DUAL MODE BIQUADRATIC FILTER USING SINGLE VDTA

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ABSTRACT

This paper presents a dual-mode biquad filter configuration using single voltage differencing transconductance amplifier (VDTA), three capacitors and two resistors. The proposed filter can be configured as voltage mode (VM) or current mode (CM) structure with appropriate input excitation choice and can be used to synthesize low pass (LP), high pass (HP) and band pass (BP) filter functions. The natural frequency (ω_0) and the quality factor (Q_0) of the proposed topology can be ortogonally tuned. The theoretical propositions are validated through SPICE simulations using 0.18 µm TSMC CMOS process parameters.

Keywords: VDTA, Voltage Mode, Current Mode, Filter, Signal Processing.

I. INTRODUCTION

The voltage differencing transconductance amplifier (VDTA) has emerged as an alternate analog building block (ABB) in recent past [1, 2] since it inherits all the advantages offered by current mode techniques [3]. It has been successfully used as an ABB for realizing a number of analog signal processing and generation circuits [1,2,4-10]. Several VDTA based filter circuits have been reported in the literature [1,2,6-10]. These structures can be classified as multiamplifier [2,8,10] or single amplifier based structures [1,6,7,9]. For the applications having power consumption as an important design constraint, single active element based filters are the useful choice. A detailed study of the existing literature on single VDTA based filters shows that

- Independent adjustment of ω_0 and Q_0 is not possible [1,7.9] in single VDTA based filters without using external resistor.
- Either VM [1, 10] or CM [2,6-9] outputs is provided by the existing structures

Therefore in this paper a single VDTA based dual-mode filter is proposed which can be used for either of the voltage or current mode operation with independently controllable ω_0 and Q_0.

II. THE PROPOSED CIRCUIT

The circuit symbol of the VDTA is shown in Fig. 1, where VP and VN are input terminals and Z, X+ and X- are output terminals. All terminals exhibit high impedance values. Using standard notation, the terminals relationship of an ideal VDTA can be written as:

$$\begin{bmatrix} I_{Z+} \\ I_{Z-} \\ I_{x^+} \\ I_{x^-} \end{bmatrix} = \begin{bmatrix} g_{m1} & -g_{m1} & 0 & 0 \\ -g_{m1} & g_{m1} & 0 & 0 \\ 0 & 0 & g_{m2} & 0 \\ 0 & 0 & -g_{m2} & 0 \end{bmatrix} \begin{bmatrix} V_{VP} \\ V_{VN} \\ V_{z^+} \\ V_{z^-} \end{bmatrix} \quad (1)$$

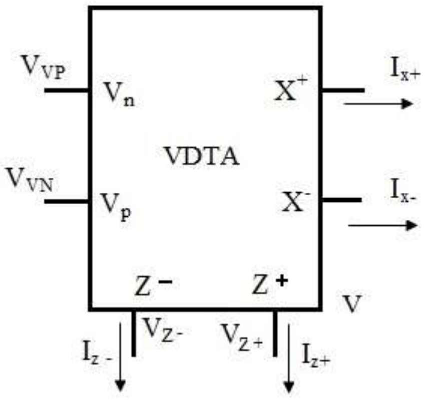


Fig. 1 Circuit symbol of VDTA

The CMOS realization of the VDTA [2] is shown in Fig. 2 and is based on two Arbel-Goldminz transconductances [11]. Input and output transconductance parameters of VDTA element, represented as g_{m1} and $g_{m2,}$ can be expressed as :

$$g_{m1} = \frac{g_1 g_2}{g_1 + g_2} + \frac{g_3 g_4}{g_3 + g_4} \quad (2)$$

$$g_{m2} = \frac{g_5 g_6}{g_5 + g_6} + \frac{g_7 g_8}{g_7 + g_8} \quad (3)$$

where, g_i is the transconductance value of the i-th transistor and is given by

$$g_i = \sqrt{\mu C_{ox} \left(\frac{W}{L} \right)_i I_{Bi}} \quad (4)$$

In (4) μ is effective carrier mobility; C_{ox} is the gate oxide capacitance per unit area, I_{Bi} represents the dc bias current and $(W / L)_i$ is the aspect ratio of the i-th MOS transistor.

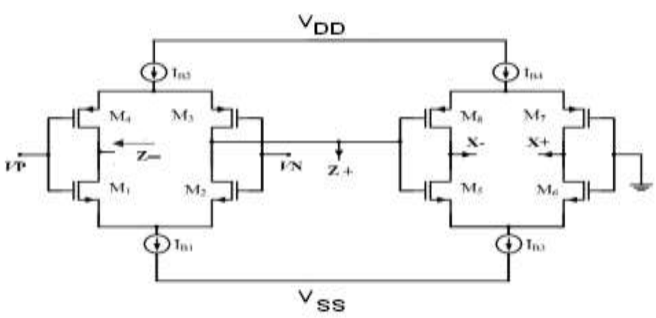


Fig. 2 The CMOS realization of the VDTA [2]

The proposed dual mode biquad filter is shown in Fig. 3 which uses single VDTA, two resistors and three capacitors. The proposed filter can be configured as VM or CM structure with appropriate input excitation choice and can be used to synthesize LP, HP and BP filter functions. Circuit analysis yields voltage-mode and current mode biquad transfer functions respectively as given by (5) – (10).

