
ELECTRONICS FOR BEGINNERS
ELECTRONICS
FOR
BEGINNERS
This is a step-by-step eBook to get you building your first electronic circuits
Written by Rui Santos & Sara Santos

Security Notice

This is the kind of thing I hate having to write about, but the evidence is clear: piracy for digital products is over all the internet.

For that reason I've taken certain steps to protect my intellectual property contained in this eBook.

This eBook contains hidden random strings of text that only apply to *your* specific eBook version that is unique to your email address. You probably won't see anything different, since those strings are hidden in this PDF. I apologize for having to do that – **but it means if someone were to share this eBook I know exactly who shared it and I can take further legal consequences.**

You cannot redistribute this eBook. **This eBook is for personal use and** is only available for purchase at:

- http://randomnerdtutorials.com/products
- https://rntlab.com

Please send an email to the author (Rui Santos - hello@ruisantos.me), if you found this eBook anywhere else.

What I really want to say is thank you for purchasing this eBook and I hope you have fun with it!

Disclaimer

This eBook has been written for information purposes only. Every effort has been made to make this eBook as complete and accurate as possible. The purpose of this eBook is to educate. The authors (Rui Santos and Sara Santos) do not warrant that the information contained in this eBook is fully complete and shall not be responsible for any errors or omissions.

The authors (Rui Santos and Sara Santos) shall have neither liability nor responsibility to any person or entity with respect to any loss or damage caused or alleged to be caused directly or indirectly by this eBook.

Throughout this eBook you will find some links and some of them are affiliate links. This means the author (Rui Santos and Sara Santos) earns a small commission from each purchase with that link. Please understand that the author has experience with all of these products, and he recommends them because they are useful, not because of the small commissions he makes if you decide to buy something. Please do not spend any money on these products unless you feel you need them.

Other Helpful Links:

- Join Private Facebook Group
- Terms and Conditions

About the Authors

Hey There,

Thank you for purchasing the "Electronics for Beginners" course!

I'm Rui Santos, founder of the [Random Nerd Tutorials blog](), founder of [RNTLab.com]() and author of [BeagleBone For Dummies]().

This eBook was a collaboration between Rui Santos and Sara Santos. You don't see Sara's work often, but she gives an essential help to Random Nerd Tutorials. She works in the background doing tasks like recording, photo shooting, content creation, etc.

If you're new to the world of Electronics, this eBook is perfect for you. If you are already familiar with electronics, I'm sure you'll also learn something new. This eBook contains the information you need to get up to speed quickly and start your own venture into the world of Electronics.

Thanks for reading,

-Rui and Sara

Join the Private Facebook Group

This eBook comes with the opportunity to join a private community of like-minded people. If you purchased this eBook, you can join our private Facebook Group today!

Inside that group you can ask questions and create discussions about everything related to ESP8266, Arduino, BeagleBone, Raspberry Pi, etc.

See it for yourself!

- Step #1: Go to -> http://randomnerdtutorials.com/fb
- Step #2: Click "Join Group"
- Step #3: I'll approve your request within less than 24 hours

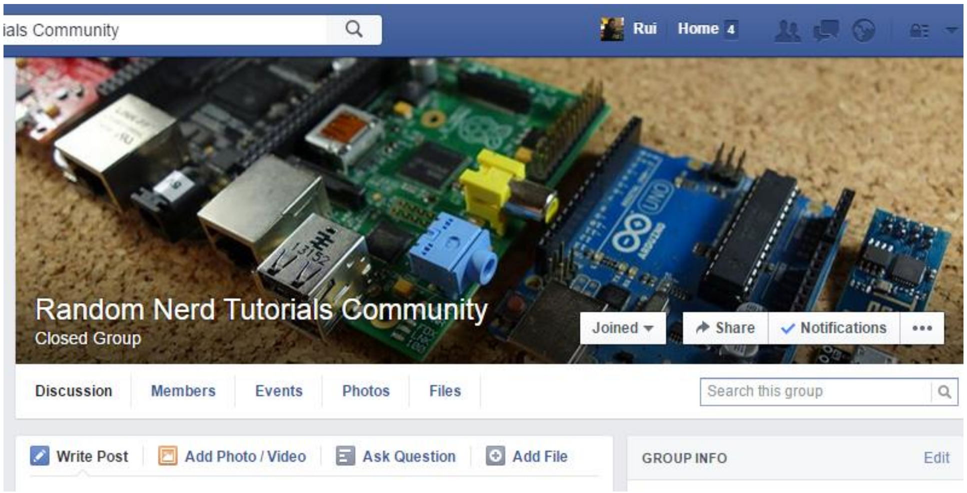


Table of Contents

Module 3

Module 4

Module 5

Module 0

Introducing Electronics For Beginners

Unit 1 - Course Overview

Hi there! Welcome to the Electronics For Beginners course.

A hands on introductory course designed to teach you simple concepts and introduce you to your first electronics circuits with simple step-by-step tutorials.

This course is designed for people who want to start with electronics. No previous knowledge is required.

The course is image and text based.

This course is divided into 4 modules

- **In the first module** you'll start learning electronics concepts such as electricity, current, voltage, resistance and basic formulas.
- **In the second module** you will be introduced to circuit diagrams and to electronics components. You will understand what they are used for and you will be able to read simple circuit diagrams.
- **In the third module** you will learn how to use a breadboard and you'll start building your very first simple circuits with LEDs, buttons and potentiometers.
- **In the fourth module** you will play with integrated circuits, more specifically with a very common IC, called the 555 timer, you'll learn how it works and you'll build more advanced circuits with it. You will also learn how to adjust the LED brightness using PWM.

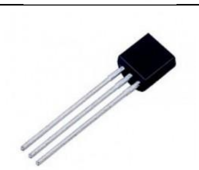
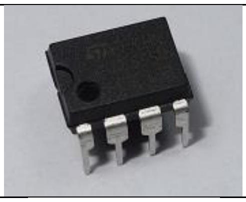
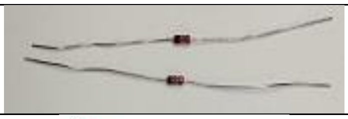
I only ask you to be ready to put in the necessary time and effort to complete this course. Thank you for your interest in **Electronics For Beginners** course

Unit 2 - List of Components and Parts

The following list shows all the components and parts required to complete the Electronics For Beginners course.

Don't worry, you don't need to buy all the components right away, because during the course we will mention the exact parts you need for each project.

Figure	Name and Quantity	eBay
	1x Breadboard	http://ebay.to/1Q3VGe0
	1x 9V Battery	http://ebay.to/1QoIn3H
	1x Battery Clip	http://ebay.to/1LvSFO5
	3x LED (5mm)	http://ebay.to/20H2Oyy
	3x 270kΩ Resistor, 1x 36Ω Resistor, 2x 1KΩ Resistor, 1x 470kΩ Resistor, 1x 470Ω Resistor, 1x 47kΩ Resistor	http://ebay.to/1KsMYFP
	1x Pushbutton	http://ebay.to/211vcRv

	1x SPST Toggle Switch	http://ebay.to/1Q5VuuE
	1x Light-dependent Resistor (LDR)	http://ebay.to/22qj3Co
	1x 2N 5089 NPN Transistor	http://ebay.to/29xMPRn
	1x 0.01uF Ceramic Capacitor	http://ebay.to/1TsZWGr
	1x 1uF Electrolytic Capacitor	http://ebay.to/24cMJW3
	1x EN555	http://ebay.to/1KYd3g7
	1x 10K Potentiometer	http://ebay.to/1PUefOb
	2x Diodes 1N4001	http://ebay.to/1VqjIjG
	Jumper Wire Cables	http://ebay.to/1PXeaJz

Unit 3 - Read This Before You Continue

I truly appreciate you taking the time to study this topic, and I hope you will enjoy the Electronics For Beginners course.

Problems during the course

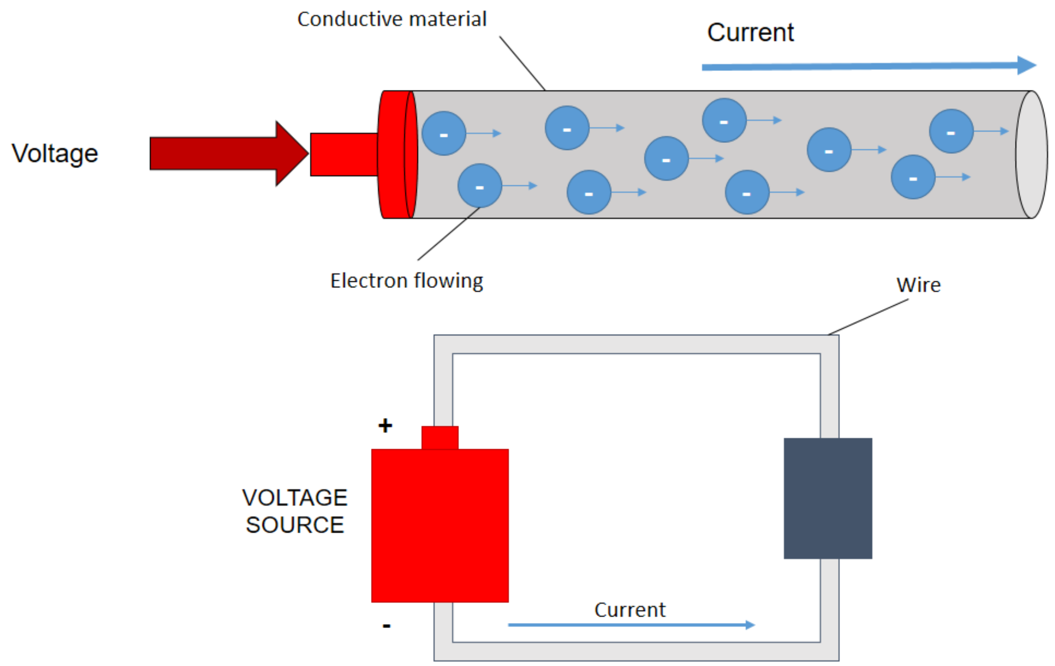
As you go through the course, it is likely that you will encounter some sort of technical problem.

I highly encourage you to spend a bit of time trying to fix technical problems by yourself. Fixing technical problems yourself is a very good way to learn things.

If you have done your best, you can always rely on the community to help you out. Join the Facebook Group to get help.

Module 1

Electricity, Current, Voltage and Resistance



Unit 1 - Electricity

This Unit gets you up to speed regarding the most basic principles of electricity, so that later you can understand what's behind your electronic projects.

It is important that you have an idea of what electricity is and the concepts related to it: **current**, **voltage** and **resistance** and how they are related.

What is Electricity?

According to the dictionary, electricity is:

"*a form of energy resulting from the existence of charged particles (such as electrons or protons), either statically as an accumulation of charge or dynamically as a current*."

"*a state or feeling of thrilling excitement*."

We are interested in the first bullet point, obviously, more specifically in current electricity, which is the one that powers our electronic gadgets.

To understand the basics of electricity we need to focus in atoms, the basic building blocks of matter.

Electricity

Electricity appears as a form of energy due to the existence of electrically charged particles, the protons and the electrons on the structure of the atom (see figure below).

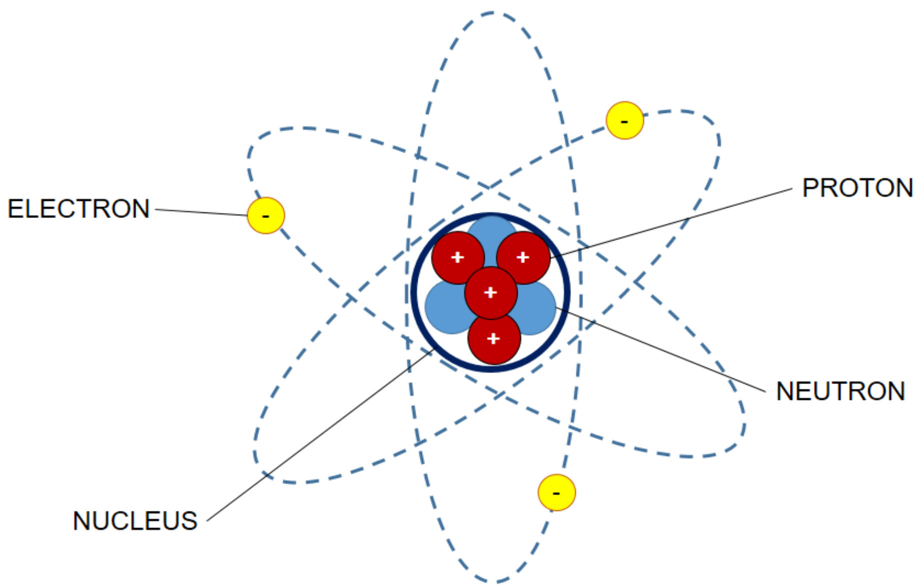


Figure 1. Structure of an atom

Structure of an atom

The **electrons** are negatively charged and spin around the center of the atom, which is the **nucleus**. The nucleus is made up of **neutrons** and **protons**. The **protons** are positively charged and the **neutrons** are not charged.

Electrons can move from one atom to another. An electric current, basically, is a flow of electrons bumping from atom to atom.

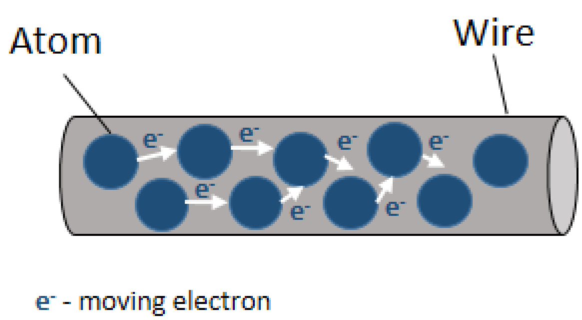


Figure 2. Electricity is a flow of electrons bumping from atom to atom

This phenomenon happens only in some materials, the ones that have conductive properties, the **conductors**, like copper for example.

Unit 2 - Current

When a flux of electrons goes from atom to atom, that phenomenon is called **electric current**. Basically, current is a flow of electrically charged particles through a conductive material.

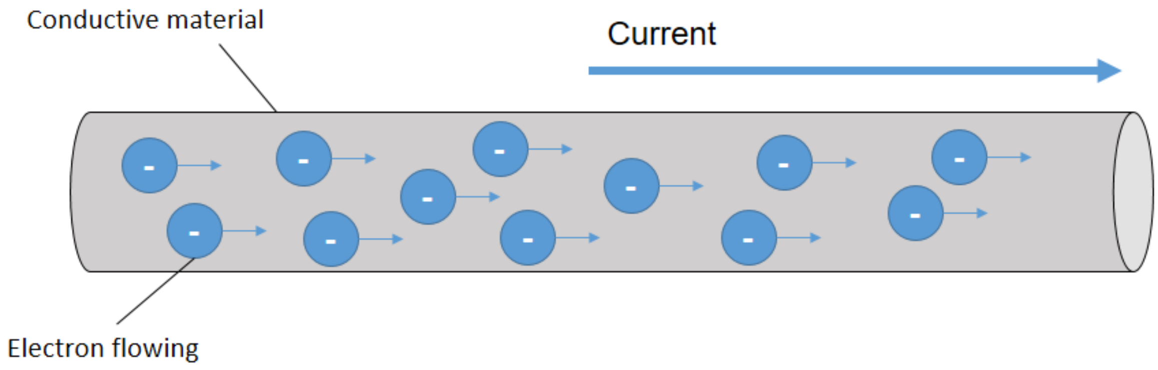


Figure 3. Flow of electrically charged particles through a conductive material

The wires used in electronics have copper in them to get the current flowing and are covered by a non-conductive material, also called an **insulator**, through which the electrons cannot pass.

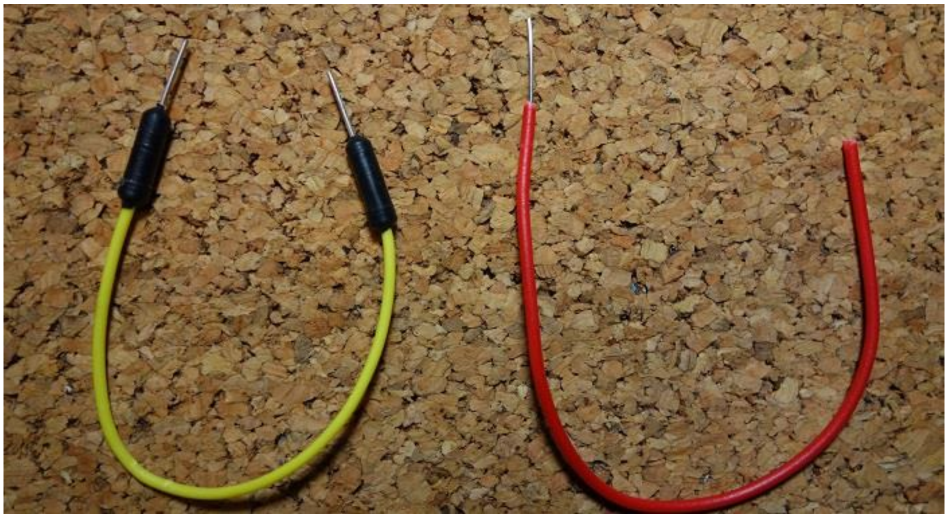


Figure 4. Wires. The colorful plastic is the insulator and the bright metal is the conductive material

In a circuit, the charged particles flow through wires and if the wire is cut, the current stops flowing.

That's why in an opened circuit nothing happens:

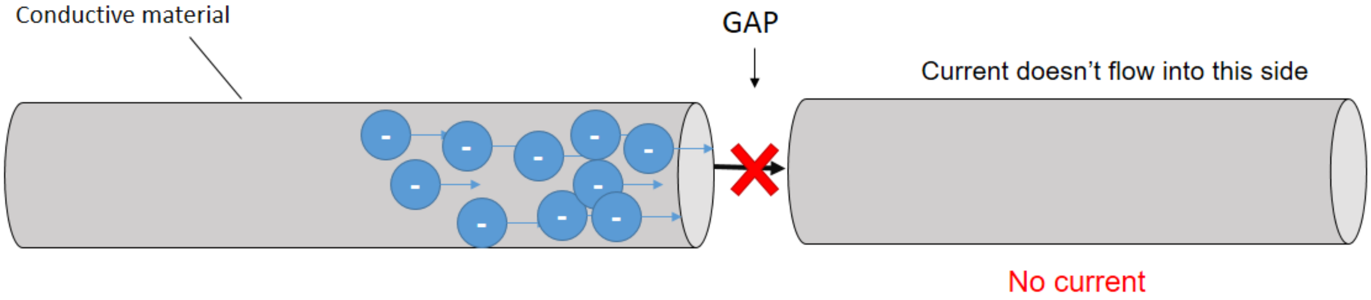


Figure 5. Cutting a wire stops the electrons from flowing

Unit 3 – Voltage and Resistance

All wires have charged particles in them. For electrons to move from one atom to another they need some sort of energy to get them moving, the **voltage**. There must be a **voltage source** to provide that energy.

Voltage

So, voltage is the force that drives the electric current forward. A **battery** creates an electric field that pushes the charged particles along, so a battery is a voltage source.

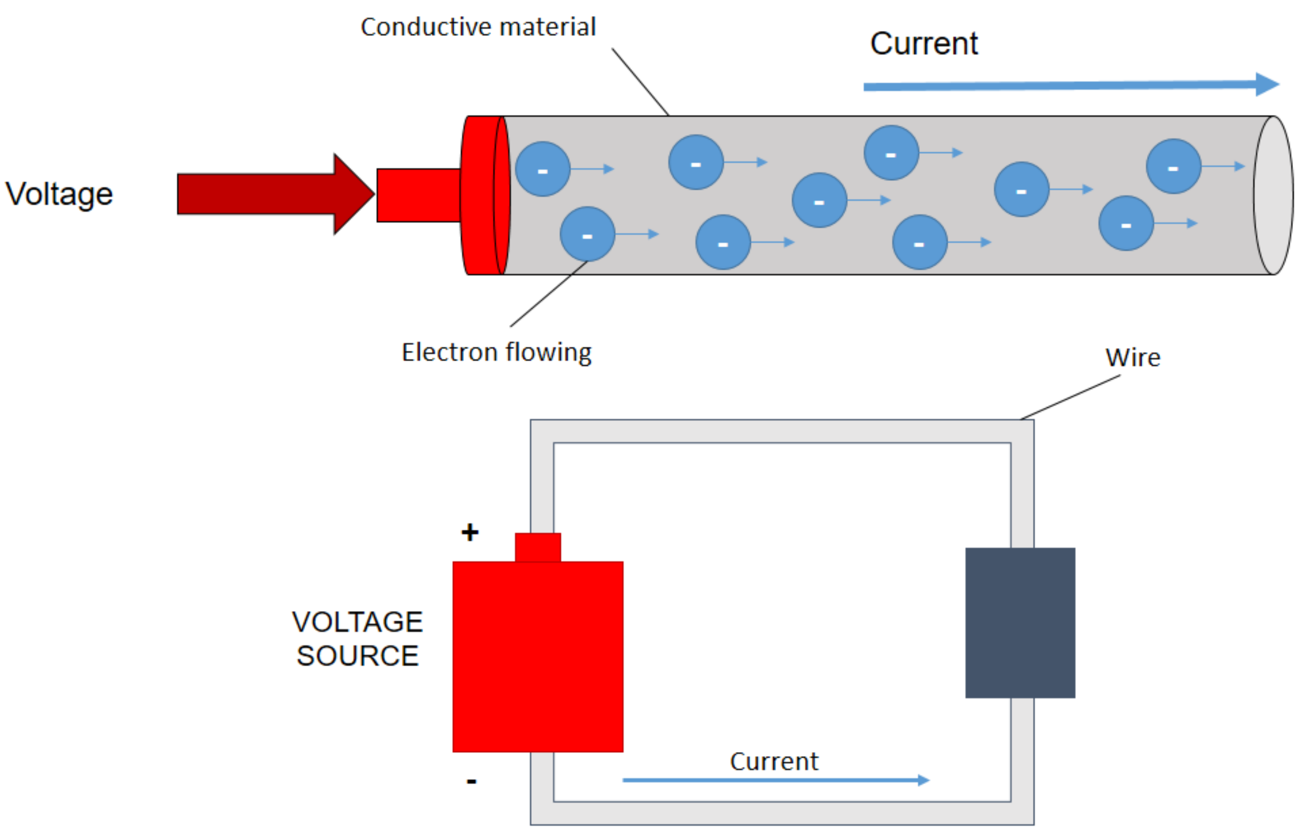


Figure 6. The voltage source is what makes the electrons flowing

Resistance

Another important concept in electricity is **electrical resistance**. All electronic components exhibit some sort of resistance, which is a material's capacity to resist electric current.

For the current to go through this material, it needs to be pushed through, so it needs more voltage.

When this happens we say that we have a **voltage drop** in the resistive component.

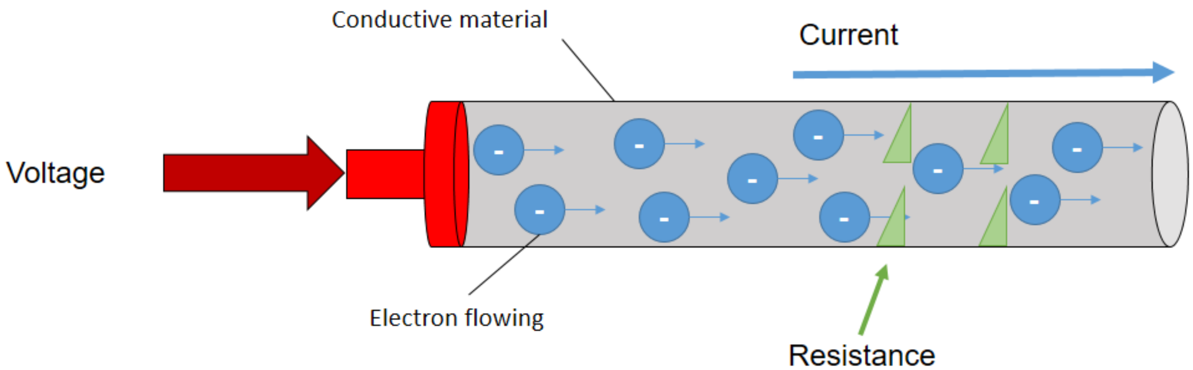


Figure 7. If we have higher resistance in a component and we want to maintain the current, we need to increase the voltage

The wires used in electronics have very little resistance, so it can be considered negligible.

Measuring current, voltage and resistance

Current, voltage and resistance can be measured using a multimeter (read the extra Unit for more info on how to use the multimeter).

- Current is measured in amperes or **amps** (A)
- Voltage is measured in **volts** (V)
- Resistance is measured in **ohms** (Ω)

Unit 4 – The Water Analogy

For most people is much easier to understand electric concepts when comparing electric current with water flow.

Imagine a system of plumbing pipes through which water flows. Some sort of force has to drive the water, such as a water **pump**, which is analogous to a **voltage** source.

Imagine that one section of the pipes has a much smaller diameter than the rest of the system. That section exhibits much higher **resistance** to the water flow.

So, for the **water current** to pass at the same speed, more force is required. The same happens with electric circuits.

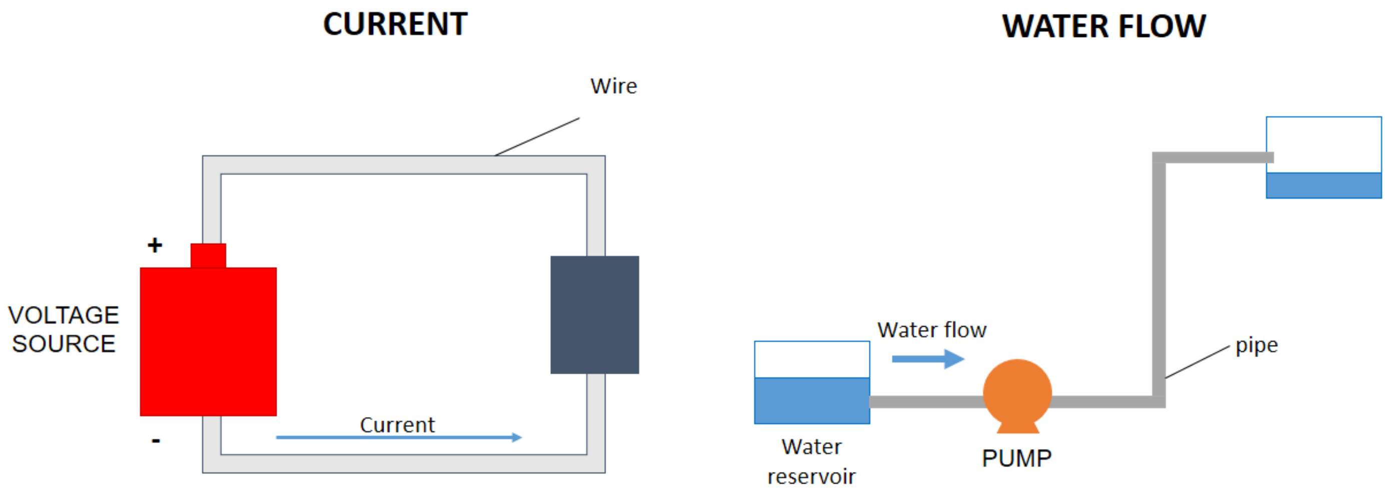


Figure 8. Analogy between electric flow and water flow

Unit 5 – Ohm's Law and Electric Power

When working with electronics there are two equations that you can't ignore, because they are the foundation of everything that happens in your circuit.

If you don't like math, don't worry.

These are very straightforward formulas and we'll show you how to use them with practical examples (later in this course)!

Ohm's Law

There is a relationship between current, voltage and resistance, which is represented by Ohm's Law.

