

# On the Transformation of a Floating Resistor Oscillator to Grounded Passive Element Oscillators

Ahmed M. Soliman

Electronics and Communication Engineering Department, Faculty of Engineering, Cairo University, Giza 12613, Egypt,  
Email: asoliman@iee.org

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## ABSTRACT:

A generalization method is used to transform a floating resistor oscillator circuit to a family of sixteen grounded capacitor oscillators using the current conveyor (CCII) or the inverting current conveyor (ICCI) or combination of both. Two of the oscillator circuits have a floating property. A new family of sixteen oscillator circuits is generated from the known circuit using the adjoint circuit theorem. It is also shown that the oscillator under consideration leads to the generation of other known and new grounded passive element oscillators employing the differential voltage current conveyor (DVCC) and the balanced output current conveyor (BOCCII).

**KEYWORDS:** Nodal Admittance Matrix Synthesis, Nullator, Norator, Pathological Current and Voltage Mirrors, Grounded R, C Oscillators, DVCC, BOCCII.

## 1. INTRODUCTION

Several oscillator circuits have been introduced in the literature [1-10] using different types of active devices like Op Amps or current conveyors (CCII) [11]. In the process of designing oscillator circuits, it is useful to follow systematic methodologies to obtain novel circuits. It is also very important to know the origin of an oscillator circuit and how it can be generated from known circuits. This is the first objective of this paper. It is also desirable to know how to transform an oscillator circuit using a floating resistor to a grounded passive element oscillator. This is the second objective of this paper.

The conventional systematic synthesis framework using nodal admittance matrix expansion (NAM) presented in [12-15] and [16-18] is used in this paper to generate grounded passive element oscillator circuits from the known floating resistor oscillator circuit.

## 2. GENERATION OF FAMILY OF GROUNDED CAPACITOR OSCILLATORS

The oscillator circuit shown in Figure 1(a) was originally introduced in [1] and republished in [8]. This circuit realizes both voltage and current outputs and it belong to a family of sixteen oscillator circuits, eight of them were generated in [2] using NAM expansion method. Alternative generation method is given next based on the known circuit topology shown in Figure 1(a) from which the NAM equation is obtained as:

$$Y = \begin{bmatrix} sC_1 + G_1 - G_3 & G_3 \\ -G_2 & sC_2 \end{bmatrix} \quad (1)$$

The circuit characteristic equation is given by:

$$s^2 C_1 C_2 + s C_2 [G_1 - G_3] + G_2 G_3 = 0 \quad (2)$$

From the above equation it is seen that necessary condition for oscillation and the radian frequency of oscillation are given respectively by:

$$G_1 = G_3 \quad (3-a)$$

$$\omega_0 = \sqrt{\frac{G_2 G_3}{C_1 C_2}} \quad (3-b)$$

Figure 1(b) represents the generalized conveyor (GC) realization obtained from Fig. 1(a) and the characteristic equation is obtained as:

$$s^2 C_1 C_2 + s C_2 [G_1 - a_1 K_1 G_3] + K_1 a_2 K_2 a_3 G_2 G_3 = 0 \quad (4)$$

From the above equation it is seen that necessary conditions for oscillation are given by equation (3-a) and the following coefficient conditions:

$$a_1 K_1 = 1, \quad K_1 a_2 K_2 a_3 = 1 \quad (5)$$

There are sixteen circuits that satisfy the conditions in equation (5) and the coefficient signs and the types of the three conveyors are given in Table 1.

The grounded resistor  $R_1$  controls the condition of oscillation without affecting the frequency of oscillation.

The grounded resistor  $R_2$  controls the frequency of oscillation without affecting the condition of oscillation.

It is seen that the floating resistor  $R_3$  can be adjusted once and is not used in tuning the condition of oscillation or the frequency of oscillation.

