.39: Two Color LED Flasher using Transistor

3.8.4 Circuit Explanation

This circuit operation is similar to that of astable multivibrator. Both the capacitors charge and discharge alternatively and thus turn on and off the transistors, causing the led to light up alternatively or in a flashing manner. By changing the capacitor and resistor values independently we can change the turn on and off time of both the leds.

3.8.5 Circuit Picture

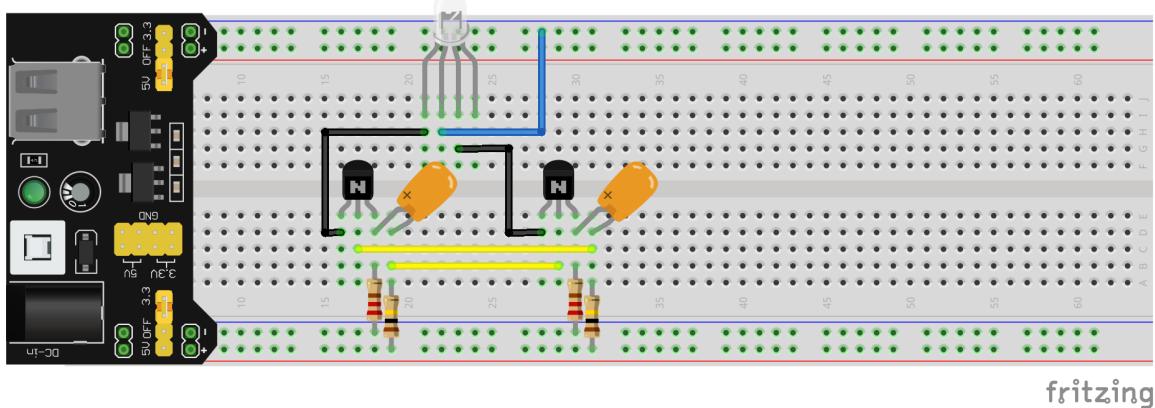


Figure 3.40: Two Color LED flasher using BJTs on Breadboard

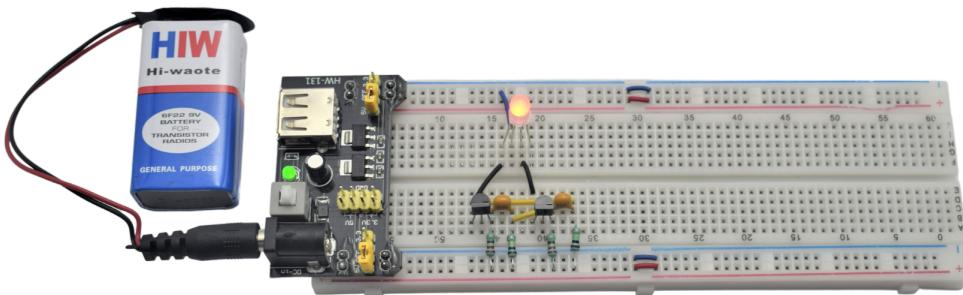


Figure 3.41: Two Color LED flasher

3.9 Lesson 10: Light Sensitive LED using LDR

3.9.1 Objective

In this activity we will make light sensitive LED, which will light up in darkness.

3.9.2 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. RGB LED (Common Cathode) × 1
6. 220Ω × 1
7. $100\text{k}\Omega$ × 1
8. LDR (Photoresistor) × 1
9. Male-Male jumper wire × 3

3.9.3 Circuit

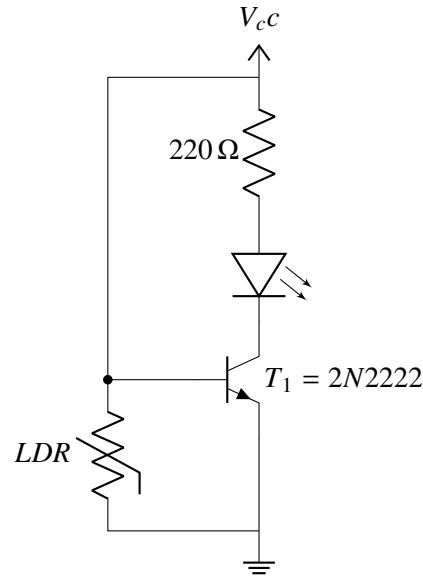


Figure 3.42: Light Sensitive LED

3.9.4 Circuit Explanation

We have used LDR in a voltage divider configuration. When there is change in light falling on the LDR, the voltage drop across it will change due to change in its resistance.

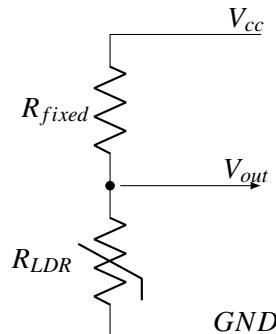


Figure 3.43: LDR as Voltage Divider

The output voltage (V_{out}) can be calculated by using the formula -

$$V_{out} = V_{cc} \times \frac{R_{LDR}}{R_{LDR} + R_{fixed}}$$

According to LDR datasheet, we can find the threshold value of R_{LDR} in dark and daylight, after that we need to find the value of R_{fixed} such that the following conditions below are met -

1. $0.7V \leq V_{out}$ in the dark.
2. $0.7V > V_{out}$ in the daylight.

3. The base current should be more than $20\mu\text{A}$
 In dark, $R_{LDR} = 550\text{k}\Omega$ and in daylight, $R_{LDR} = 6\text{k}\Omega$.
 Let's work out each condition one by one.

The first condition

$$\begin{aligned} 0.7\text{V} &\leq V_{out} \\ V_{out} &\leq V_{cc} \times \frac{R_{LDR}}{R_{LDR} + R_{fixed}} \\ 0.7\text{V} &\leq 5\text{V} \times \frac{550\text{k}\Omega}{550\text{k}\Omega + R_{fixed}} \\ R_{fixed} + 550\text{k}\Omega &\leq \frac{5}{0.7} \times 550\text{kohm} \\ R_{fixed} &\leq 3928.57\text{k}\Omega - 550\text{k}\Omega \\ R_{fixed} &\leq 3.38\text{M}\Omega \end{aligned}$$

The second condition

$$\begin{aligned} 0.7\text{V} &> V_{out} \\ V_{out} &> V_{cc} \times \frac{R_{LDR}}{R_{LDR} + R_{fixed}} \\ 0.7 &> 5\text{V} \times \frac{6\text{k}\Omega}{6\text{k}\Omega + R_{fixed}} \\ R_{fixed} + 6\text{k}\Omega &> \frac{5}{0.7} \times 6\text{k}\Omega \\ R_{fixed} &> 42.86\text{k}\Omega - 6\text{k}\Omega \\ R_{fixed} &> 36.86\text{k}\Omega \end{aligned}$$

The third condition

$$\begin{aligned} V_{cc} &> 0.7\text{V} + R_{fixed} \times I \\ R_{fixed} &< \frac{5 - 0.7}{20\mu\text{A}} \\ R_{fixed} &< 215\text{k}\Omega \end{aligned}$$

Now, analysing all the above three conditions we see that -

$$36.86\text{k}\Omega < R_{fixed} < 215\text{k}\Omega$$

We have selected $R_{fixed} = 100\text{k}\Omega$.

3.9.5 Circuit Picture

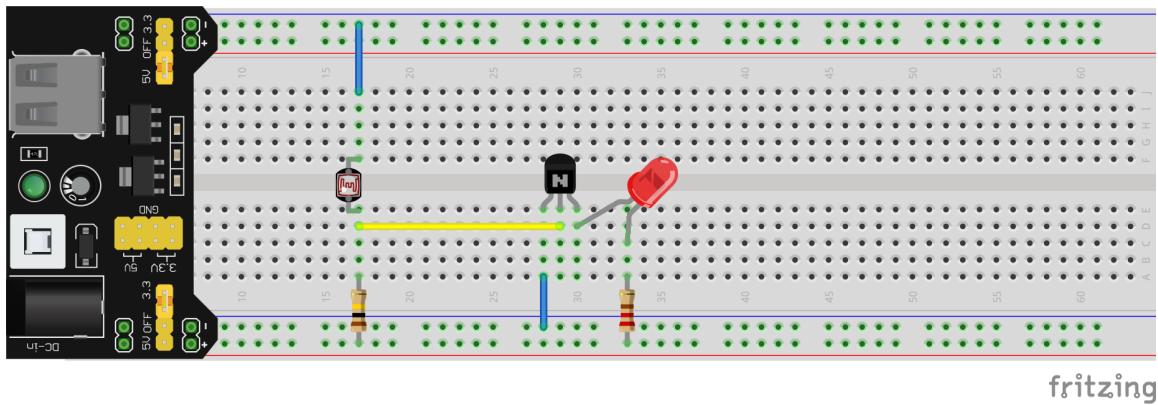


Figure 3.44: Light sensitive LED on Breadboard

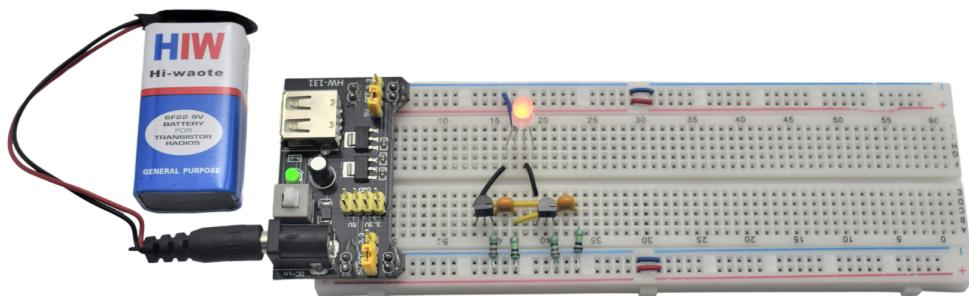


Figure 3.45: Light sensitive LED

4. 555

4.1 Overview

In this section you'll learn about one of the most famous integrated circuit (IC) in use. Each year millions of 555 Timer ICs are manufactured and sold. It's named 555 because there are three $5\text{ k}\Omega$ resistors inside the IC. And as the name suggest, it is a timer circuit. The timing interval is controlled by an external resistor/capacitor network. And by changing the values for the resistor and capacitor the timing duration can be easily varied.

