LEARNING ELECTRONICS

MOST POPULAR DEVICES

By Intelli Int

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PREFACE

This book gives the characteristics of various more popular electronic groups of components, used in the majority of the circuits, and useful for the amateur to the electronics. The book is structured in twelve chapters that it is described subsequently: The first is dedicated to the resistance, in which we relate the importance and principle of operation of the resistance together with the Ohm´s Law.

The chapter two treats upon the variable resistors or potentiometers, functions and types. The chapter three develops the theme of an indispensable component in any electronic circuit: the condenser. The chapter four treats upon the inductance coils some characteristic and general formulae. The chapter five explains the operation of the diode and its types more usual. The chapter six develops the theme of the BJT or bipolar transistor, another present device in almost all the electronic circuits of today. The remaining chapters include also electronic devices, frequent use such as the relays, the transformers, heat sinks, electric switches, connectors and the last chapter, to the identification of some electric symbols in a schematic diagram.

CHAPTER 1
THE RESISTOR

The resistor is one of the essential components in the construction of any electronic equipment since it allows to properly distribute the voltage and electric current to all the necessary points. In the construction of resistors, materials with high resistivity are used to achieve the necessary values in small sizes that allow easy use. To define the value of the resistor or difficulty that opposes the current, a unit of measurement called ohm is used, which is represented by the Greek symbol Ω (omega).

TOLERANCE

Another important factor in the definition of a resistance is tolerance, which appears as a consequence of the impossibility of obtaining a totally exact ohmic value in the manufacture of it. It is necessary, then, to establish the maximum and minimum extremes between which the resistance will be included; these values are usually expressed as a percentage of the theoretically assigned ohm value. There are, logically, resistances of great precision in their value, which implies setting very low tolerances, but it will be necessary to take into account that their price will increase considerably and will only be necessary in very special applications; being normally intended for general uses and standardized tolerances of ±5%, ±10% and ±20%, although the latter is disappearing from the market due to its low use and that the manufacturing processes have progressively improved, with which the other two tolerances are obtained without difficulty and practically at the same prices.

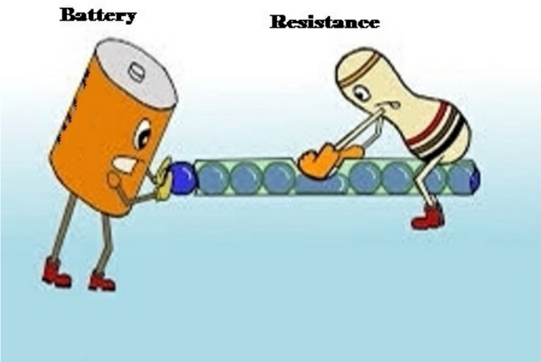

Fig. 2.— Ohm's Law. The electric current, represented by the balls, has to overcome the difficulty presented by the resistor R, in which it loses part of its energy.

VALUE SERIES

Attending, then, to the ohmic value and tolerance, a series of values was established in a standard way, so that with them I could obtain the entire range of resistances from 1 Ω onwards these values are the following:

1,5- 2,2- 3,3- 4,7- 6,8- 10

1,8- 2,7- 3,9- 5,6- 8,2

1,1-1,3-1,6-2,0- 2,4- 3- 3,6- 4,3- 5,1- 6,2- 7,5- 9,1

The first line indicates the values corresponding to the tolerance of 20%, the first two lines are those defined for 10% and the complete table forms the set of values of 5%. The total set of values of the entire range is obtained by multiplying by 10, 100, 1,000, 10,000, 1,000000 or 10,000,000 *the table above*

To avoid the use, always cumbersome, of a high number zero in the designation of the value of a resistor, two letters are used; K and M, which designate a multiplicative factor of 1,000 and 1,000,000 respectively. As an example, we will take any value from the previous table: 2.7 Ω, to this same if we add a K we will obtain 2.7 KΩ, that is, 2,700 Ω, and if we add an M we will have 2.7 MΩ, which will indicate 2,700,000 Ω. The easiest values to obtain in electronic components stores are those that correspond to the 10% series.

COLOR CODE

Identify the value of a resistor, a system is used by means of colors that allows to cover the entire range of the previous one. This system is called color code and consists of painting around the resistance and at one end, four rings of certain colors, corresponding the first two, to the two numbers indicative of the value of the table of values above, the third to the number of zeros that need to be added and the fourth to the tolerance.

POWER

An important, additional factor to take into account in the choice of a resistor, is the dissipation of power in the form of heat that it is able to withstand. This phenomenon of heat dissipation is due to the fact that the current when crossing the resistor loses a certain amount of energy used to "overcome" the difficulty that it presents. This energy is transformed into heat and logically depends on the intensity of the current that circulates, therefore, for a fixed value of resistor, for example 100 Ω, an amount of heat will be dissipated to the environment four times greater if a current of two amps circulates than if one of one ampere does. Power dissipation is a factor that affects the physical size of the resistor and requires in some cases the use of special so-called high-power designs.

BASIC LAWS

Ohm's law gives us the relationship between the intensity that circulates through a resistor, and the tension applied at its ends and can be expressed in different ways:

$$I = \frac{V}{R} \quad R = \frac{V}{I} \quad V = I \cdot R$$

Joule's law, which for direct current has a simple expression, tells us the power developed in watts, in the form of heat, in a resistor.

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

TYPES OF RESISTORS

In order to be able to use the most suitable type of resistor, there are different manufacturing processes with different materials that provide a wide range of possibilities in choosing the most suitable type for the application in question. Among the most commonly used types of resistors are those of composition that are also called agglomerates. They consist of a mixture of coal, and an insulating material, finely ground, and bound by a binder. Then cylindrical zones are created by extrusion, and at their end metal terminals are fastened. The body of the resistor is covered with wax or varnish, and the marking is carried out according to the color code.

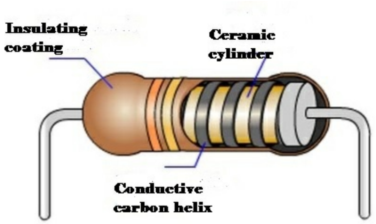

Fig. 2.— Metal film resistor. External and internal structure.

The most common type of low power is the paralytic, which consists of a small ceramic cylinder covered by a layer of carbon with two metal bushings that support the terminals inserted at the ends, fixing the ohmic value through a process of spiralling the film that removes the carbon according to a propeller along the cylinder. On the resistive body, thus prepared a coating with insulating paint is made and on it the bands of the color code are placed. Of this type are on the market sizes corresponding to powers of: 1/8, 1/4, 1/3, 1/2, 1 and 2 watts with tolerances of 1%, 2%, 5%, 10% and 20%. Another widely used resistance is the winding, whose use is usually reserved at points of greater thermal dissipation and that do not require very high precisions of ohmic value. They are built by winding on a ceramic cylinder resistive thread, placing metal bushings with the connection terminals at their ends and in contact with the thread, covering the whole set with a vitrified enamel or with a layer of insulating paint. The usual tolerance is 10% and they are able to dissipate powers above 100 watts, being necessary sometimes, to have adequate means of ventilation. There are, in addition to the aforementioned types, other precision resistors, built by means of a metal film, exhaled in the same way as in the paralytic ones, on a cylindrical or flat ceramic. With this procedure, very stable resistances are obtained with temperature and with very low tolerances.

Fig. 3.—Set of common resistors of different powers.

CHAPTER 2
VARIABLE RESISTORS AND POTENTIOMETERS

The vast majority of circuits require that a certain number of internal adjustments are made on them that depend on the way of operation or certain corrections according to the user's taste that are made at the user's will. In this case there are the external controls of general purpose electronic devices, such as volume control, tone control, the brightness of a TV screen and others. This effect is achieved thanks to the use of variable resistors through the action of external controls. The term variable resistance is applied to the component of two terminals, in which the resistance between them is varied by means of a mechanical action. Although it is more common to use potentiometers because they constitute by themselves a voltage divider.

INTERNAL STRUCTURE

The internal structure of a potentiometer is common to the generality of existing types on the market. It consists of a fixed resistor attached to two connection terminals, on which a mobile contact slides, acted by an external control, capable of crossing it from one end to the other. This contact is attached to a third connection terminal. In this way, the desired resistance value can be obtained between either end of the potentiometer and the moving point. The second possibility is to obtain a certain voltage in the terminal corresponding to the mobile contact, when between the ends a fixed potential difference is applied.

CARBON LAYER POTENTIOMETERS

The types of potentiometer that exist today are very varied, so that each one adapts to special needs. The most used in practice are those of carbon layer and windings. The carbon layer is formed by a band of phenolic resin, in the form of a flat ring, on which a suspension of carbon is deposited, finely divided into particles, mixed with liquid resin. This set is subjected to a heat treatment with which a very hard resistive layer is obtained. The ends of the resistance are metallized with silver to achieve proper contact. On this layer is placed a piece of bronze with some points of contact that will be responsible for sliding on the resistance and on a central conductive track, concentric with the other, from where the connection of the variable contact is taken. The connection terminals corresponding to the ends are located on the metalled points. Above all the previous set is an axis that moves the bronze contact, introducing everything in a metal or plastic box that performs a protective function. The final shape of these potentiometers is not unique since there are models prepared for mounting on panel, by means of a threaded nut on a concentric area with the axis, or for insertion in a printed circuit, in a horizontal position, parallel to the plane of the circuit, or vertical. The normalized values of this model are between 50 Ω and 10 MΩ), with tolerances of 10% and 20%. The powers that are capable of dissipating vary, depending on the model, reaching a maximum of the order of 2 watts.

WINDED POTENTIOMETERS

Winding potentiometers are constructed

by winding a resistive wire on a curved phenolic resin band in the form of a closed ring. The connection terminals are made of silver brass and are placed at the ends of the winding. The mobile contact or cursor is placed on an axis that occupies the center of the ring, so that it slides over one of the edges of it. The electrical junction is taken from the shaft, leading it to the outer connection terminal. The whole set is placed in an outer protective box. From this model there are values between 50 Ω and 50 KΩ, with tolerances of 5% and 10%.

There are two different technologies depending on the power they will be able to withstand. Low power ones reach dissipations of up to 8 W.

