AlfaMag PC Mount Toroidal Transformers Improve Linear Power Supply Performance

In many modern electronic products, single phase linear power supplies are still the topology of choice due low parts count, high reliability, and DC output free of high frequency harmonics that can interfere with sensitive circuitry. Two customary drawbacks to linear supplies are lower efficiencies and high radiated magnetic emissions. Also, physical size can be an issue, due to the size of the power transformer. These drawbacks can be reduced or eliminated, by utilizing a toroidal power transformer in place of the traditional E-I transformers.

Linear power supplies require a transformer to provide a voltage to the rectifier/filtering circuit that is lower than the power line. Often, due to their low cost, traditional E-I or U-I transformers are selected. However, for linear power supplies under 30-40 watts, AlfaMag's new line of 50/60Hz PC mount toroidal transformers offer superior performance to their E-I and U-I counterparts. The inherent performance advantages can generally be summarized as:

1) Nearly ideal magnetic circuit, which results in
2) Lower magnetic stray fields,
3) Less volume and weight
4) Less audible hum
5) Higher efficiency

Which benefits are of interest in a particular application depend on the type of product and sensitivity of other circuitry to stray magnetic fields.

TOROID'S IDEAL MAGNETIC PATH

Grain oriented silicon steel is the material most typically utilized in the construction of 50/60Hz power transformers. As the steel is produced, the molecular structures of the ferrous particals are aligned in a common direction. The steel is rolled into long, flat sheets that are typically between 0.006" to 0.012" in thickness (for transformers to be used in electronic products). Sheets may be rolled much thicker, for very high power transformers used in the power grid. The steel is coated on both sides with an insulating barrier of silicon, to prevent stacked layers from shorting together and creating large eddy current domains within the steel structure of the transformer.

In an E-I structure, the matching "E" and "I" components are stamped as sheets from the thin steel coil. Because of this structure, it is difficult to align the grain orientation of the steel with the direction of the magnetic flux, over the entire magnetic path. This misalignment of the magnetic path and grain orientation leads to higher core loss and less efficient operation. Conversely, toroidal iron cores are made from a continuous strip of silicon steel, which is wound onto a cylindrical mandrel like a tight clock spring. The ends are tacked into place with small spot welds, to prevent the coiled steel from unwinding. Finally, the core is insulated with an epoxy coating, or multiple wraps of insulating Mylar film, so the transformer windings can be applied directly onto the core itself. If the windings are properly applied, this method of construction almost perfectly aligns the transformer's magnetic lines of flux with the direction of the grain in the steel. The result is a much more efficient magnetic circuit. Figure 1 shows a comparison of the grain alignment with the magnetic flux path for toroidal and E-I laminate transformers.

