Generation of Grounded Capacitors Minimum Component Oscillators

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Abstract

The oscillators considered in this chapter uses the minimum number of passive elements namely two capacitors and two resistors. The generated oscillators employ two grounded capacitors and all reported circuits except two have the advantage of their ability to absorb parasitic resistance and parasitic capacitance elements effects. Four classes of oscillators are generated in this chapter, the class I oscillator circuits include three nodes, the classes II and III oscillator circuits include four nodes and the class IV oscillator circuits include five nodes.

1. Introduction

It is not possible to realize a sinusoidal oscillator using a single operational amplifier (Op Amp) and the minimum number of passive circuit elements namely two resistors and two capacitors. Several minimum passive circuit element oscillators are available in the literature [1-9] using a single voltage controlled voltage source (VCVS), a single voltage controlled current source (VCCS), a single current conveyor (CCII+) [10] and a single inverting current conveyor (ICCII-) [11].

The objective of this chapter is to apply nodal admittance matrix (NAM) expansion to generate three node, four node and five node oscillator circuits using members of the CCII and ICCII families.

Recently, a symbolic framework for systematic synthesis of linear active circuits based on NAM expansion was presented in [12].The matrix expansion process begins by introducing blank rows and columns, representing new internal nodes, in the admittance matrix. Then, nullators and norators are used to move the resulting admittance matrix elements to their final locations, properly describing either floating or grounded passive elements. Thus, the final NAM is obtained including finite elements representing passive circuit components and unbounded elements, so called infinity-variables, representing nullators and norators. In this framework, nullators and norators ideally describe active elements in the circuit are used. The nullator and norator are pathological or singular elements that possess ideal characteristics and are specified according to the constraints they impose on their terminal voltages and currents. For the nullator shown in Fig. 1(a) V = I = 0, while the norator shown in Fig. 1(b) imposes no constraints on its voltage and current. The attractive feature of the two nullor elements is their ability to model active circuits [13]. Despite the ability of nullor elements to describe many active building blocks, they fail to represent devices like the CCII+. Other passive elements like resistors are combined with nullators and norators in order to obtain the nullor representation of the CCII+ [6]. In order to avoid the use of passive elements in the nullor representation of any building block, additional pathological elements called mirror elements describing the voltage and current reversing actions are introduced in [11]. The voltage mirror (VM) shown in Fig. 1(c), is a lossless two-port network element used to represent an ideal voltage reversing action and it is described by:

$V_1 = -V_2$ (1-a)

$I_1 = I_2 = 0$ (1-b)

The current mirror (CM) shown in Fig. 1(d), is a two-port network element used to represent an ideal current reversing action and it is described by:

V_1 and V_2 are arbitrary (1-c)

$I_1 = I_2$, and they are also arbitrary (1-d)

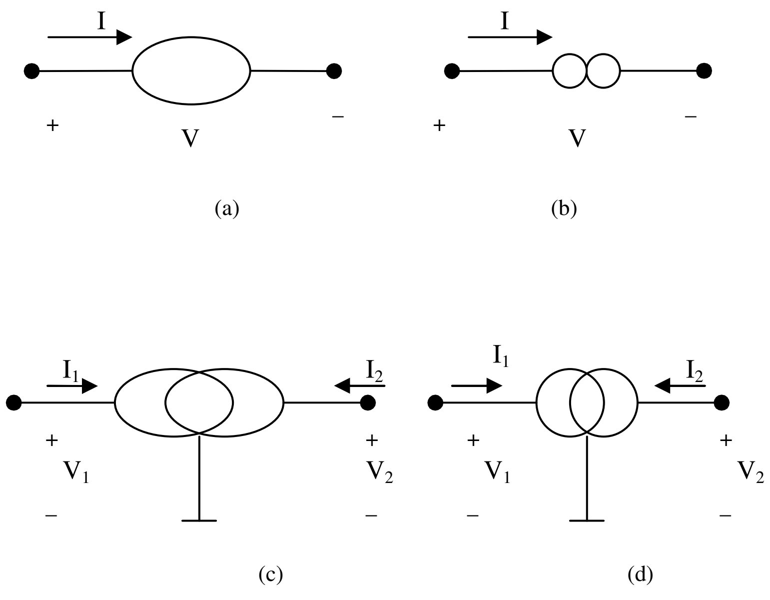

Fig.1. (a) Nullator (b) Norator (c) Voltage mirror (d) Current mirror.

Very recently the systematic synthesis method based on NAM expansion using nullor elements [12] has been extended to accommodate mirror elements. This results in a generalized framework encompassing all pathological elements for ideal description of active elements [14]. Accordingly, more alternative realizations are possible and a wide range of active devices can be used in the synthesis procedure.

In this chapter, the conventional systematic synthesis framework using NAM expansion presented in [15] to synthesize oscillator circuits is applied to the minimum passive component oscillators. The oscillators are classified according to the number of nodes in the circuit and the nature of the two resistors whether being grounded or floating as shown in Fig. 1. Several new as well as well known oscillator circuits are generated in this chapter; using CCII or ICCII or combination of both.

2. Formulation of the NAM equation

The oscillators considered in this chapter are grounded capacitors second order oscillators using two resistors and two capacitors. The state matrix equation is described as follows:

$$\begin{bmatrix} sV1 \\ sV2 \end{bmatrix} = \begin{bmatrix} a11 & a12 \\ a21 & a22 \end{bmatrix} \begin{bmatrix} V1 \\ V2 \end{bmatrix} \qquad (2)$$

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

$$a_{11}+a_{22} = 0, \ \omega_o = \sqrt{a_{11}a_{22}-a_{12}a_{21}} \qquad (3)$$

From the above equation it is seen that a_{11} and a_{22} must have opposite polarities, also a_{12} and a_{21} must have opposite polarities. If both a_{11} and a_{22} are zero there will be no control on the condition of oscillation.

The oscillator circuits considered in this chapter are canonic grounded capacitor oscillators represented by one of the four general configurations shown in Fig. 2.

Four different classes of oscillators are considered in this chapter. The class I oscillators has one grounded resistor and one floating resistor and each of the two resistors shares a node with one of the capacitors and it is a three node oscillator circuit as shown in Fig. 2(a).On the other hand in the class II oscillators the grounded resistor does not share a node with one of the capacitors and it is a four node oscillator circuit as shown in Fig. 2(b). In the class III oscillators both resistors are grounded and do not share nodes with the two grounded capacitors and it is a four node oscillator circuit as shown in Fig. 2(c).This class of oscillators has no condition of oscillation and will be discussed briefly in this chapter. The class IV oscillators has two floating resistors and one of them shares a node with one of the capacitors and it is a five node oscillator circuit as shown in Fig. 2(d).

The class V oscillator has one grounded resistor and one floating resistor and both resistors do not share nodes with the two grounded capacitors. It is also a five node oscillator circuit with no control on condition of oscillation as in the class III and will not be discussed in this chapter.

