DESIGN AND CONSTRUCTION OF A HEART RATE MONITOR USING A LOW COST MICROCONTROLLER

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DECLARATION

I, *Chime Nnamdi Chinonso* declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

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DEDICATION

I dedicate this project to my dearest mother Mrs. Florence Ifeyinwa Chime, who has been there for me from my childhood days till now. Her never ending love and encouragement has led me to success throughout my undergraduate studies. I must say that I am blessed to have a mother like her.

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I would like to give thanks to the Almighty God for His grace and infinite mercies that has enabled me to start and complete my undergraduate studies. He has been the secret of my success and has showered love and good health on me. I owe it all to him.

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Finally, I want to thank my project supervisor, Head of Department (HOD) of Electrical and Computer Engineering, Engr. Dr. Y.A. Adediran, for his wisdom, kindness and patience in the course of my project. May God bless you and help you always in all that you do, Amen.

ABSTRACT

This project describes the design of a simple low cost microcontroller based heart rate measuring device with LCD output. The design considerations for this project are mostly influenced by the proposed users of the system. These users are medical practitioners in developing countries, who have very limited medical infrastructure. Hence, low cost, low power, portability, and ease of use are factors that are considered at every stage of the design. This system explores the AT89C52 microcontroller which is a low-power, high-performance CMOS 8-bit microcomputer. The device is manufactured using Atmel's high density non-volatile memory technology and is compatible with the industry standard 80C51 and 80C52 instruction set and pin out. Heart rate of the subject is measured from the finger using infra-red transmitter and received sensor box and the rate is then averaged and displayed on a text based LCD. The device has the advantage that it is microcontroller based and thus can be programmed to display various quantities, such as the average, maximum and minimum rates over a period of time. Another advantage of such a design is that it can be expanded and can easily be connected to a recording device or a PC to collect and analyze the data for over a period of time. Lastly, this device can be used by non- professional people at home to measure their heart rate easily and safely.

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CHAPTER ONE

INTRODUCTION

According to World Health Organization (WHO) estimates, 16.7 million people around the globe die of cardiovascular disease (CVD) each year. This is over 29 percent of all deaths globally [1]. Today, men, women and children are at risk, and 80 percent of the burden is in low and middle income countries. By 2020, heart disease and stroke will become the leading cause of both death and disability worldwide, with the number of fatalities projected to increase to more than 20 million a year and to more than 24 million a year by 2030 [2]. In countries without a good health care system such as Nigeria, this number is much closer to 100%. A portable system equipped to monitor heart rhythms would serve as a means for exposure of possible fatal cardiac activity and would be a very useful product.

The goal of this project is to create a heart rate monitor that is efficient and affordable in Nigeria and also can be used by non–professional people at home to measure their heart rate easily and safely. This device would be easy to operate, easy to transport and would be used to monitor admitted patients in these areas, patients who unfortunately can't afford the luxury of accommodation in the few well equipped hospitals that exist in their locale. This device will also prove invaluable in a war zone. Injured soldiers close to the front line may need cardiac monitoring at the on-site medical facility. In a situation like this, where there is need for something portable, inexpensive and reliable, this system will be able to provide some level of temporary cardiac monitoring. Heart rate measurement is one of the very important parameters of the human cardiovascular system. An adult's normal pulse or heart rate, while at rest is between 60 and 100 beats per minute. Lower resting heart rate is common for people who exercise regularly e.g. athletes. Infants and children normally have much higher resting heart rates. The heart rate rises gradually during exercises and returns slowly to the rest value after exercise. The rate when the pulse returns to normal is an indication of the fitness of the person. Lower than normal heart rates are known as bradycardia, while higher than normal heart rates are known as tachycardia [3].

Heart rate is traditionally measured by placing the thumb over the subject's arterial pulsation and feeling, timing and counting the pulses usually in a 30 second period. Heart rate (bpm) of the subject is then found by multiplying the obtained number by 2. This method although simple is not accurate and can give errors when the heart rate is high. More sophisticated methods to measure the heart rate utilize electronic techniques. An electrocardiogram (ECG or EKG) is a recording of the heart's electrical signals on paper. The heart's electrical signals are recorded by a machine from electrodes that attach to the skin over the chest. ECG is an expensive device and it is used for the measurement of the heart rate only that it is not economical. Low-cost devices in the form of wrist watches are also available for the instantaneous measurement of the heart rate. Such devices can give accurate measurement but their cost is usually in thousands of Naira, thus making them uneconomical. Most hospitals and clinics in the United Kingdom use integrated devices designed to measure the heart rate, blood pressure and temperature of the subject. Although such devices are useful, their cost is usually high and beyond the reach of individuals.

This project describes the design of a very low cost device which measures the heart rate of the subject by inserting one of the subject's finger in an infra-red transmitter and receiver sensor box and then displaying the result on a text based LCD. The device has the advantage that it is microcontroller-based and thus was programmed to display the average rate over a period of time. Another advantage of such a design is that it can be expanded and can easily be connected to a recording device or PC to collect and analyze the data over a period of time.

Finally, this project is desirable because its cost is much more affordable than the heart rate measuring devices or monitors previously discussed. Apart from athletes who really need this device, adults can equally use it to constantly monitor their high and low heart rates for medical purposes [3].

1.1 Historical Background

Dutch Scientists Rudolph Van Koelliker and Heinrich Muller using frogs discovered electric activity related to the heart beat. Donder recorded the frog's heart muscles twitches, producing first electrocardiograph signal. British physiologist Augustus D. Waller originally observed the electrocardiogram in 1889 using his pet bulldog as the signal source and the capillary electrometer as the recording device.

In 1893, Dutch Physiologist Willem Einthoven introduced the term electrocardiogram (ECG) at a meeting of the Dutch Medical Association, (Later claims that Waller was first to use the term). In 1903, Einthoven enhanced the technology by employing the string galvanometer as the recording device and using a human subject with a variety of cardiac abnormalities. In 1924, Einthoven received the Nobel Prize for his life's work in developing the ECG.

The earliest and most functional heart rate monitor indicator of cardiac activities is the Electrocardiogram (ECG/EKG) [4]. The electrocardiogram is a diagnostic tool that measures and records the electrical activity of the heart in exquisite detail. Interpretation of these details allows diagnosis of a wide range of heart conditions. These conditions can vary from minor to life threatening. The ECG has evolved over the years, the standard 12-lead ECG that is used throughout the world was introduced in 1942. It is called a 12-lead ECG because it examines the electrical activities of the heart from 12 points of view. This is necessary because no single point (or even 2 or 3 points of view) provides a complete picture of what is going on. To fully understand how an ECG reveals useful information about the condition of your heart requires a basic understanding of the anatomy (the structure) and physiology (the function) of the heart [5].

1.2 Problem Statement

In the hospital and health community in Nigeria, lack of standard medical equipment has been the cause of some of the deaths that could have been prevented. Basic equipment like heart rate monitor could have saved lives if used to diagnose cardiac abnormalities.

The problem this project seeks to address is that of the unavailability of a low cost heart rate monitor. Heart rate monitors are in existence already in hospitals in the country but not everyone has got access to it and more so people are nonchalant towards going to the hospital to check up their heart rate.

This project is intended to bring this medical device to their doorsteps to ensure that people are constantly aware of their heart conditions and if any cardiac abnormality is being detected it could be treated before it escalates to something deadly. This device is of low cost and low power consumption which provides a cheap and reliable method for monitoring patients in developing countries like Nigeria. You may need to count your pulse for several reasons.

1. You may have an irregular heartbeat.
2. You may be taking a special drug to control irregular heartbeats, and you need to be sure it is working.
3. You may have a pacemaker.
4. You may need to check your heart rate as part of an exercise program

1.3 Aims And Objectives

1. To show how the heart rate of subject is measured from the finger using infra-red transmitter and receiver sensor box.
2. To display on a text based LCD the average rate using a low cost microcontroller
3. To possibly inform the subject of cardiac abnormalities like tachycardia (high heart rate) and bradycardia (low heart rate)

1.4 Scope Of The Project

Generally, this project describes how the heart rate of a subject can be measured through the finger using a low-cost microcontroller and how the results can be averaged and displayed on a text-based LCD. It also shows how heart abnormalities like tachycardia (high heart rate) and bradycardia (low heart rate) can be detected.

1.5 Methodology

The heart rate of the subject is measured by inserting one of the fingers in an infra-red transmitter and receiver sensor box and then displaying the result on a text based LCD. The circuit basically consists of 2 operational amplifiers, a low-pass filter, a microcontroller, and an LCD. The first amplifier is set for a gain of just over 100, while the gain of the second amplifier is around 560. The cut-off frequency of the filter was chosen as 2Hz. The AT89C52 microcontroller was programmed to display the average rate over a period of time. A 78L05 voltage regulator was used to regulate the voltage to 5V.

1.6 Justification

The design of this system was greatly influenced by a specific set of users and hence, was tailored towards them and their environments. My inspiration comes from my experiences growing up in a developing country like Nigeria where the health care system is very different from that of the western world. Most places have little to no infrastructure, and there is a lack of basic amenities such as water, food, electricity, hospital, etc, things that come standard in the western world. Since there is no reliable source of constant power supply, and there is lack of medical equipment, this project focuses on the design of a portable, low power and low cost alternative to the sophisticated cardiac monitoring systems that are found in most hospitals in the western world.

