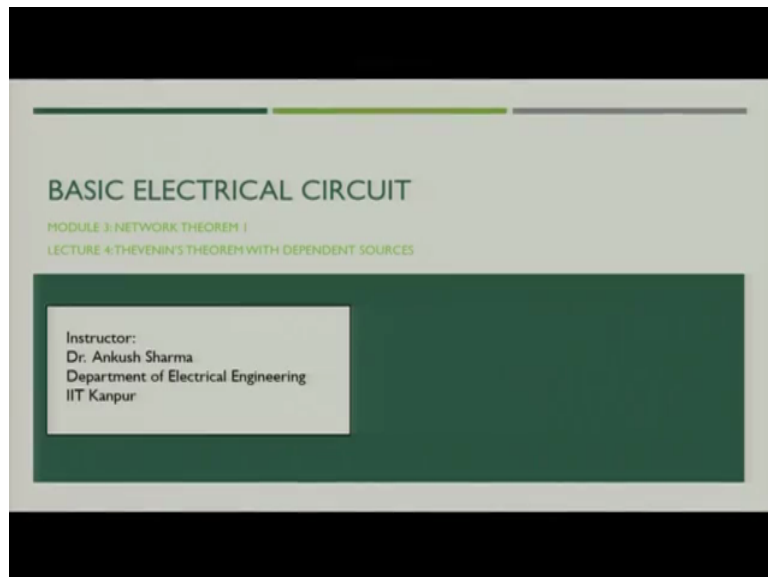


**Basic Electric Circuits**  
**Professor Ankush Sharma**  
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**Module 3**  
**Network Theorem 1**  
**Lecture – 15**  
**Thevenin's Theorem with Dependent Sources**

Namaskar. So, in this week we discussed few important properties of the network. We started with linearity property of the circuit where we discussed what is homogeneity and additivity and then we (proceed) proceeded towards the superposition theorem and then we discussed the other concepts like source transformation and the duality and then in the last class we started our Thevenin's theorem.

So, in the last class we basically discussed the Thevenin theorem aspect when the source is non-dependent source, so that can be like voltage or current both were independent sources. So, in this class we will continue our discussion on the Thevenin's theorem but we will discuss more about the dependent sources that may be the voltage or current.

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### RECAP: THEVENIN'S THEOREM

- **Thevenin's theorem:** a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source  $V_{Th}$  in series with a resistor  $R_{Th}$ , where  $V_{Th}$  is the open-circuit voltage at the terminals and  $R_{Th}$  is the equivalent resistance at the terminals when the independent sources are turned off.
- When terminals  $a - b$  are open circuited by removing the load, i.e. no current flows through the load, the open circuit voltage across the terminals  $a - b$  in the circuit on the left must be equal to the voltage source  $V_{Th}$  in the circuit on the right

So, now let us start. First, let us recap what we discussed in the last class. We discussed Thevenin's theorem and we discussed that the linear two terminal circuit can be replaced by an equivalent circuit consisting of the voltage source  $V_{Th}$  in series with a register  $R_{Th}$  where  $V_{Th}$  is an open circuit voltage at the terminals and  $R_{Th}$  is the equivalent resistance at the terminals when the independent sources are turned off.

So, when we calculate  $R_{Th}$  we make the independence sources turned off, which means that independent voltage source would be short circuited and independent current source will be open circuited. So, if we have a fairly large circuit and we want to study the load connected across two terminals then the circuit which is left at the nodes a and b is equal to the voltage and resistances shown in the figure.

So, voltage would be can set as a Thevenin voltage and resistance would be consider as Thevenin resistance and we will see that the V-I characteristic across terminal a and b will be same in both of the cases. So, that means that both of the circuits are equivalent because their V-I characteristics are same.

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•  $V_{Th}$  is the open circuit voltage across the terminals as shown in the circuit on the left in the figure below.

•  $R_{Th}$  is the input resistance at the terminal when the independent sources are turned off.

$V_{Th} = v_{oc}$

$R_{Th} = R_{in}$

The slide contains two circuit diagrams. The left diagram shows a box labeled 'Linear two-terminal circuit' with terminals 'a' and 'b'. The voltage across terminals 'a' and 'b' is labeled  $v_{oc}$  and  $V_{Th} = v_{oc}$ . The right diagram shows a box labeled 'Linear circuit with all independent sources set equal to zero' with terminals 'a' and 'b'. An arrow labeled  $R_{in}$  points into terminal 'a', and the input resistance is labeled  $R_{Th} = R_{in}$ .

