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Current Mode Oscillators Using Inverting CCII

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New current mode Wien bridge oscillators using ICCII are introduced. Two Wien bridge oscillators using two single-output ICCII are given first together with a single ICCII minimum component oscillator. Two modified grounded capacitors Wien oscillators are given next. Four grounded passive component oscillators using two balanced output or double output ICCII are also given. Detailed analysis of the effects of the parasitic components is given. Spice simulation results are included to demonstrate the practicality of the current mode oscillator circuits.

Keywords: Current mode; oscillators; inverting current conveyor.

1 INTRODUCTION

The inverting second generation current conveyor (ICCII) was introduced in [1] as a new block to be added to the current conveyor family [2]. The ICCII is considered to be a special case from the Differential Voltage Current Conveyor (DVCC) introduced in [3–4] with a single Y input only. The symbolic representation of the single output ICCII is shown in Figure 1(a). The relation between terminal voltages and currents is given by [1].

$$\begin{pmatrix} I_y \\ V_x \\ I_z \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 \\ -1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{pmatrix} \begin{pmatrix} V_y \\ I_x \\ V_z \end{pmatrix} \tag{1}$$

The voltage at terminal X is the inversion of the voltage at terminal Y. The current at terminal Z follows the current at terminal X in magnitude.

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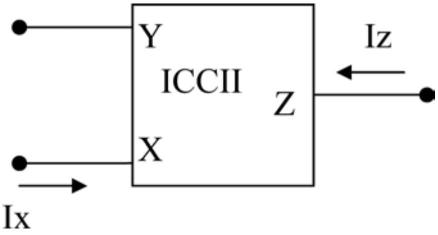

FIGURE 1A
Symbol of single output ICCII.

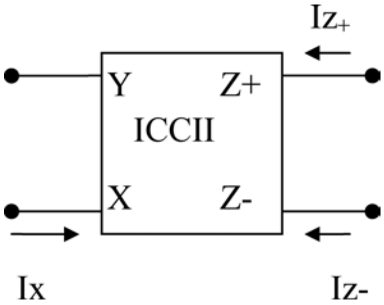

FIGURE 1B
Symbol of balanced output ICCII.

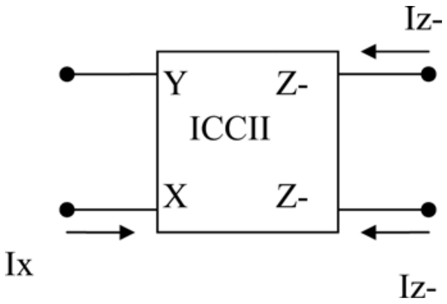

FIGURE 1C
Symbol of double output ICCII.

The ± 1 specifies the type of the current conveyor (ICCII+ or ICCII−).

The symbol of the balanced output ICCII is shown in Fig. 1(b) and the symbol of the double output ICCII is shown in Fig. 1(c).

The ICCII has been used in several filter applications [3–5] and is considered to be a very useful building block and it serves together with the CCII to demonstrate generation methods of filter circuits [5].

In this paper the application of the ICCII in current mode oscillator realizations is discussed in details together with the study of the effects of the parasitic elements on the condition of oscillation and on the frequency of oscillation.

2 CURRENT MODE WIEN OSCILLATORS USING ICCII

The Wien oscillators considered in this section are classified to three different types.

2.1 Oscillators using single output ICCIIs

Current mode Wien oscillators using single output CCII+ to realize a Voltage Controlled Voltage Source (VCVS) of gain K, was introduced in [6]. It is also possible to use two single output ICCII+ and two grounded resistors to realize a VCVS of gain K as shown in the dotted box of Fig. 2(a) and 2(b). The oscillators shown in Fig. 2 has one floating resistor and one floating capacitor. For $R_1 = R_2$ and $C_1 = C_2$ the condition of oscillation is given by $K = 3$ and the radian frequency is the same as given by:

$$\omega_o = \frac{1}{RC} \tag{2}$$

The circuits are self compensated for the parasitic elements R_{x1} and R_{x2} by subtracting their values from R_3 and R_1 respectively. On the other hand the