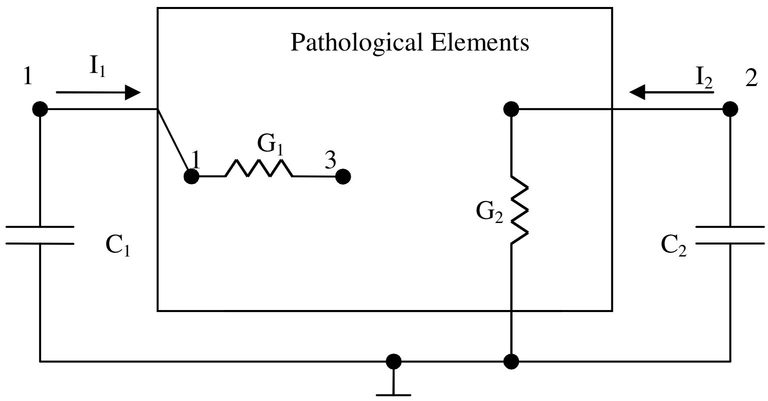

Fig. 2(a) Class I three node generalized configuration

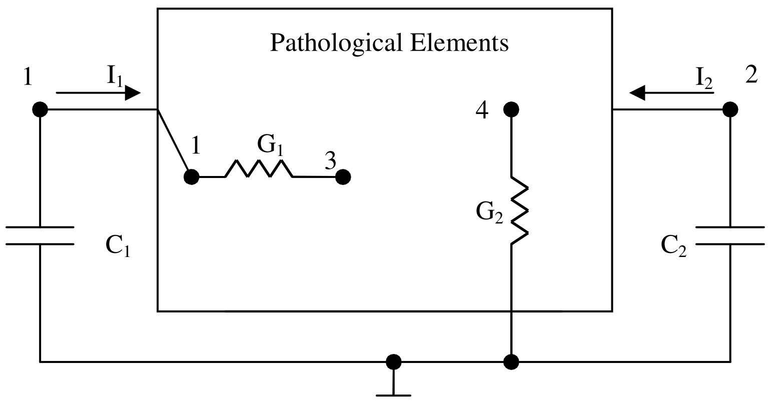

Fig. 2(b) Class II four-node configuration

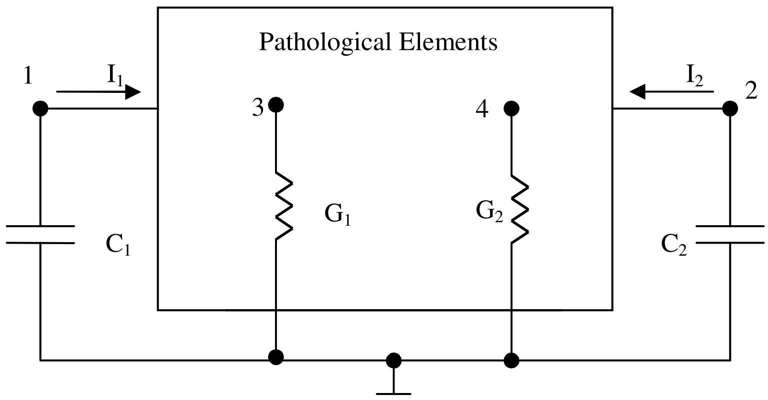

Fig. 2(c) Class III four-node configuration

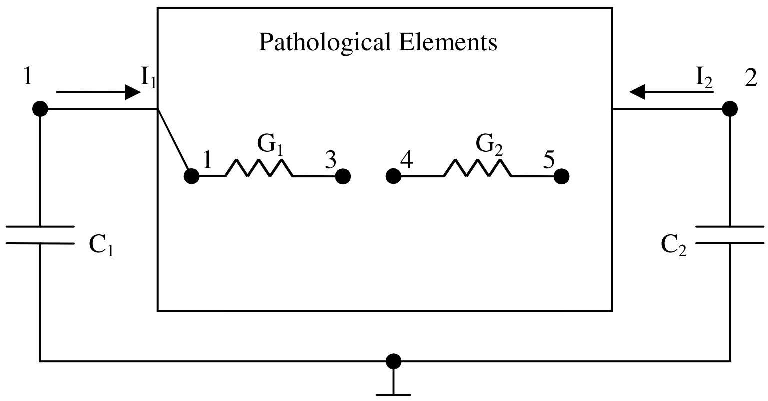

Fig. 2(d) Class IV five node generalized configuration

3. Class I oscillators

The generalized class I oscillator configuration shown in Fig. 2(a) has two types and can be described by the state equations as given in Table I. The admittance matrix Y of the two port oscillator circuit taking the capacitors C_1 and C_2 as external elements at ports 1 and 2 is formulated from the state matrix by interchanging the signs of the admittance parameters.

3.1.1 Class I- type A

The NAM in this case is given by:

$$Y=\begin{bmatrix} G_1 & -G_1 \\ G_1 & -G_1+G_2 \end{bmatrix} \quad (4)$$

Table 1 Summary of the state matrix equation of the four classes of oscillators

Class	State Matrix Equation	Oscillation Condition	# of nodes
I- A I- B	$\begin{bmatrix} sC_1V1 \\ sC_2V2 \end{bmatrix}=\begin{bmatrix} -G_1 & \pm G_1 \\ \mp G_1 & G_1-G_2 \end{bmatrix}\begin{bmatrix} V1 \\ V2 \end{bmatrix}$	$\frac{C2}{C1}+\frac{G2}{G1}=1$	3
II- A II- B	$\begin{bmatrix} sC_1V1 \\ sC_2V2 \end{bmatrix}=\begin{bmatrix} -G_1 & \pm G_1 \\ \mp G_1 \mp G_2 & G_1 \end{bmatrix}\begin{bmatrix} V1 \\ V2 \end{bmatrix}$	$C_2 = C_1$	4
II- C II- D	$\begin{bmatrix} sC_1V1 \\ sC_2V2 \end{bmatrix}=\begin{bmatrix} -G_1 & \mp G_1 \mp G_2 \\ \pm G_1 & G_1 \end{bmatrix}\begin{bmatrix} V1 \\ V2 \end{bmatrix}$	$C_2 = C_1$	4
III- A III-B	$\begin{bmatrix} sC_1V1 \\ sC_2V2 \end{bmatrix}=\begin{bmatrix} 0 & \mp G_1 \\ \pm G_2 & 0 \end{bmatrix}\begin{bmatrix} V1 \\ V2 \end{bmatrix}$	No condition	4
III- C III-D	$\begin{bmatrix} sC_1V1 \\ sC_2V2 \end{bmatrix}=\begin{bmatrix} 0 & \pm G_2 \\ \mp G_1 & 0 \end{bmatrix}\begin{bmatrix} V1 \\ V2 \end{bmatrix}$	No condition	4
IV- A IV-B	$\begin{bmatrix} sC_1V1 \\ sC_2V2 \end{bmatrix}=\begin{bmatrix} -G_1+G_2 & \mp G_2 \\ \pm G_1 & 0 \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$	$G_2 = G_1$	5
IV- C IV-D	$\begin{bmatrix} sC_1V1 \\ sC_2V2 \end{bmatrix}=\begin{bmatrix} -G_1+G_2 & \pm G_1 \\ \mp G_2 & 0 \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$	$G_2 = G_1$	5

Adding a third blank row and column and connecting a nullator between columns 2 and 3 to move $-G_1$ from 1, 2 position to the 1, 3 position and also to move $-G_1$ from 2, 2 position to the 2, 3 position, the following NAM is obtained:

$$Y=\begin{bmatrix} G_1 & 0 & -G_1 \\ G_1 & G_2 & -G_1 \\ 0 & 0 & 0 \end{bmatrix} \tag{5}$$

Connecting a CM between rows 2 and 3 to move G_1 from 2, 1 position to the 3, 1 position and also to move $-G_1$ from 2, 3 the position to the position 3, 3, the following NAM is obtained:

$$Y=\begin{bmatrix} G_1 & 0 & -G_1 \\ 0 & G_2 & 0 \\ -G_1 & 0 & G_1 \end{bmatrix} \tag{6}$$

The pathological realization for the above equation after adding the two capacitors at nodes 1 and 2 is shown in Fig. 3(a). The nullator and CM are realized by a CCII+ results in the well known oscillator circuit reported in [1, 4, 6].

