



A maker's intro to (e)bikes

Mark Batty then Simon Cooksey

What we'll talk about

Mark: What is a bike and how do I make one?

Simon: A technical primer on ebike batteries, motors and controllers.

“Bikes”



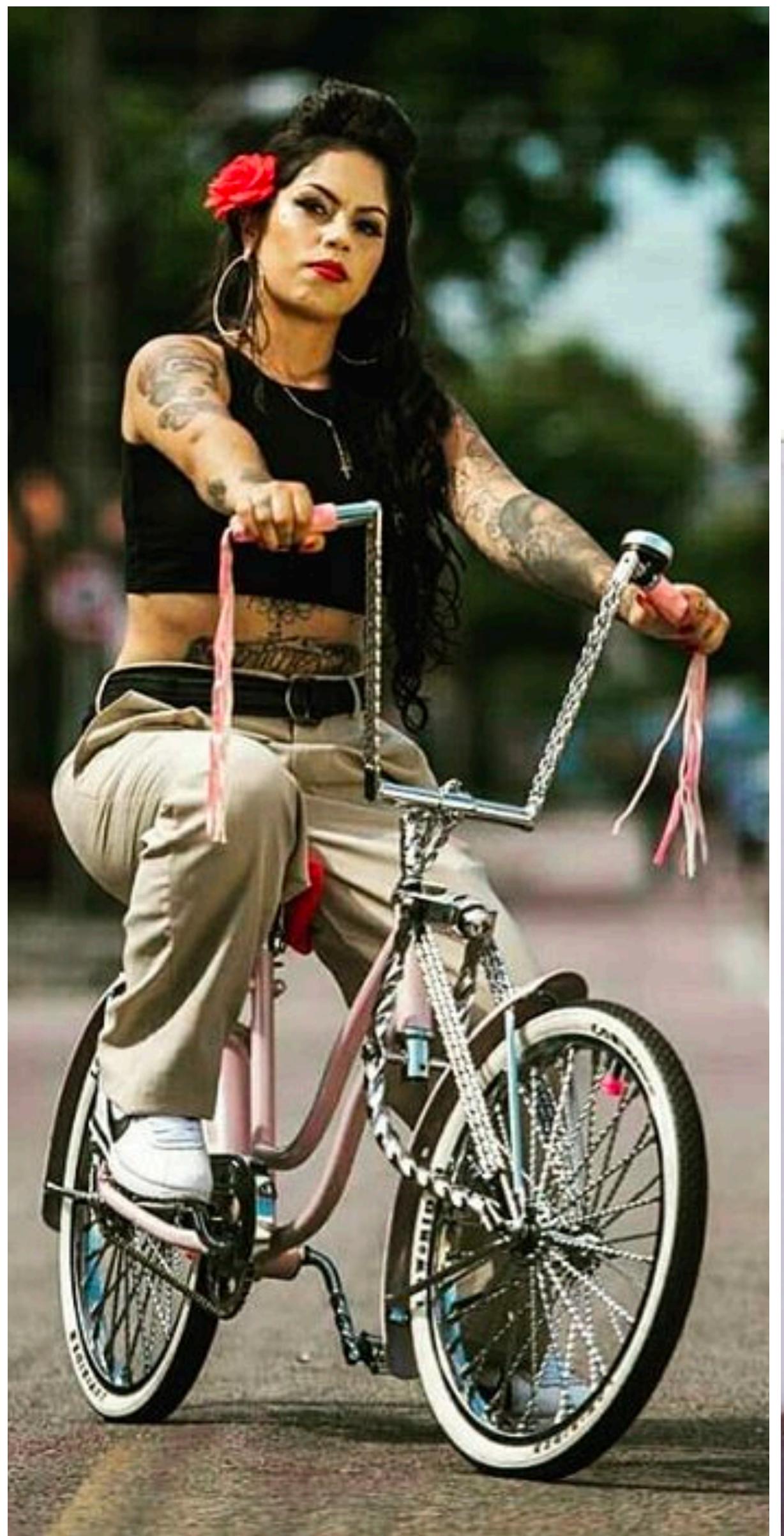
Geometries



Cargo bikes



Subcultures





Velocars



Velomobiles and streamliners



Experiments



Outlaws





Bikes in UK law (approx!)

Legal on road and cycle paths without registration, license or insurance.