The relationship is very simple, the voltage drop on a resistive component is proportional to its resistance and the current flowing through it.

$$V = I \times R$$

Where:

- V = Voltage in volts (V)
- I = Current in amps (A)
- R = Resistance in ohms (Ω)

Electric Power

The power is the amount of energy that your circuit consumes per second.

It is measured in watts (W) and can be calculated as follows:

$$P = V \times I$$

Where:

- P = Power in watts (W)
- V = Voltage in volts (V)
- I = Current in amps (A)

Unit 6 – A Basic Circuit Example

Here's an example of a basic circuit diagram:

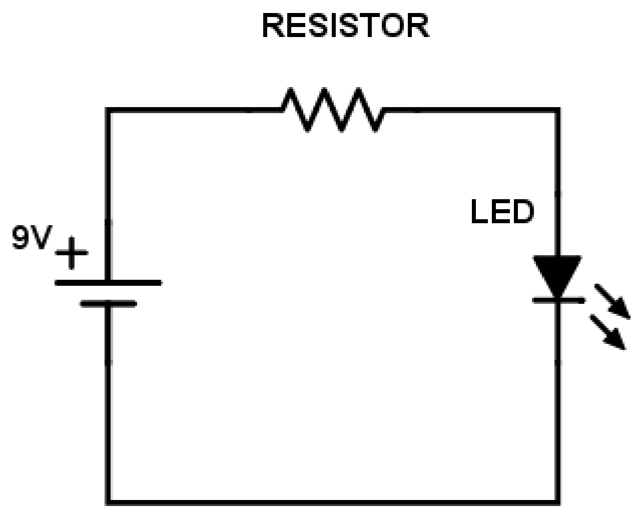


Figure 9. Circuit example

This circuit consists of a voltage source of 9V, typically a battery, a resistor and a light-emitting diode (LED).

Don't worry if you don't understand the circuit diagram above (you'll learn how to read schematics in the next Module).

WARNING

The LED has a specific amount of voltage that it needs in order to work properly. If you apply 9V directly to your LED, it will fry. That's why a resistor is needed to reduce the voltage applied in your LED.

What resistor value should you use in this case?

The LED needs 2V and draws about 0.03A to work properly. So, the circuit needs to get rid of the extra 7V.

You can calculate the value of the resistor, using Ohm's Law:

- V = 9 - 2 = 7V
- A = 0.03A
- So, R = $\frac{7}{0.03} \approx 233\Omega$

As you can imagine, you don't have every single resistance value available, so if you use an approximated value it's ok.

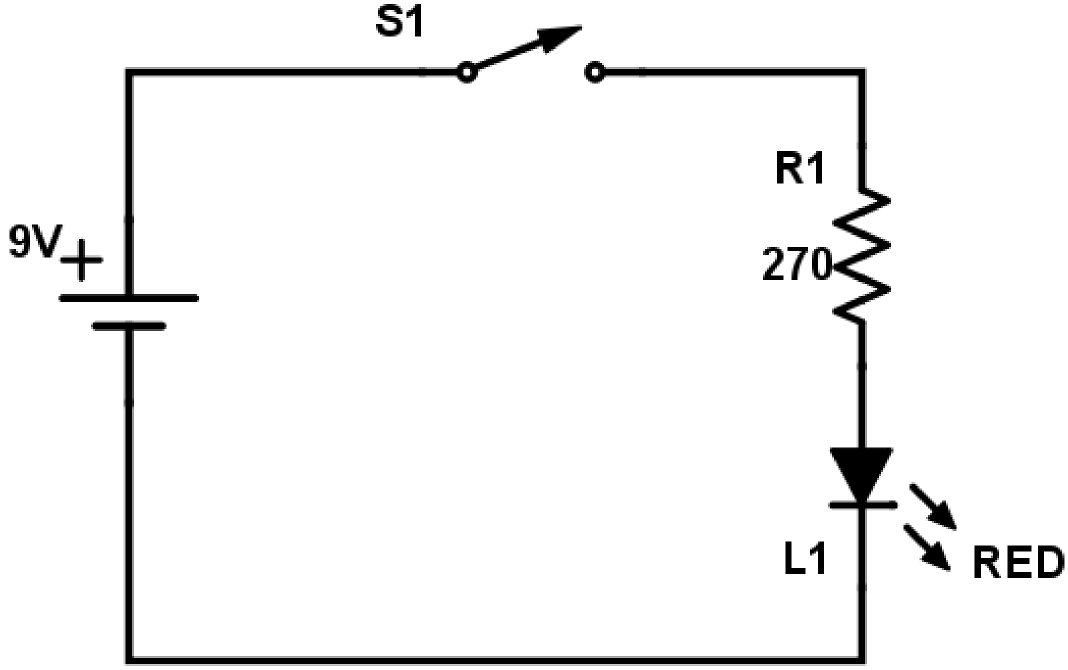
In this example, you need a 233 Ω resistor, but if you use a 270 Ω it will work just fine.

NOTE

It's recommended to always use resistors with higher resistance than you need. Because with higher resistance you avoid feeding more current than you should.

Module 2

Circuit Diagrams and Basic Electronic Components



Unit 1 – Circuit Diagrams

This Unit gets you acquainted with circuit diagrams.

You'll learn how to identify the most common electronic components and what they are used for.

Circuit Diagrams

A circuit diagram, or also called a **schematic**, is basically a graphic representation of an electric circuit.

It tells you which components you'll need and how to connect them to make your circuit work.

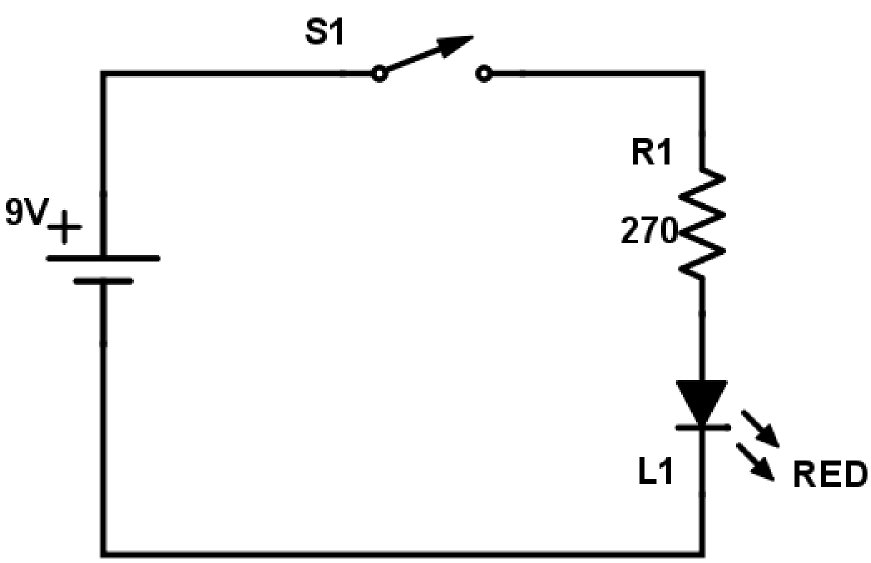


Figure 10. Circuit diagram example

Making your own projects, usually involves searching on the Internet for people who have made something like the thing you want to make.

The good news is that on the Internet you can usually find a circuit very similar to what you are trying to do.

Conventions for Circuit Diagrams

Circuit diagrams obey a few simple conventions. Not everyone adopts these conventions, but it is a good practice to do it.

Here are some conventions adopted:

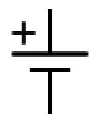
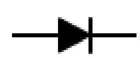
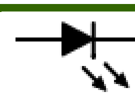
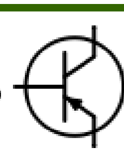
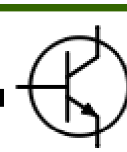
- **Positive voltages are uppermost.** If you look at the circuit diagram above, the positive pole of the battery is at the top
- **Things happen left to right.** The battery is often represented on left side and then, the other components
- **Each component should be labeled with a name and specified with a value**
- **Each component is represented by a specific symbol**

In the next Unit, we will cover the most common components and their symbols.

Unit 2 – Most common components and their symbols

There are lot of components and consequently, lots of symbols to represent them. In this course, we'll just cover the most common electronic components.

Here's a table with the components names and their respective symbols:

Component Name	Symbol Figure
DC power supply/batteries	
Resistor	
Potentiometer	
Diode	
Light emitting diode (LED)	
Capacitor	
Switch	
Transistor	PNP  NPN 

Unit 3 - Batteries

The DC voltage source powers up your circuit.

The required voltage depends on the application of your circuit. For example, most DC motors require more voltage than a simple LED.

Figure 11. Battery examples

Some of the most common batteries in simple electronics projects are the 9V batteries. They are very easy to find and to use. You will also need a battery clip.

Figure 12. Battery and a battery clip

This battery clip has two wires: one **black** and one **red**.

The **red** wire is the positive (+) lead and the **black** is the negative (-) lead.

Polarity

Since the battery has one positive (+) side and one negative (-) side, you need to be sure that you are connecting the battery correctly.

Don't worry, if this sounds two abstract right now. When you actually start building your first projects, it will be easier to understand.

WARNING

If the negative pole and the positive pole of a battery touch each other, you will have a ***short-circuit***, which will damage your battery. So, when you're not using the battery, leave the battery clip off.

TIP

We recommend using rechargeable batteries. They are a little bit more expensive, but they will save money in the long run.

Unit 4 – Resistors

The resistor controls the voltage and current supplied that reach the other components in your circuit.

The most common used resistors in simple electronics projects are ¼-watt through-hole resistors.

In the figure below this type of resistor is the second counting from top to bottom.

Figure 13. Several types of resistors

TIP

We recommend buying cabinet organizers, so that you can store your components in an organized way. Otherwise you'll spend a ton of time looking for the right resistor value (and other components).

Figure 14. Cabinet organizers

Unit 5 – Resistor color chart

The resistance of a resistor is given in ohms (Ω) and is defined by the color bands that appear along it.

The bands are read from left to right. The resistor has 4 bands, and you can see that there are 3 bands and then a bigger gap and the 4^{th} band.

The following figure shows the right way of reading the resistor colors.

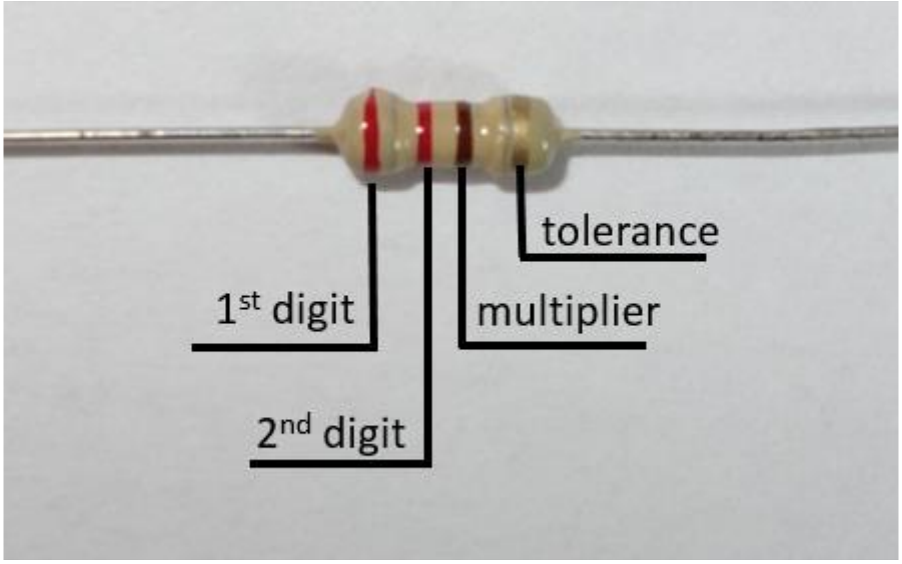


Figure 15. Resistor bands

Each band means something:

- The first two bands represent the numbers of the first two digits
- The third band represents the number of zeros after those digits, the multiplier
- The fourth band is the tolerance of the resistance

The tolerance means the value isn't precisely what's indicated by the colors, it means that the value of resistance can be between two values. You'll see an example in the next section.

Resistor Color Chart

The following table explains those values.

Resistor Color Chart			
Color	**Value**	**Multiplier**	**Tolerance**
Black	0	$\times10^0$	-
Brown	1	$\times10^1$	±1%
Red	2	$\times10^2$	±2%
Orange	3	$\times10^3$	-
Yellow	4	$\times10^4$	±5%
Green	5	$\times10^5$	±0.5%
Blue	6	$\times10^6$	±0.25%
Violet	7	$\times10^7$	±0.1%
Grey	8	$\times10^8$	±0.05%
White	9	$\times10^9$	-
Gold	-	$\times10^{-1}$	±5%
Silver	-	$\times10^{-2}$	±10%

Determining the value of resistance

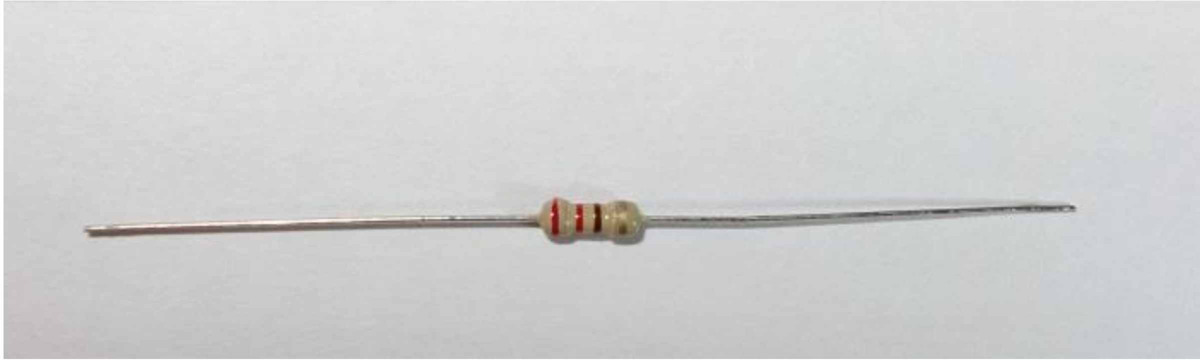


Figure 16. Resistor

Let's determine the resistance value of the resistor above:

- **1st band** is red – the first digit is 2
- **2nd band** is red – the second digit is 2
- **3rd band** is brown – the multiplier is 10^1 = 10
- **4th band** is gold – the tolerance is 5%

The value of resistance is 22×10 = 220Ω.

The tolerance is 5%, which means that the value of resistance can be between 220Ω ±5%. So it can have any value between 209Ω and 231Ω.

TIP

It's useful to know how to determine the value of a resistor. However, if you search on Google "resistor calculator", you'll find several websites where you select the colors of your resistor, and it automatically calculates the value of resistance.

Unit 6- Resistors in Series and in Parallel

You can combine resistors to have a specific value of resistance. For instance, you can combine resistors **in series** or **in parallel**.

The figures below show how to calculate the resistance for both situations:

Resistors in Series

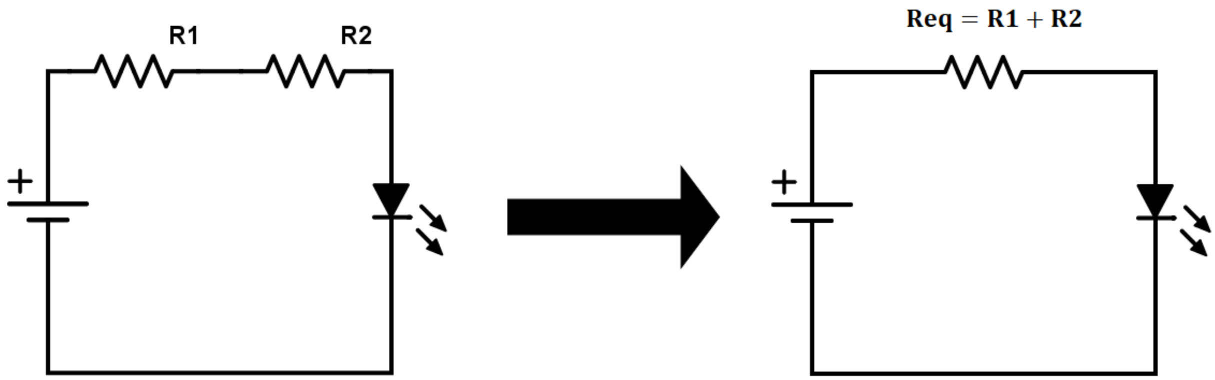


Figure 17. Resistors in series

Resistors in Parallel

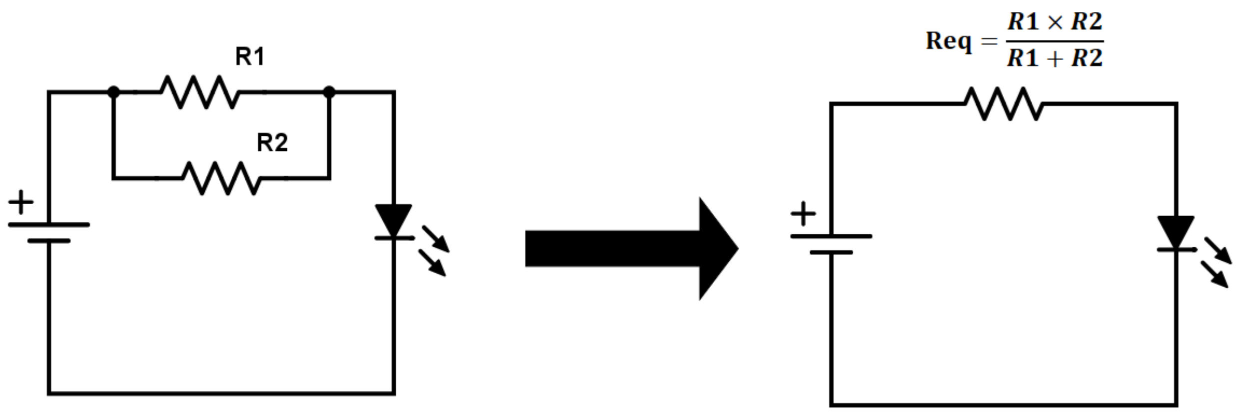


Figure 18. Resistors in parallel

Example

Imagine that R1 = 220Ω and R2 = 270Ω. What's the total value of resistance in the first and in the second situation?

- **Resistors in series:** Req = 220 + 270 = 490 Ω
- **Resistors in parallel:** Req = $\frac{220 \times 270}{220 + 270} \approx 121\ \Omega$

Unit 7 – Diodes and LEDs

Diodes

Diodes force the current to flow in only one direction, like a one-way valve. That's why its symbol is represented by an arrow.

Figure 19. Diode

Diodes have a **negative lead (-)** and a **positive lead (+)**, which are called the cathode and the anode, respectively.

If the anode is at a higher voltage than the cathode (it has two be greater by about half a volt), it conducts electricity, and we say that it is "**forward-biased**". If not, we say that it is "**reverse-biased**" and the current doesn't flow.

LEDs

An LED is a diode that lights up (when it is forward-biased). There are lots of LED sizes, shapes and colors.

Figure 20. Various LEDs

Diodes and LEDs have polarities. If you take a close look at an LED, you'll see that it has two distinct legs (also called leads).

One lead is longer than the other.

- **Longest lead: Anode (+)**
- **Shortest lead: Cathode (-)**

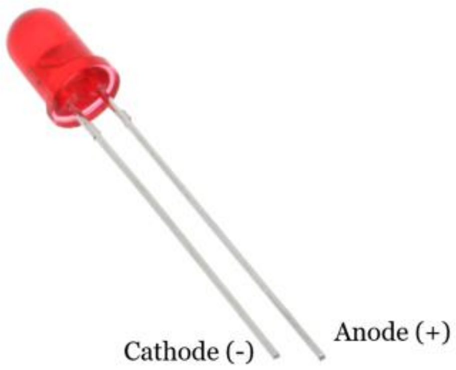


Figure 21. LED polarity

The current flows from the anode to the cathode. So, you should connect the anode lead to the positive supply.

An ordinary LED won't work if the leads are connected in reverse to a power supply.

WARNING

You should always use a resistor connected in series with your LED when connected to a voltage source, otherwise it will fry.

Unit 8 – Capacitors

Basically, capacitors are components that store charge, a bit like a battery, *but not much charge*. Capacitors can store that charge and then, release it very quickly. Capacitors are mainly use to solve problems like the instability of a circuit or unwanted noise.

There are two main types of capacitors:

- **Electrolytic**
- **Ceramic**

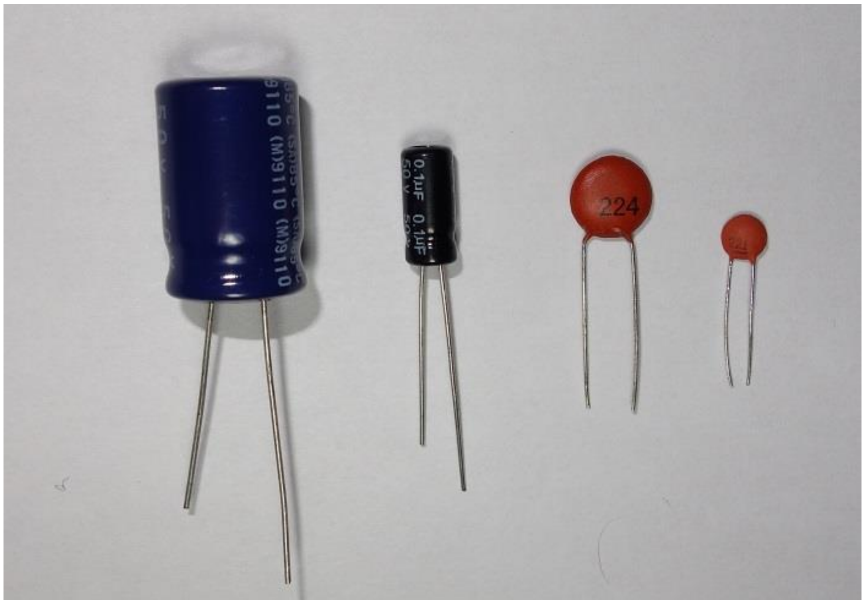


Figure 22. Two electrolytic capacitors and two ceramic capacitors

Electrolytic capacitors exhibit polarity. You should connect the (+) pin to the side that current is coming from.

The capacitance of a capacitor is measured in **farads (F)**.

In electronics, the most common values for capacitors are within the range of **micro-farad**, **nano-farad** or **pico-farad**.

Unit 9 – Switches, Transistors and Integrated Circuits

Switches

Switches allow electric current to flow by closing the circuit, or stop electric current from flowing by opening the circuit. There are several types of switches as you can see in the figure below.

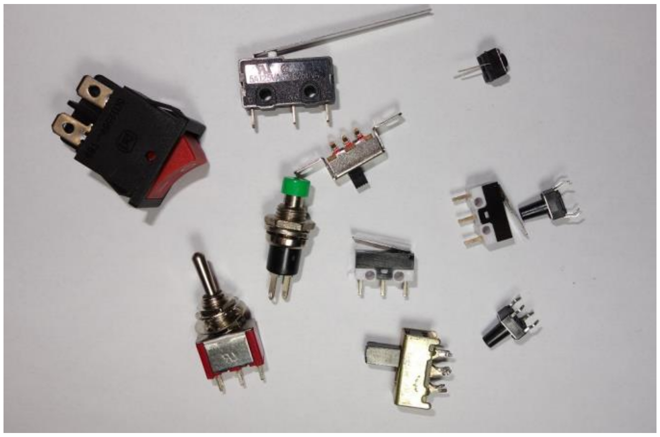


Figure 23. Several types of switches

Transistors

There are different types of transistors. There are two types of Bipolar Junction Transistors (BJTs) transistors, the NPN and the PNP.

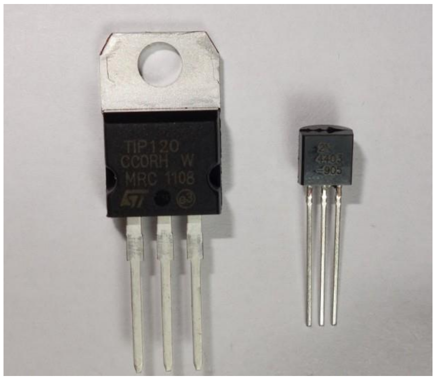


Figure 24. Two transistors

Transistors have three pins: the emitter (e), the base (b) and the collector(c).

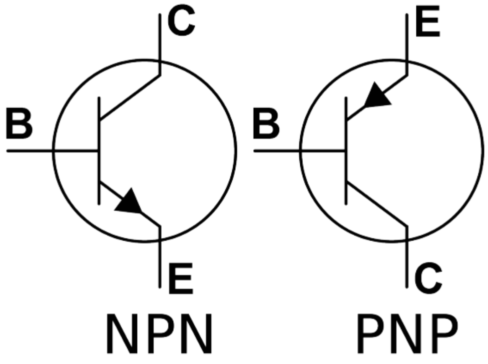


Figure 25. NPN and PNP transistors symbols

Basically, transistors can be thought of as an automatic switch. They control a big current, and are controlled by a small current.

Integrated circuits

Basically, an integrated circuit (IC) is a fully functioning circuit inside a small plate of silicon. There are lots of different integrated circuits for multiple purposes.

With ICs, you don't need to know what's going on inside the circuit, you just need to know what goes in (input pins) and what comes out (output pins).

Integrated circuits have datasheets with information about input and output pins.

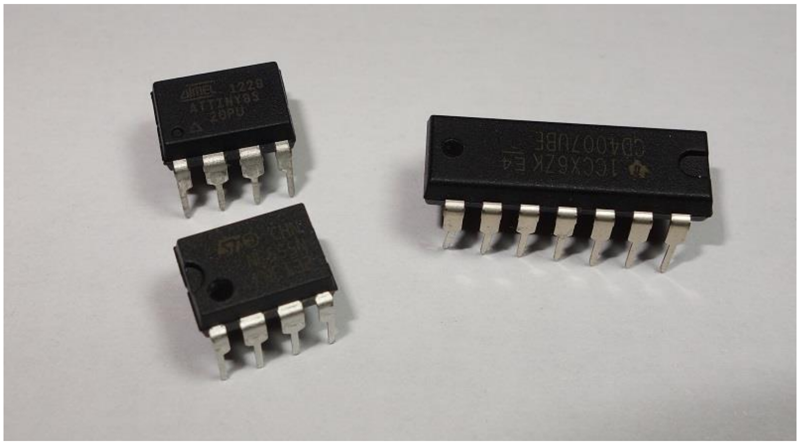


Figure 26. Integrated Circuits (ICs)

Unit 10 - Potentiometers

A potentiometer, also referred to as pot, may come in a variety of shapes and are used in many applications, for example to control the audio volume of the radio. In the picture below you can see some potentiometer examples:

Figure 27. Potentiometers

In a circuit diagram, a potentiometer is represented by one of the two symbols below:

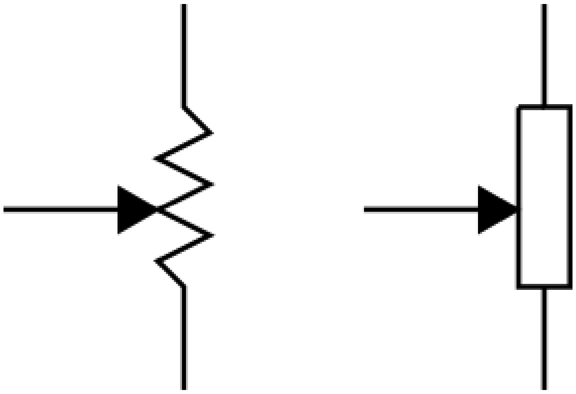
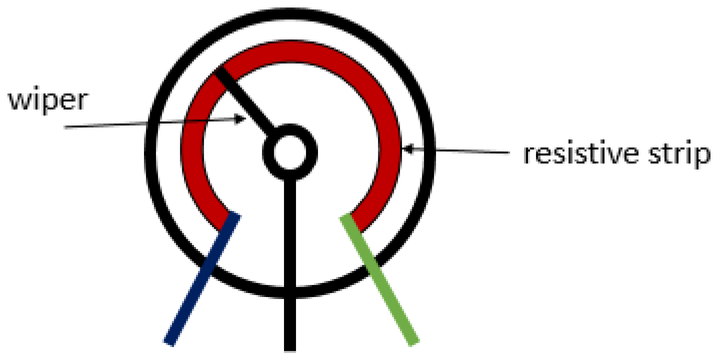


Figure 28. Potentiometer symbols

How Does a Potentiometer Work?

