Sudan University of Science and Technology

COLLEGE OF ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

A project submitted in partial fulfillment for the degree of

B.Sc. in Biomedical Engineering

Design and construction a prototype of ECG simulator

By:

Alia Abdallah Mohmed

Amal Tawfeeg Abbas

Gadi Ahmed Abdallah

Rasha Abd-Alrahime Suliman

Supervised By:

Dr.Eltaher Mohmed

October 2016

1

الآية

بسم الله الرحمن الرحيم

﴿يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ﴾

صدق الله العظيم

المجادلة الاية (11)

Dedication

To who has reached the message .. Advised the nation .. to the Prophet of mercy and the light of the Worlds Prophet Muhammad, peace be upon him.

To the God-given dignity and prestige.. Who taught me to tender without waiting ..I bring his name proudly I ask God to give you at your age to see the fruit is ripe for the picking After long waiting.. And your words will remain guided by the star today and tomorrow and forever. .

My dear father

To my angel in life..To the meaning of love and the meaning of compassion and dedication ..To the spirit of life, the mystery of existence.. To who was praying to the secret of my success ..And affection surgeon Balm ..The most expensive people to my beloved mother.

Acknowledgment

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

We must go back to the days we spent in the university campus with our professors,Who have given us a lot exerting great efforts.

To all our professors Distinguished

Special thanks goes to the most trustworthy, delightful, and inspiring mentor Dr.Eltaher Mohamed Husain.

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

Our grateful thanks to 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.

Abstract

Electrocardiographs (ECG) are medical devices that record the rhythm of the heart, particularly abnormal rhythms caused by damage to the conductive tissue that carries electrical signals, or abnormal rhythms caused by electrolyte imbalance. Electro Cardio Graph Simulators (ECGS) are devices that generate electrical signals that emulate human heart electrical signals so that the ECG recorders or monitors can be tested for reliability and important diagnostic capabilities. Modern ECG instruments with automatic wave recognition, measurement and interpretation would need for testing, a carefully selected set of test signals.

المستخلص

أجهزة رسم القلب, هي الأجهزة الطبية التي تسجل ايقاع القلب, ولا سيما ايقاعات غير الطبيعية الناجمة عن الأضرار التي لحقت الأنسجة الموصلة التي تحمل اشارات كهربائية, أو ايقاعات غير طبيعية سببها عدم التوازن المنحل بالكهرباء.

اختبار تخطيط القلب هي الأجهزة التي تولد اشارات كهربائية التي تحاكي اشارات كهربية قلب الانسان بحيث تسجل تخطيط القلب أو تراقب تخطيط القلب للموثوقية وقدرات التشخيص الهامة. ان أدوات تخطيط القلب الحديثة بحاجة للاختبار ومجموعة مختارة بعناية من اشارات الاختبار.

Table of content

CHAPTER ONE

Introduction

The bioelectrical signal generated by heart muscles is known as Electrocardiogram. This signal is the electrical signature of functioning of heart.

The ECG signal is picked up from body using bio potential electrodes. In clinical practice there are 12 conventional leads, which may be divided into two groups depending upon their orientation to the heart. The frontal plane leads and the horizontal plane leads.

ECG has a great clinical importance for diagnosis of diseases related to the heart .Traditionally ECG signal is recorded by an ECG machine on a graph with time along the X-axis and voltage along the Y-axis. A typical ECG beat tracing of the cardiac cycle (heart beat) consists of a P-wave, a QRS complex and a T wave.

1.1 Problem Statement

It has been explained that from a safety standpoint human beings cannot be used in the development phase or the testing phase of ECG equipment. In order to test the performance of an ECG devices and to develop diagnostic, the best test input is actual human ECG waveforms.

However, it appears that currently there are no portable ECG simulators in the hospitals because of high cost.

1.2 Objective:

The main objective of this project is to design a practical ECGS device which can be used to testing of ECG recorders.

1.3 Research Methodology

A prototype of ECG simulator well be designed to test ECG equipments create an ideal signal.

Creating by different single signals and The P, Q, R, S, T signals are formed in different steps and then are put together in the right sequence.
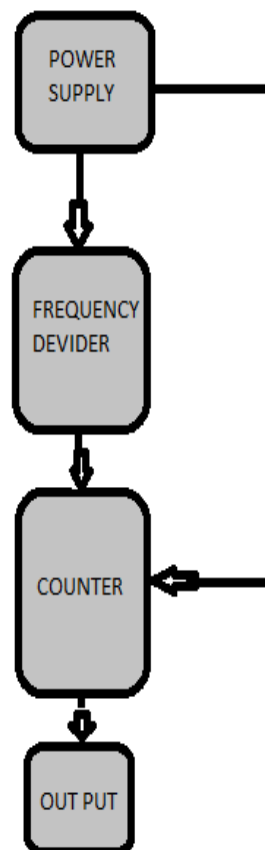

Fig1.1 methodology of design, to achieve the thesis objectives.

1.4 Important of project:

ECG simulator circuit is very useful in the medical community. Such as development of bio-medical engineering.

The device is useful for both of physicians and patients may be the ECG reading misleads them from right and best diagnosing and treating for the patient heart situation.

It is also important for the clinical engineer or the technician working in the hospital or medical institution to save their time, and to decide to maintain the device or that there are other problems.

1.5 Thesis Layout:

This research consist of six chapters, along with appendixes:-
Chapter one is an introduction, previous studies are given in chapter two, chapter three represents the theoretical background, the proposed design is represented in chapter four, chapter five consist of results and discussion, chapter six demonstrates whether or not the goals are fulfilled, concludes the thesis, and provide recommendation.

CHAPER TWO
Literature review

Introduction:

To understand how to construct ECG simulator and its work .The past studies have considered. That is to start where the other stopped, try to solve problems and understanding the difficult of such project and what would it add to the scientific community.

In this chapter, selections of previous studies on ECG patient simulator are mentioned, and then compared to our study.

R. Karthik designed ECG simulator produce the typical ECG waveforms of different leads and as many arrhythmias as possible. This ECG simulator is a MATLAB based simulator and is able to produce normal lead II ECG waveform.

The use of a simulator has many advantages in the simulation of ECG waveforms. First one is saving of time and another one is removing the difficulties of taking real ECG signals with invasive and noninvasive methods. The ECG simulator enables us to analyze and study normal and abnormal ECG waveforms without actually using the ECG machine. One can simulate any given ECG waveform using the ECG simulator [1].

Main features of this simulator: Any value of heart beat can be set, Any value of intervals between the peaks (ex-PR interval) can be set, Any value of amplitude can be set for each of the peaks, Fibrillation can be simulated, Noise due to the electrodes can be simulated, & Heart pulse of the particular ECG wave form can be represented in a separate graph [1].

Peter M. van Dam *et al*, designed ECGSIM which is an interactive simulation program that enables one to study the relationship between the electric activity of the heart and the resulting potentials on the thorax: PQRST wave forms as well as body surface potential maps. Solving the problem of the previous versions of ECGSIM, in which only a single heartbeat can be simulated, limiting its possibilities in inspecting changes in ECG morphology over time. This contribution introduces a new version in which changes in a sequence of heart beats can be displayed [2].

The possibilities of ECGSIM are considerably extended by the new feature to create rhythm strips. Its potential is demonstrated by the simulation of atrial tachycardia and the typical changes in the ECG of a Brugada patient elicited by the administration of Ajmaline. As before, the clinical data used for the new cases are made available at the ECG simulator website (www.ecgsim.org). They feel confident that these new applications will increase even further the interest in ECGSIM and stimulate further the present collaboration with other researchers in identifying new applications [2].

Sangita Das et al, described the development of a 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 standalone 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 [3].

8-bit resolution has been used for the quantized ECG database; 10-bit resolution can also be used. For 8 bit quantization all the databases are given a constant gain (500) and constant dc shift (+2.5). So, the wave form is not deformed and the clinical information is not affected by this manipulation. This is an 8051 based system so it is very much economical. Here 12 lead ECG signals are used to generate simulated ECG signal. Both normal and abnormal ECG signal can be generated by this simulator. The serial communication protocol (RS-232) is the simplest communication protocol and the connector (DB9) is available with almost all PCs. This system is also capable of generating other types of biomedical signals like EEG, EMG using proper amplification factor for the database. The noisy effect is not removed from the simulated ECG signal so whenever clean signal is required de-noising has to be done. Multi lead ECG signal for a 12 lead system can be generated by slightly modification of the developed software programming and hardware circuit. The ptb- db database for multi lead ECG signal can be send over the same serial communication line, in time multiplexed technique. In this case the serial communication baud rate or the data sampling rate (both for the RS-232 protocol and the microcontroller) has to be increased by multiplying with a number which is equal to the number of leads used. And also a multichannel DAC is required at the output [3].

