Are Lithium Batteries for You?

Rev 11-10-23

Sherry & Dave McCampbell

Article: *svsoggypaws.com -> Workshop -> Electrical*

Presentation: *svsoggypaws.com/presentations.htm*

Justin Taylan

Pacific Wrecks

• PacificWrecks.com

PacificWrecks.com

Pacific Wrecks

Our Mission:

- Locate Missing In Action (MIA)
- Research and share information
- Protect sites for historical preservation

About Us:

- 501(c)(3) Not-For-Profit founded 1995
- Credited for finding dozens of MIAs
- Acclaimed info source worldwide

Introduction to lithium batteries

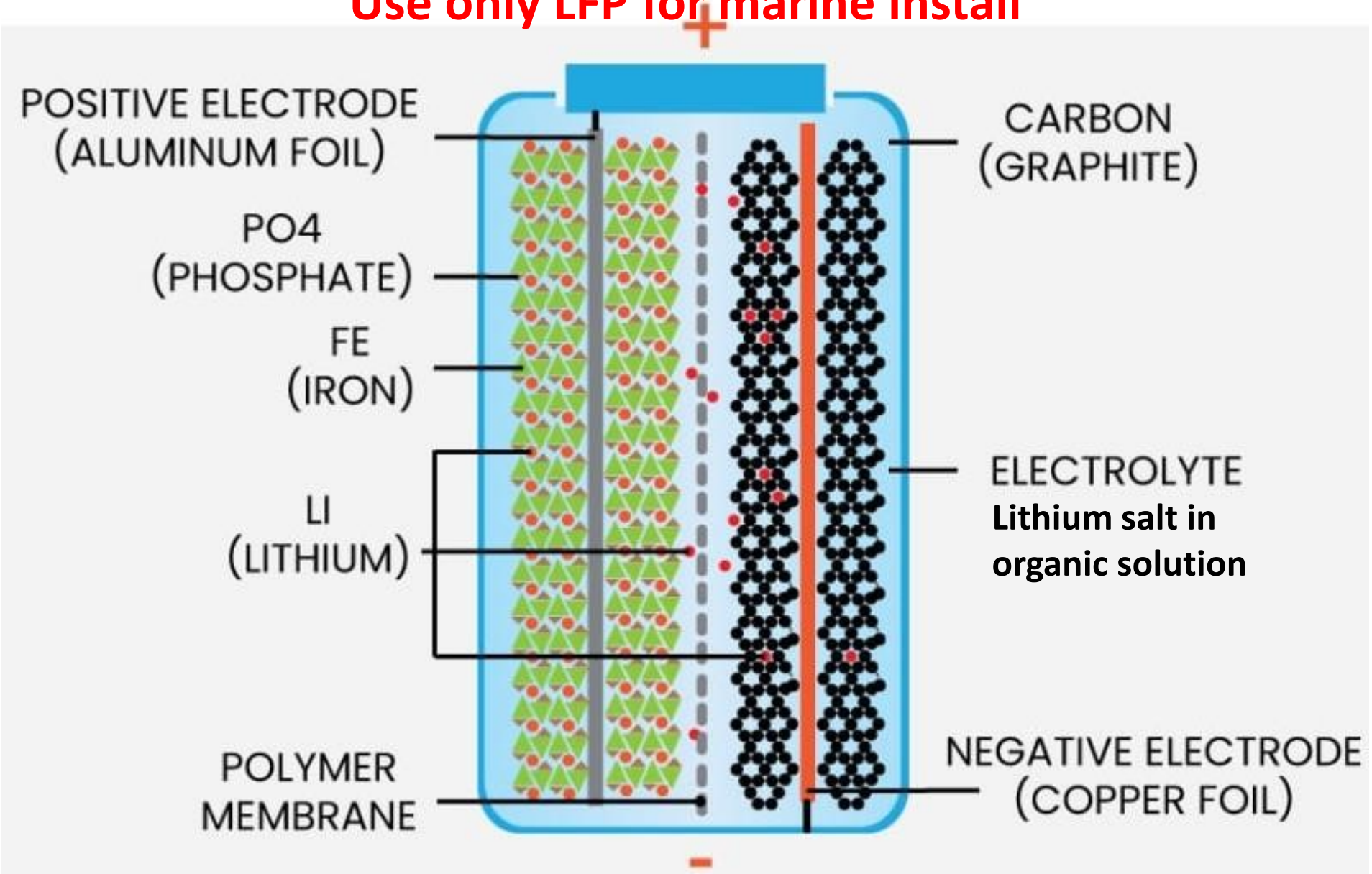
- **Seats, cell phones off, questions later, Scott 30 secs!**
- **Guest videographer- Justin Taylan Pacificwrecks.com**
- **Audience questions.**
- **SPaws DIY lithium install 3 years ago during Covid**
- **Part time research 6 mos, 2 months to install**
- **Neither degreed electrical engineers, learned by reading and doing**
- **If we can do it so can you!**
- SV Soggy Paws CSY 44 Walkthrough monohull
- SV Soggy Paws St Francis 44 Mk 2 Cat
- Left FL/USA 2007, 16+ years underway

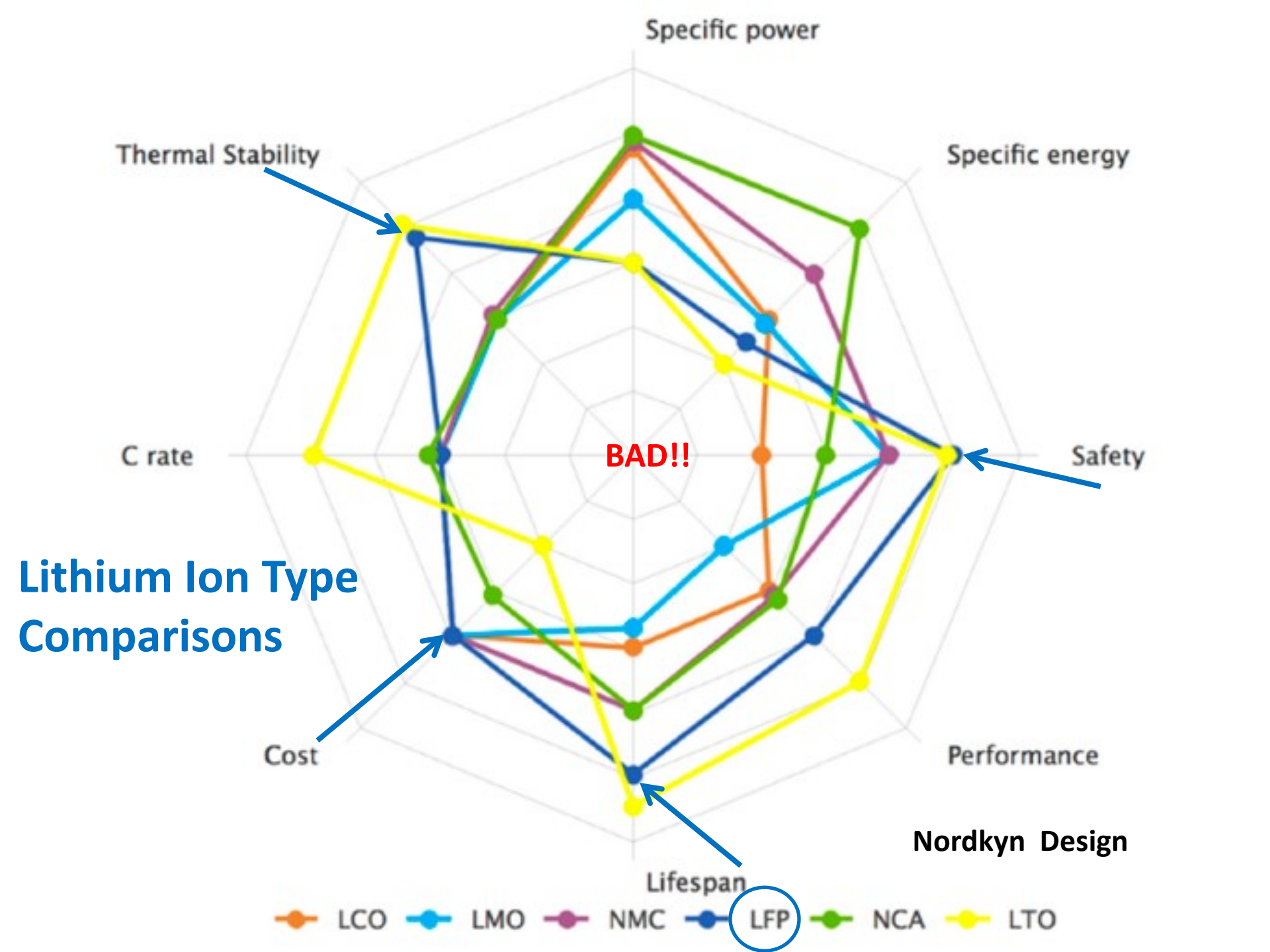
Today's Presentation

- Originally done as install information repository
- This shorter summary about 110 slides
- Focus on:
  - Lithium basics
  - Decision making
  - Equipment options
  - Advice summaries
- Caution be careful: information overload on internet
- Lots of ways to do lithium install, some advice better than others
- Must research best way for you
- Roundtable on Sunday for details & questions
- This on our website in Presentations section

What is a Lithium Iron Phosphate (LFP) battery?

