An Electronic Controllable, Simple Current-mode Oscillator Using Single MO-CCCCTA and Grounded Capacitors

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***Abstract*- This article presents a simple current-mode oscillator using single multiple-output current controlled current conveyor transconductance amplifier (MO-CCCCTA) 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-CCCCTA, 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. The maximum power consumption is approximately 2.51mW at ±1.5V power supply voltages.**

I. INTRODUCTION

An oscillator is an important basic building block, which is frequently employed in electrical engineering applications for example, in telecommunications, medical instrument, electronic laboratory, control system [1]. 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].

The high-output impedance of current-mode oscillators are of great interest because they make it easy to drive loads and they facilitate cascading without using a buffering device [3-5]. Moreover, circuits that employ only grounded capacitors are advantageous from the point of view of integrated circuit implementation [5-7].

From our survey, we found that several implementations of current-mode oscillators employing different high-performance active building blocks, such as, Four-Terminal Floating Nullors (FTFN) [3-4], current conveyors [6], current follower [8-19], OTAs [10, 16], differencing voltage current conveyor (DVCCs) [11], current controlled current differencing buffered amplifiers (CCCDBAs) [12], current controlled current differencing transconductance amplifiers (CCCDTAs) [13-14] and fully-differential second-generation current conveyor (FDCCII) [15], have been reported. Unfortunately, these reported circuits suffer from one or more of following weaknesses:

- Excessively use the passive elements, especially external resistors [3-4, 6, 11].
- Cannot be electronic controllable [3-4, 6, 8-9, 11].
- Output impedances are not high [3-4, 6, 8-10, 16].
- Use of a floating capacitor, which is not convenient to further fabricate in IC [11].
- The oscillation conditions and oscillation frequencies cannot be independently controllable [8-10].

The current conveyor transconductance amplifier (CCTA) is a reported active component, especially suitable for a class of analog signal processing [17]. The fact that the device can operate in both current and voltage-modes provides flexibility and enables a variety of circuit designs. In addition, it can offer advantageous features such as high-slew rate, higher speed, wide bandwidth and simple implementation. However, the CCTA cannot be controlled by the parasitic resistance at X (R_x) port so when it is used in some circuits, it must unavoidably require some external passive components, especially the resistors. This makes it not appropriate for IC implementation due to occupying more chip area, high power consumption and without electronic controllability. On the other hand, the recently introduced current-controlled current conveyor transconductance amplifier (CCCCTA) [18] has the advantage of electronic adjustability over the CCTA.

The purpose of this paper is to introduce a current-mode oscillator, based on single MO-CCCCTA. The oscillation condition and oscillation frequency can be adjusted by electronic method. The circuit construction consists of 1 MO-

CCCCTA and 2 grounded capacitors. The PSPICE simulation results are also shown, which are in correspondence with the theoretical analysis.

II. Circuit Principles

A. Basic Concept of MO-CCCCTA

Since the proposed circuit is based on MO-CCCCTA, a brief review of MO-CCCCTA is given in this section. Generally, MO-CCCCTA properties are similar to the conventional CCTA, except the MO-CCCCTA has finite input resistance R_x at the x input terminal. This parasitic resistance can be controlled by the bias current I_{B1} as shown in the following equation

$$\begin{bmatrix} I_y \\ V_x \\ I_{z1,z2} \\ I_{o1} \\ I_{o2} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ R_x & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & g_{m1} & 0 \\ 0 & 0 & 0 & g_{m2} \end{bmatrix} \begin{bmatrix} I_x \\ V_y \\ V_{z1} \\ V_{z1} \\ V_{z2} \end{bmatrix}. \quad (1)$$

For a BJT MO-CCCCTA, the R_x, g_{m1} and g_{m2} can be expressed to be

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

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

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-CCCCTA are illustrated in Fig. 1(a) and (b), respectively.

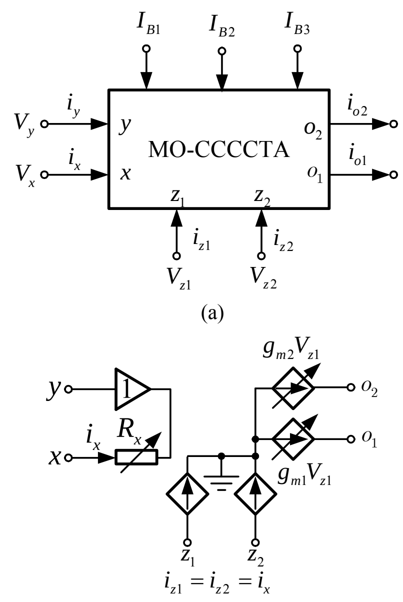

Figure 1. MO-CCCCTA (a) Symbol (b) Equivalent circuit

B. The proposed simple oscillator

Fig. 2 demonstrates the circuit scheme of the proposed oscillator. It consists of single MO-CCCCTA and 2 grounded capacitor. From routine analysis of the circuit in Fig. 2, the following characteristic equation is obtained

$$s^2C_1C_2R_x + s\left(C_2 - C_1g_{m1}R_x\right) + g_{m2} - g_{m1} = 0. \quad (5)$$

