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ANALOG ELECTRONICS

1. INTRODUCTION TO ANALOG ELECTRONICS

1.1.Electrical or Electronic?

What is the difference between electricity and electronics? Ultimately, both are based in the movement and control of electrons.

The main concern of **electrical technology** is the supply and consumption of energy for use in domestic and industrial devices.

Electrical technology serves to generate electrical energy, transport that energy to homes and industrial facilities and facilitate (by way of cables, distributors, etc.) the arrival of energy to a whole series of useful tools.

Electronic technology, on the other hand, aims to process information that is transmitted by electric currents. These currents can be interpreted as signals that are analyzed, transformed and retransmitted.

Electronic technology is involved in, among other things, the fabrication of integrated circuits and computer chips. Its principal use is in the processing of digital or analog signals.

1.2. Electronic systems

All electronic devices are designed to automatically respond to changes in their environment. This includes obtaining information, processing it and, finally, responding.

To sum up, electronic systems must:

1. Obtain information about their surroundings through the use of an electrical signal. To do this, they use inputs: switches, remote controls, sensors, timers, etc.
2. **Process the incoming electrical signal.** The system can filter, amplify or mix it with another signal, create new signals, etc.
3. Transform the processed signals into useful responses, also known as outputs: the sound of an alarm, the light of a lamp, the ignition of a machine, etc.

1.3. Analog electronics

Electronics is basically the technology of capturing, processing and responding to information using electrical signals. An electrical signal is a sequence of variations in electrical magnitude (especially in tension or intensity), which is capable of transmitting information.

Analog electronics works with continuous signals that can be of any value within a given range.

On the other hand, digital electronics use signals of a finite number of values.

ANALOG SIGNALS

- **Direct current:** With DC, the voltage is constant.
- **Alternating current:** With AC, the sign of the voltage changes in a smooth and continuous way. Specifically, the oscillation follows a sine wave.
- **Audio signal:** The electrical current supplied to some speakers is comprised of a series of continuous variations that replicate the variations of sound waves**.**
- **Electrocardiogram:** A heart beats regularly. This beating is controlled by the nervous system which, as you know, functions using electrical signals. An electrocardiogram allows a user to visualize variations in these signals, as well as to detect any possible anomalies.

DIGITAL SIGNALS

- **Binary signal:** This signal is composed of only two values and the change between the two values is discontinuous: there either is a current or there isn't. Computers, DVDs, MP3 players, etc., use this type of signal for processing information.
- **Ternary signal:** The signal is composed of three possible values and the change between them is discontinuous.

2. ELECTRICAL COMPONENTS

2.1. Resistance control

Thanks to our knowledge of electricity, we know that resistive components reduce the current and cause a drop in the voltage. Consequently, resistive components allow us to modify the amount of current passing through a part of the circuit, as well as to modify the potential difference in each of its components.

In the world of electronics, there are both fixed and variable resistance control components. Types of variable components include those we adjust manually, and those whose resistance depends on light or temperature.

2.1.1. Resistance (physical principles)

An electrical current consists of the movement of electrons through a conductive material. The collision of these electrons against the particles of the conductive material is manifested as a sort of friction; a resistance to the flow of current.

At a given potential difference, if the resistance is high, the current intensity will be low (and vice versa, as stated by Ohm's Law).

2.1.2. The resistor

This component is designed to provide a constant and known resistance to the flow of a current. This resistance practically does not change in response to changes in the voltage or current in the circuit. It is also unaffected by changes in the light or temperature conditions. Resistors have two main applications: to obtain a lower voltage than that provided by the power source, and to limit the current intensity that passes through a given segment of a circuit.

Its main characteristics are:

- **Resistance**

  It determines the degree of opposition the component gives to the flow of the electrical current. It is measured in ohms or multiples or submultiples of ohms. Ohm's law mathematically establishes this relationship::

$$I=V/R$$

- **Maximum power**

  The maximum amount of heat a resistor can dissipate per unit of time. The greater the current the resistor has to handle, the more heat it will dissipate.

$$P=I^2\cdot R$$

  This is why resistors with equal resistances but of different sizes are manufactured. A large resistor can handle dozens of Watts, while a small one can be burnt out by just a few tenths of a Watt.

