DESIGN AND CONSTRUCTION OF ELECTROCADIOGRAPHY (ECG) FOR MEASURING THE ELECTRIC ACTIVITY OF THE HEART

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Abstract: This work describes the design and construction of a system that can be used to measure the electrical activities of the heart using the principles of Electrocardiography (ECG). When there is a depolarization of the heart muscle, which occurs in every heartbeat, electrical signals are triggered. The motivation behind the research was the need for a portable and ultra-low power ECG recording system that can be built from commercially available electronics components to analyze heart beat rate signals in real-time as well as allows the medical practitioners to get the heart beat in order to interpret and attend appropriately to any abnormalities of the heart. Electrcardiography is a medical diagnostic test that captures the electrical workings of the heart. It is useful in the understanding of the rhythm of the heart and any irregularities associated with it. It can also be used to control or monitor patients or athletes over a long period of time and the result of the test is called Electrocardiogram (ECG). The system reads and analyses the heart beat signals rate respectively and display the signals on its display unit in real-time (Analog) and can also send the data of these signals into a PC connected to it.

Keywords: *Electrical activities, Cardiography, heartbeat and Signals.*

I. INTRODUCTION

The major function of the heart is to pump blood. It does this in two ways, through the lungs to oxygenate the blood and also to deliver oxygen and nutrients to the tissue. Both ways are also aimed at removing carbon dioxide from the system. When this is carried out, the heart is said to function well. Electric signals are triggered due to heart muscle depolarization which occurs during every heartbeat. The ECG is a simple but crucial tool in clinical practice. It is a non-invasive produced by an electrocardiographic device, and particularly useful in diagnosing rhythm disturbances. The electrodes are placed on different parts of the skin over different parts of the heart to measure the electrical activity. An ECG displays the voltage difference between pairs of electrodes which not only indicate the rhythm of the heart, but weakness or damage in certain parts of the heart muscle. Its importance is undisputed.

When the heart is working properly, it is a masterpiece of timed precision, with heart valves opening and closing on cue to prevent backward blood flow. Heart valves, chambers, electrical impulses, coronary arteries and veins all of these must be in perfect working order for the heart to function at its best.

The heart consists of four chambers, the left and right ventricles and left and right atrium. The atria are separated from the ventricles by the base, where the four cardiac valves are situated, the tricuspid valve between the right ventricle, the aortic valve between the left ventricle and the aorta and the pulmonary valve between the right ventricle and pulmonary artery. The atria are relatively thin walled cavities that function as a weak filling pump for the ventricles. The right and left ventricle(RV)

pumps blood into the pulmonary system and left ventricle(LV) pumps blood through the aortic valve into the aorta providing the rest of the body with oxygenated blood. The LV has a thicker wall than the right ventricle, since the RV only has to serve the pulmonary system and the LV needs to work against a higher pressure to pump blood into the systematic circulation.

The heart tissue, the myocardium, is composed out of muscle cells, the myocytes. The muscle cells have the ability to contract to fulfill the pumping function of the heart. To initiate contraction the myocytes are electrically stimulated. The myocyte are mechanically and electrically connected through intercalated disc.

Electrocardiography (ECG) is a medical diagnostic test that captures the electrical workings of the heart. It is useful in the understanding of the rhythm and any irregularities associated with it [1]. The result of the test is called an Electrocardiogram. It is used to monitor the human heartbeat rate.

In medical science, information about the functioning of the heart is mainly obtained by electrocardiography and various non-invasive such as magnetic resonance tagging (MRT). The ECG and the deformation pattern obtained with these clinical measurements give more information about the status of the myocardium and about abnormalities in the tissue, such as a conduction disorder or cardiac ischemia.

II. **MATERIALS AND METHOD**

Various component of this circuit diagram used for the construction of the ECG are explained in this section

RESISTOR

A resistor is an electrical component that limit or regulates the flow of electrical current in an electronics circuit. Resistors can also be used to provide a specific voltage for an active device such as a transistor. All other factors being equal, in a direct-current (DC) circuit, the current through a resistor is inversely proportional to its resistance, and is directly proportional to the voltage across it. Resistor can be fabricated in a variety of ways. The most common type in electronic devices and systems is the carbon –composition resistor.