3.1.2 Class I- type B

The NAM in this case is given by:

$$Y=\begin{bmatrix} G_1 & G_1 \\ -G_1 & -G_1+G_2 \end{bmatrix} \tag{7}$$

Adding a third blank row and column to the above equation and connecting a VM between columns 2 and 3 and a norator between rows 2 and 3 the following NAM is obtained:

$$Y=\begin{bmatrix} G_1 & 0 & -G_1 \\ 0 & G_2 & 0 \\ -G_1 & 0 & G_1 \end{bmatrix} \tag{8}$$

The pathological realization for the above equation after adding the two capacitors at nodes 1 and 2 is shown in Fig. 3(b). The VM and norator are realized by an; ICCII- results in the well known oscillator circuit reported in [1, 2].

For each of the two circuits of the class I oscillators the condition of oscillation and the radian frequency of oscillation are given by:

$$\frac{C2}{C1}+\frac{G2}{G1}=1,\ \omega o=\sqrt{\frac{G1G2}{C1C2}} \tag{9}$$

Of course it is not possible to use equal G or equal C with this class of oscillators.

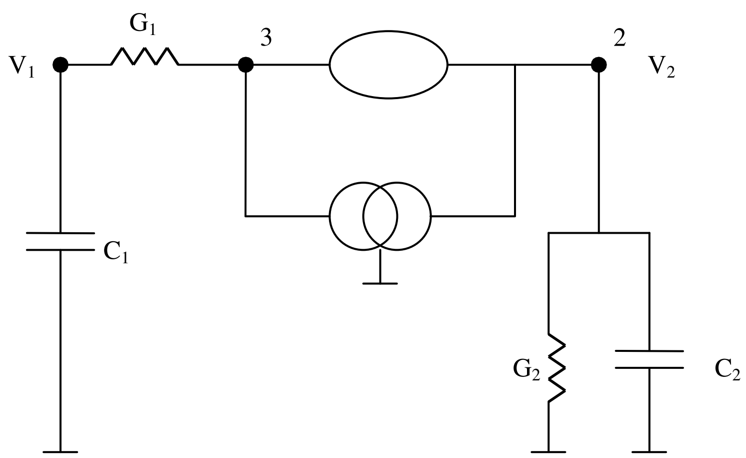

Fig. 3(a) Pathological realization of class I- type A oscillator

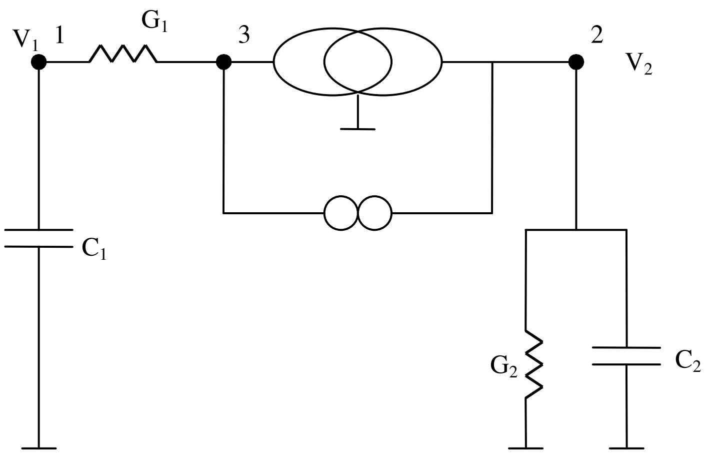

Fig. 3(b) Pathological realization of class I-type B oscillator

4. Class II oscillators

The class II oscillator configuration is shown in Fig. 2(b) has four types and can be described by the state equations as given in Table I. The condition of oscillation for this class is $C_1 = C_2$. This class of oscillators was generated in [1] from eight alternative grounded frequency dependent negative resistor (FDNR) circuits.

4.1.1 Class II- type A

The NAM in this case is given by:

$$Y=\begin{bmatrix} G_1 & -G_1 \\ G_1+G_2 & -G_1 \end{bmatrix} \tag{10}$$

Adding a third blank row and column and connecting a nullator between columns 2 and 3 to move $-G_1$ from 1, 2 position to the 1, 3 position and also to move $-G_1$ from 2, 2 position to the 2, 3 position, the following NAM is obtained:

$$Y=\begin{bmatrix} G_1 & 0 & -G_1 \\ G_1+G_2 & 0 & -G_1 \\ 0 & 0 & 0 \end{bmatrix} \tag{11}$$

Connecting a CM between rows 2 and 3 to move G_1 from 2, 1 position to become $-G_1$ at the 3, 1 position and also to move $-G_1$ from the position 2, 3 to become G_1 at the diagonal position 3, 3 thus the following NAM is obtained:

$$Y=\begin{bmatrix} G_1 & 0 & -G_1 \\ G_2 & 0 & 0 \\ -G_1 & 0 & G_1 \end{bmatrix} \tag{12}$$

Adding a fourth blank row and column to the above equation and then adding a nullator between columns 1, 4 and a norator between rows 2, 4 in order to move G_2 to the diagonal position 4, 4; the following NAM is obtained:

$$Y=\begin{bmatrix} G_1 & 0 & -G_1 & 0 \\ 0 & 0 & 0 & 0 \\ -G_1 & 0 & G_1 & 0 \\ 0 & 0 & 0 & G_2 \end{bmatrix} \tag{13}$$

The pathological realization for the above equation after adding the two capacitors at nodes 1 and 2 is shown in Fig. 4(a). The corresponding CCII- and CCII+ oscillator circuit is shown in Fig. 4(b) [1, 16]. There is a second circuit that belongs to class II-type A having the same topology, which can be generated and it uses an ICCII+ and a CCII+ and was introduced in [1].

4.1.2 Class II- type B

The NAM in this case is given by:

$$Y=\begin{bmatrix} G_1 & G_1 \\ -G_1-G_2 & -G_1 \end{bmatrix} \tag{14}$$

Following similar steps as in the previous section two oscillator circuits having same circuit topology as the class II-type A can be generated. One of the two oscillators uses two ICCII- and the other uses a CCII+ and an ICCII-.

