

LEARN ELECTRONICS WITH BASIC THEORY AND HOME EXPERIMENTS!

Volume 1 - Basic Theory and Experiments

**Basic Analog Electronics and
Basic Electronics for Arduino,
Raspberry Pi and others**

**Basic electronic components and circuits for
practical home experiments!**

**Fully illustrated: more than 300 images of components, circuits,
uses, measurements, tips, step-by-step, etc.!!**

1st Edition – Author's Edition

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Cover photo courtesy SparkFun Electronics - USA

Dedication

With affection, for my family, Rita, Xexa, Paulinho and Rô from which I "stole" hours to make this book.

To all who are looking for something ... It may be that you do not find what you want, but surely you will find what you need!

Presentation

D.I.Y = Do it yourself. Term used to designate one who does things, instead of buying them, in any area, be it electronics, mechanics, robotics, motorsports, carpentry, modeling, etc. This can occur in the following cases:

1. It is cheaper to do.
2. Want to learn the know-how and "get your hands dirty".
3. There is no ready.

This eBook has as its primary focus the beginner in electronics, with no or little prior knowledge, who wants to "do" their assemblies, prove the theory and at the same time learn the basic theory behind it. At the same time, this eBook can also be considered a great learning tool for the electronics student, the novice engineer and those who have a hobby where electronics is used.

Another very important focus for this book is the people who need to change their professional career, either of their own volition or by the demands of the labor market. In this year in which this eBook was written, the situation in several countries often requires a change of course in our professional activities and why not choose electronics because of its use in almost everything in our lives?

Let's not forget the retired, seasoned professionals, the "seniors," who also want an occupation after retirement! The learning of electronics can be done from 12 years (or before) until after 100!!

It is very important that you, when purchasing this eBook, keep in mind the following:

1. **Learn Electronics with Basic Theory and Home Experiments! – Volume 1**, is a fairly well-illustrated book on basic analogical electronics theory, covering electron-to-circuit operational issues in an easy, fluid, non-stumbling or math manner.
2. In the initial presentation of each chapter you will find the basic theory necessary for the subject being studied, with examples, diagrams, images and simple applications.
3. . The reader will use a Protoboard mounting board, using external components and equipment, as reported in the eBook text.

4. . Included in the text you will find some basic experiments to do, using the knowledge learned in the volume. These experiences are for you to learn to identify some electronic components, make contact with the use of Protoboard and its assemblies and also to use the DMM, which will be a very important instrument in our practices. In summary, it is a "tasting" of the many practical experiences that are in the second volume of our eBooks.
5. . In the second volume **Learn Electronics with Basic Theory and Home Experiments! – Volume 2**, you will find a series of practical experiments to do at home, with materials ease to find. It is a practical eBook, based on the theory studied in **volume 1**.

How to acquire material for experiments

If you live in a large city, you have a high probability of having one or more stores that sell electronic components in retail. However, most of these stores sell spare parts for repairs in electrical appliances such as microwave ovens, televisions, DVD players, etc.

But the material we are going to need is very simple and we hope you can find the vast majority in these stores.

If you reside in small towns or cities that do not have the type of commerce discussed above, the solution is to purchase electronic components over the Internet, shipped by Post Office or carrier

For this to work properly, without you experiencing embarrassing situations, it is interesting to follow some tips.

1. Does the store actually exist (have physical facilities) or is it only virtual? Give preference to stores that have physical facilities. See in the ads on the Internet if you have an address and you can withdraw your purchases at hand.

2. When choosing a store, check sites of "Claim Here" to see if they have any more serious complaints. Complaints you will see that all companies have, because sometimes the customer wants to be more **real than the king** ...

3. Compare prices, freight, delivery times, etc. Look for, if possible, stores in your state or as close as possible as freights greatly increase prices. Try to buy several components at once.

4. Care of electronic components coming from "unknown geographical location" as this is full in online stores. See photos, look on other websites, see the manufacturer's catalog, etc.

5. Send e-mail or enter suppliers' chats, for questions, doubts, etc.

6. Stores with good reputation, usually accept returns, but not all do this. There is a lot of picking! Try to know this in case of wrong purchase of any component.

7. If you have conditions, you can purchase your components abroad either directly or on websites such as "Ebay®" where negotiations seem to be more serious. Talk to people who have already made this kind of purchase. Other overseas sites where you can consult abroad are AliExpress® and Banggood®

8. Some electronic components have such a small monetary value that they are sold in packs of 5 or more pieces. The carbon resistor, for example, can be found in packs of 10 or 20 pieces. Simple diodes and small transistors, too.

9. The freight is the "terror" of the buyers in virtual stores, I ask for less here in Brazil. Many electronic components cost a few dollars and most of the time freight is much more expensive than the purchase itself. Try to group the items into one purchase.

10. If possible and your "money box" looks good, get some spare parts of your component. Do not buy "only one" resistor ... Purchase at least 10 pieces, as it is a very cheap and small / light freight item. Same for capacitors, diodes, common transistors, etc. over time, you will have a small reserve of the main components used in electronic circuits.

Why is this book an eBook?

With the arrival of eReaders (digital book readers), tablets, iPad®, Kindle®, Galaxy®, etc., I decided to make this book directly in the digital format, because the cost would be less, both production and sale for the reader. Combine with this is the disinterest of the publishers and the prohibitive cost of making a colorful printed book.

The text of the two eBooks was done in the form of "step by step", with the presentation of an enormous number of photos, drawings and diagrams, to better understand and illustrate what should be done.

You can open your computer or tablet next to your Protoboard board and electronic components and read the theory or make the practical experiments. The

use in tablet and computer, allows you to have colored images, zoom of these images for better details, access to sites with more information, etc.

Other books of the author

- **Coleção** [“MONTAGENS ELETRÔNICAS PARA QUE NÃO É TÉCNICO”](#).
 - Vol 1 – Teoria básica e componentes eletrônicos
 - Vol 2 - Circuitos eletrônicos básicos
 - Vol 3 – Prática de Montagem
 - Vol 4 – Fontes de alimentação
 - Vol 5 – Projetos de instrumentos de medidas
 - Vol 6 – Amplificadores de áudio e receptores
 - Vol 7 – Transmissores de rádio e antenas
- [Monte seu Projeto Eletrônico Facilmente!](#) Montagens Eletrônicas para principiantes. Viu um esquema na revista e quer ver funcionar?
- [Lance seu primeiro eBook!!](#): Publicando seu livro na Amazon - Roteiro passo a passo para fazer seu eBook (WORD®)
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- [CADSOFT EAGLE PCB® para iniciantes!](#) Faça o layout das suas Placas de Circuito Impresso
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- [Não chame o marido de aluguel! Faça você mesma!](#) Pequenos reparos em Eletricidade, Telefonia e Alarmes.
- [Laptop para Sêniores! Primeiros Passos.](#) Passo a passo para você aprender a pilotar um!
- [Monte facilmente seus projetos eletrônicos](#) - eBook interativo, para leitura no Apple® iPad. Publicado através da Apple iTunes Store.

■ [Como usar o multímetro! Multímetros digitais e analógicos!](#) Técnicas de uso corretos dos multímetros analógicos e digitais.

■ [Eletronica Básica para o Arduino: Treinamento em Eletronica Básica voltado exclusivamente para o Arduino e RedBoard.](#)

■ [Projetos Práticos com o Arduino e a RedBoard:](#) 22 projetos para serem desenvolvidos com a RedBoard e o Arduino.

Notes on the text of this eBook:

The language used in this eBook is informal colloquial. I am talking to the readers in an informal way, as I believe this leads to better results, gives more fluidity to the text and achieves the proposed learning objective. See below the definition of "informal colloquial language" given by Wikipedia®, if you still have questions.

In [linguistics](#), **colloquialism** is [vernacular](#) language including everyday language, everyday speech, common parlance, informal language, colloquial language, general parlance, and common expressions. It is the most used [linguistic variety](#) of a [language](#), the language normally used in [conversation](#) and other informal [communication](#).

Notice that you will probably find typos, grammatical errors and others in this eBook.

It was a long, tiring job and failures are always lurking! I did not have the money to hire a proofreader for the text, but I think readers are more interested in the techniques and experiments taught in the eBook than in the vernacular purism.

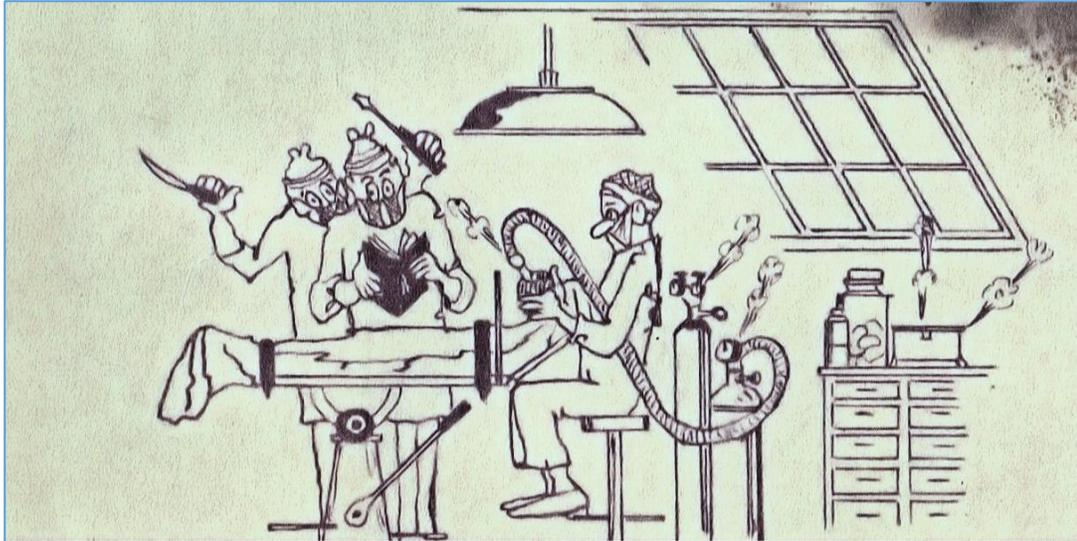
If these errors are more important to you than the technical content of the eBook, solve this easily: return your book to Amazon and you will be reimbursed. On the other hand, if you want to help correct these very obvious mistakes, feel free, because at the beginning of the book you have my e-mail. How about being partners instead of just being critical? I find it very helpful for the reader to work with the author to perfect the text! Thank you in advance.

1. Colors and geometric shapes were used in the various images to help clarify important points. This use of colors is also due to the fact that you will probably have to use this eBook on your computer or tablet or another color device.

2. Almost all images used in this eBook were digitally cut and treated to make them more readable. Some images were placed vertically for clarity of the presented elements.

3. The websites whose screens an address is presented in this eBook were consulted during the months of June 2018 to January 2019. After this date, they may be modified.

4. Some subjects covered by this eBook are repeated, due to their importance for success in the use of the theoretical and practical eBook. One of these matters, very important, is related to the knowledge of the various electronic components with which we are going to work. These repetitions gradually increase the information and knowledge about these electronic components.



Read the manual before operating!!

DISCLAIMER OF LIABILITY

This eBook (digital book) is provided for the purpose of information and self-improvement as well as entertainment.

The author of this eBook ensures that have done his best to provide the latest, correct and safe information available at the time, to write this book.

The author and distributor are not responsible for any types of accidents that may occur to readers, materials and measurement instruments, due to misuse, assembly errors, misinterpretation and attempts to use them for applications other than those specified, etc.

The reader should proceed with caution, especially the beginners, when measuring voltages or currents, mainly in alternating current (AC). The eBook is packed with alerts, warnings, and safety recommendations regarding the reader and used equipment.

NOTE: At some points in this book, I suggest that you do not leave children near your assemblies, especially during the act of soldering components. This is due to the fact that hot welding spills can occur and injure a child or even adult. And until you are not using safety equipment such as glasses, etc.

However, personally, I think this creates a lack of encouragement for the child or other people, for the use of tools, assemblies, etc. Curiosity seems to be natural in all ages, much greater in children.

So, if you agree, use these magical moments to teach the little ones something: fix the children's toys along with them, assemble small "trunks" that are simple and bring some results like lights, sounds, movements, talk about safety, teach handling and care with common hand tools, etc.

Try the above with adults!

The above text is not to frighten them but to alert them about the conditions of use of electronic circuits. You must have respect for electricity and not fear!

Follow the above advice religiously!

INFORMATION

Before we proceed, let's have a few words about the direction of the electric current. Where does it come from and where does it go?

You can find books, magazines and articles on the Internet, which use different meaning than we use here. To avoid confusion, in the studies of diodes and transistors, we will clarify.

An electric current is the movement of electrons in a given direction, through a conductor or semiconductor.

Since the electrons move from a negatively charged region to a positively charged region, why does the arrow draw in the yes graphic cake of a diode point in the opposite direction to it? Basically, there are two reasons for this;

1. It was traditionally assumed that the electric current moves from a positively charged region to a negatively charged region. The discovery of the electron has changed this thinking. However, many circuits drawn today still use this old thought and so are drawn.

2. In a semiconductor, the "holes" travel in a direction opposite to the electron flow. Thus, it is common to refer to "positive current flow" in a semiconductor.

In this eBook, we will use the current flow direction of the electrons, that is, from the negative pole of a battery to the positive pole of the same, through the circuit.

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1. In Portuguese

2. In English

Chapter 1

Learning basic analog electronics

Introduction

In this first chapter, you will get in touch with some important subjects before you begin to study and assemble your experimental circuits of basic electronics.

General objectives

1. Familiarize you with this basic theory of the eBook: **“Practical Experiments for You Learning Electronics at Home” - Volume 1**.
2. Understand what it is and know how to use the various electronic components used in practical experiments.
3. Contact the **Physical Assembly System** that we are going to use, based on a **"Protoboard"**, its functions, connections, uses, care, etc.

The method to be used

All the Practical Experiments you will do, will be based on the use of a **"Protoboard"** board and various electronic components that will be embedded in this board to form the various circuits.

You must purchase the Protoboard and mount a battery holder (power supply) that will power the circuits of your experiments. At this point you should also get a **DMM - Digital Multimeter**, for your measurements in the experimental circuits. Going forward you will have all the information you need for these acquisitions.

As experiments are presented, you will be able to acquire the other necessary material, according to the list included in the script of each experiment.

In practice

Follow the steps:

1. Read the theoretical part of the eBook, where you will learn important concepts to build your experiment to the best of your ability.

2. After this part, no doubt, go to the practical part of the eBook, which are the numbered experiments, such as "Experiment 1", etc.

3. Read through all experiment before beginning assembly.

4. If necessary, reread the basic text for more information on components, circuits, measurements, etc. Look for the "Summary" and see what is available.

5. See the circuit, components, important tips, points of safety, etc.

6. Mount the experiment, without using any connected power supply, be it batteries or a battery or USB from the computer.

7. Check your assembly with the drawings and photos provided in the text of the experiment.

8. All right? Plug in the power supply and go ahead!

9. If something goes wrong, turn off the power to the circuit and read the tips under problems, always presented under the subheading **"What if there is a problem in the mounts of my experiments?"**.

Sequence of theoretical and practical texts

Sometimes we will need to do experiments whose components or circuits have not yet been fully studied.

In other words, for example, we will experiment with series and parallel resistors. However, these series and parallel circuits have not yet been fully studied.

Since we have to follow the order of the experiments, I always put some basic theory in the experiment itself or even in the eBook text, in a reduced way. Then, these same points are studied again in more detail.

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Chapter 2

Good practices in the laboratory and at home

Introduction

Before you can begin your experiments in electronics, it is important to know some information and tips, for your safety, environmental safety and for great success in the experiments!

Safety

It is of great importance that you can work safely when starting your assemblies, measurements, etc., even if the potential for electric shock is extremely remote.

The experiments you will carry out are designed with your safety in mind, as they can be carried out by young people and adults. You will only work with batteries and your maximum working voltage is 9 VDC and shocks and other similar accidents will not occur!

But do not worry, then, a set of good quality batteries, such as alkaline well-known brands, will power your circuits through a whole series of experiments. If you are a teenager and need help, ask for the supervision of an adult with basic electricity.

Hints

- ▶ Find out how to turn off the power of your home in case of an accident.
- ▶ Whenever you are making connections between cables and components, work with the circuit switched off. Turn it on only when circuit is assembled.
- ▶ Do not work in wet places or exposed to weather. These experiments are approved for indoor use only in dry locations.
- ▶ Avoid wearing rings, bracelets, necklaces and long hair when working with experiment circuits. These metal trimmings may come in contact with exposed wires and components and cause accidents.

▶ Do not eat or drink while you are experimenting. Not even if it's a high-priced imported beer ... Leave it later ...

Basic tools

▶ So that you can work better with your wires, cables and components, when setting up experiments, it is interesting to have a small set of pliers and basic tools. This will allow you to strip the wires and terminals of the components, cut, bend, fit, etc.

These pliers are easily found in trade and used by artisans who make costume jewelry. See below a picture of a set of these. In several places they are known as "pliers for costume jewelry".



Figure 1 - Simple tools for use in electronics.

▶ A fine, small tip tweezers also help a lot in assembling and disassembling components. See a tweezers model in the photo above.

Assembling your experiments at home

▶ Find a place for you to study and make your experiments. It does not have to be elaborate: a small table and a comfortable chair. If not, use the kitchen table and organize your material and components into cardboard boxes.

▶ Read the full description of the experiment before you start assembling.

- ▶ Take advantage of the experiments. Do not do it mechanically, just for doing it. Examine the components, their physical format, their value, how it is embedded in the circuit, etc.
- ▶ Observe, think, act and try to find out what will happen to the outcome of an experiment!
- ▶ Read related topics in books, magazines and the Internet.
- ▶ Avoid bending the component terminals at right angles to the body of the components. Always give a clearance of 2 to 3 mm between the body and the first fold of the terminal.
- ▶ Sometimes the terminals of the components may be dirty or with some kind of oil due to handling. Clean them with fine sandpaper.
- ▶ Before dismantling a circuit, make sure if it will be used in the later experiment.
- ▶ Circuits used in experiments are simple circuits with a minimum of components. In practice, if you are going to build something similar, check books, magazines, etc.
- ▶ You may get some results slightly different from the ones that are placed in this eBook. Please, do not forget that the components have tolerance, variations, etc. The readings of the multimeter, in current, voltage, resistance, etc. also vary a little from meter to meter in view of the low cost of these multimeters. For example, the **DMM** might give a close reading of the **VOM** and this is normal.
- ▶ To remove the insulator of the wires and cables, you can use a cutting stylus, but very carefully. In the tool shops you find a safer tool, called "**wire cutter pliers**". If possible, use it.
- ▶ Pack a notebook or block and make your notes regarding circuits, assemblies, replacements, measurements, suggestions for future experiments and assemblies, etc.

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Chapter 3

Basic electricity

Introduction

Before we begin the study of electronics, we need to know some basic concepts of electricity.

Let us present these concepts in a very basic way, because for the purpose of this book, we do not need to know the whole theory of the subject.

If you are more interested in basic electricity, there are thousands of books that talk about the subject. See in the format of eBooks that are more economical.

Chapter Objectives

- Present the basic concepts of electricity, atoms, electrons, charges, insulation, conductors, etc.
- Electric current, Ohm law and types of electric current are also presented.

The Basics of Electricity - Atoms and Electrons

We do not see the electricity, but when it works, we can feel its effects on our computers, tablets, radios, TV, etc.

The best way to begin to understand electricity is to examine the atom, the smallest component of which all matter is made. The drawing of an atom is shown in **figure 1**, in a stylized way.

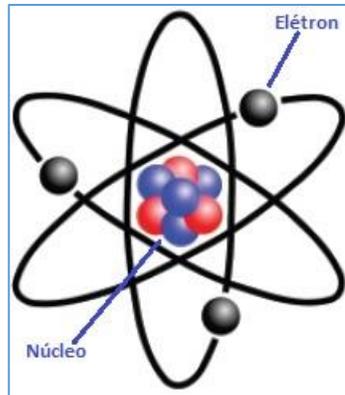


Figure 1 - Atom

The lithium atom has three electrons and its nucleus consists of three protons and four neutrons. Each electron is about 1,800 times smaller than neutrons and protons.

Each of these atomic components, electrons, protons and neutrons, has a charge, which is a kind of invisible force that reacts in a certain way with other particles in the atom.

Particle	Charge
Electron	Negative
Proton	Positive
Neutron	No charge (neutral)

Usually atoms have equal numbers of electrons and protons. This causes the atom to have no charge at all.

By certain means it is possible to dislodge some of these electrons from certain atoms. When an atom loses an electron, that balance of charges that existed previously is lost and the atom becomes negatively charged. In this case, it is called a positive ion.

When the atom gains an electron, it then becomes a negative ion. See **figure 2**.

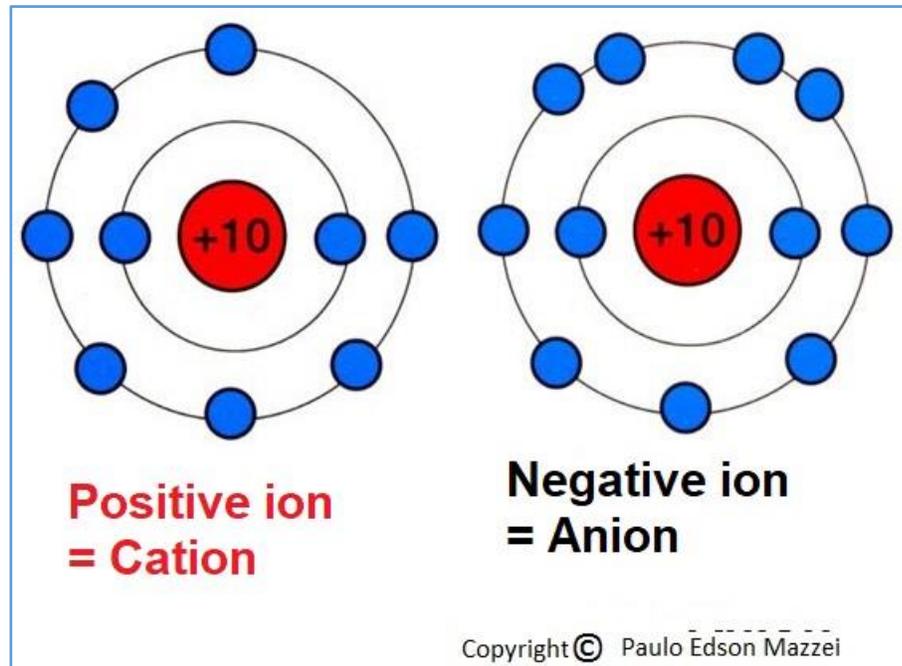


Figure 2- Cations and anions.

Electrons

Positive ions can "**give**" electrons since they have "**gained**" one or more electrons. Negative ions can "receive" more electrons, because they "**have lost**" electrons.

These electrons that have been given or received, are called **free electrons** and can "**travel**" (circulate) in certain metals like copper, silver, aluminum, gold, etc. They can also circulate in gases and in vacuum.

The number of free electrons in the above metals is huge and when nothing "**forces**" them to **move**, they are at **rest** in the metal. These free electrons at rest cause a negative static electric charge on the material.

When the free electrons move, we have an electric current that circulates through the material in an ordered movement. If placed near a number of positive ions (lost electrons and can receive more electrons in its structure), the free electrons are attracted by the positive ions and form this **electric current**.

Some mechanical actions may remove electrons from the surface of a material, such as friction, light, heat, or some chemical reaction. In this situation, positively charged atoms on the surface of the material cause a positive static electric charge.

Static charges

It has probably happened to you, take a little shock by holding the handle of a car door in very dry weather. This is the **static electricity** that has accumulated on the door handle and it circulates in a small current through your body. You feel it as a "**shock**"! **Figure 3.**

Make the famous and well-known comb experience, which when passed through a person's hair, acquires a charge that can attract small pieces of paper, for example. They are static charges deposited on the surface of materials.

For attraction, such as the comb case with small pieces of paper, the static charge on the comb must be different from the static charge on the piece of paper.

Hence the statement: Different charges are attracted and equal charges repel each other. Maybe this is why divorces occur between couples ...

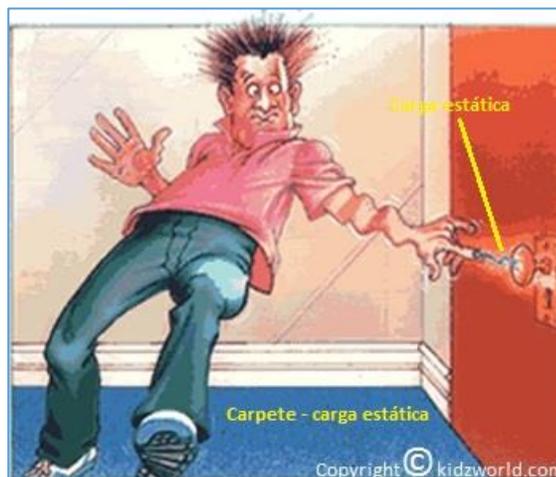


Figure 3 – A big shock!

Conductors and insulators

Certain materials such as copper, silver, gold, aluminum and iron allow the passage of a certain flow of free electrons, that is, an **electric current**. These materials are called **conductors**. In your daily life, at home, at work, in the car, etc. you have many conductors that are the electrical wires and cables of your home, your radio, your TV, etc.

On the contrary, materials such as glass, plastics, dry wood, rubber, etc., do not allow the passage of an electric current and are called **insulators**. For example, the plastic cover of the wires and cables are insulation.

Direct current - DC

As described earlier in this eBook, it is clear that the electric current (represented by the letter "I") moves from a region of high charges or high potential, to a region of low charges or low potential.

An electric current can move in one direction or in two directions as a function of time. As this current move in a single direction it is called a **direct current (DC)** and when it moves in two directions (not at the same time ...), it is called an **alternating current (AC)**.

The electric current is measured in **Amperes** (abbreviated "**A**") and is the number of electrons passing at a given point per second. Do you want to know what it is? It's 6.28×10^{18} electrons per second!

Who causes the movement of this electric current by a conductor, for example, is the **voltage**, that is, a "pressure" applied at the ends of the conductor? This pressure is also called **potential**. The voltage (represented by the letters "**V**" or "**E**") is measured in **Volts** (abbreviated **V**).

Voltage drop is the difference in voltage that occurs at both ends of a conductor when an electric current pass through it.

Think of voltage as the pressure that causes water (electric current) to move through a water pipe in the hydraulic grid of your home.

The **power (P)** is the work developed by the electric current, when it circulates. Electrical power is measured in **watts** (abbreviated **W**). The power in an electric circuit of direct current (DC), is equal to voltage multiplied by the current, i.e., **$P = V \times I$** .

Resistance (R) is the opposition offered by a conductor to the passage of electric current. The resistance is measured in **Ohms** (abbreviated **Ω** = omega). No conductor is perfect and always has a resistance to the passage of electric current.

This resistance often needs to be introduced at strategic points in an electronic circuit in order for it to function properly. They then enter the resistors, which are the most common components of an electronic circuit.

Herr Ohm, a German born in 1789, related current, voltage and resistance, in a law known as the "**OHM Law**" and says: $V = I / R$, as shown in **figure 4**.

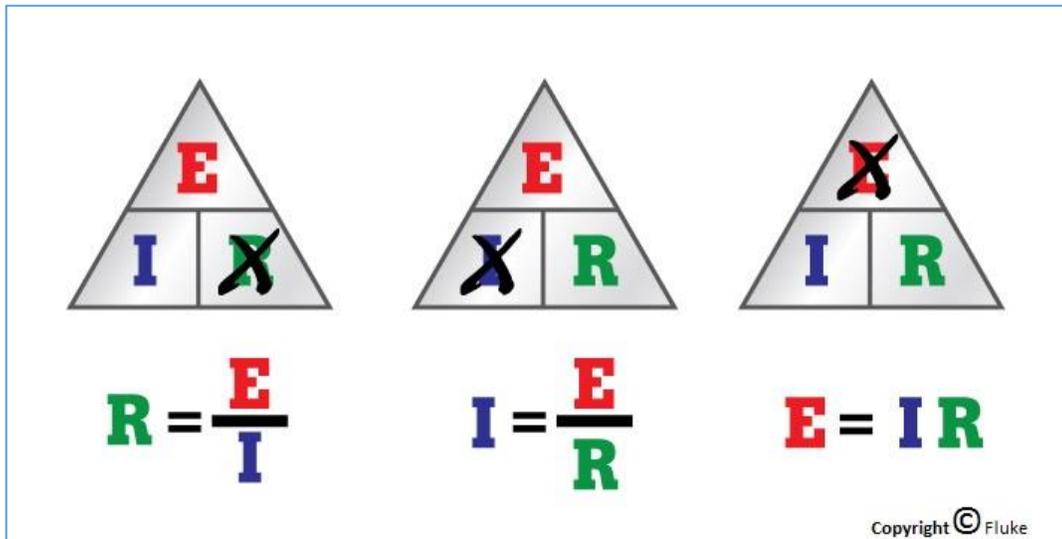


Figure 4 – Ohms' Law.

DC is supplied by batteries. Pile is a basic unit, which can supply a voltage of 1.2 to 1.5 Volts. Battery is a set of piles, usually connected in series, to provide a higher voltage. See **figure 5**.

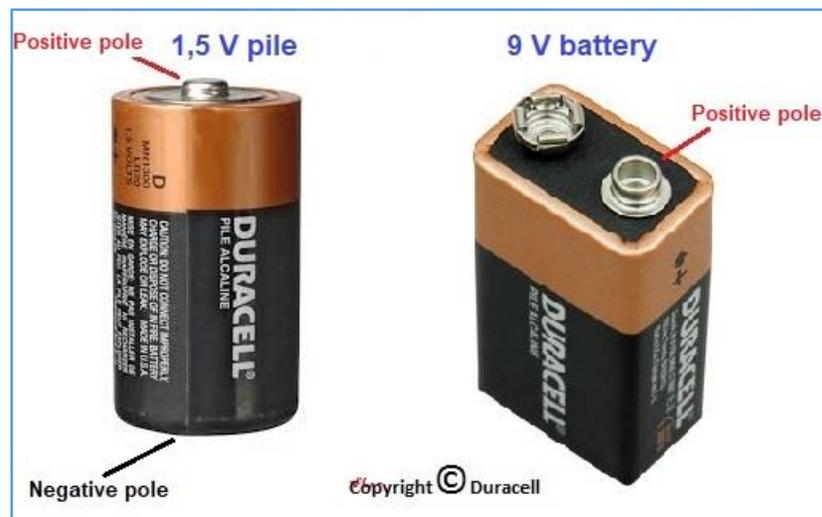


Figure 5 – Pile and battery.

Alternating Current – AC

The **alternating current (AC)** moves in two directions depending on the frequency of the current. In our residences, we use alternating current of 127 or 220

VAC, provided by the power plant that distributes it through the electric network to our residence. The **frequency is 60 Hz (Hz)**.

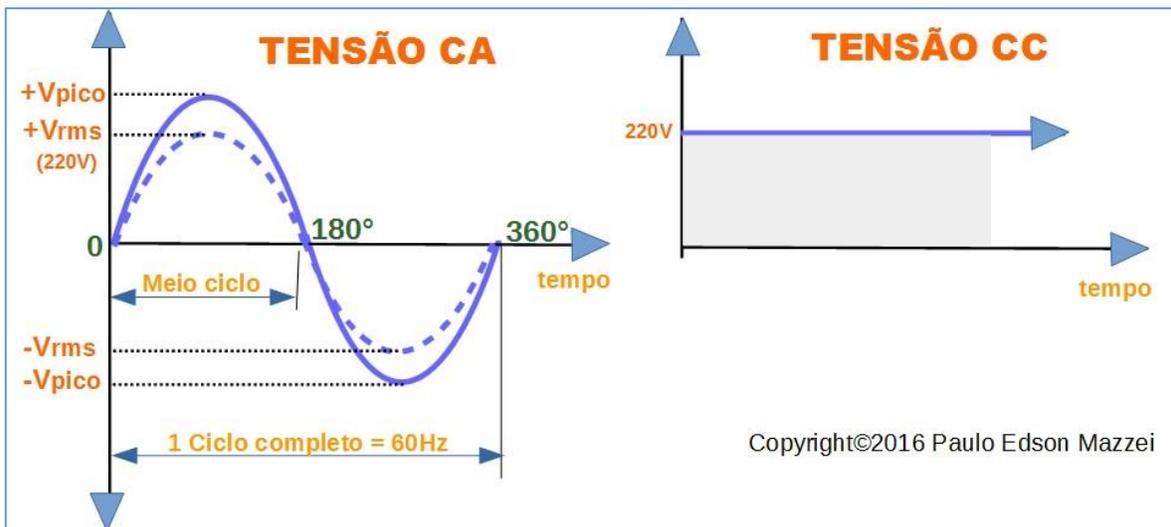


Figure 6 - Graphical representation of AC and DC shapes.

Alternating current is more appropriate for long-distance transmission, rather than direct current. This you can see in the electric power towers, usually at the roadside, that transmit AC at high voltages to the downstream stations located near the cities. The current types are shown in **figure 6**.

Circuits

For the electric current to flow, we need a **circuit**. A circuit is a closed path made up of a conductive material. As if it were the race track of a racetrack, where running horses represent the charges that move through the closed track circuit.

A very simple circuit, can be a piece of wire, connected end to end. But in reality, this never happens and in these circuits that we are going to work, we will have several electrical and electrical components that control the current in the same. See a very simple circuit in **figure 7**, where a battery is connected to a small bulb, through a switch (or switch) on / off. In fact, this is the electric circuit of a simple hand-held flashlight.

In drawing **(a)** of **figure 7**, we see that the switch is **open** (off) and because it is an open circuit, there is no electric current flowing and the lamp does not light up.

In **(b)** of the same figure, the key was **closed** (off), forming a perfect circuit for the electric current, which circulates, causing the lamp to light.

So, the only rule for this simple circuit, for it to work, is to be a closed circuit.

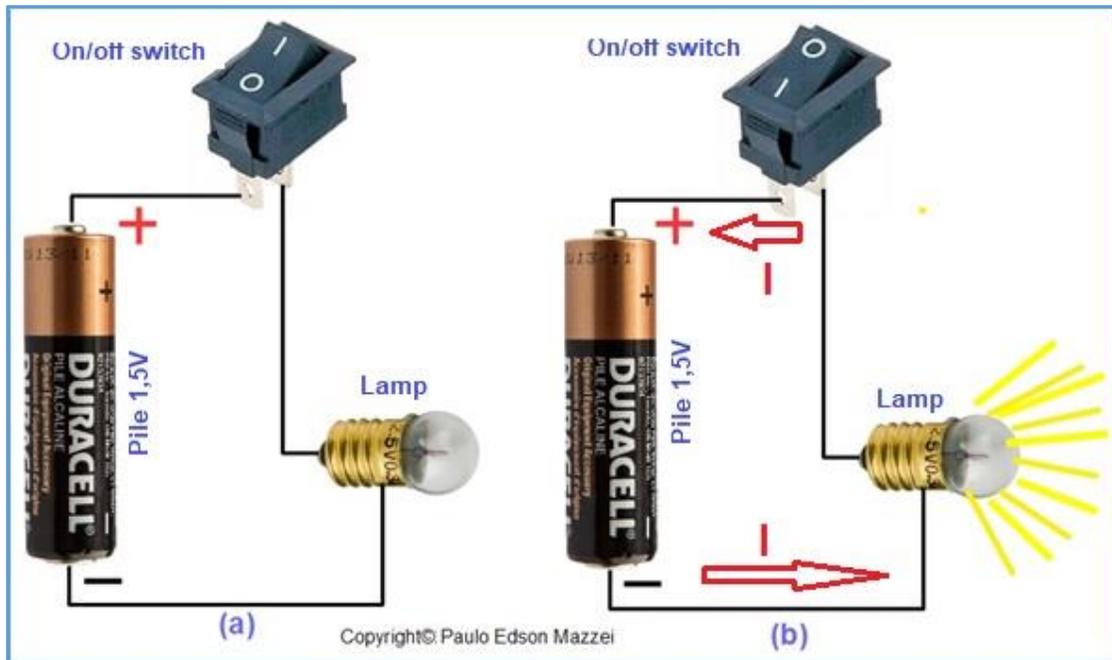


Figure 7 – Simple electric circuit.

In short: free electrons circulate through a conductor when we have a closed circuit. It remains to be seen what makes these electrons move in a given direction in order to completely define the electric current.

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Chapter 4 - System of Units and Prefixes

Introduction

When you start working with electricity and electronics, you will notice that the values of several components use multiples and submultiples of the main unit of measure.

When we go to the Supermarket, we buy beans, rice, flour, etc., per gram, abbreviated "g". **Gram** is the unit of mass and is a measure of selling various products from a supermarket. One gram equals one-thousandth of a kilo = 0.001 kg

That is, we need 1,000 grams to form a kilogram. Kilogram is abbreviated as kg, which means "**kilogram**" (kilogram or kilogram).

In the case of electricity and electronics, for example, we have a very simple component, such as a resistor, which has its value supplied and measured in **Ohms**. Most of the time, we use resistors whose value has thousands or millions of ohms, that is, we need to use multiples of the value.

Another widely used component is the capacitor, which has its value supplied and measured in **Farads**. However, Farad is a very large value to express the value of capacitors we normally use in electronics. Hence the use of submultiples for the value of these capacitors!

How to express this correctly and easily, without using too small or too large numbers? Using the metric prefix and the **International System of Units (SI)**, we can do it easily!

The SI units

With the evolution of the system of measures, nowadays we have dozens of units, for example, to measure length: meter, inch, foot, yard, parsec, etc.

To standardize these measures, in order to have a better communication between countries, we use the **International System of Units**, abbreviated **SI**. This allows a scientist in another country to measure the length of a particular piece and this length provided will be understood throughout the planet, allowing the scientist to disclose his findings without understanding problems. See **figure 8**.

SI physical units

Quantity	SI Unit	Unit abbreviation
Time	second	s
Length	meter	m
Mass	gram	g
Temperatura	kelvin	K
Force	newton	N

Figure 8 – SI physical units.

Although the Physical Units of figure 8 are the standards, it is still common to find literature mentioning:

- ▶ Inch, feet or miles, for distance, rather than meters,
- ▶ Liters for volume, instead of m^3 ,
- ▶ Celsius and Fahrenheit for temperature, instead of °K.

Most Common Electronic Units

As we will soon start our work with electronics, it is important for you to know that you have some that are important to you to know. See table in **figure 9**.

Next, let's see how prefixes are used in conjunction with these Units.

Quantity	SI unit	Unit abbreviation
Voltage - Difference of electric potential	volt	V
Electric current	ampere	A
Power	watt	W
Energy, work and heat	joule	J
Electric charge	coulomb	C
Resistance	ohm	Ω
Capacitance	farad	F
Inductance	henry	H
Frequency	hertz	Hz

Figure 9 – Most Common electronics units.

The prefix

The most commonly used prefixes are provided in the table in **figure 10**. However, as we advance in our electronics studies, you will see that others will appear. Do not worry about them at the moment.

Prefix (simbol)	Power	Numerical representation
kilo (k)	10^3	1,000
hecto (h)	10^2	100
deca (da)	10^1	10
—————	10^0	1
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
mili (m)	10^{-3}	0.001

Figure 10 – Most used prefixes in electronics units.

The prefixes for large numbers, which you can find in electronics and electricity, are shown in the table in **figure 11**.

Prefixes	Power of ten	Numeric representation
tera (T)	10^{12}	1 quadrilhão
giga (G)	10^9	1 trilhão
mega (M)	10^6	1 milhão
kilo (K)	10^3	1 mil
—————	10^0	1

Figure 12 – Prefixes for big quantities.

Prefixes	Power of ten	Numeric representation
tera (T)	10^{12}	1 quadrilhão
giga (G)	10^9	1 trilhão
mega (M)	10^6	1 milhão
kilo (K)	10^3	1 mil
—	10^0	1

Figure 11 – Prefixes for small amounts.

Looking at the prefixes, we can see that those using lowercase letters are for small amounts while prefixes that use uppercase letters are for large quantities.

Be careful not to make mistakes when writing or reading.

- 1 mW is not the same as 1 MW!!
- 1 millionth of a second equals 1 microsecond (1 μ s).

And so on ...

Conversions

Within the same unit of measurement, you can convert some of them.

- ▶ 1 mA (1 milliamps) is the one-thousandth part of the amp.
- ▶ 1 amp has 1,000 milliamps.
- ▶ 1 MHz (megahertz) has 1,000,000 Hertz.
- ▶ 1 μ F (one microfarads) has 1 millionth part of Farad (F).
- ▶ 1 M Ω (one megohms) has 1 million ohms or 1,000 k Ω .

In this [article](#) on the Internet you find detailed and useful information about our system of measures, abbreviations, uses, etc.

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Chapter 5

Voltage, current, resistance and OHM's Law

Introduction

In previous chapters we have learned some very important definitions, listed below.

- **Voltage** is the difference of charges between two points.
- **Current** is the ratio in which charges are traveling.
- **Resistance** is a kind of opposition to the flow of the current.

Voltage, current and resistance

We define voltage as the amount of potential energy between two points in a circuit. This charge difference between two points is the voltage.

The voltage is measured in volts or in its multiples and submultiples as kilovolts (kV), millivolts (mV), microvolts (μV), etc.

A very common analogy used to describe the relationship between voltage, current and resistance is that of a water tank. In this analogy, the charge is represented by a certain amount of water. The voltage is represented by the water pressure. Finally, the current is represented by the flow of water in the pipes.

- **Water = Load**
- **Pressure = Voltage**
- **Water flow = Current**

In the water tank shown in **figure 12**, we have a study of the analogy of a water box (water circuit) with an electric circuit, where we can correctly define and visualize what is voltage, current and resistance.

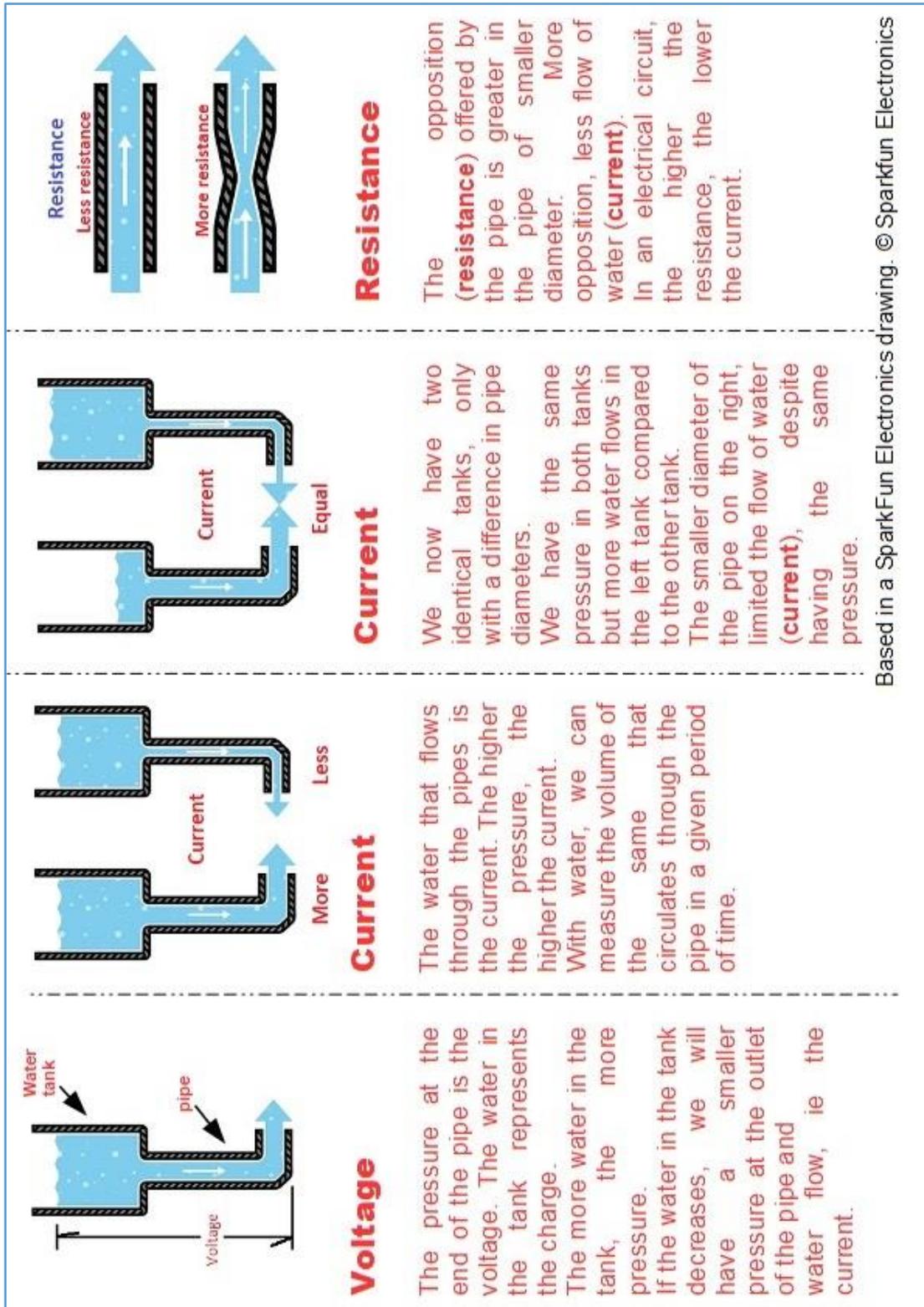


Figure 12 - Analogy of a water tank with voltage, current and resistance.

Ohm`s Law

Combining the elements of voltage, current and resistance, Mister (Herr) Ohm developed the formula:

$$V = I \times R$$

Where:

V = Voltage in Volts

I = Current in Amperes

R = resistance in Ohms

If we have a circuit with a current of 1 amp, a resistance of 1 ohm, the potential difference being applied to the circuit is 1 volt.

Ohm's law can be deployed in two other formulas for the calculation of current **I** or resistance **R**:

$$I = V/R \qquad R = V/I$$

Where:

V = Voltage in Volts

I = Current in Amperes

R = Resistance in Ohms

In the formulas you will find in books and resistors, sometimes the voltage symbol **V** is replaced by **E**. See a simple drawing in **figure 13** to help memorize Ohm's formulas.

An experiment with Ohm's Law - OPTIONAL

Are you ready for a hands on?

We have not yet analyzed more deeply electronic components such as the resistor, the battery and an LED. We also do not know how to properly use the digital multimeter. But this will not stop us from doing a little experiment to prove Ohm's Law!

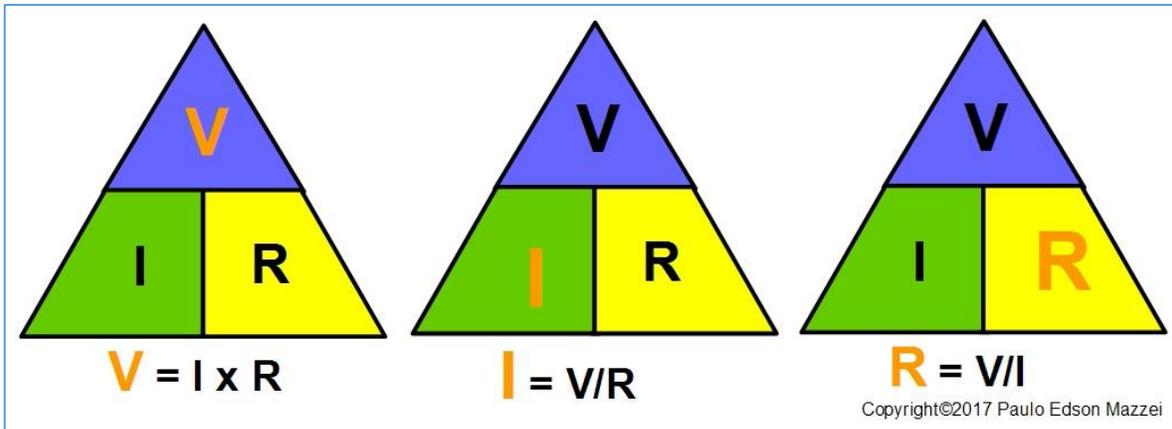


Figure 13 - Formulas derived from Ohm's Law.

List of materials for the experiment:

- ▶ A simple digital multimeter.
- ▶ A 9V battery, with clip to the terminals.
- ▶ A 560 ohm (560 Ω) or close to this carbon resistor. Color bands: green, blue, brown, gold. Read from one end.
- ▶ An ordinary 5 mm LED of any color.

See **figure 14**.

NOTES:

- ▶ Any store that sells electronic components, even the simplest ones, has the necessary material for you to make your experiments. Look for a repair shop that does radio and TV repairs and it sure will have these components.
- ▶ You can also make your purchase through the Post Office, looking for virtual stores on the Internet, which are sold by the Post Office. The prices will be better and you get in your house. Disadvantages: You need to pay for freight and need to wait a few days for the material to arrive.
- ▶ If you know someone in your city who has electronics as a hobby, chances are you have tips on how to get these components as soon as possible. Also look for hams, they usually build small electronics for their radio stations and they can help you.

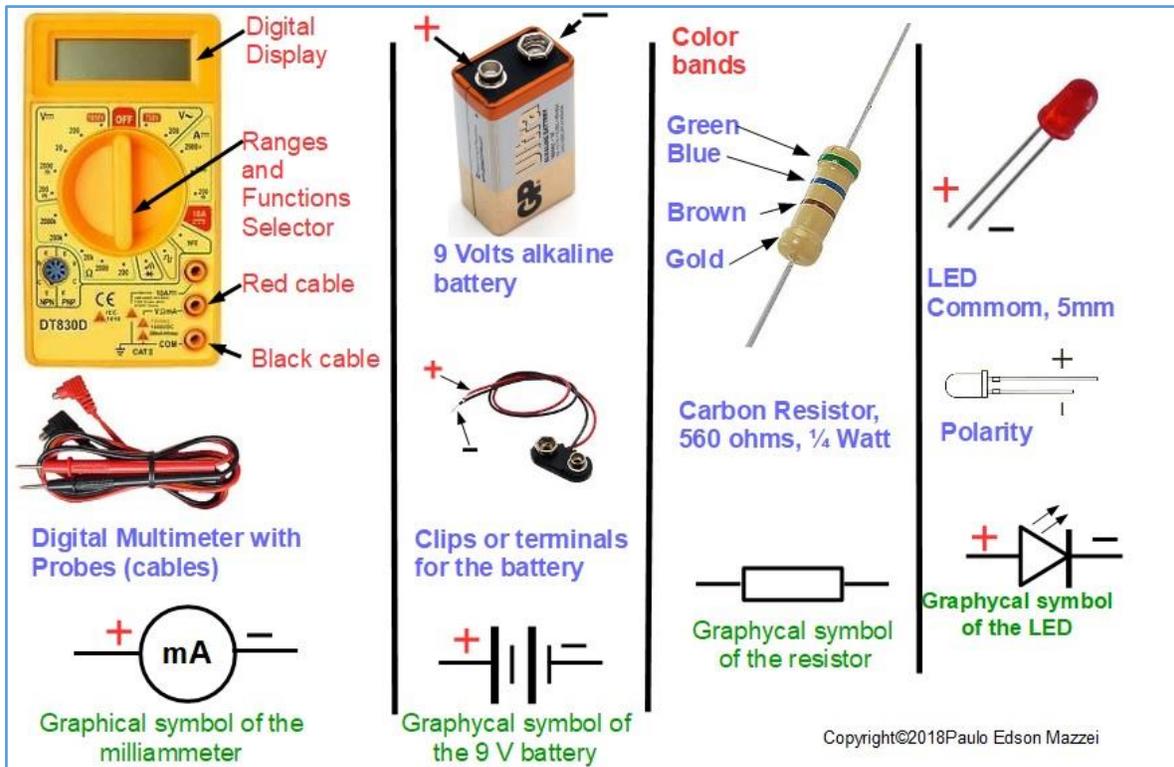


Figure 14 - Material to be used in the Ohm Law experiment

Important information:

- The LED is a component known as "non-ohmic". This means that it does not apply to Ohm's Law and its variations.

- The LED is also an electronic component that operates at low voltages, about 1.5 to 1.8 V, on simple models. Therefore, we cannot apply directly to it a voltage of 9V. If we do this, an electric current will circulate greater than the LED supports and it will be damaged!

- In order to avoid the above, we need to put in series with the LED a protection resistor that will limit the circulation of electrical current and prevent its destruction. An ordinary 5 mm LED has an operating current of about 18 mA (18 milliamps = 0.018 A). Our current limiting resistor has to make sure this happens.

- If we connect the LED directly to the 9V battery, we would have the current would be:

$$I = V/R \rightarrow I = 9/0 \rightarrow I = \infty$$

Theoretically, current **I** would be infinitely large, but in practice the current would reach values that the battery could provide but enough to melt the LED and wiring!

Therefore, the 560 Ω current-limiting resistor is placed in the circuit in the "path" of the current, preventing it from reaching disastrous values.

- The current limiting resistor can be easily calculated by:

$$R = V/I \rightarrow R = 9 \text{ V}/0,018 \text{ A} \rightarrow R = 500 \Omega$$

Since it is difficult to find a resistor with this value, we use the closest up which is **560 Ω**

- We can draw this circuit, using the electronic graphic symbols, which we will see in more detail later. Each electronic and electrical component has a graphic symbol associated with it, allowing easy drawing of electrical and electronic diagrams rather than using the physical format of these components. See the graphic symbols that we will use in **figure 15**.

Circuit or Schematic Diagram

Using the basic graphic symbols, we have learned, let's draw our circuit to experience. See **figure 15**.

Note:

1. In **(a)** we have the schematic diagram of the LED circuit, using graphic symbols. Note the direction of the electric current, which is a flow of electrons, from the negative of the battery to the positive of the same.
2. In **(b)** we can see the same circuit of the mounted LED, now using the physical (actual) format of the electronic components.
3. The battery and LED have polarity. Observe carefully when assembling.
4. For more electronics circuit symbols, look for this [site](#).
5. You can assemble the circuit in three simple ways:
6. If you already have the Arduino experiment kit, then you have a Protoboard or Breadboard. It is an array of contacts, for insertion of

electronic components and wires. More on Protoboard forward in this eBook.

Attach the components to the Protoboard according to the circuit diagram.

7. You can weld the components together, if you already know this process, have the necessary tools and know the care that needs to be taken.

8. Or you can simply wrap the terminals together following the diagram drawing and observing the polarities.

- You do not need an **on / off** switch since you can use the battery clip by inserting and removing it, as appropriate.

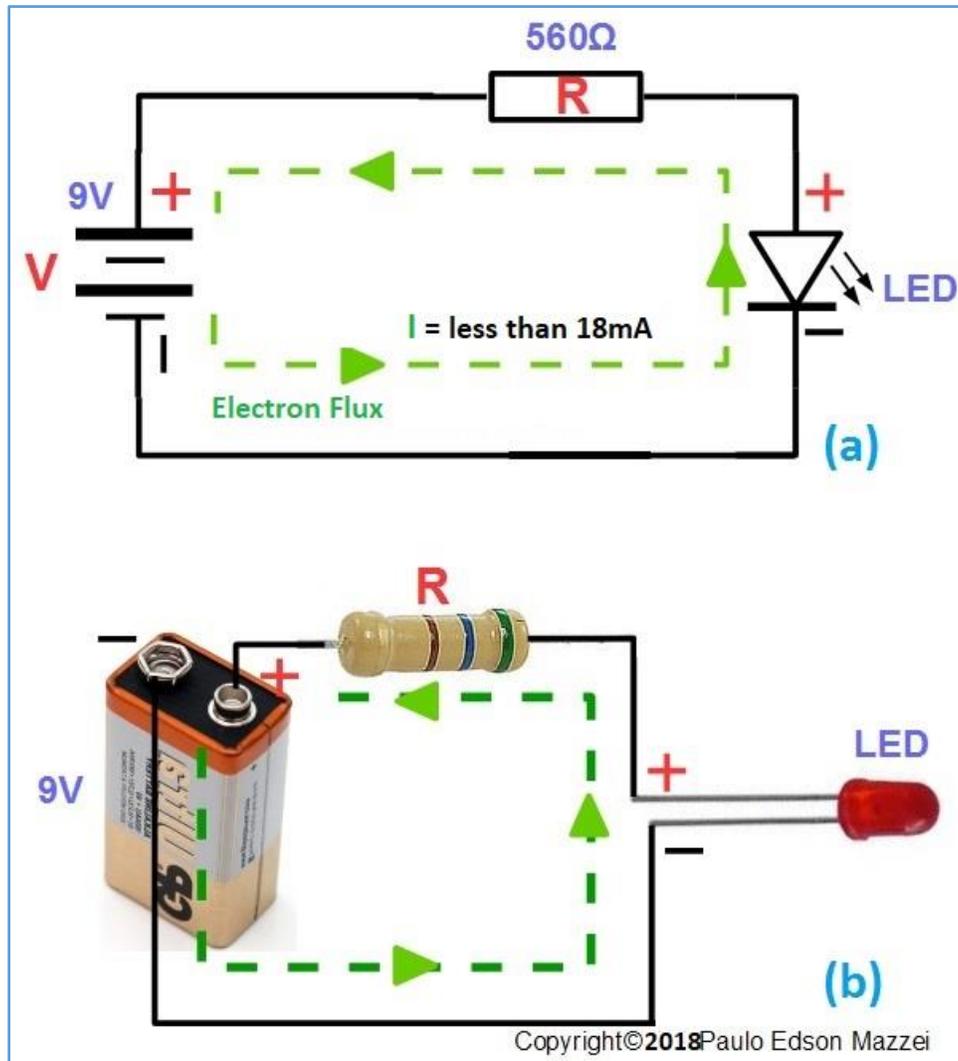


Figure 15 - Schematic diagram of the LED circuit.

See **figure 16** as is the circuit assembly of figure 15, only wrapping the thermals together without welding.

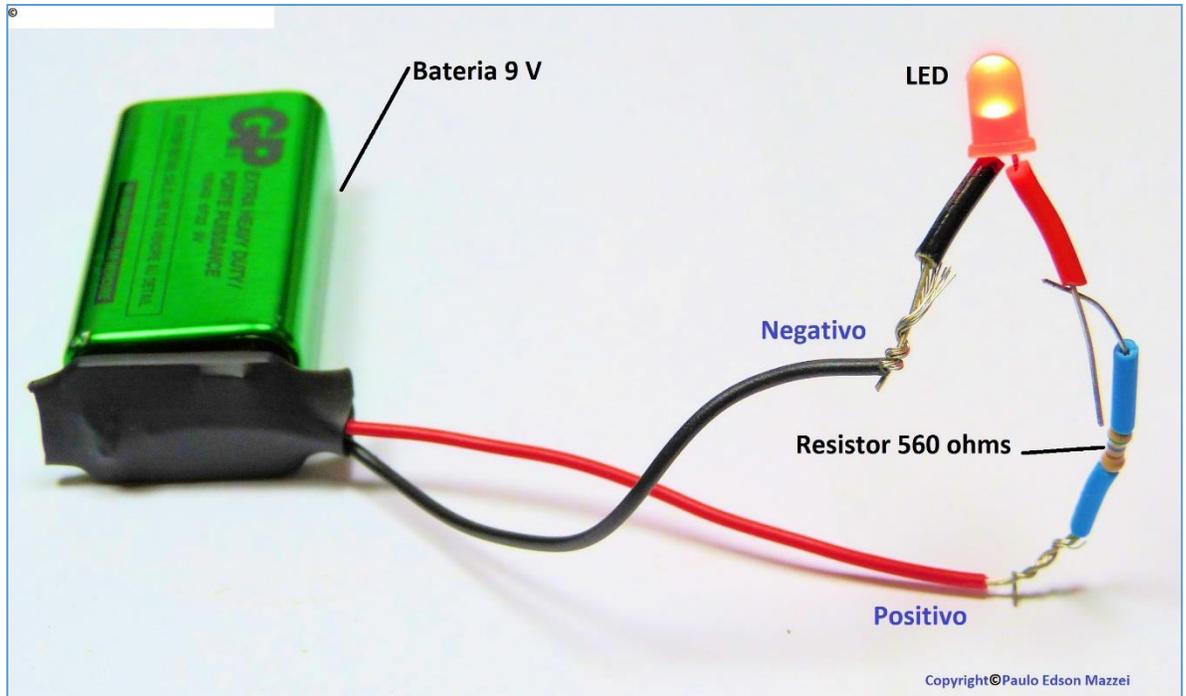


Figure 16 -Circuit assembly



See the measurements in the next chapter.

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Chapter 6

Measurements in Continuous and Alternating Current.

Introduction

For our practical experiments, to be made later, you will need to use a multimeter for various measurements.

The multimeter is one of the most important measurement instruments and with it you can make measurements of voltages, currents, resistors, diodes, transistors, etc.

It is a worthwhile investment and can be a cheap model, even if it is of "unknown geographical origin"! I have a simple model, which is what I will use for our work, examples, images, etc.

Objectives

- Take knowledge with digital and analog multimeters.
- Learn the use, care and long life for your multimeter.
- Measurement techniques using the multimeter.

Recalling electrical quantities for measurements

The three most important electrical quantities for us at the moment are voltage, current and resistance.

Remember, see the table in **figure 17**.

Electric Quantities		
Common multiples and submultiples		
Voltage measured in Volts	V	millivolt = mV kilovolt = kV
Current measured in Amper	A	milliamper = mA
Resistance measured in Ohms	Ω	kilohm = k Ω Megohm = M Ω

Figure 17 - Quantities, units of measurement and submultiples.

Virtually all electrical quantities have their multiples and submultiples. In our case, we give the most used to not complicate much. With the use of the multimeter you will learn others that are necessary.

In addition, you can measure the first two quantities (Current and Voltage) in DC - Continuous Current.

Types of multimeter

There are two basic types of multimeters you'll find in a huge number of physical stores and on the Internet: The **Analog Multimeter (VOM = Volt Ohm Meter)** and the **Digital MultiMeter (DMM)**.

VOMs (analog) show the magnitude measured on a range of an analog meter with a pointer. The **DMM** (digital), already show the greatness measured through an LCD display (liquid crystal).

For our work and experiment assemblies, the ideal is a small digital multimeter. Today, January / 19, its cost this around US\$ 12.00 for a basics, but that will help us a lot. See **Figure 18**. For learning purposes, several of our measurements are presented with DMM and VOM.

However, many readers may already have an analog VOM multimeter and then we will also use this model in our readings and experiments. In addition, some

experiments may require a measuring instrument that shows fast voltage or current variations and the VOM is ideal for visualizing these rapid variations.

The VOM is more fragile than the DMM and sometimes the readings are difficult to read due to the position of the pointer over the range and range division. VOMs cost slightly more than DMMs.

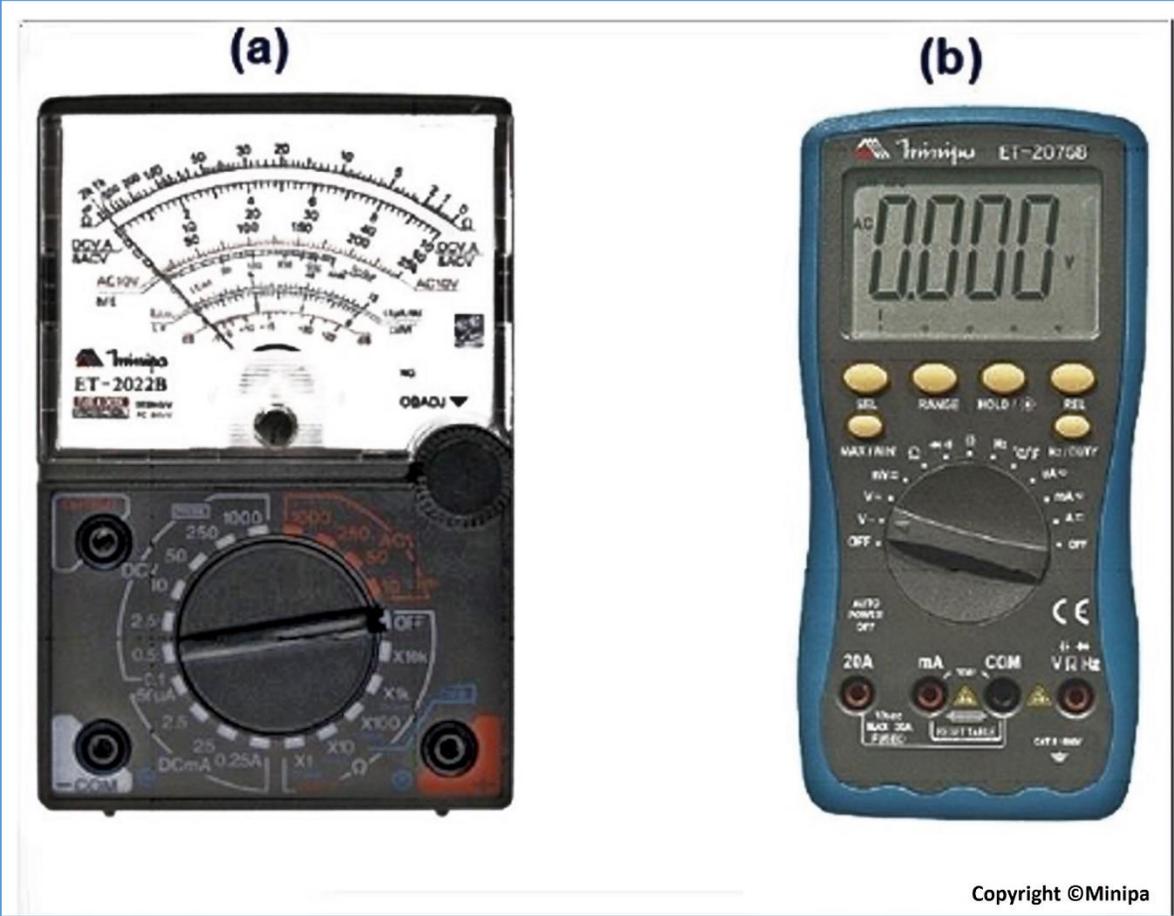


Figure 18 – Analog multimeter in (a) and digital multimeter in (b).

Currently the price of digital multimeters has dropped significantly and with the emergence of offers "of unknown geographical origin," the prices of these devices have dropped. It will probably be easier to buy a digital multimeter from a known brand than to try to assemble the components to assemble it.

Choose a digital multimeter that meets your basic measurement needs, voltage (AC / DC), current (AC / DC), and resistance.

The analog measures the magnitudes by moving a pointer over a calibrated range. See (a) in **figure 18**.

In digital, there is already a digital display (LCD), to inform the value of the measured magnitude. See **figure 8** on the side.

- The analog multimeter is a bit harder to read and is more sensitive than the digital multimeter. Good quality ones are expensive.

- The digital multimeter is a bit more robust than the analog and has models for all pockets. It is easier to read the greatness measured.

- You will find in the market, digital multimeters from about US \$ 8.00 (!) to more than US\$ 500.00. The cheaper ones are of unknown geographic origin, but they work and will help you a lot. Often the price of a good 9 V battery, for the multimeter, costs more expensive than the meter itself!! Is there an explanation? It has The manufacturers of 9V alkaline batteries should explain ...

- For analog multimeters - VOM, the same thing happens. Some models use a 9V battery and two more AA batteries! The price of analog meters at the time (January / 2019) is about US\$ 17.00 for the simpler models, like mine, used in this eBook.

- Many stores that sell imported trinkets usually have these multimeters, usually packaged in a plastic carton (blisters). If you go to buy direct, open the package, put the 9V battery (must come along) and see if it turns on and shows the digits on the display. If it measures right, it's another story!!

- If you already have a basic understanding of the operation of the digital or analog multimeter, when purchasing, carry some resistors and some batteries to measure. Measure the AC mains voltage in the store.

- **Before using the digital or analog multimeter, read the instruction manual that comes with the box or carton.** Yes, the Instruction Manual needs to be read before!! Do you know which one? That booklet that most people throw away when they open the packaging of a new product, they have bought ...

- If your "money box" is high, nothing prevents you from getting better quality multimeters. See Minipa®, Icel®, Fluke®, etc. brand names on the Internet.



Never go threading the test tips in the first hole you find ahead!! This is an invitation to disaster!!

To learn how we use the digital multimeter, we will use the model of **figure 19**. In this figure you can see the multimeter and the probes for the measurements. Black for negative (-) and red for positive (+).

For the analog multimeter, the tips come later.

In **figure 19**, you have the multimeter with its ranges and the correct names of the functions, connection of probes, etc.

Very complicated? No...



Figure 19 - The Minipa ET-1002 digital multimeter

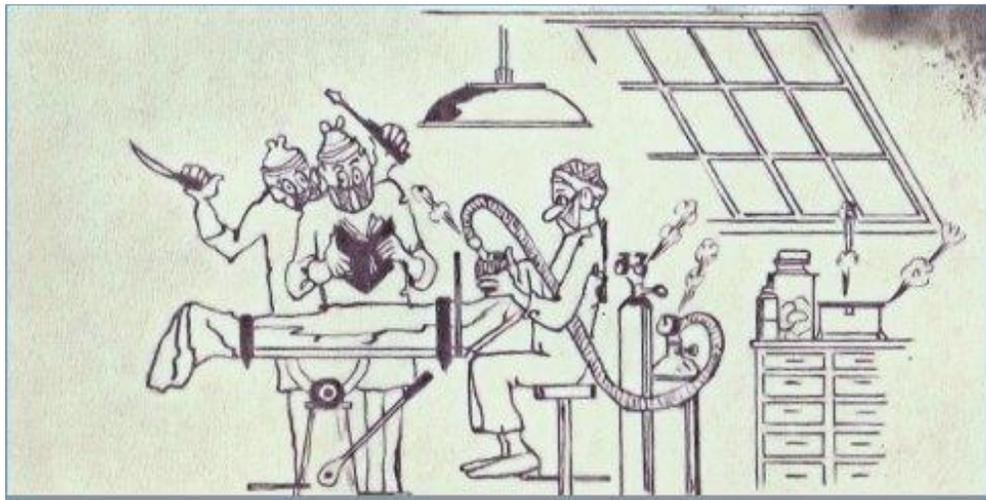
a) Display: The display is LCD (liquid crystal display) and has 3½ digits, i.e., three digits (to the right) are complete, with indication from 0 to 9 and the first digit (the left) is incomplete, indicating "1." You will see that a range of "2000" actually measures up to "1999".

b) Selector switch: It allows to select the various **functions** (DC voltage - and AC ~), current, resistance, etc.) and the **ranges** that can be used within each function. Therefore, in the case of DC voltages, the selector switch allows you to choose between the 200 mV, 2000 mV (2 V), 20 V, 200 V and 1000 V ranges. Remember that these values are range "or maximums.

c) Special measurements: Two ranges, at the bottom right, allow the measurement of **semiconductor diodes** (diode symbol) and **transistors**. In addition, high DC currents up to 10A can be measured with the selector switch in the "10A--" position and the red test lead on the 10A terminal.

d) Terminals: three terminals allow the use of test leads, to connect the multimeter to the points where the various measurements are to be made. The multimeter is supplied with two probes: one red and one black. By convention, the black tip is connected to ground (Common - Common) or circuit ground to be measured. On the multimeter, this end will be connected to the terminal marked "COM" (common).

a) Power: The digital multimeter is powered by a 9 V battery, preferably alkaline. To replace the battery, read the Instruction Manual.



Before operate, read the Instruction Manual!

See **figure 19** for the digital multimeter that we will use as a model and example of measurements, descriptions, etc. The DMM shown is the ET-1002 model, manufactured and / or assembled by Minipa do Brasil Ltda®, in Brazil in January 2019 the value of it was about US \$ 12.00 in several online sellers. If DMM gives you a problem during the warranty period, you have technical assistance in several cities in Brazil.

Please note that in another country you have to choose a similar DMM, with the same functions and ranges. A lot of them can be found in Amazon®, eBay®, Alibaba®, etc.

Please note that there are many other multimeters equal to or greater than the Minipa ET-1002®. I preferred Minipa because I already have other equipment from this manufacturer.

The important thing is that it meets our goals, is cheap and if it gives problems, throw away and acquire another due to the low cost.

The digital multimeter model Minipa® ET-1002

Figure 20 shows the **ET-1002** DMM, with its ranges, functions, tests, etc.

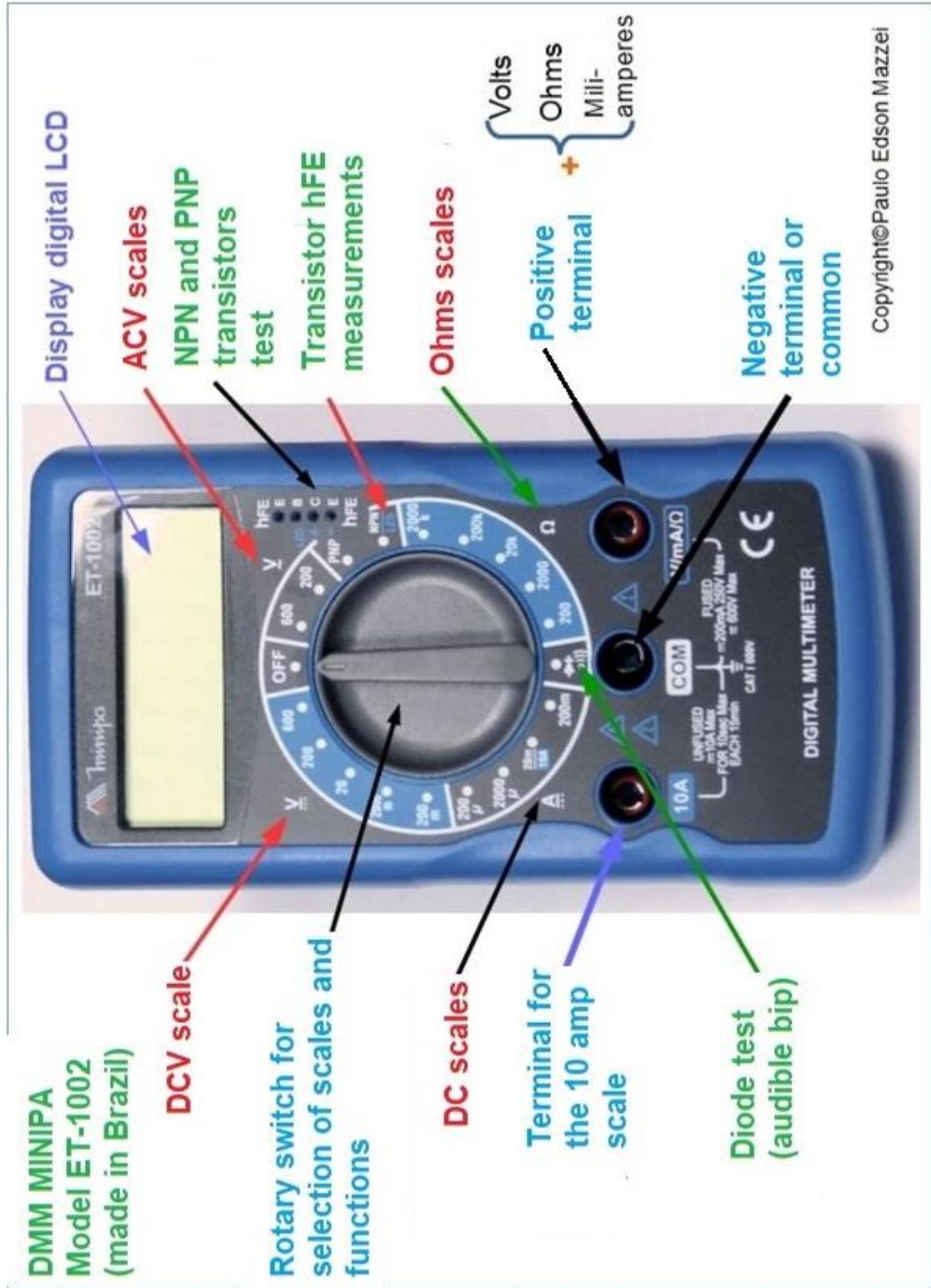


Figure 20 DMM Minipa® ranges and functions.

Now let's look at just the functions and ranges you will use for your experiments. As necessary, we will describe others. As you study these functions and ranges, keep the **DMM Instruction Manual** open for you to follow up on this data discussed.

DMM functions and ranges

First, place the probes in your DMM. Red tip at the terminal marked **V Ω mA** and black tip at the "**COM**" terminal. Leave the selector switch in the "**OFF**" position, which shuts off all DMM.

1. Function: **DC voltage measurement.**

The DMM measures from 200 mVDC (200 mV) up to 600 VDC, on five ranges, as shown in **figure 21**. Simply place the selector switch in the positions indicated in the figure. When changing the position switch, remove the test leads from the circuit you are measuring.

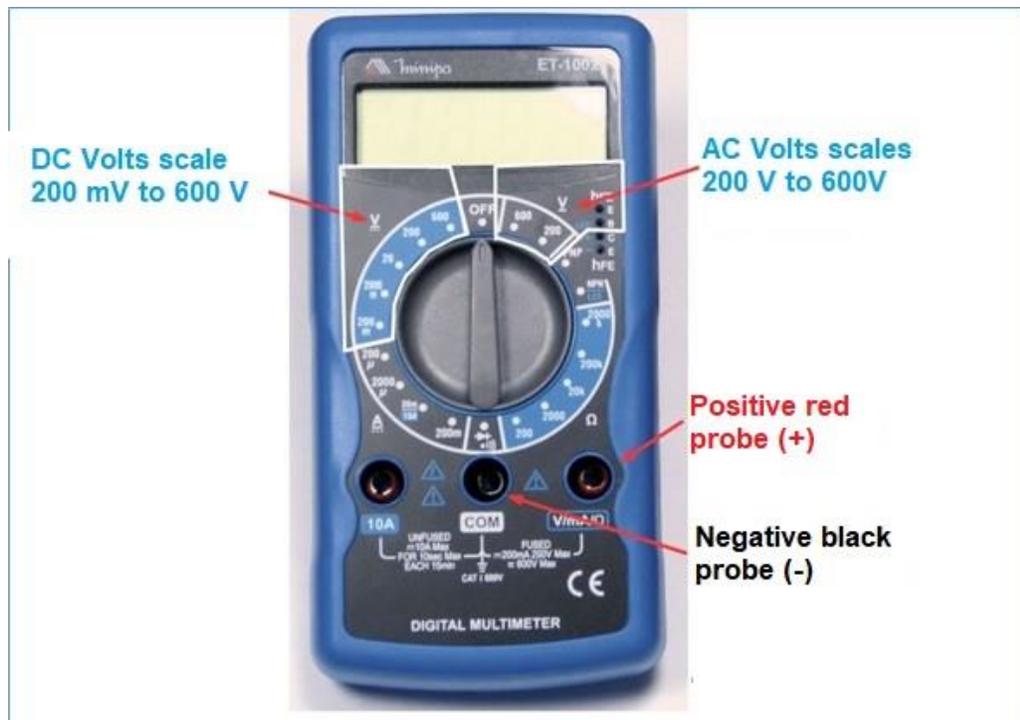


Figure 21 – DC and AC volts ranges in the DMM.

2. Function: **AC voltage measurement.**

The DMM measures 200 V up to 600 V on two ranges, as shown in **figure 21**. Simply place the selector switch in the positions indicated in the figure.

3. Function: **DC current measurement (DC only).**

The DMM measures 2000 μA (2000 microamps) at 200 mA (200 milliamps), on three ranges, as shown in **figure 21** on the right.

4 Function: **Resistance measurement.**

The DMM measures 200 ohms to 2 megohms (2000 k Ω), in 5 ranges, as shown in **figure 21** on the left.

Care of the Digital Multimeter

You've got a great digital multimeter and you're crazy to start measuring something!



Beware, DO NOT insert the probes into the first wall socket you find!! It's never too much to repeat ... Even if you enjoy living dangerously, do not do this ...

Some safety rules you must follow, for your own safety and long life for your multimeter:

1. Make sure that the function selector switch and test leads are in the correct positions and positions. Check three times. Check it again!

2. Do not use the Meter if the probes are damaged, loose or with the stripped cables.

3. Never measure the resistance of a component or circuit if it is energized.

4. Never touch test leads that are connected to an energized circuit, especially in AC voltages.

5. Do not use the common multimeter to attempt measurements above those carried by the apparatus.

6. Always start on the larger range by measuring an unknown current or voltage. By the type of circuit and the supply voltage of the same you already have an order of magnitude of this value.

7. Never change the ranges of a multimeter, with it connected to a live circuit. This can irreparably damage it.

8. Always check the condition of the battery that powers the Meter: if they are worn out, they may give erroneous measurements. Some types of digital multimeters charge batteries discharged, indicating "**LOW BATTERY**" on the display. It's time to replace the battery ...

9. Do not subject the Meter to mechanical shocks or shocks. Do not let it get wet or exposed to the sun.

10. When storing your meter, always leave it on the "OFF" range. If any stranger tries to stick the probes into a 220 VAC outlet, it will not damage it.

Experiments

I know you "are crazy" to stick the probes somewhere and show your family, girlfriend and friends your new digital multimeter! It's very normal ...

The idea is that you wait until we begin the practical experiments, where I will show everything, how to measure, ranges, care, how to interpret values etc.

However, since I am not to break any heart ... Let's go to some "little measurements" so you do not feel like it!

DC measurements:

▶. When you know the supply voltage of the equipment to be measured, select a measurement range above that value. Connect the negative (black) test lead and then move the positive test lead (red) at the various points on the circuit, where you need to measure. Please note that DC has polarity plus (+) and minus (-).

▶ If you measure the voltage of a 9 V battery, you already know that this type of voltage is "DC", as explained above.

▶ Since the 9 V voltage is written to the battery body, you must choose a voltage on the multimeter range that is above this value. See **figure 22**.

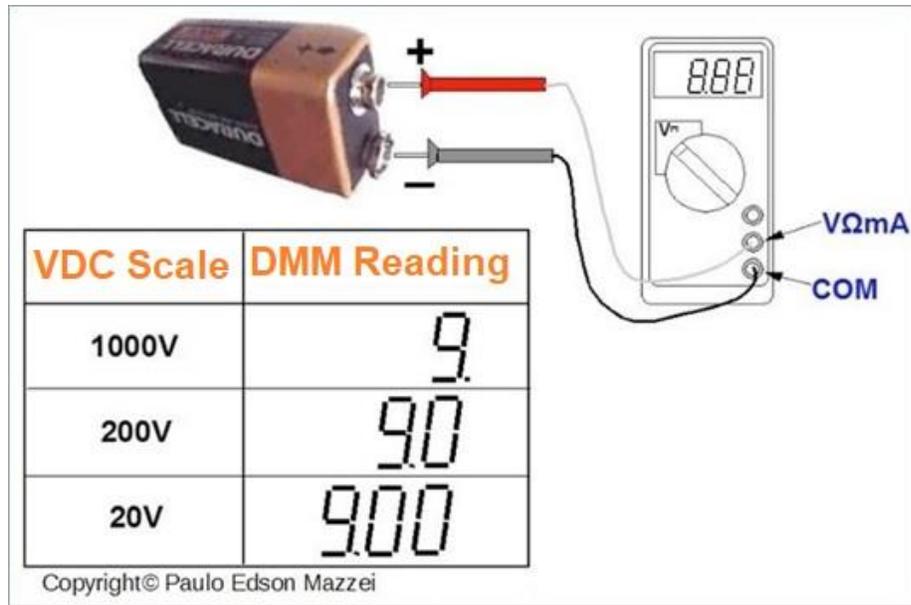


Figure 22 - Measurement of the voltage of a 9 Volt battery.

► If you do not know the value of the DC voltage to be measured, always start with the larger range and go lower until you have an accurate reading. Do not forget that each time you go down the range, on the selector switch, the



Figure 23 – Measuring the voltage of a 1.5 V battery. Range is 200 mV.

The multimeter must be disconnected from the custom circuit. For example, see **Figure 22** for measuring the voltage of a 9 V battery. In **Figure 22**, the most accurate reading is on the 20 V range.

Figure 23 and **24** shows the DC voltage measurement for a typical alkaline "AAA" type battery and should be close to 1.5 V. Note that a reading of 1562 on the DMM range means 1562 millivolts since the range selector of the DMM is in the range of 2000 mV. You already know that 1562 mV equals 1,562 V.

See what happens with the readings on the various ranges used.



Do not change ranges with connected probes!

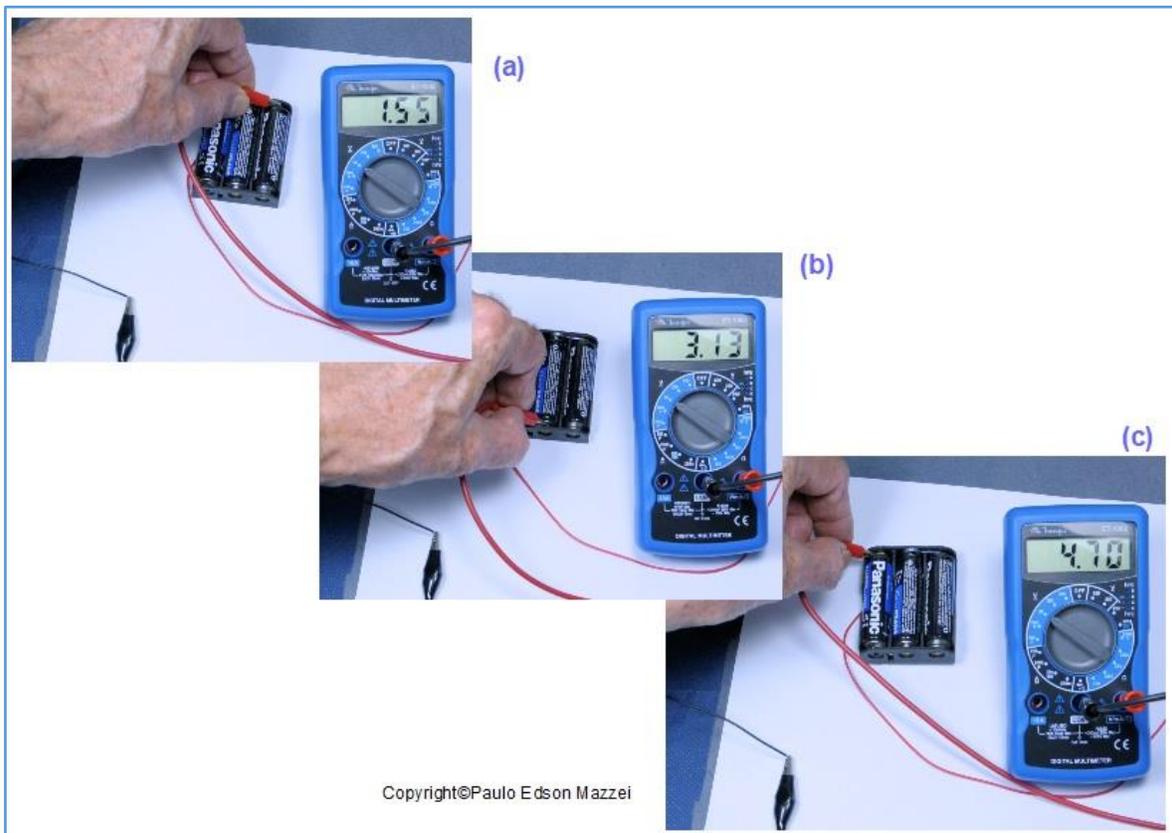
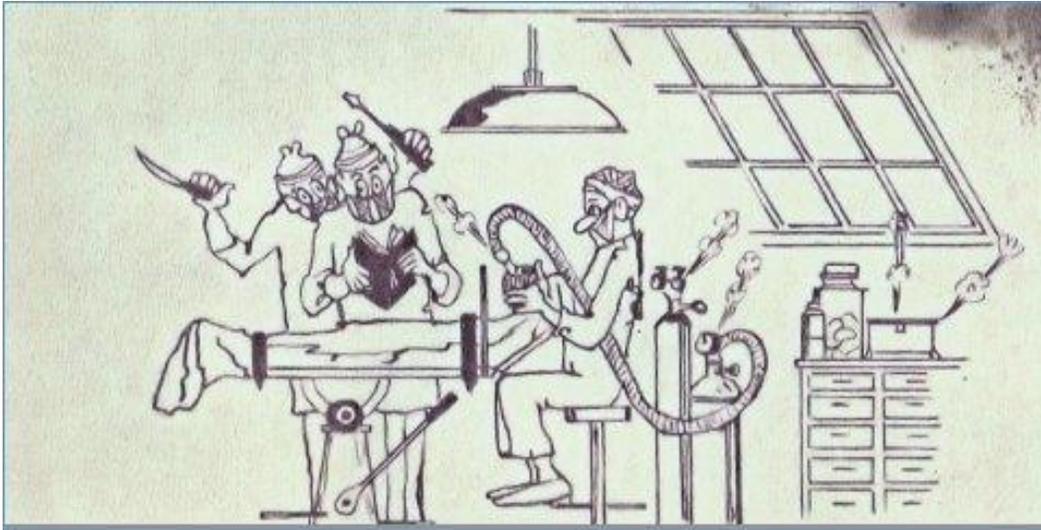


Figure 24 – Measuring the voltage of 3 1.5 V battery, mounted in a battery case.



Before operate read the manual!

AC measurements



As I know you like to live dangerously, let's now measure the voltage of your home's electrical grid! It's a joke!! In homes, it is common to have two AC voltages: 127 VAC (**may vary in other countries**) for most household and 220 VAC for energy-intensive appliances such as showers, air conditioners, washing machines and dryers, etc.

Choose an easy-to-reach wall outlet where you usually connect devices made to operate with 127 VAC.

See **Figure 25** for a drawing of how to measure the AC voltage of a wall outlet.



Do not touch the metal parts of the probes!

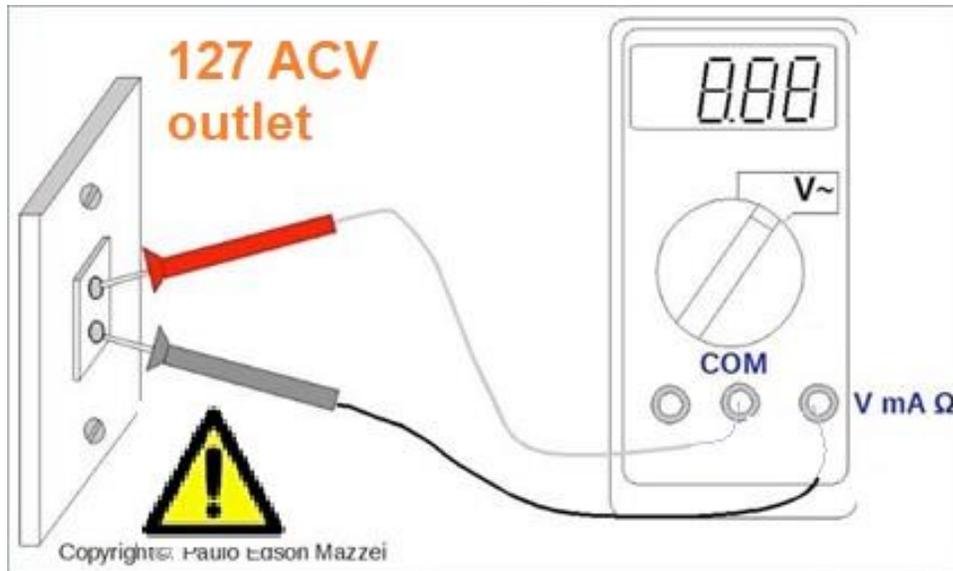


Figure 25 - Measuring the voltage of a 127VAC outlet.

 **ATTENTION: Do not change ranges with test leads (probes) connected.**

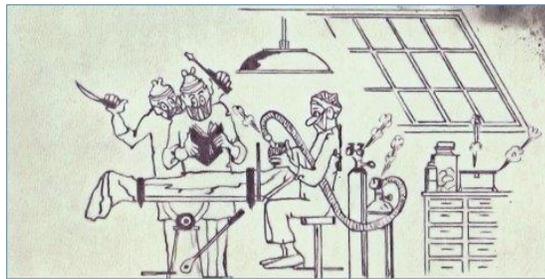
See in **figure 26**, the results read in my residence as we changed the range.



Figure 26 - 127VAC voltage, measured at two different DMM ranges.

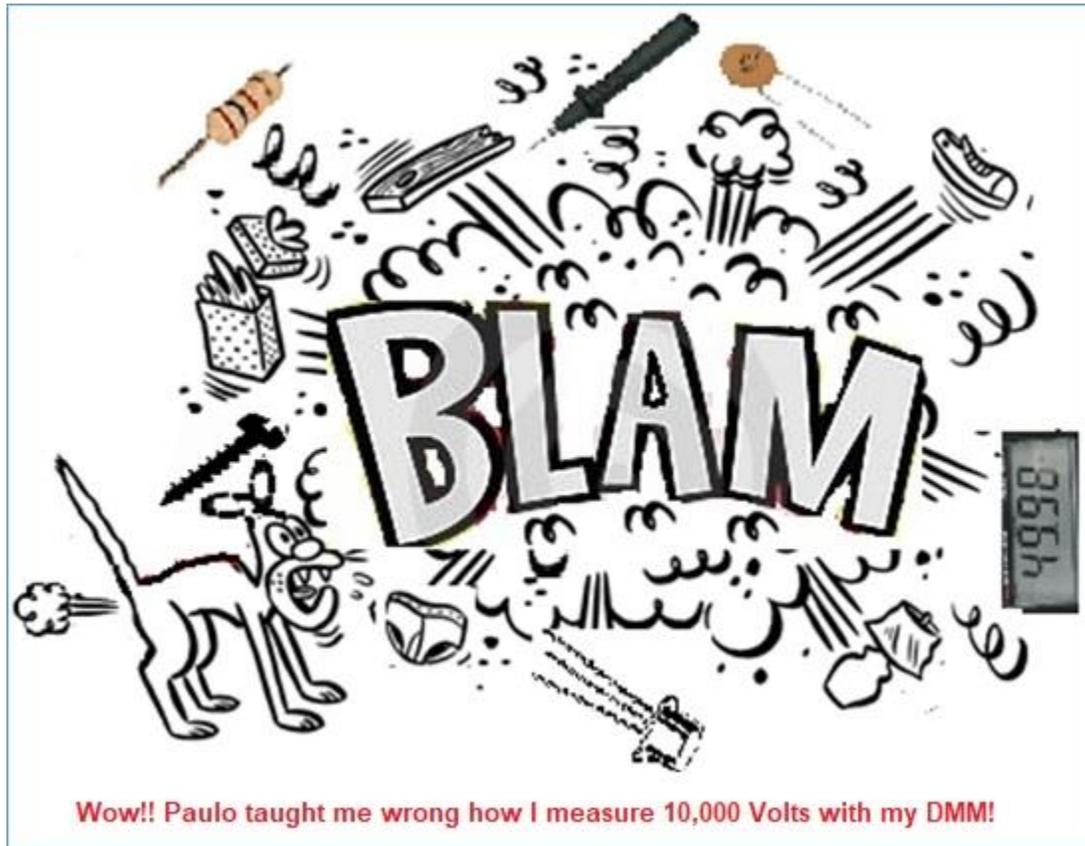
Reading to the left indicates 122 VAC, in the 600 V range and reading to the right shows 123.5, with the DMM in the 200 VAC range.

NOTE: Why cannot I read the 127V? Depending on the time when you measure the voltage of the network, it will have different values. In the period from 7:00 p.m. to 8:00 p.m., you will probably find the lower voltages.



Before operate read the Instruction Manual

Pleased?? Great, read the manual of the multimeter, follow all precautions and safety rules I gave and will not happen as shown in the following figure!



The DMM battery

The 9 V battery that powers the Meter is housed in the DMM's back inside the DMM housing.

Loosen the rear cover, where there is a small "Phillips" screw. See **figure 27**.



Figure 27 – Changing the DMM 9 V battery.

Types of probes (test leads)

When purchased, the DMM comes with only one type of probes: male connector type banana and the other end the test lead.

There is a variety of probes that can be connected to your multimeter, but in fact the one that comes with it and two more types that we made in the chapter on soldering, will be enough for all your work. See **figure 28**.

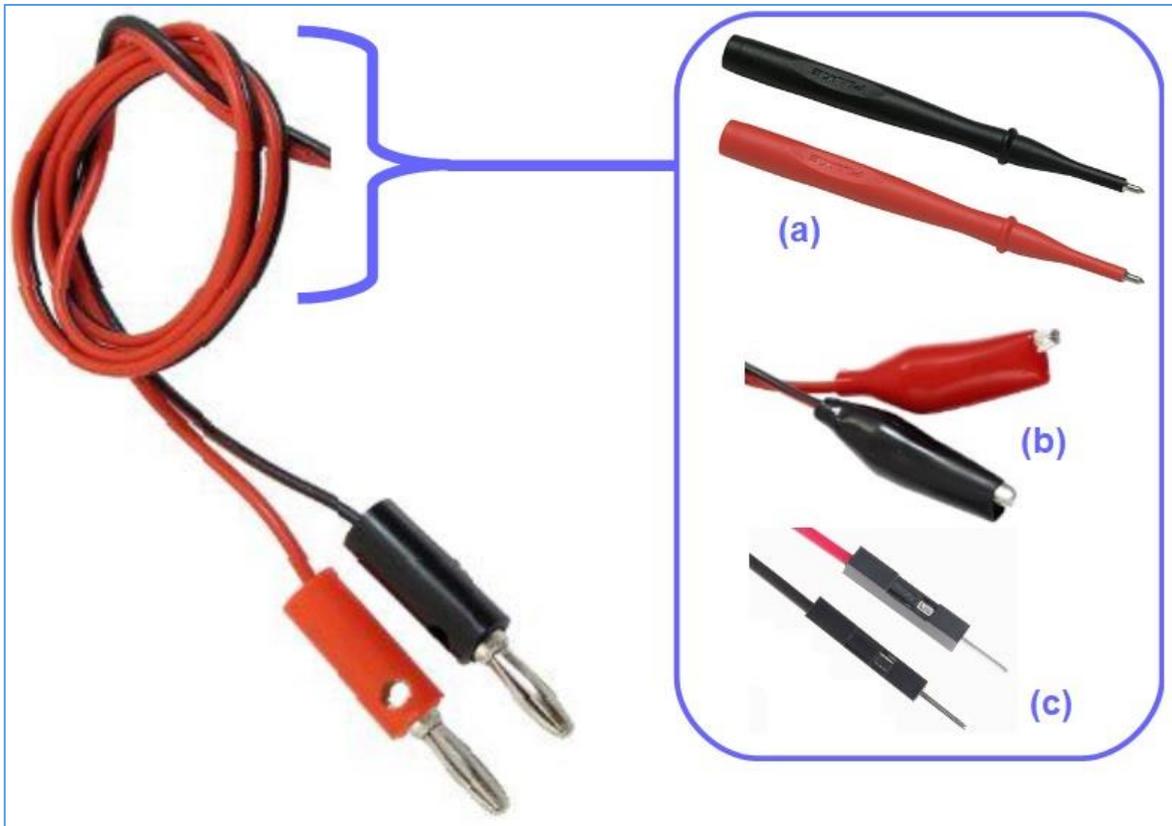


Figure 28 - Possibilities of probes. (a) normal tip (tip), (b) alligator clip and (c) pins for use in Protoboard.

In **Figure 28** it is possible to see the three types of test points we can use to facilitate our work on measurements with DMM in our experiments and assemblies.

(a) Common test point, which always accompanies the DMM. The tips are applied directly to the point to be measured.

(b) "alligator" type claws to attach to the terminals of a component, for example, where we will make some measurements.

(c) Pins used in Protoboards. They serve for connection between the Arduino board or RedBoard board and Protoboard board.

Figure 29 shows where the three test tips are used.

If you have all the material and you want to make your test tips already, go to **chapter 20**. Read the same carefully, see welder care and the welding process itself and get to work!

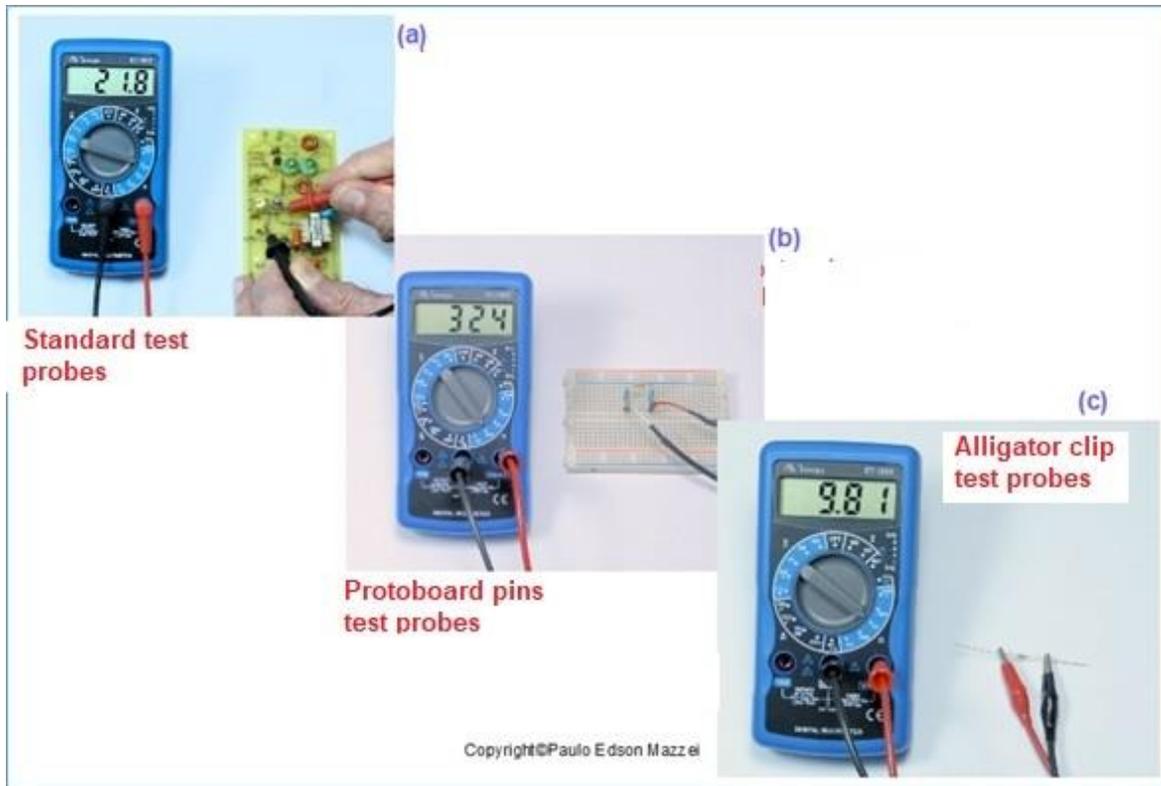


Figure 29 – Using the three types of probes (test leads).

The analogic multimeter - VOM

a) Galvanometer: The galvanometer is the analog meter itself and has good sensitivity and accuracy at the cost of the VOM.

b) Selector switch: It allows to select the various functions (DC voltage - and AC \sim), current, resistance, etc.) and the ranges that can be used within each function. Therefore, in the case of DC voltages (DCV), the selector switch allows to choose between the ranges 0.1 V, 0.5 V, 2.5 V, 10 V, 50 V, 250 V and 1000 V. forget that these values are "full range" or maximum values"

c) Special measurements: One range allows "hFE" measurement of transistors and another range allows continuity measurement with buzzer and warning light (LED in upper left corner).

d) Terminals: three terminals allow the use of test leads, to connect the multimeter to the points where the various measurements are to be made. The multimeter is supplied with two probes: one red and one black. By convention, the black tip is connected to ground (Common - Com) or circuit ground to be measured.

On the multimeter this end will be connected to the terminal marked "- COM" (common).

d) Power supply: the analog multimeter is powered by a 9 V battery, plus two 1.5 V AA batteries, preferably alkaline. To replace the battery, read the instruction manual that came with the device.

The AT360TR analog multimeter

Figure 30 shows the AT360TR, with its ranges, functions, tests, etc. This multimeter is part of a "family" of analog multimeters, called the "360". If you are looking to purchase, you will see that it has several models like 360tnr, yx-360tr, ft-360r, etc. What varies is that some models do not have the continuity test and the LED warning light. Be aware, therefore, sometimes the seller does not supply the battery. Then it's going to be expensive.

All the ranges, functions, tests, etc. are described in **figure 31** and the following text.



Figure 30 – AT-360TR analog multimeter - VOM

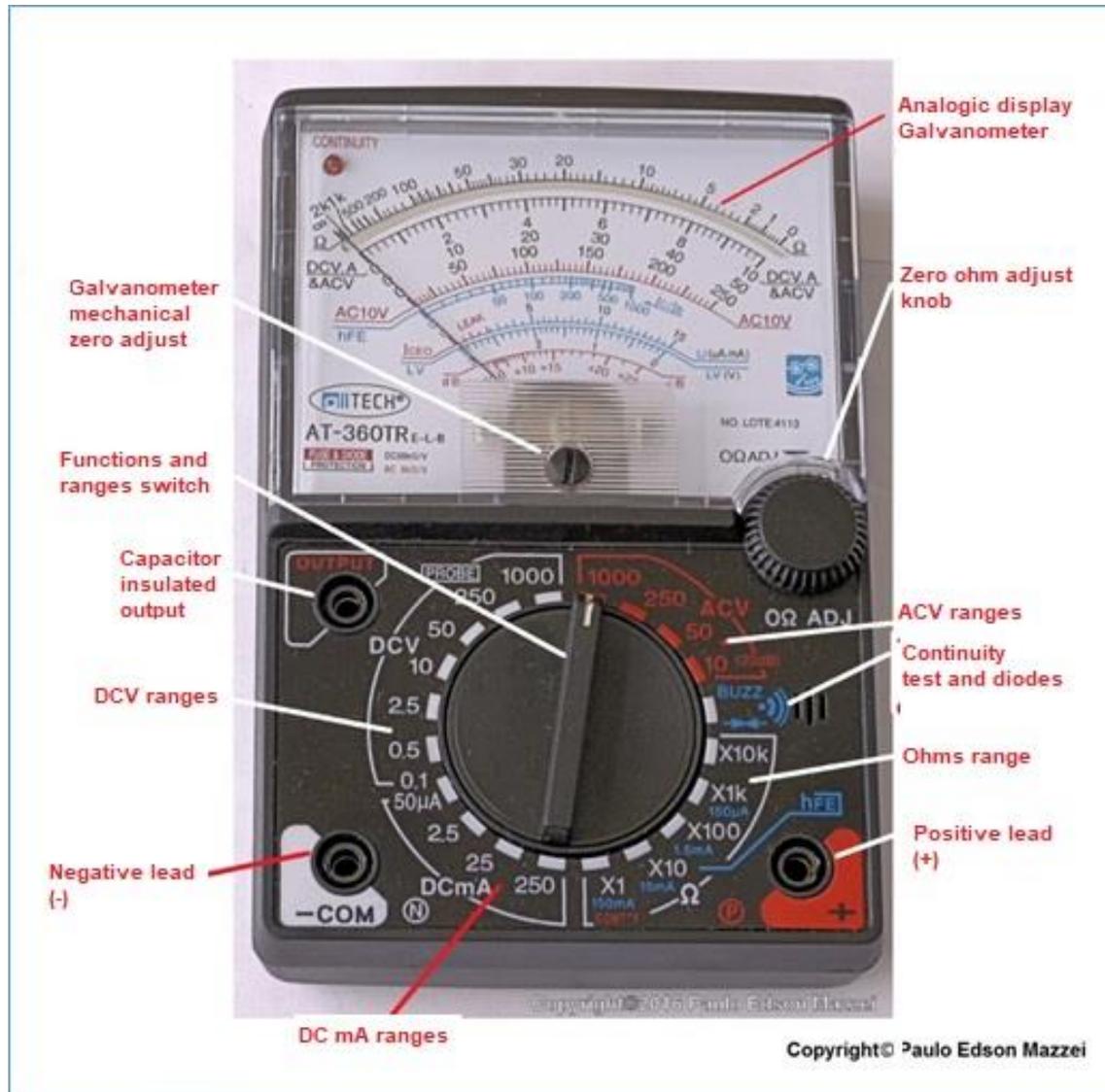


Figure 31 - VOM functions, ranges, tests, etc.

Now let's look at just the functions and ranges you will use for your experiments. As necessary, we will describe others. As you study these functions and ranges keep your VOM Instruction Manual open for you to follow up on this data discussed.

Functions and ranges

First, place the probes on your VOM. Red tip at the terminal marked **V Ω mA** and black tip at the "COM" terminal. Leave the selector switch in the "1000ACV" position for VOM protection.

1. Function: DC voltage measurement.

The VOM measures from 0.1 VDC (100 millivolts) to 1000 VDC, on seven Ranges, as shown in **Figure 32**. Simply place the selector switch in the positions shown in the **figure**.

2. Function: AC voltage measurement

The VOM measures from 200 V up to 750 V on two Ranges, as shown in **figure 32**. Simply place the selector switch in the positions shown in the figure.

3. Function: DC current measurement (DC only).

The VOM measures from 50 μ A (microamps) to 250 mA (milliamps), on four Ranges, as shown in **figure 32** on the right.

4. Function: Resistance measurement.

The VOM measures from X1 ohm (times 1 ohm) to X10 k (times 10,000 ohms) on five Ranges, as shown in **figure 32** on the left. This translates to: measures from about 0.2 Ω to 20 M Ω .



Figure 32 – VOM. DCV ranges at left (a) and ACV at right (b).

Care of your analogic multimeter

You got a nice analog multimeter and you're crazy to start measuring something!



Beware, DO NOT insert the probes into the first wall socket you find!! It's never too much to repeat ...

Some safety rules you must follow, for your own safety and long life for your multimeter:

1. Make sure that the function selector switch and test leads are in the correct positions and positions. Check three times. Check it again!

2. Do not use the Meter if the probes are damaged, loose or with the stripped cables.

3. Never measure the resistance of a component or circuit if it is energized.

4. Never touch test leads that are connected to an energized circuit, especially in AC voltages.

5. Do not use the common multimeter to attempt measurements above those carried by the apparatus.

6. Always start on the higher range by measuring an unknown current or voltage. By the type of circuit and the supply voltage of the same you already have an order of magnitude of this value.

7. Never change the Ranges of a multimeter, with it connected to a live circuit. This can irreparably damage it.

8. Always check the condition of the battery that powers the Meter: if they are worn out, they may give erroneous measurements. If you can no longer adjust the zero by joining the probes to reset the VOM to resistance measurements, it is time to replace the battery and batteries ...

9. Do not subject the Meter to mechanical shocks or shocks. Do not let it get wet or exposed to the sun.

10. When storing your analog meter, always leave it on the "**1000VAC**" Range. If any stranger tries to stick the probes into a 220 VAC outlet, it will not damage it.

Measurements with de VOM

I know you "are crazy" to stick the probes somewhere and show your family, girlfriend and friends your new VOM! It's very normal ...

The idea is that you wait until we begin the practical experiments, where I will show everything, how to measure, Ranges, care, how to interpret values etc.

However, since I am not the subject of breaking any heart ... Let's go to some "little things", so you do not feel like it!

Voltage measurements

1. DC Voltage Measurements:

▶ When you know the supply voltage of the equipment to be measured, select a measurement range above this value. Connect the negative (black) test lead and then move the positive test lead (red) at the various points on the circuit, where you need to measure. Please note that **DC** has polarity plus (+) and minus (-).

▶ If you measure the voltage of a 9 V battery, you already know that this type of voltage is "**DC**", as explained above.

▶ Since the 9 V voltage is written to the battery body, you should choose a voltage on the multimeter Range that is above this value. See **figure 33**.



Figure 33 Measuring the DC volts of a 9 V battery.

► If you do not know the value of the **DC** voltage to be measured, always start with the larger Range and go down until you have an accurate reading. Keep in mind that each time you Range down the selector switch, the multimeter needs to be disconnected from the custom circuit. For example, see **Figure 33** for measuring the voltage of a 9 V battery. In this figure, the most accurate reading is on the 10 V Range.

The figure below shows the DC voltage measurement for a typical alkaline "AA" type battery and should be close to 1.5 V.

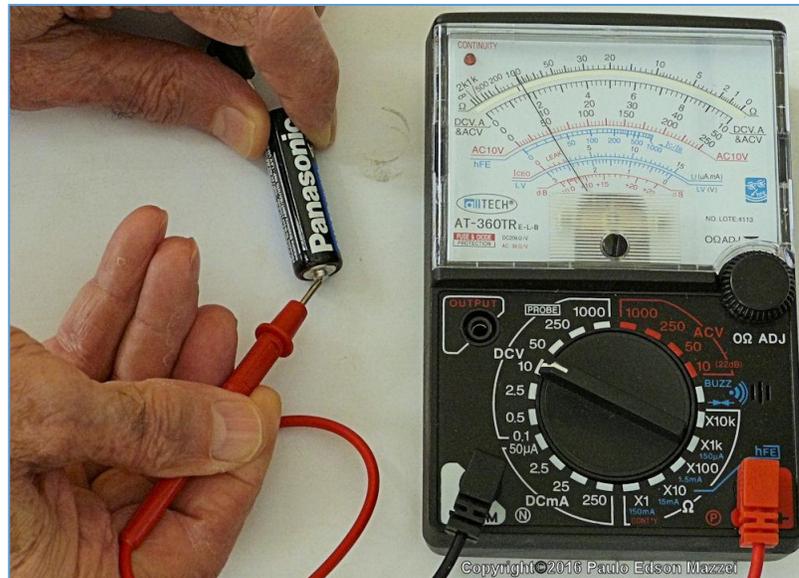


Figure 34 - Measuring the voltage of an AA battery. VOM on the 10 V Range, reading approx. 1.7 V.

See what happens with the readings on the various Ranges used.



ATTENTION: Do not change the ranges with the test leads connected to the circuit.

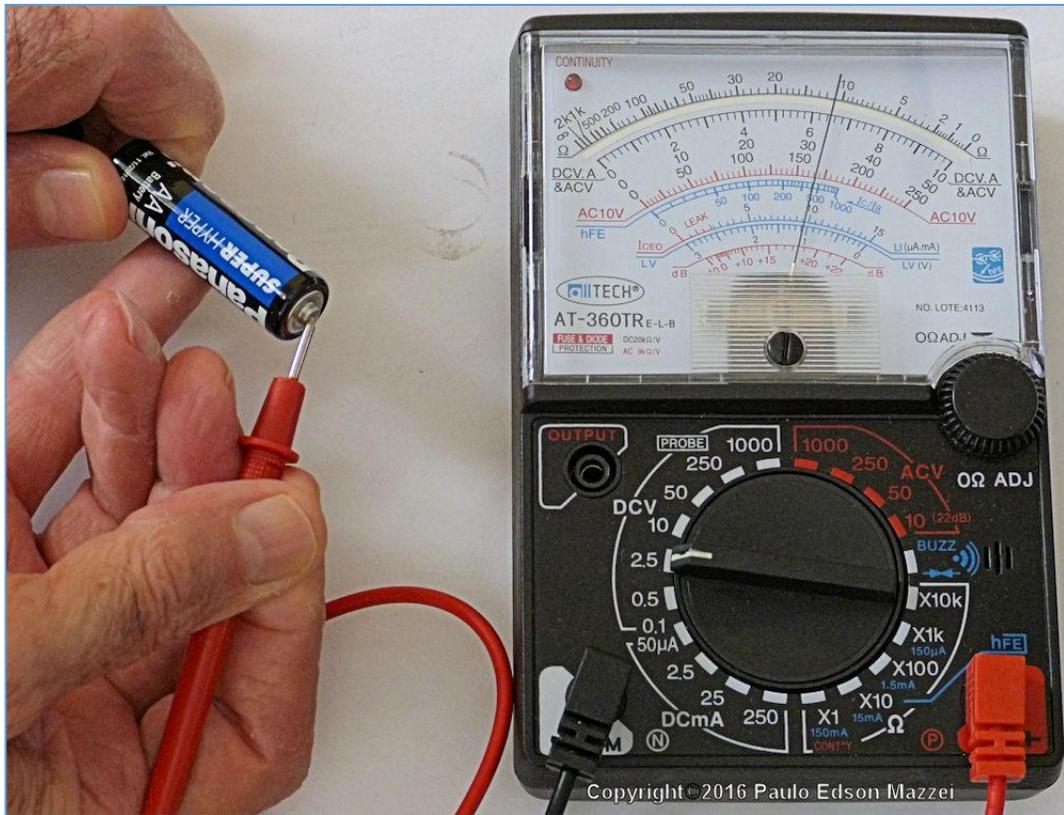
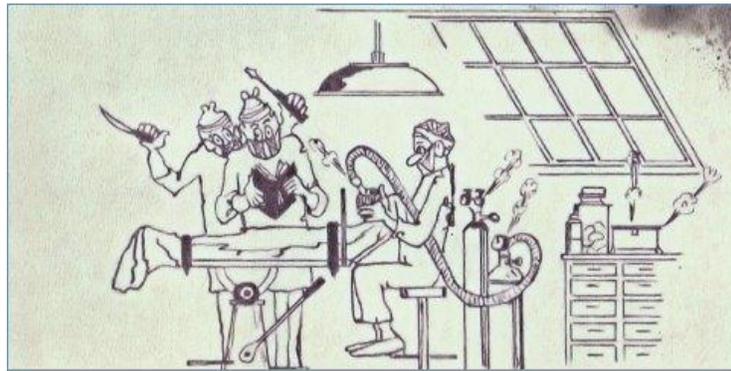


Figure 35 - Changing the VOM range to 2.5 V. The reading is much more accurate because the Range value is close to the value of the battery voltage. Remove the test leads to change the range.



Read the Instructions Manual before operate!!



As I know you like to live dangerously, let's now measure the voltage of your home's electrical grid! In homes, it is common to have two AC voltages: 127 VAC for most household and 220 VAC for appliances that consume lots of energy such as showers, air conditioners, washing machines and dryers, etc.

Choose an easy-to-reach socket where you usually connect devices made to operate with 127 VAC. Many manuals, books, articles still talk about "110 VAC" but in reality, the correct value is 127 VAC (in Brazil)! Use this or other if you live in a country with different ACV standards.

See **Figure 36** for a drawing of how to measure the AC voltage of a wall outlet, with the results read as we change the Range.



ATTENTION: Do not change the ranges with the test leads connected to the wall outlet!!

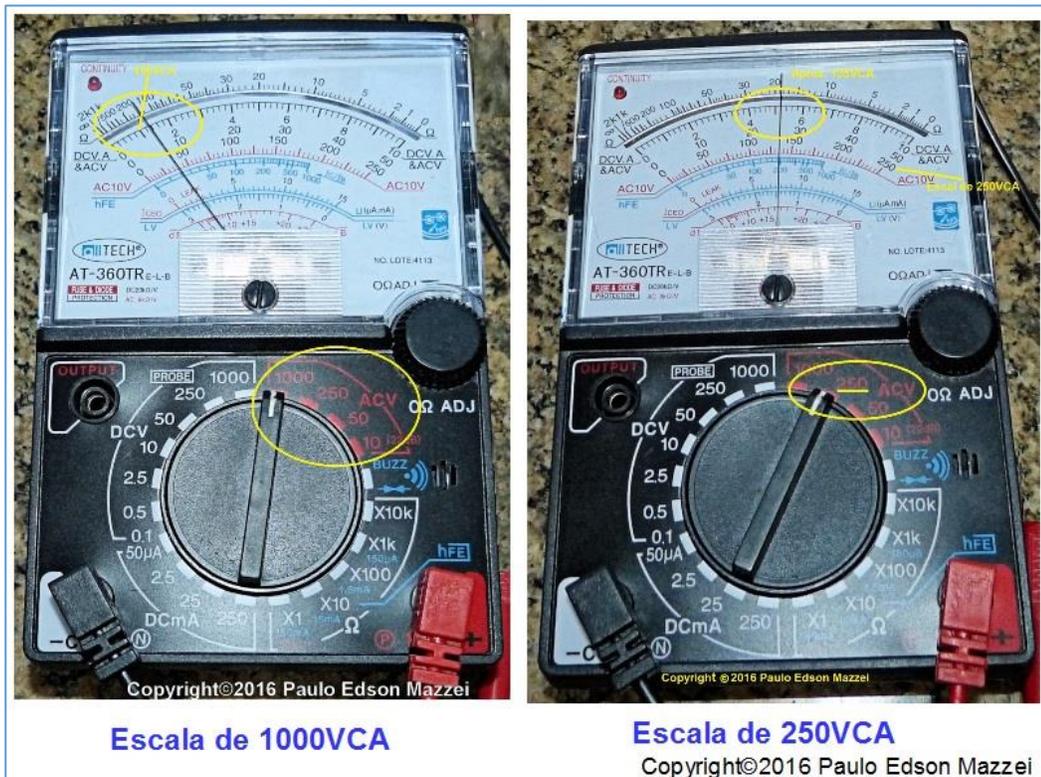


Figure 36 – 127 VAC voltage, measured on two different VOM Ranges. Reading left indicates 130 VAC, on 1000 V Range and reading right shows 135 V, with DMM on the 250 VAC range.

Now a question that will not shut up! How do I know how much each division of the ranges is worth between the two "chopsticks", since I can select several ranges to read in the same division of the galvanometer?

See **figure 37** and all your doubts will be healed.