DIODE

Diode is a two-terminal electronic component with asymmetric conductance; it has low (ideally zero) resistance to current in one direction and high (ideally infinite) resistance in the other. The most common function of a diode is to aloe an electric current to pass in one direction (called diode's forward direction), while blocking current in the opposite direction (the reverse direction). Thus, the diode can be viewed as an electronic version of a check valve. This unidirectional behavior is called rectification, and is used to convert alternating current to direct current.

CAPACITOR

A capacitor is a passive two-terminal electrical component used to store energy electrostatically in an electric field. The forms of practical capacitors vary widely, but all contain at least two electrical conductors (plates) separated by a dielectric (i.e. insulator). The conductors can be thin films of metal, aluminum foil or disks, etc. An ideal capacitor is characterized by a single constant value for its capacitance. Capacitors are widely used in electronics circuit for blocking direct current while allowing alternating current to pass. In analog filter network, they smooth the output of power supply.

In electrical power transmission systems, they stabilize voltage and power flow.

THE LM 324 INTERGRATED CIRCUIT

LM324 series are low-cost which contain four independent high gain operational amplifiers with internal frequency compensation. They have several distinct advantages over standard operational amplifier types in single supply applications. The four amplifier can operate at supply voltages as low as 3.0V or as high as 32V with quiescent currents about one-fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The features of LM324 are as follow;

- Internally frequency-compensated for unity gain
- True Differential Input Stage
- Wide power supply range:

  Single supply: 3VDC to 32VDC

  Dual supplies: ±1.5VDC to ±16VDC

- Short Circuited Protected Outputs
- Large Output Voltage Swing: 0VDC to Vcc-1.5VDC
- Power drain suitable for battery operation
- Industry standard pin outs.

SOFTWARE DESIGN

In this research work, the implementation of two different pieces of software is presented. All are written in the general purpose C programming language. The software is based on two parts design. One is for getting and processing ECG signal, which is implemented within the PIC16F876A microcontroller, while the other one is a Graphic Unit Interface easy to use by patient. All are written in the general purpose program developed by using a C^+ language under Windows as operating system.

The software that was developed for this system is divided into two programs: a program associated to the microcontroller, and the second is for the applications to other hardware of the system as well as its connection with a computer system.

III. **THE ELECTROCARDIOGRAPHY**

The recording on the body surface of the electrical activities generated by the heart is done based on the principles of electrocardiography. Meanwhile, early diagnosis for heart disease is typically based on tape recording of electrocardiogram (ECG) signal which is then studied and analyzed using a microcomputer designed by [2].

The first electrical measurement from the heart was conducted by [3], they used the electrometer to record the electrical activity of an exposed frog's heart and later, [4] published the first human electrocardiogram. He observed the ECG using his pet bull dog as the signal source and the capillary electrometer as the reading device. [5] enhanced the technology by employing the string galvanometer as the recording device and using human subject with a variety of cardiac abnormalities. He also used an improved electrometer and a correction formula developed independently of Burch, distinguishes five deflections which he named P, Q, R, S and T. Einthoven is chiefly responsible for introducing some concept still in used today including the labeling of various waves, defining some of the standard recording sites using the arms and legs, and developing the first theoretical construct whereby the heart is modeled as a single time-varying dipole.

Einthoven starts transmitting electrocardiograms from the hospital to his laboratory 1.5km away via

telephone cable. On March 22nd the first 'telecardiogram' is recorded from a healthy and vigorous man and the tall R waves are attributed to his cycling from laboratory to hospital for the recording. [5] Einthoven publishes the first organized presentation of normal and abnormal electrocardiograms recorded with a string galvanometer. Left and right ventricular hypertrophy, left and right atrial hypertrophy, the U wave (for the first time), notching of the QRS, ventricular premature beats, ventricular big eminy, atrial flutter and complete heart block are all described.

The Research is aimed at investigating the essential value of using a simple system designed with a single-chip microcontroller to display and monitor the working principle of a heart as well as discover any abnormalities in the heart beat. To achieve this, the following are the objectives of the research;

(1) To observe the principles and application of electrocardiography (ECG)
(2) To design a system capable of detecting and displaying the electrical signal generated as a result of a heart beat in an electrocardiographic signal
(3) To observe the signal produced and compare this with the normal signal to be generated according to the principles of electrocardiography.

The methodology was based on embedded system implementation using the PIC16F876 microcontroller from microchip. It also deals with the construction of the ECG device designed in this project as well as the device specifications and the various components used in the design.

