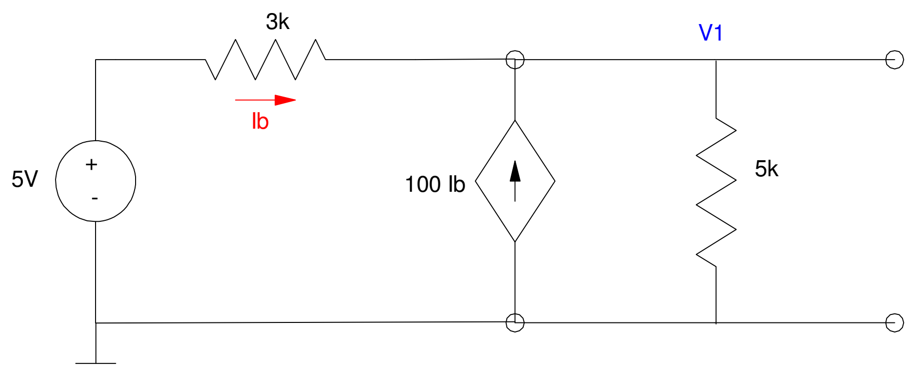
More Thevenin and Norton Equivalents

Sometimes, the Thevenin resistance isn't obvious. In that case, you can apply a test voltage and calculate the resulting current draw. Then from V = IR, you can calulate the Thevenin resistance.

Example 1: Determine the Thevenin equivalent for the following circuit



Vth: Determine the open-circuit voltage. Write the voltage node equation at V1

$$I_b = \left(\frac{5-V_1}{3k}\right)$$

$$\left(\frac{V_1-5}{3k}\right) - 100 I_b + \left(\frac{V_1}{5k}\right) = 0$$

Substitute and solve

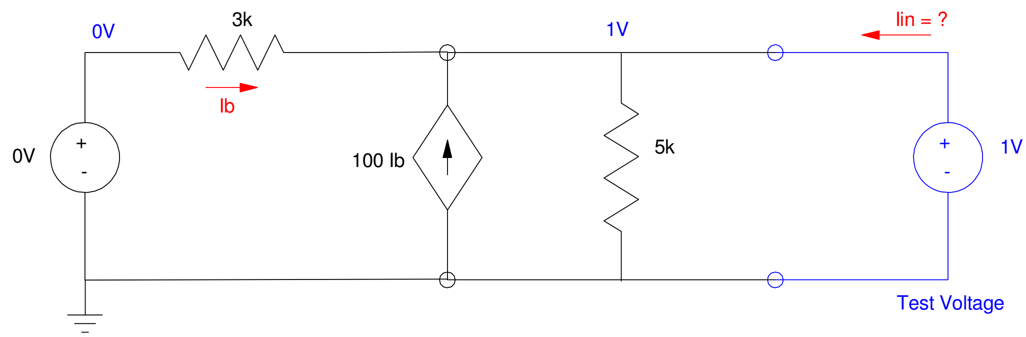
$$V_1 = \left(\frac{\left(\frac{101}{3k}\right)}{\left(\frac{101}{3k}\right)+\left(\frac{1}{5k}\right)}\right) 5V = 4.9705V$$

This is Vth.

To find Rth,

- Turn off the voltage source
- Measure the resistance

This isn't obvious. In that case, apply a 1V test voltage and compute the current draw



For this circuit

$$I_b = \left(\frac{0V - 1V}{3k}\right)$$

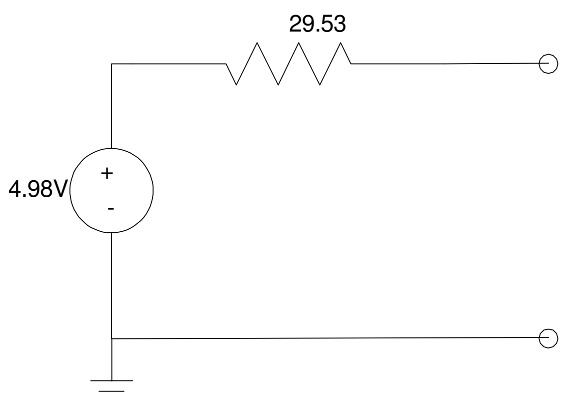
$$I_{in} = \left(\frac{1V - 0V}{3k}\right) - 100 I_b + \left(\frac{1V}{5k}\right)$$

