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Health Auditing Scheme Utilizing Electrocardiogram

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ABSTRACT
The project topic that we have selected-"Health Auditing Scheme" is highly generic and can have several implications depending on the parameter of choice. The ECG (Electrocardiogram) machine is central to any Health Auditing Scheme because it gives an accurate representation of the function of "driving force" of the Human Body, i.e., the HEART. An electrocardiogram (EKG or ECG) is a device which graphically records the electrical activity of the muscles of the heart. It is used to identify normal and abnormal heartbeats. First invented in the early 1900s, the EKG (derived from the German electrokardiogramma) has become an important medical diagnostic device. Using an EKG allows doctors to measure the relative voltage of these impulses at various positions in the heart. Electrocardiograms are possible because the body is a good conductor of electricity. If the ECG indicates a heart attack or possible coronary artery disease, further testing is often done to completely define the nature of the problem and decide on the optimal therapy.

Keywords
HPF, LPF, ECG, Arduino, MATLAB, Xilinx, PCB, DSO

1. INTRODUCTION
1.1 Understanding health auditing scheme
From the ECG tracing, the following information can be determined:

- The heart rate.
- The heart rhythm.
- Whether there are “conduction abnormalities” (abnormalities in how the electrical impulse spreads across the heart)
- Whether there has been a prior heart attack
- Whether there may be coronary artery disease
- Whether the heart muscle has become abnormally thick

All of these features are potentially important. If the ECG indicates a heart attack or possible coronary artery disease, further testing is often done to completely define the nature of the problem and decide on the optimal therapy.

1.2 Problem definition
Modern ECG machines are extremely expensive devices and can perform only a dedicated task. The widely available ECG machines cannot be interfaced with other medical signal conditioning devices. The main aim in this project is to develop a generic device that can be interfaced with different sensing modules namely-ECG, EMG, Blood Pressure, Body temperature, etc. The aim is to maximize the portability of this generic device without compromising on accuracy. In this project we have designed a single module, i.e., ECG sensor.

1.3 Project Undertaken
- As mentioned earlier the ECG sensor is an integral part of any Health Auditing Scheme.
- It provides information about the vital activity of the body.
- In this project we are going to design the ECG sensing circuit using an instrumentation amplifier with filtering and amplifying circuits.
- The output of the sensing circuit is connected to a comparator which will convert the analog pulses to TTL (0V-5V) pulses.
- These pulses are acquired using an Arduino dev. A board which will further cause a speaker to beep or LED to flash at the heart rate of the subject.
- The analog ECG waveform can be observed on a DSO.

2. LITERATURE SURVEY
2.1 Modern ECG machine
Modern ECG monitors are computerized data acquisition and display systems that typically provide continuous monitoring of multiple patient parameters. Most can display:

- The ECG
- Respirations/Impedance pneumograph (via the ECG leads)
- Blood pressure (continuous invasive or intermittent noninvasive)
- Oxyhemoglobin saturation (SpO2)

Bedside units are usually modular in design. In these systems, additional modules can be added to provide monitoring of other parameters, such as end-tidal CO2. ECG monitors are designed to identify and warn clinicians of abnormal changes in a patient's heart rate or rhythm, and to provide data essential in arrhythmia management. Continuous bedside monitoring of the ECG is a standard of care for critically ill and/or unstable patients. This would normally include any patient in an Adult, Pediatric or Neonatal Intensive Care Unit or those in Coronary Care or Post anesthesia/Cardiac Recovery Units. Patients admitted to the Emergency Department who are hemodynamically unstable, unconscious or who have chest pain should also undergo continuous ECG monitoring, at least until their underlying problem is diagnosed.

