Analog Integrated Circuits and Signal Processing, 32, 79–81, 2002

On the Voltage Mirrors and the Current Mirrors

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Abstract. The voltage mirror and the current mirror are two pathological elements used to represent active devices featuring voltage or current reversing properties. The properties of these ideal elements are presented and it is demonstrated that they form a complete set analogous to that formed by the nullator and the norator.

Key Words: mirror elements, singular elements

Introduction

The nullor elements have been found useful in solving circuit analysis and design problems [1–2]. The nullor set shown in Fig. 1 includes the nullator defined by: $V = I = 0$ and the norator defined by: V and I are arbitrary. The attractive feature of the two nullor elements is their ability to model active circuits independently of the particular realization of the active devices with the possibility of generating a number of equivalent idealized circuits from which the best practical ones can thereafter be selected [2–3]. Despite the ability of nullators and norators to represent many active building blocks, they fail to represent the positive type second-generation current conveyor (CCII+) proposed in [4]. Other elements like resistors are combined with the nullators and norators in order to obtain the nullor representation of the CCII+ [5]. In order to avoid the use of the resistors in the nullor representation of any building block, two elements are defined and given names: the current mirror and the voltage mirror [6]. These elements are basically used to represent active devices with current or voltage reversing properties.

This letter demonstrates that the two mirror elements form a complete set and can be used to represent the two nullor elements. On the other hand, other elements need to be combined with the nullor elements in order to replace the mirror elements.

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The Mirror Elements Definition

The voltage mirror, shown in Fig. 2(a), is a lossless two-port network element used to represent an ideal voltage reversing action and it is described by:

$$V_1 = -V_2 \tag{1a}$$

$$I_1 = I_2 = 0 \tag{1b}$$

The current mode version of the voltage mirror is the current mirror shown in Fig. 2(b), which is used to represent a current reversing action and it is described by:

$$\begin{aligned} &V_1 \text{ and } V_2 \text{ are arbitrary} \\ &I_1 = I_2, \text{ and they are also arbitrary} \end{aligned} \tag{2}$$

Although the current mirror element, shown in Fig. 2(b) has the same symbol as that defined by Wilson in [7], it is a bi-directional element and has a theoretical existence.

It is worth noting that each of the voltage mirror and the current mirror symbols shown in Fig. 2 has a reference node, which is set to ground and although these elements are two-port network elements, they are used as two terminal elements with the reference node unused.

The Mirror Elements Properties

Generally, the voltage mirror (or the nullator) is combined with the current mirror (or the norator) in order to represent active devices. The main advantage of defining the mirror elements is to extend the nullor-based

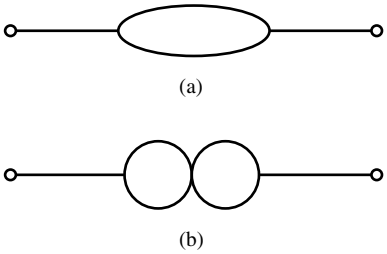

Fig. 1. The symbolic representations of (a) the nullator (b) the norator.

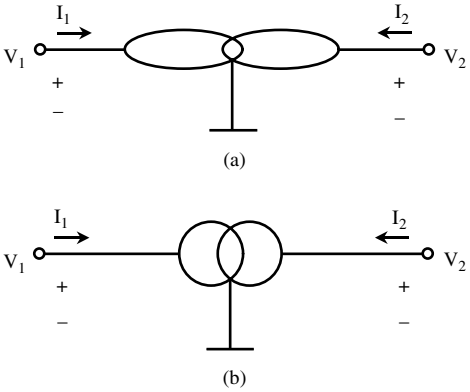

Fig. 2. The symbolic representations of (a) the voltage mirror (b) the current mirror.

generation methods and voltage-mode to current-mode transformation methods to include circuits consisting of active devices that are represented using the mirror elements. For example, the mirror elements were used to define the adjoint building block of the CCII+ as the negative type inverting current conveyor (ICCII–) [6]. This result is achieved by obtaining the ideal representation of the CCII+ as a combined nullator and current mirror, then the adjoint representation consists of a combined voltage mirror and norator, which is the ideal representation of the ICCII–.

Moreover, the nullator can be represented by cascading two (or an even number) of voltage mirrors as shown in Fig. 3(a). Similarly, Fig. 3(b) shows the norator representation using two cascaded current mirrors. On the other hand, other elements like resistors must be combined with the nullator and the norator in order to realize the voltage mirror and the current mirror as shown in Fig. 4. Hence, The voltage mirror and the current mirror form a complete set similar to that formed by the nullator-norator.

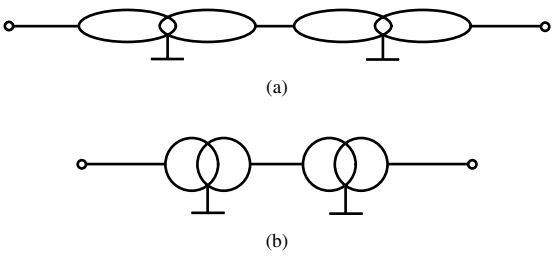

Fig. 3. (a) Nullator representation using the voltage mirror. (b) Norator representation using the current mirror.

