B. TECH. PROJECT REPORT

On

Cost-effective Data Logger For Continuous Heart Beat Monitoring

BY

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DISCIPLINE OF ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY INDORE

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Cost-effective Data Logger For Continuous Heart Beat Monitoring

A PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the degrees

of

BACHELOR OF TECHNOLOGY

in

ELECTRICAL ENGINEERING

Submitted by:

Hans Raj (180002019)

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Dr. Srivathsan Vasudevan

INDIAN INSTITUTE OF TECHNOLOGY INDORE

May 2022

CANDIDATE'S DECLARATION

I hereby declare that the project entitled **"Cost-effective data logger for continuous heart beat monitoring"** submitted in partial fulfillment for the award of the degree of Bachelor of Technology in 'Electrical Engineering' completed under the supervision of **Dr. Srivathsan Vasudevan, Associate professor** IIT Indore is an authentic work.

Further, I declare that I have not submitted this work for the award of any other degree elsewhere.

हंसराज
19/05/22

Hans Raj (19/05/2022)

CERTIFICATE by BTP Guide(s)

It is certified that the above statement made by the students is correct to the best of my/our knowledge.

Signature of BTP Guide(s) with dates and their designation

Preface

This report on "**Cost-effective Data Logger For Continuous Heart Beat Monitoring**" is prepared under the guidance of Dr. Srivathsan Vasudevan .

Through this thesis, We have tried to work on a system model which solves three major challenges faced by Heart beat monitoring:

1. designing ADC using LAUNCHXL-F2839D
2. filerization of the main pulse signal
3. Amplification of heart beat signal

We have tried our best to present the analysis carried out in a lucid manner with the help of graphs,circuit diagrams and by theoretical explanation.

Hans Raj

180002019

B.Tech. IV Year

Discipline of Electrical Engineering

IIT Indore

Acknowledgements

I wish to thank Dr. Srivathsan Vasudevan for his kind support and invaluable guidance over my work on the project. Dr. Srivathsan’s optimism and cheerfulness kept me striving to work hard. His confidence in me was a driving force for my interest in the project. I am immensely grateful for his direction and help.

I am grateful to the Institute for providing me an opportunity to be exposed to research which has substantial practical importance and is important for solving real life problems.

Sincere thanks to everyone who helped us to complete this project.

Hans Raj

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B.Tech. IV Year

Discipline of Electrical Engineering

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Abstract

Protecting one's health is essential for long life and happiness. Due to the public's lifestyle and eating habits, heart attacks have become quite prevalent. Early identification of a heart attack can assist to lessen the severity of the occurrence and protect the patient's health. In healthcare, technology has always been employed and has proven to be incredibly valuable. In the realm of IoT, sensors are crucial. A pulse sensor is used to monitor the patient's heartbeats in order to offer a system that can detect heart attacks early. The heartbeats are detected using a sensor. If the pulses are above or lower than the threshold value then it will be considered as an abnormal condition and this can be helpful to save someone's life.

Motivation

It is clear that heart rate monitoring is critical in the early stages of heart rate monitoring. Monitoring one's heart rate can also reveal how the body reacts to various situations. It's become quite effective for anyone suffering from any form of cardiac ailment. Even if you're in good physical health, heart rate monitoring can help you keep track of your health.

Contents

1.Chapter

Introduction

1.1_Motivation

Heart Attack nowadays has become globally leading death cause and the occurrence reason is also unknown always.The number people died by heart attack has been increasing from 2014. while in 2014 the number was around 14,345 which became twice in just the next five years. That record is only for delhi. If someone already has heart disease then surviving a heart attack becomes a poor possibility.

Heart attacks are very fatal but if someone gets an early idea of heart attack then he/she can take medical help. So it can be seen that a heart attack detector is a life saver.
Usually the price of a heart attack is high so it can not be afforded by everyone. The overall goal of this project is to make a heart attack detector with a very low pricing rate.

Most heart patients need continuous monitoring of heart beat monitoring. There are two ways for that: first is the patient hospitalized himself/herself and then the patient can be monitored by a doctor. And second is the patient buying some portable ecg monitor and monitor herself/himself.

Obviously second way is more practically possible because a heart patient can't be alwayse monitor by doctor and patient can't be hospitalized for long period of time because most of the bad of hospital are already occupied and hospital environment also affect patient psychologically. And it is not economically favorable.

But most of the portable heart beat monitors are in the range of 4k to 8k which is expensive for some people.

Here we tried to develop a low cost heart monitoring system.

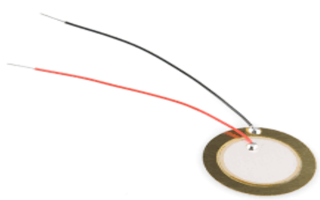
1.2 Introduction

Heart beat monitoring has been performed by combining four different circuit elements- Sensors ,filters, ADC ,Amplifier .

1.2.1 Sensors

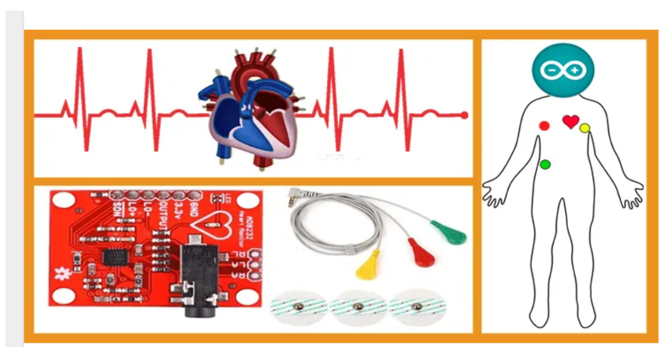
A sensor is a device that produces an output signal for the purpose of sensing a physical phenomenon. In this project, **three sensors** were used in order to sense pulse signals.

1. Piezoelectric sensor
2. Pulse sensor
3. AD8232 sensor



Piezoelectric sensor(Figure 1)

Pulse sensor(Figure 2)



AD8232 Sensor(Figure 3)

A. Piezoelectric sensor

The **piezoelectric sensor** is used in this project in order to get pulse beat and convert into electrical signals. Because of its low power consumption, small size, and simple signal conditioning needs, piezoelectric sensors are widely used. They also do not require any external electrical biasing.

B. Pulse sensor

Pulse sensor works on reflection and receiving of reflected signals from the wall of blood vessels. some signal is absorbed by hemoglobin in blood because of that the amount of reflected light is vary and we get our heart beat pattern.

C. AD8232 With electrodes

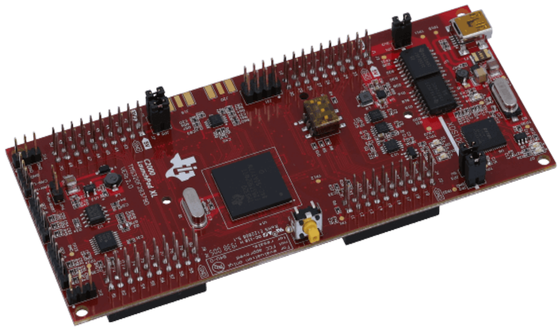
AD8232 sensor which is an electrode based sensor. AD8232 has 3 electrodes which are connected to our chest and other parts to AD8232. electrodes measure our hearts electrical activity, then interpreted and after that we can display on laptop or on portable display. During signal acquisition no electrical signal is sent to our body.

1.2.2 Analog to digital signal converter

Microprocessor-controlled circuits, Arduinos, Raspberry Pis, and other digital logic circuits need Analogue-to-Digital Converters (ADCs) to connect with the outside world. Many digital systems interact with their surroundings by monitoring the analogue signals from such transducers, which originate from numerous sources and sensors that can measure sound, light, temperature, or movement in the actual world.

An analogue to digital converter, in essence, takes a snapshot of an analogue voltage at one point in time and generates a digital output code that reflects this analogue value. The amount of binary digits, or bits, required to represent this analogue voltage value is determined by the A/D converter's resolution.

In this project we used LAUNCHXL-F28379D and Arduino uno in order to generate ADC.



LAUNCHXL-F28379D BOARD (Figure4)

Arduino Uno(Figure 5)

1.2.3 Filters

A filter is a device or technique in signal processing that removes undesired components or features from a signal. Filtering is a type of signal processing that involves the entire or partial suppression of one or more aspects of the signal.

A band pass filter (also known as a BPF or pass band filter) is a device that enables frequencies within a certain frequency range to pass through while rejecting (attenuating) frequencies outside that range.

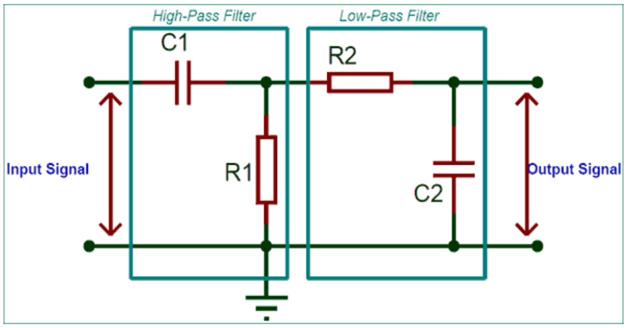
Signals with frequencies greater than the cutoff frequency are isolated using the low pass filter. Similar to the low pass filter, the high pass filter is used to isolate signals with frequencies lower than the cutoff frequency.

By connecting the high pass and low pass filters in a cascade, another filter is created that permits signals within a specified frequency range or band to pass through while attenuating sounds outside of that band. Band Pass Filter is the name for this type of filter.

Filtering by cascading three passive band pass RC filter

There are two cutoff frequencies in the Band Pass Filter. A high pass filter provides the initial cutoff frequency. This determines a band's higher frequency limit, also known as fc-high (cutoff frequency of high pass filter). The low pass filter's cutoff frequency is the second. This is also known as fc-low (cut off frequency of low pass filter).

As the frequency range for heart beat lies between 0.5Hz to 5Hz. So, In order to get noise free pulse signal ,a band pass filter has been added and in order to enhance filtration 3 band pass filters cascaded. The inbuilt filter was activated in the case of the pulse sensor and the AD8232 sensor.



Band pass RC filter(Fig. 6)

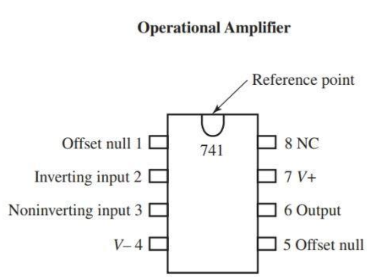
1.2.4 Amplifier

An electronic amplifier is a device that can boost the strength of a signal (a time-varying voltage or current). It's a two-port electrical circuit that uses electricity from a power source to boost the amplitude of a signal applied to its input terminals, resulting in a signal with a correspondingly higher amplitude at the output. The gain of an amplifier is defined as the ratio of output voltage, current, or power to input voltage, current, or power.

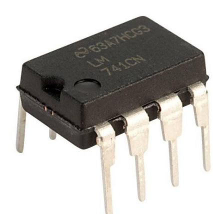
A circuit with a power gain larger than one is known as an amplifier.

In the current project, the need of an amplifier is to amplify the signal received after filtration.

In order to design the amplification circuit, IC 741 was used.



IC 741 Pin configuration (Figure7)

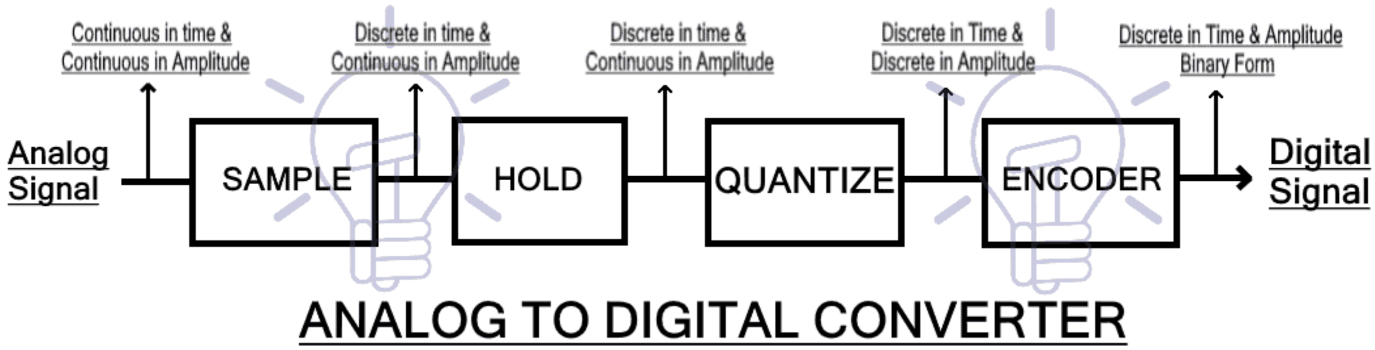


IC 741 (Figure 8)

2.Chapter

Principle behind heart beat monitoring

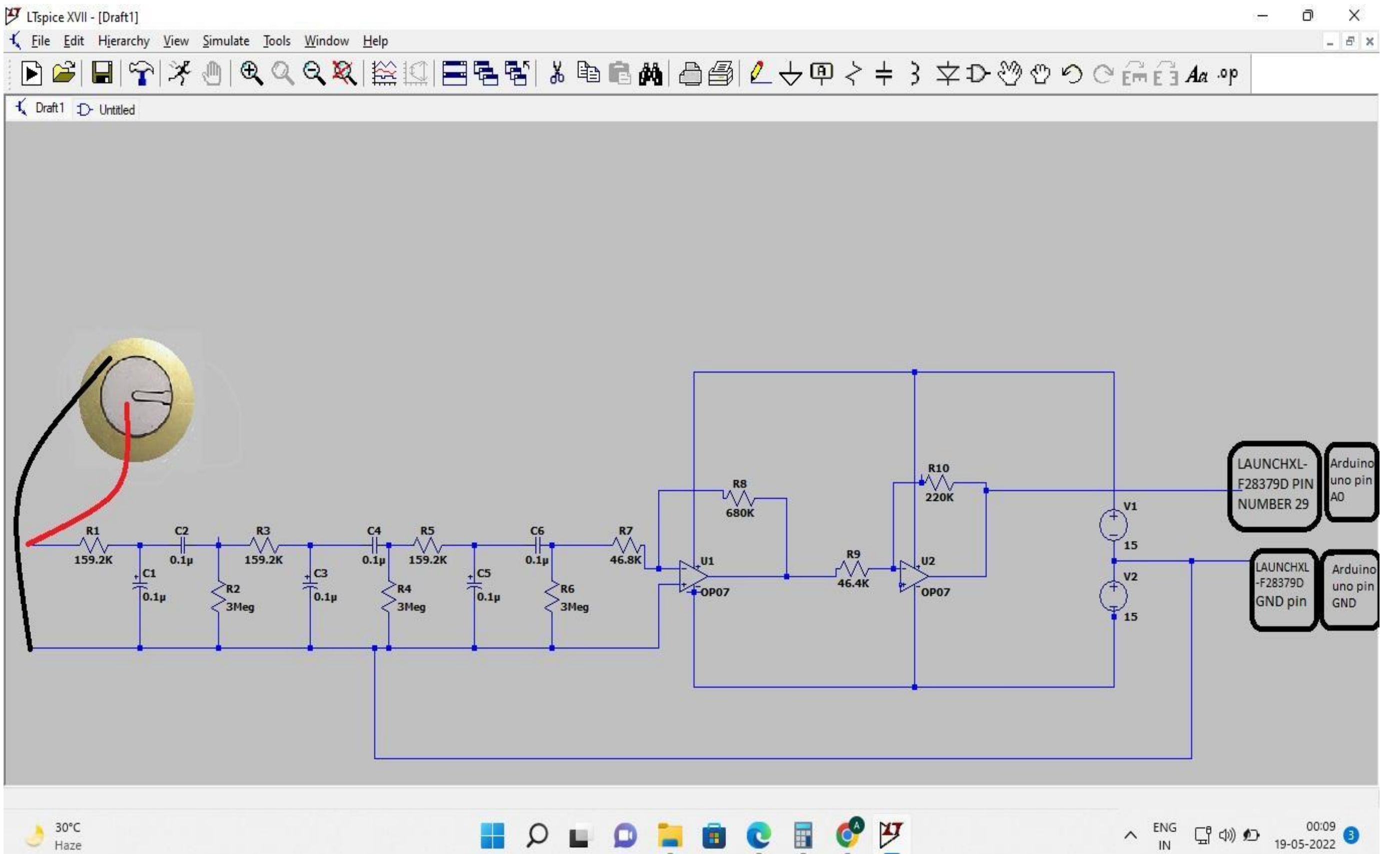
- The principle behind heart beat monitoring is **periodicity of heart activity(like electrical activity, pumping)**. We can detect this periodicity by many forms like heart beat vessels pressure, heart electrical activity, periodic flow of hemoglobin in blood etc.
- The principle behind the working of the piezoelectric Sensor is **piezoelectric effect**.According to this principle, The capacity of some materials to create an electric charge in response to mechanical stress is known as the Piezoelectric Effect.
- The principle behind IR transmitter & receiver is **reflection of light by the wall of blood vessels** as some part of signal is absorbed by hemoglobin and after that some of it is reflected as over heart pump periodically because of that hemoglobin count also varies periodically at certain positions of blood vessels. When Infrared light is sent by an IR transmitter if the hemoglobin count is high at that position we get less reflected light and if hemoglobin count is less then we get more reflected light and hence we get a periodically repeating pattern of heart activity. This phenomenon is used in pulse sensors.
- AD8232 sensor works on the principle of **taking electrical signals from 3 sensors(electrodes) and then creating a heart beat pulse.**
- Here comes the role of our filerization circuit , the three cascaded RC band pass filter system removes the unwanted frequency signal.
- In the process of filtration, the main pulse signal gets weak. Now the amplifier works for its role and amplifies the signal.IC 741 used which works on the **principle of taking power from DC supply and using it to amplify the main AC signal.**
- In the end, ADC used and displayed the heart beat monitoring on my PC.The principle of the ADC is divided into four steps: (i)**sampling** (ii)**holding** (iii) **Quantization** (iv)**Coding**


