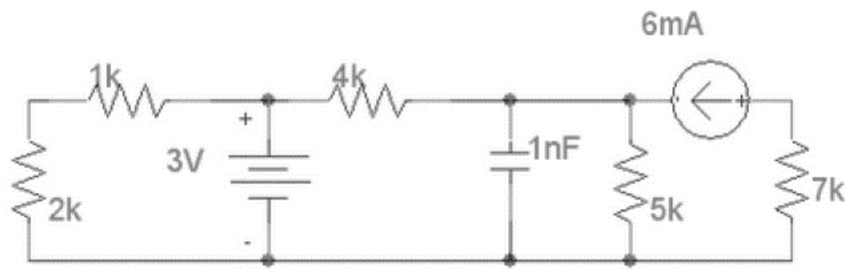
# Tutorial 1

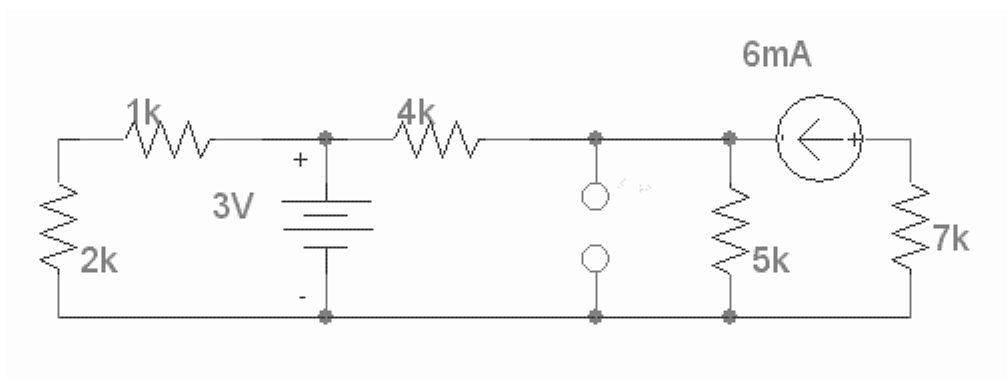
31/07/2015

Q1: Find the Thevenin equivalent circuit with respect to the capacitor

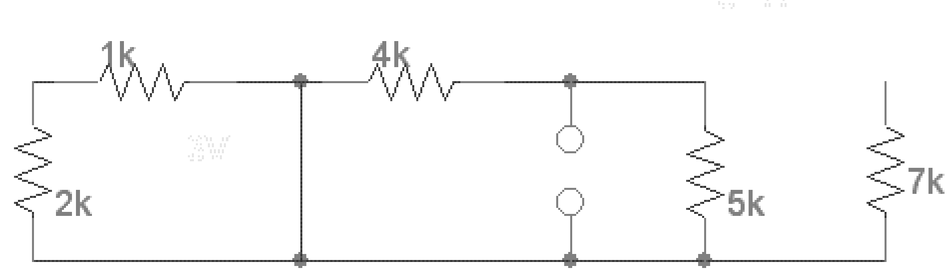



Soln:

Since we are finding the Thevenin with respect to the capacitor, we also take the cap out of the circuit and consider the resistance seen from the terminals where the cap was.



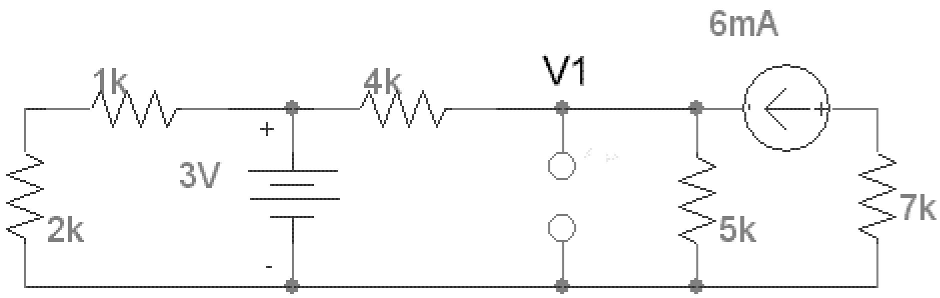

The Thevenin equivalent has two parts, Vth and Rth. We will do the easier one first -- Rth. To find the Thevenin resistance, deactivate all sources (short voltages and open currents).