So, this is what we discussed in the last class and then we established that Thevenin voltage is nothing but open circuit voltage across the linear two terminal circuit and  $R_{Th}$  is nothing but the input resistance at the terminal when independent sources are turned off. So, if you look into the terminal a and b the equivalent resistance which you will see from here is nothing but the Thevenin resistance.

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• To find out  $R_{Th}$  we need to consider two cases.

• **Case 1:**

- If the network has no dependent sources, we turn off all the independent sources.
- $R_{Th}$  is the input resistance of the network looking between terminals a and b, as shown in the previous figure.

• **Case 2:**

- If the network has dependent sources, we turn off all independent sources only, leaving dependent sources connected with the circuit.
- The dependent sources cannot be turned off as they are controlled by circuit variables.
- We apply a voltage  $v_o$  at terminals a-b and determine the current  $i_o$ .

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Now, we also discussed that for calculation of Thevenin resistance we need to consider two cases. What was the first case? In first case the network has no dependent sources and we turn off all the independent sources. As we just discussed that voltage source would be short

circuit and current source will be open circuited and then  $R_{Th}$  is the input resistance of the network looking between the terminals a and b that was shown in the previous figure.

Now, in this session we will discuss more about the case 2. In this case the network has dependent sources, we cannot turn off the dependent source because it is dependent upon some circuit variable. So, we will keep dependent source connected with the circuit while we can turn off all the independent sources only and then since the dependent source cannot be turned off, because they are controlled by the circuit variables, we will keep them in the circuit and we will apply voltage that is  $v_0$  at the terminal ab and determine the current  $i_0$ .

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• Then,  $R_{Th}$  is given by  $\rightarrow R_{Th} = v_0 / i_0$

Circuit with all independent sources set equal to zero

$R_{Th} = \frac{v_0}{i_0}$

• Alternatively,  $R_{Th}$  can be evaluated by inserting a current source as shown in the figure below.

Circuit with all independent sources set equal to zero

$R_{Th} = \frac{v_0}{i_0}$

• Again  $R_{Th}$  is  $v_0 / i_0$ .

So, what does it mean? If you have circuit with all independent sources set equal to zero and the keeping all the dependent sources connected with the network, the terminal a and b would be supplied with voltage  $v_0$  which will supply some current  $i_0$ . So, in that case if you solve the circuit with the help of either Kirchhoff Voltage Law or Kirchhoff Current Law you will be able to find out the value of Thevenin resistance which would be nothing but  $v_0/i_0$ .

So, when you have dependent source available in the circuit which you cannot remove you will first remove all the independent sources and then apply voltage  $v_0$  and try to measure the current  $i_0$  and accordingly you can find out the value of Thevenin resistance. Now, alternatively  $R_{Th}$  can also be evaluated by inserting a current source. So, instead of voltage source if you apply current source you will measure the voltage across these two terminals and when you measure you will get again the value of  $R_{Th}$  as  $v_0/i_0$ .

So, in both of the cases you can use either of them and you will get eventually the same result.

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**When the circuit contains a dependent source –**

- To find  $R_{Th}$ , set the independent source equal to zero but leave the dependent source connected.
- Because of the presence of the dependent source, the network is excited with a voltage source  $v_0$  connected to the terminals.
- We may set  $v_0 = 1\text{ V}$  to ease calculation, since the circuit is linear.
- Our goal is to find the current  $i_0$  through the terminals, and then obtain  $R_{Th} = v_0/i_0$ .
- Alternatively, we may insert a  $1\text{ A}$  current source.
- Accordingly, find the corresponding voltage  $v_0$ , and then obtain  $R_{Th} = v_0/1$ .

So, what the process we need to follow when the circuit contains a dependent source? We have to find  $R_{Th}$  that is Thevenin resistance we have to set the independent sources equal to zero and leave the dependent sources connected. Now, since the network has dependent sources we have to excite the network from outside with the help of either voltage  $v_0$  or maybe the current source  $i_0$  which would be connected to the terminals.