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2.2 Working principle of ECG

Cells in humans act like little batteries. These cells have different ion concentrations inside and outside of their membranes which create small electric potentials called bio potentials. When there is a disturbance in a bio potential this gives rise to an action potential which is the depolarization and repolarization of the cell as shown in Figure 1. Essentially, the action potentials from different nodes in the heart are what make up electrocardiograph (ECG) signals. ECG signals are comprised of the superposition of the different action potentials from the heart beating as shown in Figure 2. ECG machines use electrodes to convert the ionic signals from the body into electrical signals to be displayed and used for data analysis. However, due to the size of the signals and outside noise, ECG requires amplification and filtering to produce high-quality signals.

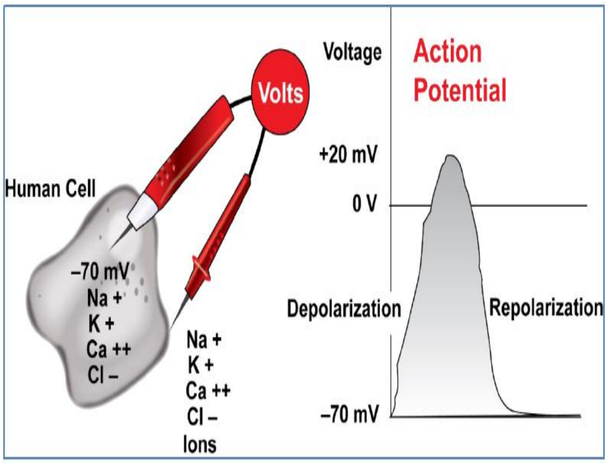

Fig.1 Depolarization and Repolarization of human cell

2.3 ECG probe placement

The term "lead" in electrocardiography causes much confusion because it is used to refer to two different things. In accordance with common parlance, the word lead may be used to refer to the electrical cable attaching the electrodes to the ECG recorder. As such, it may be acceptable to refer to the "left arm lead" as the electrode (and its cable) that should be attached at or near the left arm. Usually, 10 of these electrodes are standard in a "12-lead" ECG.

Alternatively (and some would say properly, in the context of electrocardiography), the word lead may refer to the tracing of the voltage difference between two of the electrodes and is what is actually produced by the ECG recorder. Each will have a specific name. For example "lead I" is the voltage between the right arm electrode and the left arm electrode, whereas "Lead II" is the voltage between the right arm and the left leg. (This rapidly becomes more complex as one of the "electrodes" may, in fact, be a composite of the electrical signal from a combination of the other electrodes). Twelve of this type of lead from a "12-lead" ECG.

To cause additional confusion, the term "limb leads" usually refers to the tracings from leads I, II, and III rather than the electrodes attached to the limbs.

Ten electrodes are used for a 12-lead ECG. The electrodes usually consist of a conducting gel, embedded in the middle of a self-adhesive pad onto which cables clip. Sometimes the gel also forms the adhesive.

2.4 ECG waveform

A typical ECG tracing of the cardiac cycle (heartbeat) consists of a P wave, a QRS complex, a T wave, and a U wave, which is normally invisible in 50 to 75% of ECGs because it is hidden by the T wave and upcoming new P wave. The baseline of the electrocardiogram (the flat horizontal segments) is measured as the portion of the tracing following the T wave and preceding the next P wave and the segment between the P wave and the following QRS complex (PR segment). In a normal healthy heart, the baseline is equivalent to the isoelectric line (0 mV) and represents the periods in the cardiac cycle when there are no currents towards either the positive or negative ends of the ECG leads. However, in a diseased heart, the baseline may be depressed (e.g., cardiac ischemia) or elevated (e.g., myocardial infarction) relative to the isoelectric line due to injury currents during the TP and PR intervals when the ventricles are at rest. The ST segment typically remains close to the isoelectric line as this is the period when the ventricles are fully depolarized and thus no currents can be in the ECG leads. Since most ECG recordings do not indicate where the 0 mV line is, baseline depression often gives the appearance of an elevation of the ST segment and conversely baseline elevation gives the appearance of depression of the ST segment

