Sudan University of Science & Technology

College of Engineering

Biomedical Engineering Department

A project submitted in partial fulfillment for the degree of B.Sc. In Biomedical Engineering

Microcontroller Based ECG Arrhythmia Biosimulator for Testing ECG Machines

محاكي اشارة القلب الكهربية المضطربة باستخدام المعالج الدقيق لمعايرة اجهزة تخطيط كهربية القلب

Prepared by:

Kholood Mohammed Salim Yagoub

Mayada Rahmtalla Mohammed

Tagwa Mohammed Mohammed Ali

Supervised by:

Dr. EL Tahir Mohammed Hussein

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Dedication

To the souls of our parents …

To our brothers and sisters…

With more warm happiness …

Feeling and wonderful memories

We would like to dedicated this research

To our families, and friends …

Teachers and colleague …

Acknowledgment

First we give thanks to Allah for blessing us with the strength to complete this project.

Special thanks go to the most trustworthy, and inspiring mentor Dr. Eltahir Mohammed Hussein.

Also we would like to thank one of the main pillars of the project and the indispensable brain Mr. Hashem Batran.

Our grateful thanks the department of biomedical engineering in Sudan University of science and technology, and the engineering section in university of science and technology.

Finally, we thank our supportive families and friends.

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List of symbols and abbreviation

ADC	Analog to Digital Convertor
AV	Atrio-Ventricular
DAC	Digitad to Analog Converter
DPOs	Digital Phosphor Oscilloscope
DMMs	Digital Multimeter Oscilloscope
ECG	ElectroCardioGram
IC	Integrated Circuit
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LPF	Low Pass Filter
ms	millisecond
Mv	milli Volt
PC	Personal Computer
SA	Sino-Atrial
SD	Serial Digital
USP	Universal serial bus
VSM	Virtual System Modeling

ABSTRACT:

In this research the design and development of Micro-controller based ECG simulator intended to use in testing, calibration and maintenance of ECG machines.

The idea of our project is firstly taking up and ECG signal which downloaded from physionet. Then the signal is saved in a memory card after processing it by using MATLAB. After that the signal was display on an oscilloscope using an Arduino UNO board. The signal which displayed on oscilloscope is that used to testing or calibrating ECG machine.

Since standard commercially available electronic components were used to construct the prototype simulator, the proposed design was also relatively inexpensive to produce.

المستخلص

هذا المشروع "محاكي إشارة القلب الكهربية ECG المضطربة بإستخدام المعالج الدقيق لإختبار ومعايرة جهاز ECG.

فكرة المشروع تتم أولا بأخذ إشارة ECG ,والتي تم تحميلها من موقع إلكتروني "physionet" ثم حفظت الإشارة في ذاكرة, بعدما تمت معالجتها بإستخدام الماتلاب.

بعد ذلك تم عرض الإشارة في راسم الاشارة بإستخدام الاردوينو , وهذه الإشارة المعروضة أو المتحصل عليها هي التي تستخدم في اختبار ومعايرة جهاز ECG.

المكونات المستخدمة في بناء نموذج المحاكاة متوفرة تجاريا, والتصميم المقترح أيضا غير مكلف نسبيا في الإنتاج.

CHAPTER ONE

Introduction

General View:

Depolarization and repolarization occur of the a trial and ventricular chambers of the heart produce an electrical activity . The ECG electrical manifestation of the contractile activity of the heart can be recorded easily with the surface electrodes on the limbs or chest. It is the most commonly recognized biomedical signal. The rhythm of heart in terms of beats per minute may easily estimated. Abnormal heart rhythms (arrhythmias) are caused by problems in the electrical system that regulates the steady, rhythmic beat of the heart. The heartbeat may be too slow or too fast; it may remain steady or became chaotic. Some arrhythmias are dangerous and cause sudden cardiac death, while others may be bothersome but are not life threatening.

Before testing ECG on monitor sing patient, it is wise to have an electronic simulator with which it can be tested. This is important for a couple of reasons. First, it is important in the, building and debugging, in order to have a test signal with which to test each new component. Second, it is important in the final safety testing stage, in order to make sure the full system is working satisfactory and safe to use on a human subject before making an electrical connections to a living being.

Problem Statement:

Before testing ECG on monitor sing patient, it is wise to have an electronic simulator with which it can be tested. This is important for a couple of reasons. First, it is important in the, building and debugging, in order to have a test signal with which to test each new component. Second, it is important in the final safety testing stage, in order to make sure the full system is working satisfactory and safe to use on a human subject before making any electrical connections to a living being

Objectives:

General objective:

Design and development of Micro-controller based ECG simulator intended to use in testing , calibration and maintenance of ECG machines.

Specific objectives are to:

1- Produce the typical ECG waveforms of different leads combinations and as many arrhythmias as possible.

2- study normal and abnormal ECG waveforms without actually connection it patients.

3-Support biomedical engineering student's education .

Methodology:

To achieve the goals mentioned above, built in simulator circuit will be designed to create an ideal two normal and three abnormal heart a rhythms signals.

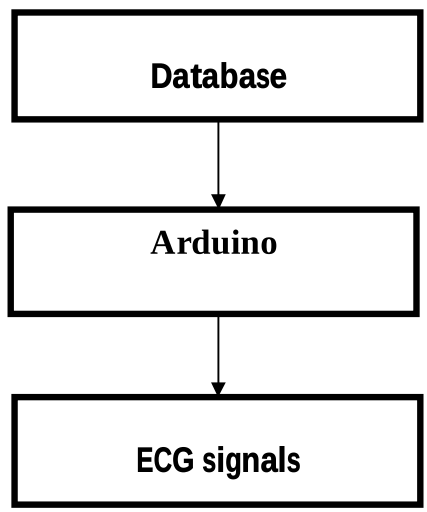


Fig 1.1 Methodology of design to achieve the thesis objective

The Thesis Layout:

The research consists of six chapters:

I. Chapter one is an introduction.
II. The previous studies are given in chapter two.
III. The concept of microcontroller based ECG arrhythmia bio simulator for testing ECG machines.
IV. Chapter four is about the proposed system.
V. The result and discussion is found in chapter five.
VI. Finally chapter six contains the conclusion and references.

CHAPTER TWO

Literature Review

2.1 Sangria Das*, Rajesh Gupta** and Madhuchhanda Mitre** ******* **Dept. of EE, Camellia School of Engineering & Technology, West Bengal, India** *****Department of Applied Physics, University of Calcutta, 92 A.P.C. Road, Kolkata, (WB)*** ***(Received 15 October, 2012 Accepted 01 November, 2012)***

This paper describes the development of microcontroller based hardware ECG simulator which generates real-time analog ECG signal in the range of 0-5 volt. The synthetic ECG signal generated by the simulator can be used for testing and calibration of medical instruments, biomedical experiments and research in laboratories. The PTB diagnostic database collected from Physionet has been used as the standard database to generate ECG signal. This database has a sampling rate of 1 kHz. The ECG database is amplified and quantized in 8-bit resolution. A MATLAB algorithm has been used to serially transmit the quantized ECG data using RS-232 protocol to an 8051 based stand alone embedded system where it gets converted into 8-bit parallel data and delivered to the digital to analog converter. At the DAC output we get the analog ECG signal in 0-5 volt range.

A single lead ptb-db data array in *mat format is used as the input data to a software program. Next, the data array is amplified and quantized with 8-bit resolution. After that the quantized data array is transmitted at a constant baud rate by the serial port of the personal computer using RS-232 protocol. The next block is the standalone embedded system which consists of four components- (i) MAX232 level converter, (ii) Atmel 89C2051 Microcontroller unit (MCU), (iii) digital to analog converter (DAC 0808) and (iv) current to voltage converter (using LM324)[1]. This standalone system converts the 8-bit serial data into 8-bit parallel data, then into an analog signal in the range of 0- 5 volt.

2.2 *Samuel E. de Lucena* Unesp – São Paulo State University, Department of Electrical Engineering, Instrumentation & Microprocessors Laboratory, Guaratinguetá, SP, Brazil, lucena@feg.unesp.br

This paperwork presents the design and test of a microcontroller-based ECG (electrocardiogram) simulator. The ECG simulator is capable of generating nine ECG signals and a calibrated square wave (1 Hz, 1 mV at Lead II). The synthesized signals are: normal sinus rhythm (60 beats per minute – BPM, and 90 BPM), sinus bradycardia (30 BPM), sinus tachycardia (120, 180 and 240 BPM), sinus rhythm with tall T wave (6EC0 BPM), ventricular tachycardia (120 BPM), and a rhythm for asynchronous ventricular pacemaker (60 BPM). The simulated ECG signals can have their amplitudes continuously varied from zero to 2 mV at lead II, through a panel potentiometer, whose knob position does not affect the amplitude of the square wave calibrated signal. The technique used to synthesize the ECG signals, a modified direct digital synthesis (DDS), appeared superior in permitting the generation of signals of very good quality and yet using a relatively small amount of memory. This latter feature enabled the use of a simple 8-bit microcontroller together with an external precision D/A converter and a 2-pole lowpass active filter. The designed ECG simulator can be a handsome instrument to daily ECG machine test, maintenance and demonstration by hospital personnel and medical equipment maintenance groups and shops[2] .

2.3 I. Valais1, G. Koulouras2, G. Fountos1, C. Michail1, D. Kandris2 and S. Athinaios2 1 Department of Biomedical Engineering, Technological Educational Institution of Athens, 12210 Egaleo, Athens, Greece 2Department of Electronic Engineering, Technological Educational Institute of Athens, 12210 Egaleo Athens, Greece

This paper reports Design and Construction of a Prototype ECG Simulator which can be used to perform the calibration and testing of ECG recorders. Various beat-rate or ECG rhythm (60, 80, 120,150 and 180 bit/min) of normal ECG waveforms produced by analog electronics simulate the standard 10 electrode ECG record. Additionally a state of arrhythmia (random selection of preset ECG rhythm) is also incorporated in order to simulate abnormal ECG rhythms, which in turn should be detected accurately by the ECG recorder. The output of ECGS is monitored by an Atmel ATmega8515 microcontroller as far as the rhythm selection and the display of it, is concerned. An audible signal triggered by the R wave is also produced for easy monitoring of the pace. The produced ECG signals have been compared to human ECG recordings and the device has been calibrated accordingly in various ECG rhythms. In conclusion this ECGS device can be used as a testing device for 12 lead ECG recorders[3, 4].

