Electrocardiogram (ECG)

Project

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Course : Electronic Workshop II

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***Abstract*—This electronic document is a report based on Electrocardiogram (ECG) designed using basic analog components. This paper explains the entire procedure of designing a simple ECG circuit. The heart beat of the person is also calculated using the ECG.**

I. INTRODUCTION

Electrocardiography is the process of producing an electrocardiogram (ECG or EKG), a recording of the heart's electrical activity through repeated cardiac cycles. Electrocardiography is performed by placing electrodes on the skin. These electrodes measure the change in electrical activity of the heart, which are a result of muscle polarization followed by depolarization.

In a resting heart cell, the inside of the cell is negatively charged compared to the outside due to an unequal distribution of ions. The heart is said to be polarized in the above state. The ions include potassium ions and sodium ions. An 'electrical jolt' received by the heart flips the situation, causing the inside of the cell to be more positively charged **as compared** to the outside. The cell is now more permeable to the positively charged sodium ions. The cell is now said to be 'depolarized'.

During a process called repolarization, as the name suggests, the cell goes back to its initial state.

Our objective is to design a circuit that measures the electrical activity of the heart as accurately as possible with the components available in the lab.

Another objective of the experiment is to calculate the heart beat of the person.

II. DESIGN APPROACH

The electrical activity of the heart is not very high. For instance, the resting membrane potential of cardiac cells is around -90 to -80 millivolts (mV) relative to the extracellular fluid during polarization. The values during depolarization are also of the order of millivolts.

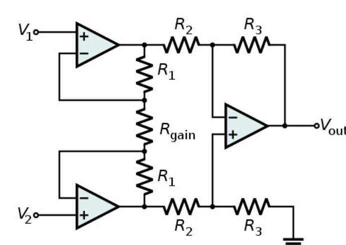
In order to clearly observe and measure the output, the ECG needs to amplified and the noise component needs to be minimized. We must only allow specific frequency values to be displayed and reject the others.

Amplification Stage:

To achieve the same, we have implemented an instrumentation amplifier. It aims to amplify low-level signals while rejecting common-mode noise.

The gain provided by an instrumentation amplifier is given by this formula:

$$A_v = \frac{V_{\text{out}}}{V_2 - V_1} = \left(1 + \frac{2R_1}{R_{\text{gain}}}\right)\frac{R_3}{R_2}$$



The advantage of using instrumentation amplifier is that we can manage the gain of amplifier using less number of resistors.

We require buffer circuits for increasing the impedance of the 2 input voltages, so instead, we also amplify the voltages with increase in impedance. Then the 3rd opamp is used as a subtractor, which gives the difference of the outputs, and accordingly amplifies based on values of R2 and R3.

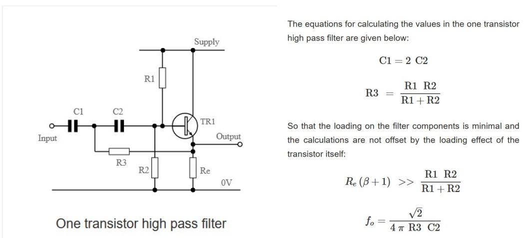
Thus, the overall circuit can give us a gain in thousands.

Filter Stage:

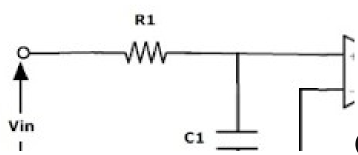
The frequency range for commercial ECG is 0.5Hz to 150Hz. So, we were required to make both a low pass and a high pass filter.

We decided to implement the high pass filter using BJT according to the requirement. The output that we would obtain would be higher based on lower frequencies. Thus, the 2nd order filter from BJT was decided to be used as high pass filter.

We have implemented an emitter follower bjt implementation for high pass filter.



The low pass filter, to cover more range, and as per mentor suggestion, we kept the cutoff to 400Hz, rather than 150Hz. It was the 1st order active low pass filter.

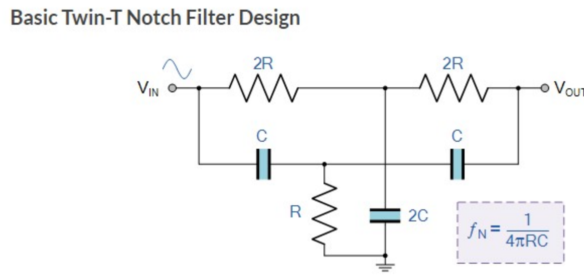


(Low pass filter)

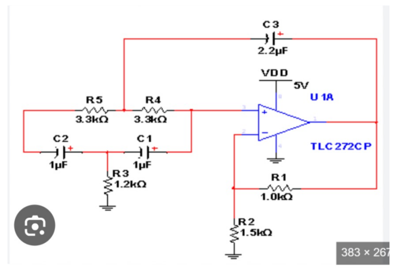
But the important part of filtering is filtering out the 50Hz supply noise coming from the device itself. To tackle that frequency, we have also incorporated two notch filters. A notch filter significantly attenuates specific frequency signals but passes all other frequency components with negligible attenuation.

