University of Utah
Electrical & Computer Engineering Department
ECE 3600 Lab 2

Model of a Power Transformer

Based on labs by: L. D. Harris & D. K. Gehmlich
A. Stolp, 9/23/08, rev, 9/24/14, 9/11/18

Objectives

1. Find an equivalent circuit of an iron-core inductor.
2. From measurements and calculations, derive a model for a power transformer.
3. Measure the power efficiency of the transformer and compare the measurements to calculations made from the model.
4. Measure the voltage regulation of the transformer and compare the measurements to calculations made from the model.

Equipment and materials to be checked out from stockroom:

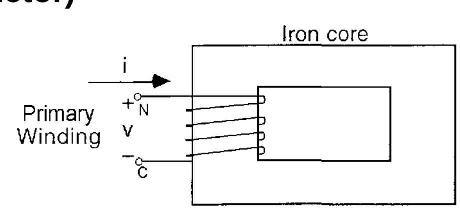
- Power wire kit
- Wattmeter panel
- Two multimeters
- Power strip
- "Suicide" cord
- 3-prong to 2-prong AC power plug adapter
- Vari-AC (Auto-transformer)
- MTC (Mountain Transformer Company) Transformer

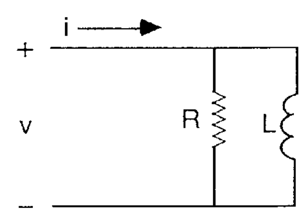
All work described below should be performed on the MTC transformer (rated 115/115 volts, 60 Hz, 250 VA). The effective cross-sectional area (A) of the iron core is 13.3 cm^2 and the effective magnetic path length (l_m) is 23.5 cm. There are 260 turns (N) on the primary.

The primary side of the transformer is labeled "P". You will use the "C" (common) and the "N" terminals of the transformer. ("N" refers to "normal" voltage, "H", and "-" are connections that can be used to get a higher or lower secondary voltage and will not be used in his lab.) Make sure that all other leads are free and clear.

Experiment 1 (Equivalent circuit of an iron-core inductor)

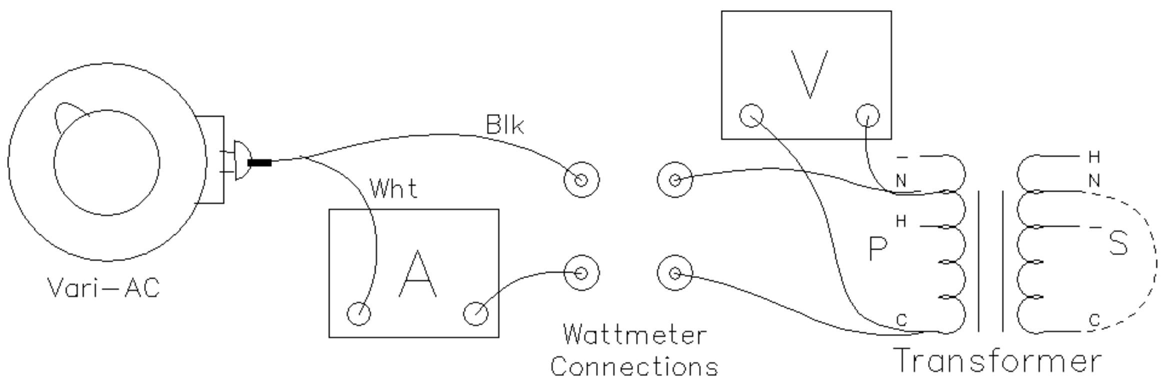
If we ignore the nonlinearities, we can model (an equivalent circuit is a model) the performance of an iron-core inductor reasonably well with the parallel combination of a resistor and pure inductor. You will make measurements and calculations that will lead to the numerical values of R and L of the model shown.





A series combination of a different R and different L could be also used as a model of the inductor; however, for this laboratory job, we will use the parallel combination. This has some advantages that are not necessarily obvious at this point.