MULTI-TURN POTENTIOMETERS

Until now, only those types of potentiometers that work with a cursor turn of less than one turn (approximately 270º) have been considered. However, in some applications where a very high precision in the adjustment is needed, it is not enough with the one offered by the previous models. To meet this demand, there is a special type called multi-turn formed by a resistive cylinder of a certain length on which the cursor slides longitudinally, moved by a spindle or endless screw acted with the external control. Thanks to this arrangement it is achieved that with each turn of rotation the variation of the resistance is very slow.

OTHER MODELS

Within the range that is used as adjustable resistors on the circuits, there are other models that it is necessary to consider. The cermet type is formed by a ceramic substrate on which a thin layer of a mixture of metals is deposited, using screen printing techniques with a subsequent heat treatment. With this technique, elements of reduced sizes are achieved, with resistances between 10 Ω and 1 MΩ and powers of up to 2 W. Of note are the potentiometers used to regulate high voltages in television receivers, manufactured according to this system. Another model of considerable use is the conductive plastic, similar to the previous one but replacing the ceramic substrate with a plastic strip that contains a resistive material. This type is cheaper than the previous one and can replace you in many applications.

Fig. 7.—Set of current potentiometers

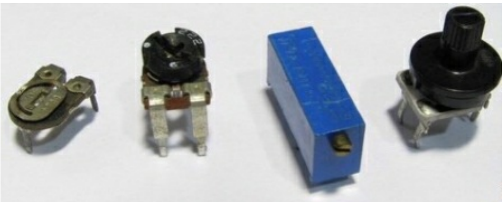

Fig. 9.—Different variable potentiometers for printed circuit. They are screwdriver operated. The blue potentiometer is multi-turn.

LAWS OF VARIATION

Normally the way in which the resistance varies in the potentiometers considered, is linear, that is, it changes proportionally to the angle rotated. There are other forms, in addition to the previous one, which are also used with some frequency. The most important is the logarithmic which with a slow variation at the beginning of the route, changes progressively with it until in the final zone there is a very fast variation. It is generally used as a volume potentiometer. Other forms of variation less used are anti logarithmic and sinus-cosine.

CHAPTER 3
THE CAPACITOR

Another component that is not usually missing in any electronic equipment is the capacitor, in some of its forms or types. A capacitor basically consists of two metal plates separated by an insulating material called a dielectric, such as air, paper, ceramics, mica, plastics, etc. Normally, this dielectric is arranged in the form of a very thin sheet to ensure that the metal plates, called armatures, are at a very short distance. The value of a capacitor, measured in terms of capacity, is determined by the surface of the armatures, as well as by the distance between them, fixed by the thickness of the dielectric, so that greater capacities will be obtained with larger armatures and very thin dielectrics. When applying a continuous voltage between the two armatures of the capacitor, there will be no passage of current through it, due to the presence of the dielectric, however there will be an effect of accumulation of electric charge in the armatures so that in the one that is connected to the negative pole of the voltage, there will be an accumulation of electrons and in the armature connected to the positive there will be a decrease in them. It will also occur on the faces of the dielectric that are in contact with the armatures, a phenomenon called dielectric polarization. If the stress that is applied to it is removed, this accumulation of charge is maintained due to the force of electrical attraction between the charged armatures. If the armatures are then joined or shorted externally, through the connection terminals, a very short current will be produced between them and the capacitor will be de-charged, remaining in the initial conditions.

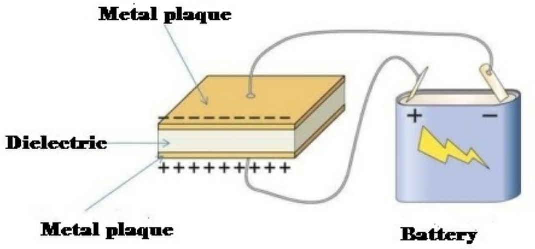

Fig. 1.— Principle of operation of capacitor. Two conductive plaques and a dielectric between them.

CAPACITY

Capacity is, therefore, the possibility of accumulation of electrical charge of a capacitor when a certain voltage is applied to it. The material used in the dielectric is a very important element in the construction of the capacitor, since it determines factors such as: maximum operating voltage without being perforated; capacity, due to the greater or lesser ease of cutting it into very thin sheets and its greater or lesser polarization; dielectric losses, since despite being an insulating material, there will always be a very weak current that will tend to discharge the capacitor in a sufficiently long time. Capacity can be defined as the amount of charge that the capacitor stores

$$C = \epsilon_r \frac{Q}{V}$$

when a voltage of 1 V is applied to it.
C=capacity (farads).
Ɛr=relative permittivity
Q=electric charge (coulombs)
V=voltage (volts)

We can calculate the capacity of a capacitor with its geometric dimensions according to the formula:

$$C = \epsilon_r \epsilon_0 \cdot \frac{A}{d}$$

C=capacity (farads)
d=dielectric thickness (m)
A=surface of facing armatures (m)
Ɛr=relative permittivity (depends on the type of dielectric)
Ɛo=vacuum permittivity

The energy stored in a capacitor can be calculated using the following formula:

$$W = \frac{1}{2} C V^2$$

W=Energy (joules)
C=Capacity (farads)
V=Applied voltage (volts)

Permittivity of some materials
Vacuum 1
Dry air 1.00059
Polyethylene 2 to 3
Impregnated paper 4 to 6
Glass 4 to 7
Mica 4 to 7
Porcelain (titanium dioxide) 80 to 100
High e Porcelain More than 1,000

ALTERNATING VOLTAGE

When an alternating voltage is applied to a capacitor, its behavior is a consequence of the one it presents to the continuous voltage. When the voltage varies periodically, the capacitor is added to a voltage in one direction during half a cycle and to the same tension, but in the opposite direction, during the next half cycle. The dielectric has to withstand alternating stresses that vary in direction very quickly and, therefore, should change its polarization at this same rate. If the frequency increases, the dielectric will not be able to follow the changes at the same speed and the polarization will decrease, resulting in a decrease in impedance. Therefore, in a capacitor the impedance decreases when the frequency increases, which means that only some very specific types of dielectrics can be used at high frequencies. Given the alternating voltage and when the described effect of successive charges and discharges occurs, it can be said that if a true circulation of current is carried out, although it does not actually flow through the dielectric, which leads to one of the main applications of the capacitor in practice, which is to separate direct currents from alternating currents, when both exist simultaneously. However, and despite the fact that the alternating current can circulate through the capacitor, there will be a "lag" between it and the applied voltage, so that when the current is at its maximum value, the voltage will pass at that same moment by the zero value, all within the normal cycle of variation that the alternating current has. When an alternating voltage is applied to a capacitor, its behavior is a consequence of the one it presents to the continuous voltage. When the voltage varies periodically, the capacitor is added to a voltage in one direction during half a cycle and to the same tension, but in the opposite direction, during the next half cycle. The dielectric has to withstand alternating stresses that vary in direction very quickly and, therefore, should change its polarization at this same rate. If the frequency increases, the dielectric will not be able to follow the changes at the same speed and the polarization will decrease, resulting in a decrease in impedance. Therefore, in a capacitor the impedance decreases when the frequency increases, which means that only some very specific types of dielectrics can be used at high frequencies. Given the alternating voltage and when the described effect of successive charges and discharges occurs, it can be said that if a true circulation of current is carried out, although it does not actually flow through the dielectric, which leads to one of the main applications of the capacitor in practice, which is to separate direct currents from alternating currents, when both exist simultaneously. However, and despite the fact that the alternating current can circulate through the capacitor, there will be a "lag" between it and the applied voltage, so that when the current is at its maximum value, the voltage will pass at that same moment by the zero value, all within the normal cycle of variation that the alternating current has.

CAPACITY MEASUREMENT

The capacity of capacitors is measured in units called farads, but and because this unit is excessively large, smaller ones are used in practice that are a fraction of the previous one, the commonly used units are the following: — Microfarad or millionth of farad (0.000.001 F), which is represented by the symbol µF. — Nano farad or billionth of farad (0.000.000.001 F=0.001 µF) represented by the symbol nF. — Pico farad or billionth of farad (0,000,000,000,001 F=0,000,001 µF=0,001 nF) represented by the symbol pF. By similarity with the form of designation of the values of the resistances and based on the one Nano farad (1 nF) equals 1,000 Pico farads (1,000 pF) is sometimes used instead of the designation nF for the Nano farad, the letter K, that is, that 1 nF is equal to 1 KpF, or what is the same, 1,000 Pico farads, so that whenever the value expressed by a number followed by the letter K is read on the body of a capacitor, it shall indicate that the Pico farad has been used in the designation of its value.

TOLERANCE

An important factor when determining the value of a capacitor is the tolerance, which in the same way as in the resistors, indicates the maximum and minimum ends that the capacitor value may have. Common tolerances are five, 10 and 20 per 100 for all capacitor models, except electrolytic whose tolerance can reach values of 50%.

TYPES OF CAPACITORS

There are a very wide assortment of different types of capacitors on the market, of which it is convenient to know their main characteristics in order to be able to use them for the most suitable application.

IMPREGNATED PAPER CAPACITORS

They are manufactured by rolling the reinforcements, consisting of aluminum, tin or copper sheets of about 0.006 mm thick between two other sheets of paper from 0.007 to 0.01 mm.
This paper is impregnated with some type of wax or oil or other appropriate material. The working voltage depends on the thickness of the paper, and can exceed 200,000 volts.

METALLIZED PAPER CAPACITORS

On a sheet of paper a very thin conductive layer is deposited. By winding two of these sheets, capacitors of great capacity are built and that occupy a reduced volume, they should not be used with voltages lower than 10 V.

MICA CAPACITORS

Mica is a mineral, whose composition corresponds to that of an aluminium-magnesium-potassium silicate, which has the property of exfoliating in very thin sheets. Because of this and their chemical inactivity, these capacitors are very stable. This type of capacitor was widely used in radio frequency, although currently its use is being reduced with the appearance of new types of dielectrics.

CERAMIC CAPACITORS

Ceramic capacitors are usually built by a tubular base of this material, whose inner and outer surfaces are metallized with silver and on them arranged the terminals, by means of a welded or wound to the tube bush. Above this set there is an insulating envelope. Its application ranges from high frequency, with temperature compensated types and low tolerances to low frequency such as coupling and step capacitors. Its external appearance can be tubular, disc or square or rectangular insert. Some, in the form of lentils, are made from a small ceramic piece, on which two silver metallizations are made that correspond to the armors, ceramic capacitors are used at high frequencies, although the ceramics used are of different types, and therefore the electrical characteristics vary markedly from one model to another.