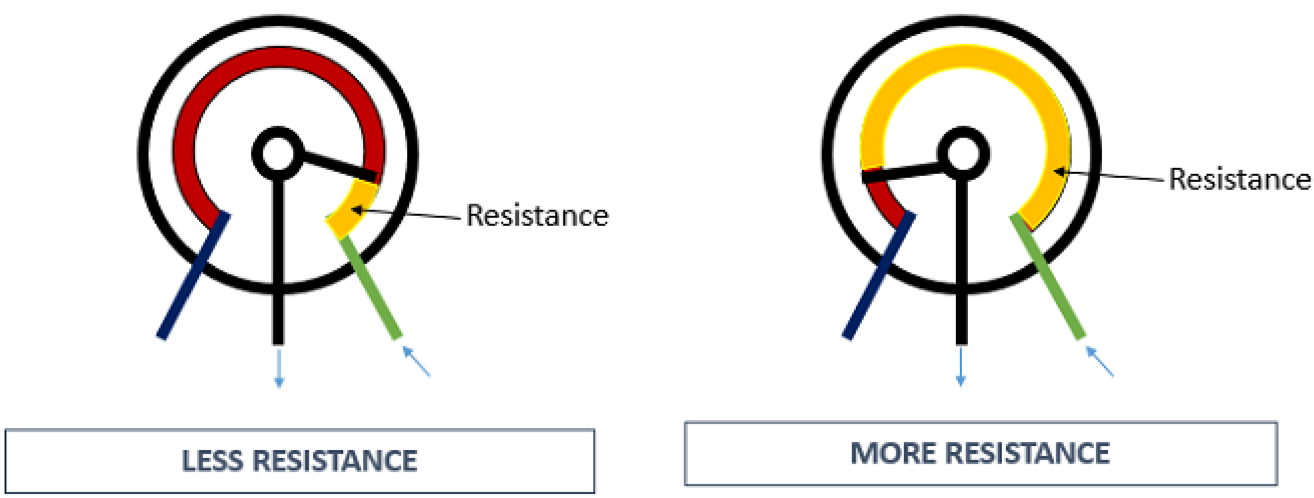
A potentiometer has 3 pins. Two terminals are connected to a resistive element and the third terminal is connected to an adjustable wiper.



The potentiometer can work as a rheostat (variable resistor) or as a voltage divider.

Rheostat

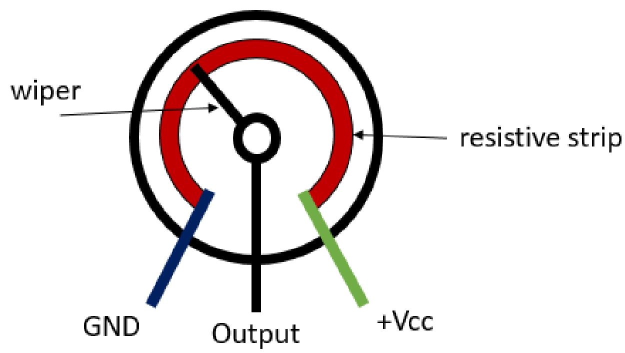
To use the potentiometer as a rheostat, only two pins are used: one outside pin and the center pin. The position of the wiper determines how much resistance the potentiometer is imposing to the circuit, as the picture demonstrates:



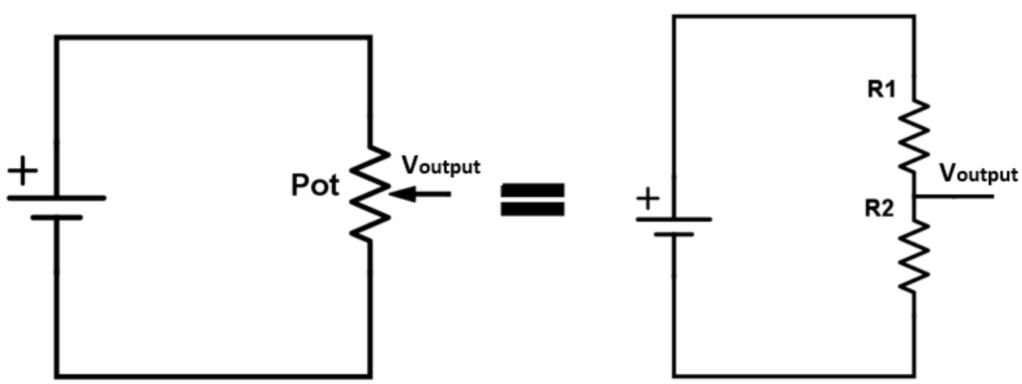
If we have a 10kΩ resistor, it means that the maximum resistance of the variable resistor is 10kΩ and the minimum is 0Ω. This means that by changing the wiper position, you get a value between 0Ω and 10kΩ.

Voltage divider

Potentiometers can be used as voltage dividers. To use the potentiometer as a voltage divider, all the three pins are connected. One of the outer pin is connected to the GND, the other to Vcc and the middle pin is the voltage output.



When the potentiometer is used as a voltage divider, the wiper position determines the output voltage. When you have the potentiometer connected this way, you have the following circuit:



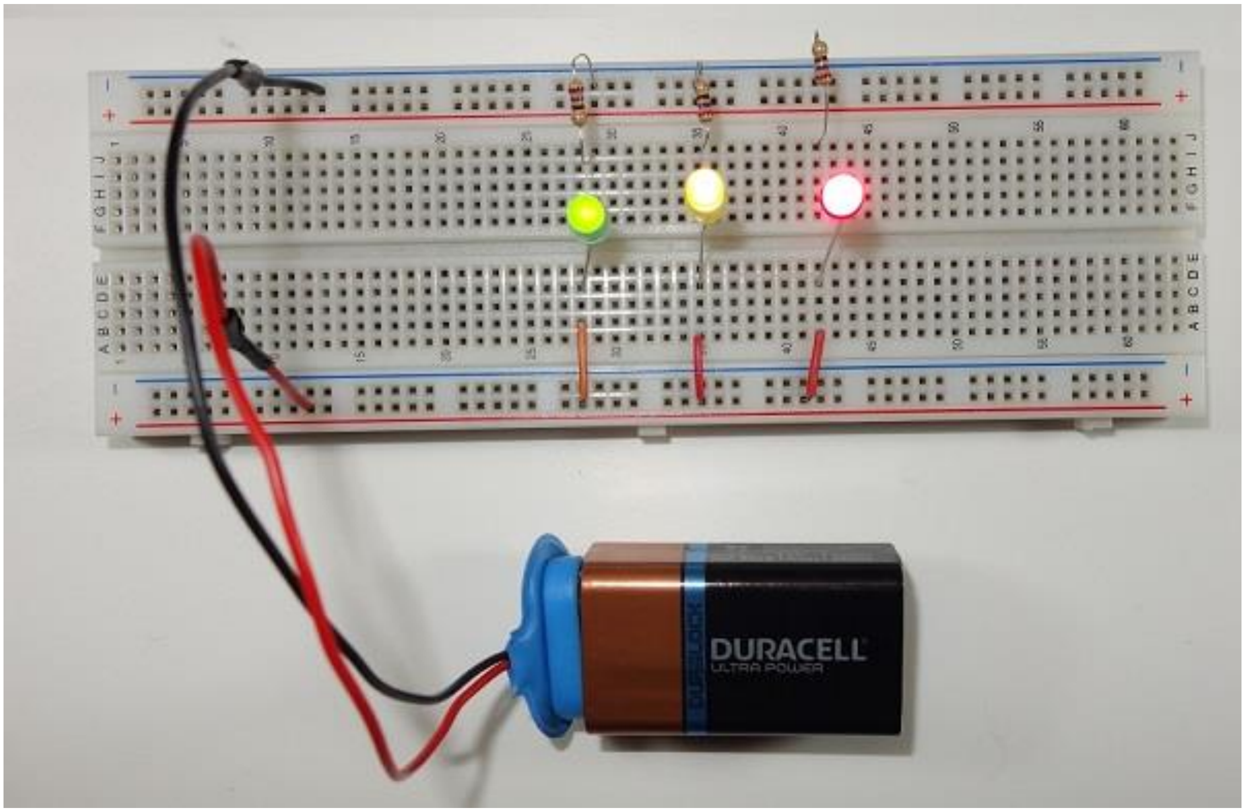
Basically, the voltage divider is used to turn a large voltage into a smaller one.

The output voltage can be calculated using the following equation obtained from Ohm's Law:

$$V_{out} = V_{cc} \times \frac{R_2}{R_{1+}R_2}$$

Module 3

Building Your First Circuits



Unit 1 – Breadboard, Prototype Board and Printed Circuit Board

Enough with theory! In this Module you'll start building your first real circuit, in other words, you'll give life to your circuit diagrams. You'll learn how to use a breadboard to do your own prototypes.

Building Circuits

Once you have a circuit diagram for a specific project, you want to translate it to the real world. So, you need to connect all your components together. There are several ways to connect your components, here's the three most common ways:

- Solderless breadboard (no soldering required)
- Prototype board (you need to solder your components together)
- PCB (Printed Circuit Board)

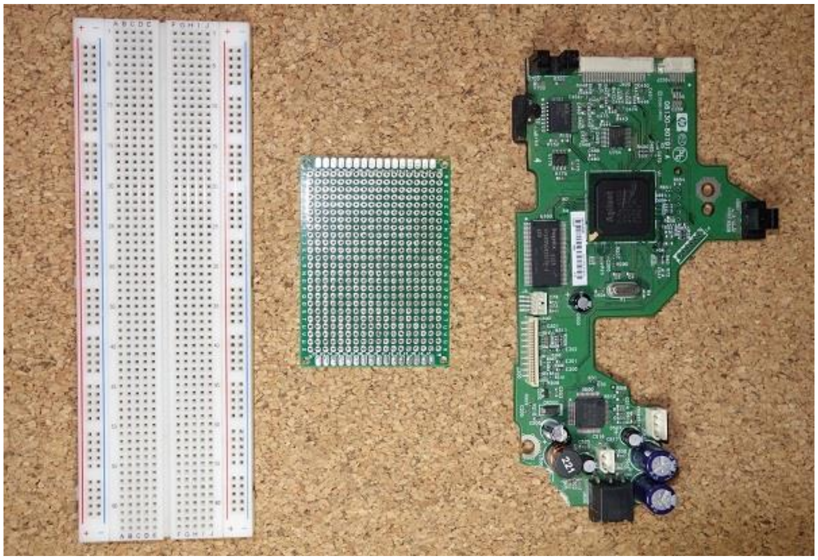


Figure 29. Breadboard, prototype board and PCB

In this course, you're going to use a solderless breadboard, because it's the easiest way to make your first circuits and doesn't require any soldering.

Unit 2 – How Does a Breadboard Work?

Here's how a breadboard looks like:

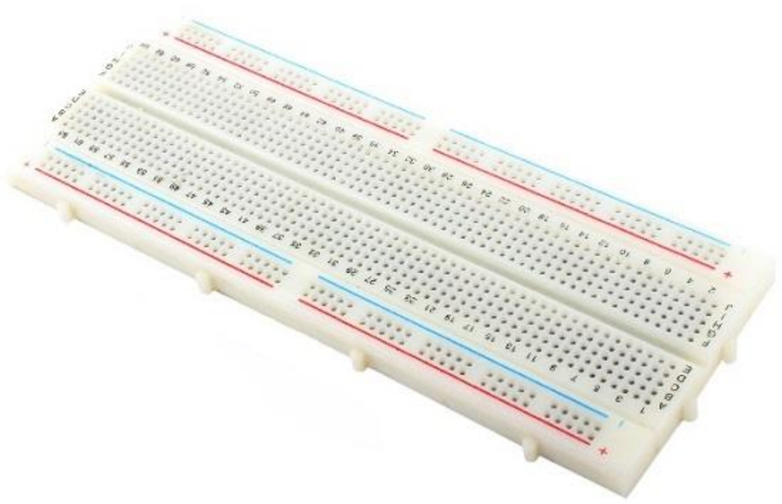


Figure 30. Breadboard

Beneath all the holes in the breadboard there are copper tracks, which allow you to create electric connections for current to pass without committing to more permanent solutions.

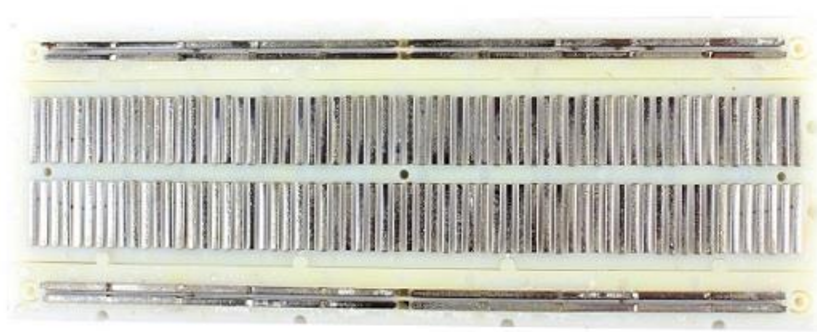


Figure 31. Breadboard copper tracks

In the figure below, you can see how the copper tracks are connected (the orange lines represent connections between the holes).

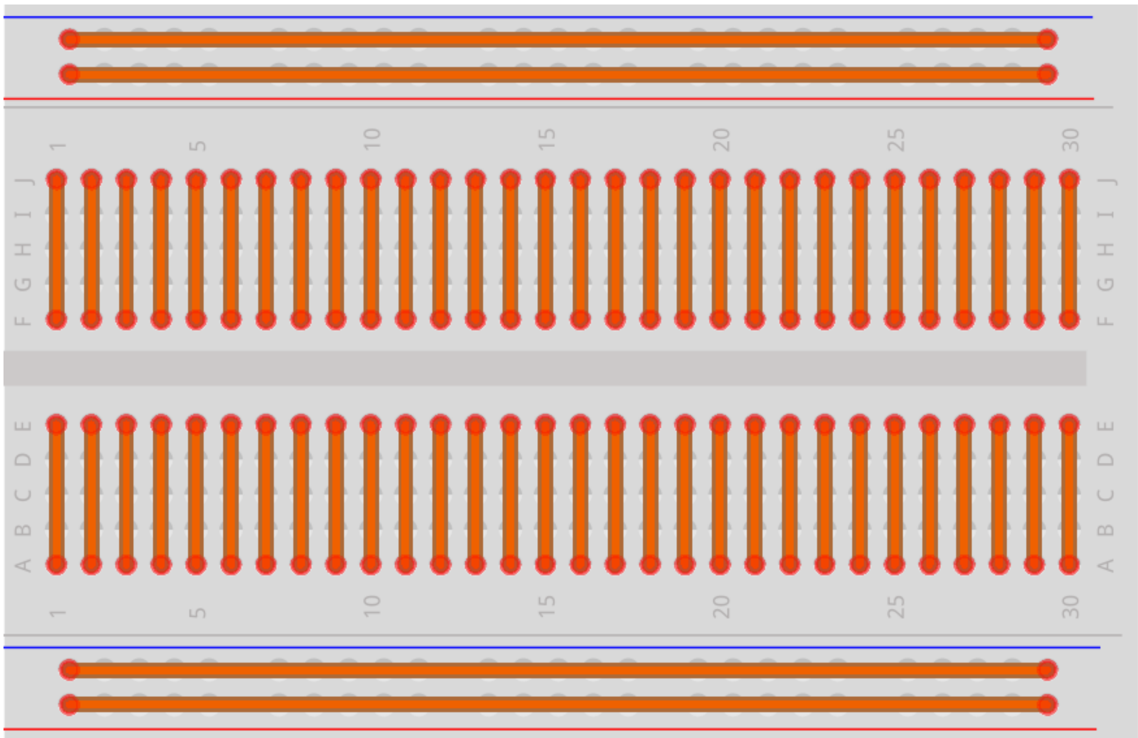


Figure 32. How holes are connected in a breadboard

Each individual orange line is electrically isolated from all the other lines.

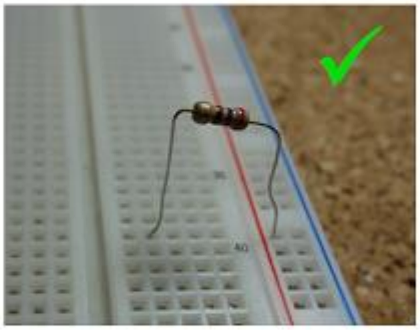
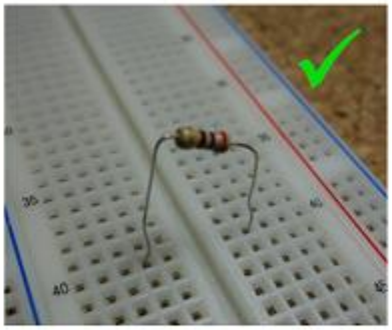
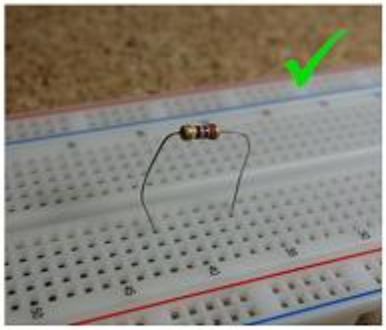
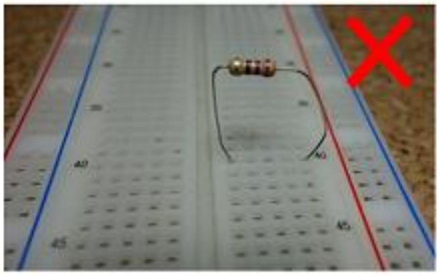
The horizontal lines are used to connect the power supply (as shown in the figure above).

This means that if you connect 5 volts on the top hole of one of the lines, you'll have 5 volts in all the holes of that line.

How to connect components

In the middle of the board is where you should connect your components.

Here's an example of how you should and how you shouldn't connect your components:

The last figure shows an incorrect connection, because both legs of the resistance are connected to the same column, and so, they are connected to each other.

In all the other situations the resistor legs don't connect with each other.

Unit 3 – Lighting up an LED

The first circuit presented in the course is the simplest one. You'll turn on an LED.

The schematic diagram is the following:

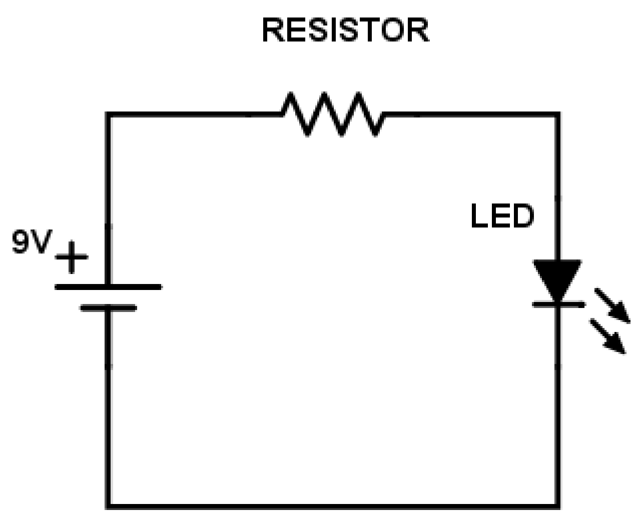


Figure 33. Circuit diagram to light up an LED

Taking a closer look at the circuit diagram, you can identify which components you'll need.

Additionally, you also need to determine which is the proper resistor to use with your LED. Basically, the resistor will limit the current flowing through the LED.

Typically, a 5mm LED needs 2V and draws about 0.03A.

So, using Ohm's Law, we will need a 233Ω resistor (if you don't know how to use Ohm's Law read one of the previous Units).

As you don't have that exact resistance value, you'll use a **270Ω resistor**.

NOTE

It's recommended to use a resistor with a higher resistance than the estimated value. If you use a higher resistance value you avoid feeding more current than you should.

Here are the components you will need:

- 9V battery
- Battery clip
- LED (5mm)
- 270Ω resistor
- Breadboard
- Wire cables

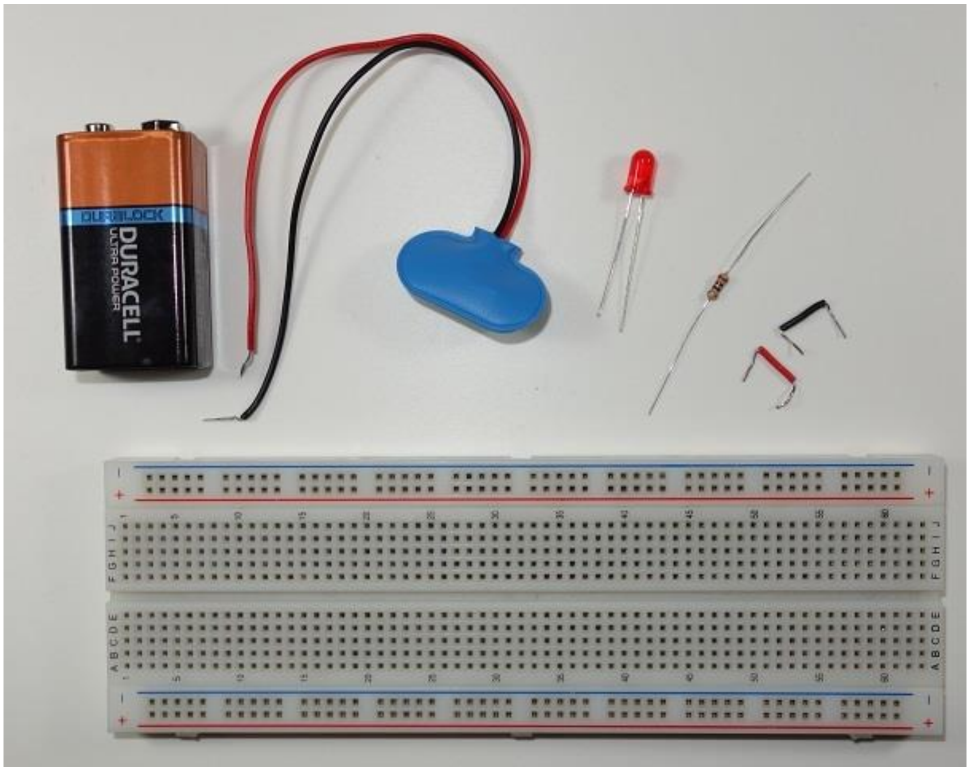


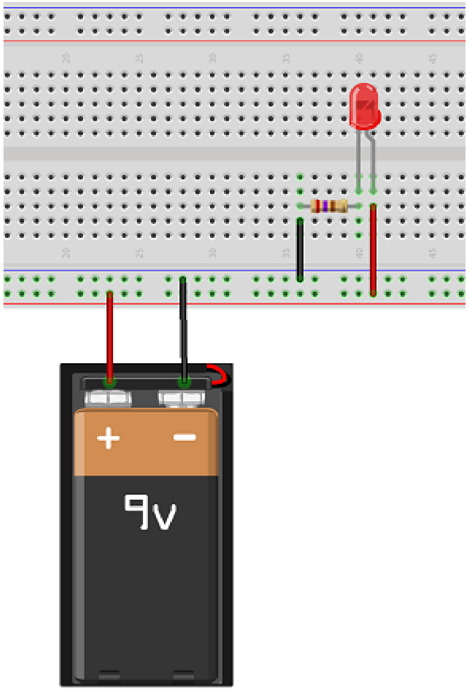
Figure 34. Required material

1. Start by bending the longest lead of the LED

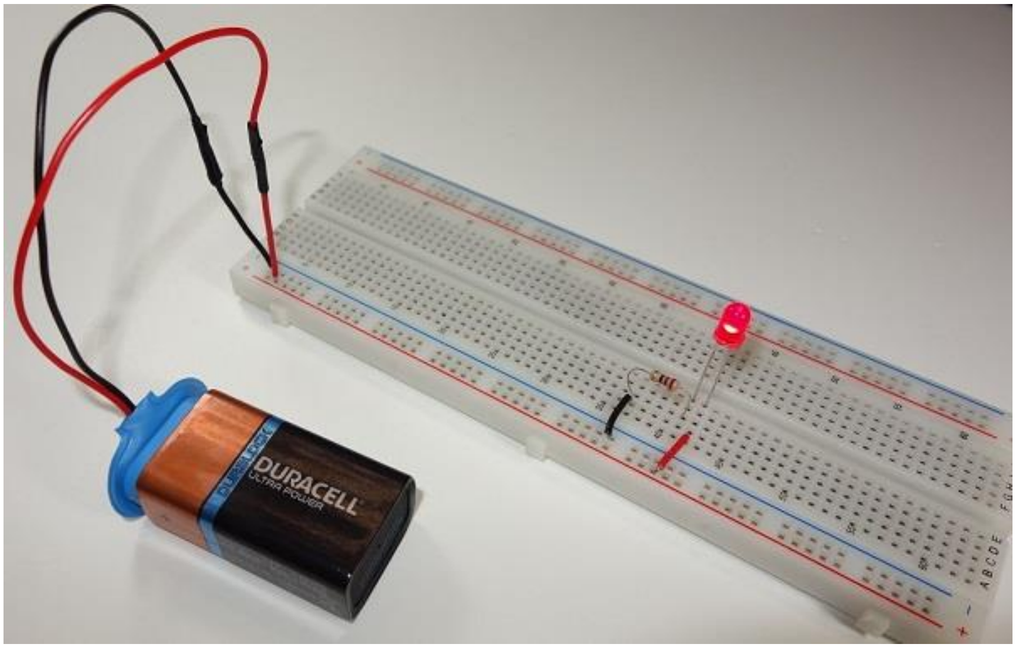
Figure 35. LED with the longest lead bend

2. Insert the LED in the breadboard
3. Insert the resistor in a way that it is connected to the LED
4. Plug the red wire of the battery clip and the black wire to the horizontal rows of the breadboard
5. Plug the battery in the battery clip

Your circuit should be connected as in the schematic below:



Your LED should be lighted on.



Unit 4 – LEDs in Series

Let's try something very similar to the previous example, but with more LEDs. First you'll use three LEDs in series and then, three LEDs in parallel.

