CCTAs based Current-mode Quadrature Oscillator with High Output Impedances

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***Abstract*—This article presents a current-mode quadrature oscillator. The proposed oscillator can provide 2 sinusoidal output currents with 90^0 phase difference. It also provides high output impedances that make the circuit able to directly drive load without additional current buffer. The condition of oscillation and frequency of oscillation can be controlled independently and electronically by adjusting the bias currents of the CCTAs. The circuit uses 3 current controlled transconductance amplifiers (CCTAs) and 2 grounded capacitors. The proposed circuit uses only grounded capacitors without additional external resistors, the proposed circuit is considerably appropriate to further developing into an integrated circuit. The results of PSPICE simulation program are corresponding to the theoretical analysis.**

***Index Terms*—high output impedances, Current-mode, quadrature oscillator, CCTA**

I. Introduction

The active building block (ABB) presented in active devices for electrical and electronics engineering is suitable for a class of analog signal processing for voltage-mode and current-mode technique, for example, current conveyor second generation (CCII) [1], second generation current controlled current conveyor (CCCII) [2], current differencing transconductance amplifier (CDTA) [3] and current conveyor transconductance amplifier (CCTA) [4], etc. Additionally, to help design a circuit and reduce passive devices used in a design process, ABB development has been required to be more qualified, such as, increasing parasitic resistances at input terminal, extending numbers of input and output terminals, etc.

Quadrature oscillator (QO) is one of oscillator which provides two sinusoidal signals with phase difference. Some applications for quadrature signal are employed in telecommunications for single-sideband modulators and quadrature mixers [5]. In the last decade, a lot of papers in electronic circuit design have been presented in current-mode technique using the current-mode building block. It is stated that the circuit designed from current-mode technique can provide the advantages, such as, larger dynamic range, inherently wide bandwidth, higher slew-rate, greater linearity and low power consumption [6]-[9].

According to recent research reviews on designing current-mode quadrature oscillator circuit using active building block, it is found that the most recommended qualifications for an appropriate circuit design: without addition external resistor, using grounded capacitors, circuit has high output impedance, and condition of oscillation and the frequency can be controlled by electronic method, and etc. From literature survey, it is found that several implementations of quadrature oscillator circuits using active building block devices have been reported. Unfortunately, these reported circuits suffer from one more of weaknesses. Many of these applications are the condition of oscillation and the frequency of oscillation cannot be electronically controlled by adjusting the bias current [19]-[22]. The proposed circuits use floating capacitor [11], [14], which is not convenient to future fabricate in integrated circuits [10]. There is excessively use of the passive elements, especially external resistors [11]-[13], [14]-[22] and the proposed circuit in Refs. [11]-[12], [14] consists of large number (more than four components) of passive components, which is not convenient to future fabricate in integrated circuits. Output impedances are not high, that make the circuit cannot directly drive load [23].

The purpose of this paper is to present the current-mode quadrature oscillator, based on current conveyor transconductance amplifiers (CCTAs). The condition of oscillation and the frequency of oscillation can be independently adjusted by electronic method. The proposed circuit consists of 3 CCTAs and 2 grounded capacitors. The circuit without additional external resisters, which is convenient to future fabricate in integrated circuits [24]-[25]. In addition, the proposed circuit can provide transferring functions which are low-pass filter (LP) and band-pass filter (BP) which is able to control pole frequency independently from quality factor. The PSPICE simulation program results are also shown which are corresponding to the theoretical analysis.

II. Theory and Principle

A. Basic Concept of CCTA

In 2005, a new active building block namely current conveyor transconductance amplifier (CCTA) is

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presented for analog signal processing [4], which suitable for a class of analog signal processing for voltage-mode and current-mode techniques. CCTA has been widely applied in current-mode circuit, for example, filter and oscillator circuits. The characteristics of the ideal current conveyor transconductance amplifier are represented by the following hybrid.

$$\begin{bmatrix} I_y \\ V_x \\ I_z \\ I_o \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & \pm g_m & 0 \end{bmatrix} \begin{bmatrix} I_x \\ V_y \\ V_z \\ V_o \end{bmatrix}. \quad (1)$$

where g_m is the transconductance of the CCTA. This can be adjusted by external input bias current. For bipolar junction transistor CCTA, the transconductance can be shown in (2). An ideal CCTA has high input impedances at the y input terminal, consists of voltage buffer circuit in the y input terminal. The symbol and the equivalent circuit of the CCTA are illustrated in Fig. 1 and Fig. 2, respectively.

$$g_m = \frac{I_B}{2V_T}. \quad (2)$$

where V_T is the thermal voltage of the transistor. The bipolar junction transistor implementation of the internal construction of CCTA can be shown in Fig. 3.

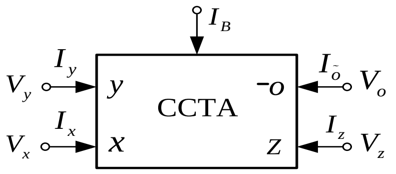

Figure 1. Symbol of the CCTA.