- **Tolerance**

  The margin of error between the true resistance of a resistor and that stated on its packaging. It is expressed as a percentage. For example, if a resistor labelled 1,000 ohms has a tolerance of 2%, its true resistance could be between 980 and 1020 ohms.

2.1.3. Variable resistors

2.1.3.1 Characteristics

Variable resistors, also known as potentiometers are resistors whose resistance can be adjusted. They have a cursor that allows the user to make these adjustments, sometimes moving it on a straight line and other times moving it circularly. Variable resistors have many users, the simplest and most common of which is to regulate the current intensity passing through one part of the circuit. Among other things, a variable resistor allows the user to gradually adjust the intensity of the light of a lamp, the volume of music of a speaker, or even the speed of a motor.

Its main characteristics are:

- **Resistance range**

  This is the total range of resistance values a variable resistor is capable of producing. The range is covered by moving the cursor from one extreme to another. One extreme corresponds to the minimum value and the other to the maximum. Moving the cursor across the range covers all intermediate values.

- **Maximum Power**

  The maximum amount of heat the variable resistor can dissipate in a given unit of time.

2.1.3.2. Connecting a variable resistor

A variable resistor always has three connection terminals, two on its sides, called common, and a central one called cursor. However, as we know, resistance is always defined between two points. So, which two terminals should we use?

If we use the two common terminals, the variable resistor will function as a fixed resistor.

If we use one of the common terminals and the cursor, resistance will depend on the position of the cursor. But, does it matter which of the common terminals we use? Yes, it does: using one common terminal will mean that moving the cursor to the right increases the resistance, while moving it to the left will decrease it. Using the other common terminal will mean the opposite.

2.1.4. The thermistor

2.1.4.1. Characteristics

A thermistor is a variable resistor whose resistance depends on the temperature. There are two types: NTC and PTC.

NTC stands for "Negative Temperature Coefficient". NTC thermistors lower their resistance as the temperature rises, and vice versa.

PTC stands for "Positive Temperature Coefficient", and these thermistors work in reverse. PTC thermistors increase their resistance as the temperature rises, and vice versa. So that they function correctly, the use of PTCs must be restricted to a certain temperature range. These temperature limits should be borne in mind when selecting PTCs for particular applications.

An important characteristic is:

- **Working interval:** The primary characteristic of a thermistor, apart from its type (NTC or PTC), is the range of temperatures within which it can function. The working interval is defined by a minimum and a maximum temperature.

2.1.4.2. Applications of a thermistor

- **Thermometer**

  As the measurement of the resistance is a problem that has been correctly solved in electrical engineering, and as there is a known relationship between the temperature and resistance of a thermistor, the thermistor can be used for manufacturing electronic thermometers. For the same reasons, thermistors are used in the following devices:

- **Heater with a thermostat**

  Many heaters need a mechanism to regulate their temperature, keeping it from climbing too high or dropping too low. Additionally, some devices generate heat as a by-product, and need a mechanism to avoid excessive increases in temperature that could damage nearby objects, or the device itself.

- **Thermal sensors**

  A thermistor can be used to control the temperature of motor oil or coolant in an automobile. Temperature information can also be displayed to the driver on the dashboard.

2.1.5. Photoresistors

Automatic door sensors, light meters in cameras and the sensors in alarm systems are just some of the many applications of photoresistors.

Photoresistors provide varying resistance to an electrical current, depending on the intensity of light that shines on them. Specifically, the more intense the light, the less resistance they give to the current. This allows them to provide information about luminosity to an electronic system, making them, along with thermistors, another type of input device.

Photoresistors are the basis of ambient light sensors and photosensitive cells, which are capable of sensing rays of artificial light (infrared, visible or ultraviolet).

Some important characteristics are:

- **Range of resistances**

  The range of possible values that a resistor can take. Many photoresistors have a range that goes from 100 Ω when the surrounding light is intense, to 1 M Ω in total darkness.

- **Working frequency**

  The range of radiation frequencies that activate a photoresistor, causing its resistance to drop. Some ranges depend on the color of the light, while others depend on the type of radiation (infrared, visible, ultraviolet, etc.).

2.2. Energy storage

Some components have the ability to store energy and then release it again later. However, unlike in batteries, this storage is only temporary. While batteries are specifically designed to provide a prolonged supply of energy, these components have several other functions.