Continuous in time &
Continuous in Amplitude
Discrete in time &
Continuous in Amplitude
Discrete in time &
Continuous in Amplitude
Discrete in Time &
Discrete in Amplitude
Discrete in Time & Amplitude
Binary Form
Analog Signal
SAMPLE
HOLD
QUANTIZE
ENCODER
Digital Signal
ANALOG TO DIGITAL CONVERTER

(Figure 9)

3.Chapter

Architecture of the Project



circuit with signal acquisition,filterzation,amplification and adc (Figure 10)

1. **Piezoelectric sensor**

- red wire → positive polarity
- black wire → ground/negative polarity

2. **IC 741**

- Pin 2 → inverting input terminal(connected to the output of the filter system)
- Pin 3 → non-inverting input terminal (connected to ground through supply)
- Pin 4 → +Vcc (connected +15 Volt power supply)
- pin 7→ -Vcc(connected -15 Volt power supply)
- pin 6 → output (connected to Arduino A0 terminal)
- other pin left open

3. **AD8232**
    - Connect the GND of the sensor to the GND of the Arduino.
    - Connect 3.3V to the 3.3V of the Arduino.
    - Connect an output of the sensor to the A0 of the Arduino.
    - Connect LO- to PIN 11 of the Arduino.
    - Connect LO+ to PIN 10 of the Arduino.
    - Keep the SDN pin unconnected.

4. **Electrodes**
    - red → right side chest
    - yellow → left side chest
    - green → right side ribs
5. **Arduino**

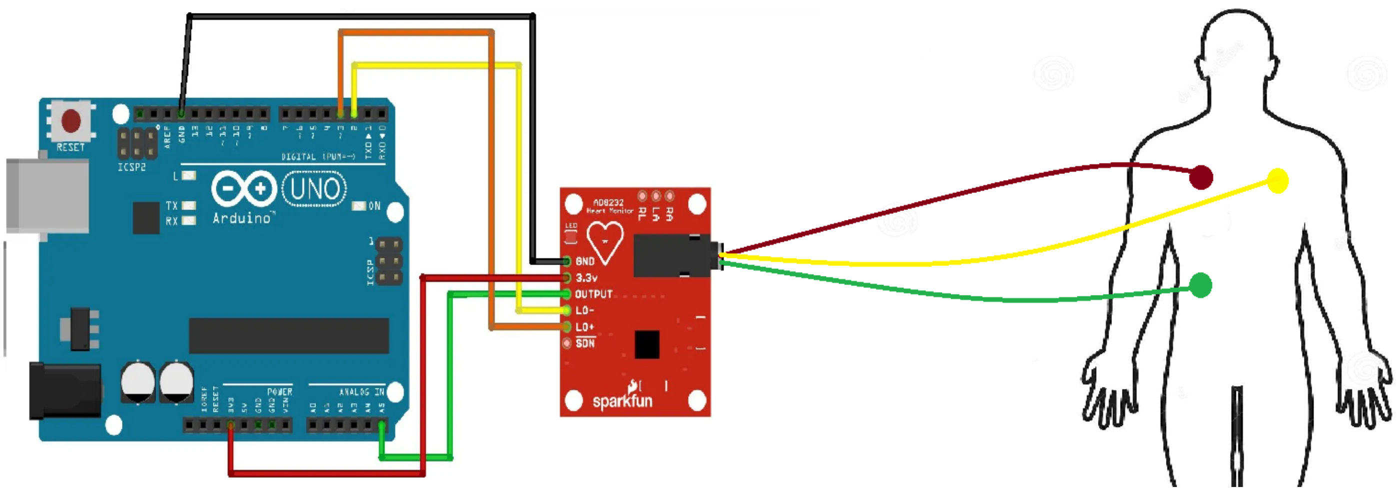
    i) With AD8232 Sensor
    - Connect the GND of the arduino to the GND of the sensor.
    - Connect 3.3V to the 3.3V of the sensor.
    - Connect the A0 output of the Arduino to the A0 of the sensor.
    - Connect PIN 11 of the Arduino to the LO- pin of the AD8232 sensor.
    - Connect PIN 10 of the Arduino to LO+ pin of the sensor.
    - keep the other pin disconnected.
    - connect USB connector to PC.

ii) With piezoelectric sensor

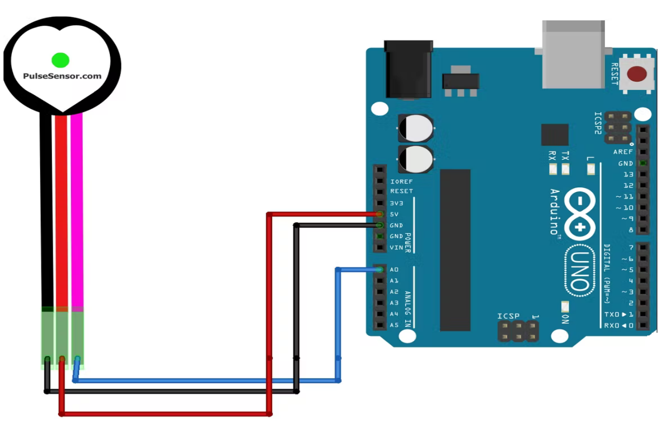
- connect the filtration circuit's output to the A0 terminal of the Arduino.
- The GND terminal of the arduino will be connected to the ground of supply.
- the USB connector connects to the PC.

6. LAUNCHXL-F28379D

- Pin 29 is connected with the output of filtration ckt.
- The gnd pin is grounded with the supply.



Arduino with AD8232 and electrode placement (Figure 11)



Pulse sensor with arduino (Figure 12)

4. Chapter

Working of Individual Components

4.1 Working of ADC

Analog to digital converter needs to work with arduino raspberry pi and many other digital circuits because these circuits can work with digital signals, and by using these circuits we can connect with the world example. analog signals are those signals which are continuous in nature and these signals change value continuously. Most of our sensors(ultrasonic sensor,piezoelectric sensor,sonar sensor,temperature sensor and many more) produce analog output. and to connect with the real world electronically we need these signals in the form of digital signals.

Digital signals are those signals which have signals in the form of 1(logic high) or 0(logic low) and are discrete in nature. whereas analog signals have an infinite number of output values. So to work with real world problems we need digital signals but the sensor gives us output in analog form so we need to convert these two continuously changing domains to discrete domains so that we can work with real life problems and here comes the role of analog to digital converter.

Basically analog to digital converter takes a snapshot of continuously changing signal at an instant of time and converts it into digital form which represents approx analog signal. The closeness to analog signal is called resolution of analog to digital converter.

4.1.1 Example to understand the working of ADC-

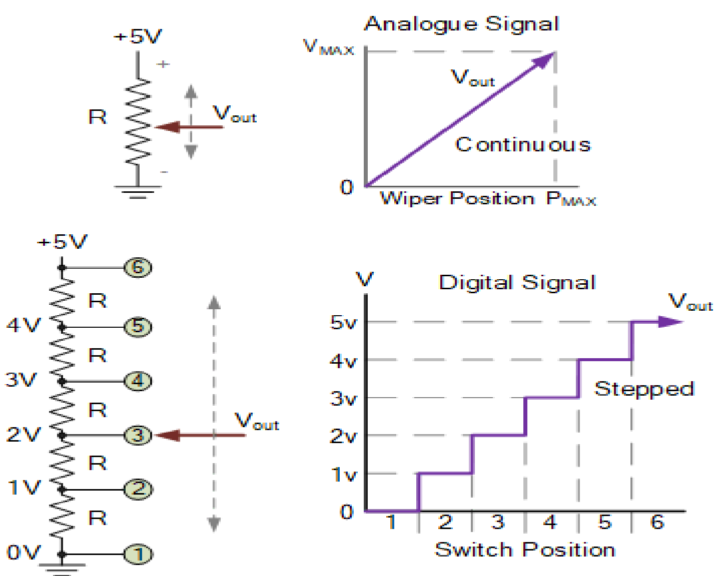


Figure 13. explaining interconnection of analog and digital signal

In the above circuit diagram we can see that the wiper terminal of potentiometer can move between 0 to vmax and take infiniter value between 0 to vmax and thus produce a continuous output as shown in the straight line graph. As we move potentiometer wire to one position to another there is no sudden change or sudden step change and because of that it produces an analog signal which is continuous in nature.Examples of analogue signals include temperature, pressure, liquid levels and light intensity.

For digital circuit potentiometer wire is replaced by rotary switch which has an equal 5 step mechanism. The resistance of potentiometer wire is equally divided and on rotating the switch resistance take equal statp and because of that the voltage takes only some finite values and the graph looks like steps. The voltage value can only be 1v,2v,3v,4v,5v. whereas in analog circuits voltage can be anything between 0 to 5 volt, like 2.6v,3v,1.24v. In digital circuits voltage changes are discrete and distinctive voltage steps. if we increase the number of steps in the rotating switch we can even finer output. If the number of steps becomes very large then the digital output looks like analog output and we can call this an increase in resolution.

For a digital circuit the potentiometer wiper has been replaced by a single rotary switch which is connected in turn to each junction of the series resistor chain, forming a basic potential divider network. As the switch is rotated from one position (or node) to the next the output voltage, VOUT changes quickly in discrete and distinctive voltage steps representing multiples of 1.0 volts on each switching action or step as shown.

So we can see that we can convert analog signals to digital signals by making high resolution using high frequency clock signals.

In the below diagram we are showing what is the importance of the clock in analog to digital conversation. As we can see that if the clock frequency is low our digital conversation accuracy is low as compared to high clock frequency.

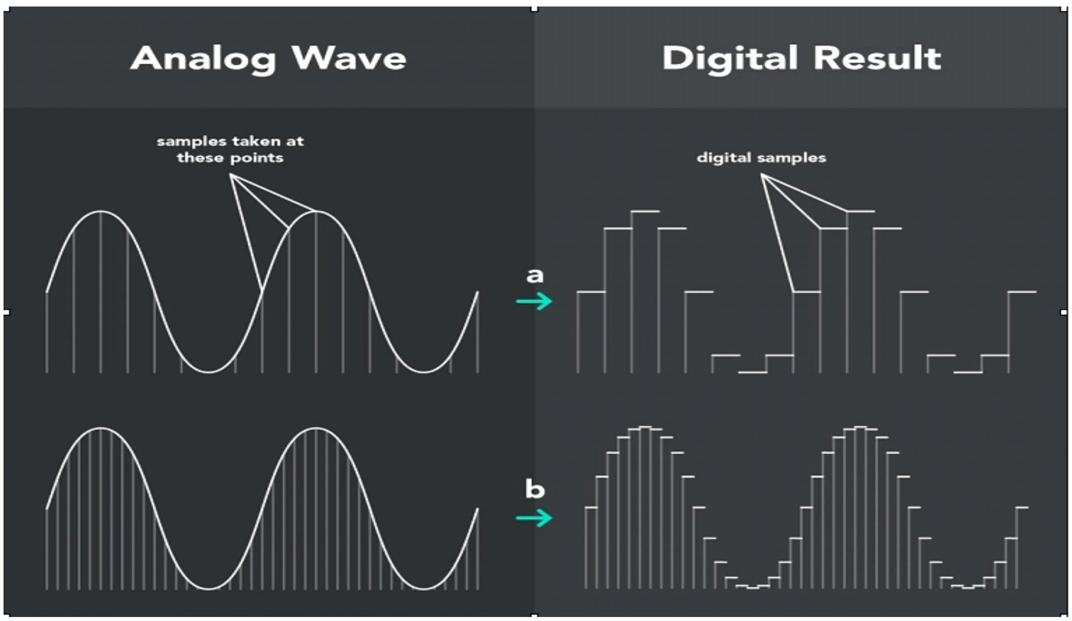


Figure 14

4.2 Working of filtration

4.2.1 What is filtering of noise?

Before filtering we need to understand what noise is. Noise is basically an unwanted signal which is associated with our desired signal. Anything other than our desired signal is noise. we can divide noise in multiple type like:-

1 Thermal noise

2 Shot noise

3 Partition noise

4 Flicker noise

5 Burst noise

6 Transit-time noise

The noise can come from anywhere, the circuit can itself produce noise, faulty circuit components, improper connection, loose component, switch used in circuit, electromagnetic interference with other equipment. Long leads of wire can also produce noise.

One of the ways to reduce the noise is reducing the length of input and output pin wire as much as practically possible . Using filter, isolation transformers, chokes and using low noise component are also noise reduction way.

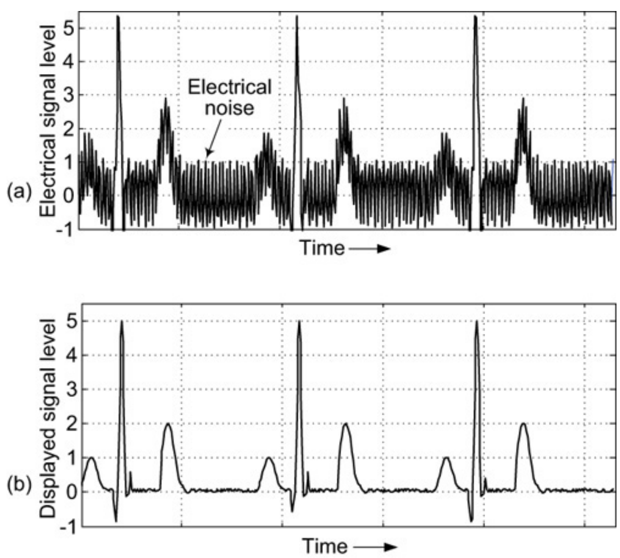


Figure 15 explaining a signal with and without noise

Electrocardiogram signals: (a) original measured noisy signal; (b) improved signal display after digital signal processing

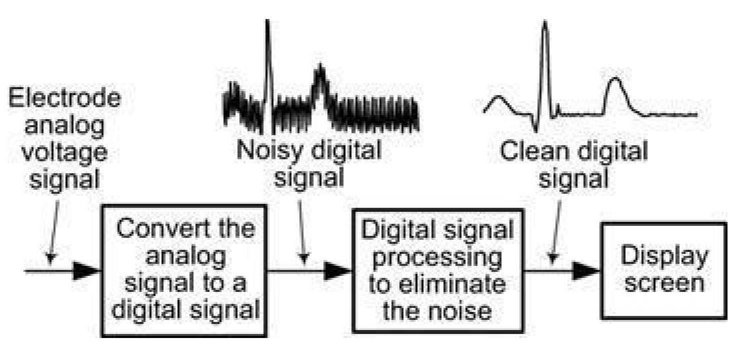


Figure 16. explaining signal processing

Using digital signal processing to improve an electrocardiogram signal display.

