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FOURTH-ORDER ACTIVE LOW PASS FILTER FOR BIOMEDICAL APPLICATIONS

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Abstract

We have designed a fourth-order active lowpass filter which is a cascade version of two-second-order lowpass filters. To achieve the application, the Sallen-Key and conventional second-order filters are used in the first stage and second stages respectively. This filter is designed especially for biomedical applications for the detection of very low frequencies in the range from 1 Hz to 100 Hz. We get stable output waveforms with high selectivity, fewer harmonics, and sharp waveform crest and trough.

Keywords: Lowpass filter; Active Filter; Bio-medical application; Fourth order filter

I. Introduction

Several biomedical instruments have been developed by biomedical engineers and scientists from every corner of the globe. Very popular biomedical instruments like Electroencephalogram (EEG) [VI], Electrocardiogram (ECG) [V], Defibrillator [II], Nebulizer [I], etc are available in every medical clinic to enhance human health. These instruments can tackle complex medical and health issues, by the analysis of the output signals.

Table1: The frequency range of common biomedical signals [VII]

Signal	Frequency Range (Hz)
PPG	0.5 – 5
EMG	50 – 150
Cardiac Auscultion	20 – 420
Gait Analysis	0 – 15

The frequency characteristics of various biomedical signals such as Cardiac Auscultation, Gait Analysis, EMG, and PPG are shown in Table 1[VII]. Amplitude and Frequency characteristics of biomedical signals are various. Frequencies are very low and the order of the amplitude is µV [IV].

A typical biomedical signal detection system is shown in Figure 1. To detect the biomedical signals, various types of sensors are used, these are Microelectromechanical system motion sensor, Flexible sensor, GluSense artificial islet system, Wearable biosensors, Biochip, Genechip, Cellchip, Biological molecular sensor, Cell-based biosensors, Implantable sensors, etc. [III, VIII, IX, X]. In this paper, we design a fourth-order lowpass active filter for the biomedical signal detection system.

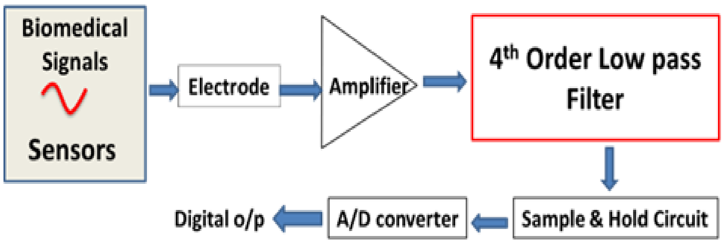


Fig 1. Second-order active Low pass filter

We have learned about first-order active filters, their design, characteristics, and frequency response, and also we have learned how to apply this type of filter in practical applications. But there were some drawbacks to it which forced Geniuses to improve the performance and design a filter that can be better than first-order active filters. Then comes a new and advanced version of first-order filters usually named "Second order active filters". A second-order active Low pass filter is shown in Figure 2. The name " Second Order " describes that there are 'Two passive filters' cascaded with each other and fed to an amplifier to amplify the Frequency Response of it. Its Roll-off rate is too steep compared to first-order low pass filters.

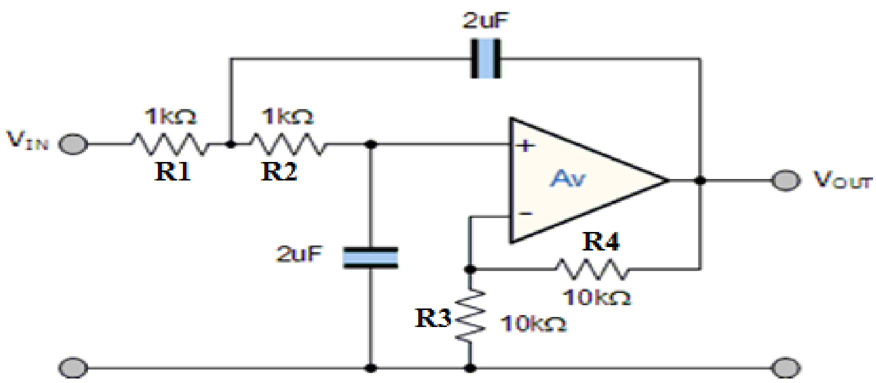


Fig 2. Second order active Low pass filter

From the basic 'Second order Active low pass filter', two Passive R-C filters are cascaded except capacitor (C1), which is connected in Positive Feedback with output instead of connecting it to Ground because it will provide a better Selectivity for which this type of Filters are mostly trending in market level as well as industry level.

