UNIVERSITY OF GAZİANTEP
GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES

DESIGN OF WIRELESS PATIENT MONITOR

M.Sc. THESIS
IN
ELECTRICAL AND ELECTRONICS ENGINEERING

BY
SAYGIN S. AHMED

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Design Of Wireless Patient Monitor

M.Sc. Thesis

In

Electrical and Electronics Engineering

Supervisor

Assoc. Prof. Dr. Nuran DOĞRU

by

Saygin S. AHMED

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This is to certify that we have read this thesis and that in our consensusopinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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“ TO MY FAMILY ”

ABSTRACT
DESIGN OF WIRELESS PATIENT MONITOR

Saygin S. AHMED
M.SC. in Electrical-Electronics Eng.
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This thesis presents the design of a wireless patient monitor in medical practice include index patients remote monitoring with medical environment. The system has capability of communication and measuring, processing of multi vital parameter or one. The proposed monitor consists of PIC16F876A microcontroller by wireless HMTR433-RS232 and transceiver unit (RF-module protocol). ECG signals are first sampled by a small portable device then the captured signals are wirelessly transmitted to PC and finally it can be sent to a healthcare network through internet. This remote monitoring provides safe, low cost, and low-power electrocardiogram. The system is also able to decrease patient waiting time in a clinic as well as reducing the work load of the physician.

Keywords: Wireless monitoring, Electrocardiogram (ECG) signals, healthcare.

ÖZET

KABLOSUZ HASTA MONITÖRÜ TASARIMI

Saygin S. AHMED

Yüksek Lisans Tezi, Elektrik-Elektronik Müh. Bölümü

Tez Yticisiö Yrd. Doç. Dr. Nuran DOĞRU

Ocak 2013, 35 Sayfa

Bu tez tıbbi uygulamalarda, kablosuz hasta monitörünün tasarımını içermektedir; bu tasarım tıbbi ortamda uzaktan kontrol edilebilme özelliğine sahiptir. Sistem, iletişim ve ölçme kapasitesine sahip olduğu gibi çoklu yaşamsal parametreleri de işleme özelliğine sahiptir. Söz konusu monitör, kablosuz HMTR433-RS232 ve alıcı-verici haberleşme ünitesince (RF-modul protokol) oluşturulmuş bir PIC16F876A microcontroller içermektedir. ECG sinyalleri ilk olarak küçük, taşınabilir bir cihaz tarafından örneklendirilir; daha sonra alınan sinyaller kablosuz ağ bağlantısı ile bilgisayara aktarılır; son olarak da internet yoluyla sağlık kurumlarının ağlarına iletilir. Uzaktan kontrol edilebilen bu monitör daha güvenli, düşük ücretli ve daha az enerjili electrocardiogram avantajı sağlamaktadır. Ayrıca bu sistem hastanın klinikte vakit kaybetmesine engel olduğu gibi , doktorun iş yükünü de azaltmaktader.

Anahtar kelimeler: Kablosoz goröntüleme, elektrokardiyogram(EKC) signali, sağlik.

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LIST OF ABBREVIATIONS

CVD	Cardio Vascular disease
EEG	Electroencephalography
ECG	Electrocardiography
EMG	Electromyography
DSP	Digital signal processing
SA	Sinoatrial
AV	Atrioventricular
VB	Visual Basic
CMRR	Common-mode rejection ratio
HPF	High - pass filter
LPF	Low - pass filter
VR	Voltage Regulator
OPA	Operation amplifier
PC	Personal computer
TX	Transmit
RX	Receive
RF	Radio frequency
DC	Direct current

AV	Atrioventricular node
ADC	Analog-to-Digital Converter
GUI	Graphical User Interface xii
RA	Right Arm
LA	Left Arm
LL	Left Leg
RL	Right Leg
NiCD	Nickel – cadmium battery
NiMH	Nickel – metal hydride battery
DAQ	Data Acquisition system
TI	Texas Instruments
mV	Millivolt
RSA	Respiratory Sinus arrhythmia
HHD	Hand Held Device
CAS	Clinical Alarm Station
USART	Universal Synchronous Asynchronous Receiver Transmitter

CHAPTER I

INTRODUCTION

Health care is one of the primary concerns in one's life. The value of life would not be the same without it. The most prevalent is Cardio Vascular disease (CVD) is one of and very serious health problems in the world. the representing 30% of all deaths worldwide an Estimated 17.5 million people died from CVD in 2005. In addition to compare the fatal cases, at least 20 million people experience every year to nonfatal heart attacks and strokes; many the costly medical care is requiring continuing[1]. A variety of physiological electrical signals from the human body can be continuously monitored including heart health (ECG or electrocardiography), brain waves (EEG or electroencephalography), and muscle response (EMG or electromyography)[2-4]. The main heart responsibility is pumping blood to carry oxygen to the entire body. To do this, it emits when a small electrical charge that cause the muscles around the heart to contract in a sequential way such that lead the blood is pumped through arteries to the target intended tissues.

These electrical activities that accompanies each cardiac cycle known as electrocardiogram (ECG). The measure and record The Electrocardiogram (ECG) is an essential diagnostic tool the electrical activity of the heart. A wide range of heart conditions can be detected when interpreting the recorded ECG signals. These qualities make the ECG a perfect instrument for patient monitoring and supervision. Recently, there has been an increased interest in using body area networks (BANs) for health monitoring. With the future development of digital signal processing (DSP) technology, however, evolved enormously of medical monitors, and use all current models are digital, which also has the advantages of miniaturization and portability [5,6]. Today the trend is toward multipara meter monitors that can track many different vital signs at once. Wireless patient monitoring has become a more established new technology and a natural step in this progress is to develop a reliable ECG system that contributes to the cable reduction in medical and physiotherapy environments [4]. As described before there is a severe shortage of health care professionals. Especially doctors and the clinical wait times have been increasing to a level that is out of the comfort zone of a patient.

CHAPTER II

LITERATURES REVIEW

2.1. Overview

As the world's population grows, the need for health care increases. In recent years progress in medical care has been rapid, especially in such fields as neurology and cardiology. A major reason for this progress has been the engineering. The disciplines of medicine and engineering are both broad. They encompass people engaged in a wide spectrum of activities from the basic maintenance of either the body, or a piece of equipment, to research on the frontiers of knowledge in each field. There is one obvious common denominator: the need for instrumentation to make proper and accurate measurements of the parameters involved.

Personnel involved in the design, use, and maintenance of biomedical instrumentation come from either the life sciences or from engineering and technology, although most probably from the latter areas. Training in the life sciences includes physiology and anatomy, with little circuitry, electronics, or instrumentation. For the engineer or electronics or physiology is usually lacking on the biomedical side.

Within the human body can be found electrical, mechanical, thermal, hydraulic, pneumatic, chemical, and various other types of systems, each of which communicates with an external environment, and internally with the other systems of the body. By means of a multilevel control system and communication network, these individual systems are organized to perform many complex functions.

Through the integrated operation of all these systems, and their various subsystems, man is able to sustain life, learn to perform useful tasks, acquire personality behavioral traits, and even reproduce himself.

2.2 Electrocardiogram (ECG)

2.2.1 The Bioelectric Potentials

A transducer consists of two electrodes, which has ability to convert ionic potentials and current into electric potentials and current is required to measure bioelectric potentials. Precise placement of an electrode inside a cell is necessary for the measurement of individual action potential. The more common form of measured biopotentials is the combined effect of a large number of action potentials as they appear at the surface of the body, or at one or more electrodes inserted into a muscle, nerve, or some part of the brain. These potentials are measured by an instrument designation of its name ends in the suffix graph whereas the waveform generally ends in the suffix gram. For example, the electrocardiogram-ECG (the name of the waveform resulting from the heart's electrical activity) is measured on an electrocardiograph (the instrument).

2.2.2 Action potentials of the heart

Cardiac contraction is controlled by specialized excitatory and conductive system. This system begins from right atrium and ends at purkinje fibers and generates spontaneously an action potential at a regular rate which starts from group of specialized cells called sinoatrial node (pacemaker) located at the top of the right atrium Each action potential in the heart originates near the top of the right atrium at a point called the pacemaker or sinoatrial (SA) node.

Then these potentials propagate in all direction along the surface of both atria toward the junction of the atria and the ventricles. The wave terminates at a point near the center of the heart, called the atrioventricular (AV) node. From this point it is rapidly spread to all parts of both ventricles by the bundle of His (pronounced "hiss") reaching purkinje fibers. Stimulation of purkinje fibers causes contraction of myocardium. The following figure shows rhythmical action potentials (in millivolts) from purkinje fiber and from a ventricular muscle fiber, recorded by means of microelectrodes.

2.2.3 Normal ECG

The biopotentials generated by the muscles of the heart result in the electrocardiogram, abbreviated ECG (sometime ECG, from the German electrocardiogram). It is a graphic recording or display of the time-variant voltage 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 electrocardiogram is used clinically in diagnosing various diseases and condition associated with the heart. It also serves as a timing reference for other measurements.

Some normal values for amplitudes and durations of important ECG parameters are as follows:

Amplitude:	P	wave	0.25 mV
	R	wave	1.60 mV
	Q	wave	25% of R wave
	T	wave	0.1 to 0.5 mV
Duration:	P-R	interval	0.12 to 0.20 sec
	Q-T	interval	0.35 to 0.44 sec
	S-T	segment	0.05 to 0.15 sec
	P	wave interval	0.11 sec
	QRS	interval	0.09 sec

An ECG is simply an electrical recording of the heart. Figure 2.1 [7] shows an ideal ECG signal frame identifying typical features. As it appears when recorded from the surface of the body. Alphabetic designation have been given to each of the prominent features.

These can be identified with events related to action potential propagation pattern. To facilitate analysis, the horizontal segment of this waveform preceding the P wave represent depolarization of the atralmusculature. The QRS complex is the combined result of the repolarization of the atria and the depolarization of the ventricles, which occur almost simultaneously. The T wave is the wave of ventricular, whereas the U wave, if present, is generally believed to be the result of after-potentials in the ventricular muscle. The P-Q interval represents the time during which the excitation wave is delayed in the fibers near the AV node.

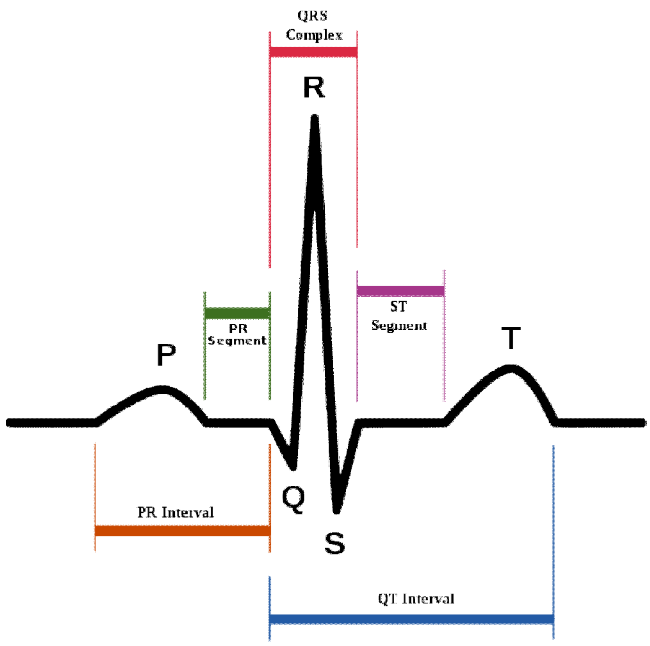

Fig. 2.1 Ideal ECG frame with typical features

The body is a volume conductor so the fluctuations in potential that represent the algebraic sum of the action potentials of cardiac muscle fibers can be recorded extracellularly. The record of these potential fluctuations during the cardiac cycle is the electrocardiogram (ECG). The electrical voltages generated by the heart and recorded by the electrocardiograph from the surface of the body are represented by the P, Q,R, S, and T wave. Each wave corresponds to the sate of the atria and ventricles whether they are depolarized or repolarized. The P wave is caused by spread of depolarization through the atria. About 0.16 second after the onset of the P wave, the QRS waves appear as a result of electrical depolarization of the ventricles. The T wave is produced by ventricular repolarization.The test subject for this section of the results is a 21 year old male.

