NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA

DESIGN OF A PORTABLE DEVICE FOR ECG SIGNAL ACQUISITION AND ITS TRANSMISSION USING BLUETOOTH FOR DIAGNOSTIC ANALYSIS

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CERTIFICATE

This is to certify that research work embodied in this thesis entitled "*Design of a Portable Device for ECG Signal Acquisition and Its Transmission Using Bluetooth for Diagnostic Analysis*" was carried out by *Tushar Kumar Chandra* (Roll. No. 111EE0203) and *Satish Kumar Mahankuda* (Roll. No. 111EE0216) at National Institute of Technology Rourkela for partial fulfillment of the Bachelor of Technology degree in Electrical Engineering during session 2014-2015, to be awarded by the institute. This is a bonafide record of the research work carried out by them under my supervision and guidance. The candidates have fulfilled all the prescribed requirements.

The report which is based on candidates' own work, have not submitted elsewhere for a degree/diploma.

In my opinion, the work done in this project till now is satisfactory and further research on this topic should be encouraged.

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Associate Professor

Acknowledgement

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Last but not the least, the authors do not hesitate to admit that the concepts and ideas contained in the papers and books listed in the Reference section have been of immense help in writing this thesis.

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Satish Kumar Mahankuda

Abstract

In the period of developing innovation, the anticipation to live more has expanded many-a-folds. If a patient prefers to visit a doctors on a day to day basis for tests like stress level detection, ECG or blood pressure tests the expenditure becomes too high. It even gets worse in remote areas where the costly equipment for the mentioned test are not available. In this paper idea about a portable device is presented, which is meant to be a portable and easy to use medical equipment for acquiring ECG signal. The raw signal generated on the human body surface due the polarization and depolarization of heart is acquired through a hand held module and transmitted to a laptop/mobile for analysis. In this way regular health check can be done with ease**.** Using a 3 lead ECG sensors, real time data is obtained directly from the subject using a DAQ (Data Acquisition Module). Then it is transmitted using Bluetooth and microcontroller, and the final analysis and display part is done on the computer/laptop/phone. Hence a low cost, low power consuming device with higher connectivity options can make great changes in health care sector.

Table of Contents

List of figures

Chapter 1

INTRODUCTION

MOTIVATION AND OBJECTIVE OF THE THESIS

LITERATURE REVIEW

ORGANIZATION OF THE THESIS

Introduction:

With the increase in demand for easy and better access to healthcare, innovation of new and low cost products is inevitable. The major challenge for engineers is to develop the sophisticated technology which is not only easy to use, but also as productive as the conventional equipment. In order to prevent congestions in medical units and to improve the access time to health services, the technical fraternity all over the world is trying to use modern information and communication technologies for distance monitoring and informing the patients, as well as for developing low-cost medical equipment appropriate to personal and home use.

Electrocardiography (ECG) is an important part of modern day healthcare system. The patient under diagnosis requires a frequent observation of ECG activities. The body basically acts like a conductor. An ECG is a recording of the electrical activities by the heart of the subject. The various views of the heart can be recorded utilizing different electrodes.
Conventionally ECG is in the form of a *transthoracic* (across the thorax or chest) interpretation of the electrical activity of the heart over a period of time and is detected by *electrodes* attached to the surface of the skin. The data is recorded and displayed by a device external to the body. It contains the information about heart's conductions system in the form of electrical impulses/waveforms generated due to the polarization and depolarization of cardiac tissue.

The *e-Health* is an innovative concept aimed at providing medical information and support to "anyone, anytime, anywhere". *M-health* or Mobile Health systems rely on smartphones and other mobile communication devices that can be also equipped with special health sensors. Widespread use of smartphones, PCs and laptops allows the incremental addition of sensors and software to enable the users to check their health information and basic human body parameters.

To propose a feasible solution to the above scenarios, this project is designed as a product based initiative, aimed at wireless acquisition of ECG signal and makes the data available for analysis on various platforms. The *Bluetooth* is a proprietary open wireless technology. It has been used in this project in order to increase the connectivity with multiple devices. The *Arduino* is a low-cost and easily available microcontroller which is used for interfacing the analog circuit and Bluetooth module. This eliminates the requirement of costly *DAQs* (Data Acquisitions Module). Also it is expected that such devices will drastically reduce the timing of getting medical advice and enable regular observation of patient even in remote areas. The proposed design enables the compatibility of the device with any mobile device running on Android® platform and with traditional Windows® based PCs.

Motivation and Objective of the thesis

Due to the increase in the life expectancy at birth, the higher income and educational levels, the aging population and modern interconnected world, the rising demand for health and social services is one of the prevailing challenge for the research community across the globe. Currently India is ranked 150th out of 193 countries, listed in the World Bank forum, with an average life expectancy of 66.21 years.

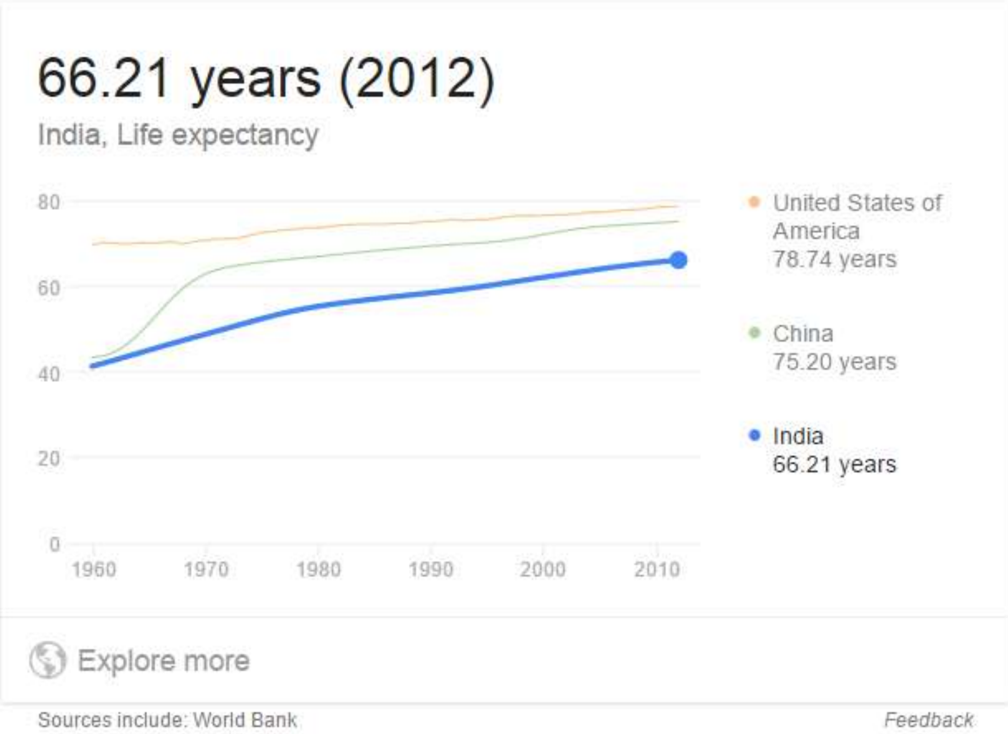


Figure 1 : Average Life expectancy of India compared to USA and China (World Bank Health Indices)

It is likely to rise to 75 years by 2050.

Also it is assumed that 40% of the Europe Union's population will be at least 65 years old by 2050. In countries like India where the total expenditure on healthcare is mere 2% of the total GDP (Figure 2), providing quality health related services at an affordable cost is a great challenge to be achieved. The scenario is similar in the developing countries. Keeping in mind the future congestion in medical units and to improve the accessibility to better health services, a general call was made by both EU (Horizon 2020) and USA for utilizing modern information and communication technologies to avail the patient with the healthcare system, without being have to physically present at the health center. This enables the distance monitoring and informing patients quite easy and affordable, all being done in real time. The same argument can be applied to the developing countries like ours, where the 'Cost' of the equipment plays the most important role for a patient to make a choice of using it or not. Hence the development of low-cost medical equipment appropriate for personal and home use is a feasible solution to the expanding healthcare problem.

ECG is one of the basic yet complex set of data about a person's heath status. Diagnostic analysis of a patient's ECG can indicate about as many as 50 diseases, besides the heart rate, blood pressure and status of the cardiac movements. Hence regular observation and availability of ECG by a patient can help to maintain a healthy body.

To make it available at a low cost and using the modern technology the possible alternative to conventional ECG acquisition device has to be developed over the existing facilities like present day wireless technologies and hosting devices. Hence the use of mobile devices and PCs with Bluetooth technology is one of the feasible application of technology in healthcare.

