High Density Integration (HDI)

HDI was created in 2011 as a mechanism for CPES and industry members to address emerging and long-term challenges in power electronic integration. While it is supported primarily by CPES membership, it also leverages sponsored research with major industries such as Delta, Dowa, GE, GM, Group Safran, Lockheed Martin, MKS, Nissan, Raytheon, Rolls-Royce, TI, Toyota, and UTRC, as well as with government agencies including the U.S. Department of Energy (ARPA-E), U.S. Department of Defense (DARPA, ONR, Army and Air Force), and National Science Foundation. The tradeoffs among reliability, efficiency, cost, electromagnetic compatibility, power density, and speed are explored as new materials, components, circuits, and applications emerge.

The commercialization of wide bandgap semiconductor devices such as silicon carbide (SiC) and gallium nitride (GaN) has shifted switching frequency beyond tens of megahertz, power rating beyond megawatts, and junction temperature beyond 250° C. Ancillaries, characterization metrology, modeling method, packaging process, and manufacturing paradigm need to be transformed.

Unique high-temperature packaging technology is an example of CPES fulfillment of these critical needs to the future power electronics industry. HDI developed die-attach materials which can be processed at low temperatures, yet are reliable at the temperature of the wide bandgap junction. Processes were developed to encapsulate ultra-thin planar packages with polymer having high glass transition temperature and dielectric strength.

Magnetic materials with low core loss-density were synthesized from magnetic metals for additive manufacturing of high-frequency magnetic components. Inductors were fabricated from heterogeneous magnetic composites to shape the EMI spectrum. Over-molding magnetic materials have been synthesized for integrating energy storage and protection functions.

Techniques to decouple the noise loops have been identified to enable high dv/dt commutation in wide-bandgap switches. Design methodologies have been documented for high-temperature capacitors, power buses, protection, sensing, digital control, etc. New breeds of gate drivers, sensors, active filters, and passive filters have been demonstrated in a wide range of products, from power adapters to power electronic building blocks. Significant improvement in power density, efficiency, and signal integrity are expected thanks to the adoption of the technological advances. HDI tasks are scoped to advance wide bandgap systems, magnetic components, and module integration.

This current scope of work includes the following topics:

Wide Bandgap Systems

- Reliability study of failure mechanisms of GaN and SiC MOSFETs.
- High-voltage high-temperature gallium oxide diode.
- Characterization of wide bandgap semiconductor switches up to highest voltage and temperature.
- Short circuit protection design for paralleled GaN module high-density laptop adaptor.
- High-frequency, low loss soft-switched converters.
- Insulation coordination study for high-voltage high-power density converter design.
- Wireless charging.

Magnetic Components

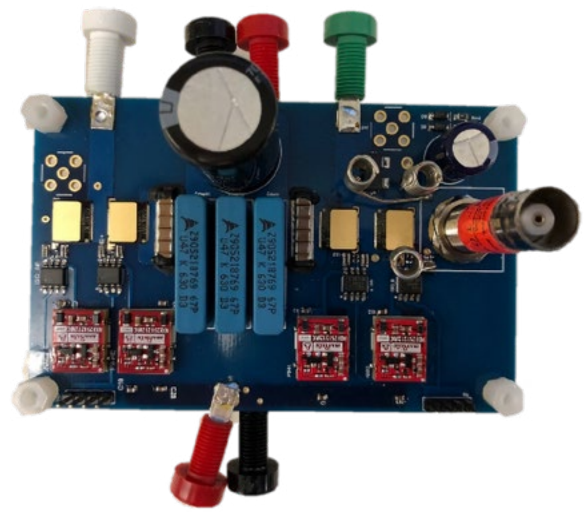
- Swinging and coupled inductors with heterogeneous magnetic cores.
- Magnetic structures with high energy density.
- Over-molding of encapsulating magnetics.
- Low profile magnetic substrate.
- Weakly coupled coils with low stray field for wireless power.
- Integration of and field interaction in common-mode and differential-mode filters.
- Integrated multi-phase inductor for voltage regulator for small portables.
- PCB-integrated magnetics for high-efficiency, high-density front-end power supply.
- Characterization of high-power inductors and materials.
- High-frequency magnetic integration.

Module Integration

- Large-area substrate-to-substrate bonding by silver sintering.
- Reliability evaluation of module interconnect.
- Current sensor integrated with SiC MOSFET module.
- High-voltage SiC module packaging.
- Integration of magnetic dice into power module.
- Electromagnetic interference (EMI).

WORK SCOPE

- **Wide bandgap devices.**
- **Material and component characterization.**
- **active module integration.**
- **High-frequency magnetic integration.**
- **Converter integration.**
- **Wide power range (10 W - 100 kW).**
- **High frequency (100 kHz - 10 MHz).**
- **High temperature ≥ 250° C.**



Dynamic R_{ds_on} Measurement.

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Delta Electronics
Ford Motor Company
GE Global Research / GE Aviation
General Motors Company
Groupe SAFRAN
Huawei / Futurewei Technologies Co. Ltd.
Hyundai Mobis
Komatsu Ltd.
Lockheed Martin Corporation
Moog, Inc.
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