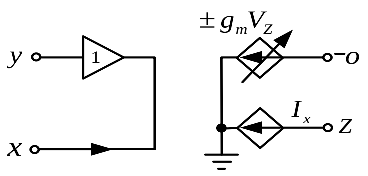

Figure 2. Equivalent circuit of the CCTA.

B. Proposed Current-mode Quadrature Oscillator

The proposed current-mode oscillator circuit consists of 3 CCTAs and 2 grounded capacitors without additional external resistors. The circuit can provide two sinusoidal current signals with 90^0 phase difference and high output impedances that are easy to drive external load without loading effect. The proposed current-mode quadrature oscillator circuit can be shown in Fig. 4 and the characteristic equation of the proposed circuit is written as

$$s^2 + \frac{g_{m3} - g_{m1}}{C_1} s + \frac{g_{m1} g_{m2}}{C_1 C_2} = 0. \quad (3)$$

From (3), the condition of oscillation and frequency of oscillation are as follows:

$$g_{m3} = g_{m1}. \quad (4)$$

and

$$w_{osc} = \sqrt{\frac{g_{m1} g_{m2}}{C_1 C_2}}. \quad (5)$$

It is found from (4) and (5) that if $g_{mi} = {I_{Bi}}/{2V}$, the condition of oscillation and frequency of oscillation are written as

$$I_{B3} = I_{B1}. \quad (6)$$

and

$$w_0 = \sqrt{\frac{I_{B1} I_{B2}}{C_1 C_2}}. \quad (7)$$

From (6) and (7), it can be found that the condition of oscillation can be adjusted independently from the frequency of oscillation by varying I_{B3} and I_{B1} while the frequency of oscillation can be adjusted by I_{B2} without disturbing the condition of oscillation.

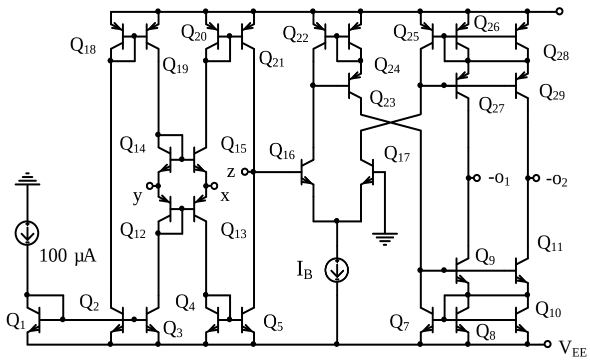

Figure 3. Internal construction of the CCTA.

In addition, the proposed circuit in Fig. 4 can be provide transferring functions which are low-pass filter (LP) and band-pass filter (BP) .The current transferring functions of proposed filter circuit are obtained

$$\text{LP}: T_{LP}(s) = \frac{g_{m1} g_{m2}}{s^2 + \frac{g_{m3} - g_{m1}}{C_1} s + \frac{g_{m1} g_{m2}}{C_1 C_2}}. \quad (8)$$

and

$$\text{BP}: T_{AP}(s) = \frac{g_{m1} s}{s^2 + \frac{g_{m3} - g_{m1}}{C_1} s + \frac{g_{m1} g_{m2}}{C_1 C_2}}. \quad (9)$$

From (8) and (9), the quality factor (Q_0) and pole frequency (w_0) can be written as

$$Q_0 = \sqrt{\frac{g_{m1} g_{m2} C_1}{(g_{m3} - g_{m1}) C_2}}. \quad (10)$$

and

$$w_0 = \sqrt{\frac{g_{m1} g_{m2}}{C_1 C_2}}. \quad (11)$$

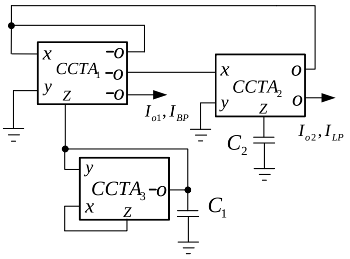

Figure 4. The proposed current-mode quadrature oscillator.

From (10) and (11), then substitute $g_{mi} = I_{Bi}/2V$.

$$Q_0 = \frac{1}{\sqrt{2V_T}} \sqrt{\frac{I_{B1} I_{B2} C_1}{(I_{B3} - I_{B1}) C_2}} . \quad (12)$$

and

$$w_0 = \frac{1}{2V_T} \sqrt{\frac{I_{B1} I_{B2}}{C_1 C_2}} . \quad (13)$$

From (12) and (13), it can be found that the pole frequency can be adjusted independently from the quality factor by varying I_{B1} and I_{B2} while the quality factor can be adjusted by I_{B3} without disturbing the pole frequency. From (12), a high quality factor circuit can be obtained by setting I_{B1} close to I_{B3} . Thus the bandwidth (BW) is given by

$$BW = \frac{w_0}{Q_0} = \frac{1}{C_1 \sqrt{V_T}} \sqrt{I_{B3} - I_{B1}} . \quad (14)$$

