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High Output-impedance Current-mode Quadrature Oscillator Using Single MO-CCCDTA

Danupat Duangmalai[1] Sayamrach Mangkalakeeree[2] Montree Siripruchyanun[3*]
[1]Department of Electronics, Faculty of Nakhonphanom Technical College, Nakhonphanom University, Mung, Nakhonphanom, 48000
[2]Department o of Electronics, Faculty of Thatphanom Industrial and Community College, Nakhonphanom University, Thatphanom, Nakhonphanom, 48110
[3]Department of Teacher Training in Electrical Engineering, Faculty of Technical Education, King Mongkut's University of Technology North Bangkok, Bangkok 10800
E-mail: mts@kmutnb.ac.th[*]

Abstract
This article presents a simple current-mode quadrature oscillator using single multiple-output current controlled current differencing transconductance amplifier (MO-CCCDTA) as active element. The oscillation condition and oscillation frequency can be electronically/ independently controlled. The circuit description is very simple, consisting of merely single MO-CCCDTA, and 2 grounded capacitors. The proposed circuit is suitable for IC architecture. The PSPICE simulation results are depicted, and the given results agree well with the theoretical anticipation.
Keywords: oscillator, MO-CCCDTA

1. Introduction
An oscillator is an important basic building block, which is frequently employed in electrical engineering applications. Among the several kinds of oscillators, a quadrature oscillator is widely used because it can offer sinusoidal signals with 90° phase difference, for example, in telecommunications for quadrature mixers and single-sideband [1]. Presently, the current-mode technique has been more popular than the voltage-mode type. This is due to requirements in low-voltage environments such as in portable and battery-powered equipment. Since a low-voltage operating circuit becomes necessary, the current–mode technique is ideally suited for this purpose, more than the voltage-mode one. Presently, there is a growing interest in synthesizing current-mode circuits because of their many potential advantages, such as larger dynamic range, higher signal bandwidth, greater linearity, simpler circuitry, and lower power consumption [2].

A reported 5-terminals active element, namely current differencing transconductance amplifier (CDTA) [3], seems to be a versatile component in the realization of a class of analog signal processing circuits, especially analogue frequency filters [3-4]. It is really current-mode element whose input and output signals are currents. In addition, output current of CDTA can be electronically adjusted. Besides, the modified version of CDTA which the parasitic resistances at two current input ports can be electronically controlled has been proposed in [5] This CDTA is called current controlled current differencing transconductance amplifier (CCCDTA).

From our survey, it is found that several implementations of oscillator employing CDTAs or CCCDTAs have been reported [6-12]. Unfortunately, these reported circuits suffer from one or more of following weaknesses: use more than two CDTAs or CCCDTAs and excessive use of the passive elements which is not convenient to further fabricate in IC, some reported circuits use multiple-output CDTA or CCCDTA. Consequently, the circuits become more complicated.

The purpose of this paper is to introduce a current-mode quadrature oscillator, based on single MO-CCCDTA. The oscillation condition and oscillation frequency can be adjusted by electronic method. The circuit construction consists of 1 MO-CCCDTA and 2 grounded capacitors. The PSPICE simulation results are also shown, which are in correspondence with the theoretical analysis.

2. Circuit Principle
2.1 A. The Multiple-output current controlled current differencing transconductance amplifier (MO-CCCDTA)
Since the proposed circuit is based on MO-CCCDTA, a brief review of MO-CCCDTA is given in this section. Generally, MO-CCCDTA properties are similar to the conventional CDTA, except that input voltages of MO-CCCDTA are not zero and the MO-CCCDTA has finite input resistances R_p and R_n at the p and n input terminals, respectively. These parasitic resistances are equal and can be controlled by the bias current I_{B1} as shown in the following equation

$$\begin{bmatrix} V_p \\ V_n \\ I_{z1,2} \\ I_{x1} \\ I_{x2} \end{bmatrix} = \begin{bmatrix} R_p & 0 & 0 & 0 & 0 \\ 0 & R_n & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & g_{m1} & 0 \\ 0 & 0 & 0 & 0 & g_{m2} \end{bmatrix} \begin{bmatrix} I_p \\ I_n \\ V_x \\ V_{z1} \\ V_{z1} \end{bmatrix}. \quad (1)$$