2.4 ZHANG Jun-an a* *Shanghai Medical Instrumentation College ,Shanghai, 200093 China*

This paper reports a precise design and development for ECG signal generator for testing and calibration of the
electrocardiogram equipment, ECG signal processing system and heart teaching tool. It can create guide □ signal of time and profile features lead □ signal across a range of ECG drawings of heart rate within 45 to 185 devices in the first device of steps. This can be set up 15 ~ the QRS 45 years old lady with a lady who resolution. P, T wave amplitude can be adjusted from 1-100% to 1% of the total of the amplitude QRS complex resolution. A color LCD touch screen is able to provide the user with input parameters facilities, depending on the output waveform parameter and a graphical representation of the output waveform. Signal generator outputting signal of poor precision through digital simulation

stage using low noise design provides accurate signal amplitude QRS the lower end of the technology range .The design is based on PIC24 micro controller family. The device provides all the power and flexibility of the advantage and micro controller and provides relevant traditional access and function which often lets a person associate to the faster processor. This device can be in 100-PinTQFP package, including 84 I/O needle, 128 KB of the program memory, 8 k data memory and a port is called a parallel port (PMP) master. The picture displays the mechanism that at any time the PMP is used for liquid crystal displays, USB interface and a wireless network. This makes the signal generator keep users based on the advantage of network and PC related design usually is isolated, but still the battery is relatively cheap and light . This is PIC24F programming development and utilization of this chip explorer 16 development kit[5].

2.5 ***A.D. Paul, K.P. Urzoshi, R.S. Datta, A. Arsalan, and A.M. Azad Dpartment of Electrical and Electronic Engineering , BRAC University, Dhaka, Bangladesh***

For the training of doctors as for design, development and testing of automatic ECG machines ,a subject with a known abnormality of hear is essentially required. ECG simulator is an electronic device use to simulate such subject for the above mentioned purpose. The significance of the ECG simulator is that the subject has been replaced. The simulator is useful tool for electrocardiograph calibration and monitoring , to incorporate in educational tasks and clinical environments for early detection of faulty behavior[6]. The device based on microcontroller and generates the basic ECG wave with variable BPM and arrhythmia using lookup table. The signals can be used for testing ,servicing ,calibration and development of the ECG monitoring instruments .This machine is very cheep than commercial machine available in the market[7] .

CHAPTER THREE

Theoretical background

3.1. Anatomy and physiology of the heart

The heart is a muscular organ that acts like a pump to continuously send blood throughout your body, The heart is at the centre of the circulatory systemThis system consists of a network of blood vessels, such as arteries, veins, and capillaries. These blood vessels carry blood to and from all areas of the body. The heart is located underneath the sternum in a thoracic compartment called the mediastinum, which occupies the space between the lungs. It is approximately the size of a man’s fist (250-350grams) and is shaped like an inverted cone. The narrow end of the heart is called the apex. It is directed downward and to the left and lie just above the arch of the diaphragm at the approximate level of the fifth or sixth rib[8]

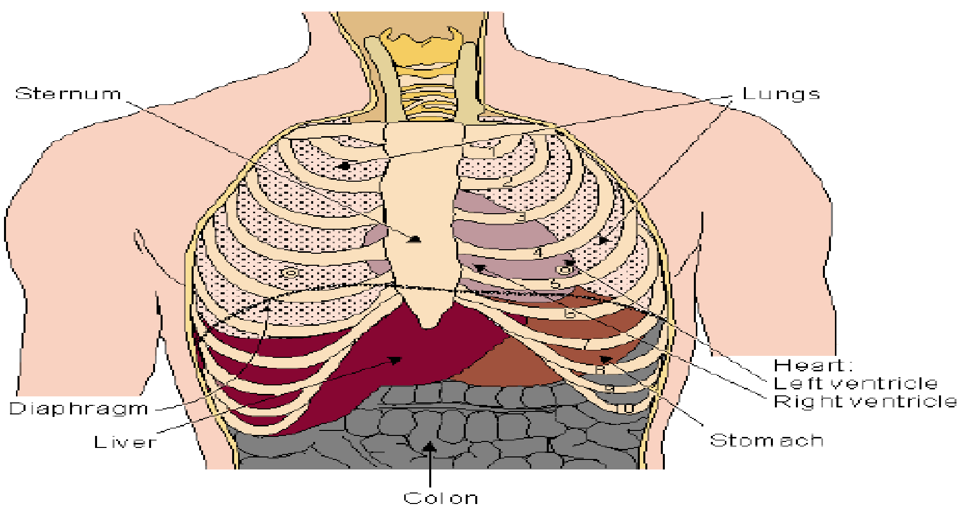


Fig .3.1 Location of the heart[9]

The heart is made up of four chambers. The superior chamber consists of the right atrium and the left atrium, which lie primarily on the posterior side of the heart. Extending anteriorly from each thin walled atrium is a small, ear-shaped appendage called auricle that[9] expands the volume of the chamber .Blood drains into the atria from the pulmonary and systemic circulatory system. Composing the lower chambers are the right ventricle and left ventricle, which are much larger than the atria. The right ventricle pumps blood through the pulmonary circulatory system and the thicker walled left ventricle pumps blood through the longer systemic circulatory system. Internally, the two ventricles are separated by a thick myocardial wall called the interventricular septum. On the anterior surface of the heart, the interventricular septum is marked by a shallow diagonal groove known as the anterior interventricular sulcus (or groove), which is occupied the anterior interventricular artery, great cardiac vein and adipose tissue. On the posterior surface of the heart, the ventricles are separated by the posterior interventricular sulcus, which contains the posterior interior artery, middle cardiac vein and adipose tissue.

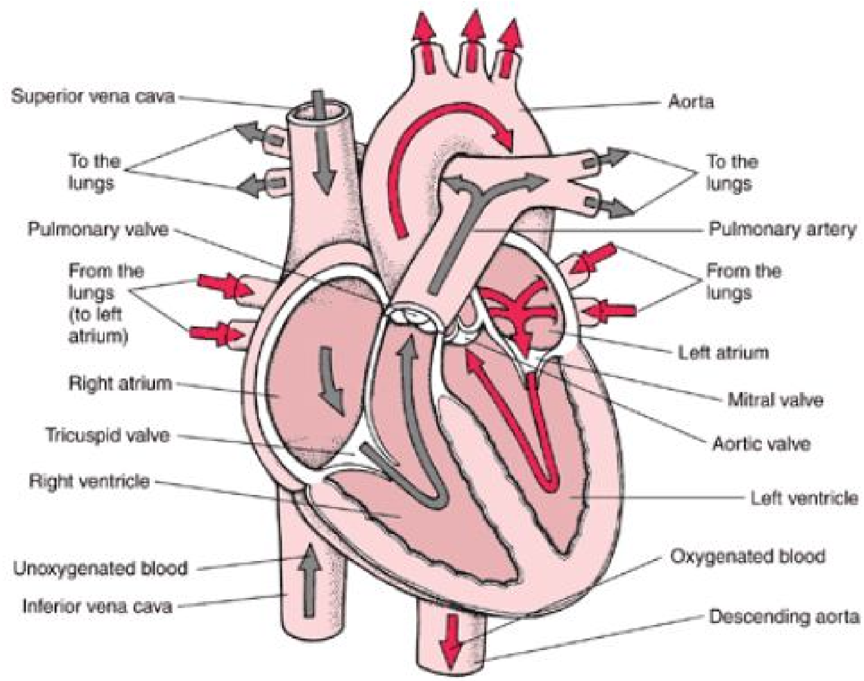


Fig .3.2 The anatomy of the heart and associated vessels.

3.2 Electric activation of the heart

The electrical activation of a single cardiac cell or even of a small group of cells does not produce enough voltage to be recorded on the body surface. Clinical electrocardiography is made possible by the activation of large groups of atrial and ventricular myocardial cells, whose numbers are of sufficient magnitude for their electrical activity to be recorded on the body surface .Myocardial cells normally lack the ability for either spontaneous formation or rapid conduction of an electrical impulse. They depend on special cells of the *cardiac pacemaking* and *conduction system* that are located strategically through the heart for these functions These cells are arranged in *nodes* , *bundles* , *bundle branches* , and branching networks of *fascicles* . The cells that form these structures lack contractile capability, but they can generate spontaneous electrical impulses (act as pacemakers) and alter the speed of electrical conduction throughout the heart. The intrinsic pacemaking rate is most rapid in the specialized cells in the atria and slowest in those in the ventricles. This intrinsic pacemaking rate is altered by the balance between the sympathetic and parasympathetic components of the autonomic nervous system.

