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CURRENT-MODE RESISTOR-LESS QUADRATURE OSCILLATORS WITH GROUNDED CAPACITORS USING SINGLE CCCDTA

Jin JIE

Jishou University, College of Information Science and Engineering, Jishou, China.
E-mail: jj67123@sina.com

This paper presents two single CCCDTA (Current Controlled Current Differencing Transconductance Amplifier)-based current-mode resistor-less quadrature oscillators (QOs) with grounded capacitors. The proposed QOs are very simple, which only consist of one CCCDTA and two grounded capacitors, and they are easy for monolithic integration. The oscillation frequency of the QOs can be electronically controlled by the bias current of the CCCDTA. Moreover, the two oscillators can provide two quadrature current outputs respectively, and the active and passive sensitivities of the QOs are low. PSPICE simulation results are provided to verify all the theoretical analysis.

Key words: current-mode, current differencing transconductance amplifier, quadrature oscillator.

1. INTRODUCTION

During the past decades, the current-mode approach has become more popular in analog integrated circuit design due to its advantages of providing larger dynamic range, wider bandwidth, lower power consumption over the voltage-mode counterparts. Various of active current mode blocks are proposed for active filters, oscillators and immittances circuit design.

Oscillator is a very important building block in modern communication and information processing systems. The realization of oscillators using a variety of active elements [1-3] have been reported. In 2003, D.Biolek proposed the current differencing transconductance amplifier [4]. It is a really current-mode element whose inputs and outputs are all current form, and it is more suitable for current-mode oscillator design. The CDTA-based oscillators are also reported in [5–13]. However, the works in [5–10] use too many active elements (more than two CDTAs); the works in [12–13] only have one CDTA, but they use more than three passive elements; the works in [5–6, 10–11] lack the electronic adjustability; the works in [5–6, 10–13] suffer from floating capacitors, and they are not suitable for monolithic integration.

In this paper, two single CCCDTA-based current-mode QOs with grounded capacitors are proposed. The proposed QOs only consist of one CCCDTA and two grounded capacitors, which are easy for monolithic integration. The oscillation frequency of the QOs can be electronically controlled by the bias current I_B of the CCCDTA. The QO can also provide two quadrature current outputs, and all the active and passive sensitivities are low.

2. CIRCUIT SYMBOL OF CCCDTA AND ITS CMOS REALIZATION CIRCUIT

Fig.1 (a) shows the symbol of CCCDTA, and Fig.1b is the equivalent circuit of the CCCDTA. The terminal relation of the CCCDTA can be characterized by the following set of equations:

$$v_p = v_n = 0; \quad i_z = i_p - i_n; \quad i_x \pm = \pm g_m v_z = \pm g_m Z_Z i_Z , \tag{1}$$

where p and n are input terminals, z and x are output terminals, g_m is the transconductance gain. The parasitic resistances (R_p and R_n) and the transconductance (g_m) can be expressed as [9]:

$$R_p = R_n = \frac{V_T}{2I_{B1}}, \tag{2}$$

$$g_m = \frac{I_{B2}}{2V_T}. \tag{3}$$

Here, I_{B1} and I_{B2} are the bias currents of the CCCDTA.

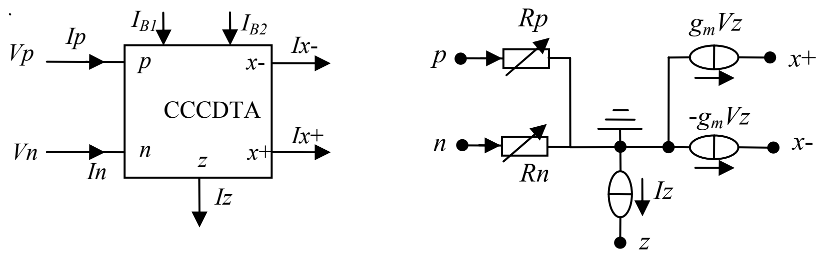


Fig. 1 – The schematic symbol and equivalent circuit of CCCDTA.

a) symbol of CCCDTA; b) equivalent circuit of CCCDTA.