From the point of view of the capacitor terminals, the 1K and 2K are shorted out. The 7K also is not included because no current can flow through it. If current was fed into the top terminal, it would flow through the 4K and 5K and then come back through the other terminal. Thus

Rth = 4K || 5K = (4K*5K)/(4K+5K) = 2.2K ohms

Next, we'll find Vth using node-voltage analysis, with one node (the bottom wire is the reference node).




Writing KCL at the node V1 (current leaving):

$$\frac{V-3}{4K}+\frac{V}{5K}-6mA=0$$

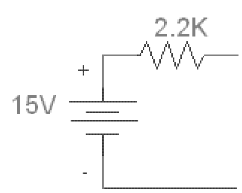
Solve for V by multiplying through by 20K:

5V - 15 + 4V - 120 = 0

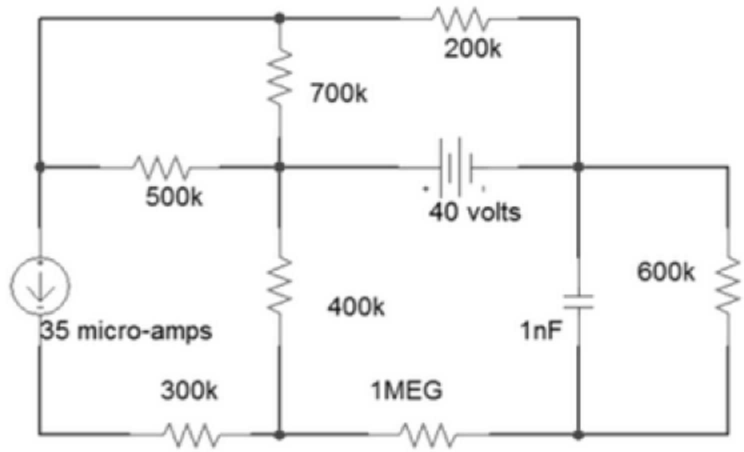
9V = 135

V = 135/9 = 15V

So the final Thevenin Equivalent is:



Q2. Find the Thevenin equivalent with respect to the 1nF capacitor. You must use super-position to find Vth, the Thevenin voltage.



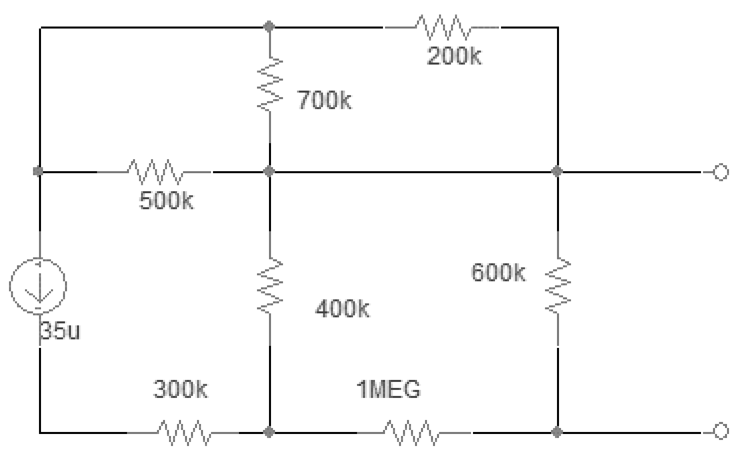

Soln.

