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Novel Applications of VDVTA: As Current-Mode SIMO-Type Biquad and Electronically Controllable Sinusoidal Oscillator

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Abstract

In this paper we present new applications of voltage differencing voltage transconductanse amplifier (VDVTA) as current-mode (CM) biquad filter and electronically controllable sinusoidal oscillator (ECSO) using single VDVTA and with four passive components, three passive components respectively. The biquad circuit realizes low pass, high pass, and band pass filter simultaneously without changing the circuit topology. The oscillator circuit also enjoys the explicit current output and also the frequency is electronically controllable. The active and passive sensitivities for both circuits are very low. Both the circuits are simulated using PSPICE with TSMC CMOS 0.18 μm process parameter

Keywords: VDVTA, CM biquad filter, Electronically Controllable Oscillator

1 Introduction

Due to longer dynamic range and wider bandwidth the current mode (CM) application is more popular as compare to voltage mode (VM) counter parts [1]. Now days the main focus of researcher is to use single active element/ building block based single input multi output filter and electronically controllable oscillator see [3-21] and the references cited therein. There are many active building block has been represented by BIOLEK, SENANI, BIOLKOVA, KOLKA, in [2]. The multi function filter is more flexible because the same circuit structure can be used for different filter responses. Single Input Multiple Output (SIMO) type filter using different active building block are available in the literature see [3-10]. Sinusoidal oscillator find a number of application in communication, signal processing, control system, instrumentation and measurement system [11-13]. ECSOs based on different active building blocks are available in the literature see [14-21] and the reference cited therein. The advantages and applications of the active building block used in this paper are available in the literature [22-23]. However to the best knowledge and belief of the authors SIMO CM biquad as well as ECSOs using single VDVTA have not been yet presented in the open literature so for.

The purpose of this paper is to propose a new SIMO-type CM biquad and ECSOs using single VDVTA along with bare minimum passive components. The active and passive sensitivities for both the circuits are very low. Both the circuits are simulated using PSPICE with TSMC CMOS 0.18 µm process parameter.

2 The Proposed Configuration

The VDVTA is a recently proposed in [23]. Fig. 1 shows the symbolic representation VDVTA, where P, N and V are input terminals and Z, V, X+ and X- are output terminals. All the terminals of VDVTA are high impedance terminals.

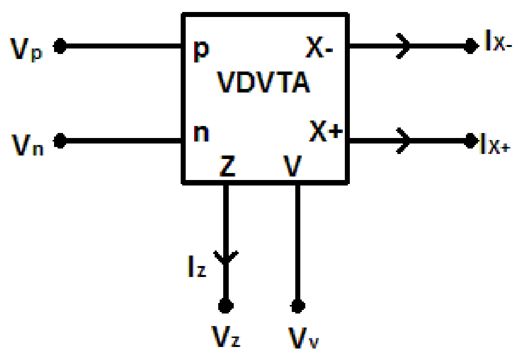


Fig. 1 Symbolic representation of VDVTA [23]

The terminal current voltage relationships of VDVTA can be given by following set of equations:

$$I_z = g_{m_1}\left(V_p - V_n\right) \tag{1}$$

$$I_{x+} = g_{m_2}\left(V_z - V_v\right) \tag{2}$$

$$I_{x-} = -g_{m_2}\left(V_z - V_v\right) \tag{3}$$

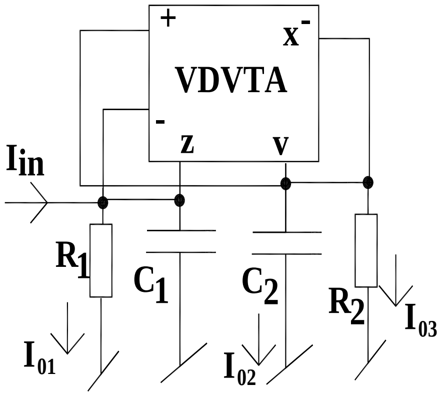


Fig. 2 Proposed SIMO-type CM- Biquad

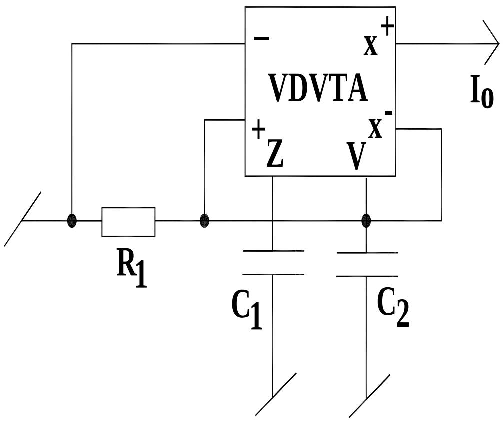


Fig. 3 Proposed CM- Electronically Controlled Sinusoidal Oscillator

The routine circuit analysis of Fig. 2 yields the following filter transfer functions of the universal filters:

