Simple Quadrature Sinusoidal Oscillator with Grounded Elements

P. Pinkaew, P. Suwanjan, and W. Jaikla

Abstract—This paper presents the current-mode quadrature sinusoidal oscillator employing current controlled current differencing transconductance amplifier (CCCDTA) as active element. The proposed oscillator can provide 2 sinusoidal waveforms with high output impedance which makes the proposed oscillator can directly drive load or cascade in current mode circuit without any current buffers. The condition of oscillation (CO) and frequency of oscillation (FO) can be orthogonally controlled by mean of electronic tuning. The circuit consists of only single CCCDTA and three grounded passive elements which are ideal for implementation on an integrated circuit (IC) chip. The predicted results confirmed with Pspice simulation using BJT technology are agreed with theoretical analysis.

Index Terms—Quadrature oscillator, Integrated circuit, CCCDTA, Current-mode.

I. INTRODUCTION

The oscillators which generate sinusoidal wave form are extremely useful for several systems for example in telecommunication, instrument and measurement system, power electronics etc. Especially, the oscillators that provide 2 sinusoidal signals with 90 degree phase difference are frequently used in telecommunication system for quadrature mixer, single sideband generator etc. [1].

Recently, the design of analog signal processing circuits in current-mode has been receiving considerable attention due to their potential advantages for inherently wide bandwidth, higher slew-rate, greater linearity, wider dynamic range, simple circuit and low power consumption [2]-[5]. The attention has turned to use the active building block (ABB) such as the operational amplifier (Opamp), the operational transconductance amplifier (OTA), current feedback opamp (CFOA), the first generation of current conveyor (CCI), the second generation of current conveyor (CCII), the current differencing buffer amplifier (CDBA) and many other active blocks [6]-[8]. The current differencing transconductance amplifier (CDTA) [9] is the interesting current-mode active ABB since it is a versatile component in the realization of a class of analog signal processing circuits, especially analogue frequency filters [10]-[11]. 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 [12]. This CDTA is called

current controlled current differencing transconductance amplifier (CCCDTA).

From literature survey, it is found that several implementations of oscillator employing CDTAs or CCCDTAs have been reported [13]-[24]. 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.
- Use floating capacitors.
- Cannot provide quadrature signal with high output impedance

The aim of this paper is to introduce a current-mode quadrature sinusoidal oscillator based on single CCCDTA. The features of the proposed circuit are the following:

- Use only single active element.
- Electronic adjustment of the CO and FO.
- High-impedance of current outputs.
- Use grounded elements which easy to implement an integrated circuit.
- Orthogonal control of CO and FO.

II. PRINCIPLE OF OPERATIONS

A. Basic Concept of Main Active Element

The CCCDTA is modified from the well-known CDTA introduced by Biolek [9]. The schematic symbol and the ideal behavioral model of the CCCDTA are shown in Fig. 1(a) and (b). The characteristics of the ideal CCCDTA are represented by the following hybrid matrix:

$$\begin{bmatrix} V_p \\ V_n \\ I_z \\ I_x \end{bmatrix} = \begin{bmatrix} R_p & 0 & 0 & 0 \\ 0 & R_n & 0 & 0 \\ 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & \pm g_m \end{bmatrix} \begin{bmatrix} I_p \\ I_n \\ V_x \\ V_z \end{bmatrix} \quad (1)$$

For the CCCDTA implemented by a BJT technology, the parasitic resistances (R_p and R_n) and transconductance (g_m) can be expressed as

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

and

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$$g_m = \frac{I_{B2}}{2V_T} \quad (3)$$

V_T is the thermal voltage. I_{B1} and I_{B2} are the bias current used to control the parasitic resistances and transconductance, respectively. The symbol and the equivalent circuit of the CCCDTA are illustrated in Fig. 1 and Fig. 2, respectively. In general, CCCDTA can contain an arbitrary number of z terminals, called z_c (z -copy) terminal [25]. The internal current mirror provides a copy of the current flowing out of the z terminal to the z_c terminal.

