## LTspice example: Thevenin Circuit Calculation and Simulation

We will look at how to use LTspice to help confirm manual calculations of circuit analysis. Here, we make use of the circuit shown on page 114 of textbook, Figure 4.45, to find the equivalent Thevenin circuit. The following information is copied from the textbook:

### Finding a Thévenin Equivalent

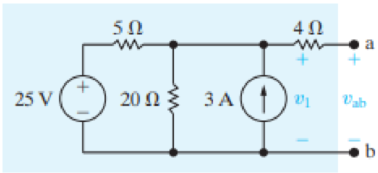



Figure 4.45 ▲ A circuit used to illustrate a Thévenin equivalent.

To find the Thévenin equivalent of the circuit shown in Fig. 4.45, we first calculate the open-circuit voltage of $v_{ab}$. Note that when the terminals a,b are open, there is no current in the 4 Ω resistor. Therefore the open-circuit voltage $v_{ab}$ is identical to the voltage across the 3 A current source, labeled $v_1$. We find the voltage by solving a single node-voltage equation. Choosing the lower node as the reference node, we get

$$\frac{v_1 - 25}{5} + \frac{v_1}{20} - 3 = 0. \tag{4.57}$$

Solving for $v_1$ yields

$$v_1 = 32 \text{ V}. \tag{4.58}$$

Hence the Thévenin voltage for the circuit is 32 V.

The next step is to place a short circuit across the terminals and calculate the resulting short-circuit current. Figure 4.46 shows the circuit with the short in place. Note that the short-circuit current is in the direction of the open-circuit voltage drop across the terminals a,b. If the short-circuit current is in the direction of the open-circuit voltage rise across the terminals, a minus sign must be inserted in Eq. 4.56.

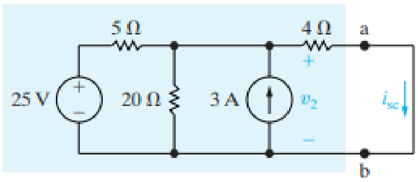



Figure 4.46 ▲ The circuit shown in Fig. 4.45 with terminals a and b short-circuited.

The short-circuit current ($i_{sc}$) is found easily once $v_2$ is known. Therefore the problem reduces to finding $v_2$ with the short in place. Again, if we use the lower node as the reference node, the equation for $v_2$ becomes

$$\frac{v_2 - 25}{5} + \frac{v_2}{20} - 3 + \frac{v_2}{4} = 0. \tag{4.59}$$

the same as the open-circuit voltage at the terminals a,b in the original circuit. Therefore, to calculate the Thévenin voltage $V_{Th}$, we simply calculate the open-circuit voltage in the original circuit.

Reducing the load resistance to zero gives us a short-circuit condition. If we place a short circuit across the terminals a,b of the Thévenin equivalent circuit, the short-circuit current directed from a to b is

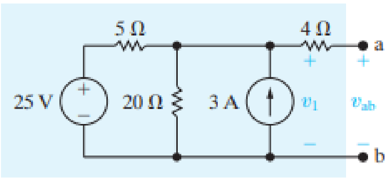
$$i_{sc} = \frac{V_{Th}}{R_{Th}}. \tag{4.55}$$

By hypothesis, this short-circuit current must be identical to the short-circuit current that exists in a short circuit placed across the terminals a,b of the original network. From Eq. 4.55,

$$R_{Th} = \frac{V_{Th}}{i_{sc}}. \tag{4.56}$$

Thus the Thévenin resistance is the ratio of the open-circuit voltage to the short-circuit current.

## Finding a Thévenin Equivalent

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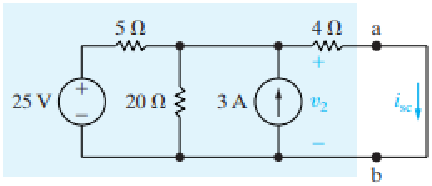



**Figure 4.46** ▲ The circuit shown in Fig. 4.45 with terminals a and b short-circuited.

The next step is to place a short circuit across the terminals and calculate the resulting short-circuit current. Figure 4.46 shows the circuit with the short in place. Note that the short-circuit current is in the direction of the open-circuit voltage drop across the terminals a,b. If the short-circuit current is in the direction of the open-circuit voltage rise across the terminals, a minus sign must be inserted in Eq. 4.56.

