EMG ANALYSIS CIRCUIT

[Hardware Project Report]

Introduction on EMG Signal and Its Processing:

EMG is generally extracted from the surface of the body. It is the sum of electrical activities in muscles under skin. The signal is generally of a low amplitude , like - 1-10 mV.

So, to acquire this signal and make it useful so that it can be measured and used in other calculations, some processing must be done.

For that, we need to design a proper circuit .

After researching through some papers and journals, we found out that EMG is very weak and gets interfered with by other signals easily. So noise cancellation methods must be used.

Here , we have used a bandpass filter with an instrumentation amplifier AD620 sandwiched in the middle (With high input impedance and high CMRR). The High-pass part of the circuit prevents any DC offset from entering the signal , as that can saturate the OP-Amps used and leave the signal to be distorted. The Amplifier gies it enough gain to pull up to the desired value , and the Low pass cuts it off at the wanted frequency], removing excess noise.

A pre-amplifier (AD620) is also used before the filters with low gain , so that it does not draw much current from the source (human body) , but also the gain is low so that the offset DC voltage is not amplified a lot before the High pass filter.

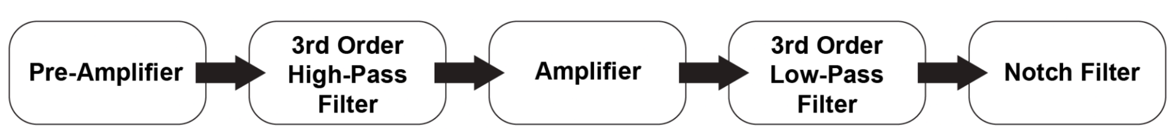


Fig. Proposed Circuit Schematic

In this project , we have been given,

The Amplitude range of EMG to be : 1 - 10 mV
The Frequency range of EMG to be : 20 - 20000 Hz

Therefore, Our target is to amplify the signal 500 times because the large threshold of EMG amplitude is 10mV and an oscilloscope can give output 5V maximum. So, overall gain of the system should be (5V/10mV) = 500.

Theoretically, we divided this 500 gain as shown below:

Circuit segment	Gain set
Pre-amplifier	5
3^{rd} order High Pass Filter	2
Amplifier	25
3^{rd} order Low Pass Filter	2
Total = 500	

Details of the Design of the Analysis Circuit:

- **Pre-amplifier**
- **High-pass Filter**
- **Amplifier**
- **Low-Pass Filter**

Bonus : Removing 50 Hz Power Line Noise

Pre-Amplifier:

Why Pre-amplifier is needed?

1. The acquired EMG signal is a weak electrical signal **within the 10mV range** which needs to be turned into an output voltage strong enough to be **noise-tolerant** and **for further processing**. Without this the final signal would be **noisy or distorted**.

2. The acquisition circuit needs to have a **constant gain.**

3. The circuit needs to have **high input impedance**:
    a. requiring only a minimal amount of current to sense the input signal
    b. to minimize loading effect
    c. to not draw current from the body

4. It also needs to have **low output impedance** (when current is drawn from the output there is minimal change in the output voltage).

5. It is needed to boost the signal strength to drive the cable to the main instrument without significantly degrading the signal-to-noise ratio (SNR). The **noise performance** of a preamplifier is critical.

6. Common Mode Rejection Ratio (CMRR) value of amplifier should **be greater than 80dB** to reduce the interference from common mode signal.

Reasons for choosing AD620 instrumentation amplifier:

1. Has an adjustable gain by an external resistor. Can be varied from **1 to 10,000 gain**.

2. The instrumentation amplifier has high input impedance and low output impedance as per required for bio-signal acquisition.

3. The **AD620** works well as a preamplifier due to its low input voltage noise of 9 nV/√Hz at 1 kHz, 0.28 μV p-p in the 0.1 Hz to 10 Hz band, and 0.1 pA/√Hz input current noise.
   From datasheet, voltage noise is in nano volt range for a high range of gain:

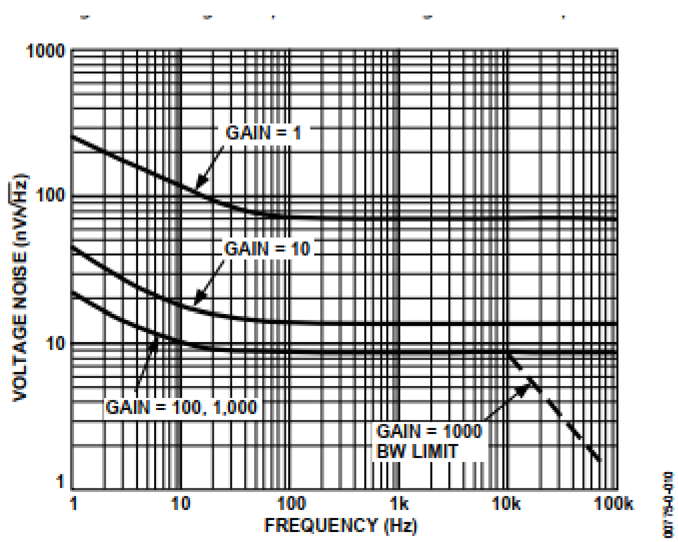


Figure 8. Voltage Noise Spectral Density vs. Frequency (G = 1−1000)

4. The low noise, low input bias current, and low power of the AD620 make it well suited for medical applications.
   From datasheet:

POWER SUPPLY	
Operating Range[4]	
Quiescent Current	V_S = ±2.3 V to ±18 V

5. Has high CMRR:
   From datasheet:

		AD620A		
Parameter	**Conditions**	**Min**	**Typ**	**Max**
Common-Mode Rejection				
Ratio DC to 60 Hz with				
1 kΩ Source Imbalance	V_{CM} = 0 V to ± 10 V			
G = 1		73	90	
G = 10		93	110	
G = 100		110	130	
G = 1000		110	130	

Gain equation of AD620:

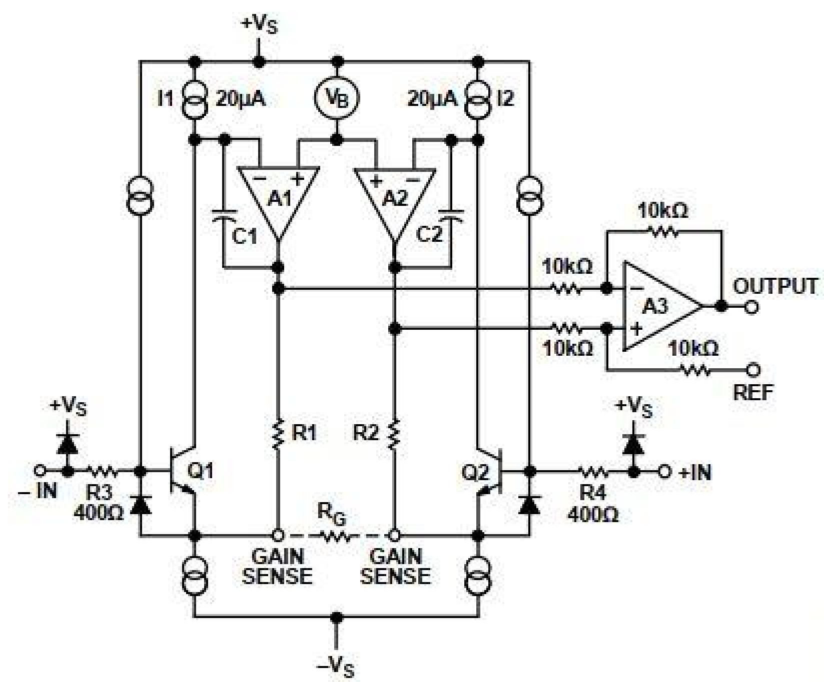


Figure 36. Simplified Schematic of AD620

Here, in the internal circuit of AD620, Feedback through Q1-A1-R1 loop and Q2-A2-R2 loop maintains a constant collector current of the input devices Q1 and Q2.
Thereby impressing the input voltage across the external gain setter Rg.

This creates a differential gain of **G=(R1+R2)/Rg + 1** with no additional gain at A3 for matched resistors.

The internal gain resistor R1 and R2 are trimmed to an absolute value of **24.7 kohm**.

