FINAL REPORT

GROUP NAME: ABI ENGINEERING

PROJECT NAME : ECG

PROJECT TEAM

İZZET KORKMAZ
AHMET YASİR CİLVEZ
BAYKAL YILMAZ

Table of Contents

Chapter 1

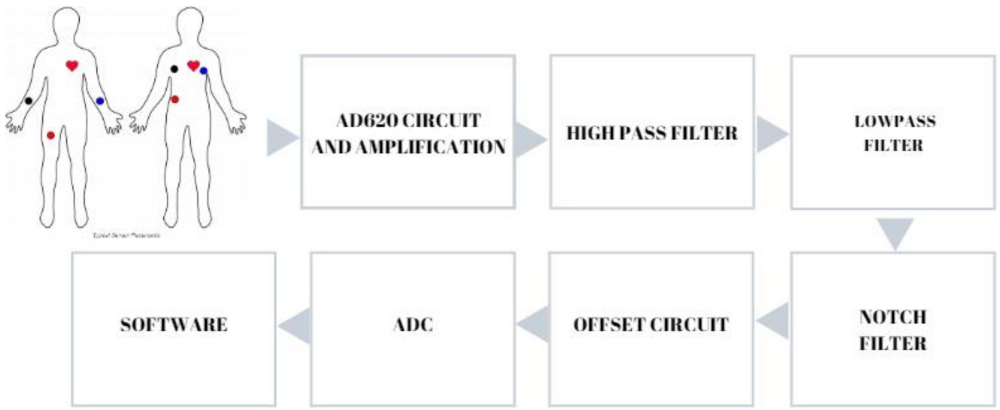
Introduction

OBJECTIVE

The main purpose of this project is to learn the analysis stages of an ECG and creating an ECG system with available components by following steps.And led and buzzer system has been added to the EKG device so that all users can easily use it.

BACKGROUND

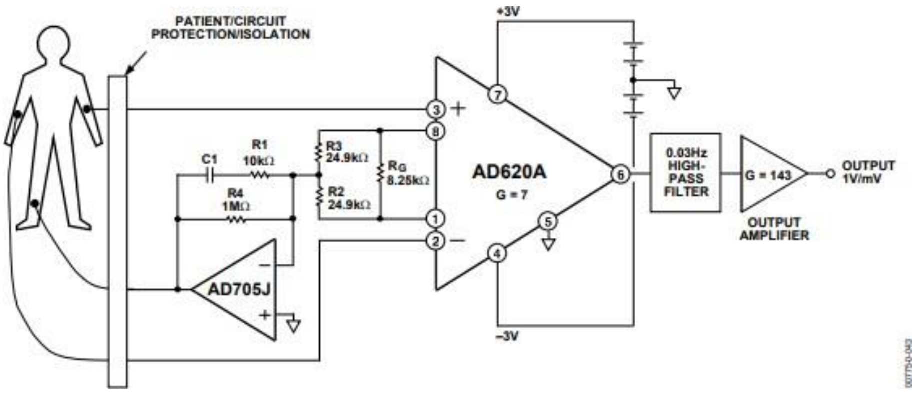
It is a waveform that records the electrical activity of the heart (the rhythm, the frequency, the rhythm of the heartbeat, the spread of the heartbeat, and the disappearance of the reaction) graphically by means of electrodes affixed to the body. Electrocardiography (ECG) is a device based on the observation of the contraction and relaxation stages of the atria and ventricles of the heart, the electrical activity that occurs during the stimulation of the heart and the transmission of the signals.



Each step will be explained.

Chapter 2

2.1 AD620 CIRCUIT:



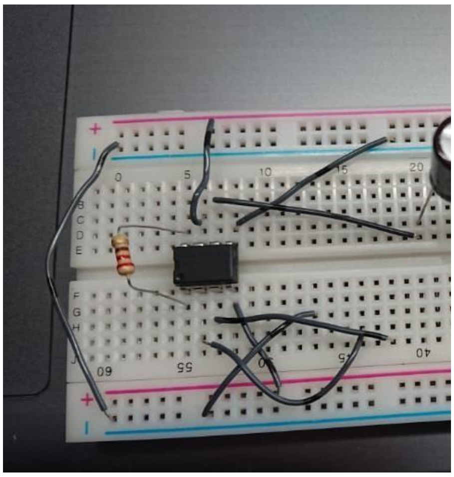
Connection Diagram of AD620

This circuit is used to receive the heart signal of the patient. The second and third ports are connected to the right and left sides respectively. And the third is connected to the ground to protect the patient. In addition, ports 4 and 7 are used to connect negative and positive power supplies, respectively. A 500 ohm resistor, called rg, is also connected between ports 1 and 8 to achieve a 100-fold gain. The 5th port is connected to the grounding line. And finally, port 6 is the output port. Here, an output signal from the op-amp, which is the result of all processing to the signals, is received and transferred to the filter lot.

$$G = \frac{49.4k\Omega}{R_G} + 1$$

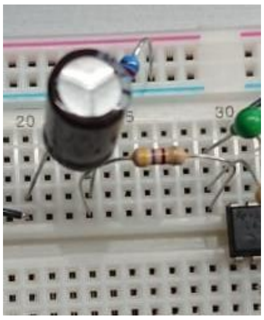
These two equations are used to calculate Rg and gain for AD620 circuit.