The short-circuit current ($i_{sc}$) is found easily once $v_2$ is known. Therefore the problem reduces to finding $v_2$ with the short in place. Again, if we use the lower node as the reference node, the equation for $v_2$ becomes

$$\frac{v_2 - 25}{5} + \frac{v_2}{20} - 3 + \frac{v_2}{4} = 0. \tag{4.59}$$

Solving Eq. 4.59 for $v_2$ gives

$$v_2 = 16 \text{ V}. \tag{4.60}$$

Hence, the short-circuit current is

$$i_{sc} = \frac{16}{4} = 4 \text{ A}. \tag{4.61}$$

We now find the Thévenin resistance by substituting the numerical results from Eqs. 4.58 and 4.61 into Eq. 4.56:

$$R_{Th} = \frac{V_{Th}}{i_{sc}} = \frac{32}{4} = 8 \text{ Ω}. \tag{4.62}$$

Figure 4.47 shows the Thévenin equivalent for the circuit shown in Fig. 4.45.

You should verify that, if a 24 Ω resistor is connected across the terminals a,b in Fig. 4.45, the voltage across the resistor will be 24 V and the current in the resistor will be 1 A, as would be the case with the Thévenin circuit in Fig. 4.47. This same equivalence between the circuit in Figs. 4.45 and 4.47 holds for any resistor value connected between nodes a,b.

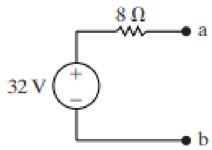
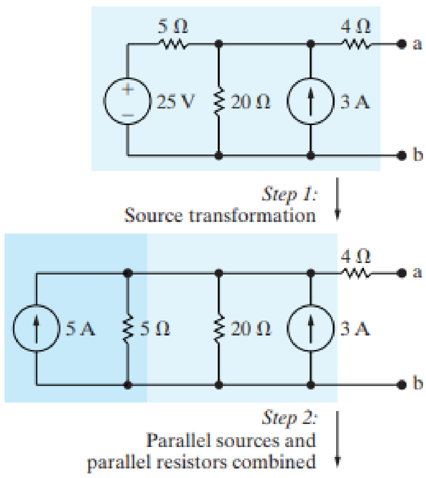



**Figure 4.47** ▲ The Thévenin equivalent of the circuit shown in Fig. 4.45.



## The Norton Equivalent

A **Norton equivalent circuit** consists of an independent current source in parallel with the Norton equivalent resistance. We can derive it from a Thévenin equivalent circuit simply by making a source transformation. Thus the Norton current equals the short-circuit current at the terminals of interest, and the Norton resistance is identical to the Thévenin resistance.

## Using Source Transformations

Sometimes we can make effective use of source transformations to derive a Thévenin or Norton equivalent circuit. For example, we can derive the Thévenin and Norton equivalents of the circuit shown in Fig. 4.45 by making the series of source transformations shown in Fig. 4.48. This technique is most useful when the network contains only independent sources. The presence of dependent sources requires retaining the identity of the controlling voltages and/or currents, and this constraint usually prohibits continued reduction of the circuit by source transformations. We discuss the problem of finding the Thévenin equivalent when a circuit contains dependent sources in Example 4.10.