Use only LFP for marine install





Lithium Ion Type Comparisons

Nordkyn Design

Lithium Iron Phospate (LFP)

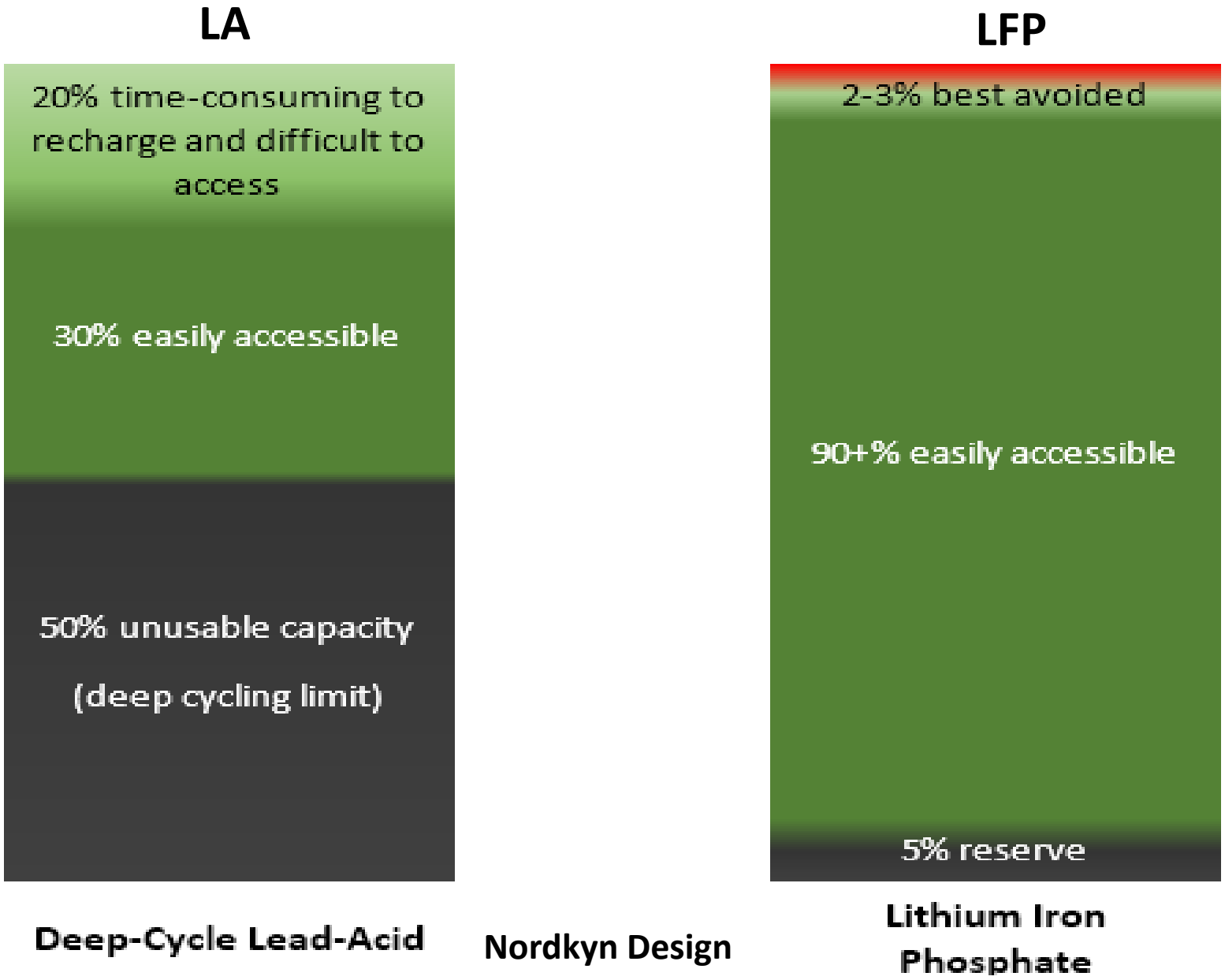
- **Useable capacity >90%**
- **Charge Bulk only, not to 100%**
- **Physical 1/3 weight, ½ size**
- **DIY cell cost similar AGM/Gel**
- **Service life up to 20 years @1.5% per year loss**
- LFP greater complexity (BMS, etc) but greater safety
- LFP cells will not self ignite, but can enter 'thermal runaway'

Lead Acid (FLA SLA AGM Gel)

- **Useable capacity <50%**
- **Bulk + long 100% Absorb daily**
- Physical 3x weight, 2x size
- Cost: AGM/Gel batts similar to LFP cells
- **Lifespan FLA/SLA 3-5 years, AGM 5-8, Gel 8-10+**

- Both LFP & LA CAN CAUSE electrical fire if shorted, poor install, bad eqpt or wrong parameters
- Service life depends on care, calendar aging, heat exposure for both

LA vs LFP Useable Capacity Comparison



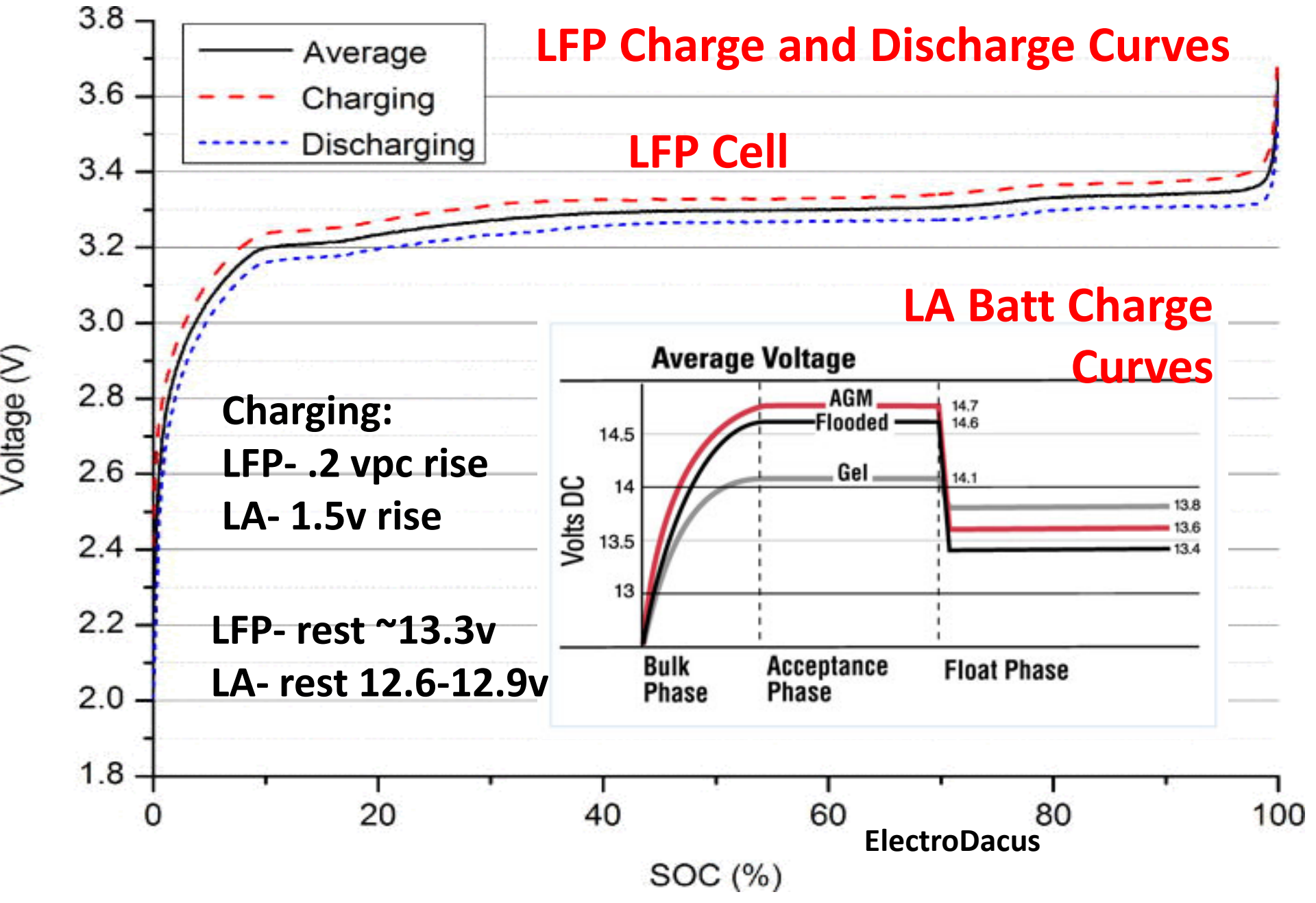
Weight Comparison example LA vs LFP:

Our 13 year old quality 6v x 600 ahr Gel house bank:

LA- 600/300 ahr = 390 lbs

LFP- 540/500 ahr = 100 lbs

1.5 times greater useable capacity, 1/3 weight!