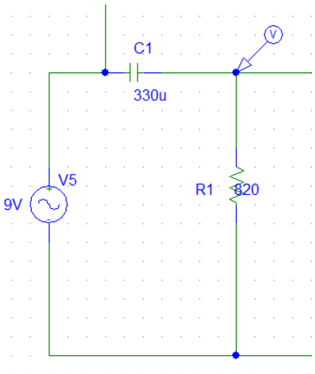
$$R_G = \frac{49.4k\Omega}{G-1}$$



2.2 Filters

2.2.1 High Pass Filter

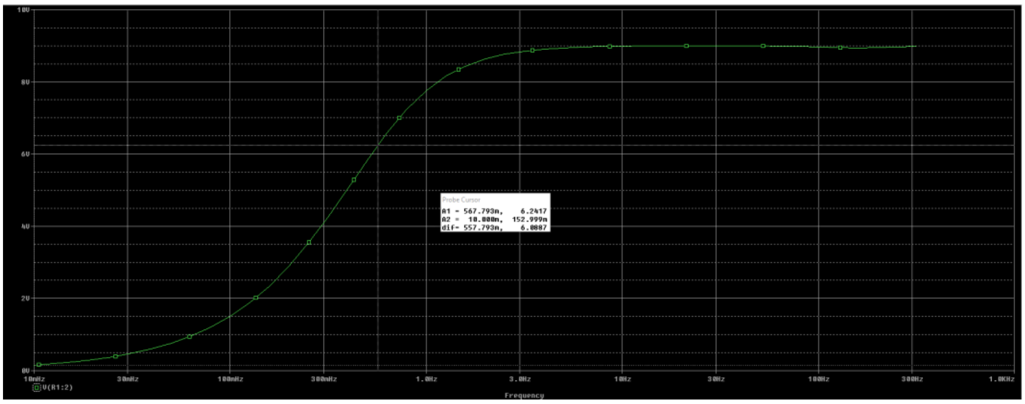




High pass filters are a type of electronic filters that pass signals which has a higher frequency than the cut-off frequency and attenuates signal which has a lower frequency than cut-off frequency.Also they can be used in blocking DC, radio frequency and if they can be combained with low pass filter to produce bandpass filter.

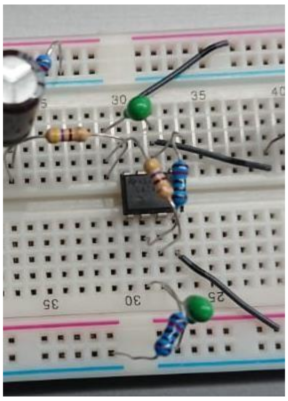
330 micro farad capacitor and 820 ohm resistor were used to adjust the cut off 0.5 Hz as shown in the circuit. In order to make the cutoff of 0.5 Hz, the following formula was used.

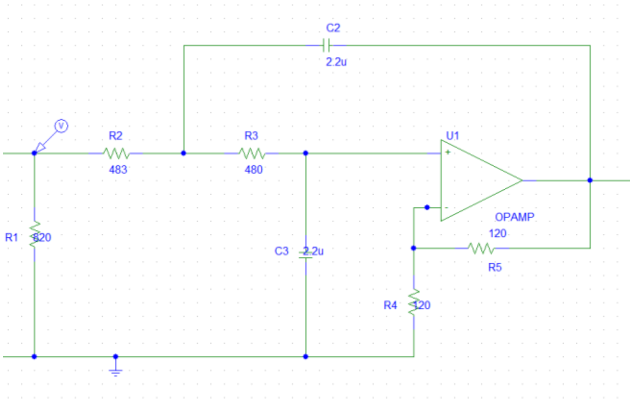
$$f_c = \frac{1}{2\pi\tau} = \frac{1}{2\pi RC},$$



Output Graph of High Pass Filter

2.2.2 Low Pass Filter





High pass filters are a type of electronic filters that pass signals which has a lower frequency than the cut-off frequency and attenuates signal which has a higher frequency than cut-off frequency. Also, they can be combined with a high pass filter to produce a bandpass filter.

The circuits shown above are a 2nd order active low pass filter circuit. If the resistor and capacitor values in the circuit are the same, the cut-off formula is the same as the above high pass filter cut-off formula, but if it is different, the following formula (title of block is “If Resistor and Capacitor values are different”)must be used. In addition, since it is an active filter, the voltage of the signal can be amplified, but the amplification is not preferred here because the AD620 circuit has been increased by about 100 times. And the cut-off was set to approximately 150 Hz for which 2 pieces 480-ohm resistors, 2 pieces 2.2 microfarad capacitors and 2 more pieces 120 ohm resistors were used.

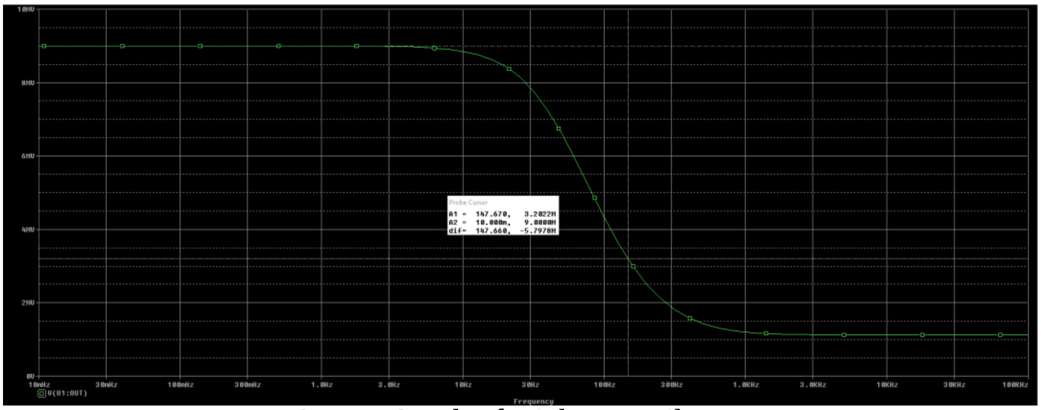
$$\text{Gain (Av)} = 1 + \frac{R_A}{R_B}$$

If Resistor and Capacitor values are different:

$$f_C = \frac{1}{2\pi \sqrt{R_1 R_2 C_1 C_2}}$$

If Resistor and Capacitor values are the same:

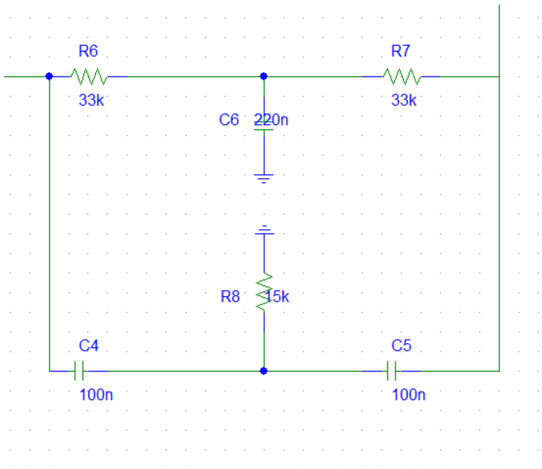
$$f_C = \frac{1}{2\pi RC}$$



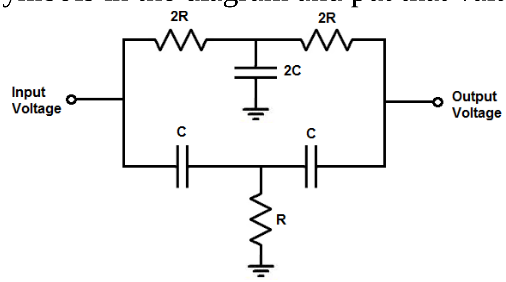
Output Graph of High Pass Filter

2.2.3 Notch Filter

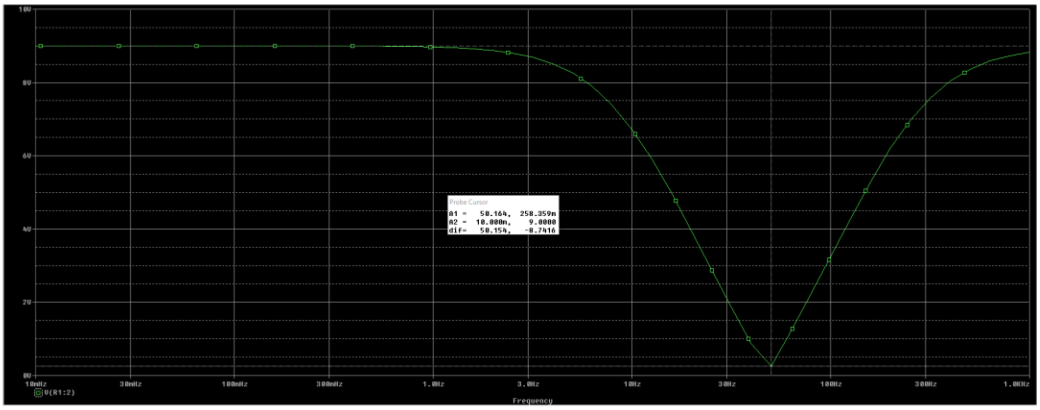
A Notch Filter is also known as a Band Stop filter or Band Reject Filter. These filters reject/attenuate signals in a specific frequency band called the stopband frequency range and pass the signals above and below this band.



The following circuit diagram and formula were used to calculate the notch filter circuit and the cut-off frequency. The cut-off frequency was set to 50 hz so that the noise signal 50 hz on the network line was not detected in the ecg signal. When calculating the cut-off, we can multiply the C and R values by using the symbols in the diagram and put that value in the formula.



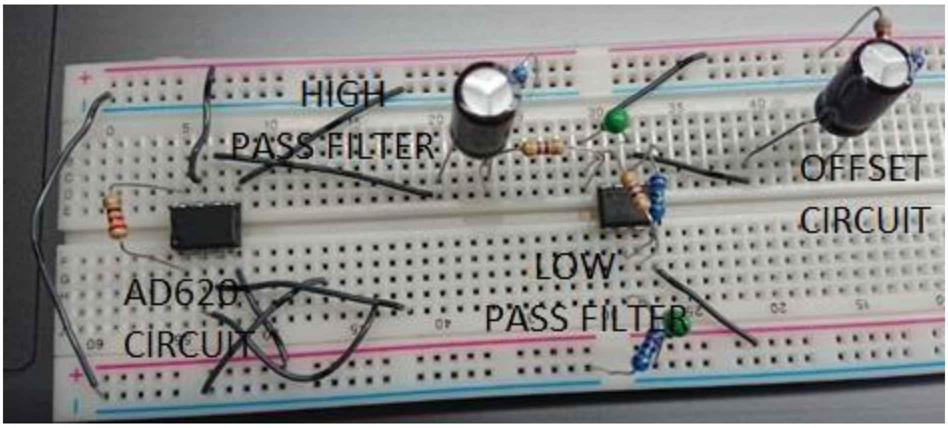
Notch Filter Frequency= $\frac{1}{4\pi RC}$



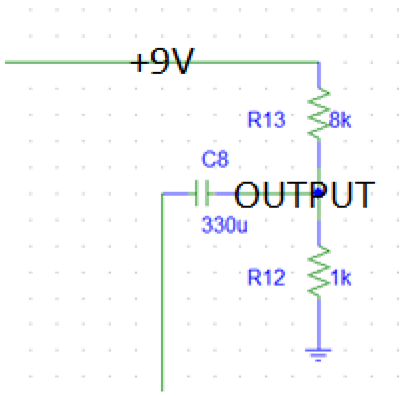
Output graph of Notch filter

When the frequency is 50, the filter reduces the signal to a minimum voltage level as shown in the graph.

