INTRODUCTION

In this tutorial, we will discuss how to simulate two common types of transformers in Multisim.

BACKGROUND

Step Down Transformer

In ECE 2110, you used a function generator to generate sine waves for various experiments when you required a voltage with alternating current (AC). In an actual circuit (say inside of the power supply for a laptop computer), if we want an AC voltage, we use a transformer. In the United States, power companies provide an AC voltage of about 115V_{RMS} at the exact frequency of 60Hz. Most circuits cannot handle 115V_{RMS}, so we use a step down transformer to “transform” the voltage from 115V_{RMS} to a lower voltage, in this case about 9V_{RMS}.

Figure 1 shows the circuit schematic for a basic step down transformer. On the left terminals, it can take as input a 115V_{RMS} sinusoid. It will then “step down” the voltage to a 9V_{RMS} sinusoid. It is simple to see that this transformer has a step down voltage ratio of (115:9) or 12.78:1. The ratio for a transformer is set by having the same ratio for the number of turns of wire in the primary coil to the number of turns or wire in the secondary coil. As an example, if one wrapped the first coil with 10,000 turns of wire, the secondary coil would then need to have 782.65 turns of wire to achieve the 12.78:1 ratio.

When one has a coil of wire, it is essentially an inductor. So, a transformer looks a lot like two coils of wire next to each other. The ratio of the inductance of each coil is related to the ratio of the voltage in each coil as stated in the equation above.
Center-Tapped Transformer

**Figure 2** above shows the type of transformer that is in the ECE 2115 parts kit. It is called a center-tapped step down transformer. It still contains only two coils, one primary, one secondary. However, now the center of the secondary coil has been “tapped” with a wire so that one can take a voltage between the top and center wire of the secondary coil, take a voltage between the center and bottom wire of the secondary coil, or take a voltage between the top and bottom wire of the secondary coil. The result is three voltage options. In the case above, the figure shows that we can take $9\,\text{V}_{\text{RMS}}$ from the top to center wire, $-9\,\text{V}_{\text{RMS}}$ from the bottom wire to the center wire, or $18\,\text{V}_{\text{RMS}}$ from the top to bottom wire of the secondary coil.

The equations remain the same for this type of transformer. One may think of this as a $115\,\text{V}_{\text{RMS}}:18\,\text{V}_{\text{RMS}}$ transformer (6.389:1) if one uses the top to bottom wires. Alternatively, one may consider this a $115\,\text{V}_{\text{RMS}}:9\,\text{V}_{\text{RMS}}$ transformer (12.78:1) if one uses the top to center wires.

**Note:** In this example, we are using a $115\,\text{V}_{\text{RMS}}$ to $18\,\text{V}_{\text{RMS}}$ transformer. In a spec sheet for a transformer, if you see the rating: $115\,\text{V}_{\text{RMS}}$ to $18\,\text{V}_{\text{RMS}}$ C.T. (center tapped), this would indicate that the voltage from the top to the bottom of the secondary coil was $18\,\text{V}_{\text{RMS}}$. 
INSTRUCTIONS

Part I – Simulating a Step Down Transformer

1. Build the circuit in Figure 3 in Multisim.
   a. Use AC Power for the voltage source.
   b. Use the 1P1S transformer. 
      Note: This stands for 1 Primary 1 Secondary.
   c. Double-click the transformer to change its turn ratio as shown below in Figure 4.
   d. Be sure to ground both sides of the circuit to ensure the correct voltage references.
2. **Run a Transient Analysis** to plot the voltage on both the primary coil and the secondary coil on the same graph. We would like to see 5 cycles of the sinusoid. Since its frequency is 60Hz, the period is 16.6ms. To see 5 cycles, we need a transient simulation to run for 83.3ms.
   a. **Set the End Time** to 0.0833s.
   b. **Select** the primary and secondary coil nodes as outputs.
   c. **Press Simulate**.

3. You should have the exact results shown below if you have set the proper turn ratio. **Interpret** the results:
   a. On the green curve (primary), look at the peaks. At 4.16ms, $V_P = 162.6344V \approx 115V_{\text{RMS}}$.
   b. On the red curve (secondary), at the same time, $V_P = 12.7279V \approx 9V_{\text{RMS}}$.
   c. This is a 115:9 or 12.78:1 voltage ratio as designed!
   d. **Notice** that the transformer does not affect the frequency of the voltage source across the primary coil of the transformer. The voltages at the primary and secondary coils are perfectly in phase.

![Figure 5 – Step Down Transformer Simulated Waveforms](image)

**Note:** If you design a transformer in Multisim, after you set the turn ratio, always be sure to perform a transient simulation like the one above to ensure that you are getting the amount of voltage you expect out of the secondary coil. This simple check will save you a lot of time if you have made a mistake in defining the transformer to begin with.
Part II – Simulating a Center-Tapped Transformer

![Center-Tapped Transformer Diagram]

**Figure 6 – Center-Tapped Transformer**

1. **Build** the circuit in Figure 6 in Multisim.
   a. **Use AC Power** for the voltage source.
   b. **Use** the 1P2S transformer. Be sure to wire the middle two pins on the secondary coil side together to make this a center-tapped transformer.
      *Note:* 1P2S stands for 1 Primary 2 Secondary. However, as explained in the Background section, a center-tapped transformer technically does not have two secondary coils. We are simply using this component to model the center-tapped transformer, which is why we tie the middle two pins together.
   c. **Double-click** the transformer to change its turn ratio as shown below in Figure 7.
   d. Be sure to **ground** the center-tap of the transformer to ensure the correct voltage references.

![Transformer Properties]

**Figure 7 – Transformer Properties**
2. **Run a Transient Analysis** to plot the voltage on both the primary coil and the secondary coil on the same graph. We would like to see 5 cycles of the sinusoid. Since its frequency is 60Hz, the period is 16.6ms. To see 5 cycles, we need a transient simulation to run for 83.3ms.
   a. **Set the End Time** to 0.0833s.
   b. **Select** the primary, top of the secondary, and bottom of the secondary coil nodes as outputs to display.
   c. **Press Simulate**.

3. You should have the exact results shown below if you have set the proper turn ratio. **Interpret** the results:
   a. On the red curve (primary), look at the peaks. At 20.83ms, \( V_P = 162.63V \approx 115V_{\text{RMS}} \).
   b. On the green curve (top of the secondary), at the same time, \( V_P = 12.73V \approx 9V_{\text{RMS}} \).
   c. On the blue curve (bottom of the secondary), at the same time, \( V_P = -12.73V \approx -9V_{\text{RMS}} \).

**Note:** If you want to use the full 18V\text{RMS} from the secondary coil, set up your circuit as shown below. The center-tap simply becomes our ground reference voltage. Using the transformer included in the parts kit, you would only connect the two outer green leads to the circuit’s load.

![Figure 8 – Center-Tapped Transformer Simulated Waveforms](image)

![Figure 9 – Center-Tapped Transformer Set Up](image)