For a BJT MO-CCCDTA, the R_p, R_n, g_{m1} and g_{m2} can be expressed to be

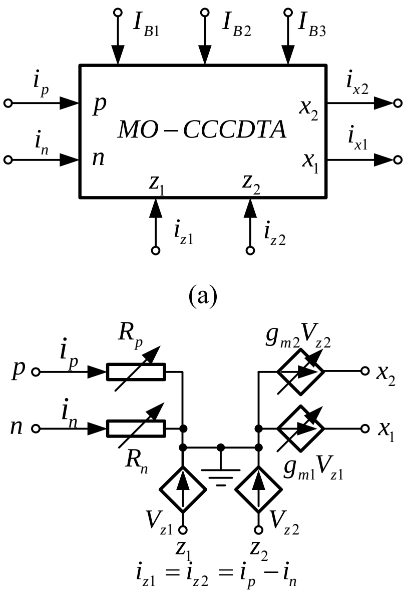
$$R_p = R_n = \frac{V_T}{2I_{B1}}, \quad (2)$$

$$g_{m1} = \frac{I_{B2}}{2V_T}, \quad (3)$$

and

$$g_{m2} = \frac{I_{B3}}{2V_T}. \quad (4)$$

I_B and V_T are the bias current and the thermal voltage, respectively. The symbol and the equivalent circuit of the MO-CCCDTA are illustrated in Fig. 1(a) and (b), respectively.



(b)

Figure 1. MO-CCCDTA (a) Symbol (b) Equivalent circuit.

2.2 The proposed circuit operating as a universal Filter

Fig. 2 demonstrates the circuit scheme of the proposed oscillator. From routine analysis of the circuit in Fig. 2, the following characteristic equation is obtained

$$s^2C_1C_2R_n + s\left(C_2 - C_1g_{m1}R_n\right) + g_{m2} - g_{m1} = 0. \quad (5)$$

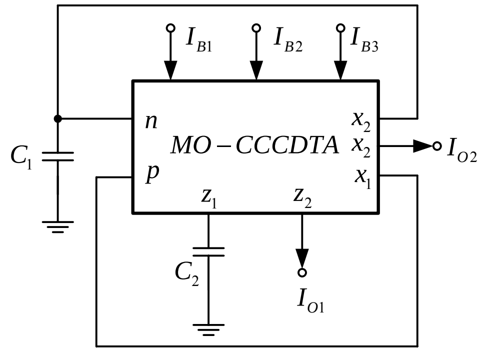


Figure 2. Proposed quadrature oscillator.

From Eq. (2), it can be seen that the proposed circuit can produce oscillations if the oscillation condition is fulfilled:

$$C_2 = C_1g_{m1}R_n. \quad (6)$$

For example, this condition can be achieved by setting

$$C_1 = C_2 \text{ and } g_{m1} = 1/R_n. \quad (7)$$

Then the characteristic equation of the system becomes

$$s^2C_1C_2R_n + g_{m2} - g_{m1} = 0. \quad (8)$$

From Eq. (8), the oscillation frequency is as follows:

$$\omega_0 = \sqrt{\frac{g_{m2} - g_{m1}}{C_1C_2R_n}}. \quad (9)$$

Substituting the intrinsic resistances and transconductance as depicted in Eqs. (2), (3) and (4) in to Eqs. (7) and (9), it yields the oscillation condition and oscillation frequency as follows:

$$C_1 = C_2 \text{ and } 4I_{B1} = I_{B2}, \quad (10)$$

and

$$\omega_0 = \frac{1}{V_TC}\sqrt{I_{B1}\left(I_{B3} - I_{B2}\right)}. \quad (11)$$