The subject has no known heart condition and therefore has a normal ECG. An ECG consists of the PQRST and U waveforms where the P wave corresponds to the atrial depolarization, the QRS complex corresponds to the depolarization of the ventricles and the T wave corresponds to the repolarization of the ventricles. The QRS complex is extremely important for the measurement of heart rate, as it is the segment of the ECG with the largest amplitude. This large amplitude is due to the fact that the ventricles have a greater mass than the atria and therefore the cardiac cells in that region produce a larger depolarization wave. By utilizing the QRS complex a peak detection algorithm can be employed to measure the heart rate in visual basic. The duration, amplitude and morphology of QRS complexes are such that they can also be used to diagnose cardiac arrhythmias, conduction abnormalities, ventricular hypertrophy and myocardial infarction.

As you can see this complex is the most important segment of the ECG. In the design of the ECG I mentioned that for an ambulatory ECG the frequency ranges from 0.5 to 30 Hz [8] but as you can see even by having a passive RC low pass filter with a cut off of 15.9 Hz most of the ECG signal is still recovered. The signal shown below in Figure 2.2 is prior to using the wireless module, as you can see the QRS waveform is clearly visible in the oscilloscope.There is minimal noise and no motion artifacts. There was however a bit of a floating ground which can be attributed to an improper ground electrode connection.

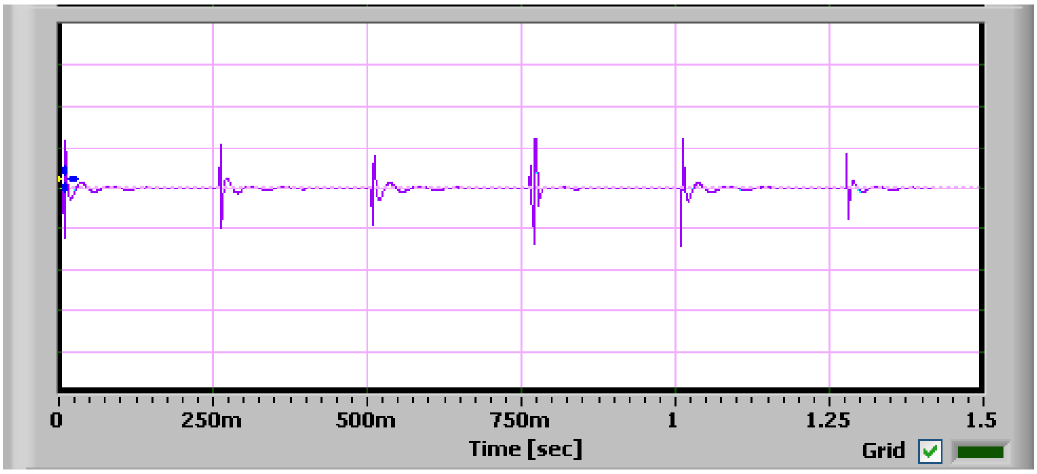

Fig. 2.2 Shows the ECG waveform prior to wireless transmission

The amplitude of this ECG signal was around 360 mV. That is using a gain of 300. The signal of a DC offset is present. This DC offset can be removed by using a simple passive RC high pass filter. In this particular system the wireless transmitter/receiver pair removed the DC offset so the high pass filter was not required.

The figure shown above Figure 2.3 shows the signal post transmission before being sent to the DAQ. As you can see there is a large amount of noise that has been added to the signal during the transmission process. This transmission noise can be significantly reduced by placing the transmitter/receiver module on a printed circuit board (PCB) with a ground plane. The ground plane is a layer of copper added to the PCB during manufacture. The ground plane appears to most signals as an infinite ground potential and can therefore reduce noise.

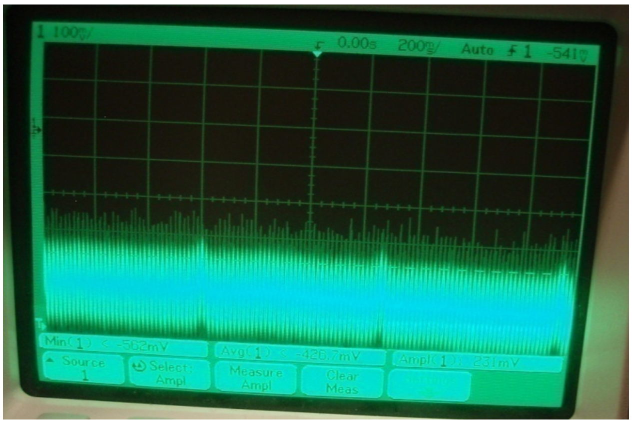

Fig. 2.3- Shows the ECG waveform post wireless transmission

The ECG waveform is still intact and the QRS complex is clearly seen even with the addition of noise. There is no DC offset after the transmission process as the analog signal was first converted into digital and then transmitted. This process removed any inherent DC offset that was present in the ECG signal. The noise that was added to the ECG signal during transmission can be removed using post processing techniques in Visual Basic. It is not viable to build an active 3th order low pass filter with a cutoff of 30Hz on the transmission end as each of the different components of the Quick Doc device require a different cut-off but using Visual Basic it is relatively easy to apply such as filter digitally to the signals during post processing.

In fact the post processing for the ECG signal involved using several such digital filters with orders ranging from 3rd to 5th on top of this a heart rate counter was also added. Figure 2.4 shows the signal prior to the post processing. The green dots on the R (refer to Appendix C) peak of the QRS complex indicate the peaks that were used to measure the heart rate [9].

The QRS complex is clearly visible as are the P and T wave forms. As you can see the cardiac rhythm and rate are clearly visible in this ECG which was one of the project's main goals. Note that the rhythm is regular; that is each beat is an equal time interval away from the next beat. By finding the time interval between each of the peaks we can find the heart rate of the patient.

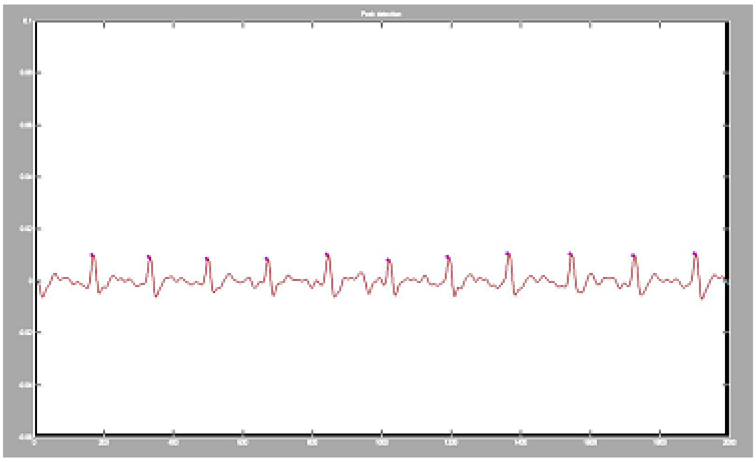

Fig. 2.4 Shows the post processed ECG waveform the heart rate was calculated to be 63beats/min

The patient here has a normal resting heart rate of 63 beats/min which was acquired by using a peak detection algorithm to identify the R wave and then using the time interval between the peaks.

By counting the number of peaks in a 10 second interval and then multiplying by 6 you can get the beats/min. As we are only looking at one section of the electrical activity in the heart we can compare this to one lead from a clinical ECG. The clinical ECG shown below in Figure 2.5 is a normal ECG acquired from a patient with no known cardiac issues.

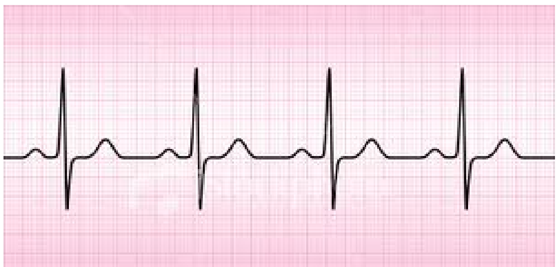

Fig. 2.5: Shows one lead of the clinical ECG acquired from a normal patient

As you can see comparatively the wearable wireless ECG is able to reproduce a single lead view with great accuracy. The view Shown in Figure 2.5 was from the aVF lead of a clinical ECG. The aVF lead is a unipolar lead whose positive is attached to the left leg. This lead provides a +90 degree axial view of the heart. The lead that the wireless ECG project mimics is the unipolar aVR lead which is measured from the right arm. This lead produces an ECG signal that is inverted. In this project the inverted ECG was turned around when measurements were acquired by simply switching the wires from the output.

2.2.4 QRS complex

The most distinctive portion of the ECG is QRS complex which resulted from depolarization of ventricle and it lasts normally less than or equal to 100 milliseconds [10]. The voltage of the QRS complex may be as great as 3 to 4 millivolts. A time versus voltage graph of the QRS complex portion of the ECG is shown in Figure 2.6. It lasts as long as depolarization of the ventricles lasts, this demonstrates the cause that there is no appearance of the repolarization of atria because its complex city an abnormally prolonged or otherwise irregular duration of the complex indicates improper electrical conduction throughout the heart. When electrocardiograms are recorded from electrodes on the two arms or on one arm and one leg, the voltage of the QRS complex usually is 1.0 to 1.5 millivolt from the top of the R wave to the bottom of the S wave. The QRS complex is extremely important for themeasurement of heart rate, as it is the segment of the ECG with the largest amplitude. By utilizing the QRS complex a peak detection algorithm can be employed to measure the heart rate in Visual Basic.

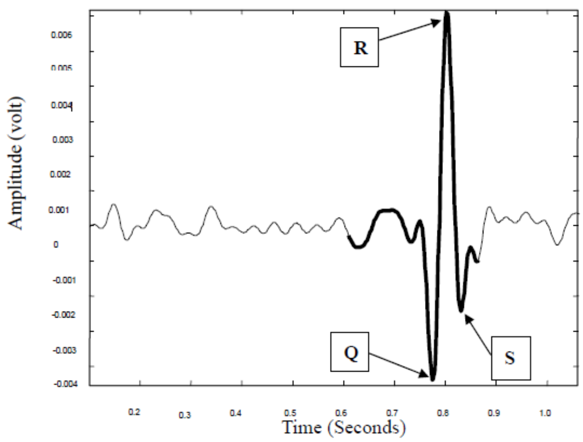

Fig. 2.6 QRS Complex, a portion of ECG[10]

2.2.5. Current Holter monitoring Systems

The ECG is often recorded continuously in hospital coronary care units, with alarms arranged to sound at the onset of life-threatening arrhythmias. Using a small portable tape recorder (Holter monitor), it is designed to support the ide identification of infrequently occurring cardiac arrhythmias it is also possible to record the ECG in ambulatory individuals as they go about their normal activities. The recording is later played back at high speed and analyzed.