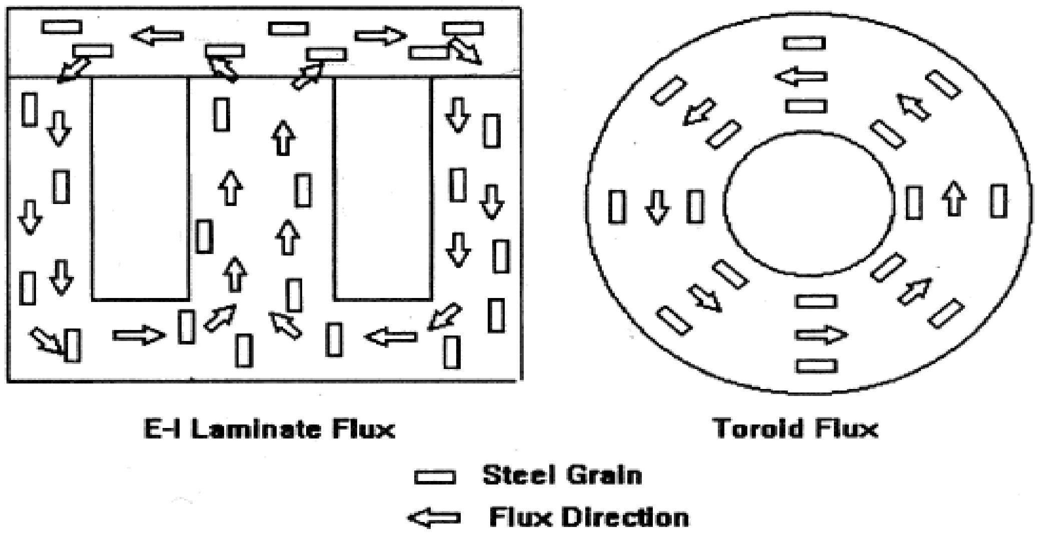

FIGURE 1

LOW STRAY FIELD

Traditional laminated transformer designs employ a bobbin wound coil placed over the center leg of a stack of “E” laminations. A equal height stack of “I” laminations, forming a “bar”, is butted to the end of the “E” stack, completing the magnetic path. The connection between the “E” and “I” stacks is never a perfect junction, giving rise to a discontinuity or air gap, in the magnetic path. This gap, having higher reluctance than steel, causes some of the magnetic flux to “leak” outside the lamination stack, resulting in much higher radiated magnetic field. Similarly, in “C” and “U” core constructions, air gaps are present at the junctions where the coils are inserted and the cut faces of the core halves meet. In any core with a gap, the properties of the gap are unpredictable and depend on pressure and the quality of the adjoining gap surfaces.

A second problem arises from the traditional transformer construction, that increases the flux which escapes into free air, is the discontinuity in the windings which surround the magnetic path. The windings are concentrated onto short regions of the lamination stack, which leaves large portions of the flux path exposed. The abrupt transition from windings to bare laminations creates another opportunity for flux to escape the confinement of the core, and form linkage paths outside the transformer. The transitions in the windings can also lead high leakage inductances.

However, as can be seen from the method of construction described in the preceding section, AlfaMag’s PC mount toroidal transformers lack this gap in the magnetic path. Since the core is produced from a continuous strip of steel, the result is a stable, predictable core free from discontinuities, holes, clamps, and gaps. Figure 2 compares the stray magnetic field at a distance of 100mm from and E-I transformer, and a toroidal transformer of equal power rating.

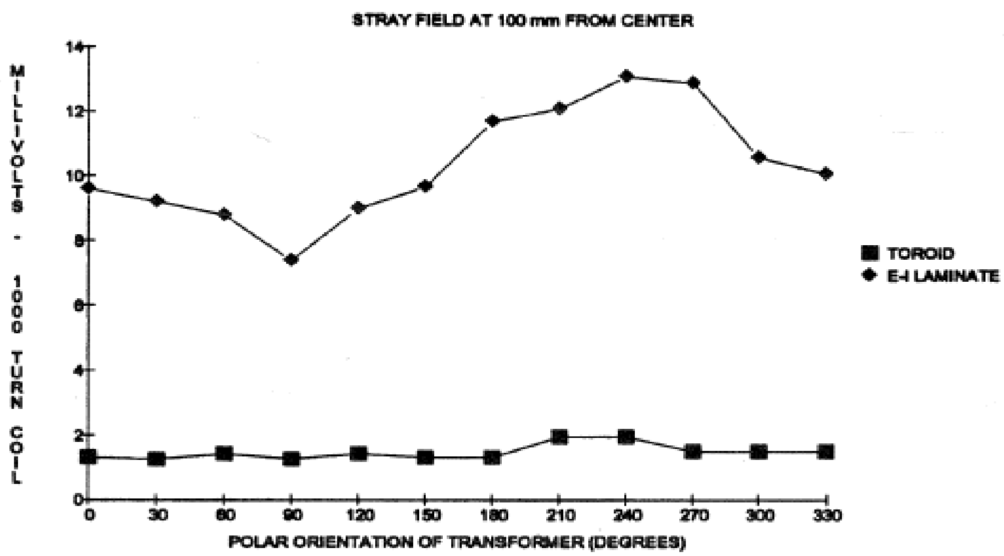

FIGURE 2

AlfaMag's toroidal transformers exhibit substantially lower stray magnetic field strength than their E-I counterparts, which may mean the difference between acceptable and unacceptable operation of sensitive circuitry, or adherence to FCC regulations.