A capacitor stores electrical energy by accumulating opposite charges on either side of an insulating layer. This, in turn, generates an electrical field that contains energy.

An inductor or reactor stores energy as a magnetic field. Any cable through which an electrical current passes generates a magnetic field. However, in the case of an inductor, a coil of cable allows to generate a field that is more intense than the one of an individual cable, intense enough to store energy efficiently.

2.2.1. Capacitors

2.2.1.1. Characteristics

Even though **capacitors** can store (and release) electrical energy, they tend to be used differently than batteries. Batteries can provide a fixed voltage for a relatively long period of time (thanks to chemical reactions), and are used to generate a DC.

While a capacitor can sometimes act as a provisional battery, the two operate differently. For example, no chemical reactions take place in capacitors. Instead, opposite charges are stored on two conductive plates (armature) which are separated by an insulating material (or "dielectric"). When the capacitor is exposed to a given voltage, the charge reaches a limit (which is determined by the dielectric and the shape and size of the capacitor itself). This limit is known as the capacitance, and is measured in farads (F). The word capacitance is the origin of the name "capacitor."

Its most important characteristics are:

- **Capacitance**

  The maximum accumulation of charge that a capacitor can produce with a given voltage. If one volt is applied to the conductive plates of a capacitor and it accumulates one coulomb on each place, the capacitance is equal to one farad:

  $$1F = 1C/1V$$

  A farad is a very large unit. In order for a capacitor to have a capacitance of one farad, it would have to be extremely large. Therefore, the capacitors that are used in electric and electronic circuits have capacitances measured in microfarads (1μF= 0.000001 F) or in even smaller submultiples, such as nanofarads (1nF = 0,000000001 F) or picofarads (1pF = 0,000000000001 F).

- **Maximum voltage**

  This is the maximum voltage a capacitor can handle without breaking. If we expose the capacitor to a voltage that is too powerful, the dielectric will start to operate as a conductor, possibly even causing the capacitor to explode.

2.2.1.2. Applications of a capacitor

- **Filter**

  A capacitor tends to smooth out variations in the current intensity, and is capable of converting an abrupt change into a smoother one. This is why capacitors are used in devices to filter signals. It can also act as an advancing device of intensity with regard to voltage in an alternating current circuit (later on, we will see that a coil or inductor can perform a complementary function as a retarding device).

- **Storage of electrical energy**

  Thanks to its ability to store electrical energy, a capacitor can release pulses of voltage in specific situations. These may include helping to light a fluorescent tube, or providing a quick boost of energy to an amplifier where necessary (it is used in audio systems for cars).

- **Radio tuner**

  By modifying the capacitance of a variable capacitor, one can adjust the frequency picked up by a radio.

- **Timer**

  By charging or discharging a capacitor at a known rate, it can be used as part of a timer.

2.2.1.3. Structure

- A capacitor has the following parts:
- **Armatures:** The plates or armatures are two surfaces of a conductive material directly opposite one another in the shape of a sphere or sheet. The material usually used is aluminium.
- **Dielectric material:** It is an insulating material located between the two armatures or plates. The materials mostly used are: ceramic, polyester, mica and even dissolved chemicals. Sometimes air is also used.
- **Terminals:** Soldered to each of the armatures, terminals allow the connection of the component into the circuit. A circular shaped section conducting material is used.

2.2.1.4. Charge and discharge

A capacitor does not store or discharge electrical energy immediately. It takes time to both charge and discharge. In order to charge the capacitor, we need a generator to provide electrical energy, and a resistor connected in series with the capacitor.

As soon as we flip the switch, the charge begins to flow through the circuit and into one of the armatures. Opposite charges begin to accumulate in the other, until the difference in charge between the two plates is the same as the difference in charge between the terminals of the generator; consequently, the current flowing through the circuit drops to zero.

The way in which the potential difference and the current in the terminals of the capacitor develop follows a rapidly rising or descending curve (of a type called exponential). After a period of transition, the potential difference in the capacitor becomes constant and equal to the voltage of the generator. The current attains a value of zero after the same time interval.

The charge time depends solely on the resistance connected in series and on the capacity of the capacitor, never on the potential difference of the battery.

2.2.2. Inductor or coil

2.2.2.1. Characteristics

A coil can store energy and release it but, unlike a capacitor, it stores it as energy of a magnetic field.

