Design and optimization of MIMO Universal Filter using current conveyor

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***Abstract*— With the progression of technology, current model-based circuits escalated massively. Here in this paper, a new voltage mode-based circuit layout of universal filter using current conveyor is presented. The configuration that has been put forward uses six resistors, six capacitors and two current conveyors. The proposed circuit realizes low pass (LP), high pass (HP) and band pass (BP) filter function while taking different input and output port combinations. Additionally, the tunability for Low Pass filter and Band Pass Filter is also performed while changing the resistance of the circuit which further affects the gain of the circuit. The response for the proposed design is simulated in PSPICE.**

***Keywords*— Current Conveyor, Low Pass Filter, High Pass Filter, Band Pass Filter, Universal filter.**

I. Introduction

In a circuit where the transmission of information is constituted by a current signal is referred as a current mode circuit. In recent times, analogue based signal processing considering current mode prospect is scalable because of its superior functionality when compared with voltage mode prospect [1]. With the expansion of science and technology, a large number of signals needs to be treated while the signal frequency is also getting elevated, henceforth because of the limitations of conversion rate and dynamic range there is a great restriction of the frequency of voltage mode devices [2].

When current is considered as the information transporter, there isn't a necessity for the exchange of current and voltage, resulting in the reduction of number of components and uncomplicating the circuit configuration [3]. Stating the known fact about active elements i.e., it offers higher bandwidth and vast dynamic range when it is treated as a current mode circuit [4].

The proposed layout showcases circuit design of a filter. Filter is a significant element or an integral component when we talk about communication systems [8]. The importance of filters can be manifested by many real-life applications, for example speech signals [9], image coding [10] and frequency-domain speech scramblers [11].

An essential element came into existence on account of researchers' countless efforts in 1968 as the accomplishment of Smith and Sedra resulted in the creation of current based device namely Current Conveyor (CC) [5]. A CC is very advantageous active device, a circuit with CC- construct is acceptable for high frequency functioning [6]. There are many kinds on CC's which includes second generation Current Conveyor (CCII), third generation Current Conveyor (CCIII), etc.

In the design that has been presented, two second generation Current Conveyors (CCII) are used wherein one of the Current Conveyors is used only for plus type and the other is used as both plus and minus type of CC. CCIIs are especially known for its wide variety of applications which includes larger signal bandwidth, higher linearity and greater dynamic range when compared with OP-AMP based circuits [6]. Other than these there are a few more advantages which include high slew rate, high transit frequency, etc [7]. Using the design, simulation has been performed on PSPICE which possess functionality for different filters namely low pass (LP), high pass (HP) and band pass (BP) when configured for different input and output port combinations.

The manuscript is structured as follows, the characteristics and block diagram were presented and explained in Section II. The design of the proposed structure with IO port combinations were explained in Section III. Section IV deals with the PSPICE simulations of the proposed circuit and a clear emphasis with tunability of low pass and band pass filters are discussed in Section V. In Section VI, a clear conclusion is drawn with results and discussion presented.

II. CURRENT CONVEYOR

The representation of a Current Conveyor can be exhibited via block diagram that has been shown in figure 1:

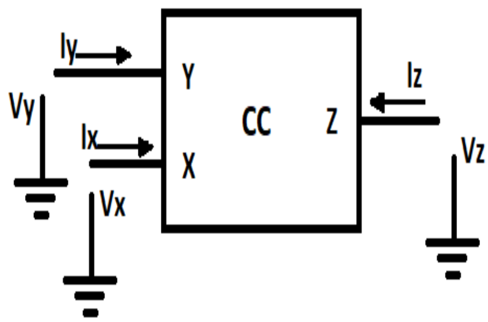

Fig 1. Block diagram of Current Conveyor

Here, there are three terminals namely X, Y and Z where X and Y are the input terminals and Z is the output terminal. The input output functionality of a CC can be described by a characteristic equation shown in figure 2:

$$\begin{bmatrix} Iy \\ Vx \\ Iz \end{bmatrix} = \begin{bmatrix} 0 & a & 0 \\ b & 0 & 0 \\ 0 & c & 0 \end{bmatrix} \begin{bmatrix} Vy \\ Ix \\ Vz \end{bmatrix}$$

Fig 2. Characteristic equation of Current Conveyor

Since the configuration that has been presented consists of CCII, the values for a, b and c in the characteristic equation are unique. For plus type Current Conveyor (CCII+), the values are given as a= 0, b= 1 and c= 1, while for minus type Current Conveyor (CCII-), the values are given as a= 0, b= 1 and c= -1.

