CIRCUITS

Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors

PROJECT DESCRIPTIONS

Cree Fayetteville, Inc. – Fayetteville, AR

Smart, Compact, Efficient 500kW DC Fast Charger (Category I) – $1,911,984

Cree Fayetteville (operating as Wolfspeed, A Cree Company) and its project team will build a DC fast charger for electric vehicles using a solid-state transformer based on silicon carbide (SiC). Such a device would offer significant improvements: efficiency (greater than 60% less power losses), size/weight (greater than 75% smaller size, 85% less weight), and cost (40% lower materials costs) over the state-of-the-art. If successful, the team will construct a 500 kW building block for a DC fast charger that is at least four times the power density of todays installed units.

Eaton Corporation – Menomonee Falls, WI

SiC-Based Wireless Power Transformation for Data Centers & Medium-Voltage Applications (Category I) – $1,988,270

Eaton Corporation and its project team will develop and validate a wireless-power-based computer server supply that enables distribution of medium voltage (AC or DC) throughout a data center and converts it to the 48 VDC used by computer servers. The Eaton team has targeted the data center sector, as it is quickly becoming a major consumer of electricity in the United States. If successful, project developments will reduce U.S. data center energy consumption and operating cost while creating a high-volume commercial market for SiC-based power converters.

Empower Semiconductor – Fremont, CA

Resonant Voltage Regulator Architecture Eliminates 30-50% Energy Consumption of Digital ICs (Category II) – $986,000

Empower Semiconductor will develop a new architecture for regulating voltage in integrated circuits like computer microprocessors. Empower's design will enable faster & more accurate power delivery than today's power management hardware, which has not been able to keep up with the need for high-quality power in modern processors, an important source of wasted energy. If successful, the project team will drastically reduce the power consumption of a digital integrated circuit while also enabling a much smaller form factor and lower cost solution.

Georgia Institute of Technology – Atlanta, GA

Grid-Connected Modular Soft-Switching Solid State Transformers (Category II) – $1,519,636

The Georgia Institute of Technology and its project team will develop a solid-state transformer for medium voltage (4 kV - 13 kV) grid applications using SiC with a focus on modularity, compact size and high-performance handling: up to 50 kW 1 phase, extending to 150 kW 3 phase. Georgia Tech's design seeks to address major roadblocks to solid-state transformer implementation, namely insulation, cooling, voltage change and magnetic field issues, as well as downstream protection against abnormal current faults. If successful, the team will greatly increase transformer functionality and reduce size over current technologies, affecting application areas like grid energy storage, solar photovoltaics and electric vehicle fast chargers, while also enabling better grid monitoring and easy retrofits.

Illinois Institute of Technology, Chicago – Chicago, IL

Wide Bandgap Solid State Circuit Breakers for AC and DC Microgrids (Category II) – $418,688

The Illinois Institute of Technology will develop ultrafast, self-powered, programmable, autonomously operated, bidirectional solid-state circuit breakers using transistors based on gallium nitride (GaN). The project team seeks to demonstrate the ability to handle high voltages (up to 1kV) and large currents while simultaneously reducing cost and improving response time (down to one microsecond) to help protect sensitive power electronics from fault conditions. If successful, such devices could be used to help protect microgrids and enable higher penetration of renewable energy sources.

Imagen Energy, LLC – New Berlin, WI

1200V SiC-Based, Extremely Compact, 500 kW, 2000Hz Inverter for High Speed Permanent Magnet Synchronous Machine (PMSM) Applications (Category II) – $847,888

Imagen and its project team will develop a SiC-based compact motor drive system to efficiently control high power (greater than 500 kW), high performance permanent magnet electric motors operating at extremely high speed (greater than 20,000 rpm). Imagen Energy's design seeks to address a major roadblock in operating electric motors at high speed, namely overcoming large back electromotive forces (BEMF). If successful, the project team will demonstrate a motor drive capable of handling large BEMF and increase motor system efficiency over a broad range of operating speeds.

Infineon Technologies Americas Corp. – El Segundo, CA

Low Cost e-mode GaN HEMT Gate Driver IC: Enables Revolutionary Energy Savings in Variable Speed Drives for Appliance Motors (Category II) – $924,392

Infineon Technologies will develop a new, low-cost gate driver integrated circuit (IC) for use with GaN switches, an important component for controlling variable speed electric motors (VSD). Most VSDs today use silicon- based semiconductors, which are limited in performance compared to those based on wide-bandgap semiconductors like GaN. If successful, Infineon's integration of a gate driver IC together with GaN switches and simple packaging will enable cost reduction by a factor of two or three, simplified integration and improvement in energy savings compared to today's solutions.