Let's take a look at the pins of 555 Timer IC:

1. **GND - Pin 1** Ground pin of the IC
2. **VCC - Pin 8** Positive supply is connected to this pin, the voltage must be at least 4.5 V and maximum 15 V.
3. **OUT - Pin 3** The output is either low (close to 0 V) or high (close to VCC).
4. **TRG - Pin 2** Trigger is active low, which means when the voltage on this pin drops below one-third of the supply voltage, the output of 555 goes high.
5. **DIS - Pin 7** This pin is used to discharge an external capacitor that works in conjunction with a resistor to control the timing of the 555 IC.
6. **THR - Pin 6** Threshold pin is used to monitor the voltage across the capacitor that's discharged by pin 7. When this voltage reaches two-third of the supply voltage, the output goes low.
7. **CTRL - Pin 5** Control pin can be used to vary the voltage level at the inverting input of the threshold comparator. It is generally connected to ground via $0.01\text{ }\mu\text{F}$ capacitor to eliminate any fluctuation on noise in the operation of the timer.
8. **RST - Pin 4** Reset pin is active low, which means when this pin is momentarily grounded the 555 timer will reset its state and will stop until it is triggered again.

Figure 4.2 shows the schematic symbol for 555 IC that we will use in this chapter's circuit examples.

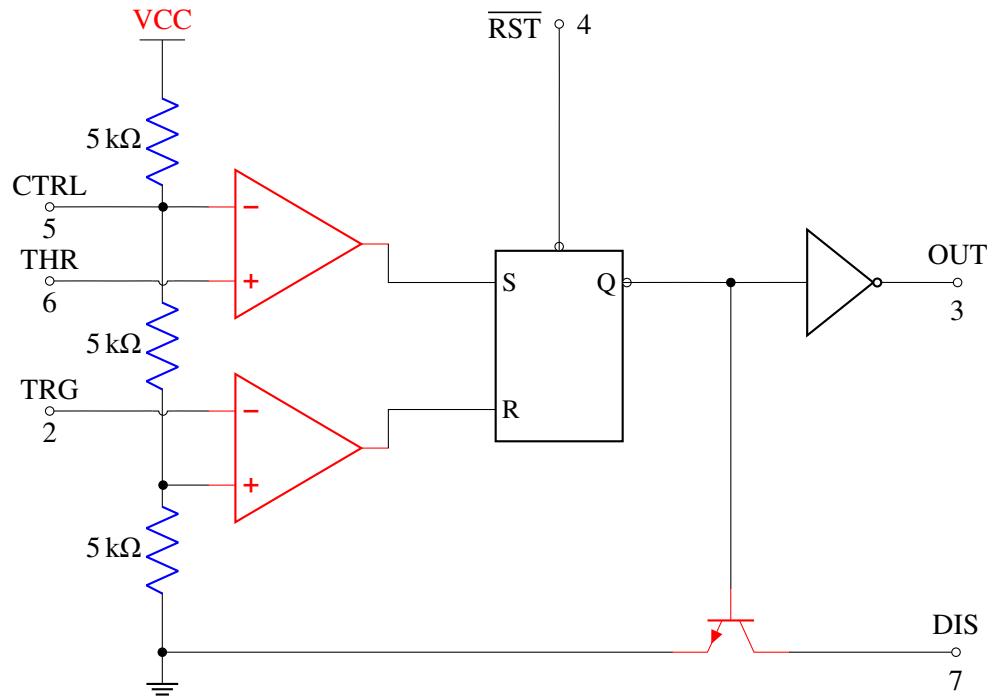


Figure 4.1: 555 Timer Circuit

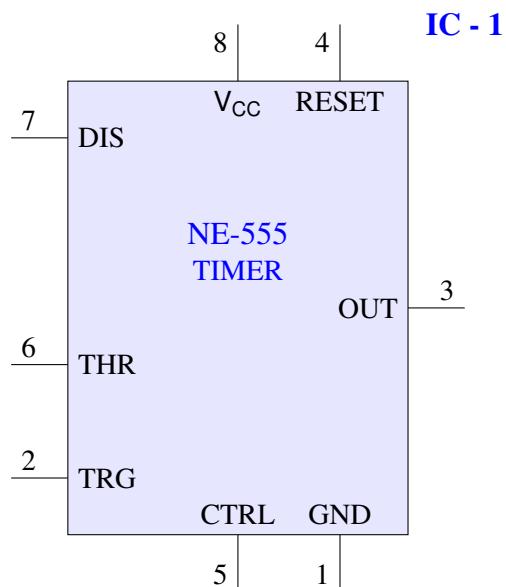


Figure 4.2: 555 Timer Symbol

4.2 555 : Operating Modes

The 555 timer has 3 modes of operation and all of the upcoming activities utilizes one or more operation modes of 555. In this section we will learn how to use different modes of operation of 555, after that we will build circuits using these modes.

4.2.1 Astable Mode

As the name suggests, in astable mode there is no stable state. The output continuously switches between high and low producing an square wave. This circuit can be used for turning an LED on and off at regular intervals or act as a clock input for digital ICs or control a motor by switching it on and off at regular time period.

4.2.2 Monostable Mode

Monostable means only one stable state. In this mode 555 has only one stable state and can produce a pulse of set duration as a response against a trigger. The output stays low (the stable state) as long as there is no trigger received by the 555. Once, a trigger event happens, the output momentarily goes to high and then falls back to low after a set duration. This circuit can be used to provide a delay pulse, or turn on LED or motor or any mechanism for a fixed duration of time.

4.2.3 Bistable Mode

In Bistable mode the 555 has two stable states. When it receives a trigger input pulse, the output goes to high state and stays there until it receives a reset pulse, which makes the output fall back to low. This circuit is sometimes called as flip/flop also, because it can store the value of it's state for as long as the device is not reset or set.

4.3 Lesson 11: 555 LED Flasher

4.3.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 1
6. Red LED × 1
7. 220Ω × 1
8. $10k\Omega$ × 1
9. $100k\Omega$ × 1
10. $100nF$ × 1
11. $10\mu F$ × 1
12. Male-Male jumper wire × 7

4.3.2 Circuit Picture

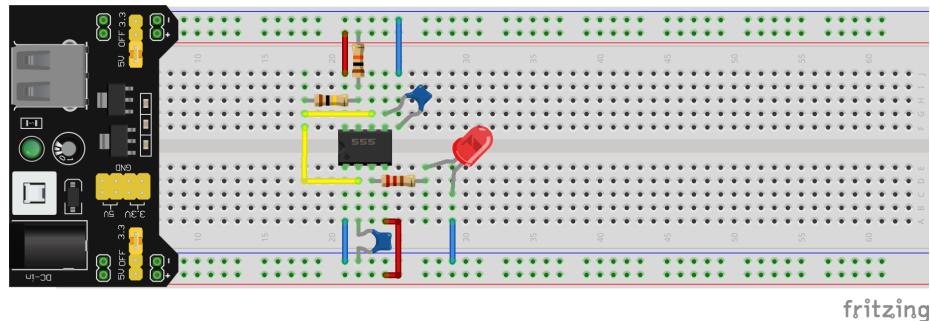


Figure 4.3: 555 LED flasher Breadboard Schematic

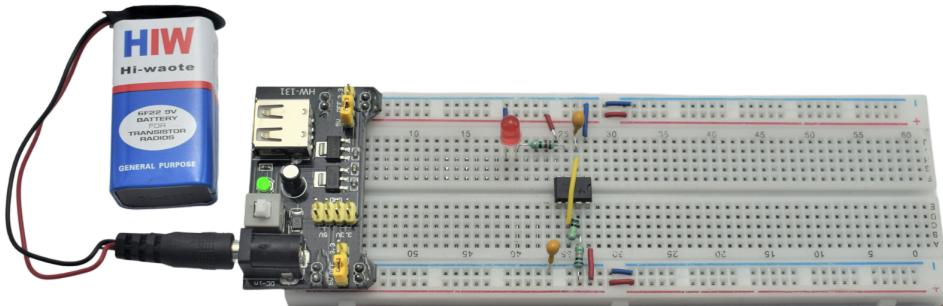


Figure 4.4: 555 LED flasher: LED OFF

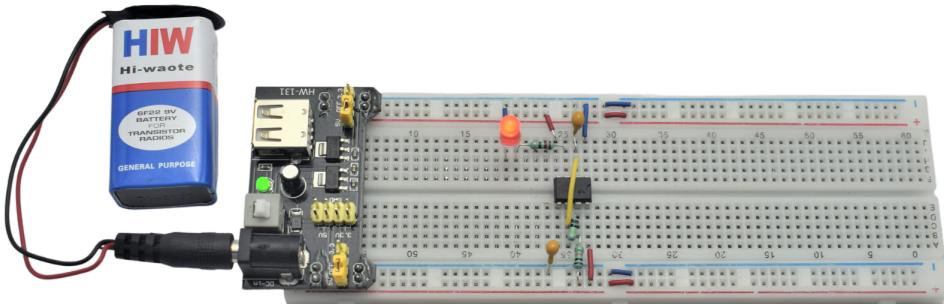


Figure 4.5: 555 LED flasher: LED ON

4.4 Lesson 12: 555 Dual LED Flasher

4.4.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 1
6. Red LED × 1
7. Blue LED × 1
8. 220Ω × 2
9. $10k\Omega$ × 1
10. $100k\Omega$ × 1
11. $100nF$ × 1
12. $10\mu F$ × 1
13. Male-Male jumper wire × 7