1.7 Definition of Terms

1. **Heart Pulse Rate:** The pulse, figured by counting the number of contraction of the heart per unit of time. When a heart beat is detected a radio (analog) or digital signal is transmitted, which the receiver uses to determine the current heart beat rate.
2. **Microcontroller:** A Microcontroller is a microprocessor that controls some or all of the functions of an electronic device (as a home appliance) or system. Unlike the "general purpose computer", microcontrollers are "special purpose computers" that means they do one thing well. Microcontrollers are "embedded inside some other device (often a consumer product) so that they can control the features or actions of that product. Another name for a microcontroller therefore is "embedded controller". Microcontrollers are often low power devices. A desktop computer is almost always plugged into a wall socket and might consume 50 watts of electricity. A battery operated microcontroller might consume 50 milliwatts. A microcontroller has a dedicated input device and often (but not always) has a small LED or LCD display for output. A microcontroller also take input from the device it is controlling and controls the device by sending signals to different components in the device [6].

3. **Heart Rate Monitor:** A heart rate monitor is a personal monitoring device that allows a subject to measure their heart rate in real time or record their heart rate for late study. Early models consisted of a monitoring box with a set of electrode leads that is attached to the chest. While there still exist, modern versions usually consist of two elements: a chest strap transmitter and a wrist receiver or mobile phone.
4. **Arrhythmias:** These are irregular heart beats. They can be thought of in three categories: fast, slow and seriously disorganized rhythms. Some arrhythmias cause no major problem or symptoms: others may cause palpitations, shortness of breath, dizziness, chest pain, or even fainting spells. Arrhythmias are also called dysrhythmias.
5. **Bradycardia:** This is an abnormal condition in which the heart contracts steady but at a rate of less than 60 beats a minute. The heart normally slows during sleep, and in some physically fit people, the pulse may be quite slow. Bradycardia may be a symptom of a brain tumor, digitalised overdose, or an abnormal response of the vagus nerve (vagotonia).
6. **Tachycardia:** This is an abnormal condition in which the heart (myocardium) contracts regularly but at a rate greater than 100 beats per minute. The heart rate normally speeds up in response to fever, exercise, or nervous excitement. Pathological tachycardia goes along with lack of oxygen (anoxia), as caused by anemia, congestive heart failure, bleeding, or shock. A slow heart beat (bradycardia) develops because the heart muscles gets too little oxygen and cannot maintain the speed –up pace. Tachycardia acts to increase the amount of

oxygen given to the cells of the body by increasing the amount of blood circulated through the vessels.

7. **Cardiovascular system:** This is the network of structures, which include the heart and the blood vessels, that pumps and caries the blood through the body. The system includes thousands of miles of blood vessels (arteries, capillaries, and venules).

8. **Electrocardiogram or Electrocardiograph (EKG, ECG):** A device used to record the electric activity of the heart to detect abnormal electric impulses through the muscles. Electrocardiography allows diagnosis of cardiac abnormalities.

   To make an ECG recording, the patient lies quietly on his or her back on a table. Leads are placed on certain spots on the patient's chest, usually with a gluey gel that helps send the electric pulse to the recording device. The ECG is also used for stress tests, which require that the patient be active (usually walking or running on a treadmill) while the machine is working.

9. **Amplifier:** In electronics, device that responds to a small input signal (voltage, current, or power) and delivers a larger output signal that contains the essential wave form features of the input signal. Amplifiers of various types are widely used in such electronic equipment as radio and television receivers, high-fidelity audio equipment and computers.

10. **Pacemaker:** Pacemaker is a device that artificially stimulates the heart when the abnormal electrical activity is absent. A pacemaker comprises a pulse generator connected to the heart by wire or electrode. The pulse generator has a battery

power source and electronic circuitry that can generate an artificial stimulus and it is only discharged when the natural activity is absent. In this way the pacemaker functions on demand, inserting an artificial beat as required.

11. **LCD (Liquid Crystal Display):** This is an electronic display (as of the time in a digital watch) that consists of segments of a liquid crystal whose reflectivity varies according to the voltage applied to them.
12. **Resistor:** A device that has electrical resistance and that is used in an electric circuit for protection, operation or current control.
13. **Filter:** A device or material used for suppressing or minimizing waves or oscillations of certain frequencies (as of electricity light, or sound)
14. **Capacitor:** A device, giving capacitance and usually consisting of conducting plates or foils separated by thin layers of dielectric (as air or mica) with the plates on opposite sides of the dielectric layers oppositely charged by a source of voltage and the electrical energy of the charged system stored in the polarized dielectric [7].

1.8 Thesis Organization

The thesis is divided into 5 chapters. The rest of the thesis is organized as follows:

CHAPTER 1: Is the introduction of the thesis. It describes the function and use of a heart rate monitor. It gives the historical background of the ECG which is the earliest form of a heart rate monitor. This chapter also contains the objective, problem statement, methodology, scope of work and justification of the research work.

CHAPTER 2: Provides a brief overview of the background and theory of the research. The ECG signal analysis, literature review and the main steps of the ECG classification are presented. The previous works of others were also stated in this chapter.

CHAPTER 3: This is the design and Implementation of the project. The steps taken in the design were carefully described. The circuit diagram of each module was drawn, critically analyzed and the selection of components was justified.

CHAPTER 4: This is the test, results and discussion of the experiments. It involves the recap of the problem statement, the study objectives and hypothesis tested, graphs, charts, tables and plates are used to arrive at reasonable results.

CHAPTER 5: This is the conclusion of the project and also gives the suggestion of the future works such as the improvement of the experiment. A summary of the work is presented in this chapter, the results obtained and problems encountered are summarized.

CHAPTER TWO

LITERATURE REVIEW/THEORETICAL BACKGROUND

2.1 Brief Introduction

This Chapter presents the theoretical background supporting the project work. It contains a brief literature review of an electrocardiogram (ECG) which is the earliest form of a heart rate monitor. This project was greatly influenced by the previous researches done by others on this same field.

2.2 Literature Review

Last year, Enyinnaya Egejuru a senior student of Illinois State University, USA designed a project which he called Microcontroller Based Heart Rate Monitor and Arrhythmia Detector. The goal of his project was to create an ECG monitoring and alert system that can detect cardiac abnormalities such as tachycardia, bradycardia and possibly other arrhythmias. The project involved an actual human connection for data acquisition. In order to test appropriately, there was need for some simulated bio-signals to analyze the system and determine functionality quickly and efficiently. He used Physiobank which is an online physiologic signal archive where many types of digitalized signals are available and free for download. A 60-second 12-Lead ECG recording (16-bit resolution, 1000Hz sample frequency) was downloaded from the site and MATLAB was used to scale the aVR and aVL signals and then to write the data to a WAV file [8].

In 2008, C. Saritha, V. Sukanya and Y. Narasimha Murthy of the Department of Physics and Electronics, Andhrapradesh, India brought out a significant research with the study of ECG signals using wavelet transform analysis. In the first step an attempt was made to generate ECG waveforms by developing a suitable MATLAB simulator and in the second step, using wavelet transform, the ECG signal was de-noised by removing the corresponding wavelet coefficients at higher scales. Then QRS complexes were detected and each complex was used to find the peaks of the individual waves like P and T, and also their deviations [9].

Another researcher, George Q. Gao a final year student at Auckland University of Technology, Auckland, New Zealand in 2003 designed a project which he called computerised detection and classification of five cardiac conditions. His research was aimed at developing a system that categorizes the ECG signals. Signal processing techniques and Artificial Neural Network (ANN) were used in his project to implement a real time processing, intelligent, cost effective and easy-to-use ECG diagnostic system. It also gives suggestion to improve the experiments and use of remote diagnostic medical systems for diagnosing at homes in the future [3].

Tracking back to 1895, Willem Einthoven a Dutch physiologist used an improved electrometer and a correction formula to distinguish between five deflections which he named P, Q, R, S and T. These deflections are electrical variations of the heart of man. The four deflections prior to the correction formula were labeled ABCD and the five derived deflections were labeled PQRST. The choice of P is a mathematical convention (as used also by DU Bois –Raymond in his galvanometer's disturbance curve' 50 years previously), by using letters from the second half of the alphabet. N has other meanings in mathematics and O is used for the origin of the Cartesian coordinates. In fact Einthoven used O… X to mark the timeline on his diagrams. P is simply the next letter. A lot of work had been undertaken to reveal the true electrical waveform of the ECG by eliminating the damping effect of the moving parts in the amplifiers and using correction formulae. If you look at the diagram in Einthoven's 1895 paper you will see how close it is to the string galvanometer recordings and the electrocardiograms we see today. The image of the PQRST diagram may have been striking to have been adopted by the researchers as a true representation of the underlying form. It would have then been logical to continue the same name convention when the more advanced string galvanometer started creating electrocardiograms a few years later [10].

The ECG is a bioelectric signal, which records the heart's electrical activity versus time; therefore it is an important diagnostic tool for assessing heart function. The electrical current due to the depolarization Sinus Atria (SA) node stimulates the surrounding myocardium (thick layer of muscle cell that form most of the heart wall) and spreads into the heart tissues. A small proportion of the electrical current flow to the body surface. By applying electrodes on the skin at the selected points, the electrical potential generated by this current can be recorded as an ECG signal.

