Electronically Controllable Current-Mode Multiphase Sinusoidal Oscillator for Biomedical Tissue Measurement Systems

S. Siripongdee, P. Suwanjan, S. Tuntrakool, and W. Jaikla

***Abstract*—The design of current-mode multiphase sinusoidal oscillator (MSO) for biomedical tissue measurement system is presented. The odd phase system can be realised using current controlled current differencing transconductance amplifier (CCCDTA)-based lossy integrators. The condition of oscillation and frequency of oscillation can be controlled electronically and independently through adjusting the current of the CCCDTA. The high output impedances facilitate easy driving an external load without additional current buffers. The proposed MSO provides odd phase signals that are equally spaced in phase and equal amplitude. The circuit requires one CCCDTA and one grounded capacitor per phase without external resistor and additional current amplifier. The results of PSPICE simulations using BJT CCCDTA are included to verify theory.**

***Index Terms*—CCCDTA, multiphase sinusoidal oscillator, integrated circuit.**

I. Introduction

Multiphase sinusoidal oscillator (MSO) is important blocks for various applications. For example, in telecommunications it is used for phase modulators, quadrature mixers [1], and single-sideband generators [2]. In measurement system, MSO is employed for vector generator or selective voltmeters [3]. It can also be utilized in power electronics systems [4]. Recently, current-mode circuits have been receiving considerable attention of due to their potential advantages such as inherently wide bandwidth, lower slew-rate, greater linearity, wider dynamic range, simple circuitry and low power consumption [5]. Many active building blocks (ABBs) have been proposed to realize the current-mode circuit. The interesting active element, called current controlled current differencing transconductance amplifier (CCCDTA) [6], [7], is introduced to provide new possibilities in the current-mode circuit. It is really current-mode element whose input and output signal are currents. In addition, output currents of CCCDTA can be electronically adjusted.

Several realizations of current-mode MSOs using different active building blocks are available in the literature. These include realizations using current follower (CF) [8], CCCII [9]-[11], CDTA [12]-[14], CDBA [15], CFOA [16], and CCCCTA [17] and CCCDTA [18], [19]. The CF-based MSO in [8] requires two current followers, one floating resistor, and one floating capacitor for each phase and thus the circuit is not suitable for monolithic integration. Moreover, it cannot be electronically controlled. The CCCII-based MSOs [9]-[11] enjoy high-output impedances and electronic tunability. However, the first one requires a large number of external capacitors. In addition, the oscillation condition can be provided by tuning the capacitance ratio of external capacitors, which is not easy to implement. The second reported circuit requires additional current amplifiers, which makes the circuit more complicated and increases its power consumption. CDTA-based current-mode MSOs in [12] is based on lossy integrators, where as the circuits in [13] and [14] contain CDTA-based allpass sections. They exhibit good performance in terms of electronic tunability, high-output impedances, and independent control of the oscillation frequency and the oscillation condition. However, MSOs in [12], [13] require an additional current amplifier, which is implemented by two CDTAs. Moreover, the output currents of the MSO, utilizing the CDTA-based lossy integrators, are of different amplitudes. The MSO employing CDTA-based allpass sections [13] requires two CDTAs in each allpass section, and the circuitry becomes more extensive. While MSO using CDTA-based allpass sections [14] requires floating capacitor. Consequently, it occupies a larger chip area for VLSI design. In addition, its power consumption is also increased.

The purpose of this study is to introduce a new current-mode multiphase sinusoidal oscillator. The features of the proposed circuit are the following: 1) Use of grounded capacitors and identical circuit configuration for each section in the MSO topology which are suitable for integration. 2) The electronic tunability of oscillation condition and oscillation frequency. 3) High-impedance current outputs. 4) The possibility of generating multi-phase signals for both an even and odd number of equally-spaced in phases. 5) Independent tuning of the oscillation frequency and the oscillation condition. 6) Equality of amplitudes of each phase due to utilizing identical sections. 7) Requirement for only one CCCDTA as the active element for each phase without any additional current amplifiers.

II. Proposed Multiphase Sinusoidal Oscillator

The main active element used to design the proposed inductance simulator is CCCDTA. Thus, the review of it will be shown here. The principle of CCCDTA was introduced in [7]. Its symbol and equivalent circuit are shown respectively in Fig. 1 a) and Fig. 1 b). The p and n which have finite resistances (R_p and R_n) are the current input terminals. z and x

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are the output terminals. The difference of input currents (i_p-i_n) will send to z terminal. The voltage at z terminal is converted to the x-terminal current via a transconductance g_m. The characteristics of CCCDTA can be described by:

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

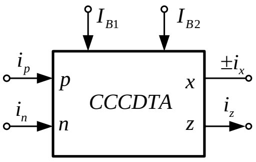
If the CCCDTA is realized using BJT technology, R_p, R_n and gm can be written as

$$R_p = R_n = \frac{V_T}{2I_{B1}} \tag{2}$$

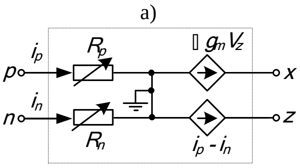
and

$$g_m = \frac{I_{B2}}{2V_T} \tag{3}$$

Here V_T is the thermal voltage. I_{B1} and I_{B2} are the bias currents used to control the intrinsic resistances and transconductance, respectively. The internal construction of BJT CCCDTA is shown in Fig. 2.



a)



b)

Fig. 1 a) Electrical circuit symbol and b) Equivalent circuit of CCCDTA.

