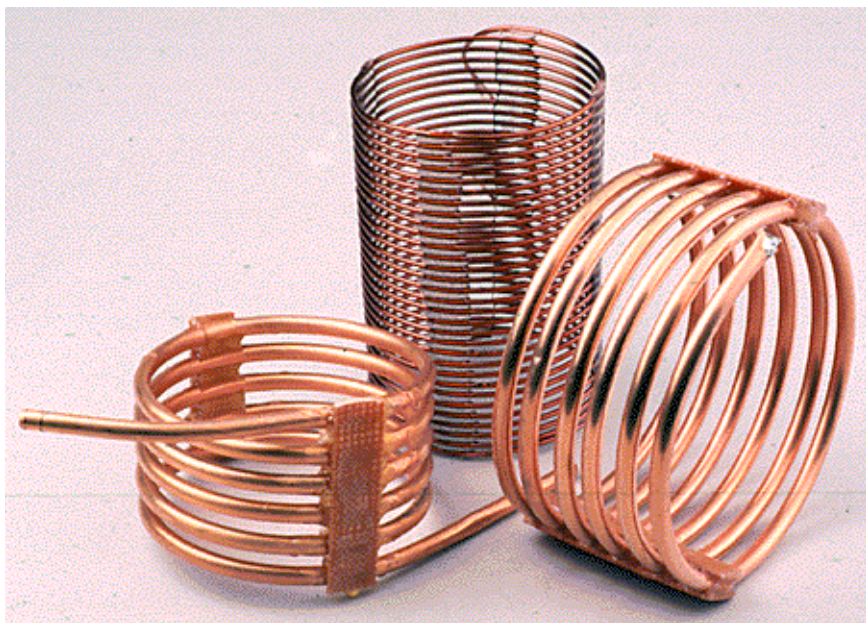


Homebrew Your Own Inductors!

Can't find the inductors you need for an antenna, a tuner or amplifier? Build your own—it's easy!

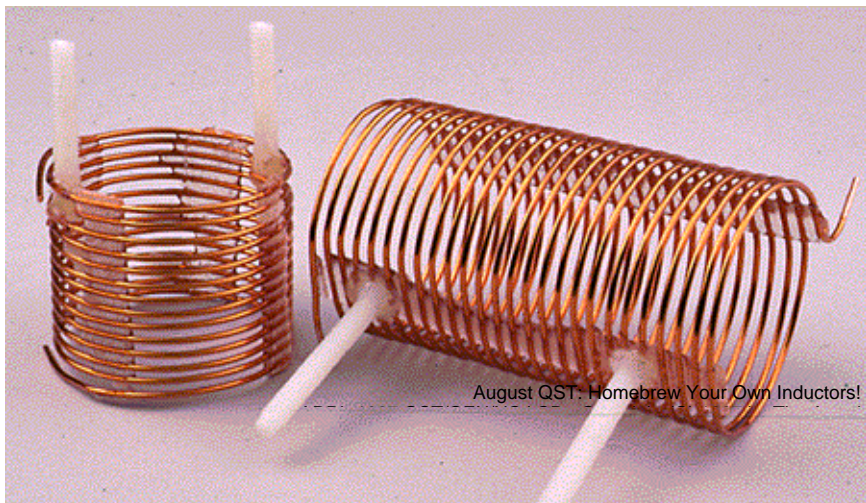
By Robert H. Johns, W3JIP



Air-dielectric inductors can be made quite easily at home. Some coils are held together by clear epoxy ribs, others use scrap pieces of PC board and epoxy. The larger coils are made from $\frac{1}{4}$ -inch-diameter copper tubing.

Corrections to this article appear in **October QST Feedback**.

Those favorites of do-it-yourselfers—Barker & Williamson's (B&W) Miniductor and Air Dux coil stocks—are getting harder to find. When you do locate a source, you'll find the inductors are rather expensive. Less-expensive inductors, such as those shown in the accompanying photographs, can be homemade, using epoxy for the supporting ribs. The coils have excellent Q—some even higher than those of shiny, tinned coils that are often used. [1, 2] Mounting posts to support the homemade coils on a chassis can be added as shown in **Figure 1**. I'll tell you how you can produce similar inductors, make coil forms that easily release a tightly wound coil after wrapping and how to wind the coils with uniform turn spacing.



