Experiment P42: Transformer
(Power Amplifier, Voltage Sensor)

Concept	Time	SW Interface	Macintosh File	Windows File
basic electricity	30 m	700	P42 Transformer	P42_XTRN.SWS

EQUIPMENT NEEDED:	
• Science Workshop™ Interface	• (2) Patch Cords
• Power Amplifier	• Primary & Secondary Coils & iron core
• Voltage Sensor	

PURPOSE

The purpose of this laboratory activity is to investigate how a transformer is used to increase or decrease an AC voltage.

THEORY

A transformer can be used to increase or decrease AC voltages. An AC voltage is applied to the **primary** coil of a transformer, which is surrounded by the **secondary** coil but is not electrically connected to it. 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 voltage in the primary coil. 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. This is called a step-down transformer.

According to Faraday's *law of induction,* the induced *emf* (voltage) is proportional to the rate of change of magnetic flux through the coil (dϕ/dt) and the number of turns (N) in the coil:

$$\varepsilon = -N\frac{d\phi}{dt}$$

Since the rate of change in flux through both coils is the same, the ratio of the *emfs* (voltages) in the coils is equal to the ratio of the numbers of turns in the coils:

$$-\frac{d\phi}{dt} = \frac{\varepsilon}{N} \rightarrow \frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p}$$

A core made of a ferrous material such as iron can change the amount of magnetic flux that influences the secondary coil.

PROCEDURE

In the first part of this activity, you will put together a step-up transformer (number of turns in the secondary coil is greater than the number of turns in the primary coil). In the second part of this activity, you will use the same coils to put together a step-down transformer (number of turns in the secondary coil is less than the number of turns in the primary coil.)

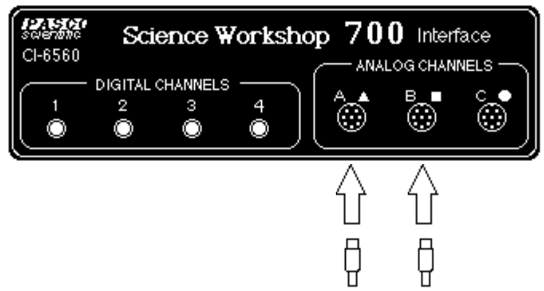
The Power Amplifier supplies the voltage to the primary coil in both transformer setups. The Voltage Sensor measures the induced emf (voltage) in the secondary coil. You will record the voltage in the secondary coil for two configurations: one with an iron core inside the inner coil, and one without the iron core inside the inner coil.

The *Science Workshop* program controls the voltage output of the Power Amplifier. It also collects and displays the voltages across both the primary coil and the secondary coil. You will use the program to compare the voltage in the primary coil to the voltage in the secondary coil.

PART IA: Computer Setup for Step-Up Transformer

1. Connect the *Science Workshop* interface to the computer, turn on the interface, and turn on the computer.

2. Connect the Power Amplifier DIN plug into Analog Channel A. Plug in the Power Amplifier's power cord. Connect the Voltage Sensor DIN plug into Analog Channel B.