Low-pass filters are very useful for the detection of health conditions in the human body. The human body generates many waveforms, and they can be captured from various parts of the body using different sensors. The four commonly used signals related to biomedical applications are outlined in Table 1.

II. Circuit Diagram:

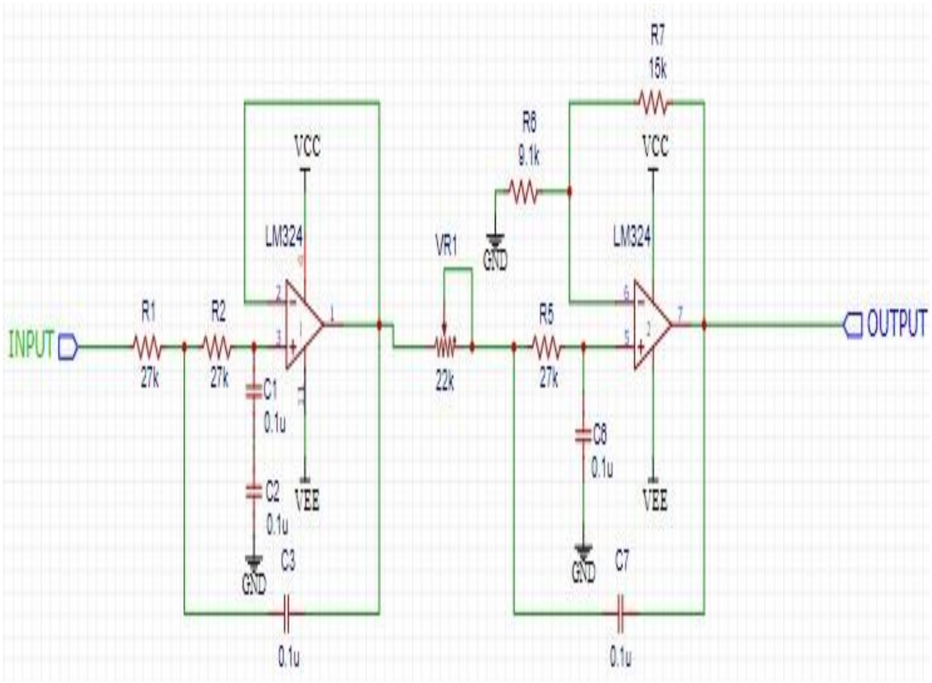


Fig 2. Fourth order Active Low Pass Filter, designed using spice simulator.

Figure 2 shows the circuit diagram of the implemented low-pass filter. The practical images of the circuit designed in a laboratory at that period from different views are given in figures 3(a-c).

