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Thevenin’s theorem states that it is possible to simplify any linear circuit, irrespective of how complex it is, to an equivalent circuit with a single voltage source and a series resistance. A Thevenin equivalent circuit is shown in the image. In the image, we see that multiple resistive circuit elements are replaced by a single equivalent resistance Rs and multiple energy sources by an equivalent voltage source Vs. Let us understand Thevenin’s Theorem with the help of an example. Example: Step 1: For the analysis of the above circuit using Thevenin’s theorem, firstly remove the load resistance at the centre, in this case, 40 Ω. Step 2: Remove the voltage sources’ internal resistance by shorting all the voltage sources connected to the circuit, i.e. v = 0. If current sources are present in the circuit, then remove the internal resistance by open circuiting the sources. This step is done to have an ideal voltage source or an ideal current source for the analysis. Step 3: Find the equivalent resistance. In the example, the equivalent resistance of the circuit is calculated as follows: With the load resistance removed and the voltage sources shorted, the equivalent resistance of the circuit is calculated as follows: The resistor 10 Ω is parallel to 20 Ω, therefore the equivalent resistance of the circuit is: \(\begin{array}{l}R_{T}=\frac{R_{1}\times R_{2}}{R_{1}+R_{2}}=\frac{20\times 10}{20+10}=6.67\,\Omega\end{array} \) Step 4: Find the equivalent voltage. To calculate the equivalent voltage, reconnect the voltage sources back into the circuit. Vs = VAB, therefore the current flowing around the loop is calculated as follows: \(\begin{array}{l}I=\frac{V}{R}=\frac{20\,V-10\,V}{20\,\Omega+10\,\Omega}=0.33\,A\end{array} \) The calculated current is common to both resistors, so the voltage drop across the resistors can be calculated as follows: VAB = 20 – (20 Ω x 0.33 A) = 13.33 V or, VAB = 10 + (10 Ω x 0.33 A) = 13.33 V The voltage drop across both resistors is the same. Step 5: Draw the Thevenin’s equivalent circuit. The Thevenin’s equivalent circuit consists of a series resistance of 6.67 Ω and a voltage source of 13.33 V. The current flowing in the circuit is calculated using the formula below: \(\begin{array}{l}I=\frac{V}{R}=\frac{13.33\,V}{6.67\,\Omega + 40\,\Omega}=0.286\,A\end{array} \) Thevenin’s theorem can be applied to both AC and DC circuits. But it should be noted that this method can only be applied to AC circuits consisting of linear elements like resistors, inductors, capacitors. Like Thevenin’s equivalent resistance, Thevenin’s equivalent impedance is obtained by replacing all voltage sources with their internal impedances. Find VTH, RTH and the load current IL flowing through and load voltage across the load resistor in the circuit below using Thevenin’s Theorem. Solution: Step 1: Remove the 5 kΩ from the circuit. Step 2: Measure the open-circuit voltage. This will give you the Thevenin’s voltage (VTH). Step 3: We calculate Thevenin’s voltage by determining the current that flows through 12 kΩ and 4 kΩ resistors. As both the resistors are in series, the current that flows across them can be calculated as follows: I = 48 V /(12 kΩ + 4 kΩ) = 3 mA The voltage across the 4 kΩ resistors can be calculated as follows: 3 mA x 4 kΩ = 12 V As there is no current flowing through the 8 kΩ resistor, so there is no voltage drop across it and hence the voltage across the terminals AB is same as the voltage across the 4 kΩ resistor. Therefore, 12 V will appear across the AB terminals. Hence, the Thevenin’s voltage, VTH = 12 V. Step 4: Short the voltage sources as shown in the figure below: Step 5: Calculate the Thevenin’s Resistance By measuring the open circuit resistance, we can measure Thevenin’s resistance. We notice that the 8 kΩ resistor is in series with the parallel connection of 12 kΩ and 4 kΩ resistors. Therefore, the equivalent resistance or the Thevenin’s resistance is calculated as follows: 8kΩ + (4k Ω || 12kΩ) RTH = 8 kΩ + [(4 kΩ x 12 kΩ) / (4 kΩ + 12 kΩ)] RTH = 8 kΩ + 3 kΩ RTH = 11 kΩ Step 6: Now, connect the RTH in series with Voltage Source VTH and the load resistor as shown in the figure. Step 7: For the last step, calculate the load voltage and load current using Ohm’s law as follows: IL = VTH / (RTH + RL) IL = 12 V / (11 kΩ + 5 kΩ) = 12 V/16 kΩ = 0.75 mA The load voltage is determined as follows: VL = 0.75 mA x 5 kΩ = 3.75 V Thevenin’s theorem is used in the analysis of power systems. Thevenin’s theorem is used in source modelling and resistance measurement using the Wheatstone bridge. Thevenin’s theorem is used only in the analysis of linear circuits. The power dissipation of the Thevenin equivalent is not identical to the power dissipation of the real system. Thevenin’s theorem states that it is possible to simplify any linear circuit, irrespective of how complex it is, to an equivalent circuit with a single voltage source and a series resistance. The open-circuit voltage that appears across the two terminals is the Thevenin voltage. Thevenin’s theorem is used in the analysis of power systems. No, Thevenin’s Theorem is not applicable to non-linear circuits. Yes, Thevenin’s theorem applies to AC circuits. Stay tuned to BYJU’S and Fall in Love with Learning! The Superposition Theorem is used to solve complex networks with a number of energy sources. It is an important concept to determine voltage and current across the elements by calculating the effect of each source individually. And combine the effect of all sources