EET 1150

1. **LAB NUMBER:** **6**

2. **TITLE:** **Thévenin and Norton Theorems and Maximum Power Transfer**

3. **OBJECTIVES:**

After completing this lab, the student will be able to:

1. determine experimentally the parameters of the Thévenin and Norton equivalent circuits,
2. verify the validity of the theorems,
3. verify the validity of the Maximum Power Transfer Theorem.

4. **EQUIPMENT:**

METEX MS-9150 Generator
Oscilloscope
Experimenter board

5. **COMPONENTS:**

1 - 10 Ω ½ watt 5% Resistor
2 - 100 Ω ½ watt 5% Resistor
1 - 470 Ω ½ watt 5% Resistor
1 - 510 Ω ½ watt 5% Resistor
1 - 560 Ω ½ watt 5% Resistor
2 - 1000 Ω ½ watt 5% Resistor
4 - 33 nF Capacitor
1 - 15 mH Inductor

6. **TEXT REFERENCE:**

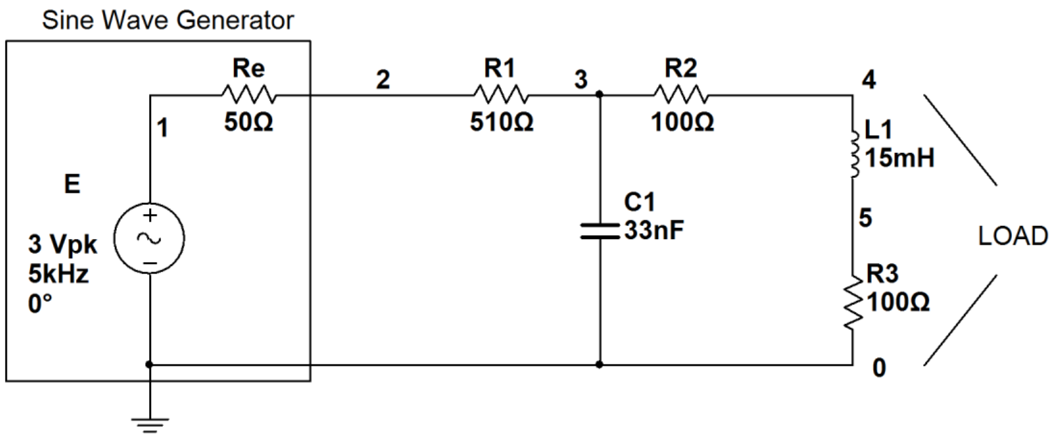
Circuit Analysis: Theory and Practice (5th Edition):
A.H. Robbins and W.C. Miller

Section 20.3: Thévenin's Theorem – Independent Source
Section 20.4: Norton's Theorem – Independent Source
Section 20.6: Maximum Power Transfer Theorem

7. PRE-LAB ASSIGMENT:

Study Fig. 1 and do the following calculations:
(Attach all your calculations as an Appendix at the end of your team's Report).

Figure 1:



A – Calculation of Z_{TH} (Z_N):

a) Redraw the circuit with the Load between points "4-0" removed and the source E shorted. Calculate the equivalent impedance Z_{TH} (or Z_N), taking Re into account. Record your result in Table 1.

Table 1:

Z_{TH} (Z_N)
Ω< °

B – Calculation of E_{TH}:

b) With the Load still removed, and E attached, calculate the voltage (that can be measured) between points "4-0 ", that voltage is E_{TH}. Don't forget to convert E into phasor form with magnitude in RMS. Record your result in Table 2.

Table 2:

E_{TH}
V< °

C – Calculation of I_N:

c) To calculate the Norton's equivalent current (I_N), draw a short between points "4-0" then calculate the current that flows in the short.

Note the direction of this current as it affects the direction of the Norton Current Source. Record your result in Table 3.

Table 3:

I_N
mA< °

d) Draw the Thévenin's and Norton's equivalent circuits.

D – Calculation of R_L for Relative Maximum Power:

e) Look at the result in Table 1 for Z_{TH} (use rectangular form) to decide if a condition for Absolute Maximum Power can be achieved. If not, calculate the value of the load Resistance R_L for Relative Maximum Power using the following formula:

$$R_L = \sqrt{R_{TH}^2 + (X_L - X_{TH})^2} \qquad \text{(Section 20.6)}$$

Table 4:

R_L
Ω

8. MEASUREMENTS:

A – Measurement of E_{TH} :

a) Connect CH1 of the oscilloscope directly to the output of the Sine Wave Generator. Increase the output until the oscilloscope shows a 3 V peak at 5 kHz. This is the no load value of the source E without any loss across Re (50 Ω).

b) Build the circuit of Fig. 1 without the load connected between points "4-0". CH1 is still connected at the output of the Generator (point "2"). Connect CH2 at point "4" to measure the open circuit voltage across the output "4-0". Record both magnitude (in RMS) and phase of this voltage in Table 5; it is E_{TH} .

