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Generation of Oscillators from Current Mode Bandpass Filters Using Single Output ICCII

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Three new oscillators using single output ICCII are introduced. The first oscillator uses minimum passive components and uses two ICCII− and is generated from a recently reported current mode bandpass filter. Two more oscillators using grounded resistors and capacitors and using three ICCII− or ICCII+ are introduced. Detailed analysis of the effects of the parasitic components is given. Spice simulation results are included to demonstrate the practicality of the three proposed oscillator circuits.

Keywords: Oscillators; inverting current conveyor; current mode.

1 INTRODUCTION

Several current conveyor (CCII) based oscillators have been reported in the literature [1–9]. One of the oscillators reported in [1] is generated from a voltage mode bandpass filter using a single CCII+ [10]. The oscillators reported in [3–4] are based on the application of a single CCII+ in realizing an ideal grounded inductor or an ideal FDNR respectively. The oscillator reported in [5] has the advantage of using grounded capacitors [11] but it is not canonic as it employs three capacitors. A Wien type oscillator using the CCII has been introduced in [6] and is generated from the conventional Wien oscillator using the nullor concept. The oscillator given in [7] employs the CCII as a negative impedance converter (NIC). Other Wien type oscillators using CCII and based on replacing the voltage controlled voltage source (VCVS) in the

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*Corresponding author: asoliman@ieee.org classical Wien oscillator by a transconductance circuit were given in [9]; these oscillators however employ floating capacitors.

Since the introduction of the Inverting Current Conveyor (ICCII) [12] and it serves in the generation of new filter circuits as well as in providing clear explanation on the link between CCII and ICCII circuits [13–14].

The ICCII is considered to be a special case from the Differential Difference Current Conveyor DDCC introduced in [13], [15] with a single Y input only. The symbolic representation of the single output ICCII– and ICCII+ are shown in Figs. 1(a) and 2(a) respectively. The relation between terminal voltages and currents is given by [12].

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

The voltage at terminal X is the negative of the voltage at terminal Y. The current at terminal Z follows the current at terminal X in magnitude. The ±1 specifies the type of the current conveyor (ICCII+ or ICCII–).

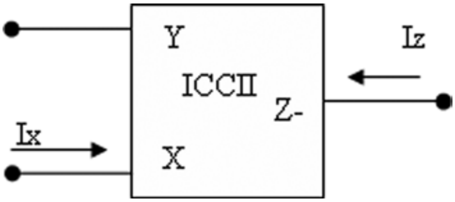

FIGURE 1A
Symbol of Inverting CCII−.

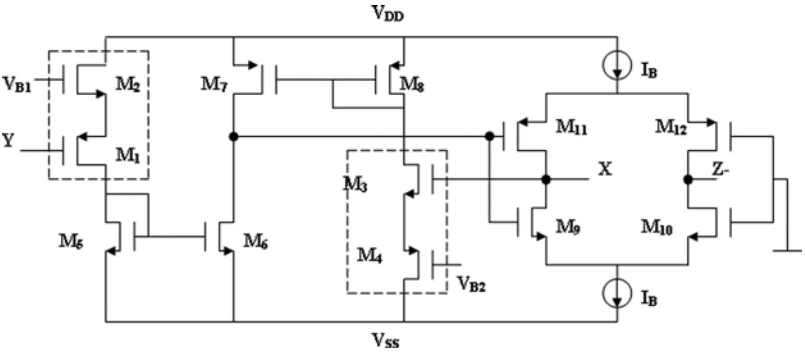

FIGURE 1B
CMOS circuit of the ICCII− [16].

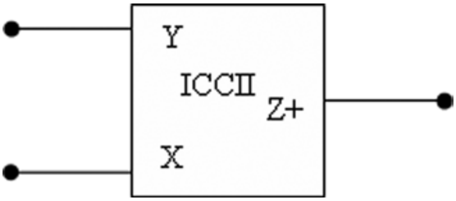

FIGURE 2A
Symbol of Inverting CCII+.