Rahul S. Patel et al, This paper the design and development of Micro-controller based ECG simulator intended to use in testing, calibration and maintenance of ECG machines and to support biomedical engineering student's education. It generates all 12lead ECG signals of varying heart rate, amplitude and different noise contamination in a manner which reflects true noninvasive conditions. Since standard commercially available electronic components were used to construct the prototype simulator, the proposed design was also relatively

inexpensive to produce. It is portable battery operated instrument with alphanumerical LCD display and keyboard for waveform selection. The operator can control the amplitudes of various signals and the name of selected signal will appear on 16X2 LCD display [4].

The aim of the ECG tester is to produce the typical ECG waveforms of different leads combinations and as many arrhythmias as possible. The ECG simulator enables us to analyze and study normal and abnormal ECG waveforms without actually connecting it patients. During testing of ECG machines it is not possible to connect it to patient hence this instrument facilitates to the task. This can also be used as teaching aid for Engineering and medical college laboratories for cardiac signal study and testing. [4]

Joachim Behar, Fernando Andreotti, Sebastian Zaunseder, Qiao Li, Julien Oster and Gari D Clifford, Accurate foetal electrocardiogram (FECG) morphology extraction from non-invasive sensors remains an open problem. This is partly due to the paucity of available public databases. Even when gold standard information (i.e derived from the scalp electrode) is present, the collection of FECG can be problematic, particularly during stressful or clinically important events [5].

In order to address this problem we have introduced an FECG simulator based on earlier work on foetal and adult ECG modelling. The open source foetal ECG synthetic simulator, *fecgsyn*, is able to generate maternal-foetal ECG mixtures with realistic amplitudes, morphology, beat-to-beat variability, heart rate changes and noise. Positional (rotation and translation-related) movements in the foetal and maternal heart due to respiration, foetal activity and uterine contractions were also added to the simulator.
The simulator was used to generate some of the signals that were part of the 2013 PhysioNet Computing in Cardiology Challenge dataset and has been posted on

Physionet.org (together with scripts to generate realistic scenarios) under an open source license. The toolbox enables further research in the field and provides part of a standard for industry and regulatory testing of rare pathological scenarios [5].

N. Kontodimopoulos, N. Pallikarakis, I. Christov & I. Daskalov, The evolution of new technologies in health care has improved both diagnosis and treatment but concurrently created questions concerning the safety and effectiveness and introduced concerns about the rising costs involved in health care services. The Clinical Engineering Departments (CEDs) of hospitals have to assume the responsibility for the overall management of this technology. Traditionally, CEDs were primarily responsible for performing preventive and corrective maintenance on medical devices as well as quality control procedures. The international trends for adopting safety standards for medical devices in addition to the introduction of those new technologies have increased tremendously the responsibility, the effort and the time required for CEDs. Moreover the ever increasing need for user training has been demonstrated and has become an objective for today's CEDs.[6]

In this direction, the Institute of Biomedical Technology (INBIT) in Patras Greece and the Center of Biomedical Engineering (CBME) in Sofia Bulgaria, collaborated for the purpose of developing a 12- lead, digital ECG simulator - tester. The project was implemented in three phases: requirements analysis, design/development and verification. The first two phases of this collaboration concluded with the production of a working prototype. The device incorporates a series of normal sinus rhythm, arrhythmia and test wave-forms for appraising the performance of ECG recorders and physiologic monitoring systems and furthermore can be used for personnel training in the recognition of various cardiac events [6].

CHAPTER THREE

Theoretical background

3.1 The heart:

The heart is a muscular organ , which pumps blood through the blood vessels of the circulatory system [7]. Blood provides the body with oxygen and nutrients, and also assists in the removal of metabolic wastes [8]. The heart is located in the chest between the lungs behind the sternum and above the diaphragm. It is surrounded by the pericardium. Its size is about that of a fist, and its weight is about 250-300 g. An overall view is given in Fig1.1 [9]
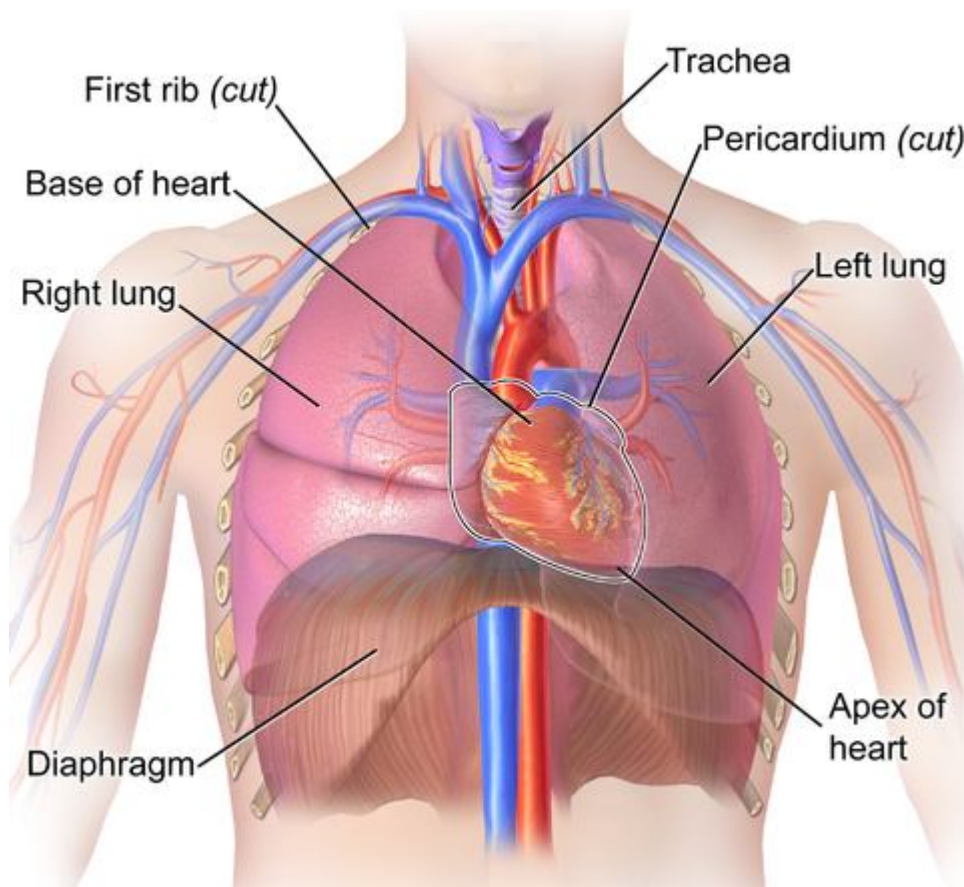
Fig. 1.1. Location of the heart in the thorax. It is bounded by the diaphragm, lungs, esophagus, descending aorta, and sternum [9]

In humans, the heart is divided into four chambers: upper left and right atria; and lower left and right ventricles. Commonly the right atrium and ventricle are referred together as the *right heart* and their left counterparts as the *left heart* [10].

The heart is oriented so that the anterior aspect is the right ventricle while the posterior aspect shows the left atrium (see Fig 1.2). The atria form one unit and the ventricles another.

