Exp.1. **Impedance matching of source and load**

Date:

Objective:

1. To design a simplified equivalent circuit in analysing the power systems and other circuits where the load resistor is subject to change in order to determine the voltage across it and current through it using thevenin's theorem.
2. To design the circuit for maximizing the power transferred from the amplifier to the loudspeaker using maximum power transfer theorem.

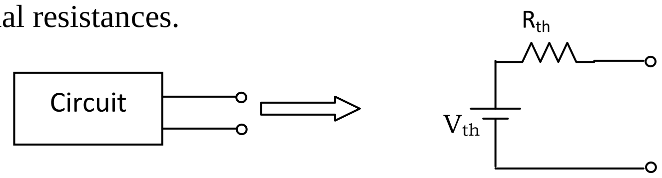
Experiment 1.a(Thevenin's Theorem)

Components Required :

S.No.	Name of the Components/Equipment	Range	Type	Quantity required
1	Resistor	100Ω, 560Ω, 270Ω	Wire wound	Each 1
2	DC power supply	(0-30)V	RPS	1
3	Voltmeter	(0-30)V	MC	1
4	Ammeter	(0-100)mA	MC	1
5	Wires	-	Single strand	Few nos
6	Bread board	-	-	1

Statement of the theorem:

Any two-terminal linear network composed of voltage sources, current sources, and resistors, can be replaced by an equivalent two-terminal network consisting of an independent voltage source in series with a resistor. The value of voltage source is equivalent to the open circuit voltage (V_{th}) across two terminals of the network and the resistance is equal to the equivalent resistance (R_{th}) measured between the terminals with all energy sources replaced by their internal resistances.



Circuit 1:

Find the current through 270Ω resistance in the figure 1 using thevenin's theorem.

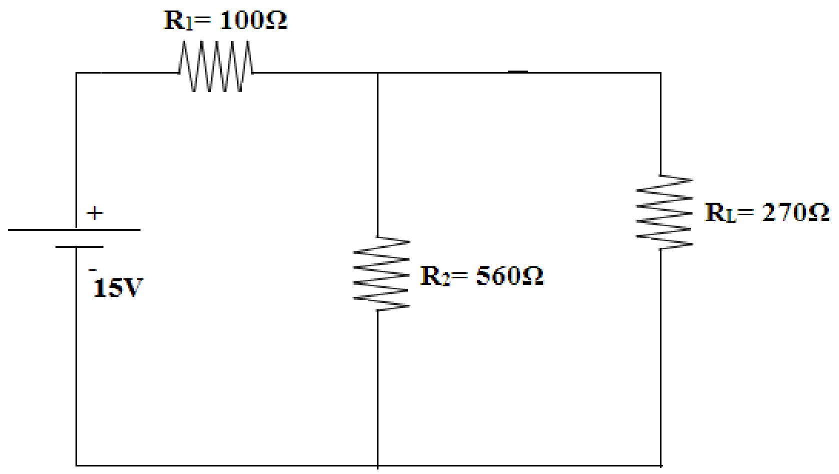


Figure 1

Step 1:

Remove the load (270Ω) (the element through which the current or voltage is going to be calculated) from the circuit and find out the open circuit voltage across the terminals.
In theoritically, the voltage can be found as follows (Figure 2)

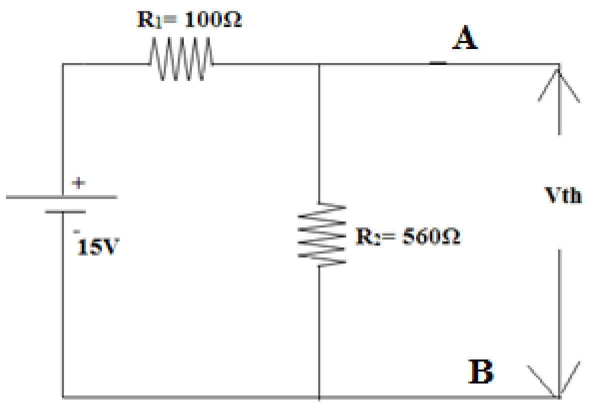


Figure 2

$V_{th}=V_{R2}=\frac{15*560}{100+560}$ =12.72V (From Voltage division rule)

Practical Circuit Diagram:

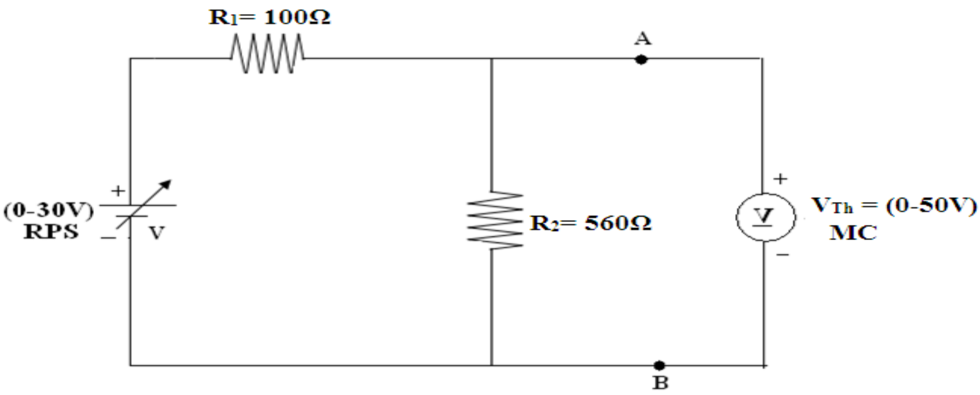


Figure 3

1. Give the connections in the breadboard as per the circuit diagram.(Figure 3)
2. Set the source voltage of 15V in the Regulated power supply.
3. Measure the thevenin's voltage in the voltmeter.

Step 2:

For finding the thevenin's resistance, the sources in the circuit must be removed. The voltage sources are short circuited and the current sources are open circuited. We have to find the looking back resistance from the open terminal.