The heart tissue, the myocardium, is composed out of muscle cells, the myocytes. The muscle cells have the ability to contract to fulfill the pumping function of the heart. To initiate contraction the myocytes are electrically stimulated. The myocytes are mechanically and electrically connected through intercalated discs. The overall alignment of the myocytes is anisotropic throughout the cardiac tissue. This anisotropic alignment gives rise to anisotropy in both contraction and conduction of the electrical stimulus. The component parts of the heart are subdivided by septa into right and left halves and a construction subdivides each half of the organ into the two cavities, the upper cavity being called the atrium, the lower cavity the ventricle. The heart therefore consists of four chambers viz, right and left atria and right and left ventricles [6].

The division of the heart into four cavities is indicated on its surface by grooves. The atria are separated from the ventricles by the coronary sulcus (auriculo ventricular groove) this contains the trunks of the nutrient vessels of the heart, and its deficient in front, where it is crossed by the root of pulmonary artery. The interartrial grooves separating the two atria, is scarcely marked on the posterior surface, while anteriorly, it is hidden by the pulmonary artery and aorta. The ventricles are separated by two grooves, one of which the anterior longitudinal sulcus is situated on the sternocostal surface of the heart, close to its left margin, the other posterior longitudinal sulcus, on the diaphragmatic surface near the right margin, the grooves extend from the base of the ventricular portion to a notch, the incisura apicis cordis on the acute margin of the heart just to the right of the apex [7].

Measurements were taken on the following categories of people:

Category 1: 20 – 30 years old male

Category 2: 20 – 30 years old female

Category 3: 31 years and above male

Category 4: 31 years and above female

V(1-5) represents each the measurement taken from the various individual tested with the device for each categories. The device is designed to generate 128 data to describe the ECG tracing it produce. The device was programmed to send those data via a plug-in cable into a computer where they can be used to plot the waveform. This is done so that the ECG tracing generated on the display unit of the device can also be printed out and given to medical practitioners to interpret.

IV. THE ELCTROCARDIOGRAM (ECG)

The ultimate result of the overall bioelectric activity of the heart mentioned in the previous session is the heartbeat. The depolarization of the atria generates an ECG wave (P wave), followed by the QRS Complex, which represents the ventricular contraction. The end of the cardiac cycle is the cell repolarization phase which appears as another deflection, the T wave; in some cases, the 'a' second deflection may appear the U wave [8].

The cardiac cycle which is a beginning of one heart beat to the beginning of the next one include all the events related to the flow of blood through the heart during one complete heartbeat. The mechanical pumping of the heart depends on electrical stimulation that causes the cardiac muscles to contract [9]. The electrical activity of the heart follows a regular pattern that defines the cardiac cycle. The electrical signal originates in the sinoatrial (SA) node. As action potentials move through the cells, the cells depolarize and contract. Once the cells have contracted, a repolarization signal follows the same pathway and causes the cells to relax [10].