The question requires that we use superposition to find Vth. There are two sources in the circuit, so we will have a reduced circuit for each source (with all other sources deactivated). The total Vth will be the sum (super-imposing) of the two subcircuit answers:

$V_{total} = V_{35uA} + V_{40V}$

$V_{35uA}$ = Vth due to 35 microamp source

We deactivate the 40V source by shorting it. The resulting circuit is:



The current source of 35uA will flow down through the 300K, then split between two branches: (a) the 400K and (b) the 1M and 600K in series. These two branches (a) and (b) are in parallel because they are connected electrically at the head (where the 400K, and 1M are conected) and the tail (where the 400K and 600K are connected). We can use a current divider to find how much of the 35uA goes down the (b) branch:

$$i_b = \left( \frac{400K}{400K + (1M + 600K)} \right) * 35uA$$
$$i_b = 7uA$$

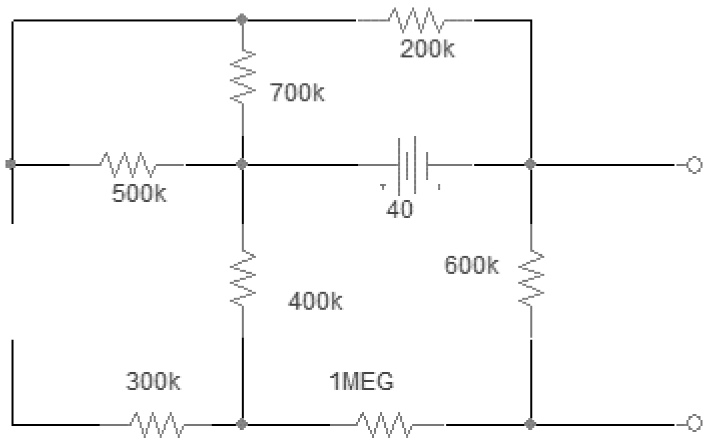
Now we can use the 7uA in branch (b) to find the voltage across the 600K (which is also the open-circuit voltage across the terminals of the capacitor). Using Ohm's law, we get:

$V_{35uA}$ = 7uA * 600K = 4.2V

Note that the voltage has polarity with the "+" at the bottom of the 600K and the "-" at the top of the 600K, because the current must flow in the "+" terminal for the passive sign convention.

$V_{40V}$ Vth due to 40V source

We deactivate the 35uA source by opening it. The resulting circuit is:




In this reduced circuit, the 300K is not connected on the left side, so we can safely ignore it. The 40V source now forms two independent voltage divider circuits:

- Above it: the series combination of the 200K and then the combined parallel 500K and 700K
- Below it: the series combination of the 400K, 1M, and 600K

These are independent, just like mountain climbers climbing up to the 40 thousand foot peak of Mt. Himalaya on the north face and another group of climbrs on the south face. The fraction of the total height for one group has no effect on the other group. So we will use a voltage divider just for the combination of 400K, 1M, and 600K, which goes across the entire voltage (height of the mountain) of 40V. The voltage across just the 600K (which is also the open circuit voltage across the capacitor) is:

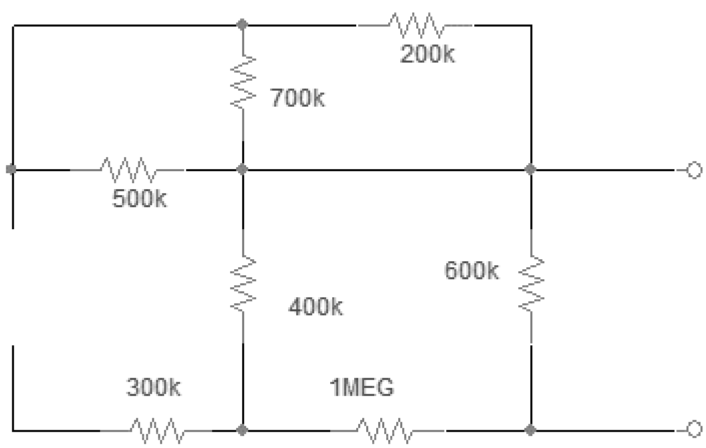
$$V_{40V} = \frac{600K}{600K + 1M + 400K} * 40V$$
$$V_{40V} = 12\,V$$

Notice that the 12V has polarity with the "+" at the bottom of the 600K and the "-" at the top of the 600K, because the voltage is higher at the "+" side of the voltage source and lower at the "-" side of the voltage source (where the "-" of the voltage source is at the top of the 600K).