From Eqns. (10) and (11), it can be seen that the oscillation condition can be adjusted independently from the oscillation frequency by varying I_{B1} and I_{B2} while the oscillation frequency can be adjusted by I_{B3}. From the circuit in Fig. 2, the current transfer function from I_{o2} to I_{o1} is

$$\frac{I_{o2}(s)}{I_{o1}(s)} = \frac{g_{m2}}{sC_2}. \quad (12)$$

For sinusoidal steady state, Eq. (12) becomes

$$\frac{I_{o2}(j\omega)}{I_{o1}(j\omega)} = \frac{g_m}{\omega C_2}e^{-j90^\circ}. \quad (12)$$

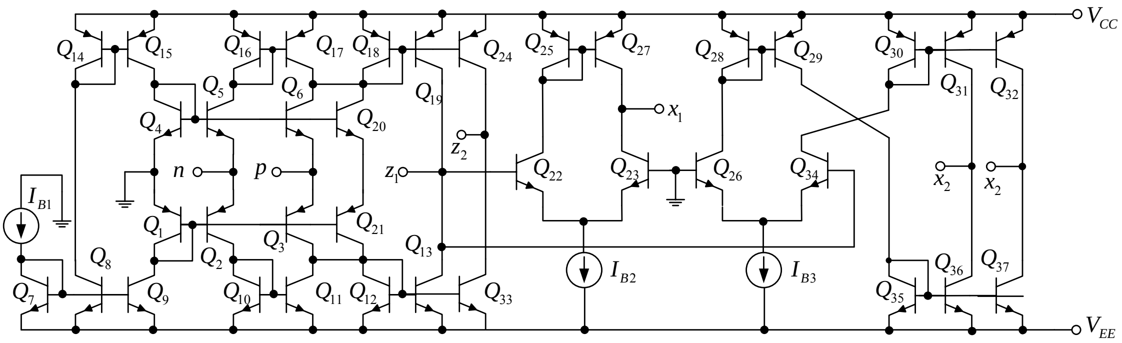


Figure 3. Internal construction of MO-CCCDTA

The phase difference ϕ between I_{o1} and I_{o2} is

$$\phi = -90° \tag{13}$$

ensuring the currents I_{O2} and I_{O1} to be in quadrature form.

3. Simulation Results

To prove the performances of the proposed circuit, a PSPICE simulation was performed for examination and experimentation. The PNP and NPN transistors employed in the proposed circuit were simulated by respectively using the parameters of the PR200N and NR200N bipolar transistors of ALA400 transistor array from AT&T [13]. Fig. 3 depicts the respective schematic description of the MO-CCCDTA used in the simulations.

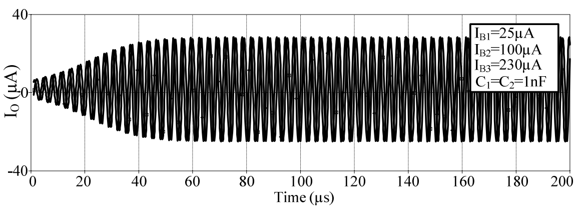


Figure 4. The current-mode sinusoidal signal in transition region

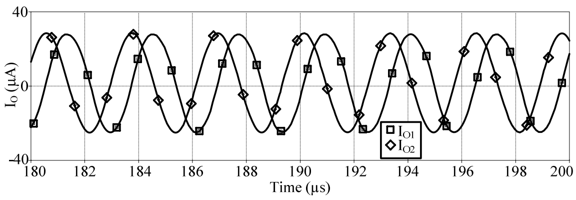


Figure 5. Simulation result of the quadrature outputs

The circuit was biased with ±1.5V supply voltages, $C_1=C_2=1nF$, $I_{B1}=25\mu A$, $I_{B2}=100\mu A$ and $I_{B3}=230\mu A$. This yields the oscillation frequency of 311kHz. The calculated value of this parameter from Eq. (11) yields 349kHz (deviated by 10.88%). Load of the circuit is 1Ω of resistor. Figs. 4 and 5 show simulated quadrature output waveforms. Fig. 6 shows the simulated output spectrum, where the total harmonic distortion (THD) is about 1.21%. The output impedances at Z_2 and X_2 terminals are 123kΩ and 25kΩ, respectively.