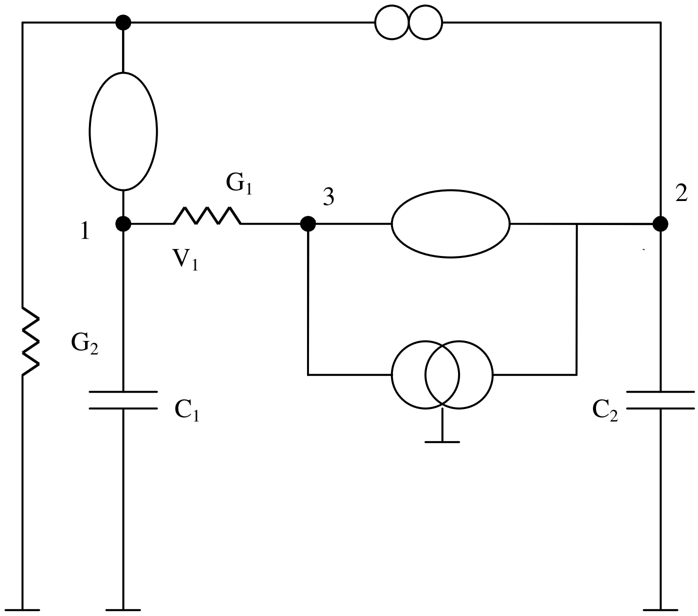

Fig. 4(a) Pathological realization 1 of class II- type A oscillator

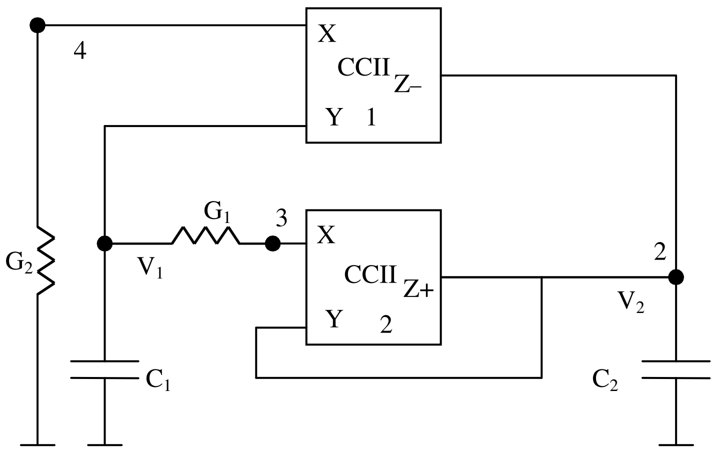

Fig. 4(b) CCII- and CCII+ oscillator circuit realizing Fig. 4(a) [1, 16]

4.1.3 Class II- type C

This is the adjoint to class II-type A [17], the NAM in this case is given by:

$$Y=\begin{bmatrix} G_1 & G_1+G_2 \\ -G_1 & -G_1 \end{bmatrix} \tag{15}$$

Following successive expansion steps the following NAM is obtained:

$$Y=\begin{bmatrix} G_1 & 0 & -G_1 & 0 \\ 0 & 0 & 0 & 0 \\ -G_1 & 0 & G_1 & 0 \\ 0 & 0 & 0 & G_2 \end{bmatrix} \tag{16}$$

The pathological realization for the above equation after adding the two capacitors at nodes 1 and 2 is shown in Fig. 4(c). The corresponding CCII- and ICCII- oscillator circuit is shown in Fig. 4(d) [1]. There is a second circuit that belongs to class II-type C having the same topology which can be generated and it uses an ICCII+ and an ICCII- and was given in [1].

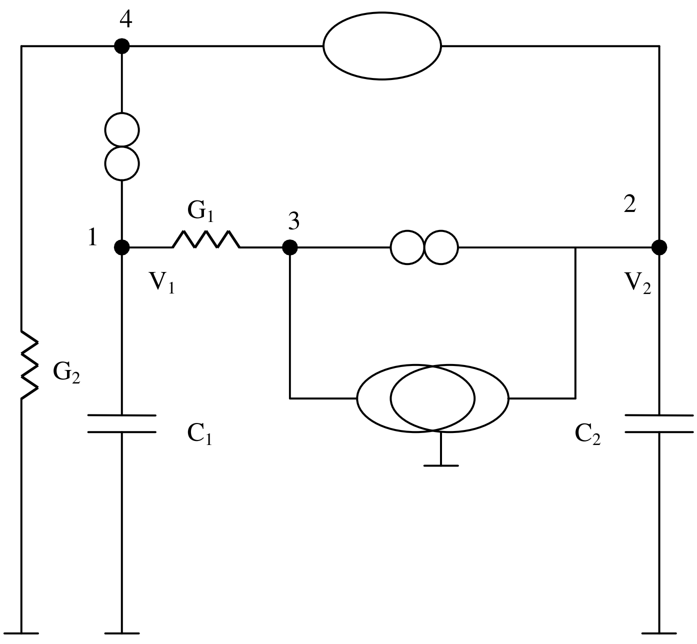

Fig. 4(c) Pathological realization 1 of class II-type C oscillator

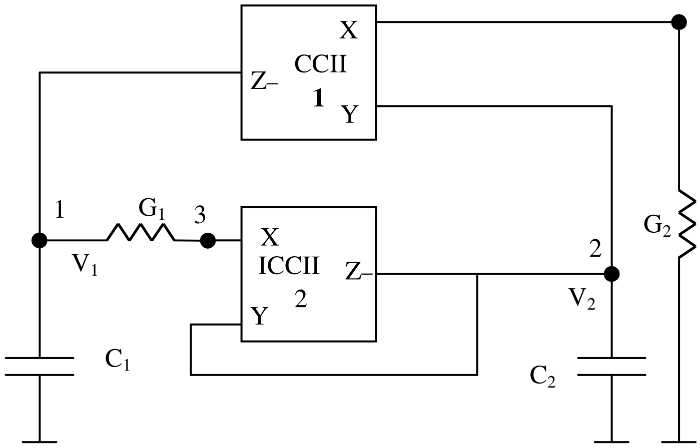

Fig. 4(d) CCII- and ICCII- oscillator circuit realizing Fig. 4(c) [1]

4.1.4 Class II- type D

This is the adjoint to class-type B [17], the NAM in this case is given by:

$$Y=\begin{bmatrix} G_1 & -G_1-G_2 \\ G_1 & -G_1 \end{bmatrix} \quad (17)$$

Following similar steps as in the previous section two oscillator circuits having same circuit topology as the class II-type C can be generated. One of the two oscillators uses two; CCII+ [1, 18] and the other use an ICCII- and a CCII+.

It should be noted that the class II oscillators were generated in [1] from eight grounded frequency dependent negative resistance (FDNR) circuits by terminating input port by a grounded capacitor.

Two more circuits that belong to this class and have different topology can be generated from types type A and type C as follows.