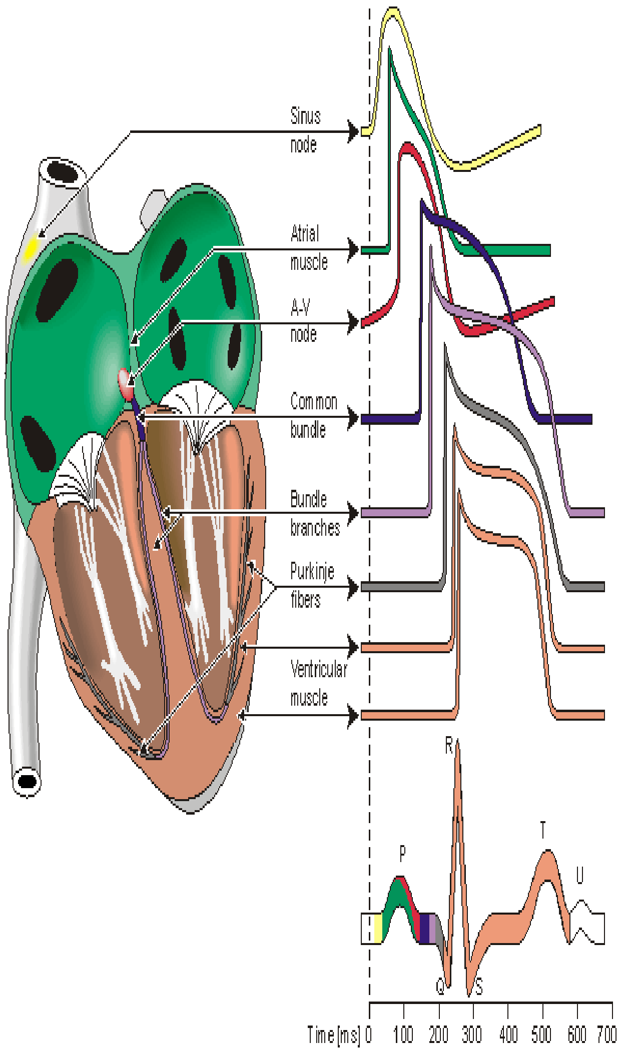

Fig.2 Superposition of various waveforms

Table 1. Electrode placement

Electrode label (in the USA)	Electrode placement
RA	On the right arm, avoiding thick muscle.
LA	In the same location where RA was placed, but on the left arm.
RL	On the right leg, lateral calf muscle.
LL	In the same location where RL was placed, but on the left leg.
V_1	In the fourth intercostal space (between ribs 4 and 5) just to the right of the sternum (breastbone).
V_2	In the fourth intercostal space (between ribs 4 and 5) just to the left of the sternum.
V_3	Between leads V_2 and V_4.
V_4	In the fifth intercostal space (between ribs 5 and 6) in the mid-clavicular line.
V_5	Horizontally even with V_4, in the left anterior axillary line.
V_6	Horizontally even with V_4 and V_5 in the mid-axillary line.

