CURRENT-MODE SINUSOIDAL OSCILLATOR USING CURRENT CONTROLLED CURRENT CONVEYOR TRANSCONDUCTANCE AMPLIFIER

ADIREK JANTAKUN, WORAWAT SA-NGIAMVIBOOL

Key words: Current-mode, Sinusoidal oscillator, Current controlled current conveyor transconductance amplifier.

The realization of current-mode sinusoidal oscillator using current controlled current conveyor transconductance amplifier (CCCCTA) and grounded elements is presented. The simple circuit configuration consists of merely one CCCCTA, one grounded resistor and two grounded capacitors. The use of only grounded capacitors is ideal for integration. The condition of oscillation and the frequency of oscillation can be electronic controled. Moreover, the output current signal can be electronically controllable of the amplitude. The high output impedance of output which facilitates cascading in current-mode configuration. The sensitivities of passive and active elements are low. The simulation results using PSPICE are given for the introduced sinusoidal oscillator to verify the theory and to exhibit the performances of the circuit.

1. INTRODUCTION

Sinusoidal oscillators are extremely useful circuits for various communication system, signal processing, instrument and measurement system [1–2] etc. Current-mode circuits have been receiving considerable attention of due to their potential advantages such as inherently wide bandwidth, higher slew-rate, greater linearity, wider dynamic range, simple circuitry and low power consumption [2–3].

Recently the previous works have proposed sinusoidal oscillator devices for compactness purpose using different high-performance active building blocks [1, 3–19], such as current conveyor (CCII), current feedback operational amplifier (CFOA), difference input buffer transconductance amplifier (DBTA), current differencing transconductance amplifier (CDTA), current differencing buffer amplifier (CDBA), four terminal floating nullor (FTFN), current conveyor transconductance amplifier (CCTA). Unfortunately these reported circuits suffer from one or more of the following weaknesses:

1. Lack of electronic tunability for the oscillation condition and the oscillation frequency [3–11].

Mahasarakham University, Department of Electrical Engineering, Kantharawichai District, Mahasarakham, 44150, Thailand, E-mail: mr.adirek@hotmail.com (Corresponding author)

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2. The circuit in Ref. [10] employs large number of passive components (eight) – six resistors and two capacitors, in Ref. [11] requires five resistors and two capacitors.
3. Use of floating capacitors [5, 7, 12–13], which is not convenient to further fabricate in an IC [14–19].
4. The circuit in Ref. [12] is very compact and employ only one CDTA element, one floating capacitor, one grounded capacitor and one floating resistor. The circuits, however, requires multiple current output terminals (*z* and *x* port), in Ref. [14] requires multiple current output terminals (*z* and *x* port), the circuits become more complicated.
5. Lack of amplitude controllable for current-output signal [3–19].

The purpose of this paper is to present a current-mode sinusoidal oscillator using CCCCTA. The proposed circuit provides the following advantage features:

1. The current-output signal from high-impedance which is easy to drive load and without using a buffering device [10, 15–17].
2. The proposed circuit uses only grounded capacitors, which is advantageous from the point of view of integrated circuit implementation [14–19].
3. Not modified or extended number of current output terminal (z port and o port), the circuit become compact and easily [17].
4. The current-output signal can be controlled amplitude of sinusoidal signal, which can provide the Amplitude Modulation (AM) and amplitude shift keying (ASK) signal that are widely used in communication systems [20].
5. Low active and passive sensitivities.

To verify the workability of the proposed sinusoidal oscillator, the PSPICE simulation results of a CMOS implementation have been include.

2. PRINCIPLE OF OPERATION

2.1. CURRENT CONTROLLED CURRENT CONVEYOR TRANSCONDUCTANCE AMPLIFIER

Since the proposed circuit is based on CCCCTA [20], a brief review of CCCCTA is given in this section. It was modified from the first generation CCTA [21]. The characteristics of the ideal CCCCTA are represented by the following hybrid matrix:

$$\begin{bmatrix} I_y \\ V_x \\ I_z \\ I_o \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 1 & R_x & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & \pm g_m \end{bmatrix} \begin{bmatrix} V_y \\ I_x \\ V_0 \\ V_z \end{bmatrix}. \tag{1}$$

For the CCCCTA implemented by a CMOS technology, the parasitic resistance R_x is given as

$$R_x = \frac{1}{\sqrt{8k_1 I_{B1}}}, \tag{2}$$

where, $k_1 = \mu_p C_{ox} \left(\frac{W}{L} \right)_{1,2} = \mu_n C_{ox} \left(\frac{W}{L} \right)_{1,2}$ the I_{B1} is the bias current to control the intrinsic resistance of the input terminal *x* and transconductance g_m is given as

$$g_m = \sqrt{k_2 I_{B2}}, \tag{3}$$

where $k_2 = \mu_n C_{ox} \left(\frac{W}{L} \right)_{14,15}$.