illustrates three different anatomic relationships between the cardiac pumping chambers and the specialized pacemaking and conduction system: Anterior precordium with less tilt right anterior precordium looking onto the interatrial and interventricular septa through the right atrium and ventricle , and left posterior thorax looking onto the septa through the left atrium and ventricle. The *sinoatrial* (SA) or *sinus node* is located high in the right atrium, near its junction with the *superior vena cava* . The SA node is the predominant cardiac pacemaker, and its highly developed capacity for autonomic regulation controls the heart's pumping rate to meet the changing needs of the body. The *atrioventricular* (AV) *node* is located low in the right atrium, adjacent to the interatrial *septum* . Its primary function is to slow electrical conduction sufficiently to asynchronize the atrial contribution to ventricular pumping. Normally, the AV node is the only structure capable of conducting impulses from the atria to the ventricles because these chambers are otherwise completely separated by nonconducting fibrous and fatty tissue. In the atria, the electrical impulse generated by the SA node spreads through the myocardium without needing to be carried by any specialized conduction bundles. Electrical impulses reach the AV node where the impulse is delayed before continuing to the intraventricular conduction pathways. The intraventricular conduction pathways include a *common bundle* (bundle of His) that leads from the AV node to the summit of the interventricular septum as well as the right and left bundle branches of the bundle of His, which proceed along the septal surfaces of their respective ventricles. The left bundle branch fans out into fascicles that proceed along the left septal endocardial surface and toward the two papillary muscles of the mitral valve. The right bundle branch remains compact until it reaches the right *distal* septal surface, where it branches into the interventricular septum and toward the free wall of the right ventricle. These intraventricular conduction pathways are composed of fibers of *Purkinje cells*, which have specialized capabilities for both pacemaking and rapid conduction of electrical impulses. Fascicles composed of Purkinje fibers form networks that extend just beneath the surface of the right and left ventricular *endocardium* . After reaching the ends of these Purkinje fascicles, the impulses then proceed more slowly from endocardium to *epicardium* throughout the right and left ventricles. This synchronization process allows activation of the myocardium at the base to be delayed until the apical region has been activated. This sequence of electrical activation is necessary to achieve the most efficient cardiac pumping because the pulmonary and aortic outflow valves are located at the ventricular bases.

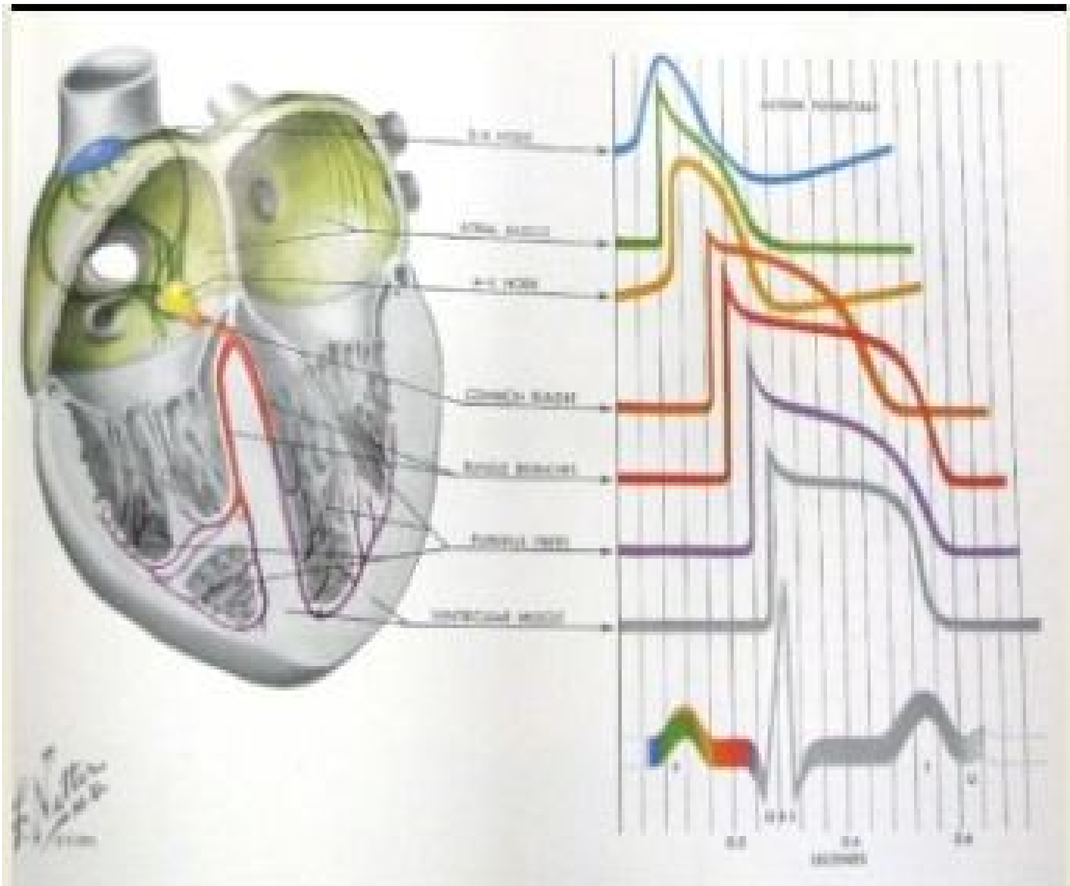
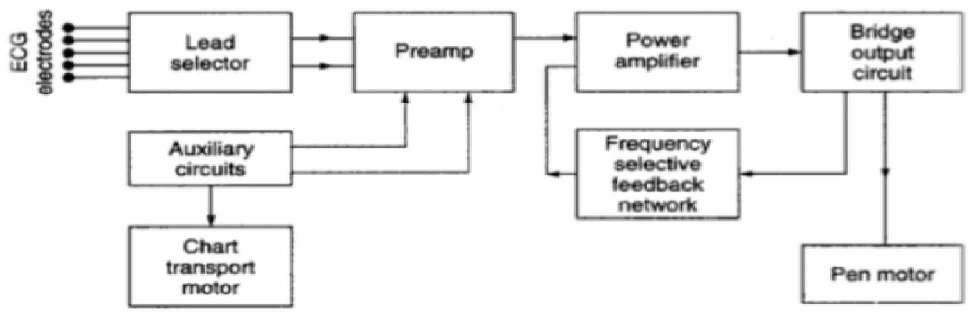


Fig.3.3 Electrophysiology of the heart. The different waveforms for each of the specialized cells found In the heart are shown [11].

3.3 ECG Device

An electrocardiogram (ECG) is a device that records electrical activities of the heart see fig.3.4.

fig 3.4 ECG Block diagram



potentials picked up by the patient electrodes selector switch are taken to the lead.here the electrodes are selected TWO by TWO according The to the lead program . The signal is given to the preamplifier .A preamplifier (preamp) ,or control amplifier, is an electronic amplifier which prepares an electronic signal for further amplification or processing . It is usually a 3 or 4 stage differential amplifier. The amplified O/P is then given to the power amplifier .The O/P of the power amplifier is fed to the pen motor which deflects the writing arm of the paper. Frequency selective network is an R-C network, which provides necessary damping on the pen The auxiliary circuits provide a 1 mV calibration signal and automatic blocking of the amplifier during change in the position of the lead switch . It also includes a speed control circuits for the chart driver motor. The electrodes on the different parts of the body detect electrical impulses coming from different directions within the heart . there are normal patterns for each electrode. Various heart disorders that can be detected include: Abnormal heart rhythms .If the heart rate is very fast , very slow , or irregular. there are various types of irregular heart rhythm with characteristic ECG patterns , A heart attack ,and if it was recent or some time ago .A heart attack causes damage to heart muscle , and heals with scar tissue .These can be detected by abnormal ECG patterns,An enlarged heart . Basically this causes bigger impulses than normal . The most commonly used clinical ECG- system ,the 12-lead ECG system ,consists of the following 12 leads , which are:

I,II,III ,a VR , a VL, a VF ,V1,V2,V3,V4,V5,V6.

Of these 12 leads , the first six are derived from the same three measurement points .Therefore ,any two of these six leads include exactly the same information as the other four Over 90% of the hearts electric activity can be explained with a dipole source model .To evaluate this dipole ,it is sufficient to measure its three independent components .In principle ,two of the limb leads (I,II,III) could reflect the frontal plane components , whereas one precordial lead could be chosen for the anterior-posterior component .The combination should be sufficient to describe completely the electric heart vector .(The lead V2 would be a very good precordial lead choice since is it directed closest to the x axis .It is roughly orthogonal to the standard limb plane , which is close to the frontal plane .)To the extent that the cardiac source can be described as a dipole , the 12-lead ECG system could be thought to have three independent leads and nine redundant leads However ,in fact , the precordial leads detect also non dipolar components, which have diagnostic significance because they are located close to the frontal part of the heart. Therefore ,the 12-lead ECG system has eight truly independent and four redundant leads. The main reason for recording all 12 leads is that it enhances patter recognition This combination of leads gives the clinician an opportunity to compare the projections of the resultant vectors in two orthogonal planes and at changed :the lead –a VR is included in many ECG recorders In summary ,for the approximation of cardiac electric activity by a single fixed-we take in to account the distributed character of cardiac sources and the effect of the thoracic surface and internal inhomogeneities we can consider only the four (of six)limb leads as truly redundant .

CHAPTER FOUR

Research Methodology

4.1 Introduction:

In this part the hardware component, measuring tools and the software of the design will be shown.

4.1.1Circuit Component:

The circuit consists of

Adriano UNO Board [12]:

Arduino/Genuino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply it connect to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

Features:

I. The ATmega328 on the Uno comes preprogrammed with a boot loader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol.

II. The Uno has a resettable polyfuse that protects your computer's USB ports from shorts and over current. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

III. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the

Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

IV. The Uno board can be powered via the USB connection or with an external power supply. The power source is selected automatically.

V. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery.

