

Customized Transformer Solutions for Enhanced Semiconductor Fabrication: Techniques for Well-Integrated Magnetics

We've seen significant enhancements in the design of power electronic systems, based on improvements in devices, materials, technical breakthroughs, and circuit topologies. This has improved performance, including greater efficiencies, higher reliability, better system economies, and compactness in size, weight, and volume.

As with any component, the design of magnetics is critical to the form and function of a system. This has led designers to combine multiple components into a single physical unit, resulting in today's magnetic integration.

CONTENTS

- 03 Semiconductor Power Supply Transformers
- 03 ANSYS Maxwell Software
- 03 The Importance of Integrated Magnetics
- 03 High-Frequency Transformers
- 03 Flyback Transformers
- 04 Single-Phase Transformers
- 04 Single-Phase Current Transformers
- 05 Three-Phase Transformers
- 05 High-Frequency Magnetics
- 05 High-Voltage Transformers
- 06 Isolation Power Transformers
- 06 Pulse Transformers
- 06 Standex Electronics

Semiconductor Power Supply Transformers

When converting AC voltages to higher or lower semiconductor levels, power supplies need transformers. While ostensibly simple, there are four key issues these transformers face that can affect reliability:

- **Dovetailing Semiconductors and Magnetics:** The unique skills and training needed to correctly employ magnetics continue to evolve in semiconductors. That's why it's common for core-winding temperatures and saturation currents to conflict — the former is often too high, and the latter is too low.
- **Hand-Built Construction:** This is a major reason why power supply transformers fail. Variations from builder to builder — like wire kinking or inadequate or insufficient safety tape — can cause problems. Here, using traces for windings on a PCB may minimize failure risk but not prevent it.
- **Extra Weight and Stress:** Besides its electrical function, a power supply transformer places added weight and stress on a PCB. Combined with shock and vibration, transformer weight can bend or even crack a board if the load is improperly supported. In extreme cases, transformers have been known to detach from the PCB.
- **Excessive Thermal Mass:** A transformer's thermal mass can rise to unusually high levels compared to the surrounding components inside a semiconductor's housing. Long oven dwell times are often needed to ensure parts reach a temperature high enough for a decent solder. Unless these temperatures are dutifully monitored, other components can be damaged.

ANSYS Maxwell Software

Weighing the risks against the need to employ power supply transformers on today's PCBs calls for close vigilance. ANSYS Maxwell software meets this need. It can accurately profile the transient non-linear motion of electromechanical parts and how they affect a drive circuit. This type of software seamlessly links components to ICs, and systems simulations can accurately gauge the performance of electromechanical systems before constructing a prototype in hardware.

ANSYS Maxwell software can simulate low-frequency electromagnetic fields within industrial electronic parts. It includes AC electromagnetic, 2-D/3-D magnetic, DC conduction, magneto-static, electrostatic, and electric transient solvers. These func-

tions work to correctly solve such field parameters as torque, force, capacitance, resistance, impedance, and inductance.

Another important aspect of this software is slice-only technology, which allows for cyclic repeatability simulation for electric motor applications. This quickly analyzes a section of the motor using non-planar boundary setups, employing symmetric mesh, and then repeating these results to the entire model.

The Importance of Integrated Magnetics

Design engineers are always on the lookout for new ways to integrate components. Several topologies are ideally suited for the integration of multiple magnetic functions. Significant benefits are realized in these cases, including reduced stress on switches and other components and a ripple reduction on the input and/or output currents. These benefits can be brought to fruition without increasing the switching frequency. For example, efficiencies rise due to reduced power losses associated with the magnetic cores as their number per topology drops. While design processes may pose a challenge, the overall performance advantages outweigh the obstacles with the bonus of simplifying manufacturability.

