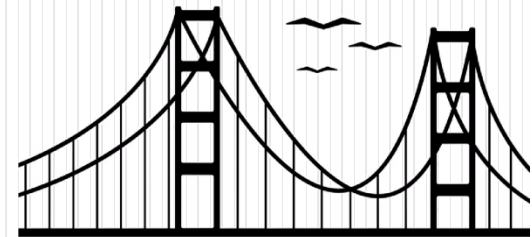


Second-Life LiFePO4 E-Bike Battery Pack Rebuild



Presented by

Marcel Stieber
AI6MS



Presented at BayCon 2021

Virtual Conference – Saturday, February 6th, 2021

Who is this guy?

- Marcel Stieber, AI6MS
- Licensed in 2008 as KI6QDJ
- Master's in Electrical Engineering
- Cal Poly Amateur Radio Club
- Cupertino ARES Repeater Trustee
- Salinas Valley Repeater Group
- Designs battery and charging systems for consumer electronics products
- Slides and video available at:
 - www.qrz.com/db/ai6ms
 - <https://twitter.com/ai6ms>
 - <https://www.youtube.com/marcelstieber>



Overview

In this presentation, we'll be converting a used lithium iron phosphate (LFP or LiFePO4) e-bike battery into a 12V amateur radio friendly battery pack!

- Background and Debug
- Rewiring the Pack
- Peripheral Modifications
- Final Testing



- For more background info on Lithium Batteries for Amateur Radio:
 - 30 min: <https://www.youtube.com/watch?v=5s360uIOM7w> (Slides)
 - 63 min: <https://www.youtube.com/watch?v=KsBRXei7M04> (Slides)

SAFETY FIRST

- Batteries are inherently dangerous!
- This presentation is by no means designed to qualify anyone to perform any of the tasks presented in the following slides.
- Anyone undertaking a battery project should only do so with proper training and procedures.
- The author/presenter hereby takes zero liability for any actions that you may undertake as a results of the material presented herein.

**LITHIUM ION
BATTERIES -
FORBIDDEN FOR
TRANSPORT ABOARD
PASSENGER AIRCRAFT**



Battery Reuse!

- Used Electric Vehicle Batteries
 - Typical end-of-life around 70-80% capacity
 - Increased internal resistance => lower ampacity
 - Perfectly usable for amateur radio!
- E-Bike Batteries are typically higher voltage (>30V)
 - In this case, they are specifically LFP chemistry



What fails?

- Packs often stop working for a number of reasons:
 - Failed BMS
 - Cell Over- or Under-Voltage Protection (OVP/UVP)
 - Blown fuse
 - Physical damage

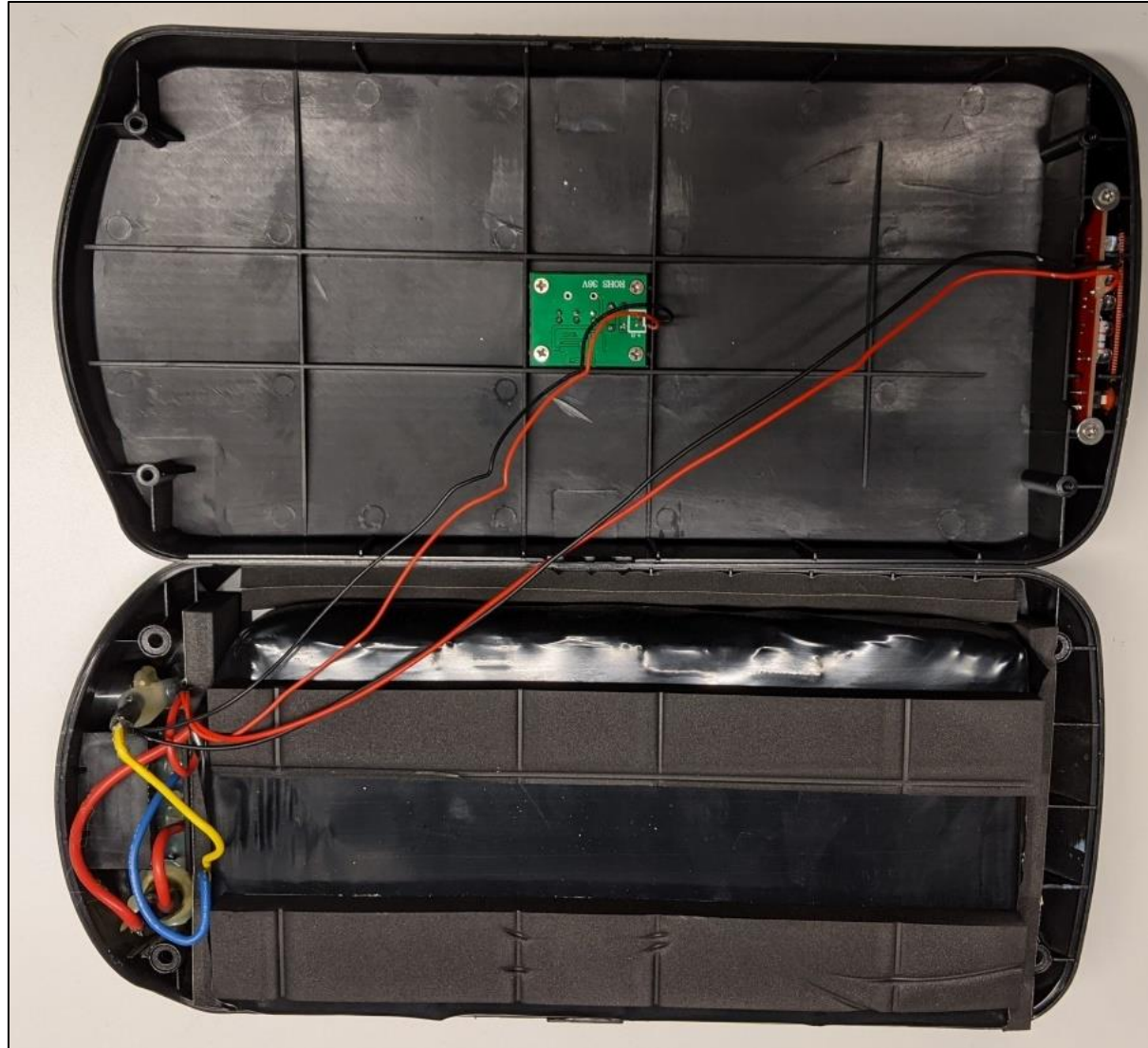
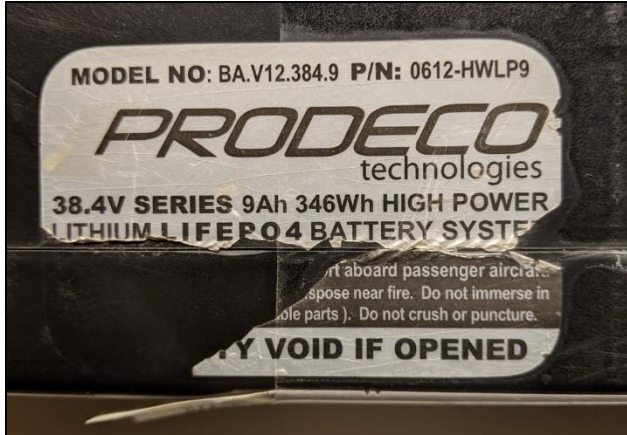


