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Minimum component current-mode universal filter

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A novel current-mode (CM) universal filter based on and employing only one second generation current conveyor (CCII+), two operational transconductance amplifiers (OTAs), and three grounded capacitors is presented. The grounded capacitor configuration of the proposed circuit is beneficial to an integrated circuit (IC) implementation. Three types of current-transfers lowpass (LP), highpass (HP), and bandpass (BP) can be achieved simultaneously while other filtering responses allpass (AP) and notch can be obtained by summing the appropriate node currents without any change to be induced in the filter structure and/or employment of additional components. The transconductance gains of OTAs are used to tune the filter characteristics electronically in an orthogonal manner. The structure is devoid of resistors and enjoys low sensitivity performance. The experimental results are included.

[Keywords: Current-mode universal filter; trensconductance amplifiers**]**
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There is overwhelming interest in the design of current-mode filters as these circuits offer certain distinct advantages such as simpler filter architecture, wider dynamic range, and higher frequency operations over their voltage-mode counterparts[1-3]. The circuit designers have evinced considerable interest in the development of current-mode analogue filtering circuits employing concurrently OTAs and CCIIs as both provide output current at high impedances thereby lending the circuit feature of cascadibility to realize higher order filters[1]. OTA is a differential voltage controlled current source (DVCCS) and is characterized by;

$$I_O = g\,(V^+ - V^-)$$

where the transconductance gain $g = I_{bias}/2V_T$ is linearly tunable over several decades through the bias current I_{bias}. In actual circuit implementation the preference is given to the use of multiple output operational transconductance amplifiers (MO-OTAs) viz-a-viz a single output OTAs as the former building block has the capability of easing current signal processing than the latter[4,5]. For the development of complex circuits for current-mode applications, the other standard building[6,7] block is CCII ±,. which is described by the port relations;

$$i_y = 0,\ v_x = v_y,\ \text{and}\ i_z = \pm\, i_x$$

One can see from the preceding equations that the terminal y exhibits an infinite input impedance and the voltage at x follows that applied to y, thus x exhibits a zero input impedance. The current supplied to x is conveyed to the high impedance output terminal z where it is supplied with either positive polarity (CCII+) or negative[8] polarity (CCII-). A critical study of the reported CM circuits reveals that these are (i) component intensive that leads to deterioration in performance due to the parasitic effects and uneconomical configurations[9,10] (ii) amenable to the changes in the circuit topology to implement additional filtering functions[11] (iii) in need of additional components to realize AP and notch filtering signals[12] (iv) using floating passive components[12] (v) having many inputs[13].

Here, we are proposing a novel absolute minimum components current-mode universal architecture capable of implementing three generic filter functions viz. LP, HP, and BP simultaneously while the realization of other two functions namely AP and notch is possible by simply connecting the appropriate output currents and for this purpose there is no requirement for change in the nature of components or additional components or topology. The architecture is such that all the filtering responses are realized without imposing any constraint on the values of passive and active components. The circuit has only one input and three outputs for as many responses, and thus offers saving in the number of terminals which is advantageous from the viewpoint of IC implementation of the circuit. The bandwidth ω_0/Q and cutoff frequency ω_0 are electronically tunable through transconductance gains

of OTAs in sequential fashion. The use of grounded capacitors in the proposed configuration is desirable in contemporary IC design, because the chip area can be used more effectively compared to that of the floating capacitor configuration. The circuit is suitable for integration, cascading and electronic tuning. Since the circuit operates in the current mode, it is superior to that in the voltage mode, particularly in the high frequency range. The active and passive sensitivities of the proposed circuit are very low thereby ensuring the improved performance of the circuit.

Circuit Description – The current transfer functions for LP, HP, and BP responses of the proposed circuit are shown in Fig.1 are as follows:

$$T_{LP} = I_{LI}/I_{IN} = g_1 g_2 / \Delta \quad \ldots(1)$$

$$T_{HP} = I_{HI}/I_{IN} = s^2 C_2 C_3 / \Delta \quad \ldots(2)$$

$$T_{BP} = I_{BP}/I_{IN} = s g_1 C_2 / \Delta \quad \ldots(3)$$

where $\Delta = s^2 C_1 C_2 + s C_2 g_1 + g_1 g_2 \quad \ldots(4)$

The allpass signal is realized by summing I_{HP}, $-I_{BP}$, and I_{LP} and is given by.

$$T_{AP} = (s^2 C_2 C_3 - s g_1 C_2 + g_1 g_2)/\Delta \quad \ldots(5)$$

The notch response is obtainable as follows:

$$T_N = I_{HP} + I_{LP} = (s^2 C_2 C_3 + g_1 g_2)/\Delta \quad \ldots(6)$$

The filtering characteristics are given as;

$$\omega_0/Q = g_1/C_1 \quad \ldots(7)$$

and $\omega_0 = (g_1 g_2/C_1 C_2)^{1/2} \quad \ldots(8)$

Inspection of Eqs. (7) and (8) reveals that ω_0/Q can be adjusted electronically and separated from the tuning of the centre frequency ω_0 through g_1 and ω_0 is controllable through g_2.

