Design and Construction of an Electrical Energy Generator using Sound Energy

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ABSTRACT

There is a huge scarcity of electricity in Nigeria and other developing countries, especially in rural communities. And for carrying out our daily activities, we need electricity. Mobile phones have become part of our basic daily needs and these mobile phones require to be charged always. This project was aimed at designing and implementing an electrical energy generator using sound energy. It converts sound into electricity with the use of transducers such as the piezoelectric crystals and condenser microphones. The system has a rechargeable battery within which the converted energy is being stored for later use. Its ability to detect sound is omnidirectional and can charge any external device that requires a voltage of not more than 2V directly from the energy generated using sound, and 4V from energy stored in the inbuilt rechargeable battery. The system has been tested in various environments to confirm its capability to work with different sources of noise. The efficiency of the system has been proven to be effective especially in places with high intensity noise.

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

We all know that there is huge scarcity of energy everywhere. And for running most of our appliances and carrying out daily work, we need electricity. We are very indulgent in the use of electricity to the point that our day to day activities depend on the availability of electricity. It is really very difficult to imagine life without electricity, (life without television, cell phones, refrigerators, air conditioners, fans, lighting etc.), our life would really stop.

Because of the increase in population and drastic rise in technology, the demand for electricity has reached its apex. Therefore, some other efficient methods should be employed in the production of electric energy to meet the high demand of electricity. Study shows that sound energy is a form of renewable energy that can be used to generate power from because sound energy is a form of mechanical energy which possesses the properties of a wave, a mechanical wave that oscillates when pressurized which requires a medium to propagate through. I.e. it can travel through a vacuum, liquid and air as well. As sound energy is a mechanical energy, it can be converted into electrical energy according to the law of thermodynamics.

Several methods of achieving the above said conversion exist, in this project, the piezoelectric method is used. The piezoelectric material is a material which converts mechanical strain into electrical energy, it also works in reverse. This property of the piezoelectric material can be used to make a device which would be able to sustainably convert the sound energy to electrical energy.

There are various ways of generating electrical energy, both conventional and unconventional like Hydro, Nuclear, Thermal, Solar etc.

Hydroelectric power is a source of energy that can be renewed. Naturally, hydroelectric power generation depends on the law of conservation of energy in which the kinetic energy produced due to the movement of the mass of water from the river is converted into electrical energy, the quantum which relies on systemic variables such as: efficiency plant, volume of water flowing through the turbine and the water head from the surface of water to the turbine. Knowing the changes in these and the correlation between them, are essentials to plan properly and management of a hydroelectric power plant. (Ajibola, et al 2018).

A thermal power is another source of energy in which heat energy is translated into electricity. At several places around the world, the turbine is driven by steam. Water is being heated, transforms into steam and spins a steam turbine, which rotates the shaft of an electrical generator thereby generating electricity. The steam, after passing through the turbine, it is liquefied in a condenser and get back to where it was heated; this is called Rankine cycle. The most significant variation in the design of thermal power stations is owing to the different sources of heat which include fossil fuel, nuclear heat energy, solar heat energy, biofuels and waste incineration. Some use the term energy center more because these kind of facilities convert forms of heat energy into electricity. Particular thermal power stations are also designed to generate heat energy for industrial uses, or district or desalination of water, besides generating electrical power (kumar 2010).

Nuclear power stations are types of power plants that use the process of nuclear fission for generating electricity. This is done by using nuclear reactors combined with the Rankine cycle, where the heat generated by the reactor transforms water into steam, which rotates a turbine and a generator. Nuclear power gives the world with around 11% of its total electrical energy, with the largest producers being the United States and France. A part from the source of heat, nuclear power plants are very identical to coal-fired power plants. But, they need different safety measures because of the use of nuclear fuel has very largely different properties from coal or other fossil fuels. They get their thermal power from splitting the atoms nuclei in the reactor core, with uranium as the dominant choice of fuel globally today. Although, Thorium also has potential use in nuclear power production, it is not presently in use. Below is the basic operation of a boiling water power plant that illustrates many components of a power plant, along with the generation of electricity (IEA 2014).

Solar power is the electrical energy produced by sunlight, using directly photovoltaic (PV), indirectly using concentrated solar power, or a combination of them. Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into an electric current using the photovoltaic effect.

As the cost of solar electricity has fallen, the number of grid-connected solar PV systems has grown into the millions and utility-scale photovoltaic power stations with hundreds of megawatts are being built. Solar PV is rapidly becoming an inexpensive, low-carbon technology to harness renewable energy from the Sun. The current largest photovoltaic power station in the world is the 850 MW Longyangxia Dam Solar Park, in Qinghai, China.

The International Energy Agency projected in 2014 that under its "high renewables" scenario, by 2050, solar photovoltaic and concentrated solar power would contribute about 16 and 11 percent, respectively, of the worldwide electricity consumption, and solar would be the world's largest source of electricity (technology roadmap: solar photovoltaic energy (IEA 2014).

1.2 Motivation

In Nigeria, we have extreme shortage of electricity. This deficiency is multidimensional and is largely attributed to inadequate renewable energy. Several sources of energy which are not harmful to the environment have been discovered, many of them are implemented to a certain extend under proper conditions to deal with the scarcity of energy. However, owing to the advancement in technology that has hit this era, there is need to explore other available sources of renewable energies and how we can make use of them.

1.3 Statement of the Problem

Due to the lack of electricity in Nigeria, people find it difficult to charge their phones consistently. Such problems are higher in rural areas where most of them do not have electricity at all. These areas rely solely on generators and power banks for which they need to pay every time they want to charge their phones.

This project is designed to overcome such problems, whereby one can store the energy generated by sound (noise) in a rechargeable battery and later use it to charge their phones.

1.4 Aim and Objectives of the Study

The aim of this study is to design and construct a rechargeable electrical energy generator using sound energy.

The objectives are to:

I. Design a circuit that converts sound energy into electrical energy.
II. Construct a rechargeable power bank.
III. Demonstrate its working principle.

1.5 Scope of the study

This study will be limited to the generation of electricity by converting sound energy into electrical energy.

1.6 Methodology

A 5v rechargeable battery will be used as a power source which will power some components such as the Condenser Microphone, Op Amp, and 555 Timer I.C.

When the sound is propagated, it will be absorbed by the condenser microphone. The condenser microphone will specifically be used because of its high sensitivity to sound in every direction. When the sound generated is picked up by the condenser microphone, it will send the output to the piezoelectric crystal in the form of vibrations (i.e. mechanical strain) and to the Op Amp as well.

The piezoelectric crystal converts the mechanical strain produced by the microphone into electrical signal, the output will then be fed to the Op Amp and also to the rechargeable battery for the purpose of charging the battery.

The operational amplifier will then amplify the input received from the microphone and the crystal to a larger value. The amplified output from the Op Amp will travel to the input terminal of the BJT transistor which will acts as a switch. The output from the transistor will be fed to the 555 timer.

