CHAPTER I

INTRODUCTION

Dielectrics used as capacitor insulators have a wide range of physical and structural characteristics which give rise to differences in their electrical behavior. Some of the most important characteristics of a dielectric capacitor are its polarization properties, electrical conductivity, power losses, and dielectric strength. Exposure to radiation is among the factors which may influence these characteristics. The effects of ionizing radiation on dielectrics used as capacitor insulators may result insignificant changes of capacitor performance within an electrical circuit.

1.1 The Aim of Study

In this study the influence of x- ray radiation on the magnitude of the capacitance of the capacitor and resistors were examined and calculated.

1.2 The problem of Study

The Operation of capacitors and resistors subject to extreme conditions, such as the presence of ionizing radiation fields, is of special concern in military industry and space technology. So may the exposure to an x ray cause a decrease of capacitance and impedance of the electrical circuit.

1.3 The Methodology

In this research experiments were carried out for four different valued-resistances, beside two capacitors before subject to irradiation through x-ray and after irradiated. Then they obtained results were analyzed.

1.4 Research Layout

Research consists of four chapters the first chapter an introduction, Chapter two Basics principles of Radiation, the third chapter the resistor and capacitor, Chapter four the practical work.

CHAPTER II

RADIATION

Radiation is energy that comes from a source and travels through some material or through space. Light, heat and sound are types of radiation. The kind of radiation discussed in this presentation is called ionizing radiation because it can produce charged particles (ions) in matter Radiation is energy in the form of waves or streams of particles. There are many kinds of radiation all around us. When people hear the word radiation, they often think of atomic energy, nuclear power and radioactivity, but radiation has many other forms. Sound and visible light are familiar forms of radiation; other types include ultraviolet radiation (that produces a suntan), infrared radiation (a form of heat energy), and radio and television signals.

1.1 Basic of Radiation

All life has evolved in an environment filled with radiation. The forces at work in radiation are revealed upon examining the structure of atoms. Atoms are a million times thinner than a single strand of human hair, and are composed of even smaller particles some of which are electrically charged. Each element is distinguished by the number of protons in its nucleus. This number, which is unique to each element, is called the “atomic number”. For example, carbon has six protons; therefore, its atomic number is 6 on the periodic table. In an atom of neutral charge, the atomic number is also equal to the number of electrons. An atom’s chemical properties are determined by the number of electrons, which is normally equal to the atomic number [1].

1.2 Isotopes

An isotope is a variant of a particular chemical element. While all isotopes of a given element have the same number of protons, each isotope has a different number of neutrons. For example, hydrogen has three isotopes (or variants):

- Hydrogen-1 (contains one proton and no neutrons).
- Hydrogen-2, which is called deuterium (contains one proton and one neutron).
- Hydrogen-3, which is called tritium (contains one proton and two neutrons).

Another example is uranium-235, which has 92 protons and 143 neutrons, as opposed to uranium-238, which has 92 protons and 146 neutrons. An isotope is stable when it has a balanced number of neutrons and protons. In general, when an isotope is small and stable, it contains close to an equal number of protons and neutrons. Isotopes that are larger and stable have slightly more neutrons than protons. Examples of stable nuclides include carbon-12 (six protons and six neutrons for a total mass of 12), phosphorus-30 (15 protons and 15 neutrons) and sodium-22 (11 protons and 11 neutrons).

1.3 Radioisotopes

Isotopes that are not stable and emit radiation are called radioisotopes. A radioisotope is an isotope of an element that undergoes spontaneous decay and emits radiation as it decays. During the decay process, it becomes less radioactive over time, eventually becoming stable. Once an atom reaches a stable configuration, it no longer gives off radiation. For this reason, radioactive sources or sources that spontaneously emit energy in the form of ionizing radiation as a result of the decay of an unstable atom become weaker with time. As more and more of the source's unstable atoms become stable, less radiation is produced and the activity of the material decreases over time to zero [1].

The time it takes for a radioisotope to decay to half of its starting activity is called the radiological half life, which is denoted by the symbol t½. Each radioisotope has a unique half-life, and it can range from a fraction of a second to billions of years. For example, iodine-131 has an eight-day half-life, whereas plutonium-239 has a half-life of 24,000 years. A radioisotope with a short half-life is more radioactive than a radioisotope with a long half-life, and therefore will give off more radiation during a given time period. There are three main types of radioactive decay [1]:

- Alpha decay: Alpha decay occurs when the atom ejects a particle from the nucleus, which consists of two neutrons and two protons. When this happens, the atomic number decreases by 2 and the mass decreases by 4. Examples of alpha emitters include radium, radon, uranium and thorium.
- Beta decay: In basic beta decay, a neutron is turned into a proton and an electron is emitted from the nucleus. The atomic number increases by one, but the mass only decreases slightly. Examples of pure beta emitters include strontium-90, carbon-14, tritium and sulphur-35.
- Gamma decay: Gamma decay takes place when there is residual energy in the nucleus following alpha or beta decay, or after neutron capture (a type of nuclear reaction) in a nuclear reactor. The residual energy is released as a photon of gamma radiation. Gamma decay generally does not affect the mass or atomic number of a radioisotope. Examples of gamma emitters include iodine-131, cesium-137, cobalt-60, and radium-226 and technetium-99.

The number of nuclear disintegrations in a radioactive material per unit time is called the activity. The activity is used as a measure of the amount of a radionuclide, and it is measured in Becquerel's (Bq).

$$1\ Bq = 1\ disintegration\ per\ second.$$

If the original source of the radioactivity is known, it can be predicted how long it will take to decay to a given activity. The decay is exponential and the isotope must go through many half-lives to become nonradioactive.

1.4 Types and Sources of Radiation

Radiation is energy in the form of waves of particles. There are two forms of radiation, non-ionizing and ionizing radiation:

1.4.1 Non-ionizing radiation

Non-ionizing radiation has less energy than ionizing radiation; it does not possess enough energy to produce ions. Examples of non-ionizing radiation are visible light, infrared, radio waves, microwaves, and sunlight [2]. Global positioning systems, cellular telephones, television stations, FM and AM radio, baby monitors, cordless phones, garage-door openers, and ham radios use non-ionizing radiation. Other forms include the earth’s magnetic field, as well as magnetic field exposure from proximity to transmission lines, household wiring and electric appliances. These are defined as extremely low-frequency (ELF) waves and are not considered to pose a health risk.

1.4.2 Ionizing radiation

Ionizing radiation is capable of knocking electrons out of their orbits around atoms, upsetting the electron/proton balance and giving the atom a positive charge. Electrically charged molecules and atoms are called ions. Ionizing radiation includes the radiation that comes from both natural and man-made radioactive materials. There are several types of ionizing radiation:

Alpha radiation (α)

Alpha radiation consists of alpha particles that are made up of two protons and two neutrons each and that carry a double positive charge. Due to their relatively large mass and charge, they have an extremely limited ability to penetrate matter. Alpha radiation can be stopped by a piece of paper or the dead outer layer of the skin. Consequently, alpha radiation from nuclear substances outside the body does not present a radiation hazard. However, when alpha-radiation-emitting nuclear substances are taken into the body (for example, by breathing them in or by ingesting them), the energy of the alpha radiation is completely absorbed into bodily tissues. For this reason, alpha radiation is only an internal hazard. An example of a nuclear substance that undergoes alpha decay is radon-222, which decays to polonium-218 [2].

