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Planar Power Magnetics

By E.J. Bloom
e/j Bloom associates, Inc.

New Low-Profile Approaches for Low-Cost Magnetics Designs

This is the first of two articles on the topic of planar magnetics. In this first part, a general overview of this technology is presented to acquaint the reader with these construction concepts.

Not long ago, an eye-catching advertisement appeared in Electronic Products magazine. What made the photo in this advertisement so notable was the presence in it of a large towering magnetic assembly sitting in the rear section of a densely populated computer board, surrounded by numerous surface-mounted IC chips and other miniature components. Figure 1 is a reproduction of that photo.

While the amusement purpose of the advertisement was to encourage readers to visit the magazine's web site, it was visual evidence for many of us working in the magnetics industries today of the way users and system engineers often view power magnetics. The physical size of these components is not the only reason that power magnetics are often viewed as "necessary-but-evil" parts in many designs. Other reasons include high costs to manufacture and assemble. In addition, they can and do add significant weight to the power supply of an system.

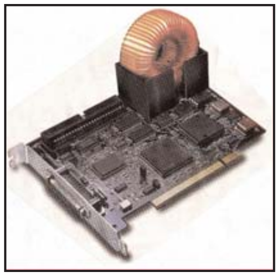

Figure 1

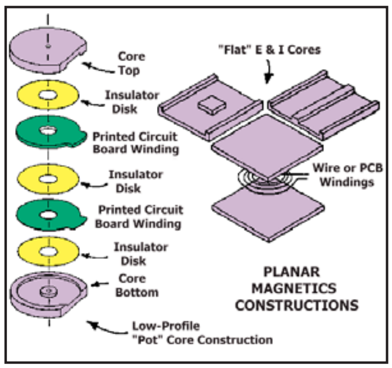

Figure 2

Thinking Thin....

To reduce the size and cost problems mentioned earlier, designers are now turning to new assembly design techniques for power magnetic components. These techniques revolve around the use of low-height magnetic cores and windings that do not require mounting bobbins. Figure 2 is an illustration of these new planar construction methods for circular ("pot-core-like") and rectangular ("box-core-like") magnetic assembles.

In the circular case in this figure, the windings are realized using printed-circuit-board (PCB) assembly methods while, in the case of the rectangular E-E or E-I core assembly shown, the winding(s) could be made from flat coils of formed wire. In either case, there is no wiring "bobbin" in either assembly approach. Figure 3 is a photo of some PCB windings used in a typical planar E-E core magnetic assembly.

Looking at the circular core-and-winding arrangement depicted in Figure 2, it is easy to see why planar magnetic construction approaches can be inexpensive, requiring no significant labor talent for assembly nor special assembly equipment. Because the windings are "built" using PCB design techniques, turns positioning are precise and consistent, yielding magnetic designs with highly controllable "parasitics" (e.g., winding resistances, leakage inductances and capacitances).

PCB Winding Patterns, Circular Shape (Top View)

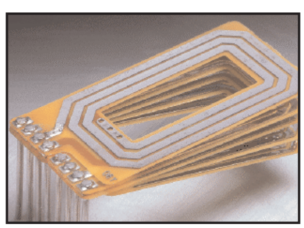

Figure 3
Rectangular Winding Shapes & Assembly View courtesy of Signal Transformer, Inc.

As far as component height is concerned, a magnetic in a medium power application today is considered a planar design if its height dimension is on the order of 0.5 inches or less. For power magnetics in modern telecommunications rack-mounted power supplies, the height requirement can be even lower, on the order of 0.25 inches!

On the other hand, low-profile power magnetics often have larger surface areas than their wired, high-profile-counterparts, requiring more packaging space as a result. However, larger surface areas gives the user more effective unit areas for cooling the part, which can be an important advantage in those cases where the magnetics in question are used in high-power applications.

Most planar magnetics assemblies today utilize power core materials of the manganese-zinc (Mn-Zn) or nickel-zinc (Ni-Zn) ceramic varieties, with the Mn-Zn material being the most popular today in applications where power-processing frequencies are less than 2 MHz. Above this frequency, the Ni-Zn material becomes more efficient, as its resistivity is several orders or magnitude larger than Mn-Zn. Because of the ease of manufacture, ferrite cores can be made in many shapes and sizes and, for this reason, is the primary core material for planar magnetics designs. The only disadvantage of ferrite material is the relatively low value of saturation flux density when compared to other core material types available today.

Planar magnetics are finding their way into every kind of power electronics application today, in high-frequency designs where power levels can range from 2 Watts all the way up to 150 kilowatts! The two photos in Figure 4 show these two extremes in power levels from a physical perspective. In Figure 4B, this particular unit was custom designed to provide a 150V output with load capability up to 1,000A and to operate at a frequency of 40kHz! The approximate height of this unit is approximately 4 inches and its volume on the order of 252 cubic inches, giving a power-handling density figure close to 600 watts/cubic inch! The copper thickness of the planar windings here was 10 oz, with trace widths on the order ot 0.5 inches. The unit shown in Figure 4B was built by UPC, Inc. in Cleveland, Ohio USA using printed circuit designs developed by Prism Circuits in Ontario, Canada (now UPC Canada Ltd). More information about this high-power unit can be found in the March 2000 issue of PCIM Magazine (name changed recently to Power

Electronics Technology Magazine).

Planar Magnetics Players.....