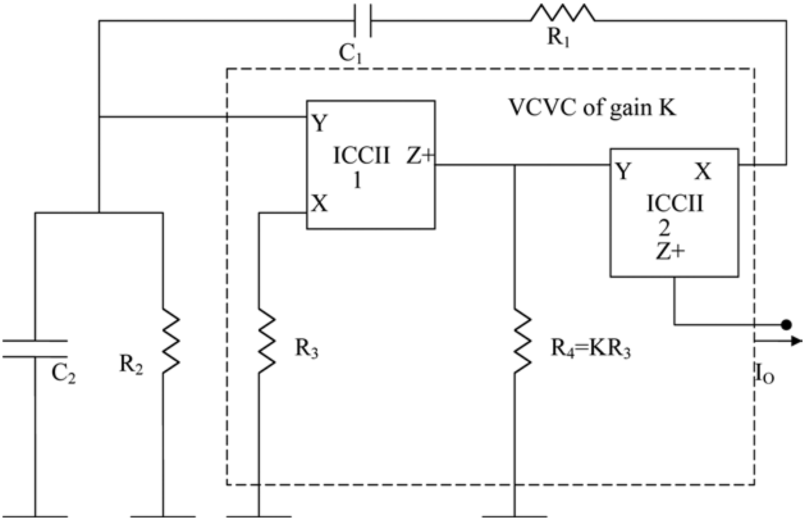

FIGURE 2A
Wien oscillator-A using two single output ICCII+.

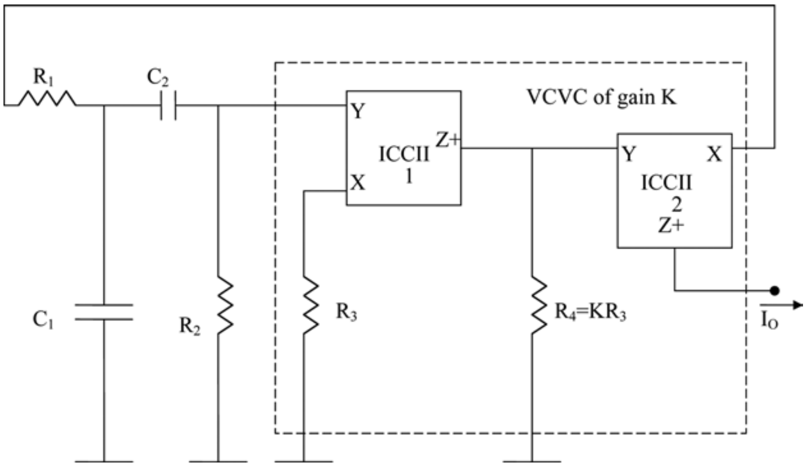

FIGURE 2B
Wien oscillator-B using two single output ICCII+.

parasitic element C_{z1} is affecting the VCVS gain equation which is modified to be frequency dependent [7–8] and is given by:

$$K_a = \frac{K}{1 + sKC_zR_3} \tag{3-a}$$

Taking the effect of Cz_1 into consideration, the actual expression for ω_0 is given by:

$$\omega_{oa} = \omega_0 [1 - 4.5\, \omega_0 C_{z1} R_3] \tag{3-b}$$

A third Wien oscillator circuit is obtainable directly from Fig. 2(b) using the RC: CR transformation [9], in this case however R_{x2} will affect circuit operation and is not self compensated as in Figs. 2(a) and 2(b).

2.2 Minimum component Wien Oscillator

Figure 3(a) represents the grounded capacitor minimum component oscillator which is based on the ICCII version of the Wien bridge oscillator. The circuit employs the ICCII as a Negative Impedance Converter (NIC).The advantage of this circuit is that it is self compensated for the parasitic resistance Rx and the stray capacitance Cz by subtracting their values from R_1 and C_2 respectively.

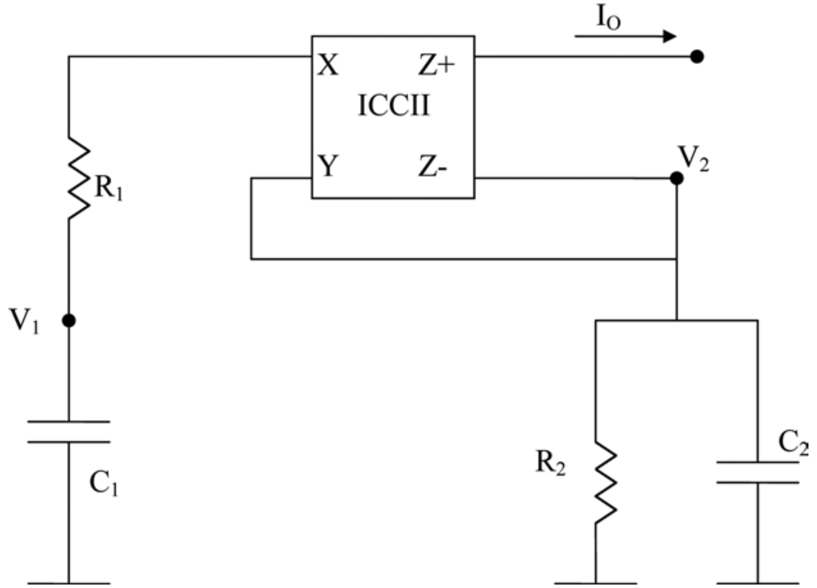

FIGURE 3A
Grounded C Wien oscillator using single ICCII.

