

Experiment #2

NETWORK THEOREMS

Objective

- To be able to reduce a complex network to a simple circuit which acts the same way

Apparatus

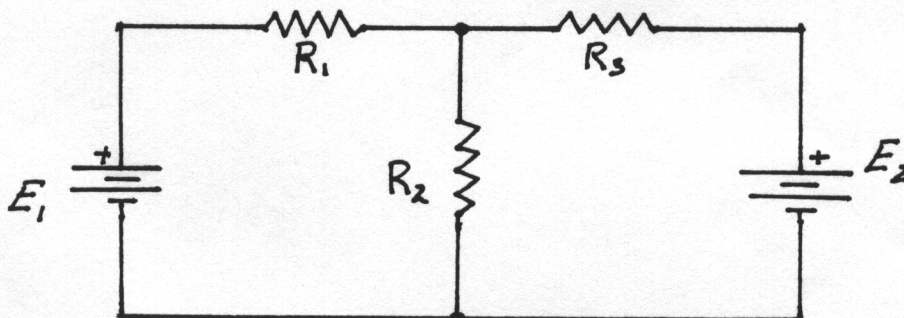
DC power supplies
DC voltmeter
DC milliammeter
resistors as required
1KOhm pot

Superposition Theorem

Any complex network of voltage sources and resistors can be reduced to as many individual circuits as there are sources. For example, if a network has 2 voltage sources, we calculate each voltage drop of each resistor with only one source at a time. The other source is replaced by its characteristic internal impedance (a short circuit for a voltage source). Then the voltage drops are calculated, with the other voltage source connected to the circuit and the first one replaced by a short circuit.

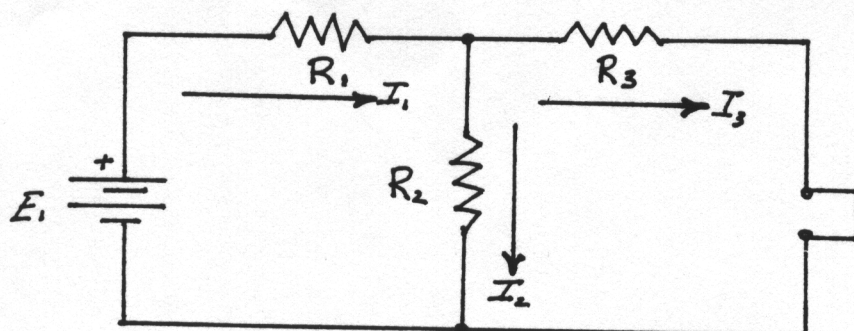
The algebraic sum of the voltage drops is the actual voltage drop across the resistor.

Example:



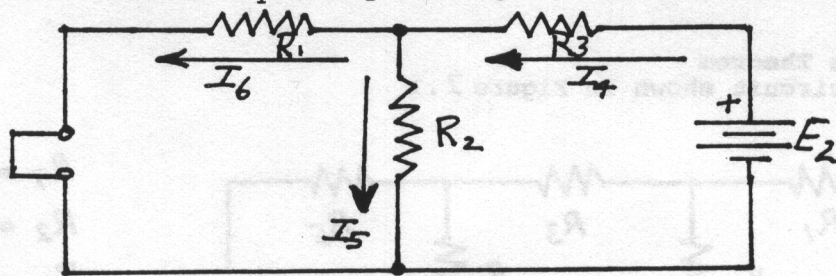
Be careful in observing polarity. Current flows from positive to negative.

Assume E_1 is in the circuit and E_2 is replaced by a short circuit.



current flows in
directions as shown by
the arrows

Now E_2 is in the circuit and E_1 is replaced by a short circuit:



The algebraic sums of currents will be

$$I_{R_1} = I_1 - I_6$$

$$I_{R_2} = I_2 + I_5$$

$$I_{R_3} = I_3 - I_4$$

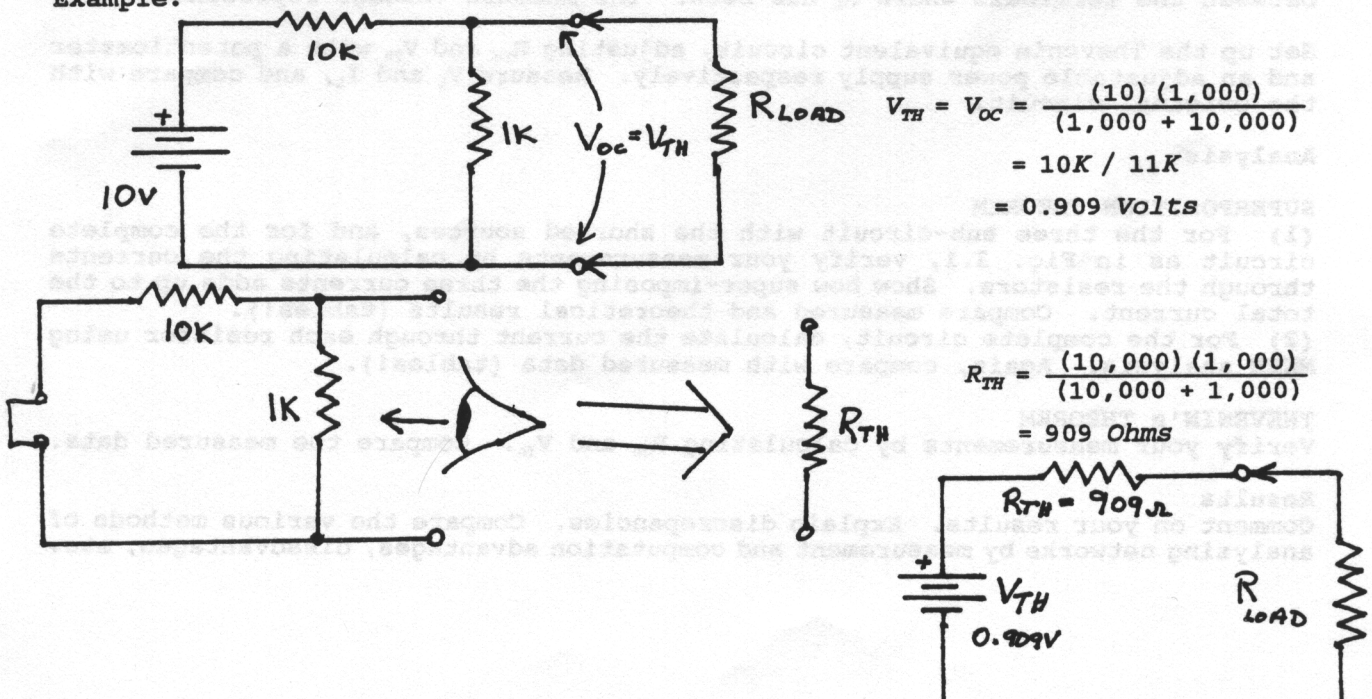
If two currents flow through the same resistor in the same direction, their algebraic sum is additive, if the currents are of the opposite direction the algebraic sum is subtractive.

Thevenin's Theorem

Any two terminal network of fixed resistors and voltage sources can be replaced by a single source of voltage E (or emf (electromotive force)) and a single series resistor R .

The " E " is the "open circuit voltage of the network and the " R " is the total equivalent resistance of the network as seen "looking" back into the output terminals towards the source with the load removed and with the source replaced by its characteristic impedance (which is ideally = zero).

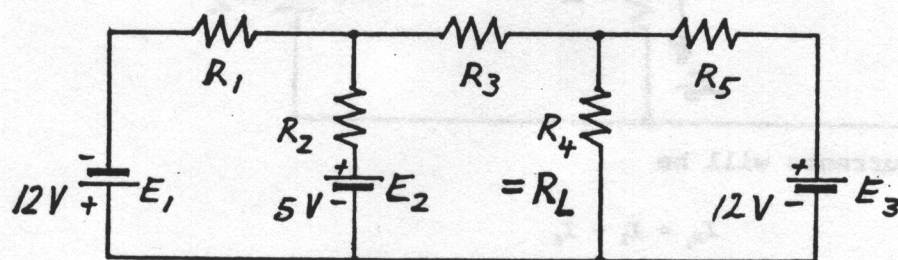
Example:



Procedures

Superposition Theorem

Connect the circuit shown in Figure 2.1



$$\begin{aligned} R_1 &= 1.0 \text{ k}\Omega \\ R_2 &= 2.2 \text{ k}\Omega \\ R_3 &= 680 \Omega \\ R_4 &= 470 \Omega = R_L \\ R_5 &= 1.5 \text{ k}\Omega \end{aligned}$$

Figure 2.1

(1) To use the superposition theorem, remove one source at a time, replace it with a short (jumper), and measure the current through each resistor of the remaining circuit (to measure the current it is easier to measure the voltage across the resistor and divide by its nominal resistance). Super-impose the currents of the three circuits measured this way (be careful about the directions of the currents!). (2) Then apply all three sources at the same time - the resulting currents should match the sum of the three currents found in the step above. (3) Consider R_4 as representing a certain load R_L . Note the load voltage V_L across R_L and the load current I_L .

Thevenin's Theorem

Using the same circuit as above, and taking $R_4 = R_L$ as a load resistor, find R_{Th} , V_{Th} and the Thevenin equivalent circuit.

To find R_{Th} : Remove all sources and replace them with shorts (jumpers). Remove R_L . Insert an Ohmmeter where R_L has been. Measured resistance represents R_{Th} .

To find V_{Th} : Reconnect all sources, but keep R_L still out. Measure the voltage between the terminals where R_L has been. The measure voltage represents V_{Th} .

Set up the Thevenin equivalent circuit, adjusting R_{Th} and V_{Th} with a potentiometer and an adjustable power supply respectively. Measure V_L and I_L , and compare with the original circuit.

Analysis

SUPERPOSITION THEOREM

(1) For the three sub-circuit with the shorted sources, and for the complete circuit as in Fig. 3.1, verify your measurements by calculating the currents through the resistors. Show how super-imposing the three currents adds up to the total current. Compare measured and theoretical results (tables!).

(2) For the complete circuit, calculate the current through each resistor using MESH analysis. Again, compare with measured data (tables!).

THEVENIN'S THEOREM

Verify your measurements by calculating R_{Th} and V_{Th} . Compare the measured data.

Results

Comment on your results. Explain discrepancies. Compare the various methods of analyzing networks by measurement and computation advantages, disadvantages, etc.