Design and Construction of Medical Electrophoresis Power Pack for Genotype Machine

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EBSU/2014/72668

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APPROVAL PAGE

This is to certify that this project has been approved by the Department of Technology and Vocational Education (Electrical/Electronics), Ebonyi State University, Abakaliki.

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CERTIFICATION

This is to certify that this research project work was carried out by **AGU PAUL MADUABUCHI** with registration number **EBSU/2014/72668** under my supervisor in the Department of Technology and Vocational Education (Electrical/Electronics), Ebonyi State University, Abakaliki**.**

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DEDICATION

This research work is dedicated to God Almighty for endowing the researcher with the wisdom, knowledge and strength to carry out this work from the start till completion.

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Finally, he thanks God Almighty for actualizing his dreams.

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ABSTRACT

This study deals with the Design and Construction of medical Electrophoresis Power Pack for Genotype Machine. The study adopted the Research and Development (R and D) Design using the Cyclic Model Approach. The population this study tends to cover is the entire society including the male and female. The construction was carried out on a Veroboard/stripboard while the casing of the project was done with 22cm x 15cm x 5.5cm knock-out box and a buffer solution tank of 15cm x 13.5cm x 3.5cm using soldering iron and soldering lead and the material used in the Design and Construction of this Electrophoresis Machine include: two resistors (220ohms/5w), capacitor (68uf/400v), input and output voltmeter, 13A fuse, Diodes (1N4007), switches, green and red LEDs, dotted Veroboard, jumper wire, flexible AV wire, and a buffer solution tank. The principal findings or results of this Research include that; when it was subjected to an extreme voltage of 220-240v during testing, it worked perfectly well without breakdown; the cost of building this project was low, which figuratively was ₦6,870.00 compared to other imported electrophoresis machine in the market sold at ₦15,000.00 and above; the project was simple in term of its design, easy to operate and carry out maintenance work on. Finally, the successful construction and testing of this project has demonstrated that more of this foreign apparatus can be properly modernized to reduce size and cost of purchase. Some recommendations were that Hospitals should introduce Electrophoresis Machine that can be automated, that is, the machine that contains a thermostat for auto-regulation; Hospitals should introduce Electrophoresis Machine that has an alarm for job completion indication; Government should empower youths in the field of Electronics for the production of more digital Electrophoresis machine for genotype testing.

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CHAPTER ONE
INTRODUCTION

- *Background of the Study*

There is no doubt that the world today is being revolutionized by technology. This is not only true now; it has always been the case since the dawn of scientific era. People continue to search for ways and means to make life more comfortable for themselves through discoveries. In fact, there is hardly any human activity where biomedical technology has not made its impact upon and will continue to do so.

One of such areas where biomedical Engineering technology has made a considerable impact is in the field of biomedical electronic device called electrophoresis machines for genotype testing. An electrophoresis machine is a machine used in detecting the genotype of human beings, which basically is AA, AS, SS, when an appropriate power is supplied to the tank containing cellulose acetate paper, its filter and buffer solution (Bier, 2013). From the construction of the electrophoresis machine power circuit, it was discovered that a complete circuit of this nature can be made simpler by utilizing locally available material and yet measures up in terms of standard and quality. However, the rates of separation of ions in most proteins differ from one another at different voltages and currents. Also, the time of separation depends on the nature of the sample. For many years, people died of many diseases out of ignorance and lack of curative measures. It was not clear to them if the death was as a result of a single disease or multiple diseases. Many couple witnessed sudden death of their children at birth or at their teens, 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 cause of different disease that cause death, the likes of cancer called sickle cell, disease at birth, and chronic liver disease. The knowledge did not only unravel the cause but also led to be development of authentic cure. Also intending couples' eye 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 known to them (Portin, 1993).

Formerly, electrophoresis machine was constructed without the use of resistors. But today, due to advancement in electronic chips, electrophoresis machine has metamorphosed into sophisticated device that have the capacity to separate blood and classifying them into types, example AA, AS, SS. According to the researcher (2018), electrophoresis machine is typically made of large plastics or metallic cubic box. The plastic will be cut in such a way that there will be division that will separate the task from the engine or two cubic boxes and one serving as the tank and the other the engine. Most locally constructed electrophoresis machine power circuit 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 electrophoresis machine is that it is cheap in the cost of production due to the purchase of the component within the locality.

With the arrival of the electrophoresis machine with resistors, locally made electrophoresis machines are gradually becoming obsolete, especially those without resistors since all their necessary features can equally be achieved by the type with resistors even at a cheaper cost. An electrophoresis machine is a machine that supplies a voltage of 200V its tank containing a cathode electrode, an 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 particle will migrate either to the cathode or to the anode (Bier, 2013). 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 electrode, it generates 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 sum on the molecule bearing a charge of q coulombs is Eq Newtons, $F=Eq$. (Babskii, Zhukov and Yudovich, 2012). 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 the 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 coefficient. In electrophoresis, the force moving the micro-molecules (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 be electrical potential $m=v/E$.

When a potential difference is applied, molecules with different 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. 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). $R=V/I$. This equation demonstrates that it is possible to accelerate an electrophoretic 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: $W=12R$ Görg, Weiss and Dunn (2004) outlined the different components possibly needed for the construction of an electrophoresis machine. To him, the machine is generally made up of components and material such as: step down transformer, power switch, selector switch (varistor), capacitor,

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diodes (SCR), resistors, input and output voltmeter, LED, soldering lead, fuse holder, fuse, transparent plastic (that is, polyvinyl chloride plastic), power cord, connecting wire/Av wire, vero board upon which the components are soldered, plastic cubic box, cellulose acetate paper, super glue etc. all of which are inter connected together and built for an efficient working of the machine.

➢ *Statement of the Problem*

For many years, people died of many diseases due to ignorance and a lack of curative measures. Many couples witnessed the sudden death of their children at birth or at their teens, without knowing the cause or how to avert it. It was not clear to them whether the death was as a result of a single disease or multiple diseases.

➢ *Purpose of the Study*

The purpose of this study is to design and construct an electro medical electrophoresis machine for genotype detection mainly used in the laboratory. Specifically, the work sought to**:**

- Construct an electrophoresis machine power pack that is inexpensive, reliable, safe, fast and easy to construct and operate.
- Identify the needed materials for the construction of electrophoresis power pack (machine).
- Identify the tools that will be used in the construction of an electrophoresis genotype machine.
- Identify the likely factors that impede efficient construction of an electrophoresis machine power pack.

➢ *Significance of the Study*

An electrophoresis genotype machine is of great importance to both male and female for detecting their genotype basically AA, AS, SS. Also intending couples enroll in genotype test to know 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 known to them. This is achieved through the use of an electrophoresis genotype machine. The knowledge also goes a long way to diagnose the cause of different disease that cause death, the like of cancer called sickle cell, disease at birth etc.

Finally, the circuit the circuit will be designed to be operated by anybody who is a specialist in the field of laboratory science. Also in painting industry, it is used to know the various components of a colour of paints, it will not need to be programmed or synchronized before proper operation, that is, it to be users friendly.

➢ *Scope of the Study*

The scope of this work is delimited to the design and construction of a medical electrophoresis genotype machine. This equipment is mostly used by medical laboratory scientists in the laboratory for supplying of the appropriate power to the tank containing the cellulose acetate paper, filter and Buffer solution (tris) of 8.7 pH during the genotype test. In fact, the major area where this medical equipment is used is in the field of medical laboratories.

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CHAPTER TWO
LITERATURE REVIEW

➢ *This Chapter Deals with the Review of Related Literature. the Related Literature for this Project Has Been Reviewed Under the Following Sub-Headings:*

- Brief history of an electrophoresis machine
- Concept of Electrophoresis machine power pack for genotype detection.
- Design and construction of electronic circuit
- Review of components used in the construction of an Electrophoresis power pack.
- Empirical Review of literature
- Summary of the reviewed related literature

➢ *Brief History of an Electrophoresis Machine*

Historical fabrication of Electrophoresis defined with the work 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 electrophoresis and related method become the basis for wide range of biochemical methods such as protein finger printing, southern blot, and similar blotting procedure, DNA sequencing and many more.

