Single-Bundle Windings Make It Easier To Build Custom Magnetics In-House

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Two decades or more ago, America had numerous magnetics parts suppliers who were willing to provide free samples for prototype builds. You could discuss intricate technical details with them by phone. Nowadays, the situation is quite different; the parts are built overseas, often in China. The magnetics supply situation for North American engineers has become more complicated. The only suppliers left in N. America are those with price-insensitive markets such as the medical industry or the military, or those making standardized parts, usually for use with converter ICs from semiconductor companies.

One solution to the custom magnetics supply problem is to do it yourself; build your own transformers and coupled inductors (collectively known as transductors). If that notion sends a red flag up in the back of your mind, this article might offer some relief. There is a way of simplifying transductor construction so that even members of a company without any assembly experience could build these components in their idle moments. At the same time, this method of construction also has electrical advantages over the usual methods.

The technique described in this article is a departure from the conventional approach to building these components. In common transductor construction, windings are treated as independent and are added sequentially to the core. However, sequential windings have disadvantages: lower coupling coefficients, higher interwinding capacitive currents, and nonuniform temperature distribution.

On the other hand, it is well-known that multifilar windings have high coupling and lower leakage inductance because the induced voltages are the same along the adjacent wires in the bundle. Each wire in the bundle is a *strand* and they are twisted together with a hand drill, in parallel. The Δv across the multifilar strands of wire throughout their length is essentially zero. Consequently, though the interwinding capacitance is higher than for sequential windings (because they are in such close proximity), it is not the capacitance but the Δv that determines the amount of interstrand parasitic capacitive current. Furthermore, because the strands are typically twisted, the thermal resistance for each of them is about the same and winding temperature is more uniform.

What emerges from these insights is *single-bundle winding* construction. Strands of wire can be placed in parallel (to reduce skin and proximity effects) and also in series, to set the turns ratios. The constraint over sequential windings is that turns ratios come in integer multiples of the basic bundle winding turns. For applications requiring highly precise turns ratios, single-bundle construction might not be preferred. However, it can often be accommodated.

For instance, a converter with 12-V input and 5-V and 12-V output can be wound with a 6-V bundle in which strands are placed in series for the 12-V windings. More-accurate turns ratios result in more strands that must be placed in series. For many converters, the optimum duty ratio, D, is not sharp but somewhat broad, and if the nominal D happens to be somewhat different than the optimum D (which is usually 0.5 for many converter circuits) it is an acceptable tradeoff.

Single-bundle winding construction makes the actual winding of the core (especially for toroids) a single task. Wind once and all the windings have been wound. There is more work in bundle construction, but it is usually easier than winding.

The bundle will have multiple-strand terminals that must be connected in series and parallel (or both) and this can add to the cost of construction. However, because the strands are identical, they can arbitrarily be chosen for configuring the windings and this simplifies strand configuration. All that is needed is to use an ohmmeter to find the other ends of the strands. The series connections, if few, can be connected using pads on the circuit-board or bobbin, or they can be floated and covered with heat-shrink tubing. Fig. 1 offers some examples of single-bundle-wound transductors (and inductors).