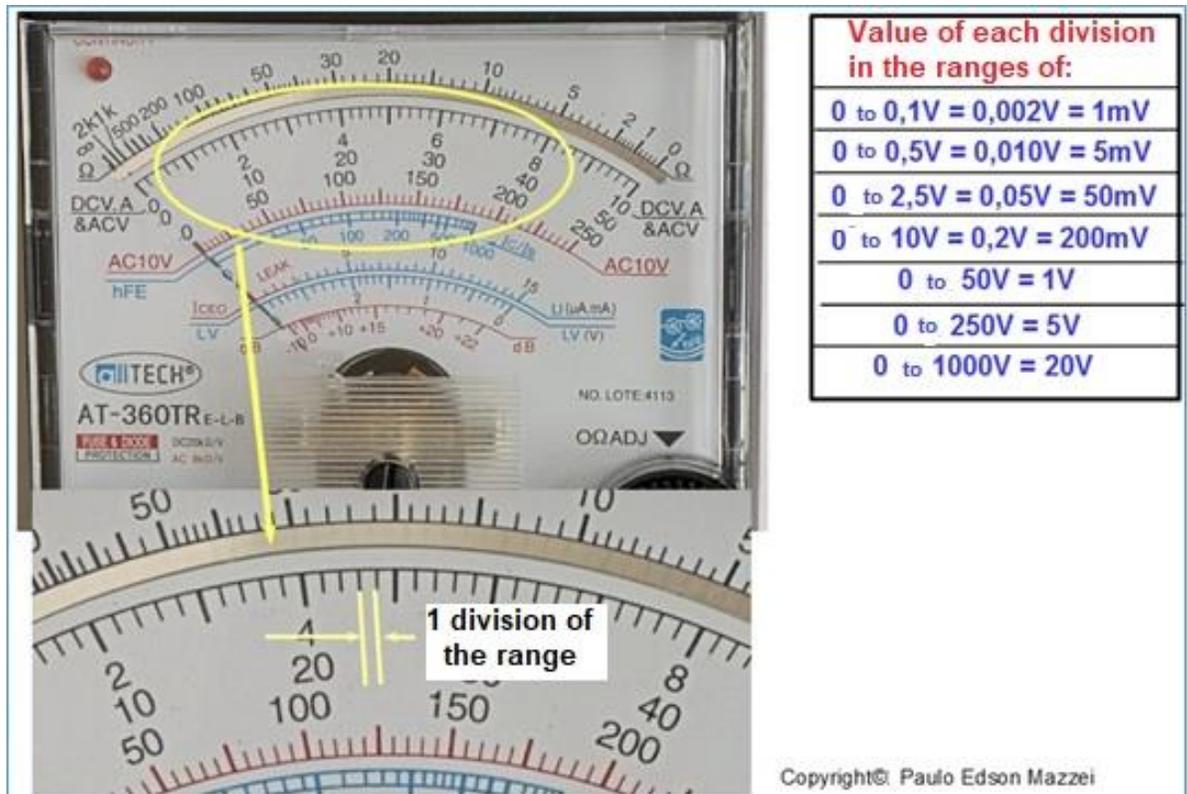
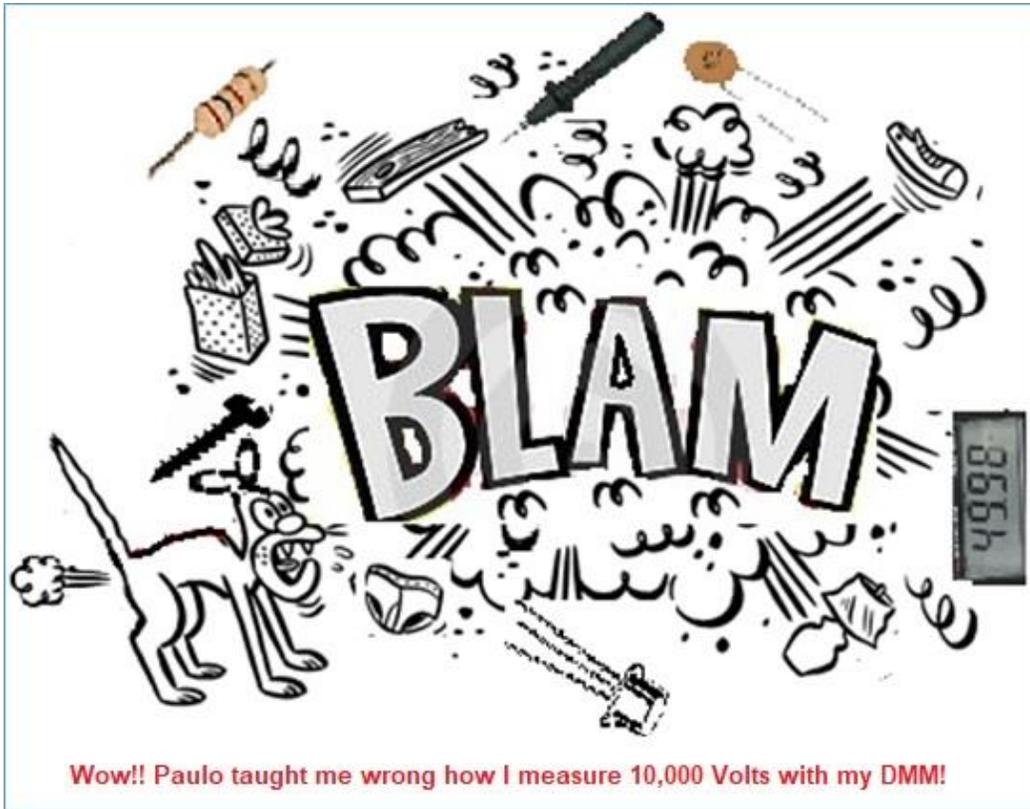


Figure 37 – Value of each range division, for several values of voltage.

Pleased?? Great, read the manual of the multimeter, follow all precautions and safety rules I gave and will not happen as shown in the following figure!

If you want to learn all about digital and analog multimeters, be sure to check out my book "**How to Use the Meter! Digital and Analog Multimeters!** Techniques for correct use of digital and analog multimeters!" On Amazon Brazil.

Did not "pay attention" to the multimeter instruction manual? Used out of spec? The following picture may happen ...



Practice for you



Check out your DMM and VOM and see all characteristics discussed in the text. Localize the functions, ranges, especial test points, display, etc.

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Chapter 7

Basic electronic components

Introduction

Let's briefly review some components so that you can recognize them when purchasing from the store or select for an experiment. Let's extend this analysis a bit, giving you the physical format of some modern electronic components.

Along with the physical formats of these electronic components, we use to pass your graphic symbols. Graphic symbols are drawings that represent a particular component in an electronic circuit.

Objectives

- Know the electronic components that you will use in the practical experiments of electronics.
- Identify these components, knowing their reading of values and models.
- Test the electronic components used in the circuits of the experiments.

The basic electronic components

Resistors: Resistors are widely used and easy to identify components. They can be constructed of carbon, metallic film and wire (nichrome). Its values are fixed and are measured in ohms (Ω), kilohms ($k\Omega$) and Megohms ($M\Omega$). Usually in electronic designs you will find resistors from 1 Ω up to 10 $M\Omega$. Ω = Greek letter "omega".

The size of a resistor shows its ability to dissipate heat (watts) and the larger, more watts. Wire resistors are used for powers from 1 to 10 W, usually.

The value of a fixed resistor, carbon or metal film is identified by a color code on the body of the resistor itself. In wire resistors, the value of the wire is printed on the body as well as the power.

The resistors are identified in the circuits by graphic symbols. In our case, you will find circuits with resistors designed in the North American standard and the IEC standard.

The resistors can be fixed, variable (potentiometer) and adjustable (trimpot). See **figure 38**.

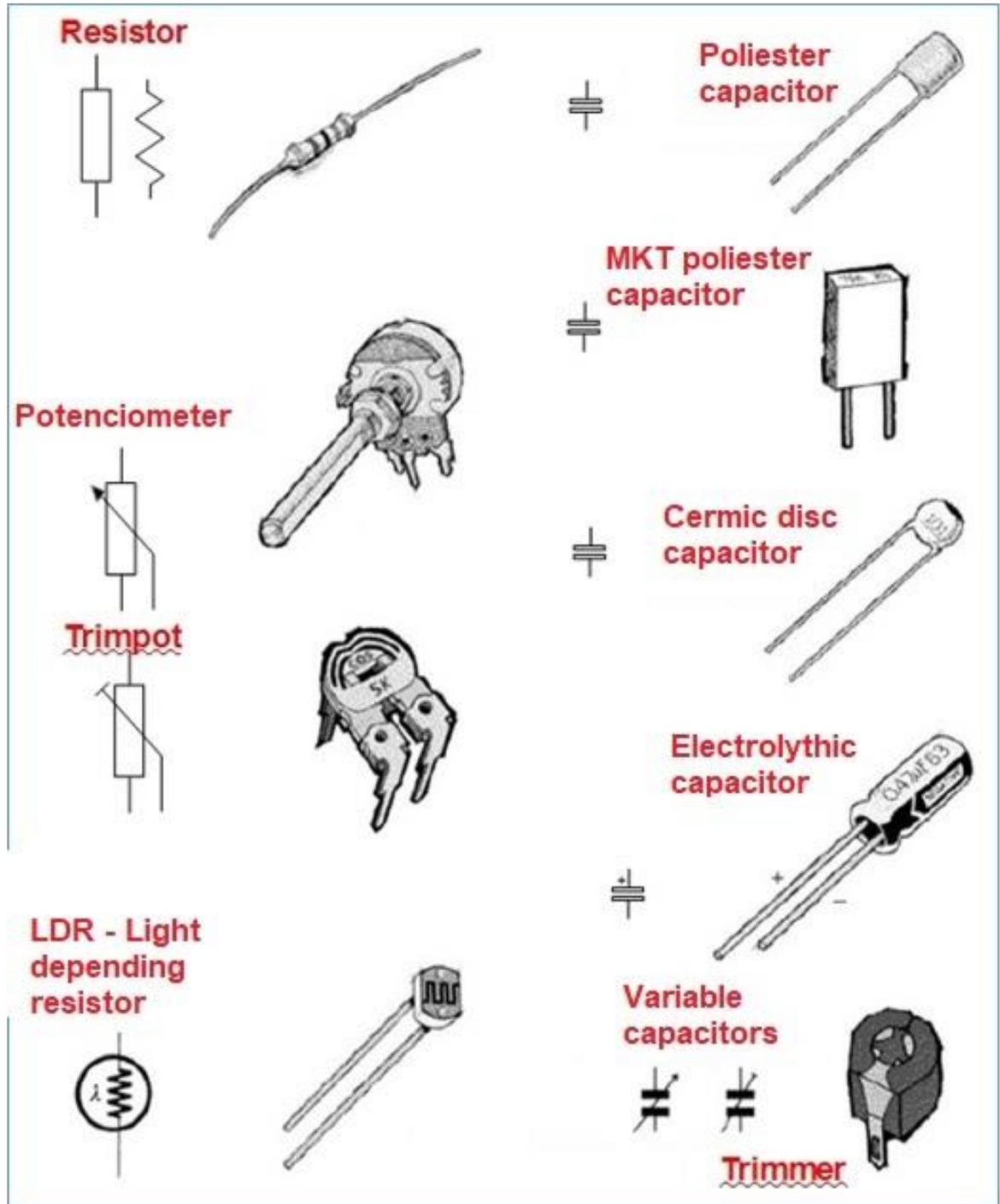


Figure 38 – Symbols for resistors and capacitors. Courtesy MadLab Org – UK.

Capacitors:

Capacitors are other widely used components and can be found in various formats as illustrated in the previous figure. Normally the material used in the construction is that it gives the name to the capacitor as ceramic, polyester, Stiroflex, mica, etc.

Most capacitors come with the value, tolerance, and working voltage already printed on the body. The electrolytic and tantalum capacitors are polarized and indicate this polarity in the body itself.

Values can be given in μF (microfarads), nF (nanofarads) or pF (picofarads).

The variable and adjustable capacitors, shown in the figure below, are used in radio receivers, transmitters, etc. The adjustable ones have a small screw to adjust their capacitance. **Figure 39.**

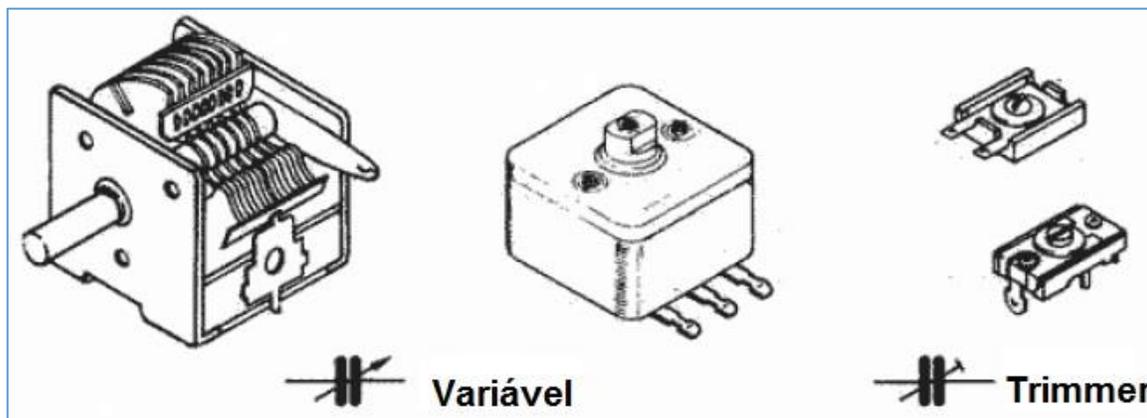


Figure 39 –Variable and adjustable capacitor symbols. Courtesy MadLab Org – UK.

- Coils and transformers:

Coils are widely used in RF (Radio Frequency) circuits. They assume the most varied forms but the ones we use most are those of air core, ferrite (baton or toroidal). Some coils are fixed while others are adjustable with the IF (Intermediate Frequency) of radio receivers, which comes in a small metal mug.

The coils have their inductance measured in Henries (H) and the values most used are around mH (millihenry) and μH (microhenry). The inductance of a coil usually only comes written on the coil body with the "micro shocks" or colored strips on the body.

Transformers are their old acquaintances and almost every device connected to the AC power grid uses one. There are power transformers, audio transformers,

impedance couplers, etc. They are wound into "EI" shaped iron plate cores or toroidal shapes.

Look at some inductors in **figure 40**.

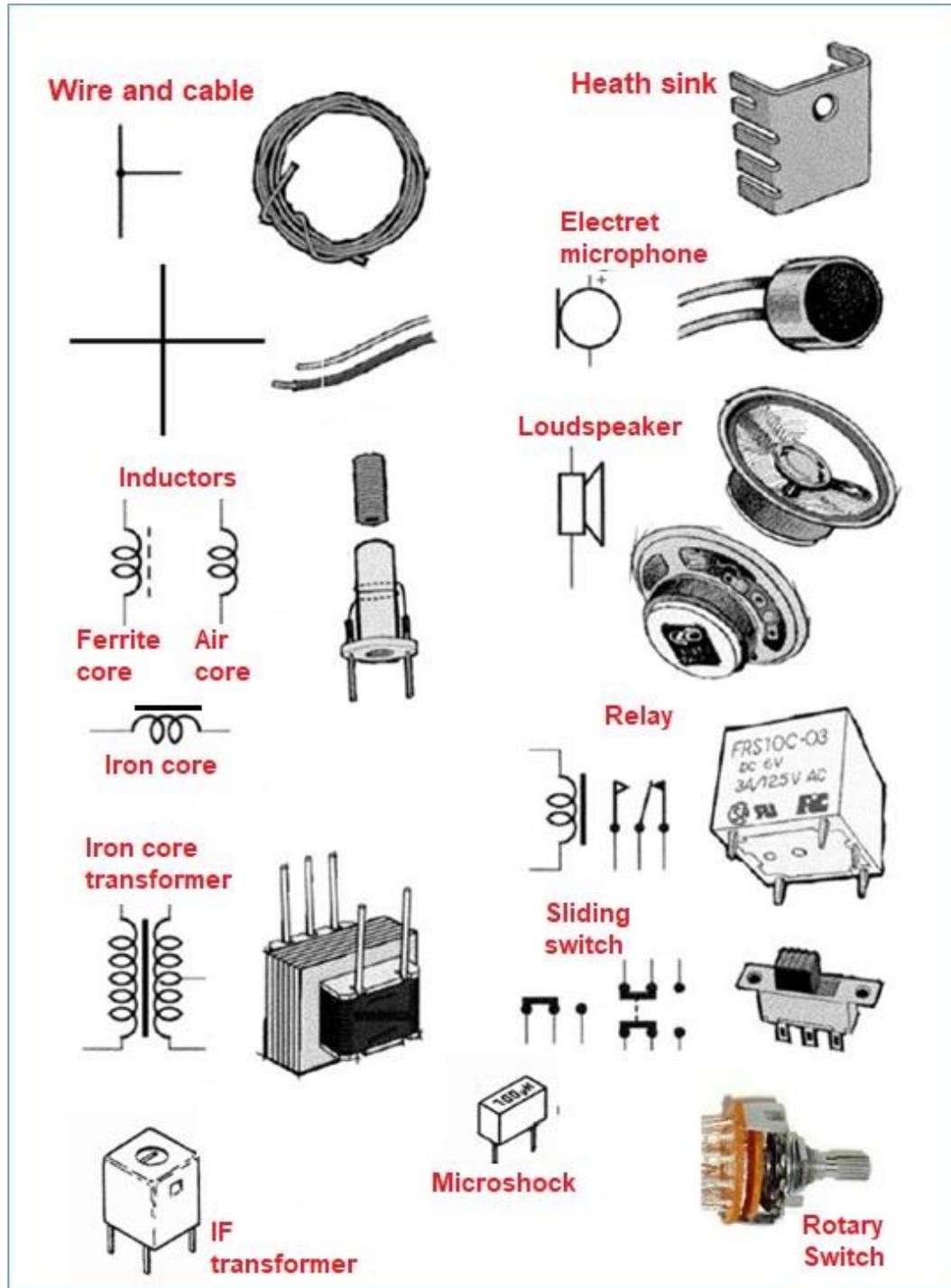


Figure 6-Inductors and Inductor Formats, Relay, and Wrenches. Courtesy MadLab Org - UK.

- Semiconductors:

In your assemblies you will find a lot of types of semiconductors like diodes, transistors, SCR, thyristors, integrated circuits (IC), displays, etc. as shown in the **figure 41**.

The author of technical articles in magazines usually provides a list of semiconductors that can replace the indicated template. Better yet, refer to the model in a "**databook**" (data catalog) that is available on various Internet sites. Check the important parameters of each type of semiconductor and see if it can even be

Note: The graphic symbols used in the figures in this section may vary slightly from the graphic symbols adopted in US. EIA symbols also, are quite common all over the world.

In magazines, books and the Internet is a great mishap because everyone uses what they think they should!

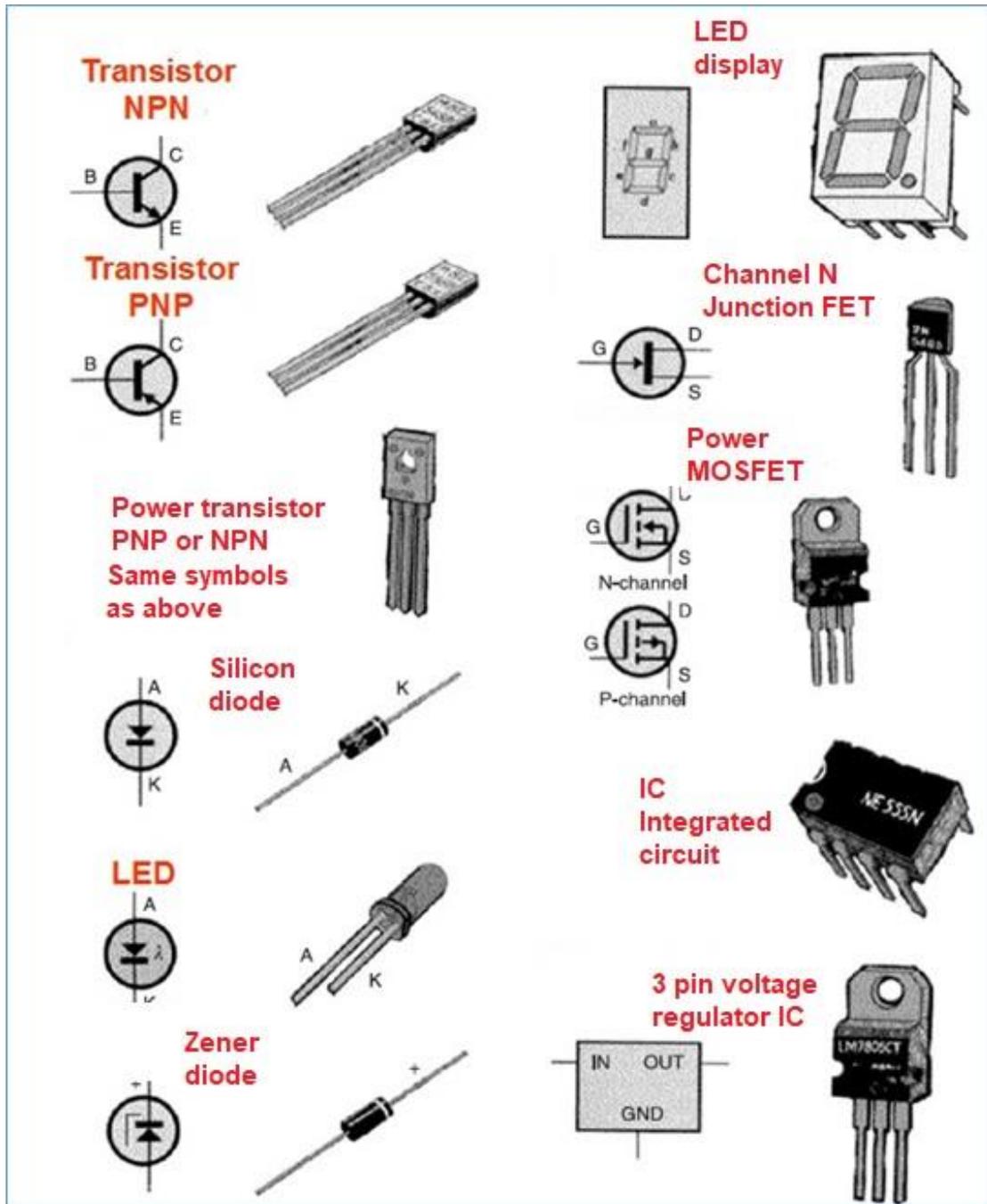


Figure 41 –Diodes, transistor, IC, etc. symbols. Courtesy MadLab Org – UK.

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Chapter 8

The “Protoboard”

Introduction

The prototype mounting plate called **Prototype Board (Protoboard)** allows the union of several electronic components, without welding, for the assembly of experimental electronic circuits.

It is much used in the laboratory because it allows to assemble a prototype, to change it as many times as necessary, until arriving at a final circuit, tested.

If you had to solder all the electronics, to carry out the experiments, the time spent would be huge and many components could be damaged in this process.

Objectives

- What is Protoboard and how does it work.
- Identify Protoboard contacts.
- Uses and care.

The Protoboard

The Protoboard consists of an array of electrical contacts, which follow a pattern as shown in **Figures 42 and 43**.

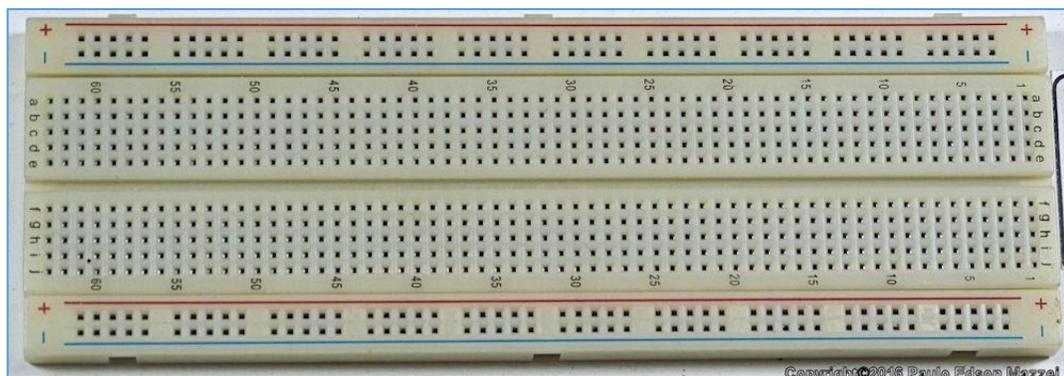


Figure 42- 830 contacts Protoboard.

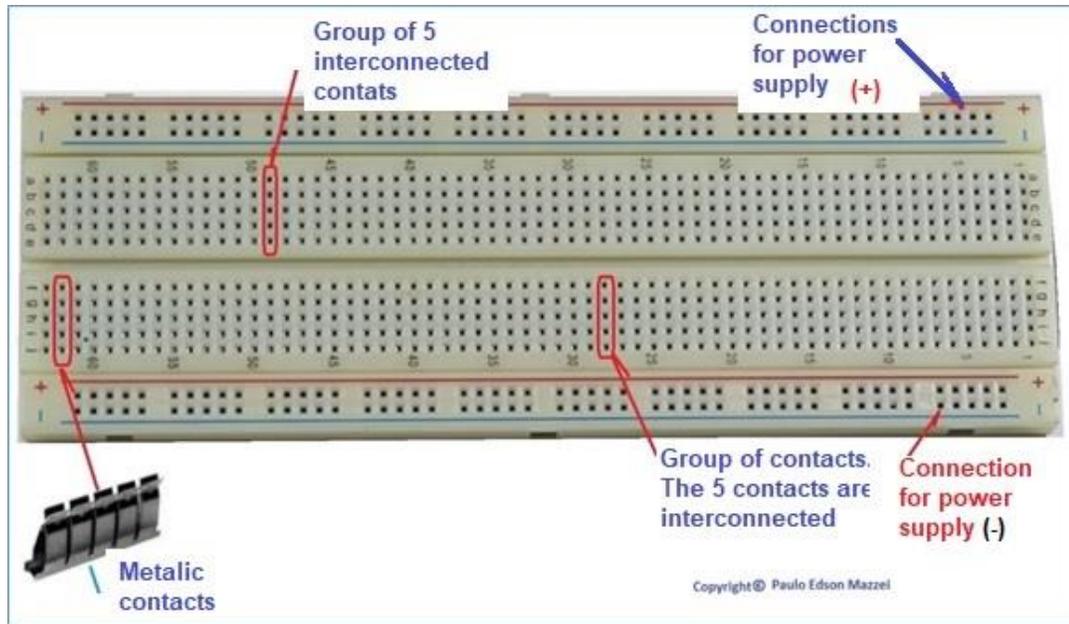


Figure 43 -Protoboard and her contacts.

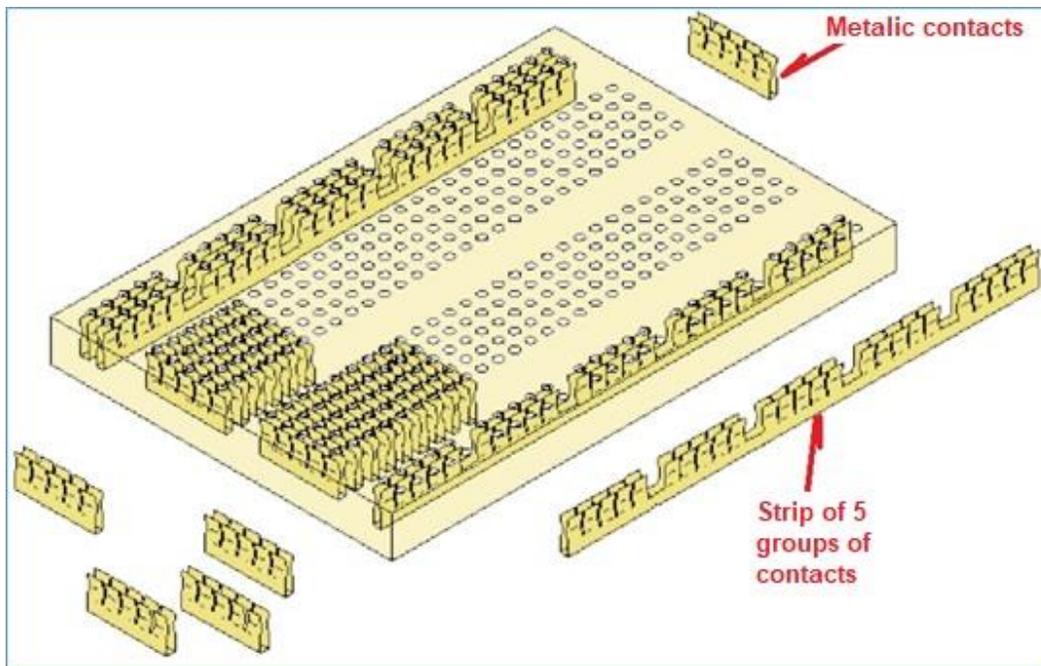


Figure 44 - Drawing of the Protoboard contacts and their assembly on the plastic plate.

Protoboards (or Breadboard) contains metal contact strips that form a pattern under the holes in the plastic plate contacts. These contact strips connect group of contacts together as shown in **Figures 43 to 45**. In this way, any electronic components inserted in these five contacts are electrically connected.

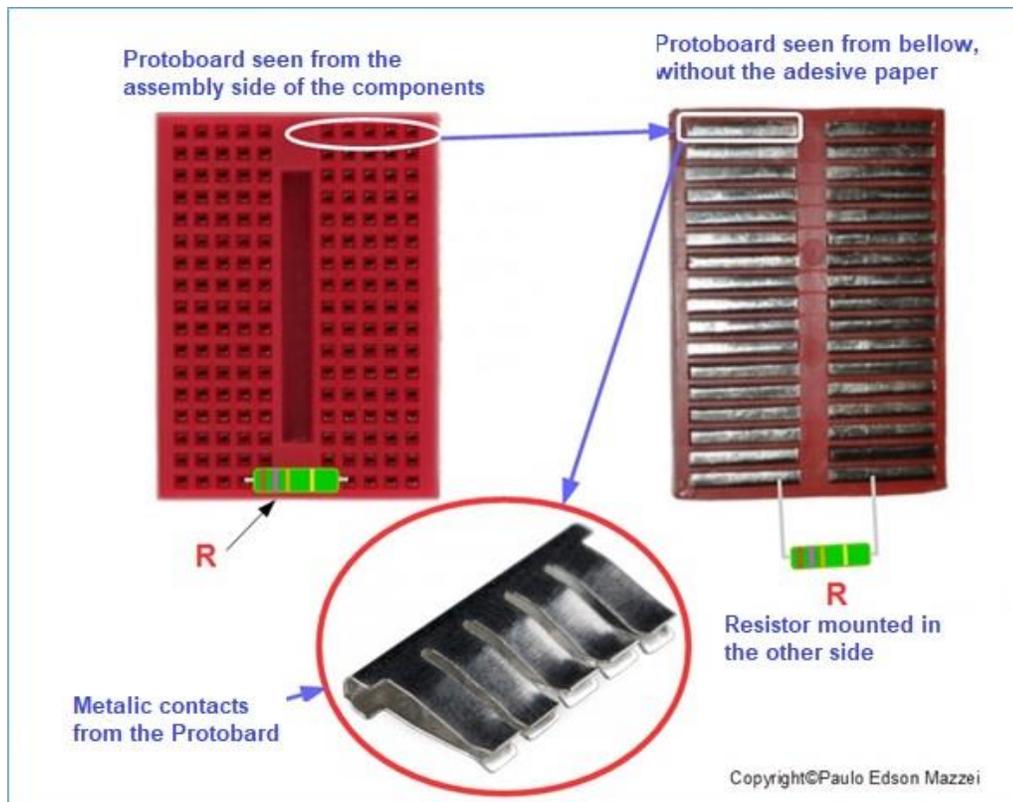


Figure 45 – Protoboard contacts.

The row of contacts marked (+) next to the red line already has contacts between all holes in the plastic plate, as shown in **figure 43**. Thus, if you connect the positive pole of the batteries or the power supply to one of the contact holes on the card, all other holes will have this positive polarity of the batteries or source. The same happens with the marked (-) row of contacts, where the negative terminal of the batteries or power supply is connected.

Contact groups can be connected, near or far, using the special cables for Protoboard (see **figure 46**) or even hard wire no. **22 AWG**, with a diameter of 0.65 mm. Please look at **figure 48**. Do not use wire of larger diameters to avoid damaging Protoboard contacts.

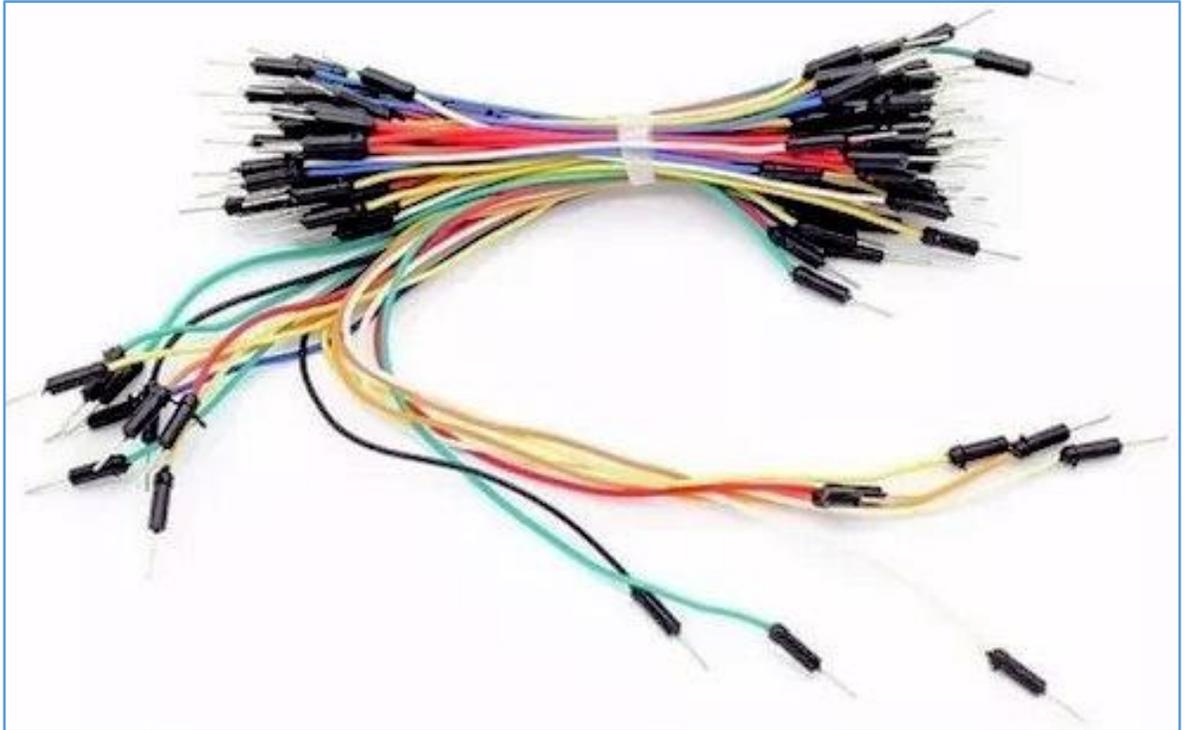


Figure 46 – Jumpers for Protoboards.

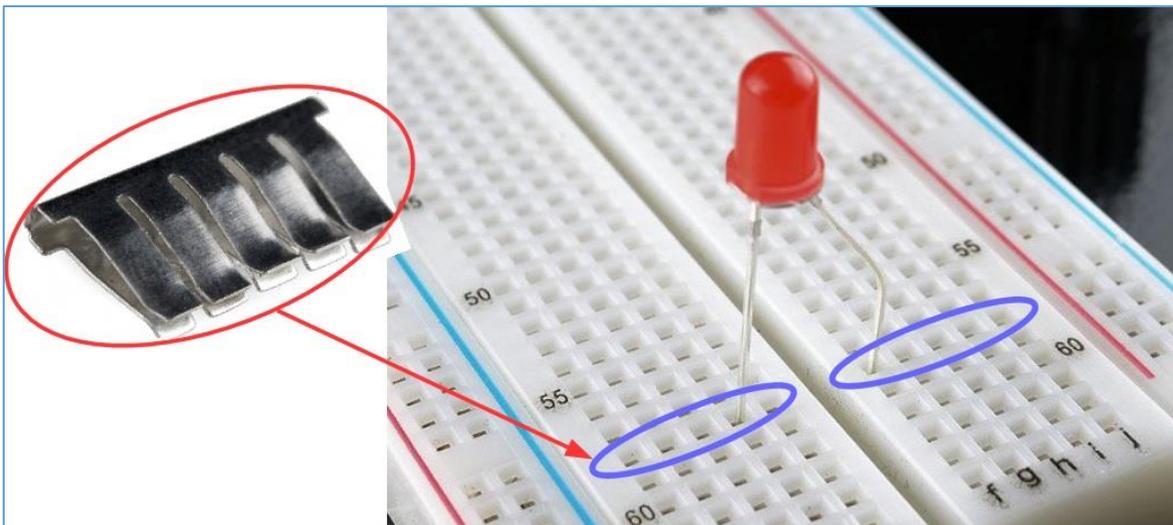


Figure 47 – Mounting a LED in the Protoboard.

One source of these thin hard wires are the cable tips of telephone lines. These wires are 24 AWG, about 0.51 mm in diameter. If this is the case, go to your local telephone company and ask for these cable tips. Dismantle the cable, which contains dozens of thin wires, with colored covers and cut the wires to the appropriate size. Remove the ends of the cover, about 6mm and you're done, you have a nice collection of interconnecting wires. See **figure 48**.

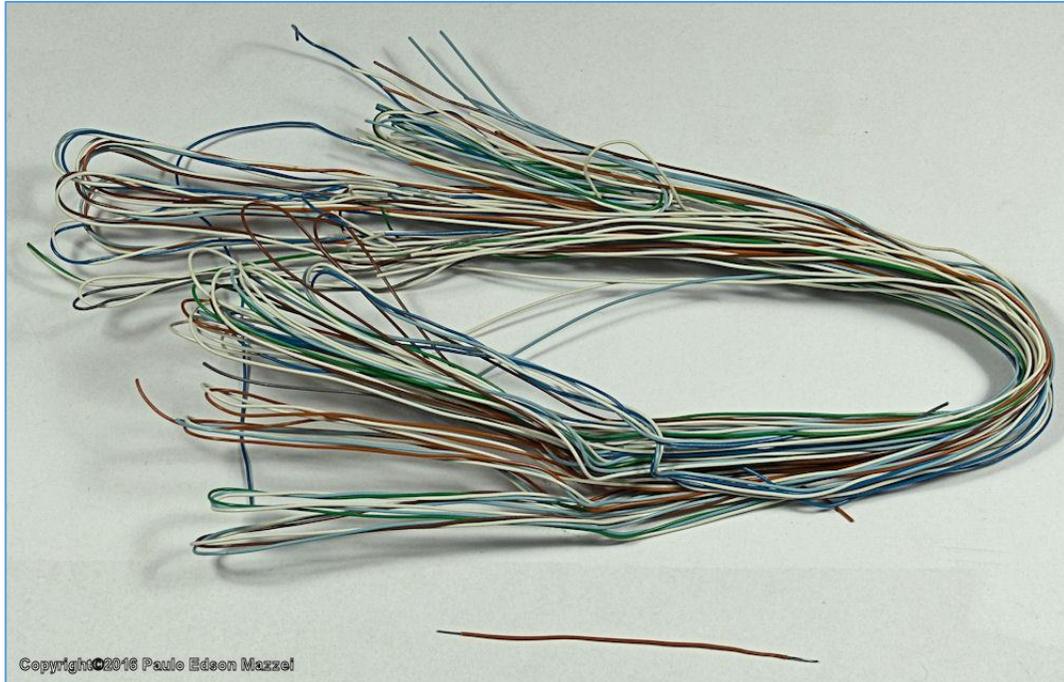


Figure 48 - Wires obtained from a "tip" of telephone cable.

Special jumper cable for Protoboards.

These cables, illustrated in **figure 46**, with special pins at both ends, are used only for on the Protoboard and already have the proper diameter for this. You cannot use it anywhere else.

They come in several colors with various lengths. If possible, try to use:

- a. Red for positive DC power supply (+ 15 V).
- b. Black to less (negative) power supply and common.
- c. Blue for negative power supply (-15 V).
- d. Green for ground connections.
- e. Always use the shortest possible cable.
- f. Do not force anything!

Figure 46 shows a set of these cables.

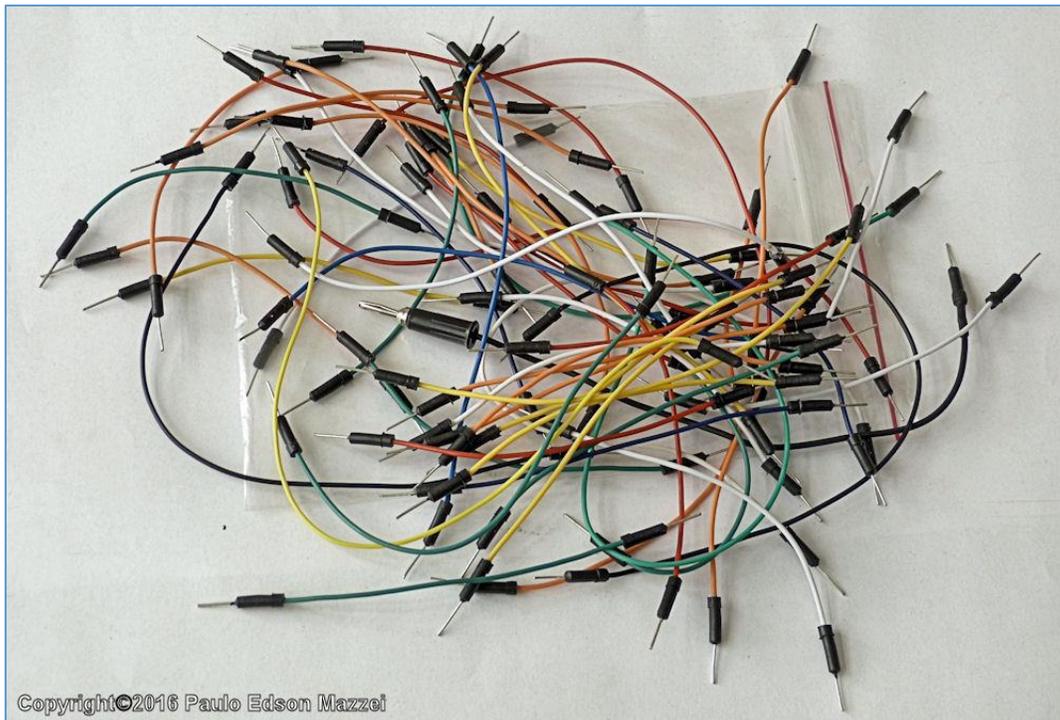


Figure 46 – Special cables for Protoboard connections.

As an example of the interconnection of points on the Protoboard, for the assembly of a circuit, follow **figure 47 to 49** and figures that follow. The figure shows a simple voltage divider, using only two resistors (R1 and R2), connected to the voltage supplied by the battery pack (+ 9 V).

- a.** One of the ends of R1 is inserted into the hole of a group of contacts, which at the same time is connected by a piece of wire (orange), to the + of the battery pack. R1 and R2 have equal values of 2.2 k Ω .

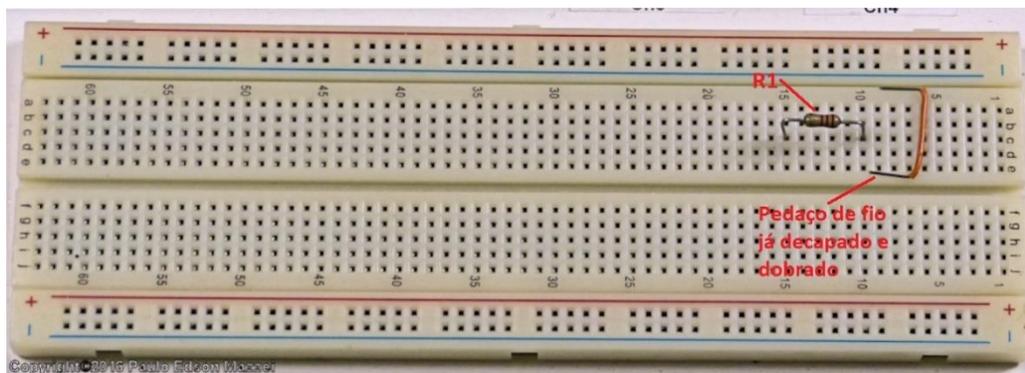


Figure 47 – R1 Figure

- b. The other terminal of R1 is inserted into the same contact group containing the R2 terminal.

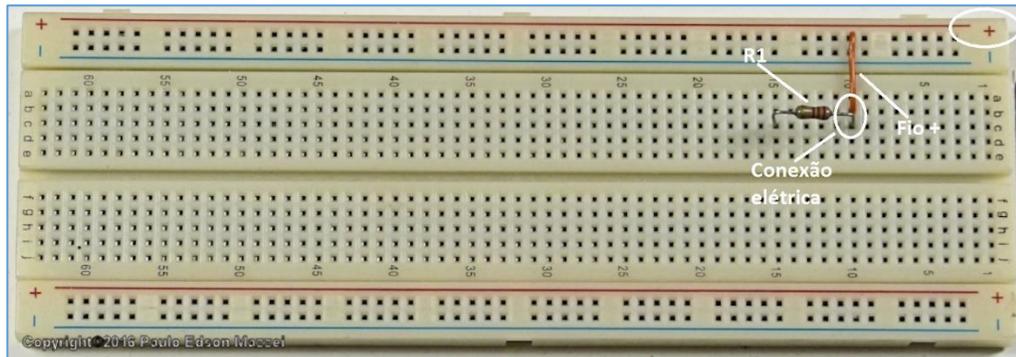


Figure 48 - Orange wire connecting R1 to positive voltage.

- c. The other R2 terminal is embedded in the Protoboard bore which is a group of contacts that connects this terminal to at least (blue = - wire, earth or circuit common point).

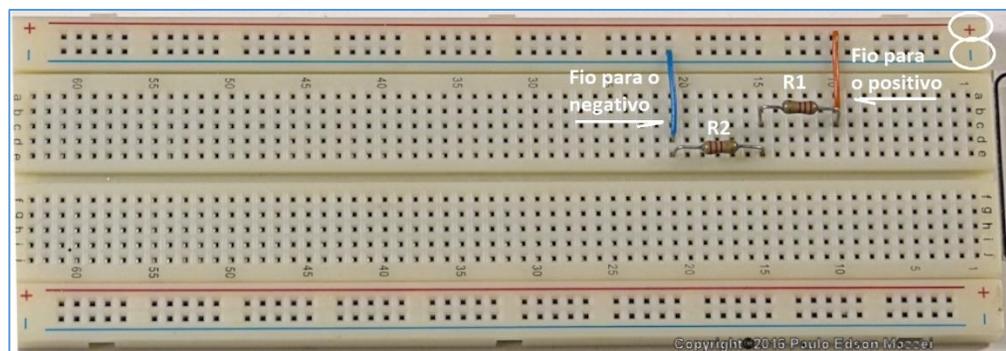


Figure 49 - Connection of negative terminal of the Protoboard.

d. From the positive contact of + 9 V (orange wire), another piece of orange wire, larger, goes from this contact to the + 9 V of the other Protoboard, where it has the output of the voltages of the battery pack.

e. See some types of component assemblies, figure 50. In part (a) of Protoboard, the components were assembled correctly. Small pieces of wire cover were placed in the terminals of the components, giving better insulation between them and changing well the appearance of the assembly, which looks more beautiful! Whim...

f. On part (b) of the same Protoboard, note that the components have been mounted in the same row of terminals, putting their terminals short! This is a common mistake of the beginner and great care must be taken not to damage more sensitive components such as diodes, transistors and integrated circuits (ICs)

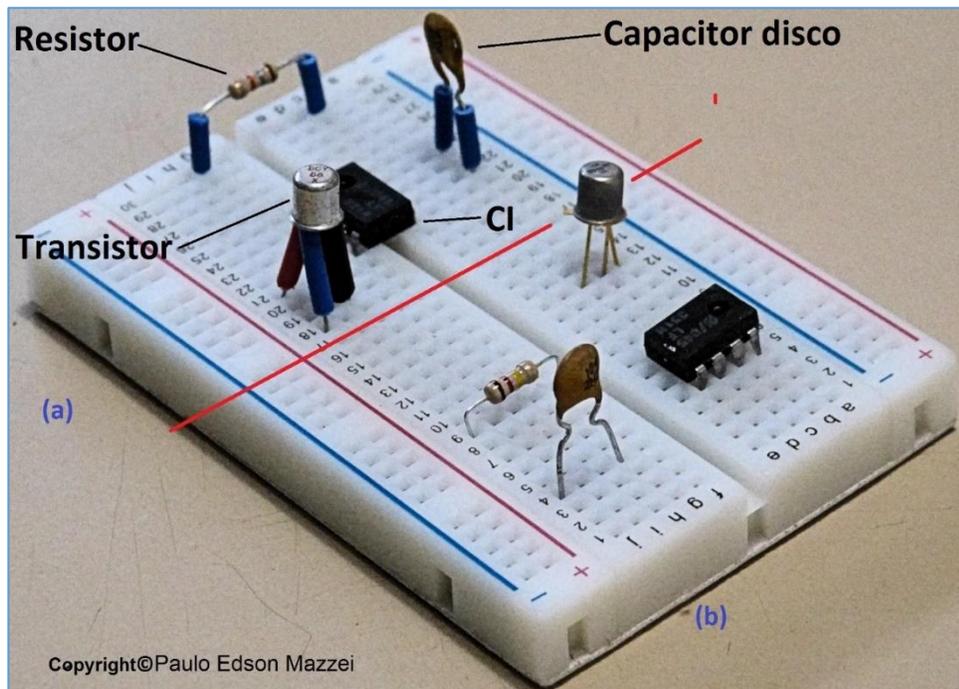


Figure 50 - Assembly of components in Protoboard. In part (a) the components were assembled correctly and (b) were assembled incorrectly.

a. Finally, it is only necessary to connect the free terminal of R2 to the negative of the battery pack. We use for this a piece of blue thread. This blue wire goes from this we are free of R2 to the Protoboard, where it has the output of the voltages of the set of batteries (negative cells).

b. In this circuit of the voltage divider with resistors, we can measure the voltage to see how it was divided by the resistors. For this, we use VOM or DMM, with specially developed test leads for the connection between the Meter and Protoboard.

c. You can use the digital or analog multimeter to identify rows or rows of contacts.

For this:

- . ■ - Verify that your digital multimeter's battery is OK.
- . ■ - Place the test leads on the multimeter as shown in figure 50.
- . ■ - These test tips that you see in the figure do not come with the digital multimeter. In the chapter on soldering show how to make these ends. If you want to do them already, go to **chapter 28**.

Rows and Columns on Protoboard

A. On the top of the white plastic Protoboard, you will find a number of numbers and letters. In our case, these numbers and letters do not have immediate use for our projects.

B. These numbers are useful in the case of an educational kit, for example, where the project author can ask to "connect a red wire from point **j1** to point **b3** of Protoboard".

Mounting CI - Integrated Circuits in the Protoboard

- a.** Every Protoboard board has a recess in its center, which looks like a ditch, along the length of the board.
- b.** This "ditch", is used for the assembly of ICs that have the casing manufactured in DIP technology. **DIP** stands for "**Dual In-line Package**". That is, it is an IC envelope where the terminals (pins) are mounted in two rows, next to the IC body, as shown in **figure 51**.

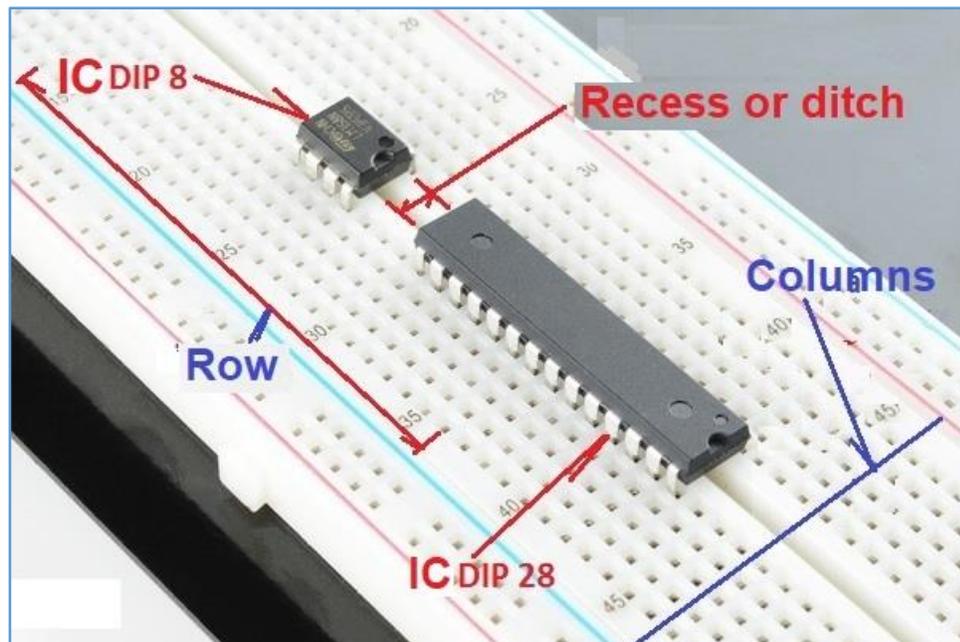


Figure 51 - IC mounting in Protoboard.

- c.** The negative of the multimeter, a black test lead, is connected to the Protoboard contact set labeled "**Negative Batteries**". The positive probe,

red color, is connected to the + 9.0 V contact set of the Protoboard for voltage output from the battery pack.

- d. The other ends of the two probes go to the terminals of the DMM or VOM. See **figure 52**. Inserting components in Protoboard



Attention: Only insert the wires, cables, and component terminals into the Protoboard, with the power turned off, either from the battery pack or from external power supplies!

- a. The wires, cables and components to be inserted into the Protoboard require special attention so that you do not damage them.
- b. The wires should be inserted vertically until it touches the bottom of the metal contact. The same for the terminals of the components.
- c. Special pins for use on Protoboard also require this care. Sometimes, when they are very long, they tend to tilt the pin, due to the weight of the cable. Make sure this does not happen.
- d. In the case of electronic components, fold the terminals of the electronics into a 90-degree angle and see to it that they do not touch. Do a good job: a well-made assembly spends the same time as a poorly made assembly and still gives less errors!
- e. If necessary, insulate the terminals of the components with small pieces of colored wire covers (see **figure 52**).

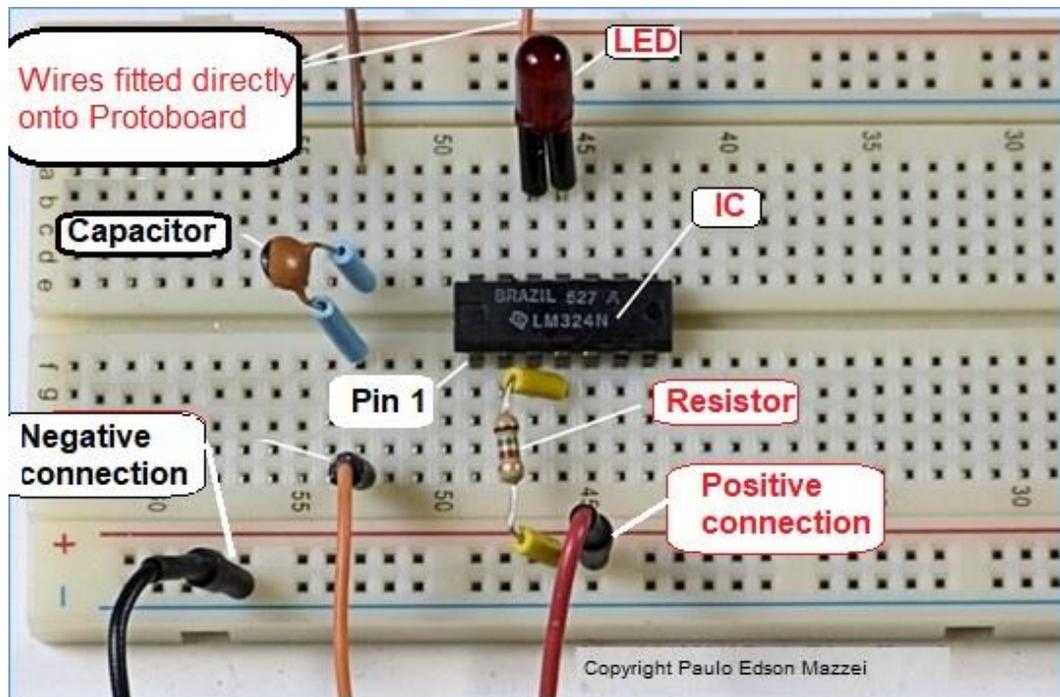


Figure 52 - Correct assembly of components in Protoboard. See text.

In Figure 51, note the following points:

1. This circuit is illustrative only. It's not a real circuit. Only part of Protoboard is shown.
2. For greater clarity of the photo, small pieces of wire covers were placed in the electronic components. Even in real circuits, this technique may be necessary a few times.
3. The IC - Integrated circuit is assembled correctly, so that none of its terminals is shorted. This IC has 13 pins and only pin number 1 has been indicated.
4. Circuit inputs (or outputs) are made with ordinary hard wire (brown and orange) or cables with special pins for Protoboard (black, orange and red).
5. The resistor is connected to the positive (red) and the terminal of the resistor is connected to pin number 4 of the IC.
6. The disk capacitor is connected between the orange and brown wires. They can be inputs or outputs of the circuit because at the moment it does not matter.
7. The red LED is connected between pins 11 and 12 of the IC.

Next, we'll look at some problems that may arise in assembling components on Protoboard. Based on **figure 53**:

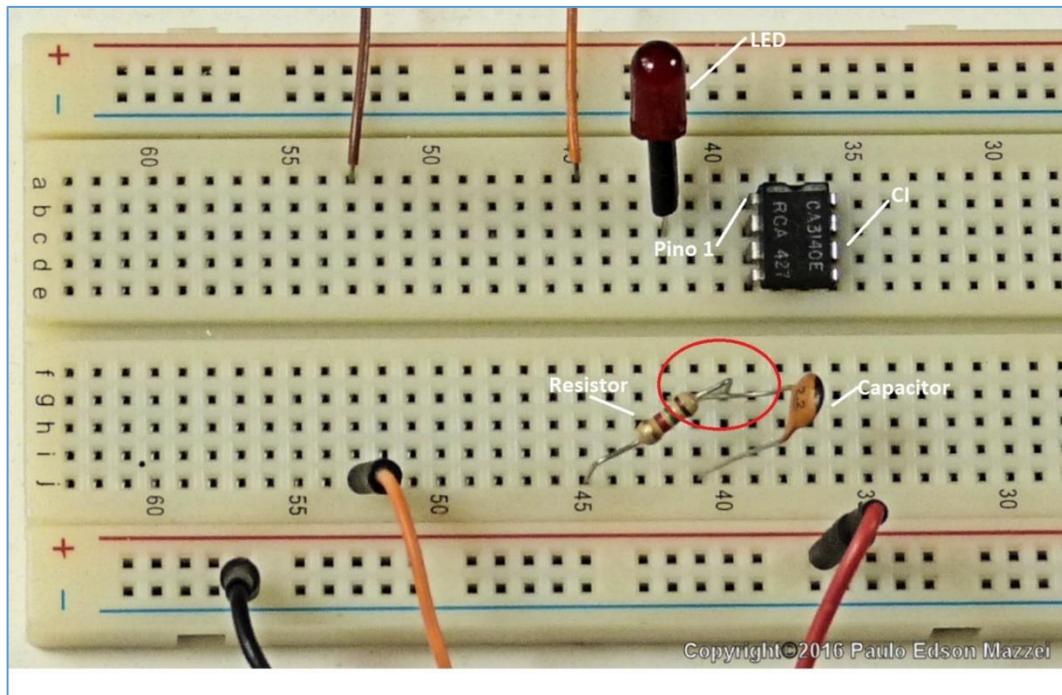


Figure 53 - Problems that can occur when assembling the components in Protoboard.

1. This circuit is illustrative only. It's not a real circuit. Only part of Protoboard is shown.
2. The IC has 8 pins and was mounted incorrectly. Note that the 4 pins on one side are all connected together in the same contact. That is, they are in short circuit. The same goes for the other 4 pins.
3. The resistor and the disk capacitor are with their terminals touching, that is, short circuit. See the detail in the red color ellipse.
4. The LED is also inserted in the same row of contacts, vertically, placing its two terminals shorted.
5. Note also that sometimes we have pieces of wire coming out of nowhere and going nowhere, like some bridge constructions in our country ...
6. If this eBook were interactive, we could show you a "set of mistakes", based on **figure 53**.
7. Good assembling techniques are very important in the assembly of electronic components in Protoboard. See example of a good assembly in **(a)** and a middle assembly in **(b)**, of **figure 54**.

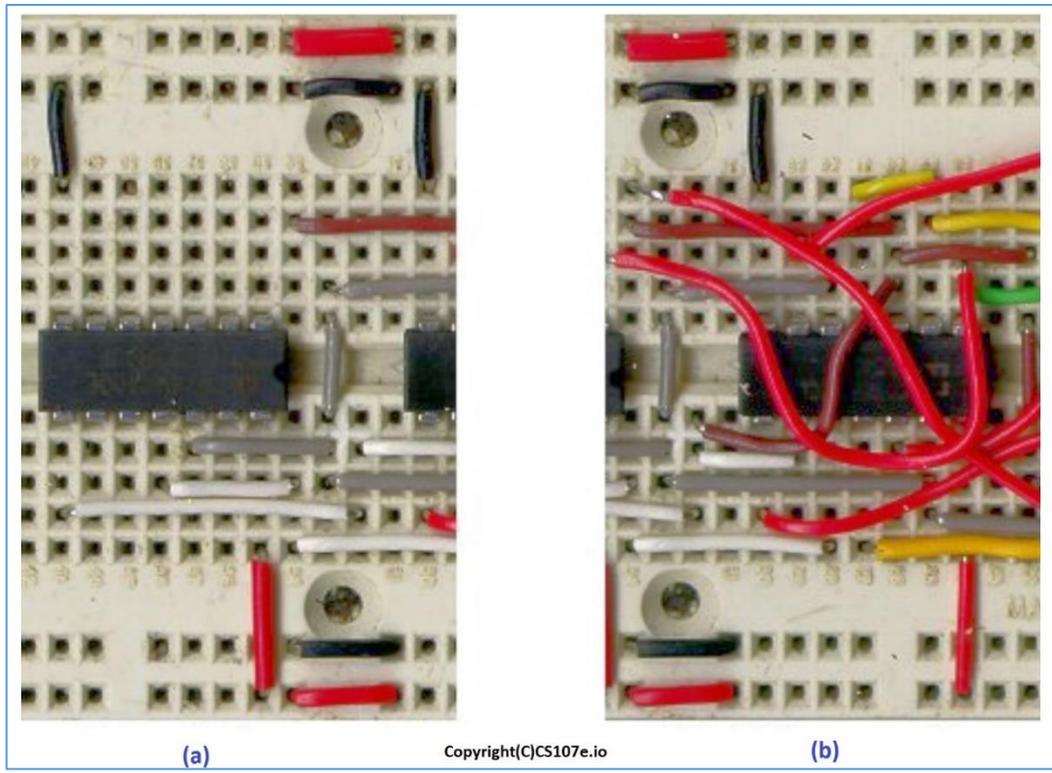


Figure 54 - Examples of a good assembling in (a) and bad assembling in (b).

[Back to Summary](#)

Experiment 1 Measuring the Ohmic Resistance of a Carbon Resistor.



Read all this text before the experiment.

OBJECTIVE

To learn to measure the values of resistors, with DMM - Digital Multimeter and VOM - Volt-Ohm-Meter Analog.

1. Components you will need.

- Carbon resistor 100 Ω
- Carbon resistor 3,3 k Ω
- Carbon resistor 68 k Ω
- Carbon resistor 270 k Ω
- Carbon resistor 1 M Ω

*All resistors = $\frac{1}{4}$ W and 5 %.

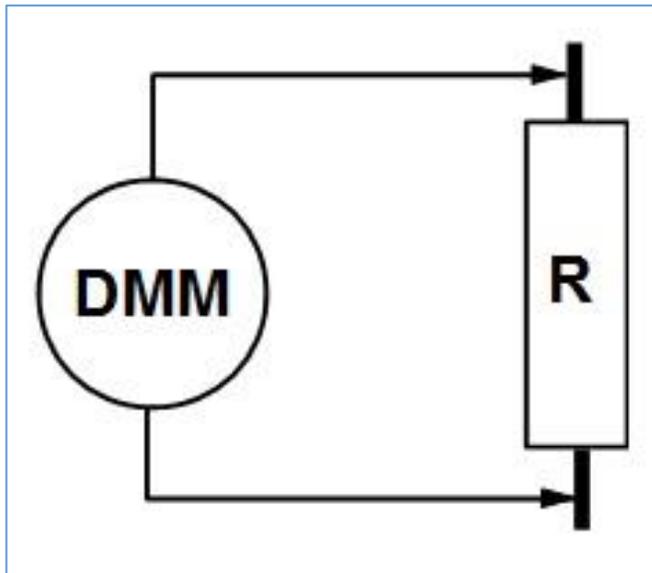
f. Protoboard

- **Instruments: DMM and VOM.**

- **Cables, Etc.**

0	0	Preto x 1	Prata $\pm 10\%$
1	1	Marrom x 10	Ouro $\pm 5\%$
2	2	Vermelho x 100	
3	3	Laranja x 1.000	
4	4	Amarelo x 10.000	
5	5	Verde x 100.000	
6	6	Azul x 1.000.000	
7	7	Violeta	
8	8	Cinza	
9	9	Branco	

2. Diagram of the circuit



Resistors are the most commonly used components in a normal electronic circuit.

The ohmic value of a resistor can be determined by the colored bands painted on its body, according to the previous table.

The first track to be read from left to right is the one that is closest to one of your terminals.

3. How Works the circuit

This experiment is for you to make measurements of the ohmic value (resistance) of several resistors. With this, you get to familiarize yourself with resistors, DMM, and VOM.

The multimeter used to measure the ohmic value of a resistor, circulates a small electric current through the resistor, causing a voltage drop in it. This voltage drop is measured by the DMM or VOM, already on a Range calibrated in ohms. This small current that flows through the resistor being measured is supplied by the batteries or batteries that power the DMM and VOM.

4. Assembling the circuit and running the experiment.

- . Mount the 100 Ω resistor (brown, black, brown) on the Protoboard, as shown in the photos. If you want, you can mount all the resistors.
- . Connect the DMM to Protoboard, observing the polarity of the terminals and probes.
- . Confirm the value printed on the resistor body (colored bands), with the value given in the DMM. Write down.
- . Repeat for the other resistors.
- . Repeat with VOM, for all values. Remember that for each measured value you will change the Range and the "zero" of the Range needs to be adjusted for each Range.

- . Make a small table with the values obtained with the DMM, the VOM and the nominal value of the resistors. Compare them. See **table** example.

Nominal value	Value measures with DMM	Value measured with VOM
100 Ω	98,7 Ω	102,5 Ω



**Caution: Be careful when attaching components and probes to Protoboard!
Do not force anything!**

5. Tips and observations

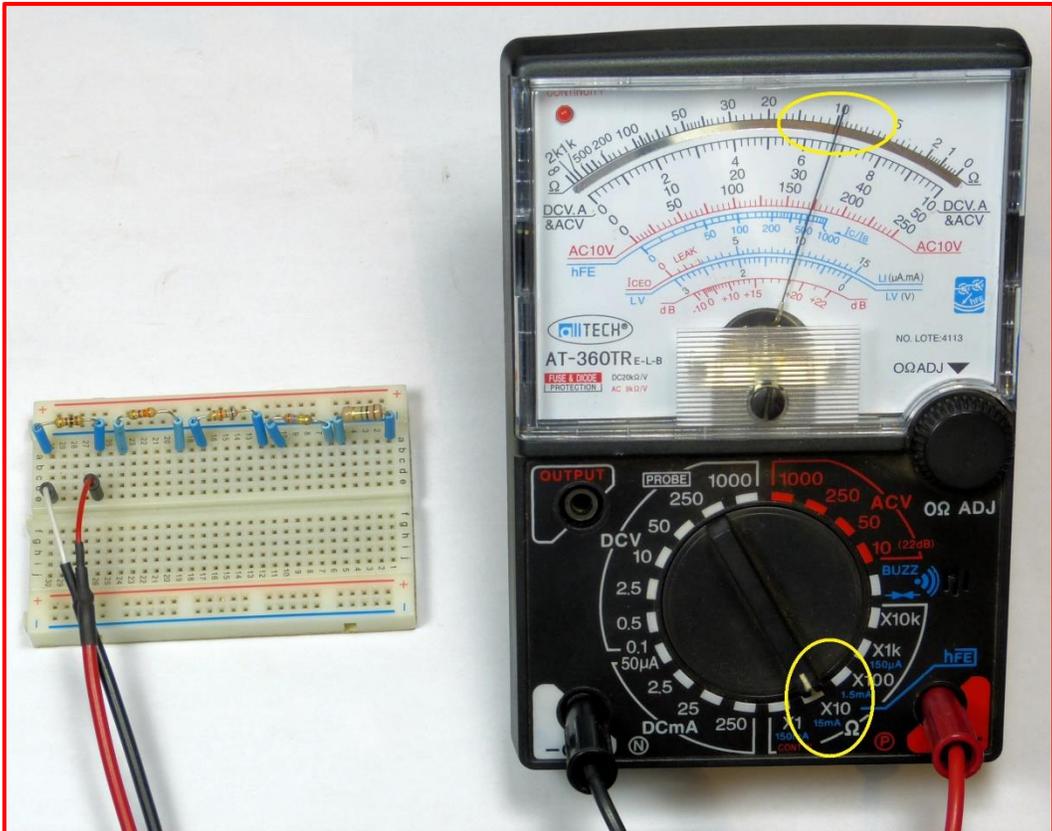
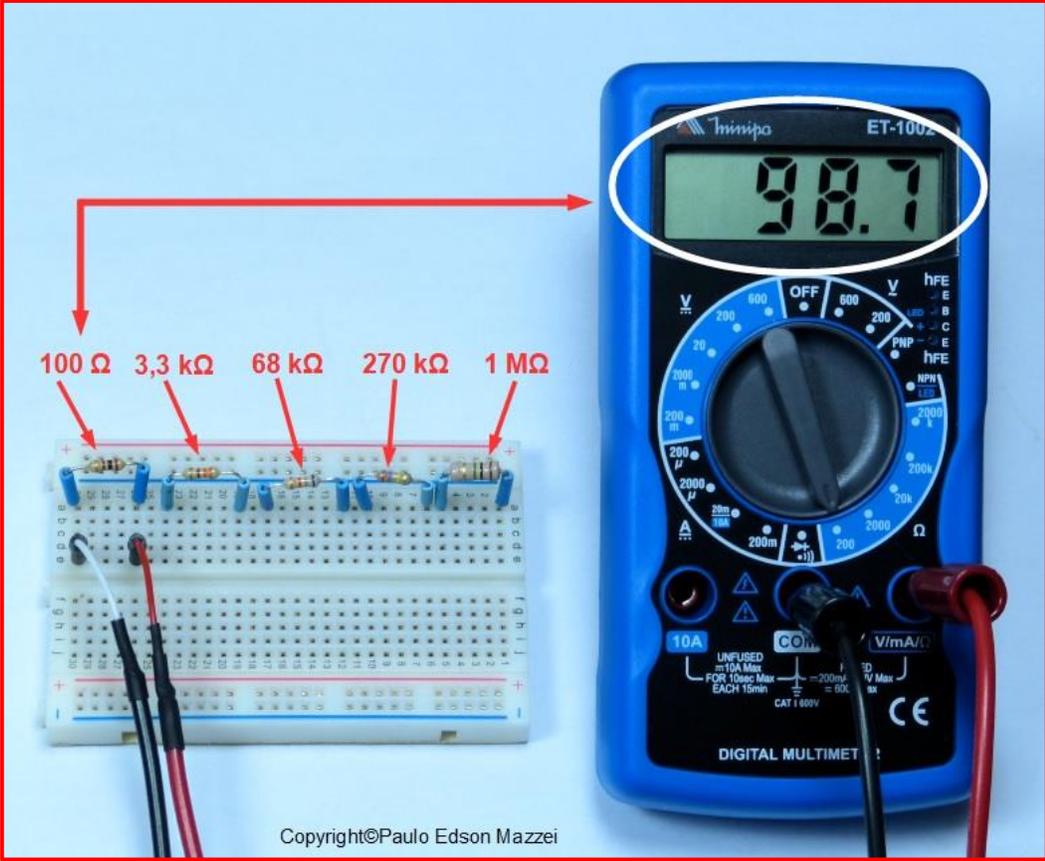
- Check the assembly before proceeding to see if everything is OK. Based on the circuit and the photos on the side.

6. Want to try more?

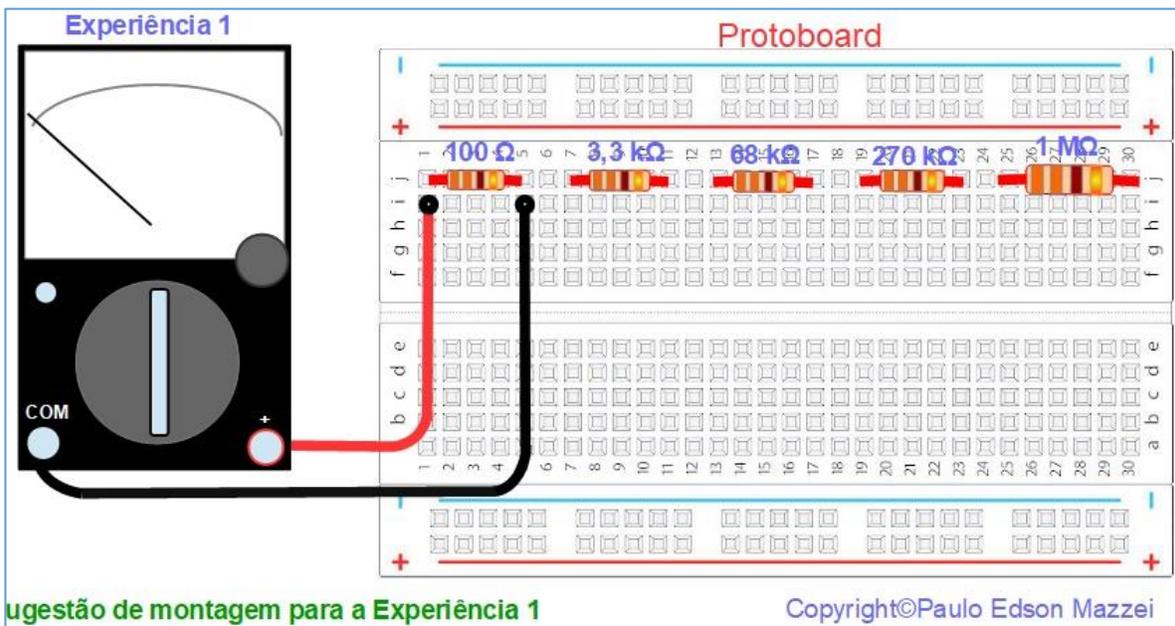
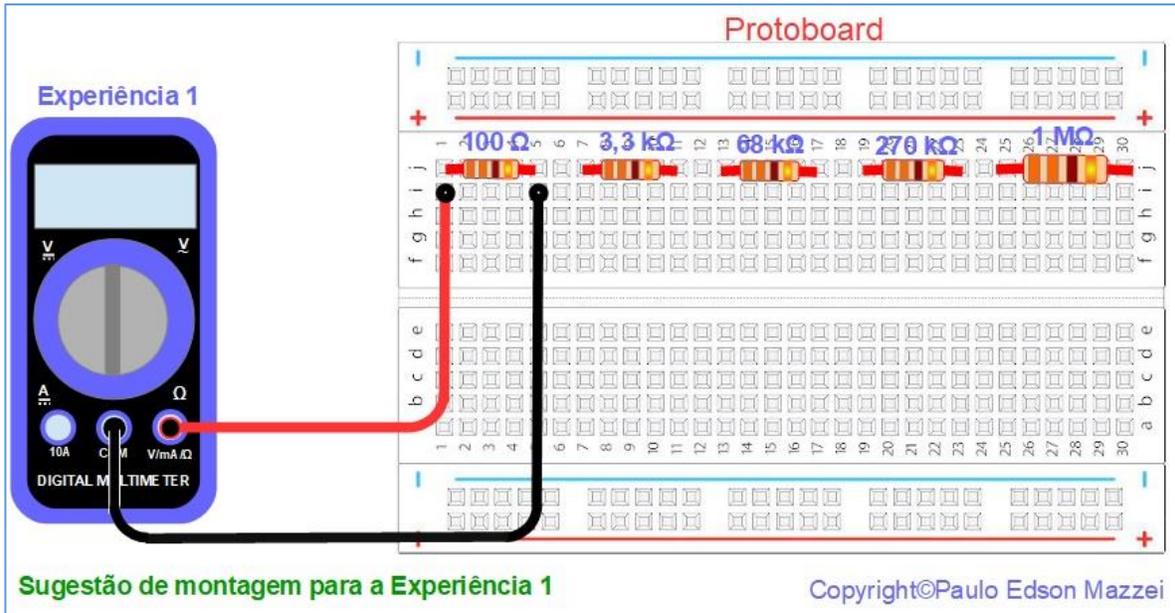


Remember that resistance values are always measured with the resistors out of the circuit. If you are measuring a resistor connected to a circuit of an appliance, make sure that the appliance is completely off.

- Check what happens to the reading if you change the polarity of the probes.
- What happens when a 1M Ω resistor is measured on the 200 Ω range?
- What is the best Range for measuring a 100 Ω resistor?
- See if the measured resistors are within the tolerance stated by the manufacturer.
- the 1 M Ω resistor is larger in size. Why?



6. Additional Information



Experiment 2

Resistors in series and parallel.



Read all this text before the experiment.

Objectives

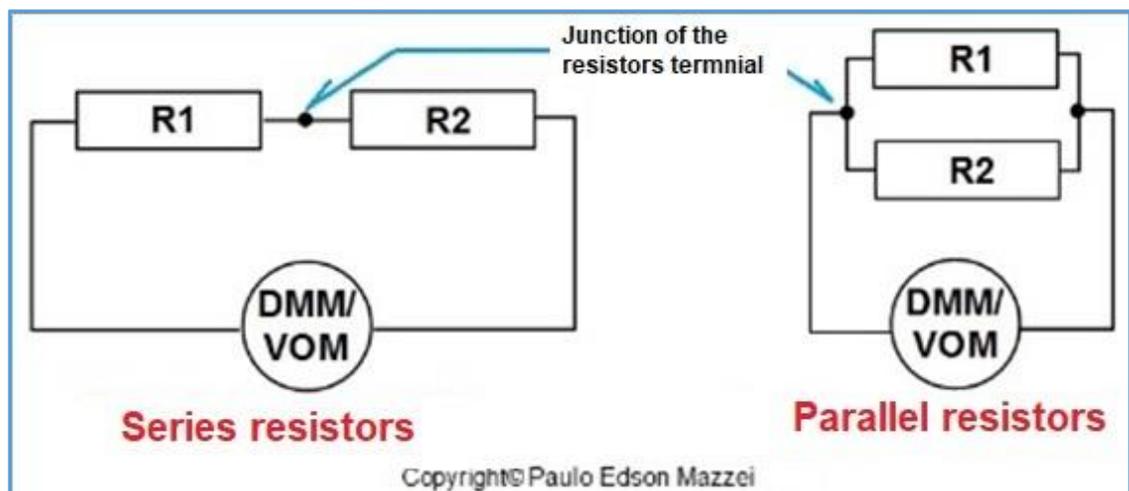
You will learn to associate resistors in series and parallel and confirm the ohmic value obtained with Ohm's Law. With the use of DMM - Digital Multimeter and VOM - Volt-Ohm-Meter Analog, you will confirm these values.

1. Components you will need.

1. Two 100 Ω carbon resistors.
2. Two 10 k Ω carbon resistors.
3. Protoboard

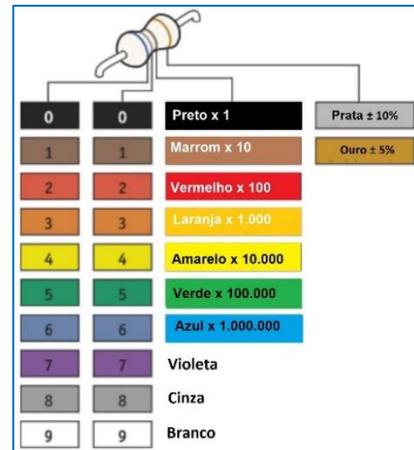
Instruments: DMM e VOM.

2. Circuit diagram



Series and parallel resistors.

Resistors can be associated in series or in parallel, to obtain other ohmic values or even to obtain greater power dissipation (in the case in parallel).



0	0	Preto x 1	Prata ± 10%
1	1	Marrom x 10	Ouro ± 5%
2	2	Vermelho x 100	
3	3	Laranja x 1.000	
4	4	Amarelo x 10.000	
5	5	Verde x 100.000	
6	6	Azul x 1.000.000	
7	7	Violeta	
8	8	Cinza	
9	9	Branco	

3. How the circuit works

This experiment is for you to prove what happens to the ohmic value of some resistor values when they are connected in series or parallel. At the same time, you continue to familiarize yourself with DMM, and VOM.

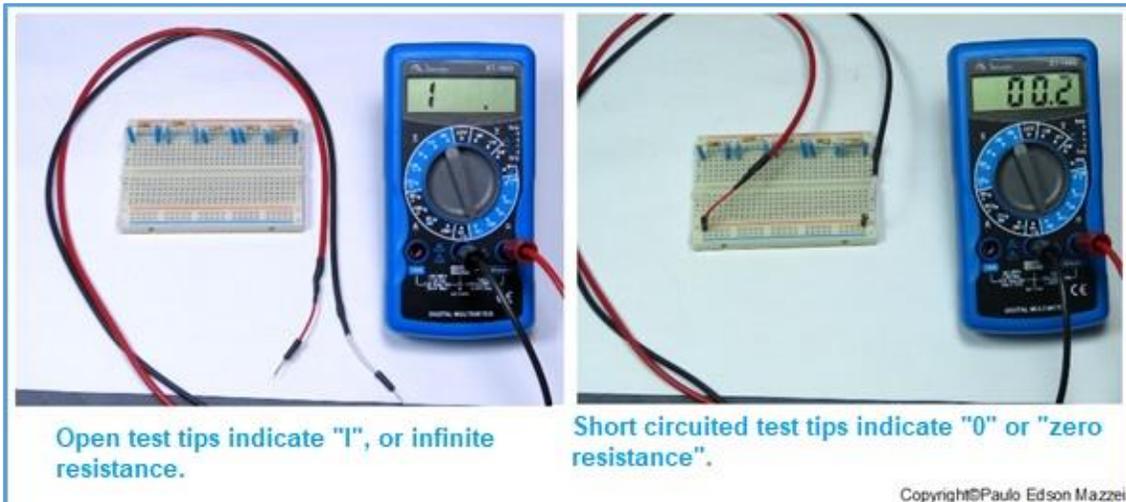
4. Assembling the circuit and running the experiment.

- Mount the two 100 Ω resistors in series on the Protoboard as shown in the pictures and drawings.
- Connect the DMM to your LEE, observing the polarity of the terminals and probes.
- Confirm the value of this resistor association, with the value read in the DMM.
- Repeat the reading with the VOM. Remember that for each measured value you will change the Range and the "zero" of the Range needs to be adjusted for this new Range.
- Mount the two 100 Ω resistors in parallel on the Protoboard as shown in the pictures and drawings.
- Confirm the value of this resistor association, with the value read in the DMM.
- Repeat the reading with the VOM
- Repeat all measurements for the two 100 kΩ resistors: series and parallel.

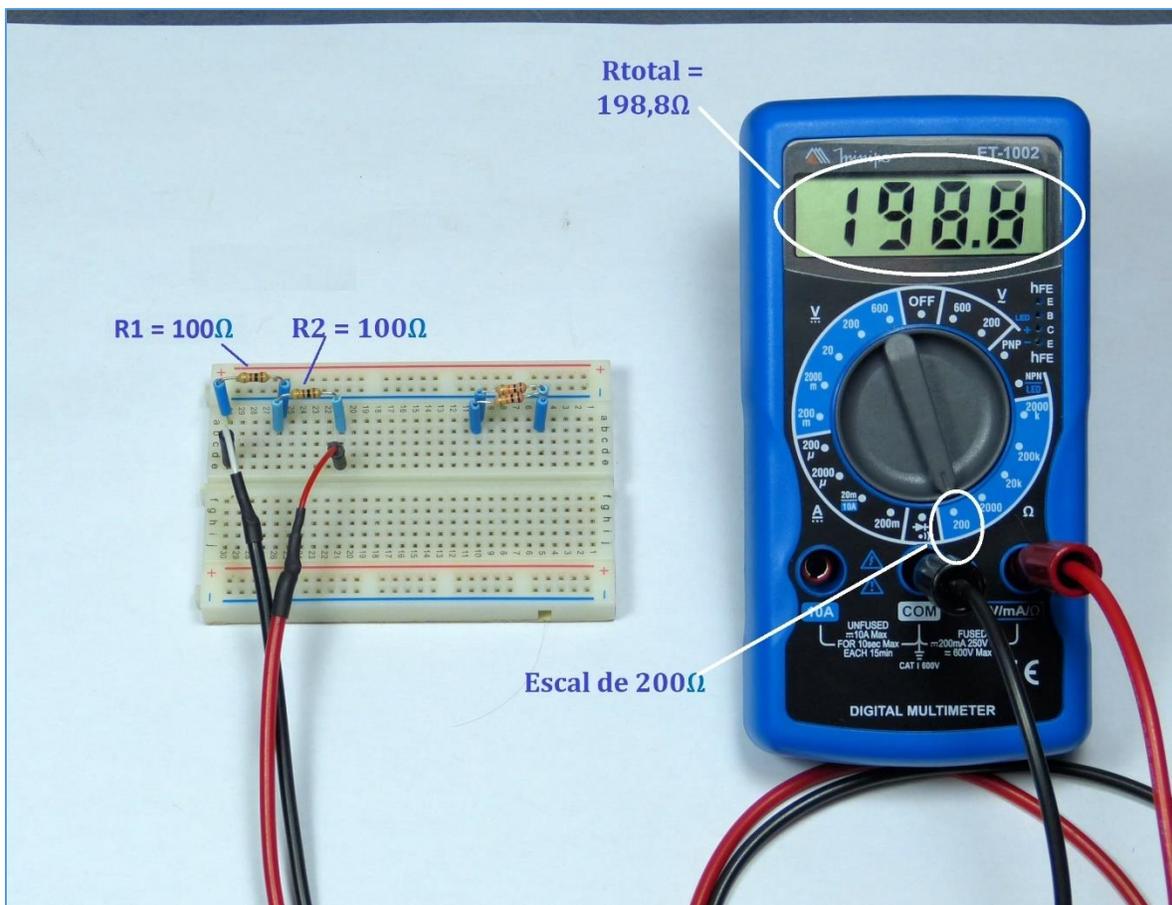


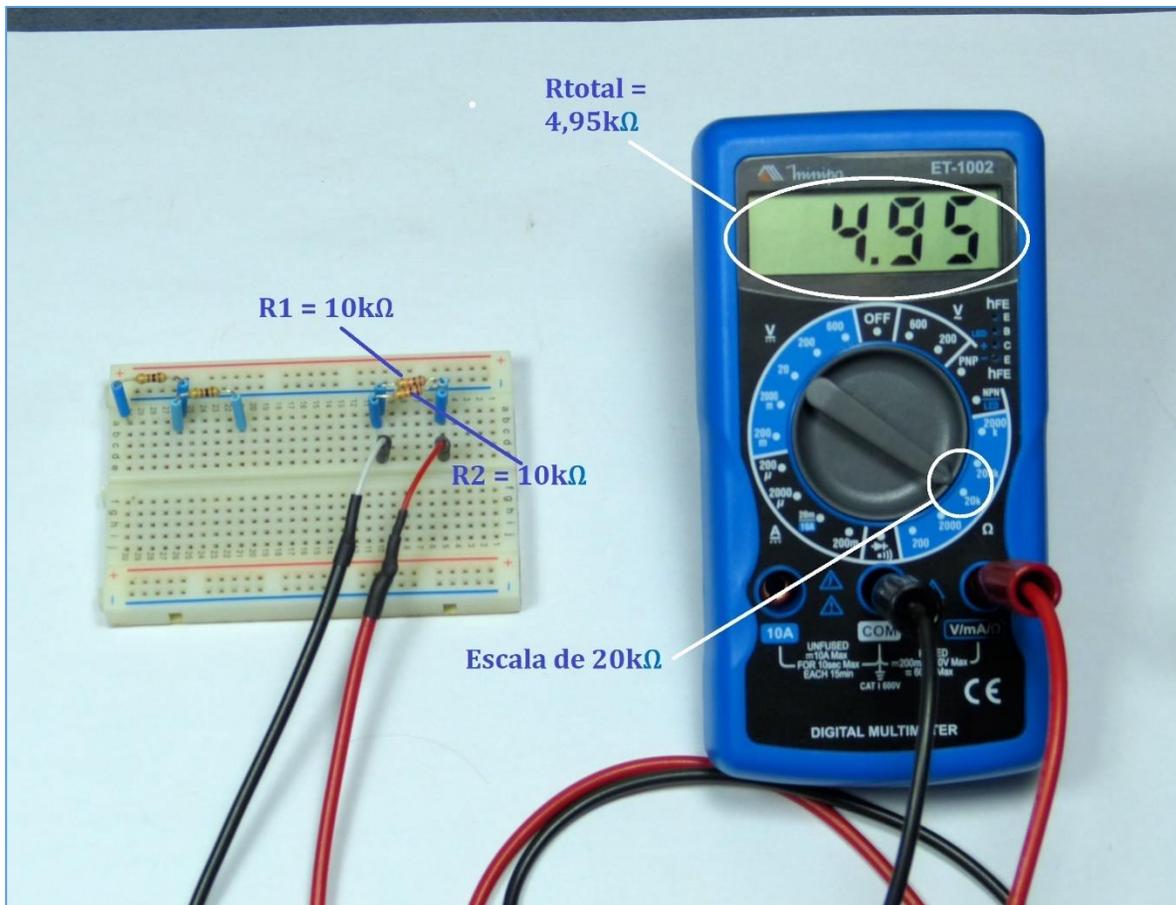
**Caution: Be careful when attaching components and probes to Protoboard!
Do not force anything!**

5. Tips and observations



Check the assembly before proceeding to see if everything is OK. Based on the circuit and the photos on the side.





6. Want to try more?



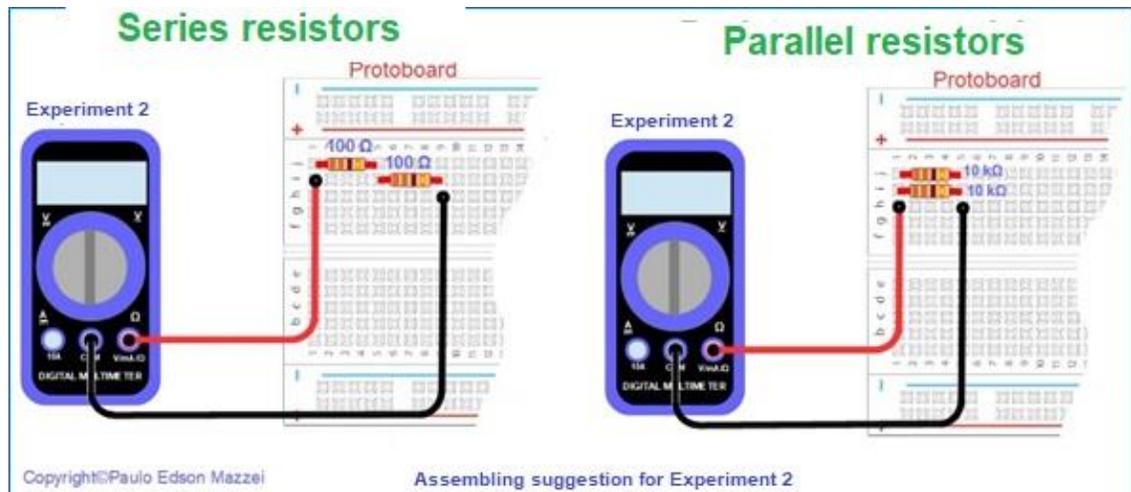
Remember that resistance values are always measured with the resistors out of the circuit. If you are measuring a resistor connected to a circuit of an appliance, make sure that the appliance is completely off.

a. Use Ohm's Law and its derivations to calculate the values obtained in the series and parallel associations. Verify that these calculated values are approximate to the values measured in DMM and VOM. See recommended reading.

b. Associate more resistors in series and in parallel and see if the mathematical calculations are approximate to the values measured in the DMM and VOM.

c. See if the measured resistors are within the tolerance stated by the manufacturer.

Additional information



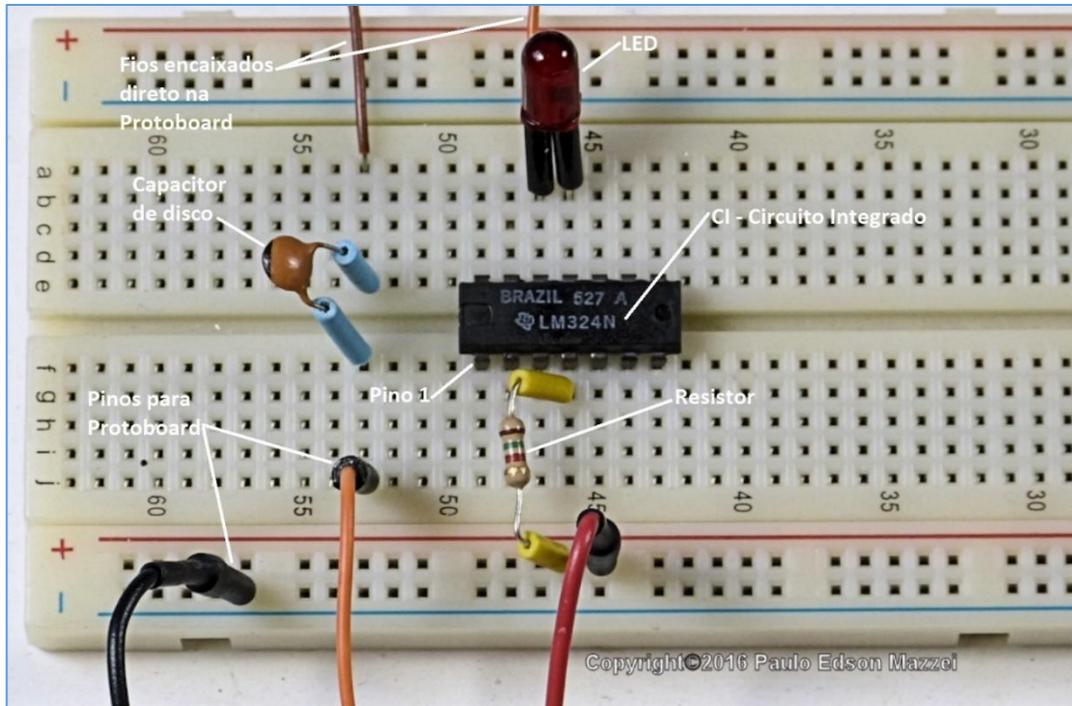
- Inserting components in the Protoboard



Attention: Only insert the wires, cables, and component terminals into the Protoboard, with the power turned off, either from the battery pack or from external power supplies!

The wires, cables and components to be inserted into the Protoboard require special attention so that you do not damage them.

- a. The wires should be inserted vertically until it touches the bottom of the metal contact. The same for the terminals of the components.
- b. Special pins for use on Protoboard also require this care. Sometimes, when they are very long, they tend to tilt the pin, due to the weight of the cable. Make sure this does not happen.
- c. In the case of electronic components, fold the terminals of the electronics into a 90-degree angle and see to it that they do not touch. A well-made mount spends the same time as a sloppy mount and still gives less errors!
- d. If necessary, insulate the terminals of the components with small pieces of colored wire covers.



Correct mounting of components on the Protoboard. See text.

What if I have a problem with my experiences?

The circuits presented here, used for you to assemble your experiments, have been tested, as well as their variations when appropriate. When nothing works, turn off the power to the battery pack using the on / off switch.

After everything is off, pause, have a coffee or a beer (one!) And go back to your circuit.

Let's look at some issues that may be occurring for you to stay tuned.

Protoboard supply

- ▶ If you have turned the power switch on, everything has gone out, some component may have failed. Study your assembly all over again to try to find the problem.

- ▶ Make sure that the batteries are correctly seated in the cradle and that they are new. Preferably always use good quality alkaline batteries. Do not use batteries with "unknown geographical origin" ...

- ▶ As you already know how to do basic measurements with the VOM and DMM, measure the output voltage of the batteries at the output of the power supply.

Voltages, with batteries in good condition, should be around the value marked on the labels.

Common components

- ▶ Check if any leads are touching other terminals. If necessary, insulate with a small piece of yarn cover.
- ▶ Is the connection of the component terminal, wire or cable, the Protoboard connection firm, securely in place? Check them all!
- ▶ Are you using all correct components in the circuit? Work in a well-lit place because the colored bands of the resistors can deceive ... In doubt, measure the resistor with VOM or DMM.

Semiconductors

- ▶ Check that the diodes are installed correctly, with cathode and anode in their proper places.
- ▶ Transistors have three terminals. Are these terminals in the correct places, marked on the circuit as base, collector and emitter?
- ▶ Check the semiconductor (diode, transistor, or CI) if the model you are using is marked on the body of this semiconductor. Use a magnifying glass if necessary, to read what is written on the component body.
- ▶ Beware of IC pins. Often, by fitting them into the Protoboard, the terminals fold under the IC's body, leaving the assembler crazy!! Check this out when using CI in your experiments.

Cable, wire and test tips (probes)

- ▶ Check wires, cables, and probes. Yarns will hardly cause you a sleepless night! But cables, especially where there are welds (cable + pin banana), may present problems with use. Measure continuity with your VOM or DMM.

General

- ▶ Do not make modifications to the circuit of an experiment before you assemble the original experience detailed in this eBook.
- ▶ It is often easier for you to totally dismantle the circuit with problems than to try to repair it. Reassemble it with double the attention that will work. If you continue to give problems, you may have some defective component.

▶ Semiconductors are the easiest to cause problems. For testing, try to replace with a new one or use that of experience in another experiment to see what happens.

▶ Finally, we are human like you and we may have made a mistake. Contact us therefore it will be a pleasure to receive your comments and suggestions!

Chapter 9

How to Power a Protoboard for Your Projects and Experiments

Introduction

Every time we set up a circuit or project on our Protoboard, we need to power it so that it produces the expected effects: a sound, a light, a movement, the triggering of something, etc.

This power supply can come and be connected to the Protoboard in several ways.

1. Through the computer's USB port.
2. Using an external power supply.
3. . A battery or battery pack to provide the necessary power.

Powering from the USB port

When you have a board ready with the design you will use, probably the board manufacturer will ask you to use a USB port on your computer, to power the board with 5 V. The voltage at the USB port is 5 V by default.

For example, the Redboard® from SparkFun Electronics is powered by a USB cable that comes with the card and allows it to be connected to the USB port of a computer. The same occurs with the Arduino Board, where you power it through the USB port. This USB cable, at one end, has a normal USB port and at the other end has a mini USB connector, as shown in **figure 55**.

Using an external power supply

An external power supply is an electronic equipment that provides adjustable excitation to power an electronic circuit. Power supplies are the most common equipment in countertops, but it is of enormous importance to those who assemble many designs or make many experiments. See an example power supply in **figure 56**.

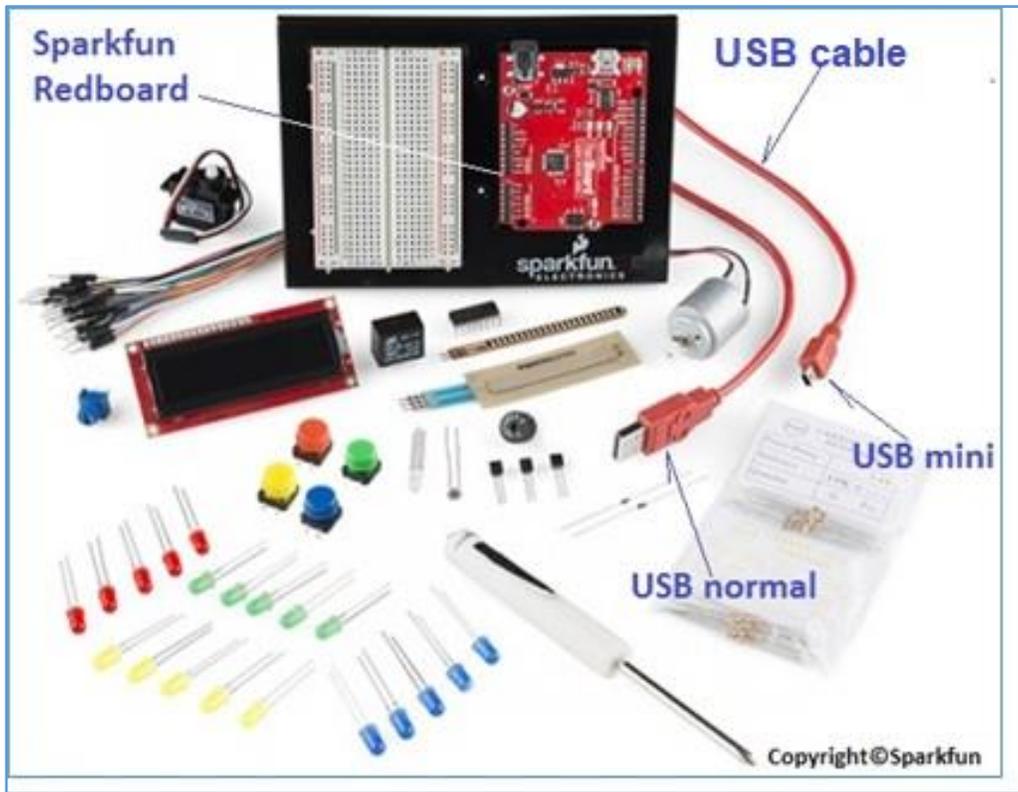


Figure 56 - Sparkfun Electronics Redboard kit. Look for the USB red cable. Courtesy Sparkfun Electronics.



Figure 57 - Variable and regulated power supply. Copyright © Minipa Brasil

As can be seen from **figure 57**, the source of the illustration has two white buttons which allow to vary the output voltage it provides and adjust the output current to certain values. Output cables, with alligator claws at the ends, allows to connect the power supply to the circuit to be fed.

As an external power source, it can be used in socket adapter, known as battery charger in mobile phones, iPad, tablets, etc. These chargers have fixed output and a certain current capacity. It is important to check whether it meets the needs of the circuit you are going to power, both in terms of voltage and current. See **figure 58**.



Figure 58 - Wall charger. Input 127 or 220V AC and 5V DC output. There are chargers for various output voltages.

How many volts will I need for my project?

This is a difficult question to answer because it depends on each type of circuit.

Batteries

With batteries to power your design, you will have fixed voltages at certain values, depending on the voltage of the batteries.

Batteries are specified by their ability to supply current during the period of one hour. This value is printed on the body of the unit and may be marked as Ah (ampere / hour) or mAh (milliamperes / hour).

A battery marked 1600 mA / h, when fully charged, can provide a current of 1.6 A (1600 mA) over a period of 1 hour.

When you use batteries to power your projects, think about the problem of size, space they occupy, and weight.

Also, it is important to check how they will be connected to the circuit, since the vast majority of batteries do not come with wires for your connection.

To learn more about batteries and batteries, read the excellent [Wikipedia](#) article (in English / Spanish).

Batteries association

We can associate batteries in series to obtain higher voltage. The batteries must be of equal voltage and of the same type. Do not mix alkaline batteries with standard batteries. Do not mix rechargeable batteries (1.2 V) with standard batteries (1.5 V).

See **figure 59** for how this stack association can be made.

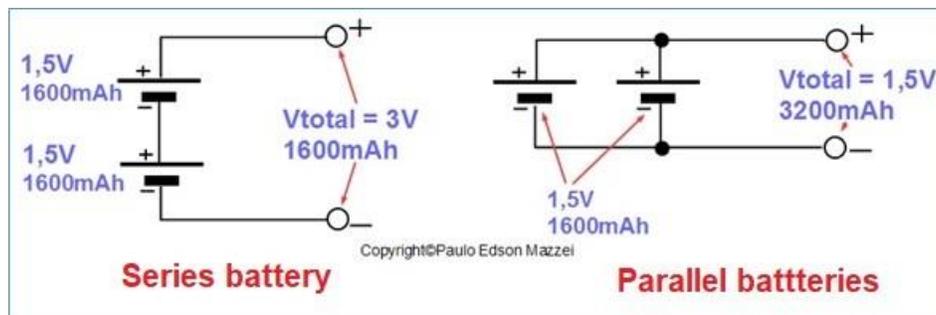


Figure 59 - association of stacks in series and in parallel.

Note that:

- When we need higher voltages) we use batteries in series. The electric current keeps the same value as one of the batteries.

- When we need higher currents, we use batteries in parallel. The voltage remains the same as one of the batteries.

How many amps will I need for my project?

If you know the current required for your project to work, it is easy to determine the current to be supplied by the batteries.

If you do not know which current your project requires, use the digital multimeter on the DC Current Range to measure.

Let us assume, that our design requires a voltage of 9V and a current of 80 mA, to function properly.

In this case, we chose to:

- ▶ six 1.5 V alkaline batteries connected in series ($6 \times 1.5 \text{ V} = 9 \text{ V}$).
- ▶ alkaline batteries with an average capacity of 2,000 mAh (2 Ah).

With these values in hand, we can calculate how long the batteries will last, powering the circuit in question:

Battery life = Requested battery / current capacity

Battery life = 2 Ah / 0.08 A = 25 hours

However, "in practice the theory is different" ... In fact, let's get a slightly smaller life for our cells.

As an alternative to using your 1.5 V batteries in series, we can use a 9 V battery, but with a shorter service life, as its current capacity is also lower.

Please note:

In several countries, a single unit of around 1,5 V is called "pile". Battery always have voltage greater than 3 V.

- Pile is a simple unit that always provides voltages around 1.5 V.
- Batteries are units made up of multiple piles, with voltages ranging from approximately 3 V to 24 V. Or more!
- If you use the term battery for a 1.5 V pile, don't worry, continue!

See **figure 60**, with the graphic symbols used for batteries. Also, in this figure you can see the supports that allow the connection of batteries to a circuit.

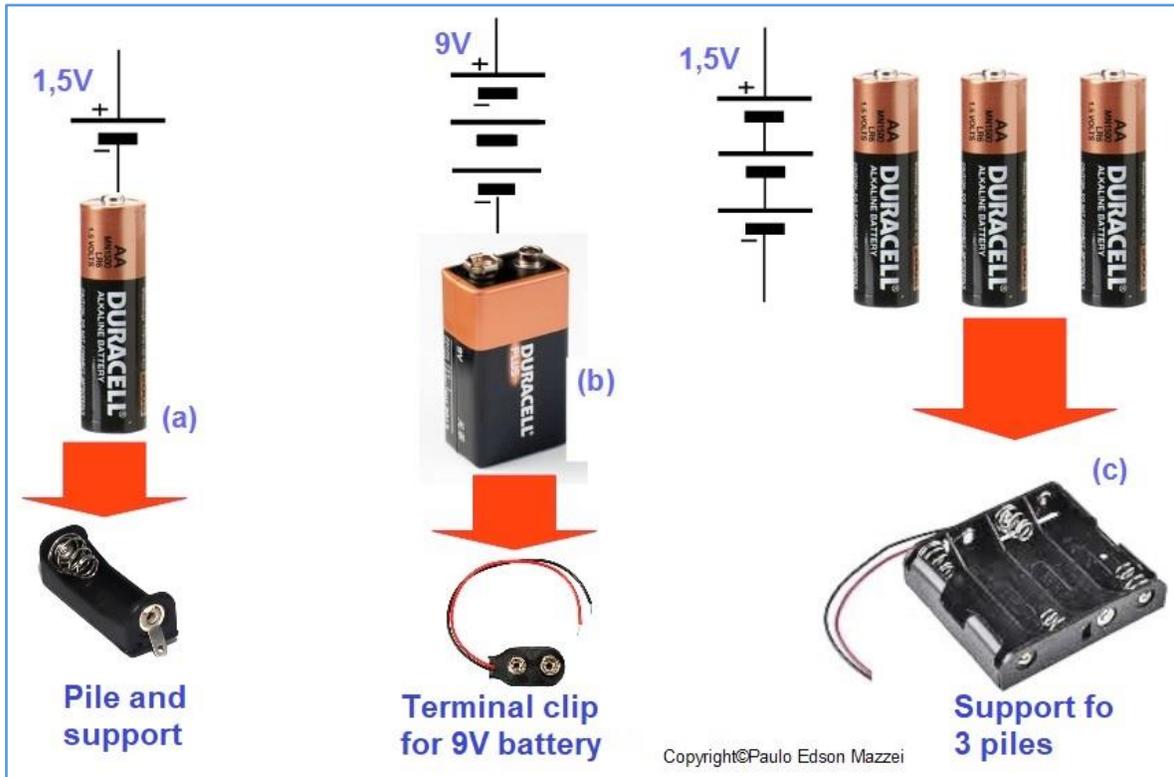


Figure 60 – Piles and batteries. Graphic symbols and connection brackets.



Figure 61 - Two useful supports to power an experience.

For an idea of how a battery runs out and how long it lasts, see the graph of **Figure 62**, where a 1.5 V Energizer® brand, AA battery is analyzed.

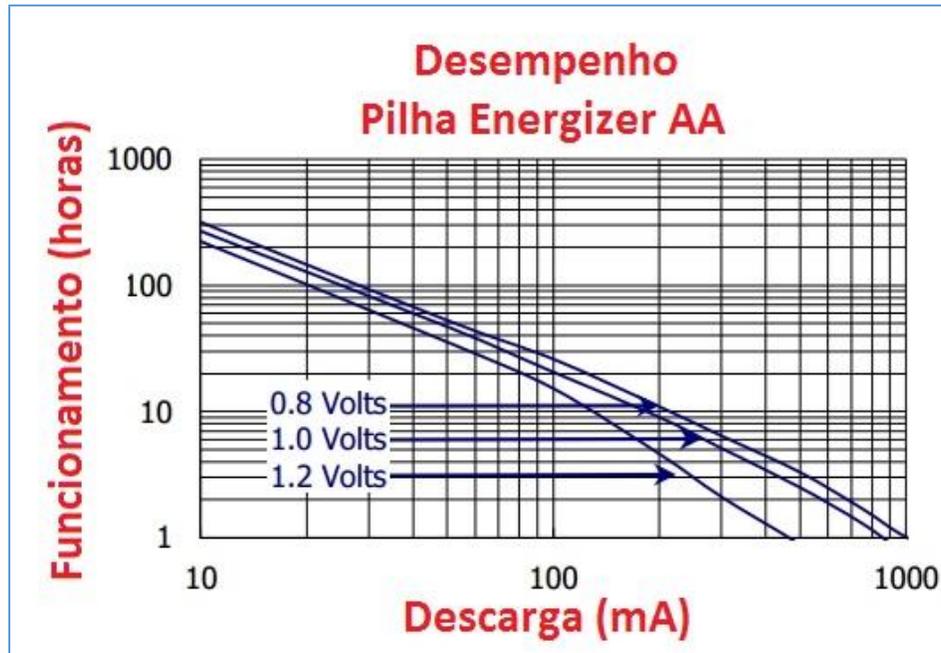


Figure 62 - Performance of an Energizer® pile (or battery), type AA. ©Copyright Energizer.

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Chapter 10

Building a Power Supply for Your Experiments

Introduction

In the previous chapter you saw various ways to power your experimental circuits, using batteries, batteries, AC power, etc.

In order for you to no longer have expenses and also be able to use some of your manual skills, we will build a personality power supply for your experiments.

In reality, there are several ways for you to build this power supply, from the simplest, as discussed here, to more sophisticated models, with box, terminals for voltages, etc.

If your money box is high and you have the tools you need, feel free to do it!

Basic Requirements

- Output voltage: maximum 9 VDC
- Batteries or batteries? AA batteries, 1.5 VDC each, preferably alkaline.
- Battery usage: lower cost and longer battery life than 9 V battery.
- Possibility of having outputs for voltages of 1,5 V, 3 V, 4.5 V, 6 V, 7.5 V and 9 V without the use of wrenches.
- Voltage output system as simple as possible.
- Built-in on/off power switch.

The simplest idea

Due to the simplicity, we soon think of locking the two- batteries supports, in a piece of wood, thinking in an output system for the various voltages and that's it.

After a few minutes of study, we arrive at the solution described below. See the photos, which illustrate the whole process, step by step.

Preparing the wires

- ▶ Cut 4 pieces of rigid, coated wire with a diameter of about 0.5 mm. Each piece with a different color, with a length of 150 mm.
- ▶ Remove the cover about 20 mm from one end of each thread color. See photos.
- ▶ With the thin-nose pliers, make a small "loop" on the copper part of the wire, which has been stripped. See photos.
- ▶ Fold the loop 90 degrees at the point where it ends in the wire. See photos.

Necessary materials

1. 4 pieces of rigid wire no. 22 AWG
2. 2 battery holders for three AA type batteries, similar to those shown in the figures.
3. 1 piece of plywood, particle board, about 135 mm (l) x 95 mm (w) x 6 mm (e).
4. 1 block of insulated terminals, for 4 mm² cables, with eight access points (eight terminals). It can be purchased at stores of electrical materials.
5. 1 slide switch, on / off type.
6. Screws for the battery holder and terminal block.
7. Tools: pliers, screwdriver, etc.

Fit the prepared wires in the battery holders

Look at the photos, how the prepared wires were fitted into the metal rings and holes of the battery holders.

Carefully note how the "loop" we have made before is located next to the battery holders' springs. When you insert the batteries into the battery holder, this prepared wire is stuck between the battery body (negative terminal, spring) and the battery holder body.

Despite seeming "no good look", the result was good. You will only touch these wires when you change the batteries, which will take a long time ...

Here comes the question: why not weld the direct wires at the correct points on the battery holders? The battery holders you normally find on the market, made

of thermoplastics, are rubbish and if you get the welder close, they melt. With enough care, experience and an appropriate welder, it can be done. We do not advise you right now.

See in sequence the photos, which are self-explanatory. Figures 63 to 66.

Assembling step by step

1. Prepare the piece of wood with the recommended measures. Use sand paper to give it a good finish. If you want, paint a bright color.

2. Make a small layout of how your power supply will be. If you want to be based on the source described here.

3. Attach the two battery cells. Keep the batteries in place so that they hold the wires in place. Use two small, wood screws, tapered head.

4. Attach the insulated terminal busbar using two small, self-tapping screws.

5. Interconnect the wires of the two battery holders with the terminal bar contacts insulated. See the connection diagram. Pay close attention to the connection points of the wires, depending on the voltages. See I used different colors of wires for each voltage.

6. Place small adhesive labels at each voltage point, such as 1.5 V, 3.0 V, etc. Note that I put a plastic strip next to the contacts, and on this strip, I put the tags together. This plastic strip also hides the wiring of the connections, giving a better look.

7. The two-black plastic "tubes" are just to hide the wires from the fittings and improve the finish. They are optional. You can use shrinkable tube used in electronic assemblies.

8. After everything is done, insert the batteries and test the voltages with your DMM and see if it is in the correct sequence.

Congratulations, the power supply for your experiments is ready!

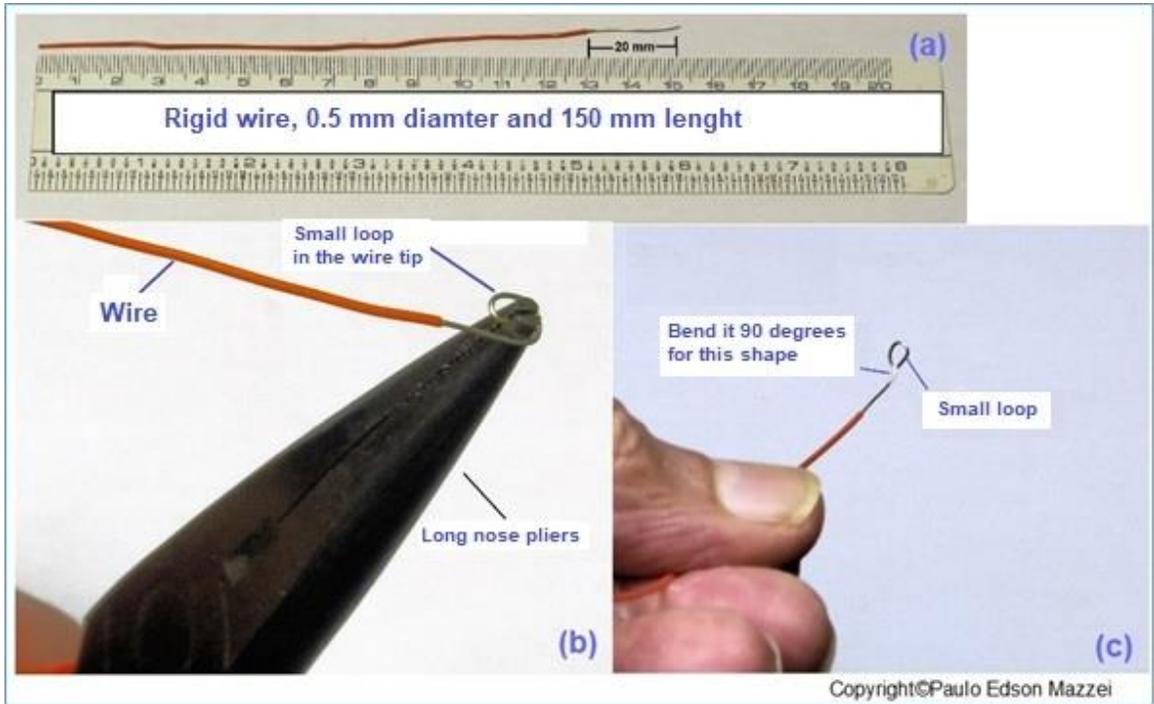


Figure 63 - Preparing the small loop in the tip of the wire.

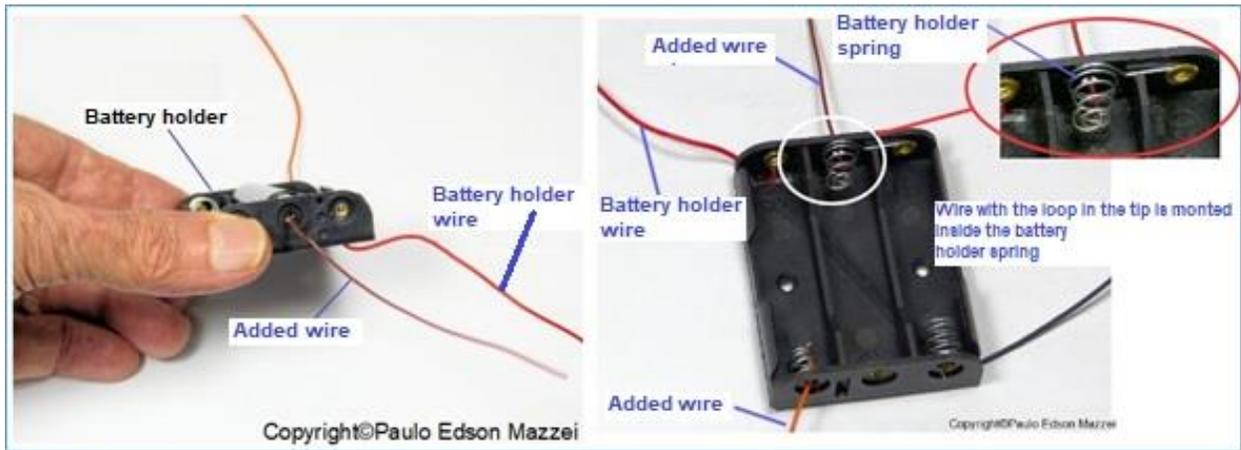


Figure 64 - Mounting the 150 mm insulated wires in the battery holders.

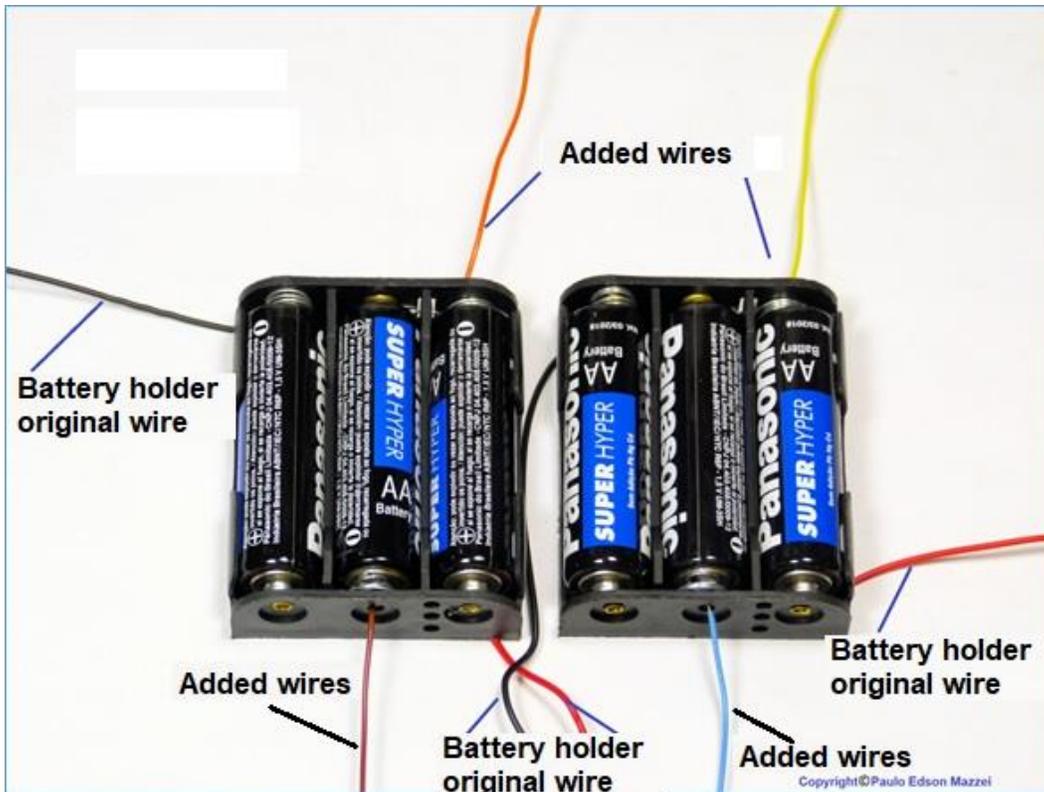


Figure 65 Look for the added wires to the battery's holders.