Specifications:

Table 4.1 Arduino Uno Specification [13]

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin 4	40 mA
DC Current for 3.3V Pin	50 Ma
Flash Memory	32 KB of which 0.5 KB used by boot loader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

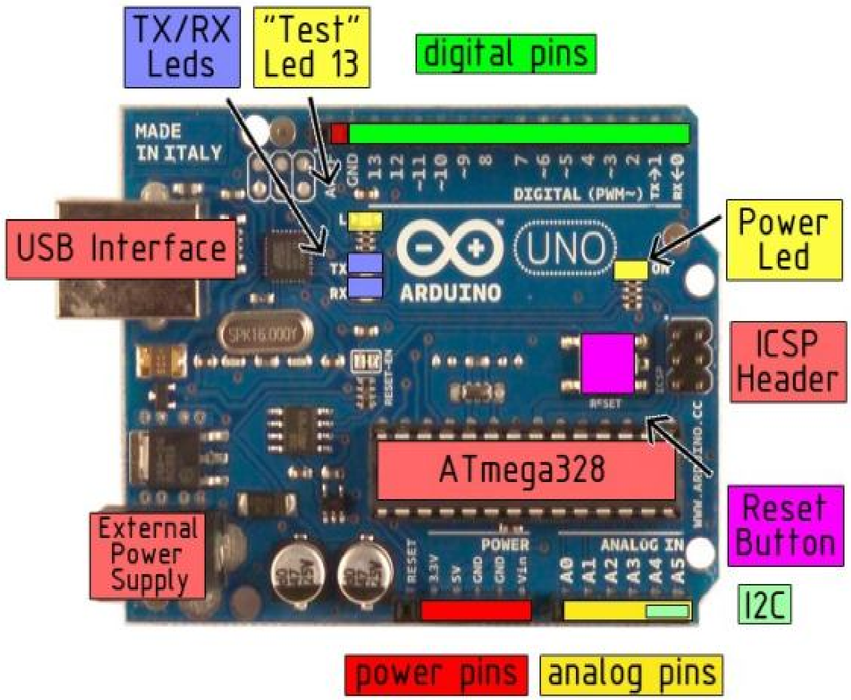


Figure 4.1 Arduino Board Parts [13]

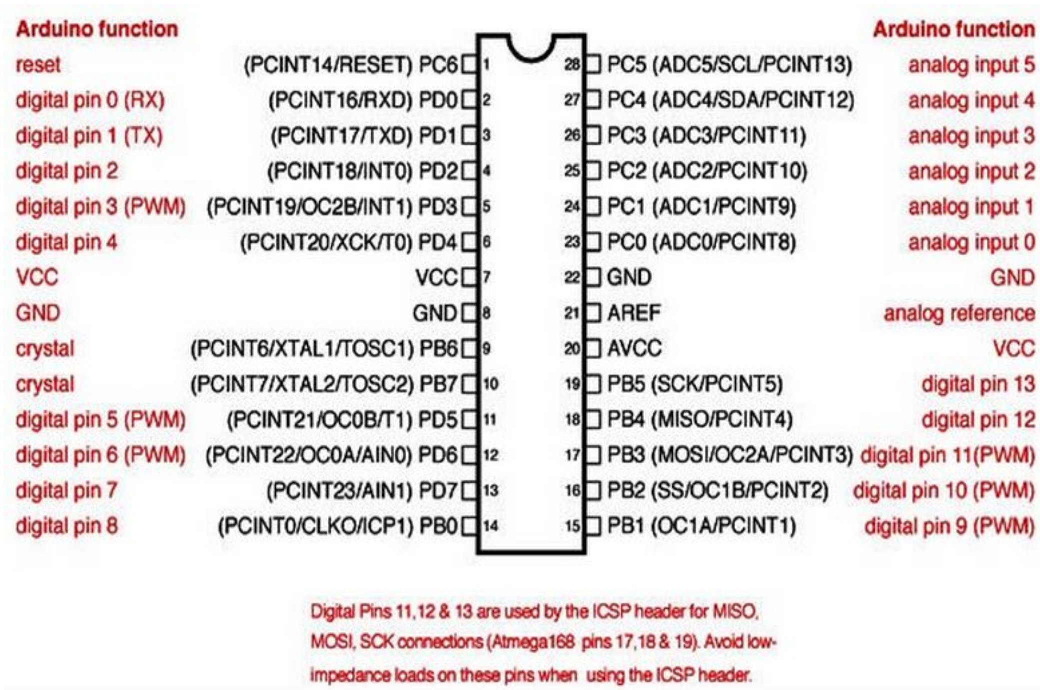
ATmega328 [14]:

The ATmega328P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega328P achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing .

Table 4.2ATmega328 Pin Description [14]

VCC	Digital supply voltage
GND	Ground
Port B (PB7:0) XTAL1/XTAL2/TOSC1/TOSC2	Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit)
Port C (PC5:0)	Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit)
PC6/RESET	If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin
Port D (PD7:0)	Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit)
AVCC	AVCC is the supply voltage pin for the A/D Converter, PC3:0, and ADC7:6
AREF	AREF is the analog reference pin for the A/D Converter
ADC7:6 (TQFP and QFN/MLF Package Only)	In the TQFP and QFN/MLF package, ADC7:6 serve as analog inputs to the A/D converter.

Figure 4.2 Atmega328 Pins Obverse Arduino Function [15]



LCD:

A liquid-crystal display (LCD) as shown in fig.4.6. below is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly.

LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images which can be displayed or hidden, such as preset words, digits, and 7-sigment displays as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger element[16].

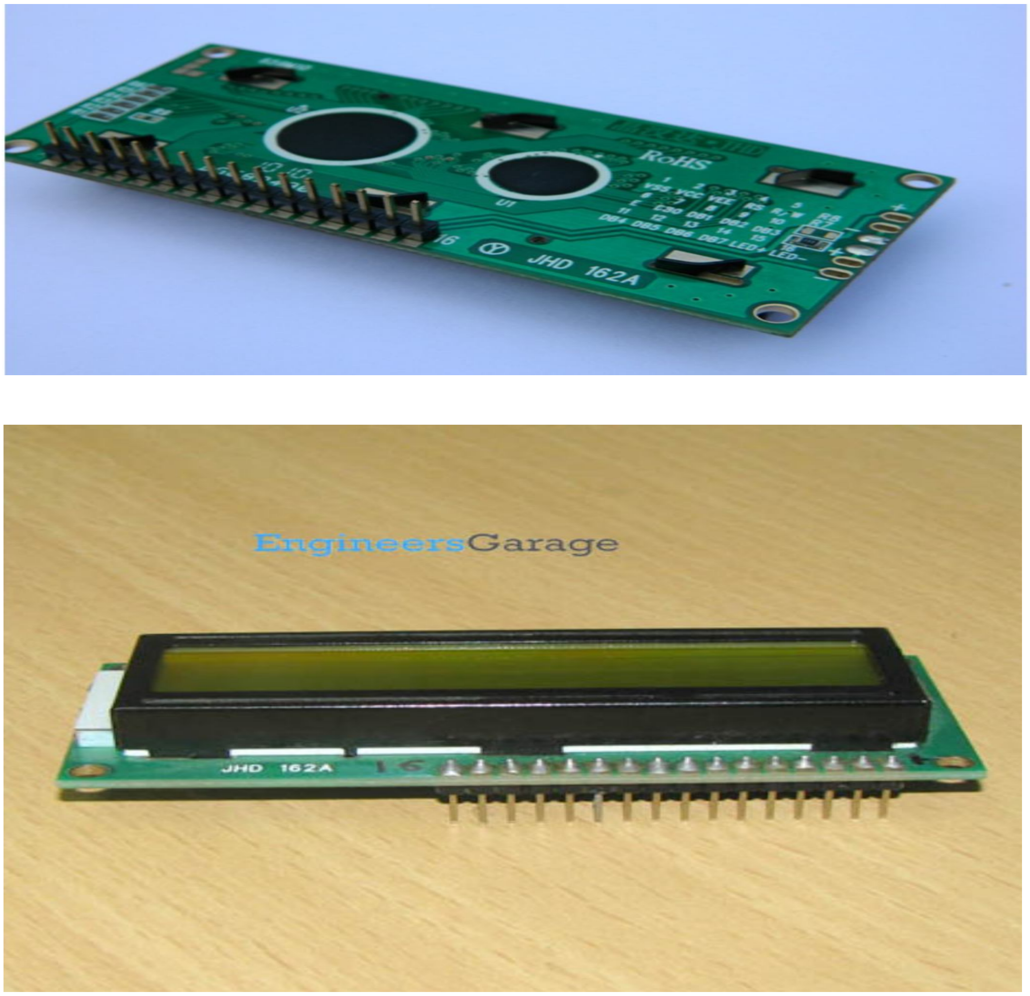


Fig.4.3. liquid crystal display (16x2 LCD module) used to display the results [16]

LM 324:[17]

The LM324 series are low−cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 32 V 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 output voltage range also includes the negative power supply voltage.

Features:

I. Short Circuited Protected Outputs

II. True Differential Input Stage

III. Single Supply Operation: 3.0 V to 32 V

IV. Low Input Bias Currents: 100 nA Maximum (LM324A)

V. Four Amplifiers Per Package

VI. Internally Compensated

VII. Common Mode Range Extends to Negative Supply

VIII. Industry Standard Pinouts

IX. ESD Clamps on the Inputs Increase Ruggedness without Affecting Device Operation

X. NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC−Q100 Qualified and PPAP Capable

XI. These Devices are Pb−Free, Halogen Free/BFR Free and are Ro HS Compliant

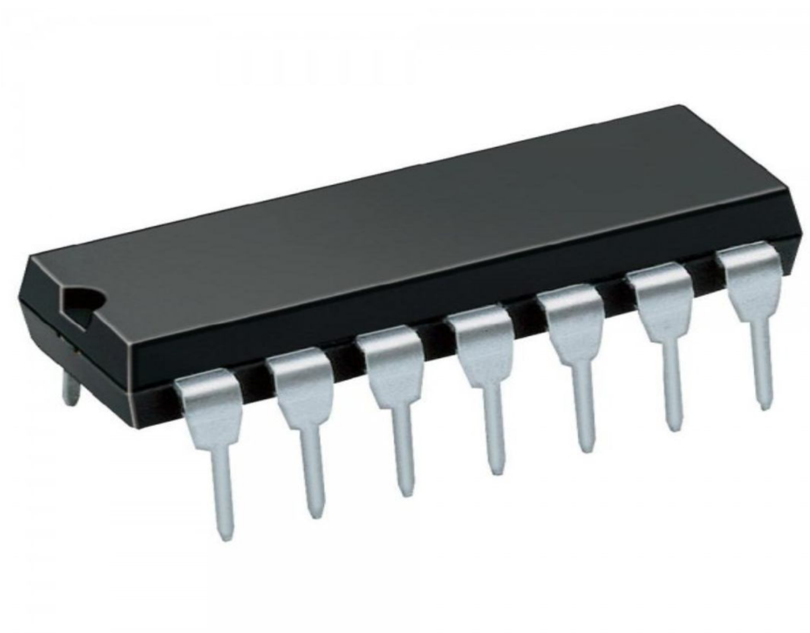


Fig 4.4. LM324 used to isolate current from output signal [17]

SD card:[18]

Micro SD Card is a Flash – Based memory card that is designed to meet the security, capacity, performance and environment requirements inherent to use in emerging audio and video electronic device. The Micro SD Card communication is based on an advance 8-pin interface (clock, command, 4x Data and 2x power lines) and the Micro SD Memory Card host interface supports regular Multi Media Card operation as well.