A classification [11] for the Holter monitoring systems is made on the following:

a) Dumb Holter systems;

b) Cardiac event monitors - recording with remoteclassification;

c) Recording plus local ECG classification but no context awareness other than the handwritten record;

d) Recording plus awareness of the level of physical activity through accelerometers.

2.2.6. Analysis of timing features of the electrocardiogram

Time intervals between the different waves of the ECG can help doctors diagnose cardiac abnormalities. Therefore, a few timing features of the Lead I ECG were processed via software to aid in medical diagnosis. The time between heart beats is one of the most basic qualities that can be extracted from the ECG. Heart malfunction due to an abnormal rhythm of the heart is called an arrhythmia.

A fast heart rate, called tachycardia, generally results from an increased body temperature, stimulation of the heart by the sympathetic nerves, or toxic conditions of the heart (Figure 2.7). The opposite condition, a slow heart rate or bradycardia, may result from problems with the heart's electrical system and natural pacemaker (Figure 2.8). Extreme cases of bradycardia may mean that the heart is not pumping enough blood to meet the body's needs. To aid in the diagnosis of such conditions, the ECG is processed to extract the average heart rate of the patient and continuously display it at the base station.

Fig.2.7- Tachycardia. Note that the peak-peak distance is approximately 2 divisions (0.20 seconds per division).

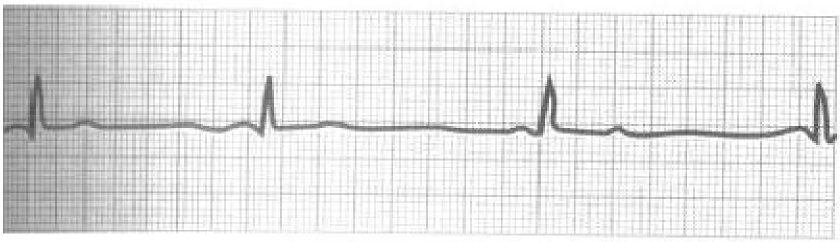

Fig.2.8- Bradycardia. Note that the peak-peak distance is approximately 7 divisions (0.20 seconds per division).

The duration of the QRS complex is also calculated and displayed at the base station. Since the QRS complex lasts as long as depolarization of the ventricles lasts, an abnormally prolonged or otherwise irregular duration of the complex indicates improper electrical conduction throughout the heart. This can be due to the deconstruction of heart muscle throughout the ventricular system that is then replaced with scar tissue, or the appearance of multiple small local blocks in the Purkinje system, the part of the heart that conducts electrical impulses to the ventricles. Anormal QRS complex lasts 0.06 to 0.08 seconds; anything longer than 0.09 seconds is considered abnormal.

2.2.7 Wireless ECG

Many patients who suffer from cardiovascular diseases are at a higher risk of sudden cardiac death and not all of these patients were at hospitals to monitor their cardiac state. So from this idea there is very necessary to have a monitoring system for monitoring their cardiac state. By using a wireless and wearable monitoring system it is possible to alert healthcare professional to the patient's condition so that the necessary action for an emergency rescue can occur. Many advanced monitoring solutions are available nowadays which are either based on standard ECG electrodes and a wired connection to a recording device or by pressing a recording device directly onto a patient's chest when a symptom arises [12]. One of these advanced system is telecommunication system. Such systems can be divided into two categories realtime mode and store-and-forward mode. Recent developments in wearable biomedical sensors have opened up possibilities for continuous wireless ECG monitoring systems.

Many current ambulatory ECG recording equipment are depending on the patient's condition this many not be possible which is also time consuming but it is necessary to develop an automatic system that will monitor the patient and send alarm conditions to a central safety alarm system. Given the fact that time is of the essence during a cardiac arrest this device has the possibility of increasing the survival chances of a patient [13]. The idea is to develop a simple smart sensor that detect critical cardiac conditions and give early alarm signals even if the patient is unconscious or unaware of cardiac. The sensor transmits the ECG information to a device on the patient. The ECG utilizes silver electrodes which acquire the signal and sent it to the amplification and transmission stages via short shielded wires.

The wires are also twisted together to reduce noise. The ECG then transmits the information wirelessly to a receiver then to a computer. The ECG signal after acquisition but with some modifications can be made to produce real time post processed data. the patient wears an ECG sensor that employs smart electronic electrodes capable of wireless transmission of ECG signals to a dedicated Hand Held Device (HHD). The HHD monitors the continuously recorded ECG signal and can detect abnormal ECG activity using an automatic arrhythmia detector. Based on this the device transmits alarm conditions to remote Clinical Alarm Station (CAS).

In order to perform continuous ambulatory ECG recordings a new wireless ECG electrodes has to be designed which can measure the ECG signal and transmit it continuously to the receiver in the HHD. This means that only one lead is used for the recording of the ECG signal. To accomplish this the authors used a compacted “double-electrode” with no wires connected. This electrode is equipped with a wireless transmitter and battery supply for several days of continuous usage. The ECG sensor includes two electrical contact points with conducting gel applied to the patient’s skin for obtaining the signals.

These points are connected electrically to the electronic circuit that consists of an amplifier, a high pass filter with a cut off of 0.5 Hz and a low pass filter with a cut off of 250 Hz. The ECG also has a power supply and wireless transmitter thereby making it wearable and viable for continuous ECG monitoring. The power supply in the ECG utilizes a 9V battery and because the power consumption of the system is only 11mW. The electrode designed by the authors uses a combination of real-time mode and store-and forward mode to produce a continuous cardiac event recorder.

2.2.8. HM-TR Wireless Data Link - 433MHz - RS232 Interface

The New standard RS232 is important in connection transparent the wireless data when link is module. The inexpensive unit is compact for direct connection to the computer system or may be through a control system for wireless data transmissions between the two points. The high accurate of unit features and reliable data transmission methods with high data rates and large transition range. Data formats and data rates can set with window software. The directly connects to computer with standard RS232 interface. The based security systems is ideal for computer, monitoring remote systems or transfer the data between 2 computers wirelessly, it’s in figure 2.9.

Features

- Frequency 433MHz
- Voltage Operating -5Vdc
- Selection Data Rate
- Reliable FSK Technology Transmission
- Standard RS232 Interface
- Long Transmission Range
- Works directly with Computer RS232 Connection
- Dimensions: Length - 43mm, Width - 24mm , Height - 12mm

Fig. 2.9 HM-TR Wireless Data Link - 433MHz - RS232 Interface

2.2.9 Placement of ECG Leads

The ECG is recorded by placing an array of electrodes at specific locations on the body. These locations are conventionally on the arms, legs and six of them are at defined places on the chest.

Three types of ECG leads are recorded by the electrodes: standard limb leads, augmented limb leads and chest leads. These electrode leads are then connected to a device that measures the potential differences between chosen electrodes and plots the characteristic tracings. For the sake of simplicity I disregard the latter two types of leads and present only the standard limb leads here:

***Lead I:** Positive electrode is on the left arm and negative electrode is on the right. It measure the potential difference across the chest between two arms.
***Lead II:** Positive electrode is on the left leg, while the negative is on the right arm.
***Lead III:** Positive electrode is on the left leg and the negative is on the left arm.

These leads form a triangle around the heart and are called Einthhoven's triangle*. If a wave of depolarisation is travelling toward the left arm, it gives a positive deflection, which is maximal if the wave propagates parallel to the axis connecting the left and right arms. If a wave of depolarisation is heading away from the left arm, the sign of deflection is negative. With the triangle arrangement of the 3-lead recording an experienced cardiologist is able to conclude the states of different parts of the heart.

2.2.10. ECG Recording

The heart is in simple terms the blood pump of the body made up of muscle tissue. Its regular contraction is controlled by the sinus node which generates the electrical stimulus every time the heart beats. This special area is located in the right upper chamber (atrium) of the heart, and is connected to the lower chambers (ventricles) by conduction pathways. Its generated energy travels down and causes these lower chambers to pump out blood. A healthy person's sine node generates roundabout 60-80 heartbeats in repose.The electrocardiogram (ECG) is a simple but crucial tool in clinical practice. It is a non-invasive recording produced by an electro-cardiographic device, and particularly useful in diagnosing rhythm disturbances. Electrodes are placed on different parts of the skin over different parts of the heart to measure the electrical activity mentioned above. An ECG displays the voltage dierence between pairs of electrodes which not only indicates the rhythm of the heart, but weaknesses or damage in certain parts of the heart muscle.[14]

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*Willem Einthoven (Semarang, May 21, 1860 | Leiden, September 29, 1927) was a Dutch doctor and physiologist. He invented the _rst practical electrocardiogram in 1903 and received the Nobel Prise in Medicine in 1924 for it.

CHAPTER III

HARDWARE DESIGN

This project was split into two main tasks, hardware and software. It is the responsibility of the hardware to collect and compare the data, filter out the harmful 60 Hz signals and transmit the data. It is the software's responsibilities to digitize the signal, package the data and synchronize the receiver and the transmitter.

3.1.Hardware

As shown in figure 3.1 a block diagram of wireless ECG module is implemented by using a custom developed ECG amplifier with low pass filter and a low power microcontroller board. Low pass filter eliminates high and undesirable frequencies. Voltage regulator is used to provide required power and stability.

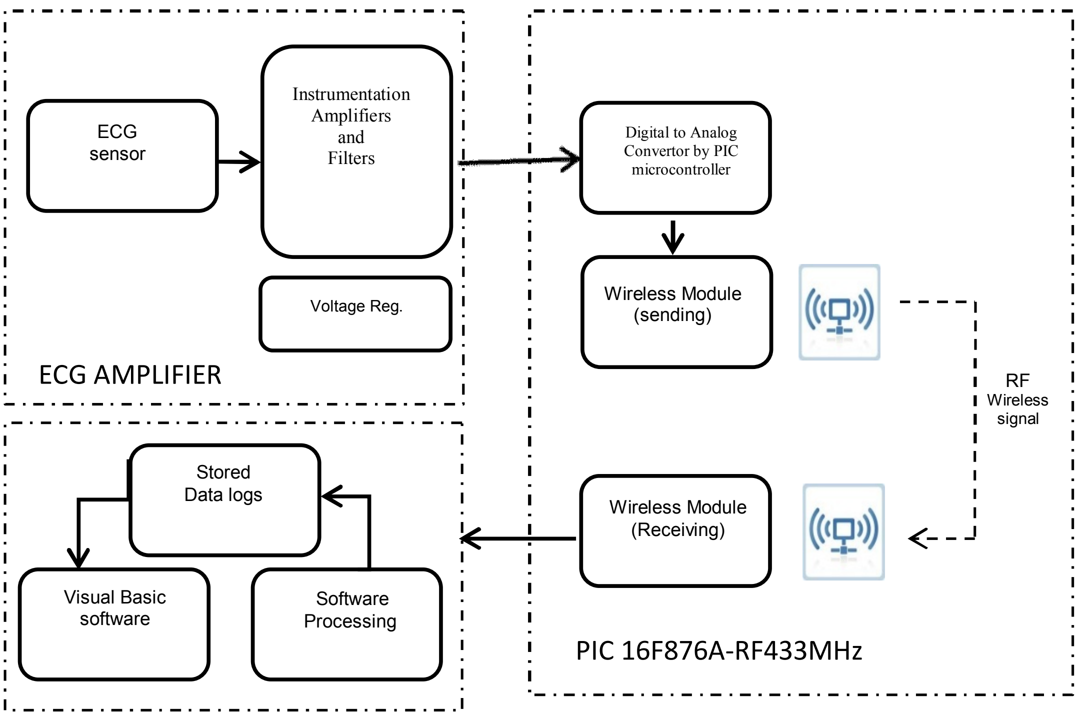

Fig.3.1 Wireless ECG module – block digram

Analog-to-digital converter within the microcontroller is used for sampling ECG signals. ECG module has ultra low power microcontroller PIC 16F876A, a radio interface in the 433 MHz band, and RF module antenna with 50 m range indoors/100m range outdoors. The ECG module of a wireless occurs by using a custom developed ECG amplifier together with a low power microcontroller board (microcontroller pic 16f876a). Since the device needs a power and stability, voltage output was used during circuit voltage regulator. Output ECG is an analog computer deals with the numeric digital introduction. So it requires a circuit to convert the analog to digital.

