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A simple oscillator using only single CCCCTA and grounded capacitors

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ABSTRACT

This article presents a simple oscillator using single current-controlled current conveyor transconductance amplifier (CCCCTA) as active elements. The oscillation condition and oscillation frequency can be electronically or orthogonally controlled via input bias currents. The circuit description is very simple, consisting of merely 1 CCCCTA, and 2 grounded capacitors. Without any external resistors and using only grounded elements, the proposed circuit is then suitable for IC architecture. The PSPICE simulation results are depicted, and the given results agree well with the theoretical anticipation. The power consumption is approximately 1.9 mW at ±1.5V supply voltages.

Key Words: Oscillator, CCCCTA

1. INTRODUCTION

An oscillator is an important basic building block, which is frequently employed in electrical engineering applications. From our survey, we found that several implementations of oscillators employing different high-performance active building blocks, such as, OTAs (Minael and Cicekoglu, 2002; Kumwachara and surakampong, 2003), current conveyors (Chen et al., 1991), Four-Terminal Floating Nullors (FTFN) (Abuelma’atti and Al-Zaher, 1999; Cam et al. 2000), current follower (Abuelma’atti, 1992), current controlled current differencing buffered amplifiers (CCCDBAs) (Jaikla and Siripruchyanun, 2006a), current controlled current differencing transconductance amplifiers (CCCDTAs) (Jaikla and Siripruchyanun, 2006b; Jaikla and Siripruchyanun, 2007), fully-differential second-generation current conveyor (FDCCII) (Horng et al., 2006), and differencing voltage current conveyor (DVCCs) (Horng, 2003), have been reported. Unfortunately, these reported circuits suffer from one or more of following weaknesses:

- Use of a floating capacitor, which is not convenient to further fabricate in IC (Horng, 2003).
- The oscillation conditions and oscillation frequencies cannot be independently controllable (Abuelma’atti, 1992; Minael and Cicekoglu, 2002).

The current conveyor transconductance amplifier (CCTA) is a reported active component, especially suitable for a class of analog signal processing (Prokop and Musil, 2005). The fact that the device can operate in both current and voltage-modes 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 (Prokop and Musil, 2005). However, the CCTA can not
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 conveyor transconductand amplifier (CCCCTA) (Srirupruchanun and Jaikla, 2007) has the advantage of electronic adjustability over the CCI1.

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 construction consists of 1 CCCCTA and 2 grounded capacitors. Without any external resistors and using only grounded elements, the proposed circuit is then suitable for IC architecture. The PSPICE simulation results are also shown, which are in correspondence with the theoretical analysis.

1.1 Principle of operation

1.1.1 Basic Concept of CCCCTA

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 $I_{Bl}$ as shown in the following equation

$$
\begin{bmatrix}
I_y \\
V_x \\
I_z \\
I_o
\end{bmatrix} =
\begin{bmatrix}
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
I_x \\
V_y \\
V_z \\
V_o
\end{bmatrix},
$$

(1)

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

$$
R_x = \frac{V_T}{2I_{Bl}},
$$

(2)

and

$$
g_m = \frac{I_{Bl}}{2V_T},
$$

(3)

where $I_{Bl}$ 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 Fig. 1(a) and (b).

![Figure 1. CCCCTA (a) symbol (b) equivalent circuit](image)

1.1.2 Proposed simple oscillator

Fig. 2 depicts the proposed simple oscillator. By routine analysis circuit in Fig. 2 and using the properties of CCCCTA in section 1, the following system characteristic equation is obtained

$$
S^2C_2C_1R_x + S(C_1-C_2)+g_m = 0.
$$

(4)

From Eq. (4), it can be seen that the circuit can be set to be the oscillator if

$$
C_1 = C_2
$$

(5)

![Figure 2. Proposed simple oscillator](image)

Eq. (5) is called the condition of oscillation, thus the characteristic equation of the system becomes
\[ S^2 + \frac{g_m}{C_1 C_2 R_x} = 0. \]  

(6)

From Eq. (6), the oscillation frequency of this system can be obtained as

\[ \omega_0 = \sqrt{\frac{g_m}{C_1 C_2 R_x}}. \]  

(7)

Substituting the parasitic resistance and transconductance as depicted in Eq. (2) and (3), it yields

\[ \omega_0 = \frac{1}{V_r} \sqrt{\frac{l_{B1} l_{B2}}{C_1 C_2}}. \]  

(8)

From Eqs. (5) and (8), the oscillation condition can be adjusted independently from the oscillation frequency by \( C_1 \) and \( C_2 \), while the oscillation frequency can be adjusted by varying bias currents. The active and passive sensitivities of the oscillator are all low and can be obtained as

\[ S_{c_1 c_2}^{\omega_0} = -\frac{1}{2}, S_{\omega_0}^{\alpha_1} = \frac{1}{2}, S_{\omega_0}^{\gamma} = -1. \]  

(9)