to get the actual voltage and current of the circuit element. Superposition theorem states that; “In any linear bilateral network having a greater number of sources, the response (voltage and current) in any element is equal to the summation of all responses caused by individual source acting alone. While other sources are eliminated from the circuit.” In other words, we will consider only one independent source acting at a time. So, we need to remove other sources. The voltage sources are short-circuited and the current sources are open-circuited for ideal sources. If the internal resistance of sources is given, you need to consider the circuit. The superposition theorem is only applied to the circuit which follows Ohm’s law. Related Post: Thevenin’s Theorem. Step by Step Guide with Solved Example The network must follow the below requirements to apply the superposition theorem. The components used in the circuit must be linear. It means, for resistors, the flow of current is proportional to the voltage; for inductors, the flux linkage is proportional to current. Therefore, the resistor, inductor, and capacitor are linear elements. But the diode, transistor is not a linear element. The circuit components must be bilateral elements. It means, the magnitude of the current is independent of the polarity of energy sources. With the help of the superposition theorem, we can find the current passes through an element, voltage-drop of resistance, and node voltage. But we cannot find the power dissipated from the element. Related Post: Norton’s Theorem. Step by Step Guide with Solved Example Steps to Follow for Superposition Theorem Step-1 Find out a number of independent sources available in the network. Step-2 Choose any one source and eliminate all other sources. If the network consists of any dependent source, you cannot eliminate it. It remains as it is throughout the calculation. If you have considered all energy sources are ideal sources, you need not consider internal resistance. And directly short-circuit voltage source and open-circuit current source. But in case, if internal resistance of sources is given, you have to replace internal resistance. Step-3 Now, in a circuit, only one independent energy source is present. You need to find a response with only one energy source in the circuit. Step-4 Repeat step-2 and 3 for all energy sources available in the network. If there are three independent sources, you need to repeat these steps three times. And every time you get some value of the response. Step-5 Now, combine all responses by algebraic summation obtained by individual sources. And you will get a final value of response for a particular element of a network. If you need to find a response for other elements, you need to follows these steps again for that element. Related Post: SUPERMESH Circuit Analysis – Step by Step with Solved Example Example: Let’s understand the working of the superposition theorem by example. Find the current (IL) passes through the 8Ω resister in the given network using the superposition theorem. Solution: Step-1 As shown in the above network, one voltage source, and one current source is given. Therefore, we need to repeat the procedure two times. Step-2 First we consider 28V voltage source is present in the network. So, you need to remove the current source by open-circuited terminals. As here, we consider the current source as an ideal current source. So, we need not connect the internal resistance. The remaining circuit is as shown in the below figure. Step-3 Find the current (IL1) passes through 8Ω resister. It gives the effect only of a voltage source. Due to the open circuit of a current source, no current passes through the 10Ω resister. So, the network consists of only one loop. Apply KVL to the loop; 28 = 6IL1 + 8IL1 28 = 14IL1 IL1 = 28/14 IL1 = 2A Step-4 Now, we repeat the same procedure for the current source. In this condition, we remove the voltage source by short-circuiting. A remaining circuit is as shown in the below figure. Here, we have to consider two loops. I1 and I2 are loop current. And find the current IL2. Apply KVL to the loop-1; 0 = 6I1 + 8I1 – 8I2 14I1 – 8I2 = 0 The current passes through the loop-2 is calculated from the current source. And it will be; I2 = 28A Put this value in the above equation; 14I1 – 8 (28) = 0 I1 = 16A Now, the 8Ω resister branch is common in both loops. So, we need to find the resultant current (IL2) passes through the 8Ω resister. IL2 = I1 – I2 IL2 = 16 – 28 IL2 = -12A Step-5 Now, we combine the effect of both sources by algebraic summation of current. So, the total current passes through the 8Ω resister are IL. Here, the direction of the current is most important. Current IL2 has a minus sign. It means during the 28A source, the current flows in opposite direction. And we cannot change the direction. That’s the reason while combining all sources, we are doing algebraic summation. IL = IL1 – IL2 IL = 2 + (-12) IL = -10A Here, we have assumed that the current passes through the 8Ω resister are in the direction of the arrow shown in the figure. Minus sign shows the opposite direction. And the amount of current is 8A. Related Post: SUPERNODE Circuit Analysis – Step by Step with Solved Example The superposition theorem experiment can be done by following the below steps. Aim Determine the current flowing through the resistors and verify the superposition theorem. Components Required DC source, Resistors, DC multimeters, Connecting Wires, Breadboard, etc. Theory Superposition theorem is used in circuit analysis