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Notes

Electronically tunable current-mode bandpass filter

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A new current-mode (CM) operational transconductance amplifier-capacitor (OTA-C) structure implementing second-order bandpass (BP) filtering response and offering a variety of performances is presented. The use of one type of sources and grounded capacitors (GC) considerably simplifies the implementation of the filter in contemporary IC form. The electronic tuning of circuit characteristics has been achieved orthogonally by adjusting the transconductance gain (gm) of OTAs. The circuit possesses low sensitivity figures having values less than or equal to unity lending it better performance feature.

[**Keywords:** Current-mode filter; electronic tunability; grounded capacitors]

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The present trend of research activities is towards the simulation of continuous-time CM circuits based on OTA-C approach. Some of the salient features of the OTA-C structures from the viewpoint of synthesis are simplified architectural design and the employment of less number of components which contribute to reduction in volume, noise, parasitic effects, and power dissipation, besides use of grounded capacitors which have the advantage of absorbing parasitic capacitances apart from requiring smaller chip area than floating ones[1-9]. It is worth mentioning here that CM filters have the additional advantages of simplicity of signal operations, high frequency operation and wide dynamic range compared with their Voltage-Mode (VM) counterparts[10-13].

In applications such as automatic control, music synthesis, communication systems and instrumentation, the need arises for filter circuits having non-interactive electronic tunable facility of circuit performance factors[14]. Towards this end we are introducing herein a CM bandpass architecture employing absolute minimum number of components contributing to reduction in chip area, parasitic effects, and power consumption. The use of two grounded capacitors (GC) which is ideal for integration has further brought reduction in the chip area as they require less chip area than floating ones. The absolute minimum requirement of OTAs is three for achieving independent electronic tunability feature for three filter characteristics[15]. The use of fourth OTA is for stabilization of passband gain and quality factor against temperature changes. To implement second-order filter function two capacitors are required. The proposed architecture is thus canonical with respect to the total component count and thus can be economically fabricated using integrated circuit technology. The novel architecture of the circuit has simplified its design procedure unlike some of the previously published component intensive circuits. The proposed circuit is free from component matching constraints and offers sequential electronic control for its characteristics, which becomes very important when the circuit is in integrated form[16]. The quality factor and passband gain of the proposed structure are insensitive to environmental changes as these are functions of ratios of transconductance gains of OTAs which are inherently sensitive to temperature variations

Circuit Description—OTA is a differential voltage controlled current source (Fig. 1) and is characterized by the following port relation:

$$I_0 = g_i\left(V^+ - V^-\right)$$

where g_i is transconductance gain of i^{th} OTA and is given by:

$$g_i = \frac{I_{bias}}{2V_T}$$

Applying Kirchoff's current law, we get:

$$I_{IN} = I_1 + I_2 + I_3 = V_1 sC_1 + V_1 g_1 + V_2 g_4$$

also $\quad V_1 g_2 = V_2 sC_2$ and $I_{OUT} = V_1 g_3$

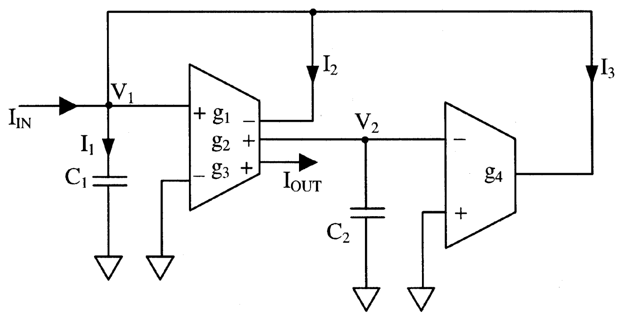

Fig. 1—Proposed bandpass filter

Solving for V_1 and V_2 we get current transfer function as:

$$T(s)=\frac{I_{OUT}}{I_{IN}}=\frac{sC_2g_3}{s^2C_1C_2+sC_2g_1+g_2g_4} \quad \ldots (1)$$