LFP Charge and Discharge Curves
LFP Cell
Average
Charging
Discharging
Voltage (V)
SOC (%)
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
0
20
40
60
80
100
Charging:
LFP- .2 vpc rise
LA- 1.5v rise
LFP- rest ~13.3v
LA- rest 12.6-12.9v
LA Batt Charge Curves
Average Voltage
Volts DC
AGM
Flooded
Gel
14.7
14.6
14.1
13.8
13.6
13.4
14.5
14
13.5
13
Bulk Phase
Acceptance Phase
Float Phase
ElectroDacus

Lithium Decision Making

- **Yes-**
  - **Full time cruising**
  - **Cruising overseas**
  - **Catamaran**
  - **Long term boat owner**
- **Maybe No-**
  - **Part time cruiser & coastal US**
  - **New batts**
  - **Budget challenged or insurance issues**
  - **Electrical challenged & not willing to learn**
- **Cost considerations-**
  - **DIY depending on eqpt needed & ability $2-4K**
  - **Pre assembled batts (PA)/DropIn & paid installer help $5-10K**
  - **SPaws example: DIY install, 540ahr cells, over 6 mos ~$2K**

Current Insurance Requirements

- Some say nothing yet about batteries or their installation
- Some say must be installed by a ‘qualified’, ‘certified’, or ‘professional’ installer
- Topsail/Global Yacht Cover Policy:
  - “Use and maintenance of lithium batts must be carried out IAW manufacturer’s recommendations, and strict records are to be kept.”
- Pantaenius- “Must adhere to ASNZ (similar to ABYC & ISO) standards.”
- Future: most US policies will probably reference ABYC E-13 standards for installation

If Yes, Basic Install Steps

- **First step: read basics on trusted resources, watch Utubes, Google**
- **If DIY study details carefully & take your time to learn how**
- **Evaluate your layout/eqpt for LFP suitability**
  - **Busses, solar, alternators, chargers, inverters, monitor, space**
- **Acquire electrical skills- NOT ROCKET SCIENCE!**
- **Cruisers must buy QUALITY eqpt, tools & spares**
- **If paid help be very careful:**
  - **Typical US labor cost $100-150+/hr, $150 x 8 hrs = $1200/day!!**
  - **Once underway overseas lithium help hard to find!**
  - 'Professional' means paid labor not 'expert'
  - How much LFP training, knowledge, experience?
  - Not all ABYC mechanics know LFP design
  - ABYC requires only 1 hour LFP course
  - Ask what LFP equipment to be used
- **Lots of ways to do LFP install, lots of opinions, be careful who you trust!**

Trusted References Homework

- Your insurance policy regarding lithium batts
- ABYC TE-13 Marine Lithium Standards (EU ISO/TS 23625)
- FB Groups- Lithium on a Boat
- FB Group - Boat Electrical Systems
- Marine How To- Rod Collins
- Nordkyn Design- Eric Bretscher
- UTube DIY Solar Power- Will Prouse
- UTube Off-Grid Garage- Andy Andreas
- Battery University
- SVSoggyPaws.com:
  - LFP article- Workshop/Electrical Systems
  - This presentation- Presentations/Equipment

Best LFP FB Group: Lithium Batteries on a Boat

Lithium batteries on a boat

+ Invite

Discussion Featured Members Events Media Files Questions

Basic Electrical FB Group: Boat Electrical Systems

Group by Marine How To

Boat Electrical Systems

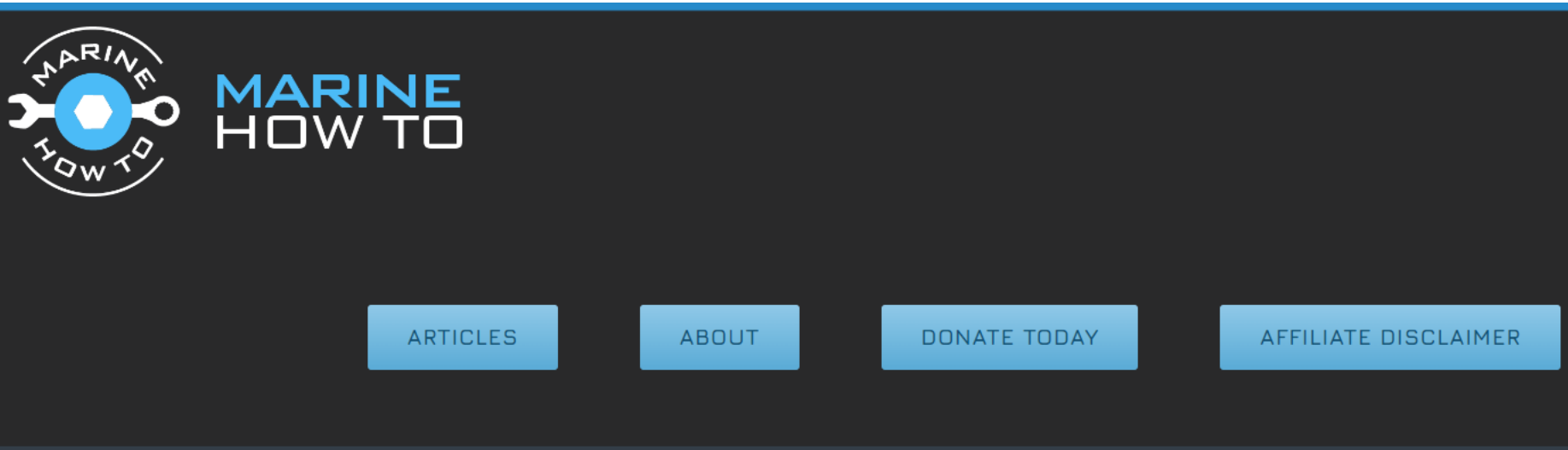
+ Invite

Discussion Featured Members Events Media Files

83°F Sunny

1:25 PM
10/21/2023

Bible Nr 1: Rod Collins Marine How To



Bible Nr 2: Eric Bretscher Nordkyn Design

NORDKYN DESIGN

SCIENCE & ENGINEERING

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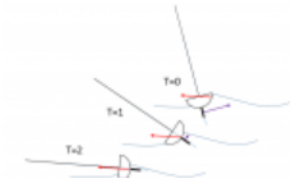
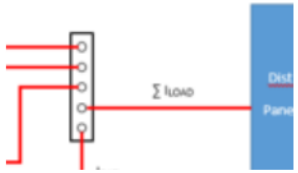


Transverse Stability, Part 4: Sailing Yachts at Sea

This article follows Transverse Stability, Part 3: Dynamic Stability Part 3 of this series dealt with changes in transverse stability taking place once a vessel starts travelling through the

Motor-Zuverlässigkeit: Ein Blick auf die Volvo Penta MDI Black Box

This German translation of the original article in English was very kindly provided by Burkhard Hermes in October 2021 to facilitate access to the content for German-speaking