$$T_1(s)\big|_{HP} = \frac{I_{o1}}{I_{in}} = \frac{s^2}{D(s)} \tag{4}$$

$$T_2(s)\big|_{BP} = \frac{I_{o2}}{I_{in}} = -\frac{s\left(\frac{g_{m_2}}{C_1}\right)}{D(s)} \tag{5}$$

$$T_3(s)\Big|_{LP} = \frac{I_{o3}}{I_{in}} = -\frac{\left(\dfrac{g_{m_2}}{R_2C_1C_2}\right)}{D(s)} \tag{6}$$

Where

$$D(s) = s^2 + \frac{s}{C_1}\left(\frac{1}{R_1} + g_{m_1}\right) + \frac{g_{m_1}g_{m_2}}{C_1C_2} \tag{7}$$

The natural frequency ω_0, BW and quality factor Q_0 are given by:

$$\omega_0 = \sqrt{\frac{g_{m_1}g_{m_2}}{C_1C_2}} \tag{8}$$

$$BW = \frac{1}{C_1}\left(\frac{1}{R_1} + g_{m_1}\right) \tag{9}$$

$$Q_0 = \sqrt{\frac{g_{m_1}g_{m_2}C_1}{C_2\left(\dfrac{1}{R_1} + g_{m_1}\right)^2}} \tag{10}$$

A routine circuit analysis of Fig. 3 shows the following characteristic equation:

$$s^2 + s\frac{1}{C_2}\left(\frac{1}{R_2} - g_{m_2}\right) + \frac{g_{m_1}g_{m_2}}{C_1C_2} = 0 \tag{11}$$

Thus the condition of oscillation (CO) and frequency of oscillation (FO) are given by

$$\left(\frac{1}{R_2} - g_{m_2}\right) \leq 0, \omega_0 = \sqrt{\frac{g_{m_1}g_{m_2}}{C_1C_2}} \tag{12}$$

Therefore, it is seen that CO is controlled by resistance R_2 and FO is electronically controllable by transconductanse g_{m1}.

Using sensitivity formula $S_x^F = \frac{x}{F}\frac{\partial F}{\partial x}$, the active and passive sensitivities of ω_0 with respect to each elements are found to be $-\frac{1}{2}$.

3 SPICE Simulation Results

To confirm the theoretical analysis, the proposed circuits have been simulated using CMOS VDVTA circuit of Fig. 3 [23]. The passive component values used for SIMO-type CM biquad as shown in Fig. 2 were C_1 = 0.005nF, C_2 = 0.01nF and R_1 = 1.583kΩ and for sinusoidal oscillator as shown in Fig. 3 were

C_1 = 0.01nF, C_2 = 0.01nF and R_1 = 1.678kΩ. In all the simulations the bias voltage of VDVTA are ± 0.9 volts D.C with bias currents $I_{B1} = I_{B2} = I_{B3} = I_{B4}$ = 150µA. The simulated frequency response of filter given in Fig. 2 is shown in Fig. 4. The transient response, steady response and the output spectrum of the sinusoidal oscillator of Fig. 3 is shown in Fig. 5. The comparison of circuit shown in Fig. 3 with other available ECSOs is shown in Table 1. These results, thus, confirm the validity of the proposed biquad and oscillator circuits.

