DESIGN AND CONSTRUCTION OF 0Ω - 1000Ω RHEOSTAT

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3/12/09.

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(2004 – 18733EE)

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DEDICATION

To my Friends and love ones, most especially Mrs Toyin Azeez, my mother.

DECLERATION

I, Raheem Olayinka Azeez, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

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First and foremost, I thank God, who love me and have strengthened me all through. My late father Mr. Fatai Azeez, mother and sister, you have all shown me love in every way, I thank you. Mr. Kazeem Azeez, my elder brother, Mr. Happy Enabeli, Mr james.A.bamidele and a host of others whose names are not mentioned here, thank you all. Your immense contribution to my life and education has paid off. Prof. Oria Usifo, my supervisor, thank you, for all your words of encouragement.

ABSTRACT

This project is design and construction of 0 – 1000Ω Rheostat. It is relatively cheap equipment for measurement of Resistance. For use in electrical workshop.

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CHAPTER ONE

1. INTRODUCTION

A rheostat is a device used in home and electrical workshop to measure resistance of difference ranges. It is an electrical component that has an adjustable resistance. It is a type of potentiometer that has two terminals instead of three. The two main types of rheostat are the rotary and slider. The symbol is a resistor with an arrow diagonally across it.

A lot of rheostat used in electrical workshop is of wire –wound types that have a long length of conductive wire coiled into a tight spiral. The linear types have a straight coil while the rotary types have the coil curved into a turns to save space. The coil and contacts are sealed inside the case to protect them from dirt which can cause an open circuit. A rheostat can also be made from other material such as carbon disks, metal ribbons, and even certain fluids. As long as the material has significant resistance change over a short length, it can probably be used to make a rheostat. They are used to make a rheostat. They are used in many different applications, from light dimmers to the motor controllers in large industrial machines. Some light dimmers use rheostat to limit the current passing through the light bulbs in order to change their brightness. The greater the resistance of the rheostat, the lower the brightness of the bulbs. Some light can not use dimmers, such as fluorescents and gas discharge lamps. These light have a large resistance loads, called ballast, that maintain a constant current through them. Rheostat is still a common and fundamental electronic component used to control the flow of current in a circuit. However, it has largely been replaced by trial, a solid state device also known as a silicon controlled rectifier (SCR). A triac do not waste as much power as a rheostat and has better reliability due to the absence of mechanical parts. Rheostat commonly fail because their contact becomes dirty or the coil wire corrodes and breaks. Motor controller also use rheostat to control the speed of a motor by limiting the flow of current through them. They are used in many appliances such as blenders, mixer, fans, and power tools. Rheostats are also used as text instrument to provide an accurate resistance value. This project features a relatively cheap, easy and efficient design of a rheostat for domestic and workshop users.

1.1 OBJECTIVES

This project is aim at the followings:

- To design and construct a relatively cheap and efficient rheostat for use in home and workshops
- To improve my skill in the theory and practice of circuit analysis and design.
- To acquaint me with basic tools and materials in electrical and electronic engineering and also develop my skill in their use.
- To encourage research and develop on research methods for data acquisition.
- To fulfill part of the requirement for the award of a degree in electrical and computer engineering.

1.2 METHODOLOGY

This project research was carried out in modules, each module being a unit of the circuit. This is represented in the project diagram as will be seen in the chapter three of the project write-up, with all necessary details.

1.3 SCOPE / LIMITATION.

This prototype measures resistance between the range of 0hms to 100Ohms, it is limited to a load not more than 50Watts.

1.4 SOURCE OF MATERIALS

A number of text books that were used some of which are listed below:

- Ed. Richard C.Darf, Electrical Engineering Handbook,
- M.W.ANYAKOHA phD, New School Physics, 1st Edition. 2003, African first publishers limited.
- Whitetaker, Jerryc Resource Handbook of Electronics
- Tony R Kuphaldt, Lessons in Electric Circuits Vol. VI- Experiment, 1st Edition, last update July 21,2002.
- John O' Malley, Basic Circuit Analysis, 2nd Edition, Mc Grawn – Hill Publishing Company.
- Stan Gibliso; Teach yourself Electricity and Electronics 3rd Edition.
- Research Project Implementation made easy in Electrical and Electronic Engineering Vol.1 1st Edition, Prof. Oria Usifo.

Various website also supplied very useful information. Some of these site include:

www.micainsulation.org/standard/ma

Wikipedia the free encyclopedia, http/en,wikipedia.org/wiki/

1.5 CONSTRAINTS

Few constraints were encountered in the course of the project work but were resolved up to limited level.

One of the major problem encountered was, how to wound the resistance wire in order to avoid contact, so that the resistance can be measured at any point on the heat resistance cylinder as the slider is moved. This problem was solved by coating the resistance wire before winding, to avoid contact.

CHAPTER TWO

2. LITERATURE REVIEW

The resistor is an electrical device whose primary function is to introduce resistance to the flow of electric current. The magnitude of the opposition to the flow of current is called the resistance of the resistor. A large resistance value indicate a greater opposition to current flow. The resistance is measured in ohms. An ohm is the resistance that arises when a current of one ampere is passed through a resistor subjected to one volt across its terminals. A resistor whose resistance can be varied is known as variable resistor whose symbol is shown below.

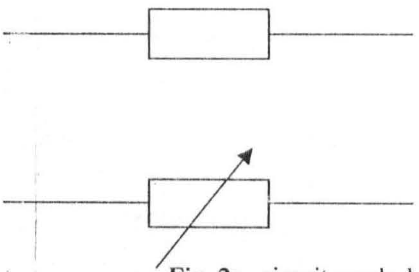

Fig. 2: circuit symbol for resistor and rheostat

The various uses of resistors include setting biases, controlling gain, fixing time constant, matching and loading circuits voltage division, and heat generation.

2.1 PURPOSE OF THE RESISTOR

Biasing

In order to work efficiently, transistors or tubes need the right bias. This means that the control electrode – the base, gate, or gride – must have a certain voltage or current. Networks of resistors accomplish this. Different bias levels are needed for different types of circuits. A radio transmitting amplifier would usually be biased differently than an oscillator or a low-level receiving amplifier. Sometimes voltage division is required for biasing.

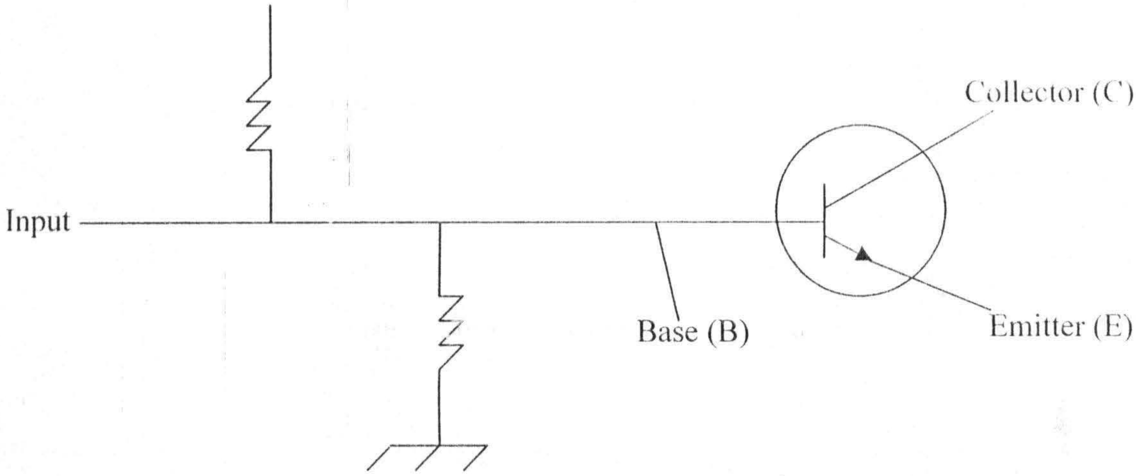

Fig. 2.1: voltage divider for biasing the base of a transistor

Current Limiting

Resistors interfere with the flow of electrons in a circuit. Sometimes this is essential o prevent damage to a component or circuit. A good example is a receiving amplifier. A resistor can keep the transistor from using up a lot of power just getting hot. Without resistors to limit or control the current, the transistor might be overstressed carrying direct current that does not contribute to the signal. An improper designed amplifier might need to have its transistor replaced often, because a resistor was not included into the design where it was needed, or because the resistor is not the right size.

