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Gain Controlled Sinusoidal Oscillator Using Current Controlled Current Conveyors

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ABSTRACT

A gain-controlled sinusoidal oscillator circuit based on current-controlled current conveyors (CCCII) is introduced. The circuit contains three CCCIIs and two grounded capacitors and no resistor. The amplitude of the output current can be controlled electronically. Hence, the proposed topology is suitable for IC implementation. The CCCII has been implemented using 0.35 µm CMOS technology and the PSPICE simulation results are given.

Keywords: *CCCII, oscillator, gain control*

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INTRODUCTION

Current conveyor has received attention in recent years as an alternative to the voltage mode operational amplifiers. When arranged with other electronic elements it can be used for the implementation of various functions operating either in the voltage-mode or current-mode [1]. Current conveyor offers many advantages over conventional operational amplifier circuits such as providing higher voltage gain over a large signal bandwidth results in large gain-bandwidth product, wider dynamic range, and low power consumption [1]. Over the last two decades or so, several schemes of design of R-C oscillator based on various current conveyors have been developed [2–14]. Most of the reported oscillators provide non-interacting controls over the condition of oscillation and frequency of oscillation. There are different techniques of amplitude control from simple nonlinear limiters [15] to sophisticated control loops which require omplicated circuitry on the loop than the primary oscillator [16].

In this paper, a CCCII-based oscillator circuit with output amplitude control is proposed. The CCCII-based current mode oscillator circuit [6] consists of two CCCII and two grounded capacitors. One CCCII + is added at the output port of this oscillator circuit, which is used to control the amplitude of the oscillator electronically and at the same time it functions as a buffer to avoid any loading effect.

CIRCUIT DESCRIPTION

The symbol of analog building block CCCII is given in Figure 1. The port relationships of CCCII are given in the matrix form in Eq. (1).

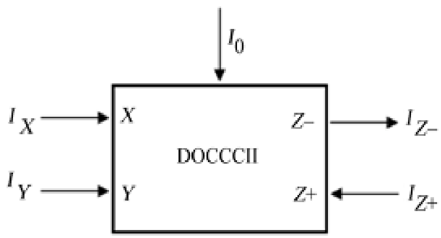

Fig.1 Block Diagram for CCCII.

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$$\begin{bmatrix} I_Y \\ V_X \\ I_Z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & R_X & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} V_Y \\ I_X \\ V_Z \end{bmatrix} \quad (1)$$

The plus and minus signs in Eq. (1) denote positive and negative types of the current-controlled current conveyors (CCCII + and CCCII −) respectively. R_X represents the intrinsic series input resistance of the conveyor at X port, which is electronically tunable via I_0 of the CMOS based CCCII as shown in Figure 2. With high enough current values of I_0 (i.e., in strong inversion), if the MOS transistors operate in saturation region, R_X can be defined as [13]

