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NOVEL CASCADABLE CURRENT-MODE TRANSLINEAR-C UNIVERSAL FILTER

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A novel cascadable current-mode universal filter employing three current-controlled conveyors (translinear conveyors) and two grounded capacitors is proposed. The circuit with single input and three high-impedance current outputs, ideal for cascading, realizes low-pass, band-pass, and inverting band-reject transfer functions. Inverting high-pass and inverting all-pass transfer functions are obtained by simply connecting the available outputs. The proposed circuit enjoys tuning through external currents, low total harmonic distortion (THD), good dynamic range, attractive sensitivity performance and is ideal for IC implementation.

Keywords: Current-mode circuits; Translinear-C filters

1 INTRODUCTION

Recently current-controlled conveyors (CCCIIs) have become an ideal choice for the realization of electronic functions as these devices provide tunability, high frequency operation, and possibility of resistor-less realizations. Thus a number of filters, oscillators, and amplifiers have been reported in technical literature [1–8]. Current-mode circuits with high output impedance are of special interest as they can be conveniently cascaded without additional active elements. Taking the above feature into consideration, some translinear-C filters have been reported [2, 4, 8]. In this article, a novel current-mode translinear-C filter with single input and three high-impedance outputs employing three multiple output CCCII+ and two grounded capacitors, ideal for IC implementation, is proposed. The novel circuit employs fewer active/passive elements than other reported works [4, 8]. The proposed circuit realizes all five standard second-order filter functions, three (or two) at a time without additional active/passive elements and no matching requirements. The circuit is electronically tunable through the external bias current of CCCIIs and enjoys good sensitivity performance. RSPICE simulation results are given to verify the proposed circuit.

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2 CIRCUIT DESCRIPTION

The following relationship characterizes a CCCII+:

$$V_x = V_y + i_x R_x, \quad i_y = 0, \quad i_z = i_x. \tag{1}$$

Additional outputs (z+) simply mirror the current at the z-terminal [3]. The intrinsic x-terminal current-controllable resistance is given as:

$$R_x = \frac{V_T}{2I_o}, \tag{2}$$

where V_T is the thermal voltage and I_o is the bias current of the translinear conveyor [1, 2].

The proposed translinear-C filter as shown in Figure 1 is analyzed using Eq. (1) for the current transfer functions:

$$\frac{I_{LP}}{I_{in}} = \frac{1/R_{x1}R_{x2}C_1C_2}{D(s)}, \quad \frac{I_{BP}}{I_{in}} = \frac{s/R_{x1}C_2}{D(s)},$$
$$\frac{I_{BR}}{I_{in}} = -\frac{(s^2 + 1/R_{x1}R_{x2}C_1C_2)}{D(s)}, \quad D(s) = s^2 + \frac{s}{R_{x1}C_2} + \frac{1}{R_{x1}R_{x2}C_1C_2}. \tag{3}$$

Equation (3) shows that the three outputs realize low-pass, band-pass, and inverting band-reject filter functions. The inverting high-pass (HP) filter function (I_{HP}) is obtained by connecting I_{BR} and I_{LP}, whereas the inverting all-pass filter function (I_{AP}) is obtained by connecting I_{BR} and I_{BP} together. It is not difficult as all the three outputs [Eq. (3)] are at high impedance (z-terminal of CCCII+). The so-derived outputs are:

$$\frac{I_{HP}}{I_{in}} = \frac{-s^2}{D(s)}, \quad \frac{I_{AP}}{I_{in}} = -\frac{(s^2 - s/R_{x1}C_2 + 1/R_{x1}R_{x2}C_1C_2)}{D(s)}. \tag{4}$$

Thus, all standard second-order filter functions can be realized from the proposed circuit. It is to be noted that no additional active/passive elements or matching conditions are required. Another important feature is the availability of current outputs at high impedance that is ideal

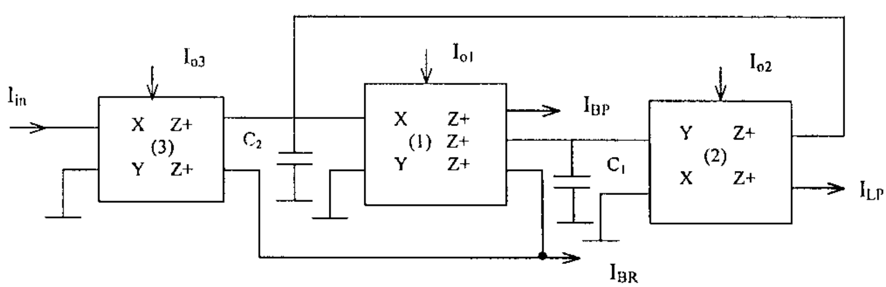

FIGURE 1 Proposed translinear-C universal filter.

