High Resistance Measurement by Leakage Method

Nvis 6061

Learning Material

Ver 1.1

An ISO 9001: 2008 company

Designed & Manufactured in India by :

Nvis Technologies Pvt. Ltd.

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CERTIFICATE OF COMPLIANCE

ICS

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This is to certify that the

QUALITY MANAGEMENT SYSTEM of

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has been assessed and registered as complying with the requirements of the following International Standard:

ISO 9001:2015

The Quality Management System applicable to:

Scope : Design And Manufacture Of Didactic Products And Clean Technologies Products Such As Solar Solutions.

Registration No.	**: RQ91/7763**
Registered Date	**: 17th June, 2012**
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High Resistance Measurement by Leakage Method

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Table of Contents

Nvis 6061 High Resistance Measurement by Leakage Method

Introduction

Nvis 6061 High Resistance Measurement by Leakage Method is very useful for measuring very high value of Resistance. DMM or LCR meters are suitable to measure the normal value of resistance (generally .1 Ω – 20 MΩ) but in the case of very high value of resistance they are unable to measure with high accuracy. Leakage method is very accurate to measure the high resistance because of very sensitive ballistic galvanometer and very low value of capacitances is used the trainer. In our trainer we provide different value of unknown high resistance on rotary selection and different value of capacitor (0.22µF, 0.33µF, 0.47µF) to measure with high accuracy.

Nvis 6061 High Resistance Measurement by Leakage Method

Features

- A complete setup with all necessary items.
- Inbuilt DC power supply
- Ballistic Galvanometer with Moving coil on large moment of inertia
- Ballistic Galvanometer with Flexible phosphor-bronze ribbon suspension
- Lamp and scale arrangement with adjustable stand
- Deflection measurement scale

Technical Specifications

Mains	:	230 V ±10%, 50 Hz
DC Power Supply	:	5V
Ballistic Galvanometer		
Suspension Wire	:	Phosphor Bronze
Reflector	:	Concave Mirror
Coil Resistance	:	500 Ω
Lamp & Scale		
Lamp	:	Laser Light Source
Scale	:	30-0-30 cm
Unknown Resistances	:	Selectable
		R1 = 20 MΩ
		R2 = 40 MΩ
		R3 = 60 MΩ
		R4 = 80 MΩ
Capacitors	:	Selectable
		0.22µF, 63V
		0.33µF, 100V
		0.47µF, 100V

“ It is recommended ,to handle the wire gently . It is not covered in warranty”

Safety Instructions

Read the following safety instructions carefully before operating the instrument. To avoid any personal injury or damage to the instrument or any product connected to the instrument.

Do not operate the instrument if suspect any damage to it.

The instrument should be serviced by qualified personnel only.

For your safety:

Use proper Mains cord : Use only the mains cord designed for this instrument. Ensure that the mains cord is suitable for your country.

Ground the Instrument : This instrument is grounded through the protective earth conductor of the mains cord. To avoid electric shock, the grounding conductor must be connected to the earth ground. Before making connections to the input terminals, ensure that the instrument is properly grounded.

Use in proper Atmosphere : Please refer to operating conditions given in the manual.

1. **Do not operate in wet / damp conditions.**
2. **Do not operate in an explosive atmosphere.**
3. **Keep the product dust free, clean and dry.**

Theory

Resistance. Resistance refers to the property of a substance that impedes the flow of electric current. Some substances resist current flow more than others. If a substance offers very high resistance to current flow it is called an insulator. If its resistance to current flow is very low, it is called a conductor. Resistivity refers to the ability of substances to resist current flow. Good conductors have low resistivity and insulators have high resistivity.

Resistance at the Molecular Level Resistance to current flow occurs at the molecular level of substances. For example, a metal conductor, such as copper, consists of atoms having free electrons in their outer most shells. However, if a potential difference, also called voltage, is applied across the conductor, such as with a battery, free electrons flow from the negative to the positive terminals. Electric current refers to the rate of flow of electric charge, which causes free electrons to flow.

For extremely low resistivity, it As electrons move through the conductor, some collide with atoms, other electrons, or impurities in the metal. It is these collisions that cause resistance. The molecular makeup of a substance determines the number of collisions, or amount of resistance, to electron flow. Since the molecular makeup of copper provides is often used as a conductor in electric circuits.

Ohm's Law In 1789-1854, German physicist George Simon Ohm formulated the relationships among voltage, current, and resistance into what is referred to as Ohm's law: according to this low “The current in a circuit is directly proportional to the applied potential difference and inversely proportional to the resistance of the circuit.”

Therefore, voltage can be calculated using the formula:

$$E = I * R$$

Resistance can be calculated using the formula:

$$R = E/I$$

It is important to note that adjusting voltage or current cannot change resistance. Resistance in a circuit is a physical constant and can only be modified by changing components, exchanging resistors for those rated at more or fewer ohms, or by adjusting variable resistors.

Here is a memory aid to help remember these formulas:

Cover up the value you wish to solve for and the equation remains.

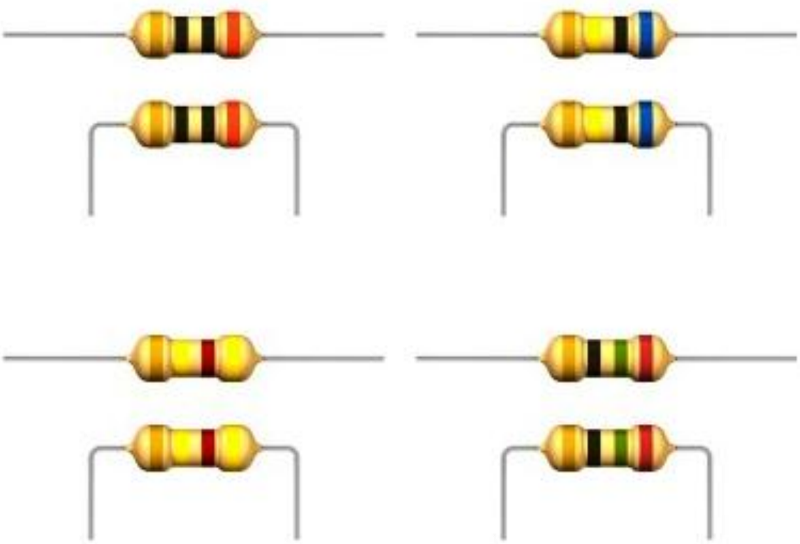
The International Standard (SI) unit of resistance is the ohm, designated by the Greek letter Ω. One ohm of resistance is equal to the resistance of a circuit in which a potential difference of one volt produces a current of one ampere.

Nvis 6061 High Resistance Measurement by Leakage Method

Resistor is a passive component used to control current in a circuit. Its resistance is given by the ratio of voltage applied across its terminals to the current passing through it. Thus a particular value of resistor, for fixed voltage, limits the current through it. They are omnipresent in electronic circuits.

The most common type of resistor consists of a small ceramic (clay) tube covered partially by a conducting carbon film. The composition of the carbon determines how much current can pass through.

Resistors are too small to have numbers printed on them and so they are marked with a number of coloured bands. Each colour stands for a number. Three colour bands shows the resistors value in ohms and the fourth shows tolerance. Resistors can never be made to a precise value and the tolerance band (the fourth band) tells us, using a percentage, how close the resistor is to its coded value. The resistor on the left is 4700 ohms.



Types of resistor

There are different types of resistor depending upon their construction, power dissipation capacities and tolerance of the value. Such as

- Carbon Composition Resistor
- Metal Film Resistor
- Carbon Film Resistor
- Non Linear Resistor
- Varistor
- Thermistor

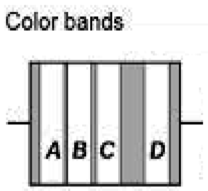
Carbon Composition Resistor

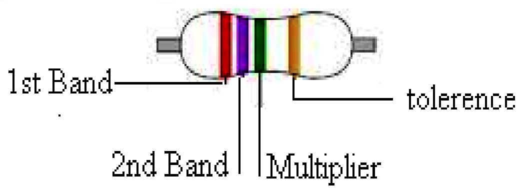
These types of resistor very commonly used low cost resistor. The construction of carbon composition resistor is very simple. It is also commonly referred as carbon resistor. It mainly made of carbon clay composition covered with a plastic case. The leads of the resistor are made of tinned copper. The main advantages of these resistors are that they are easily available in local market in very low cost and they are very durable too. But the main disadvantage is that they are very much temperature sensitive. These resistors are available in wide range of values. It is available in as low as 1 Ω value and it is also available in as high as 22 Mega Ω value. The tolerance range in resistance of carbon composition resistor is of ± 5 to ± 20 %. Such resistor has a tendency of electric noise due to passage of current from one carbon particle to other. Where low cost is the main criteria of designing a circuit rather than it's performance, these resistors are normally used.

These carbon resistors are providing with different colored band on their cylindrical body. These color bands are code for the resistance values of carbon composition resistor along with their tolerance range.

Resistor Color Code

There are mainly four color bands provided on the body resistors and each color indicates unique digit. Such as Black ⇒ 0, Brown ⇒ 1,Red ⇒ 2, Orange ⇒ 3, Yellow ⇒ 4, Green ⇒ 5, Blue ⇒ 6, Violet ⇒ 7 Gray ⇒ 8, White ⇒ 9. The first and second color bands indicate a two digits number. The 3rd color band indicates the power of ten as multiplier. The fourth band indicates the tolerance.





To distinguish left from right there is a gap between the C & D bands

Band A is first significant figure of component figure
Band B is the second significant figure
Band C is the decimal multiplier
Band D if present, indicates tolerence of value in percent (no band means 20%)

Resistor Rating Color Code Table

Color	1st Band	2nd Band	3rd Band	4th Band	5th Band
Black	0	0	0	1	
Brown	1	1	1	10	
Red	2	2	2	100	
Orange	3	3	3	1,000	
Yellow	4	4	4	10,000	
Green	5	5	5	100,000	
Blue	6	6	6	1,000,000	
Violet	7	7	7	10,000,000	
Gray	8	8	8	100,000,000	
White	9	9	9	1,000,000,000	
Gold				0.1	5%
Silver				0.01	10%
None					20%

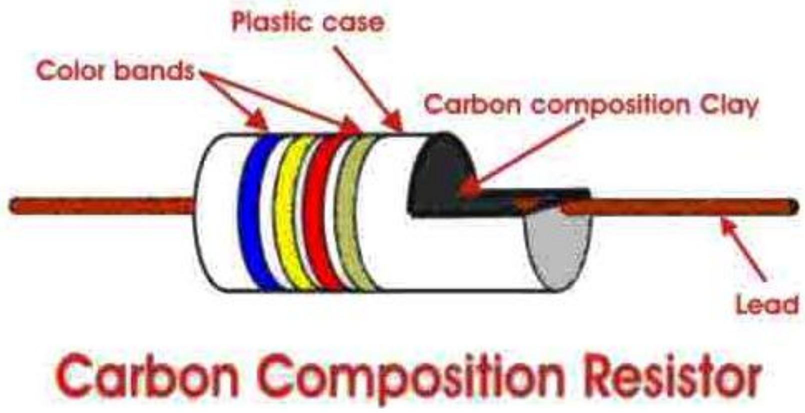
Composition resistors generally have four color bands. The color code is read as follows:

- First, look up the number values of the first two bands on the table and combine the two numbers.
- Then multiply this two digit number by the value of the 3rd band, the multiplier band.
- The resulting number is the resistance value of the resistor in ohms.
- The fourth band is the tolerance band. If the 4th band is gold, the resistor is Warranty to be within 5% of the rated value. If the 4th band is silver, it is warranted to be within 10%. If there is no 4th band, the resistor is warranted to be within 20% of the rated value.

For example, the color code of the above resistor in figure is read as follows:

- The 1st band is brown. The first band is always the band closest to the end of the resistor. From the table you can see that the number value of brown in the 1st band column is 1.
- The 2nd band is black. The number value of black in the 2nd band column is 0.
- Combining the two numbers gives you 10.
- The 3rd band is red. This is the multiplier band. The multiplier value of red is 100.
- Multiplying the combined digit of 10 by the multiplier gives us 1,000.