4.4.2 Circuit Picture

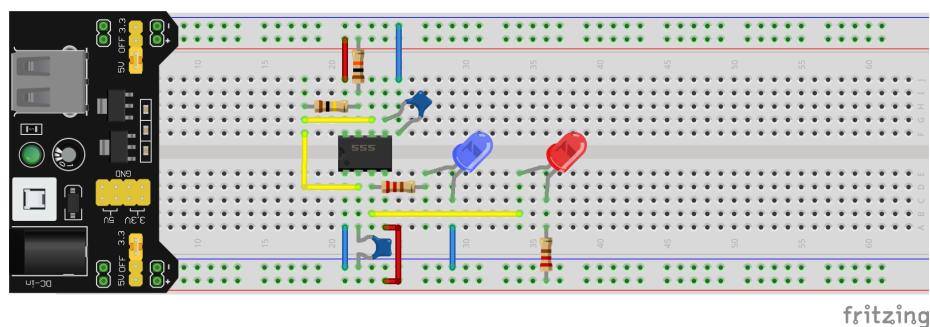


Figure 4.6: 555 Dual LED flasher Breadboard Schematic

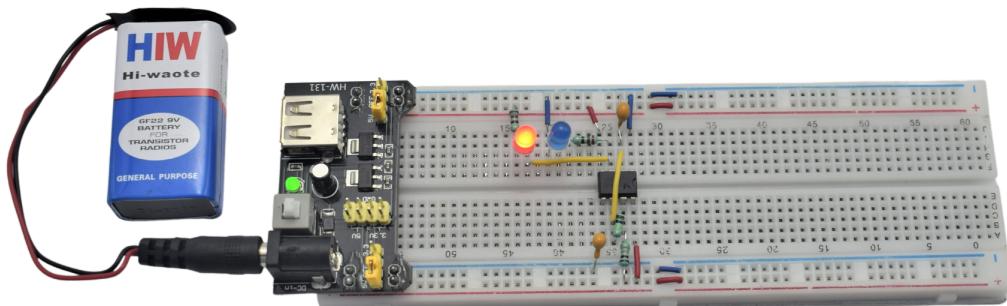


Figure 4.7: 555 Dual LED flasher 1

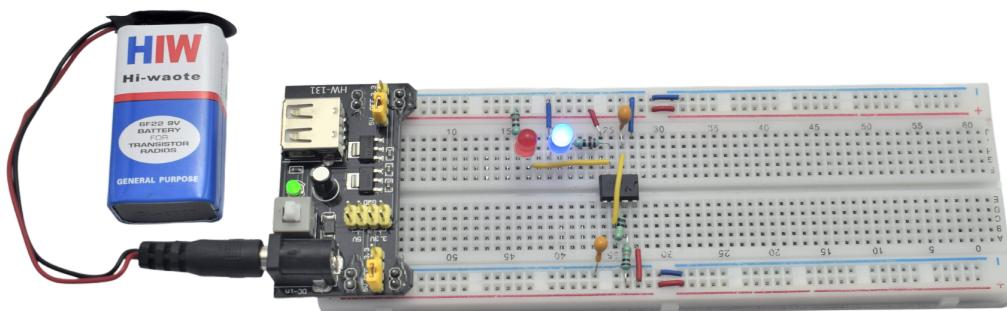


Figure 4.8: 555 LED flasher 2

4.5 Lesson 13: Fading LED using 555

4.5.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 1
6. Red LED × 1
7. 2N2222 × 1
8. 220Ω × 1
9. $10k\Omega$ × 1
10. $100k\Omega$ × 1
11. $1M\Omega$ × 1
12. $100nF$ × 1
13. $10\mu F$ × 2
14. Male-Male jumper wire × 11

4.5.2 Circuit Picture

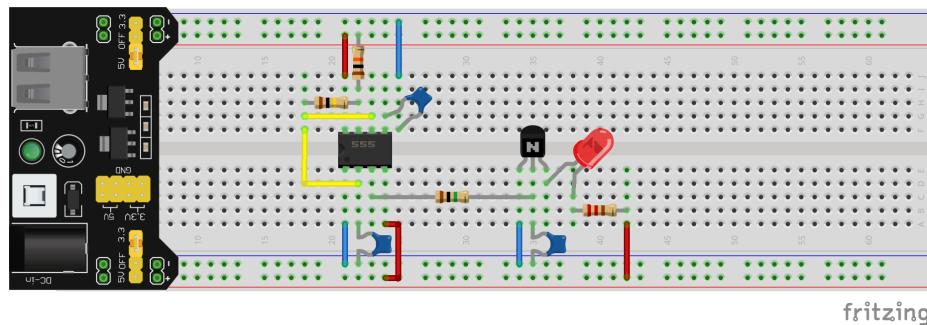


Figure 4.9: Fading LED using 555 Breadboard Schematic

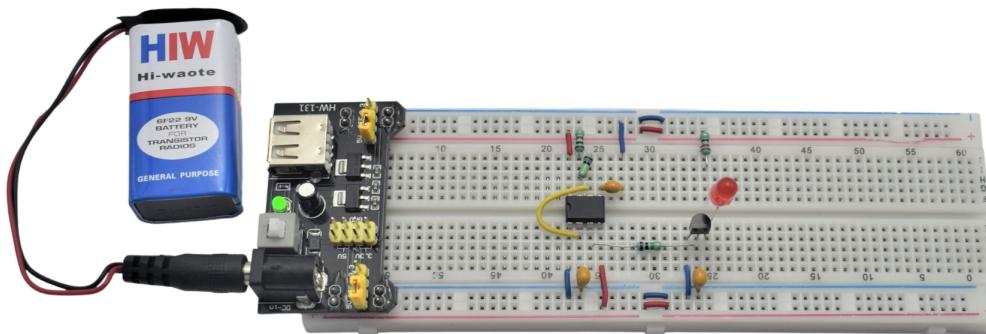


Figure 4.10: LED fading 1

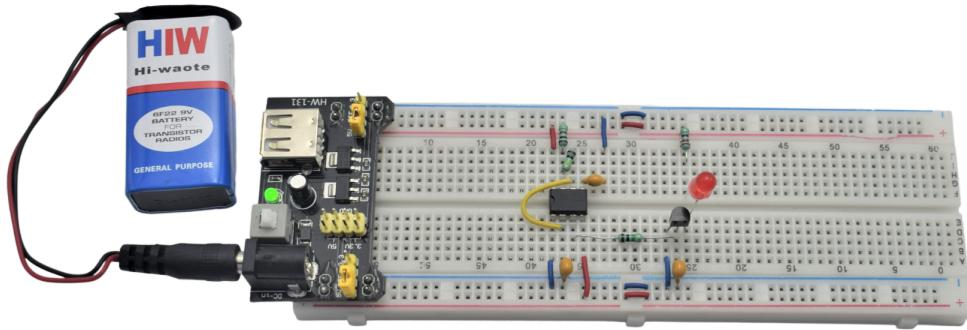


Figure 4.11: LED fading 2

4.6 Lesson 14: Bistable Button Flip/Flop using 555

4.6.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 1
6. Red LED × 1
7. Push Button × 2
8. 220Ω × 1
9. $10k\Omega$ × 2
10. $100nF$ × 2
11. Male-Male jumper wire × 9