III.PROPOSED CIRCUIT DESIGN

A fresh layout of circuit technology is presented which realizes different filters i.e., low pass (LP), high pass (HP) and band pass (BP) for different configurations of input and output ports. The structure of the circuit is shown in figure 3:

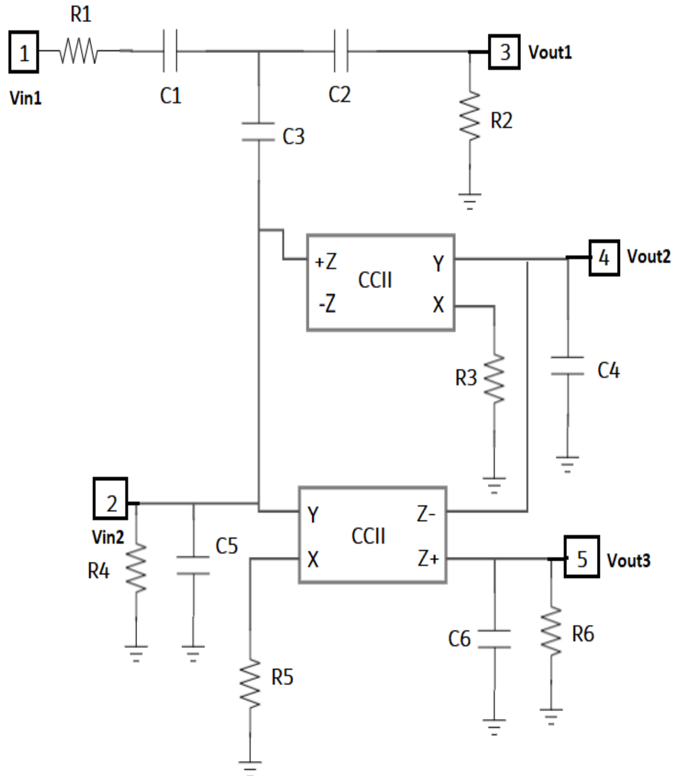

Fig 3. Proposed Circuit of Universal Filter

For PSPICE simulation, the values of resistors are given as R1= 10kΩ, R2= 10kΩ, R3= 10kΩ, R4= 2kΩ, R5= 10kΩ, R6= 10kΩ and the values of capacitors are given as C1= 1.56nF, C2= 1.56nF, C3= 1.60nF, C4= 0.47nF, C5= 1nF, C6= 1nF.

For simulation, the AC sweep analysis is done with the start frequency set to 10Hz and end frequency to 1MHz.

A. *Low Pass Filter*

For obtaining the accurate results of a low pass filter, port number two is considered as the input port and port five is considered as the output port. Port 1 is grounded and port 3 and 4 are floating.