LEDs in Series

With LEDs in series our circuit diagram will be:

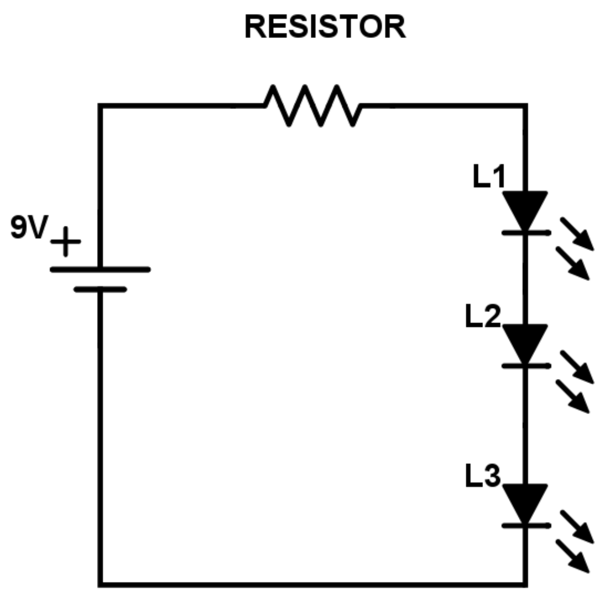


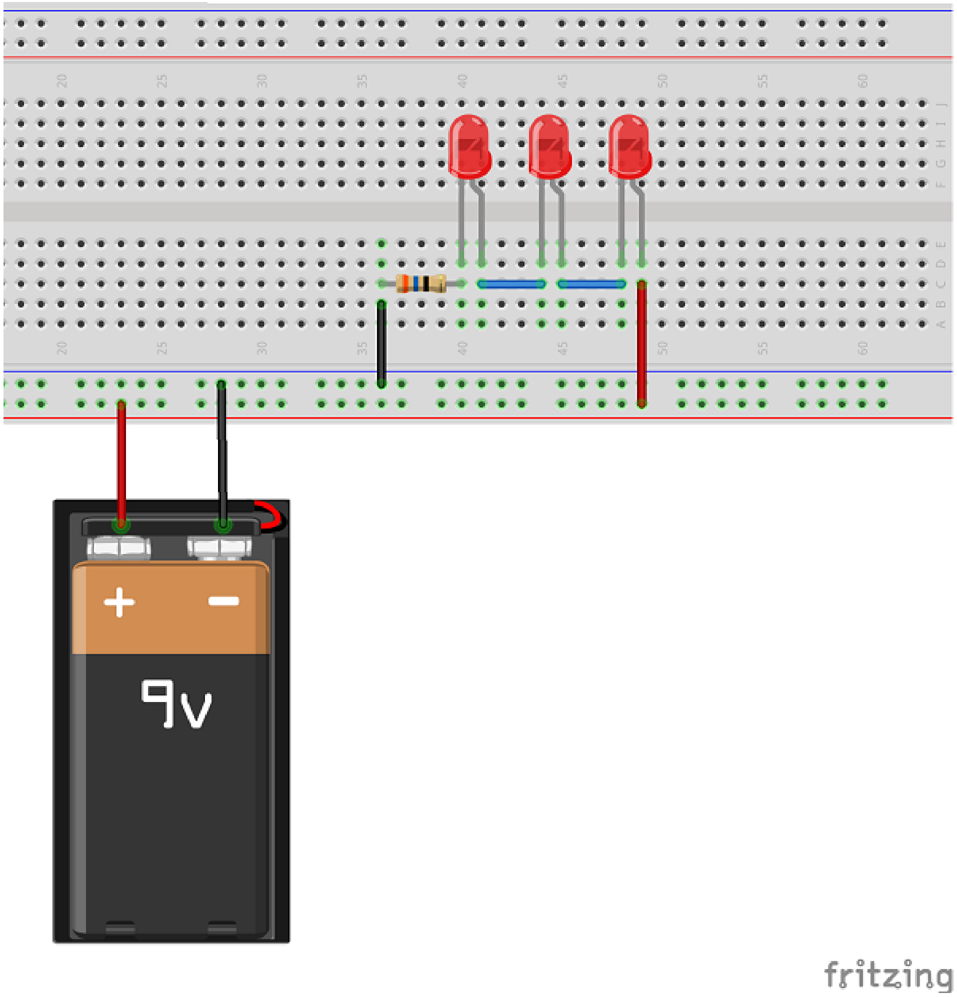
Figure 36. Circuit diagram with LEDs in series

When we have LEDs in series, the voltage will be divided equally for all LEDs. Since we have a 9V power source, we will have 9/3 = 3V for each LED. So, we will need to dissipate 1V in a resistor. Applying Ohm's Law:

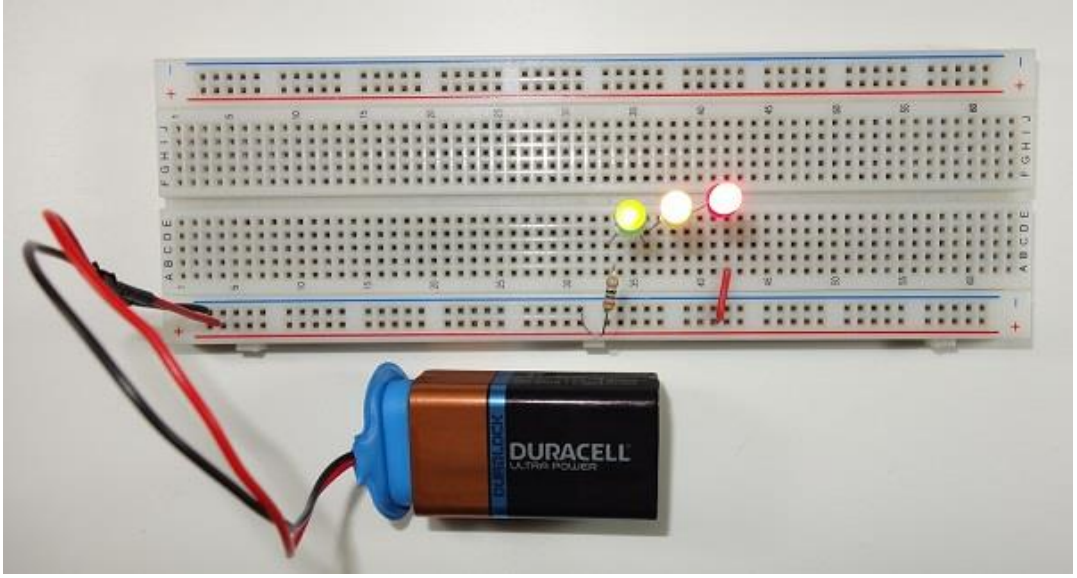
R = 1/0.03 = 33.33Ω

You'll use a **36Ω resistor**.

Assemble everything together. It is very easy, simply follow the following figure:



This is the final result:



Unit 5 – LEDs in Parallel

With LEDs in parallel the circuit diagram looks like this:

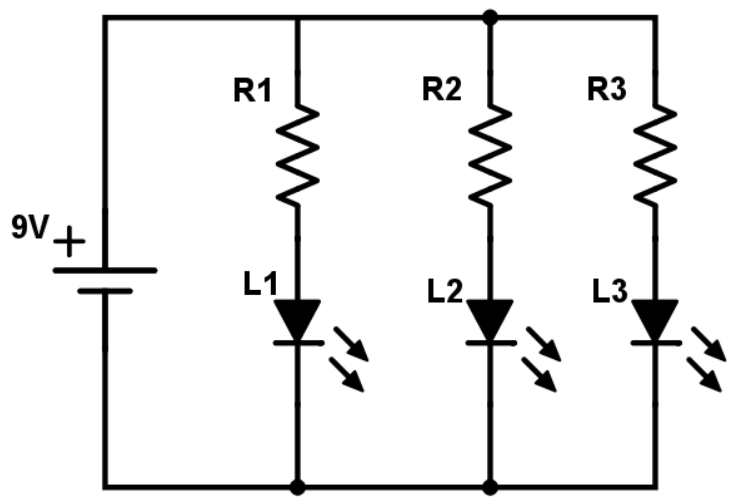
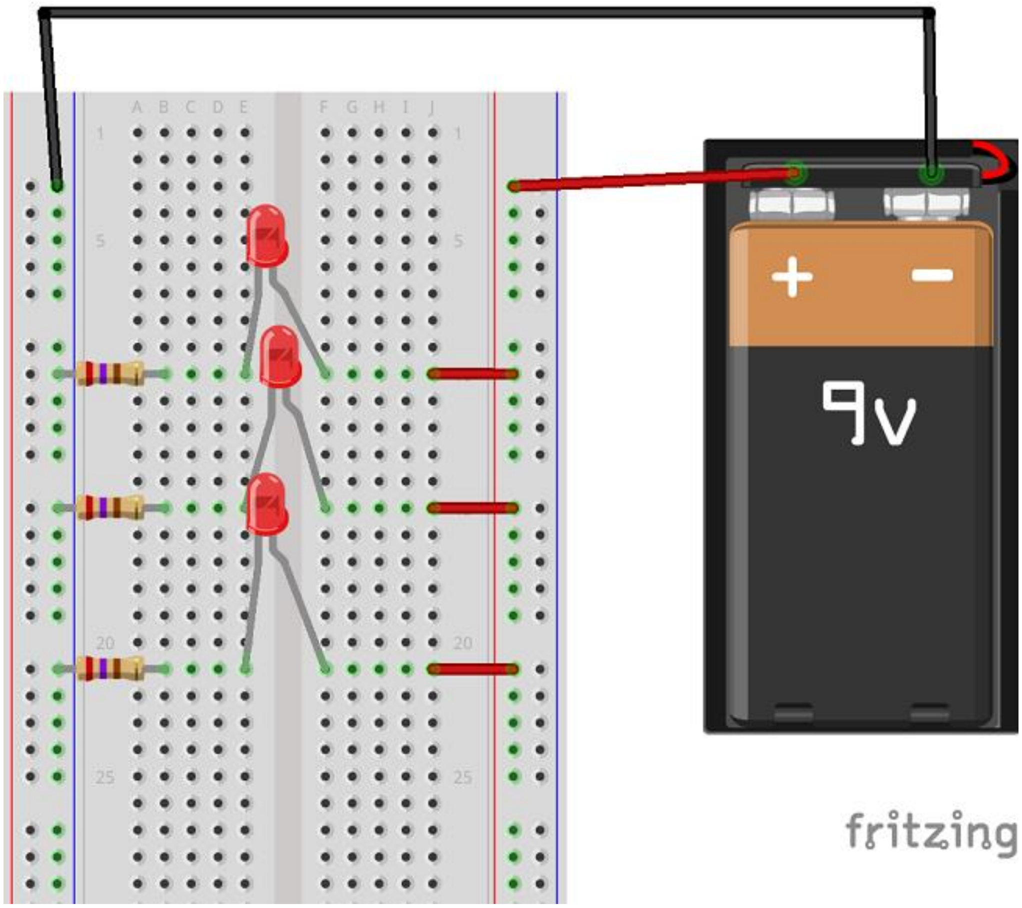


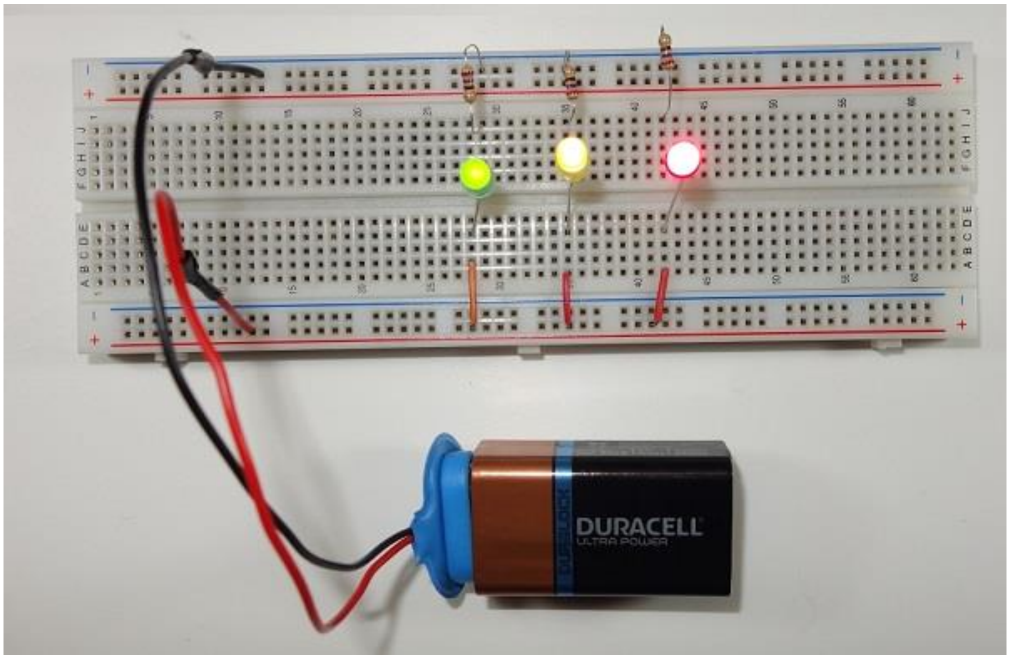
Figure 37. Circuit diagram with LEDs in parallel

When you have LEDs in parallel, all LEDs receive the voltage specified by the power supply. So, when you have LEDs in parallel you should use one resistor for each LED. In this case, we use a 270Ω resistor.

There are many ways to organize LEDs in parallel in a breadboard. Follow the next schematic:



Here's the final result:



Unit 6- How to Make a Simple Flashlight with a Pushbutton

A circuit with an LED always on it's not very useful. But it can be if you add a switch, so it acts as a flashlight.

Pushbutton

A pushbutton comes in many types. Here's some pushbuttons examples:

Figure 38. Pushbuttons

How does the pushbutton work?

There are two types of pushbuttons: **normally open** and **normally closed**.

Here, we will use a normally open pushbutton. In this case, when the pushbutton is in its normal state (not pushed), the current doesn't flow.

When you press the pushbutton, you allow the current to flow. It helps taking a look at the figure below.

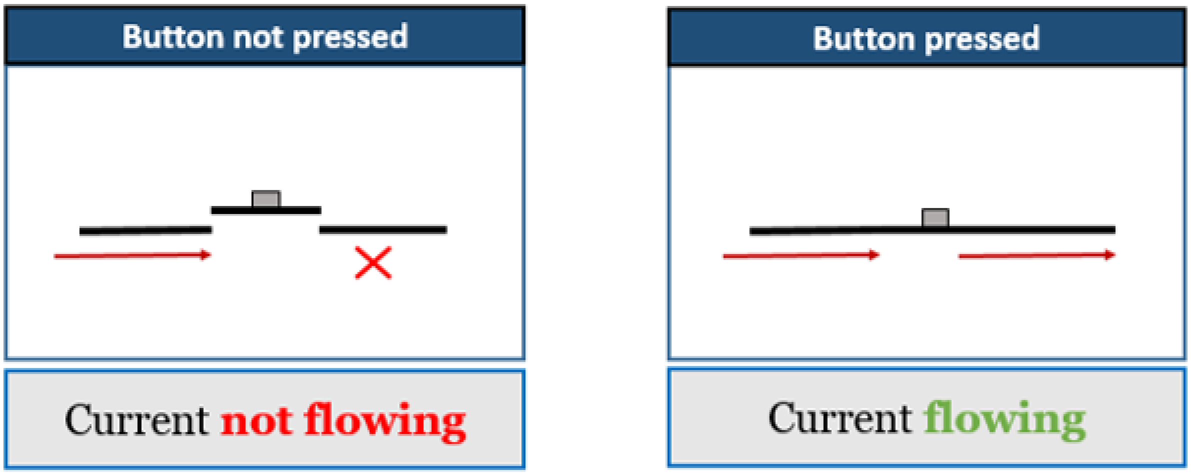


Figure 39. How a normally open pushbutton works

Pushbuttons usually have four legs. These legs are always connected in a pair. When the pushbutton is pressed, all the 4 legs are connected and the current flows.

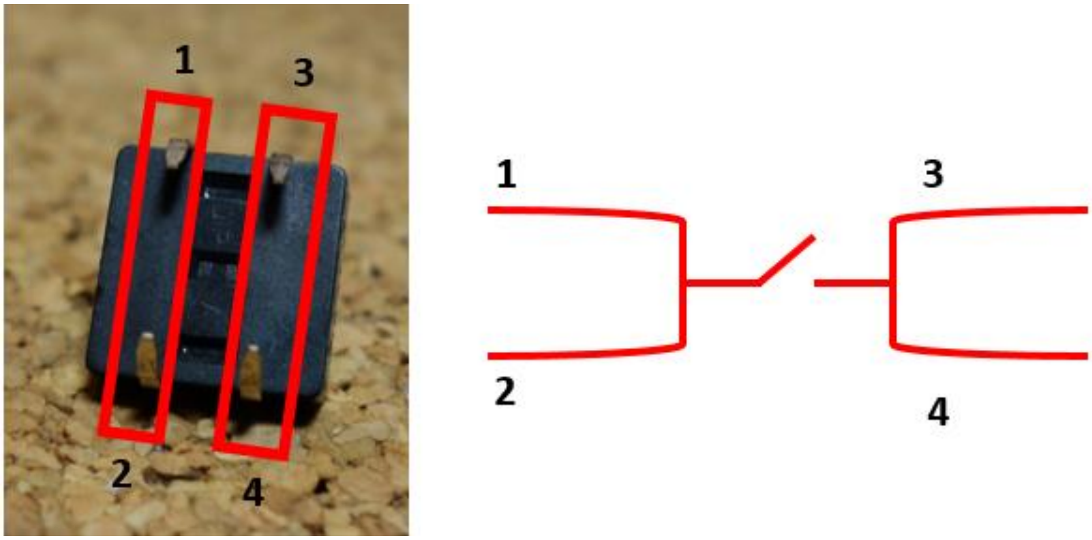


Figure 40. How a pushbutton is internally connected

Here are the components that you'll need for this project:

- 9V battery
- Battery clip
- LED (5mm)
- 270Ω resistor
- Pushbutton
- Breadboard
- Wire cables

Use a pushbutton like this:

Figure 41. Pushbutton used in this circuit example

So, your circuit diagram is the following:

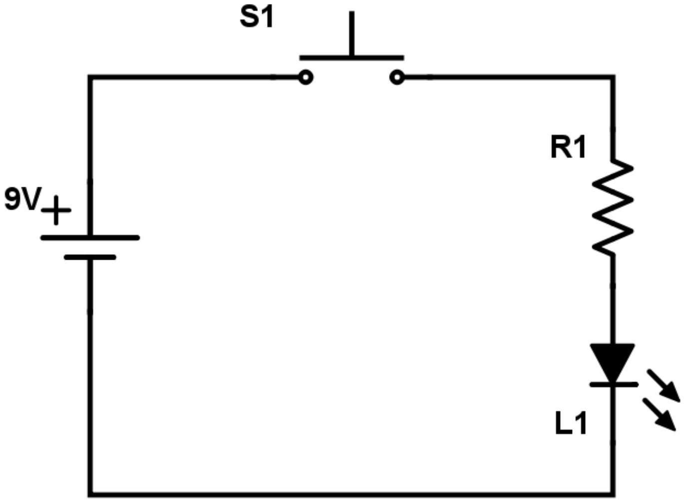
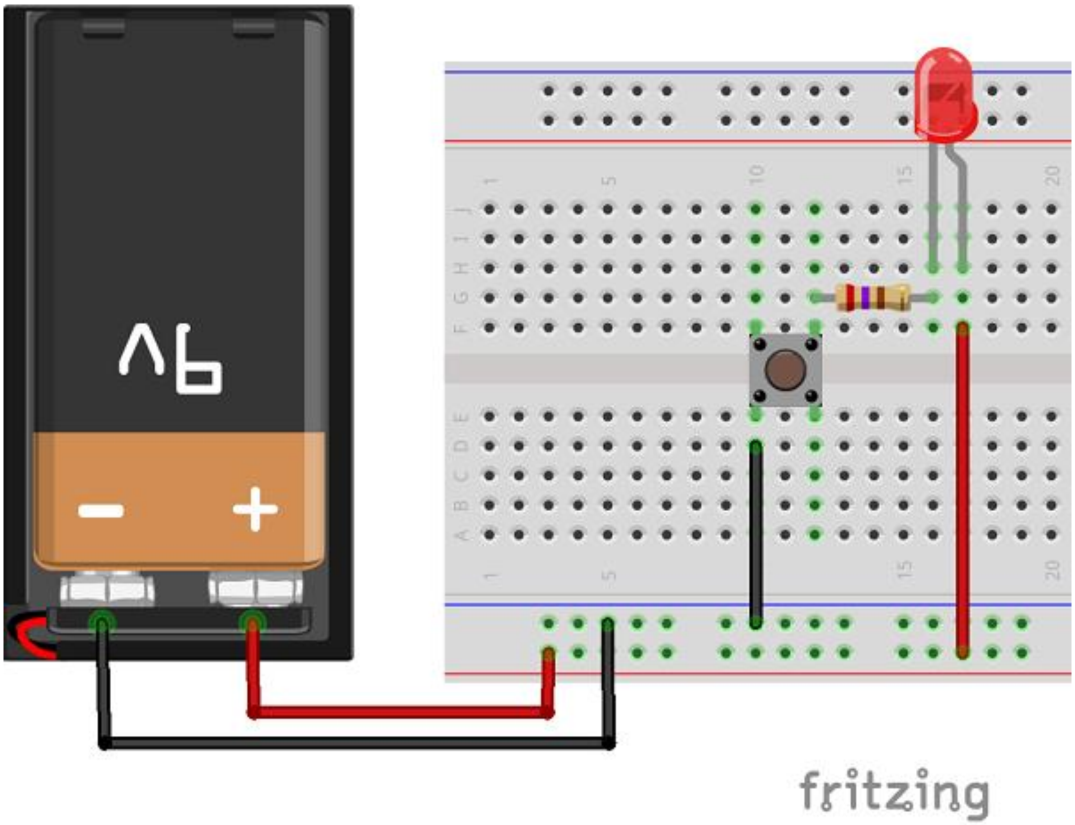
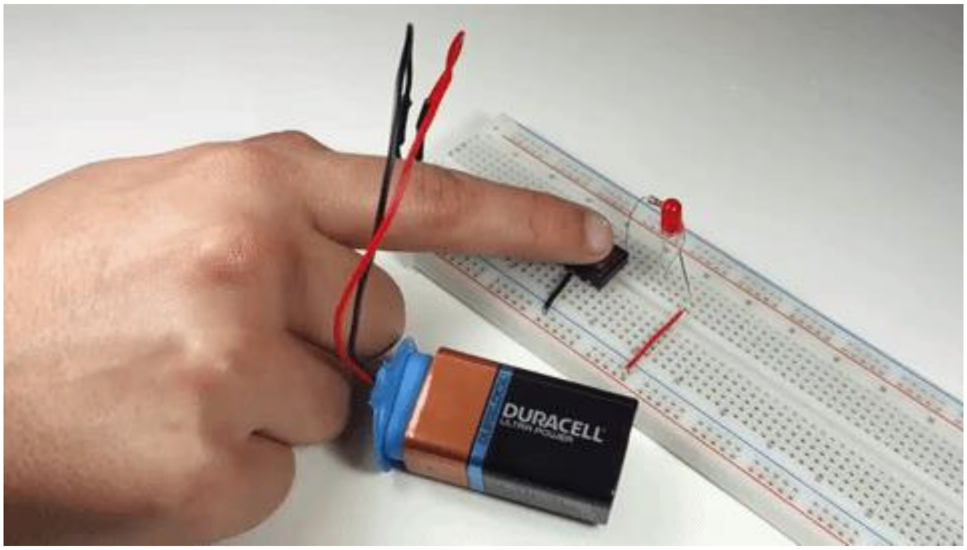


Figure 42. Circuit diagram to control an LED with a pushbutton

All the components should be connected as in the schematic below:



When you press the pushbutton the LED turns on, and when you don't press it, it is turned off.



Unit 7 – Flashlight Circuit with a Toggle Switch

A toggle switch comes in several varieties. Here's a few examples:

Figure 43. Toggle switches

How does a toggle switch work?

Basically a toggle switch is an on-off switch. There are several types of toggle switches.

In this Unit, you will use an SPST toggle switch, which is the simplest way of turning a circuit on or off. SPST toggle switches have 2 leads and, basically, they close or open the circuit depending on its position. One example of SPST toggle switch:

Figure 44. SPST toggle switch

Here are the components that you need for this project:

- 9V battery
- Battery clip
- LED (5mm)
- 270Ω resistor
- SPST toggle switch
- Breadboard
- Wire cables

The circuit diagram is very similar to the previous Unit:

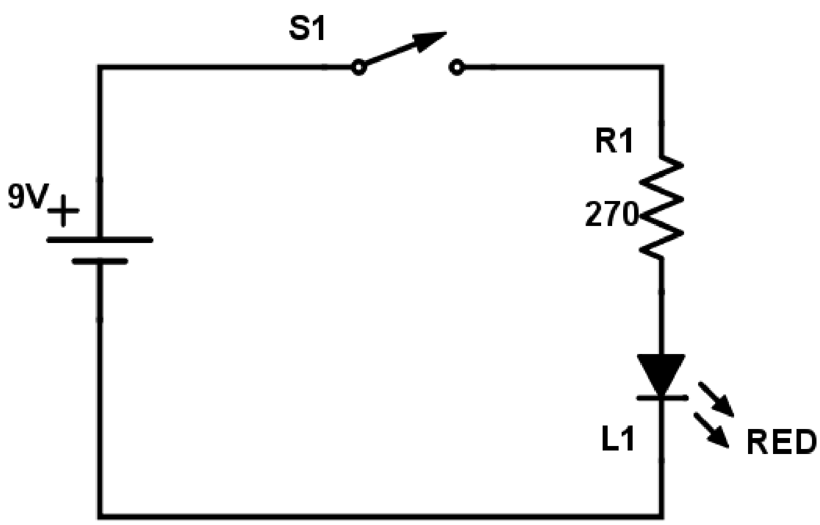
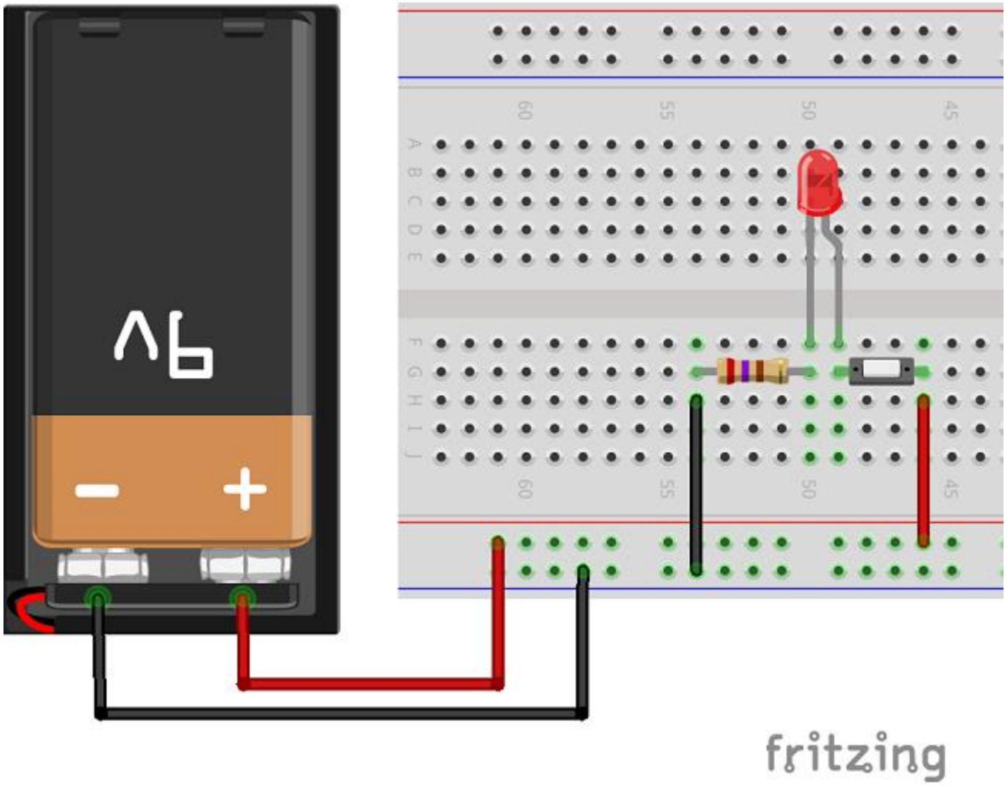
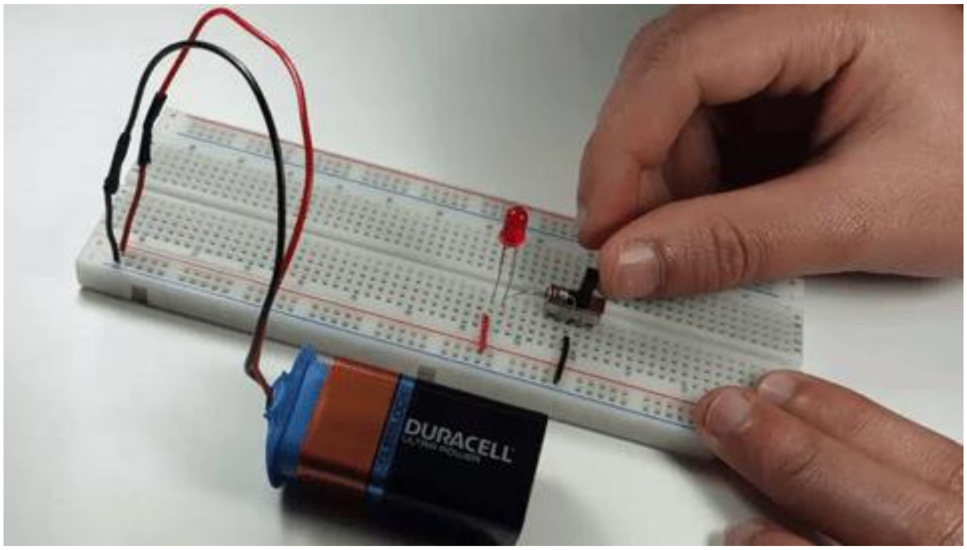


Figure 45. Controlling an LED with a toggle switch

Here's the schematics:



When you move the toggle switch to the left the LED turns on, and when you move it to the right, it is turned off.