4.6.2 Circuit Picture

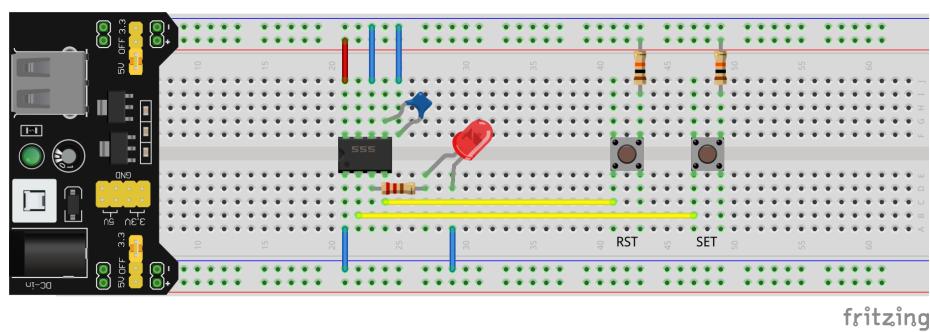


Figure 4.12: Bistable Button Flip/Flop using 555 Breadboard Schematic

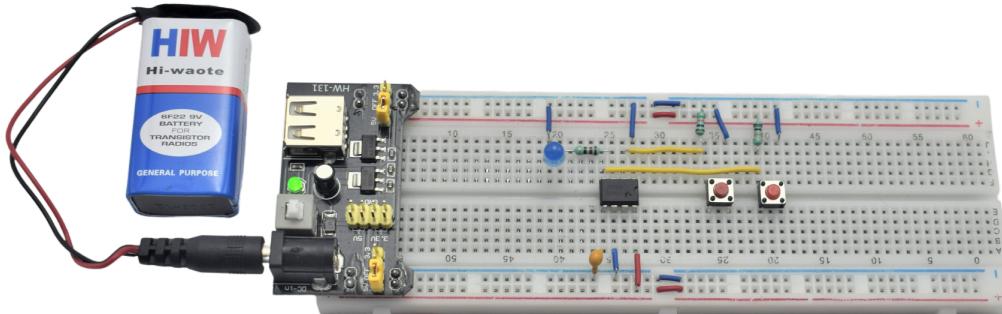


Figure 4.13: FF Idle

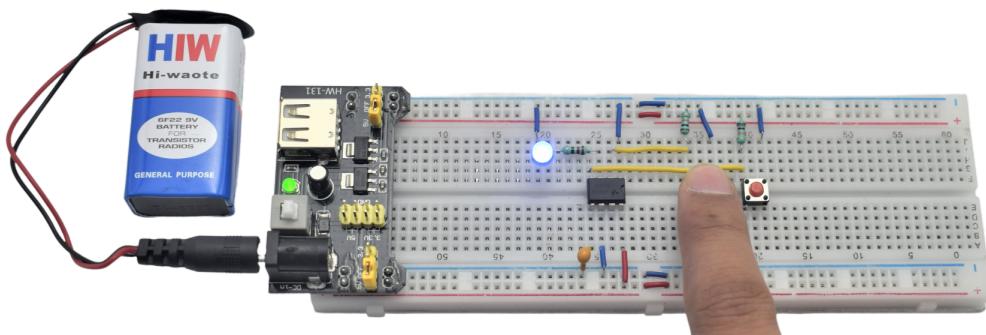


Figure 4.14: FF SET Button Pressed

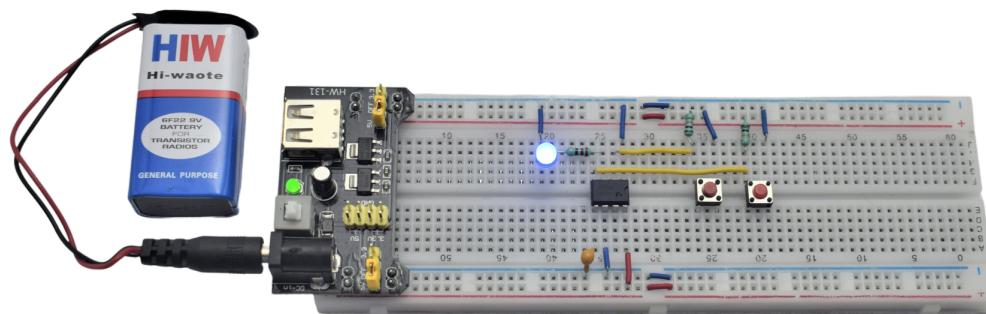


Figure 4.15: FF Idle after leaving SET button

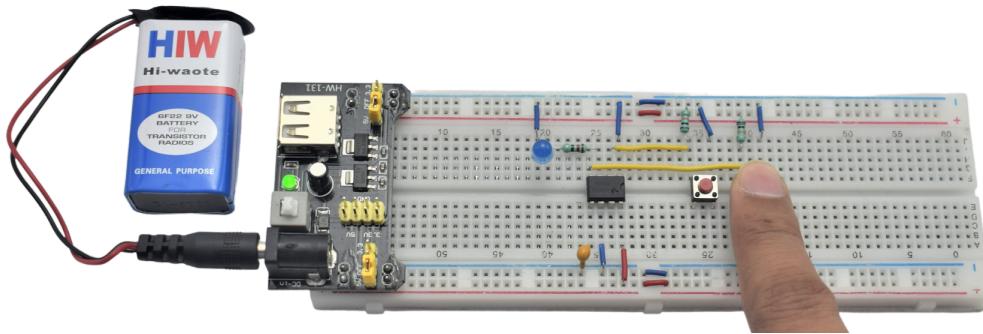


Figure 4.16: FF RST Button Pressed

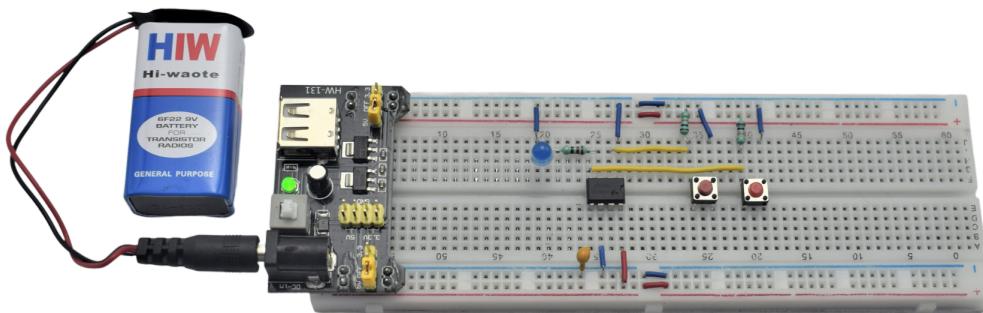


Figure 4.17: FF Idle after leaving RST Button

4.7 Lesson 15: Toggle Switch with 555

4.7.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 1
6. Red LED × 1
7. Push Button × 1
8. 220Ω × 1
9. $10\text{k}\Omega$ × 2
10. $100\text{k}\Omega$ × 1
11. 100nF × 2
12. Male-Male jumper wire × 11

4.7.2 Circuit Picture

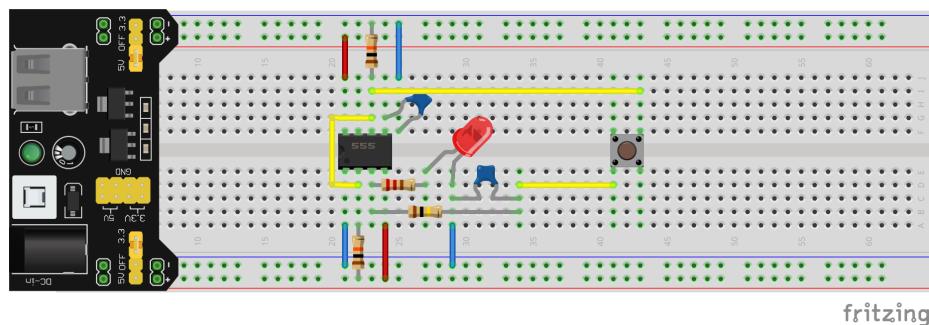


Figure 4.18: Toggle Switch using 555 Breadboard Schematic

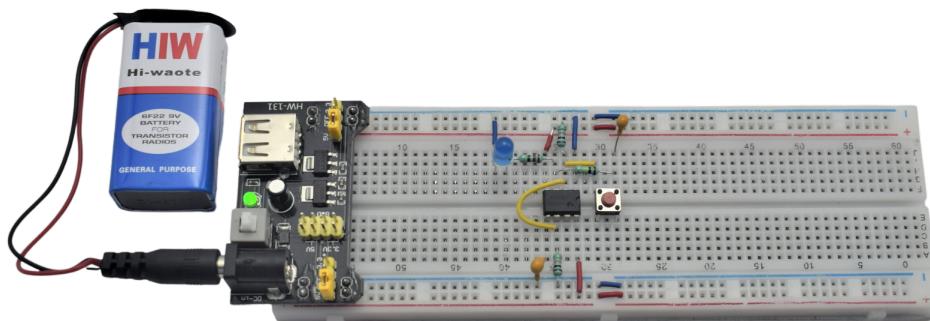


Figure 4.19: Idle

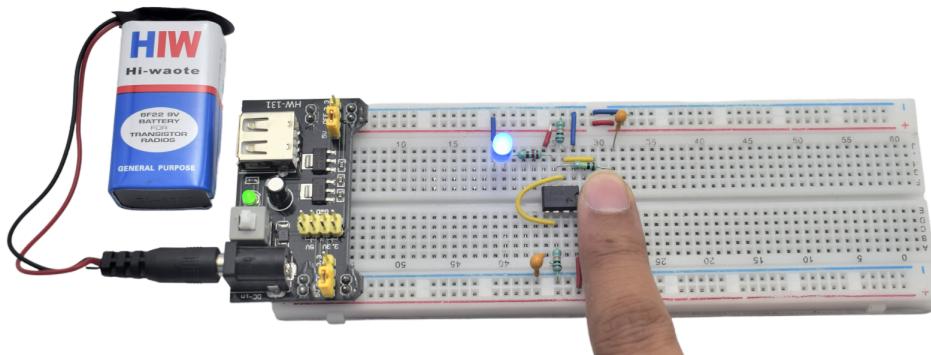


Figure 4.20: Button Pressed: LED turned ON

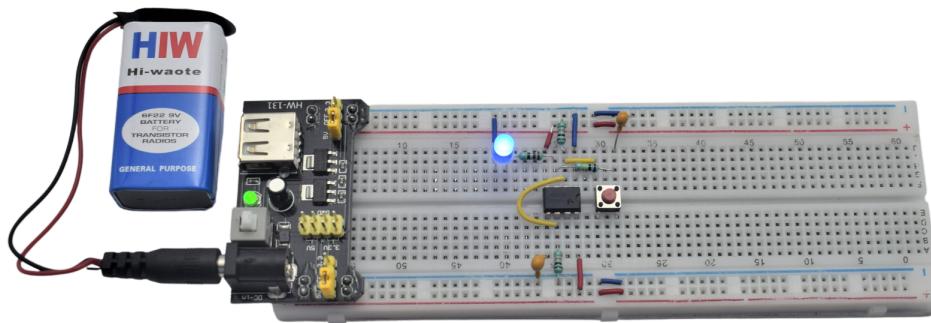


Figure 4.21: Button released

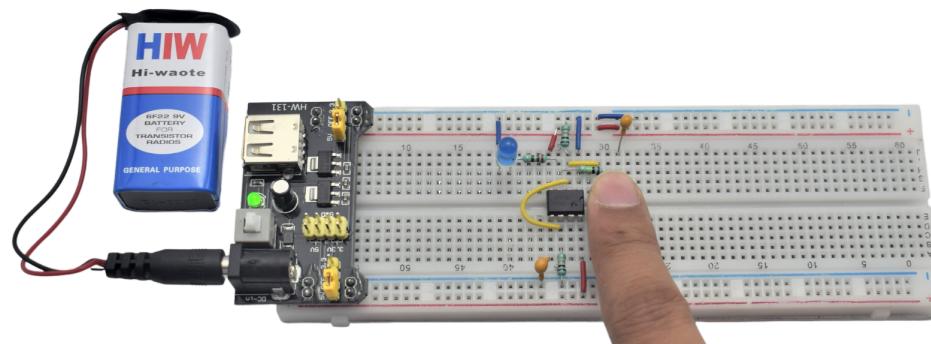


Figure 4.22: Button Pressed: LED turned OFF

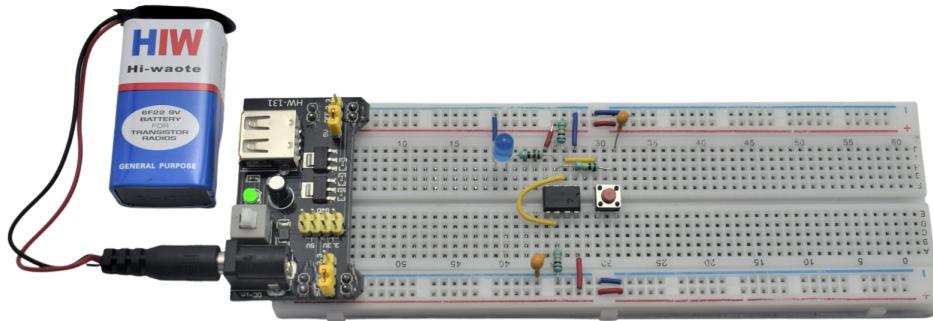


Figure 4.23: Button released

4.8 Lesson 16: Timer Delay using 555

4.8.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 1
6. Red LED × 1
7. Push Button × 1
8. 220Ω × 1
9. $10k\Omega$ × 1
10. $1M\Omega$ × 1
11. $100nF$ × 2
12. $100nF$ × 2
13. Male-Male jumper wire × 11

