THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

SCHOOL OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
ECE 2115: ENGINEERING ELECTRONICS LABORATORY

Tutorial #2:
Simulating Transformers in Multisim

INTRODUCTION

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

BACKGROUND

Step Down Transformer

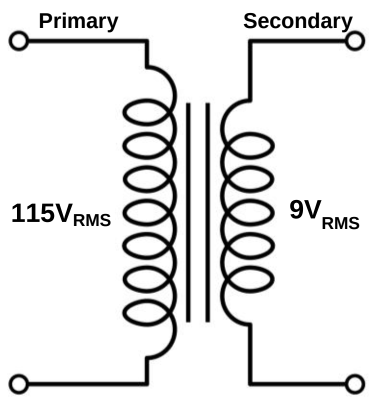

Figure 1 – Step Down Transformer

Basic Transformer Equation
Voltage Turns to Inductance Ratio:

P = Primary Coil S = Secondary Coil
V = Voltage N = # of turns L = Inductance

$$\frac{V_P}{V_S} = \frac{N_P}{N_S} = \sqrt{\frac{L_P}{L_S}}$$

Equation 1 – Transformer Equation

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

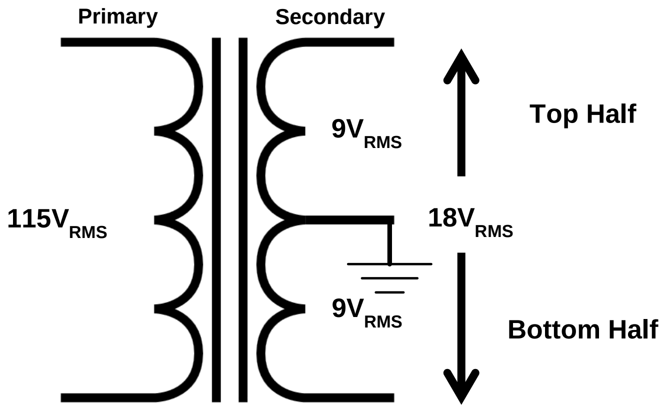

Figure 2 – Center-Tapped Transformer

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 $9V_{RMS}$ from the top to center wire, $-9V_{RMS}$ from the bottom wire to the center wire, or $18V_{RMS}$ 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 $115V_{RMS}$:$18V_{RMS}$ transformer (6.389:1) if one uses the top to bottom wires. Alternatively, one may consider this a $115V_{RMS}$:$9V_{RMS}$ transformer (12.78:1) if one uses the top to center wires.

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

INSTRUCTIONS

Part I – Simulating a Step Down Transformer

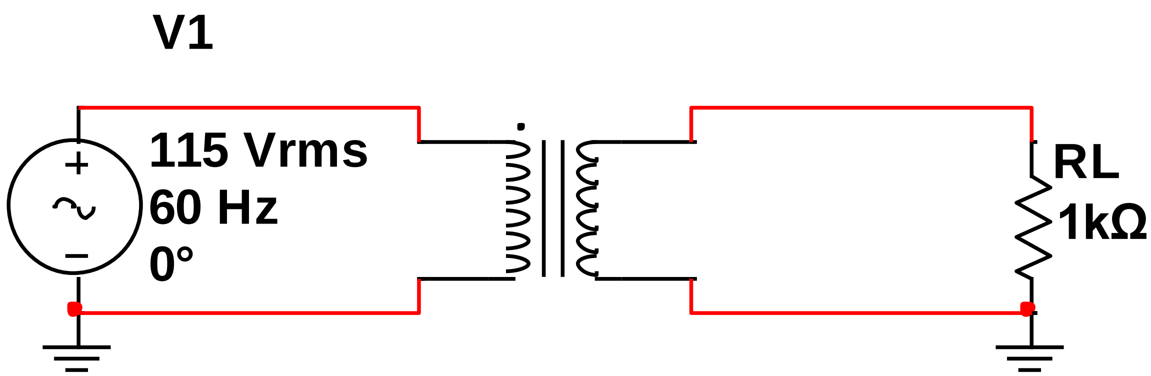

Figure 3 – Step Down Transformer

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.