A coil can act as a retarding device of intensity with respect to voltage, unlike the capacitor, which produces an advance.

The flow of electrical current through the cable coil creates a magnetic field (magnetic induction). In turn, the lines of the magnetic field, when passing through other coils or through the coil itself, can create currents (electrical induction or the Faraday effect).

Due to the fact that electromagnetic induction is critical for the operation of the coils, these coils are also called inductors.

Their most important characteristics are:

- **Self-inductance coefficient**

  It measures the capacity of the coil to generate a magnetic flow when a given current flows through it, also its capacity to generate a self-induced electromotive force when a given change of current takes place. It is measured in henries (H).

- **Resistance**

  Since a coil is made out of a cable of conductive material, it has a certain resistance to the flow of current, which must also be taken into account, along with the effects of self-inductance.

2.2.2.2. Applications of a coil

- Processing analog signals

  Inductors, along with capacitors and other components, can be used to make adjustable circuits that can enhance or filter signals according to certain characteristics, such as their frequency. In particular, they can be used in the circuits of radio tuners.

- **A barrier against interference**

  A small, doughnut shaped coil wrapped around a cable can help keep the cable from interfering with radio signals.

- **Blocking alternating current**

  Certain types of coils which exhibit an increased inductance in response to certain frequencies can be used to block alternating currents, while allowing direct currents to flow through them.

- **Transformer**

  A combination of two or more coils, when properly adjusted, can be used to increase or decrease the voltage and intensity of alternating current. It is a very used device with a great technological importance.

2.2.2.3. Structure of a coil

A coil can be made by wrapping a wire around a straight axis, creating a cylinder (tube-shape). They can also be wrapped around a circle, resulting in a toroidal (doughnut) shape.

Each turn of the wire around the axis forms a spiral. Each of them creates a magnetic field and the combination of all of them is precisely the coil, whose magnetic field is the sum of the fields of the individual spirals.

The wire tends to be wrapped around a material that is itself magnetic, in order to strengthen the magnetic field.

2.2.2.4. Self-inductance

Self-inductance is a key phenomenon in a coil or inductor. It is called self-inductance because the variations in the magnetic field generated by the coil influence this coil; they cause a voltage (Faraday's Law) with an opposite charge to the above mentioned change in the magnetic field (Lenz's Law).

In an electrical circuit, when the intensity going through an inductor changes, a voltage resisting this change tends to appear in the terminals of the circuit. When the current is changing at a fast rate, the voltage between the terminals of the inductor is high.

2.3. Active components

The components we have seen so far modify the signal, but they do not allow us to actually control it. Because of this, they are known as passive components.

However, active components are capable of changing what they do depending on the incoming signal. For example, an active component may only let the current flow when the incoming signal is of a certain type, it can direct the course of the current, and even increase its intensity.

They are fundamental to any electronic control system. In fact, modern information technology as we know it wouldn't exist without components like diodes or transistors, components we are about to study.

2.3.1. The diode

2.3.1.1. Introduction

As we know, a current can flow in both directions in a circuit. However, for many purposes, it is preferable that the flow of current be limited to one direction.

Diodes are useful because they let current pass through their two terminals in only one direction. That is, a diode functions as a good conductor for the current flowing in one direction and a good insulator for the current flowing in the other.

Diodes can help protect devices that only accept a current flowing in a given direction; they can also be used to make a converter that changes a current from AC to DC.

2.3.1.2. Connecting a diode

The order in which the two terminals of a diode are connected is important because all diodes have **polarity**. The positive pole is called the anode and the negative pole is called the **cathode**.

If the largest voltage is applied to the anode, the diode will let the current pass through it, acting as a good conductor. In this case, we say the diode is **directly polarized.**

If, on the other hand, we do the reverse, the diode will act as a good insulator. In this case we see the diode is **inversely polarized**.

2.3.1.3. Real diode characteristic curve

So far, we have been describing how an ideal diode works. An ideal diode is one that lets 100% of the current through during direct polarization (offering no resistance whatsoever) and none of the current through during inverse polarization, regardless of the voltage.

Unfortunately, any real diode falls a little short of this ideal. It is precisely the nature of the difference between real diodes and ideal ones that is used to characterise diodes, and which allows us to choose a specific one for a given purpose.