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 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 suspended. These observations are considered to be the origin of what we now call electrophoresis. Electrophoresis is the migration of charged particle under the influence of an electric field (Gorg et al., 2004) To him, it is a method that separate macro-molecules either nucleic acid or protein on the basic of size, electric charge and other physical properties. ELECTRO refers to the energy of electricity. PHORESIS, from the Geek 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.

➢ *Concept of Electrophoresis Machine Power Pack for Genotype Machine*

According to Bier (2013) electrophoresis machine power pack is an electro-medical machine that supplies 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 particle will migrate, either to the cathode or to the anode. Bier (2013) pointed out that, to completely understand the separation of charged particle in electrophoresis, it is important to look at some simple equation relating to electrophoresis. When potential difference (voltage) is applied across the electrodes, it generates a potential gradient (E) which is the applied voltage (v) divided by the distance (d) between the electrode. $E=v/d$. when the potential gradient E is applied, the some on a molecule bearing a charge of q coulombs is Eq (newtons). And $F=Eq$. it is this force that drives a charged molecules toward an electrode. There is also a frictional resistance that slows down the movement of this charged molecule know as varistor. The frictional force is a measure of the hydro dynamic size of the molecule, the shape of the molecules, the pore size of the medium in which electrophoresis is taking place and viscosity of the buffer.

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 i.e. $m=v/E$. Even molecules with similar charges will begin to separate if they have different molecular sizes. 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 (1), voltage (v), and resistance (R). $R=V/I$, this equation demonstrates that it is possible to accelerate an electrophoretic separation by increasing the applied voltage, which would result in a corresponding increase in the current flow. However, increasing the voltage according to Researcher (2018) would ignore one of the major problems for most forms of electrophoresis machine, namely the generation of heat. To him, during electrophoresis the power (W, watts) generated in the supporting medium is given by $W=12R$. Perry (2018) stated that, to construct a functional electrophoresis machine, components such as a transformer, power switch basically for tuning ON and turning OFF the machine, a selector switch used as a varistor, A capacitor for storing the electrical energy in the form of electric charge, a SCR circuit for converting the input Ac voltage into an equivalent DC voltage, A resistor for limiting the amount of current to be supplied to a components connected to it, LED indicator, an input and output voltmeter for displaying both input AC voltage and output DC voltage, A fuse for protecting the machine against excess current surge, A PVC plastic, power cord, connecting wire and AV wire, Veroboard for mounting the components and lines, soldering iron and lead.

➢ *Design and Construction of Electronic Circuit*

Design according to Dorst (2015) is the creation of a plan or convention for the construction of an object, system or measurable human interaction as in architectural blue print, engineering drawings, business processes, circuit diagrams and sewing patterns. He further defined design as to convince or fashion in the mind; invent, and to formulate a plan. Construction on the other hand, is an imperative aspect of a design process. Construction is a general term meaning the art and science to form objects, system, or organization. Put simply, construction connotes putting together of parts to form an integrated object (Perry, 2018).

➢ *Design Model*

According to DITC (2006), there are seven design models. These include;

- *Linear Design Model:*

  this model portrays different strategies that are done once in a fixed order.

- *Cyclic Design Model:*

  this model has strategies in a specified order but which can be repeated through various iterations.

- *Spiraling Design Cycle:*

  this improved cyclic model shown the evolution of ideas as they move through iteration of design strategies in a given order.

- *Dialectical Design Model:*

  the back and forth (dialectical movement between design idea and concrete reality shown how designers progress from early brainstorming work to the making of final products.

- *Conversation-With Material Model:*

  here designing involves interacting with material while ideas emerge and develop.

- *Learning by Design Cycle:*

  here designers move between inquiry and design in meeting customers or consumer's need, by applying a "need to know" and "need to do" approach.

- *Symmetric Design Cycle:*

  this is a design strategy in which design are done in particular order and framed within the overall process of finding and solving main design problems and their sub-problems.

➢ *Cycle Design Model*

As aforementioned the cycle design has strategies in a specified order but which can be repeated through various iterations. The model however, is adopted for this project due to its merits which include and not limited to the following as pointed out by Onele (2006).

- It is interactive in nature in that the design can check list with his aims and objectives at any stage of the design.
- Error is easily detected and eliminated as soon as they occur.
- It has a specified order which can be followed without making unnecessary error methods of constructing.

➢ *Electronic Circuit Printed Circuit Boards (PCB)*

For high performance fast digital circuit, with many thousands of pins, multi-layer PCBs (at least 4 layers) are the preferred choice. This allows two layers for routing with supply and ground connection each having a whole layer. The result is excellence noise characteristics and relatively easy and compact routing, which is usually done automatically.

➢ *Surface Mount Technology*

This construction methods utilizes the technology of micro-chipping. Smaller components on both sides of the PCB. This method has even led to greater possibilities in automation, reducing labour cost and increase production rates.

➢ *Through Hole/Strip Board (Vero board) Construction*

In this construction method, the components are firmly secured into the holes on the Veroboard and are soldered at the back of the board. This is the method beloved of hobbyists because it produces a reasonably neat and robust result for minimum cost (Onele, 2006). Here components are laid on a strip board (Veroboard). This method however, utilize a board which one of its sides is covered with copper separated into tracts 2.54mm apart with interval of 2.54mm (Onele, 2006).

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➢ *Review of Component Used in the Construction of the Electrophoresis Power Pack Machine.*

The electronic components used in the construction of an Electrophoresis machine power pack for genotype test are reviewed in this segment.

➢ *Transformer*

A transformer is a static electrical device that transfers energy by inductive coupling between its winding circuits (Winders, 2002). A varying current in the primary winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic flux through the secondary winding. He further maintained that this varying magnetic flux induces a varying electromotive force (EMF) or voltage in the secondary winding. Transformers come in a variety of sizes, from tiny thumbnails used in microphones to massive units that connect the electricity grid and weigh hundreds of tons. Electric power and electronic applications require a variety of transformer designs. Transformers, often known as step-up or step-down transformers, are used to either increase or reduce voltages. Primary and secondary windings with varying numbers of turns make up this structure. In order to reduce the supply voltages to a level appropriate for the low voltage circuits they contain, transformers are also often utilized in electronic products.

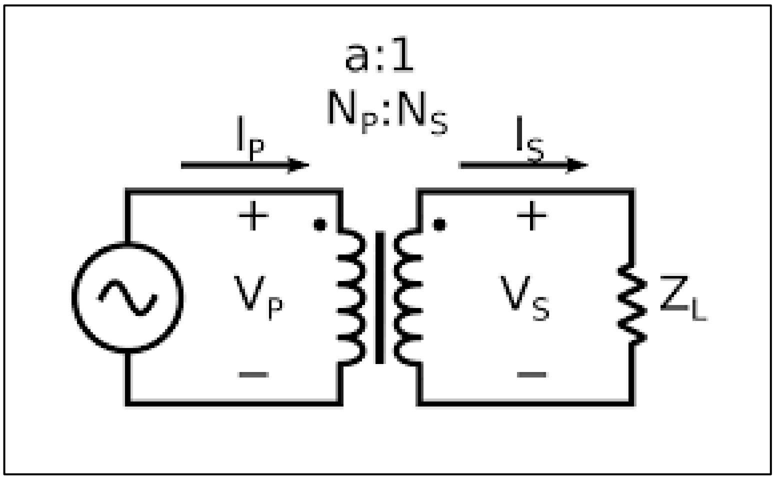

Fig 1 Symbol of Transformer.

➢ *SCR Diode*

In electronics, a diode is a semiconductor device that converts A.C to D.C (Alternating current to a direct current). A diode is a type of two terminal electronic components with nonlinear voltages characteristics. In semiconductor diode, the common type today is a crystalline piece of conductor material connected to two electrical terminals. The most common function of a diode is to allow 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 (Tan, Tran and Chua, 2016). 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. Diodes are used to regulate voltages (Zenner diodes), to protect circuit from high voltages surges (Avalanche diodes), to electronically tune radio frequency oscillations (tunnel, gum IMPACT diodes) and to produce light (light emitting diodes). Diodes were among the first semiconductor electronic devices with crystal rectifying abilities (Ferdinand 1874).