- Have pedals, wheels and 2 brakes: one for all front wheels, one for all rear.
- Need lights and reflectors at night.
- Motor must be labeled $\leq 250\text{w}$, only driven while pedalling, and only up to 15.5mph.

<https://www.cyclinguk.org/cyclists-library/regulations/eapc-regulations>

Future transport

Cycling infrastructure improving.

A shift from car to (e)bike is a colossal net safety win, regardless of helmet use.



Govt consulting on ebikes and e-scooters.

Makers should be heard – respond here! (closes 22nd May)

<https://www.gov.uk/government/consultations/future-of-transport-regulatory-review-call-for-evidence-on-micromobility-vehicles-flexible-bus-services-and-mobility-as-a-service>





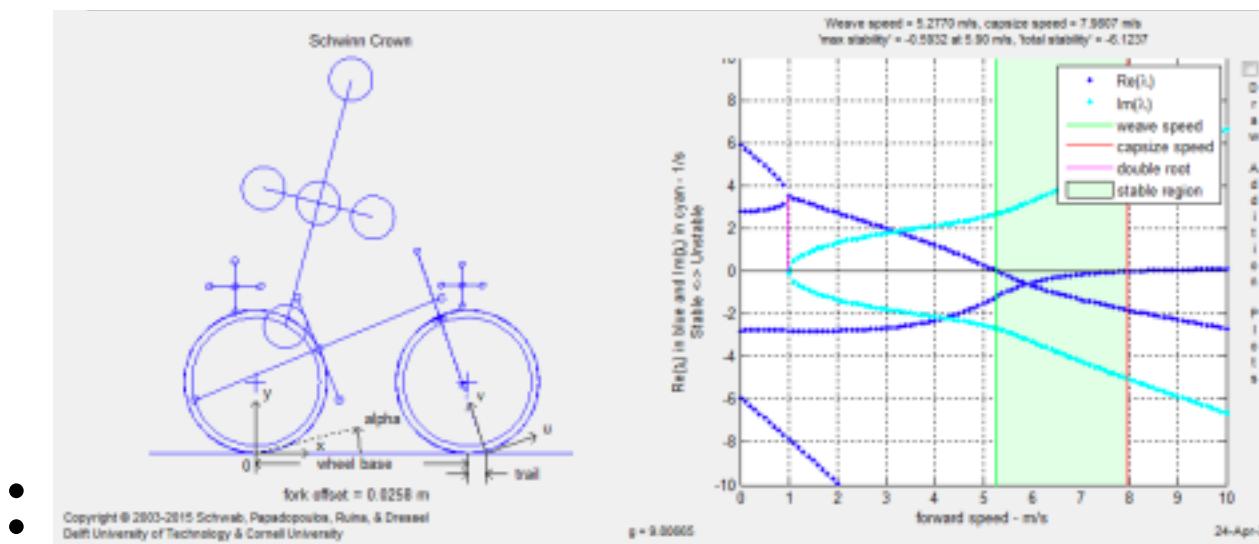
How do I make one?

Sheldon Brown is survived by his incredible bicycle maintenance site:
<https://www.sheldonbrown.com/>

Weird geometries can be unrideable.

Check stability with jbike6 in Matlab:

http://ruina.tam.cornell.edu/research/topics/bicycle_mechanics/JBike6_web_folder/index.htm



This calculator helps gear brushed motors or small wheels:

<http://www.gear-calculator.com/>

Maker strategy

First ebike? find bike – add motor.

