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Three input and one output voltage-mode universal filter

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A three-input and one output voltage-mode (VM) universal biquadratic filter using a single current-feedback amplifier (CFA), a single operational transconductance amplifier (OTA), a single resistor and two capacitors is presented. The circuit without requiring component matching is capable of realizing from the same configuration all the standard filtering responses viz. lowpass (LP), highpass (HP), bandpass (BP), notch (BR), and allpass (AP). The cut off frequency ω_0 and bandwidth ω_0/Q are independently tuneable. The low sensitivity figures is the additional advantage of the circuit. The circuit has been simulated using personal computer-simulation program with integrated circuit emphasis (PSPICE) and results are found to be in close conformity with theoretical analysis.

[**Keywords**: Circuit design, Voltage-mode universal filter, Universal filter, Continuous-time circuits, Filter configurations, Electronic tunability, Simulation]

1 Introduction

The advantages of having constant bandwidth independent of open-loop gain and the higher slew rate enjoyed by CFA, have attracted the circuit designers to the increasing use of this active block to simulate continuous-time circuits including filtering signals. Also, the feature of electronic tunability enjoyed by the OTA can be exploited to achieve electronic adjustment facility of parameters of interest. The reported circuits using only CFAs have higher component count[1-4], require component-matching conditions[5], need a change in the topology to be induced to realize different filtering functions[6], and are devoid of electronic tunability feature which have overwhelming importance in contemporary integrated circuit (IC) design. Thus, to negotiate most of the advantages offered by IC design techniques, a filter configuration is proposed having three inputs and one output using only one CFA, one OTA, one resistor and two capacitors.

The circuit is capable of implementing all the standard biquadratic filtering signals without requiring change to be induced in the circuit topology, moreover, no component matching conditions are required to be satisfied. The ω_0/Q of the circuit is electronically tunable through the bias current of OTA ($gm = I_B/2V_T$) which is highly desirable in IC technology while independent adjustment of ω_0 can be achieved through R_1. The circuit enjoys low active and passive sensitivity figures.

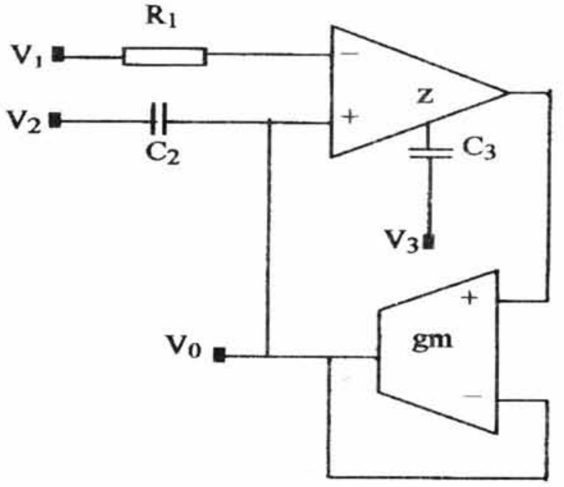

Fig. 1 — Voltage-mode universal filter

2 Circuit Analysis and Description

The configuration of the proposed filter is shown in Fig. 1. The CFA and the OTA are respectively characterised by the port relations $I_y=0$, $I_x=\pm I_Z, V_X=V_Y$ and $V_Z=V_O$ and $I_o=(V^+-V)g_m$. A routine analysis of the circuit yields the following equation:

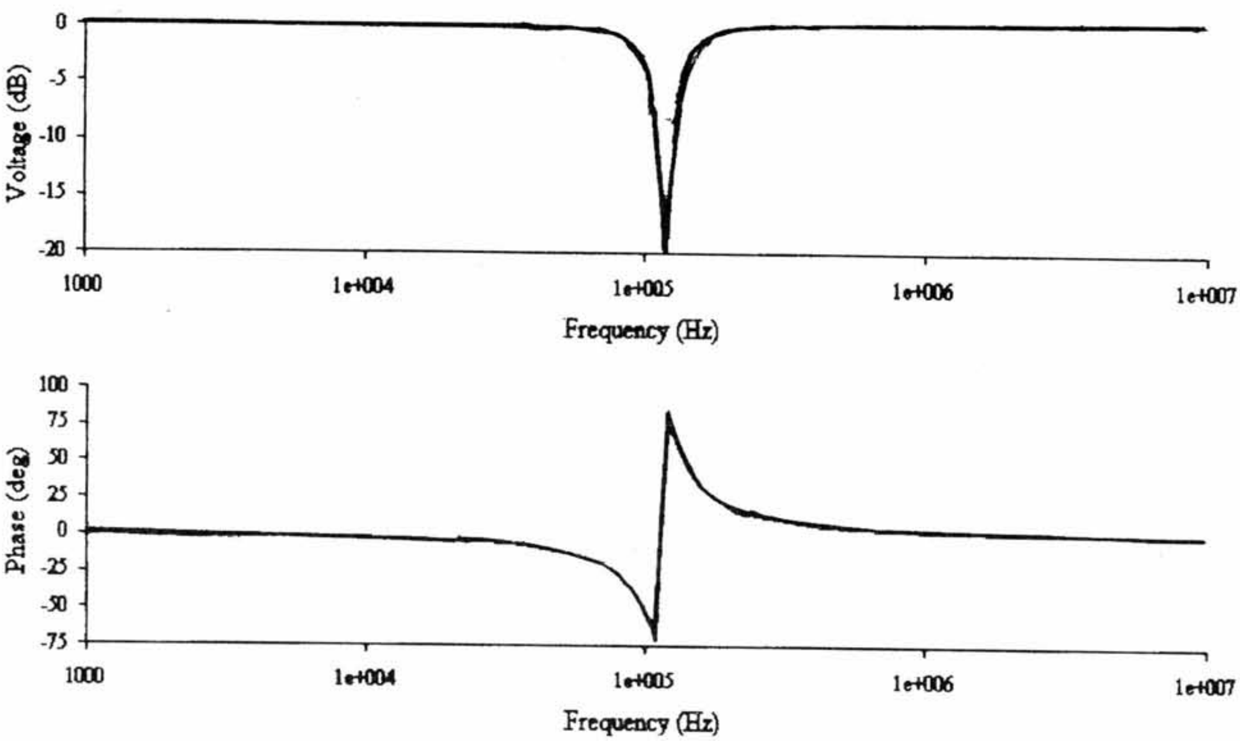

Fig. 2 — Notch response

$$V_O=(V_2s^2C_2C_3+V_3sC_3g_m+V_1g_m/R_1)/(s^2C_2C_3+sC_3g_m+g_m/R_1) \quad \ldots(1)$$

An inspection of Eq. (1) reveals that, the circuit is capable of realizing different filtering functions through suitable choice of the inputs as depicted below:

i). second-order LP is obtained by choosing $V_2=V_3=0$,

ii). second-order BP is obtained by choosing $V_2=V_1=0$,

iii). second-order HP is obtained by choosing $V_1=V_3=0$,

iv). second-order BE is obtained by choosing $V_2=V_1, V_3=0$, and

v). second-order AP is obtained by choosing $V_1=V_2=-V_3$

It is to be noted that, to realize AP filtering function, an inverter is needed to invert V_3. It is worth mentioning here that, for HP and BP functions, one of the terminals of the resistor R_1 gets grounded, facilitating its replacement by a field effect transistor (FET), which is a voltage variable resistor and as a sequel to lending electronic tunability feature to ω_0. The circuit parameters ω_0 and ω_0/Q obtained from Eq. (1) are as follows:

$$\omega_0=(g_m/R_1C_2C_3)^{1/2} \quad \ldots(2)$$

$$\omega_0/Q=g_m/C_2 \quad \ldots(3)$$

From Eqs (2) and (3), we get:

$$Q=(C_2/R_1g_mC_3)^{1/2} \quad \ldots(4)$$

A study of Eqs (2) and (3) reveals that, ω_0 and ω_0/Q can be orthogonally tuned through R_1 and g_m. The active and the passive sensitivities are less than unity and are given by:

$$S^{\omega_0}_{g_m}=-S^{\omega_0}_{R_1,C_2,C_3}=1/2 \text{ and } S^{Q}_{C_2}=-S^{Q}_{C_3,g_m,R_1}=1/2$$

3 Simulation Results

To verify the potentialities of the proposed circuit PSPICE simulation was carried out. The CA 3080 macro model of OTA with R_i =100 KΩ C_i = 2.6 pF R_o = 70 MΩ and C_o = 3.6 pF was used. The negative polarity CFA has been implemented by

cascading two AD844. The following setting was selected to obtain LP, BP, and HP filters at cut-off frequency 143 kHz and $Q = 1$, $C_3 = C_2 = 3.5$ nf and $g_m = 1$mS $R_1 = 100\Omega$. The simulation result of notch is in Fig. 2, validating the theoretical calculations.

4 Conclusions

A new three input and one output VM universal filter realising all the generic filtering signals is proposed. The additional novelties of the circuit are: (i) it facilitates non-interactive control of ω_0 and ω_0/Q, (ii) it employs a minimum number of components, and (iii) it has low sensitivity figures.

References

1 Abuelmaatti M T & Al-Shahrani S M, *Int J Electron*, 8((1996) 753.

2 Hou C L, Huang C C, Lan Y S, Shaw J J,& Chang C M *Int J Electron*, 86 (1999) 929.

3 Roberts G W & Sedra A S, *IEEE Trans: Circuits &* *Systems*, 39 (1992) 257.

4 Dong-Shiuh Wu, Ho-Tsan Lee, Yuh-Shyan Hwang, & Yan-Pei Wu, *Int J Electron*, 77 (1994) 1059.

5 Jiun-Wei Horng, *Int J Electron*, 88 (2001) 153.

6 Liu S I, *Electron Lett*, 31 (1995) 629.