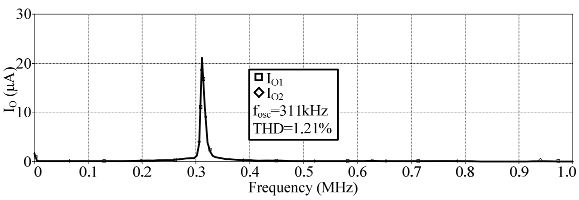


Figure 6. Simulation result of the output spectrum

4. Conclusions

A current-mode quadrature oscillator based on single MO-CCCDTA has been presented. The features of the proposed circuit are that: oscillation frequency an oscillation condition can be orthogonally adjusted via input bias current; the proposed circuit, due to high output impedances, enables easy cascading in current mode: it consists of single MO-CCCDTA and 2 grounded capacitors, which is convenient to fabricate. The PSPICE simulation results agree well with the theoretical anticipation.

References

[1] Khan, I.A. and Khawaja, S. 2000. An integrable gm-C quadrature oscillator. International Journal of Electronics, 87: 1353-1357.

[2] Toumazou, C., Lidgey, F.J. and Haigh, D.G. 1990. Analogue IC design: the current-mode approach, London: Peter Peregrinus.

[3] Biolek, D. 2003. CDTA – building block for current-mode analog signal processing. In Proceedings of the European conference on circuit theory and design 2003, Krakow, Poland, 397–400.

[4] D. Biolek, "CDTA – building block for current-mode analog signal processing," In Proceedings of the European conference on circuit theory and design 2003, Krakow, Poland, pp. 397–400, 2003.

[5] Biolek, D. and Biolkova, V. 2003. Universal biquads using CDTA elements for cascade filter

design. In Proceeding of the 13th International Multiconference on Circuits, Systems, Communications & Computers (CSCC2003), Corfu, Greece, 8–12.

[6] Siripruchyanun, M. and Jaikla, W. 2007. Realization of current controlled current differencing transconductance amplifier (CCCDTA) and its applications. ECTI Transactions on Electrical Engineering, Electronics, and Communications, 5: 41-50.

[7] Jaikla W. and Siripruchyanun, M. 2007. CCCDTAs-based versatile quadrature oscillator and universal biquad filter, Proceedings of ECTI2007 Conference, Chieng Rai, Thailand, May 9-11, 2007: 1065-1068.

[8] Jaikla W. and Siripruchyanun, M. 2006. A versatile quadrature oscillator and universal biquad filter using dual-output current controlled current differencing transconductance amplifier, Proceedings of ISCIT2006, Bangkok, Thailand, Oct. 18-20, 2006: 1072-1075.

[9] Keskin, A.U. and Biolek, D. 2003. Current mode quadrature oscillator using current differencing transconductance amplifiers (CDTA). IEE Proceedings-Circuits, Devices and Systems, 153: 214–218.

[10] Biolek, D., Biolkova, V. and Keskin, AU. 2006. Current mode quadrature oscillator using two CDTAs and two grounded capacitors. In Proceedings of the 5th WSEAS International Conference on System Science and Simulation in Engineering, Tenerife, Canary Islands, Spain, 368-370.

[11] Tangsrirat, and W. Tanjaroen, W. 2008. Current-mode multiphase sinusoidal oscillator using current differencing transconductance amplifiers. Circuits Systems and Signal Processing. 81–93.

[12] Tangsrirat, W., Tanjaroen, W. and Pukkalanun, T. 2008. Current-mode multiphase sinusoidal oscillator using CDTA-based allpass sections," International Journal of Electronics and Communications (AEU), online first.

[13] Frey, D. R. 1993. Log-domain filtering: an approach to current-mode filtering. IEE Proceeding of Circuit Devices Systems, 140: 406-416.