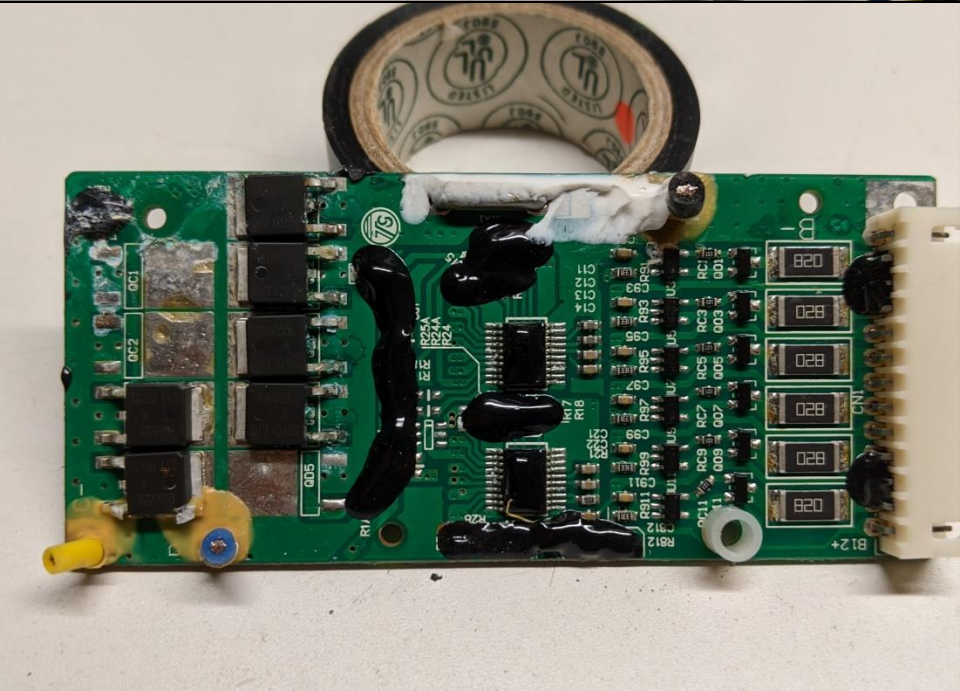
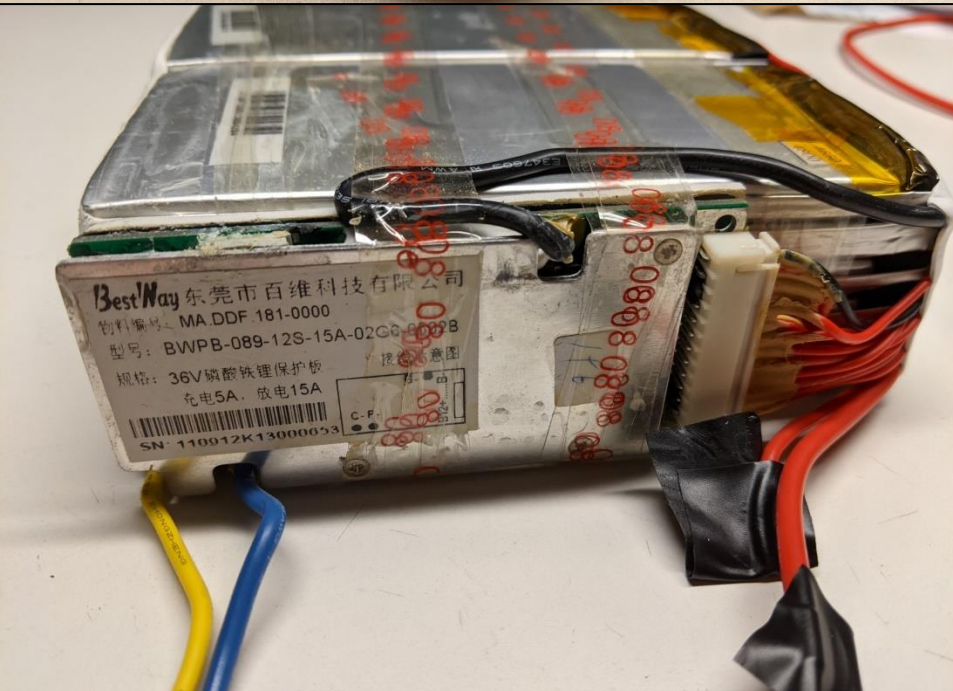
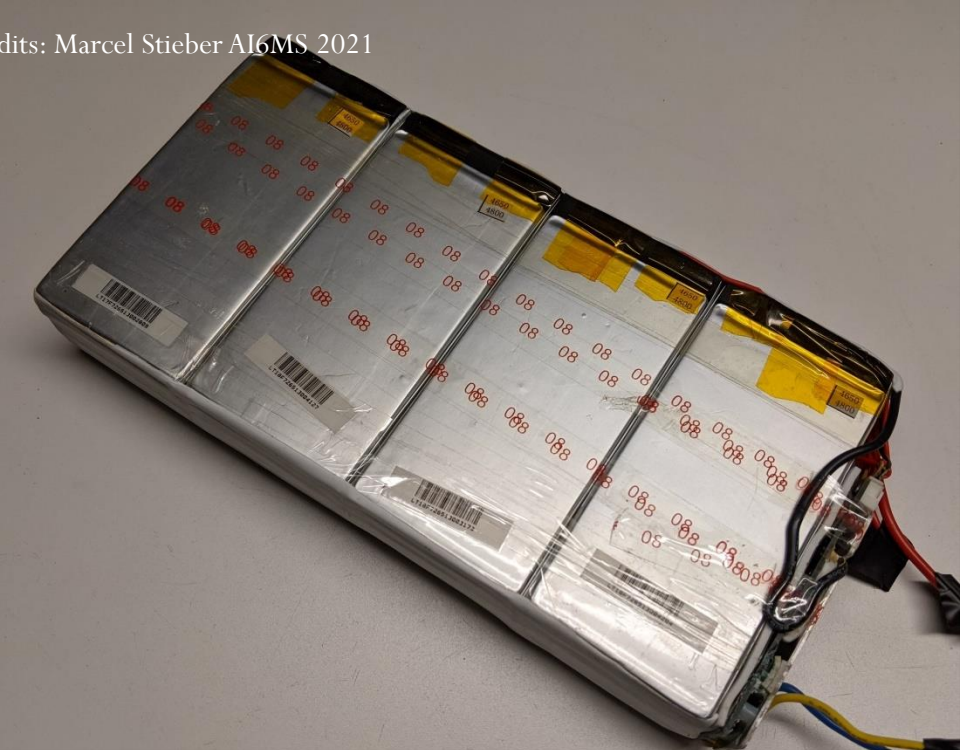
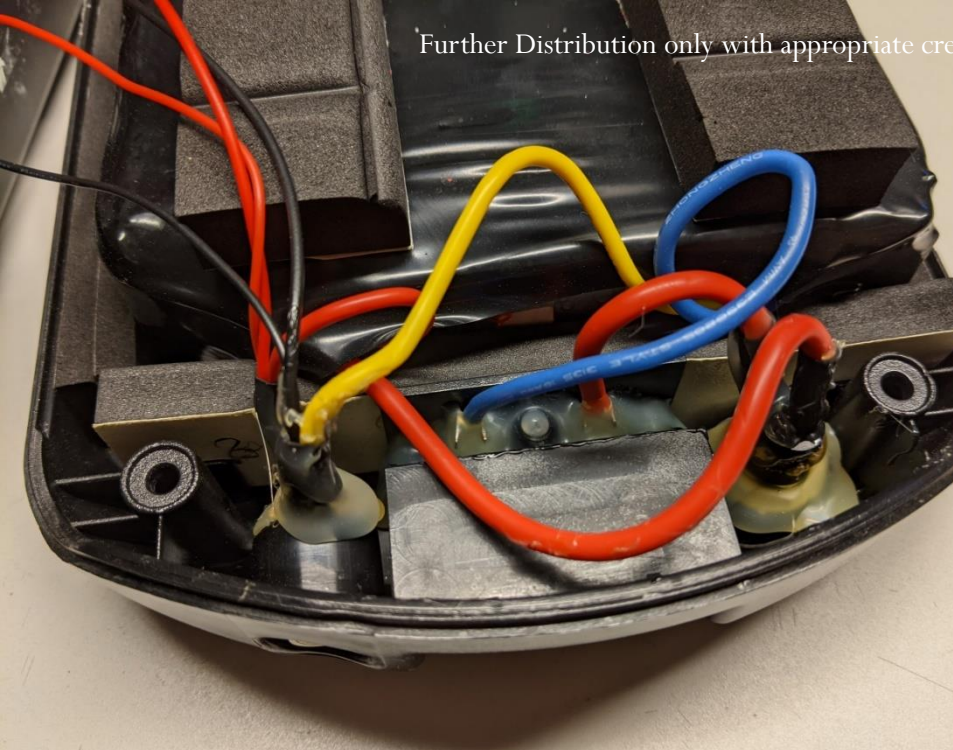
Inspect and Decide!