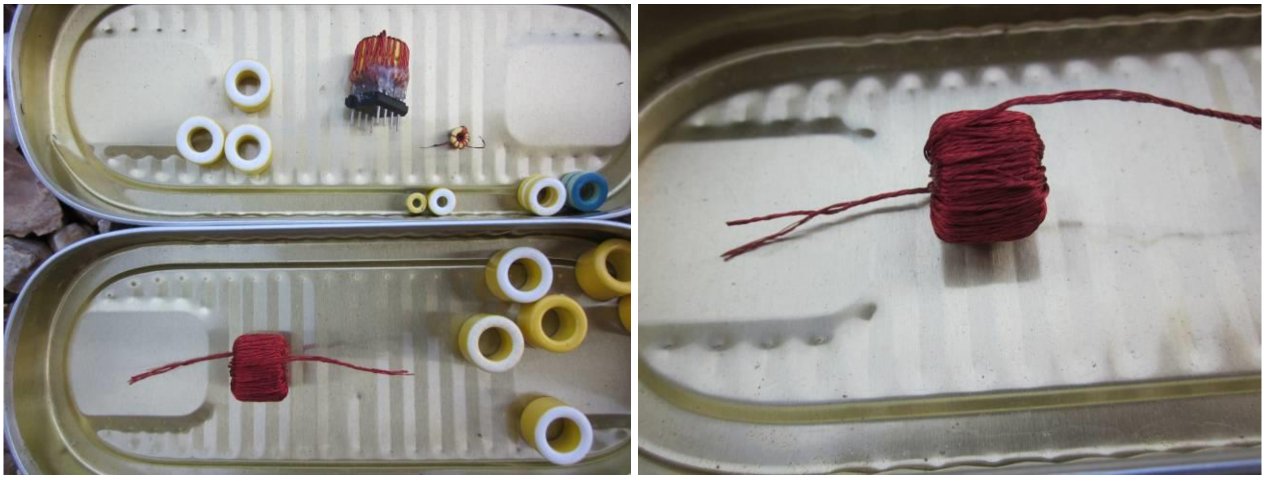

Fig. 1. Single-bundle-wound transductors.

The smallest part shown in Fig. 1 is a common-mode input transductor wound on a T20-26 with two strands of bifilar wire, one per winding. A close-up of this transductor is shown in the bench vise while being wound (Fig. 2.) This is the smallest core size recommended for winding—unless you have very small fingers!

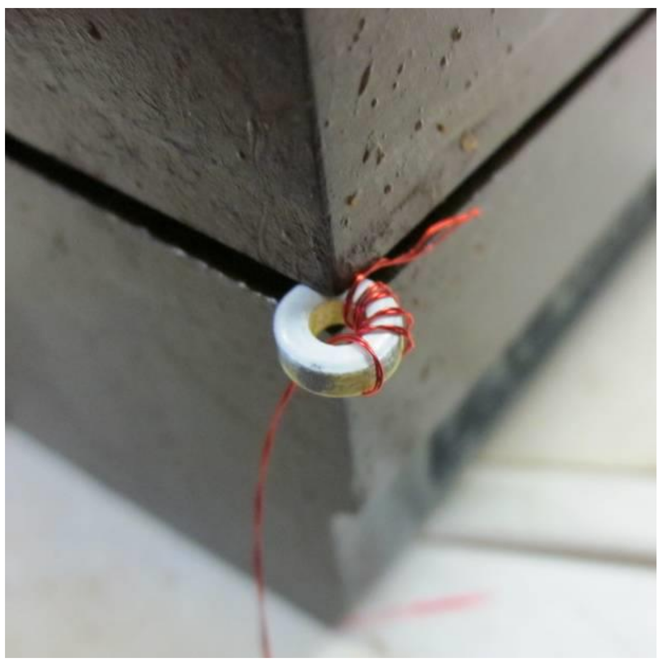

Fig. 2. A common-mode input transductor (coupled inductor) being wound on a T20-26 with two strands of bifilar wire. The T20-26 is generally the smallest core size recommended for winding.

The larger coupled inductor (X1, shown in Fig. 3, upper right) is mounted on a DIP-8 socket for easy insertion into and removal from the board socket. To reduce the number of turns in the bundle, the bundle turn count was set to 26 turns and strands were soldered externally in series, using the extra pins of the DIP-8 socket. This resulted in a bundle of 26 turns of 8 strands of #34 wire. Both X1 and the inductor L2 are visible (upper center, L2 to left of X1) in the following photo (Fig. 3), which shows the pc-board for a boost converter charger. The schematic for this charger is shown in Fig. 4.

