**A**

**PROJECT**

**ON**

**THE DESIGN AND CONSTRUCTION OF AN ELECTROPHORESIS MACHINE**

**BY**

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**CHAPTER ONE**

**1. O INTRODUCTION**

Electrophoresis machine is a machine used in detecting the genotype of human being which basically is AA, AS, SS.

For many years, people died of many diseases they have no knowledge of nor do they have idea of how to curve. It was not clear to them if the death was as a result of a single disease or multiple of diseases.   
People worked tirelessly and laboriously but the produce from their farm was not enough to feed their family not to talk of selling them to generate a sustainable income.  
Many couple witnessed sudden death of their child at birth or at their teen, without knowing the cause or how to avert it.  
The advent of the knowledge of electrophoresis threw light on the genotypic constitution of cells. This gave rise to hybrid as a result of cross bred, which eventually solved the problem of low yield (harvest).  
The knowledge also goes a long way to diagnose the causes of different diseases that causes death, the likes of cancer called multiple myelona, sickle cell, diseases at birth, chronic liver disease etc.  
The knowledge did not only unravel the causes but also led to the development of authentic cure. Also intending couple’s eyes were opened to their genotype status, giving them room to decide on whether to go on with their marriage or not, as the likelihood or otherwise of having sickler as a child is made know to them.

**1.2 BRIEF HISTORY OF ELECTROPHORESIS MACHINE**

Historical fabrication of electrophoresis defined with the work of Arne Tiselius in the 1930s, and new separation processes and chemical analysis technique based on electrophoresis continued to be developed into the 21st century. Tiselius with the support from Rockefeller foundation developed the Tiselius apparatus for moving boundary electrophoresis which was described in 1937 is the well known paper “a new apparatus for electrophoretic analysis of colloidal mixtures”. The method spread slowly until the advent of effective zone electrophoresis method in the 1940s and 1950s, which used filter paper or gel as a supporting media. By the 1960s, increasingly sophisticated gel electrophoresis made it possible to separate biological based on minute physical and chemical differences, helping to drive the rise of molecular biology. Gel electrophoreses and related method became the basis for wide range of biochemical methods such as protein finger printing, southern blot, and similar blotting procedure, DNA sequencing and many more.

**ELECTROPHOSIS BEFORE TISELIUS**

Early work with the basis principle of electrophoresis dates to the early 19th century, based on Faraday’s law of electrolysis proposed in the late 18th century and other early electrochemistry. Experiments by Johann Wilhelm Hiltort, Walter Nernst, and Friedrich Kohlrausch to measure the properties and behavior of small ions moving through aqueous solutions under the influence of an electric field led to general mathematical description of the electrochemistry of aqueous solutions.

Kohlrausch created equation for varying concentrations of charged particles moving through solution including sharp moving boundaries of migrating particles. By the beginning of the 20th century, electrochemist had found that such moving boundaries of charged particles could be created with u-shaped glass tubes.

By the late 1940s, new electrophoresis methods were beginning to address some of the short comings of the moving boundaries electrophoresis or Tiselius apparatus, which was not capable of completely separating electrophoretically similar compounds.

Rather than charged molecules moving freely through solutions, the new methods used solid or gel matrices to separate compounds into discrete and stable bands. In 1950 Tiselius dubbed these method ‘zone electrophoresis.

Zone electrophoresis found widespread application in biochemistry after oliver Smithies introduced starch gel as an electrophoretic substrate in 1955. Starch gel enabled the efficient separation of proteins making it possible with relatively simple technology to analyze complex protein mixtures and identify minute differences in related proteins.

**1.3 BACKGROUND OF STUDY**

Formerly, electrophoresis was constructed without the use of resistors. But today, due to advancement in electronic chips, electrophoresis machine has metamorphosed into sophisticated devices that have the capacity to separate blood and classifying them into types, example AA, AS, SS.

Locally, electrophoresis is typically made of large plastics or metallic cubic box. The plastic will be cut in such a way that their will be division that will separate the tank from the engine or two cubic boxes and one serving as the tank and the other, the engine.

Most locally constructed electrophoreses machine do not make use of resistors and this cause a lot of damage to the machine electrically and functionally. Electrically, it can destroy the diode due to high voltage and functionally, it can tear the cellulose acetate paper in the separation tank.

The advantage of this locally made electrophoreses machine is that it is cheap in the cost of production due to the purchases of the components within our locality.

With the arrival of electrophoreses machine with resistors, locally made electrophoreses machines are gradually becoming obsolete especially the one without resistors since all its necessary features can equally be achieved by the type with resistors even at cheaper cost.

**1.4 PROJECT AIMS AND OBJECTIVES**

The objective of this project is to construct an electrophoresis machine that is inexpensive, reliable, safe, fast, easy to construct and operate.

The cost of this work will be reduced by using non-critical readily available materials and electronic components. The total components that will be used in this project will be very few when compared to other contemporary electrophoreses machine.

The reliability will be achieved by avoidance of complicated circuit. The project will contain one circuit and resistors as the active component and soldering circuit board construction technique will be employed.

Automated voltage regulator, this will be achieved with the help of the resistors. Instead of increased voltage passing into the machine and tank to destroy the diode and acetate paper, the resistor will it to the normal voltage useable by the machine.

Safety is another factor that will be considered by the designer. The circuit is to have operating voltage of about 220volts. This will eliminate the risk of high voltage leakage during fault to the main circuit.

Finally, the circuit will be designed to be operated by any body. It will not need to be programmed or synchronized before proper operation, that is, it is to be users friendly.

**CHAPTER TWO**

**2.0 LITERATURE REVIEW**

This brief overview outlines the development of electrophoresis from its first observation some 200 years ago via conventional gels for macromolecule separation and capillary electrophoresis (CE) to current developments centred around lab-on-chip. By definition electrophoresis separates ionic molecules so it is ideal for the separation of simple ions to macromolecules, which are mostly ionic in nature. Most important classes of small biomolecules e.g. amino acids, nucleotides and sugars are highly charged and are easy to separate by electrophoresis. However prior to the development of CE, the application of electrophoresis was limited since it required indirect detection which was at best only semi quantitative and HPLC came to dominate their measurement. Macromolecules, such as RNA, DNA and protein, are readily separated by electrophoresis and conventional electrophoresis still dominates their separation.  
  
Today electrophoresis remains a very important, if somewhat neglected, analytical technique and is now seen to have three dominant modes i.e. planar, capillary and nano separation formats. However it is just over 200 years since Ferdinand Frederic Reuss published his observations of the migration of colloidal clay particles when an electric field was applied to the solution in which they were suspended1. In the same experiment he also found that there was an opposite flow of water (electroosmosis) associated with the movement of the clay particles. These observations are considered to be the origins of what we now call electrophoresis. In 1816  
Porret quantified the flow of water (electroosmosis) through filter paper impregnated with egg albumin. Within a few years of Reuss’s observation the movement of colored proteins, such as hemoglobin, had been observed. The early history of electrophoresis has been told by Righetti2 and its relevance to the discovery and analysis of proteins has been reviewed by Perrett.  
Electrophoresis is the migration of charged particles under the influence of an electric field. Electrophoresis is a method that separates macromolecules – either nucleic acids or protein – on the basis of size, electric charge and other physical properties. ELECTRO refers to the energy of electricity. PHORESIS, from the Greek verb PHOROS, means “to carry across”. Thus, electrophoresis refers to the technique in which molecules are forced across a span of gel, motivated by an electric current. In 1955, smithies was the first to introduced a major development in electrophoresis by using remarkable resolving power of starch gel electrophoresis for serum protein.  
  
Electrophoresis machine is a machine that supply a voltage of 200V its tank containing cathode electrode, anode electrode and a buffer solution of pH 8.6 and the blood serum to be tested. Many important biological molecules such as Amino acids, exist at any given pH solution as electrically charged particle either as cations (+) or anion (-). Depending on the nature of the net charge, the charged particles will migrate either to the cathode or to the anode.  
  
To completely understand the separation of charged particles in electrophoresis, it is important to look at some simple equation relating to electrophoresis. When potential difference (voltage) is applied across the electrodes, it generate a potential gradient (E), which is the applied voltage (V) divided by the distance (d) between the electrodes.  
E = v/d  
When the potential gradient E is applied, the some on a molecule bearing a charge of q coulombs is Eq newtons.  
F = Eq.  
It is this force that drives a charged molecule towards an electrode.  
  