The 555 timer will receive the output from the transistor and hold the charge for some time before feeding it to LED indicator as well as the USB port. It acts as a bridge.

The LED is there for the purpose of indicating the flow of electric current. The USB port is where we can connect our cable and be able to charge our mobile phones.

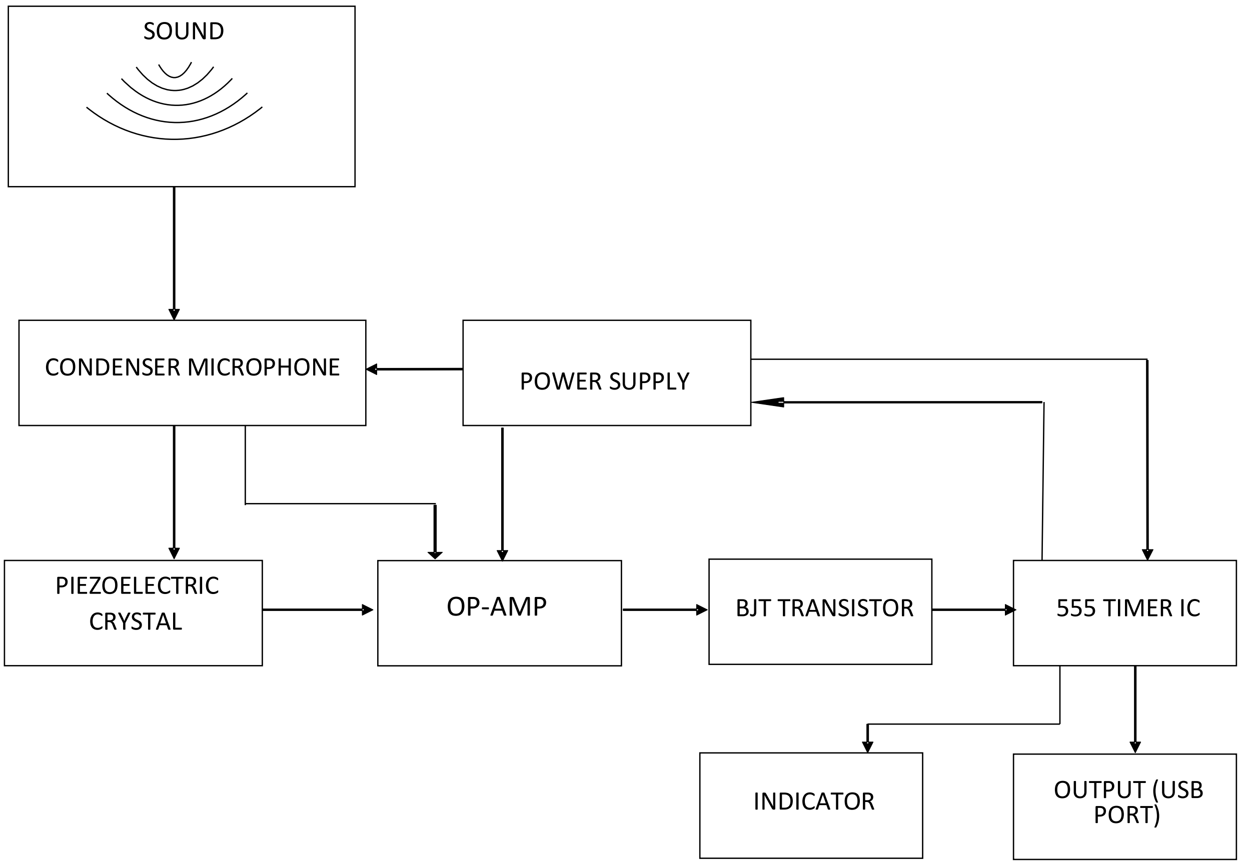

Figure 1.1. Block diagram of the Electrical Energy Generator

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The need for more efficient ways of energy production is sharply increasing. Yet, most of power needs around the world depend on the exploitation of the non-renewable fossil fuels. However, previous estimates put the use of oil and coal up to 2030, after which the world will need to foster the need for a more efficient and wide spread use of technology. The search for a renewable source of energy that can satisfy our ever growing needs is the need of the hour. Solar & wind energy have already been tapped as a source of renewable source of energy, and are now being widely accepted as one of the replacements for fossil fuels. However, their availability and dependence to natural factors such as weather conditions. However, a largely ignored and more readily available source of energy is available in the form of sound energy. Sound, on the one hand, is another source of energy which has a large potential that has been left largely untapped as we move forward further towards using Renewable and sustainable sources of energy. There has been an attempt in the past to convert sound energy into electrical energy in order to reduce the scarcity of electricity worldwide. But, consequently, this conversion was only able to produce electricity in small amounts which is not enough to even charge a smart phone. This project will bring this problem to a minimum and use sound energy to provide a reliable electricity source, converting the sound energy into electricity. The production of energy through sound can therefore convert into generation of electrical energy by one of the most regularly available form of pollution.

2.2 Conversion of Sound Energy to Electricity

One of the first to achieve this feat was the researchers from Los Alamos National Laboratory in collaboration with the Northrop Grumman Space Technology, USA. They built a compact generator which used the movement of helium gas to generate sound waves that drives a piston to move a coiled Copper wire. However, since the sound in this manner was artificially created to produce electrical energy, it does not transform naturally or already available sounds and noises present in the environment into electrical energy. Also, the use of a non- renewable source of energy to create a comparatively lesser efficient source of energy is not a feasible output.

Bhatnagar (2012) converted sound to electricity by applying strain on a piezo electric crystal which in turn provides electrical signals.

Ovaiz.A, et al (2016) generated electricity from industrial noise by using a suitable transducer in which a speaker and a transformer are used to convert noise produced by industrial machines into electrical energy through the principle of electromagnetic induction. The received signal was stepped up using a transformer.

Ansari (2017) performed his conversion by using both microphone and piezoelectric crystals. His experiment was performed on a mobile phone, when sound was propagated to his circuit the mobile started to charge and when the sound was turned off it stopped charging.

Kulkarni, et al (2017) carried out their conversion with the use of piezoelectric transducers. The produced electric energy from multiple piezoelectric transducers were stored in multiple super capacitors which were then summed up and amplified through adder and voltage multiplier circuits.

2.3 Methods of Converting Sound Energy to Electricity

There are several methods of converting sound into electricity which are in existence today, these include;

Electromagnetic induction, sound to heat, and by using piezoelectric materials.

2.3.1 Electromagnetic Induction

The first method illustrates the use of the Faraday's law of electromagnetic induction which states that the induced electromotive force (Ɛ) in any closed circuit is equal to the negative of the time rate of change of the magnetic flux (Φ) through the circuit. $\varepsilon = - d\Phi B/dt$

A very thin layer of diaphragm will be place, in this method, which will be fluctuated by the pressure produced by the sound energy. A conductor will be coupled with the diaphragm which will be placed between the two magnetic poles. Consequently, when the diaphragm oscillated by the sound waves, the conductor will have magnetic flux around it altered and as the faradays law states, the emf is induced in that conductor, causing the current flowing to conductor (Gupta, et al 2014).