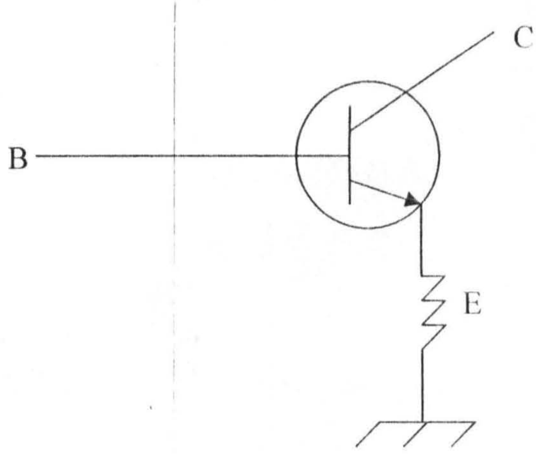

Fig. 2.2: current-limiting resistor fo˜ a transistor

Power dissipation

Dissipating` power as heat is not always bad. Sometimes a resistor can be used as a "dummy' component, so that a circuit "see" the resistor as if it were something more complicated. In radio, for example, a resistor can be used to take the place of an antenna. A transistor can then be tested in such a way that it does not interfere with signals on the airwaves. The transistor output heat the resistor, without radiating any signal. But as far as the transistor knows it is hooked up to a real antenna. Another case, in which power dissipation is useful is at the input of a power amplifier. Sometimes the circuit driving the amplifier (supplying it's input signal) has to much power for the dissipation this excels so that the power amplifier does not got to much drive.

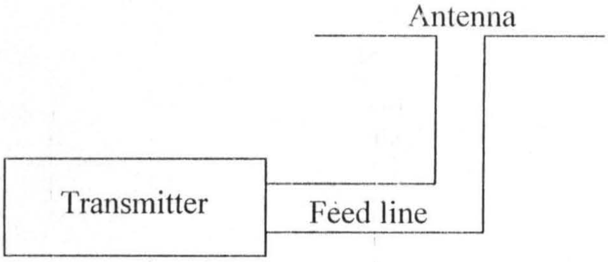

Fig. 2.3a Transmitter is hooked up to a real antenna

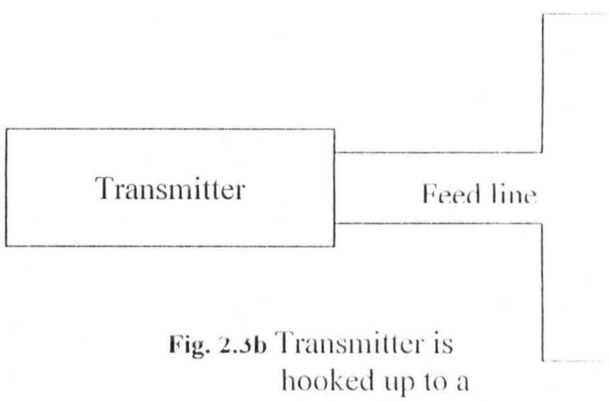

Fig. 2.3b Transmitter is hooked up to a resistive "dummy" antenna

2.2 RESISTOR TYPES

The carbon-composition resistor

Probably the cheapest method of making a resistor is to mix up finely powered carbon (a fair electrical conductor) with some non-conductor substance, press the resulting clay-like stuff into a cylindrical shape, and insert wire leads in the ends. The resistance of the final product will depends on the ration of carbon to the non conducting material, and also on the physical distance between the wire leads. The non conductive material is usually phenolic, similar to plastic. This result to a carbon-composition resistor.

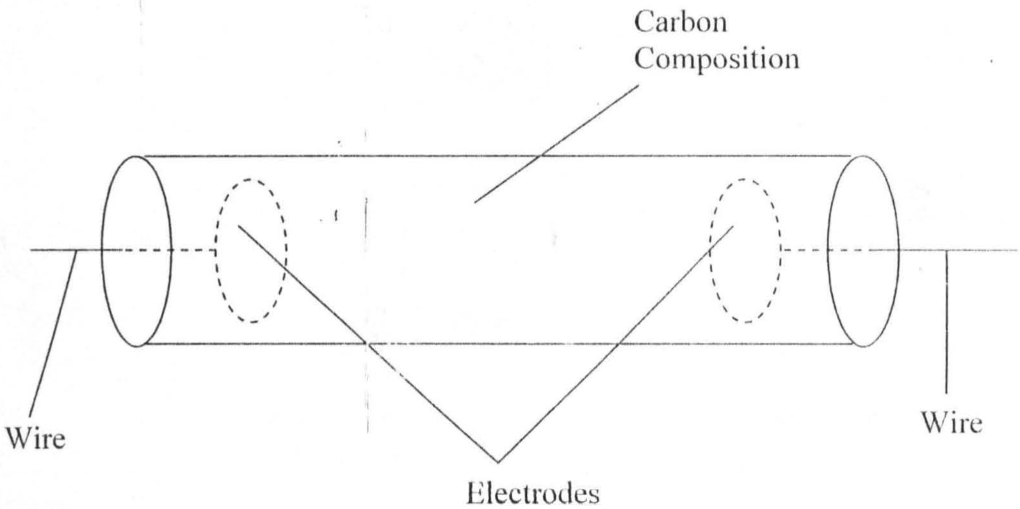

Fig. 2.4 Construction of Carbon – Composition Resistor

This kind of resistor has the advantage of being pretty much non reactive. That means that it introduces almost pure resistance into the circuit, and not much capacitance or inductance. This makes the carbon-composition resistor useful in radio receives and transmitters. Carbon- composition resistor dissipate power according to how big, physically they are.

THE WIRE WOUND RESISTOR.

A more obvious way to get resistance is to use a length of wire that is not good conductor. Nichrome is most often used for this. The wire can be wound around a cylindrical form, like a coil. The resistance is determined by how well the wire metal conducts, by its length. This component is called a wire-wound resistor.