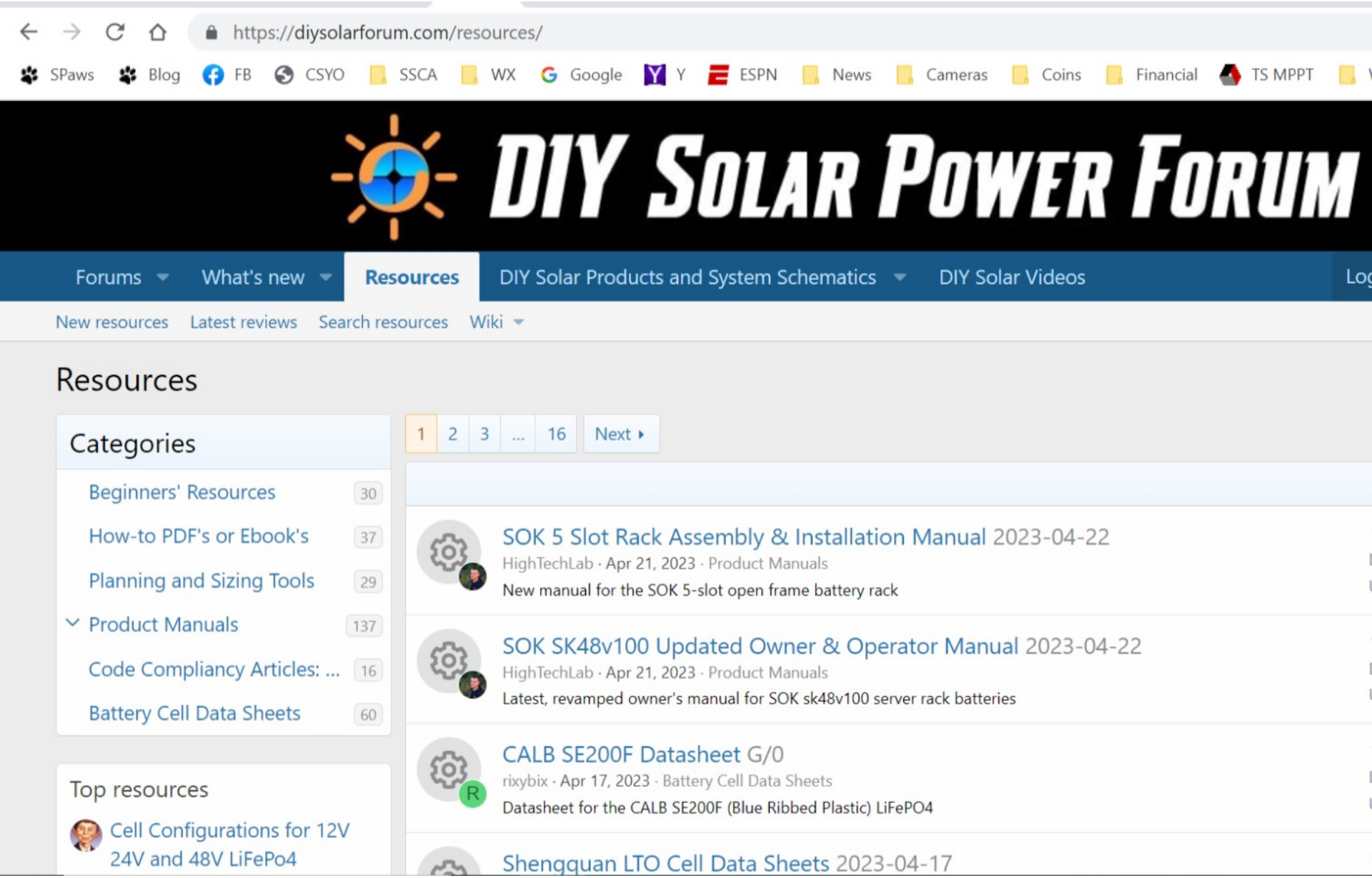
Charging Marine Lithium Battery Banks

This article is part of a series dealing with building best-in-class lithium battery systems from bare cells, primarily for marine use, but a lot of this material finds relevance for low-voltage off-grid systems as well. Lithium iron phosphate (LiFePO4)

Engine Reliability: A Look at the Volvo Penta MDI Black Box

In this article, we have a look at the Volvo Penta MDI electronic black box while relocating it off the side of a Volvo Penta D2-40B engine in order to protect it from the heat and vibrations. IF YOU OWN A FAILED MDI BOX

Basic Lithium/Solar Website/Forum/YouTube:
Will Prouse



Best YouTube: Andy Andreas Off-Grid Garage

https://off-grid-garage.com

log FB CSYO SSCA WX Google Y ESPN News Cameras Coins Financial TS MPPT Watch »

the Off-Grid Garage

DIY Solar-Battery Projects

Learn more about solar energy, batteries and energy storage!

Subscribe to our YouT
Channel to learn more

Here on the Off-Grid Garage website, you will find easy to understand videos and instructions, explaining how to build and

Our Install Details, Electrodacus Info, Trickle Charging, Solar, Node Red Display, etc

St Francis 44

SOGGY PAWS

Home Page

Workshop Home

Old CSY Workshop Pages

Engine

Electrical Systems

Plumbing Systems

Refrigeration

Rig & Sails

Hull

Cockpit

ELECTRICAL SYSTEMS

New LiFePO4 Lithium House Bank

Trickle Charging Start Battery

Alternator Repair

Battery Charging System Philosophy

Solar Charging System

Lightning Issues

LiFePO4 Reference Sources

Last Updated: 04/09/2023

The electrical systems and issues on our previous boat, a 1980's CSY monohull, were quite different than those on our 2004 St. Francis Catamaran. For all the great stuff I did over the years on the CSY electrical system, go to this link: CSY Electrical Systems.

Future Additions:
Alternator-Regulator Engine Charging With a Wakespeed 500

Lithium LifePO4 Battery Upgrade

When we purchased our St. Francis 44 catamaran 7 years ago, the house bank consisted of six 6-volt Sonnenschein Solar Block 200 batteries, for a rated total of 600 Ahrs at 12 volts. They are very high quality German Gel batteries. :ked down by COVID in the Philippines, and with our Gel battery bank then 13 years old, we decided

https://svsoggypaws.com/electricalsystems.htm#lifepo4-reading

SPaws Lithium Slide Presentations

St Francis
44

SOGGY PAWS

In these pages you will find the story of the sailing vessel Soggy Paws, her crew Sherry and Dave, and her trip around the world.

Soggy Paws is currently in Malaysia, readying for a 2024 dash to the Med!

Our Blog

Where Are We?

Cruising Plans

Where Have we Been?

Workshop

Presentations

Articles

Satellite Charts

Eqpt

The New Soggy Paws in the Gulf of Davao, Philippines, August 2015

Not all who wander are lost...
- JRR Tolkien

Looking for our 'Cruising Guides'??

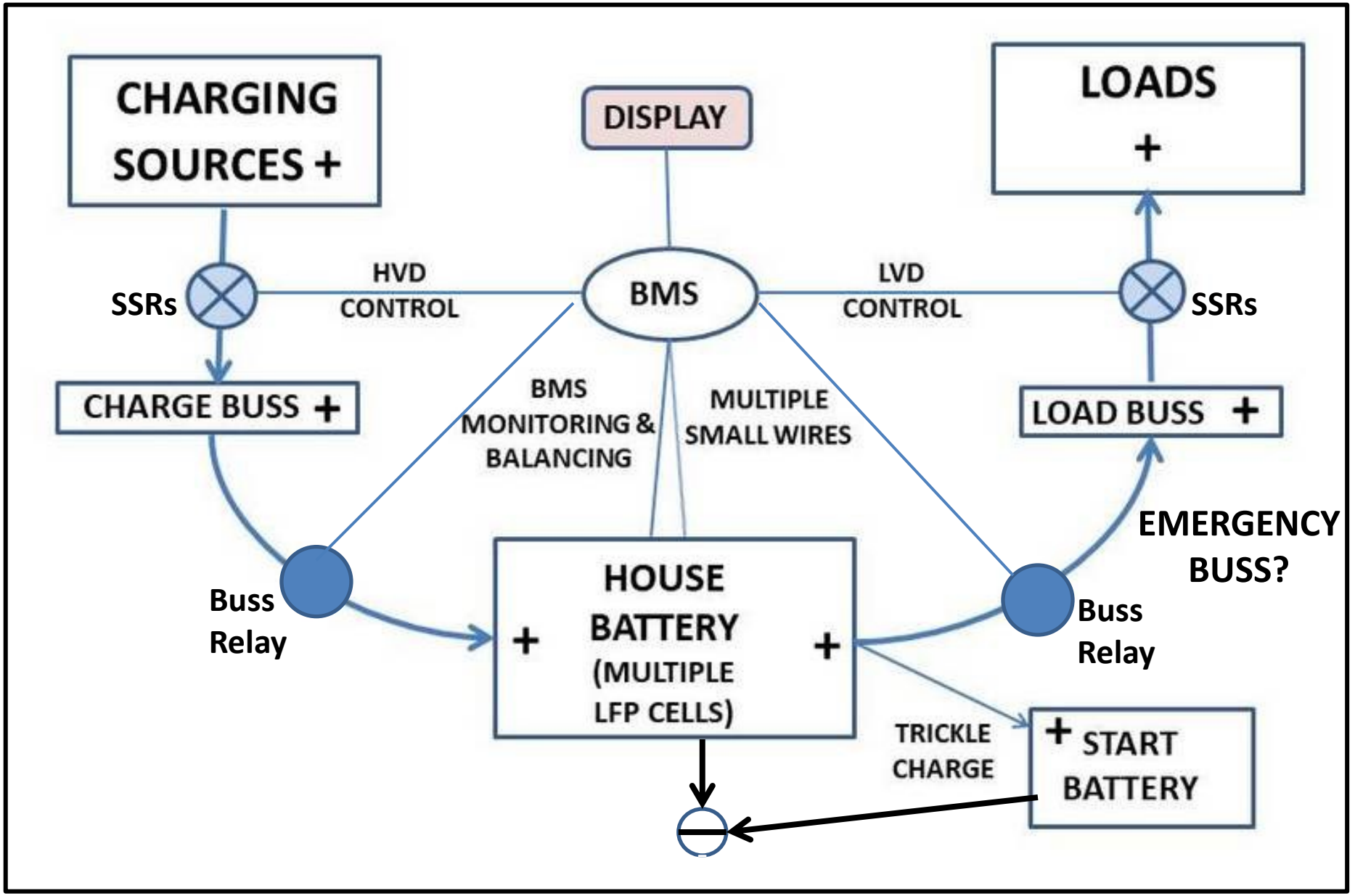
The Marshall Islands Compendium
The Fiji-to-Marshalls Compendium
The Fiji Compendium
The Tonga Compendium
The Cooks and Samoas Compendium
The Societies Compendium

