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On the Four Terminal Floating Nullor (FTFN) and the Operational Mirror Amplifier (OMA)

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Several realizations for the CCII− and CCII+ are reviewed. It is pointed out that introducing a polarity for the norator to model the CCII+ is not correct. It is also pointed out that introducing a polarity for the Four Terminal Floating Nullor (FTFN) in order to serve a purpose in circuit realization is also not correct. It is emphasized that both Norator as well as the FTFN have no polarity and the pathological current mirror and the Operational Mirror Amplifier (OMA) serves to correct this ambiguity.

Keywords: Operational mirror amplifier; nullor; CCII+; pathological current mirror.

1 INTRODUCTION

The Four Terminal Floating Nullor (FTFN) [1–2] also known as the operational floating amplifier (OFA) [3] is one of the basic building blocks in analog circuits [4]. It consists of a nullator as input port and a norator as output port in a two port network as shown in Fig. 1(a). The port voltage and current of the nullator are always zero, while the port voltage and current of the norator can independently take any value [2].

That is the Nullor is represented by the equations:

$$V_i = 0, \qquad I_i = 0 \tag{1-a}$$

$$V_o \text{ and } I_o \text{ arbitrary} \tag{1-b}$$

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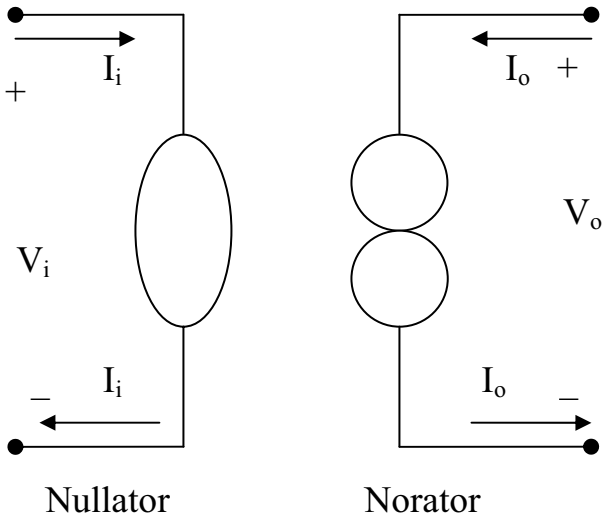
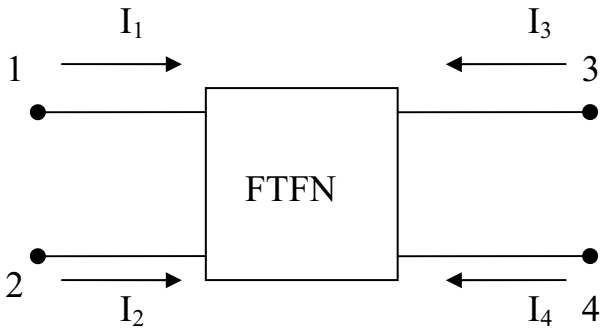


(a)



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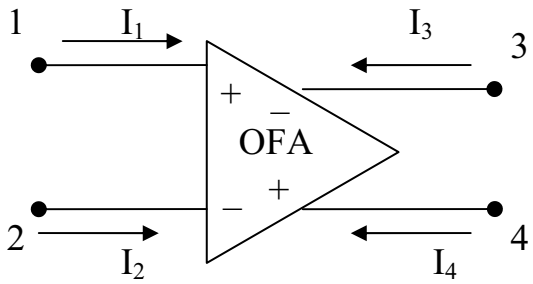

(c)

FIGURE 1
Three alternative symbolic representations of the FTFN.