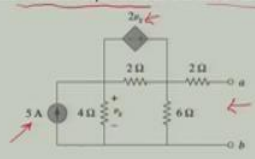
Generally, we set  $v_0$  equal to 1 because it will be easier for our calculation and since the circuit is linear that means that we follow the homogeneity concept. So, whether it is 1 volt or 10 volt the response of the circuit will be scaled up accordingly and being a linear circuit, it is very easy for us to apply any voltage which we want across the terminal, but the easiest is 1 volt because it makes calculations easier.

Now, we have to find out the value  $i_0$  because we have added voltage  $v_0$  across the circuit. So,  $i_0$  we can calculate which would be flowing through the terminals with the help of either KVL or KCL and then we obtain the value of Thevenin resistance that would be nothing but  $v_0/i_0$ .  $v_0$  is in this case 1 so it will become  $1/i_0$ . We may insert 1 ampere current source so this will give you the  $R_{Th}$  value as  $v_0/1$  because 1 is the value of current source.

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EXAMPLE:

❖ For the below circuit find the Thevenin equivalent to the left of terminals a-b?



SOLUTION: The circuit contains dependent source.

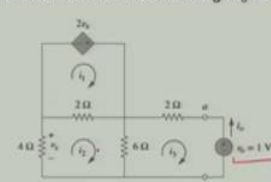
Now, let us understand this concept of how to solve the circuit when we have the dependent source with the help of one example. Now, let us see this particular circuit where you will see we have one independent current source of 5 ampere value additionally we have one voltage source which is dependent voltage source and the value of voltage is depending upon the voltage across 4 ohm resistance.

Now, what we have to do? We have to find the Thevenin equivalent to the left of the terminal ab. So, we have to find out the Thevenin equivalent which would be the equivalent of the complete circuit.

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To find  $R_{Th}$  we set the independent source to zero but leave the dependent source connected.

As there is a dependent source we excite the network with a source voltage  $v_0$  connected to the terminals as shown in the circuit below.



We may set  $v_0 = 1V$  to ease the calculation, since the circuit is linear.

EXAMPLE:

✦ For the below circuit find the Thevenin equivalent to the left of terminals a-b?

SOLUTION: The circuit contains dependent source.

Now, let us solve it, what we have to do first? First, we have to solve for  $R_{Th}$  that is Thevenin resistance, in that case what we can do? We can remove all the independent sources, in this case this is a current source. You can make it open circuited. So, the resultant circuit would be like this and what we need to do is that? We need to add one voltage source  $v_0$  that is equal to 1 volt which would be connected across the terminals a and b and then solve the circuit.

So, here we have made the current source as open circuit which was connected across 4 ohm resistance and additionally we have added one voltage source across terminal a, b that is  $v_0 = 1$  volt. So, the updated circuit is as shown in the figure then you will see that how you will solve? You can use Mesh Analysis which we discussed earlier. So, here we have three meshes connected so we will have three mesh currents like  $i_1$ ,  $i_2$  and  $i_3$ .

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The next step is to find the current  $i_0$  through the terminals and then evaluate  $R_{Th} = \frac{1}{i_0}$ .

Alternatively, we can also insert a 1 A current source and find the corresponding voltage  $v_0$  and, accordingly, obtain  $R_{Th} = \frac{v_0}{1}$ .

Now, applying mesh analysis to loop 1 of the circuit results in.

$$-2v_x + 2(i_1 - i_2) = 0 \Rightarrow v_x = i_1 - i_2$$

But  $-4i_2 = v_x = i_1 - i_2$ , hence

$$i_1 = -3i_2$$

Applying KVL to loops 2 and 3 gives.

$$4i_2 + 2(i_2 - i_1) + 6(i_2 - i_3) = 0$$

$$6(i_3 - i_2) + 2i_3 + 1 = 0$$

$$6i_3 - 6i_2 + 2i_3 = -1$$

$$8i_3 - 6i_2 = -1$$

$$-6i_3 + 18i_2 = 0$$

Now, what we have to do? We have to solve the circuit using mesh analysis. So, what would be the value of the mesh equation in case of loop 1? So this is loop 1 so when you solve since it is going from minus to plus across the dependent voltage source it will become

$$-2v_x + 2(i_1 - i_2) = 0 \Rightarrow v_x = i_1 - i_2$$

Now, if you see this particular mesh you will come to know the voltage drop across 4 ohm resistance is nothing but 4 ohm into current  $i_2$ . Now, since the direction of current is opposite of the polarity of the voltage so what will happen? You can simply say,

$$-4i_2 = v_x = i_1 - i_2$$

So, in that case you can simplify and you will get

$$i_1 = -3i_2$$

Next what we have to do? We have to apply KVL for loop 2 and 3. So, for loop 2 if you apply KVL what will happen?