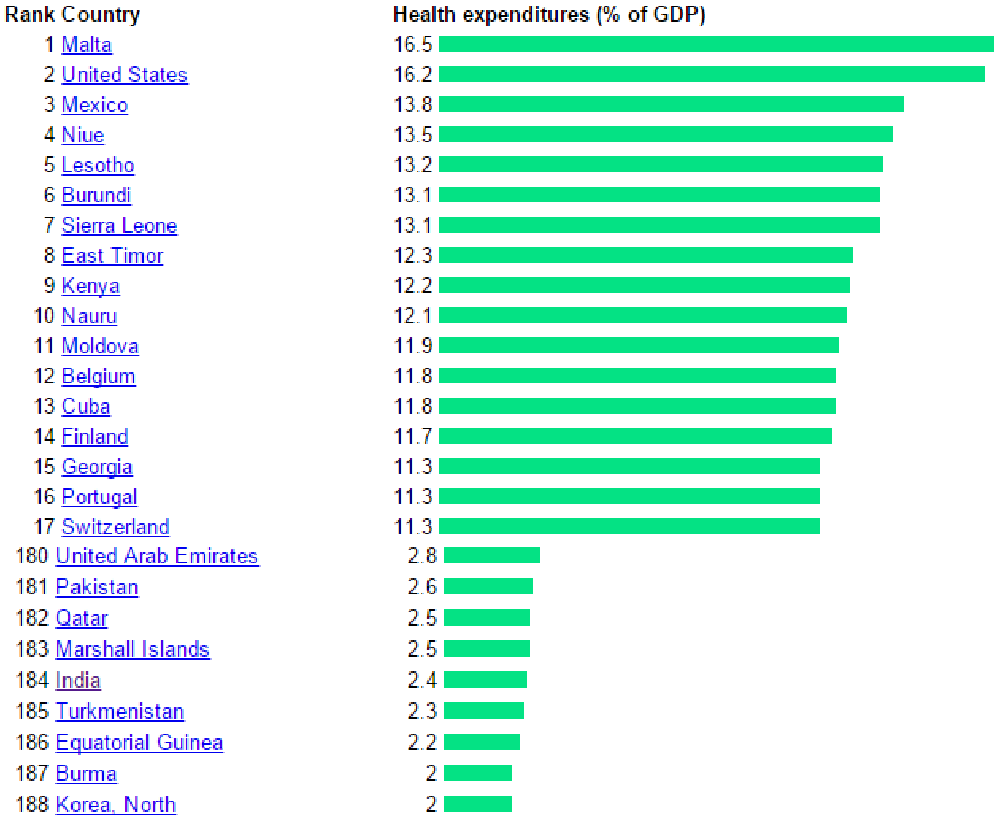


Figure 2 : Health expenditure as a percentage of GDP

The main objective of the thesis are:-

- *ECG signal acquisition from the body*
  ECG signal is generated by the nerve impulse stimulation of heart. The generated electrical current is thus diffused around the surface of the body and develops a voltage drop, which is a normally 0.0001V to 0.003V and the signals are within the frequency range of 0.05 to 100 Hz. ECG signals are always affected by *noise*, such as low frequency noise, muscle noise and electromagnetic noise.

The main challenge in *acquisition* of ECG signal is eliminating noise and amplifying the body signal in order to obtain an approximate ECG signal.

In order to *transmit* the signal wirelessly, it has to be converted into digital form and then sent through a secure and interference free channel. *Analog to Digital Conversion* at proper resolution and transmission of data at proper rate is desired in order to eliminate any kind of distortion in the received data.

Prior to sending to ADC channel of Arduino® it must be kept in mind that the input must be positive, as it will discard the negative values and make them zero. So for that the bipolar signal must be converted to unipolar signal. The main challenges in this part is that the signal must retain its linearity with no phase change, as it would be difficult to get back the original signal.

- *Wireless transmission of the signal using Bluetooth*

  Now the unipolar signal generated from the level shifter circuit is given as input to ADC of Arduino®, which will be transmitted wirelessly using Bluetooth. The main challenges here are: the rate of transmission, the rate of A/D conversion, maintaining data integrity, proper framing of digital bits to be transmitted, proximity of communication.

- *Recreation and analysis of signal from received data in real time*

  Now the final part of the work comprises of getting back the signal in the actual form as it is originally. The *regeneration* of signal requires proper retrieval of the data bits from the received frames, assembly of the bits in order to obtain the signal waveform. This is done in MATLAB and visual studio using C# in the presentable form, i.e in the stream able real time basis. The major challenges in this are making a proper GUI, and retaining the signal in original form.

Literature Review:

The increased benefit of wireless communication for medical technologies is also confirmed by numerous applications recently developed in this interdisciplinary area.

A special research interest is now devoted to *short range wireless technologies*, including radiofrequency identification (RFID), ZigBee, visible light communication (VLC), and Bluetooth systems. *RFID* are especially interesting for applications requiring low power consumption which may use even passive RFID transponders. But with RFID the noise due to interference with surrounding EM radio signals. *The Zigbee*® is a low power and low data-rate technology allowing the decentralization of a wireless ad-hoc mesh networks. It is widely used in medical data collection, especially in home patient monitoring. However, it is not implemented in hand-held devices such as mobile phones, tables, and laptops. *The VLC represents* an emerging wireless communication technologies based on remarkable progress achieved by solid state lighting devices. The use of novel *LED* can offer not only a universal solution for illumination but also provide the additional function of short-range wireless communications for illumination devices. But it is a relatively new technology which is still in research stage.

The Bluetooth is a proprietary open wireless technology suitable for use in e-Health systems because of high interconnection capabilities between sensor, medical equipment and terminal devices such as cell phones, tablets, laptops and personal computers.

For *e-Health* purpose DAQs like *LabView USB DAQ 6008*® are used in many portable application based devices. It costs a lot and can only be installed in a bigger area.

Organization of the thesis

- CHAPTER 1: This chapter contains the introduction, motivation and objective of work along with the literature review on the title of the thesis.
- CHAPTER 2: This chapter gives and insight on ECG, its types and application
- CHAPTER 3: This chapter gives the information about the process of ECG data acquisition from the subject's body and its conversion process into a transferable signal.
- CHAPTER 4: This chapter describes the transmission system used in this work. This includes the Bluetooth module, microcontroller interfacing and serial communication along with A/D conversion.
- CHAPTER 5: This chapter comprises of the media used for signal recreation and display.
- CHAPTER 6: Here, the conclusion, discussion and future work are represented

Chapter 2:

WHAT IS ECG?

HOW IS ECG MEASURED?

What is ECG?

ECG now a days has become an important part of modern day healthcare system. The patient under diagnosis requires a frequent observation of ECG activities. The body basically acts like a conductor. The so called electrical activities of the heart is recorded by the ECG i.e. electrocardiography. An ECG is used to measure the heart's electrical conduction system. It picks up impulses generated by the polarization-and-depolarization of cardiac tissues and translates them into a waveform.
Most ECGs are performed for diagnostic or research purposes on human hearts for diagnosis of heart abnormalities or for research purpose. The ECG device detects and amplifies the tiny electrical charges on the skin that are caused when the heart muscles depolarizes during each heartbeat, which is detected as tiny rises and falls in the voltage between two electrodes placed either side of the heart.

ECG Signal

The above description of ECG even makes it quite relevant to know its properties. The actual ECG signals taken from the body are of the order of millivolts and also contains a lot of noise components. So in order to work in this field it becomes very important to understand its properties. The characteristics of the ECG signal are as follows:

- The ECG signal comprises of low amplitude voltages in the vicinity of high amplitude offsets and noise.

- The extensive offsets exhibit in the framework are because of half-cell potential created at the anodes.

- Ag/AgCl (Silver-silver chloride) is the regular cathode utilized as a part of ECG frameworks and has a greatest balanced voltage of +/ - 300 mV.

- The real coveted signal is +/ - 0.5 mV superimposed on the anode balance.

- the framework additionally gets the 50 dB noise from the electrical cables which frames the basic mode signal.

- The amplitude of the electrical cable noise may be high. Along these lines, it must be separated.

Looking at a ECG tracing it consists of

- a P wave

- a QRS complex
- a T wave
- a U wave (invisible in 50-75 % of ECG)

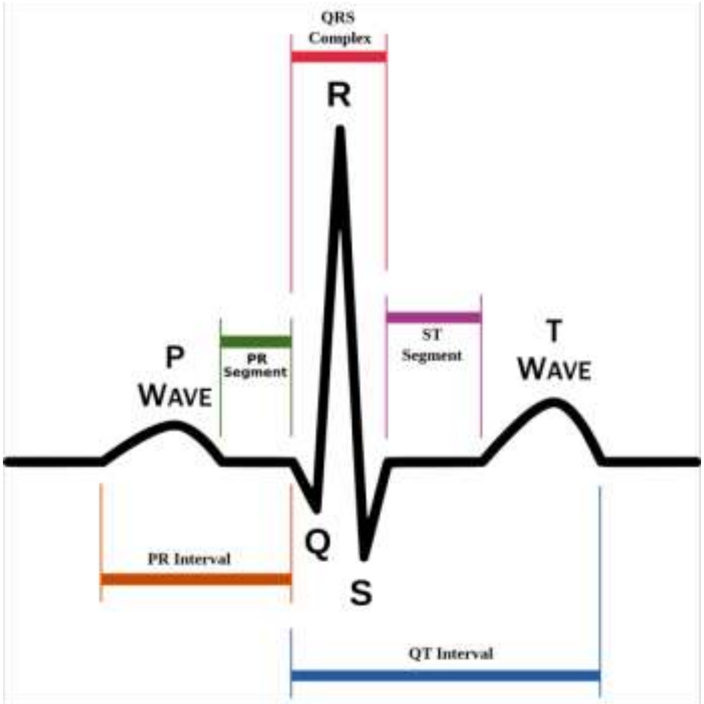


Figure 3: A typical ECG wave

Why is ECG needed?

Now after knowing the typical wave and its characteristics its importance must also be

-to check how well prescriptions are functioning and whether they are bringing on symptoms that influence the heart.

-to check the health of the heart when different sicknesses or conditions are available, for example, high B.P., high cholesterol, diabetes, and so on.

-to survey if the patient has shown some heart attack or proof of a past heart attacks.

-to watch the impacts of medicines utilized for coronary heart diseases.

-to check whether there are few minerals in the blood.

-to diagnose poor blood flow to the heart, heart attack and irregularities of the heart.

How is ECG measured?

For measurement usually more than two electrodes are used, and they can be combined into a number of pairs. The output from each pair is known as lead. Depending upon the number of leads the various types of ECG are:

1. 3 lead
2. 5 lead
3. 12 lead

The various "views" of the heart can be recorded utilizing different electrodes.