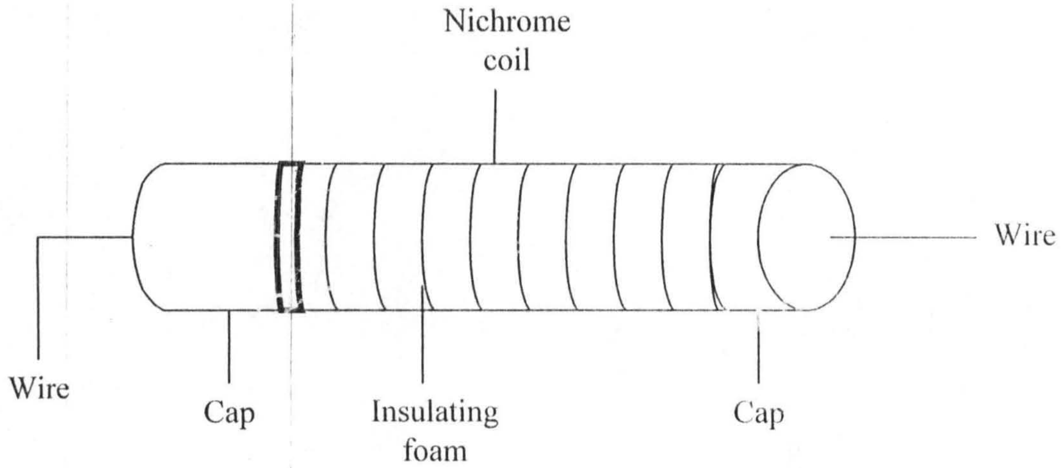

Fig. 2.5: wire wounded resistor

One of the advantages of wire-wound resistor is that they can be made to have values within a very close range. That is, they are precision components. Another advantage is that wire wound resistor can be made to handle large amount of power.

A disadvantage of wire-wound resistor, in some applications, is that they act like inductor. This makes them unsuitable for use in most radio- frequency circuits.

FILM TYPE RESISTORS.

Carbon, nichrome, or some mixture of ceramic and metal (cement) can be applied to a cylindrical form as a film, or thin layer, in order to obtain a desired value of resistor. This type of resistor is called a carbon --firm resistor or metal- firm resister. It look like a carbon composition type, but the construction technique is difficult.

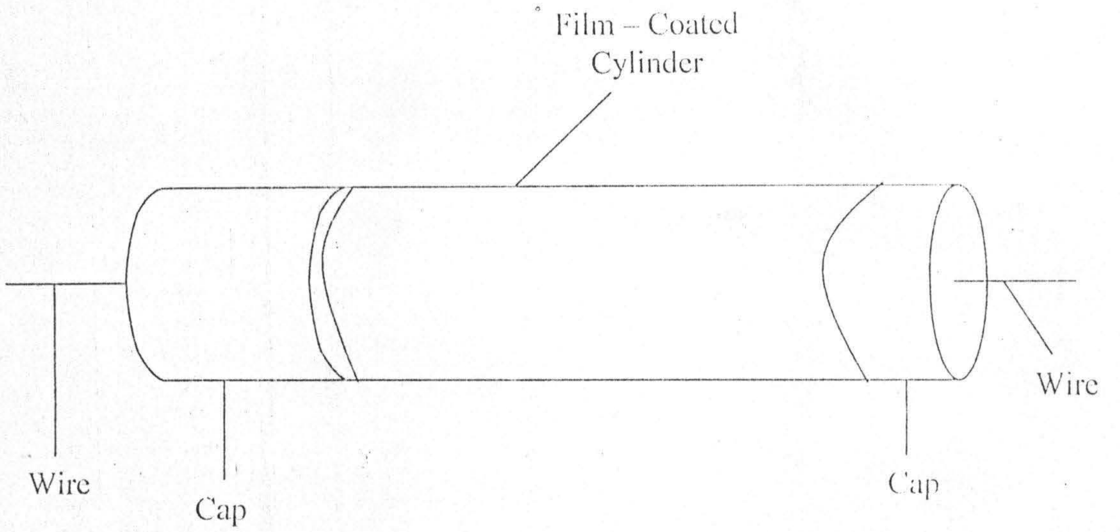

Fig. 2.6: film type resistor

The cylindrical form is made of an insulating substance, such as porcelain. The film is deposited on this form by various methods, and the value tailored as desired. Metal film units can be made to have nearly exact values. Film type resistors usually have low to medium high resistance.

A major advantage of film type resistors is that they, like carbon-composition units, do not have much inductance or capacitance. A disadvantage in some applications is that they can not handle as much power as the more massive carbon-composition units.

INTEGRATED- CIRCUIT RESISTOR.

Increasingly, whole electronic circuits are being fabricated on semiconductor waters know as integrated circuit (Ics). It is possible nowadays to put a whole radio receiver into a couple of Ics, or chips, whose total volume is about the same as that of the tip of your little finger.

In 1930, a similar receiver would have been as large as a television set. Resistors can be fabricated onto the semi conductor chip that makes up an Ic. The thickness, and the types and concentrations of impurities added. Control the resistance of the components.

Ic resistor can only handle a tiny amount of power because of their small size. But because Ic circuit in general are designed to consume minimal power. This is not a problem. The small signal produced by Ics can be amplified using circuit made from discrete components.

2.3 RESISTOR VALUES.

In theory, a resistor can have any value from the lowest possible (such as thaft of solid silver). In practice, it is unusual to find resistor with values less than about D.I.R, or more than 100mn.

Resistors are manufactured in standard values that might at first seem rather odd. The standard number are 1.0,1.2,1.5,1.8,2.2,2.7,3.3 and 8.2 units are commonly made with values derived from these values, multiples by some power of 10. Thus, there are units of 47n,180n, 8.8kn, or 18mn, but not 380n or 650kn.

In addition to the above values, there are others that are used for resistors made with greater precision, or tighter tolerance. These are power of 10 multiples of 1.1, 1.3, 1.8, 2.0, 2.4, 3.0 and 9.1.

TOLERANCE

The first set of numbers above represents standard. Resistance values available in tolerance of plus or minus 10 percent. This means that the resistance might be as much as 10 percent more or 10 percent less than the indicated amount. In the case of a 470Ω resistor, for example the value can be off by as much as 47Ω and still be within tolerance. That is a range of 432 to 51700. The tolerance is calculated according to the specified valued of resistor, not the actual value. The value of a 470Ω resistor can be measured and found to be 427, and it will be within 10 percent of the specified value: if it measures 420Ω, it is outside the 10 percent range and id a "reject".

The second set, along with the first set, of numbers represents standard resistance value available in tolerance of plus or minus 5 percent. A 470Ω, percent resistor will have an actual value of 470Ω plus or minus 24Ω, or a range of 446 or 4934Ω.

Some resistors are available in tolerance tighter than 5 percent. These precision units are employed in circuits where a little error makes a big difference. In some audio and radio –frequency oscillator and amplifiers, 10- percent or 5- percent tolerance is good enough. In many cases, even a 20-percent error is all right.

POWER RATING.

All resistors are given a specification that determines how much power they can safely dissipate. Typical values are ¼ w, ½ and 1W. Unit also exist with rating of 1/8 or 2W. These dissipation ratings are for continuous duty.

The amount of current a given resistor can handle can be figured out by using the formula for power (p) in term of current (I) and resistance (R)

$P = I^2R$

Working this formula backwards, plugging in the power rating for P and the resistance of the unit for R, and solve for I or by finding the square root of P/R. Remember to use amperes for current, ohms for resistance and watts for power.

2.4 VARIABLE RESISTORS

These are resistor, in which the value of the resistance varies with the applied 'stimulus' from the popular equation R=P×L/a, we can see that the stimulus has to change one or more of those quantities to give rise to variation in resistance. There are four types of stimuli and correspondingly. The followings four type of variable resistors.

1. Mechanically variable resistors e.g potentiometer rheostat.
2. Thermally / voltage variable resistors (Thermistors)
3. Electrically / voltage variable resistors (Varistors)
4. Optically / light variable resistors (Photoresistors)

SPECIFICATION OF VARIABLE RESISTORS.

