IDEA-iPEBB

Innovative Design Automation Framework for integrated Power Electronics Building Block (iPEBB)

ELECOMP Capstone Design Project 2025-2026

Sponsoring Company:

University of Rhode Island Power Electronics Laboratory (URI PEL)

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Company Overview:

The University of Rhode Island Power Electronics Laboratory (URI-PEL) is conducting cutting-edge research in the field of power electronics. Our vision is to develop highly reliable and intelligent power conversion systems (PCSs) and to accelerate the design process for power electronics in various applications. Based on our strong foundation in power electronics, we have advanced various multidisciplinary research projects.

Our work has been published in distinguished journals and conference papers and is supported by various federal and state agencies, including the Office of Naval Research (ONR), the United States Geological Survey (USGS), etc.

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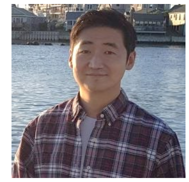

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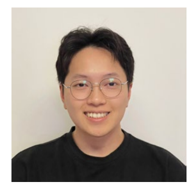

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Project Motivation:

The design process plays a critical role in determining the performance of power conversion systems (PCSs). Traditionally, industry has relied on the expertise of human designers, but this approach is often labor-intensive, time-consuming, and may not always produce optimal results. Additionally, each PCS application and model comes with its own unique design objectives and constraints, requiring repeated design efforts. These can range from simply adjusting parameters within an existing circuit topology to more extensive revisions, such as redesigning the system architecture or adopting entirely new topologies. These efforts are primarily aimed at improving key performance metrics like conversion efficiency and power density.

To address these challenges, there is a growing shift toward faster and more intelligent design methods, including the use of machine learning (ML), which has shown significant promise in identifying optimal design parameters more accurately and efficiently. In this context, the proposed capstone design project will focus on developing a novel framework inspired by modular power conversion systems, specifically integrated power electronics building blocks (iPEBBs), to accelerate the PCS design and manufacturing process. This project aligns with ongoing work supported by the Office of Naval Research (ONR) and will adapt the same principles for different applications, such as unmanned aerial vehicles (UAVs).

Anticipated Best Outcome:

The expected best outcome of this project, as illustrated in Figure 1, is the development of two fully functional PCS prototypes (PCSs #1 and #2) designed for two different drone applications: a 6-stack (S) hexacopter and a 4-stack quadcopter. The process will begin with the design, implementation, and testing of a single PEBB, capable of meeting the electrical requirements for a 2-stack configuration (6 to 8.4 V input range and 15 A maximum output load). After successful evaluation, multiple iPEBBs will be integrated, tested, and ultimately assembled into the two drone platforms for final demonstration.

The completed project will be showcased not only at the URI Capstone Design Summit but also at the student project demonstrations during the 2026 IEEE Energy Conversion Congress and Exposition (ECCE), one of the premier international conferences in the field of power electronics. For reference, information about the 2025 IEEE ECCE student demos can be found here: https://www.ieee-ecce.org/2025/student-project-demonstrations/.

