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ELECTRONICALLY CONTROLLABLE SINUSOIDAL OSCILLATORS BASED-ON CCCCTAs AND GROUNDED CAPACITORS

Angkana Charoenmee and Worawat Sa-Ngiamvibool

Department of Electrical Engineering
Faculty of Engineering, Mahasarakham University
Kantharawichai District
Mahasarakham, 44150, Thailand
e-mail: angkann@yahoo.com

Abstract

This article describes three current-mode sinusoidal oscillator circuits with amplitude controllability. Each circuit consists of 2 CCCCTAs together with 2 grounded capacitors. The condition of oscillation and the frequency of oscillation can be electronically controlled by means of adjusting DC bias current of CCCCTAs. Furthermore, the amplitude of sinusoidal output signal can also be electronically adjusted which easily and conveniently used in communication system or for the demonstration purpose in laboratory. The output terminals of signals have high impedances that can be directly connected or coupled to next stages or loads. The PSPICE simulation results confirm that the proposed circuits have provided a good performance in accordance with the theoretical analysis.

1. Introduction

Sinusoidal oscillator is extremely researched and published [1-15] since it has been applied in various systems such as communication system,

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instrument/measurement system, control system and power electronics system [10-14]. Moreover, sinusoidal signal is very important for teaching and learning of electrical/electronic engineering which is used in laboratories. For basic communication system has studied about amplitude modulating (AM), amplitude shift keying (ASK), etc. As well, AM communication system is useful in radio broadcasting and navigation system. Thus, the synthesis or design the sinusoidal oscillator should be electronically adjusted the amplitude of output signals. It will be conveniently/easily used in communication system or study in laboratories of electrical/electronic engineering [13-15].

Nowadays, the synthesis and design of analog signal processing circuit with current-mode circuit is mostly interested than voltage-mode. Because, it have been variously advantage such as easily circuit, wide bandwidth, high slew rate, wide dynamic range, etc. Furthermore, the use of a grounded capacitor or capacitor to ground will be a better circuit performance. Since, a grounded capacitor can be compensated and eliminated the stay capacities at nodes or ports of circuit.

Notwithstanding, the sinusoidal oscillator base-on CCCCTA have been published in the literature [1-15]. The advantages and disadvantages of these circuits can be detailed as follow. The sinusoidal oscillators in [1-6] are used single CCCCTA combined with grounded capacitors which is minimized and compacted of circuit. Also, the frequency of oscillation can be electronically tuned that is used in automatic/microprocessor system [15]. However, the circuits in [1-3] require multiple output terminals ($2g_m$) by modification of the internal construction of CCCCTA which is become complicated of circuit. As well, the proposed circuits in [3-5, 15] are included external resistor which are the circuit will be difficult for implementation of IC and may also loss of power consumption [16]. The proposed sinusoidal oscillators in [7-14] introduced the frequency and condition of oscillation can be electronically adjusted and provided 2 CCCCTAs and 2 grounded capacitors which is good for fabrication of IC. Nevertheless, the amplitude of output signals in [1-3, 5-13] cannot be electronically adjusted. In this way, they are required additional external modulator/amplifier when applications in AM system. Those are discomfort and complication. The proposed circuits in [5, 14-15] present advantages in electronic adjusting of amplitude but it can be adjusted with only single output.

The purpose of this article is presented the current-mode sinusoidal oscillator based-on CCCCTAs and grounded capacitors. The advantages of proposed circuits have been listed as:

- The proposed circuits are used grounded capacitors which are suitable for IC fabrication and compensation the stay capacity at nods/ports of circuits.
- The frequency and condition of oscillation can be electronically controlled with DC bias currents of CCCCTAs.
- The output signals are high impedances that good for current-mode configuration.
- The both of amplitude of output currents can be electronically adjusted which is convenient for AM/ASK system.

The performances of proposed sinusoidal oscillators are verified with PSPICE simulation.