Starting from eqn. (11) and adding a fourth blank row and column and connecting a nullator between columns 1, 4 to move G2 to the position 2, 4 and a norator between rows 2 and 4 to move G1 and –G1 from row 2 to row 4,it follows that:

$$Y=\begin{bmatrix} G_1 & 0 & -G_1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ G_1 & 0 & -G_1 & G_2 \end{bmatrix} \quad (18)$$

Adding a CM between rows 4 and 3 to move G_1 and $-G_1$and from row 4 to row 3 to become $-G_1$ and G_1, it follows that:

$$Y=\begin{bmatrix} G1 & 0 & -G1 & 0 \\ 0 & 0 & 0 & 0 \\ -G1 & 0 & G1 & 0 \\ 0 & 0 & 0 & G2 \end{bmatrix} \tag{19}$$

The oscillator circuit representing the above equation uses a CCII+ and a CCII- and is shown in Fig. 5(a) [1, 19]. This oscillator circuit can be obtained from the unity gain current mode band-pass filter given in [20] by feeding-back output current to input port [20].

Similarly the circuit shown in Fig. 5(b) can be generated by expanding the NAM equation of the class II-type C, this circuit was reported in [1, 21]. It should be noted that the circuits of Fig. 5 are affected by the stray resistance R_X of conveyor 1 and the capacitance C_Z of conveyor 2.

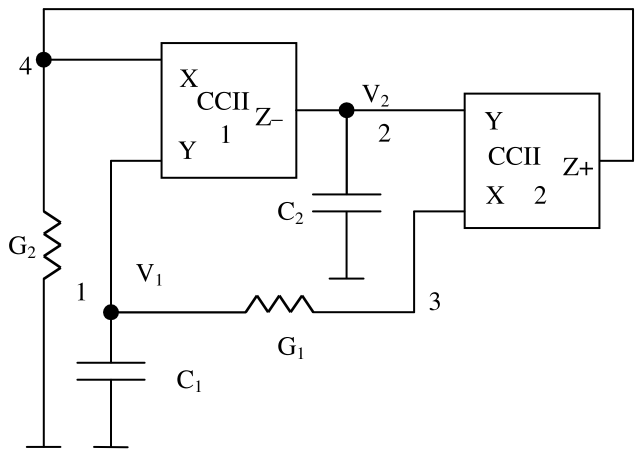

Fig. 5(a) Alternative topology of a class II- type A oscillator [1, 19]

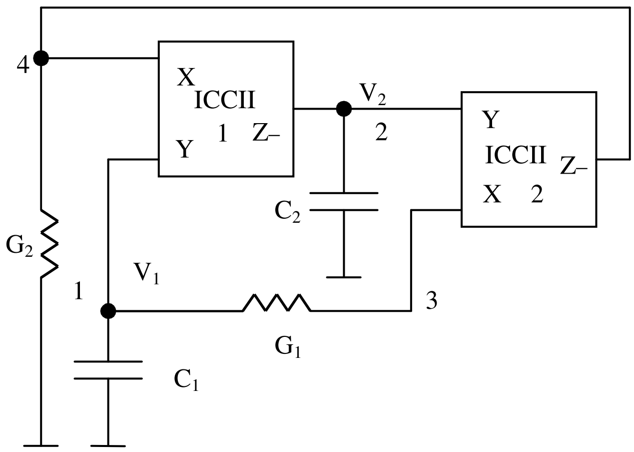

Fig. 5(b) Alternative topology of a class II-type B oscillator [1, 20]

5. Class III oscillators

The class III oscillator configuration is shown in Fig. 2(c) has four types and can be described by the state equations as given in Table I. There is no condition of oscillation for this class. The eight oscillators belonging to this class can be obtained from the eight gyrators reported in [22] by terminating the two ports of the gyrators by the two capacitors.

5.1.1 Class III- type A

The NAM in this case is given by:

$$Y=\begin{bmatrix} 0 & G_1 \\ -G_2 & 0 \end{bmatrix} \tag{20}$$

By successive expansions the following NAM is obtained:

$$Y=\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & G_1 & 0 \\ 0 & 0 & 0 & G_2 \end{bmatrix} \tag{21}$$

The above equation results in the class III-type A realization 1 using a CCII+ and a CCII- as shown in Fig. 6(a) [23].

The class III-type - A oscillators include three more realizations and can be obtained in a similar way and are summarized as follows: realization 2; using a CCII+ and an ICCII+, realization 3; using an ICCII- and a CCII-, realization 4; using an ICCII- and an ICCII+.

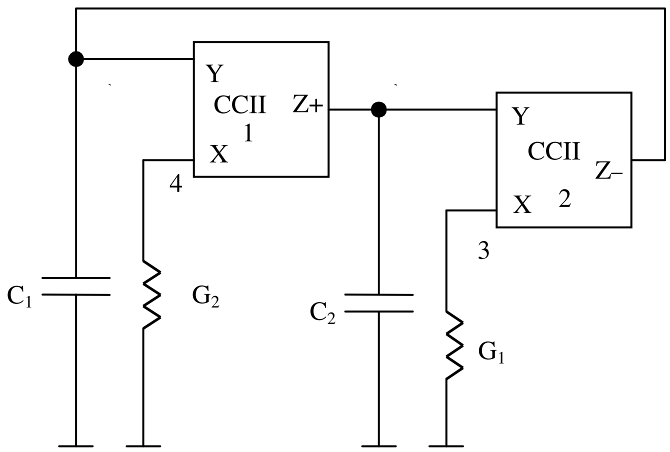

Fig.6 (a) CCII+ and CCII- class III- type A oscillator circuit 1 [23]

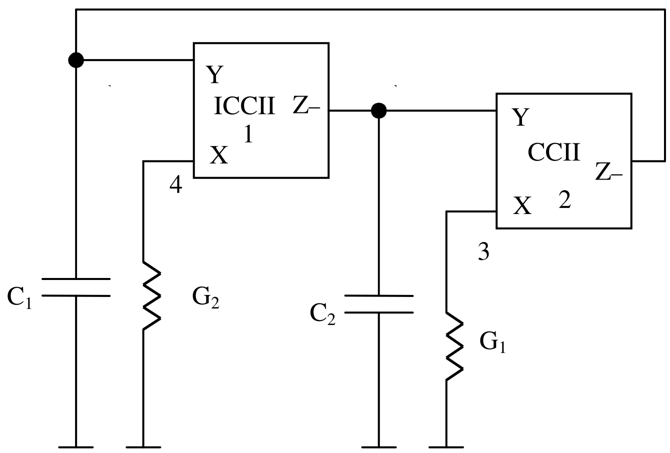

Fig.6 (b) ICCII- and CCII- class III- type C oscillator adjoint to Fig. 6(a)

5.1.2 Class III- type B

The class III-type B oscillators include also four circuits and can be obtained in a similar way and are realizable using CCII-, CCII+ or ICCII+, CCII+ or CCII-, ICCII- or ICCII+, ICCII-.

5.1.3 Class III- type C

This represents the adjoint oscillator circuits to class III- type A. The four oscillator circuits realizing the type A realize also the type C oscillators after interchanging ports 1 and 2. For example the oscillator circuit shown in Fig. 6(b) is the adjoint of that of Fig. 6(a) and is obtainable from realization 3 of class III- type A after interchanging the two ports 1 and 2.

5.1.4 Class III- type D

This represents the adjoint oscillator circuits to class III- type-B. The four oscillator circuits realizing the type-B realize also the type-D oscillators after interchanging ports 1 and 2.