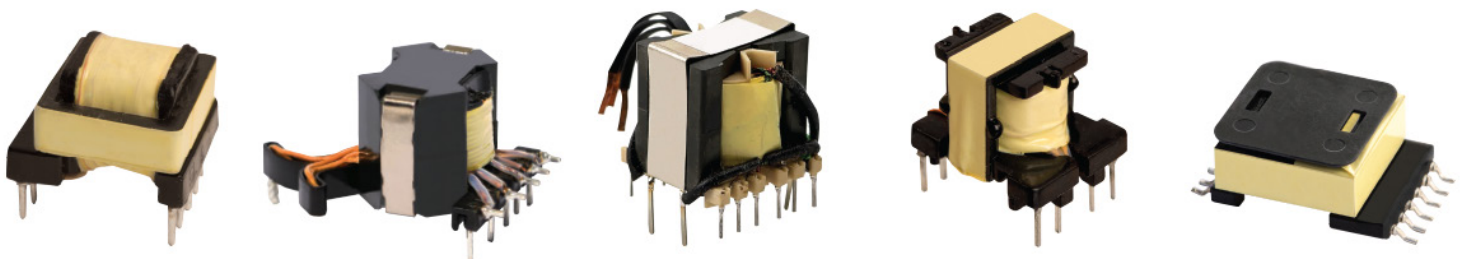
High-Frequency Transformers

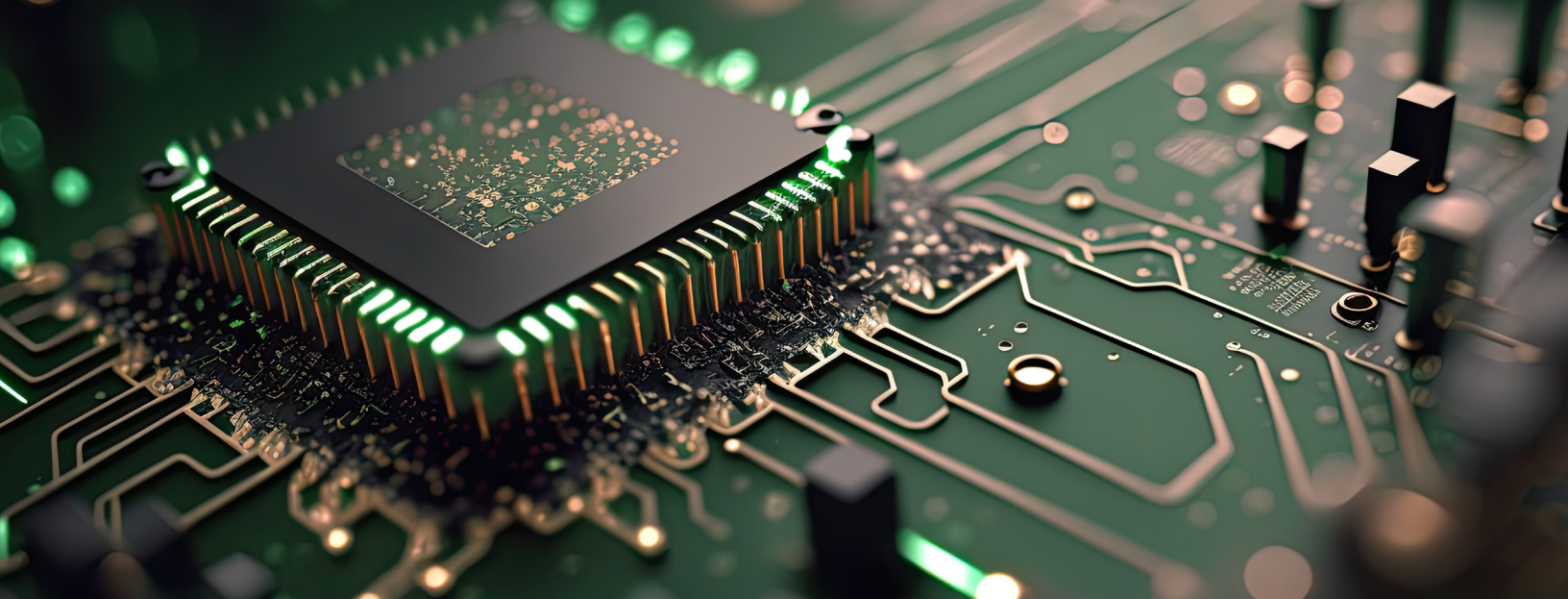
Today's increasingly sophisticated electronics call for transformers that can dovetail into compact applications. And the growing demand for electronic systems increasingly calls for additional high-frequency transformers. This new breed of transformer is often constructed of many different materials and designed to exact specifications. Uniquely designed and built to efficiently and safely provide the highest levels of power, these components reduce both hysteresis and 'skin effect' losses. Applications for high-frequency transformers can include:

