VESC Balance Board Build #6

Thor300 controller, Superflux motor, 20s2p 21700 (P45B) split pack

Kevin Pedersen AKA Kevin McDangersen (facebook), butoursgoto11 (reddit), goto11 (pev.dev)

Disclaimer **2**
Planning **2**
Key Components 2
Overview **3**
Parts Selection 3
Assembly and Modification Process 3
Wiring Schematics **5**
Controller & Controller Box 5
Power Switch 5
Motor Connector 5
Battery, BMS & Box 5
Connection & Setup **6**
Wiring Harness and Split Pack 6
CAN Bus 6
Lights 6
Controller Box Assembly 7
Footpads 8
Charger 8
Android VESC Tool (mobile app v6.02 → v6.05) 9
Setup Reference 9
Pushback (formerly called Tiltback in VESC settings) 10
Re-running Motor Calibration 10
IMU Setup 11
Re-running IMU Calibration 11
Conclusion and Build Photos **12**

Disclaimer

There are many ways to build a one-wheeled VESC balance board. All builds will require you to conduct your own research, then select from multiple options based on your own priorities and needs. This document should not be trusted as accurate, definitive or comprehensive. Thanks to the amazing onewheel VESC community for others' knowledge, experience and hard work that I drew from in writing this guide. The choices I made are described here, and I assume my own risk for the potential consequences if something should go wrong. In reading further, you assume your own risk for any and all consequences of building a dangerous personal electric vehicle.

This guide works on mobile devices, but graphics may be best viewed on a larger screen.

Planning

Make sure you have all of the parts listed below to build your DIY one-wheeled balance board. Lead times can be quite long for these parts, so plan ahead.

Key Components

A one-wheeled electric balance board consists of 5 main components:

1. **Controller Box** - Under front footpad.
    a. Ports
    b. Controller
    c. Headlight
    d. Front Bumper
    e. Other options: remote interface, buzzer, light controller
2. **Footpads** - Where your feet stand.
    a. Front Footpad
        i. Grip Tape
        ii. Sensor
        iii. Sensor cable
    b. Rear Footpad
    c. Grip Tape
3. **Rails** - Run the length of the board and tie everything together.
    a. Cable Clips
    b. Fender
4. **Wheel Motor**
    a. Bearings
    b. Stator + Axle
    c. Axle Blocks (connects axle to rails with lift/lower option)
    d. Hall Sensor
    e. Motor Cable (to controller box)
    f. Rim
        i. Magnets
        ii. End Cap
5. **Battery Box** - Under rear footpad.
    a. Battery Pack
    b. BMS (Battery Management System)
    c. Wiring Harness (to controller box)
    d. Taillight
    e. Rear Bumper

Overview

This is one of the easiest “from scratch” VESC builds out there, but there’s still a long list of modifications needed to make everything fit together and work properly. This is not intended to be a step-by-step guide, but is written as a general overview followed by specific instructions, so it’s important to read through this entire build guide before starting the process.

Parts Selection

Fungineers:

- Thor300 Controller Box Complete (I went with anodized CNC instead of die-cast)
- Rear LED (sold separately)
- Superflux HS Mk II motor

Indy Speed Control p45b 20s2p Split Pack (includes xlite v4 BMS and wiring harness)

The Float Life:

- WTF BTG rails
- TORque Box
- BANG bumpers

Stocked Stock v4 Sensor

Other parts per personal preference: Maxxis T18 11x6.5-6 treaded tire, Platypus footpads, Life Saver rim guards, Dragan toe hooks.

Assembly and Modification Process

This is the overall sequence to modify and assemble the parts selected for this build. Details on wiring schematics and assembly are in the following sections.