This has special importance to the electric function of the heart, which will be discussed later. The left ventricular free wall and the septum are much thicker than the right ventricular wall. This is logical since the left ventricle pumps blood to the systemic circulation, where the pressure is considerably higher than for the pulmonary circulation, which arises from right ventricular outflow [11].
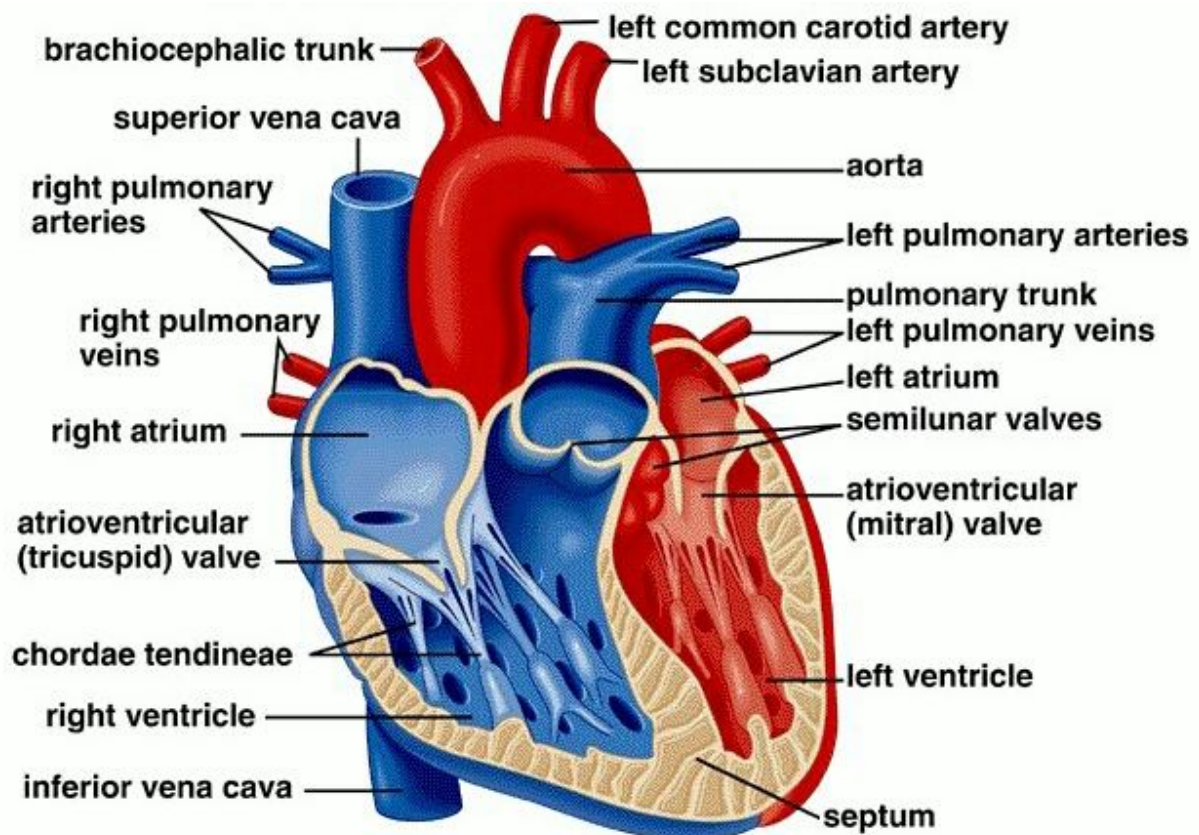

Fig. 1.2. The anatomy of the heart and associated vessels. [11]

The chambers of the heart alternately contract and relax in a rhythmic cycle. During the period of contraction (systole), the heart pumps blood out through the arteries; during the period of relaxation (diastole), the heart fills with blood. One complete sequence of filling and pumping blood is called a cardiac cycle, or heartbeat. The heart's rhythm of contraction is controlled by the Sino-atrial node (SA node).

The SA node in humans is in the shape of a crescent and is about 15 mm long and 5 mm wide. The SA nodal cells are self-excitatory, pacemaker cells. They generate an action potential at the rate of about 70 per minute. From the sinus node, activation propagates throughout the 18 atria, but cannot propagate directly across the boundary between atria and ventricles, as noted above [12].

the AV (atrioventricular) node. This node sits just above the ventricles. Here, the electrical impulse is held up for a brief period. This delay allows the right and left atrium to continue emptying blood into the two ventricles (called the "PR interval" of the ECG). The AV node thus acts as a "relay station" delaying stimulation of the ventricles long enough to allow the two atria to finish emptying.Following the delay, the electrical impulse travels through both ventricles (via special electrical pathways known as the right and left bundle branches). The electrically stimulated ventricles contract and blood is pumped into the pulmonary artery and aorta (called the "QRS complex" of an ECG). The ventricles then recover from this electrical stimulation and generate what is called the "S-T segment" and the T wave on the ECG [13], [14].
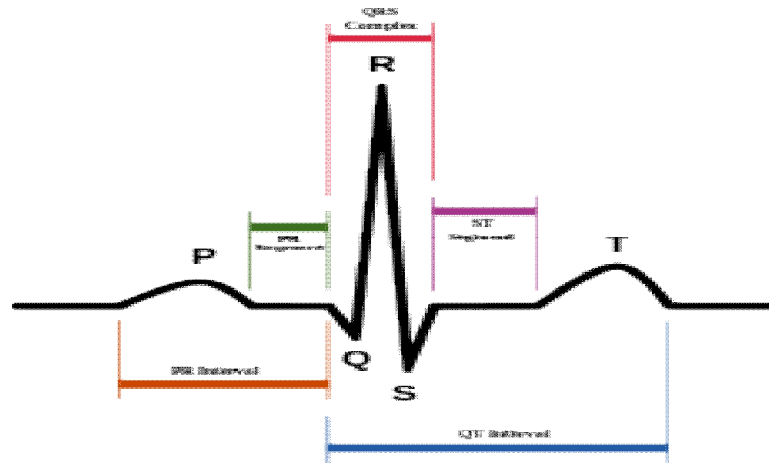
Figure1.3 Basic ECG Wave.

3.2 ECG Device:

ECG is a device that record an electrical activity of the heart when depolarization and repolarization occur of the atrial and ventricular chambers of the heart [15]. 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 [16]. 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.

CHAPTER FOUR

The Proposed system

4.1 Circuit Components:

The circuit consist of:

Resistors:

A resistor as shown in fig 4.1 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 elements, and terminate transmission lines among other uses. [17]

Fig.4.1. resistor is a passive two-terminal electrical component. [17].

Capacitors:

Ceramic capacitor is a fixed value capacitor in which ceramic material acts as the dielectric. It is constructed of two or more alternating layers of ceramic and a metal layer acting as the electrodes. The composition of the ceramic material defines the electrical behavior and therefore applications. Ceramic capacitors are divided into two application classes:

- Class 1 ceramic capacitors offer high stability and low losses for resonant circuit applications.
- Class 2 ceramic capacitors offer high volumetric efficiency for buffer, by-pass, and coupling applications.[18]

Fig 4.2 ceramic capacitor. [18]

Diodes:

The 1N4148 and 1N4448 are high-speed switching diodes fabricated in planar technology, and encapsulated in hermetically sealed leaded glass SOD27 (DO-35) packages.

Fig 4.3 high-speed switching diodes

LED:

A light-emitting diode (LED) as shown in fig 4.4. below is a two-lead semiconductor light source. It is a p-n junction diode, which emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. [20]

Fig.4.4. light emitting diod

Frequency Divider (4521):

        As shown in fig 4.8. Below Consists of a chain of 24 toggle flip-flops with an overriding asynchronous master reset input (MR), and an input circuit that allows three modes of operation.

The single inverting stage (A2 to Y2) functions as: a crystal oscillator, an input buffer for an external oscillator or in combination with A1 as an RC oscillator. The crystal oscillator operates in Low-power mode when pins VSS1 and VDD1 are supplied via external resistors. [21]

Fig.4.5. frequency divider (IC 4521B)

Counter (IC 4017):

The 4017 Decade counter as shown in fig 4.7. below is an integrated circuit which has ten outputs which go HIGH in sequence when a source of pulses is connected to the CLOCK input and when suitable logic levels are applied to the RESET and ENABLE inputs. [22]
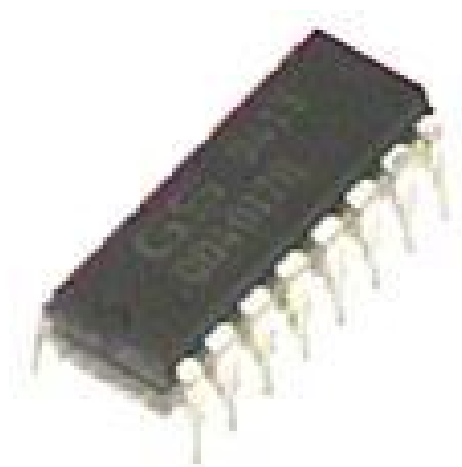
Fig.4.6. counter (IC 4017)

Breadboard:

A breadboard also known as proto-board is a type of solder-less electronic circuit building. You can build an electronic circuit on a breadboard without any soldering. It was designed by Ronald J Portugal of EI Instruments Inc. in 1971. [23]
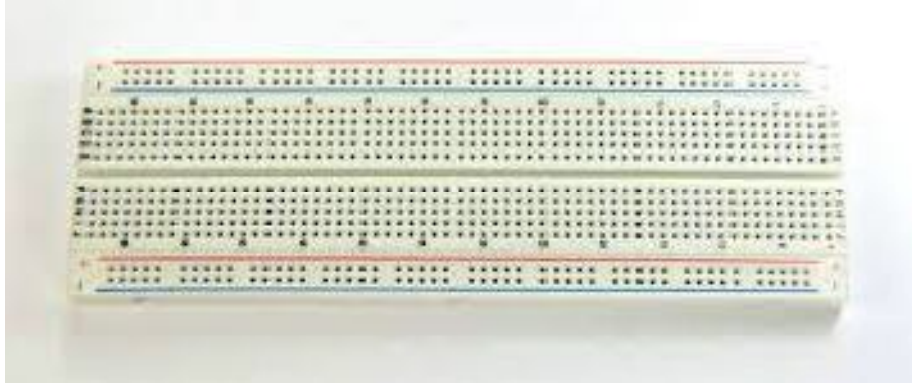
Fig. 4.7. Breadboard used is building prototype electronic circuits

Digital oscilloscope:

A digital storage oscilloscope as shown in fig 4.11. below is an oscilloscope which stores and analyses the signal digitally rather than using analogue techniques. It is now the most common type of oscilloscope in use because of the advanced trigger, storage, display and measurement features which it typically provides. [24]

Fig 4.8. GW Instek digital oscilloscope with wide frequency range.

Digital Multi meter:

   A digital multi meter is one the most versatile and useful instruments in your auto shop. It is important to own a good model and understand how to use it properly. A digital multi meter is actually three devices in one. It is a voltmeter that measure electrical potential across a device in volts .It is an ammeter that measures the amount of electric current through a device. This is measured in amps. Finally, a digital multi meter is an ohmmeter that measures electrical resistance of a device. Electrical resistance is measured in ohms.

Fig.4.9.Digital Multi meter with Temperature

Power Supply:

Fig 4.10.super extra heavy duty 9v

Function generator:

One essential tool needed for experimenting with electronic. It's outputs various waveforms which can be used in experiments .common waveforms are sine ,triangle ,square and sawtooth .The waveforms can be adjusted by frequency's , amplitude and shape .

Fig.4.11.function generat

4.2 Hardware:

A shift register does the sequence of the signal (P.Q.R.S), RC combinations the frequency and amplitude of the single waves.

IC_1 contains an oscillator and a shift register. At the output of pin10 a signal with 16 Hz triggers IC_2. IC_2 is a counter with 10 outputs. When output 0 of IC_2 is active (pin3) the R-C combination R_8, C_5 creates the P-wave. When the counter jumps to output 3 (pin7) the R-wave is created by R_4, C_4. The negative part is reduced by the two diodes and simulate the following S-wave. When output 5 is active (pin1) the T-wave is created by R_7 and C_5. The outputs which are not connected create the needed pauses between the signals. All signals are put together through R_3 and R_6 which level the respective amplitudes.

When one sequence is finished the shift register stops. Output 9 (pin11) is connected with EN-input (pin13). Only when a reset pulse reaches the counter (pin15) the counter starts again. This reset is also created by IC_1. Because in addition to the 16 Hz trigger signal the IC also provides a 1 Hz and a 0.5 Hz signal at pin14 and pin13 which correlate a heartbeat rate of 60 and 120 (switch 2). Therefore the square signal has to be transformed in a positive needle pulse. This is the duty of the combination C_6, R_{11}, D_4, R_{10}. Because this pulse comes earlier or later (0.5 Hz or 1 Hz) only the lengths of the U period is shorter or longer. The PQRST wave form is not effected.

A small LED D_3 with resistor R_5 connected to output 3 (pin7, IC_2), flashes during the R- period.

The final resistor combination R_{12}-R_{15} converts the bipolar signal from the electronic board into the needed three pole output signal.
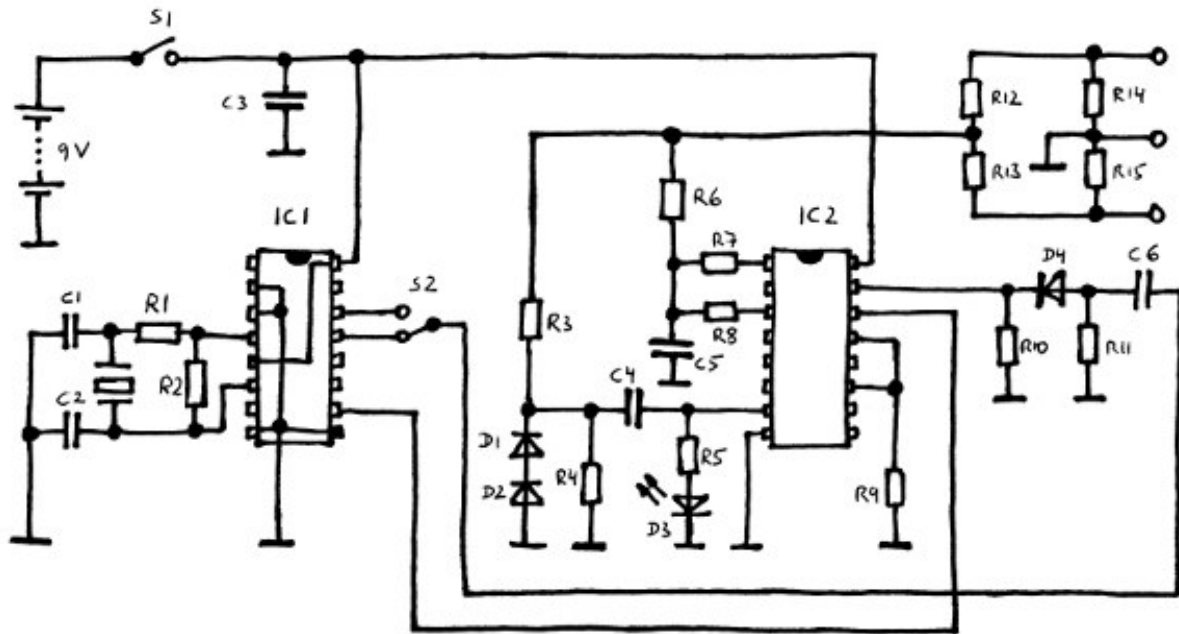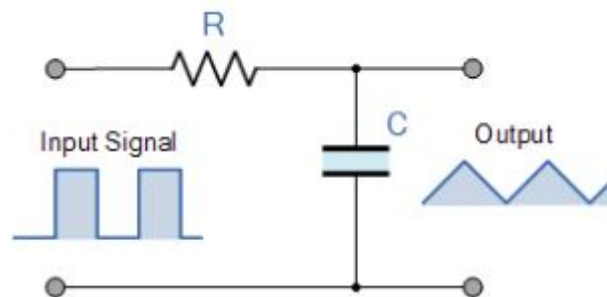
Fig.4.12.An electronic circuit that is supposed to create ideal ECG signal.

RC Combination (RC waveform):

A capacitor(C) has the ability to both charge ,discharges itself through a series connected resistor, (R) at an amount of time equal to 5 time constants or 5T when a constant DC voltage is either applied or removed.

But what would happen if we changed this constant DC supply to a pulsed or square-wave waveform that constantly changes from a maximum value to a

minimum value at a rate determined by its time period or frequency. How would this affect the output **RC waveform** for a given RC time constant value?