**3. GENERATION OF ADJOINT FAMILY OF OSCILLATORS**

A second family of sixteen oscillators is introduced in this section and is generated from Figure 1(a) using the adjoint circuit theorem [19-20]. Figure 2(a) represents a new floating oscillator circuit using three ICCII- and is the adjoint of the circuit of Figure 1(a). The NAM equation of the circuit of Figure 2(a) is given by:

$$Y = \begin{bmatrix} sC_1 + G_1 - G_3 & -G_2 \\ G_3 & sC_2 \end{bmatrix} \quad (6)$$

Figure 2(b) represents the generalized conveyor realization obtained from Figure 2(a) and the characteristic equation is obtained as:

$$s^2 C_1 C_2 + s C_2 [G_1 - a_1 K_1 G_3] + a_1 a_2 K_2 K_3 G_2 G_3 = 0 \quad (7)$$

From the above equation it is seen that necessary conditions for oscillation are given by equation (3-a) and the following coefficient conditions:

$$a_1 K_1 = 1, \quad a_1 a_2 K_2 K_3 = 1 \quad (8)$$

There are sixteen circuits that satisfy the conditions in equation (8) and the coefficient signs and the types of the three conveyors are given in Table 2.

**4. GENERATION OF GROUNDED PASSIVE ELEMENT OSCILLATORS**

In this section three alternative sets of grounded R and C oscillators with independent control on the condition of oscillation and on the frequency of oscillation are generated from the circuit of Figure 1(a). The differential voltage current conveyor (DVCC) and the balanced output current conveyor (BOCCII) are used in the following circuits.

**4.1. New single DVCC and two CCII+ oscillators**

Two new grounded passive element oscillators are introduced next and are generated from Figure 1(a) by replacing the third CCII+ acting as a voltage follower by a DVCC acting as a differential transconductor as shown in Figures 3 (a) and 3(b). Equations (1) to (3) apply to these two new circuits.

**4.2. Single output DVCC and single CCII+ oscillators**

The circuit shown in Figure 1(a) can lead to the generation of the oscillators shown in Figure 4 using NAM expansion as explained next.

Starting from equation (1) and adding a third blank row and column and connecting a nullator between nodes 1 and 3 and a current mirror (CM) between nodes 2 and 3 in order to move  $-G_2$  from the 2, 1 position to the diagonal position 3, 3 as  $G_2$  it follows that:

$$Y = \begin{bmatrix} sC_1 + G_1 - G_3 & G_3 & 0 \\ 0 & sC_2 & 0 \\ 0 & 0 & G_2 \end{bmatrix} \quad (9)$$

Adding a fourth blank row and column and connecting a nullator between nodes 1 and 4, a voltage mirror (VM) between nodes 2, 4 and a CM between nodes 1 and 4 in order to move  $-G_3$  from 1, 1 position and  $G_3$  from 1, 2 position to the diagonal position 4, 4 as  $G_3$  it follows that:

$$Y = \begin{bmatrix} sC_1 + G_1 & 0 & 0 & 0 \\ 0 & sC_2 & 0 & 0 \\ 0 & 0 & G_2 & 0 \\ 0 & 0 & 0 & G_3 \end{bmatrix} \quad (10)$$

The above equation is realizable by a DVCC+ and a CCII+ as shown in Figure 4(a). This circuit was published before as circuit 10 in [9].

An equivalent circuit can be obtained by the following alternative NAM expansion to equation (9).

Adding a fourth blank row and column to equation (9), a VM between nodes 1 and 4, a nullator between nodes 2 and 4 and a norator between nodes 1 and 4 in order to move  $-G_3$  from 1, 1 position and  $G_3$  from 1, 2 position to the diagonal position 4, 4 as  $G_3$  it follows that:

$$Y = \begin{bmatrix} sC_1 + G_1 & 0 & 0 & 0 \\ 0 & sC_2 & 0 & 0 \\ 0 & 0 & G_2 & 0 \\ 0 & 0 & 0 & G_3 \end{bmatrix} \quad (11)$$

The above equation is realizable by a DVCC- and a CCII+ as shown in Figure 4(b). This circuit was published before as circuit 11 in [9].