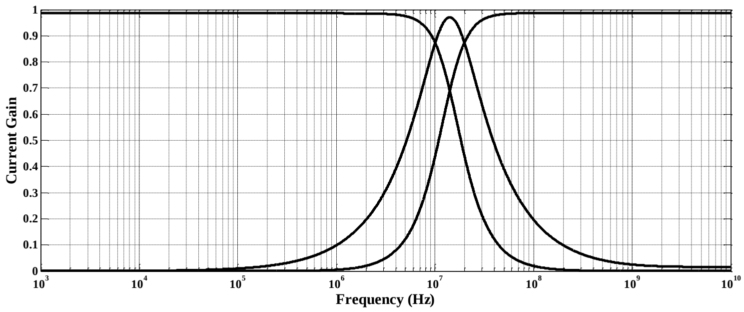
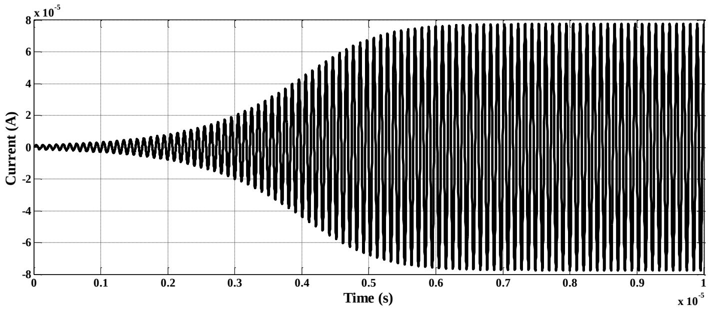
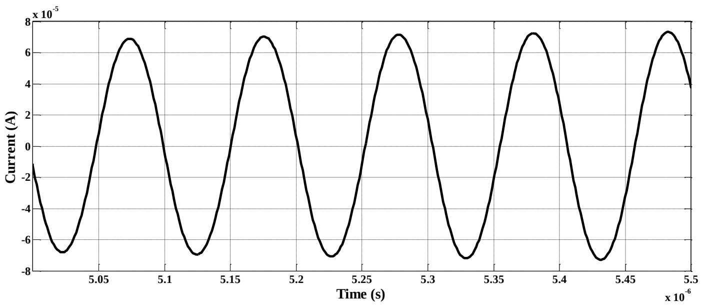


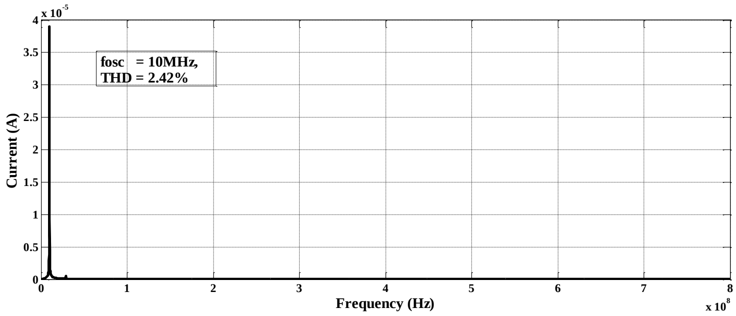
Fig. 4 Frequency response of proposed biquad of Fig. 2



(a)



(b)



(c)

Fig. 5 (a) Transient output waveform, (b) Steady state response of the output and (c) Simulation result of the output spectrum of Fig. 3

Table 1

Reference	**Active Component**	**Grounded Capacitors**	**Floating Capacitors**	**Resistors**	**Availability of Explict current-mode output**	**Electronic Tunability**
[16]	1	3	0	5	YES	NO
	1	2	1	4	YES	NO
	1	1	2	4	YES	NO
	1	1	1	5	YES	NO
[17]	1	2	0	3	YES	NO
[18]	1	2	0	3	YES	NO
[19]	1	0	3	3	YES	NO
	1	1	2	3	YES	NO
[20]	1	2	0	3	YES	NO
[21]	1	0	2	5	YES	NO
Proposed	**1**	**2**	**0**	**1**	**YES**	**YES**

4 Conclusion

Two new applications of voltage differencing voltage transconductance amplifier are proposed in this paper one is current mode SIMO–type universal biquad and second is electronically controllable sinusoidal oscillator using single active building block. The proposed filter realizes second order low pass, band pass, and high pass filters simultaneously. The other proposed oscillator circuits offers (1) independent control of FO and CO, (2) use of grounded capacitors which is desirable from the viewpoint of IC implementation, (3) availability of explicit CM output and (4) low active and passive sensitivities. Both the circuit offers low active and passive sensitivities of ω_0. SPICE simulations have established the workability of both the circuits.

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