

# Using Standard Transformers in Multiple Applications



## Creative Use of Alternate Winding Connections

### Introduction

Many Coilcraft transformers were designed for optimal performance in a specific application. Catalog information presents the transformers based on the specifications for that original application. However with a little creative thinking, most transformers can be adapted to a variety of circuit uses just by considering different connections for the windings.

### What to Consider

A transformer winding might be constructed of multiple wires intended to be connected in parallel. The user might instead consider connecting those wires in series to increase the resulting inductance or turns ratio. Careful consideration of all the resulting variables should be made before attempting alternate configurations. Those variables include:

- inductance value (L)
- dc resistance (DCR)
- rms current (Irms)
- temperature rise (due to current and resistance)
- peak / saturation current (I<sub>pk</sub> or I<sub>sat</sub>)
- self resonant frequency (SRF)
- voltage / isolation between wires / safety

For example, assume a coil winding, either primary or secondary side, is made with two parallel (bifilar) wires.

### Inductance (L)

Inductance is proportional to the square of the number of turns (N<sup>2</sup>) when wound on the same core. So two equal coils, wound on the same core and connected in series have about **four times the inductance** of the parallel configuration.

When connecting two equal-turn windings in parallel on the same core, the **inductance does not change**, but the **DC resistance is half** of that of each single winding. This is often confused with connecting separate inductors in parallel, for which the inductance is halved. When the two windings are in parallel on the same core, it is effectively replacing a single wire by two wires, and therefore the inductance remains the same.

### DC Resistance

When connecting two equal windings in parallel, the combined DC resistance is half that of each winding.

When connecting two equal windings in series, the combined **DC resistance is two times that of each winding**. When equal windings are connected in series, the **DC resistance is fourfold (4x)** compared to the same windings in a parallel combination.

### RMS Current

The rms current rating is based on temperature rise, which is related to power loss.

The amount of current flowing through the series combination that causes the same temperature rise as the parallel combination is calculated as follows:

$$I_s^2 \times DCR_s = I_p^2 \times DCR_p$$

Therefore:

$$\frac{I_s}{I_p} = \sqrt{\frac{DCR_p}{DCR_s}} = \frac{1}{2}$$

**For equal windings**, I<sub>rms</sub> for the series connection is half that of the parallel connection and yields the same temperature rise.

### Saturation Current

Saturation of ferrite or powdered iron cores is related to the energy storage capability of the inductor as indicated by the volt-time product (V × t). An approximation of the volt-time product can be calculated from the equation:

$$V = L \times di/dt$$

$$\text{rearranged in the form } V \times T = L \times I_{sat}$$

Where:

V × T is the volt-time product in volt-μs

L is the inductance in μH

and it is assumed that:

**dt** is approximated by T, and

**di** is approximated by I<sub>sat</sub> (the rated saturation current shown on the data sheet)

With two equal windings in parallel, I<sub>sat</sub> is the same as that of one winding. With two equal windings in series, the number of turns is doubled, which doubles V × T, quadruples L, and therefore results in an I<sub>sat</sub> that is half of the single-winding and (equal) parallel winding I<sub>sat</sub>.

## Self Resonant Frequency (SRF)

The self resonant frequency of two bifilar-wound wires depends on the inductance and capacitance. When connected in series, the interwinding capacitance and winding capacitance to ground may change. The effective capacitance change may be small compared to inductance but should be considered. Since inductance is 4 x, the self resonant frequency is proportional to  $1/\sqrt{L \times C}$  so the series SRF will be about  $1/\sqrt{4}$ , approximately half that of the parallel configuration.

## Voltage / Isolation / Safety

Coilcraft typically specifies isolation between windings that are intended to be used separately, such as with coupled inductors or transformers. We do not normally specify isolation between wires on multi-wire (bifilar, trifilar, etc.) windings designed to be connected in parallel.

When wires are bifilar wound, the isolation between them will be quite small, and not routinely tested. Therefore, it is recommended that sufficient testing of samples be performed to verify a safe isolation voltage for the application.

## Conclusion

The example discussed is a best-case simple two-wire coil, yet it illustrates many of the variables to consider when using our products in connection configurations for which they were not designed. More complicated wiring configurations could require additional considerations that are not discussed here.