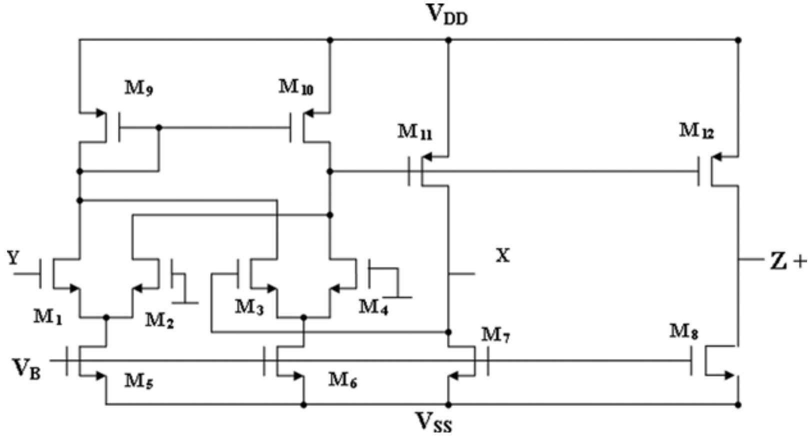

FIGURE 2B
CMOS circuit of the ICCII+ [13].

The ICCII has been used in several filter applications [12–16] and is considered to be a very useful building block.

A CMOS realization of the ICCII– which avoids the use of current mirrors is shown in Fig. 1(b) [16]. A CMOS realization of the ICCII+ is shown in Fig. 2(b) [13].

In this paper the application of the ICCII in generating oscillator circuits from unity gain current mode bandpass filters 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 MINIMUM PASSIVE COMPONENT OSCILLATOR

Oscillators can be generated from current mode unity gain bandpass filters by setting $I_{BP} = Ii$ .This is achieved physically by feeding back the output I_{BP} to the input node. This idea is used in the generation of new oscillator circuit

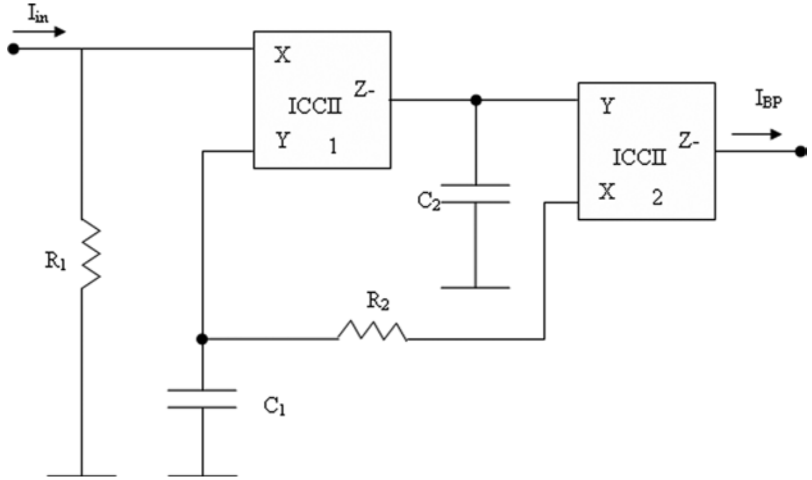

FIGURE 3
Current Mode Bandpass filter using two ICCII−.

from the recently reported bandpass filter [14] shown in Fig. 3 whose transfer function is given by:

$$\frac{I_{BP}}{I_i} = \frac{sC_1R_1}{s^2\, C_1\, C_2\, R_1\, R_2 + s\;\, C_2R_1 + 1} \tag{2}$$

For a unity gain at the center frequency the two capacitors must be equal.