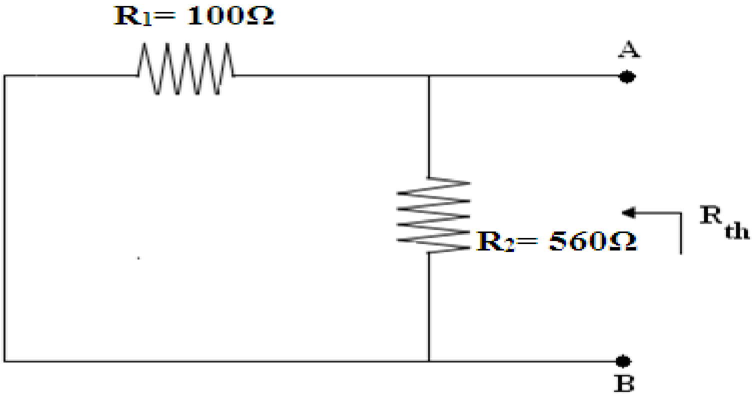


Figure 4

Theoretically, $R_{th} = \frac{100*560}{100+560} = 84.84\Omega$

Practical Circuit Diagram:

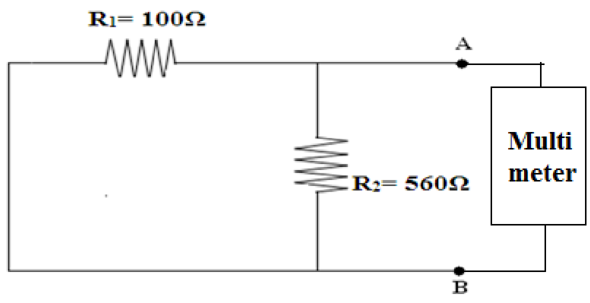


Figure 5

1. Give the connections in the breadboard as per the circuit diagram(Figure 5)
2. Measure the resistance across AB using multi meter.

Step 3:

After finding thevenin's voltage and thevenin's resistance, we can draw the thevenin's equivalent circuit by connecting V_{th} in series with R_{th}. (Figure 6.a)

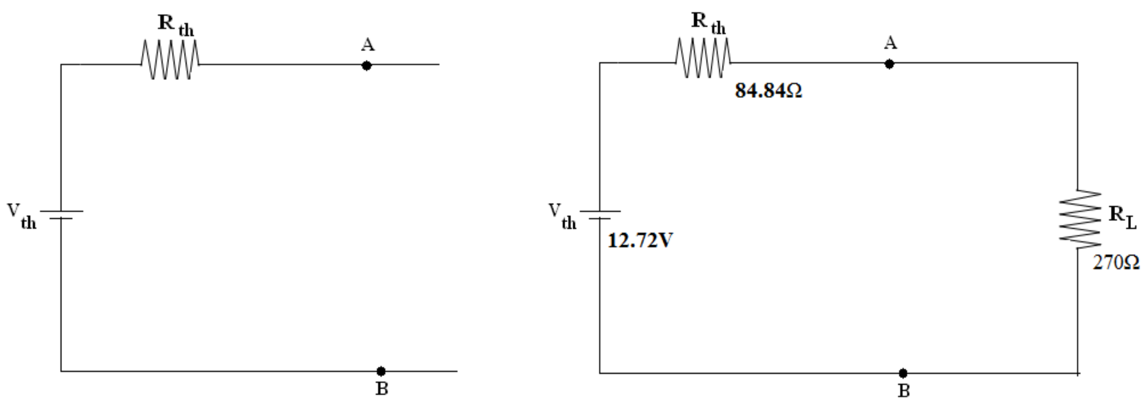


Figure 6

The load (270Ω) can be connected in series with the thevenin's equivalent circuit.(Figure 6.b) Theoretically, we can calculate the current through the load from the thevenin's equivalent circuit.

$I_{load}=\frac{12.72}{84.84+270}$ =35.84mA.

Practical Circuit Diagram:

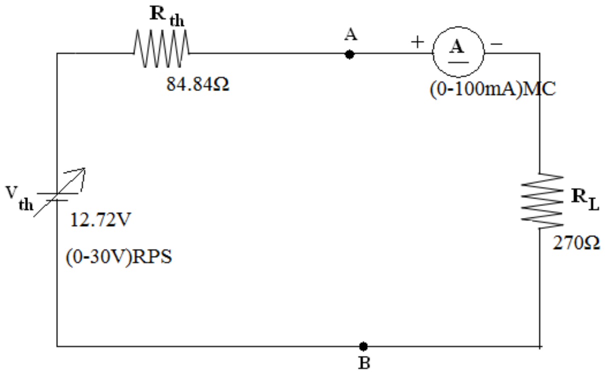


Figure 7

1. Give the connections in the breadboard as per the circuit diagram(Figure 7)
2. Measure the current through the load resistance in the Ammeter.

Step 4:

The load current can be verified using Kirchoff's laws.

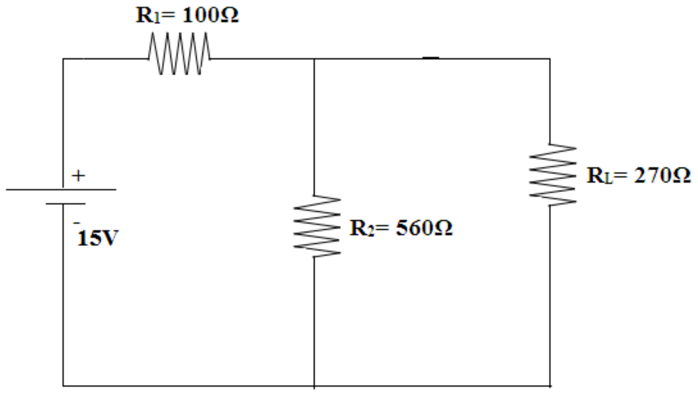


Figure 8

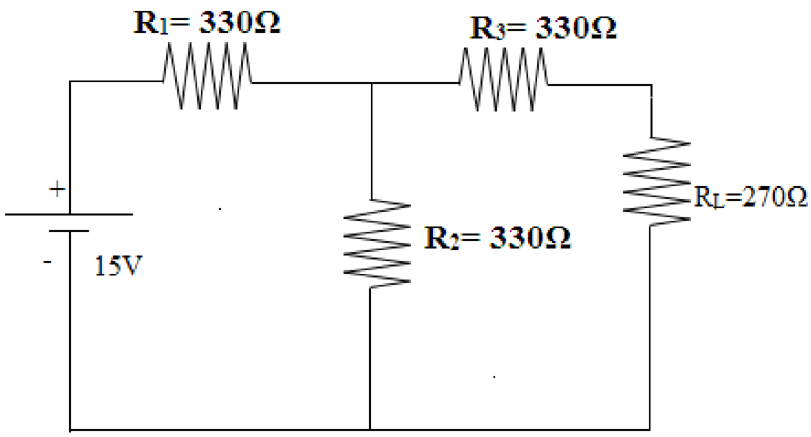
Total resistance = $\frac{560*270}{560+270} + 100 = 282.16\Omega$