The FTFN is also represented symbolically as shown in Fig. 1(b) and is also represented as an OFA as shown in Fig. 1(c) [3] and in this case the circuit equations are given by:

$$V_1 = V_2, \qquad I_1 = I_2 = 0 \tag{2-a}$$

$$I_3 = -I_4 \quad \text{and are arbitrary,} \quad V_3 - V_4 \text{ also arbitrary} \tag{2-b}$$

The FTFN has been used in the realization of filters [5–10], oscillators [11–12] and in the realization of floating impedances [13–14].

2 REALIZATION OF THE FTFN

The FTFN can be practically implemented by employing the op amp in the supply current sensing mode using two pairs of cascode current mirrors as given in Fig. 2 of [11]. Fig. 2 represents such a realization in symbolic form as given in [7–10]. Several designs of class A and class AB operational floating amplifier are given in [3]. An attractive CMOS implementation of the OFA for the MHz range is given in [15].

3 THE NULLOR AND CURRENT CONVEYOR

It is well known that the FTFN with one terminal of the norator being grounded realizes an op amp. The FTFN with a common terminal between

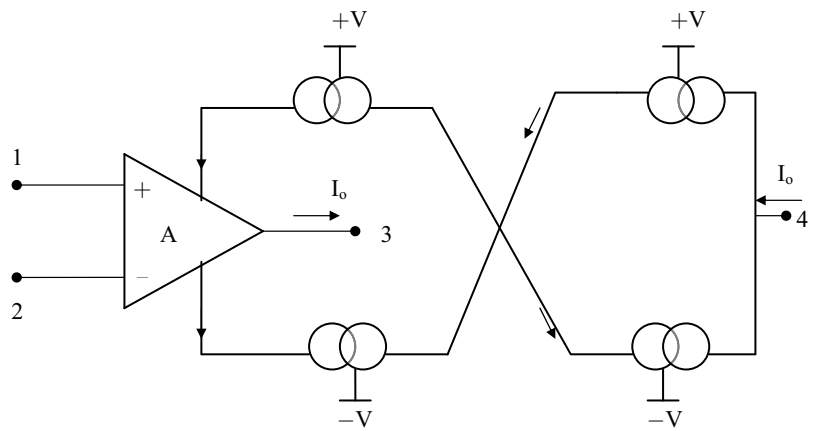

FIGURE 2
Realization of FTFN using op amp based on supply current sensing and using cross coupled mirrors [8].

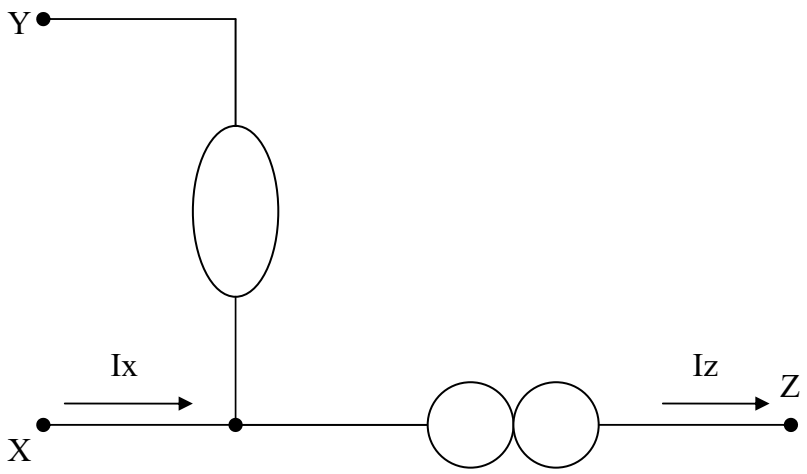

FIGURE 3
Nullor with a common terminal realizing a CCII-[16].