The interpretation of the ECG signal is an application of pattern recognition. The purpose of pattern recognition is to automatically categorize a system into one of a number of different classes. An experienced cardiologist can easily diagnose various heart diseases just by looking at the ECG waveforms print out. In some specific cases, sophisticated ECG analysis achieve a higher degree of accuracy than that of cardiologist, but at present there remains a group of ECG waveforms that are too difficult to identify by computers. However, the use of computerized analysis of easily obtainable ECG waveforms can considerably reduce the doctor's workload. Some analyzers assist the doctors by producing a diagnosis; others provide a limited number of parameters by which the doctor can make his diagnosis.

As illustrated in figure 2.1 there are four major steps to ECG signal pattern recognition, namely, pre-processing of the signal, QRS detection, ECG feature extraction and ECG signal classification.

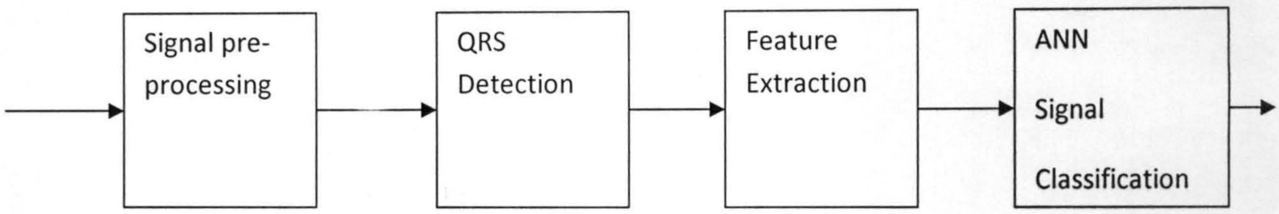

Fig. 2.1: Pattern Recognition

The first step is the measurement of acquisition period, which requires a wide range of the ECG signal collection including different abnormalities. The data could be collected from real subjects in the future, but it is presently available from the database. The second step is QRS detection which corresponds to the period of ventricular contraction or depolarization. The third step is to find the smallest set of features that maximize the classification performance of the next step. ECG features extraction is mainly used in this step.

The choice of features depends on the techniques used in the fourth step. Consequently the set of features that are optimal for one technique are not necessarily optimal for another. Because of the unknown interactions of different sets of features, it is impossible to predict the optimum features for a chosen classification technique.

Different techniques such as statistical classifiers artificial neural network and artificial intelligence can be used for ECG classifications. Neural networks are especially useful for classification function, which are tolerant of some imprecision if plenty of training data is available. If there are enough training data and sufficient computing resources for a neural network, it is possible to train a feed forward neural network to perform almost any signal classification solution.

Generally, the ECG is one of the oldest and the most popular instrument bound measurements in medical applications. It has followed the progress of instrumentation technology. Its most recent evolutionary step to the computer based system, has allowed patients to wear their computer monitor or has provided an enhanced, high resolution ECG that has opened new scene of ECG analysis and interpretations [4].

2.3 The Heart Function and ECG

The heart contains four chambers and several one-way valves as shown in figure 2.2. A wall or septum divides the heart into left and right sides, in a double pump configuration. Each side is then further divided into an upper chamber, the atrium, and a lower chamber, the ventricle.

The right side of the heart receives de-oxygenated blood from the various systems, which is then pumped to the lungs via the pulmonary loop, where the carbon dioxide in the blood is exchanged for oxygen. The left side of the heart receives the oxygenated blood from the lungs and pumps it into the systemic loop for distribution throughout the body.

The contraction of the various muscles of the heart enables the blood to be pumped. While the myocardial muscles cells can contract spontaneously, under normal conditions these contractions are triggered by action potentials originating from pacemaker cells situated in two areas of the heart the Sino-Atrial (SA) and Atrio-Ventricular (AV) nodes.

The SA pacemaker cells can spontaneously generate action potentials at 60-80 times per minute, but are themselves under the control of the sympathetic and parasympathetic nervousa system. The SA node is generally the site to trigger the action potential for a heartbeat, but the AV node can take over this role if some reason the SA node fails.

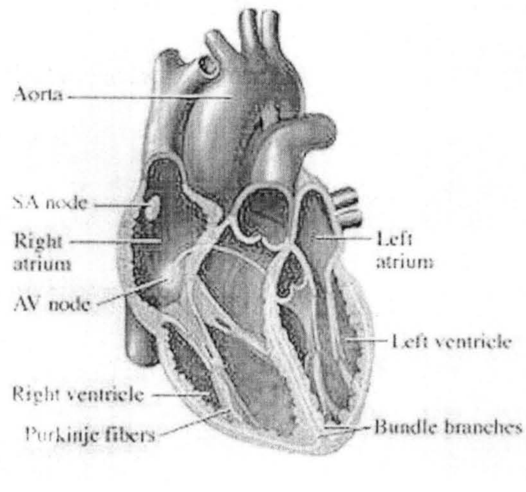

Fig. 2.2: The Structure of the Heart

The normal cycle of a heartbeat has the following sequence of events:

a) The SA node generates an action potential, which spreads across both atria.

b) This spreading action potential results in the simultaneously contraction of the left and right atria

c) This action potential is also passed to the AV node via the inter-nodal conducting fibres; taking about 40msec.

d) During the contraction of the atria, blood from the atria is pushed to the respective ventricle.

e) The AV node's own action potential is triggered by the action potential arriving from the SA node. The AV action potential is spread to the ventricles via further conducting fibres, resulting in a delay of about 110msec, which is sufficient time to ensure that the atrial contraction has finished.

f) The AV action potential triggers both ventricles to contract and push blood into the arterial system. The left ventricle supplies the systemic arterial system while the right ventricle supplies the pulmonary system where the blood is oxygenated by the lungs.

g) All muscles of the heart then relax and blood continues to flow due to the elastic recoil of the arterial walls.

During this period both atria and ventricles fill with blood as it returns from the body via the venous system. A series of one way valves at the input and outputs of the atria and ventricles determine the direction of blood flow.

2.4 Electrocardiography

The various propagating action potentials within the heart produce a current flow, which generates an electrical field that can be detected, in significantly attenuated form, at the body surface, via a differential voltage measurement system. The resulting measurement, when taken with electrodes in standardized locations, is known as the electrocardiogram (ECG). The ECG signal is typically in the range of ±2mv and requires a recording bandwidth of 0.05 to 150Hz.

The ECG is a graphic representation of the electrical activity of the heart's conduction system recorded over a period of time. Under normal conditions, ECG tracing have a very predictable direction, duration, and amplitude. Because of this, the various components of the ECG tracing can be identified, assessed, and interpreted as to normal or abnormal function. The ECG is also used to monitor the heart's response to the therapeutic interventions. Because the ECG is such a useful tool in the clinical setting, the respiratory care practitioner must have a basic and appropriate understanding of ECG analysis.

2.5 THE STANDARD 12 ECG SYSTEM

The standard 12 ECG systems consist of four limb electrodes and six chest electrodes. Collectively, the electrodes (or leads) view the electrical activity of the heart from 12 different positions, 6 standard limb leads and 6 pericardial chest-leads showed in Table 2.1. Each lead:

1) Views the electrical activity of the heart from a different angle.
2) Has a positive and negative component, and
3) Monitors specific portions of the heart from the point of view of the positive electrode in that lead.

Table 2.1: ECG Lead System

Standard Leads	Limb Leads	Chest Leads
Biopolar Leads	Unipolar Leads	Unipolar Leads
Lead I	AVR	V1
Lead II	AVL	V2
Lead III	AVF	V3
		V4
		V5
		V6

The explanation of their three lead systems will be discussed later in this chapter.

The ECG, over a single cardiac cycle has a characteristics morphology as shown in figure 2.3 comprising of a P wave, a QRS complex and a T wave. The normal ECG configurations are composed of waves, complexes, segments, and intervals recorded as voltage (on a vertical axis) against time (on a horizontal axis). A single wave form begins and ends at the baseline. When the wave form continues past the baseline, it changes into another wave form. Two or more waveforms together are called a complex. A flat, straight, or isoelectric line is called a segment. A waveform, or complex, connected to a segment is called an interval. All ECG tracings above the baseline are described as positive deflections. Waveforms, below baseline are negative deflections.

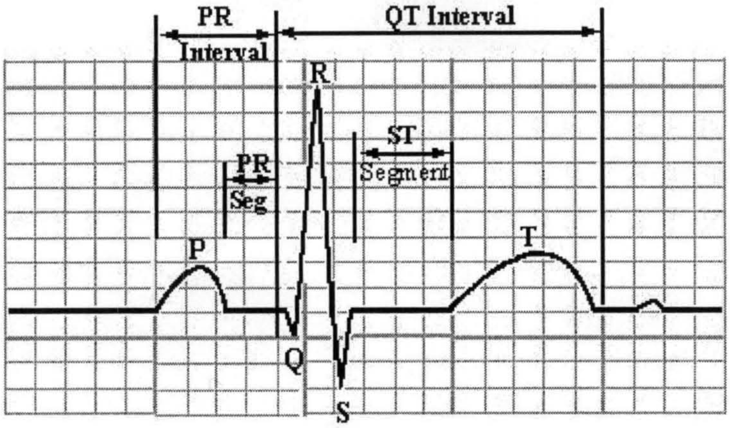

Fig. 2.3: The Human ECG Signal Over One Cardiac Cycle

2.5.1 The P Wave

The propagation of the SA action potential through the atria results in contraction of the atria (depolarization), producing the P wave. The magnitude of the P wave is normally low (50-100uV) and 100msec in duration.