Therefore, the above resister is rated at 1,000 ohms, which can be written as 1Ω. The 4th, or tolerance, band of the resister is silver. Therefore, the resistor is Warrantyd to have a resistance value within 10% of 1KΩ.



If fourth band is of golden color the resistors may have ± 5 % tolerance in its value, if fourth band is of silver color, the resistor must have ± 10 % tolerance and if there is no fourth band provided, then the carbon resistor may have ± 20 % tolerance in it's value.

Wire Wound Resistor

The construction of this type of resistor is also very simple. In wire wound resistor a wire of manganin or constantan is wound around a cylinder of insulated material. The temperature coefficient of resistance of these two materials is almost zero. So there would no resistance variation with temperature. The wounded wire is covered with an insulating material such as baked enamel. This cover of insulating heat resistive material, is provided to resist the effect of ambient temperature variation. Different sizes and ratings of wire wound resistor can easily be achieved by using different lengths and diameters of the wire. This resistors are easily available for wide range of ratings. The range of resistance values varies from 1 Ω to 1 MΩ. Typical tolerance limit of these resistors varies from 0.01 % to 1 %. They can be used for high power applications of 5 to 200 W dissipation ratings. The cost of these resistors is much higher than carbon resistor. Normally wire wound resistor is used where carbon composition resistor can not meet the purpose because of its limitations.

The main disadvantage of this resistor is the inductance that arises because of its coil like structure. At high frequency the behavior of the circuit may be changed due to its reactance. This problem can be solved if one half of the wire is wound in one direction and other half in opposite direction so that the inductance due to these two halves cancel each other hence net inductive effect of the resistor becomes nil. The non – inductive wire wound resistor is ideal for high frequency circuit but it is costlier than ordinary one.

Metal Film Resistor and Carbon Film Resistor

Basic structure of these type of resistor is constructed by means of film deposition technique of deposition a thick film of resistive material such as pure carbon or metal on to an insulating core. The desired value of resistance of metal film resistor or carbon film resistor can easily be obtained by either trimming the layer of thickness or by cutting helical grooves of suitable pitch along its length. That means for different resistance values, the length and depth of the helical grooves is maintained accordingly.

Metallic contact cap is fitted at both ends of the resistor. The caps must be in contact with resistive film or helical grooves. The lead wires are welded to these end caps. Metal Film Resistor or Carbon Film Resistor can be made up to a value of 10,000 MΩ and size of this type of resistor is much smaller than wire wound resistor resistor. Because of their constructional features these resistor are fully non – inductive. The accuracy level of metal film resistor can be of order ± 1 % and they are suitable for high grade applications.

Resistor Rating Color Code Composition resistors are colour coded to indicate resistance values or ratings. The color code consists of various color bands that indicate the resistance values of resistors in ohms as well as the tolerance rating. The Resistor Rating Color Code Table below is used to identify the resistance rating of resistors.

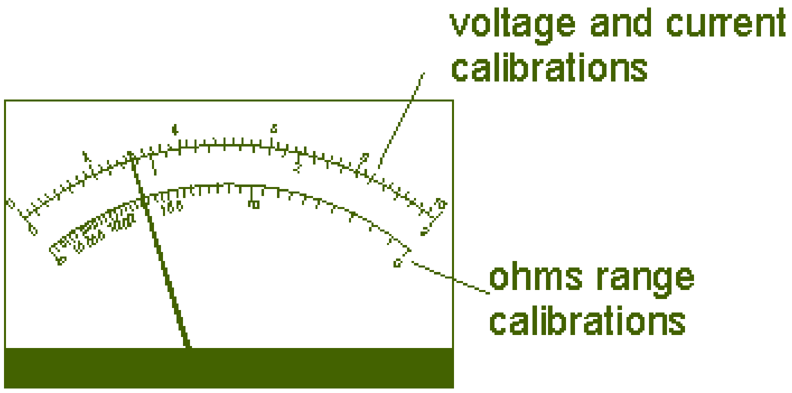
Basics of measuring resistance

When measuring resistance, all multimeters use exactly the same principle whether they are analogue multimeters or digital multimeters. In fact other forms of test equipment that measure resistance also use the same basic principle.

The basic idea is that the multimeter places a voltage at the two probes and this will cause a current to flow in the item for which the resistance is being measured. By measuring the resistance it is possible to determine the resistance between the two probes of the multimeter or other item of test equipment.

How to measure resistance with an analogue multimeter

Analogue multimeters are good at measuring resistance, although they are a few points to note about the way in which it is done. The first point to note is that as the meter itself responds to current flowing through the component under test, a high resistance which corresponds to a low current appears on the left hand side of the dial, and a low resistance which corresponds to a higher current appears on the right hand side of the dial as shown below. It will also be noticed that the calibrations become much closer together as the resistance becomes higher, i.e. on the left hand side of the dial.



The calibrations on an analogue meter face

Another aspect of using an analogue multimeter for measuring resistance is that the meter needs to be "zeroed" before making a measurement. This is done by connecting the two probes together so that there is a short circuit, and then using the "zero" control to give full scale deflection on the meter, i.e. zero ohms. Each time the range is changed, the meter needs to be zeroed as the position may change from one range to the next. The meter needs to be zeroed because the full scale deflection will change according to aspects such as the state of the battery.

There are a few simple steps required to make a resistance measurement with an analogue multimeter:

1. Select the item to be measured: This may be anything where the resistance needs to be measured and estimate what the resistance may be.
2. Insert the probes into the required sockets. Often a multimeter will have several sockets for the test probes. Insert these or check they are already in the correct sockets. Typically these might be labeled COM for common and the other where the ohms sign is visible. This is normally combined with the voltage measurement socket.
3. Select the required range. The range selected should be such that the best reading can be obtained. Normally the multimeter function switch will be labeled with the maximum resistance reading. Choose the one where the estimated value of resistance will be under but close to the maximum of the range. In this way the most accurate resistance measurement can be made.

4 Zero the meter: The meter needs to be zeroed. This is done by firmly placing the two probes together to give a short circuit and then adjusting the zero control to give a zero ohms (full scale deflection) reading. This process needs to be repeated if the range is changed.

5. Make the measurement with the multimeter ready to make the measurement the probes can be applied to the item that needs to be measured. The range can be adjusted if necessary.

6. Turn off the multimeter. Once the resistance measurement has been made, it is wise to turn the function switch to a high voltage range. In this way if the multimeter is used to again for another type of reading then no damage will be caused if it is inadvertently used without selecting the correct range and function.

Analogue multimeter is ideal pieces of test equipment for measuring resistance. They are relatively cheap and they offer a reasonably good level of accuracy and general performance.

How to measure resistance with an digital multimeter, DMM

Measuring resistance with a digital multimeter is easier and faster than making a resistance measurement with an analogue multimeter as there is no need to zero the meter.

There are a few simple steps required to make a resistance measurement with a digital multimeter:

1 Select the item to be measured: This may be anything where the resistance needs to be measured and estimate what the resistance may be.

2. Insert the probes into the required sockets often a digital multimeter will have several sockets for the test probes. Insert these or check they are already in the correct sockets. Typically these might be labeled COM for common and the other where the ohms sign is visible. This is normally combined with the voltage measurement socket.

3 Turn on the multimeter and select the required range. The digital multimeter needs on and the required range selected. Choose the one where the estimated value of resistance will be under but close to the maximum of the range. In this way the most accurate resistance measurement can be made.

4 Make the measurement with the multimeter ready to make the measurement the probes can be applied to the item that needs to be measured. The range can be adjusted if necessary.

5 Turn off the multimeter, once the resistance measurement has been made, the multimeter can be turned off to preserve the batteries. It is also wise to turn the function switch to a high voltage range. In this way if the multimeter is used to again for another type of reading then no damage will be caused if it is inadvertently used without selecting the correct range and function.

Digital multimeter are ideal pieces of test equipment for measuring resistance. They are relatively cheap and they offer a high level of accuracy and general performance.

General precautions when measuring resistance

As with any measurement, when measuring resistance, there are some precautions to observe. In this way damage to the multimeter can be prevented, and more accurate measurements can be made.

- Measure resistance when components are not connected in a circuit: It is always advisable not to measure the resistance of an item that is in a circuit If a measurement is made in-circuit, then all the other components around it will have an effect. Any other paths that will allow current to pass will affect the readings, making them inaccurate to some degree.
- Remember to ensure the circuit under test is not powered on under some circumstances it is necessary to measure resistance values actually on a circuit. When doing this it is very important to ensure the circuit is not powered on. Not only will any current flowing in the circuit invalidate any readings, but should the voltage be high enough, the current resulting could damage the multimeter.
- Ensure capacitors in a circuit under test are discharged. Again when measuring resistance values in a circuit, it is necessary to ensure that any capacitors in the circuit are discharged. Also any capacitors in the circuit that are discharged may charge up as a result of the current from the multimeter and as a result it may take a short while for the reading to settle.
- Remember diodes in a circuit will cause different readings in either direction When measuring resistance in a circuit that includes diodes the value measured will be different if the connections are reversed. This is because the diodes only conduct in one direction.
- Leakage path through fingers can alter readings in some cases. When making some resistance measurements it is necessary to hold a resistor or component onto the multimeter test probes. If high resistance measurements are being made the leakage path through the fingers can become noticeable. Fortunately the levels of voltage used in most multi-meters when measuring resistance is low, but some specialized meters may use much higher voltages. It is wise to check.

Capacitor

A capacitor is a passive electronic component that stores energy in the form of an electrostatic field. In its simplest form, a capacitor consists of two conducting plates separated by an insulating material called the dielectric. The capacitance is directly proportional to the surface areas of the plates, and is inversely proportional to the separation between the plates. Capacitance also depends on the dielectric constant of the substance separating the plates.

The standard unit of capacitance is the farad, abbreviated F. This is a large unit; more common units are the microfarad, abbreviated µ F (1 µ F =10-6F) and the Pico farad, abbreviated pF (1 pF = 10-12 F). Capacitors can be fabricated onto integrated circuit (IC) chips. They are commonly used in conjunction with transistors in dynamic random access memory (DRAM). The capacitors help maintain the contents of memory. Because of their tiny physical size, these components have low capacitance. They must be recharged thousands of times per second or the DRAM will lose its data.

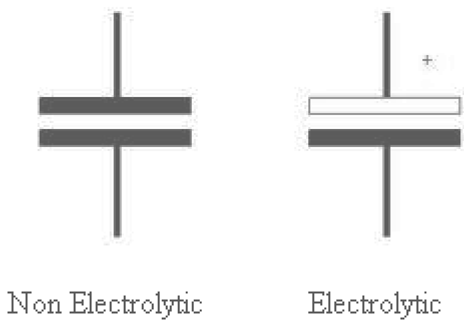
Large capacitors are used in the power supplies of electronic equipment of all types, including computers and their peripherals. In these systems, the capacitors smooth out the rectified utility AC, providing pure, battery-like DC.

The capacitor is constructed with two electrode plates facing each other, but separated by an insulator. When DC voltage is applied to the capacitor, an electric charge is stored on each electrode. While the capacitor is charging up, current flows. The current will stop flowing when the capacitor has fully charged.

The value of a capacitor (the capacitance), is designated in units called the Farad (F). The capacitance of a capacitor is generally very small, so units such as the microfarad (10-6F), nanofarad (10-9F), and picofarad (10-12F) are used.

Recently, a new capacitor with very high capacitance has been developed. The Electric Double Layer capacitor has capacitance designated in Farad units. These are known as "Super Capacitors."