Up until the early 1980's, planar magnetic design techniques were mostly confined to in-house applications in products for the military and aerospace industries. One of the first persons to publish design information on planar magnetics in that time period was Alex Estrov, then a staff member of Theta-J Corporation in Wakefield, MA USA. In 1986, he published the details some of his work associated with the low-profile magnetics design of a 1 MHz resonant converter. Shortly thereafter, Estrov formed his own company, Multisource Technology, which offered a variety of off-the-shelf planar power transformers and inductors. He is now an executive member of the Payton Power Magnetics Ltd. group based in Boca Roca, Florida USA. Figure 5 is a photo of a collection of the many "off-the-shelf" planar assemblies offered by Payton Ltd. today.

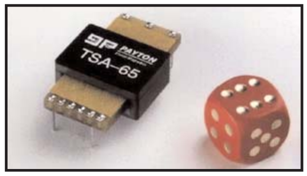

Figure 4a
Low-Power Planar Transformer Assembly (photo courtesy of Payton Planar Power Magnetics Inc)

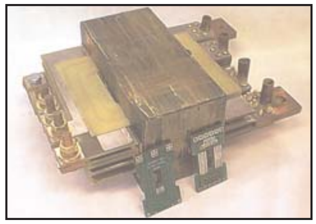
Figure 4b
A 150KW Planar Transformer Assembly The two small PCBs laying against the front of this unit are typical windings used in lower-power planar designs. (photo courtesy of UPC Inc.)

Payton's planar assemblies, as well as comparable units available from Signal Transformer, (another major US manufacturer of planar magnetics), employ special patented isolation bobbins to meet safety creepage and spacing requirements. Figure 6 shows an "exploded" view of typical planar transformer assembly with these special bobbins identified. Also shown in this illustration are two different planar winding types. For the primary winding, two PCB-style windings are used while, for the two high-current single-turn secondaries, stamped metal windings (lead frames) are indicated. In this latter case, the 1-turn windings are physically supported and secured in the assembly by the isolation shrouds. Good energy transfer between primary and secondary is accomplished in this construction by the interleaving scheme for the windings in Figure 6.

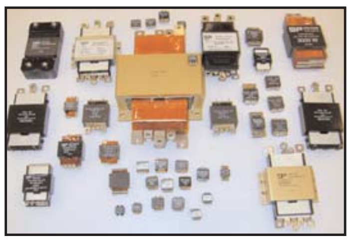
Figure 5
A photo collection of planar magnetics assemblies that use low-profile E-E and E-I core sets. (photo courtesy of Payton Planar Power Magnetics Ltd.)

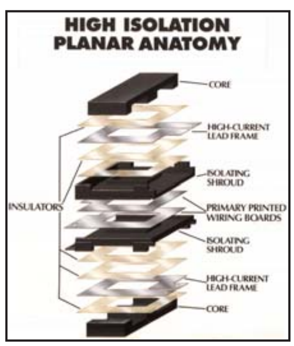

Figure 6
Typical construction methods used in Signal Transformer and Payton planar power magnetics assemblies (Illustration courtesy Signal Transformer Inc.)

Over the past ten years, many other manufacturers have entered the planar magnetics arena. In most cases, the planar designs offered employ low-profile E-E or E-I cores. However, with the recent introduction by core manufacturers of new planar "circular" cores of the RM, PQ and DS varieties, this situation will change soon. The base reason for the extensive use of E-E and E-I cores up to now has been lower cost and availability than the "circular" shapes, plus the E-E/E-I cores are open shapes, permitting easy access to internal windings. Circular designs offer lower overall PCB winding resistance than do rectangular designs for a given winding area. Therefore, in designs where winding losses must be minimized as much as possible, planar circular core shapes with circular PCB windings are preferred.

Rolling Your Own.....

Even though there is a wide variety of planar magnetics to be purchased on the open market today, in many instances they may not meet the needs of a particular power conversion design. Such needs include shape, size and, of course, height as well as special electrical requirements. An example of the latter need are high-frequency transformers with a multiplicity of primary and/or secondary windings. In most cases, "off-the-shelf" planar (or surface-mountable) power inductors can be found for the majority of applications. Unfortunately, these planar inductors are usually more expensive than conventional inductors who have the same electrical characteristics.

Today, there is more selection of low-profile cores for planar magnetics than was the case five years ago. Most major magnetic core manufacturers offer some types of ferrite planar cores now. Most of them can also cut and/or grind a standard core size down to the dimensions needed at minimal expense. This is an excellent prototyping alternative, allowing a designer to optimize core dimensions during the design phase without investing money in new tooling for pressing a special core size at this point in the design cycle.

Summary....

Planar magnetic design and construction techniques today offer viable cost-effective alternatives to traditional magnetic manufacturing approaches. More and more applications are being found now for these unique components, and some say that planar construction methods will replace conventional bobbin-oriented magnetic components in the years to come.

Information Sources.....

At this time, there are no technical books dedicated to planar magnetics design principles and construction methods. The best sources for technical information on planar magnetics today can be found in applications articles offered primarily by manufacturers of planar magnetics assemblies and low-profile magnetic cores.

Do It Yourself, Coming Up.....

In Part 2 of this article in the next issue of Magnetics Magazine, design procedures and details of custom planar core-and-winding arrangements will be explored. Included in Part 2 are discussions of PCB winding styles and new space-saving planar assemblies where inductive and transformer windings can share common flux paths in magnetic core structures.

Ed Bloom is the President & CEO of e/j BLOOM associates Inc., a San Francisco-based company that has been specializing in educational products, courses and design services for power electronics industries worldwide since 1981.

Bloom is a Senior Member of the IEEE Power Electronics Society and the Professional Association of Technical Consultants in Northern California. He holds BS and MS degrees in Electrical Engineering from the Universities of Kentucky and San Diego State, and has been working actively in the fields of power electronics for 39 years. He has given over 120 technical courses and presentations on his work experiences, and has been awarded eight United States patents for his unique circuit designs. Contact him at ejbloom@compuserve.com.

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