- Check Voltage
- Capacity Test
- BMS function
- Fuse
- Age
- Usage
- Storage
- Damage?



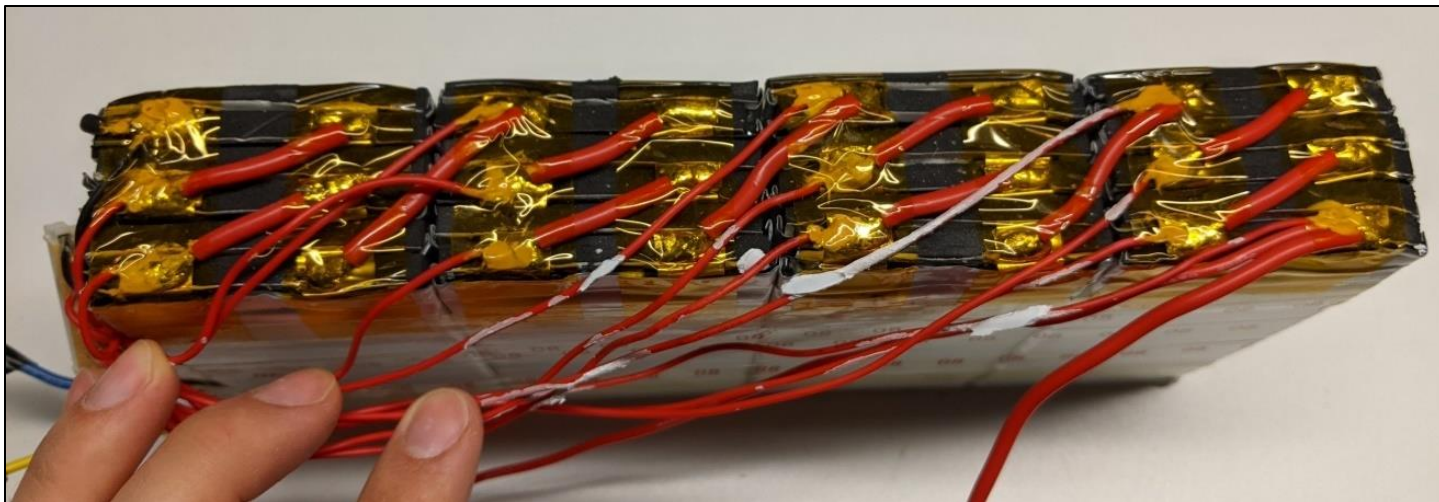
Open it up!



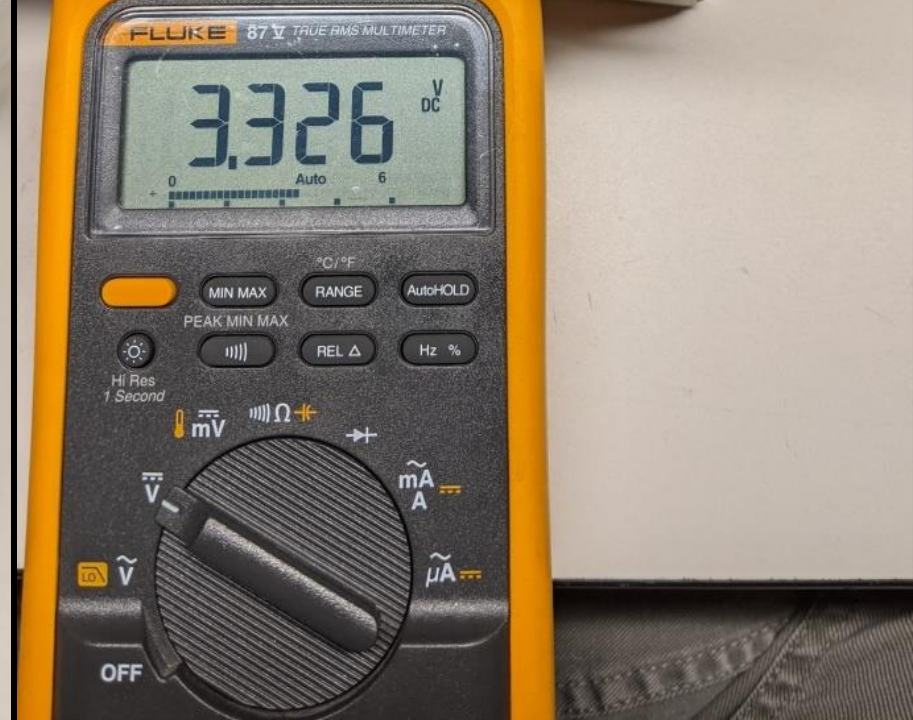
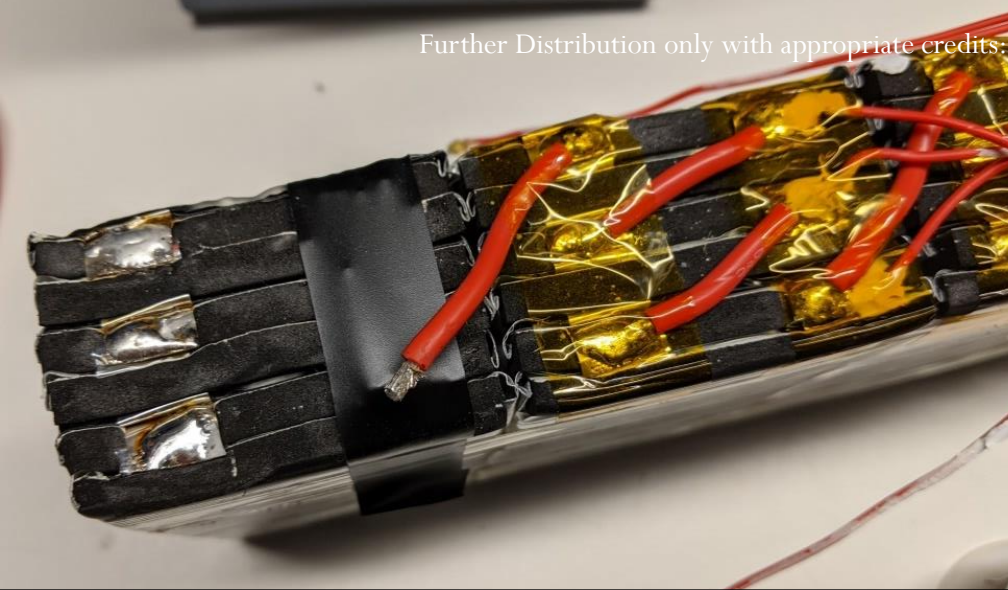