Capacitors are short term charge-stores, a bit like an electrical spring. They are used widely in electronic circuits. It consists of two metal plates separated by a layer of insulating material called a dielectric. The symbol for a capacitor is shown below:



There are two types of capacitor, electrolytic and non-electrolytic. We won't worry at the moment what these terms mean, other than to say:

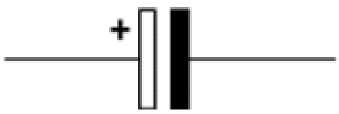
- Electrolytic capacitors hold much more charge.
- Electrolytic capacitors have to be connected with the correct polarity, otherwise they can explode.

If we pump electrons onto the negative plate, electrons are repelled from the negative plate. Since positives do not move, a positive charge is induced. The higher the potential difference, the more charge is crowded onto the negative plate and the more electrons repelled from the positive plate. Therefore charge is stored. The plates have a certain capacitance.

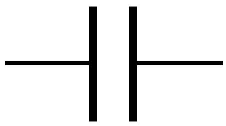
Capacitance

Capacitance (symbol C) is a measure of a capacitor's ability to store charge. A large capacitance means that more charge can be stored. However 1F is very large, so prefixes (multipliers) are used to show the smaller values:

- µ (micro) means 10-6 (millionth), so 1000000µ F = 1F
- n (nano) means 10-9 (thousand-millionth), so 1000nF = 1µ F
- p (pico) means 10-12 (million-millionth), so 1000pF = 1nF



Polarized capacitor symbol



Unpolarized capacitor symbol

Capacitance is defined as the charge required to cause unit potential difference in a conductor.

Or

1 Farad is the capacitance of a conductor, which has potential difference of 1 volt when it carries a charge of 1 coulomb.

So we can write from this definition:

$$Capacitance(F) = \frac{Charge\ (C)}{Voltage\ (V)}$$

Capacitance is measured in units called farads (F).

Types of Capacitors

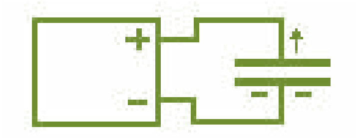
Different types of capacitors use different materials for the dielectric. Some of these are:

Electrolytic Capacitors (Electrochemical type capacitors)

An electrolytic capacitor is a type of capacitor that uses an ionic conducting liquid as one of its plates. This is especially the case in power-supply filters, where they store charge needed to moderate output voltage and current fluctuations, in rectifier output. They are also widely used as coupling capacitors in circuits where AC should be conducted but DC should not.

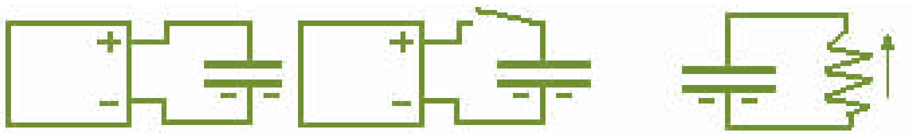
Electrolytic capacitors can have a very high capacitance, allowing filters made with them to have very low corner frequencies.

Appling a voltage to a capacitor:

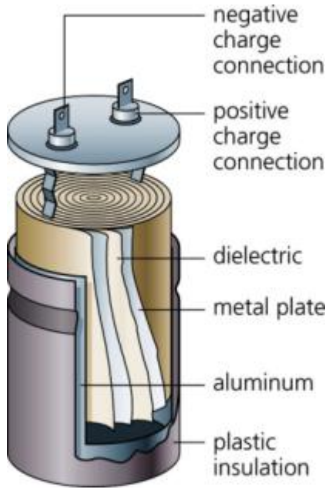


As voltage is applied, electrons flow from the negative side of the voltage source and into one plate. Electrons repel other electrons, so the surplus of electrons on the plate connected to the negative supply will repel the electrons on the other plate. These electrons flow away into the positive supply terminal. A current is flowing. After a

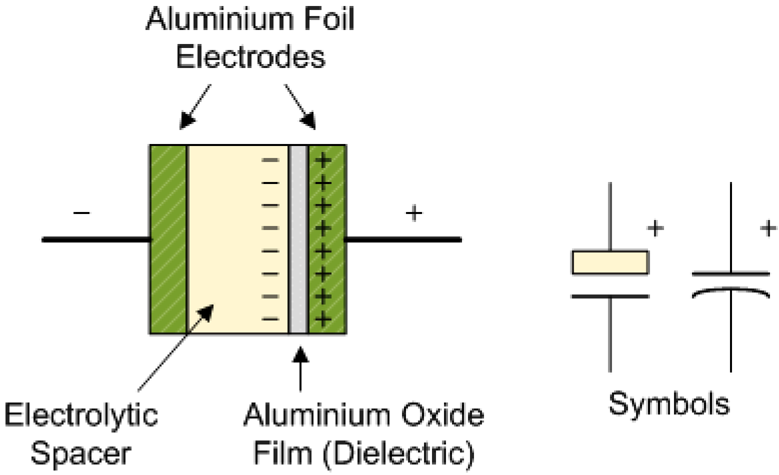
time interval, the power supply in not able to crowd more electrons together on the negative plate (voltage is really a measure of how hard your supply can stuff electrons together), so the current peters out and stops. We now say that the capacitor is charged; there is a surplus of electrons on one plate, and a corresponding lack of electrons on the other.



Next, we could disconnect the capacitor. The charge will stay on it. If we connect a load circuit over it, the electrons start flowing from the crowded (negative) plate to the empty (positive) plate; a current flows. When an equal level of electrons on both plates is reached, the current stops. We say that the capacitor is discharged.

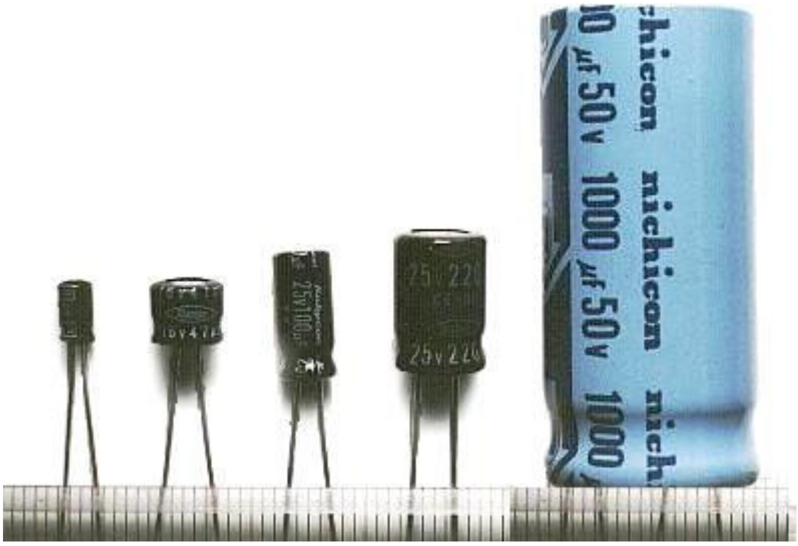


Aluminum is used for the electrodes by using a thin oxidization membrane. Large values of capacitance can be obtained in comparison with the size of the capacitor, because the dielectric used is very thin.



The most important characteristic of electrolytic capacitors is that they have polarity. They have a positive and a negative electrode [Polarized]. This means that it is very important which way round they are connected. If the capacitor is subjected to voltage exceeding its working voltage, or if it is connected with incorrect polarity, it may burst. It is extremely dangerous, because it can quite literally explode. Make absolutely no mistakes

Generally, in the circuit diagram, the positive side is indicated by a "+" (plus) symbol. Electrolytic capacitors range in value from about 1µ F to thousands of µ F. Mainly this type of capacitor is used as a ripple filter in a power supply circuit, or as a filter to bypass low frequency signals, etc. Because this type of capacitor is comparatively similar to the nature of a coil in construction, it isn't possible to use for high-frequency circuits. (It is said that the frequency characteristic is bad.)



The above figure is an example of the different values of electrolytic capacitors in which the capacitance and voltage differ.

From the left to right:

1μ F (50V) [diameter 5 mm, high 12 mm]

47μ F (16V) [diameter 6 mm, high 5 mm]

100μ F (25V) [diameter 5 mm, high 11 mm]

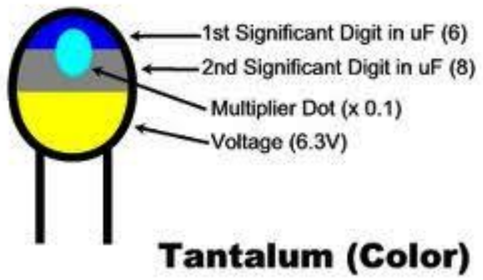
220μ F (25V) [diameter 8 mm, high 12 mm]

1000μ F (50V) [diameter 18 mm, high 40 mm]

The size of the capacitor sometimes depends on the manufacturer. So the sizes shown here on this page are just examples.

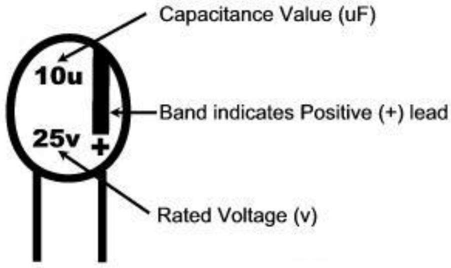
Tantalum Capacitors

Tantalum Capacitors are electrolytic capacitor that is use a material called tantalum for the electrodes. Large values of capacitance similar to aluminum electrolytic capacitors can be obtained. Also, tantalum capacitors are superior to aluminum electrolytic capacitors in temperature and frequency characteristics. When tantalum powder is baked in order to solidify it, a crack forms inside. An electric charge can be stored on this crack.



0.33 μF (35V) 0.47 μF (35V) 10 μF (35V

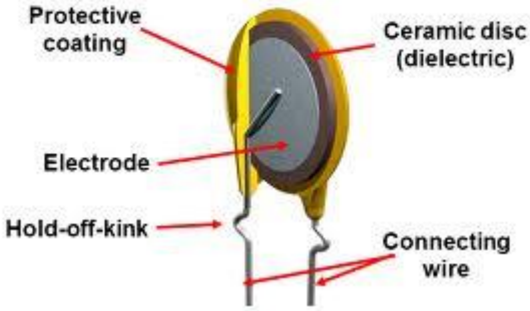
These capacitors have polarity as well. Usually, the "+" symbol is used to show the positive component lead. Do not make a mistake with the polarity on these types. Tantalum capacitors are a little bit more expensive than aluminum electrolytic capacitors. Capacitance can change with temperature as well as frequency, and these types are very stable. Therefore, tantalum capacitors are used for circuits which demand high stability in the capacitance values. Also, it is said to be common sense to use tantalum capacitors for analog signal systems, because the current-spike noise that occurs with aluminum electrolytic capacitors does not appear. Aluminum electrolytic capacitors are fine if you don't use them for circuits which need the high stability characteristics of tantalum capacitors.



The "+" symbol is used to show the positive lead of the component. It is written on the body.

Ceramic Capacitors

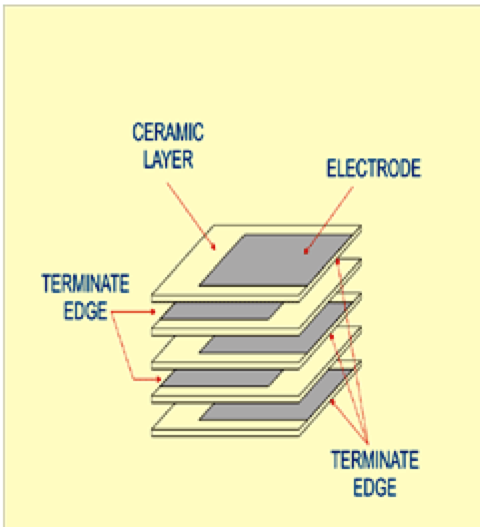
Ceramic capacitors are constructed with materials such as titanium acid barium used as the dielectric. Internally, these capacitors are not constructed as a coil, so they can be used in high frequency applications. Typically, they are used in circuits which bypass high frequency signals to ground. These capacitors have the shape of a disk. Their capacitance is comparatively small.