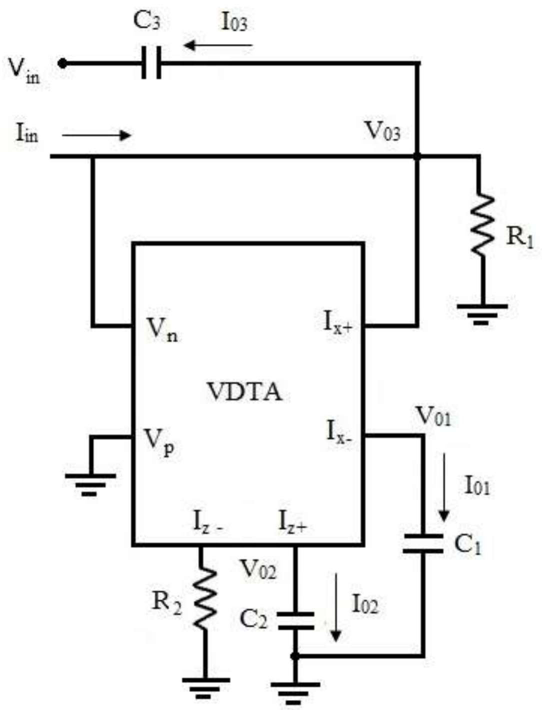


Fig. 3 The Proposed Dual Mode Biquad

2.1 Voltage Mode

The proposed configuration will work in voltage mode if I_{in} is removed and the transfer functions at various nodes can be derived as:

$$\left.\frac{V_{01}}{V_{in}}\right|_{LP} = \frac{-\dfrac{g_{m1}g_{m2}}{C_1C_3}}{s^2 + \dfrac{s}{R_1C_2} + \dfrac{g_{m1}g_{m2}}{C_2C_3}} \tag{5}$$

$$\left.\frac{V_{02}}{V_{in}}\right|_{BP} = \frac{\dfrac{g_{m1}}{C_1}s}{s^2 + \dfrac{s}{R_1C_2} + \dfrac{g_{m1}g_{m2}}{C_2C_3}} \tag{6}$$

$$\left.\frac{V_{03}}{V_{in}}\right|_{HP} = \frac{-g_{m1}R_3s^2}{s^2 + \dfrac{s}{R_1C_2} + \dfrac{g_{m1}g_{m2}}{C_2C_3}} \tag{7}$$

2.2 The CM Configuration

Removing voltage source V_{in} in Fig. 3 leads to CM operation of the filter.Using routine analysis the following transfer functions are obtained:

$$\left.\frac{I_{01}}{I_{in}}\right|_{LP} = \frac{\frac{g_{m1}g_{m2}}{C_2C_3}}{s^2 + \frac{s}{R_1C_2} + \frac{g_{m1}g_{m2}}{C_2C_3}} \quad (8)$$

$$\left.\frac{I_{02}}{I_{in}}\right|_{BP} = \frac{\frac{g_{m1}}{C_1}s}{s^2 + \frac{s}{R_1C_2} + \frac{g_{m1}g_{m2}}{C_2C_3}} \quad (9)$$

$$\left.\frac{I_{03}}{I_{in}}\right|_{HP} = \frac{s^2}{s^2 + \frac{s}{R_1C_2} + \frac{g_{m1}g_{m2}}{C_2C_3}} \quad (10)$$

The natural frequency ω_0 and quality factor Q_0 for both voltage and current mode is same and are given as follows

$$\omega_0 = \sqrt{\frac{g_{m1}g_{m2}}{C_2C_3}} \quad (11)$$

$$Q_0 = R_1\sqrt{\frac{g_{m1}g_{m2}C_2}{C_3}} \quad (12)$$

III. TRACKING ERROR

Considering the non-ideal characteristics of the VDTA, the port relations of current and voltage in equation (1) get modified as:

$$\begin{bmatrix} I_{Z+} \\ I_{Z-} \\ I_{x^+} \\ I_{x^-} \end{bmatrix} = \begin{bmatrix} \beta_1 g_{m1} & -\beta_1 g_{m1} & 0 & 0 \\ -\beta_1 g_{m1} & \beta_1 g_{m1} & 0 & 0 \\ 0 & 0 & \beta_2 g_{m2} & 0 \\ 0 & 0 & -\beta_2 g_{m2} & 0 \end{bmatrix} \begin{bmatrix} V_{VP} \\ V_{VN} \\ V_{z^+} \\ V_{z^-} \end{bmatrix} \quad (13)$$

where β_1 and β_2 respectively are the tracking errors for the first and second stages of the VDTA. Re-analysis the proposed circuit of Fig.3 using above equation yields the following non-ideal filter parameters.