We saw previously that the capacitor charges up to 5T when a voltage is applied and discharges down to 5T when it is removed. In RC charging and discharging circuits this 5T time constant value always remains true as it is fixed by the resistor-capacitor (RC) combination. Then the actual time required to fully charge or discharge the capacitor can only be changed by changing the value of either the capacitor itself or the resistor in the circuit and this is shown below.
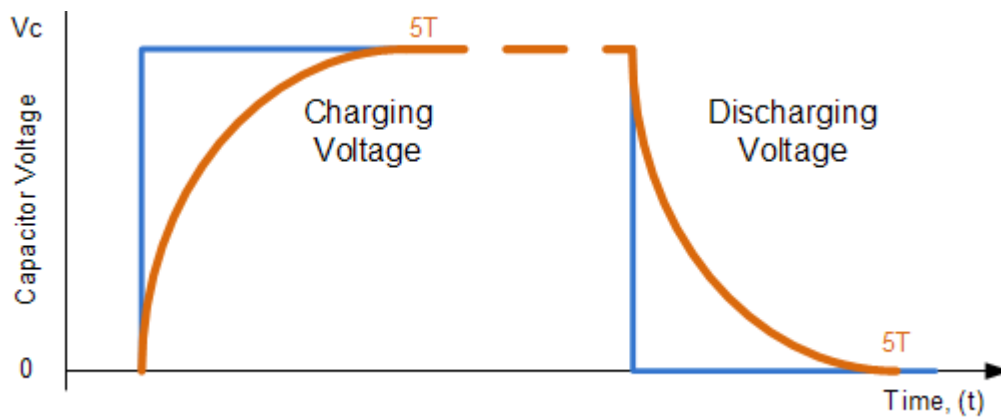
Fig.4.13.Typical RC Waveform

Square Wave Signal

Useful wave shapes can be obtained by using RC circuits with the required time constant. If we apply a continuous *square wave* voltage waveform to the RC circuit whose pulse width matches that exactly of the 5RC time constant (5T) of the circuit, then the voltage waveform across the capacitor would look something like this:
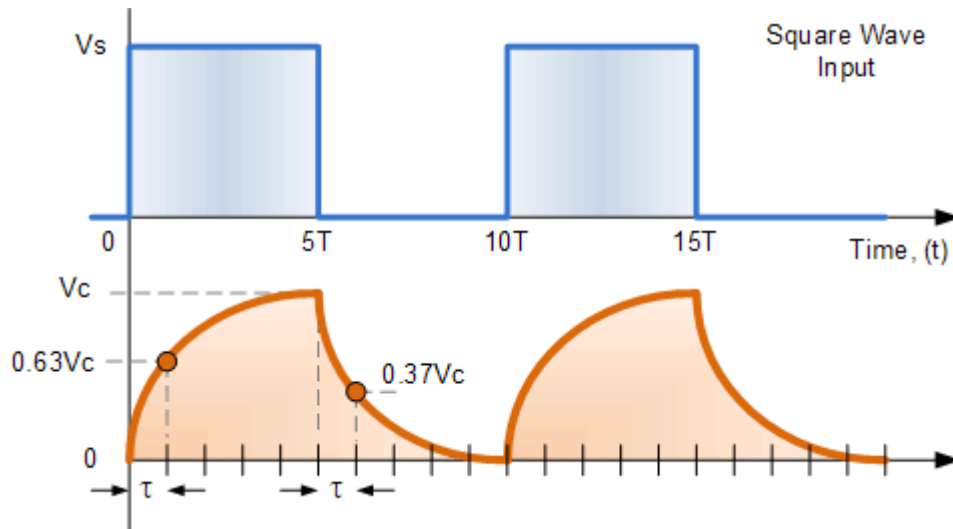
Fig.4.14.A 5RC Input Waveform

The voltage drop across the capacitor alternates between charging up to Vcand discharging down to zero according to the input voltage. Here in this example, the frequency (and therefore the resulting time period, $f = 1/T$) of the input square wave voltage waveform exactly matches twice that of the 5RC time constant.

This (10RC) time constant allows the capacitor to fully charge during the "ON" period (0-to-5RC) of the input waveform and then fully discharge during the "OFF" period (5-to-10RC) resulting in a perfectly matched RC waveform.

If the time period of the input waveform is made longer (lower frequency, $f < 1/10RC$) for example an "ON" half-period pulse width equivalent to say"8RC", the capacitor would then stay fully charged longer and also stay fully discharged longer producing an RC waveform as shown.
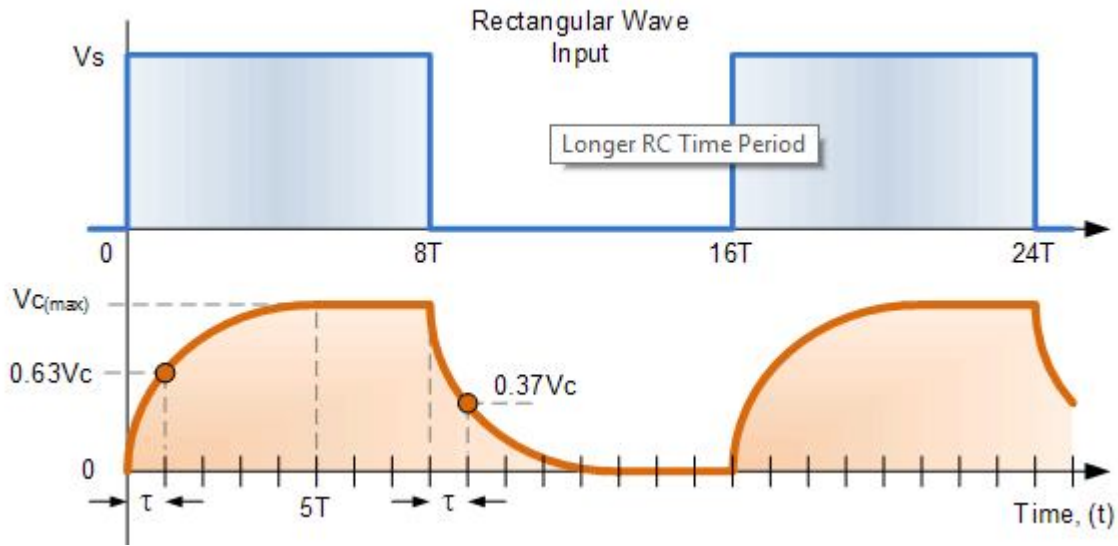
Fig.4.15.A Longer 8RC Input Waveform

If however we now reduced the total time period of the input waveform (higher frequency, $f > 1/10RC$), to say "4RC", the capacitor would not have sufficient time to either fully charge during the "ON" period or fully discharge during the "OFF" period. Therefore the resultant voltage drop across the capacitor, Vc would be less than its maximum input voltage producing an RC waveform as shown below.
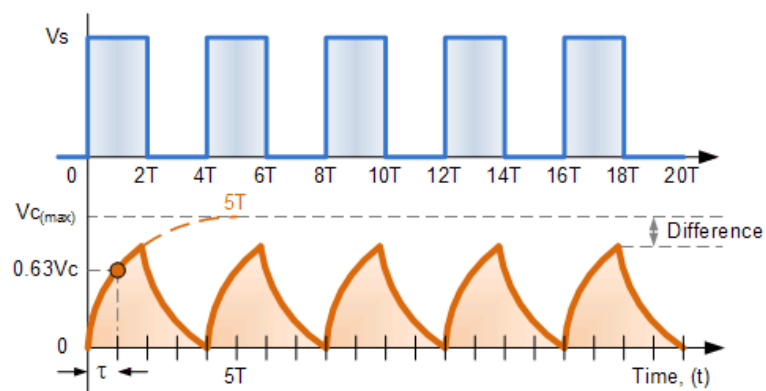

Fig.4.16.A Shorter 4RC Input Waveform

Then by varying the RC time constant or the frequency of the input waveform, we can vary the voltage across the capacitor producing a relationship between Vc and time, t. This relationship can be used to change the shape of various waveforms so that the output waveform across the capacitor barely resembles that of the input.

Frequency Response:

The RC Integrator:

The Integrator is a type of Low Pass Filter circuit that converts a square wave input signal into a triangular waveform output. As seen above, if the 5RC time constant is long compared to the time period of the input RC waveform the resultant output will be triangular in shape and the higher the input frequency the lower will be the output amplitude compared to that of the input.
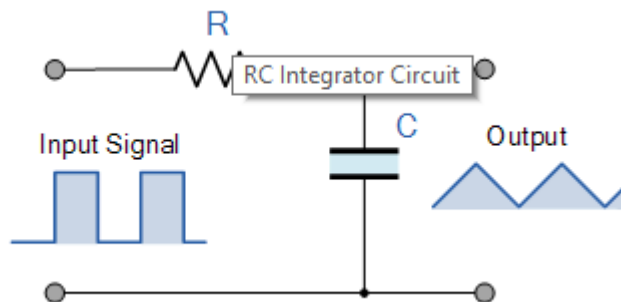
From which we derive an ideal voltage output for the integrator as:

$$V_{out} = \frac{1}{RC} \int_0^t V_{in}\, dt$$

The RC Differentiator:

The **Differentiator** is a **High Pass Filter** type of circuit that can convert a square wave input signal into high frequency spikes at its output. If the 5RC time constant

is short compared to the time period of the input waveform, then the capacitor will become fully charged more quickly before the next change in the input cycle.