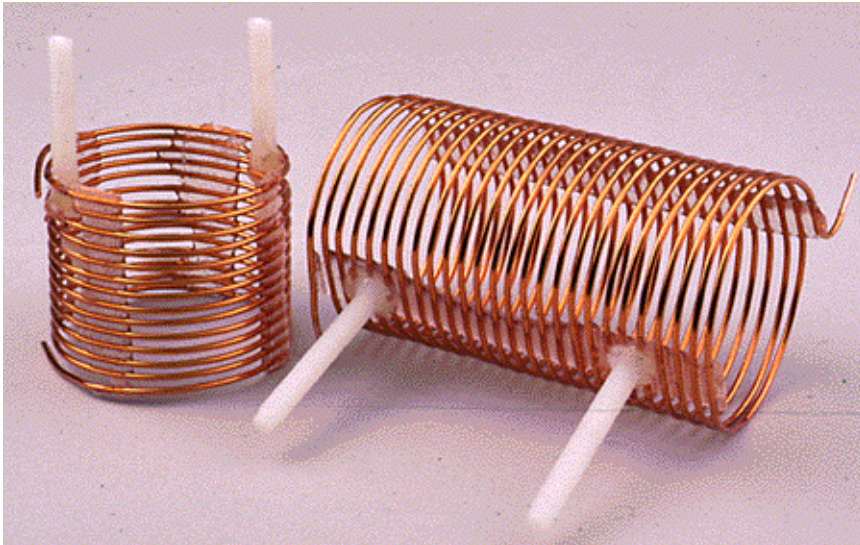


Figure 1—Mounting posts for these coils are made from flat-head nylon bolts attached to the coils with epoxy.

For greater coil strength, rib-reinforcing strips made from PC board and perf-board can be used to further strengthen the inductor assembly. For these coils, I use magnet wire because the epoxy attaches firmly to the wire's plastic coating. Bare copper wire can also be used, but its bond with the epoxy is not as strong.

Coil Forms

You'll need some forms on which to wind the coils. Such forms are readily made from inexpensive PVC pipe (see Figures 2 and 3). Slots ($\frac{3}{8}$ inch wide or more) cut into the pipe walls allow the form to collapse and release a coil after it has been wound and the epoxy ribs applied. While the coil is being made, the coil-form walls are supported by a block of wood or piece of pipe inside the form. After the epoxy sets firmly, the block is removed, the ends of the coil wire cut away from the form and the coil-form walls are pushed in to free them from the finished coil. The small holes in the form are used to secure the wire to the form at the beginning and end of the winding.

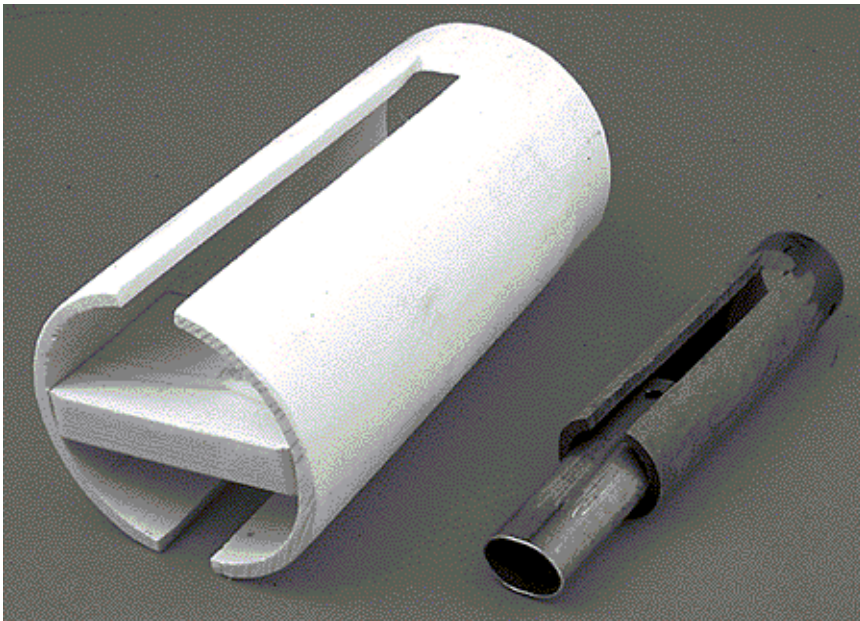


Figure 2—Coil-winding forms made from PVC pipe. The slots allow the sides of the cylinders to collapse to release the coil. Epoxy for the support ribs is applied to the wire turns over the slots of the forms.