- Industrial equipment
- Solar converters
- Personal electronics
- Energy conversion
- PCs
- Electric drives

Flyback Transformers

Featuring a coupled inductor with a gapped core, flyback transformers are efficient and cost-effective for isolated power sup-





plies in the 120-watt range. They isolate circuits and transform voltages in flyback converters. In every cycle, when voltage is inputted to the primary winding, the core's gap stores energy, which is subsequently induced by the secondary winding to provide energy to a load. These can even be controlled over a broad range of input voltages and varying loads. Since transformers store the energy, the flyback arrangement needs no individual output filter inductor, as is called for in other isolated designs. So fewer components are required, simplifying circuit requirements. Flyback transformers are employed in many applications, including:

- Capacitor charging
- Battery charging
- Solar Microinverters
- DC-DC power supplies
- Telecom
- LED Lighting
- Power over Ethernet (PoE)
- AC-DC power supplies

Off-the-shelf flyback transformers can generally be used for applications that call for low cost, small size, and high efficiency. These transformers are often used in DC-DC controllers in telecom voltage ranges of 37 to 72V DC. They can also serve in applications with extended voltages from 2 to 400 VDC or within universal AC line input voltages from 85 to 265 VAC. Flyback transformers are often specified for output currents below 10 Amps and output power levels of less than 100 Watts. Forward-mode, push-pull, or half-bridge/full-bridge designs are more efficient for higher currents and powers.

Choosing the right flyback transformer starts with evaluating several competing trade-offs in performance, size, efficiency, cost, and weight. Both core and wire sizes must be correctly selected for high energy storage to avoid saturation or overheating insulation. In addition, the wire diameter must tolerate high output currents without overheating the wire's insulation. Core

shape and bobbin selection must be considered to minimize the winding length and minimal DCR. High switching frequencies can be employed to reduce transformer size, but here, increased AC core losses, proximity effect, and skin effect must be considered.

Single-Phase Transformers

Ideal for consumer electronics and compact industrial gear, Single-Phase Transformers provide conversion and power management for a variety of industries. These include step-up/step-down assemblies, industrial controls, isolation, and applications that use low voltages, as well as in heating and lighting assemblies.

Single-Phase Current Transformers

These provide several key advantages, including direct measurement and offline isolation. They can also measure large currents, especially a clamp-on.

Available single-phase transformers may include:

- **50/60Hz Transformers:** These single-phase transformers safely isolate end users from a main power source and are made for 60Hz (US power) and 50Hz (European power). They control the line voltage to what the circuit requires.
- **400Hz Transformers:** Used primarily in military applications, these units are highly efficient and reliable at 400Hz. More compact than their 50/60Hz counterparts, the transformers use high-grade materials and come in specialized designs.
- **PCB Mount Transformers:** Often found on PCBs and other electronic applications, these transformers are reliable, compact, and easy to use for various electronic assemblies.

Single-phase transformers are sometimes designed to serve an industry's custom needs when manufacturing and delivering them. These include PCB mountable, chassis mount, completely encapsulated, and various special assemblies. Sin-

gle-phase transformers are sometimes computer-modeled with proprietary software and computer-tested for quality and performance.

Three-Phase Transformers

Used for power systems and other applications, 3-phase transformers act like three sets of standard transformers but are highly efficient with a compact profile. In motor environments, for instance, 3-phase models can be synchronized, turning the motor one-third rotation per phase, thereby ensuring a continuous motor cycle. Some types of 3-phase transformers currently available include:

- **Standard Units:** These often allow simple modifications like lead wire lengths, connectors, and mounting configurations.
- **Custom Units:** For special or off-standard designs, these units meet a project's unique specs for improved performance, reduced operating costs, and a longer lifespan.
- **Complete Assemblies:** Often designed by adding parts and processes for a variety of magnetics projects.