Background

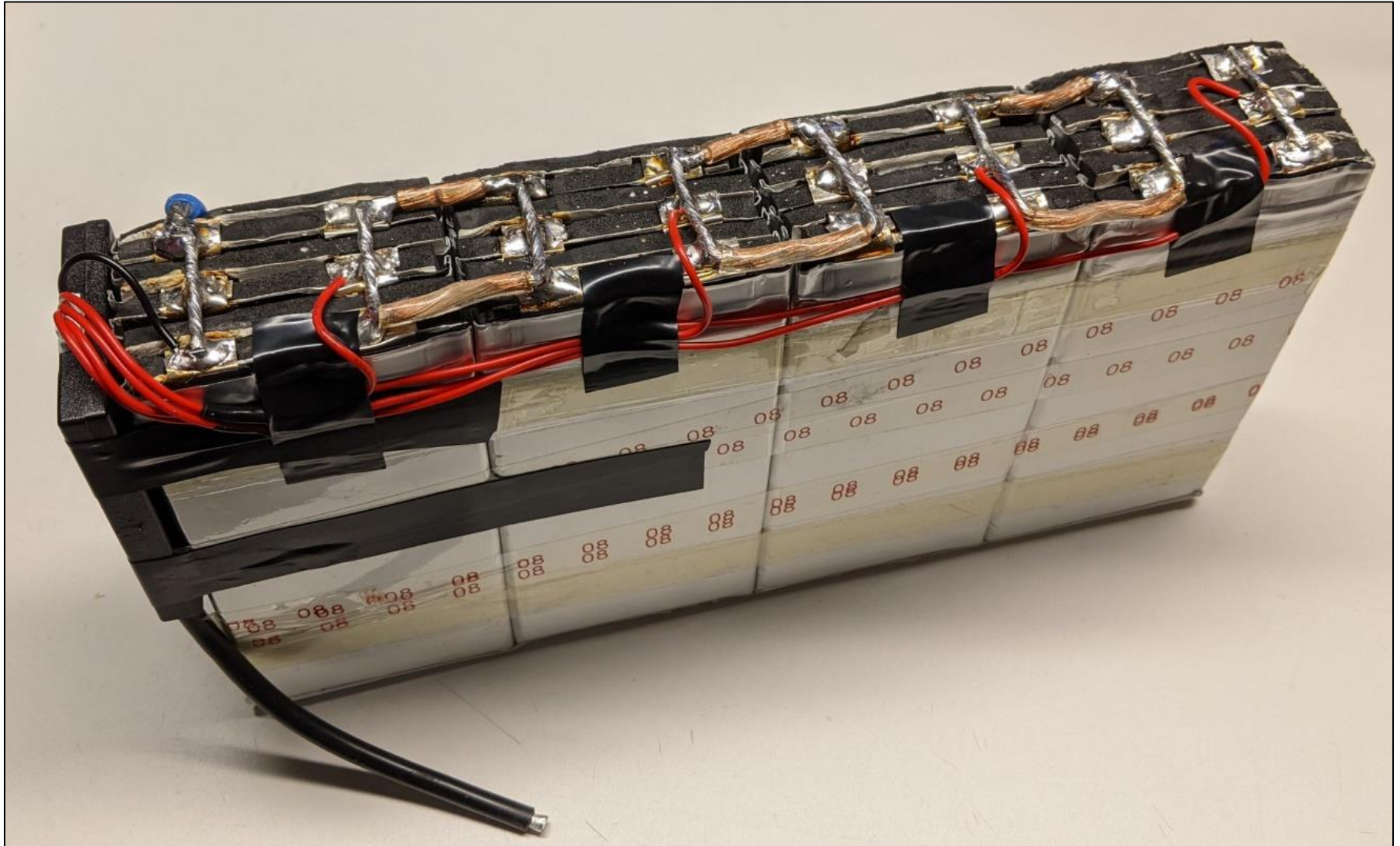
- This particular battery is a Prodeco Technologies
 - 38.4V 9Ahr 346Wh LiFePO₄ Battery
 - 12s2p battery
 - 24 individual pouch cells, 3.2V nominal
- For 12VDC amateur radio use we need 4s6p
 - $4 \times 3.2V = 12.8VDC$ nominal







Rewiring complete!



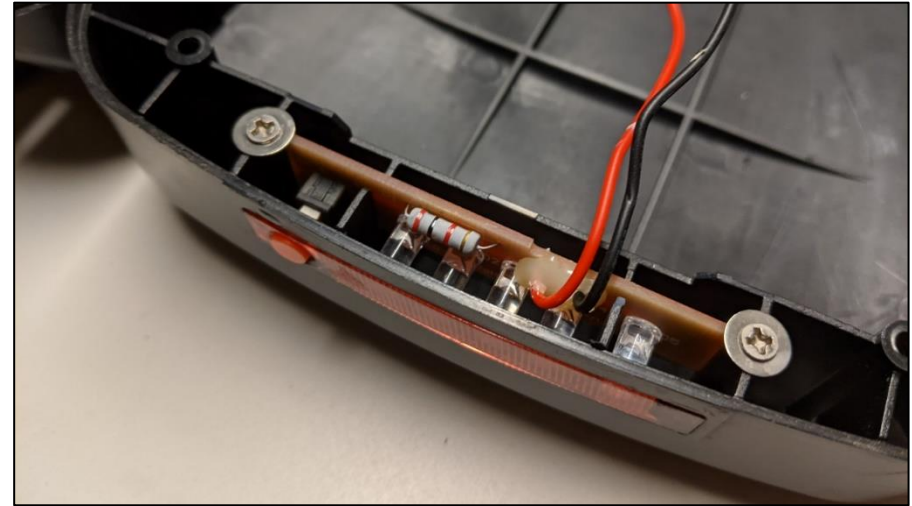
Battery Management System

- Absolutely required!
- Daly BMS 4S LiFePO4
 - 20A - \$12, 60A - \$24
- Daly Smart BMS 4S LiFePO4
 - Bluetooth, settings, configuration
 - 60A - \$48, Bluetooth - \$12
- Ideally size the BMS to the cells
 - Or oversize a Smart BMS and adjust settings for your cells
- Or cheaper no-name options?!