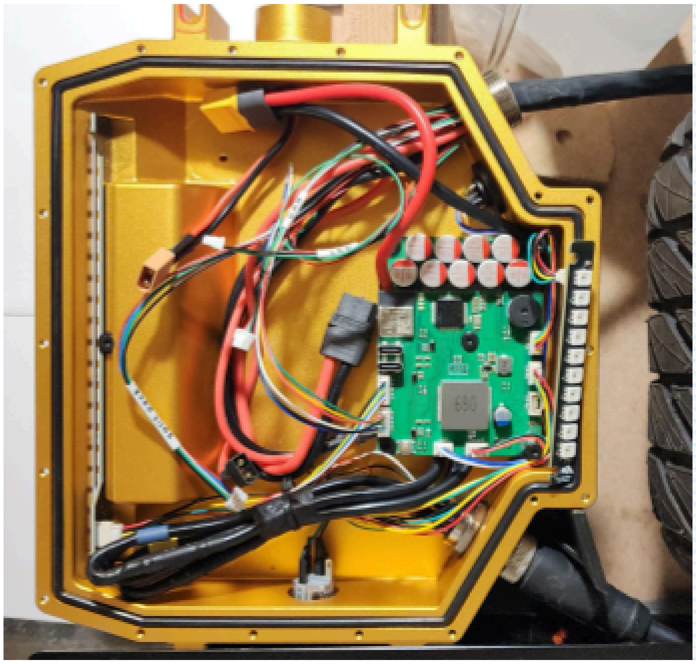
1. Preassemble rails, motor and boxes after installing the wiring harness in the boxes with the female XT60 end in front and the male XT60 end in back (don’t plug anything in yet).
2. Modify TORque box:
    - Remove gland and replace with Indy wiring harness gland.

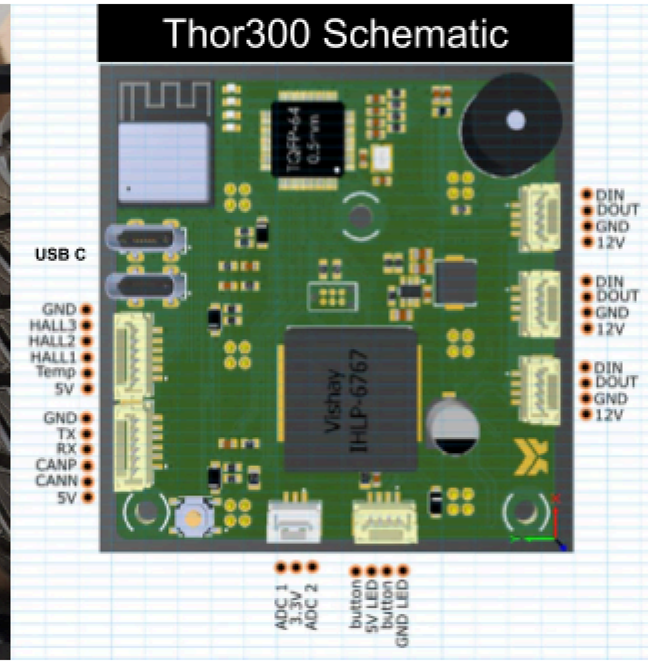
    - Depending on the LED bar, you may have to remove ribs from the LED slot.
    - Add fish paper to protect BMS.
    - Fix BMS and cables in place with hot glue.
    - Add silica dioxide moisture absorber pack.
    - Seal with silicone and pressure test.
    - Add Gore-Tex vent plug.
3. Modify Wiring Harness (Indy):
    - Follow steps for the rear only in Assembly of the 20s2p Vexxer split pack! for BMS to balance leads, charge, discharge, and split pack.
    - After initial connection, adjust wire lengths in battery box by pulling excess length into controller box.
    - Replace or install JST GH connectors to fit rear LED and controller CAN connector.
    - Cut excess XT60 wiring in controller box and re-solder new XT60 end.
    - Shrink the heat shrink tubing around the harness.
4. Modify Split pack (Indy):
    - Melt or cut away excess shrink wrap to fit mounting blocks.
    - Modify mounting blocks as necessary to clear PCB.
    - Cut m3 bolts (not included) to length and install mounting blocks with plastic safe threadlock.
5. Modify Controller box (Fungineers):
    - Remove gland and replace with Indy wiring harness gland.
    - Add fuse to XT30 charge port.
    - Shorten phase wires, solder on new bullet connectors, add color-coded elctrical tape to join each set of phase wires.
    - Cable management with zip ties and hot glue.
    - Add silica dioxide moisture absorber pack.
    - Seal with silicone.
    - Install mud guards.
6. Disassemble rails and motor blocks, remove burrs in cable channel, reassemble everything with plastic-safe threadlock.
7. Modify Footpads and bumpers:
    - Customize front footpad as needed for sensor cable and status LED pass-through.
    - Install sensor, grip tape, sensor cable, and seal with hot glue.
    - Install footpads and bumpers.
8. Upgrade firmware and packages as needed. Run through VESC setup procedure, then go back and optimize settings, including Refloat Config.