Beta radiation (β)

Beta radiation consists of charged particles that are ejected from an atom’s nucleus and that are physically identical to electrons. Beta particles generally have a negative charge, are very small and can penetrate more deeply than alpha particles. However, most beta radiation can be stopped by small amounts of shielding, such as sheets of plastic, glass or metal. When the source of radiation is outside the body, beta radiation with sufficient energy can penetrate the body’s dead outer layer of skin and deposit its energy within active skin cells. However, beta radiation is very limited in its ability to penetrate to deeper tissues and organs in the body. Beta-radiation-emitting nuclear substances can also be hazardous if taken into the body. An example of a nuclear substance that undergoes beta emission is tritium (hydrogen-3).

Photon radiation (gamma (γ) and X-ray)

Photon radiation is electromagnetic radiation; there are two types of photon radiation of interest for the purpose of this document, gamma (γ) and X-ray. Gamma radiation consists of photons that originate from within the nucleus, and X-ray radiation consists of photons that originate from outside the nucleus, and are typically lower in energy than gamma radiation. Photon radiation can penetrate very deeply and sometimes can only be reduced in intensity by materials that are quite dense, such as lead or steel. In general, photon radiation can travel much greater distances than alpha or beta radiation, and it can penetrate bodily tissues and organs when the radiation source is outside the body. Photon radiation can also be hazardous if photon-emitting nuclear substances are taken into the body. An example of a nuclear substance that undergoes photon emission is cobalt-60, which decays to nickel-60 [2].

Neutron radiation (n)

Apart from cosmic radiation, spontaneous fission is the only natural source of neutrons (n). A common source of neutrons is the nuclear reactor, in which the splitting of a uranium or plutonium nucleus is accompanied by the emission of neutrons. The neutrons emitted from one fission event can strike the nucleus of an adjacent atom and cause another fission event, inducing a chain reaction. The production of nuclear power is based upon this principle. All other sources of neutrons depend on reactions where a nucleus is bombarded with a certain type of radiation (such as photon radiation or alpha radiation), and where the resulting effect on the nucleus is the emission of a neutron. Neutrons are able to penetrate tissues and organs of the human body when the radiation source is outside the body. Neutrons can also be hazardous if neutron-emitting nuclear substances are deposited inside the body. Neutron radiation is best shielded or absorbed by materials that contain hydrogen atoms, such as paraffin wax and plastics. This is because neutrons and hydrogen atoms have similar atomic weights and readily undergo collisions between each other.

1.4.3 Natural sources of ionizing radiation

Radiation has always been present and is all around us in much form, Life has evolved in a world with significant levels of ionizing radiation, and our bodies have adapted to it. Many radioisotopes are naturally occurring, and originated during the formation of the solar system and through the interaction of cosmic rays with molecules in the atmosphere. Tritium is an example of a radioisotope formed by cosmic rays interaction with atmospheric molecules. Some radioisotopes (such as uranium and thorium) that were formed when our solar system was created have half-lives of billions of years, and are still present in our environment. Background radiation is the ionizing radiation constantly present in the natural environment [1].

1.5 Interaction of Radiation with matter

Radiation is detected through its interaction in matter. Every detection system works following the same sequence: it starts with the interaction of a given radiation with the detection medium; the result of the interaction is transformed into signals, which are readout and usually recorded. The interaction processes depend on both the type and energy of the incoming particles(or photon). The detection media to be used in particular application have to be carefully selected as function of particle type of energy [2].

CHAPTER III

RESISTORS AND CAPACITORS

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity [5].

3.1 Resistors

Resistors are electronic components which have a specific, never-changing electrical resistance. The resistors resistance limits the flow of electrons through a circuit; they are passive components, meaning they only consume power (and can't generate it). Resistors are usually added to circuits where they complement active components like op-amps, microcontrollers, and other integrated circuits. Commonly resistors are used to limit current, divide voltages, and pull up I/O lines.

3.1.1 Resistor Units

The electrical resistance of a resistor is measured in ohms. The symbol for an ohm is the Greek capital-omega: Ω. the (somewhat roundabout) definition of 1Ω is the resistance between two points where 1 volt (1V) of applied potential energy will push 1 ampere (1A) of current [6]. As SI units go, larger or smaller values of ohms can be matched with a prefix like kilo-, mega-, or giga-, to make large values easier to read. It's very common to see resistors in the kilo (kΩ) and mega ohm (MΩ) range (much less common to see milliohm (mΩ) resistors). For example, a 4,700Ω resistor is equivalent to a 4.7kΩ resistor, and a 5,600,000Ω resistor can be written as 5,600kΩ or (more commonly as) 5.6MΩ.

3.1.2 Resistor Schematic Symbol

All resistors have two terminals, one connection on each end of the resistor. When modeled on a schematic, a resistor will show up as one of these two symbols:

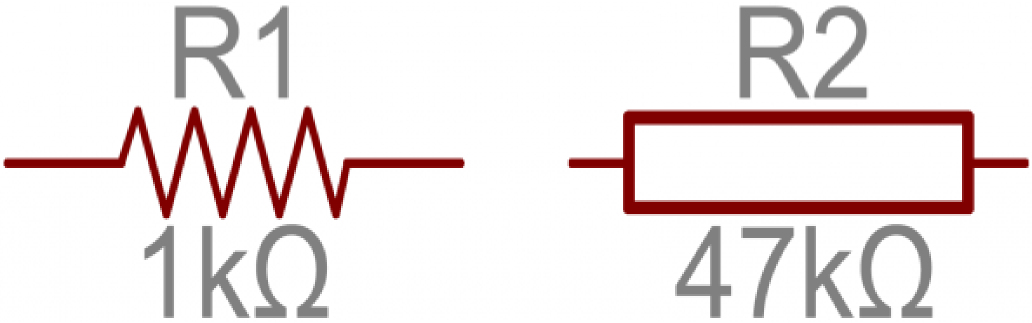

Figure 3.1 Resistor schematic symbols.

Figure 3.1 Two common resistor schematic symbols. R1 is an American-style 1kΩ resistor, and R2 is an international-style 47kΩ resistor.

The terminals of the resistor are each of the lines extending from the squiggle (or rectangle). Those are what connect to the rest of the circuit. The resistor circuit symbols are usually enhanced with both a resistance value and a name. The value, displayed in ohms, is obviously critical for both evaluating and actually constructing the circuit. The name of the resistor is usually an *R* preceding a number show in Figure 3.1. Each resistor in a circuit should have a unique name/number. For example, here are a few resistors in action on a 555 timer circuit show in Figure 3.2 [3].