2. Current Controlled Current Conveyor Transconductance Amplifier

Current controlled current conveyor transconductance amplifier or CCCCTA is researched and published by Siripruchyanun and Jaikla on 2008 [6]. It has several advantages such as high slew rate, wide bandwidth, higher speed and simple implementation. The symbol and equivalent circuit of CCCCTA displayed in Figure 1, respectively, where y is input voltage terminal, x is input current terminal. Also, the parasitic resistance (R_x) at x terminal can be electronically controlled with DC bias current I_A. The output current at z terminal is equal x terminal and the voltage of z terminal is transferred into current using transconductance g_m. Moreover, the output current of o terminal can be electronically controlled via DC bias current I_B. The electrical characteristic of CCCCTA can be exhibited in equation (1).

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

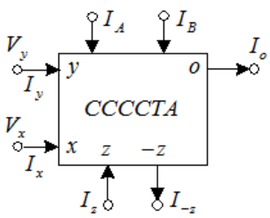
If the CCCCTA implemented with bipolar technology, then the parasitic resistance R_x can be written as

$$R_x = \frac{V_T}{2I_A}, \quad (2)$$

and the transconductance g_m can be expressed as

$$g_m = \frac{I_B}{2V_T}. \quad (3)$$

V_T is the thermal voltage (26mV at room temperature).



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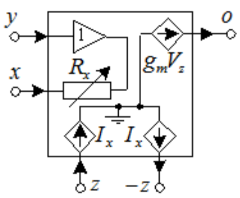


(b)

Figure 1. CCCCTA (a) symbol, (b) equivalent circuit.

3. Proposed Current-mode Sinusoidal Oscillator

The configuration of current-mode sinusoidal oscillator is shown in Figure 2(a)-(c). They are provided 2 CCCCTAs and 2 grounded capacitors. The grounded capacitor is ideal for IC implementations which are scaled down the size of IC and it can be compensated/eliminated of parasitic capacitances at nodes/ports of circuit [16-19]. It can be seen that three sinusoidal oscillator circuits have same features. Assuming the characteristic of CCCCTA in (1), the characteristic equation of all proposed circuits can be expressed as

$$s^2C_1C_2R_{x1}R_{x2} + s(C_2R_{x2} - C_1R_{x1}) + 1 = 0. \quad (4)$$

From (4), the condition of oscillation (CO) can be seen as

$$C_2R_{x2} \cong C_1R_{x1}. \quad (5)$$

If the CO is satisfied, the all proposed circuits will be produced oscillation with frequency of oscillation (FO) of

$$\omega_{osc} = \frac{1}{\sqrt{C_1R_{x1}C_2R_{x2}}}. \quad (6)$$

Substituting parasitic resistance R_x in equations (5)-(6), the CO and FO are rewritten by

$$I_{A2}C_1 = I_{A1}C_2, \quad (7)$$

and

$$\omega_{osc} = \sqrt{\frac{4I_{A1}I_{A2}}{V_T^2C_1C_2}}. \quad (8)$$

Thus, the CO and FO can simply be adjusted simultaneously with electronic tuning by I_{A1} and I_{A2}. For simplicity, setting $C_1 = C_2 = C$ and $I_{A1} = I_{A2} = I_A$, the FO is becomes

$$\omega_{osc} = \frac{2I_A}{V_TC}. \quad (9)$$

Simultaneously, if the voltages at the z terminal of both CCCCTAs are sinusoidal, the both output currents are sinusoidal and can be obtain as

$$I_{O1} = g_{m1}V_{z1}, \tag{10}$$

and

$$I_{O2} = g_{m2}V_{z2}. \tag{11}$$

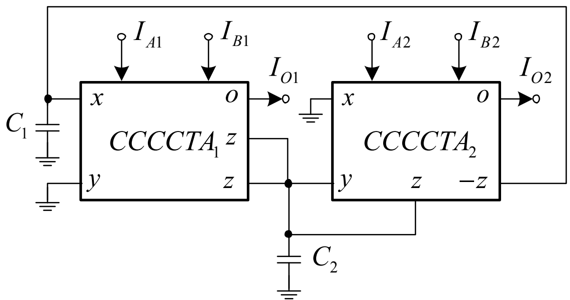
Substituting the transconductance g_m shown in (3) into (10)-(11), the output currents are shown as

