Current Tunable Quadrature Oscillator Using Only CCCDBAs and Grounded Capacitors

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Abstract- **An electronically tunable quadrature oscillator using only two current-controlled current differencing buffered amplifiers (CCCDBAs) and two ground capacitors without external passive resistor is proposed. The outputs of two sinusoidal waveforms with 90° phase difference are available from the configuration. The oscillation condition and the oscillation frequency ω_o of the proposed oscillator circuit are tunable by electronically through controlling the external dc bias currents of the CCCDBAs. The simulation results with PSPICE are used to verify the theory.**

I. INTRODUCTION

The quadrature sinusoidal oscillator plays an essential electronic circuit, because it can produce two sinusoidal outputs of identical frequency but of 90° phase shift, as for example in telecommunications for quadrature mixers and single-sideband generators [1] or for measurement purposes in vector generator or selective voltmeters [2]. Therefore, quadrature oscillators are widely used in many communications, signal processing and instrumentation systems. Many quadrature oscillator circuits have been reported in [3]-[11]. Note that these earlier quadrature oscillators in [3]-[7] produced voltage-mode signals, whereas the ones in [8]-[11] generated current-mode signals.

Since an introduction of the current differencing buffered amplifier (CDBA) in 1999, it has been acknowledged to be a versatile active building block in designing analog circuits [12]. The CDBA can be considered as a collection of current-mode and voltage-mode unity gain amplifiers, it thus offers large dynamic range and wide bandwidth similar to its current-mode counterparts such as a second-generation current conveyor (CCII) and a current feedback amplifier (CFA) [13]. Numerous CDBA-based applications have been reported by various researchers [13]-[17]. The CDBA is also useful for sinusoidal oscillator design [18]-[19]. Ozcan *et al.* introduced six CDBA-based sinusoidal oscillator circuits that each consists of one CDBA, three resistors and two floating capacitors. However, the oscillation conditions and oscillation frequencies of these oscillators cannot be independently controllable. Moreover, these sinusoidal oscillators use floating capacitors, which is not suitable for integration [20]. In 2002, Horng proposed a new technique for implementing a quadrature oscillator circuit that consists of two CDBAs, four resistors and two grounded capacitors. Its oscillation condition and oscillation frequency can independently controllable. However, this configuration still uses a large number of passive resistors. On the other hand, by recently introducing the current-controlled current differencing buffered amplifier (CCCDBA) [21], it allows the design of analog circuits with electronically tunable circuit parameters, while offering all the advantages of the conventional CDBA. Also considering the absence of the external resistors in circuit realizations, the CCCDBA-based circuits seem to be good choices to use for the realization of IC oscillator circuits…

In this paper, proposed an electronically tunable quadrature oscillator using only two CCCDBAs and two grounded capacitors without external passive resistor requirement is proposed. The proposed oscillator circuit provides two sinusoidal signals with 90 phase difference. The oscillation condition and the oscillation frequency ω_o of the proposed oscillator circuit are tunable by electronically through controlling the external dc bias current. The circuit also displays low passive and active sensitivities. The employment of only grounded capacitors is a very attractive feature for monolithic integrated circuit technology [20].

II. CURRENT-CONTROLLED CURRENT DIFFERENCING BUFFERED AMPLIFIER (CCCDBA)

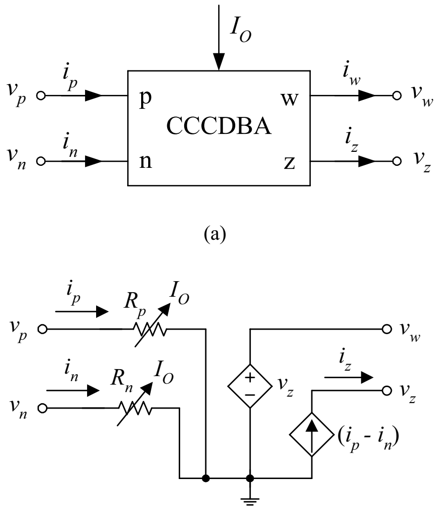
The circuit representation and the equivalent circuit of the CCCDBA are shown in Fig.1, where p and n are input and w and z are output terminals. The CCCDBA is defined by the flowing matrix equation [21].

