CURRENT-MODE GROUNDED-CAPACITOR SINGLE-ELEMENT-CONTROLLED BANDPASS AND LOWPASS FILTERS

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New circuit configurations for realizing bandpass and lowpass current-mode second-order filters are proposed. Each configuration uses a single first-generation current conveyor, a transconductance amplifier, three grounded capacitors, and two resistors at most. The parameters ω_0 and ω_0/Q_0 of the bandpass and lowpass realizations are not interdependent and, therefore, single element control of the bandpass and lowpass characteristics is possible. Also, the feasibility of realizing a single element current-controlled sinusoidal oscillator is considered.

1. INTRODUCTION

In the recent past, a number of current-mode bandpass filter and lowpass filter realizations has been presented.^(1–5) None of these realizations, however, meet simultaneously the following attractive features for integration: 1. use of grounded capacitors and 2. independent control of the parameters ω_0 and ω_0/Q_0 . For example, while the circuit proposed by Chang⁽¹⁾ uses two grounded capacitors, its parameters ω_0 and ω_0/Q_0 are interdependent. On the other hand, while the circuit proposed by Liu et al.⁽²⁾ enjoys independent control of the parameters ω_0 and ω_0/Q_0 , it uses two capacitors, at least one of them is floating. The circuit proposed by Alami et al.⁽⁶⁾ is, therefore, the preferred formulation as it uses two grounded capacitors and its parameters ω_0 and ω_0/Q_0 are independent. However, it requires three current conveyors to take out the output current exhibiting bandpass operation. Moreover, it requires two floating resistors and it can not realize a lowpass filter.

It is, therefore, the major intention of this letter to present two new configurations. The first can realize a current-mode bandpass filter using two grounded capacitors and one floating resistor and the second can realize a lowpass filter using three grounded capacitors and two resistors, one of them grounded. In both cases, parameters ω_0 and ω_0/Q_0 of the proposed bandpass and lowpass filters are not interdependent. Moreover, the feasibility of obtaining a single-element-controlled sinusoidal oscillator will be considered.

2. PROPOSED CIRCUIT

Consider the circuit shown in Fig (1). Assuming ideal CCI and OTA with

$$I = g_m(V^+ - V^-), I_x = I_y = I_z, V_x = V_y$$

routine analysis shows that the transfer function I_{O1}/I_i can be expressed as

$$\frac{I_{O1}}{I_i} = \frac{-s(1 + g_m R)/C_1 R}{s^2 + \frac{C_2 - C_1}{C_1 C_2 R} s + \frac{g_m}{C_1 C_2 R}} = \frac{-\alpha_1 s}{s^2 + \frac{\omega_0}{Q_0} s + \omega_0^2} \quad (1)$$

Equation (1) corresponds to the transfer function of a second-order bandpass filter with $\alpha_1 = (1 + g_m R)/C_1 R$, center frequency $\omega_0^2 = g_m/C_1 C_2 R$, and $\omega_0/Q_0 = (C_2 - C_1)/C_1 C_2 R$. It is obvious that the parameters ω_0 and ω_0/Q_0 are not interdependent as ω_0 can be controlled by adjusting g_m without affecting the parameter ω_0/Q_0 . Moreover, if the condition $C_1 = C_2 = C$ is satisfied, the circuit can oscillate with a frequency of oscillation $\omega_0^2 = g_m/C^2 R$. Thus, the frequency of oscillation and the condition of oscillation are not interdependent, as the frequency of oscillation can be tuned by adjusting g_m without affecting the condition of oscillation. And since g_m can be adjusted by the bias current I_{ABC} of the operational transconductance amplifier, then it is possible to realise a current controlled oscillator.

FIGURE 1 Proposed bandpass filter.

FIGURE 2 Proposed lowpass filter.

Now consider the circuit of Fig (2). Routine analysis, assuming ideal CCI and OTA shows that the transfer function I_{o2}/I_i can be expressed as

$$I_{02}/I_1 = \frac{g_m/CC_1R_2}{s^2 + s \frac{C_1R_1 + CR_2 - CR_1}{C_1CR_1R_2} + \frac{1}{C_1CR_1R_2}} = \frac{\alpha_2}{s^2 + s \frac{\omega_0}{Q_0} + \omega_0^2} \quad (2)$$

Equation (2) corresponds to the transfer function of a second-order lowpass filter with $\alpha_2 = g_m/CC_1R_2$, $\omega_0^2 = 1/C_1CR_1R_2$ and $\omega_0/Q_0 = (C_1R_1 + CR_2 - CR_1)/C_1CR_1R_2$. By selecting $R_1 = R_2$ (or $C_1 = C$), it is easy to show that the parameters ω_0^2 and ω_0/Q_0 are not interdependent, that is, the parameter ω_0 can be tuned without disturbing the parameter ω_0/Q_0 .

3. SIMULATION RESULTS

The current transfer functions presented in this letter have been checked using SPICE. The current conveyor required was simulated using the circuit proposed by Heurtas,⁽⁸⁾ because of its simplicity, with 1 KOhm for the current sensing resistors and 100 KOhm and 200 KOhm for the other resistors. Fig (3) shows the simulated and calculated transfer functions of the bandpass filter of eqn (2). From Fig (3) it is obvious that the agreement between the simulated and calculated results appears to be good.

FIGURE 3 Simulated characteristics of the bandpass filter of Fig (1). $g_m = 2 \text{ mA/V}$, $R = 1 \text{ M}\Omega$, $C_1 = 0.1 \text{ nF}$, $C_2 = 10 \text{ nF}$.

. Calculated

— Simulated

4. CONCLUSION

In this letter, new topologies for realizing current-mode bandpass and lowpass filters have been presented. In both filters, grounded capacitors are used. Also, the parameters ω_0 and ω_0/Q_0 are not interdependent. These are attractive features for integration. The feasibility of obtaining a single-element-controlled sinusoidal oscillator has been considered.

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