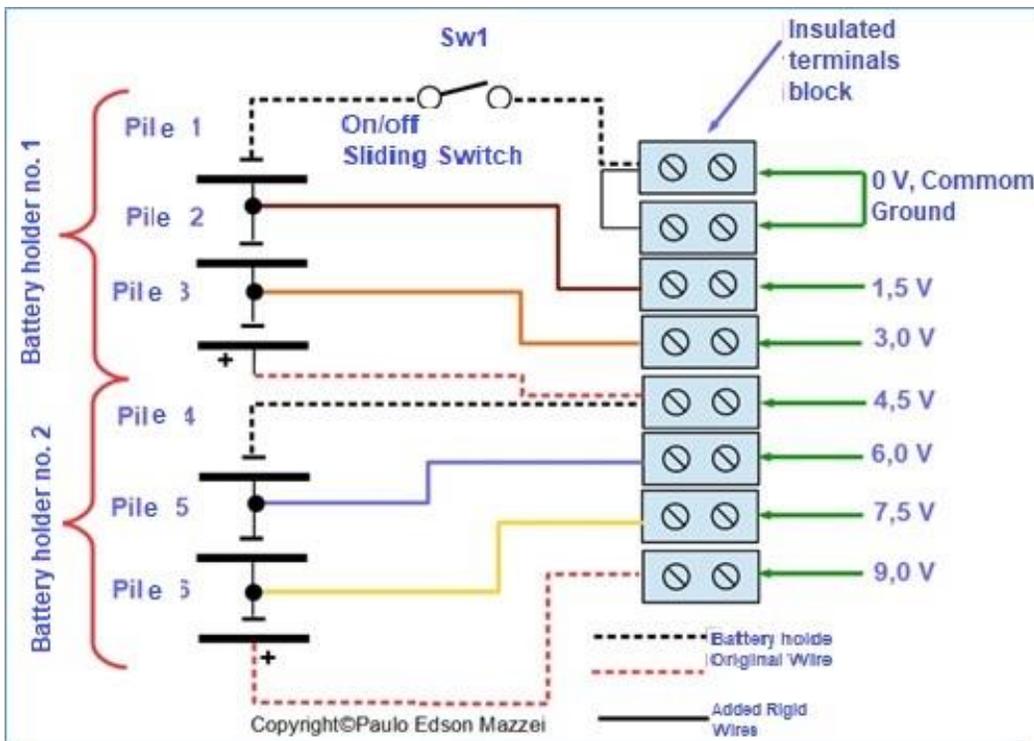
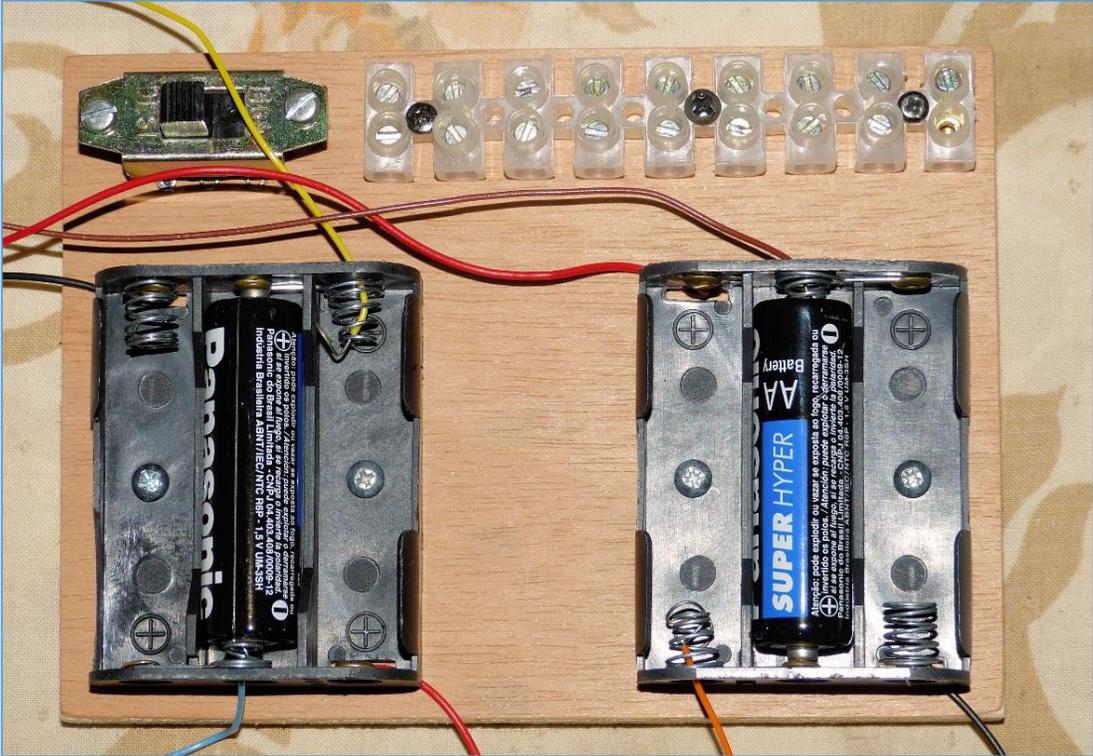
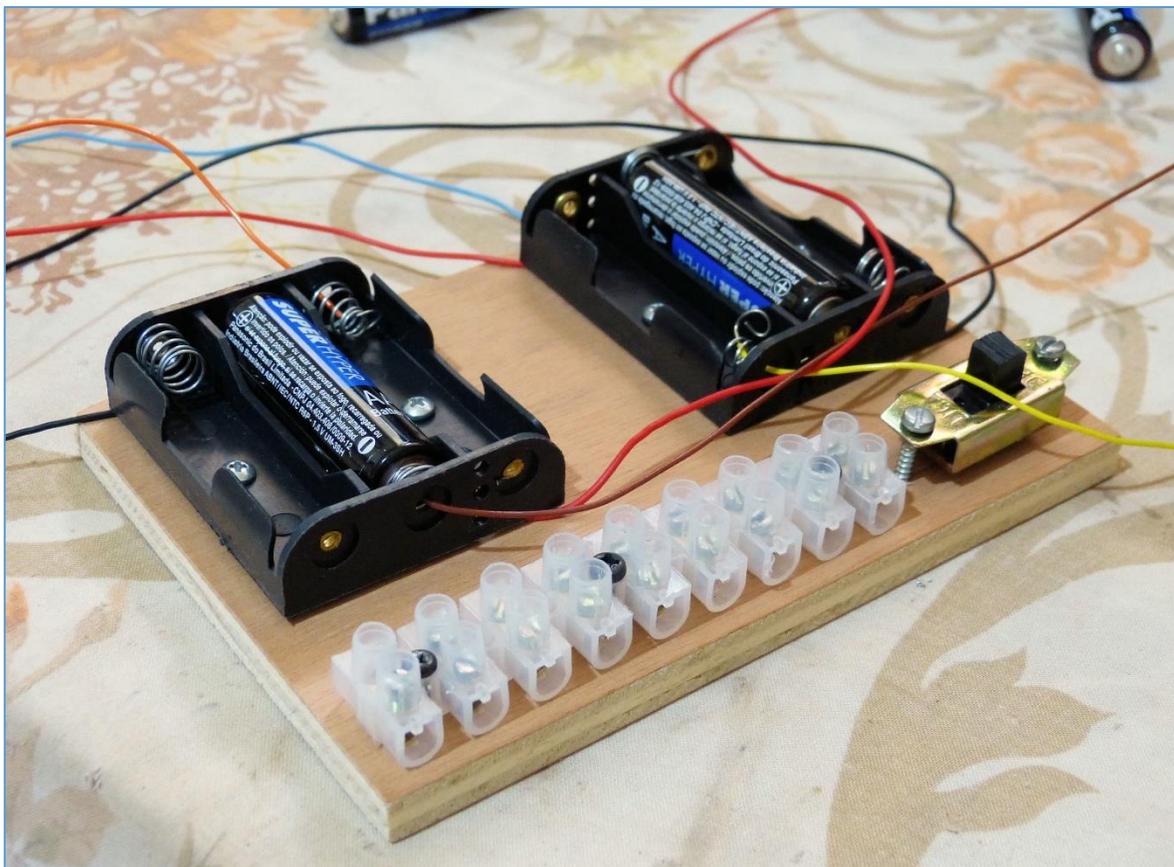
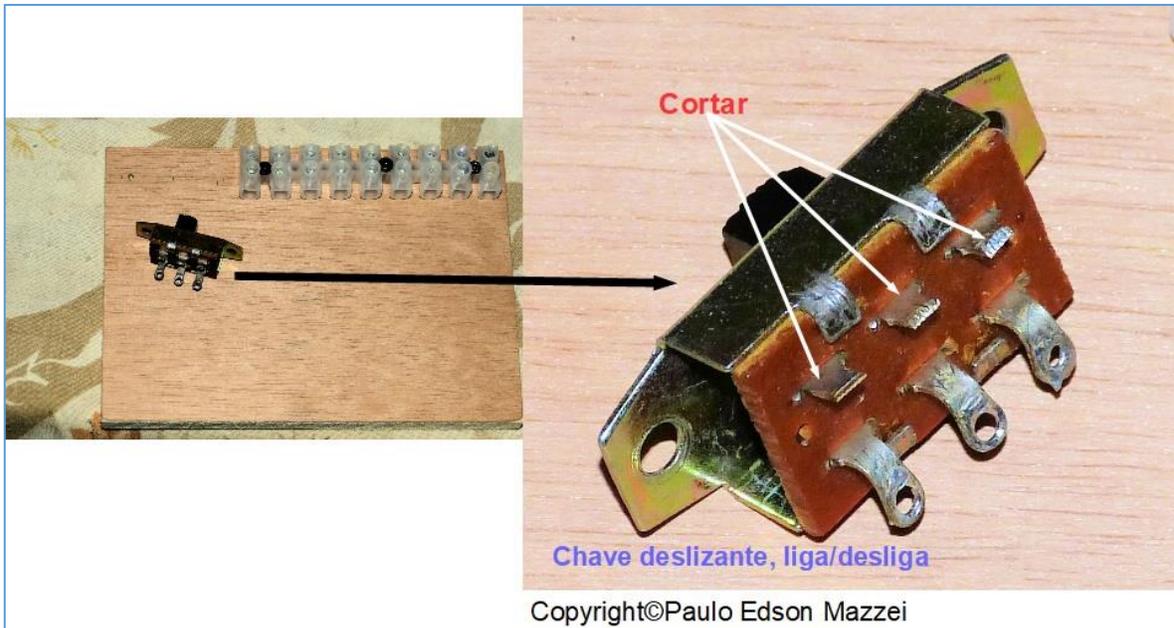


Figure 66 - Homebrew power supply circuit

More photos of the homebrew power supply.





Measuring the output voltages of the power supply

With the power supply ready, we can check the output voltages at each of the insulated connector block terminals. Use your digital multimeter for this.

Remember that the batteries are new and are not connected to any circuit and because of this, the voltages you will get, will not be exactly 1,5 V and 1,567 V, for example.

Note also that we leave two terminals for the 0 V (earth or common point), so we can have different voltages in the same circuit. In my photo you will see that I put a terminal bar with 9 terminals and not 8. No problem, leave a reserve.

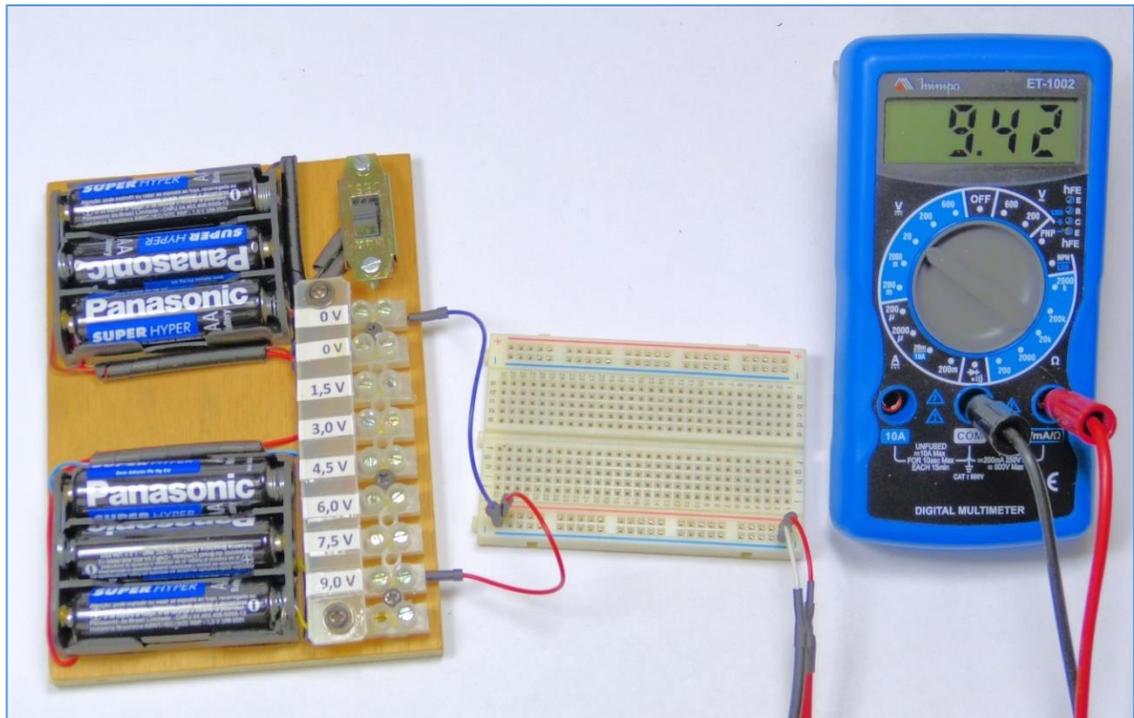


Figure 67 - The highest voltage of the power supply is measured as 9.42 VDC.

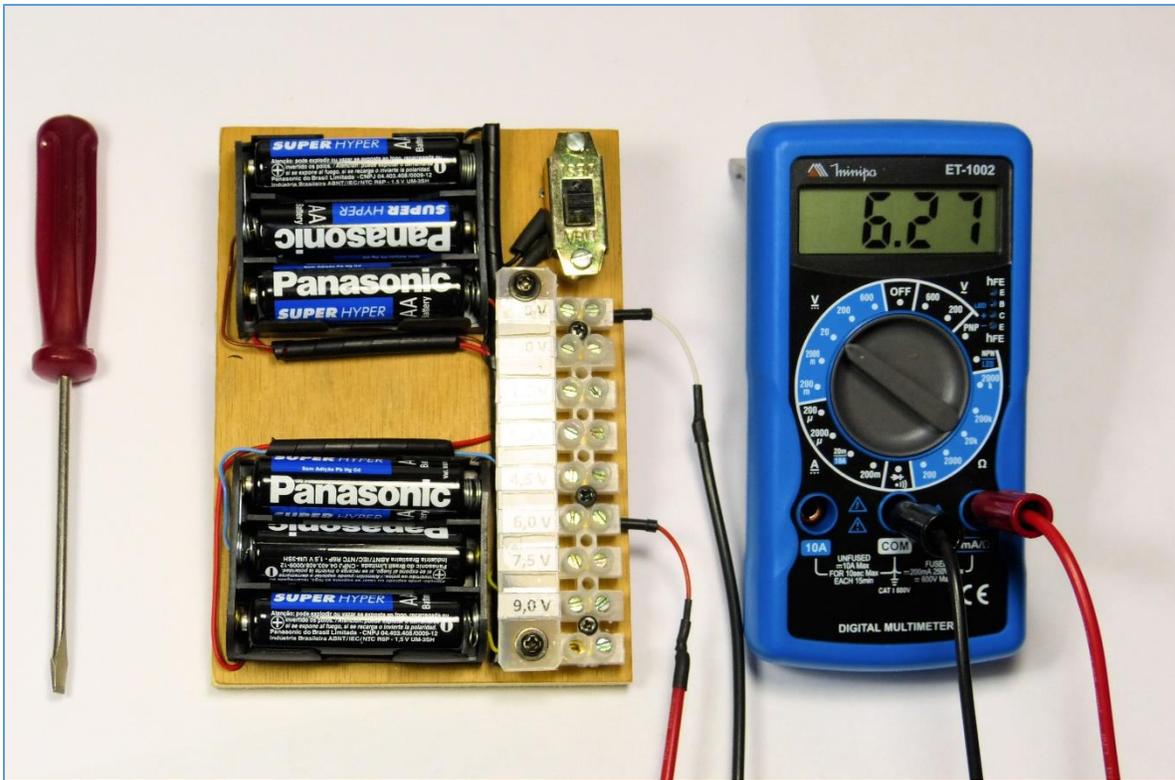


Figure 68 - Measuring the voltage at the "6 VDC" point.

We could use the diagram in **Figure 69** to represent our power supply, as shown in **(a)** of the figure.

In order to simplify the circuit drawings, let's use the common representation for cells and batteries, indicating next to the symbol which voltage will be used, with in **(b)** of the figure in question.

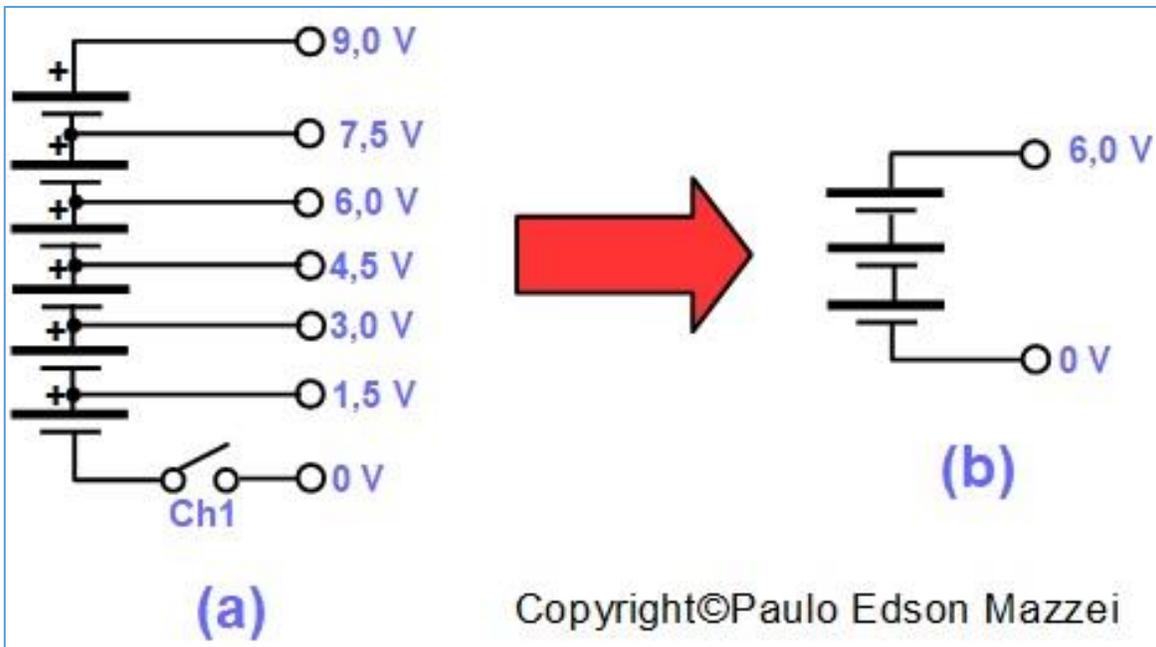


Figure 69 - Circuit representation of the power supply.

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Chapter 11

Electric circuits

Introduction

An electric circuit is any assembly of electrical or electronic components interconnected, which allows the circulation of an electric current (I).

This assembly of electronic components can be tremendously simple as the interconnection of a 1.5VDC battery to a small flashlight, also 1.5VDC.

Or it can be tremendously complex, like the circuit of a powerful computer that performs an unimaginable number of calculations per second!

Objectives

- Identify an electrical circuit.
- Assemble a simple electric circuit.

Example of a simple electric circuit

Let's show a small electric circuit, consisting of a lamp connected to a 1.5 VDC type battery, as shown in **figure 70**.

The battery, with voltage equal to 1.5 V, provides an electric current (electron flow) through its negative (-) pole. This electric current (flux) circulates around the lamp by lighting it and goes towards the positive (+) battery pole.

The battery is the **source of current** and the lamp is called a "**load**". Anything you put in the place of the bulb represents a load to the battery. It could be a small engine, an LED, etc.

There are three types of electric circuit:

- The electric circuit in **series**;
- The electric circuit in **parallel** and
- The **series-parallel** circuit.

Figure 71 illustrates the three types of electrical circuits.

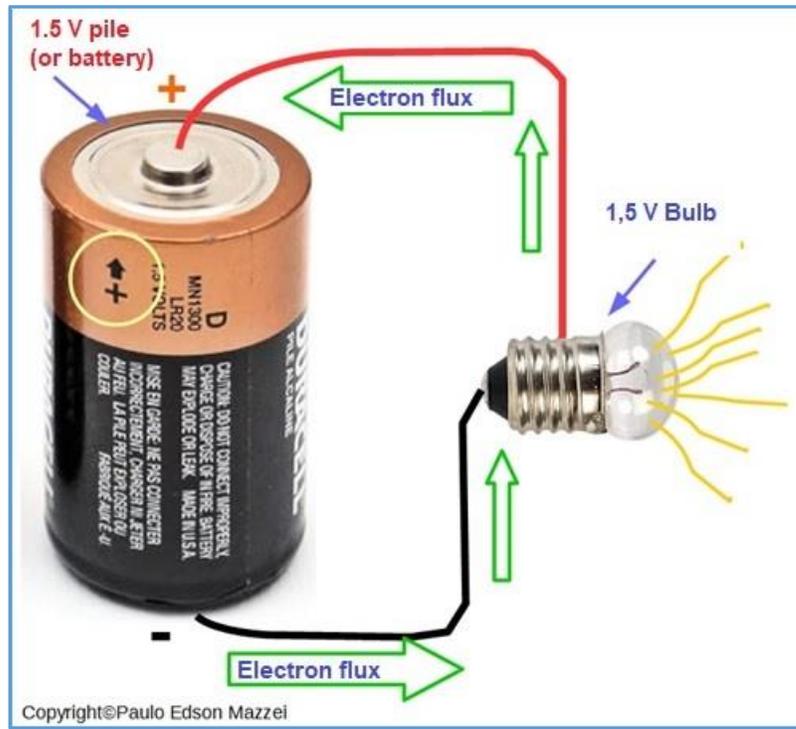


Figure 70 - A very simple electric circuit.

At the moment this is what you need to know and identify the three types of electrical circuits.

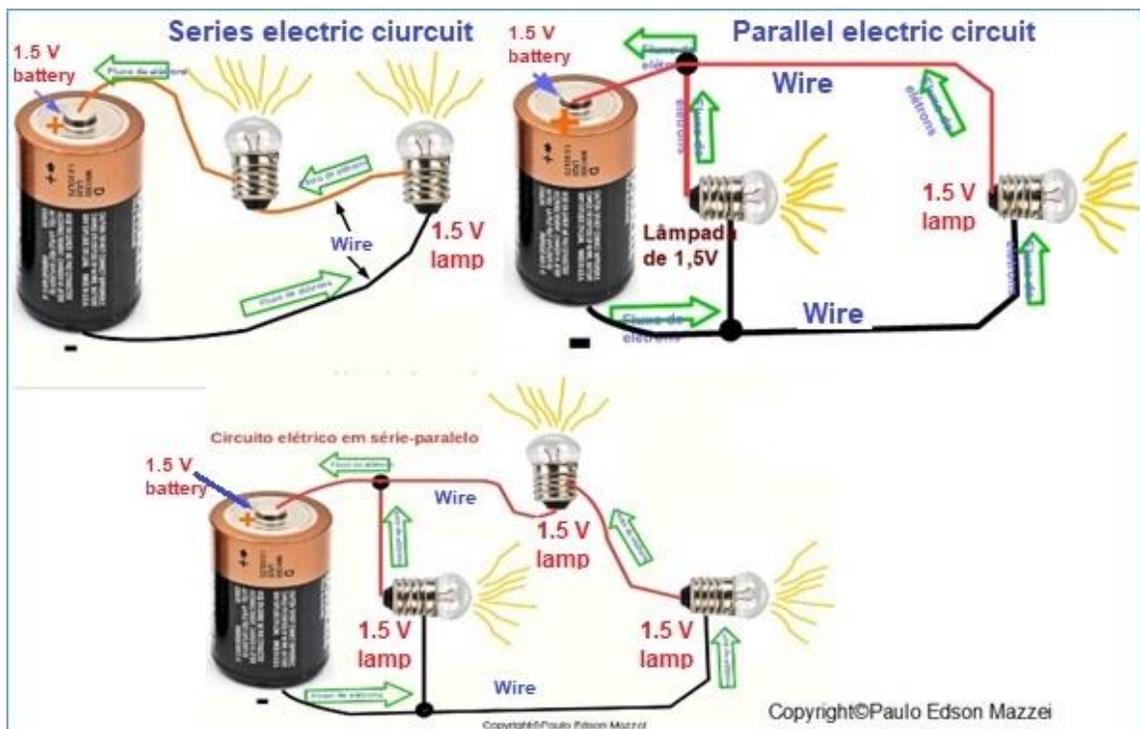


Figure 71 – The three types of electrical circuit.

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Chapter 12

Assembling and analyzing a simple circuit with power supply, LED and resistor.

Introduction

In this chapter, we will assemble a very simple circuit, in series, with a power supply of 9 V, a resistor and an LED. This circuit is illustrative, so we can discuss a number of important details in it. Next, we will make various tension measurements at various points, resistance and current. In the next chapter, we will discuss in more detail the electronic circuits.

The circuit

Let's build a simple circuit, which encompasses:

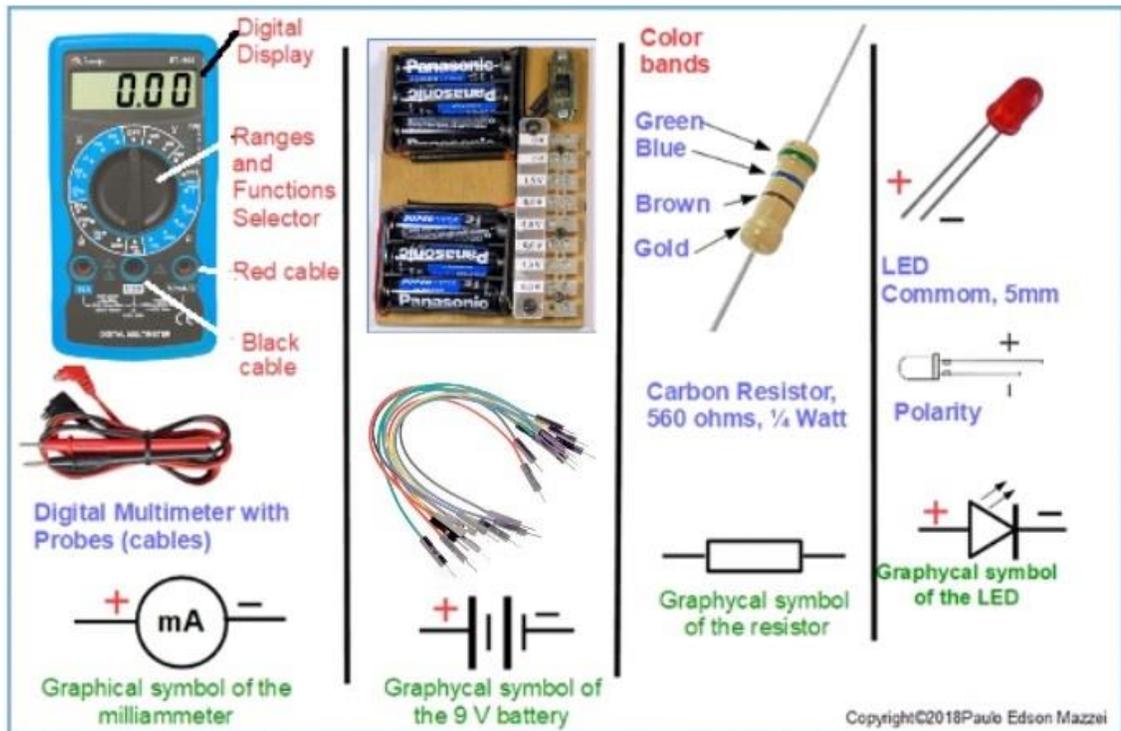
- Use of electronic components
- Using an LED
- Using a resistor
- Use of Protoboard
- Assembly techniques
- Measures of voltage, current and resistance.
- Proof of Ohm's Law.

What will you need:

- 1 Protoboard
- 1 9 V power supply
- 1 560 Ω resistor, 1/4 W, 5%, carbon
- 1 common LED, 1.8 V / 20 mA
- Wires and cables
- Digital multimeter

NOTE: Some pictures may show the use of a 9V battery. Replace it with the power supply you mounted, if any.

Note: The following circuit is a repetition of the LED circuit shown in Chapter 3. In this circuit we did not do a more comprehensive analysis as we will do now. Let's use some pictures of that first circuit.



The schematic diagram

As we mentioned, we use graphic symbols to design the electronic components and use them in a circuit. These graphical symbols attached, form the schematic diagram of the circuit or design that you are riding. See **figure 72**.

Based on the schematic diagram of our simple circuit and with the components in hand, we will mount our circuit on Protoboard.

Note that in **Figure 72**, where the circuit components that we are going to use appear, we use small pieces of wire cover to protect the terminals of the resistor and the LED.

Measuring the resistance of the resistor

With digital multimeter, measure the resistance of the 560 Ω resistor.

1. Let's now measure the resistance of the 560 Ω resistor. Calculated previously, to limit the voltage of the LED, when it is connected to a high operating voltage. The resistor must be out of the circuit.

2. Use the same probes to secure the cables to the 560 Ω resistor.

3. In **figure 73** you can see the multimeter's function selector switch in the 2000 Ω position, i.e. 2 k Ω . It measures resistance from 0 Ω to 1999 Ω (0 to 1.999 k Ω).

4. Now see the resistance measurement of the 560 Ω resistor in Figure 63.

5. Note that the value measured by the digital multimeter is correct because as the resistor has a tolerance of $\pm 5\%$ its value could be between 532 Ω and 588 Ω . Actually, 555 Ω is a very good value!

6. The value of this resistor is calculated according to:

Battery voltage - LED voltage = 9 V - 1.8 V = 7.2 V should be the voltage drop in the 560 Ω resistor.

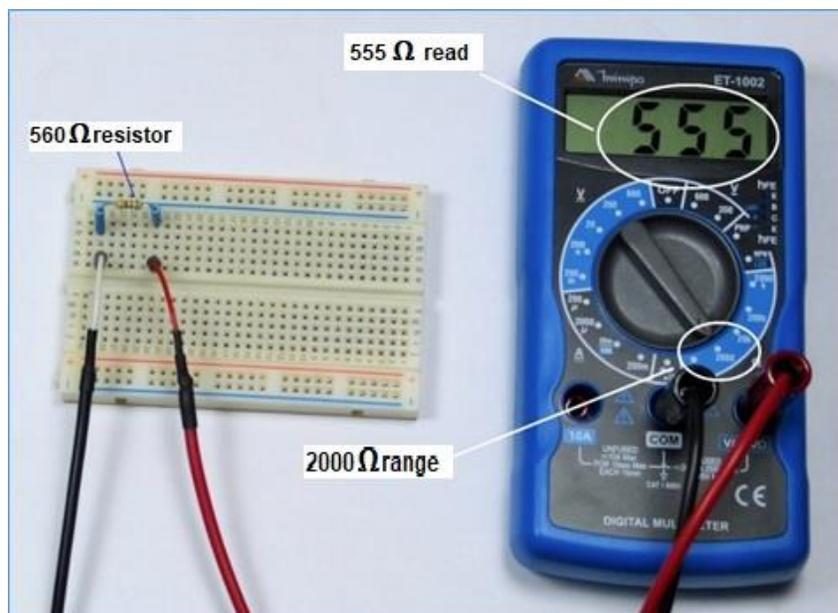


Figure 73 - Measuring of the 560 ohms resistor.

- Note that we use a value higher than the calculated because we do not need all the brightness of the LED and at the same time, we save our battery of 9 V, because it will provide a lower current.

- Since the current to be circulated is about 18 mA, we have that the value of the resistor is:

$$R = 9 \text{ V} / 0.018 \text{ A} = 500 \ \Omega.$$

The closest value of 500 Ω , to get a correct resistor, would be the one resistor of 560 Ω .

Power supply output voltage

With the digital multimeter, measure the voltage of the 9 V power supply. For this:

1. You should have new batteries in your power supply and digital multimeter or one in good condition. If it does not, you may get wrong readings.

2. Selects the 20 VDC Range, i.e. 20 volts DC. On this Range your Meter measures DC - Continuous Current voltages from 0 to 20 V.



DCV symbol.

3. Connect the red (positive) probe to the positive (+) terminal of the power supply and the black (negative) probe to the negative (-) terminal of the power supply. See following figures. The probes used have an alligator-type terminal at the end that is connected to the circuit.

4. In figure 60 you can see the material needed for the experiment.

5. Figure 74 shows the voltage measurement of power supply. Note the polarity of the probes and the power supply. Also note that the digital multimeter panel shows the symbol for "Continuous Current". In the case of AC Voltage - Alternating Current measurements, the symbol shown is.



ACV symbol.

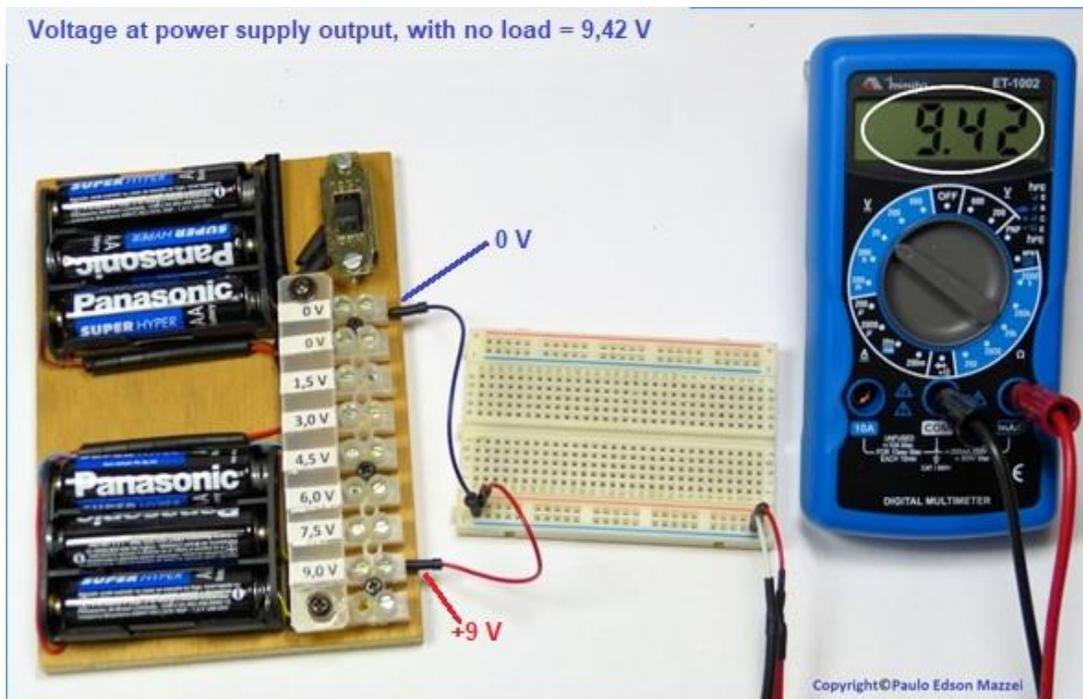


Figure 74 - Voltage output of the power supply at the 9 V point.

1. The voltage read on the digital multimeter is **9.42 V**. This value is for new batteries in the power supply, charged and not connected to any circuit. You should get values close to 9 V.

2. Note that two interconnect cabling were used between Protoboard and the power supply. In the power supply, the metal pin of the cab is screwed to the terminal block: black at terminal **0 V** and red at terminal **9.0 V**. Be careful not to tighten the screw tightly as you can cut the tip of the metal pin

Assembling the LED circuit

- a. Let us now use the Protoboard and mount the circuit with LED. The circuit is shown in **figure 75**.
- b. . Put the Protoboard in front of you, on a table.
- c. . Separate the LED, the 560 Ω resistor, and the interconnect wiring.
- d. . If you want a "neater" assembly, use small pieces of colored wire cover to cover and insulate the resistor and LED terminals. See the pictures.

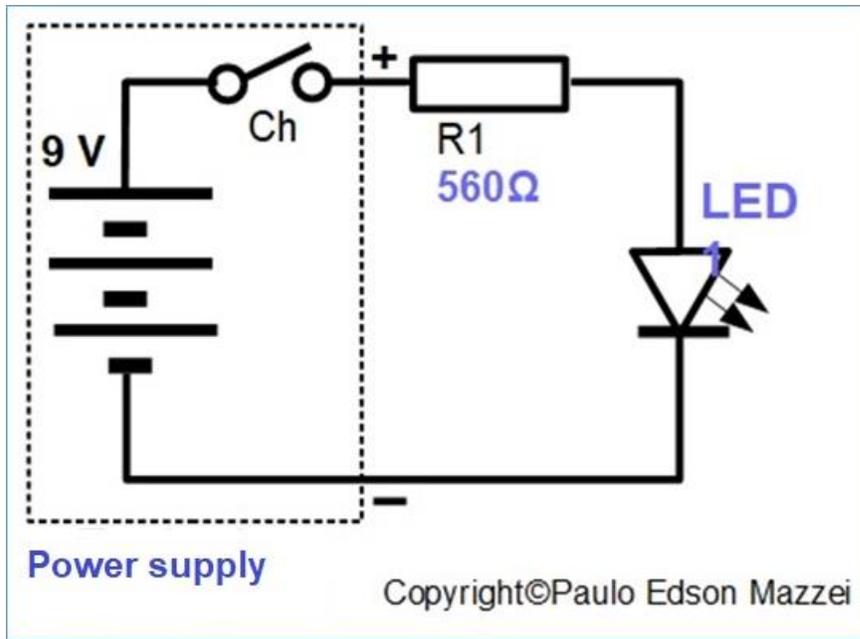


Figure 75 - Schematic diagram of the LED circuit.

- e. . Over the resistor terminals and cut a part of them. About 7 mm, as shown in **figure 76**. These measurements are approximate and you can change them. Try it..



Figure 76 – Bending the terminal of the 560-ohm resistor.

- f. Do the same for the LED. Please see **figure 77**.



Figure 77 – LED and resistor with small pieces of cover in their terminals.

- g. Mount the resistor and LED on the Protoboard, as shown in **Figure 78**. Note that the Protoboard contacts (rows numbers 17, 25 and 27) are interlocked vertically. In this way, the positive terminal of the LED (red) is connected to one of the terminals of the 560 Ω resistor in the contact row number 25.

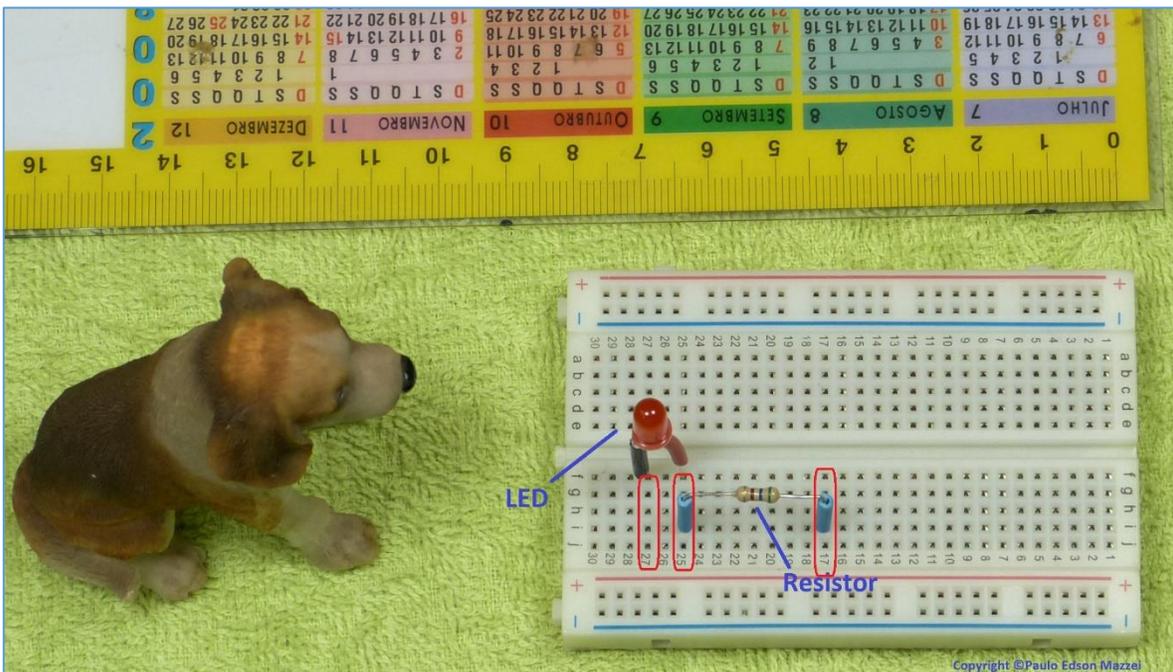


Figure 78 – Assembling of the LED and resistor in the Protoboard. the Beagle is a mere observer.

Next, connect the 9 V power interconnect wiring to the LED circuit and resistor. See **figure 79**.

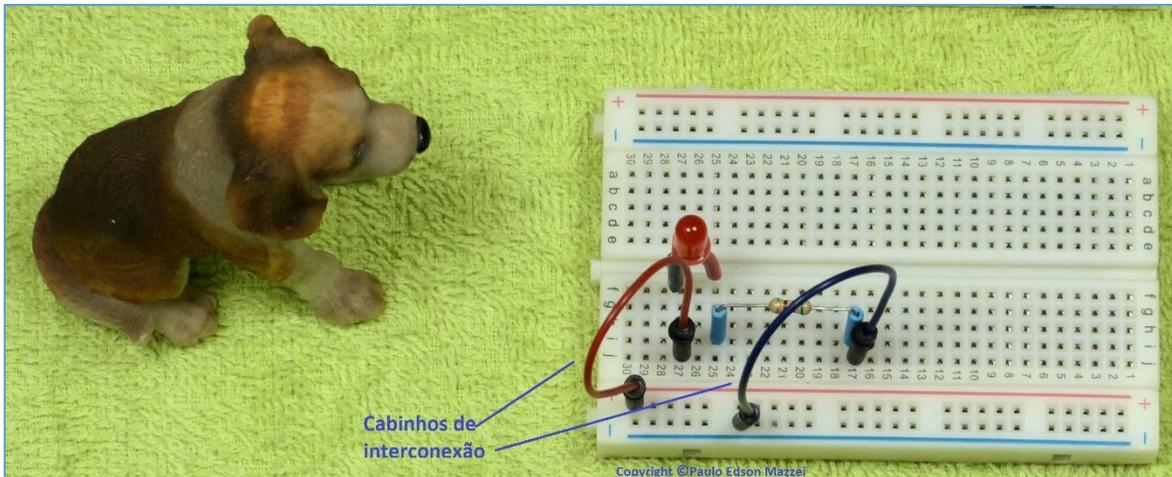


Figure 79 – Circuit connection to the positive and negative tracks of the Protoboard.

- h. Now let's go to the “time of truth”: connect the positive and negative of the power supply to the circuit assembled in the Protoboard, as shown in figure 80 and 81.
- i. Turn on the power supply switch. The LED will light up if everything is correct. If the LED does not light, disconnect the source from the circuit and review all connections. Pay attention to the polarity of the LED. If you reverse the polarity of the LED nothing will happen to it: just will not light.

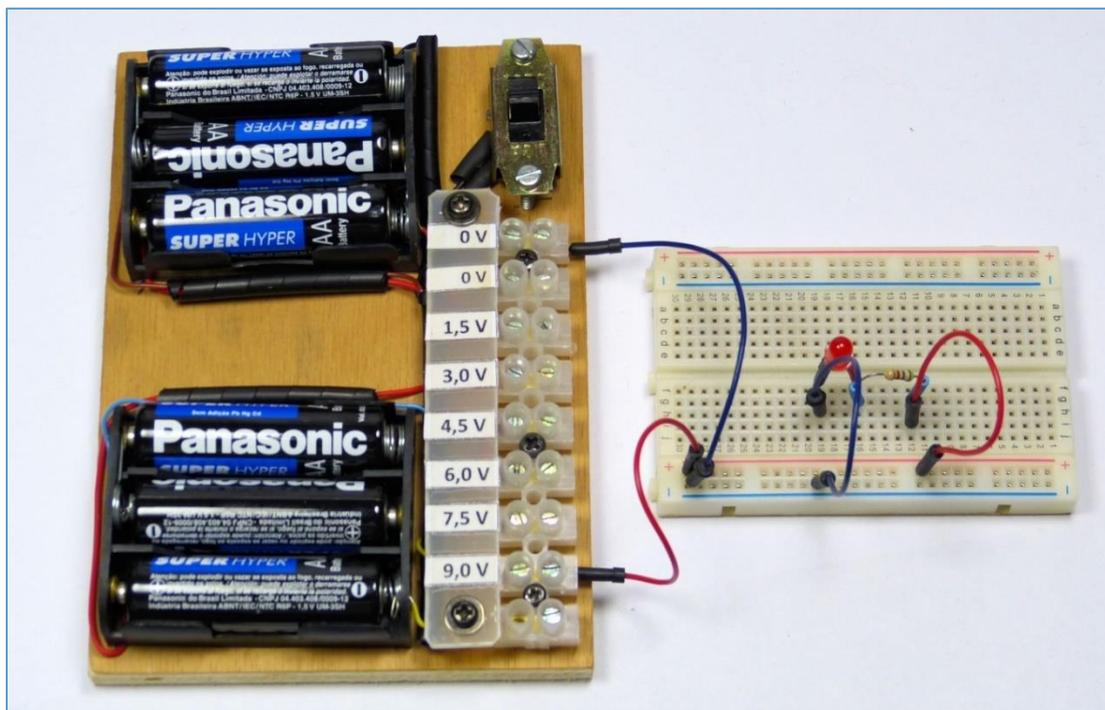


Figure 60 - Protoboard circuit connected to power supply. On/off switch is "off".

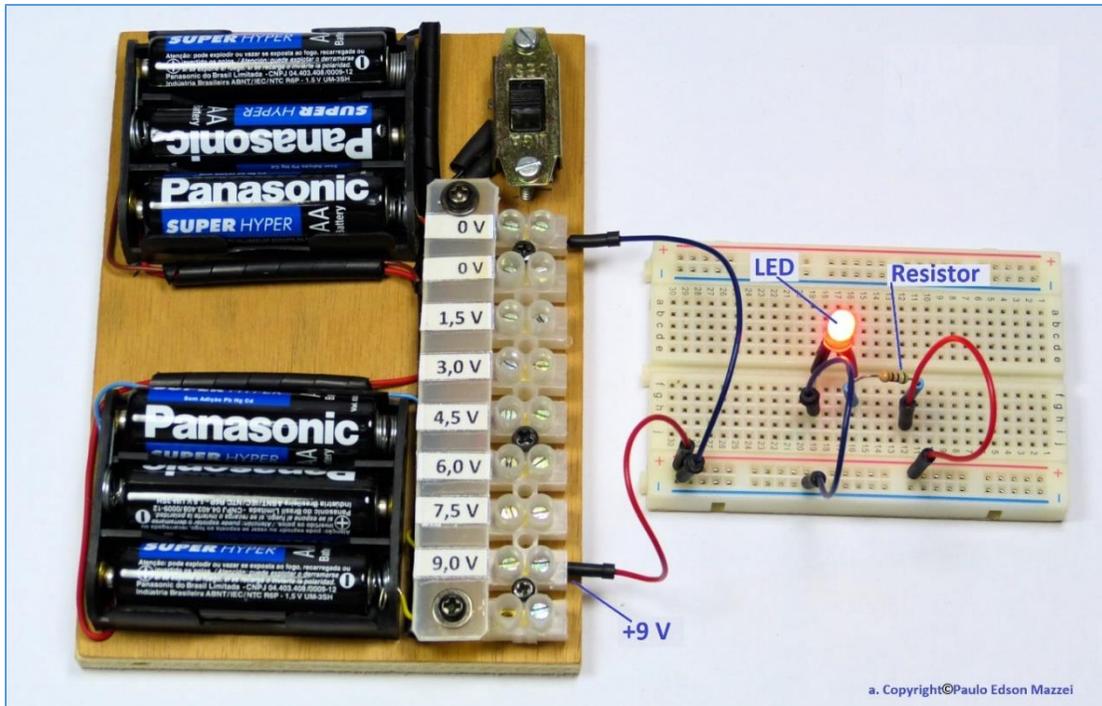


Figure 81 - Protoboard circuit connected to power supply. On/off switch is "on".

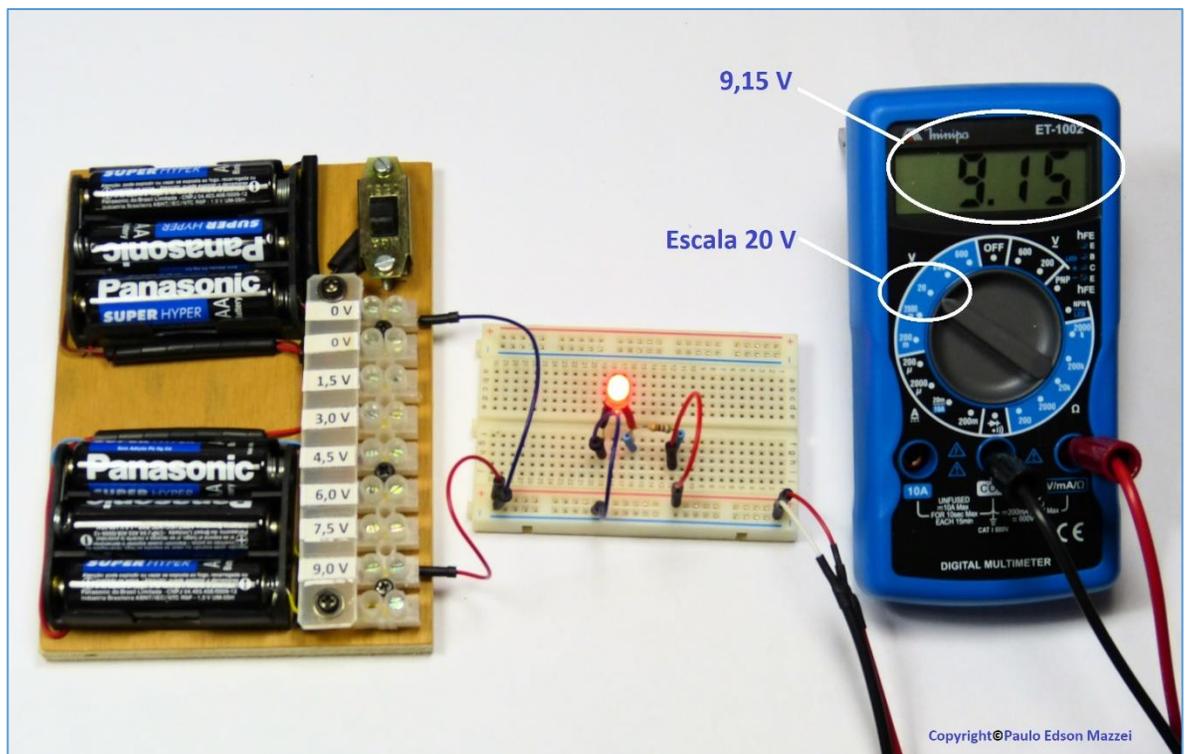


Figure 82 - Measuring the power supply voltage.

In **figure 82**, the voltage of the power supply is 9.15 V. Note that this value is with the circuit switched on and the LED is on. When we measured the voltage of the battery without the circuit switched on it was 9.42 V. This drop, with the circuit on, is normal.

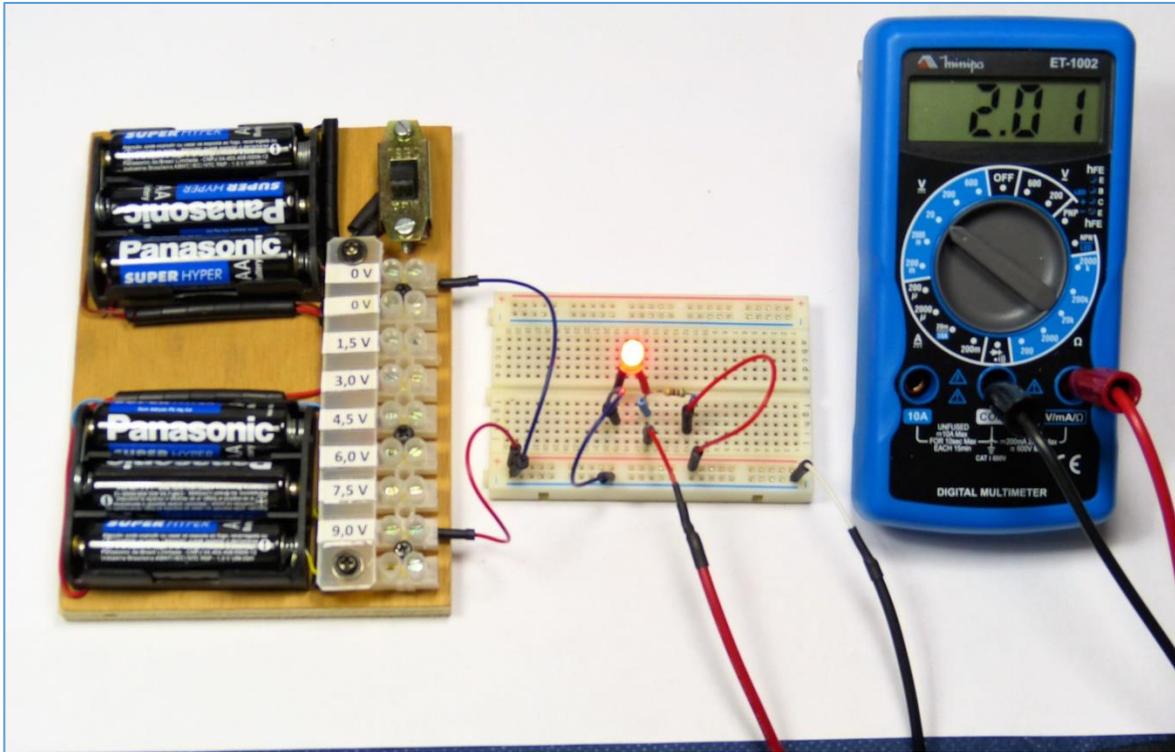


Figure 83 Measuring the voltage on the LED, with the circuit running.

Measuring the voltage on the LED

Figure 83 shows measurements at the LED terminals. This value is 2.01 V, corresponding to **voltage drop** in the LED. Note that this voltage is measured in parallel with the LED, with the circuit switched on.

Measuring the voltage on the resistor.

The voltage at the resistor is shown in **figure 84** and is e 7.1 V. As in the case of LED. This voltage is measured in parallel with the resistor, with the circuit connected.

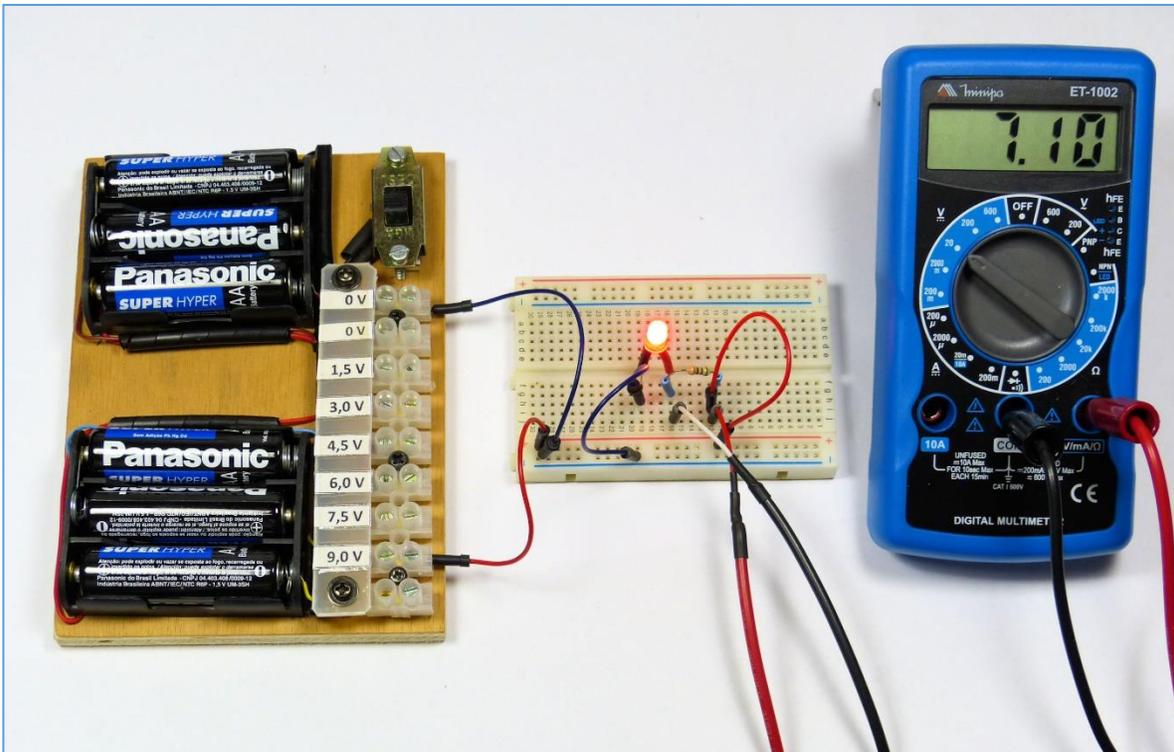


Figure 84 - Measuring the voltage drop on the resistor.

Measuring the current in the circuit

To measure the current in a circuit, you need to "open it", i.e. interrupt the circuit, so that we can insert the milliammeter at this open point, see **figure 85** which shows a "milliammeter" where we open the circuit and we introduce the DMM, in the Range of 2000 mA, that is, 2 A.

The measured current was 12.5 mA, as shown in the **figure 85**.

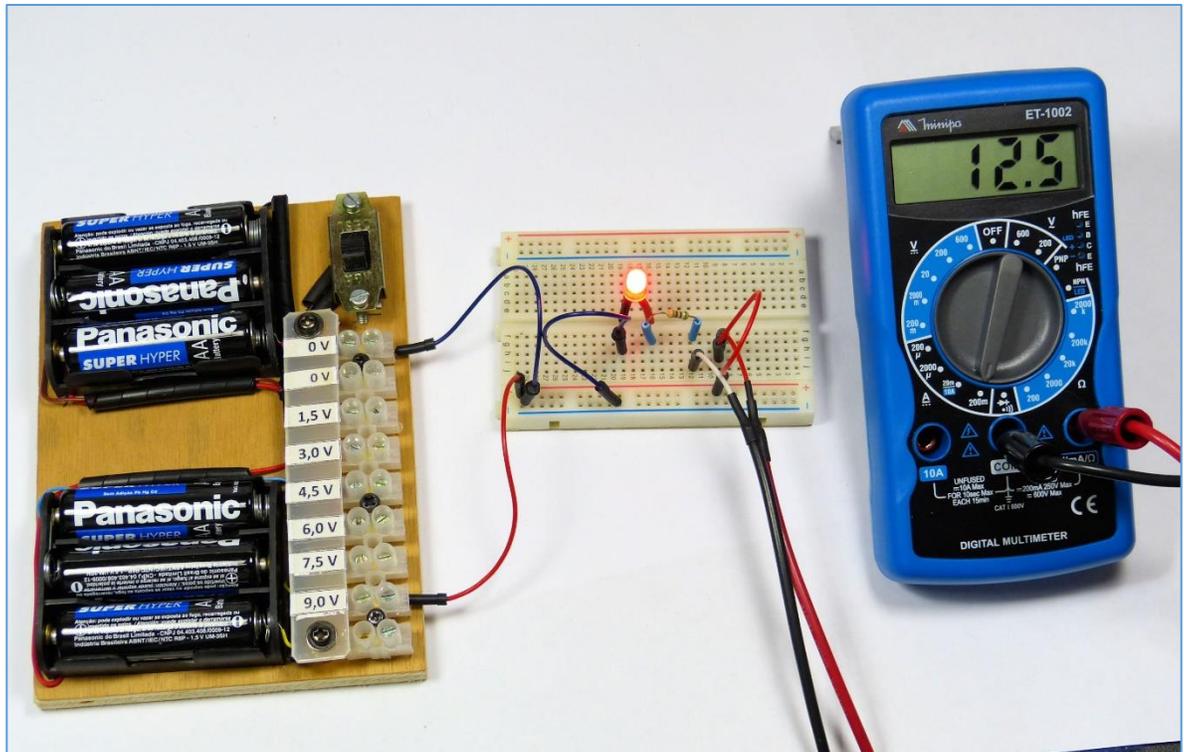


Figure 85 - Measuring the current in the circuit which is 12.5 mA.

Analysis of the values found

■ The sum of voltage drops in a series circuit must be equal to the voltage applied by the power supply. In our case we have:

> **Voltage drop in resistor = 7,01 V**

> **LED voltage drop = 2.01 V**

> Total voltage drops = 9.02 V, which is a very close value of 9.15 V, which was the voltage of the power supply, when connected to the circuit.

■ The circuit current is 12.5 mA and the voltage drop in the resistor is 7.01 V. Using the Ohm's Law, we can check the value of the resistor in series in the circuit:

> **$R1 = V_{\text{resistor}} / I_{\text{circuit}} = 7.01 \text{ V} / 0.0125 \text{ A}$**

> **$R1 = 560.8 \text{ ohms}$, very close to the 560Ω of resistor R1.**

■ Observe that these measurements and calculations fully prove Ohm's Law.

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Experiment 3**A simple circuit with an LED.**

Read all this text before the experiment.

Objective

Now let's set up our first circuit so you can get to know some new electronics, use DMM and VOM, and work with Protoboard.

Information

Why do we always use a switch to turn a circuit on and off?

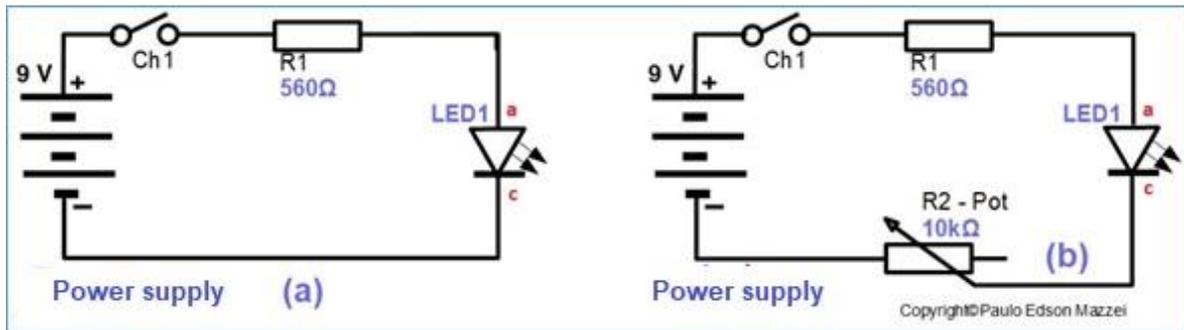
If there is an error in the installation, it may damage some of the components of the circuit or measurement instruments (DMM and VOM) through the switch ", you can turn off the supply voltage quickly, before the damage is greater! If this is the case and everything is working, you can turn the key off and connect the 9 V voltage directly to the rest of the circuit.

Remember that in addition to the Sw1 on / off switch, we still have a similar key in our power supply, which can be used in case of emergencies (smoke, bursts, sparks ...).

1 Components you will need.

- a. Led, red, 5 mm, diffuse.
 - b. Key switch or lever.
 - c. Potentiometer (pot) of 10 k Ω .
 - d. Resistor 560 Ω , carbon, 1 / 4 W, 5 %
 - e. Power supply at 9 V voltage.
- I- nstruments: DMM and VOM.

2. Circuit diagram



3. How the circuit works.

This experience is very simple because the switch that will be used will act as "on / off" for the LED. This switch will be used in several other circuits of our future experiences. The resistor R1 limits the current in the LED.

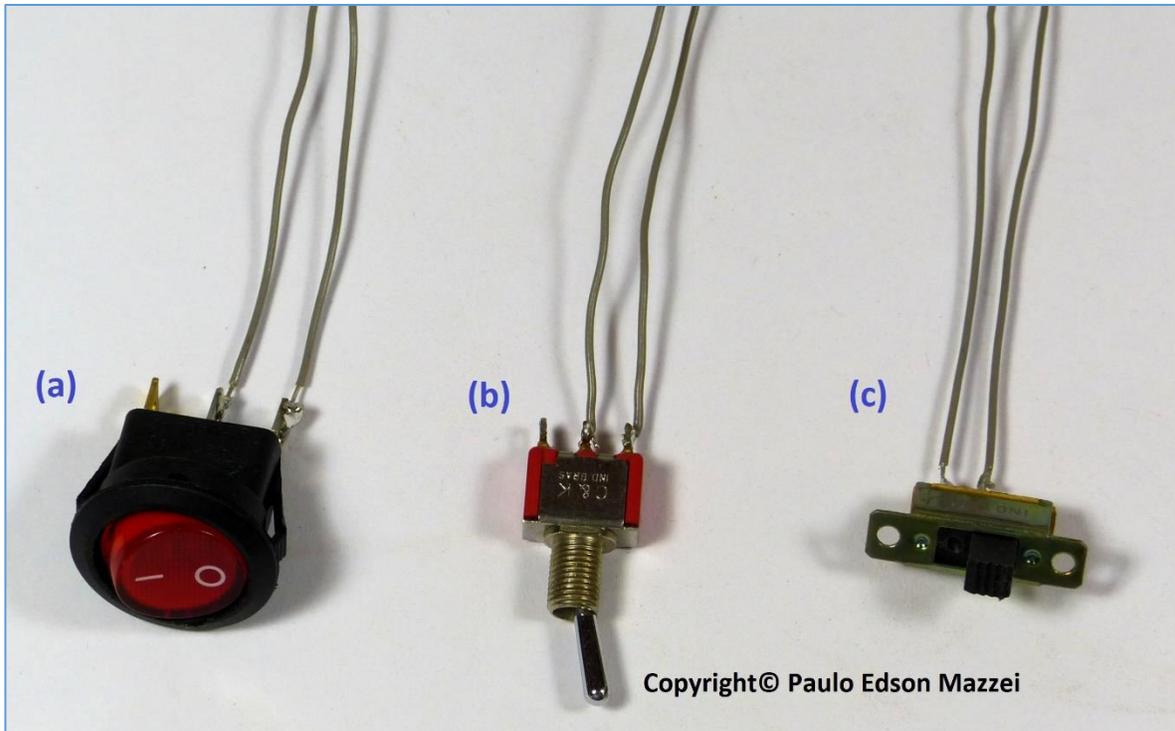
Using the potentiometer, in the other circuit (b), you can control the brightness of the LED.

4. Assembling the circuit and running the experiment.



Note: You can solder the wires to the on / off switch and to the potentiometer. For this, go to **chapter 28** regarding soldering.

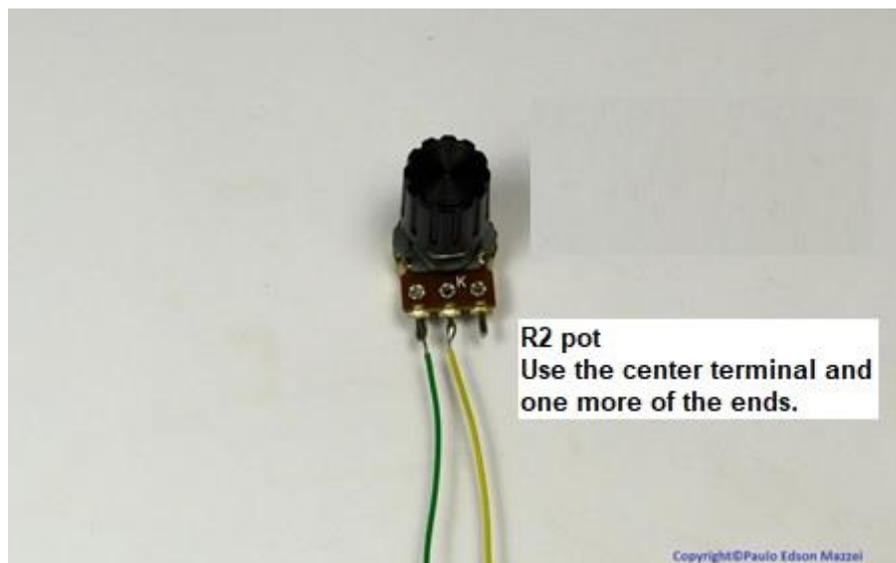
- Use the cables to make the connections between the components on the panel and the Protoboard.
- First use the circuit shown on the left (a), without the potentiometer.
- Leave key Ch1 off until you finish all assembly.
- Observe the polarity of the LED when mounting it on the Protoboard and connecting it to other components. Note that one LED terminal is larger than the other (a = anode) and still has an indication on the body, with the beveled part.

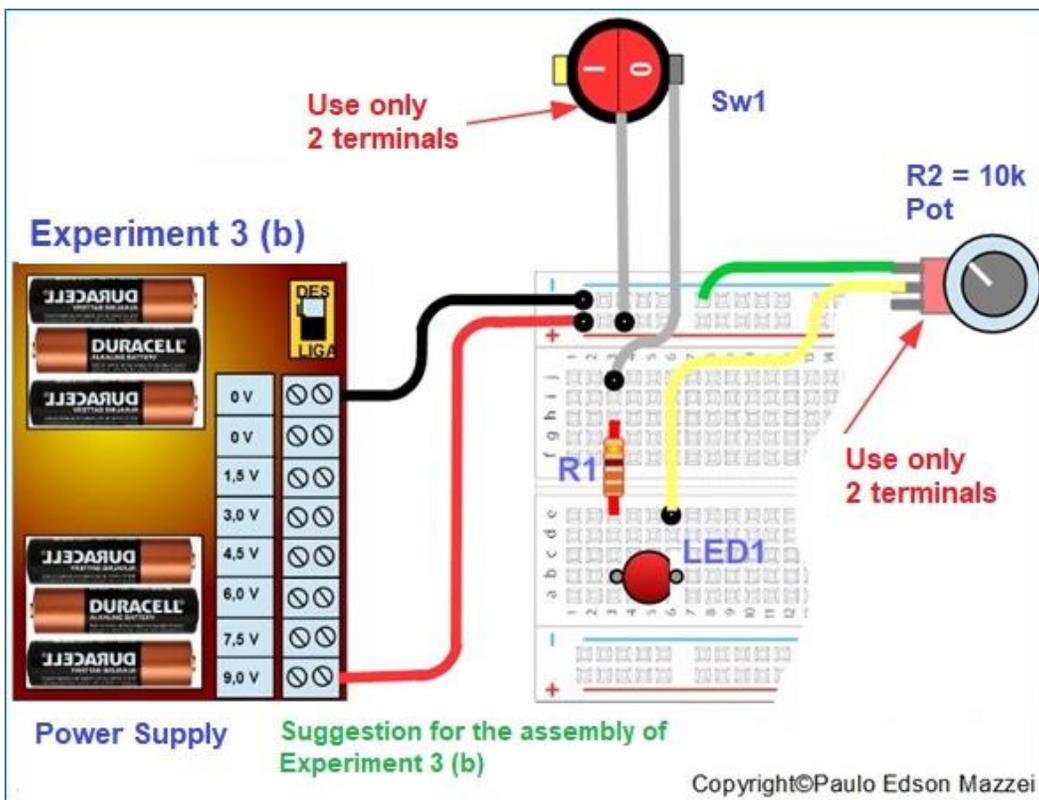
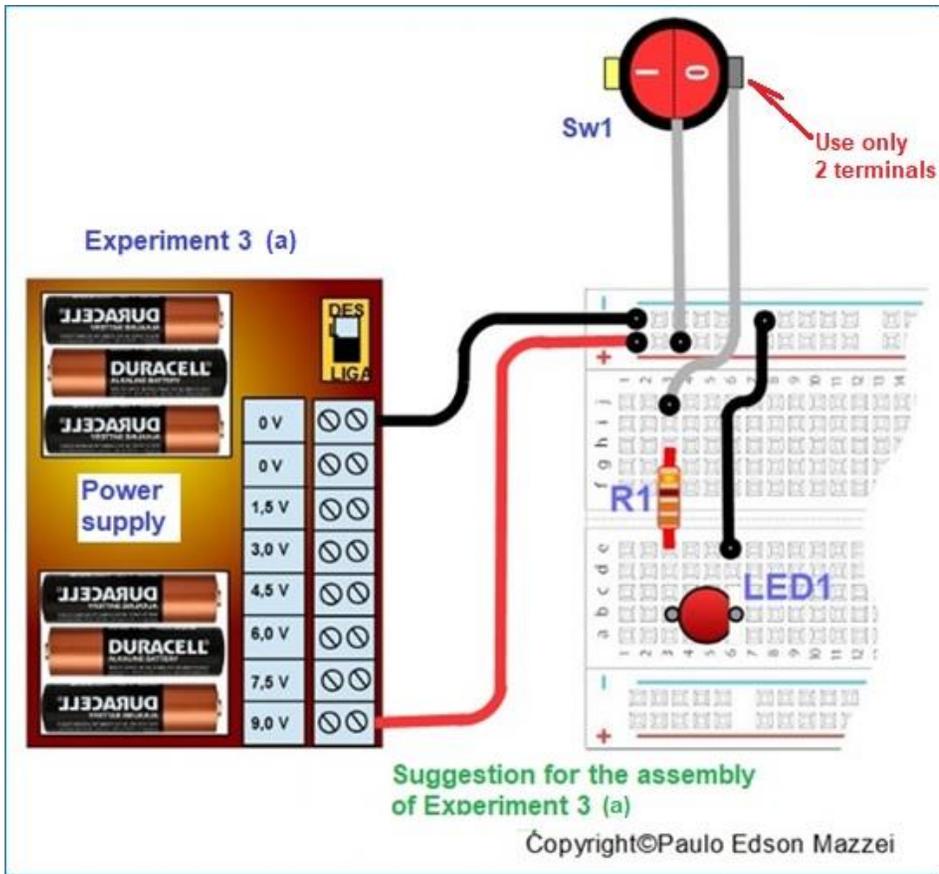


□. The photos illustrate a possible assembly of this circuit. Note that this layout can change a lot, depending on the paths you choose to interconnect.

□. Let's start using a very simple color code for the cables used in our assembly: positive (+ from the batteries or from the internal source) will be red and the negative (- from the batteries or from the internal source) will be colored black

□. Turn on the key used and see if the LED lights up.





- . Repeat for the right circuit (b), now including the potentiometer

**Caution: Be careful when attaching components and probes to Protoboard!
Do not force anything!**

5.Hints and observations.

- Check the assembly before proceeding to see if everything is OK. Based on the circuit and the photos on the side.

6. Want to try more?

- a. Use other type of switch mounted on the panel.
- b. What happens if you use a voltage less than 9.0 V to power the circuit?
- c. Calculate the value of resistor R1 if you supply the circuit with a voltage of 4.5 V. What happened to the ohmic value of the resistor?
- d. Even with a 10 K Ω pot in series in the circuit, do we still need to use the 560 Ω limiter resistor? Because?

7.Additional information

No. additional information.

What if I have a problem with my experiences?

The circuits presented here, used for you to assemble your experiments, have been tested, as well as their variations when appropriate. When nothing works, turn off the power to the battery pack using the on / off switch.

After everything is off, pause, have a coffee or a beer (one!) And go back to your circuit.

Let's look at some issues that may be occurring for you to stay tuned.

Protoboard supply

▶ If you have turned the power switch on, everything has gone out, some component may have failed. Study your assembly all over again to try to find the problem.

▶ Make sure that the batteries are correctly seated in the cradle and that they are new. Preferably always use good quality alkaline batteries. Do not use batteries with "unknown geographical origin" ...

▶ As you already know how to do basic measurements with the VOM and DMM, measure the output voltage of the batteries at the output of the power supply. Voltages, with batteries in good condition, should be around the value marked on the labels.

Common components

▶ Check if any leads are touching other terminals. If necessary, insulate with a small piece of yarn cover.

▶ Is the connection of the component terminal, wire or cable, the Protoboard connection firm, securely in place? Check them all!

▶ Are you using all correct components in the circuit? Work in a well-lit place because the colored bands of the resistors can deceive ... In doubt, measure the resistor with VOM or DMM.

Semiconductors

▶ Check that the diodes are installed correctly, with cathode and anode in their proper places.

▶ Transistors have three terminals. Are these terminals in the correct places, marked on the circuit as base, collector and emitter?

▶ Check the semiconductor (diode, transistor, or CI) if the model you are using is marked on the body of this semiconductor. Use a magnifying glass if necessary, to read what is written on the component body.

▶ Beware of IC pins. Often, by fitting them into the Protoboard, the terminals fold under the IC's body, leaving the assembler crazy!! Check this out when using CI in your experiments.

Cable, wire and test tips (probes)

▶ Check wires, cables, and probes. Yarns will hardly cause you a sleepless night! But cables, especially where there are welds (cable + pin banana), may present problems with use. Measure continuity with your VOM or DMM.

General

▶ Do not make modifications to the circuit of an experiment before you assemble the original experience detailed in this eBook.

▶ It is often easier for you to totally dismantle the circuit with problems than to try to repair it. Reassemble it with double the attention that will work. If you continue to give problems, you may have some defective component.

▶ Semiconductors are the easiest to cause problems. For testing, try to replace with a new one or use that of experience in another experiment to see what happens.

▶ Finally, we are human like you and we may have made a mistake. Contact us therefore it will be a pleasure to receive your comments and suggestions!

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Experiment 4 DC voltage measurement



Read all the text before the experiment.

OBJECTIVES

Learn how to measure direct current (DC) voltages using the DMM - Digital Multimeter and the VOM - Volt-Ohm-Meter Analog.



ATTENTION: For DMM and VOM, take the following precautions when measuring voltages:

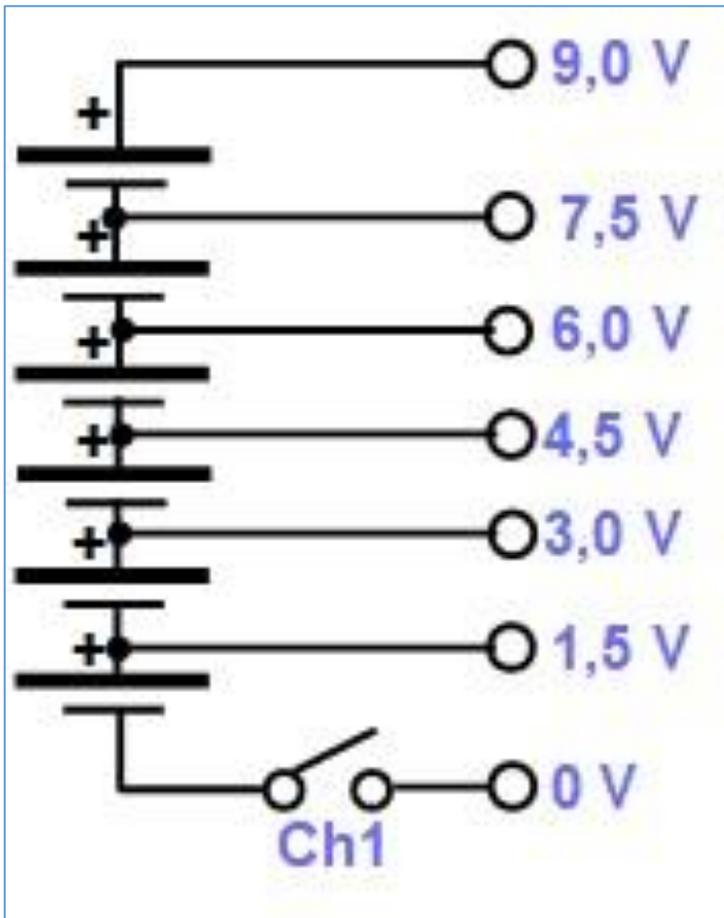
- a. **Never invert the probes!! Black in the negative (less, common circuit) and red in the voltage positive to be measured.**
- b. **Never change the Ranges of DMM and VOM, with the same ones connected to the circuit being measured!! Remove the red colored probe, change the Ranges of the DMM or VOM and turn the red test lead in the place you were measuring.**
- c. **If you have questions about the voltage value you are going to measure, always place DMM or VOM on a larger Range: 600VDC for DMM and 1000VCC for VOM.**

1. Components you will need.

1. Protoboard
 2. Cables and wires
- Instruments: DMM and VOM.**

2. Circuit diagram

Note that the voltages listed on the Power Supply, 1.50, 3.00 V, 4.50 V, etc., are "nominal" voltage values. A battery of 1.5 V nominal voltage, when new, will have around 1.6 to 1.7 V. With the use this voltage goes falling until reaching unacceptable values.



3. How the circuit works

This experiment is for you to practice some voltage measurements. At the same time, you continue to familiarize yourself with DMM, and VOM.

4. Assembling the experiment and running.

- Connect the DMM to Power Supply, observing the polarity of the terminals and probes.
- Repeat for the other voltages provided by the internal batteries.
- Repeat with the VOM for

all voltage values.

- Make a small table with the values obtained with DMM and VOM.



Caution: Be careful when attaching components and probes to Protoboard! Do not force anything!

5. Hint and observations.

- Check the assembly before proceeding to see if everything is OK. Based on the circuit and the photos on the side.

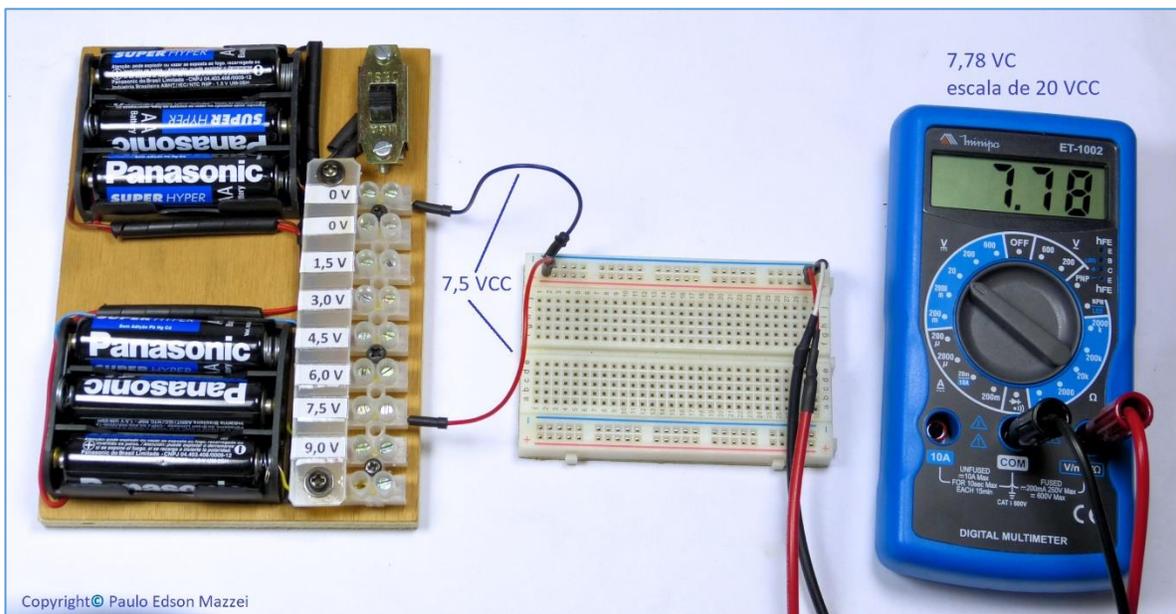
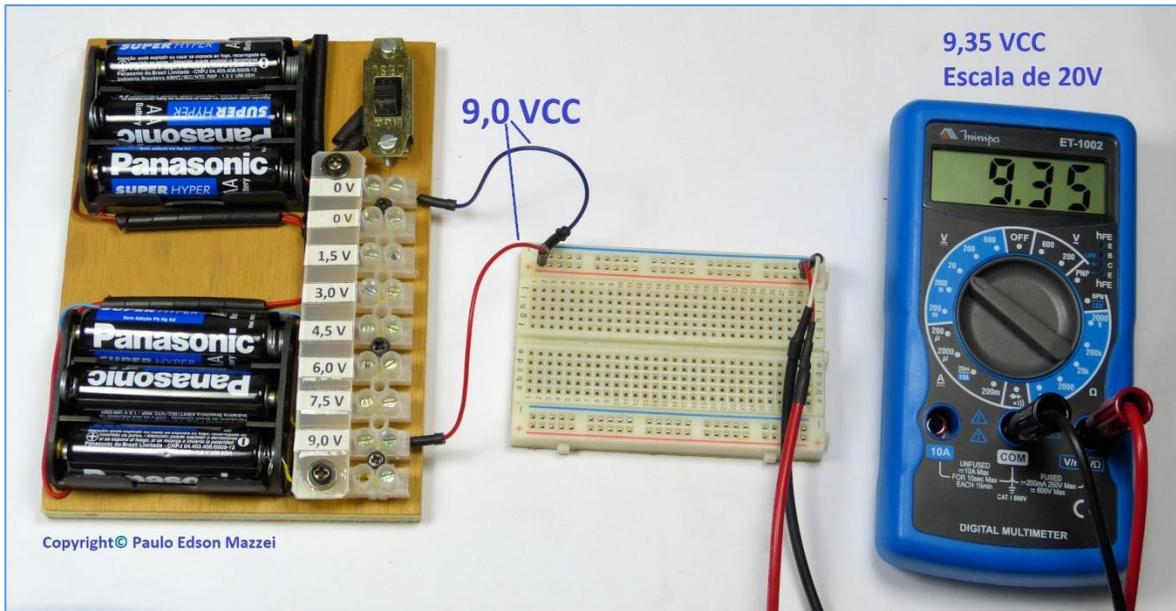
6. Want to try more?

a Check what happens to the reading if you change the polarity of the probes, **only in the case of DMM.**



Do not reverse the probes on the VOM as it may be damaged.

- b. What happens when a voltage of 1.5 V is measured on the 200 VDC Range?
- c. What is the best Range for measuring a voltage of 250 VDC.
- d. Check that the measured voltages are in accordance with the values indicated on the Power Supply.



7. Additional information

Experiment 5

Voltage divider with resistors



Read all the text before the experiment.

Objectives

You will get in touch with the voltage dividers, learning to calculate one of them. The voltages will be measured with the DMM - Digital Multimeter and the VOM - Volt-Ohm-Meter Analog.



ATTENTION: For DMM and VOM, take the following precautions when measuring voltages:

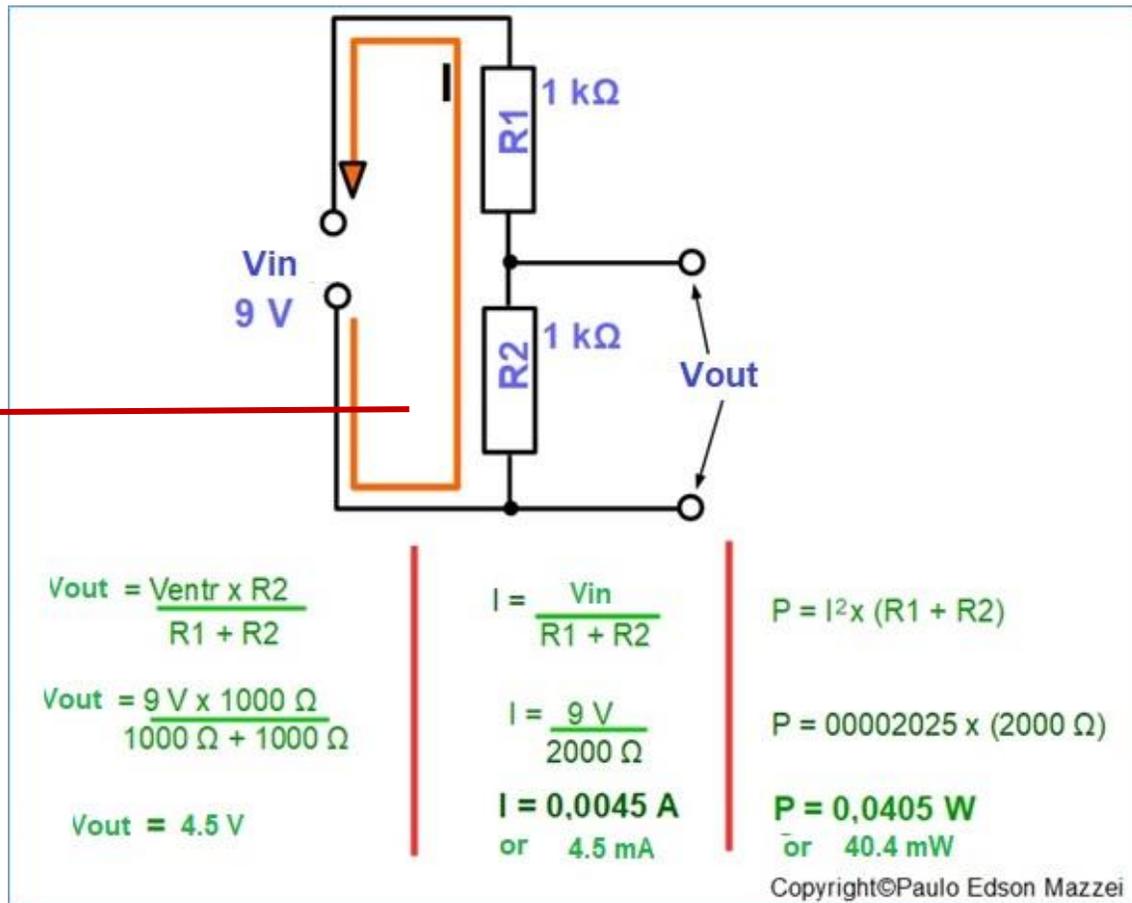
- a. Never invert the probes!! Black in the negative (less, common circuit) and red in the voltage positive to be measured.
- b. Never change the Ranges of DMM and VOM, with the same ones connected to the circuit being measured!! Remove the red colored probe, change the Ranges of the DMM or VOM and turn the red test lead in the place you were measuring.
- c. If you have questions about the voltage value you are going to measure, always place DMM or VOM on a larger Range: 600VDC for DMM and 1000VCC for VOM.

1. Components you will need.

- a. 2 - 2,2 k Ω carbon resistors
- b. 9 V power supply.

Instruments: DMM and VOM. Cables and probes.

2. Circuit diagram



3. How the circuit works.

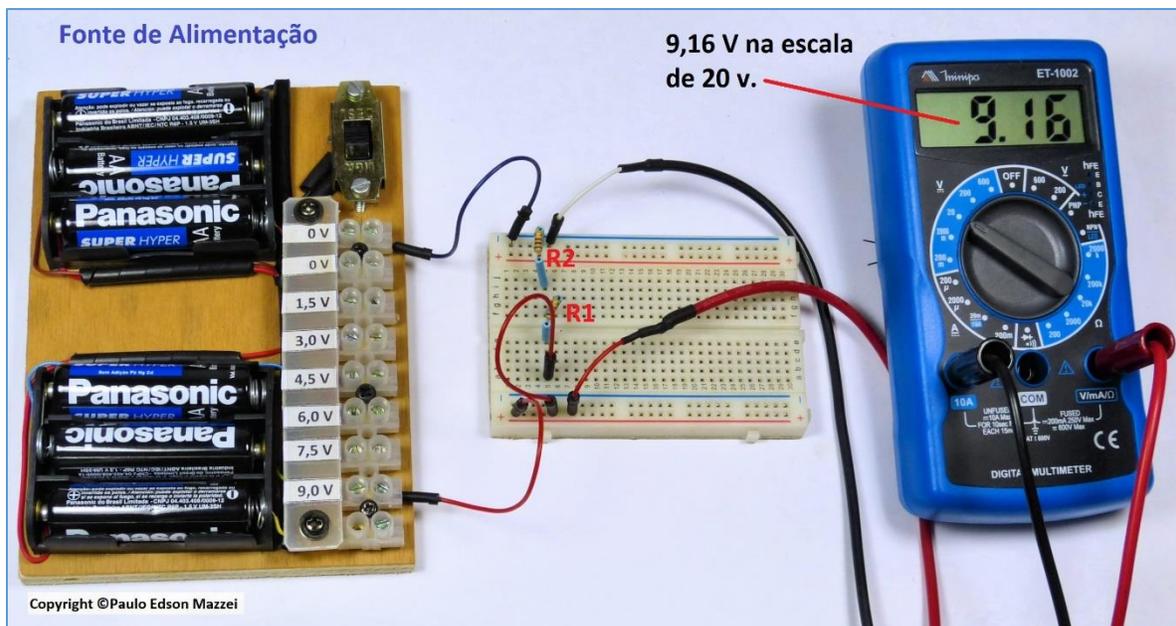
Current I of approximately 4.5 mA (calculated) circulates through resistors R_1 and R_2 . In the case of the resistor R_2 , where we connect the DMM or the VOM, the current that flows through it produces a voltage drop that can be calculated by the above formula, as V_{saida} .

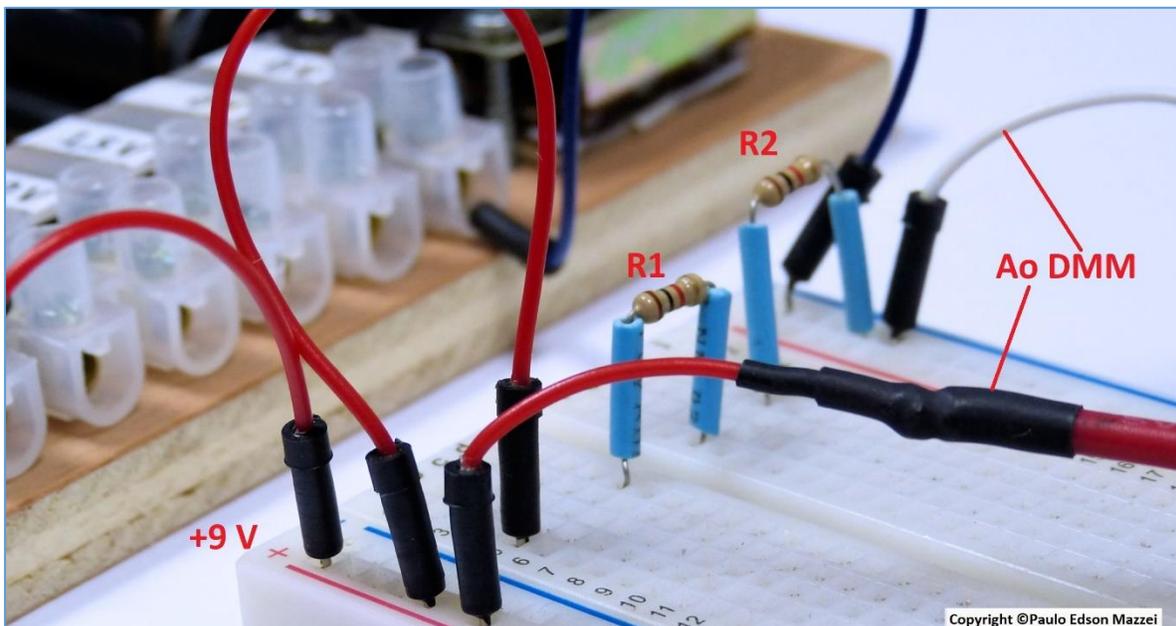
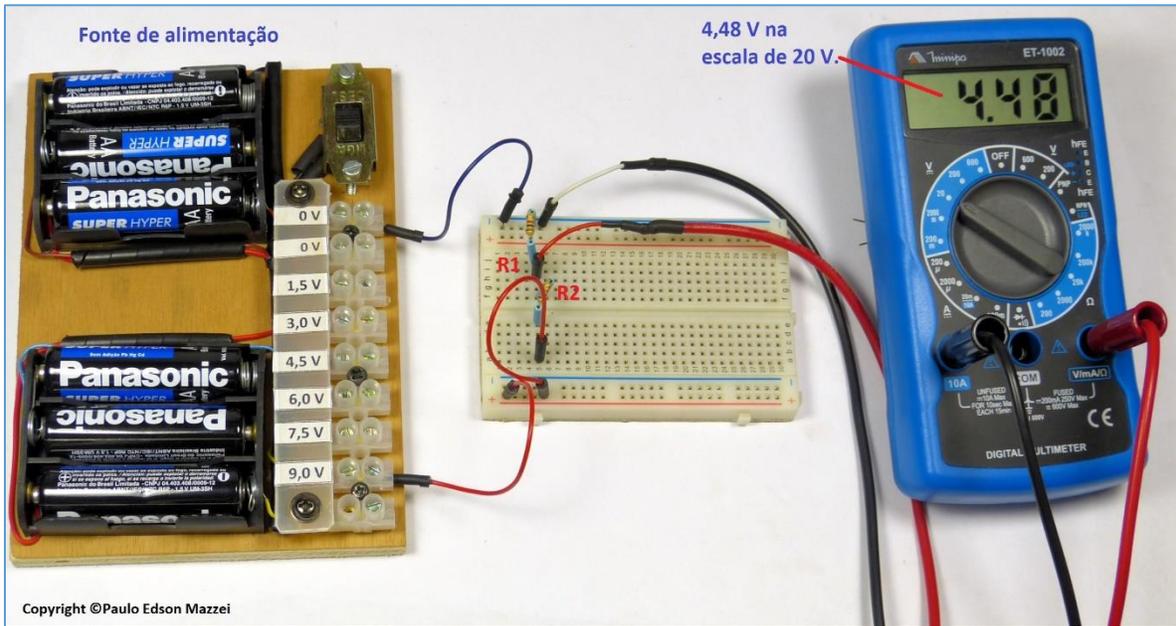
In voltage dividers with resistors, it is very important to define the current that the load will "pull" because if it is large, it may damage the resistor. Because of this, voltage splitters are used only in low power circuits. When acquiring the resistors, always use a factor of X3 (times 3) in the power. If the calculated power is 0.5 W, use 1.5 W!

The resistors we use for our experiments are $\frac{1}{4}$ Watt, i.e. 0.25 W and can be used only in low current circuits.

4. Assembling the circuit and running the experiment

- Guided by the drawing of item 2 above and the following photos.
- Mount the two 1 k Ω resistors on the Protoboard according to the circuit.
- Connect the DMM to the Protoboard.
- Using the Protoboard wiring harnesses, connect the white lead from the battery negative to one end of the voltage divider.
- Using another yellow colored plug, connect the +9 V of the batteries to the other end of the voltage divider.
- Connect the DMM to read the input and output voltages, as shown in the above circuit.
- Red probe on the red post (three red posts are interlocked) and black probe on the central black post.
- To measure the circuit current, you must remove the white wire and place the DMM in the 20-mA range. Black test lead in the "Negative Batteries" and red test lead on the end of the voltage divider, where the white wire was previously.
- Repeat all measurements with the VOM

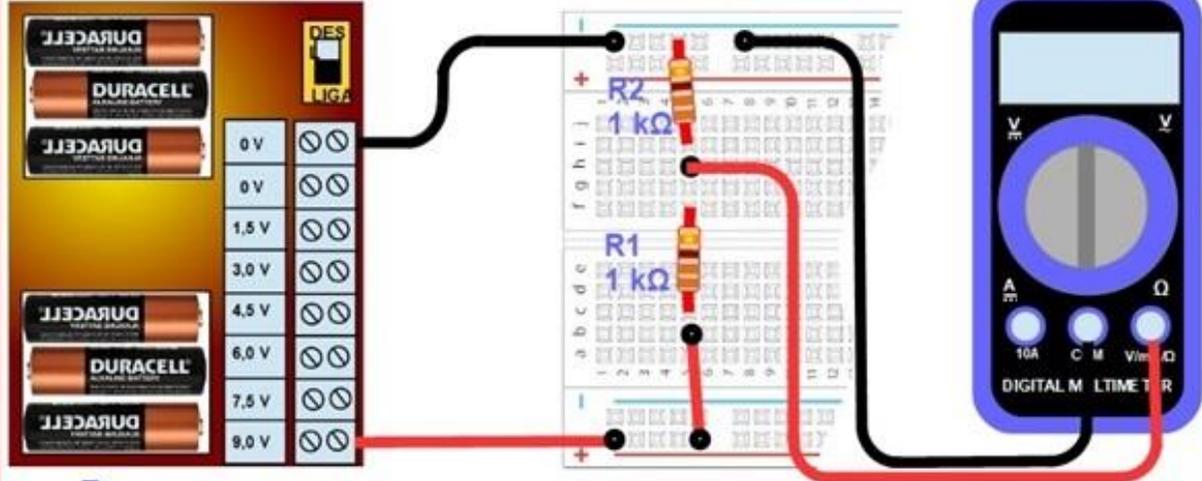




7. Additional information

Note: The voltages shown in the DMM and VOM figures may vary due to battery voltage, variation in resistor values, meter type reading, etc.

Experiment 5



Power supply

Mounting suggestion for experience 5

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Experiment 6

The use of switches in electronics.



Read all the text before the experiment

Objectives

You will learn how to connect two types of switches, to turn a buzzer on and off. It is an example of a very simple circuit, showing the actuation of two types of switches.



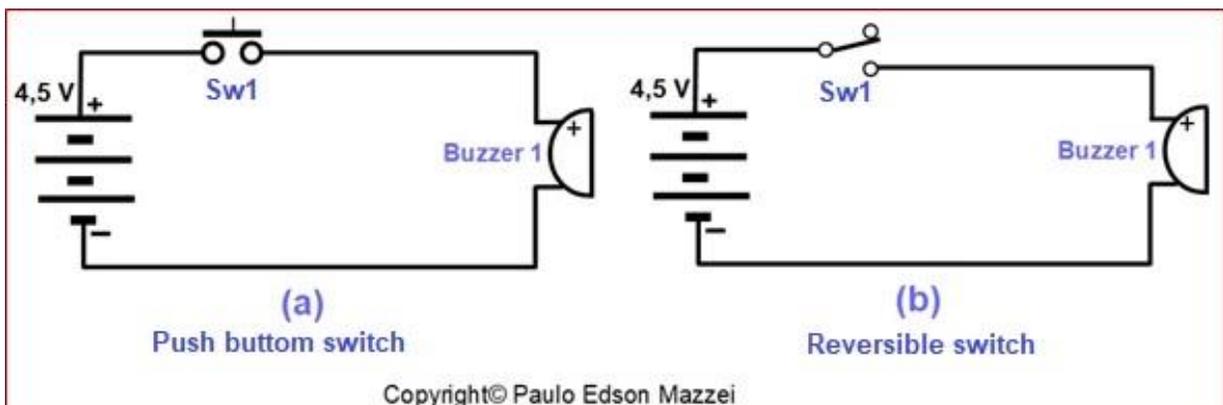
Do not apply a voltage greater than 5 VDC to the buzzer. Voltages above this value will damage it.

1. Components you will need.

- reversible switch (b),
- push button switch (a).
- buzzer, 5 VDC. Look for the correct polarity.

Instruments: DMM and VOM.

2. Circuit diagram



3. How the circuit works

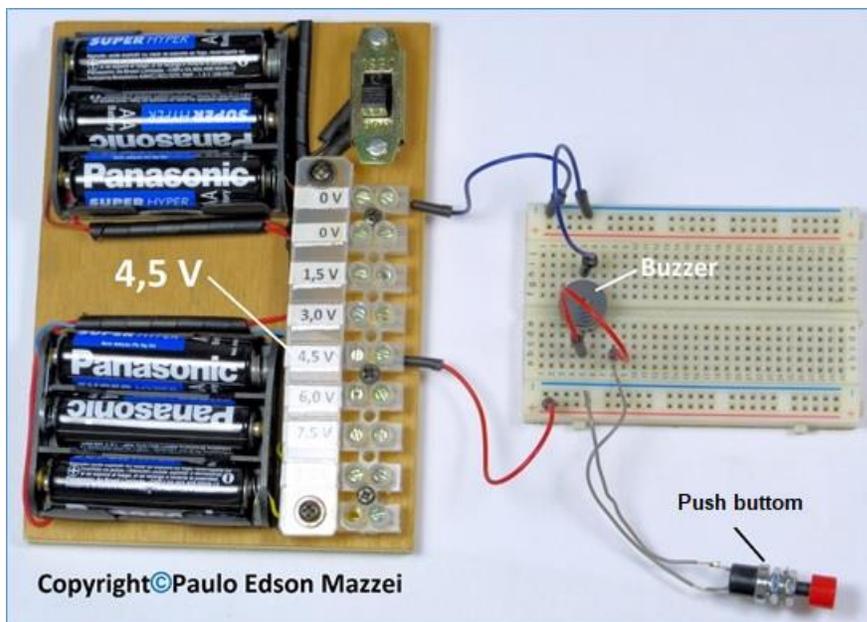
This experience is very simple because the switches that will be used will act as "on / off" of a component (buzzer). These switches will be used in several other circuits of our future experiences.

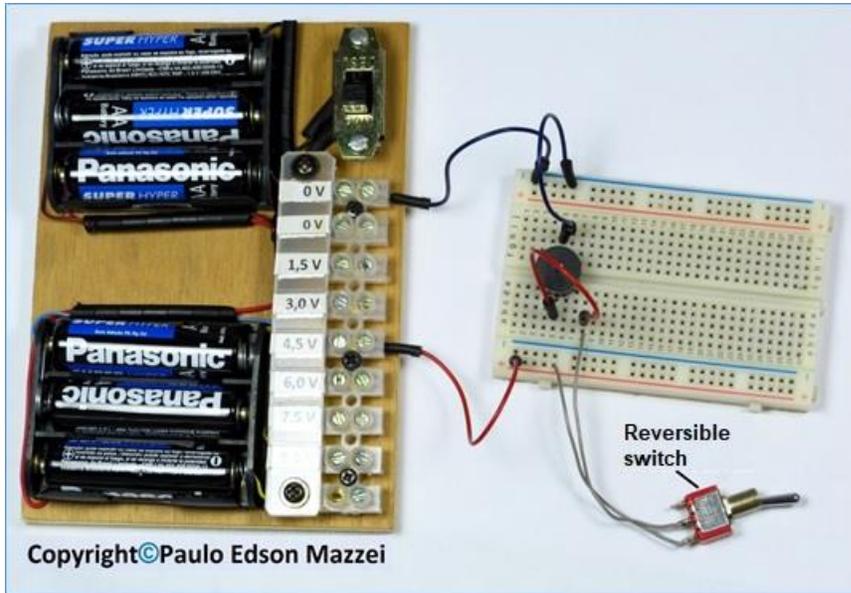
4. Assembling and running the experience

- . Use the cables to make the connections between the components on the panel and the Protoboard.
- . Leave the used switch off until you have finished all assembly.
- . The photos illustrate a possible assembly of this circuit. Note that this layout can change a lot, depending on the paths you choose to interconnect.
- . Let's start using a very simple color code for the cables used in our assembly: positive (+ from the batteries or from the internal source) will be red and the negative (- from the batteries or from the internal source) will be colored black
- . Turn on the key used and see if you get a beep on the buzzer,
- . Repeat for the other key.



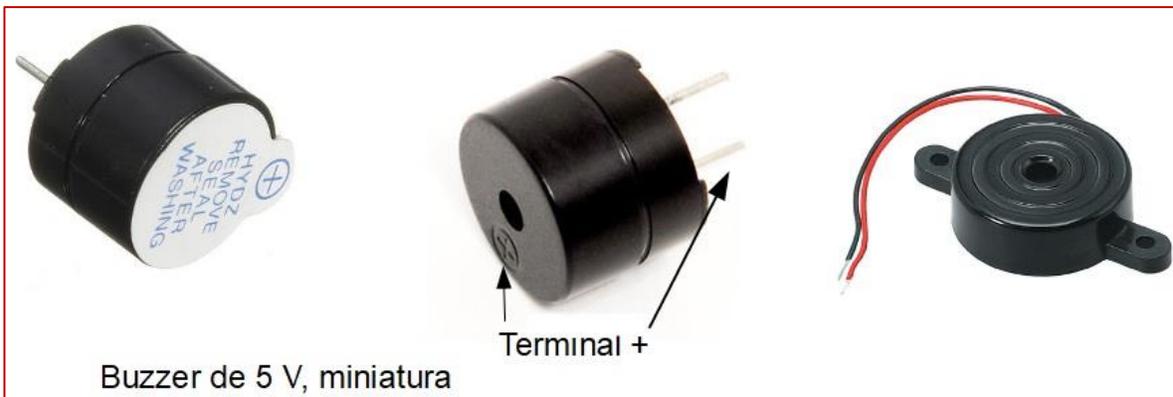
Caution: Be careful when attaching components and probes to Protoboard! Do not force anything!





5. Hints and observations

Check the assembly before proceeding to see if everything is OK. Based on the circuit and the photos on the side.

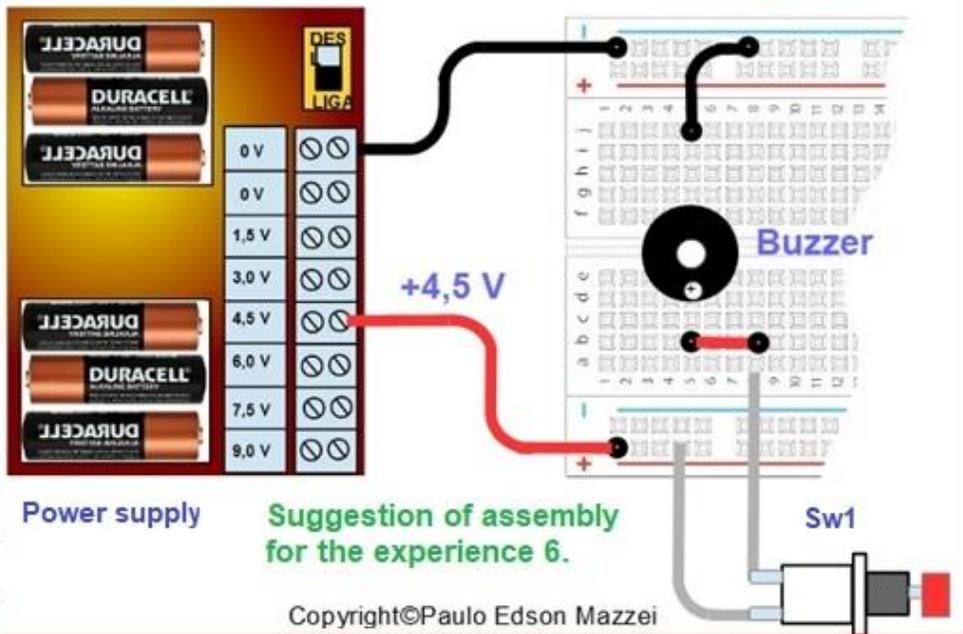


6. Want to try more?

- What are the differences between the two keys used?
 - What happens if you use a voltage of 1.5 V or 3.0 V to power the buzzer?
- Try it...

7. Additional information

Experiment 6



Chapter 13

The schematic diagram

Introduction

So far, we have used in this eBook the drawing with the physical format of the electronic components that you will use. Only in **Chapter 3** did we begin to associate graphic symbols with electronic components.

So, from now on, we will use the graphic symbols used in electricity and electronics, to represent the various circuits in which we analyze, assemble, test, etc.

It is very important that you understand the symbols well and how they are used in a schematic diagram.

Objectives

- Understand the importance of the schematic diagram in the assembly, repairs and analysis of electronic circuits.
- Know and identify the main electronic symbols used.

The schematics diagrams

The **schematic diagram** of the electrical circuit shows, through graphic symbols, how the various electronic components are interconnected to form any electronic device. Without this schematic diagram, it would be impossible to assemble an electronic circuit.

The schematic diagram or simply "**schematic**" is a drawing that, through graphic symbols, shows how the various components of a circuit are interconnected to perform a certain function.

It would not be possible to show the actual drawing of all the components of a circuit, hence the need to show the various interconnected symbols. This same type of representation is used in several areas, such as in the design of a house, where walls, doors, windows, etc. are shown by symbols specific thereto.

As an example of a very simple schematic diagram, see the circuit of **figure 86**. At this point do not worry about understanding what this circuit does. It shows a 9 V battery, connected to a LED (D1), through a resistor of 100 ohms (R1).

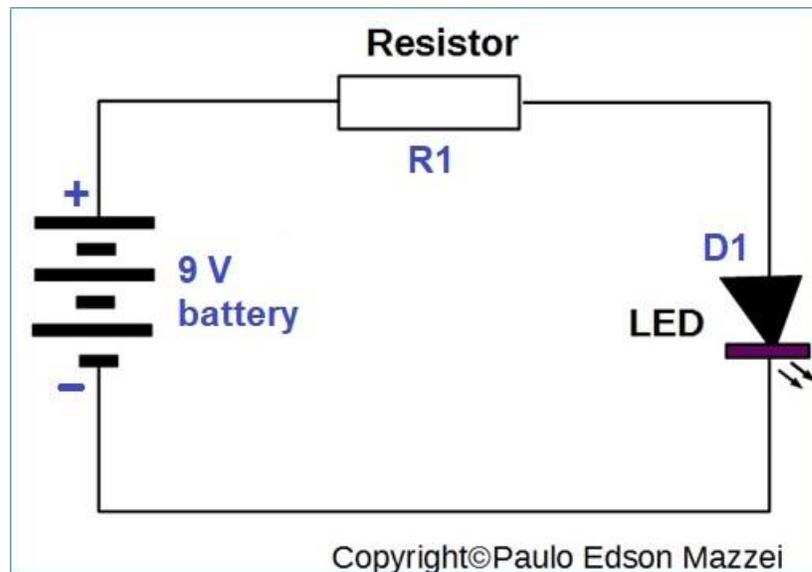


Figure 86 – Simple schematic diagram.

The block diagram

With the increasing complexity of electronic circuits, the **block diagram** is a very useful tool to show how a circuit works. In this diagram, each set of components that performs a function is shown as a **block**. Nothing better than an example to show this work.

In **figure 87** is the block diagram of a regulated power supply.

In the figure are shown the various blocks that make up a regulated source: transformer, rectifier, filter and regulator. Also used is the drawing of the voltage waveforms (in red) at the output of each block. Just below each block, we have the main electronics that are inside each block.

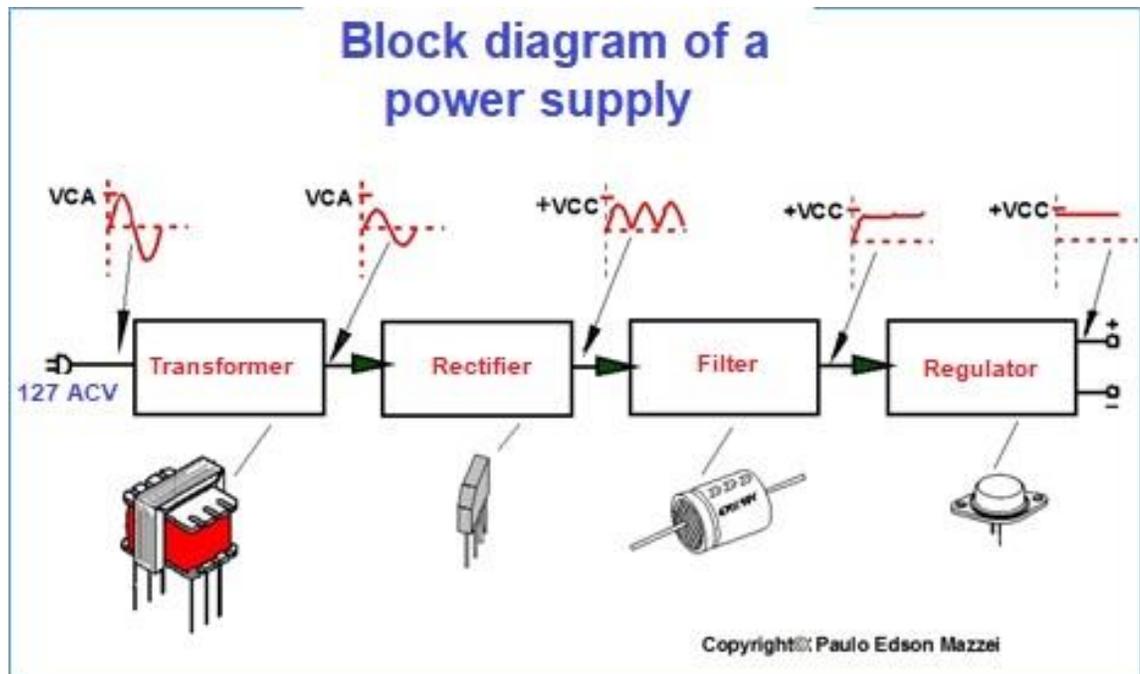


Figure 87 – Block diagram for a power supply.

The actual schematic diagram

The schematic diagram already uses the standard graphic symbols, which you have studied, for the various electronic components. Thus, for example, a transformer connected to a pair of rectifier diodes is shown as the graphic symbol of the transformer, interconnected to the diodes, through wires. Review **Figure 88. (a)**.

Note that wires, represented by lines, only have electrical contact when joined by a **small black circle**. In the diagram the wires can cross, and without this "ball" they have no electrical contact. If two bare wires cross, with mechanical contact, you will get the so-called "short circuit", recognized by bursts, sparks and smoke.

Typically, schematic diagrams are "read" from left to right and top to bottom. Note that the identification of the various components also follows this route.

In **(b)** of the same figure, the real interconnected components are shown in a circuit that works.

In several types of other circuits, in addition to the power supply, there is one more convention used for power, batteries and signal path. Let's see the next figure, which is a small amplifier for microphone.

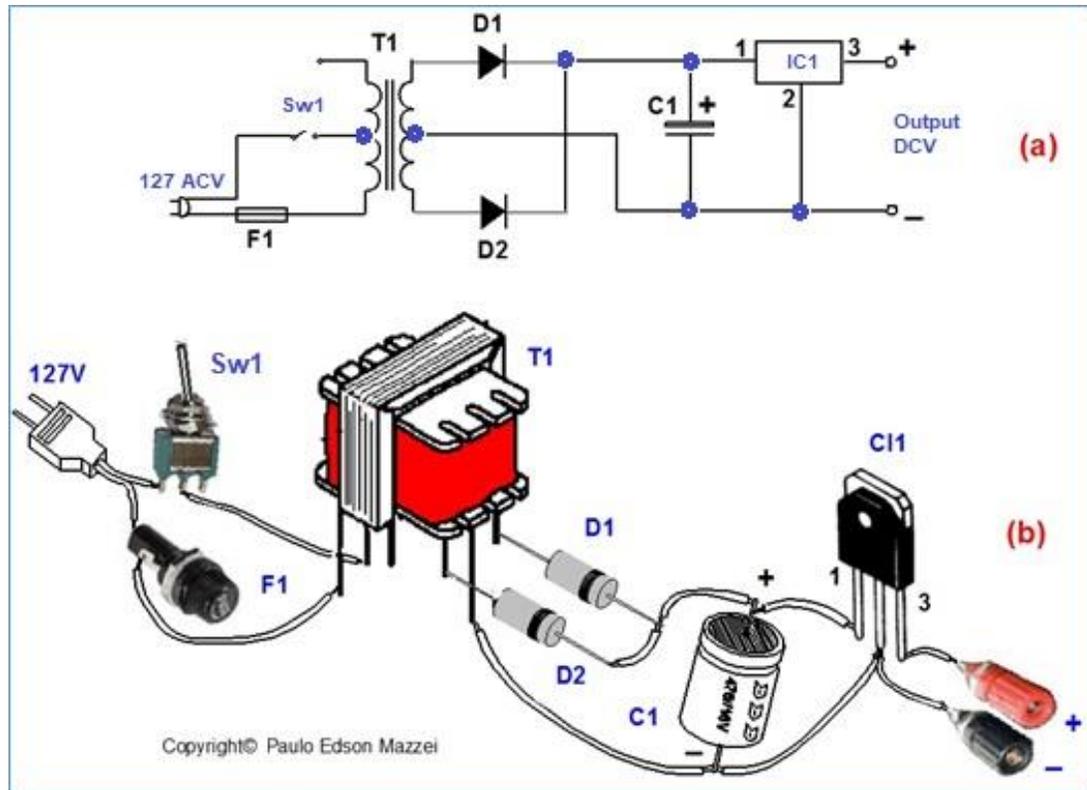


Figure 88 - Real schematic diagram in (a) and assembly using real components in (b)

, of the same schematic diagram.

Four details are important in the diagram of **figure 88**, since they are almost the standard for the drawings of other schematic diagrams:

a) The signal input (Microphone) is placed to the left, while the (Speaker) output is to the right. The signal flow is always from left to right,

b) The components are also numbered from left to right, top to bottom,

c) The power supply to the circuit, in this case a 9V battery, is placed to the right. When we use power supply for 127 / 220V, it is usually drawn to the left of the circuit.

d) The line that feeds the circuit is with the plus (+) at the top and at least (-) at the bottom. Note that all components drawn on the line marked with the letter "A" inside the arrow are all connected to the positive pole of the 9 V battery via the switch Sw1. In the line marked "B", at the base of the diagram, the components are connected to ground, earth or "circuit common point".

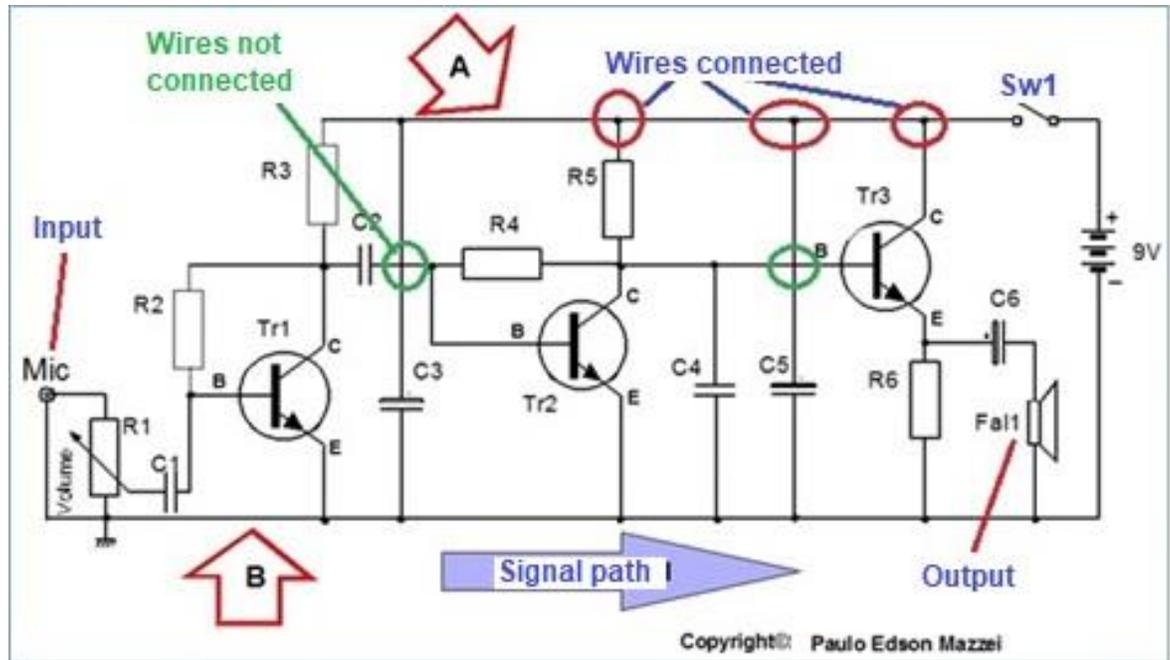


Figure 89 - Schematic diagram of a small audio amplifier.