Unit 8 – Controlling the LED Brightness

In this Unit you will adjust the brightness of an LED using a potentiometer as a rheostat. So, your circuit diagram will look like:

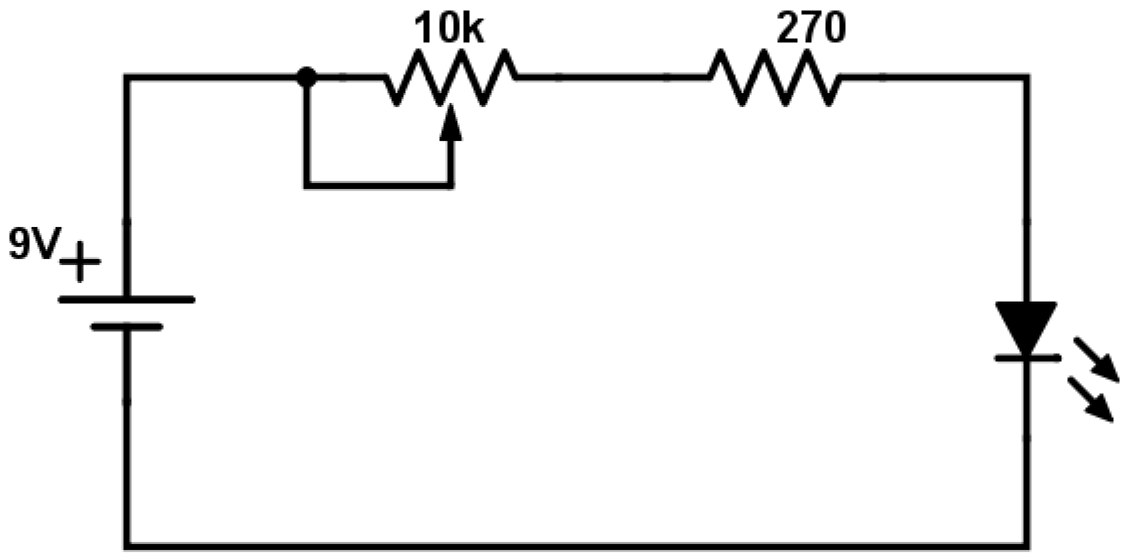


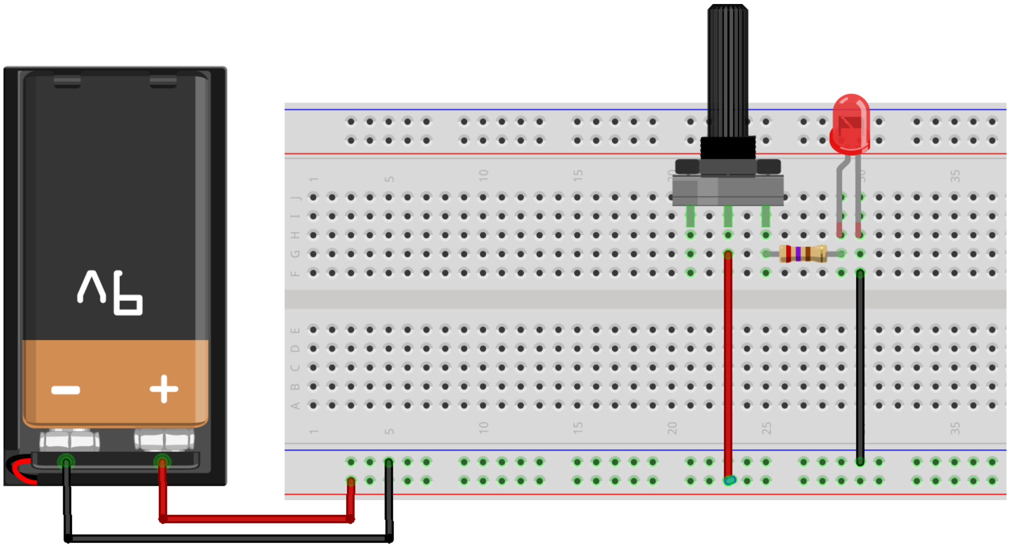
Figure 46. Adjusting the LED brightness with a potentiometer

The components you'll need are:

- 10kΩ potentiometer
- 270Ω resistor
- LED
- 9V battery
- Hookup wire

Wiring the Circuit

Your circuit diagram should look like this:



The final result will be something like this:

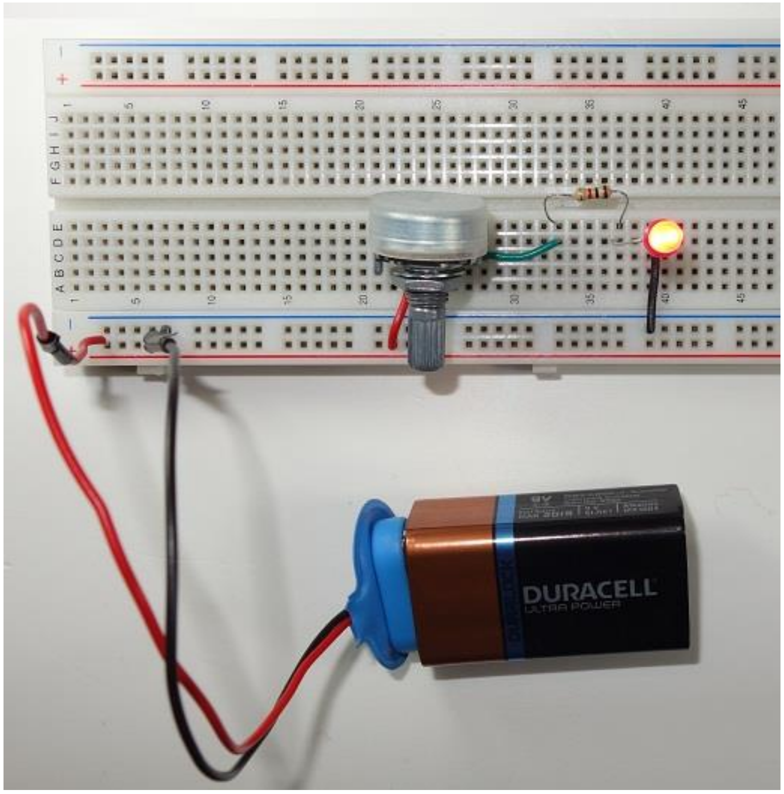


Figure 47. Adjusting the LED brightness with a potentiometer

NOTE

If you turn the shaft to one side and to another, you will see the brightness increasing and decreasing. However, you can't turn it off. When the potentiometer is at its highest resistance, the led doesn't turn off. In reality you should use PWM (pulse width modulation) to control the brightness of your LED. That's what you're going to do in the next tutorial.

Unit 9 – Automatic Light Triggered LED with Transistor and LDR

Transistors are semiconductor devices with three terminals that can act as **amplifier controls** or **electrically controlled switches**.

- **Amplifier**: when it works as an amplifier, it takes a tiny electric input current at one lead and produces a bigger output current at the other lead
- **Switch**: a small electric current through a lead can switch on a bigger current flow through the other leads of the transistor

In the figure below you can see several types of transistors:

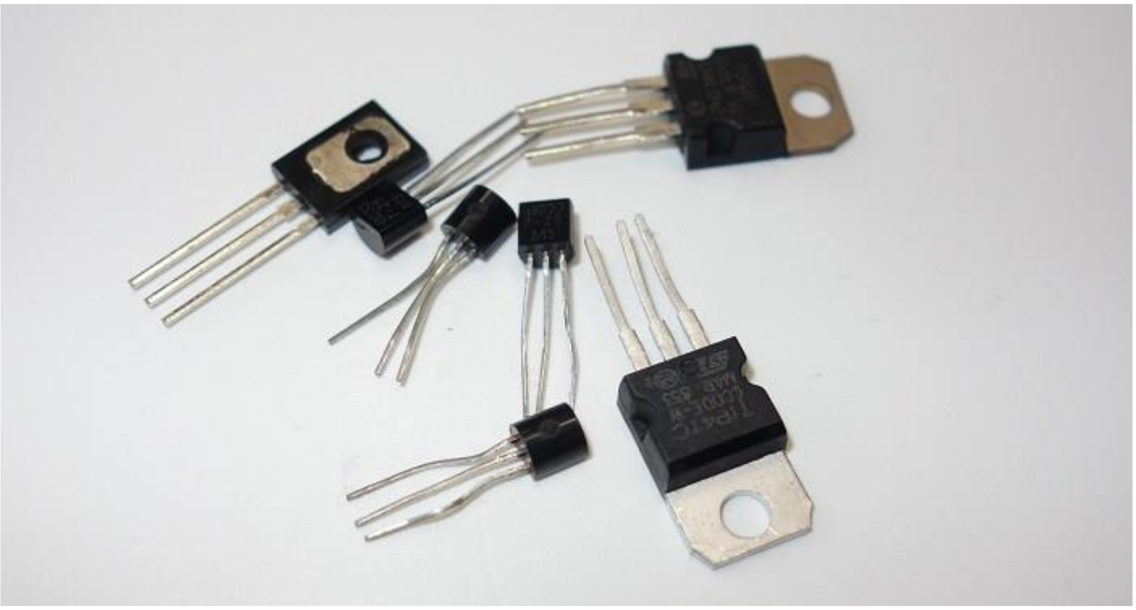


Figure 48. Examples of Transistors

Semiconductors

Transistors are made of silicon which is a semiconductor. A semiconductor is a material that is not a pure conductor, it has higher resistance than a conductor, but much lower resistance than insulators.

N-Type

We can introduce impurities into silicon, so that it works in a specific way, this process is called doping.

If we dope the silicon with chemical elements such as phosphorous, arsenic or antimony, which have 5 valence electrons, the silicon gains free extra electrons that can carry an electric current.

When we add these elements, we are introducing electrons. As electrons are negative, this type of semiconductor is called **N-Type (negative type)**.

P-Type

On the other hand, we can dope silicon with other elements like boron or gallium. As these elements have only three outer electrons, when they are mixed into the silicon matrix, they create "holes" with absence of electrons.

So, this type of silicon has less extra free electrons, and so it is called the P-Type (positive type).

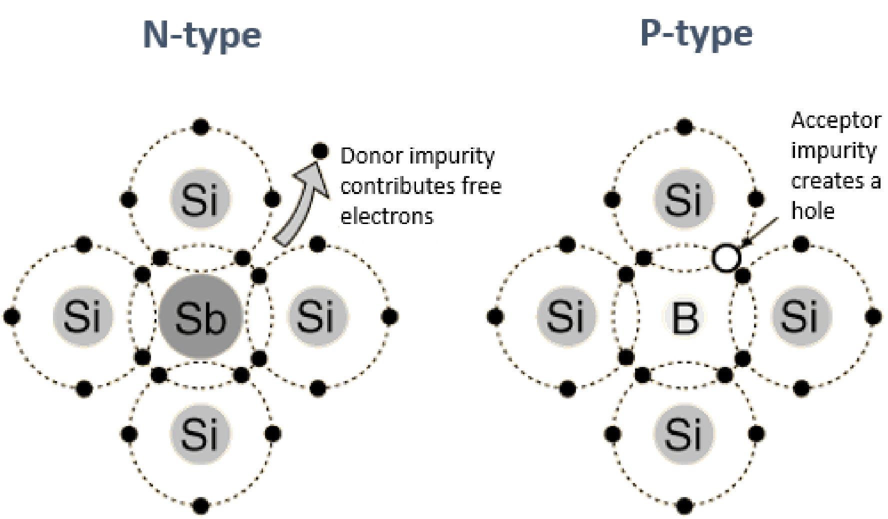


Figure 49. Atomic structure of N-type and P-type transistors

Water Analogy

To understand electronics basic concepts there's nothing better than a water analogy.

Imagine a faucet in which water is flowing. The water comes from somewhere (in flow) and comes out of the faucet (out flow). The flow of water can be controlled by a **control knob**.

The same happens in a transistor, the current flows from one lead to another. The current that flows from one lead to another depends on a small voltage/current applied to a control lead. So, the control lead controls the electric flow through its two leads.

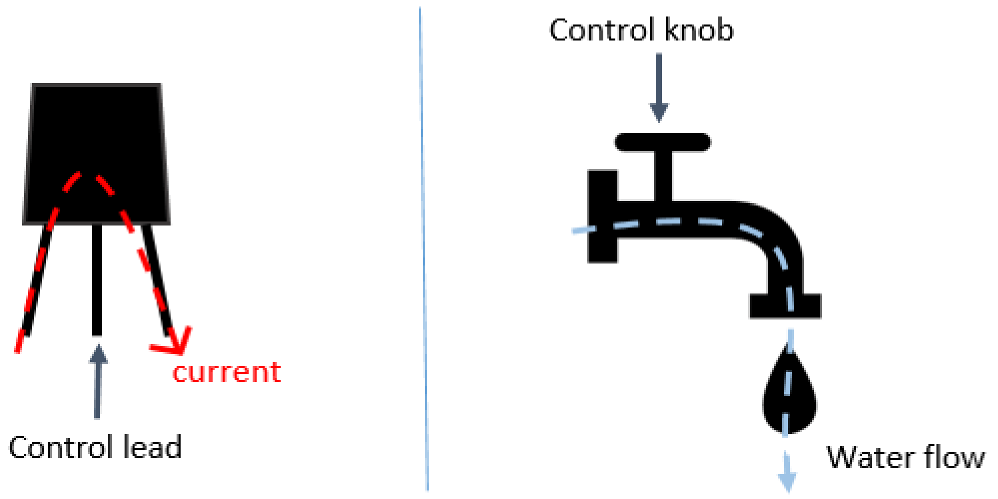


Figure 50. Analogy between water flow through a knot and electric current through a transistor

The two major families of transistors are bipolar junction transistors (BJTs) and field-effect transistors (FETs).

- **Bipolar junction transistors** require an input or output current at their control leads
- **Field-effect transistors** practically don't require current, only voltage

Bipolar Junction Transistors (BJTs)

Bipolar junction transistors consist of a three-layer sandwich of doped semiconductor materials. We can have two types of bipolar junction transistors: the N-P-N and the P-N-P. Each layer has a pin. On bipolar junction transistors the three pins are labeled:

- Collector (C)
- Base (B)
- Emitter (E)

NPN transistor

In an NPN transistor, the current flows from the collector to the emitter. The base of an NPN transistor must be connected to the positive voltage for current to flow in.

With the increasing current to the base, the transistor is increasingly turned on until conducting the current fully from the collector to the emitter.

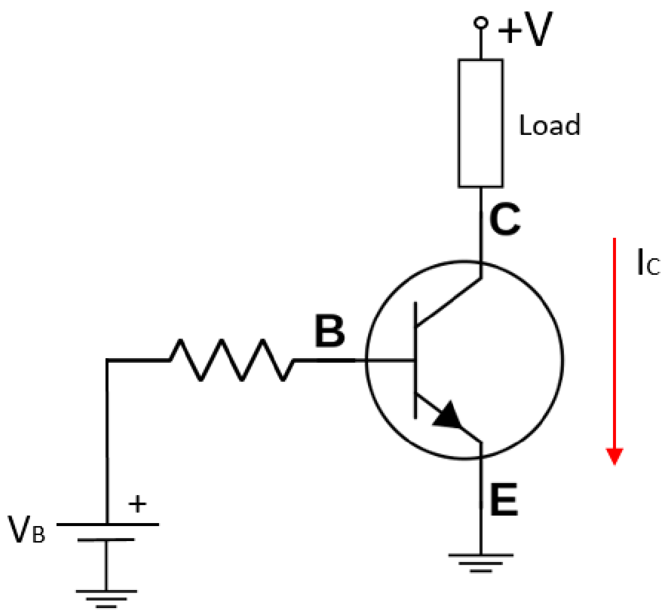


Figure 51. NPN transistor

PNP transistor

In a PNP transistor, current flows from the emitter to the collector, for that the base must be connected to the ground.

We can say that a PNP transistor is normally off. However, when there's a small output current and negative voltage at the base in relation to the emitter, the transistor will turn on, and a larger current will flow from the emitter to collector.

Basically, the PNP transistor will conduct current from the emitter to the collector, if the base and collector are negative in relation to the emitter.

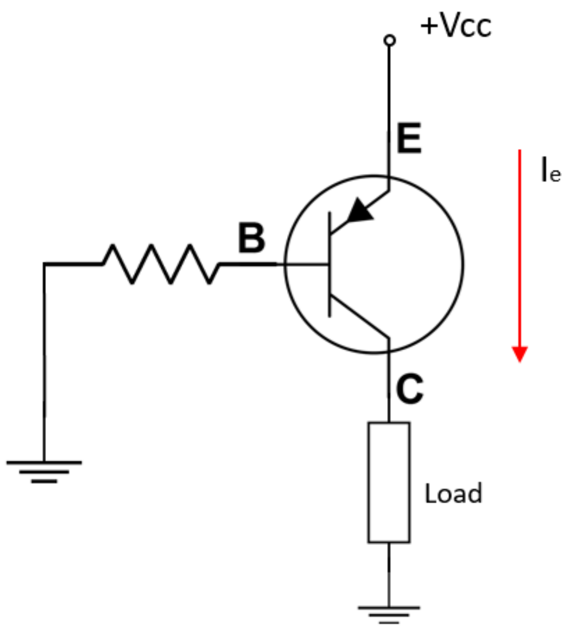


Figure 52. PNP transistor

Automatic Light Triggered LED with Transistor

In this section, I'm going to share with you a simple transistor application. When it's dark, the LED turns on, and when there's light the LED turns off.

We will use an LDR (light-dependent resistor) to turn on an NPN transistor that powers an LED. A light-dependent resistor (LDR) is a light-controlled variable resistor. The resistance of a photoresistor decreases with increasing incident light intensity.

Figure 53. Light-dependent resistor (LDR)

Parts Required

Here are the components that you'll need:

- 9V battery
- Battery clip
- Light-dependent resistor (LDR)
- 2N 5089 NPN transistor
- LED with any color you want
- 47kΩ resistor
- 470Ω resistor
- Wire cables

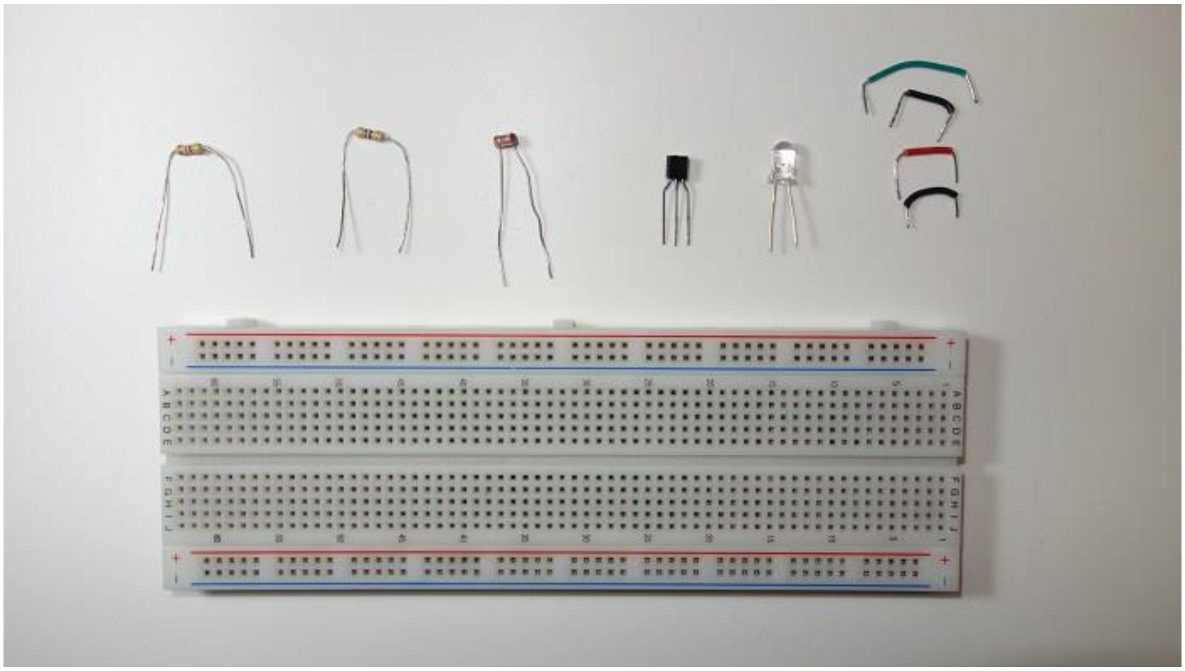


Figure 54. Required components

Circuit

Here's the circuit diagram for this project:

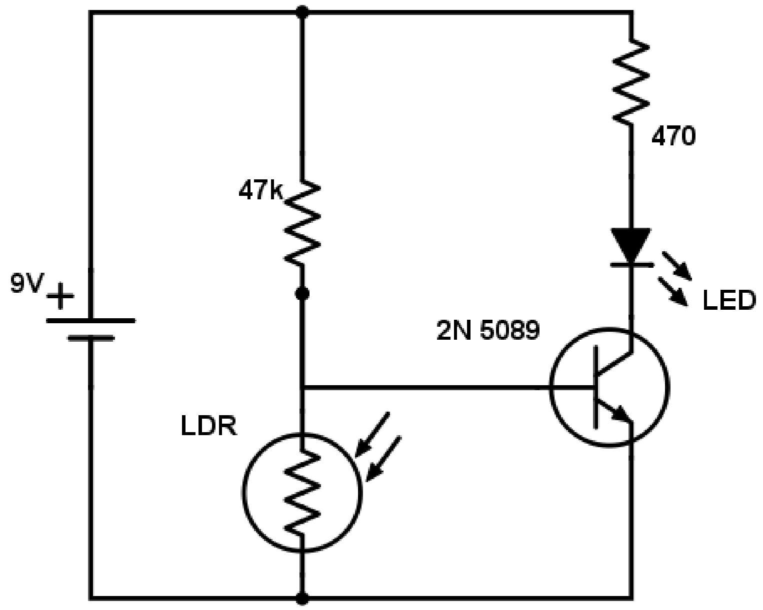
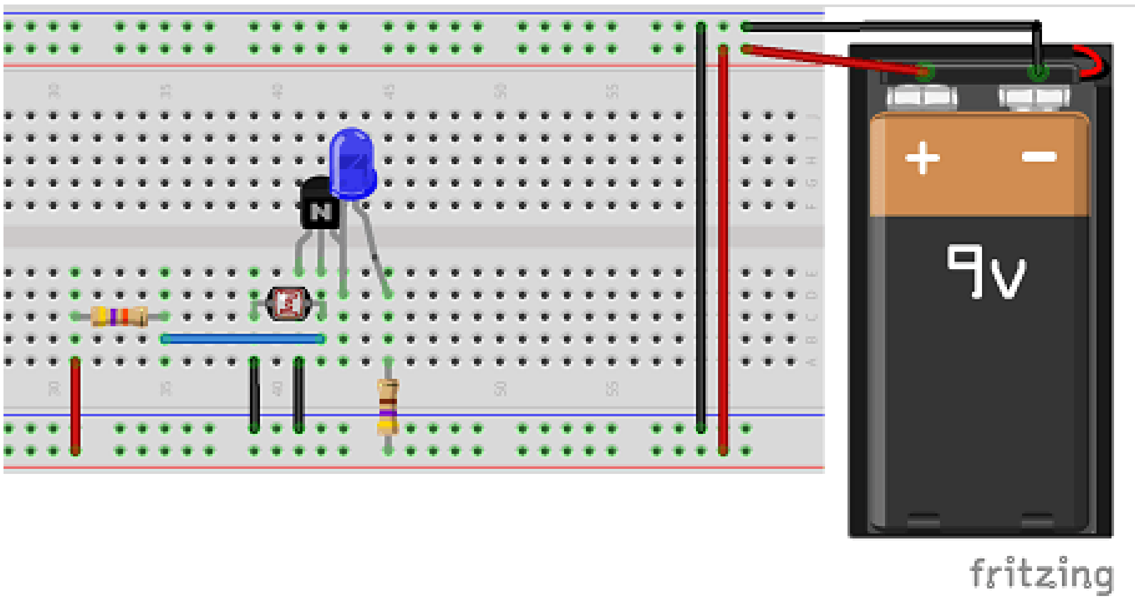


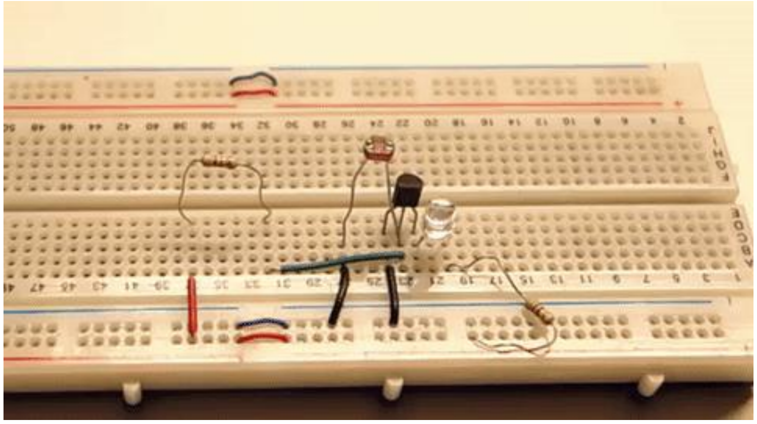
Figure 55. Circuit diagram for automatic light triggered LED with transistor

Place all the components into the breadboard and test your circuit. Here's the schematics:



Testing the Circuit

When the light turns off the LDR activates the transistor that ultimately turns the LED on. Here's the final result:

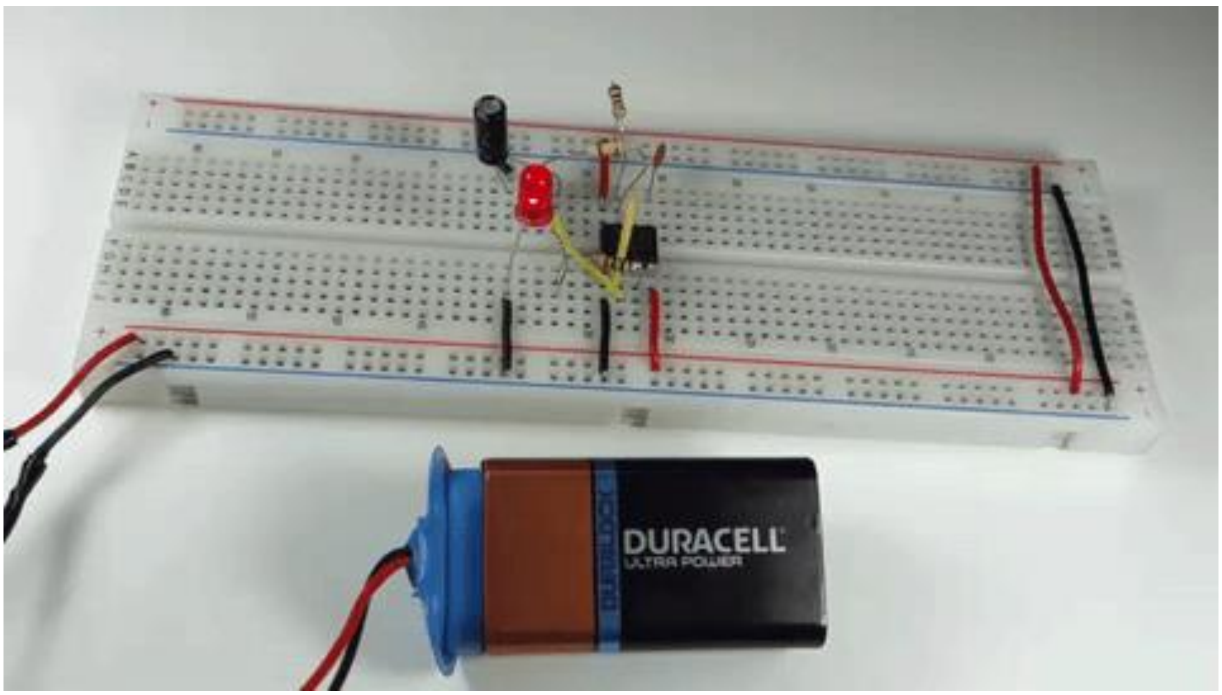


You can measure the resistance of your LDR using a multimeter with different light intensities (from dark to light), so you can see what's going on.

