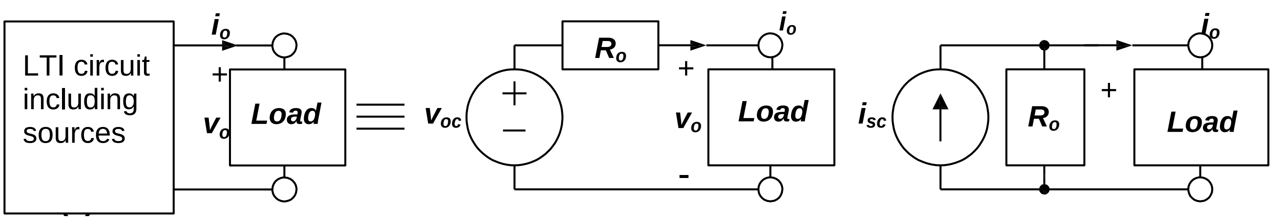
Basics of Electrical and Electronic Circuits

Experiment 04 **Spring 2025**

Thevenin's and Maximum Power Transfer Theorems

Thevenin's and Norton's theorems enable us to construct very simple models to represent a linear time-invariant circuit including independent voltage/current sources, as "seen" by a load connected between any pair of terminals of the circuit. The general structures of Thevenin and Norton equivalents are shown in **Fig.1**. v_{OC}(**Open-Circuit Voltage**) denotes the voltage v_O measured between the terminals when the load is an open-circuit (i_O = 0), and i_{SC} (**Short- Circuit Current**) denotes the current i_O flowing into the load when the load is a short-circuit (v_O= 0). R_o denotes the **Output Resistance** of the circuit, defined to be the resistance measured between the two terminals of the circuit with the load disconnected and all **independent** sources "removed" (replaced with internal resistance) from /within the circuit. It can be proved that R_O is given by the ratio of the open-circuit voltage v_{OC} and the i_{SC}: $R_O = v_{OC} / i_{SC} = R_{th}$ Thus the Thevenin and Norton equivalents for any given circuit can be obtained if the values of v_{OC} and i_{SC} are measured. But exact open- circuit (i_O = 0) and short-circuit (v_o = 0) conditions are difficult to achieve in practice, and hence one measures v_O and i_O for several values of R_L and determines v_{OC} and i_{SC} by extrapolation.



(a) Actual Circuit **(b) Thevenin Equivalent** **(c) Norton Equivalent**

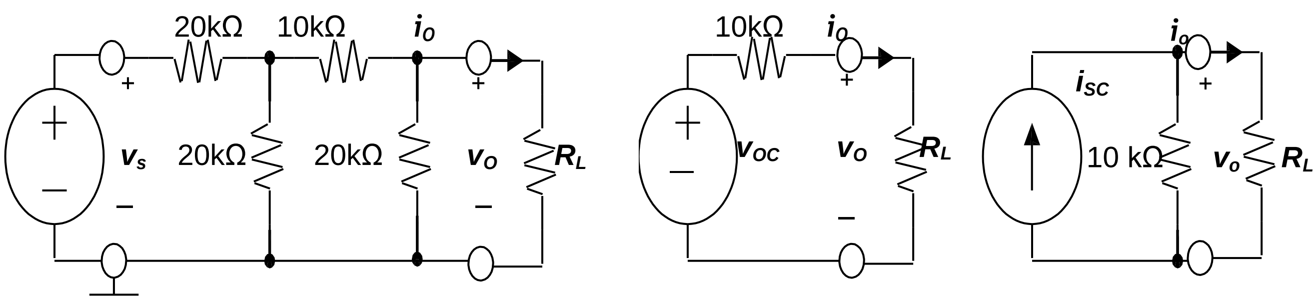
Fig. 1 Equivalent circuits based on Thevenin's and Norton's theorems

The Thevenin resistance, Thevenin voltage and Norton current are related by

$$R_{th} = V_{th} / I_N$$

A. <u>Thevenin and Norton equivalents for resistive load</u>

1. Assemble the resistive circuit shown in **Fig. 2(a)**, where R_L denotes the load resistance and v_S is the WAVEGEN output. Set the WAVEGEN for a **1kHz** sinusoidal output having V_{pp}= 4V and offset = 2V, so that we can expect the voltage v_S to have a minimum level = **0V** and a maximum level = **4V**. However, as WAVEGEN output levels are not very precise, set the Y1 and Y2 cursors precisely at the levels 0V and 4V, and adjust the settings of V_{pp} and offset of the WAVEGEN repetitively to obtain the **minimum** and **maximum** levels of v_S at 0V and 4V **exactly**, as desired.