$$I_{O1} = I_{B1}\frac{V_{z1}}{2V_T}, \tag{12}$$

and

$$I_{O2} = I_{B2}\frac{V_{z2}}{2V_T}. \tag{13}$$

It evident that the amplitude of current outputs I_{O1} and I_{O2} can be electronically/independently adjusted with electronic method by I_{B1} and I_{B2}. As well, the output impedances of I_{O1} and I_{O2} are high that is directed to drive load or next stages of circuit without a buffering device. Moreover, when I_{B1} and I_{B2} are information/data signals, the AM/ASK can be produced at all output currents that are conveniently and easy for uses in AM/ASK system as well as studying/learning in laboratories of electrical/electronic engineering.



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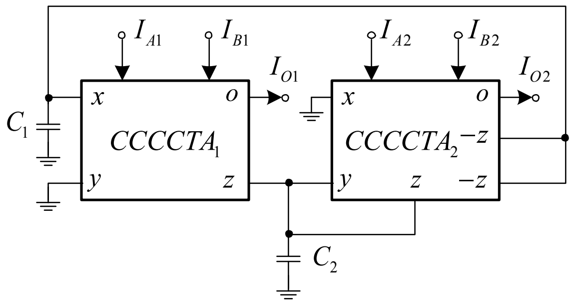

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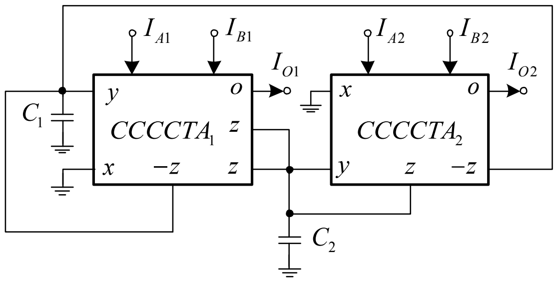


(c)

Figure 2. Proposed circuits.

4. Computer Simulation

The performance of proposed sinusoidal oscillator can be verified with PSPICE program. The proposed circuit in Figure 2(c) is chosen for example. The internal construction of CCCCTA is shown in Figure 3, where it is used for this simulation with PNP and NPN transistor parameters of a transistor array ALA400. The external capacitors for simulation are selected as $C_1 = C_2 = 0.5nF$. The CCCCTAs are biased with ±3V voltages supply and DC bias currents are chosen as $I_{A1} = I_{A2} = I_{B1} = I_{B2} = 100\mu A$.

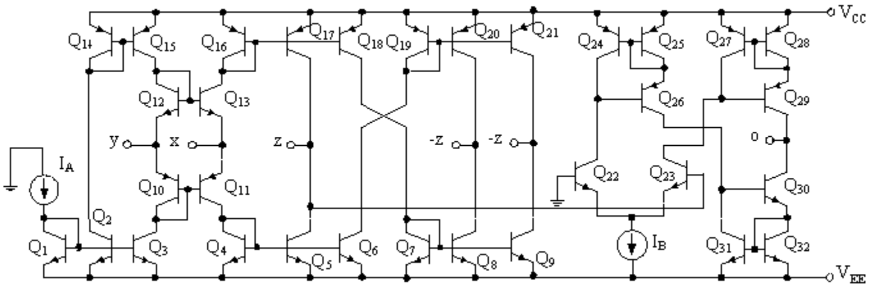


Figure 3. Internal construction of CCCCTA.

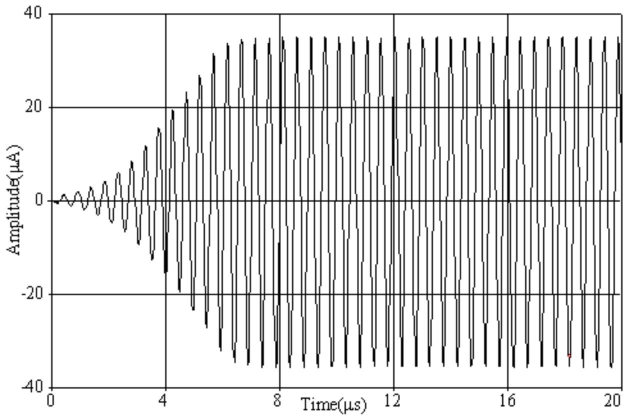


Figure 4. Transient response of output signals.