In the above two diagrams we can see that by using digital signal processing we can remove noise from our desired signal. One method of removing noise is using filters in digital signal processing. In our project we are using filters to reduce noise in our circuit.

4.2.2 Filter and its most common type

Filter:-In the field of signal processing, a filter is a device or process that, completely or partially, suppresses unwanted components or features from a signal. This usually means removing some frequencies to suppress interfering signals and to reduce background noise.

Type of filter:

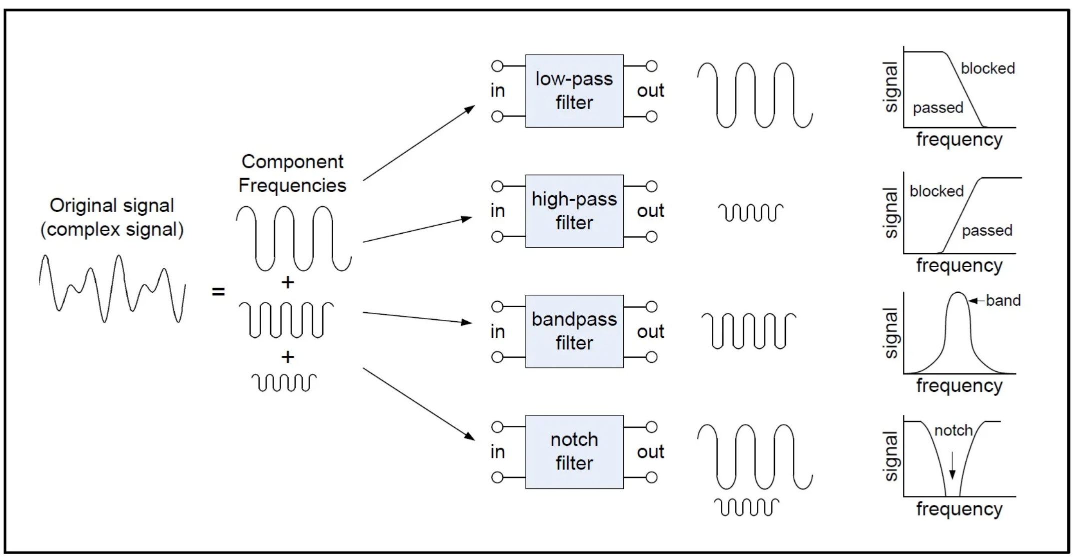


Figure 17 explaining filter outputs

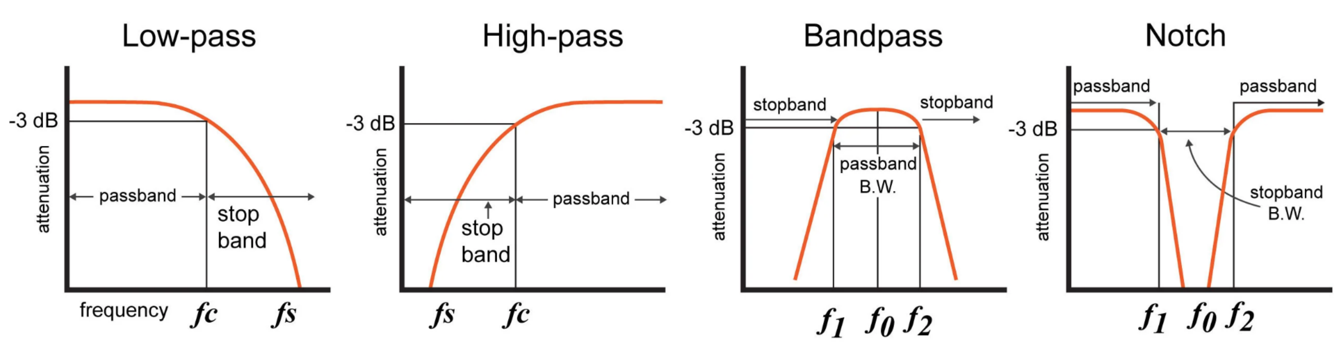


Figure 18 explaining pass band of each filter

A. Low pass filter: A low pass filter allows only those frequency signals which have frequency lower than cutoff frequency.

B. High pass filter: A high pass filter allows only those frequency signals which have frequency higher than cutoff frequency.

C. Band pass filter:A Band pass filter allows only those frequency signals which have frequency higher than lower cutoff frequency and lower then higher cutoff frequency.

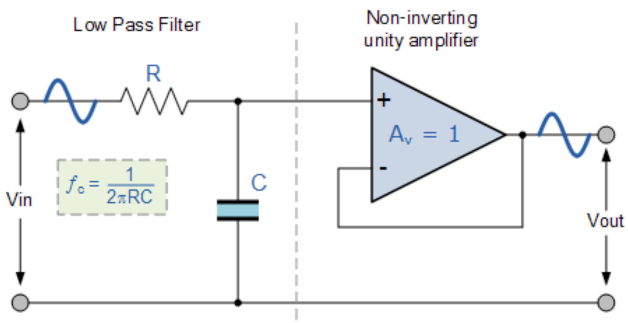
D. Notch Filter(Band stop filter with high Q value):-A notch filter allows only those frequency signals which have frequency lower than lower cutoff frequency or higher then higher cutoff frequency.

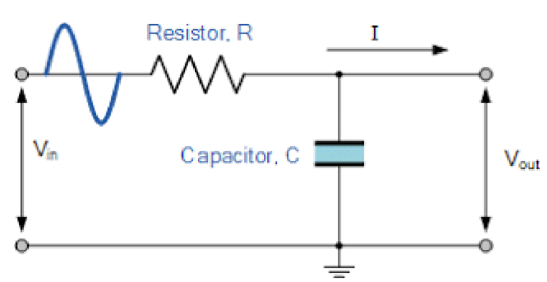
We can also divide filters on the bases of components used in the filter. we can say this filter as active and passive filters.

E. Active filters-Filter which is made of active components like opamp, in addition to resistors and capacitors, but not inductors.

F. Passive filters- Filter which is only made of passive components like resistor, capacitor, inductor etc.

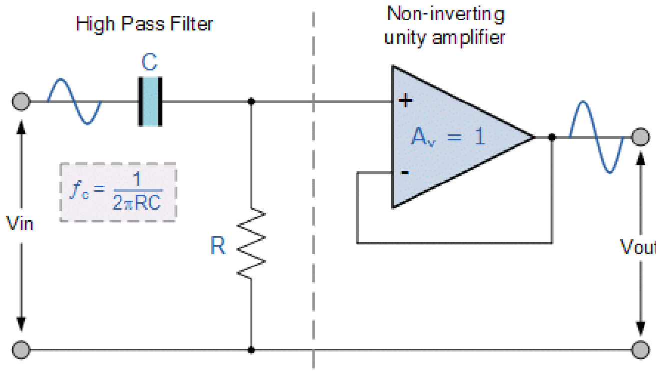
G. Active low pass filter-By combining passive low pass with opamp we can get active low pass filter with amplification.



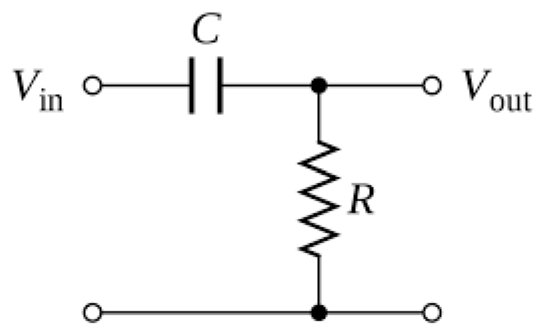


Active low pass filter (Figure 19) Passive low pass filter (Figure 20)

H. Active high pass filter- By combining passive high pass filter with op amp, we can get an active high pass filter.



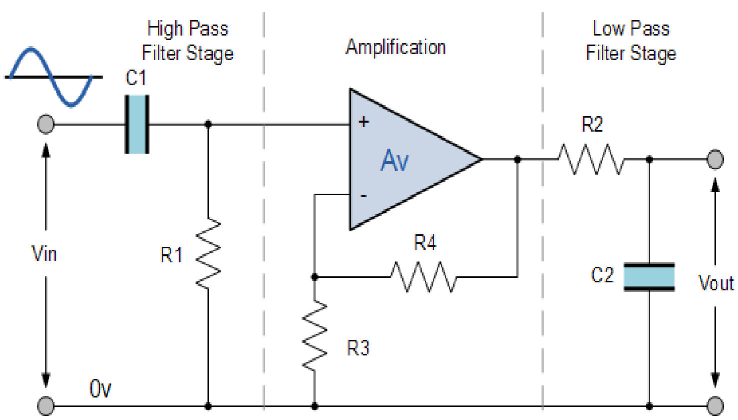
Active high pass filter (Figure 21)



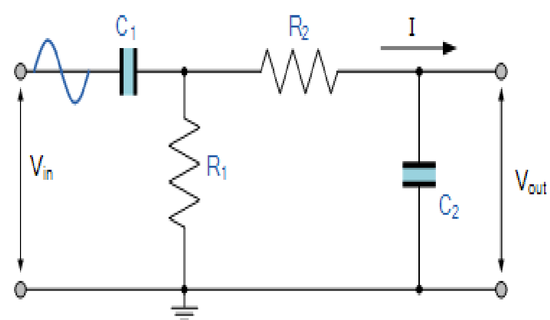
Passive high pass filter (Figure 22)

I. Active band pass filter- It is a second order filter type because it has two reactive components, basically two capacitors in the circuit.

An active band pass filter is a 2nd Order type filter because it has "two" reactive components (two capacitors) within its circuit design.



Active band pass filter (Figure 23)



Passive band pass filter (Figure 24)

because of two reactive components it has two cutoff frequencies (-3db frequency). one is lower cutoff and other is higher cutoff frequency. peak response occurs at resonant frequency or central frequency, which is the geometric mean of lower or higher cutoff frequency.

resonant frequency(Fr=(Fl*Fh)power(0.5)

Where: → Fr is the resonant or Center Frequency

Fl is the lower -3dB cut-off frequency point

Fh is the upper -3db cut-off frequency point

4.3 Working of IC 741(Op amp amplification)

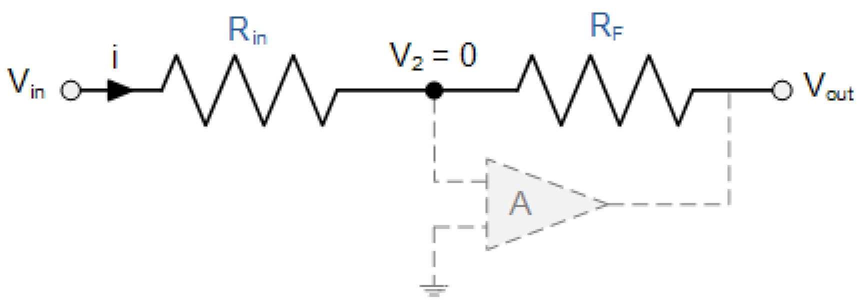


Figure 25 op amp in inverting formation.

$i = \frac{Vin-Vout}{Rin+Rf}$

therefore, $i = \frac{Vin-V2}{Rin} = \frac{V2-Vout}{Rf}$

$i = \frac{Vin}{Rin} - \frac{V2}{Rin} = \frac{V2}{Rf} - \frac{Vout}{Rf}$

So, $\frac{Vin}{Rin} = v2\left[\frac{1}{Rin} + \frac{1}{Rf}\right]-\frac{Vout}{Rf}$

and as, $i = \frac{Vin-0}{Rin} = \frac{0-Vout}{Rf} => \frac{Rf}{Rin} = \frac{0-Vout}{Vin-0}$

The closed loop gain(Av) is given as, $\frac{Vout}{Vin} =- \frac{Rf}{Rin}$ **(equation 1)**

The gain is because of power conversion of dc power drawn from applied voltage across pin 4 and pin 7 of the IC to the A.C voltage signal delivered to the load.

4.4 Working of sensors

4.4.1 Working of Piezoelectric sensor

In a piezoelectric sensor, a piezoelectric crystal is sandwiched between two surfaces of the sensor; on appling any force around the surface of the sensor there will be deformation in crystal shape. Because of this it produces charge around the crystal and the crystal acts as a capacitor. The voltage across the crystal can be measured by applying force on the crystal.
The below figure shows the basic structure of a piezoelectric sensor.

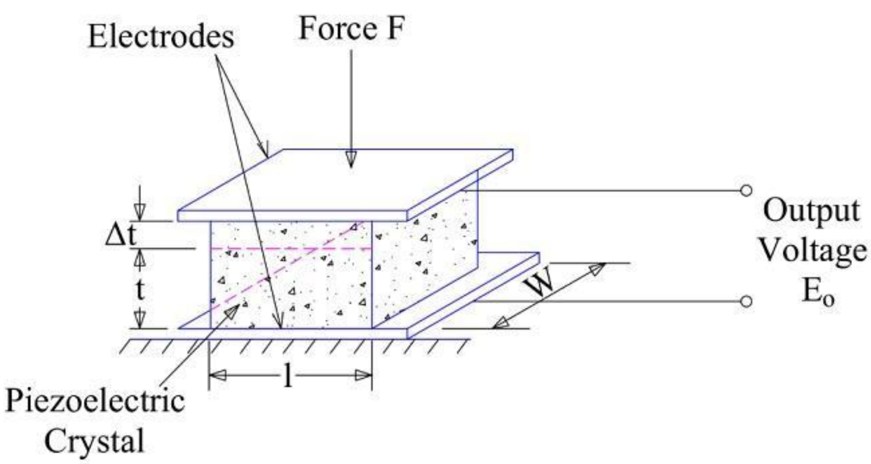


Figure 26 internal structure of piezoelectric sensor.

Piezoelectric is not useful for measuring the static pressure because it is continuously losing charge developed across the crystal. We can use piezoelectric sensors to measure continuously changing pressure, as our heart continuously pumps and because of this our veins have changing pressure and we can measure this by piezoelectric sensor. a piezoelectric sensor should have dynamic sensitivity. Dynamic sensitivity means the sensor should be able to detect very low changes in pressure even in a very high pressure environment.

Piezoelectric effect is direction sensitive which means the polarity of induced voltage is not the same as tensile and compressive force. The polarity of tensile and compressive voltage is just opposite of each other.

The charge produced due to applied force is directly proportional to applied force. let take produces charge is Q and applied force as F. then the charge force relation looks like:-

$Q = KF$............ (2)

Here K is proportionality constant which is also known as charge sensitivity of piezoelectric sensors. This constant varies upon the material used in making of crystal. the constant defined as charge generated on applied unit force on crystal.

let area of crystal as A, thickness of crystal as d then the charge generated on surface of crystal and voltage developed across the surface of crystal is given by:-

$Q = CV$

Here C is capacitance of a capacitor formed by a piezoelectric crystal.

$C = \frac{\varepsilon A}{d}$

Therefore,

$Q = \frac{\varepsilon AV}{d}$ .... (3)

From (2) and (3),

$$KF = \frac{\varepsilon AV}{d}$$

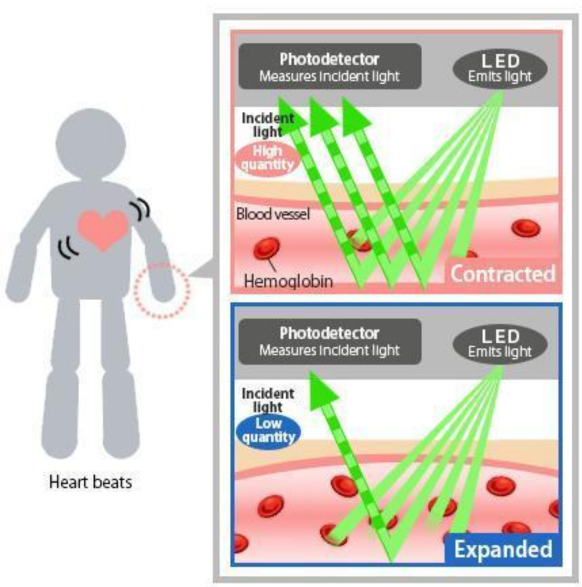
$$F = \frac{\varepsilon AV}{dK} \text{............} (4)$$

By observing equation 4 we can see that the A,d,K,ε are constant.

It can be concluded that force applied on piezoelectric is directly proportional to voltage and vice versa.

4.4.2 Working of IR transmitter and receiver(pulse sensor)

The ir transmitter and receiver are placed on a blood vessel, after that the ir transmitter sends ir light to our blood vessels and some of the light is reflected by the blood vessels wall and received by photodiodes(ir receiver) and some of the light is absorbed by hemoglobin.



