04.1 nlnmul.tx Transformers

Electrical transformers are *two-port linear* elements that consist of two tightly coupled coils of wire. Due to the coils' magnetic field interaction, time-varying current through one side induces a current in the other (and vice-versa).

Let the terminals on the **primary (source) side** have label "1" and those on the **secondary (load) side** have label "2," as shown in Fig. tx.1. These devices are very efficient, so we often assume no power loss. With this assumption, the power into the transformer must sum to zero, giving us one voltage-current relationship:

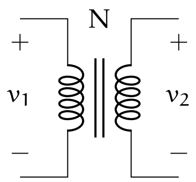

Figure tx.1: circuit symbol for a transformer with a core. Those with "air cores" are denoted with a lack of vertical lines.

Note that with two ports, we need two elemental equations to fully describe the voltage-current relationships. Another equation can be found from the magnetic field interaction. Let N_1 and N_2 be the number of turns per coil on each side and $N \equiv N_2/N_1$. Then

These two equations can be combined to form the following elemental equations.

Definition 04 nlnmul.1: transformer elemental equations

$$v_2 = N v_1 \qquad i_2 = -\frac{1}{N} i_1$$

So we can **step-down** voltage if $N < 1$. This is better, in some cases, than the voltage divider because it does not dissipate much energy. However, transformers can be bulkier and somewhat nonlinear; moreover, they *only work for ac signals*. Note that when we step-down voltage, we step-up current due to our power conservation assumption.
If $N > 1$ we can **step-up** voltage. Voltage dividers cannot do this! It is not amplification, however, because power is conserved—we simultaneously step-down current. So with a transformer, we can *freely trade ac voltage and current*.

Example 04.1 nlnmul.tx-1 re: transformers and impedance

Given the circuit shown, what is the effective impedance of Z_L on the source side?