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Two Tunable Sinusoidal Quadrature Oscillators Employing One DDCC and Two OTAs

CHUN-LI HOU* AND YU-SHU CHEN

Department of Electronic Engineering
Chung Yuan Christian University
Chung-Li 32023, Taiwan, R.O.C.

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ABSTRACT

In this paper, two novel tunable sinusoidal quadrature oscillators employing one DDCC and two OTAs are presented. The proposed circuits both use a DDCC (Differential Difference Current Conveyor), two OTAs (Operational Transconductance Amplifiers), two grounded resistors, and two grounded capacitors. The proposed circuits have been simulated by Hspice using 0.35μm CMOS technology. The main advantages of the circuits are: (1) uncoupled oscillator, (2) wide frequency range, (3) frequency tunability, (4) all grounded passive components ideally for integration, (5) the sensitivities are all less than unity, (6) full use of the capability of the DDCC, and (7) acquirement of two sinusoidal waveforms with about 90°C phase difference.

Key words: *DDCC, OTA, Oscillator.*

I. Introduction

Sinusoidal oscillators are widely used in communication, control systems, signal processing, instrumentation, and measurement systems. Recently, many variable frequency sinusoidal oscillators have been proposed using active-R, active-C and active-RC techniques [1-5]. In general, current-mode circuits are receiving much attention for their potential advantages such as inherent wider band-width, simpler circuitry, and wider dynamic range [6]. Therefore, the proposed sinusoidal oscillators are based on current-mode active components as DDCC (Differential Difference Current Conveyor) and OTAs (Operational Transconductance Amplifiers). The proposed circuits both use a DDCC, two OTAs, two grounded resistors, and two grounded capacitors.

II. Circuit description

The Differential Difference Current Conveyor (DDCC) was proposed by [7]. In this paper, the schematic implementation for positive type DDCC with CMOS technology in [8] is shown in Fig. 1, and the ideal characteristic equations are given by

$$\begin{cases} I_{Y1} = I_{Y2} = I_{Y3} = 0 \\ V_X = V_{Y1} - V_{Y2} + V_{Y3} \\ I_X = \pm I_Z \end{cases} \quad (1)$$

The DDCC is convenient to design circuits because that V_x acts like a summer to combine three input voltages V_{Y1}, V_{Y2}, and V_{Y3}.

The Operational Transconductance Amplifier (OTA) is basically an op-amp without an output buffer. In this paper, the schematic implementation for OTA with CMOS technology in [9] is shown as Fig. 2, and the ideal characteristic function is given by (2). The OTA provides highly linear electronic tunability and wide tunable range of its transconductance gain. It has been found to be versatile and flexible to realize various applications because the transconductance gains of OTA may be played as a resistor.