There is also a frictional resistance that slows down the movement of this charged molecule. The frictional force is a measure of the hydrodynamic size of the molecule, the shape of the molecule, the pore size of the medium in which electrophoresis is taking place and viscosity of the buffer. The velocity (v) of a charged molecule in an electric field is given by the equation.  
V = Eq  
f  
where f is the frictional co-efficient.  
In electrophoresis, the force moving the micro molecule (nucleic acids or proteins) is the electrical potential, E. The electrophoresis mobility (???) of an ion is the ratio of the velocity of the particle, (v) to the electrical potential.  
= V  
E  
Electrophoresis mobility is also equal to the net charge of the molecule, Z divided by the frictional coefficient, f.  
= Z  
When a potential difference is applied, molecules with different overall charges will begin to separate due to their different electrophoresis mobilities. Even molecules with similar charges will begin to separate if they have different molecular sizes. Since they will experience different frictional forces.   
The current in a solution between the electrodes is conducted mainly by the buffer ions with a small proportion being conducted by the sample ions. Ohm’s law expresses the relationship between current (I), voltage (V), and resistance (R).  
R = V  
This equation demonstrates that it is possible to accelerate an electrophonetic separation by increasing the applied voltage, which would result in a corresponding increase in the current flow. The distance migrated will be proportional to both current and time.  
However, increasing the voltage would ignore one of the major problems for most forms of electrophoresis, namely the generation of heat. During electrophoresis the power (W, watts) generated in the supporting medium is given by:  
W = 12 R

It is generally made up of components such as; power switch, selector switch, capacitor, diodes, resistors, soldering lead, fuse holder, fuse, transparent plastic i.e. polyvinyl chloride plastic, power cord, connecting wire and AV wire, vero board, metallic cubic box, cellulose acetate paper, buffer solution, super glue, etc.  
**2.1.1 TRANSFORMER**

A **transformer** is a static electrical device that transfers energy by [inductive coupling](http://en.wikipedia.org/wiki/Inductive_coupling) between its winding circuits. A varying [current](http://en.wikipedia.org/wiki/Electric_current) in the primary winding creates a varying [magnetic flux](http://en.wikipedia.org/wiki/Magnetic_flux) in the transformer's [core](http://en.wikipedia.org/wiki/Magnetic_core) and thus a varying magnetic flux through the secondary winding. This varying magnetic flux [induces](http://en.wikipedia.org/wiki/Electromagnetic_induction) a varying [electromotive force (emf)](http://en.wikipedia.org/wiki/Electromotive_force) or [voltage](http://en.wikipedia.org/wiki/Voltage) in the secondary winding.

Transformers range in size from thumbnail-sized used in microphones to units weighing hundreds of tons interconnecting the [power grid](http://en.wikipedia.org/wiki/Power_grid). A wide range of transformer designs are used in electronic and electric power applications. Transformers are essential for the [transmission](http://en.wikipedia.org/wiki/Electric_power_transmission), [distribution](http://en.wikipedia.org/wiki/Electric_power_distribution), and utilization of [electrical energy](http://en.wikipedia.org/wiki/Electric_power).

Transformers are used to increase voltage before transmitting electrical energy over long distances through [wires](http://en.wikipedia.org/wiki/Wire). Wires have [resistance](http://en.wikipedia.org/wiki/Electrical_resistance) which loses energy through joule heating at a rate corresponding to square of the current. By transforming power to a higher voltage transformers enable economical transmission of power and distribution. Consequently, transformers have shaped the [electricity supply industry](http://en.wikipedia.org/wiki/Electrical_power_industry), permitting generation to be located remotely from points of [demand](http://en.wikipedia.org/wiki/Electrical_load). All but a tiny fraction of the world's electrical power has passed through a series of transformers by the time it reaches the consumer

Transformers are also used extensively in [electronic products](http://en.wikipedia.org/wiki/Consumer_electronics) to step-down the supply voltage to a level suitable for the low voltage circuits they contain. The transformer also electrically isolates the end user from contact with the supply voltage.

Signal and audio transformers are used to couple stages of [amplifiers](http://en.wikipedia.org/wiki/Amplifier) and to match devices such as [microphones](http://en.wikipedia.org/wiki/Microphone) and [record players](http://en.wikipedia.org/wiki/Record_player) to the input of amplifiers. Audio transformers allowed [telephone](http://en.wikipedia.org/wiki/Telephone) circuits to carry on a [two-way conversation](http://en.wikipedia.org/wiki/Hybrid_coil) over a single pair of wires. A [balun](http://en.wikipedia.org/wiki/Balun) transformer converts a signal that is referenced to ground to a signal that has [balanced voltages to ground](http://en.wikipedia.org/wiki/Balanced_line), such as between external cables and internal circuits. We have the ideal transformer and the real transformer.

In some applications increased leakage is desired, and long magnetic paths, air gaps, or magnetic bypass shunts may deliberately be introduced in a transformer design to limit the [short-circuit](http://en.wikipedia.org/wiki/Short-circuit) current it will supply. Leaky transformers may be used to supply loads that exhibit [negative resistance](http://en.wikipedia.org/wiki/Negative_resistance), such as [electric arcs](http://en.wikipedia.org/wiki/Electric_arc), [mercury vapor lamps](http://en.wikipedia.org/wiki/Mercury_vapor_lamp), and [neon signs](http://en.wikipedia.org/wiki/Neon_sign) or for safely handling loads that become periodically short-circuited such as [electric arc welders](http://en.wikipedia.org/wiki/Arc_welding).

Air gaps are also used to keep a transformer from saturating, especially audio-frequency transformers in circuits that have a DC component flowing through the windings.

Knowledge of leakage inductance is for example useful when transformers are operated in parallel. It can be shown that if the percent impedance (Z) and associated winding leakage reactance-to-resistance (X/R) ratio of two transformers were hypothetically exactly the same, the transformers would share power in proportion to their respective volt-ampere ratings (e.g. 500 [kVA](http://en.wikipedia.org/wiki/Kilovolt-ampere) unit in parallel with 1,000 kVA unit, the larger unit would carry twice the current). However, the impedance tolerances of commercial transformers are significant.

a practical transformer's physical behavior may be represented by an [equivalent circuit](http://en.wikipedia.org/wiki/Equivalent_circuit) model, which can incorporate an ideal transformer.

Winding joule losses and leakage reactances are represented by the following series loop impedances of the model:

* Primary winding: *R*P, *X*P
* Secondary winding: *R*S, *X*S.

In normal course of circuit equivalence transformation, *R*S and *X*S are in practice usually referred to the primary side by multiplying these impedances by the turns ratio squared, (*N*P/*N*S)2 = a2.

Real transformer equivalent circuit

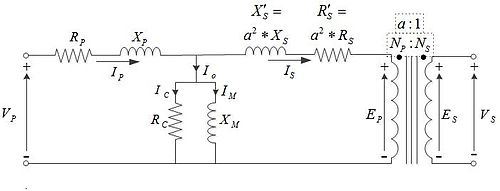
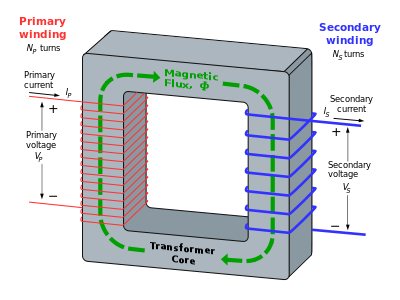
Core loss and reactance is represented by the following shunt leg impedances of the model:

* Core or iron losses: *R*C
* Magnetizing reactance: *X*M.

*R*C and *X*M are collectively termed the magnetizing branch of the model.

Core losses are caused mostly by hysteresis and eddy current effects in the core and are proportional to the square of the core flux for operation at a given frequency. The finite permeability core requires a magnetizing current *I*M to maintain mutual flux in the core. Magnetizing current is in phase with the flux, the relationship between the two being non-linear due to saturation effects. However, all impedances of the equivalent circuit shown are by definition linear and such non-linearity effects are not typically reflected in transformer equivalent circuits. With [sinusoidal](http://en.wikipedia.org/wiki/Sinusoidal) supply, core flux lags the induced emf by 90°. With open-circuited secondary winding, magnetizing branch current *I*0 equals transformer no-load current.

The resulting model, though sometimes termed 'exact' equivalent circuit based on [linearity](http://en.wikipedia.org/wiki/Linearity) assumptions, retains a number of approximations. Analysis may be simplified by assuming that magnetizing branch impedance is relatively high and relocating the branch to the left of the primary impedances. This introduces error but allows combination of primary and referred secondary resistances and reactance by simple summation as two series impedances.Transformer equivalent circuit impedance and transformer ratio parameters can be derived from the following tests: [Open-circuit test](http://en.wikipedia.org/wiki/Open_circuit_test),[short-circuit test](http://en.wikipedia.org/wiki/Short_circuit_test), winding resistance test, and transformer ratio test.



**2.1.2 DIODE**

In electronics a diode is a semi-conductor that converts A.C to D.C [alternating current to a direct current]. A diode is a type of two terminal electronic components with a nonlinear current voltage characteristic. In semiconductor diode, the common type today is a crystalline piece of conductor material connected to two electrical terminals. A vacuum tube diode [now rarely used except in some high power technologies is a vacuum tube with two electrodes: a plate and a cathode.]

The most common function of a diode is a to allow an electric current to pass in one direction [ called the diode’s forward direction while blocking current in the opposite direction, that is the reverse direction], thus the diode can be brought of as an electronic version of a check value. This unidirectional behavior is called rectification and it is used to convert alternating current to direct current and to extract modulation from radio signal in radio receivers. However, diode can have more complicated behavior than this simple on-off action. Semi-conductor diode do not begin conducting electricity until a certain threshold voltage is present in the forward direction [ a state in which the diode is said to be forward]. The voltage drops across a forward biased diode varies only a little with the current, and is a function of temperature; effect can be used as a temperature sensor or voltage reference. Semi conductor diodes have nonlinear electrical characteristics, which can be tailored by varying the construction of their P-N junction. These are exploited in special purpose diode that can perform many different functions. For example, diode are used to regulate voltage [zener diodes], to protect circuits from high voltage surges [Avalanche diodes], to electronically tune radio frequency oscillations [ tunnel diodes, gum diodes, IMPACT diodes], and to produce light [light emitting diodes]. Tunnel diodes exhibit negative resistance, which makes them useful in some types of circuits.