$$4i_2 + 2(i_2 - i_1) + 6(i_2 - i_3) = 0$$

For loop 3 what you will get?

$$6(i_3 - i_2) + 2i_3 + 1 = 0$$



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Solving the above equations we get,

$$i_3 = -\frac{1}{6}\text{A}$$

But  $i_0 = -i_3 = 1/6\text{A}$ . Hence,

$$R_{Th} = \frac{1\text{V}}{i_0} = 6\ \Omega$$

To determine  $V_{Th}$ , we find  $v_{oc}$  in the circuit shown below.

So, when you will solve you will get the value of

$$i_3 = -\frac{1}{6}\text{A}$$

Now, as we know that  $i_2$  is equal to  $-i_3$  if you see this circuit  $i_0$  is in the opposite direction of  $i_3$ . So, we can say

$$i_0 = -i_3 = 1/6\text{A}$$

So, what you will get for  $R_{Th}$ ?

$$R_{Th} = \frac{1\text{V}}{i_0} = 6\ \Omega$$

Now, we have to find out the  $v_{oc}$  because  $R_{Th}$  we have already found for finding out the value of  $v_{oc}$  what we have to do? We have to find out the voltage across terminal a and b. So, we will add the 5 ampere independent current source again in the circuit and then we will solve. So, again we have three meshes created in the circuit that is  $i_1$ ,  $i_2$  and  $i_3$ , we will write the mesh equation for all three meshes.

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Applying mesh analysis we obtain,

$$i_1 = 5$$

$$-2v_x + 2(i_3 - i_2) = 0 \Rightarrow v_x = i_3 - i_2 \quad \text{--- (1)}$$

$$4(i_2 - i_1) + 2(i_2 - i_3) + 6i_2 = 0 \Rightarrow 12i_2 - 4i_1 - 2i_3 = 0 \quad \text{--- (2)}$$

But  $4(i_1 - i_2) = v_x$ . Solving these equations leads to  $i_2 = 10/3$ .

Hence,

$$4i_1 - 4i_2 = v_x = i_3 - i_2$$

$$i_3 + 3i_2 = 20 \quad \text{--- (3)}$$

$$12i_2 - 2i_3 = 20 \quad \text{--- (4)}$$

$$v_{th} = v_{oc} = 6i_2 = 20V$$

The Thevenin equivalent is as shown in the adjacent figure.

So, if you see this one you will simply get  $i_1$  is nothing but 5 ampere because this is the independent current source connected to this. For next this mesh what you will get?

$$4(i_2 - i_1) + 2(i_2 - i_3) + 6i_2 = 0 \Rightarrow 12i_2 - 4i_1 - 2i_3 = 0$$

Now, let us talk about the mesh number three what you will get?

$$-2v_x + 2(i_3 - i_2) = 0 \Rightarrow v_x = i_3 - i_2$$

Now, we know that value of  $i_1 = 5$  and also, we know from the dependency because this is the constraint value that  $4(i_1 - i_2) = v_x$ .

So, when we solve these equations by putting the value of

$$4(i_1 - i_2) = v_x = i_3 - i_2$$

Now,  $i_1 = 5$ . So, this will become

$$i_3 + 3i_2 = 20$$

So, to get another equation which is only in terms of  $i_2$  and  $i_3$  you will use  $i_1$  you will get

$$12i_2 - 2i_3 = 20$$


Now, you have these two equations where only unknowns are  $i_2$  and  $i_3$ . So, you can simply solve and finally you get the value of  $i_2 = 10/3$  ampere. Now,

$$V_{th} = v_{oc} = 6i_2 = 20V$$

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EXAMPLE:

◆ For the below circuit find the Thevenin equivalent to the left of terminals a-b?