The proposed oscillator circuit generated from this bandpass filter is shown in Fig. 4(a). The circuit employs the minimum number of passive circuit components with one floating resistor. The circuit has the advantage of using grounded capacitors [11]. The oscillator state matrix equation is given by:

$$\begin{bmatrix} \dfrac{dv_1}{dt} \\ \\ \dfrac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} -\dfrac{1}{C_1R_2} & -\dfrac{1}{C_1R_2} \\ \\ \dfrac{1}{C_2R_2} + \dfrac{1}{C_2R_1} & \dfrac{1}{C_2R_2} \end{bmatrix} \begin{bmatrix} v_1 \\ \\ v_2 \end{bmatrix} \tag{3}$$

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

$$C_2 = C_1 \tag{4-a}$$

$$\omega_0 = \frac{1}{\sqrt{C_1C_2R_1R_2}} \tag{4-b}$$

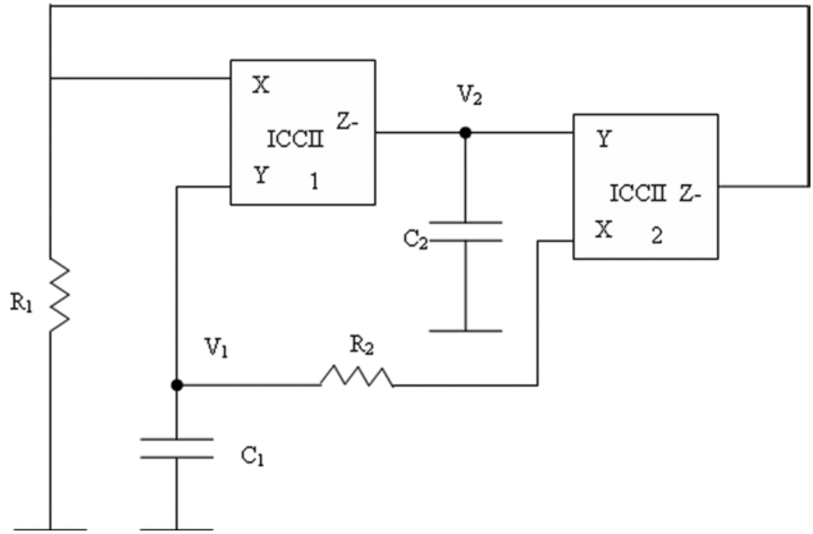

FIGURE 4A
Minimum passive component oscillator using two ICCII−.

The grounded resistor R_1 controls the frequency of oscillation without affecting the oscillation condition. On the other hand the oscillation condition can not be independently controlled. It is obvious that the oscillation condition is the same as the condition for unity center frequency gain of the bandpass filter of Fig. 3.

The effect of parasitic parameters is considered next. The two dominant parasitic elements of the ICCII are R_x and C_z .The circuit is self compensated for the parasitic elements R_{x2} and C_{z1} by subtracting their values from R_2 and C_2 respectively. On the other hand the parasitic elements R_{x1} and C_{z2} are affecting the circuit basic equations.

Taking the effect of C_{z2} of the second ICCII into consideration the state matrix equation is modified to:

$$\begin{bmatrix} \frac{dv_1}{dt} \\ \frac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{1}{C_1R_2} & -\frac{1}{C_1R_2} \\ \frac{1}{C_2R_1} + \frac{1}{C_2R_2} - \frac{C_{Z2}}{C_1C_2R_2} & \frac{1}{C_2R_2} - \frac{C_{Z2}}{C_1C_2R_2} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \tag{5}$$