Features:

I. Targeted for portable and stationary applications
II. Capacity of Memory (standard capacity is 2 GB, high capacity more than 2GB including 32GB and extended capacity more than 32GB including 2TB).
III. Voltage range(2.7-3.6 V)
IV. Designed for read-only and read/write cards.

V. Compliant SD Card Specification ver. 3.01

VI. Bus Speed Mode (using 4 parallel data lines)

VII. Switch function command supports High-Speed, and future functions

VIII. Correction of memory field errors

IX. Card removal during read operation will never harm the content

X. Content Protection Mechanism - Complies with highest security of SDMI standard.

XI. Password Protection of cards (CMD42 - LOCK_UNLOCK)

XII. Write Protect feature using mechanical switch

XIII. Built-in write protection features (permanent and temporary)

XIV. Card Detection (Insertion/Removal)

XV. Application specific commands

XVI. Comfortable erase mechanism

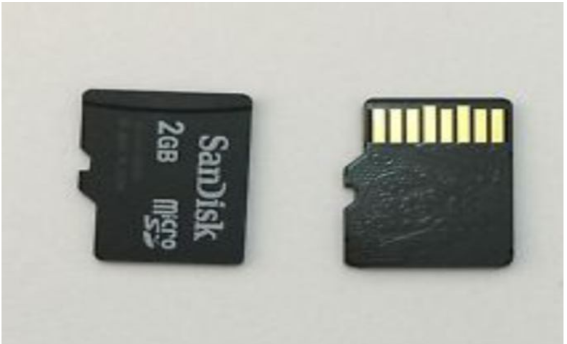


Fig 4.5 SD card (2 GB) used for storing the signals [18].

SD card adapter:[19]

The micro-SD Card Adapter allows you to easily connect a micro-SD Flash memory card to your Propeller chip or other microcontroller. This adapter contains the components required for an SPI interface between the host microcontroller and a micro-SD memory card. The adapter also includes a card detect switch which allows you to detect when a memory card is physically present in the socket. Mounting holes allow you to install the adapter in your application.

Features

I. SPI support components already installed on the PCB
II. Includes mounting holes for use in applications
III. Card detect switch allows detection of memory card insertion
IV. SIP header makes breadboard use easy
V. Supporting objects for the Propeller chip are available on the Propeller Object Exchange
VI. All I/O lines from the SD card are brought out to support SD Bus Mode if desired

Key Specifications

I. Power requirements: 3.3 VDC; power consumption determined by micro-SD card used + 0.5 mA when card is inserted
II. Communication: SPI (or SD Bus Mode)
III. Operating temperature: 32 to 158 °F (0 to 70 °C)
IV. Dimensions: 1.11” L x 1.00” W x 0.47” H (28.22 mm L x 25.40 mm W x 11.92 mm H)

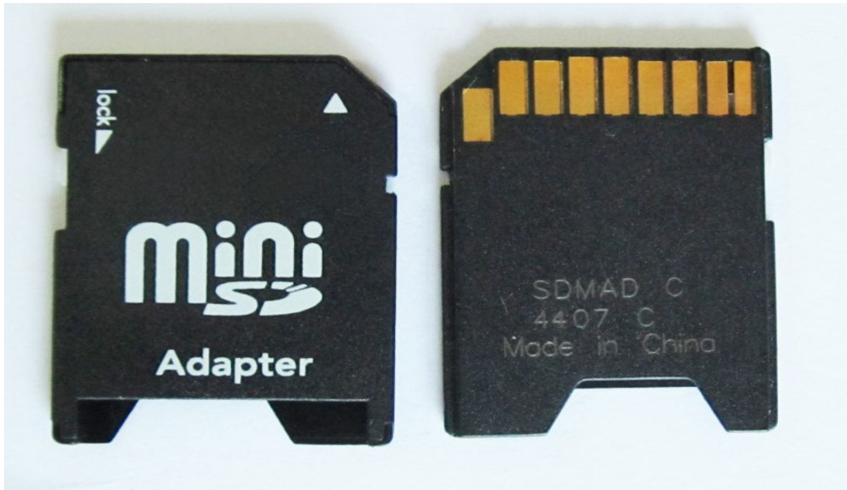


Fig 4.6 SD card adapter [19] .

Resistor:[20]

A resistor as shown in fig 4.7. Below is a passive two-terminal electrical component that implements electrical resistance as a circuit element. Resistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits. In electronic circuits, resistors are used to limit current flow, to adjust signal levels, bias active element, and terminate transmission lines among other uses [9].

Fig 4.7. Resistor for complete the low pass filter and voltage divider circuit [20]

Capacitor:

A capacitor as shown in fig 4.6. Below is a passive two-terminal electrical component used to store electrical energy temporarily in an electric field. The forms of practical capacitors vary widely, but all contain at least two electrical conductors (plates) separated by a dielectric. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, an ideal capacitor does not dissipate energy. Instead, a capacitor stores energy in the form of an electrostatic field between its plates [8].

Fig 4.8 capacitor used to complete the low pass filter [21].

Variable resistor:

Manually adjustable, variable, electrical resistor. It has a resistance element that is attached to the circuit by three contacts, or terminals. The ends of the resistance element are attached to two input voltage conductors of the circuit, and the third contact, attached to the output of the circuit, is usually a movable terminal that slides across the resistance element, effectively dividing it into two resistors.

Fig 4.9 variable resistor (10k) for set the contrast of the LCD[22]

Push button:

It is a micropower, pushbutton on/off controller that manages system power by generating a clean enable output from the supply monitor input and the debounced pushbutton input. It features an interrupt output that notifies the system of a pushbutton or low supply event. When the system is ready, it may use the power kill input to shut off power. If the pushbutton remains pressed for more than the configurable turn-off duration, the system power is forced off. The supply input covers a wide range from 1.5V to 36V. The robust pushbutton input handles wide voltage swings of 36V and ESD strikes to 25kV (human body model) without latch up or damage. A low 1.2μA supply current maximizes battery run time. Separate versions are available for positive or negative enable polarities.

Fig 4.10. Push button

4.1.2 Measuring Tools:

Digital Oscilloscope:

The oscilloscope is basically a graph-displaying device – it draws a graph of an electrical signal. In most applications, the graph shows how signals change over time: the vertical (Y) axis represents voltage and the horizontal (X) axis represents time. The intensity or brightness of the display is sometimes called the Z axis. the Z axis can be represented by color grading of the display.

a digital oscilloscope uses an analog-to-digital converter (ADC) to convert the measured voltage into digital information. It acquires the waveform as a series of samples, and stores these samples until it accumulates enough samples to describe a waveform. The digital oscilloscope then re-assembles the waveform for display on the screen. Digital oscilloscopes can be classified into digital storage oscilloscopes

(DSOs), digital phosphor oscilloscopes (DPOs), and sampling oscilloscopes[10].

Fig 4.11 Gw Instek Digital Oscilloscope with wide frequency range

Multimeter:

To measure voltage (ac, dc), current (ac, dc) and resistance, two types of instruments, analog and digital meters, are utilized. The measurements of these fundamental electrical quantities are based on either one of the following:

i) Current sensing. The instruments are mostly of the electromagnetic meter movement type, such as an analog multimeter.

ii) Voltage sensing. The instruments are mostly electronic in nature, using amplifiers and semiconductor devices, such as a digital multimeter. While most analog meters require no power supply, give a better visual indication of trends and changes, suffer less from electric noise and isolation problems, and, are simple and inexpensive, digital meters offer higher accuracy and input impedance, unambiguous readings at greater viewing distances, smaller size, and a digital electrical output (for interfacing with external equipment) in addition to visual readout. The main part of most of the digital multimeter (DMMs) is the analog to digital converter (A/D) which converts an analog input signal to a digital output.

Fig .4.12 Fluke digital multimeter that measures current, voltage, resistance and capacitance in both DC and AC

4.1.3 Software:

Proteus:

Proteus 8.0 is a Virtual System Modelling (VSM) that combines circuit simulation, animated components and microprocessor models to co-simulate the complete microcontroller based designs. This is the perfect tool for engineers to test their microcontroller designs before constructing a physical prototype in real time. This program allows users to interact with the design using on-screen indicators and/or LED and LCD displays and, if attached to the PC, switches and buttons. One of the main components of Proteus 8.0 is the Circuit Simulation -- a product that uses a SPICE3f5 analogue simulator kernel combined with an event-driven digital simulator that allow users to utilize any SPICE model by any manufacturer. Proteus VSM comes with extensive debugging features, including breakpoints, single stepping and variable display for a neat design prior to hardware prototyping.
In summary, Proteus 8.0 is a program used to simulate the interaction between software running on a microcontroller and any analog or digital electronic device connected to it.