SOLUTION: The circuit contains only dependent source, unlike the circuit given in the previous example. There are no independent sources.


So now, let us see another example. In this circuit if you see the circuit we want to find out the Thevenin equivalent but in this particular circuit we do not have any independent voltage or current source, so the circuit would have only dependent source. So, here in this case we have the current source which is dependent.

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- The circuit contains a  $2\Omega$  resistor in parallel with a  $4\Omega$  resistor.
- These are in turn parallel with a dependent current source.
- The first thing to consider is that, since we have no independent sources in this circuit, we must excite the circuit externally.
- In addition, when you have no independent sources you will not have a value for  $V_{th}$ , you will only have to find  $R_{th}$ .
- The simplest approach is to excite the circuit with either a  $1\text{ - }V$  voltage source or a  $1\text{ - }A$  current source.

EXAMPLE:

◆ For the below circuit find the Thevenin equivalent to the left of terminals a-b?



SOLUTION: The circuit contains only dependent source, unlike the circuit given in the previous example. There are no independent sources.

So, what we have to do? We just see that this circuit contains 2 ohm resistance in parallel with 4 ohm resistance so these two are in parallel and they in turn are in parallel with the dependent current source. Now, first thing which we have to consider is that since we do not have any independent source in the circuit we must excite the circuit externally, what does it mean?

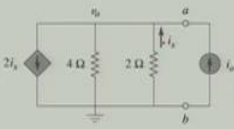
Then we have to apply either the voltage or the current source across the a and b terminals so that we can excite this circuit from outside to find out the value of Thevenin equivalent. Now, another thing which we have to consider is that since we do not have any independent source we need not to find the value for Thevenin voltage, why? Because if you see this figure the value of this particular current source is depending upon the current flowing through 2 ohm resistance.

So, until unless we have any external source you cannot energize this particular circuit that means that if you are having the a and b terminal as open circuited and you want to find out the open circuit voltage across terminal a and b this will always be zero because there is no independent source to supply power to the circuit. So, in that way you can say that we do not have any we need not to calculate  $V_{Th}$  for this type of source, so what is left is that we need to find out the value of only Thevenin resistance.

So, next the simple approach is either you apply 1 volt voltage source or 1 ampere current source.

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- Since we will end up with an equivalent resistance (either positive or negative), the preferred method is to use the current source and nodal analysis which will yield a voltage at the output terminals equal to the resistance (with 1 A flowing in,  $v_o$  is equal to 1 times the equivalent resistance).
- As an alternative, the circuit could also be excited by a 1-V voltage source and mesh analysis could also be used to find the equivalent resistance.
- To apply nodal equations apply a current source as shown in the circuit.



So, now let us apply one current source and try to solve it. Now, what we will do? We will see that this particular circuit has 1 node the voltage across this particular circuit a, b would be nothing but the voltage across both of the resistances also because all those elements are in parallel.

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• Writing the nodal equations for the circuit assuming  $i_0 = 1\text{A}$ , we get

$$2i_x + \frac{v_0 - 0}{4} + \frac{v_0 - 0}{2} + (-1) = 0 \quad \text{--- (1)}$$

• Since there are two unknowns and only one equation, we will need a constraint equation

$$i_x = \frac{0 - v_0}{2} = -\frac{v_0}{2}$$

• Substituting the above obtained value of  $i_x$  in the first equation, we get,

$$2\left(-\frac{v_0}{2}\right) + \frac{v_0 - 0}{4} + \frac{v_0 - 0}{2} + (-1) = 0$$

$$v_0 = -4\text{V}$$

So, what we will do? We will solve it with the help of Nodal equation because it is easier to apply Kirchhoff Current Law in this particular circuit. So, let us try to apply Nodal equation while putting the value of  $i_0$  as 1 ampere. Now, if you see this node whether this is a or this node or this node all are act same potentials so eventually this will be considered as a single node.

So, at this node if you apply the Kirchhoff Current Law first thing is that the at this particular node current going outside is  $2i_x$ , another current going outside is  $\frac{v_0}{4}$ , another current going outside of this node is  $\frac{v_0}{2}$  and then the current going inside is the current  $i_0$ .