PLASTIC CAPACITORS

Currently, they are widely used. Plastic capacitors are made of two thin strips of polyester metallized on one side, leaving an uncovered band on the edge and in opposite places on each side, rolled together. The terminals are fixed at the two bases of the cylinder thus formed so that each one will be in contact only with the metallic strip that does not have a side band on the edge. The whole is coated with an insulating envelope. They are used at low or medium frequencies and as step capacitors and sometimes for high frequency. It has the advantage of being able to achieve relatively high capacities at voltages up to 1,000 V; in addition, if there is a perforation of the dielectric due to an excess of tension, the metal vaporizes in a small area surrounding the perforation and avoiding the short circuit, so that the condenser is not destroyed and can continue to operate

Fig. 3-Plastic or polyester capacitors. The size depends on the capacity and the applied voltage.

ALUMINIUM ELECTROLYTIC CAPACITORS

Aluminum and tantalum electrolytic capacitors have the highest capacity of all for a given size. The aluminum ones are formed by a sheet of tape or band of this metal covered by a layer of aluminum oxide that acts as a dielectric, on the oxide there is a sheet of paper, impregnated with a conductive liquid, called electrolyte and on it a second sheet of aluminum that provides the electrical contact to the paper. The whole set is wound and inserted into a hermetically closed aluminum tubular container and that, in many cases, is used as an electrical contact to the second aluminum sheet and allows one of the terminals to be fixed in it, the other being connected to the other sheet. This type of capacitor is of fixed polarity, that is, it can only work if the external continuous voltage is applied, with the positive attached to the anode corresponding to the oxide-coated aluminum sheet and the negative to the metal box or cathode. Therefore, it is used in those points where there is a continuous voltage, normally applied in rectifier filters, low frequency decoupling and step capacitors. Its behavior in high frequency is not good. So it is not recommended to use it.

Fig. 2.—Aluminium electrolytic capacitors.

TANTALUM ELECTROLYTIC CAPACITORS

Tantalum electrolytic capacitors have a certain similarity with aluminum, achieving with them a greater capacity for a certain size. Instead of aluminum, a sheet of tantalum is used, and the electrolyte is usually dry. It is advisable to use it, almost exclusively as a capacitor for passage between low frequency stages, due to its low electrical noise factor, in which it far exceeds that of aluminum. In addition to the tubular type, they are also manufactured in the form of a "drop" which is perhaps the format by which they are best distinguished.

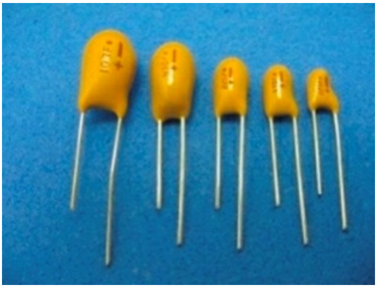

Fig. 4.—Tantalum capacitors, the "drop" model.

CHAPTER 4
COILS OR INDUCTANCES

Inductances or coils are another of the essential components in a circuit, especially for the control and processing of alternating currents or signals. This element, also known by the name of reactance or shocks depending on the application to which they are intended, is composed of two basic parts: core and thread winding. Depending on the cases and the designs, it will be necessary or not an intermediate reel that performs the function of housing the winding. Its external appearance is very similar to that of the transformer since the same standardized materials are used for its construction. There are also, as in other components, some standard types that are offered in the specialized trade. In any case and in a large part of the cases, it is necessary to carry out the construction of the coil by oneself, depending on the complete characteristics of the application in question. The most important particularity to take into account when designing the coil is the need that during its normal operation it will or will not be crossed by a direct current.

This circumstance is very common in those cases where shocks are used as rectifier filters in alternating current to direct current conversion systems. In these cases there is a uniform magnetic field that can cause that the nucleus to become saturated, losing the filtering efficiency.

For this type of coils and in all those cases in which considerable powers are handled and the frequencies to be eliminated are low, components similar to those used to manufacture transformers are used. The reels that support the winding are the same, as well as the core, usually with the E-I format. The difference is that only a winding is carried out and that it is necessary to leave an interspersion between the two parts that form the nucleus to avoid saturation with continuous currents. In any type of inductance, there will be a certain resistance caused by the resistivity of the wire itself that will be necessary to take into account for many applications since its effect overlaps that of the coil itself.

UNITS OF MEASUREMENT

The unit of measurement of inductance is the Henry. Its definition is as follows: The Henry is the inductance of a coil that creates a potential difference of one volt between its ends, when it is crossed by an alternating current that varies at a rate of 1 ampere per second. It is represented by the letter H. There are other units smaller than the Henry that are used much more frequently than this one because it is excessively large for applications other than those of filter inductances for rectifiers. These units are the millihenrium, represented by mH and the microhenrium or μH. The first is the thousandth part of the Henry (0.001 H) and the second, the millionth part 0.000.001 H).

MAGNETIC PERMEABILITY

The core used in the construction of the coils has a great influence on the value of their inductance. There are materials such as ferromagnetic, which are very sensitive to magnetic fields and produce high inductance values. Others, on the contrary, do not present any magnetic property and their behavior is indifferent. It is necessary, therefore, to take into account a factor that determines the degree of response of the material used as a core to the magnetic phenomenon. This factor is called magnetic permeability and is represented with the letter μ (mu). The higher this parameter, the greater the inductance, based on a constant number of loops.

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***Fig. 1.*— High frequency coil. It has an adjustable ferrite core.**

QUALITY FACTOR

There is an important factor to take into account, which relates inductance and the resistance of the wire in a coil. This factor, therefore, defines the degree of quality, since the coil will be all the better the higher its inductance value with respect to the resistance. To represent him, the letter Q is used. It is calculated using the formula:

$$Q = \frac{2 \cdot \pi \cdot f \cdot L}{R}$$

As can be seen, it also depends on the frequency therefore the same inductance will have a higher-quality factor (Q) at high frequencies than at low frequencies.

SELF-INDUCTION COEFFICIENT

The coefficient of self-induction or simply self-induction of a circuit (L) is equal to the relationship between the magnetic flux produced, and the intensity that produces it.

$$L = \frac{\Phi}{i}$$

Self-induction can be calculated in general using the formula:

$$L = \mu \frac{N^2 S}{l}$$

Where
μ=permeability
N=number of loops
S=effective kernel section (m)

l=mean magnetic circuit length (m)

PRACTICAL FORMULAS

Inductances for high frequencies are made by winding one or more layers of wire on a supporting cylinder inside which a ferrite core can be accommodated. In other cases no core is used, in which case the magnetic permeability will be that of air whose value is $4.\pi.10^{-7}$. To calculate the inductance of a single-layer coil of wire, with air core, the following formula can be used:

$$L = \frac{D \cdot n}{45 \cdot D + 101 \cdot l}$$

Where L is the value to be obtained expressed in micro henries (μH), D is the diameter of the coil in cm and l is its length, also in cm. If ferrites are used as cores, the material factor shall be taken into account. This parameter defines the inductance value (L) for a number of loops equal to 1,000 and is defined in the characteristics of each manufacturer's catalog.

$$A_L = \frac{L\ (\text{in mH})}{1.000\ \text{turns}}$$

With it you can calculate the number of turns that must be made to achieve the necessary inductance. Assuming that you want to calculate a coil that has an L=50 mH with a ferrite that has an Al=20, it will turn out that according to the formula of AL, 1,000 turns will be necessary to have 20 mH, therefore the total number of loops will be:

$$n = \frac{50}{20}.1000 = 2{,}5.1000 = 2500 \text{turn}$$

CHAPTER 5
DIODES

The semiconductor diode consists mainly of a P-N junction, adding a connection terminal to each of the metal contacts of its ends and a capsule that houses the whole

assembly, leaving the terminals that correspond to the anode (P zone) and the cathode (N zone) to the outside. The diode lets the current circulate through it when the positive pole of the battery is connected to the anode, and the negative to the cathode, and opposes the passage of the same if the opposite connection is made. This interesting property can be used to perform the conversion of alternating current into direct, this procedure is called rectification.
In fact, if an alternating voltage is applied to this diode, current circulation will only occur on the occasions when the anode is more positive than the cathode, that is, in the positive alternations, being blocked in the negative alternations, which prevents the passage of the current because it is on these occasions the anode more negative than the cathode. The resulting current will be "pulsating", since it will only circulate at certain times, but through the appropriate devices and circuits located below it can be converted into a constant direct current, which is the one currently used almost exclusively; it has some fundamental

advantages over the vacuum:

— It is much smaller in size, which contributes to the miniaturization of the circuits.
— It only has two terminals, which makes it much easier to assemble, especially on a printed circuit.
— The amount of heat generated during operation is less, as it does not need any filament heating.
— It works with much lower voltages, which makes it possible to use it in circuits powered by batteries or batteries.
— They can be used in equipment that handles large currents, an application that with vacuum diodes was sometimes prohibitive due to their large size.
Very small semi-conductive diodes exist for applications that do not require high current conductions, such as demodulation in radio receivers. These are usually encapsulated in a cylindrical glass box with the terminals at the ends, although plastic encapsulation is also used for them.

***Fig. 1.*— There is a wide variety of diodes for the various applications.**

CLASSIFICATION

Within the wide set of models and different types of semiconductor diodes that currently exists in the market, a classification can be made, so that they are grouped into several families, taking into account those most outstanding characteristics and that, in fact, are those that determine their applications. In this way the following can be found: — Rectifier diodes of the entire power range, with individual or bridged encapsulation.

-General purpose signal diodes.

— Switching diodes.

— High-frequency diodes.
— Voltage stabilizer diodes.
— Special diodes.