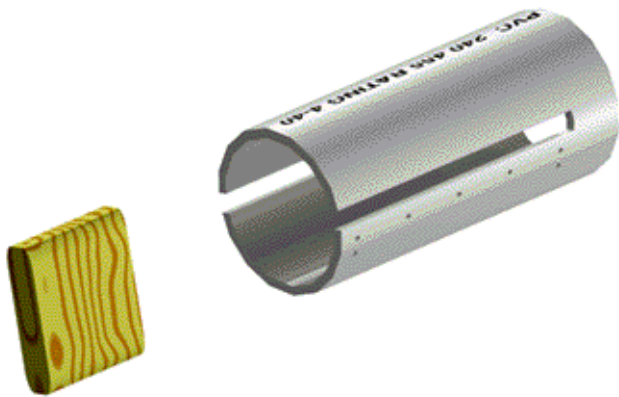


Figure 3—Drawing of a typical coil-winding form and its insert. Dimensions are dependent on the size of the coil (see Table 1). The slot width, *t*, should be a minimum of $\frac{3}{8}$ inch. The text explains how to use the form’s insert.

Table 1—Coil and Form Data

<i>Approx. Coil Diameter</i>	<i>Coil Length</i>	<i>PVC Pipe Size</i>	<i>L</i>	<i>S</i>	<i>t</i>	<i>Block Width or Pipe Size</i>
1.1	3.5	$\frac{3}{4}$ Sch 80	5	4	0.5	0.5 (copper pipe)
1.7	4	1 $\frac{1}{4}$ Sch 80	6	5	0.5	1 (copper pipe)
2.4	5	2 Sch 40	7	6	0.9	2
3.5	7	3 Sch 40	9	8	1.0	3
4.5	7	4 Sch 40	9	8	1.0	4

All dimensions are in inches. The size columns refer to *pipe sizes* and not actual pipe dimensions. Schedule 40 PVC pipe is commonly available in hardware and plumbing supplies. Schedule 80 pipe has a thicker wall and is available from larger distributors. The size and schedule numbers are clearly marked on all PVC pipe. *L*, *S* and *t* are the dimensions referred to in **Figure 3**.

Table 1 gives the dimensions of some of the coils and forms illustrated. These dimensions can be modified if you want to build longer coils. The width of a spacing block made from one-inch board ($\frac{3}{4}$ -inch thick, finished) is also in the table. After a coil is wound, the tightly wound wire firmly holds the block within the coil form. Cut the spacing block to the size given in **Table 1**, then round its edges until it is a snug fit in the end of the form that *isn't* slotted. The block is removed from the coil form by tapping it out with a hammer and a dowel.

A metal tube brace—instead of a wood block—is used for the two smaller coil forms. The tube is flattened to create an *oval* inside support. A coil is wound on the form with the long diameter of the tube’s ellipse holding the form sides apart. When the coil winding is finished, the tube is simply rotated a quarter turn and removed. It helps to roughen the outside of a coil form so that there is less of a tendency for the wire to slip while the coil is being wound; coarse sandpaper or a file will do the trick.

Winding Coils

It is possible to space the coil turns as you wind them, and then even out the spacing after the coil is finished. A better approach is to wind a *spacing cord* between the wire turns. (See **Figure 4**.) Nylon monofilament line works well. Large sizes (0.065, 0.080, and 0.095-inch diameter) of this material are sold in hardware stores and departments as rotary trimmer (weed cutter) line. For wider

turn spacing, use zip cord or speaker wire having two parallel conductors. Wider turn spacing improves coil efficiency; closer turn spacing increases the coil inductance. A good compromise is to space the coil turns about one wire diameter apart.

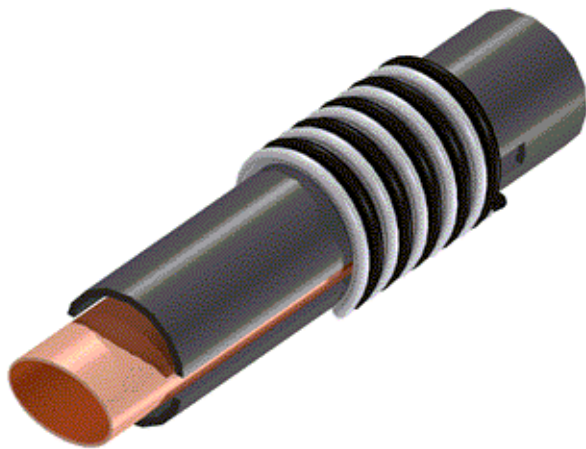


Figure 4—Wire and a spacing line are simultaneously wound on a form. The spacing line is removed once the winding is complete. See text.