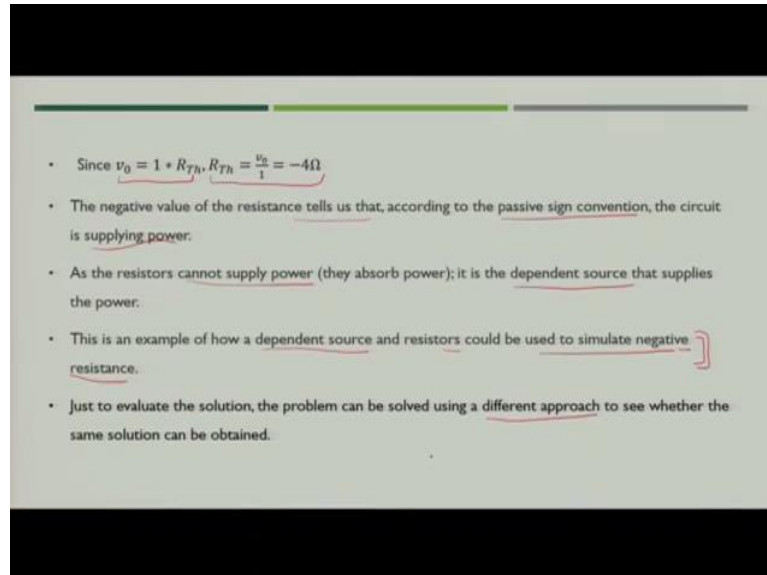
$$2i_x + \frac{v_0 - 0}{4} + \frac{v_0 - 0}{2} + (-1) = 0$$

Now, if you solve it what you will get? You will get the equation in terms of  $v_0$  and  $i_x$ . Now, the problem would be that since we have only one equation and we have two variables means we need at least one more equation to solve this circuit. So, from where we will get the second equation? The second equation we will get from the constraint, that is, the constraint in this case is, current  $i_x$  which is defining the value of dependent current source that is  $2i_x$ .

Now, if you see the value of  $i_x$ ,  $i_x$  is nothing but  $-\frac{v_0}{2}$  because the direction of  $i_x$  is opposite to natural flow of current if voltage  $v_0$  is having higher potential than the reference so in this way this will become  $-\frac{v_0}{2}$ . So, what we can do? We can simply put the value of  $v_0$  in this equation so finally when you put these values here you will have only  $v_0$  as an unknown in this equation.

So, you can simply solve it by putting the value of  $i_x = -\frac{v_0}{2}$  and when you solve it you will get the value of  $v_0 = -4V$ .

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Now, since  $v_0 = 1 * R_{Th}$  because  $i_0 = 1$  ampere simply the value of Thevenin resistance would be minus of 4 ohm. Now, the negative value of resistance will tell us that according to the passive sign convention the circuit is supplying power. Since the resistor cannot supply power who will supply is this power? The dependent source which is connected to the network.

Now, in this example we have seen how a dependent source and resistor could be used to simulate the negative resistance so these properties are very important sometimes you need to insert negative resistance in the circuit and you can realize with the help if this type of circuits. Now, if you solve this problem using different approach whether the same solution would be obtained or not let us see.

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- Let us try connecting a  $9\Omega$  resistor in series with a  $10\text{-V}$  voltage source across the output terminals of the original circuit and then find the Thevenin equivalent.
- To make the circuit easier to solve, we can change the parallel current source and  $4\Omega$  resistor to a series voltage source and  $4\Omega$  resistor by using source transformation.
- This, with the new load, gives us the circuit shown below.

Now suppose we have load of  $9\Omega$  resistance and  $10\text{V}$  source connected across the terminal, so what happens? Suppose you are not following the Thevenin theorem and you want to analyze the circuit what you will do? You will see the circuit to find that one current source is in parallel with one  $4\Omega$  resistance. Source transformation can be applied and you can solve it by converting the combination of current source in parallel with  $4\Omega$  resistance with the voltage source in series with  $4\Omega$  resistance, that is the source transformation technique which we studied earlier. So, what will happen in this case? The value of the voltage source that is definitely would be the dependent voltage source because this is the dependent current source.