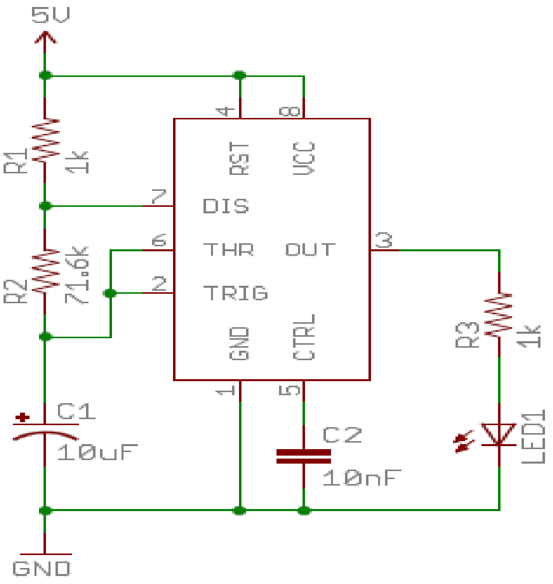

Figure 3.2 Show resistors play a key role in setting the frequency of the 555 timer's output. Another resistor (R3) limits the current through an LED.

3.1.3 Types of Resistors

Resistors come in a variety of shapes and sizes. They might be through-hole or surface-mount. They might be a standard, static resistor, a pack of resistors, or a special variable resistor.

3.1.4 Resistors Composition

Resistors can be constructed out of a variety of materials. Most common, modern resistors are made out of either a carbon, metal, or metal-oxide film. In these resistors, a thin film of conductive (though still resistive) material is wrapped in a helix around and covered by an insulating material. Most of the standard, no-frills, through-hole resistors will come in a carbon film or metal-film composition [3]**.** Carbon composition resistors (CCR) consist of a solid cylindrical resistive element with embedded wire leads or metal end caps to which the lead wires are attached. The body of the resistor is protected with paint or plastic. Early 20th-century carbon composition resistors had uninsulated bodies; the lead wires were wrapped around the ends of the resistance element rod and soldered. The completed resistor was painted for color-coding of its value [7]. These resistors are non-inductive that provide benefit when used in voltage pulse reduction and surge protection applications [8]**.**

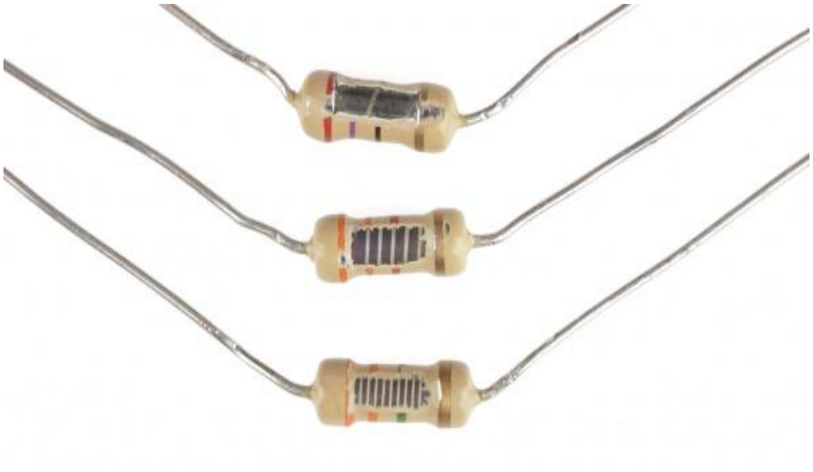

Figure 3.3 Carbon resistors

Peek inside the guts of a few carbon-film resistors. Resistance values from top to bottom: 27Ω, 330Ω and a 3.3MΩ. Inside the resistor, a carbon film is wrapped around an insulator. More wraps means a higher resistance.

These resistors, however, if never subjected to overvoltage nor overheating were remarkably reliable considering the components size [9], other through whole resistors might be wire wound or made of super-thin metallic foil. These resistors are usually more expensive, higher end components specifically chosen for their unique characteristics like a higher power-rating, or maximum temperature range. Surface mount resistors are usually either thick or thin-film variety. Thick film is usually cheaper but less precise than thin. In both resistor types, a small film of resistive metal alloy is sandwiched between a ceramic base and glass/epoxy coating, and then connected to the terminating conductive edges [3].

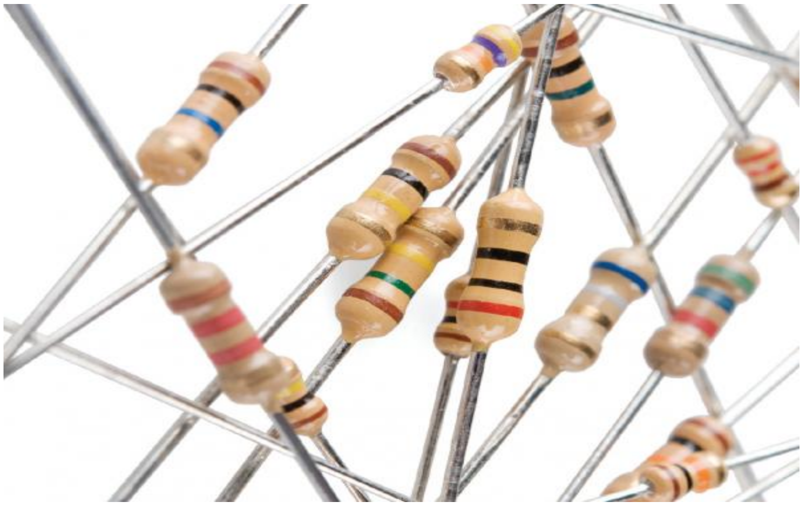

Figure 3.4 Multi size carbon resistors

The first two bands indicate the two most-significant digits of the resistor’s value. The third band is a weight value, which multiplies the two significant digits by a power of ten. The final band indicates the tolerance of the resistor. The tolerance explains how much more or less the actual resistance of the resistor can be compared to what its nominal value is. No resistor is made to perfection, and different manufacturing processes will result in better or worse tolerances. For example, a 1kΩ resistor with 5% tolerance could actually be anywhere between 0.95kΩ and 1.05kΩ.

How do you tell which band is first and last? The last, tolerance band is often clearly separated from the value bands, and usually it'll either be silver or gold. Here is a table of each of the colors and which value, multiplier or tolerance they represent [3].

Table 3.1 Resistor colors

Tolerance	Multiplied Out	Multiplier	Digit value	Color
	1	10^0	0	Black
	10	10^1	1	Brown
	100	10^2	2	Red
	1,000	10^3	3	Orange
	10000	10^4	4	Yellow
	100,000	10^5	5	Green
	1,000,000	10^6	6	Blue
	10,000,000	10^7	7	Violet
	100,000,000	10^8	8	Gray
	1,000,000,000	10^9	9	White
±5%				Gold
±10%				Silver

Here is an example of a 4.7kΩ resistor with four color bands:

Figure 3.5 Carbon resistor color bands

When decoding the resistor color bands, consult a resistor color code table like the one above. For the first two bands, find that color's corresponding digit value. The 4.7kΩ resistor has color bands of yellow and violet to begin - which have digit values of 4 and 7 (47). The third band of the 4.7kΩ is red, which indicates that the 47 should be multiplied by 10^2 (or 100), 47 times 100 is 4,700, if you trying to commit the color band code to memory, a mnemonic device might help. There are a handful of (sometimes unsavory) mnemonics out there, to help remember the resistor color code. A good one, which spells out the difference between black and brown, is "Big brown rabbits often yield great big vocal groans gingerly snapped." Or, if you remember "ROY G. BIV", subtract the indigo (poor indigo, no one remembers indigo), and add black and brown to the front and gray and white to the back of the classic rainbow color order.