Marquette University – Milwaukee, WI

Advanced Parallel Resonant 1MHz, 1MW, Three Phase AC-to-DC Ultra-Fast EV Charger (Category I) – $632,437

Marquette University will develop a small, compact, lightweight, and efficient 1 MW battery charger for electric vehicles. The team aims to use state-of-the-art MOSFET switches based on SiC to ensure the device runs efficiently while handling very large amounts of power in a small package. This project endeavors to triple the current state-of-the-art in power density and double specific power of chargers today. If successful, such a device could help to dramatically reduce charging times for big batteries, like those in electric vehicles, to a matter of minutes.

Northeastern University – Boston, MA

A Universal Converter for DC, Single-phase AC, and Multi-phase AC Systems (Category I) – $628,205

Northeastern University will develop a new class of universal power converters that use the unique properties of wide-bandgap SiC switches to significantly reduce system weight, volume, cost, power loss, and failure rates. The proposed 10 kW converter topology takes advantage of the high switching frequency of the SiC devices to minimize the size of passive components used to transfer power. If successful, the proposed converter and its innovative control strategy has the potential to create a new paradigm in power electronics that could influence numerous applications, such as electric vehicles, wind energy systems, photovoltaic systems, industrial motor drives, residential variable frequency drive systems, and nanogrid applications.

Opcondys, Inc. – Manteca, CA

A Bidirectional, Transformerless Converter Topology for Grid-tied Energy Storage Systems (Category II) – $3,061,449

Opcondys will develop a high voltage (800 VDC to 14.5 kVAC), 60 kW power converter design for energy storage systems connected directly to the power grid. The team seeks to achieve significant efficiency gains over existing systems while also dramatically reducing the system size and cost. The converter will rely on a high-speed, optically switched, SiC-based power electronics device to produce extremely high-efficiencies of 99% while eliminating complexity. If successful, project developments could open the door to increased integration of grid-level energy storage at much lower cost.

Teledyne Scientific Company – Thousand Oaks, CA

SiC-Based Direct AC-AC Power Converter for Motor Drives (Category I) – $1,602,275

Teledyne Scientific Company and its project team will develop a 14 kW power converter for 480 VAC electric motors capable of reaching very high levels of efficiency and power density. The team's lightweight direct AC- to-AC converter obviates the need for conversion to DC, a wasteful intermediate step, and will operate at temperatures as high as 200 ^{o}C. If successful, project developments will advance the state of present motor drive systems with the potential to reduce electricity consumption in the energy-intensive manufacturing sector.

United Technologies Research Center I – East Hartford, CT

Power Conversion Through Novel Current Source Matrix Converter (MxC) (Category 1) – $1,899,939

United Technologies Research Center and its project team will develop a SiC-based, single stage, 15 kW direct AC-to-AC power converter that avoids the need for an intermediate conversion to DC or energy storage circuit elements. The team seeks to build a device that weighs as little as half as much as available converters while demonstrating scalability for a broad power range (from kW to tens of MW) and achieving conversion efficiencies of 99.5%. If successful, the UTRC team will produce advances that help greatly reduce energy losses in a range of industrial applications while simultaneously opening new possibilities in aircraft power systems, electric locomotives and ship propulsion, thanks to the reduced weight and complexity of the converter.

United Technologies Research Center II – East Hartford, CT

Ultra-dense Power Converters for Advanced Electrical Systems (Category II) – $1,583,576

United Technologies Research Center and its project team will develop an extremely efficient, high-power power converter capable of handling kilowatts of electricity at ultra-high power densities. The team will leverage the superior performance of SiC and GaN devices to achieve its efficiency and power density goals while eliminating electromagnetic "noise" in the circuit. If successful, the UTRC team will achieve landmark power densities in its converter while reducing cooling requirements, useful for applications such as aircraft starter motors.

University of Arkansas – Fayetteville, AR

Reliable, High Power Density Inverters for Heavy Equipment Applications (Category II) – $2,163,630

The University of Arkansas and its project team will develop a 2 by 250 kW power inverter system for use in the electrification of heavy equipment and other higher volume transportation applications (e.g., trucks, buses, cars). The team will leverage SiC power electronics devices to achieve high levels of efficiency while greatly increasing the volumetric and gravimetric power density of its system over existing ones. If successful, the team will achieve an improvement of four times the power density and reduce converter cost by 50% compared to today's technology.

