Realization of Universal Filter Using CCII

Md. Shahbaz Alam, Amit Agrawal, Kulwant Singh, and Ashish Shrivastava

Abstract During the last couple of decades, the trends of current mode approach have followed in the modern applications of analog signal processing, where the electric current is used to represent the information signals. Current conveyors are among the main building block used in current mode circuits. In this chapter, a comparative study of the realization of Universal filters using the realizations of the second generation current conveyor in current as well as voltage modes are presented. As compared to the conventional operational amplifiers, the current conveyor circuit provides high frequency range of operation. Two circuit configurations, current mode having two CCII+ and voltage mode having three CCII+, have been chosen to design Universal filters (LPF, BPF, and HPF). A comparison has been done in respect of input range, bias voltage, and cutoff frequency. PSPICE results of time response and frequency response of all the circuits have been presented.

Keywords Current conveyor · Universal filter · Translinear CCII+

1 Introduction

In this paper, a comparative study of biquad realizations using different realizations of the second generation current conveyor is presented. As compared to the conventional operational amplifiers, the current conveyor circuit provides high frequency range of operation [1–3]. Two circuit configurations have been chosen. One of the

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configurations belongs to the one input many output type filter category while the other configuration belongs to the many input and many output category. The first Universal filter circuit is having two CCII+ in current mode, and the second circuit is in voltage mode filter having three CCII+s. Both the filters have been simulated with all the realization of the current conveyors presented in below, and a comparison has been done in respect of input range, bias voltage, and cutoff frequency. PSPICE results of time response and frequency response of all the circuits have been presented. The simulation results of various active filters, low pass filter, band pass filter, and high pass filter, in current as well as voltage mode have given below.

2 Introduction to Current Conveyor (CCII)

Current conveyors are the most important building blocks in the field of analog signal processing in current mode as well as in voltage mode, but the current mode current conveyor circuits are widely used due to better performance and better results. In the most fundamental form, the CCII that is second generation of current conveyors are widely used. It is a four terminal device, these terminals are *x*, *y*, *z,* and ground. The *x* is an input terminal having low input impedance, *y* is also an input terminal having high input impedance, on the other hand *z* is an output terminal having high output impedance, and the fourth one grounded. It can perform many useful functions of analog signal processing when they are arranged in particular circuitry with other passive components [4–6]. In CCII, no current flows through terminal *Y*, in order to increase the flexibility of current conveyors. The ideal CCII appeared as an ideal transistor, with the perfect characteristics [1–3]. At the gate or base, no current flows through them, which is represented by terminal *Y*. The emitter or source voltage (appeared at terminal *X*) follows the voltage at terminal *Y*, as there was no base-emitter or gate-source voltage drop. There is infinite input impedance at gate or base (terminal *Y*); whereas, the emitter or source (*X*) has zero input impedance. The current that comes out of the emitter or source (terminal *X*) that reflects as a current in at the collector or drain (*Z*), but with an infinite output impedance (Fig. 1).

The CCII can be expressed as a matrix as shown in Fig. 2 (Table 1):

