Points to Note about Superposition and Thévenin Theorems

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1 Introduction

This short note is to bring to your attention those important points about Superposition theorem and Thévenin theorem which you might miss during a casual reading of the text-book.

2 Superposition Theorem and 'Diamonds are forever'

To find voltage across or current through any branch in a linear circuit, effect of one *independent* source at a time can be considered. When the effect of any *independent* source is being considered all the other *independent* sources have to be removed. Superposition theorem says nothing about *dependent* voltage sources. This means that you cannot consider the effect of dependent sources in turn and *don't* remove any dependent source while considering the effect of other independent sources.

Independent Voltage Source To remove a voltage source means to set the voltage to zero. Voltage is set to zero by *shorting* the voltage source. It is a common mistake with students that instead of shorting the voltage source they open it. Remember that to remove the effect of a voltage source means to short it.

Independent Current Source A current source is set to zero by *opening* the current source. An open current source means that zero current is flowing through the source.

Incidentally Superposition theorem is rarely helpful in actually solving any circuit. It is a conceptual thing and many other theorems are proved using the superposition principle. Don't be tempted to use superposition theorem to numerically solve a circuit. If you want to understand or conceptualise something then superposition theorem is a great tool.

3 Thévenin Theorem

Simply stated Thévenin theorem says that a network can be replaced by a voltage (Thévenin) source in series with a (Thévenin) resistance without effecting its terminal characteristics. It so happens that the Thévenin voltage is the open-circuit voltage measured at the terminals *ab* and the Thévenin resistance is the equivalent resistance looking into the network from terminals *ab*. Figure 1 captures this idea. In the following we have assumed that network B has no voltage or current sources.

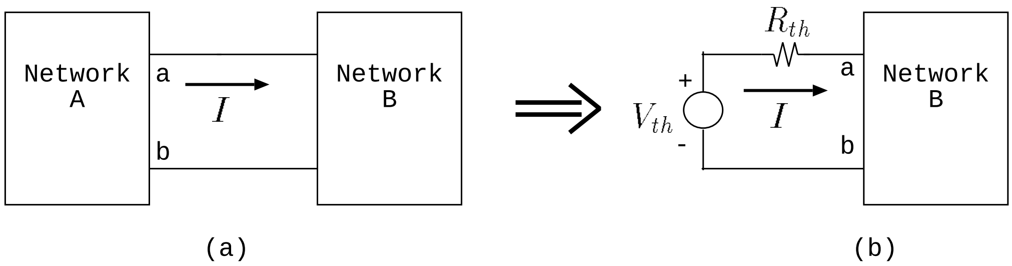

Figure 1: Thévenin Equivalent Circuit

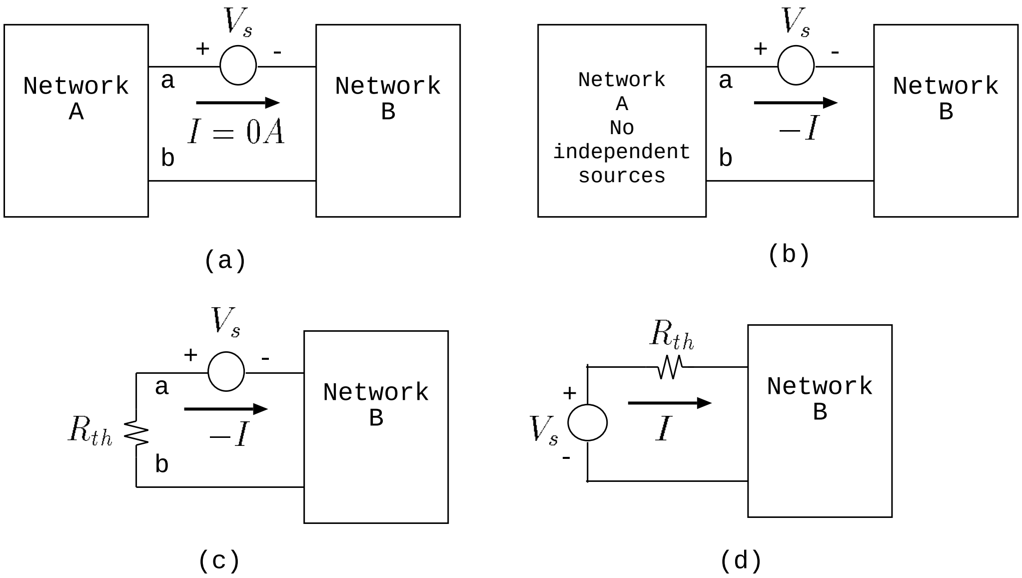

Figure 2: Proof of the Thévenin Theorem. (a) A series source, (b) Superposition principle and removing all the independent sources from the Network A, (c) Replacing Network A with its equivalent resistance, R_{th}, (d) The circuit in a conventional setting.

It is instructive to look at the proof of the Thévenin theorem. As shown in Figure 2(a), first we put a voltage source in series with network A and the network B. The voltage V_s of this series source is adjusted till the current flowing from network A to B is zero. Since the current coming out of network A is zero it means that the voltage across terminals ab is the open-circuit voltage. On writing the KVL equation around the loop we see that $V_{oc} - V_s -$Voltage drop across the network B $= 0$. Since no current flows into network B, the voltage drop across the network B is zero and we have $V_{oc} = V_s (= V_{th})$.

Next remove all the independent sources in network A, leaving only the the series source V_s. Let the current due to this source be $-I$ then using the superposition principle we have that the current due to the sources in network A will be I. Using this fact the original network can be drawn as shown in Figure 2(b)-(d). This also tells that to find the Thévenin equivalent resistance, remove all the independent sources and find the resistance looking from terminals ab.

Equivalent Resistance R_{th}

In the case where there are no dependent sources finding R_{th} is straight forward. When there are dependent sources in network A then a simple way to find R_{th} is to first remove all the independent sources (leaving all the dependent sources in the network) and then inject 1A current from the terminals ab as shown in Figure 3; then

$$R_{th} = \frac{V_{ab}}{1}$$

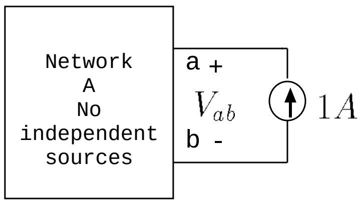

Figure 3: Equivalent Resistance R_{th}