**4.3. Balanced output CCII and single CCII+ oscillator**

The circuit shown in Figure 2(a) can also lead to the generation of the well known oscillator shown in

Figure 5 [10] using NAM expansion as explained next.

Starting from equation (6) and adding a third blank row and column and connecting a nullator between nodes 2, 3 and a CM between nodes 1 and 3 in order to move  $-G_2$  from the 1, 2 position to the diagonal position 3, 3 as  $G_2$  it follows that:

$$Y = \begin{bmatrix} sC_1+G_1-G_3 & 0 & 0 \\ G_3 & sC_2 & 0 \\ 0 & 0 & G_2 \end{bmatrix} \quad (12)$$

Adding a fourth blank row and column, a nullator between nodes 1 and 4 to move  $-G_3$  from 1, 1 position to 1, 4 position as well as to move  $G_3$  from 2, 1 position to 2, 4 position as follows:

$$Y = \begin{bmatrix} sC_1+G_1 & 0 & 0 & -G_3 \\ 0 & sC_2 & 0 & G_3 \\ 0 & 0 & G_2 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad (13)$$

Next adding a norator between nodes 2, 4 and a CM between nodes 1 and 4 in order to move both  $-G_3$  and  $G_3$  to the diagonal position 4, 4 as follows

$$Y = \begin{bmatrix} sC_1+G_1 & 0 & 0 & 0 \\ 0 & sC_2 & 0 & 0 \\ 0 & 0 & G_2 & 0 \\ 0 & 0 & 0 & G_3 \end{bmatrix} \quad (14)$$

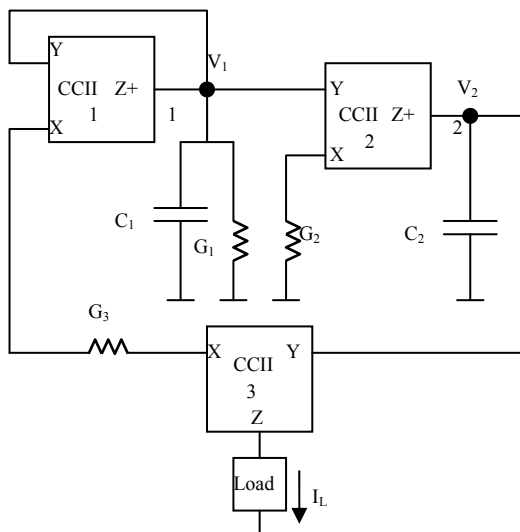


Fig. 1(a). Grounded capacitor voltage and current mode oscillator [1]

The above equation is realizable by a BOCCII and a CCII+ as shown in Figure 5 which was reported before in [10].

### 5. PARASITIC ELEMENT EFFECTS

According to the CCII or ICCII model including the parasitic elements that are mainly represented by the X terminal resistance  $R_X$  and the Z terminal parasitic capacitance  $C_Z$ . Thus, the values of the actual capacitances to be connected at these terminals can be varied from their nominal values and adjusted so that to accommodate the added capacitances introduced by the parasitic elements seen at these terminals.

For the circuit of Figure 1(a) the design value of  $C_1$  can be reduced by the magnitude of the parasitic capacitance  $C_{Z1}$ . Similarly the design value of  $C_2$  can be reduced by the magnitude of the parasitic capacitance  $C_{Z2}$ .

Similarly the design value of  $R_2$  can be reduced by the magnitude of the parasitic resistance  $R_{X2}$ . Similarly the design value of  $R_3$  can be reduced by the magnitude  $(R_{X1} + R_{X3})$ .

Similarly for all circuits considered in this paper except the circuits of Figure 3 in which the only two parasitic elements affecting the circuit are  $R_{X1}$  and  $C_{Z3}$  and they act as a first order lowpass filter affecting the current transfer from  $Z_3$  to  $X_1$  by the following transfer function:

$$\frac{I_a}{I} = \frac{1}{1 + sC_{Z3}R_{X1}} \quad (15)$$

The above equation determines the frequency limitation of the circuits of Figure 3.