The oscillators of the class III can be designed with equal C and equal G.

6. Class IV oscillators

The class IV oscillator configuration is shown in Fig. 2(d) has four types and can be described by the state equations as given in Table I.

6.1.1 Class IV- type A

The NAM in this case is given by:

$$Y=\begin{bmatrix} G_1-G_2 & G_2 \\ -G_1 & 0 \end{bmatrix} \tag{22}$$

Adding a third blank row and column to the above equation and connecting a norator between columns 2 and 3 in order to move $-G_1$ from the 2, 1 position to the position 3, 1 the following NAM is obtained:

$$Y=\begin{bmatrix} G_1-G_2 & G_2 & 0 \\ 0 & 0 & 0 \\ -G_1 & 0 & 0 \end{bmatrix} \tag{23}$$

Adding a fourth blank row and column to the above equation and then adding a nullator between columns 2, 4 in order to move G_2 to from the position 1, 2 to the position 1, 4 the following NAM is obtained:

$$Y = \begin{bmatrix} G_1-G_2 & 0 & 0 & G_2 \\ 0 & 0 & 0 & 0 \\ -G_1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \tag{24}$$

Adding a norator between rows 1, 4 in order to move –G2 and G_2 to from the first row to the fourth row the following NAM is obtained:

$$Y = \begin{bmatrix} G_1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -G_1 & 0 & 0 & 0 \\ -G_2 & 0 & 0 & G_2 \end{bmatrix} \tag{25}$$

Adding a fifth blank row and column and connecting a nullator between columns 1 and 5 in order to move-G_2 from the position 4, 1 to the position 4, 5 therefore:

$$Y = \begin{bmatrix} G_1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ -G_1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & G_2 & -G_2 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{26}$$

The indefinite admittance matrix has the property that each row and each column sum to zero [24]. Connection of a norator between nodes 5 and zero will allow the row zero terms to be brought to row 5. Similarly, a connection of a nullator between nodes 3 and zero will allow the column zero to be brought to column 3 [24] as follows:

$$Y=\begin{bmatrix} G_1 & 0 & -G_1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ -G_1 & 0 & G_1 & 0 & 0 \\ 0 & 0 & 0 & G_2 & -G_2 \\ 0 & 0 & 0 & -G_2 & G_2 \end{bmatrix} \tag{27}$$

The above equation results in the class IV-type A pathological realization 1 shown in Fig. 7(a). The corresponding realization using three CCII- is shown in Fig. 7(b). It should be noted that this new oscillator circuit can also be obtained from the unity gain band-pass filter introduced in [25] by connecting the band-pass output to the input port through a voltage follower to provide isolation to band-pass output port.

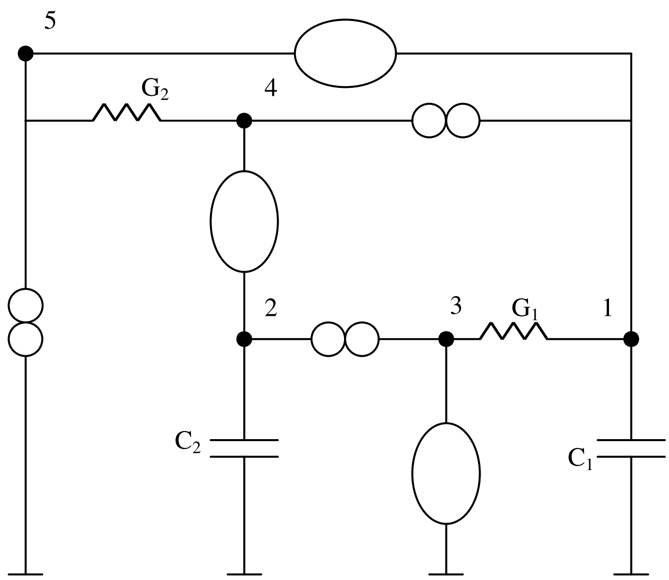

Fig. 7(a) Pathological realization 1of class IV-type A oscillator

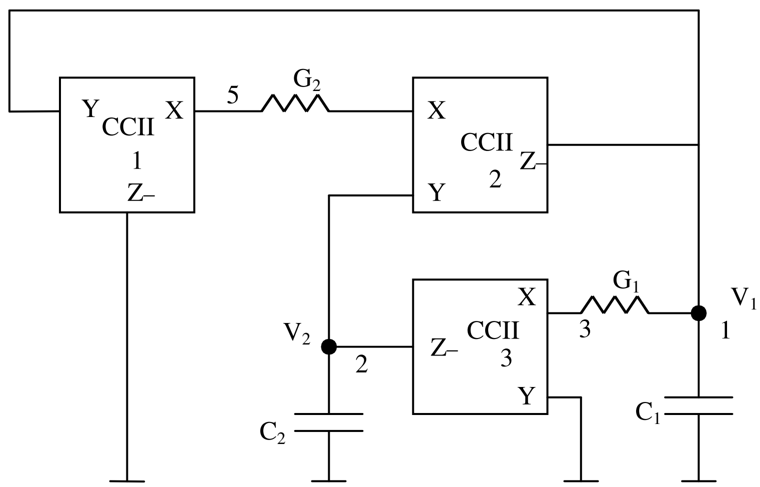

Fig. 7(b) Three CCII- realization 1of class IV-type A oscillator

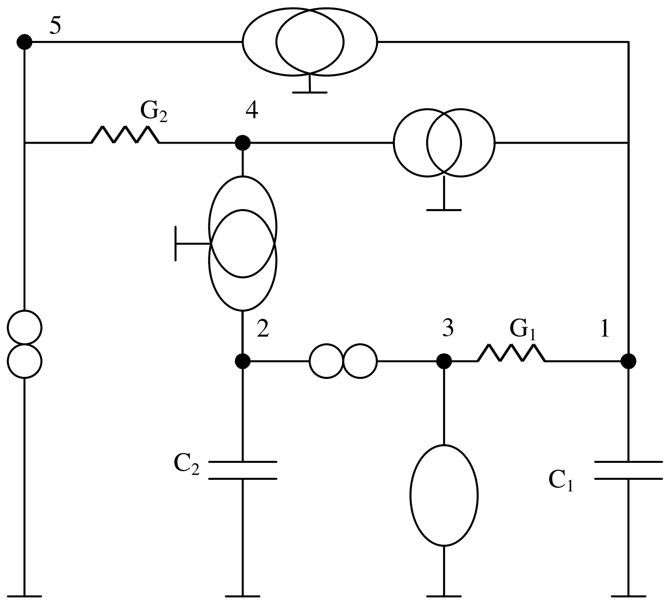

Fig. 8 (a) Pathological realization 2 of class IV-type A oscillator

Following similar steps as in the previous section a second pathological realization is obtained and is shown in Fig. 8(a) can be obtained and the corresponding conveyor circuit is shown in Fig 8(b).