$$\begin{bmatrix} v_p \\ v_n \\ i_z \\ v_w \end{bmatrix} = \begin{bmatrix} 0 & 0 & R_p & 0 \\ 0 & 0 & 0 & R_n \\ 0 & 0 & 1 & -1 \\ 1 & 0 & 0 & 0 \end{bmatrix} . \begin{bmatrix} v_z \\ i_z \\ i_p \\ i_n \end{bmatrix} \quad (1)$$

where R_p and R_n are respectively the parasitic resistances at the terminals p and n of the CCCDBA. A possible bipolar realization of the CCCDBA is shown in Fig.2. In this case, the resistances R_p and R_n can be given by

$$R_p \cong R_n = \frac{V_T}{2I_o} \qquad (2)$$

where V_T is the thermal voltage that is equal to 26 mV at room temperature. Equation (2) shows that it is possible to tune the values of R_p and R_n by means of an external dc bias current I_O.



(a)

(b)

Fig.1 The CCCDBA

(a) circuit symbol (b) equivalent circuit

III. PROPOSED CONFIGURATION

Fig.3 shows the proposed electronically tunable quadrature oscillator using CCCDBAs as active elements. The oscillator circuit employs only two CCCDBAs and two grounded capacitors without passive resistor requirement, which is ideal for integration [20]. Circuit analysis yields the characteristic equation of the circuit as follows :

$$s^2 + \left(\frac{1}{R_{p2}} - \frac{1}{R_{p1}}\right)\frac{s}{C_1} + \left(\frac{1}{R_{n1}R_{p2}C_1C_2}\right) = 0 \qquad (3)$$

where R_{pi} and R_{ni} denote the parasitic resistances R_p and R_n of the i-th CCCDBA (i = 1, 2), respectively. Thus, the oscillation condition and the oscillation frequency (ω_o) obtained from the proposed circuit are given by :

$$R_{p1} = R_{p2} \qquad (4)$$

and

$$\omega_o = \frac{1}{\sqrt{R_{n1}R_{p2}C_1C_2}} \qquad (5)$$

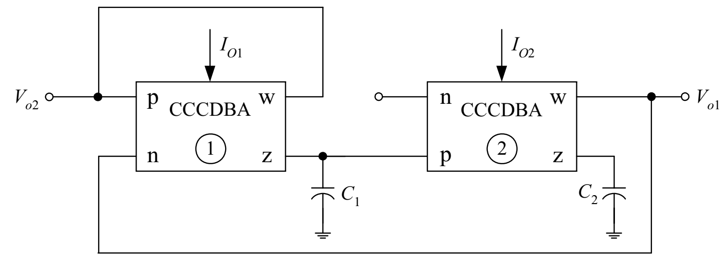


Fig.3 Proposed electronically tunable quadrature oscillator using CCCDBAs.

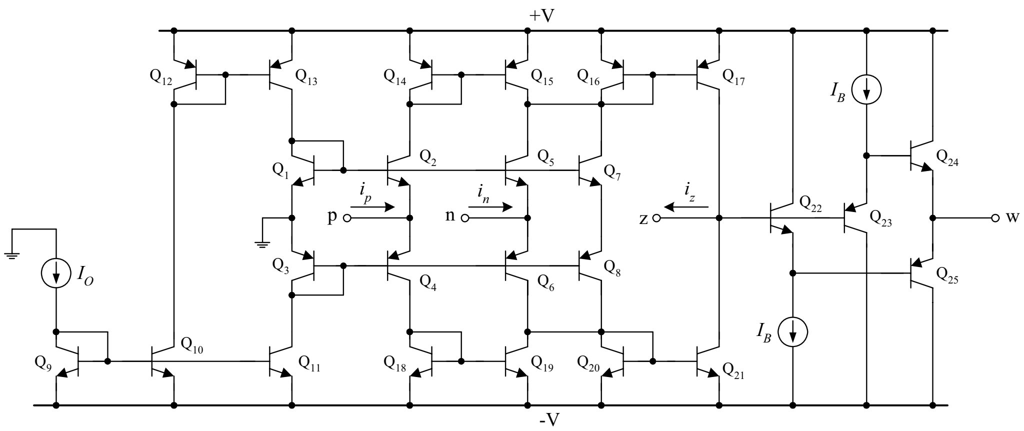


Fig.2 Bipolar realization of the CCCDBA.