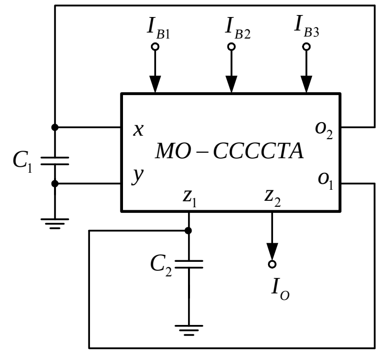

Figure 2. Proposed simple oscillator

From Eq. (5), it can be seen that the proposed circuit can produce oscillations if the oscillation condition is fulfilled:

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

For example, this condition can be achieved by setting

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

Then the characteristic equation of the system becomes

$$s^2C_1C_2R_x + g_{m2} - g_{m1} = 0. \quad (8)$$

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

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

Substituting the intrinsic resistance 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

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

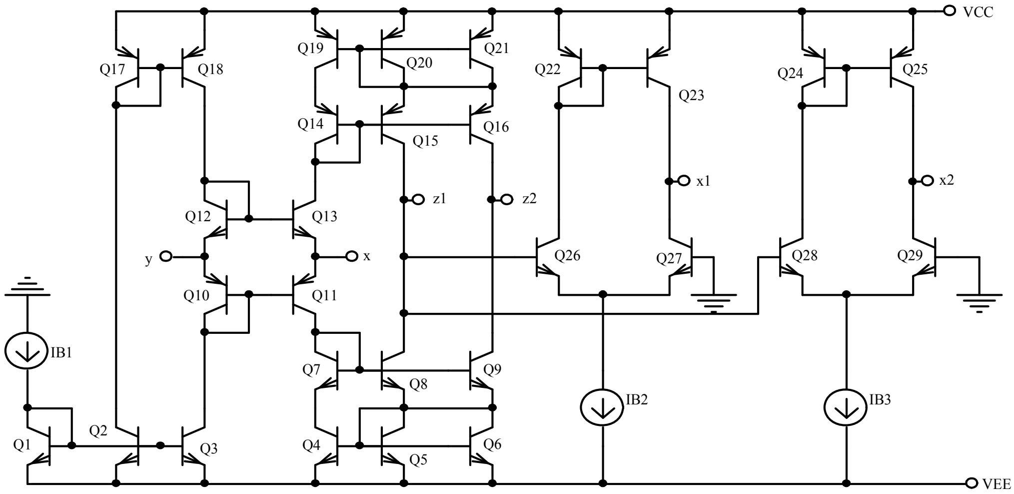

Figure 3. Internal construction of MO-CCCCTA

From Eqs. (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}.

C. Non-ideal case

For non-ideal case, the V_x, I_z, I_{O1} and I_{O2} of MO-CCCCTA can be respectively characterized by

$$V_x = \beta V_y + I_x R_x \,, \tag{12}$$

$$I_z = \alpha I_x \,, \tag{13}$$

$$I_{o1} = \gamma_1 g_{m1} V_{z1} \,, \tag{14}$$

and

$$I_{o2} = \gamma_2 g_{m2} V_{z1} \,. \tag{15}$$

α , γ and β are transferred errors deviated from one. For the non-ideal case, reanalyzing the proposed filter circuit in Fig. 2 yields characteristic equation

$$s^2 C_1 C_2 R_x + s\left(C_2 - \gamma_1 C_1 g_{m1} R_x\right) + \alpha\gamma_2 g_{m2} - \gamma_1 g_{m1} = 0 \,. \tag{16}$$

For non-ideal case, the oscillation condition and oscillation frequency can be expressed to be

$$C_2 = \gamma_1 C_1 g_{m1} R_x \,, \tag{17}$$

and

$$\omega_0 = \sqrt{\frac{\alpha\gamma_2 g_{m2} - \gamma_1 g_{m1}}{C_1 C_2 R_n}} \,. \tag{18}$$

Practically, the α , γ , and β originate from intrinsic resistances and stray capacitances in the MO-CCCCTA. These errors affect the sensitivity to temperature and high frequency response of the proposed circuit, thus the MO-CCCCTA should be carefully designed to minimize these errors. Consequently, these deviations would be very small and can be ignored.