Total current= $\frac{Voltage}{Resistance} = \frac{15}{282.16} = 53.16mA$

Current through 270Ω = $\frac{Total\ current*Opposite\ resistance}{Total\ resistance} = \frac{53.16*560}{560+270} = 35.84mA$

(Current Division rule)

Circuit 2:



Find the current through R_L using thevenin's theorem.

OBSERVATION TABLE

S. No	V_s (Volts)	V_{TH} (Volts)	(R_{th}) (Ω)	Current through Load Resistance I_L(mA)	
				Practical Value	Theoretical Value

Application Circuits:

Example 1

Suppose a 12 volt lead-acid battery has an internal resistance of 20 milli-ohms (20 mΩ):

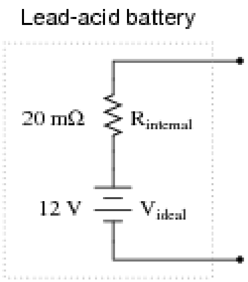


Figure 9

Now suppose three of these batteries are connected directly in parallel with one another

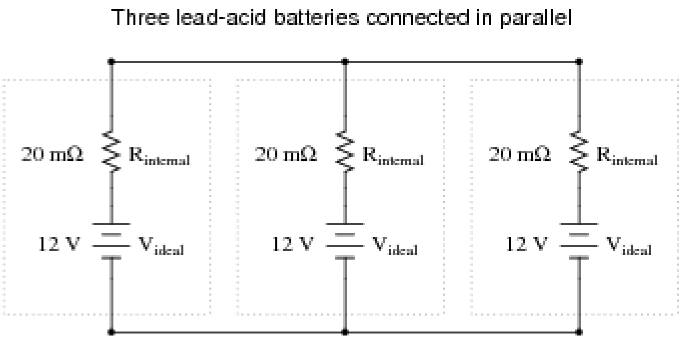


Figure 10

Reduce this network of parallel-connected batteries into a Thévenin equivalent circuit, and then calculate the fault current available at the terminals of the three-battery “bank” in the event of a direct short-circuit.

Example 2

Thevenin’s theorem is used in Digital to Analog Converter (DAC). The equivalent diagram for the DAC is shown in figure 11.

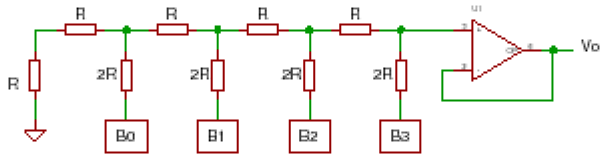


Figure 11

In the first ladder R is taken as R_{th} as shown in figure 12.

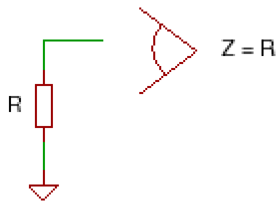


Figure 12

For the next ladder the equivalent Thevenin resistance is taken as the combination of R -2R resistance as shown in figure 13 and 14.

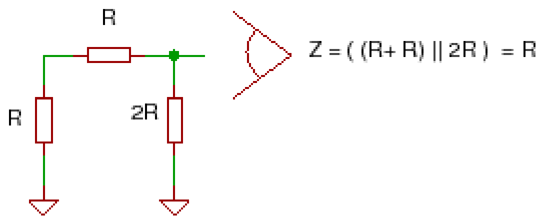


Figure 13

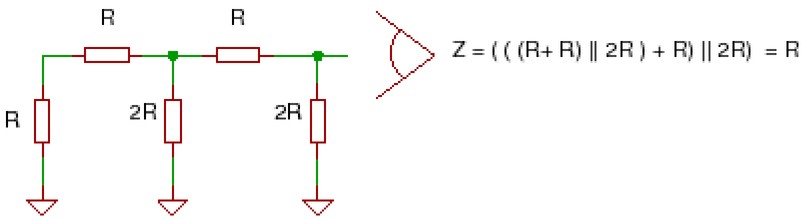


Figure 14

Using Thevenin's theorem you can work out the voltage contribution of each bit. A Thevenin's circuit is the equivalent of a network of resistances and voltage sources (and current sources). You can replace the network with a Thévenin equivalent circuit and it will work in exactly the same way as the original network.

To use the Thévenin theorem, replace all voltage sources with short circuits and all current sources with open circuits - calculate the resistance looking into the port for the Thévenin resistance Rth. For the Thévenin voltage, calculate the no load output voltage.

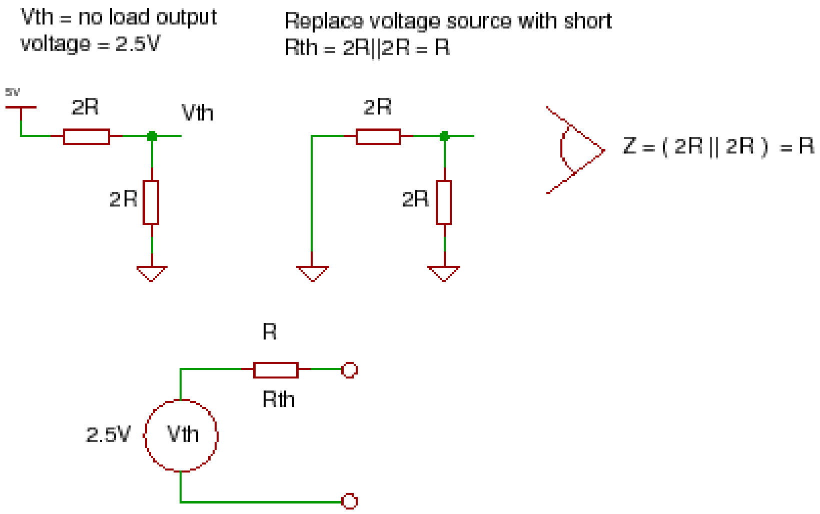


Figure 15

Contribution if bit 3 is active (the MSB):