You may need to adjust the value of the 47kΩ resistor to another value depending on the light intensity of your surroundings. For that, it may be more useful to replace the 47kΩ resistor with a potentiometer.

Module 4

Introducing Integrated Circuits



Unit 1 – Introducing the 555 Timer

In this Module, we will introduce the **555 Timer** Integrated Circuit (IC). You'll explore how it works and build some projects.

This Module aims to give you the basic knowledge to work with ICs, later you'll also learn about potentiometers and PWM.

The 555 Timer (EN555)

The 555 timer is an integrated circuit, it is extremely versatile and can be used to build lots of different circuits.

The EN555 is usually used to generate continuous series of pulses. These series of pulses allow you to continuously blink an LED, for example.

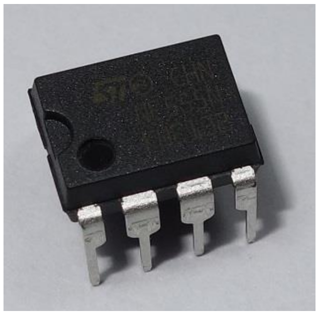


Figure 56. EN555

The 555 timer can operate in three different modes:

- **Monostable mode**: usually used to create time delays
- **Astable mode**: outputs an oscillating pulse signal
- **Bistable mode**: the 555 timer changes its output depending on the state of two inputs

In this Unit, you'll use the astable mode.

Pinout

If you search on Google *555 timer datasheet*, one of the first results should be a PDF datasheet.

This is a document with a lot of information, but what you really need to pay attention right now is to the pinout. Here's the EN555 pinout:

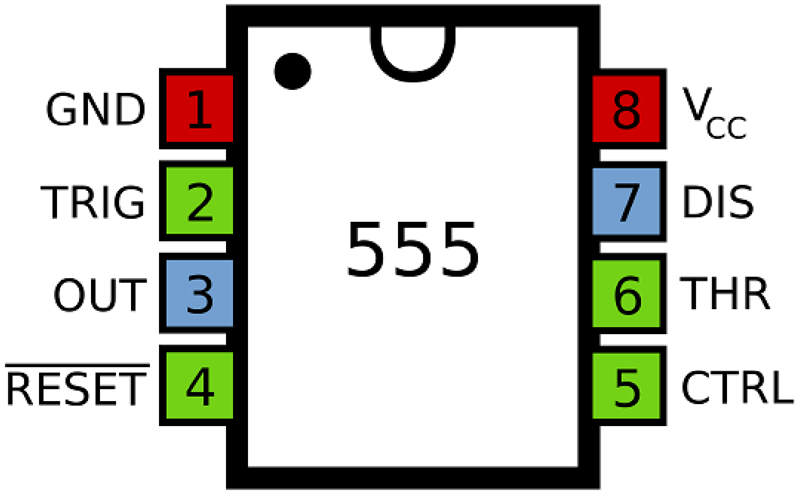


Figure 57. EN555 pinout

This IC has 8 pins:

1. Ground
2. Trigger
3. Output
4. Reset
5. Control Voltage
6. Threshold
7. Discharge
8. VCC

In a circuit diagram, usually the 555 timer is drawn as follows:

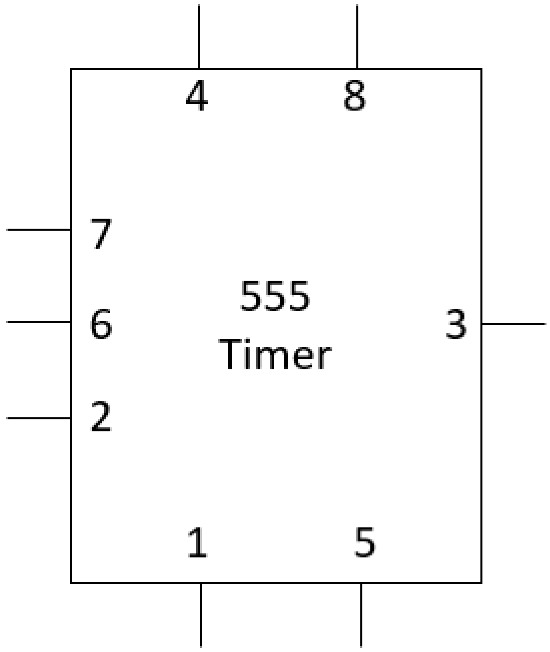


Figure 58. EN555 represented in a schematic diagram

Output

Pin 3 is the output. This pin generates an oscillation. The voltage is high, then low, then high, then low again and so on (this is called astable mode).

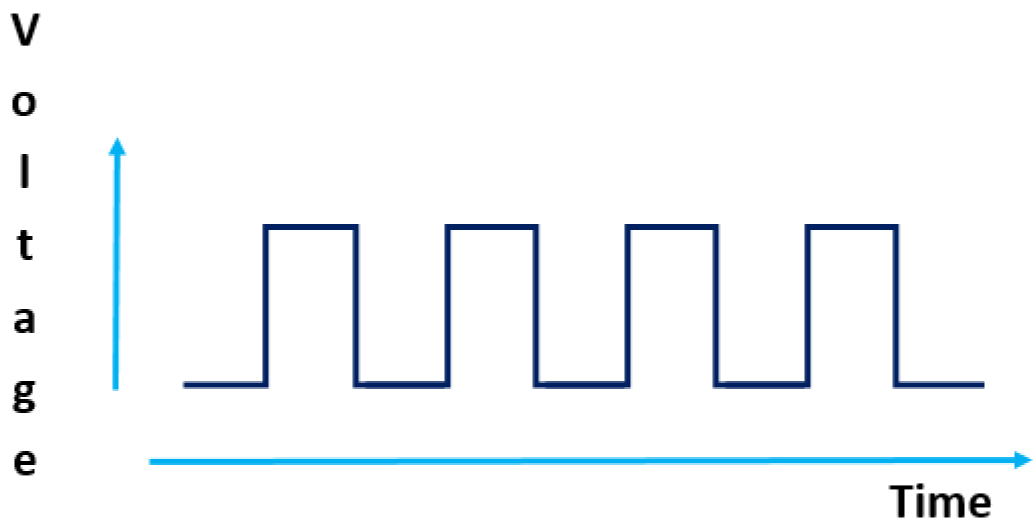


Figure 59. Voltage output versus time in astable mode

Astable mode

To make the 555 timer work in astable mode, you should wire your circuit like this:

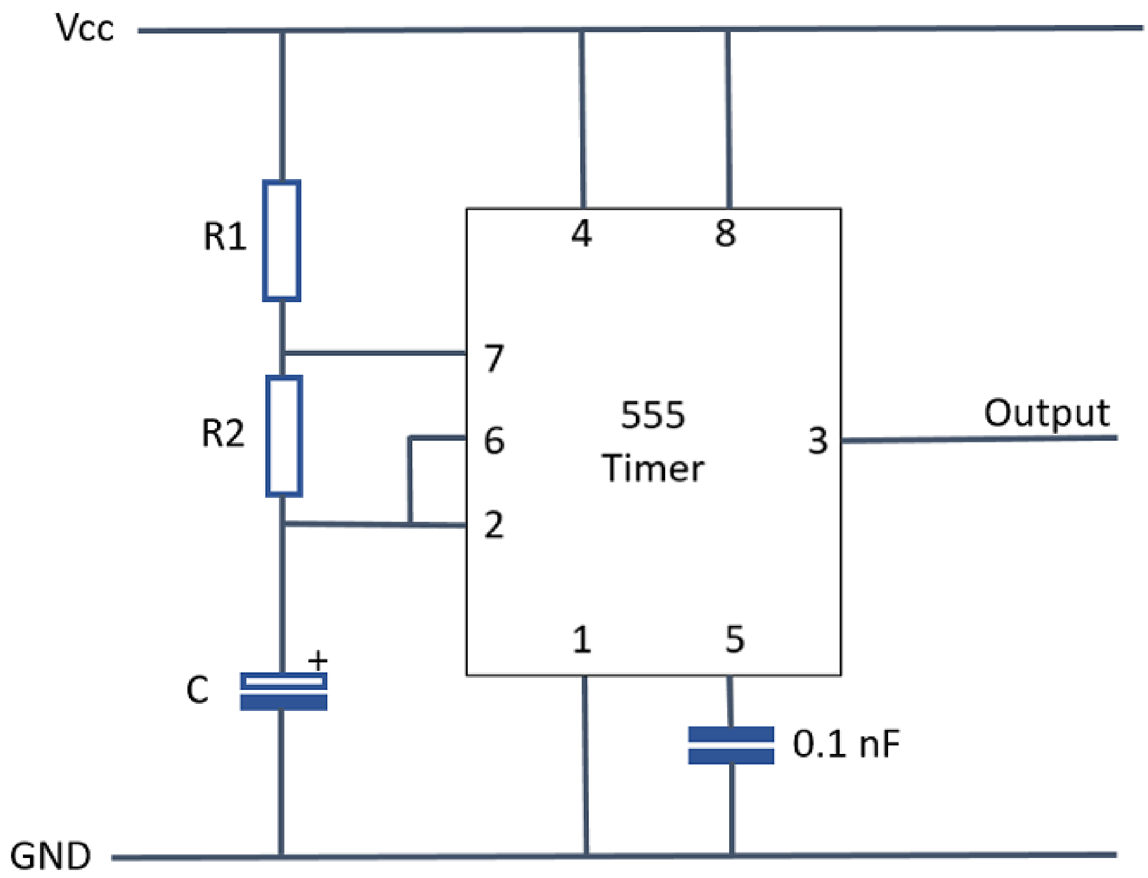


Figure 60. EN555 circuit diagram - astable mode

NOTE

This circuit is represented in a slightly different way from all previous diagrams in this course. Components connected to Vcc are connected to the positive pole of the battery. Components connected to GND are connected to the negative pole of the battery.

The frequency of the oscillation can be adjusted by changing the values of the resistors R1 and R2 and the capacitance of the capacitor C.

The frequency can be calculated using the following expression:

$$f = \frac{1.44}{(R1 + 2 \times R2) \times C}$$

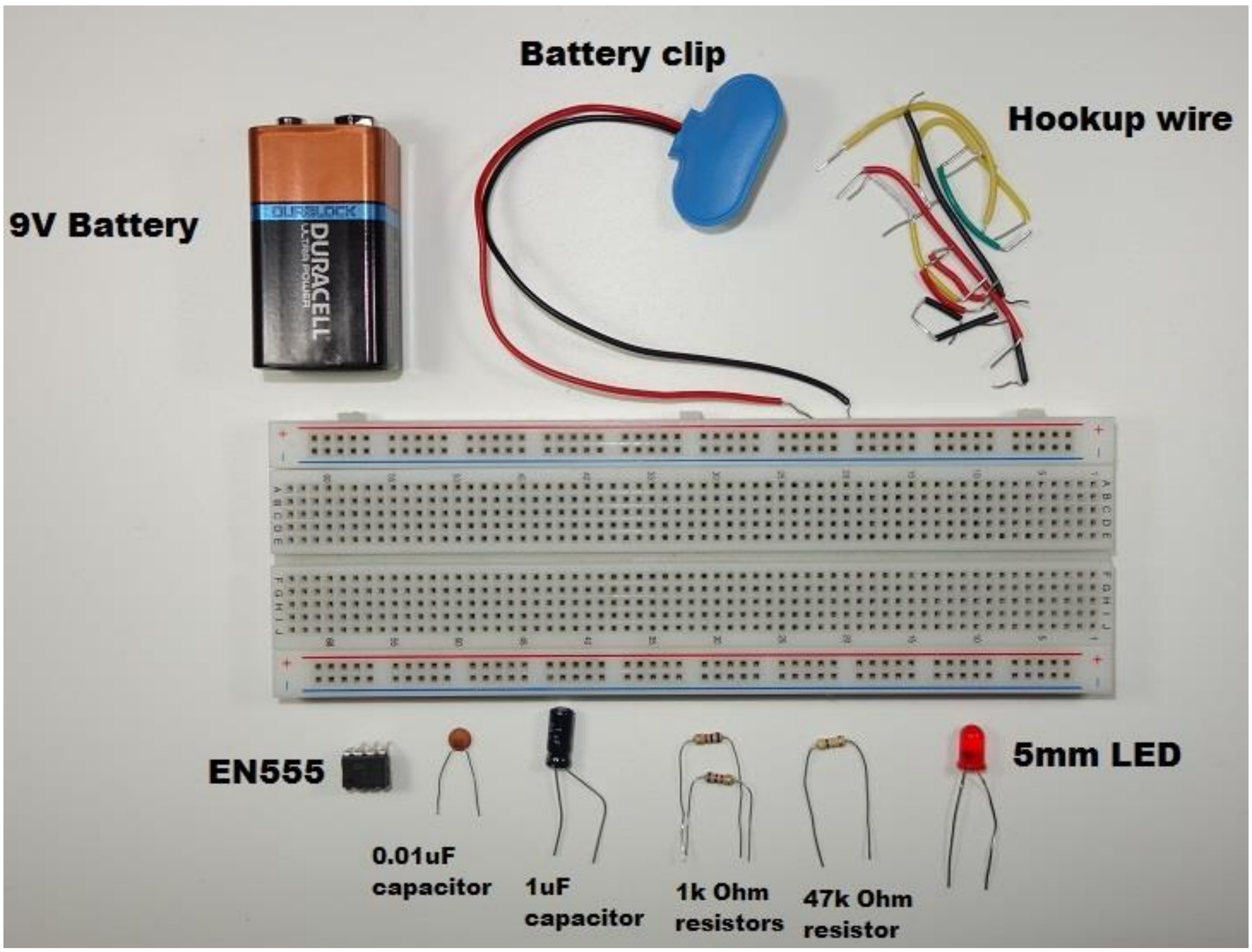
With the output voltage that comes from pin 3, you can control anything you want (like an LED, speaker, motor, etc.).

Unit 2 – Flashing an LED with the 555 Timer

In this Unit, you will flash an LED using the 555 timer in astable mode. So, we just need to add an LED to the output of the previous circuit.

Required Components

These are the components you'll need:



Required componentes:

- 9V battery
- Battery clip
- Breadboard
- EN555
- Red LED
- 2× 1kΩ resistor
- 470kΩ resistor
- 0.01uF capacitor (non-polarized)
- 1uF capacitor (electrolytic)
- Hookup wire

Circuit Diagram

This is the circuit diagram:

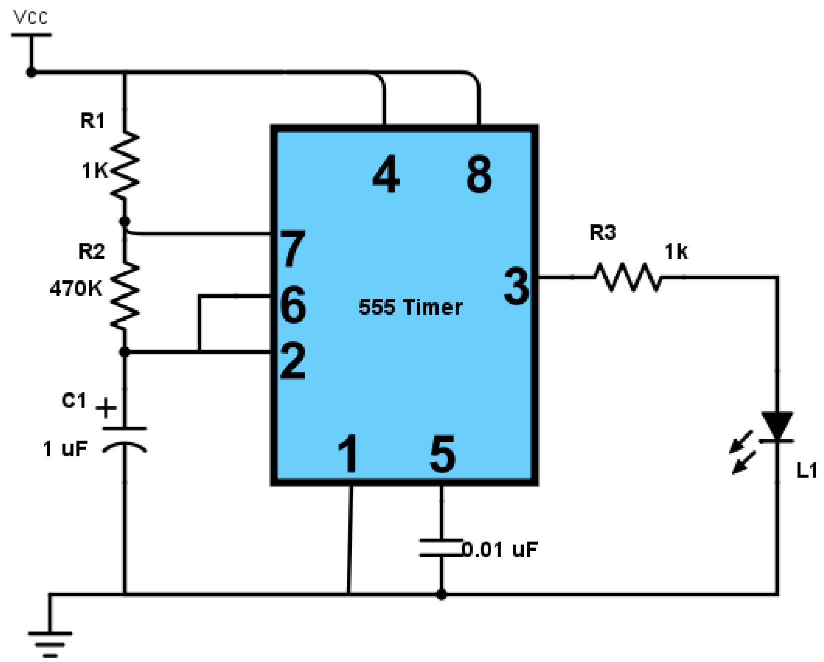
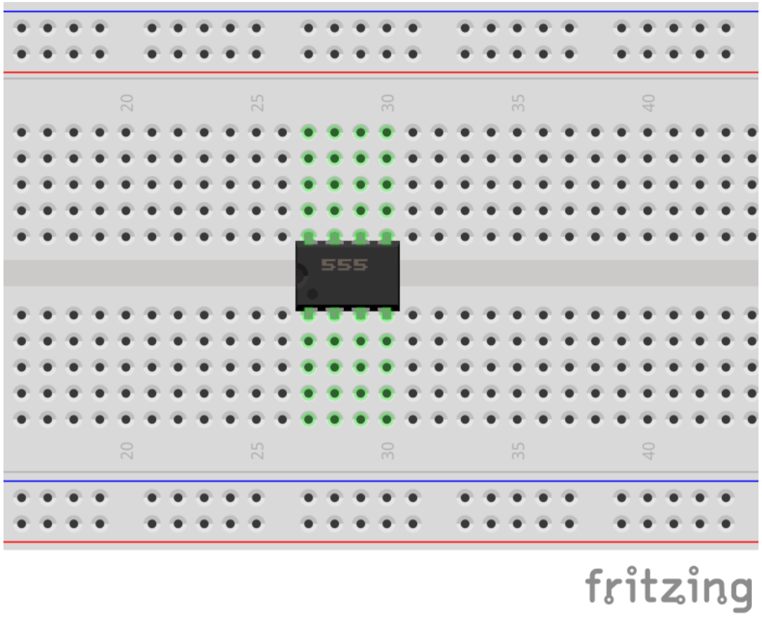


Figure 61. Flashing an LED

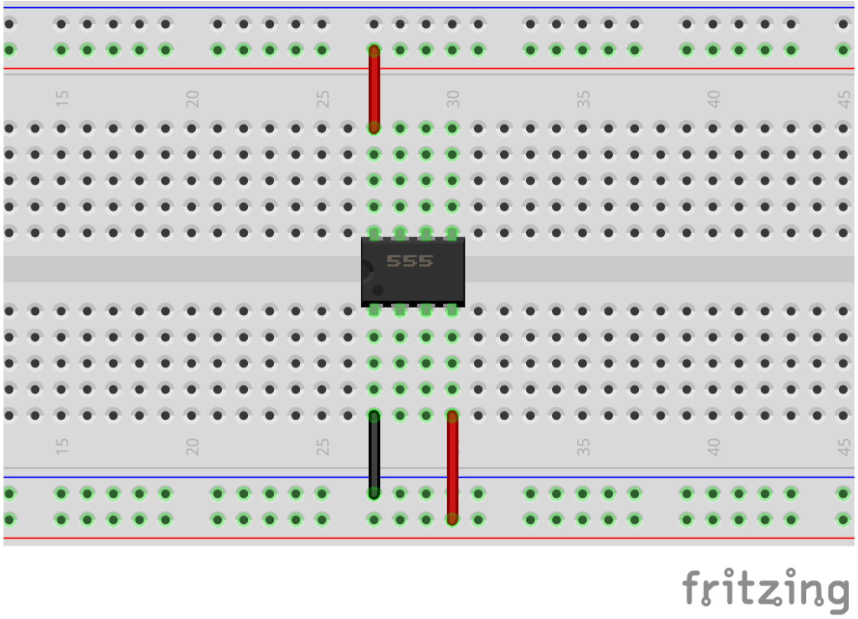
Wiring the Circuit

Here are the steps to connect all the components. Note that there isn't a right way neither a right order to connect the components.

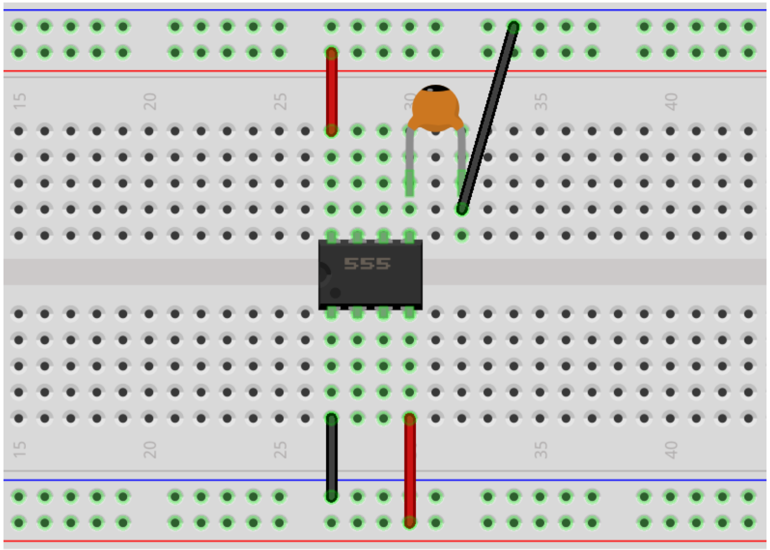
1. Start by plugging the EN555 into the breadboard:



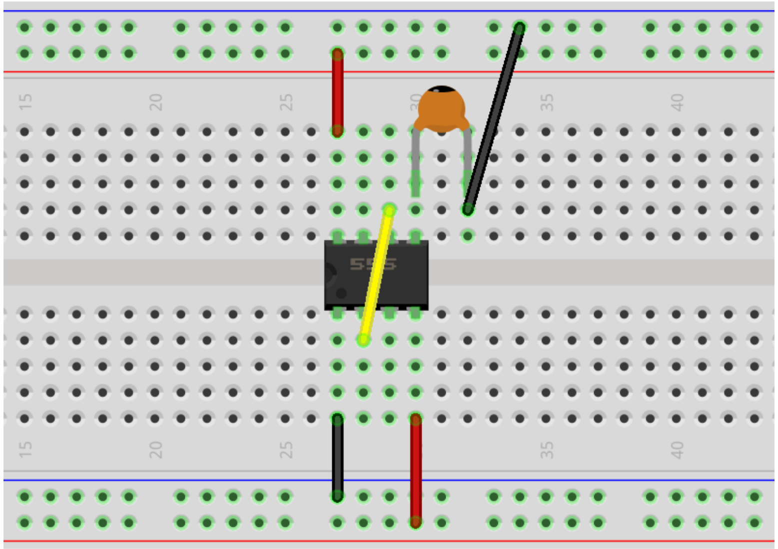
2. Wire pin 1 to GND. Wire pin 4 and pin 8 to VCC:



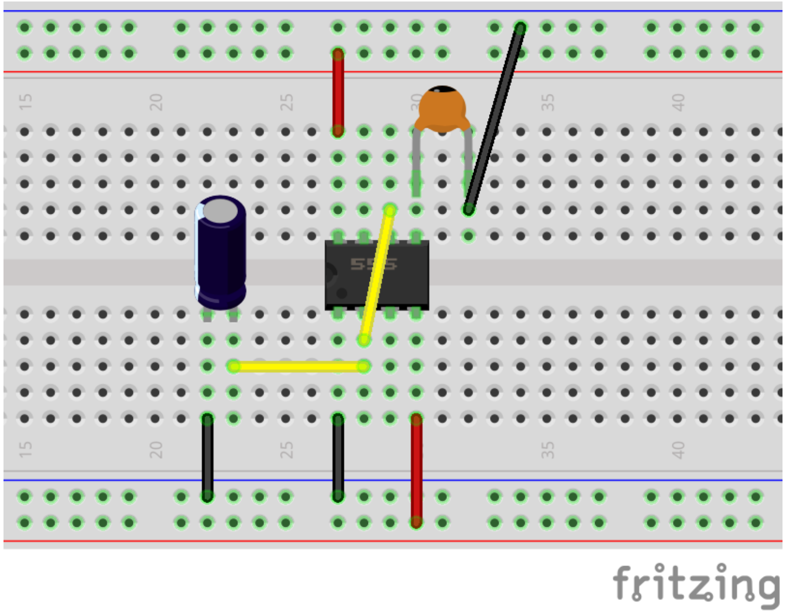
3. Connect the 0.01uF capacitor to pin 5 and to GND