Wiring Schematics

Controller & Controller Box

A Thor300 VESC was chosen for this build primarily because it was included with a controller box that could fit the split pack, and because it could handle the higher currents used by the Superflux motor without overheating.





I chose the CNC box because machined aluminum has double the thermal conductivity of die-cast aluminum (~180 w/m.k. vs. ~90 w/m.k.), which means my controller will be less likely to overheat.

Power Switch

The Funwheel Controller Box Complete comes pre-wired with a power switch.

Motor Connector

The Funwheel Controller Box Complete comes pre-wired with a Superflux motor connector with Hall sensor and phase wires in a single plug.

Battery, BMS & Box

The battery pack consists of a Molicel P45B 20s2p split pack from Indy Speed Control. The split pack comes with a wiring harness and Ennoid Xlite v4 BMS. A TORque Box was chosen for the battery box because it's strong, waterproof, and fits up to an 18s2p 21700 battery pack.

Connection & Setup

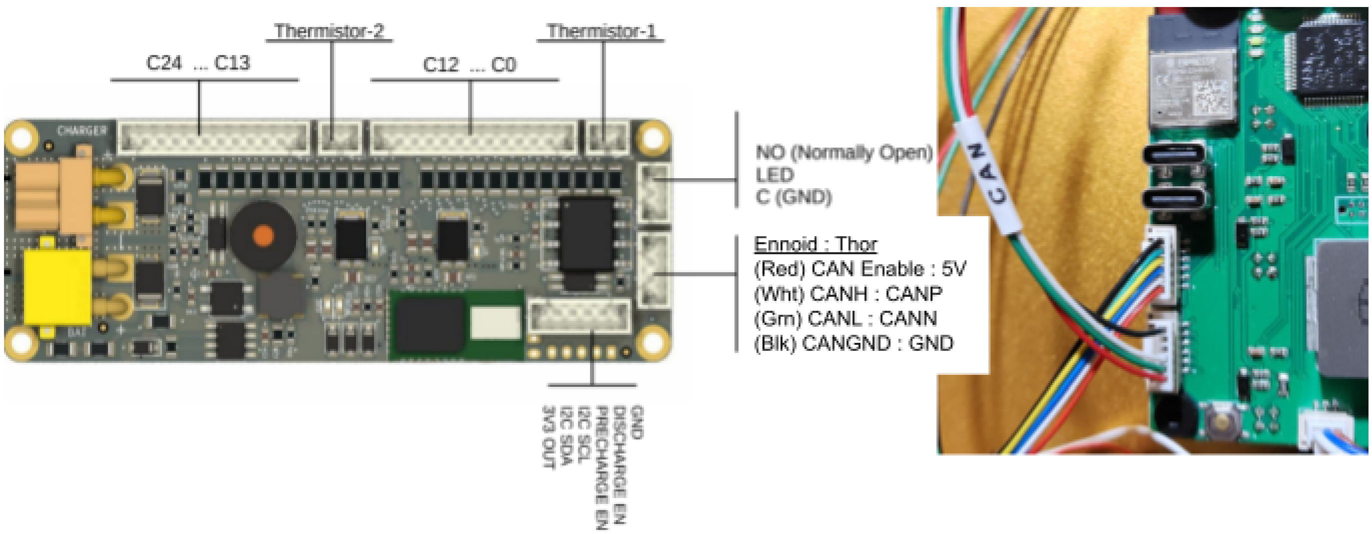
Wiring Harness and Split Pack

The wiring harness, Xlite v4 BMS, and split pack 20s2p (18s2p rea, 2s2p front) came from [Indy Speed Control](). Installation is mostly covered in the Assembly of the 20s2p Vexxer split pack! video, except for the controller-side CAN bus and rear LED.

Do not shrink the heat shrink of the wiring harness (like I did) until after the cables are connected, since you may need to pull some cables through to adjust the length in the battery box. For example, the CAN cable needed to be pulled through the harness to reach the connector on the BMS.