REDUCED VOLUME AND WEIGHT

In addition to compromised efficiency, the E-I's misalignment of flux with the direction of the grain in the steel results in a transformer that is larger and heavier than a toroidal of comparable rating. Approximately 25 percent of the flux path is not aligned with the grain orientation of the steel, causing higher magnetization losses and a reduction in the maximum flux density that can be utilized in the core. For a given cross section, the voltage induced in the windings is directly proportional to the flux density and number of winding turns. A core that allows much higher flux densities requires fewer turns of wire in all windings, to achieve the same result as a core that requires more turns to compensate for higher magnetic losses.

Toroidal cores can operate at much higher flux densities, due to the absence of discontinuities in the core and the fact that windings can be distributed 360 degrees around the core. It can be seen in Fig 1 that the flux in a toroidal core is 100% aligned with the grain of the steel, and exposed areas of the core after winding are eliminated.

Since toroids can achieve the same apparent power with much higher flux densities, they are proportionately smaller and lighter than their laminated counterparts. It is true that the empty center hole in the toroidal transformer (needed for winding processes) results in unutilized area, but the deficit is typically overcome by the toroids with ratings above 30VA. Toroids with lower ratings may not have a significant size/weight advantage over laminated transformers, but they still exhibit much better efficiency, reduced magnetic stray fields, and lower audible hum.

LESS AUDIBLE HUM

Audible hum in transformers is caused by vibration of the windings and the layers of steel in the core, due to forces between coil turns and laminations when the transformer is energized. The level of hum may vary, depending on the load current.

In the case of E-I transformers, the hum is typically resolved by mechanical means, such as clamps, bands, rivets, welding, or varnishing. However, mechanical solutions cannot bond the entire structure, allowing some portion of the lamination stack to vibrate. Varnish degrades over time, becoming brittle and releasing the bond between layers of steel. Eventually, a varnished transformer will begin to exhibit very high audible hum, as if it were not varnished at all.

The nature of the toroidal core's construction helps to dampen the effects of "magnetostrictive" forces within the core, reducing audible hum. The core is so tightly wound in it's clock spring fashion, that vibration between layers of steel is reduced. Also, the core is coated with epoxy resin and the windings are applied over 360 degrees of the core, further "clamping" the core and reducing hum in a more permanent manner.

In addition to the construction of the basic transformer, AlfaMag's PC mount toroidal transformers are fully encapsulated within an attractive plastic housing. The suspension of the transformer inside the epoxy helps to minimize any vibration that might be transferred to the printed circuit board, or the chassis. If any audible hum is heard, it will be immediately after application of power and then die down to an imperceptible level within a few seconds. This momentary hum is caused by inrush current, which quickly dissipates.

HIGHER EFFICIENCY

The efficiency of a transformer can be expressed as the power out (Pout) divided by the power in (Pin). The difference between Pin and Pout is consumed by losses in the core and windings. The more ideal magnetic circuit of the toroid, and the ability to operate at higher flux densities than traditional transformers, reduces the number of winding turns and/or the core cross sectional area. Either benefit reduces the losses. Toroidal transformers are typically 10-15% more efficient that laminated transformers. With new efficiency regulations in many countries, simply switching from a traditional transformer to an AlfaMag PC mount toroidal transformer may make the difference between compliance and non-compliance.

SUMMARY

In conclusion, it can be seen that due to the near ideal magnetic path of the toroidal core geometry, that many tangible advantages may be realized. Lower size and weight, greater efficiency, reduced magnetic stray fields and reduced audible hum are the primary advantages. In certain sensitive applications, the toroidal transformer may be the best solution for solving many perplexing problems.

AlfaMag offers a complete line of 50/60Hz PC mount toroidal transformers, from 1.6VA up to 50VA. Dual 115VAC primary windings can be utilized in parallel (115V) for domestic products or in series (230V) for export. All ranges are approved to UL5085-1 Low Voltage

Transformers, and VDE 61558-1 (except for 2x22V models). Constructed to the highest quality standards possible, utilizing a UL approved Class F insulation system, you can be sure AlfaMag's PC mount toroidal transformers will provide many, many years of reliable service. You can view the data sheets by visiting our website, at www.alfamag.com, or by accessing them on the Digikey website.