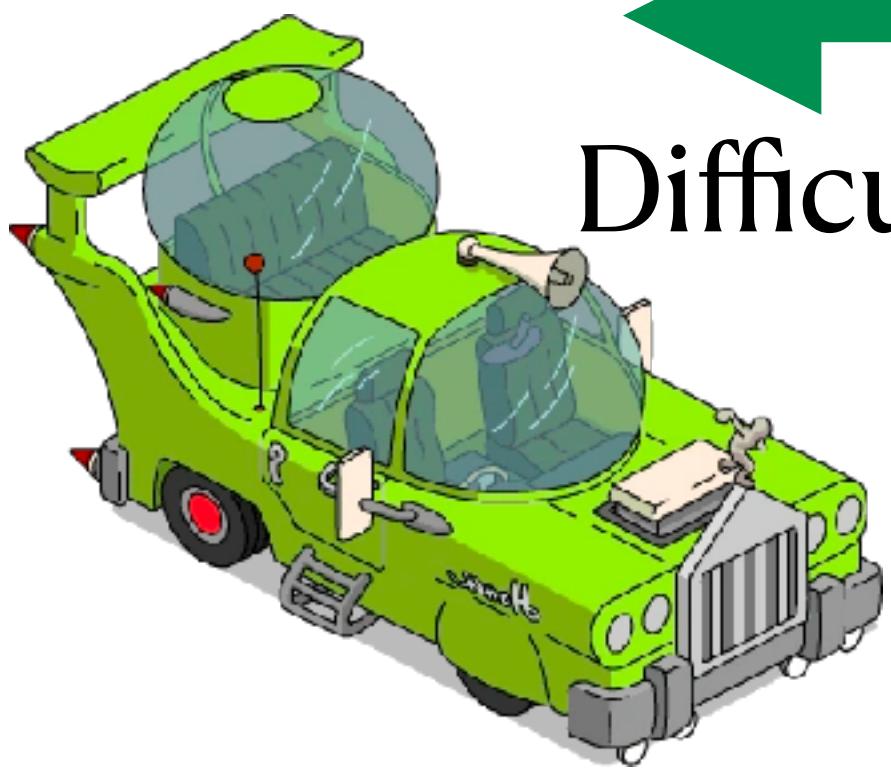
Parts are fairly cheap and attainable.

Suggest width: $\leq 850\text{mm}$. (measure **your** route!)

Weird
Difficult

Conventional

Easy



Dan: +motor, +battery, +light

Simon: +motor, +battery

Mark: +battery, +bucket



2nd bike:
velocar with
plywood body?



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3 components

Battery

Controlle

Motor



Battery setup

Building a custom battery pack

Choosing a size & configuration

Buying cells

Welding cells



Understanding Specs

- Most ebike batteries are made with 18650 cells.
- 18650 is a size, like AA.
- Cell capacity is measured in Ah
- A typical 18650 might be 2.75 Ah
- I used 2.9Ah Samsung 29E cells
 - (\$1.99 ea, \$1.89 in volume)
 - I buy mine from endless-sphere



Battery theory

- Capacity: Amp hours (Ah)
- Energy (Wh) = Capacity (Ah) * Voltage (v)
- 1000 Wh is the energy consumed by a 1000W load in 1 hour.
- Series rating (e.g. 6S) is the number of series cells in a pack
- Parallel rating (e.g. 4P) is the number of paralleled batteries in a pack
- I have a 13S7P battery pack
- 13 cells in series * 7 batteries in parallel (91 total cells)
- At 2.9Ah capacity per cell we can calculate the energy in the pack