(a) Actual Circuit **(b) Thevenin Equivalent** **(c) Norton Equivalent**

Fig. 2 Resistive circuit with Resistive Load

2. Verify that the circuit of **Fig. 2(a)** gets reduced by repeated source transformations to the two equivalents given in **Fig. 2(b)** and **Fig. 2(c)**, where Thevenin's voltage $V_{th} = v_{OC} = v_S/4$ and Norton's current $I_N = i_{SC} = v_S/(40k\Omega)$.
3. Measure the **minimum** and **maximum** levels of the output voltage v_O in the circuit of **Fig.2(a)** with the DSO for the following 7 values of the load resistance R_L: 1.00, 2.20, 4.70,10.0, 22.0, 47.0 and 100 (all in kΩ). Verify that the minimum level is close to zero in all cases and plot the **peak-to-peak /rms** value of v_O against the **peak-to-peak/rms** value of i_O on a linear graph paper and draw the best approximation of a straight line passing through the points corresponding to different values of R_L.

Table-1: Measurement Table for given circuit (Fig. 2a)

Load Resistance (R_L)	v_o (min)	v_o (max)	$v_{o(rms)}$	$i_{o(rms)} = v_{o(rms)}/R_L$	Power ($v_{rms} * i_{rms}$)

Also save /draw input and output waveforms.

4. Determine the **peak-to-peak** values of the **Open-Circuit Voltage** v_{OC} and the **Short-Circuit Current** i_{SC} from the intercepts of the straight line on the two axes and hence calculate the value of the **Output Resistance** $R_O = R_{th}\ v_{OC}/i_{SC}$. Verify/compare that, this value is the same as the value R_{th} and R_N indicated in the equivalent circuits of **Fig. 2(b)** and **Fig. 2(c)** respectively.

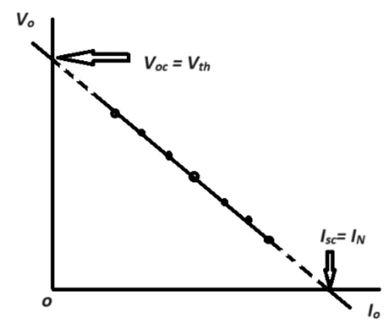


Fig.3. v_o **and** i_o **plot to extract** V_{th} **and** I_N

5. Connect a **0.01μF capacitor** as the **Load** instead of the resistance R_L in the circuit of **Fig.2(a)**. Sketch the input and output waveforms and measure the **minimum** and **maximum** levels of the output voltage v_O.
6. Connect the given **diode** as the **Load** instead of the resistance R_L in the circuit of **Fig.2(a)**. Choose the polarity of the diode so as to ensure the flow of current through the diode. Sketch the input and output waveforms and measure the **minimum** and **maximum** levels of the output voltage v_O.

Table-2: Measurement Table for given circuit (Fig. 2a)

Load	v_o (min)	v_o (max)	$v_{o(rms)}$	$i_{o(rms)} = v_{o(rms)}/R_L$	Power ($v_{rms} * i_{rms}$)
Capacitor(0.01 μF)					
Diode					

B. <u>Thevenin equivalent with Resistive, Capacitive and Nonlinear Loads</u>

1. Now set up the Thevenin equivalent circuit given in **Fig. 2(b)**, with a Load Resistance R_L =10kΩ, and adjust the **maximum** level of the WAVEGEN output to **1V**, keeping the **minimum** level at **0V**, so that the input voltage is the same as expected value of v_{OC} (= $v_S/4$). Measure the **minimum** and **maximum** levels of the output voltage v_O and

compare these values with the values measured in step **A.3** for the same Load Resistance (R_L = 10kΩ).

2. Now connect the same **0.01μF capacitor** as used in step **A.5** as the Load instead of the 10kΩ resistor in the circuit of **Fig. 2(b)**. Sketch the input and output waveforms and measure the **minimum** and **maximum** levels of the output voltage v_O. Compare these measured values with those obtained in step **A.5**.

4. Now connect the same **diode** as used in step **A.6** as the Load instead of the 10kΩ resistor in the circuit of **Fig. 2(b)**. Sketch the input and output waveforms and measure the **minimum** and **maximum** levels of the output voltage v_O. Compare these measured values with those obtained in step **A.6**.

Table-3: Measurement Table for given circuit (Fig. 2b)

Load	v_o (min)	v_o (max)	$v_{o(rms)}$	$i_{o(rms)} = v_{o(rms)}/R_L$	Power ($v_{rms} * i_{rms}$)
R_L = 10kΩ					
Capacitor(0.01 μF)					
Diode					

C. <u>Verification of Maximum Power Transfer Theorem</u>: Plot Power (P) with respect to R_L values obtained in Table-1. Identify the maximum power transfer condition (i.e. the value of load resistor R_L and its relationship with R_{th} at which P_{max} occurs) and find the P_{max} value.

Results:

Conclusion: It must be in your words and be based on your understanding/ learning in the experiment.