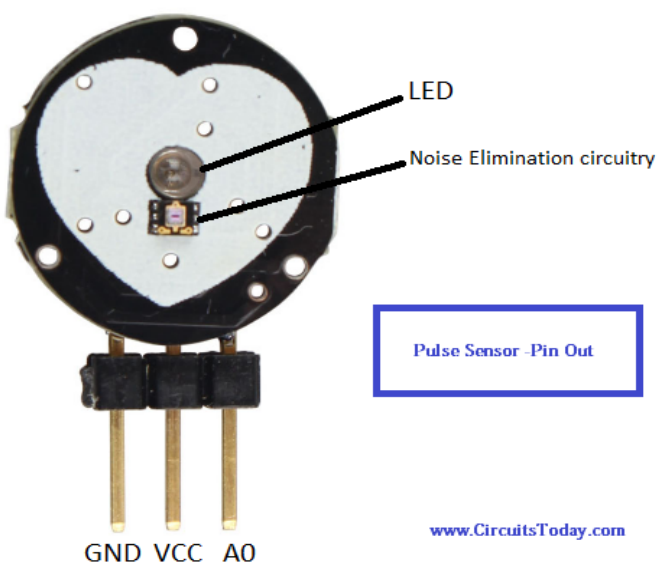


Figure 27 ir signal absorption and reflection   Figure 28 pulse sensor

As our heart pump periodically, at the same position of blood vessel some time the amount of hemoglobin is high and some time low and this pattern is also periodically repeating because of that the light received by photodiode is also periodically changing and we get heartbeat waveform from blood vessels and ir transmitter receiver pair.

4.4.3 Working of AD8232 sensor

The AD8232 Heart Rate Monitor has nine pins that you may glue pins, cables, or other connectors to: SDN, LO+, LO-, OUTPUT, 3.3V, GND. These pins are necessary for using this monitor with an Arduino or other development board..

For ECG and other biopotential measuring applications, the AD8232 is an integrated signal conditioning block. It's made to collect, amplify, and filter tiny biopotential signals in noisy environments like those caused by mobility or remote electrode placement. The output signal may be easily acquired using an ultralow-power analog-to-digital converter (ADC) or an embedded microcontroller with this architecture.

A two-pole high-pass filter on the AD8232 may be used to eliminate motion artifacts and the electrode half-cell potential.This filter is strongly integrated with the amplifier's instrumentation design, allowing huge gain and high-pass filtering in a single stage, saving space and money.

The AD8232 may build a three-pole low-pass filter to eliminate extra noise thanks to an uncommitted operational amplifier. To fit different sorts of applications, the user may adjust the frequency cutoff of all filters.The AD8232 contains a rapid restoration function that shortens the high-pass filters' otherwise extended settling tails.

The AD8232 automatically adapts to a higher filter cutoff after a sudden signal change that rails the amplifier (such as a leads off situation). This feature allows the AD8232 to recover fast, allowing for accurate measurements to be taken as soon as the electrodes are connected to the patient.

5.Chapter

Simulations and Analysis

5.1 Raw heart beat signal analysis using matlab

As our raw signal contains noises associated with the desired signal, we have to analyze this signal so that we can get the frequencies of our desired signal.

For signal analysis we use matlab. We are getting a signal from a piezoelectric sensor without any filter or any circuit component.

We connect piezoelectric sensor with arduino by following connection.

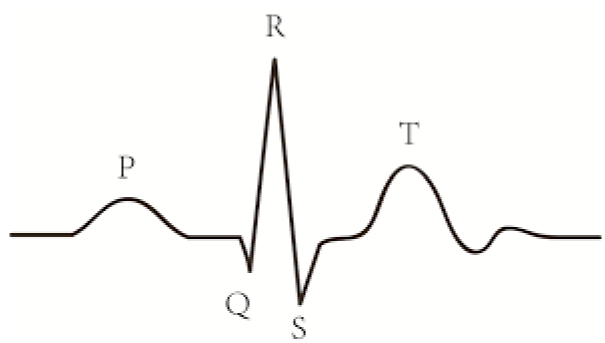
- connect piezoelectric sensor positive wire with arduino A0 terminal.
- connect piezoelectric sensor negative wire with arduino GND terminal.

After connecting the sensor with the arduino, connect the arduino with the laptop and upload this code.

After that open serial plotter in tool option in arduino ide and click on send. wait for 5-10 second until our signal stabilizes. After that, close the serial plotter and open the serial monitor and get data for 10 seconds, after that remove the arduino power cable from laptop and copy serial monitor data.

After that open matlab live script and paste this code. this is our data, we got this from the serial monitor.

In the below digam we are showing our result obtained from matlab.



Standard heart beat signal waveform(Figure 29)

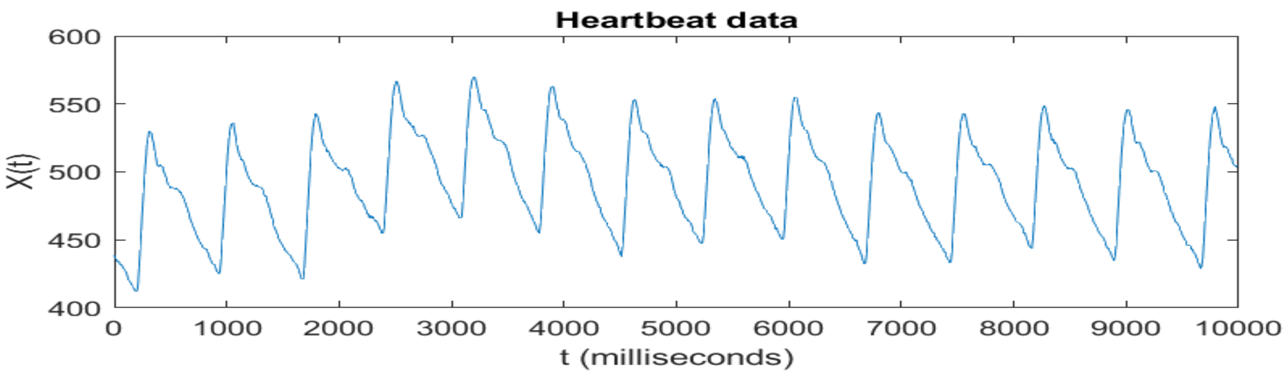


Figure 30 heartbeat waveform plotted from raw data using matlab

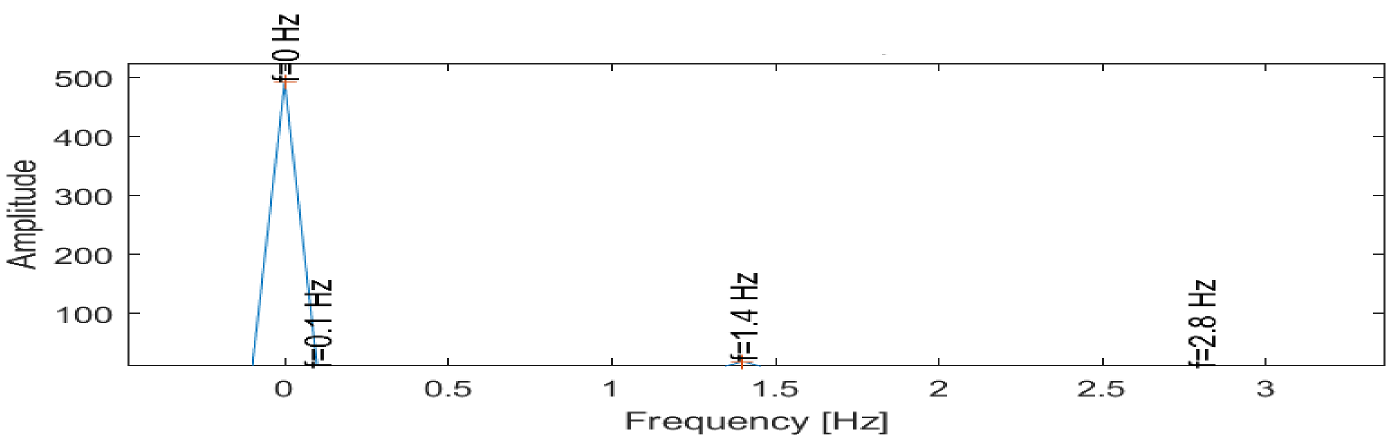


Figure 31. this figure represents the important frequency component along with there amplitude

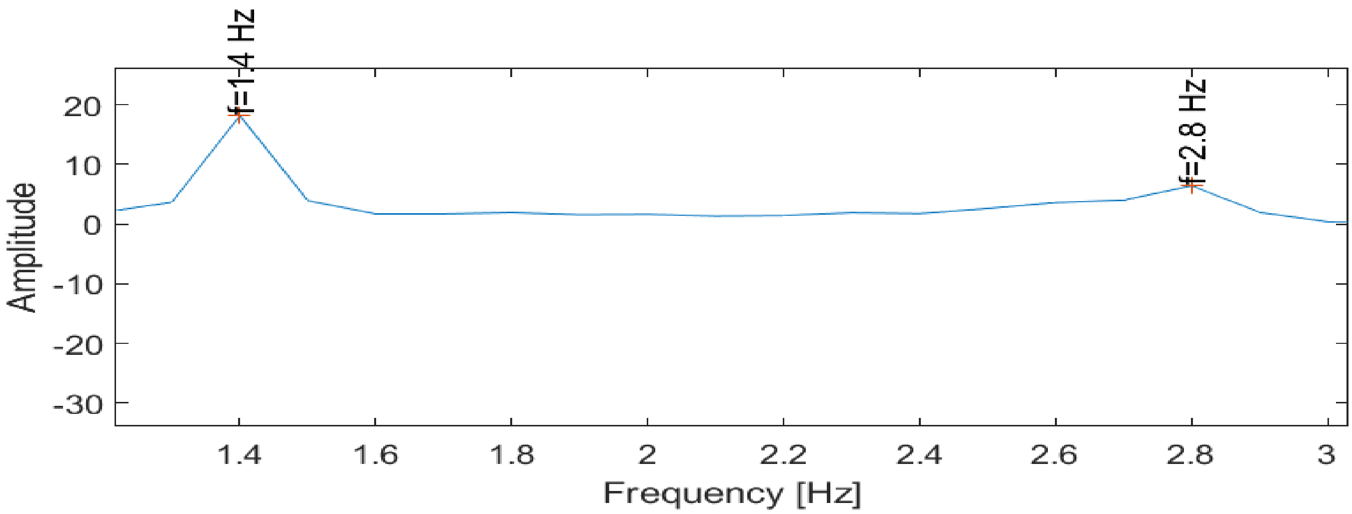


Figure 32 important frequency component after dc offset component

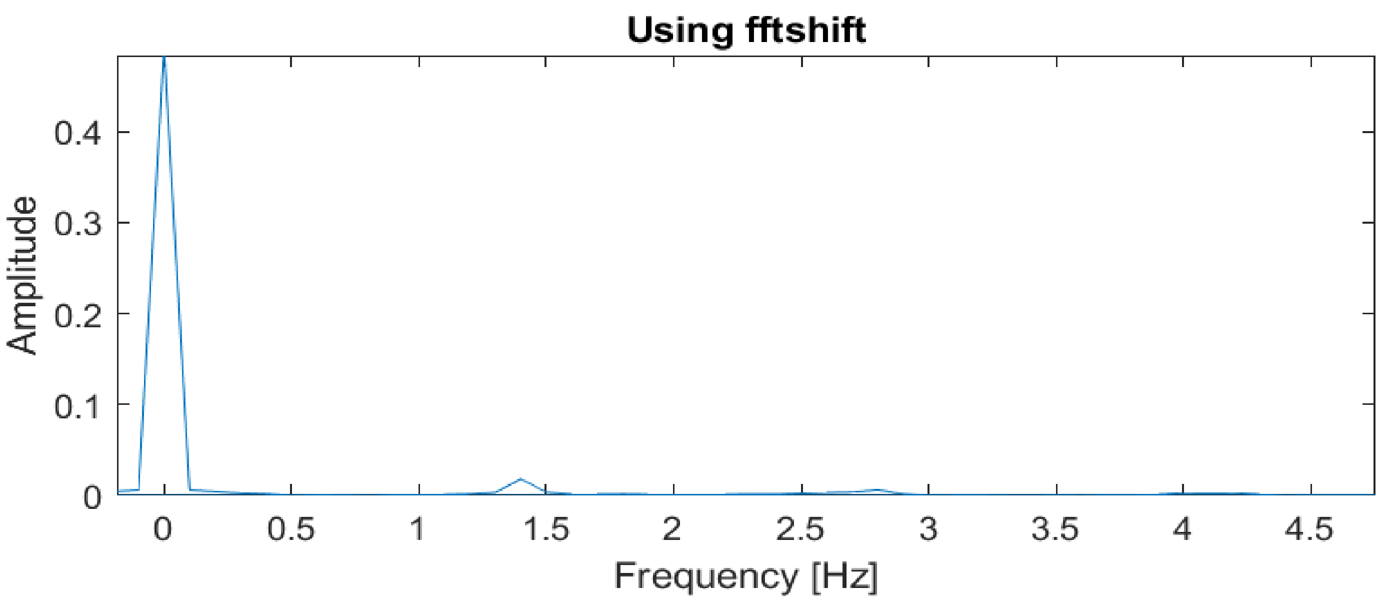


Figure 33 Represent all frequency component having amplitude greater than 5 millivolt

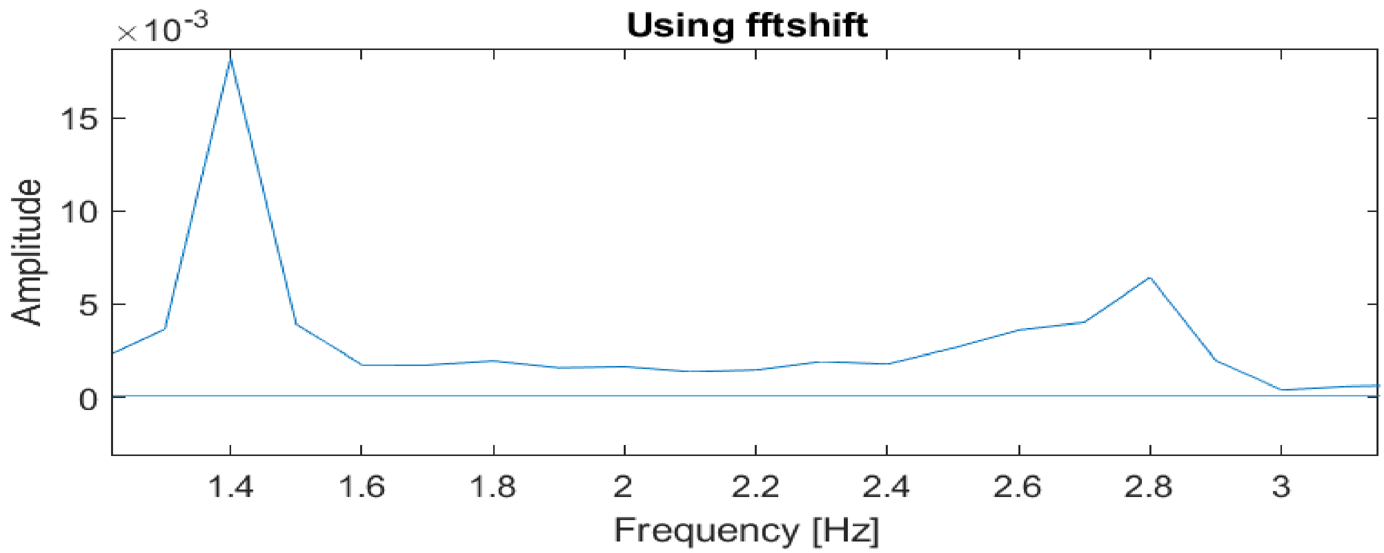


Figure 34 represents the amplitude of 2 main frequency components.