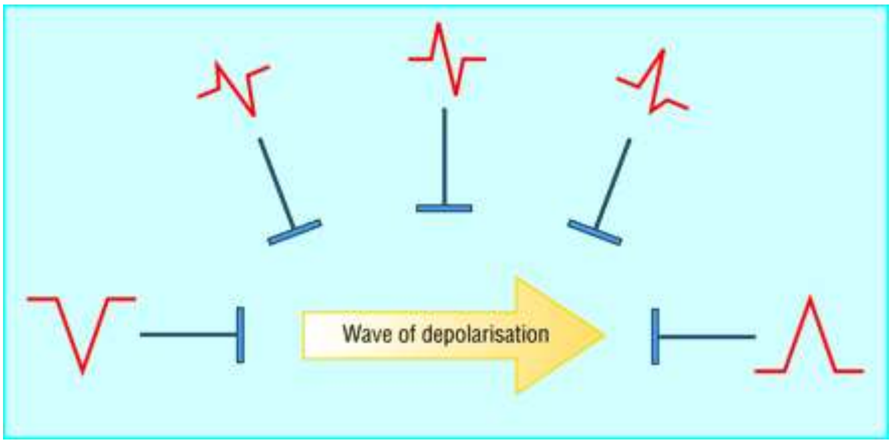
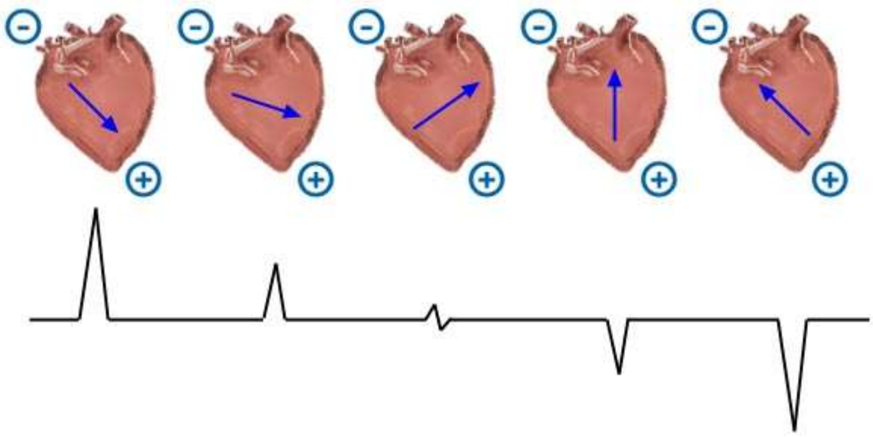


Figure 4: various views of heart

Customarily this is as a transthoracic (over the thorax or chest) translation of the electrical activity of the heart over a time of time, as detected by electrodes appended to the surface of the skin and recorded or showed by a gadget outer to the body. It contains the data about heart's conductions framework as electrical impulses/waveforms produced by the polarization and depolarization of cardiovascular tissue.

Figure 6: the current



Voltage of cardiac

Figure 5: Voltage developed in the heart

Using 3 lead Electrodes

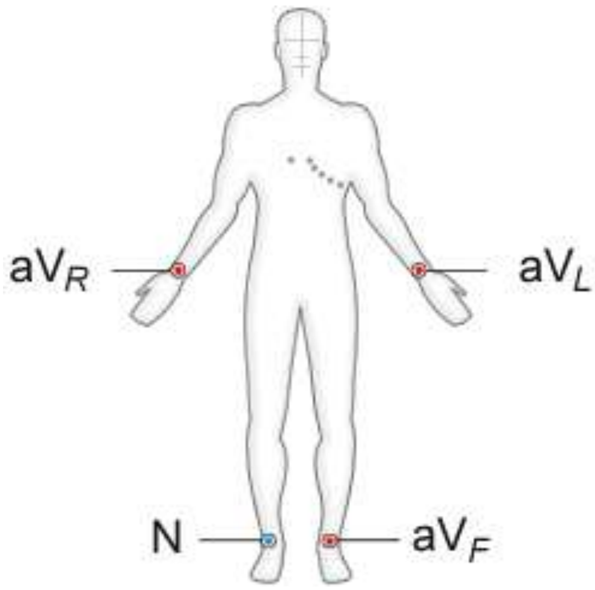


Figure 7: Electrodes position

For a 3 lead system the following analysis is done:

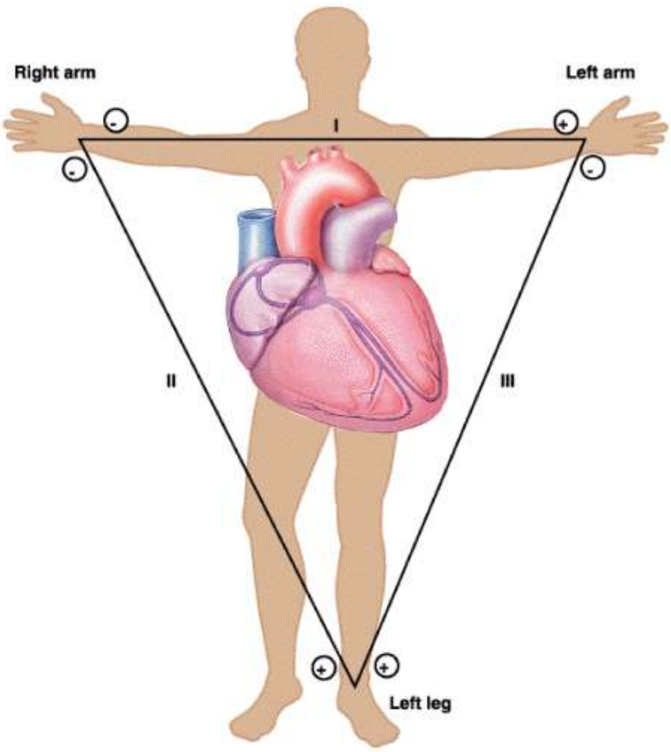


Figure 8: Positions for 3 lead connection

Lead I

LA = electrical voltages of the heart that are transmitted to the left arm

RA = electrical voltages of the heart that are transmitted to the right arm

The electrocardiograph subtracts RA from LA and the difference appears as lead I.

Lead one 'travels' horizontally.

Its left pole (LA) is positive and its right pole (RA) is negative.

Therefore, lead I = LA minus RA

Shows a positive wave when an impulses moves towards the left arm, negative wave when an impulse moves away from the left arm.

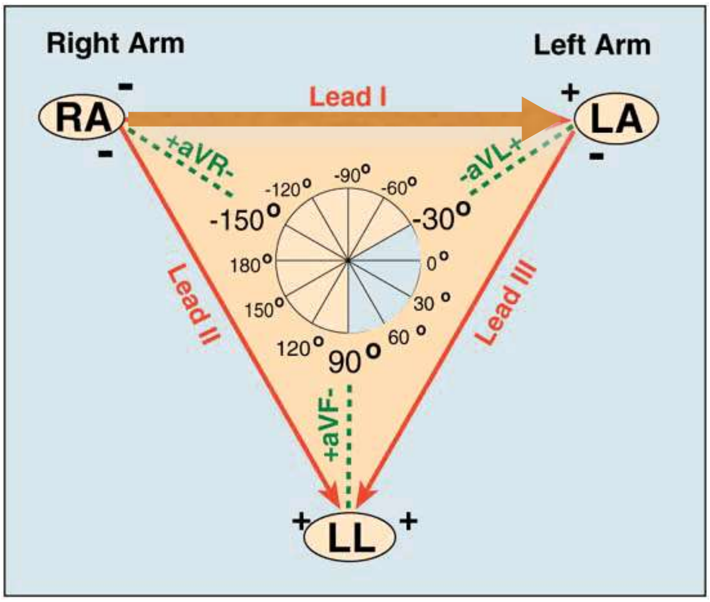


Figure 9: Lead I wave

Lead II

Lead II points downward diagonally

Lower pole (LL) is positive and upper pole (RA) is negative.

Lead II = LL minus RA

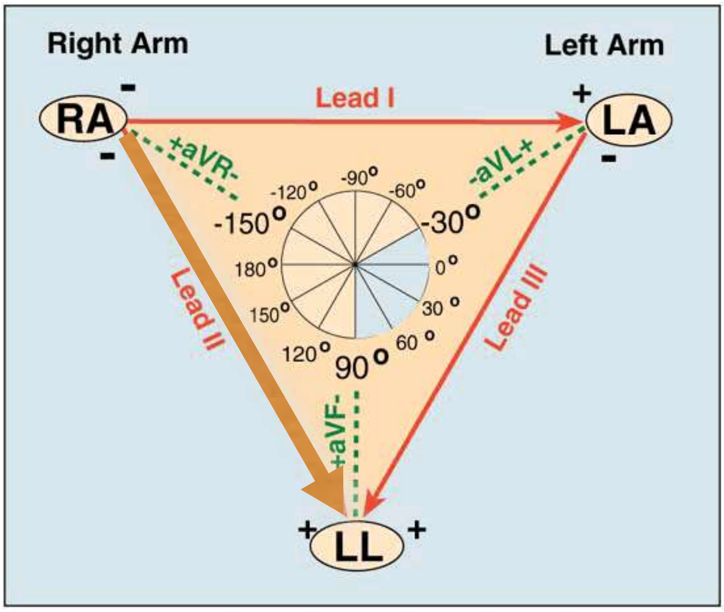


Figure 10: Lead II wave

Lead III

Lead III points downward diagonally

Lower pole (LL) is positive and upper pole (LA) is negative.

Lead III = LL minus LA

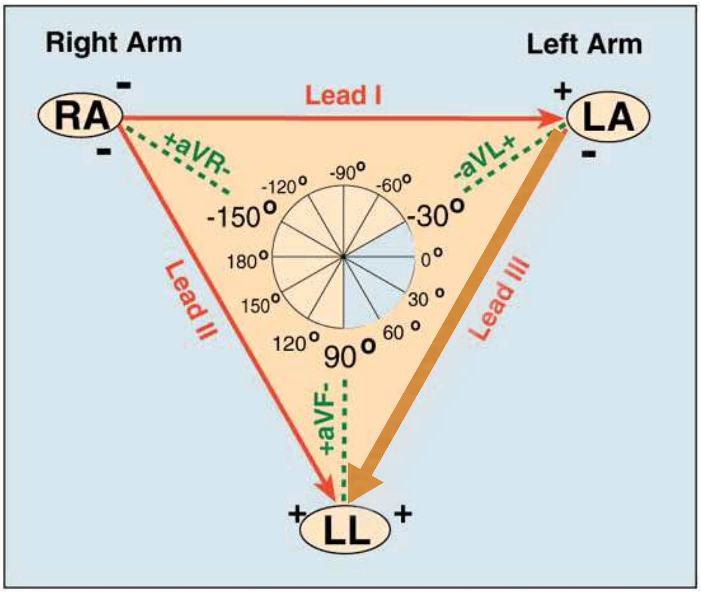


Figure 11: Lead III wav

Chapter 3:

ECG ACQUISITION CIRCUIT:

SIMULATION OF DATA ACQUISITION MODEL

CIRCUIT HARDWARE

ECG ACQUISITION FROM SUBJECT

ECG Acquisition Circuit:

The functional diagram of hardware architecture for the proposed model is:

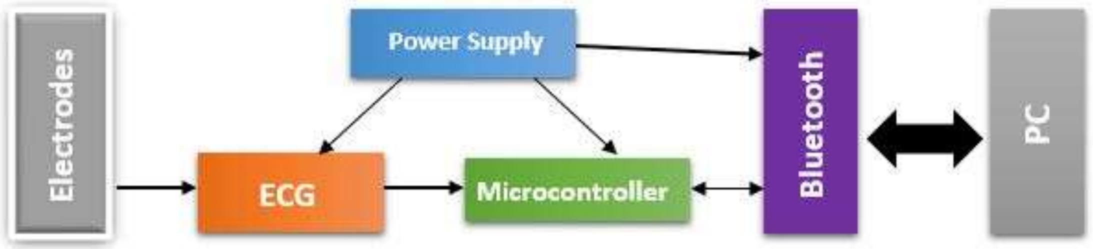


Figure 12 : Functional Diagram of Hardware architecture

Our work can be broadly classified into three main streams. Firstly we were concerned about the ECG signal acquision part. So for that we gave emphasis on developing our own circuits rather than purchasing an inbuilt sensor.