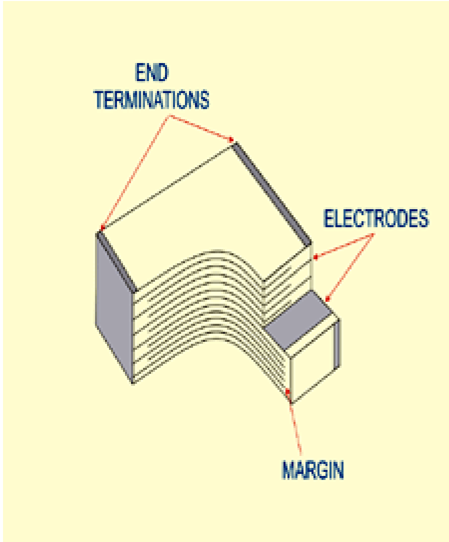


The capacitor on the left is a 100pF capacitor with a diameter of about 3 mm. The capacitor on the right side is printed with 103, so 10 x 103pF becomes 0.01 μ F. The diameter of the disk is about 6 mm. Ceramic capacitors have no polarity. Ceramic capacitors should not be used for analog circuits, because they can distort the signal.

Multilayer Ceramic Capacitors

The multilayer ceramic capacitor has a many-layered dielectric. These capacitors are small in size, and have good temperature and frequency characteristics. Square wave signals used in digital circuits can have a comparatively high frequency component included.





This capacitor is used to bypass the high frequency to ground.

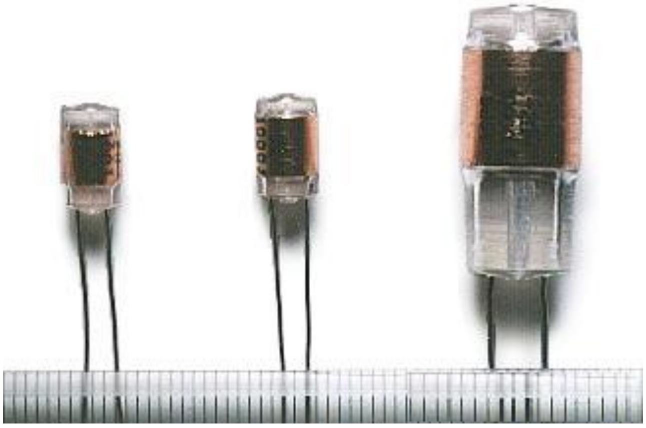
In the photograph, the capacitance of the component on the left is displayed as 104. So, the capacitance is 10 x 104 pF = 0.1 µ F. The thickness is 2 mm, the height is 3 mm, and the width is 4 mm. The capacitor to the right has a capacitance of 103 (10 x 103 pF = 0.01 µ F). The height is 4 mm; the diameter of the round part is 2 mm. These capacitors are not polarized. That is, they have no polarity.

Polystyrene Film Capacitors

In these devices, polystyrene film is used as the dielectric. This type of capacitor is not for use in high frequency circuits, because they are constructed like a coil inside. They are used well in filter circuits or timing circuits which run at several hundred KHz or less.

The component shown on the left has a red color due to the copper leaf used for the electrode. The silver color is due to the use of aluminum foil as the electrode.

The device on the left has a height of 10 mm, is 5 mm thick, and is rated 100pF. The device in the middle has a height of 10 mm, 5.7 mm thickness, and is rated 1000pF.



The device on the right has a height of 24 mm, is 10 mm thick, and is rated 10000pF. These devices have no polarity.

Electric Double Layer Capacitors (Super Capacitors)

This is a "Super Capacitor," which is quite a wonder. The capacitance is 0.47 F (470,000 µ F). I have not used this capacitor in an actual circuit.

Care must be taken when using a capacitor with such a large capacitance in power supply circuits, etc. The rectifier in the circuit can be destroyed by a huge rush of current when the capacitor is empty. For a brief moment, the capacitor is more like a short circuit. A protection circuit needs to be set up. The size is small in spite of capacitance. Physically, the diameter is 21 mm, the height is 11 mm. Care is necessary, because these devices do have polarity.

Polyester Film Capacitors

This capacitor uses thin polyester film as the dielectric. They are not high tolerance, but they are cheap and handy. Their tolerance is about ±5% to ±10%.

From the figure above:

Capacitance: 0.001 µ F (printed with 001K)

[the width 5 mm, the height 10 mm, the thickness 2 mm]

Capacitance: 0.1 µ F (printed with 104K)

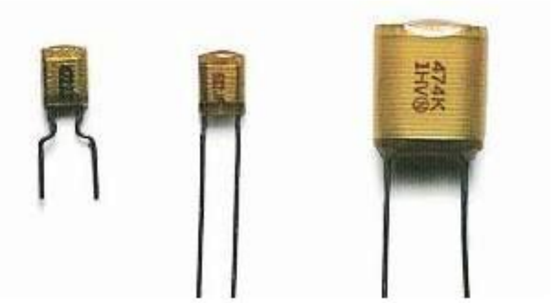
[the width 10 mm, the height 11 mm, the thickness 5mm]

Capacitance: 0.22 µ F (printed with .22K)

[the width 13 mm, the height 18 mm, the thickness 7mm]

Care must be taken, because different manufacturers use different methods to denote the capacitance values.

Here are some other polyester film capacitors



Starting from the left

Capacitance: 0.0047 µ F (printed with 472K)

[the width 4mm, the height 6mm, the thickness 2mm]

Capacitance: 0.0068 µ F (printed with 682K)

[the width 4mm, the height 6mm, the thickness 2mm]

Capacitance: 0.47 µ F (printed with 474K)

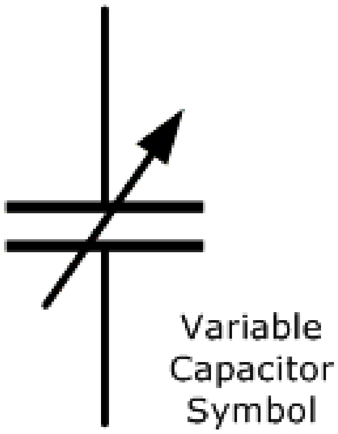
[the width 11mm, the height 14mm, the thickness 7mm]

These capacitors have no polarity.

Variable Capacitors

Variable capacitors are used for adjustment etc. of frequency mainly.

On the figure is a "trimmer," which uses ceramic as the dielectric. Next to it on the right is one that uses polyester film for the dielectric. The pictured components are meant to be mounted on a printed circuit board.



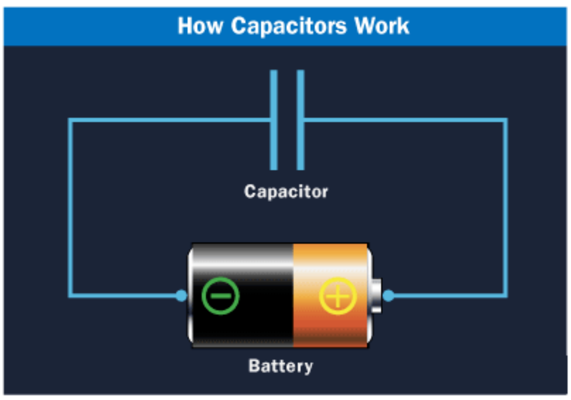
When adjusting the value of a variable capacitor, it is advisable to be careful. One of the component's leads is connected to the adjustment screw of the capacitor. This means that the value of the capacitor can be affected by the capacitance of the screwdriver in your hand. It is better to use a special screwdriver to adjust these components. Pictured in the upper left photograph are variable capacitors with the following specifications.

Capacitance: 20pF (3pF - 27pF measured)

[Thickness 6 mm, height 4.8 mm]

There are different colors, as well. Blue: 7pF (2 - 9), white: 10pF (3 - 15), green: 30pF (5 - 35), brown: 60pF (8 - 72).

When you **connect a capacitor to a battery**, here's what happens:



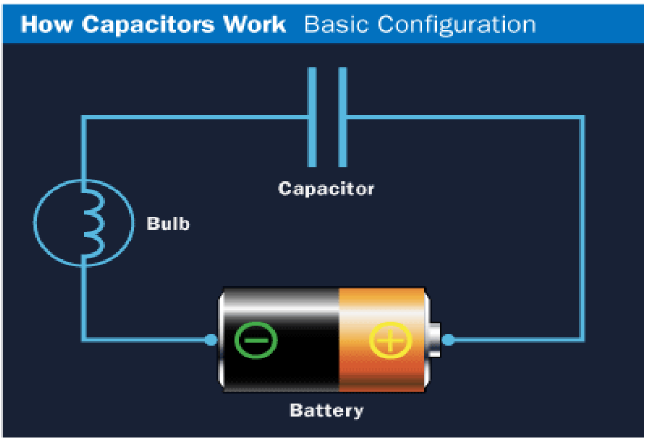
The plate on the capacitor that attaches to the negative terminal of the battery accepts electrons that the battery is producing.

The plate on the capacitor that attaches to the positive terminal of the battery loses electrons to the battery.

Once it's charged, the capacitor has the same voltage as the battery (1.5 volts on the battery means 1.5 volts on the capacitor). For a small capacitor, the capacity is small. But large capacitors can hold quite a bit of charge. You can find capacitors as big as soda cans that hold enough charge to light a flashlight bulb for a minute or more.

Even nature shows the capacitor at work in the form of lightning. One plate is the cloud, the other plate is the ground and the lightning is the charge releasing between these two "plates." Obviously, in a capacitor that large, you can hold a huge amount of charge!

Let's say you hook up a capacitor like this:



Here you have a battery, a light bulb and a capacitor. If the capacitor is pretty big, what you will notice is that, when you connect the battery, the light bulb will light up as current flows from the battery to the capacitor to charge it up. The bulb will get progressively dimmer and finally go out once the capacitor reaches its capacity. If you then remove the battery and replace it with a wire, current will flow from one plate of the capacitor to the other. The bulb will light initially and then dim as the capacitor discharges, until it is completely out.

In the next section, we'll learn more about capacitance and take a detailed look at the different ways that capacitors are used.

Charge and Energy Stored

The amount of charge (symbol Q) stored by a capacitor is given by: Charge,

$$Q = C \times V$$

Where:

Q = charge in coulombs (C)

C = capacitance in farads (F)

V = voltage in volts (V)

When they store charge, capacitors are also storing energy: Energy,

$$½QV = ½CV^2$$

Where

E = energy in joules (J).

Note that capacitors return their stored energy to the circuit. They do not 'use up' electrical energy by converting it to heat as a resistor does. The energy stored by a capacitor is much smaller than the energy stored by a battery so they cannot be used as a practical source of energy for most purposes.

Capacitive Reactance X_C

Capacitive reactance (symbol X_C) is a measure of a capacitor's opposition to AC (alternating current). Like resistance it is measured in ohms, Ω , but reactance is more complex than resistance because its value depends on the frequency (f) of the electrical signal passing through the capacitor as well as on the capacitance, C.

Capacitive reactance, XC = ½ πfC

Where:

X_C = reactance in ohms (Ω)

f = frequency in hertz (Hz)

C = capacitance in farads (F)

The reactance X_C is large at low frequencies and small at high frequencies. For steady DC which is zero frequency, X_C is infinite (total opposition), hence the rule that capacitors pass AC but block DC.

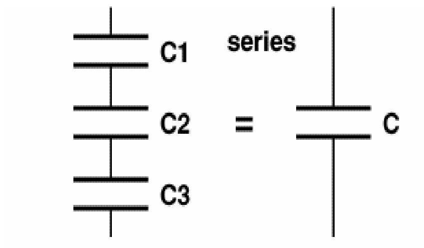
For example a 1µ F capacitor has a reactance of 3.2k for a 50Hz signal, but when the frequency is higher at 10 kHz its reactance is only 16.

Note: the symbol X_C is used to distinguish capacitative reactance from inductive reactance XL which is a property of inductors. The distinction is important because XL increases with frequency (the opposite of X_C) and if both X_L and X_C are present in a circuit the combined reactance (X) is the difference between them

Capacitors in Series

In series combination the distance between the plate's increases, so the total capacitance is reduced when the capacitors are connected in series. The net capacitance is less than the lowest capacitance present in the series circuit. The result is exactly the same as the resistances in parallel.

