CURRENT-MODE OSCILLATOR CONFIGURATION USING SINGLE CURRENT OPERATIONAL AMPLIFIER

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ABSTRACT

In this study, a general configuration for realizing current-mode sinusoidal oscillators is proposed. The circuits obtained from the general configuration employ single current operational amplifier (COA), two capacitors and at most three resistors meaning that the realizations are canonic and also minimal. The proposed oscillators are insensitive to parasitic input capacitances and resistances due to internally grounded input terminals of COA. They have also very low passive sensitivities. PSPICE simulation results are given to verify the theoretical analysis.

I. INTRODUCTION

The generation of sinusoidal waveforms is an important task for electronics engineering. Oscillators are widely used in signal processing circuits, communication, control and measurement systems. Many sinusoidal oscillators employing operational amplifier (op-amp) have been reported up to now. However, the classical op-amp suffers from limited gain-bandwidth product affecting oscillation condition and frequency of the oscillators designed by using op-amp. Therefore, they remain unsatisfactory at higher frequencies [1]. To overcome this problem, several sinusoidal oscillators have been introduced which use operational transconductance amplifier, current conveyor, current feedback operational amplifier or four-terminal floating nullor as the active element [2-9]. Some of these oscillator circuits are voltage-mode [2, 3, 5-7] and some others are current-mode [4, 8, 9].

Recently, attention has concentrated on the use of COA as true current-mode active element in current-mode signal processing circuits. Both input terminals of COA are characterized by low impedance, thereby eliminating response limitations incurred by capacitive time constants. The input terminals are internally grounded leading to circuits that are insensitive to the stray capacitances. The output terminals of COA exhibit high impedance so that COA-based current-mode circuits can easily be cascaded without additional buffers [10-12]. The purpose of this paper is to introduce a current-mode oscillator configuration employing single COA to make use the above mentioned advantageous features of this active element. Four of the circuits obtained from the proposed configuration are single-frequency oscillators with two capacitors and two resistors; one of them is a single-resistance-controlled oscillator (SRCO); and the others provide adjustment of oscillation condition without affecting the oscillation frequency.

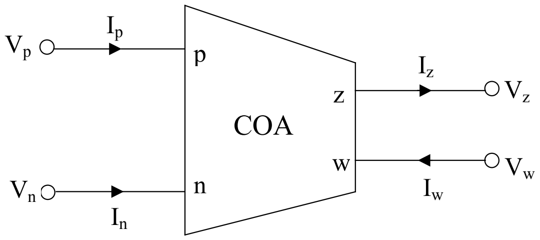

Figure 1. Circuit symbol of COA

II. PROPOSED OSCILLATOR CONFIGURATION

The COA, which is shown in Fig. 1, is a current-controlled current source whose defining equation can be given as

$$\begin{aligned} V_p &= 0 \\ V_n &= 0 \\ I_z &= B(I_p - I_n) \\ I_w &= I_z \end{aligned} \tag{1}$$

where B is the open-loop current gain of COA and ideally approaches infinity.

Proposed current-mode oscillator configuration is shown in Fig. 2. Routine analysis yields the characteristic equation as

$$\begin{aligned} &Y_1(Y_2(Y_3 - Y_4)(Y_5 + Y_6 + Y_7) + Y_3(Y_6(Y_5 + Y_7) + Y_4(Y_5 - Y_6 + Y_7)) - Y_4Y_6(Y_5 + Y_7 + Y_8)) \\ &+ Y_2(-Y_4Y_5(Y_6 + Y_7) + Y_3(Y_4(Y_5 - Y_6 - Y_7) + Y_5(Y_6 + Y_7 + Y_8))) \\ &+ (-Y_4Y_5Y_6 + Y_3(Y_4(Y_5 - Y_6) + Y_5Y_6))(Y_7 + Y_8) = 0 \end{aligned} \tag{2}$$