Although the circuit includes now three capacitors it still remains as a second order circuit. The condition of oscillation is modified to:

$$C_1 = C_2 + C_{z2} \tag{6}$$

The above condition can be easily satisfied by increasing C_1 value or decreasing the C_2 value. This however will slightly affect the radian frequency of oscillation. For example if the desirable design value of the capacitor $C_1 = C$, take $C_2 = C - C_{z2}$ and for $R_1 = R_2 = R$, the actual expression for ω_0 is given by:

$$\omega_{0a} = \omega_0 [1 + C_{z2}/2C] \tag{7}$$

Taking the effect of R_{x1} into consideration the state matrix equation is modified to:

$$\begin{bmatrix} \frac{dv_1}{dt} \\ \frac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{1}{C_1 R_2} & -\frac{1}{C_1 R_2} \\ \left(\frac{1}{C_2 R_1} + \frac{1}{C_2 R_2}\right)\left(\frac{1}{1+\frac{R_{x1}}{R_1}}\right) & \frac{1}{C_2 R_2}\left(\frac{1}{1+\frac{R_{x1}}{R_1}}\right) \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \tag{8}$$

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

$$C_1 = C_2[1 + R_{x1}/R_1] \tag{9-a}$$

$$\omega_0 = \frac{1}{\sqrt{C_1 C_2 R_1 R_2 (1 + R_{x1}/R_1)}} \tag{9-b}$$

For example if the desirable design value of the capacitor $C_1 = C$ and for $R_1 = R_2 = R$, the actual expression for ω_0 is given by:

$$\omega_{0a} = \omega_0 = 1/RC \tag{9-c}$$

That is the circuit is considered to be easily compensated for the parasitic resistance R_{x1} without the addition of external elements.

The circuit of Fig. 4(a) is simulated using the CMOS ICCII– of Fig. 1(b) with the aspect ratios shown in Table 1 and with $V_{DD} = 1.5$V, $V_{SS} = -1.5$V.

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

It is worth noting that a current mode bandpass filter with the same topology as in Fig. 3 and using CCII– and CCII+ was reported in [17].

TABLE 1
Transistor aspect ratios of the ICCII− shown in Fig. 1(b).

Transistor	**W(μm)/L(μm)**
M1, M2, M3, M4	35/1.05
M5, M6	8.75/1.05
M7, M8	26.25/1.05
M9, M10	17.5/0.35
M11, M12	35/0.35

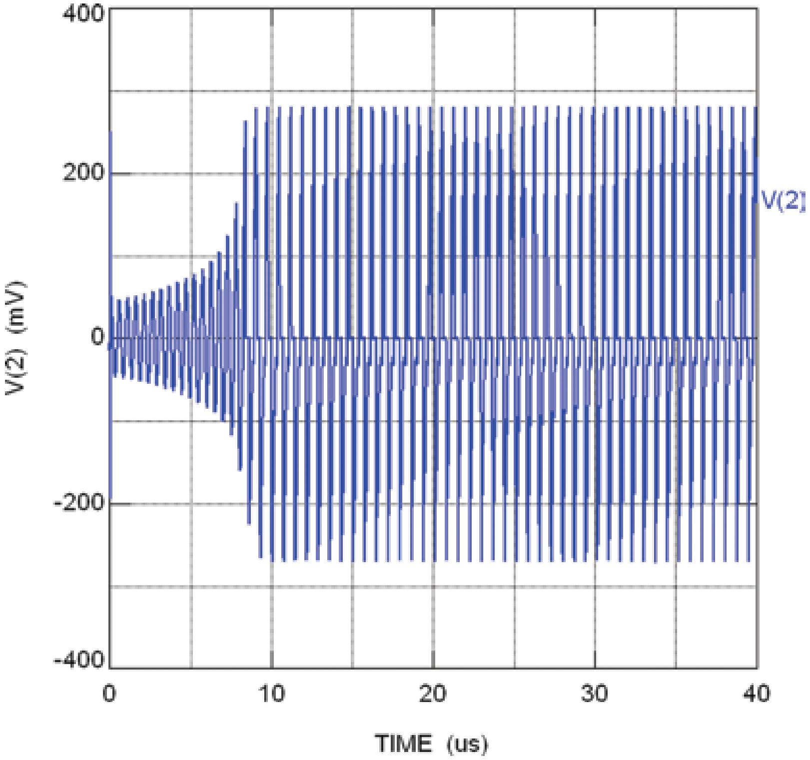

FIGURE 4B
Simulated output waveform for oscillator of Fig. 4(a).