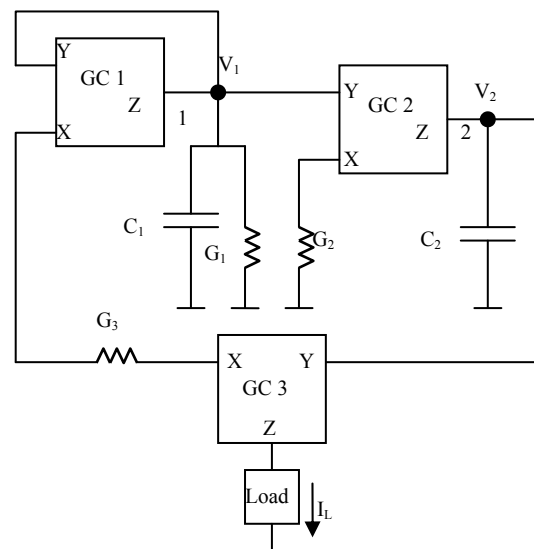


Fig. 1(b). Grounded capacitor generalized conveyor oscillator

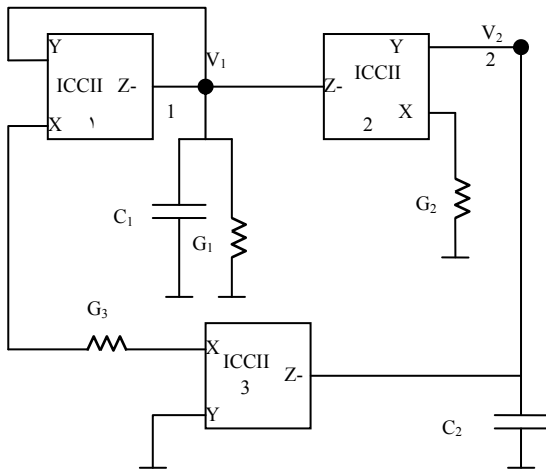


Fig. 2(a). Adjoint to oscillator circuit of Figure 1(a)

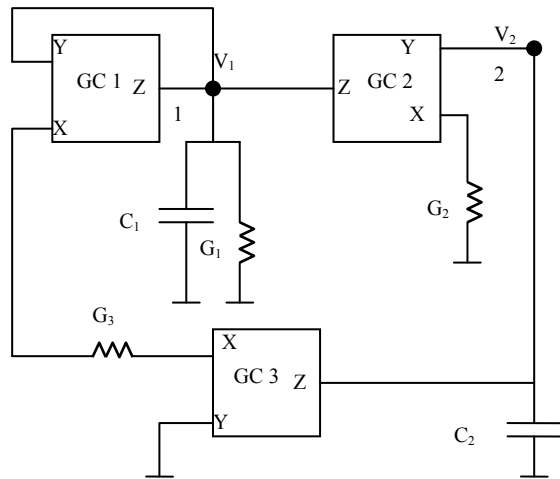


Fig. 2(b). Generalized conveyer realization of Figure 2(a)