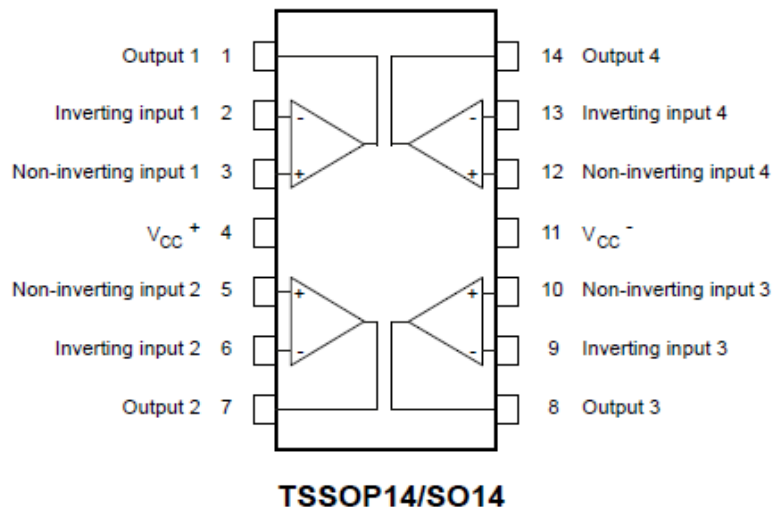
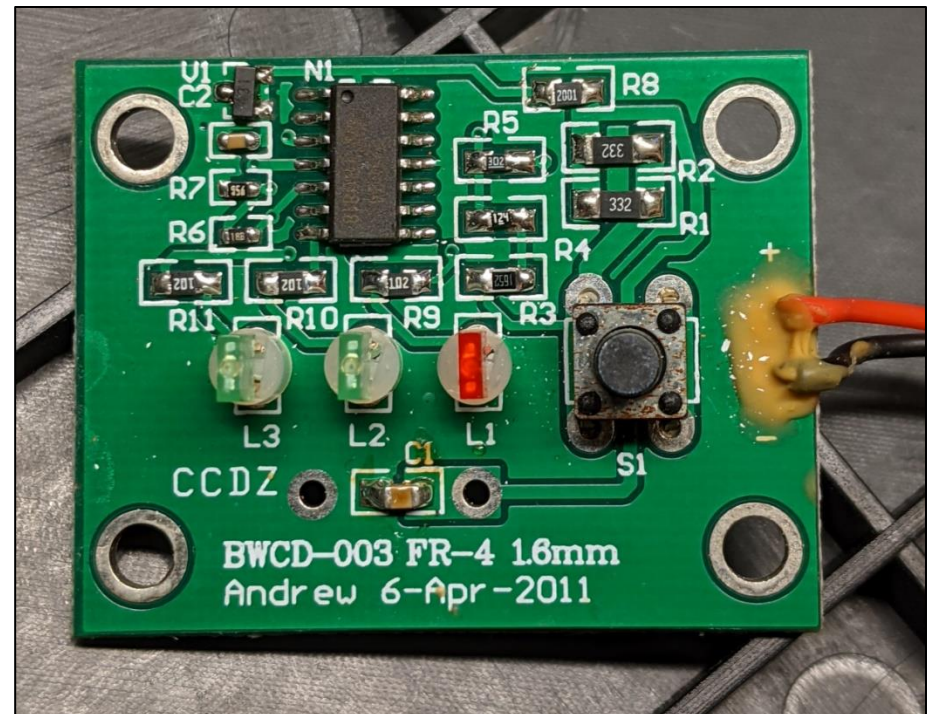
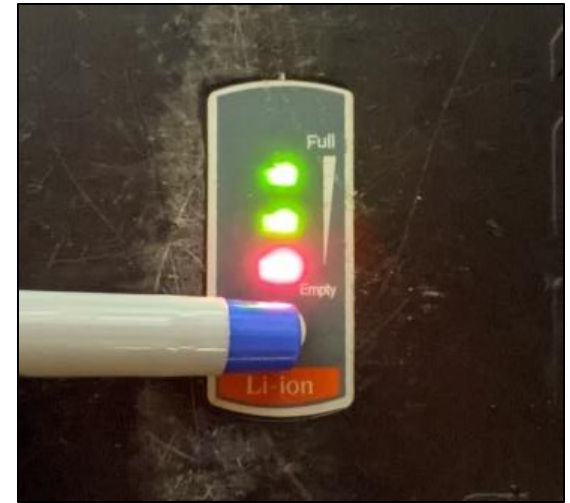
Red LED Tail Light

- Designed for $\sim 40\text{V}$, 15mA
 - $R1 = 2\text{k}\Omega$ (0.45W)
- Redesign for $\sim 15\text{V}$, 15mA
 - $R1 = 333\Omega$ (0.075W)



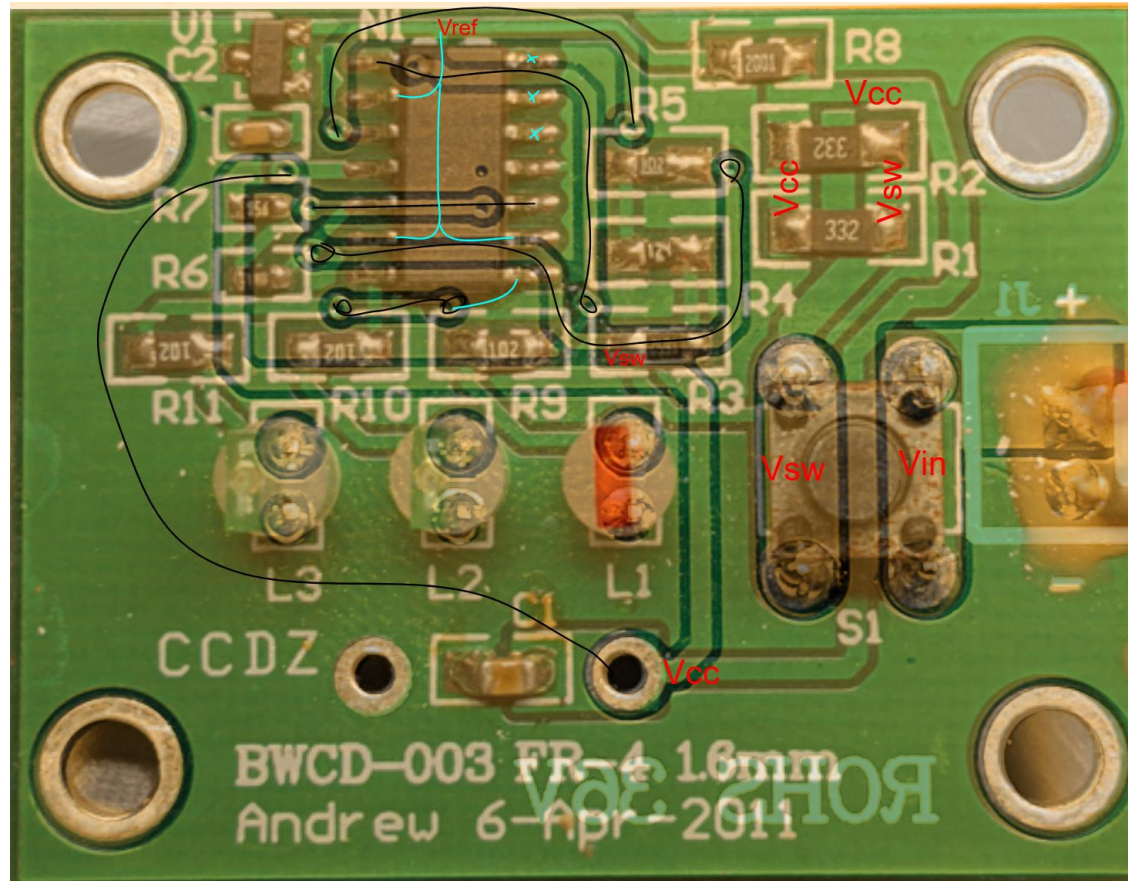
Capacity Meter

- 3-LED Voltage Meter
- ST LM324 Quad Op Amp
- Operating range: 27-41V
- How to adjust this one?!