Note in relation to figure 89:

- The (Mic) = microphone input is where the signal being amplified is applied and heard on the speaker (Fal1 = Loudspeaker 1), which is the output.
- The red circles show interconnected wires. They have electrical and mechanical contact with each other. The green circles show insulated wires simply intersecting, with no electrical or mechanical contact
- The arrow marked "A" shows where the circuit components are powered by the 9V battery. See the battery symbol. The Sw1 switch allows the circuit to be switched on and off.
- The arrow marked "B" shows the common point of the circuit, or earth or the point where the battery goes "-".
- Resistors use the letter "R" for circuit representation. The capacitors use the letter "C". The transistors use the letter "Tr", the diodes use the letter "D" and the transformers use the letter "T". R1 is a variable resistor, i.e. a potentiometer.
- The signal path being amplified is always drawn from left to right.

The Bill of Materials

Along with the schematic diagram of the project you are going to assemble, the **bill of materials**, containing the specifications of the components used, is provided. See **Figure 90**. This list of material was taken from a technical article in an electronics magazine.

She usually lists:

- a)** Resistors, with value, dissipation, tolerance;
- b)** Capacitors, with value, working voltage, type of construction (ceramic, plastic, etc.);
- c)** Semiconductors such as diodes, transistors, integrated circuits, display, LED, with models and possible replacements;
- d)** Inductors, such as transformers, coils, RF shocks, etc.;
- e)** Finally, several, where data on the box for the project (sometimes), wires, cables, screws, fuses, etc. are entered.

Bill of materials	
Semiconductors	
TR1	— Transistor MOSFET 40673, BFR84
Resistors: 1/4 W, 5%, carbon	
R1	— 120 k Ω
R2	— 100 k Ω
R3	— 560 Ω
Rx	— 470 Ω , linear pot
Capacitors: see the type in diagram	
C1	— 150 pF
C2	— 330 pF
C3	— 0,022 μ F (ou 22.000 pF)
Others	
L1, L2	- Coils, see the text
PCB, wires, solder, etc.	

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Figure 90 - Bill of materials to be used in a particular electronic project.

The concept of common point or earth.

Let's take this opportunity to introduce you to a concept related to earth, or to the connections of electronic components to earth. This concept will facilitate the circuit drawings that I present in the experiments, as well as will facilitate the assembly of your experiments.

The earth, as we have seen, is a common point of the circuit for connecting the cables, wires and electronic components of an electronic circuit. Usually on the ground we connect the negative terminals of a power supply, the negative terminals of an electrolytic capacitor (polarized), the shielding of an audio cable or RF (Radio Frequency), etc.

The symbols that you will find in the literature, to indicate a connection to earth, are the ones shown below, being the most used is the **(a)**, of **figure 91**.

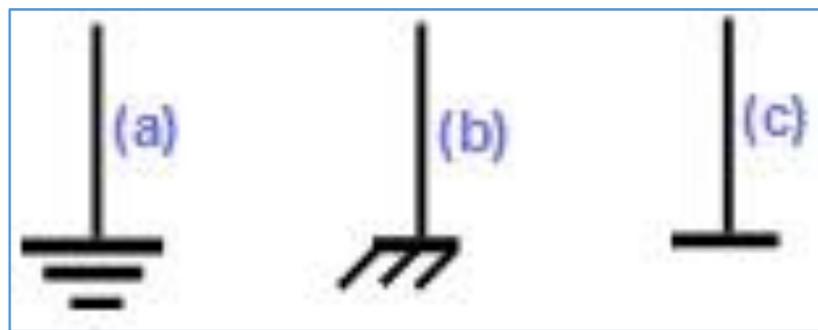


Figure 71 - Symbols for ground.

Please note drawings (a), (b) and (c) of figure 92:

- a.** What do they have different? Just the drawing because electrically they are identical circuits! What we did in the three drawings was to omit some data that is obvious.
- b.** The less of the circuit supply (5 V), is connecting the relay RI1, the other to the 4.5 V supply and the common to the speaker (**drawing (a)**). All of these points are common.
- c.** . In **drawing (b)** of the same figure, the three points that were previously interconnected with the drawing of a line (a conductor), are now "grounded", that is, interconnected via a ground connection. Electrically is exactly the same as the drawing circuit (a).
- d.** . In **drawing (c)**, we omitted the ground connections from the negative (minus) poles of the feeds. This implies that when studying drawing (c) you already know that the negative terminals of the sources go to the common point (earth, less), without the need to draw them. Electrically is exactly the same as the drawing circuit (a).

- e. . Look at the drawing (c) of **figure 92** and note that the drawing is much simpler, with no connection needs that are obvious.

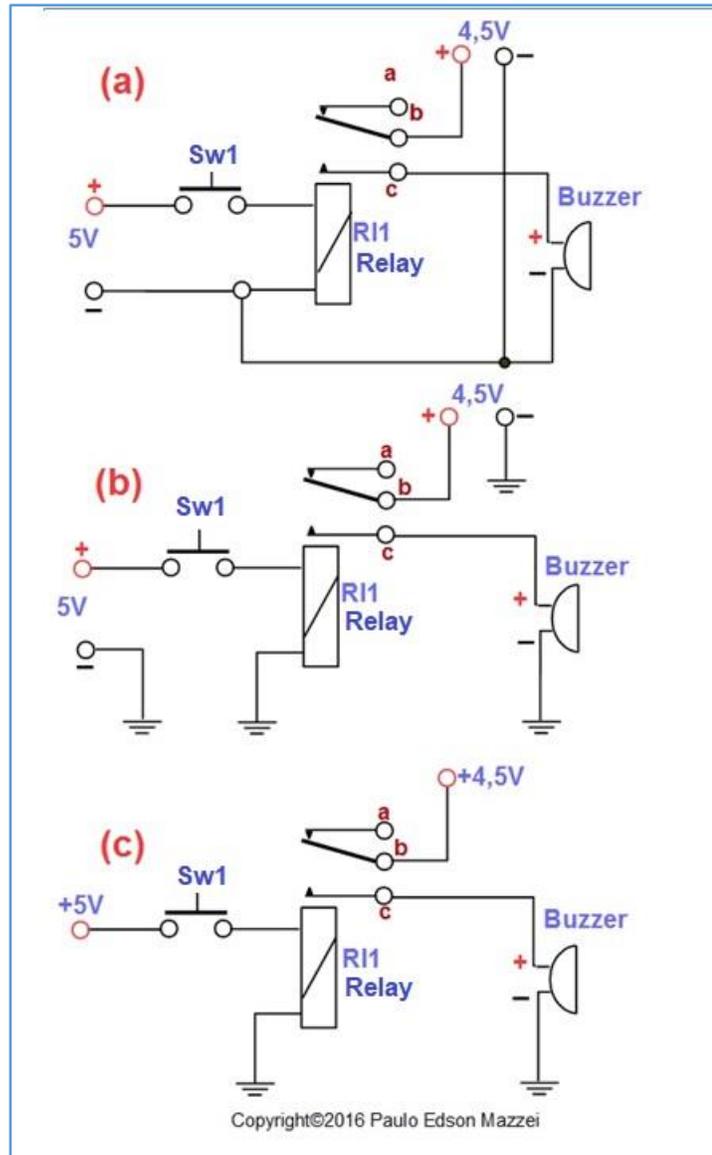


Figure 92 - Common point concept and diagram drawing.

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Chapter 14

Waves, pulses and signals

Introduction

Electronics is the study of the behavior of electrons, their effects and applications.

In electronic circuits, from the simplest to the most complex, signals, pulses, waves and noises always appear.

Let's see, in a simple way, how they may be useful sometimes or cause problems in certain situations.

Pulses

For example, the simplest application of the effect of electrons in a circuit is the circuit shown in **Figure 93** where an LED is connected to a 9 V battery through a series resistor. We cannot connect the LED directly, because the current that would circulate would destroy the LED.

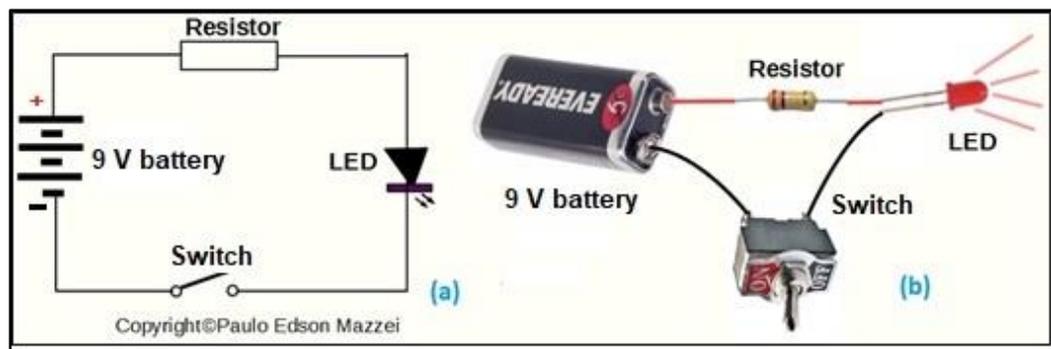


Figure 93-Simple electric circuit.

It is actually a very simple circuit and in principle, it seems that it has no use at all, other than turning on the LED.

However, if you open and close the circuit, using the lever switch Sw1, the LED will turn on and off, emitting flashes of light. These flashes of light can be converted and interpreted as a signal. This was used on ships, when they sent signals from one to another, using the Morse Code for messages. Light on and light off!

These LED flashes can be drawn and interpreted as a diagram, shown in **figure 94**.

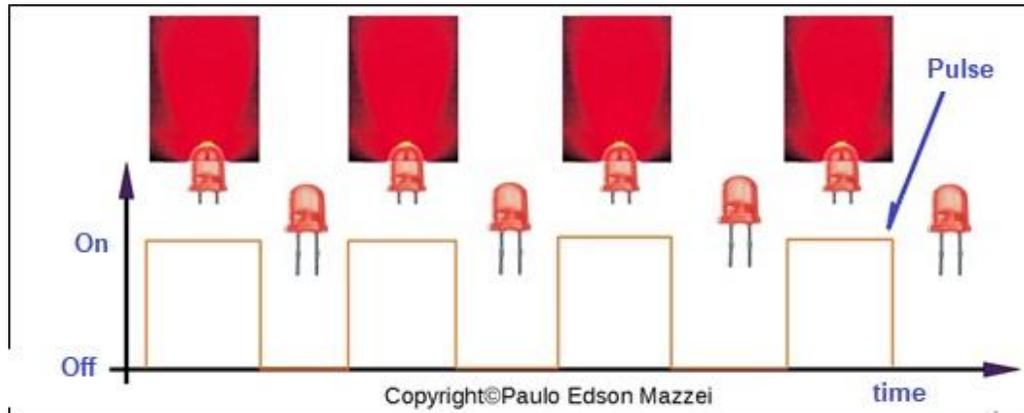


Figure 94- Pulses generated when turning on and off an LED.

Signals or pulses like those in **Figure 94** can be transmitted and some of their data changed to become a code, a voice signal, and so on.

We can define as **pulse** a rapid variation in the amount of current (I) circulating in a circuit as a function of time. These pulses are represented by diagrams as in **Figure 94** and are very important in electronic circuits.

Note in relation to this figure:

- There is no "perfect" pulse, i.e. it would reach a maximum value of 100% in (0 seconds) and would be stable at 100% for a certain time (pulse width) and then drop abruptly (0 seconds) from 100 % to 0%! See **(a)**, **(b)** and **(c)** in **figure 95**.
- Due to this, the "real" pulse would take some time to reach a maximum value and a certain time to drop from the maximum value to zero. Note also that the pulse is not stable at its maximum value or fall. See **(d)** in **figure 95**.
- In this way, the actual pulse is "a bit" different from the ideal pulse. With special electronic circuits, we can greatly enhance the shape of the actual pulse.

Waves

A **wave** is a periodic fluctuation in a voltage or current.

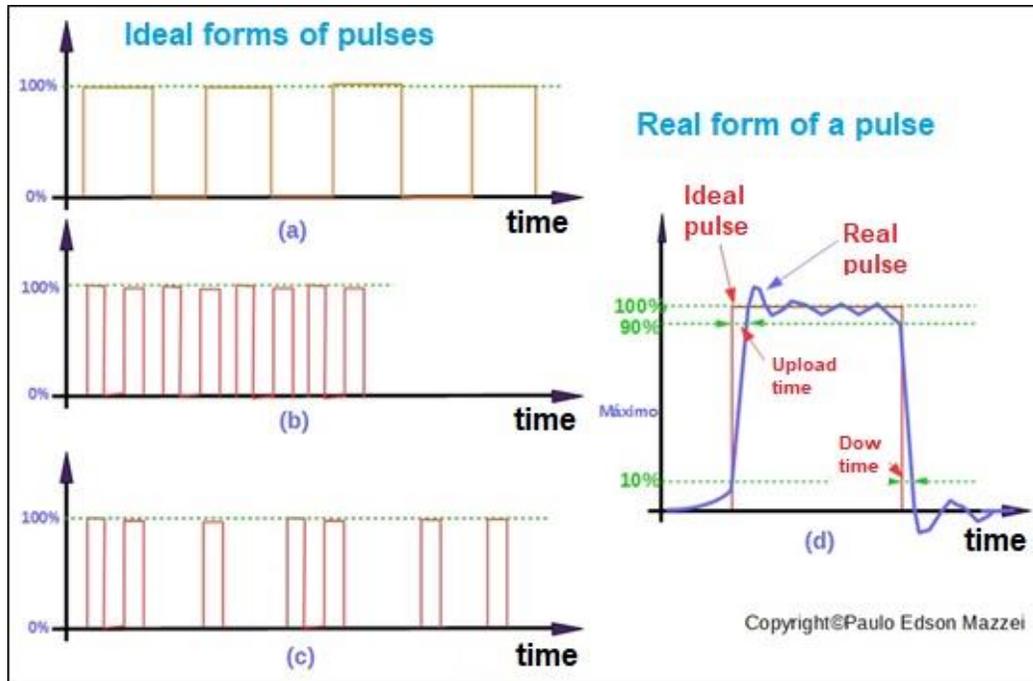


Figure 95 - "Ideal" and "real" pulse forms.

A wave may have a single polarity, such as DC, which varies from 100% of a given value. Or, it can have two polarities, positive and negative, like the waveform of the sinusoidal voltage present in the electrical outlets of our homes, of 127V or 220V.

The oscilloscope is an electronic test and measurement device that allows you to see the waveforms and pulses of various signals. See how it is in **figure 96**.



Figure 96 - Oscilloscope showing two waveforms on your screen.

The waves can take on the most diverse formats. See some examples in **figure 97**.

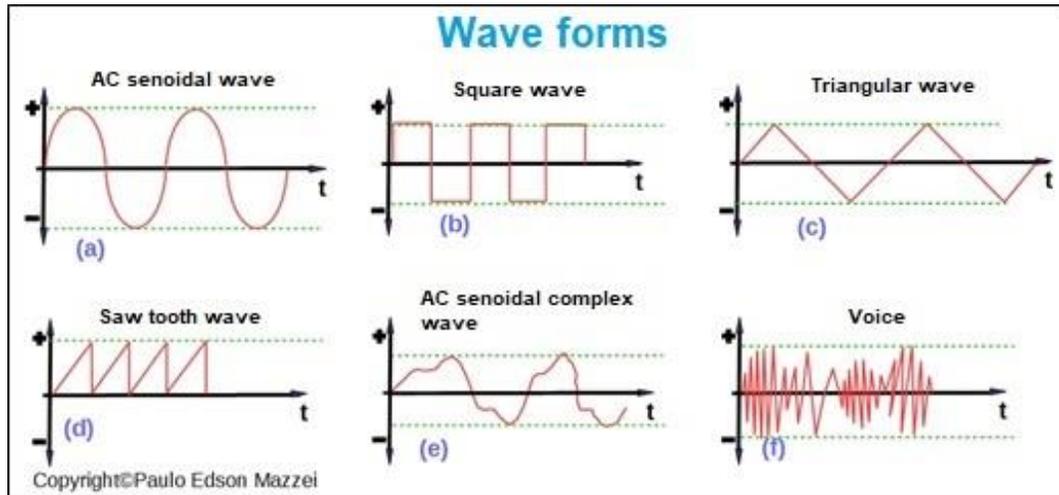


Figure 97 Wave forms.

Signals

Signals are periodic waveforms that carry information. The process that generates this wave is called **modulation**.

Radio signals are radio frequency (high frequency) signals, which have been modulated with voice signals. The modulating can be AM (Modulated Amplitude) or FM (Frequency Modulated).

AM radio waves range from approximately 550 kHz (kilohertz) to 30 MHz. FM's, you know, range from 88 MHz (megahertz) to 108 MHz.

See example of an OM (Medium Wave) radio station, operating at 600 kHz, in **figure 98**.

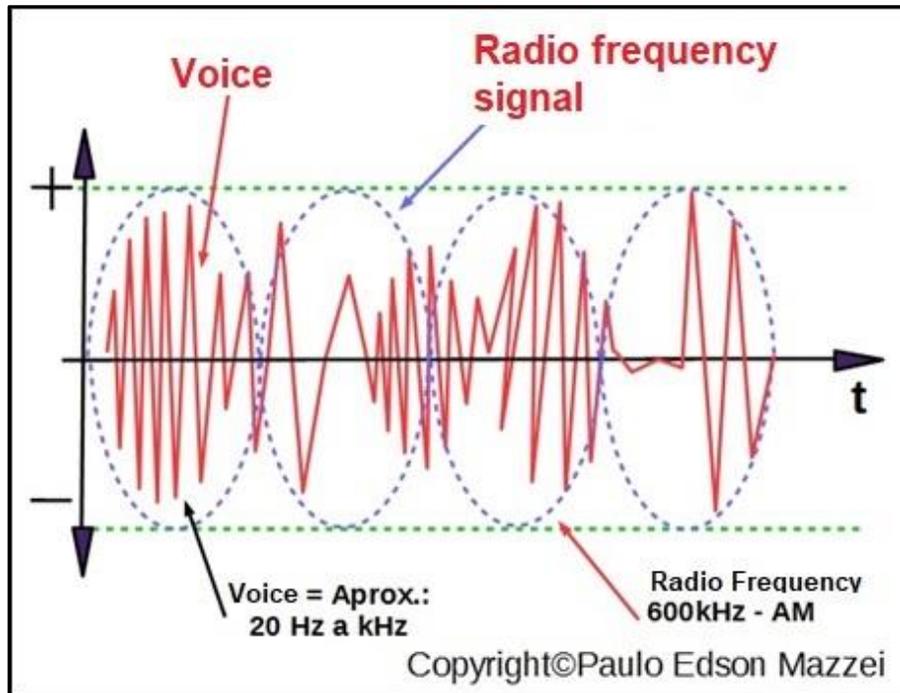


Figure 98 - Modulated radio signal from an AM station at 600 kHz.

Noise

All electronic devices generate small sporadic electrical signals, usually undesirable. When these signals (current or voltage) are undesirable, in most cases, they receive the name of **noise**. Often, they disrupt communications, television, radio, etc., as you may have seen and heard. See **figure 99**.

Many of the noises that appear on signals and waves are of human origin, such as cars, electric power generators, electric motors, radio and TV stations, and the electric power grid of our homes. There are also the rays and lightnings sent by the Creator!

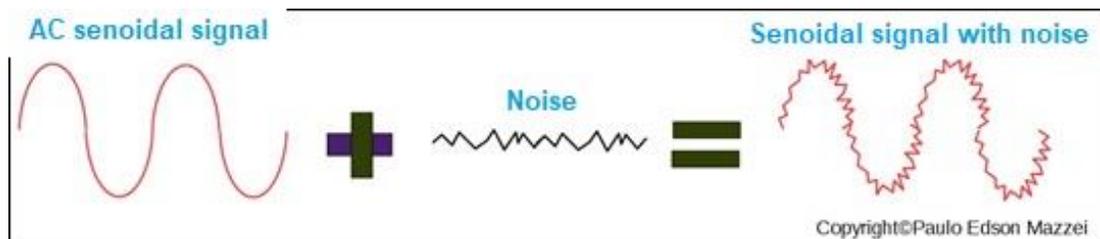


Figure 99 – Senoidal signal with noise.

Usually the noise signals have small intensity (amplitude) but can cause serious problems.

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Chapter 15

Electronic components

Introduction

In **Chapter 4**, we introduce you to the basic electronic components and their physical forms. In **Chapter 5**, we have seen the graphic symbols of these basic electronic components.

Now is the time to study some more electronic components, with more information about them.

You will need this extra knowledge when it comes to putting together your experiments, checking your results and finding possible problems.

Objectives

- Analyze the main electronic components in more detail.
- Identify these electronic components as well as read their value, model, etc.

Wire and cables

The wires and cables of an electric or electronic circuit are who "carry" the electric current because they are made of materials that are good conductors, like copper.

The wires are rigid and contain only one conductor, while the cables are flexible and contain several conductors of small diameter. The wires and cables can be "naked" (without insulation) or normal, with a cover made of insulation material such as PVC.

The wires can still be enameled. They are bare wires, which have received a special and very resistant layer of an insulating varnish, usually of golden or dark brown color. These enameled wires are used in transformers and inductors.

In Brazil, wires and cables are specified by their section, in square millimeters (mm^2). This section (wire area) is what gives the wire's ability to carry a certain electric current. In US the AWG Standards are used.

Figure 100 shows a wire table with various useful information.

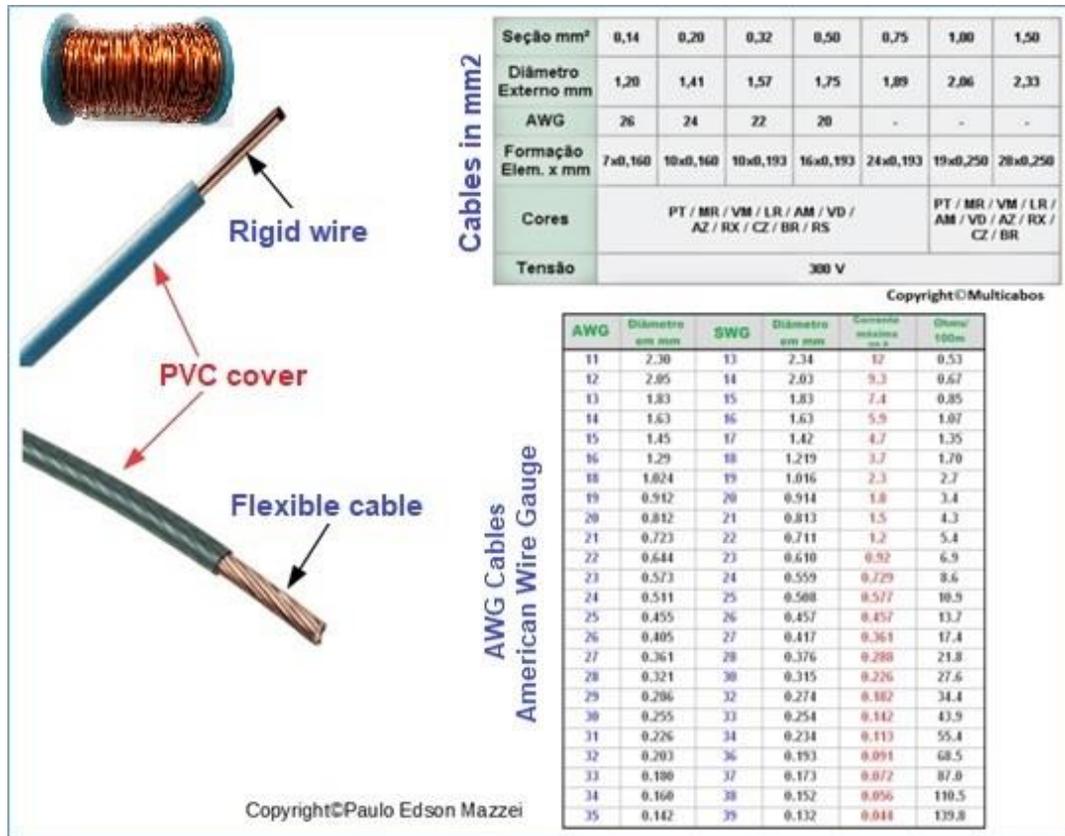


Figure 800- Table of wires and cables. Table in mm2 and AWG.

Regarding wires and cables, it is important to note the following:

1. Use only insulated cables and wires of good quality. You will experiment with a "PROTOBOARD" board, which requires insulated hard wires of small diameters: approximately 0.644 mm in diameter or 22 AWG. Let's go back to this subject further.
2. Each wire and cable diameter are made to withstand a nominal electric current, supplied in Amps. For example, a 1 mm² area cable supports a maximum current of the order of 17 amps. This value is quite high because we will work with much smaller currents. If you exceed this value, the cable will heat up and can catch fire!

Switches

Switches are mechanical devices that allow interrupting the passage of electric current in an electrical circuit. The most common are "on / off" switches used in various electronic devices.

See **figure 101** for the most common switches and switches we will use.

Regarding this figure, note:

(a) Knife type switch. This model is very old, used in electrical installations. "On / Off" Type See graphic symbols. Also called 1 pole x 1 position.

(b) Alternative symbol for the switch, on / off switch.

(c) Toggle switch, on / off type.

(d) Alternate symbol for the lever switch.

(e) Rocker On / off switch.

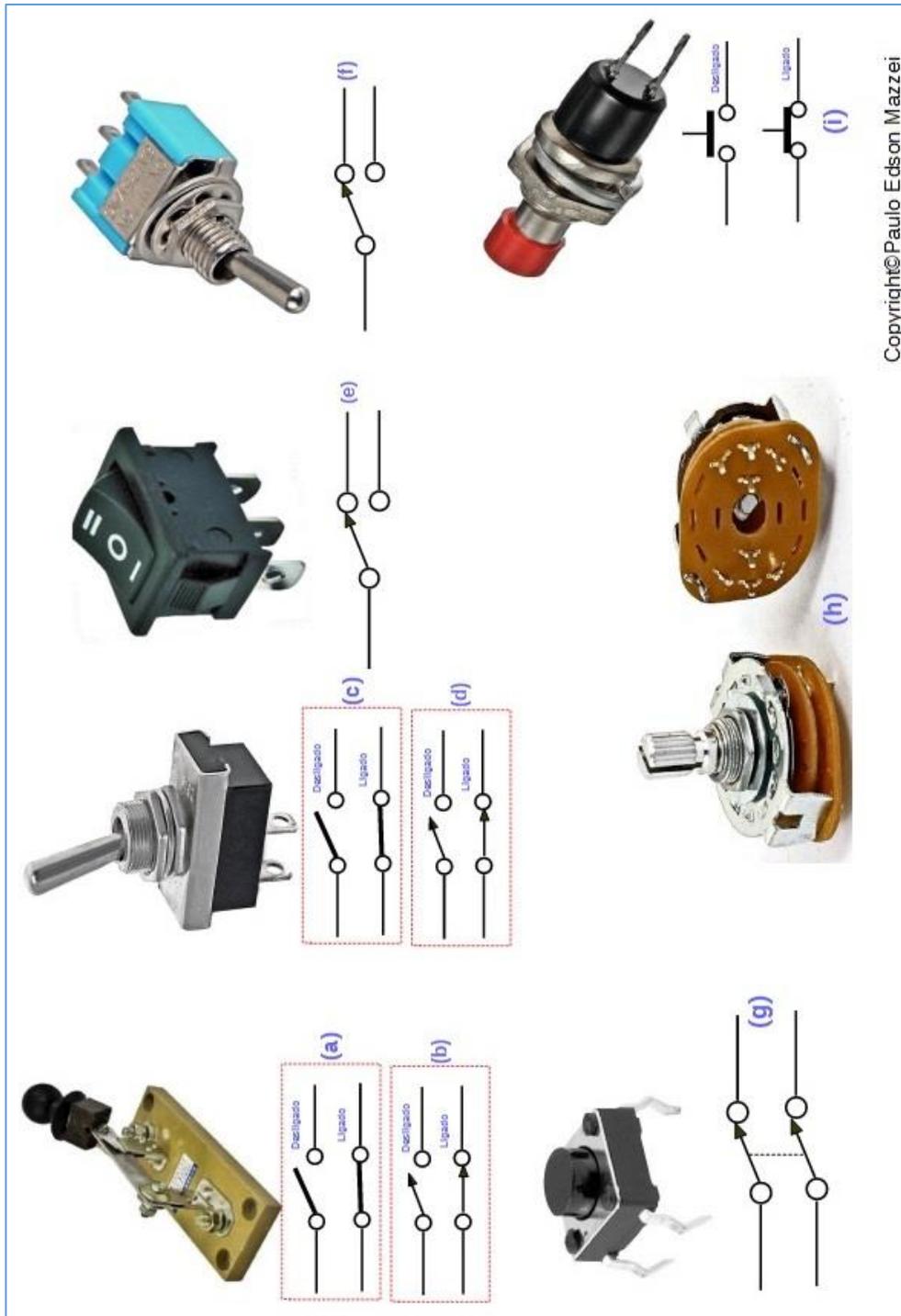
(f) "Lever" switch, on / off.

(g) Push button switch for PCI (Printed Circuit Board) mounting. See the graphic symbols. Also called 2-pole x 2-position.

(h) Rotary switch with multiple poles and various positions.

(i) Push button, momentary contact.

The number of switches and switches is enormous, they can be of various sizes, various voltage and current capacities, various poles and positions, illuminated on the keys, etc.



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Figure 101 – Common types of switches.

Relays

The relay is a type of switch, but actuated through the voltage applied to the coil thereof. It is an electromagnetic device.

When a voltage is applied to the internal coil of the relay, the electromagnetic field formed, attracts the contacts of the relay, closing or opening a circuit or several circuits.

See some relay types in **figure 102** and a drawing shows how it works.

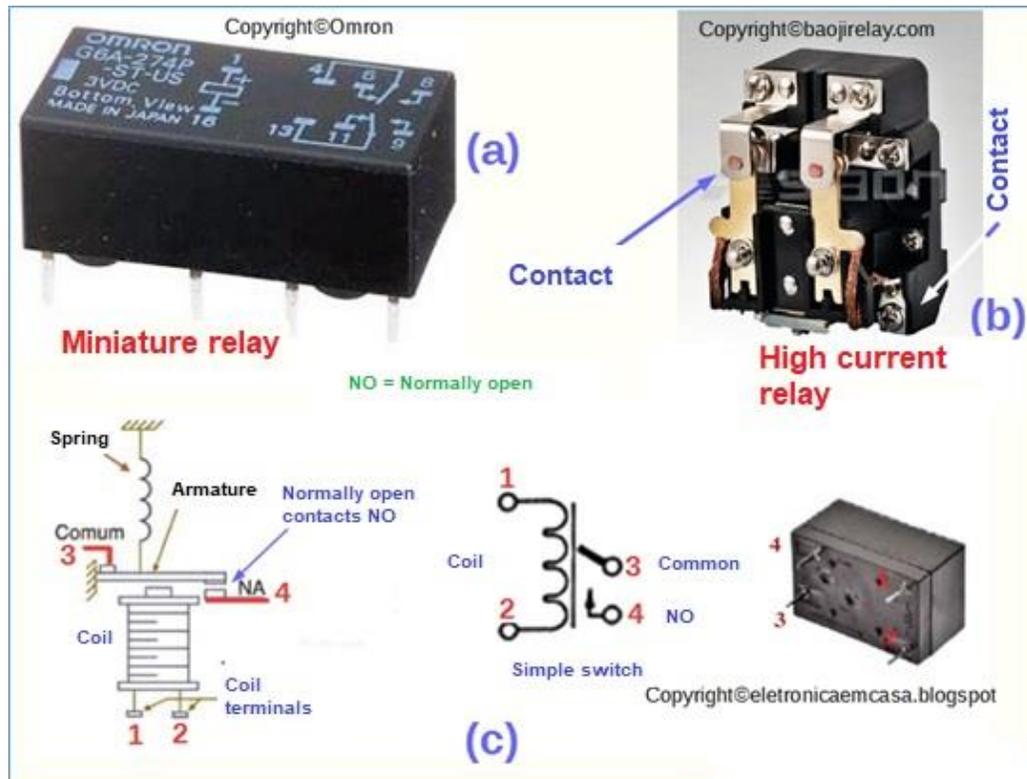


Figure 102- Miniature and standard relays. Relay operation.

In drawing (c) of the **figure 102**, a voltage is applied to the coil at terminals 1 and 2. This voltage varies greatly, depending on the circuit and the applications. This voltage creates an electromagnetic field on the coil, which attracts the contact marked with the number 4. Before it was drawn, it was away due to the action of the spring vertically.

With the attraction of this contact 3, the electric current finds a way through the other contact, marked 4. Next to the design of the relay can be seen the graphic symbol for this miniature type relay.

Reed switch relays

Another type of very small relay, used in electronics, is the relay of blades or the so-called "reed switch". In this relay, the contacts are enclosed in a glass vial

and a small external coil actuates the contacts located at the ends of the blades, as shown in **Figure 103**.

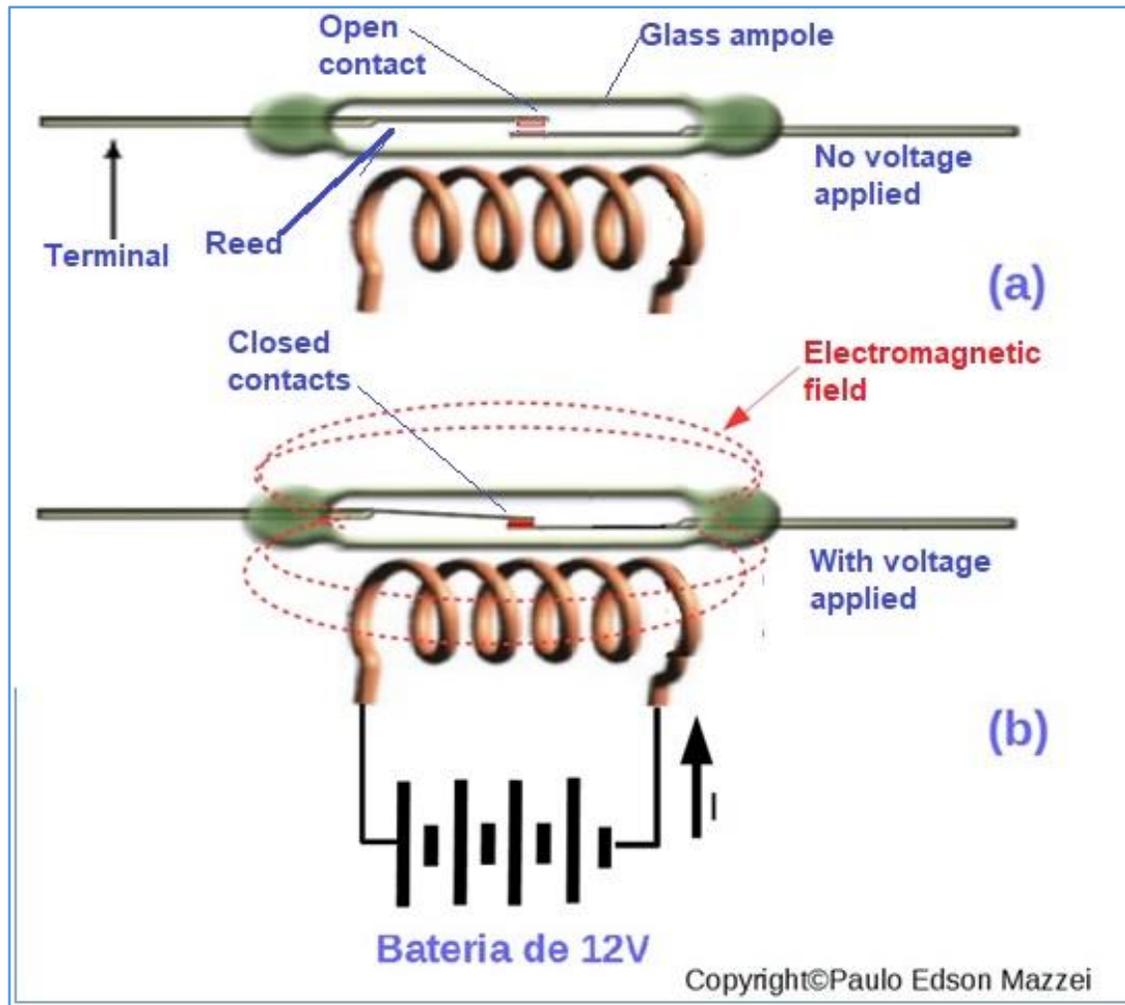


Figure 103 - Reed relay open (a) and closed with battery voltage applied (b).

Coil Meters – Galvanometer

Mobile coil meters or galvanometers are the analog meters used in analog voltmeters, stereos, etc. See **figure 104**. For our work on electronic experiments, we will use the DMM - Digital Multimeter as discussed in **Chapter 2**. Galvanometers are expensive, fragile and difficult to find.

Next to the photo of the galvanometer you will find the graphic symbol of it. The letters that go into the circle indicate what type of current the instrument can measure. In our case, it is a "microammeter".

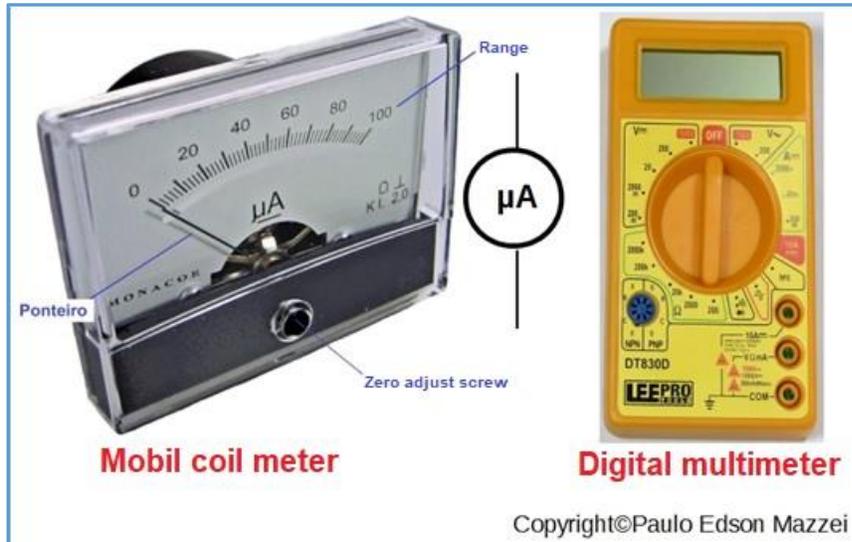


Figure 104 - Galvanometer and digital multimeter.

Microphones and Loudspeakers

Both the microphone and the speaker are called "**transducers**", because they convert one form of energy into another form of different energy.

The **microphone** converts sound waves into electrical signals.

There are several types of microphones, such as charcoal (old phones), crystal, dynamic, condenser, etc.

Loudspeakers convert electrical signals into sound, that is, the inverse of the microphone. Let us use in our experiments the "buzzer", which is a kind of loud speaker, used as a bell, alarm, etc. See **figure 105**.

The electret microphone (**b**) will also be used in our experiments, further on. The female readers can get the earphones with Swarovski crystals inlaid, as in (**e**) of the figure!!



Figure 905- Microphones, loudspeakers and earphones.

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Chapter 16

Resistors

Introduction

In **Chapter 4**, we introduce you to the basic electronic components and their physical forms. In **Chapter 5**, we have seen the graphic symbols of these basic electronic components.

In the previous chapter, **Chapter 15**, we have already seen some electronic components to be used in their assemblies and their projects. Now, in this chapter, we will continue with more electronic components, which will be used more in the future.

Objectives

- Identification and characteristics of the main electronic components, for use in the experiments.
- How resistors, capacitors, inductors, diodes, transistors, etc. are used.

Resistors and the color code

The resistor, the most commonly used component in electronic circuits, has the basic function of limiting the electric current that flows through it. Its "resists" the passage of the electric current!

Resistors are found in hundreds of values, shapes, colors, dissipations (in Watts), precision (%), etc.

The great majority of the resistors we are going to use are those of carbon composition. In this type of resistor, a thin layer (film) of carbon is deposited on top of a small cylindrical porcelain rod (insulation).

The thickness of the carbon layer gives the value of the resistor in ohms (Ω).

There are also metal film resistors. Instead of the carbon a thin metallic film is deposited. They are more accurate and reach 1% accuracy. They are more expensive than carbon.

In carbon and metal film resistors, the ohmic value, tolerance, accuracy is given through colored bands painted on the resistor body itself. This is illustrated in figure 106.

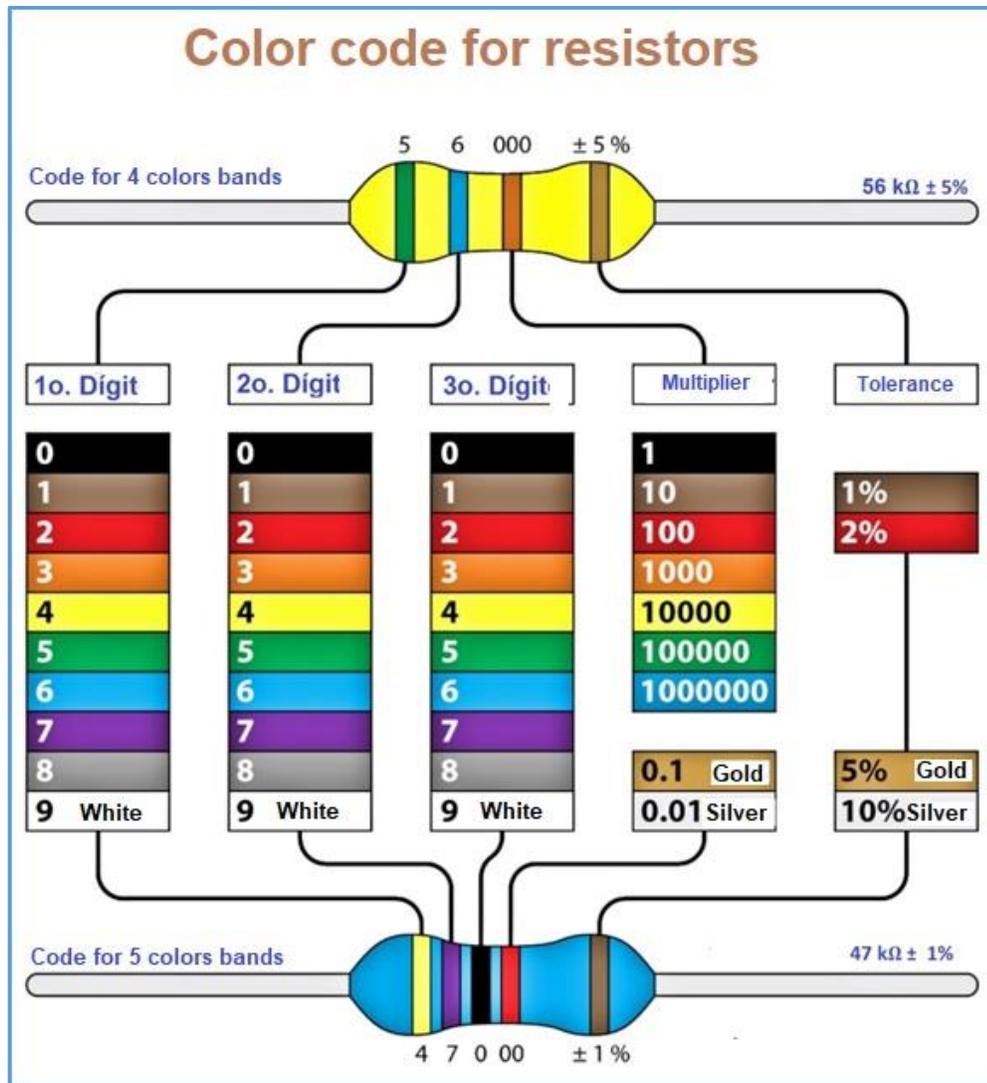


Figure 106 – Color code for resistors.

In the case of SMD resistors, the values are printed on the body itself, using a special code for this. Figure 107 illustrates some values.



Figure 107 – SMD resistors values

When selecting a resistor for your experiments or even mounting an electronic circuit, you need to specify:

1. Type: Carbon resistor, metal film or wire?
2. Physical value.
3. Power dissipated by the resistor, in Watts (W).
4. Tolerance.

Another type of resistor is the **wire resistor** that is manufactured by winding a special wire around a ceramic stick. They are used for larger powers and can be found from 1 to 100 W!! Wire resistors do not use color coding and their ohmic, tolerance, and dissipation values are written to the resistor body itself. **See figure 108.**

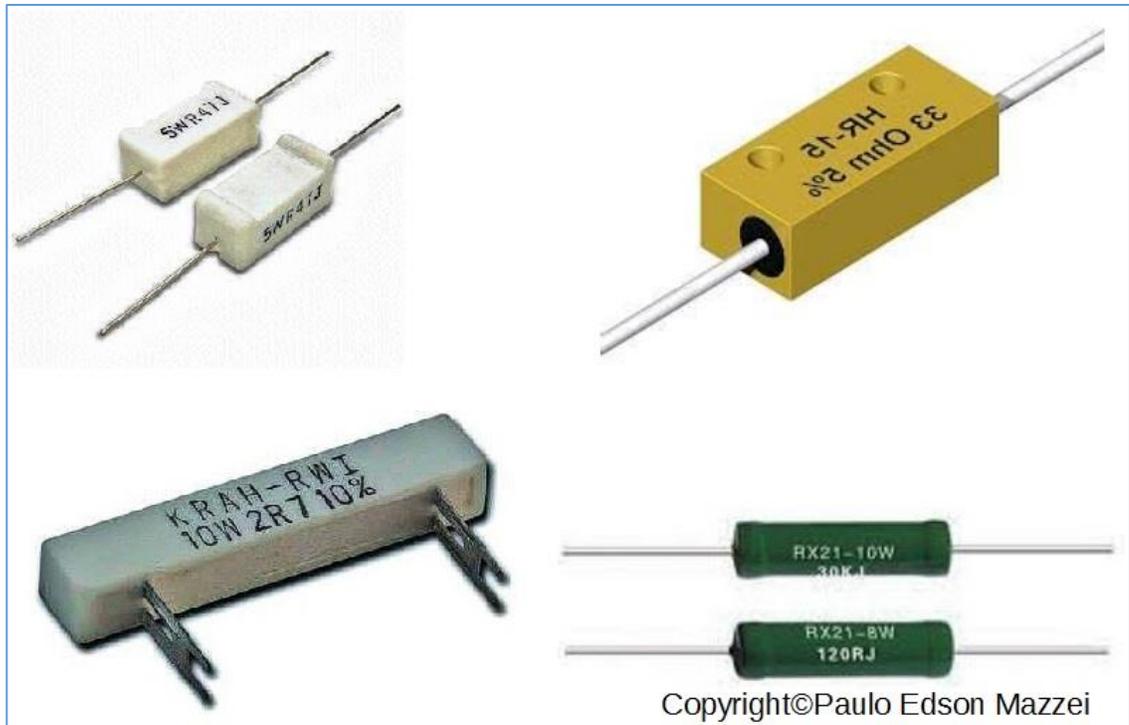


Figure 1008- Wire wound resistors.

Other types of resistors

- a. **Photo resistors** or photo cells: are resistors that when exposed to light, change their resistance. This allows the creation of interesting control circuits.
- b. **Thermistor**: As the name says, thermistors, when exposed to heat (temperature variation), change their resistance.
- c. **Variable resistors**: They are resistors whose value can vary, through an axis coupled to it. The **potentiometers** (pots) are the most typical example of the variable resistor.
- d. **Adjustable resistors**: These are resistors whose value varies once for the adjustment or calibration of an electronic circuit. Generally, this set value is not changed. They are called **Trimpots**.

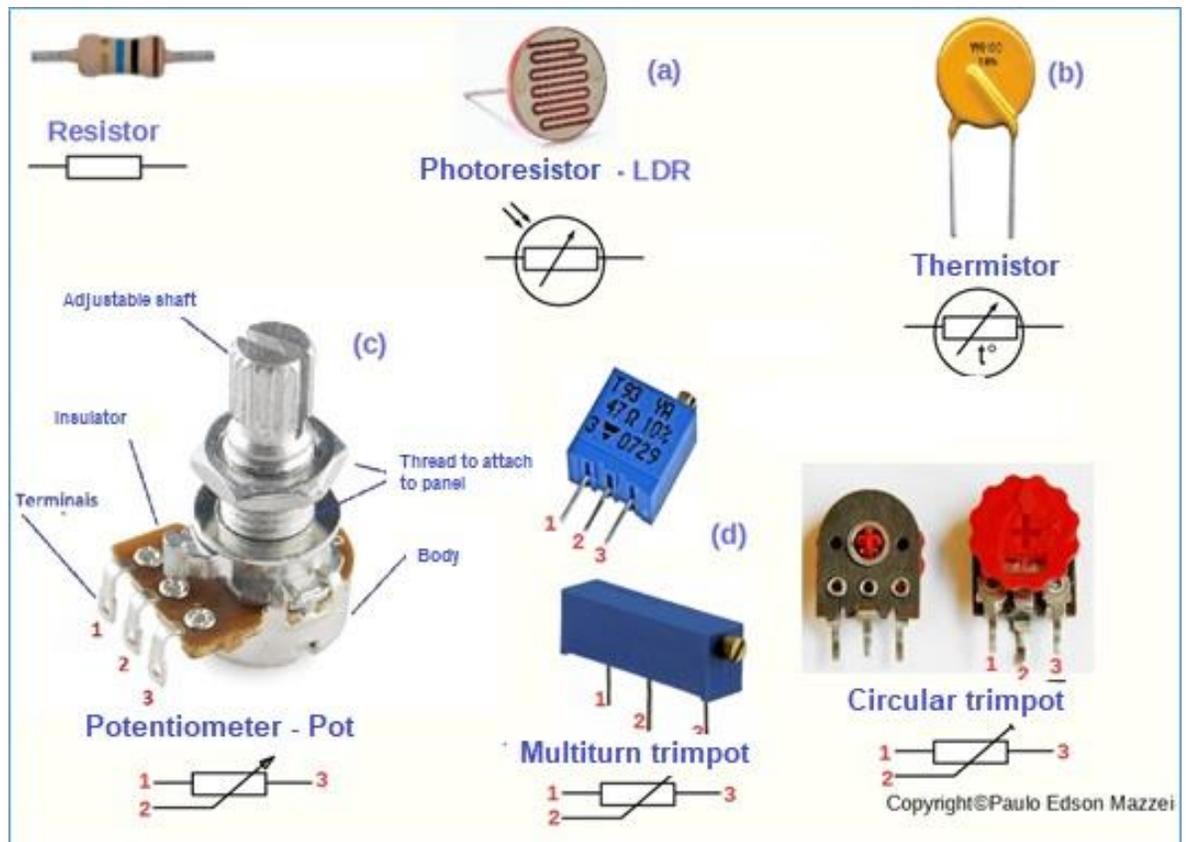


Figure- Types of resistors.

Figure 109 illustrates the types of special resistors.

SMD resistors

The **SMD** technology resistors usually have the shape of a small black rectangle with the silver ends. At these extremes is where the soldering of the resistor is done on a PCB. See **figure 110**.

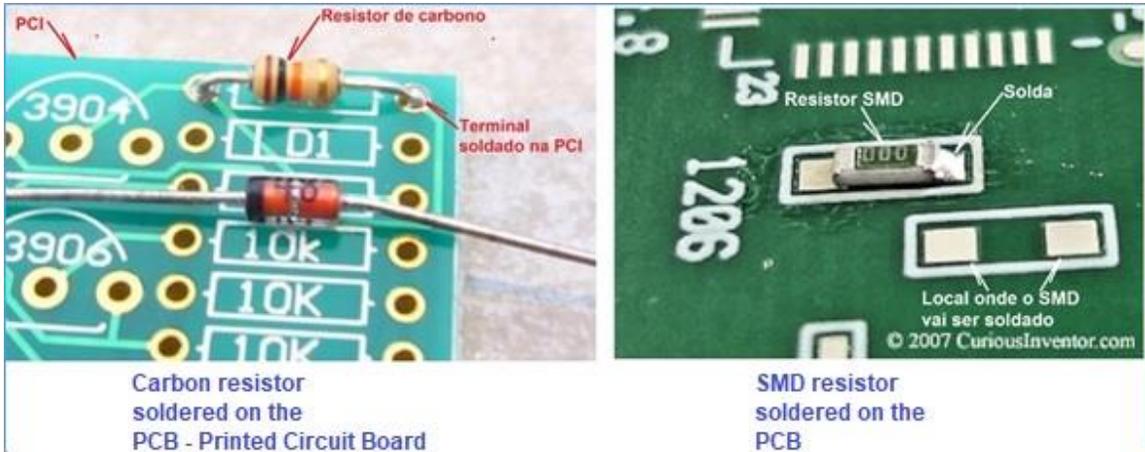


Figure 110 - Examples of welding of the two most common types of resistors. Courtesy SparkFun Electronics - USA

How resistors are used

The resistors can be associated, using what we call the circuit in series and circuit in parallel. With this we can divide currents, voltages, "manufacture" ohmic values that we do not have to use in a certain electronic circuit, etc. See **figure 111**.

In this **figure 111** you can see that in the series association, the individual values of each resistor are added to the total value. In parallel association, the total value is half the individual value, provided that the individual values are equal.

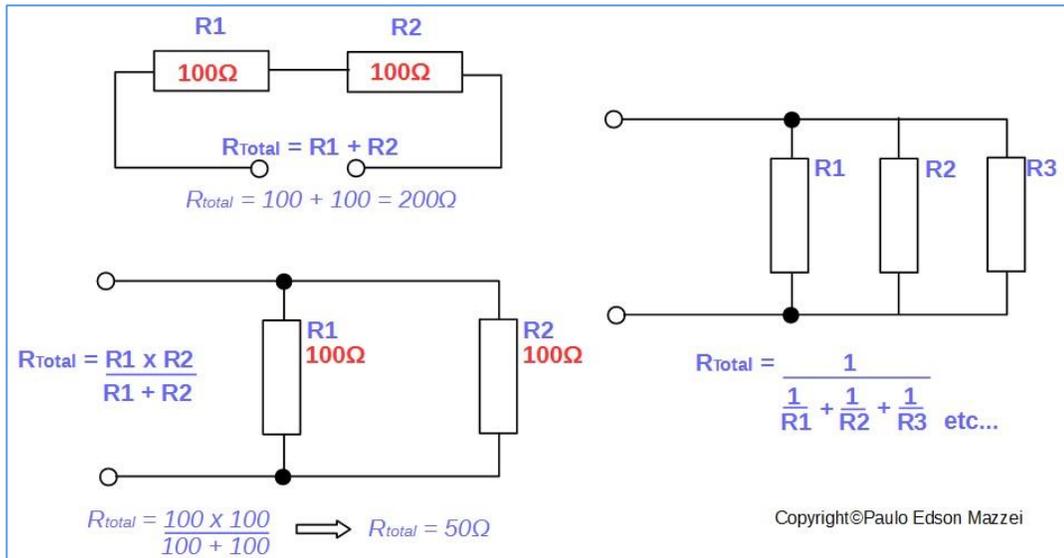


Figure 111 – Series and parallel resistor association.

For parallel circuits with more than two resistors, apply the formula shown in **figure 111** to find R_{total} .

A voltage divider with resistors

Voltage divider with resistors are very tight arrangements in electronic circuits! This is why it is important to see how it works and how to use it. See **figure 112**.

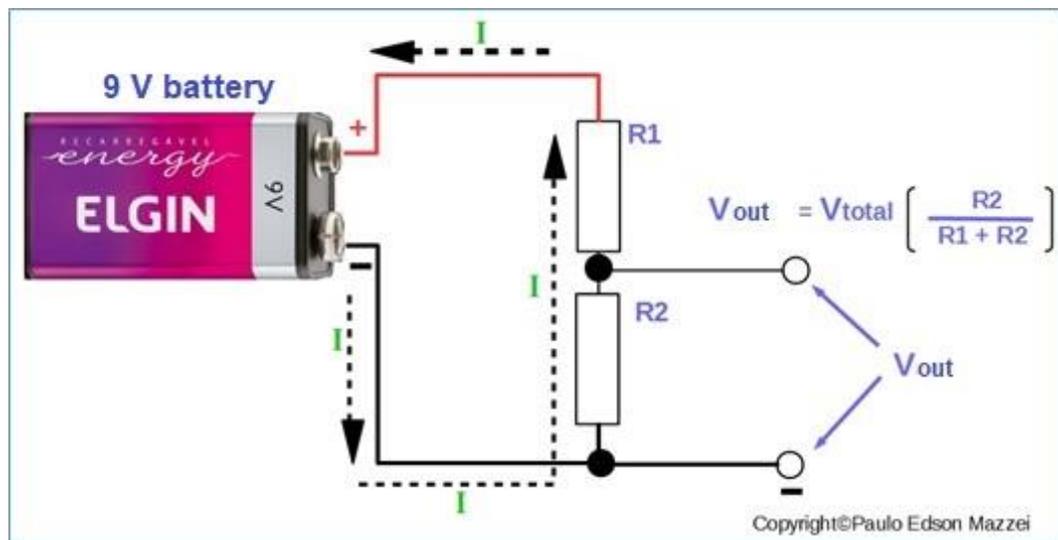


Figure 112 – Voltage divider with two resistors.

Note in relation to the voltage divider of figure 112:

- The input voltage is supplied by the 9V battery.
- The current "I" running through the two resistors is supplied by the battery.
- This current I, when circulated by the R2 resistor, produces a voltage drop proportional to the value of R2 and the current flowing. This voltage drop in R2 is the output value (V_{out}), marked in the drawing.
- By changing the value of R2, you get other values for the output voltage. This value is calculated by the formula given in **figure 112**.

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Chapter 17

Capacitors

Introduction

Capacitors are electronic components that store small amounts of energy. Like a small battery, they also cause a current flow in a circuit, for a short time. They cannot provide power for long periods of time.

The capacitance of a capacitor is measured in how much energy it can store.

In its simplest form, a capacitor consists of two metal plates separated from each other. Air or other insulation material is usually used between the plates. The larger the plates, the greater the capacitance of the capacitor. See **figure 113**.

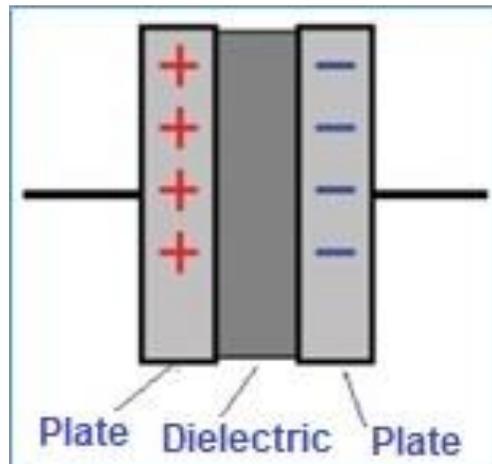


Figure 1113- Basic construction of a capacitor.

To construct high capacitance capacitors, without having a large volume, the metal plates take the form of strips of thin aluminum, rolled in the form of a "rocambole", as shown in **figure 114**.

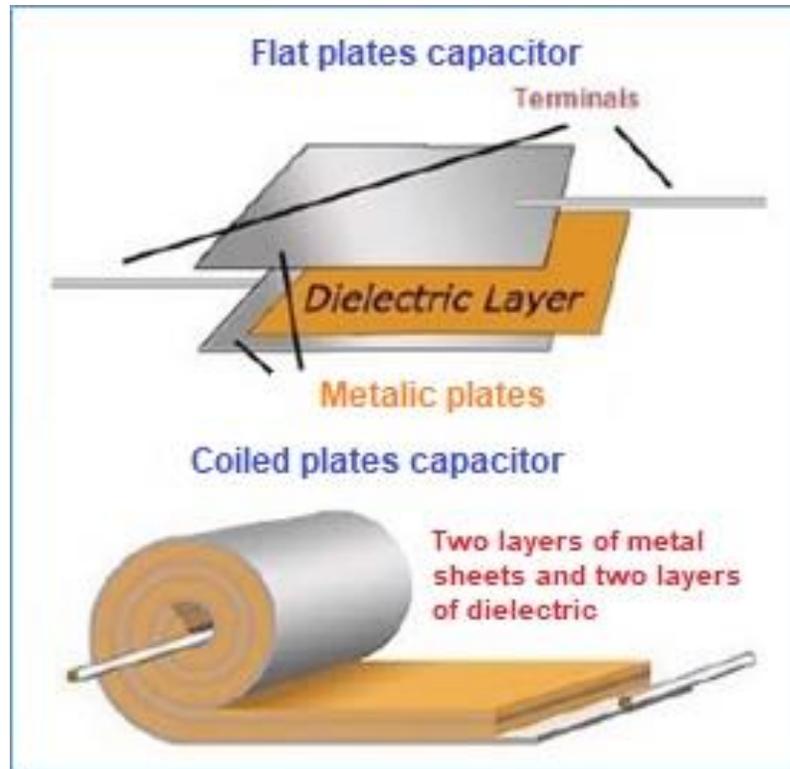


Figure 114 - Plate of a capacitor coiled with the dielectric.

Another way to change the capacitance of a capacitor is to change the material that is used between the metal plates. This material is called **dielectric**. Dielectric are made of ceramic, polyester, mica, the most common of which are ceramics.

Farad	Micro Farad	Nano Farad	Pico Farad
1 F	1 μ F (um microfarad)	1nF (um nanofarad)	1pF (um picofarad)
1 F	0,000001F	0,000000001F	0,000000000001F
	1 x 10 ⁻⁶ F	1 x 10 ⁻⁹ F	1 x 10 ⁻¹² F

Figure 115 Farad submultiples.

The capacitance of a capacitor is measured in **Farads**. A 1 Farad capacitance is too big! Because of this, our electronic assemblies will use capacitors of very small value. These values are indicated by letters that make Farad submultiples, as in the table in **figure 116**.

The basic capacitor models are:

- Non-electrolytic (ceramic, plastic, mica, etc., **non-polarized**)
- Electrolytic (**polarized**, with + and -)

Electrolytic capacitors are polarized and have their terminals marked + and -, as in the photo on the side. These capacitors usually have high capacitance values and can store high energy values. Since this capacitor has polarity, it needs to be properly connected to the circuit. They may even explode when their polarity is reversed.

The capacitance of a capacitor comes printed on the capacitor body itself. In the case of electrolytic, the working voltage is also indicated.

Types of capacitors

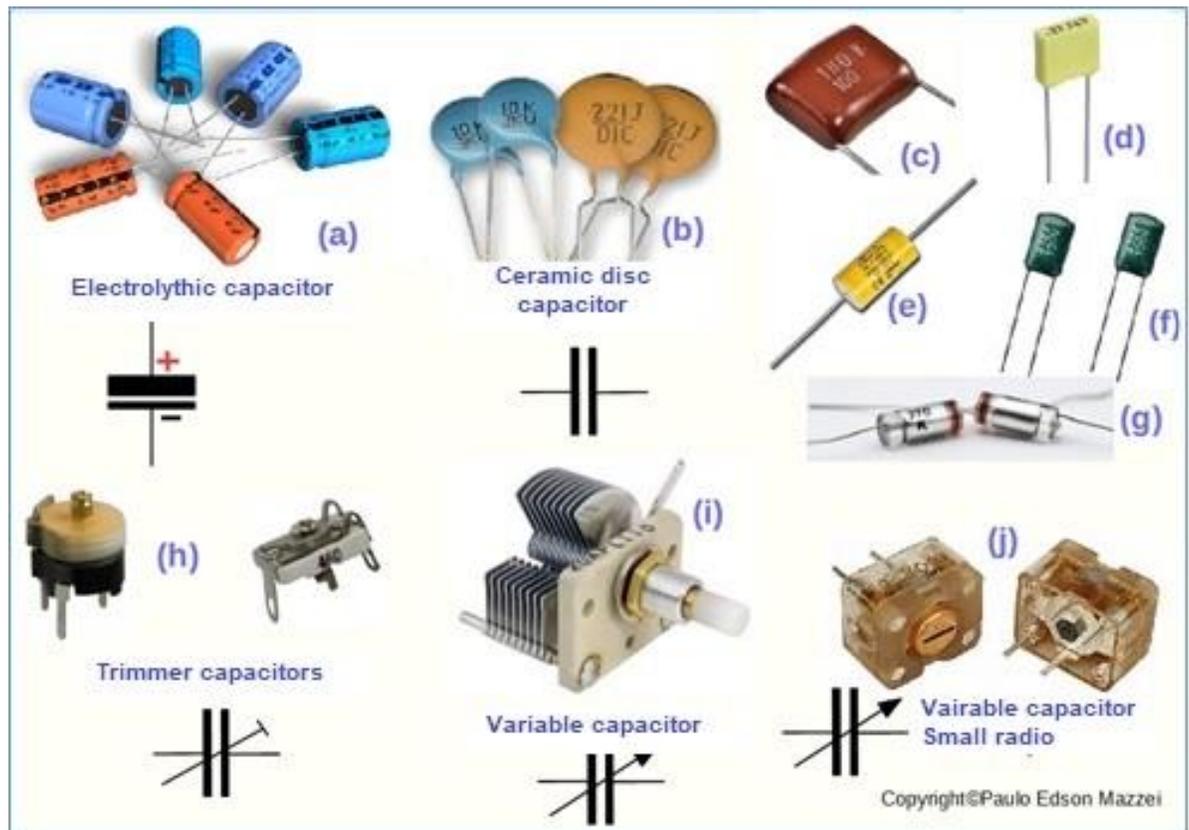


Figure 1216- Types of capacitors.

In **figure 116** you can see some models of capacitors and their graphic symbols.

Note in relation to figure 116:

- The electrolytic capacitors in (a) are polarized. The capacitance, working voltage and polarity values are printed on the capacitor body itself. Note the graphic symbol with the + and - sign.

- The capacitors from (b) to (g) use plastic dielectric, such as polyester and Plexiglass (g). The same graphic symbol shown is used for all non-polarized fixed capacitors.
- "Trimmer" capacitors are adjustable capacitors (h). See the graphic symbol.
- Variable capacitors allow continuous variation of their capacitance (i) and (j). The plastic variable capacitor model, in (j), is used in small portable radios to tune radio stations.

Charge and discharge of a capacitor

When a capacitor is connected to a battery, it starts charging (storing charge). At first the current flows rapidly and a charge begins to form on its plates: a negative charge and a positive charge. As the capacitor charges, it begins to counteract the passage of the current circulating in the circuit. The current decreases as the capacitor plates become fully charged.

If the terminals of a capacitor are shorted (connected together), the capacitor will discharge quickly at the beginning and more slowly at the end of the discharge. If the terminals of a charged capacitor are connected to a resistor, the capacitor discharge time varies with the resistor value.

If the terminals are simply connected to each other, a spark may form at the terminals, especially in large capacitance electrolytic capacitors.

We have seen that when a capacitor is fully charged, the current flow ceases. This means that a constant current cannot flow forever through a capacitor. A constant current is called DC, abbreviated "DC". Remember that the DC is supplied only by batteries.

An alternating current "AC" can circulate through a capacitor. The alternating current constantly reverses its flow direction. The 127 and 220V voltage we have in our homes is an alternating current and it reverses direction 60 times per second (60 Hertz). With this, the AC continuously charges and discharges the capacitor, allowing its passage. The AC is supplied by generators that are in the hydroelectric power plants and distributed through the electric power grid to our homes.

Usually these two types of current, DC and AC are represented graphically as shown in **figure 117**.

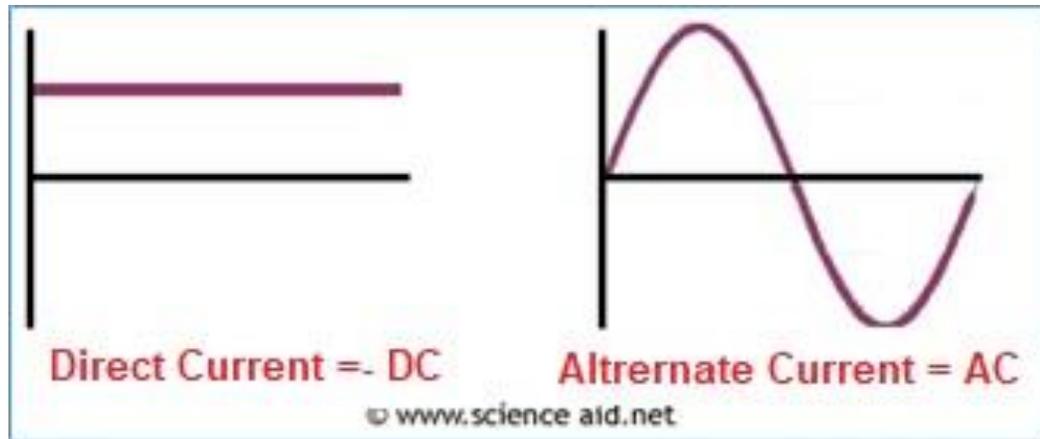


Figure 1317- Direct current and Alternating Current.

One more important item regarding capacitors is that in addition to their capacitance in Farads (or microfarads, or picofarads), it is important to specify their **working voltage** in DC volts.

For example, we can have an electrolytic capacitor of 100 microfarads, at voltages of 5, 10, 15, 25, 50 Volts, etc.

In common circuits, the vast majority of capacitors are for 25- or 50-volts DC. Carefully observe the working voltage of the capacitor when replacing this component.

The value of the capacitor usually ranges from $\pm 5\%$ or 10% up to $\pm 100\%$ on the electrolytic capacitors.

In order to charge a capacitor, you can use the circuit of **figure 118**. This type of circuit is very important and is applied to several other electronic circuits.

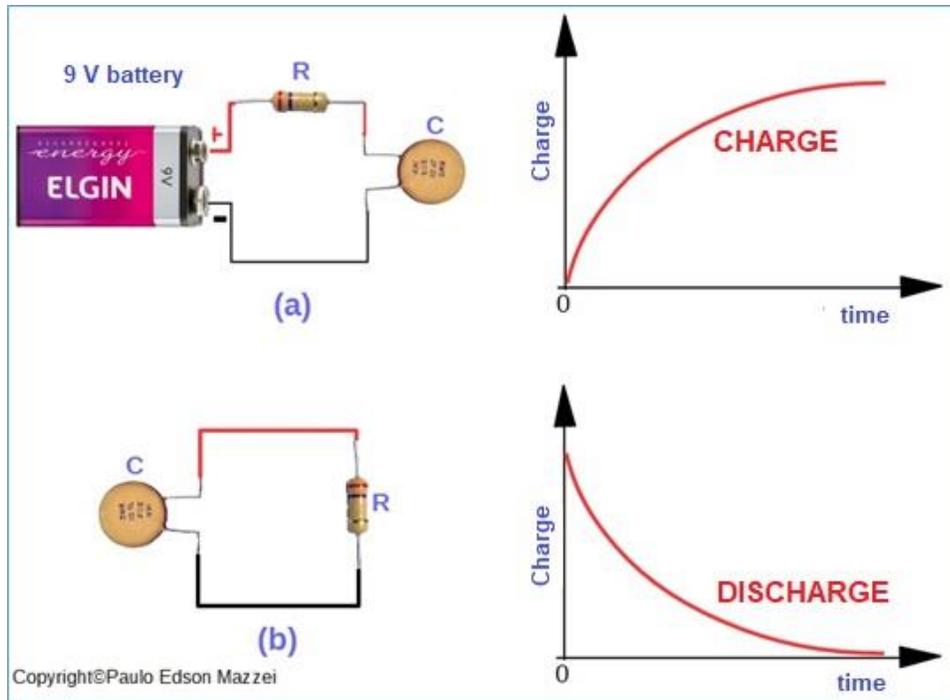


Figure 118 – Charge and discharge of a capacitor.

In **figure 118**, drawing **(a)**, the capacitor is connected to a 9 V battery through a resistor. The resistor is used to limit the charge current.

In **(b)** of the same figure, the charged capacitor, after a certain time, is connected to a resistor to discharge. The resistor causes the discharge to be slower.

You then see that by changing the value of the resistor, we can change the charge and discharge time of a capacitor.

Charging and discharging a capacitor

When the charges come together on the plates of a capacitor, the capacitor is charged. At some point in a process of charging a capacitor, the plates become so charged that no more electric current flows.

If we connect this charged capacitor to a single circuit, the charges begin to circulate to a point where the capacitor is discharged.

Let's look at the circuit shown in **figure 119**.

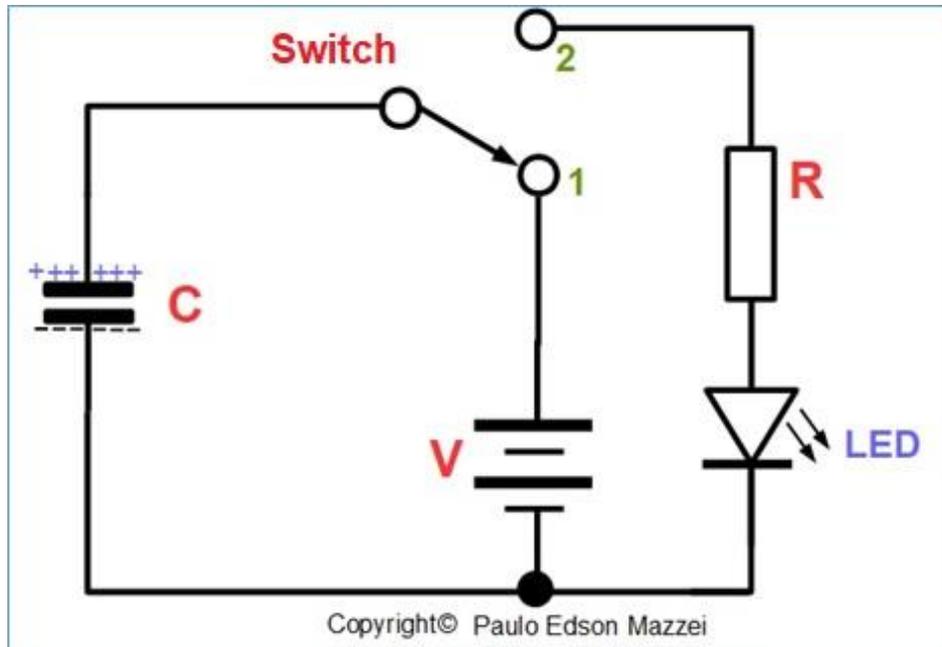


Figure 119 – Charging and discharging process in a capacitor.

Observe in figure 119:

- a. A capacitor is connected to a battery and a resistor.
- b. A switch allows you to select whether the capacitor will be connected to the battery or to the resistor.
- c. In position 1, the capacitor is connected to the battery.
- d. In position 2 of the switch, the capacitor is connected in the resistor and LED.
- e. Initially we set the switch to position 1, as shown in the circuit of figure 74.
- f. In this position 1, the battery is connected directly to the capacitor, which starts charging. After a certain time, no more current flows and the capacitor is charged.
- g. We then passed the switch to position 2, which connects the capacitor directly to the resistor and LED. A current is then circulated and the energy previously stored in the capacitor switches on the LED briefly.

How capacitors are used

Capacitors, such as resistors, can be connected in series and in parallel, as shown in figure 120.

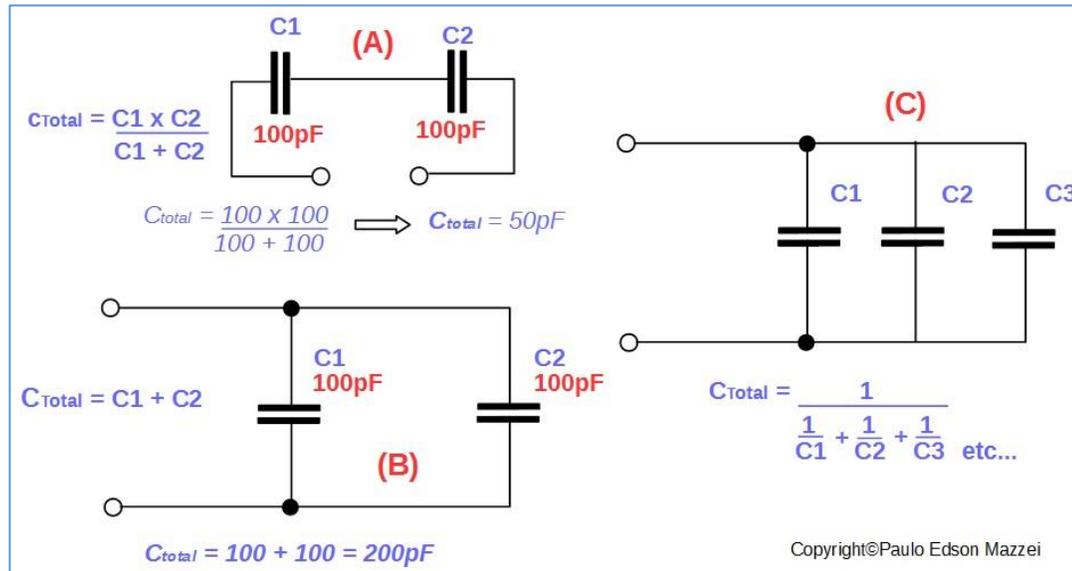


Figure 120 - Association in series and parallel capacitors.

Types of capacitors

In your experiments in electronics, you will see that there are many types of capacitors and, depending on the circuit where it will be used, you choose the type, etc.

- **Size:** in terms of physical volume and capacitance. Generally higher capacitance requires higher physical volume, such as in electrolytic capacitors.

- **Maximum working voltage:** Each capacitor has a maximum working voltage, that is, the maximum voltage that can be applied to its terminals without the capacitor being damaged. You will find capacitors from 1.5 VDC up to over 250 VDC.

- **Tolerance:** it is difficult to make a capacitor in a certain value, exactly. Therefore, the values presented for the capacitance, are within a certain tolerance. They can have excellent tolerances as 1.5% and may have higher tolerances, above 20%, as is the case with electrolytic capacitors.

Ceramic capacitors

They are capacitors whose dielectric is ceramic. Quite used in electronic circuits they stand out because of the small physical size. Usually the values of these capacitors go up to 10 μ F. Please, look at **figure 121**.

In (a) very used ceramic capacitor, with a value of 470 nF, 50 V. A ceramic disk capacitor is shown in (b), value of 1000 pF and maximum working voltage of 2 kV (2000 V). In (c) another ceramic type disk capacitor, with a value of 470 nF. A ceramic capacitor in SMT (Surface Mount Technology) technology is shown in (d).

The ceramic capacitors shown have no polarity.

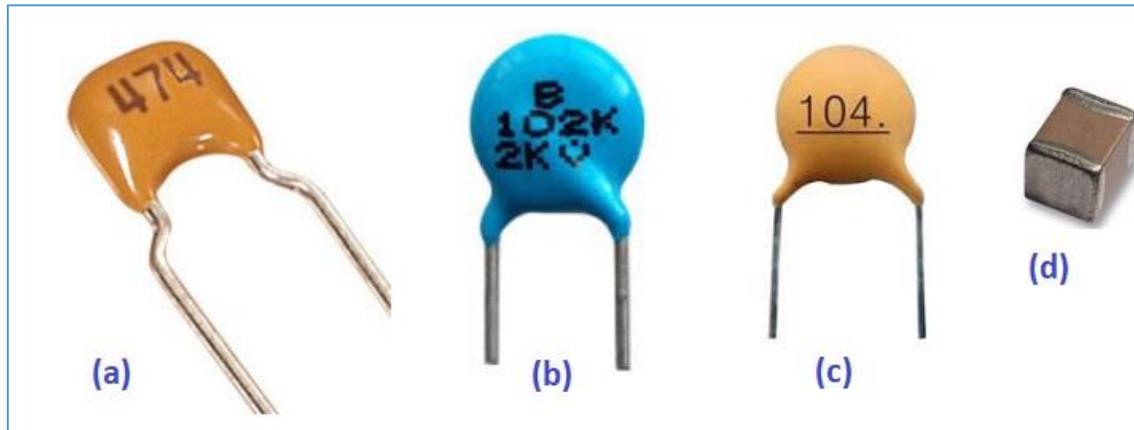


Figure 121 Ceramic capacitors.

Electrolytic capacitors

Electrolytic capacitors are polarized and are constructed in two types of materials: aluminum and tantalum. These types of capacitors have high capacitance in reasonable physical sizes.

Usually we can find them in a value of 1 μF to about 1 mF, with work voltages that can reach up to approximately 250 VDC.

Aluminum electrolytic capacitors are the most popular. See some types in **figure 122**.

Note in this figure:

(a) Aluminum electrolytic capacitor, capacitance of 470 μF and maximum working voltage of 35 VDC. Indicated on the capacitor body is the negative, shorter terminal.

(b) Two aluminum electrolytic capacitors, capacitance of 300 μF / 100 V and 150 μF / 100 V. Indicated on the capacitor body the negative, shorter terminal.

(c) Miniature electrolytic capacitor, 1000 μF x 6.3 V. Negative terminal indicated by the black band at the top.

(d) Tantalum capacitor, 2.2 μF and maximum working voltage of 25 V. Observe the indication of the positive terminal.

(e) High voltage electrolytic capacitor, 470 μF x 450 VDC. Terminal polarity location is at the base of the capacitor, where the terminals are mounted.

(f) High voltage electrolytic capacitor, 1000 μF x 450 VDC. Terminal polarity location is at the base of the capacitor, where the terminals are mounted.

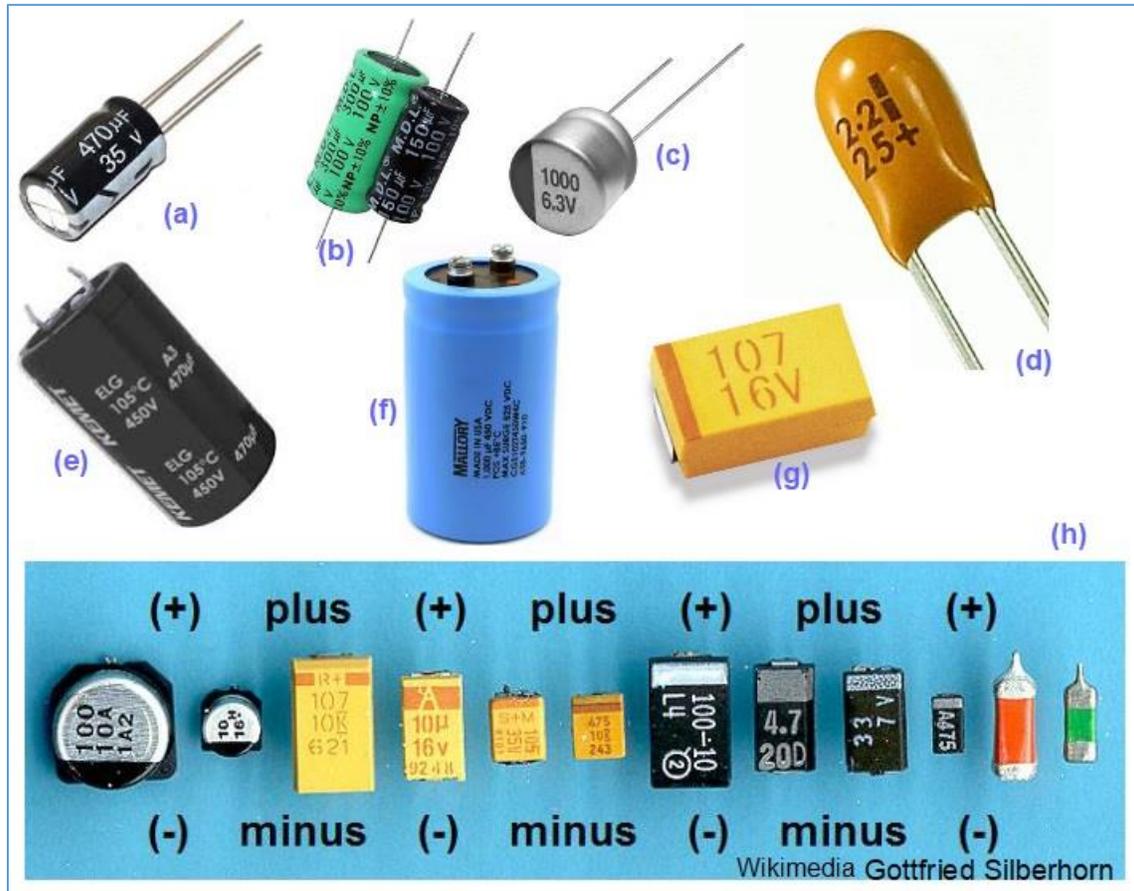


Figure 122 – Types of polarized capacitors.

Super capacitors

Super capacitors are electrolytic with capacity of the order of millifarads and Farads. They can store a huge charge but at low voltages.

Super capacitors are used in applications that require high energy for a short period of time. See **figure 123** for some super capacitors.

In (a) of the figure is a super capacitor of 1.0 F with maximum working voltage of 5VDC. A super capacitor of 15 F x 2.7 VDC is shown in (b). Note that the more

the capacitance increases, the physical size of the capacitors increases and the working voltage decreases, as shown in (c) where a super capacitor has 3000 F, with a working voltage of only 2.7 V!



Figure 123 - Super capacitors.

Others types of capacitors

If you go to work or experiment with **RF - Radio Frequency** circuits, you will still get in touch with the adjustable capacitors (trimmer) and the capacitance. See figure 78 for the physical appearance of these capacitors.

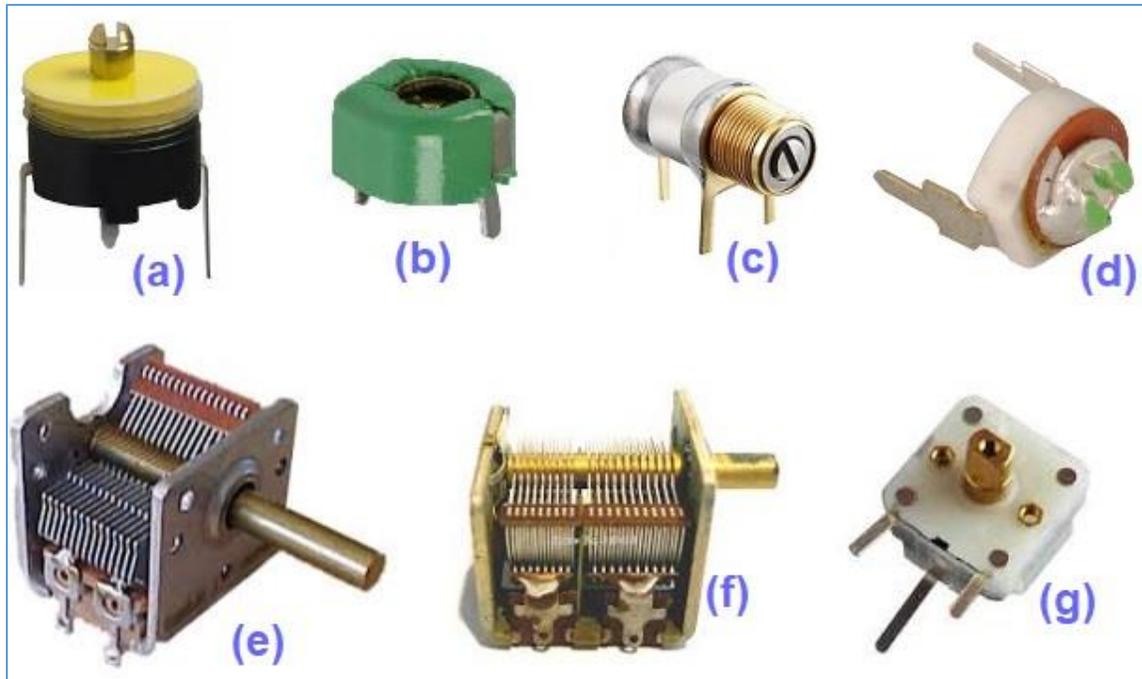


Figure 124 - Adjustable capacitors (trimmers) and variable capacitors.

- (a) Plastic trimmer of few picofarads. Dielectric of plastic.
- (b) Plastic trimmer of few picofarads. Dielectric of plastic.
- (c) "Piston" type ceramic trimmer of few picofarads. Ceramic dielectric.
- (d) Ceramic trimmer of few picofarads. Ceramic dielectric.
- (e) Simple variable capacitor, about 250 pF. Dielectric of air.
- (f) Double variable capacitor, about 250 pF, each section. Dielectric of air.
- (g) Variable capacitor used in portable type radios. Dielectric of plastic.

Association of capacitors

Like resistors, capacitors can also be associated to obtain higher capacitance or higher working voltage.

Capacitors in parallel

When capacitors are connected in parallel, the total capacitance is the sum of the individual capacitances. See the circuit in **figure 125**.

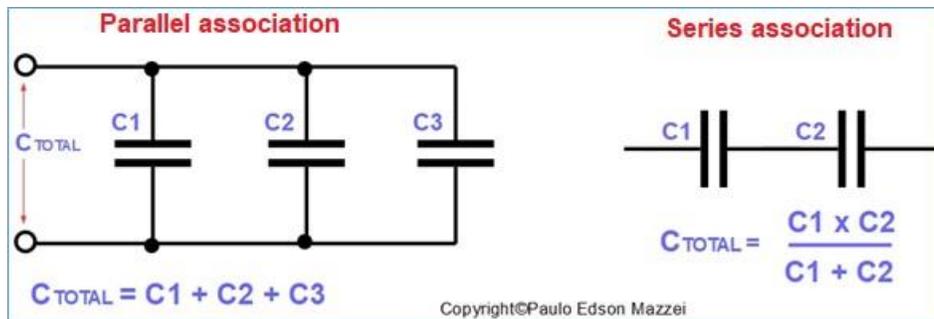


Figure 125 - Association in parallel and in series of capacitors.

In the **parallel association**, if we have two capacitors of 100 nF, the total capacitance will be 200 nF. The maximum working voltage is the same as that of each capacitor. Try not to associate voltage capacitors with different work. In this case, if each capacitor is 50 V, we have at the end: 200 nF x 50 VDC.

In the case of the **series association**, the capacitor values are calculated as the formula. If we have two capacitors of 100 nF x 50 V. when connected in series they provide a capacitance of 50 nF and the working voltage will be of 100 V. The working voltage is the sum of the individual voltages.

Application of capacitors

There are a large number of applications of a capacitor in an electronic circuit.

Decoupling

Decoupling capacitors are those that suppress high frequency noise in DC power supplies - DC. These high frequency noises can damage small ICs - Integrated Circuits powered by a power source. Hence the need to remove it from the wiring of the sources.

See an application of decoupling capacitors in **figure 126**.

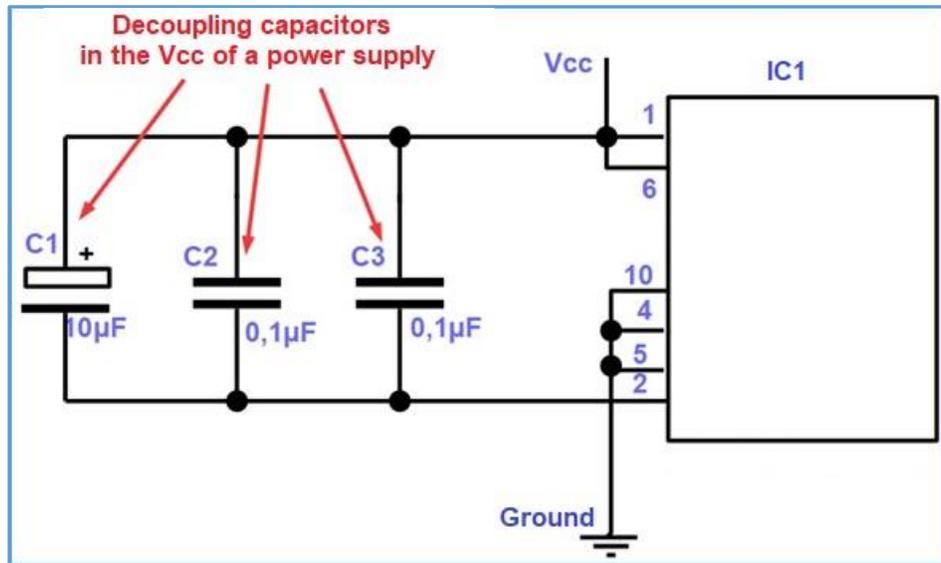


Figure 126 - - Application of decoupling capacitors.

Note that the decoupling capacitors are connected between the + VCC and the supply earth of the IC1 - Integrated Circuit. It used to put capacitors of different values, depending on the frequencies of the noises that must be "bypassed" to the earth. The DC supply voltage is not affected by the decoupling capacitors.

See application of two decoupling capacitors, type SMT, mounted near the IC of a board of SparkFun Electronics. **Figure 127** Each capacitor is 0.1 µF. The larger black capacitor is a 10 µF tantalum electrolytic capacitor.

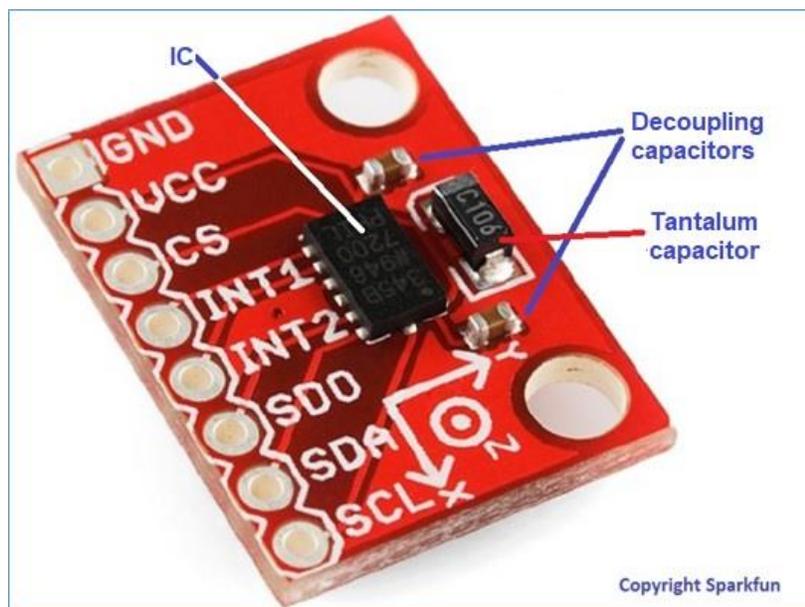


Figure 127 - Application of decoupling capacitors in a real circuit. Courtesy SparkFun Electronics - USA

Filtering on power supply

This is a widely used application and all power supplies use capacitors to improve the voltage supplied.

In a power supply, rectifier diodes are used to transform the AC voltage into DC voltage. However, only rectifying diodes are not sufficient to transform an AC into a pure or good DC for use in electronic circuits.

Let's take as an example a simple power supply, those used to charge the cell phone battery as well as tablets, iPods, etc. See the block diagram of this source in **figure 128**.

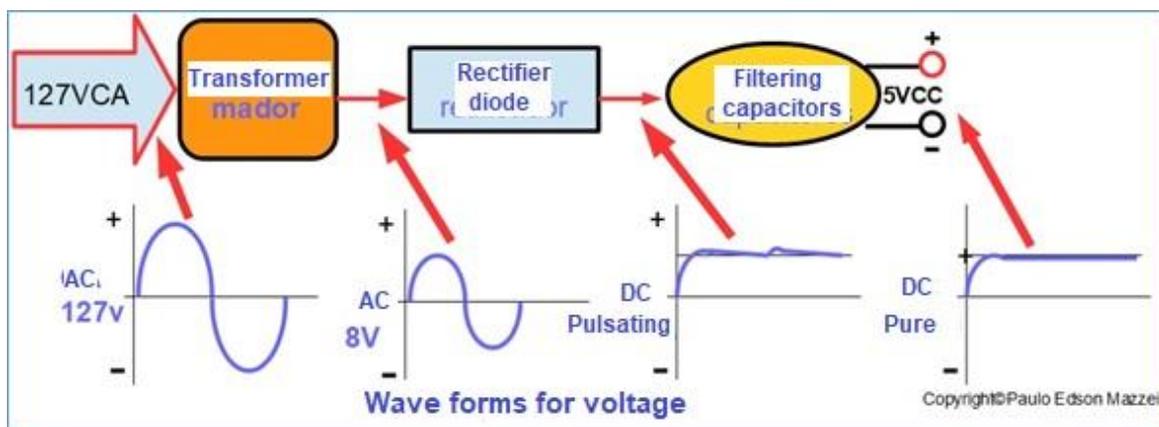


Figure 128 - Block diagram of a small power supply.

Note the power supply shown in **Figure 128**. The drawings and description are simplified.

- On the left side of the "Transformer" block, we apply the voltage of the grid of electric power of 127 V alternating current. This AC waveform is called a sine wave. The function of this transformer is to lower the mains voltage from 127 V to something around 8 V, still alternating current.

- The output of the 8 VAC transformer, and applied to the rectifier diode, which "transforms" the AC into a DC, which we call "pulsating DC." It's not a pure DC yet.

- The pulsed DC output of the diode is applied to the filter circuit, usually consisting of one or more high capacitance electrolytic capacitors.

- At the filter outlet, we have a pure direct current, very similar to that supplied by batteries.

The waveforms can be observed in a common power supply, using an oscilloscope.

Flash lamp for photography

The flash used for photography lighting uses a high capacitance capacitor. This capacitor is charged by batteries or batteries, which are mounted internally in the flash housing.

When the flash is fired, the charge that was stored in the capacitor is discharged into the flash lamp in a short period of time, giving the flash we know.

Frequency divider filters for loudspeakers

Probably the speaker you use in your sound has two or more speakers. With capacitors and inductors, we can separate the bass sounds from the high sounds and send them to the correct speaker.

- ▶ Sharp sounds, high frequencies, go to the tweeter speaker.
- ▶ Serious sounds, low frequencies, go to the woofer speaker.

This filter is already mounted inside the speaker. See **Figure 129**.

See in this link a video that shows what happens when we do not correctly observe the maximum working voltage of a capacitor.

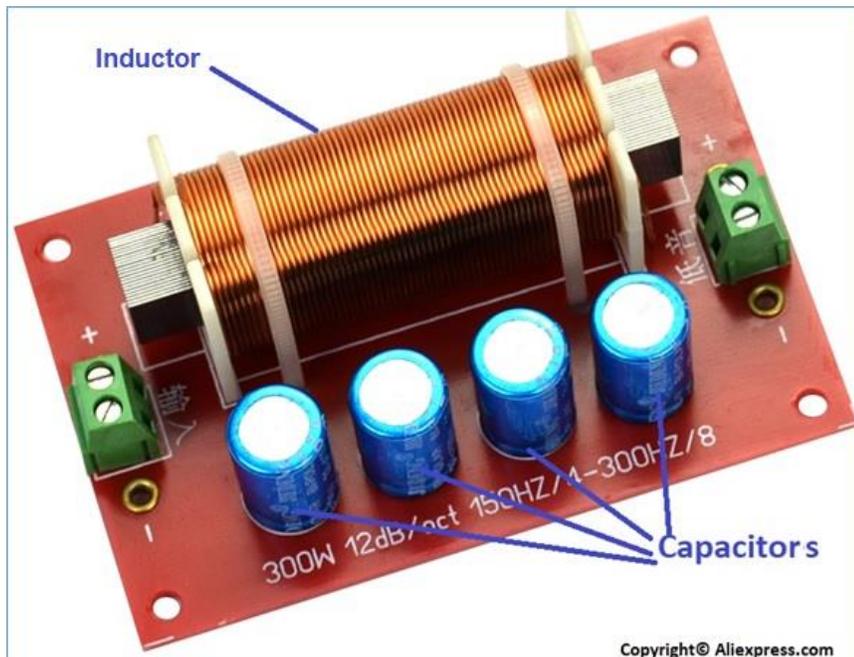


Figure 129 - Frequency divider filter for loudspeakers.

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Chapter 18

Some applications for resistors and capacitors

Introduction

Resistors and capacitors can be considered as very important components in electronic circuits.

Often together and sometimes apart, each one performing his function, as we shall see.

Objectives

- Analyze some practical applications of resistors and capacitors.

Power supply filters

A power supply is a "**black box**" with electronic circuitry inside, which is used to power electronic equipment. For example, what we usually call a "cell phone charger". It is actually a small power supply.

As an illustration, in **Figure 130**, we can see the schematic diagram of a power supply. For ease of analysis, let's repeat this figure here. In **Figure 87** you can see the block diagram of a power supply, with the capacitor marked by a red ellipse.

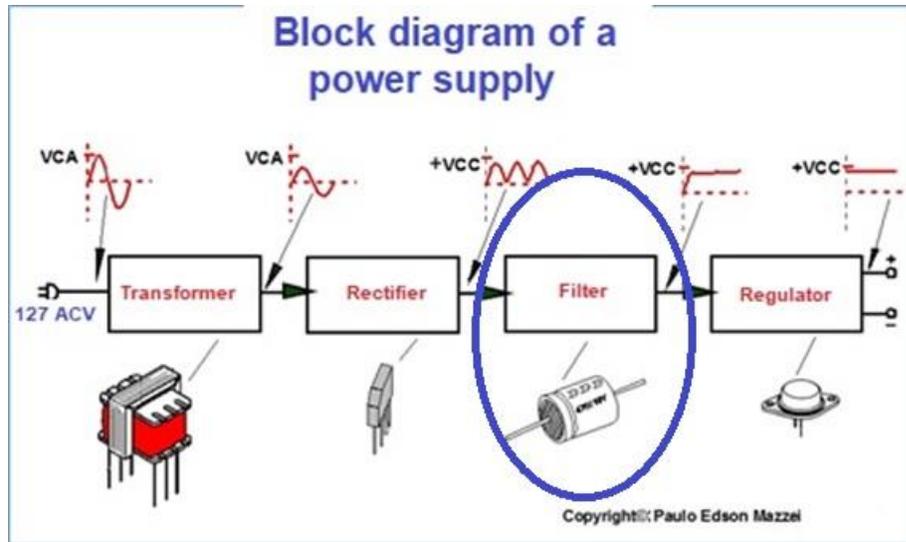


Figure 130 - Block diagram of a power supply.

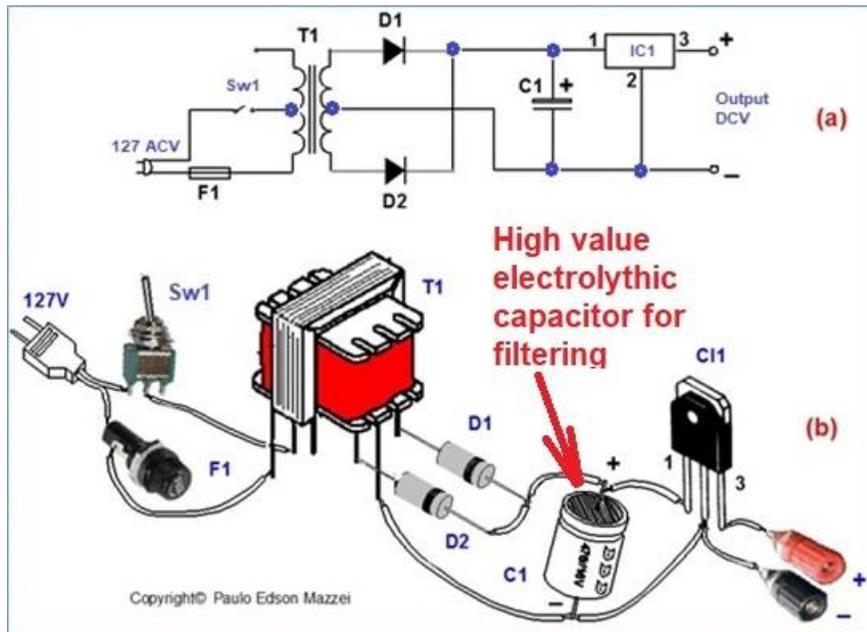


Figure 131 - Power supply and filter capacitor.

Theoretically, the power supply should have 127 VAC at its input and at the output should provide almost pure DC voltage. Since the voltage output in the rectifier diodes is a still pulsating (not pure) voltage, we put a high-value polarized capacitor, such as a 47,000 μF electrolytic capacitor.

Removal of voltage surges (peaks)

For example, digital logic circuits (we'll see later), when connected to a power source, initially draw a large electric current, causing a current spike or "current surge." This happens when you turn the power on and off of these circuits. See **figure 132** in (a).

Selective filter in DC and AC

Sometimes an AC signal may be along with a DC signal, interfering with the processing of something.

If the signal is passed through a capacitor, the DC component of the signal will be blocked, as shown in (b) of **figure 132**. The capacitor will let the floating signal through and completely block the DC component by the use of the capacitor.

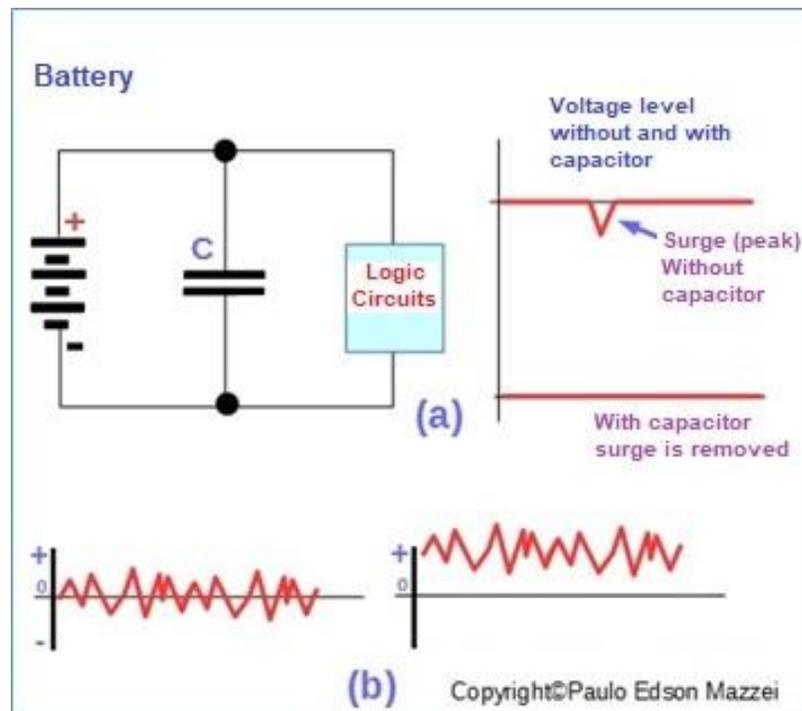


Figure 132 - Applications of a capacitor.

RC circuits

RC (resistor / capacitor) circuits are also widely used in electronic circuits, as you will see later in the experiments we are going to put together.

The RC circuits serve to change the format of signals and waves that enter a given circuit. There are two basic types of RC circuits: **the integrator and the differentiator**.

The product of R and C in these circuits is called the RC time constant. For the circuits shown in **Figure 133**, the RC time constant is at least ten times the interval between the pulses or cycles of a wave. This time is measured in seconds (s).

The integrator RC circuit is shown in (a) of **figure 133**. This circuit may operate with a filter, which lets only pass signals below a given amplitude.

The RC Circuit differentiator can be seen in (b) of the figure under discussion. This circuit is used to make pulse generators for circuits of TV sets and to trigger digital logic circuits.

The RC constant of a circuit is the time in seconds to charge or discharge a capacitor, up to 63.3% of the load variation.

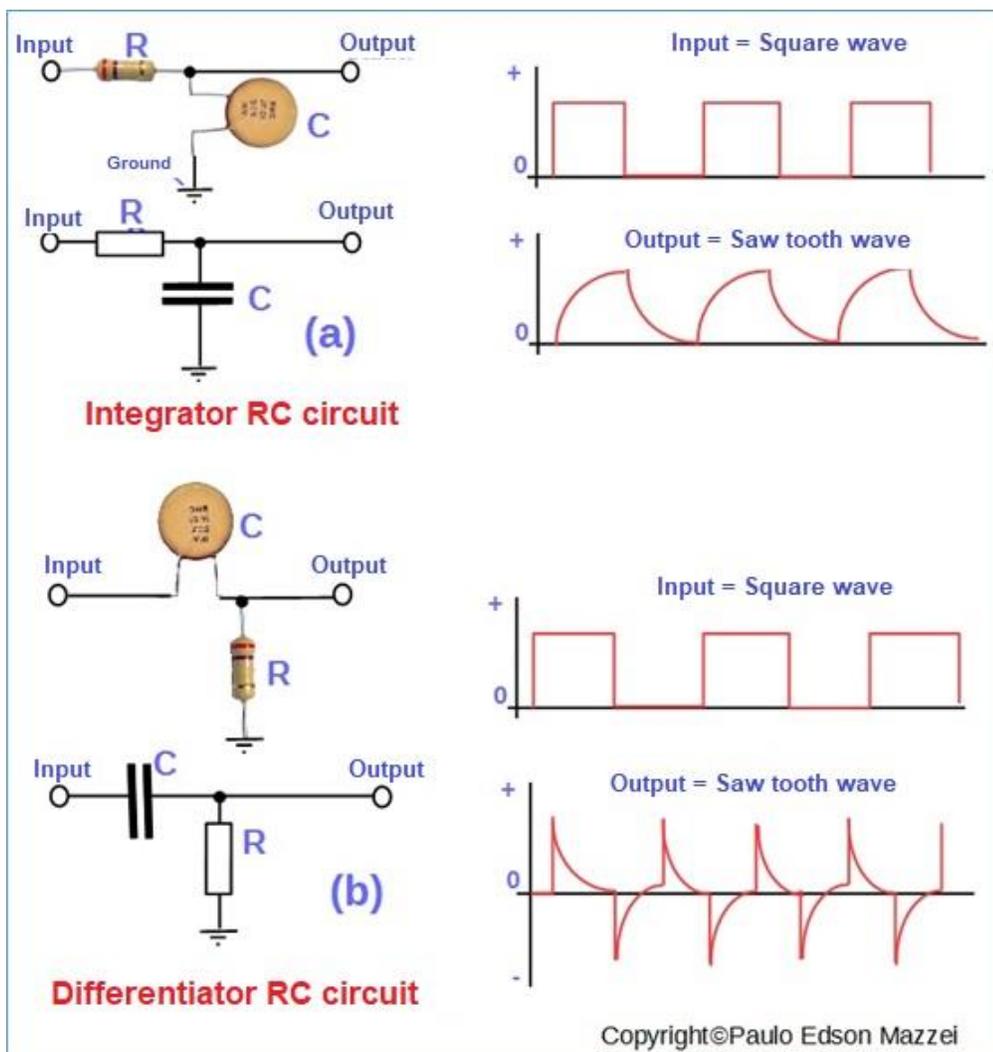


Figure 133 – Integrator and differentiator RC circuits.

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Chapter 19

Inductors

Introduction

Electrons that circulate through a conductor wire cause the appearance of an electromagnetic field around the conductor. This field cannot be seen, but can be measured, used, felt, etc.

If this wire is glued together in the form of a coil, the electromagnetic field concentrates and stays strong.

These coils allow the construction of relays, solenoids, motors, transformers, etc.



Objectives

- Analyze the basic characteristics of inductors.
- Transformers and their operation.

Coils

A coil has the property of resisting a rapid change in the electric current (AC) circulating through it. At the same time, the DC passes freely through the coil.

Figure 134 illustrates what happens when several types of waveforms travel through the coil.

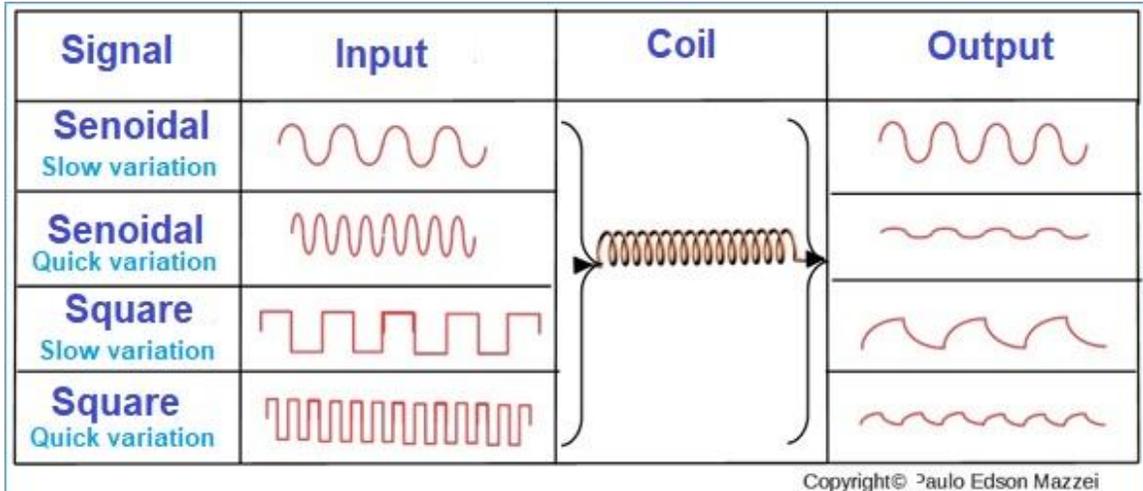


Figure 134 - Waveforms applied to a coil.

Part of the energy in the electromagnetic field formed in the coil can be induced (transferred) to a second coil that is very close to the first coil. Transformers use this principle to work. Please refer to **figure 135**.

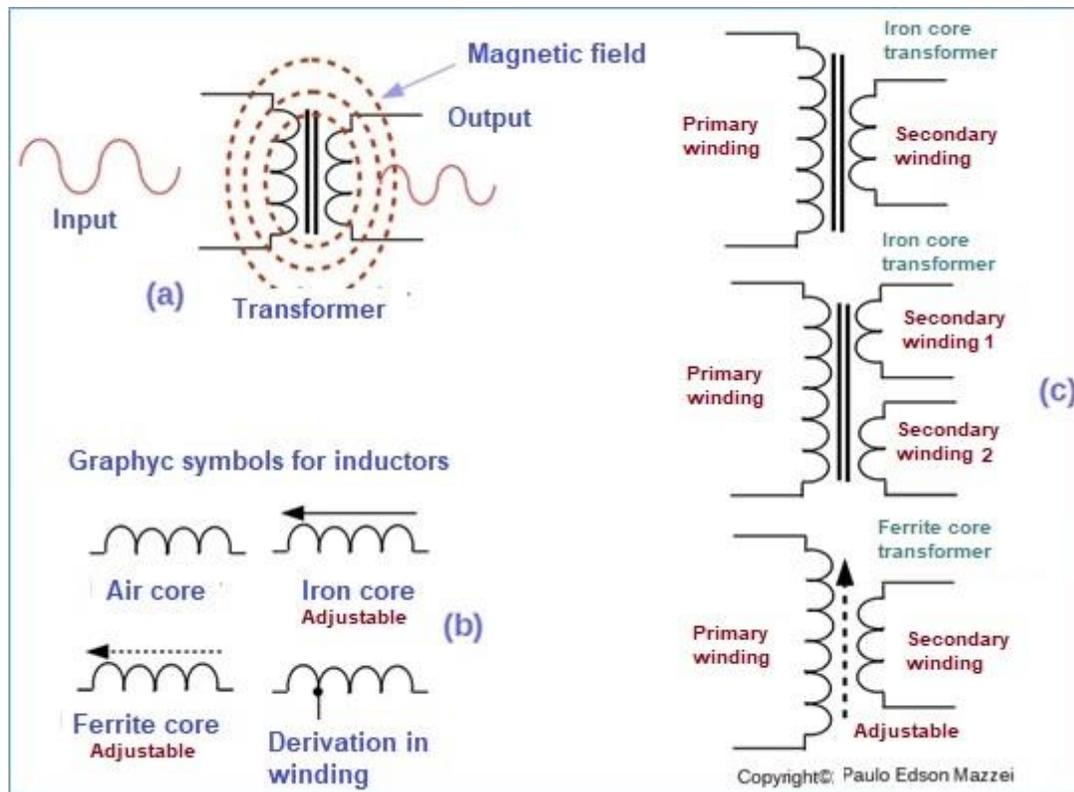


Figure 135 - Transformer operation, graphic inductor symbols and examples of transformers.

Referring to figure 135 note:

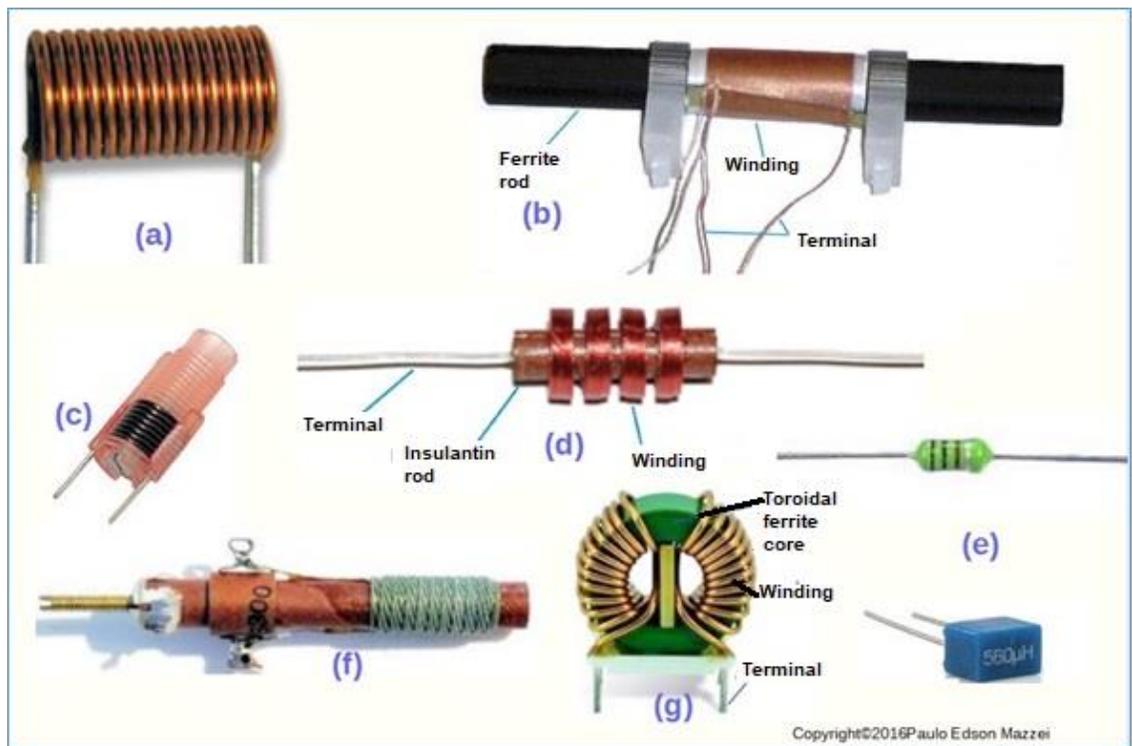
- ▶ The inductor has a certain inductance, as measured in **Henries** (Henry - H). Usually a 1 H inductance is very large and in our electronic circuits we use inductances of the order of mH (milliHenries) and μ H (microHenries).
- ▶ The operation of a transformer is shown in (a). In this case, it is a force transformer, with an iron core. This component is a step-down transformer because it lowers the mains voltage (127 or 220 VAC) to a voltage of its own to operate the electronic circuits. This AC voltage value is around 6 to 24 VAC, in the secondary winding.
- ▶ In (c), graphical symbols and examples of transformers and inductors are shown.
- ▶ In (b) you can see graphic symbols for inductors, commonly used in RF (Radio Frequency) circuits, such as TVs, radios, radio transmitters, etc.
- ▶ The cores refer to the shapes or supports where the inductors and transformers are wound. In the case of air core, only the form of insulation material, such as phonolite or plastic, is used. Iron cores are used in power transformers and

are special iron blades, stacked inside the transformer windings. Ferrite cores, a special magnetic material, are commonly used in **RF** inductors.

Types of inductors and coils

The number of types of coils or inductors is enormous! See figure 136.

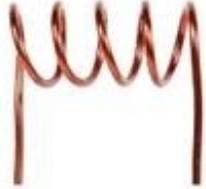
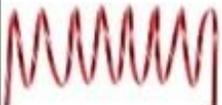
- a. Air core coil.
- b. Antenna coil used in portable radios.
- c. . Miniature coil with adjustable ferrite core.
- d. . Normal RF Shock
- e. . Two examples of micro shocks (miniature inductors).
- f. . Inductor with adjustable ferrite core.
- g. . Toroidal inductor. The enameled wire is wrapped around a ferrite toroid.



How an inductor works

See the table in **figure 137**, how the inductance of an inductor is influenced by the type of winding, core, etc. This table shows that four main factors influence the inductance of a coil or inductor:

- ▶ Number of turns
- ▶ Spacing between turns
- ▶ Winding diameter
- ▶ Material used in the core

Factors influencing inductance				
Inductance 	Number of turns	Spacing between turns	Coil diameter	Core material
Smaller				
Bigger				

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Figure 137 - Factors influencing the inductance in an inductor.

Transformers

Usually **transformers** are the heaviest components of an electronic circuit. The so-called power transformers are used to lower or raise the voltage of the electrical network (AC), for lower or higher voltage values, according to the needs of a certain electronic circuit.

The cores of these transformers are made of cast iron, called "**silicon iron**". The winding that is connected to the voltage of the electric power grid, is called the primary winding and the other winding, connected to the load, is called the secondary

winding. See figure 96, the operation of a power transformer, which in this case, is raising the mains voltage, since there are more turns in the secondary.

The windings of power transformers are made with enameled copper wire.

The AC current flowing in the primary winding forms a magnetic field in the iron core and induces a voltage in the secondary winding. Transformers do not run on direct current.

How transformer works

Note that transformers do not create or generate anything. They only transform one voltage or AC current and another value higher or lower. Never the power consumed by the primary transformer, may be less than the power offered in the secondary. The transformer always introduces a loss of power in the conversion.