4.2 Proposed System:

In this part the system design description will be shown.

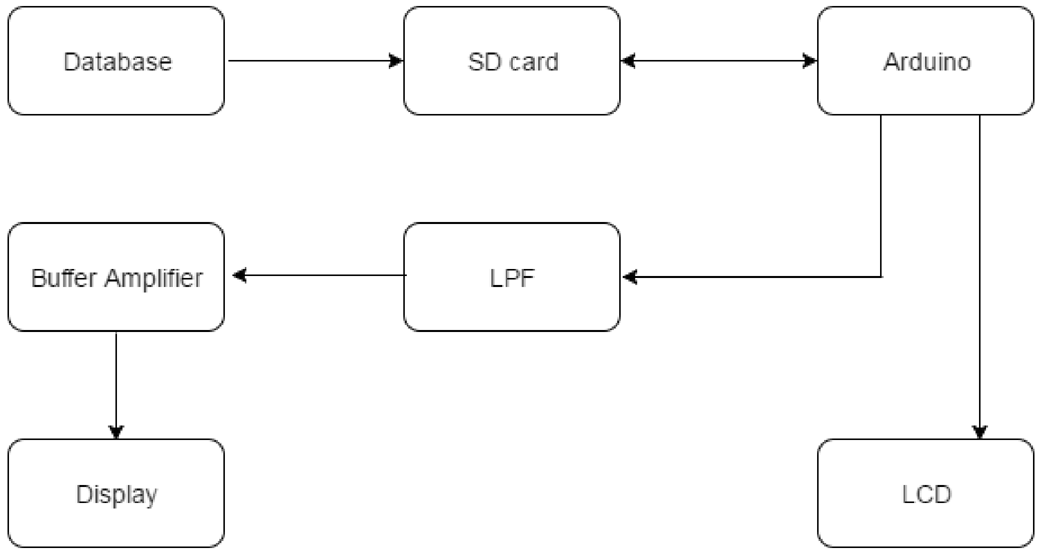


Fig 4.13 Block digram of proposed system

The Hardware:

The electronic circuit illustrated in fig.4.13. was designed to output a signal used to test ECG machines. Our main focus was to find the best ECG simulator circuit with regard to quality of signal, how close it was to the ideal ECG, and availability and cost of the circuit components.

Signals were downloaded from an electronic location called physionet and processed by using MATLAB. Afterwards the processed signals were saved in a memory card which connected to the arduino UNO. The memory card has four pins. Three of the pins were used to input instructions transmitted from the arduino UNO to the memory card when the signal is needed from memory. The fourth pin is used to output the signal to transmit from the memory card to the arduino UNO.

When the arduino UNO receives the signal from the memory card it loads the signal to its own memory because the speed of the memory card is slow. Afterwards the signal is derived into a function called the fast pulse modulator. This is done to create pulse width modulation for the signal which converts the signal from squire wave to sine wave and then outputs the signal. The equation of the pulse width modulation is:

$$\text{Vout} = \text{Duty cycle} * \text{Vin}$$

$$\text{Duty cycle} = \frac{t\ on}{t\ on + t\ off}$$

$$\text{Vout} = \frac{t\ on}{t\ on + t\ of} * \text{Vin}$$

The outputted signal contains some noise. Due to this a low pass filter is needed to interpolate the noise and make the signal smooth. During this time the arduino UNO transmits instructions to the LCD to display the information about the displayed signal. The equation of the low pass filter is:

$$\text{Vout} = \frac{1}{\sqrt{\omega^2 R^2 C^2 + 1}} * \text{Vin}$$

$$\omega = \frac{\sqrt{3}}{RC}$$

The signal which passes through the filter contains some current and cannot be derived to the ECG. Because of this a buffer amplifier is used to isolate the current from the signal.

The quantity of the outputted voltage from arduino is 5v, and the memory operates by 3.3v. Because of this there are voltage divider circuits connected to the input pins of the memory (pin CS, DI, and CLK). There are also two voltage divider circuits after the buffer amplifier to output two signals 1v and 1mv because the 5v outputted cannot be used to calibrate the ECG machine. The voltage divider equation is:

$$\text{Vout} = \frac{R2}{R1+R2} * \text{Vin}$$

For memory inputs:

$$\text{Vout} = \frac{10k}{4.7k+10k} * 5\text{v} = 3.3\text{v}$$

For outputs used to calibrate ECG machine:

$$\text{Vout1} = \frac{3k}{3k+12k} * 5\text{v} = 1\text{v}$$

$$\text{Vout2} = \frac{200}{200+1.1M} * 5\text{v} = 0.009 * 10\text{^-3} = 1\text{m}$$

The final simulator circuit hardware:

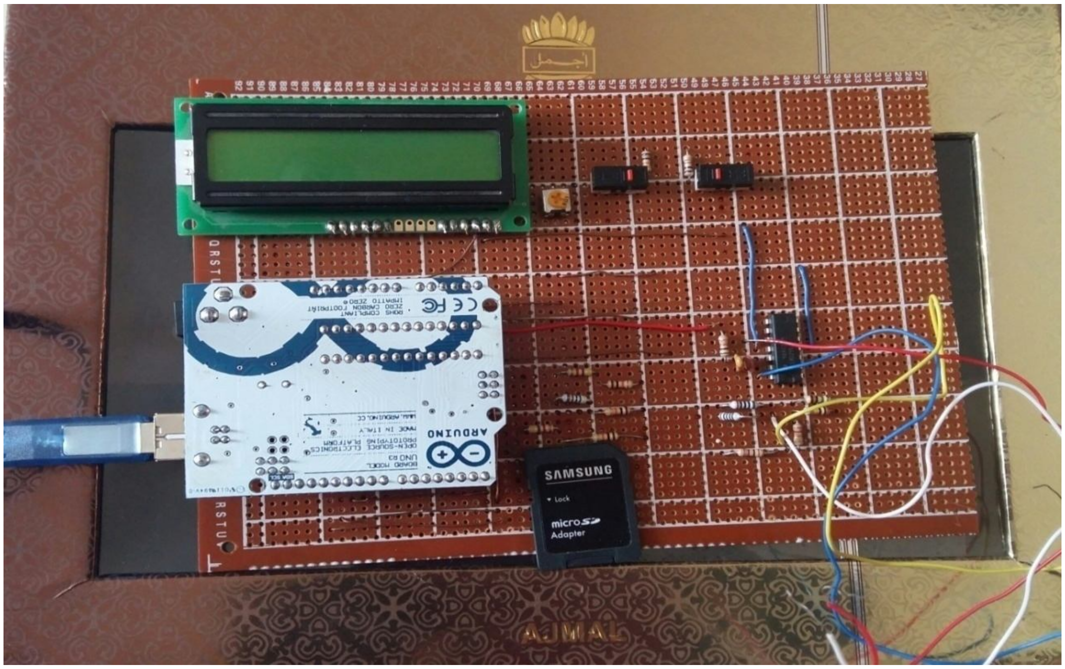


Fig.4.14. the actual circuit of the simulator.

4.2.2. Software:

Before designing the actual circuit the ISIS Professional is used to simulate the output as shown in fig.4.12. Since there is no memory in the proteus there is an override signal saved in the memory of the arduino UNO. It is displayed as though there is no memory or as if there is a problem with the memory. This signal is a normal ECG signal can be used to calibrate the ECG device.

The arduino UNO is the brain of this circuit. It controls the loading of the signal from memory as well as outputting the signal for use in the calibration of the ECG machine. This specific microcontroller was selected because of its high performance, high speed, and its programming code is easy to write. The code was written by using C++ language in the arduino program. The following code was written:

```
#include <FastPWMdac.h>

#include <LiquidCrystal.h>

#include <SPI.h>

#include <SD.h>

File file;

const byte dacPin = 9;

FastPWMdac fastPWMdac;

int ypin = 1,npin = 0;

int
sig[105]={57,51,56,59,53,60,62,54,59,61,57,57,61,59,61,58,61,60,58,59,57,60,62,73
,84,84,68,66,67,92,209,29,73,71,73,76,75,77,77,82,85,94,99,104,109,106,91,74,62,6
0,58,62,62,64,62,61,58,58,57,57,56,57,54,56,58,57,57,60,56,58,61,61,58,67,76,81,67
,56,56,62,255,0,58,62,58,62,66,66,67,72,79,82,88,96,99,98,85,64,56,52,52,54,54,56,
57};

String sigList[5] = {"norm1","norm2","MyoC","ArtFib","Arithmia"};

String fList[5] = {"n1.txt", "n2.txt","b1.txt","b2.txt","b3.txt"};

String sigInfo[5] = {"F, hrt= 65 bpm", "M, hrt= 96 bpm","M, hrt= 56 bpm","F, hrt=
89 bpm","M, hrt= 57 bpm"};

String hld = “”;

char option[16] = "YES          NO";

int idx = 0;

bool selected = false,canc = false,MMC = true,loaded = false,ovrid= false;


----------------//RS, En,D4,D5,D6,D7
```

```
LiquidCrystal lcd(8, 7, 6, 5, 4, 3);


void printlcd(String txt,int x,int y,bool cls){
    if(cls == true)
      lcd.clear;()
    lcd.setCursor(y, x);
    lcd.print(txt);
 }
void printlcd(int txt,int x,int y,bool cls){
    if(cls == true)
      lcd.clear();
    lcd.setCursor(y, x);
    lcd.print(txt);
}


void menu(){
  if ((digitalRead(ypin) == HIGH || canc == true) && MMC == true){
      canc = false;
      while(digitalRead(ypin) == HIGH){;}
      lcd.clear();
      while(!selected){
        printlcd(sigList[idx],0,2,false);
```

```
    printlcd(option,1,0,false);
    if(digitalRead(npin) == HIGH){
     while(digitalRead(npin) == HIGH){;}
     lcd.clear();
     idx++;
     if(idx > 4)idx=0;
} else if(digitalRead(ypin == HIGH)) {
     while(digitalRead(ypin) == HIGH) {;}
     selected = !selected;
}
}
}
}
void loadSig(int idx) {
 loaded = false;
 printlcd("loading signal",0,0,true);
 printlcd(">>>>>>>>>>>>>>>>",1,0,false);
 file = SD.open(fList[idx] );
 if(file){
  int iter = 0;
  while (file.available()) {
   byte incoming = file.read();
```

```
      if (incoming != '\n') {
        hld += (char)incoming;
      } else {
        sig[iter] = hld.toInt();
        iter++;
        hld =“”;
}
      loaded = true;
}
    file.close() ;
} else{
    printlcd("file not found!",0,0,true);
    delay(2000);
    canc = true;
    loaded = false;
}
}

void setup()
{
  lcd.begin(16, 2);
  pinMode(ypin,INPUT);
```

```
  pinMode(npin,INPUT);
  printlcd("ECG Simulator",0,2,false);
  printlcd("Menu",1,0,false);
//  initialization for 8 bit resolution
  fastPWMdac.init(dacPin, 8);
    if (!SD.begin(10)) {
    //Serial.println("initialization failed!");
      printlcd("SD failed",0,0,true);
      delay(1000);
      printlcd("override signal",0,0,true);
      printlcd(">>>>>>>>>>>>>>>",1,0,false);
      delay(1000);
      lcd.clear();
      MMC = false;
      ovrid = true;
      return;
  }
}
void loop()
{
  int iter = ;
  menu();
```

```
  if (selected == true){
    selected = fals;
    loadSig(idx);
}
  if(loaded == true || ovrid == true) {
    if (ovrid == true){
        printlcd("signal on ...",0,0,false);
} else {
       printlcd(sigInfo[idx],0,0,true);
}
    printlcd("stop",1,11,false);
    while(canc == false){
        fastPWMdac.analogWrite8bit(sig[iter]); // sawtooth output, period = 31.25Khz
        delay(9);
        iter++;
        if (iter == 104)iter =0;
        if(digitalRead(npin == HIGH)) {
          canc = true;
          fastPWMdac.analogWrite8bit(0);
          while(digitalRead(ypin) == HIGH) {;}
}       }
}       }
```

