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Symbolic analysis of active device containing differencing voltage or current characteristics

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ABSTRACT

The behavioral modeling of active devices using pathological nullor–mirror elements has shown advantages comparing with their representations using nullor elements only. In order to model the terminal characteristic of active devices containing current or voltage differencing properties, the pathological representations of current and voltage differencing cells are presented. Each proposed model includes the non-ideal effects of input and output parasitics and transfer characteristics. They are used to model some active devices with the consideration of their non-ideal effects. Symbolic nodal analyses (NA) using the non-ideal models of active devices are given to demonstrate the usefulness of the proposed models.

1. Introduction

Symbolic analysis is to calculate the behavior or characteristics of a circuit in terms of symbolic variables. It is a powerful tool for the analysis of electronic circuits to gain insight into the behavior of circuits. Compared with the nodal admittance matrix formulation using the limit-variables method that a limit to infinity is always required to simplify the symbolic expressions [1–3], the symbolic nodal analyses (NA) using pathological element-based models shows the advantage of easier operational procedure [4–6]. The pathological nullor–mirror elements are used to enhance the efficiency of symbolic NA since the nullor–mirror equivalent representation of a circuit may have lower complexity compared with its nullor equivalence. In the recent time, many pathological representations of active devices had been reported in the literature [5,7–14]. Some reported models only consider the ideal behaviors of active devices [7–11,13,14]; others consider the practical behaviors with only partial non-ideal effects of active devices [5,12]. Namely, the non-idealities of gain effects and the parasitics of active devices are not all been included in the reported models. The more complete nullor equivalents of the pathological voltage mirror (VM), current mirror (CM) and multiple-output current mirror was proposed in [15]. The proposed models include the effects of non-ideal gain and parasitics of each terminal and they are applied to symbolic NA of nullor networks successfully.

It is known that many popular active devices are featured by their differencing current or voltage properties to achieve the improved immunity to noise, such as the current differencing buffered amplifiers (CDBA) also known as the differential current voltage conveyor (DCVC) [8], the differential voltage current conveyor (DVCC) [16] and the differential difference current conveyor (DDCC) [17]. To model these active devices for symbolic NA, the nullor–mirror representations of the current and voltage differencing cells with non-ideal effects are proposed in this article. The nullor–mirror representations possess the reduced circuit complexity compared to their nullor alternatives [18]. Each of the proposed representations of the differencing cells includes the non-idealities of input and output parasitics and transfer characteristics. They are used to construct the non-ideal models of several active devices for illustration. Symbolic NA examples containing the presented active device models are given to demonstrate the usefulness of the proposed models.

2. Nullor–mirror representations of differencing current and voltage cells

The symbolic representations of pathological elements VM and CM [7] are used to represent an ideal voltage reversing property and an ideal current reversing property, respectively, as shown in Fig. 1. The mirror elements are conductive to modeling active

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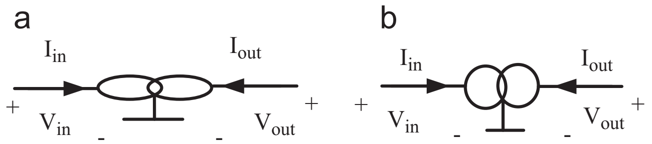

Fig. 1. The symbolic representations of the mirror elements [7]. (a) VM and (b) CM.

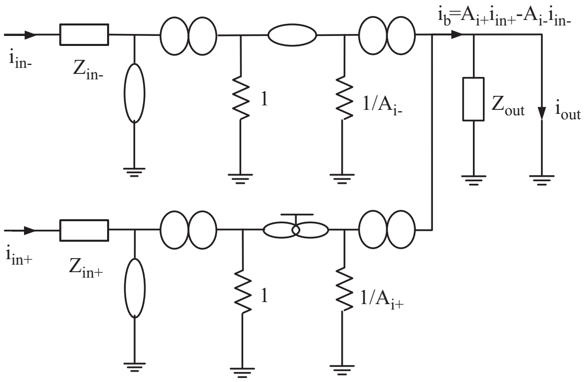

Fig. 2. Nullor–mirror equivalent of the non-ideal current differencing cell.

devices in concise form [18] and achieving efficient symbolic NA [5,6], so they are used for building the proposed models. The operation of the non-ideal current differencing cell, for example, is described by the following expression:

$$i_b = A_{i+} i_{in+} - A_{i-} i_{in-} \tag{1}$$

The nullor–mirror equivalent of the non-ideal current differencing cell is shown in Fig. 2. In this representation, Z_{in+} and Z_{in-} are connected in series to the currents i_{in+} and i_{in-}, respectively, and they model the input parasitics of the positive and negative current inputs of the current differencing cell. The Z_{out} is connected in parallel to the output current i_{out} and it models the output parasitic of the current differencing cell. In Fig. 2, the resistors of value $1/A_{i+}$ and $1/A_{i-}$ are useful in the NA formulation because its corresponding admittances becomes A_{i+} and A_{i-} and they model the current gains or the current tracking errors of the positive and negative current outputs of the current differencing cell, respectively.