Combined capacitance (C) of capacitors when they are connected in series:

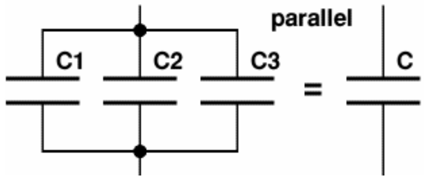


$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}.$$

Capacitors in Parallel

When capacitors are connected in parallel their value is added up. The reason is that the capacity is increased due to larger plate surface area. The formula for parallel capacitor is same as the resistance in series.

Combined capacitance (C) of capacitors when they are connected in parallel:



$$C = C1 + C2 + C3 + ...$$

Two or more capacitors are rarely deliberately connected in series in real circuits, but it can be useful to connect capacitors in parallel to obtain a very large capacitance, for example to smooth a power supply.

Charging a capacitor

The capacitor (C) in the circuit diagram is being charged from a supply voltage (VS) with the current passing through a resistor (R). The voltage across the capacitor (VC) is initially zero but it increases as the capacitor charges. The capacitor is fully charged when VC = VS. The charging current (I) is determined by the voltage across the resistor (VS - VC):

Charging current, I = (VS - VC) / R   (note that VC is increasing)

At first VC = 0V so the initial current, I_0 = VS / R

VC increases as soon as charge **(Q)** starts to build up (VC = Q/C), this reduces the voltage across the resistor and therefore reduces the charging current. This means that the rate of charging becomes progressively slow

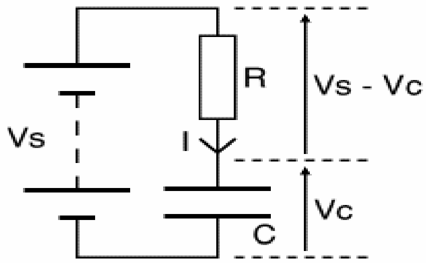
$$\text{Time constant} = R \times C$$

Where:

Time constant is in seconds (s)

R = resistance in ohms (Ω)

C = capacitance in farads (F)



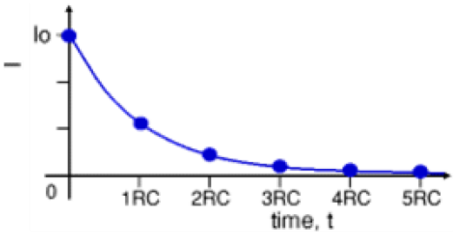
For example

If R = 47 k Ω and C = 22 μ F, then the time constant, RC = 47 k Ω × 22 μ F = 1.034 s.
If R = 33 k Ω and C = 1 μ F, then the time constant, RC = 33 k Ω × 1 μ F = 33ms.

A large time constant means the capacitor charges slowly. Note that the time constant is a property of the circuit containing the capacitance and resistance; it is not a property of a capacitor alone.

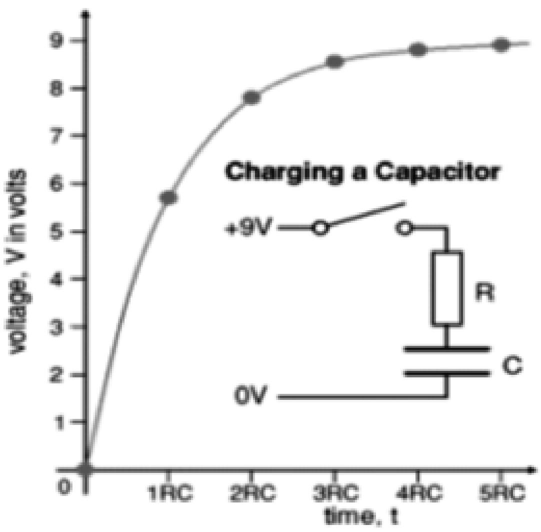
The time constant is the time taken for the charging (or discharging) current (I) to fall to 1/e of its initial value (I0). 'e' is the base of natural logarithms, an important number in mathematics (like π). e = 2.71828 (to 6 significant figures) so we can roughly say that the time constant is the time taken for the current to fall to 1/3 of its initial value.

After each time constant the current falls by 1/e (about 1/3). After 5 time constants (5RC) the current has fallen to less than 1% of its initial value and we can reasonably say that the capacitor is fully charged, but in fact the capacitor takes for ever to charge fully!



Graphs showing the current and voltage for a capacitor charging

The bellow graph shows how the voltage (V) increases as the capacitor charges. At first the voltage changes rapidly because the current is large; but as the current decreases, the charge builds up more slowly and the voltage increases more slowly.



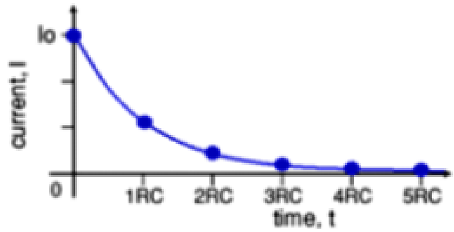
Time	Voltage	Charge
0RC	0.0V	0%
1RC	5.7V	63%
2RC	7.8V	86%
3RC	8.6V	95%
4RC	8.8V	98%
5RC	8.9V	99%

After 5 time constants (5RC) the capacitor is almost fully charged with its voltage almost equal to the supply voltage. We can reasonably say that the capacitor is fully charged after 5RC, although really charging continues for ever (or until the circuit is changed).

Discharging a capacitor

The graph shows how the current (I) decreases as the capacitor discharges. The initial current (I0) is determined by the initial voltage across the capacitor (V0) and resistance (R):

Initial current, $$I_0 = \frac{V_0}{R}$$

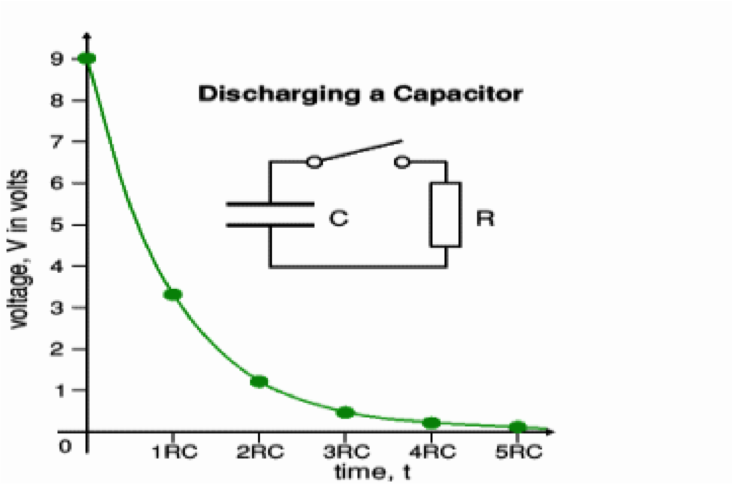


Graphs showing the current and voltage for a capacitor discharging

Note that the current graphs are the same shape for both charging and discharging a capacitor. This type of graph is an example of exponential decay.

The bellow graph shows how the voltage (V) decreases as the capacitor discharges. At first the current is large because the voltage is large, so charge is lost quickly and the voltage decreases rapidly. As charge is lost the voltage is reduced making the current smaller so the rate of discharging becomes progressively slower.

After 5 time constants (5RC) the voltage across the capacitor is almost zero and we can reasonably say that the capacitor is fully discharged, although really discharging continues for ever (or until the circuit is changed).



Time	Voltage	Charge
0RC	9.0V	100%
1RC	3.3V	37%
2RC	1.2V	14%
3RC	0.4V	5%
4RC	0.2V	2%
5RC	0.1V	1%

Ballistic Galvanometer and its types

Ballistic Galvanometer

A ballistic galvanometer is used to measure the total quantity of electrical charge that passes through it as a sudden discharge. The moment of inertia of the moving system is very large and hence it is slow to begin its motion under the impulse of the charge so that the whole of the charge passes through the galvanometer before the moving system has appreciably moved from its position of rest.

Types of ballistic galvanometer

There are two types of ballistic galvanometers:

1. Moving Magnet Type

In this galvanometer the charge q is given by the relation

$$q = \frac{B_H T}{\pi G} \sin(\frac{\theta}{2}) \qquad (1)$$

Where,

BH is the horizontal component of Earth's magnetic field

T time period of magnet

G galvanometer constant

$$G = \frac{m_0}{4} \frac{2pn}{R}$$

Where,

n is number of turns

R is radius of coil

2. Moving Coil Type

In this galvanometer the charge q is given by the relation

$$q = \frac{T}{2p} \frac{C}{NBA} q \qquad (2)$$

Where,

C is the restoring couple per unit angular twist of the suspension wire, T is time period of the coil, N is the number of turns, A is area of coil, B is magnetic field & θ is first throw

For any given instrument,

$$K = \frac{T}{2\pi} \frac{C}{NBA}$$

$$q = k\theta$$

$$K = \frac{q}{q}$$

The ratio q/θ is known as ballistic constant or charge sensitivity of ballistic galvanometer

When the deflection is measured with a lamp and scale arrangement, charge sensitivity is defined as the charge in micro coulomb, required to produce a deflection of one mm on a scale placed at a distance of one meter from the ballistic galvanometer mirror.

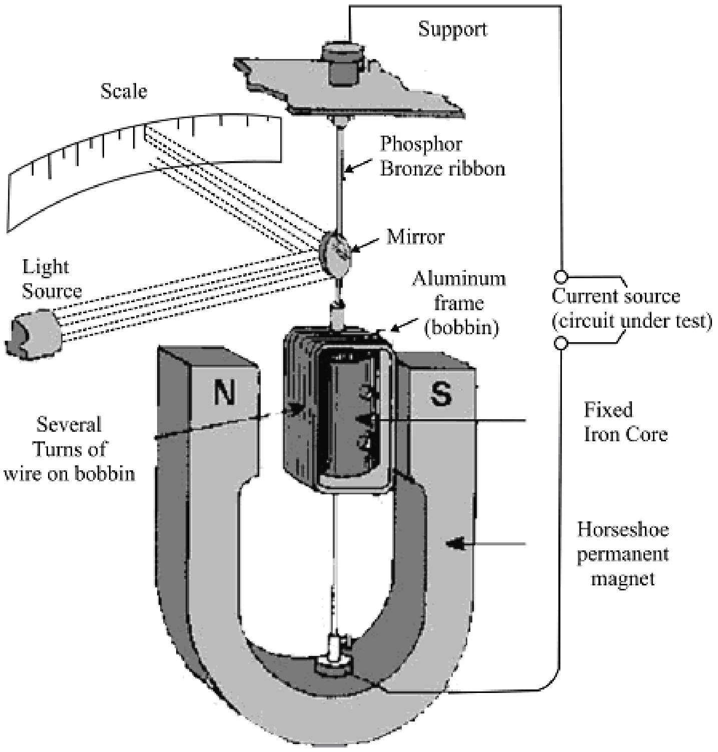
If d is the deflection in mm produced by a charge of q micro coulomb, then

k = q / d micro coulomb per mm

In moving coil type ballistic galvanometer the damping oscillation of reflecting spot occurs, which can be reduced by winding the coil on a non conducting material.

Galvanometer and its basic concept

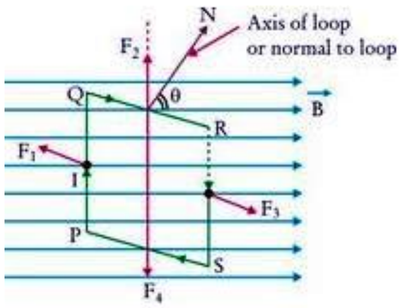
In galvanometer indicating system consists of a light coil of wire suspended from a metallic ribbon between the poles of a permanent magnet. The magnetic field produced by a current passing through the coil reacts with the magnetic field of the permanent magnet, producing a torque or twisting force. The coil, to which an indicating needle or mirror is attached, rotates under the action of the torque; the angle through which it rotates to balance the torsion of the suspension provides a measure of the current flowing in the coil. The angle is measured by the movement of the needle or by the deflection of a beam of light reflected from the mirror.