2.5.2 The PR Interval

The PR interval begins with the onset of the P wave (Pi) and ends at the onset of the Q wave (Qi). It represents the duration of the conduction through the atria to the ventricles. Normal measurement for PR interval is 120ms-200ms. It is shown in figure 2.4

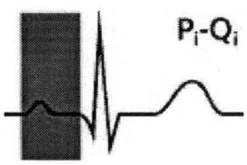

Fig. 2.4: PR Interval

The PR segment begins with the endpoint of the P wave (Pt) and ends at the onset of the Q wave (Qi). It represents the duration of the conduction from the atrioventricular node, down the bundle of its end through the bundle branches to the muscle. It is shown in figure 2.5.

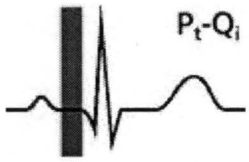

Fig. 2.5: PR Segment

2.5.3 The QRS Complex

The QRS complex corresponds to the period of ventricular contraction or depolarization. The atrial depolarization signal is swamped by the much larger ventricular signal. It is the result of ventricular depolarization through the Bundle Branches and Parkinje fibre.

The QRS complex is a much larger signal than the P wave due to the volume of ventricular tissue involved, although some signal cancellation occurs as the waves of depolarization in the left and right sides of the heart is not functioning properly. The size of the QRS complex may increase. As shown in Figure 2.6.

QRS can be measured from the beginning of the first wave in the QRS to where the last wave in the QRS returns to the baseline. Normal measurement for QRS is 60ms-100ms.

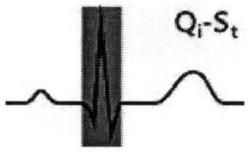

Fig. 2.6: QRS Duration

2.5.4 The ST Segment

The ST segment represents the time between the ventricular depolarization and the repolarization. The ST segment begins at the end of the QRS complex (called J Point) and ends at the beginning of the T wave. Normally, the ST segment measures 0.12 second or less.

The precise end of depolarization (s) is difficult to determine as some of the ventricular cells are beginning to repolarize. It is shown in figure 2.7.

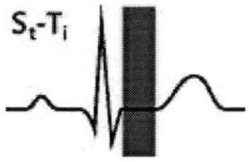

Fig. 2.7: ST Segment

2.5.5 The T Wave

The T wave results from the repolarization of the ventricles and is of a longer duration than the QRS complex because the ventricular repolarization happens more slowly than depolarization. Normally, the T wave has a positive deflection of about 0.5mv, although it may have a negative deflection. It may, however, be of such low amplitude that it is difficult to read. The duration of the T wave normally measures 0.20 second or less.

2.5.6 The QT Interval

The QT interval begins at the onset of the Q wave (Qi) and ends at the end point of the T wave (Tt), representing the duration of the ventricular depolarization/repolarization cycle.

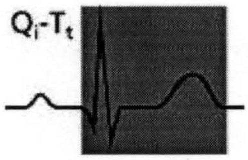

Fig. 2.8: QT Interval

The normal QT interval measures about 0.38 second, and varies in males and females and with age. As a general rule, the QT interval should be about 40% of the measured R-R interval. The QT interval is shown in Figure 2.8.

2.6 The ECG Lead System

Traditionally, the differential recording from a pair of electrodes in the body surface is referred to as a lead. Einthoven defined three leads numbered with the Roman numerals I, II and III. They are defined as:

$$\text{Lead I} = V_{LA} - V_{RA} \quad (1.1)$$

$$\text{Lead II} = V_{LL} - V_{RA} \quad (1.2)$$

$$\text{Lead III} = V_{LL} - V_{LA} \quad (1.3)$$

Where the subscript RA = right arm, LA = left arm, and LL = left leg. Because the body is assumed purely resistive at ECG frequencies, the four limbs can be thought of as wires attached to the torso. Lead I could be recorded from the respective shoulders without a loss of cardiac information. The relationship of them is I = II + III.

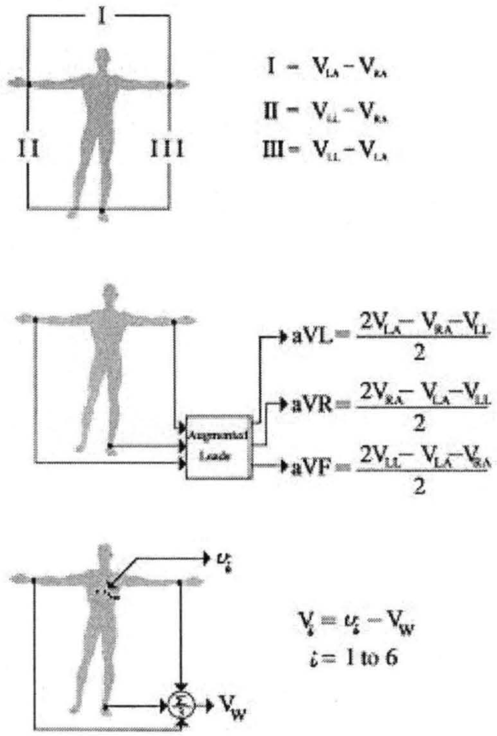

Fig. 2.9: Development Procedure of the 12-lead ECG

Not long after Einthoven described his string galvanometer, efforts were begun in the United States to create an electrocardiograph that used vacuum tubes. Between introduction of the string galvanometer and the hot stylus recorder for ECG, attempts were made to create direct inking ECG recorders. Despite the instant availability of inked recording of the ECG, those produced by the string galvanometer were superior, and it took some time for a competitor to appear. Such an instrument did appear in the form of the hot stylus recorder.

In 1933, Wilson added the concept of a "unipolar" recording, where tying the three limbs together creates a reference point and averaging their potentials so that individual recording sites on the limbs or chest surface would be differentially recorded with the same reference point.

However, from the mid-1930s until today, a standard 12 lead ECG systems comprises 3 limb leads, 3 leads in which the limb potentials are referenced to a modified Wilson terminal, and 6 leads placed across the front of the chest and referenced to the Wilson terminal. Figure 2.9 shows the development procedure of the 12 lead ECG and the 3 lead systems as were indicated in table 2.1.

The final step toward modern electrocardiography was the introduction of the hot stylus recorder by Haynes. J. R of the Bell Telephone Laboratories in New York. Following the end of World War II, vacuum tube electrocardiographs with heated stylus recorders became very popular and are still in use today. The vectorcardiogram uses a weighted set of recording sites to form an orthogonal XYZ lead set, providing as much information as the 12 lead system, but with fewer electrodes. Cardiac surface mapping uses many recording sites (>64 electrodes) arranged on the body so that the cardiac surface potential can be computed and analyzed over time. Other subsets of the 12 lead ECG are used in limited mode recording situations such as the tape recorded ambulatory ECG (usually 2 leads) or intensive care monitoring at the bedside (usually 1 or 2 leads) or telemeter within regions of the hospital from patients who are not confined to bed (I lead).

Automated ECG interpretation was one of the earliest uses of computers in medical applications. This was initially achieved by linking the ECG diagnostic machine to a centralized computer via phone lines or computer network. The modern ECG machine is completely integrated with an analogue front end, a high resolution analogue to digital converter and a microcomputer.

2.6.1 Computerized ECG Interpretation

Application of the computer to the ECG for machine interpretation was one of the earliest uses of computers in medicine. Of primary interest in the computer based systems was replacement of the human reader and elucidation of the standard waves and intervals. Originally this was performed by linking the ECG machine to a centralized computer via phone lines or computer network. The modern ECG diagnostic machine is completely integrated with an analogy front and end, a 12-to-16 bit analogy to digital (AID) converter, a central computational microprocessor, and dedicated input and output (I/O) processor. The above-mentioned systems can compute a measurement matrix derived from the 12 lead signals and analyze this matrix with a set of rules (such as neutral network) to obtain the final set of interpretive statements.

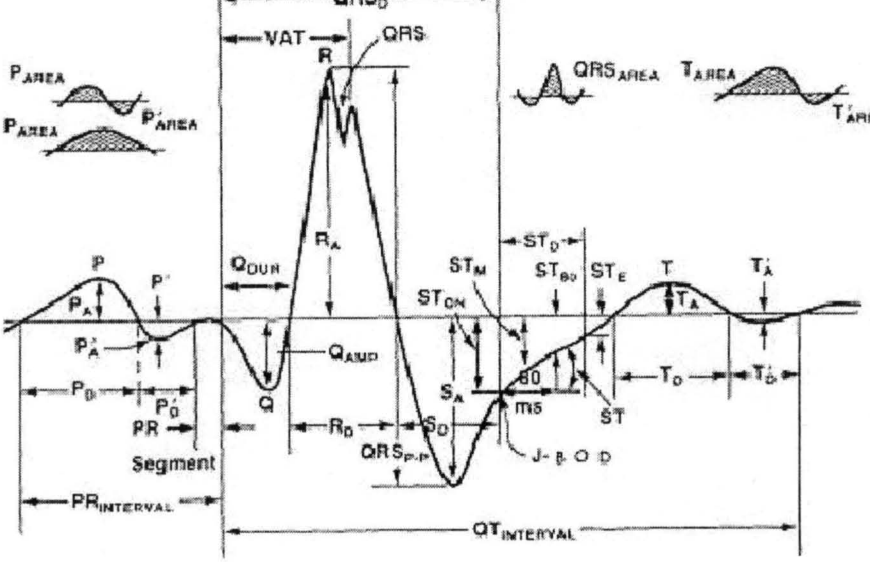

Fig. 2.10: The ECG measurements that can be made with computer-based algorithm.