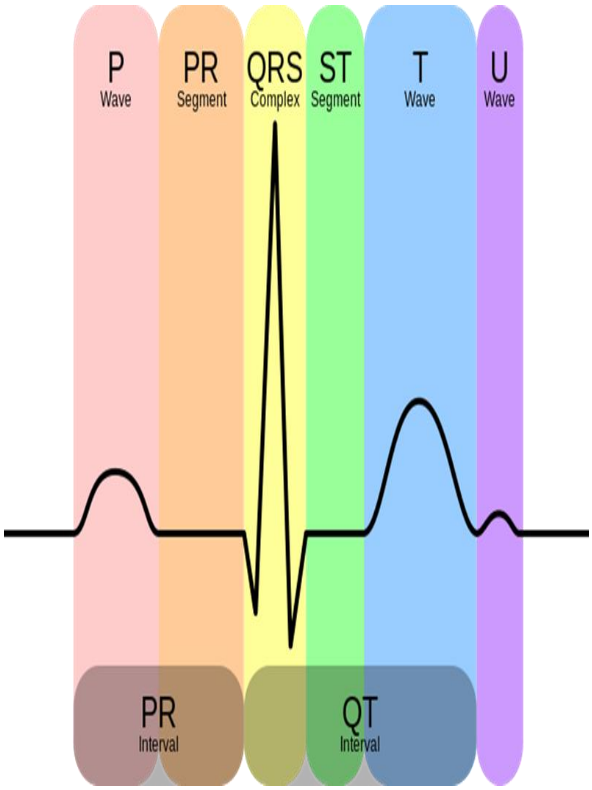

Fig. 3 ECG waveform

3. EXPERIMENTATION

3.1 Programming the Arduino board

```
// This program reads the incoming signal from the electrocardiograph and outputs the heart rate

// Pin D7 is connected to the signal input

// Pin D6 is connected to a mini-speaker

// For the connection to the liquid crystal display, see the LiquidCrystal Librairy

// External variables

const int signal = 7;    // Pin connected to the filtered signal from the circuit

unsigned long time;

unsigned long frequency;

// Internal variables

int period = 2000;

int starttime = 2000;

int input = 0;

int lastinput = 0;

unsigned long death = 0;

// include the library code:

#include <LiquidCrystal.h>

// initialize the library with the numbers of the interface pins

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

byte heart[8] = {
  0b00000,
  0b01010,
  0b11111,
  0b11111,
  0b11111,
  0b01110,
  0b00100,
  0b00000
};

void setup() {
  pinMode(signal, INPUT);
  lcd.createChar(1, heart);
  // set up the LCD's number of columns and rows:
  lcd.begin(16, 2);
  // Print a message to the LCD.
  lcd.write(1);
  lcd.setCursor(1,0);
  lcd.print("    BPM :      ");
  lcd.setCursor(0,1);
```

```
 lcd.print("waiting... ");
 delay(3000);
 Serial.begin(9600);
}
void loop() {
 lcd.setCursor(1,0);
 time = millis();
 input = digitalRead(signal);
 if ((input != lastinput)&&(input == HIGH)) {
  // If the pin state has just changed from low to high (edge detector)
   period = time - starttime; // Compute the time between the previous beat and the one that has just been detected
   starttime = time; // Define the new time reference for the next period computing
   death = time;
   tone(6,800,100); // Output a short "bip" through the speaker
 }
 lastinput = input; // Save the current pin state for comparison at the next loop iteration
 if (period < 0) {
  frequency = 0;
 }
 else {
  frequency = 60000/period; // Compute the heart rate in beats per minute (bpm) with the period in milliseconds
 }
 if ((time - death) > 3000) { // Detect if there is no beat after more than 2 seconds
  tone(6,900); // Output a continuous tone to the speaker
  lcd.print("--------");
  lcd.setCursor(0,1);
  lcd.print("No i/p detected ");
 }
 else {
  char freq[3];
  if (frequency/100 == 0) {
   freq[0] = 32; // Print a space to the first character if the frequency is below 100 bpm
  }
  else {
   freq[0] = frequency/100+48; // Sort the hundreds character and convert it in ASCII
  }
  freq[1] = (frequency/10)%10+48; // Sort the thents character and convert it in ASCII
  freq[2] = frequency%10+48; // Sort the units character and convert it in ASCII
  lcd.print(freq);
  lcd.setCursor(0,1);
  lcd.print("i/p detected ");
  Serial.print("Heart rate = ");
  Serial.print(freq);
  Serial.print("bpm");
  Serial.println();
 }
}
```

3.2 Operation of circuit

- First the electrodes must be place without powering the circuit according the configuration mentioned earlier.
- After connecting the power supply the LCD will display "   BPM:" on the first line and "waiting... “On the second line.
- The notch filter output must be connected to the oscilloscope in order to observe the ECG waveform.
- If input is detected, the first line will display "XX BPM:" and the second line will display "i/p detected” the speaker will beep or the LED will flash depending on the heart rate.
- Erroneous beeps might indicate EMG noise. In order to prevent this noise, keep the subject in a relaxed position.
- Adjust the position of the probes to get a clear output waveform.
- If no input is detected for 3 seconds the speaker will output a continuous long beep and the LCD will read "--------" on the first line and "No I/P detected " on the second line.
- In case the LCD fails to function the heart rate can also be monitored on the serial monitor (Ctrl+Shift+M).
- The subject must be in a completely relaxed state and his/her feet must NOT touch the ground. Touching the feet to the ground might cause erroneous frequencies from ground to affect the ECG circuit.