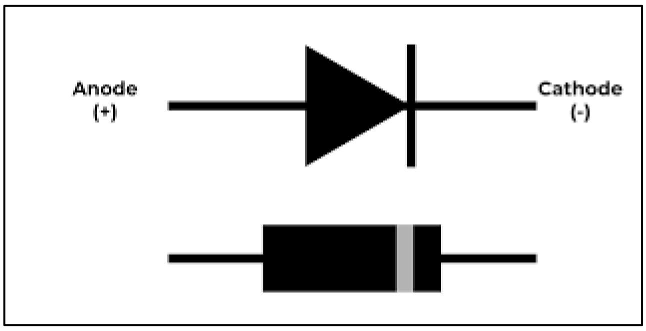

Fig 2 Symbol of a Diode

➢ *Capacitor*

A capacitor originally known as a condenser is a passive two-terminal electrical component used to store energy electro statically in an electric field. An ideal capacitor is characterized by a single constant value, capacitances. It is usually made up of an insulating medium known as dielectric. When there is a potential difference (voltage) across the conductors, a static electric field

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develops across the dielectric, causing positive charge to collect on one plate and negative charge on the other plate. Energy is stored in the electrostatic field. The S.I unit of capacitance is the farad which is equal to one coulomb per volt. Capacitors are widely used in electronic circuit for blocking direct current while allowing alternating current to pass. In analog filter networks, they smooth the output of power supplies, act as a reservoir of charge. The different types of capacitors are ceramic, electrolytic, paper, mica, metalized polyester film, plastic film capacitors, glass capacitors each plate and dielectric arranged in various ways depending on the designed ratings of the capacitor.

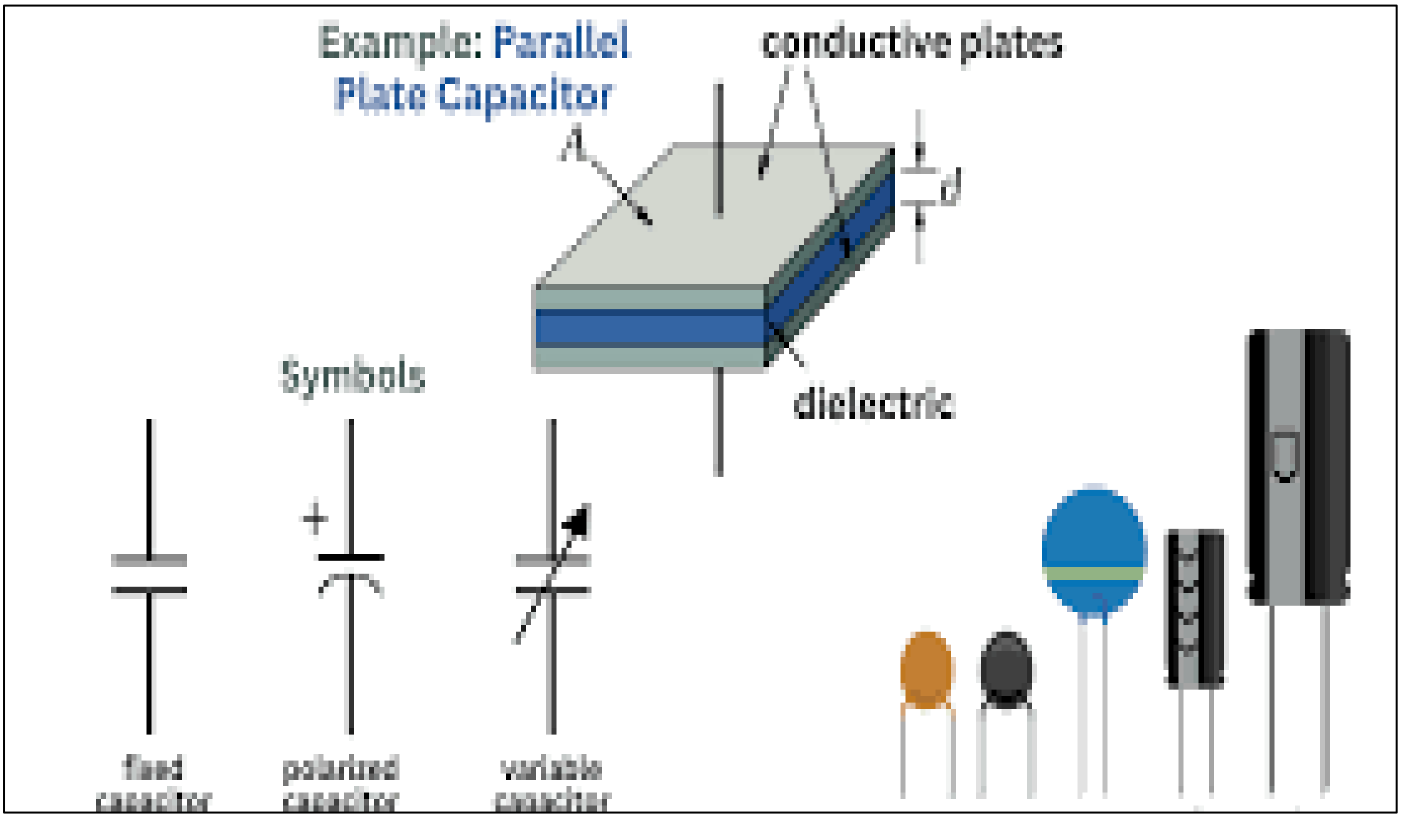

Fig 3 Symbol of Capacitor

➤ *Resistors*

Resistor generally is a two-terminal electronic device that 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 widely used in electronic devices and are frequently found in electrical networks and electronic circuits. In addition to resistance wire like nickel-chrome, practical resistors can be constructed from a variety of compounds and films. Depending on how they are constructed, resistors can be fixed or vary. Higher power rating resistors are not harmed by heat during soldering, but they are physically larger and may need a heat sink. In a circuit, a resistor can be connected in parallel or series.

➤ *They Are Colour-Coded as Shown in the Table Below:*

Table 1 Resistor Colour Codes

Colours	Values	Decimal Multiplier	Tolerance %
No band	___	___	20%
Silver	___	0.01	10%
Gold	___	0.1	5%
Black	0	1	-
Brown	1	10^1	
Red	2	10^2	2%
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Grey	8	10^8	
White	9	10^9	

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Resistance is the opposition offered to the flow of electric current by a resistor. Resistance is measured in Ohm's. Resistor values are often given in K and M (i.e. kilo and mega). The symbol is shown below.