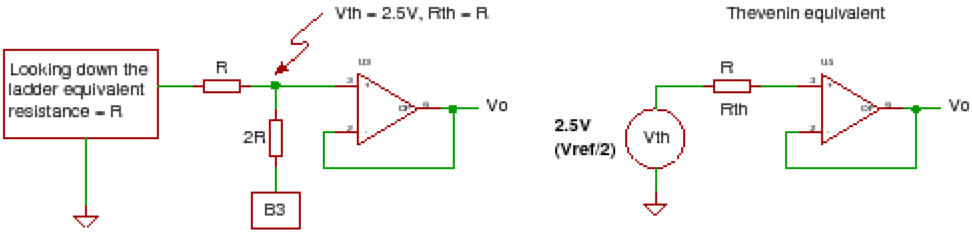


Figure 16

Contribution if bit 2 is active (the MSB):

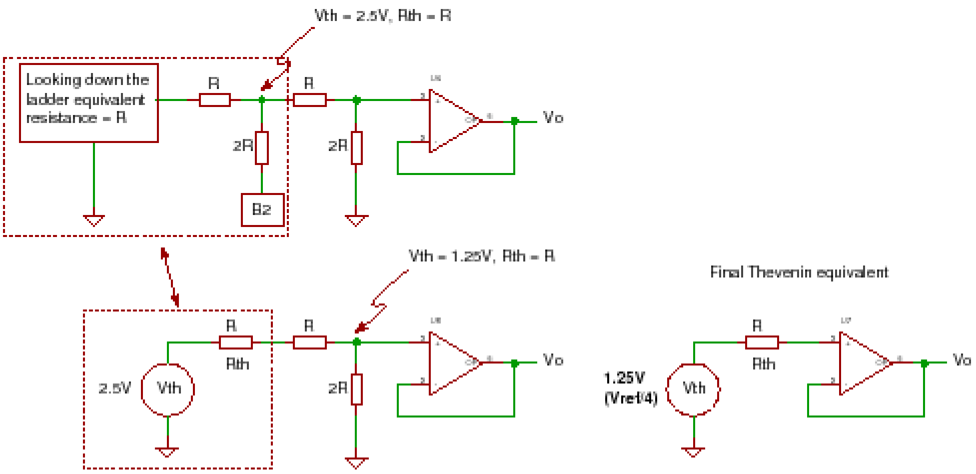


Figure 17

Contribution if bit 1 is active (the MSB):

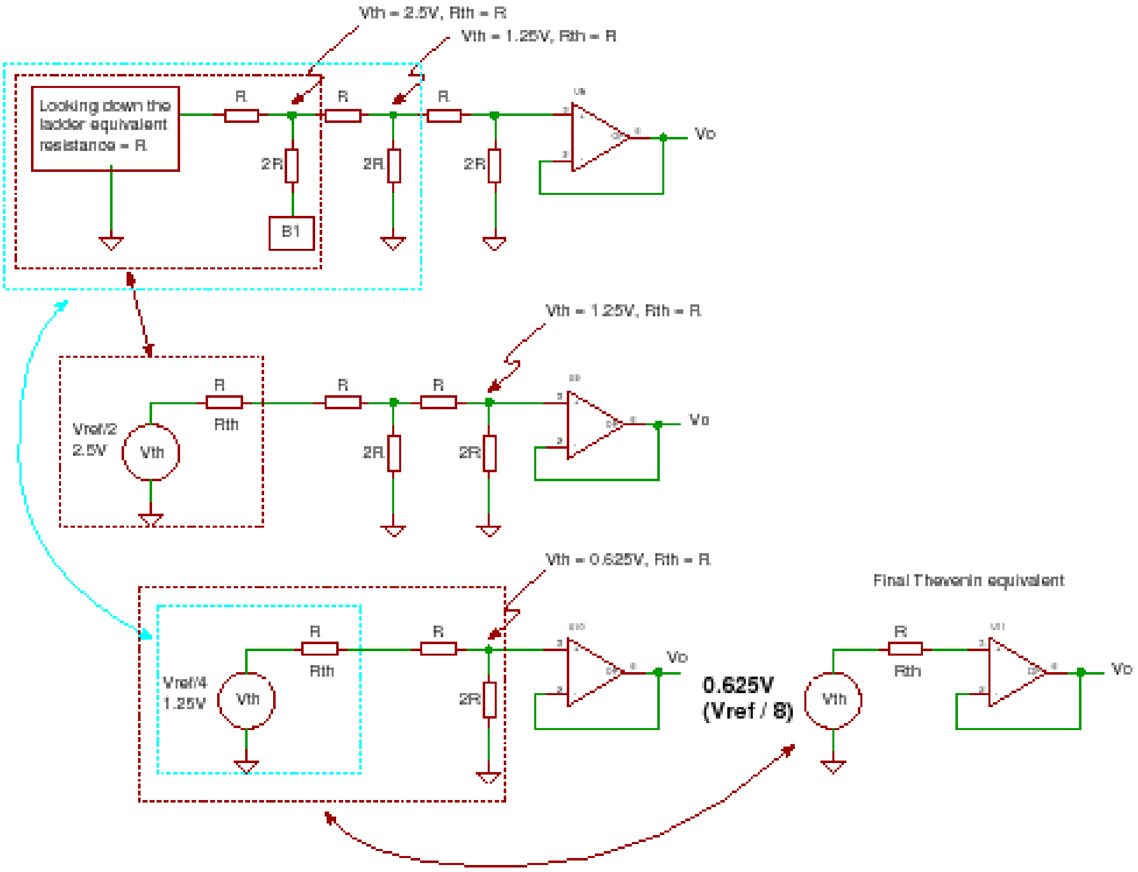


Figure 18

When each bit is active it contributes a binary weighted voltage to the output Vo.