Oscillations will be fast because the frequency of the sound waves is high and usable quantity of electricity could be generated. However, it has only one limitation; we require sound of very high decibels of sound is needed to produce considerable amount of electric power i.e. it will be effective only in a place where there is high decibel of sound. For instance, nuclear power plants and industries use large and noisy machines.

2.3.2 Sound to Heat

Here, we could generate electricity by converting sound energy to heat energy since sound waves travel when the particles of the medium oscillate. So when sound energy travel through the medium it will disturbs the particle of the medium. These disturbance created by sound will be utilized to convert it into heat energy as when the particles of the medium will be pushed by the sound wave it will collides with adjacent particle of the medium this collision will result in production of heat energy the production of heat energy will be more in the denser medium so for more heat production we will need a material with very high density. This heat energy will be converted into electricity.

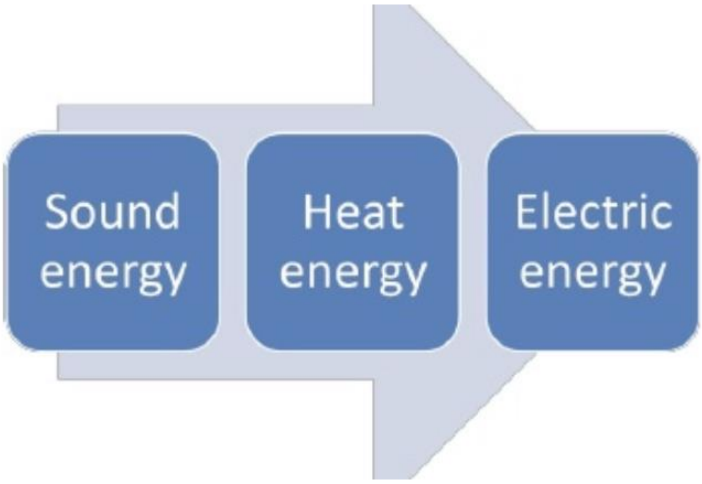

Figure 2.1 transformation of energy (Bhatnagar 2012)

This method lacks efficiency owing to much of loss of energy occurring when conversion of sound energy to heat energy and then heat energy to electric energy. Other methods are more efficient than this one. As here the conversion is done two times .you may think that according to Newtown's law energy can't be created nor destroyed it could be only converted from one form to another...so how there could be an energy loss. So while conversion of sound energy to heat energy, some loss of sound energy occurs as some of the sound energy would be converted into another form. Also while converting from heat energy to electric energy all energy would not be converted into electric energy, some of the heat energy would get converted into another form of energy. Therefore, our major concern is to convert sound energy to electric energy, so conversion into other form of energy is loss of energy for us (Bhatnagar 2012).

2.3.3 Using Piezoelectric Materials

Conversion of sound energy to electrical energy using piezoelectric material (piezoelectric materials are the crystals that generate electricity when subjected to mechanical stress).

Piezoelectric Material

Piezoelectric materials are transducers that could convert mechanical strain to electricity. The crystals are natural forming substances e.g. quartz, bone, DNA etc. and artificially ZnO, lithium niobatet Lead Metaniobateetc (Bhatnagar 2012).

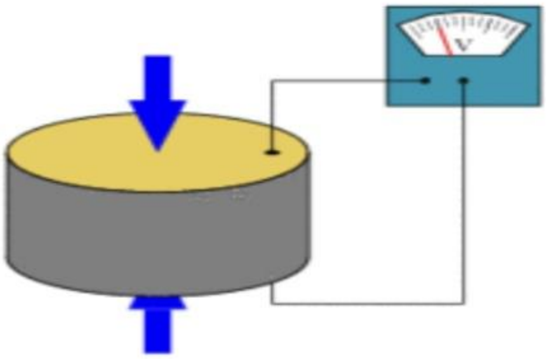

Figure 2.2 piezoelectric material (Bhatnagar 2012)

Properties of Piezoelectric Materials

Some particular crystals depict the following characteristics: If the crystal is deformed, (here by sound waves) or it is mechanically strained by the application of an external force, electric charges appear on the surfaces of the crystal and when the direction of the strain reverses, the polarity of the electric charge is also transposed. This is called the direct effect of piezoelectric, and the crystals that exhibit such property are classified as piezoelectric crystals (Bhatnagar 2012).

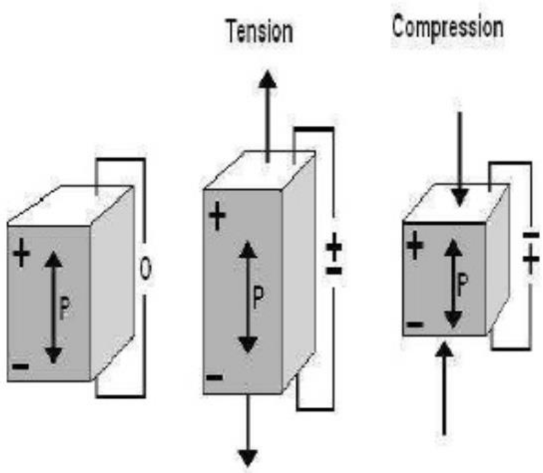

Figure 2.3 direct piezoelectric effect (Bhatnagar 2012)

Reversely, when a piezoelectric crystal is placed in an electric field, or when current is externally applied to its faces, the crystal depicts mechanical strain, i.e. the dimensions of the crystal altered. When the direction of the applied electric field is changed, the direction of the resulting stress is changed. This is called the piezoelectric crystal inverse effect.

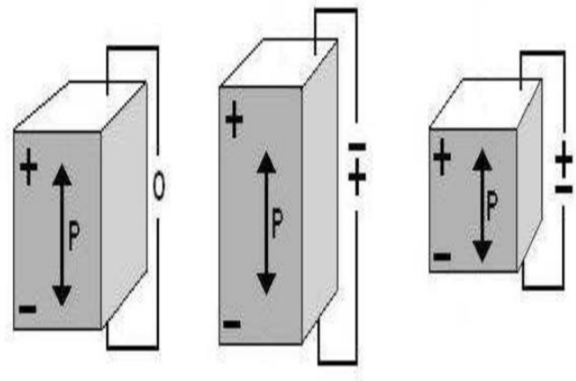

Figure 2.4 inverse piezoelectric effect (Bhatnagar 2012)

So it's shown that when the sound waves propagates enough to stress piezoelectric material, it produces strain in the crystal and then reverses it and the strain is converted into electrical energy. This property of piezoelectric material is called direct effect of piezoelectric material and could be used for making the device to convert sound energy to electric energy.