3.1.1 ECG amplifier

A custom made device (2-lead have ECG amplifier), Figure 3.2 shows the designed ECG amplifier board which included and applied in the present study.

Figure 3.3 [15] each channel has gain of 500, the coupled DC and band limited to100 Hz. The ECG amplifier has high common mode rejection (>90dB); the impedance of high input (>10 MΩ) and cause fully floating of patient inputs.

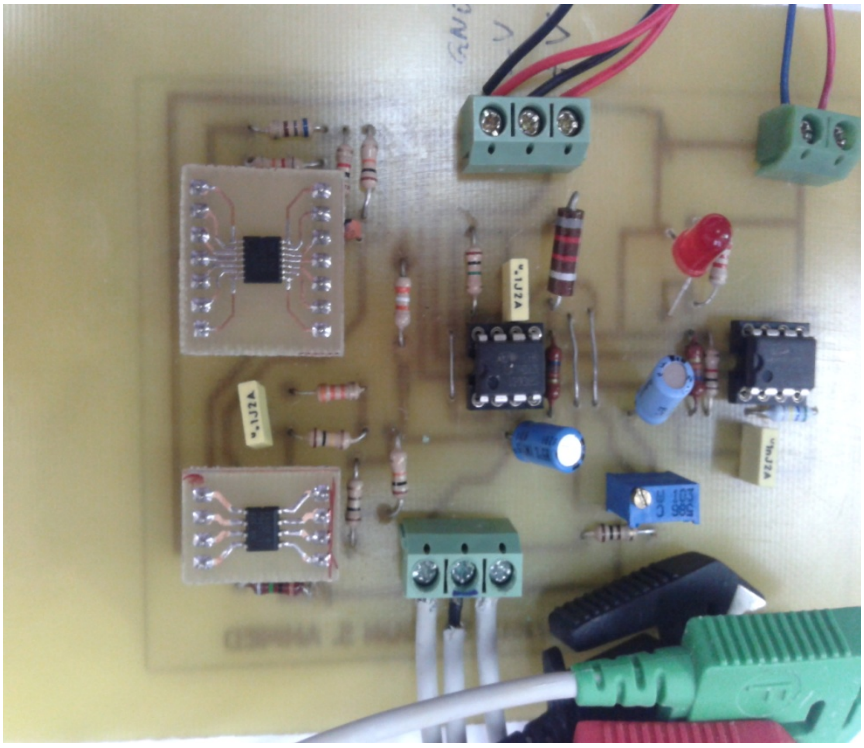

Fig 3.2 ECG amplifier board (a designed and applied board of this study)

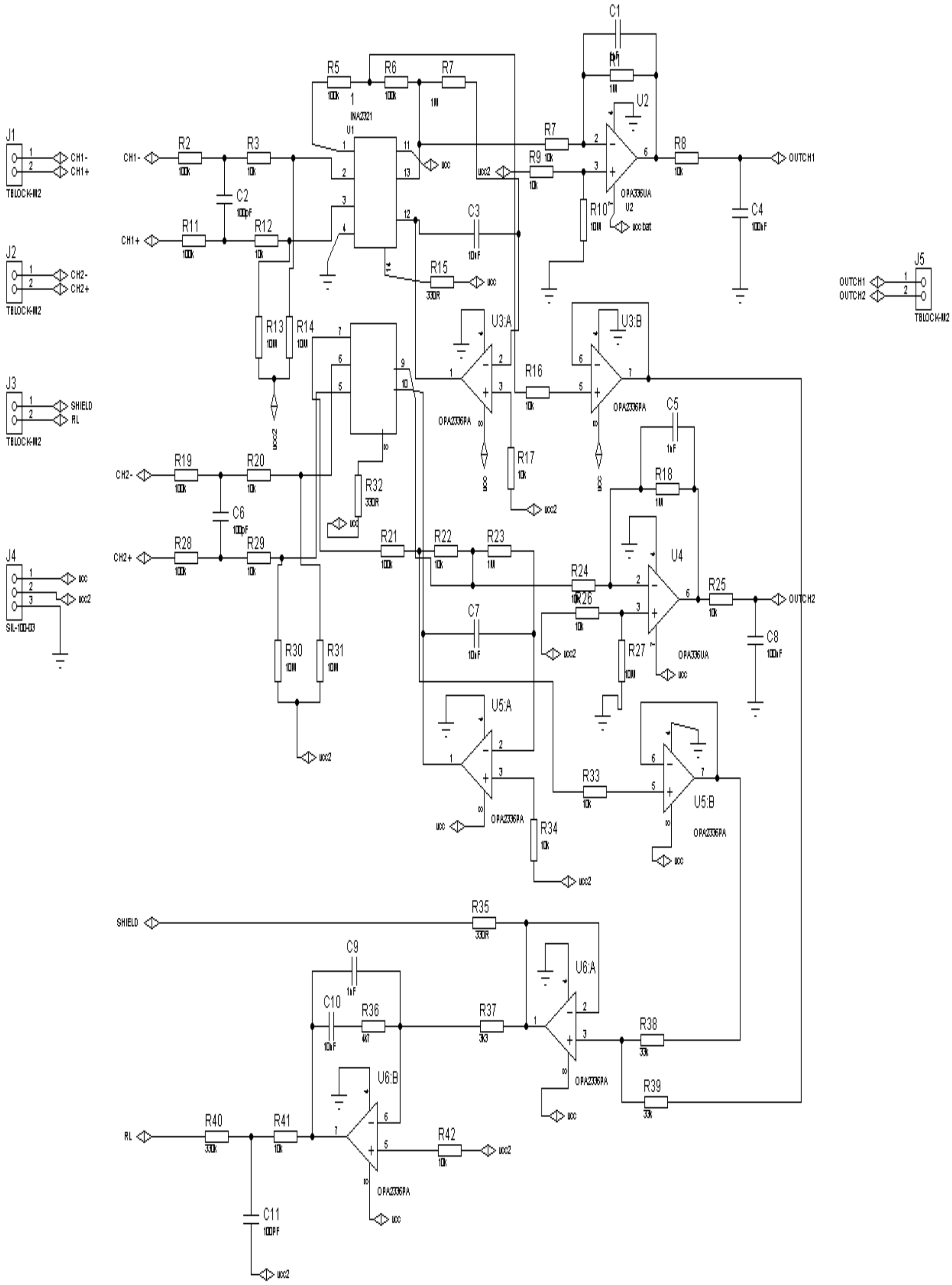

Fig. 3.3 – ECG amplifier – schematic.

Differential amplifiers are used to have a good signal to noise ratio. The circuit has a good common mode rejection because of the output is proportional to difference between two voltages. To avoid the limitation of the differential amplifier's performance, a dual instrumentation amplifier incorporated in place of the differential amplifier. The impedance between pins 1, 12, and 13 (or 7, 9 and 10), internally set gain of 5 per amplifier is determines the gain of the INA2321, the gains greater than 5 with gain error guaranteed can be programmed to be less than 0.1%. External resistors errors add directly to the guaranteed error, the error source might become dominant.

The circuit of gain in 10 was chosen for this stage. The diodes ESD will conduct if the input voltages exceed the power supplies by more than 500 mV protect the INA2321 inputs. Moment voltage is greater than 500 mV beyond the power supply can be tolerated if the current through the input pins is limited to 10 mA. This is simply carried out by input resistors (100K). The second stage is a low pass filter with a gain of 10 and it is used to eliminate the high frequency noise above 100 Hz. The frequency response of the ECG amplifier (one lead) is represented in the Figure 3.4.

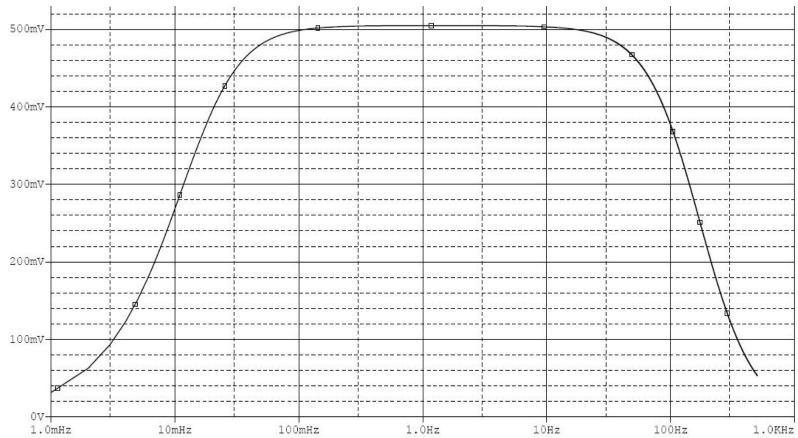

Fig. 3.4 The frequency response of the ECG amplifier

3.1.2 Operational Amplifier

The operational amplifier used in the right-leg common-mode feedback circuit is the OPA2366, a dual amplifier. The circuit sends an inverted version of the common-mode interference to the patient's right leg, with the aim of cancelling the interference and protecting the signals from the leads by shielding the signal cable. The operation amplifiers used in the application was chosen based on the electrical characteristics. The requirement that were essential for the operation amplifier that had to be fulfilled was;

• Single supply voltage at 3.3 V.
• Quad operation amplifier, due to the size requirement of the ECG sensor system size.
• High output current, the operation amplifier should be able to put out enough current so it can drive the Right Leg Drive function for an efficient reduction of 50Hz noise.

• Rail to Rail input and output, essential for high resolution output.

When deciding on operation amplifiers other characteristics were looked upon, not essential for the application, but important for functionality of the ECG amplifier. The most important characteristics here were;

• Low noise, eliminating disturbances in every step will make the ECG more reliable and make a high resolution possible.

• Low input offset, DC offset on the input will escalade and disturb the base line off ECG - signal.

• Low power consumption, the application will be power by battery and less power leads to longer battery life time.