Fig. 1 Circuit symbol of CCII

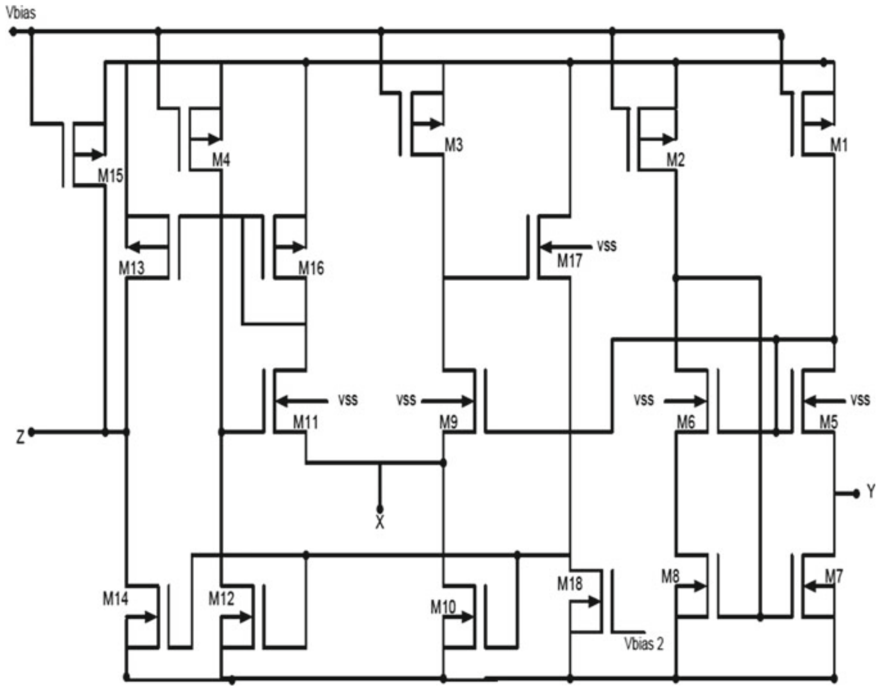

Fig. 2 CMOS realization of CCII

Table 1 Aspect ratio for the CCII+ in transistor mode

Transistors	W (um)	L (um)
All pMOS	100	0.5
All nMOS	50	0.5

$$\begin{bmatrix} I_Y \\ V_X \\ I_Z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} V_Y \\ I_X \\ V_Z \end{bmatrix}$$

CCII+ that is shown in Fig. 2 uses 0.5 µm CMOS technology. When we apply the input at Y terminal, i.e., $V_{Y,}$ and then we check the voltage at X terminal, i.e., V_X, the relationship between X and Y is shown in Figs. 3, 4, 5, and 6.

3 Filter Designing Using CCII

In this paper, a comparative study of biquad realizations using different realizations of the second generation current conveyor is presented. The current conveyor circuit

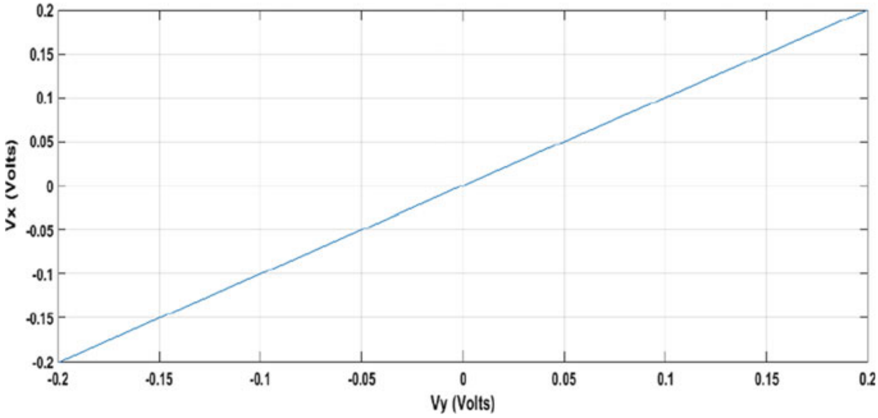

Fig. 3 Port relationship between V_X and V_Y when we applied input DC sweep at Y terminal

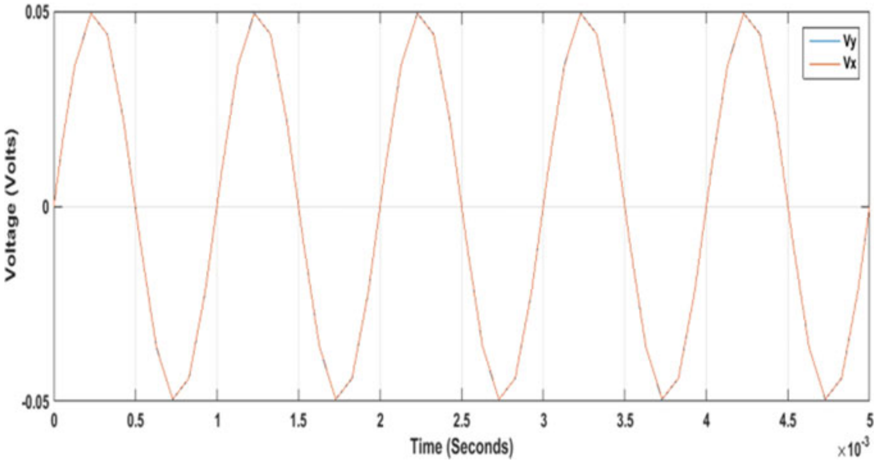

Fig. 4 Port relationship between V_X and V_Y when we applied sinusoidal input voltage at Y terminal

provides high frequency range of operation as compared to conventional operational amplifiers. Two circuit configurations have been chosen. One of the configurations belongs to the single input multiple output type filter category while the other configuration belongs to the multiple input and multiple output category. The first circuit is a current mode universal filter using two CCII+ and the second circuit is a voltage mode filter using three CCII+s. Both the filters have been simulated with the realization of the current conveyor presented above, and a comparison has been done in respect of input range, bias voltage, and cutoff frequency. PSPICE results of time response and frequency response of all the circuits have been presented.