2.4 Conversion of Sound Energy to Electrical Energy Modification

From the review of previous works done, knowledge on how to carry out a successful conversion was obtained, consequent to that, a rechargeable electrical energy generator using sound energy is proposed in order to overcome the inefficient amount of output voltage resulting from the conversion. This project is designed to overcome the above mentioned issue by using multiple piezoelectric crystals and also a rechargeable battery. The use of multiple piezo crystals is to increase the amount of voltage generated. The rechargeable battery is used to power some components as well as store the charge for later use.

2.4.1 Rechargeable Battery

A rechargeable battery is a device that can be charged again after being discharged by applying DC from an external source. It is used to store electric charges for later use. Rechargeable batteries enable for multiple usages from a cell, thereby minimizing waste and generally providing a better long-term investment in terms of money spent for usable device time. This is true even factoring in the higher purchase price of rechargeable batteries and the requirement for a charger.

A rechargeable battery is generally a more sensible and sustainable replacement to one-time use batteries, which generate current through a chemical reaction in which a reactive anode is consumed. The anode in a rechargeable battery gets consumed as well but at a slower rate, allowing for many charges and discharges. In use, rechargeable batteries are the same as conventional ones. However, after discharge the batteries are placed in a charger or, in the case of built-in batteries, an AC/DC adapter is connected.

Many types of rechargeable cells created for consumer devices, including AA and AAA, C and D batteries, produce a lower voltage of 1.2V in contrast to the 1.5V of alkaline batteries. Though this lower voltage doesn't prevent correct operation in properly-designed electronics, it can mean a single charge does not last as long or offer the same power in a session. This is not the case, however, with lithium polymer and lithium ion batteries. Some types of batteries such as nickel cadmium and nickel-metal hydride can develop a battery memory effect when only partially discharged, reducing performance of subsequent charges and thus battery life in a given device. Rechargeable batteries are used in many applications such as cars, all manner of consumer electronics and even off-grid and supplemental facility power storage (Rouse 2015).

2.4.2 Condenser Microphone

Condenser Microphones generally consist of a diaphragm that is caused to vibrate by impinging waves of acoustic pressure, a back plate and air gap. In its simplest form, a diaphragm is stretched over a conductive back plate and supported by post so that there is a gap between the membrane and the back plate. Fig 2.6 below shows the basic structure of the condenser microphone. A metallized diaphragm is stretched by a tensile force, T, is put front of a fixed conducting back plate by means of a surrounding border which assures a separation distance, d, to create a capacitance with respect to the back plate and biased with a DC voltage. An acoustic wave striking the diaphragm causes its flexural vibration and changes the average distance from the back plate. The change of distance will produce a change in capacitance and charge, giving rise to a time varying voltage, V, on the electrodes (Ganji and Majlis 2004).

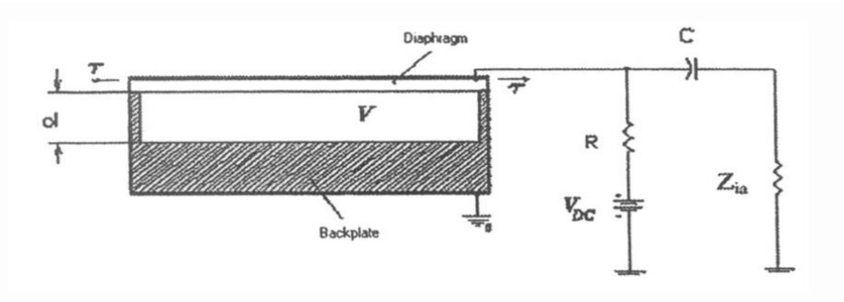

Figure 2.5 the basic structure of the condenser microphone (Ganji and Majlis 2004)

A high mechanical sensitivity requires the use of a low stress material to construct a thin membrane with a large surface area and small air gap between the diaphragm and the back plate. Losses, due to the compression of air in the air gap, can be minimized by providing holes or acoustical ports in the back plate. Damping is caused by losses in the diaphragm and viscous loses associated with the air streaming in and out of the air gap. The perforation of the back plate to create acoustical ports provide same a means to control streaming losses and therefore the damping characteristics of the microphone structure. A low damping property can be obtained using a highly perforated back plate. The shape of the frequency response of the microphone is determined by the damping and resonance behavior of the microphone structure, which depends mainly on the size and stress of the diaphragm.

CHAPTER THREE
DESIGN AND IMPLEMENTATION

3.1 Introduction

This chapter presents design and analysis of a circuit that will generate an electrical energy using sound energy system. The chapter details the analysis and calculations of all the units that make up the system; this includes the power supply unit, the sound unit, the condenser microphone and piezoelectric crystal unit, the op-amp unit, switching, indicator and output USB port unit. The design is based on the availability of the components for the system realization. The various units were designed and tested separately.

3.2 Project Design

The approach used in this design is modular one where the whole circuit is first broken into six functional units, where each unit represents a section of the circuit that carries out a specific function. The functional block diagram as illustrated in Fig. 3.1 shows the interconnections between these units.