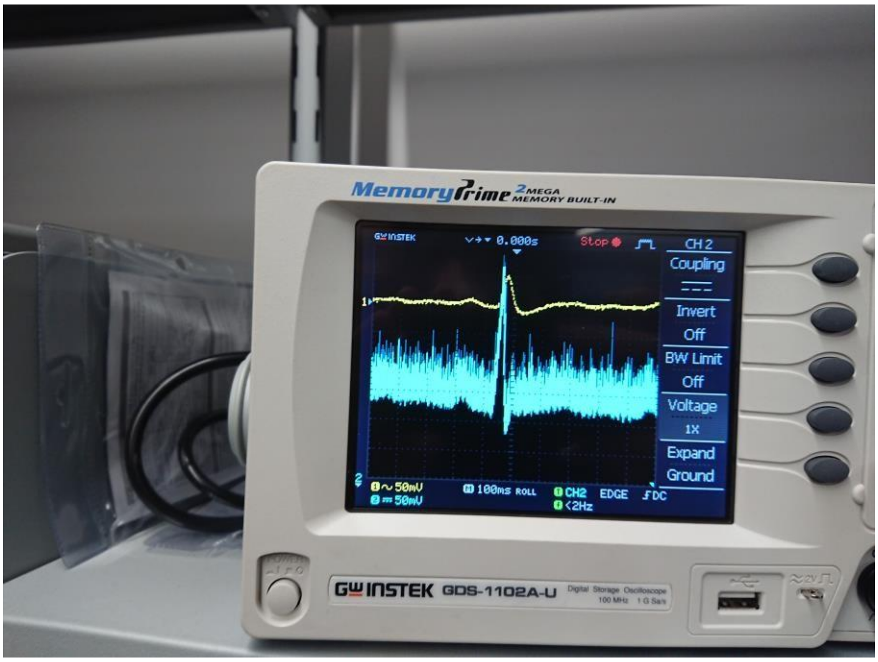
2.2.4 Whole Circuit



After the optimization and connections of the whole circuit, the possible circuit will be shown as above. And +9 and -9 volt batteries were used to feed the circuit and the op-amps. In the last part, the offset circuit can be seen. The reason for the offset is that the serial communication is done by using Arduino and Arduino is able to send signals with values of 1V and above, so the offset circuit was needed.



An offset circuit can be formed simply by a capacitor and a voltage divider circuit. A voltage divider is used to increase the voltage level of ecg signal and a capacitor that is the same value as the capacitor in a high pass filter and to prevent dc flow back to the circuit. If the above voltage divider is analyzed, approximately 1 v is added to the ECG signal.



The blue signal is the output of the ad620 circuits but the yellow signal is filtered signal.

2.2.5 Reason for Setting Cut-offs

The common frequencies of the important components on the ECG:

- Heart rate: 0.67 – 5 Hz (i.e. 40 – 300 bpm)
- P-wave: 0.67 – 5 Hz
- QRS: 10 – 50 Hz
- T-wave: 1 – 7 Hz
- High frequency potentials□: 100 – 500 Hz

The common frequencies of the artifact and noise on the ECG:

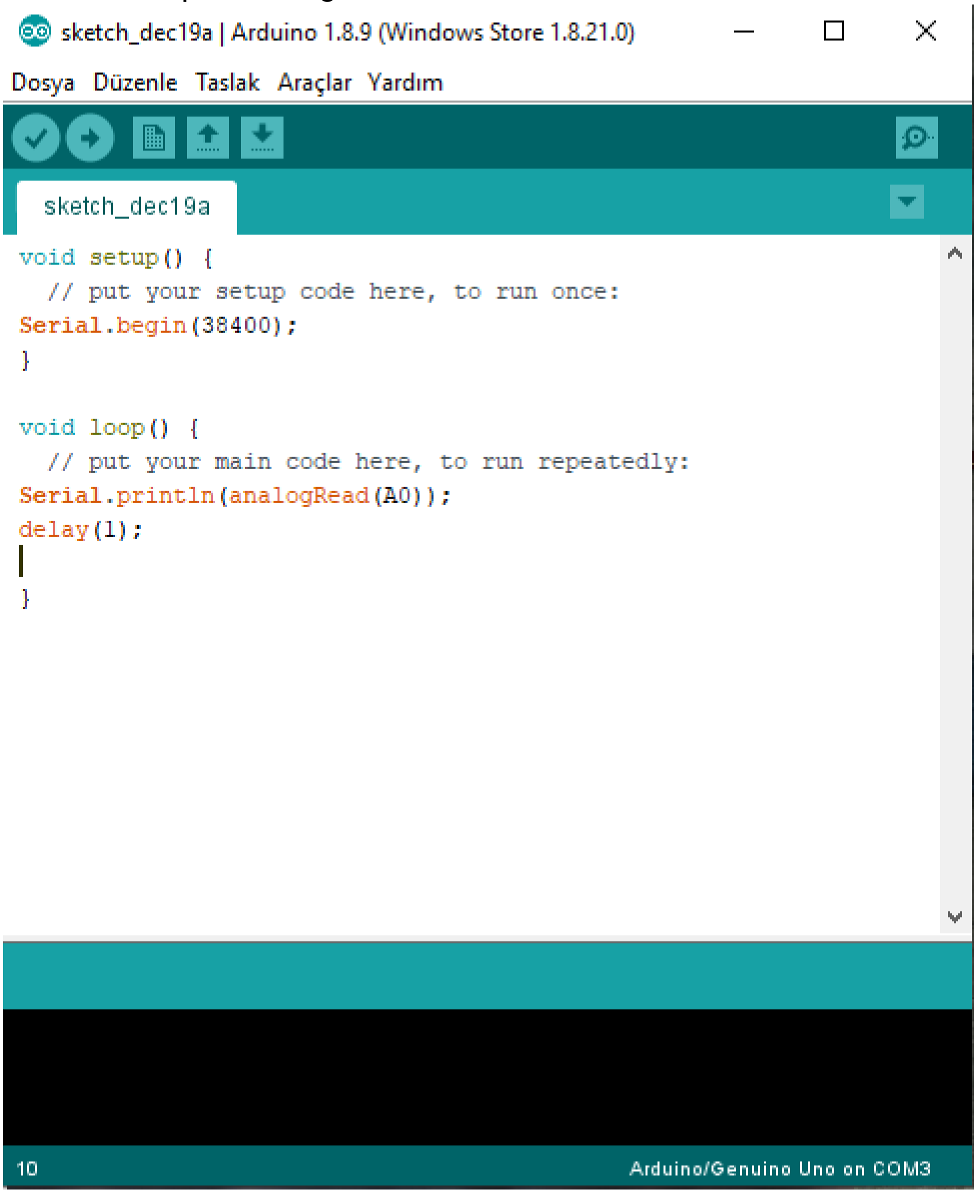
- Muscle: 5 – 50 Hz
- Respiratory: 0.12 – 0.5 Hz (e.g. 8 – 30 bpm)
- External electrical: 50 or 60 Hz (A/C mains or line frequency)
- Other electrical: typically >10 Hz (muscle stimulators, strong magnetic fields, pacemakers with impedance monitoring)