From the above characteristic equation, the filter parameters are given by:

Resonant frequency $\omega_0=\sqrt{\frac{g_2g_4}{C_1C_2}}$ … (2)

Quality factor $Q=\frac{1}{g_1}\sqrt{\frac{g_2g_4C_1}{C_2}}$ … (3)

Passband gain $H=\frac{g_3}{g_1}$ … (4)

An inspection of Eqs (2), (3), and (4) reveals that ω_0, Q, and H can be tuned in a non-interactive manner through separate transconductance gains g_2 and/or g_4, g_1 and g_3 in that order. Since the passband gain and quality factor are functions of ratios of transconductance gains thereby stabilizing these parameters against the changes in temperature.

Sensitivity—The active and passive sensitivities of ω_0, Q, and H are:

$$S_{g_2}^{\omega_0}=S_{g_4}^{\omega_0}=-S_{c_1}^{\omega_0}=-S_{c_2}^{\omega_0}=0.5$$
$$-S_{g_1}^{Q}=S_{g_2}^{Q}=S_{g_4}^{Q}=S_{c_2}^{Q}=S_{c_2}^{Q}=0.5$$
$$S_{g_3}^{H}=-S_{g_1}^{H}=1$$

all of which are not more than unity.

Simulation Results—PSPICE simulation was carried out to check the workability of the proposed filter. The CA 3080 was used for simulation as

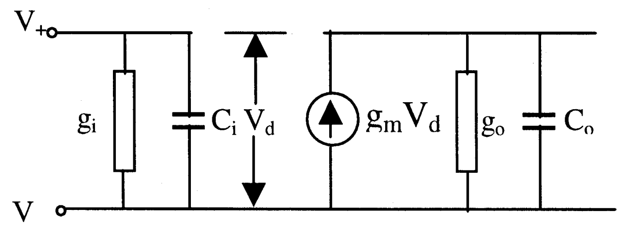

Fig. 2 —OTA macro model

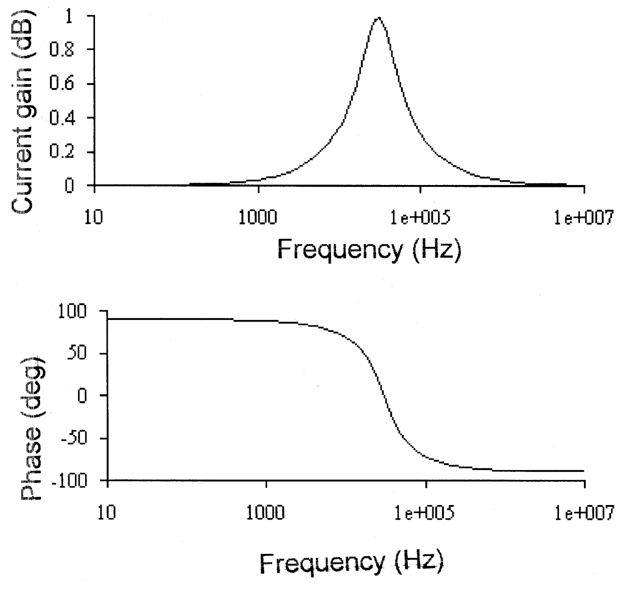

Fig. 3 —Magnitude and phase response of filter shown in Fig. 1

shown in Fig. 2. The filter was designed for the natural frequency of 30 KHz, Q = 1 and H = 1. The design values selected are $g_1 = g_2 = g_3 = g_4$ = 2 mS and $C_1 = C_2$ = 10.6 nF. Figure 3 shows the simulated results.

Conclusions—The CM bandpass filter having the advantage of non-interactive tuning of performance factors has been presented. The circuit has low sensitivity figures and its passband gain and quality factor is temperature insensitive. The circuit is amenable for production in IC form as it employs the same type of sources viz. OTAs and two grounded capacitors.

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