The state equation of the circuit of Fig. 3(a) in matrix form is given by:

$$\begin{bmatrix} \frac{dv_1}{dt} \\ \\ \frac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{1}{C_1R_1} & -\frac{1}{C_1R_1} \\ \\ \frac{1}{C_2R_1} & \frac{1}{C_2R_1}-\frac{1}{C_2R_2} \end{bmatrix} \begin{bmatrix} v_1 \\ \\ v_2 \end{bmatrix} \tag{4}$$

The condition of oscillation and the radian frequency of oscillation are given by:

$$\frac{C_2}{C_1}+\frac{R_1}{R_2}=1 \tag{5-a}$$

$$\omega_o=\frac{1}{\sqrt{C_1C_2R_1R_2}} \tag{5-b}$$

The disadvantage of this oscillator circuit is that there is no independent control on the condition of oscillation or on the frequency of oscillation.

It should be noted that the CCII+ version of this oscillator was first introduced in [10]. Other Wien oscillators using CCII were introduced in the literature in [11–12].

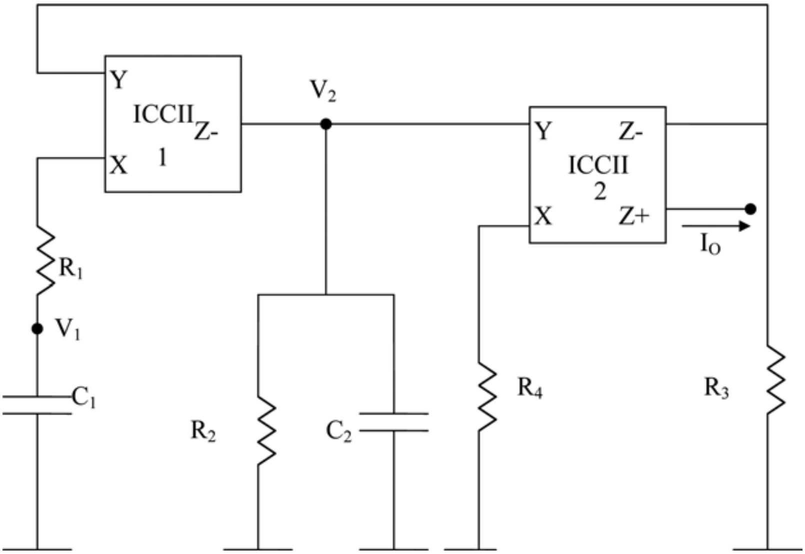

FIGURE 3B
Grounded C modified Wien oscillator-A using two ICCII.

2.3 Modified Wien oscillators using two ICCIIs

Two new Wien type oscillators with independent control on the condition of oscillation are given next.

Figure 3(b) represents a modified Wien oscillator to that of Fig. 3(a) using an additional ICCII and two more grounded resistors. The state matrix equation is given by:

$$\begin{bmatrix} \frac{dv_1}{dt} \\ \frac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{1}{C_1R_1} & -\frac{R_3}{C_1R_1R_4} \\ \frac{1}{C_2R_1} & \frac{R_3}{C_2R_1R_4} - \frac{1}{C_2R_2} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \tag{6}$$

The condition of oscillation is given by:

$$\frac{R_3}{R_4} = \frac{C_2}{C_1} + \frac{R_1}{R_2} \tag{7}$$

It is seen that R_3 controls the condition of oscillation without affecting the radian frequency of oscillation which is given by Equation (5-b).

The circuit is self compensated for the parasitic resistances R_{x1} and R_{x2} by subtracting their values from R_1 and R_4 respectively. The circuit is also, self compensated for the parasitic capacitance C_{z1} by subtracting its value from C_2. On the other hand the parasitic capacitance C_{z2} results in increasing the circuit order to three and defining V_3 to be the voltage at Z_{-2} node the state matrix equation becomes:

$$\begin{bmatrix} \frac{dv_1}{dt} \\ \frac{dv_2}{dt} \\ \frac{dv_3}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{1}{C_1R_1} & 0 & -\frac{1}{C_1R_1} \\ \frac{1}{C_2R_1} & -\frac{1}{C_2R_2} & \frac{1}{C_2R_1} \\ 0 & \frac{1}{C_ZR_4} & -\frac{1}{C_ZR_3} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} \tag{8}$$

The characteristic equation is obtained as:

$$\begin{aligned} &s^3\, C_1\, C_2\, C_zR_1\, R_2R_3 + S^2 \left[C_1C_2\, C_1C_2 + \left(C_1\, R_1 + C_2\, R_2\right)C_z\, R_3\right] \\ &+ s\left[C_1\, R_1 + C_2\, R_2 + C_zR_3 - \frac{C_1\, R_2R_3}{R_4}\right] + 1 = 0 \end{aligned} \tag{9}$$

