Standex Electronics

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Synergy of Power and Planar Magnetics in Missile Electronics

The United States Department of Defense is continually developing state-of-the-art missile defenses of all ranges. All call for integrated, layered architectures. These system architectures include:

- High-voltage bus to regulated low-voltage board inputs. (5, 12, 24 and 48V).
- DC/DC conversion from high-voltage batteries to regulated high-voltage bus.

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Advanced Modeling and Simulation to Reduce SWaP

To ensure an elaborate defense system operates at peak efficiency and readiness, missile electronic systems are continually tested and new compact improvements are evaluated. Reducing the size, weight, and power (SWaP) of missile electronics calls for reducing the volume, power needs, and geometric details of critical components. In light of today's ever-changing ballistic missile threats, highly advanced modeling and simulation activities have resulted in significant improvements in electronic systems. To confront the challenges of miniaturization and the increased component density of missile electronics, the industry has addressed some critically important design elements. Not the least of which has been the introduction of planar technology.

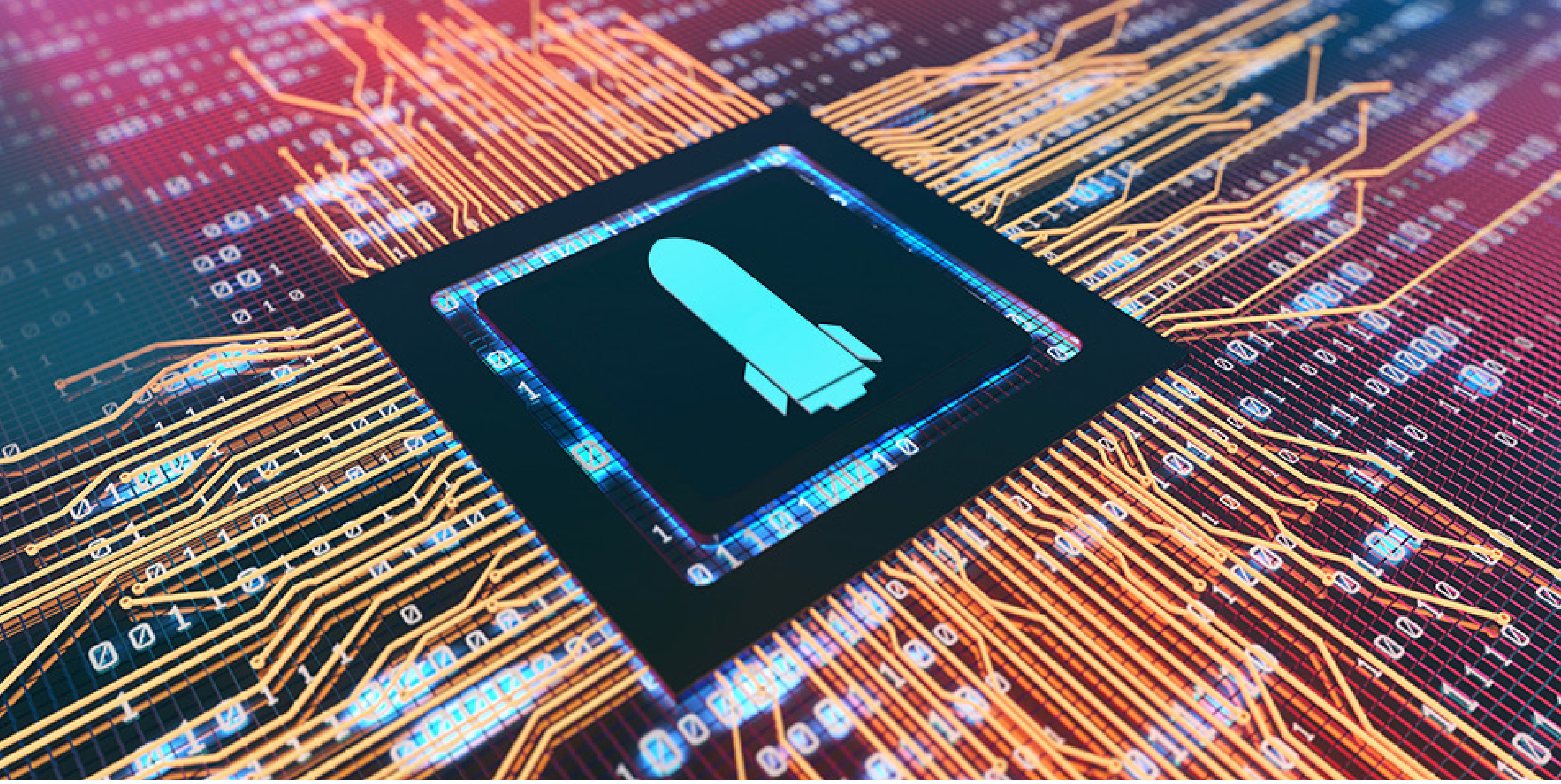
The Rise of Planar Tech

Thus, it's no surprise that in today's competitive military applications, a renewed call for cost-saving, high-efficiency solutions has sent designers back to their drawing boards. This industry, perhaps like no other, needs higher power densities for improved performance. It has become a mandate to meet the ever-growing demands of today's and tomorrow's missile technologies. And it's now clear that planar magnetics can significantly improve power electronics in terms of efficiency, cost, and space requirements as well as heat dissipation.

Planar magnetic technology has steadily gained worldwide interest due to the spread of PC board technologies. Planar components can take the form of transformers or inductors consisting of planar copper windings. These components are typically flat copper sheets wound around a rigid or flex PCB. In some cases, these can also be hybrid, inserted in a low-profile magnetic core made of "soft" ferrite. Such designs differ from conventional wire-wound components with circular cross-sections in that their copper tracks have rectangular cross-sections.