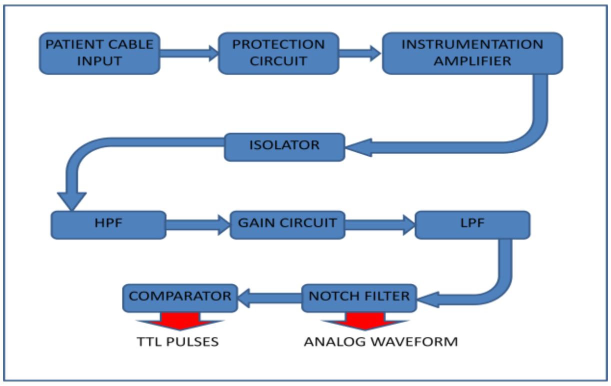

Fig. 4 Block diagram of ECG sensing module

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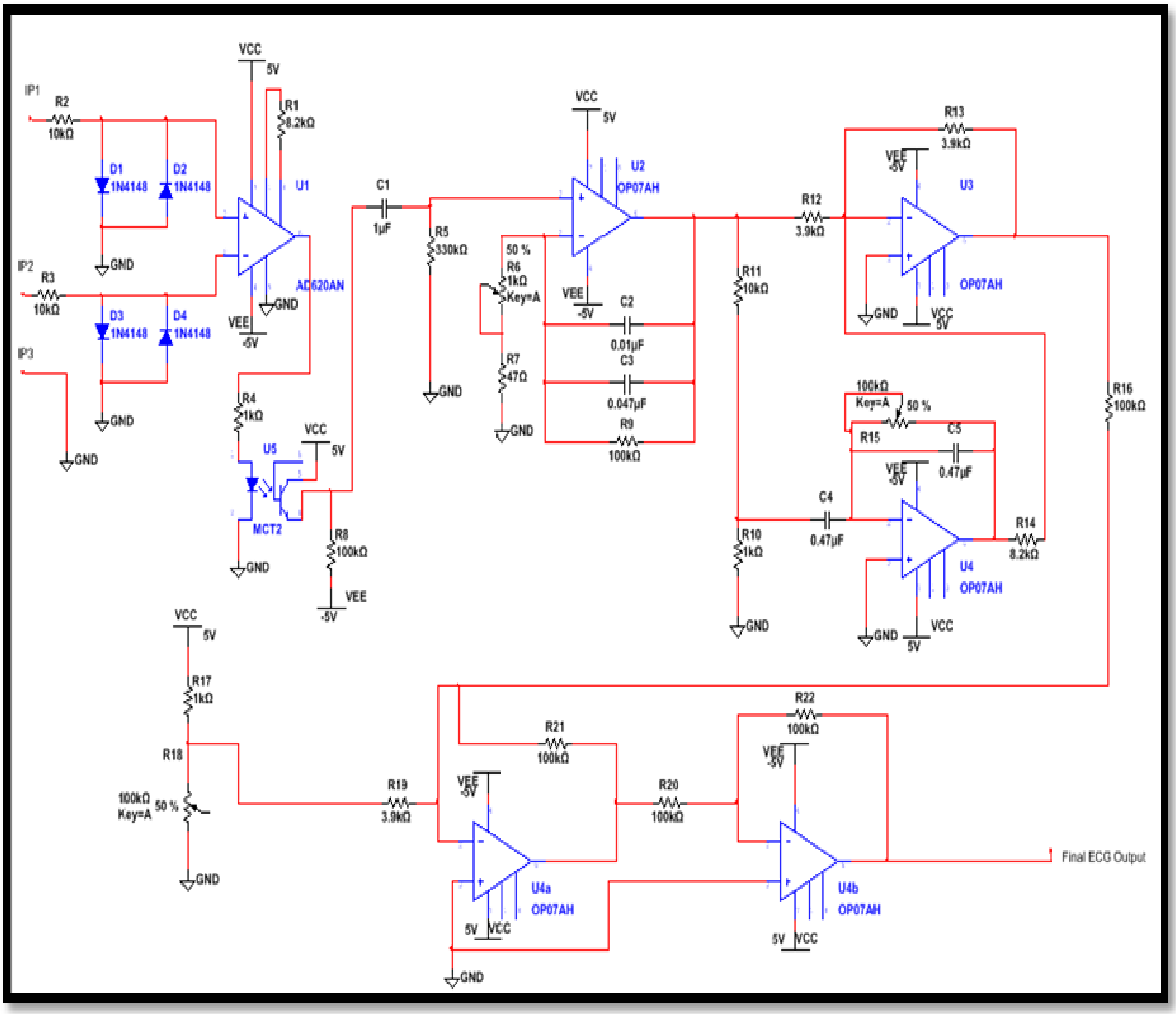