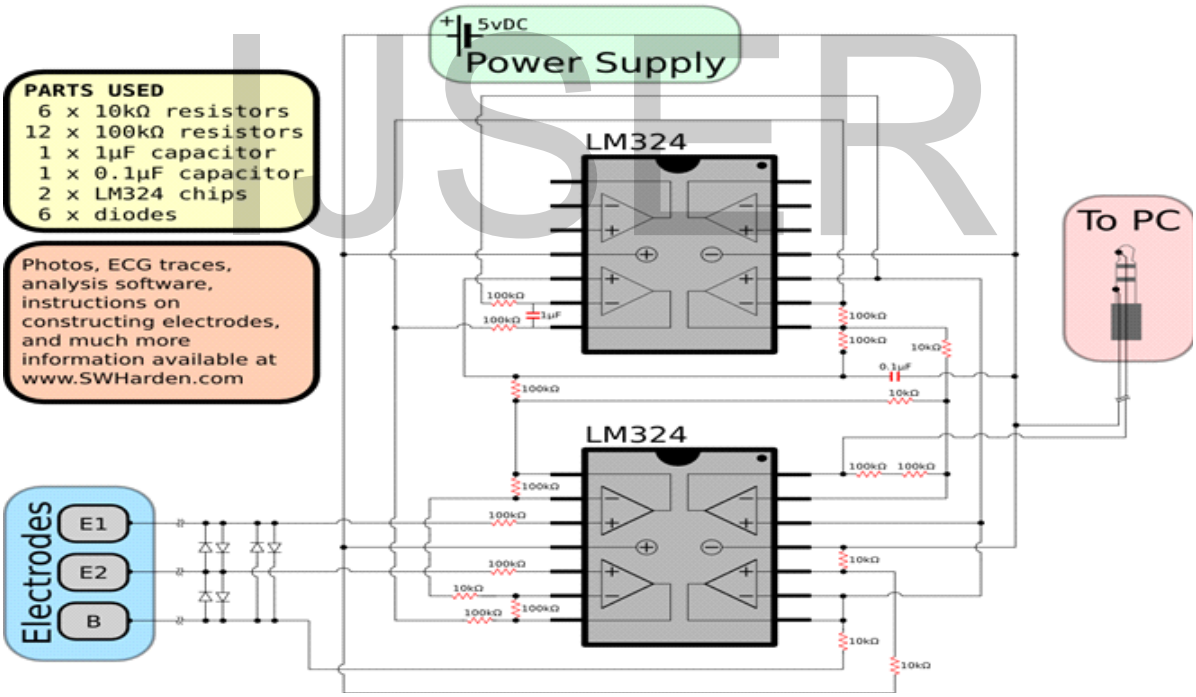

Figure 1: Circuit of The Electrocardiograph System

V. RESULTS AND DISCUSSION

An ECG recording and various system parameter were carried out to benchmark the built device and give a picture of its capabilities at its actual form. The device displays a prototype of Electrocardiogram (ECG) in a standard hospital. The session below gives the table of data collected by the device for projecting the ECG tracing in one

second. Four different categories of people are used in testing the device, each comprising of five individuals.

Being aware of the limitations of the circuit is crucial, when it comes to testing. The results always have to be assessed by taking them into account, and treating the outcome accordingly. Below are the ECG tracing of all the data generated above.

TABLE 1: GENERATED DATA FOR CATEGORIES 1, 2 AND 3

CATEGORY 1: 20 – 30 YEARS OLD MALE

NUMBER OF DATA	V1	V2	V3	V4	V5
1	368	379	7	7	745
2	337	360	315	315	743
3	9	63	411	411	744
4	263	661	517	517	746
5	513	637	289	289	744
-	-	-	-	-	-
-	-	-	-	-	-
110	10	13	431	431	747
111	9	616	635	635	747
112	9	467	567	567	745
113	8	598	449	449	743
-	-	-	-	-	-
122	194	458	99	99	744
123	282	520	12	12	745
124	367	13	7	7	744
125	131	642	7	7	746
126	261	124	23	23	747
127	680	374	181	181	745
128	731	498	7	7	745

CATEGORY 2: 20 – 30 YEARS OLD FEMALE

NUMBER OF DATA	V1	V2	V3	V4	V5
1	481	731	738	686	747
2	476	731	692	603	746
3	359	634	626	740	745
4	191	600	493	745	745
-	-	-	-	-	-
-	-	-	-	-	-
109	38	9	538	741	746
110	44	7	338	681	750
111	644	357	431	664	745
112	135	547	571	740	744
113	100	685	736	744	745
-	-	-	-	-	-
-	-	-	-	-	-
122	20	730	256	570	745
123	128	714	95	632	744
124	15	651	365	600	744

125	512	491	131	730	745
126	526	357	54	715	747
127	493	384	12	670	747
128	550	370	7	659	746

CATEGORY 3: 31 YEARS AND ABOVE MALE

NUMBER OF DATA	V1	V2	V3	V4	V5
1	18	9	732	700	745
2	18	240	287	737	746
3	44	119	55	559	746
4	58	373	9	605	746
5	59	296	142	698	746
-	-	-	-	-	-
110	736	391	407	435	746
111	735	355	216	483	746
112	735	8	5	558	747
113	165	20	326	347	746
-	-	-	-	-	-
-	-	-	-	-	-
122	572	348	566	647	746
123	734	407	546	662	748
124	595	490	604	350	748
125	677	99	454	622	748
126	629	32	258	673	747
127	735	17	568	706	746
128	128	9	271	338	746

CATEGORY 4: 31 YEARS AND ABOVE FEMALE

NUMBER OF DATA	V1	V2	V3	V4	V5
1	731	589	415	693	746
2	426	731	330	740	746
3	723	726	15	689	746
4	723	541	13	612	746
5	734	216	9	707	747
-	-	-	-	-	-
-	-	-	-	-	-
109	11	6	36	577	748
110	581	8	9	479	745
111	588	90	9	441	746
112	563	197	6	663	746

113	638	326	11	654	745
-	-	-	-	-	-
-	-	-	-	-	-
122	8	552	212	612	745
123	12	601	363	724	744
124	7	706	51	743	745
125	162	8	20	725	746
126	185	8	8	684	745
127	141	6	7	745	745
128	218	7	7	720	746

V(1-5) represents each the measurement taken from the various individual tested with the device for each categories. The device is designed to generate 128 data to describe the ECG tracing it produce. The device is programmed to send those data via a plug-in cable into a computer where they can be used to plot the waveform using an application on the computer (i.e. Microsoft Excel).