RECTIFIER DIODES

The family of rectifiers is designed especially for this application, although low power types can also be used as signal diodes or switching in continuous or low frequency circuits and in those of digital type that do not require very high speeds. The encapsulation of these diodes depends on the power they have to dissipate. For those of low and medium power, plastic is used up to a limit of around 1 watt. Above this value, a metal encapsulation is necessary and at higher powers the capsule must be prepared so that the diode can be installed on a heat radiator, by means of a screw fastening system. Any current rectifier system, both single-phase and three-phase or polyphasic, is made using several diodes according to a form of connection called a bridge. However, another system with two diodes is also used, as an alternative to the bridge, in some single-phase

feeding circuits.
Due to the large worldwide consumption of diodes that are later used in bridge assemblies, the manufacturers decided, at a certain time, to make this arrangement themselves, joining the four diodes in the factory and covering them with a common package. This resulted in the emergence of various models of diode bridges with different maximum current intensities and therefore with more or less high power dissipations, in the same form as simple diodes. In the types of higher dissipation, the bridge capsule is metallic and is prepared to be mounted on a radiator.

CHARACTERISTICS

Any rectifier diode is characterized by the following factors:
— Maximum direct current (If).
— Direct voltage (Vd), for a given current If.
— Maximum reverse peak working voltage (VRWM).
— Maximum repetitive peak reverse voltage

(VRRM).
— Maximum peak current (Ifsm).
— Peak maximum reverse current (MRI), measured at VRRM.
— Total power (P/tot).
These characteristics must be taken into account when choosing the most appropriate model for each application, taking care not to conform too much to the limit values, since this would excessively shorten the duration of the component.

SIGNAL DIODES

General purpose signal diodes are used in signal processing functions, within a circuit or to perform digital-type operations as part of logical "gates" and equivalent circuits. They are low power. The characteristics of these diodes are:
— Reverse voltage (Vr), up to 75 V maximum.
— Direct current (If), 100 mA.
— Maximum power (P/tot), 200 milliwatts (mW).
The encapsulation is in the form of a

miniature cylinder, made of plastic or glass, with the two connection terminals located at the ends. On the body must be marked the connecting wire corresponding to the cathode, by means of a ring located in the vicinity of it.

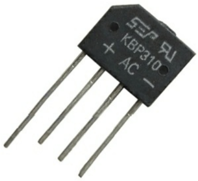


Fig 2.Diode rectifier bridge

SWITCHING DIODES

Switching or fast diodes are characterized by being able to work with digital or "logical" signals that present very short up and down times of their flanks. The factor or parameter that characterizes these diodes is the reverse recovery time (TRR) that expresses the time it takes for the P-N junction to dislodge the electrical charge it accumulates, when it is inversely polarized (an effect similar to the accumulation of charge of a capacitor), and suddenly receives a change of voltage that polarizes it in a direct direction. Those diodes with a TRR of less than 400 nanoseconds can be considered fast, in medium power models, for those of low power this type is of the order of 5 nanoseconds.

HIGH FREQUENCY DIODES

High-frequency diodes are used in those parts of a circuit that must operate at frequencies greater than 1 megahertz (1 million cycles per second). They are characterized by a low diffusion capacity (Cd) between the two semiconductor zones that form the P-N junction, when they are polarized in a direct direction.

ZENER DIODES

Voltage stabilizer diodes are used, as the name suggests, to produce a constant voltage between their ends and relatively independent of the current that passes through them. They take advantage, for their operation, of a very interesting property that the semiconductor union presents when it is inversely polarized, above a certain level.

Fig. 5.—Frequently used Zener diodes.

Normally a diode that receives a reverse polarization does not allow the passage of current or does so by letting a very weak intensity pass. However, when reaching a certain voltage, called Zener voltage, there is an increase in the amount of current, so that this potential difference "between its ends remains practically constant, even if you try to increase or decrease by varying the intensity that crosses it. There is a wide range of types classified by a series of normalized Zener voltages and by the power that they are able to dissipate, from 250 milliwatts to tens of watts, with plastic or metal encapsulate.

The parameters that characterize a zener diode are:
— Zener voltage (Vz).
— Minimum current to reach the Vz (Iz).
— Maximum power (P/tot).

Special diodes

Within the group of special diodes are included varicap diodes, tunnel diodes and Ied diodes. The first is constructed seeking to accentuate to the maximum the property that present the P-N union to behave in a way analogous to a capacitor, when it is polarized inversely. The resulting capacity is also variable with the applied voltage; which allows to have a very simple form of variable capacitors, controlled by a potential difference. Its use is very widespread in stages of tuning of radio and TV receivers.

CHAPTER 6
TANSISTORS BJT

The BJT transistor (Bipolar Junction Transistor) is currently the fundamental and essential component in any electronic circuit that performs functions of amplification, control, data processing, numerical calculation, radio and TV, voltage or current stabilization, etc. There are two basic forms of application, as an element usable individually or discreetly, or incorporated into an integrated circuit of which it always forms the basic cell of operation. Here we will deal with the first way described.

PRINCIPLE OF OPERATION

The transistor is a semiconductor element that has the property of being able to govern at will, the current intensity that circulates between two of its three terminals, through the action of a small current, much lower than the previous one applied to the third terminal. The first two terminals are called emitter and collector and the third is called the base. The effect described is, in short, an amplification of current since thanks to the action of a weak intensity that can have any form of variation in time, such as sound signals, radio, TV, etc., it is possible to obtain the same shape on a higher current, provided by a power circuit, which allows the power to perform, in the successive steps the transformation of a very weak signal, into another strong enough to be able to produce sound on a speaker, image on a TV, etc.

TRANSISTOR ORIGIN

The word transistor was obtained from the composition of two other TRANsferreSISTOR) describing its most immediate application or resistance transfer. It was discovered in 1948 by Shockley as a result of work previously done by Bardeen and Brattain on electrical phenomena on the surface of semiconductors. All three scientists received the Nobel Prize in Physics in 1956.

OPERATION OF THE BIPOLAR TRANSISTOR

The inner workings of the transistor can be described based on the concepts developed in the chapter dedicated to the semiconductor diode. Unlike this one, the transistor has two semiconductor junctions separated by a very thin layer of material. Suppose that there is a structure formed by two zones of semiconductor material type N (formed by germanium or silicon on which a second material has diffused or diluted that has an excess of electrons, such as phosphorus or arsenic) and between them there is a very thin layer of another, type P (formed from the same base material as N, with the addition of one second that produces an electron defect, such as indium or boron).

POLARIZATION

If an external voltage, coming from a battery or any power circuit, is now applied to the first N-P junction, whose two zones are called emitter and base respectively, directly or with the negative applied to the emitter the positive to the base will produce a circulation of current between both regions. By applying a second external voltage to the remaining P-N junction, formed by the base and a third zone called the collector in the opposite direction (negative to the base and positive to the collector) it will be achieved that the electron current that was generated with the first applied voltage is attracted by the positive potential difference applied to the collector, despite the strong opposition that originates the base-collector union polarized in the opposite direction, so that the current that left the emitter will reach practically in its entirety to the collector, except for a very small fraction that would come out through the base connection.

Well, this fraction of current is the one that is able to govern or "modulate" the main one, with the effects already described, since this will always be a multiple of the base. If we assume, as an example, that the main current, I is 100 times the base current Ib and this is 5 mA, I will be 500 mA; if Ib is lowered to 2 mA, I will become 200 mA; it can easily be observed then that a small variation (of 3 mA) in the base current produces a large variation (of 300 mA) in the main stream between emitter and collector. The current expansion factor (100 in the example above) is generally referred to as β (Beta).

CRITERION IN THE SENSE OF THE CURRENT

Until now and through out the previous exhibition, the current circulation sense actually followed by electrons has been used. However, according to the conventional form used universally in this regard, the current for an NPN transistor is always considered as incoming by the collector and the base and outgoing by the emitter. Another way to build transistors, maintaining the same functional bases, is obtained using materials type P for the collector and emitter and N for the base. Thus, the resulting element is called PNP transistor. Its only differences with the NPN model are that the currents that cross it are exactly the opposite direction, being necessary to use external voltages of polarization of opposite sign.

HOLLOWS

To complete everything related to the

internal structure of the transistor, it is important to know a term that is used very frequently in all the texts that exist on this subject. This word or term is the hollow. Its concept is quite simple, since it defines the absence or defect of an electron in a certain material, which supposes a potential capacity to be "filled" by it, going from a neutral state to be negatively charged.
Using this concept, a P-type semiconductor material will be one that has a certain excess of holes and the operation developed during the union of a hole with an electron is called recombination.

CONSTANT CURRENT

A very interesting property of the transistor is its ability to deliver a fixed and constant current intensity to a resistance in a form independent of its value, therefore, the current variations obtained by the action of the base, will produce on the resistance voltage variations, which can be calculated by applying Ohm's law (V = l x R), and will therefore depend on the base current and the value of the resistance R that is located in the collector giving higher values the higher this R is, being the limit fixed, obviously, by the external supply voltage. The result of all this will be a voltage amplification, calculated as the relationship between the voltage, obtained on the resistance, called load and the voltage that was applied in the base-emitter union to generate the current that has been called base.

Fig 1.— Germanium BJT transistor with metal encapsulation.

CLASSIFICATION

Within the denomination of transistors are included four models manufactured with different technologies and with quite different characteristics and physical properties; are as follows:

— BIPOLAR transistors.
— FET transistors.
— MOSFET transistors.
— UNIUNION transistors.
The first are those already mentioned above and of which its internal structure is known formed by three parts called emitter, base and collector, being able to be found in the NPN or PNP types.

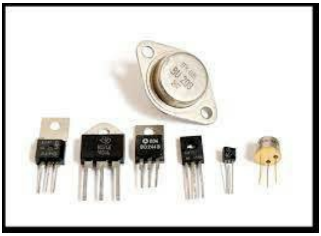


Fig. 2.—Family of bipolar transistors. Some common types that exist in the market can be observed.

CHARACTERISTIC CURVES

These transistors are studied and analyzed using curves drawn on coordinate axes that are called characteristic curves of a transistor.

With them, the behavior or electrical operation of the element can be completely characterized, expressing the graphic relationships of the ib, Ic and le currents, depending on the external voltages applied and for any of the configurations in which it can be used to the transistor: common emitter, common base and common collector. The curves are not universal, therefore, each particular type of transistor has its own, usually different from those of the others, although similar in shape. On the other hand, these curves do not correspond exactly to each transistor unit, but represent the average characteristics of a manufacturing system with a large number of units.