3.2 Capacitors

The capacitor is a component which has the ability or "capacity" to store energy in the form of an electrical charge producing a potential difference (Static Voltage) across its plates, much like a small rechargeable battery. There are many different kinds of capacitors available from very small capacitor beads used in resonance circuits to large power factor correction capacitors, but they all do the same thing, they store charge. In its basic form, capacitors consists of two or more parallel conductive (metal) plates which are not connected or touching each other, but are electrically separated either by air or by some form of a good insulating material such as waxed paper, mica, ceramic, plastic or some form of a liquid gel as used in electrolytic capacitors. The insulating layer between capacitors plates is commonly called the Dielectric [4]**.**

Figure 3.6 Typical Capacitor

Due to this insulating layer, DC current cannot flow through the capacitor as it blocks it allowing instead a voltage to be present across the plates in the form of an electrical charge. The conductive metal plates of a capacitor can be square, circular or rectangular, or they can be of a cylindrical or spherical shape with the general shape, size and construction of a parallel plate capacitor depending on its application and voltage rating. When used in a direct current or DC circuit, a capacitor charges up to its supply voltage but blocks the flow of current through it because the dielectric of a capacitor is non-conductive and basically an insulator. However, when a capacitor is connected to an alternating current or AC circuit, the flow of the current appears to pass straight through the capacitor with little or no resistance. There are two types of electrical charge, positive charge in the form of Protons and negative charge in the form of Electrons. When a DC voltage is placed across a capacitor, the positive (+ve) charge quickly accumulates on one plate while a corresponding negative (-ve) charge accumulates on the other plate. For every particle of (+ve) charge that arrives at one plate a charge of the same sign will depart from the (-ve) plate, then the plates remain charge neutral and a potential difference due to this charge is established between the two plates. Once the capacitor reaches its steady state condition an electrical current is unable to flow through the capacitor itself and around the circuit due to the insulating properties of the dielectric used to separate the plates. the flow of electrons onto the plates is known as the capacitors Charging Current which continues to flow until the voltage across both plates (and hence the capacitor) is equal to the applied voltage Vc, at this point the capacitor is said to be “fully charged” with electrons. The strength or rate of this charging current is at its maximum value when the plates are fully discharged (initial condition) and slowly reduces in value to zero as the plates charge up to a potential difference across the capacitors plates equal to the source voltage. The amount of potential difference present across the capacitor depends upon how much charge was deposited onto the plates by the work being done by the source voltage and also by how much capacitance the capacitor has and this is illustrated below.

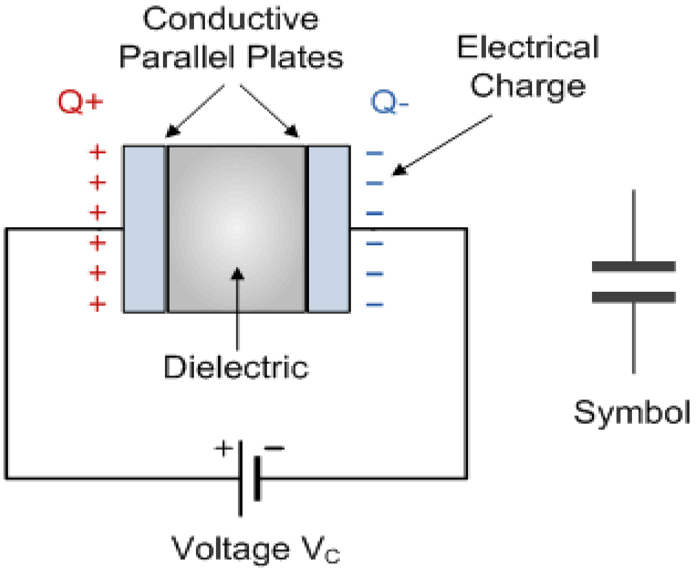

Figure 3.7 The parallel plate capacitor.

The parallel plate capacitor is the simplest form of capacitor. It can be constructed using two metal or metalized foil plates at a distance parallel to each other, with its capacitance value in Farads, being fixed by the surface area of the conductive plates and the distance of separation between them. Altering any two of these values alters the value of its capacitance and this forms the basis of operation of the variable capacitors. Also, because capacitors store the energy of the electrons in the form of an electrical charge on the plates the larger the plates and/or smaller their separation the greater will be the charge that the capacitor holds for any given voltage across its plates, in other words, larger plates, smaller distance, more capacitance [3].

By applying a voltage to a capacitor and measuring the charge on the plates, the ratio of the charge Q to the voltage V will give the capacitance value of the capacitor and is therefore given as: $C = Q/V$ this equation can also be re-arranged to give the more familiar formula for the quantity of charge on the plates as: $Q = C \times V$.

Although we have said that the charge is stored on the plates of a capacitor, it is more correct to say that the energy within the charge is stored in an "electrostatic field" between the two plates. When an electric current flows into the capacitor, charging it up, the electrostatic field becomes stronger as it stores more energy. Likewise, as the current flows out of the capacitor, discharging it, the potential difference between the two plates decrease and the electrostatic field decreases as the energy moves out of the plates. The property of a capacitor to store charge on its plates in the form of an electrostatic field is called the Capacitance of the capacitor. Not only that, but capacitance is also the property of a capacitor which resists the change of voltage across it. Capacitance is the electrical property of a capacitor and is the measure of a capacitors ability to store an electrical charge onto its two plates with the unit of capacitance being the Farad (abbreviated to F) named after the British physicist Michael Faraday. Capacitance is defined as being that a capacitor has the capacitance of One Farad when a charge of One Coulomb is stored on the plates by a voltage of One volt. Capacitance, C is always positive and has no negative units. However, the Farad is very large units of measurement to use on its own so sub-multiples of the Farad are generally used such as micro-farads, nano farads and Pico-farads, for example [4].

3.2.1 Standard Units of Capacitance

- Microfarad (μF) $1\mu F = 1/1{,}000{,}000 = 0.000001 = 10^{-6}$ F.
- Nanofarad (nF) $1nF = 1/1{,}000{,}000{,}000 = 0.000000001 = 10^{-9}$ F.
- Picofarad (pF) $1pF = 1/1{,}000{,}000{,}000{,}000 = 0.000000000001 = 10^{-12}$ F.

Then using the information above we can construct a simple table to help us convert between pico-Farad (pF), to nano-Farad (nF), to micro-Farad (μF) and to Farads (F) as in Table 3.2.