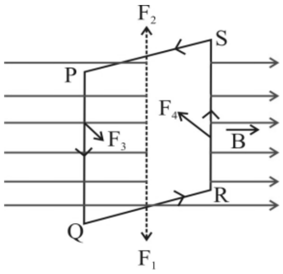
Nvis 6061 High Resistance Measurement by Leakage Method

The ballistic galvanometer is designed to deflect its indicating needle (or mirror) in a way that is proportional to the total charge passing through its moving coil or to a voltage pulse of short duration. Any conventional galvanometer may also be employed as a ballistic type, but the latter has smaller torque and higher inertia in the coil.

Torque experienced by a current loop in a uniform magnetic field



Consider a rectangular loop PQRS placed in a uniform magnetic field B. Let q be the angle between the plane of the loop and the direction of the magnetic field. The axis of the coil is perpendicular to the magnetic field.



Current loop placed in magnetic field

PQ and RS are equal by mathematical calculation. We find that, the forces F1 and F2 act along the axis of the coil in opposite directions. Moreover they are equal in magnitude; they do not produce any torque. Their resultant is zero. Forces F3 and F4 are equal in magnitude and opposite in direction. So they constitute a couple. Let the coil turn through an angle q due to this couple.

Torque = BIA cosθ

Where, A is area of the coil.

If the coil consists of N turns, then

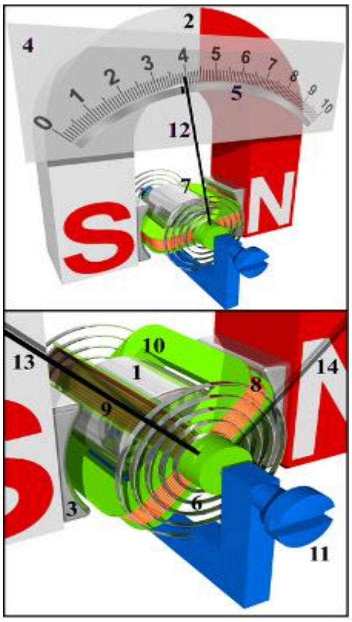
t = NBI A cosθ

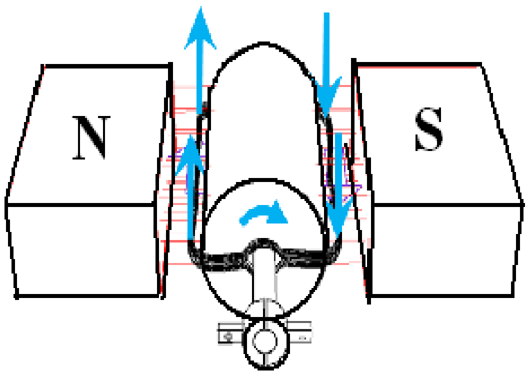
When θ = 0 then torque is maximum (NBIA)

When θ = 90, then torque is minimum (0)

So when the coil is parallel to the magnetic field the torque will be maximum, and when the coil is perpendicular to the magnetic filed the torque will be minimum.

Principle of Moving Coil Galvanometer





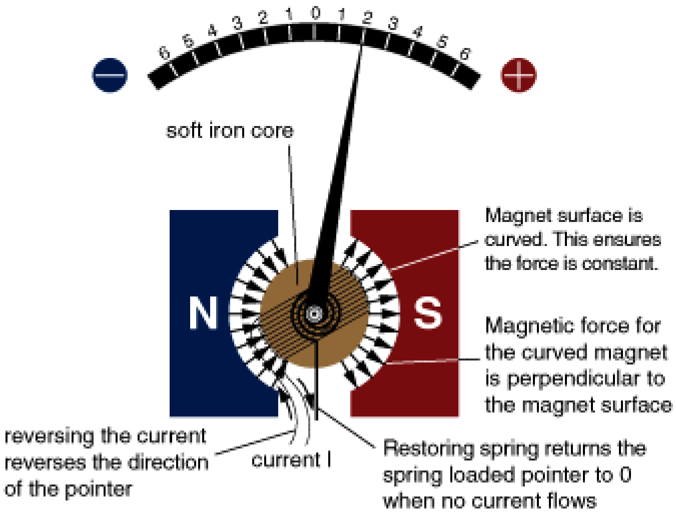
When a current carrying coil is placed in magnetic fields, it experiences a torque. It consists of a narrow rectangular coil PQRS consisting of a large number of turns of fine insulated copper wire wound over a frame made of light, non magnetic metal. A soft iron cylinder known as the core is placed symmetrically within the coil and detached from it the coil is suspended between the two cylindrical pole-pieces (N and S of a strong permanent horse shoe magnet) by a thin phosphor bronze strip, the upper end of which is connected to a movable torsion head T. The lower end of the coil is connected to a hair spring s of phosphor bronze having few turns.

To avoid disturbance, whole arrangement is kept in compact case having a glass window on the front. Leveling screws are provided at the base. The torsion head T is connected to a binding terminal T1. So, the phosphor-bronze strip acts as one 'current lead' to the coil. The lower end of spring s is connected to a binding terminal T2. A plane mirror or a concave mirror of large radius of curvature is rigidly attached to the phosphor bronze strip. This helps to measure the deflection of the coil by lamp and scale arrangement.

Radial magnetic field

The magnetic field in the small air gap between the cylindrical pole-pieces is radial. The magnetic lines of force within the air gap are along the radii an account of this, the plane of the coil remains always parallel to the direction of the magnetic field i.e., the angle between the plane of the coil and the magnetic field is zero in all the orientation of the coil.

Radial magnetic field



Let

I = current flowing through the coil

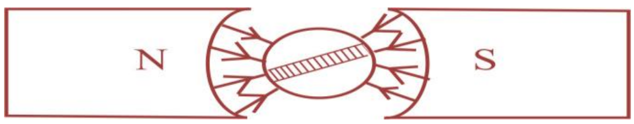
B = magnetic field l = length of coil

b = breadth of coil

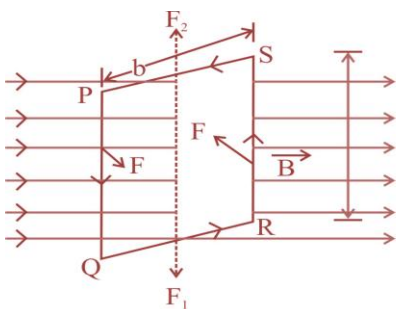
N = number of turns in coil

A = area of coil

Since the field is radial, therefore, the plane of coil remains parallel to the magnetic field in all the orientations of the coil. So, the sides SP and QR remain parallel to the direction of the magnetic field. So, they do not experience any force. The sides PQ and RS remain



perpendicular to the direction of the magnetic field. These sides experience forces perpendicular to the plane of the coil.



Current loop placed in magnetic field

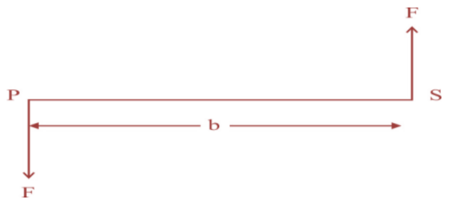
Force on PQ, F = NBIL

Force on RS, F = NBIL

The forces on the sides PQ and RS are equal in magnitude and opposite in direction. So, these two forces constitute a couple. These couple tends to deflect the coil and is known as deflecting couple.

Moment of deflecting couple = NBIL X b = NBIA

The field is radial. The forces on the sides PQ and RS always remain perpendicular to the plane of the coil. So, the perpendicular distance between the forces is always equal to b as shown in Figure.



When the coil deflects, the suspension strip gets twisted due elasticity, a restoring couple is set up in the fiber. This couple is proportional to the twist. If α be the angular twist, then

Moment of restoring couple = k α

Where k is restoring couple per unit angular twist. It is also known as torsional constant.

For equilibrium of coil,

NBIA = k alpha or I = (k / NBA) α

Or I = K α

Where K = k / NBA is galvanometer constant.

Now I α $\propto$

Or α = I

So the deflection of the coil is proportional to the current flowing through the coil. This deflection is measured by a linear scale.

Current sensitivity of galvanometer

Current sensitivity of a galvanometer is deflection of the meter per unit current, i.e.

$$\alpha / I.$$

$$\alpha / I = NBA / k$$

The sensitiveness can be increased by increasing N, A and B and decreasing the value of k. Value of N and A can not be increased much because this will increase the length and consequently the resistance of he coil. In that case, the galvanometer will not respond to weak electric currents.

B can be increased by using a strong magnet. K can be decreased by using phosphor bronze for suspension. K can be further reduced by using quartz suspension fiber.

Voltage sensitivity of galvanometer

It is defined as the deflection of the meter per unit voltage, i.e. α / v

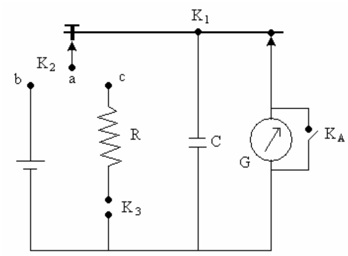
Now, α / V = α / RI or α / V = (NBA / k)R

Experimental theory

If a capacitor C after being charged to a potential difference V0 is instantaneously discharge throw a ballistic galvanometer giving a rise to a first throw θ0 then the charge on the capacitor

$$q_0 = CV_0 = Kq_0\left|1 + \frac{l}{2}\right| \quad (3)$$

Where K is the constant of the ballistic galvanometer and λ is the logarithmic decrement.



The capacitor is again charged to the same potential and the charge is allowed to leak through a high resistance R for a known time t so that the potential falls from V0 to Vt.If the remaining charges q on the capacitor is allowed to pass through the galvanometer so that a first throw θ1 is produced, then

$$q_0 = CV_1 = Kq_1\left|1 + \frac{l}{2}\right| \quad (4)$$

$$\frac{q_0}{q_1} = \frac{V_0}{V_1} = \frac{q_0}{q_1}$$

If V is the potential difference across the capacitor at any instant during the time the charge is leaking and dq/dt is the rate of loss of charge, then

$$i = -\frac{dq}{dt} = -\frac{dCV}{dt} = -C\frac{dV}{dt}$$

Also $$i = \frac{V}{R}$$

Hence $$\frac{V}{R} = -C\frac{dV}{dt}$$

or $$\frac{dt}{RC} = -\frac{dV}{V}$$

Integrating for the time t, and solving above equation, we have

$$R = \frac{t}{C´ \log_e \frac{q_0}{q_1}}$$

$$R = \frac{t}{2.3026´ C´ \log_{10} \frac{q_0}{q_1}}$$

Experiment

Objective : To determine the value of High Resistance by Leakage Method.

Items Required

1. Nvis 6061 Trainer
2. Mains cord
3. Ballistic galvanometer
4. Lamp & Scale arrangement
5. Connecting wires

Procedure

A) Setting of ballistic galvanometer and lamp & scale arrangement:

1. Place ballistic galvanometer at plane surface.
2. Look at coil of ballistic galvanometer at the middle of core and moves freely.
3. If coil does not centered properly, than use leveling screw.
4. Place lamp and scale arrangement at a distance of one meter from the mirror of galvanometer.
5. Incident laser light at the mirror of ballistic galvanometer.
6. Adjust lamp and scale arrangement so that spot of light moves freely on scale.
7. Set rest position of spot at zero division of scale. (Slide scale horizontally and vertically if necessary).
8. Give slight rotation to the coil (use upper screw) and see reflecting spot moves freely straight on full scale (both side of scale without up and down and italic motion of spot).
9. If reflecting spot does not move freely straight- wise than again use leveling screw or change a bit position of scale vertically.
10. When spot move freely straight wise on full scale than galvanometer is prepare for experimental procedure.