Figure 2.10 shows the ECG of a heartbeat and the types of measurement that might be made on each of the component waves of the ECG and used for classifying each beat type and subsequent cardiac rhythm. The depiction of the 12 analogy signals and this set of interpretive statement form the final output, are shown in figure 2.11.

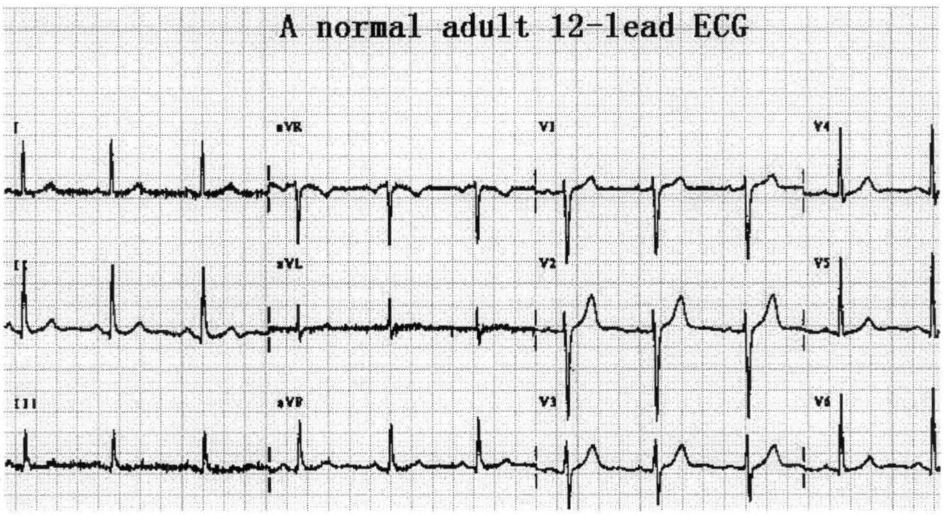

Fig. 2.11: Example of an interpreted 12-Lead ECG

The Physician will over-read each ECG and modify or larger hospital based system will record this correction and maintain a large database of all ECGs accessible by any combination of parameters. There are hundreds of interpretive statements from which a specific diagnosis is made for each ECG, but there are only about five or six major classification groups for which the ECG is used. The first step is analyzing an ECG requirement determination of the rate and rhythm for the atria and ventricles. Included here would be any conduction disturbance either in the relationship between the various chambers or within the chambers themselves. Then one can proceed to identify features that relate to the events that would occur with ischemia or an evolving myocardial infraction [4].

2.6.2 ECG Signal Analysis

The ECG records the electrical activity of the heart, where each heartbeat is displayed as a series of electrical waves characterized by peaks and valleys. Any ECG gives two kinds of information. One, the duration of the electrical wave crossing the heart which in turn decides whether the electrical activity is normal or slow or irregular and the second is the amount of electrical activity passing through the heart muscles which enables to find whether the parts of the heart are too large or overworked.

Normally, the frequency range of an ECG signal is of 0.05-100HZ and its dynamic range of 1 -10mV. The ECG signal is characterized by five peaks and valleys labeled by the letters P, Q, R, S, T. In some cases we also use another peak called U. The performance of ECG analyzing system depends mainly on the accurate and reliable detection of the QRS complex, as well as T and P waves. The P wave represents the activation of the upper chambers of the heart, the atria, while the QRS complex and T-wave represent the excitation of the ventricles or the lower chamber of the heart. The detection of the QRS complex is the most important task in automatic ECG signal analysis. Once the QRS complex has been identified a more detailed examination of ECG signal including the heart rate, the ST segment etc. can be performed.

In the normal sinus rhythm (normal state of the heart) the P-R Interval is in the range of 0.12 to 0.2 seconds. The QRS interval is from 0.04 to 0.12 seconds. The Q – T interval is less than 0.42 seconds and the normal rate of the heart is from 60 to 100 beats per minute. So from the recorded shape of the ECG, we can say whether the heart activity is normal or abnormal.

The electrocardiogram is a graphic recording or display of the time variant voltages produced by the myocardium during the cardiac cycle. The P-, QRS- and T-waves reflect the rhythmic electrical depolarization and repolarization of the myocardium associated with the contractions of the atria and ventricles.

The ECG is used clinically in diagnosing various abnormalities and conditions associated with the heart.

Amplitude	P – Wave	-	0.25mV
	R – Wave	-	1.60mV
	Q – Wave	-	25% R wave
	T – Wave	-	0.1 to 0.5mV
Duration	P – R interval	:	0.12 to 0.20s
	Q – T interval	:	0.35 to 0.44s

S – T interval	:	0.05 to 0.15s
P – Wave interval	:	0.11s
QRS interval	:	0.09s

The normal value of the heart lies in the range of 60 to 100 beats/minute. A slower rate than this is called bradycardia (Slow heart) and a higher rate is called tachycardia (fast heart). If the cycles are not evenly spaced, an arrhythmia may be indicated. If the P – R interval is greater than 0.2 seconds, it may suggest blockage of the AV node.

- Certain disorders, involving heart valves cannot be diagnosed from ECG. Other diagnostic techniques such as angiography and echocardiography can provide information not available in ECG.
- Each action potential in the heart originates near the top of the right atrium at a point called the pacemaker or sinoatrial (SA) node.
- The wave generated by action potential, terminates at a point near the center of the heart, called the atrioventricular (AV) node.

The horizontal segment of this waveform preceding the p-wave is designated as the baseline or the isopotential line. The P-wave represents depolarization of the atrial musculature. The QRS complex is the combined result of the repolarization of the atria and depolarization of the ventricles, which occur almost simultaneously.

The T-wave is the wave of ventricular repolarization, where as the U-wave, if present is generally believed to be the result of after potentials in the ventricular muscles. So, the duration amplitude and morphology of the QRS complex is useful in diagnosing cardiac arrhythmias, conduction abnormalities, ventricular hypertrophy, myocardial infection and other diseases states.

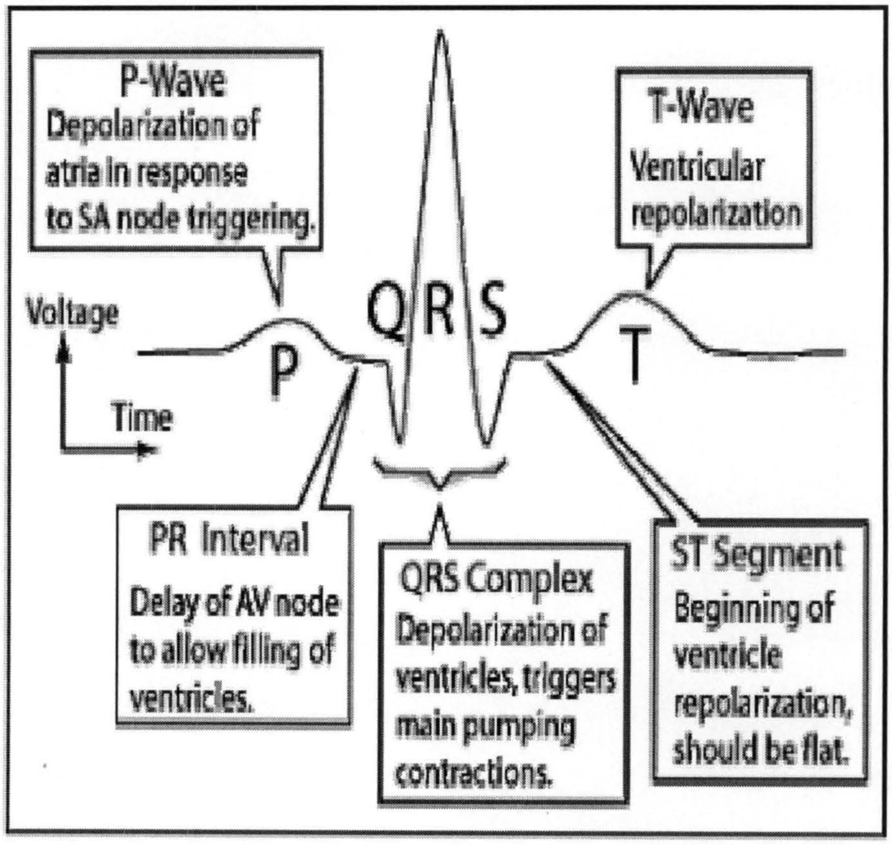

Fig. 2.12: The Normal ECG Waveform.