$$R_X = \frac{1}{g_{m2} + g_{m4}} \quad (2)$$

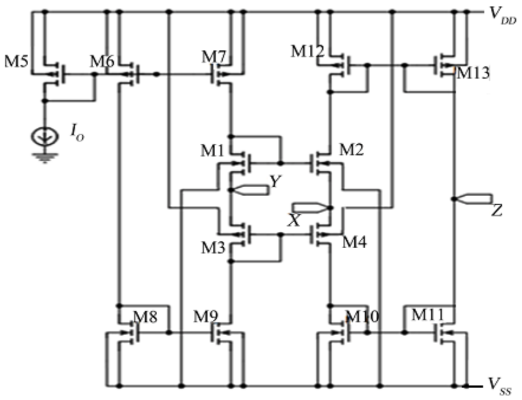
where,

$$g_{mi} = \sqrt{2\beta_i I_0} \qquad (i = 2,4) \quad (3)$$

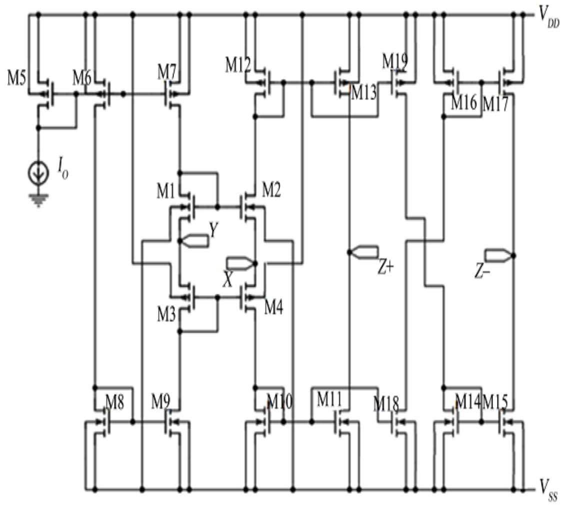
and

$$\beta_i = \frac{\varepsilon_0 \varepsilon_{ins} \mu_i W_i}{t_{ox} L_i} \quad (4)$$

where, g_{m2} and g_{m4} are the transconductances of M_2 and M_4 respectively.



(a)



(b)

Fig.2 CMOS-Based Internal Circuits of (a) CCCII +, and (b) CCCII−.

The CCCII-based current mode oscillator circuit with gain control is shown in Figure 3. The routine analysis yields the characteristic equation [6] as

$s^2 R_{x1} R_{x2} C_1 C_2 + (R_{x1} C_1 + R_{x2} C_2 - R_{x1} C_2)s + 2 = 0$ (5)

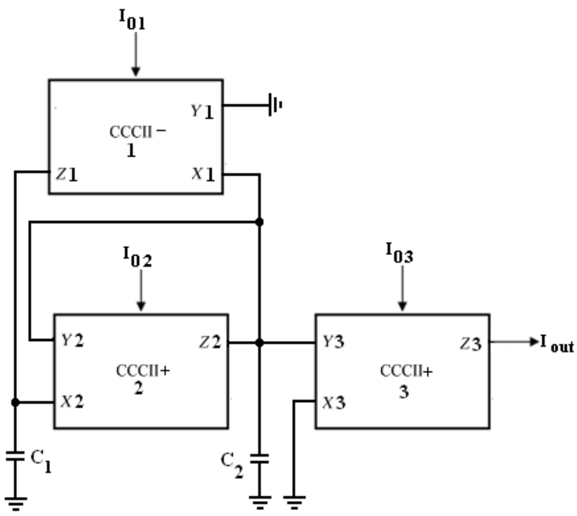


Fig. 3 CCCII-Based Oscillator Circuit with Gain Control.

The frequency of oscillation is obtained as

$$\omega_0 = \frac{2}{\sqrt{2R_{X1}R_{X2}C_1C_2}} \quad (6)$$

and the condition of oscillation assuming $C_1 = 2C_2$ is

$$R_{X1} = 2R_{X2} \quad (7)$$

From Eqs. (2), (3), (4) and (7) the oscillation condition is obtained as

$$I_{02} = I_0 \quad (8)$$

Further analysis gives output of the oscillator as

$$I_{out} = \frac{V_{Y3}}{R_{X3}} \quad (9)$$

Equations (6) and (9) reveal that the frequency of oscillator can be varied electronically with bias currents I_{01} and I_{02} without disturbing the amplitude of the output signal. Similarly, the amplitude of the output signal can be varied electronically with I_{03} without disturbing the frequency of oscillation. It may also be noted that the current output is obtained at high impedance output port. Hence the circuit is suitable for cascading without any additional buffer.

SIMULATION AND RESULT

The proposed gain control oscillator circuit has been simulated using the CMOS-based CCCII circuit given in Figure 2. The parameters of the AMS 0.35 µm CMOS technology are used for all MOSFETs in the circuit. The dimensions of the NMOS and PMOS transistors used in this circuit are given in Table I [13].

Table I MOS Dimensions Used in the Circuit.