III. Simulation Results

To verify the theoretical prediction of the proposed current-mode quadrature oscillator in Fig. 4, the PSPICE simulation was built with $C_1 = C_2 = 0.5nF$, $I_{B1} = 100mA$, $I_{B2} = 150mA$ and $I_{B3} = 95mA$. The BJT implementation of the internal construction of CCTA used in simulation is shown in Fig. 3. The PNP and NPN transistors employed in the proposed circuit were simulated by using the parameters of the PR200N and NR200N bipolar transistors of ALA400 transistor arrayed from AT&T [26]. The circuit was biased with $\pm 2V$ supply voltages. This yields oscillation frequency of 640.641kHz, where the calculated value of this parameter from (7) yields 749.708Hz (deviated by 14.548%). Fig. 5 and Fig. 6 show the simulated quadrature output waveforms during initial state and steady state, respectively. Fig. 7 shows the simulation result of output spectrum, where the total harmonic distortion (THD) of I_{o1} and I_{o2} are about 0.977% and 1.158%, respectively.

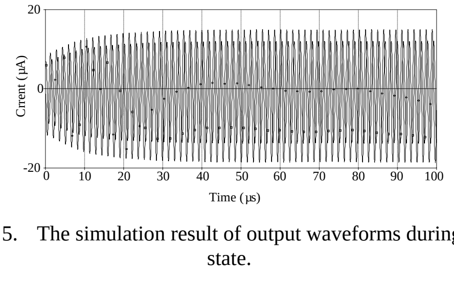

Figure 5. The simulation result of output waveforms during initial state.

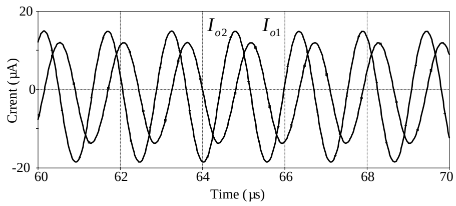

Figure 6. The quadrature output waveforms in steady state.

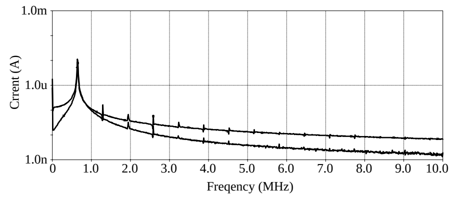

Figure 7. The output frequency spectrum.

In addition, to verify the theoretical prediction of the proposed filter, the PSPICE simulation was built with $C_1 = C_2 = 0.5\text{nF}$, $I_{B1} = I_{B2} = 100mA$ and $I_{B3} = 150mA$. The circuit was biased with $\pm 2V$ supply voltages. Fig. 8 shows the gain responses of the low-pass and band-pass filter. Fig. 9 show the gain responses of the band-pass function, where I_{B3} is set to $100mA$, $150mA$, and $200mA$, respectively. This shows that the bandwidths of the responses can be adjusted by the input bias current I_{B1} . Fig. 10 shows simulated gain responses of the band-pass function, where I_{B2} is set to $60mA$, $90mA$, and $150mA$, respectively.

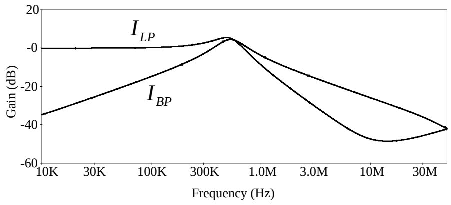

Figure 8. Gain responses of the proposed filter.

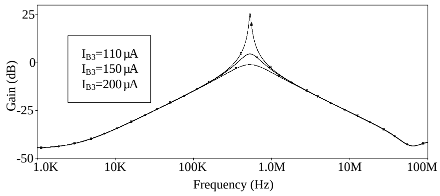

Figure 9. Band-pass responses at different value of I_{B3} .

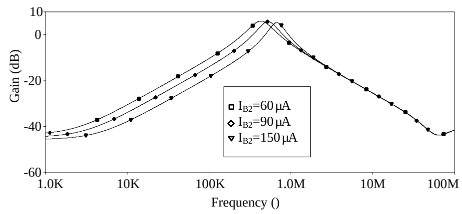

Figure 10. Band-reject responses at different value of I_{B2} .

IV. Conclusion

The current-mode quadrature oscillator has been presented. The condition of oscillation and the frequency of oscillation can be independently adjusted by electronic method. The proposed oscillator consists of CCTAs and grounded capacitors without addition any external resistors and not used parasitic resistances, which is ideal for integrated circuit. PSPICE simulations are included to verify the theoretical analysis. Simulated and theoretical results are in close.

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