Observation from graph:-

1. from figure 30. we can see that we have a dc offset of around 500 millivolt.
2. From figure 31. we can see that the dc offset which is around 500 millivolt says that it has frequency of 0hz which is obvious and proving point 1.
3. from the standard heart beat signal wave we can see that max amplitude is from QRS peak and from QRS peak we can calculate heart beat per minute.
4. from figure 32. We can see max amplitude waveform after dc offset wave, having frequency 1.4 Hz. And from point number 3 it is our heart beat frequency and our heart beat is 1.4*60=84 beats per minute.
5. from the heartbeat standard wave from we can see that P and T peaks have approx similar amplitude values. and the value of amplitude for P and T is next highest after the QRS peak.
6. From figure 32. we see that there is also an important frequency which has amplitude just less than 1.4Hz wave amplitude. Which has frequency Just double of 1.4Hz, that is 2.8Hz. which is satisfying point 5.

7. from Figure 33. We can see that our most desirable frequency components have frequency less than 5Hz and greater than 0Hz.
8. From point 7 we have decided to choose our filter parameter. The filter should be a band pass filter with lower cutoff frequency 0.5Hz and Higher cutoff frequency 10Hz(considering no loss of desired signal and filter is not ideal).

5.2 Filtration & amplification analysis using LTspice Software

As per above Raw heart beat signal analysis using matlab, all important pulse frequency components will lie in the range of 0.5-10 hz.

- As shown in the above figure in architecture ,in this project three RC band pass filters(all have cutoff frequencies 0.5hz and 10hz)cascaded in order to remove noise from the main pulse signal.
- Then for amplification two op-amp IC 741 added .

Analyze by taking example input signal

LTspice software is used to analyze the circuit and simulate it.

To assess the circuit, two signals were added and the system was supplied as an input. If the system passes only signals that fall within the band pass filter range, then the system design is correct.

three cases of i/p s have taken

1) **one signal with 5v amplitude, 5hz frequency and another signal with 2v amplitude, 200 hz frequency.**

Expectation from the output

In contrast to another signal with a frequency of 200hz, the output will have a frequency of 5hz since it falls inside the band pass filter's range.

2) **one signal with 5v amplitude, 5hz frequency and another signal with 2v amplitude, 0.05 hz frequency.**

Expectation from the output

In contrast to another signal with a frequency of 0.05hz, the output will have a frequency of 5hz since it falls inside the band pass filter's range.

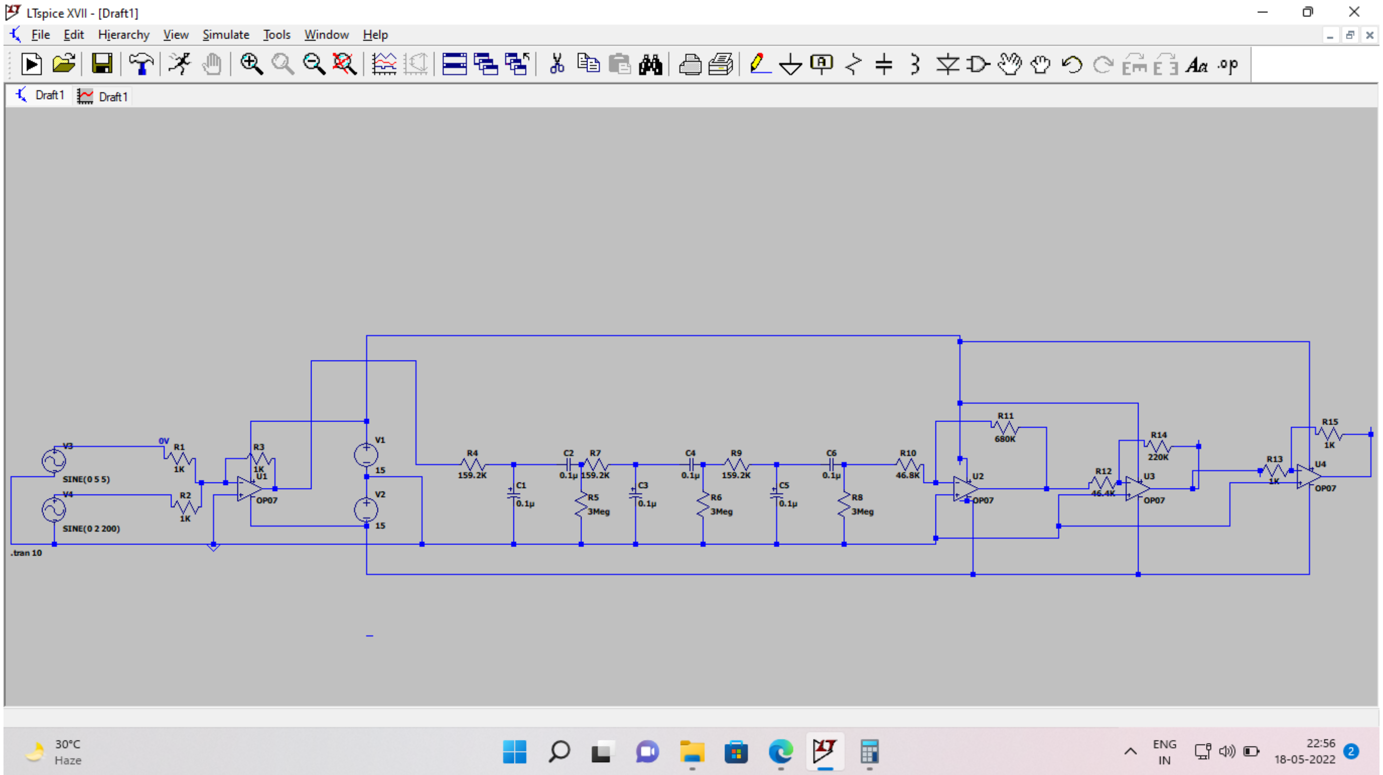
3) **one signal with 5v amplitude, 5hz frequency and another signal with 2v amplitude, 1.5hz frequency.**

Expectation from the output

Because both signals have frequency values in the band pass filter range, the output signal would be the response received by the adder.

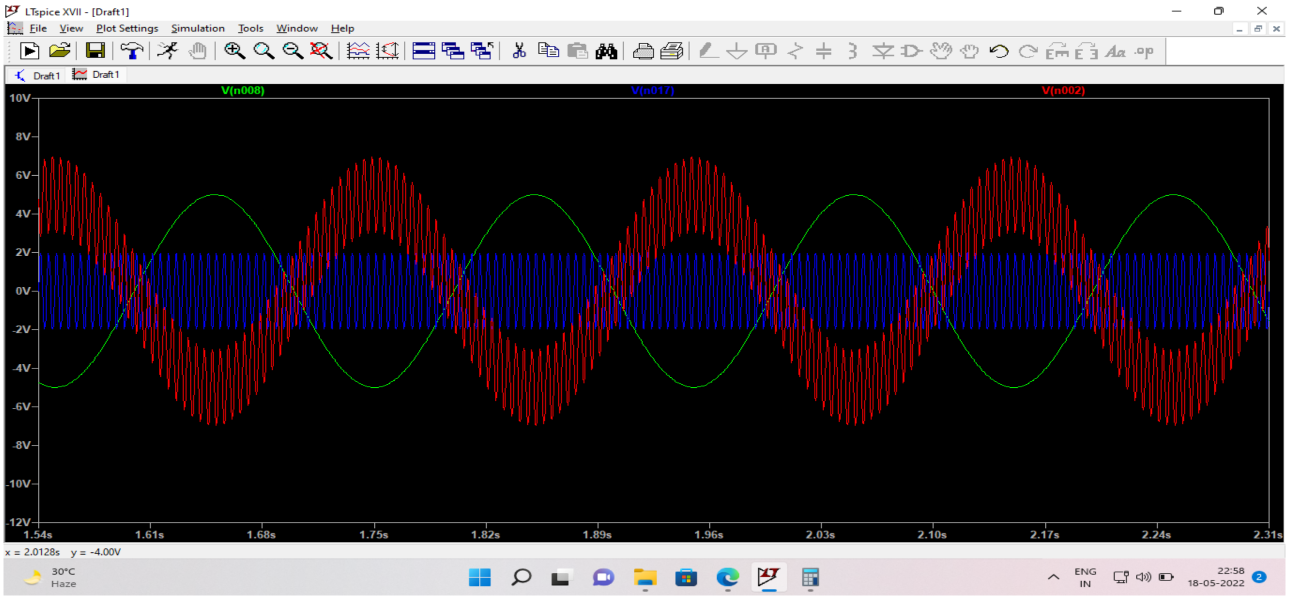
1. **One signal with 5v amplitude, 5hz frequency and another signal with 2v amplitude, 200 hz frequency**

One adder (to add the input signals) is created in the fig 35, whose response will be the filter input. Following that, a filter and amplification circuit are created. Finally, an inverting op-amp is used to cancel out the adder's influence on the signal phase.



Circuit for Filtration & Amplification (Figure35.)

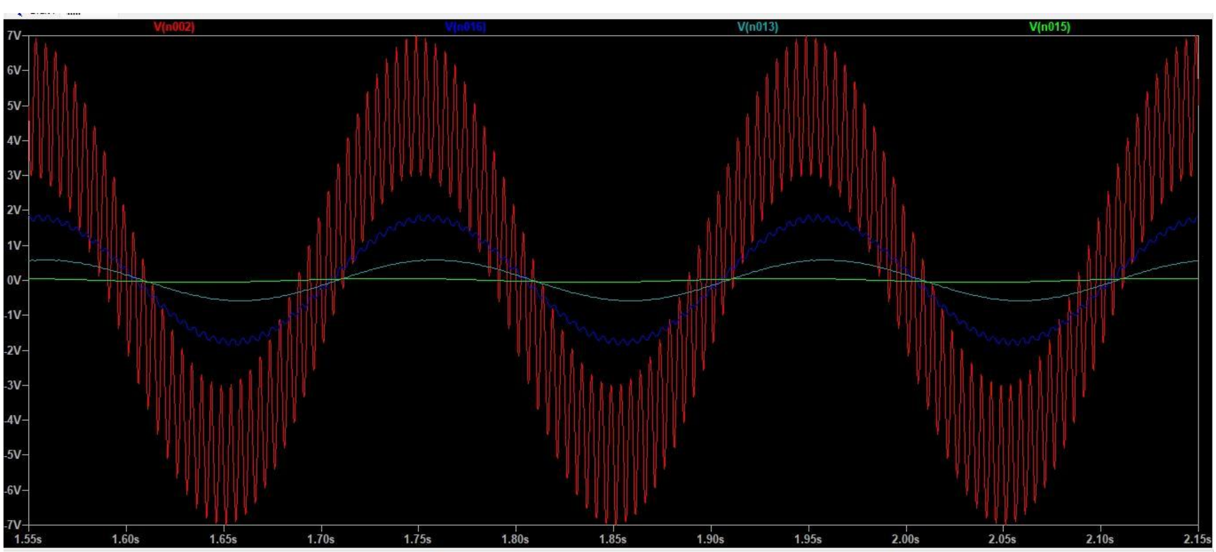
The below figure 36 shows signal with 5hz frequency(green), signal with 200 hz frequency (blue) and the adder’s output(red).



sine wave input signals(blue & green) and adder response(red) (Figure36.)

The response of all three cascaded filters is shown in the diagram below, one by one(blue ,light blue and green) with the adder's response signal(red).

It can be seen that→ 1. As the number of cascaded filters rises, the noise is eliminated more efficiently, as the noise is totally removed in the last filter's response. 2. The signal intensity drops as the number of cascaded filters grows.

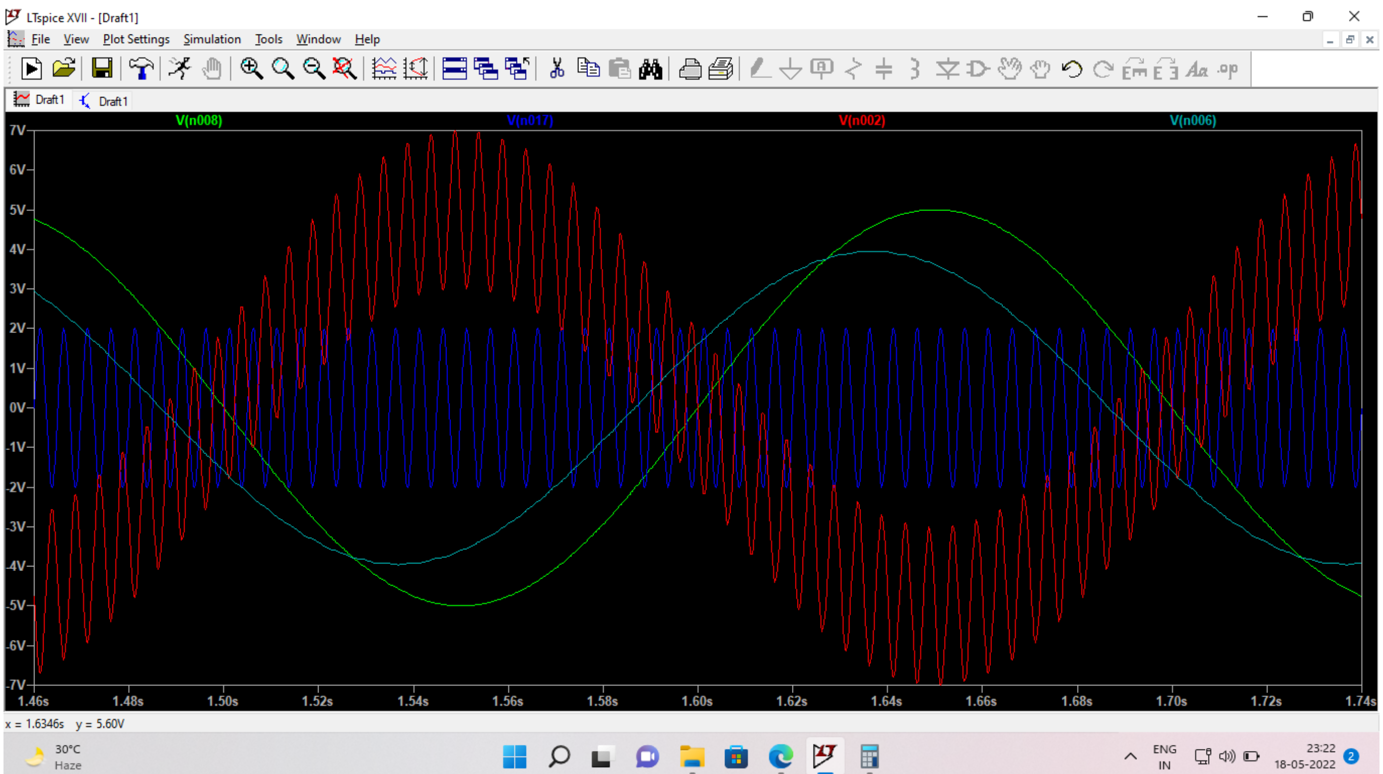


Adder response (red) and all three filter stage responses(blue,light blue,green) (Figure 37.)

The amplifier added and received the final signal in order to examine it better (light blue).