Diodes were among the first semi-conductor electronic devices. The discovery of crystals rectifying abilities was made by germane physicist Ferdinand Braun in 1874, the first semi conductor diodes, called cat’s whisker diodes, developed around 1906, were made of mineral crystals such as galena. Today most diode are made of silicon, but other semi conductors such as German are sometimes used.

There are several types of [p–n junction diodes](http://en.wikipedia.org/wiki/P%E2%80%93n_diode), which either emphasize a different physical aspect of a diode often by geometric scaling, doping level, choosing the right electrodes, are just an application of a diode in a special circuit, or are really different devices like the Gunn and laser diode and the [MOSFET](http://en.wikipedia.org/wiki/MOSFET):

Normal (p–n) diodes, which operate as described above, are usually made of doped [silicon](http://en.wikipedia.org/wiki/Silicon) or, more rarely, [germanium](http://en.wikipedia.org/wiki/Germanium). Before the development of silicon power rectifier diodes, [cuprous oxide](http://en.wikipedia.org/wiki/Cuprous_oxide) and later [selenium](http://en.wikipedia.org/wiki/Selenium) was used; its low efficiency gave it a much higher forward voltage drop (typically 1.4 to 1.7 V per "cell", with multiple cells stacked to increase the peak inverse voltage rating in high voltage rectifiers), and required a large heat sink (often an extension of the diode's metal [substrate](http://en.wikipedia.org/wiki/Substrate_%28semiconductor%29)), much larger than a silicon diode of the same current ratings would require. The vast majority of all diodes are the p–n diodes found in [CMOS](http://en.wikipedia.org/wiki/CMOS)[integrated circuits](http://en.wikipedia.org/wiki/Integrated_circuits), which include two diodes per pin and many other internal diodes.

Diode symbol

**2.1.3 CAPACITOR**

A capacitor (originally known as a condenser) is a[passive](http://en.wikipedia.org/wiki/Passivity_%28engineering%29)[two-terminal](http://en.wikipedia.org/wiki/Terminal_%28electronics%29)electrical component used to store [energy](http://en.wikipedia.org/wiki/Energy)[electrostatically](http://en.wikipedia.org/wiki/Electrostatic) in an [electric field](http://en.wikipedia.org/wiki/Electric_field). The forms of practical capacitors vary widely, but all contain at least two [electrical conductors](http://en.wikipedia.org/wiki/Electrical_conductor) separated by a [dielectric](http://en.wikipedia.org/wiki/Dielectric) ([insulator](http://en.wikipedia.org/wiki/Insulator_%28electricity%29)); for example, one common construction consists of metal foils separated by a thin layer of insulating film. Capacitors are widely used as parts of [electrical circuits](http://en.wikipedia.org/wiki/Electrical_circuit) in many common electrical devices.

When there is a [potential difference](http://en.wikipedia.org/wiki/Potential_difference) (voltage) across the conductors, a static [electric field](http://en.wikipedia.org/wiki/Electric_field) develops across the dielectric, causing positive charge to collect on one plate and negative charge on the other plate. [Energy](http://en.wikipedia.org/wiki/Energy) is stored in the electrostatic field. An ideal capacitor is characterized by a single constant value, [capacitance](http://en.wikipedia.org/wiki/Capacitance). This is the ratio of the [electric charge](http://en.wikipedia.org/wiki/Electric_charge) on each conductor to the potential difference between them. The [SI](http://en.wikipedia.org/wiki/SI) unit of capacitance is the [farad](http://en.wikipedia.org/wiki/Farad), which is equal to one [coulomb](http://en.wikipedia.org/wiki/Coulomb) per [volt](http://en.wikipedia.org/wiki/Volt).

The capacitance is greatest when there is a narrow separation between large areas of conductor, hence capacitor conductors are often called plates, referring to an early means of construction. In practice, the dielectric between the plates passes a small amount of [leakage current](http://en.wikipedia.org/wiki/Leakage_%28electronics%29) and also has an electric field strength limit, the [breakdown voltage](http://en.wikipedia.org/wiki/Breakdown_voltage). The conductors and [leads](http://en.wikipedia.org/wiki/Lead_%28electronics%29) introduce an undesired [inductance](http://en.wikipedia.org/wiki/Equivalent_series_inductance) and [resistance](http://en.wikipedia.org/wiki/Equivalent_series_resistance).

Capacitors are widely used in [electronic circuits](http://en.wikipedia.org/wiki/Electronic_circuit) for blocking [direct current](http://en.wikipedia.org/wiki/Direct_current) while allowing [alternating current](http://en.wikipedia.org/wiki/Alternating_current) to pass. In [analog filter](http://en.wikipedia.org/wiki/Analog_filter) networks, they smooth the output of [power supplies](http://en.wikipedia.org/wiki/Power_supply). In [resonant circuits](http://en.wikipedia.org/wiki/LC_circuit) they tune [radios](http://en.wikipedia.org/wiki/Radio) to particular [frequencies](http://en.wikipedia.org/wiki/Frequency). In [electric power transmission](http://en.wikipedia.org/wiki/Electric_power_transmission) systems they stabilize voltage and power flow

Capacitor is a device used to store electrical charge. They are used with resistor in timing circuits because it takes time for a capacitor to full with charge. They are used to smooth varying D.C [direct current] supplies by acting as a reservoir of charge. They are also used in filter circuits because capacitors easily pass A.C [ alternating current] charging signals but block D.C[ constant] signals.

## Capacitor types

## Practical capacitors are available commercially in many different forms. The type of internal dielectric, the structure of the plates and the device packaging all strongly affect the characteristics of the capacitor, and its applications.

Values available range from very low (picofarad range; while arbitrarily low values are in principle possible, stray (parasitic) capacitance in any circuit is the limiting factor) to about 5 kF [super capacitors](http://en.wikipedia.org/wiki/Electric_double-layer_capacitor).

Above approximately 1 microfarad electrolytic capacitors are usually used because of their small size and low cost compared with other technologies, unless their relatively poor stability, life and polarized nature make them unsuitable. Very high capacity super capacitors use a porous carbon-based electrode material.

### Dielectric material

Capacitor materials. From left: multilayer ceramic, ceramic disc, multilayer polyester film, tubular ceramic, polystyrene, metalized polyester film, aluminum electrolytic. Major scale divisions are in centimeters.

Most types of capacitor include a dielectric spacer, which increases their capacitance. These dielectrics are most often insulators. However, low capacitance devices are available with a vacuum between their plates, which allows extremely high voltage operation and low losses. [Variable capacitors](http://en.wikipedia.org/wiki/Variable_capacitor) with their plates open to the atmosphere were commonly used in radio tuning circuits. Later designs use polymer foil dielectric between the moving and stationary plates, with no significant air space between them.

In order to maximize the charge that a capacitor can hold, the dielectric material needs to have as high a [permittivity](http://en.wikipedia.org/wiki/Permittivity) as possible, while also having as high a [breakdown voltage](http://en.wikipedia.org/wiki/Breakdown_voltage) as possible.

Several solid dielectrics are available, including [paper](http://en.wikipedia.org/wiki/Paper), [plastic](http://en.wikipedia.org/wiki/Plastic), [glass](http://en.wikipedia.org/wiki/Glass), [mica](http://en.wikipedia.org/wiki/Mica) and [ceramic](http://en.wikipedia.org/wiki/Ceramic) materials. Paper was used extensively in older devices and offers relatively high voltage performance. However, it is susceptible to water absorption, and has been largely replaced by plastic [film capacitors](http://en.wikipedia.org/wiki/Film_capacitor). Plastics offer better stability and aging performance, which makes them useful in timer circuits, although they may be limited to low [operating temperatures](http://en.wikipedia.org/wiki/Operating_temperature) and frequencies. Ceramic capacitors are generally small, cheap and useful for high frequency applications, although their capacitance varies strongly with voltage and they age poorly. They are broadly categorized as [class 1 dielectrics](http://en.wikipedia.org/wiki/EIA_Class_1_dielectric), which have predictable variation of capacitance with temperature or [class 2 dielectrics](http://en.wikipedia.org/wiki/EIA_Class_2_dielectric), which can operate at higher voltage. Glass and mica capacitors are extremely reliable, stable and tolerant to high temperatures and voltages, but are too expensive for most mainstream applications. Electrolytic capacitors and [supercapacitors](http://en.wikipedia.org/wiki/Supercapacitor) are used to store small and larger amounts of energy, respectively, ceramic capacitors are often used in [resonators](http://en.wikipedia.org/wiki/LC_circuit), and [parasitic capacitance](http://en.wikipedia.org/wiki/Parasitic_capacitance) occurs in circuits wherever the simple conductor-insulator-conductor structure is formed unintentionally by the configuration of the circuit layout.