Table 3.2 Units of Capacitance

Farads (F)	Micro-Farad (μF)	Nano-Farad (nF)	Pico-Farad (pF)
	0.001	1.0	1,000
	0.01	10.0	10,000
	1.0	1,000	1,000,000
	10.0	10,000	
	100	100,000	
0.001	1,000	1,000,000	
0.01	10,000		
0.1	100,000		
1.0	1,000,000		

The capacitance of a parallel plate capacitor is proportional to the area A in metres^2 of the smallest of the two plates and inversely proportional to the distance or separation, d (i.e. the dielectric thickness) given in metres between these two conductive plates. The generalized equation for the capacitance of a parallel plate capacitor is given as: $C = \varepsilon\ (A/d)$ where ε represents the absolute permittivity of the dielectric material being used. The permittivity of the vacuum, ε_o also known as the "permittivity of free space" and it has the value of the constant 8.84×10^{-12} Farads per meter. To make the math's a little easier, this dielectric constant of free space, ε_o which can be written as: $1/(4\pi \times 9\times10^9)$, may also have the units of pico farads (pF) per metre as the constant giving: 8.84 for the value of free space. Note though that the resulting capacitance value will be in pico farads and not in farads.

Generally, the conductive plates of a capacitor are separated by some kind of insulating material or gel rather than a perfect vacuum. When calculating the capacitance of a capacitor, we can consider the permittivity of air, and especially of dry air, as being the same value as a vacuum as they are very close.

3.2.2 The Dielectric of a Capacitor

As well as the overall size of the conductive plates and their distance or spacing apart from each other, another factor which affects the overall capacitance of the device is the type of dielectric material being used, in other words the “Permittivity” (ε) of the dielectric. The conductive plates of a capacitor are generally made of a metal foil or a metal film allowing for the flow of electrons and charge, but the dielectric material used is always an insulator. The various insulating materials used as the dielectric in a capacitor differ in their ability to block or pass an electrical charge. This dielectric material can be made from a number of insulating materials or combinations of these materials with the most common types used being: air, paper, polyester, polypropylene, Mylar, ceramic, glass, oil, or a variety of other materials [4].

The factor by which the dielectric material, or insulator, increases the capacitance of the capacitor compared to air is known as the Dielectric Constant, k and a dielectric material with a high dielectric constant is a better insulator than a dielectric material with a lower dielectric constant. Dielectric constant is a dimensionless quantity since it is relative to free space. The actual permittivity or “complex permittivity” of the dielectric material between the plates is then the product of the permittivity of free space (ε_o) and the relative permittivity (ε_r) of the material being used as the dielectric.

3.2.3 Complex Permittivity

If we take the permittivity of free space, ε_o as our base level and make it equal to one, when the vacuum of free space is replaced by some other type of insulating material, their permittivity of its dielectric is referenced to the base dielectric of free space giving Multiplication factor known as “relative permittivity”, ε_r. So the value of the complex permittivity, ε will always equal to the relative permittivity times one.

Typical units of dielectric permittivity, ε or dielectric constant for common materials are: Pure Vacuum = 1.0000, Air = 1.0006, Paper = 2.5 to 3.5, Glass = 3 to 10, Mica = 5 to 7, Wood = 3 to 8 and Metal Oxide Powders = 6 to 20 etc. This then gives us a final equation for the capacitance of a capacitor. One method used to increase the overall capacitance of a capacitor while keeping its size small is to "interleave" more plates together within a single capacitor body. Instead of just one set of parallel plates, a capacitor can have many individual plates connected together thereby increasing the surface area A of the plates. For a standard parallel plate capacitor as shown above, the capacitor has two plates, labeled A and B. Therefore as the number of capacitor plates is two, we can say that $n = 2$, where "n" represents the number of plates. However, the capacitor may have two parallel plates but only one side of each plate is in contact with the dielectric in the middle as the other side of each plate forms the outside of the capacitor. If we take the two halves of the plates and join them together we effectively only have "one" whole plate in contact with the dielectric. As for a single parallel plate capacitor, $n – 1 = 2 – 1$ which equals 1 as $C = (\varepsilon_o.\varepsilon_r \text{ x } 1 \text{ x } A)/d$ is exactly the same as saying: $C = (\varepsilon_o.\varepsilon_r.A)/d$ which is the standard equation above [4].

3.2.4 Multi-plate Capacitor

If there are five plates connected to one lead (A) and four plates to the other lead (B). Then BOTH sides of the four plates connected to lead B are in contact with the dielectric, whereas only one side of each of the outer plates connected to A is in contact with the dielectric Modern capacitors can be classified according to the characteristics and properties of their insulating dielectric:

- Low Loss, High Stability such as Mica, Low-K Ceramic, Polystyrene.
- Medium Loss, Medium Stability such as Paper, Plastic Film, High-K Ceramic.
- Polarized Capacitors such as Electrolytic's, Tantalum's.

3.2.5 Voltage Rating of a Capacitor

All capacitors have a maximum voltage rating and when selecting a capacitor consideration must be given to the amount of voltage to be applied across the capacitor. The maximum amount of voltage that can be applied to the capacitor without damage to its dielectric material is generally given in the data sheets as: WV, (working voltage) or as WV DC, (DC working voltage). If the voltage applied across the capacitor becomes too great, the dielectric will break down (known as electrical breakdown) and arcing will occur between the capacitor plates resulting in a short circuit. The working voltage of the capacitor depends on the type of dielectric material being used and its thickness. The DC working voltage of a capacitor is just that, the maximum DC voltage and NOT the maximum AC voltage as a capacitor with a DC voltage rating of 100 volts DC cannot be safely subjected to an alternating voltage of 100 volts. Since an alternating voltage has an r.m.s. value of 100 volts but a peak value of over 141 volts. Then a capacitor which is required to operate at 100 volts AC should have a working voltage of at least 200 volts. In practice, a capacitor should be selected so that its working voltage either DC or AC should be at least 50 percent greater than the highest effective voltage to be applied to it. Another factor which affects the operation of a capacitor is Dielectric Leakage. Dielectric leakage occurs in a capacitor as the result of an unwanted leakage current which flows through the dielectric material. Generally, it is assumed that the resistance of the dielectric is extremely high and a good insulator blocking the flow of DC current through the capacitor (as in a perfect capacitor) from one plate to the other. However, if the dielectric material becomes damaged due excessive voltage or over temperature, the leakage current through the dielectric will become extremely high resulting in a rapid loss of charge on the plates and an overheating of the capacitor eventually resulting in premature failure of the capacitor. Then never use a capacitor in a circuit with higher voltages than the capacitor is rated for otherwise it may become hot and explode [4].

CHAPTER IV

DISCUSSION AND CONCLUSION

This research looks at the effects of X RAY radiation on components (RS 56 22 220 Ω resistors, and the 10, 1000μ F electronic capacitors). The aim of these experiments was to record the change in performance so as to predict their behavior in a hostile environments. The importance of these tests arises from their use in the HV filter for the VPT in the End cap calorimeter of CMS, since these components would be tested destructively, it was imperative to obtain as much data as possible. This information was obtained from two media; the Capacitance and Conductivity of the capacitors as well as the Resistance and Parasitic Capacitance of the resistors was measured with current voltage characteristic as ohms law.