3.1.3 Voltage Regulator

The ECG amplifier is powered by two batteries through the voltage regulator. The consists of this circuit completely of two similarly stages for the DC voltage regulator by using an integrated circuit of the type LM78XX. The ECG amplifier need to 9 volt an additional small standard voltage regulator (LM78XX) The regulator in built LM 78XX circuit and the circuit shown in the figure 3.5.

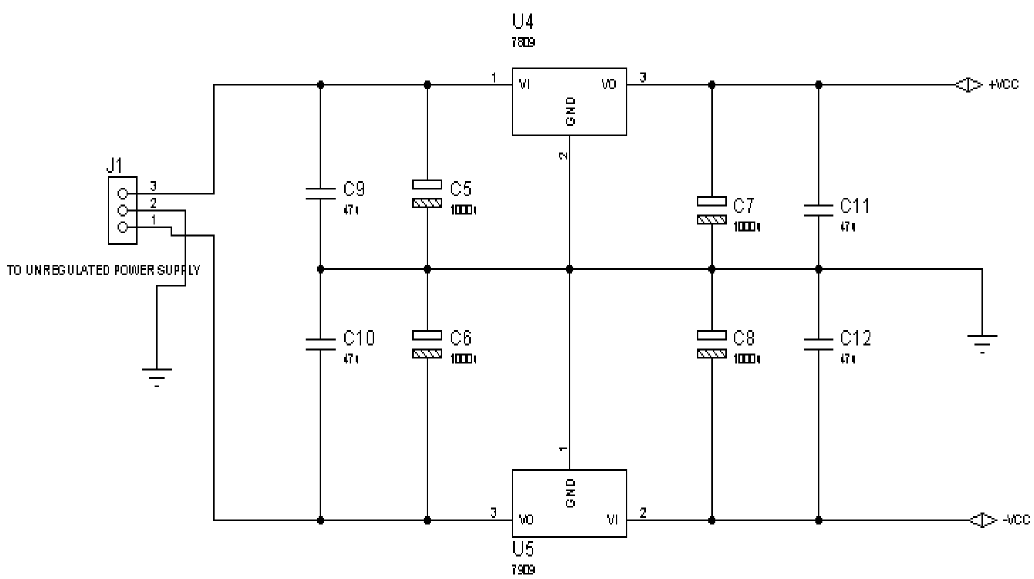

Fig. 3.5 Voltage regulator – schematic.

The LM 78XX regulated charge pumps that generates a 9V±5% output voltage from a 11.5 V to 23 V input voltage. The device is typically powered by Alkaline, NiCd, or NiMH battery cells and operates down to a minimum supply voltage of 7.7 V.

3.2 Filters

The difference signal obtained from the instrumentation amplifier still contains a large amount of noise. Some of the noise derives from electrical interference present in the environment of the patient whether that is from appliances in the vicinity, power lines overhead, or the electrical system of the building. Also, a DC offset may be present due to non-ideal input currents in the op-amps in the circuit itself. Therefore, before the signal is of any use, it must first be filtered to remove noise as much as possible.

3.2.1 Low-pass filter

A low pass filter is a filter that allows low frequency signals to pass but reduces the amplitude of signals with frequencies higher than the cut-off [16]. There are many different types of low pass filter circuits each one responds differently to a changing frequency. Examples of low pass filter circuits include the simplest filter, first order RC, Butterworth filter, the Chebyshev filter, Bessel filter to name a few.

The characteristics of a low pass filter can be summed up by its cutoff frequency and its rate of frequency roll off. Every low pass filter attenuates the input power by -3dB at the cutoff frequency. But the amount of additional attenuation for higher frequencies is determined by the order of the filter [16]. What this means is that a second order filter will attenuate the higher frequencies more steeply than a first order filter.

The frequency response of a low pass filter is generally represented by a Bode plot. The Bode plot is a graph of the logarithm of a transfer function versus the frequency (plotted in log-frequency). The filter used in this project is a first order RC filter. The RC filter consists of a resistor in parallel with a capacitor [16]. On the Figure 3.6 you can see the basic RC filter circuit used in this project. V_{in} is the input voltage from the instrumentation amplifier and V_{out} is the output to the wireless module. The resister value of R is 10K and the capacitor value is 1uF. The transfer function for this filter along with the formula for calculation of the cutoff frequency (f_c).

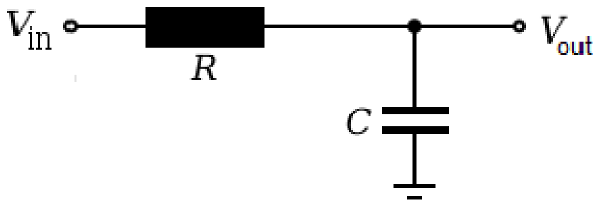

Fig. 3.6 Shows the RC filter circuit, transfer function and the formula for fc

$$H(s) = \frac{V_o(s)}{V_i(s)} = \frac{1}{1 + s\,RC}$$ ……………………………………..(3.2.1)

$$f_c = \frac{1}{2\pi\tau} = \frac{1}{2\pi RC}$$ …………………………………………………(3.2.2)

By using the formula given in Figure 14 we can find the cutoff frequency f_c. f_c = 1/(2π*10k*1u) = 15.91 Hz. As the ambulatory ECG requires a frequency range of between 0.5~30 Hz you are probably wondering why the cutoff for this is 15.91 Hz. At first I used a cutoff of 33Hz for this filter but this did not attenuate the 60 Hz to the extent that the ECG was visible.

I could have used a filter with a higher order but then the filter would have to be active which would have resulted in more power being drawn from the single 9V battery. After experimenting for some time with different resistor and capacitor values I found that a 15.9 Hz cutoff is perfect for my purposes of obtaining the cardiac rate and rhythm. The cut-off does not remove the ECG signal it only suppresses the higher frequencies of the ECG waveform.

3.2.2 The Gain Circuitry

The ECG signal is Vp.p from the user is about 1.6mV. The Vp.p Several gain stages was added to fully utilize the rail levels (set to –4.5V, 4.5V by our power supply). Due to the fact the initial low level of the signal, noise was a major issue. Less noise affects the input signal that is used by the patient. The input signals directly with a scope, the signal would look indistinguishable from the scope readout with nothing connected up to its probes. On account of this problem a differential amplifier was used, which allows to ignore effectively the common signal between the negative and positive leads from the user (the common signal being the less noise). A INA2321 Burr-Brown, low-power instrumentation amplifier was used. we aimed to set to ten by a resistor (5.55k) in the stage with single-ended output. A simple RC high-pass filter was used to block any DC bias.

3.2.3 Microcontroller

The microcontroller which was used in this application was a PIC16F876A (figure 3.7) and it is responsible for converting of analog to digital (ADC), data packaging and transceiver. The main features of used microcontroller are:

- Synchronous Serial Port with SPI.
- In circuit programming via RS232.
- 10 bit ADC.
- Universal Synchronous Asynchronous Receiver Transmitter (USART).
- Low operating current < 0.6 mA.
- 3 timers.
- Simple (35 single word instructions to learn).

The mplifier ECG signal is fed into the on-board ADC of the PIC. The PIC provides 10-bit resolution. Each of three analog leads had their own ADC channel and are sampled sequentially in figure 3.7. A designed and applied analog to digital conversion board is demonstrated in Figure 3.8.

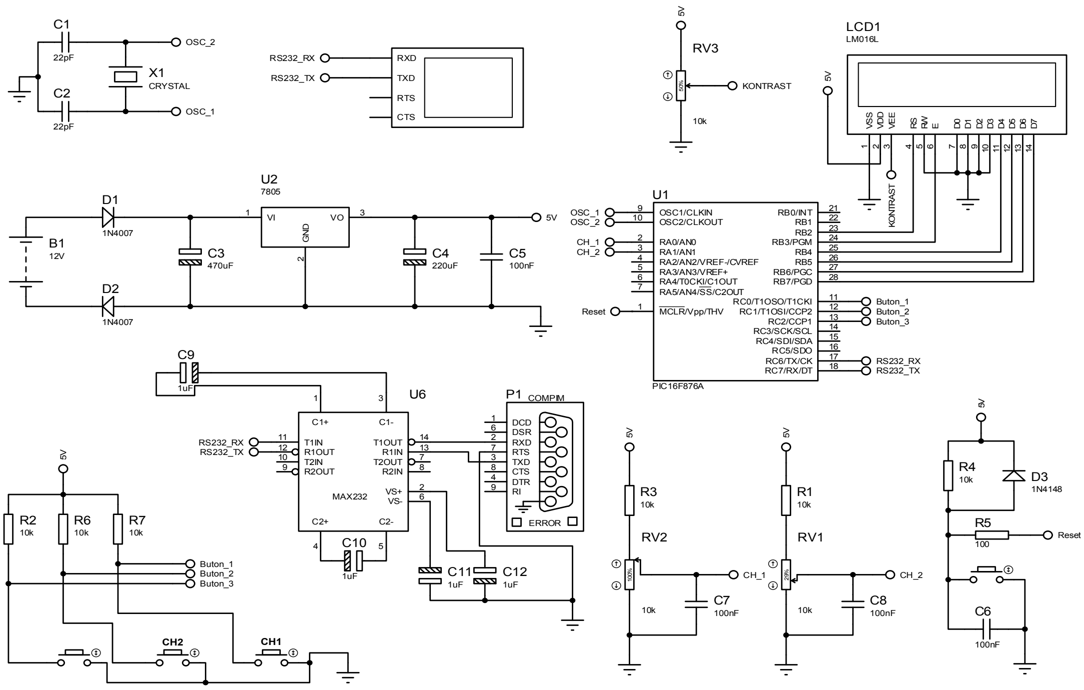

Fig.3.7 Analog to digital conversion - schematic

Fig.3.8 PIC 16F876A analog to digital conversion board with the RS232 module

3.2.4 **Software System**

The software program is based on the design of two parts. First, to get a ECG signal with in the Micro Controller PIC16F876a, and the second was used the interface a Graphic Unit Interface by the patient.

3.2.5 Software Microcontroller

The case Calculation of method consists of each minute of a cardiovascular of person. Needed to amplify the signal and step filtration devices to eliminate the noise. Has been investigated several algorithms to choose the method for the microcontroller is best fit [17, 18]. The pulse of QRS can be detected his higher energy heart and pulse can be detected all branches of 5 to 6 zeros crossing signal. The statistical computation is taken by reference value. The heart rate in normal adult is 70 and 90 beats in range, but the enfant range is 100 and 170 beats per minute in at rest[19]

CHAPTER IV

SIMULATION

4.1 ECG simulation using Visual Basic

We designed a Visual Basic based simulator which is able to produce normal lead II ECG waveform. The main advantages of the ECG simulator are time saving and removing the difficulties of taking real ECG signals with invasive and noninvasive. This ECG simulator performs analyzing and studying normal and abnormal ECG waveforms without actually using the ECG machine.

4.2 Significant features of ECG waveform

A typical scalar electrocardiographic lead which represented by significant features of the waveform; P Q R S and T waves and time intervals in millisecond, marked by P-R,S-T, and Q-T intervals which represents each wave duration is shown in figuer 4.1.