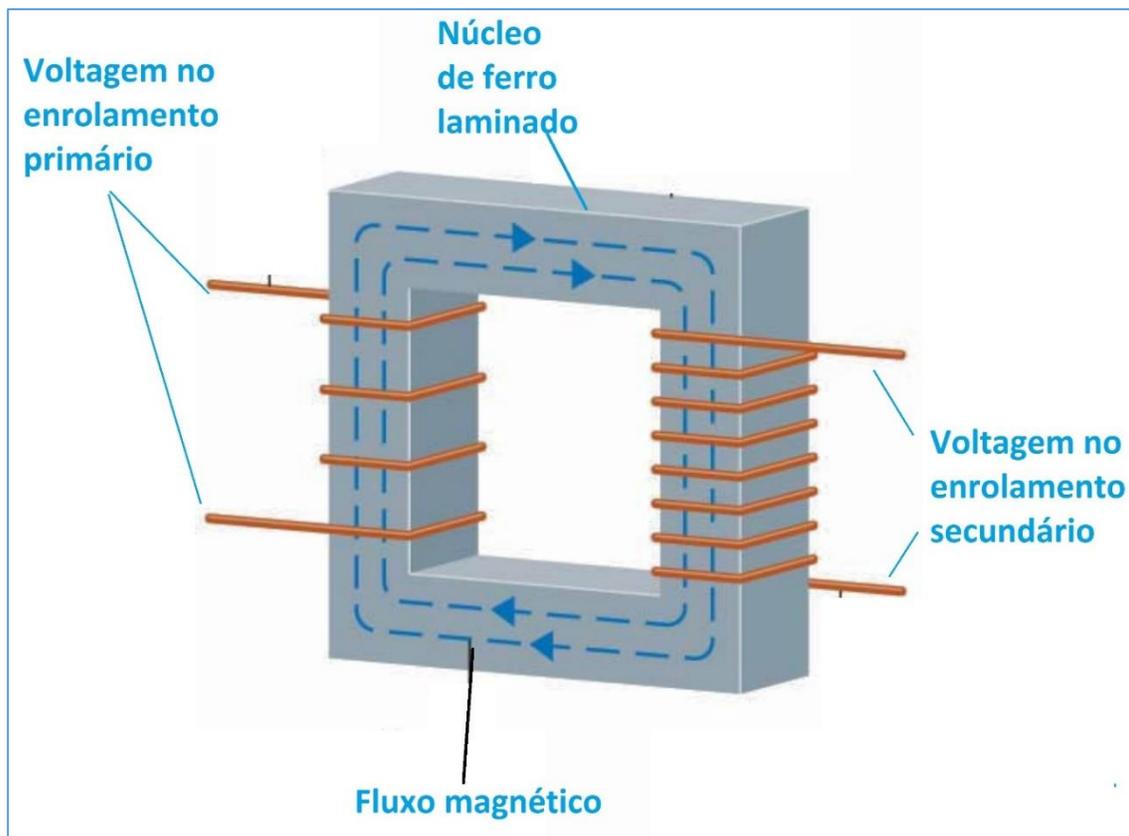


Figure 1438 – How Transformers Works.

Please refer to **figure 138**.

Spiral ratio: The ratio of turns of the secondary winding to the primary winding always determines the voltage ratio of a transformer. See **figure 139**.

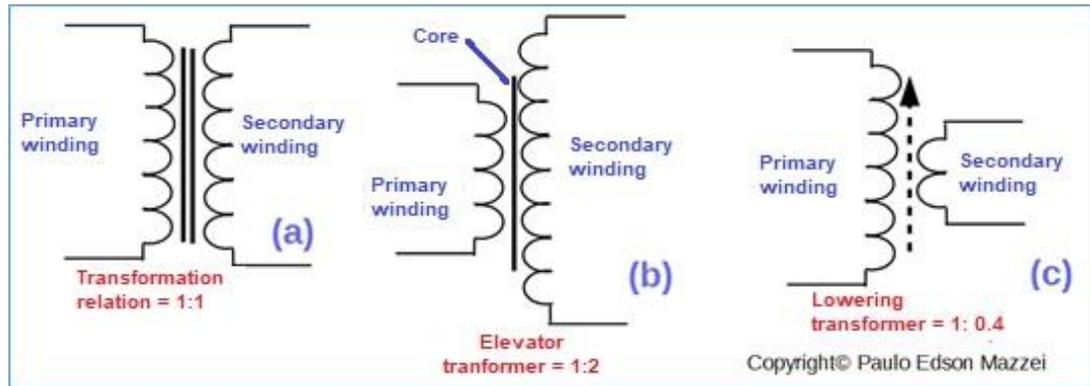


Figure 139 - Transform ratio in transformers.

Types of transformers

Please, refer to **Figure 140** for some types of transformers used in electronics.

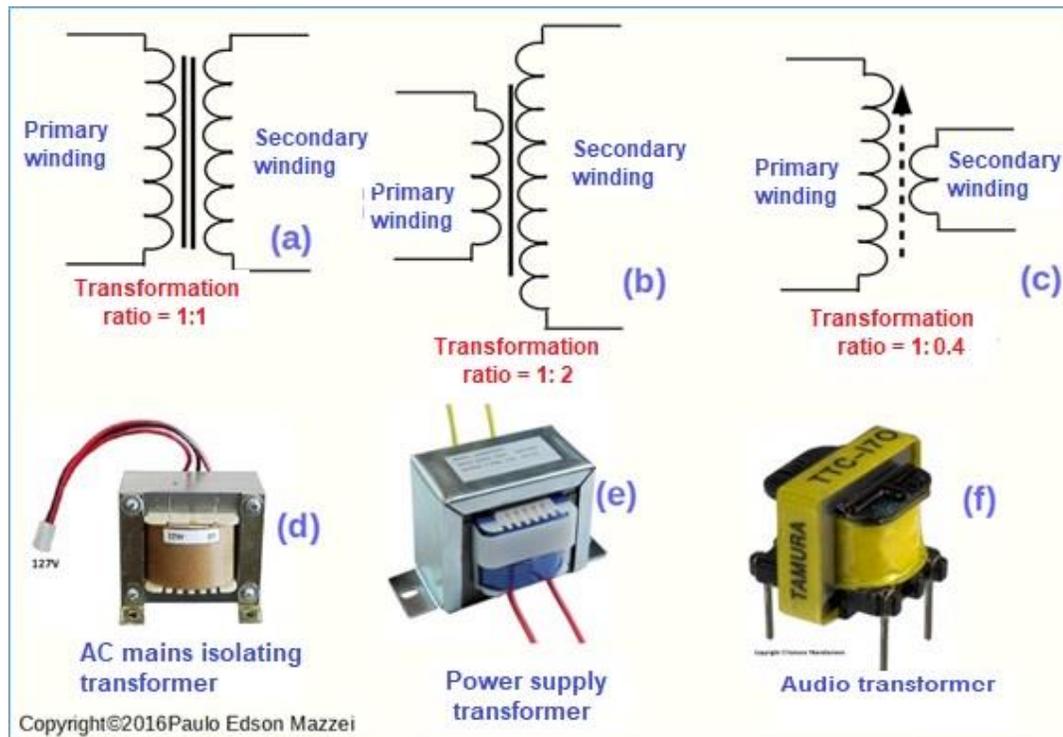


Figure 140 -Types of transformer.

Figure 141 shows a small power (or power) transformer with the following characteristics:

- **Primary** = Voltage of 120 VAC (in Brazil the voltage of the grid is 127 AC).
- **Secondary** = Voltage of 12.6 VAC with a maximum current of 300 mA or 0.3 A.

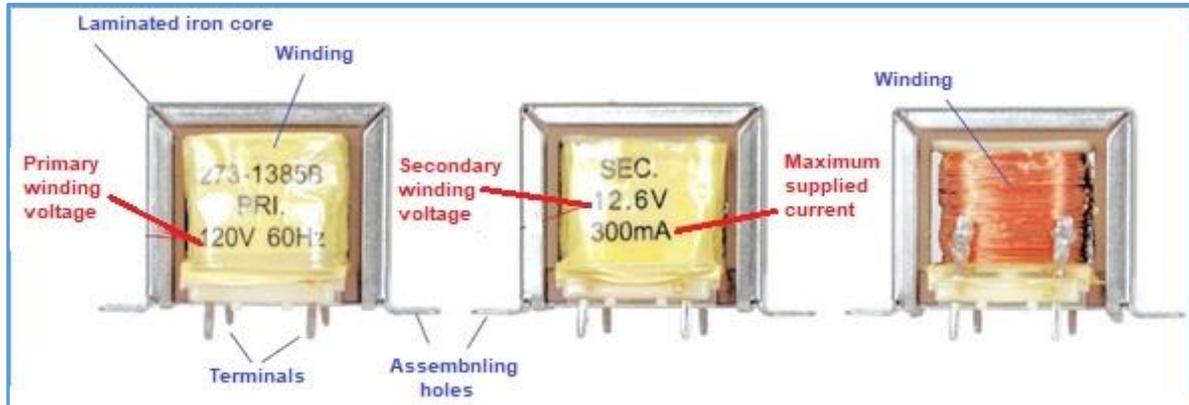


Figure 141 - Small power transformer. Copyright © Instructables - USA

A little experience

Figure 142 shows how to make an electromagnet with a 9 V battery, enameled copper wire and a nail.

- ▶ Pack a nail into wood, about 10 to 12 centimeters long. The diameter of the nail can be the normal, about 5 to 6 millimeters.

- ▶ On the nail, wrap a fine piece of enameled, fine copper wire. To trim this wire, go to an electrician's or auto electrical workshop and order a piece of enameled copper wire for the experience. Explain to the technician what you are going to do and say it needs to be fine wire. If you use thick wire, it will work, but your battery will run out quickly ...

- ▶ You can wind up more than one layer and the electromagnet will get stronger. Look again at **Figure 142** and see how to make a good winding!

- ▶ Remove the cover of the ends of the threads with a fine sandpaper or a knife or cutting stylus to remove the enamel.

- ▶ Connect the battery to the ends of the winding, using the battery clip or pieces of wire with an alligator clip on the end.

- ▶ Approach your powerful electromagnet near paper clips and see what happens!

- ▶ Explain why this happens.

Good luck!

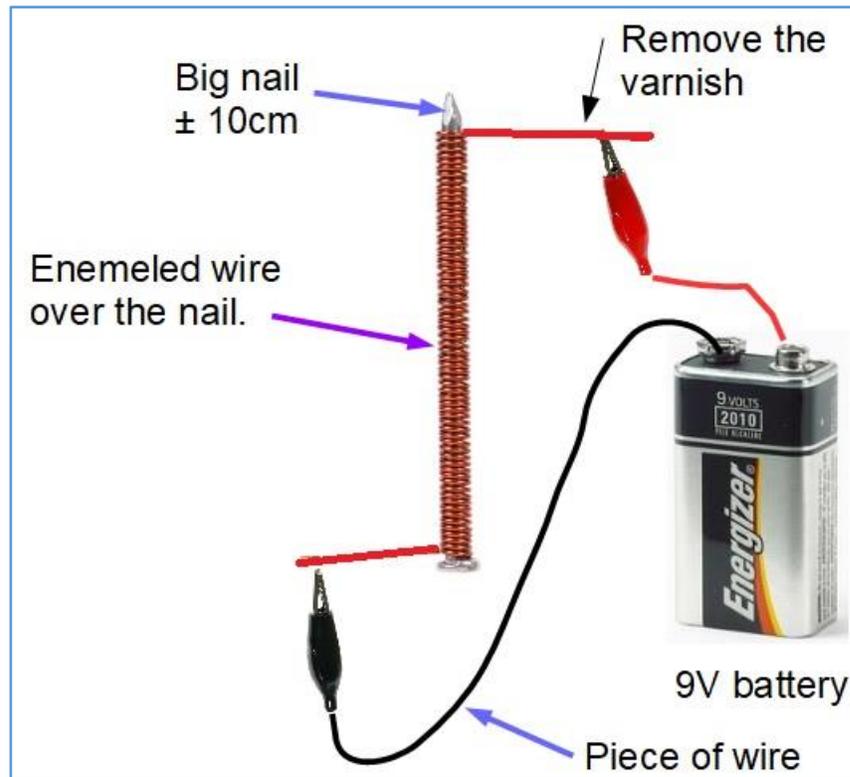
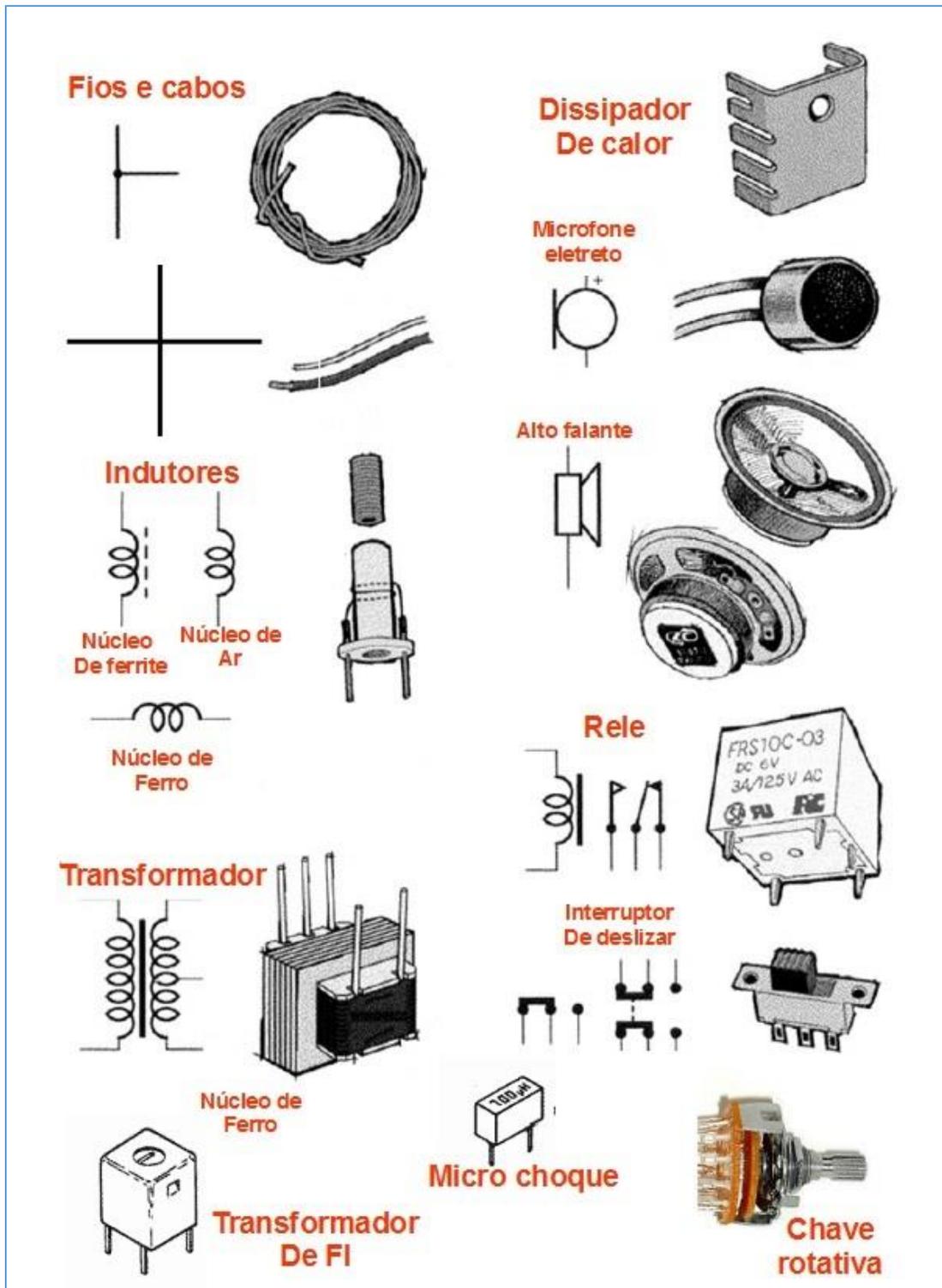


Figure 142- A little experience with magnetic fields.



Inductors and Switches

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Chapter 20

Relays

Introduction

Relays are other electromechanical devices that you will use in your experiments with [RedBoard](#) and [Arduino](#).

Relays are switches (keys) operated remotely, allowing to turn equipment on and off at a certain distance. It is also possible to use relays to operate equipment that demands high power, from low power controls.

Basically, a relay consists of a coil, some electrical contacts and a structure that supports all this. **Figure 143** shows the basic construction of a relay.

On the left side of **figure 143**, we can see the relay at rest, with no voltage applied to its coil. The contacts are on the blades marked **NF = Normally Closed**.

In the right part of the figure, a voltage of 5 VDC was applied to the coil. The magnetic field formed in the core of the coil attracts the movable armature and lifts the movable blade to make contact with the upper fixed blade. The contacts that were previously NA passes to **NF = closed**.

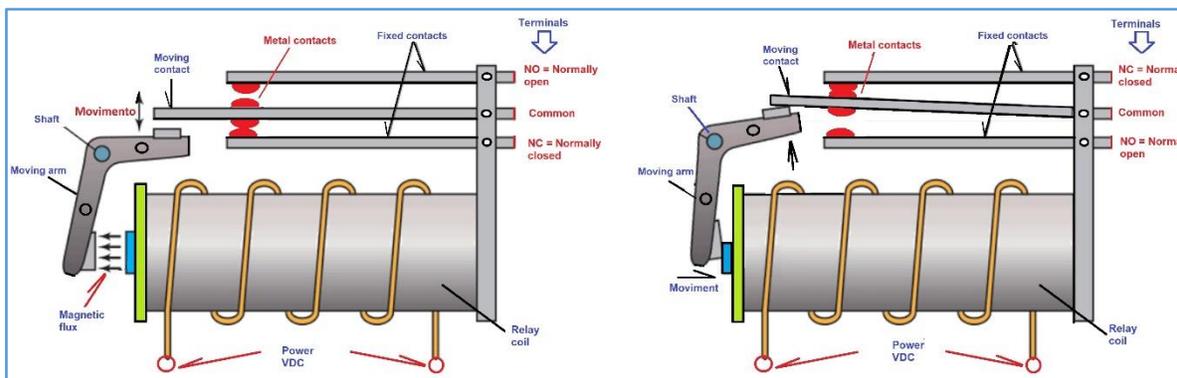


Figure 143- Operation of a relay.

A 5 VDC relay widely used in RedBoard and Arduino circuits is shown in **figure 144**, with the location of its terminals and symbol.

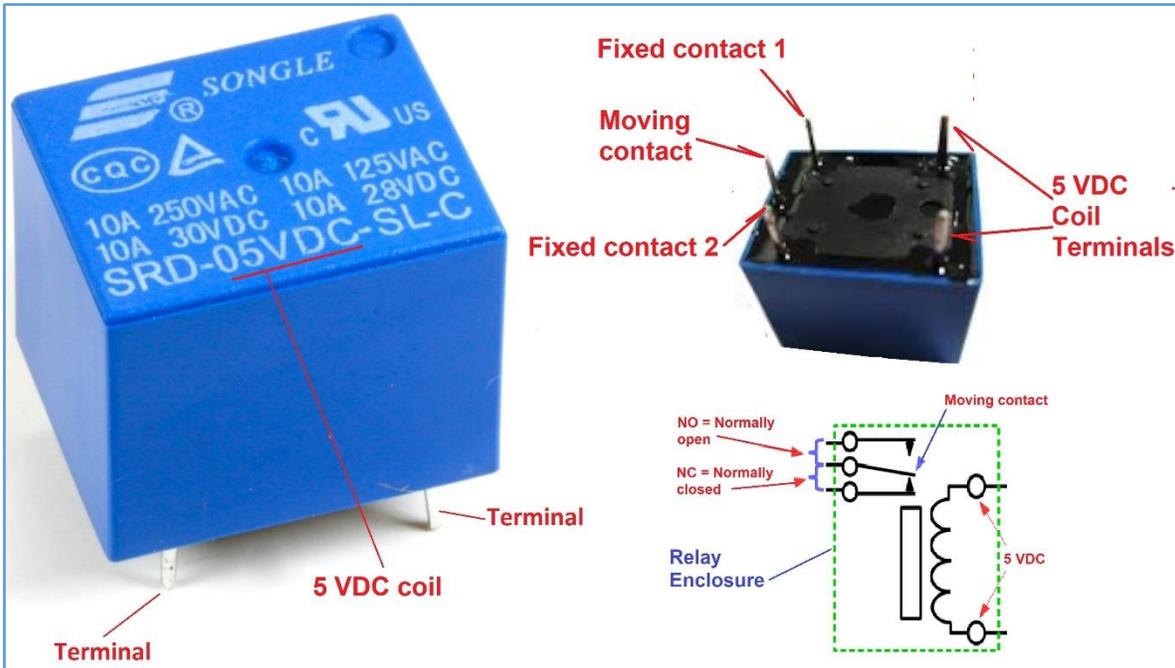


Figure 144 5VDC miniatures relay.

Relay contacts and symbols

In **figure 1454** you can see the symbols and contacts of the types of relays most commonly used in electronics.

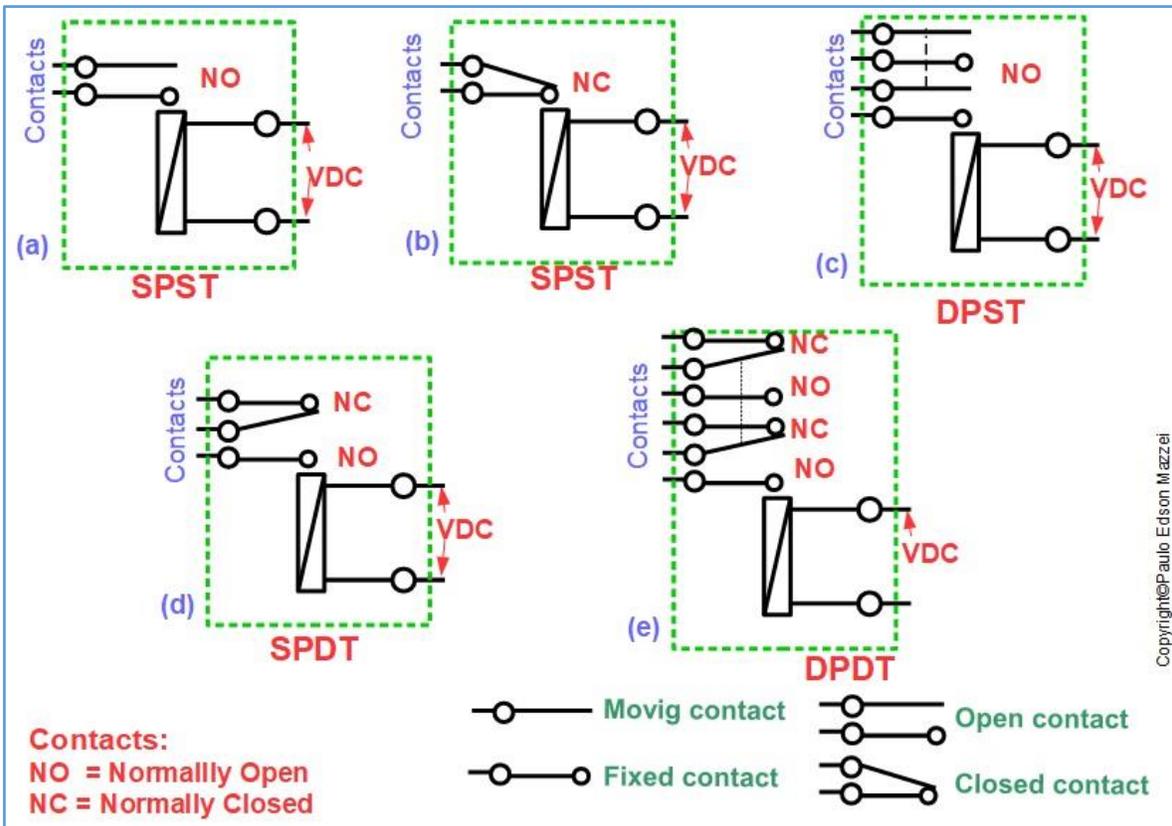


Figure 145– Relays contacts and symbols.

Refer to **figure 145**:

- (a) **SPST = “Single Pole Single Throw”**
- (b) **SPST = “Single Pole Single Throw”**
- (c) **DPST = “Double Pole Single Throw”**
- (d) **Contacts = 1 pole x 2 contacts, NA/NF. SPDT = “Single Pole Double Throw”**
- (e) **DPDT = “Double Pole Double Throw”**

A very simple application for the relay

In **figure 146** a simple circuit is shown, where a relay activates a buzzer (small bell). The relay is driven by the Sw1 switch or some other system that can power the circuit with a voltage of 4.5 V.

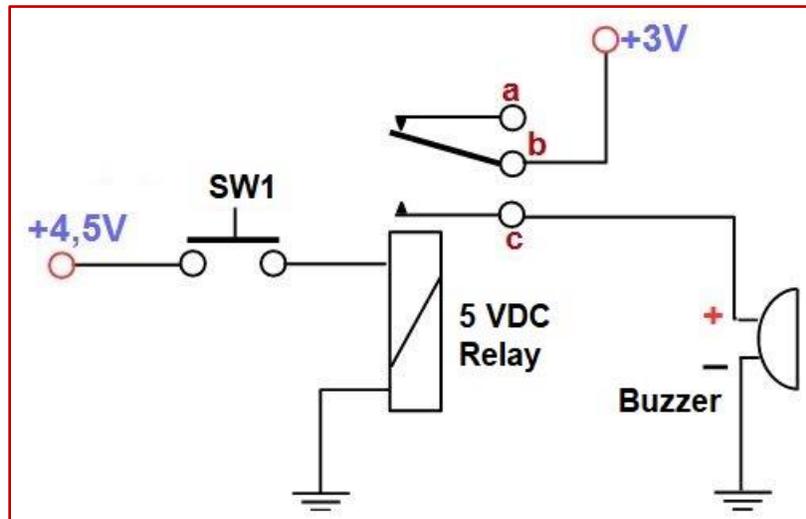


Figure 146 - Simple application of the relay in a circuit.

When an electric current flow through the relay coil, the magnetic field attracts the relay contact blade, closing the circuit and sounding the buzzer.

Note that in the relay symbol, the contacts (a) and (b) are closed but no external connection. When the blade is drawn by the magnetic field formed in the relay coil, blades (b) and (c) close the circuit and you will hear the buzzer sound.

The relay and buzzer have a maximum voltage of 5VDC. The battery is powered by an external source or a 5V battery at maximum.

The relay is activated by the on / off pressure switch SW1

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Chapter 21

Switches

Introduction

The vast majority of electronic equipment, whether domestic or laboratory, use switches for their operation.

In common language, switch is the name given to the device used in AC - Alternating Current (127 or 220V), which we have on the walls of our homes and serves to light a lamp, turn on an air conditioner, start a fan, etc.

There are a lot of types of switches but we will focus on the one used in electronic circuits. See **figure 147** for some types of switches used in electronics.



Figure 147 – Switches used in electronic circuits.

What is a switch?

Switches are mechanical devices that open and close a certain point on the circuit. In other words, they are mechanical devices that turn on and off a circuit in its simplest application.

A switch can also select points that must be connected to a circuit, for the choice of connection alternatives. Study **figure 148** to see the action of a key in the circuit.

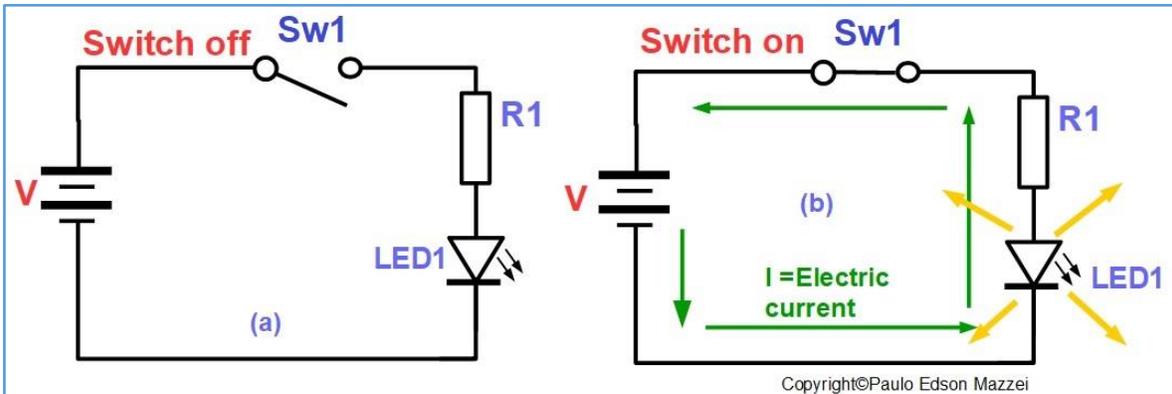


Figure 148- Actuation of a switch in a simple circuit.

Observe the circuit shown in figure 148:

- (a) In this circuit the switch Sw1 is open and due to the above there is no electric current. There is no closed circuit for the circulation of an electric current.
- (b) In this circuit, Sw1 is closed (connected) which allows the circulation of an electric current I through the closed circuit. The LED will light up.
- (c) This type of switch is commonly referred to as an "on / off switch". Technically it would be a "1-pole x 1 contact switch".

Basic Switch Features

Method of actuation of the switch

There are five basic methods by which a switch used in electronics can be actuated (triggered, linked, closed). The table shown in **Figure 149** illustrates these methods.

Method of actuation of the switch				
Pressure (push)	(rocker)	Sliding (slide)	Lever (toggle)	Reed (magnetic)
				

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Figural– Methods of actuation of the switch.

Momentary or permanent contact

Any switch, may be of momentary contact, i.e. we push a button (or a lever, etc.) on the key and its contact closes (on). When you release the button (or a lever, etc.), the contact opens.

Permanent contact occurs when we press a button (or a lever, etc.) on the switch and its contact closes (on), remaining on even after we release the button (or a lever, etc.).

When you start studying RedBoard and Arduino Boards, you will find the two types of contact, more momentary contact keys.

How switches are assembled

You can mount your switches on a Protoboard, a hole in a metal panel, a PCB - Printed Circuit Board, etc. See examples in **figure 150**.

In the photo on the left, the instrument panel shows the three types of switches that were used: On / off lever, Permanent pressure, Momentary pressure.

The small tactile keys are attached directly to the Protoboard or can also be soldered onto a Printed Circuit Board – PCB.

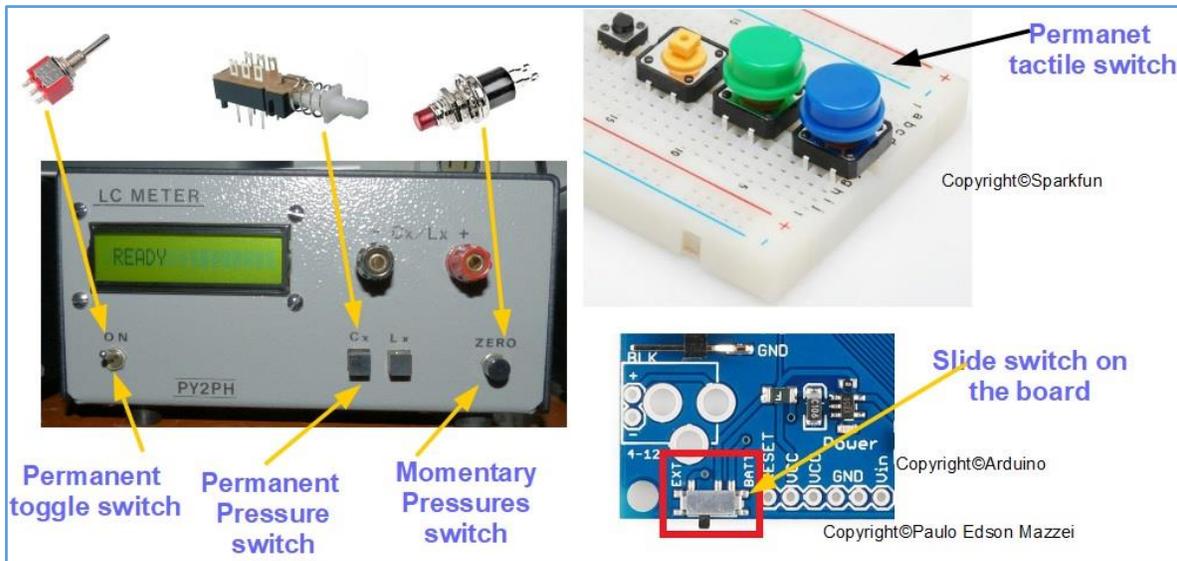


Figure 150- Use of some of the switches discussed in the text.

Poles and contacts

In order for us to choose a switch for a certain circuit, we need to know some more important information, such as the number of **poles** and switch **contacts**.

You have noticed that a switch must have at least 2 terminals: 1 pole and 1 contact. However, this simplicity does not always occur.

The number of "**poles**" in a switch tells you how much circuitry it can control. If a switch has 3 poles, it can control (turn on / off) three independent circuits.

The term "**contacts**" in a switch specifies how many position numbers the pole can be contacted.

We use capital letters, next to the keys, to identify them in relation to the poles and counted. "P" for pole, see **figure 151**.

In **figure 152** you can see a lever switch, with multiples contacts. Notice that the graphic symbol has four sections, from **a** to **d**.

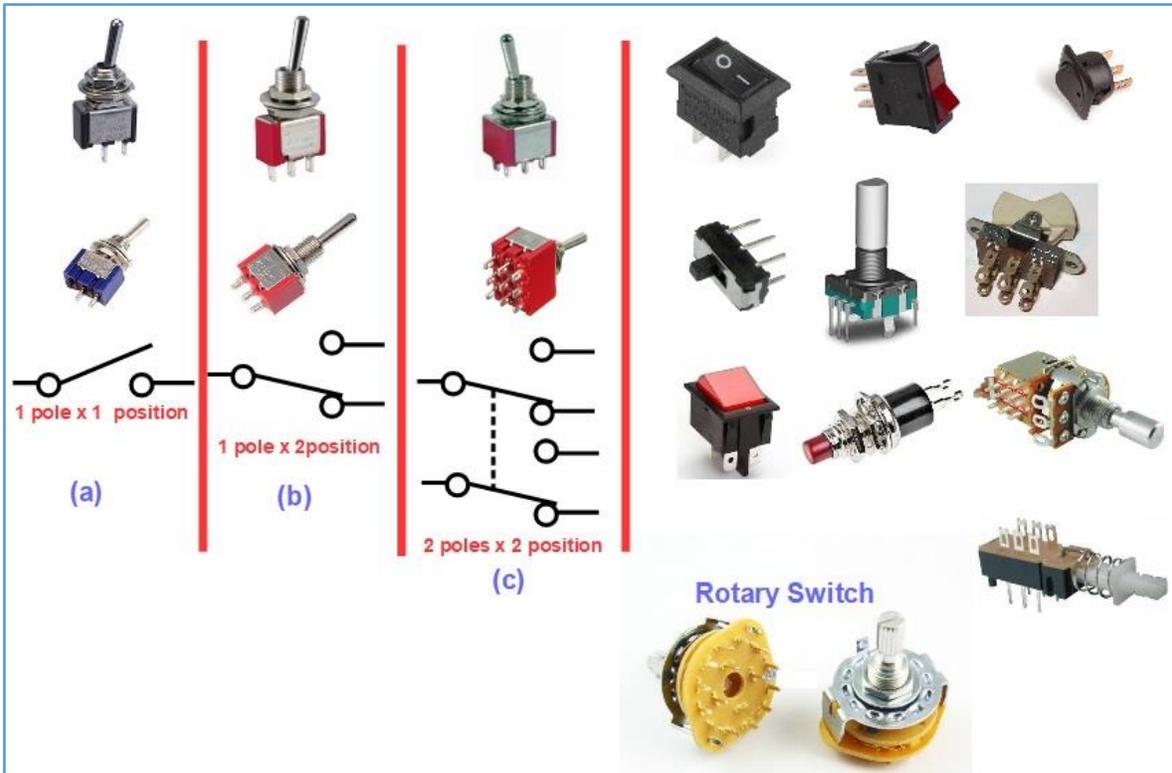


Figure 151 – Poles and contacts in switches.

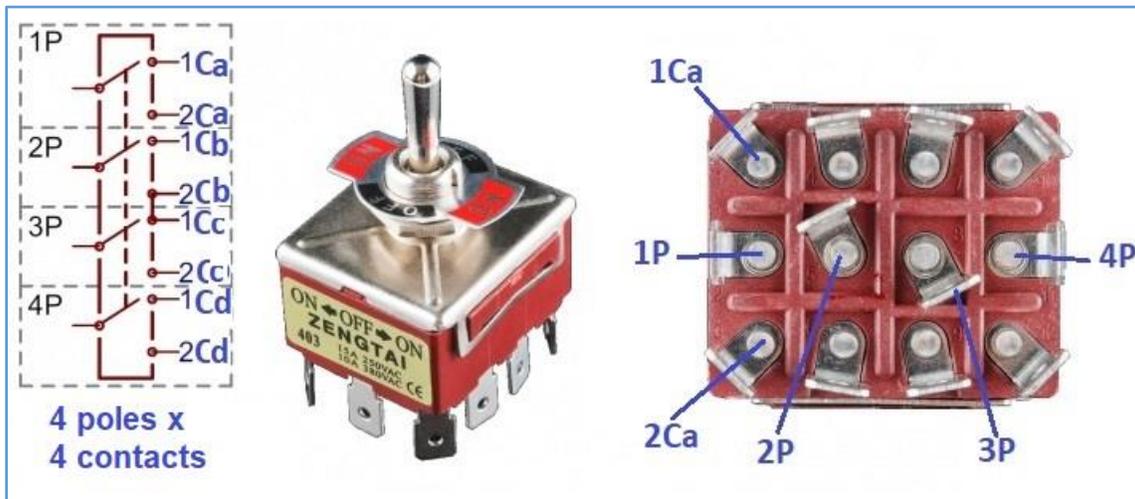


Figure 152 - Multi-contact switch. Four sections.

Keyboards are also switches, connected in a certain matrix. In your experiments with Redboard and Arduino boards, you will use small keyboards for data inputs, as shown in **figure 153**.

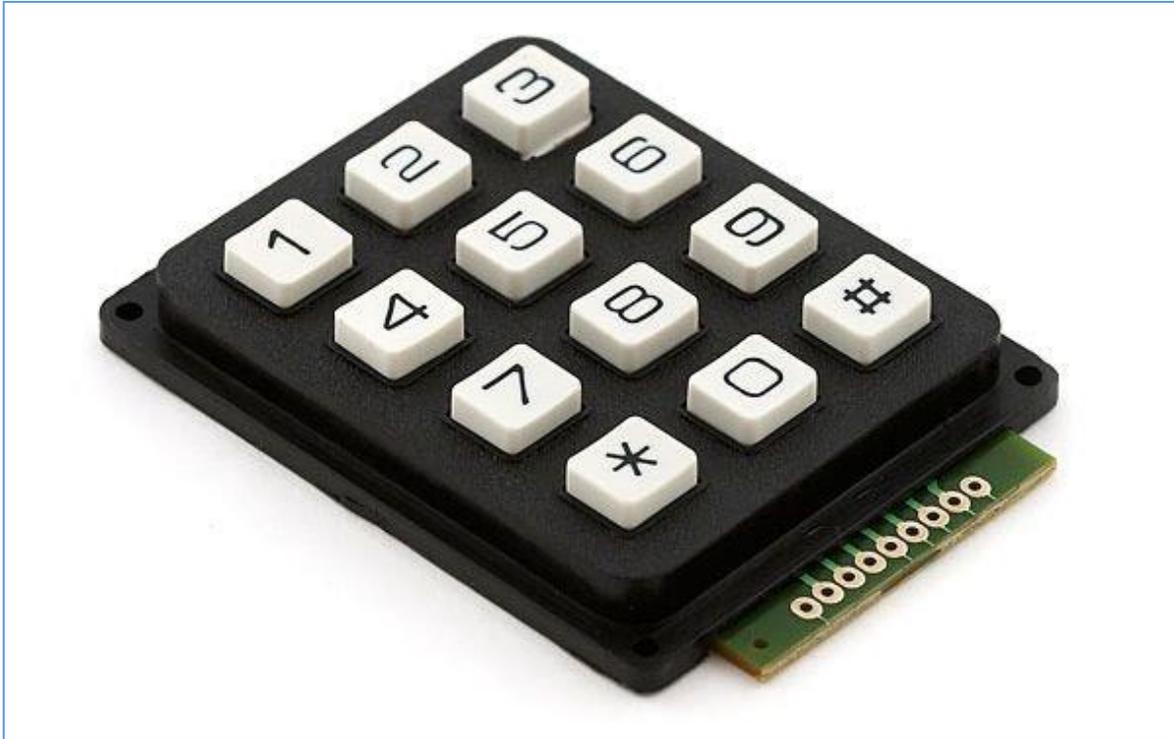


Figure 153 – Keyboard. Copyright© SparkFun Electronics - USA

Another type of switch that you will use with RedBoard and Arduino boards is the "joystick", built with 4 microswitches and a control stick. See **figure 154**.



Figure 154 - Joystick e PCB showing construction. Copyright© SparkFun Electronics - USA

The so-called "reed switch" in English is our "blade switch".

The blade switch works by the action of a magnetic field, which is supplied by a coil wound around the blade switch body. The blades are mounted inside a small glass ampoule and the coil goes in a small spool around the glass ampoule as shown in **figure 155**. The coil usually operates at a low voltage of about 3 to 12VDC.

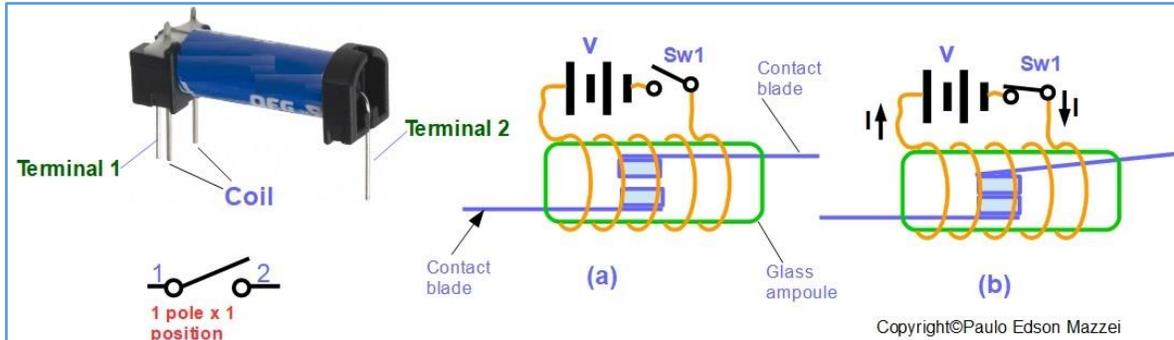


Figure 155 - Slide switch operation.

(a) When there is no current flowing through the coil, there is no magnetic field and the blades remain at a distance.

(b) A voltage was applied to the coil via the Sw1 switch. The current that circulates causes a magnetic field around the contacts, attracting them and closing contact. In these contacts can be connected anything: an alarm lamp, a siren, etc.

Key Specifications

In addition to the type of switch, number of poles, number of contacts, assembly, you must specify:

- **Maximum contact voltage**
- **Maximum current that can flow through the contacts.**

In the practice of using switches, we never chose values close to those specified by the manufacturer. For example, a lever 1-pole x 1-position (on / off) will be mounted on a circuit where a current of 1 A, a 127 VAC power circulates.

It is interesting to use a practical value of about 60 to 70% of the value given by the manufacturer at the time of choosing. Components with "unknown geographical origin" should be evaluated. See **figure 156**.

On/off common switch



Figure 156 - Electrical specifications of a common on / off switch.

Application of switches

In the explanations given above, you have seen some circuits that use switches. Maybe the simplest application is that of a lever, 1 pole x 1 position, to switch on and off an electronic device.

But switches also have many functions like selecting circuits, changing voltages, etc.

The "deep switch" is a miniature key (or several) mounted on an IC type enclosure - Integrated Circuit. Therefore, the deep switch can be embedded in a Protoboard without problems. **Figure 157** illustrates a deep switch with 8 switches.

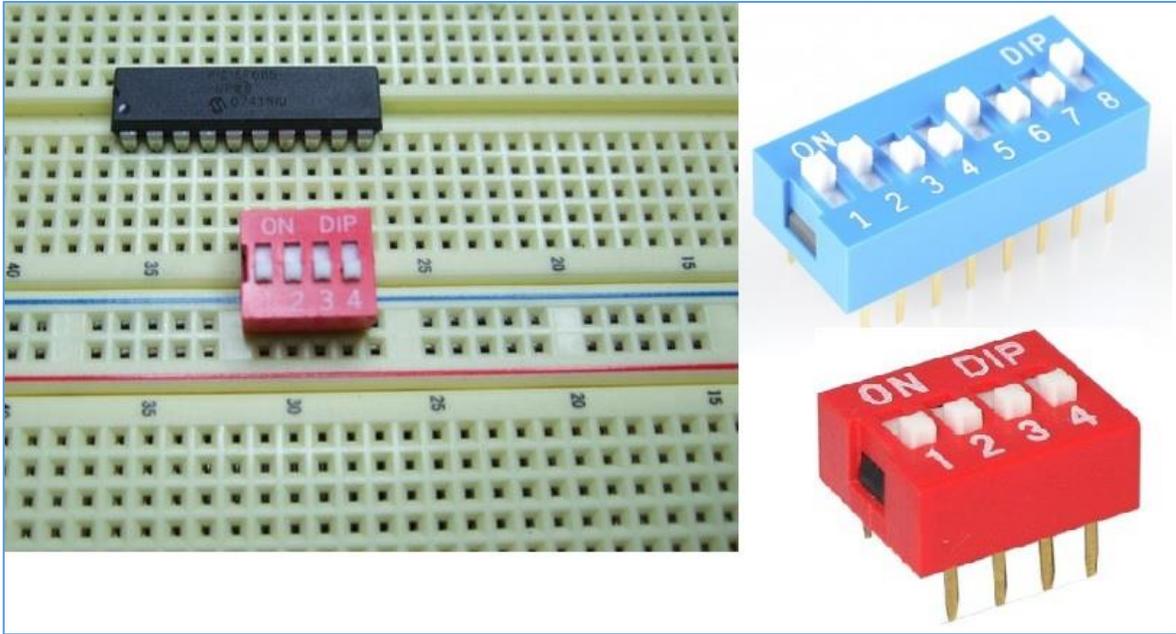


Figure 157 - Deep switch.

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Chapter 22

Wires and cables

Introduction

In electronics we use some types and sizes of wires and cables, usually without major problems. The electric currents are usually low and we can then use wires and cables of relatively small and flexible diameters.

Whether or not electric wires and cables are present in our lives, our homes, our car, our smartphone, etc.

Wires and cables are used to serve as the "way" for electric current to go from one point to another.

The wires and cables are made of copper and in electronics we use the types wrapped with a PVC cover.

Rigid x flexible

We use the word "**wire**" when the conductor is rigid, consisting of single wire.

The "**cables**", on the other hand, are flexible and constructed of several thin wires of small diameter, wrapped together by the PVC layer. See **figure 107**.

- (a) Hard wire
- (b) Flexible cable
- (c) Multi-vein cable or flat cable
- (d) PP power cable, or bipolar cable, for use in 127 and 220VAC
- (e) PP power cable, (or network cable), for use in 127 and 220VAC
- (f) Flat or multi-vein cable with connectors.

Interconnecting cables

Small-diameter interconnect cabling is used to make connections between RedBoard or Arduino boards and Protoboard. They are purchased ready, colorful, already with the small connectors at the ends. Look at **figure 158**.

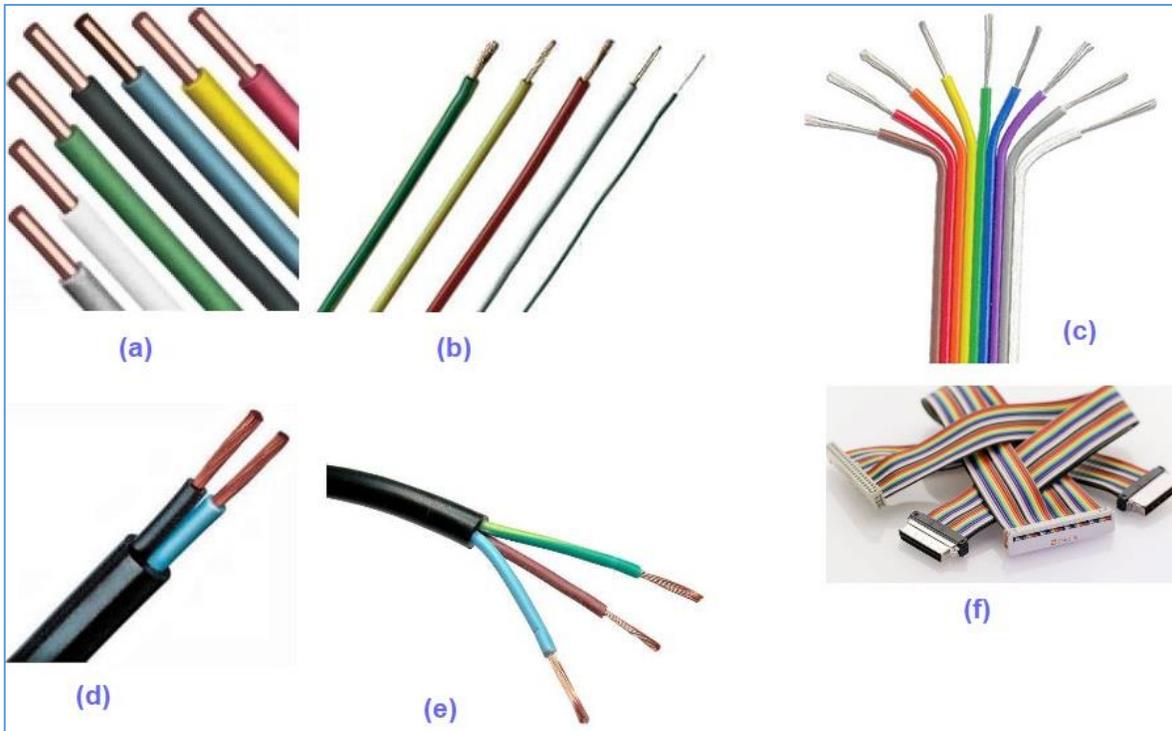


Figure 157 - Types of wires and cables used in electronics.

Interconnect cables are very useful for any type of assembly on Protoboard. See **figure 159**.

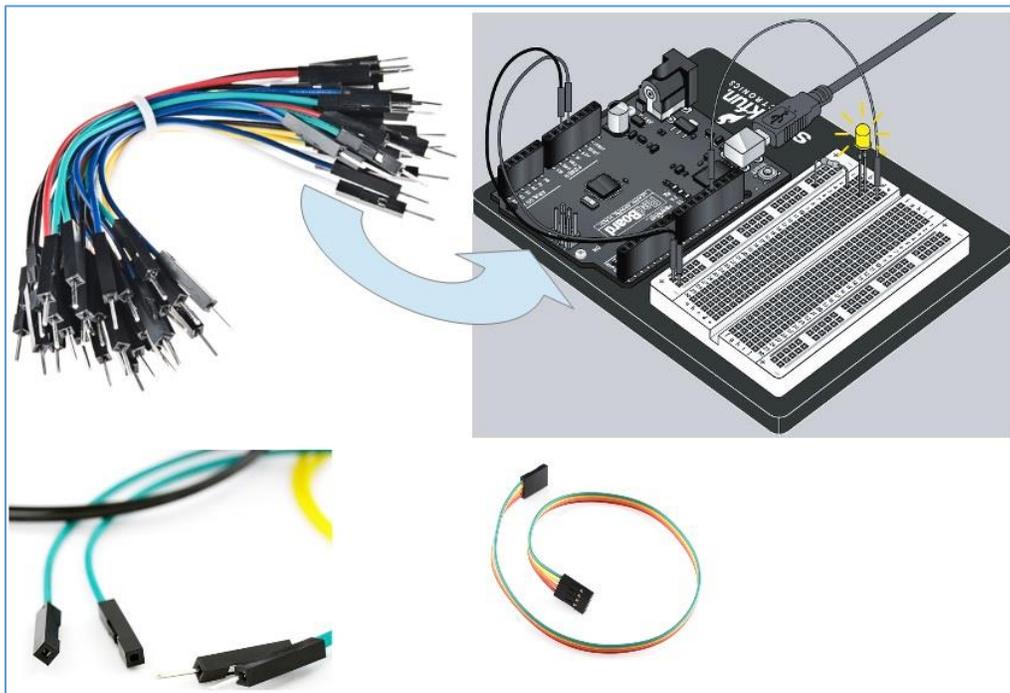


Figure 159 - Interconnection cables. SparkFun Redboard board.

The interconnect cable has a unique disadvantage, if you like to make good look assemblies: they stand on the components on the Protoboard and can cause a tangle of wires, with difficult vision of the assembled electronic components.

The solution would be to use rigid wires of small diameter, around 0.5 mm, to make the interconnections in the Protoboard. These wires can be obtained free of charge from some workshops, such as telephone cable tips. Comes in dozens of colors and allows for a neater assembly. The phone companies in your city can have these tips and with a "talk" you can get free. See **figure 160**.

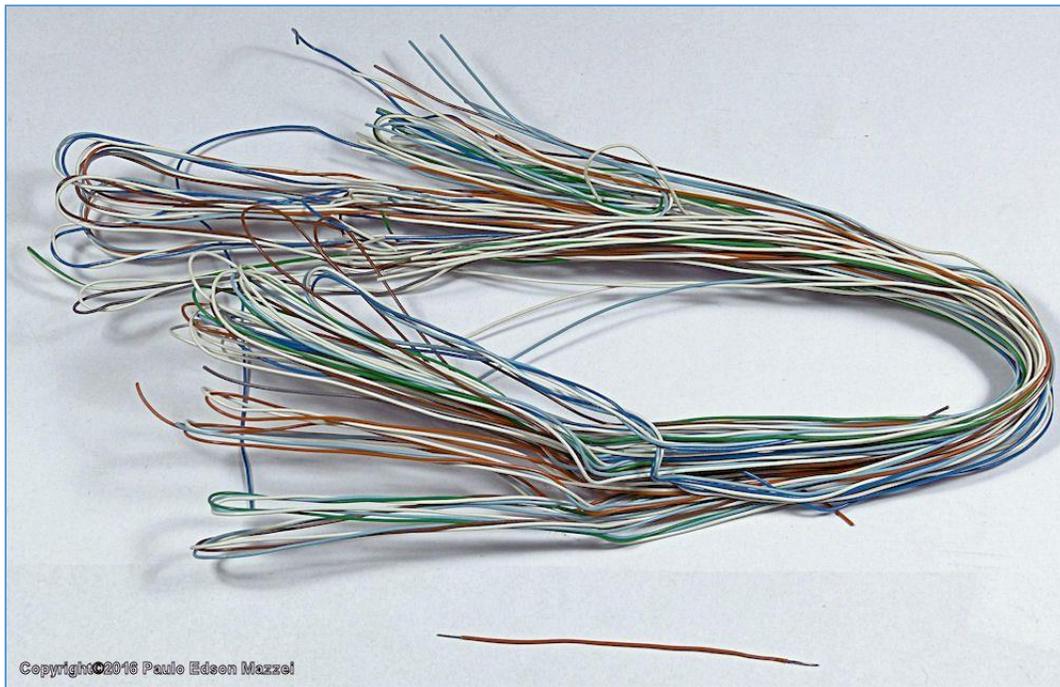


Figure 160- Telephone cable wires.

Compare two assemblies on the Protoboard, with flexible "phone" flexible wiring loops, **figure 160**.

The interconnecting cable has pins with a diameter of 0.6 mm while the rigid telephone line has diameters of 0.5 mm.

The rigid telephone wire assembly is "cleaner" than the assembly with interconnect cables. With the use of interconnect cables, the metal contacts in the Protoboard connector are a bit "loose" with use.

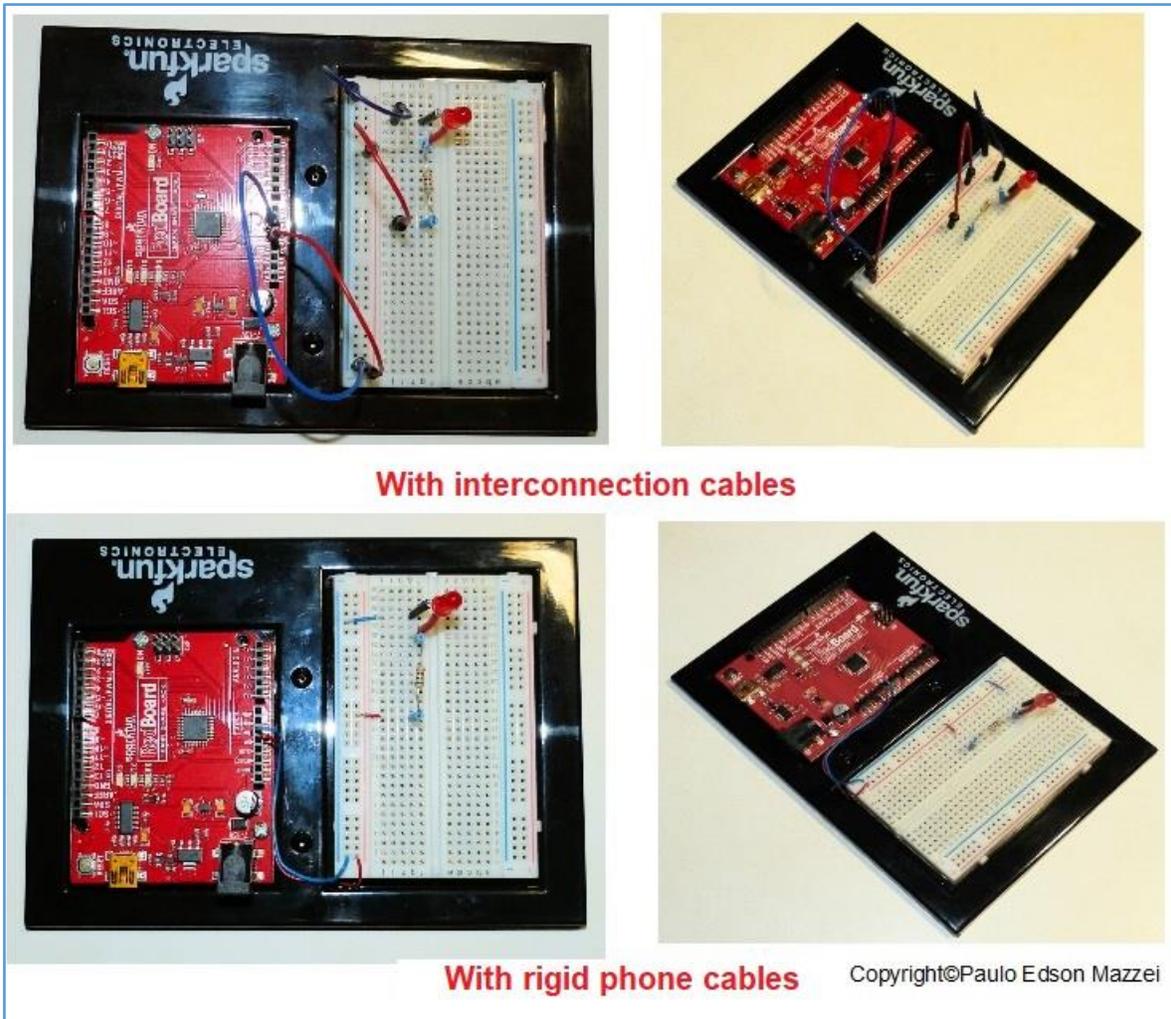


Figure 160 - Mounting using interconnect cabling x mounting using telephone hard wire.

Plate: SparkFun Redboard.

Copper cable and wire sizes

Wires and cables, whether wrapped or not, use a measuring system to define their diameter. This is necessary because each diameter of wire or cable has a maximum capacity of electric current that can flow through it. Thicker wires and cables carry greater electrical current.

There are two systems used to determine the gauge (the wire and cable number): the **AWG** and the **SWG**. The difference between the two is minimal, for the purpose of this eBook and in view our uses.

In Brazil, we use a gauge depending on the current capacity of the wire or cable. This gauge is given in **square millimeters** (mm²). See **Figure 161** for a wire table with wire area in mm² and equivalency with the **AWG** table.

Wires and Cables - AWG / MCM Standards					Wire and Cables Metric Standards	
<i>American Wire Gauge e 1000 Circular Mills (1 mil = .0254 mm)</i>						
Size	Diameter (mm)	Section mm ²	Resistance (ohm/m)	Current Maximum (Amp)	Section Nominal (mm ²)	Current Maximum (Amp)
40 AWG	0,08	0,005	3,4	-	-	-
39 AWG	0,09	0,006	2,7	-	-	-
38 AWG	0,10	0,008	2,2	-	-	-
37 AWG	0,11	0,010	1,7	-	-	-
36 AWG	0,13	0,013	1,4	-	-	-
35 AWG	0,14	0,016	1,1	1	-	-
34 AWG	0,16	0,020	0,86	-	-	-
33 AWG	0,18	0,025	0,68	-	-	-
32 AWG	0,20	0,032	0,54	-	-	-
31 AWG	0,23	0,040	0,43	-	-	-
30 AWG	0,26	0,051	0,34	2	0,05	2
29 AWG	0,29	0,064	0,27	-	-	-
28 AWG	0,32	0,081	0,21	-	-	-
27 AWG	0,36	0,10	0,17	-	-	-
26 AWG	0,41	0,13	0,13	-	-	-
25 AWG	0,46	0,16	0,11	-	-	-
24 AWG	0,51	0,21	0,084	4	0,20	4
23 AWG	0,57	0,26	0,067	-	-	-
22 AWG	0,64	0,33	0,053	6	0,30	6
21 AWG	0,72	0,41	0,042	-	-	-
20 AWG	0,81	0,52	0,033	9	0,50	9
19 AWG	0,91	0,65	0,026	-	-	-
18 AWG	1,0	0,82	0,021	11	0,75	10
17 AWG	1,2	1,0	0,017	-	-	-
16 AWG	1,3	1,3	0,013	13	1,0	12
15 AWG	1,5	1,7	0,010	-	-	-
14 AWG	1,6	2,1	0,0083	16	1,5	15
13 AWG	1,8	2,6	0,0066	-	-	-
12 AWG	2,0	3,3	0,0052	22	2,5	21
11 AWG	2,3	4,2	0,0041	-	-	-
10 AWG	2,6	5,3	0,0033	35	4	28
9 AWG	2,9	6,6	0,0026	-	-	-
8 AWG	3,3	8,4	0,0021	50	6	36
7 AWG	3,7	10	0,0016	-	-	-
6 AWG	4,1	13	0,0013	62	10	50
5 AWG	4,6	17	0,0010	-	-	-
4 AWG	5,2	21	0,00082	70	16	68
3 AWG	5,8	27	0,00065	-	-	-
2 AWG	6,5	34	0,00051	90	25	89
1 AWG	7,4	42	0,00041	110	35	111

Figure 161 - Table of equivalence of wires and cables AWG and Brazilian standard in mm2.

In the table of **figure 161**, we highlight the cable or **wire no. 22**, since it is widely used for assemblies between Redboard / Arduino and Protoboard boards.

From the table we see that this wire or cable has a diameter of 0.64 mm and the maximum current it supports is 6 A, which is more than enough for our experiments. The approximate section of it is 0.33 mm², which is equivalent to a wire or cable of Brazilian standard of 0.30 mm².

In physical electrical stores or on the Internet, you can easily find these cables and wires to purchase, in a lot of colors. Have a few meters of each color always at hand!

How to remove the cover of a wire or cable

Tool

The tool we use is wire and cable stripper pliers. There are several models and, on the Internet, you can find a portion, with various prices. Many are of unknown geographical origin and care is needed.

I often use the two models shown in **figure 162** that can be purchased from hardware stores or the Internet.



Figure 162 - Wire strippers' pliers.

The pliers shown on the left are a type that has the fittings to place the wires according to their diameter. The pliers shown on the right are an automatic model, that is, simply put wires of any diameter on your cheeks and it does the stripping process.

See examples of use of these pliers in **figure 163**.

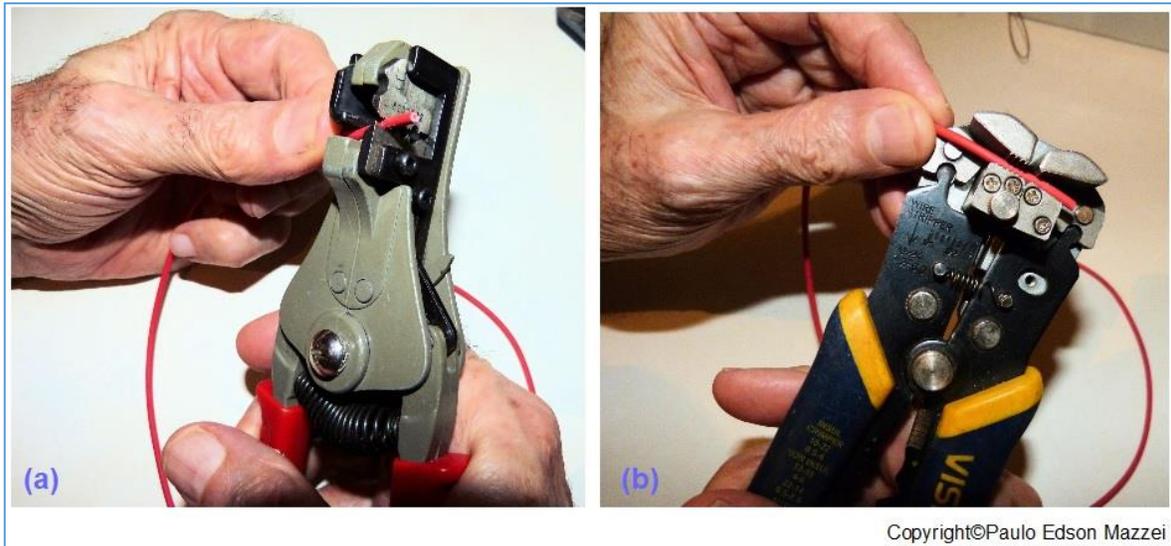


Figure 163 - Stripping wires with both types of pliers.

The USB cables

The **USB 2 (Universal Serial Bus)** cable is used to connect your PC (notebook, desktop) to the RedBoard or Arduino card.

This cable is a data cable and should preferably be purchased from the supplier of the Redboard or Arduino Board. Watch out for USB type cables that are used in battery chargers and the like.

For use in the SparkFun Electronics RedBoard card, a cable should be used as shown in **figure 164**.

Note that at one end the cable has a USB 2 connector, type "**A**" (normal) and at the other end it has a mini USB connector, type "**B**". The USB connector A, goes to the PC and the USB connector B, mini, goes to the Redboard.

In the case of the Arduino board, the USB B connector, mini, is replaced by the USB-B connector.

Other types of USB connectors are also shown in this figure.

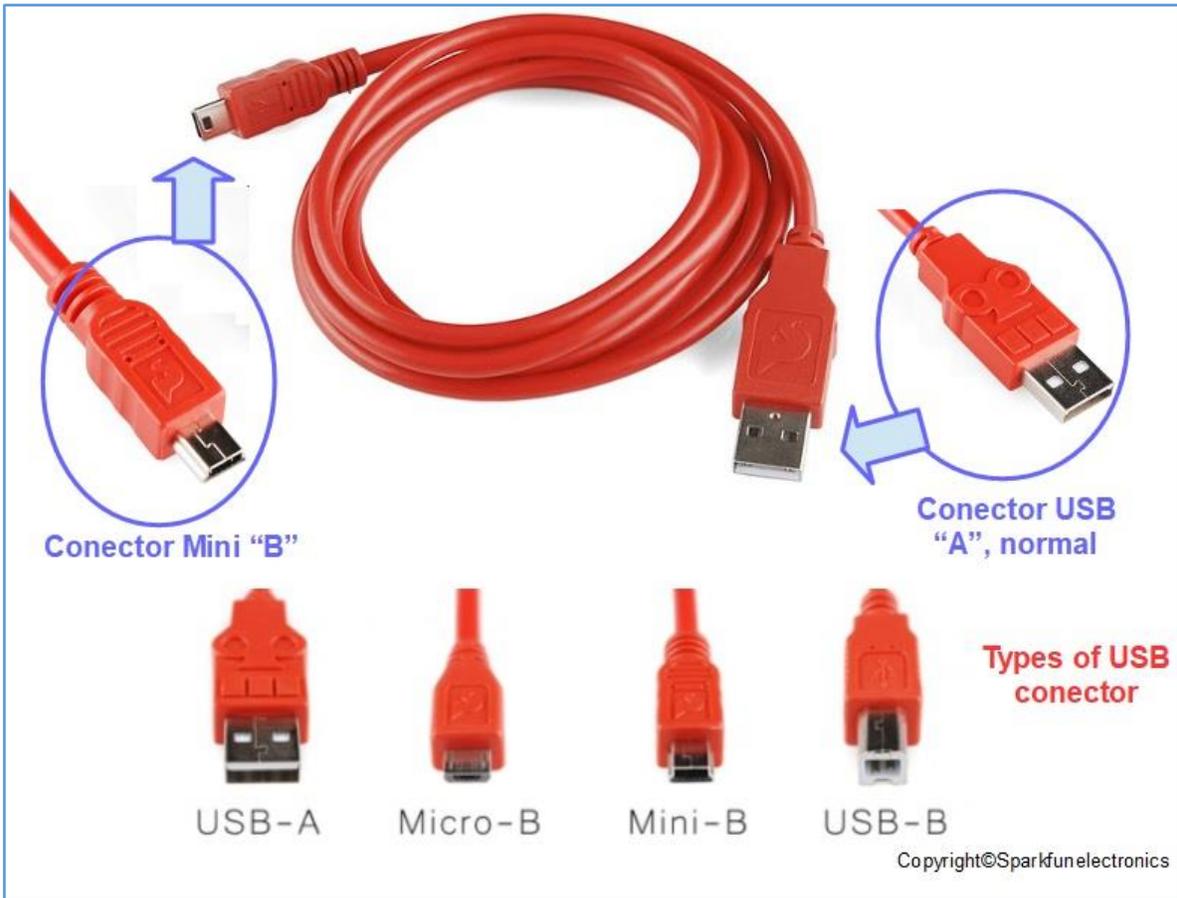


Figure 164 - USB 2 cable, to be used on the Redboard and Arduino board. Copyright © SparkFun Electronics - USA

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Chapter 23

Polarity

Introduction

In the early days of the electronics age, polarity was used to indicate whether a component was **symmetric** or not. A **non-polarized** component could be connected in any way (any direction of the terminals) to a circuit and its operation would be as expected.

A symmetrical component, that is, without polarity, rarely has more than two terminals.

A **polarized (non-symmetric)** component can only be connected one way to a circuit so that it works as expected. A polarized component may have only two terminals or a portion of terminals such as one hundred or more! When a polarized component is mistakenly connected to an electrical or electronic circuit, it is often damaged and sometimes damages the components associated with it. This is simple to see because you will have smoke, sparks and stench ...

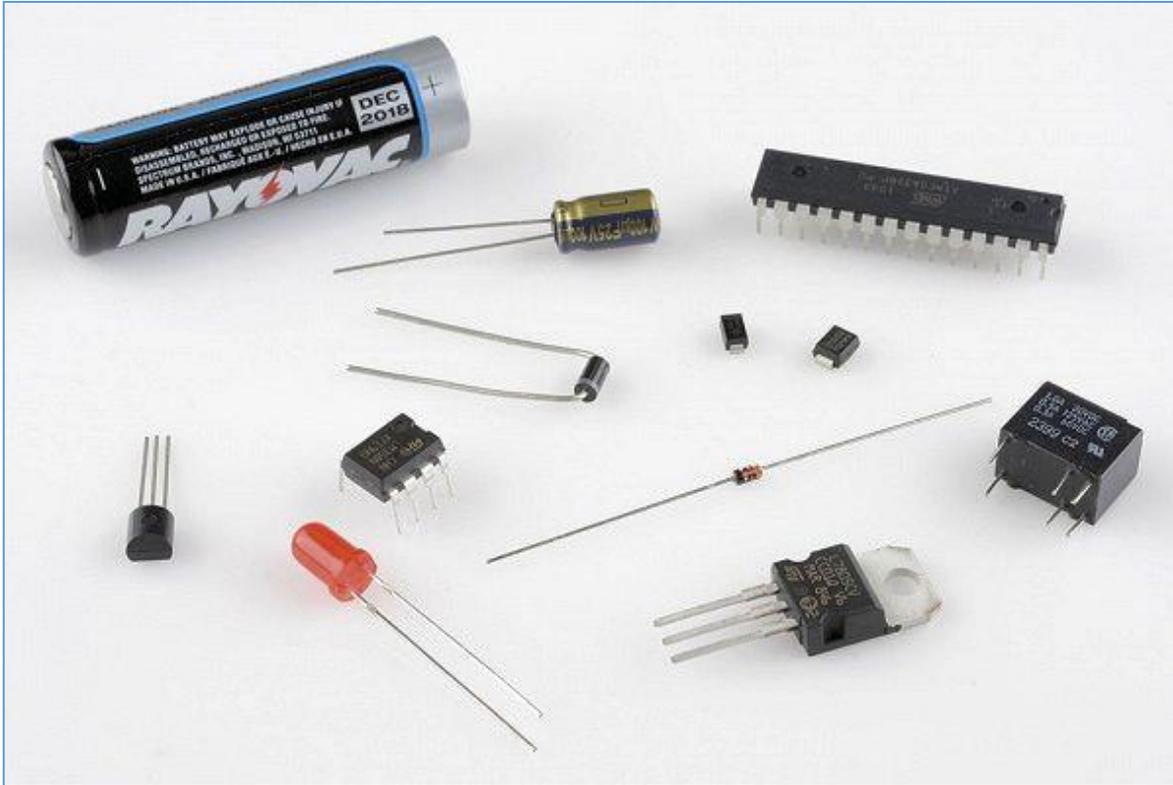


Figure 165 - Examples of polarized electronic components

Copyright © SparkFun Electronics - USA

In **Figure 165**, we show several types of polarized components, such as diodes, LEDs, transistors, IC - Integrated Circuits, relays, etc.

Polarity of LEDs and semiconductor diodes

LEDs are devices that emit light when they are circulated by a small electrical current. LEDC that say "**Light-Emitting Diode**".

Together with the diodes, LEDs are the most basic polarized components you will find in your experiments in electronics.

In an LED, polarity is indicated in two ways:

- One of the terminals is longer than the other and represents the **positive** or "**anode**" pole.
- One side of the body is chamfered, near one of the terminals, and indicates the **negative** pole or "**cathode**". See **figure 166**.

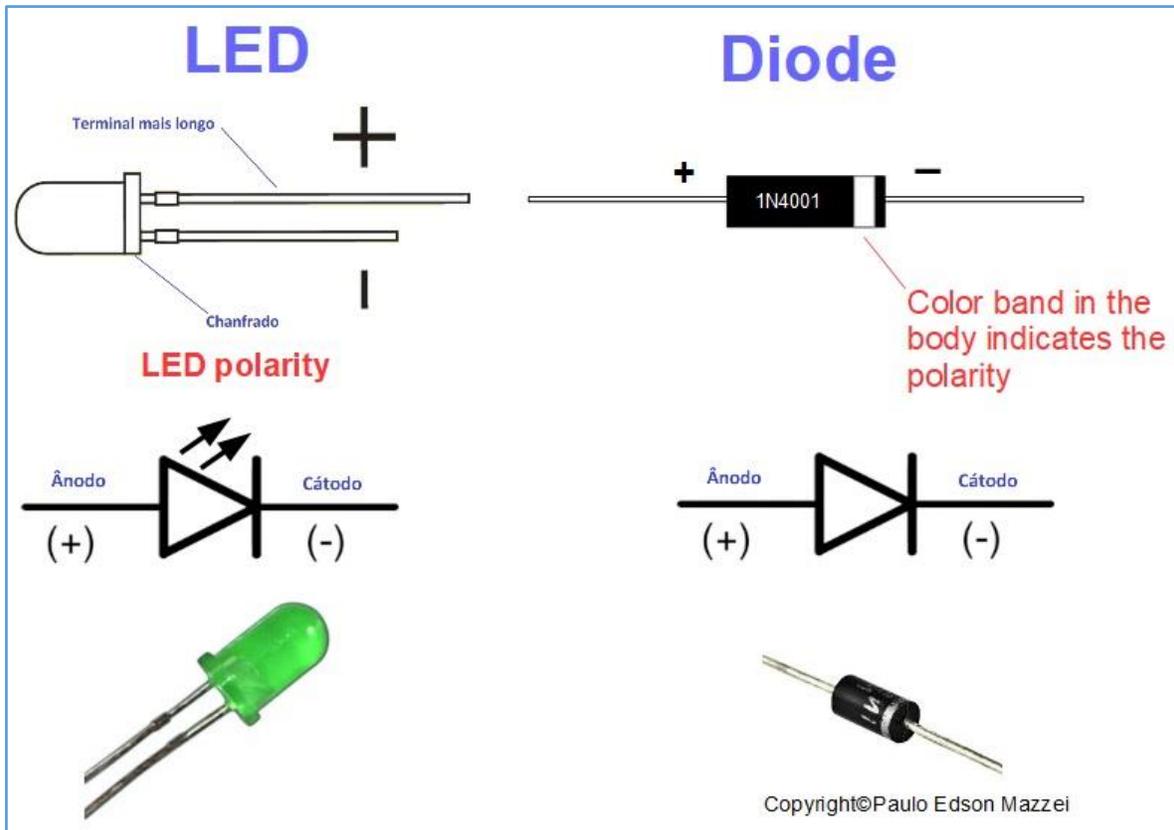


Figure 166 – LED and common diode polarity.

Testing polarity with the Digital Multimeter

The polarity of a LED or a diode can be easily tested with a digital multimeter, since the vast majority of these instruments have a unique diode test (diode = two-terminal component).

1. Set your digital multimeter to the "Diode" function, represented by the diode symbol. If the digital multimeter provides a buzzer in conjunction with the diode test, it will have a sound wave symbol associated with the diode symbol.



2. Place the test leads, red and straight at any of the LED terminals. Do not worry about the polarity of the LED at this time as this measurement with the digital multimeter will not damage it.

3. There are two situations for reading on the digital multimeter:

► The LED will light and the Meter will indicate an "1" reading. In this condition, the **positive terminal of the multimeter** (red) is connected to the anode and the negative terminal of the multimeter is connected to the cathode. See **Figure 167, (a)**. This reading of "1" does not mean anything.

► The LED will not light and the Meter will indicate an "1" reading. In this condition, the **negative terminal of the multimeter** (black) is connected to the cathode and the positive terminal of the multimeter is connected to the anode. See **figure 167, (b)**.

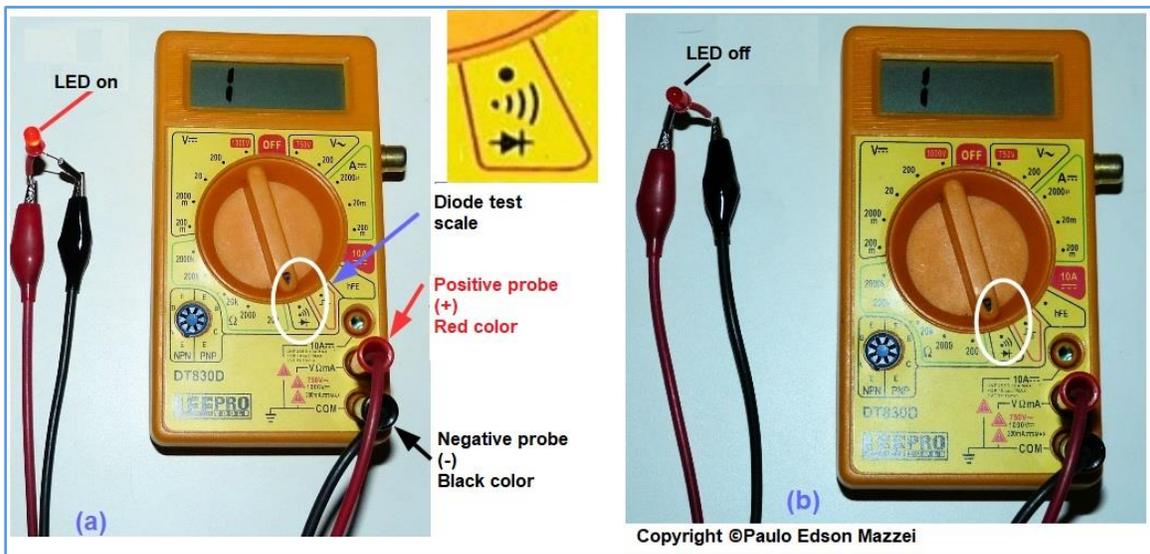


Figure 167 - Finding the polarity of an LED with the digital multimeter.

Polarization in IC – Integrated Circuits

ICs can have eight pins or more than 40 ... So, there is a pattern for pin identification of an IC, based on your body.

Usually the ICs that we work on our experiments and mounted on a Protoboard, have their pins lying next to an epoxy body. This provision comes from the English word "DIP" which means "Dual-Inline Package", i.e. "Envelope with terminals arranged side by side, in lines".

Figure 168 illustrates how pin 1 of an IC could be identified, which is the reference pin for locating other pins.

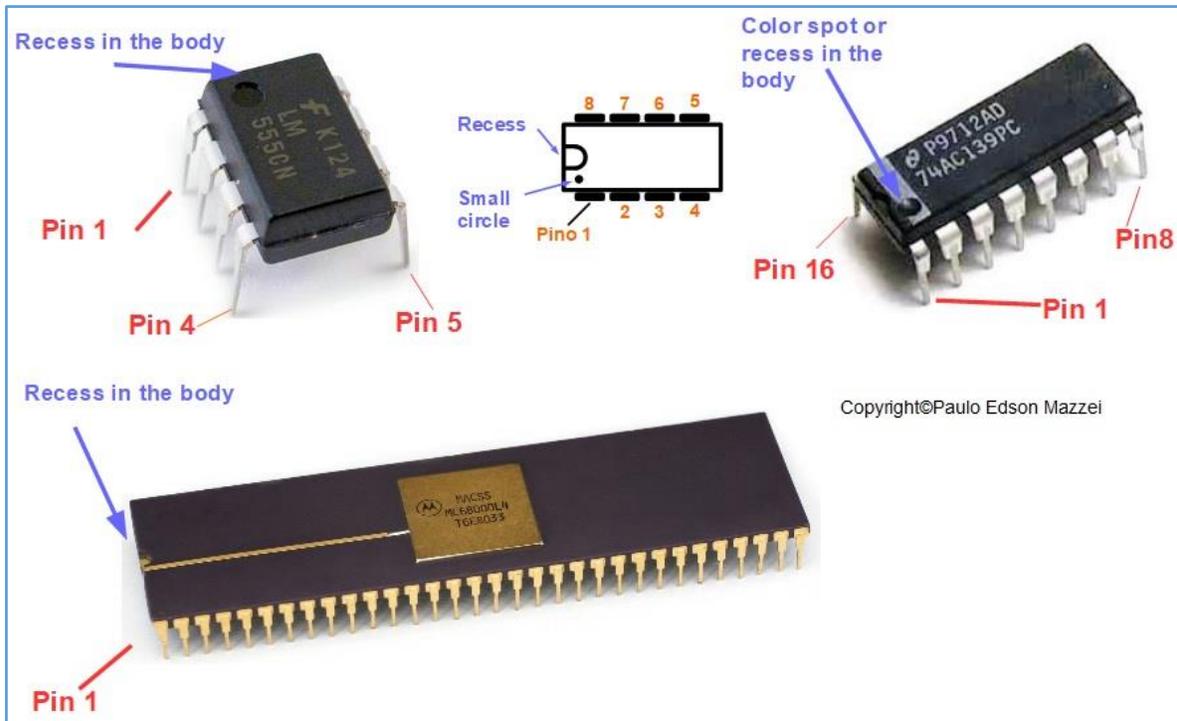


Figure 168 - Identification of the pins of an IC.

Polarization in electrolytic capacitors

Electrolytic capacitors, both aluminum and tantalum, are polarized.

The polarization of these capacitors is marked in the body of the same, along with the value in microfarads (μF) and the maximum working voltage in DC.

Figure 169 illustrates some of these polarized capacitors.



Figure 169 - Polarity in aluminum and tantalum electrolytic capacitors.

Polarization in batteries

For your circuits to work properly you need to feed them properly. In addition to the correct voltage and current of the source and power, you need to observe the polarity of the voltage being applied to the circuit.

A reversal of the polarity of the supply voltage could completely damage the circuit electronics and ruin your assembly work.

In the case of batteries, we all know that there is a **positive pole** and a **negative pole**. These poles are always indicated on the body of the battery or battery, marked "+" for positive and "-" for negative. See **figure 170** for some examples.



Figure 170 - Polarity of batteries

- (a) Common 1.5 V battery.
- (b) 9 V battery.
- (c) Battery type used on cordless phones. Because they fit in only one way, polarity is sometimes not indicated.
- (d) Battery of the type used in cordless phones, toys, etc. Note the small plug connector on the end of the red and black wires. The red wire is the positive.
- (e) Two types of mercury batteries, used in watches, cameras, etc.

Polarity for other electronic components

Transistors

Many electronic components, besides those discussed, have polarity. They are very important in relation to polarity, the various transistors and semiconductors that will be addressed in the corresponding chapter.

Connectors

Connectors in most cases have polarity.

A very simple example is the small battery chargers that you use on your smartphone or tablet. It has polarity to be able to correctly feed the circuits of the devices in question.

See **Figure 171** for some connectors, cables, and others that have polarity.



Figure 171 - Polarity in components.

(a) Connector used in small cell phone battery chargers, tablets, etc. The positive is the center pin, and the negative is the outer metal part of the connector. When using, make sure this is the case because connectors of "unknown geographic origin" may be different ...

(b) Support for two AA batteries, giving a total voltage of 3.0 V.

(c) Support for four AA batteries, with total voltage and 6.0 V. Note that the red colored wire is the positive.

(d) Digital multimeter, with its positive and negative connectors, for fitting probes. The red connector is positive.

(e) Test tips for use in multimeters and others. The red test tip is positive.

Polarity in making your experiments and assemblies

What are the colors of wires and cables that can be used in our experiments and small-circuit assemblies?

- For power, positive pole, use red color.
- For power supply, negative pole, use black.
- If the circuit has more than one supply voltage, use the orange color.
- Ground connection (ground, if applicable) uses green color.
- If you have AC - AC voltage coming into your experience or project, use the gray color.

This "code" above will help you visually identify what "goes through" each wire or cable and what kind of measurement should be done there.

Please note you can make your own "color code" for your assembly. The suggested above is the one I use for years!

In the case of semiconductors, you can create your "code" because it will help you a lot in checking the connections of a transistor on the Protoboard. For example:

■ **Transistors:**

Base = Green

Emitter = Blue

Collector = Orange

■ **Diodes:**

Etc....

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Chapter 24

Alternated current and direct current

Introduction

Alternating Current - AC and **DC – Direct Current** are the two types of electric current we use in our projects and experiments with electronic circuits.

The DC runs in only one direction on a circuit, whereas the AC switches its direction periodically.

In our homes, we use alternating current and in our electronic circuits we use direct current. It is recalled that "current", that is to say flow of electrons that is displaced by a conductor.

AC alternating current is used in homes, factories, laboratories, etc. due to its ease of:

- ▶ It can be easily transmitted from one place to another. For example, from the power plant to its residence.

- ▶ The AC can also be converted to higher or lower values, basically with the use of a transformer. For example, turn your home's 127 VAC voltage to 9 VAC to power a particular electronic circuit after it's converted to DC.

Alternated current - AC

The word "Alternate", used in the acronym "CA", describes the flow of electrons (charges) that change direction periodically.

Because of this, the generated voltage levels also periodically alternate. In our residences we use 127 VAC and some points, we have 220 VAC, for showers, air conditioners, etc. These are points where the requested power of the electric power grid is higher.

AC generation

The **alternator** is the device that produces alternating current. The alternator is specially designed to generate AC.

In a very simple description, a conductor wire loop is rotated in a magnetic field, which induces an electric current in the conductor. This rotating spin of conductive material (copper) can be rotated in several ways:

- Steam turbine
- Water flow
- Wind turbine (wind driven)
- Etc.

Due to the fact that the turn turns and cuts magnetic fields of different polarities, the voltage and current also alternate in the wire loop.

On YouTube you can see dozens of animations of how an Alternating Current generator works. Visit YouTube® and search there ...

AC waveforms

The alternating current can have various shapes and wave if you look at it on an oscilloscope. The oscilloscope is a test and analysis instrument, used in electronic circuits, that allows you to see the waveform of the voltage that circulates at a certain point in the circuit.

In the case of AC that we use in our residences in electronic circuits, the most common form is the sinusoidal one. See the sine wave form and others in **figure 172**.

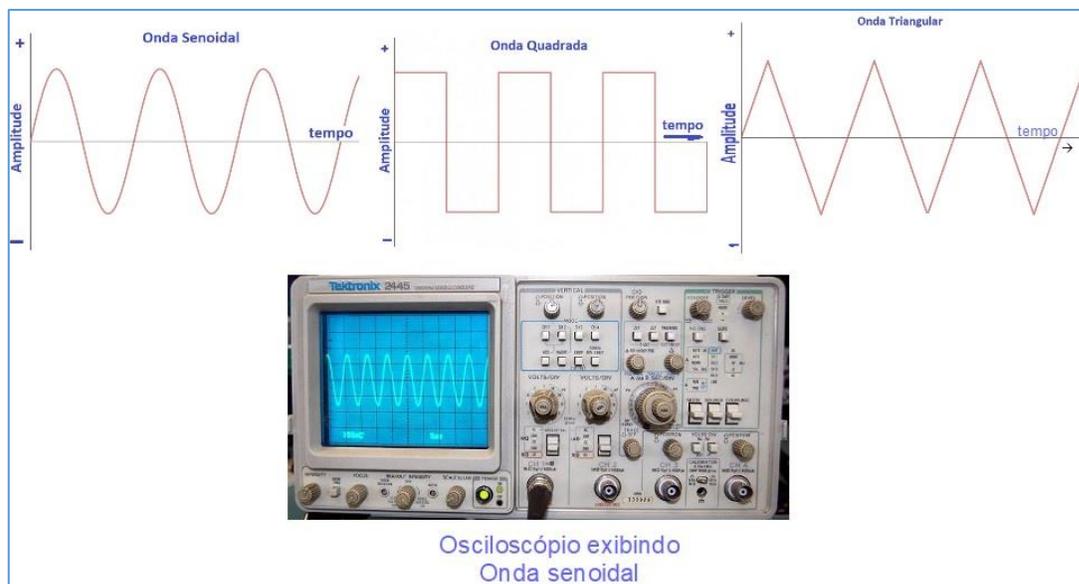


Figure 172 - Types of waveform and image of a sine wave on an oscilloscope.

A steroidal wave

To completely describe a sine wave, we would need mathematical terms. But this is not the idea of our eBook. Let's try to analyze this waveform, using as few mathematical concepts as possible. See the sine wave in **figure 173**.

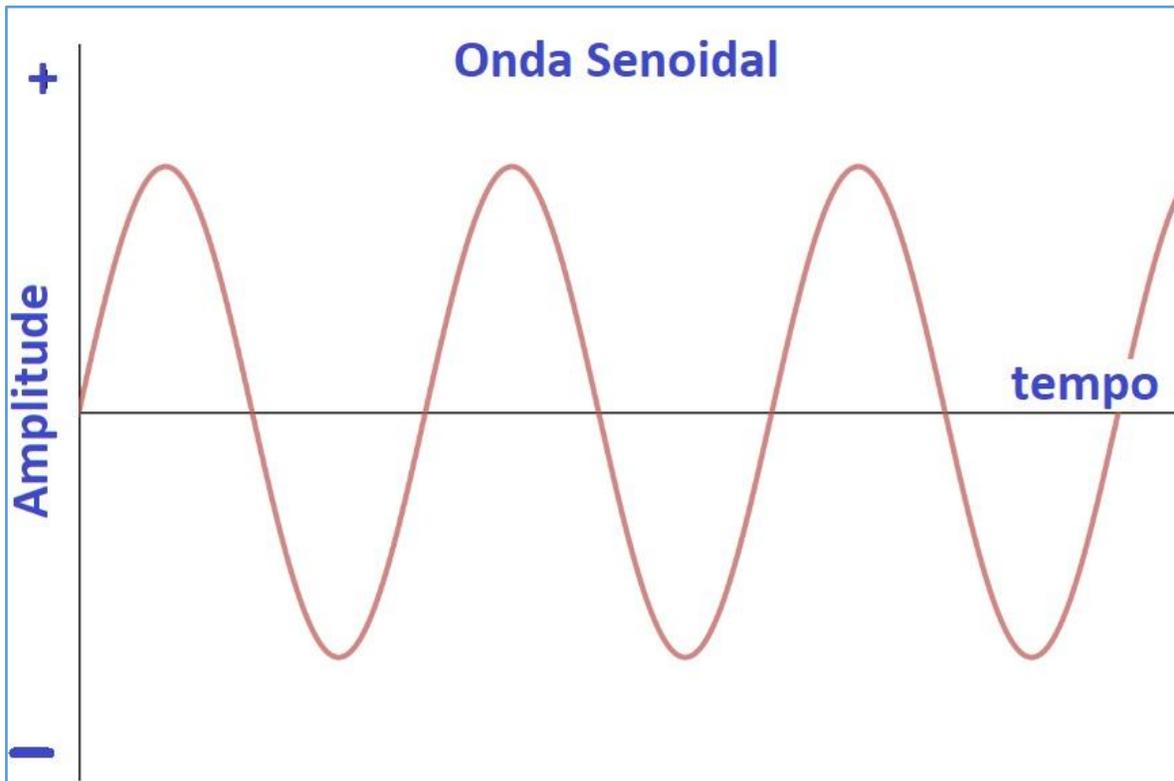


Figure 173 - Analysis of a sine wave.

We see that the graph of **figure 173** uses an X-Y axis system. On the horizontal axis, we have the time, which can be measured in seconds. In the vertical axis the amplitude of the **sine wave**, which for example, can be measured in volts AC.

Note also that the values above the time axis are positive values and the values below the time axis are negative

The frequency of the sine wave, that is, the number of complete cycles it makes in one second, is measured in **Hz** (Hertz)

In Brazil, the alternating current supplied to our homes has a frequency of **60 Hz**. See **figure 174**.

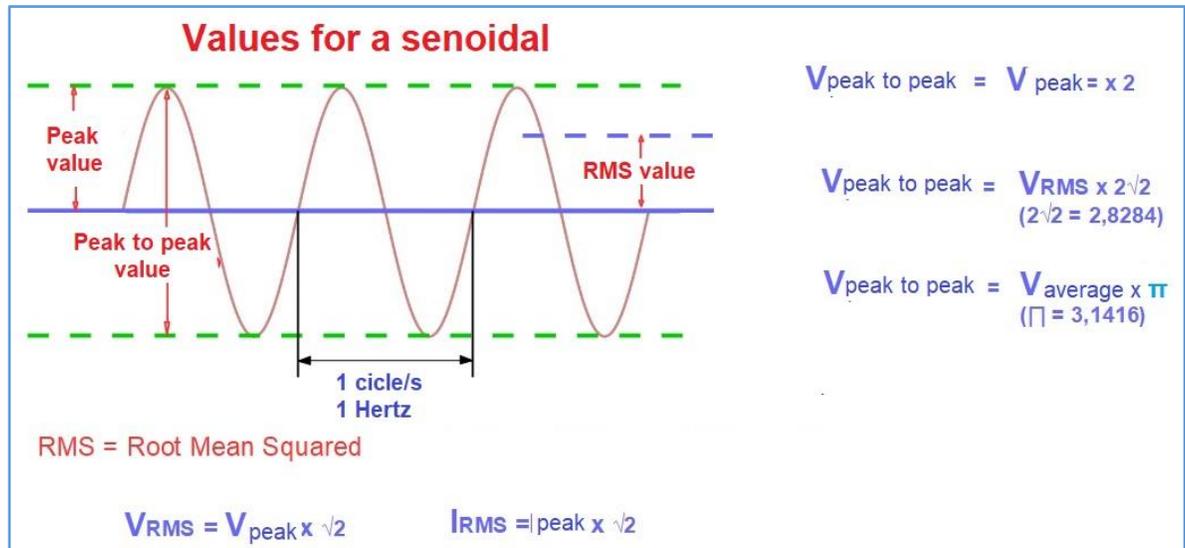


Figure 174 – Values for a senoidal wave.

The maximum points of the sinusoidal signal are called peak values. π

When an electrical and electronic equipment is connected to the AC network, it does not absorb all the power supplied. This actually absorbed value is called **effective value**, in English = **RMS**.

Thus, an **effective alternating current** is equivalent to direct current in amount of transferring the power to the electro-electronic equipment.

The values described in the technical literature and in this eBook are **effective values**, both voltage and current; A common multimeter, connected to a power grid, measures effective voltage.

In this way, if we measure the voltage in an electrical outlet of our residence and obtain 127 VAC, this value is effective or RMS. The peak voltage of this value would be $V_{pico} \times 1.4142 = 179.61 V_{pico}$. Your digital multimeter will read a voltage of 127 VAC at this outlet.

Complicated? No ... analyze the graphics, the text and the formulas you will understand everything!

Direct current

Direct current or **DC** is unidirectional, unlike AC. Its analysis is easier than alternating current.

The flow of electric current supplied does not vary in time. It is easier to analyze the DC if we assume that it is constant.

For example, the waveform of a 1.5 V stack could be represented by the graph of **Figure 175**.

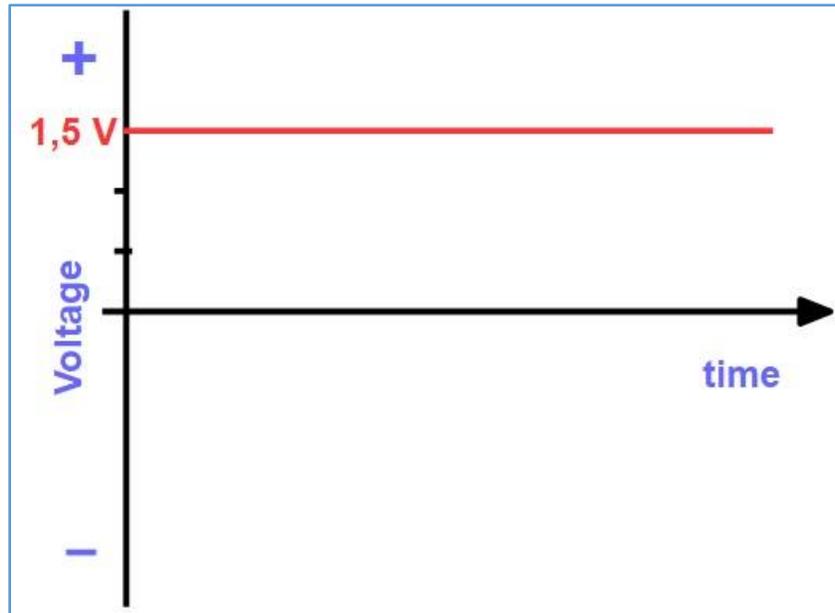


Figure 175 – Direct current representation.

Batteries provide virtually constant voltage over time. Note that this time depends on the ability to supply current from the battery.

As already stated, practically all electronic circuits work with CC. Therefore, your TV that is connected to the 127 or 220V AC power grid needs smaller DC Current voltages to work properly. This is done internally, with the use of a power supply, which performs these two functions.

You can power your experiments or projects with batteries, batteries, power supplies or the USB cable by connecting it to your computer.

External power supplies are commonly called battery chargers, AC adapter, wall adapter, etc. They can be found with various output voltages and for different currents. See **figure 176**.



Figure 176 - Alternating Current Adapter. Input from 100 to 240VAC and output of 5.25VDC - 2.4 A.

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Chapter 25

Connectors

Introduction

Connectors are used on printed circuit boards to attach certain sections or connect to external equipment. Sometimes connectors are placed for future expansions of a circuit.

Connectors are found in a wide variety of types, formats, number of pins, etc.

Terminology used in connectors

This terminology is used to specify a **connector**.

Genre

Gender refers to whether a connector is "**male**" or "**female**". Sometimes we will have difficulty determining whether a connector is male or female. But let's see how to correctly identify them. See **figure 177**, the simplest example of male and female connectors.



Figure 177 - Simple example of "male" and "female" connector.

Contacts

A connector's contacts are the most important parts of the component. These contacts are made of metal with certain properties for this application. When one contact touches another, we have a path to the electric current.

Over time, use, environment, these contacts tend to rust and the "spring" effect of them becomes increasingly weak.

Contacts spacing

Many of the connectors we use and have in Redboard and Arduino boards, consist of multiple contacts, as shown in **figure 178**.

The spacing between contact, refers to the distance between the center of each contact. The standard distance for many connectors is 0.1 inch, or 2.54 mm.

In **Figure 178** you can see a series of connectors used in PCB - Printed Circuit Boards, Redboard and Arduino boards.

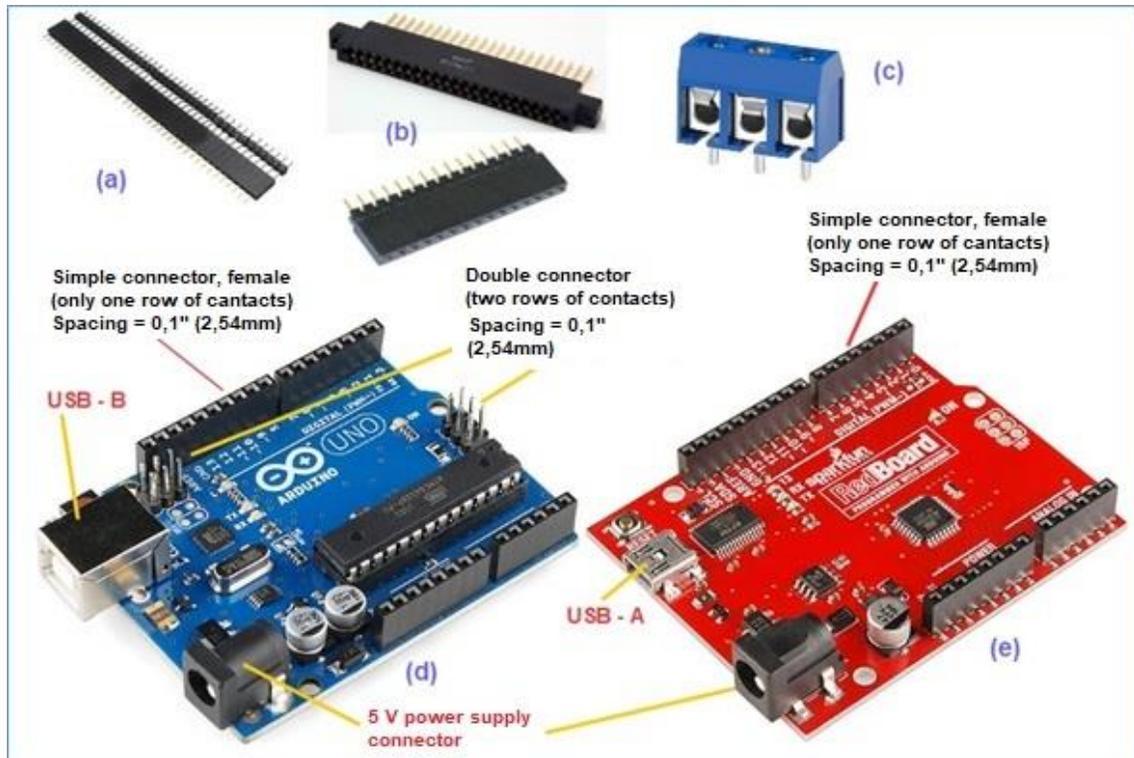


Figure 178 - Examples of connectors and their application. Copyright © SparkFun Electronics – USA

Audio connectors

There is a family of connectors for use in audio frequency (sounds from 20 Hz to 20 kHz), which you should already know: the connector to which you connect the headphones of your iPod or iPhone.

The most common type of this connector is 3mm in diameter (actually = 1/8").

Figure 179 illustrates some of the most commonly used types of audio connectors.

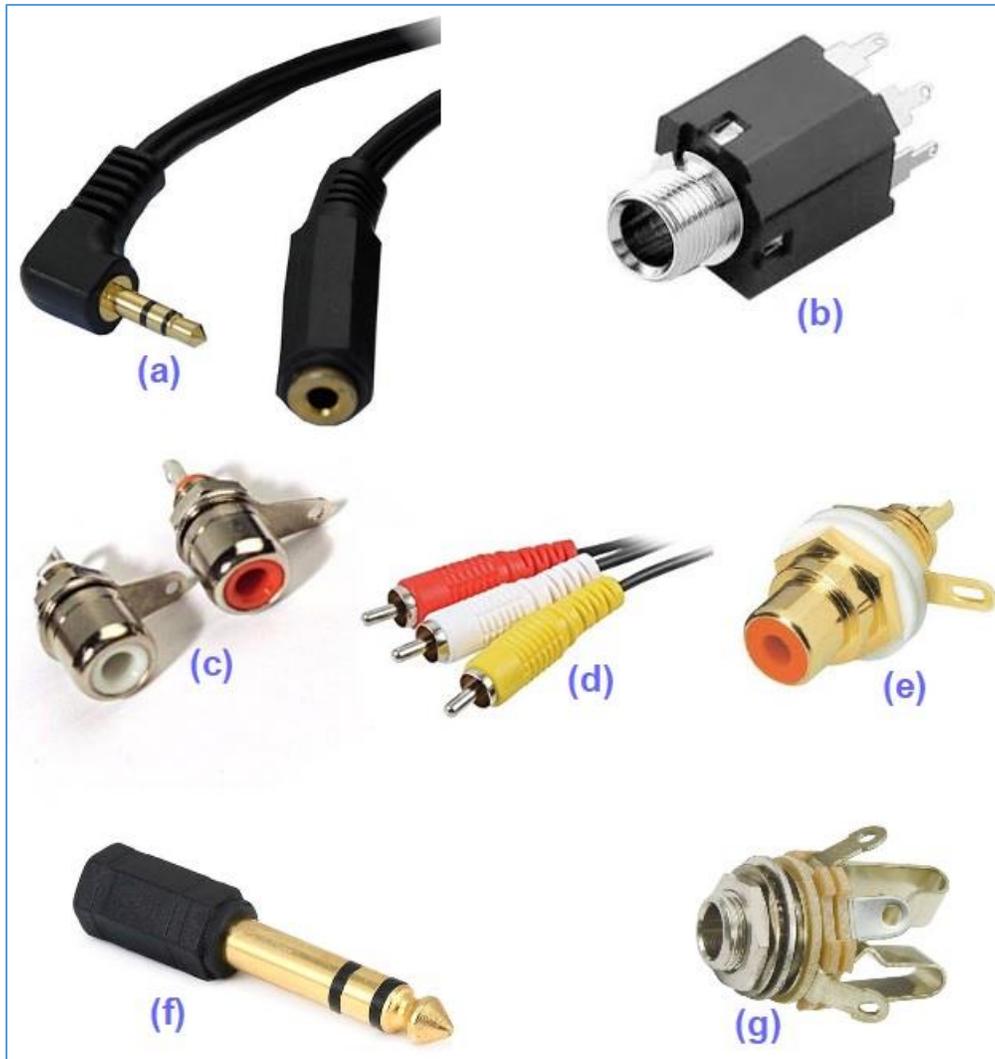


Figure 179 – Audio connectors.

In figure 179, note:

- (a) Male and female connector, 3mm.
- (b) Female connector for 3mm pin, panel mounting.
- (c) Female RCA connectors.
- (d) Male RCA connectors. Mounting on cables.
- (e) Female RCA connector, panel mount.
- (f) Male connector, 1/4 "diameter, cable assembly.
- (g) Female connector, 1/4 "diameter, panel mounting.

Power connectors

Power connectors are used to connect wires and cables that power the printed circuit board or to connect peripherals that require larger power.

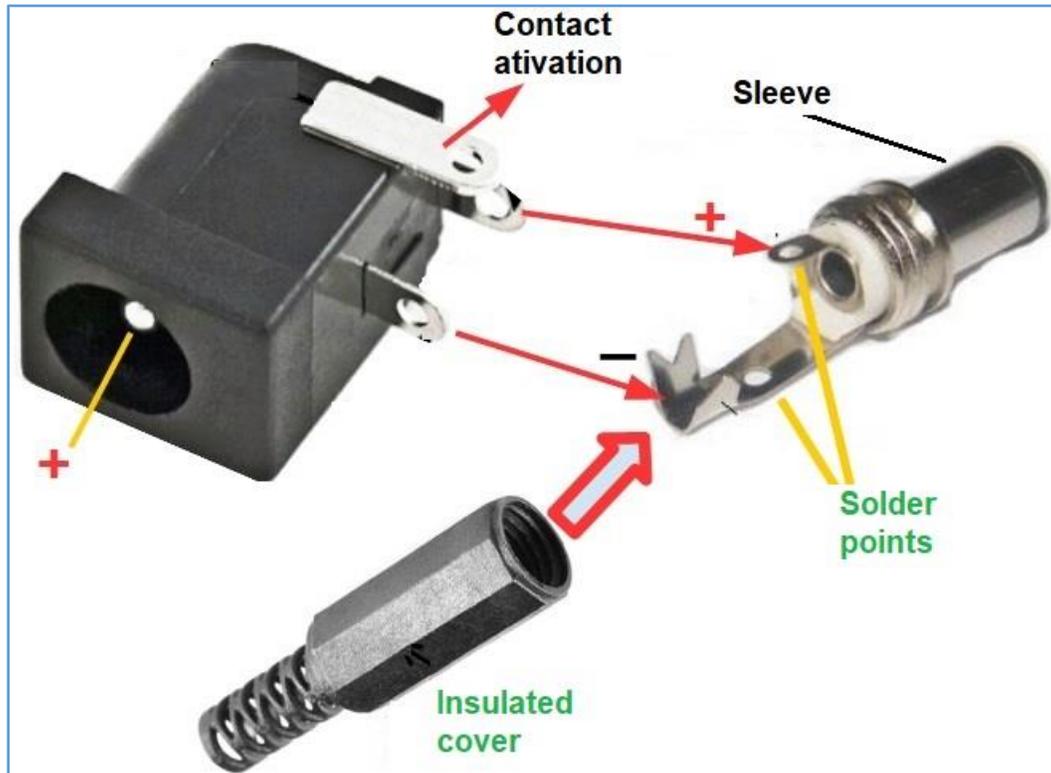


Figure 138 - Power connector.

Other data you need to know about the power connectors are:

- Diameter of the sleeve (or sleeve, the outer metal tube of the male connector). The sleeve is the connection (-). This diameter varies from 3.5 to 5 mm, depending on the model.

- Diameter of the center pin (+ connection) of the female connector. This diameter, when it is 5 mm, may cause problems with intermittent defects. Better to use the 3.5 mm sleeve and the 1.3 mm diameter pin. When buying, see specifications.

Polarity is one of the points to watch closely. Some battery chargers and wall adapter sometimes come from "unfamiliar geographic regions" and may be replaced with what we think is a "standard". See **figure 180**.

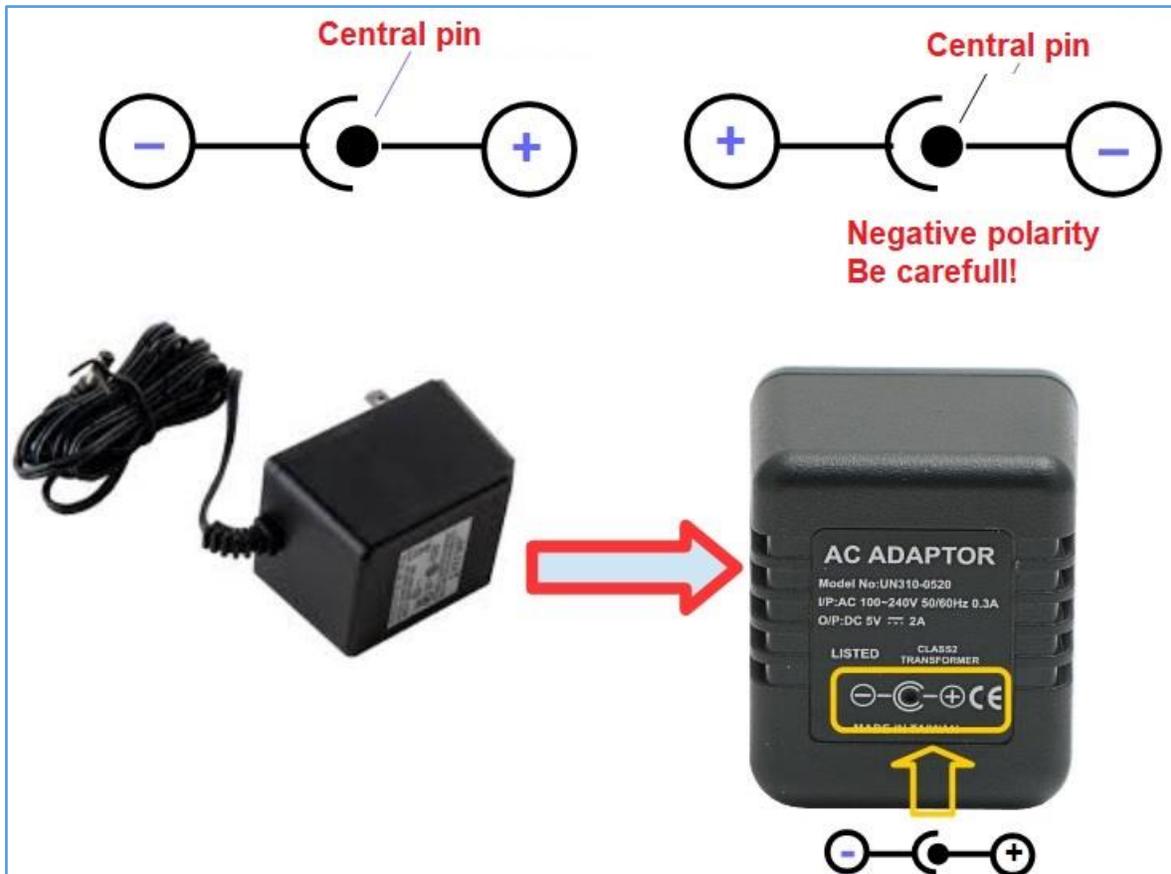


Figure 180 - Polarity of the center pin of the power connector.

Power connectors with fastening screws

These connectors, shown in **Figure 181**, are also known as "**screw connector block**" and are found in a number of formats and number of contacts.

They are assembled with solder, direct in the PCB and are used in circuits with larger powers or peripheral output in PCBs.

JSC connectors

JSC is a Japanese company that makes polarized connectors of great quality. Hence its use in many Arduino PCI and the like.

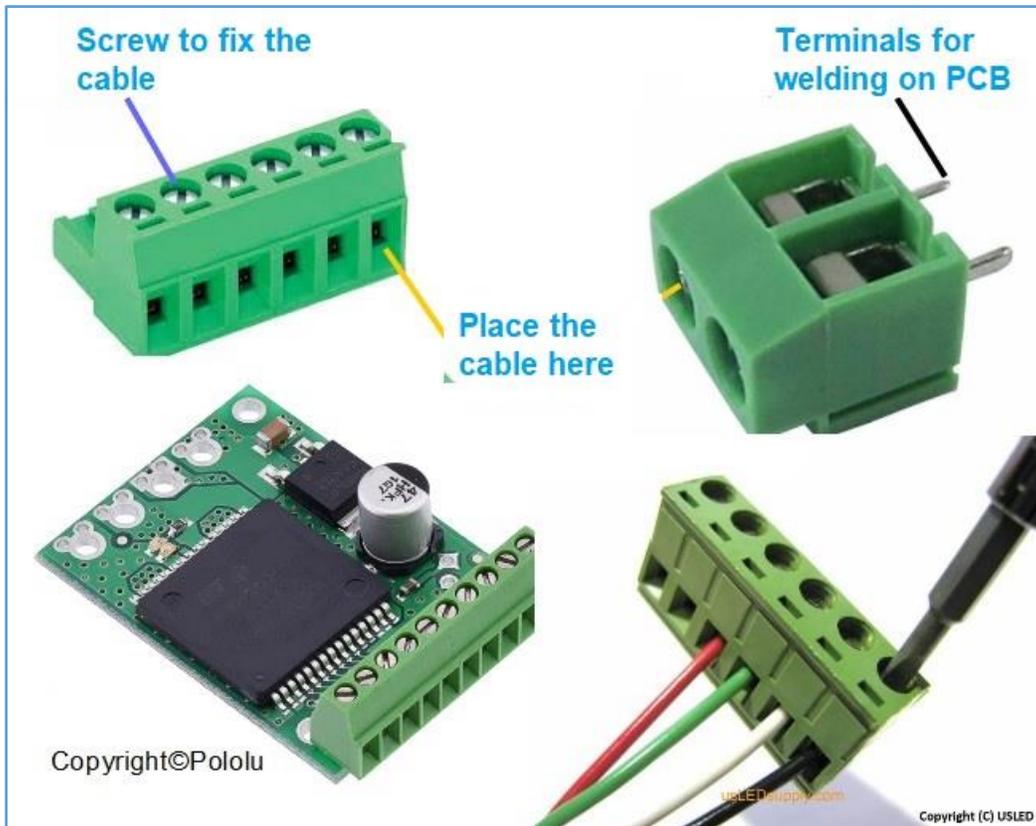


Figure 181 - Terminal block with screws.

The primary use for JSC connectors is in the connection of external power to printed circuit boards. See **figure 141**.

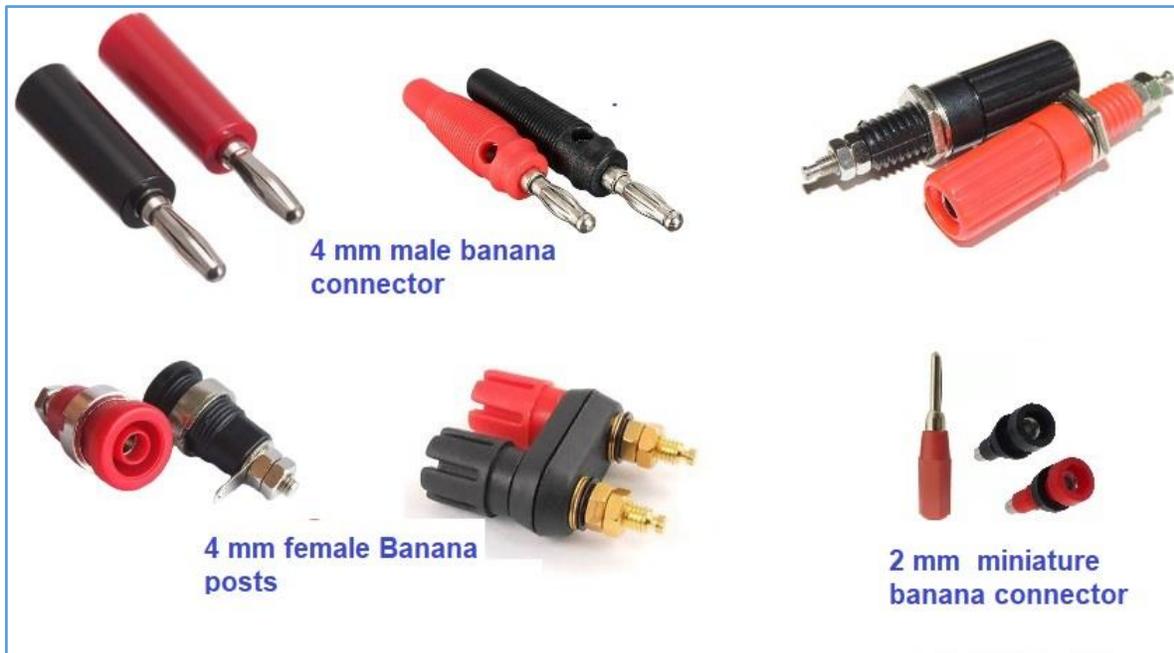


Figure 183 - Models of banana pins and banana pins and posts.

RF – Radio Frequency connector

Connectors for **RF - Radio Frequency** are used in circuits and PCBs that involve radio signals.

RF signals can be generated by an FM transmitter, a Fire Station transmitter, a TV station, or a Wi-Fi and Bluetooth device on your RedBoard or Arduino card.

RF signals are measured in Hertz as the frequency of our 60 Hz electrical network. Examples of RF signals:

- ▶ Signals of an FM radio station - Modulated Frequency. Around 100 MHz (100 megahertz).
- ▶ Signals of a TV station - Television. Around 200 MHz (200 megahertz).
- ▶ Signals of a satellite TV station. Around 2 GHz (2 GHz).
- ▶ Wi-Fi signals from a local wireless network, around 2 to 5 GHz.

These connectors come in several standard formats and are specified depending on the working frequency and the power to be used. In Wi-Fi and Bluetooth there is no power problem because they are signals of very low power. Frequencies used in these services are of the order of 2 to 5 GHz.

In **figure 184** you can see some of the more common types of RF connectors.



Figure 184 - RF Connectors - Radio Frequency.

- (a)** SMA male and female connectors.
- (b)** UHF type male and female connectors.
- (c)** Type N male and female connectors.
- (d)** BNC type male and female connectors.

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Chapter 26

Calculations in circuits

Introduction

From your previous studies you know that a battery has a certain voltage, for example, 9 VDC. You also know that a wall outlet in your home has 127 or 220 VAC.

This present electricity, in order to be useful, needs to move, forming what you already know as the electric current. When the electric current circulates, "things" happen: a motor turns to provide movement, a lamp provides illumination, a television shows an image, and so on.

In the circuit shown in (a) of **figure 185**, we have an LED connected to a 5-volt power source. Note that only one LED terminal is connected to the positive source. In these conditions we have no electric current (I), circulating because we do not have a circuit, to form a "path" for the electric current.

In electronic and electrical circuits, the graphic symbols of electronics and electricity are used, as we have seen in previous chapters.

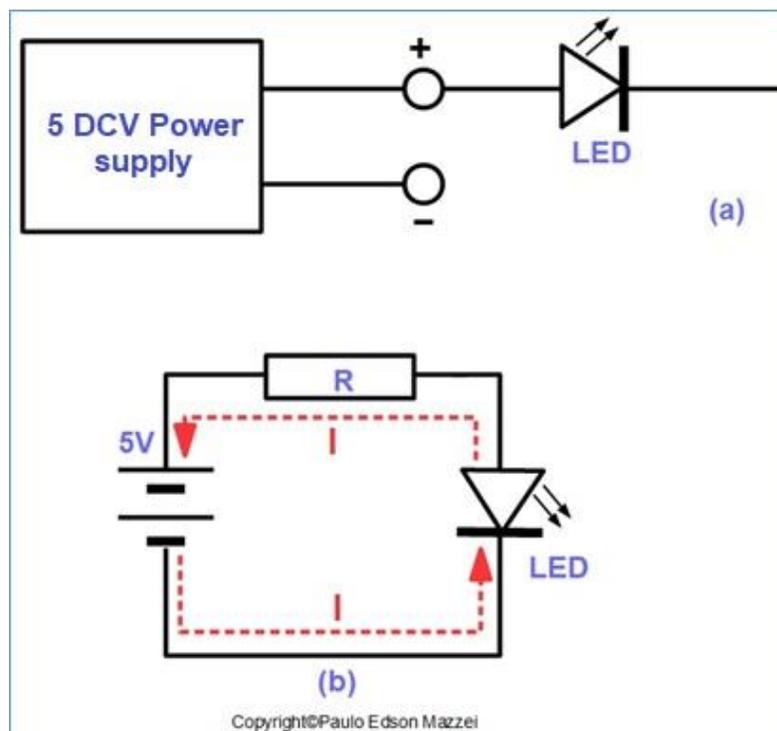


Figure 185 – Simple electric circuit.