Here $k_1 = \mu_n C_{ox} \left(\frac{W}{L} \right)$ is the physical parameter of CMOS transistor (C_{ox} is the gate oxide capacitance per unit area, μ_n is the electron mobility in the channel, *W* and *L* are the channel width and length, respectively). The I_{B2} is control current adjusting the transconductance g_m of the CCCCTA. The symbol and equivalent circuit of the CCCCTA are illustrated in Figs. 1a and b, respectively.

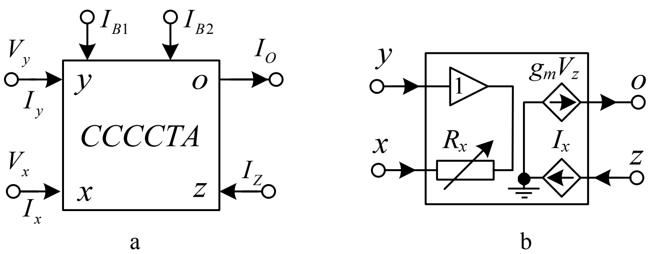

Fig. 1 – CCCCTA: a) schematic symbol; b) equivalent circuit.

2.2. PROPOSED CIRCUIT

The completely sinusoidal oscillator is shown in Fig. 2. It uses a single CCCCTA, two grounded capacitor and a grounded resistor. The grounded resistor may easily be implemented as a variable resistor using only two CMOS [22]. Using (1) and doing routine circuit analysis, the system characteristic equation can be expressed as

$$C_1 C_2 R_1 R_x s^2 + (C_1 R_1 + C_2 R_x - C_2 R_1)s + 1 = 0. \tag{4}$$

From (4), it can be seen that the proposed circuit can produce oscillations if the condition of oscillation is fulfilled

$$C_2 R_1 \geq C_1 R_1 + C_2 R_x. \tag{5}$$

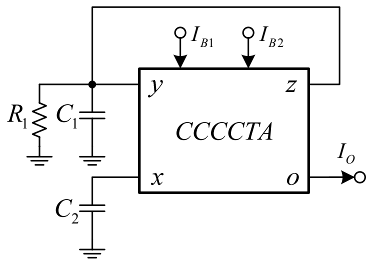

Fig. 2 – The proposed sinusoidal oscillator using CCCCTA.

If the above condition of oscillation is satisfied the circuit produces oscillations with frequency of

$$\omega_{osc} = \frac{1}{\sqrt{C_1 C_2 R_1 R_x}} . \tag{6}$$

Substituting the parasitic resistance R_x as respectively shown in (2) into (5) and (6), it is found that the condition of oscillation and the frequency of oscillation can be electronically controlled by setting I_{B1}.

The current-output I_O can be obtained as

$$I_O = g_m V_z . \tag{7}$$

From (7), the voltage V_z is the sinusoidal signal that means the amplitude of sinusoidal signal in current-mode I_O can be electronically controlled by I_{B2}. So if I_{B2} is a modulating signal, the AM and ASK signal can be obtained at I_O. In addition the output-current I_O is high-impedance, it is easy to drive load without using a buffering device.

2.3. SENSITIVITY ANALYSIS

The sensitivity is a measure of the performance criterion of an active network. The sensitivity of some performance measure y with respect to a network element value x to be

$$S_x^y = \frac{x}{y} . \frac{\partial y}{\partial x} . \tag{8}$$

Using definition of (8), the relative sensitivities of the frequency of oscillation to variation of active and passive value are given as

$$S_{C_1}^{\omega_{osc}} = S_{C_2}^{\omega_{osc}} = S_{R_1}^{\omega_{osc}} = S_{R_x}^{\omega_{osc}} = -\frac{1}{2} . \tag{9}$$

It is evident from (9) that the absolute value of sensitivities less than unity in magnitude. Thus, the proposed oscillator exhibits a low sensitivity performance.