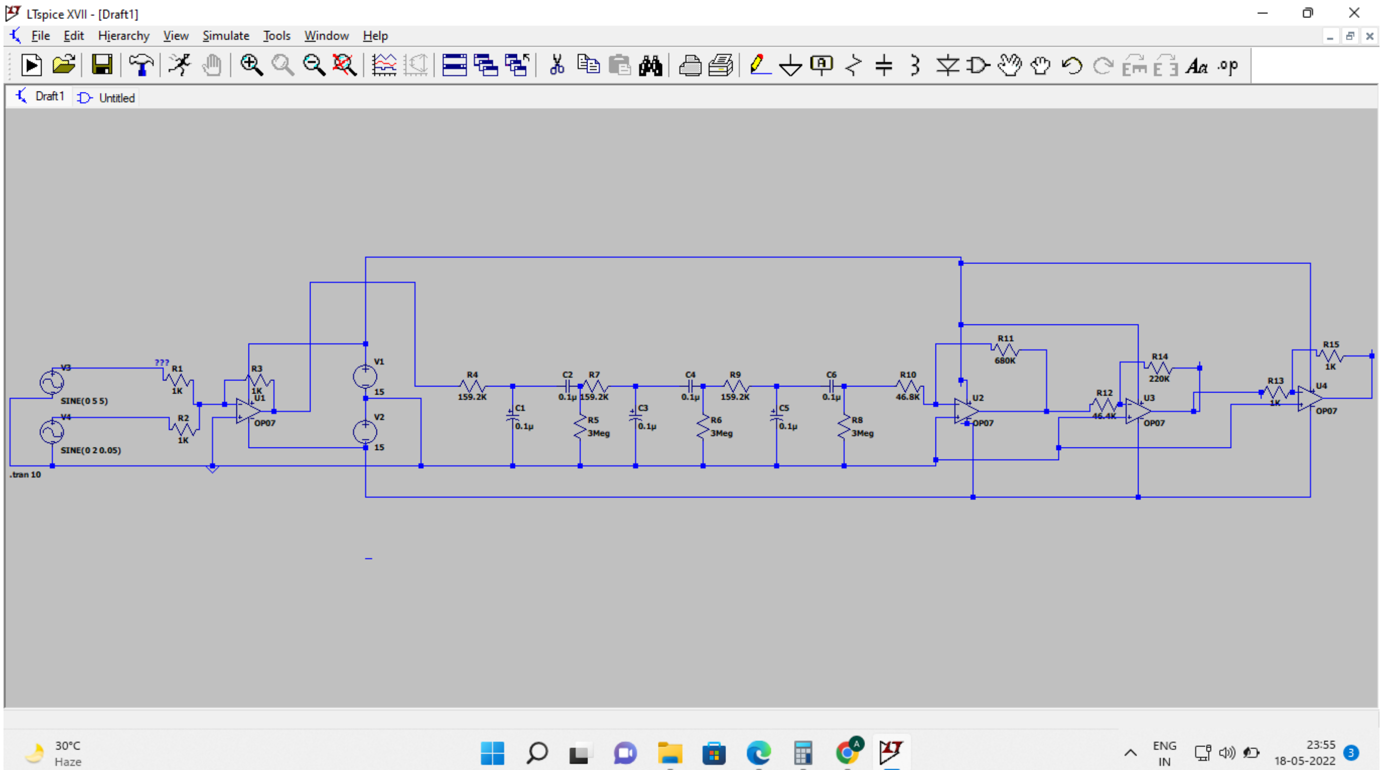
It can be observed by the below figure 38 that The signal with a frequency of 200 hz (blue) is deleted from the adder's response because the final signal has the same frequency as the signal with a frequency of 5 hz (green).

This type of result is already expected which means the filtration & amplification gets passed in the first test.



Final system output and sine wave i/ps and adder response (Figure38.)

2. **One signal with 5v amplitude, 5hz frequency and another signal with 2v amplitude, 0.05 hz frequency**

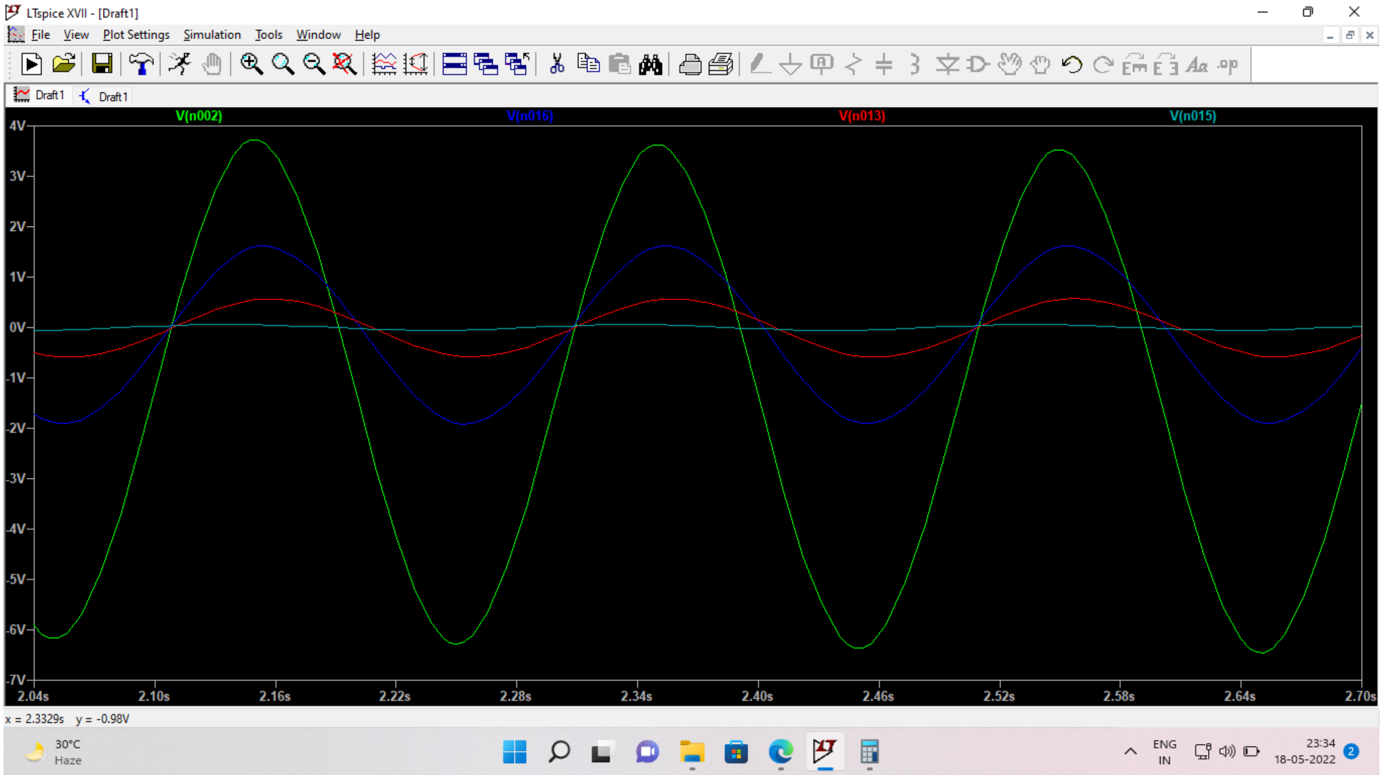


Circuit for Filtration & Amplification (Figure 39.)

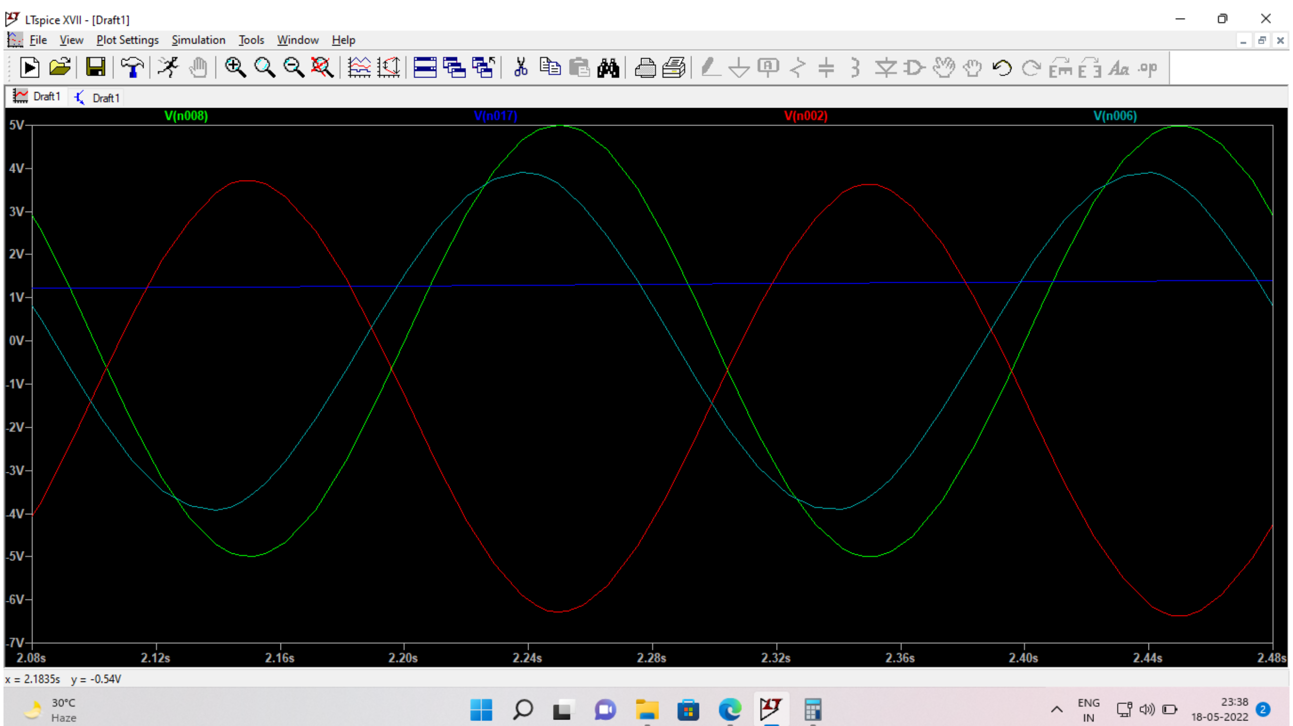
Observations

1. As the number of cascaded filters rises, the noise is eliminated more efficiently, as the noise is totally removed in the last filter's response(fig 40)
2. The signal intensity drops as the number of cascaded filters grows.(fig 40)
3. When the final signal (light blue) is compared to the signal with a 5hz frequency (green), it can be observed that both have the same frequencies, implying that the system negated the 0.05 hz frequency (blue) since it was beyond the band pass filter's range. (fig 41)

This is also consistent with our expectations, thus our system passes this test as well.

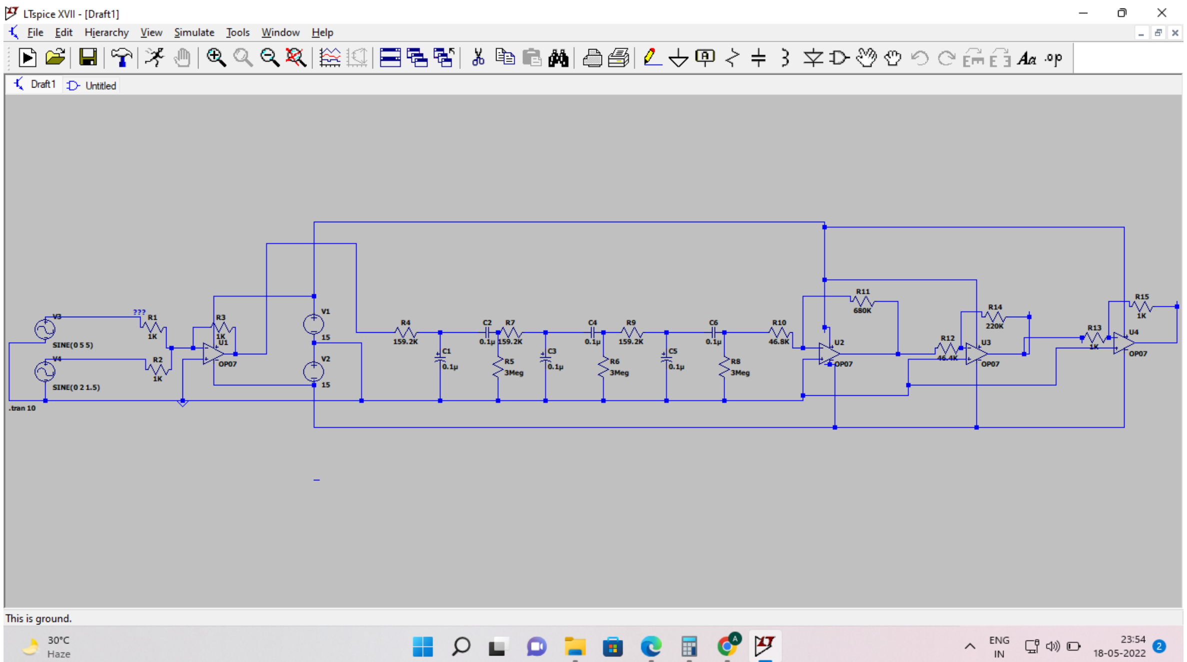


Adder response (green) and all three filter stage responses(blue,red,light blue) (Figure 40.)



Final system output(light blue) and sine wave i/ps(green&blue)& adder response(red) (Figure 41.)

3. **One signal with 5v amplitude, 5hz frequency and another signal with 2v amplitude, 1.5 hz frequency**

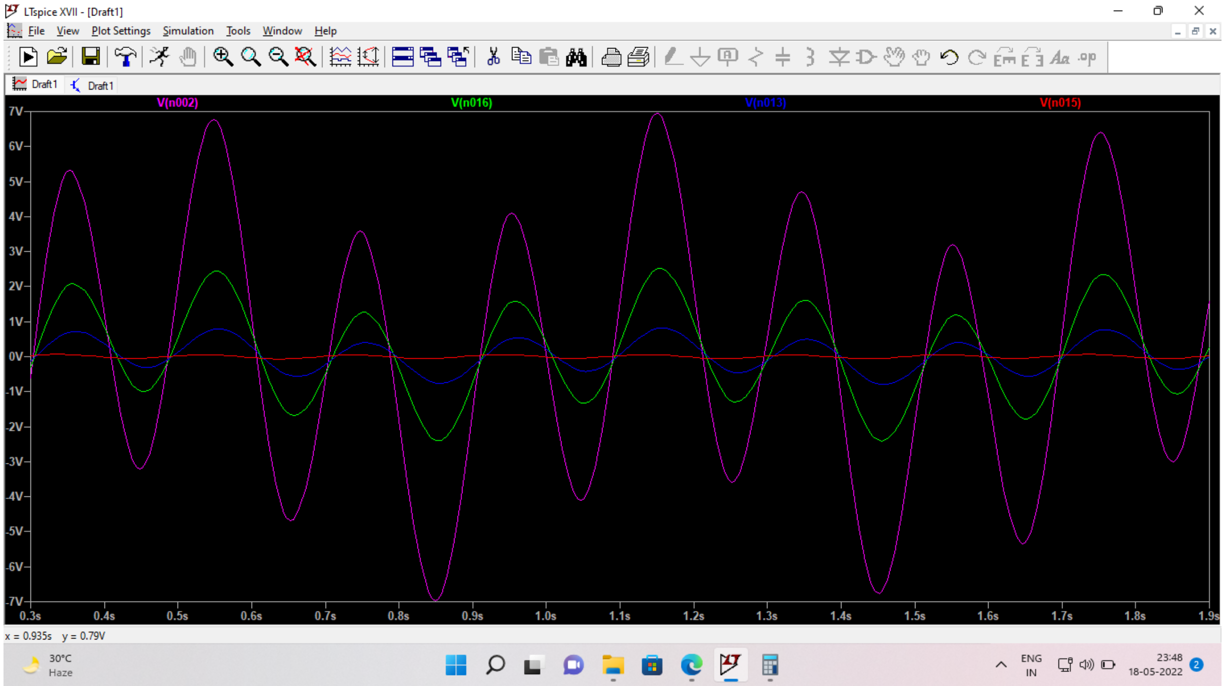


Circuit for Filtration & Amplification (Figure42.)

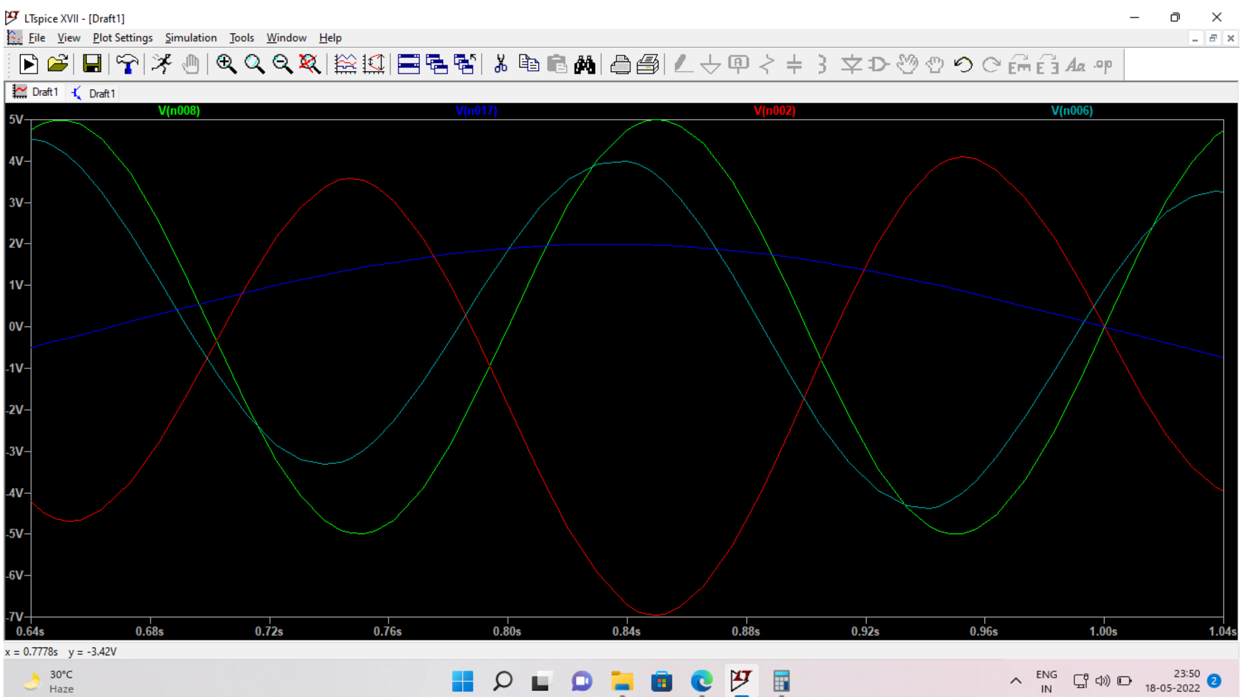
Observations

1. As the number of cascaded filters rises, the noise is eliminated more efficiently, as the noise is totally removed in the last filter's response(fig43)
2. The signal intensity drops as the number of cascaded filters grows.(fig43)
3. When the end signal (light blue) is compared to the adder response signal, it can be observed that both have the same frequency, implying that this time system did not halt any frequency signal since all input signal frequencies are within the band pass filter's range.(fig44)
4. This is also consistent with our expectations, thus our system passes this test as well.