In addition to the specification mentioned in the case of fixed resistors, the variable resistors have the following specifications.

2. The stimulus responsible for the variation in the resistance, e.g temperature, magnetic field, light intensity , etc
3. The range of the stimulus that can be applied
4. The range of resistance variation
5. The law governing the resistance variation.

MECHANICALLY VARIABLE RESISTORS.

In this category generally the length of the resistor is changed with the application of a mechanical stimulus like pressure or displacement (e.g wire wound resistors) or with graphite particles depressed. In an elastic medium (e.g carbon resistors). Such resistors can give varying value of resistance in the circuit in which they are connected. They are commercially called 'pot' (Potentiometers). Tone control, contrast, brightness, volume controls, In Radio and TV are carried out by these pots. The two types are:

1. Wire Wound
2. Carbon Construction

WIRE WOUND VARIABLE RESISTORS.

These are constructed by winding a high resistivity material wire on a porcelain core. At their centre. There is a shaft which can be rotated to change to change the value of the resistance.

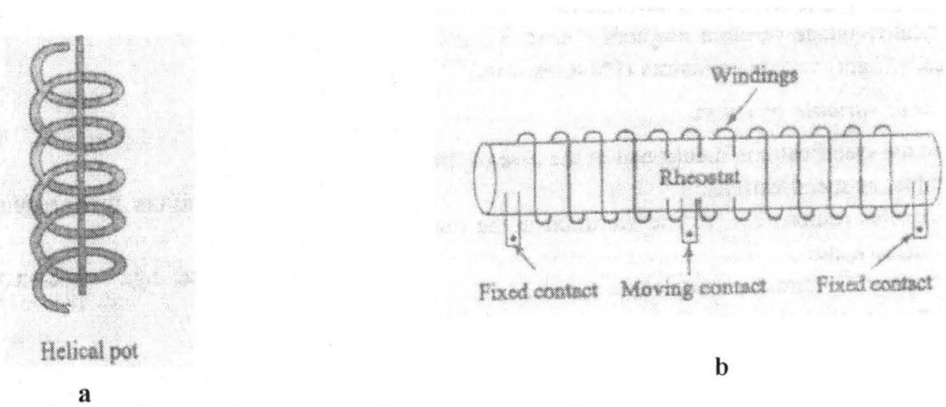

Fig 2.7: wire wound variable resistor

CARBON VARIABLE RESISTORS

Low power variable resistors are made of carbon composition either in solid track or a coating of carbon film. They are available from IK to 5MR with power from 1/2 W to 2W. a thin carbon coating on a pressed paper or a moulded carbon disc gives a carbon resistor.

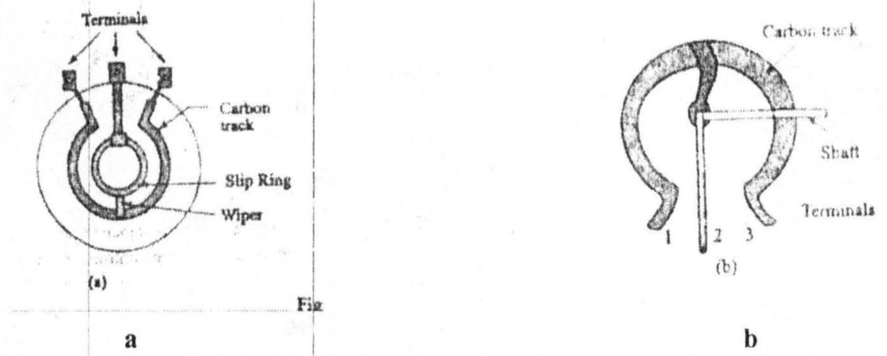

Fig 2.8: form of carbon pots

Mechanically variable resistor can also be classified into another two types namely:

i. Linear pots

ii. Non- Linear or Logarithmic pots

i. LINEAR POTS

In this, the coil is wound on a linear former and therefore resistance varies linearly with the rotation of the contact. These are used in electronic circuits for general purpose.

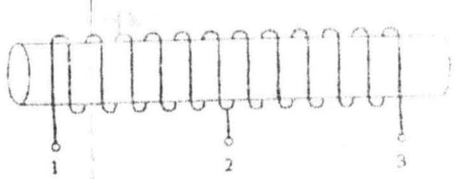

Fig. 2.9 Linear pot

ii. NON- LINEAR OR LOGARITHMIC POTS

In this type, the coil is wound on a non-uniform former and therefore resistance varies non-linearly or logarithmically with rotation of the contact. These pots are used as volume control of sound.

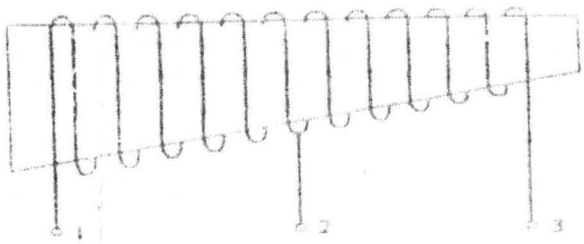

Fig. 2.10: non-linear or logarithmic pot

THERMALLY VARIABLE RESISTORS. (THERMISTORS)

Thermistors mean 'thermal resistors'. These are usually semi-conductors, which behave as resistors with a very high negative temperature coefficient of resistance. They are highly resistive to temperature and therefore used in precision.

Measurement and in thermal relays. They are made of oxides like: N102, $Mn0_2$ etc. Thermistors are also used for surge protection, amplitude control, power measurements and regulation.

Theremistors are made from materials whose resistivity changes with temperature. The thermistors may be:

i. PTC thermistors these exhibit high positive temperature coefficient (PTC) of resistance. Unusually a conductor like iron wire evaporated in hydrogen atmosphere is used.

ii. NTC thermistors. They exhibit a "negative temperature coefficient (NTC) of resistance. Usually semi-conductor materials like oxides of nickel, manganese, cobalt are used. Their Expression for temperature coefficient is given by

RT=Ro [B (1/To -1/T)] where

B is bandwidth

SPECIFICATION OF TYPICAL PTC THERMISTORS

i. Resistance of at $25^{o}C$: 60R

ii. Resistance at $125^{o}C$:15K.

iii. Maximum temperature coefficient + 5%/^{o}c maximum voltage: 22V.

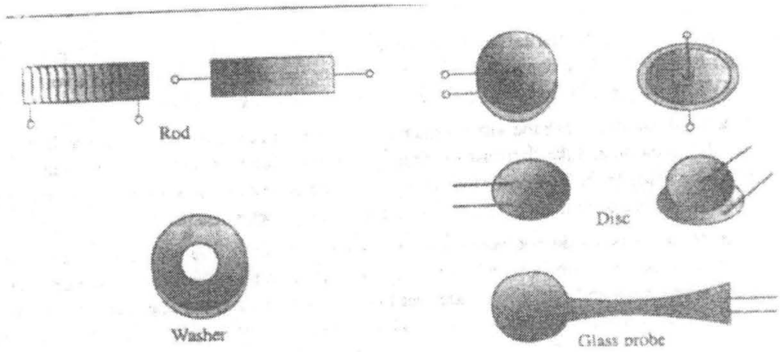

Fig. 2.11: various types of thermistors

ELECRTRICALLY (OR VOLTAGE) VARIABLE RESISTORS (VARISTORS)

In this type of variable resistance, the value of resistance changes with the applied voltage. This is achieved by choosing a material in which the charge carrier transportation depends upon field electron emission. These are usually made from conductor, insulator and semi-conductor composite materials, e.g composites of silicon carbide, graphite and sodium silicate in which resistivity decreased with increase in applied voltage. This happen because of the increased transport of charge carriers across thin insulating layer of sodium silicate surrounding the silicon carbide and graphite granules.