If the wire is *tightly* wound on the coil form, a neater coil results. One way to keep the wire taut is to pass it between the jaws of a vise, with a heavy rag between the wire and the jaws. As you pull the wire through the vise jaws, it is kept taut and you can adjust the tension with the vise. Don't go overboard with this tightening—the wire needs only to stay in place while you apply the epoxy for the ribs.

To start winding a coil, put the spacing block or tube inside the form and insert one end of the coil wire and spacing line in the side-by-side holes at one end of the form. Wind the coil by rotating the form on its axis. When you have filled the form (or made as large a coil as you need), cut off the wire supply and feed the wire end into the nearest small hole in the form. Tighten the coil ends by grasping the wire inside the form with needlenose pliers and rotating the pliers. Again, don't overtighten—the wire needs just to stay in place. Allow the spacing line to unwind and remove it from the form.

Building Ribs

To make epoxy ribs for a coil, lay the coil on two separated strips of wood or between the jaws of a vise, so that the work surface doesn't interfere with the setting epoxy. An inner mold is needed so that the epoxy won't drip through the turns. For the three largest coil forms, stick a length of electrical tape to the inside of the coil, in the slot of the form. The tape will easily pull away from the epoxy after it has hardened. For the two smaller forms—where there isn't much room inside for hands to work—I use craft sticks (wooden Popsicle sticks about $\frac{3}{8}$ -inch wide) covered with electrical tape. Epoxy doesn't adhere to the nonadhesive side of the tape, either. The tape-covered sticks are supported by the tapered ends of the slots and by tape or shims at the open ends of the slots.

Use regular-setting-time epoxy (4 to 6 minutes) for coil ribs, not the quick or long-working-time epoxies. Mix only enough epoxy to make one rib at a time. Apply a bead of epoxy to the coil and let it sink to wet the coil wires. Add as much epoxy as you need, without having the epoxy spread wider than the inner mold or get onto the form. Getting this right takes a little practice. With one rib setting, after a few minutes turn the coil over to apply epoxy to the other side.

Removing the Coil from the Form

Allow the epoxy to set thoroughly (overnight to be sure) before removing the coil from the form. Cut off the wire ends that pass

through the form and pull this scrap out of the form. Remove the spacer block (or oval tube) from inside the form. Press together the ends of the two halves of the coil form. If you don't have too many epoxy spills and drips, the coil will come free of the form and be self-supporting. The slots in the coil form should extend beyond the coil so that the collapsing walls of the form will separate from the coil. That is why the holes for the coil wires are not at the ends of the slots.

If you need a sturdier coil, give it four ribs. Simply stick two more strips of electrical tape to the inside of the coil and add epoxy. I have been surprised at the strength of the epoxy ribs, because of the strength of its bond to the wire and the elasticity of the cured epoxy.

Cutting and Connecting to the Coils

A long coil can be divided by cutting the ribs with a hacksaw. Wire turns can be removed from a coil by breaking the wire out of a rib, or by nipping off a turn or two at each rib with end cutters.

Before attaching wires to the coil, remove the wire's plastic coating. Making connection to the inductor at locations other than the ends is not difficult. First, push in the turns *on either side* of the turn you want to tap to. This gives you room to scrape off the enamel coating, wrap the connecting wire around the turn and solder it. If you possess a steady hand and a small soldering iron, you can scrape the outside diameter of a turn, tin the wire and solder a tap wire to the top of the bared turn.

Mounting Coils

The coil-mounting posts shown in **Figure 1** are 2-inch-long, 1/4-20 flat-head nylon screws. The nylon-to-epoxy bond is not very good, but the strength of the joint results from the grip of the epoxy around the edges of the flat heads. With the flat bolt head on a rib, the applied epoxy forms a channel around the head, which traps it to the coil. The mounting posts can be attached at the same time you make the ribs, or later.

The end mounting posts are also 1/4-inch-diameter nylon bolts, with their heads cut off. To attach them to the coil, one turn near each end of the coil is pushed in, and the nylon post is threaded between this turn and the neighboring coil turns. Epoxy blobbed around this joint makes a positive grip on the post by penetrating into the screw threads. They're strong mounting posts.

Wire Sizes

There is no given wire size that must be used for a particular coil size. For example, you can make coils on a 1.7-inch diameter form using #20 to #12 (or even larger) wire. Your application dictates the wire size and physical size of the coil.

