

# DOUG'S DESK

CONSTRUCTION PROJECTS, TECHNIQUES, AND THEORY

## Some Practical Aspects of Toroids

**A**lthough few of today's construction projects are without toroidal tuned circuits or toroidal broadband transformers, a vast number of builders are confused about how to wind and use toroids. Many articles on this subject have been published in recent decades, but still the need for practical knowledge remains. We authors receive numerous letters concerning how the windings should be placed on toroid cores. Information on how to wind balun or "binocular" cores (see photo B) is also frequently requested. Most authors are pleased to answer such letters if the writer includes an SASE with his or her request: The cost of postage and envelopes can be significant for authors who may receive several letters per week.

Toroids are popular because they provide compact transformers and inductors, compared to air-wound equivalent components. Generally speaking, the Q of a given toroidal coil, if wound on the proper type of core, can exceed that of an air-wound coil. This is because less wire, and a larger wire diameter, is used to obtain a specified inductance. This reduces the AC or RF resistance of the coil and improves the Q (desirable). Another advantage provided by toroids is their self-shielding characteristic. Apart from stray capacitive coupling to nearby circuit components, an unshielded toroid is equivalent to an air-wound inductor in a metal shield. This enables the builder to develop compact equipment that operates in a stable manner.

### Coil Turns and Wire Length

In order to determine how many turns of wire

P.O. Box 250, Luther, MI 49656

to use for obtaining a given inductance, the user must have knowledge of the AL factor of the particular toroid or balun core. The equations for calculating the number of turns are provided in the *ARRL Handbook* and in a catalog that is available from Amidon Associates, Inc.<sup>1</sup> AL factors are also given in the catalog. A quick answer to this question can be had by using VE3ERP's HAMCALC software.<sup>2</sup> Murphy's program runs under DOS and is written in GW BASIC. Complete data for selecting the right Amidon core, and determining the correct number of turns, is in the software program. Numerous other circuit design programs are included on the VE3ERP diskette.

The exact length of wire needed for a specified inductance can be determined by first wrapping one complete turn on the toroid core, then unwinding and measuring it. Multiply this dimension by the total number of turns. Allow three additional inches of wire to ensure that the pigtailed are long enough to reach the connection points on the PC board.

### Winding The Toroid

I received an interesting letter in which the reader asked, "Do I wind the wire around the outer perimeter of the toroid?" Definitely not! The wire always goes through the core, as shown in the accompanying photos.

Fig. 1 contains examples of the methods I use when winding toroids and balun cores. Example (A) shows a 30-degree gap between the ends of the winding. This is the prescribed procedure for best performance. In other words, the winding should occupy approximately 330 degrees of the core area.

Illustration (B) shows a toroid that would be

used in a narrow-band tuned circuit. I prefer to wrap the smaller (primary) winding over the grounded or Vcc end of the larger (secondary) winding for this application. This minimizes the transfer of unwanted harmonic currents to the secondary via capacitive coupling. The smaller winding can, however, be wound over the entire secondary winding, as seen at (C) in fig. 1. The method shown at (C) is recommended for use when winding broadband transformers.

A balun core with two windings is seen at (D) of fig. 1. If the secondary has a center tap (terminal 4), it is made at the far end of the core where wires 1 and 2 exit the holes. Make certain that the bare wire at the tap point does not short circuit the adjacent coil turns. A shorted turn will spoil the Q of the winding. It is wise to place a small piece of meat-wrapping paper under and around the tap point on any toroid or balun-core transformer. This will help prevent a shorted turn. An example of a toroid with many taps may be seen in photo C. Since the turns are well separated from one another, it is unnecessary to insulate the taps with paper or tape. The taps were made by scraping the enamel insulation from each affected turn (at the tap point), then soldering a piece of bare wire to the appropriate turn, as shown. The small toroid with two windings (lower right foreground) has its primary wound over one end of the main winding, as illustrated in fig. 1(B).

Toroids with two or more windings should have their windings placed on the core in the same clockwise or counterclockwise sense or direction. A layer of insulating tape, such as 3M glass tape or masking tape, may be desirable between windings if one of them carries DC voltage. However, high-quality enamel- or form-



Photo A— Some generic versions of toroid cores.