Transistors	W(µm)	L(µm)
M_1, M_2	20	0.35
M_3, M_4	60	0.35
M_5, M_6, M_7	30	2
M_8, M_9	10	2
M_{10}, M_{11}, M_{14}, M_{15}	10	1
M_{12}, M_{13}, M_{16}, M_{17}	30	1

The power supplies for the CCCII ± are taken as ± 2.5 V. The capacitor values are taken as $C_1 = 24$ nF and $C_2 = 10$ nF. Theoretically $C_1 = 2C_2$, but due to non-ideal behavior of the CCCII ±, the oscillation is obtained at slightly deviated value of C_1. Output of the oscillator at $I_{01} = 50$ µA, $I_{02} = 200$ µA and $I_{03} = 100$ µA is shown in Figure 4. To show the electronic controllability of amplitude of oscillator, a triangular wave of amplitude 400 µA, as shown in Figure 5, is applied at I_{03} of the oscillator circuit. The corresponding amplitude-modulated output of the oscillator is shown in Figure 6. It is found that the amplitude of the output current is varying according to the variation of bias current I_{03}. To check the quality of output signal, the percentage total harmonic distortion (% THD) is obtained as shown in Figure 7. It shows that the percentage total harmonic distortion (% THD) is well within the acceptable limit.

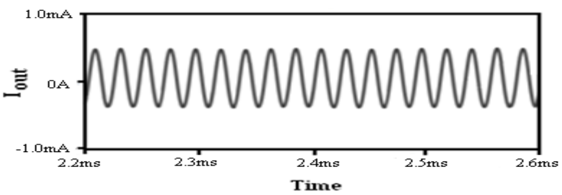


Fig. 4 Oscillation Obtained with $I_{01} = 50$ µA $I_{02} = 200$ µA and $I_{03} = 100$ µA

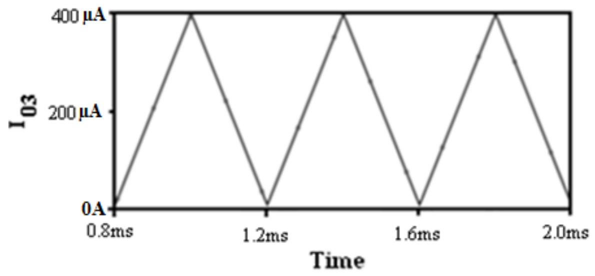


Fig. 5 Input Current Waveform in I_{03} = 400 µA.

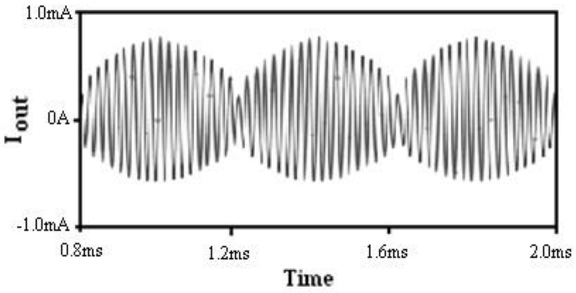


Fig. 6 The Amplitude-Modulated Waveform for I_{03}.

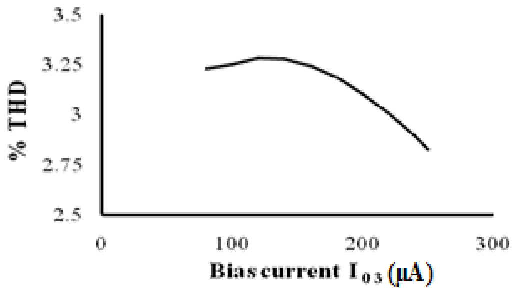


Fig. 7 Variation of %THD vs Bias Current (I_{03}).

CONCLUSIONS

An oscillator with gain control mechanism is proposed. The simulated result verifies that the proposed circuit can offer orthogonal electronic tunability to amplitude of oscillation and frequency of oscillation. The proposed circuit does not use any resistor. Its capacitors are grounded and output impedance is high, hence suitable for IC design.

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