From Fig. 2, it can be observed that $Z_{in+}=0$, $Z_{in-}=0$, $Z_{out}=\infty$ and $A_{i+}=A_{i-}=$unity in the ideal case. For the representation in Fig. 2, it can be found that the flow direction of current will be changed if we replace any norator with a CM and vice versa, or any ungrounded nullator with a VM and vice versa. Thus the representation can be modified slightly with the same characteristic.

The operation of the non-ideal voltage differencing cell, for example, can be described by the following expression:

$$V_{out} = A_{v+} V_{in+} - A_{v-} v_{in-} \tag{2}$$

The proposed nullor–mirror representation of the non-ideal voltage differencing cell is shown in Fig. 3. In this description, Z_{in+} and Z_{in-} are connected in parallel to the input-ports V_{in+} and V_{in-}, respectively, and they are used to model the input parasitics. The Z_{out} is connected in series to the output-port and it models the output parasitic of the voltage differencing cell. In Fig. 3, the resistor of value $1/A_{v+}$ and $1/A_{v-}$ are useful in the NA formulation to model the voltage gains or the voltage tracking error of the positive and negative current outputs of the voltage differencing cell, respectively. From Fig. 3, it can be observed that $Z_{in+}=\infty$, $Z_{in-}=\infty$, $Z_{out}=0$ and $A_{v+}=A_{v-}=$unity in the ideal case. For the representation in Fig. 3, it can be found that the different voltage polarities are due to the properties of a nullator and a voltage mirror. The representation with the same property can also be obtained by appropriately replacing the norator by a current mirror.

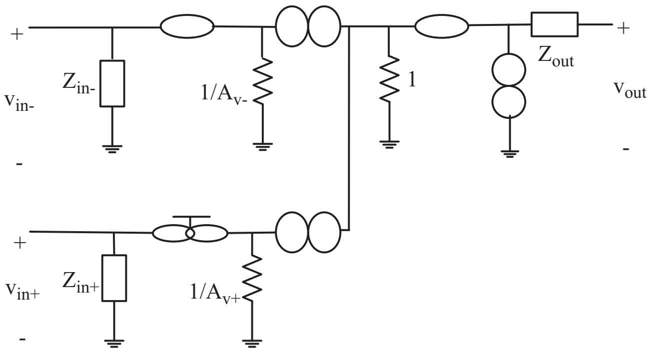

Fig. 3. Nullor–mirror equivalent of the non-ideal voltage differencing cell.

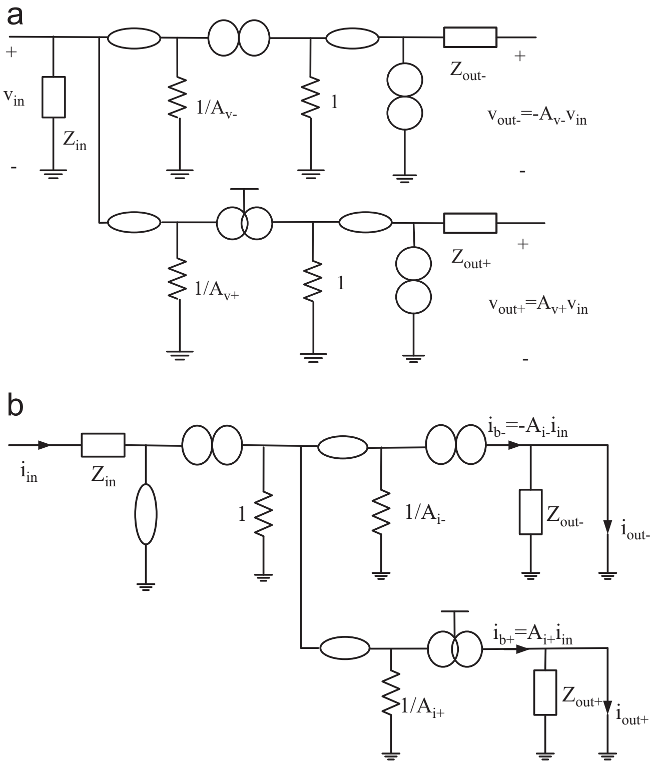

Fig. 4. (a) Pathological equivalent of the non-ideal balance-output voltage mirror cell and (b) Pathological equivalent of the non-ideal balance-output current mirror cell.

From Figs. 2 and 3, by applying the adjoint network theorem [19,20], it can be found that the pathological current differencing cell and the voltage differencing cell are the adjoint networks of the pathological balance-output voltage mirror cell and balance-output current mirror cell respectively, as shown in Fig. 4. It must be noted that the configuration in Fig. 4(a) is called as balance-output voltage mirror cell since in the ideal case ($A_{v-}=A_{v+}=1$) the input voltage is conveyed to the output ports with the plus and the minus sign. Furthermore, it can be observed that the nullor–mirror models in Figs. 2 and 3 can be easily extended to model more inputs by adding additional similar branches. One example will be given in Section 3. Besides, it is noted that we prevent the use of negative