Fig. 1. Symbolic notation of CCCDTA

Fig. 2. Equivalent circuit of CCCDTA

B. Proposed Current-Mode Quadrature Oscillator

The proposed current-mode oscillator is shown in Fig. 3. It consists of single CCCDTA, single resistor and two grounded capacitors. The output currents I_{out1} and I_{out2} are high output impedance which can be directly drive load without additional current buffer and 90° phase difference. Considering the proposed oscillator and using the CCCDTA properties as described in above section, the characteristic equation is obtained as

$$s^2 + s \left(\frac{1 - Rg_m}{C_2 R} \right) + \frac{g_m}{C_1 C_2 R_p} = 0 \quad (4)$$

From (4), the condition of oscillation and frequency of oscillation can be written as

$$1 = Rg_m \quad (5)$$

$$\omega_{osc} = \sqrt{\frac{g_m}{C_1 C_2 R_p}} \quad (6)$$

If R_p and g_m are equal to (2) and (3), respectively, the CO and FO are re-written as

$$1 = R \frac{I_{B2}}{2V_T} \quad (7)$$

$$\omega_{osc} = \frac{1}{V_T} \sqrt{\frac{I_{B1} I_{B2}}{C_1 C_2}} \quad (8)$$

It can be evidently seen from (7) and (8) that the CO is controlled by R without disturbing FO. Also, the FO can be electronically tuned by I_{B1} without affecting CO. From Fig. 3, the current transfer function of I_{out1} and I_{out2} is written as

$$\frac{I_{out2}}{I_{out1}} = sC_1 R_p \quad (9)$$

It is evident from (9) that current output I_{out1} is phase-shifted by 90° from current output I_{out2} and thus the oscillator can be used as quadrature oscillator.

The sensitivities of oscillation frequency are given as

$$S_{C_1, C_2, R_p}^{\omega_0} = -\frac{1}{2}; S_{g_m}^{\omega_0} = \frac{1}{2} \quad (10)$$

Fig. 3. Proposed simple current-mode oscillator

Fig. 4. Internal construction of CCCDTA

III. SIMULATION RESULTS

To investigate the theoretical analysis, the proposed oscillator in Fig. 2 is simulated by using the PSPICE simulation program. Internal construction of CCCDTA used in simulation is shown in Fig. 4. The PNP and NPN transistors employed in the proposed topology were simulated by respectively using the parameters of the PR200N and NR200N bipolar transistors of ALA400 transistor array from AT&T [26]. The circuit was biased with $\pm 2.5V$ supply voltages, $C_1=C_2=0.2nF$, $R=0.4k$, $I_{B1}=50\mu A$ and $I_{B2}=122\mu A$. This yields simulated oscillation frequency of 1.891MHz. The calculated value of FO in (8) is 2.39MHz. Fig. 5 shows simulated quadrature output waveforms. It is seen that I_{out1} and I_{out2} are 90° phase difference as explain in (9). Fig. 6 shows the simulated output spectrum, where the total harmonic distortion (THD) for I_{out1} and I_{out2} are about 0.1170% and 0.1321%, respectively. The plot of simulated and calculated FO is compared in Fig. 7 where I_{B1} was varied from $10\mu A$ - $200\mu A$ and C ($C_1=C_2=C$) was changed to three values. It is found that the FO can be tuned by I_{B1} as shown in (8). The power dissipation is approximately 4.66mW.

Fig. 5. Output voltage waveforms

Fig. 6. Output Spectrum

Fig. 7. Simulated FO versus calculated FO

IV. CONCLUSION

A simple current-mode quadrature oscillator based on CCCDTA has been presented. The frequency of oscillation and condition of oscillation can be orthogonally adjusted. It consists of 1 CCCDTA, 1 resistor and 2 grounded capacitors, which is convenient to fabricate. The performances of the proposed oscillator were verified by PSpice simulation. The simulated results agree well with the theoretical anticipation.

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