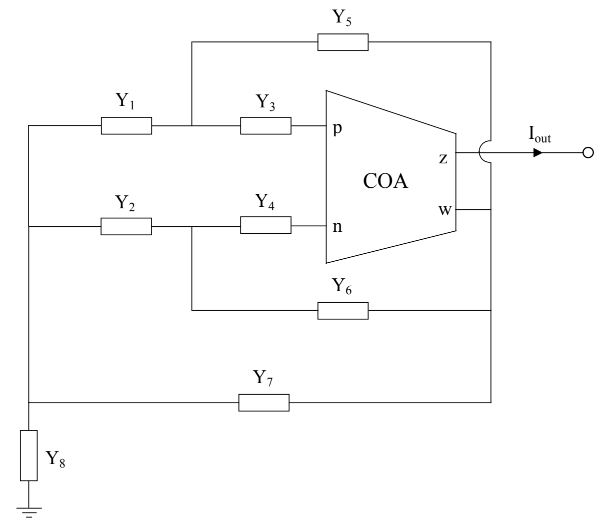

Figure 2. Proposed oscillator configuration

Many oscillators based on the general configuration of Fig. 2 can be derived by different combination of admittances in equation (2). The resulting circuits are given in Table 1. The oscillation conditions and the oscillation frequencies of these circuits are tabulated in Table 2. As it can be seen from Tables 1 and 2, the first four circuits are single-frequency oscillators containing only two capacitors and two resistors. The oscillation frequency of the fifth circuit can independently be adjusted by a grounded resistor without affecting the oscillation condition. If we interchange each capacitor with a resistor and each resistor with a capacitor in oscillator-5, the resulting circuit is still a SRCO in the expense of using one more capacitor that violates the canonic realization. With the last five circuits in Tables 1 and 2, it is possible to achieve independent control on the oscillation condition without affecting the oscillation frequency. All of the tabulated circuits employ only two dynamical elements meaning that the proposed oscillators are canonic. The single-frequency oscillators utilize two resistors. The remaining six circuits use three resistors for independent control of the oscillation frequency or the oscillation condition. In this respect, they contain minimum number of passive elements.

It can easily be shown that all the passive sensitivities of the oscillation frequencies of circuits except for oscillator-5 are one half in magnitude. For the fifth circuit sensitivities are

$$\begin{aligned} &S_{G_6}^{\omega_0} = -S_{C_2}^{\omega_0} = -S_{C_7}^{\omega_0} = \frac{1}{2} \\ &S_{G_3}^{\omega_0} = \frac{1}{2}\frac{G_3}{G_3 + G_8} \\ &S_{G_8}^{\omega_0} = \frac{1}{2}\frac{G_8}{G_3 + G_8} \end{aligned} \tag{3}$$

which are not more than one half in magnitude.

III. SIMULATION RESULTS

To verify the theoretical study, the proposed oscillator circuits have been simulated using PSPICE program. As an illustrating example the simulation results of the SRCO are given. Passive components are chosen as $R_3=R_8=1\text{k}\Omega$, $R_6=2\text{k}\Omega$, $C_2=C_7=100\text{pF}$, which result in 1.59 MHz oscillation frequency. The PSPICE simulations were performed using the CMOS realizations of COA shown in Fig. 3.

PSPICE simulations were performed on the basis of AMS 0.8μm MOS transistor parameters. Supply voltages are taken as V_{DD}=2.5V and V_{SS}=-2.5V. Typical output waveform of the oscillator circuit is given in Fig. 4. The tunability of oscillation frequency trough R_8 without influencing oscillation condition is shown in Fig. 5.

IV. CONCLUSION

A general current-mode sinusoidal oscillator configuration employing single COA is given in this study. To the best knowledge of authors, this is the first oscillator topology constructed with COA. The presented circuits use minimum number of passive elements. Since input terminals of COA are internally grounded, the oscillators are insensitive to parasitic input capacitances and resistances. All the passive component sensitivities are no more than one half in magnitude. PSPICE simulation results, which agree with the predicted theory, are included.

Table 1. Admittances of the oscillators derived form the general configuration of Figure 2

Oscillator	Admittances							
	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
1	0	$G_2 + sC_2$	$\left(\frac{1}{G_3} + \frac{1}{sC_3}\right)^{-1}$	∞	∞	0	∞	0
2	∞	∞	$G_3 + sC_3$	$\left(\frac{1}{G_4} + \frac{1}{sC_4}\right)^{-1}$	0	0	∞	0
3	∞	sC_2	G_3	∞	0	G_6	sC_7	0
4	∞	G_2	sC_3	∞	0	sC_6	G_7	0
5	∞	sC_2	G_3	∞	0	G_6	sC_7	G_8
6	∞	G_2	sC_3	∞	0	sC_6	G_7	G_8
7	G_1	G_2	G_3	sC_4	∞	0	0	sC_8
8	$\left(\frac{1}{G_1} + \frac{1}{sC_1}\right)^{-1}$	G_2	G_3	∞	∞	0	0	sC_8
9	0	G_2	G_3	sC_4	∞	0	G_7	sC_8
10	0	G_2	G_3	∞	∞	0	$\left(\frac{1}{G_7} + \frac{1}{sC_7}\right)^{-1}$	sC_8