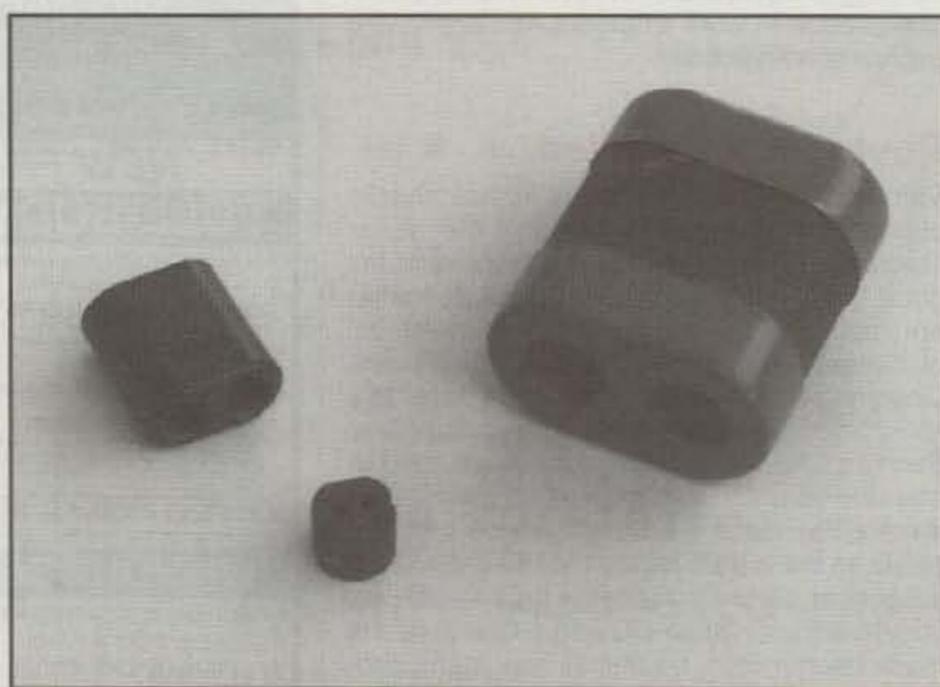


Photo B— Photograph of three styles of ferrite balun or binocular cores. The larger one is typical of those used for broadband matching transformers in push-pull solid-state RF power amplifiers.