Simulation and analysis reveal that the system is highly effective at filtering and amplification.



Adder response (purple) and all three filter stage responses(green,blue,red) (Figure 43.)



Final system output(light blue) and sine wave i/ps(green&blue) and adder response(red) (Figure 44.)

6.Chapter

Calculation & Component Required

6.1 Calculation

6.1.1 Calculation for filtration

From above fourier analysis using matlab and circuit analysis of matlab we have chosen following circuit component value:-

For low pass filter:-

Resistance(approx)=159KΩ

Capacitance=100nF

Cutoff frequency=$\frac{1}{2\pi * R * C}$ => $\frac{1}{2*\pi*159*10^{3}*100*10^{-9}}$

=10.009Hz => 10Hz (approx)

For high pass filter:-

Resistance=3MΩ

Capacitance=100nF

Cutoff frequency=$\frac{1}{2\pi * R * C}$ => $\frac{1}{2*\pi*3*10^{6}*100*10^{-9}}$

=0.530Hz=>0.5Hz (approx)

Lower cutoff frequency = 0.5Hz

Higher cutoff frequency = 10Hz

Bandwidth = higher cutoff frequency-lower cutoff frequency

= 10Hz-0.5Hz => 9.5Hz

6.1.2 Calculation for amplification

From circuit component:-

Theoretical:-

From working of ic 741, we have derived what is amplification of an inverting op amp.

we find that gain $\frac{Vout}{Vin} = -\frac{Rf}{Rin}$.

from the architecture of project we can see that for first stage amplification:-

Rf = 680KΩ

Rin = 46.8KΩ => 47KΩ (approx)

First stage gain = $-\frac{680}{46.8}$ = -14.5

from the architecture of project we can see that for second stage amplification:-

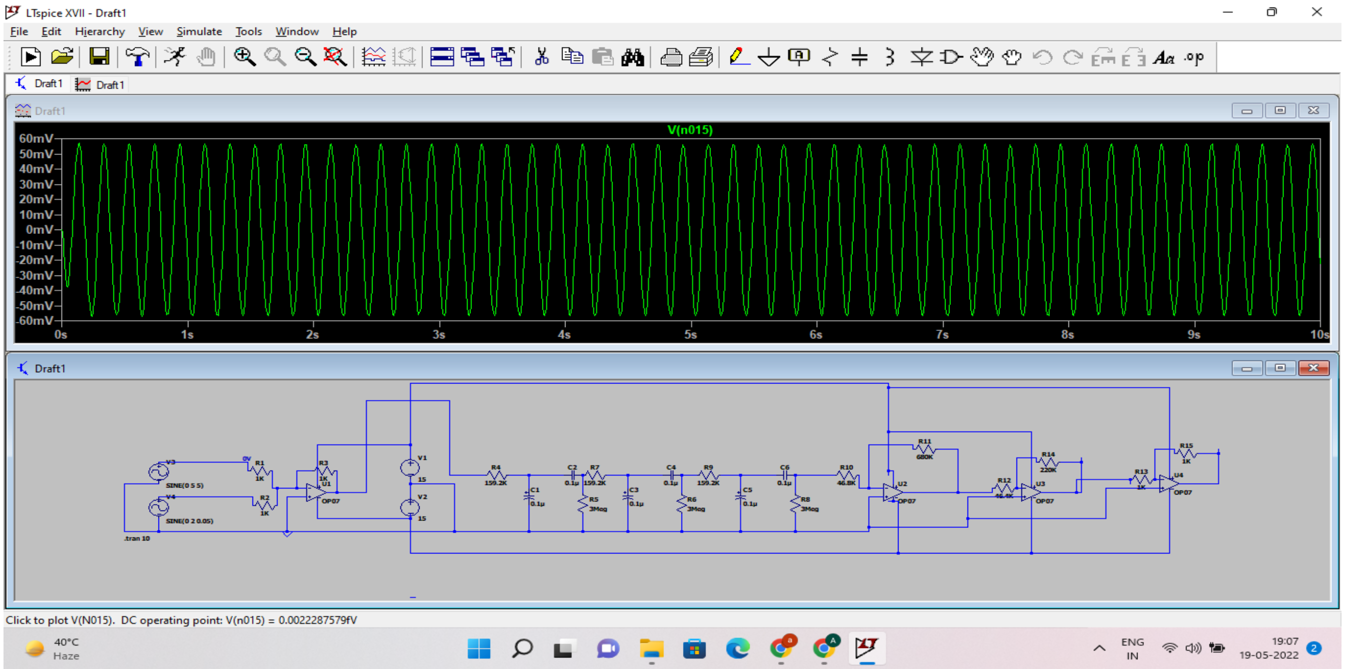
Rf = 220KΩ

Rin = 46.4KΩ => 47KΩ (approx)

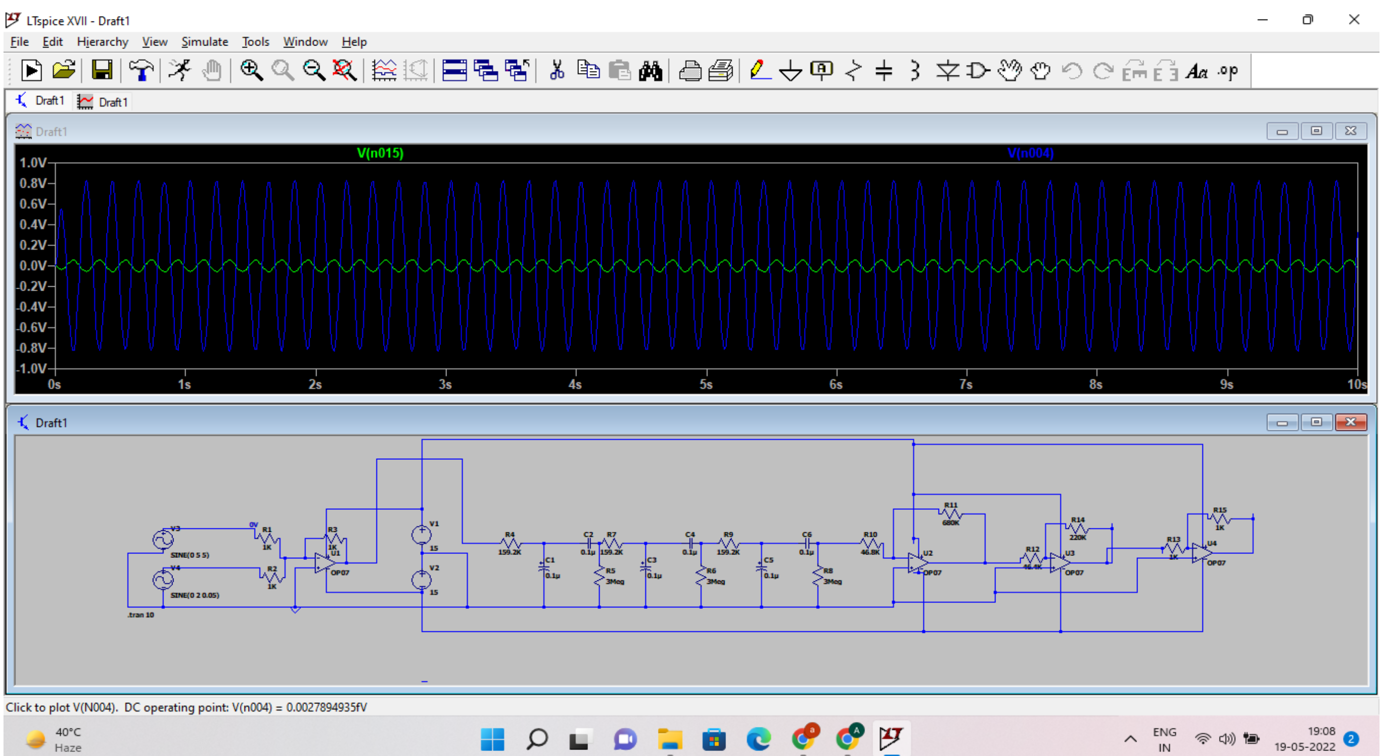
Second stage gain = $-\frac{220}{46.4}$ = -4.74

overall gain = First stage gain*second stage gain = -14.5*-4.74 = 68.73

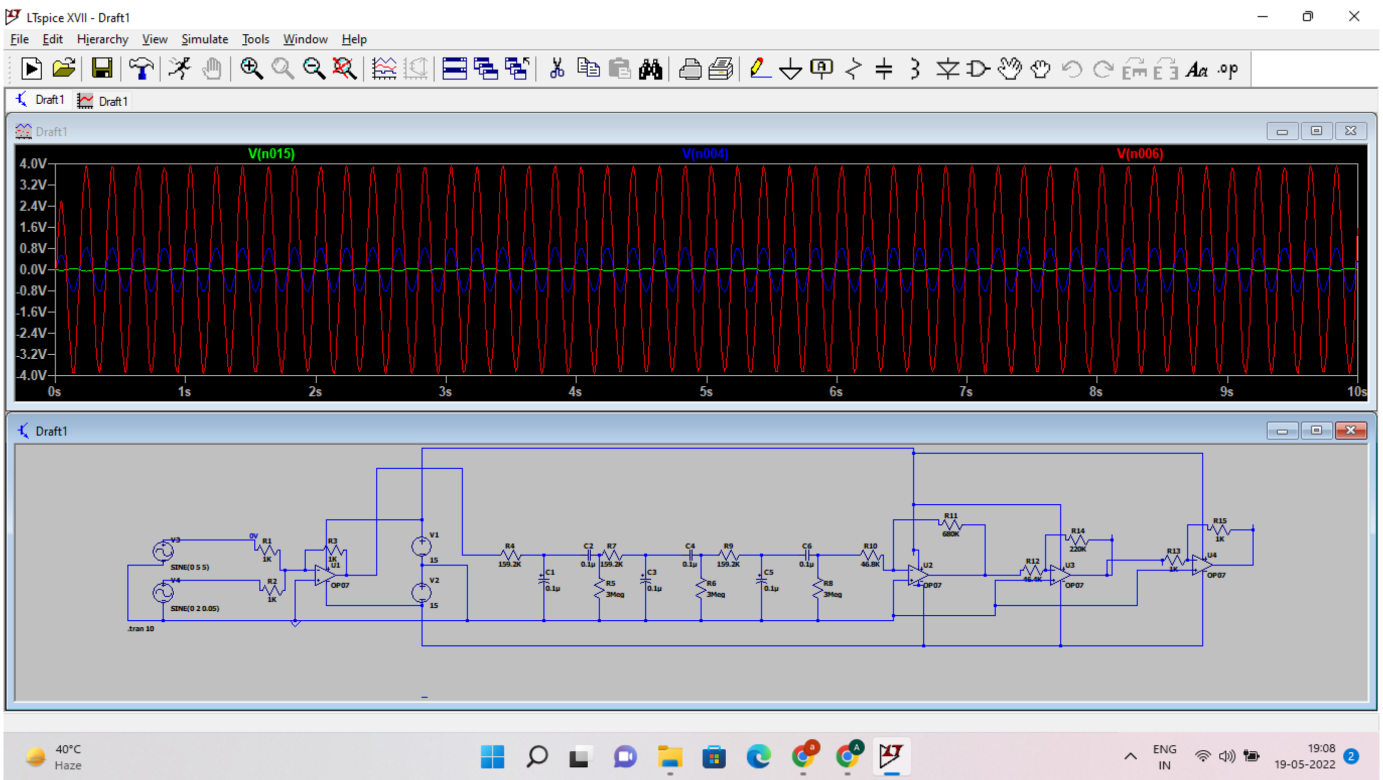
From graph:-



We can see that the output after the 3rd filter has an amplitude around 58mv(green signal). (Figure 45)



We can see the output after the first amp. has an amplitude around 0.85V (blue signal). (Figure 46)



We can see that the output after second amplification has an amplitude around 4V(red signal). (figure 47)

So first amplification gain$= - \frac{0.85}{58*10^{-3}} = - 14.65$

Second amplification gain$= - \frac{4}{0.85} = - 4.70$

	first stage amplification	second stage amplification	overall amplification
amplification from circuit component	**-14.5**	**-4.74**	**68.73**
amplification from graph	**-14.65**	**-4.7**	**68.85**

From the above result we can see our result of graph and circuit components(theoretical) are matching.

6.2 Component required

1. Piezoelectric sensor × 1
2. Pulse sensor
3. AD8232 sensor and electrodes
4. Arduino Uno × 1
5. LaunchXL-F28379D board × 1
6. Mini-Breadboard × 1
7. 159.2kΩ × 3, 47kΩ × 2, 680kΩ × 1, 3MΩ × 1, 220kΩ × 1 resistors
8. 0.1μf × 6 capacitors
9. IC 741 × 2
10. Power Supply($\pm$15v)
11. Connection Wires

7.Chapter

Challenges During Project & Overcome

1. **Challenge** → Didn't had idea about heart beat signal and its frequency range
   Overcome → After reading various research papers to gain a basic understanding of heartbeat behavior, we created a pulse signal analysis utilizing the fourier transform and Matlab (from the data we collected from piezoelectric sensor using arduino)
2. **Challenge**→ Interference of noise with signal due to loose connection of circuit component
   Overcome→We attempted to solve the problem in several ways. First, repeatedly changing the breadboard or circuit, and then using PCB (printed circuit board), which took time and required more concentration and delicacy.
3. **Challenge**→ Completely new environment of LAUNCHXL-F28397D
   Overcome→ first we went through the datasheet and then searched on other platforms like youtube too.
4. **Challenge**→ Code Composer Studio(didn't get much content available on platforms like youtube).
   Overcome → search and learn things specifically required in a project.

8.Chapter

Future Work

Heart beat monitoring has many applications so there can be a lot of future work by extension of this project.