$$2.9 \text{ Ah} \times 13 \times 7 \times 4.2 \text{ v} = 1108 \text{ Wh}$$

Battery technology

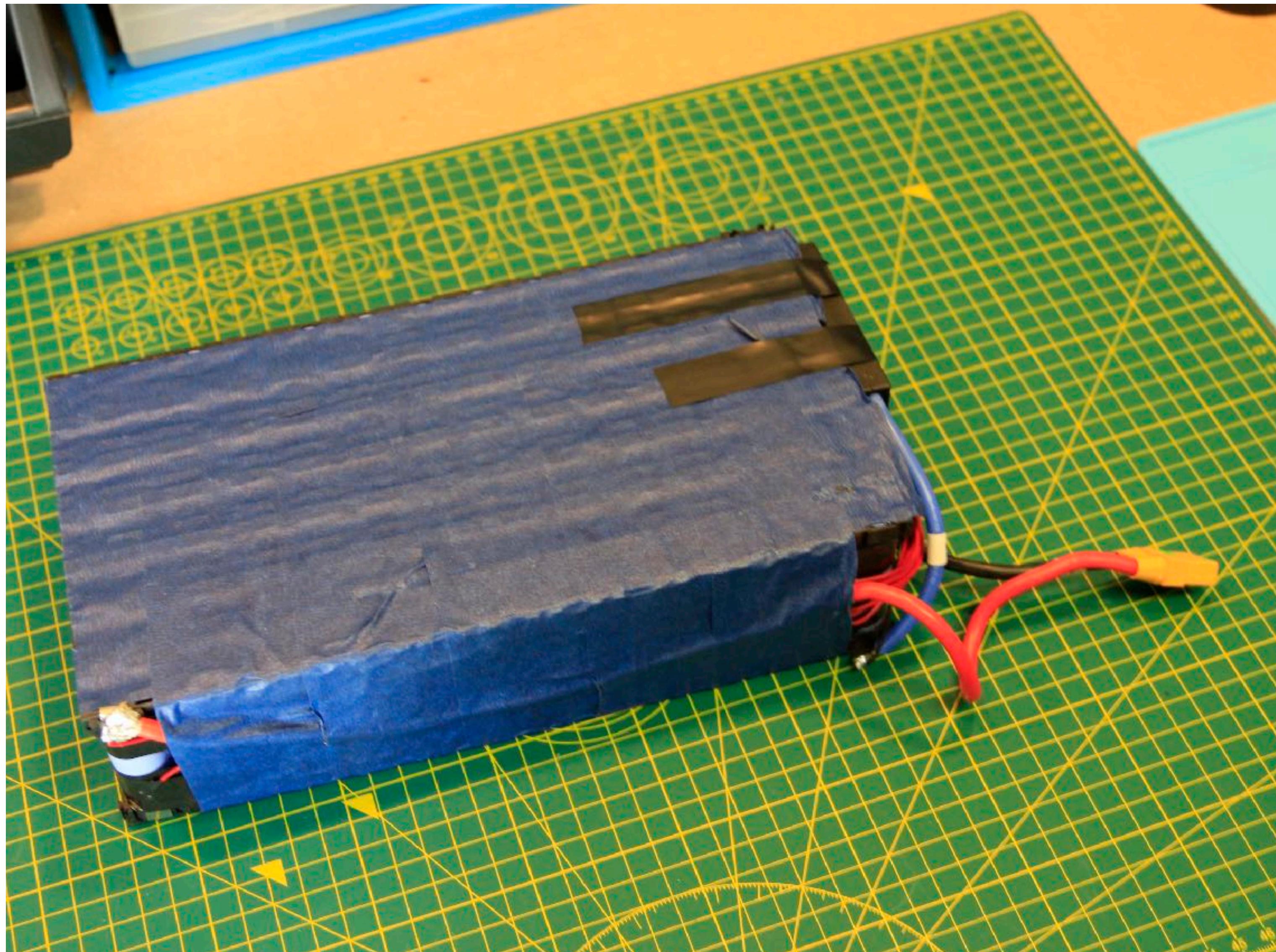
- LiPo
 - RC plane and drone batteries
 - Come in a variety of sizes and configurations
 - Higher voltage batteries can be harder to obtain
 - High cost (£0.38 /Wh)
- Li-Ion
 - Very common
 - Available commercially, and for DIY
 - Can be low cost (£0.13 /Wh DIY; £0.61 /Wh commercial)
- Lead Acid
 - Cheap entry
 - Disappointing performance
 - Low cost (£0.20 /Wh)