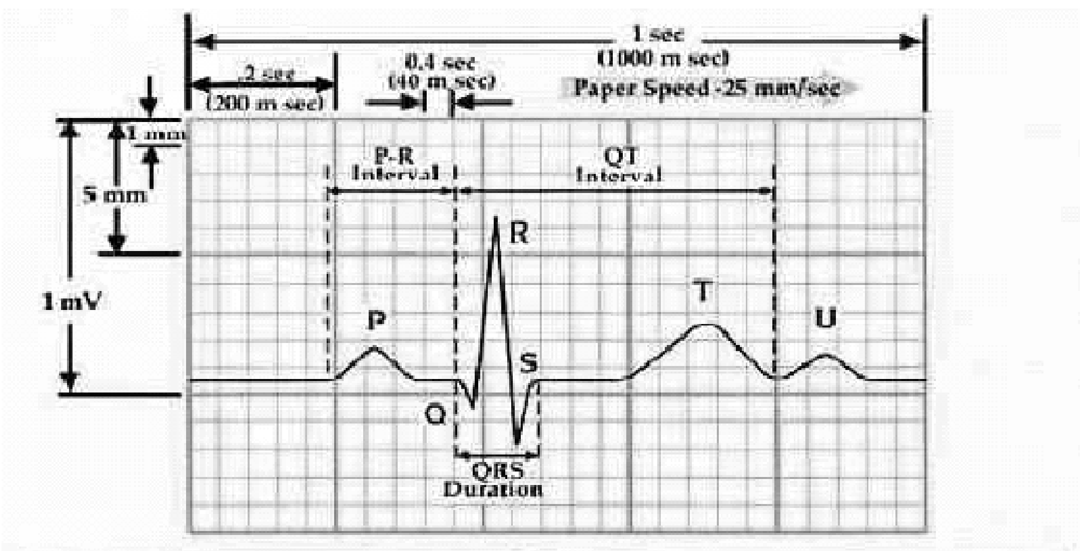

fig 4.1 Typical ECG signal

Main features of this simulator:

- Any value of heart beat can be set
- Noise due to the electrodes can be simulated
- 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
- Heart pulse of the particular ECG wave form can be represented in a separate Graph

4.3 Problems with ECG Amplification

In testing the ECG amplifier once it had been soldered onto the circuit board in comparison to testing it on the breadboard, it was found that the soldered circuit produced atypical results. The amplitudes of the waveforms generated by the soldered circuit were smaller -1.5V compared to 4.5V of the breadboard version.

This could be the result of a damaged op-amp. This, however, could also be potentially seen as a benefit in that if a lead has an unusually good connection to the patient's body, the device would still be able to operate functionally.

4.3.1 Receiving the Data

The data is received through the serial port using COMM 2 at a baud rate of 115.2 kbps in 500us intervals. The application receives the data for the three leads of the ECG signal continuously in the following order: Lead I data byte, Lead II data byte, Lead III, data byte. As the data is received, the appropriate display area is updated.

4.3.2 X-Plot

The display is meant to behave as an oscilloscope although limited in functionality. To observe the ECG signal moving in time from the left to right, the x-coordinate is incremented with each new data value received. A “scale factor” controls the rate that the screen is refreshed. Horizontal scaling provides a means of controlling the number of pulses displayed. The person observing the signal has limited control over how long it. Takes the ECG signal to pan the width of the display through a scroll bar located directly beneath the display. The horizontal range was chosen to be able to display 2 beats. Heart rates can vary between 40 and 240 beats per minute or 1.5 and 0.25 seconds per beat respectively so the refresh rate was chosen to vary between 0.125 sec and 3 sec. To achieve refresh rates wihthin 0.125 sec and 3 sec, the display width was set to be between 500 and 6000 pixels. The scroll bar controls this “scale factor”

4.3.3 Y-Plot

The y-coordinate is obtained directly from the incoming data. Since the incoming data is within the range of 0 to 255, the vertical scaling for each lead translates to the same range.

Part list

Components used with current prices from Elfa and Farnell.[20][21]

Type	Value	Qty.	Single price	Price
HM-TR433-TTL RF Model	-	1	28.000$	28.00 $
HM-TR433-RS232 RF Model	-	1	34.000$	34.00 $
ANTENNA	SAA100N	2	2.810 $	5.62 $
Integrated circuits (IC)	INA2321EA	1	7.000 $	7.00 $
Operations Amplifier	2336PA	1	2.820 $	2.82 $
Operations Amplifier	336UA	2	3.000$	6.00 $
Integrated circuits (IC) PIC	16F876A	1	8.000 $	8.00 $
Integrated circuits(IC)	MAX232	1	0.550 $	0.55 $
Character LCD	2x16	1	0.280 $	0.28 $
Voltage regulator	LM7805	1	0.280 $	0.28 $
Capacitor	100nF	11	0.001 $	0.011 $
Capacitor	1uF	6	0.001 $	0.006 $
Capacitor	470uF	1	0.001$	0.001 $
Capacitor	220uF	2	0.001 $	0.002 $
Capacitor	47uF+10 uF	2	0.001 $	0.002 $
Capacitor	22pF	2	0.001 $	0.002 $
Crystal	20MHz	1	0.017$	0.27 $

Diode	1N4007	2	0.001$	0.002 $
Diode	1N4148	3	0.001$	0.003 $
Diode	1N4001	1	0.001$	0.001 $
Transistor	BC550	1	0.010$	0.010 $
Transistor	BC547	1	0.010$	0.010 $
Resistance	22kΩ+68k Ω	4	0.001$	0.004 $
Resistance	18kΩ+8.2k Ω	2	0.001$	0.002 $
Resistance	10kΩ+39k Ω	13	0.001$	0.013 $
Resistance	100Ω+470Ω	2	0.001$	0.002 $
Resistance	1M+100k Ω	4	0.001$	0.004 $
Resistance	1k Ω +560k Ω	2	0.001$	0.002 $
Potansiyometre	10kΩ	5	0.010$	0.050 $
Fuse	1A	1	0.010$	0.010 $
Button	-	4	0.010 $	0.040 $
Switch	-	1	0.001$	0.001 $
DC Jack	-	5	0.001$	0.005 $
D-SUB connector 9 Pin	-	2	0.010$	0.020 $
Green and Red LED	-	3	0.001$	0.003 $
Board copper electronic	-	1	1.100$	0.100 $
	TOTAL		**93.126 $**	

CHAPTER V

Results and Conclusion

The result of the present project revealed that. The capable of prototype recording and presenting of 3 channel in ECG continuous of tests in real situation suited for the use of purposes in statistical. When record ECG levels of magnitudes is normal, 0-2mV, within 0-3Vin output. Implementation of visualization and analysis software were done on the On the personal server module The facilities software are Visual Basic for ECG waveforms; the patient's parameters is received sensors displays; the commands and medical decisions of the patient is must be sends. The example, For ECG amplifier samples two leads is 250 Hz in each at a frequency.

The filtered raw data with a low- pas - filter to high frequency eliminate and movement artifacts. A significant part of the most ECG analysis systems, is shown in figure 5.1, which constitutes the recognition of the ECG waves in process & applications is performed to rhythm detection, the R wave is required only location.find and recognize the ECG signal necessary In other applications, the P and T waves, or segment of ST, necessary in automated classification and diagnosis.

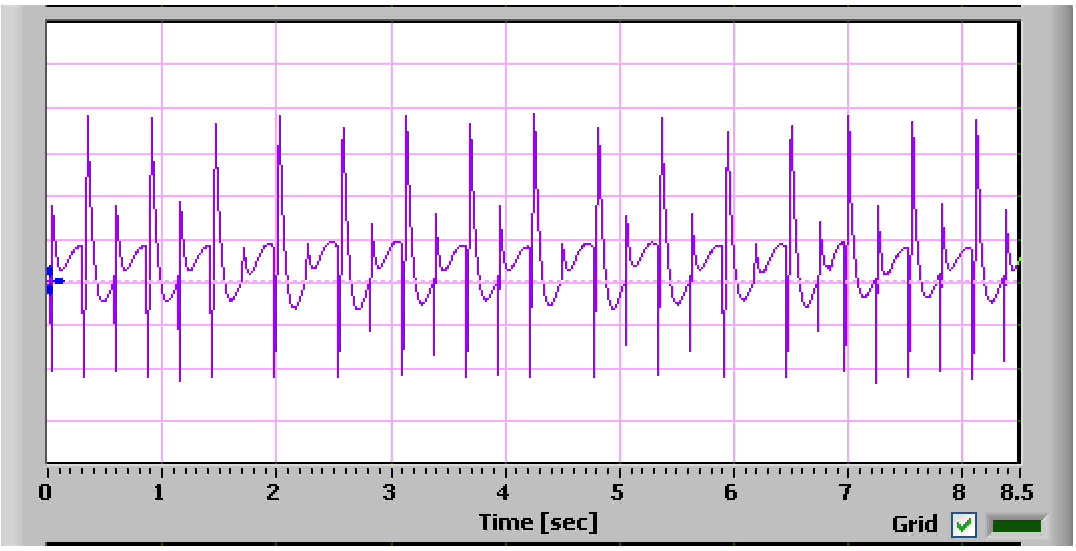

Fig. 5.1 – PQRST waves and location important points.

After that, the wave's amplitudes and shapes is easy to determine. Finding the exact location of the waves is to first filter the ECG signal is important strategy to recognize QRS complex, the finally is recognized the T wave and P wave, is amplitude in smallest to wave. We must computed baseline and the ST segment.

The wearable ECG wireless system in beginning of project to achieved the objectives. The ECG system has ability to detect an ECG signal. To wireless transmission we amplified required level and can gather information about the cardiac rhythm and rate. By utilizing a power supply that requires a 9 volts two battery the ECG system is portable. The use of low power instrumentation amplifiers has allowed the system to become power efficient.

This filter (first order RC) the ECG system has suppressed some of the high end frequencies of the ECG waveform but as shown in result, this has not affected the ECG adversely. The main QRS complex is even visible after transmission via the wireless module. The output voltage from the ECG is detected by the wireless transmitter which is crucial if we want to transmit the signal. Most of the 60Hz noise is removed in the ECG due to the shielding in the short electrode wires as well as the instrumentation amplifiers. There are no motion artifacts mainly due to the short electrode wires.

Recommendations

- Replacement of the silver electrodes with the new insulated bioelectrodes.
- The project may need improvement like reducing the system noise and excluding the electrode wires which can be achieved by combination of both electrodes to use a single electrode with a separated distance 3 cm located on the chest of the patient.
- Change the passive low pass filter with a notch filter at 60Hz.
- Use of an expensive and new instrumentation amplifier in further projects to accompany with new technology development.