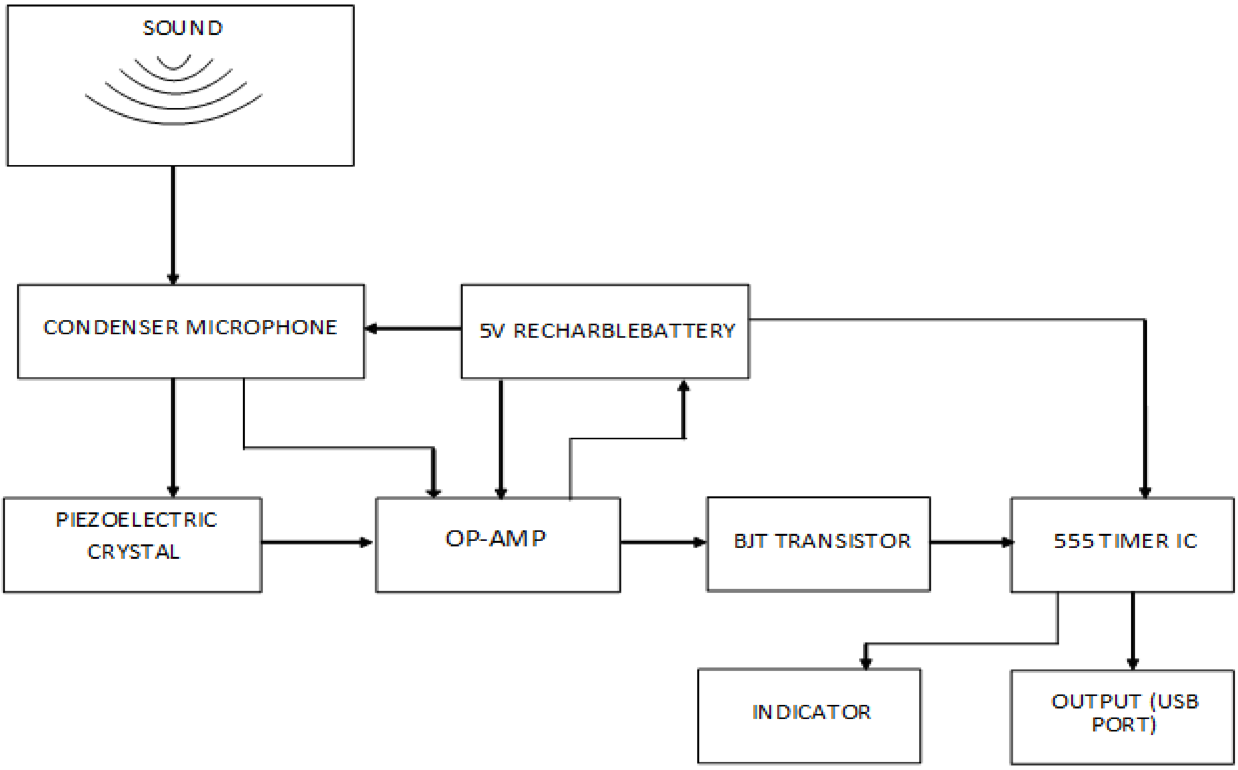

Figure 3.1 Block diagram of the electrical energy generator

3.2.1 Power Supply Unit

The power supply unit comprised of a 6V rechargeable battery which is regulated to 5V using 7805 voltage regulators.

A rechargeable battery is a kind of electric battery that can be recharged after it is discharged by a load connected to it, discharged and charged again many times, as opposed to a disposable or primary battery, which is sold fully charged and becomes useless after being discharged.

In this system, 3.7V Lithium-iron Phosphate is used because it has highest power density of any rechargeable battery. Li – iron phosphate increased abuse tolerance, because it is less prone to reactivity under such conditions which makes it the perfect power solution for this system. It does not also have the problem of what is called the memory effect (when batteries become harder to charge overtime) and also supplies more current than the other types.

Figure 3.2: Li-Iron Phosphate

3.2.2 Microphone and Piezoelectric Crystal

Condenser means capacitor, an electronic component which stores energy in form of electrostatic field. So, the condenser microphone uses a capacitor to convert acoustic energy into electrical energy. Battery is used to power the condenser microphone. Condenser Microphones generally consists of a diaphragm that is caused to vibrate by impinging waves of acoustic pressure, a back plate and air gap. In its simplest form, a diaphragm is stretched over a conductive back plate and supported by post so that there is a gap between the membrane and the back plate. A metalized diaphragm is stretched by a tensile force, T, is put front of a fixed conducting back plate by means of a surrounding border which assures a separation distance, d, to create a capacitance with respect to the back plate and biased with a DC voltage. An acoustic wave striking the diaphragm causes its flexural vibration and changes the average distance from the back plate. The change of distance will produce a change in capacitance and charge, giving rise to a time varying voltage, V, on the electrodes. A voltage is needed across the capacitor for this work and battery supplies the voltage.

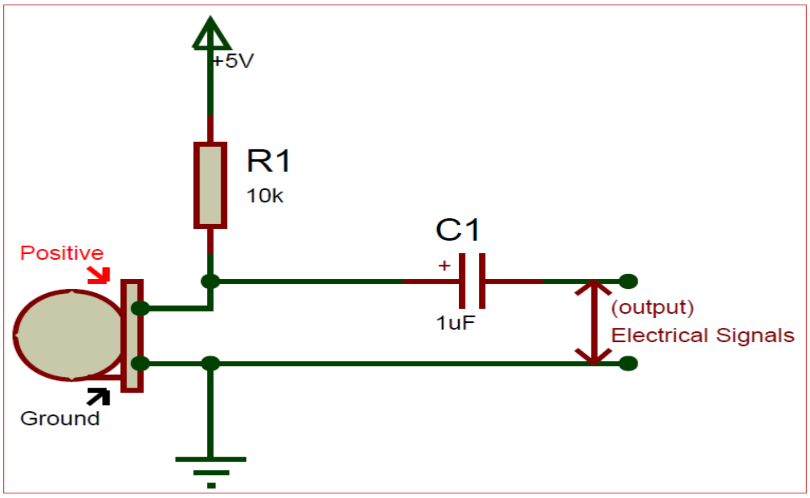

Figure 3.3 Condenser microphone circuit diagram

The value of R1 (10k) is used for limiting the current to flow through the microphone (maximum should be 0.5mA) and 1uF capacitor is used for filtering the DC noise that might be attached to the analog electrical signal (output). The microphone rated frequency is 20Hz to 20 kHz.

Therefore, $R_1 = V_{ref}/I_{DSS}$, where $I_{DSS} = 0.5$mAis the current required by the microphone from the datasheet and $V_{ref}= 5V$. Ohm's law is applied to calculate the value of resistance that limits the current to the required value of I_{DSS}, thus,

$$V = IR \quad (3.1)$$

$$R_1 = 5V/0.5 \times 10^{-3} = 10k\Omega$$

$$C_1 = \left(\frac{I}{2fVr}\right) \quad (3.2)$$

$$C = \left(\frac{0.5}{2 \times 50 \times 5}\right) = 1.0\times10^{-6}F = 1.0\mu F$$

3.2.3 Piezoelectric Crystal

Piezoelectric materials are transducers that can convert mechanical stress to electrical energy. These crystals are forming naturally e.g. quartz, bone, etc. and artificially ZnO, lithium niobatet Lead Metaniobate etc.

These materials used in the system to generate electrical charges when subjected to mechanical stress (sound). Each piezoelectric crystal generates 1mV. Four piezoelectric crystals are used to produce more voltage as each piezoelectric crystal produces 1mV of voltage. Hence, the total voltage generated by the four piezoelectric is 4mV.

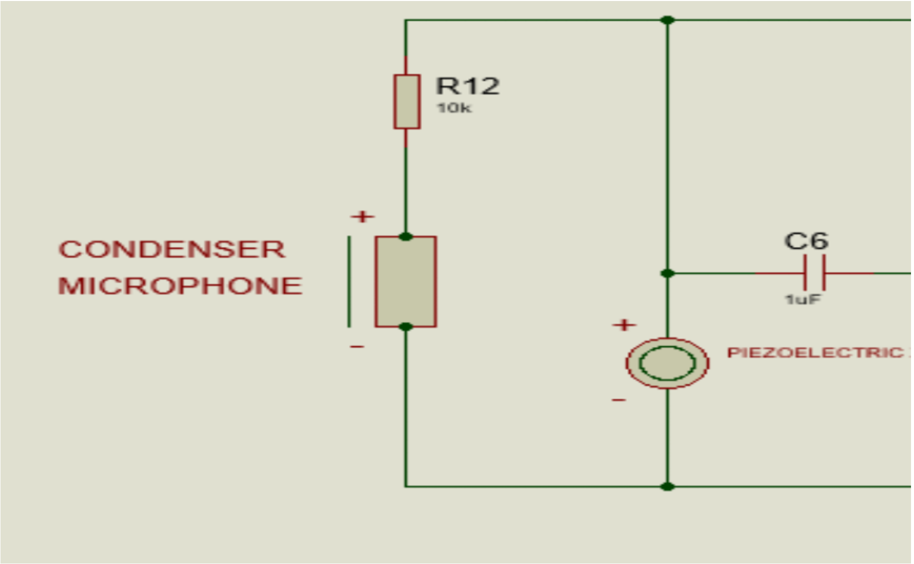

Figure 3.4 Condenser Microphone and Piezoelectric crystal circuit diagram

3.2.4 Switching Unit

The switching circuit was built around the popular general purpose npn transistor 2N2926. The transistor has the emitter, base and collector terminals as shown below:

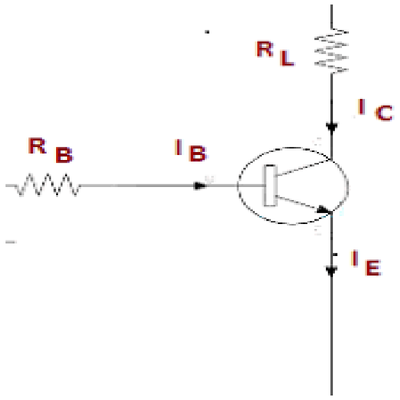

Figure 3.5 2N292 NPN transistor Circuit Diagram

Since $\mathbf{I_C}$(max) must be greater than $\mathbf{I_L}$and from the datasheet $\mathbf{I_C}$ (max) = 50mA

$$\mathbf{I_C > I_L}$$

Using the equation:

$$I_C = \beta \times I_B \qquad (3.3)$$

Where,

I_C is thecurrent of thecollector, β is the DC current gain of the transistor and I_B is the current to the base of the transistor. From the transistor Datasheet, the DC Current Gain β was about 100. Therefore, calculatingthe base current needed to provide the required collector current, we get

$$I_B = {}^{Ic}/_{\beta} \quad \ldots\ldots \quad (3.4)$$

Substituting these values in equation 3.9

$$I_B = \frac{0.03}{100} \text{ A} = 0.03 \text{ mA}$$

To calculate for Base Resistor, R_2

$$R_2 = {}^{V_{BB} - V_{BE}}/_{I_B} \quad \ldots\ldots \quad (3.5)$$

Where,

V_{BB} is the base voltage and V_{BE} is emitter-base current

V_{BB}= 5v and V_{BE} = 0.7v (for silicon transistor)

Substituting these values in equation3.10

$$R_2 = \frac{5-0.7}{3.0\times10^{-2}}$$

$$R_2 = 150\Omega$$

Standard resistor nearest to the above calculated value and commercially available is 100Ω and 47Ω therefore 100Ω and 47Ω resistors were chosen and connected in series.

3.2.5 Operational Amplifier

An op-amp is used to amplify the piezoelectric crystal's output voltage (4mV) to the desired voltage.

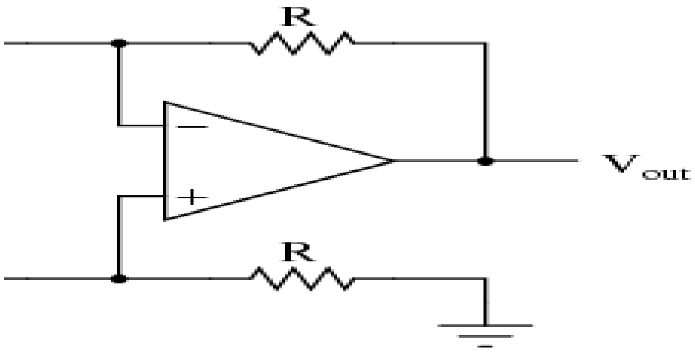

Figure 3.6 Operational Amplifier circuit diagram

The resistors (47Ω and 100Ω) set the DC voltage of the base. The 1.0F capacitor acts to filter out the DC current. An essential part of building a voltage amplifier is knowing how much the voltage will be amplified by. The voltage gain is determined by choosing the appropriate resistors. The voltage gain is simply the ratio of the resistor's collector voltage (Vout) to its base voltage (Vin). This ratio is equivalent to the negative of the ratio of the collector and emitter resistors, Rc and Re, thus;

$$Gain = \left(\frac{Vout}{\mathrm{Vin}}\right) = -Rc/Re \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.6)}$$

In order to obtain high output voltage, the gain has to be high. To get high gain which will produce reasonable amount of output voltage, the value of Rc is chosen to be much larger than the value of Re. thus,

Let Rc = 54kΩ and Re = 100Ω

$$gain = \left(\frac{54000}{1000}\right) = 54$$

The output voltage of the amplifier is the product of inverting input voltage and a gain. Thus,

$$Output\ Voltage = 54\ \times 4mV = 2.2V \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.7)}$$

The output voltage is fed to the base of transistor and LED is used to indicate the passage of the charges.

3.2.6 Load Switching Unit

The switching circuit was built around the popular general purpose npn transistor BC547. The transistor has the emitter, base and collector terminals as shown below:

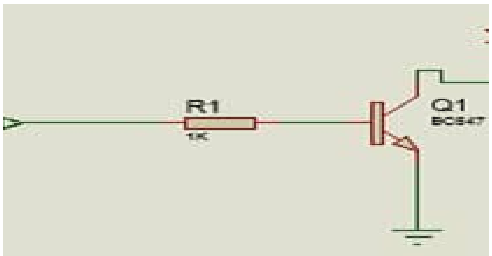

Figure 3.7 BC547 NPN transistor

Voltage supply to the load = 2.2V... (3.8)

Load resistance = 150Ω

Load current $I_L = \frac{Voltage\ supply\ to\ the\ load}{load\ resistance}$................................ (3.9)

$= \frac{5}{150} = 30mA$

Since $\mathbf{I_C}$(max) must be greater than $\mathbf{I_L}$and from the datasheet $\mathbf{I_C}$ (max) = 50mA

$\mathbf{I_C} > \mathbf{I_L}$

Using the equation:

$I_C = \beta \times I_B$.. (3.10)

Where,

I_C is thecurrent ofcollector, β is the DC current gain of the transistor and I_B is the base current of the transistor. From the transistor Datasheet, the DC Current Gain β was about 100. Therefore, calculating the base current needed to provide the required collector current. Thus,

$I_B = {}^{Ic}/_{\beta}$ .... (3.11)

Substituting these values in equation 3.9

$I_B = \frac{0.05}{100}$ A .... (3.12)

= 0.005 mA

To calculate for Base Resistor, R_2

$R_2 = {}^{V_{BB} - V_{BE}}/_{I_B}$.. (3.13)

Where,

V_{BB} is the base voltage and V_{BE} is emitter-base current

V_{BB}= 5v and V_{BE} = 0.7v (for silicon transistor)

Substituting these values in equation3.10

$R_2 = \frac{5-0.7}{0.5\times10^{-3}}$ .... (3.14)

$R_2 = 860\Omega = 0.86K\Omega$ .... (3.15)

Standard resistor nearest to the above calculated value and commercially available is 1KΩ, therefore 1KΩ resistor was chosen.