nullator and norator realizes a current conveyor with Z− (CCII−) as shown in Fig. 3[16]. On the other hand the realization of a CCII+ using nullators and norators only is not possible. Four alternative realizations for the CCII+ using nullators, norators and additional circuit components are given in Fig. 4. The realization shown in Fig. 4(a) uses two nullators, two norators and two equal floating resistors and was introduced in [17] and also given in [18]. The realization shown in Fig. 4(b) uses two nullators, two norators and two equal grounded resistors. The realization given in Fig. 4(c) uses one nullator, one norator and a current controlled current source of gain −1, to invert the output current at port Z. The realization given in Fig. 4(d) uses an op amp and employing two current mirrors and supply current sensing technique as given in [19–21]. It should be noted that each of the two current mirrors used employ four bipolar transistors and biased with the proper supply voltage [20]. It is worth noting that the current mirror used is not a symmetrical two port networks and is unidirectional that is there is a difference between the input and output terminals. The symbol of the current mirror (No matter how many transistors are used) includes an arrow indicating both the input terminal of the mirror and mirror polarity [21].

Comparing Figs. 3 and 4 it is seen that the CCII− realization with a single nullor is much simpler than the CCII+ realization of Fig. 4. Authors tried to represent the CCII+ in a similar way as the CCII− of Fig. 3 so a polarity was assigned to the norator [22]. Of course this is not accurate as the norator has a definite and fixed definition and it is not up to authors to change this basic definition. The norator with the positive sign given in [22] was realized correctly in [23] using a nullor, two norators and two equal grounded resistors

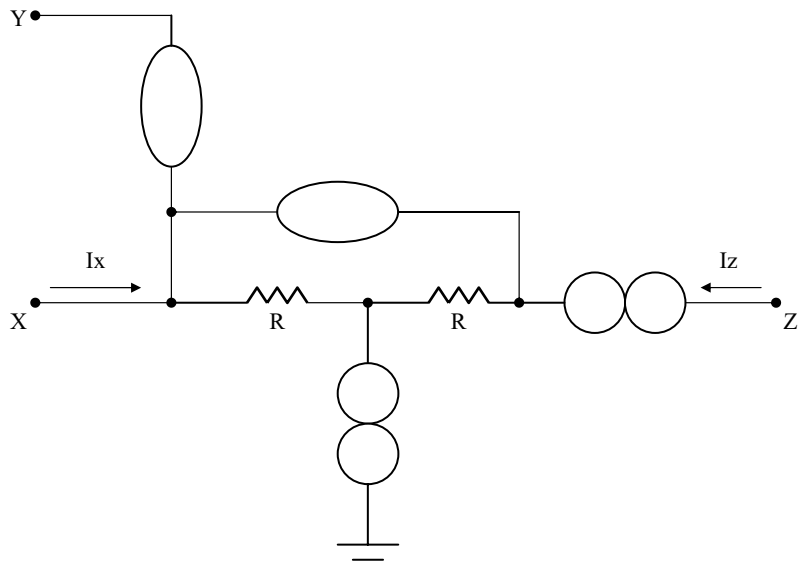

FIGURE 4(A)
Realization of a CCII+ using two nullors and two equal floating resistors [17–18].

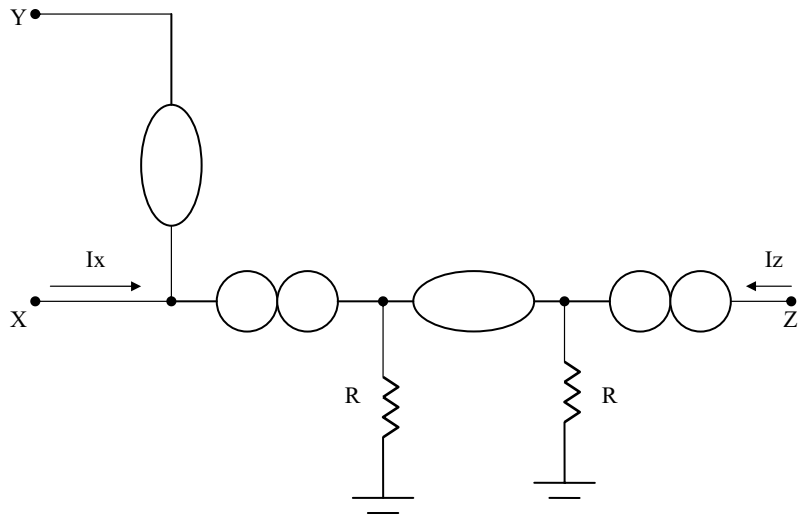

FIGURE 4(B)
Realization of a CCII+ using two nullors and two equal grounded resistors [23].