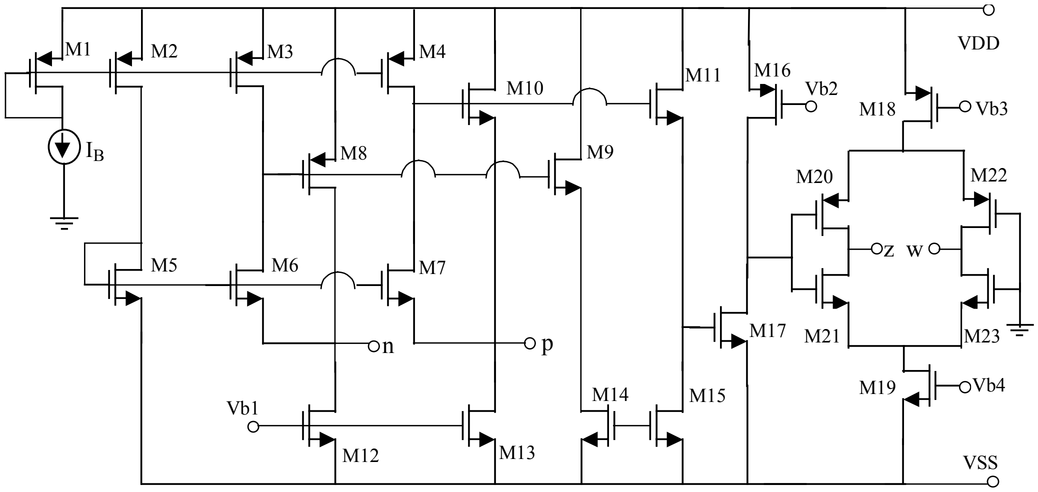

Figure 3. A CMOS realization of COA

Table 2. Oscillation conditions and frequencies of the presented oscillators

Oscillator	Oscillation condition	Oscillation frequency
1	$C_2G_3 + C_3G_2 = C_3G_3$	$\sqrt{\frac{G_2G_3}{C_2C_3}}$
2	$C_3G_4 + C_4G_3 = C_4G_4$	$\sqrt{\frac{G_3G_4}{C_3C_4}}$
3	$(C_2 + C_7)G_6 = C_7G_3$	$\sqrt{\frac{G_3G_6}{C_2C_7}}$
4	$C_6(G_2 + G_7) = C_3G_7$	$\sqrt{\frac{G_2G_7}{C_3C_6}}$
5	$(C_2 + C_7)G_6 = C_7G_3$	$\sqrt{\frac{G_6(G_3 + G_8)}{C_2C_7}}$
6	$C_6(G_2 + G_7 + G_8) = C_3G_7$	$\sqrt{\frac{G_2G_7}{C_3C_6}}$
7	$(C_4(G_1 + G_2) + C_8G_2)G_3 = C_1G_1G_2$	$\sqrt{\frac{G_1G_2}{C_4C_8}}$
8	$(C_1(G_1 + G_2) + C_8G_1)G_3 = C_1G_1G_2$	$\sqrt{\frac{G_1G_2}{C_1C_8}}$
9	$(C_4(G_2 + G_7) + C_8G_2)G_3 = C_4G_2G_7$	$\sqrt{\frac{G_2G_7}{C_4C_8}}$
10	$(C_7(G_2 + G_7) + C_8G_7)G_3 = C_7G_2G_7$	$\sqrt{\frac{G_2G_7}{C_7C_8}}$

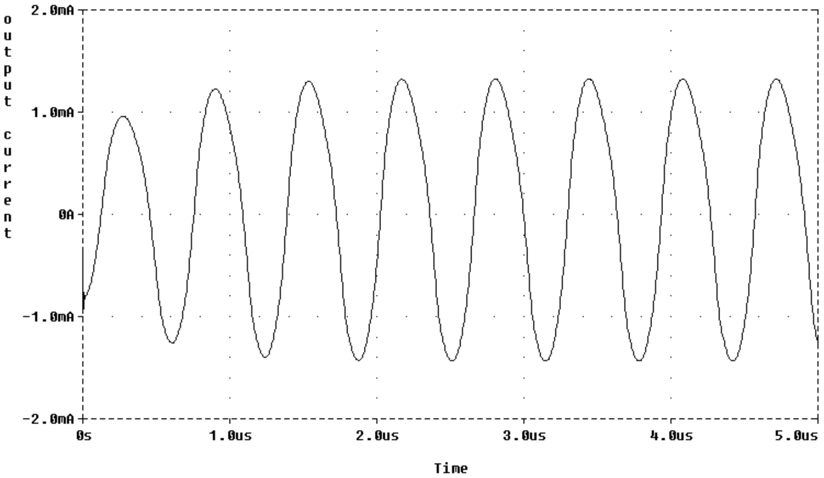

Figure 4. The output waveform of the SRCO

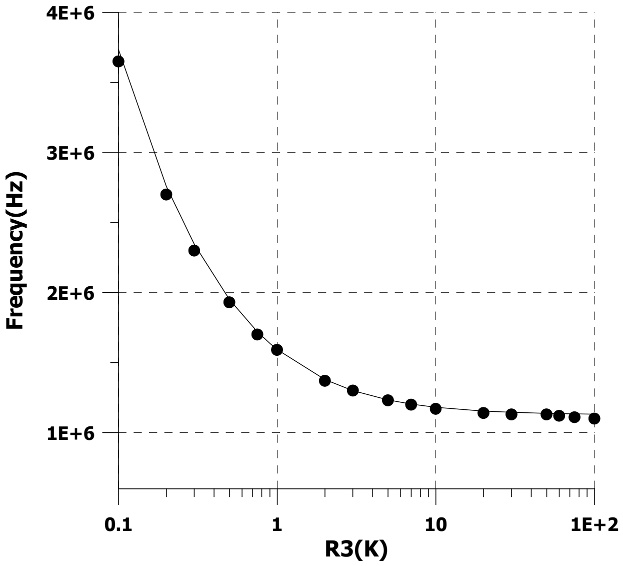

Figure 5. Variation of the oscillation frequency of the SRCO through R_8

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