A combined CCII– and CCII+ oscillator with the same topology as in Fig. 4(a) was independently reported in [18] which can also be generated from the current mode bandpass filter given in [17].

The generation method can be applied to other current mode bandpass filters [19] resulting in new oscillators as discussed in the next section.

3 GROUNDED R AND C OSCILLATOR USING THREE ICCII–

The second ICCII– oscillator circuit is generated from the bandpass filter shown in Fig. 5 [19]. The circuit has the advantage of using grounded resistors and capacitors and has independent control on the condition of oscillation and on the frequency of oscillation. The oscillator state matrix equation is given by:

$$\begin{bmatrix} \dfrac{dv_1}{dt} \\ \\ \dfrac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} 0 & -\dfrac{1}{C_1R_2} \\ \\ \dfrac{1}{C_2R_1} & \dfrac{1}{C_2}[\dfrac{1}{R_4}-\dfrac{1}{R_3}] \end{bmatrix} \begin{bmatrix} v_1 \\ \\ v_2 \end{bmatrix} \tag{10}$$

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

$$R_4 = R_3 \tag{11-a}$$

$$\omega_0 = \frac{1}{\sqrt{C_1C_2R_1R_2}} \tag{11-b}$$

The condition of oscillation is controlled by R_3 or R_4 without affecting ω_0 which is independently controlled by R_1 or R_2.

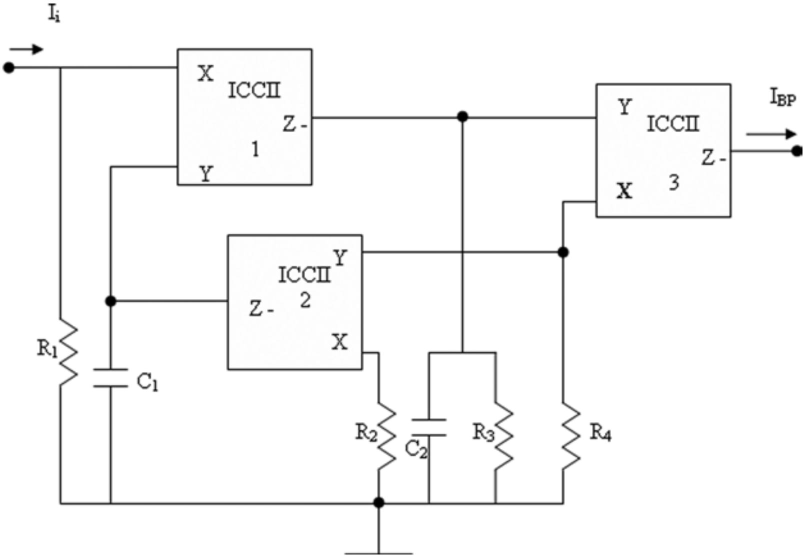

FIGURE 5
Current Mode Bandpass filter using three ICCII−.

The effect of parasitic parameters is considered next .The circuit is self compensated for the parasitic elements R_{x2}, R_{x3}, C_{z1} and C_{z2} by subtracting their values from R_2, R_4, C_2 and C_1 respectively. On the other hand the parasitic elements R_{x1} and C_{z3} are affecting the circuit basic equations as explained next.

