VOLTAGE MODE TOW THOMAS UNIVERSAL FILTER: A CURRENT CONTROLLED CONVEYOR APPROACH

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Abstract

In this paper, Tow Thomas universal filter based on current controlled conveyor (CCCII) is presented. The proposed configuration utilizes six CCCII-s, two grounded capacitors and two grounded resistors. The circuit enjoys a number of advantages: composed of solely minus type of current conveyors, offers high input impedance, uses all grounded passive components, independent electronic control of ω_0, Q_0, and gain with biasing currents of CCCII-s and grounded resistor. The filter also exhibits low sensitivity with respect to passive components. PSPICE simulation results are included to verify theory.

Introduction

Recently there has been a great emphasis on realization of various analog signal processing circuits using second generation current conveyors. This is attributed to their potential advantages such as wider dynamic range, inherent wider bandwidth, simple circuitry and lower power consumption [1, 2]. Active filters with high input impedance are useful because several such cells can be cascaded directly to implement higher order filters. The configuration simplifies with the use of only one type (plus type or minus type) of current conveyor [3].

Already some voltage mode single input and single output (SISO) universal biquadratic filter realizations of various complexity and features have been reported in the literature [3-7]. Tomazou and Lidgey [4] proposed an active filter configuration that can realize all second – order functions namely low pass, band pass, high pass, notch and all pass but requires seven current conveyors (both plus and minus type), an operational amplifier buffer, two grounded capacitors and eight grounded resistors. Tek and Anday [5] presented a configuration which can realize notch, high pass, band pass and low pass biquadratic

functions employing four current conveyors (both plus and minus type), three grounded capacitors and five grounded resistors. The configuration [6] implements notch, high pass, band pass and low pass biquadratic functions and employs four plus type current conveyors, three grounded capacitors and five grounded resistors. The filter configuration of Ref.[3] is similar to Ref. [4] that can implement notch, high pass, band pass, low pass and all pass biquadratic functions employing same number of active and passive components but uses only plus type current conveyors and does not require a change in type of active component to realize all pass function [4]. The filter configuration [7] is based on well known state variable filter design namely Tow Thomas filter employing six current conveyors (both plus and minus type), two grounded capacitors and eight grounded resistors.

In this paper we propose a new SISO voltage mode universal filter based on Tow Thomas filter using solely six minus type current controlled conveyors (CCCII-s), two grounded capacitors and two grounded resistors. The proposed configuration is generated from conventional Tow Thomas biquad circuit [8,9] using recently reported transformation method [10] followed by summing currents at z terminal instead of x terminal. The workability of the proposed structure has been confirmed by PSPICE simulations.

Circuit Description

The proposed biquad as shown in figure 1 is evolved by implementing [10] the inverting lossy and lossless integrators and summer of Tow Thomas biquad by CCCII and adding currents at z terminal instead of terminal x. The proposed network employs only CCCII-s as active elements. The network thus obtained has all passive components grounded which is beneficial from integrated circuit implementation point of view.

The second-generation current controlled conveyor (CCCII) can be designed from translinear elements and current mirrors [11]. It has finite intrinsic resistance R_x at terminal x controllable by bias current I_0 and is expressed as $R_{xi} = V_T/ 2I_{0i}$ where V_T is the thermal voltage and i = 1, 2… 6.

Using standard notations the current and voltage relationships of ports of an ideal CCCII- can be characterized by

$v_x = v_y + i_x|R_x(I_{0i})|$, $i_z = - i_x$ and $i_y = 0$

The transfer function of the proposed network of fig.1 can be expressed as

$$V_{out} / V_{in} = -R_8 N(s) / R_{x5} D(s) \tag{1}$$

where $N(s) = s^2 + (1/R_1C_1 - R_{x5}/R_{x1}R_{x2}C_1)s + R_{x5}/R_{x2}R_{x4}R_{x6}C_1C_2$ and

$$D(s) = s^2 + s/R_1C_1 + R_8/R_{x2}R_{x3}R_{x4}C_1C_2$$

The transfer function is characterized by

$\omega_0 = (R_8/R_{x2}R_{x3}R_{x4}C_1C_2)^{1/2}$, $\omega_0/Q_0 = 1/R_1C_1$ and

$$Q_0 = R_1(R_8C_1 / R_{x2}R_{x3}R_{x4}C_2)^{1/2} \quad (2)$$

Hence we see that parameter Q_0 can be adjusted independently with grounded resistance R_1. The parameter ω_0 can be adjusted with bias currents I_{02}, I_{03} and I_{04} without disturbing