For equal R and C the actual radian frequency is obtained as:

$$\omega_{oa} = \omega_0\,[1 - \omega_0 C_z R_3] \tag{10}$$

Figure 3(c) represents an alternative modified oscillator circuit obtained from Fig. 3(b) by interchanging the R_1 C_1 branch with the R_4 branch. The state matrix equation is given by:

$$\begin{bmatrix} \frac{dv_1}{dt} \\ \frac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{1}{C_1R_1} & -\frac{1}{C_1R_1} \\ \frac{R_3}{C_2R_1R_4} & \frac{R_3}{C_2R_1R_4} - \frac{1}{C_2R_2} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \tag{11}$$

The condition of oscillation is the same as given by Equation (7) and the radian frequency of oscillation is given by Equation (5-b).

3 GROUNDED PASSIVE COMPONENT OSCILLATORS

Four grounded resistors and capacitor circuits are given in this section.

Figure 4(a) represents a two ICCII oscillator circuit which has the same topology as the CCII circuit introduced in [13].The state matrix equation is given by:

$$\begin{bmatrix} \frac{dv_1}{dt} \\ \frac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} \frac{1}{C_1R_1} - \frac{1}{C_1R_3} & -\frac{1}{C_1R_2} \\ \frac{1}{C_2R_1} & 0 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \tag{12}$$

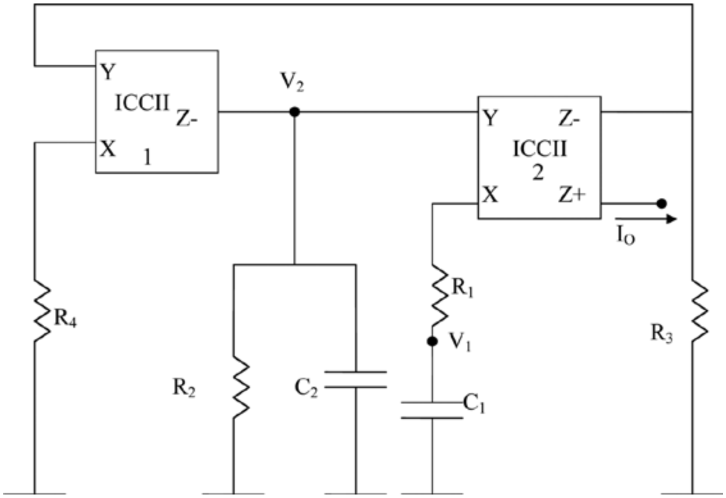

FIGURE 3C
Grounded C modified Wien oscillator-B using two ICCII.

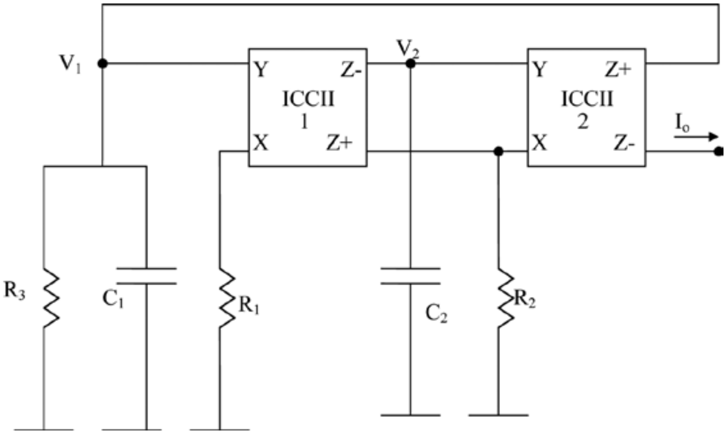

FIGURE 4A
Grounded passive component oscillator using two ICCII.

The condition of oscillation and the radian frequency of oscillation are given by:

$$R_3 = R_1 \tag{13-a}$$

$$\omega_o = \frac{1}{\sqrt{C_1 C_2 R_1 R_2}} \tag{13-b}$$

The grounded resistor R_3 controls the condition of oscillation without affecting ω_0 which is independently controlled by R_2.