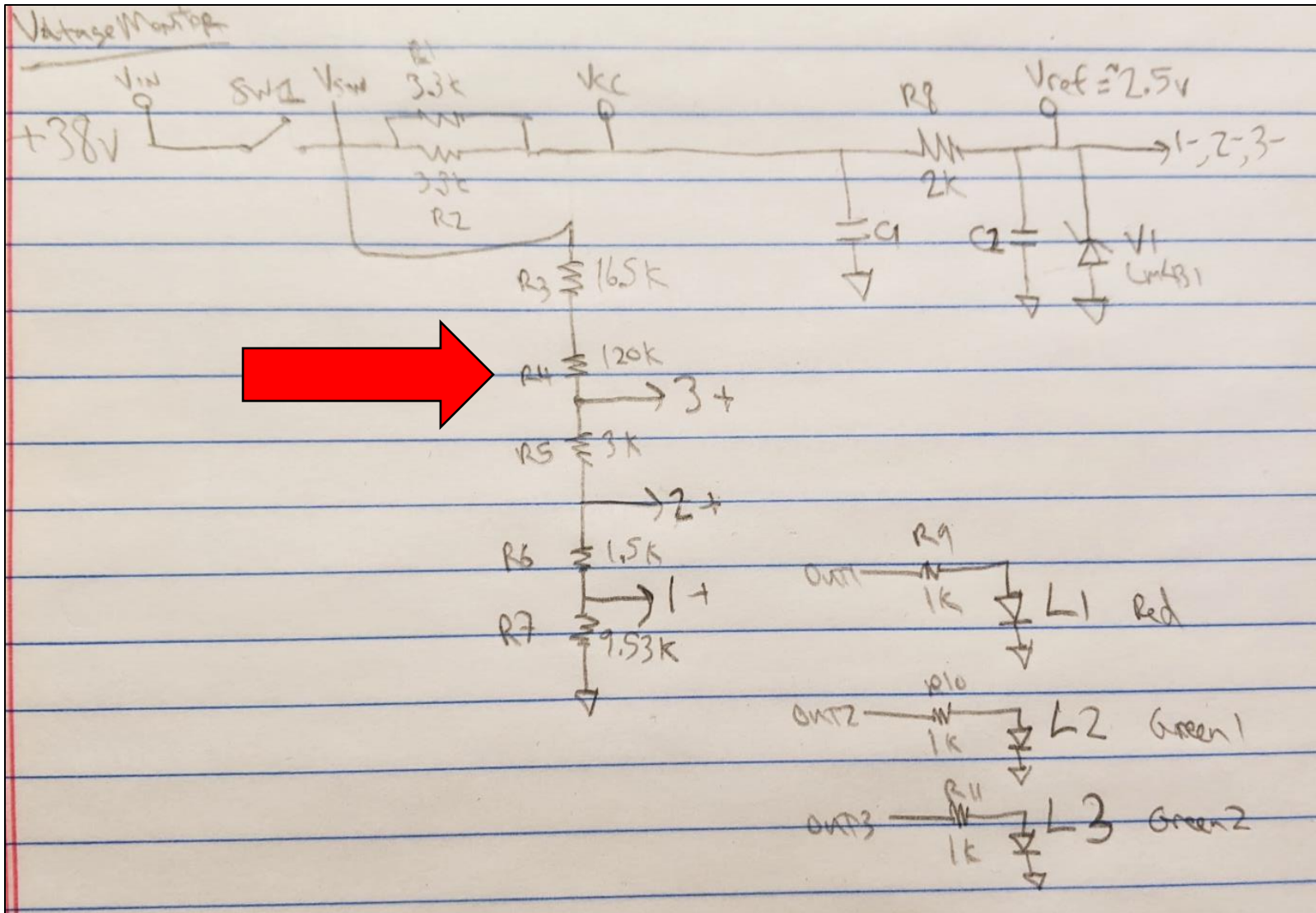


A little reverse engineering...

Existing PCBA				
<i>refdes</i>	<i>Marking</i>	<i>Value</i>	<i>Tolerance</i>	<i>To which nodes</i>
R1	332	3.3k	5%	SW,VCC
R2	332	3.3k	5%	SW,VCC
R3	1652	16.5k	1%	R4, S1
R4	124	120k	5%	3+, R3
R5	302	3k	5%	2+, 3+
R6	18B	1.5k	1%	2+, R7, R5
R7	95B	9.53k	1%	GND, 3+
R8	2001	2k	1%	1-, 2-, 3-, V1, C1
R9	102	1k	5%	L1, Out1
R10	102	1k	5%	L2, Out2
R11	102	1k	5%	L3, Out3
C1				SW,VCC
V1, C2	431	~2.5V		



How much needs to change?

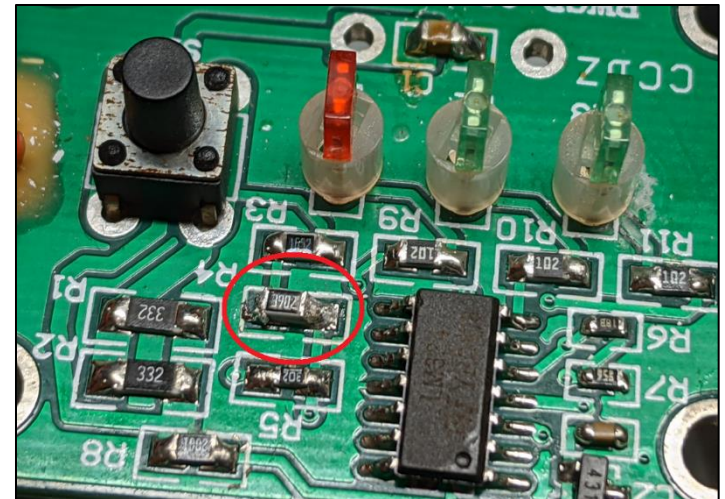


Just one little modification!

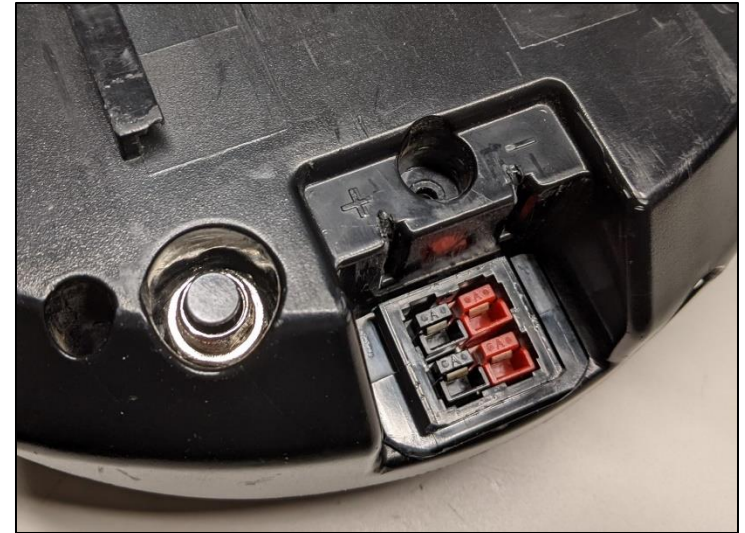
- Change R4 from 120k to 19.5k ohms
- The math checks out!

Bench Tested Voltage Levels for 12S (120k)				
LED State	12S Input Voltage	3+	2+	1+
Off	27.4	2.5538	2.0077	1.7347
Red	27.7	2.5818	2.0297	1.7537
1 Green + Red	35.1	3.2715	2.5719	2.2222
2 Green + Red	41	3.8214	3.0043	2.5957

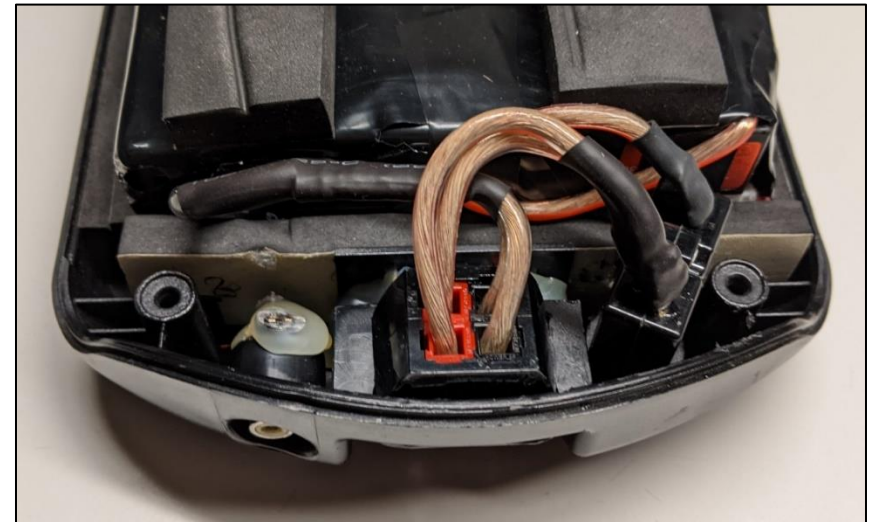
New Calculated Thresholds for 4S (19.5k)				
LED State	4S Input Voltage	3+	2+	1+
Off	9.13	2.5613	2.0136	1.7398
Red	9.23	2.5893	2.0357	1.7588
1 Green + Red	11.70	3.2811	2.5795	2.2287
2 Green + Red	13.67	3.8326	3.0131	2.6033