as shown in Fig. 4(b). This improper representation of the norator with a polarity [22–23] although is used as an intermediate step and the final circuit with CCII+ is obtained correctly [22–23] has been used in many papers and resulted

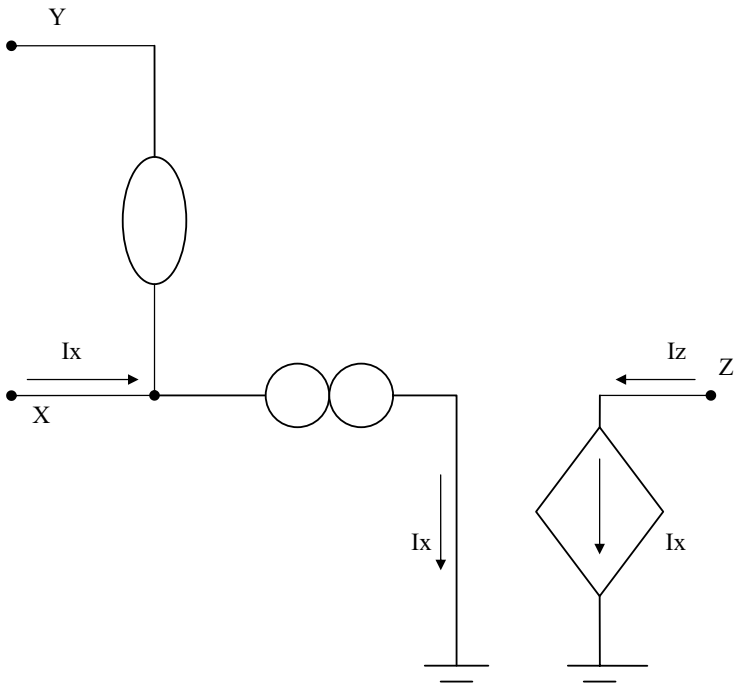

FIGURE 4(C)
Alternative realizations of CCII+ using a Nullor and a CCCS [16].

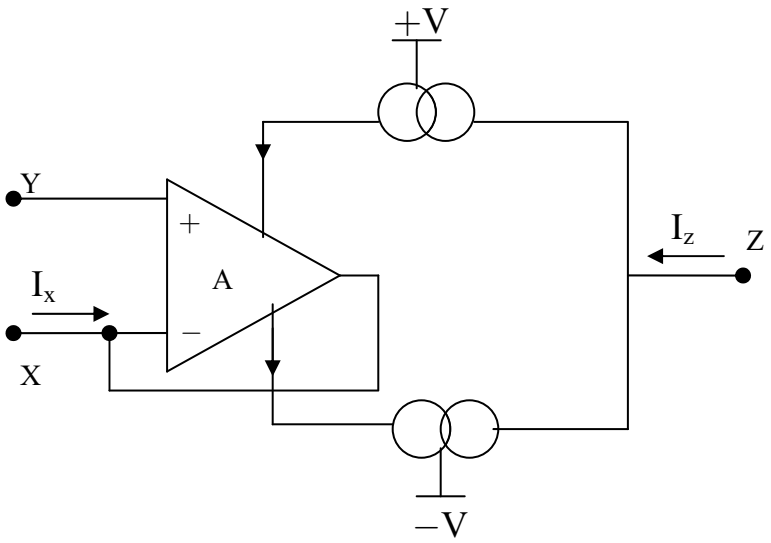

FIGURE 4(D)
CCII+ realization using op amp with supply current sensing technique [19–21].