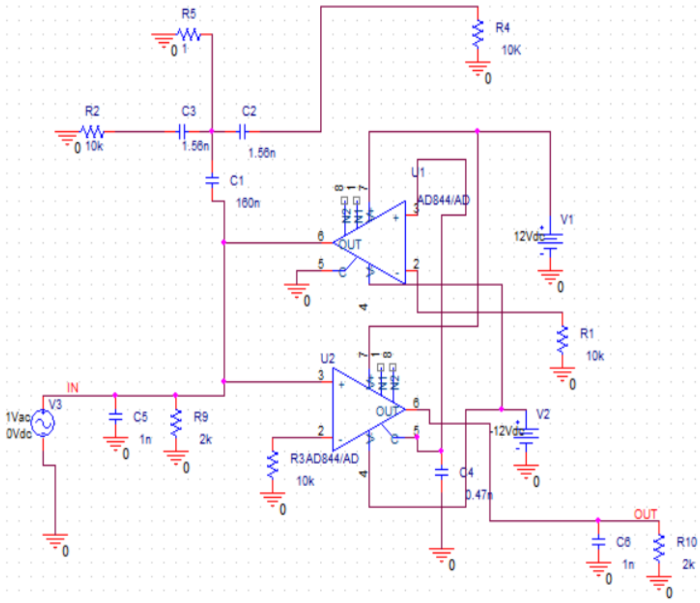

Fig 4. Circuit Design of Low Pass Filter in PSPICE

B. *High Pass Filter*

For obtaining the accurate results of a high pass filter, port number one is considered as the input port and port three is considered as the output port. Port 2, 4 and 5 are floating.

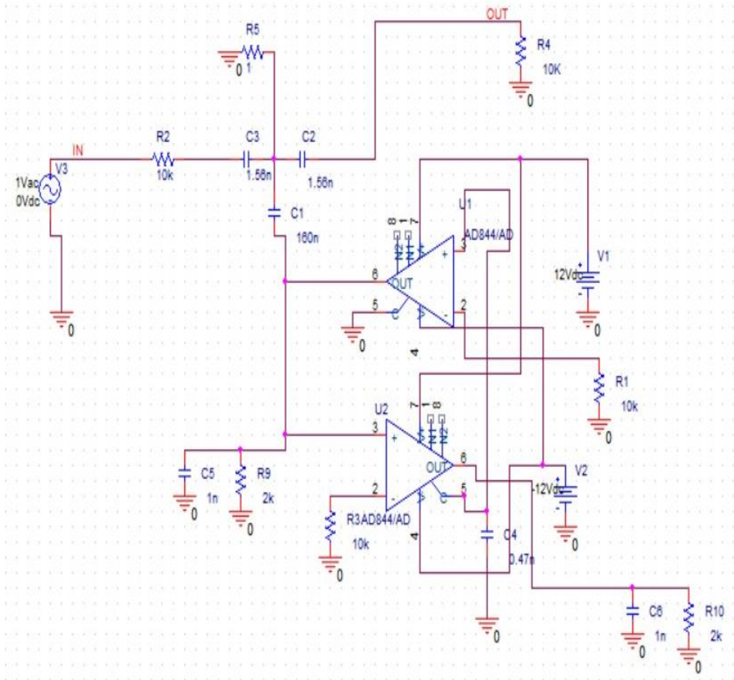

Fig 5. Circuit Design of High Pass Filter in PSPICE

C. Band Pass Filter

For obtaining the accurate results of a band pass filter, port number one is considered as the input port and port four is considered as the output port. Port 2, 3 and 5 are floating.