$$I_O = (V_+ - V_-) \cdot g_m \quad (2)$$

The circuit of the first proposed oscillator is shown

* Author for Correspondence: Chun-Li Hou
E-mail: clhou@cycu.edu.tw

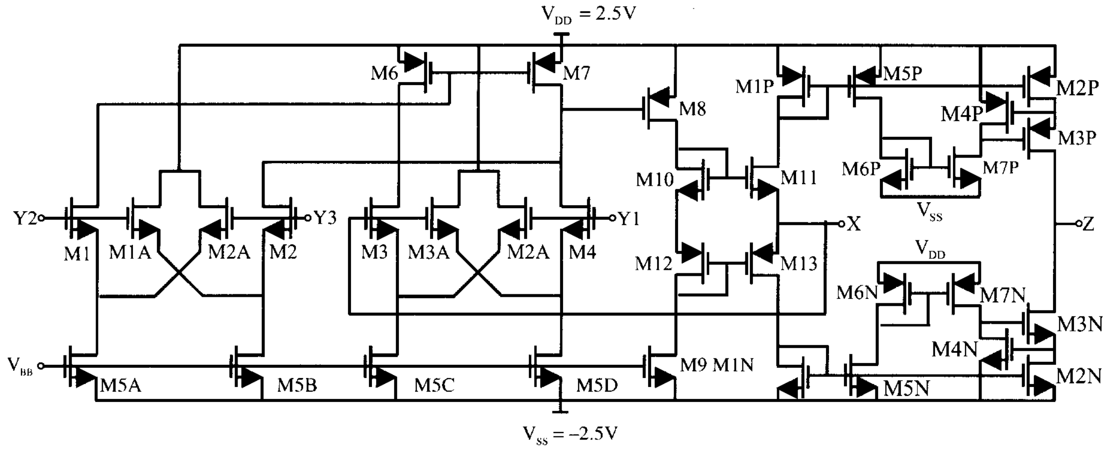

Fig. 1 The schematic implementation for positive type DDCC.

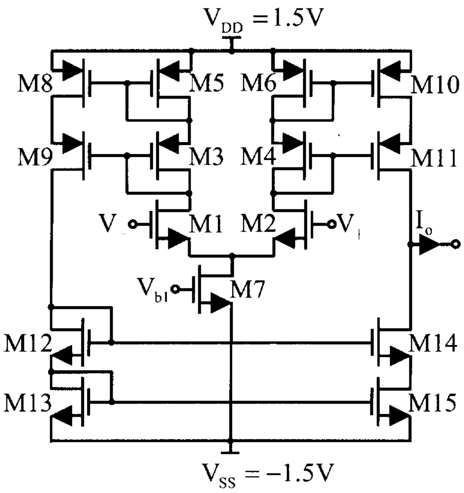

Fig. 2 The schematic implementation for OTA.

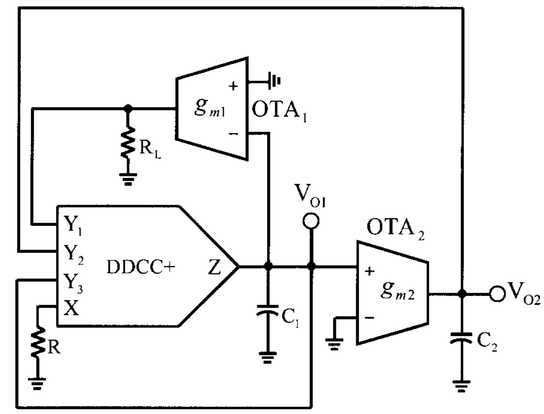

Fig. 3 The circuit of the first proposed oscillator.

in Fig. 3. The circuit uses a DDCC (Differential Difference Current Conveyor), two OTAs (Operational Transconductance Amplifiers), two grounded resistors, and two grounded capacitors.

Assuming the DDCC and OTAs are ideal, the matrix form of the circuit in Fig. 3 can be expressed as

$$\begin{bmatrix} \dfrac{dV_{O1}}{dt} \\ \dfrac{dV_{O2}}{dt} \end{bmatrix} = \begin{bmatrix} \dfrac{1-g_{m1}R_L}{RC_1} & \dfrac{-1}{RC_1} \\ \dfrac{g_{m2}}{C_2} & 0 \end{bmatrix} \begin{bmatrix} V_{O1} \\ V_{O2} \end{bmatrix} \qquad (3)$$

and according to equation (3), the condition of oscillation (CO) and the frequency of oscillation (FO) are given by

$$\text{CO: } g_{m1}R_L = 1 \qquad (4)$$

and

$$\text{FO} = f_0 = \frac{\sqrt{g_{m2}/(RC_1C_2)}}{2\pi} \qquad (5)$$

From equation (4), the condition of oscillation can be adjusted by transconductance gain g_{m1} or/and grounded resistor R_L. Since in equation (5) the frequency of oscillation can be tuned by transconductance gain g_{m2} or/ and grounded capacitor C_2. For above descriptions, the frequency of oscillation and condition of oscillation can be independently controlled. From equation (5), the active and passive f_0 sensitivities are obtained as

$$S^{f_0}_{R_L, g_{m1}} = 0 \text{ and } S^{f_0}_{g_{m2}} = -S^{f_0}_{R, C_1, C_2} = \frac{1}{2} \qquad (6)$$

where the active and passive f_0 sensitivities are all less than unity. In this circuit, the use of all grounded passive components is particularly attractive for integrated circuit implementation.