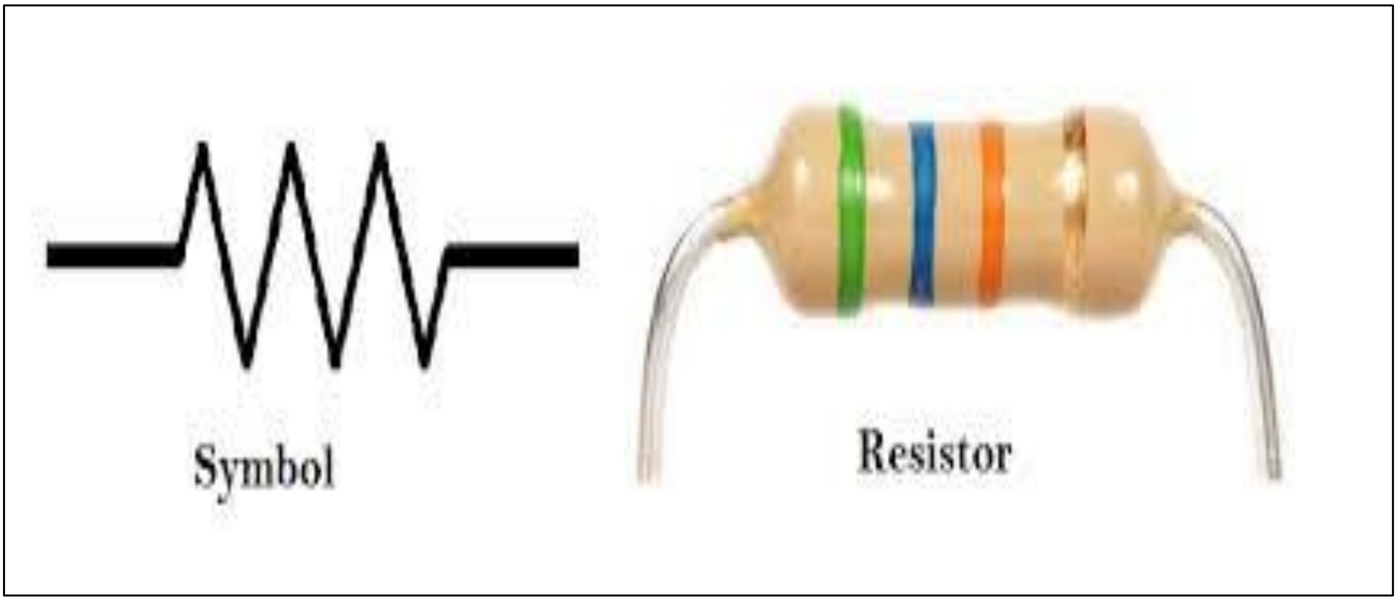

Fig 4 Symbol of Resistor

➢ *Switch*

A switch is a component or electrical safety device that has the ability to create and destroy electrical circuits by rerouting electricity from one conductor to another or stopping it altogether. The most common type of switch is an electromechanical device that is manipulated by hand and has one or more sets of electrical connections. There are two possible states for each set of contacts: closed, which indicates that the contacts are in contact and that electricity can move between them, and open, which indicates that the contacts are apart and the switch is not conducting. When these states (open and closed) change, a "toggle" (flip switch for continuous "ON" or "Off" or momentary) type of mechanism may be at work.

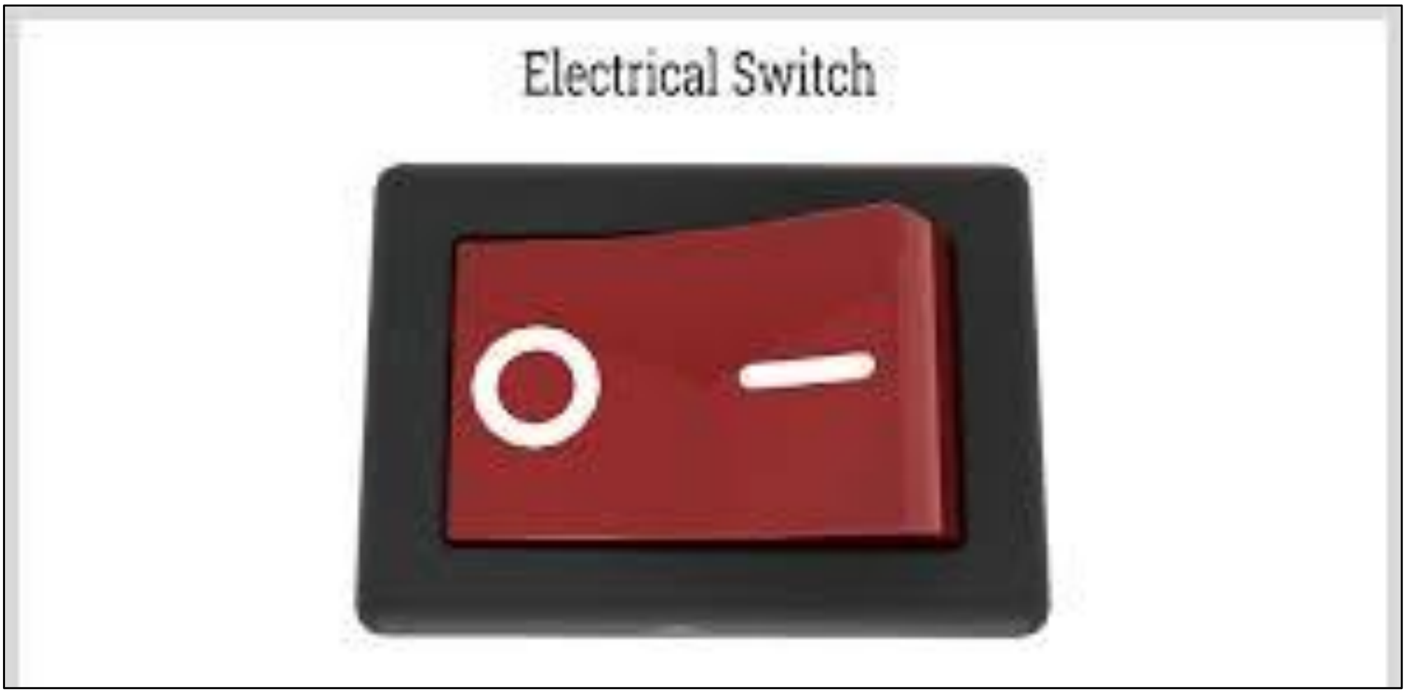

Fig 5 Symbol of Switch

➢ *LED Indicator Light*

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

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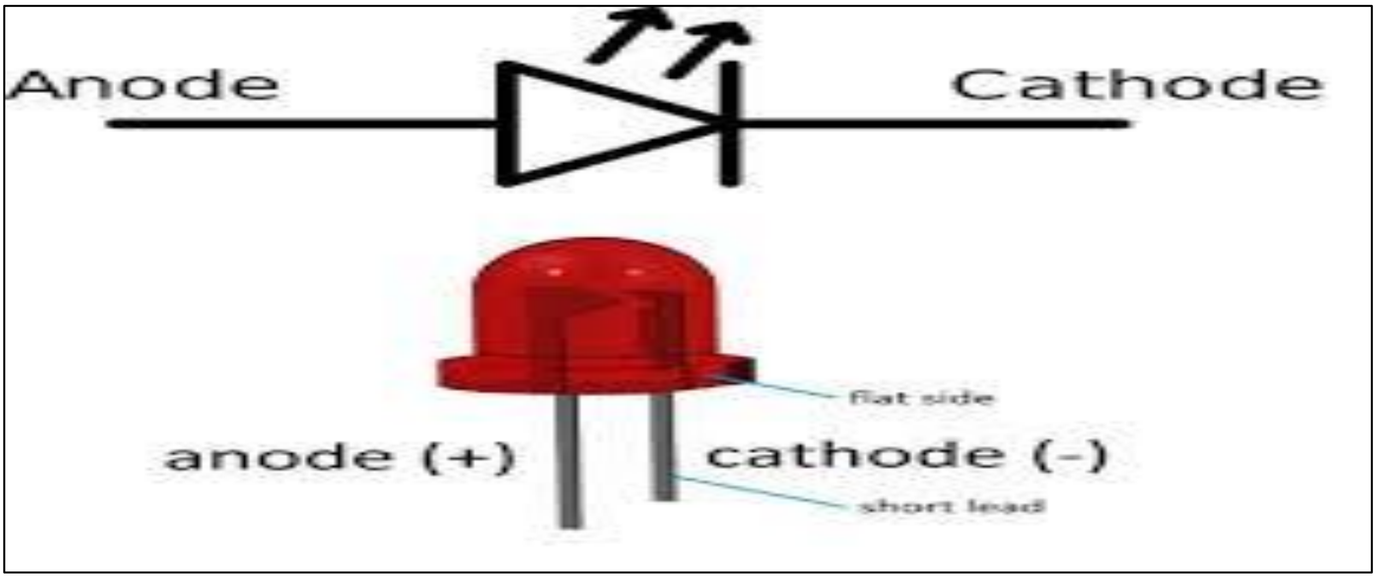

Fig 6 Diagram of Different Indicator Light Shapes are

➢ *Fuse*

In electronic and electrical Engineering, a fuse is a type of low-resistance resistor that acts as a sacrificial device to provide overcurrent protection of either the load or source circuit (Tan, Tran and Chua, 2016). Its essential component is a metal wire or strip that melts when too much current flows, which interrupts the circuit in which it is connected. Short circuit, overloading, mismatched loads or device failure are the prime reasons for excessive current. According to Tan et al., (2016) a fuse interrupts excessive current (blows) so that further damage by overheating or fire is prevented. Wiring regulation often define a maximum fuse current rating for a particular circuit. To him, over-current protection devices are essential in an electrical system to limit the threat to human life and property damage. Fuse selection depends on the load's characteristics. A standard fuse may require twice its rated current to open in one second, a fast blow fuse many require twice its rated current to blow in 0.1 seconds, and a slow-blow fuse many require twice its rated current for tens of seconds to blow.