The gain equation becomes:

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

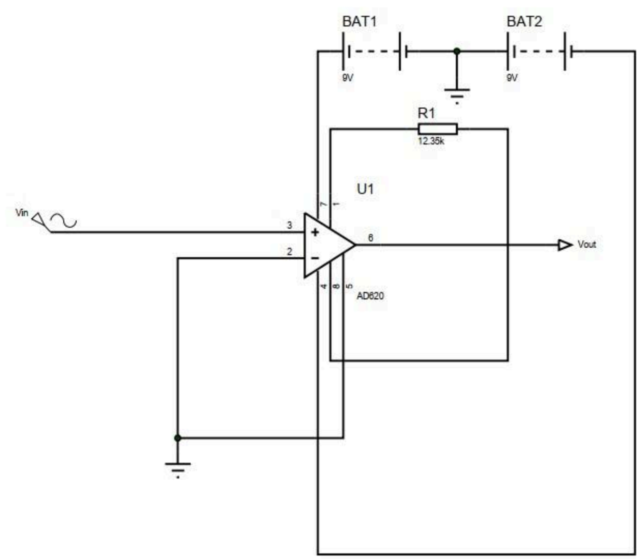
$$R_G = \frac{49.4k\Omega}{G-1}$$

Theoretical design and evaluation:

<u>Gain needed in Pre-amp: </u>5

<u>External Resistor Value:</u>

Rg = 49.4 / (5-1) =12.35 kohm



Circuit Design : ***Proteus***

Pin Diagram and Circuit Connection:

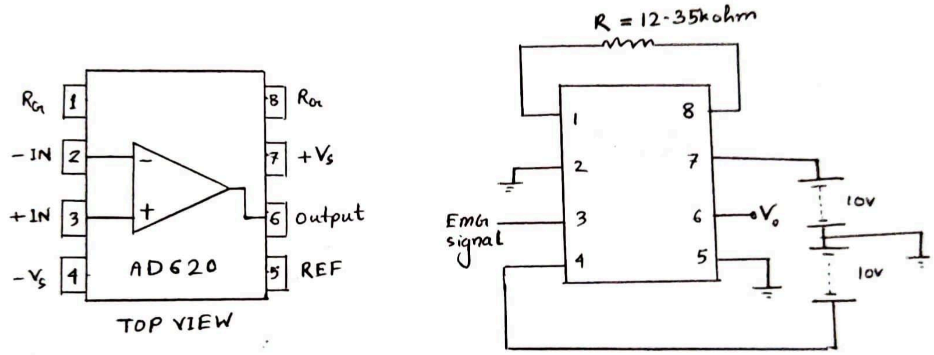


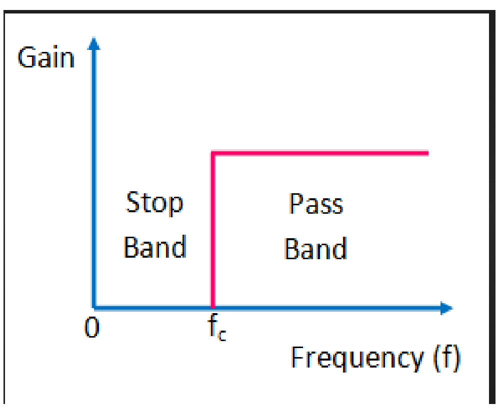
Fig. AD620 Pin Diagram

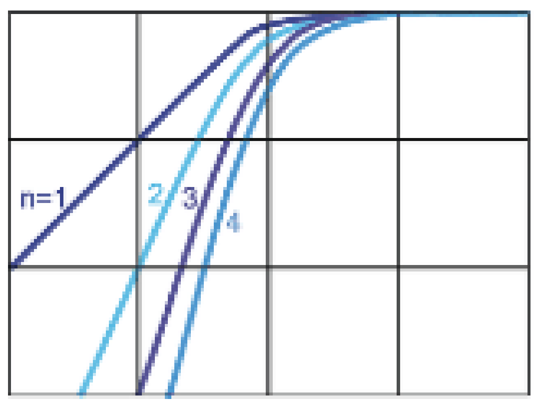
High-Pass Filter:

High Pass (HP) Filter allows certain signals whose frequencies are higher than cut-off frequencies by attenuating signals of lower frequencies. The cut-off frequency value depends on the design of the filter. A series of capacitors and resistors are connected in a basic HP Filter. The capacitor receives the input signal while the output is drawn across the resistor.

In RC High Pass filter, the reactance of the capacitor decreases when frequency increases and therefore the output and gain increases. The capacitor provides a significant amount of reactance at low frequencies and hence it blocks them. But, at high frequencies it provides little reactance and allows them to pass through it. At very high frequencies the reactance becomes very small such that the output is almost equal to input and gain is equal to unity. As the circuit blocks low frequencies and allows high frequencies to pass through it, we call it as R-C Circuit.

The frequency response for an ideal high pass filter is steep and sharp.





But in reality a wide band of frequency response is seen. To reduce this higher order high pass filter is used. The higher the order is, the more steep the frequency response is. The roll off rate for 1st,2nd,3rd,4th order are consecutively 20,40,60,80 db/decade. For our cause we find 3rd order high pass filters more convenient.

Deriving the Equation for 3rd Order High-pass Filter Gain and Cutoff frequency:

For Gain:

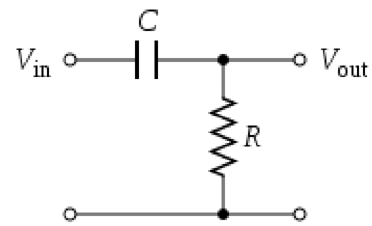
We know, for a first order passive filter ,

Transfer Function , $H(s) = V_{out}/V_{in}$

$=(R)/(R+1/sc)$

$=(RCs)/(1+Rcs)$

$=s/((1/RC)+s)$



Then, Frequency Response ,

$$H(j\omega)=j\omega/((1/RC)+j\omega)$$

Magnitude ,

$|H(\omega)| = |RCs/(1+RCs)|$

$= |RCj\omega/(1+RCj\omega)|$

$= RC\omega/ \sqrt{(1+(Rc\omega)^2)}$

Then, we can write for a third order passive filter ,

$H(s)=(RCs/(1+RCs))^3$

$H(\omega)=(RCj\omega/(1+RCj\omega))^3$

Then, $|H(\omega)|=(RC\omega/ \sqrt{(1+(Rc\omega)^2)})^3$

Again, $\omega=\omega_c$ [For Cutoff Frequency]

And $\omega_c=1/Rc$

Then, $|H(\omega)| = ((\omega/\omega_c)/ \sqrt{1+(\omega/\omega_c)^2})^3$

Replacing ω/ω_c with f / f_c , $|H(\omega)| = ((f/f_c)/ \sqrt{1+(f/f_c)^2})^3$

So, Gain of a passive third order filter = $((f/f_c)/ \sqrt{1+(f/f_c)^2})^3$

However, we are using a non-inverting differential Op-amp as this is an active third order filter.

So, the Gain non-inverting Op-Amp gain / The maximum gain of the filter will be ,

$$A_F = 1+ R_f / R_1$$

So ,

The total gain of the active 3rd Order filter, $G=A_F \times$ Gain of passive filter

$$\mathbf{G = (1+ R_f / R_1)(((f/f_c)/ \sqrt{1+(f/f_c)^2})^3)}$$

<u>For Cutoff frequency:</u>

$$\omega=\omega_c$$

Then the transfer function or gain of the passive filter,

$$|H(\omega)| = 1 /\sqrt{2} .$$

Or, $(RC\omega/ \sqrt{(1+(Rc\omega_c)^2)})^3 = 1 /\sqrt{2}$

Or, $((Rc\omega_c)^2/ (1+(Rc\omega_c)^2))^3 = 1 /2$.