$$I_{in} = 33.87mA$$

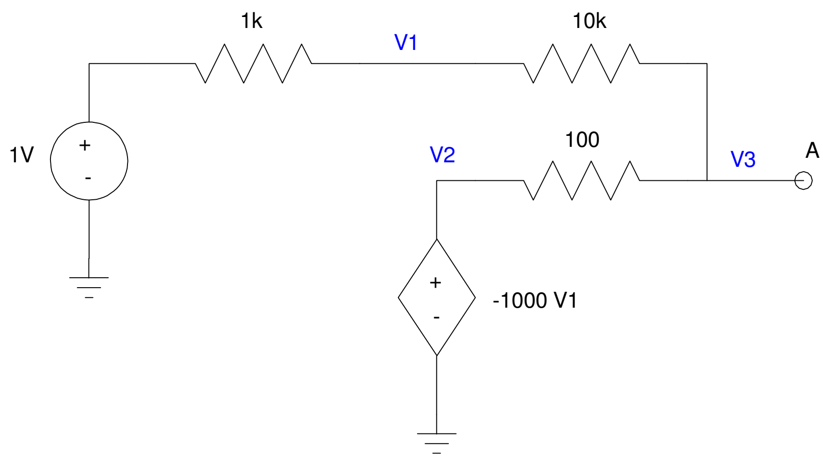
So

$$R_{th} = \frac{V_{in}}{I_{in}} = \frac{1V}{33.87mA} = 29.53\Omega$$

The Thevenin equivalent is thus:



Example 2: Determine the Thevenin equivalent for the following circuit (this models an op-amp with a gain of -10: a circuit we'll cover later)



Example 2: Find the Thevenin equivalent of this active amplifier

Open-Circuit Voltage: Write the voltage node equations

$$V_2 = -1000 V_1$$

$$\left(\frac{V_1 - 1}{1k}\right) + \left(\frac{V_1 - V_3}{10k}\right) = 0$$

$$\left(\frac{V_3 - V_1}{10k}\right) + \left(\frac{V_3 - V_2}{100}\right) = 0$$

Solve (time passes....)

$$\begin{bmatrix} 1000 & 1 & 0 \\ 11 & 0 & -1 \\ -1 & -100 & 101 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 10 \\ 0 \end{bmatrix}$$

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>> A = [1000,1,0;11,0,-1;-1,-100,101]

        1000           1            0
          11           0           -1
          -1        -100          101

>> B = [0;10;0]

     0
    10
     0

>> inv(A)*B

V1     0.0100
V2    -9.9891
V3    -9.8901
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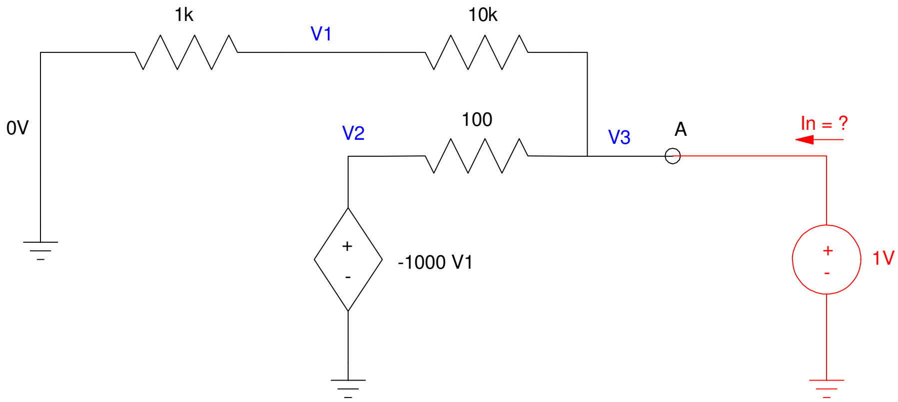
The net results is the open-circuit voltage is -9.8901V. This is Vth.

Thevenin Resistance: Turn off voltage sources and measure the resistance. Since this isn't obvious, apply a 1V test voltage and compute the current the circuit draws:



To find the Thevenin resistance, apply a 1V test votlage and compure the current, Iin.

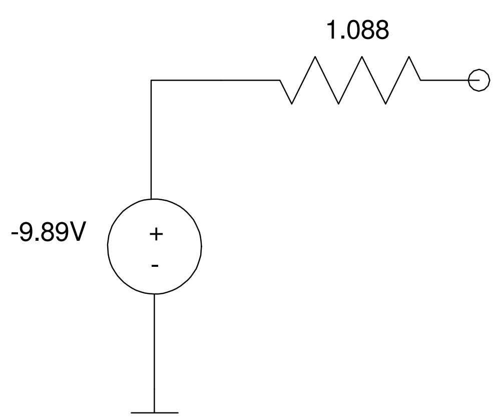
$$V_1 = \left(\frac{1k}{1k+10k}\right) \cdot 1V = 90.91mV$$

$$V_2 = -1000V_1 = -90.91V$$

$$I_{in} = \left(\frac{1V}{11k}\right) + \left(\frac{1V-(-90.91V)}{100}\right) = 919.2mA$$

$$R_{in} = \frac{V_{in}}{I_{in}} = \frac{1V}{919.2mA} = 1.088\Omega$$

So, this circuit has the Thevenin equivalent of:



Thevenin equivalent of example #2.