As it is already described that generally the ECG signal contains frequency range of the order of 0.5 Hz to 200 Hz. So in the Data Acquisition Circuit care must be taken to incorporate filters as well. So we require here both low pass and high pass filters. Now the circuit can be described as:

- *Use of Instrumentation Amplifier:*

Rather than using the traditional amplifiers we have used instrumentation amplifier. These have a very high common mode rejection ratio (CMRR) and high input impedance which is required for capturing ECG signals. The Analogue Devices AD620/INA 128EN was chosen for implementation in the system. These are highly-precision, low-noise, and low-power instrumentation amplifier designed primarily for use with bio-electronics. The gain in this stage was approximately 2500.

- *OPAMP based comparator*

Here again we have used OP07EN operational amplifier which are Ultra low offset voltage instrumentation OPAMPs. This helped to reduce the common-mode gain. Thus efficiency and accuracy is increased many times.

- *Design of Integrator Circuit*

Now the DC off-set from the output of the amplifier was eliminated using an integrator circuit having a cut-off frequency of 15.9 Hz.

- *Design of Low pass filter*

The low-pass filter was implemented as cascaded RC, or passive filters. The signal was band-limited using a second order passive filter having a cut-off frequency of 740 Hz (approx.). The band-limitation of the signals was also achieved this way.

Mathematical calculations:

1. The gain in the INA 128EN can be calculated by the following relation:

$$Gain = 1 + \frac{50k\Omega}{R_G}$$

Where R_G = resistance between pins 1 and 8.

$$So\ gain = 1 + \frac{50k\Omega}{20\Omega} = 2501,$$

Which is approximately equal to gain of ~2500 times.

2. The cut-off frequency of the low pass filter can be calculated by the formula:

This is a second order

$$Fc = \frac{1}{2 * \pi * RC}$$

With R=470 Ω, C= 1 μ F (1^{st} Stage)
and R=100 Ω , C=1 μ F (2^{nd} Stage)
When cascaded will have a cut-off frequency of about 742 Hz, which is large enough for the signal to pass.

3. Now to remove the DC -off set we have used an integrator:

Now for the integrator, the transfer function is given by:

$$\frac{Vo(s)}{Vi(s)} = -\frac{1}{sRC}$$

$$=> Vo(s) = -\frac{1}{sRC} Vi(s)$$

$$Giving\ the\ values\ of\ R = 100\ k\ \Omega\ and$$

$$C = 50\ n\ F,$$

$$we\ get\ the\ cut-off\ frequency\ to\ be\ about\ 15.8\ Hz$$

Simulation of Data acquisition model

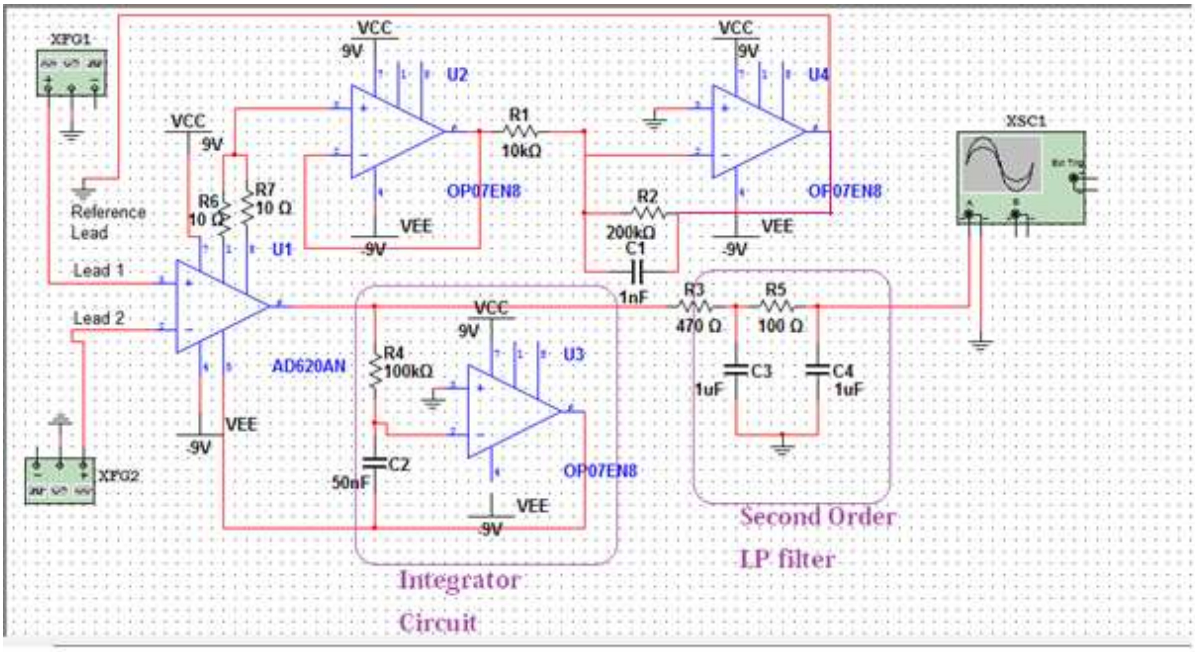
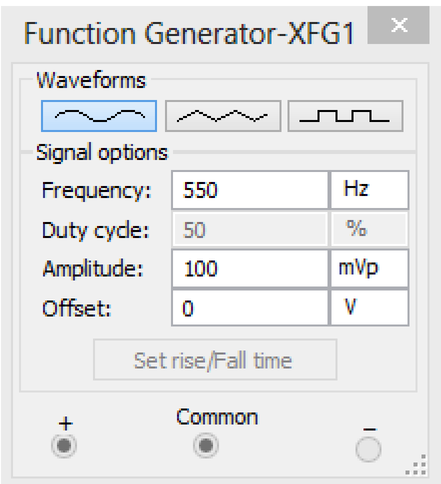


Figure 13 : Schematic diagram for data acquisition module

For testing this circuit we provided a sample input to the lead 1 and lead 2 and grounded the reference, and the output was coming as desired.

- Input signal to reference lead: Grounded
- Input signal to lead 1:



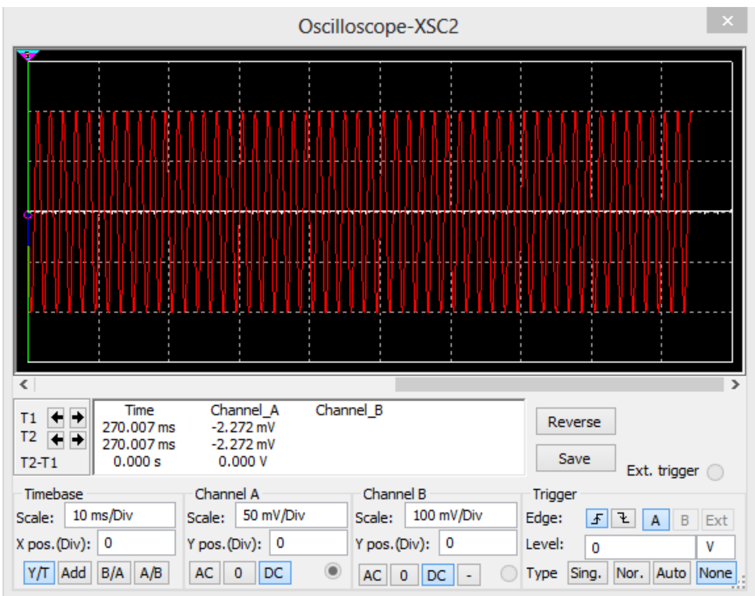
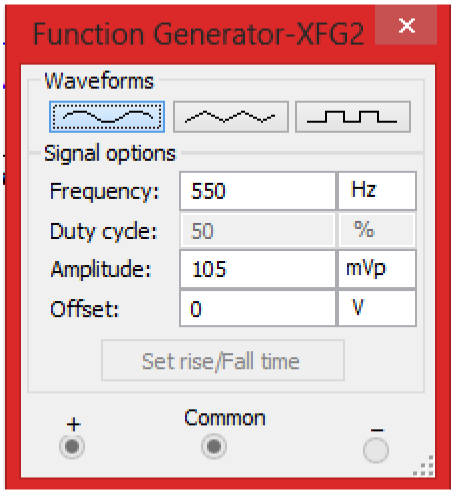


Figure 14 : Input signal in lead 1 during test

- Input signal to lead 2:

In this lead, the frequency is kept same as that of signal in lead 1, however there is slight mismatch in the amplitude.