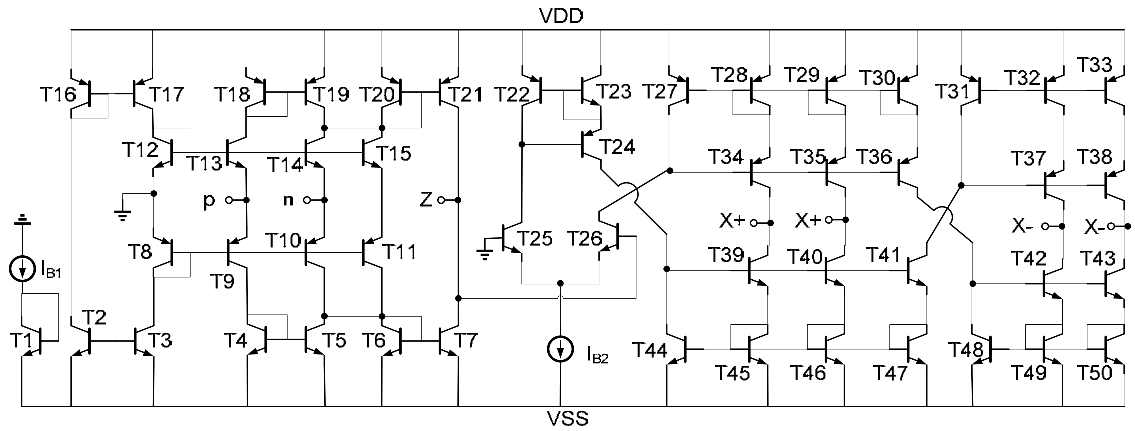
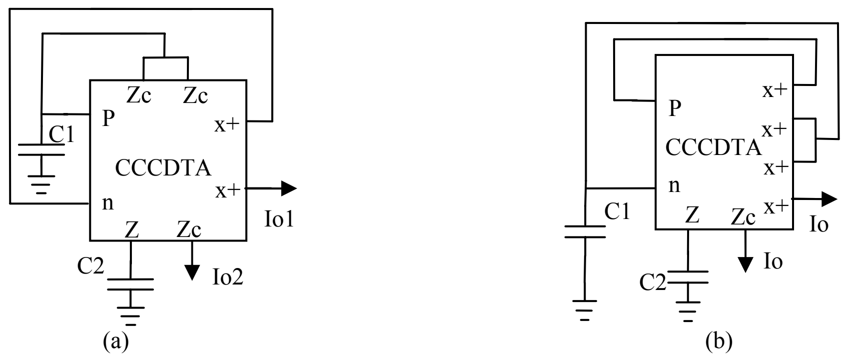


Fig. 2 – BJT-based CCCDTA in this work [9].

The CCCDTA used in this work is shown in Fig. 2.

3. THE PROPOSED QUADRATURE OSCILLATORS

The proposed QOs are shown in Fig. 3, which employ only one CCCDTA and two grounded capacitors.



(a) (b)

Fig. 3 – Proposed current-mode quadrature oscillators.

A routine circuit analysis using equation (1), we can get the characteristic equation of the proposed QOs are:

$$s^2 + (\frac{g_m}{C_2} - \frac{1}{R_p C_1})s + \frac{g_m}{R_p C_1 C_2} = 0\,, \tag{4a}$$

$$s^2 + (\frac{1}{R_n C_1} - \frac{g_m}{C_2})s + \frac{g_m}{R_n C_1 C_2} = 0\,, \tag{4b}$$

where g_m stands for the transconductance of the CCCDTA, R_p and R_n are the parasitic resistance of the terminals p and n of the CCCDTA.

From equation (4), the condition of oscillation (CO) and frequency of oscillation (FO) of the two QOs can be expressed as:

$$\frac{g_m}{C_2} = \frac{1}{R_p C_1}\,, \tag{5a}$$

$$\frac{1}{R_n C_1} = \frac{g_m}{C_2}\,, \tag{5b}$$

$$\omega_0 = \sqrt{\frac{g_m}{R_p C_1 C_2}}\,, \tag{6a}$$

$$\omega_0 = \sqrt{\frac{g_m}{R_n C_1 C_2}}\,. \tag{6b}$$

From Fig. 3, the current transfer function between I_{o1} and I_{o2} is:

$$\frac{I_{o1}(s)}{I_{o2}(s)} = \frac{g_m}{sC_2} = \frac{I_{o1}(j\omega)}{I_{o2}(j\omega)} = \frac{g_m}{\omega C_2} e^{-j90^o}\,, \tag{7a}$$

$$\frac{I_{o1}(s)}{I_{o2}(s)} = \frac{g_m}{sC_2} = \frac{I_{o1}(j\omega)}{I_{o2}(j\omega)} = \frac{g_m}{\omega C_2} e^{-j90^o} \tag{7b}$$

From equation (7), the phase difference between Io1 and I_{o2} is 90^o, and the two output currents of the two QOs are quadrature.

4. NON-IDEAL ANALYSIS

Taking the non-idealities of the CCCDTA into account, the port relations of the non-ideal CCCDTA can be rewritten as:

$$v_p = v_n = 0; \quad i_z = \alpha_p i_p - \alpha_n i_n\,, \tag{8}$$

where $\alpha_p = 1 - \varepsilon_p$ denotes the current tracking error from terminal p to z, and $\alpha_n = 1 - \varepsilon_n$ denotes the current tracking error from terminal n to z of the CCCDTA, respectively. Using equation (8), the characteristic equation of the QOs for the non-ideal case can be written as:

$$s^2 + \left(\frac{\alpha_n g_m}{C_2} - \frac{2\alpha_p - 1}{R_p C_1}\right)s + \frac{\alpha_n g_m}{R_p C_1 C_2} = 0, \tag{9a}$$

$$s^2+\left(\frac{1}{R_nC_1}-\frac{\alpha_p g_m}{C_2}\right)s+\frac{g_m\left(2\alpha_p-\alpha_n\right)}{R_nC_1C_2}=0. \tag{9b}$$