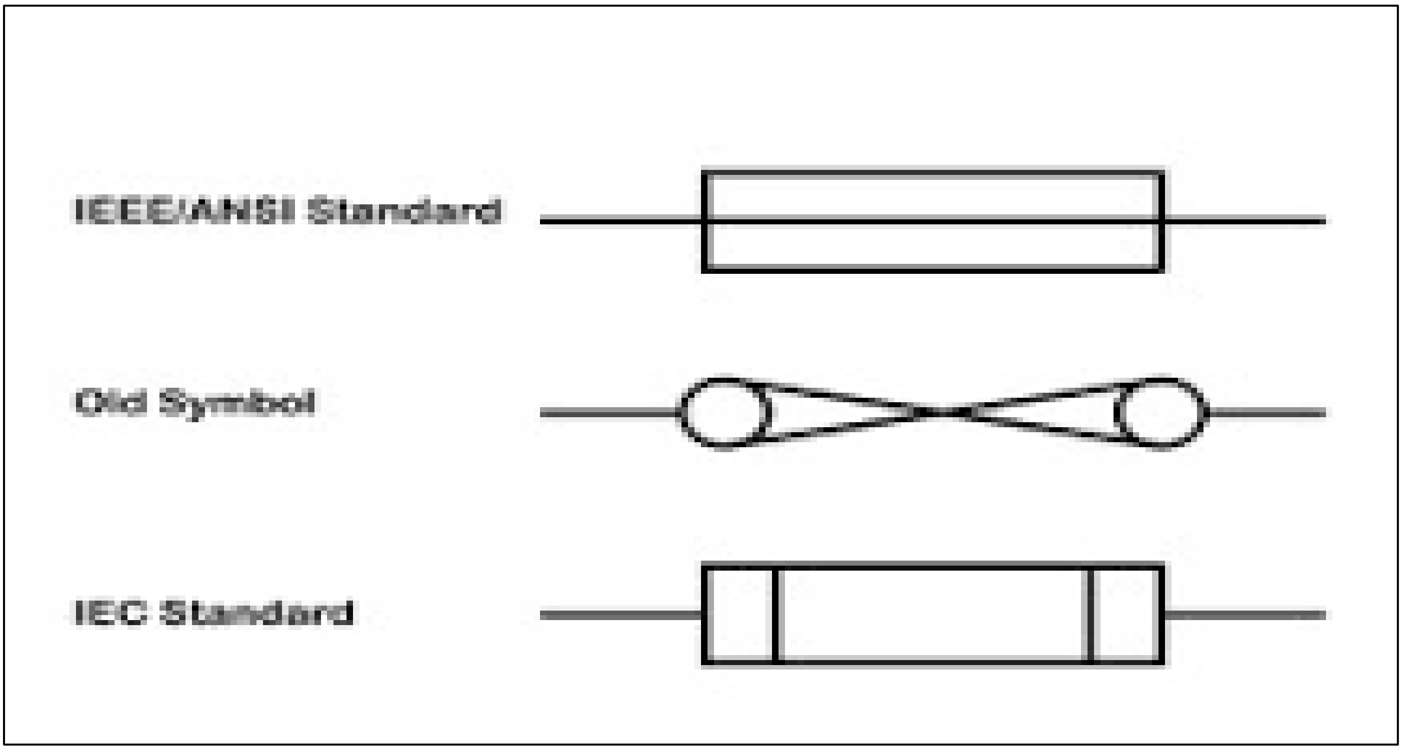

Fig 7 Diagram of Fuse

➢ *Connecting Wires*

The connecting wires are used for connecting electric components in the circuit and also from the engine to the tank.

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- *Input and Output Volt Meter*

A meter is an instrument used for detecting the value and quantity of electrical components. In electronics there two types of meters namely; the digital meter and the analog meter. A meter may be constructed to measure voltages, current, resistance etc. voltmeters are meters designed to measure voltage across any electrical system both incoming voltages known as input voltage and the voltages going out of the system known as output voltage (Tan et al., 2016).

- *Empirical Review of Literature*

Adefemi et al., (2018) worked on "Design and Construction of a Low-Cost Hemoglobin Electrophoresis (Genotype) Machine for the Diagnosis of Inherited Genotype Disorder. He however, adopted the learning by design cycle model" as his design approach. In this method, he moved between inquiry and design in meeting consumer's needs, by applying a "need to know" and "need to do". He asked questions like" will the device be easy to operate by even the layman? And will the cost of building the circuit be low? The design and construction team incorporated a power supply unit, buffer solution (tris), cellulose acetate paper, filter paper, electrodes (anode and cathode), switch, cable, capacitor, fuse, and other necessary components. The successfully constructed genotype machine was validated for effective and efficient diagnostic purposes for detecting different types of haemoglobin genotypes by testing it using several specimens of known haemoglobin genotypes of different types. The researchers compared the results from this testing process with those obtained from a standardized haemoglobin genotype machine. The test result obtained from this verification and validation process showcases that the low-cost haemoglobin electrophoresis ma-chine using cellulose acetate paper can effectively separate, distinguish and identify different haemoglobin variants such as HBAA, HBAS, HBAC, HBCC, HBSS, HBSC, HBF, HBAC, HBAF with few limitations. His work is related to this project, because it sought to design and construct an electrophoresis machine. The only difference between his work and this project is that the former sought to design and construct an electrophoresis machine using I.C while the latter sought to design and construct an electrophoresis machine power pack for genotype test using local components like a resistor, capacitor, SCR and LED.

Also, Ekuma (2017), worked on design and construction of transformer type electrophoresis machine. He adopted the linear design model as his design approach. Here, he portrayed different design strategies, which was done once and on a fixed manner. His work however, is related to this project because it sought to design and construct a transformer type of electrophoresis machine. However, the difference between Ekuma (2017) work and this project is that the former sought to design and construct a transformer type of electrophoresis machine while the latter sought to design and construct electrophoresis machine without using transformer.

Finally, Joel (2010) worked on "design, construction and troubleshooting electronic devices". In his research, he adopted the cyclic design model as his design approach. Here, he portrayed several design strategies in a specified order, where it was done through various iterations until the desired design was achieved. Joel (2010), work is similar to this project because both deals with design and construction. The predominant difference between his project and the work is that, his work is only implied in the educational sector while this project can be applied not only in the educational sector but all sectors of the economy and most especially in hospitals and laboratory.

- *Summary of the Reviewed Related Literature*

The review of literature relating to the design and construction of an electrophoresis machine revealed that, the cyclic design model adopted by Adefemi et al., (2018) and Joel (2010) was most appropriate and as such was chosen for this work because of its availability and simplicity to use.

The review further revealed that, the existing electrophoresis in the market are too complex in term of its design and structure since the systems are too complex, they need regular preventive maintenance to make sure that the system operates well. Also, the cost of maintaining the existing equipment is expensive. To support this, the study tends to cover the gap by designing and constructing a low-cost electrophoresis machine power pack that is cheap in terms of price, affordable by middle laboratory scientist for testing, easy to operate in terms of utilizing the device and of course to carry out maintenance work on.

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CHAPTER THREE
METHODOLOGY

This chapter presents the methods adopted for the design and construction of a medical electrophoresis power pack for a genotype machine.

➢ *This is Done in the Following sub-Heading:*

- Design of the study
- Choice and selection of materials
- Tools and materials used
- Functional design
- Science and calculation of the Design
- Construction procedure
- Assembly of the component
- Precautions to be observed in the construction procedure

➢ *Design of the Study*

The type of design adopted by this research was Research and Development (R and D) method. The cyclic Model Approach was adopted for the project. The cyclic design model has strategies in a specified order but which can be repeated through various iterations. Research and development make use of the cyclic design model and its approach. This is the type of design that involves several repetitions before arriving at the desired /intended product because it involves the design and construction of an electronic system.