In drawing (b) of figure 85, we already have a circuit with the LED and a resistor connected to both terminals of the power supply. Under these conditions, the LED will light due to the flow of electric current (I), which flows through the circuit.

Notice in circuit (b) that the electric current is "coming out" of the negative pole of the battery and going towards the positive pole of the battery. This is the direction of the electric current, representing a stream of electrons from a place that has an excess of electrons (negative) to a place that has a lack of electrons. (positive).

Open and closed circuits

We set up an electronic or electric circuit so that it is of some use to us, whether professionally (electrician) or amateur (hobby).

What we connect to a 9VDC battery or to a 127VAC power outlet, we call charge.

In the previous chapters you have already learned the basics of voltage, current, resistance and power.

Now what we are interested in are the closed circuits or "short circuits" and the open circuits.

Short-circuit

If you connect a copper wire (conductor) between the positive and negative terminals of a battery, you will have a short circuit. The same thing happens if you connect this copper wire between the pins of a wall outlet.



But do not do this!! Careful: danger

If you do you will have disastrous results with sparks, noises and smoke!!

What happens when we cause a short circuit is that the electric current reaches enormous values, since the resistance of the small copper wire, and this current burn everything that is in the way!

In the case of the battery, if you use a thick wire, the 9VDC battery will run out quickly or it may explode, which is worse. In case of mains voltage at the 127 VAC outlet, you will have lightning, smoke, etc. with the consequent disarming of the circuit-breakers in the power frame of your house.

That being so, if you notice excessive heat, fire, smoke or sparks coming out of your circuit or experience, turn everything off quickly and check for possible short circuits!!

Open circuit

Open circuits are the opposite of short circuits. Review figure 147 and see what situations may occur.



(a) Closed circuit. Copper wire has low resistance.

(b) LED circuit directly connected to the 9 VDC battery voltage. The LED will burn because it works with low voltages around 2 V. Nothing limits the electric current and when circulating by the LED, will damage it.

(b) A current limiting resistor has been placed in the circuit, in series with the LED. With the appropriate resistance value, the LED will light up correctly.



(c) With an open part in the circuit conductor, an electric current does not circulate and nothing will happen.

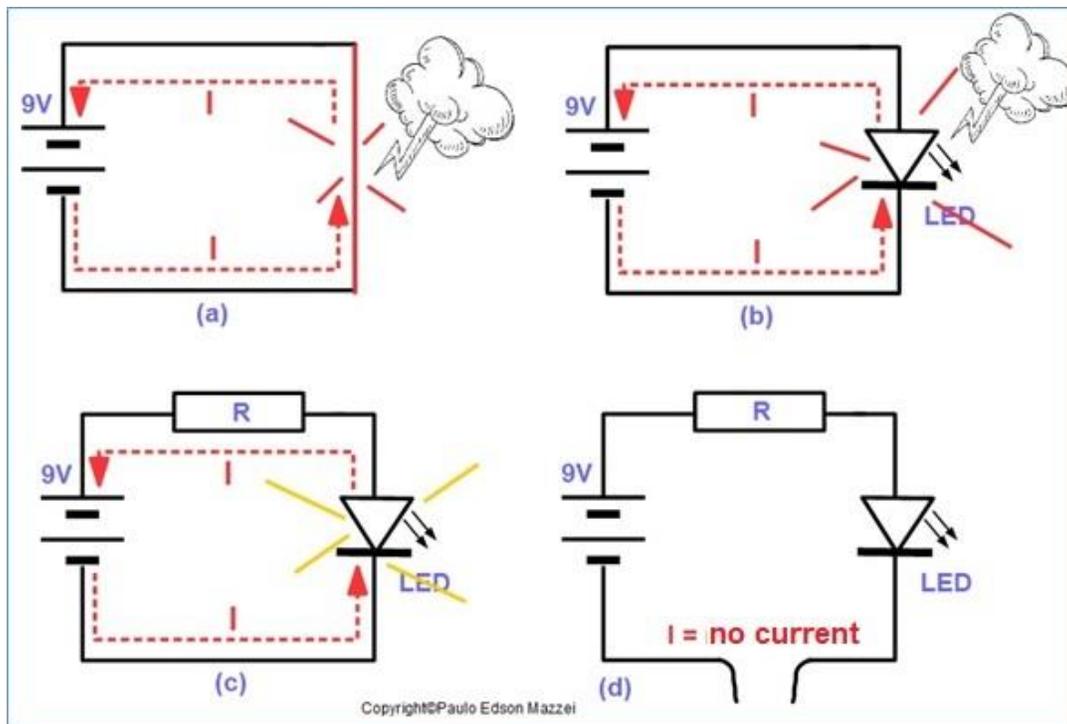


Figure 186 - Situations that can occur in a simple electric circuit.

Therefore, if the circuit you assembled does not work, examine for short circuits and open circuits. These two situations can be easily detected with the use of a digital multimeter. Just measure the resistance at several points:

- Very high or infinite resistors (∞) may signal an open circuit somewhere.
- Very low or zero resistors may be a sign of a short circuit somewhere.

In the practice of your experiments and assemblies, you will see that the circuits are usually a bit more complicated than circuit (c) of **figure 186**.

Series and parallel circuits

Electrical circuits can be divided into three types, for the purpose of analysis and association of electrical and electronic components.

1. Circuit in series

2. Parallel Circuit

3. Series-parallel circuit.

Before proceeding with the presentation and analysis of the series circuit, it is important to analyze the "nodes" and the currents in a circuit. Please, see **figure 187**.

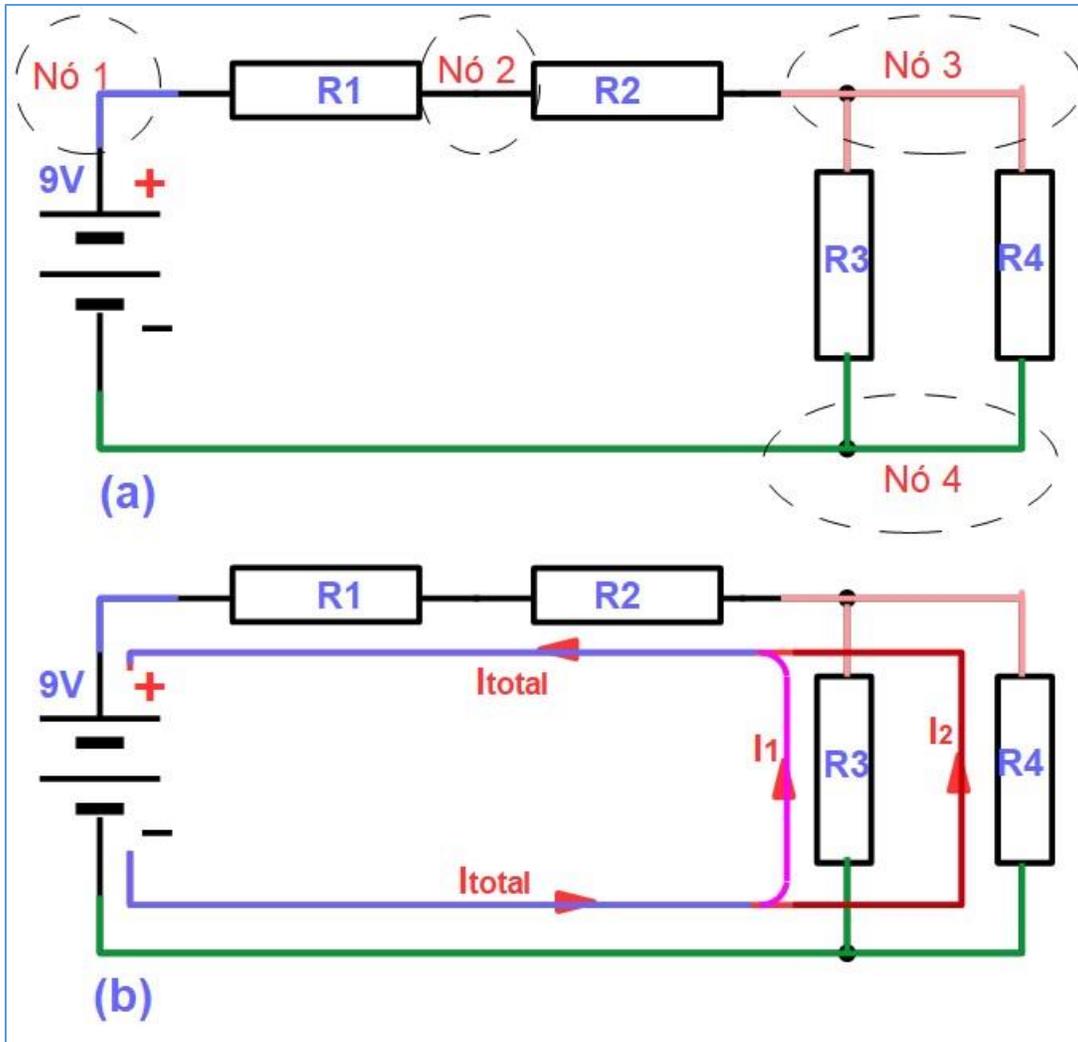


Figure 187 - Analysis of the circuit nodes.

Circuit nodes are the connections that exist between the various components. In circuit (a) of **figure 187**, we have four nodes, shown in different colors:

Node 1: Connection between battery positive and R1.

Node 2: Connection between R1 and R2.

Node 3: Connection between R3 and R4.

Node 4: Connection between the battery negative and R3 and R4.

With the circuit nodes defined, we can analyze how the electric current circulates, where and how it divides. Examine circuit (b) of **figure 146** and see that each current in a different color to facilitate.

The $I_{total} = I_1 + I_2$.

The resistors R1 and R2 are in series in the circuit while the resistors R3 and R4 are in parallel. In both resistors in series, the current is the same in both and in the two resistors in parallel it is divided. This concept is the key to understanding the analysis of parallel circuits and series circuits.

Series circuit

Two components are in series if they form a common node and through them circulate the same current. See the circuit of **figure 188**.

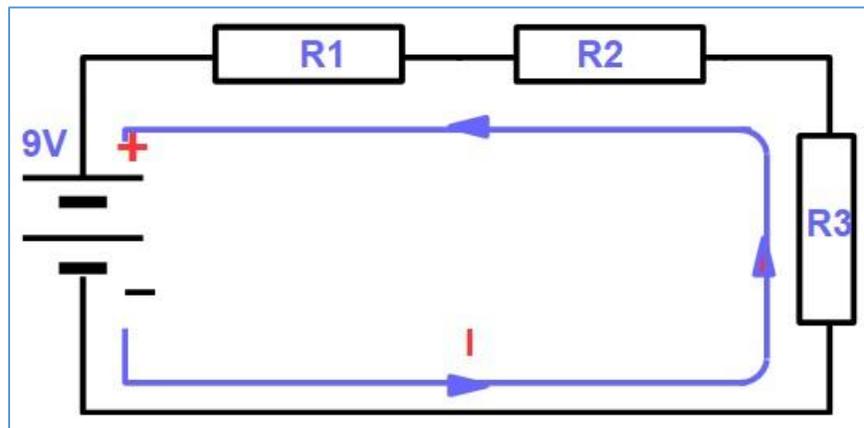


Figure 188 – Series circuit.

Note in the circuit of figure 188:

- There is only one electric current circulating I and it is the same in all three resistors.
- Each terminal of the resistors is connected to only one (one) resistor.
- When the current I circulate through a resistor, it causes a voltage called the "**voltage drop**" at the ends of the resistor.

Equivalent resistance in series circuits

The equivalent resistance in a series circuit would be the total value of the resistors. See **figure 189**.

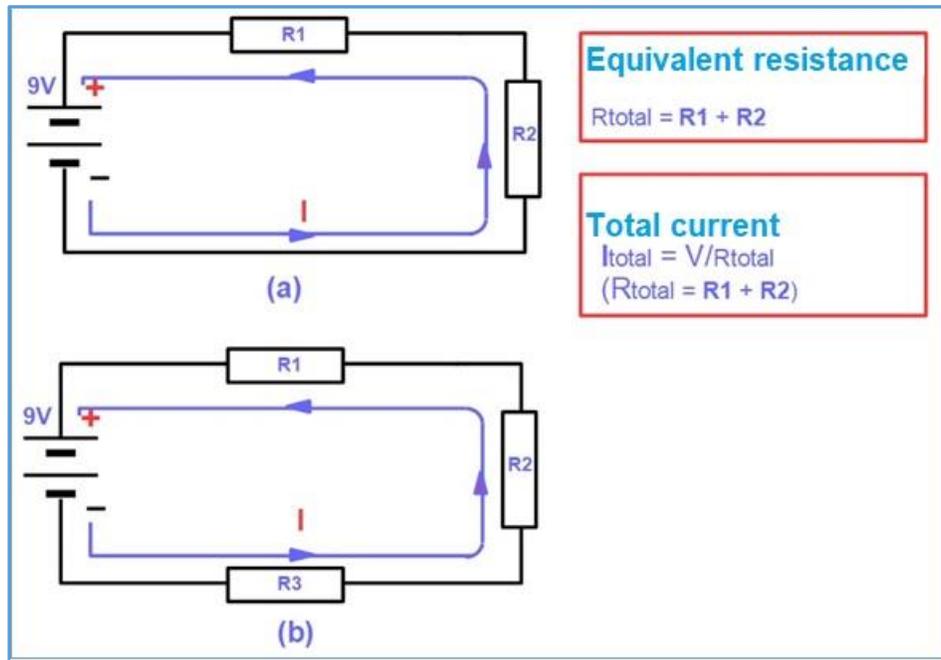


Figure 189 - Current and resistance in a series circuit.

Note on the series circuit of Figure 148:

(a) With two resistors in the circuit and series the total resistance will be

$$R_{total} = R1 + R2$$

(b) With three resistors the total resistance will be:

$$R_{total} = R1 + R2 + R3$$

(c) The current circulating in a series circuit and the same, at any point in the circuit?

$$I_{total} = V / R_{total}$$

(d) If the value of each resistor is 1 k Ω , we shall have

$$R_{total} = R1 + R2 + R3 = 1000 + 1000 + 1000 \rightarrow R_{total} = 3000 \Omega \text{ or } 3 \text{ k}\Omega.$$

(e) In this circuit to have resistors in series, with the value of $R_{total} = 3 \text{ k}\Omega$, we have that the current is:

$$I = V / R_{total} \rightarrow I = 9V / 3000 \Omega \rightarrow I = 0.003 \text{ A or } 3 \text{ mA}.$$

Examples of series circuit calculations

We have already seen that in the series circuit the current is the same in all elements of the circuit.

However, what happens to the voltage in each of the resistors? Examine **figure 190**.

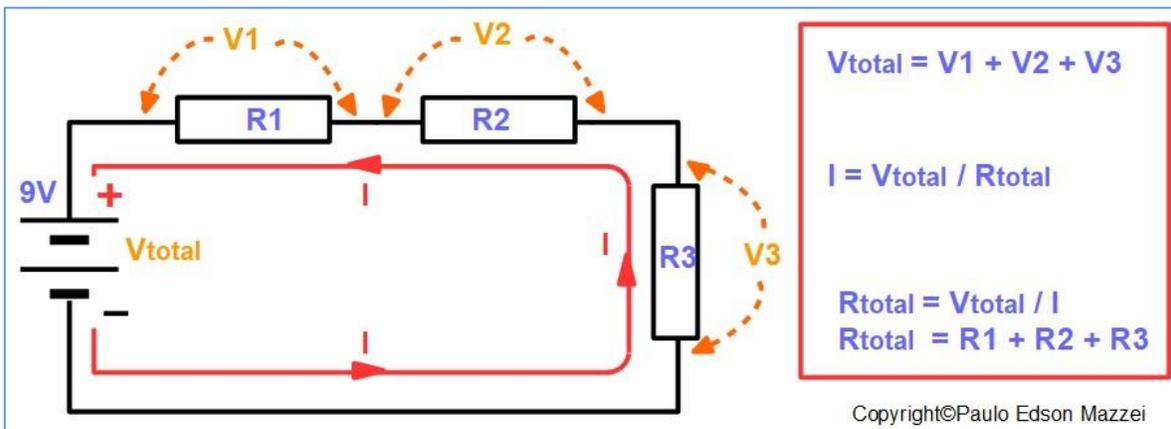


Figure 190 - Analysis of a series circuit.

In the series circuit we have:

- ▶ The voltage supplied by the battery is divided by the value of the resistors.
- ▶ The current I, when circulating through the resistors, causes what we call a voltage drop. If $R_1 = R_2 = R_3$, then we have that $V_1 = V_2 = V_3$. That is, each voltage drop is equal to 1/3 of the value of the battery voltage, equal to 3 V.
- ▶ The current is the same in all circuit components.

Equivalent resistance in parallel circuits

The equivalent resistance value in parallel circuits is shown in **figure 191**.

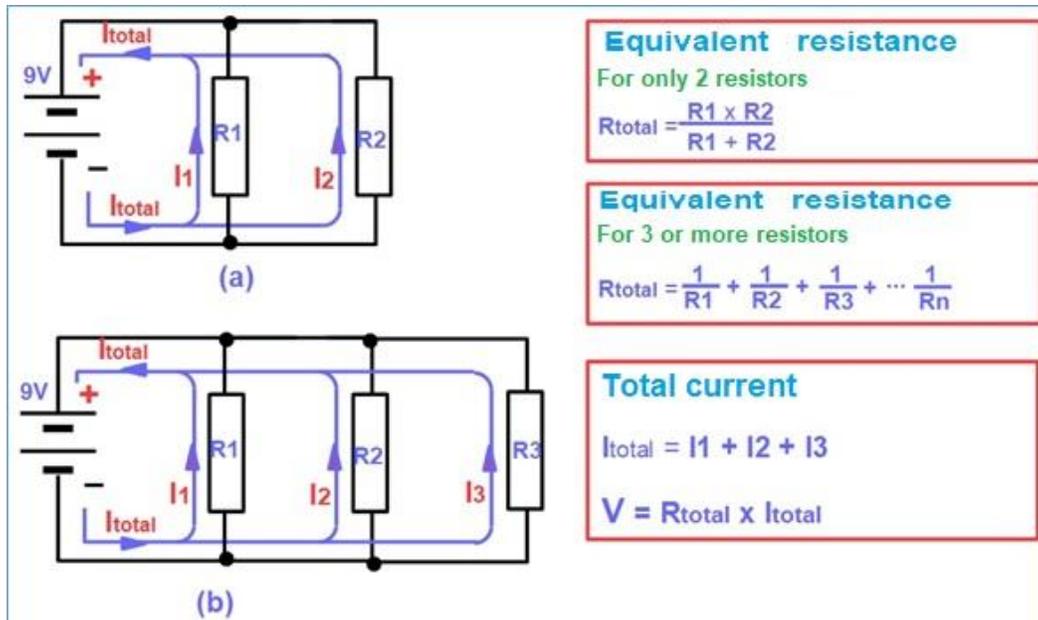


Figure 191 – Parallel circuit.

Observe in the parallel circuit of figure 150:

(a) With two resistors in the circuit and series the total resistance will be:

$$R_{total} = R1 \times R2 / R1 + R2$$

If $R1 = R2 = 50 \Omega$, then times $\rightarrow R_{total} = 50 \Omega$.

(b) With three resistors the total resistance will be:

$$R_{total} = R1 + R2 + R3$$

If $R1 = R2 = R3 = 50 \Omega$, then we have $\rightarrow R_{total} = 16.67 \Omega$.

(c) The current circulating in a parallel circuit is divided by the resistors.

(d) $I_{total} = V / R_{total}$

(e) In this circuit to have resistors in parallel, with the value of $R_{total} = 16.67 \Omega$, we have that the current is:

$$I = V / R_{total} \rightarrow I = 9V / 16.67 \Omega \rightarrow I = 0.54 \text{ A or } 540 \text{ mA.}$$

(f) The voltage is the same as that of the battery in each of the resistors.

Examples of Parallel Circuit Calculations

We have already seen that in the parallel circuit the voltage is the same in all elements of the circuit. Looking at the circuit of **figure 150**, we can see that the three resistors are connected directly to the poles of the battery.

However, what happens to the current in each of the resistors? Look at **figure 192**.

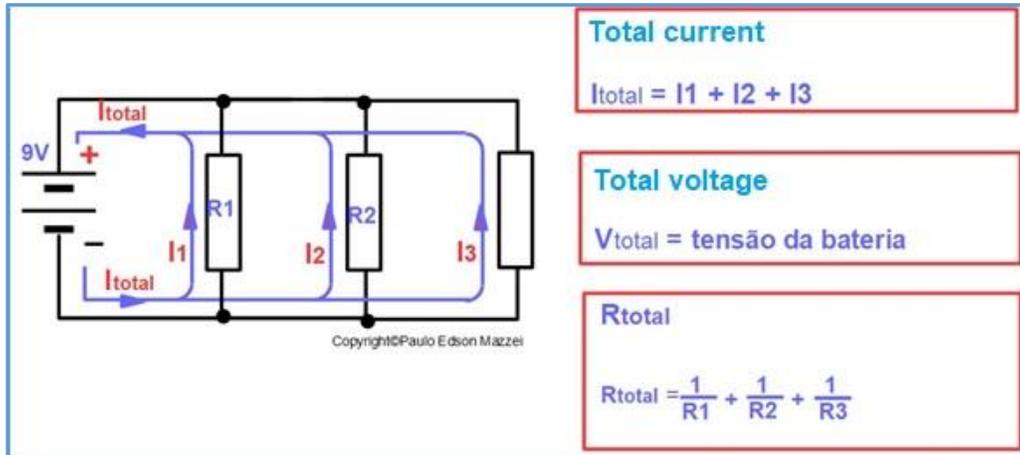


Figure 192 - Parallel circuit analysis.

Observe in the parallel circuit of figure 151:

(a) With three resistors in the parallel circuit the total resistance will be:

$$R_{total} = 1 / R_1 + 1 / R_2 + 1 / R_3$$

If $R_1 = R_2 = 50 \Omega$, then times $\rightarrow R_{total} = 16.67 \Omega$.

If $R_1 = R_2 = R_3 = 50 \Omega$, then we have $\rightarrow R_{total} = 16.67 \Omega$.

(b) The current flowing in a parallel circuit is divided by the resistors.

(c) $I_{total} = I_1 + I_2 + I_3$

(d) $I_{total} = V / R_{total}$

(e) In this circuit to have resistors in parallel, with the value of $R_{total} = 16.67 \Omega$, we have that the current is:

$$I = V / R_{total} \rightarrow I = 9V / 16.67 \Omega \rightarrow I = 0.54 \text{ A or } 540 \text{ mA.}$$

(f) The current in each of the resistors will be:

$$I_1 = V / R_1 \rightarrow I_1 = 9/50 \rightarrow I_1 = 0.18 \text{ A or } 180 \text{ mA.}$$

Since the three resistors have an equal value of 50 Ω , we must

$$I_1 = I_2 = I_3 = 0.18 \text{ A.}$$

$$I_{\text{total}} = I_1 + I_2 + I_3 \rightarrow 0.18 + 0.18 + 0.18 \rightarrow I_{\text{total}} = 0.54 \text{ A or } 540 \text{ mA.}$$

Other specifications for series and parallel circuits

Equal resistors in parallel

Calculating the value of two or more resistors in series, is very easy! But to calculate the total value of two or more resistors in parallel, it becomes more complicated ... See the tips:

- When two resistors of equal value, $R_1 = R_2 = 10 \Omega$, are placed in parallel the total value of the set is the value of one of them divided by two: $10 \Omega / 2 = 5 \Omega$.

- When three or more resistors of equal value are placed in parallel the equivalent resistance value is R / n , where r is the individual value of a resistor, divided by the number of resistors associated in parallel. Four 4.7 k Ω resistors connected in parallel give a total value of 1175 Ω or 1.175 k Ω .

Tolerance

Let's assume that for a special design, you need a 3.2 k Ω resistor. The simplest solution would be:

- Two parallel 6.4 k Ω resistors.
- Three 9.6 k Ω parallel resistors.

And so on. In fact, the most advisable would be to use at most two or three resistors in parallel to get the desired value or close to it. We will not find a resistor of 9.6 k Ω and even the resistor of 64 k Ω .

However, if we put three resistors of 10 k Ω , with tolerance of $\pm 5\%$ in parallel, we will have $10000/3 = 3330 \Omega$ or 3.33 k Ω . Resistors of 10 k $\Omega \pm 5\%$ are very easy to find!

Note that at 3.33 k Ω we are very close to the value we need 3.2 k Ω . And tolerance, how is it?

▶ 3.2 k Ω with tolerance of $\pm 5\%$ goes from 3.135 k Ω to 3.465 k Ω .

▶ The three 10 k Ω resistors we wish to associate have a total resistance of 3.33 k Ω and a tolerance of $\pm 5\%$. Its value can vary from 3.163 k Ω to 3.496 k Ω , which is great for our application.

Power in the association of resistors

- **Serial Association:** The maximum power that can be used equals the minimum power used in the resistors. For example, a 0.5 W resistor, associated with a 2 W resistor, will give a maximum dissipation power of 0.5 W, which is the weakest link in the current.

- **Association in parallel;** the maximum power that can be used and the sum of the powers of the resistors. For example, a 0.5 W resistor connected in parallel with another 1.5 W resistor can be used with powers up to 1.5 W.

Resistors of different values in parallel

So far, we have always talked about connecting resistors of equal values, for a parallel association. But what if the resistors do not have the same ohmic values?

The parallel combination of two resistors, with different ohmic values, will always be less than the smallest value of any of them. A 100 Ω resistor combined in parallel with another 1 k Ω resistor will always have a total value lower than the 100 Ω resistor. Do the math and see.

Beware of making this combination described! Very attention!

Another very important point is when we combine two power resistors and different ohmic values in a parallel combination.

General tip number 1: when associating resistors, always try to combine resistors of the same ohmic values and of the same dissipation power.

General tip number 2: Always measure the combination, whether serially or in parallel, with the digital multimeter and see if the value and tolerance are within the desired parameters.

Series and parallel circuits with capacitors

As we saw in the chapter on capacitors, they can be connected in series and in parallel.

Two capacitors of identical value, when connected in series, have as total capacitance half the value of one of them. Note that this is the inverse of what happens with series resistors.

Two capacitors of identical value, when connected unparallelled, have as total capacitance twice the value of one of them. Note that this is the inverse of what happens with resistors in parallel.

Figure 193 illustrates the series and parallel circuits with capacitors.

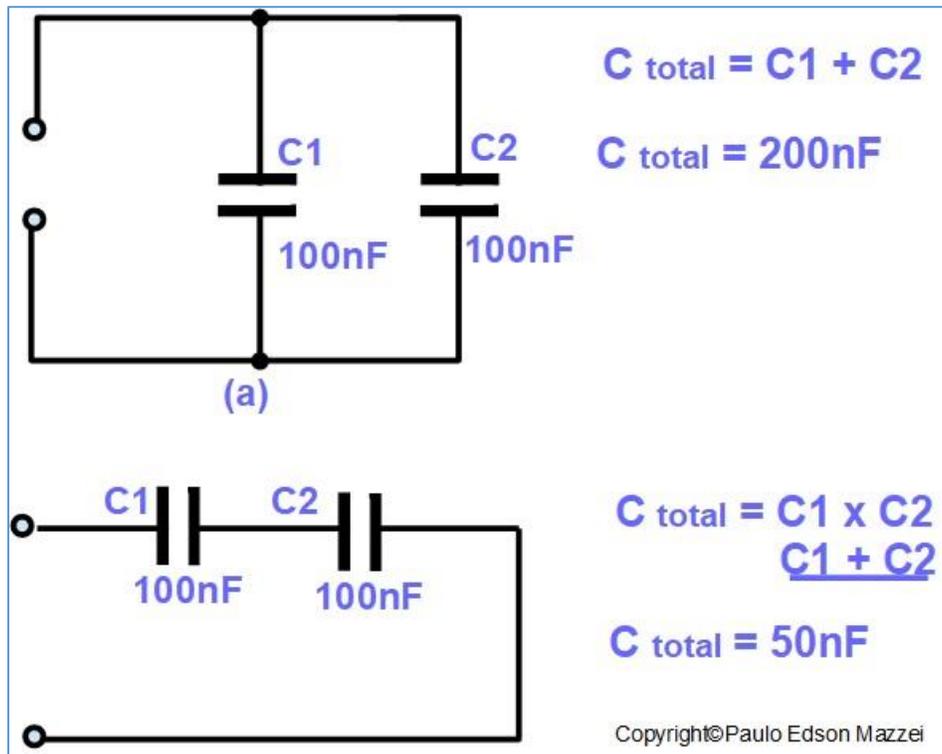


Figure 193 – Capacitors in series and parallel.

General tip number 3: When attaching capacitors, always try to use identical capacitors with the same working voltage.

Series and parallel circuits with inductors

As we saw in the chapter on inductors, they can be connected in series and in parallel.

Two inductors of identical value, when connected in series, have as total inductance twice the value of one of them. Note that this is the same as for series resistors.

Two inductors of identical value, when connected in parallel, have as total capacitance half the value of one of them. Note that this is the same as for parallel resistors.

Figure 194 illustrates series and parallel circuits with inductors.

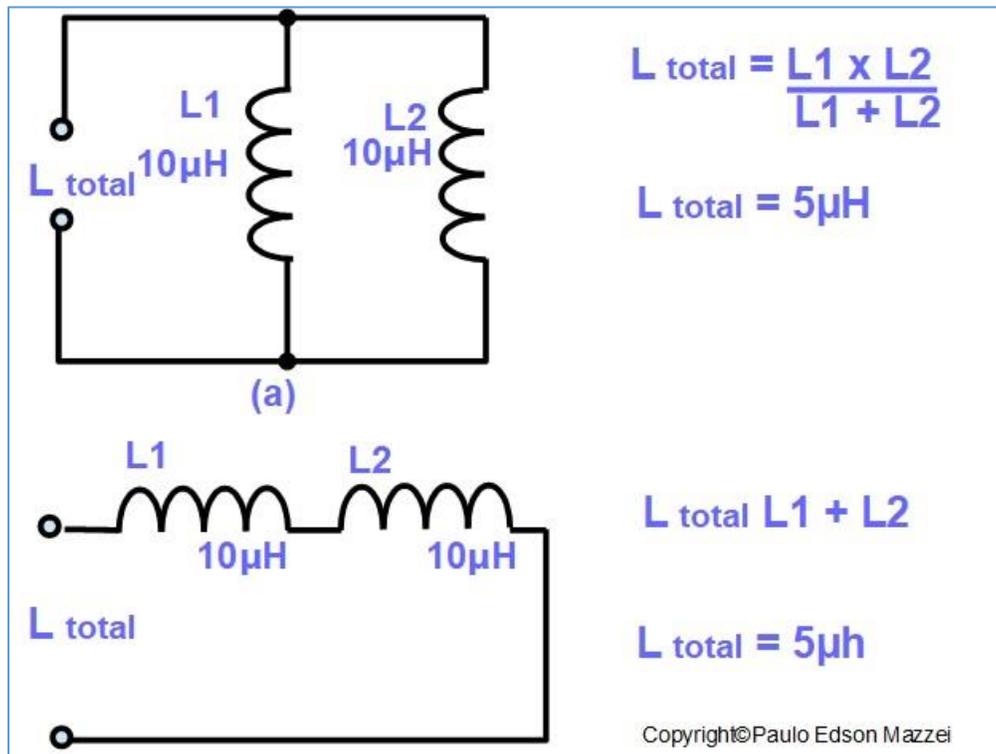


Figure 194 Inductors association.

General tip number 4: When attaching inductors, always try to use identical values inductors.

Time constant in RC circuits

Now, let's take advantage of our knowledge already acquired and associate a resistor in parallel with a capacitor, to see what happens.

You can measure resistance directly with your digital multimeter, easily. However, capacitance is not so easy to measure because you need a better-quality multimeter with this function or a special meter called "**capacimeter**".

In the specific chapter on capacitors, we saw what happens when a capacitor charges from zero volts. An electric current flow through the capacitor until it is charged. In this situation, the electric current ceases.

As we have seen, the initial charge current of a capacitor can reach high values if there is no resistance to limit this action. This charge occurs in a very small amount of time, such as **milliseconds** (ms) or **microseconds** (μs), for example.

When we have a capacitor in series with a resistor, we can determine the **time constant**, i.e. how long the capacitor will take to discharge into the resistor. The time constant is given by the formula

$$T = R \times C$$

At where:

τ = Time constant, τ = Greek letter "tau", in seconds

R = resistance value in ohms

C capacitance value in Farads.

See **figure 195**, where a 10 k Ω resistor is connected in series with a capacitor of 100 μF .

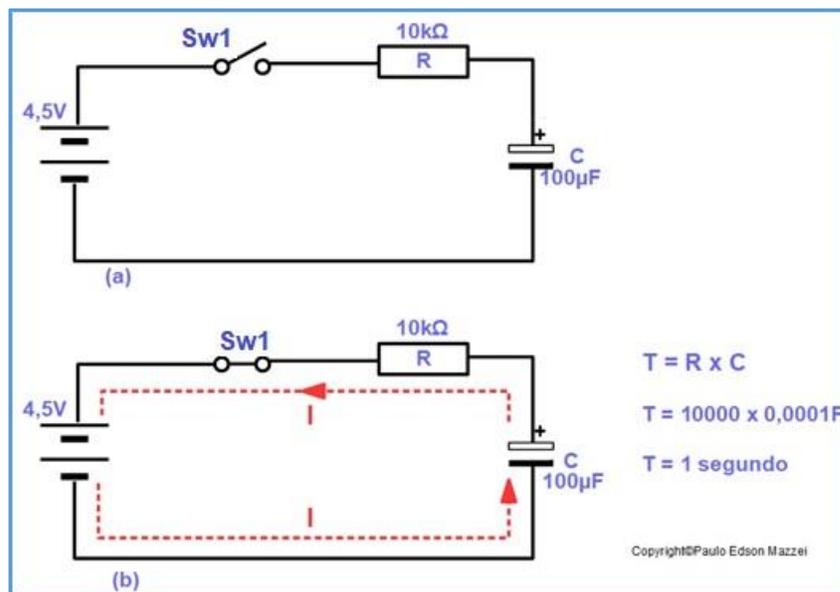


Figure 195 - RC circuit and calculation of the time constant.

The calculation for the time constant for these values of the figure indicates that it is 1 second (1 s). The charge curve of the capacitor is represented graphically by **figure 196**.

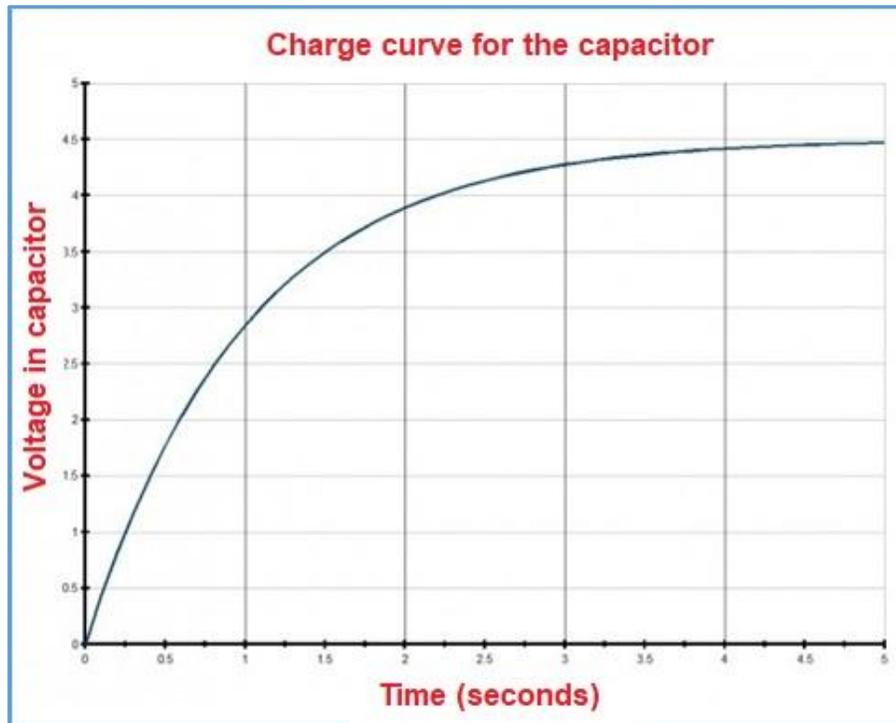


Figure 196 - Load Charge curve of the capacitor.

In **figure 196**, we can see that when closing the key Sw1, initially a large current flow through the circuit, carrying the capacitor of 100 μF . Over time, this current begins to decrease, since the capacitor is almost full load, as shown in **figure 196**.

Experiments with resistors and capacitors

Resistors in series

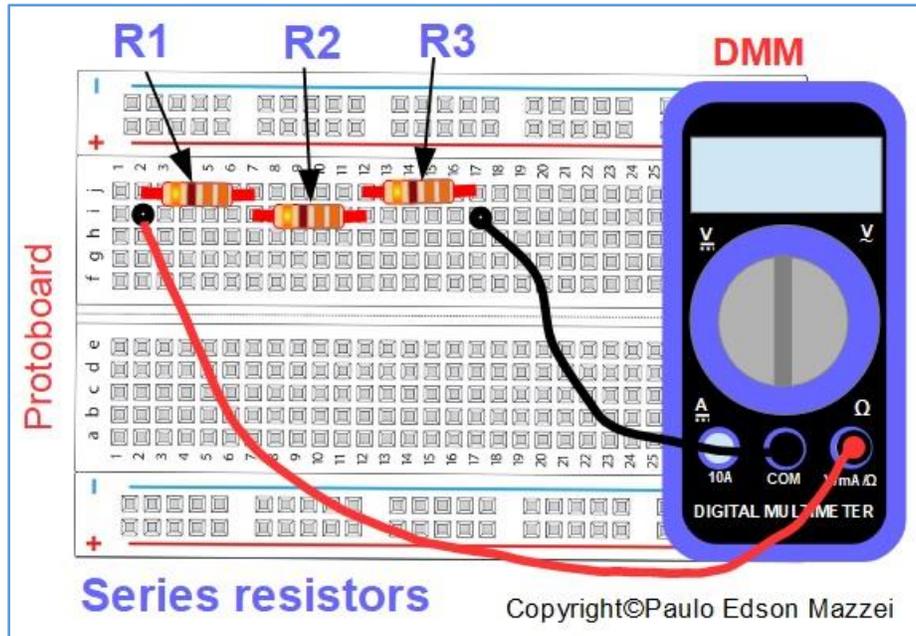
Value of total resistance for series connected resistors. These resistors will be mounted on the Protoboard.

■ Material:

- Protoboard
- Resistors of 10 $\text{k}\Omega$, $\pm 5\%$, $\frac{1}{4}\text{W}$
- Digital multimeter
- Interconnecting cables

■ Mounting:

Refer to for mounting the resistors on the Proto- board and also make the Meter connections to each resistor and set of resistors.



Reading the value of resistors and series associations.

■ Results

Check the reading values on the digital multimeter with a nominal value of 10 kΩ.

See if the value read on the digital multimeter is within the tolerance of the resistor.

Resistors in parallel.

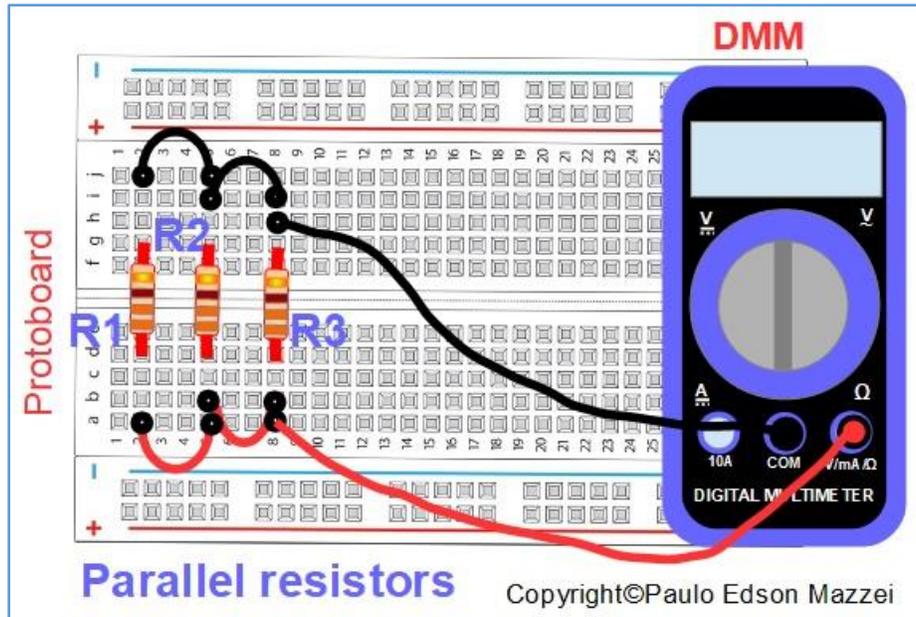
Measure the resistance of resistors connected in parallel. These resistors will be mounted on the Protoboard.

■ Material:

- Protoboard
- 10 kΩ resistors, ±5 %, ¼ W
- Digital multimeter
- Interconnecting cables

■ Mounting:

Refer to mount the resistors on the Protoboard and also make the Meter connections to each resistor and resistor set.



- Reading in the association of resistors in parallel.

■ Results

Check the reading values on the digital multimeter with a nominal value of 10 kΩ.

See if the value read on the digital multimeter is within the tolerance of the resistor.

Calculate the value of the association in parallel and check with the value read.

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Chapter 27

Analogic x digital

Introduction

Our world is analog.

Colors, sounds, odors, etc., produce endless possibilities of use. We can paint a canvas with infinite colors, even if sometimes our eyes cannot distinguish them. There is an infinite amount of tones even though sometimes we cannot hear them.

The analytical sign refers exactly to these inputs and their infinite possibilities that we can have.

Digital signals work in the world of the finite and discrete meaning that there is a limited set of values that these signals can be.

The objects we have in our homes, workplaces and entertainment can be analog or digital. See some examples in **figure 197**.



Figure 197 - Analog and digital objects.

In the case of our work with electronics, in our assemblies and experiments, we always have analog and digital signals. Our electronic projects interact with the real world, analog, but when we use computers, controllers, logic blocks, we are working in the digital world.

Some electronics work only with analog signals and others only with digital signals. There are “bilinguals” who work with analog and digital signals.

Analogic signals

Electronic signals are variable over time and carry some kind of information. In our work of experimenting and assembling projects, what usually varies over time are the voltages and sometimes the electric currents.

The signals are applied to electronic components and circuits, so that they can receive and transmit information. This information can be an audio signal (voice), a video signal (picture), etc.

The propagation medium may be a conductor, such as a wire or a semiconductor in an electronic circuit or may be air, with RF - Radio Frequency signals.

An example of signals on leads may be the microphone connected to a sound amplifier. In the case of airborne propagation, we can use as an example the RF signal between a tablet and a Wi-Fi router.

Graphic representation of an analog signal

As the analog signals vary over time, it is very useful to be able to represent them by a graphical system, with axes, as shown in **figure 198**.

Although a signal such as that shown in **figure 198** varies within a certain range (+5 V to -5 V), there are infinite values within this range. For example, if you measure the AC voltage in a socket in your home, you will have something very close to 127 V. If you increase the resolution of a certain measure, you can find values such as:

54 V

54.7 V

54.73 V

54,735 V and so on.

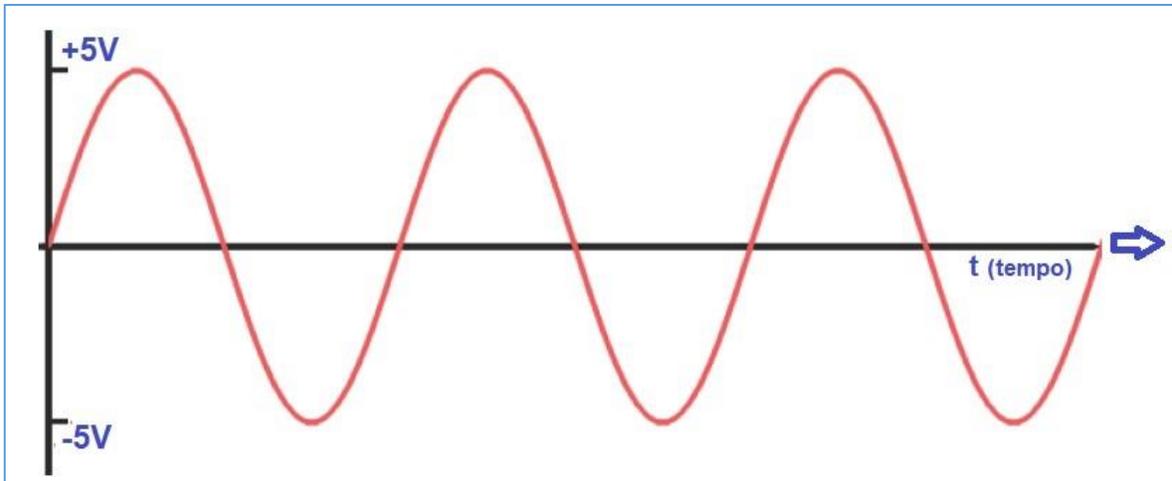


Figure 198 - Sine analog signal.

An example analog signal may be the composite video signal we have at the input of our television, usually on an RCA type connector. See **figure 199**.

Small changes in the level of this signal already cause changes in the image, color, etc.

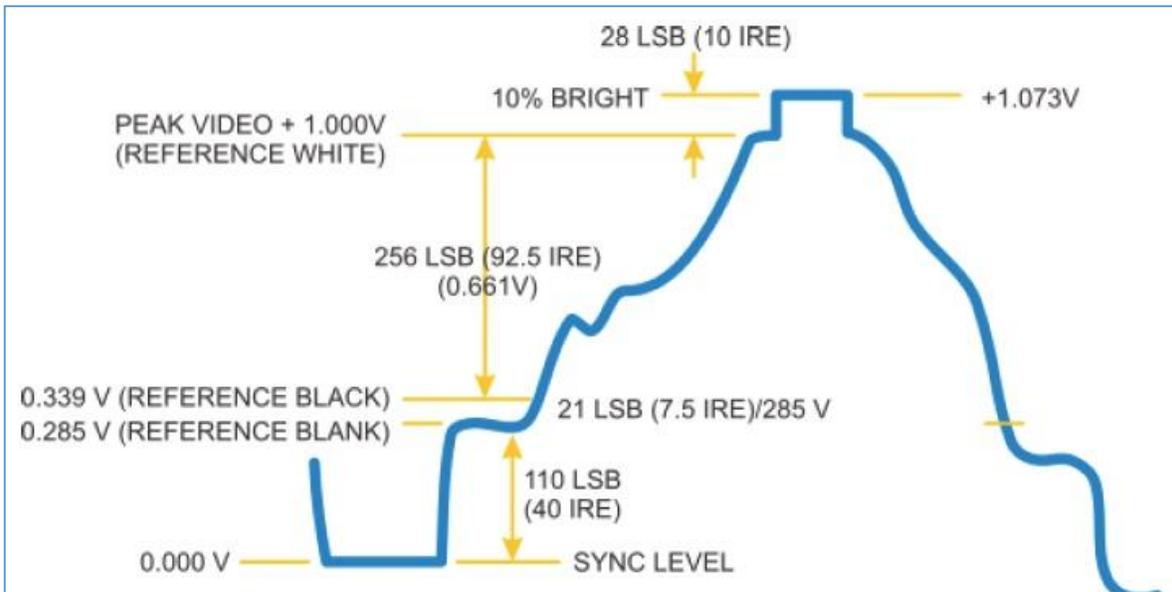


Figure 199 - Composite video signal;

Digital signals

Digital signals have a finite set of possible values. This number of values can be neither any point between, for example, 2 and a noninfinite number of values.

Many digital signals are usually represented by two values, for example 0 and +5 V. Representing this type of signal, we would have the graph shown in **figure 200**.

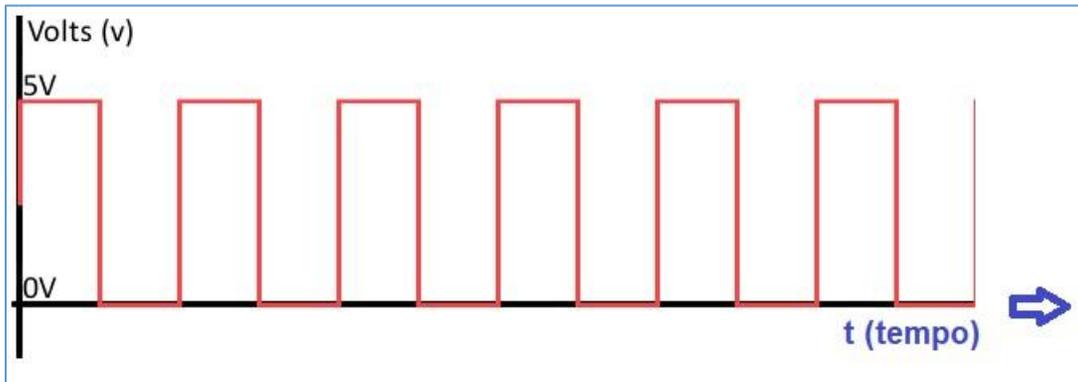


Figure 200 - Analog composite video signal.

Sometimes a digital signal may look like analog signal. See, for example, in **figure 201**.

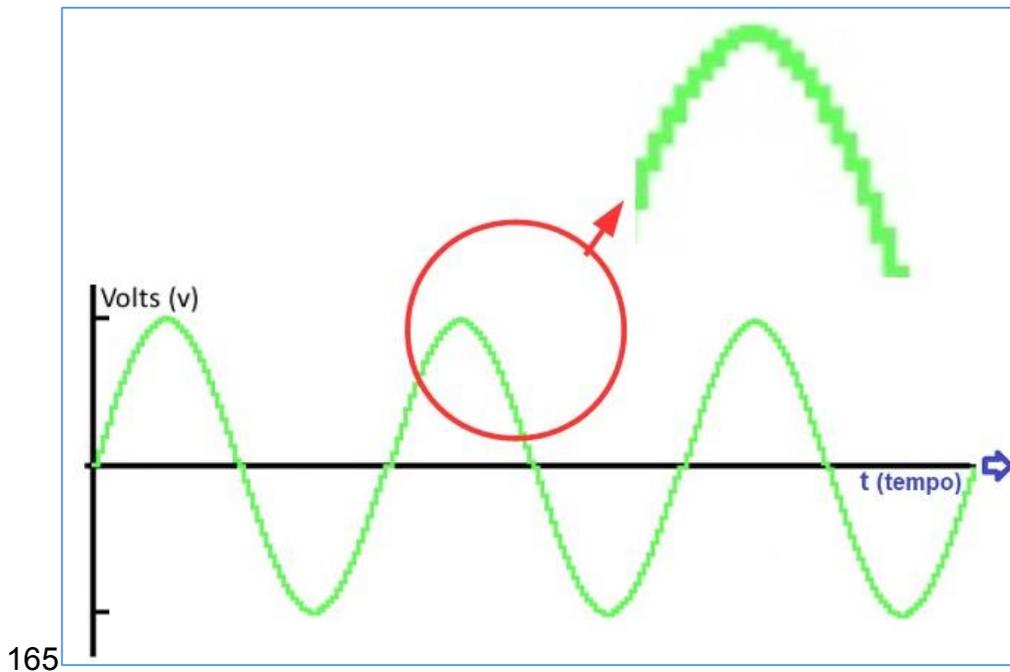


Figure 201 - Sign that looks analog, but in reality, is digital.

See an example of a digital signal in **Figure 202**. This signal uses differential digital signals to transmit data between peripherals.

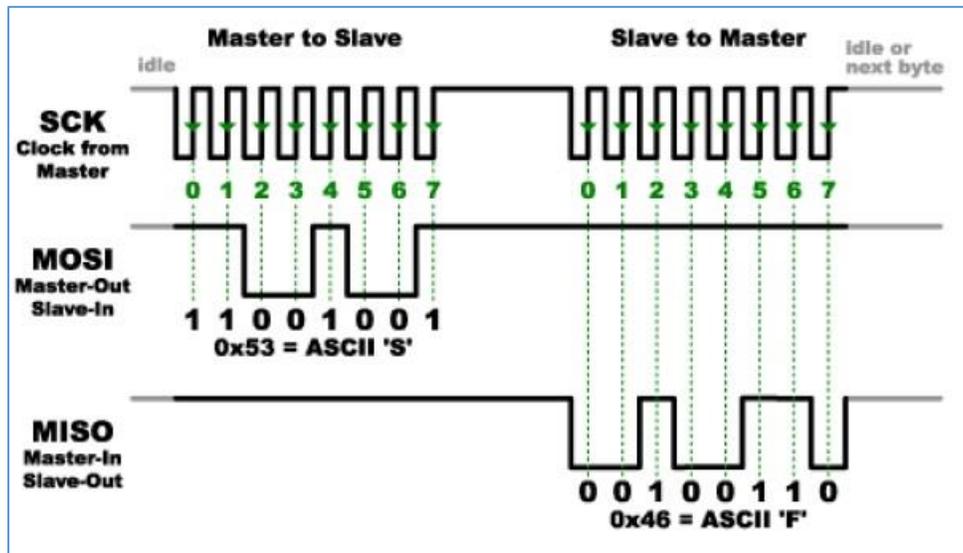


Figure 202 - Example of a digital signal.

Analog and digital circuits

The basic electronic components we have seen so far, such as resistors, capacitors, inductors, semiconductors, etc. are used in analog circuits.

Circuits that combine these components are called analog circuits. The audio amplifier shown in **figure 203** is an analog circuit. All of its components work for analog signals.

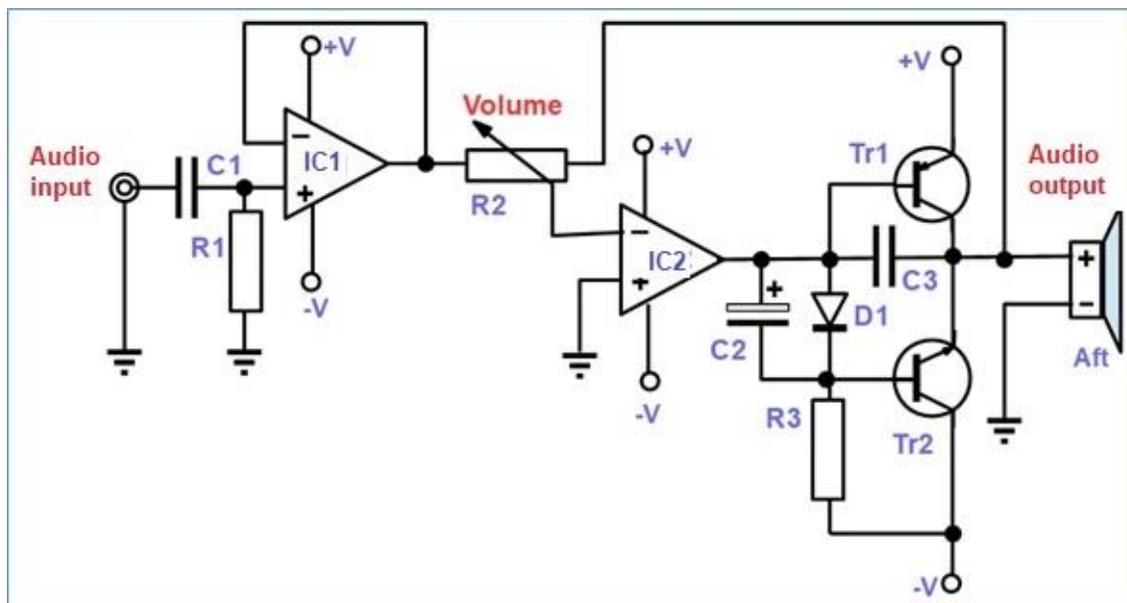


Figure 203 - Analog Circuit - Audio Amplifier.

In fact, it is much easier to use digital components to draw a circuit than analog components. Also, analog circuits are more susceptible to noise.

Digital circuits operate using discrete digital signals. These circuits are usually a combination of transistors and logic gates. Redboard and Arduino use analog and digital components in their circuit. See a digital circuit in **figure 204**.

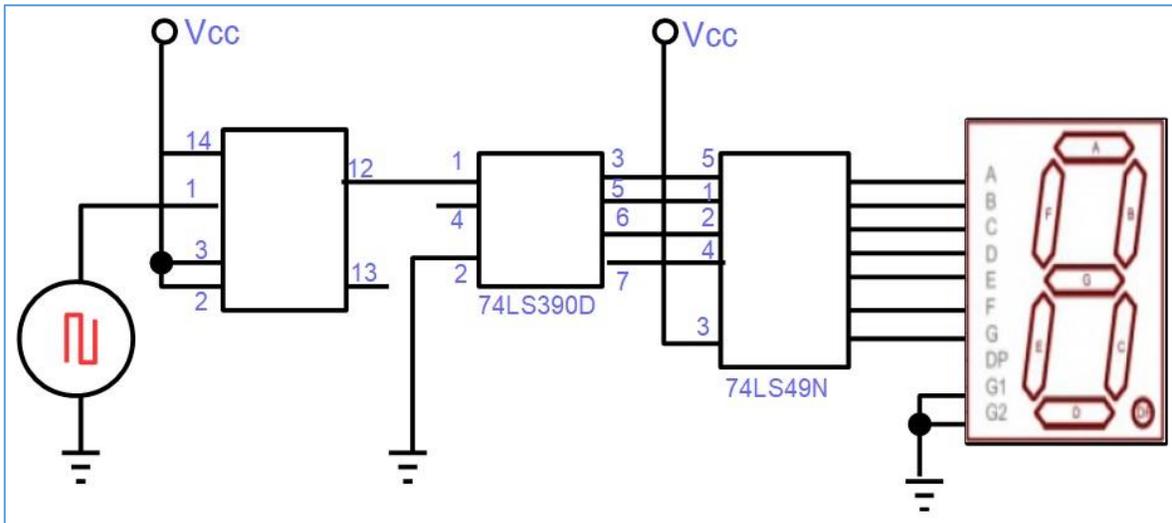


Figure 204 – Digital circuit.

You can find mixed analytical and digital components in a circuit and this is more common than we think. There are special integrated circuits to convert from analog signals to digital and vice versa.

Typically, the sensors to be used with RedBoard and Arduino provide an analog output signal and need to be converted to digital for use.

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Chapter 28

Soldering of electronic components and PCB

Introduction

The soldering process, or simply "**soldering**" as it is known in the area of Electronics, allows the electronic components to be joined together, usually through a base known as a **Printed Circuit Board – PCB**.

For welding we will need some tools, besides the welding itself and the soldering of tin.

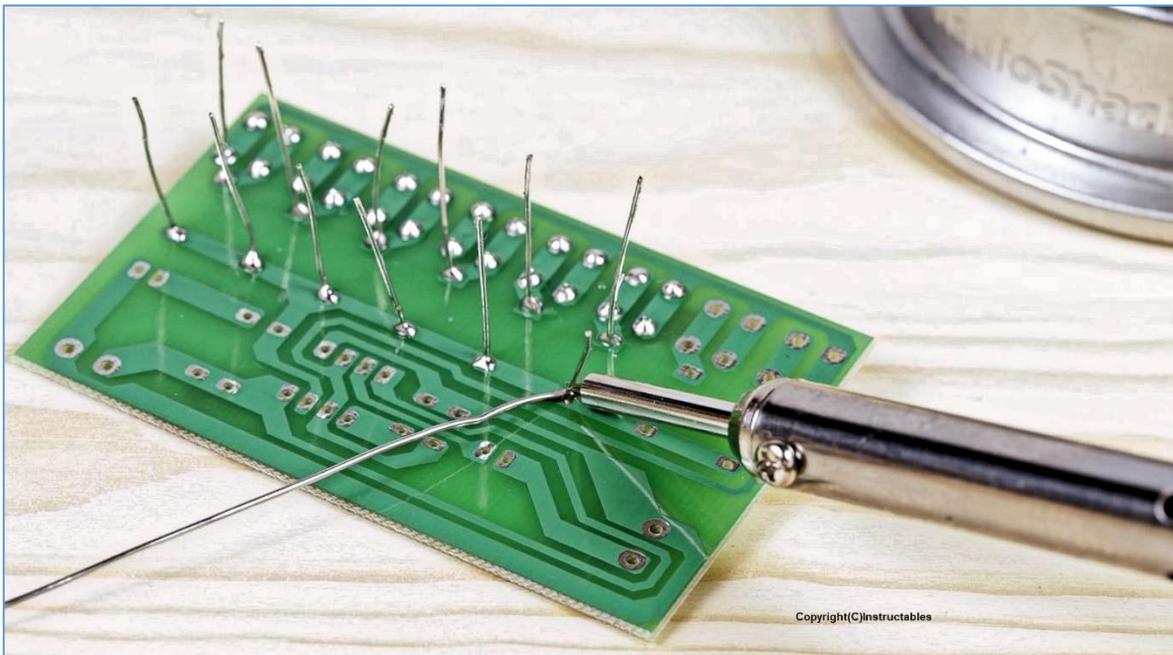


Figure 205 - Welding of electronic components on Printed Circuit Board.

Tools for electronics

For our process of soldering components in the PCB or even a simple union of two pieces of wires, we need some basic tools. It may even be that you already have a set of tools from a thousand and one utilities.

If you are acquiring new, look for good quality tools in isolation. Avoid buying sets with millions of useless little things. The exception goes to the sets of pliers and screwdrivers.

Pliers set

A small set of miniature pliers, the kind used by someone who makes jewelry, helps a lot! See this game in **figure 206**, manufactured by Stanley®.



Figure 206 - Set of miniature pliers. Copyright © Stanley.

Regarding this figure, note:

- (a) "Bolt cut" pliers, 4 ", 101 mm.
- (b) "Round Tip" pliers, 5 ", 127 mm.
- (c) "Fine nozzle type pliers, half-cane", 5 ", 127 mm.

(d) Diagonal cutting pliers, 4 ", 101 mm.

(e) Set of miniature screwdrivers.

These sets can be found from other brands, colors, etc. Care of tool sets coming from "**unknown geographical locations**".

Screwdriver set

In the previous figure you have seen a set of small screwdrivers, which came together with the set of miniature pliers. However, this does not always happen and it is good to have a small set of small screwdrivers, as illustrated in **Figure 207**.

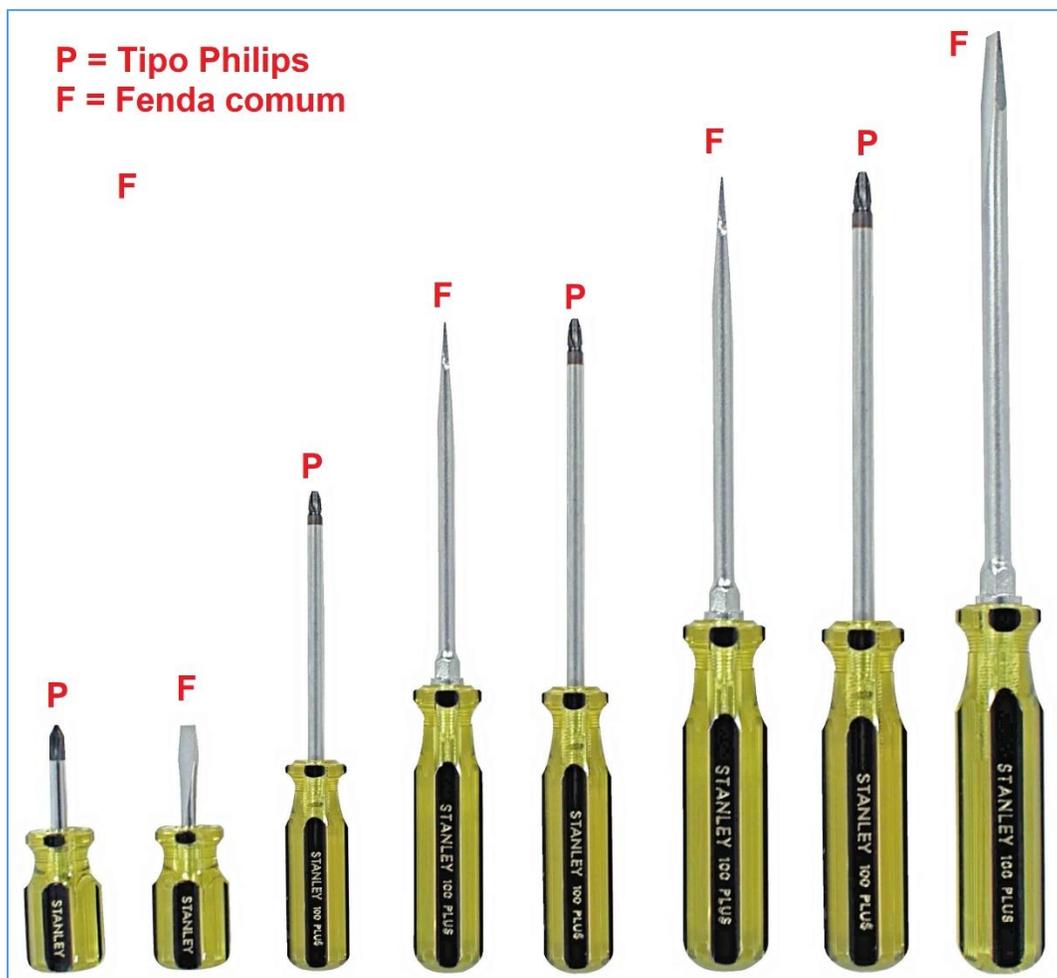


Figure 207 - Set of standard Phillips screwdrivers and Philips, from Stanley®.

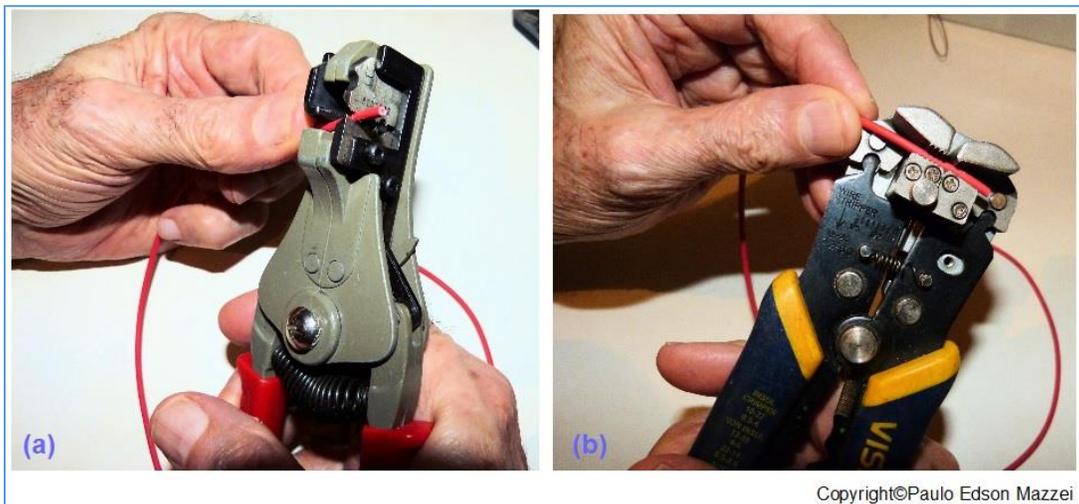
Wire stripping pliers

In the chapter on wires and cables, we show you two models of wire stripping pliers and wires that you must have. The automatic model is easier to use because

you do not need to select the diameter of the cut to the wire diameter. See **figure 208**.



Figure 208 - Wire picking pliers. The "Vise Grip" model is automatic.



Copyright©Paulo Edson Mazzei

Figure 209 - Stripping wires with both models of pliers.

Hobby knife



Figure 174 Hobby knife. Copyright© Stanley.

The hobby knife, as shown in **figure 210**. It is of great use and most people have one at home to break any branch!!

Choose a sturdy, locking blade model to prevent accidents.

Third hand

The third hand as the name already says, is a “thing” that greatly helps the welding of small wires and components. See **figure 211** for the third hand.



Figure 211 Third hand to assist in welding of small components.

Soldering iron

The **soldering iron** and the tool that allows welding (or welding wire) to be welded, for joining wires, electronic components, PCB, etc.

You will find many models of soldering iron on websites on the Internet or in physical stores. Choose one that has about 25 Watts to 40 Watts and runs on the voltage of your home, either 127 or 220 VAC.

The welding iron from Weller®, are of great quality and I have used it for a long time, without problems. If your "money box" is high, choose a base model, temperature setting, and cleaning sponge. If it is not possible, you would only buy the loose iron because the cleaning wicker you acquired separated in popular sites. See iron based on **figure 212**



Figure 212 - Weller welding iron with base, temperature regulation and sponge. Copyright © Weller.

Solder wire

The solder or solder wire, used in electronics, must be of the "**Lead Free**" type, that is, without lead.

This solder consists of a wire, with a special resin inside this wire. The resin serves as a flux to the weld, improving and aiding in the welding process.

Solder wire is an alloy of various metals, but mainly tin, copper and silver, with a diameter of about 0.5 mm and 1 mm.



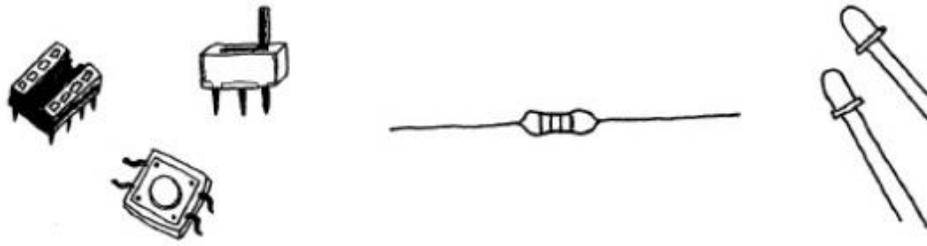
Figure 213 – Solder wire.

Always:

- Work in ventilated places as welding fumes can be harmful.
- Wash your hands after a welding session.
- Wear safety glasses.
- Never put your finger or hand on a hot welder.
- Keep children away.

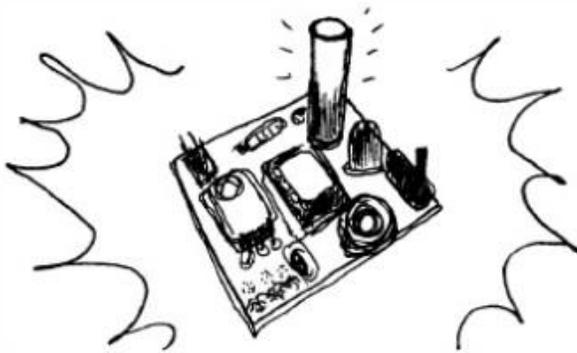
The soldering process

The following is a way to teach the welding process using a comic developed by [Mitch Altman](#), [Andy Nordgren](#) and [Jeff Keizer](#). The authors encourage the use and distribution of this [material](#).



SOLDERING IS EASY

HERE'S HOW TO DO IT



BY: **MITCH ALTMAN**
(*SOLDERING WISDOM*)

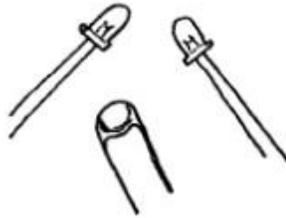
ANDIE NORDGREN
(*COMICS ADAPTATION*)

JEFF KEYZER
(*LAYOUT AND EDITING*)



DISTRIBUTE WIDELY!

DOWNLOAD THIS COMIC BOOK AND
SHARE IT WITH YOUR FRIENDS!
[HTTP://MIGHTYOHM.COM/SOLDERCOMIC](http://mightyohm.com/soldercomic)



SOLDERING

IS A REALLY USEFUL SKILL.

IT IS ALSO WAY EASY!

REALLY, IT IS!
YOU'LL SEE.

SOLDERING IS ALSO LOTS OF FUN!

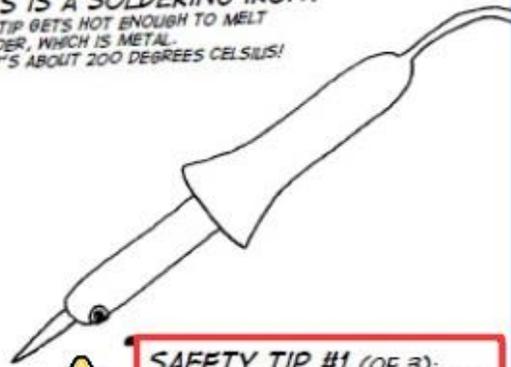


IF YOU KNOW HOW TO SOLDER, YOU CAN MAKE JUST ABOUT ANYTHING WITH ELECTRONICS, WHICH IS JUST TOO COOL!
THERE ARE MANY WAYS TO MAKE GOOD SOLDER CONNECTIONS. I'M GOING TO EXPLAIN HOW I DO IT.

LET'S GET STARTED!

THIS IS A SOLDERING IRON.

ITS TIP GETS HOT ENOUGH TO MELT SOLDER, WHICH IS METAL.
THAT'S ABOUT 200 DEGREES CELSIUS!



SAFETY TIP #1 (OF 3):
IF YOU TOUCH THE TIP, YOU WILL LET GO VERY QUICKLY!

IT IS ACTUALLY HOLLOW AND FILLED WITH ROSIN (SIMILAR TO THE STUFF USED TO MAKE BOWS FOR VIOLINS STICKY).



Solder wire

THE ELEMENTS
SN AND PB

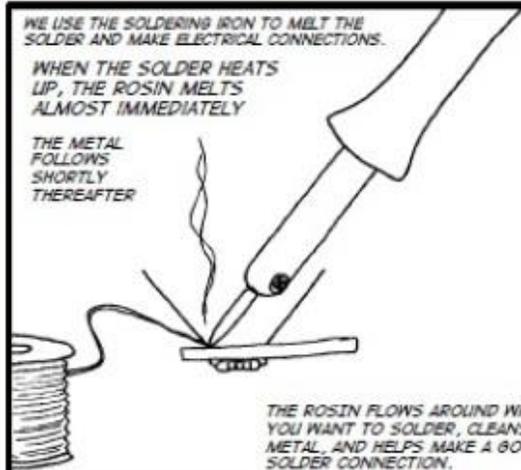
THIS IS SOLDER.

IT IS MADE OF METAL, USUALLY TIN AND LEAD.

WE USE THE SOLDERING IRON TO MELT THE SOLDER AND MAKE ELECTRICAL CONNECTIONS.

WHEN THE SOLDER HEATS UP, THE ROSIN MELTS ALMOST IMMEDIATELY

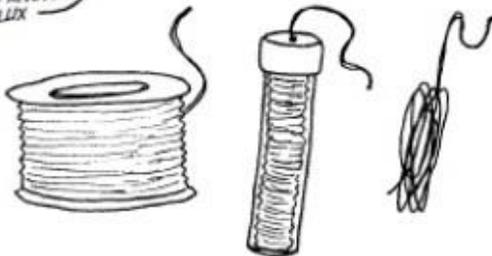
THE METAL FOLLOWS SHORTLY THEREAFTER



THE ROSIN FLOWS AROUND WHAT YOU WANT TO SOLDER, CLEANS THE METAL, AND HELPS MAKE A GOOD SOLDER CONNECTION.

THE BEST SOLDER FOR ELECTRONICS HAS ROSIN CORE AND IS 60% TIN, 40% LEAD.

ALSO KNOWN AS FLUX



THERE ARE OTHER TYPES. FOR INSTANCE LEAD-FREE SOLDER, BUT IT HAS TOXIC CHEMICALS IN ITS CORE, AND IT IS NOT QUITE AS EASY TO USE AS SOLDER WITH LEAD. IT ALSO CORRODES SOLDERING IRON TIPS QUICKLY. IF YOU CAN ONLY GET LEAD-FREE SOLDER WHERE YOU LIVE, IT'S OK, BUT PLEASE DON'T BREATHE IN THE NASTY SMOKE.

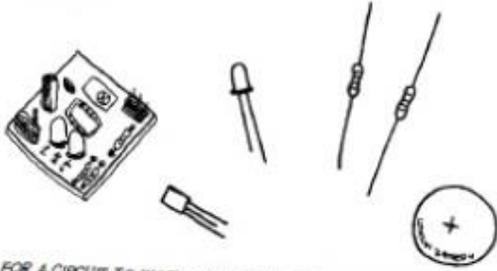
SAFETY TIP #2 (OF 3):

LEAD IS POISONOUS. IT GETS ON YOUR SKIN WHEN YOU HOLD THE SOLDER, SO WASH YOUR HANDS AFTER SOLDERING!



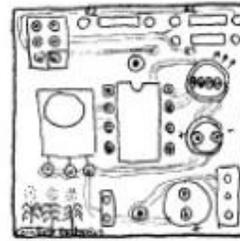
IF YOU DON'T WASH YOUR HANDS AFTER SOLDERING, THE LEAD MAY GET IN YOUR BODY, WHERE IT GETS STORED IN YOUR BRAIN FOR YOUR ENTIRE LIFE. IF ENOUGH COLLECTS THERE THEN YOU GO INSANE, AND YOU LOSE ALL OF YOUR FRIENDS. SO - WASH YOUR HANDS AFTER SOLDERING, AND KEEP YOUR FRIENDS!

ELECTRONIC CIRCUITS ARE MADE UP OF ELECTRONIC PARTS CONNECTED TOGETHER.



FOR A CIRCUIT TO WORK CORRECTLY, WE NEED TO CONNECT TOGETHER EVERYTHING THAT SHOULD CONNECT TOGETHER, AND NOT CONNECT ANYTHING THAT SHOULD NOT BE CONNECTED TOGETHER.

THERE ARE MANY WAYS TO CONNECT ELECTRONIC PARTS TOGETHER, BUT PERHAPS THE EASIEST WAY IS WITH A **PRINTED CIRCUIT BOARD**

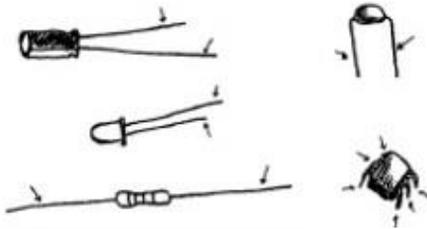


PCB OR JUST "THE BOARD"

THE PCB MAKES IT EASY BECAUSE IT HAS **PADS** FOR EACH PART.

IF YOU LOOK CAREFULLY AT THE PCB, YOU WILL SEE LINES CONNECTING PADS TOGETHER WITH OTHER PADS - THESE LINES ARE CALLED **TRACES**.

ALL OF THE PARTS HAVE WIRES STICKING OUT OF THEM:

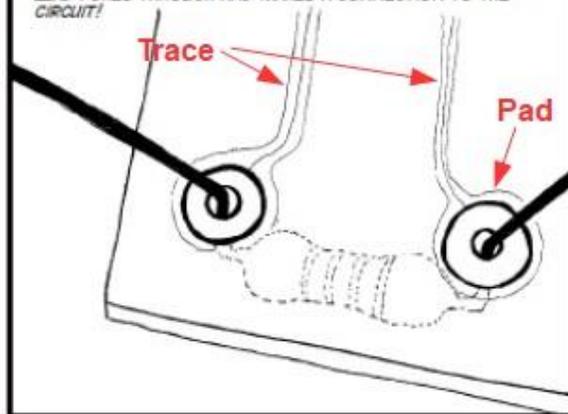


(PRONOUNCED "LEEDZ")

ALL OF THESE WIRES, REGARDLESS OF WHAT THEY LOOK LIKE, ARE CALLED

LEADS SINCE THEY LEAD TO THE PARTS.

MOST PADS HAVE A HOLE IN THE MIDDLE - THIS IS WHERE THE LEAD POKES THROUGH AND MAKES A CONNECTION TO THE CIRCUIT!



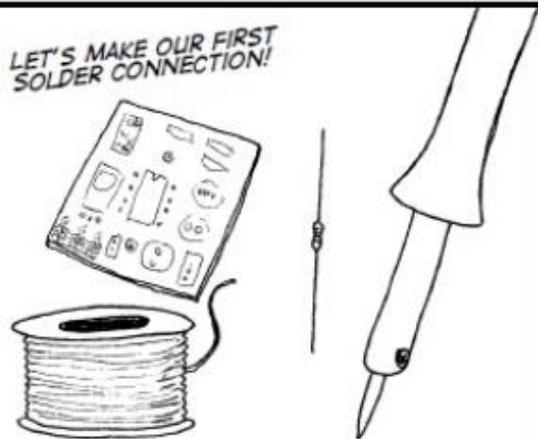
IF YOU PUT ALL OF THE LEADS FROM THE PARTS INTO THE CORRECT PADS FOR THE PARTS AND IF YOU PUT ALL OF THE PARTS IN THE CORRECT ORIENTATION AND IF YOU MAKE ALL GOOD SOLDER CONNECTIONS

SOME PARTS CAN GO IN THE WRONG WAY!



THEN **THE CIRCUIT WILL JUST WORK!** THIS IS BECAUSE THE BOARD CONNECTS EVERYTHING THAT SHOULD BE CONNECTED, AND NOTHING THAT SHOULD NOT BE CONNECTED.

LET'S MAKE OUR FIRST SOLDER CONNECTION!



WE'LL START WITH A RESISTOR.



RESISTORS HAVE TWO LEADS AND (UNLIKE SOME PARTS, SUCH AS DIODES, WHICH HAVE A "PLUS" SIDE AND A "MINUS" SIDE) CAN BE PLACED IN THEIR PADS IN EITHER DIRECTION.



PCBS USUALLY HAVE MARKINGS TO SHOW WHERE EACH PART GOES (AND IF THE ORIENTATION MATTERS, THE PCB USUALLY HAS SOME WAY TO SHOW YOU THIS).



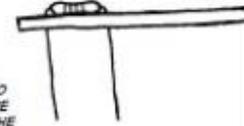
SINCE THE WORD "RESISTOR" STARTS WITH THE LETTER "R", THE PCB USUALLY MARKS PLACES WHERE RESISTORS GO WITH AN "R", FOLLOWED BY THE RESISTOR'S NUMBER, SUCH AS "R3".

SO, TO SOLDER IN THE RESISTOR, YOU START BY FINDING THE CORRECT VALUE OF RESISTANCE FROM THE PROJECT'S DOCUMENTATION.

THEN BEND THE TWO LEADS OF THE RESISTOR DOWN THE WIDTH OF THE PART, LIKE THIS:



THEN PLACE THE TWO LEADS THROUGH THE TWO PADS ON THE PCB FOR THIS RESISTOR.



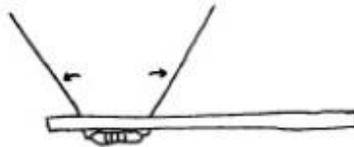
YOU PUSH THE RESISTOR'S LEADS THROUGH THE PADS UNTIL THE PART RESTS FLAT ON THE PCB.

(SOMETIMES YOU MAY NEED TO WIGGLE AND TUG GENTLY ON THE LEADS FROM THE BOTTOM OF THE PCB TO DO THIS).

FOR MOST PCBs, ALL OF THE PARTS ARE PLACED THROUGH THE PADS ON THE PRINTED SIDE OF THE PCB (WHICH WE'LL CALL THE TOP OF THE BOARD), AND WE'LL SOLDER ALL OF THE PADS ON THE BOTTOM OF THE BOARD.

THEN YOU TURN THE PCB OVER SO WE CAN SOLDER THE TWO PADS.

AS YOU TURN THE PCB OVER, YOU WILL NEED TO HOLD THE RESISTOR WITH YOUR FINGER SO IT DOESN'T FALL OUT OF THE BOARD.



THEN YOU BEND THE LEADS OF THE RESISTOR OUTWARDS AT ABOUT 45 DEGREES SO THE PART WON'T FALL OUT WHILE WE SOLDER IT IN PLACE.

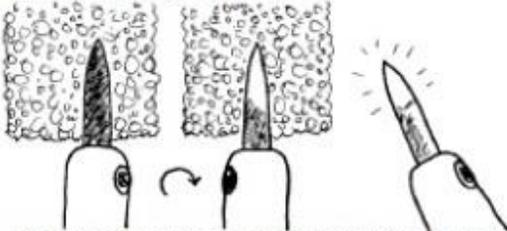
GOT IT? GREAT!

AS I SAID EARLIER, SOLDERING IRONS GET HOT ENOUGH TO MELT METAL. THAT MEANS THAT THE TIPS GET HOT ENOUGH TO OXIDIZE QUICKLY, WHICH BASICALLY MEANS THAT THEY GET DIRTY JUST SITTING IN THE AIR!



THE OXIDES ARE AN INSULATOR FOR HEAT, SO WE WANT TO CLEAN THEM OFF THE TIP BEFORE EACH SOLDER CONNECTION SO THE HEAT FLOWS NICELY AND WE CAN MAKE GOOD SOLDER CONNECTIONS.

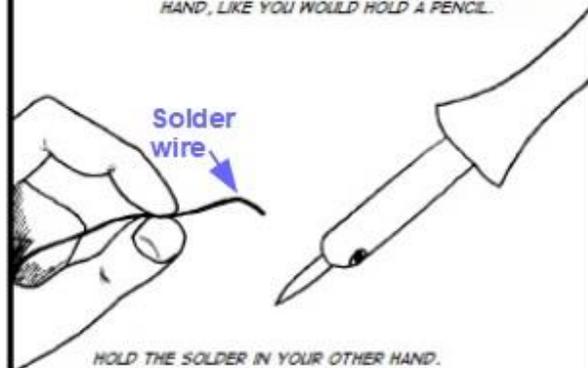
THIS IS WHY WE HAVE A WET SPONGE. TO CLEAN THE OXIDES OFF THE TIP, JUST SCRAPE THE TIP ACROSS THE SPONGE GENTLY, THEN ROTATE THE IRON AND SCRAPE GENTLY ACROSS THE SPONGE AGAIN.



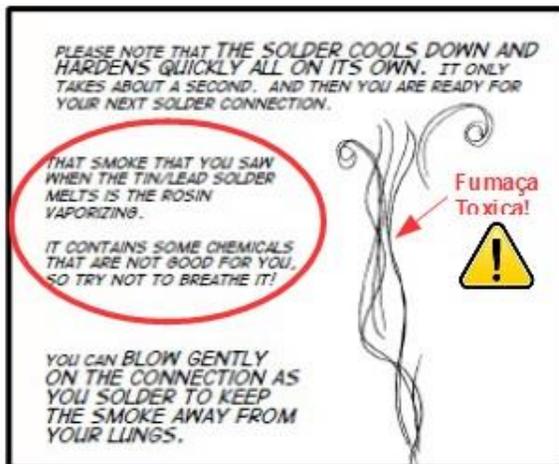
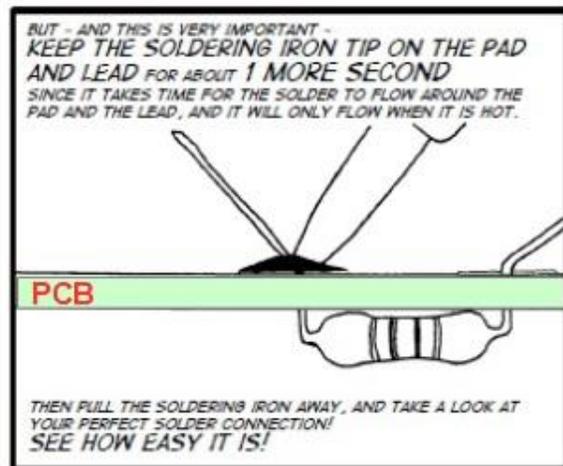
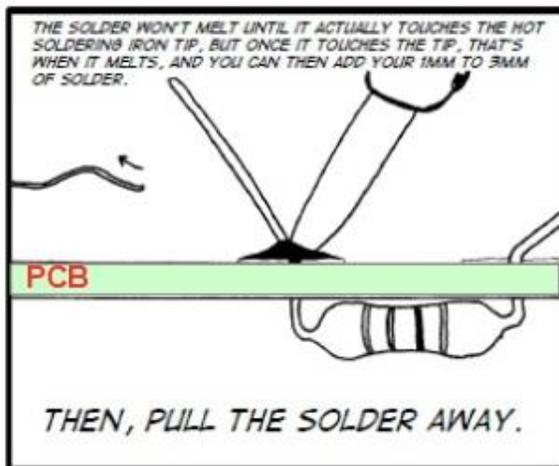
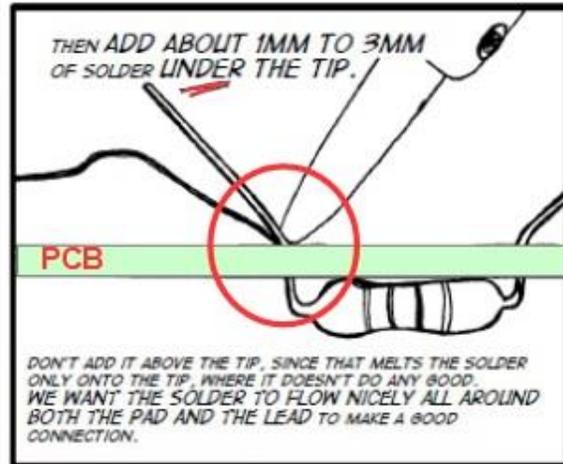
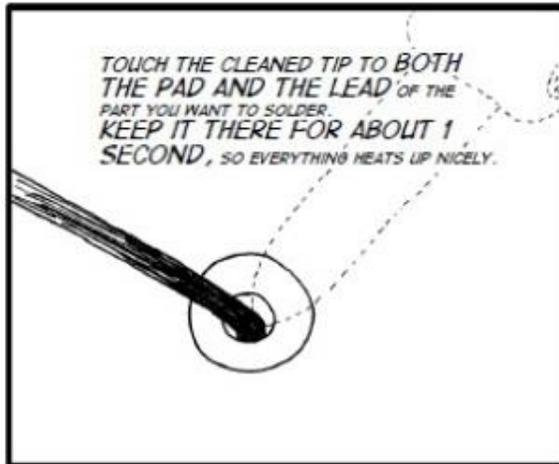
THIS SHOULD MAKE THE TIP SILVERY AND SOMEWHAT SHINY - READY TO SOLDER. REMEMBER TO CLEAN THE TIP LIKE THIS BEFORE EACH CONNECTION YOU MAKE - THE TIPS OXIDIZE QUICKLY! IF THE TIP IS NICE AND SILVERY AND SHINY, YOU CAN MAKE GOOD CONNECTIONS.

TIME TO ACTUALLY SOLDER!

HOLD THE SOLDERING IRON IN YOUR DOMINANT HAND, LIKE YOU WOULD HOLD A PENCIL.



HOLD THE SOLDER IN YOUR OTHER HAND.



LET'S TAKE A LOOK AT WHAT MAKES A GOOD SOLDER CONNECTION.

YOU CAN TELL A GOOD SOLDER CONNECTION BECAUSE THE SOLDER TOTALLY COVERS THE PAD AND SURROUNDS THE LEAD.

ALSO, THE SOLDER MAKES A SMALL BUMP.

Glossy finish, no "fish scales"

IF YOU CAN SEE ANY OF THE HOLE OR PAD OR IF THE SOLDER IS FLAT ALONG THE BOARD

THEN YOU DIDN'T ADD ENOUGH SOLDER AND SO THERE MAY NOT BE A CONNECTION WHERE WE NEED ONE.

IF THIS IS THE CASE, NO PROBLEM - JUST REPEAT THE PROCEDURE (CLEAN THE TIP, TOUCH THE TIP FOR 1 SECOND ON THE PAD AND LEAD, ADD 1MM TO 3MM OF SOLDER, PULL THE SOLDER AWAY, KEEP THE TIP ON THE PAD AND LEAD FOR 1 MORE SECOND, AND PULL THE TIP AWAY), AND IT SHOULD THEN BE TOTALLY FINE.

IF THERE IS TOO MUCH SOLDER, THAT MEANS THAT YOU ADDED SO MUCH SOLDER THAT THERE IS A SOLDER BLOB ON A PAD THAT IS BIG ENOUGH TO ALSO TOUCH ANOTHER PAD, CREATING A CONNECTION WHERE THERE SHOULD NOT BE ONE. THIS CAN HAPPEN.

Too much solder!

IF IT DOES, NO PROBLEM! JUST CLEAN THE TIP, HOLD THE TIP TO THE SOLDER BLOB BETWEEN THE PADS FOR 1 SECOND

THEN BANG THE BOARD AGAINST YOUR WORK TABLE TO FLING THE EXCESS MOLTEN SOLDER TO THE TABLE

THE CONNECTIONS SHOULD THEN BE FINE (THOUGH YOU MAY NEED TO LIGHTLY SCRAPER ANY EXCESS SOLDER FROM THE PCB, WHICH YOU CAN USUALLY DO WITH YOUR FINGERNAIL)

YOU MAY WANT TO WEAR SAFETY GLASSES!

You must Use!!

IN BETWEEN TOO MUCH AND TOO LITTLE SOLDER IS A LOT OF LEEWAY. THIS IS ONE REASON WHY SOLDERING IS EASY.

BOTH GOOD!

GOOD TOO!

SOME PEOPLE LIKE TO SOLDER PARTS TO THEIR PADS AFTER ADDING A BUNCH OF PARTS TO THE BOARD.

I PREFER TO ADD AND SOLDER ONLY ONE PART TO THE BOARD AT A TIME. I FIND THIS EASIER SINCE THERE AREN'T SO MANY LEADS THAT CAN GET IN THE WAY OF MY SOLDERING IRON.

ALSO, IF I ADD MORE THAN ONE PART TO THE BOARD I SOMETIMES MISS SOLDERING A PAD, SINCE IT ISN'T SO EASY (AS YOU MIGHT THINK IT WOULD BE) TO SEE WHICH CONNECTIONS ARE SOLDERED.

AFTER SOLDERING ALL OF THE LEADS OF THE PART YOU ARE SOLDERING, IT IS TIME TO CUT OFF THE EXCESS LEADS.
THIS MUST BE DONE TO ENSURE THAT THE EXCESS LEADS DO NOT BEND OVER AND SHORT TO ANOTHER LEAD OR PAD.

IF THIS HAPPENS, THEN THERE WILL BE A CONNECTION WHERE WE DO NOT WANT ONE.

TO CUT THE LEAD, WE'LL USE A SMALL WIRE CUTTER. ONE SIDE HAS FLAT CUTTING EDGES, AND THE OTHER SIDE HAS A DEEP GROOVE.

PLACE THE FLAT EDGE DOWN, PARALLEL TO THE PCB, JUST AT THE TOP OF THE LITTLE BUMP OF SOLDER.
SQUEEZE THE HANDLES, AND THE CUTTING EDGES SNAP SHUT.

WHICH TURNS THE EXCESS LEAD INTO A PROJECTILE THAT HITS YOU RIGHT IN YOUR EYE!

SAFETY TIP #3 (OF 3): ALWAYS HOLD THE LEAD YOU ARE CUTTING WITH ONE HAND WHILE YOU CUT WITH YOUR OTHER HAND.

IF THE EXCESS LEAD IS TOO SHORT TO HOLD ONTO (BUT LONG ENOUGH TO POTENTIALLY SHORT OUT TO SOMETHING ON YOUR PCB), THEN POSITION THE WIRE CUTTER, HOLD YOUR FINGERS OVER THE LEAD,

AND THEN SQUEEZE.

THIS WILL KEEP THE EXCESS LEAD FROM HITTING ANYONE IN THE EYE (OR SHORTING OUT SOMEWHERE ON YOUR PROJECT).

YOU MAY ALSO WANT TO WEAR SAFETY GLASSES!

IF YOU ALWAYS DO THIS, YOU WILL ALWAYS BE SAFE.

LEADS THAT ARE ALREADY VERY SHORT, SUCH AS IC SOCKETS, DO NOT NEED TO BE CUT - THEY HAVE LEADS THAT ARE TOO SHORT TO BEND OVER AND MAKE SHORTS.

IF YOU MAKE A MISTAKE, IT IS TOTALLY OK. ALL MISTAKES ARE FIXABLE (THOUGH SOME ARE EASIER THAN OTHERS).

AND MAKING MISTAKES IS HOW WE LEARN TO BECOME BETTER AT EVERYTHING WE DO.

WHILE SOLDERING IS EASY, UNSOLDERING TAKES LOTS OF PRACTICE. AND IF YOU MAKE A MISTAKE, YOU GET TO HAVE SOME PRACTICE!

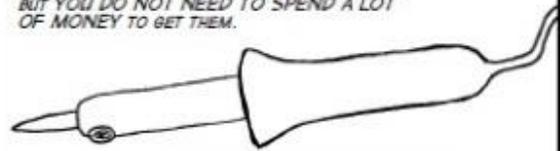
Practice, practice, practice...

AS YOU SOLDER MORE, YOU WILL PICK UP MANY TIPS AND TRICKS THAT WILL MAKE SOLDERING EVEN EASIER.



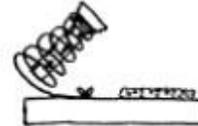
BUT YOU ARE NOW TOTALLY READY TO SOLDER JUST ABOUT ANYTHING!

IF YOU LIKE SOLDERING, AND WANT TO SOLDER WELL, YOU'LL WANT TO BUY SOME GOOD TOOLS. BUT YOU DO NOT NEED TO SPEND A LOT OF MONEY TO GET THEM.



YOU CAN BUY A DECENT SOLDERING IRON (IN THE SHAPE OF A LONG, FAT PENCIL) FOR ABOUT US\$15

YOU'LL NEED A SOLDERING IRON STAND THAT FITS A WET SPONGE, WHICH WILL COST YOU ABOUT US\$6



IF YOU REALLY WANT TO GET FANCY, OR IF YOU THINK YOU WILL BE SOLDERING LOTS, OR SOLDERING A BUNCH OF SMALL THINGS YOU CAN BUY A DECENT SOLDERING STATION, COMPLETE WITH A STAND AND SPONGE FOR ABOUT US\$60



THEN YOU'LL NEED AN OK WIRE CUTTER, FOR ANOTHER US\$6

BUY A POUND ROLL (OR A 500G ROLL) OF DECENT SOLDER FOR ABOUT US\$35 AND YOU'LL BE SET FOR YEARS OF SATISFYING SOLDERING



IF YOU CAN GET IT, I RECOMMEND 60/40 TIN/LEAD WITH ROSIN CORE (AS I MENTIONED BEFORE LEAD-FREE SOLDER WILL WORK FINE, BUT IT IS NOT AS EASY TO WORK WITH).

Lead free!!



YOU REALLY DON'T NEED MORE

BUT YOU MIGHT ALSO WANT LONG NOSE PLIERS (ABOUT US\$6) AND WIRE STRIPPERS (ABOUT US\$10). (AND SAFETY GLASSES CAN BE BOUGHT FOR AS LITTLE AS US\$2.)



DISTRIBUTE WIDELY!

ENJOY!

NARRATION BY MITCH ALTMAN
[HTTP://CORNFIELDELECTRONICS.COM](http://cornfieldelectronics.com)

COMICS ADAPTATION BY ANDIE NORDBREN
[HTTP://LOG.ANDIE.SE](http://log.andie.se)

EDITED BY JEFF KEYZER
[HTTP://MIGHTYOHM.COM](http://mightyohm.com)

TRANSLATE IT, USE IT, SPREAD IT, COLOR IT, TEACH WITH IT!
[HTTP://MIGHTYOHM.COM/SOLDERCOMIC](http://mightyohm.com/soldercomic)



Soldering...

Arrange your place of work

Arrange a place without movement and with a table where you can make your experiments and assemblies. **Must have:**

- Electrical installations for you to connect soldering iron, drill, etc.
- Appropriate lighting and, if possible, that can be moved.
- Comfortable chair
- Natural or artificial ventilation with a small fan.
- Away from children!
- Peaceful, if you can!
- Safety items such as glasses and others.

Install the soldering iron in a place where it is not dangerous for someone who comes close and also for you. It should have a base, depending on the type of soldering iron you chose. The temperature of the tip can reach 200 degrees centigrade!

On the table place only, the material you are going to work on and the tools you will use. Over time, more experiments and assemblies, you will be able to organize, even if you have only one corner available.

Do not miss a spot for a table, mess up you assemblies and experiments! In the last case, use the kitchen table!

How to hold your soldering iron and tin the tip

The welding iron must always be held by the insulated cable, as if it were a pencil or a pen. Keep your elbow resting on the table while you hold the iron.

When the welding iron is "brand new", it will be shiny in the part where it has the resistance that heats the tip. Over time, it gets dark, as you will see in the following photos.

Before using the iron for the first time or using a new tip for it, you need to tin this tip so that it is shaped and cleaned correctly. Please, look at **figure 214**.



Figure 214 - How to hold the soldering iron.

To tin the iron tip, plug it into the AC outlet of your home and wait until it reaches the correct operating temperature.

At the correct temperature, cover every part of the soldering iron tip with the soldered solder wire as shown in figure 215.

The tip of the soldering iron should be covered with soldering tin and should be smooth and shiny. If any part is not covered due to dirt on the tip, lightly brush a wire brush to clean.

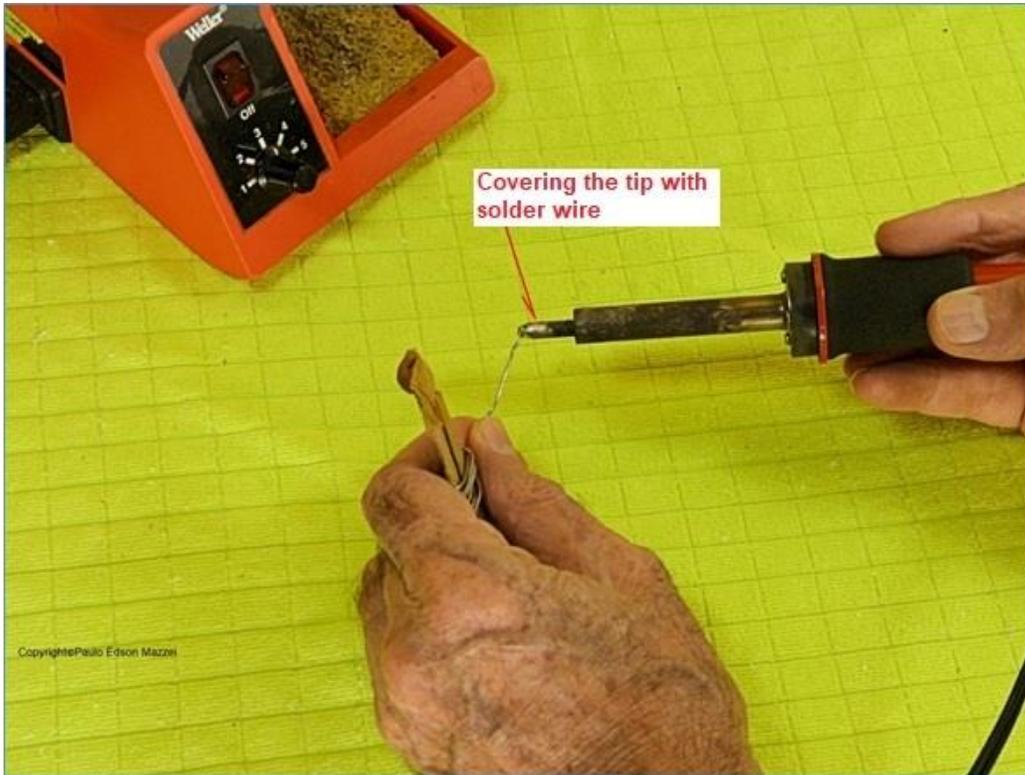


Figure 215 - Tinning the tip of the soldering iron.

Your first welding!



Now that you know all the welding tips, the tools you need, the welder, etc., it's time to make your first solder

To simplify, let's join two small pieces of flexible wire, it may be some piece you already have there. **Follow the steps:**

1. Prepare your workplace.
 2. Put on the goggles.
 3. Nobody around? It can splash melted solder ...
 4. Connect your welder with the tinned tip.
 5. Remove a piece of the cover at the tip of each strand, about 1.0 cm.
 6. Twist this part of the wire that you have stripped, that is, the copper tips.
tips.
 7. Use the flat-nose pliers to twist these ends of wire until they are securely attached to each other.
 8. Hold them with the "third hand" alligator clip so you can solder them.
 9. Solder them by heating the ends of the copper wire and placing the tin on top. Note that this needs a few seconds. How many?? Only practice will tell, but until the heat of the heated wire begins to melt the tin that is on it.
 10. Cover all rolled ends of the two wires with the solder.
 11. Wait cool and see your work. Is the soldering without barnacles? Are you brilliant, smooth? Covered every surface of copper? Very well!
- See the result of your soldering, in **Figure 216, 217 and 218**.

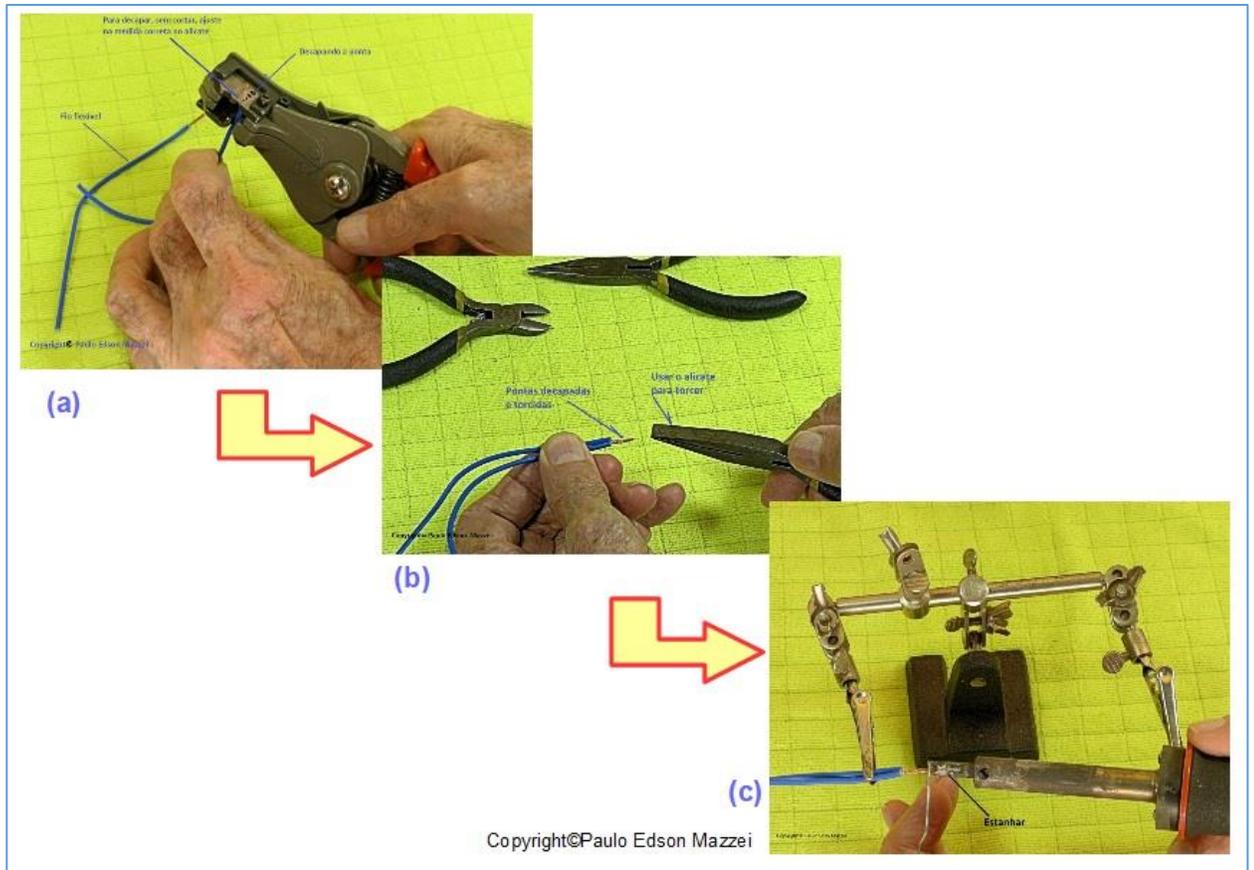


Figure 216 – Preparing the wire sans soldering.

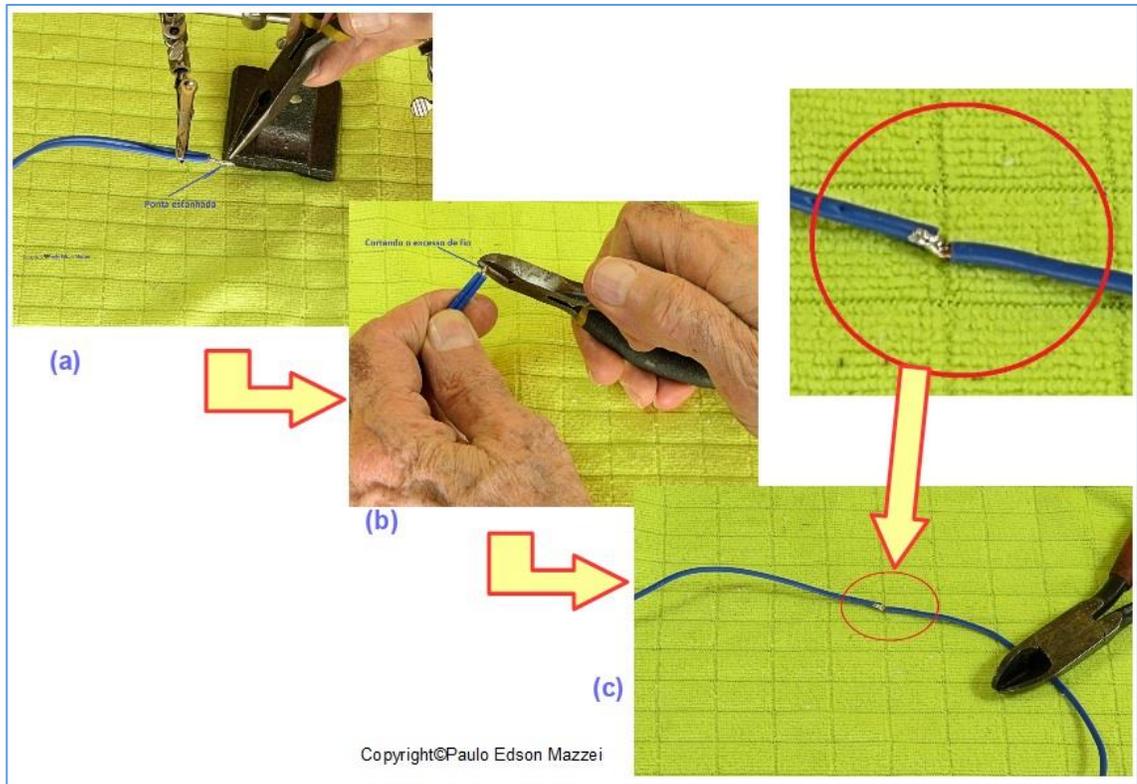


Figure 217 – Insulating with Shrinkable tube

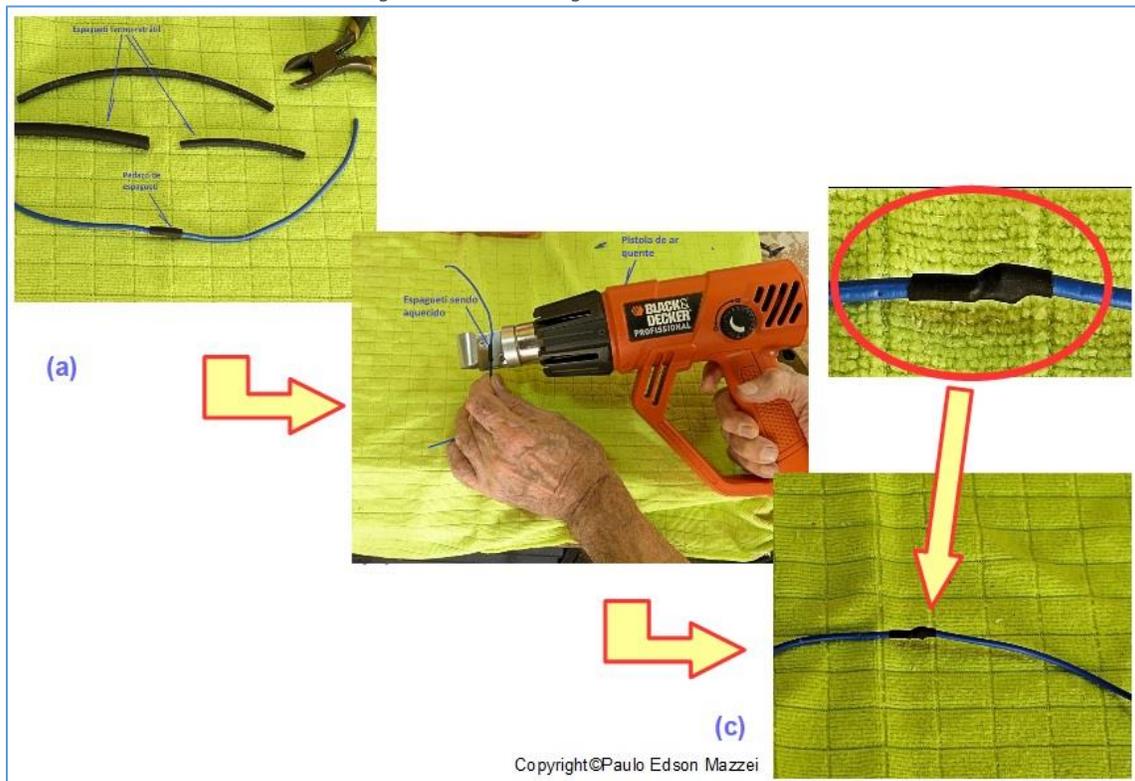


Figure 218 – Insulating with plastic tube.

Figure 216:

(a) Stripping the wires with the stripper pliers. If you do not have pliers of this type, use a hobby knife, very carefully.

(b) Join the two pickled tips (copper) and twist them. Then continue the twist with the flat-nose pliers for greater firmness. Do not exaggerate...

(c) Weld the ends that were twisted. Check the quality of the weld: solder without excess, shiny and smooth.

Figure 217

(a) Wires already soldered, looking good.

(b) Cut excess wire, leaving 4 to 5 mm bristle welded.

(c) View of soldered and aligned wires.

Figure 218:

(a) Placing a piece of retractable thermo spaghetti on the wire splicing. Choose a piece of about 12 to 15 mm. Retractable termite spaghetti are sold in stores of electrical material in various dimensions. By the Internet you can get already cut, colored. You can also use good quality insulation tape for this insulation.

(b) Warming up the spaghetti, it contracts, sealing the welded joint of the two strands. To warm up, we use a hot air gun or the hair dryer of the mother or sister.

(c) Finally, the finished masterpiece! Welded and protected with spaghetti, ready for use.

Soldering of components in PCB

In your process of assembling small electronic equipment, you will come across the assembly of electronic components in a PCB. If you purchase a kit to assemble, you will surely receive a PCB together to place and solder the components.

If you are going to build a simple circuit with diodes, capacitors, resistors, transistors, etc., a good idea is to use an already stuck PCB, called a "standard board" (one of its many names). The one you can find in the country is shown in figure 174.

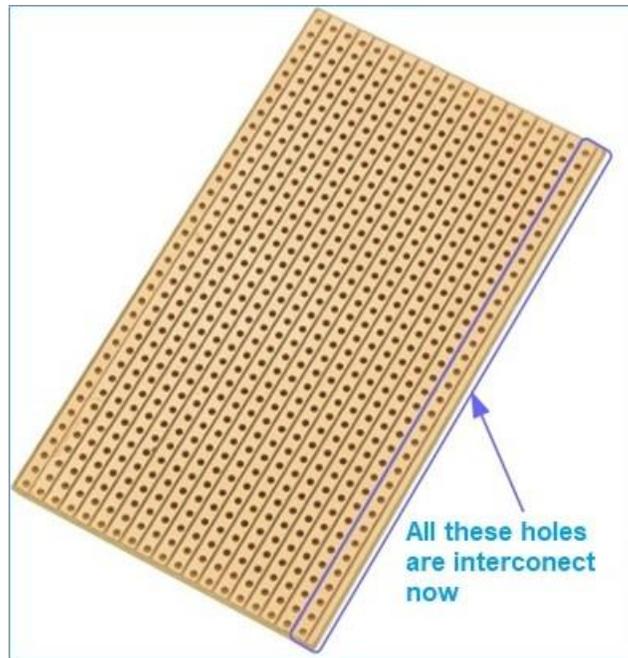


Figure 219 - Standard PCB board.

Note that in practice you will need to interrupt clues to make the circuit possible.

See **Figures 220** and **221** for a welding sequence of a resistor on the PCB.

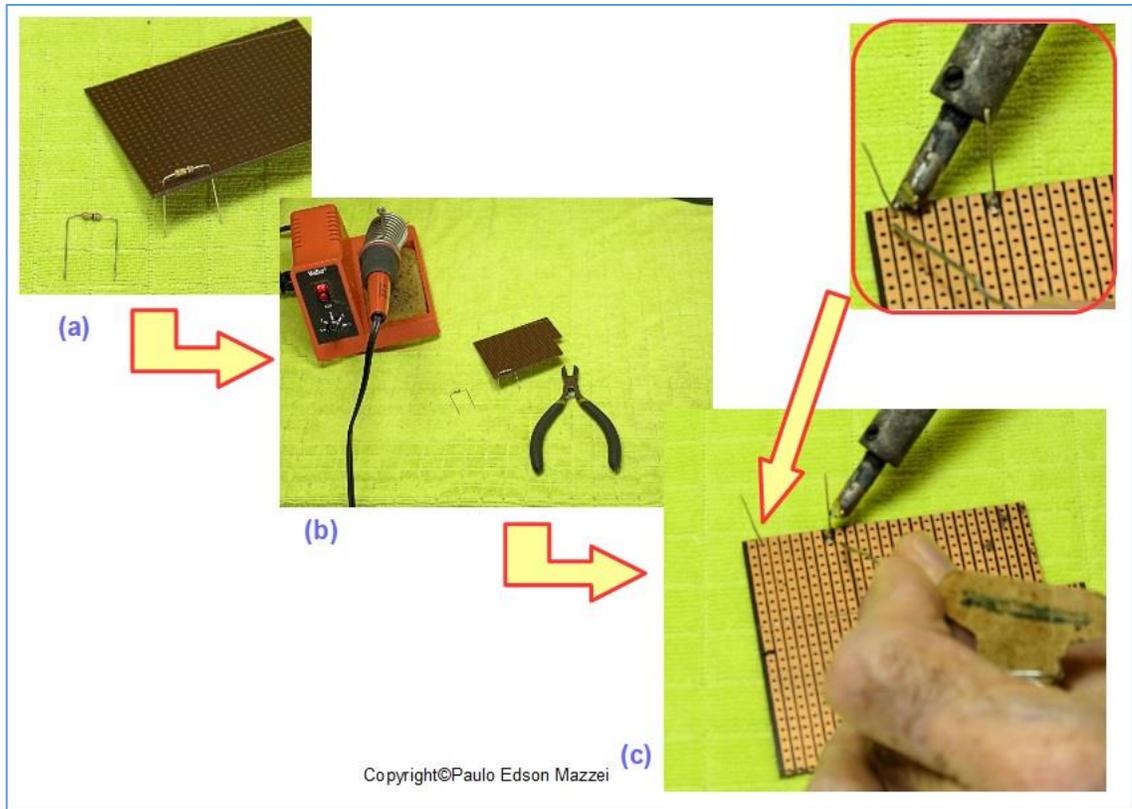


Figure 220 - Sequence of welding of a resistor in the PCI.

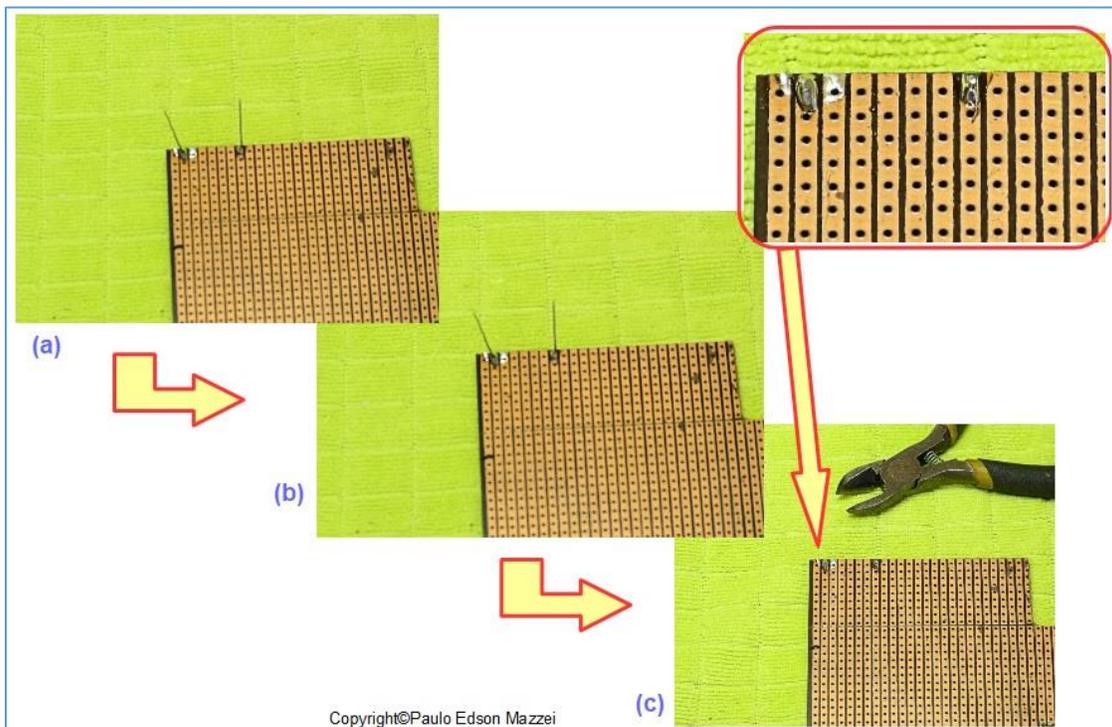


Figure 221 - Continued welding of a resistor in the PCI.

Figure 220:

- (a) Folding the resistor terminals and snapping into the PCI.
- (b) Preparing to weld ...
- (c) Soldering the terminals in the PCB.

Figure 221:

- (a) Wire already soldered, looking good.
- (b) Cut excess yarn, leaving 4 to 5 mm bristle welded.
- (c) View of already cut terminals.