CATEGORY 1: 20 AND 30 YEARS OLD MALE

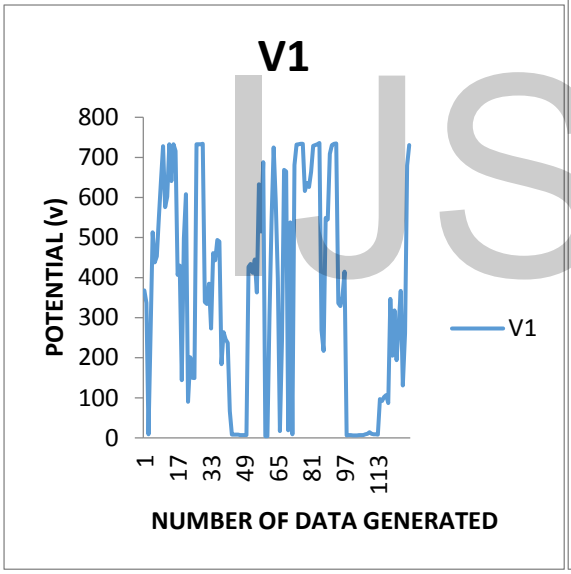

Figure 2: Potential (V1) versus Amount of Data Generated for Male within ages 20 to 30 Years

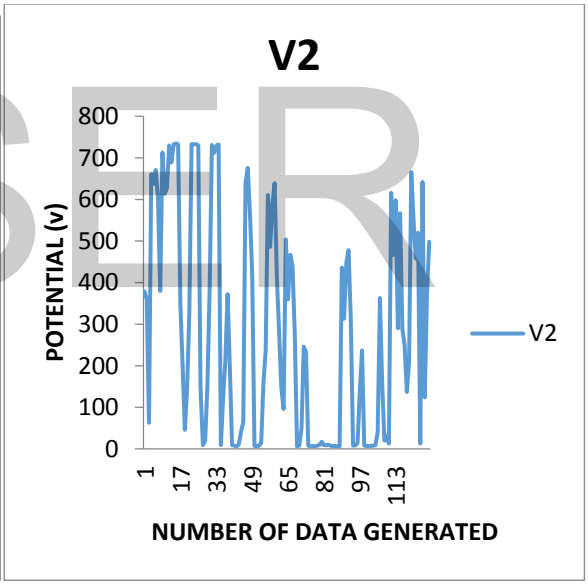

Figure 3: Potential (V2) versus Amount of Data Generated for Male within ages 20 to 30 Years

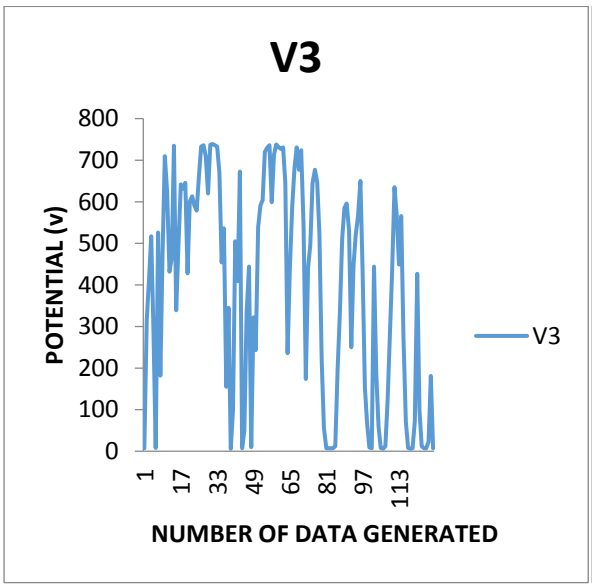

Figure 4: Potential (V3) versus Amount of Data Generated for Male within ages 20 to 30 Years