4.8.2 Circuit Picture

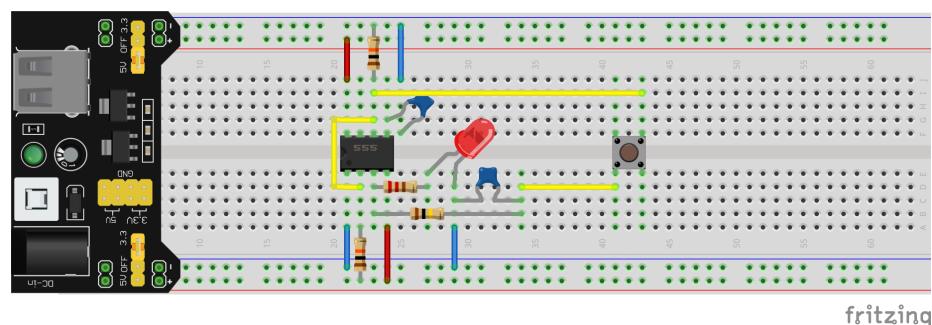


Figure 4.24: Timer Delay using 555 Breadboard Schematic

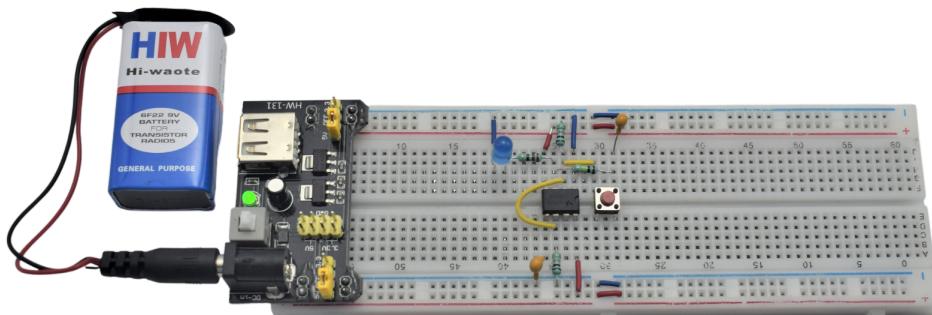


Figure 4.25: Idle

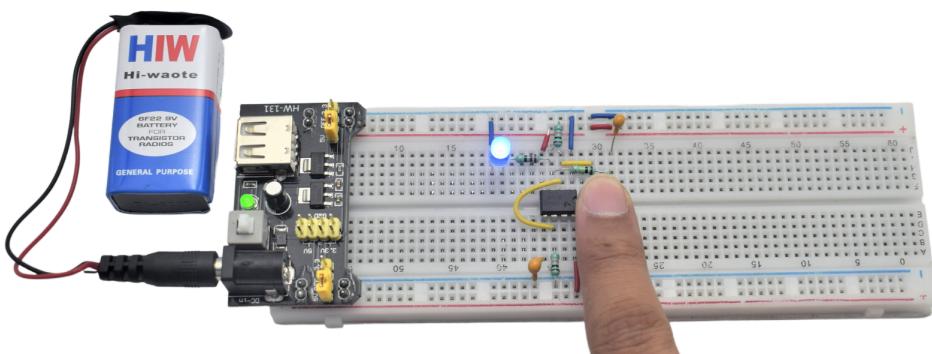


Figure 4.26: Button Pressed

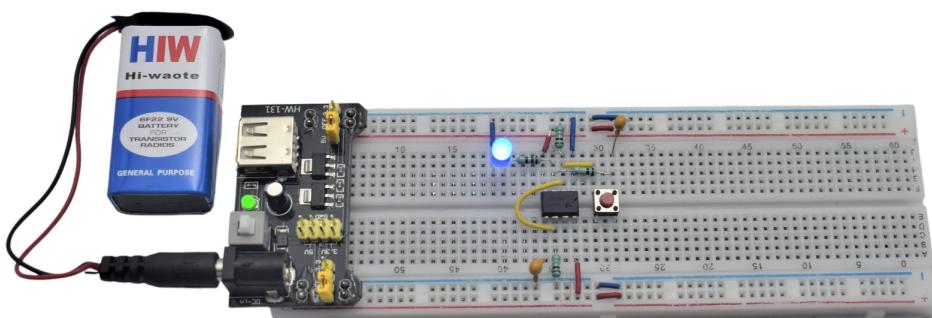


Figure 4.27: Button released

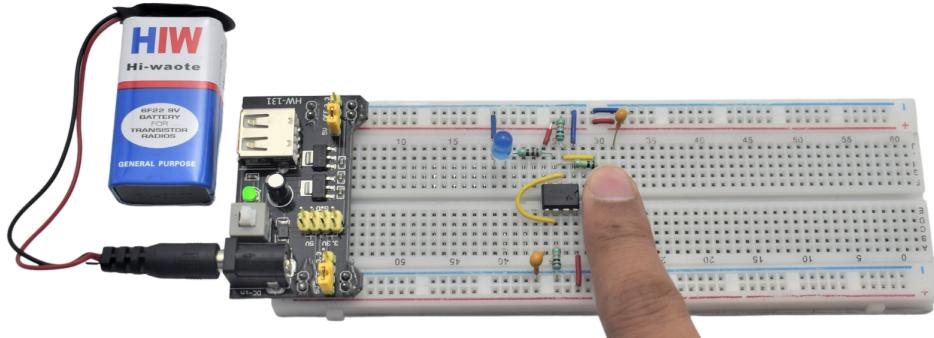


Figure 4.28: LED turned off after delay time

4.9 Lesson 17: Single Tone Buzzer with 555

4.9.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 1
6. Active Buzzer × 1
7. 10 kΩ × 1
8. 100 kΩ × 1
9. 100 nF × 1
10. 10 µF × 1
11. Male-Male jumper wire × 7

4.9.2 Circuit Picture

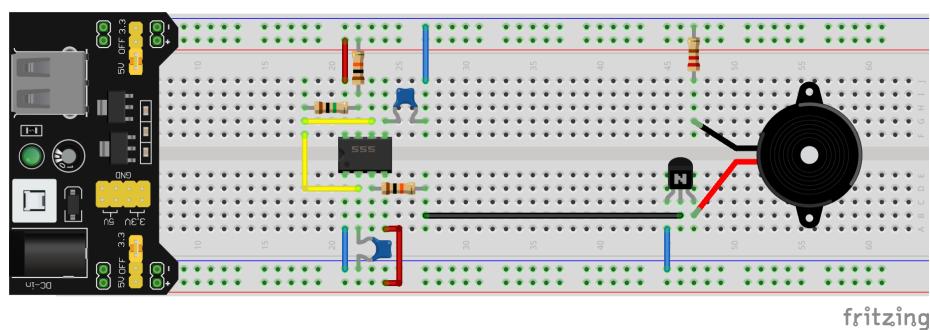


Figure 4.29: Single tone Buzzer with 555 Breadboard Schematic

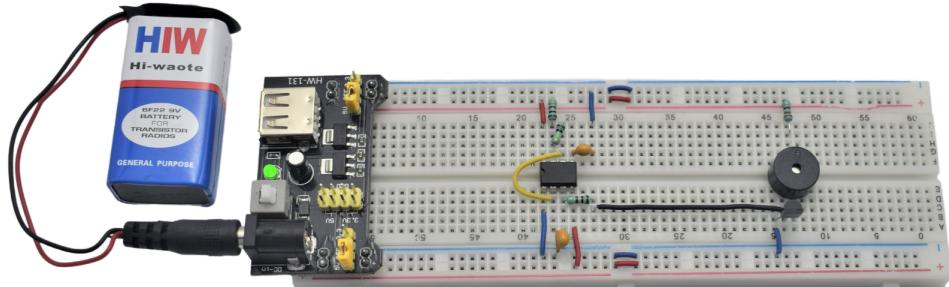


Figure 4.30: Single tone Buzzer

4.10 Lesson 18: Short Beep

4.10.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 1
6. Active Buzzer × 1
7. 1N4007 Diode × 1
8. 10kΩ × 1
9. 100kΩ × 1
10. 1 MΩ × 1
11. 100 nF × 1
12. 2.2 μF × 1
13. Male-Male jumper wire × 10

4.10.2 Circuit Picture

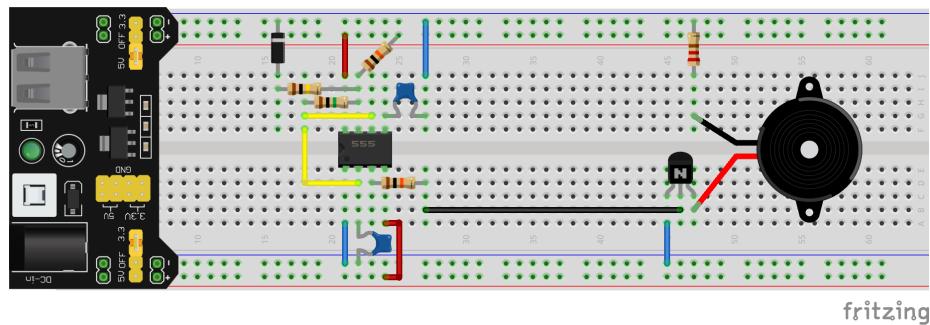


Figure 4.31: Short Beep using 555 Breadboard Schematic

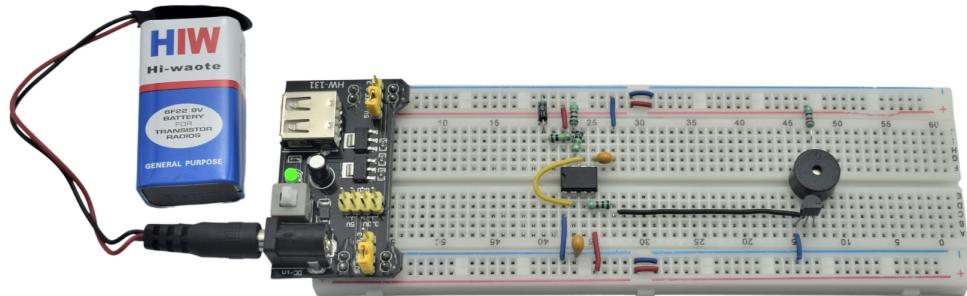


Figure 4.32: Short Beep

4.11 Lesson 19: Break Beam Detector using 555 and LDR

4.11.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 1
6. Passive Buzzer × 1
7. White LED × 1
8. LDR × 1
9. 220Ω × 1
10. $10k\Omega$ × 3
11. $100nF$ × 2
12. $10\mu F$ × 1
13. Male-Male jumper wire × 15

