Calculating $\mu_r$

The Relative Permeability of a Ferrite Toroid Core

Robert Weaver, 2013-04-15

**Step 1:** Determine the $A_L$ value with a test winding. Wind several turns of wire on the core, or use an existing winding that it may already have.

Measure the inductance $L$ in nanoHenries, and count the turns $N$.

The $A_L$ value is given by:

$$A_L = \frac{L}{N^2}$$

If you’re only interested in finding out how to wind a coil of a given inductance, then this is all the information you need. The above formula can be rearranged to give the required number of turns for a specific inductance:

$$N = \sqrt{\frac{L}{A_L}}$$

Or, it can be rearranged to give inductance for a given number of turns:

$$L = A_L N^2$$

(Remember that units are nH. To convert to $\mu$H, divide by 1000.)

Now, to help identify the actual core material, which determines the range of frequencies over which it is useful, then the permeability must be determined using the method given in the remaining steps.

**Step 2:** Referring to the diagram, measure the core dimensions in millimeters: Inside diameter $d_I$, Outside diameter $d_O$, and Height $h$.

**Step 3:** Calculate the core cross sectional area $A_C$ and the magnetic path length $X_C$:

$$A_C = \frac{(d_O - d_I)h}{2} - \pi r^2$$

The magnetic path length is given by:

$$X_C = \frac{(d_O + d_I)\pi}{2}$$

**Step 4:** Calculate $\mu_r$:

$$\mu_r = \frac{A_L X_C}{0.4\pi A_C}$$

The formula can also be written as:

$$\mu_r = \frac{A_L (d_O + d_I)}{0.4h (d_O - d_I) - 0.8\pi r^2}$$

The value often listed by ferrite manufacturers and suppliers is initial permeability $\mu_i$, which for most practical purposes is the same as the value calculated here.

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