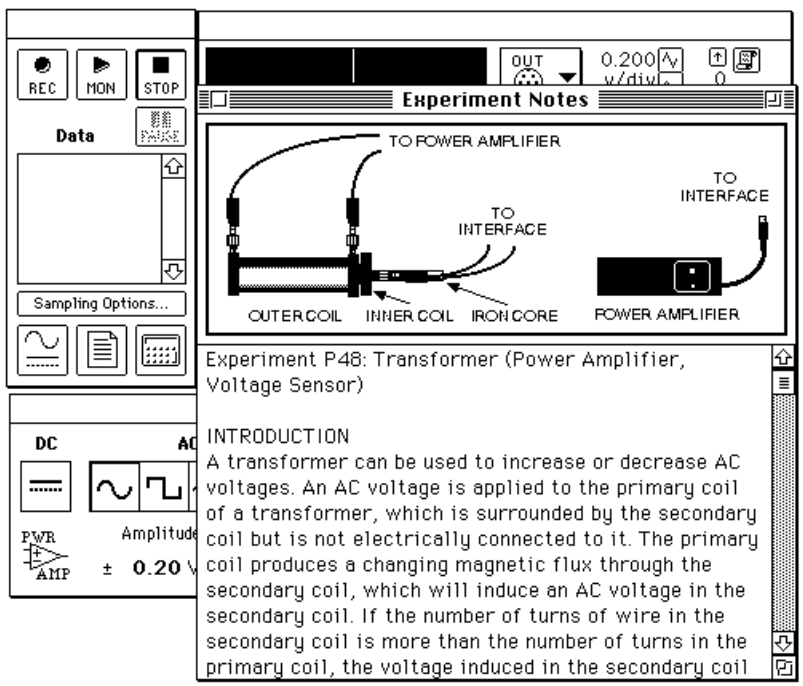


3. Open the *Science Workshop* document titled as shown:

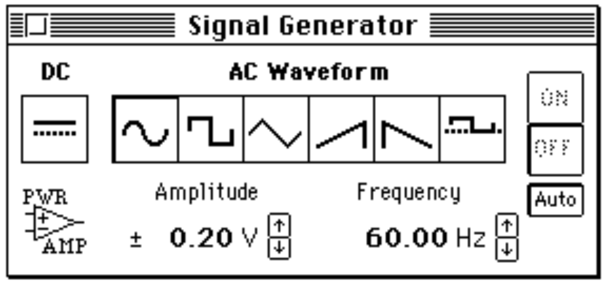
Macintosh	Windows
P42 Transformer	P42_XTRN.SWS

- The document opens with a Scope display of Voltage for both the Power Amplifier (output) and the Voltage Sensor (input), and the Signal Generator window.

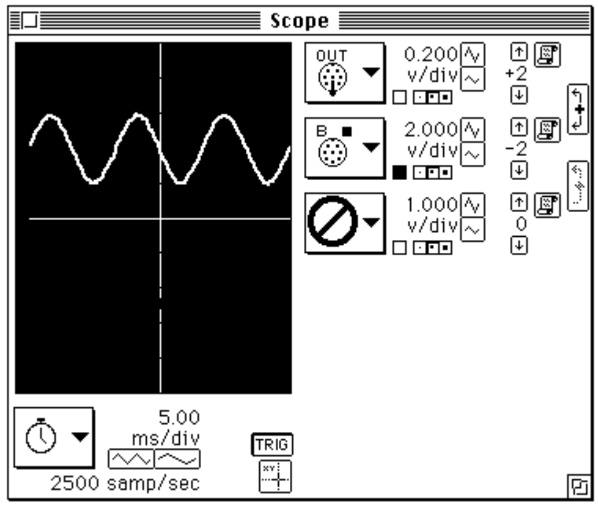
- Note: For quick reference, see the Experiment Notes window. To bring a display to the top, click on its window or select the name of the display from the list at the end of the Display menu. Change the Experiment Setup window by clicking on the **Zoom** box or the **Restore** button in the upper right hand corner of that window.)



4. The Signal Generator is set to output a sine AC Waveform at an Amplitude of 0.20 Volts and a Frequency of 60 Hz. It is set to **Auto** so it will start automatically when you click **REC** or **MON** and stop when you click **STOP** or **PAUSE**.



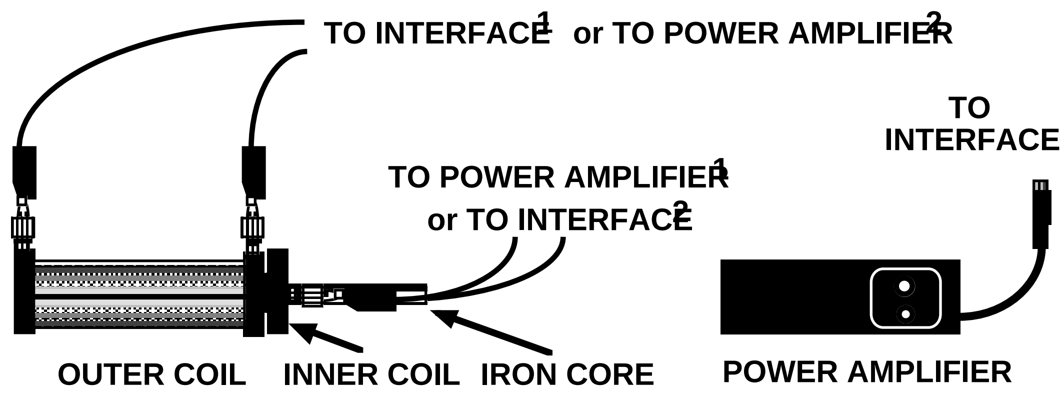
5. The Scope shows the trace of output voltage in the top part of the display, and the trace of input voltage from the secondary coil in the bottom part of the display. The Sweep Speed (horizontal axis scale) is set to 5.00 ms/div (or 2500 samples per second).



PART IIA: Sensor Calibration and Equipment Setup Step-Up Transformer

- You do not need to calibrate the Voltage Sensor or the Power Amplifier.
- The Primary and Secondary Coils consist of an inner coil with about 200 turns of heavy gauge wire, an outer coil with about 2000 turns of thinner gauge wire, and an iron core that fits inside the inner coil. The inner coil fits inside the larger outer coil.