The circuit of the second proposed oscillator is shown in Fig. 4. It uses the same amount of active and

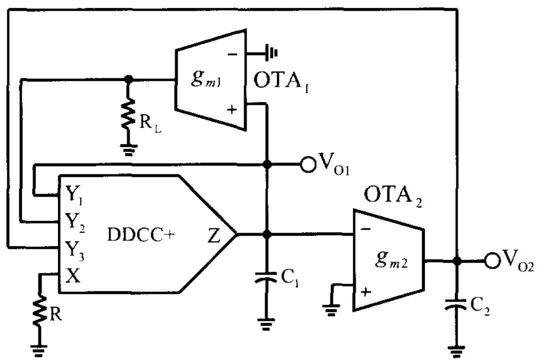

Fig. 4 The circuit of the second proposed oscillator.

passive components as the first proposed oscillator.

If the DDCC and OTA are ideal, the matrix form of the circuit in Fig. 4 can be expressed as

$$\begin{bmatrix} \frac{dV_{O1}}{dt} \\ \frac{dV_{O2}}{dt} \end{bmatrix} = \begin{bmatrix} \frac{1 - g_{m1}R_L}{RC_1} & \frac{1}{RC_1} \\ -\frac{g_{m2}}{C_2} & 0 \end{bmatrix} \begin{bmatrix} V_{O1} \\ V_{O2} \end{bmatrix} \qquad (7)$$

where matrix form is different with equation (3) but the condition of oscillation (CO) and frequency of oscillation (FO) are equivalent to the equation (4) and (5), respectively. The active and passive f_0 sensitivities are also the same as equation (6). The DDCC and OTAs of proposed circuits are implemented by Fig. 1 and Fig. 2.

III. Simulation results

The circuits of Fig. 3 and Fig. 4 have been simulated by Hspice using TSMC 0.35μm CMOS technology. Fig. 5 shows the simulated results of V_{O1} and V_{O2} of Fig. 3 and Fig. 4 with R_L = 1KΩ, R = 40KΩ, $C_1 = C_2 = C$ = 10pF, VBB of Fig. 1 = -1.7V, and V_{b1} of Fig. 2 = -0.4V. The results of Fig. 5 show that the oscillatory frequency of Fig. 3 and Fig. 4 are 3MHz and