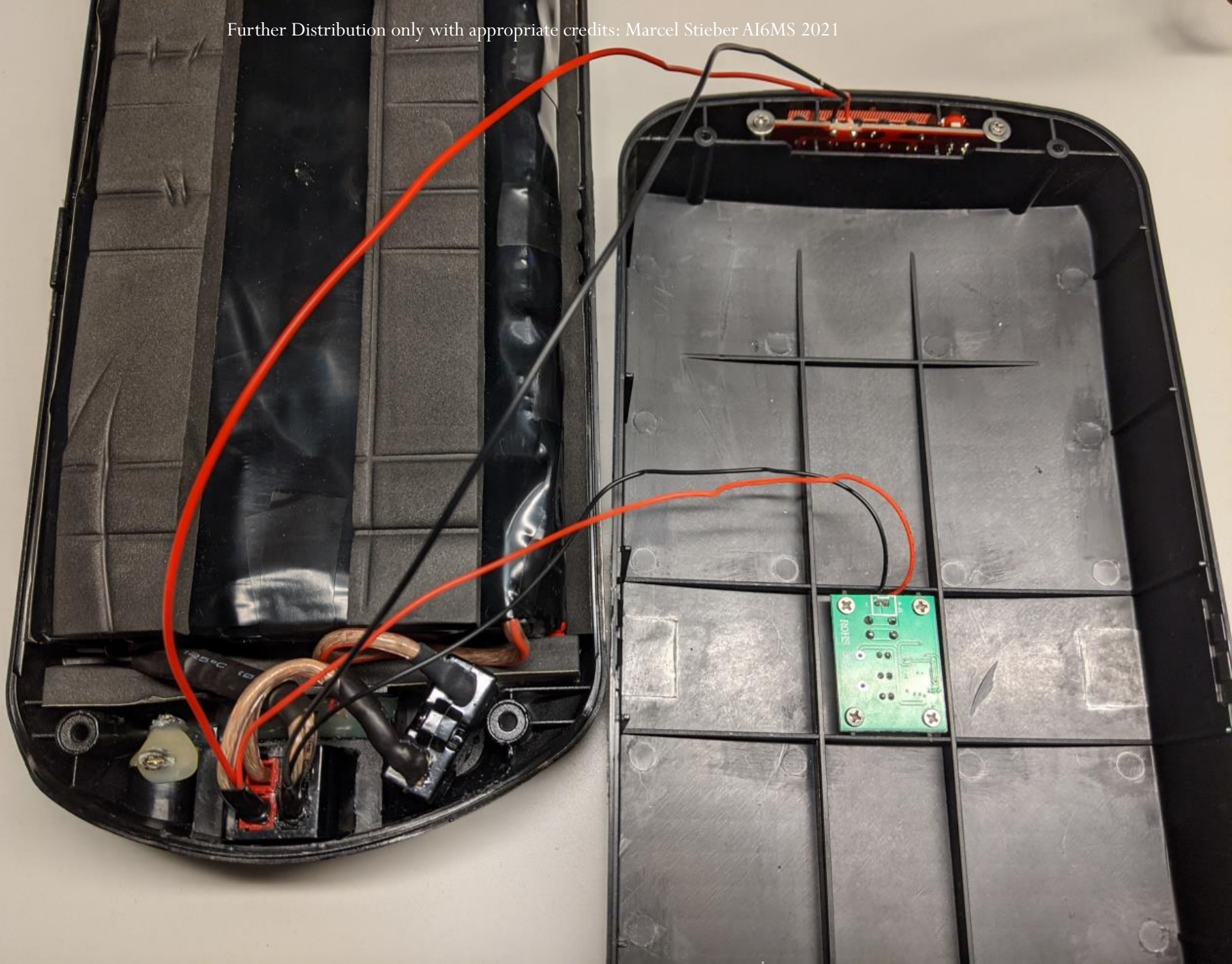


Finishing Touches



- Power Pole panel mount
- 30A thermal breaker
- Disconnect everything else!



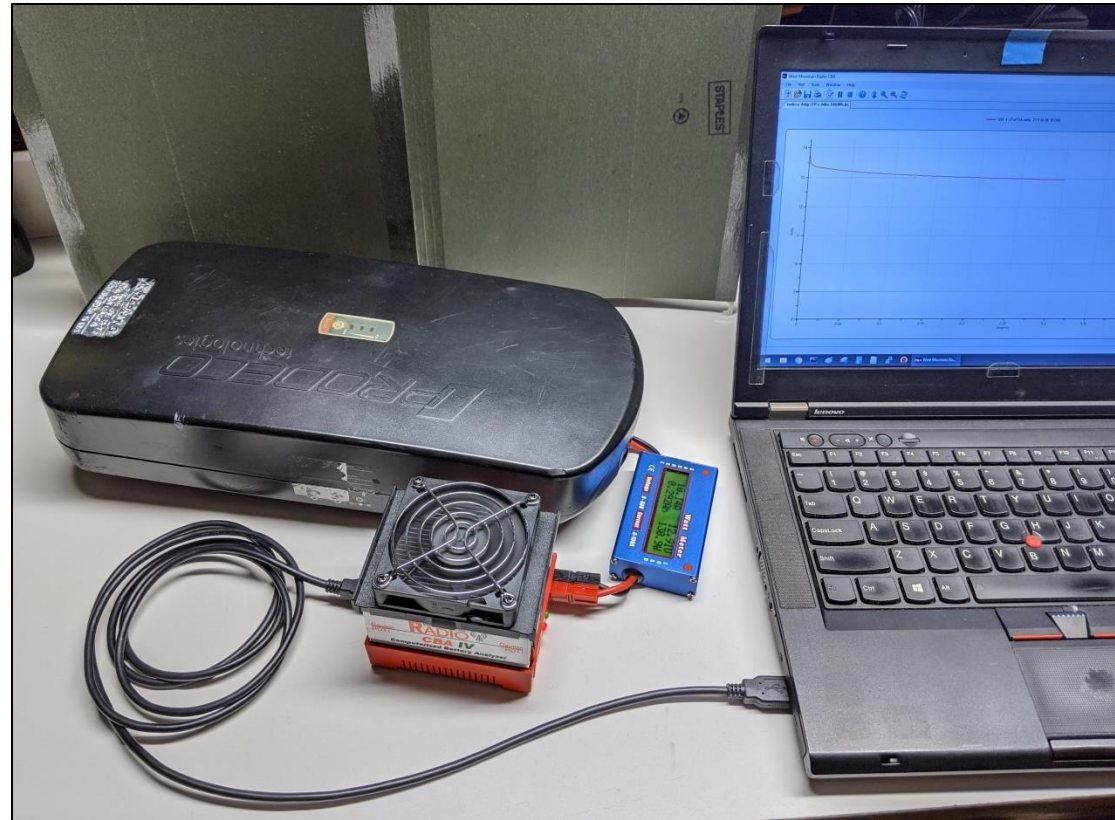




- Stickers!
- Labels!
- Specifications!