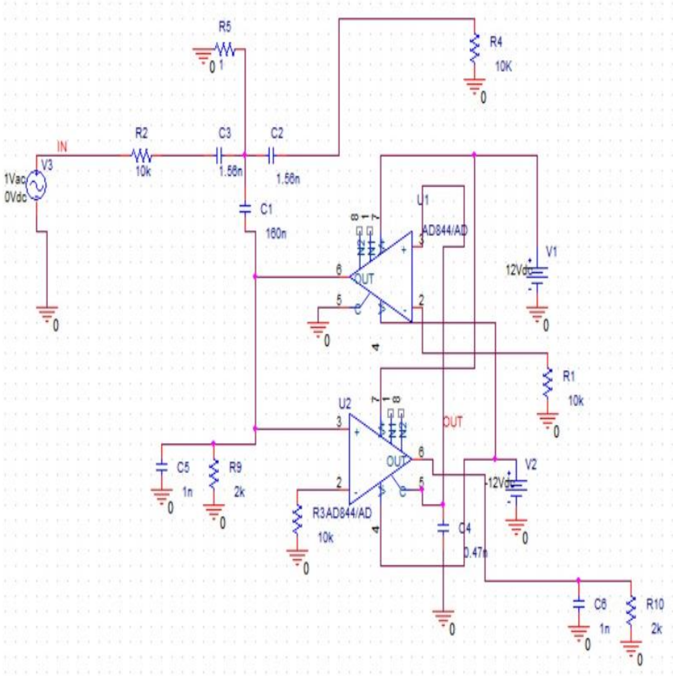

Fig 6. Circuit Design of Band Pass Filter in PSPICE

IV. PSPICE SIMULATIONS

To examine the functionality of the voltage mode-based circuit design that has been presented, PSPICE is used for the simulation or realization for the same. Responses of each filter i.e., low pass (LP), high pass (HP) and band pass (BP) are shown in the figures. In each of these figures X-axis represents the frequency and Y-axis represents the gain.

A. *Low Pass Filter*

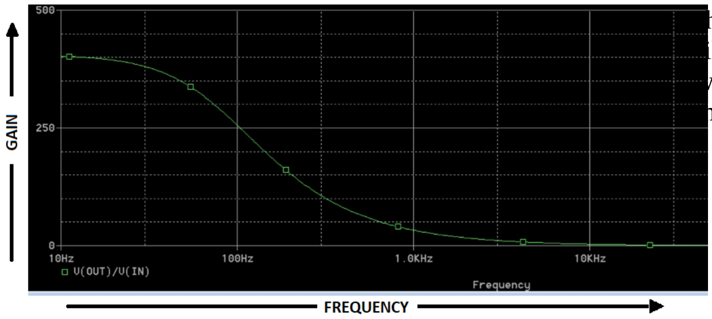

Fig 7. Simulated Frequency Response of Low Pass Filter

From figure 7, we can see that the simulation of the filter showcases the characteristics similar to that of a low pass filter wherein only lower frequencies are passed while stopping the higher frequencies and hence we can say that the results are verified.

B. *High Pass Filter*

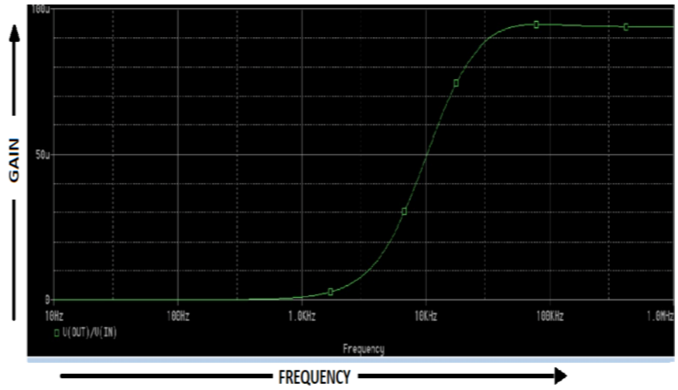

Fig 8. Simulated Frequency Response of High Pass Filter

From figure 8, we can see that the simulation of the filter showcases the characteristics similar to that of a high pass filter wherein only higher frequencies are passed through while stopping the lower frequencies and hence we can say that the results are verified.

C. *Band Pass Filter*

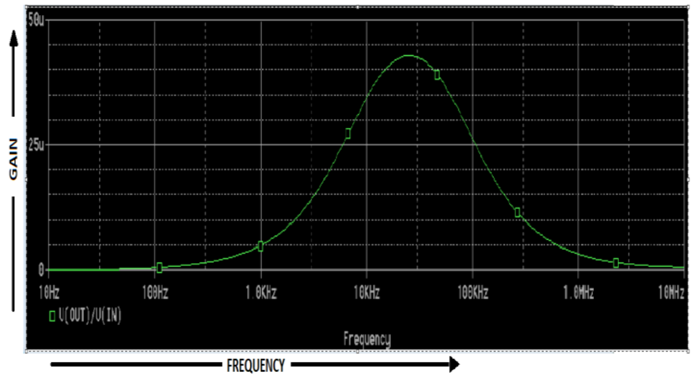

Fig 9. Simulated Frequency Response of Band Pass Filter

From figure 9, we can see that the simulation of the filter howcases the characteristics similar to that of a band pass lter wherein only a particular band of frequencies are passed hile stopping all other frequencies and hence we can say that he results are verified.