This study describes in its first chapter the methodology used for the measurements, each subsequent chapters would be dedicated to the degree of radiation received by the components, after which a comparison between the results would be made, in order to carry out the experiments, two facilities at physics Lab. University of Sudan for science and technology of delivering x-ray radiation using x ray apparatus.

4.1 Methodology

In order to study the trends, a set of 2 nominally identical capacitors and 2 resistors were tested. However, this raised the problem of providing the correct method for identification. It was important therefore, that the method in which each sample should be identified, complied with the next requirements. The method should not be intrusive, i.e. adding or removing anything that could, under some condition, affect the performance of the component before or after the radiation has taken place.

The identification should be clear, unique and permanent (at least for the duration of the study), i.e. the method of identification should not degrade with radiation, to the point that identification between samples becomes impossible. With this in mind, it was concluded that the samples should be contained individually on recipients as well as its identification; therefore, the component was not labeled, or marked in any other way.

4.1.1 Un-irradiated Component Data

Since the aim of this report is to study the effects of radiation on the components, it is obviously clear the need to perform the measurements on the components before any damage is done to them.

Table 4.1 Resistor 56 Ω

V/V ± 0.5	I/mA ± 1
1	9
1.5	26
2	35
2.5	44
3	53
3.5	61
4	70
4.5	79
5	88

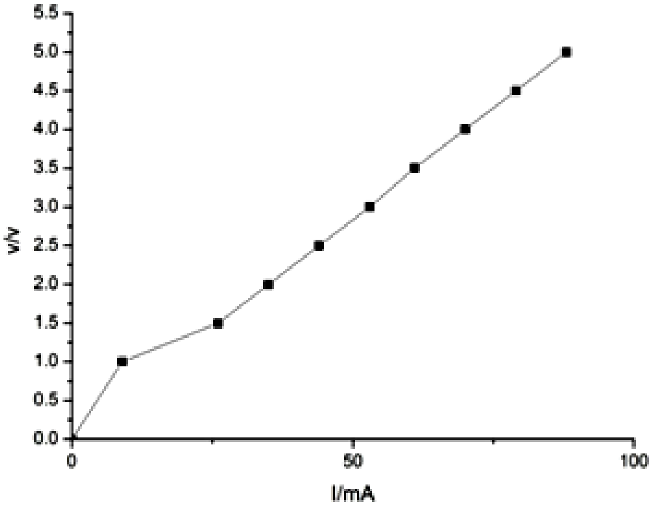

Figure 4.1 Resistor 56 Ω

Table 4.2 Resistor 1770 Ω

V/V ± 0.2	I/mA ± 0.1
0.2	0.07
0.4	0.16
0.6	0.35
0.8	0.50
1.0	0.60
1.2	0.72
1.4	0.85
1.6	0.98
1.8	1.1
2	1.2

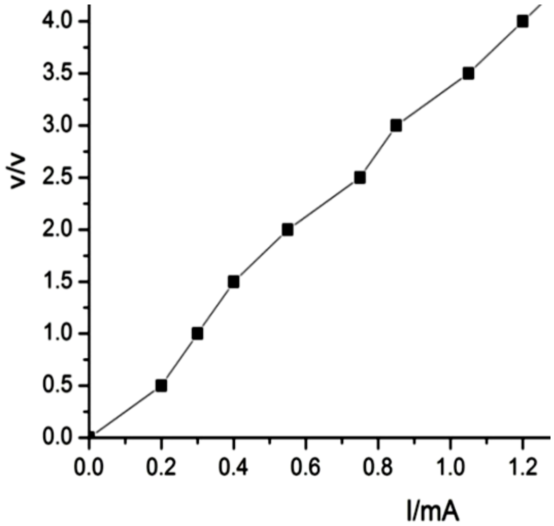

Figure 4.2 Resistor 1770 Ω

Table 4.3 Capacitor 10μ F

V/V ± 1	I/mA ± 0.1
1	4.0
2	7.5
3	10.6
4	14
5	17.4
6	20.7
7	24.2
8	27.8
9	30.6
10	34.1

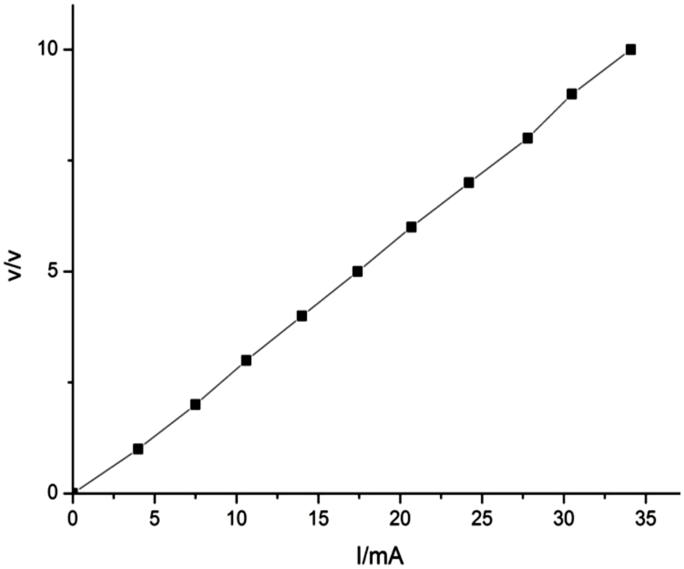

Figure 4.3 Capacitor 10μ F

Table 4.4 Capacitor 1000μ F

V/V ±0.5	I/mA ±0.01
0.5	0.25
1	0.45
1.5	0.6
2	0.75
2.5	0.9
3	1.05
3.5	1.2
4	1.4
4.5	1.55
5	1.75

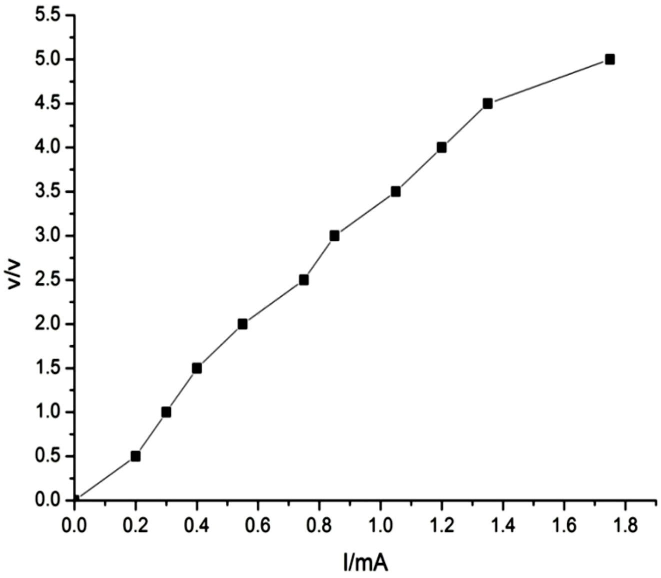

Figure 4.4 Capacitor 1000μ F

4.1.2 First Irradiation

After the first dose of radiation was completed, it was calculated that the components received 35 KV of X-ray radiations at rate of 10 second and cell temperature of 30 C with applied current of 1mA. The components were then subject to the same experiments described on the previous chapter, so as to compare the effects of such dose. After the first dose of radiation, measurements were taken and the results. The first dose of radiation was not very high; in fact, this dose of radiation was well within the radiation resistance of the capacitors.

