New SRCO with Explicit Current-Mode Output Using Two CCs and Grounded Capacitors

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Abstract

A new Grounded-Capacitor Single Resistance Controlled Sinusoidal Oscillator (SRCO) with explicit current output using two Current Conveyors (CCs) and five passive elements is presented. The proposed circuit offers (i) independent control of condition of oscillation and frequency of oscillation, (ii) low active and passive sensitivities, (iii) use of both the grounded capacitors (suitable for IC implementation) and (iv) reasonably good frequency stability. The workability of the proposed configuration has been confirmed by the PSPICE simulations.

1. Introduction

Single Resistance Controlled Sinusoidal Oscillators (SRCOs) find numerous applications in communication, control systems, signal processing, instrumentation and measurement systems, see [5]-[7] and the references cited therein. SRCOs with explicit current-mode output may be employed as test signal generators for the testing of various current-mode signal processing circuits (e.g. current-mode filters, current-mode precision rectifiers, etc.) which would otherwise require an additional voltage-to-current converter circuit when tested by using conventional mode oscillators.

Among various types of SRCOs those which employ only two CCs and two grounded capacitors along with three grounded resistors (such as those in [3] and [9]) are particularly interesting because of the following reasons: (i) grounded capacitors are attractive for IC implementation and (ii) grounded resistors facilitate electronic control of oscillation condition and frequency of oscillation by replacing them with appropriate VCRs realized by JFETs/MOSFETs.

Although a few circuits of this kind have been proposed in the literature they suffer from the draw backs of non-availability of explicit current-mode output and/or employment of more than two current conveyors [8] and/or use of more complex form of CCs having multiple number of output terminals [4]. In this communication, we present a new circuit which by contrast, employs only two normal types of CCs and provides explicit current output while employing five passive elements (namely, two grounded resistors, one floating resistor and two grounded capacitors).

2. Proposed Circuit

The proposed new current-mode SRCO configuration with explicit current output is shown in Fig.1.

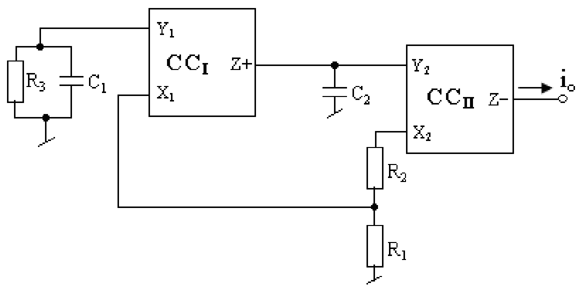


Fig.1 The proposed configuration

Assuming the CCI+ to be characterized by

$$\begin{bmatrix} I_Y \\ V_X \\ I_Z \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} V_Y \\ I_X \\ V_Z \end{bmatrix} \tag{1}$$

and CCII- to be characterized by

$$\begin{bmatrix} I_Y \\ V_X \\ I_Z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} V_Y \\ I_X \\ V_Z \end{bmatrix} \tag{2}$$

a routine analysis of the circuit reveals the following characteristic equation:

$$s^2 + s\left(\frac{1}{C_1R_3} - \frac{1}{C_1}\left(\frac{1}{R_1} + \frac{1}{R_2}\right) + \frac{1}{C_2R_2}\right) + \frac{1}{C_1C_2R_2R_3} = 0 \tag{3}$$

From this characteristic equation, when $C_1 = C_2$ the condition of oscillation (CO) is

$$R_1 \le R_3 \tag{4}$$

and frequency of oscillation (FO) is

$$f_o = \frac{1}{2\pi}\sqrt{\frac{1}{C_1 C_2 R_2 R_3}} \tag{5}$$

Thus, it is seen that FO can be controlled independently by R_2 and CO can be tuned by R_1.

3. Non Ideal Analysis

Considering the non-idealities of CCI and CCII into account, namely, $V_{X1} = \beta_1 V_{Y1}$, $\beta_1 = (1- \varepsilon_v)$ where ε_v ($\varepsilon_v <<1$) denotes the voltage tracking error of port X_1, $I_{Y1} = \gamma_1 I_{X1}$, $\gamma_1 = (1- \varepsilon_i)$ where ε_i ($\varepsilon_i <<1$) denotes the current tracking error of port Y_1, $I_{Z1} = \alpha_1 I_{X1}$, $\alpha_1 = (1- \varepsilon_i)$ where ε_i ($\varepsilon_i <<1$) denotes the current tracking error of port Z_1. $V_{X2} = \beta_2 V_{Y2}$, $\beta_2 = (1- \varepsilon_v)$ where ε_v ($\varepsilon_v <<1$) denotes the voltage tracking error of port X_2 and $I_{Z2} = -\alpha_2 I_{X2}$, $\alpha_2 = (1- \varepsilon_i)$ where ε_i ($\varepsilon_i <<1$) denotes the current tracking error of port Z_2.