Electrolytic capacitors use an [aluminum](http://en.wikipedia.org/wiki/Aluminum) or [tantalum](http://en.wikipedia.org/wiki/Tantalum) plate with an oxide dielectric layer. The second electrode is a liquid [electrolyte](http://en.wikipedia.org/wiki/Electrolyte), connected to the circuit by another foil plate. Electrolytic capacitors offer very high capacitance but suffer from poor tolerances, high instability, gradual loss of capacitance especially when subjected to heat, and high leakage current. [Poor quality capacitors](http://en.wikipedia.org/wiki/Capacitor_plague) may leak electrolyte, which is harmful to printed circuit boards. The conductivity of the electrolyte drops at low temperatures, which increases equivalent series resistance. While widely used for power-supply conditioning, poor high-frequency characteristics make them unsuitable for many applications. Electrolytic capacitors will self-degrade if unused for a period (around a year), and when full power is applied may short circuit, permanently damaging the capacitor and usually blowing a fuse or causing failure of rectifier diodes (for instance, in older equipment, arcing in rectifier tubes). They can be restored before use (and damage) by gradually applying the operating voltage, often done on antique [vacuum tube](http://en.wikipedia.org/wiki/Vacuum_tube) equipment over a period of 30 minutes by using a variable transformer to supply AC power. Unfortunately, the use of this technique may be less satisfactory for some solid state equipment, which may be damaged by operation below its normal power range, requiring that the power supply first be isolated from the consuming circuits. Such remedies may not be applicable to modern high-frequency power supplies as these produce full output voltage even with reduced input.

Tantalum capacitors offer better frequency and temperature characteristics than aluminum, but higher [dielectric absorption](http://en.wikipedia.org/wiki/Dielectric_absorption) and leakage.

[**Polymer capacitors**](http://en.wikipedia.org/wiki/Polymer_capacitor) (OS-CON, OC-CON, KO, AO) use solid conductive polymer (or polymerized organic semiconductor) as electrolyte and offer longer life and lower [ESR](http://en.wikipedia.org/wiki/Equivalent_series_resistance) at higher cost than standard electrolytic capacitors.

A [Feedthrough](http://en.wikipedia.org/wiki/Feedthrough) is a component that, while not serving as its main use, has capacitance and is used to conduct signals through a circuit board.

Several other types of capacitor are available for specialist applications. [Supercapacitors](http://en.wikipedia.org/wiki/Supercapacitor) store large amounts of energy. Supercapacitors made from carbon [aerogel](http://en.wikipedia.org/wiki/Aerogel), carbon nanotubes, or highly porous electrode materials, offer extremely high capacitance (up to 5 kF as of 2010) and can be used in some applications instead of [rechargeable batteries](http://en.wikipedia.org/wiki/Rechargeable_battery). [Alternating current](http://en.wikipedia.org/wiki/Alternating_current) capacitors are specifically designed to work on line (mains) voltage AC power circuits. They are commonly used in [electric motor](http://en.wikipedia.org/wiki/Electric_motor) circuits and are often designed to handle large currents, so they tend to be physically large. They are usually ruggedly packaged, often in metal cases that can be easily grounded/earthed. They also are designed with [direct current](http://en.wikipedia.org/wiki/Direct_current) breakdown voltages of at least five times the maximum AC voltage.

The arrangement of plates and dielectric has many variations depending on the desired ratings of the capacitor. For small values of capacitance (microfarads and less), ceramic disks use metallic coatings, with wire leads bonded to the coating. Larger values can be made by multiple stacks of plates and disks. Larger value capacitors usually use a metal foil or metal film layer deposited on the surface of a dielectric film to make the plates, and a dielectric film of impregnated [paper](http://en.wikipedia.org/wiki/Electrical_insulation_paper) or plastic – these are rolled up to save space. To reduce the series resistance and inductance for long plates, the plates and dielectric are staggered so that connection is made at the common edge of the rolled-up plates, not at the ends of the foil or metalized film strips that comprise the plates.

The assembly is encased to prevent moisture entering the dielectric – early radio equipment used a cardboard tube sealed with wax. Modern paper or film dielectric capacitors are dipped in a hard thermoplastic. Large capacitors for high-voltage use may have the roll form compressed to fit into a rectangular metal case, with bolted terminals and bushings for connections. The dielectric in larger capacitors is often impregnated with a liquid to improve its properties.

Capacitors may have their connecting leads arranged in many configurations, for example axially or radially. "Axial" means that the leads are on a common axis, typically the axis of the capacitor's cylindrical body – the leads extend from opposite ends. Radial leads might more accurately be referred to as tandem; they are rarely actually aligned along radii of the body's circle, so the term is inexact, although universal. The leads (until bent) are usually in planes parallel to that of the flat body of the capacitor, and extend in the same direction; they are often parallel as manufactured.

Small, cheap discoidal [ceramic capacitors](http://en.wikipedia.org/wiki/Ceramic_capacitor) have existed since the 1930s, and remain in widespread use. Since the 1980s, [surface mount](http://en.wikipedia.org/wiki/Surface_mount) packages for capacitors have been widely used. These packages are extremely small and lack connecting leads, allowing them to be soldered directly onto the surface of [printed circuit boards](http://en.wikipedia.org/wiki/Printed_circuit_boards). Surface mount components avoid undesirable high-frequency effects due to the leads and simplify automated assembly, although manual handling is made difficult due to their small size.

Mechanically controlled variable capacitors allow the plate spacing to be adjusted, for example by rotating or sliding a set of movable plates into alignment with a set of stationary plates. Low cost variable capacitors squeeze together alternating layers of aluminum and plastic with a [screw](http://en.wikipedia.org/wiki/Trimmer_%28electronics%29). Electrical control of capacitance is achievable with [varactors](http://en.wikipedia.org/wiki/Varactor) (or varicaps), which are [reverse-biased](http://en.wikipedia.org/wiki/Reverse-biased)[semiconductor diodes](http://en.wikipedia.org/wiki/Semiconductor_diode) whose depletion region width varies with applied voltage. They are used in [phase-locked loops](http://en.wikipedia.org/wiki/Phase_locked_loop), amongst other applications.

## Capacitor markings

Most capacitors have numbers printed on their bodies to indicate their electrical characteristics. Larger capacitors like electrolytics usually display the actual capacitance together with the unit (for example, **220 μF**). Smaller capacitors like ceramics, however, use a shorthand consisting of three numbers and a letter, where the numbers show the capacitance in [pF](http://en.wikipedia.org/wiki/Picofarad) (calculated as XY × 10Z for the numbers XYZ) and the letter indicates the tolerance (J, K or M for ±5%, ±10% and ±20% respectively).

Additionally, the capacitor may show its working voltage, temperature and other relevant characteristics.

### Example

A capacitor with the text **473K 330V** on its body has a capacitance of 47 × 103 pF = 47 nF (±10%) with a working voltage of 330 V.

## Applications

### Energy storage

A capacitor can store electric energy when disconnected from its charging circuit, so it can be used like a temporary [battery](http://en.wikipedia.org/wiki/Battery_%28electricity%29). Capacitors are commonly used in electronic devices to maintain power supply while batteries are being changed. (This prevents loss of information in volatile memory.)

Conventional capacitors provide less than 360 [joules](http://en.wikipedia.org/wiki/Joule) per kilogram of [energy density](http://en.wikipedia.org/wiki/Energy_density), whereas a conventional [alkaline battery](http://en.wikipedia.org/wiki/Alkaline_battery) has a density of 590 kJ/kg.

In [car audio](http://en.wikipedia.org/wiki/Car_audio) systems, large capacitors store energy for the [amplifier](http://en.wikipedia.org/wiki/Amplifier) to use on demand. Also for a [flash tube](http://en.wikipedia.org/wiki/Flash_tube) a capacitor is used to hold the [high voltage](http://en.wikipedia.org/wiki/High_voltage).

### Pulsed power and weapons

Groups of large, specially constructed, low-inductance high-voltage capacitors (capacitor banks) are used to supply huge pulses of current for many [pulsed power](http://en.wikipedia.org/wiki/Pulsed_power) applications. These include [electromagnetic forming](http://en.wikipedia.org/wiki/Electromagnetic_forming), [Marx generators](http://en.wikipedia.org/wiki/Marx_generator), pulsed [lasers](http://en.wikipedia.org/wiki/Laser) (especially [TEA lasers](http://en.wikipedia.org/wiki/TEA_laser)), [pulse forming networks](http://en.wikipedia.org/wiki/Pulse_forming_network), [radar](http://en.wikipedia.org/wiki/Radar), [fusion research](http://en.wikipedia.org/wiki/Z_machine), and [particle accelerators](http://en.wikipedia.org/wiki/Particle_accelerator).

Large capacitor banks (reservoir) are used as energy sources for the [exploding-bridgewire detonators](http://en.wikipedia.org/wiki/Exploding-bridgewire_detonator) or [slapper detonators](http://en.wikipedia.org/wiki/Slapper_detonator) in [nuclear weapons](http://en.wikipedia.org/wiki/Nuclear_weapon) and other specialty weapons. Experimental work is under way using banks of capacitors as power sources for [electromagnetic](http://en.wikipedia.org/wiki/Electromagnetism)[armour](http://en.wikipedia.org/wiki/Vehicle_armour) and electromagnetic [railguns](http://en.wikipedia.org/wiki/Railgun) and [coilguns](http://en.wikipedia.org/wiki/Coilgun).