Setup
Switch off the power strip and plug it in. Switch off the vari-AC, turn it to 0V and plug it into the power strip. Use the following hookup, WITHOUT the secondary shorted (dashed-line connection). The secondary winding should be left unconnected, so the transformer primary will look like a simple iron-core inductor. Use one of the multimeters as the ammeter in one of the normal AC ranges. Draw your setup in your notebook.



Measurements needed
1. Switch on the power and turn up the vari-AC, until you measure115 V at the primary of the transformer. If you have problems getting a voltmeter reading, check the fuses. You can probably find the problem if you move the voltmeter lead normally hooked to transformer connection “C” back to all the connections in the neutral path, one-at-a-time. The ammeter fuse can also be checked by measuring the continuity of the meter with another meter.

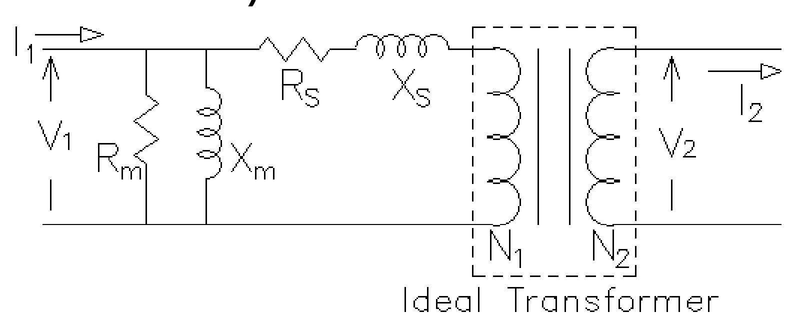
2. Measure and record P, V, and I. Since you are looking for a linear model, assume a sinusoidal current.

3. Turn down the vari-AC and switch off the power.

Calculate R and L and draw the model of the inductor (the transformer primary) with the part values.

Experiment 2 (Model of a Power Transformer)

Background
Refer to section 3.5 (esp. Starting p105) in your text and your transformer notes handed out in class. The transformer model we will use is shown at right. X_m represents the inductance of the primary and is called the “magnetizing reactance”. R_m accounts for the no-load core power losses. These losses are due to the hysteresis in the B-H curve and to eddy-currents in the core. The series impedances, R_S and X_S account for winding resistance and leakage reactance. Both of these effects depend on the load current, I_2.



In experiment 1, you found the equivalent circuit of an iron-core inductor which happened to be the primary of a transformer. Thus, you essentially performed an open-circuit (OC) test on this transformer and found R_m and L_m, which can be translated to X_m. In this experiment you will perform a short-circuit (S.C.) test and find R_S and X_S to complete the transformer model. Finally, you will compare some lab measurements to calculations made using the model.

Setup for the Short-Circuit Test

Use the same circuit as above, WITH the secondary shorted (dashed-line connection). It is now critical that the voltmeter connections (including the voltmeter part of the wattmeter) are on the transformer-side of any ammeters. That's necessary because there can be a significant voltage drop across the ammeters which can throw off your measurements.

This MTC transformer is rated 115/115 volts, 250 VA, 60 Hz. Determine the rated primary current. Make sure that your ammeter can handle that current. If it can't, use another ammeter. Change the ammeter to its "10A" or "20A" connections and setting if necessary.

Measurements needed

1. With the vari-AC turned down to zero, turn on the power.

2. **Slowly** and **carefully** turn up the Vari-AC until the rated current flows in the primary. **DO NOT EXCEED 2.25 A.** Measure P, V, and I.