When the capacitor is fully charged the output voltage across the resistor is zero. The arrival of the falling edge of the input waveform causes the capacitor to reverse charge giving a negative output spike, then as the square wave input changes during each cycle the output spike changes from a positive value to a negative value.
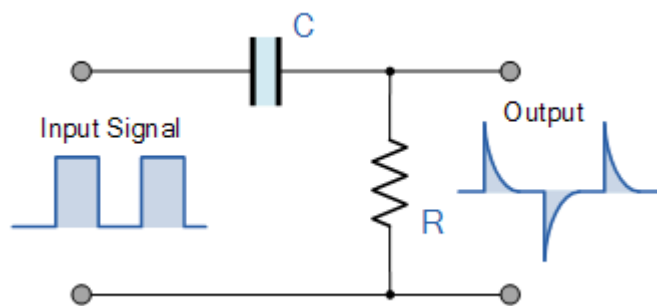
from which we have an ideal voltage output for the Differentiator as:

$$V_{out} = RC \frac{dV_{in}}{dt}$$

Alternating Sine Wave Input Signal

If we now change the input RC waveform of these RC circuits to that of a sinusoidal Sine Wave voltage signal the resultant output RC waveform will remain unchanged and only its amplitude will be affected. By changing the positions of the Resistor, R or the Capacitor, C a simple first order Low Pass or a High Pass filters can be made with the frequency response of these two circuits dependant upon the input frequency value.

Low-frequency signals are passed from the input to the output with little or no attenuation, while high-frequency signals are attenuated significantly to almost

zero. The opposite is also true for a High Pass filter circuit. Normally, the point at which the response has fallen 3dB (cut-off frequency, fc) is used to define the filters bandwidth and a loss of 3dB corresponds to a reduction in output voltage to 70.7 percent of the original value.

RC Filter Cut-off Frequency:

$$fc = \frac{1}{2\pi RC} \text{ in Hertz}$$

where RC is the time constant of the circuit previously defined and can be replaced by tau, T. This is another example of how the *Time Domain* and the *Frequency Domain* concepts are related.

4.2.1 Values of component:

$R_1 = 4K7$

$R_2, R_8 = 1M$

$R_3, R_4, R_9, R_{10}, R_{11}, R_{12}, R_{13} = 100K$

$R_5 = 1K$

$R_6, R_7 = 470K$

$R_{15}, R_{14} = 220$

$C_1 = 22$ p

$C_2 = 82$ p

$C_3, C_4, C_5, C_6 = 220n$

$IC_1 = 4521$

$IC_2 = 4017$

$D_1, D_2, D_4 = 1N4148$

Crystal = 4.1943 MHz

$D_3 =$ LED 3 mm

IC_1 was replaced with two clocks (In simulation and practical), the signal form this circuit did not meet standards, no Q-wave, the QRS complex amplitudes and duration was far from the ideal signal .The simulation done by using ISIS Professional program.
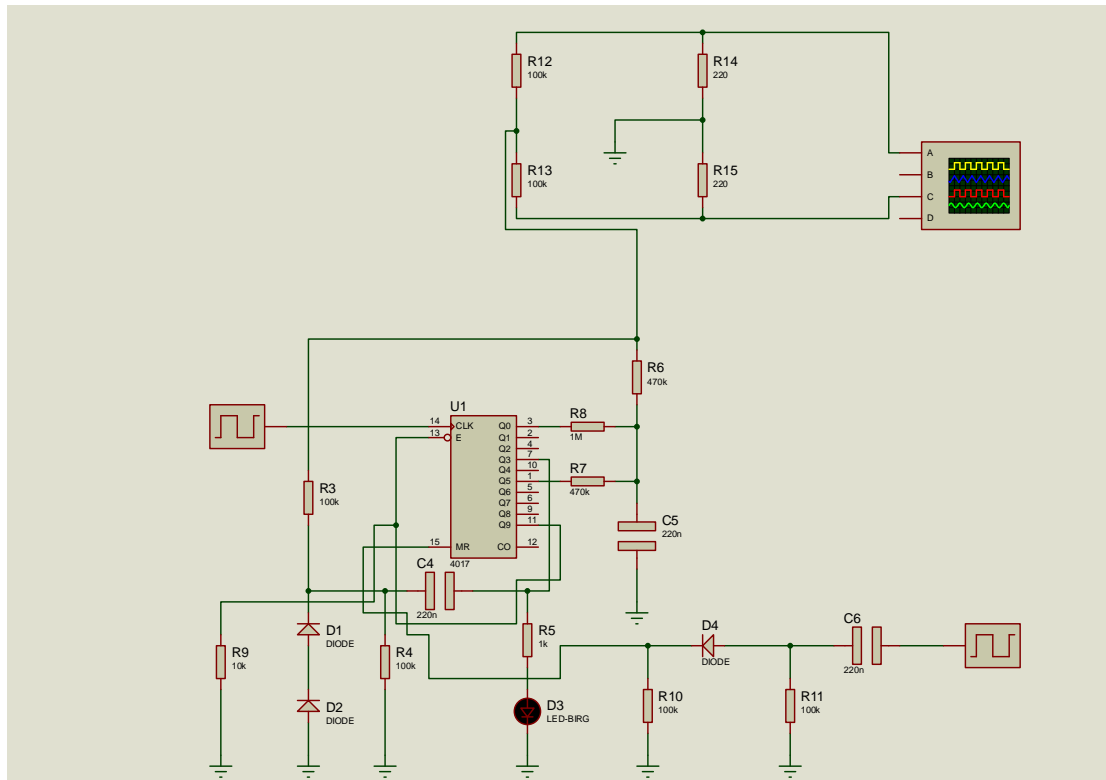
Fig.4.13.The final project circuit simulated using ISIS professional program.

The values of capacitors and resistors are chosen depend on the below laws:

$Q=Q0xe-RC*t$…………………….. (1)

Q::the charge

Q0:: the maximum charge.

T:: time of capacitor's working.

$V_c=V_s(1-\exp(-t/RC))$………. (2)

V_c:: voltage of capacitor's output.

V_s:: voltage of source.

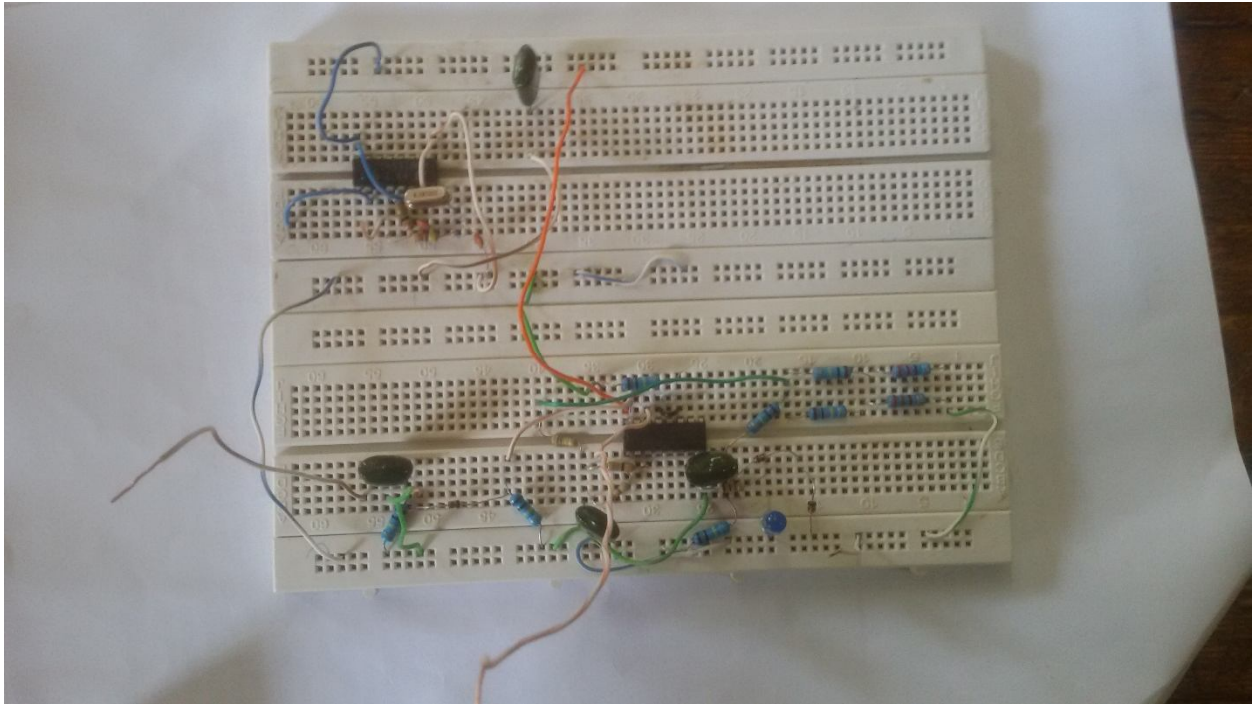## 4.3 The final simulator circuit hardware:

Fig. 4.14. The final project circuit

Chapter Five

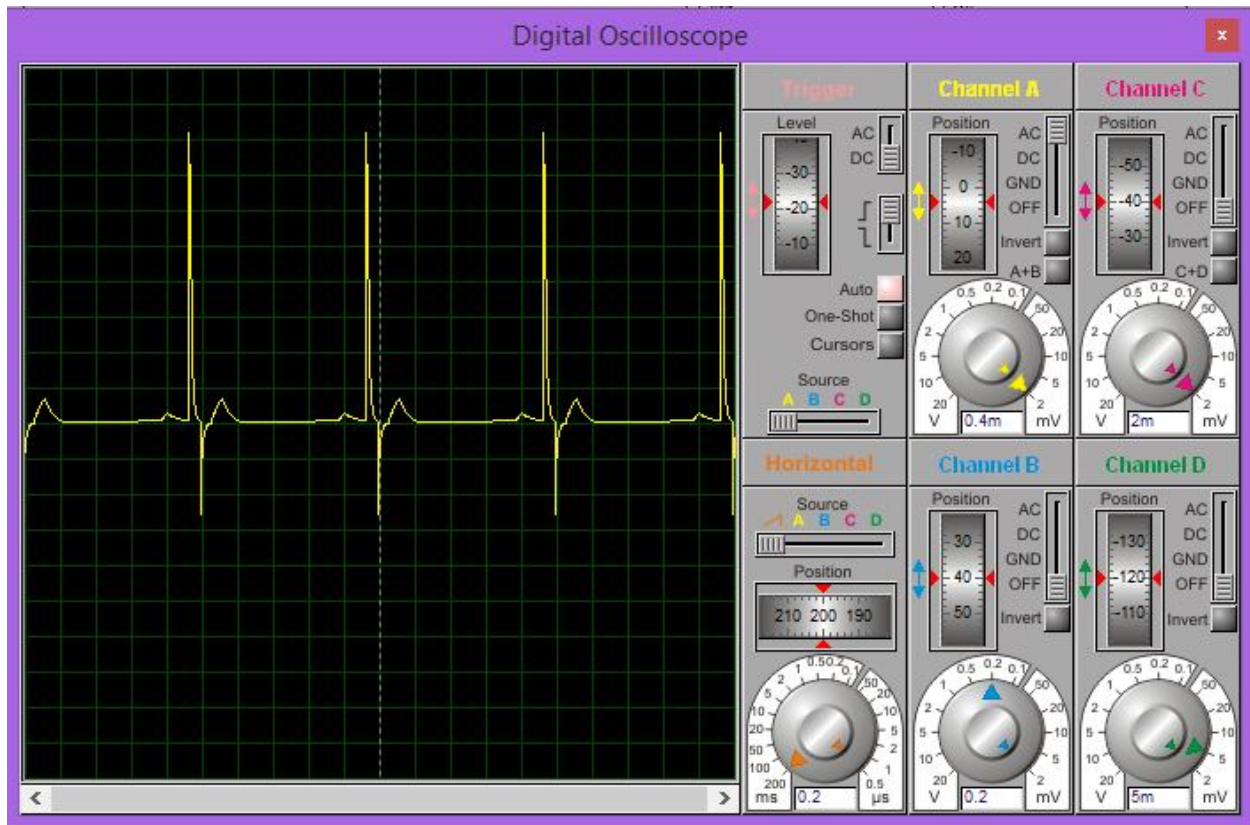# Results and Discussions

5.1 Simulator Results:

Fig.5.1. simulator output.

Table 5.1 Ideal ECG waves amplitude vs. Simulator waves amplitude.

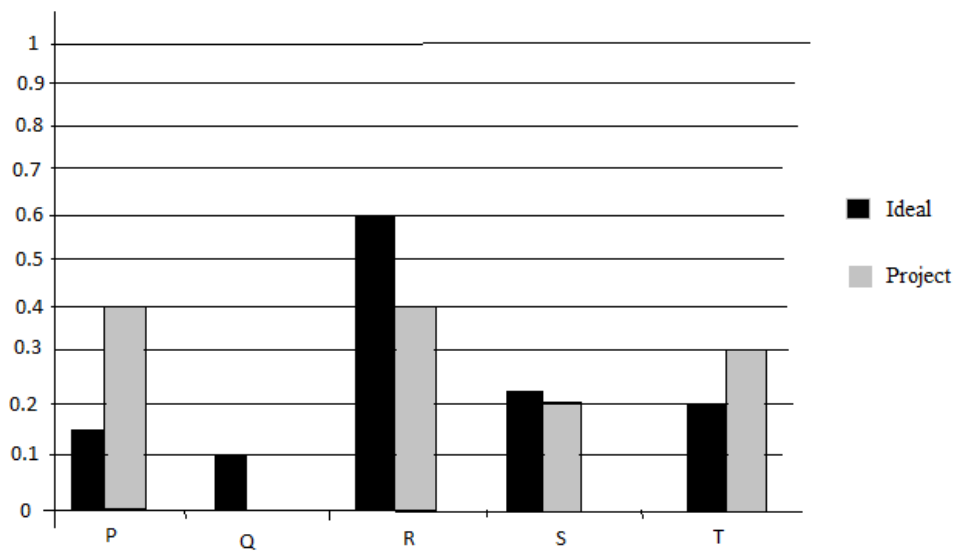| Amplitude					
	P(mV)	Q(mV)	R(mV)	S(mV)	T(mV)
Ideal Sig.	0.15	0.1	0.6	0.23	0.2
Project sig.	0.4	0	0.4	0.20	0.3

Fig.5.1 .Ideal ECG waves amplitude vs. simulator waves amplitude

Table 5.2 Ideal ECG time intervals vs. Simulator time intervals.

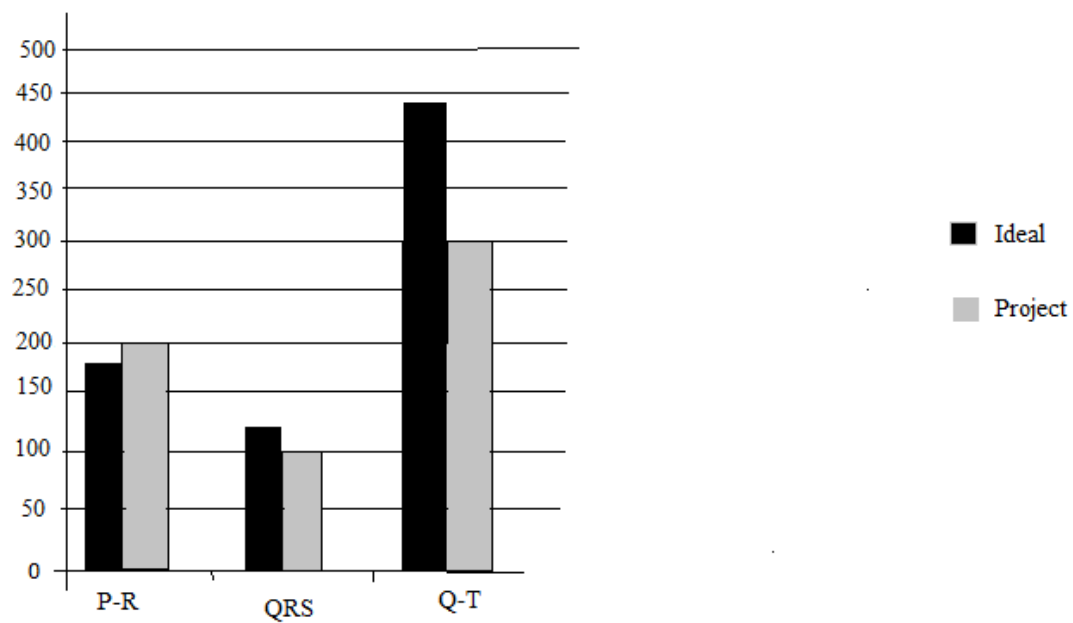|	Time Interval		
	P-R(m S)	QRS(m S)	Q-T(m S)
Ideal sig.	172	120	440
Project sig.	200	100	300

Fig.5.2. Ideal ECG time intervals Vs simulator time intervals.