III. 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 [19]. Fig. 3 depicts the respective schematic description of the MO-CCCCTA used in the simulations. The circuit was biased with ±1.5V supply voltages, C_1=C_2=1nF, I_{B1}=25μA, I_{B2}=105μA and I_{B3}=200μA. This yields the oscillation frequency of 264kHz. The calculated value of this parameter from Eq. (11) yields 298kHz (deviated by 11.44%). Load of the circuit is 1Ω of resistor. Figs. 4 and 5 show simulated output waveforms. Fig. 6 shows the simulated output spectrum, where the total harmonic distortion (THD) is about 2.51%. The output impedances at Z_1 terminal is 123kΩ. Fig. 7 depicts the plots of the simulated and theoretical oscillation frequency versus the bias currents: I_{B3} , where C_1 and C_2 are identical to 0.1nF, 1nF and 10nF. It is seen that the simulation results are in accordance with the theoretical analysis as shown in Eq. (11). Maximum power consumption is about 2.51mW.

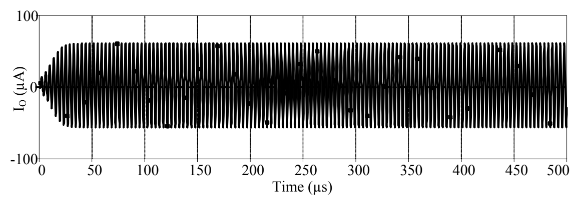

Figure 4. The current-mode sinusoidal signal in transition region

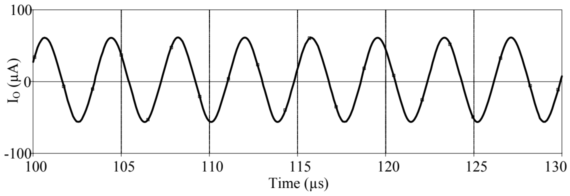

Figure 5. Simulation result of the output waveform

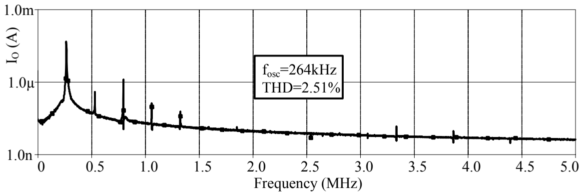

Figure 6. Simulation result of the output spectrum

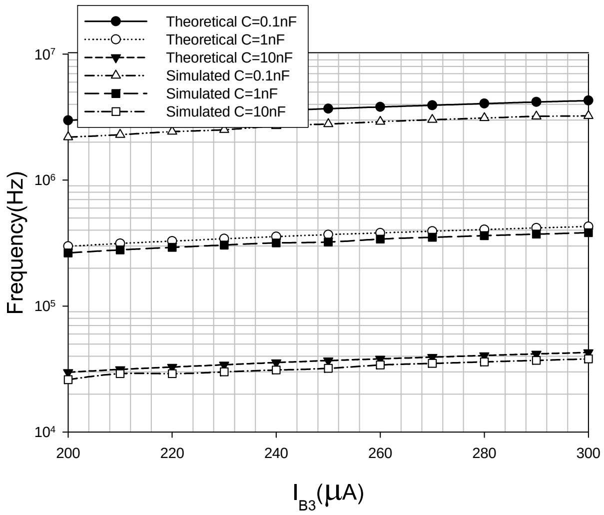

Figure 7. Oscillation frequencies against I_{B3} in the proposed circuit for various capacitances

IV. CONCLUSION

A simple current-mode oscillator based on single MO-CCCCTA 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 impedance, enables easy cascading in current mode: it consists of single MO-CCCCTA and 2 grounded capacitors, which is convenient to fabricate. The PSPICE simulation results agree well with the theoretical anticipation.

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This article presents a simple current-mode oscillator using single multiple-output current controlled current conveyor transconductance amplifier (MO-CCCCTA) 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-CCCCTA, 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. This paper presents a universal current-controlled current-mode biquad filter employing current controlled cur-rent conveyor trans-conductance amplifiers (CCCCTAs). The proposed filter employs only three MO-CCCCTAs and two grounded capacitors. The proposed filter can simultaneously realize low pass (LP), band pass (BP), high pass (HP), band reject (BR) and all pass (AP) responses in current form by choosing appropriate current output branches. In addition, the pole frequency and quality factor of the proposed filter circuit can be tuned independently and electronically over the wide range by a This article presented current-mode sinusoidal oscillator using CCCCTA. The proposed circuit is very simple comprise of single CCCCTA and has 2 grounded capacitors without external passive resistor. It is suitable for integrated circuit implementation. Furthermore, the proposed circuit can be electrically tuned for oscillation condition and frequency.