INSTITUT NATIONAL DES SCIENCES APPLIQUÉES TOULOUSE

Designing a Low-Tech, Open-Source Motor Controller for Electric Cargo Bikes

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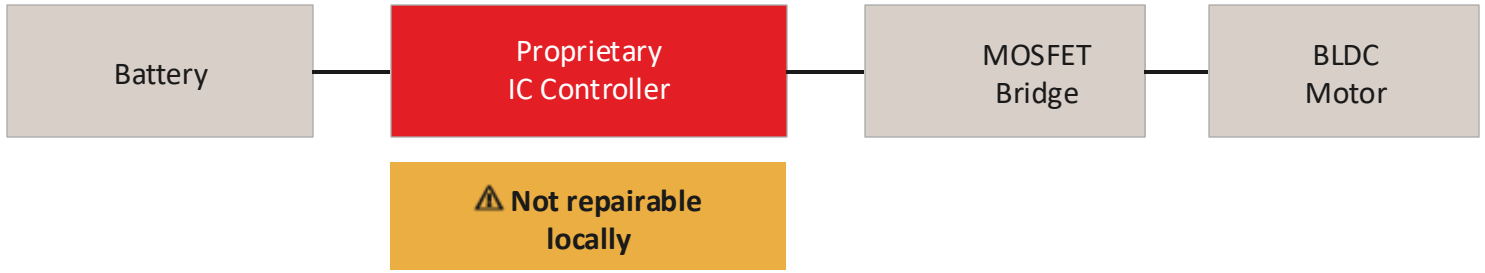
Commercial controllers limit local repair

Typical commercial e-bike controller



*L*aMAD's answer: VESC open-source project

The VESC project

Open-source firmware & hardware for BLDC motor control
Widely adopted — but **not designed** for local fabrication or repairability

Urban cargo bikes need reliable, repairable controllers

Proprietary ICs make field repair nearly impossible

LaMAD builds sustainable, open, community-maintained products

Open-source controllers lack low-tech and repairability design

What exists	What is missing
✓ FOC vs Trapezoidal comparative studies (torque ripple, efficiency, cost)	✗ Low-tech adaptation of open-source controllers
✓ High-performing VESC controllers, well documented	✗ Local fabrication with standard, off-the-shelf components
✓ Torque ripple: 18.38% (FOC) vs 35.67% (Six-Step) at 500 RPM [1]	✗ Repairability documented for non-specialist communities
✓ BLE integration for diagnostics and tuning	✗ Bluetooth security for decentralised, community-run fleets

Research gap: no controller combines open-source firmware, local manufacturability, repairability, and BLE security

[1] Jomsa-Nga et al., IEEE ISC2, 2024

Aim: design a low-tech, repairable, open-source BLDC controller

Design, assemble and validate a VESC-based controller for LaMAD cargo bikes — prioritising local manufacturability at INSA Toulouse.