The final ISIS professional circuit:

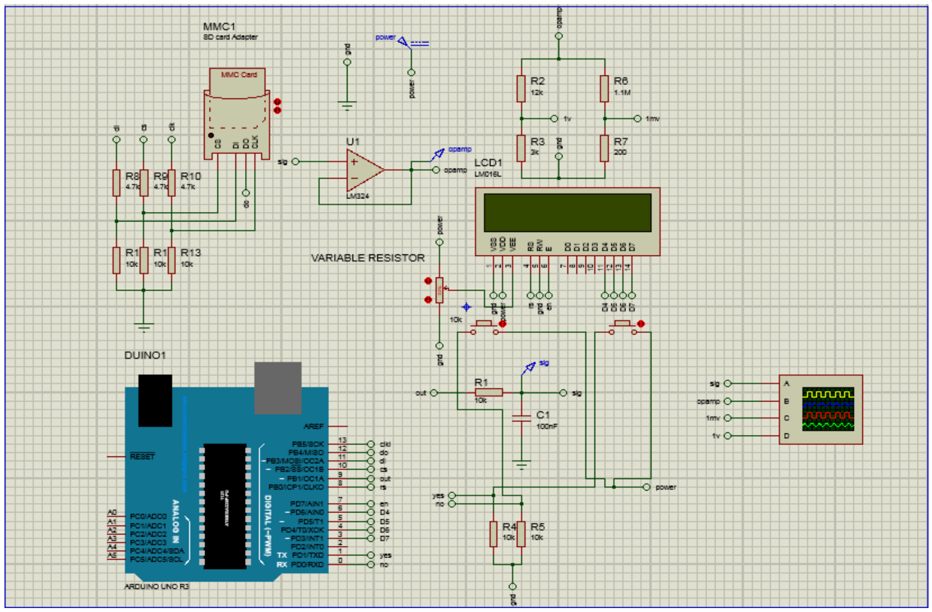


Fig.4.15. the final simulator circuit on ISIS professional

CHAPTER FIVE

Results and Discussion

5.1 Simulation Result:

As mentioned previous the output of the protous is the normal ECG signal called override signal.

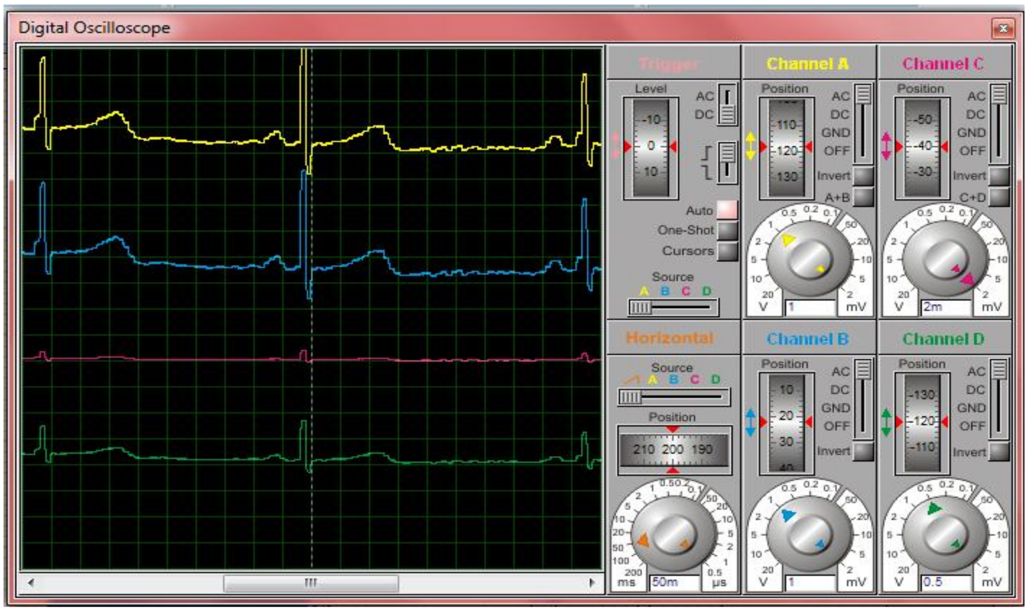


Fig.5.1. simulator output

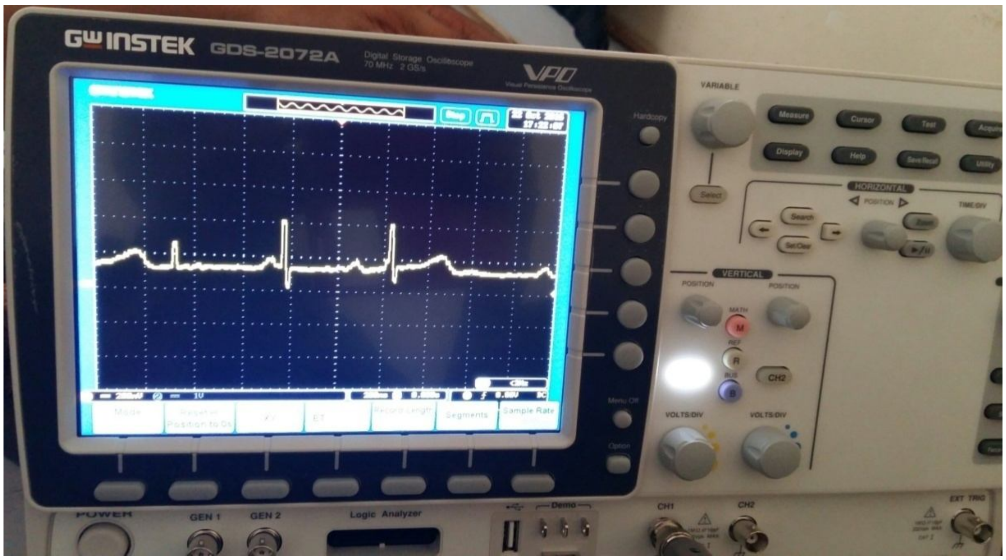
There are four signals with various voltages shown on the figure above, the yellow colored one is 5v which displayed directly from the low pass filter, the blue colored one is also 5v but after isolating the current by buffer amplifier, the third one which colored with pink is 1mv and final one colored with green is 1v, both are appropriate to enter the ECG signal and calibrate it.

5.2 Hardware Results:

The hardware results were shown in figures below. There is a slight difference between the hardware result and the software this is mainly due to the factors like noise, wiring and environmental conditions.

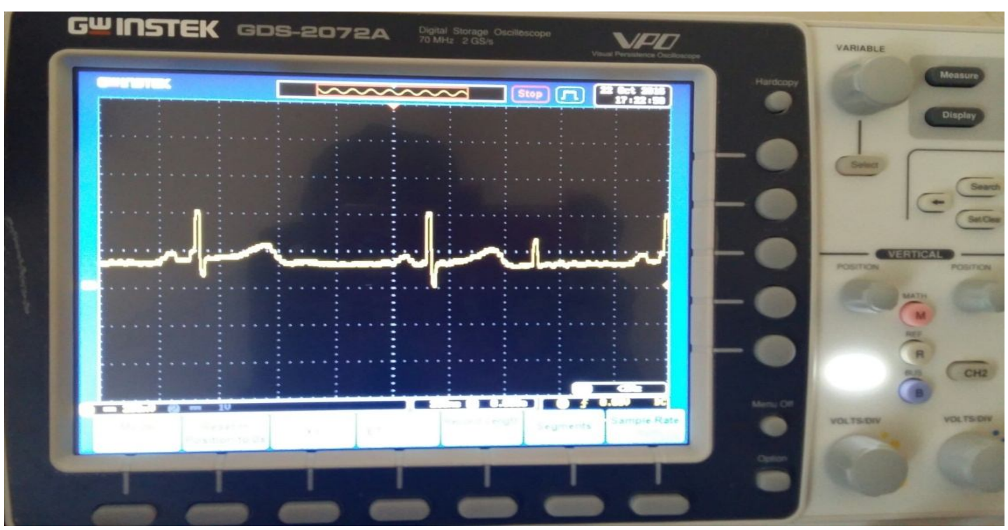
But the major difference is coming from the fact that the point of output taken, as shown above in the ISIS professional output.