The expression for their resistance varying with the applied voltage is given as

$Rv = Rvo[Bv(V-Vo)]$

Where Bv is the voltage coefficient of resistance (negative) and other symbols have their usual meanings. Coating of selenium oxide on nickel plated steel and is used as a high voltage rectifier (40v per unit). They can be used at even higher voltage by connecting them in series.

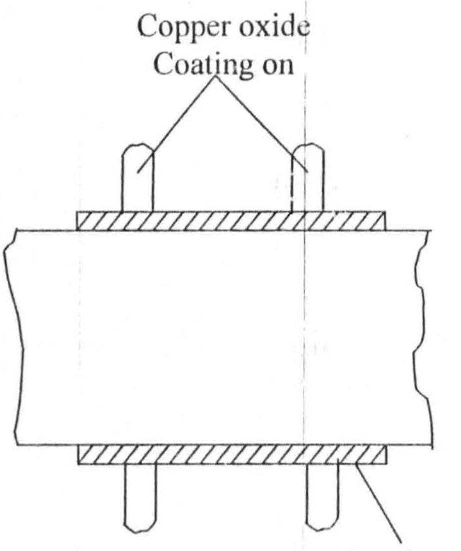

Fig. 2.12a: copper oxide rectifier

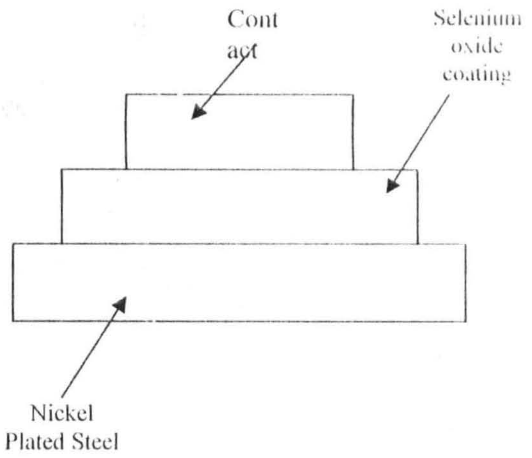

Fig. 2.12b: Selenium Oxide Rectifier

OPTICALLY VARIABLE (LIGHT DEPENDENT) RESISTORS (LDR OR PHOTORESISTORS)

These resistors change their value with the intensity of light falling on them. They have a ceramic substrate, over which a photo resistive material (usually cadmium sulphide Cds) is deposited in Zigzag from to increase the length. Hence the values of resistance Fig 2.14 which vary from 15K down to 500hm, from darkness to light, respectively are available. Their power rating is from 50MW to 0.5W. They are used for automatic brightness control in TV, etc. As mentioned above the resistance of an LDR changes with the intensity of incident light. This is achieved by using a semi-conductor material, in which the absorbed light of appropriate wave length can generate electrons and holes which lead to change in the resistivity. Such materials are Cds, Zns and Pbs which are 'photocrystalline'

The variation in resistance with intensity of light is given by

$$R = AL^{-\&}$$

Where L= Intensity of light

A= a constant

&= another constant, whose value lies between 0.7 and 0.9

SPECIFICATIONS:

Maximum power dissipated: 0.2W

Maximum voltage: 100v

Temperature range: 20-60^{0}c

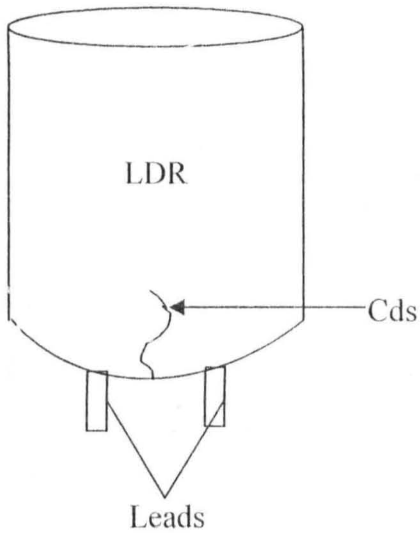

Fig 2.13 Shows LDR

2.5 ARMATURE WINDING

The armature windings are usually former-wound. These are first wound in the form of flat rectangular coils and are then pulled into their proper shape in a coil puller. Various conductors of coils are insulated from each other. The conductors are place in the armature slots which are lined with tough insulating material. This slot insulation is folded over the armature conductors place in the slot and is secured in place by special hardwood or fibre wedges.

TERMS USED IN CONNECTION WITH ARMATURE WINDING.

POLE-PITCH

It may be defined as:

1) The periphery of the armature divided by the number of pole of the
2) Generator i.e the distance between two adjacent poles.
3) It is equal to the number of armature conductor (or armature slots) per pole.

CONDUCTOR

The length of a wire lying in the magnetic field and in which an EMF is induced, is called a conductor (or inductor) as, for example, length AB or CD in figure 2.14a.

COIL AND WINDING ELEMENT.

With reference to figure 2.14a, the two conductors AB and CD along with their end connections constitute one coil of the armature winding. The coil may be single-turn (figure 2.14a) or multi-turn coil (figure 2.14b). A single-turn coil will have two conductors. But a multi-turn may have many conductors per coil side. In figure 2.14b, for example, each coil has 3 conductors. The group of wires or conductors constituting a coil side of multi-turn coil is wrapped with a tape as a unit (figure 2.14c) and is place in the armature slot. It may be noted that since the beginning and the end of each coil must be connected to a commutator bars, there are as many commutator bars as coils for both lap and wave windings. The side of a coil (1-turn or multi-turn) is called a winding element. Obviously, the number of winding element is twice the number coils.

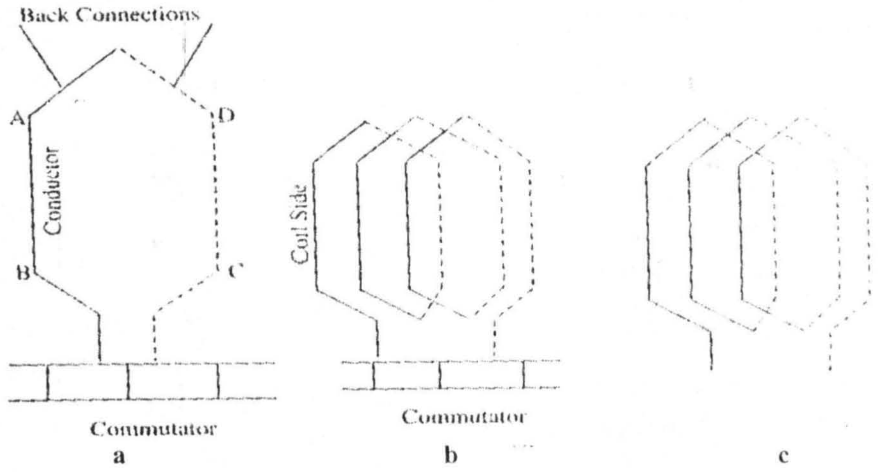

Fig 2.14: conductors

COIL SPAN OR COIL-PITCH (Ys).