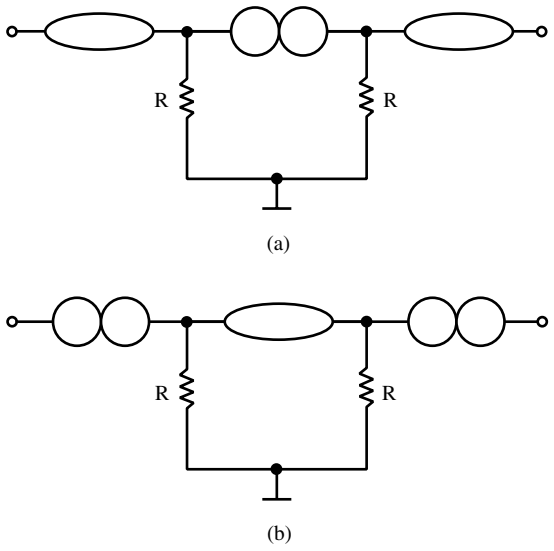

Fig. 4. Nullor based (a) voltage mirror representation (b) current mirror representation.

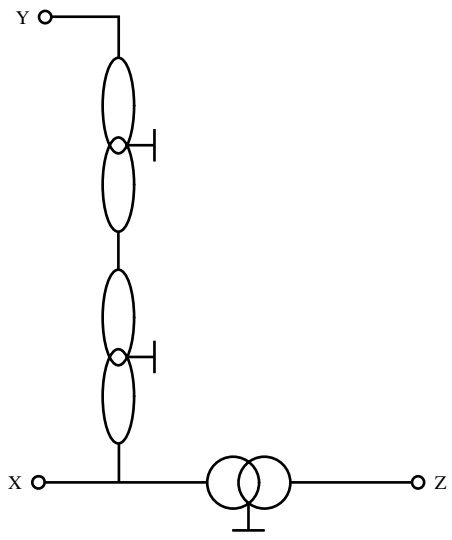

Fig. 5. The CCII+ mirror representation.

Applications

To illustrate the importance of the mirror elements, two examples are considered that could not be realized using nullators and norators. The first example is the CCII+, which is shown in Fig. 5. The voltage

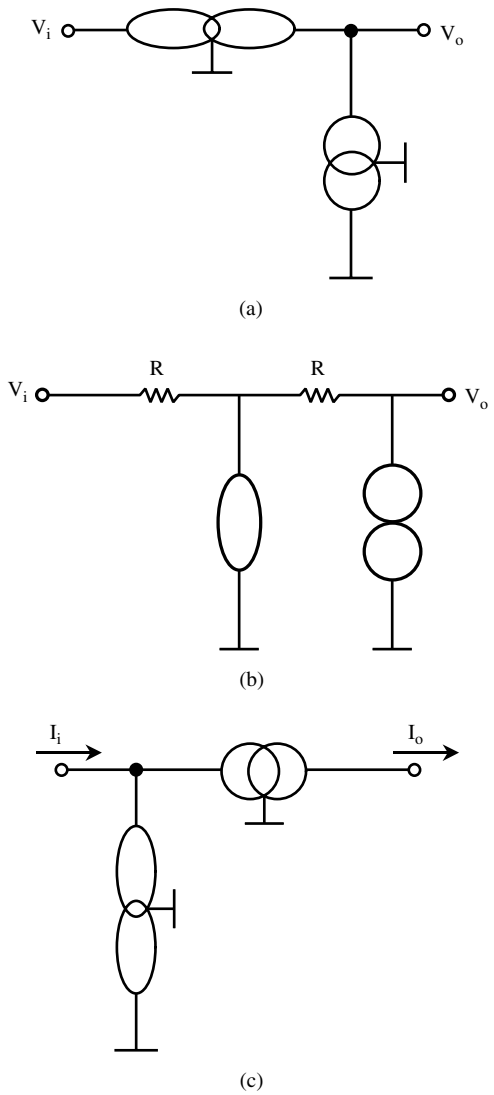

Fig. 6. (a) The voltage inverter mirror representation. (b) Nullor-based voltage inverter representation. (c) The current inverter mirror representation.

following property between the CCII+ X and Y terminals is represented using two cascaded voltage mirrors while the current reversing property between the X and Z terminals is represented using a current mirror. The second example is the realization of a voltage controlled voltage source (VCVS) with gain equal to -1 (voltage inverter) using a voltage mirror and a current mirror as shown in Fig. 6(a). This voltage inverter could not be realized using the nullor elements without the use of external resistors as shown in Fig. 6(b). In order to obtain the adjoint realization of the voltage inverter, each element in Fig. 6(a) is replaced by its adjoint element then the input and output terminals are exchanged. The resulting adjoint realization is shown in Fig. 6(c) and it represents an inverting current controlled current source (CCCS) with gain equal to -1 (current inverter).

Conclusion

The mirror elements set consisting of the voltage mirror and the current mirror is a complete set and can be used to represent the nullor elements. Examples of the realization of the CCII+ and the voltage inverter demonstrate that the mirror elements set is more powerful than the nullator and the norator set.

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