Or, $1+(1/(Rc\omega_c)^2) = 2^{1/3}$

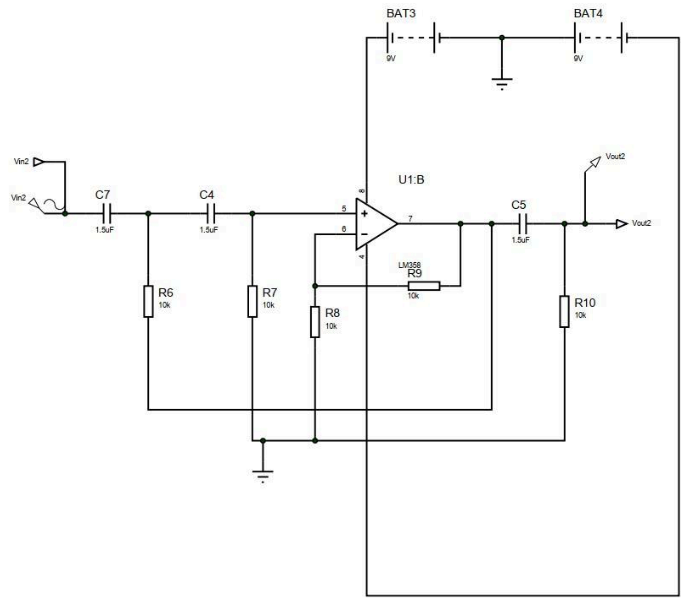
Or, $1/(Rc\omega_c)^2 = 2^{1/3} - 1$

From this we can write, $\omega_c = 1 / Rc$

$$\mathbf{f_c = 1 / 2\pi Rc}$$

Theoretical design and evaluation:

Circuit Design:
Proteus



Calculation:

We derived that the cutoff frequency of the 3rd order high pass filter is

$$f_c = 1 / 2\pi Rc$$

from our our designed circuit,

we get,

$$f_c = 1 / (2\pi \times 10000 \times 1.5 \times 10\text{^}{-6}) \text{ Hz}$$

$$= 10.61 \text{ Hz}$$

And Maximum gain of our 3rd order high pass filter is

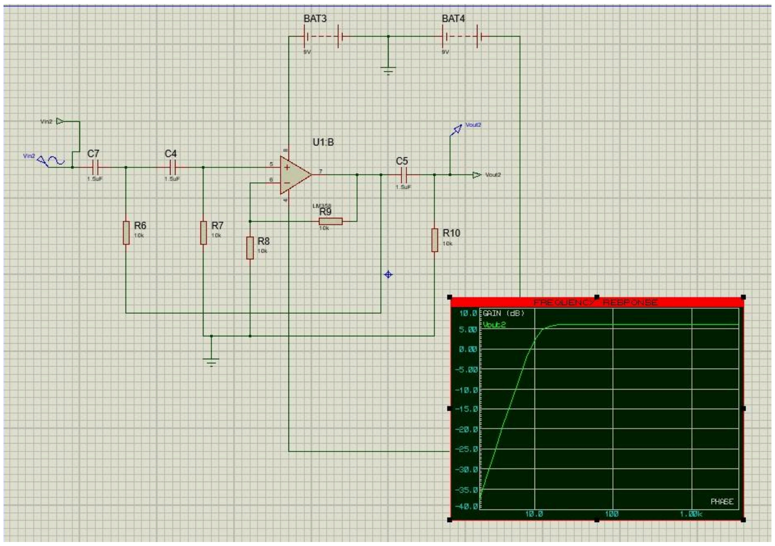
$$G = A_F$$

$$= (1+ R_f / R_1)$$

$$=1+10000/10000$$

$$= 2$$

Frequency Response Graph in Proteus:



Frequency Response Graph in Proteus:

(Gain vs Frequency)

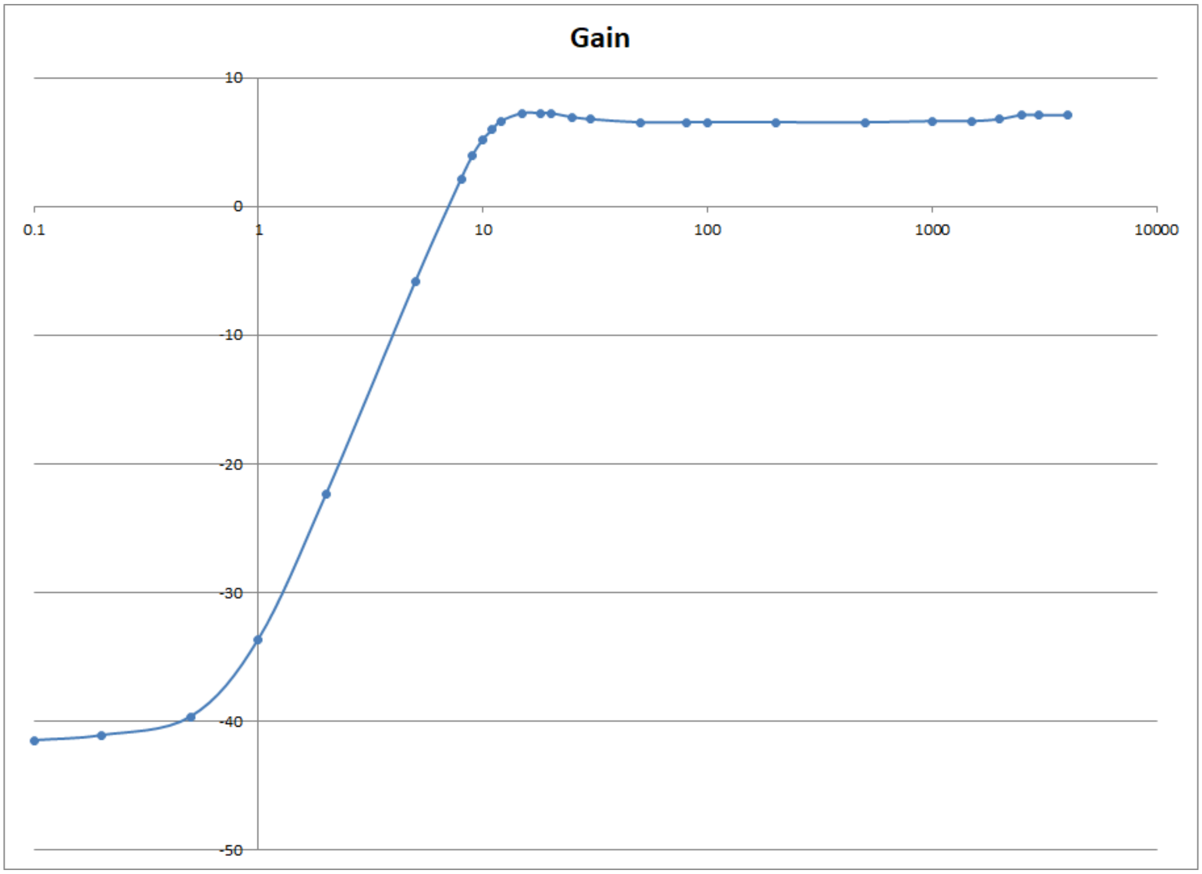
Practical Evaluation:

Data collection for 3rd Order High Pass Filter -

Freq	Vin	Vout	Gain (dB)	Av
0.1	2	0.0168	-41.5144	0.0084
0.2	2	0.0176	-41.1103	0.0088
0.5	2	0.0208	-39.6593	0.0104
1	2	0.0416	-33.6387	0.0208
2	2	0.152	-22.3837	0.076
5	2	1.02	-5.8486	0.51
8	2	2.56	2.144199	1.28
9	2	3.16	3.973142	1.58
10	2	3.64	5.201428	1.82
11	2	3.96	5.933304	1.98
12	2	4.28	6.608275	2.14

15	2	4.6	7.234557	2.3
18	2	4.6	7.234557	2.3
20	2	4.6	7.234557	2.3
25	2	4.44	6.927059	2.22
30	2	4.36	6.76913	2.18
50	2	4.24	6.526717	2.12
80	2	4.24	6.526717	2.12
100	2	4.24	6.526717	2.12
200	2	4.24	6.526717	2.12
500	2	4.24	6.526717	2.12
1000	2	4.28	6.608275	2.14
1500	2	4.28	6.608275	2.14
2000	2	4.36	6.76913	2.18
2500	2	4.52	7.082169	2.26
3000	2	4.52	7.082169	2.26
4000	2	4.52	7.082169	2.26

Frequency response plot:



Amplifier:

Theoretical design and evaluation :

Biosignals such as EMG require to be amplified significantly before further processing and this task is usually accomplished by use of instrumentation amplifiers.

There are several important characteristics of an instrumentation amplifier that set it apart from operational amplifier.

1. Instrumentation amplifiers have finite gain which is selectable within precise value of range with high gain accuracy and gain linearity.
2. The instrumentation amplifier has a high impedance differential input.
3. The instrumentation amplifier has a high common mode rejection ratio (CMMR) and a high common mode voltage range.
4. Instrumentation amplifiers have high stability of gain with low temperature coefficient.