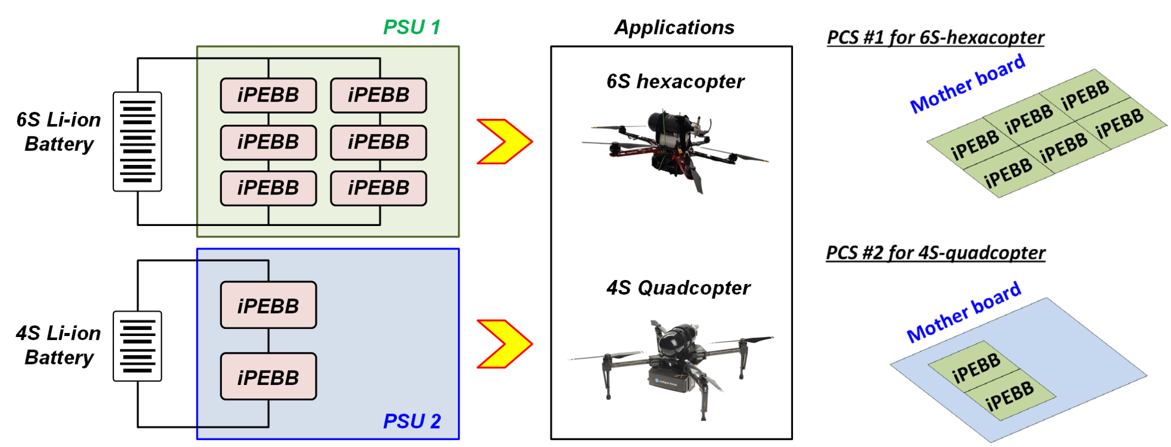


Figure 1. Overview of Capstone Design Project.

Project Details:

An UAV, commonly known as a drone, is an aircraft without a human pilot, crew, or passengers on board. Initially developed for military missions, UAVs have expanded into many non-military applications as their prices have dropped. These applications include aerial photography, environmental monitoring, infrastructure inspections, and entertainment. Compared to other electric mobility, UAVs require relatively small power ratings, making them suitable for undergraduate-level projects. Moreover, their structure is similar to other electric transport, such as aircraft, ships, and electric vehicles. Currently, the URI PEL has one drone with partially configurable parts and aims to develop two systems. The components for drones are listed below:

Drone		
Type	**6S Hexacopter**	**4S Quadcopter**
Frame	DJI F550 + Extended arms	TBD
Receiver	Futaba R7008SB	TBD
Flight Controller	Pixhawk4, Pixhawk 4 PMU	TBD
GPS	Pixhawk, Neo-M8N GP	TBD
ESC, Motor, Propellers	DJI E800 Propulsion (6S)	TBD

The hardware system of the UAV has a straightforward structure, as shown in Fig. 2. The energy source is a battery, from which the PCS delivers energy to the motors via electronic speed control (ESC). Additionally, it supports various electronic devices, including flight controllers, GPS, and receivers. The required specifications for PCSs are as follows:

1) Input voltage: 4S: 12.8-16.8 V, 6S: 19.2-25.2 V.
2) Output voltage: 4S: 14.8 V, 6S: 22.2 V.
3) Output maximum current: 15 A.
4) Other functions, projections: overvoltage, overcurrent, fast transient, and balance.

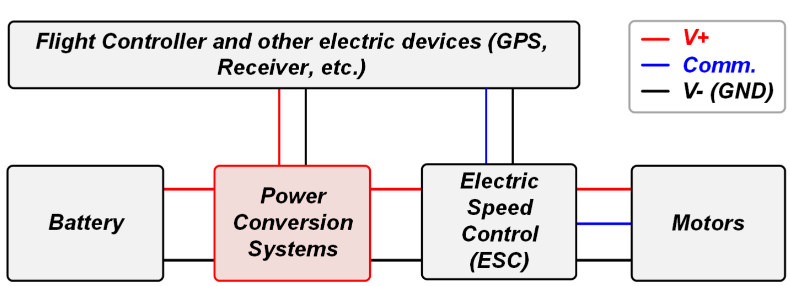
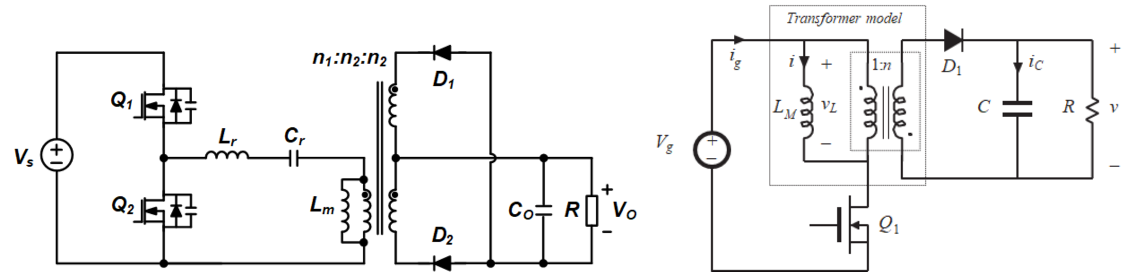


Figure 2. Block diagram of the hardware circuit for PCS in drone applications.