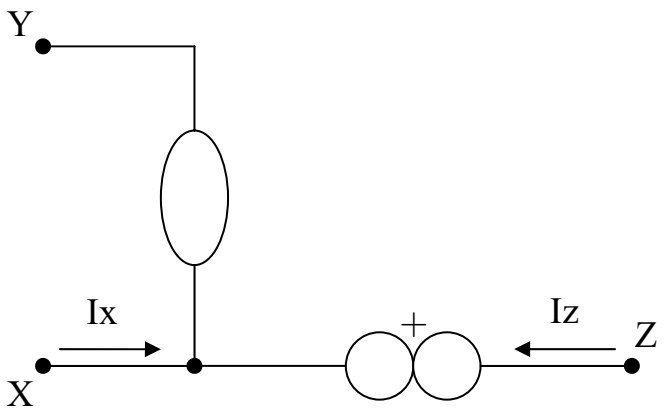

FIGURE 5
Incorrect representation of CCII+.

in introducing a polarity for the FTFN which is not correct [24–30]. The final circuits obtained with FTFN having a polarity are completely against the FTFN basic definition [1–2] which should not be violated by authors. To demonstrate further that it is not only violation for basic definitions of norator and FTFN, but also violation of the basic Kirchoff's Current Equation (KCL), consider the incorrect circuit of the CCII+ shown in Fig. 5.The input currents to the circuit are $I_x + I_z = 2I_x$ and no output current as norator is a two terminal element. The same concept applies to the improper circuit of FTFN using a norator with a positive sign.

Although the supply current sensing of the Operational Mirror amplifier (OMA) using an op amp and two current mirrors shown in Fig. 6 is known since long time [31] it has only been used by few authors to realize filters [32].

4 THE PATHOLOGICAL MIRROR ELEMENT AND CCII+

It seems that authors tried for a long time to find a pathological element to use with the nullator to represent the CCII+. This problem was solved by the introduction of the pathological current mirror [33–35] and is defined next.

The current mirror (CM), shown in Fig. 7(a), is a two-port network element used to represent an ideal current reversing action and it is described by

$$V_1 \text{ and } V_2 \text{ are arbitrary} \tag{3-a}$$

$$I_1 = I_2, \text{ and they are also arbitrary} \tag{3-b}$$

Although the current mirror element shown in Fig. 7(a) has the same symbol as the regular current mirror, it is a bi-directional element and has a theoretical existence. It is worth noting that the current mirror symbol shown in

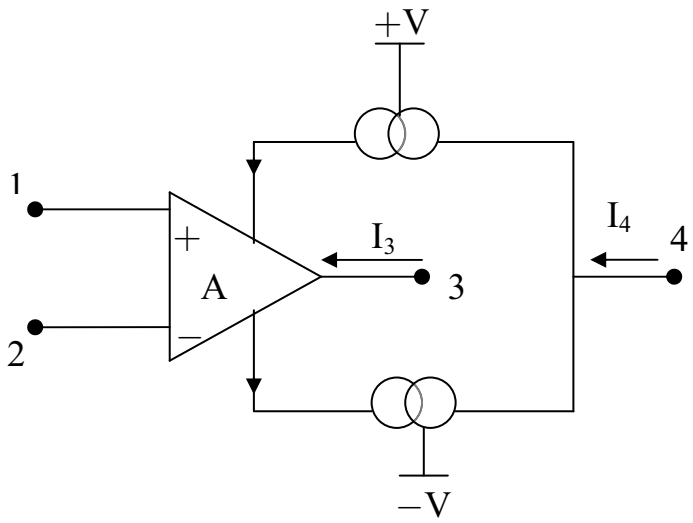

FIGURE 6
Operational Mirror Amplifier realization using supply current sensing.