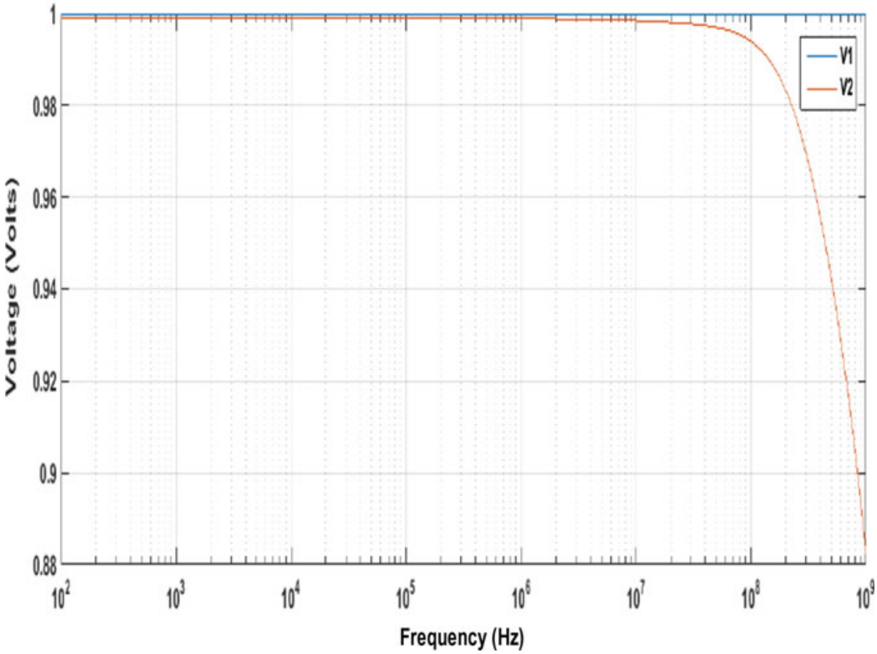

Fig. 5 Port relationship between V_X and V_Y when we applied AC input voltage at Y terminal

3.1 Current Mode Universal Filter

The Circuit shown in Fig. 7 represents the current mode Universal filter using two CCII+.

It may be noted that the three output currents are flowing through grounded elements and additional current followers will be required to drive the loads. The various transfer functions are as given below

$$T_1(s) = \frac{I_{out1}(s)}{I_{in}(s)} = -\frac{1}{R_1R_2C_1C_2s^2 + R_2C_2s + 1} \tag{1}$$

$$T_2(s) = \frac{I_{out2}(s)}{I_{in}(s)} = -\frac{R_2C_2s}{R_1R_2C_1C_2s^2 + R_2C_2s + 1} \tag{2}$$

$$T_3(s) = \frac{I_{out3}(s)}{I_{in}(s)} = \frac{R_1R_2C_1C_2s^2}{R_1R_2C_1C_2s^2 + R_2C_2s + 1} \tag{3}$$

The three transfer functions are, respectively, of low pass filter ($T_1(s)$), band pass filter ($T_2(s)$), and high pass filter ($T_3(s)$) with unity gain. The above universal filter is designed using translinear implementation of CCII+, CCII+ using flipped voltage follower, and CCII+ using AD844. Designed for $f_o = 50$ kHz and $Q = 0.707$, with