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[20] https://www.elfa.se/elfa3/StartPage.do

[21] http://se.farnell.com/texas-instruments

Extension

Firmware

Listed below is the PIC C CODE program listing.

```
//////// Standard Header file for the PIC16F876A device ////////////////

#device PIC16F876A

#nolist

//////// Program memory: 8192x14  Data RAM: 367  Stack: 8

//////// I/O: 22   Analog Pins: 5

//////// Data EEPROM: 256

//////// C Scratch area: 77   ID Location: 2000

//////// Fuses: LP,XT,HS,RC,NOWDT,WDT,NOPUT,PUT,PROTECT,DEBUG,NODEBUG

//////// Fuses:
NOPROTECT,NOBROWNOUT,BROWNOUT,LVP,NOLVP,CPD,NOCPD,WRT_50%

//////// Fuses: NOWRT,WRT_25%,WRT_5%

////////

////////////////////////////////////////////////////////////////// I/O

// Discrete I/O Functions: SET_TRIS_x(), OUTPUT_x(), INPUT_x(),

//                         PORT_x_PULLUPS(), INPUT(),

//                         OUTPUT_LOW(), OUTPUT_HIGH(),

//                         OUTPUT_FLOAT(), OUTPUT_BIT()

// Constants used to identify pins in the above are:

#define PIN_A0  40

#define PIN_A1  41

#define PIN_A2  42

#define PIN_A3  43
```

```
#define PIN_A4  44

#define PIN_A5  45

#define PIN_B0  48

#define PIN_B1  49

#define PIN_B2  50

#define PIN_B3  51

#define PIN_B4  52

#define PIN_B5  53

#define PIN_B6  54

#define PIN_B7  55

#define PIN_C0  56

#define PIN_C1  57

#define PIN_C2  58

#define PIN_C3  59

#define PIN_C4  60

#define PIN_C5  61

#define PIN_C6  62

#define PIN_C7  63

//////////////////////////////////////////////////////////////////// Useful defines

#define FALSE 0

#define TRUE 1

#define BYTE int8

#define BOOLEAN int1

#define getc getch
```

```
#define fgetc getch

#define getchar getch

#define putc putchar

#define fputc putchar

#define fgets gets

#define fputs puts

/////////////////////////////////////////////////////////////////// Control

// Control Functions:  RESET_CPU(), SLEEP(), RESTART_CAUSE()

// Constants returned from RESTART_CAUSE() are:

#define WDT_FROM_SLEEP  3

#define WDT_TIMEOUT     11

#define MCLR_FROM_SLEEP 19

#define MCLR_FROM_RUN   27

#define NORMAL_POWER_UP 25

#define BROWNOUT_RESTART 26

/////////////////////////////////////////////////////////////////// Timer 0

// Timer 0 (AKA RTCC)Functions: SETUP_COUNTERS() or SETUP_TIMER_0(),

//                              SET_TIMER0() or SET_RTCC(),

//                              GET_TIMER0() or GET_RTCC()

// Constants used for SETUP_TIMER_0() are:

#define RTCC_INTERNAL   0

#define RTCC_EXT_L_TO_H 32

#define RTCC_EXT_H_TO_L 48

#define RTCC_DIV_1      8
```

```
#define RTCC_DIV_2      0

#define RTCC_DIV_4      1

#define RTCC_DIV_8      2

#define RTCC_DIV_16     3

#define RTCC_DIV_32     4

#define RTCC_DIV_64     5

#define RTCC_DIV_128    6

#define RTCC_DIV_256    7

#define RTCC_8_BIT      0

// Constants used for SETUP_COUNTERS() are the above

// constants for the 1st param and the following for

// the 2nd param:

////////////////////////////////////////////////////////////////// WDT

// Watch Dog Timer Functions: SETUP_WDT() or SETUP_COUNTERS() (see above)

//                         RESTART_WDT()

// WDT base is 18ms

//

#define WDT_18MS        0x8008

#define WDT_36MS        9

#define WDT_72MS       10

#define WDT_144MS      11

#define WDT_288MS      12

#define WDT_576MS      13

#define WDT_1152MS     14
```

```
#define WDT_2304MS     15

////////////////////////////////////////////////////////////////// Timer 1

// Timer 1 Functions: SETUP_TIMER_1, GET_TIMER1, SET_TIMER1

// Constants used for SETUP_TIMER_1() are:

//      (or (via |) together constants from each group)

#define T1_DISABLED         0

#define T1_INTERNAL         0x85

#define T1_EXTERNAL         0x87

#define T1_EXTERNAL_SYNC    0x83

#define T1_CLK_OUT          8

#define T1_DIV_BY_1         0

#define T1_DIV_BY_2         0x10

#define T1_DIV_BY_4         0x20

#define T1_DIV_BY_8         0x30

////////////////////////////////////////////////////////////////// Timer 2

// Timer 2 Functions: SETUP_TIMER_2, GET_TIMER2, SET_TIMER2

// Constants used for SETUP_TIMER_2() are:

#define T2_DISABLED         0

#define T2_DIV_BY_1         4

#define T2_DIV_BY_4         5

#define T2_DIV_BY_16        6

////////////////////////////////////////////////////////////////// CCP

// CCP Functions: SETUP_CCPx, SET_PWMx_DUTY

// CCP Variables: CCP_x, CCP_x_LOW, CCP_x_HIGH
```

```
// Constants used for SETUP_CCPx() are:
#define CCP_OFF                         0
#define CCP_CAPTURE_FE                  4
#define CCP_CAPTURE_RE                  5
#define CCP_CAPTURE_DIV_4               6
#define CCP_CAPTURE_DIV_16              7
#define CCP_COMPARE_SET_ON_MATCH        8
#define CCP_COMPARE_CLR_ON_MATCH        9
#define CCP_COMPARE_INT                 0xA
#define CCP_COMPARE_RESET_TIMER         0xB
#define CCP_PWM                         0xC
#define CCP_PWM_PLUS_1                  0x1c
#define CCP_PWM_PLUS_2                  0x2c
#define CCP_PWM_PLUS_3                  0x3c
long CCP_1;
#byte   CCP_1    =                  0x15
#byte   CCP_1_LOW=                  0x15
#byte   CCP_1_HIGH=                 0x16
long CCP_2;
#byte   CCP_2    =                  0x1B
#byte   CCP_2_LOW=                  0x1B
#byte   CCP_2_HIGH=                 0x1C
//////////////////////////////////////////////////////////////////// SPI
// SPI Functions: SETUP_SPI, SPI_WRITE, SPI_READ, SPI_DATA_IN
```

```
// Constants used in SETUP_SPI() are:

#define SPI_MASTER       0x20

#define SPI_SLAVE        0x24

#define SPI_L_TO_H       0

#define SPI_H_TO_L       0x10

#define SPI_CLK_DIV_4    0

#define SPI_CLK_DIV_16   1

#define SPI_CLK_DIV_64   2

#define SPI_CLK_T2       3

#define SPI_SS_DISABLED  1

#define SPI_SAMPLE_AT_END 0x8000

#define SPI_XMIT_L_TO_H  0x4000

////////////////////////////////////////////////////////////////// UART

// Constants used in setup_uart() are:

// FALSE - Turn UART off

// TRUE  - Turn UART on

#define UART_ADDRESS           2

#define UART_DATA              4

////////////////////////////////////////////////////////////////// COMP

// Comparator Variables: C1OUT, C2OUT

// Constants used in setup_comparator() are:

#define A0_A3_A1_A3  0xfff04

#define A0_A3_A1_A2_OUT_ON_A4_A5  0xfcf03

#define A0_A3_A1_A3_OUT_ON_A4_A5  0xbcf05
```

```
#define NC_NC_NC_NC  0x0ff07

#define A0_A3_A1_A2  0xfff02

#define A0_A3_NC_NC_OUT_ON_A4  0x9ef01

#define A0_VR_A1_VR 0x3ff06

#define A3_VR_A2_VR 0xcff0e

#define CP1_INVERT  0x0000010

#define CP2_INVERT  0x0000020

#bit C1OUT = 0x9c.6

#bit C2OUT = 0x9c.7

////////////////////////////////////////////////////////////////// VREF

// Constants used in setup_vref() are:

//

#define VREF_LOW  0xa0

#define VREF_HIGH 0x80

// Or (with |) the above with a number 0-15

#define VREF_A2   0x40

////////////////////////////////////////////////////////////////// ADC

// ADC Functions: SETUP_ADC(), SETUP_ADC_PORTS() (aka SETUP_PORT_A),

//               SET_ADC_CHANNEL(), READ_ADC()

// Constants used for SETUP_ADC() are:

#define ADC_OFF              0            // ADC Off

#define ADC_CLOCK_DIV_2   0x10000

#define ADC_CLOCK_DIV_4    0x4000

#define ADC_CLOCK_DIV_8    0x0040
```

```
#define ADC_CLOCK_DIV_16   0x4040
#define ADC_CLOCK_DIV_32   0x0080
#define ADC_CLOCK_DIV_64   0x4080
#define ADC_CLOCK_INTERNAL 0x00c0           // Internal 2-6us
// Constants used in SETUP_ADC_PORTS() are:
#define NO_ANALOGS                    7    // None
#define ALL_ANALOG                    0    // A0 A1 A2 A3 A4
#define AN0_AN1_AN2_AN4_VSS_VREF          3    // A0 A1 A2 A4 VRefh=A3
#define AN0_AN1_AN3                   4    // A0 A1 A3
#define AN0_AN1_VSS_VREF                  5    // A0 A1 VRefh=A3
#define AN0_AN1_AN4_VREF_VREF          0x08    // A0 A1 A4 VRefh=A3 VRefl=A2
#define AN0_AN1_VREF_VREF              0x0D    // A0 A1 VRefh=A3 VRefl=A2
#define AN0                        0x0E    // A0
#define AN0_VREF_VREF                  0x0F    // A0 VRefh=A3 VRefl=A2
#define ANALOG_RA3_REF        0x1        //!old only provided for compatibility
#define RA0_RA1_RA3_ANALOG     0x4        //!old only provided for compatibility
#define RA0_RA1_ANALOG_RA3_REF 0x5        //!old only provided for compatibility
#define ANALOG_RA3_RA2_REF            0x8   //!old only provided for compatibility
#define RA0_RA1_ANALOG_RA3_RA2_REF      0xD   //!old only provided for compatibility
#define RA0_ANALOG                  0xE   //!old only provided for compatibility
#define RA0_ANALOG_RA3_RA2_REF         0xF   //!old only provided for compatibility
// Constants used in READ_ADC() are:
#define ADC_START_AND_READ     7   // This is the default if nothing is specified
#define ADC_START_ONLY        1
```

```
#define ADC_READ_ONLY          6

//////////////////////////////////////////////////////////////////// INT

// Interrupt Functions: ENABLE_INTERRUPTS(), DISABLE_INTERRUPTS(),

//                      CLEAR_INTERRUPT(), INTERRUPT_ACTIVE(),

//                      EXT_INT_EDGE()

//

// Constants used in EXT_INT_EDGE() are:

#define L_TO_H              0x40

#define H_TO_L                 0

// Constants used in ENABLE/DISABLE_INTERRUPTS() are:

#define GLOBAL                    0x0BC0

#define INT_RTCC                  0x0B20

#define INT_RB                    0xFF0B08

#define INT_EXT                   0x0B10

#define INT_AD                    0x8C40

#define INT_TBE                   0x8C10

#define INT_RDA                   0x8C20

#define INT_TIMER1                0x8C01

#define INT_TIMER2                0x8C02

#define INT_CCP1                  0x8C04

#define INT_CCP2                  0x8D01

#define INT_SSP                   0x8C08

#define INT_BUSCOL                0x8D08

#define INT_EEPROM                0x8D10
```

```
#define INT_TIMER0              0x0B20

#define INT_COMP                0x8D40

#list
```