Furthermore, if we setting $I_{O1} = I_{O2} = I_O$ and $C_1 = C_2 = C$, then the proposed oscillator circuit of Fig.2 can be controlled to oscillate at the oscillation frequency of

$$f_o = \frac{\omega_o}{2\pi} = \frac{I_O}{\pi V_T C} \tag{6}$$

It is clearly seen from equation (6) that the oscillation frequency of the proposed circuit can be controlled electronically by linearly adjusting the bias current I_O. It is also to be noted that the ω_o is temperature sensitive, the temperature compensation scheme is essential under varying environmental conditions [22]. Moreover, owing to the output impedance at the terminal w of the CCCDBA is very small, the output signal V_{o1} and V_{o2} can be directly connected to the next stage.

From Fig.3, the two quadrature outputs V_{o2} and V_{o1} can be expressed as:

$$\frac{V_{o2}}{V_{o1}} = sC_2R_{p2} \tag{7}$$

Therefore, the phase difference (ϕ) between V_{o2} and V_{o1} is equal to

$$\phi = 90^\circ \tag{8}$$

which guarantees that the voltages V_{o2} and V_{o1} are to be quadrature outputs.

IV. Effects of The CCCDBA Non-idealities

By taking into consideration of the non-ideal CCCDBAs, the relationship of the terminal currents and voltages given with equation (1) can be rewritten as :

$$\begin{bmatrix} v_p \\ v_n \\ i_z \\ v_w \end{bmatrix} = \begin{bmatrix} 0 & 0 & R_p & 0 \\ 0 & 0 & 0 & R_n \\ 0 & 0 & \alpha_p & -\alpha_n \\ \beta & 0 & 0 & 0 \end{bmatrix} . \begin{bmatrix} v_z \\ i_z \\ i_p \\ i_n \end{bmatrix} \tag{9}$$

where $\alpha_p = 1-\varepsilon_p$, ε_p ($\varepsilon_p << 1$) is the current tracking error from p terminal to z terminal, $\alpha_n = 1-\varepsilon_n$, ε_n ($\varepsilon_n << 1$) is the current tracking error from n terminal to z terminal, and $\beta = 1-\varepsilon_v$, ε_v ($\varepsilon_v << 1$) is the voltage tracking error from z terminal to w terminal of the CCCDBA, respectively. Re-analysis the circuit configuration of Fig.3, the non-ideal characteristic equation becomes :

$$s^2 + \left(\frac{1}{R_{p2}} - \frac{\beta_1\alpha_{p1}}{R_{p1}}\right)\frac{s}{C_1} + \left(\frac{\beta_1\beta_2\alpha_{n1}\alpha_{p2}}{R_{n1}R_{p2}C_1C_2}\right) = 0 \tag{10}$$

where α_{pi} , α_{ni} and β_i are the parameters α_p, α_n and β of the *i*-th CCCDBA, respectively. In this case, the modified oscillation condition and oscillation frequency (ω_{on}) can be rewritten as :

$$R_{p1} = \beta_1\alpha_{p1}R_{p2} \tag{11}$$

and

$$\omega_{on} = \sqrt{\frac{\beta_1\beta_2\alpha_{n1}\alpha_{p2}}{R_{n1}R_{p2}C_1C_2}} \tag{12}$$

It may be pointed out from equations (11) and (12) that the modified oscillation condition and ω_{on} due to the CCCDBA non-idealities will be slightly changed from the ideal case. Moreover, from equation (12), the passive and active sensitivities of this circuit are calculated as :