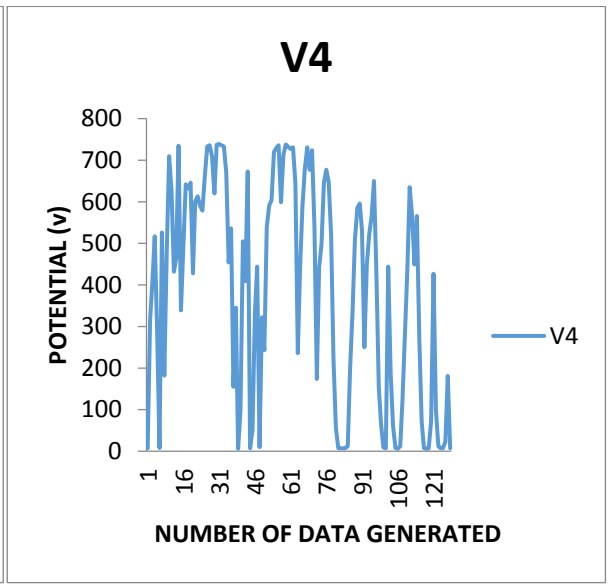

Figure 5: Potential (V4) versus Amount of Data Generated for Male within ages 20 to 30 Years

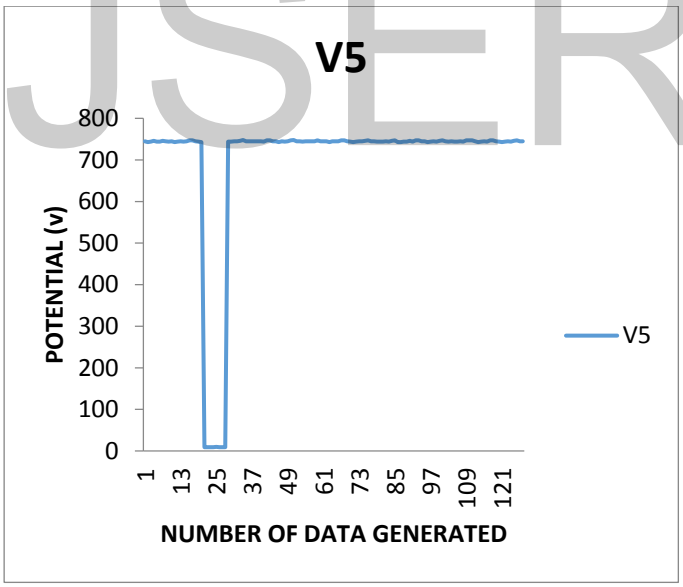

Figure 6: Potential (V5) versus Amount of Data Generated for Male within ages 20 to 30 Years

CATEGORY2:20-30 YEARS FEMALE

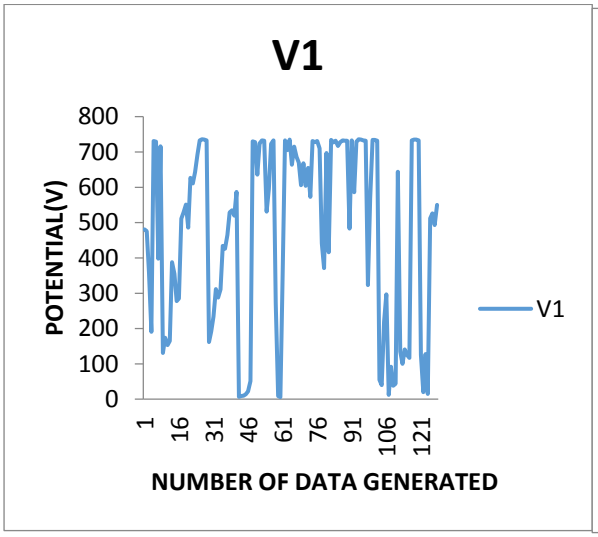

Figure 7: Potential (V1) versus Amount of Data Generated for Female within ages 20 to 30 Years