Depending on the voltage to which a diode is subject, this diode will act in different ways:

- The **threshold voltage** (V Threshold) is the minimum direct polarization at which the diode continues to conduct. As long as the voltage is under this level, the diode will continue to function as an insulator.
- In direct polarization, at voltages exceeding V Threshold, the diode acts as a good conductor. An ideal diode would offer null resistance, but all real diodes oppose a **little internal resistance**. Because of that, the slope is not completely vertical.
- In inverse polarization, an ideal diode would not let the current pass. But a real diode will always let a little intensity pass, which in most applications is not important (for example, it is not enough to produce light in a light bulb).
- When inverse polarization grows and reaches a critical voltage called **breakdown voltage** (VBreakdown), the diode suffers some internal changes which allow the passing of current, and which also cause a permanent damage to the diode.

2.3.1.4. Characteristics of a diode

- **Threshold voltage:** The minimum tension at which a diode in direct polarization lets a current flow through it. The typical values of VThreshold go from 1V to 3V. It is interesting to understand the threshold voltage as a barrier. That is why it is also called potential barrier of a diode. This perspective allows understanding that, once the barrier is surpassed, even when current begins to flow, there is a drop in the voltage in the terminals of the diode that is equal to the threshold voltage.
- **Maximum intensity:** it is the maximum current intensity that a diode can handle without running the risk of breaking.
- **Breakdown voltage:** in inverse polarization, it is the maximum voltage that the diode can handle before it is internally damaged and it allows the flow of inverse current.

2.3.2. The LED

2.3.2.1. A diode traffic light

You may never suspect that a traffic light runs using diodes.

Yes, it does! Some diodes emit light when a current flows through them. These are known as LEDs, which stands for "Light Emitting Diodes".

So, why have some cities decided to swap their old incandescent light bulbs in their traffic lights for LEDs? Have a look at the advantages of using them in the list below.

- **Increased useful life:** They last a long time.
- **Greater energy efficiency:** They transform most of the energy into light (they have few losses in the form of heat).
- **Quick response:** LEDs light up and switch off nearly instantaneously.
- **They are monochromatic:** They emit light of only one color.
- **Reduced size.**

2.3.2.2. The LED (Light Emitting Diode)

LEDs emit light during direct polarization as long as they are exposed to a voltage greater than their threshold voltage VThreshold. In other words, they emit light when the diode lets current flow through it.

Within lighting, LEDs are increasingly applied, thanks to their many advantages, over incandescent and even fluorescent light bulbs.

Furthermore, the production of LEDs is relatively cheap, and causes less damage to the environment than the production of fluorescent light bulbs.

Therefore, the most important characteristics of a LED are:

- **Threshold voltage:** The minimum voltage (during direct polarization) that is necessary for a diode to let a current flow through it. In this case, it is the minimum voltage, from which it will start to emit light.
- **Maximum intensity:** When intensity increases, the diode will emit more and more light. However, there is a maximum intensity from which the diode will break down, and which we must never exceed.
- **Light color or wave length:** It is the color of the emitted light (which can be physically measured from the wave length of the radiation). Some LEDs emit light that is not visible. For example, the LEDs of a remote control emitting infrared radiation.

2.3.2.3. Parts of a LED

The parts of a diode are:

- **Epoxy lens:** A covering made of plastic that is stronger than the glass used in normal light bulbs. It protects the semiconductor chip inside. They are often colored for aesthetic reasons, though this does not affect the color of the light emitted.
- **Cathode terminal:** The longest terminal. It must be connected to the highest voltage (for example, the positive terminal of a battery) if the diode is to be directly polarized and emit light.
- **Anode terminal:** The shortest terminal. It must be connected to the lowest voltage (for example, the negative terminal of a battery) if the diode is to be directly polarized and emit light.

- **Semiconductor chip:** Inside the lens, there are two joined semiconductors, each the size of a grain of sand, one for the anode and the other for the cathode. This union is the basis of the functioning of a LED, and of any diode in general.

2.3.3. The relay

2.3.3.1. Characteristics

A relay allows a current to flow through one circuit (known as the power circuit) as long as current is flowing through another circuit (known as the command circuit). In this way, the **command circuit** acts as a switch in the **power circuit**.