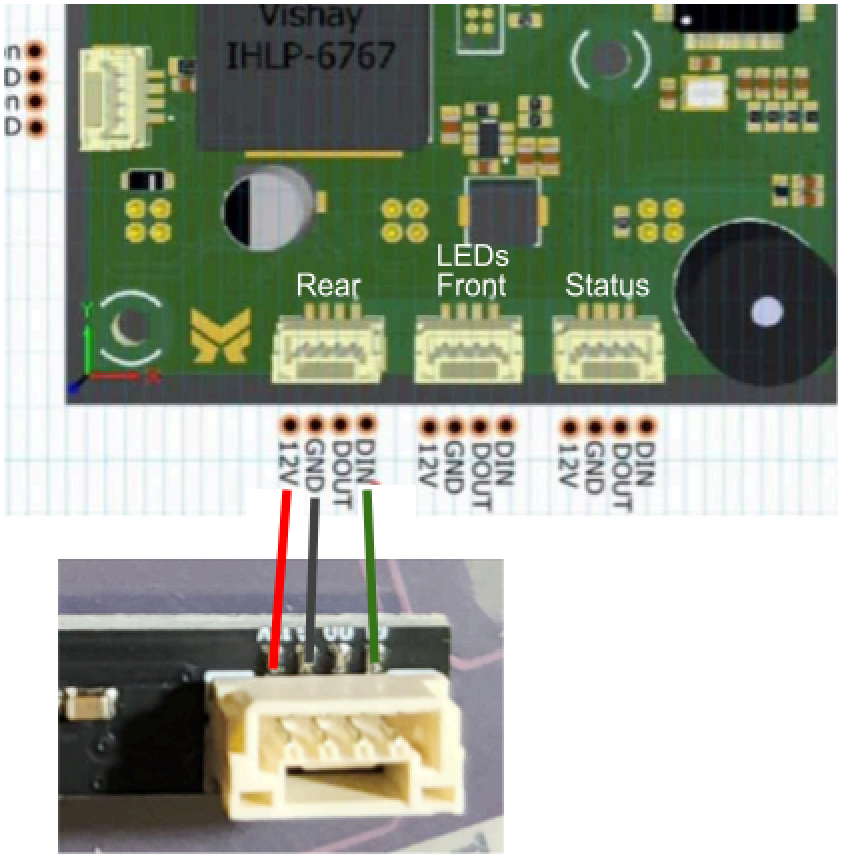
CAN Bus

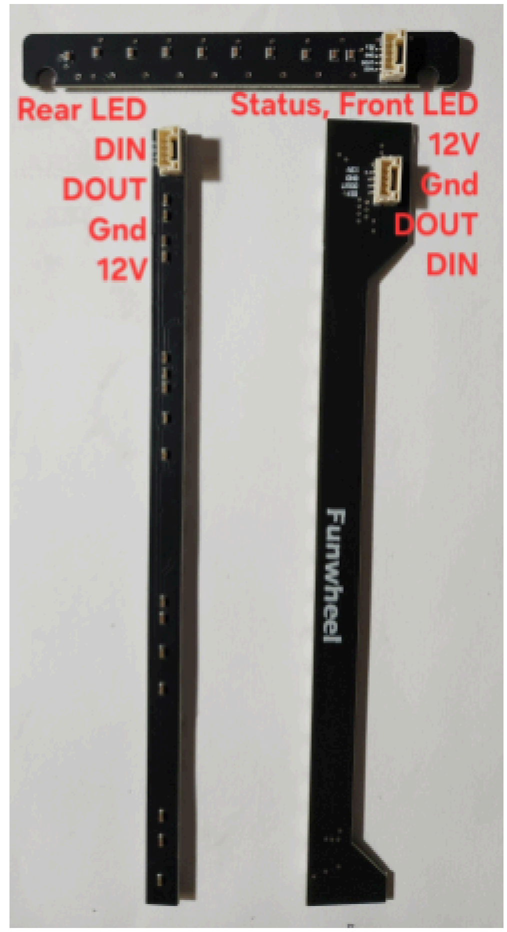
The CAN cable in the Indy Speed Control wiring harness has a 4 pin JST GH connector on each end of the cable, while the Thor300 has a 6 pin JST GH connector, so the controller-side cable needed to be re-pinned for the 6-pin connector as shown below.