QUESTIONS/ANSWERS

Q.1 To what type of circuit Thevenin's theorem is applicable?
A. Linear and bilateral

Q.2 What is the use of Thevenin's theorem?
A. To convert the complex ckt into a voltage source and a series resistance

Q.3 How R_{TH} is connected with the circuit?
A. In series

Q.4 How is R_{TH} connected with the load resistance?
A. In series

Q.5 What modification is done in galvanometer to convert it into an ammeter?
A. A large resistance in parallel

Q.6 What modification is done in the galvanometer to convert it into a voltmeter?
A. A series resistance

Q.7 Resistance is an active element or the passive?
A. Passive

Q.8 How will you calculate the R_{TH}?
A. The resistance between the two terminals by making all the sources as inactive.

Q.9 In place of current source, what is placed while calculating R_{TH}?
A. Replace current source by open ckt

Q.10 In place of voltage source which electrical parameters is placed?
A. A short ckt.

Q.11 What are the advantages of Thevenin's theorem?

i) It reduces a complex circuit to a simple circuit.

ii) It greatly simplifies the portion of the circuit of the lesser importance and enables us to view the action of the part directly.

iiii) This is particularly useful to find current in a particular branch of a network as the resistance of that branch is varied while all other resistances and e.m.f sources remain constant.

Experiment 1.b(Maximum power transfer Theorem)

Components Required :

S.No.	Name of the Components/Equipment	Range	Type	Quantity required
1	Resistor	100Ω, 560Ω, 270Ω	Wire wound	Each 1
2	DC power supply	(0-30)V	RPS	1
3	Voltmeter	(0-30)V	MC	1
4	Ammeter	(0-100)mA	MC	1
5	Wires	-	Single strand	Few nos
6	Bread board	-	-	1
7	Decade resistance box	(0-10KΩ)		1

Statement of the theorem:

The Maximum Power Transfer Theorem states that maximum power is delivered from a source to a load when the load resistance is equal to source resistance.

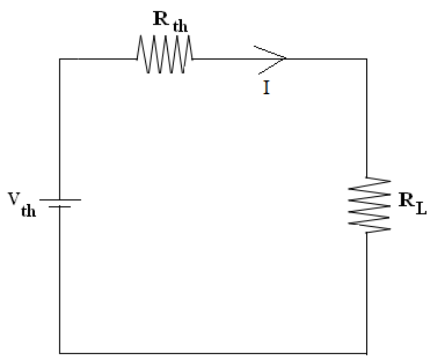


Figure 19

In the thevenin's equivalent circuit, the maximum power will be delivered from source to the load when the load resistance (R_L) is equal to the thevenin's resistance (R_{th}).

Circuit 1:

For finding the thevenin's equivalent circuit, the steps 1 to 4 in the experiment 1.a is repeated. Then as per the maximum power transfer theorem, maximum power will be delivered to the load when the load resistance is equal to the internal or thevenin's resistance of the network.

For the given problem in experiment 1,

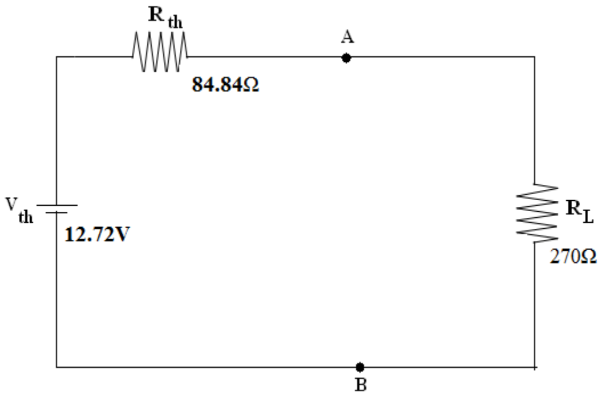


Figure 20

The power delivered to the load can be calculated theoretically as follows:

S.No	R_L	R_{TH}	I_L(mA)	$P_L=I_L^2R_L$(mW)
1	50	84.84	94.33	444.9
2	60	84.84	87	462.7
3	84.84	84.84	74.96	476
4	100	84.84	68.8	473.5
5	200	84.84	44.65	398.8
6	270	84.84	35.8	346.9
7	300	84.84	33	327.7

Practical Circuit:

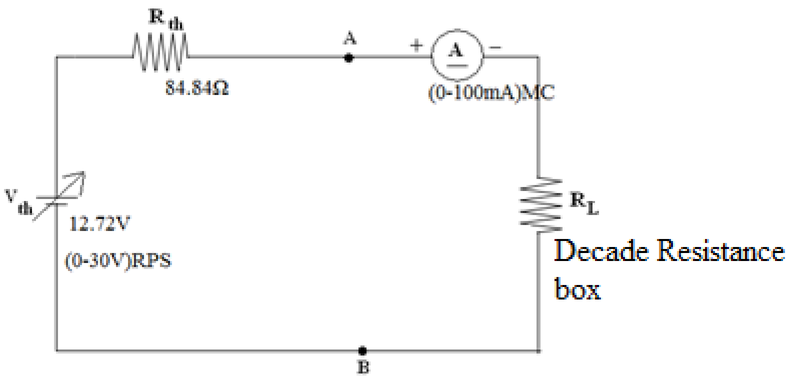


Figure 21

Model Graph

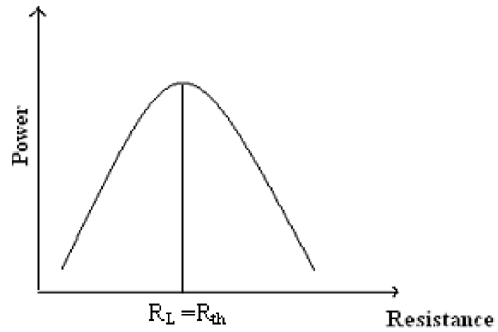
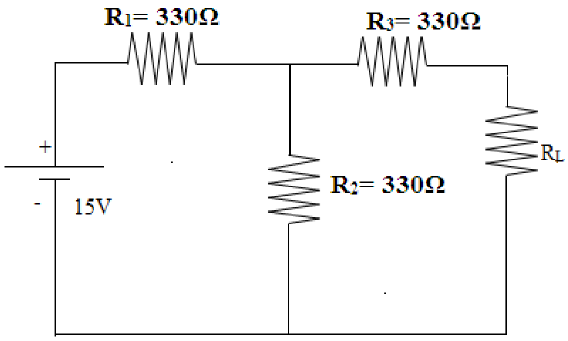


Figure 22

Circuit 2:



Find the maximum power delivered to the load using maximum power transfer theorem.