Fig. 5 Circuit diagram of ECG sensor

4. RESULTS AND DISCUSSIONS

4.1 Simulation results and PCB artwork

First stage of building any project is its simulation before its actual implementation. Hence we had implemented the circuit on Multisim 12. Following are the results of the simulation- From the response of the first stage of notch filter we can see that it provides a high gain at approximately 60Hz. The next stage is a subtraction or that will subtract this output from the input signal. This will cause elimination of the band at 60Hz. The PCB layout for the entire sensor circuit was designed using the ORCAD PCB software platform. For proper layout design minimal steps to be followed are:

- Get the final circuit diagram and component list.
- Choose the board types, single sided / double sided / multilayer
- Identify the appropriate scale for layout.
- Choose the correct board size keeping in view the constraints.
- Select appropriate layout technique, manual / automated.
- Document in the form of the layout scale.

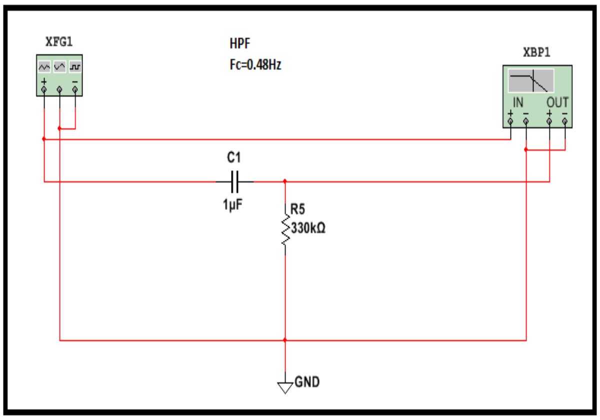

Fig. 6 HPF circuit

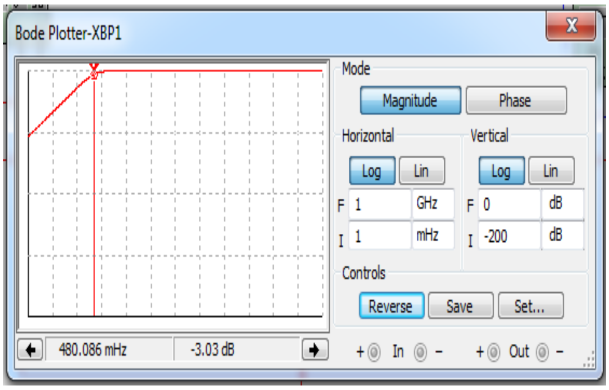

Fig. 7 HPF response of Bode plotter

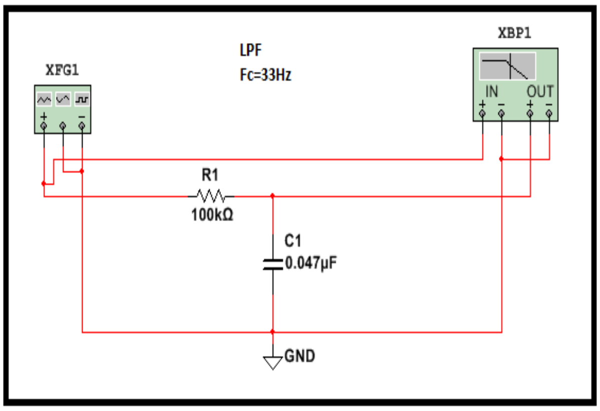

Fig. 8 LPF circuit

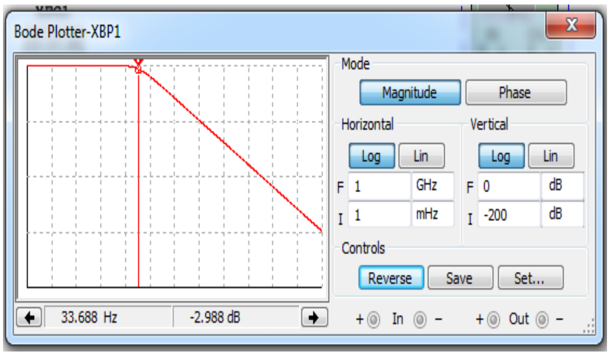

Fig. 9 LPF response of Bode plotter

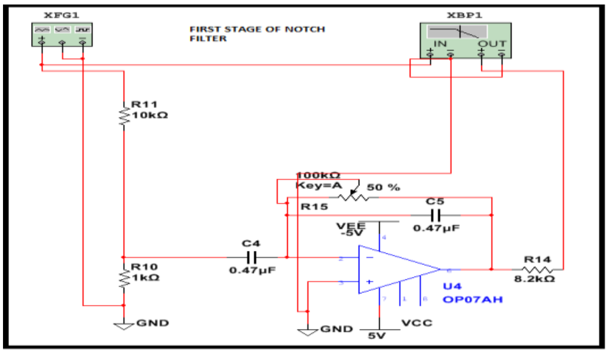

Fig. 10 First stage of notch filter

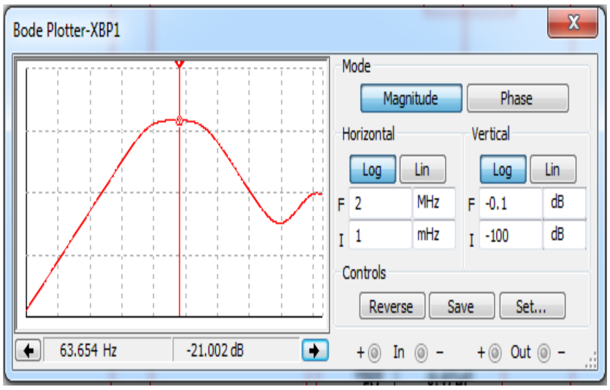

Fig. 11 Response of First stage

4.2 Results

The objective of this project is to design and implement a prototype of an ECG sensor. The importance of this project is that it has scope for multiple device interface using Arduino platform at minimum cost without compromising on accuracy. Following are the operations that are implemented in this project-

- Determine the heart rate of user.
- Analyze the analog ECG waveform on DSO.
- Displays signals such as
  - ➢ I/P detected.
  - ➢ No I/P detected.
  - ➢ Heart rate in BPM etc.