Taking the effect of C_{z3} into consideration the state matrix equation of the circuit of Fig. 6(a) is modified to:

$$\begin{bmatrix} \dfrac{dv_1}{dt} \\ \\ \dfrac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} 0 & -\dfrac{1}{C_1R_2} \\ \\ \dfrac{1}{C_2R_1} & \dfrac{1}{C_2}[\dfrac{1}{R_4} - \dfrac{1}{R_3} - \dfrac{C_{Z3}}{C_1R_2}] \end{bmatrix} \begin{bmatrix} v_1 \\ \\ v_2 \end{bmatrix} \tag{12}$$

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

$$R_4 = R_3/[1 + C_{z3} R_3/C_1R_2] \tag{13-a}$$

$$\omega_0 = \frac{1}{\sqrt{C_1C_2R_1R_2}} \tag{13-b}$$

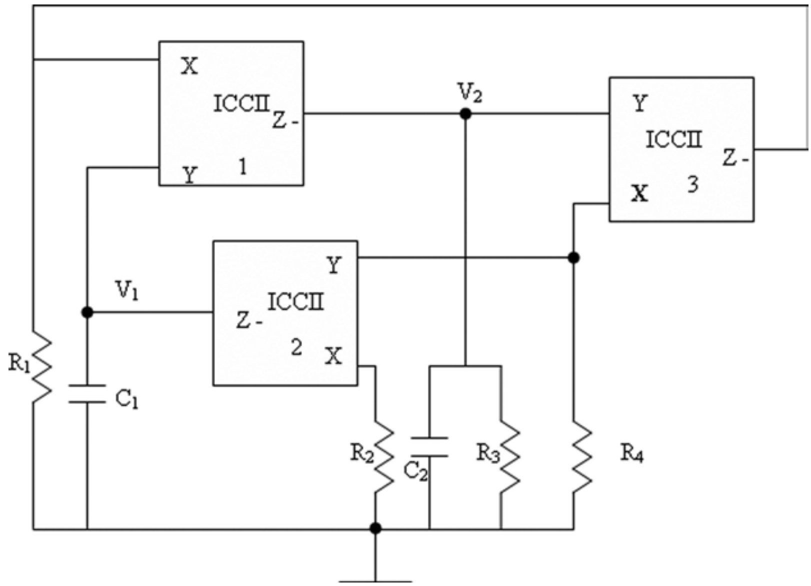

FIGURE 6A
Grounded passive elements oscillator using three ICCII−.

Next taking the effect of R_{x1} into consideration the state matrix equation is modified to:

$$\begin{bmatrix} \dfrac{dv_1}{dt} \\ \\ \dfrac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} 0 & -\dfrac{1}{C_1 R_2} \\ \\ \dfrac{1}{C_2 R_1 [1 + \dfrac{R_{x1}}{R_1}]} & \dfrac{1}{C_2 R_4 [1 + \dfrac{R_{x1}}{R_1}]} - \dfrac{1}{C_2 R_3} \end{bmatrix} \begin{bmatrix} v_1 \\ \\ v_2 \end{bmatrix} \tag{14}$$

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

$$R_3 = R_4 [1 + R_{x1} / R_1] \tag{15-a}$$

$$\omega_0 = \frac{1}{\sqrt{C_1 C_2 R_1 R_2 (1 + R_{x1} / R_1)}} \tag{15-b}$$

Figure 6(b) represents the output waveform of the oscillator of Fig. 6(a) using the CMOS circuit of Fig. 1(b) and designed for fo equal to 2 MHz by taking $C_1 = C_2 = 40\,\text{pF}$, $R_1 = R_2 = 2\,\text{k}\Omega$.