Application Circuit:

Example 1

Consider the practical example of a speaker with an impedance of 8 ohms is driven by audio amplifier with its internal impedance of 500 ohms. The Thevenin's equivalent circuit is also shown in figure.

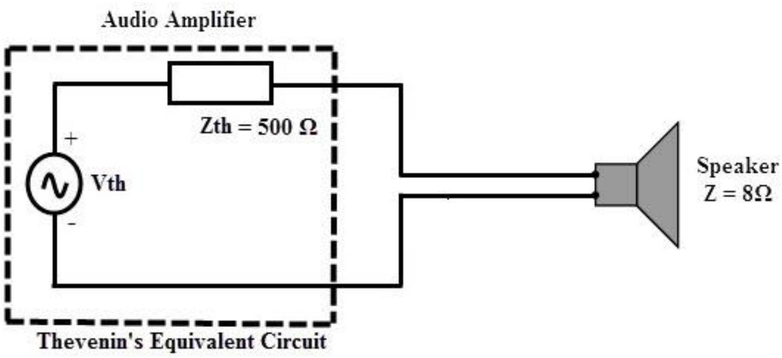


Figure 23

According to the maximum power transfer theorem, the power is maximized at the load if the load impedance is 500 ohms (same as internal impedance). Or else internal resistance has to be changed to 8 ohms to achieve the condition however it is not possible. So it is an impedance mismatch condition and it can be overcome by using an impedance matching transformer with its impedance transformation ratio of 500:8.

Q.1 What is load matching?
A. The process of adjusting the load resistance for maximum power transfer is called load Matching

Q.2 What is max power transfer formula?
A. $P_{max}=E_{th}^2/4R_L$

Q.3 What is the field of application of this theorem?
A. Motorcars, Telephone lines and TV aerial leads

Q.4 What is electric network?
A. An electric circuit arises when a no. of parameters or electric elements coexist or combine in a certain arrangement.

Q.5 What is necessary to know the polarity of voltage drop across a resistance?
A. Direction of current through the resistance.

Q.6 What is the reason that terminal voltage is less than emf?
A. Because there is some drop across the internal resistance.

Q.7 What is the resistance of ideal voltage source?
A. Zero
Q.8 When will the power extracted from a circuit is maximum?
A. When R_L is equal to the internal resistance of the circuit.

Q.9 How is the ammeter connected in circuit?
A. In series

Q.10 To find the voltage drop across a resistance, where should the voltmeter be connected?
A. In parallel.

Software

1. Open LTspice.

2. Open a new file – **File**, **New Schematic**.

3. Get the components you will need. For resistors, capacitors, inductors and diodes you will see shortcuts on the top toolbar (, , and respectively). For other components (as well as the aforementioned ones) click . A new window will appear. This gives access to a huge library of pre-defined components. For example, if you use the scrollbar to scroll across you will come to **res**. Click on this and a box will appear with the circuit symbol for a resistor and some text to confirm that it is indeed a resistor. If you now click on OK the box disappears and you will be able to place resistors on the main window by clicking the left hand mouse button. When you have enough resistors click the right hand mouse button to halt the procedure. You will also need a voltage source follow the same procedure as you did for resistors except click on **voltage** in the component list. Finally you will need a ground for your circuit. There is a shortcut for this on the top toolbar, click on and then place your ground on the main window. If everything has gone to plan then your main window should look something like Fig. 2 below.

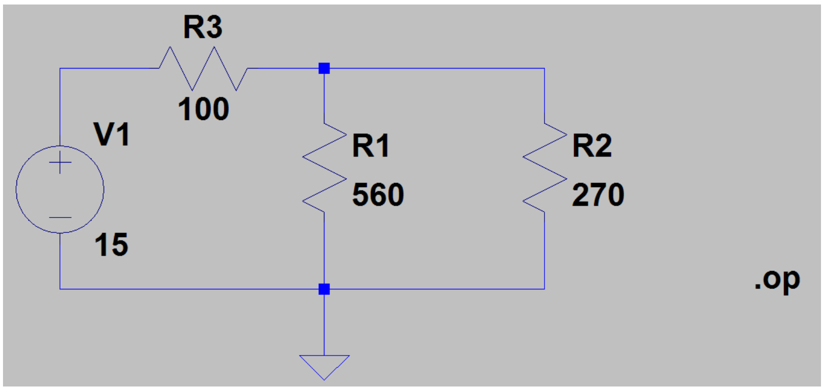


Figure 1

4. Now you need to orientate your components and wire them up into a circuit. Usually some sort of square formation works well. Accordingly, select one of your resistors. To do this, click on from the top toolbar, and then click on the resistor. Now enter Ctrl+r – this

rotates the resistor so that it is horizontal. Alternatively, select the component you want to rotate and click on the  symbol from the top toolbar. Click on the left mouse button. You can click on all of your components whilst  is highlighted and drag them to where you want them. Now wire up your circuit. To do this click on  from the top toolbar and align the cross-hairs that appears with one of the component terminals. Trace a path with the mouse in order to link the component with the next component in the circuit. Click the left mouse button if you need to put a right-angled bend into the wire. Also click the left mouse button when you reach the next component. You can repeat this process until all components form a circuit. Finally attach your ground point using the wiring tool. Notice that this creates a node, which appears as a square dot on your circuit. This square dot indicates that there is an electrical connection. In LTspice wires can cross each other without an electrical connection existing in that case there is no square dot. You should now have something like Fig. 3 below.