Table 4.5 Resistor 56 Ω

V/V ± 1	I/mA ± 0.001
1	0.015
2	0.035
3	0.050
4	0.065
5	0.085
6	0.100
7	0.120
8	0.140
9	0.155
10	0.175

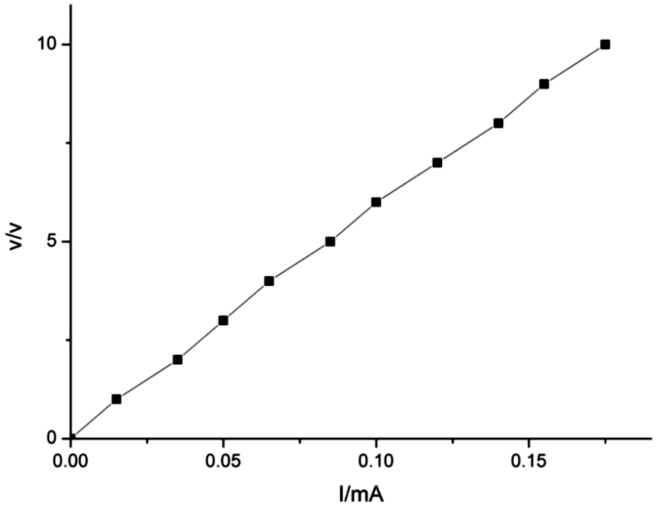

Figure 4.5 Capacitor 56 Ω

Table 4.6 Resistor 1770 Ω.

V/V ± 1	I/mA ± 0.01
1	0.60
2	1.16
3	1.69
4	2.16
5	2.68
6	3.39
7	4.15
8	5.32
9	5.80

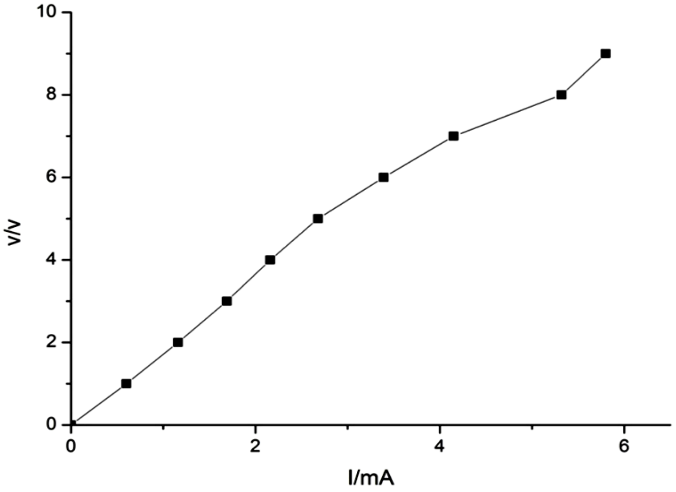

Figure 4.6 Resistor 1770 Ω.

Table 4.7 Capacitor 10 μ F

V/V ±1	I/mA ±0.1
1	4.1
2	7.7
3	11
4	14.3
5	17.5
6	20.9
7	24.3
8	27.7
9	31.5
10	34.5

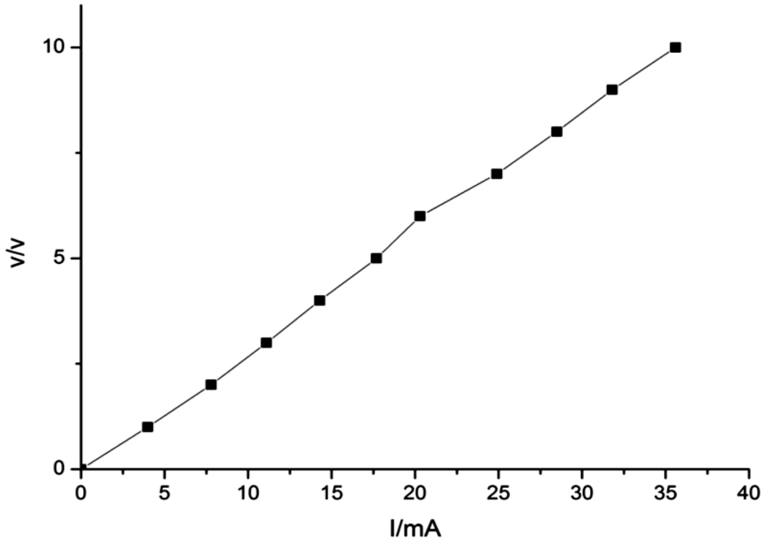

Figure 4.7 Capacitor 10μ F.

Table 4.8 Capacitor 1000 μ F

V/V ±0.5	I/A ±0.01
0.5	0.20
1	0.30
1.5	0.40
2	0.55
2.5	0.75
3	0.85
3.5	1.05
4	1.20
4.5	1.35
5	1.75

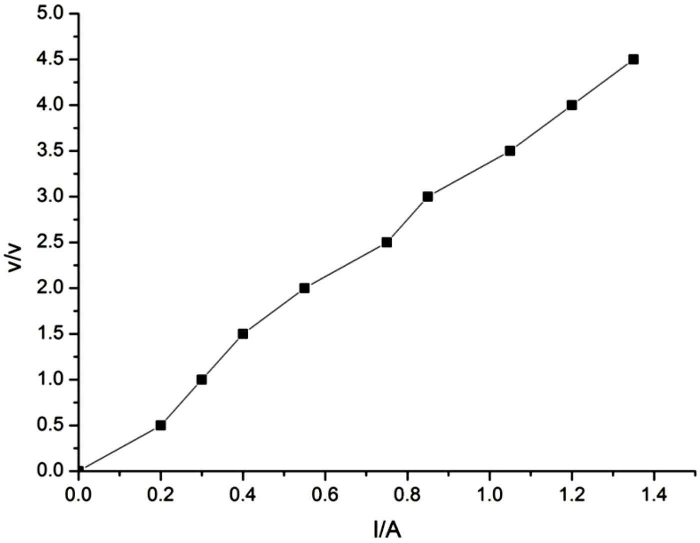

Figure 4.8 Capacitor 1000 μ F.

4.1.3 Second Irradiation

On the preparation for the second dose of radiation, it was estimated that, due to the time irradiation. The components were then premeasured to see the effects of a large dose on their properties.