CHAPTER 7
RELAYS

The relay whose name derives from the French word "relais", which can be translated as relay, can be defined as the component that when receiving a certain electrical excitation acts as an intermediary to feed or control a certain electrical apparatus or circuit. Another possible definition is that of a multiplier element of signals or control orders since it is capable of transforming a certain stimulus of a circuit into several simultaneous orders, as many as independent circuits it possesses. Its use in electricity dates back to the year 1850 and since then they have undergone a strong development and modernization being today one of the key components in many electronic circuits, which are the ones that currently originate the highest world consumption of this component. At present two basic forms of relays can be found, which are electromagnetic and static. They are the basic component of conventional telephone exchanges.

Fig. 1.—Set of relays of different shapes and models.

STRUCTURE

Electromagnetic relays can be considered divided into two blocks or sets, namely:
— Excitation circuit.
— Switching circuits.

The excitation circuit is responsible for receiving the control signal in the form of a certain voltage or current and generating from it the actions necessary for the performance of the switching circuits. It consists of the coil and magnetic assembly. The coil is responsible for producing enough magnetic field for the magnetic assembly to act. It is formed by a rolling of enameled copper wire. Its characteristics are defined according to the resistance, number of loops and diameter of the thread. Relays with more than one winding in the coil are sometimes used for different uses and applications.

The magnetic assembly is formed by the core that is the piece that is inside the coil, the fixed armature whose function is to support the relay and the mobile armature that is the piece that moves attracted by the magnetic field developed in the core and that in turn causes the movement of the contacts. These three pieces are made of sweet iron in order to prevent them from accumulating a certain remnant magnetism. Switching circuits are the set of moving contacts driven by the moving armature Each group of contacts can be formed by two sheets that would correspond to a switch or three sheets for a switch or inversed contact. The number of independent circuits contained in a relay depends on its applications and the manufacturer of the relay. The sheets contain at their ends one or two points of contact riveted or welded to them. The material that forms these contacts as well as their shape and dimensions depends on the function they must play, highlighting as important characteristics to take into account at the time of making the choice: the operating voltage, the intensity of the current, the type of load to be controlled, the frequency of work and the climatic conditions of the workplace. Generally, two groups or families of contacts classified by the intensity of the current that must be switched or interrupted are considered, they are the following:

— Contacts for weak currents. They are of small dimensions, of the order of 2 millimeters in diameter and are made from silver, silver-palladium and gold. They are used in streams up to one Amp.
— Contacts for strong currents. They are of higher dimensions up to 6 millimeters in diameter, and use hard silver and tungsten as a material. They are used for currents greater than one Amp.

Normally each set of two or three sheets provided with their corresponding contacts are grouped into blocks of circuits, together with the insulating parts that electrically separate the sheets but at the same time make possible their mechanical fixation. The complete relay assembly is normally isolated from the outside by a hermetic or not capsule, and which in many cases is metallic, in order to make an adequate magnetic shield on the relay. The connection points of the relay appear to the outside in the form of terminals, there are several types from which the one that best suits the application in question will be chosen.

CHARACTERISTICS

When choosing a certain type of relay, it is necessary to previously define the following characteristics:

— Excitation conditions of the coil: this shall consider whether the coil will receive continuous or alternating voltages, as well as the maximum voltage or intensity or the minimum admissible resistance.

— Characteristics and number of circuits, expressing the necessary number of contacts, whether they are to be switches or inverters and whether they will work with weak currents or strong currents.

This last condition is very important since it completely determines the mechanical load on which the magnetic field created by the coil must act, so that it must be sufficiently high to overcome this load. The difference between strong and weak contacts from the point of view of their performance is that the former need a higher pressure and are located at a greater distance than the latter, so the mechanical resistance they oppose to the movement is much higher.

The magnetic excitation force is determined by the number of amperes-turns needed. The ampere-turn is a unit of measurement of magnetic field strength obtained by the product between the intensity that circulates through a coil and the number of loops of the same, therefore the same effect will be achieved in a coil of 100 loops with a current of one Amp A as with another of 500 loops crossed by 0.2 A, since: Field=100.1=500.0,2=100 amps-turn. With all the above data, it will be possible to define the most appropriate type of relay for a specific application, however, it is interesting

to list the set of characteristics that usually contains any catalog of relays of those existing in the market. They are as follows:
Referring to the excitation coil or coils:

— Nominal voltage: Voltage for which the coil is sized and to which it must be subjected.
— Rated current: The current that will circulate through the coil when the rated voltage is applied.
— Minimum actuation or response voltage: The lowest voltage at which the relay is operated. It is lower than the nominal and is usually of the order of 80% of it.
— minimum actuation or response intensity: Current to circulate through the coil when the minimum actuation voltage is applied.
— Drop voltage: Voltage at which the relay regains its resting position.
— Drop intensity: Intensity corresponding to the drop voltage.
Regarding contacts:
— Nominal contact voltage: This is applied to contacts before they are closed.
— Maximum rated voltage: Maximum

voltage applicable between the contacts (depends on insulation).
— Maximum permissible current: This is the maximum intensity that the contacts can tolerate depending on the material chosen.
— Contact pressure: This is the force that contacts apply to each other when they are closed. The higher it is, the greater the operating safety it will be.
— Contact resistance: It is the ohmic resistance that appears between the two points joined by pressure.
— Accompaniment of contacts: It is the displacement made by the two points of contact once they have joined, thus facilitating the self-cleaning of them.

TYPES AND APPLICATIONS

Given the enormous diversity of different applications that exist today for relays, a wide range of types have been developed accordingly whose characteristics try to approximate, as much as possible, the needs and specifications that result from each specific use.

REED RELAYS

A type that is increasingly being used in electronic devices is the so-called reed relay, which is worth highlighting for obeying a slightly different concept from the other conventional relays described above. The construction of the reed relay is based on two basic elements:
— Acting coil.
— Contacts reed.

The actuate coil is conventional, although its reel-support has a longitudinal hole along its axis that in conventional relays is occupied by the metal core. You can have one or more independent windings in the same way as in the rest of the relays. The reed contacts have the particularity of being made from a magnetic material, which allows them to be opened or closed when the magnetic field of the coil is generated, thus avoiding the need for intermediate mechanical elements of action, such as the reinforcements of the rest of the relays. The contacts being enclosed in an airtight glass capsule make them immune to dust and other atmospheric agents, being manufactured in the form of switches or inverters. Both elements, coil and contacts, can be supplied separately, thus facilitating the realization of a wide range of combinations between the two, based on the different types found on the market. In some cases where several sets of contacts are required, coils are used that have several accommodations in their center on which the necessary reed capsules are installed. Interlocking or bistable relays can also be obtained if a cylindrical magnet of the appropriate diameter is inserted inside the coil, along with the rest of the reed capsules, acting the relay in a similar way to conventional ones. Since the principle of operation is the magnetic attraction between the contacts, it may happen that external fields, sufficiently strong, can act the relay. This is avoided by using those models equipped with an external metal box specially prepared to make a shield on the contact set.

Fig 2. Reed relay with a metal capsule for magnetic shielding on the contacts.

PRINTED CIRCUIT RELAYS

Another very interesting group of relays is formed by all those of very small dimensions, specially designed to be mounted on printed circuit. Its external shape is flat in order to be able to adapt perfectly on low-rise circuits. They are usually driven by continuous voltages, containing up to a maximum of four inverters with contacts for medium or weak currents. They allow a high number of actions reaching 100 million in some cases. They are generally used in a wide variety of electronic equipment such as: computer systems, measuring devices, high fidelity, television, etc.

CHAPTER 8 POWER TRANSFORMERS

The transformer is an element capable of converting an alternating current system with a certain voltage and intensity into another with different voltages and intensities, so that the power remains constant. Its operation is based on the phenomenon of electromagnetic induction, so that the variable magnetic field produced by a conductor coiled on a core of magnetizable material, when an alternating current circulates through it, produces a certain voltage, also alternating, in another conductor, independent of the previous one, rolled on the same core. Indeed, when an electric current circulates through a coil of conductive wire, it behaves as if it were a magnet. This effect occurs with both direct and alternating currents. In other words, around the coil, a magnetic field will extend that will be constant in the case of a direct current and fluctuating in the case of an alternating one and that will exert its influence on all the objects located in its proximity, regardless of whether or not they are in contact with the coil. If it is rolled over an iron core in the form of a closed ring, the magnetic field will concentrate in this ring. When rolling another coil on the same core. It will be crossed by the field produced by the first, which we will call the primary. If the field produced by it is constant, no useful effect will be obtained on the second coil that we will call secondary. However, if the field is variable, as would be obtained by applying an alternating voltage in the primary, a variable current will be induced in the secondary if it is connected to a closed circuit. This current is proportional to the speed of the change in the intensity of the primary current and will be very similar in characteristics to the one that generated it. On the other hand, both the intensity and the tension can be higher or lower than those of the primary. This is because the number of turns or loops of both coils may be different.

TRANSFORMATION RELATIONSHIP

In conclusion, the transformation properties depend almost entirely on the number of loops of the primary and the secondary and in the ideal case, the relationship between the voltage obtained in the secondary or output and that of input to the primary, will be the relationship between the numbers of loops of both. Let's take an example: consider a transformer that has 10 loops in the primary and 20 in the secondary. Dividing the number of spires of the secondary by those of the primary yields the transformation ratio n=20/10=2. This means that if an alternating voltage of 1 volt is applied to the primary, 2 volts will be obtained in the secondary. What is most important to note is that through the coupling between the two windings an electrical power is transmitted.

This means that if in the previous example the voltage obtained at the output is applied on a load, a current will circulate through it that will force another to circulate through the primary, whose intensity will also depend on the transformation relationship. In effect, suppose that a resistance of 2 Ω is connected to the secondary, the intensity that will circulate through it will be, applying Ohm's law, Is=V/R=2 volts/2 ohms=1 ampere. The power consumed by the resistor is 2 volts x 1 ampere = 2 watts. This same power must be delivered by the primary, therefore the current that will circulate through it will be Ip=power/voltage=2 watts/1 volt=2 amps. The ratio of the output current to the input current will then be Is/Ip=1/2=0.5; result which is the inverse of the transformation relation which was n=2, 1/n=0.5. As can be seen, thanks to the transformers, electric currents can be transmitted with certain voltage and intensity conditions and in the same place of use, they can be converted into others more suitable for consumption. A very notable example is the distribution of electrical energy from the generating plant to the towns or places of use. Electricity comes out of the plant at a voltage of around 500,000 volts, so that the intensity is not excessively high and there is no excessive losses due to the influence of the resistance of the distribution cables, many kilometers long. These conditions become, by measuring transformers, the normal ones that we all know (125 or 220 volts) in our homes.

