Circuit with Dependent Sources

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1 Introduction

We know *Independent* sources (voltage or current) are those sources whose characteristic remains same no matter in which circuit has it been connected. In a circuit there may exist *dependent* voltage or current sources or both.The magnitude or strength of such sources depends on voltage or current of some other branches. Figure 1 shows the symbol of a dependent voltage source and a dependent current source. For the voltage source shown, magnitude of the voltage across the terminals AB is $5 \times i_1$ where i_1 is the current in some branch. Similarly for the current source. In a transistor operating in active region, collector current I_c depends on base current I_b and in the collector circuit we can think a current source is present of value βI_b. In mutually coupled coils, current i_1 of coil-1 causes a voltage source to be present in coil-2 and magnitude of the voltage is $M\frac{di_1}{dt}$.

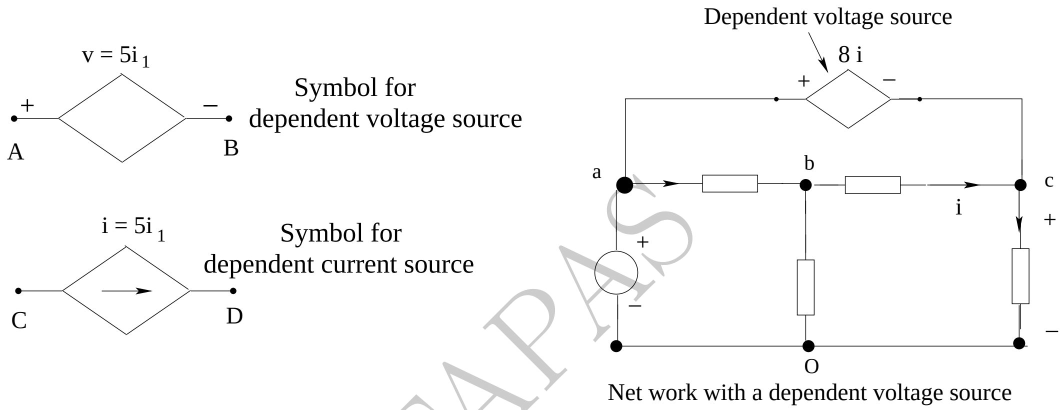


Figure 1: Symbols for dependent source

In this note, we shall analyze circuit having both independent and dependent sources. Since KVL and KCL must be satisfied, so any known method can be used to analyze such circuits. You should however be careful to calculate V_{th} and R_{th} of such circuit. Go through the following solved example to understand how to handle such circuit.

2 Example

Consider the network shown in figure 2. We have to calculate the current i_2 flowing through the $2\,\Omega$ resistance.

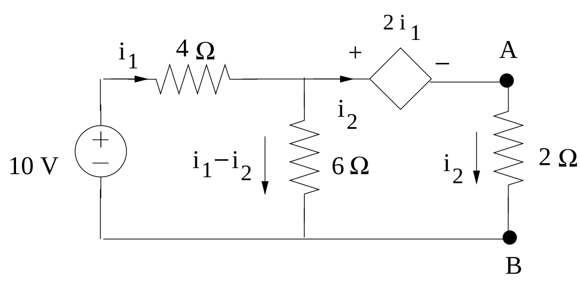
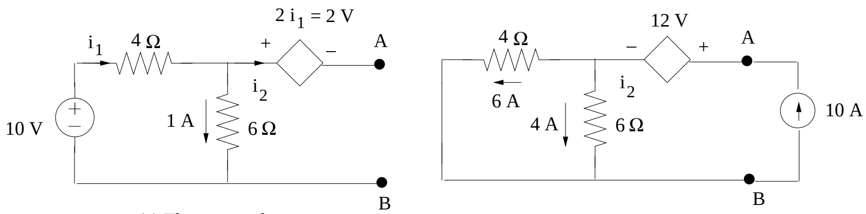


Figure 2:

$$
\begin{aligned}
\text{KVL in left hand mesh: } 4i_1 + 6(i_1 - i_2) &= 10 \\
\text{or,} 10i_1 - 6i_2 &= 10
\end{aligned}
$$

$$\begin{aligned}
\text{KVL in the over all outer loop: } 4i_1 + 2i_1 + 2i_2) &= 10 \\
\text{or,} 6i_1 + 2i_2 &= 10 \\
\text{solving we get, } i_2 &= \frac{5}{7}\,\text{A}
\end{aligned}$$

Suppose we want to get i_2 by applying Thevenin theorem. To calculate Thevenin voltage we have to remove $2\,\Omega$ and calculate open circuit voltage across A and B i.e., $V_{th} = V_{AB}|_{O.C}$ Refer to figure 3(a) to calculate V_{th}. As can be seen $V_{th} = 6 \times 1 - 2 = 4$ V.



(a) Thevenin voltage (b) Calculating Thevenin resistance

Figure 3:

To calculate the Thevenin resistance across A & B one has to follow the following steps.

1. Deactivate the independent sources as usual i.e, short circuit the independent voltage sources and open circuit the independent current sources.

2. Keep all the dependent sources in the circuit.

3. Excite the circuit from terminals A & B with a known external voltage source V and solve the circuit to calculate the current drawn I from from V. Ratio of V and I gives R_{th}.

4. Alternatively you can excite the circuit by a known current source I from A & B and solve the circuit to calculate V_{AB}. The ratio of V_{AB} and I will also give R_{th}.

For the present problem we excited the circuit with a 10 A current source from terminals AB and replaced the independent source 10 V by short circuit without disturbing the dependent voltage source $2i_1$ as shown in figure 3(b). Current in the $6\,\Omega$ resistor is $10 \times \frac{6}{(4+6)} = 6$ A. So $V_{AB} = 4 \times 6 + 12 = 36$ V. Therefore, $R_{th} = 36/10 = 3.6\,\Omega$. We already know $V_{th} = 4V$. Current through the $2\,\Omega$ resistance in the original circuit is $i_2 = 4/(3.6 + 2) = 5/7$ A. The result obtained is same as obtained earlier by KVL method.