Table 2.2: Various abnormalities and their characteristic features

S.No	Name of Abnormality	Characteristic features
1	Dextrocardia	Inverted P –wave
2	Tachycardia	R – R interval < 0.6s
3	Bradycadia	R – R interval > Is
4	Hyperkalemia	Tall T- Wave and absence of P – wave
5	Myocardial ischaemia	Inverted T – wave
6	Hypercalcaemia	QRS interval < 0.1s
7	Sinoatrial block	Complete dropout of a cardiac cycle
8	Sudden cardiac death	Irregular ECG

CHAPTER THREE

DESIGN AND IMPLEMENTATION

This chapter describes the design and implementation of a heart rate monitor. The chapter is divided into seven sections, these are; the Sensor section, the amplifier section, the filter section, the microcontroller section, the LCD section, the power supply section and the firmware section.

The block diagram of the project is shown in figure 3.8 at the last page of the chapter. From the block diagram, the sensor section is used to get the pulse from the finger of the user; the pulse is then amplified and fed to a filter to remove unwanted frequencies. The output frequency is then measured by a microcontroller and displayed on an LCD.

3.1 SENSOR SECTION

The section is used to get the pulse rate from the finger of the user. This section consists of an Infrared transmitter (IR LED), an Infrared receiver (IR transistor) and two resistors. The circuit diagram of the sensor section is shown in figure 3.1.

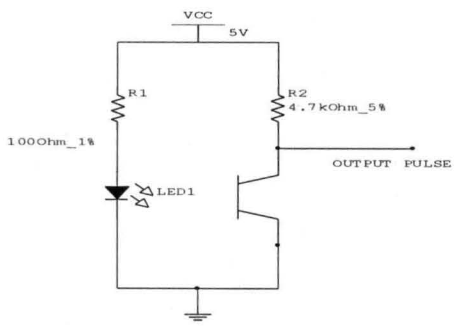

Fig. 3.1 Sensor Circuit

From the circuit diagram above, resistor R1 is used to limit the current through the infrared LED, while resistor R2 is acting as a pull-up resistor.

3.2 AMPLIFIER SECTION

The output signal from the sensor circuit is very small; therefore it was necessary for the signal to be amplified. The amplifier section is used to amplifier the output of the sensor circuit to a reasonable level so that it can be fed to a microcontroller.

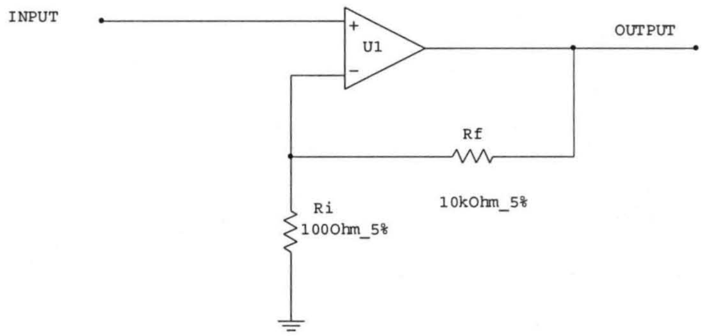

Fig. 3.2 Amplifier Circuit

Figure 3.2 shows a configuration of an operational amplifier configured as a non-inverting amplifier. The gain of the amplifier was chosen to be around 100; therefore the values of the resistors can be calculated as shown below.

$$Gain\ A = \frac{R_f}{R_i} + 1$$

where

$A = 100$

R_f = feedback resistor = 10kΩ

R_i = input resistor = ?

therefore

$$R_i = \frac{R_f}{A - 1}$$

$$= \frac{10000}{100 - 1} = 101.01\,\Omega$$

For the gain of the amplifier to be around 100, the input resistor (Ri) has to be around 100 ohms.

3.3 FILTER SECTION

The filter circuit is used to remove unwanted signal from the desired one. This unwanted signal could surfaces due to one of the following.

1. Background noise
2. Distortion due to the amplifier

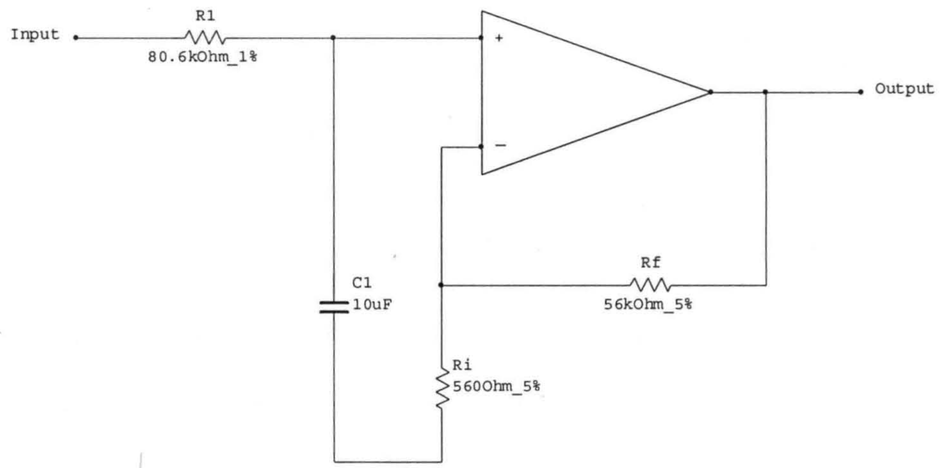

Fig.3.3: Filter circuit

The circuit above is a low pass filter, whose cut off frequency is around 2Hz and a gain of 560. The cut off frequency was chosen to be 2Hz because the maximum beat per minute is around 120bpm (which is 2Hz). The values for the resistors and capacitor can be calculated as shown below.

$$Gain\ A = \frac{R_f}{R_i} + 1$$

$$Cut\ off\ frequency\ \mathrm{f_c} = \frac{1}{2\pi R_1 C_1} = 2\mathrm{Hz}$$

where

$\pi = 3.1428$

$\mathrm{C_1} = 10uf$

$\mathrm{R_1}$ = input resistor = ?

therefore

$$\mathrm{R_1} = \frac{1}{2\pi \mathrm{f_c C_1}} = 79.54k\Omega$$

3.4 MICROCONTROLLER UNIT

This unit is the brain of the Heart Rate Monitor, it consist of a microcontroller and some configuration component. The microcontroller used for the project is an 8051 microcontroller from Atmel Corporation (AT89C52). Features of the AT89C52 include;

* Compatible with MCS-51™ Products

* 8K Bytes of In-System Reprogrammable Flash Memory

* Endurance: 1,000 Write/Erase Cycles

* Fully Static Operation: 0 Hz to 24 MHz

* Three-level Program Memory Lock

* 256 x 8-bit Internal RAM

* 32 Programmable I/O Lines

* Three 16-bit Timer/Counters

* Eight Interrupt Sources

* Programmable Serial Channel

* Low-power Idle and Power-down Modes

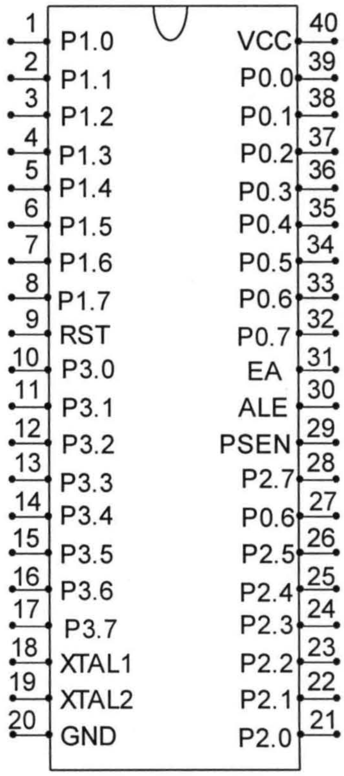

Fig. 3.4: Pin out of an AT89C52

The AT89C52 microcontroller will not function without a program loaded into its program memory. The programme that will be loaded into the AT89C52 will be discussed later.

3.4.1 Configuration of an AT89C52

The AT89C52 needs to be hardware-configured. The circuit below shows how this can be done. The circuit consists of a reset circuitry and an oscillating circuitry.

