1 Overview

The Vehicle Control Unit (VCU) is used to coordinate and process inputs from vehicle peripherals and smart devices, to instruct and augment vehicle operation. It acts as the brain, controlling system hardware (e.g. displays, lights, motor controllers) through infinitely adjustable software-defined control schemes that run on it. *NOTE: This is not a motor controller itself! Motor control requires additional hardware the VCU will command.*

This additional layer of control and technology enables several opportunities in electric vehicles. As a vendor independent unit it can be reconfigured to suit differing battery and motor systems - not locked into a specific ecosystem or subset of products. Acting as a supervisor of other hardware it can allow systems to influence one another that would previously operate in isolation. The VCU also has the ability to do data logging which when combined with its Internet of Things (IoT) capabilities makes it possible to enable fleet monitoring and management. All this, while still being able to replicate the functionality of simpler modules that handle just throttle or lights.

The VCU is flexible enough to be implemented during prototyping and proof-of-concept stages, as well as used in series production vehicles, while remaining small and light enough to fit in even the smallest of micro-mobility vehicles. It can be configured to operate an entire vehicle on its own, or be used in a network with other units to handle operating more complicated vehicles by distributing tasks across the individual units. For example one VCU can operate a tractor vehicle which connects to a trailer with a separate VCU to operate trailer systems.

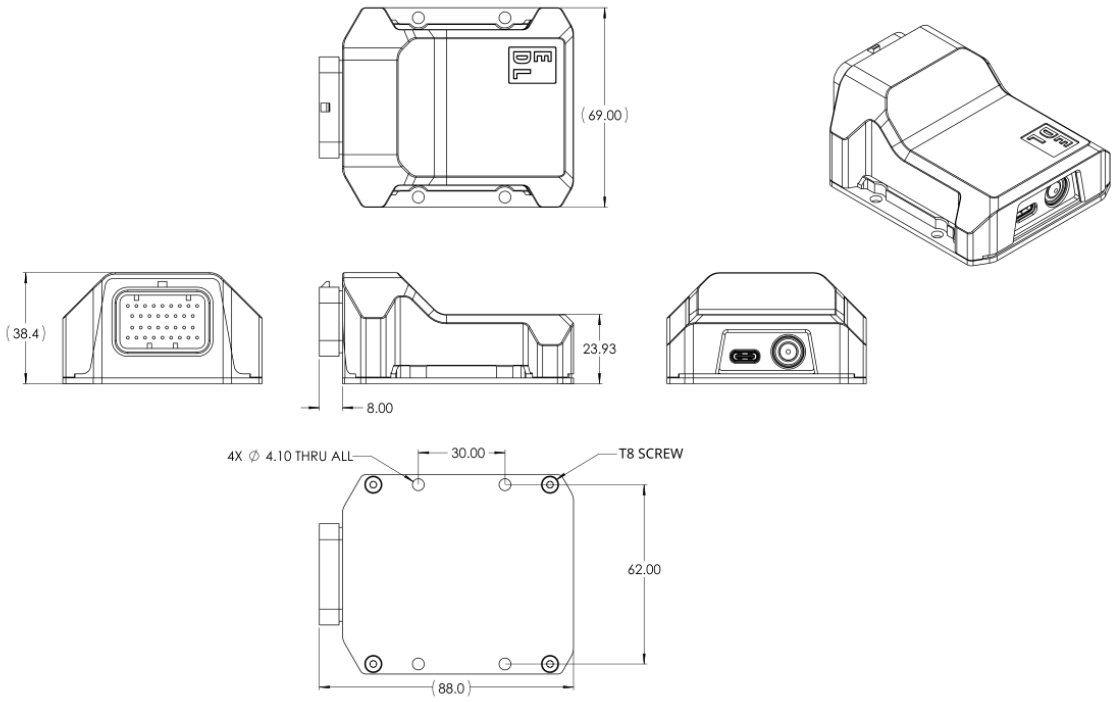
The system is initially configured/programmed by Engineering Design Lab (EDL) to suit client design requirements for their vehicles, although it may be reprogrammed after delivery by either party. Features made possible by adding such a controller to a vehicle:

- Over the air (OTA) firmware updating
- Field adjustable vehicle behaviour, either by the user or centrally for fleets
- Smartphone based access control
- Multiple VCUs can be networked together for more complicated vehicles or modular assemblies
- Rollover/crash detection
- Implementation of a gradual user training program, for example, unlock full power after 100 km ridden.
- "Limp home" mode to conserve battery
- Reactive power limits based on incline
- Region-specific configurations/features such as legal speed limits
- Adjusting regenerative braking based on battery level
- Traction control
- Electrically controlled "differential" for multi-motor systems, front-rear and/or left-right
- Tamper detection
- Stability control
- Torque vectoring

2 Mechanical Features

The VCU can be purchased as a either just the circuit board, or with EDL's custom enclosure. The enclosure has the following features:

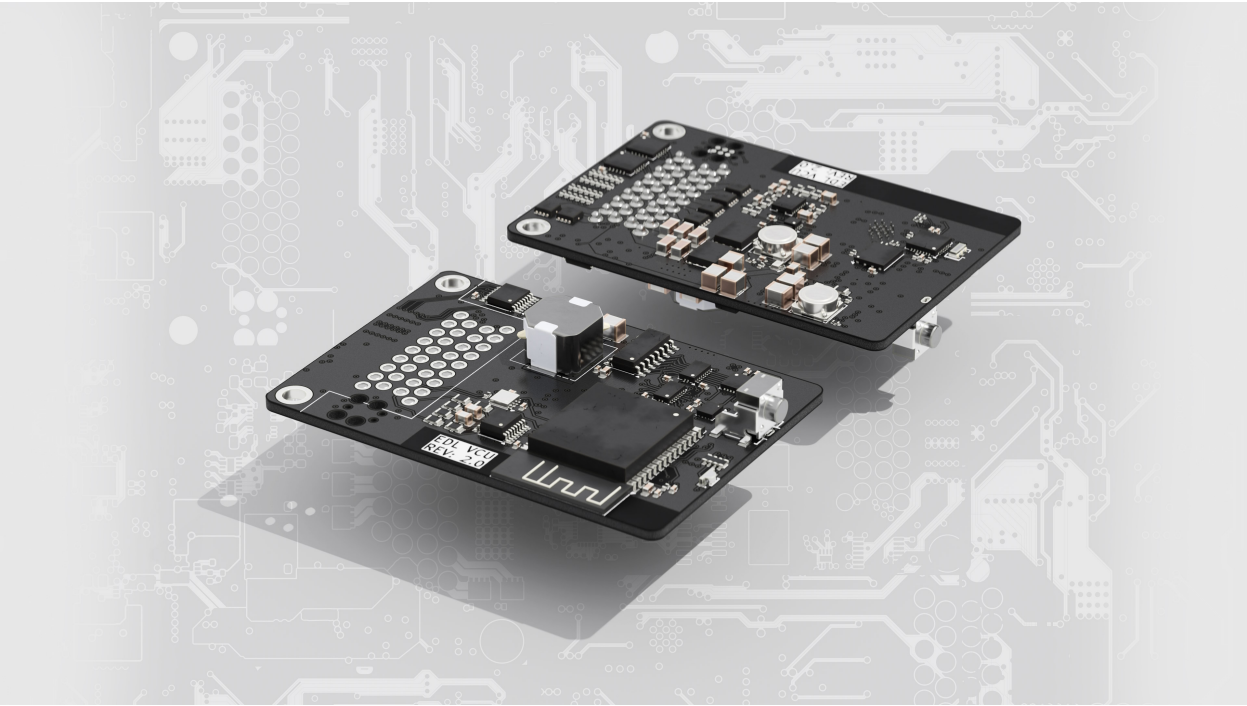
- Maximum dimensions: 88 x 69 x 39 mm (3.46 x 2.72 x 1.54 in)
- Approximate weight: 270 g (0.6 lbs / 9.5 oz.)
- IP67 enclosure and connectors
- Rugged and vibration resistant
- Rated temperature range: -40 °C to 85 °C (-40 °F to 185 °F)
- Primarily plastic enclosure with metal base used for mounting and heat dispersal
- Designed for ease of repair and/or replacement
- Mounting hole pattern for M4 socket head screws in a 30 x 62 mm (1.18 x 2.44 in.) pattern



3 Electrical Features

The core electronic features embedded in the VCU are listed below. These can be extended with the appropriate expansion boards.

- Working power input voltage range from 12 V to 95 V
- Wifi and Bluetooth Low Energy connectivity
- Two independent CAN communication buses
  - One bus supports CAN 2.0B
  - One bus supports CAN-FD (and CAN 2.0B)
- 100 V, 1.5 A tolerant output lines to control high power peripherals (e.g. alarm, lights)
- 100 V tolerant inputs for system monitoring (e.g. key) (threshold voltage for "high" is 20 V)
- Analog inputs for user input devices (e.g. throttle or steering)
- Low-voltage general purpose input/output pins configured for either 5 V or 12 V operation
- RGB status LED
- Dedicated flash chip with 16 MiB of space for storing logs, configurations, etc.
- 32-bit Processor with 8 MiB flash, 512 KiB RAM
- Six-axis Inertial Measurement Unit (IMU) (acceleration, gyroscope) on board
- Button for user input which can be used reset the VCU if held for several seconds
- USB-C interface for programming and debugging, *requiring no dedicated programming hardware*
- Internal header for connecting expansion boards to provide new capabilites



4 Inputs and Outputs

The main connector for the VCU is a 34-pin TE Connectivity SUPERSEAL 1.0mm connector (TE 6437288-2) which mates with TE 4-1437290-1 and tolerates up to 7 A per pin. The connector offers two independent CAN buses, 22 general purpose input/output pins, and two regulated power rails at 5 V and 12 V.

Given the varied abilities of the pins on the VCU, they have been grouped into "ports" based on shared capabilities. All the pins that belong to a port will have the same abilities such as accepting analog input or being able to output at 12 V. The detailed breakdown of the available ports and VCU signals is below *(all pins are digital only unless specified otherwise)*:

Main VCU Connector Connections

Port	Pins	Notes
0	6	5 V GPIO or 12 V Output
1	6	5 V GPIO or 12 V Input, Analog Input at either range
2	6	100V tolerant low-side sinks to battery negative (1.5 A each)
3	2	100V tolerant digital input
4	2	Digital potentiometer (12 V max). *One pin is upper end of pot., the other is the wiper.*
X	4	Expansion board GPIO. *Functions vary based on expansion installed.*
CAN1	2	CAN H/L connections for CAN-2.0B bus
CAN2	2	CAN H/L connections for CAN-FD bus
5V	1	5 V 1 A rail
12V	1	12 V 4 A rail

In addition to the main connector for the VCU, there is a USB-C connector on the opposite face (next to the button and status LED) for communication to the microcontroller within. This is initially configured to be a development interface for the VCU's firmware, allowing for firmware upload as well as live debugging of the system during development. It can be reconfigured to allow users to exchange data with the vehicle such as configurations or ride logs.