The circuit is self compensated for the parasitic resistance R_{x1} by subtracting its value from R_1. The circuit is also, self compensated for the parasitic capacitances C_{z-1} and C_{z+2} by subtracting its value from C_2 and C1 respectively. On the other hand the parasitic capacitance C_{z+1} results in the following state matrix equation:

$$\begin{bmatrix} \dfrac{dv_1}{dt} \\ \\ \dfrac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} \dfrac{1}{C_1R_1} - \dfrac{1}{C_1R_3} - \dfrac{Cz_1}{C_1C_2R_1} & -\dfrac{1}{C_1R_2} \\ \\ \dfrac{1}{C_2R_1} & 0 \end{bmatrix} \begin{bmatrix} v_1 \\ \\ v_2 \end{bmatrix} \tag{14}$$

The stray capacitance C_{z1} is not affecting ω_0, the condition of oscillation however is obtained as:

$$R_3 = \frac{R_1}{1 - \dfrac{Cz_1}{C_2}} \tag{15}$$

Figure 4(b) represents an alternative grounded resistors and capacitors two ICCII oscillator circuit. The state matrix equation is given by:

$$\begin{bmatrix} \dfrac{dv_1}{dt} \\ \\ \dfrac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} \dfrac{1}{C_1R_1} & -\dfrac{1}{C_1R_3} \\ \\ \dfrac{1}{C_2R_1} & -\dfrac{1}{C_2R_2} \end{bmatrix} \begin{bmatrix} v_1 \\ \\ v_2 \end{bmatrix} \tag{16}$$

The condition of oscillation and the radian frequency of oscillation are given by:

$$C_1 R_1 = C_2 R_2 \tag{17-a}$$

$$\omega_o = \frac{1}{\sqrt{C_1C_2R_1R_2}} \sqrt{\frac{R_2}{R_3} - 1} \tag{17-b}$$

There is no independent control on the condition of oscillation. The resistor R_3 controls ω_0 without affecting the condition of oscillation.

Figure 5(a) represents a self compensated grounded passive element oscillator with independent control on the condition of oscillation and the frequency of oscillation. The state matrix equation is given by:

$$\begin{bmatrix} \dfrac{dv_1}{dt} \\ \\ \dfrac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} \dfrac{1}{C_1R_1} - \dfrac{1}{C_1R_3} & \dfrac{1}{C_1R_2} \\ \\ -\dfrac{1}{C_2R_1} & 0 \end{bmatrix} \begin{bmatrix} v_1 \\ \\ v_2 \end{bmatrix} \tag{18}$$

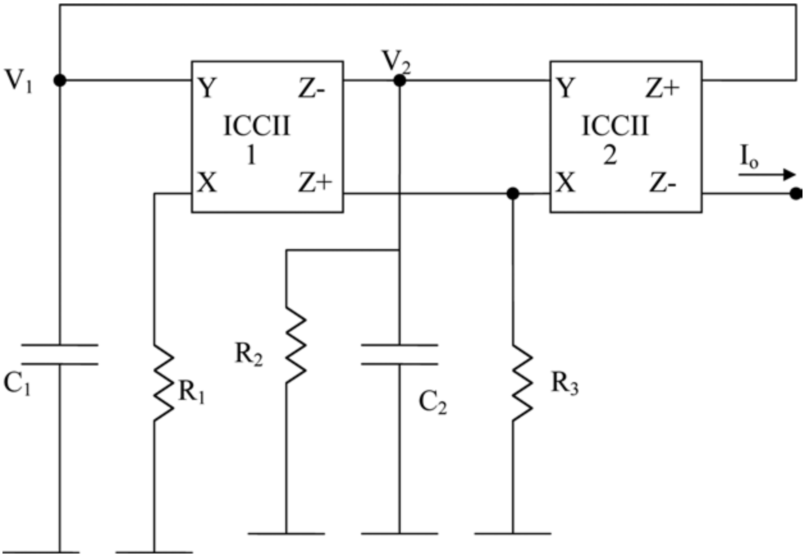

FIGURE 4B
Grounded passive component oscillator using two ICCII.

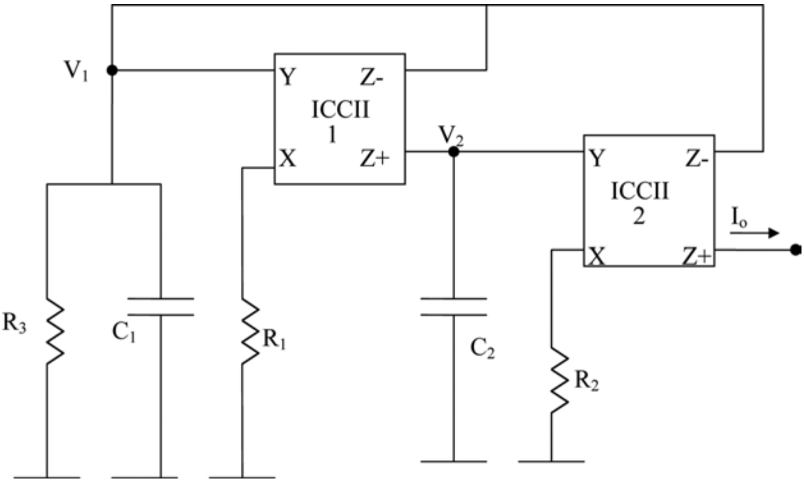

FIGURE 5A
Grounded passive component oscillator using two ICCII.