Commercial

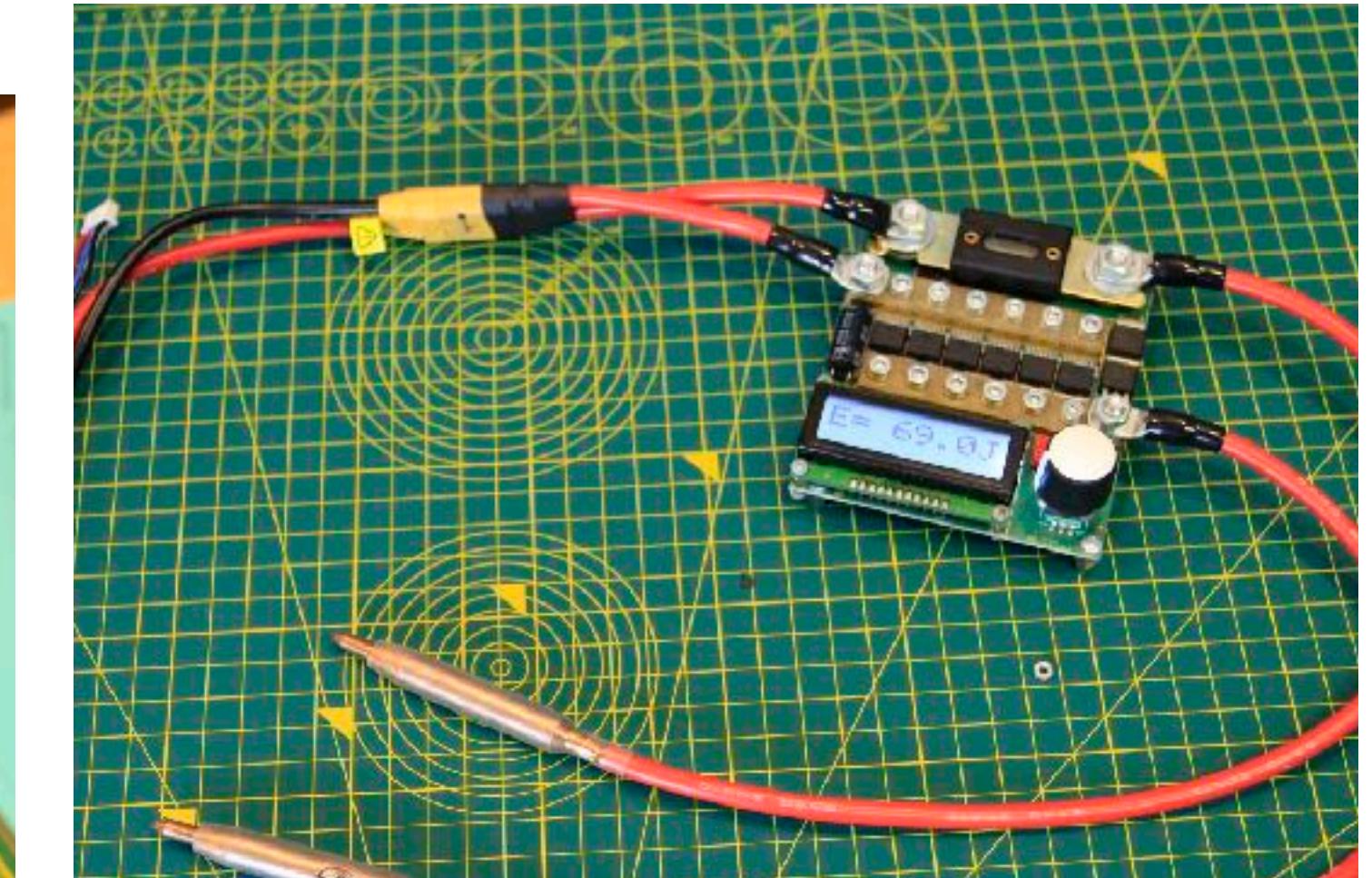
Li-Ion

DIY





Completed battery pack with BMS. 13S7P
(54.6 v, 20 Ah, 1108 Wh)



Battery spot welder



Some 29E 18650 cells

Motors

Current, torque, power



Bottom
Bracket
Drive



Brushed
DC Motor

Motor trade off

- Brushed DC
 - Very cheap, controller and motor
 - Simple wiring
 - Lower torque, really needs gearing
 - Loud
- Brushless hub motor
 - Can be cheap
 - Quiet - depending on the controller
 - Very heavy wheels, can lead to a strange feeling bike
- Bottom bracket motor
 - Expensive
 - Quiet - depending on the controller
 - Lightweight, leaves bike dynamics very similar