3.2.7 555 Timer IC and LEDs Selection

The 555 time is used to acts as a bridge which holds the signal received from the transistor and then passes it to green LED indicator that indicate the flow of electric current to rechargeable battery which is used to power the components as well as the USB port where USB can be connected to charge a phone with a moderate battery capacity.Red LED is used to indicate that the system is powered.

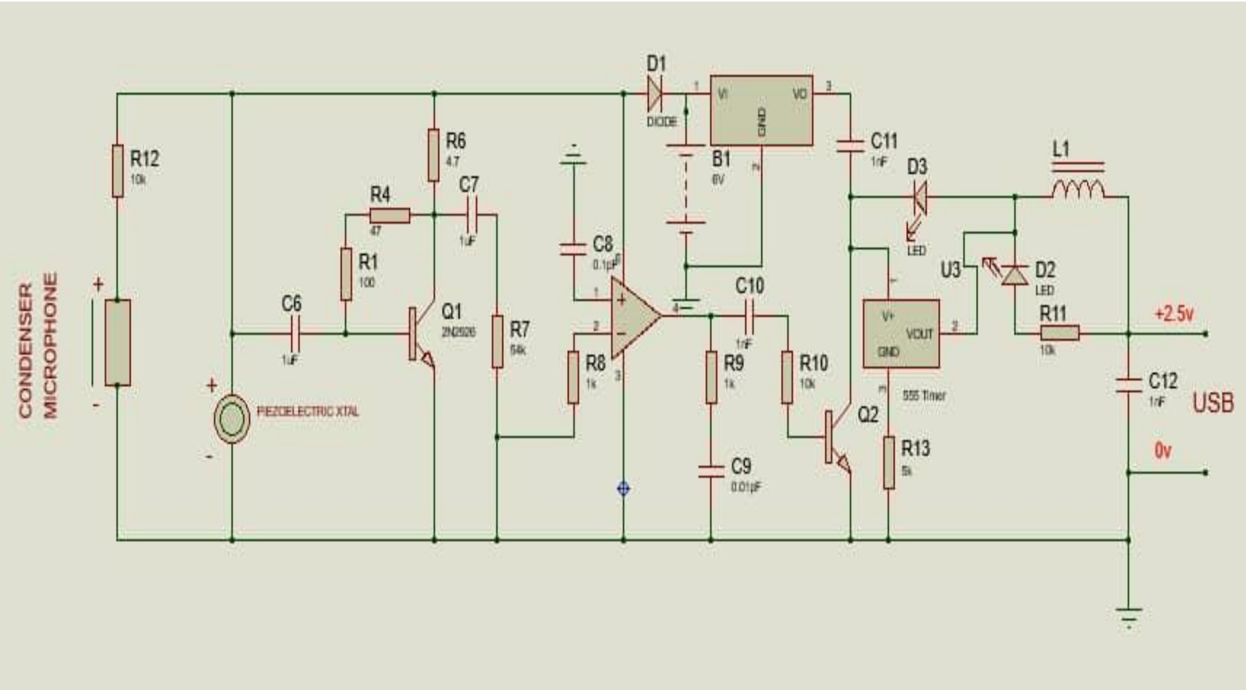

Figure3.8 Circuit Diagram of the System

CHAPTER FOUR
RESULT AND DISCUSSION

4.1 Introduction

This chapter explains the description of the implementation details and test conducted on the project and their corresponding results ascertained from the analysis of the design. However, emphasis will be given on the implementation of the designed circuit which includes selection of equipment, use of correct component size, construction, and packaging.

4.2 Construction

Before the construction of the project, the components were tested separately and found to be in good working condition. The components were mounted on the breadboard in sequence with the circuit diagram. This process was carried out to help identify faulty components before they were assembled on a Vero board. After circuit testing on the breadboard, the components in the same order were transferred onto the Vero board, soldered and tested again.

The circuit was then packaged in a plastic casing; the circuit itself was tied on the main frame but was isolated from the main frame electrically for safety. As it was on the Vero board, wire is connected from one end to the other without any component attached. These wires are called jumper wires which are used to transfer current or signal from one point to the required point.

4.2.1 Circuitry and Design Architecture

The external architecture of the electric energy generated using sound energy. It is a device that uses sound as a source of energy for the rechargeable battery and external devices which can be connected via USB port. It also includes a power and charging indicator. There are two LEDs that indicates the status of the battery. The Yellow LED indicates that the system is powered on and the Green LED indicates two conditions; one is when the LED is standby, which means an external device can be connected and the supply is from the battery and secondly, when the LED is fluctuating according to the intensity of the sound, which means that the battery is charging and an external device can be charged directly by the sound being absorbed. The push button is used to change the state of the system. On the one side of the device is the USB port where the external device can be connected and a condenser microphone while on another side the piezoelectric crystals are implemented.

Figure 4.1. External architecture of project

The internal architecture of the system, there are two lithium-ion batteries connected in series to maintain the input and the 5V output for external device. There is also an operational amplifier which amplifies the output of the piezoelectric crystals by multiplying it with a gain of 54.

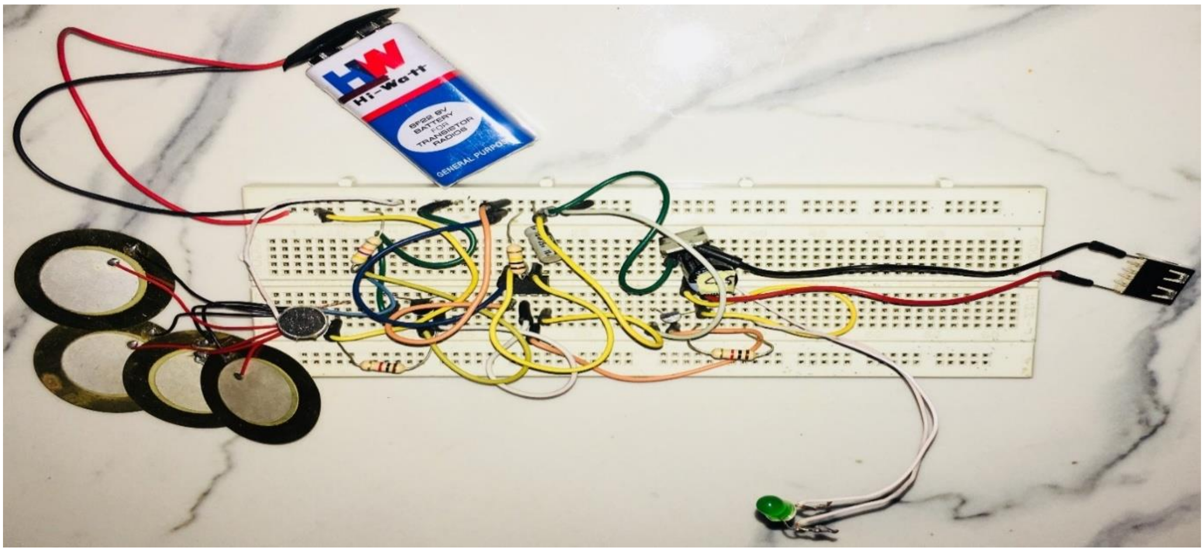

Figure 4.2. Internal architecture of project

4.2.2 Materials used in Construction

- Vero board
- Soldering iron
- Lead
- Jumper wires
- Side cutters and screw driver, etc