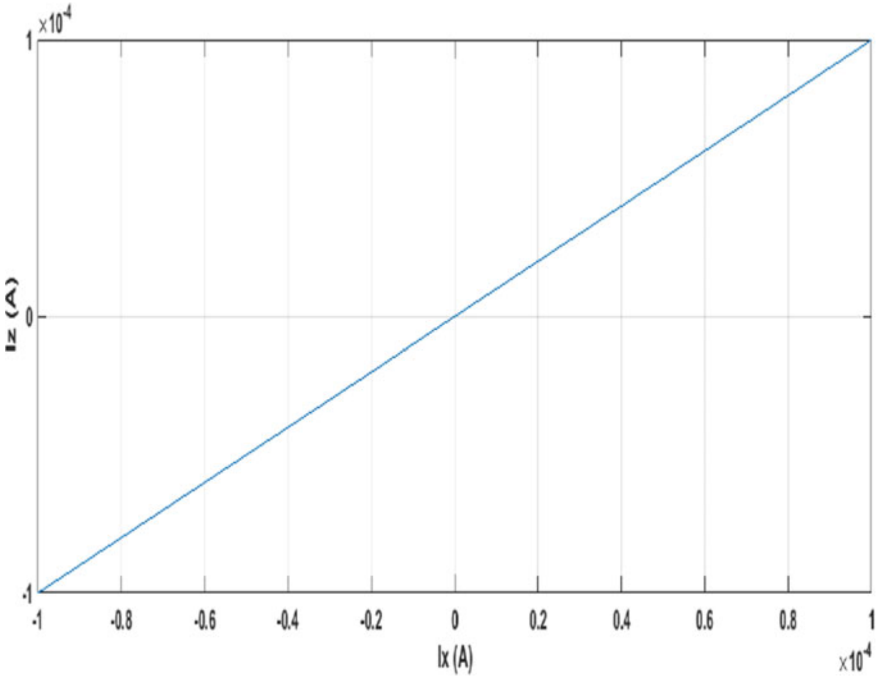

Fig. 6 Port relationship between I_X and I_Z when we applied input DC sweep at X terminal

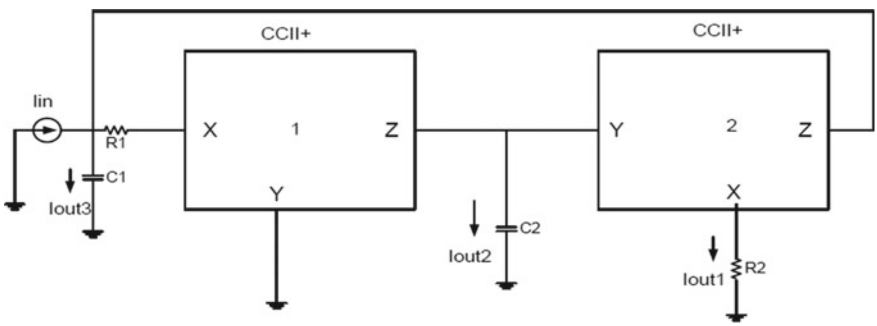

Fig. 7 Current mode universal filter

$R_1 = 10\ \text{k}\Omega$, $R_2 = 20\ \text{k}\Omega$, and $C_1 = C_2 = 0.225$ nF (Figs. 8, 9, 10, 11, 12, 13, 14, and 15).

From the responses, we have analyzed the highest frequency, lowest supply voltage, and lowest input current for low pass filter, band pass filter, and high pass filter. Table 2 summarizes these comparisons for the LP, BP, and HP filters.