This singal was taken from a female whoes heart rate is 65 bpm[25].



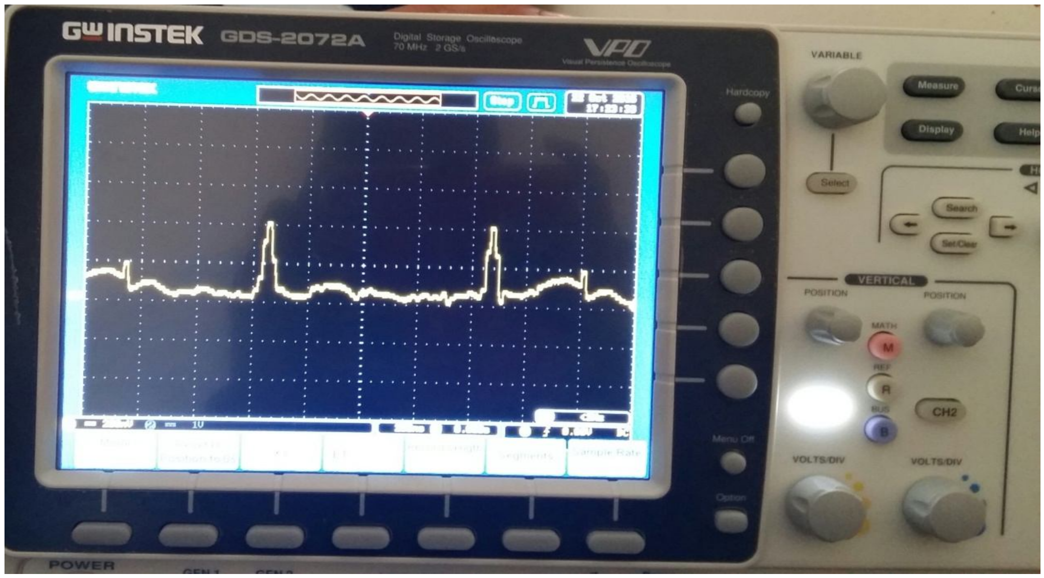
Normal ECG signal Fig.5.2

This singal was taken from a male whoes heart rate is 96bpm[25]



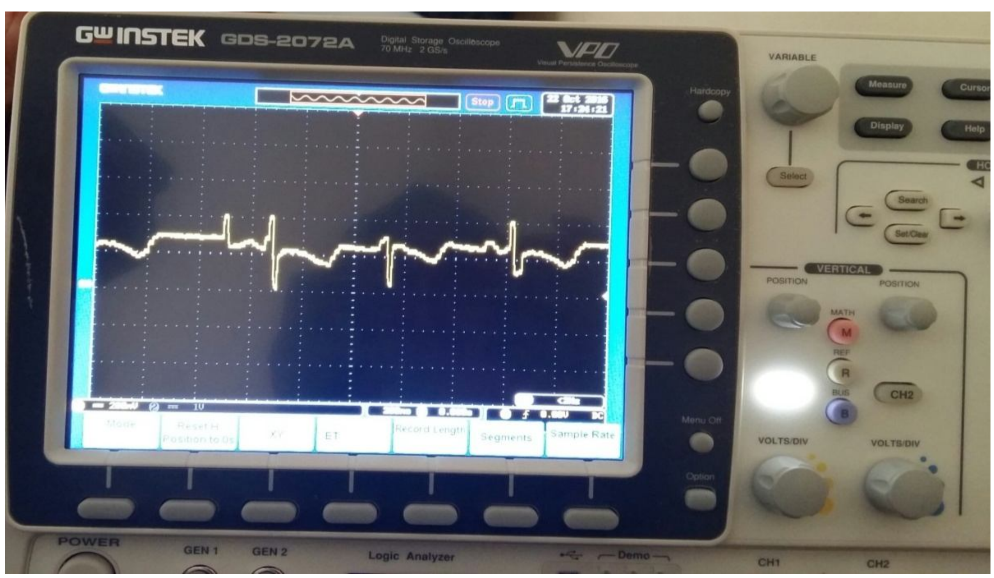
Normal ECG signal Fig.5.3

This singal was taken from a male whoes heart rate is 56 bpm and suffer from myocardia[25]



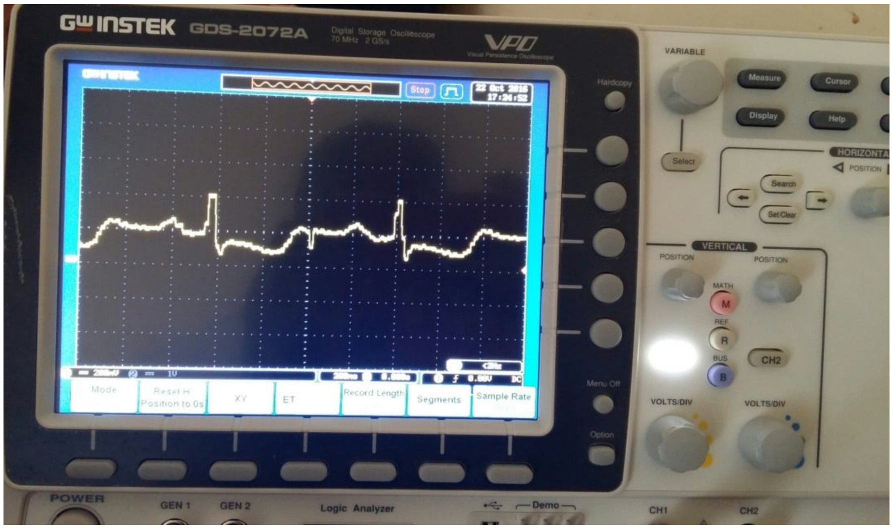
Myocardial ECG signal fig 5.4

This singal was taken from a female whoes heart rate is 89 bpm and suffer from Arterial fibrillation[25]



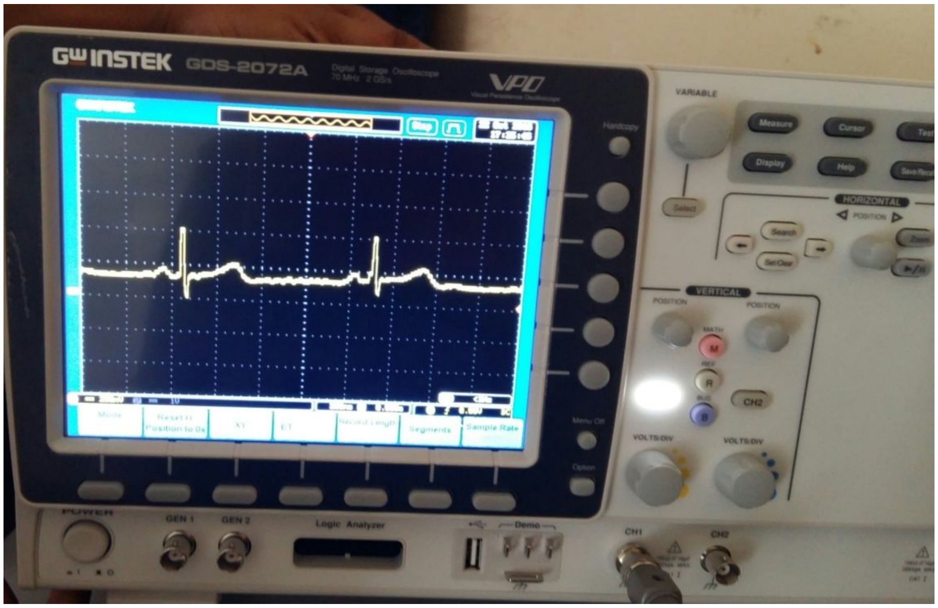
Arterial fibrillation ECG signal fig 5.5

This singal was taken from a male whoes heart rate is 57 bpm and suffer from A rrythmia[25]



ArrhythmiaECG signal fig 5.6

The figuer below represent a signal which displayed when the memory card is lost or faild.



Override signal fig 5.7

CHATER SIX

Conclusion and Recommendations

6.1 Conclusion:

From the previously done work the main objective of this project was met, The ECG machines can be tested and calibrated with standard recognized signals from simulator so as to improve production quality.Specifically this was done by first designing a circuit that simulate the human heart in the cardio electric behavior, then the microcontroller software was written to control the whole system and finally this circuit was tested or measured by using oscilloscope and multimeter. So the circuit is ready to use in calibrating ECG machine.The drawbacks of this method can be categorized into two sections, drawbacks of the thought itself as this method of calibrating the device will increase the cost of ECG device calibrating because it is stand alone device.Another drawbacks arose from the use of the arduino UNO, it has an issue relating to the limitation of its memory Despite the mentioned drawbacks this method in calibration is considered very successful, simple and more accurate than whichever path was taken into this direction in the past, and can be a very powerful tool to increase the efficiency of the healthcare delivery.

6.2 Recommendations are:

1. Due to the mentioned memory issue of the arduino the first recommendation is to use a more powerful controller like arduino mega, arduino leonarde, raspberry pie etc...
2. Any modification should be done by taking electronic complication into account. In fact, simplifying the circuit can make it more effective.

3. A more sophisticated system is needed in order to interpret the cause of the error in the machine and not just detect it.
4. The last recommendation is to develop our circuit to calibrate the ECG machines automatically.

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