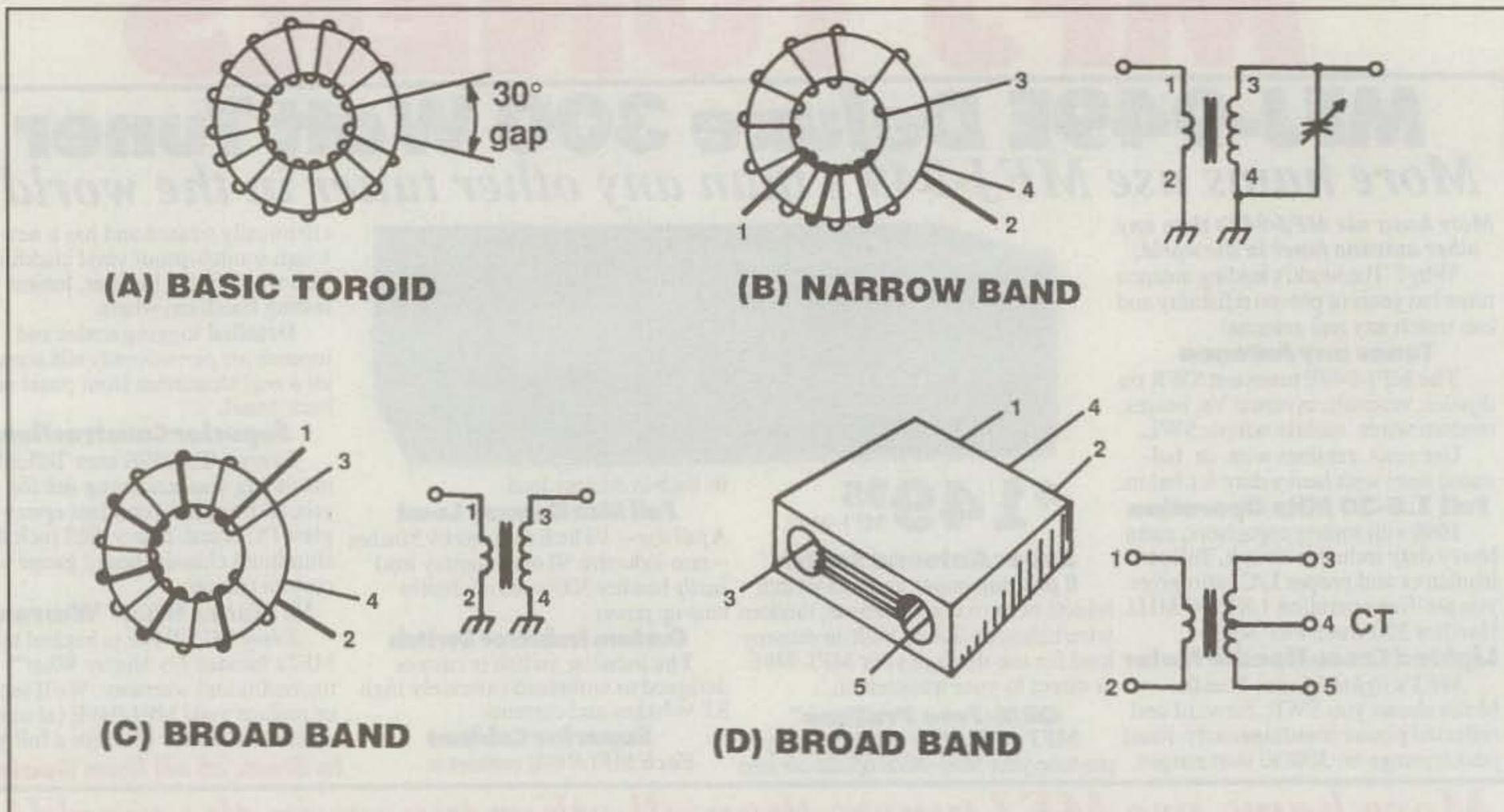


Fig. 1— Various ways to wind toroidal and balun-core inductors and transformers. The 30-degree gap at (A) is recommended for best performance. Illustration (B) shows the smaller primary winding wound over the grounded end of the secondary winding (see text). Drawing (C) shows both transformer windings wound over 330 degrees of the core. This is standard procedure for most broadband transformers. (D) depicts how a balun or binocular core is wound. Two rows of ferrite toroids may be glued together and used in the same manner.

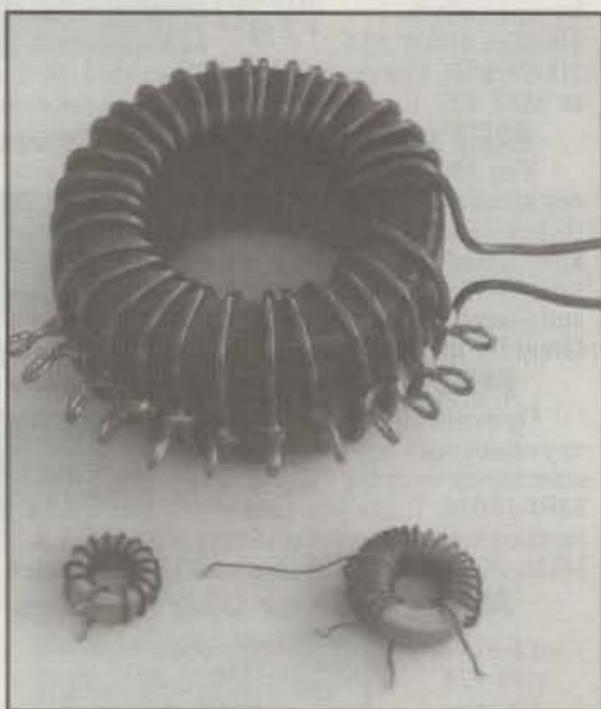


Photo C— Photograph of a tapped toroid inductor and two smaller cores that have been wound (see text for a discussion about the small core at the lower right).

var-insulated magnet wire that has not been abraded should require no additional insulation.