4.11.2 Circuit Picture

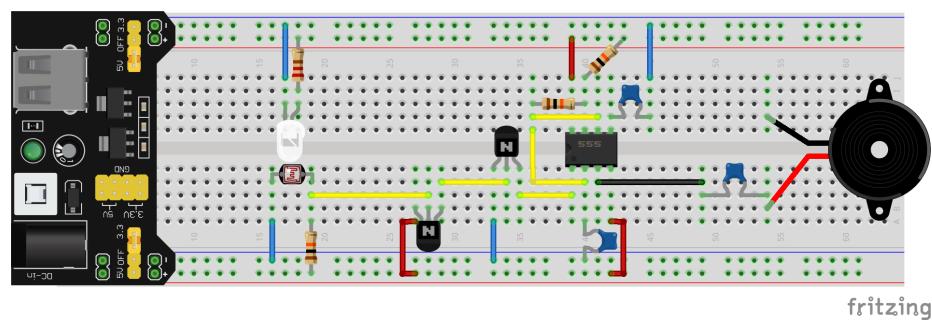


Figure 4.33: Break Beam Detector using 555 and LDR Breadboard Schematic

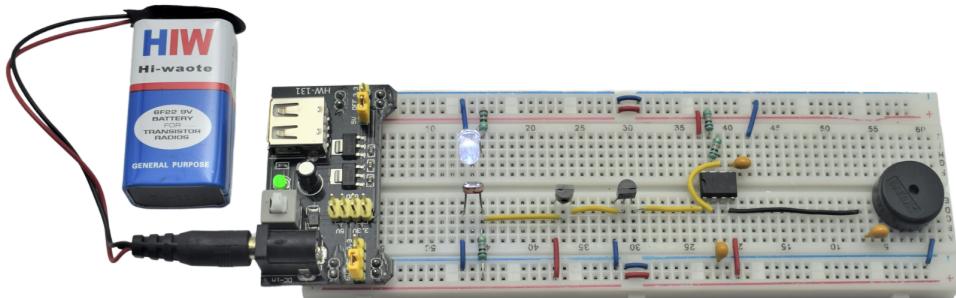


Figure 4.34: No Obstacle: Buzzer OFF

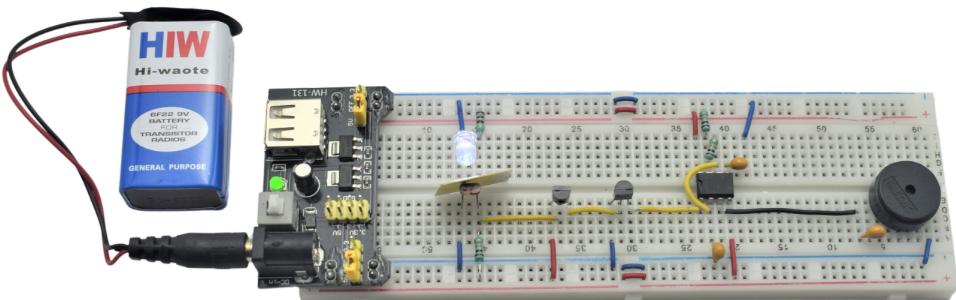


Figure 4.35: Obstacle: Buzzer ON

4.12 Lesson 20: Light reactive buzzer using 555 and LDR

4.12.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 1
6. Passive Buzzer × 1
7. LDR × 1
8. $10\text{ k}\Omega$ × 1
9. 100 nF × 2
10. $10\mu\text{F}$ × 1
11. Male-Male jumper wire × 9

4.12.2 Circuit Picture

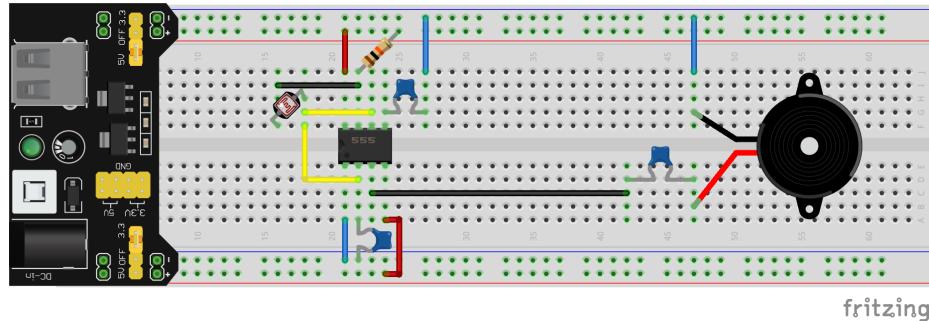


Figure 4.36: Light reactive Buzzer Breadboard Schematic

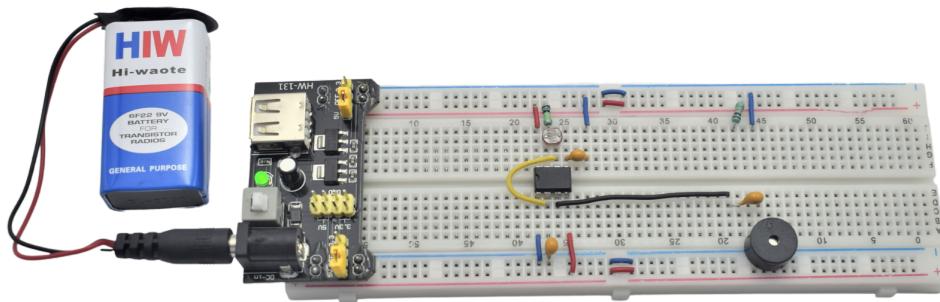


Figure 4.37: Light reactive Buzzer

4.13 Lesson 21: Audio Tone/Siren

4.13.1 Components Required

1. Breadboard Power Supply × 1

2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 2
6. Passive Buzzer × 1
7. 10 kΩ × 5
8. 100 kΩ × 1
9. 100 nF × 2
10. 10 μF × 2
11. Male-Male jumper wire × 14

4.13.2 Circuit Picture

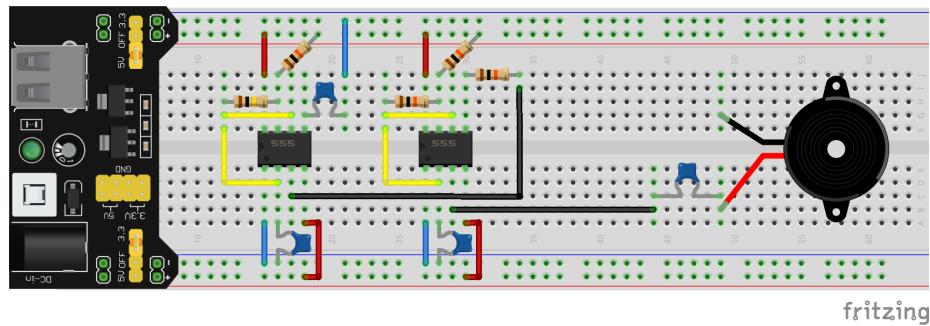


Figure 4.38: Audio Tone/Siren Breadboard Schematic

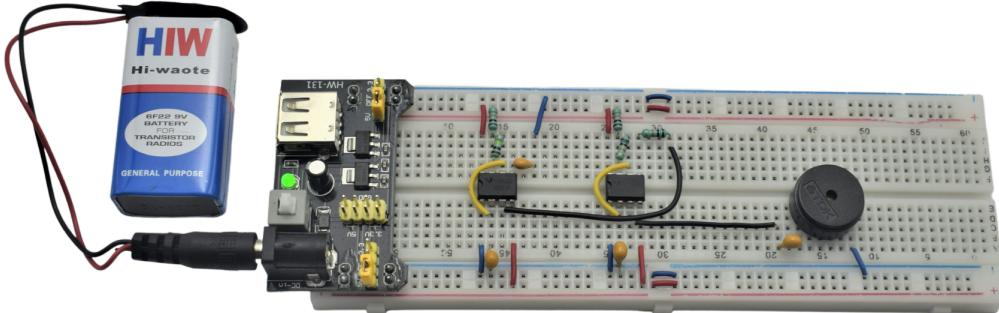


Figure 4.39: Audio Tone/Siren

4.14 Lesson 22: Traffic Light

4.14.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1

5. 555 IC × 2
6. Red LED × 1
7. Yellow LED × 1
8. Green LED × 1
9. 2N2222 × 1
10. $220\Omega \times 3$
11. $330\Omega \times 3$
12. $10k\Omega \times 2$
13. $1M\Omega \times 2$
14. $100nF \times 2$
15. $2.2\mu F \times 1$
16. $10\mu F \times 2$
17. Male-Male jumper wire × 22