to find the current and voltage across the elements in a given circuit. This theorem is useful when the number of sources is more. According to the superposition theorem, the response of elements is an algebraic summation of response from the individual energy sources. First, we will calculate the current passes through resistors in a given network. When all sources are connected. After that, we remove sources and find currents for individual sources. At last, the summation of current measured from the individual sources is similar to the current measures with all sources connected. Procedure We consider the linear bilateral circuit given in the below figure. Connect all elements on the breadboard as given in the above circuit using connecting wires. Connect ammeter with all resisters to find the current passes through the resistors. Here, we have two voltage sources. In the first case, measure the current that passes through all resisters when both voltage sources are present in the circuit. The current flowing through the resistor R1, R2, and R3 is I1, I2, and I3 respectively. Now remove the 12V voltage source from the circuit. Short the terminals A’ and B’ as shown in the above figure. Here we have assumed that the voltage sources are ideal. So, no need to connect internal resistance. Now, measure the current I1′, I2′ and I3′ which is the current that passes through the resistor R1, R2, and R3 respectively. Similarly, remove the 9V voltage source and the remaining circuit is as shown in the above figure. Again, measure the current flowing through all resisters and name it I1″, I2″, and I3″. Related Post: Maximum Power Transfer Theorem for AC & DC Circuits Put all values in below observation table. Observation Table Source Connection R1 R2 R3 Both sources are connected I1 I2 I3 Only 12V is connected I1′ I2′ I3′ Only 9V is connected I1″ I2″ I3″ Calculation: I1 = I1′ + I1″ I2 = I2′ + I2″ I3 = I3′ + I3″ To verify the superposition theorem, we compare the algebraic summation of current passes through resisters when an individual source is connected with the current measured when both sources are connected in a circuit. If the above calculation satisfies, we can prove the superposition theorem. Conclusion In this experiment, we can prove that the current that passes through the resistance is an algebraic summation of current when an individual energy source is connected. And it proves the superposition theorem. Application of Superposition theorem Superposition theorem can be used for AC and DC networks. When the number of independent sources is more, it is easy to find a response of the network. It helps to calculate current passes and the voltage across the element by calculating the effect of each energy source individually. And after we can determine the combined effect on elements from all sources. Drawback of Superposition Theorem Superposition theorem cannot apply to the circuit having only a dependent source. It needed at least two independent sources. This theorem only applicable to the network which consists of linear elements. It cannot apply to the non-linear elements like a diode, transistor, etc. We cannot calculate power by this theorem. As the power is proportional to the square of voltage and current as it becomes non-linear. This theorem is not applicable in a condition where the resistance varies with voltage and current. For all energy sources, the value of resistance must remain constant. This theorem only applicable to the bilateral elements. If the response of the network depends on the direction of the current, this theorem is not applicable. Related Electric Circuit Analysis Tutorials: In this tutorial, we present a powerful method that can simplify through some transformation steps, complex circuits into elementary circuits and this method is commonly known as Thevenin’s theorem. Originally, it was the German physicist Hermann von Helmholtz who first demonstrated the theorem in 1853, but history kept the name of the French engineer Leon Thevenin, who in 1883, unawarely of the work of Helmholtz, proposed a more elegant method to prove the theorem. Thevenin’s theorem affirms that any linear electrical circuit is equivalent to an ideal voltage source in series with an equivalent resistor. We will illustrate this statement in the first section where we also define the bold terms of the theorem. In the second section, we present the method to follow in detail, in order to apply Thevenin’s theorem to a circuit. Finally, some Thevenin transformations are fully depicted in the last section with real circuits taken as examples. Presentation and definitions As previously mentioned, Thevenin’s theorem can only be applied to linear electrical circuits (LEC). The internal structure of LEC consist of interconnected ideal sources and resistors. Reactive components such as capacitors and inductors must be excluded since their voltage/current characteristics are not described by a linear formula. An ideal voltage source consists of a generator that delivers a constant value of voltage regardless of the current flowing in the circuit. This means that the same ideal source will always deliver the same voltage Vs for any circuit connected at its terminals. This property ensures that the voltage/current characteristic of an ideal voltage source is constant and therefore is linear. fig 1: Representation of an ideal voltage source along with its voltage/current characteristic Ideal current sources can also be found in LEC and consist of generators that provide a constant value of current