Two notch filters have been used to minimize the 50Hz noise component as much as possible. Here is the circuit diagram of the same.

Below is the circuit diagram of a passive notch filter:



Characteristic ECGs lie within a frequency band of 0.5 Hz-150 Hz (Source: NASA). We would be needing a high pass and low pass filter to achieve this.

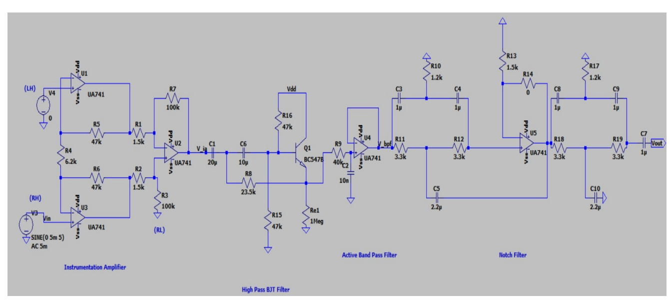


(Active 50Hz Notch Filter)

Here is the final circuit diagram for the same:

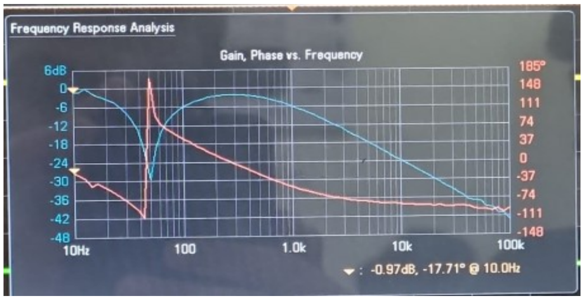
There are a total of three electrodes needed to capture the electrical activity of the heart. Two are connected near the radial nerve of each wrist. The third electrode acts as a reference electrode and is placed near the left ankle.

Apart from displaying the electrocardiogram, the heartbeat (measured in beats/min) has also beat calculated by taking the ECG as input to the Arduino.



III. RESULTS

The output waveform from the circuit is:



The frequency response analysis on the oscilloscope showcased the functioning of the low pass filter of 400Hz and the notch filter of 50Hz.

The output range is 150mV – 250mV.
The observed gain is lesser than the desired (theoretical) gain because the notch filter, apart from attenuating the 50Hz also attenuates slightly the other immediate frequencies.

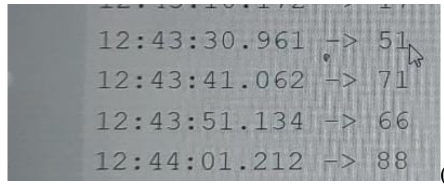
A Major Tradeoffs:

1. Attenuation of 50Hz noise for overall gain.

   To remove the 50Hz noise more efficiently, we implemented 2 notch filters in our circuit. Due to this the side lobes also got widened due to attenuation, decreasing the frequency components of output also.

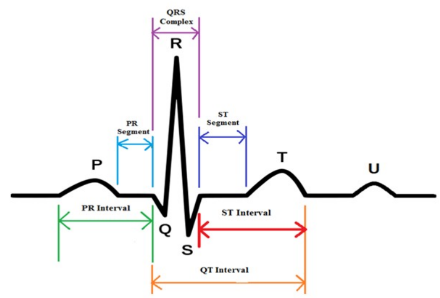
   Thus, to counter this attenuation, we had gain of almost 4500, so as to get output in desired voltage range.

The heartbeat was calculated every 10seconds using Arduino UNO, the DAC in Arduino with corresponding threshold, gives us the binary data regarding the analog output, which was then used to calculate the heartbeat.

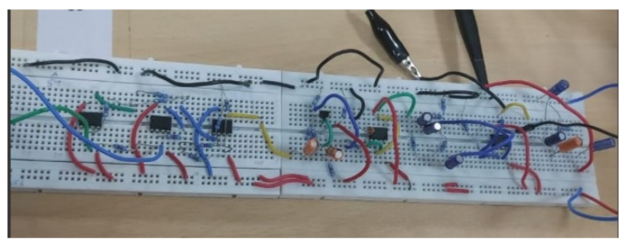


(Heartbeat output)

The output nature of an ECG:



Overall Circuit Image:



Placing of electrodes:

Both the electrodes on 2 hands according to vein or artery positioning.

And the 3rd one as reference point (connected to Ground) to leg near ankle. It can be said like neutralizing the leg point voltage relatively to 0.

IV. REFERENCES

1. www.instructables.com
2. www.allaboutcircuits.com
3. www.electronic-notes.com