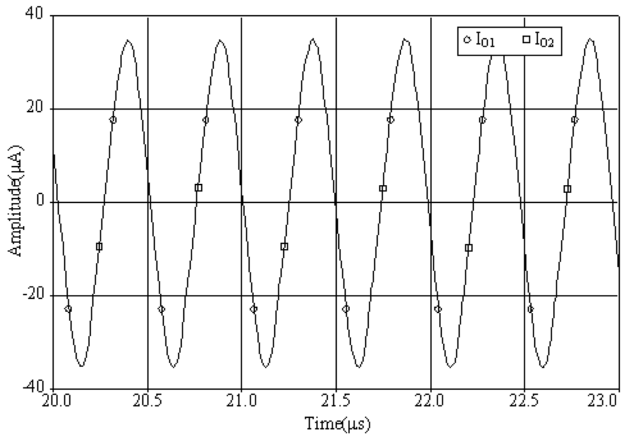


Figure 5. Steady state response of output signals.

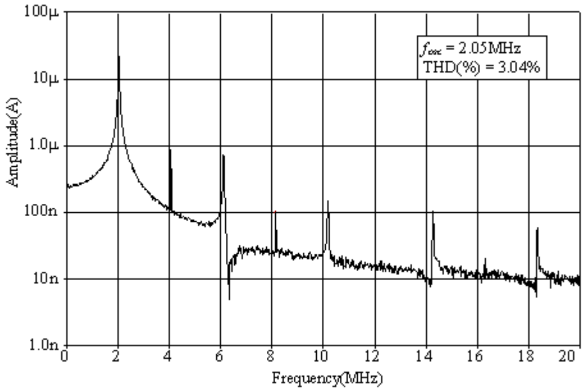


Figure 6. Frequency spectrums of output signals.

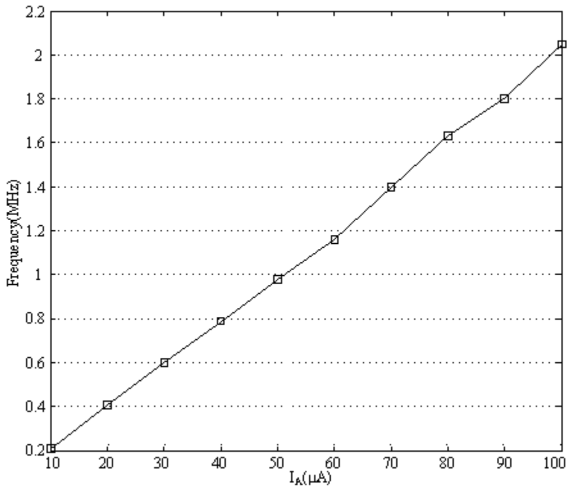


Figure 7. The FO versus I_A.

The simulation results in Figure 4 is depicted the output signals of I_{o1} and I_{o2} in transient response. Also, the steady state response of both output signals can be displayed in Figure 5 and the oscillation produces with the frequency of 2.05MHz. In addition, the frequency spectrums of output signals are plotted in Figure 6. The total harmonic distortion (THD) of output signals are about 3.04%. The FO for adjusting DC bias current I_A is demonstrated in Figure 7, where I_A is varied from $10\mu A - 100\mu A$. It evident that FO is proportional with DC bias current I_A that is accordant with the theoretical analysis in equation (9). The demonstration of electronic adjusting of amplitude I_{o1} is shown in Figure 8. It can be seen that, when the DC bias current I_{B1} is increased, the amplitude of I_{o1} is higher. These results are harmonized with theoretical analysis in equation (12).