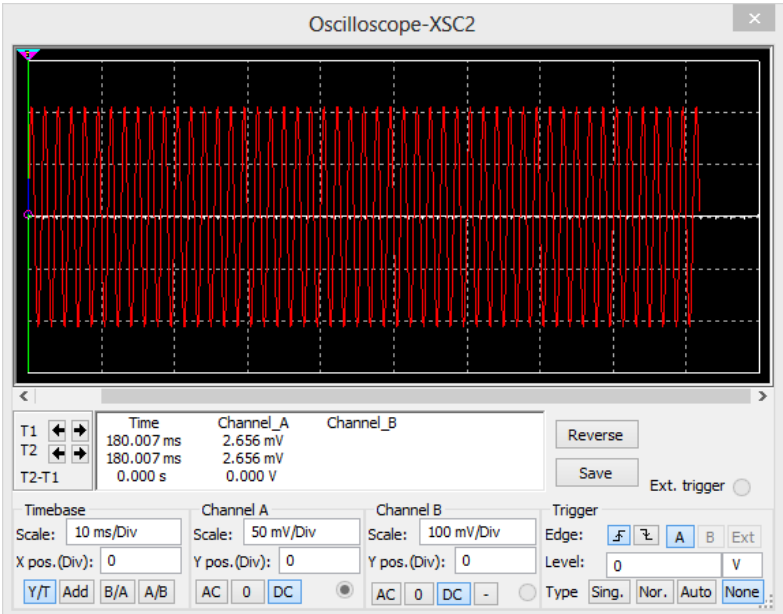


Figure 15 : Input signal to lead2

- Output waveform:

As we can see that despite the slight mismatch in the amplitude of input waveforms, the output waveform is perfectly sinusoidal.

Thus the data acquisition circuit is verified.

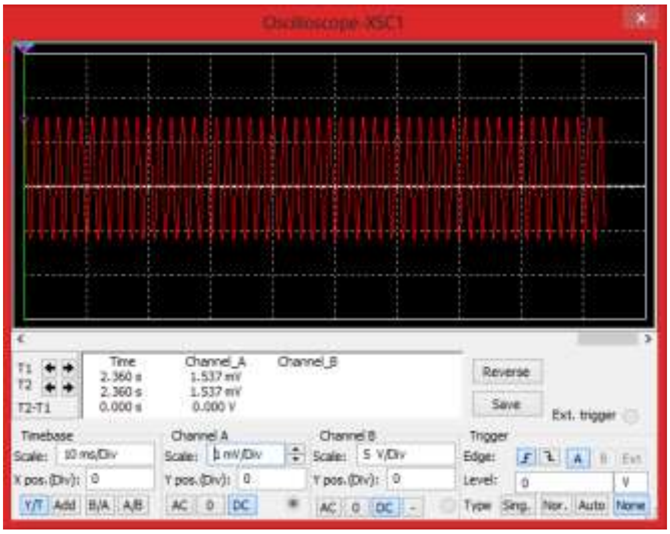


Figure 16: Output signal of the DAQ module

Circuit Hardware:

Both the ECG acquisition circuit and the signal shift circuit (discussed later) were embedded into a single unit which can operate separately without the microcontroller. The schematics for the circuit is shown in Figure 20 and the designed PCB circuit is shown in Figure 19.

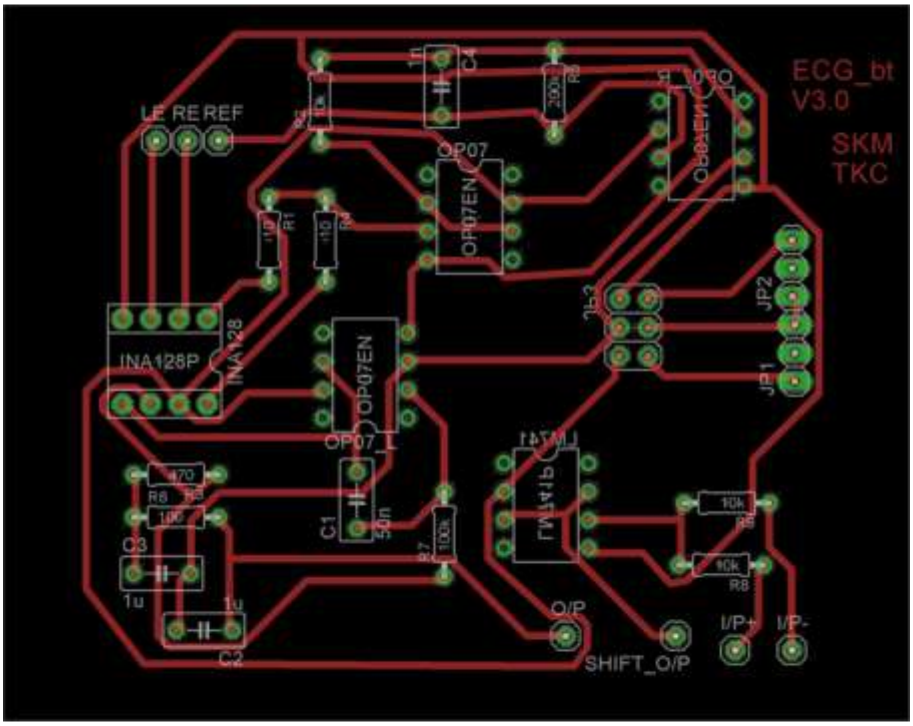


Figure 17: Schematics in Eagle software

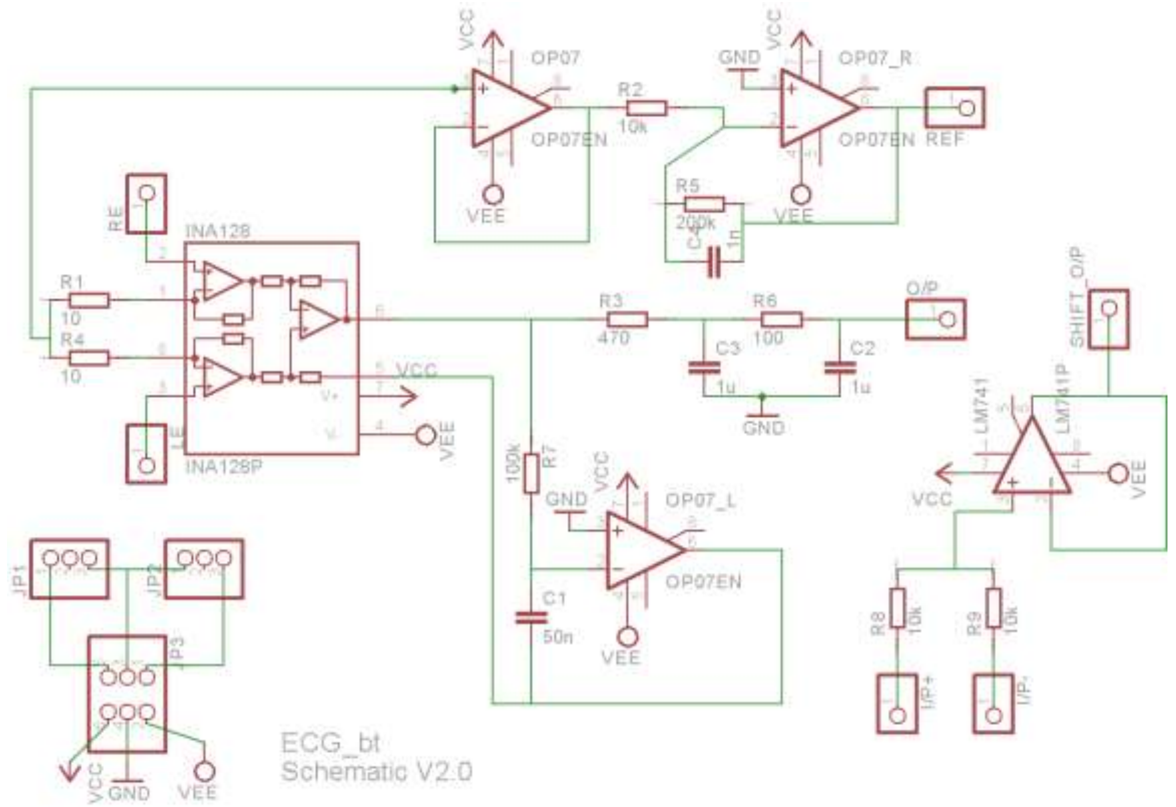


Figure 18: PCB layout for DAQ

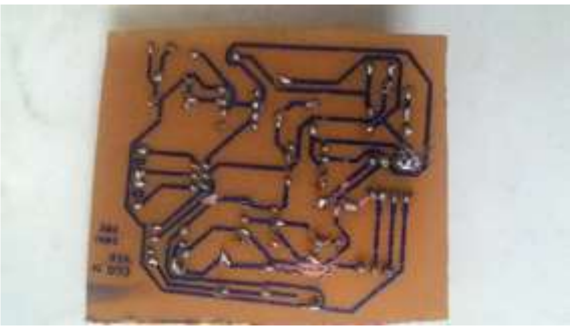


Figure 20 : Final Circuit of ECG DAQ (Rear)

Figure 19 : Final Circuit of ECG DAQ (Front)

ECG acquisition from subject

The designed ECG DAQ circuit is used to obtain the signal directly from human body. The set up consists Clip type electrodes, used with permission from the Pattern Recognition Lab, Department of Electronics and Communication. The primality signal obtained with substantial noise as shown in Figure 10. The circuit is then modified by including a second order filter. The modified signal is shown in Figure 11. Further modification in the circuit is required to obtain the accurate PQRST pulses of the ECG signal.