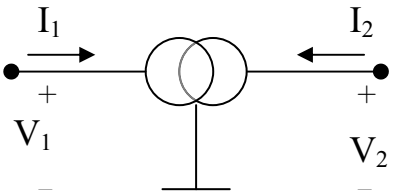

FIGURE 7(A)
Pathological current mirror [33–35].

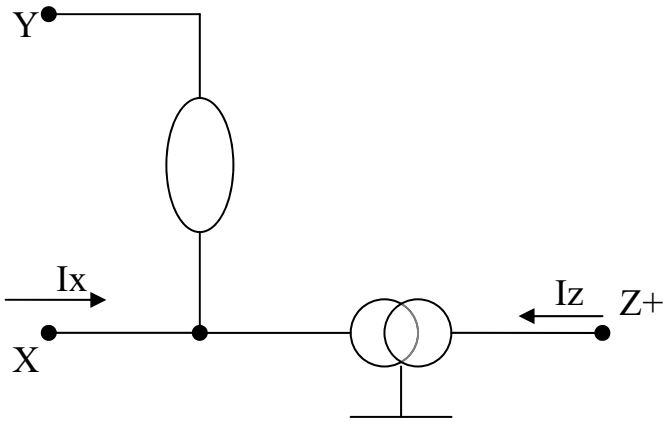

FIGURE 7(B)
Nullator and Pathological CM with a common terminal realizing a CCII+ [33–35].

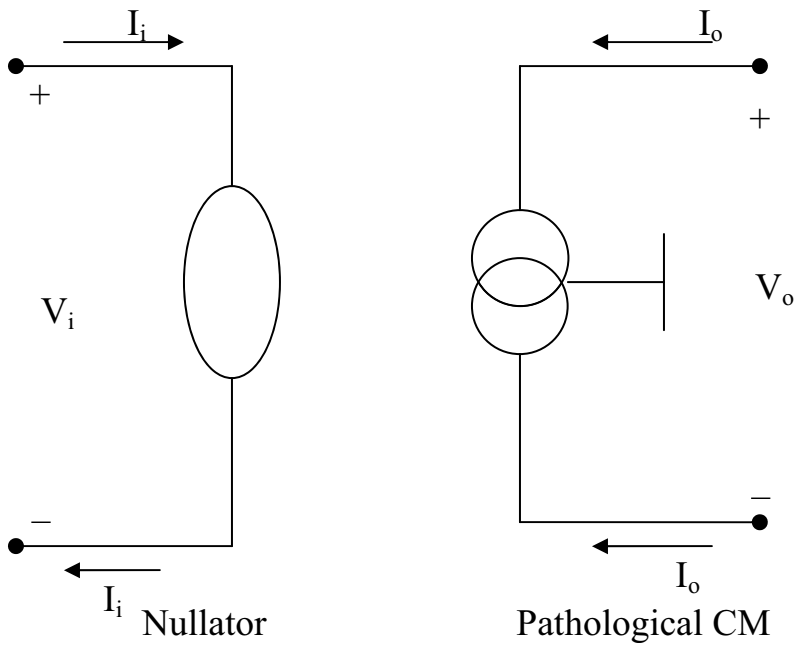

FIGURE 7(C)
Nullator and Pathological CM Element realizing OMA [35].

Fig. 7(a) has a reference node, which is set to ground in most applications. Fig. 7(b) represents the pathological element representation of the CCII+ [33–35]. Fig. 7(c) represents the pathological element representation of the Operational Mirror amplifier (OMA) [33–35].

5 CONCLUSIONS

The CCII+ should be modeled correctly by a nullator and the pathological current mirror as shown in Fig. 7(a). Similarly the incorrect use of the FTFN with polarity defined as FTFN+ or PFTFN (Positive FTFN) should be stopped and authors should use the correct term namely Operational Mirrored Amplifier (OMA) which is represented by pathological elements as shown in Fig. 7(c).

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