Table 5:

E_{TH}
V< °

c) Compare Table 5 to Table 2.

B – Measurement of I_N :

d) Use a 10 Ω sense resistor connected between points “4-0” to simulate a short circuit condition. Connect CH2 to measure the magnitude (convert to RMS) and phase of the voltage <u>across this sense resistor</u>. Calculate the short circuit current, it is I_N . Record your result in Table 6.

<u>Table 6:</u>

Vsense	I_N
mV< °	mA< °

e) Compare Table 6 to Table 3.

C – Determination of Z_{TH} (Z_N):

f) We cannot measure Z_{TH} directly, but we can determine it indirectly through the relationship between Thévenin and Norton circuits, that is:

$$Z_{TH} = \frac{E_{TH}}{I_N}$$

g) Use the results of Tables 5 and 6 to calculate Z_{TH} .
Record your result in Table 7

<u>Table 7:</u>

Z_{TH} (Z_N)
Ω< °

h) Compare Table 7 to Table 1.

D – Compare Original circuit and Thévenin’s Equivalent circuit:

i) Add the load to points “4-0” of the original circuit of Fig. 1. Connect CH2 to point “5” and measure the voltage across this resistor (VR3); this voltage will give you the magnitude and phase of the Load Current I_L . Record your result in Table 8.

<u>Table 8:</u>

VR3	I_L
V< °	mA< °

j) Build the Thévenin’s equivalent circuit using the values in Tables 5 and 7. You must first re-adjust the source E <u>without anything connected</u> to the value of E_{TH} then use the available components either in series or parallel to create a simple network with an impedance equal to (or within 5% of) Z_{TH} **.**

k) Draw this circuit and build it with the same Load attached. CH1 is still connected at the output of the Generator, CH2 is connected at point "5" to measure new VR3. Record your results in Table 9.

Table 9:

VR3	I_L
V< °	mA< °

l) Compare Table 8 to Table 9.

E – Relative Maximum Power:

m) Change the value of R3 to five different values as in Table 10 (including R_L**,** we can use the approximate value of 560Ω). Use CH2 to determine the magnitude (RMS) of the voltage across this resistor. From these voltages, calculate the Power dissipated in this resistor. Record your results in Table 10.

Table 10:

R3 (Ω)	VR3 (V)	P (mW)
100		
200		
R_L (560)		
1000		
2000		

n) Plot a curve showing Power as a function of R3. Does a curve show a maximum point?

9. LAB REPORT REQUIREMENT:

Your team's Lab Report should contain the followings:

A Cover Page with Lab Number, Lab Title, Team members' Names and Date.
An Introductory Page with list of Equipment and Components used.

Result Pages with:

A – Measurement of E_{TH} :

Procedure:

(Summarize the main activities that your team did (past tense) in this section).

Results:

Show a copy of Table 5.

Discussions:

1) Answer 8 (c).
2) Discuss factors that cause the differences in results.

B – Measurement of I_N :

Procedure:

(Summarize the main activities that your team did (past tense) in this section).

Results:

Show a copy of Table 6.

Discussions:

1) Answer 8 (e).
2) Discuss factors that cause the differences in results.

C – Determination of Z_{TH} (Z_N):

Procedure:

(Summarize the main activities that your team did (past tense) in this section).

Results:

Show a copy of Table 7.

Discussions:

1) Answer 8 (h).
2) Discuss factors that cause the differences in results.
3) Explain why we cannot measure Z_{TH} using a meter like a DMM.

D – Compare Original circuit and Thévenin's Equivalent circuit:

Procedure:

(Summarize the main activities that your team did (past tense) in this section).

Results:

Show copies of Tables 8 and 9.

Discussions:

1) Answer 8 (l).
2) Discuss factors that cause the differences in results.
3) As far as the Load is concerned, are the two circuits equivalent?

E – Relative Maximum Power:

Procedure:

(Summarize the main activities that your team did (past tense) in this section).

Results:

Show a copy of Table 10.
Show the Power vs. R3 curve

Discussions:

1) Answer 8 (n).
2) Instead of using individual R3's, what type of component can we use to have a better (smoother) curve?

F – Conclusions:

1) Are the Thévenin and Norton theorems valid? Explain your answer.

2) How accurate is the formula for Relative Maximum Power? Explain your answer.

3) Are all the Lab Objectives met? Explain if some are not.

Appendix:

Attach all your Pre-Lab calculations.