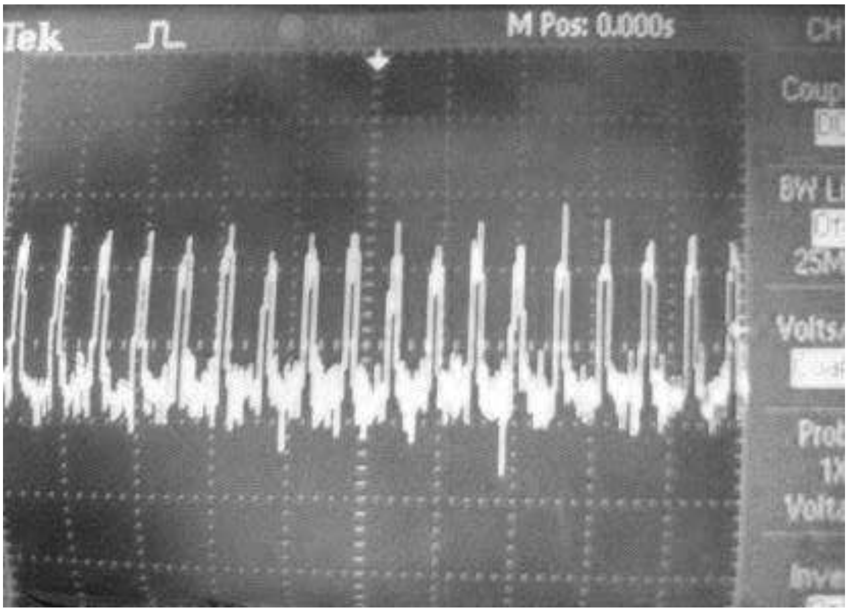


Figure 21 : ECG signal obtained in the sircuit without filter

Figure 22 : ECG Signal in second run

Chapter 4

WIRELESS COMMUNICATION

BLUETOOTH TECHNOLOGY

SHIFT CIRCUIT

MICROCONTROLLER AND A/D CONVERSION

Wireless Communication

This is the crux of the project. Data transmission is totally dependent on this part. So for communication we have used wireless mode of communication using Bluetooth technology. So the process can be explained in this manner. After acquiring data for ECG, say final data after filtering and amplification, this will be fed to first input to voltage shifter circuit for the ADC channel of the Arduino (Microcontroller) which is connected to the Bluetooth module. Now from this data will be sent and received back from the Bluetooth connected in PC/laptops. Now this data will be processed and regenerated so that it can be plotted and studied further.

So here we are dealing with the following things: first conversion of bipolar signal (with voltage swing in both the directions across zero) to unipolar signal (kind of DC signal only), and then use of Microcontroller i.e its interfacing, and also the serial communication through ADC pin, then its transmission using a Bluetooth module.

While sending and receiving data proper care must be taken of the synchronism as if this is lost it will be very much difficult to get back the original signal. So proper baud rate must be set and it should be same for Receiving end as well as sending end.

Bluetooth technology

In this project we have used the HC Bluetooth serial interface module family. Here this will transmit whatever data it will receive from the connected Arduino board through serial communication. Now this Bluetooth module has 3 families:

1. HC-04
   It has 2 types of modules; HC-04M for master mode and HC-04S for slave mode.
2. HC-05
   It has both the modes i.e. Master and Slave modes. By default it is in master mode. However if needed the slave mode can be activated using the AT commands.
3. HC-06
   This functions only in slave mode. The pairing with this module can be done by a master device upon triggering the sequence. The device is in “AT mode” before communication in which we can set different parameters, such as Baud Rate, name of Bluetooth etc.

   Here slave and master modes are describes a number of times. So its better to know their meanings.

   - Master Mode: In this mode the module has no function to remember the last paired slave device. So it can be made to pair with any of the slave devices.
   - Slave Mode: However in this mode, the module remembers the last paired device.

For our purpose we require that the module should remember the last paired device. So we have used the HC-06 Bluetooth module. Its interfacing with PC has been discussed in the next chapters.

Shift Circuit

The next part is converting the bipolar signal into unipolar so that it can be compatible with the Arduino ADC protocol and can be transmitted without any substantial loss in data. So for this we have used a summing circuit, which enables the shifting of the portions of the signal which are on the negative half to positive half by simple mathematical operation. This circuit is shown below

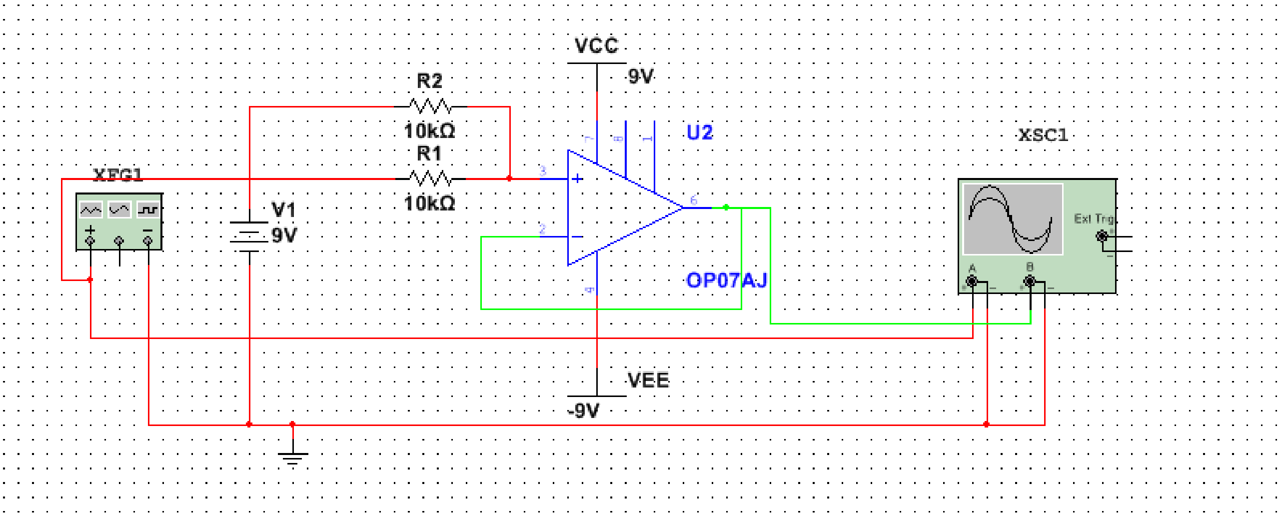


Figure 23 : Schematic diagram of summing circuit

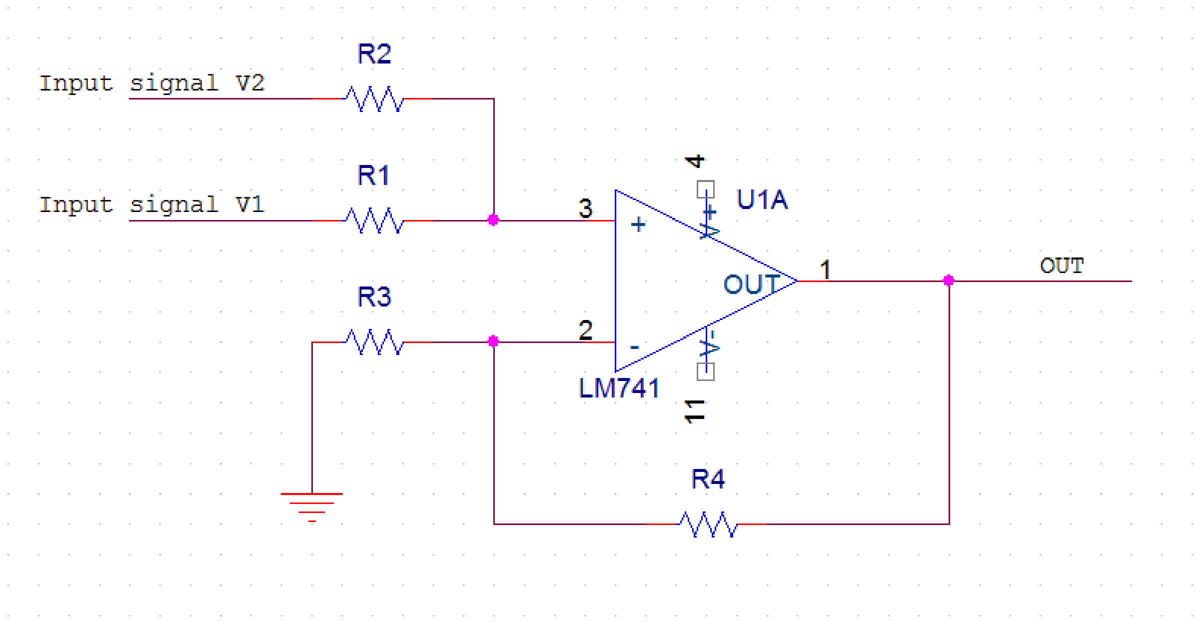


Figure 24 : basic model of summing circuit

Where, $V_2 = reference\ input\ for\ setting\ the\ off\ set\ voltage$

$V_1 = Input\ signal$

$V_{out} = output\ signal$

Mathematical derivation:

For proper A/D conversion on the microcontroller side, the bipolar voltage signal has to be converted to a unipolar voltage. The design includes a summing circuit (Figure 3) for the purpose of up shifting the amplitudes of the input signal. As per the requirement in our circuit, an operating signal in the ±5V range is expected which is then scaled in between 0V to +5V, without any phase lag.

The general expression for finite gain op-amp, with gain K is

$$V_{OUT} = V_{IN} * K + V_{OFFSET}$$

The initial voltage swing is from -5V to +5V, i.e. 10V and finally the permissible swing is from 0v to +5V, i.e. 5V. So the gain has to be $K = 0.5$. With this gain, the voltage will swing from -2.5V to +2.5V. In order to keep the signal above 0V, and offset signal of +2.5V is applied. Thus

$$V_{OFFSET} = +2.5V$$

$$V_{OUT} = \frac{1}{2} * V_{IN} + 2.5V$$

The output signal expression is given by:

$$V_{OUT} = \left[\left(V_1 * \frac{R_1}{R_1+R_2}\right) + \left(V_2 * \frac{R_1}{R_1+R_2}\right)\right]\left[1 + \frac{R_4}{R_3}\right]$$

Comparing it with the obtained equation, R_4 Becomes 0Ω and R_3 becomes infinite. Hence the branch containing R_4 is shorted and the branch containing R3 is disconnected from ground.

Microcontroller and ADC

So now the signal is converted into unipolar in nature i.e. it has only positive values. The basic reason to do this is that ADC requires only positive voltage and if negative voltage is given its internal circuit will get damaged.

The microcontroller which we are using is Arduino UNO.

Arduino UNO has a 6 channel, 10 bit analog to digital converter. This means that it can map input voltage between 0 to 5 V into inter values ranging from 0 to 1023.

The resolution of the ADC is therefore:

$$\frac{5V}{1024\,units} = 0.0049\,\frac{V}{unit} = 4.9\,mV\ per\ unit$$

However there is a provision to change the input Range and Resolution using the analogReference() function.