for current-mode cascading. Filter parameters, namely natural angular frequency, bandwidth, and quality factor, are given as:

$$\omega_o = \frac{1}{\sqrt{R_{x1}R_{x2}C_1C_2}}, \quad \frac{\omega_o}{Q} = \frac{1}{R_{x1}C_2}, \quad Q = \sqrt{\frac{R_{x1}C_2}{R_{x2}C_1}}. \tag{5}$$

It is seen that the filter parameters can be electronically controlled, as per Eq. (5), by varying the bias current of the conveyors. Natural angular frequency can be tuned independent of quality factor by varying both I_{o1} and I_{o2} in the same ratio. It is to be noted that the indexes 1 and 2 at 'R_x' are for the CCCII (1) and CCCII (2), respectively. From Eq. (5), the sensitivity of parameters to active and passive elements is analyzed and found to be within 0.5 in magnitude that represents a low value. Thus the proposed circuit enjoys attractive sensitivity performance.

3 SIMULATION RESULTS

To validate the theory presented in the above sections, the proposed circuit is simulated using the CCCII+ implementation with transistor NR100N and PR100N parameters [3, 9]. The proposed translinear-C filter circuit is designed for $Q = 1$ with the design values as $C_1 = C_2 = 0.01\ \mu F$, $I_{o1} = I_{o2} = 100\ \mu A$. The bias current of CCCII (3), used only to mirror the input current, is taken large ($I_{o3} = 500\ \mu A$) so as to keep the X-terminal resistance small. The simulated frequency response of the circuit is shown in Figure 2 that gives four responses, namely low-pass, band-pass, band-reject, and HP. It is to be noted that HP response is obtained by connecting outputs (I_{BP} and I_{LP}) as mentioned in Section 2. The simulated natural angular frequency obtained is 110 kHz and is in agreement with the theory.

The practical utility of the proposed translinear-C filter is next studied by injecting a sinusoidal input of frequency 1 MHz. The amplitude of the input is varied and the HP output response studied for the harmonic distortions. The output is found to show a THD within 1% for nearly two decades variation of the input current amplitude as shown in Figure 3. This confirms the low THD, good dynamic range, and high frequency performance of the proposed circuit.

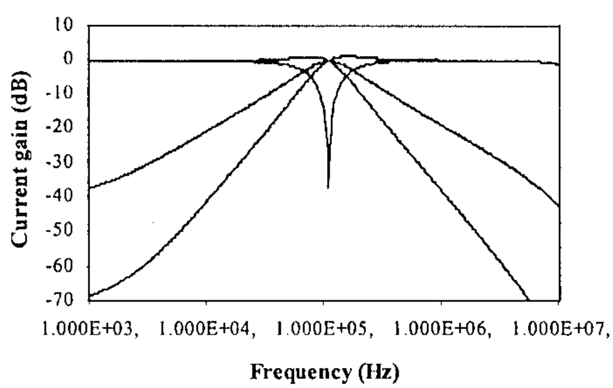

FIGURE 2 Simulated gain plots showing LP, BP, BR, and HP response.

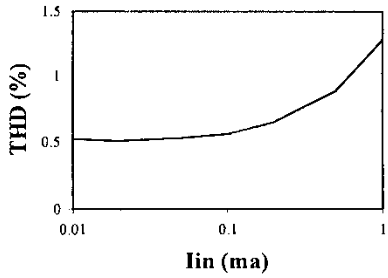

FIGURE 3 THD variation of HP output for 1 MHz sinusoidal input with amplitude.

4 CONCLUSION

A new cascadable current-mode translinear-C universal filter is proposed, which can realize five standard second-order filter functions. The circuit employs grounded capacitors and only one type (positive) of CCCIIs, thus, ideal for IC implementation. The active and passive sensitivities are low and the circuit possesses low THD, good dynamic range, and high frequency performance. RSPICE simulation results confirm the practical utility of the proposed universal filter.

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