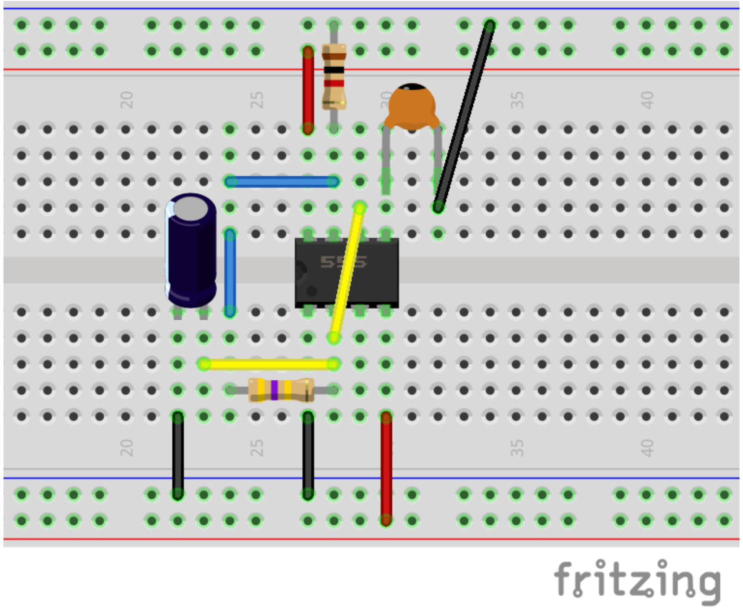
4. Connect pin 2 to pin 6



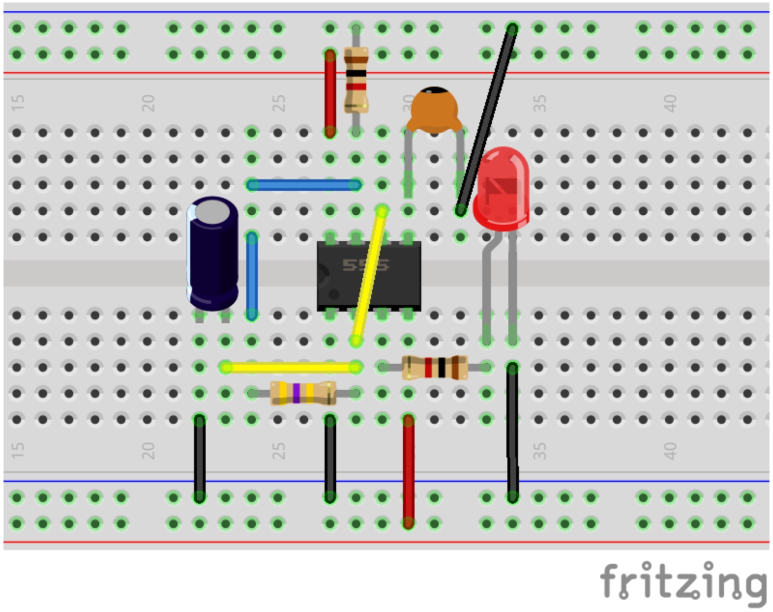
5. Connect the 1uF capacitor to pin 2 and to GND



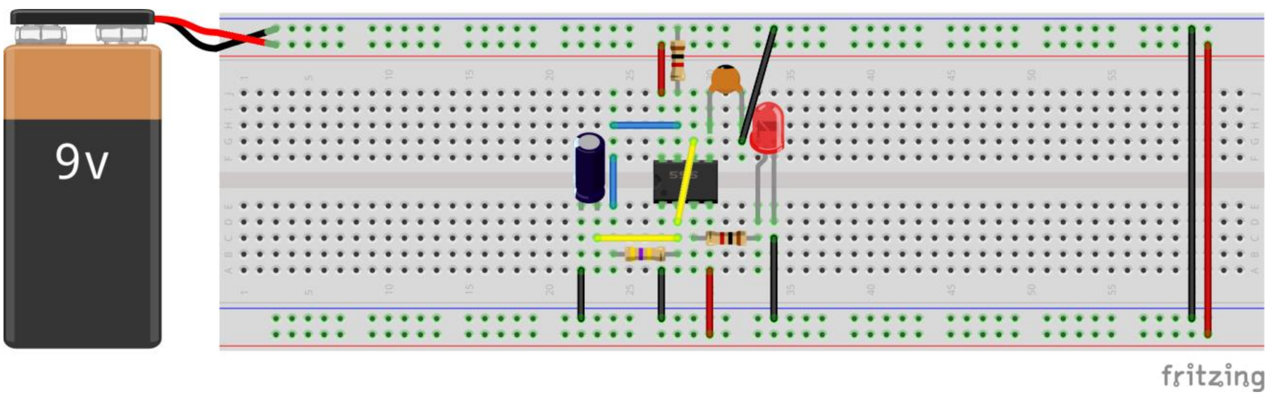
6. Connect one leg of the 470kΩ Resistor to pin 2 and the other leg of the resistor to pin 7 (blue wires). Then, connect a 1kΩ resistor from pin 7 to GND



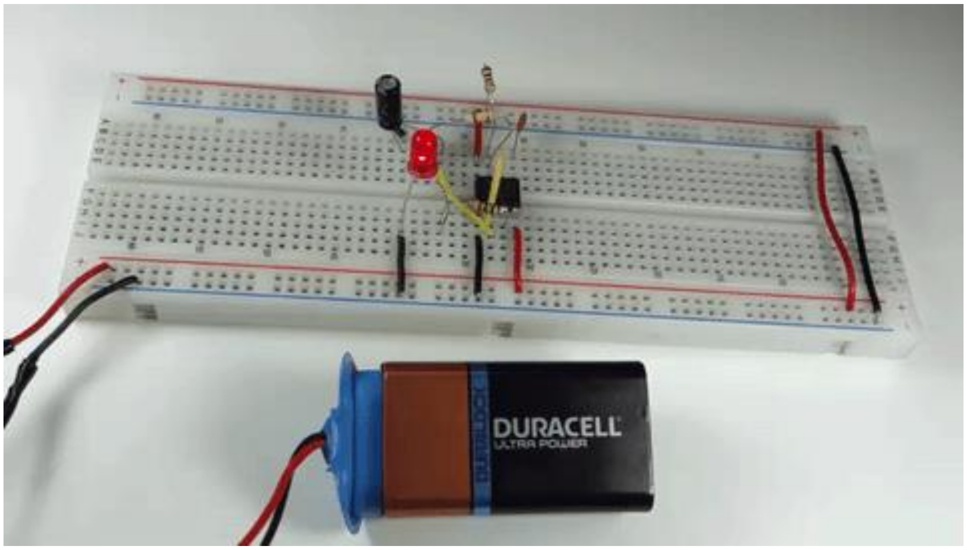
7. Connect pin 3 in series with the 1k resistor and the LED



8. Power up your circuit by connecting the battery to your breadboard:



Here's how your circuit looks like in the end:



TIP

Replace your 1uF electrolytic capacitor with another one with lower capacitance (for example 0.1 uF) and see the LED flashing at a different rate. With lower capacitance values, the flash rate increases.

Unit 3 – Controlling the LED Brightness with PWM

Remember the 555 timer used in the earlier Units? Now, you will use it to control the brightness of an LED using PWM (pulse width modulation).

What is PWM?

PWM allows to "simulate" varying levels of power by oscillating the output from the EN555. As you remember, using the EN555 we have a certain output or 0V output voltage, and there aren't middle level voltages.

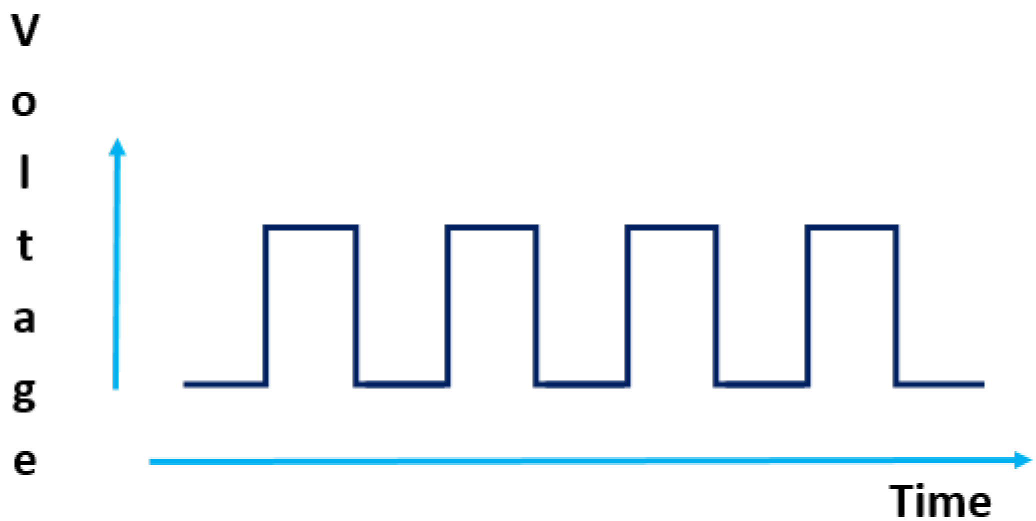


Figure 62. EN555 output voltages

However, you can produce "fake" middle level voltages. If you alternate an LED's voltage very very fast, you won't be able to keep up with the speed at which the LED goes on and off. You will see some mid-level brightness.

Varying the time that the LED is on and off, you will have various mid-level brightness. See figure below:

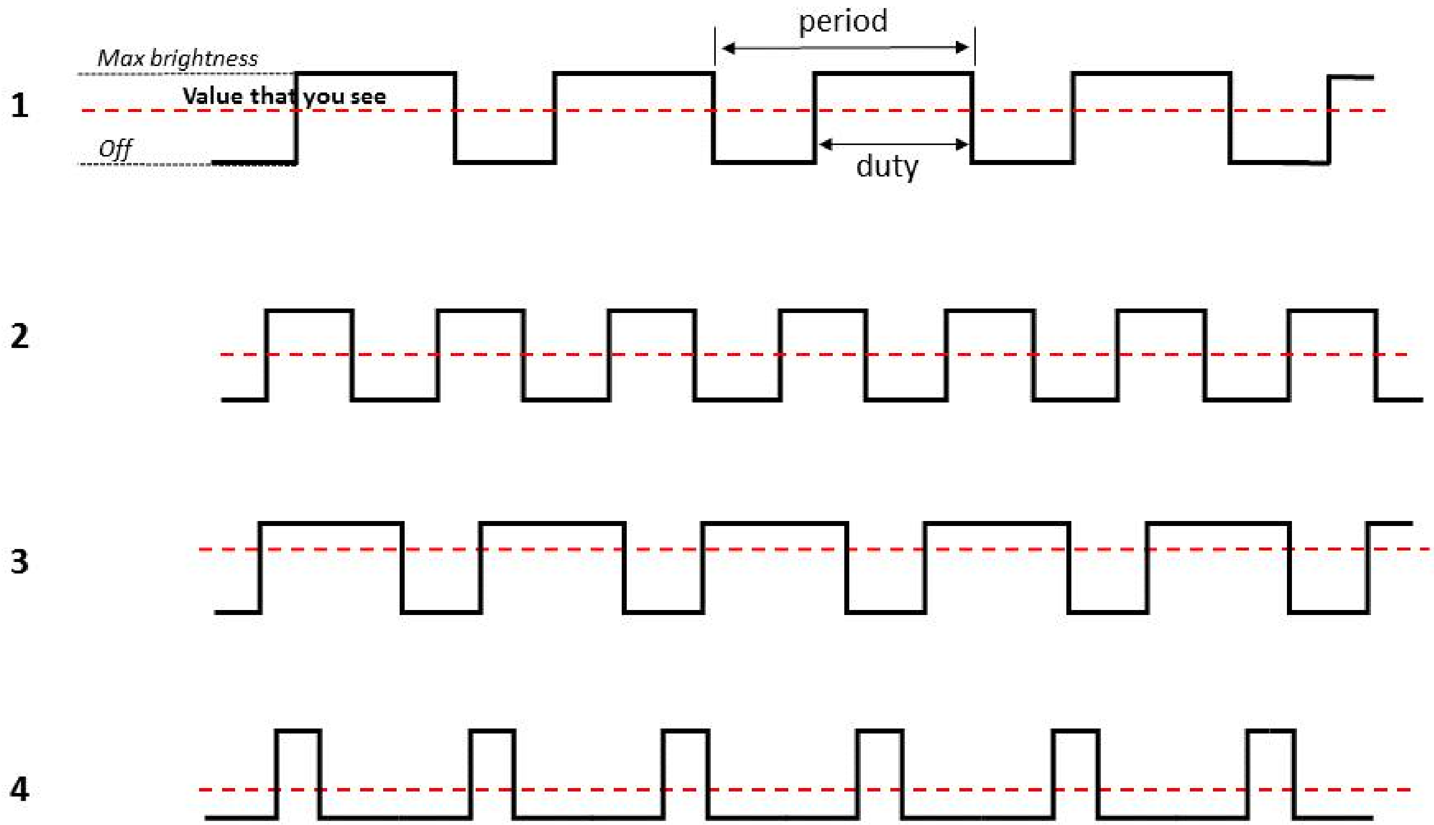


Figure 63. How PWM works

Now, that you understand what PWM is, let's build the circuit.

Controlling the LED Brightness with the EN555

The circuit diagram will be the following (it has just a few modifications compared with the one used in the previous Unit):

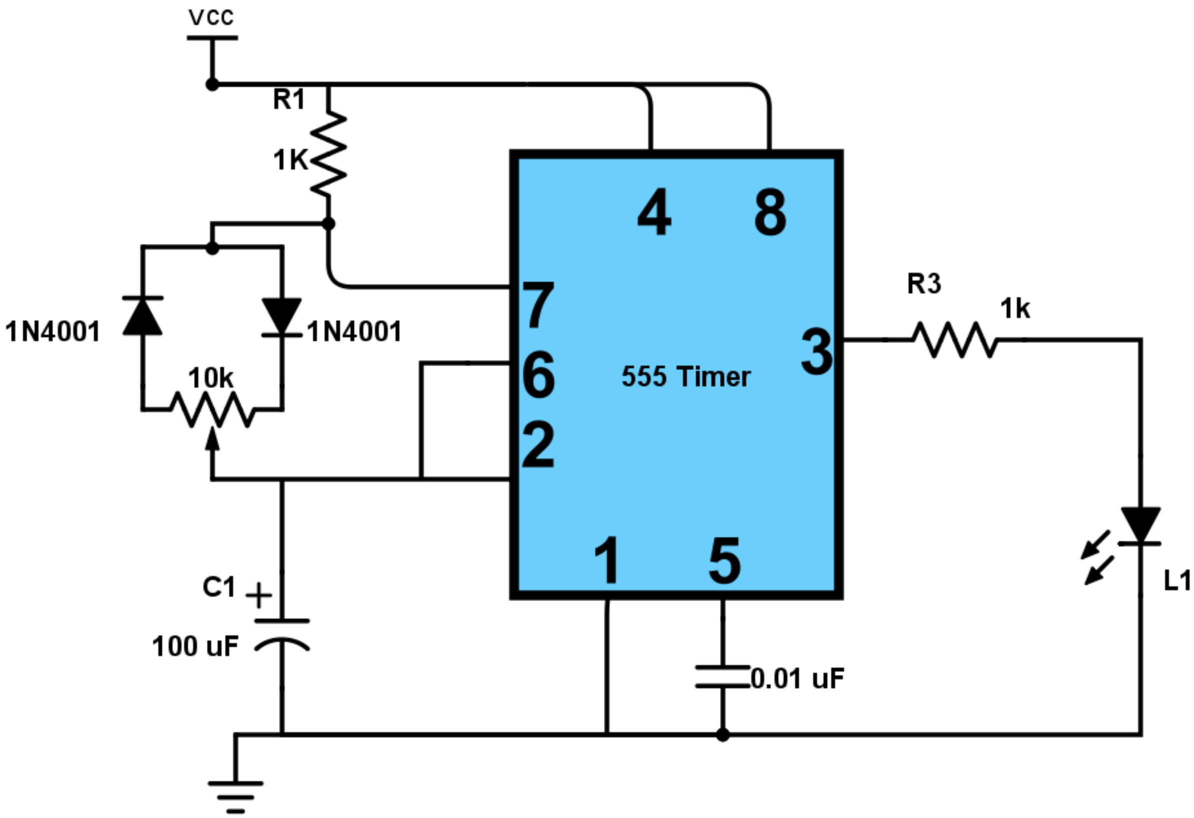


Figure 64. Controlling the LED brightness using the EN555

The components for this project are:

- EN555
- 9V battery
- Battery clip
- Breadboard
- 10kΩ potentiometer
- 2× 1kΩ resistor
- 2× 1N4001 diodes
- 100uF capacitor (electrolytic)
- 0.01uF capacitor (ceramic)
- LED
- Hookup wire

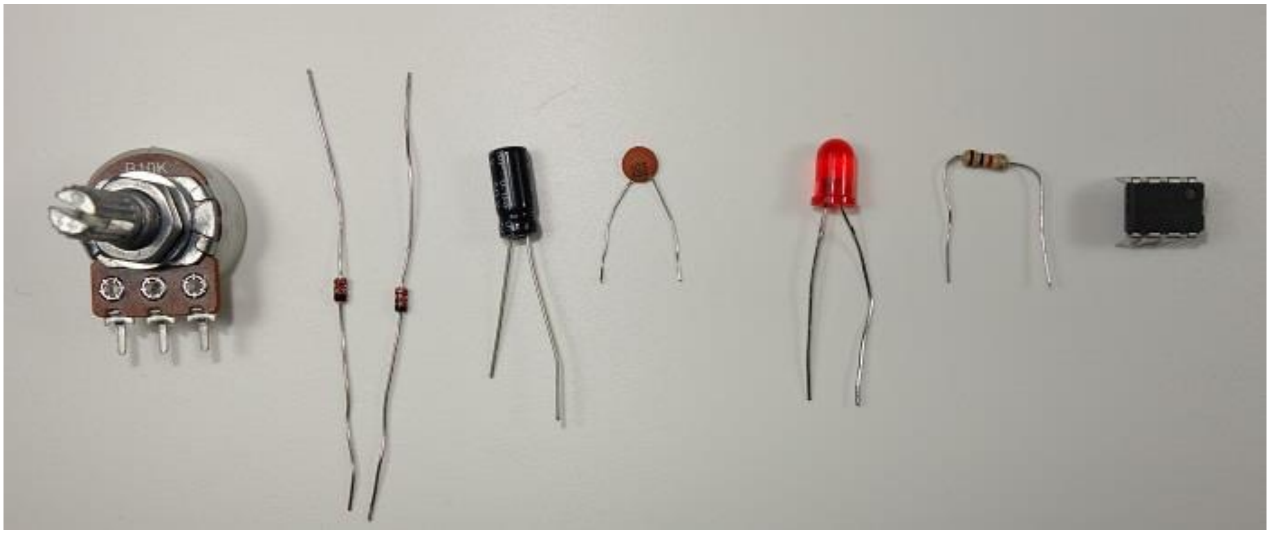
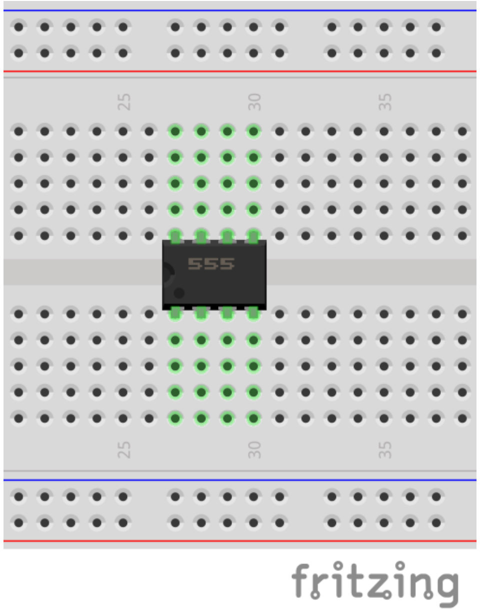


Figure 65. Components required

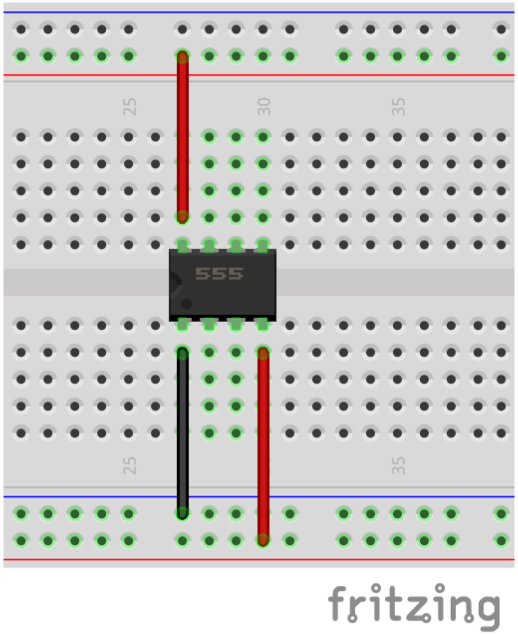
Wiring the Circuit

Here are the steps to connect all the components:

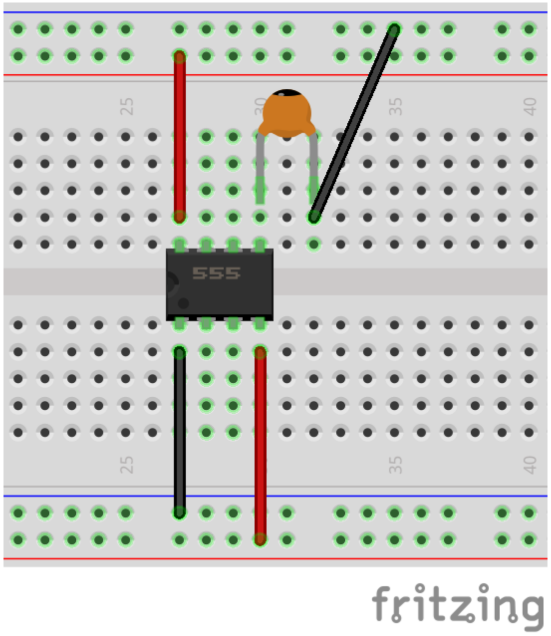
1. Start by plugging the EN555 into the breadboard as in the schematic below



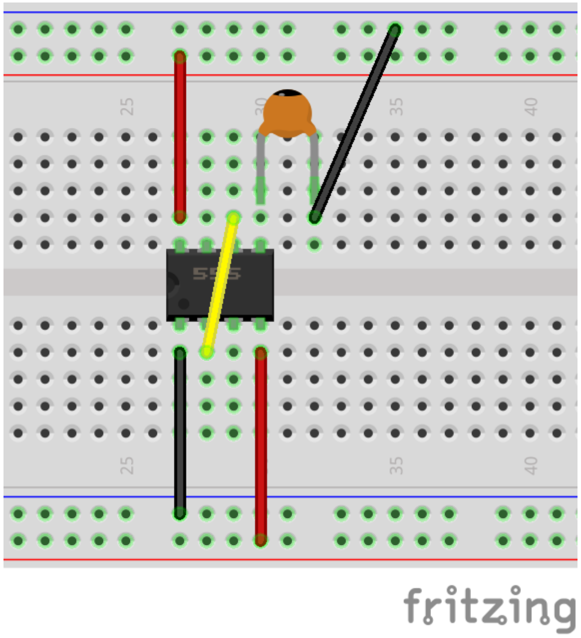
2. Wire pin 1 to GND and pin 4 and pin 8 to VCC



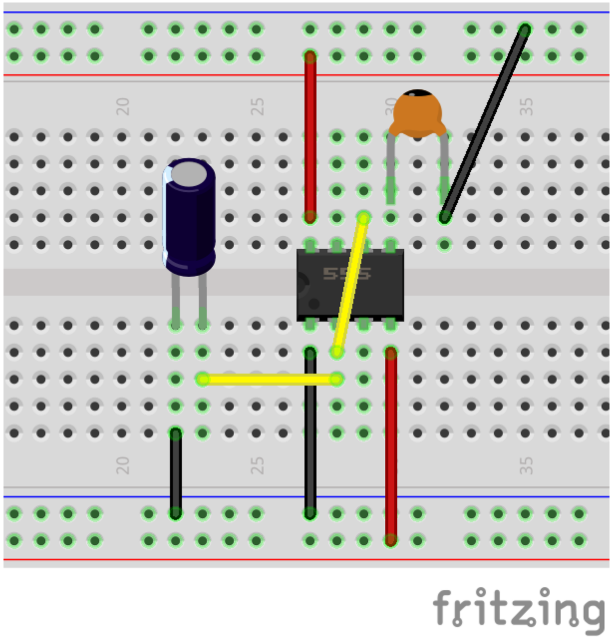
3. Connect the 0.01uF capacitor to pin 5 and to GND



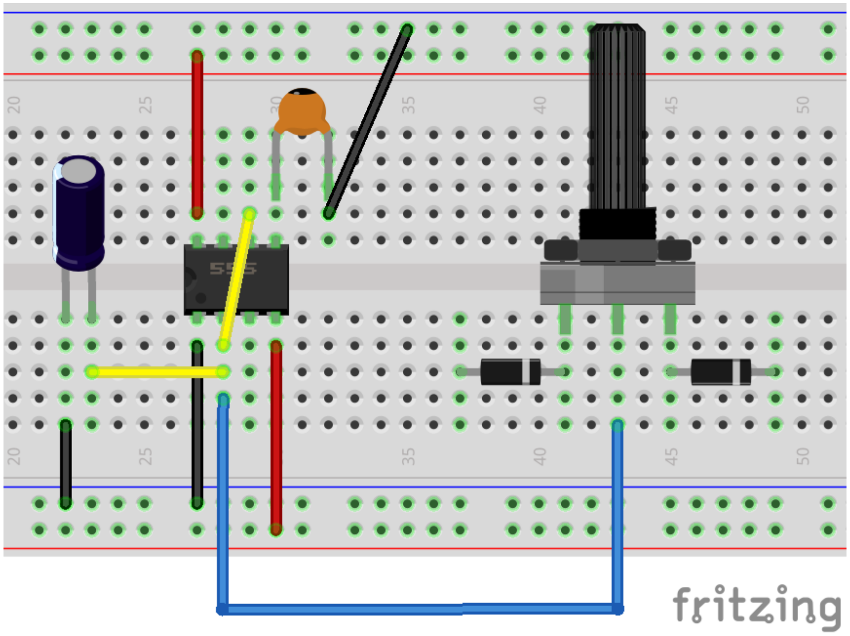
4. Connect pin 2 to pin 6



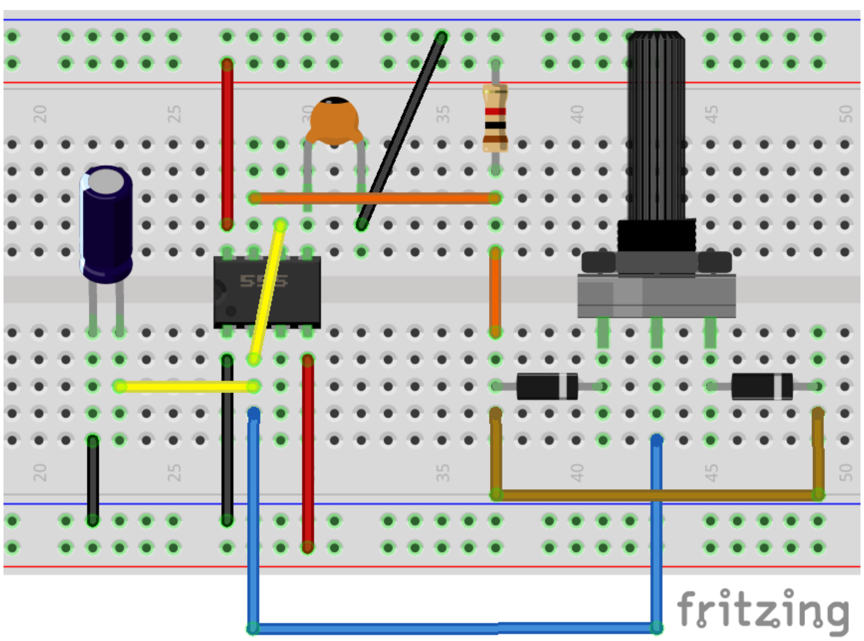
5. Connect the 1uF capacitor to pin 2 and to GND