The condition of oscillation and the radian frequency of oscillation are the same given by Equation (13).

It is worth noting that this is the ICCII version of the CCII oscillator given in Fig. 5 of [14] and the circuit is also given as circuit 4 in [15].

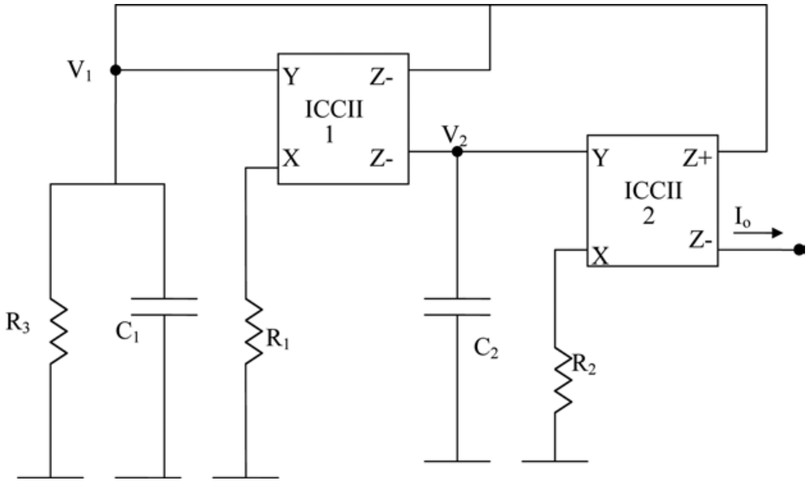

FIGURE 5B
Grounded passive component oscillator using two ICCII.

Figure 5(b) represents another self compensated grounded passive element oscillator with independent control on the condition of oscillation and the frequency of oscillation. The state matrix equation is given by:

$$\begin{bmatrix} \dfrac{dv_1}{dt} \\[2ex] \dfrac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} \dfrac{1}{C_1R_1} - \dfrac{1}{C_1R_3} & -\dfrac{1}{C_1R_2} \\[2ex] \dfrac{1}{C_2R_1} & 0 \end{bmatrix} \begin{bmatrix} v_1 \\[2ex] v_2 \end{bmatrix} \tag{19}$$

The condition of oscillation and the radian frequency of oscillation are the same given by Equation (13).

Alternative grounded resistors and capacitors oscillators using three ICCIIs and generated from the CCII oscillators in [13] have been reported in [16].

4 SIMULATION RESULTS

The active building block used in all simulations included in this paper is DVCC given in [3]. This block is very powerful as it realizes each of ICCII+, ICCII− and balanced output ICCII as special cases.

Figure 6 represents the CMOS balanced output ICCII circuit [3], the transistor aspect ratios is given in Table 1 based on the 0.5 μm CMOS model from MOSIS. The supply voltages used are ± 1.5 V and $V_{B1} = -0.52$ V and

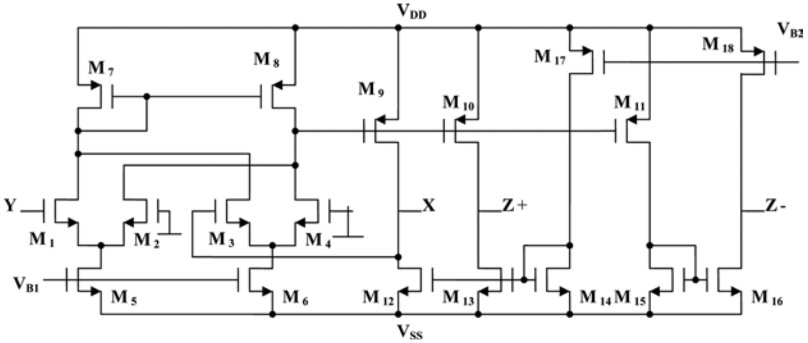

FIGURE 6
The CMOS realization of the ICCII [3].

TABLE 1
Dimensions of the MOS Transistors of the DVCC of Fig. 6.

NMOS Transistors	**W(μm)/L(μm)**
M_1, M_2, M_3, and M_4	2.5/1
M_5 and M_6	8/1
M_{12}, M_{13}, M_{14}, M_{15}, and M_{16}	20/2.5
PMOS Transistors	**W(μm)/L(μm)**
M_7 and M_8	10/1
M_9, M_{10}, M_{11}, M_{17}, and M_{18}	40/2

TABLE 2
Comparison of current mode oscillator circuits.