➢ *Choice and Selection of Materials*

The materials and components used in this project were chosen based on their colour coding, rating, value and the role they play in the circuit. Their mechanical properties were also considered while choosing materials and components. However, the component and materials used in this project and their amount are presented in the table below:

➢ *Bill of Engineering Measurement and Evaluation (BEME) of an Electrophoresis Machine Power Pack*

Table 2 Bill of Engineering Measurement and Evaluation (BEME)

Item No	Description of material and components	Quantity	Rate ₦	Amount ₦
1.	Resistors-R1(220jΩ/5w) R2 (68kΩ)	2	50	100
2.	Capacitor 68uf/400v	1	200	200
3.	Voltmeter	2	300	600
4	13A fuse and fuse holder	1	200	200
5.	Diodes (IN4007)	4	20	80
6.	Switches (Sw1 and Sw2)	2	100	200
7.	LED (Green and Red)	2	20	40
8.	Vero Board (Dotted)	1	150	150
9.	Jumper Wire	1 yard	50	100
10.	Flexible AV Wire	2 yards	100	200
11.	Casing (6cm x 9cm)	1	1000	1000
12.	Buffer Solution Tank	1	4000	4000
	Grand Total		₦	**6,870**

➢ *Tools and Materials Used*

The major tools used in carrying out this project include:

- Digital multimeter
- Soldering iron
- Solder wire /lead
- Soldering stand
- Side cutter
- Hand Drilling machine
- Sand paper
- Plier (long-nose)
- Razor Blade

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- Screw Driver (flat and star)
- Measuring tape
- Pencil
- Meter Rule

➢ *Materials for the Tank are:*

- PVC plastic
- Super glue
- Cutter
- AV female port
- Soldering lead Electrode

➢ *Functional Design*

This functional design will present the schematic diagram of this project as designed by the researcher. The researcher went through various iterations to come up with the final schematic diagram. However, the schematic diagram of this project work is presented below:

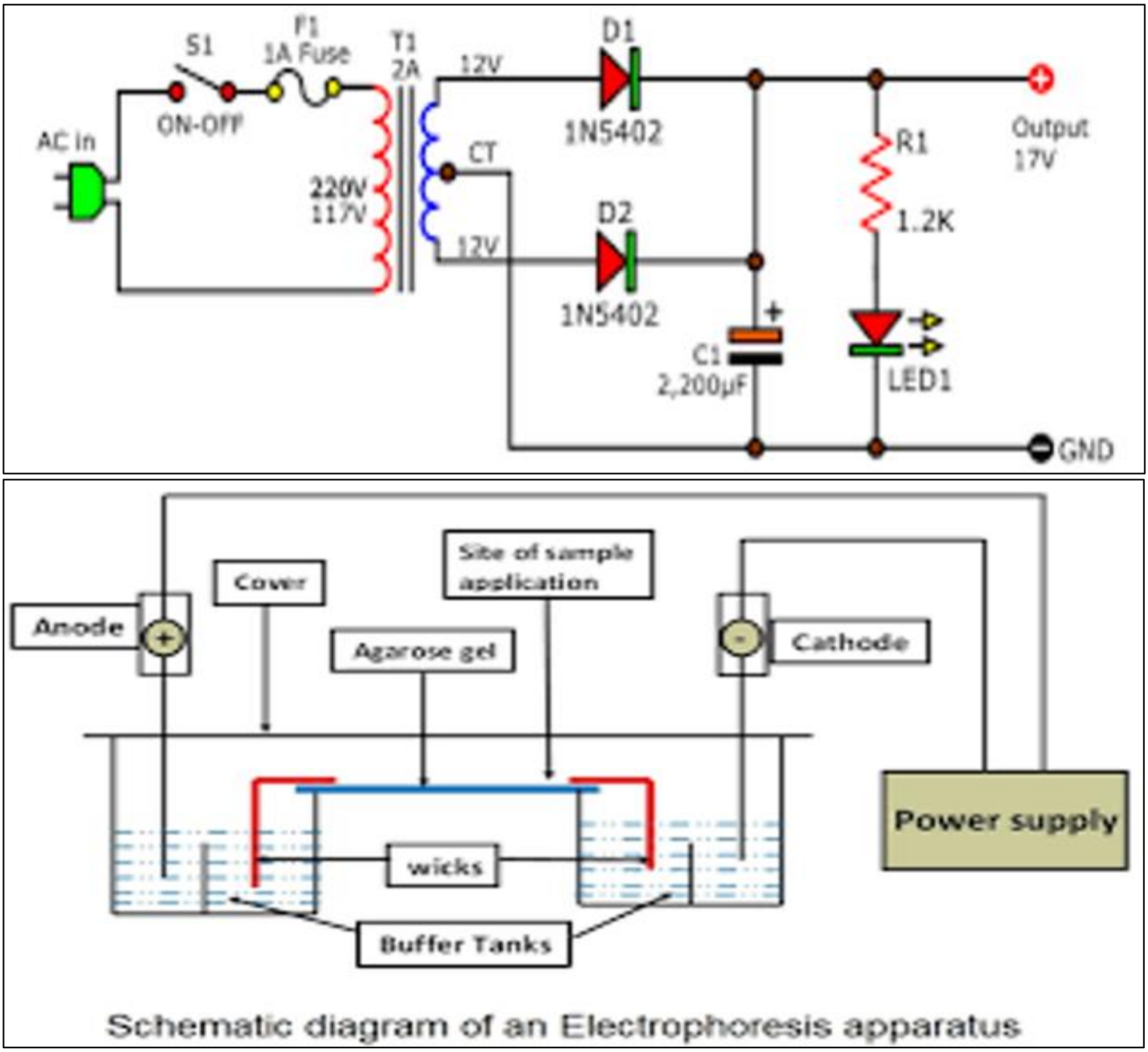

Fig 8 Schematic Diagram of Medical Electrophoresis Power Pack for Genotype Machine.

➢ *Science and Calculation of the Design*

The calculations involved in the design of this project work are analyzed as follows:

Supply voltage (VS) =240v
VAC =VDC =240V

Considering Resistor, R1, using ohm's law
Where, V=IR
Current (1) through RI, I =V/R
Where, V=240V, R=68K=68000Ω
Hence, I, 240/68000= 0.00353A=353mA
Also considered LED, in series to R1

Resistance in LED, $R = \frac{Vs\text{-}VLED}{I\ LED}$

Where Vs=supply voltage =240V
VLED=3V (standard for red LED) And ILED =10MA (standard for Red LED)
Therefore, RLED i.e LED Resistance =

$$\frac{240\ \text{-}3}{10 \times 10^{-3}} = \frac{237 \times 10^{3}}{10}$$

$$RLED = \frac{237000}{10} = 23700\Omega$$

Therefore, R_{LED}=23.7kΩ
Analyzing the capacitor, C1=68mf=68x10^{-6}f
Quantity of charge stored, q =CV But, C=68x10^{-6}f, V =240v
Q=68x10^{-6}x240
Q=68x240x10^{-6}=16320C
Notes VAC =VDC =240
Voltage Drop across R1=V=IR
But I=V/R=240/22=10A
Vdp across R2, V=IR
Vdp=10x22 =220V DC
Power consumed, P=IV=0.00353x240=0.85W

➢ *For the Tank*

The mathematical description of the force in the tank during electrophoresis is simple. An electric force (Fe) is exerted on the charged particle. The magnitude of the charge force equals the product of the charge q of the particle and the electric field E generated between the two electrodes. Hence, Fe = q x E

When an electric field is applied and the charged particles are accelerated by the electric force, a drag force (Fd) called friction will also be exerted, and the force Fd is a linear function of the velocity (V) of the particle; Hence,
Fd =F x V and Q x E =F x V.

Once the magnitude of the two opposing force becomes equal as shown above, the resultants force becomes equal as shown above, the resultant force becomes zero. Therefore, each particle will move at a constant velocity characteristic of the given particle at the given accelerating potential and medium. Therefore, the electrophoretic mobility (m) of the particle is given by the equation or formular: m =V/E =q/f.