regardless of the voltage at their terminals. A representation of an ideal current source along with its and voltage/current characteristic is proposed in Figure 2 below: fig 2: Representation of an ideal current source along with its voltage/current characteristic An equivalent resistor Req is simply a concept that represents the association of a set of interconnected resistors (R1, R2,…) into a single component. The association of resistors is dictated by two rules: If the resistors share the same current (in series), the equivalent resistance is the sum of the resistors. If the resistors share the same voltage (in parallel), the inverse of the equivalent resistance is the sum of the inverses of the resistors. fig 3: Rules of equivalent resistance associations Now that these various definitions have been detailed, we can illustrate Thevenin’s theorem with the following Figure 4: fig 4: Illustration of Thevenin’s transformation The simpler circuit obtained from the Thevenin transformation is known as the Thevenin model. The equivalent source and resistance are labeled with the subscript Th as a reference to the name of the theorem. In the next section, we give the abstract method in order to determine this model from any LEC. Thevenin model determination The goal of this section is to present how the Thevenin parameters VTh and RTh are determined. Thevenin’s voltage VTh is the voltage between the terminals of the LEC when the load is disconnected and it is also known as the open-circuit voltage. Similarly, Thevenin’s resistance RTh is the resistance at the terminals of the circuit when the load is disconnected and all the circuit’s sources are disabled, the voltage sources are replaced with short-circuits and the current sources with open-circuits. We propose therefore a series of steps to follow in order to determine the Thevenin model of any LEC: Remove the load at the terminals of the LEC Compute the voltage of the open-circuit Replace any voltage sources with short-circuits and the current-sources with open-circuits Compute the equivalent resistance Reconnect the load and draw the Thevenin model thanks to the knowledge of VTh and RTh In the following section, we illustrate this method by determining the Thevenin model of some LEC examples with increased architecture complexity. Thevenin’s model of some LEC Single voltage source For the first example, we consider a basic LEC composed of only one voltage source and two resistors in a parallel configuration: fig 5: Single voltage source LEC In order to determine Thevenin’s model, first of all, we proceed to steps number 1 and 2 explained in the previous section. When disconnecting the load Z from the circuit, we compute the voltage at the terminals of the LEC, that is to say across the resistor R2, by applying the voltage divider method: After replacing the parameters by their values, we obtain VTh=2.5 V. We consider now the circuit by replacing the voltage source by a wire. The equivalent Thevenin resistance is the parallel association of the resistors R1 and R2: The numerical application gives RTh=500 Ω. The circuit presented in Figure 5 can, therefore, be simplified by the equivalent Thevenin’s model presented in Figure 6: fig 6: Thevenin’s model of the single voltage source LEC The voltage and current across any load Z are now much easier and faster to compute. As an example, if Z=100 Ω, we can use again the voltage divider formula to find VZ=0.4 V. The current is obtained by applying Ohm’s law to the resistance Z: I=VZ/Z=4 mA. Single current source For the second example, we consider a similar circuit than in Figure 5, but replacing the voltage source by an ideal current source and rearranging the resistors: fig 7: Single current source LEC First of all, we disconnect the load Z from the circuit in order to determine VTh: When applying Kirchoff’s Voltage Law in the loop highlighted with the red symbol, we find VTh=V2-V1. However, since the circuit is opened, no current is observed across R1 and therefore VTh=V2. The current flowing in R2 is thus equal to the current source, we finally apply Ohm’s law to R2 in order to find VTh=100×2=200 V. Thevenin’s resistance RTh is found by replacing the current source by an open circuit, the equivalent resistor is determined by the series association of R1 and R2: RTh=R1+R2=150 Ω. Figure 8 below illustrates the Thevenin model of the circuit presented in Figure 7: fig 8: Thevenin’s model of the single current source LEC Multi-current/voltage sources For this last example, we propose a more complex circuit that includes both current and voltage sources: fig 9: Multi-source LEC Welcome to the Engineering Library. This Living Library is a principal hub of the LibreTexts project, which is a multi-institutional collaborative venture to develop the next generation of open-access texts to improve postsecondary education at all levels of higher learning. 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Forecasting its path and intensity was uncertain, resulting in widespread and often unnecessary preparations. Claudette caused one death and moderate damage in Texas, mostly from strong winds, as well as extensive beach erosion. Because of the damage, President George W. Bush declared portions of South Texas as a Federal Disaster Area. Claudette also caused significant rainfall and minor damage in the Mexican state of Quintana Roo, as well as minor damage on Saint Lucia. (This article is part of a featured topic: 2003 Atlantic hurricane season.) 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