4.14.2 Circuit Picture

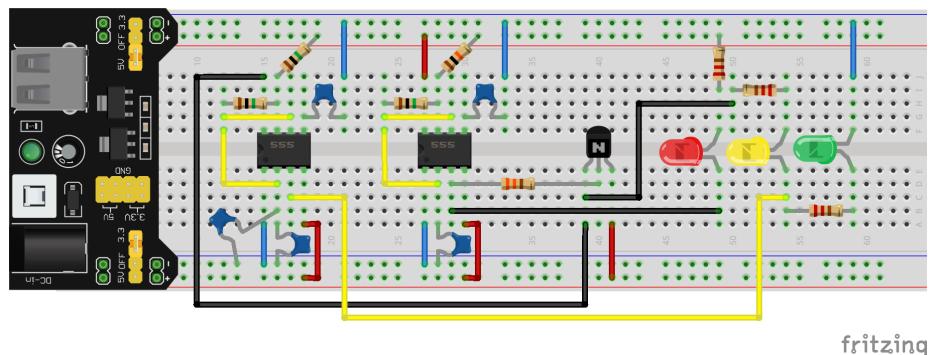


Figure 4.40: Traffic Light Breadboard Schematic

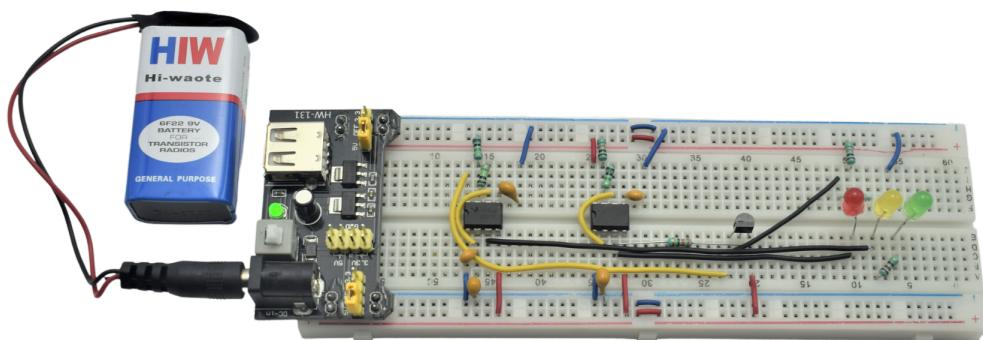


Figure 4.41: Green Light On

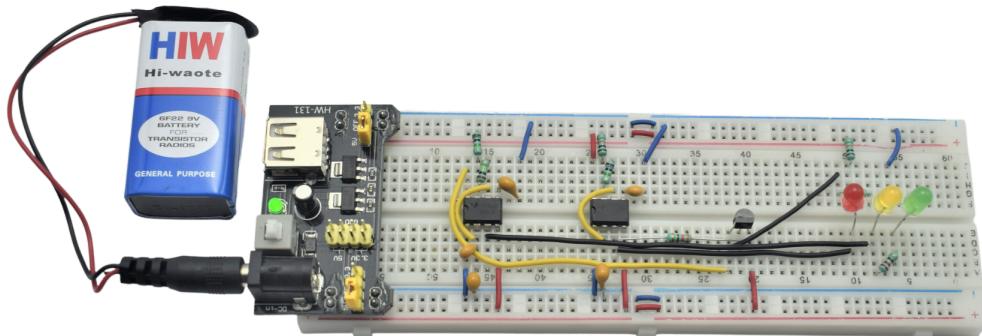


Figure 4.42: Yellow Light On

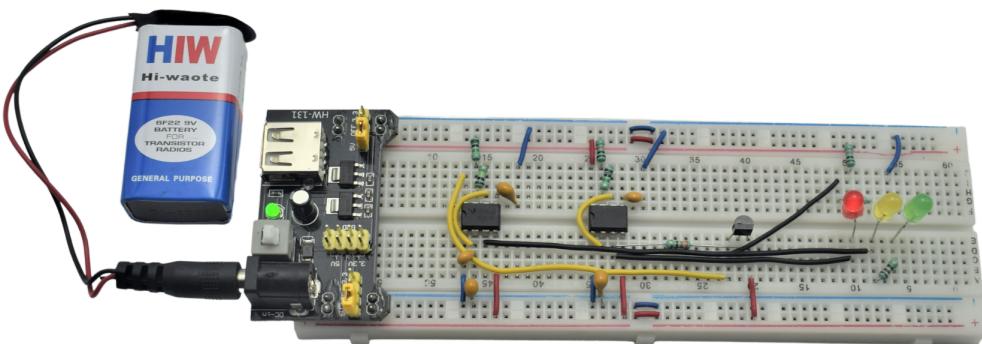


Figure 4.43: Red Light On

4.15 Lesson 23: Doorbell

4.15.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 2
6. 2N2222 × 3
7. Passive Buzzer × 1
8. Push Button × 1
9. $1\text{ k}\Omega$ × 3
10. $10\text{ k}\Omega$ × 3
11. $1\text{ M}\Omega$ × 1
12. 100 nF × 2
13. $1\text{ }\mu\text{F}$ × 1
14. Male-Male jumper wire × 23

4.15.2 Circuit Picture

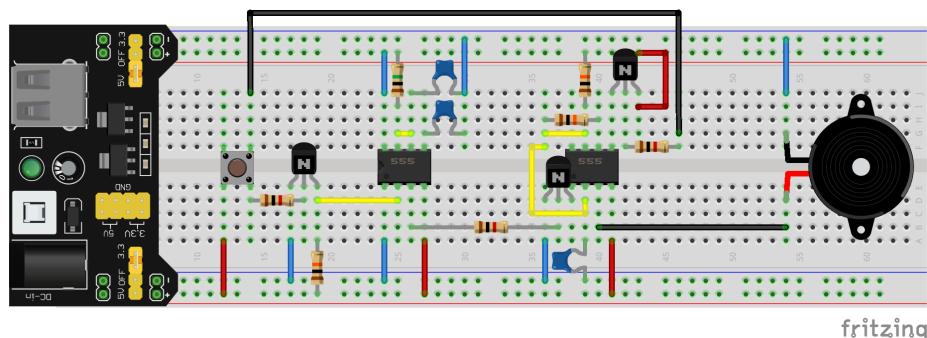


Figure 4.44: Doorbell Breadboard Schematic

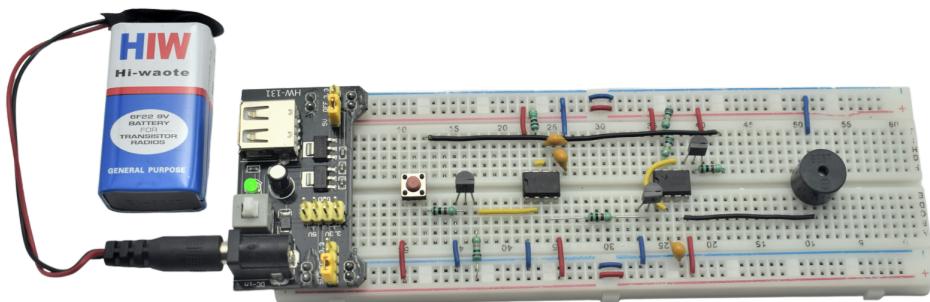


Figure 4.45: Idle: Buzzer OFF

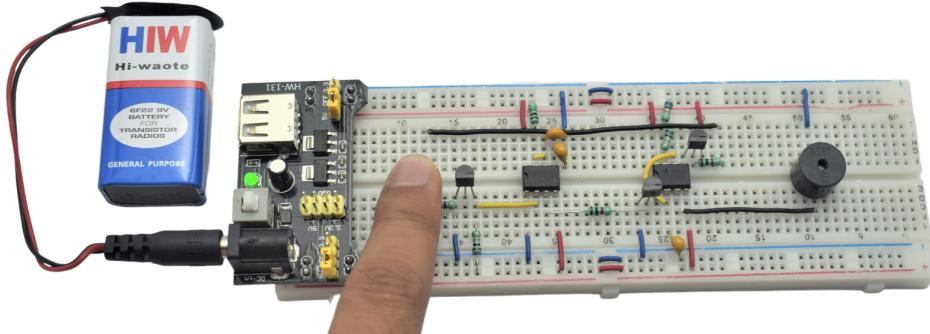


Figure 4.46: Button Pressed: Buzzer ON for sometime

4.16 Lesson 24: PWM Speed Controller

4.16.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 1
6. 2N2222 × 1
7. DC Motor × 1
8. Propeller × 1
9. 1N4007 Diode × 2
10. 1 kΩ × 1
11. 2 kΩ × 1
12. 10 kΩ × 1
13. 10 kΩ Potentiometer × 1
14. 100 nF × 2
15. 10 µF × 1
16. Male-Male jumper wire × 11