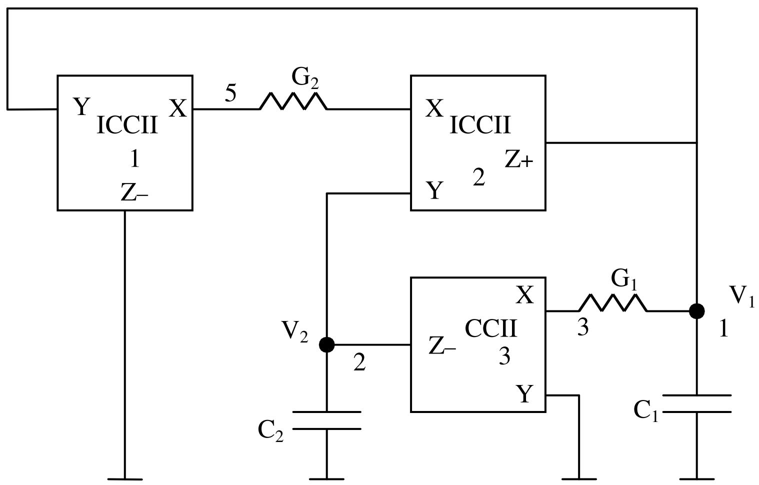

Fig. 8 (b) CCII and ICCII realization 2 of class IV-type A oscillator

6.1.2 Class IV- type B

The NAM in this case is given by:

$$Y=\begin{bmatrix} G_1\text{-}G_2 & -G_2 \\ G_1 & 0 \end{bmatrix} \tag{28}$$

By successive NAM expansion steps the above Y matrix can be expanded to the following form:

$$Y=\begin{bmatrix} G_1 & 0 & -G_1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ -G_1 & 0 & G_1 & 0 & 0 \\ 0 & 0 & 0 & G_2 & -G_2 \\ 0 & 0 & 0 & -G_2 & G_2 \end{bmatrix} \tag{29}$$

The above equation results in the class IV-type B pathological realization 1 shown in Fig. 9(a). The second pathological realization of the class IV- type B is shown in Fig. 9(b).

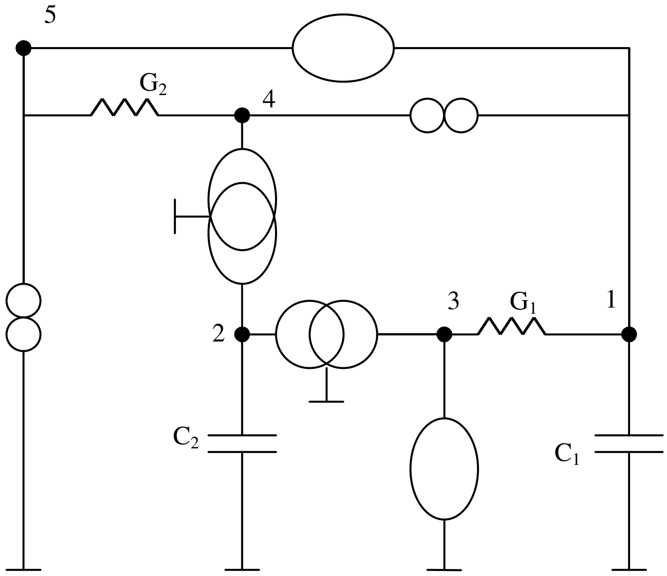

Fig. 9(a) Pathological realization 1of class IV-type B oscillator

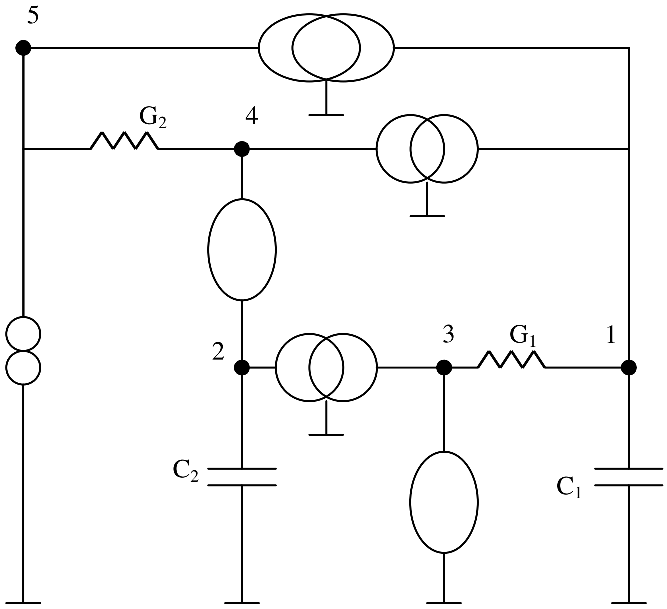

Fig. 9(b) Pathological realization 2 of class IV-type B oscillator

The realizations of class IV-types C and D can be obtained following similar steps as before.

7. Alternative topology realizations of class IV oscillators

In this section a brief discussion on a second topology realization of class IV-types A and B is given.

7.1.1. Class IV- topology II-type A

Apply NAM expansion to eqn. (22) the following Y matrix is obtained:

$$Y=\begin{bmatrix} G_1 & 0 & -G_1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ -G_1 & 0 & G_1 & 0 & 0 \\ 0 & 0 & 0 & G_2 & -G_2 \\ 0 & 0 & 0 & -G_2 & G_2 \end{bmatrix} \quad (30)$$

The above equation results in the pathological realization 1 shown in Fig. 10(a). The corresponding realization using a CCII+ and two CCII- is shown in Fig. 10(b). A second pathological realization can be derived and results in the pathological realization shown in Fig. 11.

Similarly for the class IV-type B a second topology can be derived and results in the pathological realization 1 shown in Fig. 12(a). The corresponding realization using two; CCII+ and one ICCII- is shown in Fig. 12(b). A second pathological realization can be derived and results in the pathological realization shown in Fig. 12(c).