1. Heart attack detector

i)explanation→

A heart attack detecting system may be created by including additional hardware and software. Following the completion of the design. Signal is detected by the first sensor. The sensor is then connected to a microcontroller, which allows the heart rate values to be checked and transmitted over the internet. The user may adjust the maximum and minimum heart rate limits. After setting these restrictions, the system begins monitoring, and when the patient's heart rate exceeds a specific threshold, the system sends an alarm to the controller, who then sends it via the internet to physicians and other interested parties. Lower heartbeats also trigger an alarm from the system.The device also displays the patient's live heart rate whenever the user signs in for monitoring. Thus, concerned individuals may monitor heart rate and get an alarm of a heart attack to the patient from anywhere, allowing the person to be saved in a timely manner.

ii) required tools→

a) Hardware specification

Atmega Microcontroller,ESP8266 Wifi Module,LCD Display,Crystal Oscillator, Resistors, Capacitors, Transistors, Cables and Connectors, Diodes, PCB and Breadboards, LEDTransformer/AdapterPush , ButtonsSwitch,ICs

b) Software specification

Arduino Compiler, MC Programming Language: C, IOT Gecko Platform

iii) Block diagram→

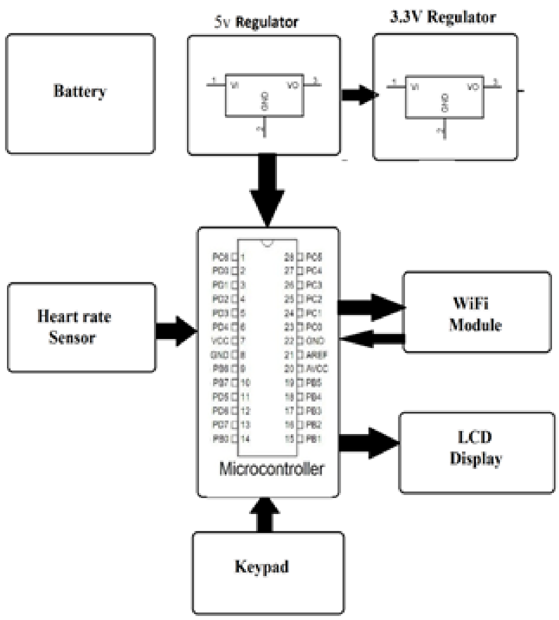


Figure 48

2. SPO2 calculation

i) explanation→

SpO2, also known as oxygen saturation, is a measurement of the proportion of oxygen-carrying hemoglobin in the blood compared to non-oxygen-carrying hemoglobin. The body cannot operate properly unless there is a specific amount of oxygen in the blood.

For SpO2 readings, the beat-to-beat mode provides the maximum resolution. The oxygen saturation is estimated with each pulse beat using the absorption of red and infrared light.

3. Decreasing response time

As in order to perform the heart rate monitoring in this project Arduino & LAUNCHXL-F28397D is used. There are many other boards available which can work more efficiently and save time .

It would totally depend on application and how fast and accurate the response should be and also budget is also a consideration point.

4. ECG or ElectroChromatography

i) introduction→

ECG or ElectroCardioGraphy is a method to measure some important parameters of a human heart. It outputs analog values that produce a particular signal that looks as shown below.

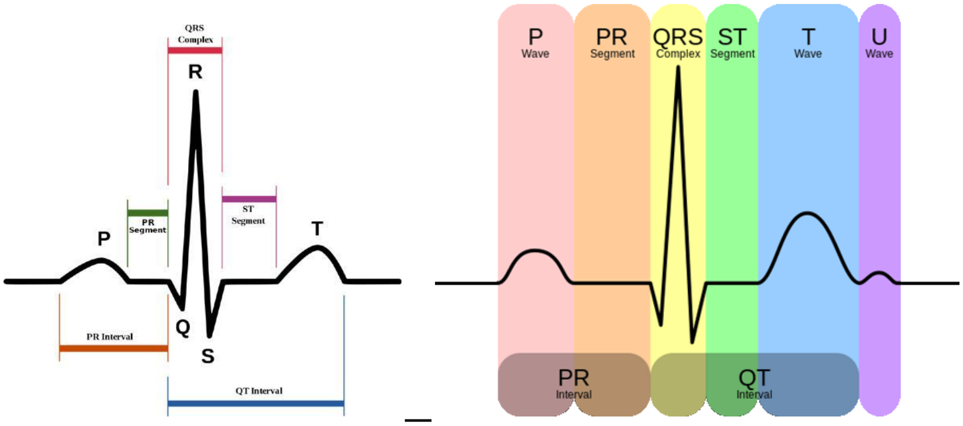


Figure 49

As can be seen, the signal includes a few peaks and crucial biological characteristics. These are highlighted Above.

Each interval has an appropriate value range, and divergence from it may be associated with a certain illness. The primary components of an ECG signal are listed below.

The P wave is the QRS complex's trailing wave on the left.

The QRS complex is a ventricular contraction-induced impulse.

The T wave is a wave that precedes the QRS complex.

Due to its low peak value, the U wave is not always visible.

There are many more characteristics, but these are the most important. We may detect a variety of heart disorders and anomalies based on the forms of the aforementioned characteristics, their intervals, and the distance between them. For instance: P-wave absence or irregular heartbeat: Atrioventricular Fibrillation More than 100 beats per minute at rest: Tachyarrhythmia Delta wave and tachyarrhythmia: WPW syndrome stands for Wolf-Parkinson-White syndrome. Atrial flutter with a sawtooth P wave ST-segment depression might suggest ischemia. ST-segment elevation may signal a myocardial infarction. As a result, ECGs are crucial for a cardiologist, or any clinician for that matter.

9.Chapter Results

9.1.Pulse sensor result(based on ir transmitter and receiver pair

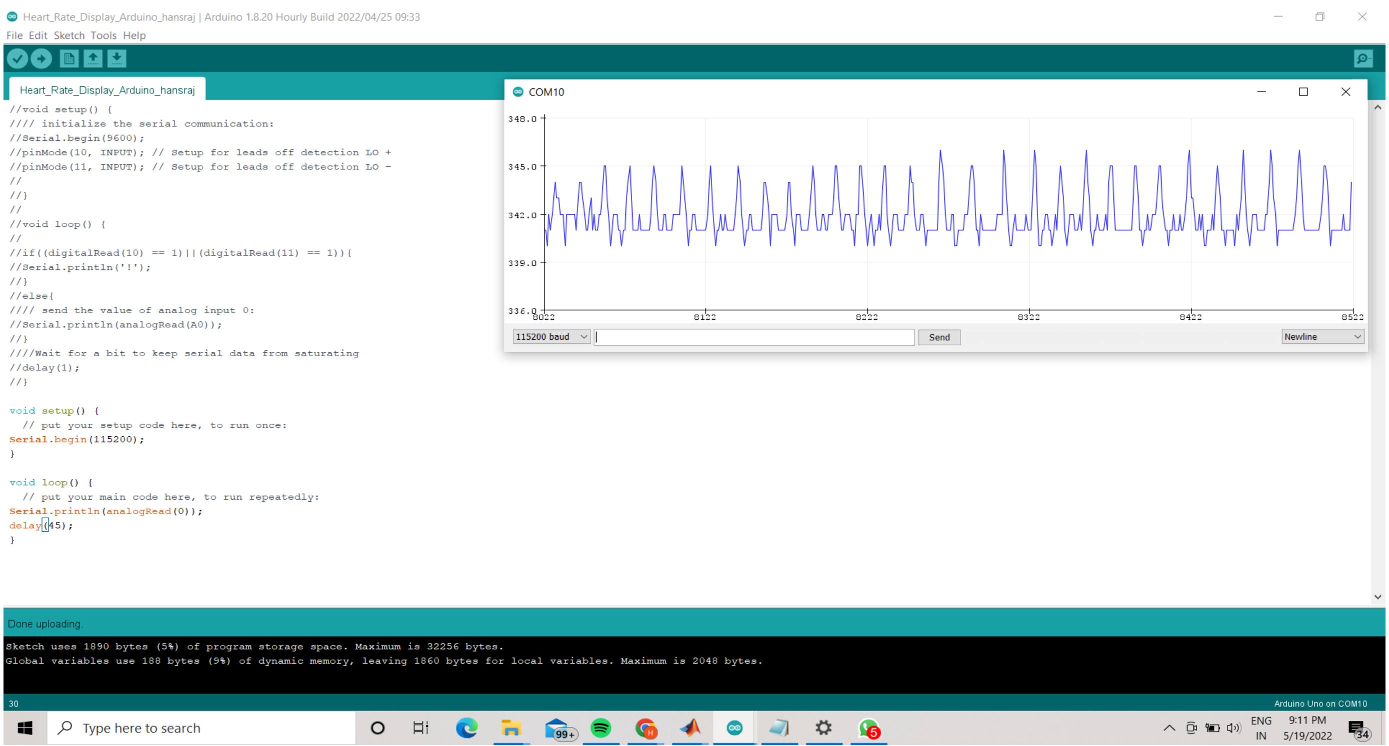


Figure 50 pulse sensor with arduino result with code.

For a demonstration video watch this.

The above result is obtained using a pulse sensor with an arduino as the sensor itself contains a filter and amplifier inside its circuit. We don't need to implement the filter and amplification part. In figure 50 we are showing a signal graph with code.

9.2.AD8232 Heart monitor sensor with ECG electrodes

For a demonstration video watch [this](#).

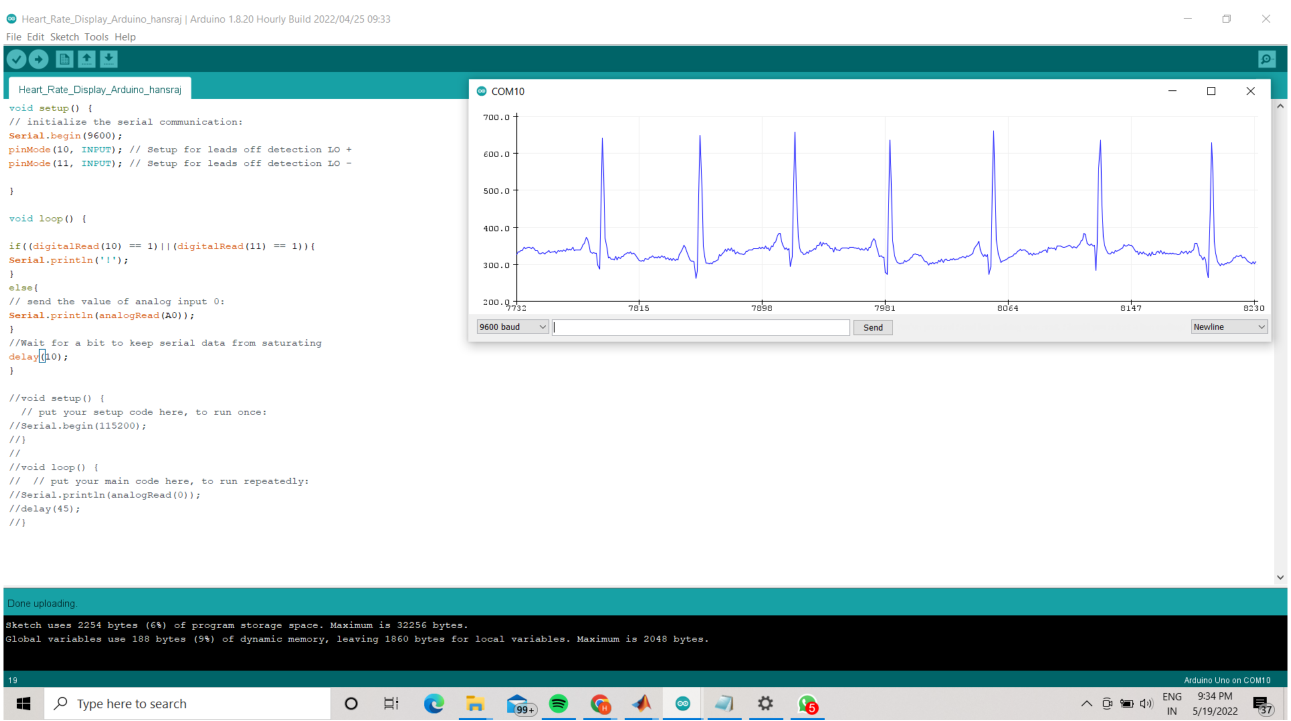
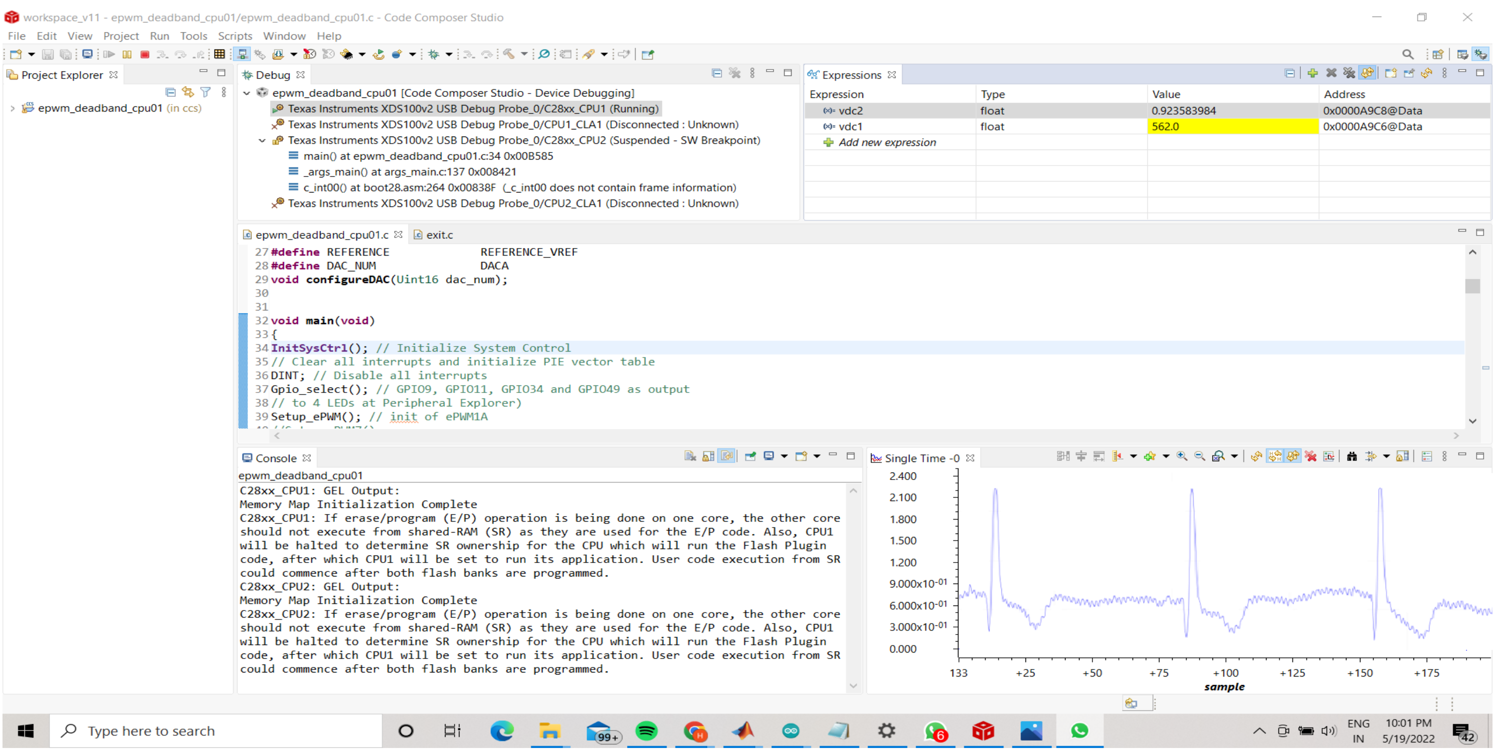


Figure 51 AD8232 with electrode using arduino

The above result is obtained using AD8232 with electrodes using arduino as the sensor itself contains a filter and amplifier inside its circuit. We don't need to implement the filter and amplification part. In figure 51 we are showing a signal graph with code.

9.3.LANCHXL-F28379D microcontroller with filter and piezoelectric sensor



. Figure 52 LAUNCHXL-F28379D microcontroller with filter and piezoelectric sensor.

In the above figure, we are showing the results of the LAUNCHXL-F28379D microcontroller with filter and piezoelectric sensor. As we need to remove noise and amplify signals we used our developed circuit for filtering and amplification of circuit. We write our code in Code composer ide.

for video demonstration click [here].

10.Chapter

Conclusions

We can see from the above three findings that the AD8232 heart rate monitor has the best performance based on noise and signal pattern, followed by the LAUNCHXL-F28379D with filter and piezoelectric sensor. The pulse sensor's performance comes at last .

In LAUNCHXL-F28379D some noise is still left compared to AD8232, whereas in pulse sensor the signal acquisition is not good.

We were able to successfully compare the outcomes of various combinations and tests. And we're working on a heartbeat monitoring system that uses piezoelectric sensors and the LAUNCHXL board, which can be utilized in real-time monitoring.

11. Chapter

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- https://www.avnet.com/wps/portal/abacus/solutions/technologies/sensors/pressure-sensors/core-technologies/piezoelectric/
- https://drive.google.com/file/d/1PXqJqbF7RaZ7OhGF5PZTBa0_ygoyo9b9/view?usp=sharing
- https://drive.google.com/file/d/1lTjrTNb8MrvQeeACPS8PoM9s9GBLUrWK/view?usp=sharing
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