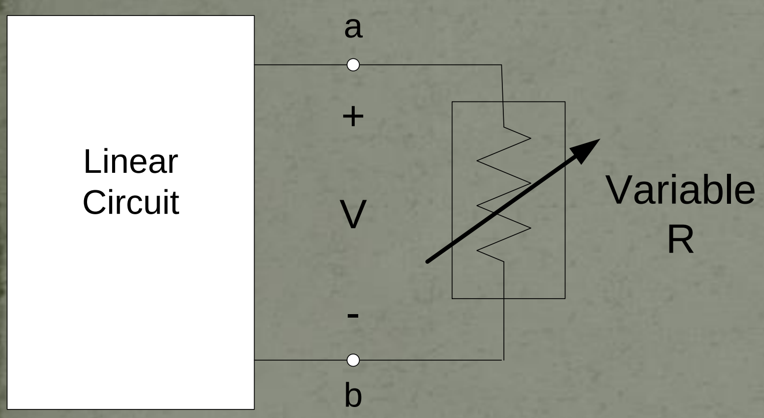
Circuit Theorems

- Linear Circuits and Superposition
- **Thevenin's Theorem**
- Norton's Theorem
- Maximum Power Transfer

Thevenin's Theorem

In many applications we want to find the response to a particular element which may, at least at the design stage, be variable.

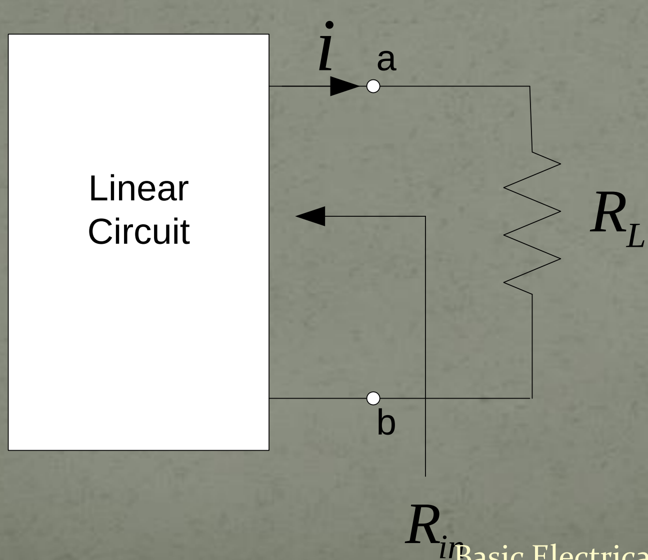


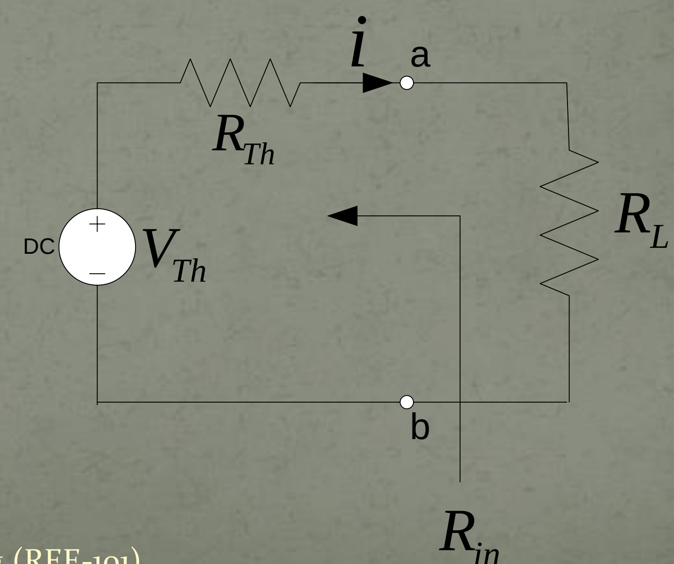
Each time the variable element changes we have to re-analyze the entire circuit. To avoid this we would like to have a technique that replaces the linear circuit by something simple that facilitates the analysis.