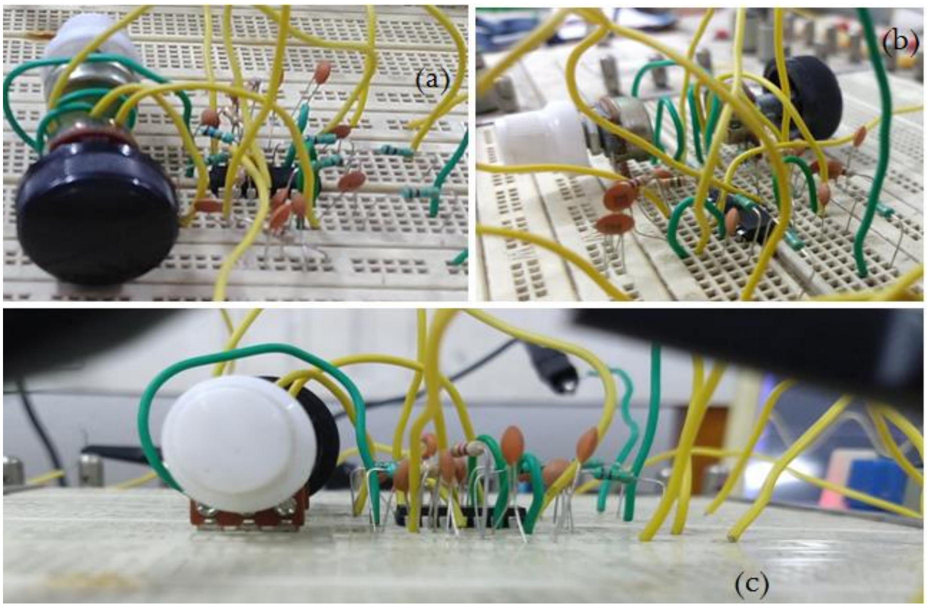
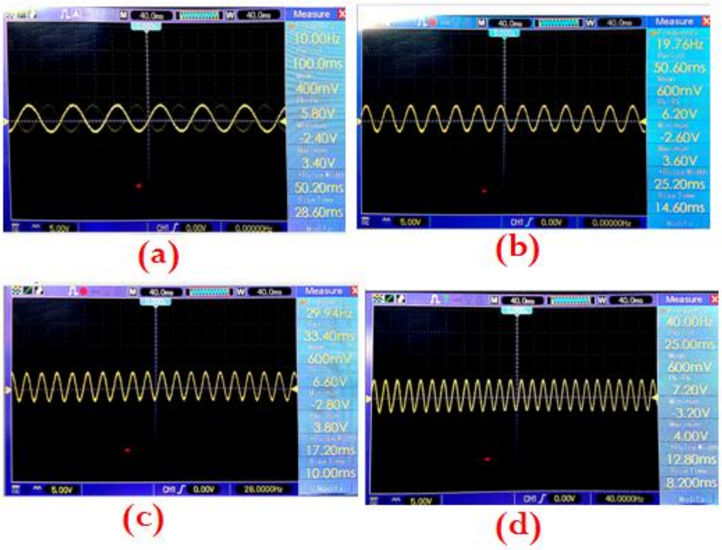


Fig 3. The practical circuit in different views (a)-(c)

III. Results and Discussion

Cathode Ray Oscillator (CRO) has been used for the measurement of output waveforms. The output waveforms of the practical circuit are starting from 10Hz and end at 120Hz when the input amplitude is set at 1Vpp. The readings are taken every 10 times of frequency. Output waveforms are shown in Figure 4 (a-l) with different filtering frequencies, starting from 10 Hz to 120 Hz, with an increment of 10 Hz.