$V_{total}$ by Superposition

Using the answers to the subcircuits above, we now have:
$V_{total} = V_{35uA} + V_{40V}$
We computed the voltage in each subcircuit with the "+" at the bottom of the 600K and the "-" at the top of the 600K, so we can add them directly now.
$V_{total} = 4.2V + 12V$
$V_{total} = 16.2V$

To find Rth, we deactivate *all* the sources, so open the current source and short the voltage source. The resulting circuit is:

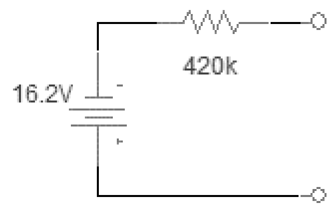



The 500K is in parallel with the 700K and that combination is in series with the 200K. However, that entire combination is shorted out by the wire where the 40V source used to be. So with respect to the capacitor, if current would flow from the capacitor into the top terminal, it would completely bypass those three resistors.

Current flowing from the capacitor into the top terminal would thus split down through the 400K and the 600K. The fraction of current through the 400K would then be forced to also go through the 1M, so the 400K and 1M are in series, and then that combination is in parallel with the 600K.

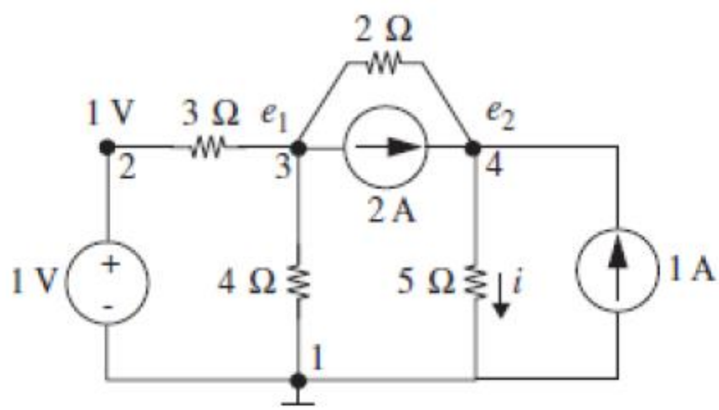
Rth = 600K || (400K + 1M)
Rth = 600K || 1.4M
Rth = (600K * 1.4M) / (600K + 1.4M)
Rth = 420K

The final equivalent circuit is then:




Q3. Determine the current i through the 5 ohm resistor in the circuit in figure

using node method .



Soln.

Let us use the node method to solve the circuit. As Step 1 of node analysis, we will choose Node 1 as our ground node as depicted in Figure 3.14.

Step 2 labels the potentials of the remaining with respect to the ground node. Figure 3.14 shows such a labeling. Since Node 2 is connected to the ground node through an independent voltage source, it is labeled with the voltage of the source, namely 1 V. Node 3 is labeled with a node voltage $e_1$ and Node 4 is labeled with a node voltage $e_2$.

Next, following Step 3, we write KCL for Nodes 3 and 4. KCL for Node 3 is

$$\frac{e_1 - 1}{3} + \frac{e_1}{4} + \frac{e_1 - e_2}{2} + 2 = 0$$

and that for Node 4 is

$$-2 + \frac{e_2 - e_1}{2} + \frac{e_2}{5} - 1 = 0.$$

Following Step 4 we solve these equations to determine the unknown node voltages. This yields