From equation (9), the CO and FO of the proposed QO get modified and are given as:

$$\frac{\alpha_n g_m}{C_2}=\frac{2\alpha_p-1}{R_pC_1}, \tag{10a}$$

$$\frac{1}{R_nC_1}\leq\frac{\alpha_p g_m}{C_2}, \tag{10b}$$

$$\omega_0=\sqrt{\frac{g_m\alpha_n}{R_pC_1C_2}}, \tag{11a}$$

$$\omega_0=\sqrt{\frac{g_m\left(2\alpha_p-\alpha_n\right)}{R_nC_1C_2}}. \tag{11b}$$

The non-ideal active and passive sensitivities of the oscillator can be expressed as:

$$S^{\omega_0}_{C_1,C_2,R_p}=-\frac{1}{2};\quad S^{\omega_0}_{g_m,\alpha_n}=\frac{1}{2};\quad S^{\omega_0}_{\alpha_p,R_n}=0, \tag{12a}$$

$$S^{\omega_0}_{C_1,C_2,R_n}=-\frac{1}{2};\quad S^{\omega_0}_{\alpha_n,g_m}\approx\frac{1}{2};\quad S^{\omega_0}_{\alpha_p}\approx 1. \tag{12b}$$

From the above calculations, it can be seen that all the active and passive sensitivities of the two QOs are less than unity.

5. SIMULATION RESULTS

For example, only the proposed quadrature oscillator in Fig. 3a has been simulated in PSpice with the 0.5μm MIETEC CMOS technology. The CCCDTA is realized as showed in Fig. 2, the supply voltages is ± 2.5V, the bias currents are I_{B1} = 120μA and I_{B2} = 210μA. The parameter values of passive element in Fig. 3a is C_1 = 260pF, C_2 = 85pF.

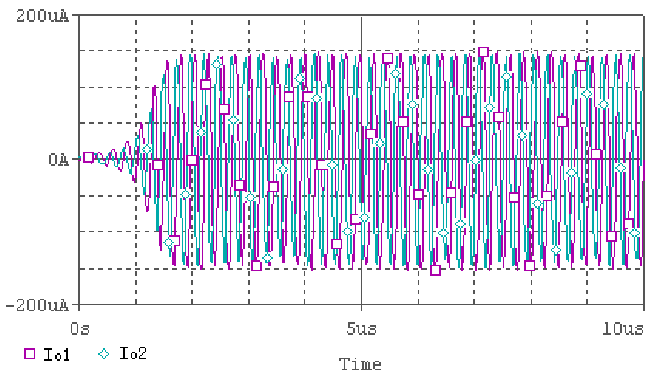


Fig. 4 – The simulated I_{o1} and I_{o2} during initial state.

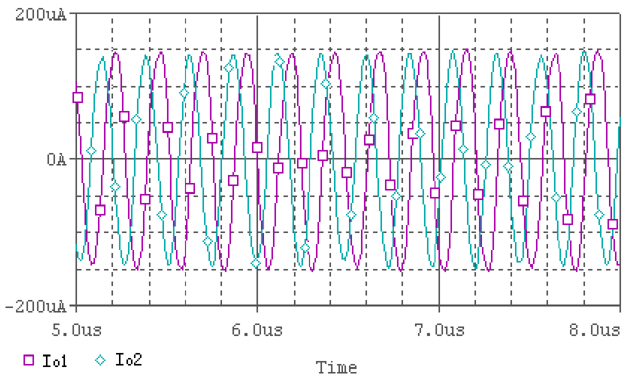


Fig. 5 – The simulated quadrature outputs I_{o1} and I_{o2}.

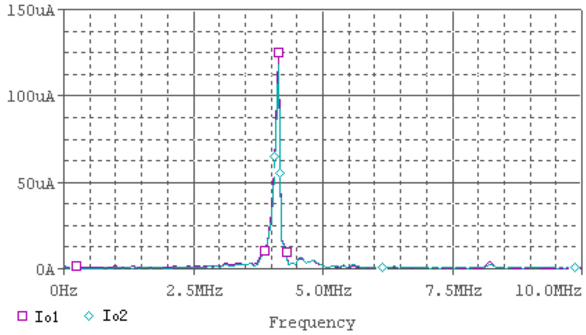


Fig. 6 – The simulated output spectrum of I_{o1} and I_{o2}.

Fig. 4 shows the simulated I_{o1} and I_{o2} during initial state; Fig. 5 shows the two quadrature output waveforms in steady state, and the simulated frequency of the outputs are about 4.13MHz.

Fig. 6 shows the simulated output spectrums of I_{o1} and I_{o2}, and the THD (total harmonic distortion) are 3.59% and 3.86%, respectively.

CONCLUSION

Two single CCCDTA-based current-mode quadrature oscillators are proposed in this paper. The proposed QOs have following advantages: (a) they only consist of one CCCDTA and two grounded capacitors, and they are easy for monolithic integration; (b) the two oscillator are completely resistor-less; (c) all the two QOs can provide two quadrature current outputs; (d) all the active and passive sensitivities of the two oscillators are low.

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