### Power conditioning

[Reservoir capacitors](http://en.wikipedia.org/wiki/Reservoir_capacitor) are used in [power supplies](http://en.wikipedia.org/wiki/Power_supply) where they smooth the output of a full or half wave [rectifier](http://en.wikipedia.org/wiki/Rectifier). They can also be used in [charge pump](http://en.wikipedia.org/wiki/Charge_pump) circuits as the energy storage element in the generation of higher voltages than the input voltage.

Capacitors are connected in parallel with the power circuits of most electronic devices and larger systems (such as factories) to shunt away and conceal current fluctuations from the primary power source to provide a "clean" power supply for signal or control circuits. Audio equipment, for example, uses several capacitors in this way, to shunt away power line hum before it gets into the signal circuitry. The capacitors act as a local reserve for the DC power source, and bypass AC currents from the power supply. This is used in car audio applications, when a stiffening capacitor compensates for the inductance and resistance of the leads to the [lead-acid](http://en.wikipedia.org/wiki/Lead-acid_batteries)[car battery](http://en.wikipedia.org/wiki/Car_battery).

In electric power distribution, capacitors are used for [power factor correction](http://en.wikipedia.org/wiki/Power_factor_correction). Such capacitors often come as three capacitors connected as a [three phase](http://en.wikipedia.org/wiki/Three_phase)[load](http://en.wikipedia.org/wiki/Electrical_load). Usually, the values of these capacitors are given not in farads but rather as a [reactive power](http://en.wikipedia.org/wiki/Reactive_power) in volt-amperes reactive (var). The purpose is to counteract inductive loading from devices like [electric motors](http://en.wikipedia.org/wiki/Induction_motor) and [transmission lines](http://en.wikipedia.org/wiki/Transmission_line) to make the load appear to be mostly resistive. Individual motor or lamp loads may have capacitors for power factor correction, or larger sets of capacitors (usually with automatic switching devices) may be installed at a load center within a building or in a large utility [substation](http://en.wikipedia.org/wiki/Electrical_substation).

### Suppression and coupling

Because capacitors pass AC but block DC [signals](http://en.wikipedia.org/wiki/Signal_%28information_theory%29) (when charged up to the applied dc voltage), they are often used to separate the AC and DC components of a signal. This method is known as AC coupling or "capacitive coupling". Here, a large value of capacitance, whose value need not be accurately controlled, but whose [reactance](http://en.wikipedia.org/wiki/Reactance_%28electronics%29) is small at the signal frequency, is employed.

#### Decoupling

A [decoupling capacitor](http://en.wikipedia.org/wiki/Decoupling_capacitor) is a capacitor used to protect one part of a circuit from the effect of another, for instance to suppress noise or transients. Noise caused by other circuit elements is shunted through the capacitor, reducing the effect they have on the rest of the circuit. It is most commonly used between the power supply and ground. An alternative name is bypass capacitor as it is used to bypass the power supply or other high impedance component of a circuit.

#### Noise filters and snubbers

When an inductive circuit is opened, the current through the inductance collapses quickly, creating a large voltage across the open circuit of the switch or relay. If the inductance is large enough, the energy will generate a spark, causing the contact points to oxidize, deteriorate, or sometimes weld together, or destroying a solid-state switch. A [snubber](http://en.wikipedia.org/wiki/Snubber) capacitor across the newly opened circuit creates a path for this impulse to bypass the contact points, thereby preserving their life; these were commonly found in [contact breaker](http://en.wikipedia.org/wiki/Contact_breaker)[ignition systems](http://en.wikipedia.org/wiki/Ignition_system), for instance. Similarly, in smaller scale circuits, the spark may not be enough to damage the switch but will still [radiate](http://en.wikipedia.org/wiki/Spark-gap_transmitter) undesirable [radio frequency interference](http://en.wikipedia.org/wiki/Radio_frequency_interference) (RFI), which a [filter capacitor](http://en.wikipedia.org/wiki/Filter_capacitor) absorbs. Snubber capacitors are usually employed with a low-value resistor in series, to dissipate energy and minimize RFI. Such resistor-capacitor combinations are available in a single package.

Capacitors are also used in parallel to interrupt units of a high-voltage [circuit breaker](http://en.wikipedia.org/wiki/Circuit_breaker) in order to equally distribute the voltage between these units. In this case they are called grading capacitors.

In schematic diagrams, a capacitor used primarily for DC charge storage is often drawn vertically in circuit diagrams with the lower, more negative, plate drawn as an arc. The straight plate indicates the positive terminal of the device, if it is polarized (see [electrolytic capacitor](http://en.wikipedia.org/wiki/Electrolytic_capacitor)).

### Motor starters

In single phase [squirrel cage](http://en.wikipedia.org/wiki/Squirrel-cage_rotor) motors, the primary winding within the motor housing is not capable of starting a rotational motion on the rotor, but is capable of sustaining one. To start the motor, a secondary "start" winding has a series non-polarized [starting capacitor](http://en.wikipedia.org/wiki/Starting_capacitor) to introduce a lead in the sinusoidal current. When the secondary (start) winding is placed at an angle with respect to the primary (run) winding, a rotating electric field is created. The force of the rotational field is not constant, but is sufficient to start the rotor spinning. When the rotor comes close to operating speed, a centrifugal switch (or current-sensitive relay in series with the main winding) disconnects the capacitor. The start capacitor is typically mounted to the side of the motor housing. These are called capacitor-start motors, that have relatively high starting torque. Typically they can have up-to four times as much starting torque than a split-phase motor and are used on applications such as compressors, pressure washers and any small device requiring high starting torques.

Capacitor-run induction motors have a permanently connected phase-shifting capacitor in series with a second winding. The motor is much like a two-phase induction motor.

Motor-starting capacitors are typically non-polarized electrolytic types, while running capacitors are conventional paper or plastic film dielectric types.

### Signal processing

The energy stored in a capacitor can be used to represent [information](http://en.wikipedia.org/wiki/Information), either in binary form, as in [DRAMs](http://en.wikipedia.org/wiki/DRAM), or in analogue form, as in [analog sampled filters](http://en.wikipedia.org/wiki/Analog_sampled_filter) and [CCDs](http://en.wikipedia.org/wiki/Charge-coupled_device). Capacitors can be used in [analog circuits](http://en.wikipedia.org/wiki/Analog_circuit) as components of integrators or more complex filters and in [negative feedback](http://en.wikipedia.org/wiki/Negative_feedback) loop stabilization. Signal processing circuits also use capacitors to [integrate](http://en.wikipedia.org/wiki/Integral) a current signal.

### Sensing

Most capacitors are designed to maintain a fixed physical structure. However, various factors can change the structure of the capacitor, and the resulting change in capacitance can be used to [sense](http://en.wikipedia.org/wiki/Sensor) those factors.

**CAPACITANCE**; this is a measure of capacitors ability to store charge. A large capacitance means that more charge can be stored. Capacitance is measured in farads, symbol F. however, if it is very large, so prefixes are used to show the smaller values. Capacitor values can be very difficult to find because there are many types of capacitor with different labeling system. There many types of capacitor but they can be split into two groups; polarized and non polarized. Each group has its own circuit symbol. Polarized capacitors [large values, IUF+] electrolytic capacitors are polarized and they must be connected with the correct way round, at least one of their head will be + or – they are not damaged by heat when soldering. There are two designs of electrolytic capacitors; axial where the leads are attached to each end [220uF] and radial where both leads are at the same end [10uF]. Radial capacitors tend to be a little, smaller and they stand upright on the circuit board.

Capacitor symbol

**2.1.4 RESISTORS**

Resistors restrict the flow of electric current, for example a resistor is placed in series with a light emitting diode [LED] to limit the current passing through the LED. Resistors are common elements of [electrical networks](http://en.wikipedia.org/wiki/Electrical_network) and [electronic circuits](http://en.wikipedia.org/wiki/Electronic_circuit) and are ubiquitous in electronic equipment. Practical resistors can be made of various compounds and films, as well as [resistance wire](http://en.wikipedia.org/wiki/Resistance_wire) (wire made of a high-resistivity alloy, such as nickel-chrome). Resistors are also implemented within [integrated circuits](http://en.wikipedia.org/wiki/Integrated_circuits), particularly analog devices, and can also be integrated into [hybrid](http://en.wikipedia.org/wiki/Hybrid_circuit) and [printed circuits](http://en.wikipedia.org/wiki/Printed_circuit_board).

The electrical functionality of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than nine [orders of magnitude](http://en.wikipedia.org/wiki/Orders_of_magnitude). When specifying that resistance in an electronic design, the required precision of the resistance may require attention to the [manufacturing tolerance](http://en.wikipedia.org/wiki/Engineering_tolerance#Electrical_component_tolerance) of the chosen resistor, according to its specific application. The [temperature coefficient](http://en.wikipedia.org/wiki/Temperature_coefficient) of the resistance may also be of concern in some precision applications. Practical resistors are also specified as having a maximum [power](http://en.wikipedia.org/wiki/Power_%28physics%29) rating which must exceed the anticipated power dissipation of that resistor in a particular circuit: this is mainly of concern in power electronics applications. Resistors with higher power ratings are physically larger and may require [heat sinks](http://en.wikipedia.org/wiki/Heat_sink). In a high-voltage circuit, attention must sometimes be paid to the rated maximum working voltage of the resistor.