B) To measure unknown High Resistance

11. Put Nvis 6061 Trainer near above setup.
12. Connect main cord to the trainer.
13. Take two patch cords from accessory box and connect them between 5 & 6 point of the trainer and ballistic galvanometer.
14. Select toggle switch S1 at **off** position and S2 at **Open** position.
15. Select toggle switch S3 and S4 on position **1**.

16. Select unknown resistance at R4 position and capacitance at .47μF by given rotary switches.
17. Now switch **ON** the trainer then DC supply switch S1, so that the supply-capacitor circuit will be complete and capacitor will be charge with same voltage.
18. After 20-25 seconds suddenly select switch S4 at position **2,** so that the galvanometer circuit will be complete and capacitor will discharge through galvanometer. Carefully note the first throw θ_0 corresponding to the charge q_0.

Note: Laser spot moves about its rest position**.** $\boldsymbol{\theta_0}$ is calculated by taking difference of the two positions of the first oscillation where it stops. If the two positions are on the opposite side of the rest position then they are added to get $\boldsymbol{\theta_0}$**.**

19. Wait till position of the spot of light on the scale set on zero position.
20. Now select S4 back on position **1**, so that capacitor will charge again with same potential.
21. Select toggle switch S3 on position **2** and immediately start the stop-watch. Now capacitor has leaked for a known time t, say 5 seconds, then immediately select toggle switch S4 on position **2** so capacitor will discharge throw galvanometer and observe the first throw θ'.
22. Repeat this self-leakage experiment for different values of leakage time i.e.15, 20, 25 seconds......etc. noting the value of the throw θ' for each time of t.
23. Again set toggles S3 and S4 on position **1** so capacitor will be charge.
24. Select toggle S2 on Short position.
25. Wait till position of the spot of light on the scale set on zero position.
26. Select toggle switch S3 on position **2** and immediately start the stop-watch. Now capacitor has leaked throw resistance R for a known time t, say 5 seconds, then immediately select toggle switch S4 on position **2** now capacitor will discharge throw galvanometer and observe the first throw θ_1.
27. Repeat this experiment for different values of leakage time i.e.15, 20, 25 Seconds ......etc. noting the value of the throw θ_1 for each time of t.
28. Repeat all experiment for different combination of R and C.
29. Note all the values in observation table given below:

Observations

Capacitance of the capacitor C = ...μF =..................... F

Initial position of the spot on the scale =.......................

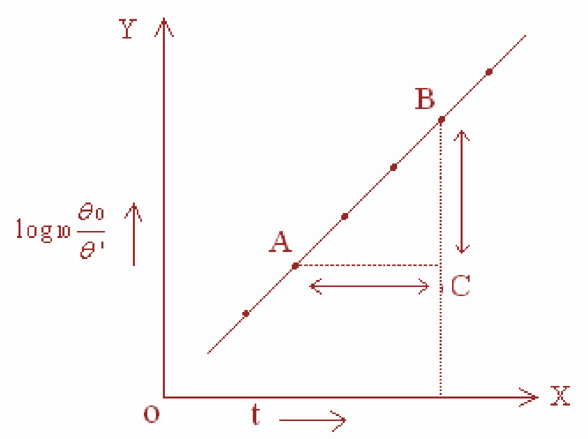
First throw due to charge q_0, θ_0 =........................

Nvis 6061 High Resistance Measurement by Leakage Method

Observation table

S.No.	Leakage Time t seconds	First throw after the charge had leaked						$\log_{10}\left(\frac{\theta_0}{\theta'}\right)$	$\log_{10}\left(\frac{\theta_0}{\theta_1}\right)$
		Self-leakage			Leakage throw R				
		Initial	final	θ'	Initial	final	θ_1		
1.	15								
2.	20								
3.	25								
4.	30								
5.	35								

30 Plot a graph taking the various values of time t along X-axis Corresponding values of $log_{10}\left(\frac{\theta_0}{\theta_1}\right)$ along Y-axis. The graph should be similar to below:



31 Find the slop of curve & calculate the self-leakage resistance r from the relation.

$$r = \frac{t}{2.3026 \times C \times \log_{10}\frac{\theta_0}{\theta'}}$$

Or

$$r = \frac{1}{2.3026 \times C}\frac{AC}{BC}$$

32. Similarly plot a graph between t and $log_{10}\left(\frac{\theta_0}{\theta_1}\right)$ & find the resistance R by following relation

$$R' = \frac{t}{2.3026\, C\, log_{10}\frac{\theta_0}{\theta_1}}$$

Or

$$R' = \frac{t}{2.3026\, C}\frac{AC}{BC}$$

If C is taken in microfarad, R is calculated directly in mega ohm.

Calculations

(1) From the graph between t and $log_{10}\left(\frac{\theta_0}{\theta_1}\right)$, we have

Slope of the Curve = $\frac{1}{t}\ log_{10}\left(\frac{\theta_0}{\theta_1}\right)$ So, Self -Leakage resistance

$$R' = \frac{t}{2.3026\, C\, log_{10}\frac{\theta_0}{\theta_1}}$$

(2) From the graph between t and $log_{10}\left(\frac{\theta_0}{\theta_1}\right)$, we have

Slope of the Curve = $\frac{1}{t}\ log_{10}\left(\frac{\theta_0}{\theta_1}\right)$ So, Combined resistance

$$R' = \frac{t}{2.3026\, C\, log_{10}\frac{\theta_0}{\theta_1}}$$

Find the value of r and R’ for different values of t and take their mean value (r & R’ both) for calculating unknown resistance R

$$\frac{1}{R} = \frac{1}{R'} - \frac{1}{r}$$

Mega Ohm

Nvis 6061 High Resistance Measurement by Leakage Method

Sample Results

Experiment

Objective: To determine the value of High Resistance by Leakage Method.

Capacitance of the capacitor C = 0.47 µF

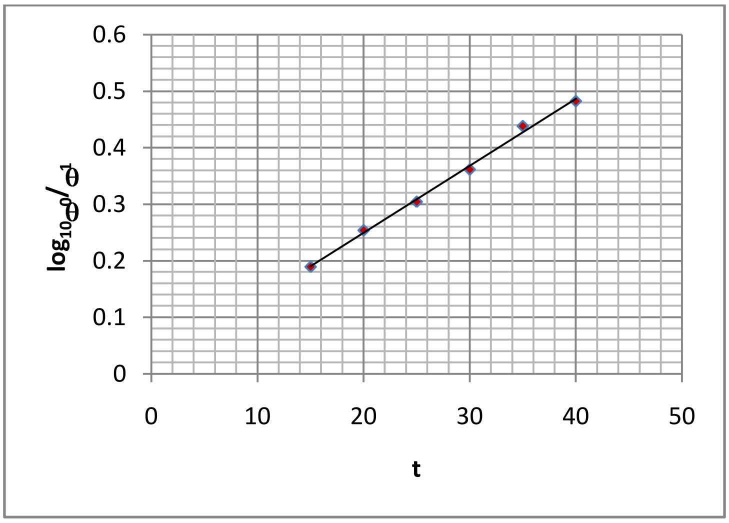
Initial position of the spot on the scale =15cm

First throw due to charge θ_0 = 42.5 cm

Observation table

For R_4

S.No.	Leakage Time t seconds	First throw after the charge had leaked						$\log_{10}\left(\frac{\theta_0}{\theta'}\right)$	$\log_{10}\left(\frac{\theta_0}{\theta_1}\right)$
		Self-leakage			Leakage throw R				
		Initial	final	θ'	Initial	final	θ1		
1	15	15	27.5	42.5	15	12.5	27.5	0	0.189056236
2	20	15	27.6	42.6	15	8.7	23.7	-0.001020669	0.253640584
3	25	15	27.7	42.7	15	6.1	21.1	-0.002038945	0.304106475
4	30	15	27.8	42.8	15	3.5	18.5	-0.003054839	0.361217202
5	35	15	27.9	42.9	15	0.5	15.5	-0.004068362	0.438057232
6	40	15	28	43	15	-1	14	-0.005079526	0.482260894



Nvis 6061 High Resistance Measurement by Leakage Method

Capacitance of the capacitor C = 0.33µF

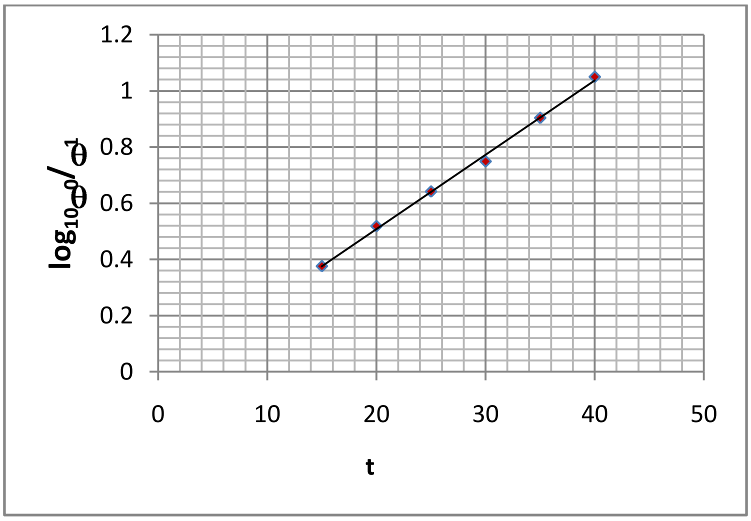
Initial position of the spot on the scale =15cm

First throw due to charge θ_0 = 28 cm

Observation table

For R3

S. No.	Leakage Time t seconds	First throw after the charge had leaked						$\log_{10}\left(\frac{\theta_0}{\theta'}\right)$	$\log_{10}\left(\frac{\theta_0}{\theta_1}\right)$
		Self-leakage			Leakage through R				
		Initial	final	θ'	Initial	final	θ1		
1	15	15	13	28	15	-3.2	11.8	0	0.375276024
2	20	15	13.1	28.1	15	-6.5	8.5	-0.001548289	0.517739106
3	25	15	13.1	28.1	15	-8.6	6.4	-0.001548289	0.640978057
4	30	15	13.1	28.1	15	-10	5	-0.001548289	0.748188027
5	35	15	13.1	28.1	15	-11.5	3.5	-0.001548289	0.903089987
6	40	15	13.2	28.2	15	-12.5	2.5	-0.003091077	1.049218023



Capacitance of the capacitor C = 0.22µF

Initial position of the spot on the scale =15cm

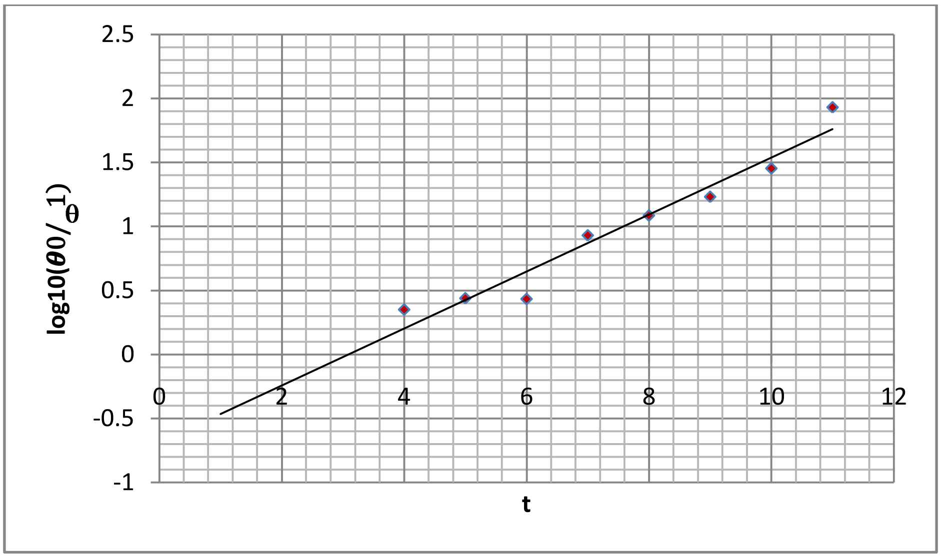
First throw due to charge θ_0 = 19 cm

Nvis 6061 High Resistance Measurement by Leakage Method

Observation table

For R_2

S. No.	Leakage Time t seconds	First throw after the charge had leaked						$\log_{10}\left(\frac{\theta_0}{\theta'}\right)$	$\log_{10}\left(\frac{\theta_0}{\theta_1}\right)$
		Self-leakage			Leakage through R				
		Initial	final	θ'	Initial	final	θ_1		
1	15	15	4	19	15	4	19	0	0.3496353
2	20	15	4	19	15	0.5	15.5	0	0.4380572
3	25	15	4	19	15	0.7	15.7	0	0.4324893
4	30	15	4	19	15	-10	5	0	0.9294189
5	35	15	3.8	18.8	15	-11.5	3.5	0.004596	1.0843209
6	40	15	3.8	18.8	15	-12.5	2.5	0.004596	1.2304489
7	50	15	3.8	18.8	15	-13.5	1.5	0.004596	1.4522977
8	55	15	3.8	18.8	15	-14.5	0.5	0.004596	1.9294189