$$S^{\omega_{on}}_{C_1,C_2} = -\frac{1}{2} \tag{13}$$

$$S^{\omega_{on}}_{R_{n1},R_{p2}} = -\frac{1}{2} \tag{14}$$

and

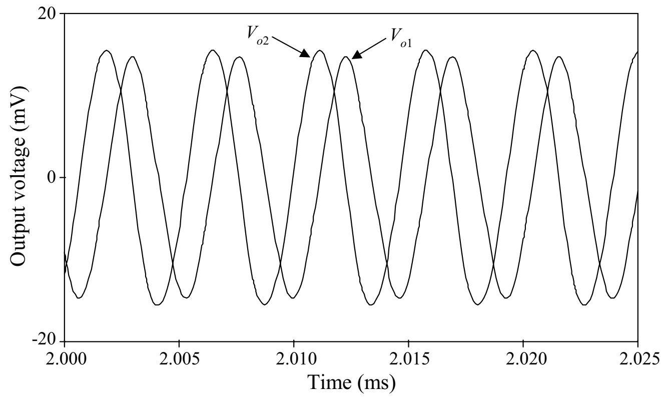
$$S^{\omega_{on}}_{\beta_1,\beta_2,\alpha_{n1},\alpha_{p2}} = \frac{1}{2} \tag{15}$$

All which are less than 0.5 in magnitude.

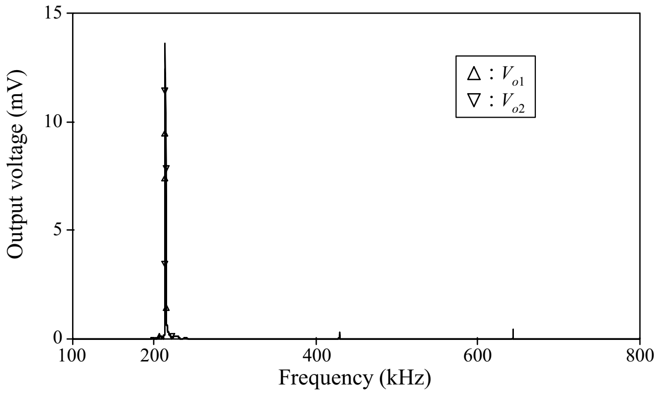
V. Simulation Results

The proposed quadrature oscillator in Fig.3 has been simulated by PSPICE to verify the given theoretical analysis. In the simulations, the AT&T ALA400-CBIC-R parameter was used [23]. The power supply voltages were selected as ±V = ±3 V. As an example, the values of capacitors are equal to $C_1 = C_2 = C = 0.01$ µF and bias currents I_B and $I_O = I_{O1} = I_{O2}$ are approximately 500 µA and 200 µA, respectively. This setting was designed to obtain the oscillation frequency f_o at 245 kHz. Fig.4(a) shows the simulated quadrature output waveforms V_{o1} and V_{o2} of the proposed CCCDBA-based quadrature oscillator of Fig.3, where the oscillation frequency f_o is measured to be 216 kHz. Fig.4(b) shows the simulated frequency spectrums of the quadrature outputs V_{o1} and V_{o2}.

The total harmonic distortion (THD) for the designed frequency has been analyzed, and it has also been observed that the THD is approximated to 7.590% for all the quadrature outputs. The results of the total harmonics distortion analysis are summarized in Table 1.



(a)



(b)

Fig.4 Simulation results of the quadrature outputs V_{o1} and V_{o2} of the proposed oscillator.
(a) output waveforms (b) output spectrums.

Table 1: Total Harmonic distortion analysis

Harmonic no.	Frequency (Hz)	Fourier component	Normalized component	Phase (Deg)	Normalized Phase
1	2.449E+05	1.455E-02	1.000E+00	-8.345E+01	0.000E+00
2	4.897E+05	1.032E-03	7.096E-02	-5.776E+01	1.091E+02
3	7.346E+05	3.150E-04	2.165E-02	-2.875E+01	2.216E+02
4	9.794E+05	1.957E-04	1.345E-02	-3.317E+01	3.006E+02
5	1.224E+06	1.317E-04	9.056E-03	-2.180E+01	3.954E+02
DC component = 1.051418E-02					
Total harmonic distortion = 7.594297E+00 PERCENT					

VI. CONCLUSIONS

A new quadrature sinusoidal oscillator employing only two CCCDBAs and grounded capacitors has also been proposed. The proposed quadrature oscillator circuit offers the following advantages ; (i) two quadrature sinusoidal output waveforms of 90° phase shift are obtained simultaneously; (ii) it provides low output impedance ; (iii) the oscillation condition and the oscillation frequency are controllable electronically; (iv) using only grounded capacitors for its realization, which is suitable for integration; (v) low passive and active sensitivities.

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