5. Now you need to give all your components values. For a resistor, point at the resistor and right click. A dialogue box will appear and you simply type the value of the resistor in the **Resistor[Ω]:** box. There are boxes for the resistor tolerance and power rating but these can be left blank. LTspice allows some useful abbreviations as follows:

p – pico = 10^{-12} , n – nano = 10^{-9} , u – micro = 10^{-6} , m – milli = 10^{-3} k – kilo = 10^{3} , meg – mega = 10^{6} , g – giga = 10^{9}

Thus, to enter a 1 MΩ resistor for example, you could either enter 1000000 or 1meg. For the voltage source, right click on it and a dialogue box will appear. You type the value of the DC voltage into the **DC value[V]:** box, and optionally a series resistance too. Notice that LTspice displays on the main window voltage source and series resistance values.

6. At this point your circuit is fully defined and so the next step is to simulate it. The only relevant simulation here is a DC analysis, known in LTspice as DC operating point. Click **Simulate**, **Edit Simulation Cmd** from the top toolbar and a dialogue box will appear. Note the various analysis modes available. Select **DC op pnt** and click **OK**. At this point the more basic side of LTspice is revealed. You will see that a box has appeared that you can drag around your schematic. Left click and in that box you will see the text **.op**. This is called an LTspice directive – originally this program was a purely command-line driven circuit simulator with no GUI, and as you have just seen, relics of this history still remain.

7. Now click **Simulate**, **Run**, or use the top toolbar shortcut  following this you will see a window appear containing the results of the simulation. If all is well, your screen should now look something like Figure 2 below.

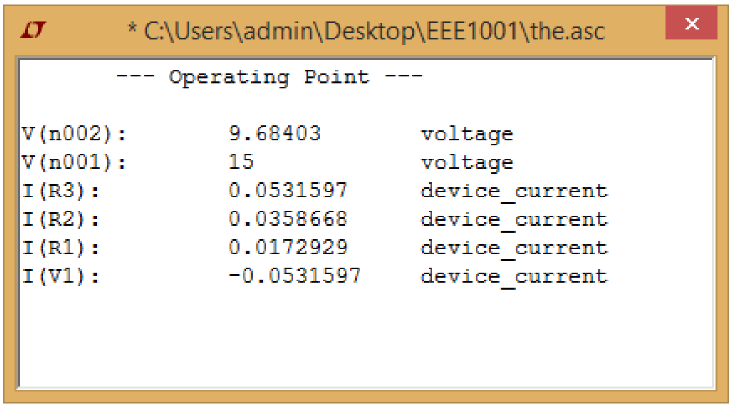


Figure 2

8. To verify thevenin's theorem, the thevenin voltage can be calculated as follows

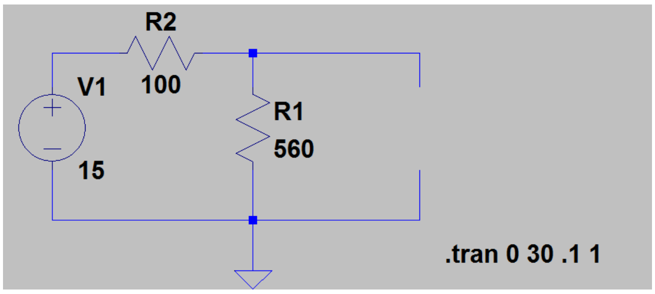


Figure 3

In simulate, go to edit simulation cmd and the give the values as follows.

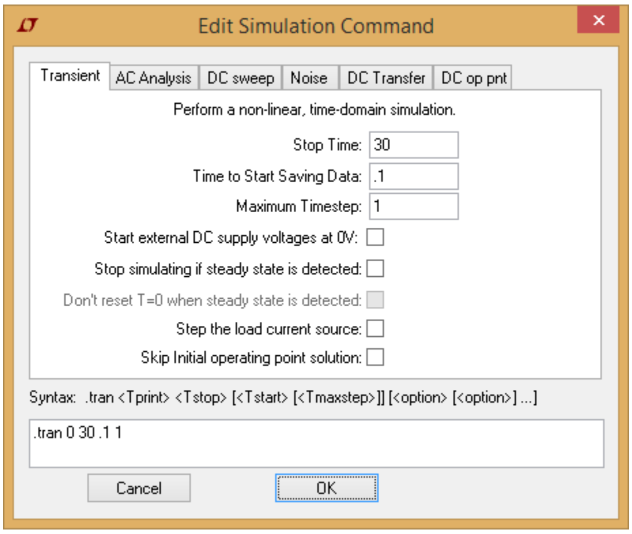


Figure 4

After entering the values, run the file. The result will display as follows

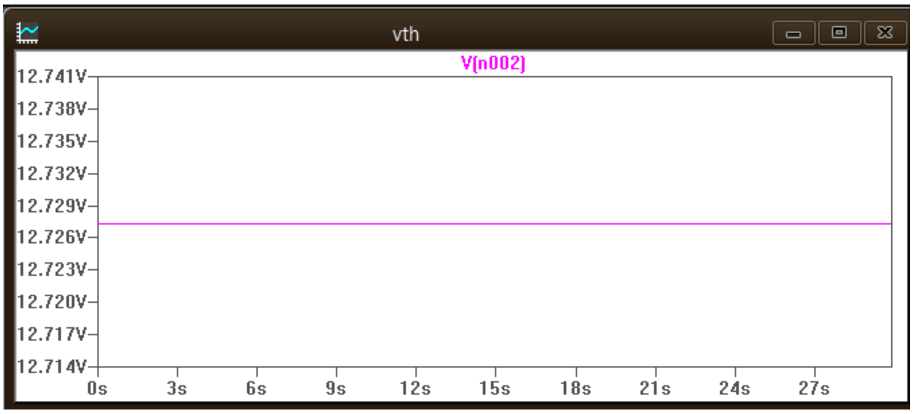


Figure 5

9. To find thevenin resistance, draw the following circuit,

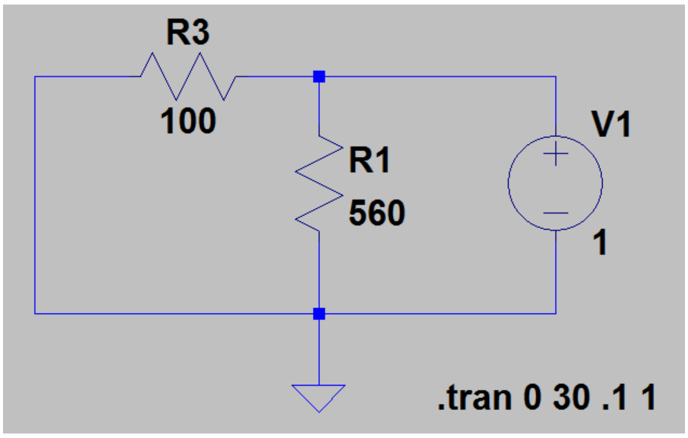


Figure 6

After running the simulation, we will get the result as follows.