Circuit Figure	Number of ICCII	Number of Capacitors	Number of Resistors	Independent Control on Condition	Independent Control on Frequency	Stray Sensitive
2(a)	2	2- One Floating	4- One Floating	Yes	Yes	Yes to C_{z+1}
2(b)	2	2- One Floating	4- One Floating	Yes	Yes	Yes to C_{z+1}
3(a)	1	2	2- One Floating	No	No	No
3(b)	2	2	4- One Floating	Yes	No	Yes to C_{z-2}
3(c)	2	2	4- One Floating	Yes	No	Yes to C_{z-2}
4(a)	2	2	3	Yes	Yes	Yes to R_{x2},C_{z+1}
4(b)	2	2	3	No	Yes	Yes to R_{x2},C_{z+1}
5(a)	2	2	3	Yes	Yes	No
5(b)	2	2	3	Yes	Yes	No

$V_{B2} = 0.33\,V$. The Spice simulation results for different oscillator circuits are given next.

Figure 7(a) represents the output waveform of the oscillator of Fig. 3(a) designed for $fo = 1\,MHz$ by taking $C_1 = 80\,pF$, $C_2 = 40\,pF$, $R_1 = 2\,k\Omega$, $R_2 = 4\,k\Omega$.

Figure 7(b) represents the output waveform of the oscillator of Fig. 3(c) designed for $fo = 1\,MHz$ by taking $C_1 = C_2 = 40\,pF$, $R_1 = R_2 = 4\,k\Omega$, $R_4 = 2\,k\Omega$, $R_3 = 4\,k\Omega$. R_3 was increased to $4.2\,k\Omega$ to start oscillations.

Figure 7(c) represents the output waveform of the oscillator of Fig. 4(a) designed for $fo = 1.59\,MHz$ by taking $C_1 = C_2 = 10\,pF$, $R_1 = R_2 = R_3 = 10\,k\Omega$.

Figure 7(d) represents the output waveform of the oscillator of Fig. 5(a) designed for $fo = 1.59\,MHz$ by taking $C_1 = C_2 = 10\,pF$, $R_1 = R_2 = R_3 = 10\,k\Omega$.

The simulation results are in good agreement with the expected ones.

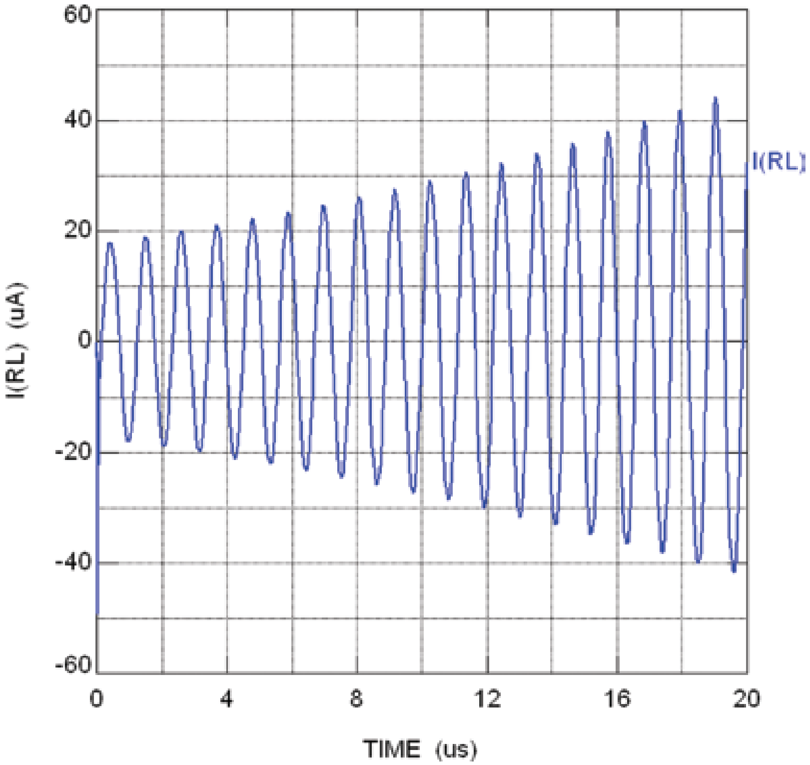

FIGURE 7A

Simulated output current waveform for the circuit of Fig. 3(a).