Lights

The Thor300 has 4 pin JST GH ports for 3 LEDs (Status, Front, and Back), driven by a 12V DC-DC converter capable of 5A. The Indy Speed Control wiring harness has a 3 pin JST GH connector on each end of the cable, which does not match the 4 pins on the front LEDs. Fortunately, the rear LED only needs 3 wires: 12V, Ground and DIN since it's the end of the LED chain (below, left).



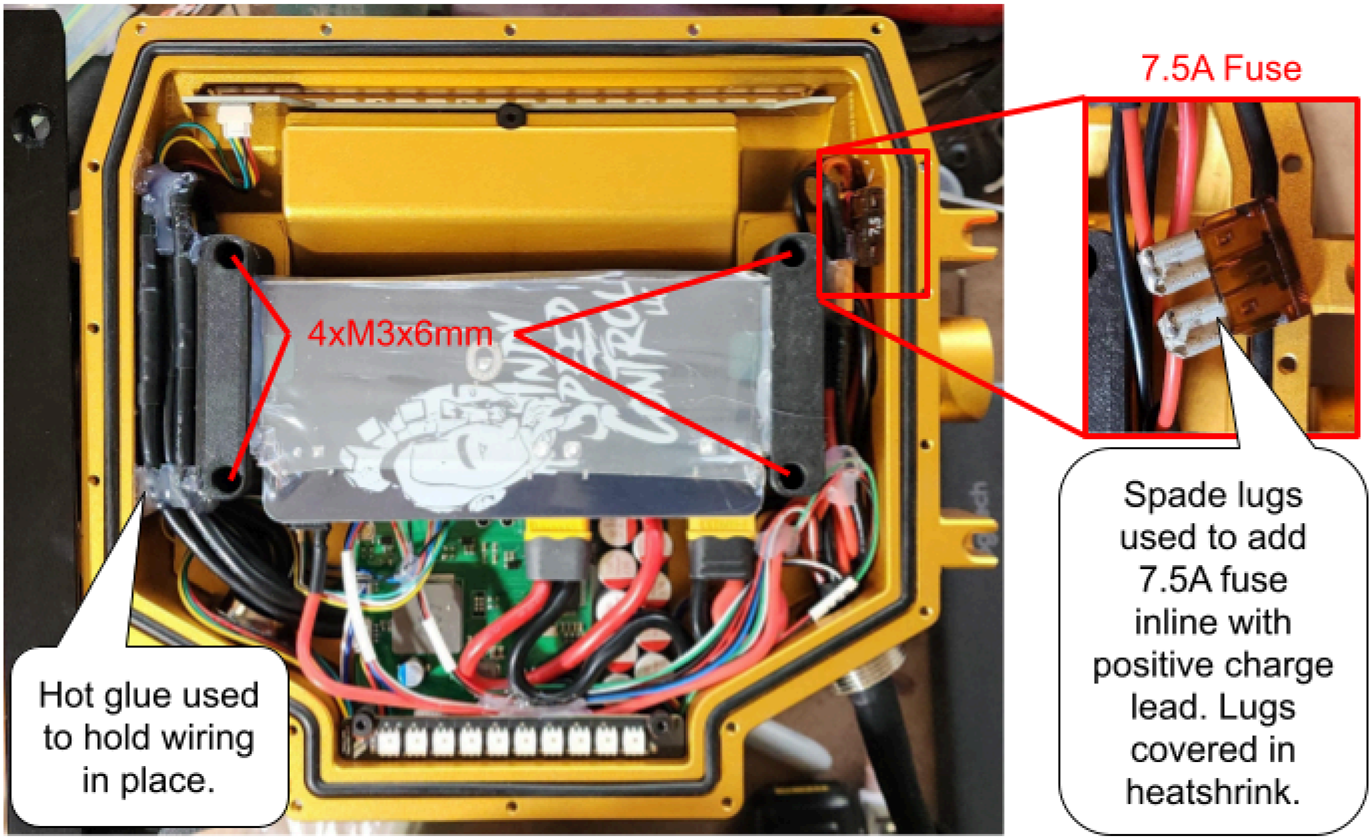


The rear LED bar is not included with the Thor300 controller box kit, but I was able to get one from Fungineers. Note the order of the pins for the rear LED bar. Mine were in reverse order from the front and status LED bars (above, right). The rear Fungineers LED strip had 18 RGB LEDs and worked as soon as it was connected properly without any software configuration. I needed to remove some ridges in the TORque Box to make my rear LED bar fit, using a Dremel tool. Once the LED bar fit without plastic rubbing on any of the components, I hot-glued it in place.