A good approach would be to have a simple **equivalent circuit** to replace everything in the circuit except for the variable part (the load).

Thevenin's Theorem

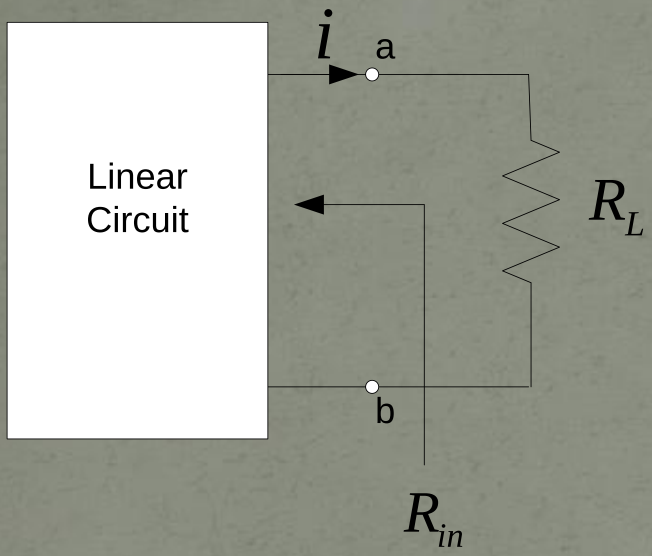
Thevenin's theorem states that a linear two-terminal resistive circuit can be replaced by an equivalent circuit consisting of a voltage source V_{Th} in series with a resistor R_{Th}, where V_{Th} is the open-circuit voltage at the terminals, and R_{Th} is the input or equivalent resistance at the terminals when the independent sources are all turned off.