It takes about 100 us to read an analog input, so the maximum rate is about 10,000 times a second.

Chapter 5

SIGNAL DISPLAY

BLUETOOTH INTERFACING WITH THE PC

MATLAB GUI

SERIAL OSCILLOSCOPE (DIGITAL)

Signal Display

This brings to the final section of the project displaying of signals in the form that can be easily understood/interpreted by a laymen. Since the data is tempered a number of times, say from sending of raw data to transmission to finally receiving of the final data, intense care must be taken not to lose any kind of data during the whole process. To understand this in a detailed manner, it must be understood as to when and how the data is affected.

To begin with we receive ECG signal from the subject which is of the order of millivolts. However the Data Acquisition Circuit plays a major role to amplify this signal upto 2500 times so that the final signal is of the order of Volts. Without losing originality let us say we have any signal in the range of -5 to 5 Volts. And we have to finally display this in this range only.

So

Step I: Conversion of Bipolar Signal to unipolar

As discussed earlier this part is taken care of nicely by using the summer circuit. Here what actually happens is that the signal gets shifted and finally lies in the range of 0-5 V which is suitable for the functioning of ADC.

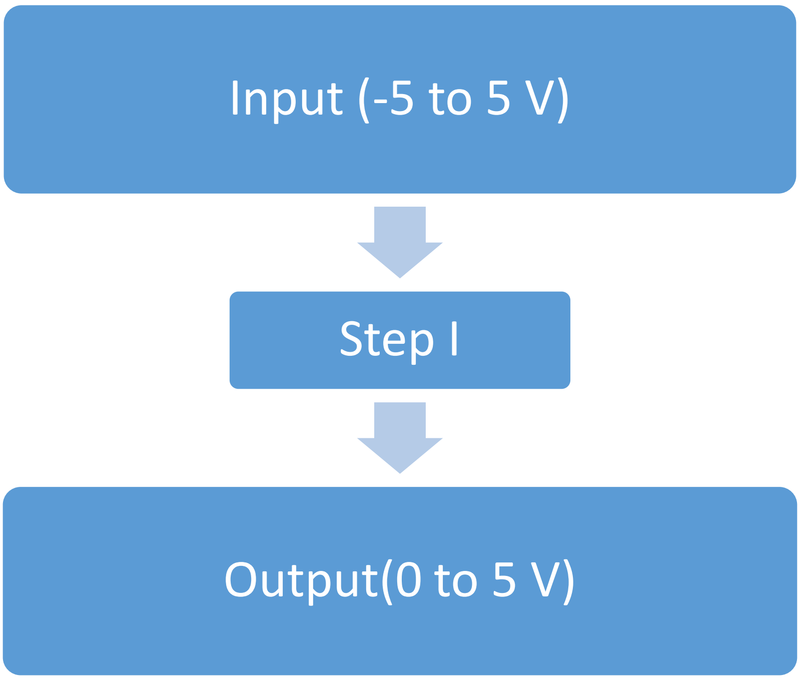


Figure 25: Step I of conversion

Step II: Discretization of signal

Now the signal must be discretized into steps which can be easily used by the ADC. This is taken care by the ADC itself. Since it is a 10 bit ADC, the number of steps generated is 2^{10} =1024 steps. This is illustrated in the figure below.

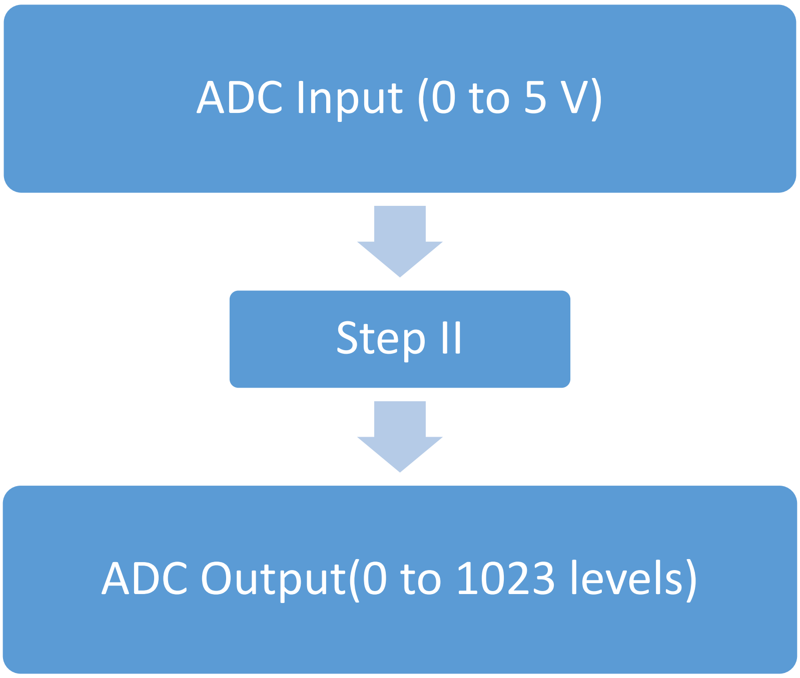


Figure 26: Step II of conversion

Step III: Final Conversion

The final stage of conversion involves getting back the original signal from the discretized levels. This is illustrated in the figure below.

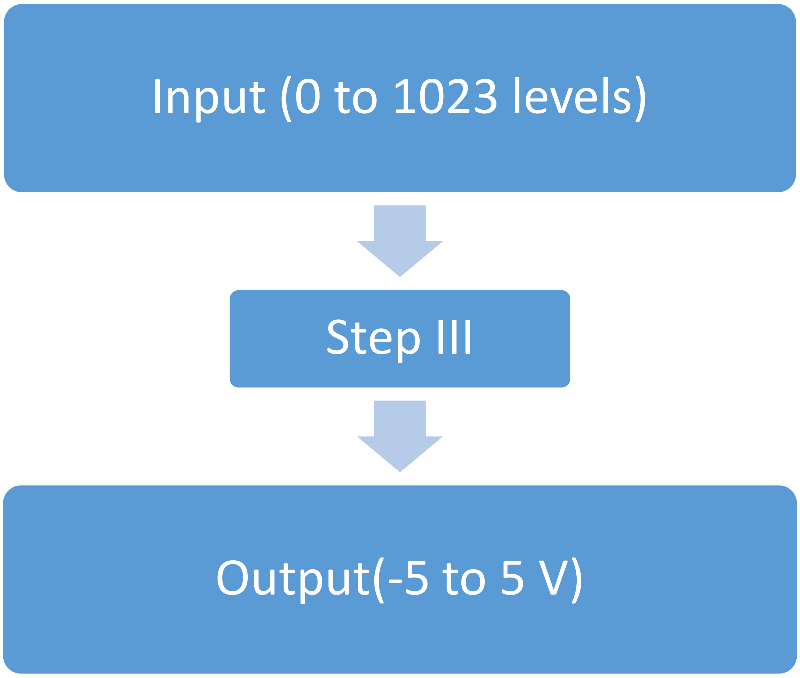


Figure 27: Final step

Bluetooth interfacing with PC

Now the code used in Arduino, to send data serially to HC-06 Bluetooth module is basically a simple Arduino library for serial communication. The signal generated from the summing circuit is then given as input to the Arduino A/D port ‘A0’. Using the command the data is then send to the HC-06 module using serial communcation. The HC-06 module then transmits the data to PC/Mobile.

The previous output is fed as an input to Arduino board which is connected to a Bluetooth module. The communication of the signal wirelessly now takes places.

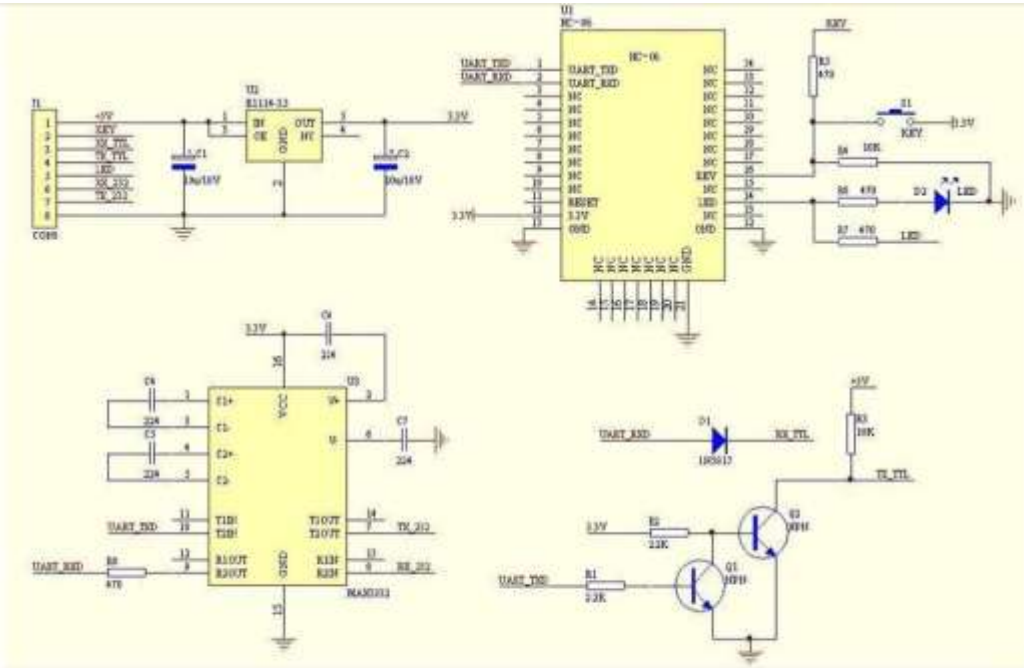


Figure 28 Peripheral arrangement for HC-06

First MATLAB has been used to access the Bluetooth object. Before this it is necessary to pair the device through PC/laptop. Then using ‘AT mode’ commands the Bluetooth can be configured as need, such as changing the Baud Rate, pass code etc.

```
Command Window
>> B = Bluetooth('btspp://00140103598A',1)

   Bluetooth Object : Bluetooth-btspp://00140103598A:1

   Communication Settings
      RemoteName:          ECGbt

      RemoteID:            btspp://00140103598A
      Channel:             1
      Terminator:          'LF'

   Communication State
      Status:              closed
      RecordStatus:        off

   Read/Write State
      TransferStatus:      idle
      BytesAvailable:      0
      ValuesReceived:      0
      ValuesSent:          0

fx >>
```

Figure 30 : MATLAB Instrument Control status for HC-06

```
Command Window
>> s=serial('COM55')

   Serial Port Object : Serial-COM55

   Communication Settings
      Port:                COM55
      BaudRate:            9600
      Terminator:          'LF'

   Communication State
      Status:              closed
      RecordStatus:        off

   Read/Write State
      TransferStatus:      idle
      BytesAvailable:      0
      ValuesReceived:      0
      ValuesSent:          0
```

Figure 29 : MATLAB Instrument control status for serial port

MATLAB GUI

In order to access the data on PC, initially a MATLAB GUI was developed. The communication between the module and MATLAB can be established once the Bluetooth module is paired with the host machine. For this the ‘MATLAB Instrument Control’ application is used. This first identifies the device ID and name using MATLAB commands as shown in below figures. Previously it was shown the result of the serial communication between the Bluetooth module and the PC, wherein a set of data is sent from Arduino continuously and then the data is received through the COM port of PC and imported to the MATLAB GUI. The GUI is made with provisions to increase/decrease the scale for both the axis. Also delay in signal receive and display can be adjusted.