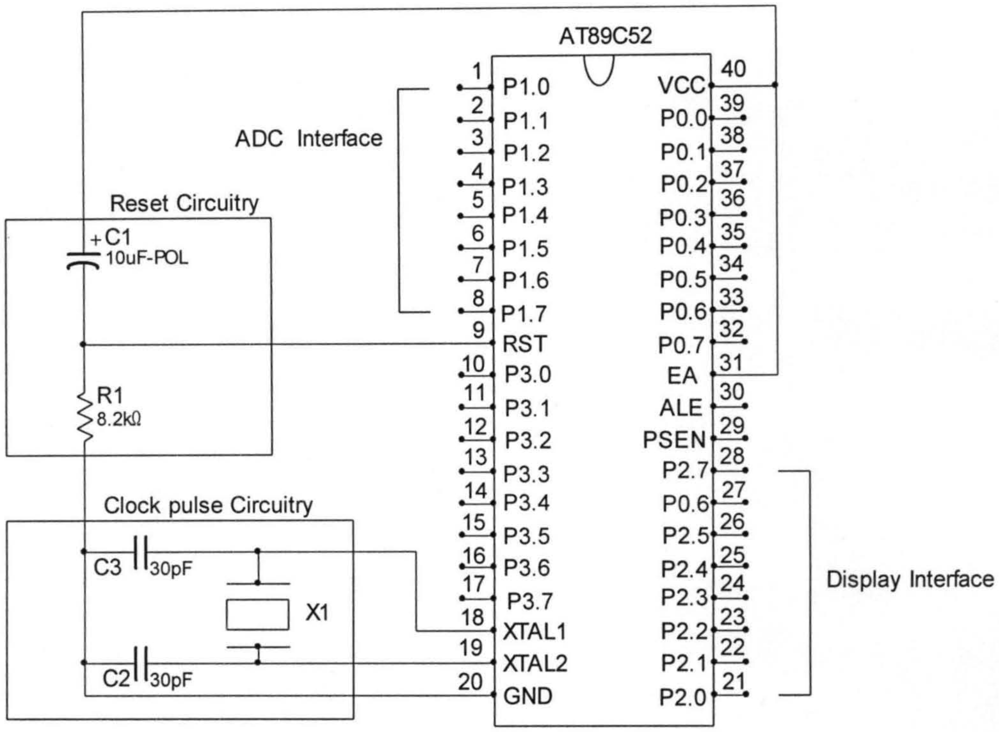

Fig. 3.5: AT89C52 hardware configuration circuitry

The reset circuitry is needed for manually resetting the microcontroller to its initial start-up state. The values for R_1 and C_1 are 8K ohm and 10uf respectively. These values where recommended by the manufacturer in the datasheet of the AT89C52.

The clock circuitry provides the necessary clock pulse for the microcontroller to execute its instructions. The conditions for selecting the values in the clock circuitry are;

$C_2 = C_3 = 30 \pm 10$pF

$X_1 \leq$ Speed of the microcontroller(24MHz)

Recommended values are 30pF and 11.0592 MHz. With the 11.0592 MHz crystal, the number of instruction the AT89C52 can executes in one second is represented mathematically as shown below;

$$\text{Number of instructions per seconds} = \frac{\text{Crystal value(Hz)}}{12}$$
$$= \frac{11059200}{12}$$
$$= 921600$$

3.5 Liquid Crystal Display Unit (LCD) Section

This unit is used to display the temperature in degree centigrade. This project will make use of a 16 by 2 Line character LCD (liquid crystal display). The Pin out of the LCD is shown below.

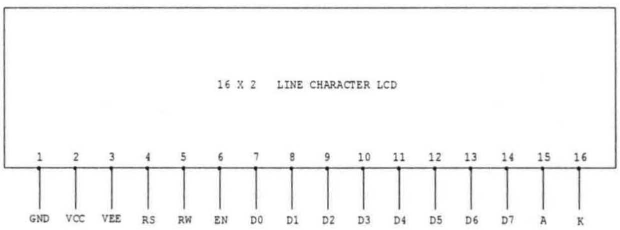

Fig. 3.6: LCD pin out.

Further information about the LCD is available in the data sheet.

3.6 POWER SUPPLY UNIT SECTION

The Heart Rate Monitor is designed to run on a battery source. This section will deliver the necessary voltage level needed by the microcontroller and the operational amplifier. According to the data sheet of the microcontroller and the operational amplifier, a 5V supply is adequate for the whole project.

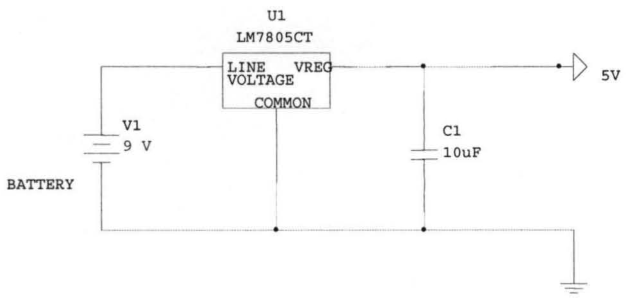

Fig. 3.7: Power supply circuitry

From the circuitry above, the 9V from the battery source is regulated to a 5V level by the voltage regulator (LM7805CT). The capacitor C1 (10uF) is used to increase the transient response of the regulator. The value of the capacitor was recommended in the data sheet of the regulator.

3.7 Firmware Section

The firmware was developed in assembly language using the popular Keil C uVision3 Integrated Development Environment IDE.

If the number of pulse counts in time T is n, then the heart rate per minute is given by N where, $N = 60n/T$

If the duration of a measurement is 10 seconds, then the heart rate is calculated as:

$N=6n$

The operation of the software is described below as a Program Description Language (PDL):

BEGIN

Initialize program variables

Configure input-output ports

Display message "**HEART RATE**"

" **MONITOR** "

Wait until switch is pressed

Sum = 0

DO 3 times

Get count in 10 seconds

Count = 6 * Count

Sum = Sum + Count

ENDDO

Calculate the average, Rate = Sum / 3

Display the average on the LCD

END

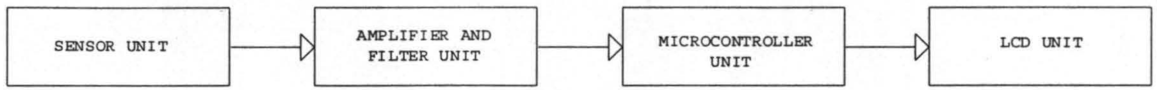

Fig. 3.8 Block Diagram

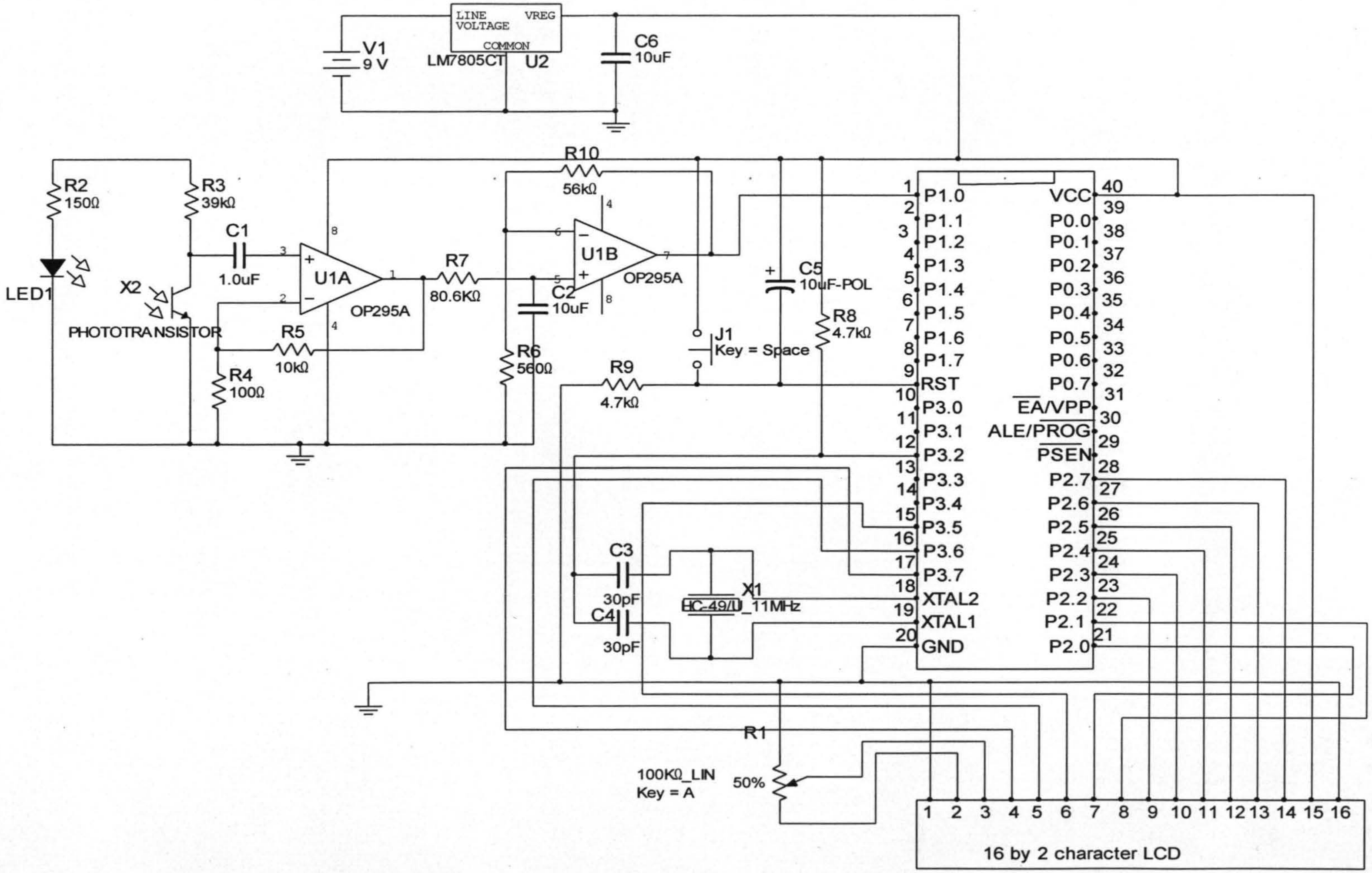

Fig 3.9. Circuit Diagram.