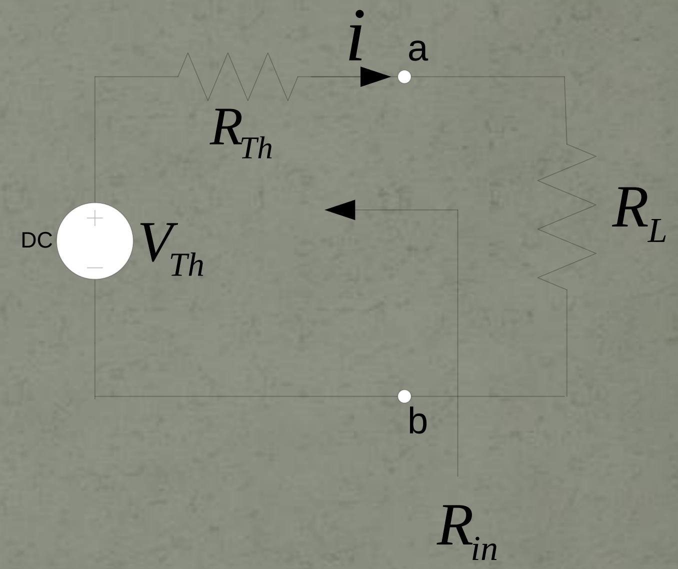




Thevenin's Theorem

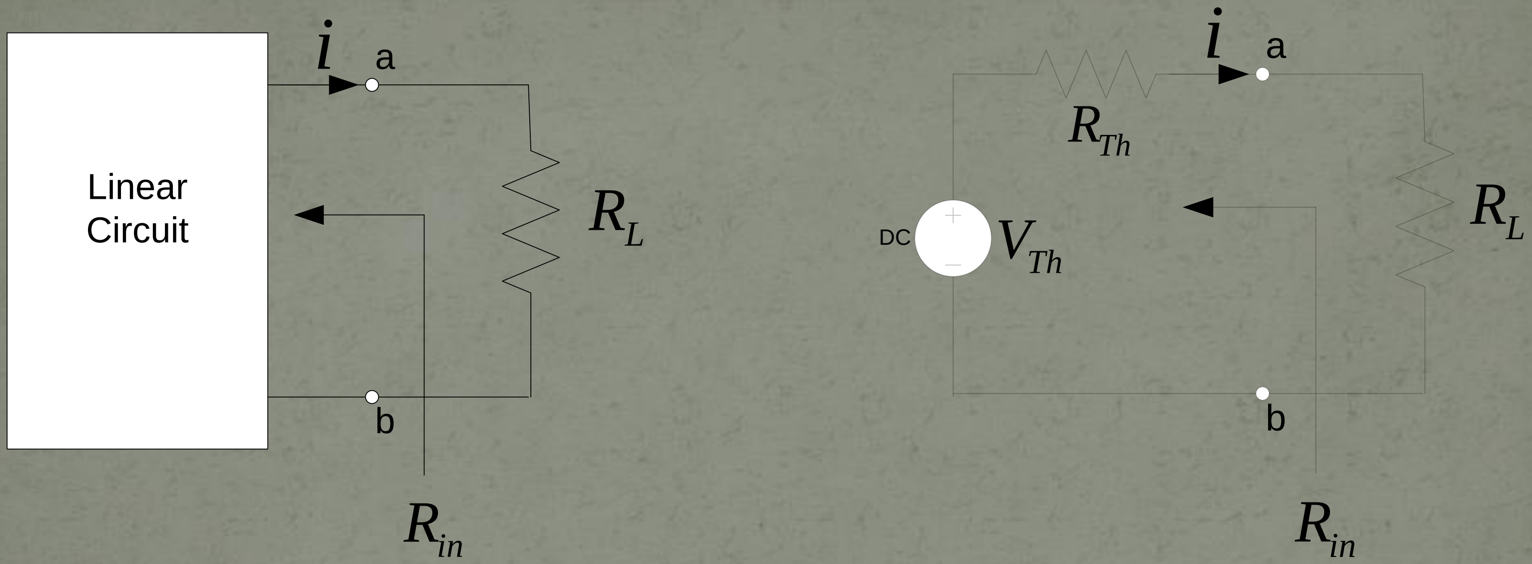
Thevenin's theorem states that the two circuits given below are equivalent as seen from the load R_L that is the same in both cases.





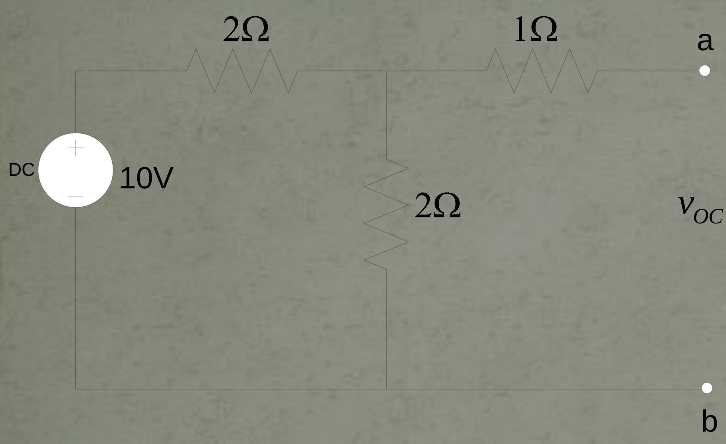
V_{Th} = Thevenin's voltage = V_{ab} with R_L disconnected (= ∞) = the open-circuit voltage = V_{OC}

Thevenin's Theorem

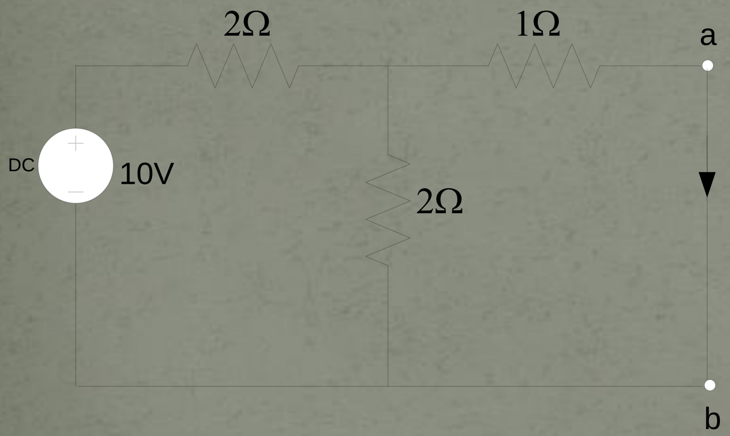


R_{Th} = Thevenin's resistance = the input resistance with all **independent** sources turned off (voltage sources replaced by short circuits and current sources replaced by open circuits). This is the resistance seen at the terminals *ab* when all independent sources are turned off.

