

Transformers¹

Equipment Needed:

- | | |
|---|-----------|
| 1 Primary and Secondary Coils | Demo Cart |
| 1 Voltage Sensor Assembly | Demo Cart |
| 1 Computer Cart/Interface and Power Amp | |

Purpose

To experience mutual inductance and how a transformer is used to increase and decrease an AC voltage.

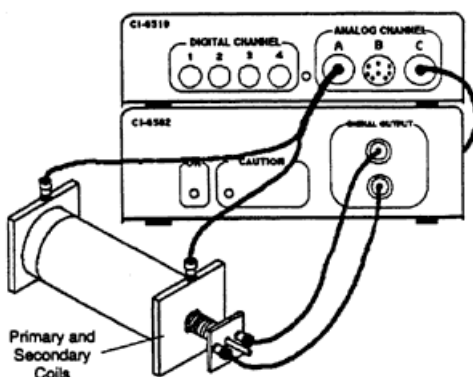


Figure 1: Equipment Layout

Theory

A transformer increases or decreases AC voltages. An AC voltage is applied to the primary coil, which is surrounded by the secondary coil but is not electrically connected to it (See Figure 1). The primary coil produces a changing magnetic flux through the secondary coil, which will induce an AC voltage in the secondary coil. If the number of turns of wire in the secondary coil is more than the number of turns in the primary coil, the voltage induced in the secondary coil will be more than the applied voltage in the primary coil and this is called a step-up transformer. If the number of turns in the secondary coil is less than the number of turns in the primary coil the voltage will be reduced and this is called a

¹Adapted from PASCO ©1994, PASCO Scientific Roseville, CA

step-down transformer.

According to Faraday's Law of Induction, the induced emf is proportional to the rate of change of magnetic flux through the coil ($\frac{d\Phi}{dt}$) and the number of turns (N) in the coil:

$$\mathcal{E} = -N \frac{d\Phi}{dt}.$$

Since the rate of change in flux through each coil is the same, the ratio of the emfs in the coils is equal to the ratio of the numbers of turns in the coils:

$$\begin{aligned} -\frac{d\Phi}{dt} = \frac{\mathcal{E}_P}{N_P} &= \frac{\mathcal{E}_S}{N_S} \\ \Rightarrow \frac{\mathcal{E}_P}{\mathcal{E}_S} &= \frac{N_P}{N_S}, \end{aligned}$$

where the subscripts "P" and "S" stands for "primary" and "secondary" coils respectively.

Setup

1. Run the Power Amplifier program by typing [PA]; [ENTER] and press [ENTER] at the title screen.
2. Before turning on the power switch on the back of the Power Amplifier, set the voltage to 0.2 V and the frequency to 60 Hz:
 - 0 - Options;** [ENTER]
 - A - Waveform Amplitude;**
 - Type [0.2]; [ENTER]
 - F - Frequency;**
 - Type [60]; [ENTER]
 - R - Return to Scope;** [ENTER]
3. Connect the inner coil to the Power Amplifier output using banana patch cords. See Figure 1.
4. Using the Voltage Sensor, connect the outer coil to Channel A of the interface box.
5. Using the Voltage Sensor, connect the outer coil to Channel A of the interface box, if not already connected.
6. Turn on the power switch on the back of the Power Amplifier.
7. The inner coil should be inserted completely into the outer coil and the iron core should be inserted completely into the inner coil.

Procedure

1. Select Channel A to be viewed on the oscilloscope screen by pressing [A]. This is the voltage across the secondary (outer) coil.
2. Adjust the gain for Channel A (using the [↑]) until the wave can be clearly seen.
3. Set the sweep speed (using [←] or [↓]) to 2 ms/div.
4. Analyze the data:
 - SELECT [F] - File
 - SELECT [D] - Analyze Data; [ENTER]
 - SELECT [P] - Plot Graph; [ENTER]
 - On - [O] - Selected Channels Only; [ENTER]
 - Prepare to take data using the oscilloscope mode:
 - On - Channel A; [ENTER] (other channels off)
 - Choose [B] - Auto Scaling for both scales; [ENTER]
 - After the graph is plotted, press [ENTER] and [E] - examine the data to find the maximum amplitude of the secondary voltage (Channel A). Record in Table 1.
5. Return to the oscilloscope:
 - [ENTER]
 - SELECT [X] - Return to Main Menu; [ENTER]
 - SELECT [R] - **Return to scope**, press [ENTER]
6. Pull the iron core out of the inner coil. Measure the secondary voltage again by repeating steps 2 through 5.
7. Now apply the output voltage of the Power Amplifier to the outer coil and monitor the voltage across the inner coil in Channel A. Increase the Power Amplifier output voltage to 2 V and insert the iron core:
 - SELECT [O] - **Options**,
 - SELECT [A] - **Waveform Amplitude**;
 - Type [2]; press [ENTER]
 - SELECT [R] - **Return to Scope**; press [ENTER]
 - Measure the secondary (inner) coil voltage.
8. Remove the iron core and measure the secondary (inner) voltage.

Table 1: **Data Collection**

Primary Coil	V_P	V_S	$\frac{V_S}{V_P}$
Inner (with core)			
Inner (w/out core)			
Outer (with core)			
Outer (w/out core)			

Analysis

1. Calculate the ratio of secondary voltage to primary voltage for each of the four measurements and record in Table 1. Express these ratios as (XX.X: 1) for the step-up cases and as (1 : XX.X) for the step-down cases so it can be easily seen by how much the voltage is multiplied or divided.
2. The number of turns in the inner coil is 235 (#18 gauge wire) and the number of turns in the outer coil is 2920 (#29 gauge wire). Calculate the ratio of the number of turns (outer/inner).

$$\frac{N_S}{N_P} = \text{_____ turns}$$

Questions

1. When the inner coil (with core) was used as the primary coil, was the ratio of the voltages equal to the ratio of the number of turns? How do you account for any difference?
2. Why did the secondary voltage change when the iron core was pulled out of the inner coil?
3. When the outer coil (with core) was used as the primary coil, why is the voltage stepped down a different amount than it was stepped up when the inner core was the primary coil?
4. Why did you have to use AC voltage in this lab instead of DC?