It is the distance, measured in term of armature slots (or armature conductors) between two sides of a coil. If the pole span or coil pitch is equal to the pole pitch (as in the case of coil A in figure 2.15 were pole-pitch of 4 has been assumed), then winding is called full- pitched. It means that coil span is 180 electrical degrees. In this case, the coils sides lie under opposite poles, hence the induced e.m.f in them are additive. Therefore, maximum e.m.f is induced in the coil as a whole, it being the sum of the e.m.f induced in the two coil sides.If the coil span is less than the pole-pitch (as in coil B where coil pitch is $\frac{3}{4}_{th}$ of the pole pitch), the winding is fractional – pitched. In this case, is a phase difference between the e.m.f in the two coil sides.

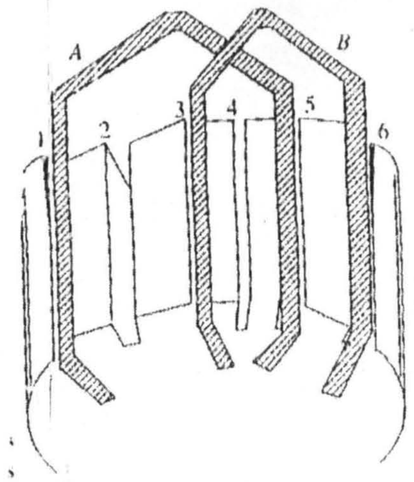

Fig. 2.15: show full pitch winding

PITCH OF A WINDING (Y)

In general, it may be define as the distance round the armature between two successive conductors which are directly together or it is the distance between the beginning of two consecutive turns.

$Y = Y_B - Y_F$ for lap winding

$= Y_B + Y_F$ for wave winding

In practice, coil – pitches as low as eight-tenths of a pole pitch are employed without much serious reduction in e.m.f fractional – pitched winding are purposely used to effect substantial saving in the copper of the end connections and for improving commutation

BACK PITCH (Y_B)

The distance measured in terms of the armature conductive, which a coil advances on the back of the armature is called back pitch and denoted by Y_B

FRONT PITCH (Y_B)

The number of armature conductors or elements spanned by a coil on the front (or commutator end of an armature) is called the front pitch and is designated by Y_F. Alternatively, the front pitch may be define as the distance (in term of armature conductors) between the second conductor of one coil and the first conductor of the next coil which are connected together at the front i.e. commutator end of the armature. Both front and back pitches for lap and wave - winding are shown in figure 2.16b.

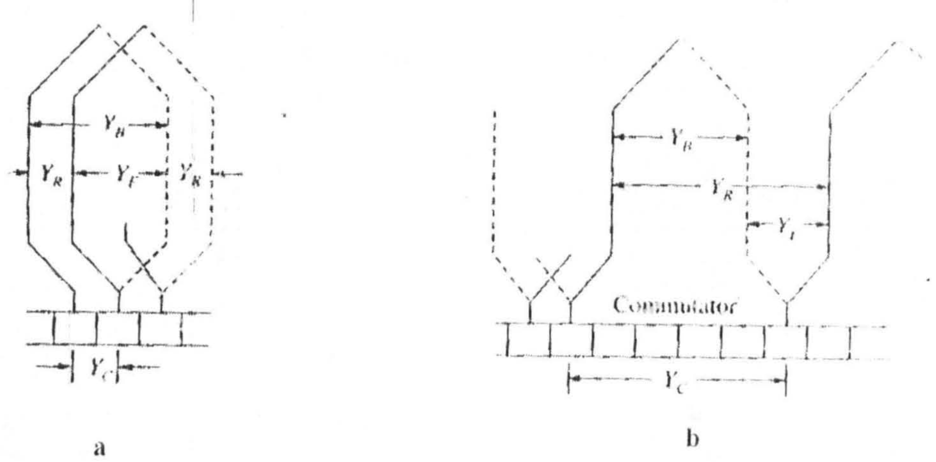

Fig 2.16: shows front and back pitches for lap and wave winding

RESULTANT PITCH (Y_R)

It is the distance between the beginning of one coil and the beginning of the next coil to which it is connected. 2.16a and 2.16b.

COMMUTATOR PITCH (Y_G)

It is the distance (measured in commutator bars or segments) between the segments to which the two ends of a coil are connected. From figure 2.16a and 2.16b. It is clear that for lap winding, Y_C is the difference of Y_B and Y_F where as for wave winding it is the sum of Y_B and Y_F. Obviously, commutator pitch is equal to the number of bars between coil leads. In general Y_C equals the 'plex' of the lap wound armature. Hence, it is equal 1,2,3,4 e.t.c. For simplex, duplex, triplex and quadruplet e.t.c. lap windings.

SINGLE – LAYER WINDING

It is that winding in which one conductor or one coil sides is placed in each armature slot as sown in figure 2.17 below.

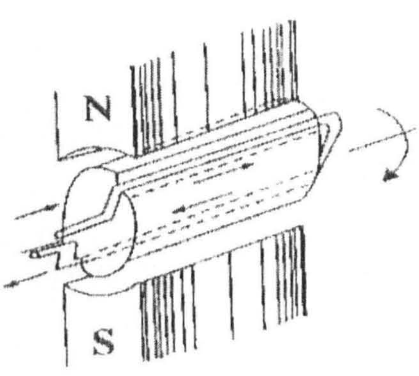

Fig. 2.17: shows a single layer winding

TWO – LAYER WINDING

In this type of winding, there are two conductors or coil sides per slot arranged in two layers. Usually, one side of every coil lies in the upper half of one slot and other side lies in the lower of half of some other slot at a distance of approximately one pitch away (figure 2.18) as shown below.

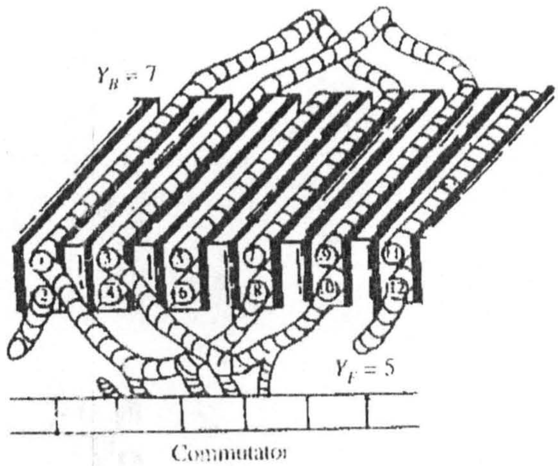

Fig.2.18: shows a two layer winding

The transfer of the coil from one slot to another is usually made in radial by means of a peculiar bend or twist at the back end as shown in figure 2.19a below. Such winding in which two coil sides occupy each slot are most commonly used for all medium – sized machines. Sometimes 4 or 6 or 8 coil sides are used in each slot in several layers because it is not practicable to have too many slots figure 2.19b. The coil side lying at the upper half of the slots are numbered odd i.e. 1,3,5,7 e.t.c while those at the lower half are numbered even 1.e. 2,4,6,8 e.t.c.

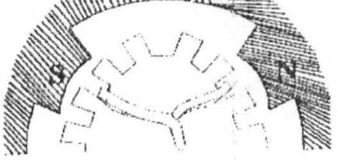

Fig. 2.19a

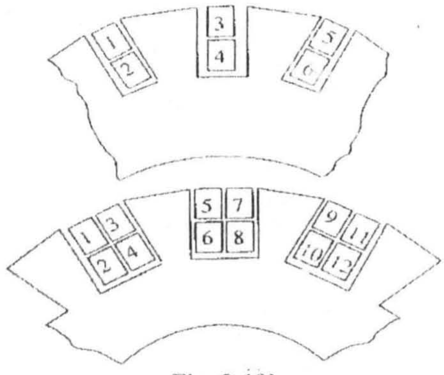

Fig. 2.19b

MULTIPLEX WINDING

In such winding, there are several sets of completely closed and independent windings. If there are two such winding on the same armature, it is called duplex winding and so on. The multiplicity affects a number of parallel paths in the armature. For a given number of armature slots and coils, as the multiplicity increases, the number of parallel paths in the armature increases thereby increasing the current rating but decreasing the voltage rating.