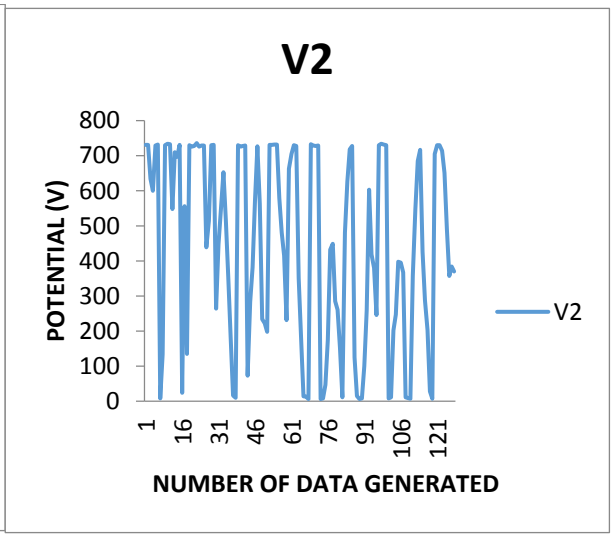

Figure 8: Potential (V2) versus Amount of Data Generated for Female within ages 20 to 30 Years

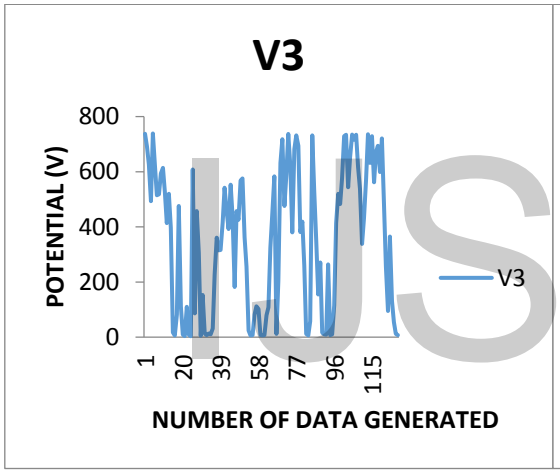

Figure 9: Potential (V3) versus Amount of Data Generated for Female within ages 20 to 30 Years

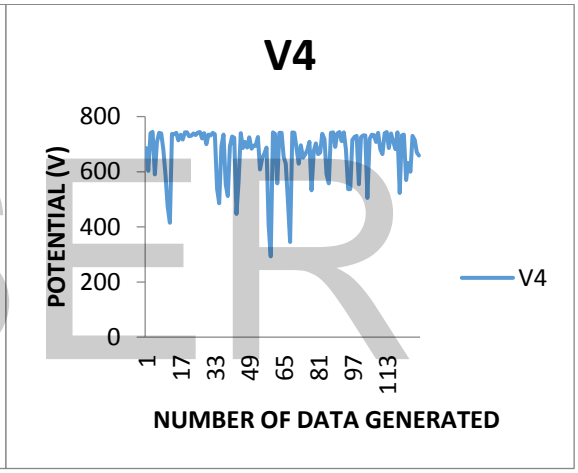

Figure 10: Potential (V4) versus Amount of Data Generated for Female within ages 20 to 30 Years

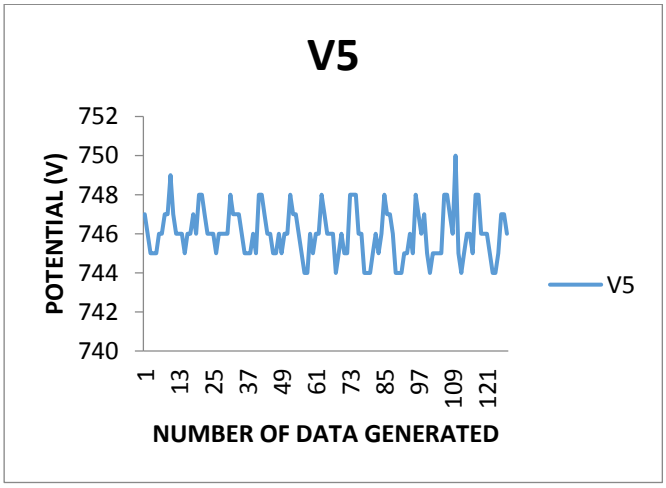

Figure 11: Potential (V5) versus Amount of Data Generated for Female within ages 20 to 30 Years