Particles learning different electrophoretic mobility i.e. those that migrate at different speeds in the same medium and electric field, can be separated by electrophoresis.

➢ *Construction Procedures*

After designing the circuit, the following steps were used in constructing the electrophoresis machine power pack for genotype test:

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- **Step 1:** The circuit diagrams for the work were drawn which in detail of how the interconnections between components in the board will be made and followed.
- **Step 2:** The circuit, so designed, was studied to know how the components were going to be placed.
- **Step 3:** The circuit diagram was simulated using a Breadboard. Here, the components were placed according to the circuit diagram in the breadboard to test the effectiveness of the circuit.
- **Step 4:** A Veroboard/strip board components layout was produced as according to the circuit.
- **Step 5:** The components were laid as of the drawing in the Veroboard components layout and jumper wire placed where necessary on the Veroboard.
- **Step 6:** Connecting wires were used to connect the voltmeters, LEDS, switch and the AV output wire to the Veroboard.
- **Step 7:** After confirming that the component was fixed according to the Veroboard components layout, the soldering was carried out
- **Step 8:** Excess protruding parts beyond the solder were trimmed and the testing of the tracks was carried out
- **Step 9:** Testing was carried out to ensure its workability.
- **Step 10:** The strip board/Veroboard was finally transferred to its casing which comprises of 6cm x 9cm knock-out PVC box.
- **Step 11:** The final testing was made to ensure everything was in place and the circuit was functioning effectively.

➢ *Assembly of the Components*

The assembling of the component had several steps. However, the detailed steps are presented below:

- **Step 1:** Drawing of the block diagram. This drawing helped the researcher to know the different modules in the electrophoresis machine so designed.

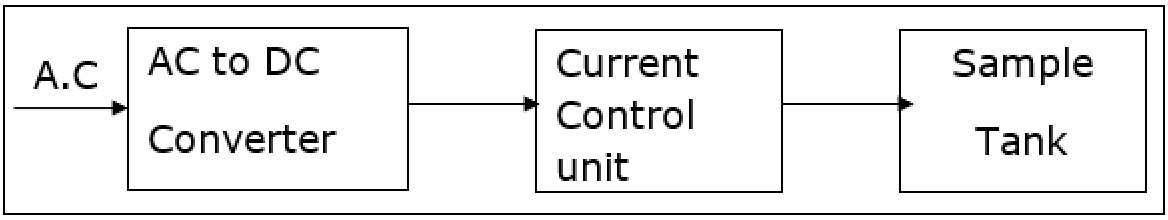

Fig 9 Block Diagram of an Electrophoresis Machine Power Pack for Genotype Test

- **Step 2:** The component to be assembled were measured using a digital multimeter. The aim of this measurement was to know if the values of each component were in keeping with the proposed components so used in the circuit design. Another purpose of the measurement was to indicate faulty components so as to make away with them.
- **Step 3:** Simulation of the circuit using a breadboard. This was done by arranging the component as of the circuit diagram on the breadboard. This was done to test the functionality of the circuit so designed to ensure neatness when the component is transferred permanently to the Veroboard.
- **Step 4:** The Veroboard component layout of the circuit was produced. This is a drawing that showed how components were going to be placed on the Veroboard.
- **Step 5:** The component was then placed on the Veroboard as according to the Veroboard components layout so drawn.
- **Step 6:** After the arrangement of the components the next thing done was to solder the components' leads to the Veroboard so that they would be firmly held to the Veroboard. This was done by using a soldering iron and a solder wire to hold the leads of the components firmly to the Veroboard.

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- **Step 7:** The component so soldered to the Veroboard was tested to ensure it gave what was intended and to avoid bridging of any of the components. This was done by using a digital multimeter to test the continuity of all the components and how they flowed to each other in the Veroboard.

- **Step 8:** The Veroboard was then transferred to the casing of the electrophoresis machine. The casing comprises of 6cm x 9cm PVC knock-out box.

A pencil and a meter rule were used to mark out where the Veroboard, switch, voltmeters and the LEDS were to be placed. The holes for switches voltmeter and the LEDs were made.

After this, the cover of the box was used to cover the electrophoresis machine and four screw nails of 1cm each were however, used to hold the cover to the box.

➢ *Precautions to be Observed in the Construction Procedures*

For this project to be effectively done, certain precautionary measures need to be observed by the researcher. These include:

- The circuit diagram should be properly studied to avoid using inappropriate components that were not in tandem with the design
- The circuit must first be simulated in a breadboard to ensure that the circuit designed could be effective and implementable
- A Veroboard components layout should be made to ensure components are neatly placed and arranged
- Each component should be tested to ensure that they are in proper working condition before being soldered on the Veroboard
- The soldering iron should be placed at an angle of 45^0 and the solder lead/wire placed on the components to be soldered to ensure proper soldering and firm grip of the components
- The tracks should be tested for continuity to ensure flow of current in the circuit
- The soldering iron should be placed on its stand to avoid burning on the researcher or other thing that may lead to fire outbreak.
- It should be ensured that the glue did not come in contact with the researcher's eyes
- Pair of gloves and a laboratory coat should be worn by the researcher to ensure safety while working.

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CHAPTER FOUR
PRESENTATION AND TESTING

➢ *This Chapter Presented the Stages Involved in the Testing of the Medical Electrophoresis Power Pack Machine So Constructed. The Chapter is However, Arranged in the Following Sub-Headings:*

- Presentation
- Performance Testing and Troubleshooting
- Skill Requirements
- Maintenance Guidelines

➢ *Presentation*

This Segment presents the working principles and concept of the medical electrophoresis machine power pack.

➢ *The Power Supply Unit*

From a single transistor and an operational amplifier circuit to a digital and microprocessor system, nearly every electronic circuit needs a single, steady voltage source. By comparing the DC output voltage with a steady reference voltage, negative feedback can be used to build a regulated power supply. Using a bridge rectifier, the input AC voltage is corrected, creating a fluctuating DC voltage that is subsequently fed through a filter capacitor. Essentially a shunt electrolytic capacitor, the filter capacitor charges the input voltage's pack value with a long discharge period to keep it from being fully discharged when the fluctuating dc voltage drops.

Therefore, a voltage output is always present across any connected load. The filter's output voltage is then fed into a linear regulator (220JΩ/5wat resistor) with a rating that can manage this voltage.

➢ *The Current Control Unit*

➢ *Theory of Operation:*

When the circuit is powered by closing switch, the diodes 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 or filtered by a 68uf/400v electrolytic capacitor through the current flow from the input. This is a better D.C output not totally free of ripples. It is then fed to the voltage regulator with small resistance of 220JΩ/5watt and a very high-power rating which not just reduces the final output of the power supply but also keep it constant for proper operation of the tank. A 68kΩ resistor is connected in series to a light emitting diode to indicate the presence of power supply through the circuit. The light emitting diode is connected in parallel to the system to still allow the normal voltage to flow through the circuit to the tank. An input and output voltmeter are also connected in parallel to the lines of connection to display the voltage going into the circuit and the voltage coming out of the circuit. The output which is connected to the tank energies for separation in the tank i.e the separation of blood samples in the tank.

➢ *Tank Contents and its Mode of Operation*

The contents of the tank are:

- Cellulose acetate paper
- Filter
- Buffer solution (Tris) of 8.7Ph
- Needles and syringes

➢ *Tank Operation*

A blood sample will be required in order to test for genotype. A determinant factor sample will be used and the AS blood sample will be used as a control for the test. The AS blood sample was used because it is a determinant factor sample. After pouring an 8.7 pH Tris buffer solution into the soldering lead tank, the cellulose acetate paper is let to soak in the solution for at least ten minutes. Cleaning the acetate paper is necessary to prevent the buffer from absorbing too much. After that, the control (A.S.) and the unknown blood samples will be arranged in a straight line. The sample moves from the positive terminal to the negative one. Alongside the unknown sample, the AS sample will be arranged linearly on top of the cellulose acetate. The deciding factor is the separation from the positive to the negative pole that occurs when the machine is activated, where the "S" migrates more quickly than the "A."

It is necessary to migrate the unknown samples. If the unknown sample is below the A band, the genotype is AA; if it is below the S band, the genotype is SS; and if it is below both the A and S bands, the genotype is AS. The samples will separate as a result of the circuit's current allowing both positive and negative current to flow through the tank.