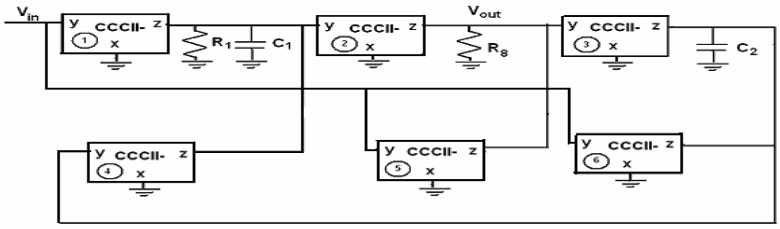

Fig. 1 CCCII- based Tow - Thomas filter

ω_0/Q_0. From eqn.1 we can see that specializations in the numerator results in the following filter functions (i) low pass filter: R_{x1}, R_{x5} open circuit, (ii) band pass filter: R_{x5}, R_{x6} open circuit, (iii) high pass filter: R_{x6} open circuit, $R_1 R_{x5} = R_{x1} R_{x2}$, (iv) notch filter: $R_1 R_{x5} = R_{x1} R_{x2}$ and (v) all pass filter: $R_1 R_{x6} R_8 = 2R_{x1} R_{x2} R_{x3}$. The results of passive sensitivity analysis of various parameters are given as

$$S_{R_{x2}}^{\omega_0} = S_{R_{x3}}^{\omega_0} = S_{R_{x4}}^{\omega_0} = S_{C_1}^{\omega_0} = S_{C_2}^{\omega_0} = -S_{R_8}^{\omega_0} = -1/2, \; S_{R_{x1}}^{\omega_0} = S_{R_{x5}}^{\omega_0} = S_{R_{x6}}^{\omega_0} = S_{R_1}^{\omega_0} = 0$$

$$S_{R_{x1}}^{\omega_0/Q_0} = S_{R_{x2}}^{\omega_0/Q_0} = S_{R_{x3}}^{\omega_0/Q_0} = S_{R_{x4}}^{\omega_0/Q_0} = S_{R_{x5}}^{\omega_0/Q_0} = S_{R_{x6}}^{\omega_0/Q_0} = S_{R_8}^{\omega_0/Q_0} = S_{C_2}^{\omega_0/Q_0} = 0$$

$$S_{R_1}^{\omega_0/Q_0} = S_{C_1}^{\omega_0/Q_0} = -1$$

Thus all the passive sensitivities are low and within 1 in magnitude. Furthermore, the gain of low pass, band pass, high pass filters, notch and all pass filters can be adjusted independently by varying bias currents I_{06} and I_{03}; I_{01} and I_{02} ; I_{05} ; I_{05} and I_{05} respectively.

Simulation

To confirm the practical validity, the proposed biquad, is simulated with PSPICE using the implementation of CCCII-[11]. The transistor models PR100N and NR100N of bipolar ALA arrays are used. The gain and phase responses for notch filter is shown in fig.2 for $I_{01} = I_{02} = I_{03} = I_{04} = I_{05} = = I_{06} = 10\mu A$, $R_1 = R_8 = 1250\Omega$, $C_1 = C_2 = 10$ nF. The circuit is also simulated for low pass, high pass, band pass and all pass filters. The simulated results show well agreement with theoretical analysis.

Conclusion

A new biquadratic voltage mode filter realization based on Tow Thomas biquad has been presented. The proposed filter uses six CCCII-s, two each grounded resistors and capacitors. The filter has the following attractive features: (i) it uses only one type of current conveyors, (ii) low passive sensitivities, (iii) independent control of ω_0 without

disturbing ω_0 /Q_0, (iv) independent control of Q_0 without disturbing ω_0, (v) presents high input impedance and thus eases higher order filter realization and (v) gain, ω_0, Q_0 and ω_0/Q_0 of the circuit are electronically tunable by biasing currents of CCCII-s.

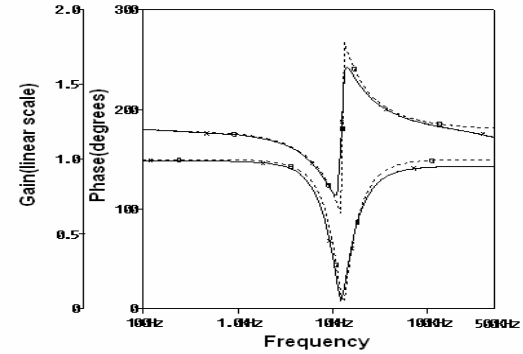

Fig. 3 Gain and phase responses of notch filter
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