The simulator circuit didn't contain the Q part creator this was the main cause of the significant difference from the ideal ECG signal as it misses the Q signal completely , the time intervals for the signal created by this circuit does differ as much as the amplitudes.
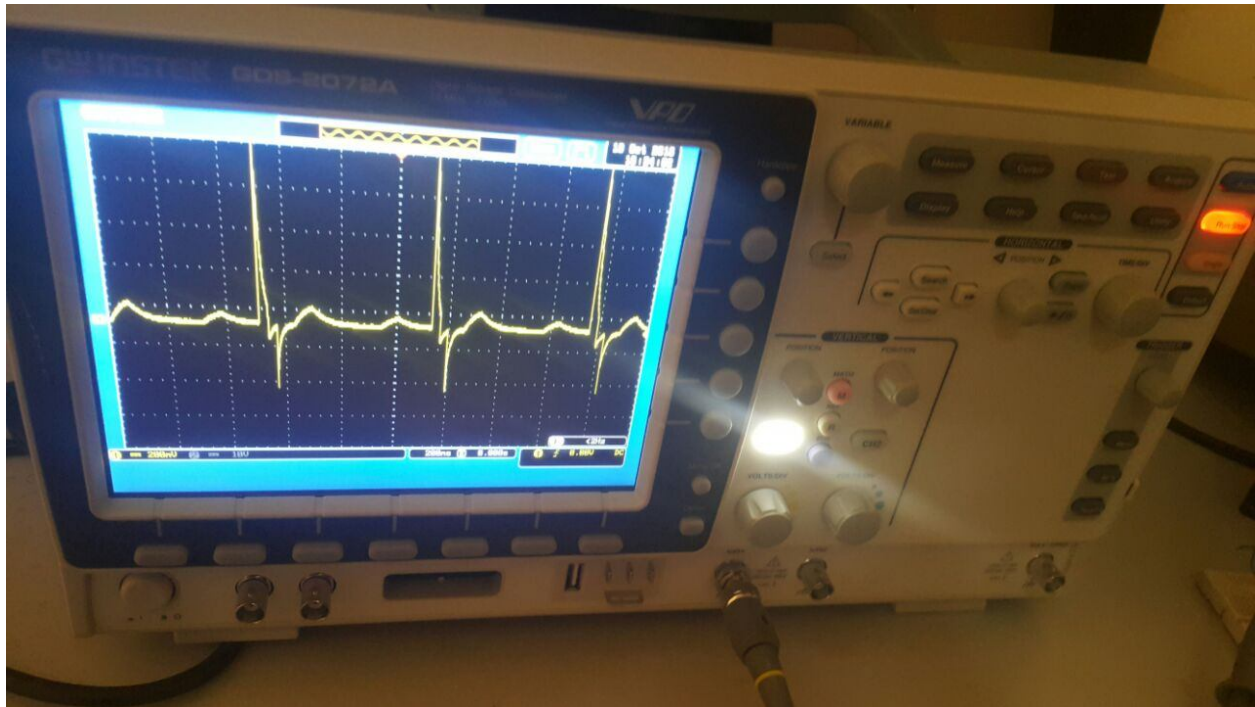
Fig 5.2.The output of the final simulator circuit (hardware) shown using an oscilloscope with scale 200m V.

Fig 5.3.The output of the final simulator circuit (hardware) shown using an
oscilloscope with scale 500m V.

There is a slight difference between the hardware results 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, this result was obtained from measuring the signal after R6 , the signal here relies on the scale of volts but if we pass the resistors network it will already be in the scale of millivolts, a signal with such specifications can only be read after amplification and filtration (which is what ECG device actually does), so this was only done to illustrate the by the digital oscilloscope which has an smallest scale of about 5 mV.

5.2 Conclusion:

From the previously done work the main objective of this project was met, by designing circuit of ECG tester which produce typical ECG wave form of different leads and many arrhythmias .The simulator have many advantages in the technician field .The ECG machine can be tested with standard recognized signals from simulator to improve quality of production.

Chapter Six

Recommendations and References

6.1 Recommendation:

The first recommendation is to improve the simulator circuit, further more progress toward the output which is ideal signal or close to ideal.

The second one that using component with high efficient and available.

The third one using IC4521 to create accurate output.

6.2 References:

[1] R. Karthik, **ECG Simulator using MATLAB**, IEEE Journal of Biomedical and Health Informatics, February 2013.

[2] Peter M van Dam, Eleco M van Dam, Adriaan van Oosterom and Thom F Oostendorp, **Interactive Simulation of Multiple Beats: A New Feature of ESGSIM**, IEEE Xplore digital library Computer in cardiology conference, August 2014.

[3] Sangita Das, Rajarshi Gupta and Madhuchhanda Mitra, **Development of an Analog ECG simulator using Standalone Embedded System**, International Journal of Electrical, Electronics and Computer Engineering, September 2012.

[4] Rahul S. Patil, Mr. Nikhil A. Samarth and Imran S. Khan, **Microcontroller based ECG Arrhythmia bio-simulator for testing ECG machines**, SSRG International Journal of Medical Science (SSRG-IJMS), August 2014.

[5]Joachim Behar, Fernando Andreotti, Sebastian Zaunseder, Qiao Li, Julien Oster andGari D Clifford , An ECG simulator for generating maternal-foetal activity mixtures on abdominal ECG recordings, Published 28 July 2014 • © 2014 Institute of Physics and Engineering in Medicine .

[6] N. Kontodimopoulos, N. Pallikarakis, I. Christov & I. Daskalov, IN-HOUSE DEVELOPMENT OF TEST EQUIPMENT FOR QUALITY CONTROL AND TRAINING CASE STUDY : A PROTOTYPE ECG SIMULATOR-TESTER, Institute of Biomedical Technology, Boukaouri 93, Patras 262 25, Greece, nikon@inbit.gr,Center of Biomedical Engineering, Akad. G. Bonchev Str., Sofia 1431, Bulgaria,ikdas@bgearn.acad.edu

[7] *Taber, Clarence Wilbur; Venes, Donald (2009). Taber's cyclopedic medical dictionary. F a Davis Co. pp. 1018–23.ISBN 0-8036-1559-0.*

[8] Guyton & Hall 2011, p. 157.

[9] Durrer D, van Dam RT, Freud GE, Janse MJ, Meijler FL, Arzbaecher RC (1970): Total excitation of the isolated human heart. Circulation 41: (6) 899-912

[10] Gray's Anatomy 2008, p. 960.

[11] Hodgkin AL, Rushton WA (1946): The electrical constants of a crustacean nerve fiber. Proc. R. Soc. (Biol.) B133: 444-79

[12] Hodgkin AL, Rushton WA (1946): The electrical constants of a crustacean nerve fiber. Proc. R. Soc. (Biol.) B133: 444-79

[13] Heart Electrical Activity, Source on the Internet: HeartSite.com, Available at: http://www.heartsite.com/html/electrical_activity.html.

[14] Cardiac action potential, Source on the Internet: Wikipedia, Available at: http://en.wikipedia.org/wiki/Cardiac_action_potential#Phase_4.

[15] C.C. Du Preez, S. Sinha, and M. du Plessis,"CMOS, EEG AND EMG waveform bio- simulator,"
IEEE transactions, June 2006.

[16] A. E. Martínez1, E. Rossi and L. Nicola Siri ,"*Microprocessor-based simulator of surface ECG signals,*" 16th Argentine Bioengineering Congressand the 5th Conference of Clinical Engineering*,*

Journal of Physics: Conference Series 90, 2007.

[17] http://www.mikroe.com/old/books/keu/01.htm, accessed October 2015.

[18] http://www.powerguru.org/film-capacitors-mkp-types-with-reduced-volume/

[19] https://en.wikipedia.org/wiki/**Ceramic_capacitor.**

[20] Floyd, Thomas L. Electronic devices: electron flow version, 9th Ed.

[21] http://www.futureelectronics.com/en/Technologies/Product.aspx, October 2015.

[22] http://www.doctronics.co.uk/4017.htm, October 2015.

[23] http://www.instructables.com/id/How-to-use-a-breadboard, October 2015.

[24] http://www.gwinstek.com, October 2015.