2.4. NON-IDEAL ANALYSIS

Considering to voltage and current tracking errors, the CCCCTA properties can be written as

$$\begin{bmatrix} I_y \\ V_x \\ I_z \\ I_o \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ \gamma & R_x & 0 & 0 \\ 0 & \alpha & 0 & 0 \\ 0 & 0 & 0 & \pm\beta g_m \end{bmatrix} \begin{bmatrix} V_y \\ I_x \\ V_0 \\ V_z \end{bmatrix}, \tag{10}$$

the characteristic equation for the proposed circuit shown in Fig. 2, get modified to

$$\alpha\gamma R_1 R_x C_1 C_2 s^2 + (R_x C_2 + R_1 C_1 - \alpha\gamma R_1 C_2)s + 1 = 0 . \tag{11}$$

Then the condition of oscillation and oscillation frequency of the proposed circuit become

$$\alpha\gamma C_2 R_1 \geq C_2 R_x + C_1 R_1 , \tag{12}$$

and

$$\omega = \frac{1}{\sqrt{\alpha\gamma C_1 C_2 R_1 R_x}} , \tag{13}$$

where γ is the parasitic voltage gain from y terminal to x terminal, respectively α is the parasitic current transfer gain x terminal to z terminal and β is the parasitic current gain associated with copies of the current from o terminal. All this gains slightly differ from their ideal values of unity by current tracking errors.

It is founded that parameters γ and α will affect bolt condition of oscillation and oscillation frequency. These parameters are dependent on temperature variations. Consequently, these errors affect the sensitivities on temperature and high frequency response of the proposed circuit, the CCCCTA should be carefully designed to minimize these errors.

Table 1

Dimension of CMOS transistors

CMOS TRANSISTORS	W(μm)/L(μm)
M1-M5	3/0.25
M6-M7	8/0.25
M8-M13	5/0.25
M14-M15	5/1
M16	8/1
M17	8.2/1
M18-M21	10/1

3. SIMULATION RESULTS

To prove the performances of the proposed circuit, a PSPICE simulation was performed for examination. The PMOS and NMOS were simulated by using the parameters of a 0.25 μm TSMC CMOS technology [23]. Fig. 3 depicts the schematic description of the CCCCTA used in the simulations with ±1.25 supply voltages. The aspect transistor ratios of PMOS and NMOS are listed in Table 1, which the size of the W and L are measured in micrometer. The sinusoidal oscillator has been design with $C_1 = 5$ pF, $C_2 = 12$ pF, $R_1 = 1.8$ kΩ, $I_{B1} = 77$ μA and $I_{B2} = 200$ μA. This yields oscillation frequency of 15.40MHz. Fig. 4 shows simulated output waveforms in steady state. Fig. 5 shows simulated output spectrum, where the total harmonics distortion (THD) of current-output is about 1.70%.

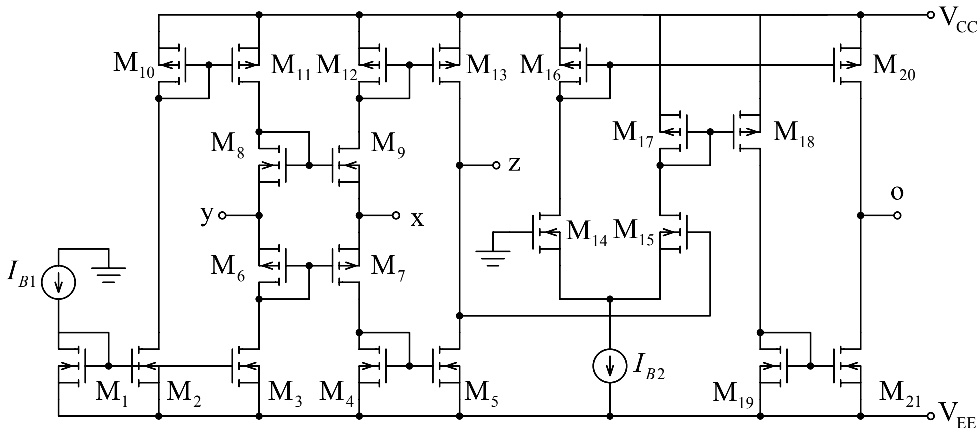

Fig. 3 – The internal construction of CCCCTA.

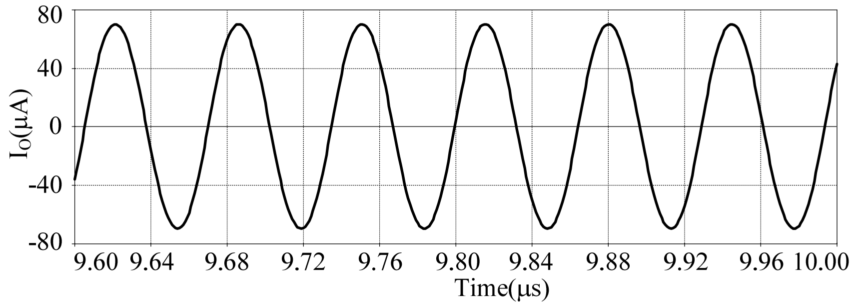

Fig. 4 – The steady state waveforms of sinusoidal oscillator.