Sensitivity

The active and passive sensitivities of the circuit are.

$$S_{g1}^{\omega_0/Q} = -S_{C2}^{\omega_0/Q} = 1.$$

$$S_{g1}^{\omega_0} = S_{g2}^{\omega_0} = -S_{C1}^{\omega_0} = -S_{C2}^{\omega_0} = 0.5$$

which are all small.

Experimental Details – To verify the theoretical prediction of the proposed circuit, the filter prototype has been realized with discrete components. AD844[14] (CCII+) and CA3080[15] type OTAs were selected to demonstrate the characteristics of biquad. The MO-OTA was implemented by connecting single output OTAs in parallel as shown in Fig. 2. The measured LP, HP, and BP responses of the proposed circuit are shown in Fig. 4 with at resonance frequency 15.9 kHz. and Q =1. The transconductance gains selected were $g_1 = g_2 = 1$ ms and $C_1 = C_2 = C_3 = 10$ nF. The measured results agree well with those of the calculated responses but however at higher frequencies the deviation observed is attributed to the presence of capacitor at x-terminal of CCII and non-ideal behaviour of CCII+ and OTAs. Fig. 4.

Conclusion – A new current-mode circuit capable of realizing all the generic filtering functions is proposed. The circuit employs a minimum number of components and facilitates electronic tunability of its characteristics. The circuit does not employ resistors

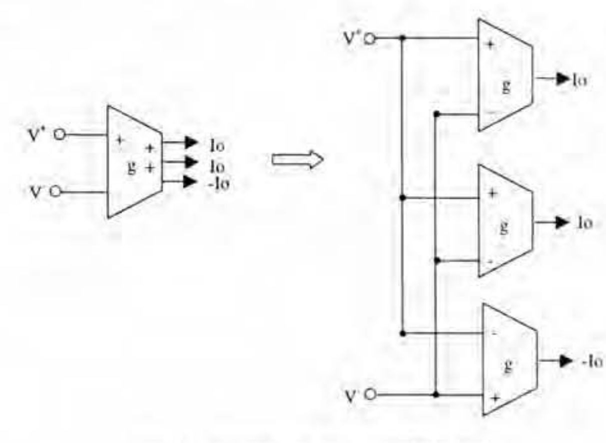

Fig. 2– Implementation of MO-OTA

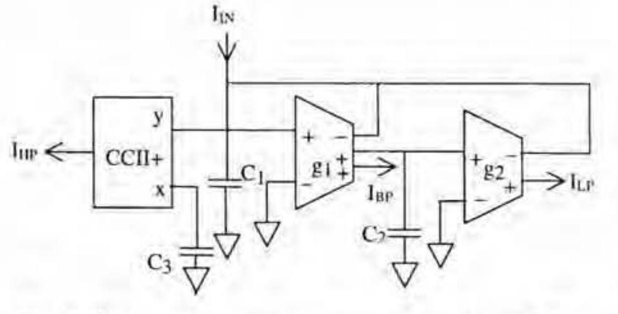

Fig. 1– Minimum component current-mode universal filter

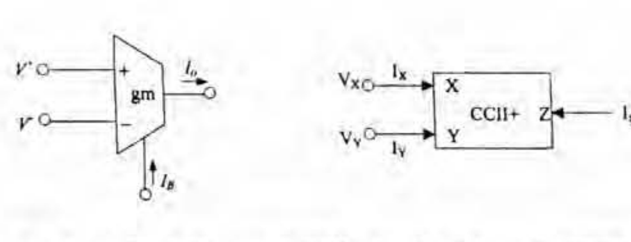

Fig. 3– (a) Block diagram of OTA;. (b) Block diagram of CCII+

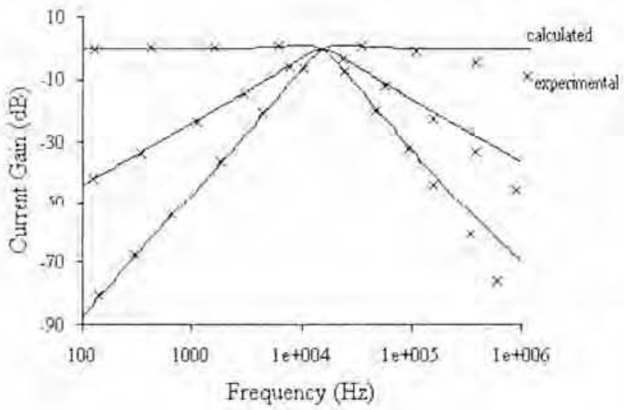

Fig. 4– LP, HP and BP responses

instead uses only grounded capacitors, making it ideal for integration. The circuit has only one input and three outputs and enjoys low sensitivity figures.

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