4.16.2 Circuit Picture

Figure 4.47: PWM Speed Controller Breadboard Schematic

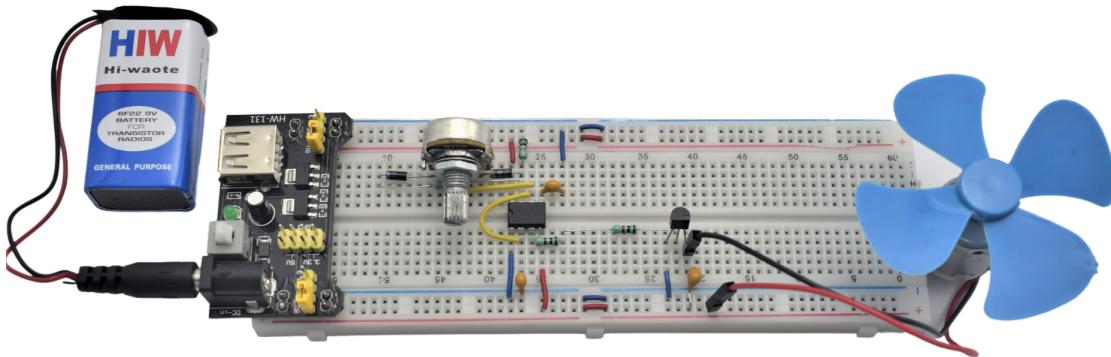


Figure 4.48: PWM 0 Duty Cycle

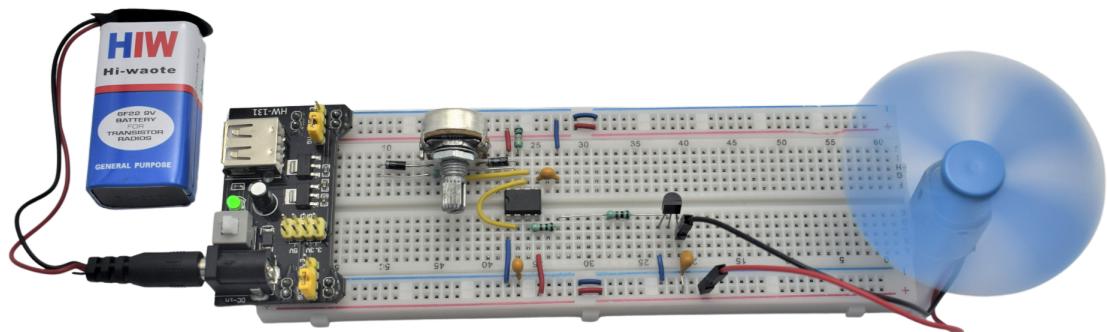


Figure 4.49: PWM half Duty Cycle

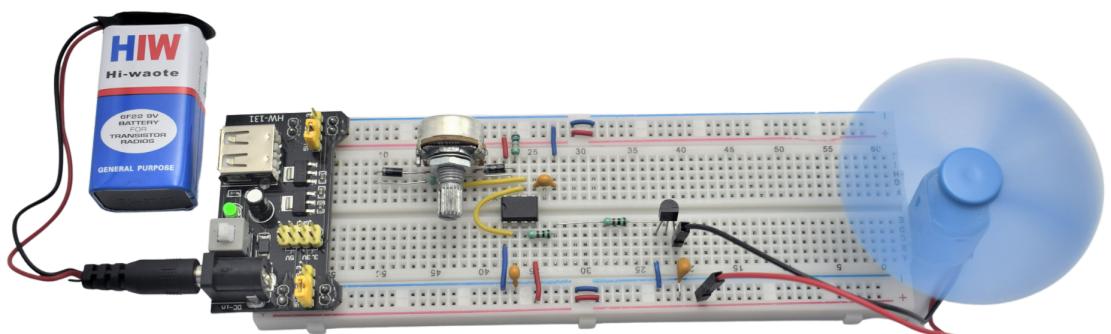


Figure 4.50: PWM full Duty Cycle

4.17 Lesson 25: 555 RGB Flasher

4.17.1 Components Required

1. Breadboard Power Supply × 1
2. 9V Battery × 1
3. 9V Battery Connector × 1
4. Breadboard × 1
5. 555 IC × 3
6. RGB LED × 1
7. 2N2222 × 3
8. 220Ω × 3
9. $10k\Omega$ × 3
10. $100k\Omega$ × 3
11. $1M\Omega$ × 3
12. $100nF$ × 3
13. $2.2\mu F$ × 1
14. $4.7\mu F$ × 1
15. $10\mu F$ × 4
16. Male-Male jumper wire × 30

4.17.2 Circuit Picture

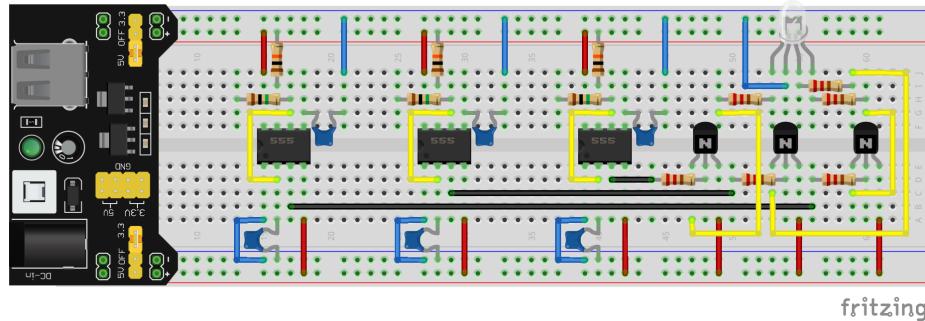


Figure 4.51: RGB LED Flasher Breadboard Schematic

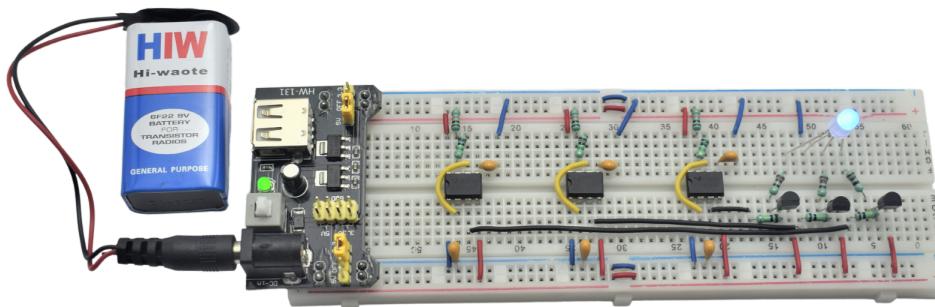


Figure 4.52: RGB Flasher

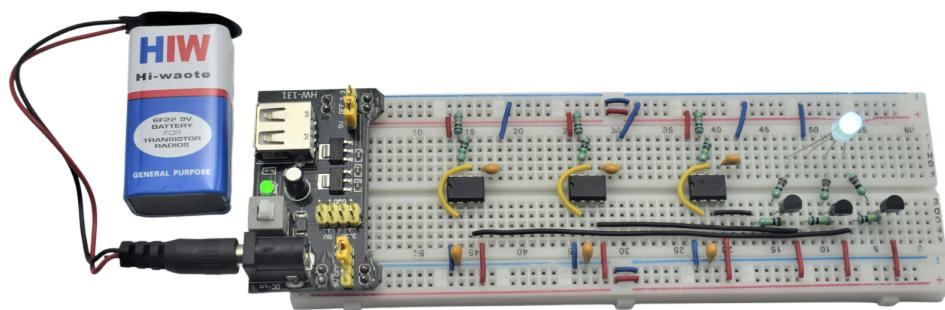
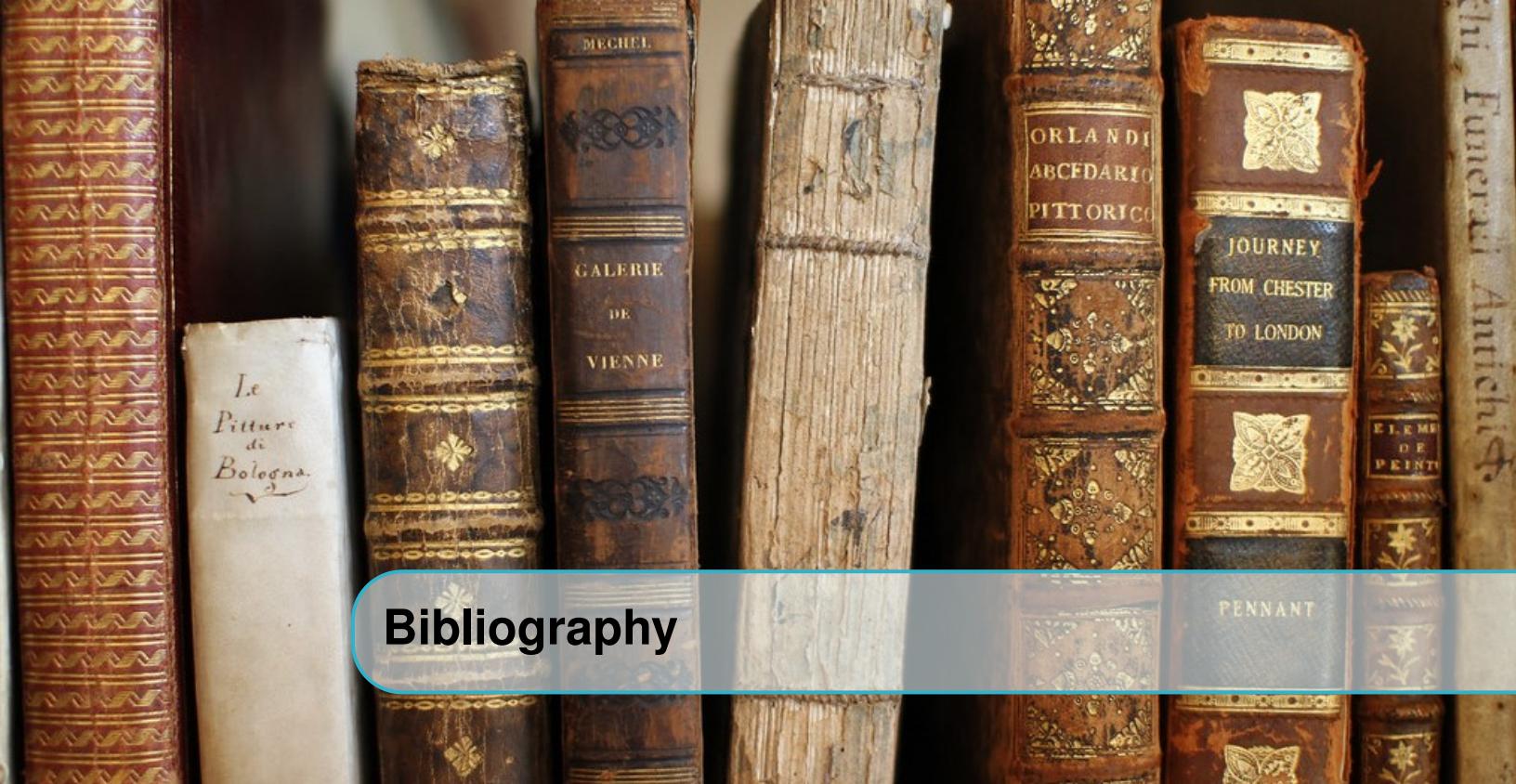


Figure 4.53: RGB Flasher



Bibliography

- [Sem13] Vishay Semiconductors. *Universal LED in Ø 5 mm Tinted Diffused Package*. <https://www.vishay.com/docs/83171/tlur640.pdf>. [Online; accessed 11-Sept-2022]. 2013.

