Current-mode Sinusoidal Oscillator Using Single CCCCTA and Grounded Elements

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Abstract
This paper presents current-mode sinusoidal oscillator using single current-controlled current conveyor transconductance amplifier (CCCCTA) as active element and external grounded passive elements. The oscillation condition and oscillation frequency can be electronically/orthogonally controlled via input bias currents. The circuit description is very simple, consisting of merely 1 CCCCTA, 2 grounded capacitors and 1 grounded resistor. The proposed circuit employs only grounded elements, then it is suitable for IC architecture. The circuit can cascades in current-mode or drive load directly without additional buffers. The PSpice simulation results are depicted, and the given results agree well with the theoretical anticipation. The power consumption is approximately 1.61 mW at ±1.5V supply voltages.

Keywords: Oscillator, Current-mode, CCCCTA

1. Introduction
An oscillator is an important basic building block, which is frequently employed in electrical engineering applications. Among the several kind of oscillators, quadrature oscillator is widely used because it can offer sinusoidal signals with 90° phase difference, for example, in telecommunication for quadrature mixers and single-sideband [1]. The current–mode technique is ideally suited for this purpose, more so than voltage-mode. Consequently, there is a growing interest in synthesizing current-mode circuits because of their many potential advantages, such as larger dynamic range, higher signal bandwidth, greater linearity, simpler circuitry, and lower power consumption [2].

The high-output impedance of current-mode oscillators are of great interest because they make it easy to drive loads and they facilitate cascading without using a buffering device [3-5]. Moreover, circuits that employ only grounded capacitors are advantageous from the point of view of integrated circuit implementation [5-7].

From our survey, we found that several implementations of oscillators employing different high-performance active building blocks, such as: OTAs [10, 16], current conveyors [6], Four-Terminal Floating Nullors (FTFN) [3-4], current follower [8-9], CCCDBAs [12], CCCDTAs [13-14], FDCCI [15], DVCCs [11] have been reported. Unfortunately, these reported circuits suffer from one or more of following weaknesses:

• Excessive use of the passive and active elements, especially resistors [3-4, 6, 11].
• Cannot be electronic controllable [3-4, 6, 8-9, 16].
• Output impedances are not high. Therefore, output current cannot be used to load directly [3-4, 6, 8-14, 16].
• Use of a floating capacitor, which is not convenient to future fabricate in IC [11].
• The oscillation condition and oscillation frequency cannot be independently controlled [8-10].

The current conveyor transconductance amplifier (CCTA) is a reported active component, especially suitable for a class of analog signal processing [17]. The fact that the devices can operate in both current and voltage-mode provides flexibility and enables a variety of circuit designs. In addition, it can offer advantageous features such as high-slew rate, higher speed, wide bandwidth and simple implementation. However, the CCTA cannot control the parasitic resistance at \( X(R_X) \) port so when it is used in some circuits, it must unavoidably require some external passive components, especially the resistors. This makes it not appropriate for IC implementation due to occupying more chip area, high power dissipation and without electronic controllability. On the other hand, the introduced current-controlled current conveyors
transconductance amplifier (CCCCTA) [18] has the advantage of electronic adjustability over the CCTA.

The purpose of this paper is to introduce an oscillator based on CCCCTA. The oscillation condition can be adjusted independently from the oscillation frequency. The circuit description consists of 1 CCCCTA, 2 grounded capacitors and 1 grounded resistor. The proposed circuit is using only grounded elements then suitable for IC architecture. The PSpice simulation results are also shown, which are correspondence with the theoretical analysis.

2. Principle of operation

2.1 Basic concept of CCCCTA

The CCCCTA properties are similar to the conventional CCTA, except that the CCCCTA has finite input resistance \( R_x \) at the \( x \) input terminal. This parasitic resistance can be controlled by the bias current \( I_{B1} \) as shown in the following equation

\[
\begin{bmatrix}
I_x \\
V_x \\
I_o
\end{bmatrix} = 
\begin{bmatrix}
0 & 0 & 0 & I_c \\
R_x & 1 & 0 & V_r \\
1 & 0 & 0 & V_s \\
0 & 0 & g_m & 0
\end{bmatrix} 
\begin{bmatrix}
I_c \\
V_r \\
V_s \\
V_o
\end{bmatrix}
\]

where \( R_x \) and \( g_m \) are the parasitic resistance and transconductance of CCCCTA respectively. For the bipolar CCCCTA, the \( R_x \) and \( g_m \) can be expressed to be

\[
R_x = \frac{V_r}{2I_{B1}}
\]

and

\[
g_m = \frac{I_{B2}}{2V_T}
\]

where \( I_B \) and \( V_T \) are the input bias current and thermal voltage respectively. The schematic symbol and equivalent circuit of CCCCTA can be respectively shown in Figs. 1(a) and (b).

\[
I_{B1} = R
\]

Eq. (5) is oscillation condition. The oscillation frequency can be written as

\[
\omega = \frac{g_m}{\sqrt{C_2R_x}}
\]

Substituting the parasitic resistance and transconductance as depicted in Eqs. (2) and (3), into Eqs. (5) and (6), it yields

\[
I_{B2} = \frac{2V_T}{R}
\]

and

\[
\omega = \frac{1}{V_T\sqrt{I_{B1/I_{B2}}}}
\]

From Eq. (7) and Eq. (8), it is seen that oscillation condition can be adjusted independently from the oscillation frequency by \( R \) and oscillation frequency can be adjusted by \( I_{B1} \) and \( I_{B2} \).

Considering the circuit in fig. 2 the transfer function of \( I_{O1} \) and \( I_{O2} \) is

\[
\frac{I_{O2}(s)}{I_{O1}(s)} = \frac{1}{sC_2R_x}.
\]

Considering in sinusoidal steady-state, Eq. (9) can be re-written as

\[
\frac{I_{O2}(j\omega)}{I_{O1}(j\omega)} = \frac{1}{\omega C_2R_x}e^{-\phi}
\]

The phase difference of \( I_{O1} \) and \( I_{O2} \) is

\[
\phi = -90^\circ
\]
3. Results
Simulation results
To prove the performances of the proposed circuit, a PSpice simulation was performed for examination. The PNP and NPN transistor employed in the proposed circuit were simulated respectively using the parameters of the PR200N and NR200N bipolar transistor array from AT&T [19]. Fig. 3 depicts the schematic description of CCCCTA used in the simulations. The circuit was biased with ±1.5V supply voltages, \(C_1=C_2=1\text{nF}, R=500\Omega, I_{B1}=50\mu\text{A}\) and \(I_{B2}=100\mu\text{A}\). Figs. 4 and 5 show simulated output signal and the spectrum of frequency at 312.618kHz where the total harmonic distortion (THD) is 1.51%. Fig. 6 shows the plot of oscillation frequency of output signal when varying bias current and capacitor. The power consumption is approximately 1.61 mW. While oscillation frequency can be adjusted by varying bias current \(I_{B1}\) and \(C_1=C_2\) shown in Fig 6.

4. Conclusions
A simple oscillator based on CCCCTA has been reported. The features of the proposed circuit are that: oscillation frequency and oscillation condition can be orthogonally adjusted via input bias currents, the proposed circuit consists of 1 CCCCTA, 1 grounded resistor and 2 grounded capacitors, which is convenient to fabricate IC. The PSpice simulation results agree well with the theoretical anticipation. The power consumption is approximately 1.61 mW at ±1.5V supply voltages.

References