Why do we make things more complicated by using a relay when a simple switch might be enough?

A very frequent case is when the power circuit works at high voltages and in an alternating current; in this case, the relay makes it possible to remotely control it through the use of switches, timers and automatic mechanisms, functioning in a parallel circuit that runs with a low voltage and a direct current, which is safer, uses less energy and also makes electronic manipulation of the signal possible.

2.3.3.2. Functioning of a relay

When a current flows through the command circuit, it enters the terminals of the coil, which begins to function as an electromagnet. This electromagnet attracts part of the armature magnetically and flips the switch. Consequently, the current flowing through the power circuit changes its path.

In this way, a push switch connected to a 12 V DC current controls another circuit operating at a much higher voltage. And a switch isn't the only option; in fact, the relay can be operated with any electronic control mechanism that runs on a low voltage and a direct current.

- **Coil:** it is the element that generates a magnetic field and magnetizes the nucleus. In order to get the coil to generate this magnetic field, a potential difference must be applied to the two sides of the coil, normally between 12 and 24 V for coils of conventional relays.

- **Soft iron or pivot:** the armature is a bar of material that must be easily attracted to magnetic fields. The attraction force that will appear at one end will be multiplied at the other end as a result of a leverage effect, and thanks to the pivot**.**

- **Contacts:** Due to the physical arrangement of the contacts, there will always be contact between the mobile one and one of the two fixed ones. The mobile contact changes its position depending on the position of the lever; that is, depending on whether current flows through the coil or not. For the manufacturing of these contacts, a flexible material is used: when the lever exercises force on them, they are deformed without being broken and, when the magnetic force disappears, they go back to their initial position. The contacts are joined to the structure by means of an insulating material, as current will flow through them**.**

2.3.4. The transistor

2.3.4.1. Introduction

Many technologists consider the transistor to be the most important discovery of information technology and telecommunications of the twentieth century. Today, thousands of transistors are integrated into the chips of our MP3 players, mobile phones, computers, etc.

But, what is so special about transistors?

The purpose of transistors may seem trivial: a transistor allows us to control an electrical current flowing through one circuit by controlling another, much lower, current. (The lower current can be hundreds, or even thousands, of times weaker than the intensity it controls).

2.3.4.2. Parts of a transistor

Physically a transistor is like a sandwich made of two diodes.

There are two different ways of connecting a pair of diodes. The first is by joining the anodes (P type), the second is by joining the cathodes (N type). There are also two types of transistors: **NPN transistors and PNP transistors**. Both their symbols and ways of working are different.

However, both varieties have three terminals: a **collector, a base and an emitter**.

The current flowing through each of the terminals is different, thought the current in the collector is the total of the other two: IC = IE + IB.

In a transistor, the intensity of the base terminal regulates the intensity of the other terminals.

2.3.4.3. Functioning

As we have seen, the intensity in the base controls the intensity in the collector. This control can be carried out in two very different ways:

- **Control is continuous (linear mode):** Incremental changes in the IB result in proportional changes in the IC. In this case, the transistor functions as an amplifier. In fact, music speakers work in this way.
- **Control is discrete (commutation mode):** The transistor functions as a relay. If no current flows through the base, the transistor acts as an open switch between the collector and the emitter, blocking the current. On the other hand, when a current does flow through the base, the transistor functions as a closed switch. All digital electronics are based on this type of signal: the tension is either on or off.

2.3.4.4. Linear transistor

A transistor amplifies the intensity entering through the base as long as it is working within the active area. (See the extension for an explanation of exactly when this happens).

While in the **active area**, the current intensity in the collector is amplified proportionally to the intensity entering the base.

$IC = IB.\beta$

The bigger the **current gain** (represented by β) is, the greater the amplification. Current gain is a very important aspect of a transistor, and can be found listed on its datasheet.

2.3.4.5. Switching transistor

A transistor can also function as a controlled switch: thus, the voltage of the base determines whether or not current can flow between the emitter and the collector. In switching or commutation mode, a transistor has two states:

- **Cut mode (open switch)**
  No current flows through the base, and the transistor functions as an open switch between the emitter and the collector. When $IB = 0$ (or is small enough) then $IC = 0$.