Fig. 1 Power reducer transformer for current use.

YIELD

A very important factor to consider in a transformer is performance. This factor appears as a consequence of the fact that the ideal conditions of all the power delivered by the primary is transmitted to the secondary, they do not occur in reality, but there are losses in the element, which means that the primary must deliver a greater power than that consumed at the output. Performance is then defined as the ratio of output power to input power, r=Pot.sec./Pot. prim.; this value will always be less than one which will be the ideal case.

CLASSIFICATION

Depending on the function they perform, transformers can be classified into several groups or families, so that each one includes those that have similar characteristics.
The most commonly used classification in practice is as follows:
— Power transformers.
— Audio frequency transformers.
— High-frequency transformers. Those indicated in the first place must always operate at the same frequency, which will be that of the electricity network; 50 cycles per second in Europe and 60 in most American countries.

NUCLEUS

This factor largely determines the size of the core since, as explained above, the transformative effect will be better the higher the working frequency, so that at higher frequencies smaller cores will be needed. Another decisive factor of great influence on the size of the core is the power that must be transmitted from primary to secondary, because it will have to withstand a more less intense magnetic field depending on it.

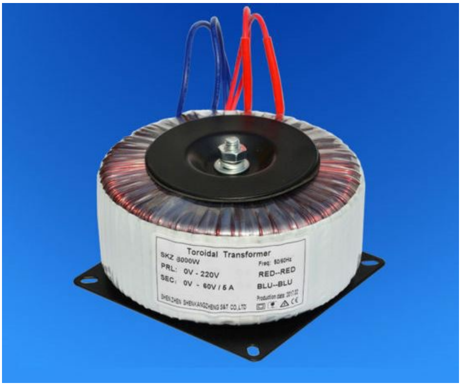


Fig. 2.—Transformer built on a toroid core.

Taking into account all the above, the cores of the most appropriate size are built, by means of a set of stacked sheets, subsequently fastened with screws. The normal format is the so-called E-1 composed of sheets with these shapes. The reel containing the winding is usually always coupled to the central branch of the E. Another format, used in very recent times is the toroidal, built by winding a closed core in the shape of a "torus" or ring of circular section.

WINDINGS

The windings of all types of transformers are made with enameled copper wire, in order to achieve adequate electrical insulation between the contiguous loops of the winding. Generally, the primary and secondary are wound stacked on top of each other, although preserving the independence between windings, being used to better guarantee the insulation between them, one or several layers of waxed paper that roll covering each winding and winding on them the next. To obtain a very high insulation between windings, reels divided into two parts are used, housing primary and secondary in these separate spaces. The section that the wire must have of each winding depends directly on the current intensity that will circulate through it. To facilitate the calculation, a factor called Current Density is used, which is the relationship between the intensity and the conductor surface that it crosses, D = I / S.

D=I/S.

The value that is usually adopted will be between 2 amps per square millimeter (A /) and 4 A / , depending on whether in the way of working the transformer is performing a continuous or intermittent service, as well as the power transmitted. So if you want to calculate the section of wire that must have a winding through which a current will circulate, for example, of 2 amps and an average current density value of 3 A / is estimated, it will be deduced from the already known formula D = I / S, that S = I / D = 2 / 3 = 0.66 mm, which is equivalent to a diameter of the thread of approximately 0.9 millimeters.

TRANSFORMERS FOR AUDIO FREQUENCY

Transformers used in services other than power services, even performing a similar basic function, taking advantage of the same physical principles, differ fundamentally from these, since they must be able to respond to certain frequency characteristics that force us to consider other more appropriate forms of design. Audio frequency transformers have as their primary function to link two parts of a circuit or device, with very different voltage and current characteristics, so that the maximum audio signal power is transmitted between them. Taking into account that the range of frequencies audible by humans is between 20 and 20,000 cycles per second, it is a very important condition for these transformers that they are able to transmit this band, without distortion and with the same response for each of the frequencies included in it. This condition is quite difficult to fulfill in practice, and the reality is that there is no model that comes very close to it; therefore, when a good frequency response is an essential requirement, you must choose to go to an alternative in which the use of the transformer is avoided.

In its construction, cores similar to those of power are used for the most economical models, and that does not require too demanding characteristics. For other types of better quality, synthesized powder cores of magnetic ceramics, known as ferrites, or special iron alloys with nickel, silicon, carbon, chromium, vanadium and cobalt are used. A form of nucleus widely used is that of the "cup" type called pot which is formed by two equal parts of circular shape, which completely close the reel with the windings, once lodged inside.

Audio transformers are very sensitive to some electromagnetic parasites, produced both by nearby power transformers that generate an audible hum at the frequency of the network, and by any other device that produces a variable magnetic field at a frequency within the band that is capable of hearing the human ear. To avoid these inconveniences as much as possible, shields are used that completely cover the element, built with a magnetic sheet of nickel steel, with the commercial name of Mumetal.

TRANSFORMERS FOR RADIO FREQUENCIES

The high-frequency transformers used mainly in receivers, both radio and television, have the mission of coupling the antenna to the first amplifier step, as well as to link the following stages until reaching the demodulator circuit, in which the low frequency signal (sound or video) is obtained. Two separate or overlapping windings are constructed on a tube of insulating material. The type used for antenna in AM usually uses a tube of a diameter usually greater than 1 centimeter with an air core or with a solid ferrite cylinder, made of nickel and zinc and known commercially as Ferroxcube. For the coupling of the following amplifier steps, called Intermediate Frequency, tubular supports of smaller diameter than the previous one are used on which the windings are rolled. The core has a cylindrical shape with a helical groove that allows it to be threaded over the support tube. There are also other forms of cores that externally surround the windings, including also threaded parts with a function similar to the previous ones.

These transformers works tuned to a certain frequency, depending on whether they are Amplitude Modulated (Long, Medium and Short Waves), Frequency Modulated or Television receivers. The tuning, an effect that will be carefully explained in another volume of this collection, is achieved by joining the two ends of the winding, both primary and secondary, a capacitor with a previously calculated capacity. The degree of tuning as well as the best or worst electromagnetic coupling between the windings is regulated with the ferrite screw. The whole of the transformer is generally shielded, by means of a box of magnetic material that avoids the influence of external magnetic fields on the element, as well as the possible radiations of this on all the components that are in its proximity. In a large number of models, tuning capacitors are also housed inside the shield. The box has a hole to make the adjustment. Intermediate Frequency transformers, unlike the other types, are quite standardized according to perfectly identifiable models, there are a certain number of manufacturers that offer them in their catalogs.

CHAPTER 9
HEAT SINKS

The radiator or heat sink is an essential complement for the assembly and use of semiconductors that need to evacuate a certain amount of heat to the environment during their operation. Remember that a semiconductor component of any kind (diodes, transistors, thyristors, triac, etc.) that is crossed by a finished electric current needs to deliver to the environment an amount of power, in the form of heat, which can be calculated by product of the intensity of current that conducts by the voltage drop that appears between the two electrodes, among which this current circulates. The result of such an operation indicates the number of watts that are transformed into heat. This calculation can be completed by the equivalence formula between these power units and the units of heat or calories 1 watt = 0.24 calorie/second. When the power dissipation of a component becomes so high as to be able to cause internal damage to its structure, it is necessary to mount it on a suitable heat sink that facilitates cooling, avoiding that a dangerous temperature is reached. There are three basic ways of transmitting heat from a body that is at a certain temperature:

— Radiation.

— Convection.

— Driving.

Heat radiation is a form of transmission through electromagnetic waves, in the same way as those used to make radiofrequency or visible light emissions. This radiation is performed at a frequency lower than that of the visible red color and is called infrared radiation. The greater or lesser radiation capacity is affected by the color of the body,

obtaining the best behavior in dark colors being the ideal black body, the one with the greatest radiation power.
In the transmission of heat by convection, the hot body delivers to the fluid that surrounds it (air, gas, etc.) a certain amount of power that causes that fluid to produce an increase in temperature by varying its density, which will rise appearing a new amount of cold fluid that will continue to cool the body. This process is called natural convection to differentiate it from the forced convection system caused by some external medium that forces the circulation of a certain flow of fluid, such as a fan. Conduction is the process of natural transmission of heat through the interior of the body that generates it, to all points of it. The maximum amount of heat that can be transmitted is that for which temperature stabilization is achieved at all points.
A heat sink normally uses all three forms of transmission simultaneously, producing a conduction from the semiconductor to the radiator and a convection and radiation from it to the air around it.

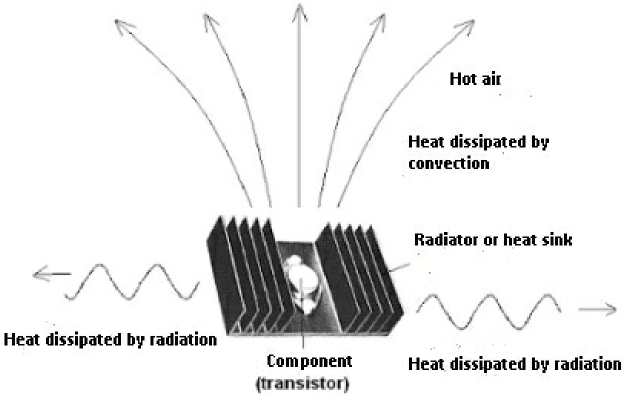


Fig. 1.—Different forms of heat transmission generated by a power semiconductor: Radiation, convection, conduction.

The amount of heat power that can be evacuated from the heat sink to the environment depends on the temperature difference that exists between the two, being all the greater the higher this difference. At the opposite extreme, the power evacuation will be null if there is no temperature difference.

THERMAL RESISTANCE

In order to analyze the behavior of a

power distribution system, as well as to calculate it, a factor called thermal resistance is used that takes into account any cause that prevents the passage of heat flow. It is specified by the symbol Rth and is expressed in the units of degrees Celsius per watt (°C/W). Thanks to the thermal resistance, a "circuit" of heat circulation can be established by analogy with the electrical circuit, since when the heat crosses, during its journey, means with different thermal resistances, from the hot point to the cold, it can be considered a total thermal resistance that will be the sum of the previous ones. The thermal circuit will then be defined by three factors: temperature difference, evacuated power and thermal resistance. The temperature difference performs the same role in the circuit as a potential or voltage difference in the electrical case.