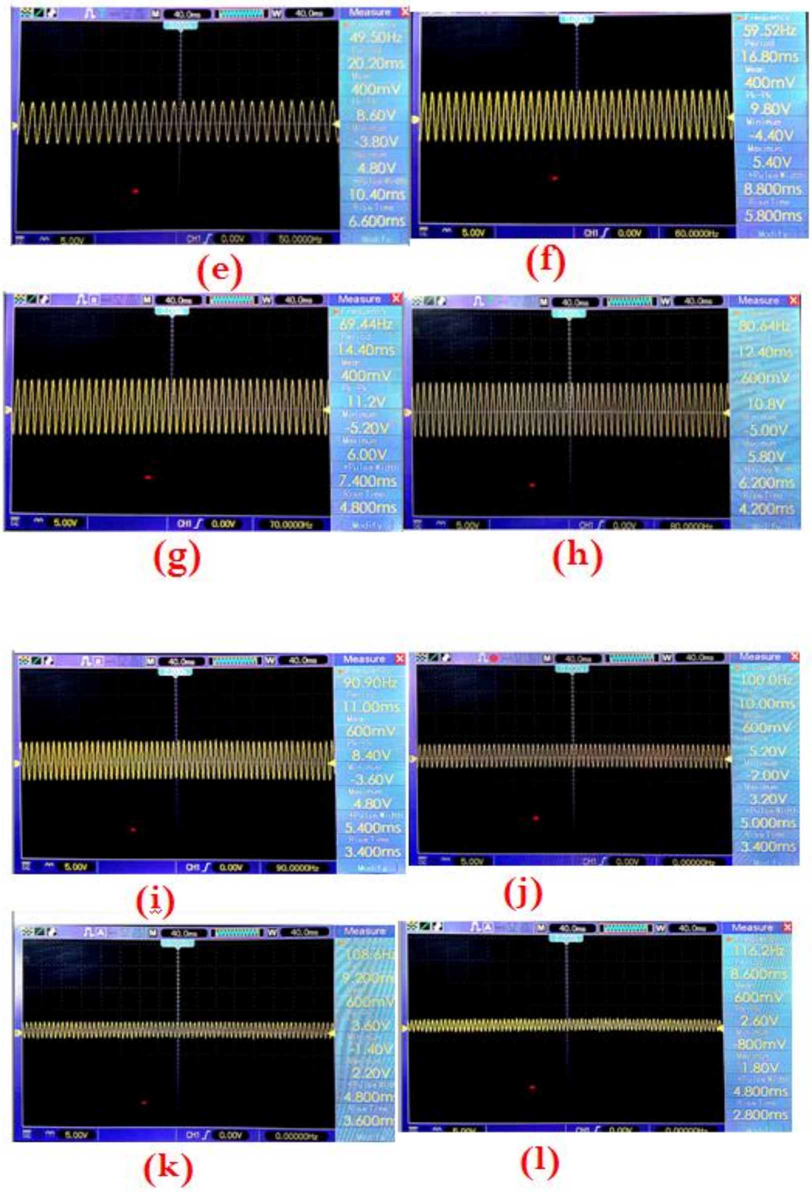


Fig 4. (a-l): Output waveforms for the frequency range from 10 Hz to 120Hz.

We have used a variable resistor (potentiometer), which is present at the conventional 2nd Order active low pass filter between one of the passive RC low pass filters. This variable resistor is varied to change the damping factor of this filter when set at a certain frequency. Here we have taken two frequency readings; 10Hz and 70Hz with an input amplitude of 1Vpp; at each frequency, the damping factor(zeta) is set to a minimum by varying the variable resistor and plotted the frequency-gain response on X-coordinate and Y-coordinate respectively. Figures 5 and 6 show the frequency responses below 10 Hz and 70 Hz respectively.

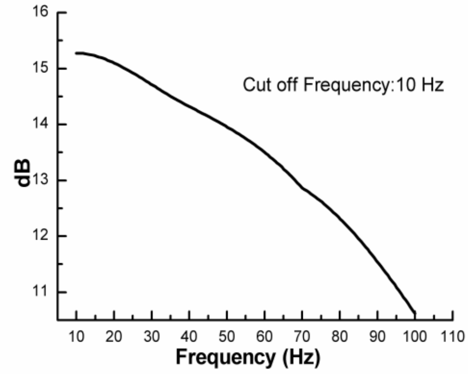


Fig.5. Frequency response for below 10 Hz

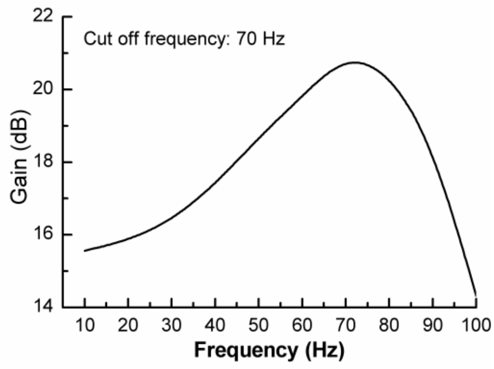


Fig. 6. Frequency response at 70 Hz

IV. Conclusions

The proposed circuit can detect low frequencies, which are related to the human body and generated by the human organs. So this circuit could be used to monitor a patient's health condition by comparing the physician's real-time data on their health parameters.

Conflict of Interest:

There was no relevant conflict of interest regarding this paper.

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