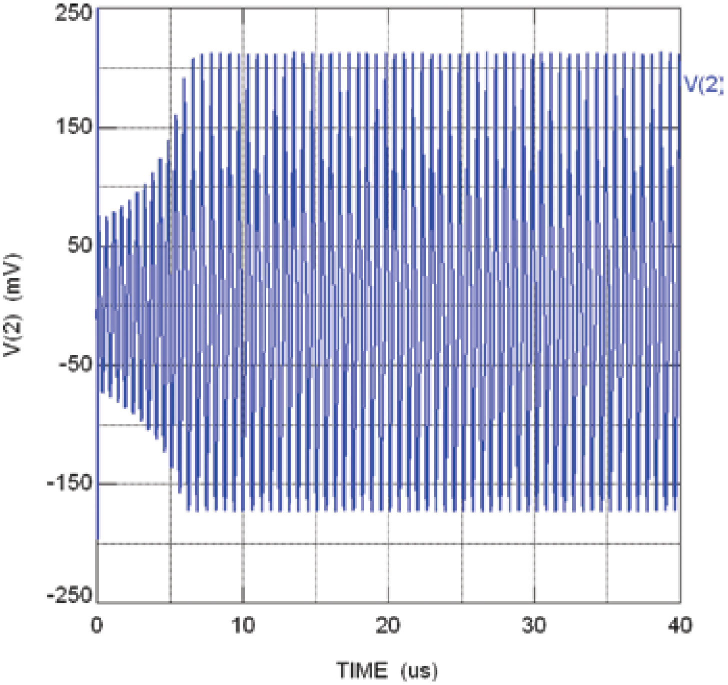

FIGURE 6B
Simulated output waveform for oscillator of Fig. 6(a).

4 GROUNDED R AND C OSCILLATOR USING THREE ICCII+

A new ICCII+ oscillator circuit is generated from the bandpass filter reported in [19]. The circuit has the advantage of using grounded resistors and capacitors and has independent control on the condition of oscillation and on the frequency of oscillation. The oscillator state matrix equation is given by:

$$\begin{bmatrix} \frac{dv_1}{dt} \\ \frac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} 0 & \frac{1}{C_1R_2} \\ -\frac{1}{C_2R_1} & \frac{1}{C_2}[\frac{1}{R_4}-\frac{1}{R_3}] \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \tag{16}$$

The condition of oscillation and the radian frequency of oscillation are the same as given by equation (11).

Taking the effect of C_{z3} into consideration the state matrix equation of the circuit of Fig. 7(a) is modified to:

$$\begin{bmatrix} \frac{dv_1}{dt} \\ \frac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} 0 & \frac{1}{C_1R_2} \\ -\frac{1}{C_2R_1} & \frac{1}{C_2}[\frac{1}{R_4}-\frac{1}{R_3}-\frac{C_{Z3}}{C_1R_2}] \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \tag{17}$$

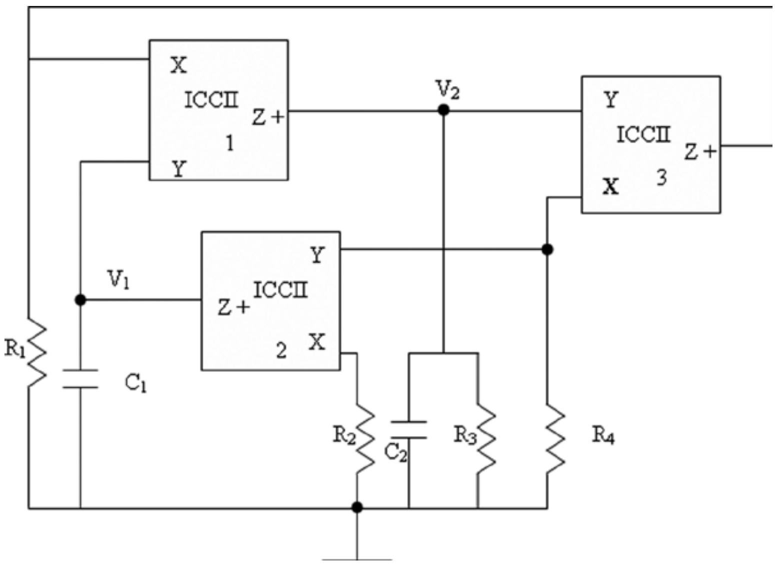

FIGURE 7A
Grounded passive elements oscillator using three-ICCII+.