Basics- Terminology to Know

- Lithium Ion- general term, many different varieties
- LFP (LiFePO4)- ONLY lithium battery for general marine use
- LA (lead acid) battery
- FLA/SLA (flooded/sealed lead acid) battery
- LFP voltages: nominal 12v, 4 x 3.2v cells 12.8v, rest ~13.3v, min/max 10/14.6v
- C (capacity rating)- 1C=100% or rated ahrs, .2C=20% or .2 x rated ahrs
- Charge termination- end of charger's (MPPT/Alt/etc) bulk charging
- BMS (Battery Management System)- functions control, monitor, balance
- HVD/LVD- BMS control (high/low voltage disconnect = HVC/LVC cutoff)
- DIY (do it yourself) cells vs PA (Preassembled/DropIn batts)
- SSR (solid state relay)
- Prismatic (rectangular)- 18650 (cylindrical) cells
- VPC (volts per cell), V (volts)
- AHRS (amphours), A (amps), Ma (milliamps)
- SOC (state of charge)
- PV (photovoltaic) solar panel
- PSW (pure sine wave) – MSW (modified sine wave) inverter
- MPPT (max PP track)– PWM (pulse width mod) solar regs

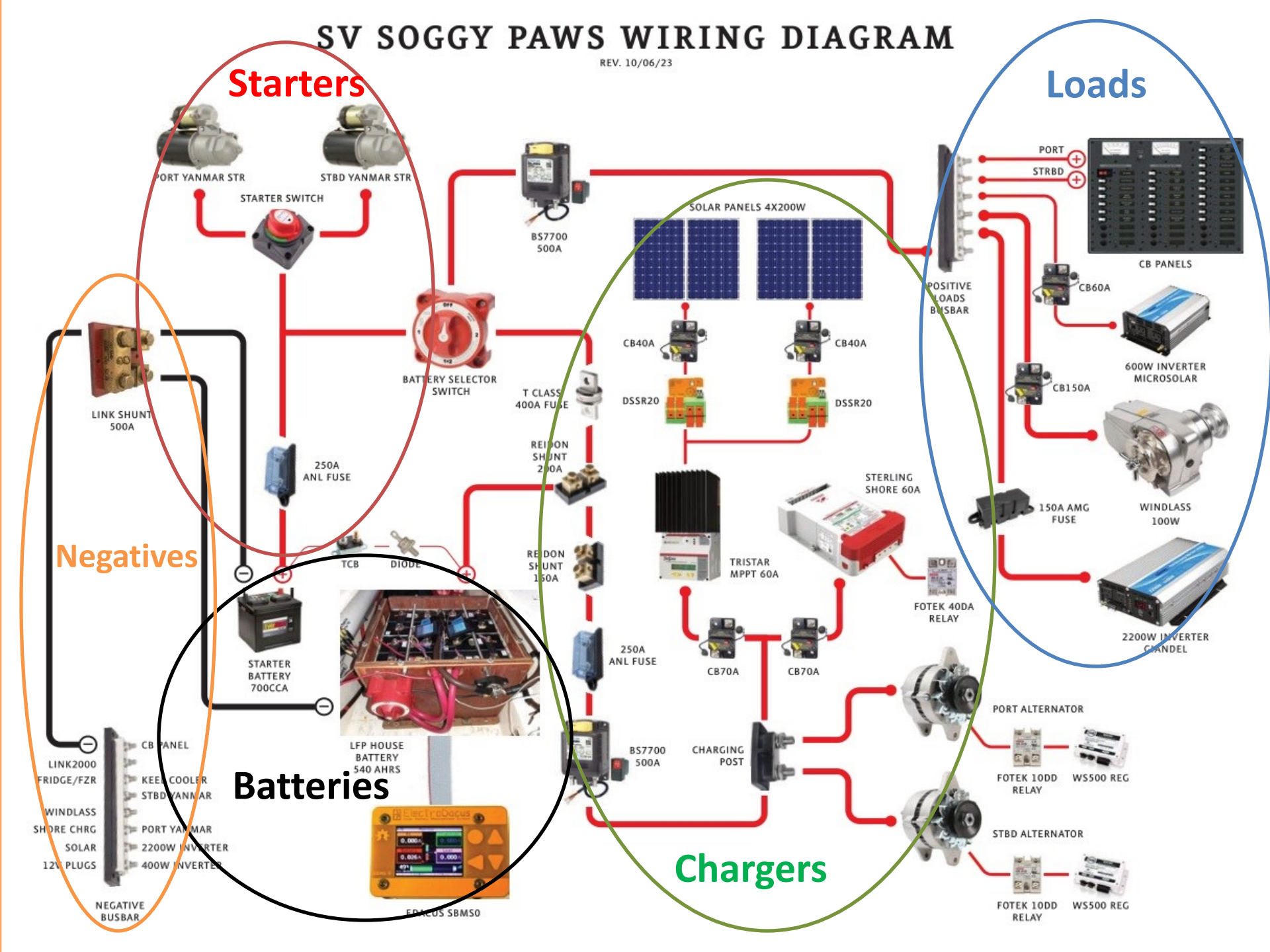
Basic 2 Buss DIY LFP

System Schematic



SV SOGGY PAWS WIRING DIAGRAM

REV. 10/06/23



Equipment- LiFePO4 Cells

- **LiFePO4 3.2v prismatic cells-**
  - **Grades A, B, C**
  - **Grade A only cells cruisers should buy**
  - **Grade B don't meet specs/rejects, C used cells**
  - **Don't buy cheap cells from resellers like Alibaba, Lazada, etc**
  - **Buy cells/batts from trusted sources**
  - **Available in many different sizes and capacities**
  - **Secure in ~12 psi compression box**
  - **Connections must be done carefully, tight and clean**
  - Larger cells may have structural strength to weight ratio issues in rough seas
  - Delivered cell Vs should be below 3.300vpc, delta less than 2mv

LFP Aluminum Case Cells

Many sizes & capacities available

Quality aluminum case cells: EVE, Lishen, RJ

Grade A prismatic aluminum case cells

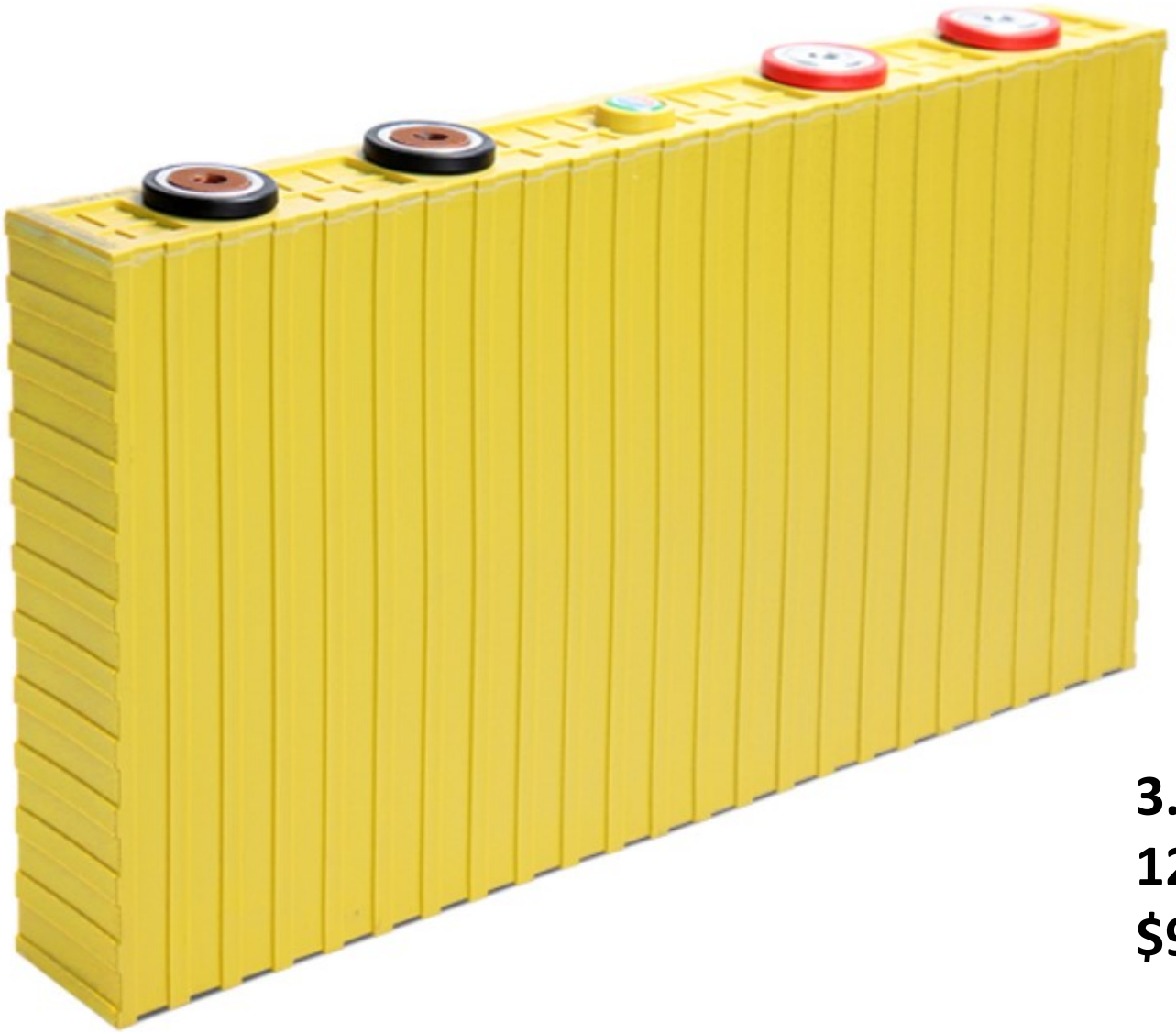
-Typical 280-304 ahr
-Meet factory specs
-Stickers intact
-Warranty 1-5 years
-Stud terminals
-Cycle life 4-5000 cycles
-Service life 20 years
~12 lbs ea
~$110 US