Solder exercises

Let's do a soldering exercise that is building two test leads for our multimeter.

These tips will make your life easier when using DMM for reading on a Protoboard or an Arduino board,

a. Make a probe with alligator clips on the ends.

Material:

- 1 pair of common probes
- 1 meter (or other measure) of cable for probes, in black color
- 1 meter (or other measure) of cable for probes, in red color.
- 1 alligator clip, small size, red color, isolated.
- 1 alligator clip, small size, black color, isolated.

NOTE: It is often easier for you to find a pair of probes than to find a vendor for the special probes cable. If this is the case, cut off the tips, to solder alligator clips and pins.

Tools:

- Solder iron
- Solder wire
- Pliers, hobby knife, etc.

Procedure: please refer to figure “a” and “b”.

1. Remove the cover in the end of the cable where you will weld the alligator. About 4 mm.
2. Lightly twist the thin copper wires.
3. Fasten on the third hand and seal the copper wire.
4. Now secure one of the alligator clips, without the insulation cover.
5. Place solder in the appropriate place where the cable will enter.
6. Thread the alligator insulation cover over the wire. Do not forget!!
7. Solder the cable to the alligator body. See the pictures and photos.
8. Wait to cool and slide the insulation cover over the wire until it covers the body of the alligator.
9. Ready!
10. Repeat for the alligator of another color.
11. Test the continuity with the multimeter.

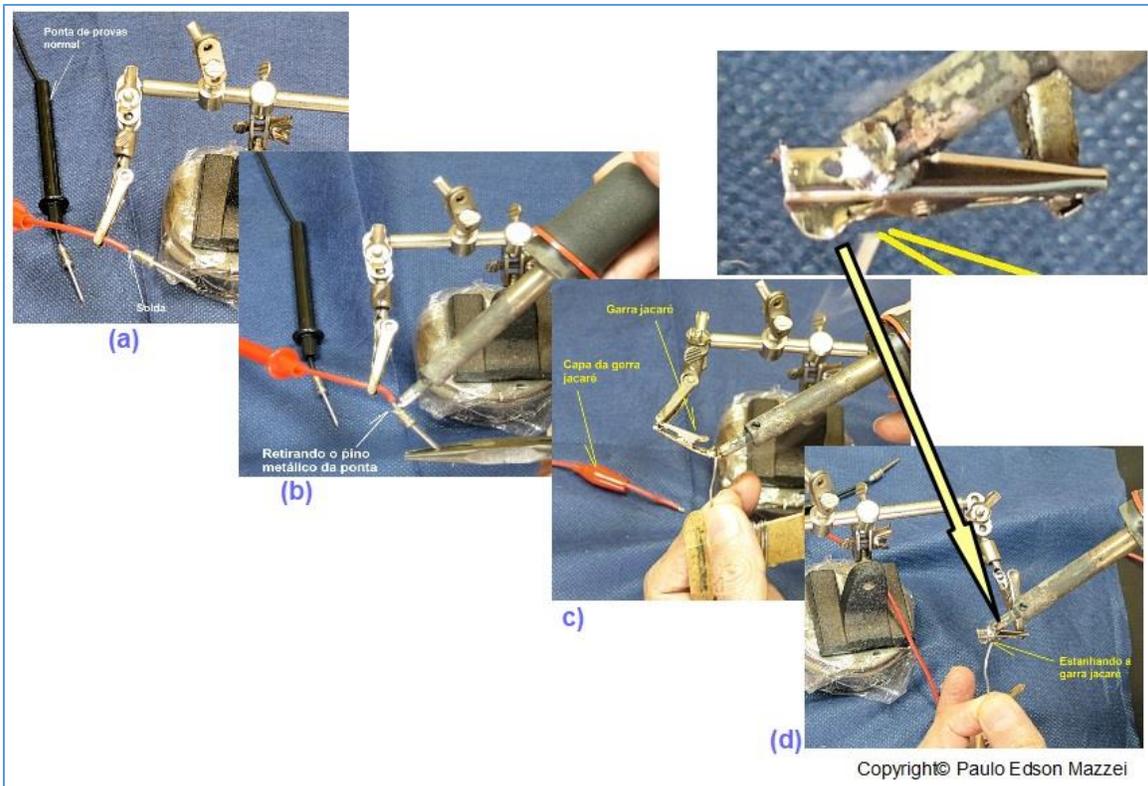


Figure a - Preparing test cable with alligator clip.

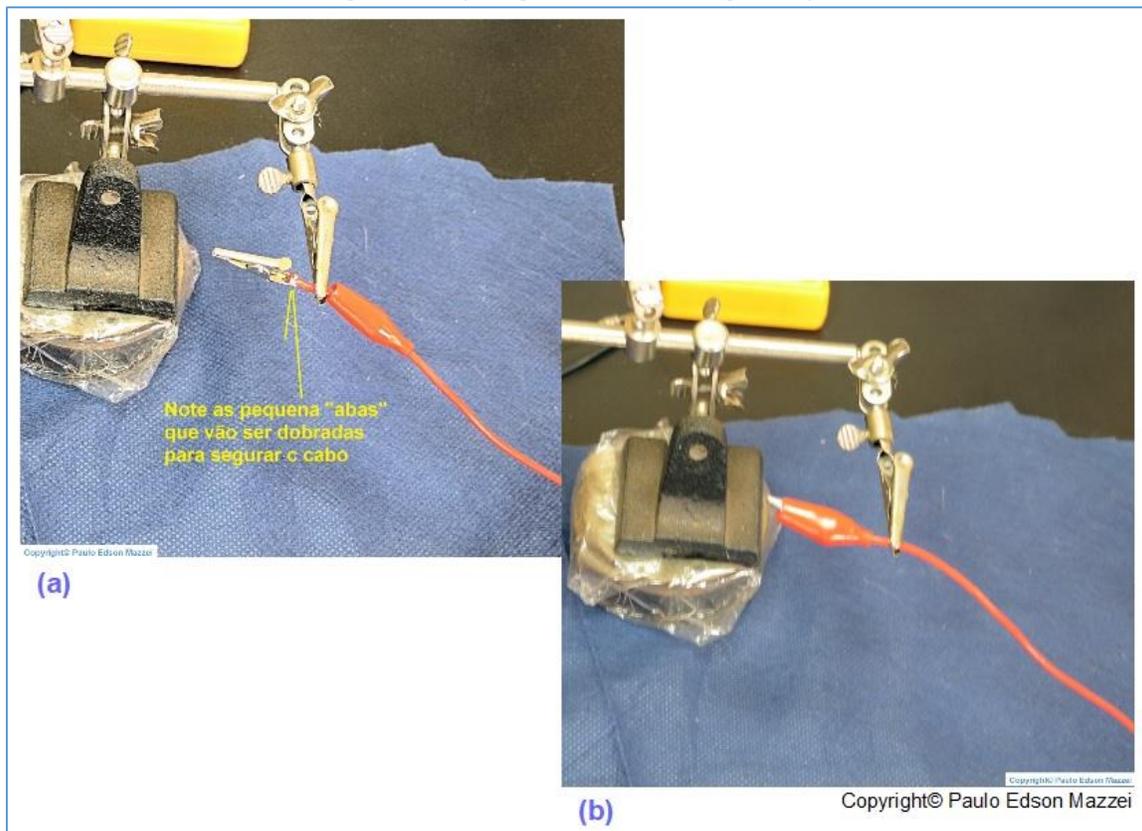


Figure b - Test tip with alligator clip.

b. Make a probe with pins on the ends.

Material:

Material:

- 1 pair of common probes
- 1 meter (or other measure) of cable for probes, in black color
- 1 meter (or other measure) of cable for probes, in red color.
- 1 pin, small size, red color, isolated.
- 1 pin, small size, black color, isolated.

NOTE: It is often easier for you to find a pair of probes than to find a vendor for the special probes cable. If this is the case, cut off the tips, to solder alligator clips and pins.

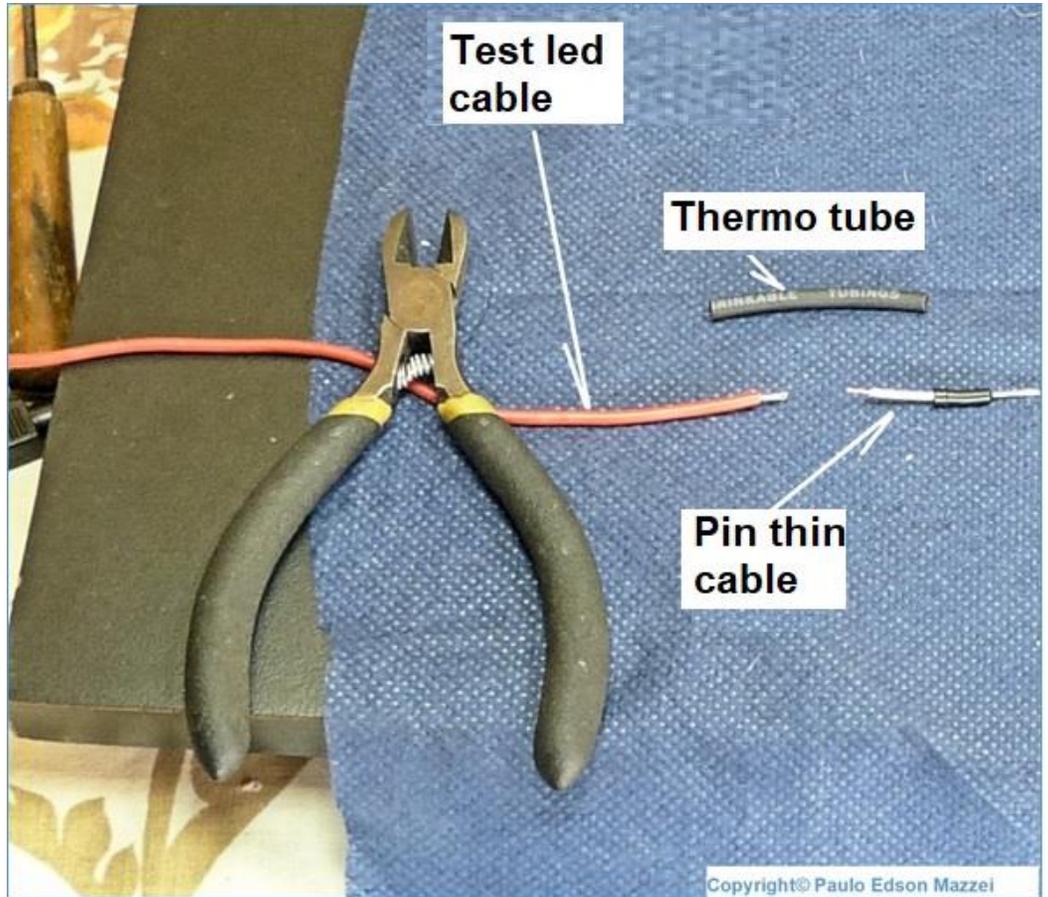
Tools:

- Solder iron
- Solder wire
- Pliers, hobby knife, etc.

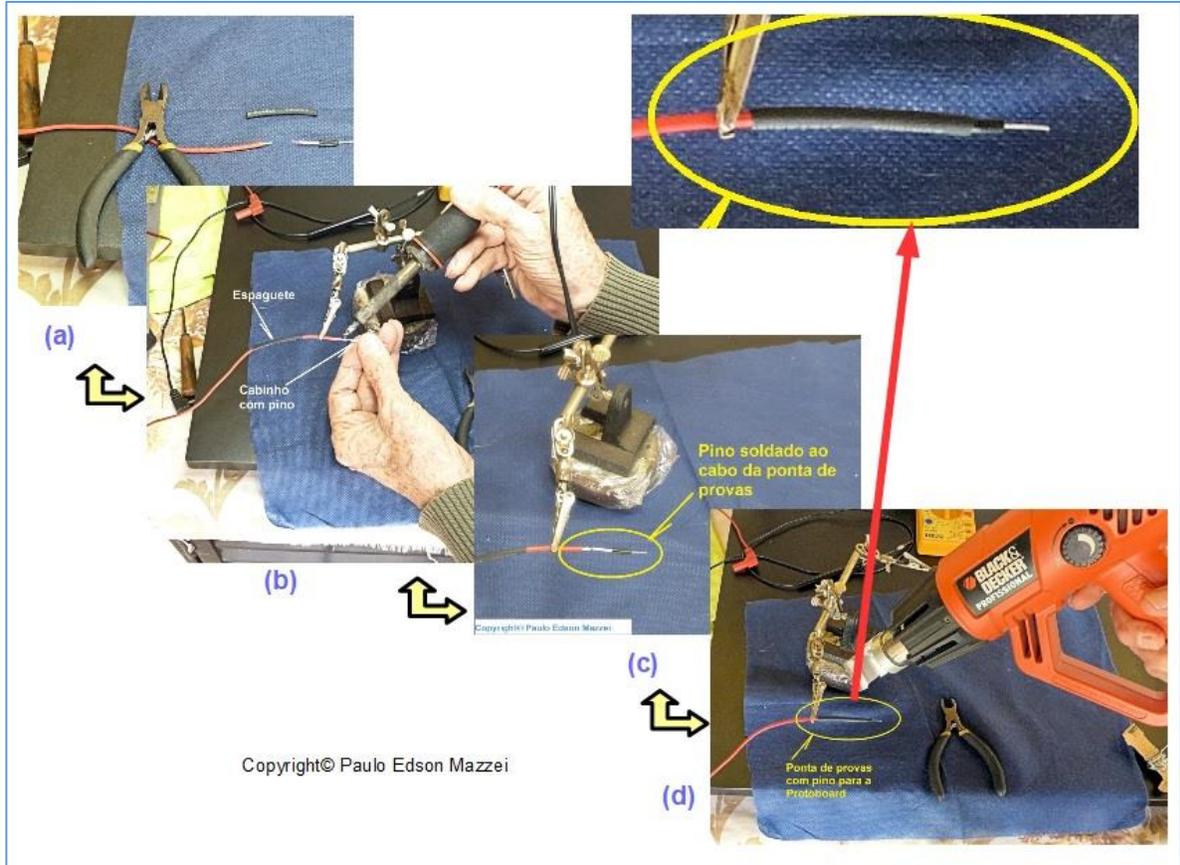
Procedure: please refer to figure “c”.

1. Remove the cover in the end of the cable where you will solder the pin. About 4mm.
2. Lightly twist the thin copper wires.
3. Cut a dowel, with the two pins, about 40 mm from the pin. See the figures. Remove the cover at the tip of the wire. About 4mm
4. Lightly twist the thin copper wires.
5. Secure the cable in the third hand and seal the copper wire.
6. Secure the pin in the third hand and seal the copper wire.
7. Note that you now have the tip of the test cable already tinned, as well as the tip of the pin, with a piece of wire. Let's unite the two,

8. Now secure one of the alligator clips, without the insulation cover.
9. Place solder in the appropriate place where the cable will enter.
10. Thread the alligator insulation cover over the wire. Do not forget!!
11. Solder the cable to the alligator body. See the pictures and photos.
12. Wait to cool and slide the insulation cover over the wire until it covers the alligator body.
13. Ready!
14. Repeat for the claw of another color.
15. Test the continuity of the cables with the multimeter.



– *Preparing the test tip with pin.*



Pin mounting sequence to test lead wire.

Uses of test. leads

See figure "d" how we can use the three types of test tips we just made. They will make your life a lot easier to do with DMM.

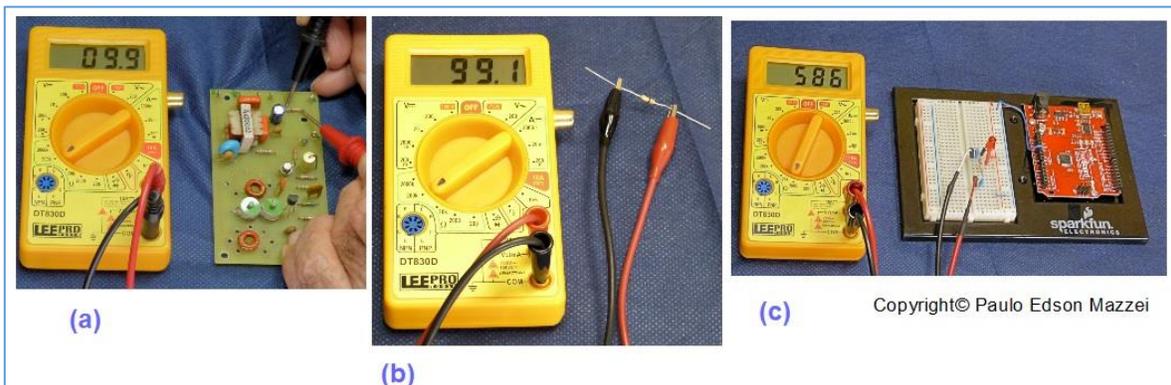


Figure "d- Uses of the test leads.

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Chapter 29

How to read schematic diagrams

Introduction

Every electronic circuit is represented by a schematic diagram, that is, a graphical representation of the parts and components from which it is constructed and the interconnections between the various components in order for it to work accordingly.

Each electronic component has its graphic symbol, as we have seen previously for several components.

In Brazil, the graphic symbols used are those standardized by ABNT - Brazilian Association of Technical Norms and differ somewhat from the symbology adopted in the United States. As we are going to read several magazines in English and Internet articles with this language, it is interesting to know these North American symbols.

In Europe the International standard is adopted, defined by the **IEC** - International Electrothechnical Comission. The **ABNT** symbols have derived practically from these standards and are very similar.

North American Symbols

Figure 222 shows the main symbols used in the USA that you will find in your searches.

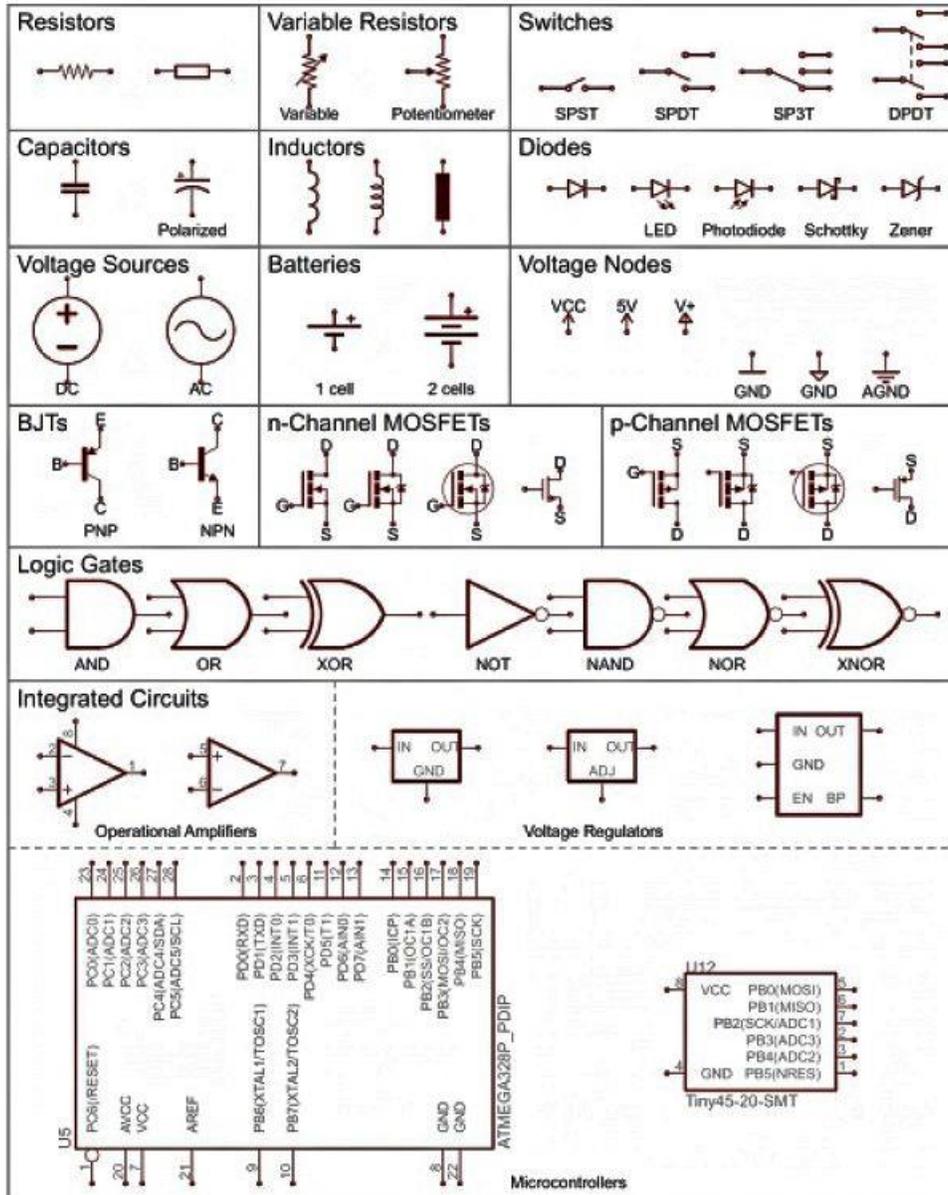


Figure 222- Graphic symbols in the North American pattern. Copyright © SparkFun Electronics – USA

IEC graphic symbols

Resistors and capacitors

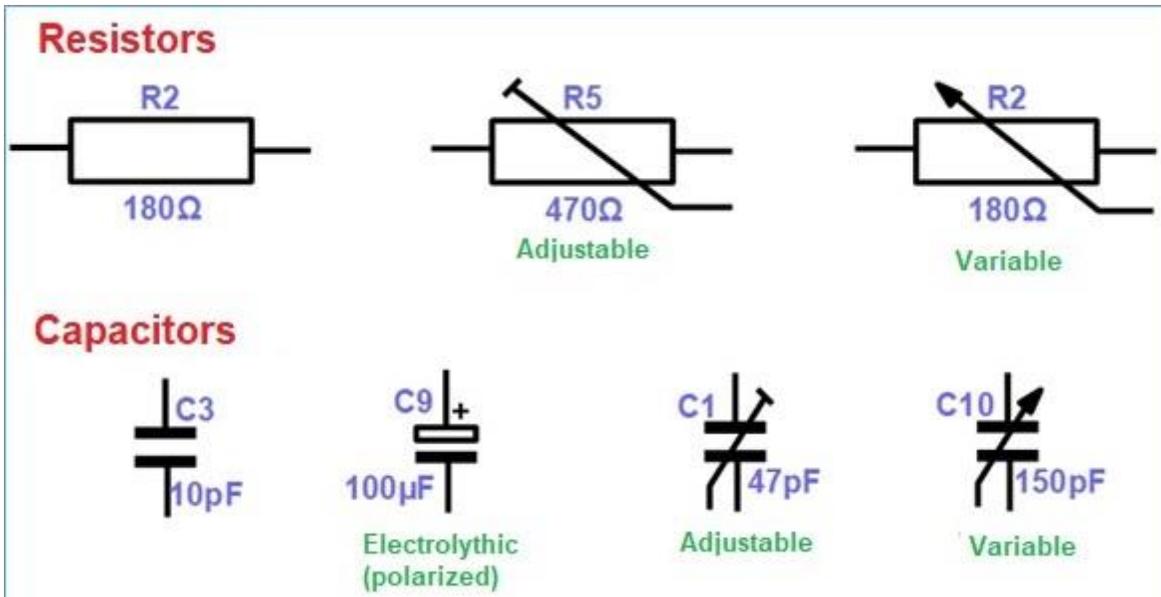


Figure 223- Resistors graphic symbols.

Inductors and switches

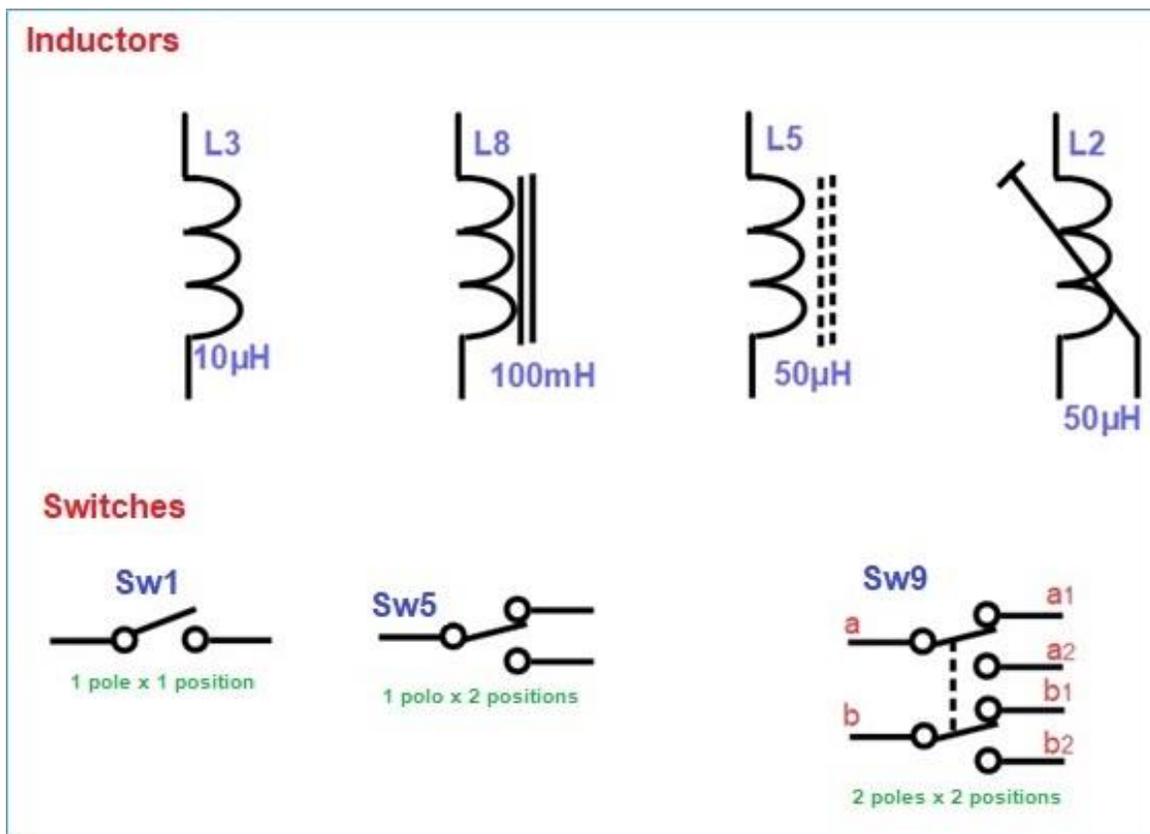


Figure 224 – Inductors and switches.

Power supply and batteries

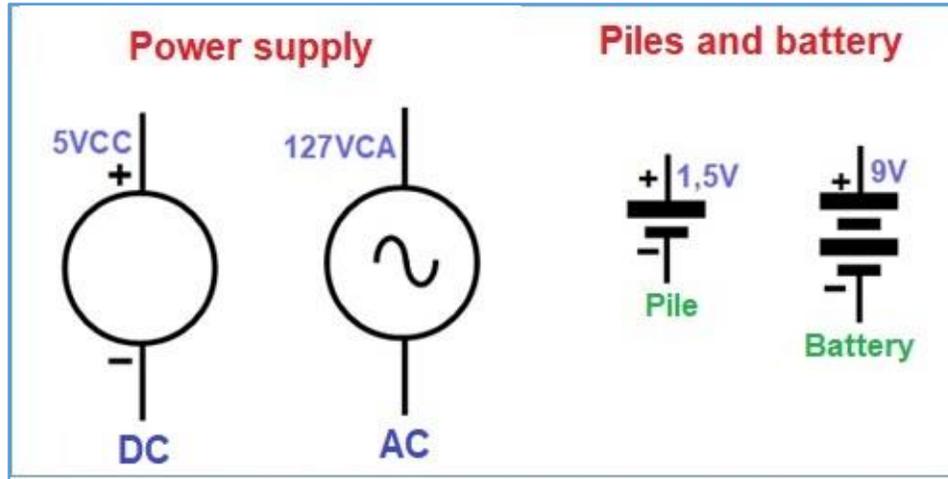


Figure 225- Power supplies, piles and batteries.

Diodes

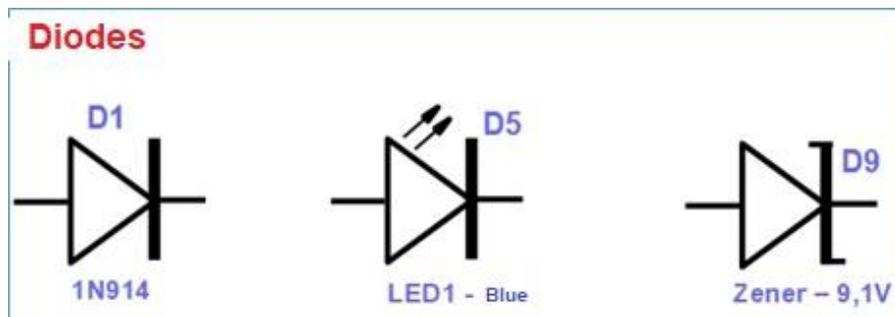


Figure 226 - Diodes.

Transistors

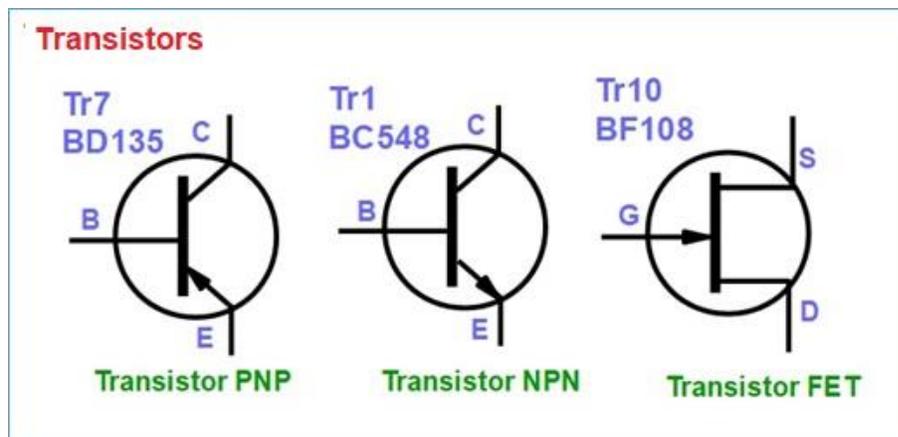


Figure 227 - Transistors.

Operational amplifiers and voltage regulators IC

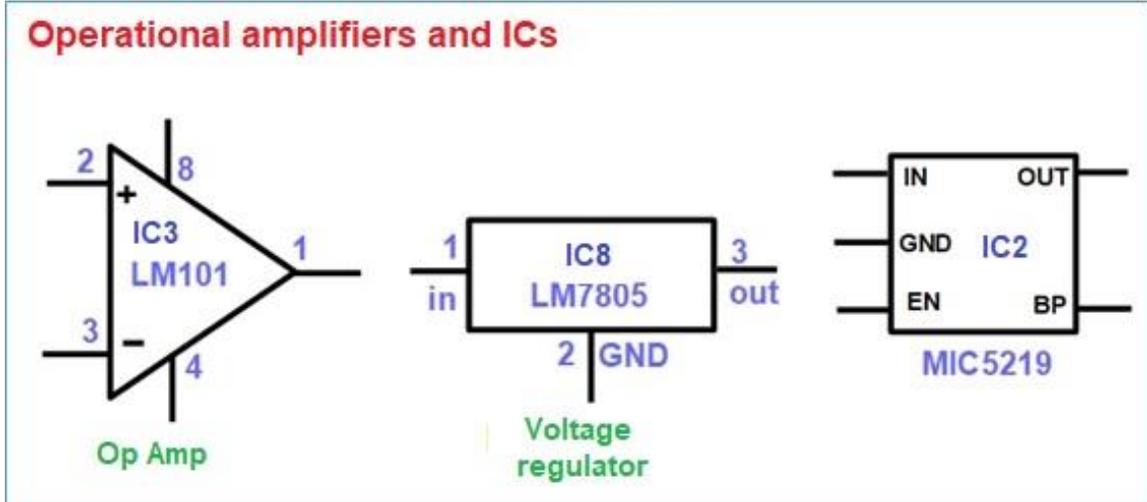


Figure 228- ICs and operational amplifiers.

Other

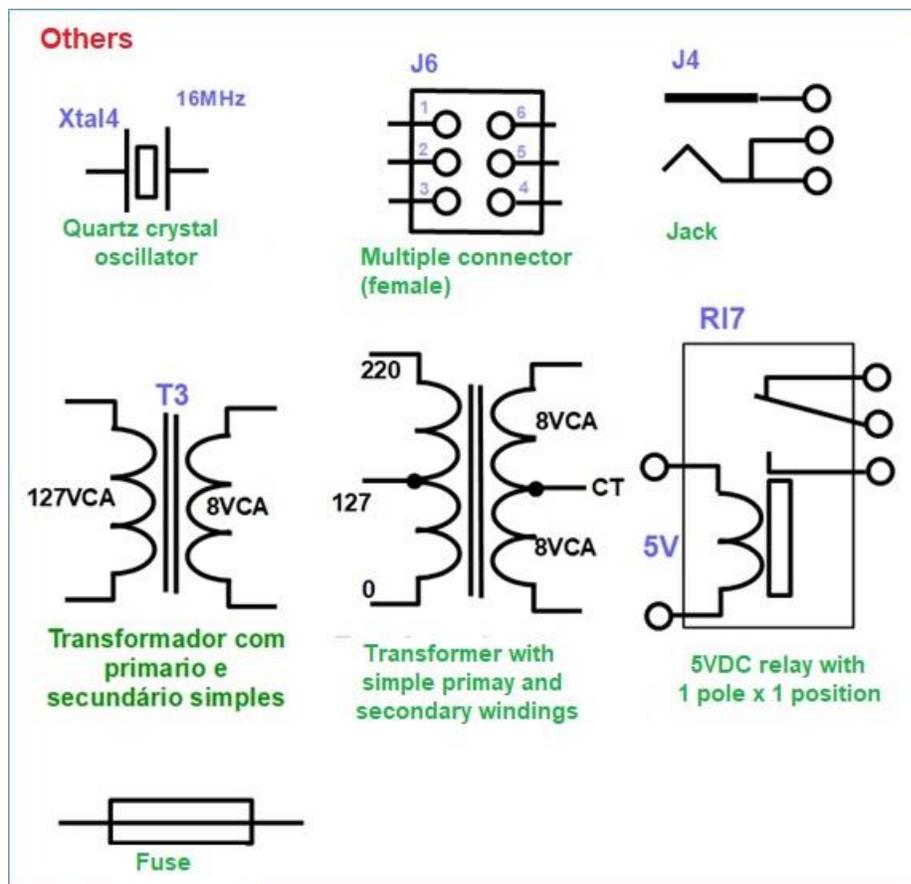


Figure 229- Other symbols.

Wire connections

Please, see **figure 230** for an explanation of the nodes (wire connections).

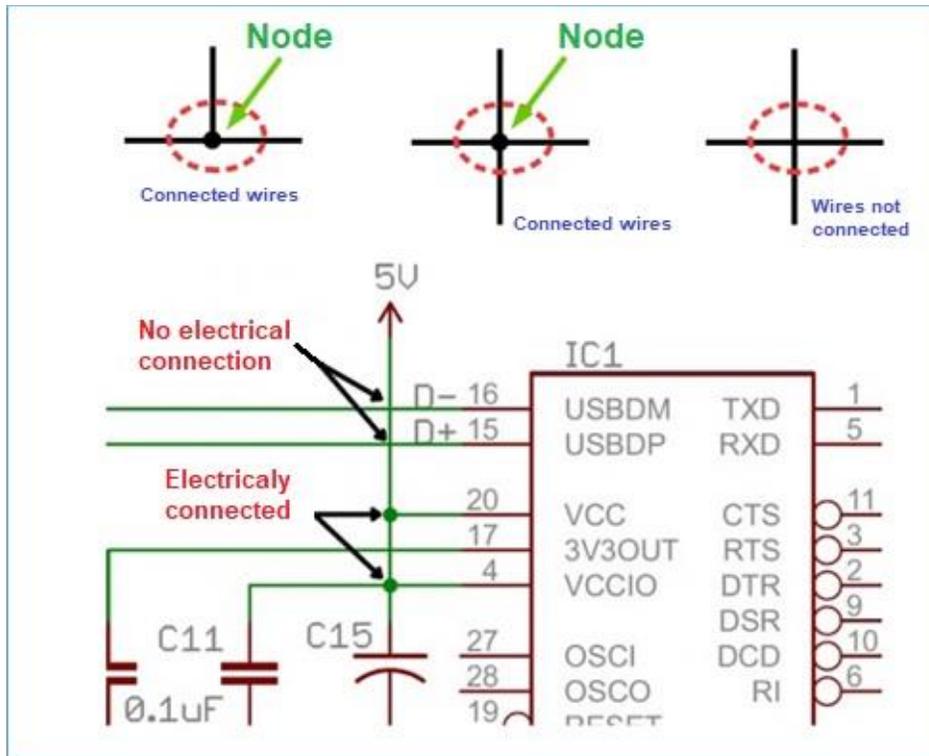


Figure 230 -Nodes and wire connections.

Real circuits

So that you can see the actual circuit, with the electronic components and at the same time the schematic diagram, see **figure 231**.

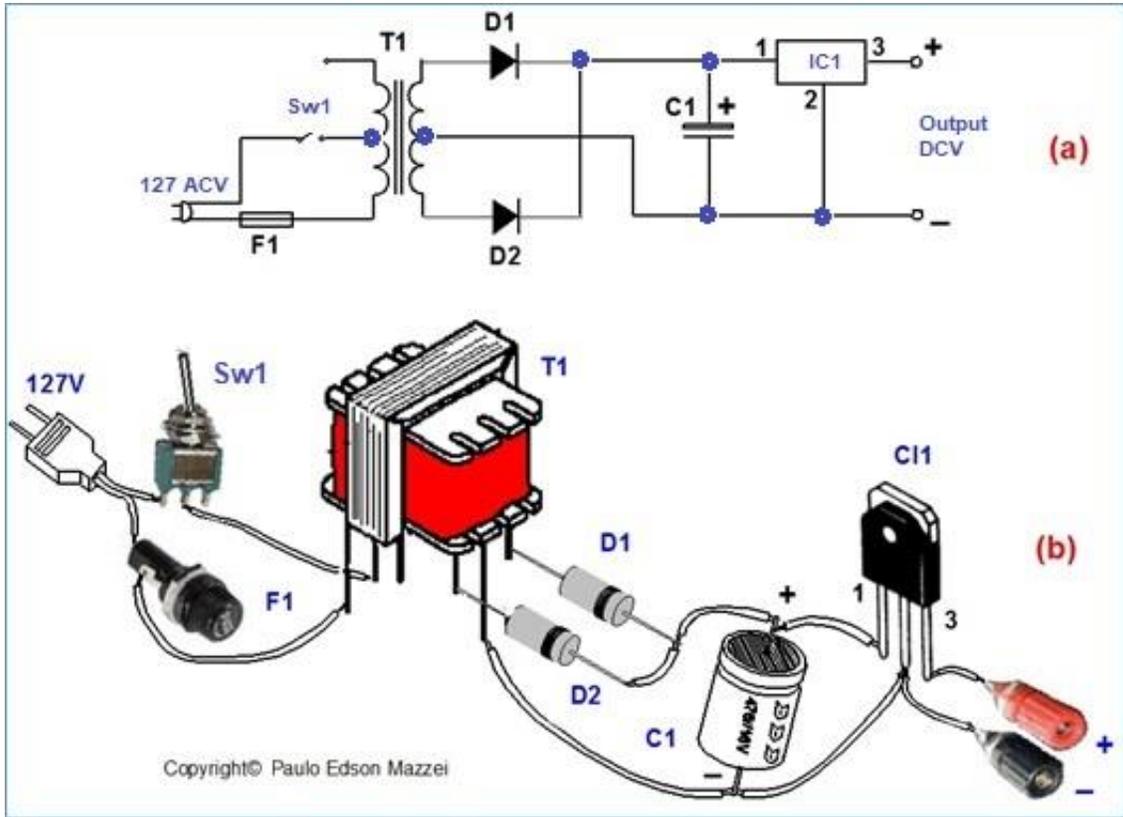


Figure 231 - Schematic diagram in (a) and circuit assembled on (b).

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Chapter 30

Semiconductors and diodes

Introduction

We now come to the **semiconductors**, electronic components very important for electronics and that allowed the construction of computers, space rockets, satellites, etc. It is not easy to understand the whole theoretical and practical part of semiconductors. Fortunately, you only need some information to be able to use them without problems.

Objectives

- Know the semiconductors that form the construction of diodes, transistors and integrated circuits.
- Diodes, polarization and applications.

Semiconductors

Are you reminded that metals are used as good conductors because they have an enormous number of electrons (**free electrons**) that can move when a voltage is applied to the material? Insulators already have their electrons fixed and do not move in the material, not allowing the circulation of a current.

Certain materials, called **semiconductors**, are insulators that have a few electrons (free electrons). These materials may have a partial current flow through them.

The free electrons in a semiconductor, when they move, leave behind positive charges which are the protons of the atoms from where the free electrons came from. Charged atoms are called ions. Positive ions have the ability to capture electrons from nearby atoms. When an electron is captured from another atom it becomes a positive ion. This process, for the purpose of explaining the working mechanism of a semiconductor, can be assumed to be a hole moving through the material in the same way as an electron moves.

Note that we now have two ways to circulate a current through a semiconductor: electron moving in one direction and holes moving and in another direction.

Of course, the holes do not actually move. They are only fixed positive ions that capture neighboring electrons. See **figure 232**.

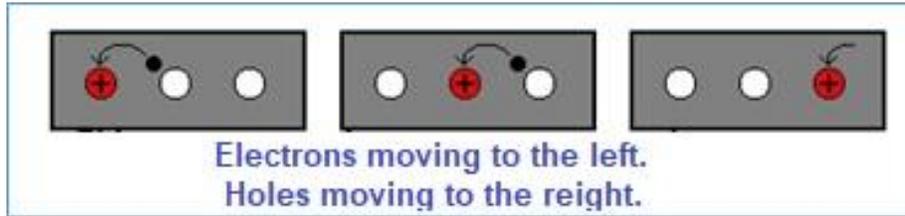


Figure 232 – Electrons and holes movement.

In a pure semiconductor there are not enough free electrons and holes that can be used. However, these electron numbers and holes can be greatly enhanced by the addition of certain "impurities," called **donors**.

If these donor substances "donate" extra free electrons, the result of the semiconductor plus the impurity, is called the **semiconductor type n** (n of negative). On the contrary, if these donor substances "remove" some of the free electrons, the result is a **semiconductor type p** (p of positive). Please see **figure 233**.

In n-type semiconductors there are more electrons than holes. It is the opposite for the type p semiconductor.

The most common materials used as semiconductors are **silicon** (Si) and **germanium** (Ge). The most commonly used impurities are arsenic and phosphorus.

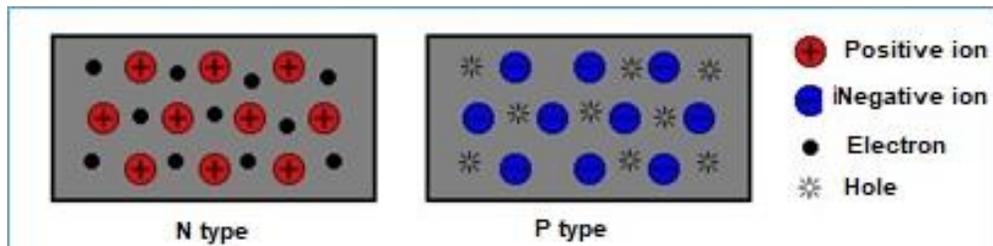


Figure 233 – Materials type N and type P.

When we combine semiconductor type p and type n, we can make phenomenal electronic components such as LED, diode, transistor, chip, etc.

The ideal diode

An **ideal component** is when it only has one operating parameter. For example, a capacitor, to be ideal, should have only capacitance. However, in practice, the theory is another In the capacitor, in addition to the capacitance, we

have a certain resistance and a certain associated inductance, making what the real capacitor is not the ideal.

The function of a **diode** is to control the direction of current flow. The diode allows current flow in only one direction, called a direct current. The current flowing in the reverse direction is blocked.

We use the ideal diode to facilitate our study and we can say:

- If the voltage across a diode is negative, i.e. reverse bias, no current will flow through it. An ideal diode would behave like an "open key."
- If the voltage across a diode is positive, i.e. direct bias, a current will flow through it. An ideal diode would behave like a "closed switch."

These two situations above could be represented by the graph of **figure 234**. A negative bias voltage produces a zero current, making the ideal diode behave with an open key.

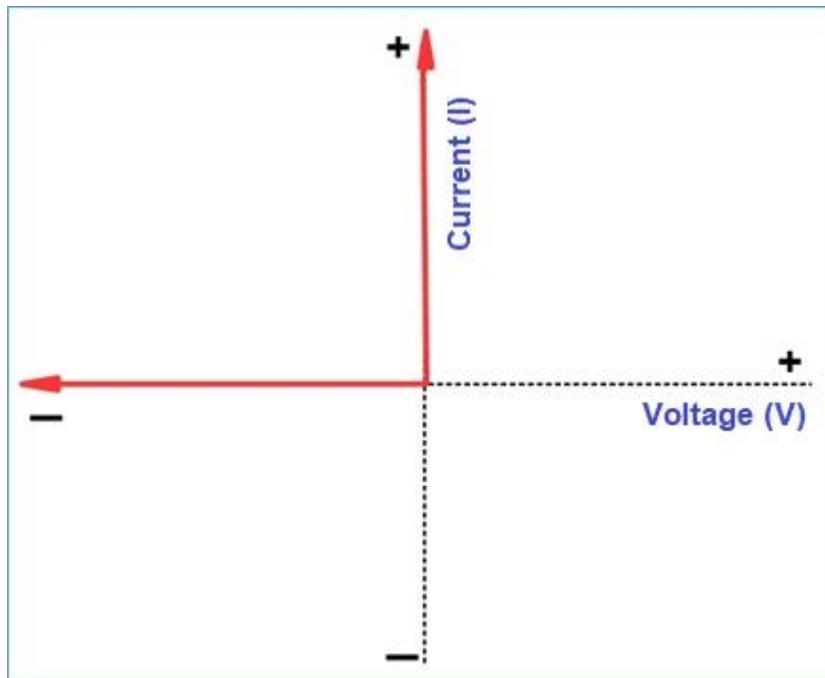


Figure 234 - Behavior of the ideal diode.

Typical diodes

A **diode** consists of a piece of n-type material and a piece of p-type material, joined together to form a **junction**.

Forward voltage (V_F)

The forward voltage, is the V_F .

For the diode to conduct a current in the direct direction, a certain minimum voltage must be applied to it. This typical voltage is called V_F . (F of "forward"). It is the voltage that "switches on" the diode.

The direct voltage V_F to a diode, depends mainly on the material used in its construction. For **Silicon** this voltage is approximately 0.6 V. For **Germanium** this voltage is approximately 0.3 V.

The LED, which is also a diode, may have a V_F greater than the 0.6 V of silicon. Schottky type diodes may have a lower V_R than germanium. V_R is the reverse voltage for a diode.

The V_R can be measured directly through a DMM that has a diode test Range, as shown in **figure 235**.

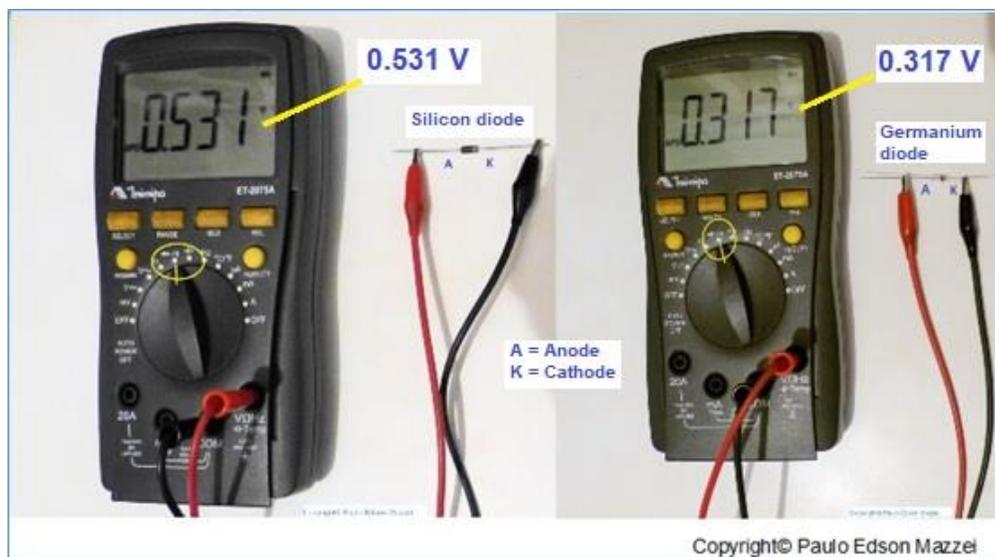


Figure 235 - Measurement of V_F in Silicon and Germanium diodes.

Breakdown voltage

The **breakdown voltage** of the diode, called a breakdown (V_{BR}).

If a large negative voltage is applied to the diode, it can allow a current in the reverse direction. This large negative voltage can be applied to the diode, it is called V_{BR} . Some diodes are specially made to work in these "dangerous" regions, but most diodes do not.

Diodes Data sheet

Data Sheet is the specification sheet for an electronic component. Since semiconductors often have many specifications, it is always interesting to know how to interpret some of them.

It is important to know that the Data Sheet you will find in books, magazines, and the Internet, for the most part, is in English.

In **figure 236** you will find the data sheet of silicon diode, type **1N4148**, a Ge diode, very popular among experimenters of electronic circuits.

Do not worry about the amount of data because not everyone is interested in the moment.

ELECTRICAL CHARACTERISTICS ($T_{amb} = 25\text{ }^{\circ}\text{C}$, unless otherwise specified)						
PARAMETER	TEST CONDITION	SYMBOL	MIN.	TYP.	MAX.	UNIT
Forward voltage	$I_F = 10\text{ mA}$	V_F			1000	mV
Reverse current	$V_R = 20\text{ V}$	I_R			25	nA
	$V_R = 20\text{ V}, T_J = 150\text{ }^{\circ}\text{C}$	I_R			50	μA
Reverse current	$V_R = 75\text{ V}$	I_R			5	μA
	$I_R = 100\text{ }\mu\text{A}, t_p/T = 0.01, t_p = 0.3\text{ ms}$	$V_{(BR)}$	100			V
Diode capacitance	$V_R = 0\text{ V}, f = 1\text{ MHz}, V_{HF} = 50\text{ mV}$	C_D			4	pF
Rectification efficiency	$V_{HF} = 2\text{ V}, f = 100\text{ MHz}$	η_r	45			%
Reverse recovery time	$I_F = I_R = 10\text{ mA}, i_R = 1\text{ mA}$	t_{rr}			8	ns
	$I_F = 10\text{ mA}, V_R = 6\text{ V}, i_R = 0.1 \times I_R, R_L = 100\text{ }\Omega$	t_{rr}			4	ns
ABSOLUTE MAXIMUM RATINGS ($T_{amb} = 25\text{ }^{\circ}\text{C}$, unless otherwise specified)						
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT		
Repetitive peak reverse voltage		V_{RRM}	100	V		
Reverse voltage		V_R	75	V		
Peak forward surge current	$t_p = 1\text{ }\mu\text{s}$	I_{FSM}	2	A		
Repetitive peak forward current		I_{FRM}	500	mA		
Forward continuous current		I_F	300	mA		
Average forward current	$V_R = 0$	$I_{F(AV)}$	150	mA		
Power dissipation	$l = 4\text{ mm}, T_L = 45\text{ }^{\circ}\text{C}$	P_{tot}	440	mW		
	$l = 4\text{ mm}, T_L \leq 25\text{ }^{\circ}\text{C}$	P_{tot}	500	mW		

Figure 236 - Data Sheet of Si Diode Model 1N4148

In the yellow horizontal line, we can see the **Direct Voltage** that can be applied to the diode that is 1 V (1000 mV). See the last two columns.

In the horizontal line, which has the red outline, we have the **collapse or breakdown voltage**, = 100 V.

The purple line shows which is the **Maximum Direct Current** that can circulate through the diode without damaging it. In the case of diode 1N4148, it is 300 mA.

The 1N4148 diode is one among thousands of diode types. In our electronics work, we usually work with diodes with medium voltages, but larger currents.

If we connect a small voltage to a diode, the current will flow in only one direction. In other words, the diode conducts in one direction and does not conduct in the other direction. This characteristic of diodes is extremely important for the construction of other semiconductors and uses in the most varied electronic circuits. For example, we can use a semiconductor diode to protect an electronic circuit against reverse polarity of a battery, which could damage every circuit. See **figure 237**.

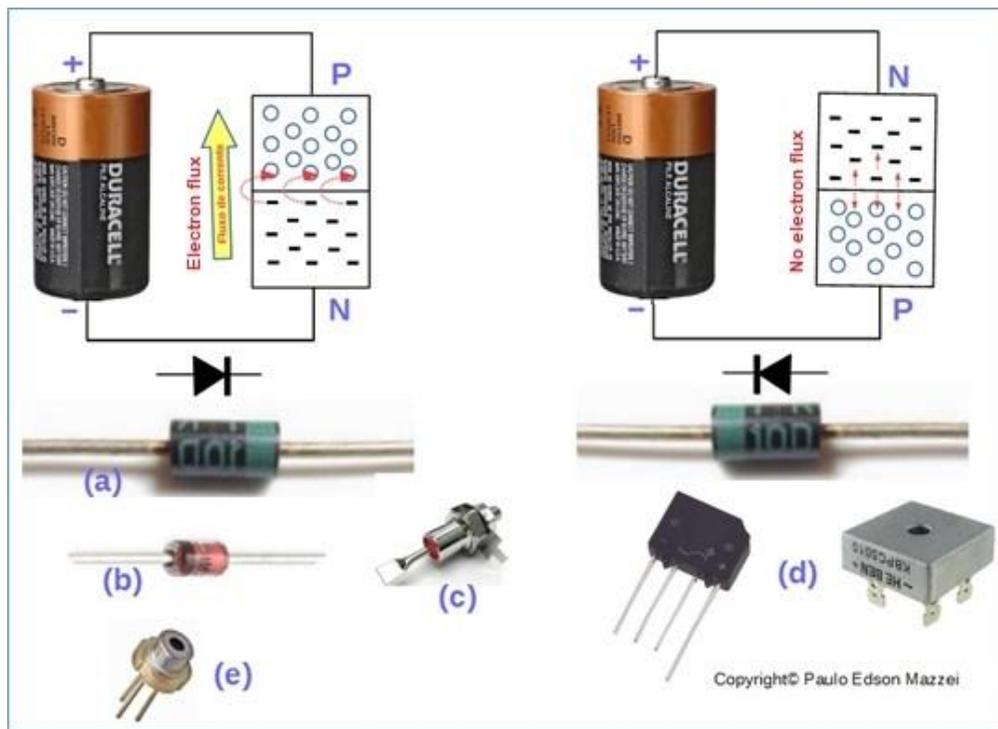


Figure 237 - PN diode operation and basic diode types.

Look at Figure 237:

- a)** Common rectifier diode. Blue band is the cathode.
- b)** Signal diode, glass encasement. Black band is the cathode.
- c)** High current rectifier diode.

d) Rectifying bridges - 4 diodes connected in a bridge inside the housing.

e) Photo diode - Note the "little window" at the top, for light input.

The diodes can be destroyed from excessive circular current by them when in direct or inverse operation. See **figure 238**.

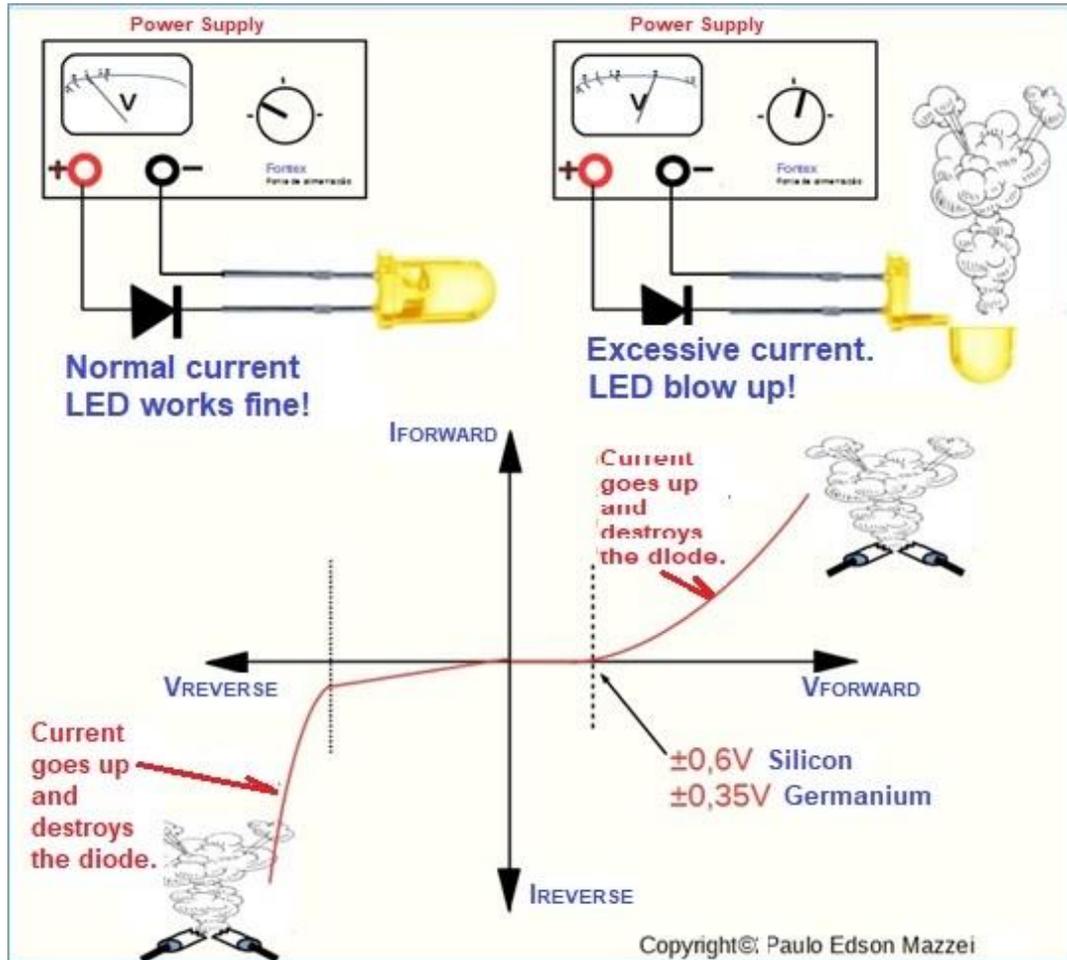


Figure 238 - If the forward or reverse currents go up too high, the diode will be destroyed.

Other types of diodes

The LED: are special diodes that provide light when they lead in the right direction. LEDs are widely used in electronic circuits. They are used as small lamps, they have great durability, can be found in various colors, etc.

The zener diode: are diodes used to stabilize voltages, in small powers. There are zener diodes for this few volts, up to tens of laps. Its format is generally the same as shown in (b) of **figure 237**

The photodiode: is the opposite of the LED, when they receive light their junction provides a small electrical current. These diodes are shaped somewhat differently from the others as their junction is exposed, protected by a clear plastic wrap. See (e) of **figure 237**.

Application of diodes.

Before we proceed, let's have a few words about the direction of the electric current. Where does it come from and where does it go?

You can find books, magazines and articles on the Internet, which use different meaning than we use here. To avoid confusion, in the studies of diodes and transistors, we will clarify.

An electric current is the movement of electrons in a given direction, through a conductor or semiconductor.

Since the electrons move from a negatively charged region to a positively charged region, why does the arrow drawn in the yes graphic cake of a diode point in the opposite direction to it? Basically, there are two reasons for this;

1. Since Benjamin Franklin, it was traditionally assumed that the electric current moves from a positively charged region to a negatively charged region. The discovery of the electron has changed this thinking. However, many circuits drawn today still use this old thought and so are drawn.

2. In a semiconductor, the "holes" travel in a direction opposite to the electron flow. Thus, it is common to refer to "positive current flow" in a semiconductor.

In this eBook, we will use the current flow direction of the electrons, that is, from the negative pole of a battery to the positive pole of the same, through the circuit.

Further on in this eBook, we will see that there are more types of diodes we will use in our experiments.

At present, two applications are very important to us, using small signal diodes and rectifying diodes. See **figure 239**.

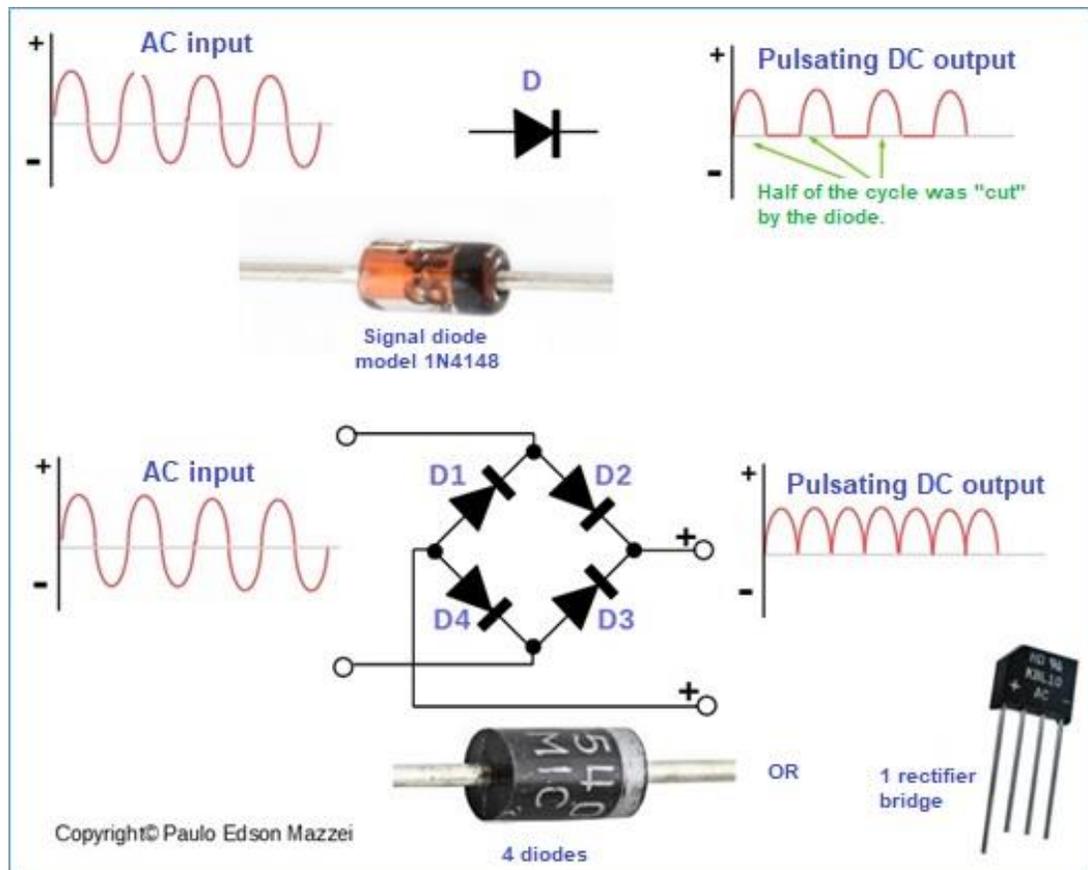


Figure 239 - Application of diodes. (a) detector circuit and (b) rectifier circuit.

Note in figure 239:

- The circuit shown in (a) is a **detector circuit**, used in radio receivers, TV, etc. It "rectifies" the AC voltage and the output thereof is a "pulsating" DC voltage. Values only vary above axis zero. And it's not pure DC.

- The circuit shown in (b) is a **full-wave rectifier circuit**, mainly used in power supplies. It also rectifies the AC voltage / current and converts it into a pulsating DC, but with twice the circuit pulses (a). Values only vary above axis zero. It's not a pure DC yet. Note that instead of using four diodes we can use a rectifier bridge, which internally already has the four diodes interconnected. In the body of the rectifier bridge is marked the AC input (AC) and the outputs plus (+) and minus (-).

Types of diodes

Signal Diodes

Signal diodes, such as model 1N4148, work with small amplitude signals, and require low voltages and currents to operate.

Note from **figure 240**, that the enclosure of these diodes is made of glass.

Power Rectifier Diodes

These types of diodes are widely used in power supplies, in the processing from turning the AC into DC (**rectifying**).

One series of these diodes, known for their versatility, are the diodes of the 1N4000 series. They are diodes that have the epoxy body (sometimes glass), for currents of 1 A.

The first diode in this series is the 1N4001. The last digit indicates the maximum working reverse voltage. The digit "1", in this case equals a voltage of 100 VDC.



Figure 240 – Types of diodes.

LEDs

The **Light Emitting Diode**, known by everyone as **LED**, is very popular and almost has no electronic circuit where it is not used! Who does not like to see a "little light" flashing?

Like the diodes discussed, the LED allows the current to flow in only one direction.

In our experiments and assemblies, we used LEDs in some models, as shown examples in figure 241.

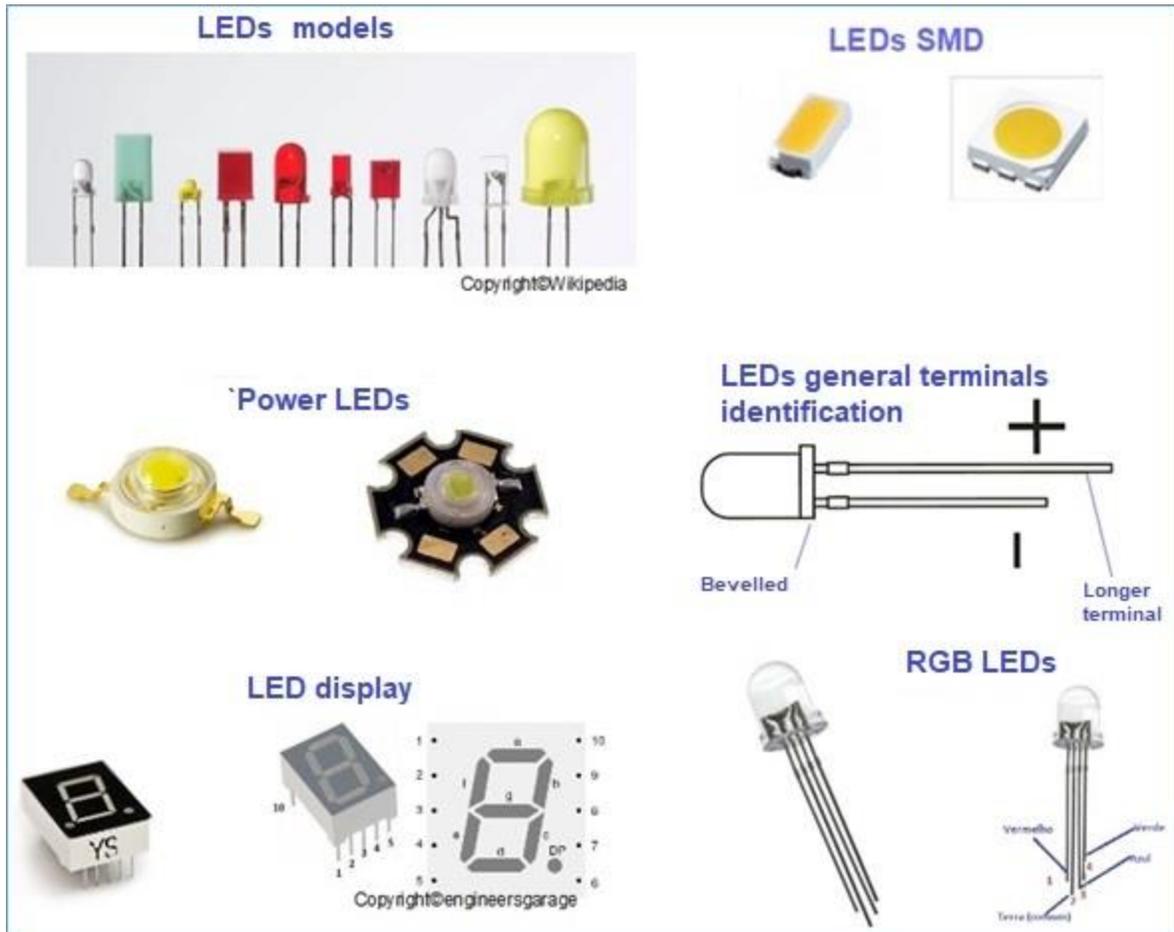


Figure 241 Some types of LEDs and displays.

Zener diodes

The zener diodes are made to conduct a reverse current, unlike ordinary diodes.

Zener diodes are used as reference voltage and voltage stylizers in electronic circuits. These diodes are made for various zener voltages, going from a few volts to tens of volts.

In the circuit of **figure. 242** we can see the zener diode acting as a reference diode in the 3.3 V voltage. See also the zener symbol.

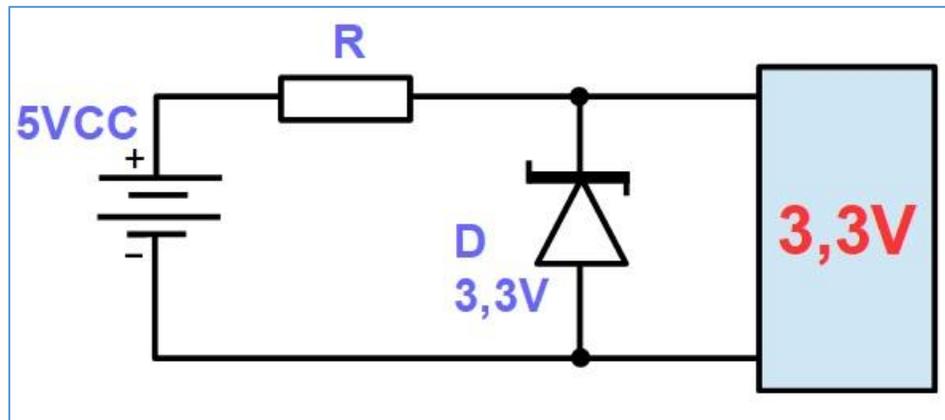


Figure 242 - Zener diode working as reference voltage at 3.3 V.

Diodes applications

The diode seems to be a very simple component, but it has a huge range of applications in electronic circuits.

Rectifier circuit

A rectifier is a circuit that converts AC to DC (almost). You already know that electronic circuits work with DC. In this way, since we have only AC - Alternating Current in our homes, we need to do this AC - DC conversion.

Here comes the famous diode to help us with a **rectifier circuit** that can be **half-wave rectifier** or **full-wave rectifier**. See **figure 243** for rectifier circuits.

In this figure, the left, we have a half wave rectifier and the right one full wave rectifier.

The half-wave rectifier "**rectifies**" only half a wave of the AC voltage, producing in the load (output) the half-wave blue waveform. The full-wave rectifier rectifies the entire wave, producing in the output a voltage more like DC, but is not yet pure DC, which can be used in electronic circuits. It's a **pulsating DC**.

The important thing is that we now have an output voltage ranging from zero to a certain positive value, without inverting the polarity, as it was in AC.

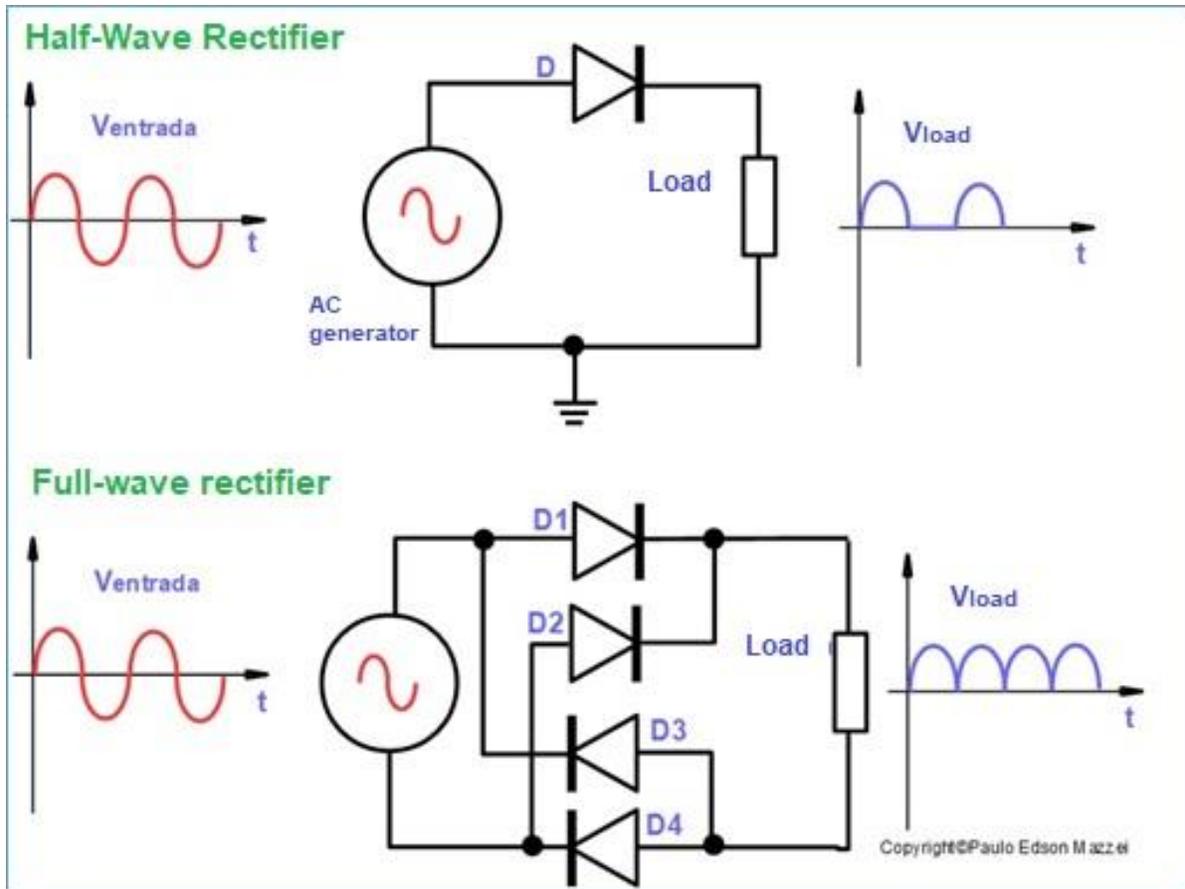


Figure 243 - Half wave and full wave rectifier circuits.

See **figure 244** for a wall battery charger, which uses four rectifier diodes and a few other components. This is the type of charger you use on your cell phone, tablet, experiments, etc.

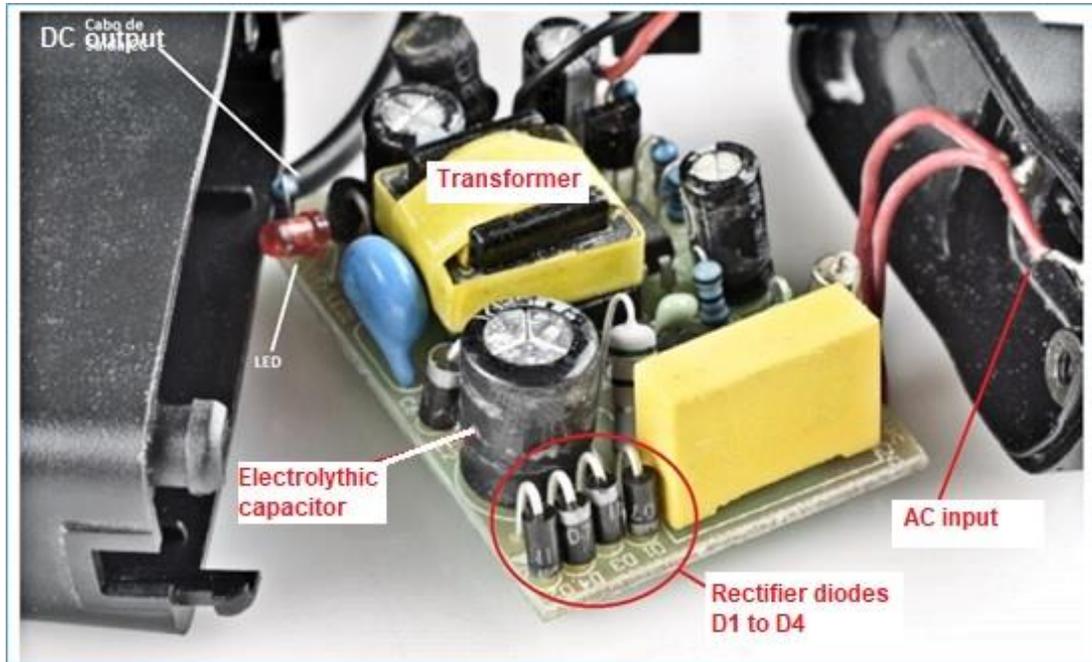


Figure 244 - Internal components of a cellular battery charger. Courtesy SparkFun Electronics.

Reverse polarity protection circuit

Who has not connected an inverted battery, shoot the first stone!!

For lack of knowledge or carelessness, we sometimes burn an electronic device because we connected an inverted battery.

Power supplies or battery chargers often have this protection against reverse polarity, since many users are lazy and can lead to disastrous results. You can put this protection on your devices with few components. See a basic circuit in Figure 217 and search the Internet for more circuits.

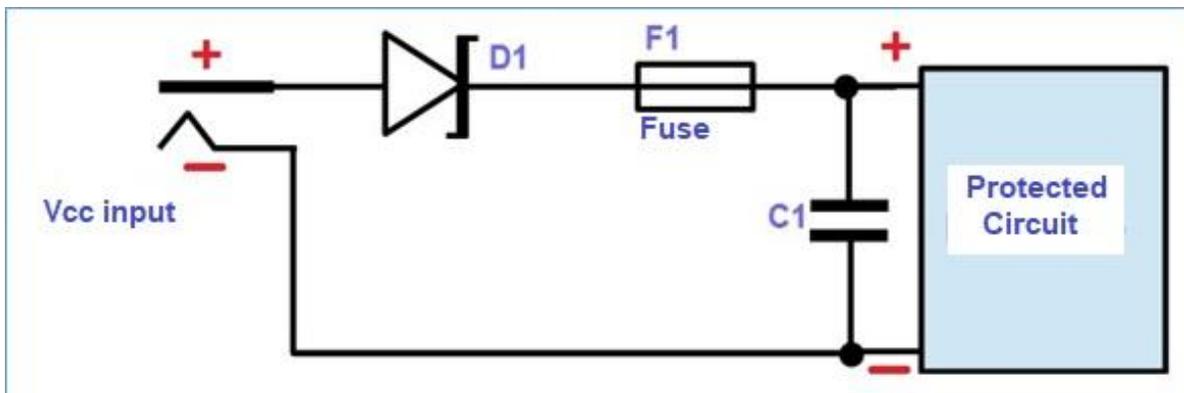


Figure 244- Protection circuit against reverse polarity.

The zener diode ensures that the load or protected circuit always has the correct polarity, preventing current flow if the polarity is reversed. The fuse protects against possible power surges.

Surge suppressor circuit

Diodes can be used to suppress voltage peaks in certain circuits. See **figure 245**.

TVS = Transient Voltage Suppression, are high power diodes built to suppress transients (surges, voltage surges). They absorb the high energy voltage peaks protecting the motor, in the case of **figure 245**.

This transient suppressor application, over time, causes the diode to wear out, requiring replacement.

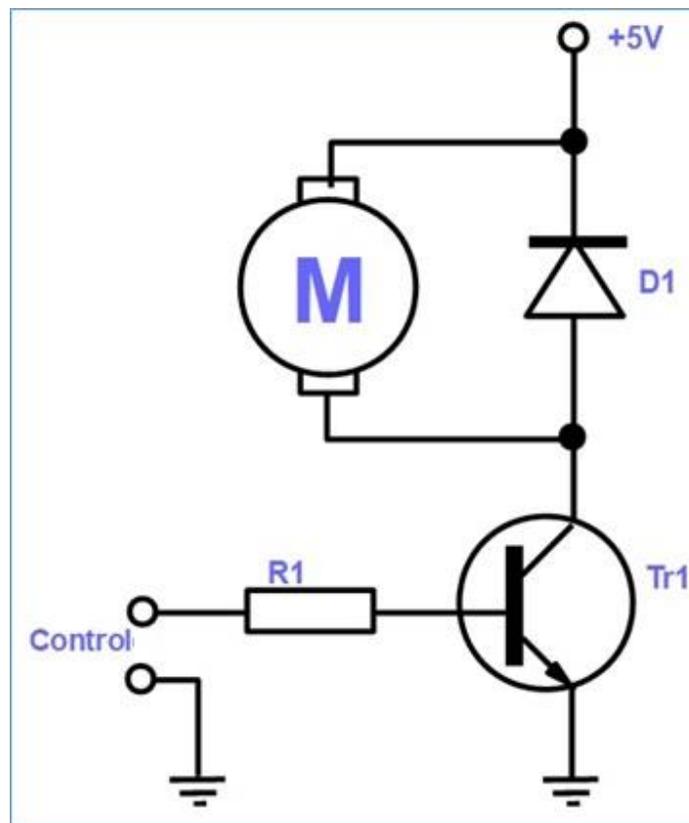


Figure 245 - Surge suppressor circuit in a motor.

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Chapter 31

LEDs

Introduction

As I asked in the chapter on diodes: who does not like to see "lights" turning on or flashing? And those panels of special ships that we see in the cinema, full of lights of all colors? Nice effect, is not it?

As the application of LEDs in electronic circuits is increasing, we have decided to include a chapter only about them.

LEDs are the Light Emitting Diodes, that is, when an electric current flow through one of them, it will light, as long as this current is in the correct direction.

The basics about LEDs

Graphic symbol and physical format

In the chapter on diodes we have already analyzed the LED, symbols, polarity and physical format, which are gathered in **figure 246**.

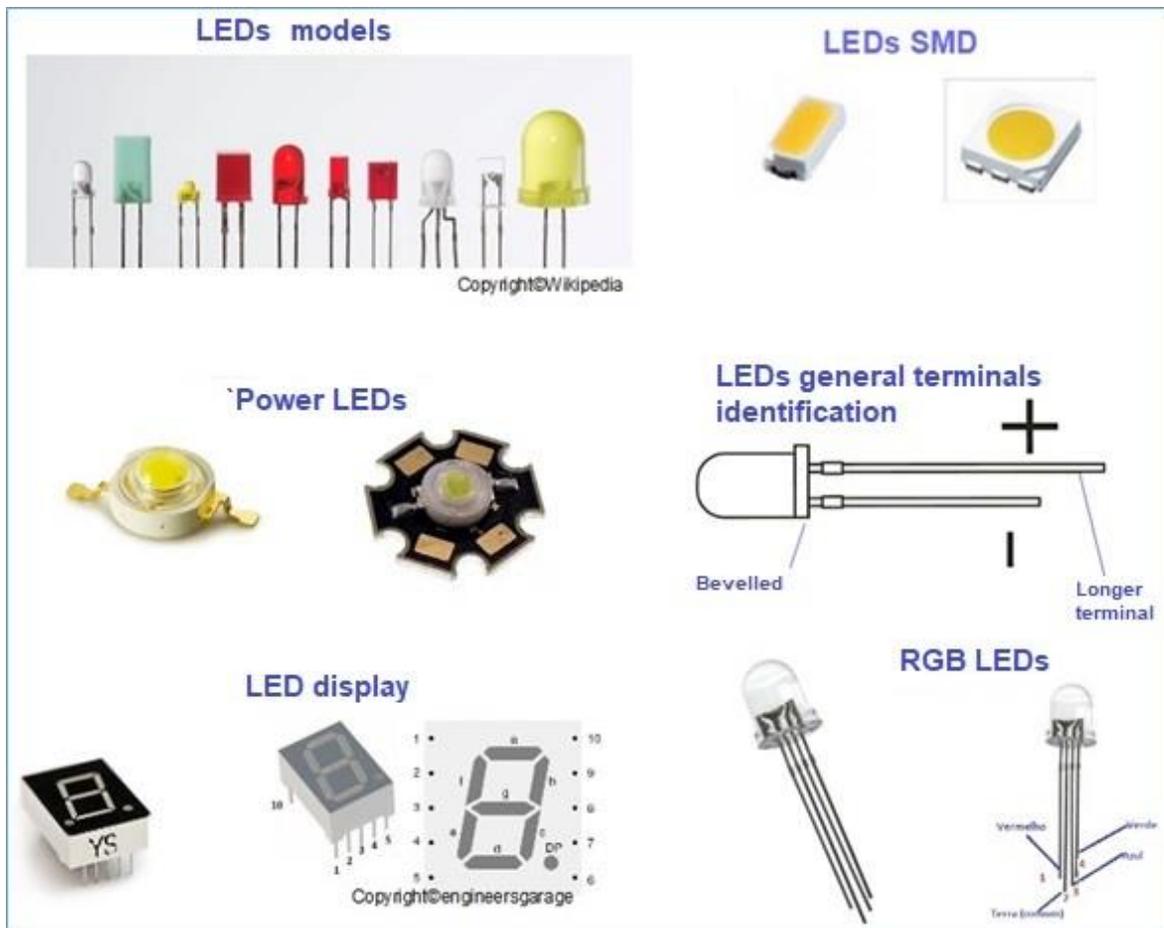


Figure 246 - LEDs, symbols, identification, physical formats.

How to use LEDs

As we have seen previously, when we analyze the use of resistors, we have seen with these components can be used in circuits with LED, to limit the current that flows through it. High currents circulating by an LED ~ will irreparably damage it.

- The LED is a component known as "non-ohmic". This means that it does not apply to Ohm's Law and its variations.

- The LED is also an electronic component that operates at low voltages, about 1.5 to 1.8 V, on simple models. Therefore, we cannot apply directly to it a voltage or voltage of 9V. If we do this, an electric current will circulate greater than the LED supports and it will be damaged!

- In order to avoid the above, we need to put in series with the LED a protective resistor that will limit the circulation of electrical current and prevent its destruction.

■ An ordinary 5 mm LED has an operating current of about 18 mA (18 mA = 0.018 A). Our current limiting resistor has to make sure this happens.

■ If we connected the LED directly to the 9 V battery, we would have the current would be:

$$I = V / R \rightarrow I = 9/0 \rightarrow I = \infty \text{ (infinitely large)}$$

Please, look at **figure 247**

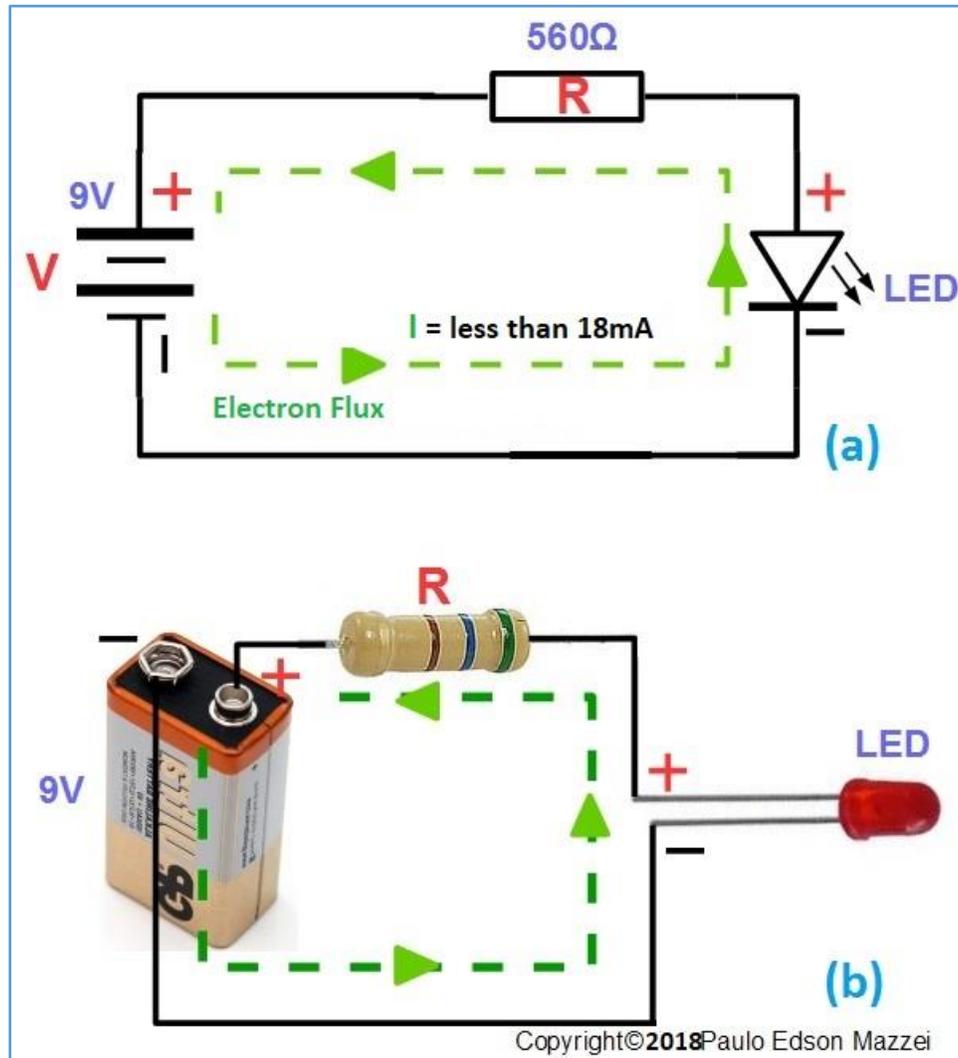


Figure 247 - Calculation of the limiting resistor of the LED circuit.

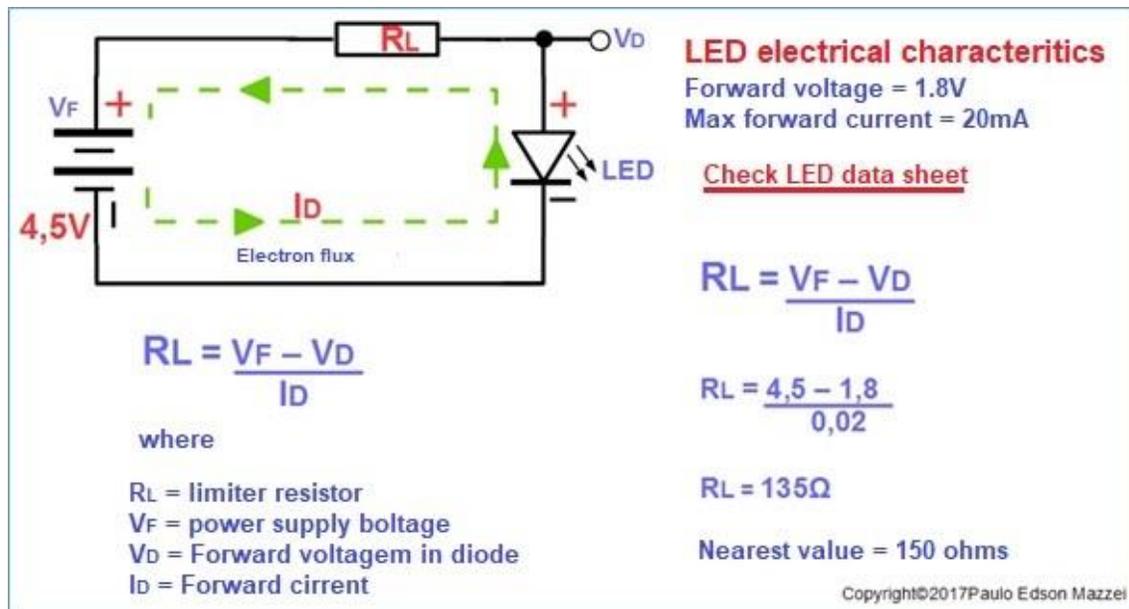


Figure 248 - Calculation of the limiting resistor, with new battery voltage.

The current in a LED

By the Data Sheet of an LED you can find its working current without damaging it. See table in **figure 249**.

ITEMS	Symbol	Absolute Maximum Rating	Unit	
Forward Current	I_F	20	mA	Corrente Direta
Peak Forward Current	I_{FP}	30	mA	Picos e corrente que o LED suporta
Suggestion Using Current	I_{su}	16-18	mA	Corrente sugerida
Reverse Voltage ($V_R=5V$)	I_R	10	uA	
Power Dissipation	P_D	105	mW	Pouco mW dissipados
Operation Temperature	T_{OPR}	-40 ~ 85	°C	
Storage Temperature	T_{STG}	-40 ~ 100	°C	
Lead Soldering Temperature	T_{SOL}	Max. 260°C for 3 Sec. Max. (3mm from the base of the epoxy bulb)		

Figure 249 – Common LED data sheet.

The voltage in a LED

Another table, within the Data Sheet of our LED, shows the following, in **figure 250**.

ITEMS	Symbol	Test condition	Min.	Typ.	Max.	Unit	
Forward Voltage	V_f	$I_f=20\text{mA}$	1.8	---	2.2	V	Queda de voltagem no LED
Wavelength (nm) or TC(k)	$\Delta \lambda$	$I_f=20\text{mA}$	620	---	625	nm	Comprimento de onda da luz
*Luminous intensity	I_v	$I_f=20\text{mA}$	150	---	200	mcd	Intensidade da luminosidade

Figure 250 – Another data sheet table.

Types of LEDs

RGB LEDs

RGB means Red - Green - Blue, that is, Red - Green - Blue. In fact, we have LEDs in one package!

Most RGB LEDs have four pins: one for each color and a common pin for the three colors.

Flashing LEDs

These LEDs have an internally integrated circuit, which causes it to "blink" without the need for an external circuit. There are also RGB, Flashing-type LEDs that produce thousands of colors.

SMD LEDs

The SMD envelop LEDs are usually normal LEDs, only shown in the SMD package. On the board of the Arduino and Redboard, you will find some.

High Power LEDs

High power LEDs, such as those produced by CREE® and Luxeon®, are great for luminaire, outdoor, residential lighting, etc. projects. Usually an LED is considered high power when it dissipates more than 1 W.

These LEDs are used in automotive flashlights and in a hundred more applications.

It is important to note that these power LEDs dissipate a lot of heat and then are mounted on an aluminum heat sink. Sometimes several LEDs are mounted on the same heatsink and some cooled with forced ventilation.

Special LEDs

On the remote control of your TV you use a special LED to send the command from the remote control to the TV.

Many of these LEDs work with wavelength colors invisible to the human eye, such as UV.

The physical formats of the types of LEDs we describe are found in **figure 251**.

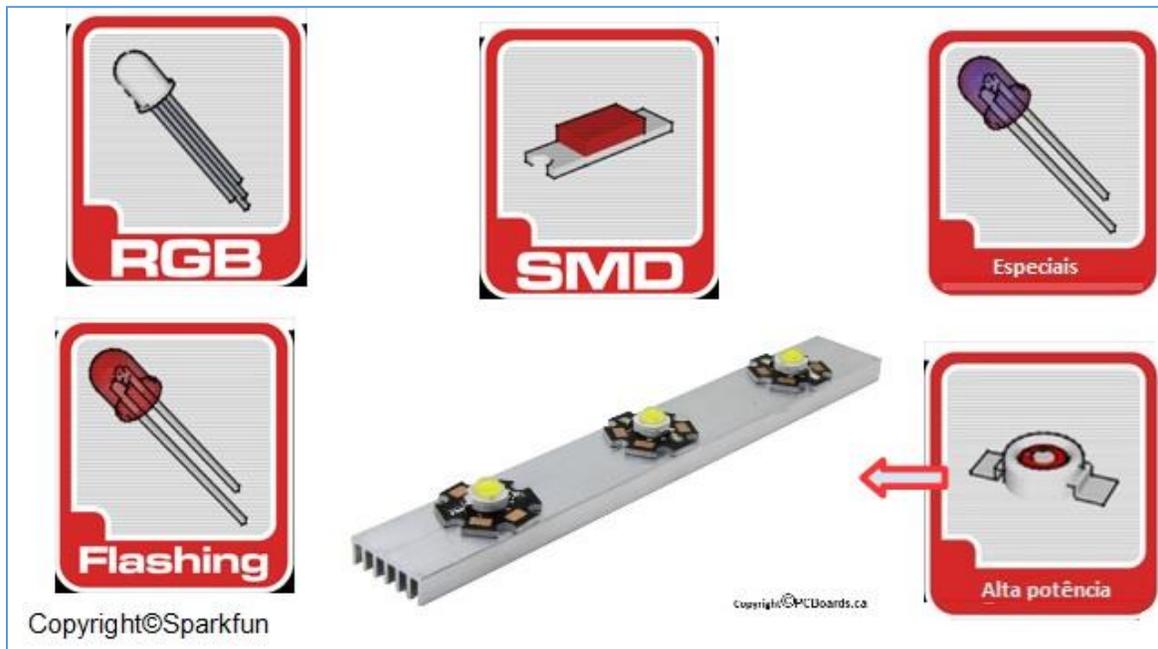


Figure 251 – Types of LEDs.

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Chapter 32

Bipolar Transistors

Introduction

Transistors are found in virtually every electronic equipment like watches, radios, tablets, smartphones, computers, etc. For example, the Pentium® chip has internally more than one million transistors.

Transistors in their simplest form is an electronic semiconductor component with three terminals. A small current applied to the input of the transistor, can control a large electric current in its output.

Basically, the transistors work in two ways:

- As switches (keys), turning on and off the current flow and
- As amplifiers, making small electrical signals larger than they originally were.

Physically, transistors are "sandwiches" of three pieces of semiconductor material type N or P. With this, we now have two joints and not one as the case of the diode.

Objectives

- The importance of transistors and their operation.
- Physical formats and symbology.
- Basic switching and amplification applications.

Transistors: the basics

For our study and practical experiments, transistors are divided into two types:

- Bipolar transistors
- Field Effect Transistor (FET).

These two junctions form the PNP and NPN transistors: the central layer (ham) is called the **base**, the other two layers (bread slices of the sandwich) are called **collector** and **emitter**.

The NPN transistor is most commonly used in most of our electronic assembly projects.

In the NPN transistor the electrons enter by the base and exit by the collector. Note that we use the conventional electric current here, which is an imaginary electron flow. This conventional current is opposite toward the current of electrons.

Note now you can see how a transistor acts as a switch on and off: a small applied voltage base (between base and emitter) "turns on" the transistor, allowing a current flow at the output of the transistor (between collector and emitter). Note that the sender is a common point of entry and exit. See **figure 252**.

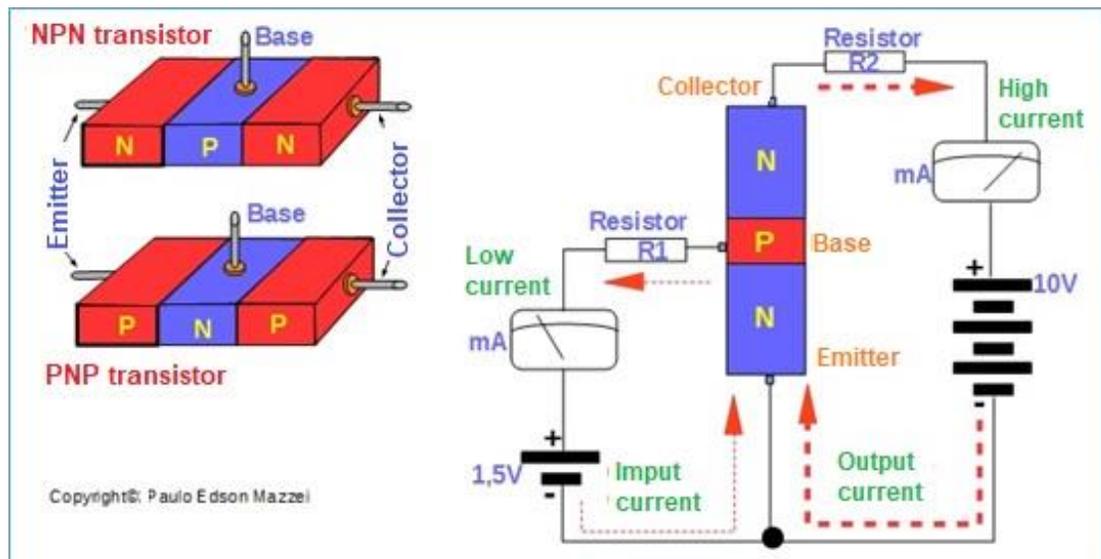


Figure 252- Transistor operation.

The transistors and diodes have their code (type) printed on the body itself. For voltage, current, applications, etc., see a databook or the manufacturer on the Internet.

Factors common to diodes and transistors. Watch:

▶ The base-emitter junction of the transistor or the junction of the diode, both silicon, only started to drive after attention applied to it, is greater than 0.6 V. For germanium, greater than $\pm 0,35$ V.

▶ If too much current flows through a transistor, the material heats up and the transistor can be destroyed. Some functional transistors attached to heat sinks.

▶ Types of transistors. If you search the Internet, you will find a huge variety of transistor types. But they can be classified into some types. See **figure 253**.

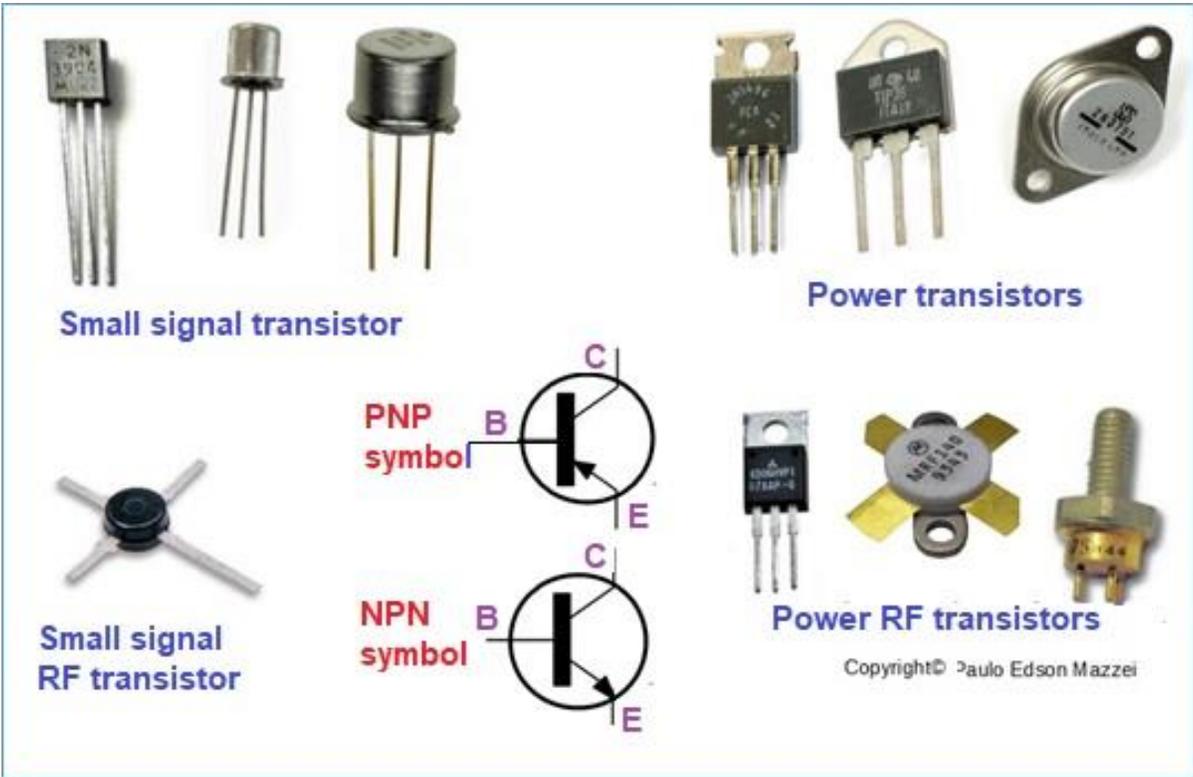


Figure 253 – Types of transistors.

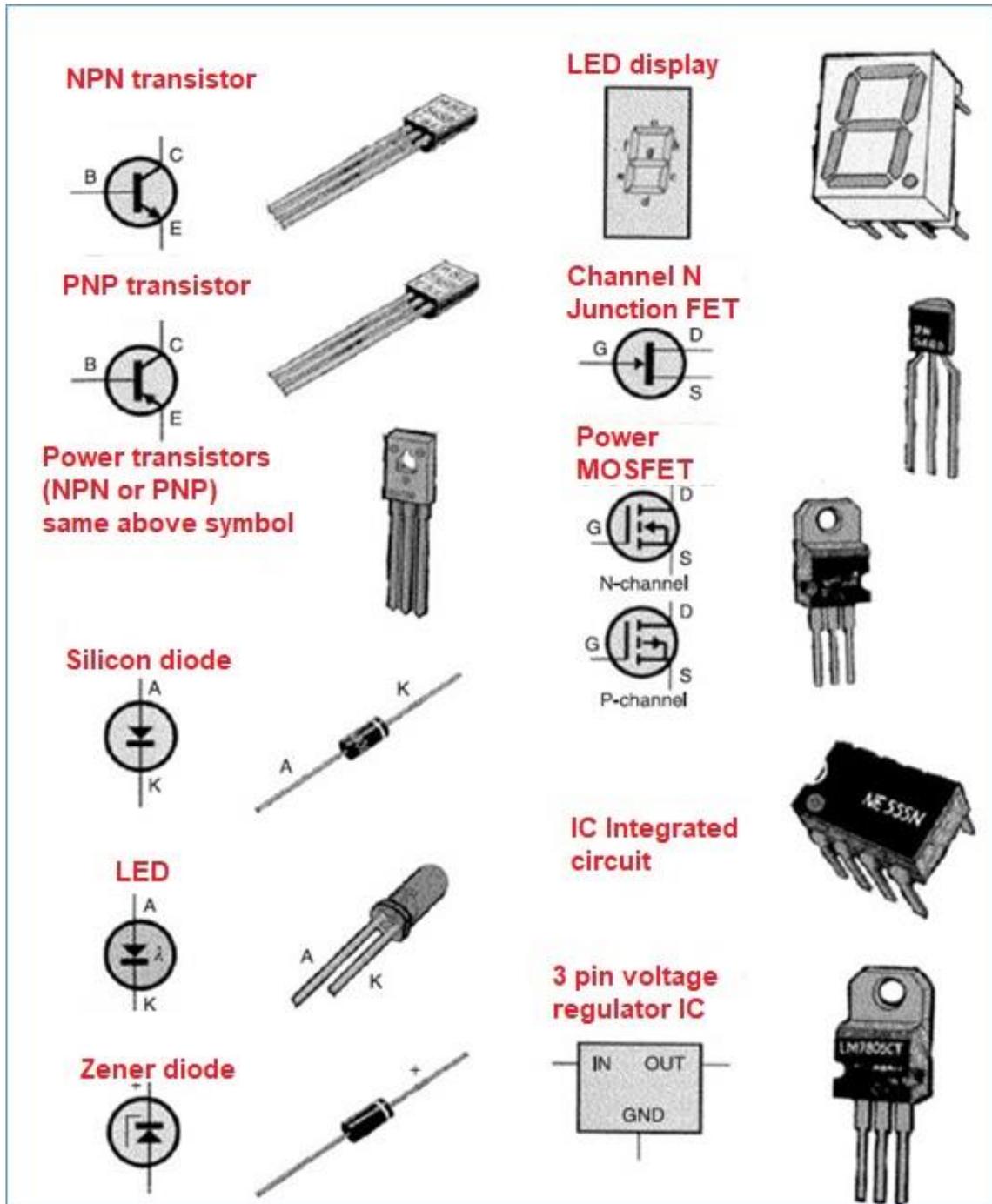


Figure 254 - Diodes, transistors and integrated circuits. Courtesy MadLab Org – UK

How bipolar transistors are used

Refer to **figure 255** and note:

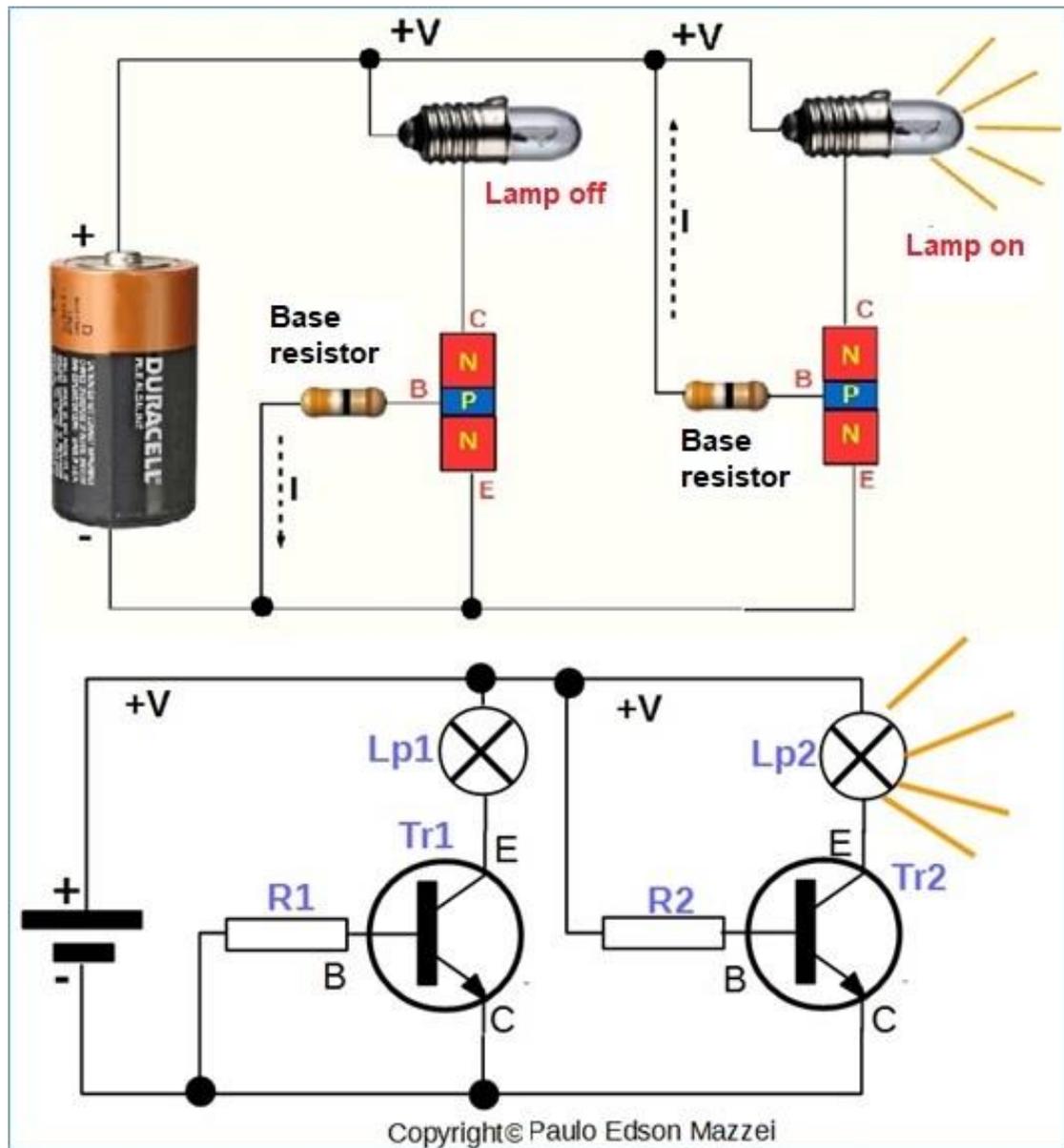


Figure 255 - Transistor configuration as key.

- If the base of a transistor is grounded (common circuit point, -), no current flows from the emitter to the collector. We say the transistor is "off." This condition is shown for transistor Tr1 in the figure.
- However, if the base is directly polarized, with a minimum of 0.6 V, a current will flow from the emitter to the collector. We say that the transistor is "on". This condition is shown for transistor Tr2 in the figure.

- The resistors R1 and R2, are the resistors of the bases of Tr1 and Tr2, respectively.

- Note the graphic symbol for the lamps, Lp1 and Lp2.

- Under the conditions described above, and simplified, the transistor will be operating as a "switch". This application is very important for our study and in the experiments, we will return to it.

- The value of R1 and R2 is around 5 K Ω to 10k Ω .

The transistor also operates as an "amplifier", which is also important for our study and in the experiments, we will go back to it. See **figure 256**.

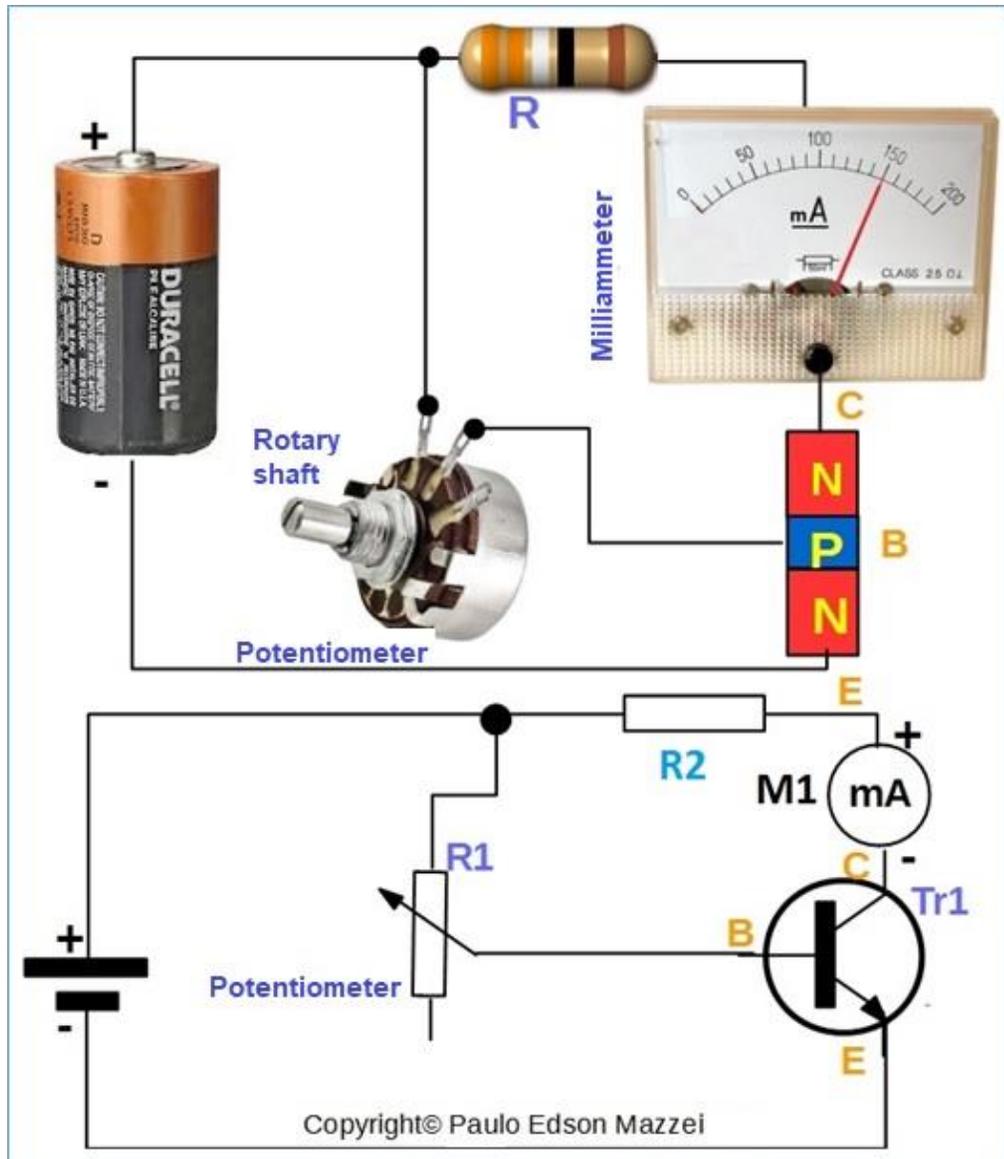


Figure 256 - Transistor as a DC amplifier.

Referring to figure 256, please note:

- ▶ The transistor is working as **DC amplifier**. It is used for signals that do not vary rapidly.
- ▶ Potentiometer R1, polarizes transistor Tr1 and controls base / emitter current. The meter (milliammeter DC) measures the current flowing between collector and emitter.
- ▶ The R2 resistor, in series with the M1 meter, protects against excessive currents.

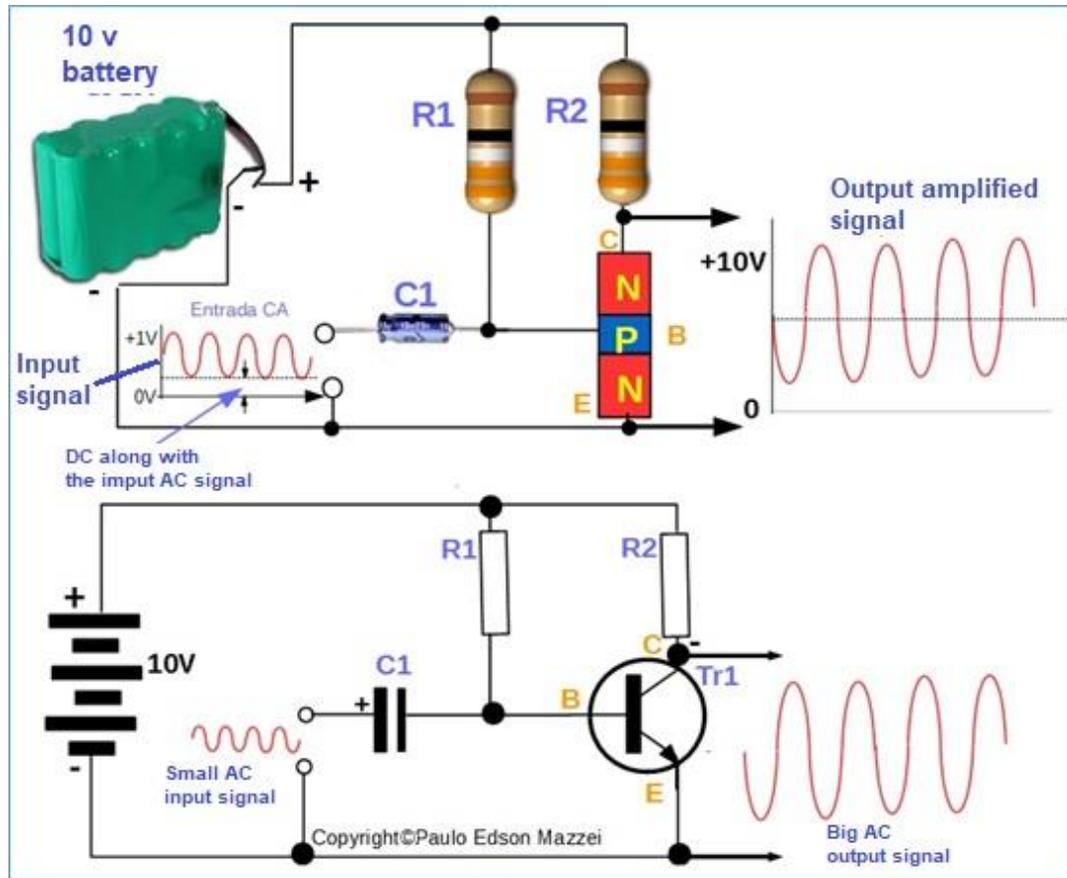


Figure 257 - Transistor as AC amplifier.

For signals that vary over time, such as sinusoidal signals, the transistor can work as an ac amplifier. Please see **figure 257**.

Please refer to **figure 257**:

- The transistor is working as an AC amplifier.
- Capacitor C1, which is an electrolytic capacitor, blocks all DC signals at the input.
- The output signal is inverted relative to the input signal. See **figure 257** drawing.
- R1, which is the polarization resistor of the base is selected so that the voltage is half the voltage of the 10 V battery.
- R2 is the load resistor connected to the Tr1 collector.

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Chapter 33

Field Effect Transistor – FET

Introduction

Field Effect Transistor (FET) transistors are easier to produce than bipolar transistors, and less silicon in their construction.

There are two types of FET:

1. Junction FET and
2. MOS FET (MOS = Metal Oxide Semiconductor = metal oxide semiconductor).

Objectives

- Familiarize yourself with the important FETs.
- Physical construction and symbology.
- Basic circuits and applications.

The Junction FET

The two main categories of junction FETs are the **N-channel** and the **P-channel**. Please refer to **figure 258**.

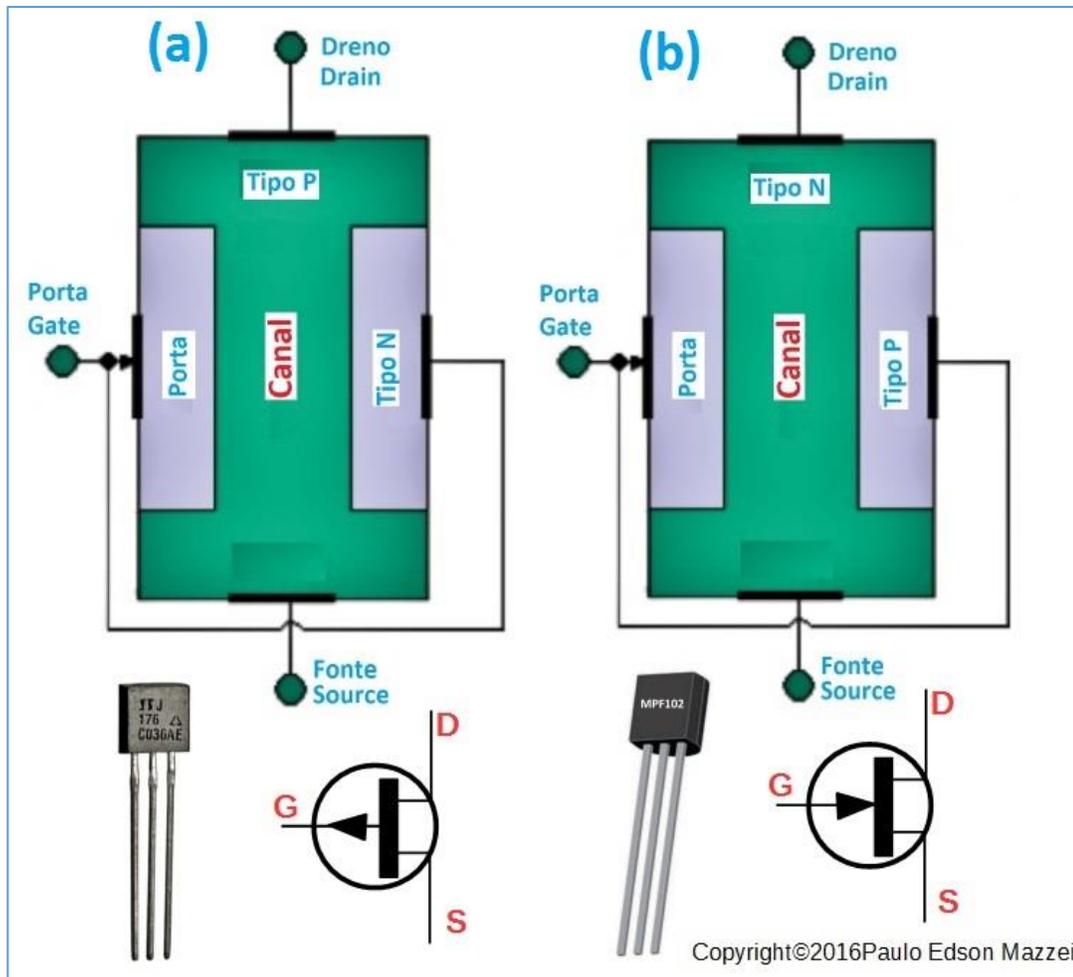


Figure 258 - FET junction transistors, P (a) channel and N (b) channel.