Large-Diameter Coils

This method of homebrewing coils can be used for making large coils by beefing up the epoxy ribs. The title photo shows a pair of coils wound from 1/4-inch-diameter, thin-wall copper tubing. This inexpensive *refrigerator tubing* is available from hardware and plumbing suppliers. A coil can be wound on any cylindrical form and then released. It retains its spiral shape by itself and can be stretched and compressed to give the desired turn spacing. Epoxy ribs are added when the coil is removed from the form.

Perfboard and PC board scrap cut into strips can be used as an inside mold for the epoxy ribs. The PC board material bonds to—and reinforces—the epoxy ribs. Roughen the board surface so that the epoxy has a greater surface area to adhere to. If additional strength is desired, add another strip to the outside of the rib. If you want a solid rib, fill the holes between coil turns with epoxy. Use strips of tape to close one end of the holes formed between the coil turns and the circuit board strips. Dribble epoxy into the rib sandwiches and fill them. Quick-setting epoxy is a help here, but it's a nuisance to work with. Fiber-filled fiberglass resin, available from auto parts stores, can be used to build large coils, but it is too noxious for indoor use.

Windup

With some inexpensive, readily available materials, you can make your own air-wound inductors. Not only will they look good and work well, you can say you made them yourself!

Robert H. Johns, W3JIP, is a physics teacher who was first licensed as a Novice in 1952. He originated the antenna trap design that uses coaxial cable for the trap's inductor and capacitor and dual-frequency traps with bifilar windings of XLP wire. [*, ±] More recently, Bob developed a way to homebrew 8-inch-diameter coils with very high Q. [++,] Bob has authored many antenna articles in amateur and shortwave magazines. You can contact him at Box 662, Bryn Athyn, PA 19009.

Notes

*Robert H. Johns, W3JIP, "Coaxial Cable Antenna Traps," *QST*, May 1981, pp 15-17.

+Robert H. Johns, W3JIP, "Dual-Frequency Antenna Traps," *QST*, Nov 1983, pp 27-30.

++Robert H. Johns, W3JIP, "Home-Brewing Large Antenna Coils," *QST*, Oct 1992, pp 45-49.

¹Verified in the ARRL Lab.

²Because of the skin effect, RF current flows mostly in the tin/lead coating of a tinned wire. Its resistance is significantly greater than that of copper, reducing the Q.

Calculating Air-Core Inductors

The approximate inductance of a single-layer air-core coil may be calculated from the simplified formula:

$$L(\mu H) = \frac{d^2 n^2}{18d + 40l}$$

where:

L = inductance in microhenrys,

d = coil diameter in inches (from wire center to wire center),

l = coil length in inches, and

n = number of turns.

This formula is a close approximation for coils having a length equal to or greater than 0.4 d. Inductance varies as the square of the turns. If the number of turns is doubled, the inductance is quadrupled. This relationship is inherent in the equation, but is often overlooked. For example, if you want to double the inductance, put on additional turns equal to 1.4 times the original number of turns, or 40% more turns.

Example: What is the inductance of a coil if the coil has 48 turns wound at 32 turns per inch and a diameter of $\frac{3}{4}$ inch? In this case, $d = 0.75$, $l = 48/32 = 1.5$ and $n = 48$.

$$L = \frac{0.75^2 \times 48^2}{(18 \times 0.75) + (40 \times 1.5)} = \frac{1300}{74} = 18 \mu H$$

To calculate the number of turns of a single-layer coil for a required value of inductance, the formula becomes:

$$n = \frac{\sqrt{L(18d + 40l)}}{d}$$

Example: Suppose an inductance of 10.0 μH is required. The form on which the coil is to be wound has a diameter of one inch and is long enough to accommodate a coil of $1\frac{1}{4}$ inches. Then $d = 1.00$ inch, $l = 1.25$ inches and $L = 10.0$. Substituting:

$$n = \frac{\sqrt{10.0[(18 \times 1.00) + (40 \times 1.25)]}}{1} = \sqrt{680} = 26.1 \text{ turns}$$

A 26-turn coil would be close enough in practical work. Since the coil will be 1.25 inches long, the number of turns per inch will be $26.1 / 1.25 = 20.9$. The proper inductance is obtained by winding the required number of turns on the form and then adjusting the spacing between the turns to make a uniformly spaced coil 1.25 inches long.—1997 *ARRL Handbook*. (See Chapter Six of the Handbook for more information on making and calculating inductors.)