ENGINEERING 12 SPRING 2008
PHYSICAL SYSTEMS ANALYSIS

LABORATORY 1: TRANSFORMERS

Objectives

In this lab, you will learn about uses of transformers for reducing or increasing voltage and current, and for impedance matching to maximize power output.

Apparatus

For this lab you will need a signal generator, an oscilloscope, an ammeter, a speaker, a sound level meter, and a variable windings transformer.

Background

Transformers take an ac voltage and current and increase them or decrease them according to the ratio of turns in the primary (input) and secondary (output) windings. The transformers you are using have between 100 and 500 windings, which can be combined in different ways. Each winding has a reference dot to define its polarity (the polarity is actually defined by the direction of the windings around the core – clockwise or counterclockwise). In the following discussion the subscript 1 will be used for the primary coil and the subscript 2 for the secondary coil.

Voltage and current transformations

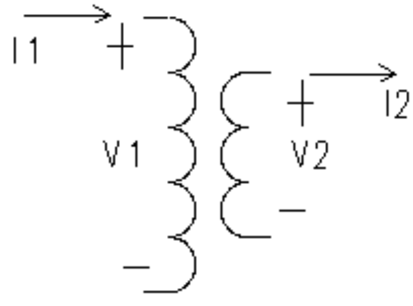
The relationship between voltages and currents in a transformer are given by the following equations:

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

and

$$\frac{I_1}{I_2} = \frac{N_2}{N_1}$$

Where V_1, V_2, I_1, and I_2 are defined as shown in the figure below, and N_1 and N_2 are the number of windings on the primary and secondary coils.



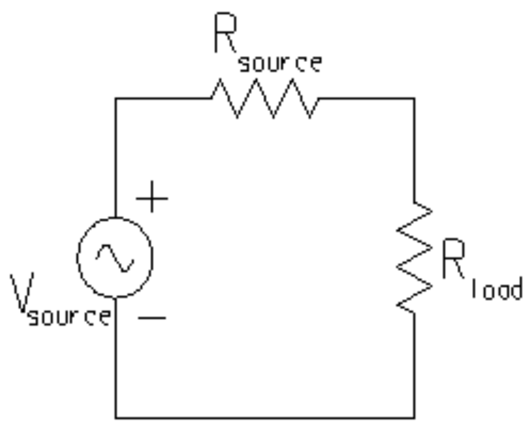
One of the most common applications of transformers is to step voltages up or down. Electrical power is distributed at a voltage of several kilovolts, and a transformer is used to reduce this to 120 volts for use in the home. Many devices (computers, stereos, printers, televisions) use another transformer to further reduce the voltage.

Impedance transformations

If there is impedance, Z_2, across the secondary windings, the impedance seen at the primary is:

$$Z_1 = Z_2\left(\frac{N_1}{N_2}\right)^2 \qquad \text{(equation 1)}$$

This brings us to another important application of transformers, impedance matching. Consider the circuit shown below:



It can be shown that the maximum power is transferred from the source to the load when the load resistance is equal to the source resistance. A transformer can be used to maximize power transfer by changing the apparent impedance of a load to match that of the source by taking advantage of the impedance relationship described by equation 1.

The Measurement of Audio Power

When measuring power, the unit of measure is decibels, defined as $10\log(P_{meas}/P_{ref})$, where P denotes power, and the logarithm is base 10. P_{meas} is the measured audio power and P_{ref} is a reference defined to be a sound pressure level of 20 mPa (Pa is Pascal, a unit of pressure, 1 Pa = 1 N/m^2). Atmospheric pressure is about 100 kPa, but you do not experience this because the same pressure is on both sides of your eardrum. The minimal audible sound is about 20 mPa (0 dB), and you experience pain at about 20 Pa (120 dB), which means you can hear sounds over a pressure range of about one million. The unit bell, $1\log(P_{meas}/P_{ref})$, is named for Alexander Graham Bell.

Procedure

1. Use a 1KHz signal and set it somewhere between 2 and 4 volts, with nothing attached to the output of the signal generator except the oscilloscope. Record this voltage and *do not change it* for the duration of this laboratory. Make your measurements with an oscilloscope.

2. Set up a transformer with N_1:N_2=2.5:5.0. Open circuit the secondary windings and connect the signal generator at the primary. Measure V_1, V_2, and I_1 (I_2=0). Although I_2=0 implies that I_1=0, there are some non-idealities in the system that lead to a small current in the primary.

3. Short circuit the secondary windings and repeat step 1 measuring V_1, I_1, and I_2 (V_2=0).

4. Connect a 1 kΩ resistor across the secondary and repeat step 1, measuring V_1, V_2, I_1, and I_2.

5. Connect the signal generator, which has a source resistance of 600Ω to a speaker, which has an impedance of 8Ω. Measure the level of sound coming out of the speaker using a sound level meter. To make the measurement you should move the meter around directly in front of the speaker. Note the position that you use and use the same position when you measure the sound level in the next part of the lab.

6. Place a transformer between the signal generator and the speaker, choosing a turns ration as close as possible to that necessary to make the speaker appear as a 600Ω load. This will transfer as much power as possible to the speaker. Measure the level of sound coming out of the speaker. Make sure you position the sound level meter in the same place as in step 5.

Report

1. No formal lab report is required for this lab. However, your results should be presented clearly.

2. Present results (experimental and theoretical, where appropriate) from steps 1, 2 3 and 4 of the procedure.

3. Show a derivation of equation 1.

4. Show that maximum power transfer occurs when $R_{load} = R_{source}$.

5. Describe why you chose the turns ratio you used in part 6 of the procedure rather than any of the others that were available to you.

6. Present results (experimental and theoretical) of parts 5 and 6. There is no way for you to predict the level of sound in 5, but you should predict the level in 6 from the results of 5.

7. Compare your experimental and theoretical results and note any discrepancies. You need not try to explain the sources of these discrepancies in this lab report, but if you are interested you will find them explained in your E11 textbook. The major contributor is losses in the transformer, both resistive and magnetic.