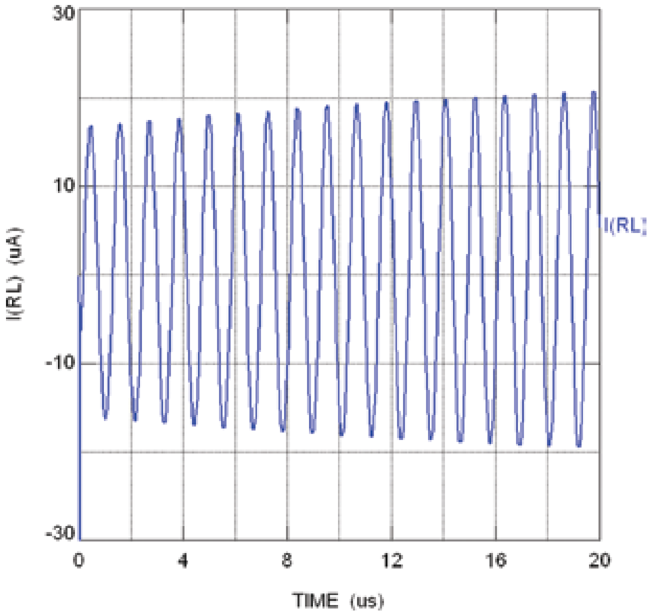

FIGURE 7B
Simulated output current waveform for the circuit of Fig. 3(c).

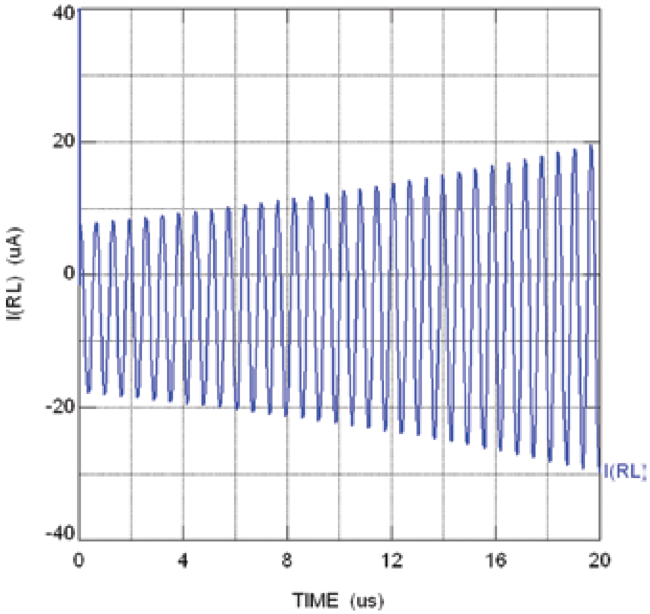

FIGURE 7C
Simulated output current waveform for the circuit of Fig. 4(a).

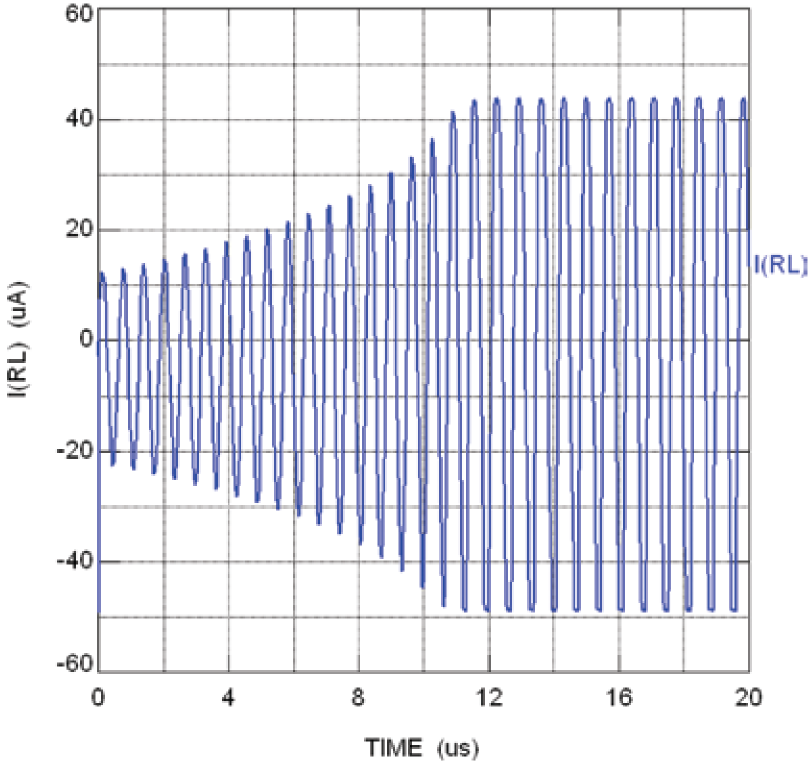

FIGURE 7D
Simulated output current waveform for the circuit of Fig. 5(a).

CONCLUSIONS

New current mode oscillators are introduced. Wien bridge oscillators using two single output ICCII are given together with a single ICCII minimum component oscillator. Four grounded passive component oscillators using two balanced output or double output ICCII are given. Detailed analysis of the effects of the parasitic components is given. Spice simulation results are included to demonstrate the practicality of the current mode oscillator circuits.

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