Winding solenoid inductors for use in high power matching networks.

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Standard commercially available inductors usually have ferrite cores which saturate under high power. Many times the easiest solution to this problem is for the user to wind his own coils with an air or non ferromagnetic core. This has not only the advantage of avoiding saturation but almost any specific inductance value can easily be fabricated with magnet wire and cores made from simple material. The shape of the coil in this note is chosen as a single layer solenoid. This geometry avoids excessive voltage between any adjacent windings and allows the use of enamel insulated magnet wire even for high voltage applications.

Equation 1 gives a simple relation between the coil inductance and the geometric parameters for the solenoid.

$$L = \frac{a^2 n^2}{(9a + 10b)} \qquad \textbf{(1)}$$

where a is the coil radius in inches, b is the length of the coil in inches, n is the number of turns, and L is the inductance in micro henries. This formula is valuable for inductances as low as a few tenths of a microhenry. Coils with inductances less than this become difficult to construct and implement properly because the lead length may provide more inductance than the coil.

The usual way to proceed in designing a coil with a specific inductance is to specify an initial length and radius and calculate the number of turns from equation 2 which is derived from equation 1.

$$n = \sqrt{\frac{L\,(9a + 10b)}{a^2}} \qquad \textbf{(2)}$$

If the calculated number of turns is too low or high, a new geometry is chosen which gives reasonable results. This is not difficult and after a short time a feeling is developed for what is needed. Wooden dowels, plastic tubes or rods, and even high power non inductive resistors with large resistance (>100 K) make good forms for winding. The resistors are particularly useful because the resistor leads provide an easy point to attach (solder) the ends of the coil wire.

The only thing remaining is to choose the correct wire size. If the individual turns are to be placed close to each other, the diameter of the wire (D) can be calculated from the length (b) and the number of turns (n).

$$D = \frac{b}{n} \qquad \textbf{(3)}$$

The closest larger wire gauge (American Wire Gauge (AWG)) can be looked up in a table or calculated from the following empirical relation.

$$AWG = -8.628 \ln(3.078\,D) \qquad \textbf{(4)}$$

Always choose a larger AWG number (smaller size) than calculated from equation 4 because it is never possible to wind the wires exactly together.

After winding, electrical tape or heat shrinkable tubing can be used to maintain the shape, and it is always a good idea to provide a good mechanical termination for the leads on the coil form. In many cases the tape or tubing may not be needed. The leads should always be kept as short as possible.

Example

Design a 10 μH coil to be wound on a 0.5 inch radius rod with a 2 inch length.

$$n = \sqrt{\frac{10\,(9\times 0.5 + 10\times 2)}{0.5^2}} = 31.3\ \textit{turns}$$

$$D = \frac{2}{31.3} = 0.0639\ \textit{inches}$$

$$AWG = -8.628\,\ln(3.078\cdot 0.0639) = 14.03$$

This wire guage turns out to be a very stiff and the coil would be difficult to wind. If these coil dimensions are desired, the solenoid can be wound with smaller diameter wire with spaces between windings. Otherwise, a smaller coil form or shorter length should be used.

Try a 10 μH coil to be wound on a 0.375 inch radius rod with a 1.5 inch length.

$$n = \sqrt{\frac{10\times(9\times 0.375 + 10\times 1.5)}{0.375^2}} = 36.1\ \textit{turns}$$

$$D = \frac{1.5}{36} = 0.0417\ \textit{inches}$$

$$AWG = -8.628\,\ln(3.078\times 0.0417) = 17.7$$

This inductor can now be wound with *AWG* 18 wire which is easier to work with than *AWG* 14.

The high voltage tuning capacitors and inductors may be obtained from:

Cardwell Condenser Corporation
80 East Montauk Highway
Lindenhurst, New York 11757
(516) 957-7200