- **Saturation mode (closed switch)**
  A current flows through the base, and the transistor functions as a close switch between the emitter and the collector. When $IB \neq 0$ it lets a current flow through the collector. However, it does not modulate or amplify the intensity IC of that current.

3. CLASSIFICATION CRITERIA

All the components we have studied can be classified according to four different criteria:

- Their structure.
- What they are made out of.
- How they work.
- The physical phenomenon their operation is based on.

Obviously, the same component may find itself in one or more of these groups.

3.1. According to their physical structure

Discrete components are those that are packed separately. All the devices we have seen so far have been discrete.

Integrated circuits, also known as **chips**, are microscopic circuits printed onto a thin board of semiconductive material. These circuits are made up of a large number of discrete components. They avoid the need to pack each component separately (along with its own pins), and therefore are very space-efficient.

Each chip has some pins for input signals and some for output ones. Each pin has a different function, such as correcting, simplifying or delaying an analog signal, etc.

3.2.According to their manufacturing material

Semiconductors are components manufactured using semiconductive material. Silicon is an especially common semiconductor in the world of electronics.

A semiconductor is neither a conductor nor an insulator. Instead, it can perform either of these functions, depending on the surrounding conditions. For example, a semiconductor may only conduct when it is exposed to sufficiently high voltages, if it is heated, if it is exposed to light, etc.

3.3. According to their functioning

Active components are capable of controlling an electronic system by doing things like starting it up, or amplifying or changing the direction of the current flowing through the circuit. Their operation is different depending on the type of input signal.

Passive components, on the other hand, always behave in the same way regardless of the type of input signal. For example, they always provide the same amount of resistance, the same storage capacity, etc. Therefore, they do not allow establishing control.

3.4. According to the physical phenomenon involved

First of all, we have components whose operation is based on **electromagnetic phenomena.**

Then, we have **electroacoustic components**, which transform electrical energy into acoustic energy, or vice versa.

Finally, we have **optoelectronic components,** which transform light into electrical energy, or vice versa.

4. ELECTRONIC CIRCUITS

It is very uncommon to find just one electronic component attached directly to a power source. Normally, several are connected together to form an electronic circuit. When building an electronic circuit, a few things must be taken into consideration:

- An electronic circuit must serve some type of a function. Possible functions include: signal amplification, voltage inversion, softening the profile of an electronic pulse, AC to DC conversion, etc.
- Care must be taken to ensure that each component used is operated within the appropriate voltage and intensity range.

Now, we will look at some examples.

4.1. Intensity limiting circuits

There are many cases in which we need to reduce the intensity reaching an electronic device. If this is not done, the device could overheat or even break.

For example, a light bulb operates correctly between 20 and 50 mA. The only power source available is 12 V. Which resistor is the most adequate for the job?

4.2. The voltage divider

It is sometimes the voltage, rather than the intensity, that needs to be reduced. A special circuit made up of two resistors can accomplish this. It is based on the phenomenon of the drop in voltage through resistors connected in series.

4.3. The alternating current rectifier

4.3.1. Introduction

The purpose of these circuits is to convert an AC input signal (usually 220 V) into a DC output signal with a constant polarity and a voltage that is usually between 12 and 24 V. Constant polarity means that the voltage always has the same sign. This is the first step in converting AC to DC.

All rectifiers are composed of, first of all, a transformer that reduces the voltage of the alternating current. Then, of a diode or connection of diodes that rectify the current and makes sure it is travelling in only one direction.

4.3.2. The half-wave rectifier

If we want to rectify a current of an oscillating polarity, just keeping the part that always circulates in a certain direction, the use of a single diode will be enough.

This process is known as half-wave **rectification**.

4.3.3. The full-wave rectifier

In the previous case, the output signal had a voltage of zero for half of the time. During this time, the diode was inversely polarized.

The connection of four diodes forming the known **Graetz bridge** solves this problem: instead of eliminating the current when the voltage is of the opposite polarity, it reverses it. The result is a signal that is closer to a constant voltage.

4.4. The dark detector

We are studying an electronic system that allows turning on a lamp automatically when we do not detect ambient light. Besides, there is a cursor under the lamp that allows regulating the sensitivity of the light sensor.

This electronic system uses a photoresistor and a potentiometer as inputs, a circuit with a transistor working in commutation for the **processing** of the signal, and finally, colored LEDs as outputs.