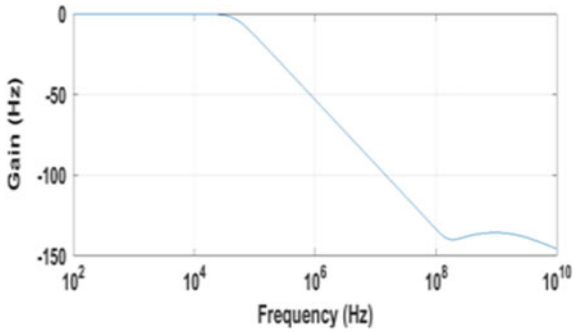

Fig. 8 Low pass filter response with a cutoff frequency of 46.43 kHz

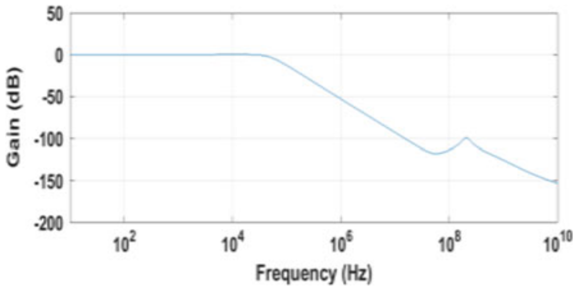

Fig. 9 LPF response with a cutoff frequency of 49 kHz

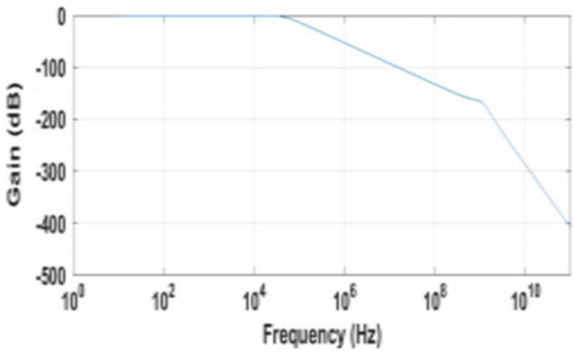

Fig. 10 LPF filter response using cutoff frequency 48.4 kHz

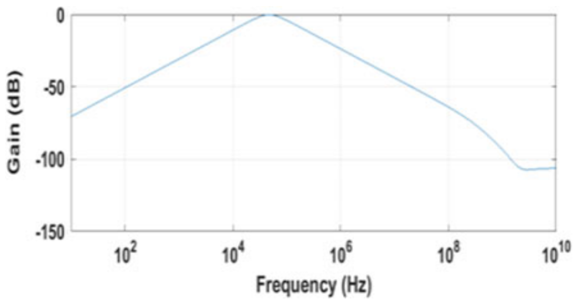

Fig. 11 BPF response using cutoff frequency 46.32 kHz

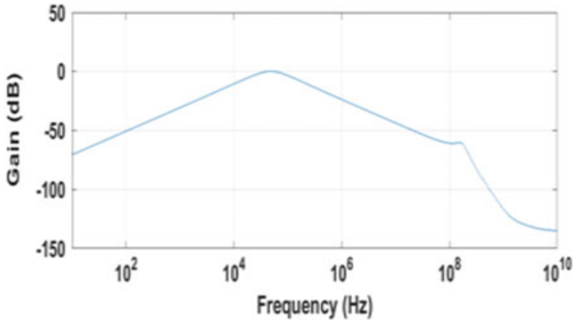

Fig. 12 BPF response with a cutoff frequency of 48.8 kHz

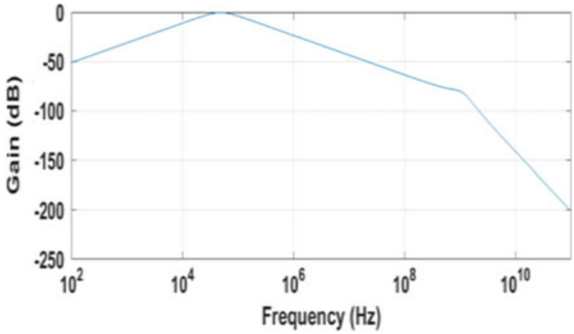

Fig. 13 BPF response with cutoff frequency 50.4 kHz

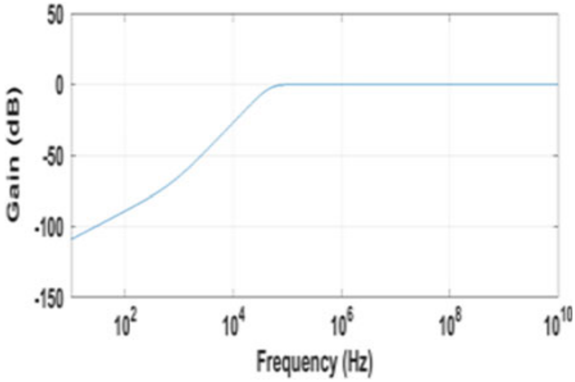

Fig. 14 HPF response with a cutoff frequency of 46.8 kHz

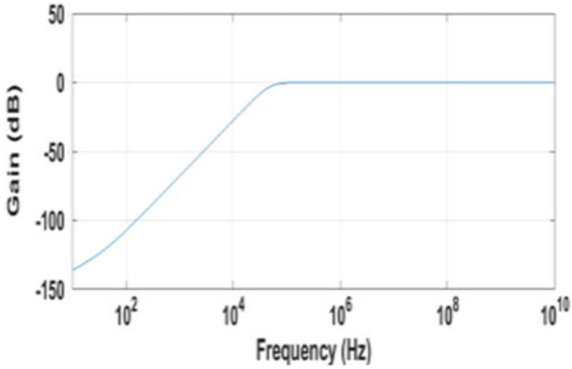

Fig. 15 HPF response with cutoff frequency 47.86 kHz

Table 2 Evaluation of current mode universal filter for LPF, BPF & HPF

Type of filter	Highest frequency (MHz)	Lowest supply voltage (V)	Lowest input current (μA)
LPF	20	±1.2	1
BPF	20	±1.2	0.2
HPF	20	±1.2	0.1

3.2 Voltage Mode Universal Filter