University of Colorado Boulder – Boulder, CO

A High-voltage, High-reliability Scalable Architecture for Electric Vehicle Power Electronics (Category II) – $2,430,591

The University of Colorado Boulder and its project team will develop new composite SiC power converter technology that achieves high power and voltage conversion (250 VDC to 1200 VDC) in a smaller package than ever achieved. The team seeks to demonstrate the power converter as an on-board, high power, multifunctional power system for both charging electric vehicles and providing power to the motor. If successful, the CU Boulder team will make important progress towards reducing the size and complexity of power systems associated with electric vehicles.

University of Illinois at Chicago – Chicago, IL

Universal Battery Supercharger (Category I) – $1,047,719

The University of Illinois at Chicago and its project team will develop a new high-power converter topology for fast charging of electric vehicles (EV). The team will use wide-bandgap-based power modules to enable rapid charging of an EV battery. As wide-bandgap device technology improves, the proposed charger topology will reduce the size and weight of EV fast charging units, envisioning the prospect that the fast charging station could be built into an EV itself. If successful, project developments will help accelerate the deployment of EV charging infrastructure.

University of Illinois at Urbana-Champaign I – Champaign, IL

Enabling Ultra-compact, Lightweight, Efficient, and Reliable 6.6 kW On-board Bi-directional Electric Vehicle Charging with Advanced Topology and Control (Category II) – $1,737,545

The University of Illinois at Urbana-Champaign and its project team will develop an on-board electric vehicle (EV) charger using a high-density conversion technology known as a flying capacitor multi-level converter (FCML). This bidirectional converter topology not only reduces charging time but also services the vehicle's auxiliary loads to maximize overall system utilization. The team will leverage recent advances in GaN devices and new control techniques to produce a 6.6 kW converter with 15 times the power density at a lighter weight and higher efficiency than currently achievable. If successful, project developments could help reduce the size and complexity of electric vehicle power systems.

University of Illinois at Urbana-Champaign II – Champaign, IL

Extreme Efficiency 240 VAC to Load Data Center Power Delivery Topologies and Control (Category II) – $780,926

The University of Illinois at Urbana-Champaign and its project team will develop an extremely efficient AC-to-DC converter based on GaN devices for use in data centers. The team seeks to develop a prototype device that converts power from the grid (110-240 V at 50-60 Hz) to 48 VDC and lower point-of-load supplies used by data centers at efficiencies exceeding 97% and power densities beyond 7.5 kW/L. If successful, project developments will greatly reduce the amount of energy lost powering data centers while significantly improving power capability over current converters.

University of Wisconsin-Madison – Madison, WI

WBG-Enabled Current-Source Inverters for Integrated PM Machine Drives (Category II) – $1,031,315

The University of Wisconsin-Madison and its project team will develop new integrated motor drives (IMDs) using current-source inverters (CSIs). Recent advances in both SiC and GaN wide-bandgap semiconductor devices make these power switches well-suited for the selected CSI topology that the team plans to integrate into high-efficiency electric motors with spinning permanent magnets. If successful, the new IMDs will be capable of producing significant energy savings in a wide variety of industrial, commercial, and residential applications ranging from air conditioners to pumps and compressors.

Virginia Polytechnic Institute & State University I – Blacksburg, VA

High Power Density 10-kV SiC-MOSFET-based Modular, Scalable Power Converters for Medium- voltage Applications (Category I) – $2,344,467

Virginia Polytechnic Institute & State University and its project team will develop high power, high voltage AC- to-DC and DC-to-DC modular power converters with a circuit topology optimized for wide-bandgap (WBG) SiC semiconductors. The team will pursue three primary applications for this novel, 2 MW, high-efficiency (99%) power converter: 1) electric motor drives, 2) power inverters for grid-scale use, and 3) a DC-to-DC converter for microgrid applications. If successful, the project's optimized circuit designs could open the door for more high efficiency, high performance, SiC-based, high power, medium-voltage converters.

Virginia Polytechnic Institute & State University II – Blacksburg, VA

Single DC Source Based Cascaded Multi-level Inverter (Category I) – $1,048,939

Virginia Polytechnic Institute & State University will develop a GaN- and SiC-based, utility scale, high power (100 kW), multilevel, medium voltage DC-to-AC inverter that can receive power from sources like batteries or solar panels and transfer it directly to the medium voltage level of the utility grid. The team will also integrate the developed inverter with an existing medium voltage AC-to-DC converter to build a bidirectional solid-state transformer that converts low-voltage AC to high-voltage AC without using heavy, low-frequency materials such as copper and iron in its design. If successful, the project could lead to the first commercially viable medium voltage solid-state transformer, using just a single-stage process to obtain ultra-high efficiency power conversion.