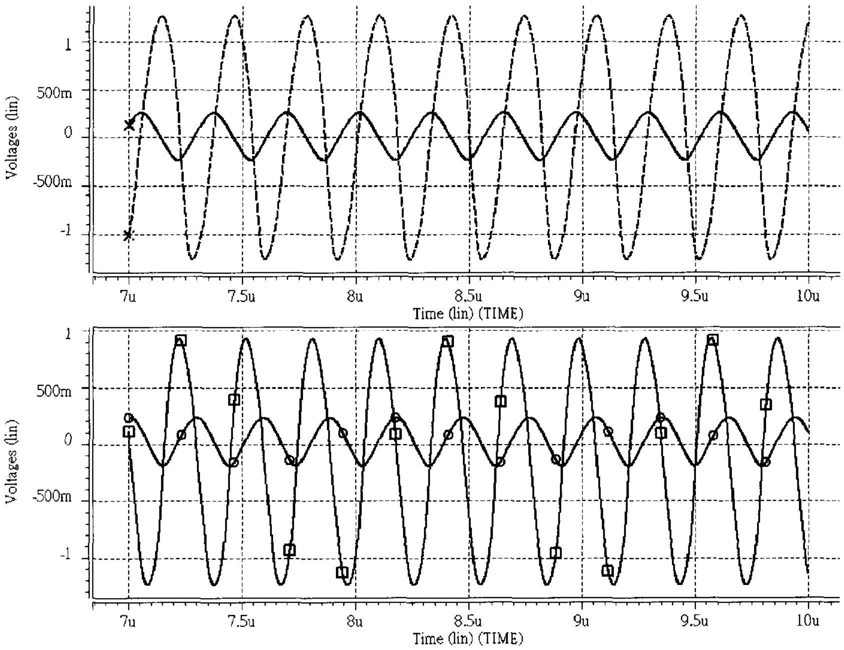

Fig. 5 Simulated results of V_{O1} and V_{O2} of Fig. 3 and Fig. 4 with R_L = 1KΩ, R = 20KΩ, $C_1 = C_2 = C$ =10pF, V_{BB} of Fig. 1 = -1.7V, V_{b1} of Fig. 2 = -0.4V. –: V_{O1} of Fig. 3, ---: V_{O2} of Fig. 3, ○: V_{O1} of Fig. 4, □: V_{O2} of Fig. 4.

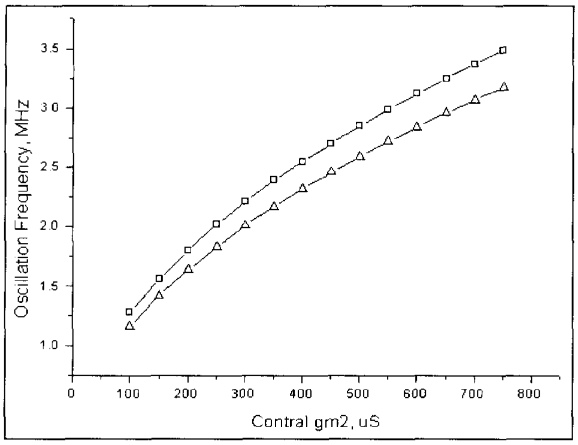

Fig. 6 Variation in the frequency of oscillation for Fig. 3 and Fig. 4 and g_{m2} is varied from 100uS to 750uS. △: Oscillation frequency of Fig. 3, □: Oscillation frequency of Fig. 4.

3.3MHz, respectively. The THD, (Total Harmonic Distortion) of Fig. 3 and Fig. 4 are 6.685% and 7.052%. Fig. 6 shows the results of Fig. 3 and Fig. 4 with R_L = 1KΩ, R = 40KΩ, $C_1 = C_2 = C$ = 10pF, VBB of Fig. 1 = -1.7V and gm2 is varied from 100uS to 750uS with an error of 3%.

IV. Conclusion

In this paper, the two novel tunable sinusoidal quadrature oscillators have been presented. The performance of the proposed circuits is demonstrated by Hspice simulations. All of simulation experimental results confirm the theoretical analysis. The proposed circuits are expected to be useful for applications in communication, instrumentation and measurement systems. For implement IC, we can use the bandgap voltage reference circuits to provide the bias voltage in the active components of proposed circuits.

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兩個使用單一 DDCC 及兩個 OTA 所組成的可調式正交弦波振盪器

侯 俊 禮　　陳 玉 樹
中原大學電子工程學系
中壢市 320 中北路 200 號

摘 要

此篇論文提出了兩個使用單一差動差分電流傳輸器(Differential Difference Current Conveyor, DDCC)以及兩個運算轉導放大器(Operational Transconductance Amplifier, OTA)所組成的可調式正交弦波振盪器。被提出的電路都是使用一個DDCC、兩個OTA、兩個接地電阻器和兩個接地電容器所組成。電路驗證部分是使用 Hspice 軟體並套用 0.35μm CMOS 製程所模擬之結果。這些電路的優點如下：(1)可獨立調整、(2)頻寬範圍大、(3)頻率可調整、(4)被動元件都接地適合積體化、(5)靈敏度皆小於1、(6)完整使用DDCC的接腳、(7)兩個輸出電壓的相位差爲 90°。

關鍵詞：差動差分電流傳輸器，運算轉導放大器，振盪器。