V. TUNABILITY OF CIRCUIT

The proposed layout of the circuit design as a filter (figure 3) is capable of tunability when we consider low pass filter and the band pass filter. Here, value of R5 in the proposed circuit is changed which will affect the gain. The change in value of resistance R5 in the proposed circuit changes the gain inversely.

Here, the value of R5 is changed from 10kΩ to 20kΩ, while keeping the input and output port combination same i.e., port 2 as input port and port 5 as output port. Circuit with changed value of R5 is given in the following figures.

A. *Low pass filter*

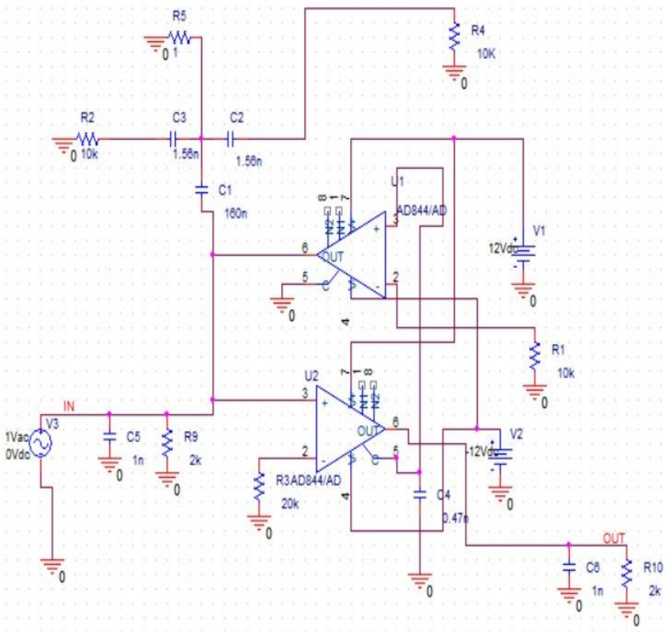

Fig 10. Proposed Circuit with increased value of R5 to 20KΩ for low pass filter

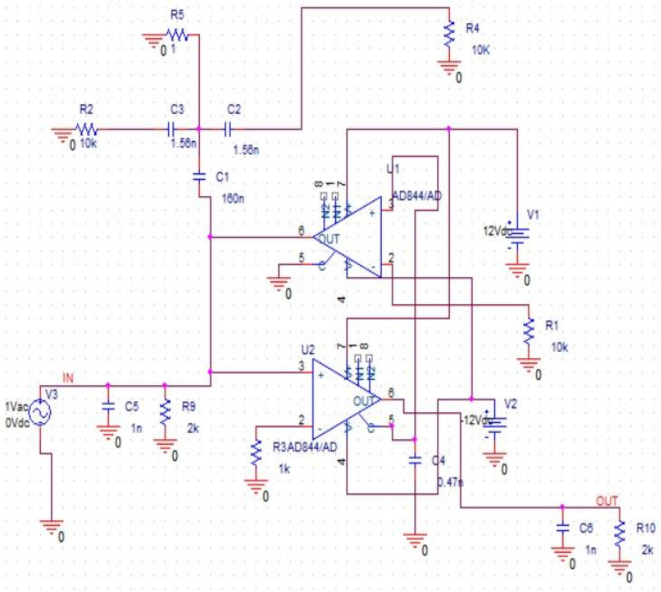

Fig 12. Proposed Circuit with decreased value of R5 to 1KΩ for low pass filter

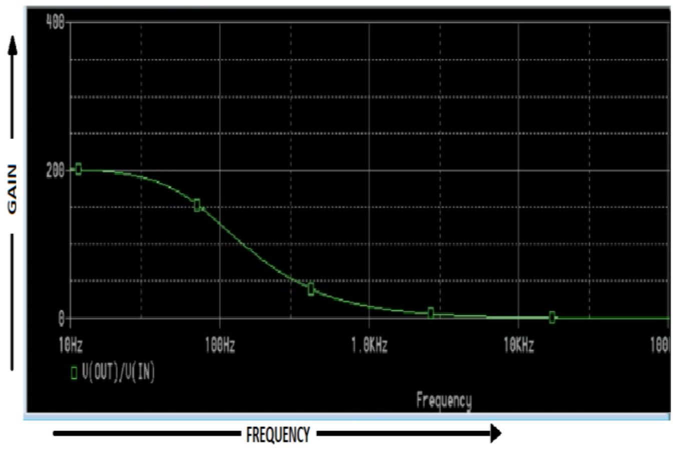

Fig 11. Simulated frequency response of Low Pass filter for Increased value of R5

Observing the simulation, after increasing the value of R5, the gain of the signal is decreased.

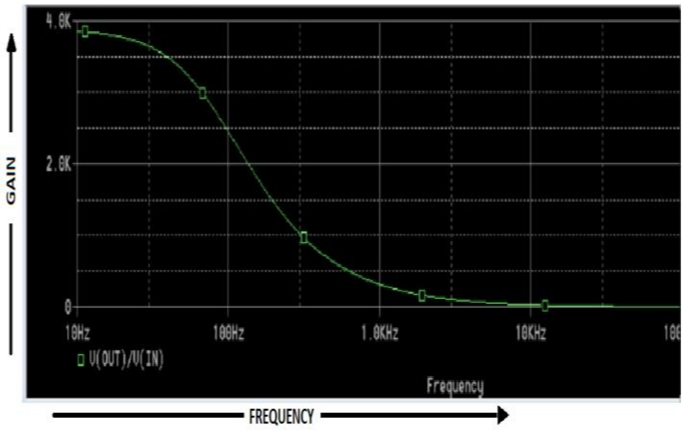

Fig 13. Simulated frequency response of Low Pass filter for decreased value of R5

Observing the simulation, after decreasing the value of R5, the gain of the signal is increased.