High-Frequency Magnetics

From job-specific industrial systems to smaller consumer electronics devices, many products depend on high-frequency transformers and magnetic inductors. Today's magnetic components have been challenged by a broader spectrum of increasing industrial demands. For example, high-frequency magnetics are increasingly expected to perform in high-kilowatt systems with reduced size and very little winding loss. Factors to be considered include:

- Inductance, capacitance, current, and voltage requirements
- Mitigating core loss with losses from windings due to coil diameter and physical profile
- Circuit design and magnetic component interference
- Reducing leakage in windings or parts designed for several different tasks

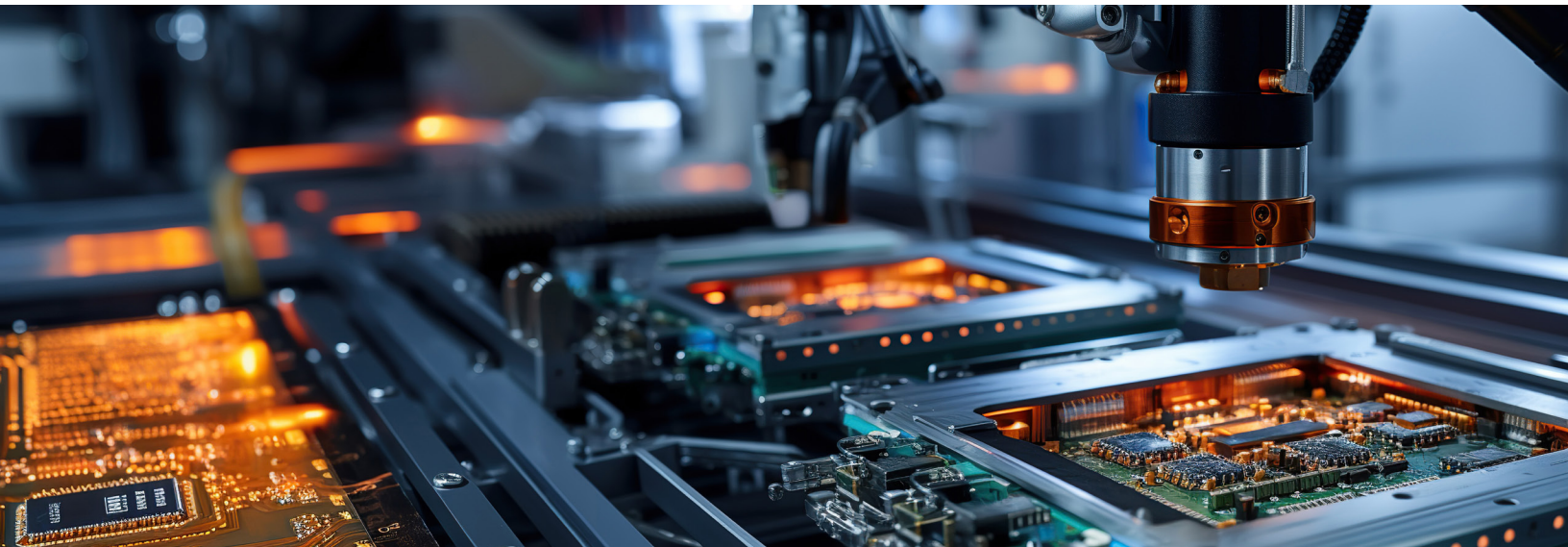
- Selecting the right trial components for performance simulations
- Appropriate terminations
- Macro vs. micro fabric

Specific products may include:

- **Custom Gate Drive Transformers:** These provide control pulses to a variety of switching components and isolation from control circuits. They connect to power transistor drive circuits and power transistor gates or bases for MOSFETs and bipolar junctions.
- **Push-Pull Buck-Derived Forward Transformers:** Unlike one-ended buck transformers, push-pull transformers operate in a magnetic fashion in either direction. This enhances the core's use and provides improved efficiency. These transformers are usually designed with a primary and secondary coil and a tap in the center of the winding.
- **RF Power Transformers:** These transformers are specially designed to modify voltage levels from opposing sides of a transformer. They are designed for unique applications that call for unconventional operating frequencies.
- **Instrument Transformers:** Made to precisely reduce high voltage and current levels to certain lower levels, Instrument Transformers transfer voltage and current from a power source to various components like meters, relays, motors, or control instruments. These transformers also protect, monitor, and control power assemblies by supplying analog data. Available in many sizes—from board mounts to compact—these special transformers are typically designed to serve specific applications and harsh industrial environments, especially those intended to meet certain predetermined voltage, VA ratings, and physical dimensions.