Practical resistors have a series [inductance](http://en.wikipedia.org/wiki/Inductance) and a small parallel [capacitance](http://en.wikipedia.org/wiki/Capacitance); these specifications can be important in high-frequency applications. In a [low-noise amplifier](http://en.wikipedia.org/wiki/Low-noise_amplifier) or [pre-amp](http://en.wikipedia.org/wiki/Pre-amp), the [noise](http://en.wikipedia.org/wiki/Noise_%28electronics%29) characteristics of a resistor may be an issue. The unwanted inductance, excess noise, and temperature coefficient are mainly dependent on the technology used in manufacturing the resistor. They are not normally specified individually for a particular family of resistors manufactured using a particular technology. A family of discrete resistors is also characterized according to its form factor, that is, the size of the device and the position of its leads (or terminals) which is relevant in the practical manufacturing of circuits using them. Resistors may be connected either way round. They are not damaged by heat when soldering. The resistor color code and color number or coding.

The following table shows the colors used to identify resistor values:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **COLOR** | **DIGIT** | **MULTIPLIER** | **TOLERANCE** | **TC** |
| **Silver** |  | x 0.01  | ±10% |  |
| **Gold** |  | x 0.1  | ±5% |  |
| **Black** | 0 | x 1  |  |  |
| **Brown** | 1 | x 10  | ±1% | ±100\*10-6/K |
| **Red** | 2 | x 100  | ±2% | ±50\*10-6/K |
| **Orange** | 3 | x 1 k |  | ±15\*10-6/K |
| **Yellow** | 4 | x 10 k |  | ±25\*10-6/K |
| **Green** | 5 | x 100 k | ±0.5% |  |
| **Blue** | 6 | x 1 M | ±0.25% | ±10\*10-6/K |
| **Violet** | 7 | x 10 M | ±0.1% | ±5\*10-6/K |
| **Grey** | 8 | x 100 M |  |  |
| **White** | 9 | x 1 G |  | ±1\*10-6/K |

Resistance is measured in ohms, the symbol for ohm is an omega. Resistor values are often given in K and M.

1K=1000, 1M=1000000

Resistors values are normally shown using colored bands. Each color represents a number as shown in the table. Most resistors have 4 bands;

* + The first band gives the first digit.
  + The second band gives the second digit
  + The third band indicates the numbers of zeros.
  + The fourth band is used to show the tolerance [precision] of the resistor, this may be ignored given below. This resistor has red[2], valued[7] yellow [4 zeros] and gold bands.

Resistor symbol

**2.1.5 SWITCH**

Switch is an electrical component that can break an electrical circuit, interrupting the current or diverting it from one conductor to another. The most familiar form of switch is manually operated electromechanical device with one or more sets of electrical contacts. Each set of contacts can be in one or two states; either closed meaning the contacts are touching and electricity can flow between them or open; this means the contacts are separated and the switch is non conducting. The mechanism acting by the transition between these states [open or close] can be either a ‘toggle’[flip switch for continuous “ON” or “OFF” or momentary ] type

oo

ON

OFF

OHDDK

Switch symbol

**2.1.6 INDICATOR LIGHT;**

This is an electric device that gives signal in light form to indicate that the machine is working or functioning. Indicator light can be of different colors; example red, orange, pink, etc. and it can be different shapes

diagram of different indicator light shapes.

**2.1.7 FUSE**

In [electronics](https://en.wikipedia.org/wiki/Electronics) and [electrical engineering](https://en.wikipedia.org/wiki/Electrical_engineering), a fuse (from the French fuser, Italian fuso, "spindle") is a type of low resistance [resistor](https://en.wikipedia.org/wiki/Resistor) that acts as a [sacrificial device](https://en.wikipedia.org/wiki/Sacrificial_device) to provide [overcurrent](https://en.wikipedia.org/wiki/Overcurrent) protection, of either the load or source circuit. Its essential component is a metal wire or strip that melts when too much current flows, which interrupts the [circuit](https://en.wikipedia.org/wiki/Electrical_network) in which it is connected. [Short circuit](https://en.wikipedia.org/wiki/Short_circuit), overloading, mismatched loads or device failure are the prime reasons for excessive current.

A fuse interrupts excessive current (blows) so that further damage by overheating or [fire](https://en.wikipedia.org/wiki/Fire) is prevented. Wiring regulations often define a maximum fuse current rating for particular circuits. [Overcurrent protection devices](https://en.wikipedia.org/wiki/Power_system_protection) are essential in electrical systems to limit threats to human life and property damage. The time and current operating characteristics of fuses are used to provide adequate protection without needless interruption. Slow blow fuses are designed to allow harmless short term higher currents but still clear on a sustained overload. Fuses are manufactured in a wide range of current and voltage ratings to protect wiring systems and electrical equipment. Self-resetting fuses automatically restore the circuit after the overload has cleared; these are useful, for example, in aerospace or nuclear applications where fuse replacement is impossible.

A fuse consists of a metal strip or wire fuse element, of small cross-section compared to the circuit conductors, mounted between a pair of electrical terminals, and (usually) enclosed by a non-combustible housing. The fuse is arranged in [series](https://en.wikipedia.org/wiki/Series_and_parallel_circuits) to carry all the current passing through the protected circuit. The resistance of the element generates heat due to the current flow. The size and construction of the element is (empirically) determined so that the heat produced for a normal current does not cause the element to attain a high temperature. If too high a current flows, the element rises to a higher temperature and either directly melts, or else melts a [soldered](https://en.wikipedia.org/wiki/Solder) joint within the fuse, opening the circuit.

The fuse element is made of zinc, copper, silver, aluminum, or alloys to provide stable and predictable characteristics. The fuse ideally would carry its rated current indefinitely, and melt quickly on a small excess. The element must not be damaged by minor harmless surges of current, and must not oxidize or change its behavior after possibly years of service.

The fuse elements may be shaped to increase heating effect. In large fuses, current may be divided between multiple strips of metal. A dual-element fuse may contain a metal strip that melts instantly on a short-circuit, and also contain a low-melting solder joint that responds to long-term overload of low values compared to a short-circuit. Fuse elements may be supported by steel or nichrome wires, so that no strain is placed on the element, but a spring may be included to increase the speed of parting of the element fragments.

The fuse element may be surrounded by air, or by materials intended to speed the quenching of the arc. [Silica](https://en.wikipedia.org/wiki/Silica) sand or non-conducting liquids may be used.

The speed at which a fuse blows depends on how much current flows through it and the material of which the fuse is made. The operating time is not a fixed interval, but decreases as the current increases. Fuses have different characteristics of operating time compared to current, characterized as fast-blow, slow-blow, or time-delay, according to time required to respond to an overcurrent condition. A standard fuse may require twice its rated current to open in one second, a fast-blow fuse may require twice its rated current to blow in 0.1 seconds, and a slow-blow fuse may require twice its rated current for tens of seconds to blow.

Fuse selection depends on the load's characteristics. Semiconductor devices may use a fast or ultrafast fuse as semiconductor devices heat rapidly when excess current flows. The fastest blowing fuses are designed for the most sensitive electrical equipment, where even a short exposure to an overload current could be very damaging. Normal fast-blow fuses are the most general purpose fuses. The time delay fuse (also known as anti-surge, or slow-blow) are designed to allow a current which is above the rated value of the fuse to flow for a short period of time without the fuse blowing. These types of fuse are used on equipment such as motors, which can draw larger than normal currents for up to several seconds while coming up to speed.

Voltage rating of the fuse must be greater than or equal to what would become the [open circuit voltage](https://en.wikipedia.org/wiki/Open-circuit_voltage). For example, a glass tube fuse rated at 32 volts would not reliably interrupt current from a [voltage source](https://en.wikipedia.org/wiki/Voltage_source) of 120 or 230 V. If a 32 V fuse attempts to interrupt the 120 or 230 V source, an [arc](https://en.wikipedia.org/wiki/Electric_arc) may result. [Plasma](https://en.wikipedia.org/wiki/Plasma_%28physics%29) inside that glass tube fuse may continue to conduct current until current eventually so diminishes that plasma reverts to an insulating gas. Rated voltage should be larger than the maximum [voltage source](https://en.wikipedia.org/wiki/Voltage_source) it would have to disconnect. Rated voltage remains same for any one fuse, even when similar fuses are connected in series. Connecting fuses in series does not increase the rated voltage of the combination (nor of any one fuse).

Medium-voltage fuses rated for a few thousand volts are never used on low voltage circuits, because of their cost and because they cannot properly clear the circuit when operating at very low voltages.

Most fuses are [marked](https://en.wikipedia.org/wiki/Conformance_mark) on the body or [end caps](https://en.wikipedia.org/wiki/IEC_60269#Markings) with markings that indicate their ratings. [Surface-mount technology](https://en.wikipedia.org/wiki/Surface-mount_technology) "chip type" fuses feature few or no markings, making identification very difficult. It melts with intense heat from high voltage

**CONNECTING WIRE**; it is used in connecting electric components in the circuit

**SOLDERING LEAD**; Solder is a thin tube, usually rolled in spools, made of various metal alloys. Its job is to hold the individual components together. The individual components and their quantities can vary, but for computer electronics, you’re usually looking at a 60% tin and 40% lead. Lead-free solder is also available, though it has higher melting temperatures and less “wettability,” meaning you may need a better soldering iron to use it and removing it can be more tedious. Lead-free solder is better for the environment and has other benefits, and they function more or less the same way.