$$\omega_0 = \sqrt{\frac{\beta_1\beta_2 g_{m1}g_{m2}}{C_2C_3}} \quad (15)$$

$$Q_0 = R_1\sqrt{\frac{\beta_1\beta_2 g_{m1} g_{m2} C_2}{C_3}} \qquad (16)$$

It is evident that the values of ω_0, and Q_0 may be slightly changed by the effect of the VDTA's tracking errors. However, the small deviation can be minimized by properly adjusting the VDTA's transconductance values.

IV. SIMULATION RESULTS

The proposed dual mode structure is verified through SPICE simulations using TSMC CMOS 0.18 μm process parameters. The aspect ratios of the transistors as used are given in Table 1[2]. Supply voltages are taken as $V_{DD} = -V_{SS} = 0.9$ V and the bias currents are taken as $I_{B1} = I_{B2} = I_{B3} = I_{B4} = 150$ μA. The DC transfer characteristic of the VDTA is shown in Fig. 4 and the simulated transconductance values of VDTA are observed to be $g_{m1} = g_{m2} = 636.3$ μA/V.

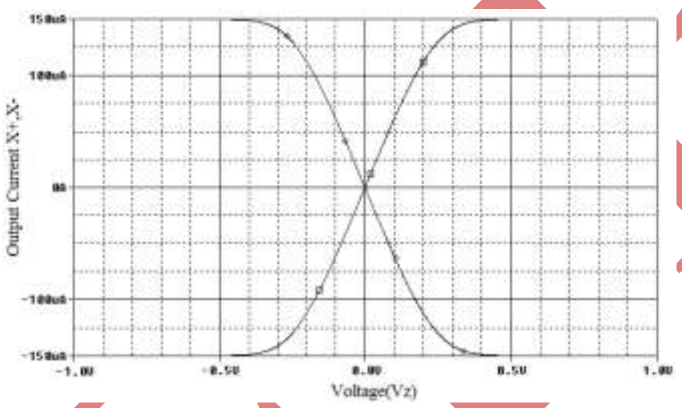
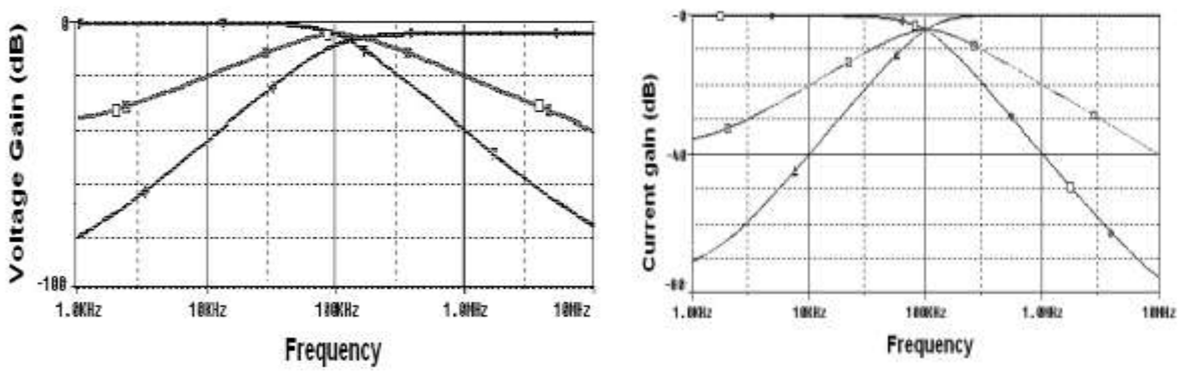


Fig. 4 The DC Transfer Characteristic Of The VDTA

The proposed circuit of Fig. 3 is simulated with the following passive element values $C_1=C_2=C_3$ = 1nF, R_1 R_2=1KΩ which results in f_0 = 101.27 KHz and Q_0 = 0.636. The frequency responses of voltage-mode and current mode filters, plotted by selecting voltage and current excitation respectively, are shown in Fig. 6(a) and (b) respectively.The simulated results are found in close agreement to the theoretical values.



(a) (b)

Fig. 6. Frequency Response (a) Voltage Mode (b) Current Mode

V. CONCLUSION

A single VDTA based dual mode filter is presented in this paper which provides either of the voltage or current mode output with due selection of input excitation. The proposed filter provides LP, HP and BP responses simultaneously.The filter parameters namely ω_0 and Q_0 of the proposed topology can be ortogonally tuned. The theoretical propositions are validated through SPICE simulations using 0.18 μm TSMC CMOS process parameters.

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