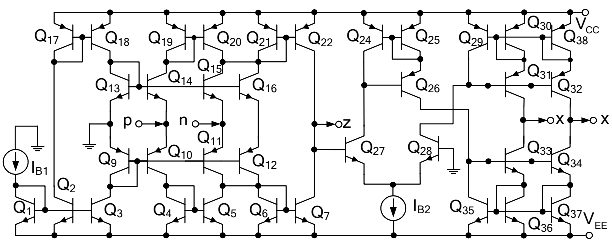


Fig. 2. Internal construction of BJT CCCDTA.

The generalized structure of MSO is designed by cascading the n identical stages (n≥3) which contains the lossy integrator (first order low pass filter) for each phase. The output of n^{th} stage is fed back to the input of the first stage. The system can provide one phase per one lossy integrator without any additional external amplifier. The current-mode odd phase MSO is shown in Fig. 3. It is found from Fig. 3 that the current mirrors are required to split the bias currents I_{B1} and I_{B2} to each lossy integrator section. In addition, it can be seen that the proposed MSO enjoy high-output impedances which facilitate easy driving an external load without additional current buffers. From circuit in Fig. 3 for $n = 3, 5, 7, ...$, the frequency of oscillation (FO) and condition of oscillation (CO) are expressed as [16]

$$FO : \omega_{osc} = \frac{1}{R_p C} \tan\frac{\pi}{n} \tag{4}$$

and

$$CO : \frac{g_m R_n}{2} \geq \sec\frac{\pi}{n} \tag{5}$$

From Eqs. (4) and (5), if R_p=R_n=V_T/2I_{B1} and g_m=I_{B2}/2V_T, the FO and CO is modified as

$$\omega_{osc} = \frac{2I_{B1}}{V_T C} \tan\frac{\pi}{n} \tag{6}$$

and

$$\frac{I_{B2}}{8I_{B1}} \geq \sec\frac{\pi}{n} \tag{7}$$

From Eqs. (6) and (7), it can be seen that the CO can be adjusted electronically/independently from the FO by varying I_{B2}.

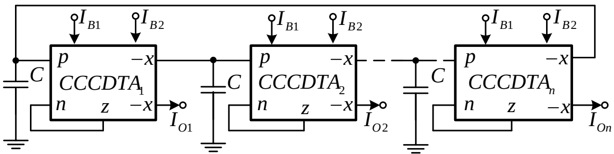


Fig. 3. Proposed MSO.

III. Simulation Results

To prove the performances of the proposed MSO, the PSpice simulation program was used for the examination. 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 array from AT&T [20]. The CCCDTA has been simulated using the bipolar technology structure of Fig. 2. The circuit was biased with ±3V supply voltages.

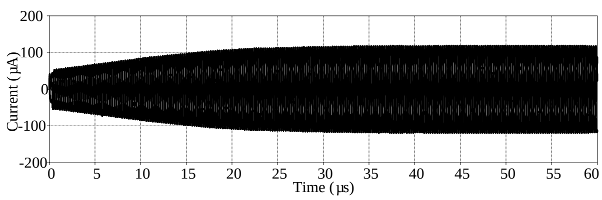


Fig. 4. Sinusoidal output currents at initial time.

An odd three-phase sinusoidal oscillator (n=3) based on the structure in Fig. 3 has been designed. The component values are as follows: I_{B1}=40 μA, I_{B2}=630 μA, C=0.5nF. The simulated output waveforms, I_{O1}, I_{O2} and I_{O3} are shown in Fig. 4 and Fig. 5. The frequency of oscillation achieved from the simulation was 1.41MHz, while the calculated FO from (6) are 1.69MHz. The frequency spectrum of output currents are shown in Fig. 6. The total harmonic distortion for I_{O1}, I_{O2} and I_{O3} are 1.13%, 1.18% and 1.14% respectively.

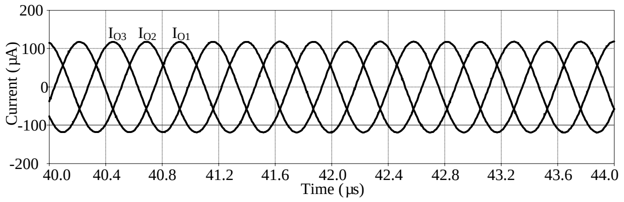


Fig. 5. Sinusoidal output waveforms.

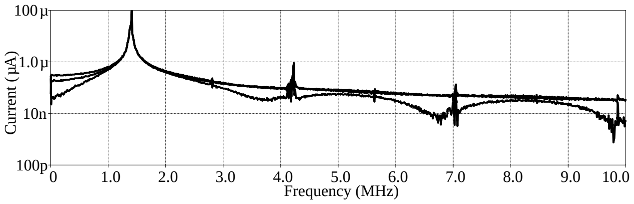


Fig. 6. Spectrum of wave forms in Fig. 5.

IV. Conclusion

New current-mode multiphase sinusoidal oscillators using CCCDTA-based lossy integrators with grounded capacitors have been presented. The features of the proposed circuit are that: oscillation frequency and oscillation condition can be independently tuned; the proposed oscillator consists of merely 1 CCCDTA and 1 grounded capacitor for each phase and no additional current amplifier and availability of explicit-current outputs from high-output impedance terminals. PSPICE simulation results agree well with the theoretical anticipation.

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