Figure 16 shows a multiple input single output type voltage mode multifunction voltage mode filter and employs three second generation current conveyor [6, 7].

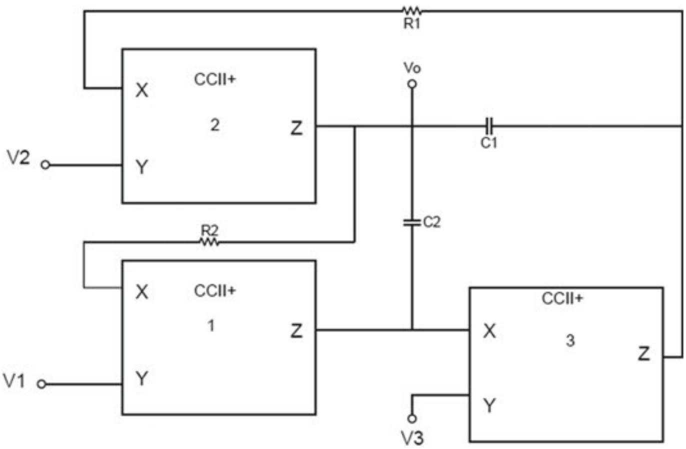

Fig. 16 Voltage mode universal filter

The output voltage V_o can be expressed as

$$V_o = \frac{s^2 C_1 C_2 V_3 + s C_1 G_1 V_2 + G_1 G_2 V_1}{s^2 C_1 C_2 + s C_1 G_1 + G_1 G_2} \quad (4)$$

From Eq. (4), we can see

If V_2 and V_3 are equal (grounded), then second-order LPF can be obtained with the transfer function of V_o/V_1.
If V_1 and V_3 are equal (grounded), then a second-order BPF can be obtained with the transfer function of V_o/V_2.
If V_1 and V_2 are equal (grounded), then a second-order HPF can be obtained with the transfer function of V_o/V_3.

Thus, the circuit is capable of realizing low pass, high pass, and band pass filter.

The transfer functions can realize low pass filter, band pass filter, and high pass filter with unity gain. The above multifunction filter is designed using translinear implementation of CCII+, designed for $f_o = 90$ kHz and $Q = 0.707$, with $R_1 = 20$ kΩ, $R_2 = 40$ kΩ, and $C_1 = C_2 = 0.0625$ nF (Figs. 17, 18, 19, 20, 21, and 22).