The evacuated power has as equivalent the intensity of electric current. Thermal resistance is equivalent to ohmic resistance. The complete thermal circuit of a semiconductor component mounted on a heat sink contains basically three thermal resistors. The power that must be evacuated is generated in the internal joints of the semiconductor, so that this will be the point that has the highest temperature, being considered, therefore, as the origin of the circuit. The first thermal resistance will be the one between the semiconductor crystal and the outer capsule of the latter, called the junction-capsule resistance (Rth_{j-c}).

The second will be the thermal resistance capsule-radiator (Rth_{c-r}) caused by the contact between these two parts, taking into account here the various factors that affect this contact, such as: mica washer, contact pressure, state of the surfaces, etc. The third and last will be the thermal resistance of the radiator to the environment (Rth_{r-a}) which is the one that exclusively affects the radiator and that must be found in the data offered by the manufacturers of heat sinks.
In some cases the radiator is also considered to have a certain capacity, which takes into

account the storage of energy by it, as well as its thermal inertia. This affects the equivalent circuit, since it will be necessary to arrange a capacitor in parallel with the initial thermal resistance.

CHOICE OF THE RADIATOR

In order to choose a specific type of radiator, the following data must be considered:

— Maximum working temperature of the heat sink.
— Temperature of the air that will surround the whole.
— Power to be evacuated.
— Form of assembly of the semiconductor.

The calculation will be carried out as follows:
The temperature of the semiconductor capsule shall be found first from the (Rth_{j-c}) of the semiconductor catalogue. If the assembly is carried out directly on the radiator, a temperature difference between the

two of 2 °C shall be considered. In the case of interspersing a sheet of mica, in order to achieve a certain electrical insulation, a thermal resistance of 122.e°C/W will be taken, being e the thickness of the mica in centimeters. The final calculation of the thermal resistance of the radiator shall be carried out by applying the formula:

$$Rth = \frac{T_e\,rad - T_e\,amb}{\text{POWER TO DISSIPATE}}$$

CASE STUDY

As an example, suppose a transient that must evacuate a power of 10 W and has a thermal resistance of the union to the capsule (Rth_{j-c}) of 2° C/W. It will be mounted with a mica sheet of a thickness of 0.01 centimeter and you want to calculate the thermal resistance of the radiator so that the temperature of the semiconductor junction does not exceed 125 ° C, for an average temperature of 25 ° C. First of all, the temperature difference that will exist between the junction and the capsule is calculated.

This will be $T_j - T_c =$ 2° C/W.10 W = 20°.
Between both sides of the mica sheet, there will be a temperature difference calculated from Rth mica = 122.0.01 = 1.22 °C/W.
T mica = 1.22°C/W.10 W = 12.2°.
Therefore, the radiator will be at a maximum temperature of:

$Trad_{MAX}$= 125 - 20-12.2 = 92.8° C.

The thermal resistance of the same must be, then:

$$Rth\ rad = \frac{92{,}8\,°C - 25\,°C}{10\,W} = 15\,°C/W.$$

With this value you will go to any catalog of heat sinks to select the most appropriate model that is greater than or equal to the calculated.

Fig. 2.—Sometimes it is necessary to use large radiators, in this case they dissipate the heat generated by power transistors with TO-3 capsule.

Fig.3 Different types heat sinks for

transistor type TO-3.

CHAPTER 10
SWITCHES

Practically all electronic equipment incorporates one or more elements capable of interrupting at will a certain internal circuit, the most common case being that of the ignition switch of the network voltage or of any battery or battery. Although at first glance the function of these components appears as quite simple, however, in its design it is necessary to take into account a relatively complex series of parameters, since in the sudden interruption of an electric current or in the sudden closure of it there are phenomena that must be known and analyzed.

The basis of the operation of these components is the existence of two points or conductive surfaces that open and closes through a mechanical drive and that form what is called an electrical contact.

The purpose of an electrical contact is to allow electrons to circulate from one part of the contact to the other, offering the minimum possible resistance to their passage. To this condition can be added another in which the duration of the contact is taken into account so that it is as long as possible.

CONTACT RESISTANCE

The two conductive parts are always rough, since it is impossible to achieve, in practice, a completely smooth surface without presenting even at the molecular or atomic level, a series of roughness or roughness that in most cases it is necessary to contemplate through the microscope. As a consequence of this, when placing both in contact, by means of a certain force that keeps them together, only some points of them will be touched, the rest being separated by the intermediate air, being the areas in which the real contact occurs very small compared to those that are isolated, although considerable pressure is exerted. The only thing that will be achieved

by increasing the force is to produce a deformation on the points that were initially in contact, and a second group of points that join may even appear. The first consequence of this is the appearance of a determined-nada contact resistance to be taken into account in all cases. As an example of the extent to which the above is applied, suppose a cylindrical conductor of several millimeters of diameter in which its electrical resistance is calculated between two points separated by a certain length L. The resistance will be R = *p* x L/S, with *p* being the resistivity of the material and S being the section. If this conductor breaks into two parts and then the two surfaces that were previously joined are put in contact, trying to make a perfect adaptation of the irregularities, so that the breakage is not visible to the naked eye, and exerting the necessary pressure so that they do not separate, it will be observed, when measuring the resistance between the previous points, which has increased by a certain amount, which indicates the value of the
the

contact resistance that has appeared in that conductor.

EFFECTS ON SURFACES

Another phenomenon that occurs on surfaces that form an electrical contact is the appearance of a thin film of oxides or other chemical compounds, formed by reacting the material that composes them with the polluting elements of the atmosphere. This layer is insulating, therefore, for contact to occur it must be removed at the necessary points. Depending on the type of contact in question, other effects such as the appearance of arcs or electric discharges through the air between the two areas of the air can also occur, having great influence in these cases the working voltage, the current or both. Accompanying the arch is a certain minuscule transport of material from one part of the contact to the other, which if made cumulative can destroys them after a certain number of actions.

DRIVE

There are two basic forms of drive in an electrical contact:
— Sliding or tangentially driven.
— Tilting or vertically driven.

In the sliding contacts one of the surfaces "slips" on the other, being necessary to apply a certain force that overcomes the friction between them, in addition there is a certain wear caused by the abrasion. In tilting contacts one of the surfaces can be fixed and the other mobile or both mobile, making the union between them by a force perpendicular to them that brings them closer until the union is achieved. According to the function performed by the contacts, they can be classified into:
— switch of one or more simultaneous contacts.
— Switch or inverters of one or more circuits.

The switches perform the opening and closing of an electrical circuit or several, in the case of having more than one contact,

being in this case all independent.
They are used for the classic applications of turning on and off electrical installations, lighting, machines, electrical appliances, etc.
In electronic circuits, apart from using them for ignition, they also find application in the definition of levels "O" or "1" of digital systems.
Their action can be permanent or momentary, with models for each of these forms.

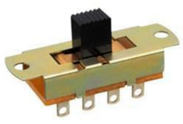


Fig.1 Switch or sliding switch for printed circuit board

CHAPTER 11
CONNECTORS

The vast majority of electronic equipment has a component that performs an important

function, such as the electrical link between two or more parts or sections thereof, permanently, but with the particularity that this union can be easily disassembled, without having to resort to tools or special tools, not even the simple welder. These elements specially designed and prepared to facilitate certain electrical contacts, are called connectors.
There are a large number of applications for connectors although the most typical and usual are the link between printed circuits or these with wire harnesses as well as everything related to the input and output connections, including power.

A WELL-KNOWN MODEL

One of the simplest and best known connectors and no less important is the popular plug that is used to attach to the industrial or domestic electrical network any device that uses this form of energy for its normal operation. A normal plug consists of two clearly differentiated parts. One of them is the female base or connector and is usually directly attached to the two or three distribution cables, depending on whether it is a single-phase or three-phase installation, by means of contacts based on pressure screws or by welding. This is the fixed element since it will be, in most cases, immobilized by screws or recessed in a partition or wall. Inside it contains two or three metal housings, stopped by insulating materials that are directly responsible for the connection, being prepared to receive the second of the mentioned parts. This can be considered as the mobile or aerial element and is usually called male connector or male plug consists of two or three contact pins of an adequate length and diameter, also separated by an insulating material and mounted on a support piece that allows its handling without risk of discharges. On its internal ends are attached the two or three wires that transmit the electric current to the apparatus in question. A first and important consideration about these plugs is the need for their design to guarantee four fundamental aspects:

— The insulation between the two or three connecting pins must be high enough to allow high voltages to appear between them (220 V in single-phase installations and 380 V in three-phase installations) without there being a current circulation that would jeopardize their normal operation.

— The cross-section of the pins must withstand the current intensity absorbed from the network by the corresponding equipment.

— The contact resistance: between the two parts of the plug (male and female) must be minimal, because otherwise there would be an automatic certain dissipation of power in the form of heat that would endanger the installation.

— The complete system must allow a certain number of connections and disconnection actions without any signs of wear or aging being observed in any of the parts of the plug that imply any deterioration of the three previous characteristics.

As can be seen, in the case of connectors used for electrical installations, certain requirements arise derived from the characteristics of this particular technique.

PRINTED CIRCUIT CONNECTORS

The same happens with other applications, in which it has been necessary to carry out a thorough study of the needs to be satisfied to design the most appropriate types and that best adapt to them. Thus, in all those cases in which it is necessary to have in a team a series of printed circuits, generally modular, capable of allowing a quick assembly and disassembly, they must be equipped with connectors. For this, several systems can be used, logically dependent on the quality and cost requirements of each specific case. The most commonly used system is to provide the printed circuit with an area for contacts on one of the edges of it, so that all the metallized surfaces that are required are obtained during the manufacturing process of the circuit, without the need to have any additional element. This procedure, which is applicable in both single-sided and double-sided circuits, requires a certain standardization as regards the distance between contacts, their dimensions and the total edge of the circuit intended for this function. This is logical, if it is taken into account that the area created corresponds to one of the parts of the connector and the other must necessarily be an independent element of those existing on the market for this application.