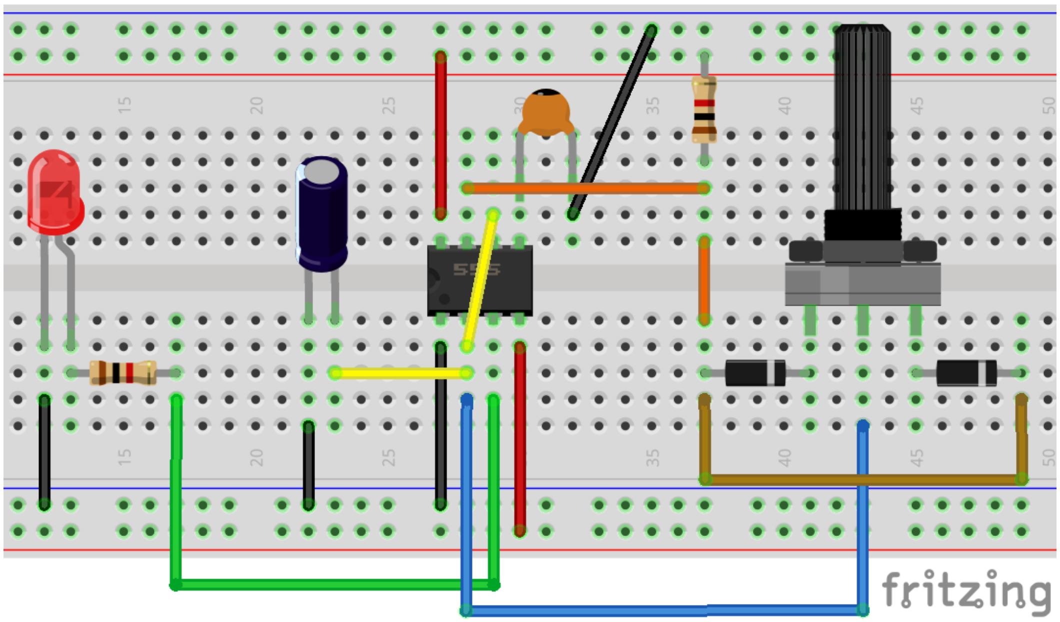
6. Connect the center pin of the potentiometer to pin 2 of the EN555 and the diodes to the outer pins



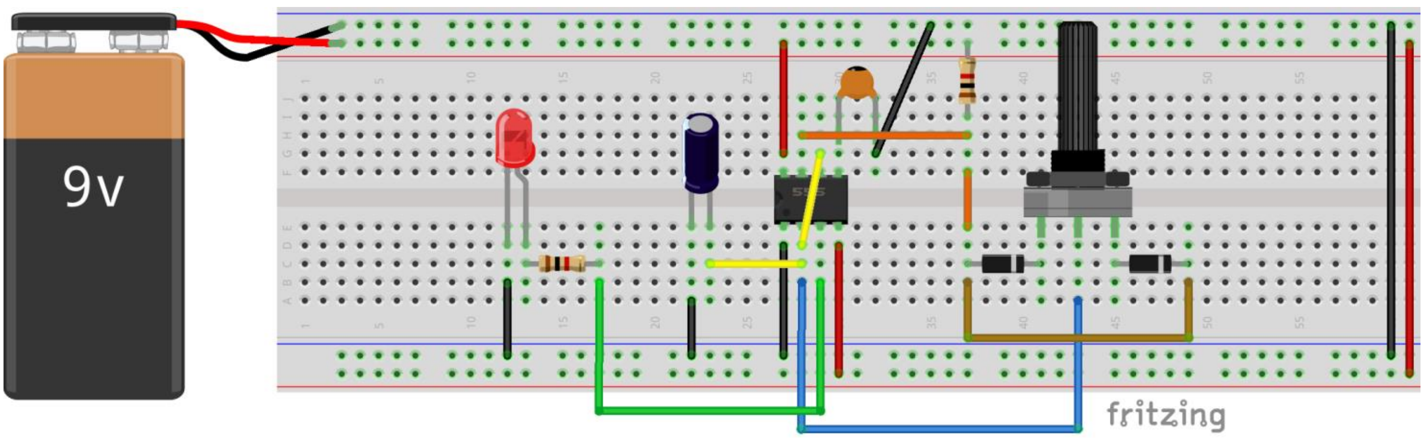
7. Connect the diodes together and connect them to pin 7. Connect a 1kΩ resistor to the diodes



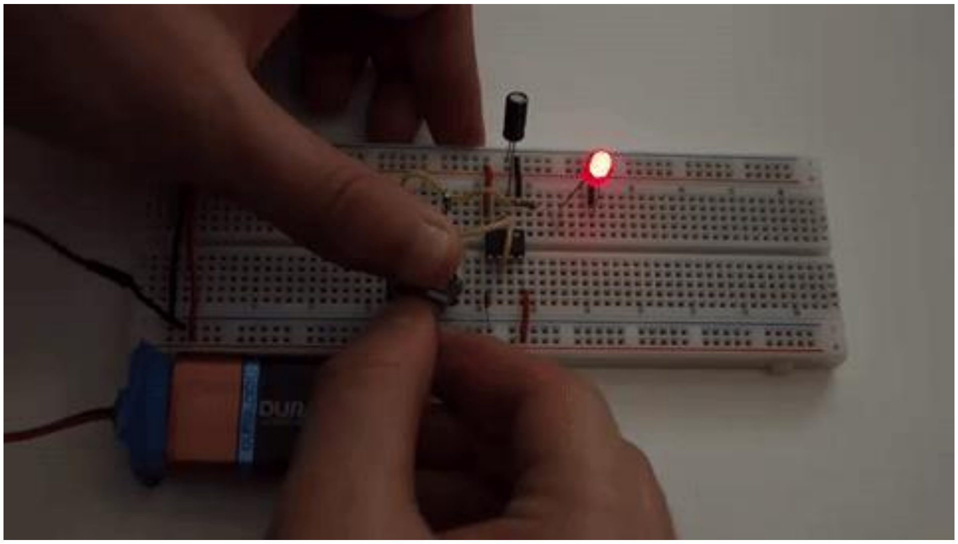
8. Connect pin 3 to the 1kΩ resistor in series with the LED



9. Power up your circuit by connecting the battery to your breadboard



Here’s the final result:



Module 5

Extra – Tools of the Trade

Unit 1 - How to use a multimeter

A multimeter is a measurement tool absolutely necessary in electronics. A multimeter allows you to measure what is going on in your circuit. Whenever something in your circuit isn't working, the multimeter will help you with **troubleshooting.**

The two basic things that are measured with a multimeter are **voltage** and **current**. Additionally, most multimeters also measure **resistance** and **continuity**.

Figure 66. Multimeter

Some situations in which you'll find the multimeter useful

- Does the switch work?
- Is this cable well connected?
- Is this cable conducting the electricity?
- How much voltage is this battery putting on the circuit?
- How much current is flowing through my LED?
- How much resistance has the potentiometer in this position?

Selecting a Multimeter

You can find a wide variety of multimeters with different functionalities and precision. A basic multimeter costs about $5 and measures the three simplest but most important values in your circuit: voltage, current, and resistance. So, it does pretty much everything that you need.

If you want a bit more advanced multimeter, I truly recommend you an auto-range multimeter. The **auto-ranging** is a great advantage, because it saves you of the hassle of having to know which range of value the electrical characteristic you're measuring falls under. You can find a good multimeter with this characteristic for about 50$. However, it's still pretty straightforward to measure with a multimeter without autorange.

Getting familiar with the multimeter

A multimeter has 4 essential parts:

- **Display**: where the results are displayed
- **Selection knob**: to select what you want to measure
- **Ports**: is where you plug in the probes
- **Probes**: A multimeter has two probes. Generally one is red and the other is black. You should connect the tip probes to the device/components you want to take measurements

Figure 67. Parts of a multimeter

Figure 68. Multimeter probes

The "COM" or "-" port is where the black probe should be connected. The COM probe is **conventionally** black.

Figure 69. Black probe connected to the COM port

NOTE

Note that there aren't any differences between the red and the black probe, just the color.

So, assuming the convention:

- the **black** probe is always connected to the **COM**
- the red probe is connected to one of the other ports depending on what you want to measure.

Ports

Figure 70. Multimeter ports

- **10A** is used when measuring large currents, greater than 200mA
- **µAmA** is used conventionally for measuring current
- **VΩ** allows you to measure voltage and resistance and test continuity

NOTE

The ports can vary depending on the multimeter that you're using.

Measuring voltage

You can measure DC voltage or AC voltage. The V with a straight line means DC voltage and the V with the wavy line means AC voltage. Here, we will only deal with DC voltage.

Figure 71. The V with the wavy line is used for measuring AC voltage

Figure 72. The V with the straight line is used for measuring DC voltage

For measuring the voltage, you should:

1. Setting the mode to V (with the dash and three dots below for DC)
2. Make sure that the red probe is connected to the port with a V next to it
3. Connect the red lead to the positive side of your component, which is where the current is coming from
4. Connect the COM lead to the other side of your component
5. Read the value on the display

TIP

To measure voltage, you have to connect your multimeter in **parallel** with the component you want to measure.
Placing the multimeter in parallel is placing each probe along the legs of the component you want to measure.

Example:

Let's start measuring the voltage of a 1.5 volt battery. You know that you'll have approximately 1.5V. So, you should select a range with the selection knob that can read the 1.5V. So you should select 2V in the case of this multimeter.

Figure 73. Measuring voltage of a 1.5 V battery

What if you didn't know what was the value of the voltage? If you need to measure the voltage of something, and you don't know the range in which the value will fall under, you need to try the several ranges.

If the range you've selected is lower than the real value, on the display you'll read 1 as shown in the picture below. The 1 means that the voltage is higher than the range you've selected.

Figure 74. Measuring the voltage of a 1.5V battery

If you select a higher range, most part of the times you'll be able to read the value of the voltage, but with less precision.

Figure 75. Measuring the voltage of a 1.5V battery

And, what if you switch the red and the black probe?

Nothing dangerous will happen. The reading on the multimeter has the same value, but it's negative.

Figure 76. Measuring the voltage of a 1.5V battery

Measuring the voltage in a circuit

TIP

Remember: Two components in parallel share a voltage, so you should connect the multimeter in parallel with the component you want to measure.

Let's measure the voltage drop across a resistance in a simple circuit. This circuit example is a circuit that lights up an LED.

Parts needed:

- 9V battery
- LED
- 470Ω resistor
- Wire cables
- Breadboard

1. You just have to place the **red** probe in one lead of the resistor and the **black** probe on the other lead of the resistor
2. The red probe should be connected to the part that the current is coming from

Also, don't forget to make sure the probes are plugged in the right ports, as in the figure below:

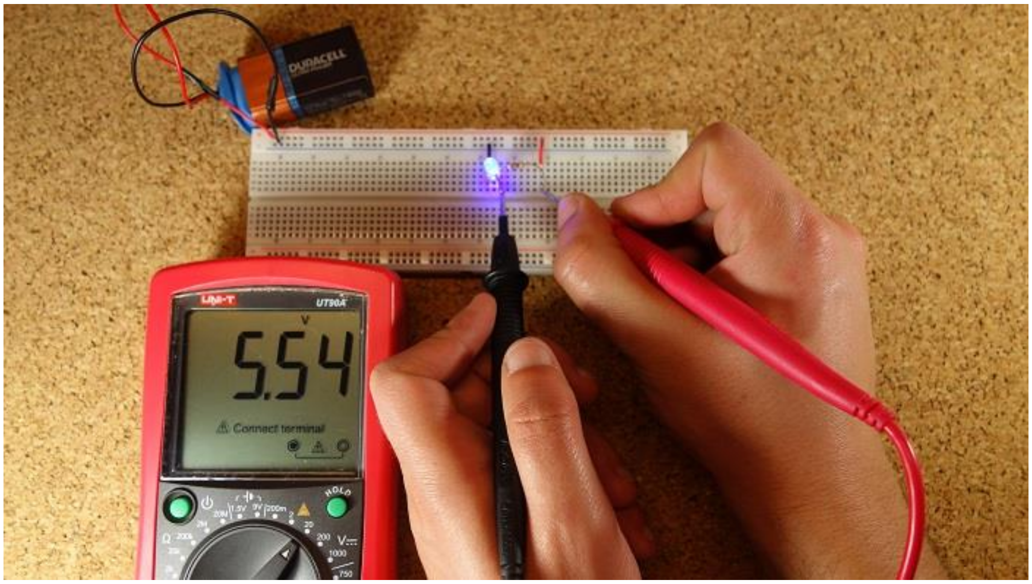


Figure 77. Measuring the voltage across a resistance in a circuit

Measuring current

For measuring current you need to bear in mind that **components in series share a current**. So, you want to connect your multimeter in line with the components of the circuit whose current you'll measure.

TIP

For you to place the multimeter in series you need to place the red probe on the leg of a component and the black probe on the next.

The multimeter acts as if it was a wire of your circuit. If you disconnect the multimeter your circuit will not work.

Before measuring the current, be sure that you've plugged in the red probe in the right port, in this case µAmA. In the example below, the same circuit of the previous example is used. The multimeter is part of the circuit.

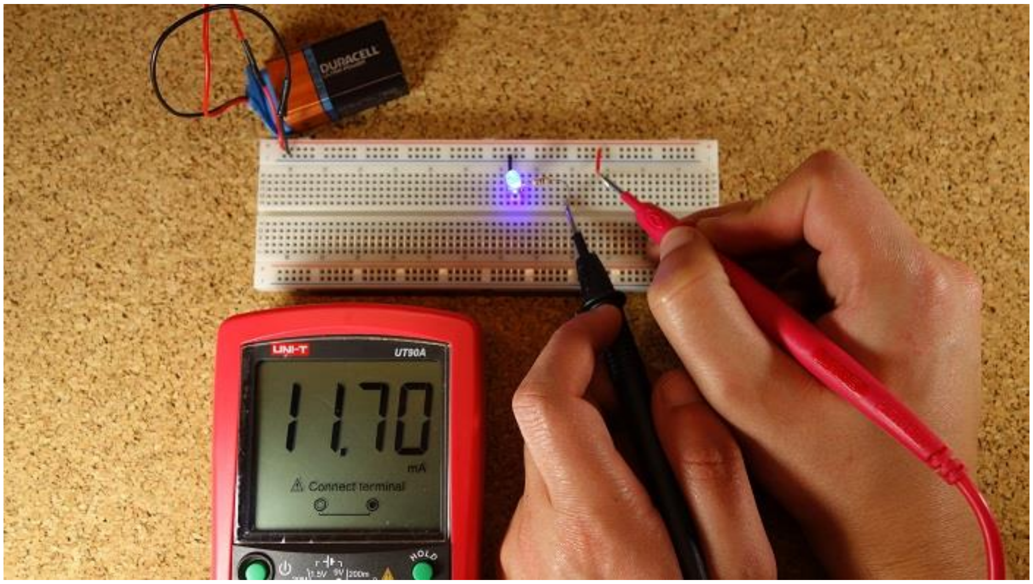


Figure 78. Measuring current

Measuring resistance

What's the purpose of measuring resistance?

- You may have variable resistors and you want to know what the value of the resistance is
- You may want to know the value of a simple resistor with more precision (remember that the value that you read from the color bands always have an error associated with it, the tolerance)
- You may not want to go through the hassle of reading the color bands.

Plug the red probe into the right port and turn the selection knob to the resistance sector. Then, connect the probes with the leads of the resistance.

You can connect the probes in each order you want. The result is the same.

Figure 79. Measuring resistance

As you can see, the 470Ω resistor, only has 461Ω.

Checking the continuity

Most multimeters now provide a feature that allows you to test the continuity of your circuit. This allows you to easily detect bugs such as faulty wires.

In other words: testing the continuity basically means that you're testing the resistance between two points. This allows you to detect if two points are connected.

To use this functionality select the mode that look like a speaker.

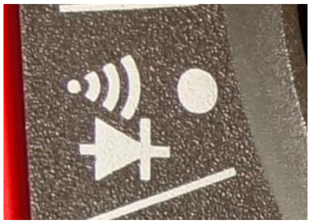


Figure 80. Continuity mode

How does it work?

If there is very low resistance, which is less than a few ohms, the two points are electrically connected and you'll hear a continuous sound.

If the sound isn't continuous or if you don't hear any sound at all, it means that what you're testing has a bad connection or it's not connected at all.

Note: To test continuity the multimeter should be connected in series as described for measuring current.

WARNING

To test continuity you should turn off the system! Turn off the power supply!

Touch together the two probes and, as they are connected, you'll hear a continuous sound.

Figure 81. The probes touching each other will create a continuous sound

To test the continuity of a wire, you just need to connect each probe to the wire tips.

Figure 82. Testing the continuity of a wire

This Unit will hopefully give you the basic knowledge on how to use the multimeter, which is a must have tool for anyone that deals with electronics.

Unit 2 – How to use a soldering iron

A breadboard is very useful to prototype your circuits, but what do you do when you're done testing?

Why you shouldn't always use a breadboard

Keeping your project in a breadboard can lead to a very common issue, such as your wires getting disconnected and your project stops working.

Breadboards were built with reusability in mind, so when you dive into a new project, you either discard your previous one or buy a new breadboard.

Sometimes, you might simply want to solder wires to components that have tricky forms or that are not breadboard-friendly.

It's more practical to use a potentiometer with wires soldered to their leads than to stick the potentiometer itself into the breadboard.

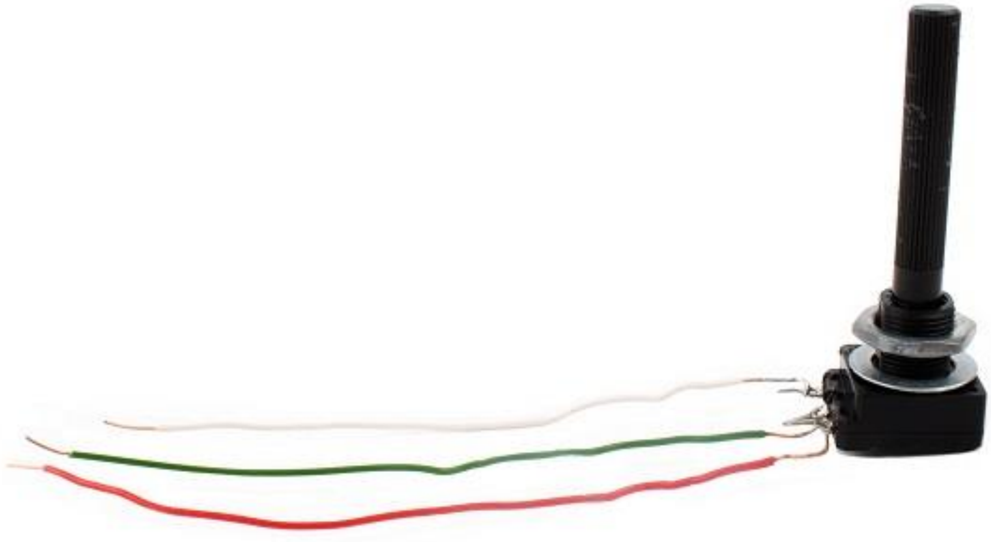


Figure 83. Potentiometer with wires soldered to its leads

Protecting yourself

Soldering means working with very high temperatures, which naturally can be potentially dangerous. Read this section carefully to ensure that you're safe while soldering.

For standard applications, most solder irons heat up to around 370 degrees ºC (700 degrees ºF).

Before plugging your soldering iron into the wall socket, you should make sure that you:

- Have a clean workspace
- Are working in a well-ventilated area, because soldering produces fumes

Warning: put on a pair of protective glasses. Tiny bits of solder might fly out while you're soldering, and the fumes may hurt not only your lungs, but also your eyes.

Soldering your first joint

Just being a little bit sloppy might mean getting a finger burned, no matter how much practice you have.

Don't touch the metal tip, and avoid touching other materials with it.

Note: if you're a minor, make sure that an adult is nearby when you're soldering. Don't get too scared, though; just don't touch the metal tip, and everything will be fine.

Recommend iron temperature

The recommended temperature for melting solder is 326 degrees ºC (620 degrees ºF). Some soldering irons allow you to choose a working temperature. If you have one of those irons, select 326 degrees ºC, as this is hot enough to melt the solder.

Let your soldering iron heat for a couple of minutes. To check whether your iron's tip is hot enough and ready to use, touch the solder with the tip. The solder should melt almost instantaneously. If that's not the case, be patient and wait a little bit longer.

Tinning and cleaning the soldering tip

The first step is to tin the tip of your soldering iron. To do that, melt a small amount of solder on the tip, as shown in the next figure.

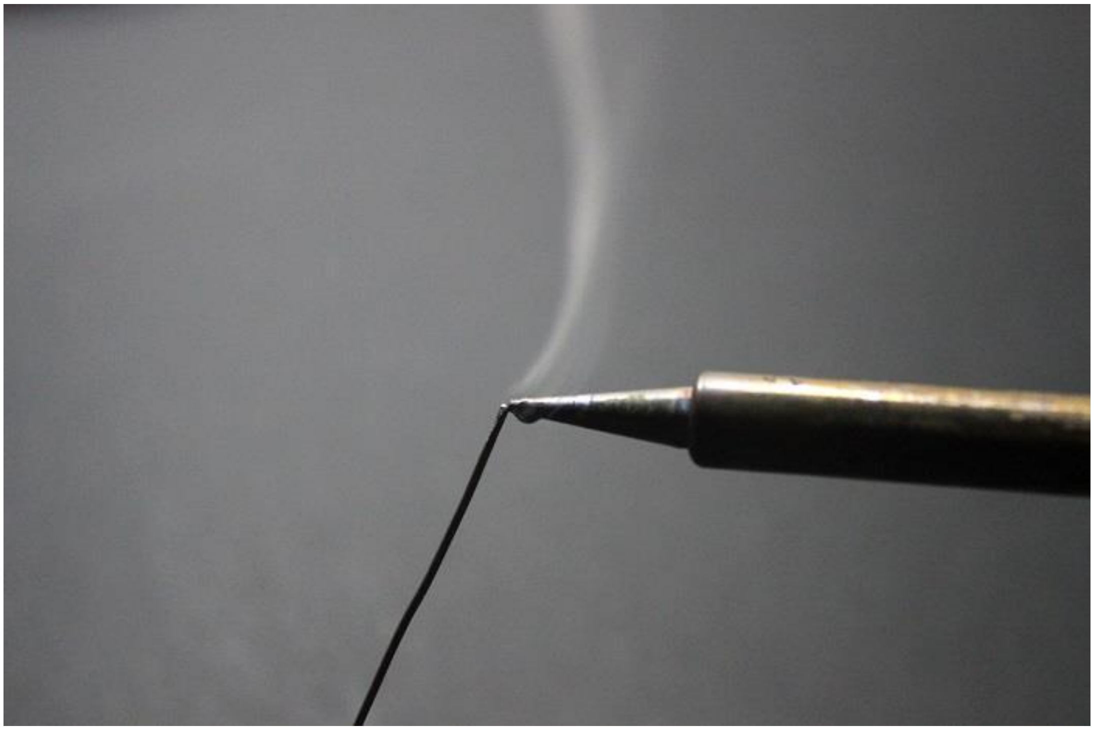


Figure 84. Tinning and cleaning the soldering tip

This process makes soldering easier and also preserves your soldering tip, protecting it from oxidation.

Adding solder to a potentiometer lead

Soldering the potentiometer leads to three wires is a good way to be initiated into soldering. Having three wires soldered to your potentiometer makes it easy to plug it into a breadboard.

Follow these steps to solder the potentiometer leads to the wires:

1. **Touch the soldering iron tip to one potentiometer lead**
2. **Let the lead heat up for one or two seconds**
3. **Touch the solder to the potentiometer lead**
   - Your solder should melt right away, solidifying shortly after.
   - You need just a small amount of solder, and this action should be really quick.
4. **If the solder doesn't melt, apply heat for a longer period**

Important: during this process, it's tempting to touch the solder to the iron tip and then spread it around the lead, rather than let it melt through the heat applied to the lead. That process is called a cold solder joint, and the result usually is a bad solder job.

Adding solder to a wire

After you've soldered the potentiometer lead, you can solder your wire as follows:

1. **Touch the soldering iron to the wire**
2. **Let the wire heat up for two or three seconds**
3. **Touch the solder to the wire to melt the solder**

You need only a bit of solder, and it should melt and then solidify very quickly.

Soldering a wire to a potentiometer

When you've soldered both surfaces, join them by following these steps:

1. **Connect the wire to the potentiometer lead with the help of a third hand (see the last figure)**
2. **Apply heat to the joined lead and wire with your iron tip**

The solder you placed previously melts, and the two components seemly stick together.

3. **Add more solder if you think that's necessary**
4. **Repeat Steps 1–3 for the other two leads of your potentiometer**

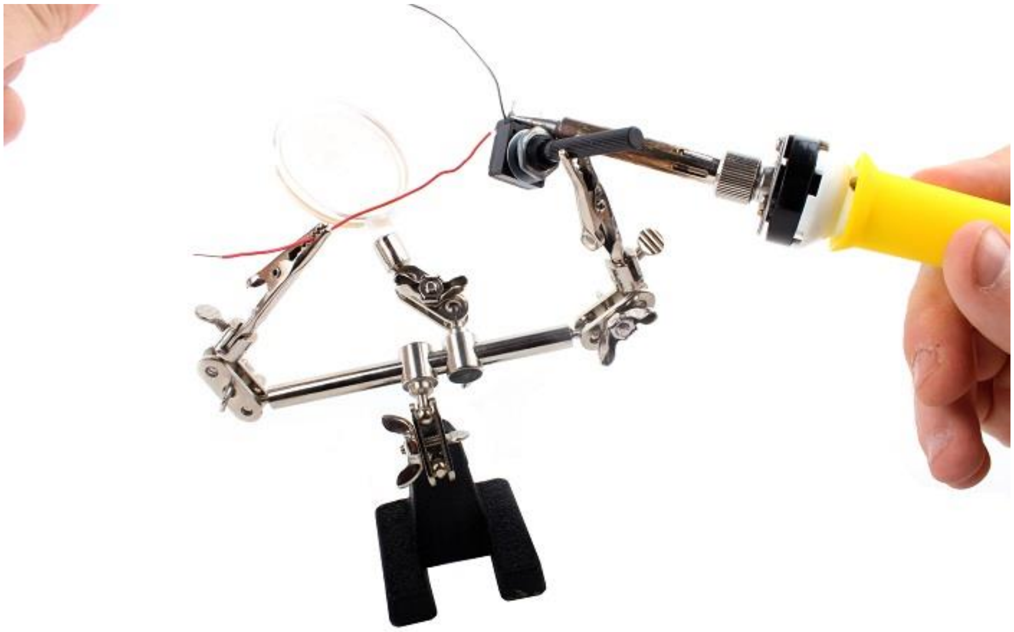


Figure 85. Soldering a wire to the potentiometer

Unit 3 – Wrapping Up

Congratulations, you've completed the Electronics For Beginners course.

Let's recap what you've learned:

- Electronics basic concepts (electricity, voltage, current, resistance and basic formulas)
- Identify electronic components and how to read simple circuit diagrams
- Build electronic circuits into a breadboard
- How to use the 555 Timer integrated circuit to blink and dim an LED
- How to use a multimeter and how to solder

So, what's next? It's up to you, however I have a couple of ideas:

1. Try new projects with the 555 Timer circuit or other integrated circuits
2. Build your circuits into a prototype board
3. Start learning Arduino. The Arduino allows you to do more advanced projects in an intuitive and easy way.

Thanks for completing the course,

Rui Santos & Sara Santos

Download Other RNT Products

Random Nerd Tutorials is an online resource with electronics projects, tutorials and reviews.

Creating and posting new projects takes a lot of time. At this moment, Random Nerd Tutorials has nearly 100 free blog posts with complete tutorials using open-source hardware that anyone can read, remix and apply to their own projects: http://randomnerdtutorials.com

To keep free tutorials coming, there's also paid content or as I like to call "Premium Content".

To support Random Nerd Tutorials you can download Premium content here. If you enjoyed this eBook make sure you check all the others.

Thanks for taking the time to read my work!

Good luck with all your projects,

-Rui Santos

P.S. Click here for more Courses and eBooks like this one.

Click here to Download other Courses and eBooks

http://randomnerdtutorials.com/products