$$e_1 = 0.65 \text{ V}$$

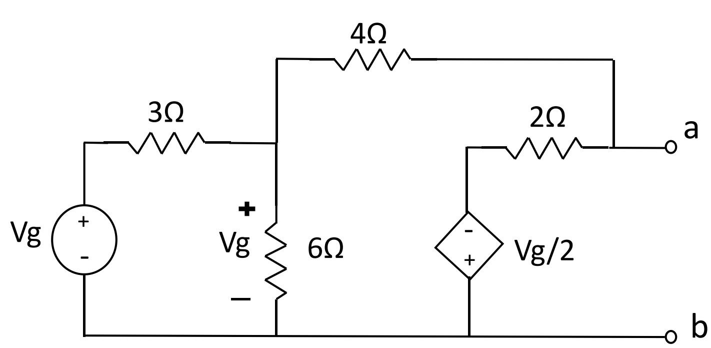
and

$$e_2 = 4.75 \text{ V}.$$

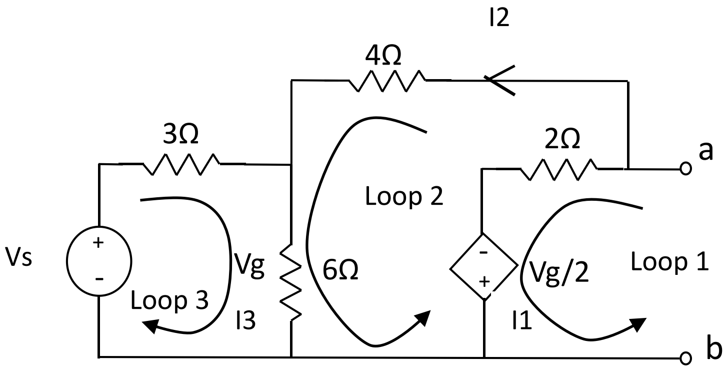
We can now determine $i$ as

$$i = \frac{4.75}{5} = 0.95 \text{ A}.$$

Q4: Find the i) Norton- equivalent circuit and ii) Thevenin-equivalent circuit for the circuit given below



Soln. For Thevenin equivalent




Let's assume a voltage source Vt across a and b. and a current It is flowing through the ckt.

I1 ➔ flows through 4Ω and I2 ➔flows through 2Ω resistor, I3 ➔ flows through 3Ω resistor

For loop 1-

Vt = 2*I1-Vg/2 -------------- (1)

From loop 2-

Vg = 6*(I2+I3) ---------------------- (2)

**For open ckt** => I1 = I2

4*I2 + Vg +Vg/2 +2*I2 = 0 ----------- (3)

- ⇨ 6*I2 + 3/2 Vg = 0
- ⇨ 2*I2 + ½ Vg = 0 ------------ (4)

Open ckt voltage across a and b

Voc = 2*I2 + Vg/2 = 0 ( from eqn 4)------------ (6)

From (2)

Vg = 6*I2 ---------------------- (5)

For Rth

4*I2 + Vg = Vt -------------- (7)

-Vg/2 + 2*I1 = Vt ------------(8)

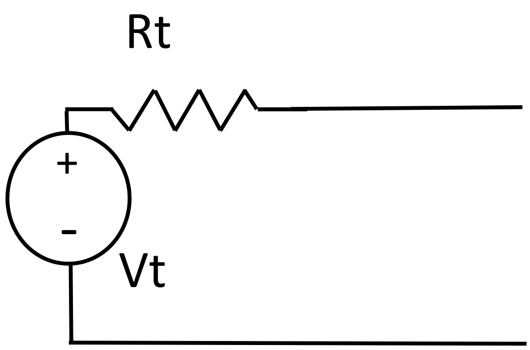
I2 *6 = Vg ---------------------(9)

From eqn (7) , (8) and (9)

We get ,

I2 = Vg/6 , I1 = 13*Vg/12 and Vt = 5Vg/3

Rth = Vt/(I1+I2) = 5/3 * 12/15 = 4/3




For Norton equivalent we will assume Vt again and will get In = 0 and Rn = 4/3