(a) (b)

Figure 3. Two potential candidates for a single PEBB.

Figure 3 illustrates two possible circuit topologies being considered for the single PEBB: an LLC resonant converter shown in Fig. 3(a), and a flyback converter shown in Fig. 3(b). These two designs will be compared in terms of performance, complexity, and suitability for the application, and one will be selected for implementation.

Phase I (Fall Semester): Preliminary Study and Single PCS Development

: During the first phase, the team will focus on conducting a preliminary study and building a single PCS, including closed-loop control implementation using either analog or digital controllers.

[Hardware/Electrical Tasks]

1. Select the power converter topology and appropriate controller for the iPEBB.
2. Design a single iPEBB using conventional methods, including the selection of key components.
3. Assemble and evaluate the iPEBB hardware, implementing closed-loop control.
4. Begin basic drone assembly in preparation for integration.

[Firmware/Software/Computer Tasks]

1. Choose a suitable controller for the iPEBB.
2. Develop and test the closed-loop control system for a single iPEBB board.
3. Establish communication between the controller and the physical iPEBB system.

Phase II (Spring Semester): Multi-iPEBB Integration and Drone Implementation

: The second phase will focus on integrating multiple iPEBBs to create two fully functional PCSs and demonstrating their application in two distinct drone platforms.

[Hardware/Electrical Tasks]

1. Develop methods for configuring multiple iPEBBs to operate together.
2. Build and test multiple iPEBB boards, integrating them into PCS #1 (hexacopter) and PCS #2 (quadcopter).
3. Install and test the completed PCSs within their respective drone platforms.

[Firmware/Software/Computer Tasks]

1. Develop control strategies to ensure voltage and current balancing among multiple iPEBBs.
2. Implement control algorithms for managing the operation of multiple iPEBBs in a unified system.
3. Evaluate system performance in both drone platforms.

Composition of Team:

3 electrical engineers, and 1 computer engineer.

Skills Required:

Electrical Engineering Skills Required:

- Analog and power electronics circuit design (ELE 212, ELE446)
- Proficiency in MatLab, Simulink, and circuit simulation (PowerSIM, LTSpice)
- Knowledge of using lab equipment, including oscilloscope, power supplies, e-load, etc.
- PCB layout experience.
- Soldering skills and experience working with various electronics circuit.

Computer Engineering Skills Required:

- Experience with microcontroller or FPGA.
- Familiarity with computer architecture.
- Experience with embedded systems.
- Ability to test, debug and validate code.

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact

The development of modular, high-efficiency power conversion systems, i.e. iPEBBs, presents a transformative opportunity for cost savings and increased productivity in the power electronics industry. By standardizing the design and enabling reuse of the same iPEBB across different applications, this approach significantly reduces the time and engineering resources required for custom circuit development. This efficiency can lower manufacturing costs and accelerate time-to-market for UAV systems and other electrified platforms. Additionally, the higher power density and improved thermal management offered by the iPEBB design contribute to better energy utilization, which can translate into long-term operational savings and enhanced performance across a range of applications. These cost and performance advantages will be particularly beneficial to companies in competitive sectors such as unmanned systems, where weight, size, and energy efficiency are critical.

Broader Implications of the Best Outcome on the Company's Industry:

Beyond its immediate application in UAVs, the successful demonstration of this modular and scalable PCS framework has the potential to reshape how power electronics are developed and deployed across multiple industries. By introducing a flexible, plug-and-play architecture that simplifies integration, the project supports a broader shift toward electrification in defense, aerospace, automotive, and industrial systems. The standardization of high-performance building blocks like iPEBBs can reduce design complexity, enhance supply chain efficiency, and facilitate faster adoption of emerging technologies, such as AI-based control, digital twins, and advanced thermal management. URI PEL leveraging this technology will be better positioned to meet the evolving demands of electrified platforms, improve product reliability, and maintain a competitive edge in rapidly advancing markets.