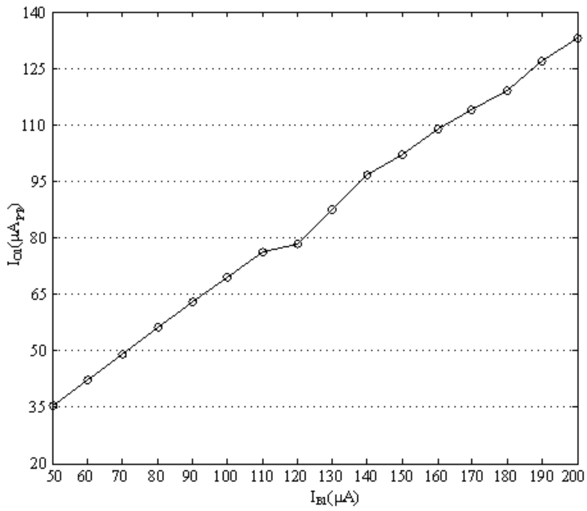
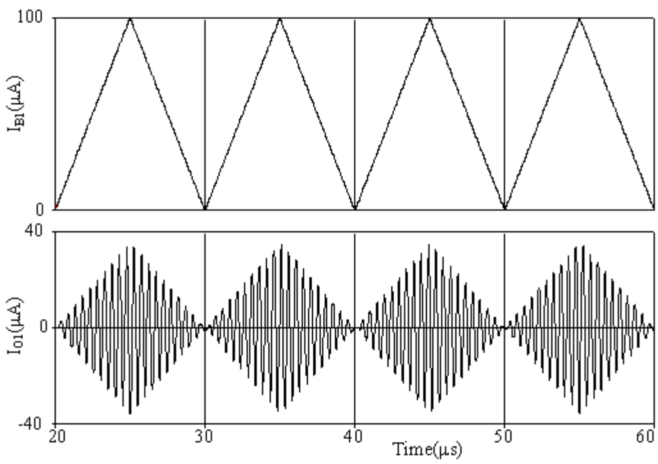
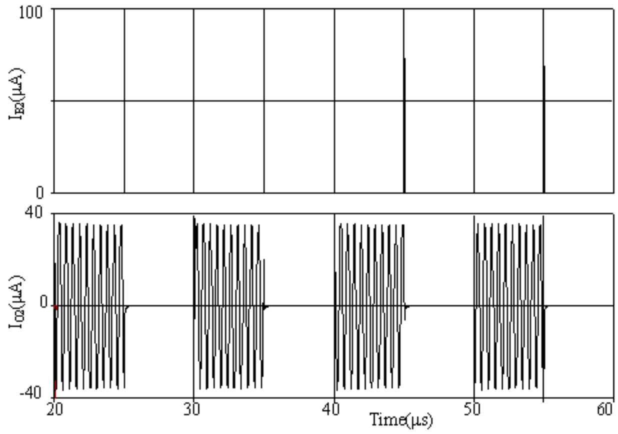


Figure 8. The amplitude of I_{o1} versus I_{B1}.



(a)



(b)

Figure 9. (a) The AM signal at I_{o1}, (b) the ASK signal at I_{o2}.

Furthermore, the output current I_{o1} can be generated the AM signal when I_{B1} is triangular signal with 100kHz frequency as shown in Figure 9(a). Simultaneously, the output current I_{o2} can be produced the ASK signal as illustrated in Figure 9(b), when fed the pulse signal into I_{B2}.

5. Conclusion

The three circuits of current-mode sinusoidal oscillator comprising of two CCCCTAs and two grounded capacitors have been presented. The grounded capacitors can reduce the fabrication area of IC and compensate the stay capacitance at node and input/output ports of CCCCTAs. The circuit features adjusted by DC bias currents of CCCCTAs can be controlled electronically, including the condition of oscillation, frequency of oscillation and the amplitude of sinusoidal outputs. For instance, they can provide the AM/ASK signals that are widely used in communication system or typically demonstrated in laboratory. In addition, the output terminals have high impedances that can directly drive load without external current buffers. The performances of proposed circuits found from PSPICE simulation well agree with the theoretical analysis.

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