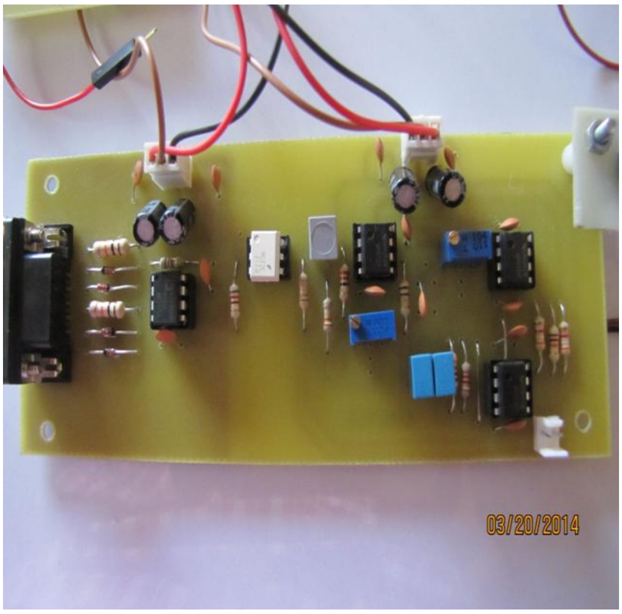

Fig. 12 Actual photograph of ECG sensor

4.3 Advantages

The prototype of EGC System comes with various advantages for general purpose use. The few advantages have been listed below –

- The software code is robust and can take care of all the possible situations that can occur in the course of the event.

- Fully automated and hence reduces human errors and investments.
- Low power electronics. It is highly accurate and precise.
- Any software malfunction can be removed by simply replacing the microcontroller. Hence low maintenance cost.
- The prototype complies with most of the standards of AHA (American Heart Academy).

4.4 Limitations

The ECG System attempted is a simple prototype. The model is primitive to those available in the commercial market. Hence the model has its own limitations. The following are the limitations of the model prototype of the project-

- Erroneous readings due to improper grounding.
- Physical limitation on the number of electrodes, most commercially available ECG machines support up to 12 electrodes.
- Lack of displaying unit as is available in most commercially available machines.
- The model prototype does not have a PC interface through which test inputs can be manually provided for simulation purpose.

5. FUTURE SCOPE

The hardware model implemented during the course of the project is just a prototype of the commercial version available in the market. This model can be further improvised to match the commercial standards .The following modifications are compatible with the prototype –

- Different bio-medical signal conditioning circuits can be interfaced with the existing module to create a Health Auditing Scheme in the true sense.
- Several front end user programs can be provided to interface different devices.
- An Arduino controlled oscilloscope can also be implemented in order to view waveforms.
- A Real Time Clock (RTC) can be incorporated into the circuit for generating a data log.
- We can interface external memory with the microcontroller. This memory can be programmed to store the ECG log of individual subjects.
- A printer can also be interfaced to take print outs of the ECG log.

6. ACKNOWLEDGEMENT

The desire to have the best and get closer to perfection has made for trying to achieve the perfection. Ability and Ambition are not enough for success. The Success of any project depends solely on support, guidance, encouragement received from the guide well wishes. Gratitude is often hardest emotion to express and often one doesn't find adequate words to convey all what one feels. We are pleased to express a deep sense of gratitude to Dr. Suhas Erande and Dr. M. N. Navale who has opened floodgates of their knowledge and their extending continuous co-operation and encouragement. At the last but not least we would like to thank other faculty members for their timely co-operation and help. Thank you for all those who have directly or indirectly contributed towards making the research successful.

7. CONCLUSION

We have successfully implemented the ECG sensor using AD620 (Instrumentation amplifier) and interfaced it with Arduino Development board. The complexity of the project lies in the sensor design. The programming and interfacing are relatively simple. The PCB has been designed in such a manner so as to put maximum functionality in a very small space. Also the design does not include any bulky material or components. Hence the weight of the model is within acceptable limits. All the elements or components used in the hardware implementation are chosen such that they are easily available and currently in mass production. The software storage does not require any external memory due to the clever selection of microcontroller. Also, as per the data published in the bill of the material, it clearly indicates towards the cost effectiveness of the prototype. The complete process right from the conceptual stage till testing stage has been a great learning experience. The undertaking of this project has provided an opportunity to learn various aspects of a project such designing, PCB manufacturing and testing. Also it has given the opportunity to work with different types of components their incorporation and the design of their support circuit.

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