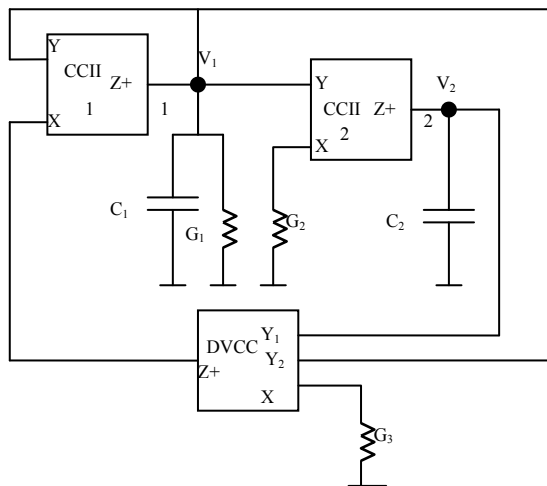


Fig. 3(a). A grounded R and C oscillator using DVCC+ and two CCII+

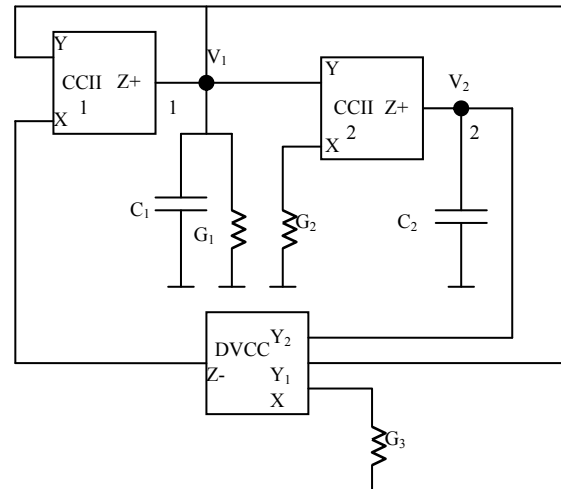


Fig. 3(b). A grounded R and C oscillator using DVCC- and two CCII+

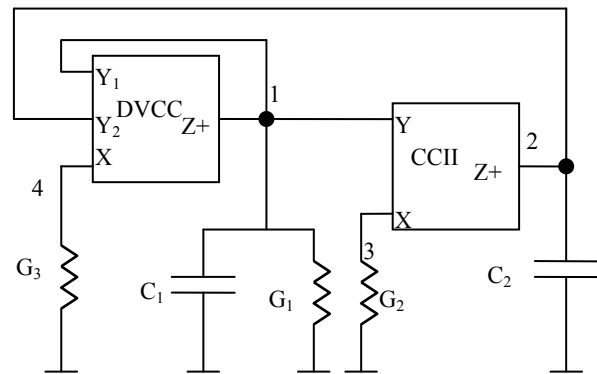


Fig. 4(a). Grounded R and C oscillator using DVCC+ and CCII+ [9]

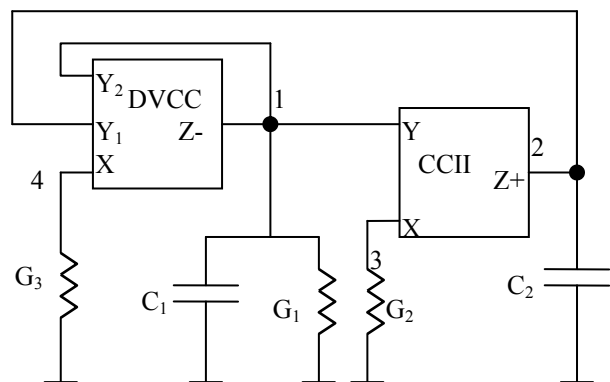


Fig. 4(b). Grounded R and C oscillator using DVCC- and CCII+ [9]

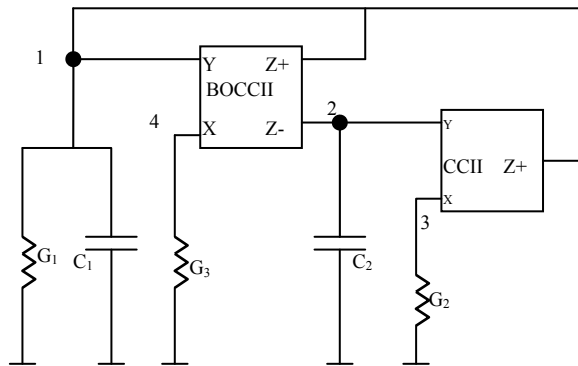


Fig. 5. Grounded R and C oscillator using BOCCII and CCII+ [10]

Table 1. Sixteen equivalent realizations to the oscillator circuit of Fig 1(b)