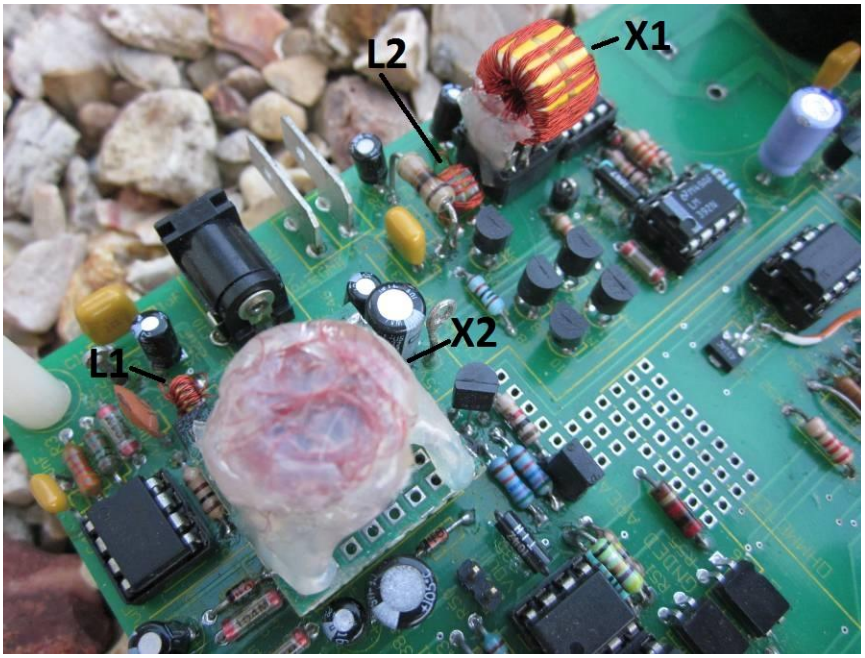

Fig. 3. A large coupled inductor (X1) is mounted to an 8-pin DIP socket for easy insertion and removal into and out of the pc board for this boost converter charger.

This use of an IC socket for mounting of X1 allows magnetics part layout using familiar circuit-board socket patterns. X1 consists of 52 turns of #34 AWG × 4 strands on two stacked T44-26 cores. The cores are easily glued together with cyanoacrylate glue while being aligned on a conical shape.

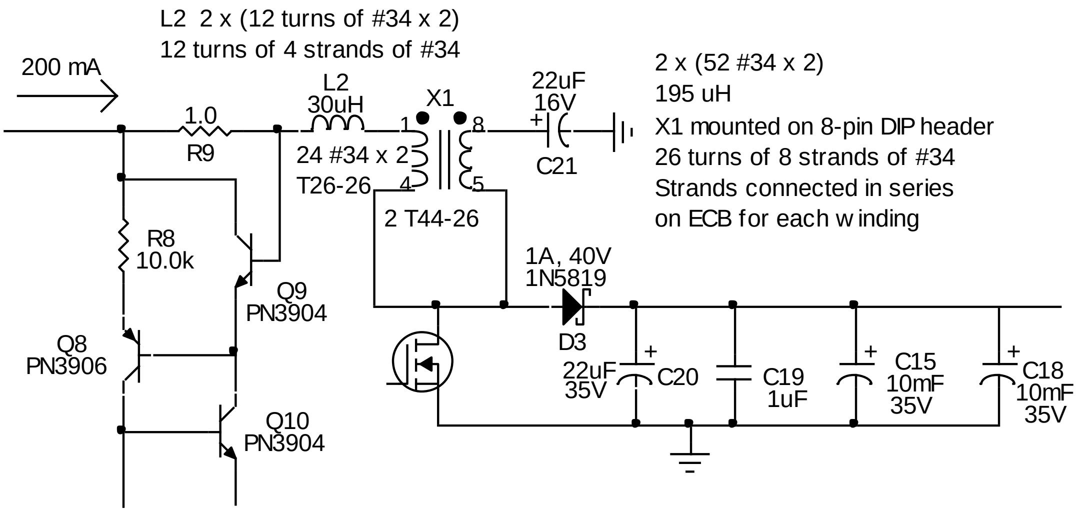

Fig. 4. Schematic of the boost converter charger pictured in Fig. 3. Both the input inductor L2 and the coupled inductor X1 use single-bundle winding construction.