These listed out characteristics make an instrumentation amplifier superior to most Op-Amps.

In this circuit, we have used **AD620** as the instrumentation amplifier. The **AD620**, with its high accuracy of 40 ppm (maximum) nonlinearity, low offset voltage of 50 μV (maximum), and offset drift of 0.6 μV/°C (maximum), is ideal for use in precision data acquisition systems such as weigh scales and transducer interfaces. Furthermore, the low noise, low input bias current, and low power of the AD620 make it well suited for medical applications such as EMG, ECG and noninvasive blood pressure monitors.

The AD620 only requires a resistor, R_G, to set its gain value and can therefore be easily set up.

The IC is provided biasing voltage, pin 7 is connected to +9V and pin 4 is connected to -9V.. The non-inverting pin (pin 2) and the inverting pin (pin 3) are connected to the signal to be amplified, here a function generator is used to provide a similar signal as EMG (1mV-10mV and 20Hz to 2000Hz).

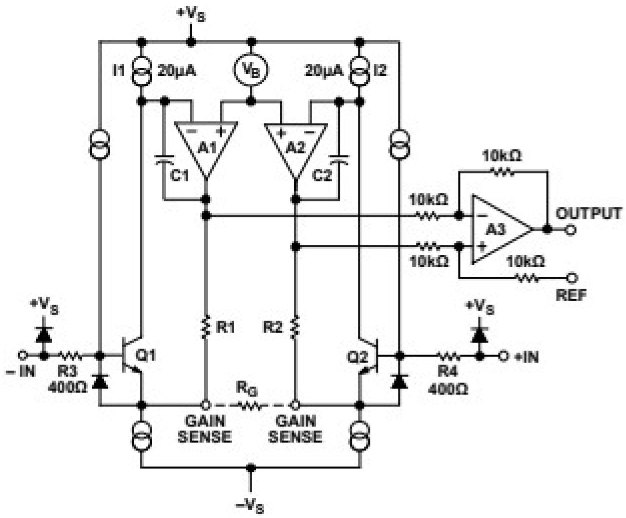


Figure 36. Simplified Schematic of AD620

In our circuit, the amplifier AD620 gets input from the 3rd order high pass filter that has been described above, and the output from pin6 goes to the input of the 3rd order low pass filter that is described below. The reference pin (pin 5) is connected to ground, the reference pin is used to direct the output to the voltage when the difference voltage between the inverter and the non-inverter pin is 0V.

The Gain of the Op-Amp is by connecting the correct resistance value to the pin $+R_G$ (pin 8) and the pin $–R_G$ (pin 1). For This amplifier , as shown before , we have selected the gain to be 25 .

The formula used to calculate the gain value (From the datasheet of AD620) has been given below.

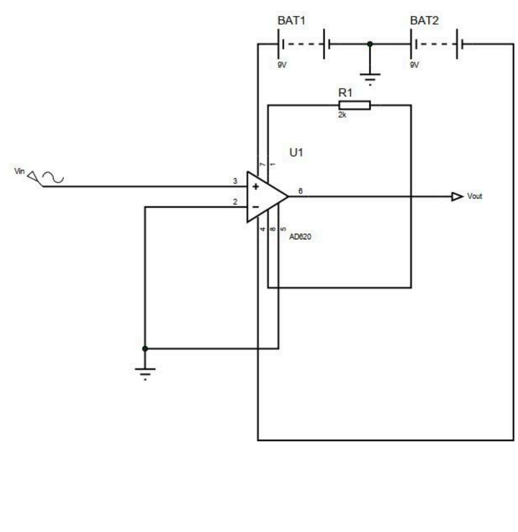
G = (49.4 k/RG) + 1

Or, R_G = 49.4k/(G-1) Ω

Or, R_G = 49.4k/(25-1) Ω

Or, R_G = 2058.333Ω

We chose to use R_G = 2kΩ , because it is close to 2058.333Ω .
It gives G = 25.7 our theoretical gain for this amplifier which is better. After implementing the circuit, we observed the practical gain for this amplifier is 26.43.



Proteus Design of the Amplifier

Low-pass Filter:

We know that For simple first-order filters the transition band may be too long or too wide, so active filters designed with more than one “order” are required. These types of filters are commonly known as “High-order” or “nth-order” filters.

The complexity or filter type is defined by the filter's “order, and which is dependent upon the number of reactive components such as capacitors or inductors within its design. We also know that the rate of roll-off and therefore the width of the transition band, depends upon the order number of the filter and that for a simple first-order filter it has a standard roll-off rate of 20dB/decade or 6dB/octave.

Then, for a filter that has an nth number order, it will have a subsequent roll-off rate of 20n dB/decade or 6n dB/octave. So a first-order filter has a roll-off rate of 20dB/decade (6dB/octave), a second-order filter has a roll-off rate of 40dB/decade (12dB/octave), and a third -order filter has a roll-off rate of 60dB/decade (18dB/octave).

High-order filters, such as third, fourth, and fifth-order are usually formed by cascading together single first-order and second-order filters.
For example, one first order and one second-order low pass filter can be cascaded together to form a third order low pass filter.

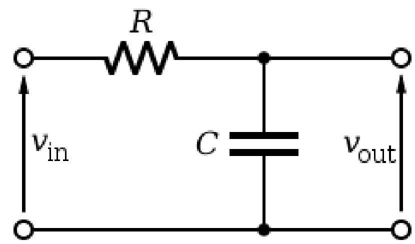
So to get a better roll off rate and remove the high frequency noises we used **3rd order low pass filter** in our circuit design .

Deriving the Equation for 3rd Order Low-pass Filter Gain and Cutoff frequency:

<u>For Gain:</u>

We know, for a first order passive filter ,

Transfer Function , $H(s) = V_{out}/V_{in}$



$=(1/sc)/(R+1/sc)$

$=1/(1+Rcs)$

$=(1/Rc)/(s+1)/Rc$

Then, Frequency Response ,

$$H(j\omega)=(1/Rc)/(1+j\omega)/Rc$$

Magnitude ,

$$|H(\omega)| = |1/(1+Rcs)|$$

$$=|1/(1+Rcj\omega)|$$

$$=1/ \sqrt{1+(Rc\omega)^2}$$

Then, we can write for a third order passive filter ,

$$H(s)=(1/ \sqrt{1+(Rcs)^2})^3$$

$$H(\omega)=(1/ \sqrt{1+(Rcj\omega)^2})^3$$

Then, $|H(\omega)|=(1/ \sqrt{1+(Rc\omega)^2})^3$

Again, $\omega=\omega_c$ [For Cutoff Frequency]

And $\omega_c=1/Rc$

Then, $|H(\omega)| = (1/ \sqrt{1+(\omega/\omega_c)^2})^3$

Replacing ω/ω_c with f / f_c , $|H(\omega)| = (1/ \sqrt{1+(f/f_c)^2})^3$

So, Gain of a passive third order filter = $(1/ \sqrt{1+(f/f_c)^2})^3$

However, we are using a non-inverting differential Op-amp as this is an active third order filter.

So, the Gain non-inverting Op-Amp gain / The maximum gain of the filter will be ,

$$A_F = 1+ R_f / R_1$$

So ,

The total gain of the active 3rd Order filter, $G=A_F \times$ Gain of passive filter

$$\mathbf{G = (1+ R_f / R_1)((1/ \sqrt{1+(f/f_c)^2})^3)}$$

For Cutoff frequency:

$$\omega=\omega_c$$

Then the transfer function or gain of the passive filter,

$$H(\omega) = 1 /\sqrt{2} .$$

Or, $(1/ \sqrt{1+(Rc\omega_c)^2})^3 = 1 /\sqrt{2}$.