CATEGORY3: 31 AND ABOVE MALE

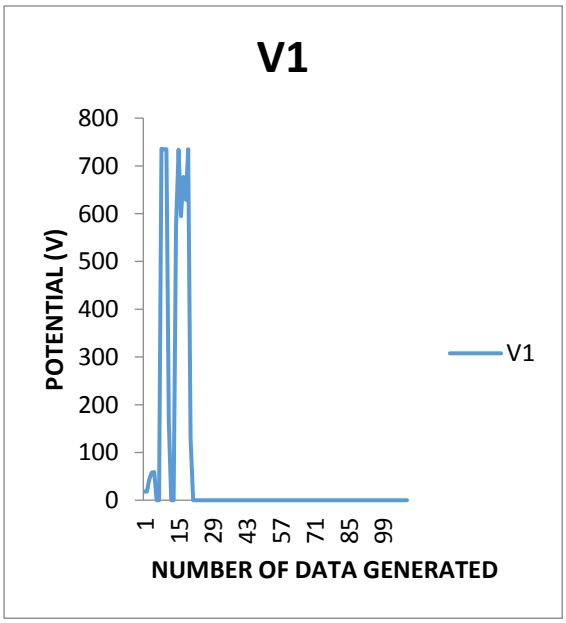

Figure 12: Potential (V1) versus Amount of Data Generated for Male for ages 30 Years and above

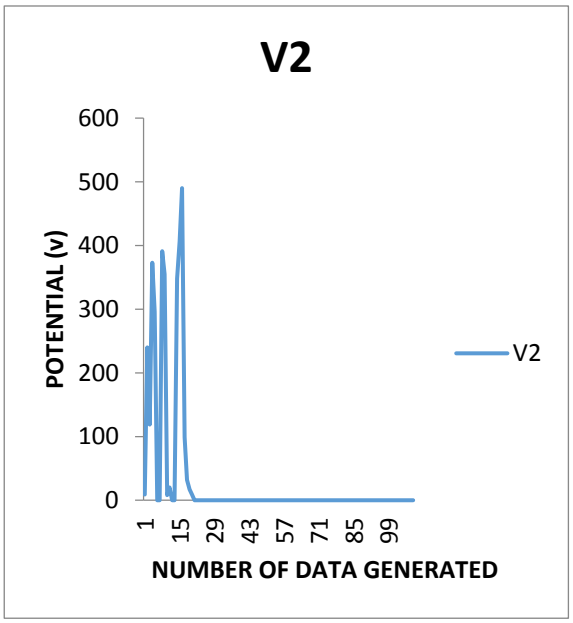

Figure 13: Potential (V2) versus Amount of Data Generated for Male for ages 30 Years and above

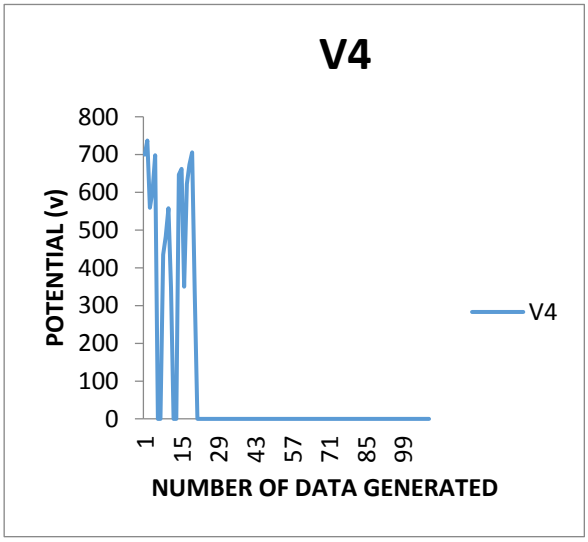

Figure 14: Potential (V4) versus Amount of Data Generated for Male for ages 30 Years and above

The ECG which is a simple but crucial tool in clinical practice is non-invasive produced by an electrocardiographic device, and particularly useful in diagnosing rhythm disturbances. The electrodes are placed on different parts of the skin over different parts of the heart to measure the electrical activity. An ECG displays (as shown in Figures 2 to 13) the voltage difference between pairs of electrodes which not only indicate the rhythm of the heart, but weakness or damage in certain parts of the heart muscle. Its importance is undisputed.

VI CONCLUSION

The focus of this project has been to design a wire ECG device using commercially available electronic components. This project works is presented starting with the aim, objectives, specification, background, history, electrical activities of the heart, cardiac cycle and electrocardiogram, circuit of the ECG system, ECG recording and tracing, result and conclusion. ECG is a device used to record on graph paper the electrical activity of the heart and it is used to assess heart rhythm, diagnose poor blood flow to the heart muscle (Ischemia), diagnose a heart attract and diagnose abnormalities of the heart such as heart chamber enlargement abnormal electrical conduction and cardiovascular screening in college athletes. This project is strongly recommended to understand the operation of electrocardiography recording and analysis.

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