Listed below is the Visual Basic code program listing

```
Dim l, t, f, s, low, high, d, n, cx, cy As Integer

Dim X1, X2, Y1, Y2 As Integer

Dim mat(10000)   As Double

Private Sub Command1_Click()

'Picture1.Scale (0, 5)-(1000, -5)

Picture1.FillColor = &H4000&

Picture1.Line (0, 0)-(X2, 0)

Dim y, n, x As Integer

y = Y2

For n = 1 To 10

Picture1.Line (0, y)-(X2, y), RGB(25, 215, 255)

y = y + Y1 / 5

Next n

Picture1.Line (0, 0)-(X2, 0), RGB(20, 220, 20)

n = 0

x = X1

For n = 1 To 10

Picture1.Line (x, Y1)-(x, Y2), RGB(25, 215, 255)

x = x + X2 / 10

Next n
```

```
End Sub

Private Sub Command4_Click()

If Timer1.Enabled = False Then

Timer1.Enabled = True

n = 1

If MSComm1.PortOpen = False Then

MSComm1.PortOpen = True

End If

Command4.BackColor = &HC0FFC0

Else

Timer1.Enabled = False

If MSComm1.PortOpen = True Then

MSComm1.PortOpen = False

End If

Command4.BackColor = &HC0C0C0

End If

End Sub

Private Sub Form_Load()

f = 0

X1 = 0

Y1 = VScroll1.Value

X2 = Val(HScroll1.Value) / 2

Y2 = -1 * VScroll1.Value

Picture1.Scale (0, VScroll1.Value)-(Val(HScroll1.Value) / 2, -VScroll1.Value)
```

```
End Sub

Private Sub optenable_Click()

'Enable Port

If MSComm1.PortOpen = False Then

MSComm1.PortOpen = True

End If

End Sub

Private Sub cmdExit_Click()

If MSComm1.PortOpen = True Then

MSComm1.PortOpen = False

End If

Close (1)

End

End Sub

Private Sub HScroll1_Change()

Timer1.Interval = HScroll1.Value

X1 = 0

Y1 = VScroll1.Value

X2 = Val(HScroll1.Value) / 2

Y2 = -1 * VScroll1.Value

Picture1.Scale (0, VScroll1.Value)-(Val(HScroll1.Value) / 2, -VScroll1.Value)

End Sub

Private Sub Picture1_MouseMove(Button As Integer, Shift As Integer, x As Single, y As Single)

Text6.Text = "T=" & Int(x * 10) / 10 & "      V= " & Int(y * 10) / 10
```

```
End Sub

Private Sub Timer1_Timer()

'   =========  Grid ++++++++++

Picture1.Cls

Picture1.Line (0, 0)-(X2, 0), RGB(0, 0, 0)

Picture1.PSet (0, 0)

'%%%%%%%%%%%%%%%%%%%%%

 cx = 1

 n = 0

'Open "C:\ECG\n" & n & ".txt" For Output As #1

txtinput.Text = ""

If MSComm1.PortOpen = False Then

MSComm1.PortOpen = True

End If

txtinput.Text = MSComm1.Input

If txtinput.Text = "" Then

Text5.Text = "0000"

GoTo 10

End If

l = Len(txtinput)

Text3.Text = l

For i = 3 To l Step 2

mat(i) = Asc(Mid(txtinput, i, 1))

Text2.Text = (mat(i))
```

```
mat(i + 1) = Asc(Mid(txtinput, (i + 1), 1))
Text4.Text = Asc(Mid(txtinput, (i + 1), 1))
low = mat(i)
high = mat(i + 1)
s = (high) And 8
high = (high) And 7
If s = 8 Then
Text5.Text = (high * 256) + low
End If
If s <> 8 Then
Text5.Text = -1 * 2047 + ((mat(i + 1) * 256) + mat(i))
End If
Text1.Text = Int(Text5.Text * 0.24) / 100
'Print #1, Text1.Text
'Print #1, Text1.Text
Picture1.Line -(n, Text1.Text), RGB(255, 0, 0)
cy = Val(Text1.Text)
n = n + 1
Next i
'Print #1, 5
'Print #1, -5
'Close (1)
'If n = 11 Then
'n = 1
```

```
'End If

10

End Sub

Private Sub VScroll1_Change()

X1 = 0

Y1 = VScroll1.Value

X2 = Val(HScroll1.Value) / 2

Y2 = -1 * VScroll1.Value

Picture1.Scale (0, VScroll1.Value)-(Val(HScroll1.Value) / 2, -VScroll1.Value)

End Sub
```

Listed below is the MATLAB program listing

P_ wave

```
function [pwav]=p_wav(x,a_pwav,d_pwav,t_pwav,li)
l=li;
a=a_pwav;
x=x+t_pwav;
b=(2*l)/d_pwav;
n=100;
p1=1/l;
p2=0;
for i = 1:n
    harm1=(((sin((pi/(2*b))*(b-(2*i))))/(b-
(2*i))+(sin((pi/(2*b))*(b+(2*i))))/(b+(2*i)))*(2/pi))*cos((i*pi*x)/l);
    p2=p2+harm1;
end
pwav1=p1+p2;
pwav=a*pwav1;
```

Q _ wave

```
function [qwav]=q_wav(x,a_qwav,d_qwav,t_qwav,li)
l=li;
x=x+t_qwav;
a=a_qwav;
b=(2*l)/d_qwav;
n=100;
q1=(a/(2*b))*(2-b);
q2=0;
for i = 1:n
    harm5=(((2*b*a)/(i*i*pi*pi))*(1-cos((i*pi)/b)))*cos((i*pi*x)/l);
    q2=q2+harm5;
end
qwav=-1*(q1+q2);
```

QRS _ wave

```
function [qrswav]=qrs_wav(x,a_qrswav,d_qrswav,li)
l=li;
a=a_qrswav;
b=(2*l)/d_qrswav;
n=100;
qrs1=(a/(2*b))*(2-b);
qrs2=0;
for i = 1:n
    harm=(((2*b*a)/(i*i*pi*pi))*(1-cos((i*pi)/b)))*cos((i*pi*x)/l);
    qrs2=qrs2+harm;
end
qrswav=qrs1+qrs2;
```

S _ Wave

```
function [swav]=s_wav(x,a_swav,d_swav,t_swav,li)
l=li;
x=x-t_swav;
a=a_swav;
b=(2*l)/d_swav;
```

```
n=100;
s1=(a/(2*b))*(2-b);
s2=0;
for i = 1:n
    harm3=(((2*b*a)/(i*i*pi*pi))*(1-cos((i*pi)/b)))*cos((i*pi*x)/l);
    s2=s2+harm3;
end
swav=-1*(s1+s2);
```

T _ Wave

```
function [twav]=t_wav(x,a_twav,d_twav,t_twav,li)
l=li;
a=a_twav;
x=x-t_twav-0.045;
b=(2*l)/d_twav;
n=100;
t1=1/l;
t2=0;
for i = 1:n
    harm2=(((sin((pi/(2*b))*(b-(2*i))))/(b-
(2*i))+(sin((pi/(2*b))*(b+(2*i))))/(b+(2*i)))*(2/pi))*cos((i*pi*x)/l);
    t2=t2+harm2;
end
twav1=t1+t2;
twav=a*twav1;
```

U _ Wave

```
function [uwav]=u_wav(x,a_uwav,d_uwav,t_uwav,li)
l=li;
a=a_uwav
x=x-t_uwav;
b=(2*l)/d_uwav;
n=100;
u1=1/l
u2=0
for i = 1:n
    harm4=(((sin((pi/(2*b))*(b-(2*i))))/(b-
(2*i))+(sin((pi/(2*b))*(b+(2*i))))/(b+(2*i)))*(2/pi))*cos((i*pi*x)/l);
    u2=u2+harm4;
end
uwav1=u1+u2;
uwav=a*uwav1;
```

Complete Matlab code

```
x=0.01:0.01:2;
default=input('Press 1 if u want default ecg signal else press 2:\n');
if(default==1)
      li=30/72;

      a_pwav=0.25;
      d_pwav=0.09;
      t_pwav=0.16;

      a_qwav=0.025;
      d_qwav=0.066;
```

```
        t_qwav=0.166;

        a_qrswav=1.6;
        d_qrswav=0.11;

        a_swav=0.25;
        d_swav=0.066;
        t_swav=0.09;

        a_twav=0.35;
        d_twav=0.142;
        t_twav=0.2;

        a_uwav=0.035;
        d_uwav=0.0476;
        t_uwav=0.433;
  else
      rate=input('\n\nenter the heart beat rate :');
      li=30/rate;

      %p wave specifications
      fprintf('\n\np wave specifications\n');
      d=input('Enter 1 for default specification else press 2: \n');
      if(d==1)
          a_pwav=0.25;
          d_pwav=0.09;
          t_pwav=0.16;
      else
         a_pwav=input('amplitude = ');
         d_pwav=input('duration = ');
         t_pwav=input('p-r interval = ');
         d=0;
      end


      %q wave specifications
      fprintf('\n\nq wave specifications\n');
      d=input('Enter 1 for default specification else press 2: \n');
      if(d==1)
          a_qwav=0.025;
          d_qwav=0.066;
          t_qwav=0.166;
      else
         a_qwav=input('amplitude = ');
         d_qwav=input('duration = ');
         t_qwav=0.166;
         d=0;
      end



      %qrs wave specifications
      fprintf('\n\nqrs wave specifications\n');
      d=input('Enter 1 for default specification else press 2: \n');
      if(d==1)
          a_qrswav=1.6;
          d_qrswav=0.11;
      else
         a_qrswav=input('amplitude = ');
```

```
        d_qrswav=input('duration = ');
        d=0;
    end



    %s wave specifications
    fprintf('\n\ns wave specifications\n');
    d=input('Enter 1 for default specification else press 2: \n');
    if(d==1)
         a_swav=0.25;
         d_swav=0.066;
         t_swav=0.09;
    else
        a_swav=input('amplitude = ');
        d_swav=input('duration = ');
        t_swav=0.09;
        d=0;
    end


    %t wave specifications
    fprintf('\n\nt wave specifications\n');
    d=input('Enter 1 for default specification else press 2: \n');
    if(d==1)
         a_twav=0.35;
         d_twav=0.142;
         t_twav=0.2;
    else
        a_twav=input('amplitude = ');
        d_twav=input('duration = ');
        t_twav=input('s-t interval = ');
        d=0;
    end


    %u wave specifications
    fprintf('\n\nu wave specifications\n');
    d=input('Enter 1 for default specification else press 2: \n');
    if(d==1)
         a_uwav=0.035;
         d_uwav=0.0476;
         t_uwav=0.433;
    else
        a_uwav=input('amplitude = ');
        d_uwav=input('duration = ');
        t_uwav=0.433;
        d=0;
    end



end

 pwav=p_wav(x,a_pwav,d_pwav,t_pwav,li);


 %qwav output
 qwav=q_wav(x,a_qwav,d_qwav,t_qwav,li);
```

```
%qrswav output
qrswav=qrs_wav(x,a_qrswav,d_qrswav,li);

%swav output
swav=s_wav(x,a_swav,d_swav,t_swav,li);


%twav output
twav=t_wav(x,a_twav,d_twav,t_twav,li);


%uwav output
uwav=u_wav(x,a_uwav,d_uwav,t_uwav,li);

%ecg output
ecg=pwav+qrswav+twav+swav+qwav+uwav;
figure(1)
plot(x,ecg);
```