Or, $1+(Rc\omega_c)^2 = 2^{1/3}$

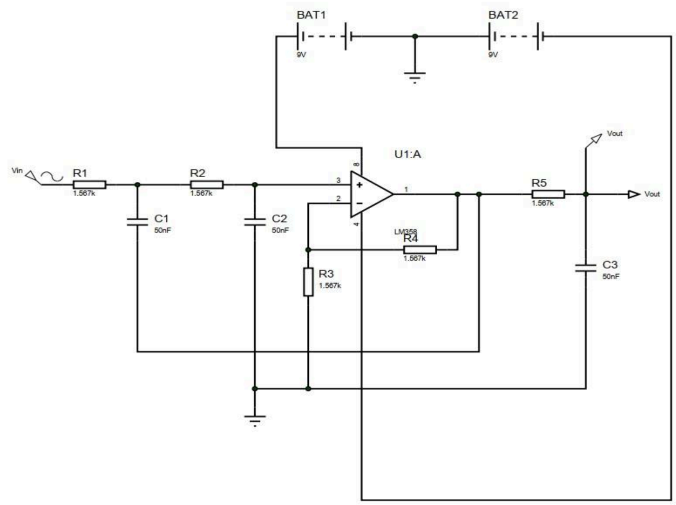
Or, $(Rc\omega_c)^2 = 2^{1/3} - 1$

From this we can write, $\omega_c = 1 / Rc$

$$\mathbf{f_c = 1 / 2\pi Rc}$$

Theoretical design and evaluation:

Circuit Design :
Proteus



Calculation:

We derived that the cutoff frequency of the 3rd order low pass filter is

$$f_c = 1 / 2\pi Rc$$

from our our designed circuit,

we get,

$$f_c = 1 / (2\pi \times 1.567 \times 1000 \times 50 \times 10^{-9}) \text{ Hz}$$

$$= 2031.33 \text{ Hz}$$

And Maximum gain of our 3rd order low pass filter is

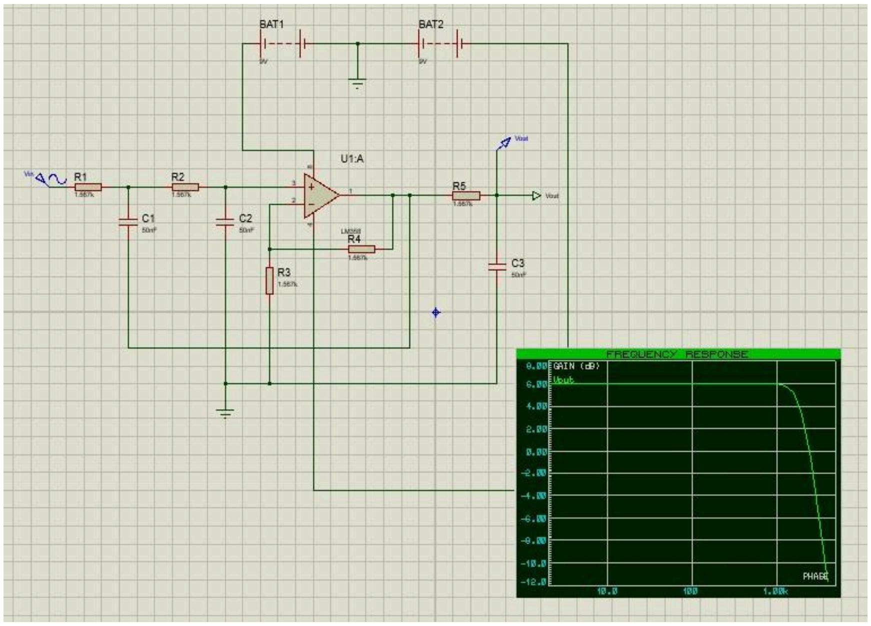
$$G = A_F$$

$$= (1 + R_f / R_1)$$

$$= 1 + 1.567/1.567$$

$$= 2$$

Frequency Response Graph in Proteus :



Frequency Response Graph in Proteus:

(Gain vs Frequency)

Practical Evaluation:

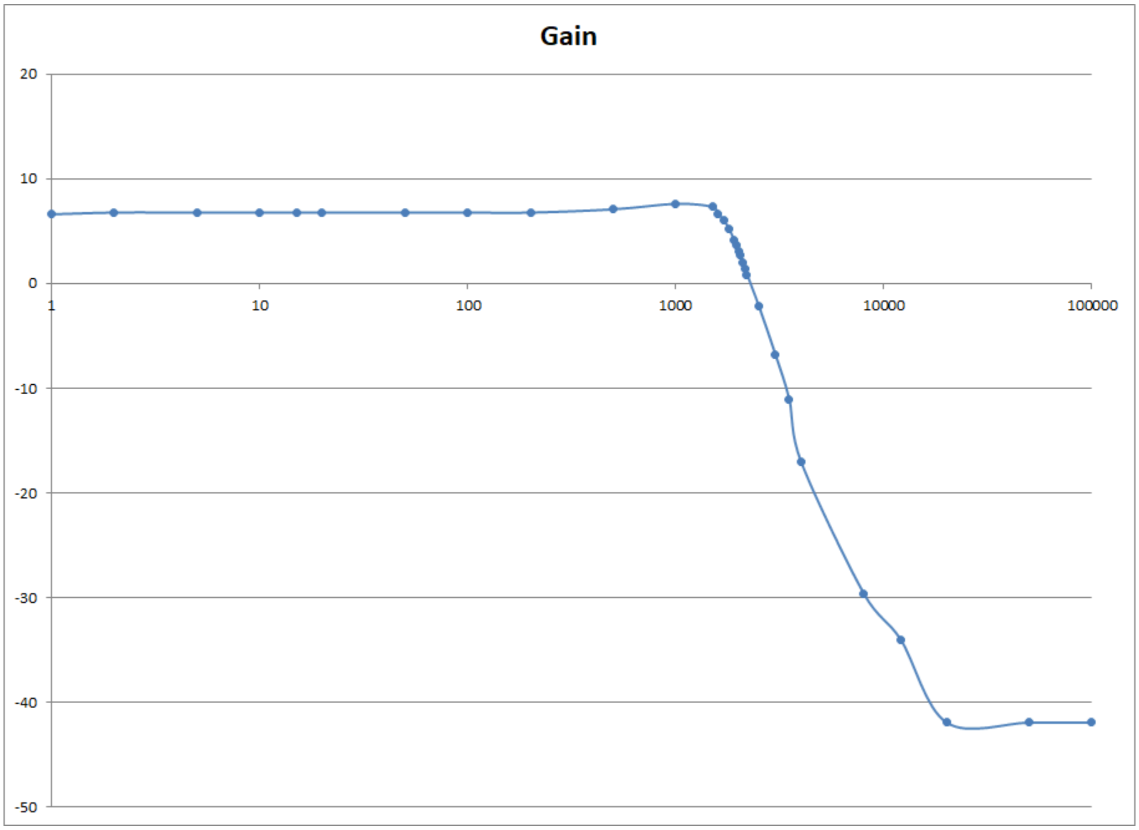
Data collection -

Freq	Vin	Vout	Gain (dB)	Av
1	2	4.28	6.608275	2.14
2	2	4.36	6.76913	2.18
5	2	4.36	6.76913	2.18
10	2	4.36	6.76913	2.18
15	2	4.36	6.76913	2.18
20	2	4.36	6.76913	2.18
50	2	4.36	6.76913	2.18
100	2	4.36	6.76913	2.18
200	2	4.36	6.76913	2.18
500	2	4.52	7.082169	2.26

Freq	Vin	Vout	Gain (dB)	Av
1	2	4.28	6.608275	2.14
1000	2	4.8	7.604225	2.4
1500	2	4.64	7.30976	2.32
1600	2	4.28	6.608275	2.14
1700	2	4	6.0206	2
1800	2	3.64	5.201428	1.82
1900	2	3.24	4.1903	1.62
1950	2	3.04	3.636872	1.52
2000	2	2.84	3.045767	1.42
2050	2	2.72	2.670778	1.36
2100	2	2.52	2.007411	1.26
2150	2	2.36	1.43764	1.18
2200	2	2.2	0.827854	1.1
2500	2	1.56	-2.15811	0.78
3000	2	0.92	-6.74484	0.46
3500	2	0.56	-11.0568	0.28
4000	2	0.28	-17.0774	0.14
8000	2	0.066	-29.6297	0.033
12000	2	0.04	-33.9794	0.02
20000	2	0.016	-41.9382	0.008
50000	2	0.016	-41.9382	0.008
100000	2	0.016	-41.9382	0.008