So, the value of voltage source would become  $8i_x$  and the direction of plus sign the polarity would be plus would be in the direction of flow of the current so that is why the below sign is plus up sign is minus and then in series with one  $4\Omega$  resistance. So, this particular segment is now converted into voltage source in series with  $4\Omega$  resistance then you add  $2\Omega$  resistance that is the part of the circuit in parallel again and this is the load component which you have connected at terminal a, b.



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• We can write two mesh equations for the previous circuit,

$$8i_x + 4i_1 + 2(i_1 - i_2) = 0 \quad \checkmark$$
$$2(i_2 - i_1) + 9i_2 + 10 = 0 \quad \checkmark$$


• Since there are three unknowns and only two equations, we will need a constraint equation

$$i_x = i_2 - i_1 \quad \checkmark$$

• This leads to a new equation for loop 1,

$$(4 + 2 - 8)i_1 + (-2 + 8)i_2 = 0 \Rightarrow i_1 = 3i_2$$

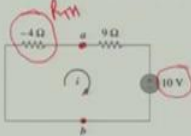
• Substituting the above relation in loop 2 KVL, we get,

$$i_2 = -\frac{10}{5} = -2A$$


So, the updated circuit would be looking like this, here we have two meshes so what we have to do? We have to write the mesh equations for both of them so these would be the two mesh equations for these two meshes plus we will have another constraint for  $i_x$  that is nothing but  $i_2 - i_1$ .


Now, if you use these three equations and solve it you will get  $i_1 = 3i_2$  and using KVL in loop 2 you will get  $i_2 = -\frac{10}{5} = -2A$  because you solve it with the help of the circuit and you get the value of current  $i_2$  because  $i_1$  is nothing but  $3i_2$  and you write the loop equation for this, this is what you have used in case of mesh two put the value of  $i_1$  here, solve it you will get  $i_2$  is nothing but  $-2$  ampere.

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- Had we used the Thevenin equivalent to solve the above problem, the circuit would be as shown in the figure below.
 
- There is only one loop for the above circuit and applying KVL gives,
 
$$-4i + 9i + 10 = 0 \Rightarrow i = -2A$$
- The above value is same as the value obtained by solving the circuit without using the Thevenin equivalent.

- We can write two mesh equations for the previous circuit,
 
$$8i_x + 4i_1 + 2(i_1 - i_2) = 0$$

$$2(i_2 - i_1) + 9i_2 + 10 = 0$$
- Since there are three unknowns and only two equations, we will need a constraint equation
 
$$i_x = i_2 - i_1$$
- This leads to a new equation for loop 1,
 
$$(4 + 2 - 8)i_1 + (-2 + 8)i_2 = 0 \Rightarrow i_1 = 3i_2$$
- Substituting the above relation in loop 2 KVL, we get,
 
$$i_2 = -\frac{10}{5} = -2A$$



- Let us try connecting a 9Ω resistor in series with a 10-V voltage source across the output terminals of the original circuit and then find the Thevenin equivalent.
- To make the circuit easier to solve, we can change the parallel current source and 4Ω resistor to a series voltage source and 4Ω resistor by using source transformation.
- This, with the new load, gives us the circuit shown below.



Now, this is what you got when you did not apply Thevenin theorem to solve this particular circuit. Now, you know that we have calculated the Thevenin resistance across these two terminals while there was no Thevenin voltage. So, if you use that concept of Thevenin theorem which we discussed we will have only one  $-4$  ohm resistance as part of the Thevenin resistance with no Thevenin voltage.

So, the left side of this which was our original circuit can be replaced by only the  $-4$  ohm resistance that is Thevenin resistance connected across terminal a and b. So, we have now very simple circuit when we consider the Thevenin theorem and we get the equivalent resistance of this particular loop as  $5$  ohm resistance and  $10$  volt voltage source is connected when you apply again the KVL in this particular circuit you will get again current  $i = -2A$ .

So, if you compare these two methods where you analyze the circuit with the help of source transformation and then you applied the mesh analysis method to find out the value of current  $i_2$ , here we used the Thevenin theorem and simplified the circuit very quickly as compare to the method where we were using the only the dependent voltage and current source when we connect them and how to create the Thevenin equivalent in that case and how to solve the circuit when we have dependent sources connected.

So, with this we close this week sessions where we studied various key concept of the circuit. We studied superposition as well as Thevenin's theorem. So, next week we will start with another theorem which is called as Norton's Theorem, thank you.