Telephony 101 – Transformers December 4, 2012

Hello All,

As always, please send any questions about the reading assignment directly to me at oldtimetelephones@goeaston.net. I will bundle questions if necessary, repeat the questions, and give answers in an e-mail to the TCI List Server before moving on to the next reading assignment. This way everyone will benefit from these questions and answers. By sending questions directly to me, we will avoid unnecessary clutter on the List Server. Previous reading assignments, notes, questions, and answers are available in the TCI Library at http://www.telephonecollectors.info/telephony-101/.

Please read the section called Transformer in the Appendix (p. 223-224). We need to understand how transformers work before starting Chapter 4.

Suppose you took two long insulated wires and wrapped them together around a pencil-size core. It would be even better if the core had some soft iron in it to boost up the magnetic field. Same wire, same number of turns, all on the same core. Don't do this at home, but we're going to imagine that we take the ends of one coil and plug them into a 120-volt, 60-cycle-per-second wall outlet. If you really did this, you might not use enough turns of wire and the current would be really high and cause a fire. So please just do this in your imagination.

Let's call the coil that is plugged into the wall the primary winding and the other coil the secondary winding. To begin the thought experiment, consider that the ends of the secondary winding are not connected to anything so no current can flow through this winding. But there is current flowing in the primary winding, and according to Oersted's principle this current will create a magnetic field. This magnetic field is varying (60 cycles per second), so according to the Faraday-Henry principle a voltage will be induced in nearby wire. In our transformer, there are two wires that are nearby: the primary winding and the secondary winding. Since these two windings are identical, the voltage induced in each is identical.

The voltage across the primary winding is 120 volts because we plugged it into the wall outlet. Therefore the voltage across the secondary winding must also be 120 volts.

Now suppose we had used twice as much wire in the secondary winding such that it had twice as many turns of wire as the primary winding. You're going to get another 120 volts out of the additional half of this winding, so altogether you will get 240 volts across this larger secondary winding. Following this logic, it is generally true that the ratio of the secondary voltage to the primary voltage is the same as the ratio of the number of turns in the secondary winding to the primary winding.

$$V_S/V_P = N_S/N_P$$

Next consider what happens when you connect the secondary winding to something (e.g., a resistor) such that current can flow in the secondary winding. The ac current in the secondary winding will now create its own changing magnetic field, and this will mess around with the magnetic field created by current in the primary winding. The net result will be a somewhat smaller overall magnetic field which would try to reduce the back voltage in the primary coil. But the primary voltage is fixed at 120 volts, so there will be an increase in current in the primary winding to put the back-voltage at 120 volts. What has happened here is that the second magnetic field has reduced the impedance of the primary winding, and the increase in current occurs to satisfy Ohm's law.

When things get really messy like this, we can sometimes introduce conservation of energy to make progress. It works here. If you multiply voltage by current you get energy available in one second. We must have the same energy on the primary side as on the secondary side because we are not adding any extra energy to the secondary circuit. So conservation of energy dictates

$$V_P \times I_P = V_S \times I_S$$

or equivalently

$$I_P = (V_S/V_P) \times I_S = (N_S/N_P) \times I_S$$

or equivalently

$$I_S = (N_P/N_S) \times I_P$$

Of course to get these equivalent equations we have substituted from the above equation for the ratio of the voltages.

The bottom line is that if the secondary winding has more turns of wire than the primary winding, then the transformer will step up the voltage, but it will reduce the current. Fewer turns of wire and it will step down the voltage and increase the current. You need to remember this bottom line, and the equations are in the Appendix if you ever need them.

If there are any questions about the current reading assignment, we will deal with the questions before moving on to the next reading assignment.

Ralph

P.S. I have used a little more formatting in the above equations than I ordinarily use in an e-mail, so if you can't read them just go to the TCI library and look at the pdf version.

Telephony 101 – Transformers December 7, 2012

Hello All,

First let me repeat that one of our readers found an error in the book on p. 224. In the paragraph following Equation 9, the text should refer to Fig. A-6, rather than to Fig. A-3. Please mark this correction in your books.

Another reader asked why a coil is called a transformer? There is some confusion in telephone terminology, but we can understand it. A single winding such as described in the Appendix section called Coil is, in fact, a coil (aka inductor and choke in electronics). Multiple windings in telephone work are called induction coils (Chapter 4 and later) or repeating coils (Chapter 16), but in other electrical applications these are called transformers. They are called transformers because they can transform a given ac voltage, current, and impedance into another ac voltage, current, and impedance.

Another question was about the equations, and specifically why is

$$V_1 = (N_1/N_2)V_2 \qquad \text{Eq. (7)}$$

equal to

$$V_1 = (N_1/N_2)^2 R_2 I_1 \text{ ?}$$

Shouldn't it be

$$V_1 = (N_1/N_2) R_2 I_2 \text{ ?}$$

Both equations are correct. Look at Equation (8) and just turn it upside down:

$$I_2 = (N_1/N_2) I_1$$

Now substitute this equation for I_2 in the previous equation and you get the equation above that (i.e., the last equation on p. 223).

The value of doing this is that Ohm's law says that

$$V_1 = R_1 I_1$$

so if we compare this with the last equation on p. 223 you can see that

$$R_1 = (N_1/N_2)^2 R_2$$

which is Equation (9).

If you have any follow-up questions, send them directly to me. We will now move on to the next reading assignment, which I will post soon.

Ralph