Figure 259 shows the following important points regarding junction FETs:

- The FET channel behaves as a resistance to the current from the source to the drain, depending on the voltage applied to the gate.
- The FET can work as a key or an amplifier, such as the bipolar transistor.
- All FET transistors must be treated with care because some are destroyed by static electricity that can accumulate in our hands (when picking up) or tools. Use a piece of steel wool attached to the terminals to avoid this problem. Only remove after mounting.

Operation of the Junction FETs

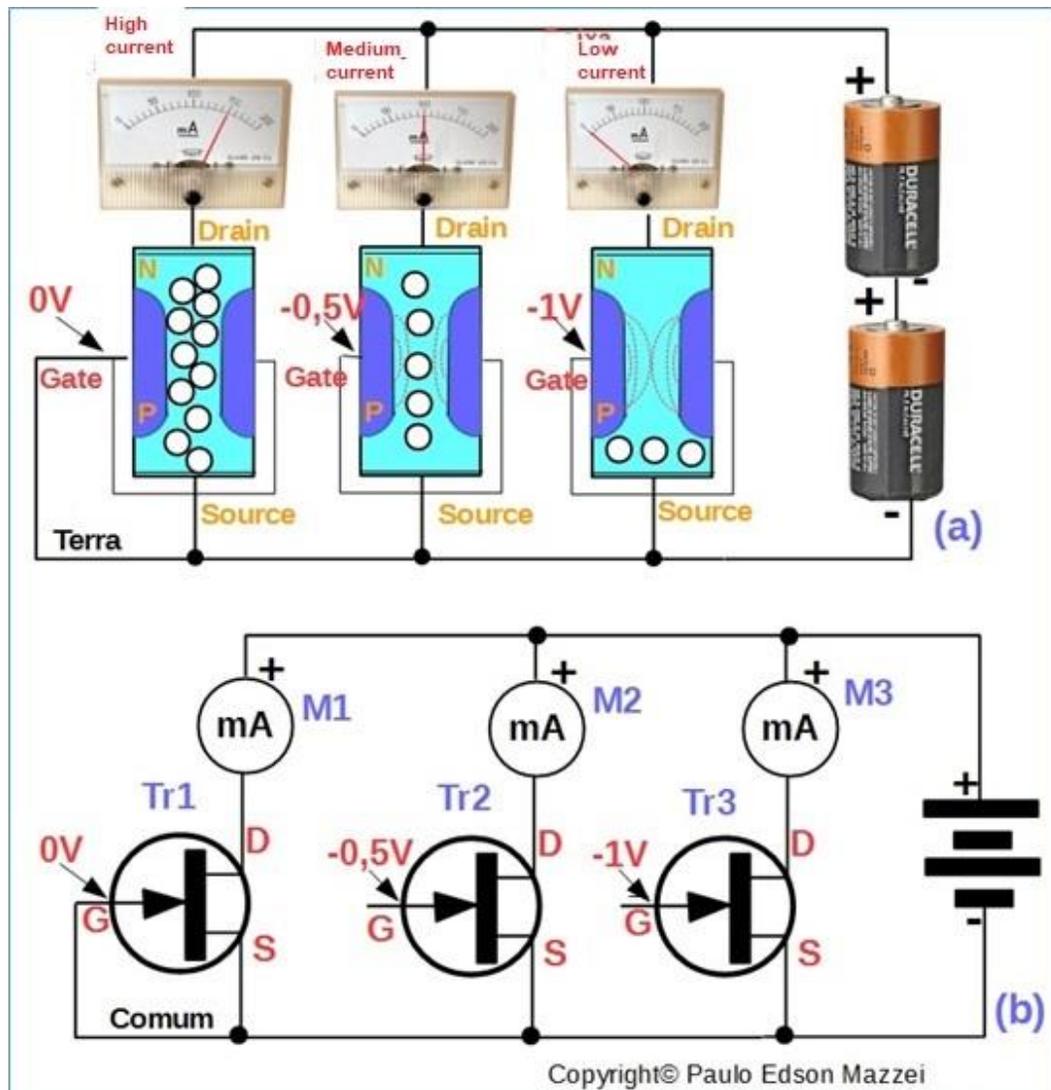


Figure 259 - Polarizations of a junction FET.

Let's look at Figure 259 and verify the following facts regarding the polarization of a junction FET:

- ▶ The figure shows three junction FETs connected in the same way.
- ▶ Note that the gates of the three FETs have different polarization voltages, so you can understand what happens with each of the polarizations.
- ▶ The negative voltages that are applied to the gates, create a certain "resistance" (fields), the passage of the electric current. This occurs in the FET channel, between the two Gate regions. Note that the two gate regions in each FET are interconnected, but externally the FET has only one terminal for the gate.

▶ In the last FET on the right, a higher voltage was applied to the gates and the fields created (resistors) were large enough to mix and virtually impede the passage of the electric current (electron flow).

▶ Because FETs are voltage controlled rather than current controlled devices like bipolar transistors, FETs have enormous advantages in many applications.

▶ Like bipolar transistors, FETs can be destroyed by excessive currents and voltages.

The MOS FET

The **MOS FET** is a metal oxide semiconductor (Metal Oxide Semiconductor).

MOSFETs are highly used devices in computer circuits and memories. Thousands of MOSFETs are mounted on a one chip forming the memories that are attached to memory cards in microcomputers.

MOSFETs are cheaper to produce, small and some types of MOSFETs consume very little energy.

The internal construction of a MOSFET is different from a junction FET, as shown in **figure 260**.

- (a) Construction of a MOSFET.
- (b) Circuit using MOSFETS and real components.
- (c) Circuit with graphic symbology.
- (d) Graphic symbols of MOSFET P and MOSFET N
- (e) Examples of MOSFET involvement.

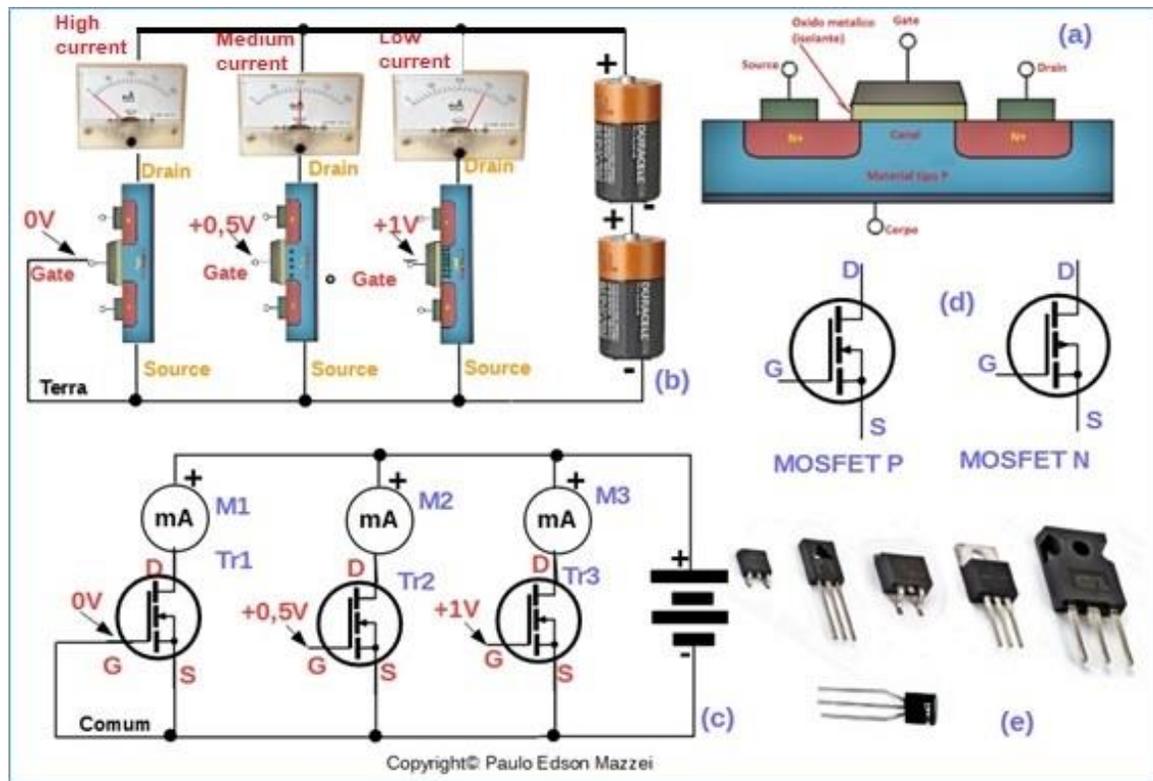


Figure 260 – MOSFETs.

Some uses for FETs and MOSFETs

- (a) FET and MOSFET can be used as amplifiers, switches and variable resistor with voltage. **Figure 261** shows three practical applications for these semiconductors.
- (b) This simple circuit is an "electrometer", which detects the presence of negative charges in a material. A plastic comb that was passed through the hair acquired a negative electrostatic charge. If this comb is approached from the MOSFET gate, the analog measurement signals a variation in the current being measured.
- (c) Lamp driver with MOSFET is shown in (b). This circuit is a typical example of how a MOSFET can be used as a switch to turn the lamp on and off. Ch is a normally open pressure switch. When pressed, Ch closes the contacts.
- (d) A "dimmer" is shown on this circuit. The variation of the resistance of the potentiometer R, makes the brightness of the lamp vary. Note that in reality, the entire circuit functions as a "variable resistor".

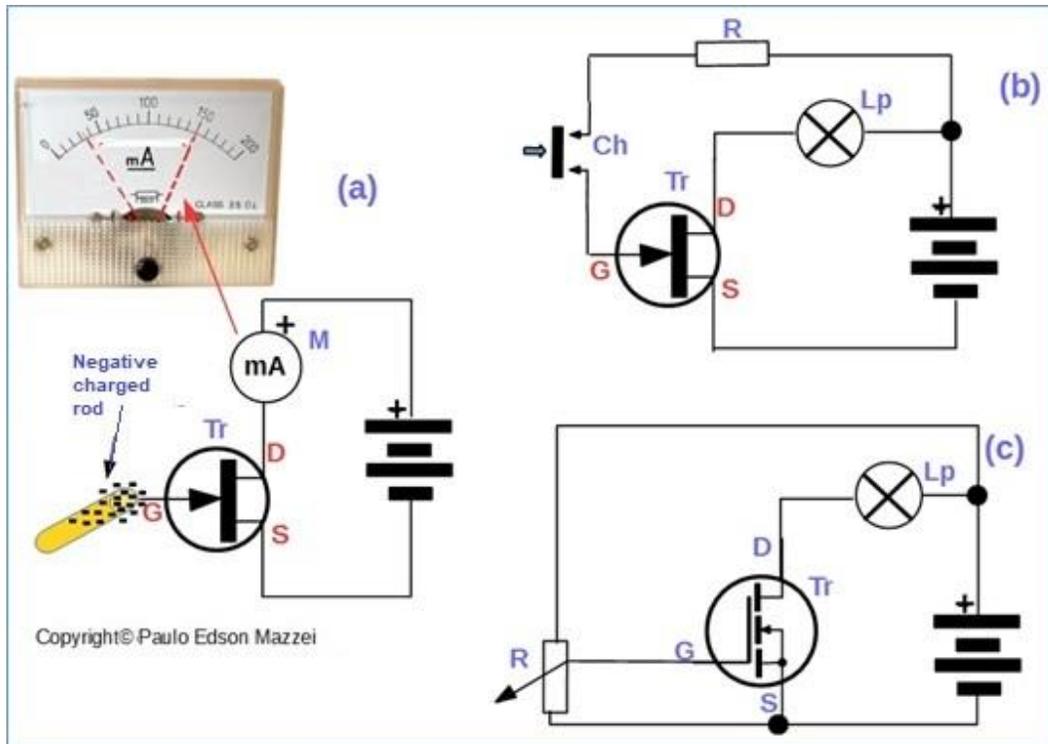


Figure 261- Three simple applications for FET and MOSFET transistors.

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Chapter 34

The Unijunction transistor - UJT

Introduction

In reality the unijunction transistor or UJT, is not quite an actual transistor. It is another diode with two cathodes.

Its basic operation is like a voltage operated switch. It does not act as an amplifier.

Objectives

- Importance of UJT in certain electronic circuits.

Operation and use of the Unijunction transistor – UJT

Refer to **figure 262**:

(a) Drawing showing the physical construction of UJT transistor.

(b) Circuit with 2 UJT transistors.

1. A small current flows between the base 1 and the base 2 (B1 and B2). This current is I_1 , as shown in drawing (d)

2. When the voltage applied to the emitter (E) reaches a certain value, called "Threshold Voltage", a high current flow from Base 1 (B1) to the emitter (E).

This current is represented by I_2 in drawing (d) of the figure. If the applied voltage does not reach this threshold value, no current flows.

(c) Graphic symbol of UJT transistor.

(d) Schematic diagram of the use of a UJT shown in (b), using only one transistor.

1. The circuit shown in (d) allows the LED to blink (on and off).

2. A current flows through the capacitor C1 (electrolytic capacitor) until the threshold voltage is reached and trip the UJT. The current that has been stored in

the charged capacitor is then discharged into the LED causing it to light until the capacitor is discharged.

3. This charge / discharge cycle repeats constantly.

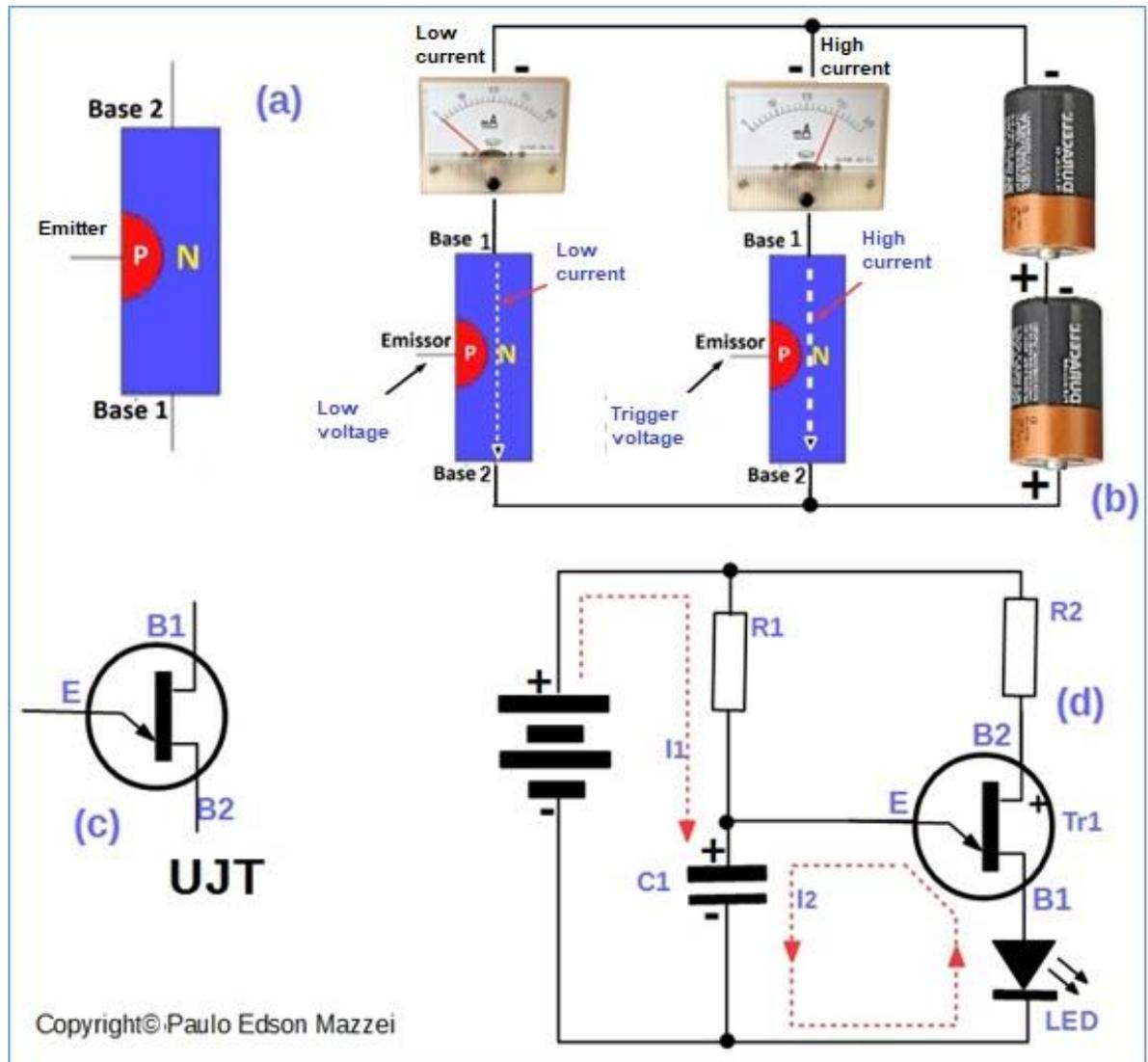


Figure 262 - Operation and application of UJT transistor.

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Chapter 35

Thyristors and SCRs

Introduction

Thyristors are three-terminal devices.

A small current in one of the terminals allows a high circular current between the other two terminals. Current controlled in this way is either on or off. In this way thyristors do not amplify signals.

In fact, they behave like solid state switches, allowing multiple applications, especially in industrial control circuits.

There are two families of thyristors: the **SCR** (Silicon Controlled Rectifier) and the **Triacs**

The SCR switches on direct current and the Triac switches AC.

Objectives

- Get in touch with SCR, Triacs, and Diacs.
- Some basic applications.

SCR - Silicon Controlled Rectifier

If the anode of an SCR is made more positive than the cathode the two most distal PN junctions will be directly polarized.

However, the reverse PN junction of the medium will be inversely polarized and there may not be an electric current flow.

A small current in the gate will suffice to polarize the PN junction of the middle of the SCR. This will allow a large flow of current through the SCR. Under these conditions the SCR will remain on, even if the power supply is turned off!

The one described above can be seen in **figure 263, (c)**.

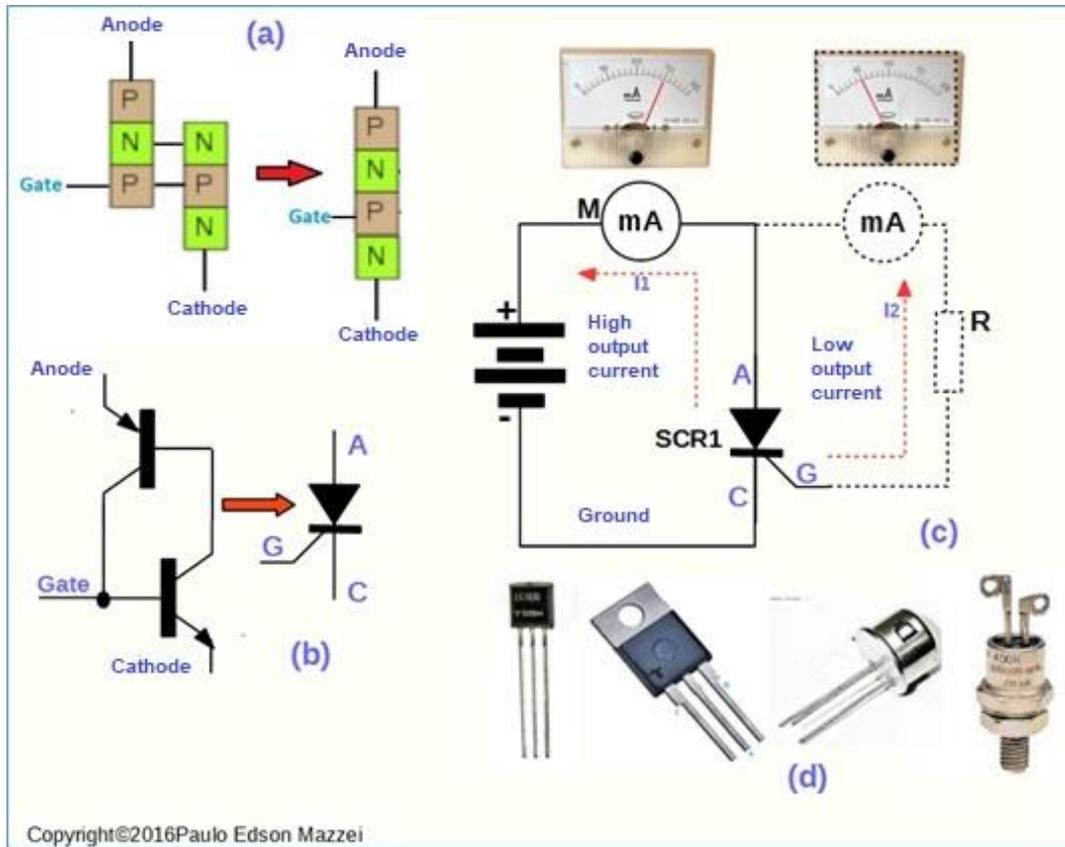


Figure 263 - SCR = Silicon Controlled Rectifier SCR physical construction.

- (a) SCR graphical symbology.
- (b) Circuit showing SCR operation.
- (c) Example of SCR enclosures. The latter, the right, is all metal, for high electric currents and is usually mounted on a heat sink.

Use of the SCR

A circuit using an SCR is shown in **figure 264**.

In this figure, an SCR is shown to control a small incandescent lamp. Other devices can be connected in place of the lamp, for control effect.

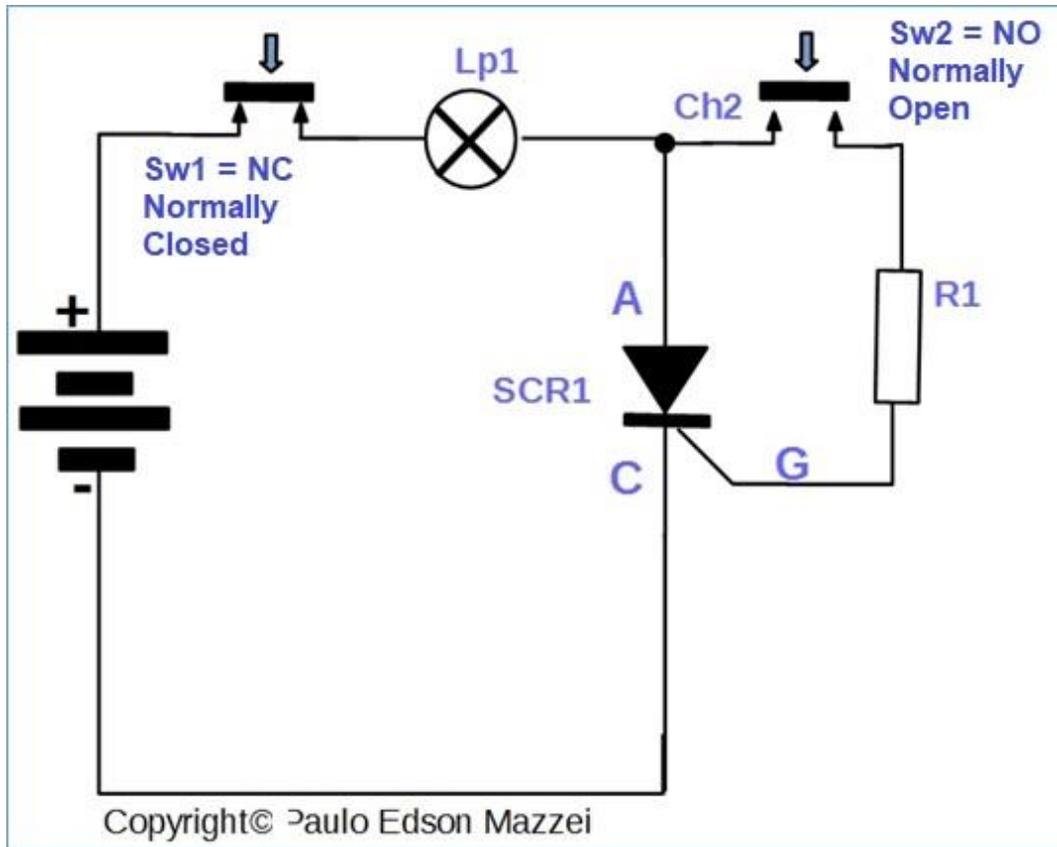


Figure 264 – Circuit with an SCR.

The Triac

The Triac is the equivalent of two SCRs connected in parallel. This means that the Triacs can switch both DC and AC.

When a Triac is connected to AC, as in figure 80, it remains in the "on" state when the gate receives an electric current. Removing this electric current, the Triac goes to the "off" state. See **figure 265**.

- (a) Physical structure of Triac.
- (b) Electrical structure.
- (c) Graphic symbol.
- (d) Circuit to measure the currents, as shown.
- (e) Triac physical format, from low power to high power.

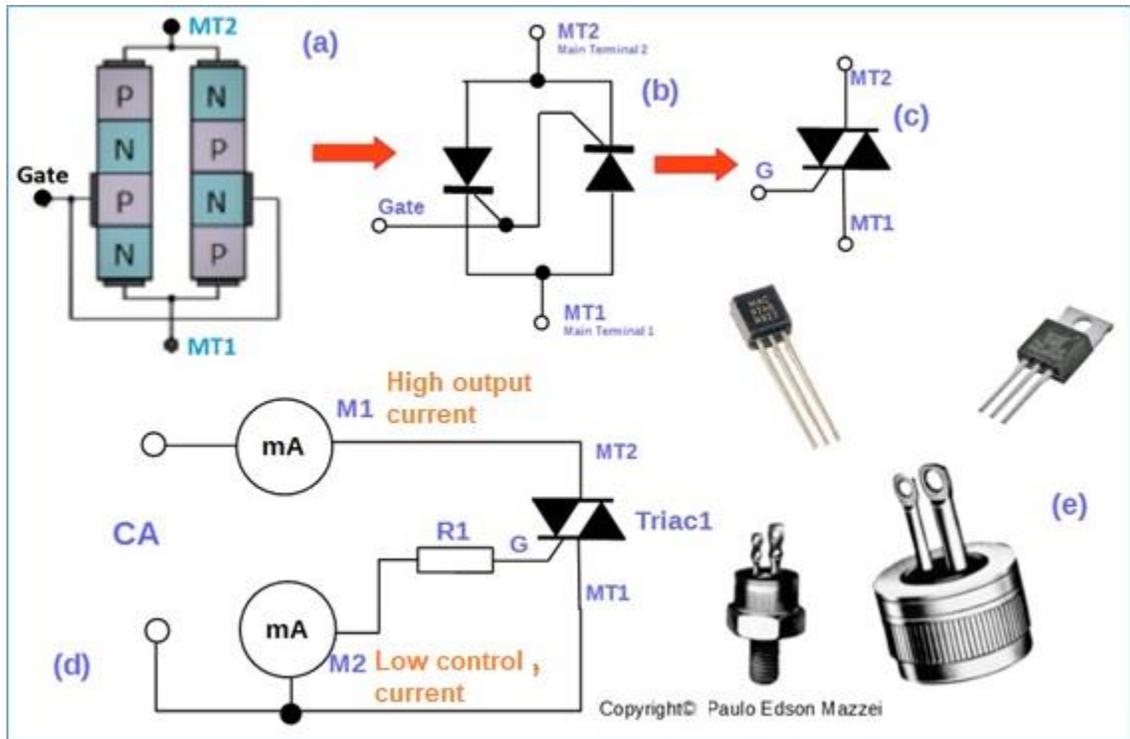


Figure 265 - Triac.

In **figure 265**, the figure to the left shows the structure of the component. Next, as indicated by the red arrow, comes the structure showing graphic symbols. Soon after, going to the right, the graphic symbol of the component is drawn. And, finally, a real photo of the component in question.

Triac operation

Figure 266 shows the basic operation of a Triac, lighting a lamp, when powered by the voltage of a 220 VAC or 127 VAC residential power grid.

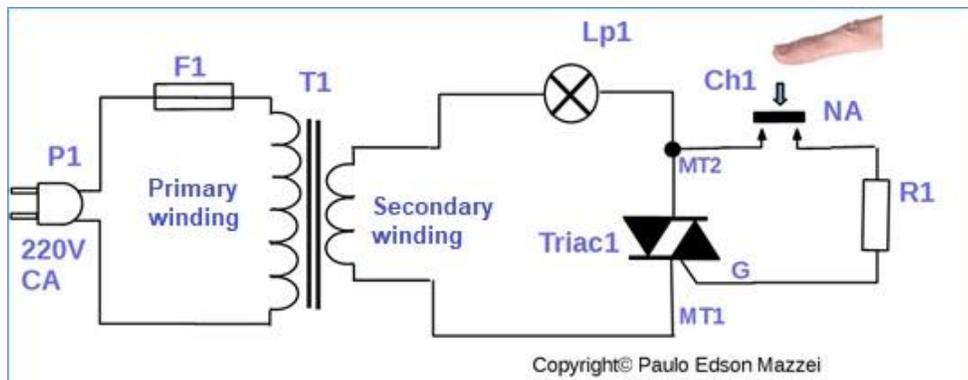


Figure 266 - Triac operation.

In this **figure 266**, you also find some new symbols:

P1 = Plug to connect the transform to a power outlet.

F1 = Fuse for protection of the circuit, connected to the primary winding of the transformer.

Lp1 = Common incandescent lamp.

Sw1 = button (or switch), open contact switch. NA = Normally Open. When pressed, it turns on the circuit.

Two-terminal thyristors

Within the thyristor family, there are still two components that are important to our work.

1. The four-layer diode which is a thyristor without a gate and
2. The **Diac** is a three-layer device, similar to the transistor, but without the base terminal.

The four-layer diode and Diac are shown in **figure 267**

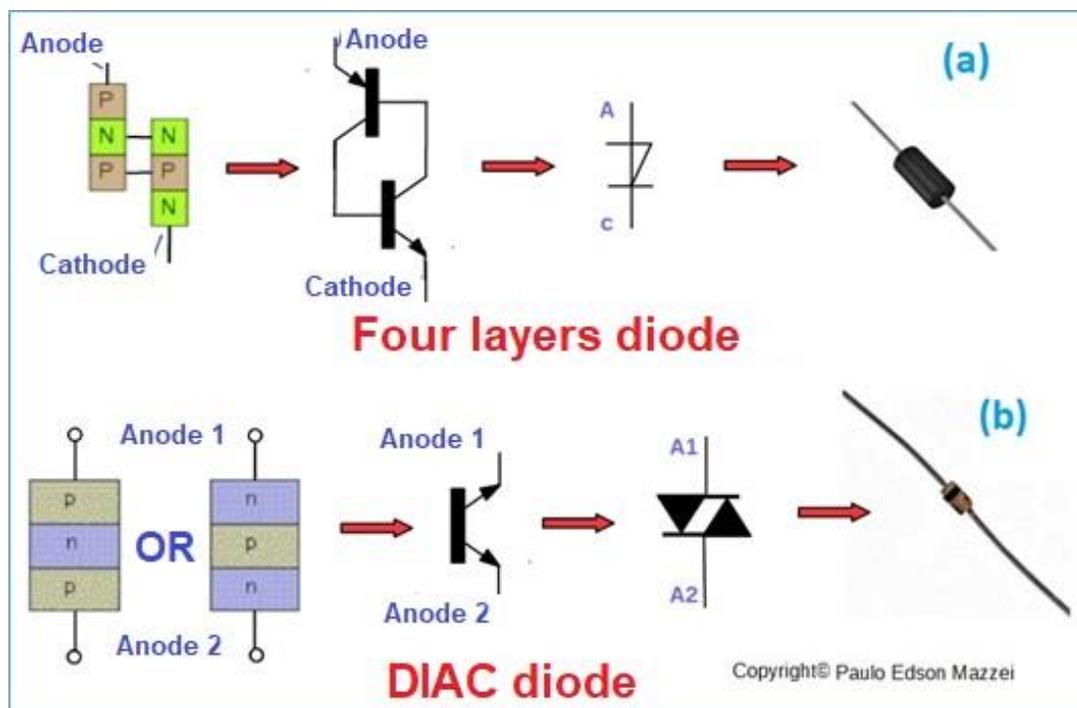


Figure 267 - Diagram of four layers and Diac.

In **figure 267**, the left drawing shows the structure of the component. Next, as indicated by the red arrow, comes the structure showing graphic symbols. Soon after, going to the right, the graphic symbol of the component is drawn. And, finally, a real photo of the component in question.

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Chapter 36

Light Sensitive Devices

Introduction

Photonics is a field that studies the generation, transmission, detection, amplification, etc. from light. In the case of electronics, it involves the semiconductor devices that make this generation, transmission, detection, etc.

It uses visible light, Ultraviolet (UV) and Infrared (IR).

Objectives

- Contact the transmitters and light detectors.
- LEDs, displays, LDR and photo-transistor.

Light and lenses

A very simple example of the use of light is the transmission of data at a certain distance. See **figure 268**.



Figure 268 - Use of a light source, lenses and a light receiver.

In **figure 268**, the lamp is a light source and we use a lens to condense light into a beam.

At the other end of the system, we use another lens to narrow the beam and apply it to a light receiver, which would be a photo diode.

If the light is turned off and on, according to a certain code, we can transmit a message through the system shown in **figure 268**.

Light sources in semiconductors

When a PN junction (majority) is struck by light, heat, electrons, or other form of energy, it emits visible or infrared light.

This effect is used to construct various types of electronic components that emit light, such as the well-known LED = Light Emitting Diode)

The LED

What the LED does is convert an electric current into light. In this way the LED is more efficient in this process than an incandescent lamp, for example. In our homes, the old incandescent lamps have been replaced by compact fluorescent lamps and today the tendency is to replace them with LED lamps.

How LEDs are used

LEDs currently have many applications in electrical and electronic circuits.

In normal electronics, radios, TV, players, computers, the LEDs are used as power indicators.

LED displays are robust when compared to an LCD display, but they consume more electrical current.

Infrared LEDs are used on remote controls of various electronic devices. They are also used in alarms to detect movements.

When you are going to use an LED, it is important to know the voltage to which it is connected as larger voltages can burn the LED. For this, we calculate a resistor and place without series with the LED, as also shown in **figure 269**.

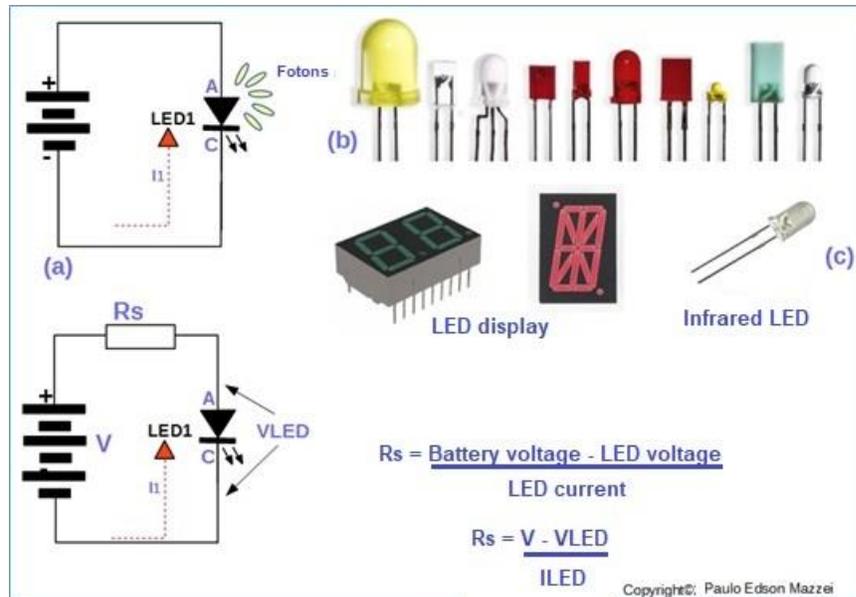


Figure 269 - Circuit with LEDs and LED formats used in common electronic circuits.

Light detectors with semiconductors

- No PN junction

Energy entering a semiconductor crystal, excite the electrons of the crystal, forming holes. These electrons and holes can recombine and emit photons.

There are two classes of light detectors with semiconductors:

- a. Without a PN join and
- b. With a PN join

An example of light detectors if a PN junction are the "photo resistors", also called LDR = Light Dependent Resistor. In these devices, their resistance is very high (MΩ) without the presence of light. However, when illuminated, its resistance drops to a few hundred ohms. Please, see **figure 270**.

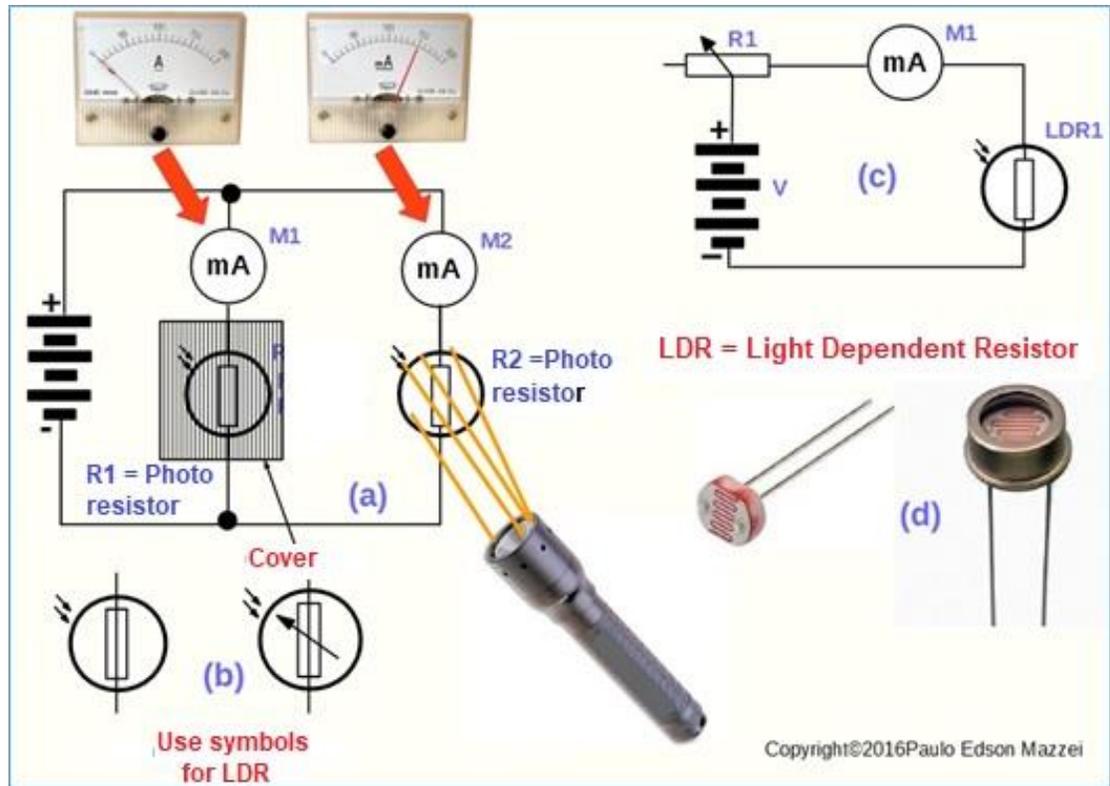


Figure 270 – LDR

- (a) Circuit with two LDR and two milliamperemeters. Note that the LDR1 (R1) is covered with a part indicated in the circuit as "cover", which prevents the light reaching the LDR1. Under these conditions, there is practically no current flowing through the LDR1. In the LDR2, the inverse happens: it is illuminated with a light coming from a flashlight and a current flow through it as indicated by M2.
- (b) The symbols of the LDR or photo resistor are shown.
- (c) Simple circuit of a "photometer", that is, a light meter, such as those used by photographers and photographic cameras. Potentiometer R1 is used to zero the meter M1.
- (d) Two examples of the physical aspect of LDRs.

- With PN junction

The PN junction detectors are made of silicon and can detect visible light and infrared light. The most known are the "**photo diodes**".

Photo diodes are used in alarms, cameras, etc. This component operates exactly like an LDR and a simple application for them, can be seen in **figure 271**.



Figure 27115 – Photo Diode.

What changes in this figure to the diode photos are the physical symbols and formats, as shown in **figure 271**?

Photo transistor

All transistors are light sensitive. The transistor photos are transistors especially for using this important function of a PN junction.

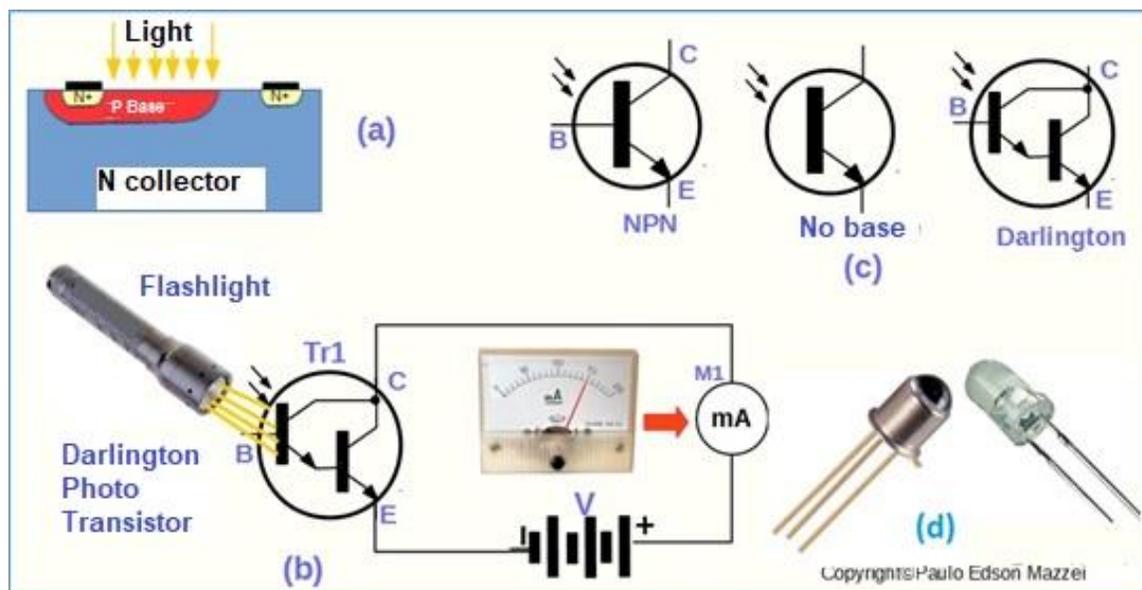


Figure 162 –Photo transistor.

Figure 272 provides various information about transistor photos:

- (a) Physical construction of a photo transistor. Note that the base P is a region larger than the common base of transistors, just to receive more light.

- (b) A very simple application circuit is shown in (b). When the flashlight illuminates the base of the photo transistor, a high current flow between the collector and the emitter, shown by the milliammeter M1.
- (c) Symbols of photo transistors. Note that in one of the models the base is not drawn. In the "Darlington" model, another transistor amplifier is mounted along with the photo resistor chip, for greater current gain.
- (d) Real photo transistor models. Note that both have a clear glass "window" for light input.

Solar cells

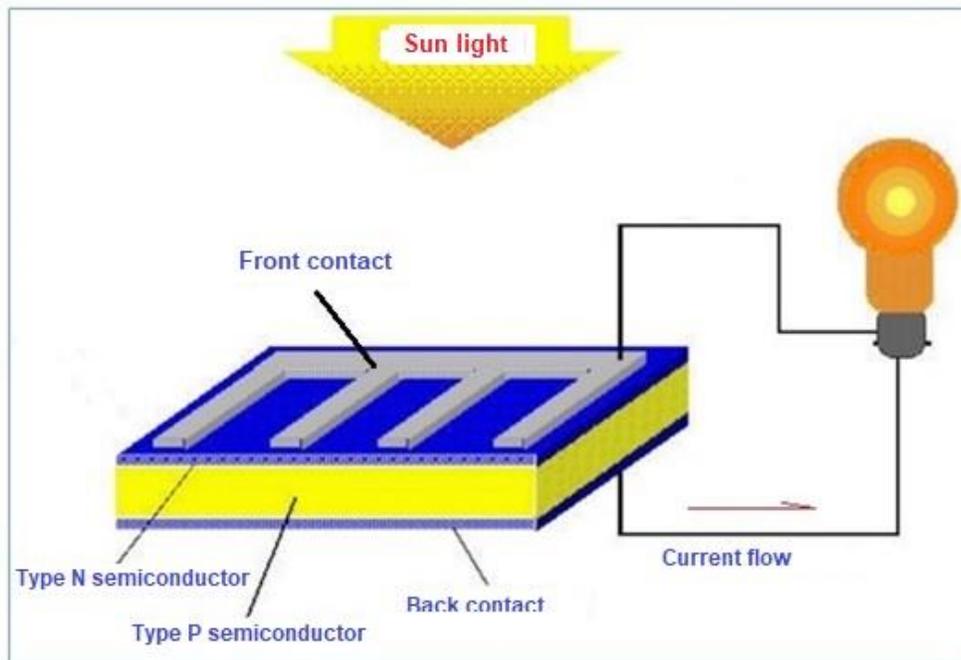


Figure 273 -Solar Cell.

Solar cells are photo PN junction resistors, with the base area too wide to receive light. In the case of silicon, the value generated is around 0.5 V. See **figure 273**.

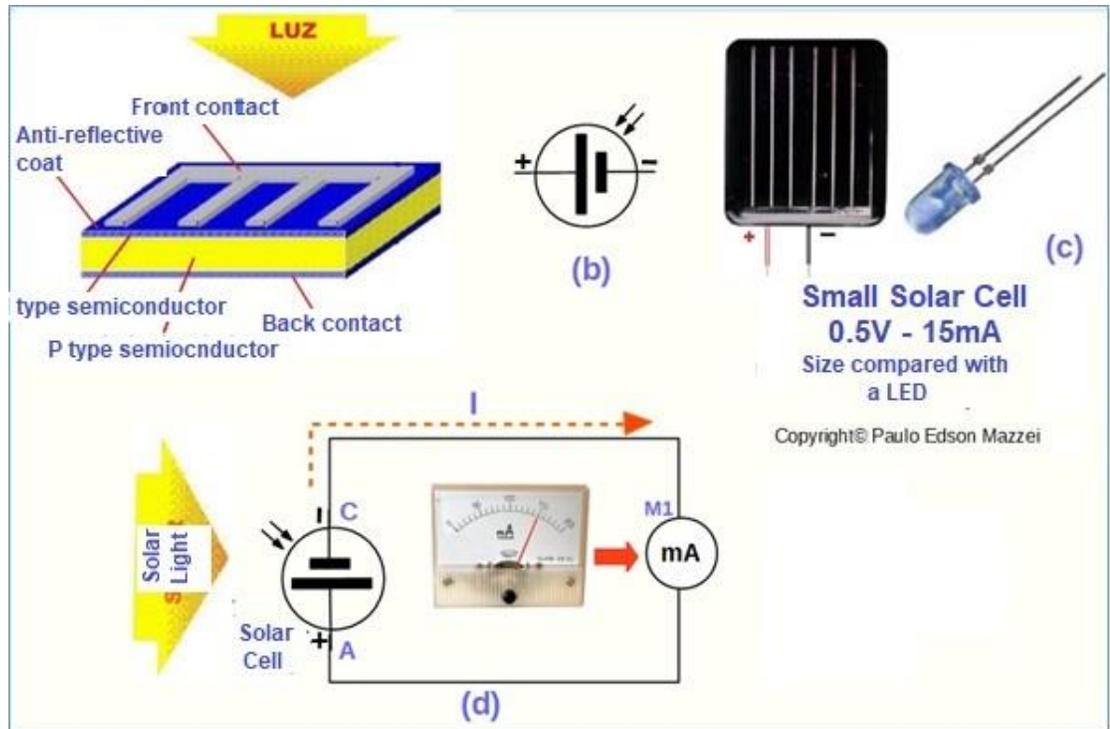


Figure 274 – Solar Cell.

Look at Figure 274:

- (a)** Physical structure of a solar cell.
- (b)** Graphic symbol of a solar cell.
- (c)** Real physical format of a small solar cell that supply 0.5 V under 15 mA of current!!
- (d)** Application circuit of a solar cell. Sunlight striking the solar cell causes it to produce a current, indicated by the meter M1.

Solar cells have huge applications and you've surely read in the newspapers about the solar panel's residences, which feed a lot of things in a residence, saving the electric power of AC produced in hydroelectric power plants.

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Chapter 37

Integrated Circuits – ICs

Introduction

Integrated Circuits (IC) are complete electronic circuits, "packed in one piece (chip). For example, we have a sound amplifier on just one chip. Internally it has hundreds of transistors, resistors, capacitors, etc.

Externally they have the connection terminals (pins) for the inputs, outputs, power, etc. Integrated circuits can be found in a huge variety of formats.

The ICs (integrated circuits) have their code (type) printed on the body itself. For voltage, current, applications, etc., see a databook or the manufacturer on the Internet.

Objectives

- Understand the importance of IC - Integrated Circuits for electronics as a whole.
- Basic analysis of analog and digital CIS.

Integrated circuits

Figure 275 illustrates the basic construction of an IC. As seen from the figure, the Cis can assume various physical formats, but the most common ones are the DIL = Dual in Line, it refers to the arrangement of the pins. See some more information in **figure 276**.

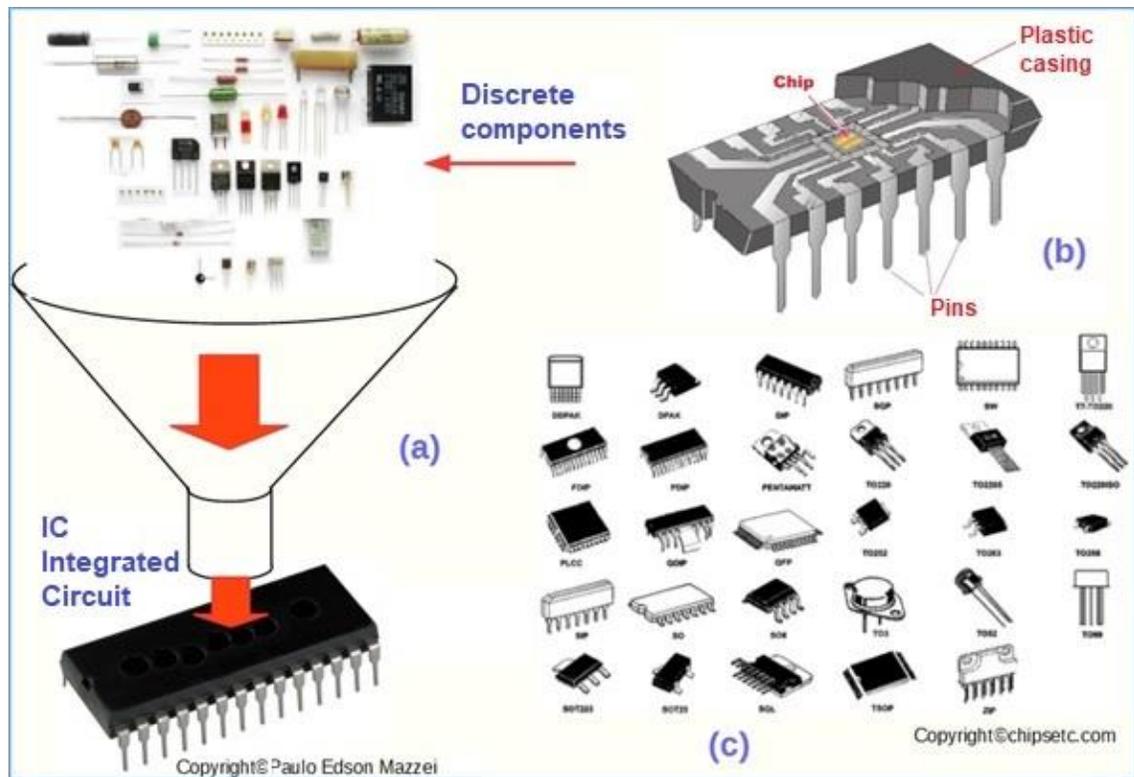


Figure 275 – IC – Integrates Circuits.

- (a) Illustration of several discrete components (standard) being "threaded" into an integrated circuit with a funnel.
- (b) Simplified, open IC, showing the Chip and how the terminals or pins are connected. The chip is the silicon chip where all the electronic components that are part of the IC are assembled.
- (c) Various physical formats that may have an IC.

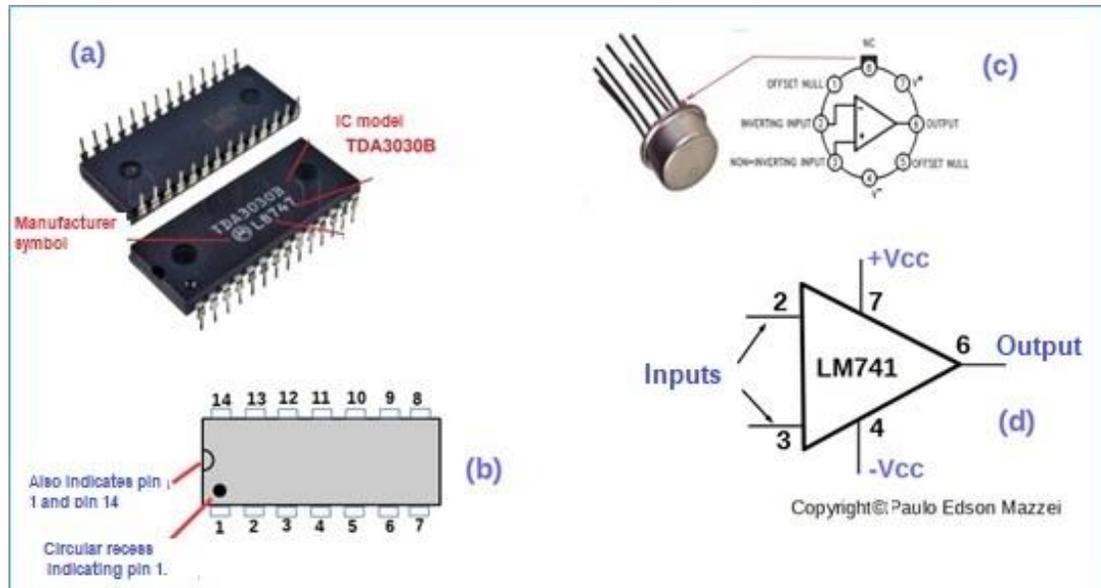


Figure 276 - Formats and arrangement of terminals in ICs.

For study purposes, we divided the ICs into two basic categories:

1. **Analog** or **linear** ICs. They are Cis, which amplify, oscillate, timer, etc.
2. **Digital** or **logic** ICs are ICs that produce or respond to digital signals of only two voltage levels. That is, they do not respond to analog signals. They are used in memories, processors, microcomputers, etc. Sometimes a digital IC can incorporate some analog circuit, such as a timer, a voltage regulator, etc.
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Chapter 38

Digital Integrated Circuits

Introduction

Digital integrated circuits are the basis of the operation of a microcomputer.

Because of this, they may seem complex and difficult for a layman to learn. However, digital or logical ICs are made up of simple blocks, which in a variety of ways make a circuit much more complex to operate.

So, our first step is to learn what these **gates** are.

Objectives

- Basic analysis of digital integrated circuits.
- Some simple applications.

The gates

Gates are the electronic equivalents of mechanical switches called "pushbuttons," which you should know very well. For the "close" switch, press the red button. This type is called NA = Normally Open (off).



The other type of this same switch is called NF = Normally Closed. To turn the switch on (off), press the red button.

See **figure 277**, how logic gates work and how they are made up.

In drawing **(a)** of **figure 277**, the lamp will only come on when the two switches, Ch1 and Ch2, are closed. The Truth Table is a table that shows the main combinations of ports and the result when they are open (off) or closed (on).

In (b) of the same figure, the switches are in parallel and the lamp will light when Ch1 or Ch2 is closed.

In (c) the Lp1 lamp will be lit and will only turn off when the switch is opened.

Note in all the circuits shown, that the line that has no drawn switch is the common point of the circuit or ground. Then the output is inverted relative to the input and this port is called "not", i.e. inverter.

In the graphic port symbols, shown in (c), the On and Off levels have been replaced by L = Low and H = High.

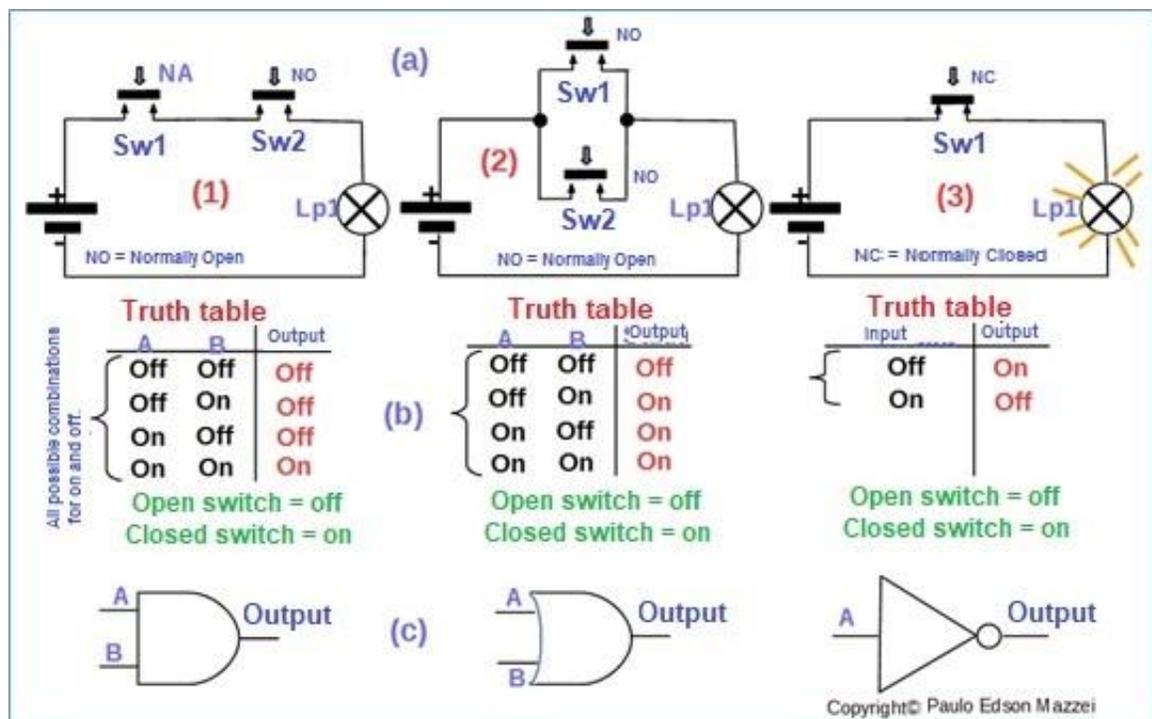


Figure 277- More used logic gates.

In reality, at the exit of the real logic gates, we have high (High - H) and low (Low = L) voltage levels, as shown in figure 278.

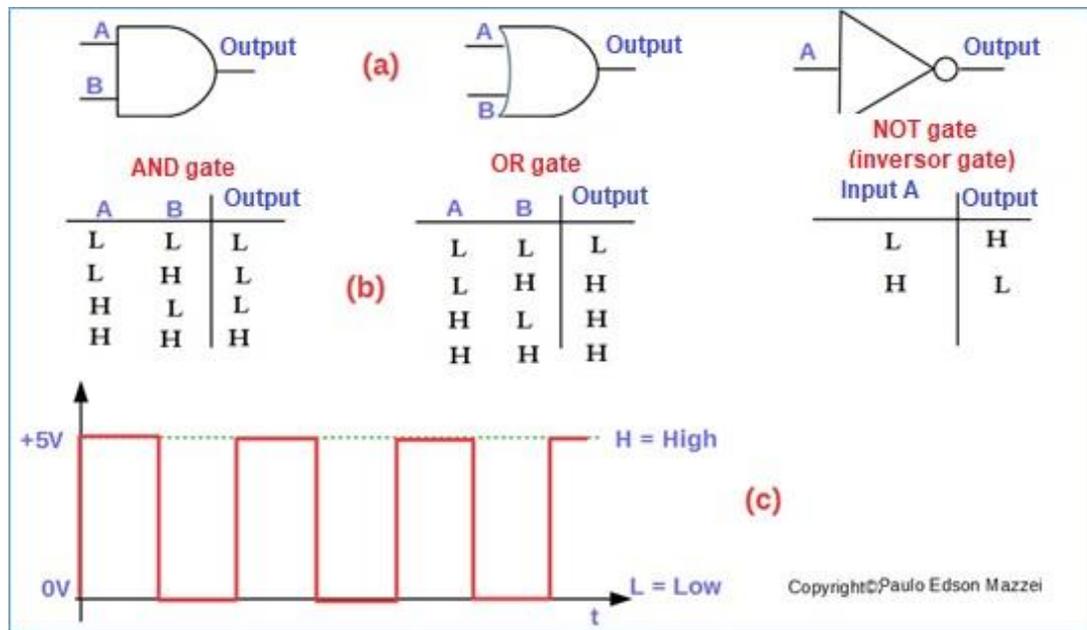


Figure 278- Logic Levels High and Low.

Some more information about logical ports.

1. Sometimes the logic ports can have more than one input.
2. In the circuits drawn, using the graphic symbols of the logic gates, the ground or common point connections of the circuit or less (-) of the power supply were not designed. Normally this does not show because it is implied that the logical port, to work correctly, must have this connection to earth.
3. Logical ports are usually associated and form very complex circuits, but that escape the scope of this eBook.

Application of logic gates in circuits

Just for the purpose of illustration, let's show how some ports can be combined to form a "decimal counter circuit". See **figure 279**.

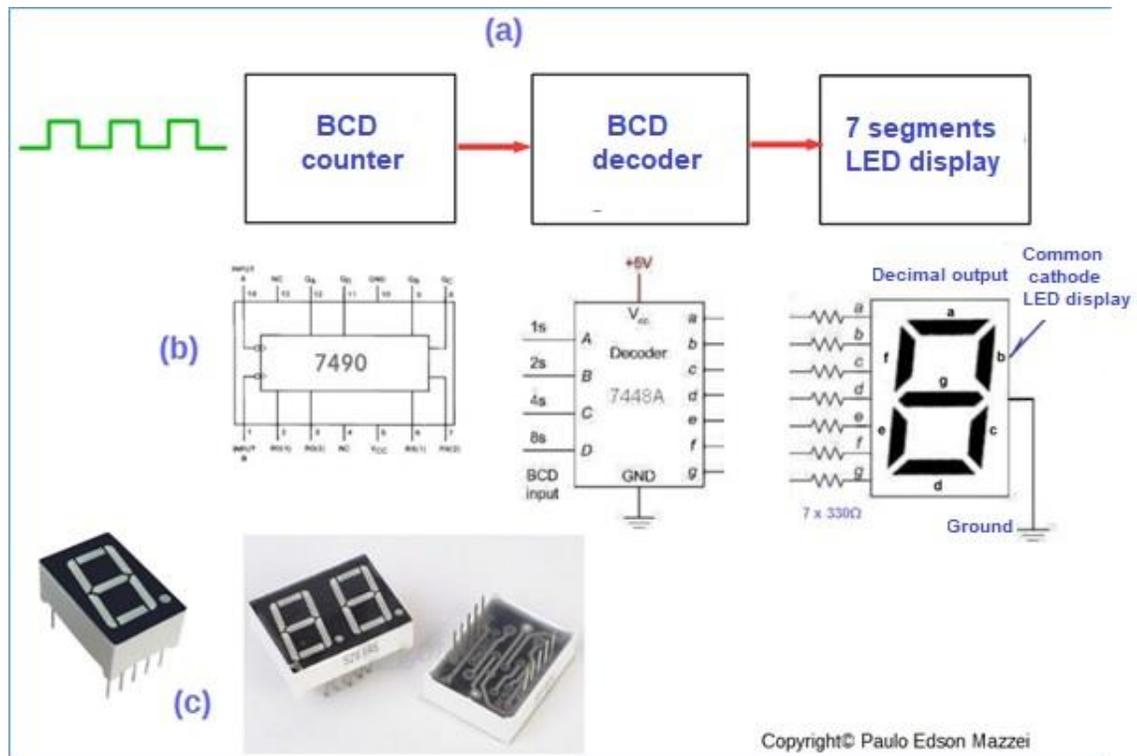


Figure 279– Decimal counter.

How does the decimal counter work?

1. . For each input pulse, green signal in (a), the BCD counter advances 1 count.
2. . When counter reaches the digit 9 (in binary = 1001), the counter recycles to the digit 0 (in binary = 0000). This is done by IC 7490.
3. . The counter output is applied to the BCD decoder to trigger a LED display (7 segments). This is done by the IC 7440.
4. . The 7440-decoder output is applied to the LED display. The 330 Ω resistors are applied to each segment of the display, protecting them in case of excessive current.
5. . Actually, each of the seven segments of the LED display is a small LED with the format shown in figure 130, at (c).
6. . This circuit must be powered by a stabilized voltage of 5VDC.

The digital IC families

Now, let's introduce them to the digital IC family. Basically, there are several families, but the basic ones are two:

1. Digital ICs made with **bipolar transistors (TTL = Transistor - Transistor - Logic)** and
2. Digital ICs made with **CMOS** transistors.

The family of bipolar ICs was the first family to appear with logic circuits. They had high current consumption. They were cheap to build and operate up to relatively low frequencies. This family had their CIs numbered with initial codes in "**74**," starting at 7400 and going forward.

Then came a younger family of "thinner people," who were ICs using the Schottky technique, with much lower current consumption than the poor TTL cousins about 20% of current consumption. The problem is that they are expensive to build. The codes of this family were "**74LS**", starting with 74LS00.

Finally, the "kings of the piece" appeared - the CMOS (Complementary Metal Oxide Semiconductor). These CMOS are fast, have low power consumption. Disadvantage: can be destroyed by static electricity!! The codes of this family were "**74C**", starting with 74C00.

In addition to the 7400 series, the logical ICs have the **4000 series**. The complete data of any IC can be found in the manufacturers databook, on the Internet.

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Chapter 39

Linear Integrated Circuits

Introduction

Linear integrated circuits work with an input and output voltage, different from logical ICs. Most often the output voltage proportional to the input voltage and hence the name "linear".

There is a huge number of linear ICs but for our study and experiments, we will only consider a few.

Objectives

- Basic analysis of linear integrated circuits.
- Some simple applications.

The basic linear integrated circuit

Both a bipolar transistor and a FET transistor can function as a linear or digital IC. In the case of the NPN transistor, you should remember that the output signal is inverted relative to the input signal.

Figure 280 shows how a properly connected and polarized NPN transistor can perform both functions.

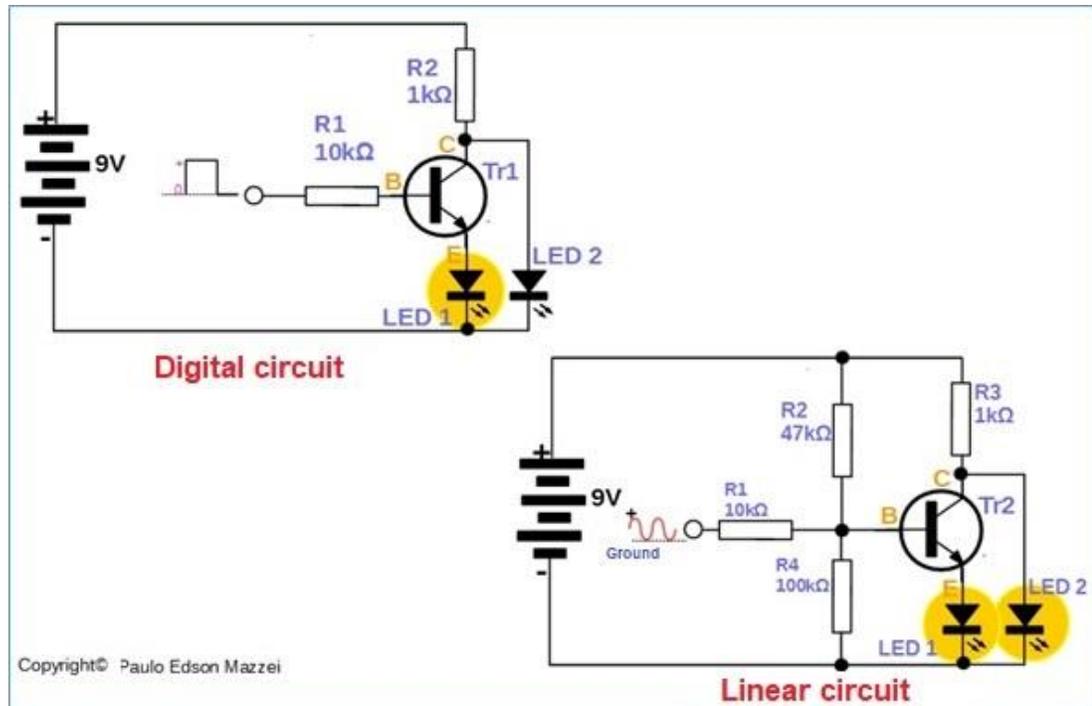


Figure 280 -Comparison between a digital and a linear circuit, with transistors.

Figure 280 shows how an NPN transistor can work with digital and analog signals. In both cases the transistor inverts the signal at the output.

In the digital circuit, the left, the transistor is working like a "key." When the input of the square wave signal is reaching the maximum value (+), Tr1 switches to the "on - off" state and LED1 lights up. When the input signal is close to "0", the transistor switches $v =$ again, going to the "off - off" state and LED1 goes out.

In the linear circuit on the right, Tr2 works as an amplifier, which works across the entire range of the input signal. The two LEDs light up.

Operational amplifiers - OpAmp

ICs called "operational **amplifiers**" have a wide range of applications and are very versatile. They amplify the difference between two voltages or signals, AC or DC, which are applied to their inputs.

One technique that is widely used with operational amplifiers is to use feedback, or feedback, where a small part of the output signal is injected into the input of the amplifier. Refer to **figure 281**

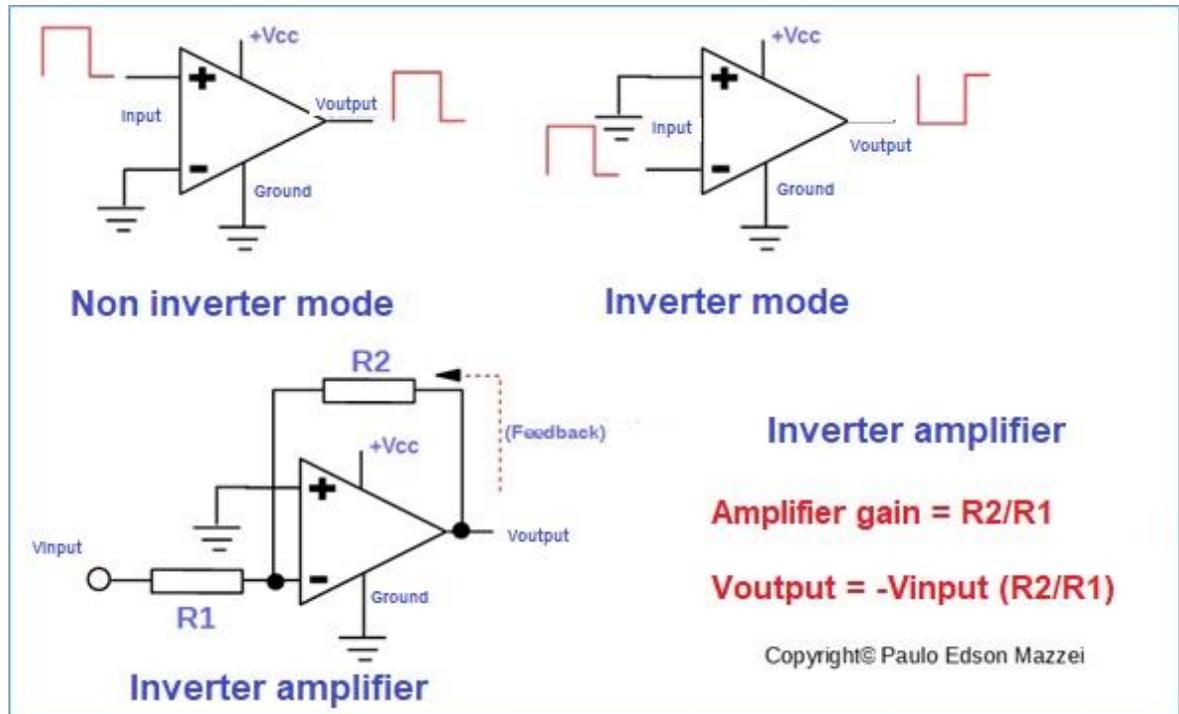


Figure 281- Inverter amplifier with linear IC. Use of feedback.

For your assemblies and experiments, you can find both bipolar operational amplifiers such as MOSFET. Often, in the same enclosure of the operational amplifier, we can find more than one operating circuit.

Timers:

When operating as a comparator, the operational amplifier can function as a timer. See the circuit in **figure 282**.

In this figure, note:

- (a) RC circuit.
- (b) Graph of the charge curve of the capacitor, as a function of time.
- (c) Schematic diagram of the timer with IC LM741.
- (d) IC photo LM741.

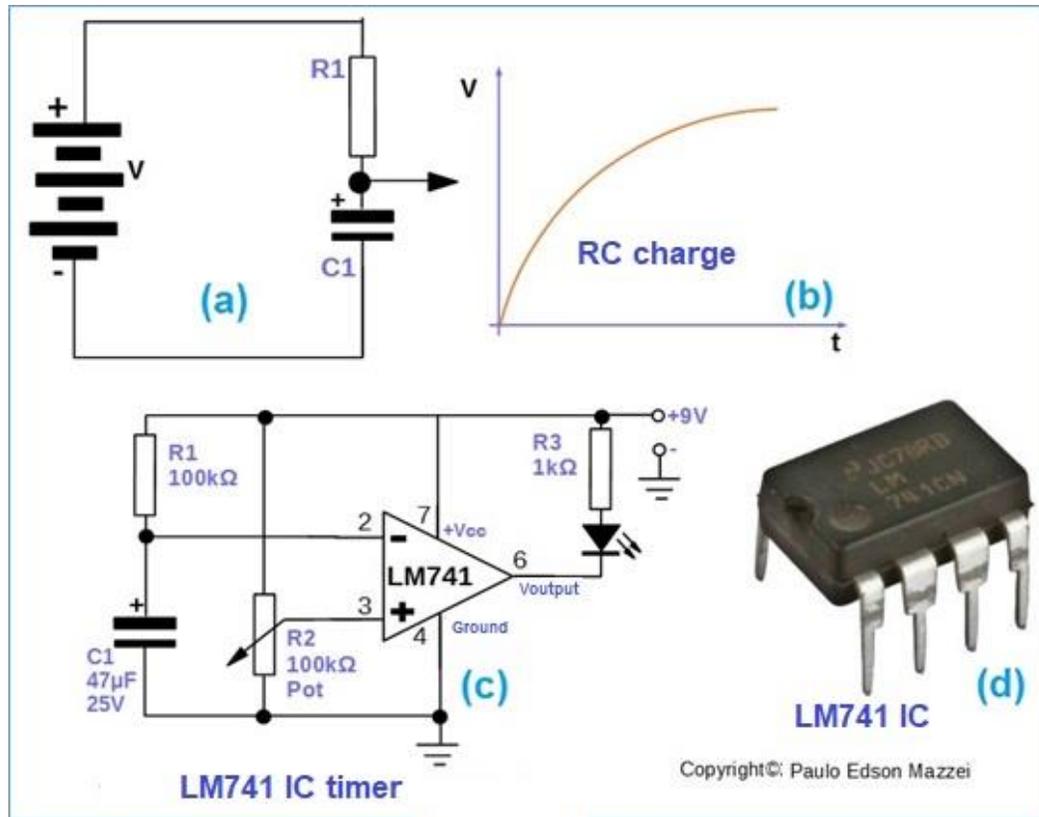


Figure 282 Timer with LM741 IC.

Function generators

You can already do a function generator using an appropriate CI.

The function generator is a test device, usually used on a bench, which produces at its output, various types of signals, for calibration, testing, maintenance of other electronic devices.

One of the ICs that does this is the ICL8038 model. This IC is a complete function generator, which generates sinusoidal, square, and triangular signals, as shown in Figure 283.

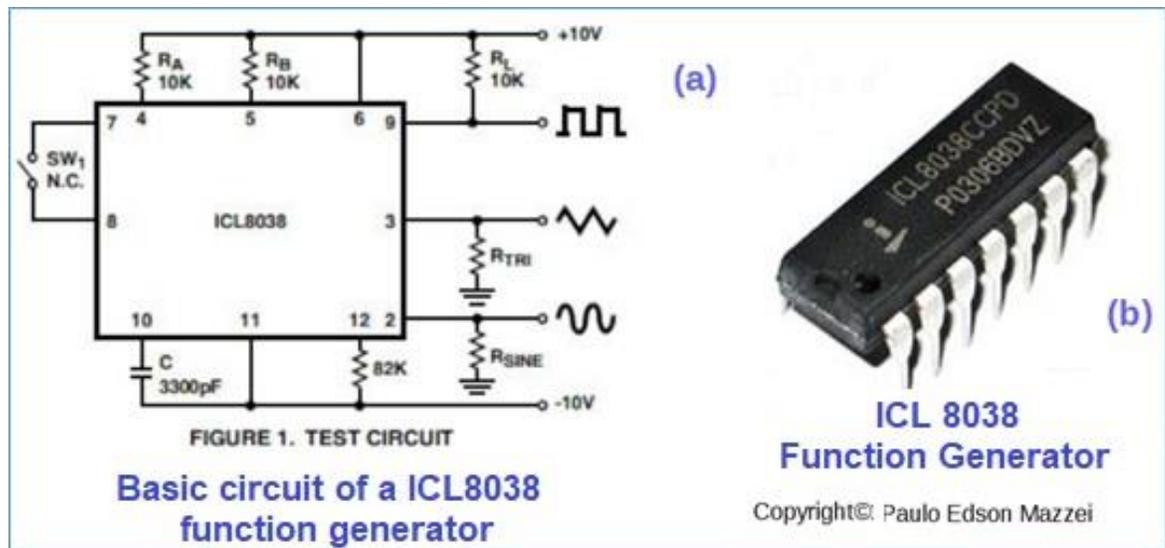


Figure 283 - IC function generator model ICL8038.

Voltage regulators

Integrated circuits can also be used as voltage regulators which makes life easier for students, technicians, assemblers, engineers, etc.

Voltage regulators convert the voltage applied to their input, at a lower voltage, but very well regulated (stable), even if this input voltage varies, within certain limits.

You will work with these ICI voltage regulators and any assembly design that uses a power supply, probably via a need for a voltage regulator IC.

There are several models, fixed and variable, usually for some standard voltages such as 5 V, 8 V, 9 V, 12 V, 24 V, etc.

The construction of these ICs is usually metallic because they heat up during operation and need to be mounted on an aluminum heat sink.

Figure 284 shows some details of a regulated power supply using the voltage regulating ICs. Watch:

(a) Simplified schematic diagram of the regulated source. The T1 transformer lowers the mains voltage from 127 VAC to 15 VAC. The rectifying bridge, consisting of D1 to D4, transforms the pulsating DC input AC into the output. In this output is the electrolytic capacitor C1, of high value, which "flattens" the pulsating DC, leaving it almost similar to a pure DC. Finally, the CI 7812 comes into play, which at its output provides a regulated voltage of 12 VDC.

(b) Two voltage regulating ICs. The left for currents up to 1.5 A and the right for currents up to 5 A. Both should be used with heat sinks.

(c) Heat sinks suitable for the ICs shown.

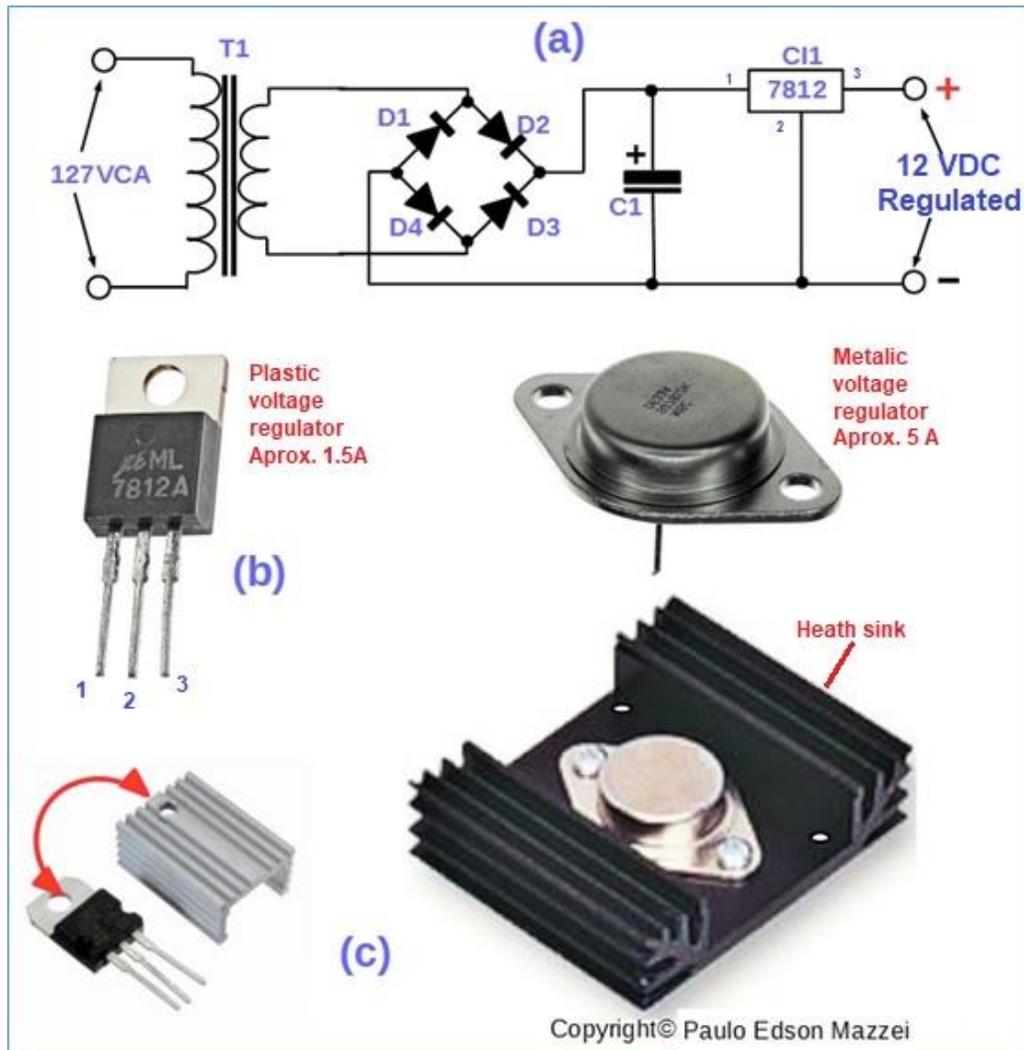


Figure 284 - Regulated power supply with IC.

Other linear ICs

Audio Amplifiers: There are several ICs intended for use as audio (sound) amplifiers. You can find these complete amplifiers from a few mW (milliwatts) to tens of Watts. Just put a few external components, feed them and that's it!

Specific ICs: For TV, audio, telephones, communications, satellites, computers, tablets, smartphones, etc. Many of these ICs have been fabricated for

special functions such as detecting temperature variations, position in space (gyroscope), proximity of objects, etc.

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Chapter 40

Printed circuit boards

Introduction

Printed Circuit Board (abbreviated PCB) are special insulation boards, consisting of an insulating layer and a conductive layer, for the assembly of a multitude of types of electronic components.

The Printed Circuit Board (PCB) eliminates almost all conductors (wires and cables) from an electronic circuit by replacing these conductors with "tracks" of copper, drawn and corroded by a special process of manufacturing. These tracks or tracks, will interconnect the various components of the circuit.

PCBs allow you to reduce the costs of an electronic device and very important, its size. Automated mounting of these boards allows the production of PCBs in large volumes.

Objectives

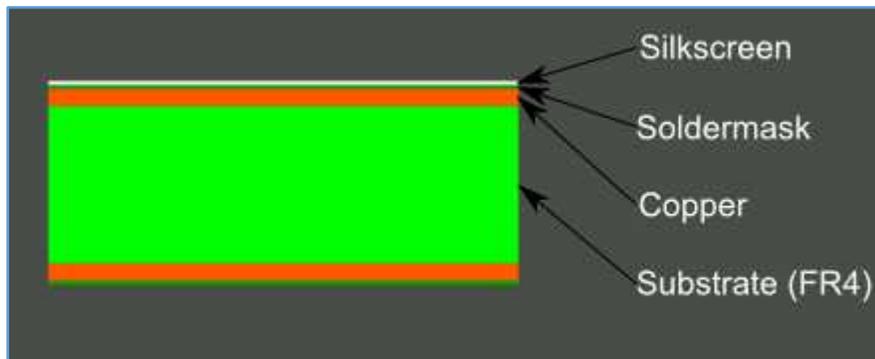


Figure 285 - -Printed Circuit Board - PCB

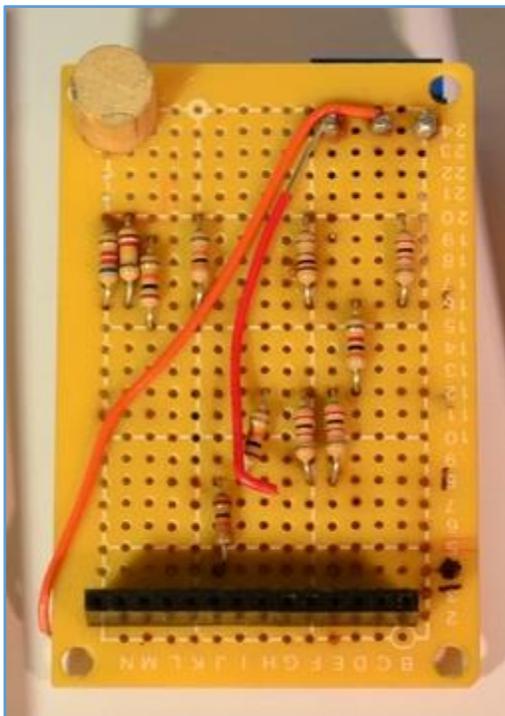


Figure 286 -- A very simple PCB for hobby assembly.

We can consider a PCB as a sandwich of several layers, which are laminated together with the application of adhesives and heat, so that in the end we have a single piece.

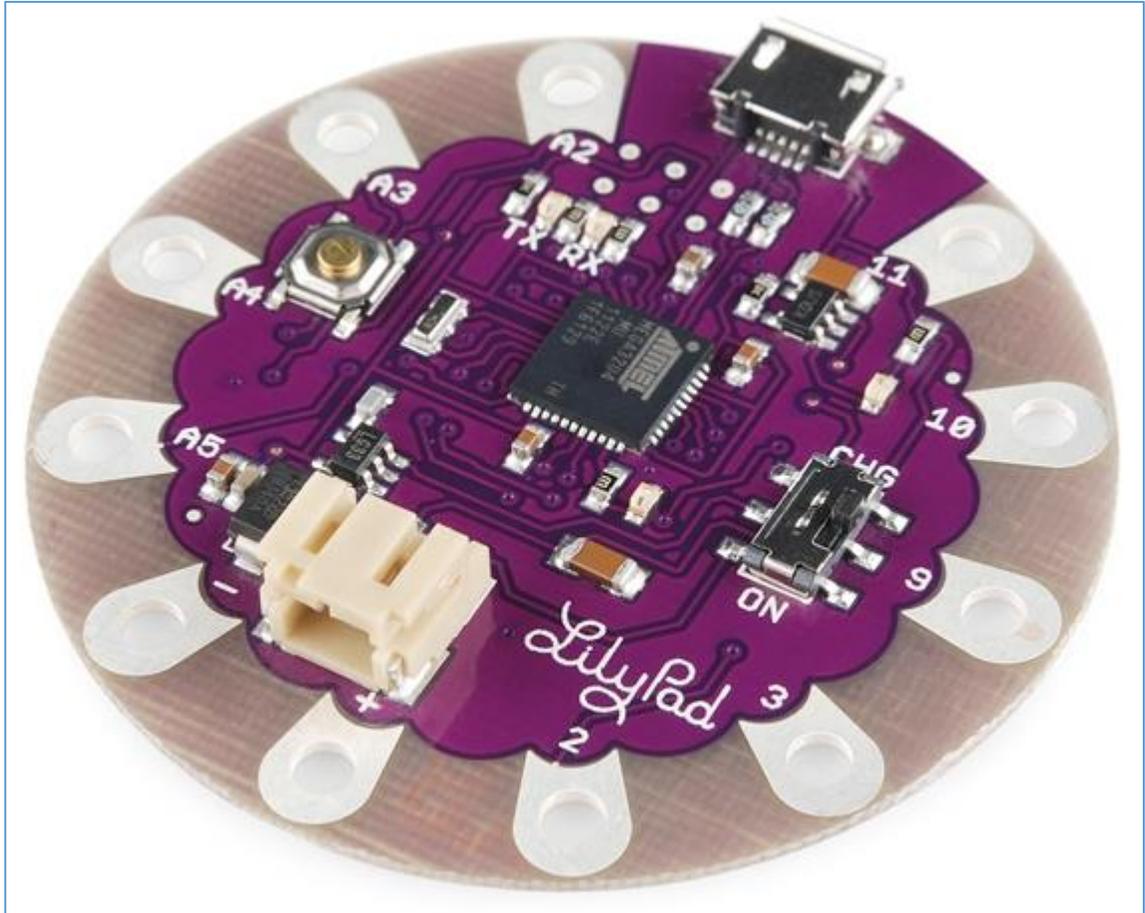


Figure 287 - PCBs can be manufactured in several formats and shapes. Courtesy SparkFun Electronics

PCB can take many shapes and sizes, such as the "LilyPad" round PCB produced by SparkFun Electronics USA.

The material commonly used in a PCB, or substrate, is an insulating material made of fiberglass, commonly called FR4.

The **fiberglass** insulation material can be produced in various thicknesses and the most common is 1.6 mm. PCB such as the Arduino, for example use a 0.8 mm thick PCB.

For common electronic circuits, we can use a **phenolite** PCB that is a great insulator and the PCBs of this material are more economical.

The copper

The thin copper sheet that is laminated on the PCB, uses adhesives and heat to be fixed on the insulation material or base.



Figure 288 -- Hobby PCB you can make at home.

In the home assemblies we use two types of laminates:

- a. **Single-sided PCB**, which only has a layer of copper on the base and
- b. **Double-sided PCB**, which has two layers of copper, one on each side of the insulation base.

In professional applications, we can have several layers, sometimes up to 16 layers.

The thickness of this thin sheet of copper is important because it will "conduct" the current of the circuit, acting as a conductor between the various components of the same.

The solder mask

The layer of a kind of paint, usually on the side of the components, is called a "solder mask". This solder mask is mostly green. Other colors can be used, such as SparkFun Electronics® that uses red color welding masks.

It serves to isolate the copper tracks (or tracks) from accidental contacts with metals, solder and even from contact with other tracks. The solder mask, causes the solder to be deposited in the correct places, during the process of soldering the components to PCB. Please refer to **figure 289**.

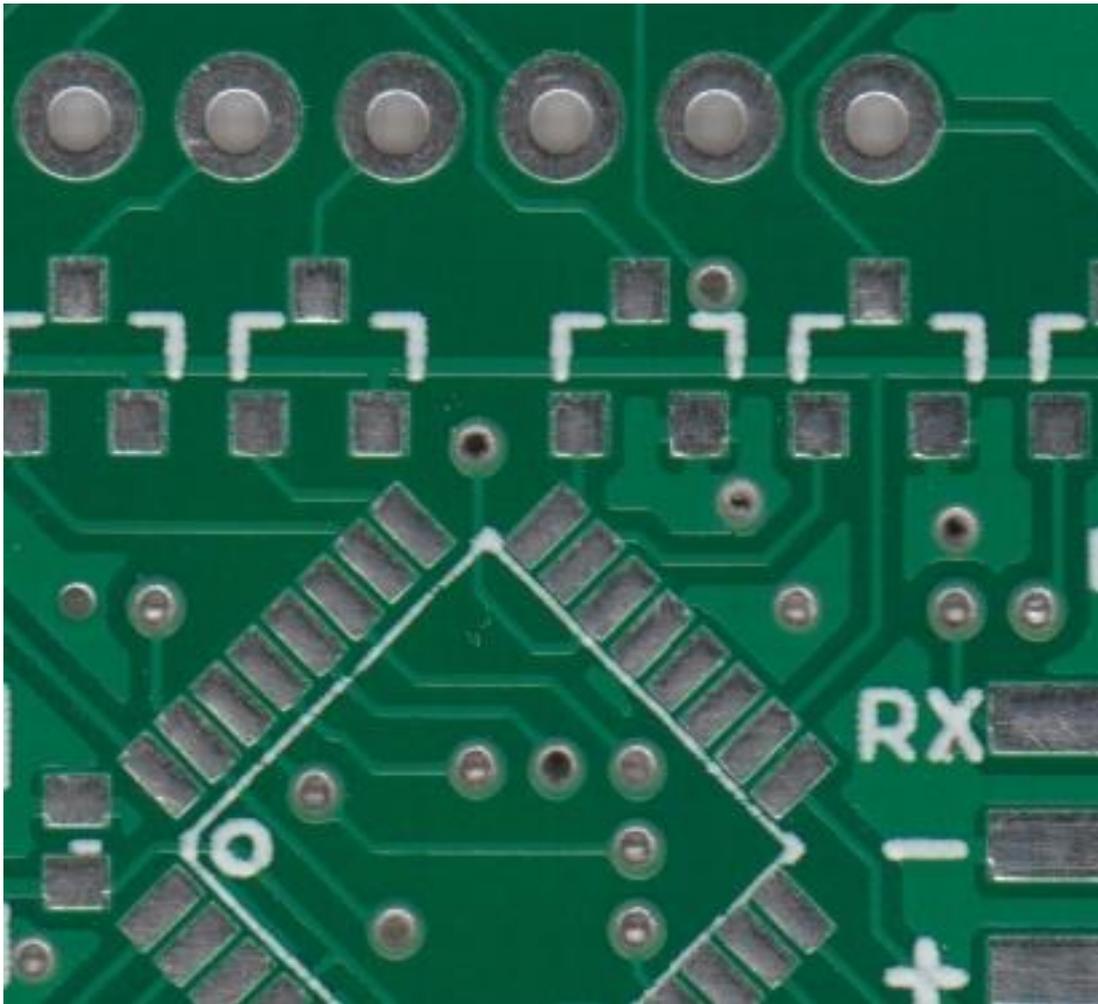


Figure 289 - The solder mask in a PCB.

In the drawing above, with the green colored welding mask, we can see that it is applied on most of the surface of the PCB but leaving out the welding points of the Integrated Circuits and pads of the SMD components.

Silkscreen

The silkscreen is the white printing process, which we can see on the PCB shown in **figure 290**.



Figure 290 - Silkscreen process in a PCB.

The Silkscreen adds letters, numbers and component formats to the surface of the board, thereby facilitating assembly and locating certain important points in the circuit. Very important also is the indication of polarity of several electronic components, with the use of silkscreen.

Make your own PCBs!

With the use of appropriate software, you can also make a PCB for your home mounts.

Search the Internet for software dedicated to this PCB layout and get it up and running. In the beginning it will be difficult but after a few plates you will do your correctly.

If you really want to learn how to make a PCB with great workmanship, check out my Amazon eBook:

■ [CADSOFT EAGLE PCB](#)® for beginners! Lay out your Printed Circuit Boards (in Portuguese).

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Chapter 41

Sensors

Introduction

In addition to being surrounded by dozens of electronic circuits in our home or work, it is important to remember that these circuits also have sensors, which "feel" the temperature of an environment, excessive noise of a machine, vibration of certain mechanical system, etc.

The sensors, as stated above, "feel" and send a signal to an electronic circuit, which "actuates" through an actuator (or transducer) causing, for example, a decrease in temperature in an environment, the stopping of a machine, the decrease or alert the vibration of a mechanical system, etc.

Transducers is a term that can be used for both sensors and actuators. Basically, transducers transform one form of energy into another.

The term sensors are more applied to a device that "senses something," such as a movement, a sound, a vibration, and so on. Actuators are used to switch voltages and electrical currents.

Sensors cause electronic circuits to communicate with the real world.

Objectives

- Basic analysis of some types of sensors.
- Some simple sensor applications.

Sensors

Sensors are used to sense a wide variety of form of energy, such as electrical signals, sounds, movements, radiation, magnetism, etc.

The sensors can be analog or digital and there is a wide variety of sensors, sometimes with "different" physical formats than we know it from day to day.

In the case of transducers, we need to know what type of signal you will be working on or processed by the electronic circuit being used.

In a general way, we define sensors and transducers as devices that convert one form of energy into another form of energy. Devices that are used in the "input" of the processing circuit, are called "**sensors**" and devices that are used in the output of this same processing circuit, are called "**actuators**". See figure 291.

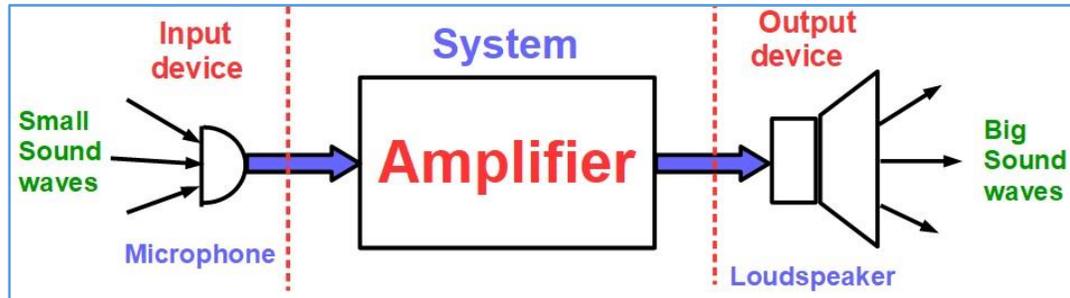


Figure 291 - Input, system and output devices.

See **figure 291**:

- The microphone picks up ambient sound waves, converts them into a small electrical signal, and applies this signal to the input of the amplifier.
- As the name says, the amplifier raises the level of small electrical signals to a level large enough to trigger the speaker.
- These higher-level signals are applied to the speaker, which converts them back into the sound wave we can hear.

The microphone can be considered an input sensor and the speaker an output transducer.

Thus, the block diagram of **figure. 291** can be considered a very simple **I / O** (Input / output) system.

Most common types of sensors and transducers

There is a huge number of sensors and transducers and now even more, with the increasing use of Arduinos and the like. The table in **figure 292** shows some of the most common.

Unit to be measures	Input sensor	Output transducer
Light intensity	LDR Photo-transistor Photo-diode Solar Cell	Light and lamps LEDs Displays
Temperature	Thermistor Thermocouple Resistive type temperature detectors	Fans Heater
Pressure/force	Load Cells Strain gauge	Elevators Hydraulic jack
Position	Potentiometers Encoders	Solenoid Motors Painel meters
Speed	Taco generator Reflective Optical Couplers	AC & Dc motors Brakes
Sound	Ceramic microphone Electret microphone	Buzzer Loudspeaker Alarm
Humidity	Specific humidity sensor	Alarm Motor Pumps
pH	Specific pH sensor	Alarm
Distance	Ultrasonic distance sensor	Brake Motor

Figure 292 - Table of most common sensors.

It is very important to note that the input sensor (or transducer) produces an output signal or a voltage that is proportional to the variation of the magnitude being measured.

The type or quantity of the sensor output signal depends on the sensor being used. In general, these sensors can be classified into two types:

- a. Active Sensors
- b. Passive Sensors

Active sensors

Active sensors require an external power supply to operate.

Active sensors are self-generating devices because they produce a voltage of 1 to 10 VDC or a current of 4 to 20 mA, for example. A good example of an active sensor is a strain gauge type sensor. Refer to **figure 293**.

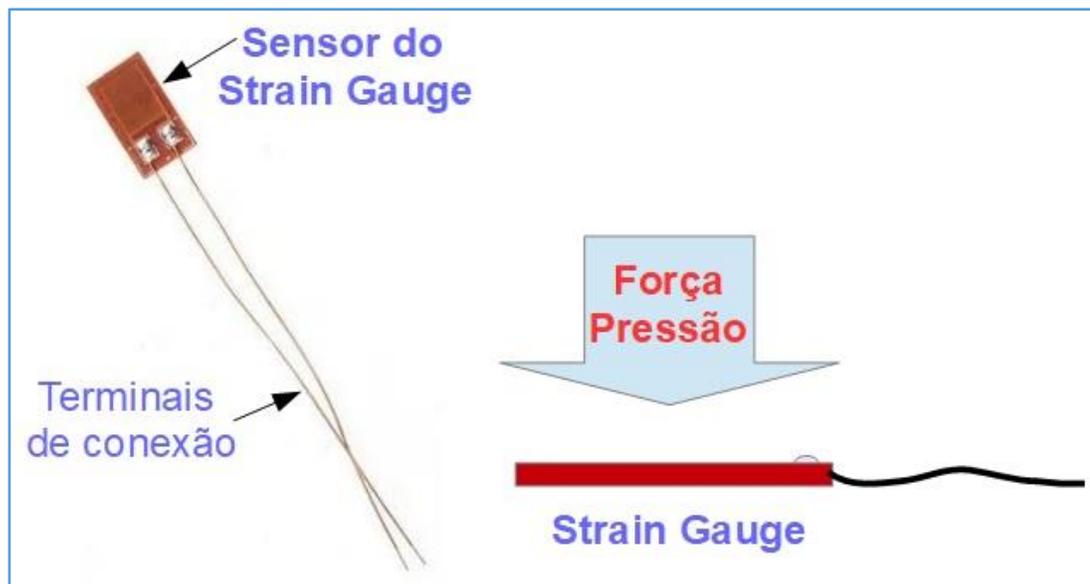


Figure 292 Strain gauge sensor.

Strain Gauge sensors are pressure sensitive on a resistive bridge that is externally polarized. The output voltage is proportional to the force or pressure applied to the sensor.

Passive sensors

A passive sensor does not need any additional power supply, being directly connected to the electronic circuit of processing. The passive sensor generates an output signal as a function of an external stimulus.

For example, the sensor known as "**thermocouple**" is used to measure temperatures. When this sensor is exposed to a temperature change it generates a small voltage at its output, which can be measured by a millivoltmeter. Some better-quality digital multimeters come with a thermocouple type sensor so you can use your DMM for temperature measurement. This is a "thermocouple" type.

Another example is thermistors, which change their internal resistance when exposed to a temperature variation.

Analogic and digital sensors

Sensors of the "**analog**" type produce an output of the continuous type, proportional to what is being measured. For example, displacement, temperature, velocity, pressure produce an analog signal.

"**Digital**" sensors produce a discrete digital signal or voltages that are actually the representation of the magnitude being measured.

Some types of sensors for Arduino and similar

Figure 293 illustrates some types of sensors that can be used in conjunction with the / Arduino board, RedBoard, etc.



Figure 293 Some types of sensor for Arduino and similar.

Use of sensors in electronics

Here are some uses where you can use sensors to measure some things. Remember that in books, eBooks and on the Internet, you can find good coverage of the subject, without my having to put everything here.

Use your Protoboard, DMM, cables and other electronic components if you want to try out some of the circuits shown.

1. A simple circuit driven by the magnetic field

Notice in **figure 294**:

- When the magnet approaches the blade switch, it switches on and turns on the circuit, lighting the lamp.

- The magnetic field of the magnet causes the switch on the blade switch to close. When the magnet is removed, the contacts open.

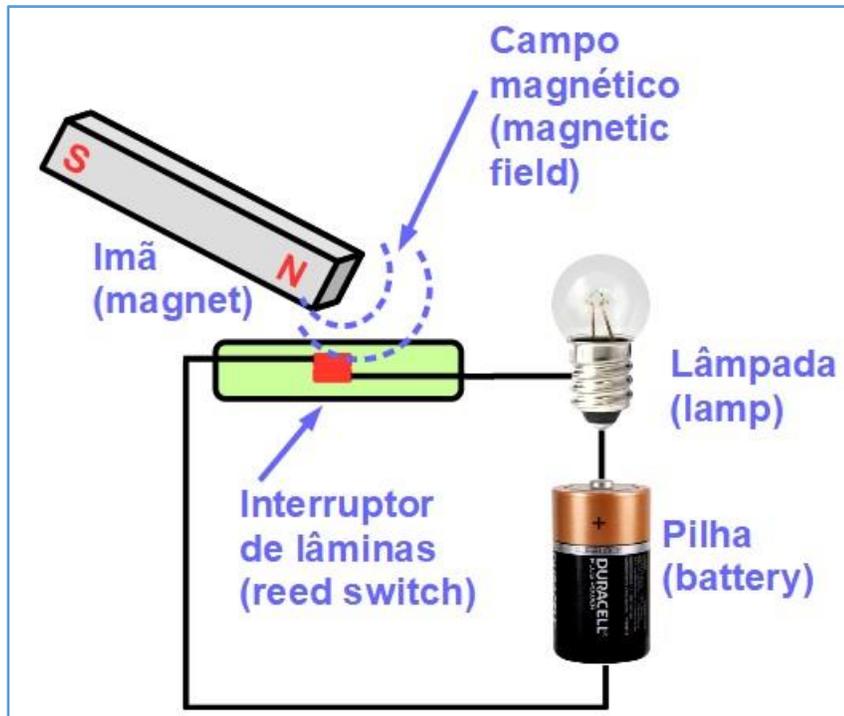


Figure 294 – Simple circuit with sensor.

■ This type of sensor with blade switch is widely used in residential alarms and is installed on doors and windows. When one of them is forced, the switch closes and triggers the alarm.

2. A circuit driven by light variation

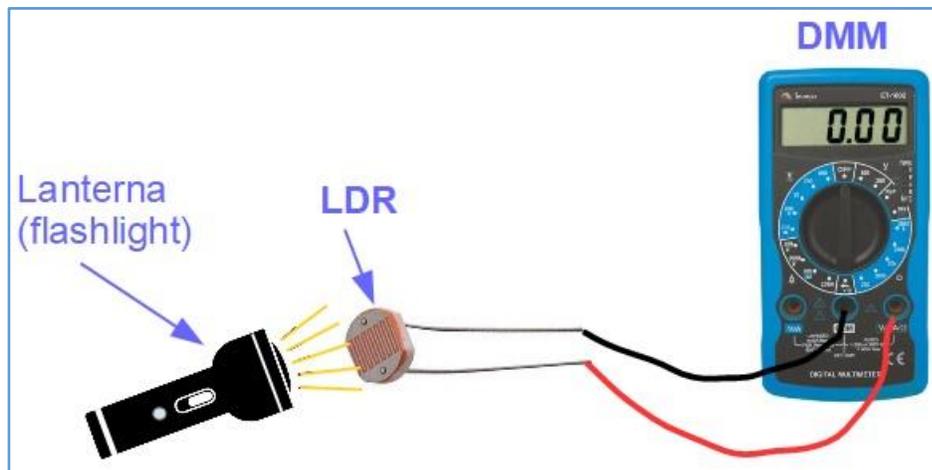


Figure 295 - Single circuit with LDR sensor.

In **figure 295** a simple circuit is shown, using an **LDR** or "**photoresistor**", as a sensor. As you have seen, the LDR varies its internal resistance depending on the intensity of the light applied to it. By varying the luminous intensity that reaches the

face of the LDR, it also varies its resistance which can trigger several actuators connected to the circuit where it is.

3. A circuit driven by temperature variation.

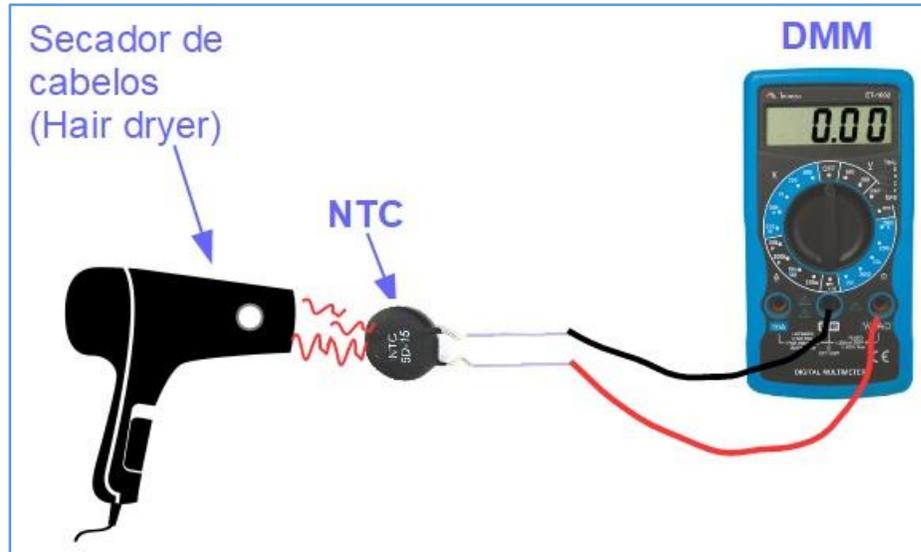


Figure 296 Simple circuit using a thermistor (NTC) as a sensor.

The operation of the circuit of figure 296 is very similar to the prior circuit. But now, we use as a sensor a thermistor, which varies its internal resistance as a function of temperature.

In all of the above circuits, it is important to note that in addition to the simplified components shown, we need to use electronic circuits that will "read" the sensor signals and drive an actuator. The actuator may be, for example, a relay, an alarm, a key, an engine, etc.

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Chapter 42

Direct Current motors

Introduction

In this chapter our subject is small **DC motors**, used widely in cars, airplanes, robots, etc. As in the future you should work with Arduino and; or RedBoard, and so on, you'll definitely want to do projects that use motions like the ones mentioned. That's where the small DC motors come in.

An engine uses electromagnetism to produce motion. In other words, it converts electrical energy into mechanical energy.

Objectives

- Basic analysis of some types of DC motors.
- Some simple DC motors applications.

The DC motor

Motors use the attraction and repulsion properties of magnets to create motion. In a standard engine, two types of magnets are used:

- ▶ A permanent magnet and
- ▶ A temporary magnet

The permanent magnet remains static inside an engine and then it is called the "stator". Inside the stator, is a coil of enameled copper wire, which rotates at high speed and is called "rotor".

Some DC motors have brushes and work in the same way as described. These brushes are static, embedded in the motor body.

Please refer to **figure 297** for some types of small DC motors.



Figure 297 – Small DC motors.

These motors are powered by a conventional power supply or by batteries. Two features are important for your application:

1. The motor speed can be controlled by adjusting the current. This rotation is measured in RPM (revolutions per minute) and
2. If the motor terminals are inverted it reverses the direction of rotation of the shaft.

The electronic circuits where the motors are connected control the above items and the corresponding actuation.

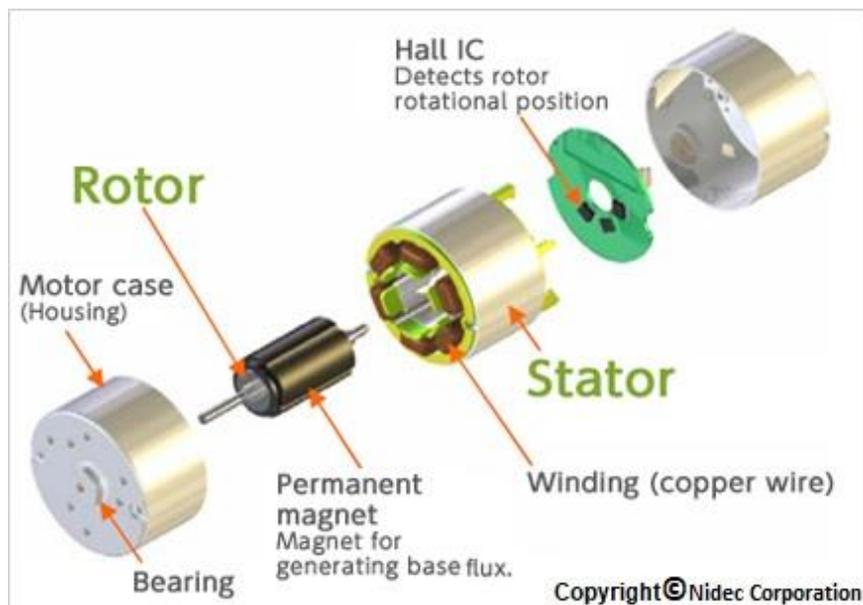


Figure 298 - construction of a small DC motor.

Step motors

The step motors have several coils in the stator allowing it to rotate and stop in certain positions and there until a new drive is needed. This drive is made by voltage pulses applied to one of the motor coils.

The name "stepper motor" is because each pulse of electricity applied to the motor causes it to spin one step. The step motors may rotate in only one direction or in two directions, depending on the polarization of the applied voltage.

The stepper motor is controlled by a "driver" that sends voltage pulses to the motor, causing it to rotate step by step. In this way, stepper motors are swivel for short and quick movements. See **figure 299** for some models.

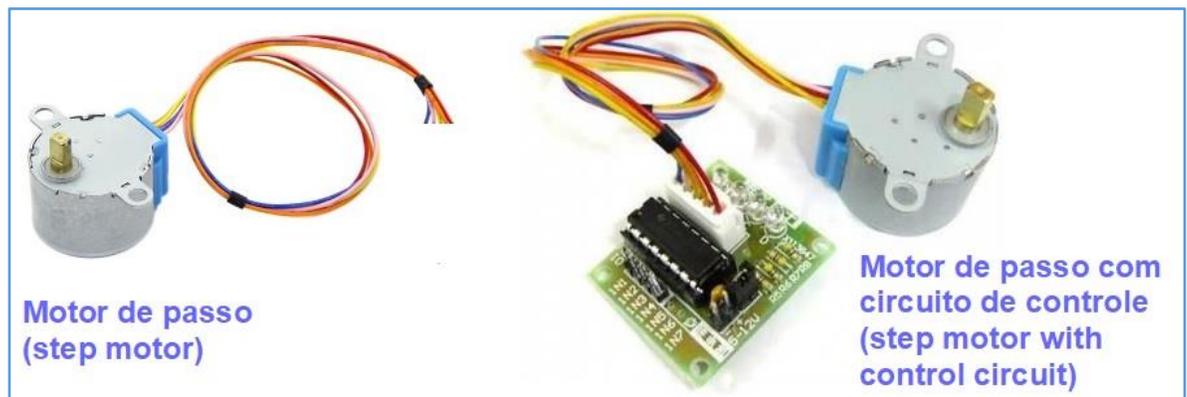


Figure 299 – Step motors.

Servo motors

Servo motors are also DC motors, designed to rotate up to a certain position and stop. This position can be between 0 and 180 degrees of rotation. Essentially the servo motor is a Cc motor controlled by a potentiometer, being coupled to some reducing gears.

Servo motors typically have three wires in red, black and yellow (orange or white). The voltage applied to the motor has the positive on the red colored wire, the ground on the correct wire (sometimes brown) and the motor control signal on the yellow colored wire (sometimes orange or white). Note that servo motors are supplied with 5 VDC voltages.

Because of this possibility to vary its rotation between 0 and 180 degrees, the servo motor is ideal for applications in robots and other projects that can have simple movements. It has a great use in the industry and even some models of cameras use servo motors to adjust the focus of the image.

In **figure 300** you can see some types of servo motors. See the detailed servo motor design by Parallax, Inc.,



Figure 300 - Examples of servo motors. See the excellent description in the design of Parallax, Inc.

Copyright Parallax, Inc.

PWM – Pulse Width Modulation

The control signal stops servo motors are of the "**PWM**" type which means "Pulse Width Modulation" (Pulse Width Modulation). PWM pulses usually range from 1.0 to 2.0 milliseconds and 1.5 milliseconds are the center of the motor's range of motion. Every 20 milliseconds a control pulse is sent to the motor.

PWM is a type of digital signal widely used in more sophisticated control circuits. It is perfect for triggering servo motors, used in robots, cars, airplanes, etc. In the future you can use them with Arduino or RedBoard for your projects.

See a figure illustrating the pulse width of the PWM and a representation of the angular rotation of the motor in **figure 301**.

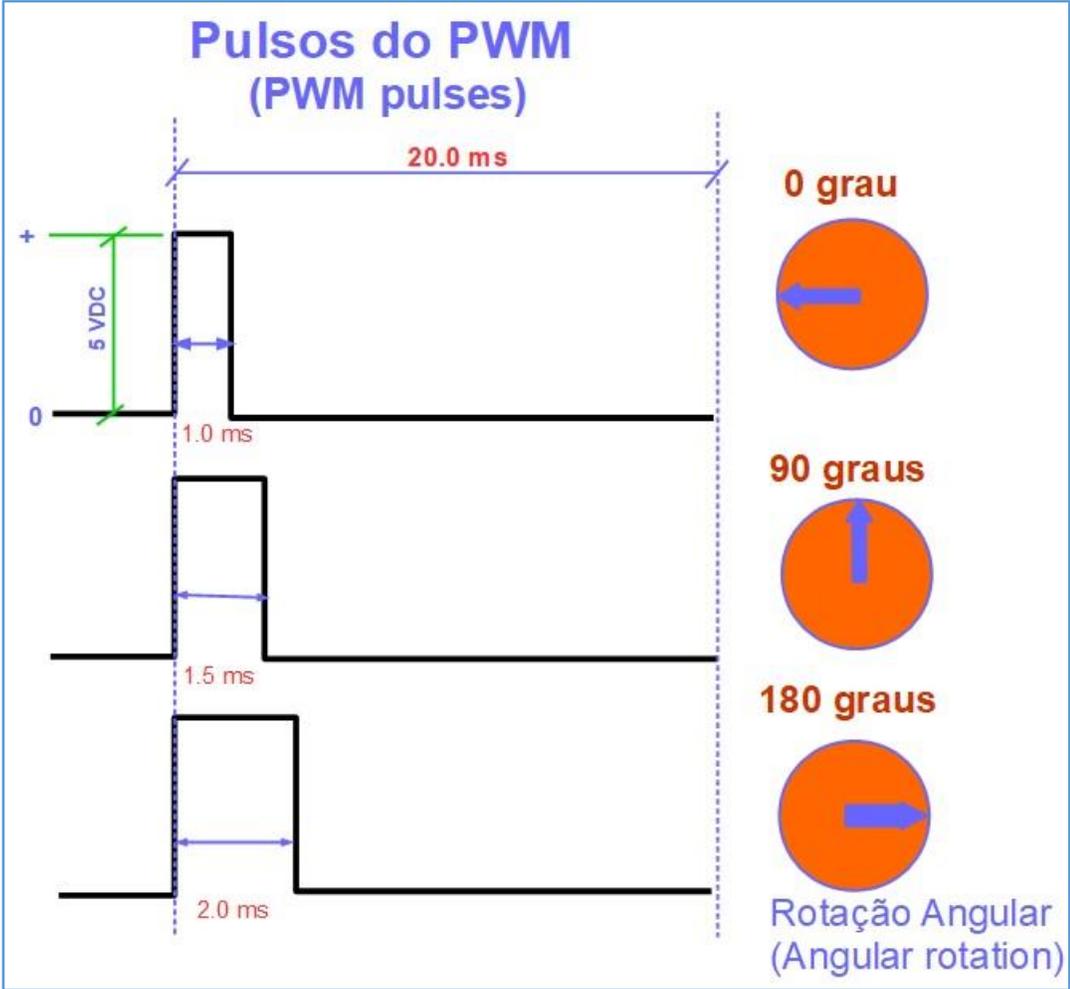


Figure 301 – Pulse width and angular rotation.

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Bibliography

1. In Portuguese

- **Coleção** [“MONTAGENS ELETRÔNICAS PARA QUE NÃO É TÉCNICO”](#).
 - Vol 1 – Teoria básica e componentes eletrônicos
 - Vol 2 - Circuitos eletrônicos básicos
 - Vol 3 – Prática de Montagem
 - Vol 4 – Fontes de alimentação
 - Vol 5 – Projetos de instrumentos de medidas
 - Vol 6 – Amplificadores de áudio e receptores
 - Vol 7 – Transmissores de rádio e antenas
- [Monte seu Projeto Eletrônico Facilmente!](#) Montagens Eletrônicas para principiantes. Viu um esquema na revista e quer ver funcionar?
- [CADSOFT EAGLE PCB® para iniciantes!](#) Faça o layout das suas Placas de Circuito Impresso
- [Monte facilmente seus projetos eletrônicos](#) - eBook interativo, para leitura no Apple® iPad. Publicado através da Apple iTunes Store.
- [Como usar o multímetro! Multímetros digitais e analógicos!](#) Técnicas de uso correto dos multímetros analógicos e digitais.

2. In English

- Electronics Learning Lab – Radio Shack – USA
- Heathkit - DC Electronics – USA
- Lessons in Electric Circuits – Volume VI – Experiments – Tony R. Kuphaldt, 2010 – USA.
- Complete Electronics Self-Teaching Guide – Earl Boysen + Harry Kibett, 2012, USA.
- “Rough Guides to Electronics”, Madlab Org - 2016 – Drawings with permission of the company.

- Getting Started in Electronics Mims, Forest – 1994, USA
- Didactic materials at **SparkFun Electronics USA site**, in the form of tutorials, resources, product data sheet, etc. Use of images and text with permission of the company.
- Didactic materials at **Instructables – USA** site, in the form of tutorials, resources, etc.
- Didactic materials at **Adafruit – USA site**, in the form of tutorials, resources, product data sheet, etc.

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