CHAPTER FOUR

TEST, RESULTS AND DISCUSSION

This project involves the analysis of biological signals which, in general, would involve an actual human connection for data acquisition. Heart rate measurement is one of the very important parameters of the human cardiovascular system. Theoretically, the heart rate of a healthy adult at rest is around 72 bpm. Athletes normally have lower heart rates than less active people. Babies have a much higher heart rate at around 120 bpm while older children have heart rates of about 90 bpm. In order to determine the workability of the project, three samples each were carried out to calculate the resting heart rate of adults and children. The averages of the three samples of both subjects were taken and compared to the theoretical values already present.

4.1 Steps Taken To Test The Work

- Three samples each were picked from both adults and children.
- One of each subject's fingers was cleaned and inserted into the infra-red transmitter and received sensor box.
- The reset button was pushed each time a subject's pulse was to be received.
- The different pulses of each subject was taken and recorded in Table 4.1.

4.2 Results

Table 4.1: Different heart rate samples gotten from adults and children

Test	Adult HR (bpm)	Theoretical value (bpm)	Children HR (bpm)	Theoretical value (bpm)
First sample	71	72	84	90
Second sample	65	72	80	90
Third sample	73	72	78	90

4.3 Discussion

Table 4.1 shows the average heart rates of the three samples of both subjects (adults and children). Clearly, there are similarities between the heart rate values of the subjects and their respective theoretical values. The three samples gotten from three different adults show a great deal of resemblance to what was expected. The first sample gave an average of 71 bpm which has a percentage error of about 1.39% compared to the theoretical value of 72 bpm. The second sample was gotten to be 65 bpm which is also less with a 9.72% variation and the third sample with an average of 73 bpm has a 2.78% variation. For the children, three samples were also taken to measure the accuracy of the device. The first child had a heart rate average of 84 bpm which has about 6.67% error when compared to the theoretical value. The second child had a heart rate average of 80 bpm which has about 11.11% variation and the last child had a heart rate average of 78 bpm which is about 13.33% variation. These results show that though the device is not as accurate as the theoretical values, it is very close to it. The reason why these results are not so accurate is because of the component used to acquire the pulse signal. To get a better reading of the heart rate an optical finger sensor is required and it is not readily available in the market so an infra-red transmitter (IR LED) and receiver (IR transistor) were used instead.

4.4 Amplifier/Filter Circuit Responses

The amplification is done by the non-inverting operational amplifier.

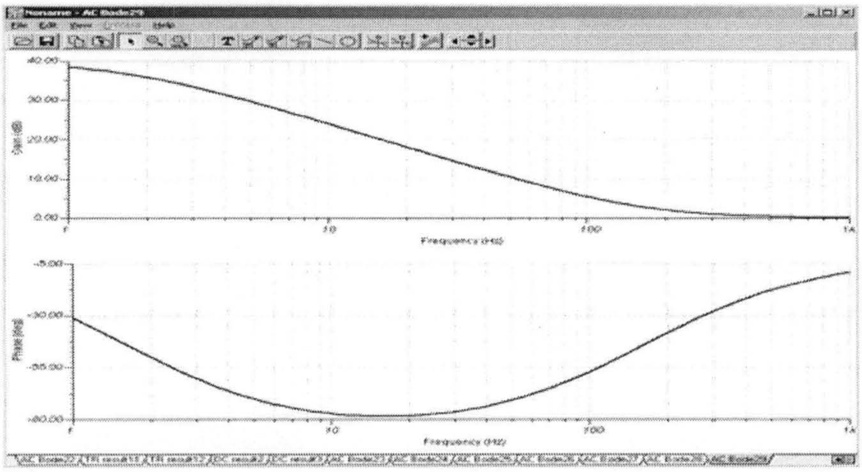

Fig. 4.1: Frequency and phase responses of the amplifier and filter circuit (obtained by connecting a PC based oscilloscope to the circuit)

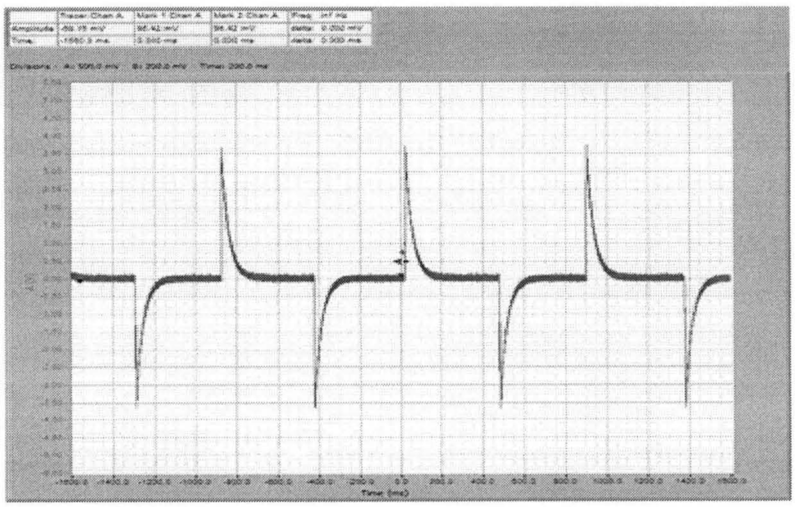

Fig. 4.2 Output response of the amplifier and filter circuit (obtained by connecting a PC based oscilloscope to the circuit).

CHAPTER FIVE

CONCLUSION

5.1 Accomplishments

All in all, this project achieved a lot of its goals. The project implemented a low cost, low power heart rate monitoring using microcontroller technology. Lists of accomplishments include:

- Adequately amplifying biological signals
- LCD average heart rate display
- Use of low power components for battery operation

The heart rates of the subjects were measured from the finger using infra-red transmitter and received sensor box and their results were displayed on a text based LCD using a low cost microcontroller. Good results were achieved and all the components performed quite successfully. The design of a low-cost microcontroller based device for measuring the heart pulse rate has been described. The device has the advantage that it can be used by non-professional people at home to measure the heart rate easily and safely.

5.2 Recommendations

The device can be improved in certain areas as listed below:

- A graphical LCD can be used to display a graph of the change of heart rate over time.

- An optical finger sensor could be used to get a more accurate pulse signal from the subject.
- Sound can be added to the device so that a sound is output each time a pulse is received.
- The maximum and minimum heart rates over a period of time can be displayed.
- Serial output can be attached to the device so that the heart rates can be sent to a PC for further online or offline analysis.
- Warning or abnormalities (such as very high or very low heart rates) can be displayed on the LCD or indicated by an LED or a buzzer.
- A 50Hz notch filter implemented within the microcontroller would significantly reduce the power line interference experienced by the system. A digital notch filter is much more efficient and reliable than an analog one. Analog notch filters are very sensitive and make very lousy filters. The notch filter would be placed immediately following ADC conversion. The signal would then be much cleaner and noise free for better analysis.

5.3 Future Work

The microcontroller based heart rate monitoring system designed in this project has a lot of advantages, but can also be improved on. There is a lot of improvement that can be made to the firmware portion of the project that would result in a more reliable system as stated in the recommendations section.

Looking ahead, as microcontrollers get more and more advanced, there will be a shift from analog amplification to digital amplification. Biological signals from the ECG electrodes can be fed directly into the microcontroller, where the front end, core, and back end work can be processed. This will significantly reduce the surface area consumed by a circuit and would lead to a smaller, more compact, and portable system.

More work can be done in the processes leading to the acquisition of these small biological signals. There are many challenges that still pose big problems in the design of systems like this. The skin/electrode interface, motion artifact, as well as AC power noise are problematic areas which would significantly increase reliability and efficiency if there are ways to minimize their effects [8].

REFERENCES

[1]. International Cardiovascular Disease Statistics. (WHO, Cardiovascular Diseases Prevention and control. www.who.int).

[2]. Atlas of Heart Disease and Stroke, WHO, September 2004. http://www.who.int/mediacentre/news/releases/2004/pr68/en/index.html

[3]. Heart rate monitor. http://www.emo.org.tr/ekler/a568a2aa8c19a31_ek.pdf

[4]. GaoQ.pdf, http://aut.researchgateway.ac.nz/bitstream/10292/141/1/GaoQ.pdf

[5]. Emedicinehealth [Cited May 22 2009]. http://www.emedicinehealth.com/script/main/art.asp?articlekey=100610

[6]. How stuff works. http://electronics.howstuffworks.com/microcontroller.htm

[7]. Encyclopedia Britannica 2008.

[8]. Eyinnaya Egejuru, Heart Rate Monitor and Arrhythma Detector, 2008. courses.ece.illinois.edu/ece445/projects/fall2008/project17_final_paper.doc

[9]. C. Saritha, V. Sukanya, Y. Narasimha Murthy, Department of Physics and Electronics, S.S.B.N. COLLEGE (Autonomous) Anantapur – 515 001, Andhrapradesh, India. http://www.bjp-bg.com/papers/bjp2008_1_68-77.pdf

[10]. ECG timeline brief history of electrocardiogram. http://www.ecglibrary.com/ecghist.html

[11]. American Heart Association. "Cardiovascular Disease Statistics" [Online Document], 2008 [Cited Dec 9 2008], Available HTTP: <http://www.americanheart.org/presenter.jhtml?identifier=4478>.