➢ *Control and Unknown Samples*

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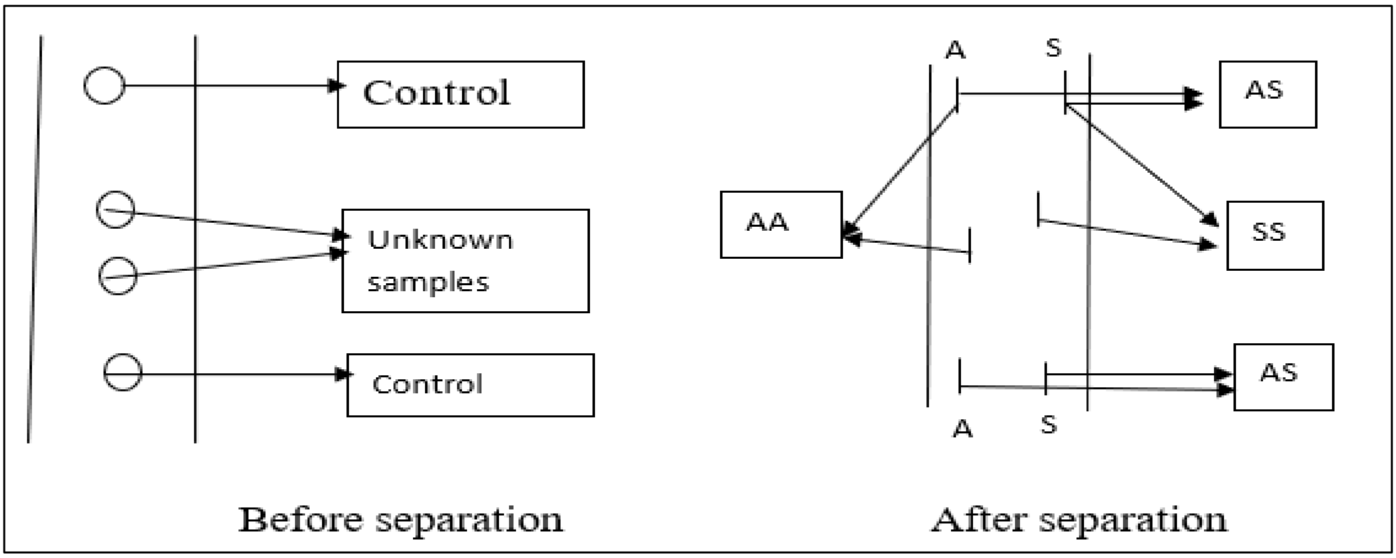

Fig 10 Separation of Blood Samples in the Tank

➢ *Performance Test and Trouble Shooting*

To finish the project, I will need to test the 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, troubleshoot a project, it will require four steps or procedures,

- Preliminary test will be performed followed by
- Operational test; if it fails any of the operational test,
- Troubleshooting begins. When the project is finally functional, then;
- A series of performance Test will be conducted. The project is ready for usage if it passes all of the tests. First, preliminary testing is carried out. This section is completed prior to the project receiving power. This is to identify mistakes that could lead to major issues if incorrect voltages and currents are permitted to reach important parts. Preventive testing is what preliminary testing is. Operational testing starts once the project passes all preliminary testing. Here, electricity is applied for the first time, and the fundamental operation of the project is established. If everything seems good at this stage, performance testing is carried out.

The project must go through the troubleshooting phase if there is an issue, such as when the electricity is not reaching the tank or is malfunctioning. The purpose of troubleshooting is to identify the issue, its cause, and the best course of action. Performance testing follows the identification and correction of the problem's root cause. To ascertain whether the project will function when it is intended to be used, performance testing is utilized. Performance tests expose the task to severe and demanding conditions. For almost two hours, this project work was exposed to high voltages of 200 to 220 volts.

➢ *Skill Requirements*

The skill required in designing and constructing this medical electrophoresis machine power pack were predominantly electronic skills. Other skills were Electrical and Technological skills. However, these skills include; Electronic Design skills gotten from electronic system and design; Electronics calculation skills gotten from circuit theorem and Analysis; soldering skills; casing design skills gotten from Engineering Drawing and AutoCAD; and electronic construction skills gotten from both electronic system Design and Biomedical Engineering Department Federal Teaching Hospital during my Industrial Training.

➢ *Maintenance Guidelines*

The maintenance guidelines for this project are presented thus:

- The electrophoresis machine should be kept in area free from dust
- The project work should also be kept in area free from vibrations to avoid making the components to break and as such causing partial contact
- The electrophoresis machine should be dusted regularly on a weekly or monthly interval
- The electrophoresis machine is not an ordinary machine and as such should be kept out of reach of non-laboratory scientist and children to avoid coming in contact with blood samples and electricity
- The system should always be kept in the laboratory and not at home
- A certified scientist should be called to carryout maintenance work on the electrophoresis machine power pack on a yearly interval.

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CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATIONS

➢ *This Chapter Presents the Overall Summary of the Findings, Conclusion and Recommendations*

- Summary
- Principal Findings
- Conclusion
- Recommendation
- Suggestions for further studies

➢ *Summary*

Human genotypes, which are essentially AA, AS, and SS, can be found using an electrophoresis equipment. In the past, electrophoresis was built without a resistor. However, because to the development of electronic chips and technology, electrophoresis machines have evolved into highly advanced systems that can separate blood and classify it into different categories, such as AA, AS, and SS. Usually, a big cubic box constructed of plastic or metal is used for local electrophoresis. A separation between the tank and the engine, or two cubic boxes, with one acting as the tank and the other as the engine, will be created by cutting the plastic in this fashion.

The majority of locally built electrophoresis machines do not employ resistors, which leads to significant electrical and functional damage to the apparatus. It can rip the cellulose acetate paper in the separation tank and, electrically, kill the diode because of the high voltage. This locally manufactured electrophoresis machine power pack has the advantage of having low production costs because the components were purchased locally.

➢ *Principal Findings*

- The project was effective because when subjected to extreme voltage of 220-240v during testing, it worked perfectly well without breakdown.

- The cost of building this project was low, which figuratively was ₦ 6,870.00 compared to other imported electrophoresis machine in the market sold at ₦ 15,000.00 and above.

- The project was simple in term of its design, easy to operate and carryout maintenance work on.

- Finally, the successful construction and testing of this project has demonstrated that more of this foreign apparatus can be properly modernized to reduce size and cost of purchase.

➢ *Conclusion*

This work deals on the design and construction of medical electrophoresis power pack for genotype machine. A genotype machine is essentially a machine use for detecting the genotype of human which specifically are AA, AS, and SS as the case may be. The design of this machine involved the use of several electronic components and materials such as resistors, diodes, capacitors, transformers, light emitting diodes, switches, and connecting wires. The principle of operation of the electrophoresis machine works in such a way that the power supply system converts the alternating current to a direct current. The direct current is then filtered using a capacitor, since a pure direct DC current is needed to power the circuit. A buffer solution, filter, cellulose acetate paper, distilled water and a blood sample are used for detecting the human genotype. The final design and construction of this system typically involves producing an efficient, reliable, and long-lasting power supply that delivers a suitable voltage and current for blood protein separation in the tank. The system is divided into different units such as the voltage or power regulation unit, the control unit, and the separation unit. The functionality of the machine after testing showed that the machine was cost-effective, accurate in terms of performance, safe in operation, and simple in design for testing for genotype in the laboratory and as well as in medical environments.

➢ *Recommendation*

Based on the finding and conclusion, the following, recommendations are hereby made:

- It is believed that it would help alleviate the problem faced by the hospitals in testing of genotype of different individuals.

- First and foremost, it would be the best thing for hospital 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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- *Suggestions for Further Studies*

Research should be carried out on the following:

- Design and construction of an automated electrophoresis machine with thermostat for auto-regulation.
- Design and construction of job completion Alarm indication electrophoresis machine power pack for genotype detection.
- Construction of Remote-control Electrophoresis machine pack for genotype detection.

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APPENDIX I

Fig 11 Appendix I