	HIGH PASS FILTER	LOW PASS FILTER	NOTCH FILTER
CUT-OFF FREQUENCY(Hz)	0.58	150	50

These table is given information about our filter's cut-off frequency. When the frequency values of the above ECG components are examined, no data loss occurs in the selected frequency range in the filters. And the waves that carry insignificant and unnecessary information that can damage the signal are filtered and the ECG signal is cleared.

2.4 Analog to Digital Converter

Arduino is used as an analog-to-digital converter (ADC) and the serial communication or Bluetooth communication is used to send the signal to MATLAB for processing.



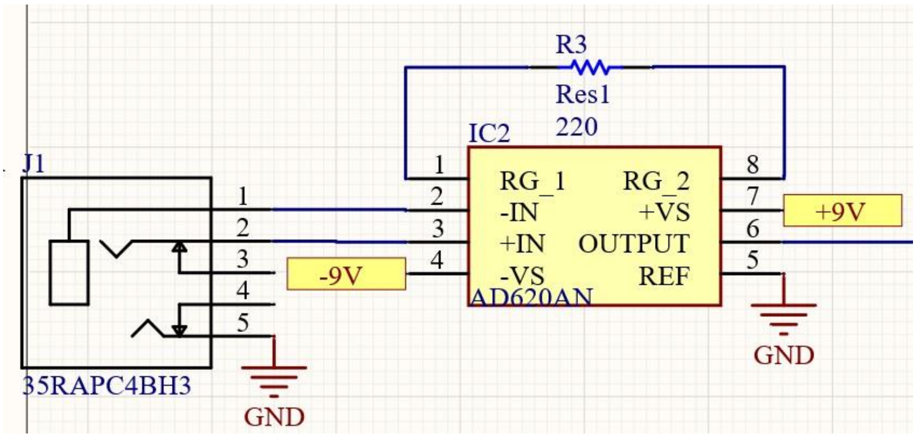
2.4 PCB

2.4.1 Making Schematic Altium

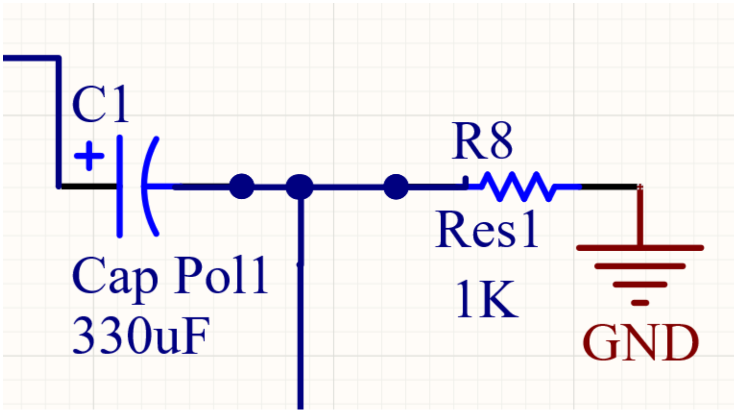
All of circuits or systems about engineering needs planning and simulating on digital platforms. The circuit which was decided last version transferred that most efficient and using at least area because of device size depends on pcb size to Altium Designer to draw PCB.