The inside of the tube is filled with “flux,” a substance that gets rid of oxidation and helps clean the surfaces involved in the fusing process. For electronic use, you want rosin-core/rosin-flux solder. Acid-flux is used in plumbing and the acid can damage the sensitive components on PCBs.

[Tin](http://en.wikipedia.org/wiki/Tin)/[lead](http://en.wikipedia.org/wiki/Lead) solders, also called soft solders, are commercially available with tin concentrations between 5% and 70% by weight. The greater the tin concentration, the greater the solder’s [tensile](http://en.wikipedia.org/wiki/Tensile_strength) and [shear strengths](http://en.wikipedia.org/wiki/Shear_strength). Alloys commonly used for electrical soldering are 60/40 Tin/lead (Sn/Pb) which melts at 370 °F or 188 °C and 63/37 Sn/Pb used principally in electrical/electronic work. The 63/37 is a [eutectic](http://en.wikipedia.org/wiki/Eutectic_point) alloy, which:

**SOLDERING IRON**

**A soldering iron is** a [hand tool](https://en.wikipedia.org/wiki/Hand_tool) used in soldering. It supplies heat to melt the [solder](https://en.wikipedia.org/wiki/Solder) so that it can flow into the joint between two workpieces.

A soldering iron is composed of a heated metal tip and an insulated handle. Heating is often achieved electrically, by passing an electric current (supplied through an electrical cord or battery cables) through a resistive [heating element](https://en.wikipedia.org/wiki/Heating_element). Cordless irons can be heated by combustion of gas stored in a small tank, often using a [catalytic heater](https://en.wikipedia.org/wiki/Catalytic_heater) rather than a flame. Simple irons less commonly used than in the past were simply a large copper bit on a handle, heated in a flame.

Soldering irons are most often used for installation, repairs, and limited production work in electronics assembly. High-volume production lines use other soldering methods.[[1]](https://en.wikipedia.org/wiki/Soldering_iron#cite_note-Bralla03-1) Large irons may be used for soldering joints in sheet metal objects. Less common uses include [pyrography](https://en.wikipedia.org/wiki/Pyrography) (burning designs into wood) and [plastic welding](https://en.wikipedia.org/wiki/Plastic_welding).

A soldering iron is a tool with a metal tip that gets really hot. We’re talking like 800 degree Fahrenheit, though you can adjust the temperature on a good iron. Its job is to transfer heat to things like wires, transistor leads, and pads on PCBs. After the appropriate areas are heated properly, solder is applied. If you plan on soldering, then you’re better off spending $30-$40 on a 20-30 Watt iron instead of on a cheap $15 one. You’ll get a longer-lasting tool that will work for a much wider variety of applications and you’ll get proper heat control to boot. There are also soldering guns available, but you should only use these when repairing thick cables and never on PCBs, as the tips have a live voltage running through them that can damage sensitive electronics.

## Types

### Simple iron

For electrical and electronics work, a low-power iron, a power rating between 15 and 35 [watts](https://en.wikipedia.org/wiki/Watt), is used. Higher ratings are available, but do not run at higher temperature; instead there is more heat available for making soldered connections to things with large [thermal capacity](https://en.wikipedia.org/wiki/Thermal_capacity), for example, a metal chassis. Some irons are temperature-controlled, running at a fixed temperature in the same way as a soldering station, with higher power available for joints with large heat capacity. Simple irons run at an uncontrolled temperature determined by [thermal equilibrium](https://en.wikipedia.org/wiki/Thermal_equilibrium); when heating something large their temperature drops a little, possibly too much to melt solder.

### Cordless iron

Small irons heated by a battery, or by combustion of a gas such as [butane](https://en.wikipedia.org/wiki/Butane) in a small self-contained tank, can be used when electricity is unavailable or cordless operation is required. The operating temperature of these irons is not regulated directly; gas irons may change power by adjusting gas flow. Gas-powered irons may have interchangeable tips including different size soldering tips, hot knife for cutting plastics, miniature [blow-torch](https://en.wikipedia.org/wiki/Blow-torch) with a hot flame, and small [hot air blower](https://en.wikipedia.org/wiki/Heat_gun) for such applications as shrinking [heat shrink](https://en.wikipedia.org/wiki/Heat_shrink) tubing.

### Temperature-controlled soldering iron

Simple irons reach a temperature determined by thermal equilibrium, dependent upon power input and cooling by the environment and the materials it comes into contact with. The iron temperature will drop when in contact with a large mass of metal such as a chassis; a small iron will lose too much temperature to solder a large connection. More advanced irons for use in electronics have a mechanism with a temperature sensor and method of temperature control to keep the tip temperature steady; more power is available if a connection is large. Temperature-controlled irons may be free-standing, or may comprise a head with heating element and tip, controlled by a base called a soldering station, with control circuitry and temperature adjustment and sometimes display.

A variety of means are used to control temperature. The simplest of these is a variable power control, much like a [light dimmer](https://en.wikipedia.org/wiki/Light_dimmer), which changes the equilibrium temperature of the iron without automatically measuring or regulating the temperature. Another type of system uses a [thermostat](https://en.wikipedia.org/wiki/Thermostat), often inside the iron's tip, which automatically switches power on and off to the element. A thermal sensor such as a [thermocouple](https://en.wikipedia.org/wiki/Thermocouple) may be used in conjunction with [circuitry](https://en.wikipedia.org/wiki/Electronic_circuit) to monitor the temperature of the tip and adjust power delivered to the heating element to maintain a desired temperature.

Another approach is to use magnetized soldering tips which lose their magnetic properties at a specific temperature, the [Curie point](https://en.wikipedia.org/wiki/Curie_point). As long as the tip is magnetic, it closes a switch to supply power to the heating element. When it exceeds the design temperature it opens the contacts, cooling until the temperature drops enough to restore magnetisation. More complex Curie-point irons circulate a high-frequency AC current through the tip, using magnetic physics to direct heating only where the surface of the tip drops below the Curie point.

**CHAPTER THREE**

**3.0 MATERIALS AND METHODOLOGY / CONSTRUCTION**

**3.1 THE MATERIALS OR COMPONENTS USED**

The major materials needed for the construction are;

* Resistors
* Regulator
* Filter capacitor 400v 33uF,
* Rectifier or Diodes,
* Two-winding transformer,
* Pilot lamp,
* Power switch,
* Rectangular Metallic Casing /box,
* Power cord, AV cable and connecting cables
* Outlet.
* Fuse and fuse holder,
* Vero board
* Soldering machine and soldering lead
* Spray paint.

The materials for the tank are;

* PVC plastic
* Super glue
* Cutter
* Soldering lead
* AV female port.

**3.2 CONSTRUCTION PROCEDURES**

The following operations were performed sequentially in order to produce this locally made electrophoresis machine;

**FOR MACHINE**;

1] Circuit diagram

2] Marking out

3] Insertion of components

4] Assembling components

5] Circuit connection

6] Coupling

7] Painting or final touching in the external body.

**FOR TANK**

1] Marking out

2] Cutting

3] Joining

4] Smoothening or finishing touches

**1] CIRCUIT DIAGRAM**; this shows in detail of how the inter connections between components in the board will be made and followed.

**2] MARKING OUT**; this process of marking out involves the use of marking out instrument such as scriber and so on to measure and mark desired size on the vero board.

**3] INSERTION**; this process involves the insertion of the required components into the vero board according as described in the circuit diagram immediately after I finished the marking out.

**4] ASSEMBLING**; it also involves bringing different components part together as one.

**5] CIRCUIT CONNECTION**; this process involves the use of connecting cables to joining the different component parts together as required in the circuit diagram. After my insertion and assembling of the components, I used the connecting cable to connect them together in order to allow free flow of current.

**6] COUPLING**; this process involves coupling the cubic box together, after the whole connections must have been done, I covered the cubic box and I coupled it.

**7] PAINTING OR FINISHING TOUCHES**; this machine was painted to prevent it from rusting which will lead to corrosion of the metal surface.

**FOR TANK**

**1] MARKING OUT**; this process of marking out involves the use of marking out instrument. I used the scriber to mark out the required length and width in the polyvinyl chloride plastic.

**2] CUTTING**; this process involves the cutting of the material into required sizes and dimension. I used a cutter to cut the PVC material into the desired sizes and shapes.

**3] JOINNING**; this process involves putting the already cut part together. I used a super glue to join the well cut sizes and shapes together.

**4] SMOOTHENING**; the various surface of the tank was smoothened mild emery cloth.

**3.1.2 POWER SUPPLY UNIT**  
Almost all the electronic circuit from simple transistor and operational amplifier circuit up to digital and microprocessor systems requires one source of stable voltage. A regulated power supply can be constructed by using negative feedback to compare the dc output voltage with a stable reference voltage.

The transformer normally, changes the mains supply voltage to a value which is safe to work with and some what more than the wanted dc voltage but which is not more than that the regulator can handle. But because a voltage of not less than 200v is needed for this project, a two-winding transformer which is same as auto-transformer in function is adopted for the transformer stage.  
The transformer output is rectified using a bridge rectifier producing fluctuating d.c voltage which is then passed through a filter capacitor. The filter is required to remove the ripple voltage of frequency equal to twice mains frequency for bridge rectification. The filter is basically a shunt electrolytic capacitor that charged up the peak value of the input voltage with a large discharge time to prevent it been completely discharged when the fluctuating d.c voltage is going low. Hence, there is always a voltage output across any load connected. The output voltage from the filter is then fed into a linear regulator whose rating is compatible to handle this voltage.