Circuit	$a_1$	$K_1$	$a_2$	$K_2$	$a_3$	$K_3$	Conveyor 1	Conveyor 2	Conveyor 3	Floating
1	+	+	+	+	+	+	CCII+	CCII+	CCII+	No
2	+	+	-	+	-	+	CCII+	ICCI+	ICCI+	No
3	+	+	-	-	+	+	CCII+	ICCI-	CCII+	No
4	+	+	+	-	-	+	CCII+	CCII-	ICCI+	No
5	-	-	+	-	+	+	ICCI-	CCII-	CCII+	No
6	-	-	-	+	+	+	ICCI-	ICCI+	CCII+	No
7	-	-	+	+	-	+	ICCI-	CCII+	ICCI+	No
8	-	-	-	-	-	+	ICCI-	ICCI-	ICCI+	No
9	+	+	+	+	+	-	CCII+	CCII+	CCII-	No
10	+	+	-	+	-	-	CCII+	ICCI+	ICCI-	No
11	+	+	-	-	+	-	CCII+	ICCI-	CCII-	No
12	+	+	+	-	-	-	CCII+	CCII-	ICCI-	No
13	-	-	+	-	+	-	ICCI-	CCII-	CCII-	Yes
14	-	-	-	+	+	-	ICCI-	ICCI+	CCII-	No
15	-	-	+	+	-	-	ICCI-	CCII+	ICCI-	No
16	-	-	-	-	-	-	ICCI-	ICCI-	ICCI-	Yes

Table 2. Sixteen equivalent realizations to the oscillator circuit of Fig 2 (b)

Circuit	$a_1$	$K_1$	$a_2$	$K_2$	$a_3$	$K_3$	Conveyor 1	Conveyor 2	Conveyor 3	Floating
1	+	+	+	+	+	+	CCII+	CCII+	CCII+	No
2	+	+	-	+	+	-	CCII+	ICCI+	CCII-	No
3	+	+	+	-	+	-	CCII+	CCII-	CCII-	No
4	-	-	+	+	+	-	ICCI-	CCII+	CCII-	No
5	+	+	-	-	+	+	CCII+	ICCI-	CCII+	No
6	-	-	-	+	+	+	ICCI-	ICCI+	CCII+	No
7	-	-	+	-	+	+	ICCI-	CCII-	CCII+	No
8	-	-	-	-	+	-	ICCI-	ICCI-	CCII-	Yes
9	+	+	+	+	-	+	CCII+	CCII+	ICCI+	No
10	+	+	-	+	-	-	CCII+	ICCI+	ICCI-	No
11	+	+	+	-	-	-	CCII+	CCII-	ICCI-	No
12	-	-	+	+	-	-	ICCI-	CCII+	ICCI-	No
13	+	+	-	-	-	+	CCII+	ICCI-	ICCI+	No
14	-	-	-	+	-	+	ICCI-	ICCI+	ICCI+	No
15	-	-	+	-	-	+	ICCI-	CCII-	ICCI+	No
16	-	-	-	-	-	-	ICCI-	ICCI-	ICCI-	Yes

## 6. CONCLUSIONS

It is shown that the oscillator of Figure 1(a) is linked to many known oscillators using the DVCC or the BOCCII. The grounded passive element oscillators of Figure 3 are new.

The oscillator of Figure 1(a) belongs to a family of sixteen member, two of them are floating as shown in Table 1.

The oscillator of Figure 2(a) is new and is the adjoint of the oscillator of Figure 1(a). The oscillator of Figure 2(a) belongs to a family of sixteen members two of them are floating as shown in Table 2.

Simulations results of the circuits of Figure 2 and 3 are included.

All circuits considered in this paper except the circuits of Figure 3 can absorb parasitic element effects. The operation of these circuits depend on the CMOS circuits used for the CCII, ICCII, BOCCII and DVCC and the power dissipation and the total harmonic distortion for each circuit will depend on the different CMOS circuits used in the realization of the oscillator circuit.

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