Parts of Schematics

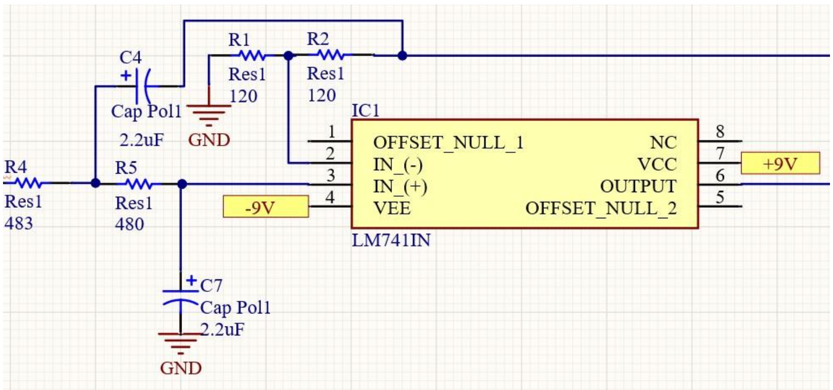
2.4.2 Jack and AD620 Connections



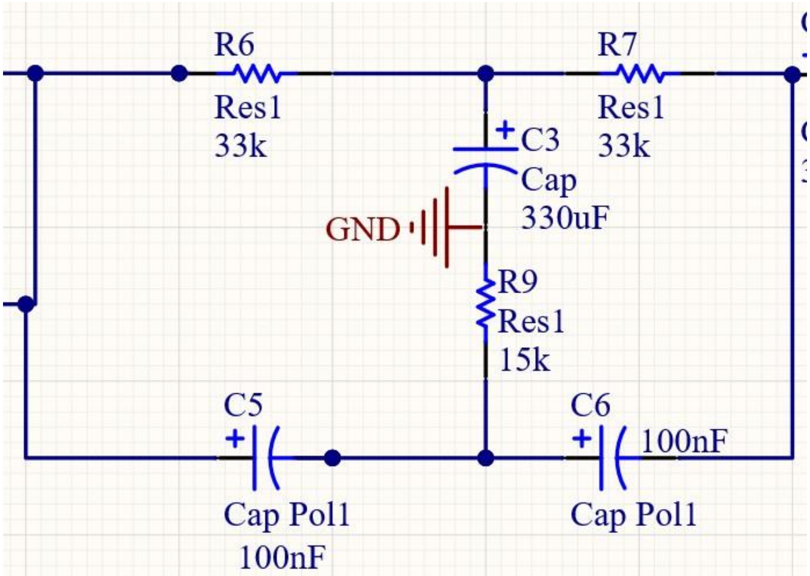
2.4.3 High Pass Filter



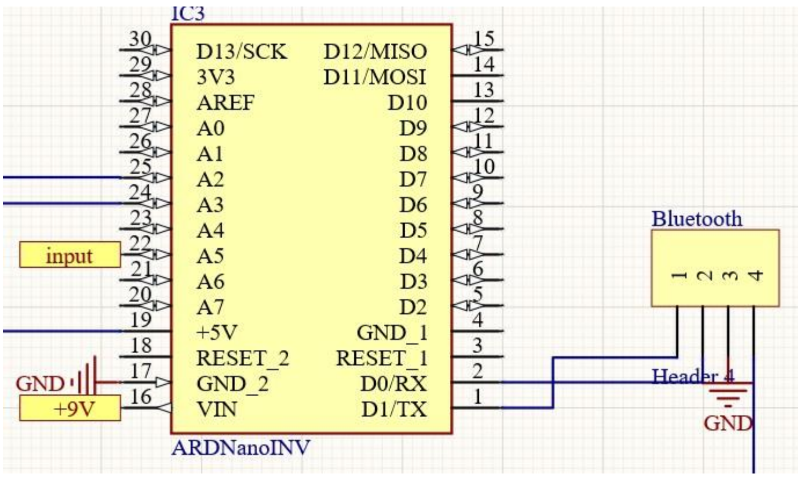
2.4.4 Filtering and Amplifying



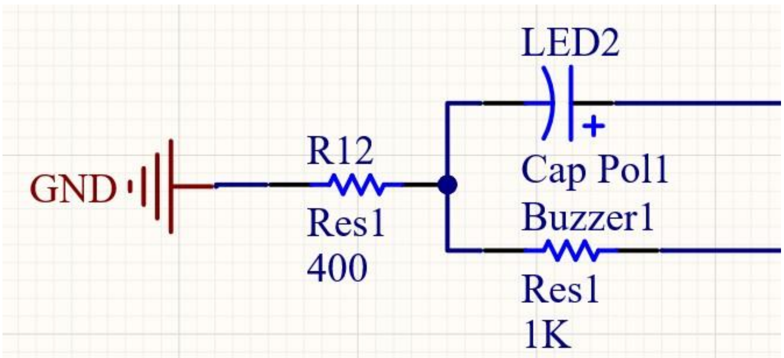
2.4.5 Notch Filter



2.4.6 Arduino and Bluetooth

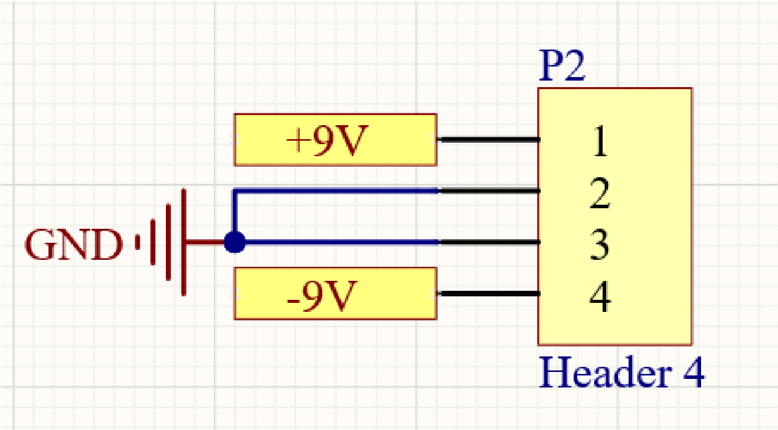


2.4.7 Led and Buzzer

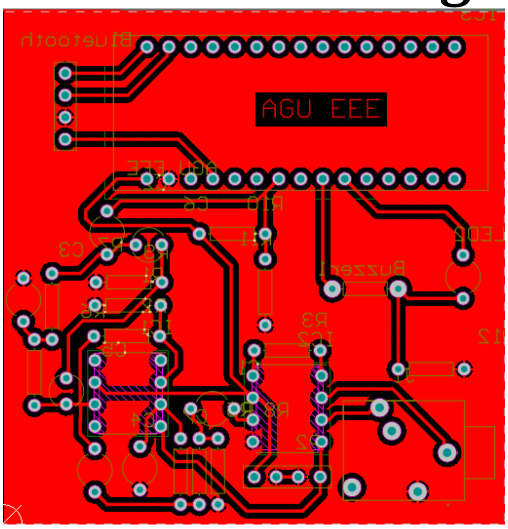


The reason for the addition of the buzzer is that users who have eye vision problems understand that the system is working with sound output. Moreover, the red LED has been added to the system for hearing impaired users.