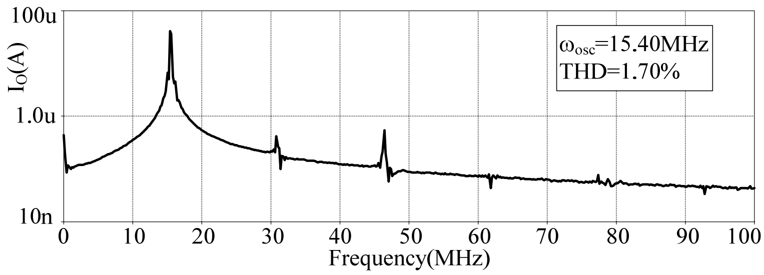

Fig. 5 – Frequency spectrum of signal in Fig. 4.

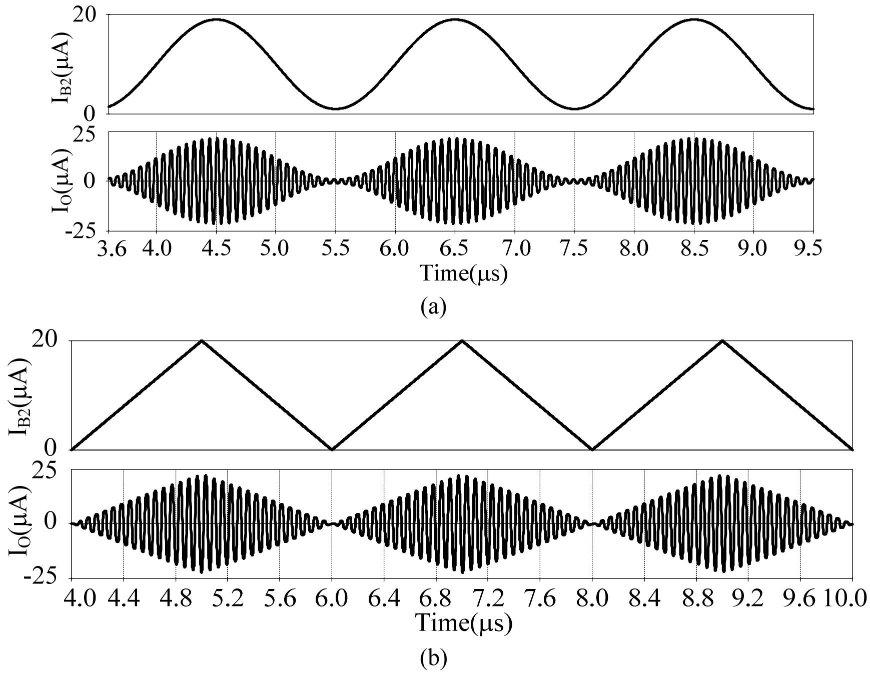

Fig. 6 – Results of operation of amplitude modulation (AM).

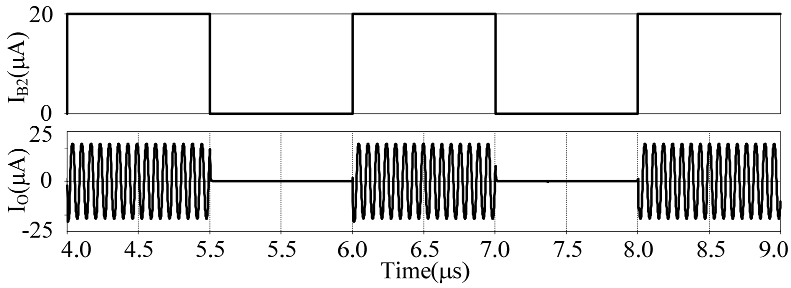

Fig. 7 – Results of operation of amplitude shift keying (ASK).

The simulated results of the proposed circuit, serving as an AM signal generator, where I_{B2} were sinusoidal and triangular signal with a 500kHz frequency are applied, respectively, are illustrated in Fig. 6a and b. Fig. 7 displays the output signal against input signal, where the proposed circuit functions as an ASK signal generator, where I_{B2} was pulse signal with a 500kHz frequency, respectively.

4. **CONCLUSION**

An amplitude controllable sinusoidal oscillator using single CCCCTA and grounded elements has been presented. The proposed circuit consists of only single CCCCTA and two grounded capacitors and one grounded resistor. An electronically control of both the condition of oscillation and the frequency of oscillation is achieved. Due to high-output impedances, it enables easy driving load without external current buffer. The amplitude of sinusoidal output terminal can be electronically tuned. Moreover, it can provide the AM/ASK signals that are widely used in communication systems. The PSpice simulation results agree well with the theoretical anticipation.

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