You can also get a 12V WS2815 LED strip from Amazon, cut it to size and solder the 12V, Gnd and DIN pins as shown above.

Controller Box Assembly

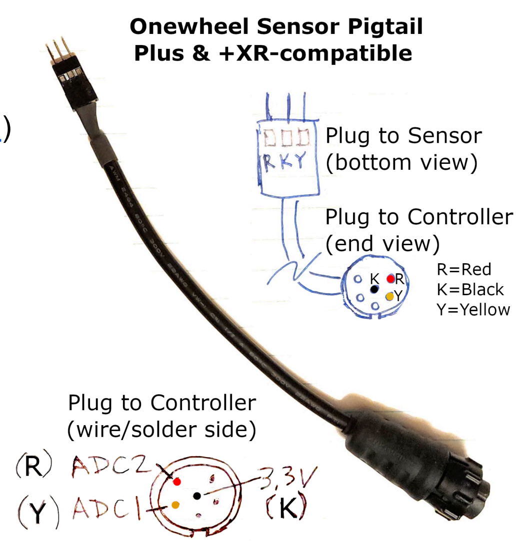
Most fast chargers don’t go over 6A, so I added a 7.5A blade-style fuse to the positive lead of the charge port to protect the battery if the pins in the charge port are shorted.



Footpads

The Fungineers complete controller box includes an XR-style footpad port, but may need a longer cable than comes with the XR footpad pigtail. If making your own footpad pigtail, you'll need the following parts or equivalent:

- Switchcraft EN3P6MX plug (Digikey)
- 3- pin sensor plug, AKA servo plug (30 set kit on Amazon)
- Sensor pigtail wire - 22AWG 3-conductor (25FT on Amazon)



Charger

I used an 84V EUC charger with a GX16-2P plug soldered onto the end. Before connecting the fused charge port to the battery, I plugged the charger into the charge port and confirmed that it had the correct polarity using a multimeter.

Android VESC Tool (mobile app v6.02 → v6.05)

The Thor300 has a VESC express on it, which is a VESC chip that provides WiFi and Bluetooth. The VESC Express in turn connects to the main controller via CAN bus. My Thor300 came with firmware 6.02 installed, and Fungineers recommends upgrading both the VESC Express and controller firmware to version 6.05.

UPGRADE AT YOUR OWN RISK. Before upgrading to 6.05, please read and understand the warnings on pev.dev. Firmware 6.05 offers some new features, but also has some bugs that cause your settings to reset to defaults, or worse. Make sure to back up your settings as soon as you get a working configuration, because you might need that backup mid-ride, as has happened to me.

I suggest that all new VESC builders watch (but not follow) Mario Contino's video VESC One Wheel Full Setup | Firmware 6.02 & Float Package to understand the entire process.

To set up the Thor300, follow the Complete Controller Box instructions linked from the Fungineers User Guides page.

Setup Reference

You may find the VESC Tool Config Helper useful in determining optimal settings. I also took some cues from Mario Contino's VESC One Wheel Full Setup video. My settings are shown below, but you should always do your own motor and IMU config, because even the same hardware has slight variations.

Battery Cell Series (20s2p battery pack): 20
Capacity for P45B: 9Ah (see FAQ - Battery on pev.dev for other battery configurations)
Wheel Diameter (Maxxis 11x6.5-6 treaded): 285mm

Always tap Read before changing values (due to FW 6.05 bug) and tap Write after changing values before going to the next tab.