Example

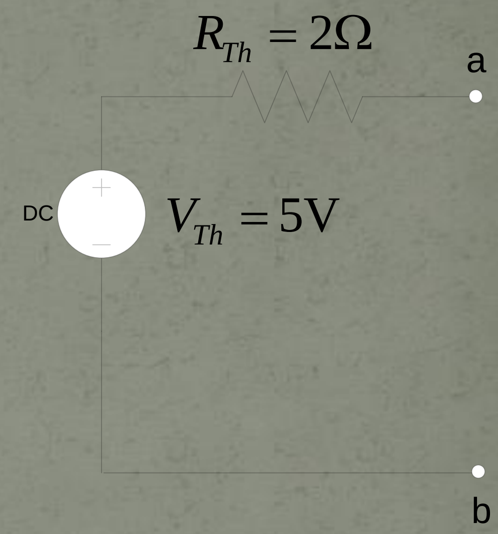


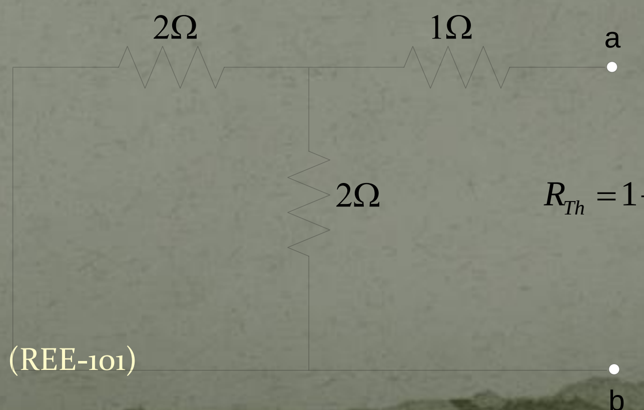
$$v_{OC} = \frac{2}{2+2} 10\text{V} = 5\text{V} = V_{Th}$$



$$i_{SC} = \frac{10}{2+\frac{2}{3}} \frac{2}{3} = \frac{10}{4} = 2.5\text{A}$$

$$R_{Th} = \frac{V_{Th}}{i_{SC}} = \frac{5}{2.5} = 2\Omega$$

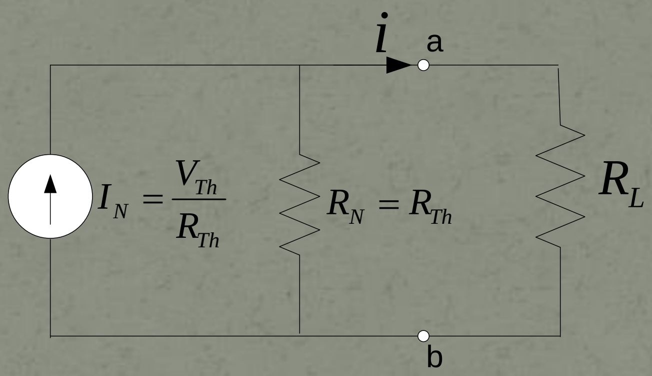




$$R_{Th} = 1 + \frac{2\times 2}{2+2} = 2\Omega$$

Norton's Theorem

Norton's equivalent circuit can be found by transforming the Thevenin equivalent into a current source in parallel with the Thevenin resistance. Thus, the Norton equivalent circuit is given below.



Formally, Norton's Theorem states that a linear two terminal resistive circuit can be replaced by an equivalent circuit consisting of a current source I_N in parallel with a resistor R_N, where I_N is the short-circuit current through the terminals, and R_N is the input or equivalent resistance at the terminals when all independent sources are all turned off.