2.4.8 Voltage Source



2.4.9 Making PCB on Altium



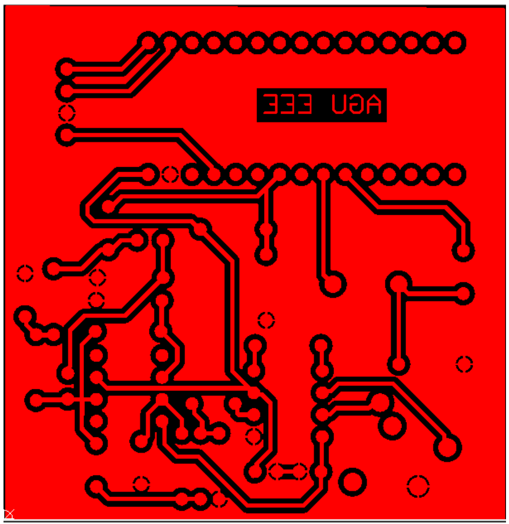
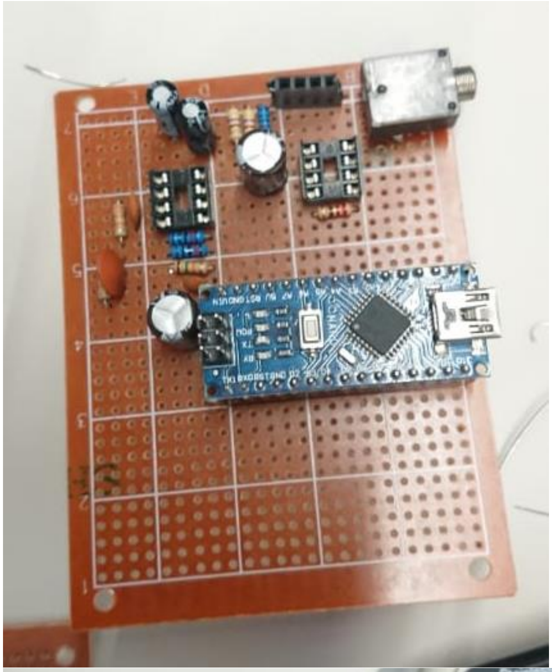
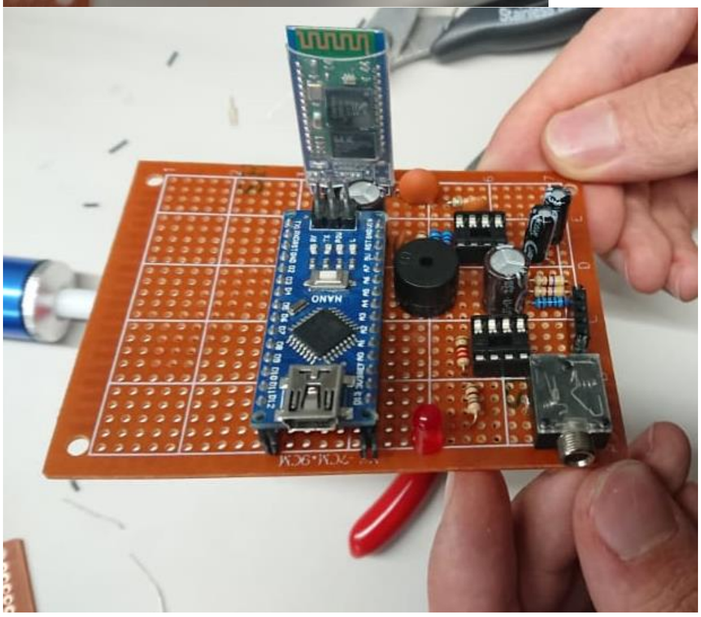


Figure: Gerber Version of Circuit **Figure 1: PCB Version of System**

All of schematic of the system is transferred to PCB to produce circuit. The PCB is almost ready to manufacturing. However, AGU's PCB CNC machine cannot print it successfully, then, even though PCB is tried by printing – ironing – acid methods, it is also gave an unsuccessfully result. Last perforated plaque method is used and circuit is set.





Chapter 3

Digital Part

After Arduino part, MATLAB code used.

The serial or Bluetooth communication between Arduino and MATLAB is used. The communication type can be determined by the user.

According to Arduino

code, the sampling frequency is measured with time code. Our sampling frequency is 770 Hz which is enough for our purposes. A four second array is created and store the signal which comes from Arduino. This array updates itself with every newdata.

```
if  qw== 0
    flushinput(app.s);
    app.Time = timeit(@() app.first_recording);
    app.Time;
    disp(app.fs)
    qw=1;
end
```

3.1 ECG signals should be plotted in real-time

According to the sampling frequency, another array is created to show time in x axis of the plot. Using 4 second array and time array, data is plottedinoneofthe Axes.

```
drawnow;
der=der+1;
for i=1:1:385
    app.Ecg=[ app.Ecg([2:end]) str2double(fgetl(app.s))]; %signal taking from arduino
    time=[time(2:end) time(end)+1];
end
p2=time/770;
app.New=app.Ecg-mean(app.Ecg);
plot(app.UIAxes,p2,app.Ecg)%plot original signal
```

3.2 FFT of the signal should be plotted in real-time

The ecg signal is obtained with using some functions. To find the FFT of the signal, FFT function is used and its absolute value is taken. An array is created for frequency. According to the Nyquist theorem the maximum frequency that can be shown is half of our sampling frequency so XLim code is used to limit the signal. After that, the signal's fft is plotted with frequency and absolute of fft of signal.

```
fft1=abs(fft(app.New));
plot(app.UIAxes2,frequancy,fft1); %plot fft of original signal
app.UIAxes2.XLim=[0 app.FS/2];
```

3.3 Digital Filter Part

Different types of filter used in this process such as Butterworth, Chebyshev, Ellictip. A system is designed such that the user can choose the filter type (Butter, Cheby) and the type (high, low or bandpass). The cutoff frequencies and the order of the filter can be determined by the user.