Semiconductor companies and power conversion research groups have taken note of planar magnetics technology offers several significant advantages:

- **Low Profile:** Planar magnetic components typically are half or less the height of their conventional counterparts.
- **Optimized Thermal Characteristics:** Planar magnetic cores offer improved thermal characteristics, conducting heat and maintaining the device to temperatures lower than their wire-wound counterparts. This is because planar magnetic cores possess a higher surface area to volume ratio for a more efficient heat exchange with their ambient environment.
- **Automation, Manufacture Ease, Cost Reduction:** Conventional assembly methods allow planar magnetic components to be manufactured with high repeatability and accuracy. Compared to the inherent difficulty in automating the winding of conventional inductors and transformers, the production and assembly processes used in planar magnetics can be leveraged with innovative technological tools to simplify automation.
- **PCB Modularity:** This allows planar magnetic cores to be assembled without extra connections. Varying core shapes and PCB constructions generate different form factors.
- **Predictable Parasitic Effects:** Planar winding layouts are easy to control and create an interleaved solution. This typically results in lower leakage effects and reduced winding capacitance.



Superior Electro-Thermo-Mechanical Performance

Clearly, the precision, reliability, and superior electro-thermo-mechanical performance of planar magnetics make them ideal for high-density and high-frequency power conversion. The advantages of planar magnetics can be further exploited through on-board integration, reducing assembly complexity, and increasing reliability. Combined with unique thermal management solutions, embedded planar magnetics can increase capacity and performance without the technical overhead of conventional wire-wound magnetics.

Eliminating Inherent Shortcomings of Wire-Wound Transformers

Like their progenitors, embedded planar magnetics are needed for the galvanic attributes and to adapt the output voltage to the correct level. Here, size is directly related to switching frequency, with higher frequencies translating into smaller volume and higher efficiencies. As frequencies above 200kHz, performance improvements in power supplies are hampered by limitations in conventional bobbin-wound transformers and companion inductors. Planar-based transformers eliminate virtually all the inherent shortcomings of wire-wound transformers. Simply put, planar designs incorporate windings made out of copper-foil lead frames, printed circuit boards, and, in some cases, flat wire assemblies. These windings are subsequently sandwiched with insulators between thin, large-area advanced ferrite cores. This arrangement provides several benefits. Chief among them are a low-profile design, improved heat dissipation, high power density, low leakage inductance, and exceptionally controllable transformer parasitics.

Reducing Copper Losses

Uneven current distribution in current-carrying conductors can increase losses at high switching frequencies. Here, the reactance can rise considerably higher than the resistance. This can be attributed to the skin effect and proximity effect. Both are the result of the interaction of electrical current and magnetic fields. The skin effect reflects the influence of a current-carrying conductor crossing a magnetic field. The proximity effect can be attributed to the electromagnetic interaction between two conductors close to each other. Both will move the current toward the surface and thus reduce the effective cross-section of round inductors. Foil inductors, on the other hand, applied in planar magnetics, reduce these effects by employing conductors with large surface areas.

Reducing Leakage Inductance

Controlling and fine-tuning leakage inductance can boost a system's efficiency. Leakage inductance can be attenuated as needed in most systems, or it can be increased using specific techniques in resonant circuits. This technology applies to several fields, especially to high-power magnetics. The imperfect coupling of primary and secondary transformer windings can result in leakage inductance. In a variety of applications, the energy stored in such an uncoupled inductor is lost, reducing its overall efficiency. Reducing the distance between primary and secondary windings solves this problem. Understandably, reducing the number of turns and the foil structure of the windings in planar magnetics serves to minimize this leakage inductance. In fact, it's not surprising that planar magnetic transformers will, in some cases, benefit from as much as a tenfold reduction in leakage than classical transformers.

Heat Dissipation Through Simple Geometry

Poor thermal conduction can result in an unsafe temperature rise and eventually a failure. Thermal conduction between the 'hot spot' of a magnetic device will eventually determine its useful power level. In PM, the geometry of a device as characterized by a large surface area can dissipate the heat more efficiently. As a result, PM designs can be more economical since they can handle more power compared to conventional magnetics. The power handling capability can be enhanced by opting for high-temperature electrical isolation and through the use of heat sinks. In addition, the large surface area of PM allows such devices to be conveniently and efficiently connected to large surfaces with or without a fan. These attributes allow for an appreciable increase in the power density of PM transformers.

The Importance of MIL-STD Qualification Testing

To ensure the highest levels of military-grade performance, the need for MIL-STD qualification testing and certifications cannot be overstated. Testing should encompass automatic CNC, toroidal hook, and shuttle windings using 52 gauge to 5 gauge magnetic wire. What's more, bobbins should be wound in layers, or using self-supporting windings of foil, flat, or square wire. In addition, mechanical designs should include impregnation, casting, molding, encapsulation, and vacuum potting for high voltage and other unique applications. solutions are fully optimized using in-house MIL-STD testing according to AS9100.

Conclusion

The success and cost efficiency of today's and tomorrow's short, medium, intermediate, and intercontinental-range missiles depend on electronics with tightly integrated, layered architectures. In no uncertain terms, higher power densities and improved performance have become vital in meeting the ever-growing demands of today's increasingly sophisticated missile technologies. It's now clear that planar magnetics can significantly improve power electronics in terms of efficiency, cost, and space requirements as well as heat dissipation. There is little doubt that planar magnetic technology has steadily gained worldwide interest due to the spread of PC board technologies. These components can be transformers or inductors, devices that incorporate planar copper windings. With so much at stake in today's uncertain world, the need for missile electronics that perform reliably, and cost effectively cannot be overstated.

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