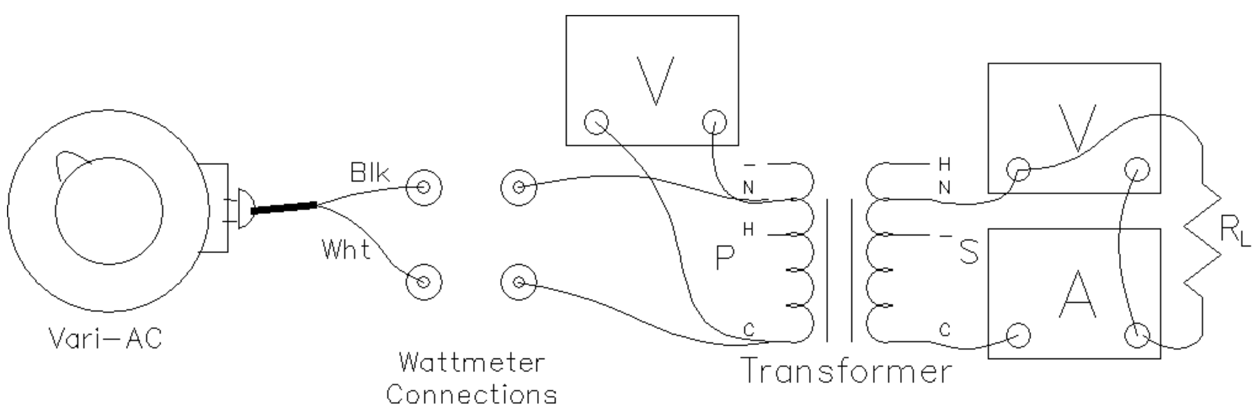
3. Turn vari-AC down and switch it off.

If you ignore the effects of X_m and R_m at this low voltage (very reasonable to do) then the transformer is just X_S in series with R_S. Find X_S in series with R_S from your measurements.

Draw the entire transformer model in your notebook with all the values that you have found.

Experiment 3 (Voltage Regulation and Power Efficiency)

Change to the following hookup, without R_L. Leave the ammeter in the high-current setting. Draw your setup in your notebook.



1. Make a table in your notebook with 4 rows, and columns for R_L , P_{in} , I_2 , V_2 , P_{out} , VR and η.

2. Turn down the vari-AC, switch it on and turn it up to 115 V (measured).

3. Measure P_{in} and V_2 , P_{out} is obviously zero (the $0\ W$ measurement). V_2 is your no-load voltage (V_{NL}).

4. Turn down the vari-AC.

5. Get one of the big resistors from your TA– be careful, it may be HOT! Hook it up as R_L.

6. **Slowly** and **carefully** turn up the Vari-AC until the rated current flows in the secondary **(DO NOT EXCEED 2.25 A)** OR the primary voltage is 115 V (measured), whichever is first. If you reached the current first, turn the vari-AC down again– something is wrong.

7. Measure P_{in} , I_2 , and V_2 quickly and turn down the vari-AC before the resistor gets too hot. As a check that everything is OK, calculate, P_{out} and make sure it's less than P_{in} .

8. Remove the HOT resistor and repeat steps 4 through 7 for two more resistors so that you end up with measurements for 4 different loads, approximately; $0\ W$, $50\ W$, $150\ W$, and $250\ W$.

You are now done with the lab measurements, assuming they were made correctly. If you need to leave the lab, you can check-off now and do the calculations and plots later.

Since you used resistors as the load, you can simply calculate the P_{out} as I_2V_2. To fill in the fifth column of your table. Fill the other two columns with calculations as shown below. For the $0\ W$ row and $V_{no\ load}$, well... if you don't know what to do it's time to look for a different major.

VR is voltage regulation: $$VR = \frac{V_{noload} - V_{load}}{V_{load}} 100\%$$

η is power efficiency: $$\eta = \frac{P_{out}}{P_{in}} 100\%$$

Plot VR vs P_{out} and η vs P_{out}. Make nice plots (a computer is the recommended plot tool).

Calculations From the model

For the $150\ W$ load, calculate the load resistor, R_L. Draw your model with this R_L transformed to the primary side in place of the ideal transformer. Use your model to calculate VR and η. Compare these numbers to those you found from measurements.

Repeat for the $250\ W$ load.

Check-off and Conclude