3.4 Hearth rate

To calculate the hearth rate, raw ecg signal is processed. First, movmean function is use to eliminate the offset of the signal and a bandpass filter used. The raw signal has high 50hz noise components so that another filter is used to eliminate 50hz signal. Then, to make the peaks sharp, the differentiation of signal. The signal is normalized between 0 and 1. Furthermore, find peaks function is used to determine the peaks with using min peak height and min peak distance. These values are founded with using experiment. After some experiment values are founded that can work for almost every signal. Find peaks function gave the locations of the peaks. Therefore, the difference between two peaks is calculated and divided with sampling frequency this gave the period of the ecg peaks. With using period, the instantaneous bpm is calculated. Then, these instantaneous bpm are stored in an array and its mean is taken and the value is rounded. After that, the bpm is shown to user in a box.

```
ecgpeak=app.Ecg;
  ecgpeak = ecgpeak-movmean(ecgpeak,50);
  [n, m]= butter(1,[3 10]/(app.FS/2),"Bandpass");
  ecgpeak = filter(n,m,ecgpeak);
  [n1,m1 ]= butter(3,10/(app.FS/2),"low");
  ecgpeak = filter(n1,m1,ecgpeak);
  ecgpeak=diff(ecgpeak);
  ecgpeak = normalize(ecgpeak,'range');
  [~,locs_Rwave] = findpeaks(ecgpeak,'MinPeakHeight',0.8,'MinPeakDistance',2);
  app.u=ones(1,length(locs_Rwave));
  for i=2:length(locs_Rwave)
      app.u(i-1)=60*app.FS/(locs_Rwave(i)-locs_Rwave(i-1));
  end
  beats=round(mean(app.u));
  app.u=ones(1,length(locs_Rwave));
  app.BPMEditField.Value=beats;
```

3.5 Signals should be recorded and be plotted.

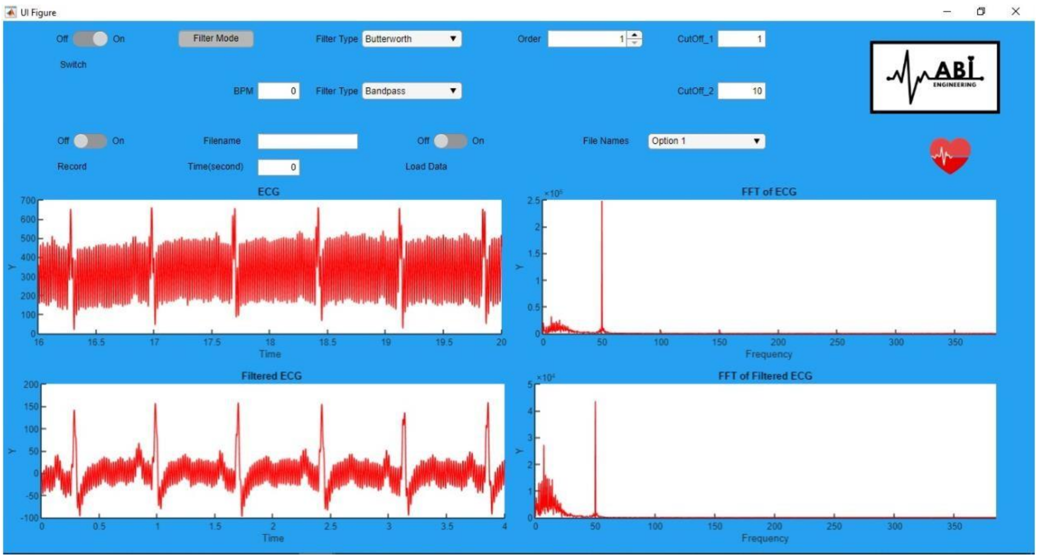
A record function is created and this function need the duration of the record in seconds and the name of the file. When the record switch on, the app asks to user where do you want to record the signal (location, folder). Then it takes the data store in an array and save it in a folder. Finally, it plots the ecg signal to show the user. There is a system to avoid the NAN values. While recording sometimes MATLAB can't take the data and it puts there a NAN value. To avoid this situation, some precautions are taken.

```
app.s=serial('COM4','BaudRate',38400);
app.s.InputBuffer = 500000;
fopen(app.s)
str=[app.filename "mat"];

fname = join(str,".");
record=ones(1,app.recordingseconds);
cd=uigetdir;
f=fullfile(cd,fname);
for i=1:app.recordingseconds
    record(i)=str2double(fgetl(app.s));
end
save(f,"record",'-mat')
plot(app.UIAxes,record)
```

3.6 Load the signal for processing

A switch for pre-recorded signals is created. When the switch on, app ask to user the location of the signals file. Then, app find the possible files make it a list to show user. The user can choose any file in that folder. The user can use filter functions and see the raw signal, fft, filtered signal and filtered signals fft plots. Finally, the heath rate will be calculated and will show the user.



General perspective of Application

4-Results and Conclusion

With using AD620 amplifier, high and low pass filters an ECG signal obtainer were created. There were some difficulties. Finding the right values for analog filters was one of them. These values can’t be random so we searched and find some values. Making the PCB was challenging for us, a circuit for PCB is designed but it did not work well. Therefore, pertinax is used to create the circuit board. Arduino is used to converting the analog signal to digital with using Bluetooth or serial communication signal is sent to MATLAB. A graphical user interface (GUI) is designed in MATLAB. Online processing, offline processing and recording function are created to process signal.

4.1 - Discussion

The degree of filters can be increased. In addition, PCBs can be used instead of pertinax to make it look more professional. The design and size of the device can be improved to appeal to the eye. Most importantly, by making an android app, people can see the analysis of ecg signals on their phone's screens and thus can be used for pre-diagnosis when they go to the hospital

5- REFERENCES

- http://ems12lead.com/2014/03/10/understanding-ecg-filtering/#gref
- https://www.electronics-tutorials.ws/filter/second-order-filters.html
- https://www.everythingrf.com/community/what-is-a-notch-filter
- http://www.learningaboutelectronics.com/Articles/Notch-filter-calculator.php
- https://learn.sparkfun.com/tutorials/ad8232-heart-rate-monitor-hookup- guide/
- https://www.canva.com/
- https://www.analog.com/media/en/technical-documentation/data-sheets/AD620.pdf
- https://www.sciencedirect.com/topics/engineering/nyquist-theorem
- PSPICE
- ALTIUM
- ARDUINO
- MATLAB