

# Equivalent Circuit of a Transformer

Sam Seyfi  
Eric Christensen  
Magnelab, Inc.  
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## Equivalent Circuit of a Transformer:

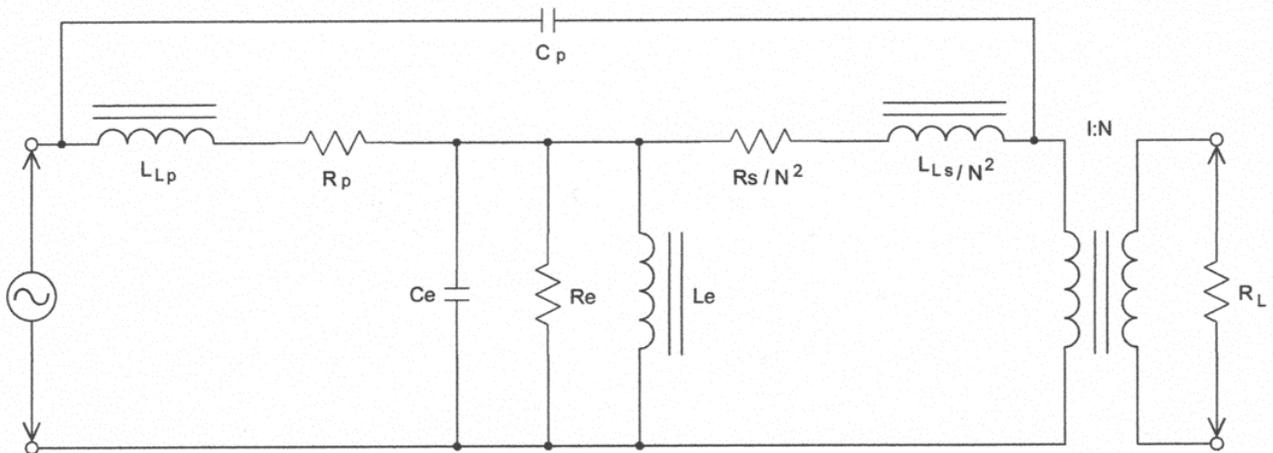


Figure 1

Understanding the equivalent circuit of a transformer plays a significant roll in the ability to design a transformer to meet specific circuit requirements as well as the ability to troubleshoot transformer design and/or operational issues.

In figure 1 above, the transformer is depicted as a perfect transformer (that is a transformer with no internal losses) with a turns ratio of 1 to N (with N representing the number of secondary turns for each primary turn). All of the transformer losses have been extracted and placed as components in front of the transformer. Each of these components must be satisfied before any power is transformed by the turns ratio and delivered to the load ( $R_L$ ).

Let's look at each of these components individually:

$L_{Lp}$  – Leakage inductance of the primary winding. This is any magnetic flux induced in the primary winding that does not link with any other windings.

$R_p$  – Primary winding resistance. The DC resistance of the primary winding measured in ohms.

$C_e$  – Intra-winding capacitance. The capacitance that develops from turn to turn

within the same winding of a coil.

$R_e$  – Core losses in the form of eddy current losses and hysteresis losses. The current through this resistor generates heat in the core.

$L_e$  – Primary inductance. The current that is drawn through this inductance is referred to as the magnetizing current.

$C_D$  – Inter-winding capacitance. The capacitance that develops between the primary winding and the secondary winding of a transformer.

$R_s/N^2$  - Secondary winding resistance. The DC resistance of the secondary winding measured in ohms. This resistance is reflected back into the primary of the transformer by the square of the turns ratio  $N$ . (see “1: $N$ ” below)

$L_{Ls}/N^2$  - Leakage inductance of the secondary winding. This is any magnetic flux induced in the secondary winding that does not link with any other windings. This inductance is reflected back into the primary of the transformer by the square of the turns ratio  $N$ . (see “1: $N$ ” below)

1: $N$  – Turns ratio. This is the number of turns in the secondary for each turn in the primary. i.e. if the primary has 5 turns and the secondary has 20 turns,  $N = 4$ .  $N$  may be a fraction for step down transformers.

$R_L$  – Represents the load on the secondary winding. This may be a single load component or an entire circuit. This load is also reflected back to the primary by the square of the turns ratio.

When designing or evaluating a transformer some of the elements of the equivalent circuit can be considered irrelevant or inconsequential depending on the characteristics of the device and its intended use. It is important, however, for the engineer to understand that these elements are present and the effect they can have on the source and/or load circuit as well as on each other. You should also be aware of ways to minimize or maximize each of the components in the design and manufacturing of the transformer to suit your requirements.

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