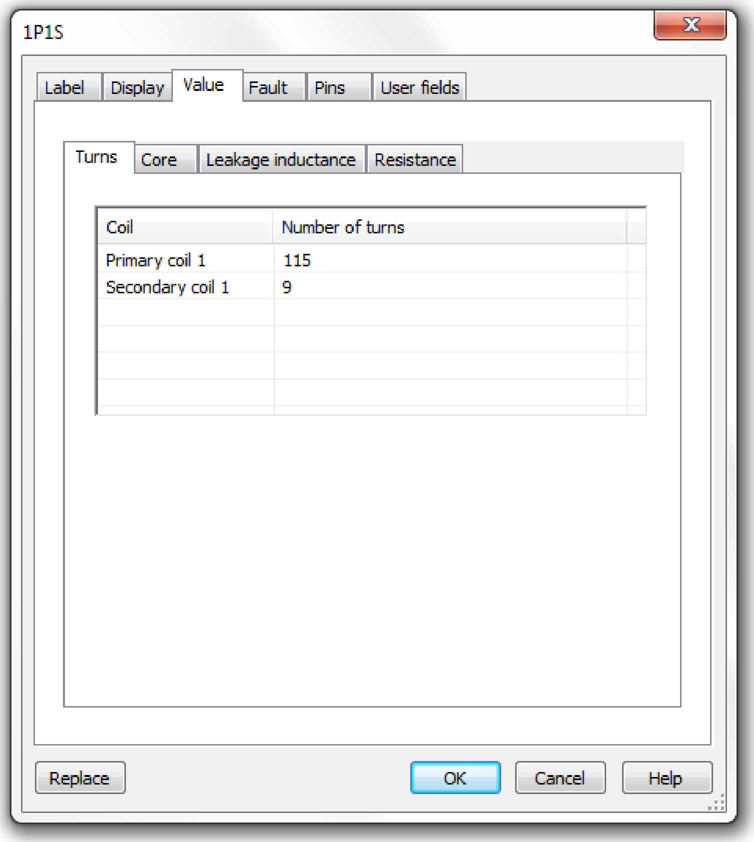

Figure 4 – Transformer Properties

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** 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 ≈ 115V_{RMS}.
   b. On the red curve (secondary), at the same time, V_P = 12.7279V ≈ 9V_{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.