1. To build a step-up transformer, use banana plug patch cords to connect the <u>inner</u> coil to the output jacks of the Power Amplifier.
2. Connect the Voltage Sensor's banana plugs to the <u>outer</u> coil.
3. Put the inner coil completely inside the outer coil. Put the iron core as far into the inner coil as it will go.



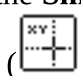
• (1= Setup for <u>Step-up</u> Transformer & 2= Setup for <u>Step-down</u> Transformer)

PART IIIA: Data Recording for Step-Up Transformer

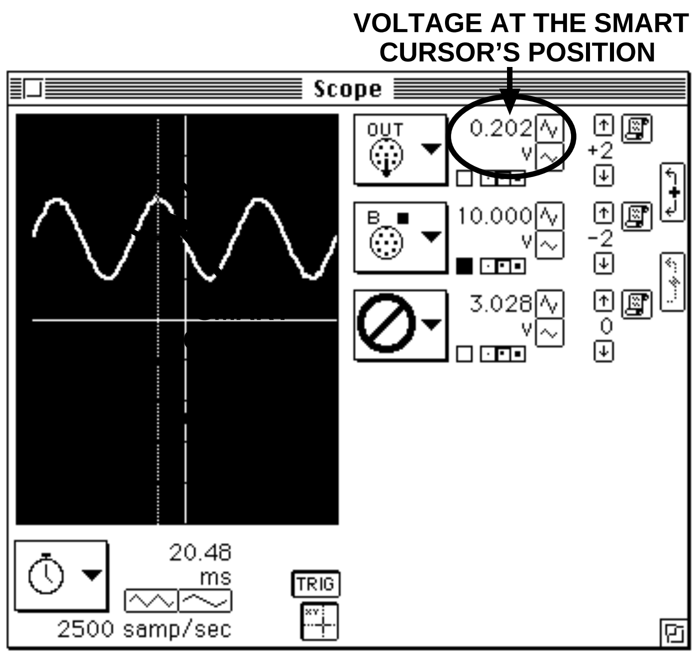
1. Turn on the switch on the back of the Power Amplifier.

2. Click the **MON** button (
) to begin monitoring data. The Signal Generator will start automatically.

3. Observe the traces of voltage in the Scope display.

4. Click the **Smart Cursor** button (
) in the Scope display (this will "freeze" the display). The cursor changes to a cross-hair shape.

   Move the cursor/cross-hair to a peak of the top trace of voltage (the primary coil voltage). The value of voltage at that point is displayed next the the channel Input Menu button.



5. Record the output voltage across the primary (inner) coil.

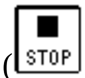
6. Move the Smart Cursor to the corresponding peak of the bottom trace of voltage (the secondary coil voltage). Record the voltage across the secondary (outer) coil.

• Click the Smart Cursor anywhere to return to the normal cursor and "un-freeze" the display.

7. Remove the iron core from the inner coil.

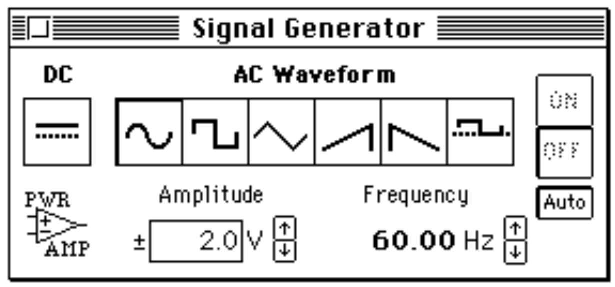
8. Click the **Smart Cursor** button again. Move the Smart Cursor to a peak on the top trace of voltage and record the output voltage across the primary (inner) coil when the core is removed.

9. Move the Smart Cursor to a corresponding peak of the bottom trace of voltage. Record the new voltage across the secondary (outer) coil when the core is removed.

10. Click the **STOP** button (
) to stop monitoring data. Turn off the switch on the back of the Power Amplifier.

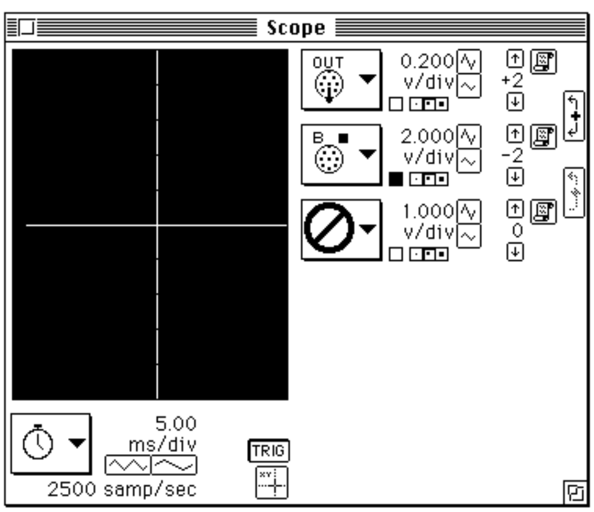
PART IB: Computer Setup for Step-Down Transformer

1. Click the Signal Generator window to make it active. Change the Amplitude from 0.2 V to 2.0 V. Press <enter> or <return> on the keyboard to record your change.