LAP AND WAVE WINDING

Two types of winding mostly employed for drum – type armatures are known as lap winding and wave winding. The different between the two is merely due to the different arrangement of the end connections at the front or commutator end of armature. Each winding can be arranged progressively or retrogressively and connected in simplex, duplex, and triplex.

The following rules, however, apply to both types of winding.

i. The front pitch and back pitch are each approximately equal to the pole – pitch i.e. windings should be full-pitched. This results in increase e.m.f round the coils. For special purpose, fractional – pitched windings are deliberately used.

ii. Both pitch should be odd, otherwise it should be difficult to place the coil (which are former – wound) properly on the armature. Example; if Y_B and Y_F were both even, then all the coil sides and conductors would lie either in the upper half of the slots or in the lower half. Hence it would become impossible for one side of the coil to lie in the upper half of one slot and the other side of the same coil to lie in the lower half of some other slot.

iii. The number of commutator segment is equal to the number of slots or coils (or half the number of conductors) because the front ends of conductors are joined to the segment in pairs.

iv. The winding must close upon itself i.e. if we start from a given point and move from one coil to another, then all conductors should be traversed and we discontinuity in between.

SIMPLEX LAP WINDING

It is shown in figure 2.17a which employs single turn coil. In lap winding, the finishing end of one coil is connected to a commutator segment and to the stating end of the adjacent coil situated under the same pole and so on, till and the coils have been connected. This type of winding derives its name from the fact it doubts or lap back with its succeeding coils.

Following point regarding simplex lap winding should be noted.

1. The back and front pitches are odd and if opposite sign. But they cannot be equal. They differ by 2 or some multiple.
2. Both Y_B and Y_F should be nearly equal to a pole pitch.
3. The average pitch $Y_A = \frac{Y_B + Y_F}{2}$. It equal pole pitch $= \frac{Z}{P}$
4. Commutator pitch $Y_C = \pm 1$ (In general, $Y_C = \pm m$)
5. Resultant pitch Y_R is even, being the arithmetical difference of two odd number i.e. $Y_R = Y_B - Y_F$

6. The number of slots for a 2 – layer winding is equal to the number of coils (i.e. half the number of coil sides). The number of commutator segment is also the same.
7. The number of parallel paths in the armature = mp where m is the multiplicity of the winding and p the number of poles. Taking the first condition, we have $Y_B = Y_F \pm 2$

a – If $Y_B > Y_F$ i.e $Y_B = Y_F + 2$, then we get a progressive or right – handed winding i.e. a winding which progresses in the clockwise direction as seen from the commutator end. In this case, obviously, $Y_C = +1$

b – If $Y_B < YF$ i.e. $Y_B = Y_F - 2$, then we get a retrogressive or left-handed winding i.e. one which advances in the anti-clockwise direction when seen from the commutator side. In this case, $Y_C = -1$

c – Hence, it is obvious that

$$\left.\begin{aligned} Y_F &= \frac{Z}{P} - 1 \\ Y_B &= \frac{Z}{P} + 1 \end{aligned}\right] \text{For progressive winding}$$

$$\left.\begin{aligned} Y_F &= \frac{Z}{P} + 1 \\ Y_B &= \frac{Z}{P} - 1 \end{aligned}\right] \text{For retrogressive winding}$$

Obviously $\frac{Z}{P}$ must be even to make the winding possible.

CHAPTER THREE

3. DESIGN AND IMPLEMENTATION

The design stage starts with the diagrammatic representation of the project considered as a module.

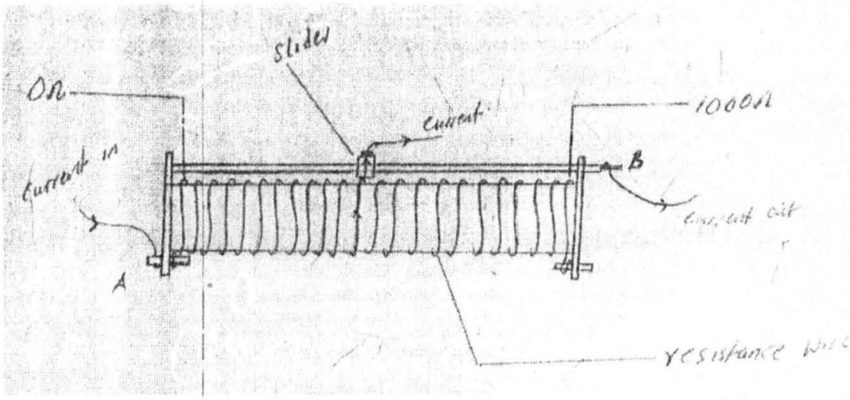

Fig. 3.0: Rheostat

3.1 NICHROME WIRE

Nichrome is an alloy used in various heating elements. Nichrome is basically a name given to nickel-chromium resistance wire. It is a non magnetic alloy which consists of 80 percent nickel and 20 percent chromium by weight, and is widely used in heating element because of its relatively high resistivity, out of the constituents of nichrome, nickel is an element with the chemical symbol N1 and atomic number 28, whereas, chromium a steely – gray and hard metal.

Nichrome, the alloy is silvery – gray in colour, resistant towards corrosion and has a high melting point.

PHYSICAL PROPERTIES OF NICHROME

The ultimate tensile strength of nichrome is 105, 000PSI (Pounds per Square Inch), yield strength is around 50,000PSI, and modulus of elasticity is 3 x 10^6 PSI.

The following are the Resistivity and thermal properties of some materials

		THERMAL PROPERTIES		
Materials	**Resistivity ρ at 20 ^{0}C nΩ - m**	**Specific heat j/kg ^{0}C**	**Thermal conductivity W/m ^{0}C**	**Melting points ^{0}C**
Aluminium	28.3	960	218	660
Constantan	500	410	22.6	11190
Copper	17.24	380	394	1080
Gold	24.4	130	296	1083
Iron	101	420	79.4	1535
Nichrome	1108	430	11.2	1400
Tungsten	55.1	140	20	3410
Nickel	85.4	460	90	1455
Silver	16.2	230	408	960
Air	-	994	0.024	-
Pure H_2O	2.6 x 10^{14}	4180	0.58	0.0

Table 3.0

DESIGN OF ELEMENT

The design is based on a voltage of 220volt and Resistance of 1000Ω

From 0hms law, we have the

$$V = IR$$

Where V = Voltage in volts (V)

I = Current in ampere (A)

R = resistance in Ω

Therefore

$$220 = I\,(1000)$$

$$I = \frac{220}{1000}$$

$$= 0.22A.$$

The power consumption is given by the equation

$$P = IV$$

$$P = 0.22 \times 220$$

$$= 48.4W$$

Therefore, the Rheostat electrical quantities are R = 1000Ω, P = 48.4W and I = 0.22A

The Area of the wire can be obtain from the relationship.

$$R = \frac{\rho L}{A}$$

Since the wire used is a Nichrome wire, the resistivity is 150×10^{-8}.