4.3 Result

4.3.1 Noise Harvested to Create Power (Voltage)

Noise is a produced by pressure in the air and in its normal state measure 43-44db for normal noise that is not polluted, which no specific quantity of sound that is required to produce power as long as the microphone catches sound waves, the microphone and the piezoelectric crystal keep on converting their inputs to electrical energy. The charging of the battery varies from how low or high the noise is propagated in a measure of time. The stronger the pressure, the shorter the charging time. But, since the measure of a sound wave travelling through air is not consistent, the time of charging will be different each time the battery charges. The expression below shows the relationship between the sound and the amount of voltage it produce;

$$\text{Sound (in decibel)} = 20\log_{10}\left(\frac{Vout}{\text{Vin}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.1)$$

Where: V_{out} is the voltage going into the device

V_{in} = is the voltage coming out of the device

The results of sound harvested that produced electric voltage. The highest voltage harvested using an electrical energy generated using sound device is 2.5V at very noisy area and the lowest voltage harvested is 1mV.

4.4 Testing

The fully charged electric energy generated using the sound device's efficiency was tested by charging different gadgets. The charging of various devices depends on the voltage and current requirements of each device. This also affects the consumption charges from the battery. It was found that charging a device with large battery capacity (3000mAh and above) such as smart phones takes much time in the stage when the supply is directly from the energy generated by sound, therefore, such phones can be charged properly from the rechargeable battery which supplies 5V to the output. However, phones with lower battery capacity (2000mAh and below) can be perfectly charged in both stages.

In the construction of this project, each stage was tested before it was coupled to the stage it succeeds. The instrument used for testing the various stages is a digital multimeter. The tested stages were then transferred to the Vero board and finally soldered.

Table 4.1: Results of the tests carried out in each unit

Source of Noise	**Condenser Microphone**	**Piezoelectric Crystal**	**Op - Amp**	**BJT**	**555 Timer**
Electrical Generator	0.055V	0.011V	3.67V	3.29V	3.27V
Car Horn	0.060V	0.012V	3.83V	3.51V	3.50V
Television	0.050V	0.010V	3.37V	3.11V	3.09V
Human Voice	0.044V	0.010V	2.98V	2.67V	2.65V

The table above shows the amount of voltages measured at the output of each unit when sound was generated by various sources of noise/sound. It was found that the condenser microphone and piezoelectric crystals produced highest electrical energy when sound was generated by a car horn, which means that the sound generated by the horn has the highest intensity than the sounds generated by the other sources of sound. The output at the operational amplifier has increased because it was amplified by the voltage gain of 54. The amount of the energy was slightly reduced at the BJT transistor's output because of the drops due to the threshold voltage of 0.3V of the transistor. The outputs of the 555 timer were almost the same with that of BJT transistors. The 555 timer is only used to control the flow of current to the rechargeable battery and the USB port.

Finally, the circuit was switched on and the Yellow LED indicated. When the next stage was switched by pressing the push button, the Green LED indicated standby and there was output at the USB port. Also, when the push button was pressed again, the Green LED was fluctuating indicating that the sound was being converted to electricity. The table below shows the results of test carried out using various sources of noise.

Table 4.2: Results of the carried out tests

Source of Noise	**Voltage Produced (Volts)**
Electrical Generator	3.21
Car Horn	3.45
Television	3.02
Human Voice	2.60

4.4.1 Discussion of the Result

The individual unit was tested and found to be working as desired. The condenser microphone serves as sound harvester which collects the sound waves or acoustic energy to be used and convert the row source to electricity. The piezoelectric crystals also extract the vibrations produced by the sound and convert it to electricity subsequently. An operational amplifier amplifies the output voltage of the microphone and piezoelectric crystal with a voltage gain of 54, Lithium Ion battery that is connected in series stores the electric charge for the external devices. The voltage regulator is used to maintain a steady amount of voltage output supplied for the external devices connected to the system. The capacitor serves as the temporary storage of electricity from the output before forwarding to the battery and finally, the diode leads the electricity to flow in one direction also keeps the current flowing.

In continuation, the light emitting diodes (LEDs) indicate power supply and electricity generated from sound which also indicate battery charging. The Yellow light emitting diode means the system is powered on, while the Green light emitting diode is used to indicate two functions; at first stage it is standby it indicates there is output to the external device directly from the battery and at the second stage, it indicates that the battery is charging as well as the external device is getting supply of power generated from the sound.

Therefore, the result obtained successfully satisfied the objectives of the project which lead to achieving the project’s aim.

4.5 Problems Encountered During the Construction

- Some components were burnt while soldering. This was due to the application of heat beyond their limit.
- Difficulty in regulating the output voltage to the desired voltage was encountered.
- During soldering, some components shorted, so the connections were disassembled and soldered again.

4.6 Precautions Taken

- It was ensured that all components used can perform their expected function before assembling them in the circuit.
- Proper connection of wires was ensured.
- The entire circuit was checked carefully to ensure proper connection of each component.

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

This project is aimed at designing an electrical energy generated using sound energy system. After construction, the realized system was found to pick noise/sound and convert it to electricity. The resulted voltage produced depends on the intensity of the sound propagated and picked up by the condenser microphone. The theoretical background of the used components was reviewed which include condenser microphone, piezoelectric crystal, operational amplifier, battery, and 555 timer. Related previous projects and their drawbacks as well as the improvements that this system provides were explained. The design of each unit was carried out starting from the power supply unit which contains two 3.7V Li-ion batteries and regulated to 5v dc at the output using a voltage regulator which is used to power condenser microphone, Op – Amp, and 555 timer. The piezoelectric crystals produce charges as a result of vibration generated by a sound. The description of the construction details and tests performed on the project were presented and their corresponding results obtained from the design analysis which shows the amount of electricity produced at various places of different sources of noise.

5.2 Conclusion

The aim of this project is to design and construct an electrical energy generated using sound energy system. The objectives of this project were met, but usually theoretical aspect is put into practice, many limitations occur, although proper alteration may give the theoretical result. Each unit of the design was tested separately and found to meet design specification.

5.3 Recommendation

The project can be improved upon by incorporating the following in the design:

- Make the system a microcontroller based system so that decibel meter can be used to measure the level of noise/decibel picked up by the microphone and display it on the LCD.
- It is recommended to use a more microphones to harvest sounds to charge the battery faster.
- Introduce a battery full charged indicator that will indicate when the battery is fully charged. Use the LEDs with smaller voltage consumption to lessen the consumption of electric charges.

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