Table 4.9 Resistor 56 Ω

V/V ± 0.5	I/mA ± 0.1
1	17.3
1.5	25.6
2	34
2.5	43
3	52.1
3.5	60
4	68
4.5	77

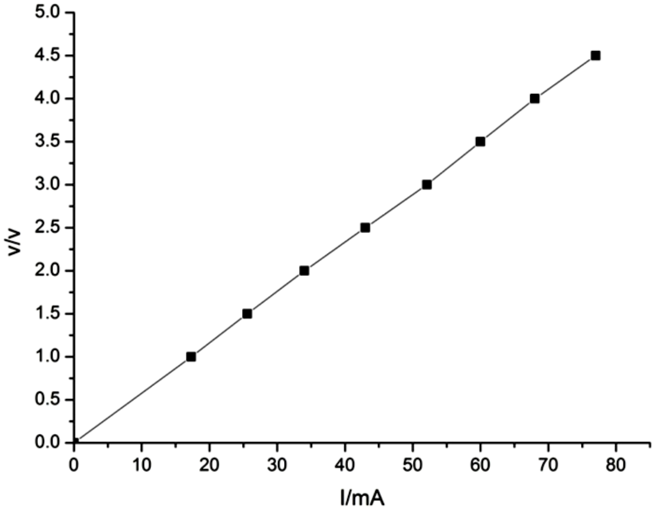

Figure 4.9 Resistor 56 Ω

Table 4.10 Resistor 1770 Ω

V/V ± 1	I/mA ± 1.01
1	0.38
2	0.85
3	1.33
4	1.73
5	2.81
6	3.16
7	3.96
8	4.51
9	4.49
10	5.04

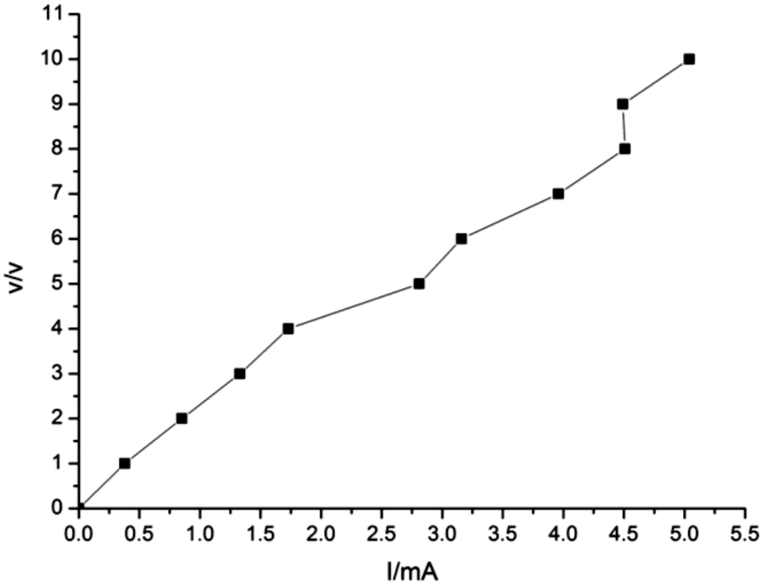

Figure 4.10 Resistor 1770 Ω

Table 4.11 Capacitor 10 μ F

V/V ± 1	I/mA ± 0.1
1	4
2	7.8
3	11.1
4	14.3
5	17.7
6	20.3
7	24.9
8	28.5
9	31.8
10	35.6

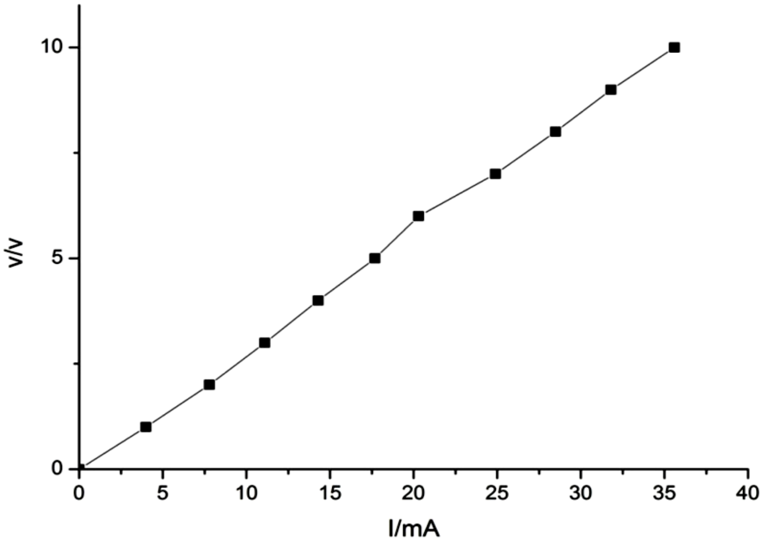

Figure 4.11 Capacitor 10 μ F

Table 4.12 Capacitor 1000 μ F

V/V ± 0.5	I/A ± 0.01
0.5	0.1
1	0.3
1.5	0.45
2	0.6
2.5	0.7
3	0.9
3.5	1.05
4	1.2
4.5	1.35
5	1.5

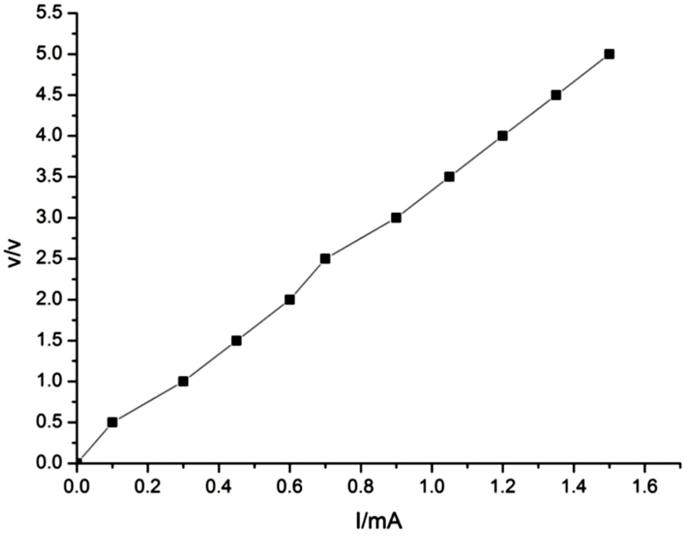

Figure 4.12 Capacitor 1000 μ F

4.2 Results and discussion

The results in the figures show that the impedance of resistors and the capacitance of capacitors are effect by radiation, and the effect increase by increasing the time of exposure. It is a fact that gradual radiation over a period of time has effects different to those from strong radiation on a shorter period, even if the radiation dose is the same. However, due to the length needed for the gradual radiation to which the components will be subject to, makes this experiment unviable. It is therefore, that the results obtained from this paper, should be only considered as a guide It is important to mention again, that measurements of the impedance was dependant on variables outside of control, such as temperature humidity, and even the temperature of the impedance meter. These factors might have altered considerably the results from the measurements.

4.3 Conclusion and recommendation

This research reported on the effects of the radiation on four resistors (56, 1770) ohm and light resistor, and tow capacitors (10, 1000) μ F, before and after each dose of radiation, we found the impedance and capacitance decrease after influence radiation.

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