**CIRCUIT DIAGRAM**

C:\Program Files\Microsoft Office\MEDIA\OFFICE14\Bullets\BD21433_.gif

A.C switch

Converter A.C to D.C current control unit sample tank

R1

D3

D1

R2

C

R3

TANK

220V

D2

D4

R4

A.C to D.C converter unit current control unit sample tank

**Circuit diagram of electrophoresis machine**

**3.4 THEORY OF OPERATION**

When the circuit is powered by closing switch, the diode D1, D2, D3, D4 converts A.C current to D.C current. The voltage from the D.C output still contains some degree of ripples. These ripples are further removed by the capacitor through the current flow through the transformer. This is a better D.C output but not totally free of ripples. It is then fed to the voltage regulator which not just reduces the final output of the power supply but also keeps it constant which is now suitable for proper operation of the tank. The resistors works with the regulator [ switches to regulate voltage flowing into the tank].

The output which is connected to the tank energies for separation in the tank. [ separation of blood samples in the tank.]

**3.5 TANK CONTENTS AND ITS MODE OF OPERATION**

The contents are;

A] Cellulose acetate paper

B] Filter

C] Buffer solution [tris] of 8.7ph

D] Needles and syringes.

**TANK OPERATION**

As for genotype, blood sample will be required for the operation, and A S will be used as a control for the test. [A S blood sample is the determinant factor]. Tris buffer of 8.7pH is poured into the tank that contains the soldering lead, cellulose acetate paper is allowed to soak with the buffer for at least 10 minutes. Acetate paper should be cleaned to avoid excess soaking of the buffer. The blood samples that are unknown will be placed in a straight linear form with the control [A S]. The sample migrates from positive to negative terminal. The A S sample will be placed on top of the cellulose acetate paper along side with the unknown sample linearly. When the machine is powered, the will be a separation from the positive to the negative pole in which the ‘S’ migrates faster then followed by the ‘A’, which is the determining factor. The unknown samples will migrate is required.

If the unknown samples lies below the A band, the genotype is AA, If the unknown sample lies below the S band, the genotype is SS, also if it lies below both the A and S bands, then the genotype is AS.

The current from the circuit will allow the flow of negative and positive current in the tank thereby causing separation of the samples.

**CONTROL AND UNKNOWN SAMPLES**

**AS**

**CONTROLLL**

**SS**

**AA**

**UNKNOWN**

**SAMPLES**

**AS**

**CONTROL**

**BEFORE SEPERATION AFTER SEPERATION**

**CHAPTER FOUR**

**4.0 CONSTRUCTION AND ASSEMBLING OF COMPONENTS.**

**4.1 DESIGN LAYOUT**

A design layout must equally be planned. The first step is to rule out the equipment number of strips of the board to be used on a plastic and on this, the components are arranged as they will look on the board.

**4.2 ASSEMBLING OF COMPONENTS.**

It is not a good idea to rush into the assembling of components [soldering] without bread boarding. Bread boarding is a circuit assembling system that allows components inter connections to be assembled and changed easily. We have two types of bread boarding. Viz; solder and solder less bread boarding. I will use the solder less type because it has some advantages over the solder type. Such advantages are it saves time, component changes are quick and easy that is, you just push a component in to the board without necessarily soldering it. It also allows the use of components over and over again because it is not permanently fixed on like other technique that requires cold soldered joints.

In this project work, all the components will be mounted on the board except the power switch. This work will require external power source to power the machine. This is to make the machine less bulky and compactible with any other power supply.

**4.3 COMPONENT INSERTION AND SOLDERING**

Before any component can be inserted into the board, the board must be cleaned thoroughly.

When the board is cleaned and dried, insert components from the non component side. Be sure to watch component orientation, those with polarity and designated lead configuration must be inserted in the correct direction. When component lead will be pressed or passed through the hole, it should be bent at about 30 degree. This is known as service bend because it allows the components to be easily serviced, in the other hand, if the lead is not bent at all, the component is likely to fall out before it can be solder in place.

Soldering is a process by which two metals or alloys are joined together with a third metal or alloy. The third metal or alloy has a much lower melting point compared to the first two metals. Soldering is different from adhesive joining. Adhesives bond by mechanical attraction having to do with mechanical surface properties of the material relative to the adhesive. In the case of solder, there is also a chemical reaction in addition to physical reaction.

Soldering is primarily used to provide a convenient joint to ensure electrical contact or seal against leakage. Solders typically do not provide high mechanical strength, given the soft nature of popular solder materials. Soldering is used extensively in the electronics industry printed circuit boards. It is also used in joining metals in industries such as cutlery, tools, metal box making etc.

**4.4 CAPACITY OF THE MACHINE.**

The machine was designed to be in rectangular form. With

**Front view**

Length = 70cm

Width = 30cm

**Side view**

Length = 20cm

Width = 30cm

For the tank that is made up of two partitions

The tanks is also rectangular in shape with;

**Front side**

Length = 45cm

Width = 10cm

**Side view**

Length = 15cm

Width = 10cm

**4.5 TESTING AND TROUBLE SHOOTING**

To finish the project, I will need to test project in order to see if it works. If it does not, I will have to find out why and correct it.

To test and if necessary trouble shoot a project, it will require four steps or procedures;

A preliminary test will be performed followed by

B operational test; if it fails any of the operational test,

C trouble shooting begins: when the project is finally functional, then

D a series of performance test will be conducted.

If the project passes all the tests, then it is ready for use.

Preliminary testing is done first. This area performed before power is applied to the project. This is to detect errors that could cause serious problem should the wrong voltage and current be allowed to reach critical components. Preliminary testing is preventive testing.

Once the project passes all preliminary test, operation test begins. Here, power is applied for the first time and basic project functioning is determined if all appears well at this point, performance testing is done. If there is a problem, say voltage is not reaching the tank [that contains the blood samples] or malfunctioning the project must under goes the trouble shooting stage.

Trouble shooting is done to determine what is wrong, why it is wrong and what to do about it. There the cause of the problem is identified and corrected and next is the performance testing.

Performance testing is used to determine if the project will work whenever and where ever it is supposed to be used. With performance test, the work is subjected to harsh and extreme condition. This project work has been subjected to extreme voltage of 200-220v for about two hours.

**4.5.1 TROUBLE SHOOTING**

It is difficult to generalize about component failure. The point is depending on the problem, some components are more likely to cause trouble than others. Most likely fail components are capacitors, diodes, and transformers. While least likely to fail are the resistors.

To trouble shoot this work whenever any problem occurs, the following stages are taken.

1. Does the indicators light turn ON?, if no, then check the power supply unit. Test the output of the regulator, for the proper output voltage of 200-220v, if no voltage, check polarities of regulator and rectifiers if the answer is still no, then check the 220v A.C outlet.
2. Does the converter [diode] passes direct current? If no, check the diode with the multimeter to rectify if it is good. If it is good then check the soldering if all the cores are well connected.
3. If everything is ok, then check the capacitor if the voltage has damage to it.

**CHAPTER FIVE**

**SUMMARY, CONCLUSION AND RECOMMENDATION**

**5.1 SUMMARY**

Electrophoresis machine is a machine used in detecting the genotype of human being which basically is AA, AS, SS.

Formerly, electrophoresis was constructed without the use of resistors. But today, due to advancement in electronic chips, electrophoresis machine has metamorphosed into sophisticated devices that have the capacity to separate blood and classifying them into types, example AA, AS, SS.

Locally, electrophoresis is typically made of large plastics or metallic cubic box. The plastic will be cut in such a way that their will be division that will separate the tank from the engine or two cubic boxes and one serving as the tank and the other, the engine.

Most locally constructed electrophoreses machine do not make use of resistors and this cause a lot of damage to the machine electrically and functionally. Electrically, it can destroy the diode due to high voltage and functionally, it can tear the cellulose acetate paper in the separation tank.

The advantage of this locally made electrophoreses machine is that it is cheap in the cost of production due to the purchases of the components within our locality.

**CONCLUSION**

This work has successfully demonstrated how different electronic components such as diode, resistors, capacitor can be used to actualize a fascinating output-electrophoresis machine [genotype machine].

Although, these are other ways of realizing the same output such as power source and operation problems.

Since, in this part of the world suffer epileptic power supply, maintenance personnel and equality operators of computerized genotype machine that can solve this problems by employing a simple circuit, low voltage power supply and easy to operate mechanism. Therefore this electrophoresis is ideal for third war countries like ours.

Finally, this electrophoresis has variable resistors that can enable control voltage in cases of eliminating incessant breakdown of our electrophoresis machine since its circuits is simple and check can be serviced by any person with little electronic knowledge.

RECOMMEDATION

Based on the findings and conclusion, the following recommendations are hereby made. It is believed that it would help alleviate the problems faced by the hospitals in testing of genotype of different individuals.

First and foremost, it would be the best thing for hospitals to introduce electrophoresis machine that can be automated, that is the machine that contains a thermostat for auto-regulation.

Secondly, hospitals should introduce this type of machine that has an alarm for job completion indication.

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