

4th-Year Capstone Project Definition

Title: GaN-Based 48V Three-Phase Inverter for Sustainable Power Applications

Project Duration: 2026–2027 Academic Year | **Industry Partner:** Infineon Canada Inc.

1. PROJECT SCOPE AND SYSTEM DESCRIPTION

1.1 System Overview

This capstone redesigns Infineon's REF_MTR_48V30A_GaN reference board into **modular PCB designs** with comprehensive firmware for motor Field-Oriented Control (FOC) and datacenter power conditioning. Students will develop three independent hardware modules (MCU control board, half-bridge power modules, main integration board) alongside embedded firmware for real-time control.

Key Specifications: 48V nominal input | 1 kW electrical / 700W mechanical output | 30 A RMS per phase | 100 kHz switching | CoolGaN™ 100V Transistors | XMC4200 microcontroller | CAN-FD/UART communication

1.2 Intended Applications & Academic Objectives

Applications: Battery-powered motor drive (drones, robots, e-scooters) and 48V datacenter power management. **Why GaN:** High-frequency switching (100+ kHz) with minimal losses reduces passive components and system size, demonstrating wide-gap semiconductor adoption in sustainable energy systems.

Learning Outcomes: (1) Advanced GaN device physics and thermal management; (2) Modular system design decomposition; (3) Cross-functional hardware-firmware integration; (4) Industry-standard PCB design and embedded control; (5) Rigorous validation testing (HALT, thermal cycling, efficiency characterization).

2. PROJECT STRUCTURE & DELIVERABLES

HARDWARE GROUP (3 students)

H1: MCU Control Board (1 student)

XMC4200 microcontroller, 5V/3.3V supplies, CAN-FD/UART transceivers, temperature/voltage monitoring, standardized board-to-board connectors. **Deliverables:** Schematic, PCB layout, BOM, functional test report, user guide

H2: Half-Bridge Power Module (1 student)

Three-phase inverter leg with dual-parallel CoolGaN™ transistors per phase, EiceDRIVER™ gate drivers, TLI4971 current sensing ($\pm 120A$), overcurrent detection (41/62.5A configurable), optimized <1 nH power loop inductance.

Deliverables: Schematic, PCB layout, gate driver characterization, thermal analysis, assembly guide

H3: Main Integration & Power Distribution Board (1 student)

Central substrate hosting all modules via board-to-board connectors, 48V power distribution, inrush limiter, overvoltage/surge protection, motor connectors, heatsink mounting, oscilloscope test points.

Deliverables: Integration schematic, PCB stackup design, mechanical drawings, FMEA safety analysis, assembly report

Grading: Schematic design (20%) | PCB layout quality (25%) | BOM & component selection (10%) | Hardware validation testing (25%) | Documentation (15%) | Cross-group integration (5%)

FIRMWARE/SOFTWARE GROUP (5 students)

F1: Low-Level Driver & HAL (1 student)

XMC4200 peripheral drivers (GPIO, SPI, CAN, UART, ADC, PWM), dead-time insertion, ADC filtering, real-time task scheduling (FreeRTOS), bootloader. **Deliverables:** Driver library, HAL API, unit tests, timing validation report

F2: FOC Algorithm (1 students)

Three-phase current measurement, Park/Clarke transforms, PI current/speed controllers, Space Vector PWM, sensorless BEMF observer (or encoder feedback), overcurrent/overvoltage/thermal protection interlocks. **Deliverables:** C implementation, MATLAB/Simulink model, parameter tuning guide, control loop characterization, HIL test results

F3: Communication & Protection (1 students)

CAN-FD protocol stack, UART command interface, telemetry transmission, fault state machine, data logging, security (message filtering, checksums). **Deliverables:** Protocol specification, CAN/UART driver library, fault handling FSM, protocol testing report, diagnostic tool

F4: Application Layer & GUI (2 students)

Motor FOC application (startup, speed ramp, soft-start), datacenter power regulation mode, UART/LCD UI, parameter configuration, real-time visualization, Makefile/CMake build system. **Deliverables:** Integrated firmware, user manual, configuration docs, functional testing report, efficiency characterization

Grading: Code quality & architecture (20%) | Algorithm correctness (25%) | Integration & stability (20%) | Testing & validation (20%) | Documentation (10%) | Cross-group collaboration (5%)

4. DELIVERABLES

Assessment: Sub-group deliverables (70%) | System integration & cross-group work (20%) | Professional communication (10%)

Final Deliverables:

- **(Hardware)** Complete schematics, Gerber files, assembled boards with validation, thermal report, BOM, assembly procedures, 50–100 pp design documentation
- **(Firmware)** Compiled C code, MATLAB models, protocol specifications, performance data, user manual, test coverage report, 50–100 pp technical documentation
- **(Joint)** Integrated system demo (motor FOC or power conditioning), efficiency characterization, final report, presentation, video demonstration

5. INDUSTRY PARTNERSHIP & CONCLUSION

Infineon Canada Inc. provides technical mentorship, design reviews, sample components (CoolGaN™, gate drivers, reference boards), application notes, and potential co-authored publication opportunity.

This capstone equips students with expertise in sustainable power electronics, embedded systems integration, and industry-grade product development. By working with cutting-edge GaN technology, students contribute to efficient, compact renewable energy systems while gaining credentials valued in power electronics and embedded systems industries.