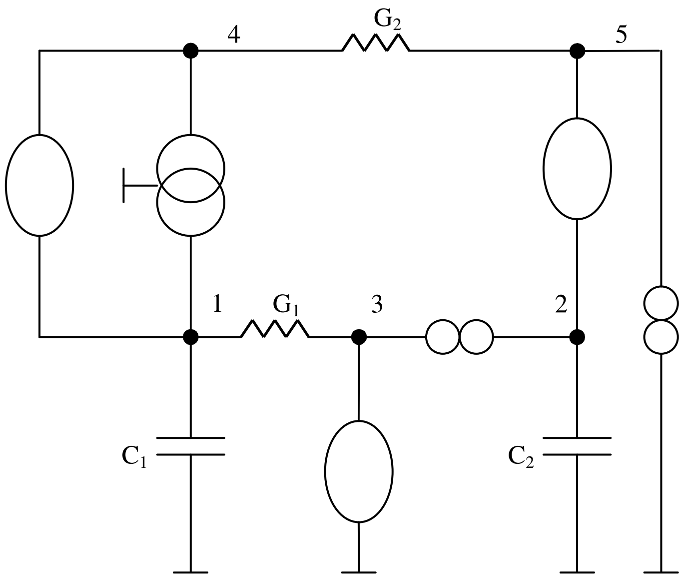

Fig. 10(a) Class IV-type A topology II pathological realization 1

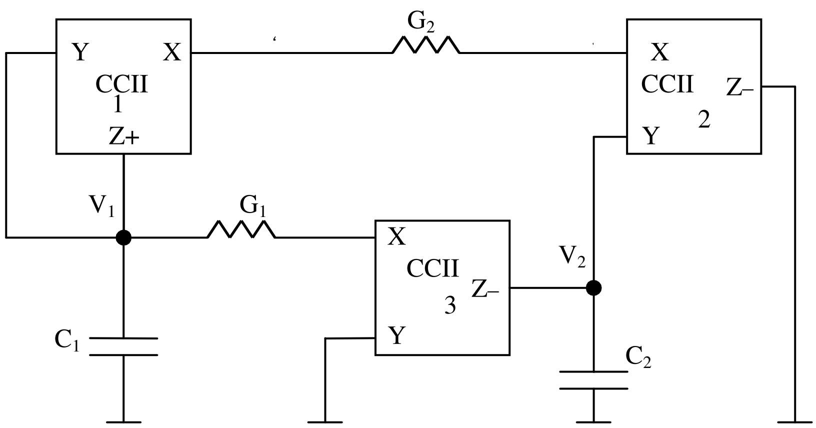

Fig. 10(b) Three CCII realization of Fig. 10(a)

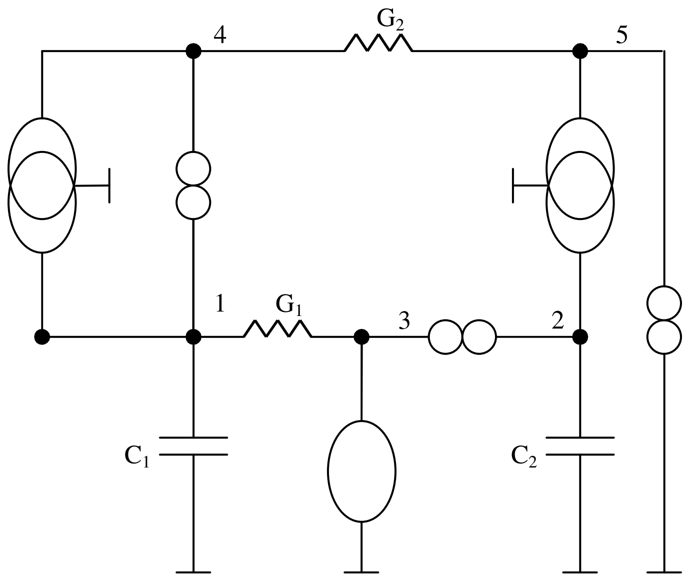

Fig. 11 Class IV-type A topology II pathological realization 2

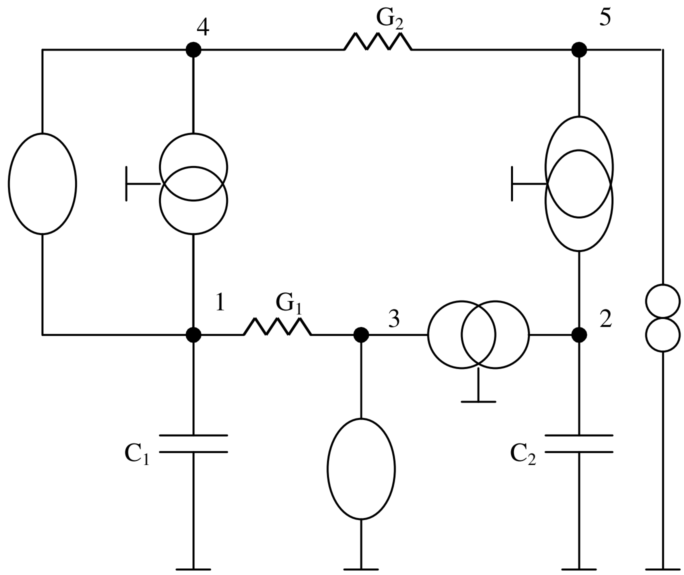

Fig. 12(a) Class IV-type B topology II pathological realization

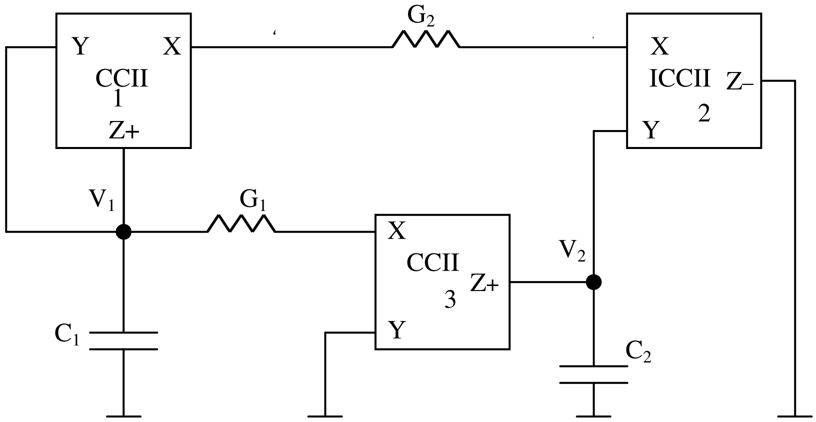

Fig. 12(b) Two CCII one ICCII realization of Fig. 12(a)

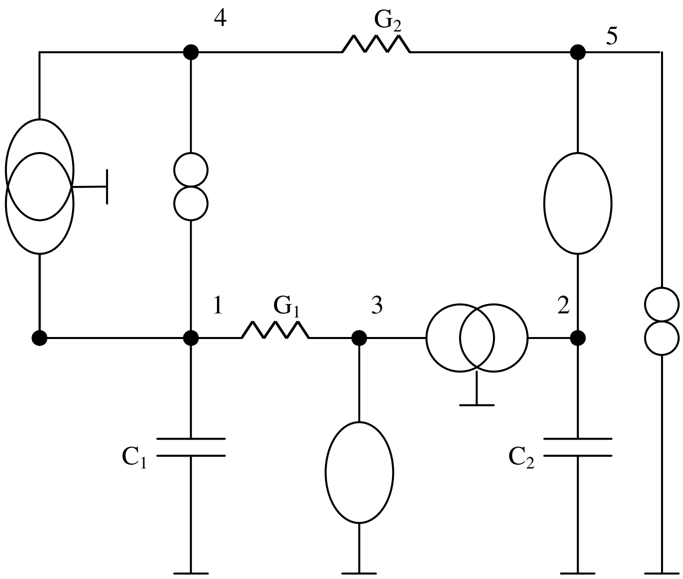

Fig. 12(c) Class IV-type B topology II pathological realization 2

8. Conclusions

Systematic generation method for realizing grounded capacitor oscillator circuits using NAM expansion is given. The oscillators considered in this chapter uses the minimum number of passive elements namely two capacitors and two resistors. All generated oscillator circuits except those of Fig. 5 have the advantage of their ability to absorb parasitic resistance and parasitic capacitance elements effects. Four classes of oscillators are generated in this chapter, the class I oscillator circuits include three nodes, the classes II and III oscillator circuits include four nodes and the class IV oscillator circuits include five nodes.

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