High-Voltage Transformers

Designed to meet a full spectrum of high voltage needs, High Voltage Transformers cover a wide range of applications using various design configurations for many different output voltages. While custom transformers may feature precision magnetics for



demanding industries like delicate instrumentation or heavy-duty military projects, these devices generally fall into three main categories:

- **50/60Hz Layer Wound:** Constructed using a silicon steel core, these transformers feature layered insulation and margins on every winding layer to ensure isolation from high voltage. These transformers can be immersed in dielectric oil to provide added isolation.
- **High-frequency magnetics (layer wound):** Smaller than 50/60Hz units, these transformers feature a ferrite core and are encapsulated using potting equipment or immersed in dielectric oil.
- **Universal Wound:** These transformers feature high-voltage secondary winding that's wound using a universal technique, one that provides extra space between turns, which allows them to tolerate a higher voltage.

Isolation Power Transformers

Designed to prevent signal interference and to direct power between independent circuits without direct wire connections, Isolation Transformers protect users from electrical shock. These units "isolate" circuits that may be accessible to the user from wall outlets or line power entering the building. Voltages (input and output) are magnetically linked via the core of these transformers without a direct electrical connection. Isolating materials like electrical grade paper, plastics, and various tapes serve to separate the two windings. Dielectric isolations from 2500VAC to 4000VAC are not uncommon, though higher isolations can be achieved. Isolation Transformers generally adhere to VDE, UL, CUL, and CE standards. Occasionally, UL and CUL notifications are specified as required. Industry Applications for Isolation

Transformers include:

- Medical devices
- Test equipment
- Consumer electronics
- Military
- Aerospace

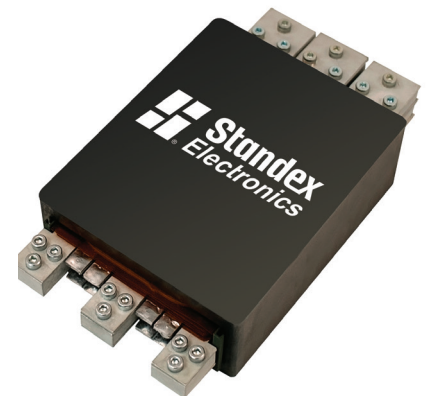
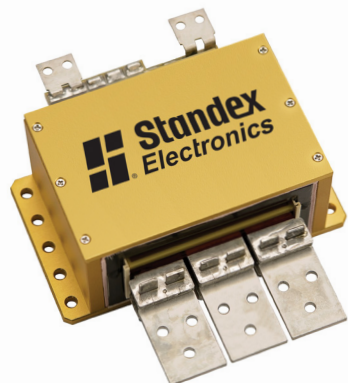
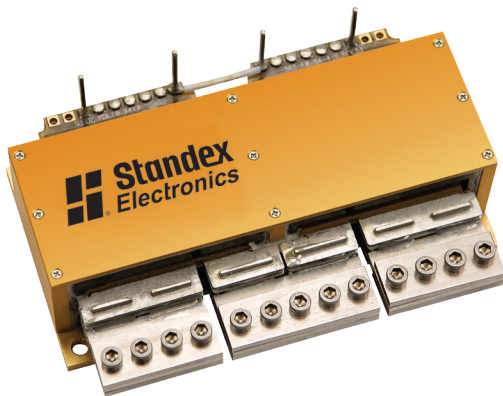
Pulse Transformers

Designed to transmit voltage pulses at "operable" signal fidelity, Pulse Transformers transmit information via analog or digital signals. Configured for a specific pulse frequency and peak voltage, these units produce right-angle pulses or square waveforms. Pulse Transformers ensure electrical signals are properly balanced. They also separate a signal's AC components, match an antenna's signal to a coaxial cable's impedance, and work in such applications as:

- Personal electronics
- Communications
- Audio
- LAN and Ethernet networks
- Antenna connections
- Power distribution

Standex Electronics

Standex Electronics' world-class magnetics experts can assist your engineering team in navigating customized transformer solutions for enhanced semiconductor fabrication and techniques for well-integrated magnetics. Standex can help bring your products to market with incredible speed and reliability.



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