The total length of wire wounded.

$$L = 106.32m$$

Therefore

$$1000 = \frac{150 \times 10^{-8} \times 106.32m}{A}$$

$$1000A = 0.000159$$

$$A = \frac{0.000159}{1000}$$

$$= 1.59 \times 10^{-7} m^2$$

DIMENSION OF THE CORE

The core is made of a cylindrical plastic bobbin.

Diameter of the bobbin = 0.042m

Length of bobbin = 0.285m

Area of the bobbin is given by

$$A = 2\pi rh + 2\pi r^2$$

Radius of the bobbin $= r = \frac{D}{2}$

$$= \frac{0.042}{2}$$

$$= 0.021m$$

Therefore

$$A = 2\pi r\,(0.285 + 0.021)$$

$$= 0.42\pi\,(0.306)$$

$$= 0.012852\pi$$

$$= 4.037 \times 10^{-2} m^2$$

The area of the bobbin is $4.037 \times 10_{-2} m^2$

3.2 BRUSHES AND BEARINGS

The brushes whose function is to collect current from commutator are usually made of carbon or graphite and are in the shape of a rectangular block. These brushes are housed in brush-holders usually of the box-type variety. As shown in fig.3.1, the brush-holder is mounted on a spindle and the brushes can slide in the rectangular box open at both ends. The brushes are made to bear down on the commutator by a spring whose tension can be adjusted by changing the position of lever in the notches. A flexible copper pigtail mounted at the top of the brush conveys current from the brushes to the holder. The number of brushes per spindle depends on the magnitude of the current to be collected from the commutator.

Because of their reliability, ball-bearings are frequently employed, through the heavy duties, roller bearing are preferable. The ball and rollers are generally packed in hard oil for quieter operation and for reduced bearing wear, sleeve bearings are used which are lubricated by ring oilers fed oil reservoir in the bearing bracket.

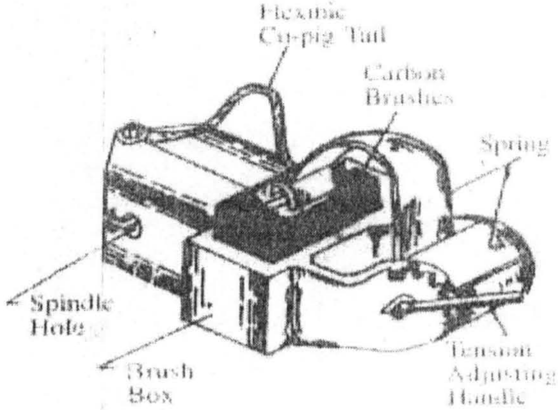

Fig. 3.1: brush

3.3 FORMER/BOBBIN

In the transformer, the coil is wrapped around a former or a bobbin is made of some insulated material such as plastic, paper, fiber e.t.c. in power transformers the bobbin is usually made of plastic fiber, this keeps the bobbin safe from the heat/cold and humidity. A paper/cardboard bobbin is used, cheap transformers, but this type of bobbin generate many problems.

When a plastic bobbin is used, always use good quality core, otherwise the heat of the core will distort the shape off the bobbin. Bobbin made using fibre may also burn if the core gets too hot.

CHAPTER FOUR

4. TEST RESULT AND DISCUSSION

4.1 TEST AND RESULT

An appropriate test method is the use of a meter (Multimeter) to ascertain the workability and response of the Rheostat. When the Rheostat is slide gradually and the reading is observed on the multimeter.

Its efficiently and durability can also be verified by connecting it to a load (circuit) within its resistance limit and operating it for an appropriate time duration. This was done and the Rheostat served its purpose.

RESULT

The result obtained can be best be explained using a curve which shows the variation of the resistance and conductivity as the slider is gradually moved.

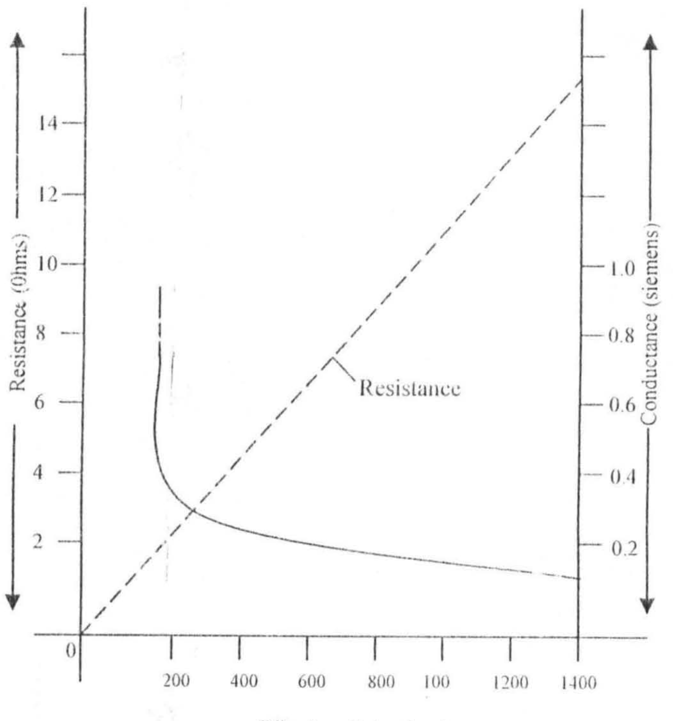

Fig 4.1 Total Resistance and conductance of a wire having 10Ω of resistivity per kilometer

4.2 DISCUSSION

According to the result obtained when the rheostat was gradually slides, with a muitimeter connected across its terminal. It shows that the resistance increases as the rheostat is being slided cross different point on the wounded wire. From the relationship

$$R \alpha L/A$$

The resistance is directly Proportional to the length of the wire and inversely proportional to the cross sectional area of the wire.

Also

$$G = I/R$$

Which show that G= conductivity is inversely proportional to the resistance of the wire.

ECONOMIC ANALYSIS (PRICED BILL OF QUANTITIES)

The cost of work done is cost implication of the research carried out in stated in this chapter below. Since the cost effect on any project determines its acceptability and competitiveness in the open market.

S/No	DESCRIPTION OF ITEM	QUANTITY	UNIT RATE N: K	TOTAL AMMOUNT N : K
1.	Nichrome wire	2	2500	5000.00
2.	Carbon brush	1	100	100.00
3.	(Bubbing) Plastic Material	1	150	150.00
4.	Casing	1	1000	1000.00
5.	Material cost Sub-Total(ST1)			6250
6.	Transport of material 5% of ST1			313.00
7.	Sub- Total 2 (ST2)			6563.00
8.	Labour 3% of ST2			1969.00
9.	Sub – Total 3 (ST3)			8532.00
10.	Overheads 5% of ST3			427.00
11.	Sub – Total (ST4)			8959.00
12.	Profit 10% of ST4			896.00
13.	Sub – Total 5 (ST5)			9855.00
14.	Contingency 5% of ST5			493.00
15.	Total cost of project			10348

Table 4.0

CHAPTER FIVE

5.1 CONCLUSION

It can thus be concluded that the performance of this project within its scope and limitations is satisfactory.

5.2 PRECAUTION

The following precautions were taken

1. The limit of the resistance was not exceeded during test.
2. Caution were taken during the winding no to exceed the number of turns required and also make the winding very tight at both ends
3. The coil and contacts are sealed inside the case to protect them from dirt which can cause an open circuits and from moisture which can cause a short circuit.

5.3 RECOMMENDATION

1. The resistance of the Rheostat can be increase by increasing the number of turns on the bobbin.
2. A ceramic bobbin can also be used in place of the plastic bobbin used in this design, for ceramic can with stand on a high temperature than plastic.

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