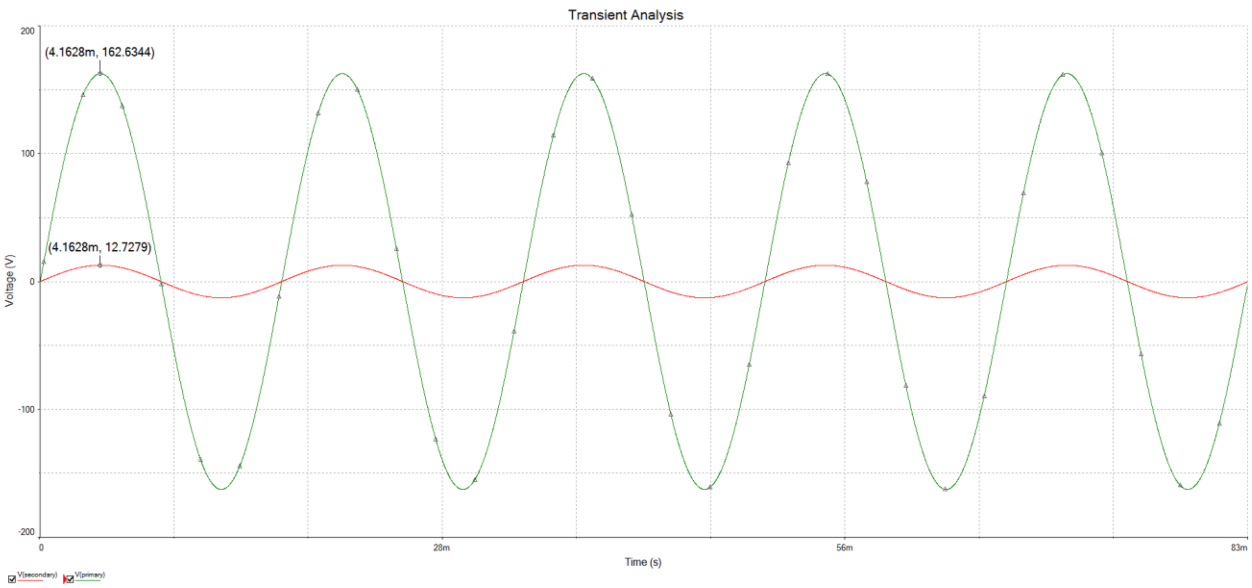

Figure 5 – Step Down Transformer Simulated Waveforms

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

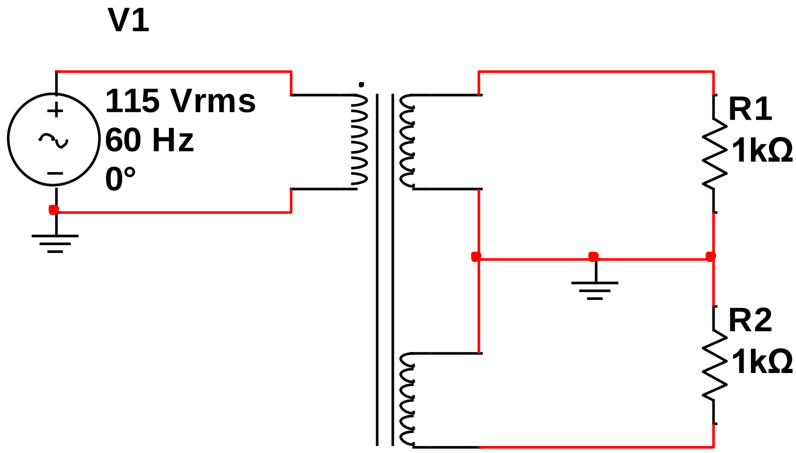

Figure 6 – Center-Tapped Transformer

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.

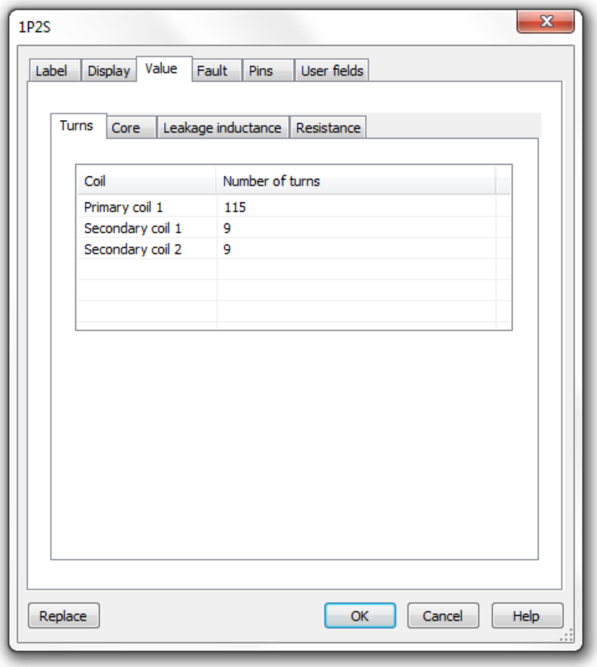

Figure 7 – Transformer Properties

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, $V_P = 162.63V \approx 115V_{RMS}$.
   b. On the green curve (top of the secondary), at the same time, $V_P = 12.73V \approx 9V_{RMS}$.
   c. On the blue curve (bottom of the secondary), at the same time, $V_P = -12.73V \approx -9V_{RMS}$.