Brands > ThunderSky Winston

3.2v 700ahr

LiFeYPO4

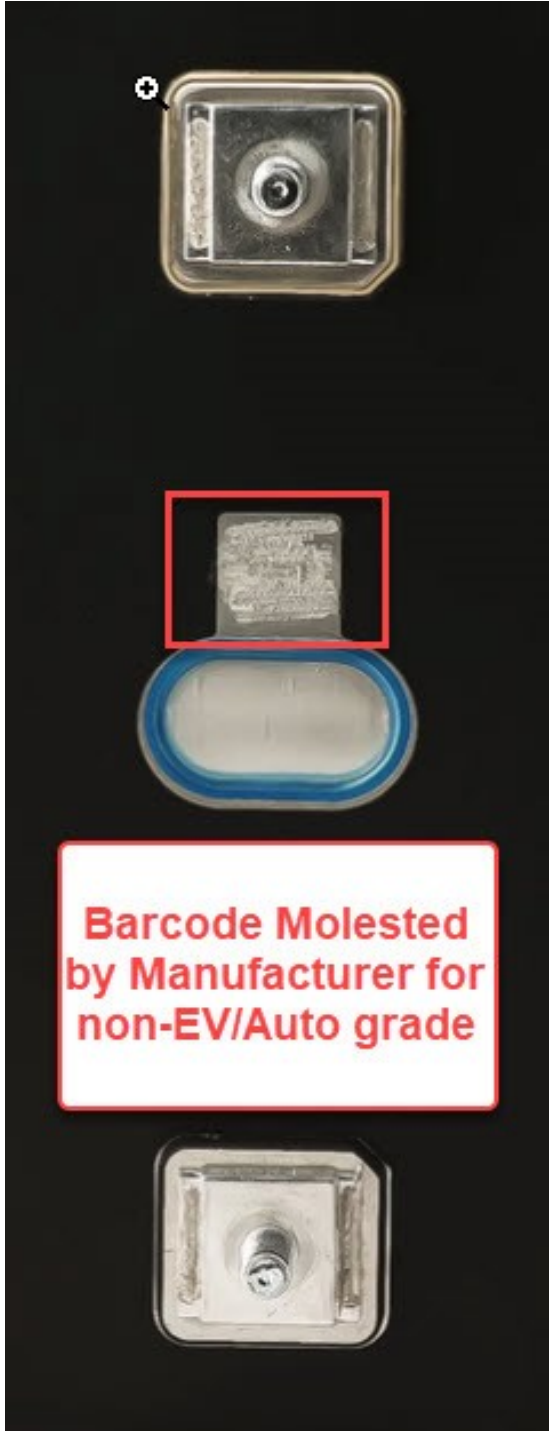
LFP Plastic Case Cells



Winston best quality plastic case cell
Others: CALB, Sinopoly

3.2v 700ah cell
12v 4S = 700 ahrs
$934 x 4 = $3736

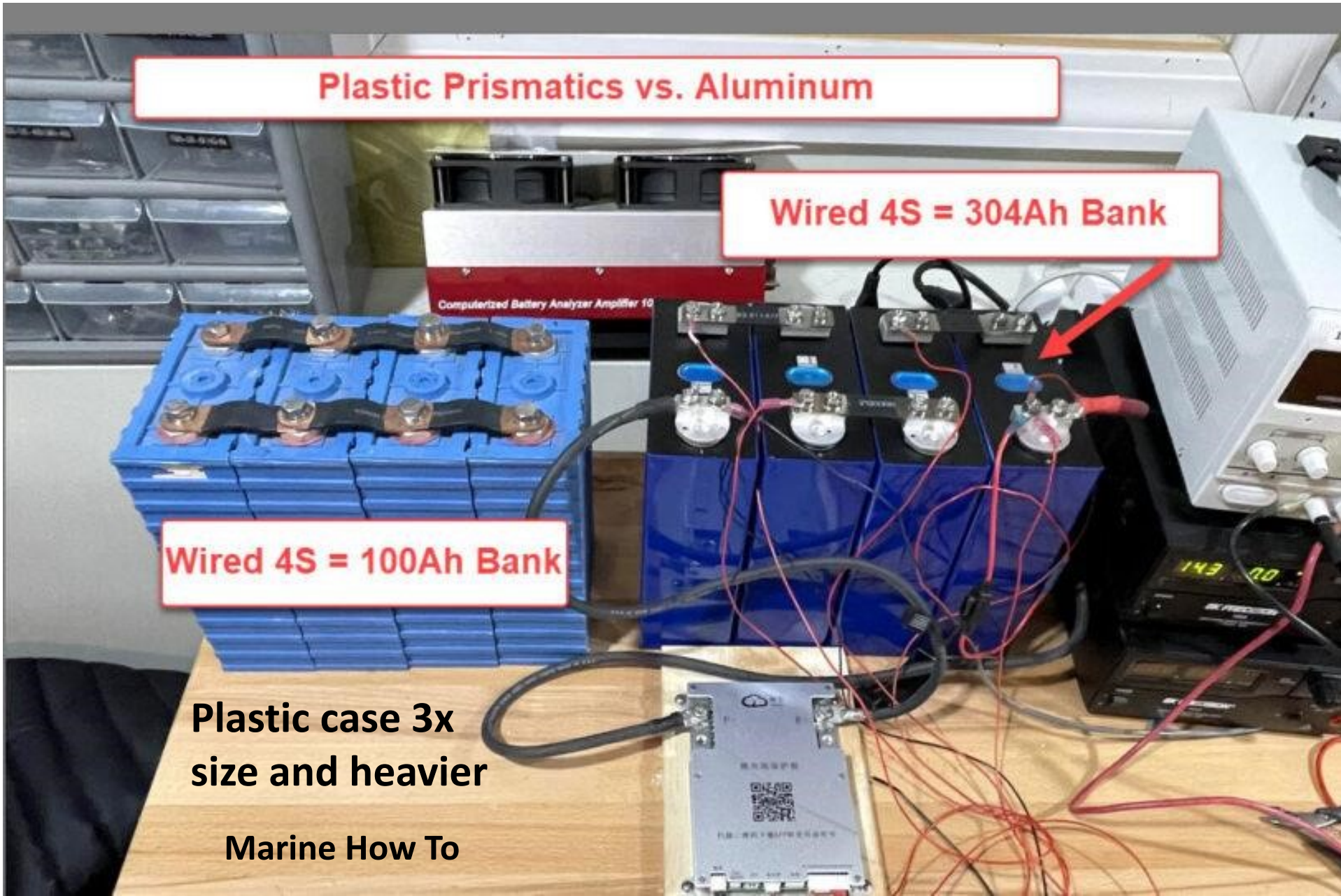
12v 304ah batt
12v 2P4S = 608 ahrs
$424 x 2 = $848



Grade B Cells

-Don’t meet factory specs
-Missing or damaged barcodes
-Less capacity
-Case damage
-Terminal damage
-Self discharge
-Other problems
-Box of chocolates!