Motor Cfg → General, General
- Invert Motor Direction = Only if motor runs in reverse

Motor Cfg → General, BMS
- BMS Type = VESC BMS (ennoid xlite v4)

Motor Cfg → General, Current
- Motor Current Max = 180A
- Motor Current Max Brake = -180A
- Absolute Max Current = 270A
- Battery Current Max = 90A
- Battery Current Max Regen = -72A

Motor Cfg → General, Voltage
- Battery Voltage Cutoff Start = 54V* (or should I use 2.3V x 20 = 46V)
- Battery Voltage Cutoff End = 50V* (or should I use 2V x 20 = 40V)

*Recommended by VESC Tool Config Helper

Motor Cfg → General, Temperature (Activates Pushback for Overtemps):
- MOSFET Temp Cutoff Start = 75C
- MOSFET Temp Cutoff End = 85C
- Motor Temp Cutoff Start = 75C

- Motor Temp Cutoff End = 85C

Motor Config → Additional Info, Setup

- Motor Poles: 30
- Gear Ratio: 1.00
- Wheel Diameter: 285.00 mm (measured)
- Battery Type: BATTERY_TYPE_LIION_3_0__4_2
- Battery Cells Series: 20
- Battery Capacity: 9Ah

Motor Config → FOC → General

- Motor Resistance: 49.8 (39.8 detected x 1.25, improved performance)
- Motor Inductance: 136.75 (detected)
- Observer Gain: 0.78 (1.55 detected x 0.5)

Motor Config → FOC → Hall Sensors

- Sensorless ERPM: 1500
- Hall Interpolation ERPM: 250

Motor Config → FOC → Field Weakening

- Field Weakening Current Max: 67.5 A
- Field Weakening Duty Start: 65.0%

Motor Config → FOC → Advanced

- Zero Vector Frequency: 27.0kHz detected (Weird “lightsaber” motor noises? Adjust +/- between 25-30 until it goes away.)

Pushback (formerly called Tiltback in VESC settings)

High Voltage Pushback is set by default to 200V, Low Voltage Tiltback at 0V. This means no tiltback whatsoever, so you have to configure this setting for your battery. Based on the information provided on pev.dev, for an 20s2p 21700 battery pack (84V):

Refloat Cfg → Specs, Voltage Pushbacks

- High Voltage Threshold = 20 x 4.3 = 86V (going downhill, prevents overcharge)
- Low Voltage Threshold = 20 x 3 = 60V (low battery)

I left the angle and speed at their default settings. Don’t forget to tap the **Write** button after changing the settings. Note that hitting the high voltage tiltback threshold may result in scary tail drags when going downhill at 100% battery, but it prevents you from overcharging and damaging your battery.

Re-running Motor Calibration

If you change your motor or swap out the rim/magnets, then be sure to first disable Refloat Package before re-running motor setup.

Refloat Cfg → Specs, Refloat Package Details

- Disable Package (disabled = right)

Re-enable after running motor setup (enabled = left).

IMU Setup

The IMU calibration is covered in several videos, but if you prefer text instructions, they can be found in Nico Aleman's IMU Calibration Wizard Guide on pev.dev. My IMU sample rate was detected as 1000 Hz, so I had to manually change it to 832 Hz for the Thor300 as follows:

App Cfg → IMU

- Sample Rate = 832 Hz

Re-running IMU Calibration

If your IMU calibration is working and you simply want to adjust for rail angle/pitch to raise or lower the nose, then you do not need to read default settings, and only need to redo the **Orientation Calibration** (under **Setup → Setup IMU**).

If your IMU calibration isn't great (e.g. Magic Flywheel mode doesn't balance), first backup your settings, then go into **App Cfg**, click the **[...]** in the lower right, tap **Read Default Settings**, then **Write** before recalibrating the gyroscope or accelerometer. Otherwise, subsequent IMU calibrations result in weird behavior like nose too high or too low, and sluggish response to tilt changes.

Conclusion and Build Photos

This build (see right, top) is an incremental improvement over my Little FOCer 3.1, Hypercore, 18s2p 50s (right, bottom), with what feels like about 20% more power to climb hills and keep the nose from dipping.

The range is almost identical between the 18s2p 50s and the 20s2p P45B packs, but the P45B pack is better at keeping the nose from dipping in high demand/low voltage situations, with less sag than the 50s pack, and it performs better in cold weather.

In addition, while the Hypercore+50s combination was mind-blowing in its ability to climb steep hills, I've been able to get up even steeper technical sections with the Superflux+P45B that were never possible without the Hypercore stalling, overheating, or both.

The other improvement of this build is that it has both headlights and taillights, something I never completed with the Little FOCer.