### The Correct Core is Important

Beware of unidentified toroid cores that are sold at amateur radio fleamarkets and by vendors of surplus electronics equipment, unless the core type is clearly specified. All toroids look alike, except for their size and color. Some are designed for use at audio or very low frequen-

cies. Others are designed to be used at HF or VHF. The lower the frequency rating the greater the core permeability in order to minimize the number of wire turns needed for larger inductances. Toroids are rated for optimum inductor over restricted frequency ranges. A low-frequency core used at HF, for example, will cause the inductor to have a very low Q. Circuit performance will suffer when this is done. Conversely, an HF type of core, when used to wind an LF inductor, may require more turns than the core can accommodate. The Amidon cata-

log lists the useful frequency range and AL factor for each type of toroid that Amidon sells.

Powdered-iron cores are used generally for resonant circuits that require high Q. These cores can handle more power than equivalent-size ferrite toroids without saturating, overheating or sustaining permanent core damage. In addition, they are more stable in terms of permeability while undergoing changes in core temperature.

Ferrite cores are used mainly for broadband transformers and balun transformers. Their



Photo D— An assembled PC board that contains seven toroids that are mounted vertically to save space (see text).

high permeability results in fewer turns of wire per core size, compared to powdered-iron toroids, to obtain a specified inductance. High Q is possible also with ferrite cores, but they are quite temperature sensitive. Hence, ferrite cores are unsuitable for use in VFOs. All balun cores are made from ferrite material, which is a semiconductor substance similar to ceramic. The foregoing rules apply also to the cores used in slug-tuned coil forms. Always use the appropriate core material for the desired operating frequency.

### Toroid Mounting and Protection

Toroids can be laid flat on a PC board, or they can be mounted upright as in photo D. Vertical mounting saves space and helps to distance the toroids from nearby components. The 30 degree winding gap (see fig. 1(A)) is placed against the PC board. A generous drop of epoxy glue may be used to affix the toroid to the board. This will prevent lead flexing and possible breakage of the wires.

The completed toroid should be coated with General Cement Q-Dope or an equivalent RF coil compound. This brand of glue has become difficult to locate, but I recommend it for coating all coils. I have found that white carpenter's glue (Elmer's Glue, for one) works well as a coil coating. Once dry, it has no measurable effect on the coil Q, and it appears to be insensitive to temperature changes.

It is beneficial to coat the toroid windings to

prevent them from shifting position, once in the circuit. This is especially important when using toroids in VFOs. Also, the coating provides protection against dirt, moisture, and abrasion.

### Other Considerations

Large ferrite toroids that are used in RF power circuits, such as balun transformers, should be wrapped with insulating material before the windings are added. 3M glass tape is excellent for this purpose. I have had success when wrapping my cores with three layers of Teflon pipe-thread tape. This material is available in most hardware stores for a nominal price. If the core is not wrapped in the foregoing manner, RF voltage in the winding may arc to the core. Other types of low-loss, heat-resistive tapes are suitable also.

Always be careful to avoid dropping a toroid on a hard surface. Both core types break easily. Ferrite cores tend to shatter when they strike a hard surface. However, if you break a core in two or three pieces, the core can be glued together with epoxy cement. It will work practically the same as before it was broken.

### Multiwire Windings

Some readers have expressed confusion about multiple windings that are identified as bifilar, trifilar, or quadrifilar types. A bifilar winding is one that has a characteristic impedance of roughly 25 ohms. These are used in what

are called "transmission-line transformers." A multifilar winding may consist of two or more insulated wires that are parallel to one another when wrapped on a core. As an alternative, they may be twisted together prior to winding them on the core. Approximately 8 twists per inch is acceptable for amateur work. The wires can be twisted by means of a vise and a hand drill. One end of the wire pair or trio is clamped in a vise. The opposite ends are tightened in the chuck of an egg-beater type of hand drill, then twisted 8 turns per inch. The major difference between conventional and transmission-line transformers, other than efficiency, is that each winding of a conventional transformer is laid on the core separately. All of the same-length transformer wires are placed on the core at the same time when working with transmission-line transformers.

I hope this article has provided answers for the numerous by-mail questions I have fielded, following my articles that specified toroids. Perhaps you will want to photocopy this presentation and file it in your workshop notebook.

### Footnotes

1. Amidon Associates, Inc., 3122 Alpine Ave., Santa Ana, CA 92704 (phone 714-850-4660).

2. George Murphy, VE3ERP, 77 McKenzie St., Orillia, Ontario L3V 6A6, Canada. Send \$5 to cover postage and handling for a free 3.5-inch diskette. Software is not copy-protected.

73, Doug, W1FB

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