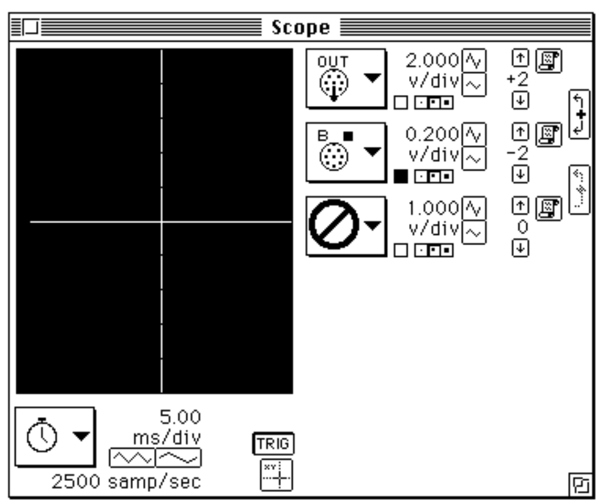


2. Click the Scope display to make it active. Use the Increase/Decrease buttons to change the Sensitivity (volts per division) for both the top trace and the middle trace. Change the top trace from 0.200 v/div to 2.000 v/div. Change the middle trace from 2.000 v/div to 0.200 v/div.

Before



After



PART IIB: Sensor Calibration and Equipment Setup for Step-Down Transformer

1. Put the iron core back inside the inner coil.

- Change the transformer from step-up to step-down.

2. Disconnect the Power Amplifier’s banana plug patch cords from the inner coil. Disconnect the Voltage Sensor’s banana plugs from the outer coil.

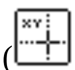
3. Connect the Power Amplifier’s banana plug patch cords to the <u>outer</u> coil. Connect the Voltage Sensor’s banana plugs to the <u>inner</u> coil.

PART IIIB: Data Recording for Step-Down Transformer

1. Turn on the switch on the back of the Power Amplifier.

2. Click the **MON** button (
) to begin monitoring data. The Signal Generator will start automatically.

3. Observe the traces of voltage in the Scope display.

4. Click the **Smart Cursor** button () in the Scope display (this will “freeze” the display). The cursor changes to a cross-hair shape. Move the cursor/cross-hair to a peak of the top trace of voltage (the primary coil voltage). The value of voltage at that point is displayed next the the channel Input Menu button.

5. Record the output voltage across the primary (<u>outer</u>) coil.

6. Move the Smart Cursor to the corresponding peak of the bottom trace of voltage (the secondary coil voltage). Record the voltage across the secondary (<u>inner</u>) coil.

- Click the Smart Cursor anywhere to return to the normal cursor and “un-freeze” the display.

7. Remove the iron core from the inner coil.

8. Click the **Smart Cursor** button again. Move the Smart Cursor to a peak on the top trace of voltage and record the output voltage across the primary (<u>outer</u>) coil when the core is removed.

9. Move the Smart Cursor to a corresponding peak of the bottom trace of voltage. Record the new voltage across the secondary (<u>inner</u>) coil when the core is removed.

- (Hint: If the voltage appears to be too small to measure, use the Increase Sensitivity button to change the volts per division to 0.050 v/div.)

10. Click the **STOP** button to stop monitoring data. Turn off the switch on the back of the Power Amplifier.

ANALYZING THE DATA

DATA

1. Calculate the ratio of primary voltage to secondary voltage for each of the four measurements and record the ratios in the Data section. Express these ratios as (XX.X : 1) for the step-up transformer and as (1 : XX.X) for the step-down transformer so it can be easily seen by how much the voltage is multiplied or divided.

Step-Up Transformer	Primary (inner) Voltage (V)	Secondary (outer) Voltage (V)
With core		
Without core		

Step-Up Transformer	Ratio: V_P/V_S
With core	
Without core	

Step-Down Transformer	Primary (outer) Voltage (V)	Secondary (inner) Voltage (V)
With core		
Without core		

Step-Down Transformer	Ratio: V_P/V_S
With core	
Without core	

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).

Ratio of turns = ________

QUESTIONS

1. When the inner coil (with core) was used as the primary coil, was the ratio of the voltages approximately 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. Which had the greater effect: Pulling the core out of the step-up transformer (inner-primary) or pulling the core out of the step-down transformer (outer-primary)? Why?

5. Why did you have to use AC voltage in this laboratory activity instead of DC?