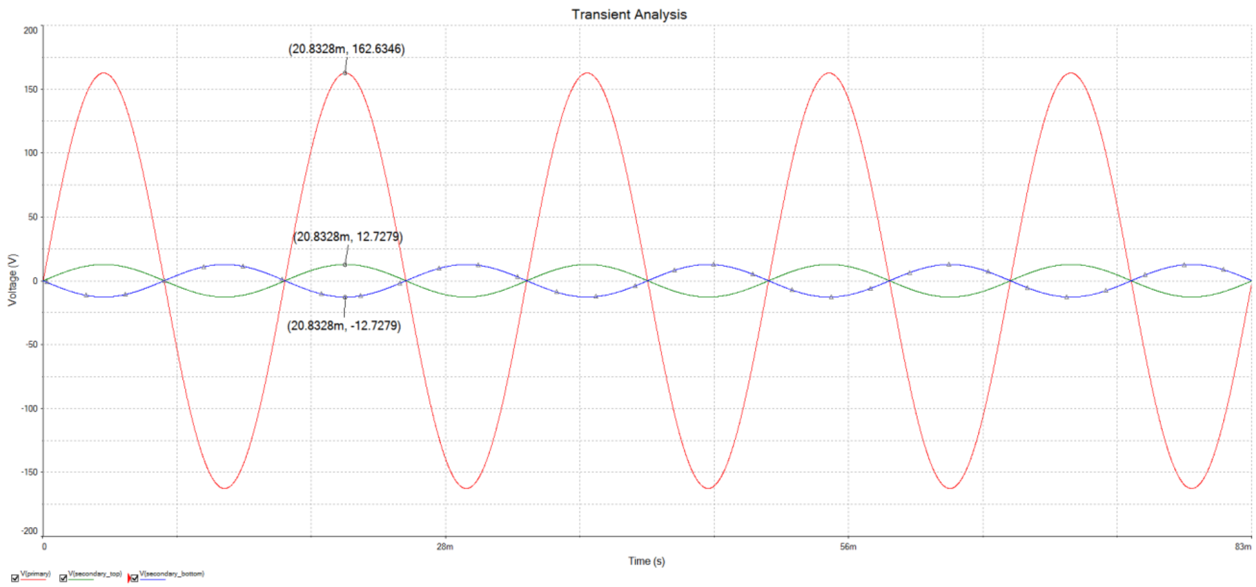

Figure 8 – Center-Tapped Transformer Simulated Waveforms

Note: *If you want to use the full* $18V_{RMS}$ *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.*

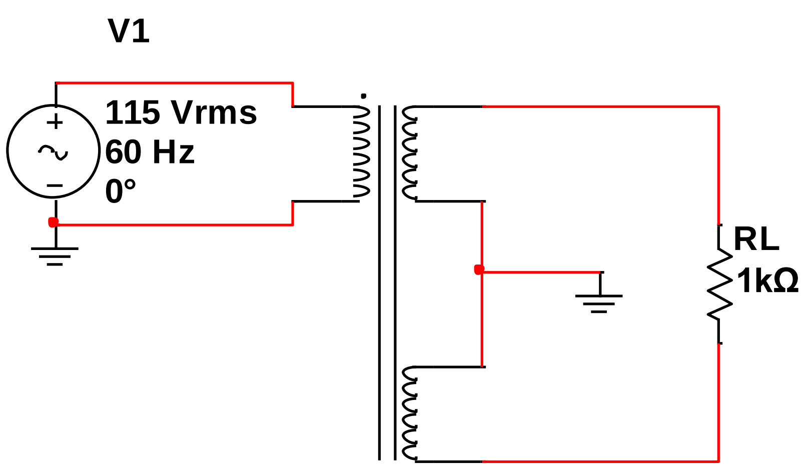

Figure 9 – Center-Tapped Transformer Set Up