Plastic vs Aluminum Case Cells

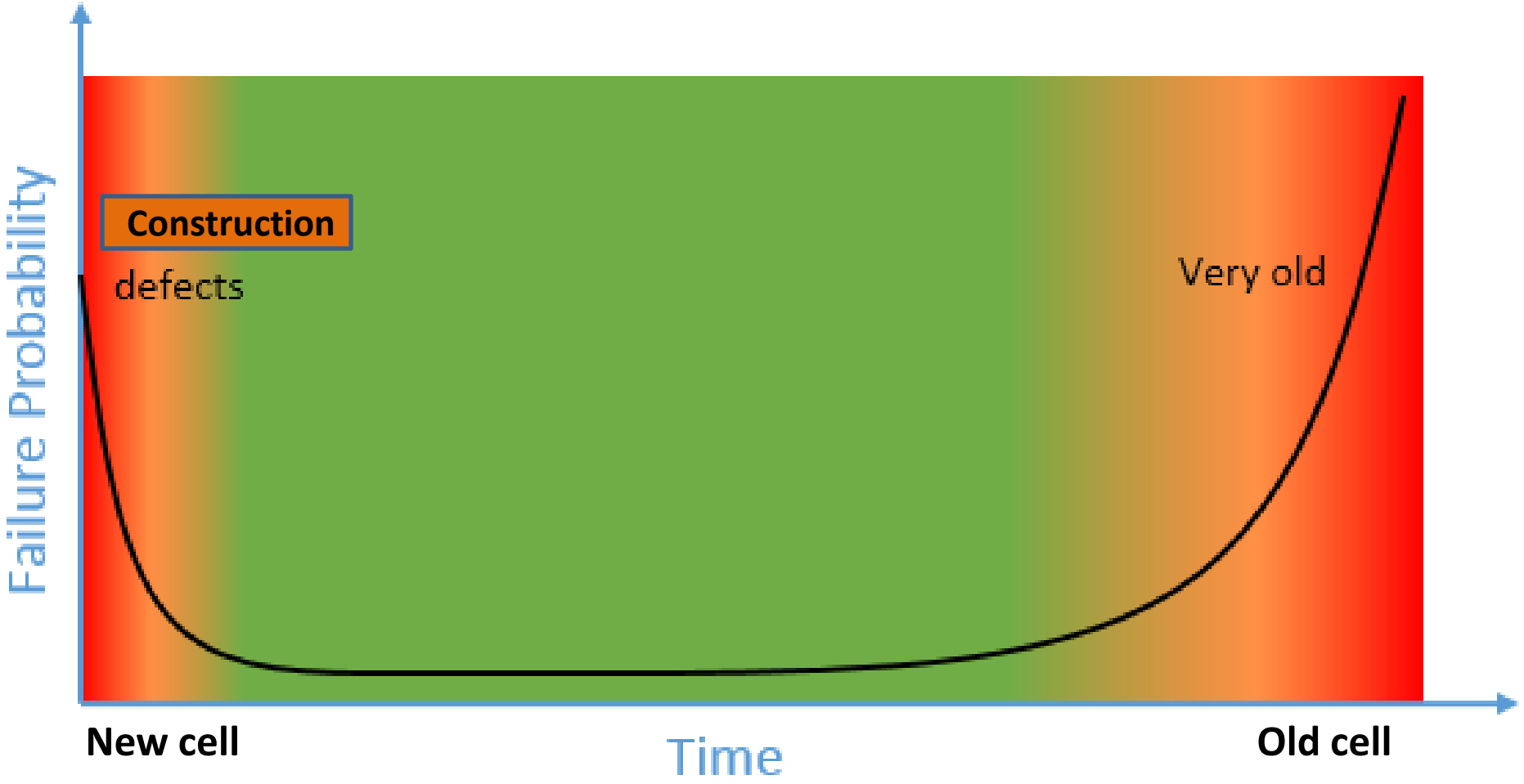


Typical packaging for shipping

Quality Cell Connecting Links

Connecting cells:
-Be careful
-Various lengths
-Flexible with multiple layers of Cu
-Compress then install links
-Spotless terminals
-Proper torque

LFP Cell Failure Probability



Nordkyn Design

LiFePO4 Voltage Chart (3.2V, 12V, 24V &

Percentage(SOC)	3.2V	12V	24V
100% Charging	3.65V	14.6V	29.2V
100% Rest	3.40V	13.6V	27.2V
90%	3.35V	13.4V	26.8V
80%	3.32V	13.3V	26.6V
70%	3.30V	13.2V	26.4V
60%	3.27V	13.1V	26.1V
50%	3.26V	13.0V	26.1V
40%	3.25V	13.0V	26.0V
30%	3.22V	12.9V	25.8V
20%	3.20V	12.8V	25.6V
10%	3.00V	12.0V	24.0V
0%	2.50V	10.0V	20.0V

Very Rough!

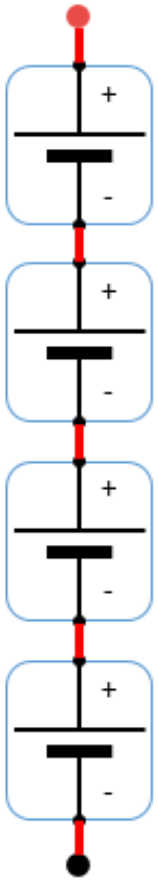
Max 14.6v
HVD ~14.2v
Chg Term 13.8-14.2v