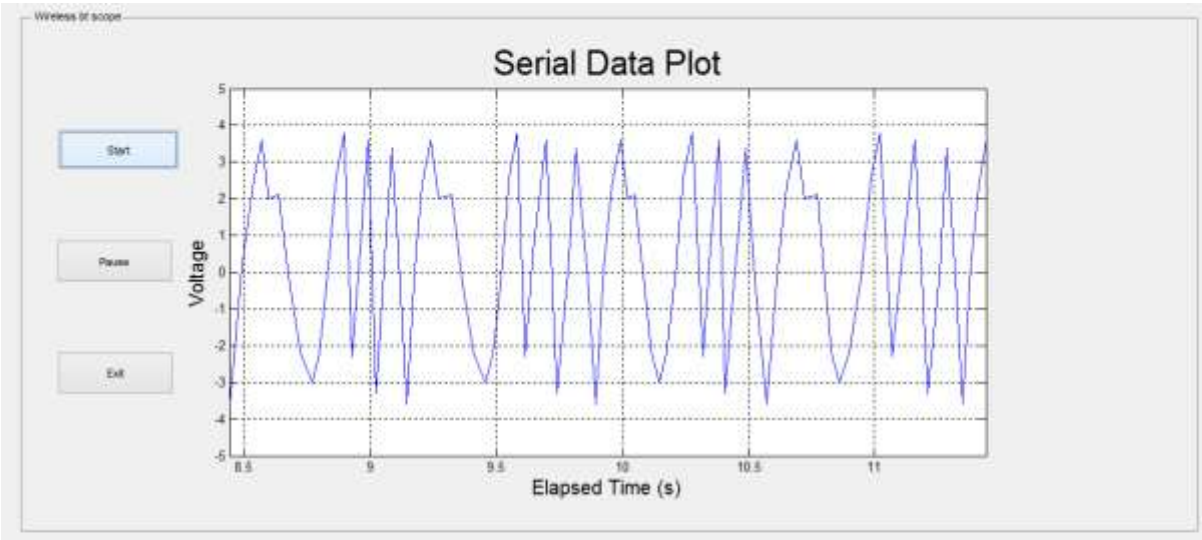


Figure 31 : MATLAB GUI for data display

As it is clear that the GUI has the provision to pause the real time signal, so that a closer analysis can be done.

For making it effective various buttons have been provided to suite the purpose.

Serial Oscilloscope (Digital)

We have also designed a real time oscilloscope which is capable of displaying and plotting data from SERIAL ports in C#. The layouts have been given in below figures. The above shows the terminal of the oscilloscope and the below figure shows the signal in the oscilloscope.

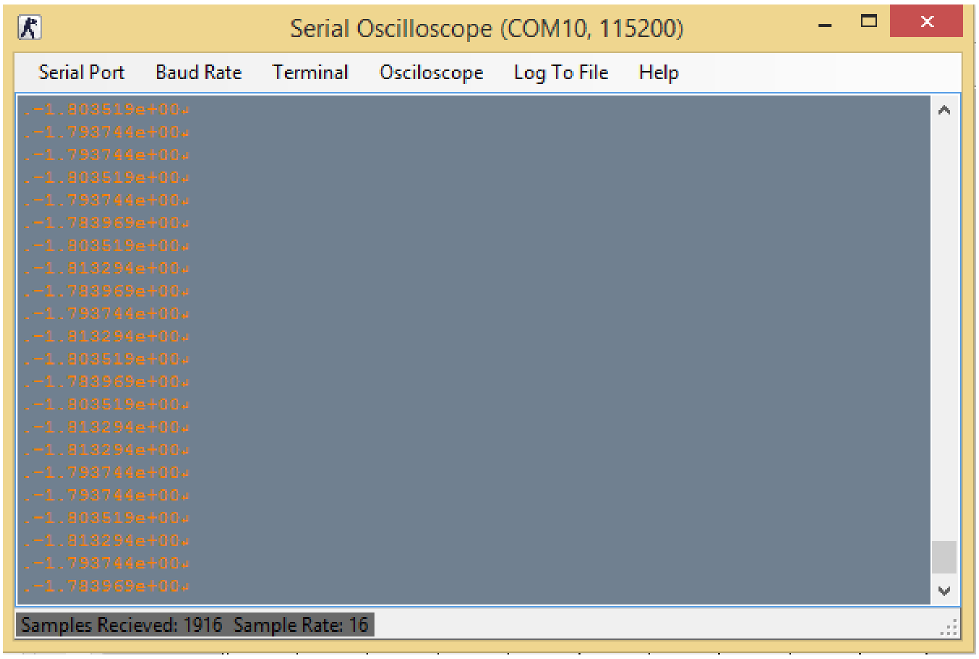


Figure 32 : Interface for Serial Oscilloscoe; Designed on C#

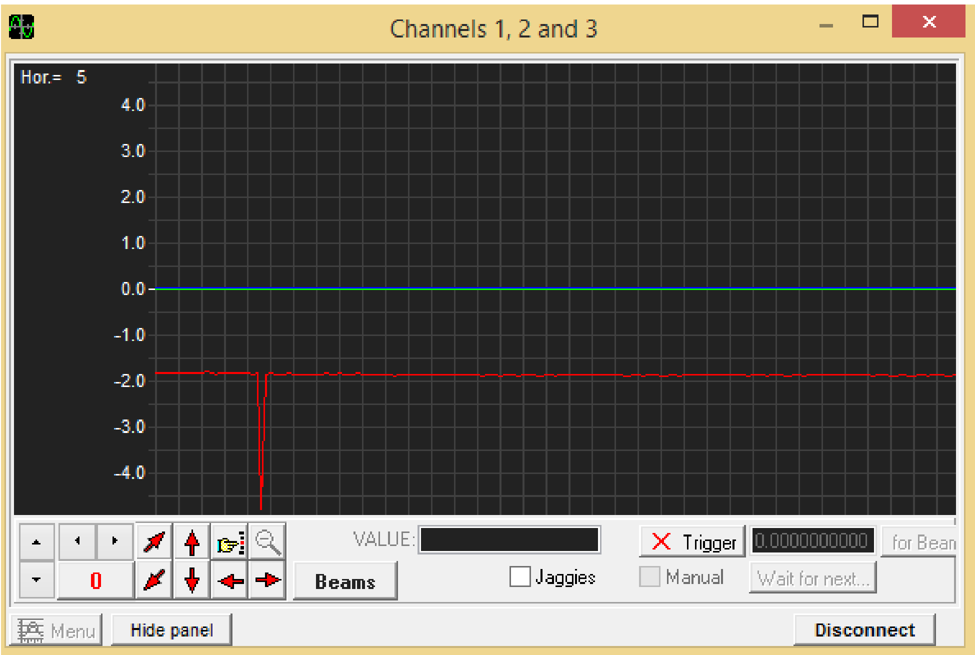


Figure 33 : Oscilloscope Pannel for the Digital oscilloscope model

The major challenge which we faced was that C# does not provide the provision of the library for the Bluetooth accessibility. So we were left with the option to create a virtual COM port, the data into which was written from MATLAB, when it was running. Thus the terminal displayed data when the Baud Rate and correct COM port was selected.

Also the Oscilloscope used here was available as an open source library. So we have integrated that very well keeping the tailor made demands of our project. So now using the oscilloscope the data can be very well seen. It also has the provisions of zooming, scaling, and bringing to zero line and lots more.

Chapter 6

Conclusion:

At this stage the primary blocks of the design are complete. The prototype is only capable of

- Acquiring almost approximate ECG signal with very low noise margin
- Digital Conversion and Wireless Transmission of any analog signal
- Obtaining any data from the serial COM port of PC and importing them into MATLAB® and other application
- Display of data on MATLAB GUI and Digital Oscilloscope designed on the windows platform.

Considering all the challenges in remote healthcare, we have planned to add features of basic health care examination such as heart rate, ECG analysis, stress meter and. Further the regenerated signal can be further analyzed for different diagnostic purpose. At every stage we have tried to keep the cost as low as possible using commonly available ICs and universally used Bluetooth.

Further we have planned to make it compatible with android devices, which are readily and widely used now a days. After further modification in the circuit and addition of sensors to measure heart rate, body temperature and blood pressure etc. it'll be one the most compact and low cost device in healthcare sector.

Future work:

- In this device only the acquisition and recreation of ECG signal is being achieved. Further addition of sensors and circuits for the detection of heart rate, blood pressure, body temperature has to be done.
- The present device only records and display the ECG signal on an application in PC or Mobile. Further the software has to be optimized with inclusion of facility to run diagnostic analysis on the received data. So that the requirement of a personnel for ECG data analysis can be eliminated.
- Implementation of BAN (Body Area Network) to test its flexibility with the obtained data and to determine the extent of its application.

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