The largest transductor shown in Fig. 3 lower left was that of an isolated ±5-V supply for a grounded isolation amplifier with an additional (floating) winding for 5 V as used elsewhere on the board. The schematic for this isolated power supply is shown in Fig. 5 and the physical circuit is shown in Fig. 6.

The supply has an input inductor (L1, adjacent and to the upper-left of X2) and the transductor (X2), as shown in its plug-in, board-mount form in Fig. 3 and covered with hot-glue to protect the many small terminal wires. A close-up of the wound X2 before mounting is also shown in Fig. 1 (right image) and Fig. 6 (right image).

Isolated Power Supply

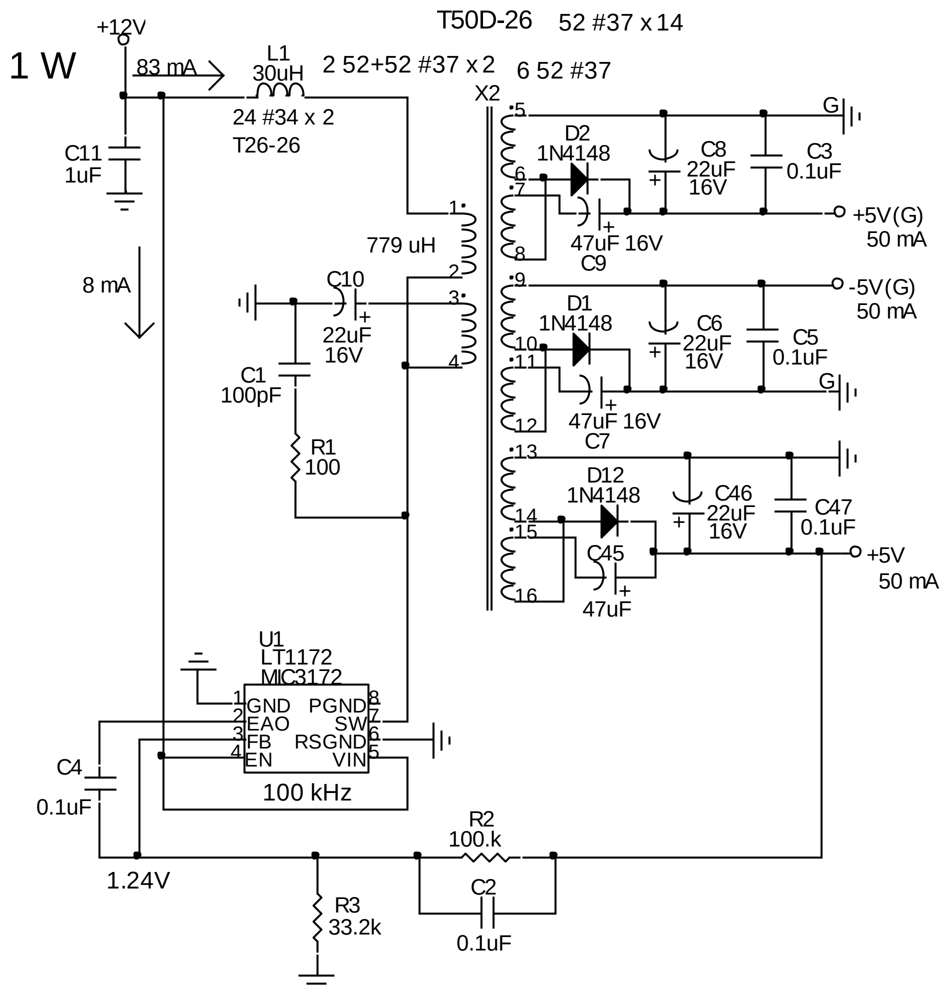

Fig. 5. Schematic of isolated ±5-V power supply employing the input inductor L1 and the transductor (coupled inductor) X2.