Charging, Balancing, and Capacity Test

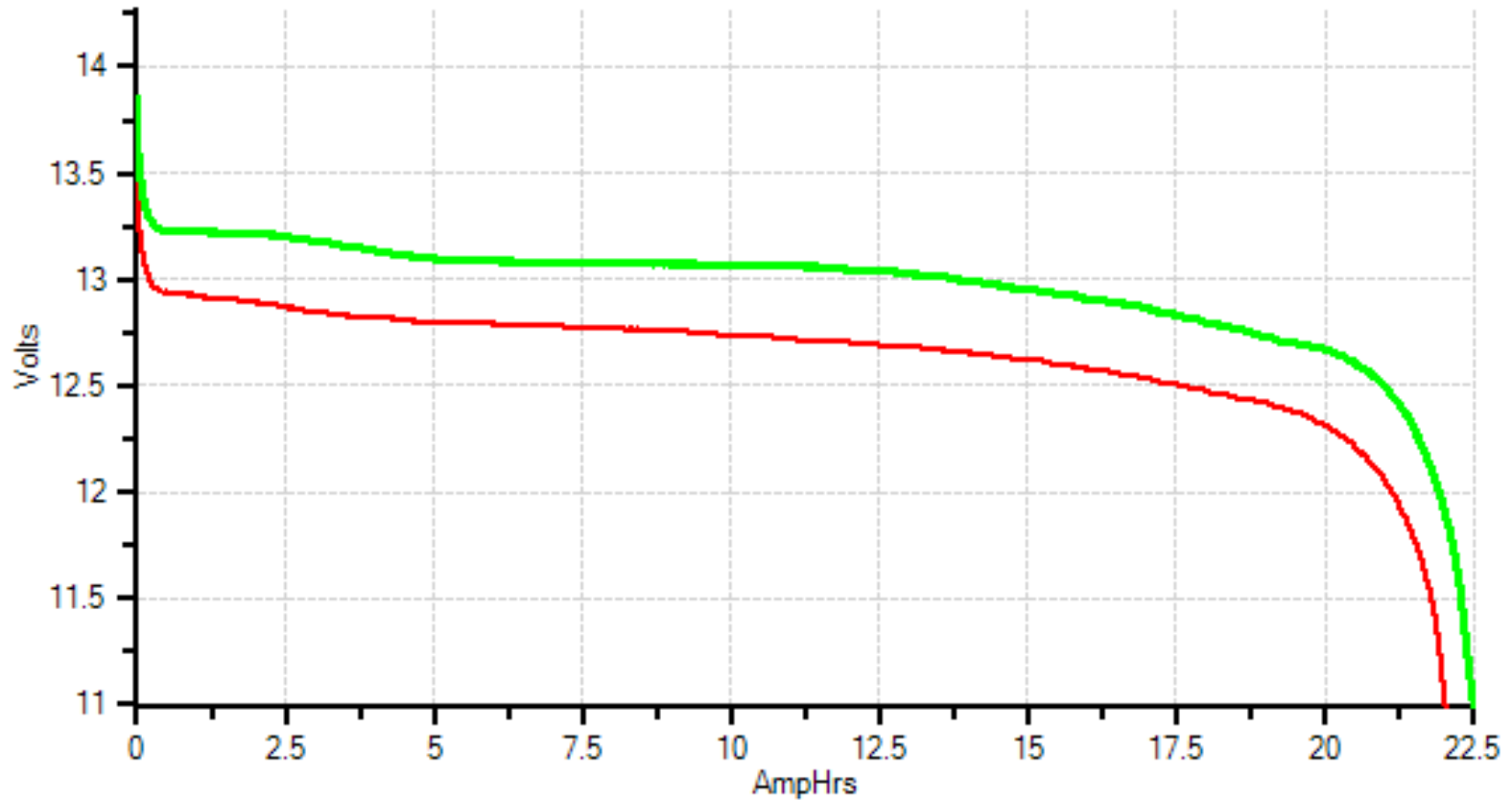


- Charge completely full!
- Allow balancing

West Mountain Radio - Computerized Battery Analyzer

ProdecoTech 4s6p LFP e-Bike Battery

— 10A: 4 LiFePO4 cells, 27.0 Ah @ 10.00A — 2A: 4 LiFePO4 cells, 27.0 Ah @ 2.00A



10A discharge = 22.06 Ahr (81.7% capacity), 2A discharge = 22.52 Ahr (83.4% capacity)

How does that compare?

- Total Cost: \$42
 - \$6 – Breaker, \$20 - Power Pole Mount*, \$16 – BMS
- Est. 3000-5000 cycles lifetime for LFP
 - With ~80% capacity remaining, say 50% of usable life?

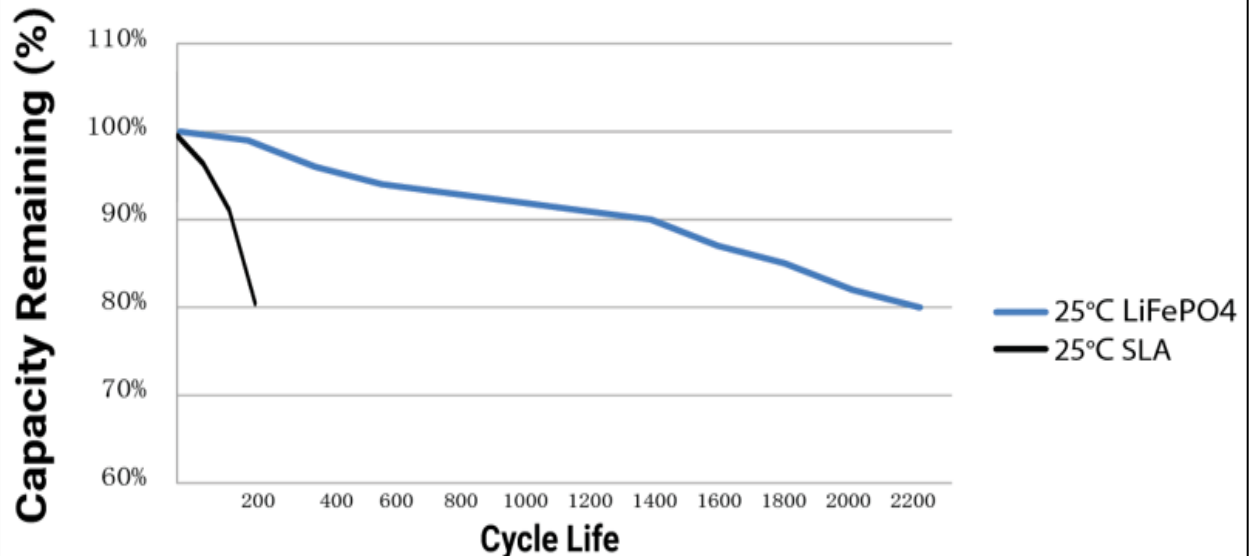


*About \$3.50 from
eBay: thecrazyham



CYCLE LIFE of LiFePO4 vs SLA at 25°C 0.2C CHARGE/0.5C DISCHARGE @ 100% DOD

POWERSONIC
TRUSTED BATTERY SOLUTIONS



Special thanks!

- A big thank you to Joel, W6TC for gifting me these battery packs to rebuild and use for this presentation!
- Consider supporting small businesses run by fellow hams!
 - www.WesternActive.com





Q&A

Presentation is available at: www.QRZ.com/db/AI6MS
Marcel Stieber, ai6ms@arrl.net

Want to get or upgrade your license? Fully-Remote Amateur Radio Exams are offered daily!
Check out: <https://hamstudy.org/sessions/online>

Special thanks to George, Jon, Rod, and Vince for helping put on this virtual conference!

Battery Safety and Shipping Info

- <https://www.fedex.com/content/dam/fedex/us-united-states/services/Shipping-Lithium-Batteries-via-FedEx-Ground.pdf>
- <https://www.ups.com/us/en/help-center/packaging-and-supplies/special-care-shipments/batteries.page>
- <https://www.cpsc.gov/Newsroom/News-Releases/2021/CPSC-Issues-Consumer-Safety-Warning-Serious-Injury-or-Death-Can-Occur-if-Lithium-Ion-Battery-Cells-Are-Separated-from-Battery-Packs-and-Used-to-Power-Devices>
- <https://www.imrbatteries.com/warning/>
- <https://www.samsungsdi.com/lithium-ion-battery/safe-information.html>

- For more background info on Lithium Batteries for Amateur Radio:
 - 30 min: <https://www.youtube.com/watch?v=5s360uIOM7w> (Slides)
 - 63 min: <https://www.youtube.com/watch?v=KsBRXeI7M04> (Slides)