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:

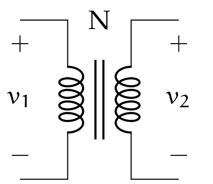

Figure tx.1: circuit symbol for a transformer with a core. Those with "air cores" are denoted with a lack of vertical lines.

primary side

secondary side

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 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.

step–down

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.

step–up

Example nlnmul.tx–1 **re: transformers and impedance**

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