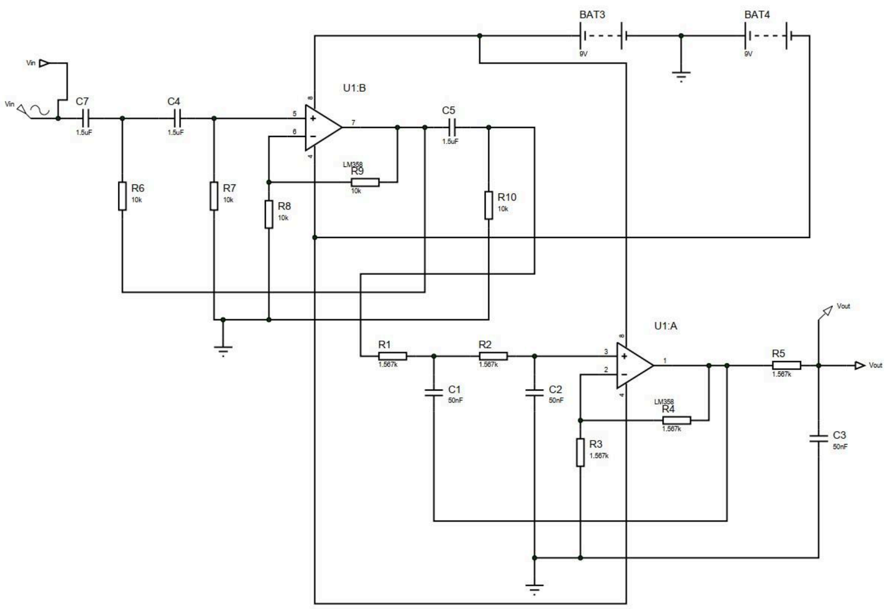
We can see the gain being attenuated at around 2000 Hz , as it is supposed to be in the low pass filter for EMG signal.

Frequency response plot:



BandPass Filter (High-Pass + Low-Pass):

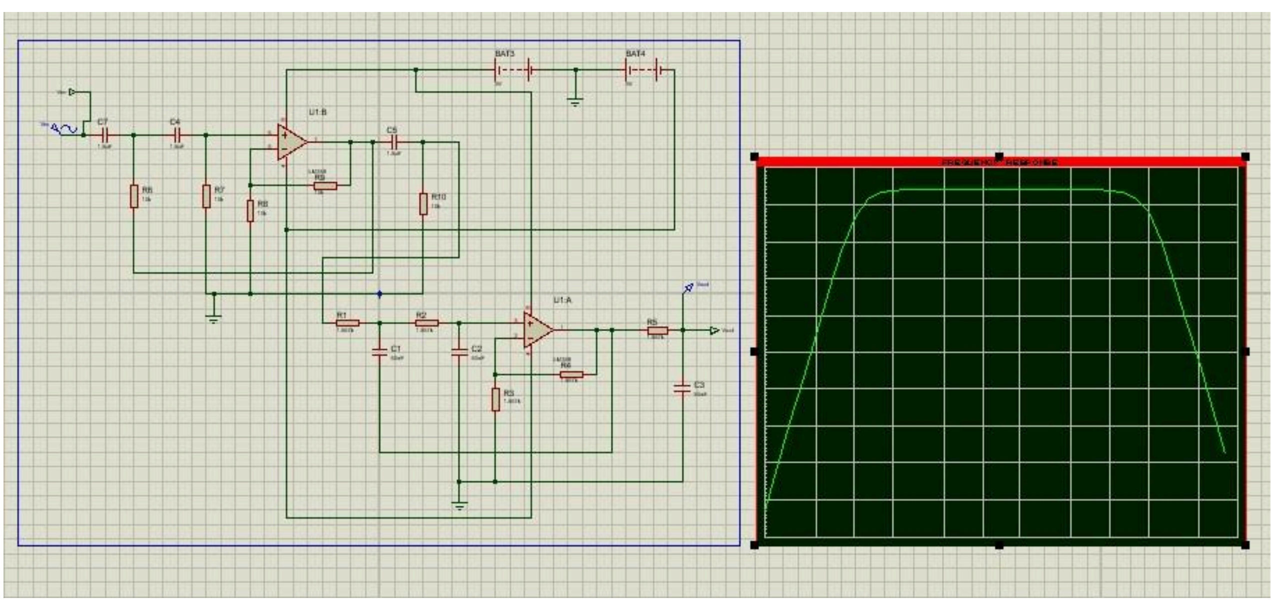
Theoretical design and evaluation:



Proteus Design (Left)

and

Frequency Response (Down)



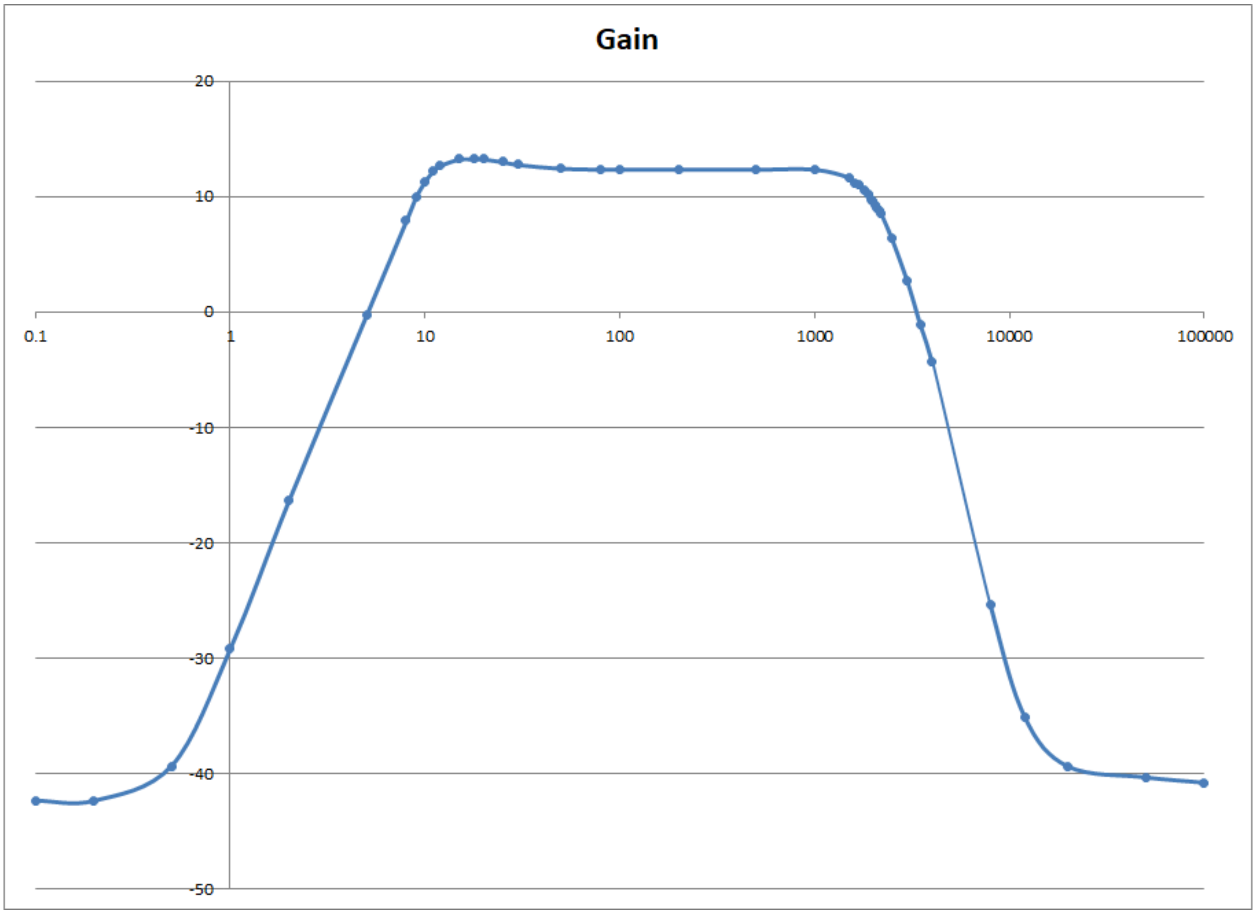
Practical Evaluation:

Data collection for 3rd Order Bandpass Filter -

Freq	Vin	Vout	Gain (dB)	Av
0.1	2	0.0152	-42.3837	0.0076
0.2	2	0.0152	-42.3837	0.0076
0.5	2	0.0216	-39.3315	0.0108
1	2	0.0696	-29.1684	0.0348
2	2	0.304	-16.3631	0.152
5	2	1.93	-0.30945	0.965
8	2	4.96	7.889034	2.48
9	2	6.32	9.993742	3.16
10	2	7.36	11.31696	3.68
11	2	8.16	12.2132	4.08
12	2	8.64	12.70967	4.32
15	2	9.2	13.25516	4.6
18	2	9.2	13.25516	4.6
20	2	9.2	13.25516	4.6
25	2	8.96	13.02556	4.48
30	2	8.72	12.78973	4.36
50	2	8.4	12.46499	4.2
80	2	8.32	12.38187	4.16
100	2	8.32	12.38187	4.16
200	2	8.32	12.38187	4.16
500	2	8.32	12.38187	4.16
1000	2	8.32	12.38187	4.16

1500	2	7.68	11.68662	3.84
1600	2	7.2	11.12605	3.6
1700	2	7.12	11.029	3.56
1800	2	6.72	10.52679	3.36
1900	2	6.48	10.2109	3.24
1950	2	6.16	9.771014	3.08
2000	2	6.08	9.657472	3.04
2050	2	5.84	9.307657	2.92
2100	2	5.68	9.066367	2.84
2150	2	5.52	8.818182	2.76
2200	2	5.36	8.562696	2.68
2500	2	4.16	6.361267	2.08
3000	2	2.72	2.670778	1.36
3500	2	1.76	-1.11035	0.88
4000	2	1.22	-4.2934	0.61
8000	2	0.108	-25.3521	0.054
12000	2	0.0352	-35.0897	0.0176
20000	2	0.0214	-39.4123	0.0107
50000	2	0.0192	-40.3546	0.0096
100000	2	0.0182	-40.8192	0.0091

Frequency response plot:



Final Circuit:

(Pre-Amplifier+High Pass Filter+Amplifier+Low Pass Filter)

Theoretical design and evaluation:

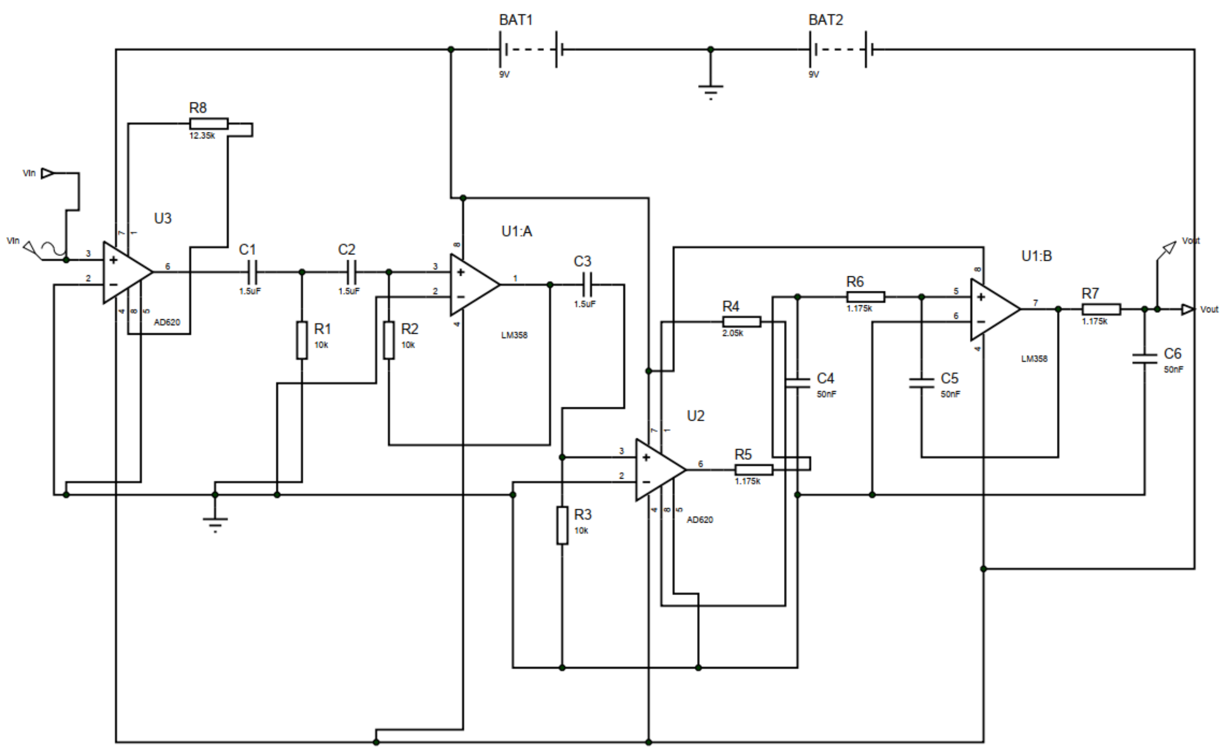
Resistors R5, R6, R7 has been changed from 1.567kΩ to 1.175kΩ to increase the higher cut-off frequency as we have observe the attenuation starts before 2000 Hz in the Low Pass and Bandpass filters.

$$f_c = 1 / 2\pi Rc$$

$$f_c = 1 / (2\pi \times 1.175 \times 1000 \times 50 \times 10^{-9}) \text{ Hz}$$

$$= 2709 \text{ Hz}$$

The higher cut-off frequency is now 2709 Hz to ensure higher gain at 2000 Hz than before.



Proteus assembly of Final Circuit

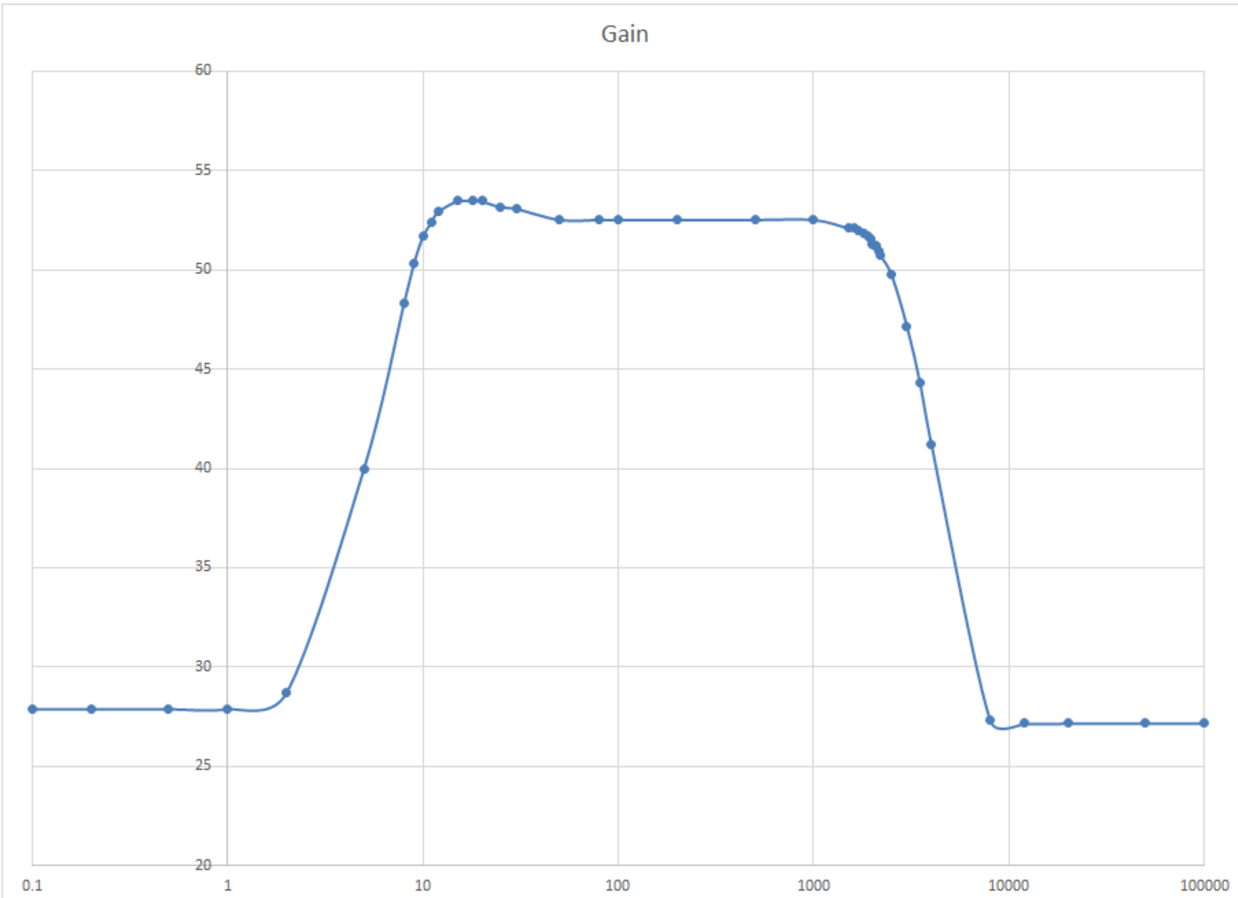
Practical Evaluation:

Data collection for Final Circuit -

Freq	Vin	Vout	Gain	Av
0.1	0.01	0.248	27.88903	24.8
0.2	0.01	0.248	27.88903	24.8
0.5	0.01	0.248	27.88903	24.8
1	0.01	0.248	27.88903	24.8
2	0.01	0.272	28.69138	27.2
5	0.01	1	40	100
8	0.01	2.6	48.29947	260
9	0.01	3.28	50.31748	328
10	0.01	3.84	51.68662	384
11	0.01	4.16	52.38187	416
12	0.01	4.44	52.94766	444
15	0.01	4.72	53.47884	472
18	0.01	4.72	53.47884	472
20	0.01	4.72	53.47884	472
25	0.01	4.56	53.1793	456
30	0.01	4.52	53.10277	452
50	0.01	4.24	52.54732	424
80	0.01	4.24	52.54732	424
100	0.01	4.24	52.54732	424
200	0.01	4.24	52.54732	424
500	0.01	4.24	52.54732	424
1000	0.01	4.24	52.54732	424

1500	0.01	4.04	52.12763	404
1600	0.01	4.04	52.12763	404
1700	0.01	3.96	51.9539	396
1800	0.01	3.92	51.86572	392
1900	0.01	3.84	51.68662	384
1950	0.01	3.8	51.59567	380
2000	0.01	3.68	51.31696	368
2050	0.01	3.64	51.22203	364
2100	0.01	3.64	51.22203	364
2150	0.01	3.52	50.93085	352
2200	0.01	3.44	50.73117	344
2500	0.01	3.08	49.77101	308
3000	0.01	2.28	47.1587	228
3500	0.01	1.64	44.29688	164
4000	0.01	1.15	41.21396	115
8000	0.01	0.232	27.30976	23.2
12000	0.01	0.228	27.1587	22.8
20000	0.01	0.228	27.1587	22.8
50000	0.01	0.228	27.1587	22.8
100000	0.01	0.228	27.1587	22.8

Frequency response plot:



Component Photographs:

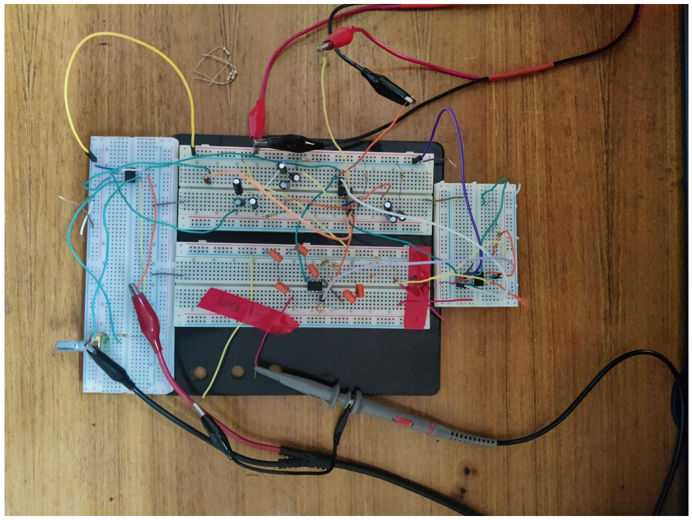


Fig. Implemented Circuit

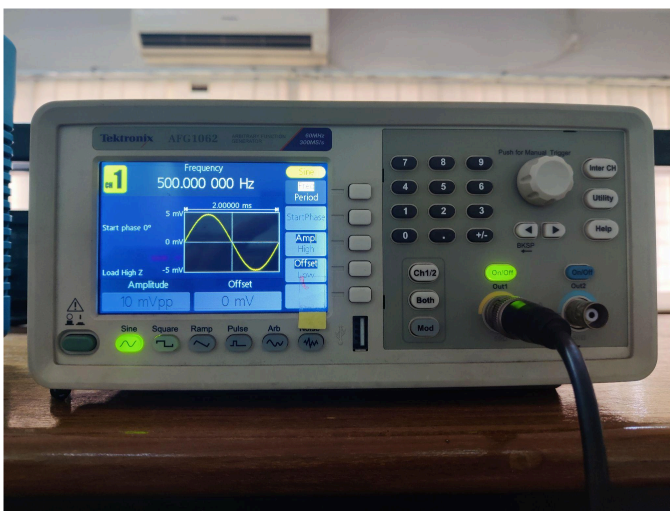


Fig. Input Wave Characteristics

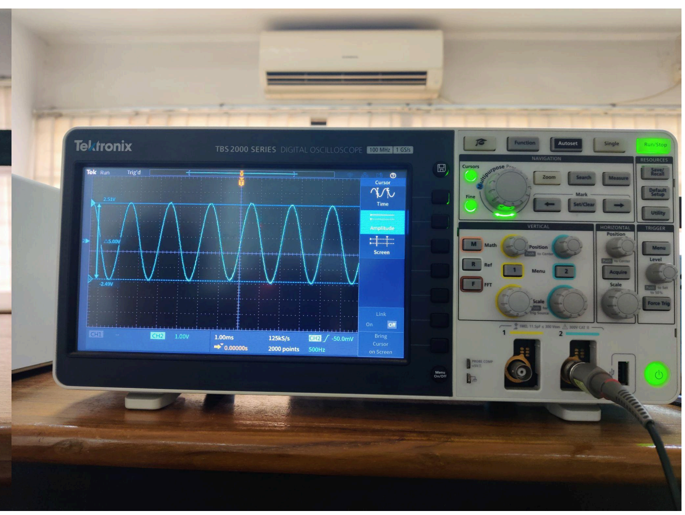


Fig.Output Wave Characteristics

Removing 50 Hz Power Line Interference:

The General approach to remove the powerline noise is to build a Notch filter. However, as EMG ranges from 20 Hz to 20000 Hz, 50 Hz stays in the middle , and when a Notch filter is used, it cuts off a wide range around 50 Hz , eventually affecting the integrity of the EMG signal.

Therefore, we have decided to not use the Notch filter.

Rather than that, it is better to use any software to conduct Frequency Transform or other digital methods to remove the powerline noise. There are some good papers on it proving such digital methods are used for better results , like - Adaptive Noise Canceling , Regression-Subtraction ,Spectrum Interpolation etc.

[References are attached]

References:

1. Baofeng Sun, Wanzhong Chen, Xin Zheng,The System Design for the Extraction and Pre-processing of Surface EMG,Physics ProcediaVolume 33,2012,Page 8-13,ISSN 1875-3892,https://doi.org/10.1016/j.phpro.2012.05.023.
   (https://www.sciencedirect.com/science/article/pii/S1875389212013363)
   Abstract: This paper design an acquisition instrument of surface EMG (SEMG)based on a high common mode rejection ratio(CMRR) preamplifier to deal with the difficulties in capturing the SEMG which is small range,low SNR,easy to be disturbed and the high prices of present acquisition equipment.This design can restain the common mode interferrence and power frequency interferrance effectively with a low price.By making use of wireless communication module PTR2000 in connecting C8051F320 MCU to host computer for data transmission,a wireless real-time acquisition system of SEMG is constitued.The complete and accurate SEMG is obtained in the host computer,providing a reliable source for the further analysis and processing of SEMG.Keywords: surface EMG ;CMRR ;PTR2000 ;C8051F320

2. Neural Networks as Cybernetic Systems - 3rd and revised Edition, Prof. Holk Cruse.

3. Mewett, D.T. & Nazeran, Homayoun & Reynolds, Karen. (2001). Removing power line noise from recorded EMG. Proceedings of the 23rd Annual International Conference on Engineering in Medical and Biological Society: Istanbul. 3. 2190 - 2193 vol.3. 10.1109/IEMBS.2001.1017205.