B. *Band pass filter*

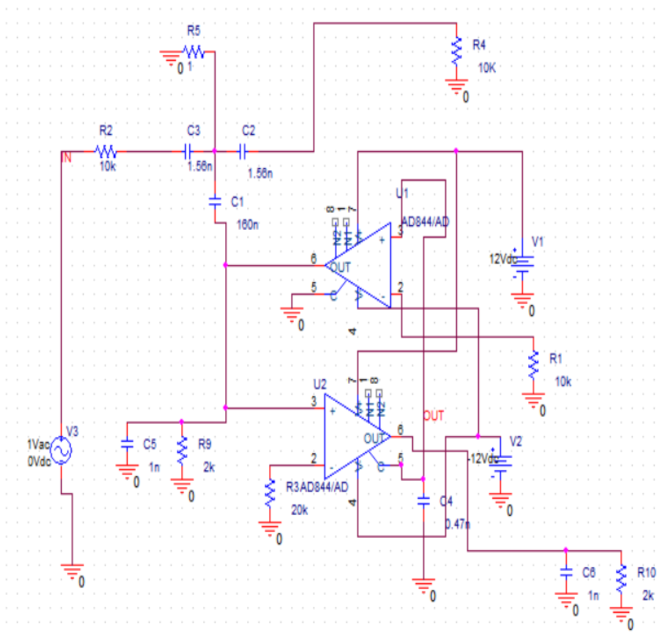

Fig 14. Proposed Circuit with increased value of R5 to 20KΩ for Band pass filter

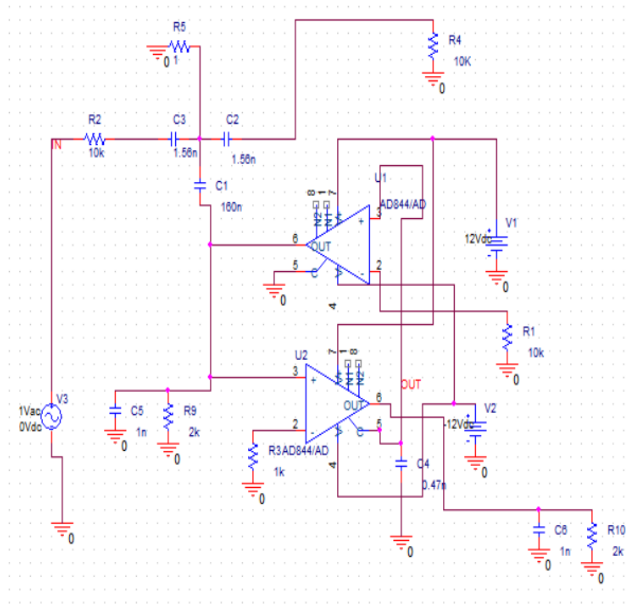

Fig 16. Proposed Circuit with decreased value of R5 to 1KΩ for Band pass filter

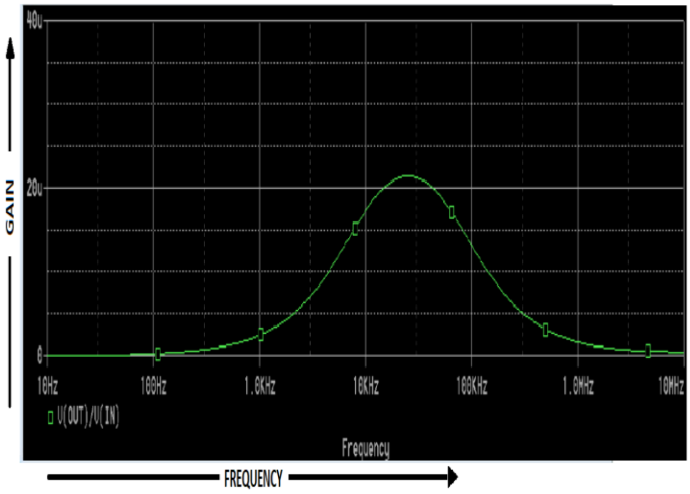

Fig 15. Simulated frequency response of Band Pass filter for Increased value of R5

Observing the simulation, after increasing the value of R5, the gain of the signal is decreased.

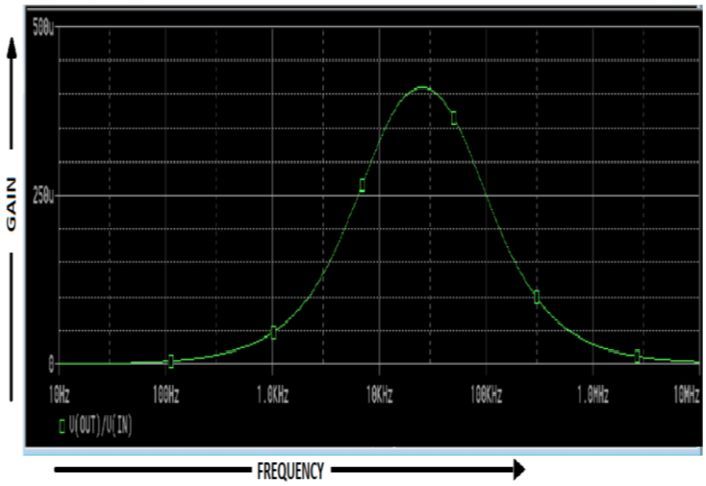

Fig 17. Simulated frequency response of Band Pass filter for decreased value of R5

Observing the simulation, after decreasing the value of R5, the gain of the signal is increased.

VI. CONCLUSIONS

The current mode-based circuit design that has been put forward is the extensive implementation of a universal filter using second generation Current Conveyor (CCII). The verification of the circuit design is done via PSPICE simulation which realizes responses for low pass (LP), high pass (HP) and band pass (BP) filters. In addition, the tunability of Low pass (LP) and High Pass (HP) filter is also performed, where total power dissipation of the circuit is also analyzed with respect to the change in resistance and gain. Moreover, the presented circuit is a simple structure or layout whose passive components are grounded and therefore suitable and accurate for integration.

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