Glossary

1. **µ.** Symbol used to represent the term micro, meaning x 10^{-6}.
2. **Ambient temperature.** Temperature of the air surrounding the capacitor, usually considered to be 20°C if in open air.
3. **Anode.** The positive electrode of a polar capacitor. Also used to refer to the capacitor during the manufacturing process.
4. **Bias.** The DC voltage onto which an AC signal is superimposed.
5. **Capacitance.** The technically correct term for capacity. It is the measure of the amount of electrical charge stored in a capacitor, usually expressed in units of microfarads. One farad is one coulomb of charge at 1volt. For Tantalum capacitors, nominal rated capacitance is measured at 20°C using a measuring bridge supplied by a 120 Hz source, free of harmonics, with a 2.2 volt DC bias.
6. **Capacitor.** Two conductive plates separated by an insulator, or dielectric which is tantalum penta oxide in a tantalum capacitor.
7. **Category voltage.** This is the maximum voltage that may be applied continuously to a capacitor. It is equal to the rated voltage up to 85°C,beyond which it is subject to linear derating, to 2/3 of rated voltage at 125°C.
8. **Chip.** Term loosely used to describe surface mount capacitors.
9. **Conductor.** A material with very low resistance, like most metals.
10. **Counter electrode.** The negative plate material of an electrolytic capacitor.
11. **Current.** A specific quantity of electrons passing a certain point per unit time.
12. **CV.** The capacity and voltage of the capacitor.CV is often used as an arithmetic product to classify a particular range.
13. **Date code.** Most capacitors are stamped with a code that gives the date and week of manufacture; for example 9410 would mean the capacitor was manufactured in the tenth week of 1994. There are several date coding systems, but year and week is the most common.
14. **Dielectric.** The insulation material that separates the two plates of the capacitor.
15. **Dielectric constant (K).** The measure of the effectiveness of a dielectric material in making capacitor size efficiency. The higher the dielectric constant the higher the size efficiency of the capacitor. A vacuum is defined as having a K of 1; tantalum penta oxide has a K of about 27.
16. **Dispersion.** A uniformly distributed particle , suspension of a solid in a liquid carrier. Suspension of a solid in a liquid carrier.
17. **Dissipation factor (DF).** A measure of the losses in the capacitor, or the extent to which the capacitor is not a perfect capacitor. DF is usually expressed as a percentage or a decimal equivalent. DF for a tantalum capacitor is measured at 120 Hz at 20°C using a measuring bridge supplied by a 120 Hz source, free of harmonics, with a 2.2 volt DC bias.
18. **Electrolyte.** The electrically active liquid (or gel) that provides the connecting path between the anode oxide layer of a wet tantalum capacitor and the cathode termination.

19. **ESL (Equivalent series inductance).** The extent to which the capacitor acts as though there was an inductor in series with the capacitor. ESL is generally only important at high frequencies.
20. **ESR Equivalent series resistance.** The extent to which the capacitor acts like a resistor when charging and discharging in an electronic circuit expressed as a resistance in series with the capacitor.
21. **Extended range.** Capacitors that are manufactured with a higher density than standard capacitors (i.e. higher capacity per unit volume), usually selling at premium prices.
22. **Failure rate.** A scientifically measured reliability rating usually expressed in units of percent per thousand hours (under maximum voltage and current, and a set circuit resistance condition) at a specified statistical confidence level (typically 60% or 90%), or expressed as mean time between failures (MTBF).
23. **Formation.** The process of building the oxide layer onto the tantalum metal. Higher voltages (with thicker oxide layers) require longer forming.
24. **Formation ratio** The ratio of the voltage to which a capacitor is formed, against the capacitor's rated voltage.
25. **Formation voltage.** The voltage at which the power supply used in the formation process changes from constant current to constant voltage. The formation voltage is proportional to the dielectric thickness.
26. **Leakage current.** Current flowing from one conductor to an adjacent conductor through an "insulating" layer. The leakage current is measured after 3 minutes at 20°C, through a 1K½ resistor connected in series with the capacitor, with rated voltage applied. Typically in micro amps or nanoamps.
27. **Low profile.** Specially designed capacitors which mount onto circuit boards with less than standard height. Low profile styles are usually more expensive than standard profile.
28. **Microfarad (µF).** Most common unit of capacity for tantalum capacitors.
29. **Open circuit.** A term used to define a failed capacitor which has become of such a high impedance that it no longer functions as a capacitor. Such failures are rare.
30. **Operating voltage.** The actual circuit voltage that the capacitor sees in the circuit application.
31. **Polar.** Capacitors that must be inserted into circuitry with the anode on the positive side and the cathode on the negative side. If connected with the wrong polarity across the capacitor, it will conduct a far higher current and will ultimately become a short circuit.
32. **Pyrolysis.** The decomposition of a substance by heat.
33. **Power factor.** The ratio of real power to reactive power in a capacitor.
34. **Rated voltage.** This is the DC rated voltage for continuous operation up to 85°C.
35. **Reform.** The process of reducing leakage current by removing manganese dioxide from sites which conduct a high current and producing a dielectric to cover the opened site.

36. **Reverse voltage.** The voltage applied to a polar capacitor in the opposite direction of the indicated polarity. Reverse voltage has the potential effect of causing the capacitor to fail.
37. **Resistivity.** A measure of the ability of a unit cross-sectional area and unit length of a material to resist the flow of an electric current through it.
38. **Ripple current.** The current passing through a capacitor when an alternating voltage is applied across its terminals. This generates heat. The maximum ripple current permissible is determined by the maximum power dissipation of the capacitor body.
39. **Ripple voltage.** The voltage across the terminals of a capacitor when an alternating current is passed through it (see also ripple current).
40. **Short circuit.** Description of a failed capacitor that results in essentially a bypass of the dielectric enabling high currents to pass.
41. **Sintering.** To coalesce under the influence of heat, without actually liquefying.
42. **Slug.** Term given to a tantalum capacitor before it is molded into the encapsulation. It is sometimes used to refer to the capacitive element which is held in the encapsulation material.
43. **SMT(Surface mount technology).** An acronym for the broad field of leadless surface mounting electronic components. SMT carries with it the idea of high speed "pick and-place" manufacturing processes, as opposed to the hybrid approach of slow assembly under a microscope.
44. **Solid tantalum.** A sintered tantalum pellet with a solid counter electrode.
45. **Steady-state.** This refers to the conditions under which the capacitor is operating once power has been applied. It assumes constant temperature, voltage, and circuit resistance and the absence of any voltage or current transients.
46. **Stringer.** Term given to a metal strip containing many tantalum slugs.
47. **Tantalum.** A metal element in the transition group of the periodic table. The ore is mined in many parts of the world.
48. **Temperature rating.** The temperature (usually in Celsius) over which the capacitor may be safely operated. With tantalum capacitors there is a lower (de rated) voltage at the high end of the temperature rating.
49. **Voltage derating.** Using a capacitor below its rated voltage. The percentage of derating applied is given by the equation:

(1 - circuit voltage) x 100% rated voltage.

50. **Volumetric efficiency.** A measure of the size or volume of a component relative to its capacitance and voltage. It takes into account the surface area of circuit board covered by the component and the height of the component.
51. **Wet tantalum.** A sintered tantalum pellet in a liquid acid electrolyte, as compared with solid tantalum.

Frequently Asked Questions

Q1. How do fixed resistors usually fail?

Ans. By becoming an open circuit.

Q2. With Ohm's law, if voltage increases and resistance stays the same?

Ans. Current increases.

Q3. Which formula shows a direct proportionality between power and voltage?

Ans. P = VI

Q4. What resistor type is found in SIPs and DIPs?

Ans. Thick film.

Q5. What are the two major categories for resistors?

Ans. Fixed and variable

Q6. With Ohm’s law what is the relation between current and resistance?

Ans. With Ohm's law: current is inversely proportional to resistance.

Q7. Power is defined as?

Ans. The rate at which energy is used.

Q8. What is the most commonly used conductor in electronics?

Ans. Copper.

Q9. With Ohm's law, no change in resistance means that current and voltage will be ?

Ans. Directly proportional.

Q10. What happens to current and resistance if the voltage doubles?

Ans. Current doubles and resistance remains the same.

Q11. With a complex circuit, a supply source senses .

Ans. Only a single resistive connection.

Q12. Which is the most important step utilized when measuring resistors?

Ans. Remove power from the circuit.

Q13. When a capacitor is fully charged?

Ans. When the voltage across the capacitor is same as applied source voltage . In this state there is no current flow between capacitor and voltage source .

Q14. A capacitor's rate of charge is considered?

Ans. Exponential .

Q15. If an open capacitor is checked with an ohmmeter, the needle will ?

Ans. Stay on infinity.

Q16. As a capacitor is being charged, current flowing into the capacitor will ?

Ans. Current flowing decrease.

Q17. In which form the capacitor stores the energy?

Ans. A capacitor stores energy within a dielectric between the conducting plates in the form of an electric field .

Q18. As a capacitor is being charged, the voltage across its terminals will be ?

Ans. It will increase .

Q19. Older types of paper capacitors have been replaced by which type of construction?

Ans. It has been replaced with plastic film.

Q20. What the Resistance is?

Ans. The opposition to current flow accompanied by the dissipation of heat.

Q21. What do variable capacitors use for dielectric?

Ans. Air, ceramic, mica, or plastic

Q22. If a charged capacitor is disconnected from a circuit, it will ?

Ans. It will leak the charge.

Q23. On which factor the strength of an electric field at a given point in a capacitor depends?

Ans. The strength of an electric field at a given point is proportional to the potential difference on the plates and inversely proportional to the plate separation.

Warranty

- We Warranty the product against all manufacturing defects for 24 months from the date of sale by us or through our dealers.
- The Warranty does not cover perishable item like cathode ray tubes, crystals, batteries, photocells etc.
- The Warranty will become void, if
    - The product is not operated as per instruction given in the learning material.
    - The agreed payment terms and other conditions of sale are not followed.
    - The customer resells the instrument to another party.
    - Any attempt is made to service and modify the instrument.
- The non-working of the product is to be communicated to us immediately giving full details of the complaints and defects noticed specifically mentioning the type, serial number of the product and date of purchase etc. 1/8 size for Warranty.
- The repair work will be carried out, provided the product is dispatched securely packed and insured. The transportation charges shall be borne by the customer.

Note: Ballistic Galvanometer is not covered in the warranty.

Nvis 6061 High Resistance Measurement by Leakage Method

List of Accessories

• Ballistic galvanometer	1 No.
• Ballistic galvanometer power supply	1 No.
• LASER and scale (30 to 30cm) Arrangement	1 No.
• Mains Cord.	1 No.
• Patch cords black 24”	1 No.
• Patch cords red 24”	1 No.
• 7. Learning Material CD	1 No.

References

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- 4 http://www.indiabix.com/electronics/resistance-and-power/204008