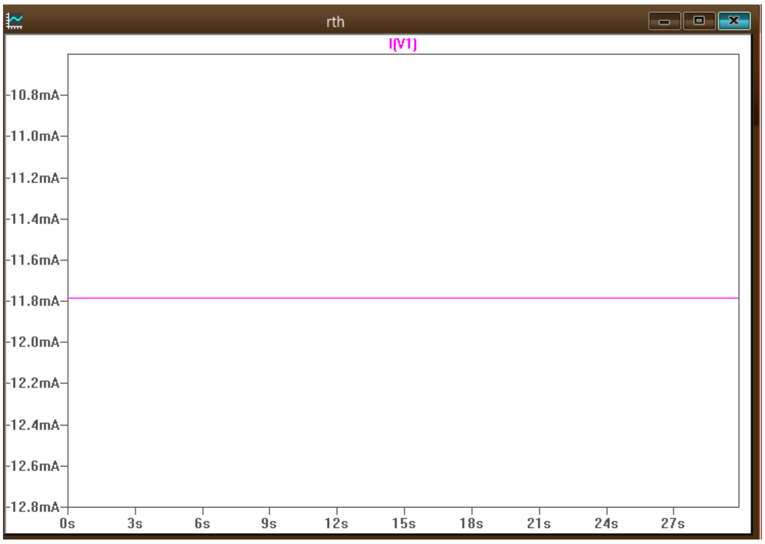


Figure 7

$R_{th}=\frac{V}{I}=\frac{1}{11.79*10^{-3}}=84.8\Omega$

10. Draw thevenin equivalent circuit as follows.

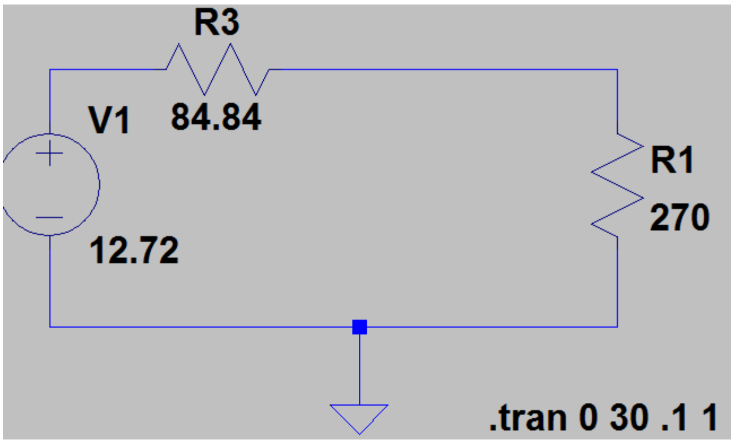


Figure 8

The result will give the current across 270Ω.

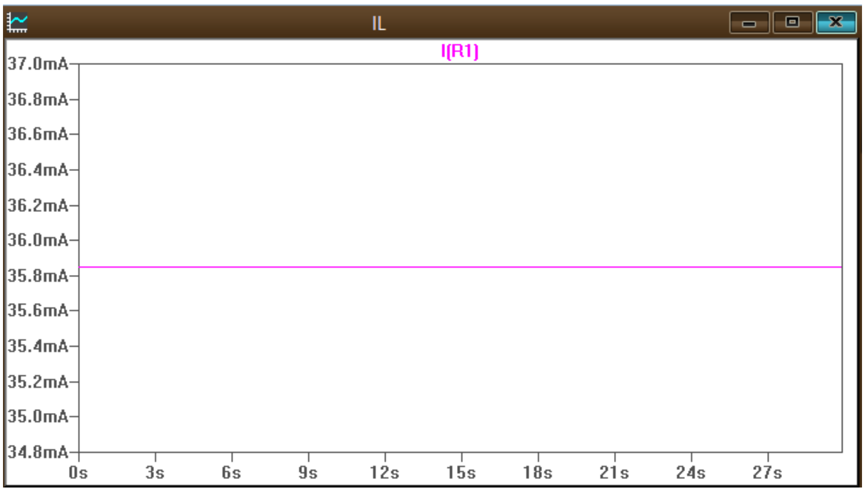


Figure 9

11. For maximum power transfer theorem, the same thevenin equivalent circuit is considered. In that circuit, for various values of load resistance, the current and power can be calculated and it is proved that the power will be maximum when the load resistance is equal to thevenin resistance. For other values of load resistance, the power will be less than the maximum and the graph will be

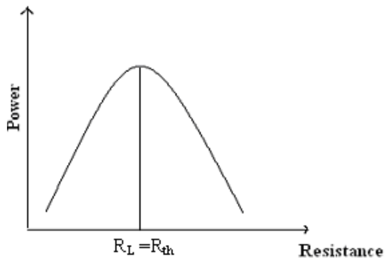


Figure 10

A graph of R_L Vs Power (P) is to be plotted and value of R_L for maximum power is to be determined**.**

Observations:

Values (ohms)	**Power (Watts)**
$R_L < R_{th}$	
$R_L < R_{th}$	
$R_L < R_{th}$	
$R_L = R_{th}$	
$R_L > R_{th}$	
$R_L > R_{th}$	
$R_L > R_{th}$	

Values	**Theoretical**	**Practical**
V_{th}		
R_{th}		
P_{max}		

Result:

Thus thevenin and Maximum Power Transfer theorem has been verified for the given circuit.