Motor Current

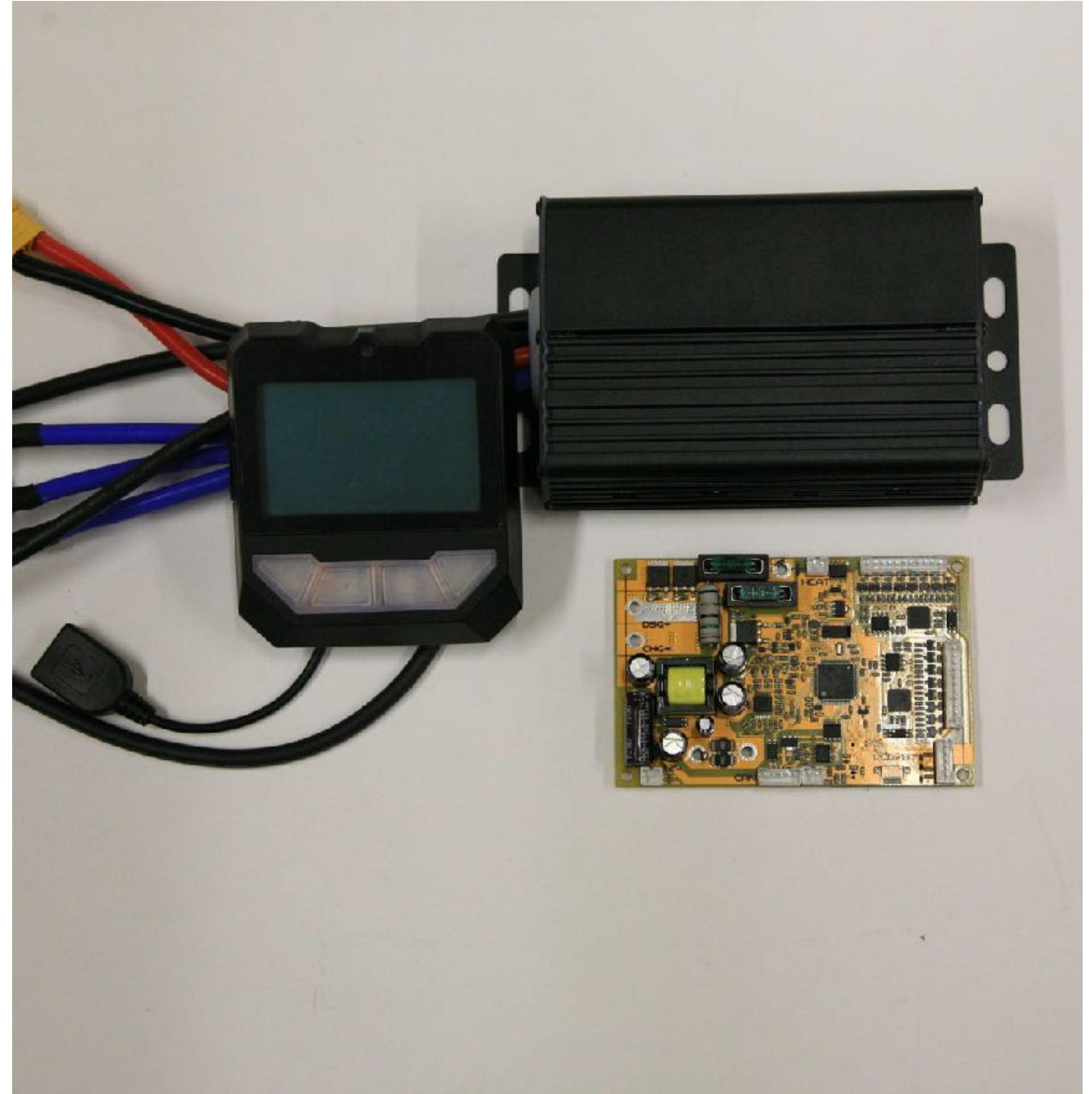
- Power = Current * Voltage
- A 1000W motor will draw about 20A at 48V
- This is important when building a battery pack: lithium cells have a maximum current rating, and deliver less energy when run close to their limit.
- Samsung 29E cells are rated for 8A peak discharge, 2.75A continuous.
- A 13S1P pack will be the right voltage for such a motor, but 20A demand will greatly exceed the current rating of the battery



Controllers

**Controllers do power and speed
limiting**

Different types of controller exist



Brushless Motor Controller options

- Trapezoidal control
 - Common in normal ebike controllers
 - Loud "coil whine" from motor
 - Pretty efficient
 - Very cheap
- Sine control
 - More efficient, quieter operation
 - Drives motor windings with sine-wave signal
 - More expensive
- Field oriented control (FOC)
 - Silent operation
 - No more efficient than sine control
 - Measures coil reactance rather than using hall sensors
 - The most expensive

Resources

- Sheldon Brown's bicycle technical info: www.sheldonbrown.com
 - Technical information about bike setup
 - Wheels, gears, brakes...
- Endless Sphere ebike forum: www.endless-sphere.com
 - Ebike discussion forum and market place for genuine 18650 cells
 - Lots of technical information about controllers, batteries, and motors
- Keen Lab: www.keenlab.de
 - High quality battery spot welder
 - Simon has one available to loan out to local makers

Links

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