Dependent Sources[*]

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Abstract

Dependent sources.

A **dependent source** is either a voltage or current source whose value is proportional to some other voltage or current in the circuit. Thus, there are four different kinds of dependent sources; to describe an op-amp, we need a voltage-dependent voltage source. However, the standard circuit-theoretical model for a transistor[1] contains a current-dependent current source. Dependent sources do not serve as inputs to a circuit like independent sources. They are used to model **active circuits**: those containing electronic elements. The RLC circuits we have been considering so far are known as **passive circuits**.
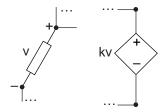
dependent sources

Figure 1: Of the four possible dependent sources, depicted is a voltage-dependent voltage source in the context of a generic circuit.

Figure 2 (op-amp) shows the circuit symbol for the op-amp and its equivalent circuit in terms of a voltage-dependent voltage source.
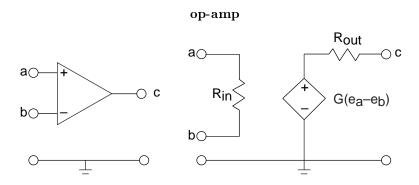
op-amp

Figure 2: The op-amp has four terminals to which connections can be made. Inputs attach to nodes **a** and **b**, and the output is node **c**. As the circuit model on the right shows, the op-amp serves as an amplifier for the difference of the input node voltages.

Here, the output voltage equals an amplified version of the difference of node voltages appearing across its inputs. The dependent source model portrays how the op-amp works quite well. As in most active circuit schematics, the power supply is not shown, but must be present for the circuit model to be accurate. Most operational amplifiers require both positive and negative supply voltages for proper operation.

Because dependent sources cannot be described as impedances, and because the dependent variable cannot "disappear" when you apply parallel/series combining rules, circuit simplifications such as current and voltage divider should not be applied in most cases. Analysis of circuits containing dependent sources essentially requires use of formal methods, like the node method[2]. Using the node method for such circuits is not difficult, with node voltages defined across the source treated as if they were known (as with independent sources). Consider the circuit shown on the top in Figure 3 (feedback op-amp).

[2]"Formal Circuit Methods: Node Method" <http://cnx.org/content/m0032/latest/>
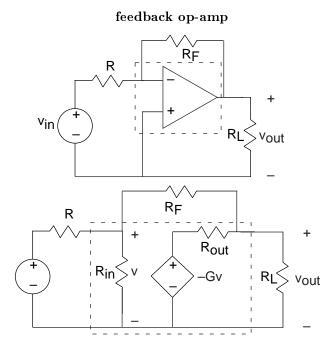
feedback op-amp

Figure 3: The top circuit depicts an op-amp in a feedback amplifier configuration. On the bottom is the equivalent circuit, and integrates the op-amp circuit model into the circuit.

Note that the op-amp is placed in the circuit "upside-down," with its inverting input at the top and serving as the only input. As we explore op-amps in more detail in the next section, this configuration will appear again and again and its usefulness demonstrated. To determine how the output voltage is related to the input voltage, we apply the node method. Only two node voltages— v and v_{out}—need be defined; the remaining nodes are across sources or serve as the reference. The node equations are

$$\frac{v - v_{\text{in}}}{R} + \frac{v}{R_{\text{in}}} + \frac{v - v_{\text{out}}}{R_F} = 0 \tag{1}$$

$$\frac{v_{\text{out}} - (-G)\, v}{R_{\text{out}}} + \frac{v_{\text{out}} - v}{R_F} + \frac{v_{\text{out}}}{R_L} = 0 \tag{2}$$

Note that no special considerations were used in applying the node method to this dependent-source circuit. Solving these to learn how v_{out} relates to v_{in} yields

$$\left(\frac{R_F R_{\text{out}}}{R_{\text{out}} - G R_F} \left(\frac{1}{R_{\text{out}}} + \frac{1}{R_{\text{in}}} + \frac{1}{R_L} \right) \left(\frac{1}{R} + \frac{1}{R_{\text{in}}} + \frac{1}{R_F} \right) - \frac{1}{R_F} \right) v_{\text{out}} = \frac{1}{R} v_{\text{in}} \tag{3}$$

This expression represents the general input-output relation for this circuit, known as the **standard feedback configuration**. Once we learn more about op-amps[3], in particular what its typical element values are, the expression will simplify greatly. Do note that the units check, and that the parameter G of the dependent source is a dimensionless gain.

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[3]"Operational Amplifiers" <http://cnx.org/content/m0036/latest/>