These connectors, of the female type, usually contain a series of contacts that will exert a certain pressure on the metallized areas of the circuit, guaranteeing good electrical continuity and low resistance. The number of connection points is variable according to models and manufacturers, however the distance between them is fixed and normalized being the most usual values: 2.54 millimeters, 3.81 millimeters, 3.96 millimeters and 5.08 millimeters. To guarantee a correct service of the complete connector over a long period of use, the printed circuit must be equipped with a coating that does not alter with the various environmental conditions (cold, heat, humidity, etc.), since otherwise it would deteriorate quickly, being useless in a short time. The material used is usually gold since it perfectly combines the two factors of passivity before atmospheric and weak agents electrical resistance.

Another alternative for the connection of the circuit is to use a male connector welded to it, instead of the edge area mentioned above, thus simplifying the board with the consequent reduction of the cost of it. This system is also used in cases where the number of contact points is high and there is not enough space at the edge of the circuit for all of them. In this case, male and female connectors with two or more parallel rows of connection pins are usually used. In the use of these connection systems, all the aspects indicated when dealing with the electrical outlets must be taken into account, since they are equally applicable.

CONNECTORS FOR SIGNALS

Another well-known family of connectors is the one intended to facilitate connections between two points between which a certain signal transmits, either low frequency, as is the case of sound equipment or high frequency in transmitters and receivers or in equipment that handles video signals.

AUDIO SIGNALS

For sound equipment, two standardized types of connectors known as DIN and CINCH or RCA are usually used. The first of them is usually incorporated in devices of European origin since it responds to a German standardization. Of it there are two basic models: three and five pins. Its design includes a mark or slit that makes it possible to connect the male and female in a single position thus avoiding any possible error. Since in most cases shielded or shielded cables will be used for these applications, the mass connection corresponding to the screen or mesh of the cable has also been standardized, always being carried out on the central pin.

The CINCH or RCA connector is mainly

used in equipment of American and Japanese origin, and its female consists of a central hollow metal cylinder surrounded by an insulating element and a concentric conductive ring. The male will therefore have a metal central pin of the appropriate diameter to fit perfectly into the hollow of the anterior cylinder as well as another ring also conductive of sufficient diameter to embrace the external area of the element mentioned above.

This will always carry the connection of the screen of the cable or mass, while the central pin will conduct the signal that is transmitted also called live terminal. Comparing both types, it is observed that the DIN can make four connections plus the common (central) while the CINCH or RCA only makes one more the common, so four CINCH or RCA connectors will be needed for each DIN (five-pin).

From a practical point of view, the latter is more comfortable; however, the first allows connections to be made, separating the masses and not the other by going all together to the same point. This aspect it can be important when handling very weak signals or the connections to be made are very long.

Fig.1 Connectors for audio or video signals type Cinch or RCA.

It is worth mentioning another of the connectors that has a group, also very numerous, of applications; it is the "jack" type connector. As in the previous cases, it is composed of the two normal elements for connection: male and female. The first is formed by an external metal tube that constitutes one of the contacts, inside which are another series of tubes of smaller diameter and greater length separated by insulating layers. The contact ends of these, appear to the outside after the first offering several cylindrical contact surfaces until reaching the tip, hemispherical, which forms the last of the contacts. On this is a small narrowing, necessary to achieve a permanent mechanical fixation between the male and female.

The most common models contain two or three connection zones and are used to transmit one or two signals simultaneously. If shielded cable is used, the meshes will be attached to the outer body or tube and the living ones to the internal ones. On the market there are several standardized models of "jack" connectors with different lengths and diameters and are usually intended for functions such as: microphone connection, input and output sockets in portable devices, monophonic (two contacts) or stereophonic (three contacts) headphone connections, etc.

VIDEO SIGNALS

The BNC connector is a high-quality connector. Designed for 50 ohm cables, although it is also used with 75 ohm cables, it is very appropriate to make fast and safe connections being nailed by a 90° turn. The

connectors of the appliances are usually panel females and the connection cable usually carries two male connectors at the ends. The inner connector pins are usually coated in gold to improve electrical contact. On the outside they have a cylinder that connects to the mesh, and that is provided with the necessary hooks to attach it to the other connector. The UHF connector is similar to the BNC but of a somewhat larger size, it is usually used in professional videos. The connection is made by threading and is used for connections of 75 ohm impedance.
The RF connector is the classic 75 ohm antenna connector of TV receivers. In its external appearance, the male and the female are the same, but the latter has the central conductor perforated and provided with a groove. It is used in RF outputs and inputs and exists in two sizes: 9.5 mm and 13 mm in diameter. There are bended models and there are also adapters for both sizes.

The DIN connector is provided with an outer shell that connects to the cable mesh and several inner pins through which different signals circulate, such as input and output video, input and output audio, control voltages, etc.

Fig. 1.— DIN connector. This model with five pins allows four simultaneous connections.

CHAPTER 12
HOW TO IDENTIFY COMPONENTS IN A SCHEMATIC DIAGRAM

It is necessary to be able to graphically represent any electronic design, so that it is compatible by the people who must work with it, to use a set of standard symbols that allow drawing each and every one of the possible components that are used in the circuits, as well as the interconnections made between them. In this way it will be possible to represent any electronic equipment, no matter how complex it may be, by means of a more or less wide set of circuits, formed in turn by components, which are joined by a certain number of connections. An electrical scheme is the representation on paper, both of the components and the interconnections between them, so that the complete set forms a circuit or block of an apparatus and performs, consequently, a certain function.

Once the electrical diagram has been drawn, it will be easy to recognize each component by its symbol, but it will not be so easy to determine the way of working that each one has, as well as the function of the circuit represented, unless you have a great experience in the interpretation of them. The knowledge of these symbols is very important for anyone who wants to enter the field of electronics for the first time and will gradually achieve an increasing skill in the handling and interpretation of them.

As can be seen in the figures, the wires and cables are represented by lines and any kind of connections between them or with component terminals, is drawn by a small black circle located at the junction between them.

The resistors as can be seen, have two different representations, being able to choose any of them, trying to maintain the same until completing the drawing of the circuit. Next to the symbol, the ohmic value and the power dissipation should be indicated.

The different types of resistors (windings, pyrolytics, metal film, etc.) are not represented in a special way, but the same symbol is used for all.

Capacitors have two different representations, depending on whether they are types with fixed polarization (electrolytic) or without it (ceramics, polyester, etc.). For the first case, the polarity shall be indicated on the symbol. In addition, the value of the capacity as well as the maximum working stress will be noted next to it. In transformers there are several representations for the core, depending on whether it is iron, ferrite or air. The primary is usually located on the left and the secondary ones on the right.

The coils have the same symbol as the transformers, but with a single winding; next to it is indicated the value of its inductance.

The diodes start from a basic symbol and adding a certain graphic complement is possible to differentiate the different models that exist of this component Zener, Varicap, tunnel, etc.). Next to it you can write the specific type in question.

For transistors, as can be seen, there are different symbols according to different families (bipolar, FET, MOSFET). In any case, the arrow that always exists in one of its three terminals, indicates the direction of the current that passes through it. In this way, the NPN and PNP types and FET or MOSFET or MOSFET of channel N or P will be identified. The type of transistor concerned shall be indicated next to it.

The symbol of vacuum valves always has two basic elements, the cathode and the plate. The different grids are drawn together according to the model in question (triode, tetrode, pen-all, heptode).

The thyristor has two symbols, depending on whether they are elements with a door or two. The representation of the Triac is unique, being a non-polarized element, capable of operating with alternating currents.

The group of switches and switches have very similar symbols, although some peculiarities can be distinguished (sliding or rotary switches).

The relays admit several representations, although the most general is the one in which the actuated coil is drawn linked by points with the contacts it controls, highlighting in the latter the resting position. For other components, a unique symbol is generally used, such as the microphone, the headset, the speaker and the batteries.

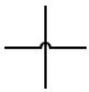
Quartz crystals, widely used in oscillators, are drawn with two different symbols, as can be seen in the figures.

The graphic representation of the antennas depends on whether they are simple or dipoles (case of television) and in the latter case they differ if it is a closed dipole (Yagi) or open. A symbol widely used in all schemes is that of mass or earth since it represents a common point of the circuit. As can be seen, there are three different symbols equivalent to each other.
Amplifiers integrated into a circuit are represented by a triangle, placing the output at the apex of the circuit and the inputs on the opposite side.

The engines, finally, generally respond to the representation seen in the figure. If necessary, the operating voltage and the specific type concerned shall be indicated next to it.

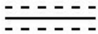
1) *CONTACT WIRE.*

UNCONNECTED CROSSING



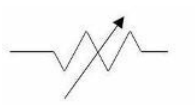
3) COAXIAL THREAD

4) SHIELDED THREAD



5) RESISTOR

6) VARIABLE RESISTANCE

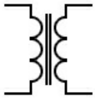


7) CAPACITOR

8) VARIABLE CAPACITOR

9) ADJUSTABLE CAPACITOR

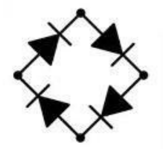
10) TRANSFORMER WITH CORE



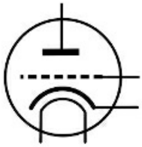
11) COIL OR INDUCTANCE

12) DIODE

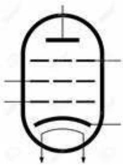
13) BRIDGE RECTIFIER



14) TRIODE VALVE

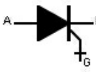


15) PENTODO VALVE

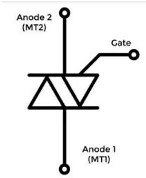


16) DIAC

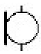
17) THYRISTOR



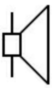
18) TRIAC



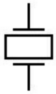
20) MICROPHONE



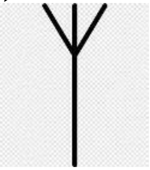
21) SPEAKER



22) QUARTZ CRYSTAL

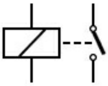


23) ANTENNA

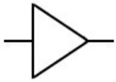


24) DIPOLE

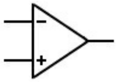
25) RELAY



26) AMPLIFIER

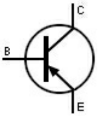


27) OPERATIONAL AMPLIFIER

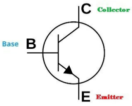


28) MOTOR

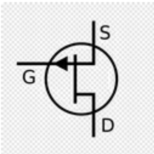
29) TRANSISTOR PNP



30) TRANSISTOR NPN



31) TRANSISTOR FET



32) BATTERY