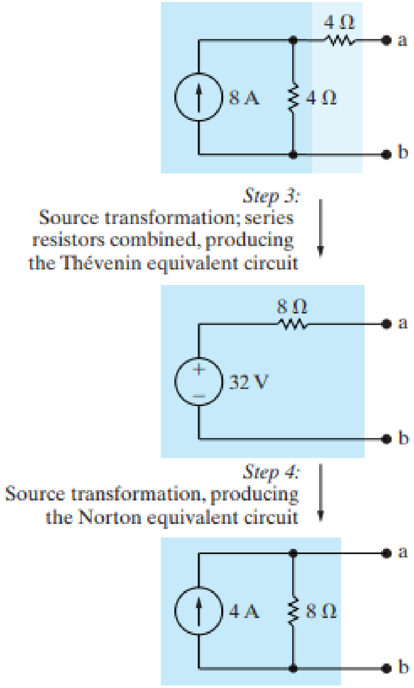
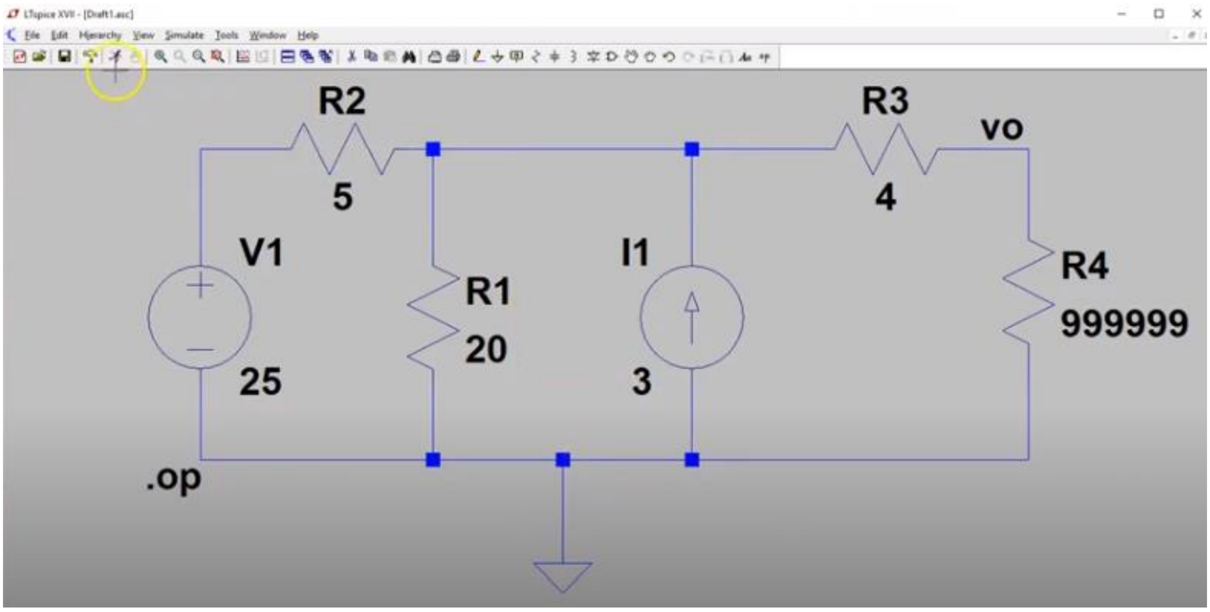


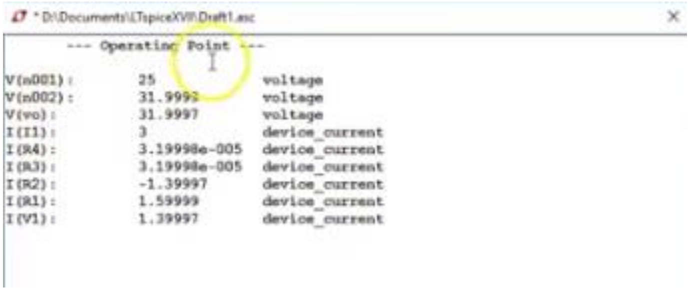

**Figure 4.48** ▲ Step-by-step derivation of the Thévenin and Norton equivalents of the circuit shown in Fig. 4.45.

### Using LTspice to confirm the calculation

Manual calculation from the textbook has shown that $V_{Th}$ = 32 V and $R_{Th}$ = 8 ohms. Now, we will make use of LTspice to help confirm the values. We start by placing the relevant circuit components and enter their values as shown below. In order to determine the open circuit voltage, we place R4 as the load resistor with a huge value of 999999 ohms. This will be equivalent to an open circuit.



Run the simulation and we will see the following window:




Note that Vo is closed to 32 V, which is similar to the calculation.

Next, in order to find the short circuit current, set R4 to be a very small value of 0.000001 ohm. We can see that the current I(R4) is 4 A, which is similar to the calculation. And the Thevenin resistor will be 32 V / 4 A = 8 ohms.

This example has shown you how to use LTspice in circuit analysis.