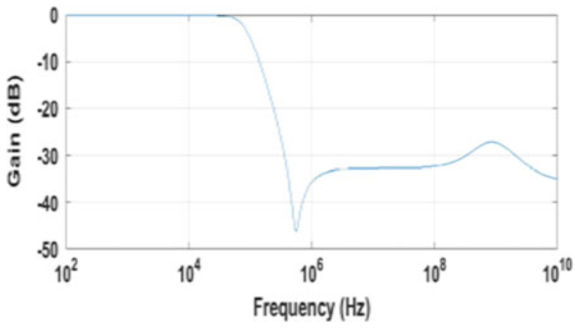

Fig. 17 LPF response with a cutoff frequency of 83.8 kHz

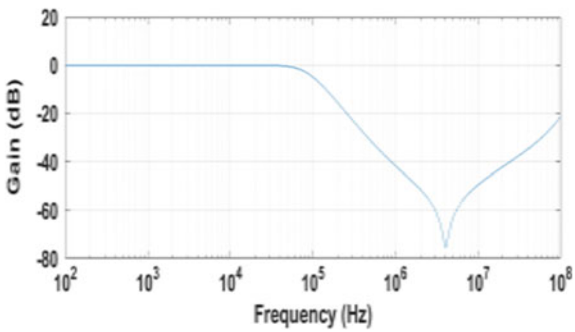

Fig. 18 LPF response with cutoff frequency 82.8 kHz

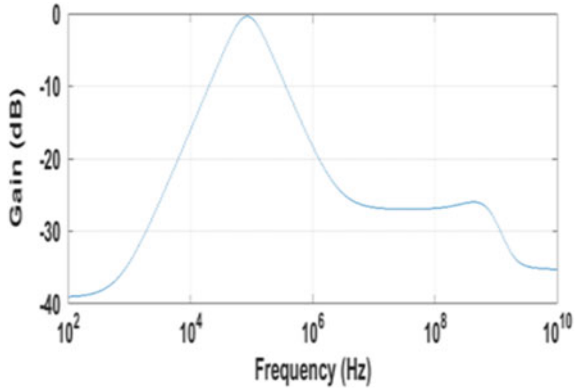

Fig. 19 BPF response with cutoff frequency 85.114 kHz

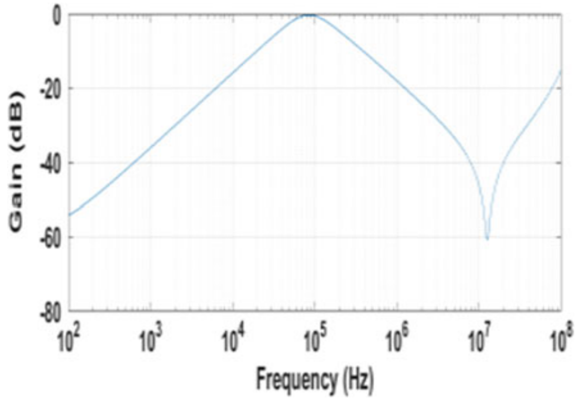

Fig. 20 BPF response with cutoff frequency 85.3 kHz

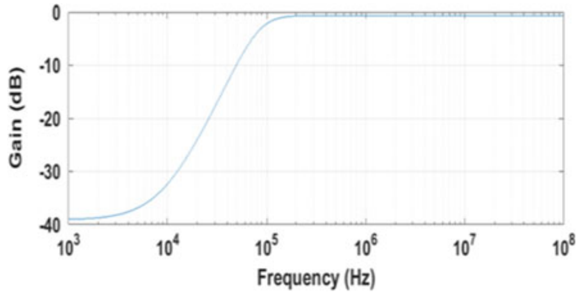

Fig. 21 HPF response with a cutoff frequency of 82.34 kHz

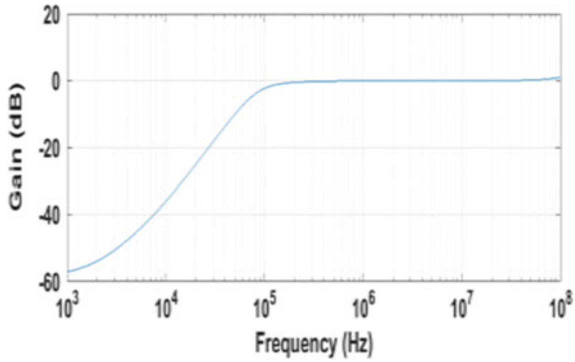

Fig. 22 HPF response with cutoff frequency of 89 kHz

Table 3 Evaluation of voltage mode universal filter for LPF, BPF & HPF

Type of filter	Highest frequency (MHz)	Lowest supply voltage (V)	Lowest input voltage (mV)
LPF	10	±0.5	10
BPF	10	±0.5	15
HPF	10	±0.5	10

From the responses, we have analyzed the highest frequency, lowest supply voltage, and lowest input voltage for low pass filter, band pass filter, and high pass filter, and the results are summarized (Table 3).

4 Conclusion

In this paper, we have carried out a comparative study of different realizations of one current mode and one voltage mode universal filter circuit in respect of input current/voltage range, cutoff frequency, bias voltages. We have used the implementations of the translinear loops and the bipolar current conveyor available in the form of second generation current conveyor (CCII). The cutoff frequency of LPF in current mode realization is lower than that of voltage mode. In current mode, lowest input current is for HPF and highest input current is for LPF, on the other hand, lowest input voltage in voltage mode is for LPF and HPF and highest input voltage is for BPF.

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