X2 has 8 windings and a 16-pin customized platform, made of ECB protoboard, square-pin headers and two rows (on the main ECB) of square-pin sockets. While in production, the transductor could be glued directly to the ECB and the terminals pinned out from there, the plug-in socket expedites diagnosis of problems in design. A prototype on a floating ECB before wiring the terminals to the pins is shown in Fig. 6. The blue nail polish marks the dotted ends of the windings.

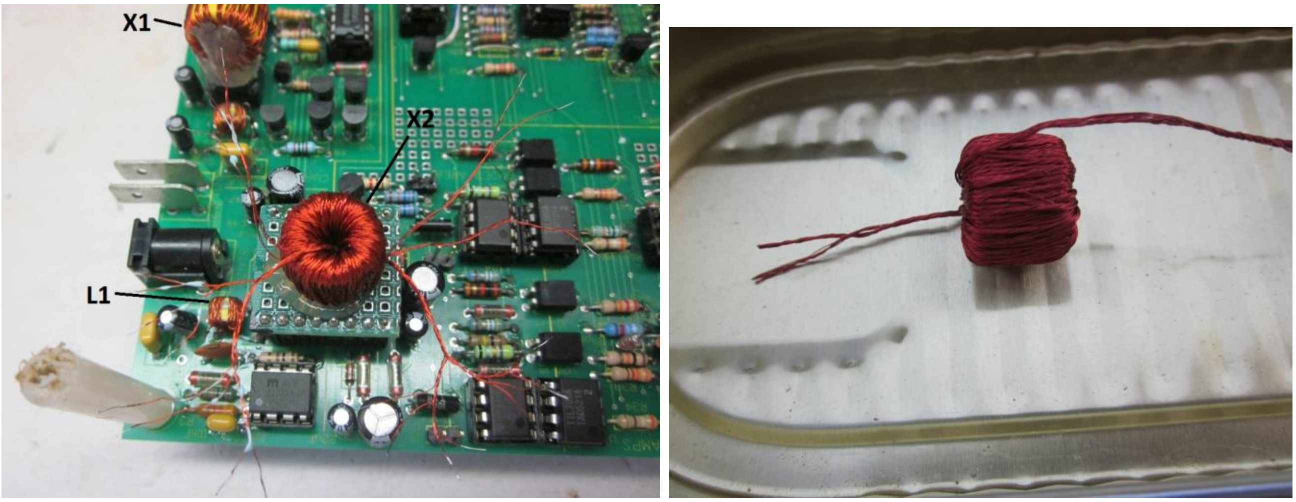

Fig.6. Isolated ±5-V power supply showing input inductor L1 and transductors X1 and X2 (photo on left). A closeup of X2 (photo on right) shows the transductor prior to installation in the circuit.

The bundle is wound on a 0.5-inch outer diameter T50D-26 iron-power core. It takes more work to construct than the winding of the core. It consists of 52 turns of #37 AWG wire by 14 strands. The bundle is assembled with a hand drill and a far hook around which the center of the bundle length is wound, to return to the drill. Fourteen strands can be built up two at a time, into 8-strand and 6-strand sub-bundles that are then twisted by drill into the final bundle. The strand length is calculated from the turn-length formula for toroids, based on the wire size, number of turns and dimensions of the core. It is advisable to make the bundle long enough to be chopped into several bundles for several cores.

Occasionally, single-bundle construction incidentally appears in the literature, though it does not seem to have emerged as an identifiable construction method. Hopefully, this article will give you some ideas and hope in making your own magnetic parts. There is a slight learning curve, and as you practice construction, you will find shortcuts and develop methods for improving the end result. You will not need an expensive winding machine or the effort required to develop skill in using it. Single-bundle magnetics might well solve much of the custom-magnetics problem for your enterprise while also saving some cost by doing the builds in-house.

About The Author

Dennis Feucht has been involved in power electronics for 25 years, designing motor-drives and power converters. He has an instrument background from Tektronix, where he designed test and measurement equipment and did research in Tek Labs. He has lately been doing current-loop converter modeling and converter optimization.

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