The non-ideal expression for the characteristic equation is given by:

$$s^2 + s\left(\frac{1}{C_1 R_3} - \frac{\gamma_1\beta_1}{C_1}\left(\frac{1}{R_1} + \frac{1}{R_2}\right) + \frac{\alpha_1\beta_2}{C_2 R_2}\right) + \frac{\alpha_1\beta_2}{C_1 C_2 R_2 R_3} = 0 \tag{6}$$

When $\gamma_1\beta_1 C_2 = \alpha_1\beta_2 C_1$, the non-ideal expressions for condition of oscillation is found to be:

$$R_1 \le \gamma_1 \beta_1 R_3 \tag{7}$$

and frequency of oscillation is found to be:

$$f_o = \frac{1}{2\pi}\sqrt{\frac{\alpha_1\beta_2}{C_1 C_2 R_2 R_3}} \tag{8}$$

From the above, the active and passive sensitivities of the non-ideal ω_o are given as:

$$S_{C_1}^{\omega_o} = S_{C_2}^{\omega_o} = S_{R_2}^{\omega_o} = S_{R_3}^{\omega_o} = -\frac{1}{2},\ S_{\alpha_1}^{\omega_o} = S_{\beta_2}^{\omega_o} = \frac{1}{2},\ S_{\gamma_1}^{\omega_o} = S_{\alpha_2}^{\omega_o} = S_{\beta_1}^{\omega_o} = 0 \tag{9}$$

The active and passive sensitivities of ω_o are found to be in the range $-\frac{1}{2} \le S_x^F \le \frac{1}{2}$, and the circuit, thus, enjoys low sensitivities.

4. Frequency Stability

The frequency stability factor S_F is defined as [10]

$$S_F = \left.\frac{d\Phi(u)}{du}\right|_{u=1} \tag{10}$$

where $u = \omega/\omega_o$ and $\Phi(u)$ represents the phase function of the open loop transfer function of Fig. 1. S_F can be found to be

$$S_F = \frac{2\sqrt{n}}{n+1} \tag{11}$$

where $C_1 = C_2 = C$, $R_1 = R_3 = R$ and $R_2 = R/n$ for this oscillator. Maximum $S_F = 1$ is obtained when n = 1. From (11) it is seen that S_F for the proposed circuit is at par with or better than most of the classical oscillators (such as Wien bridge, RC phase shift etc.)

5. Simulation Results

To verify the validity of the proposed configuration, circuit simulation of the current mode oscillator has been carried out using the CMOS CCI from [1] (Fig. 1 therein) and CMOS CCII from [2] (Fig. 2 therein). PSPICE simulation implementation was based upon a CMOS CCI and CCII in 0.35µm technology where in the aspect ratios of the MOSFETs are shown for CCI and CCII in Table 1 and 2, respectively.

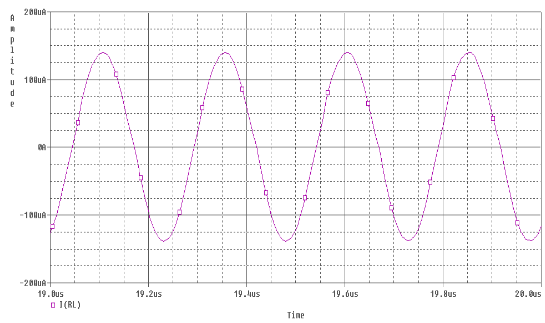
Table 1. Aspect ratios of MOSFETs CCI.

MOS transistors	W/L
M_1, M_3, M_7, M_8, M_{10}	63.5/0.65
M_2, M_4, M_5, M_6, M_9	72.5/0.55

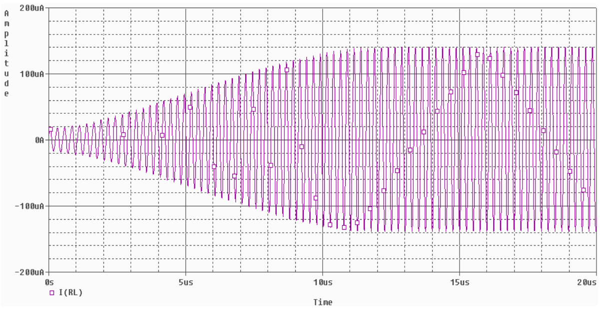
Table 2. Aspect ratios of MOSFETs CCII.

MOS transistors	W/L
M_1– M_4	10/0.35
M_5, M_6	16/0.35
M_7, M_8 , M_{13} – M_{16}, M_{21}- M_{24} M_{27}, M_{28}	5/0.35
M_9– M_{12}, M_{17} – M_{20}, M_{25}, M_{26}	60/0.35

The CMOS CCI and CCII were biased with DC power supply voltages $V_{DD} = +1.5V$, $V_{SS} = -1.5V$ as well as CCII has $V_1 = -0.38V$ and $V_2 = -0.9V$. To achieve the oscillator with $f_o = 4.172$ MHz, the component values chosen were $R_1 = R_3 = 1.5k\Omega$, $R_2 = 0.55k\Omega$, $C_1 = C_2 = 0.042nF$. The PSPICE generated output frequency 4.032 MHz is shown in Fig 2.



(a)



(b)

Fig. 2. PSPICE Simulation results of the proposed circuit
(a) Output waveform
(b) Transient waveform

6. Concluding Remarks

Where as there are a number of configurations known in the literature which realize an SRCO with explicit current output and grounded capacitors but such circuits usually require more than three CCs or else more complex forms of CCs possessing multiple number of output terminals. Note also that there are other CCI/CCII based SRCO using exactly same number of active and passive components (as in the proposed circuit) such as [3] and [9], however, the quoted circuits do not provide explicit current output. In view of the above, the new circuit has clear advantage over the circuits of references [3] and [9] quoted above.

7. References

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