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

Next taking the effect of R_{x1} into consideration the state matrix equation is modified to:

$$\begin{bmatrix} \frac{dv_1}{dt} \\ \\ \frac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} 0 & \frac{1}{C_1R_2} \\ \\ -\frac{1}{C_2R_1[1+\frac{R_{x1}}{R_1}]} & \frac{1}{C_2R_4[1+\frac{R_{x1}}{R_1}]} - \frac{1}{C_2R_3} \end{bmatrix} \begin{bmatrix} v_1 \\ \\ v_2 \end{bmatrix} \tag{18}$$

The condition of oscillation and the radian frequency of oscillation are the same as given by equation (15).

The circuit of Fig. 5(a) is simulated with the ICCII+ of Fig. 2(b) with $V_{DD} = 1.5\,V$, $V_{SS} = -1.5\,V$ and with aspect ratios given in Table 2.

Figure 7(b) represents the output waveform of the oscillator designed for fo equal to 2 MHz by taking $C_1 = C_2 = 40\,pF$, $R_1 = R_2 = 2\,k\Omega$.

CONCLUSIONS

Three new oscillators using single output inverting CCII (ICCII) are introduced. The first oscillator uses minimum passive components and uses two ICCII– and is generated from a recently reported current mode bandpass filter. Two more oscillators using grounded resistors and capacitors and using three ICCII– or ICCII+ are introduced. Detailed analysis of the effects of the parasitic components is given. Spice simulation results are included to demonstrate the practicality of the three proposed oscillator circuits. The advantage of the reported oscillators is that they employ identical ICCII with single output. The CCII versions of the reported oscillators employ combination of CCII+ and CCII–.

TABLE 2
Transistor aspect ratios of the ICCII+ shown in Fig. 2(b).

Transistor	**W(μm) / L(μm)**
M_1, M_2, M_3, M_4	2.5/1
M_5, M_6	8/1
M7,M8	20/2
M_9, M_{10}	10/1
M_{11}, M_{12}	40/2

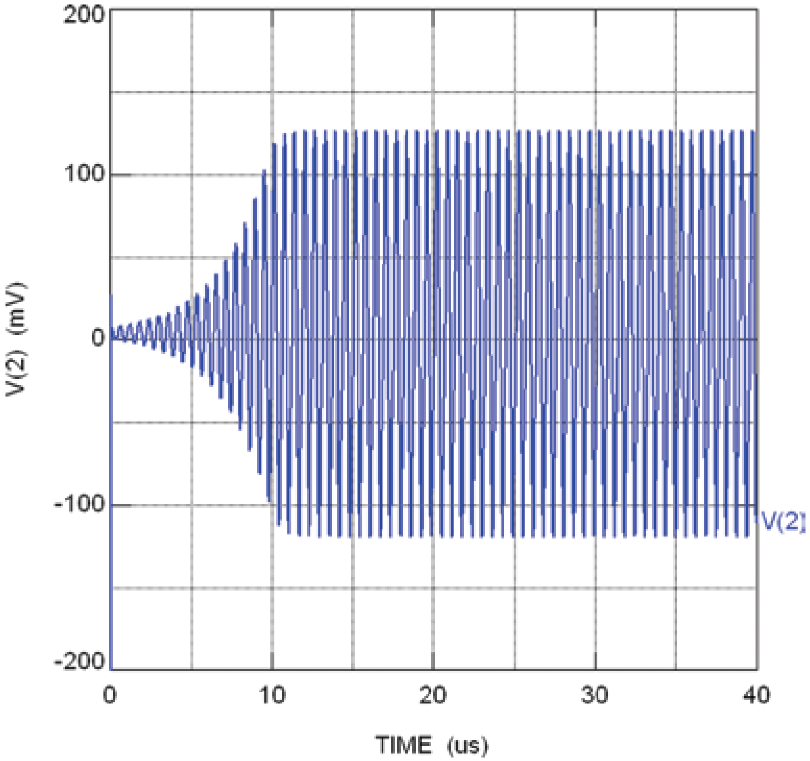

FIGURE 7B
Simulated output waveform for oscillator of Fig. 7(a).

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