1.1.3 Non ideal case

In non-ideal case, the CCCCTA can be characterized by

\[ V_x = \beta V_y + R I_{x} I_{z} = \alpha_1 I_{x_1} = \gamma V_z \]  

(10)

where \( \beta, \alpha \), and \( \gamma \) are transferred error values deviated from one. In the case of non-ideal and reanalyzing the proposed filter circuit in Fig. 2, it yields the system characteristic equation as

\[ s^2 C_1 C_2 R_x + s(C_1 - \alpha \beta C_2) + \alpha \gamma g_m = 0. \]  

(11)

In this case the oscillation condition and oscillation frequency are changed to be

\[ C_1 = \alpha \beta C_2, \]  

(12)

and

\[ \omega_0 = \sqrt{\frac{\alpha \gamma g_m}{C_1 C_2 R_x}}. \]  

(13)

Practically, the \( \beta, \alpha \), and \( \gamma \) originate from intrinsic resistances and stray capacitances in the CCCCTA. These errors affect the sensitivity to temperature and high frequency response of the proposed circuit, then the CCCCTA should be carefully designed to achieve these errors as low as possible.

2. RESULTS

Simulation results

To prove the performances of the proposed circuit, a PSPICE simulation was performed for examination. The PNP and NPN transistors employed in the proposed circuit were simulated by respectively using the parameters of the PR200N and NR200N bipolar transistors of ALA400 transistor array from AT&T (Frey, 1993). Fig. 3 depicts the schematic description of CCCCTA used in the simulations. The circuit was biased with \( \pm 1.5 V \) supply voltages, \( C_1 = 1 \) nF, \( C_2 = 1.028 \) nF, \( I_{B1} = 100 \) \( \mu A \) and \( I_{B2} = 200 \) \( \mu A \). Figs. 4 and 5 show simulated output waveforms. Fig. 6 shows the simulated output spectrum, where the total harmonic distortion (THD) is about 6.64%. The results of the \( V_o \) total harmonic distortion analysis are summarized in Table 1. The power consumption is approximately 1.9 mW.

![Figure 3. Internal topology of CCCCTA](image-url)
Figure 4. The simulation results of output waveforms during initial state

Figure 5. The simulation results of output waveforms during steady state

Figure 6. The simulation result of output spectrum

Table 1. Total harmonic distortion analysis of $V_o$ in Fig. 3.

<table>
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<tr>
<th>Harmonic no.</th>
<th>Frequency (Hz)</th>
<th>Fourier component</th>
<th>Normalized component</th>
<th>Phase (Deg)</th>
<th>Normalized Phase</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>6.300E+05</td>
<td>1.389E-01</td>
<td>1.000E+00</td>
<td>7.057E+01</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>2</td>
<td>1.260E+06</td>
<td>2.430E-03</td>
<td>1.750E-02</td>
<td>-1.262E+02</td>
<td>1.499E+01</td>
</tr>
<tr>
<td>3</td>
<td>1.890E+06</td>
<td>8.809E-03</td>
<td>6.344E-02</td>
<td>-1.527E+02</td>
<td>-3.644E+02</td>
</tr>
<tr>
<td>4</td>
<td>2.520E+06</td>
<td>4.403E-04</td>
<td>3.171E-03</td>
<td>-9.798E+01</td>
<td>-3.803E+02</td>
</tr>
<tr>
<td>5</td>
<td>3.150E+06</td>
<td>1.135E-03</td>
<td>8.171E-03</td>
<td>-1.783E+01</td>
<td>-3.707E+02</td>
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<td>6</td>
<td>3.780E+06</td>
<td>7.236E-05</td>
<td>5.211E-04</td>
<td>-8.298E+01</td>
<td>-3.751E+02</td>
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<tr>
<td>7</td>
<td>4.410E+06</td>
<td>2.182E-04</td>
<td>1.571E-03</td>
<td>1.226E+02</td>
<td>-3.714E+02</td>
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<tr>
<td>8</td>
<td>5.040E+06</td>
<td>3.712E-05</td>
<td>2.673E-04</td>
<td>-1.150E+02</td>
<td>-6.796E+02</td>
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<tr>
<td>9</td>
<td>5.670E+06</td>
<td>8.216E-05</td>
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<td>-8.241E+01</td>
<td>-7.176E+02</td>
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<tr>
<td>10</td>
<td>6.300E+06</td>
<td>5.117E-05</td>
<td>3.685E-04</td>
<td>-1.868E+01</td>
<td>-7.244E+02</td>
</tr>
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DC COMPONENT = 3.490894E-04
TOTAL HARMONIC DISTORTION = 6.841719E+00 PERCENT

3. CONCLUSIONS

A simple oscillator based on CCCCTA has been presented. The features of the proposed circuit are that: oscillation frequency an oscillation condition can be orthogonally adjusted via input bias current; the proposed consists of 1 CCCCTA and 2 grounded capacitors, which is convenient to fabricate. The PSPICE simulation results agree well with the theoretical anticipation.

4. REFERENCES