01

FOC + Trapezoidal

Support both commutation strategies on the VESC firmware

02

Positional control

Achieve position control with the current hardware setup

03

Bluetooth security

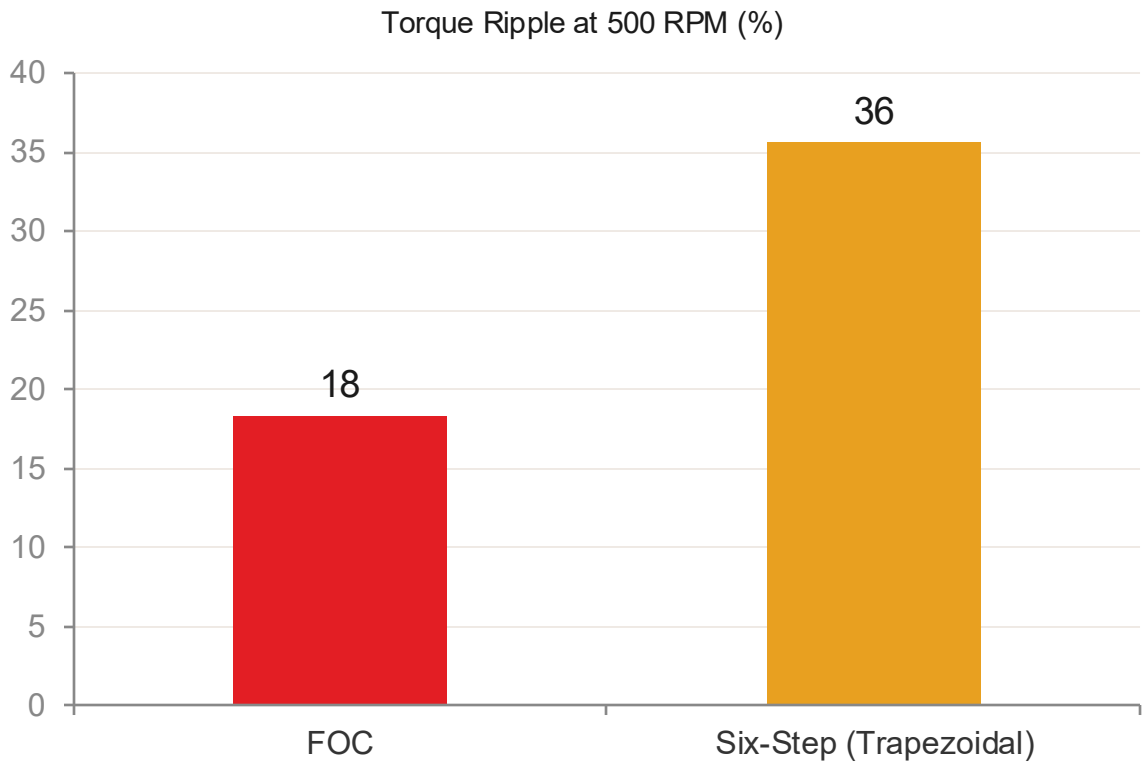
Identify and patch open BLE access vulnerabilities

04

Local fabrication

PCB manufacturable at INSA with standard, discrete components

FOC reduces torque ripple by half compared to Six-Step control



Source: Jomsa-Nga et al., IEEE ISC2, 2024

Criterion	FOC	Six-Step
Torque ripple	~18 %	~36 %
Low-load efficiency	Better	Adequate
High-speed switching loss	Higher	Lower
Implementation complexity	High	Simple
Hardware cost	Higher	Lower
Dynamic response	Fast	Standard

VESC implementation: adapting firmware for both modes · Testing on real BLDC motor · Comparing performance, ripple, and power draw

Open BLE access poses an unauthorized control risk

Bluetooth Security

Vulnerability identified

VESC standard firmware exposes Bluetooth without authentication.

Risks

Unauthorized motor control and remote parameter modification.

Proposed solution

Local key or offline mode — disabling or restricting BLE.

Test protocol

BLE scan, unauthenticated connection attempt, patch validation.

Repairability

Discrete-component PCB

No proprietary ICs — each component replaceable individually.

Standard housings

Off-the-shelf connectors, fully open-source documentation.

Open schematics & BOM

Gerber files and bill of materials published for community reproduction.

LaMAD repair tests

Repair procedures validated by LaMAD's non-specialist team.

A low-tech, repairable, open-source controller is achievable

Preliminary results

✓ Adapted VESC controller drives target motor in both FOC and Trapezoidal modes

✓ Positional control achieved with current hardware configuration

✓ Open Bluetooth access identified as a security vulnerability

Future work

Real-world testing on LaMAD cargo bikes

Publishing PCB design and firmware

Adding simple Bluetooth authentication

Training LaMAD teams in repair procedures

Open-source, low-tech, locally repairable motor control is possible and community-ready.

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Questions?

Thank you for your attention

References

[1] Jomsa-Nga et al., Torque ripple mitigation using FOC for BLDC in small EVs, IEEE ISC2, 2024.

[2] Gieras & Shen, Modern permanent magnet electric machines, CRC Press, 2023.

[3] Patil et al., Analysis of FOC & trapezoidal method, INCET, 2025.

[4] Li, Yao & Lee, Quantitative comparison: sensorless six-step vs FOC, IEEE ECCE, 2019.

[5] Mohammd Taher et al., MPC-based torque ripple reduction in BLDC, PEDSTC, 2021.