LVC ~12.0v
Min 10.0v

BatteryFinds.com

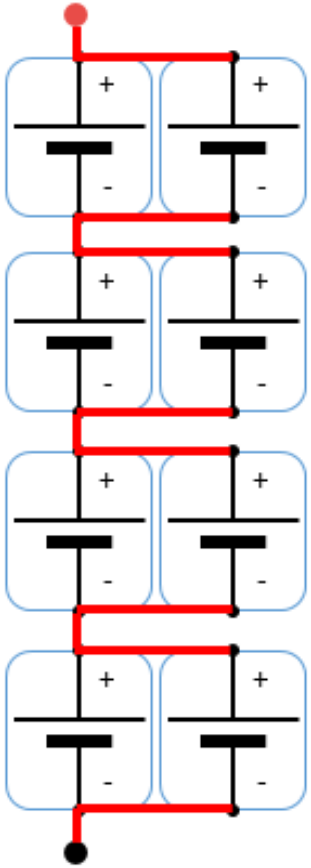
LFP Cell Configurations

S = series, P = parallel



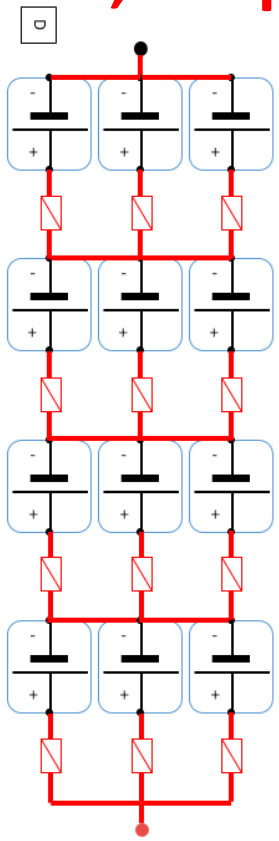
A

4S



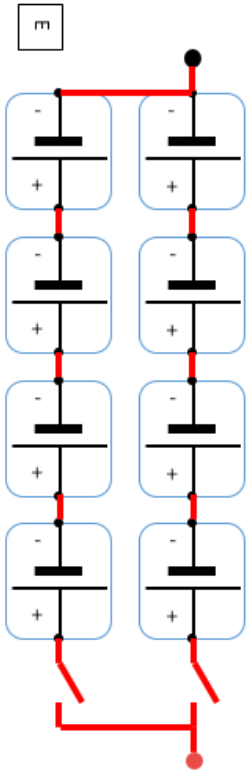
B

2P4S



D

3P4S



E

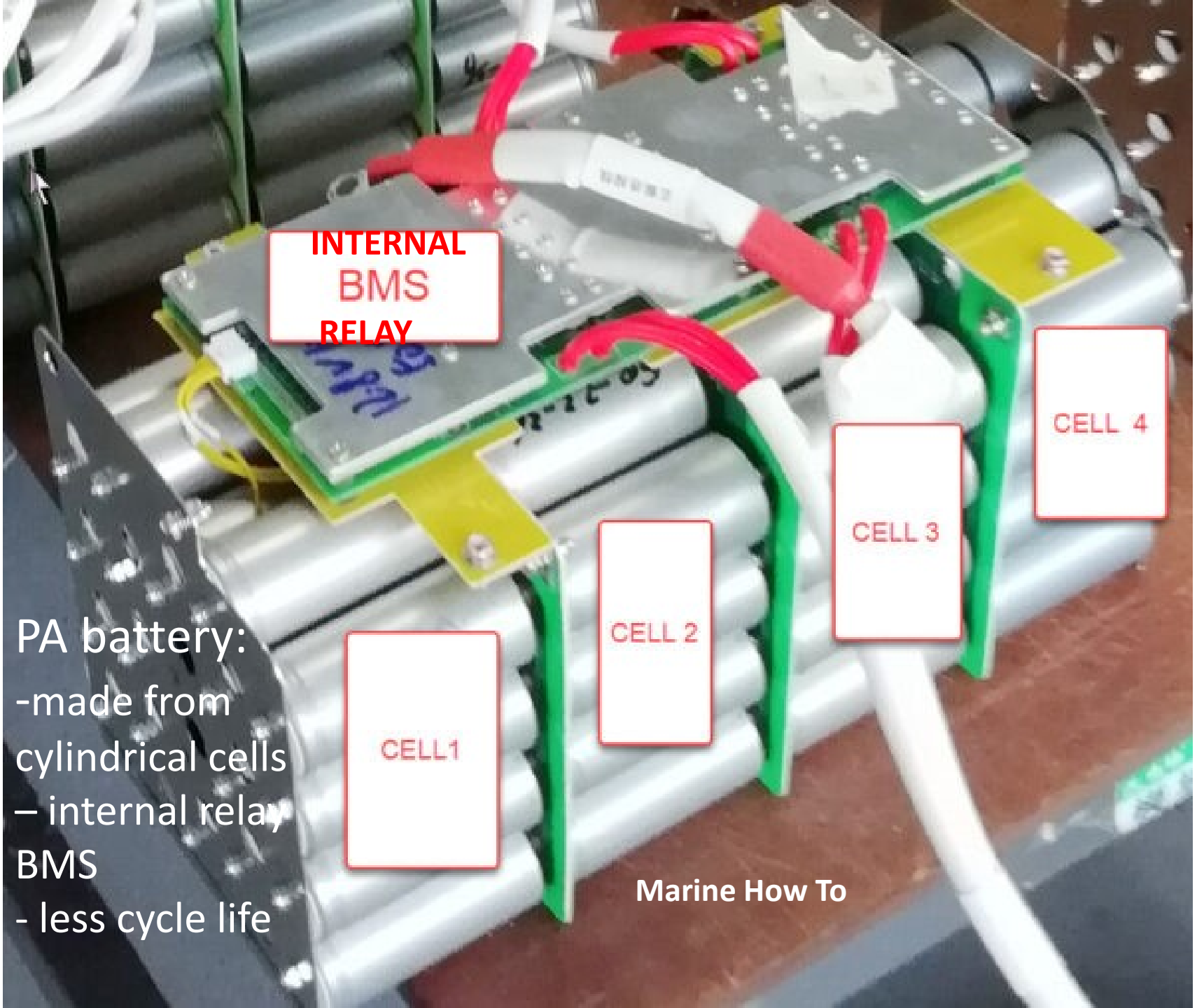
4S2P

Nordkyn Design

Battery University- 4S2P is TWO 4S batts in parallel and is not the best choice for cruisers (balance, 2BMS)

LFP Batteries and Cylindrical Cells

- **Preassembled (PA) batteries, aka DropIns**
  - **Much more expensive for quality eqpt**
  - **If sealed hard to TShoot and repair at sea**
  - **Less communications and BMS options**
  - **Expensive to carry spare**
  - **Paid electrician favorite- more profit, less complexity & install time**
  - **Marginal for use in a marine cruising install**
  - If use multiple batteries- balance problems
  - High amperage/heat, enclosed/sealed BMS
  - Better for fishing and nearshore boats
- **18650 cylindrical cells**
  - **Not a good choice for marine install**
  - No or minimal parameter info available
  - Spot welds subject to vibration damage
  - Impossible to find and repair cell problems


INTERNAL
BMS
RELAY
CELL 4
CELL 3
CELL 2
CELL1
PA battery:
-made from cylindrical cells
– internal relay BMS
- less cycle life
Marine How To

ReLion 300 Ahr LFP PA Battery

High quality, but sealed, 18650 cells, 3500 cycles, no external comms, 10 year warranty $2500!

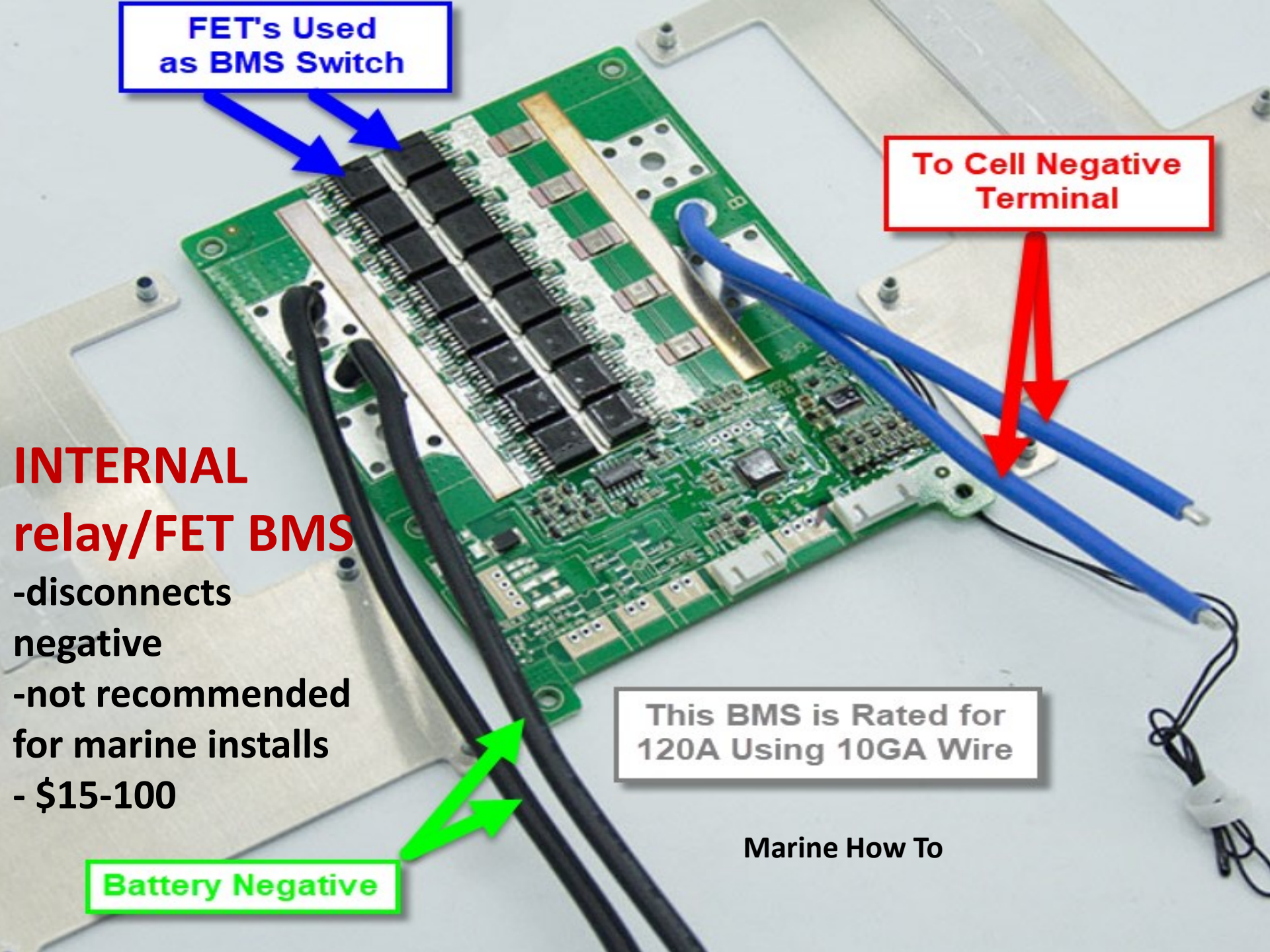

Epoch 300 Ahr
LFP PA Battery
High quality, BlueTooth, 6000 cycles, heated, MHT recommended, 11 year warranty $1200
EPOCH
LiFePO4
12.8V
300Ah
Nomadic Supply Compan


300 ahr RJ PA
Battery
Newer RJ model, accessible internal prismatic cells, 5 year warranty, JBD BMS, 5000 cycles
$800

Typical Chinese LFP factory production line

Battery Management Systems

- **Functions-**
  1. **Control HVD/LVD at cell level**
  2. **Monitors & communicates cell parameters**
  3. **Balances cells to millivolt level**
- **Two basic types:**
  - **EXTERNAL Relay- uses external relays, preferred for marine installs, more flexible eqpt choice, safer**
  - **INTERNAL Relay- uses internal Mosfet relays, may have heat, high amp, batt disconnect & communications issues**
- **Communications:**
  - **WiFi- to most any device worldwide via internet**
  - **Bluetooth- to same devices but nearby only**
  - **Wired- to some external display**
- **Many options $15-$600 US**
- **Marine best practice: external relay, $100+**


FET's Used as BMS Switch
To Cell Negative Terminal
INTERNAL relay/FET BMS
-disconnects negative
-not recommended for marine installs
- $15-100
This BMS is Rated for 120A Using 10GA Wire
Battery Negative
Marine How To

Daly BMS

Typical INTERNAL relay, but <u>not MHT recommended</u>, Chinese ~$50-$200

DALY BMS Li-Ion 17s 60v 30A 40A 50A 60A 100A 120A 150A 200A 250A 300A 4
500A bms mit balance funktion und FAN

Zusätzlicher 2 % Rabatt

★★★★★ 4.8 ⌄ 5 Bewertungen 43 Bestellungen

US $130.00 ~~US $200.00~~ 35% günstiger

US $15.00 günstiger Shop-Coupon Holen Sie sich Coupons

Farbe: 200A with Fan

Orion Jr External Relay BMS

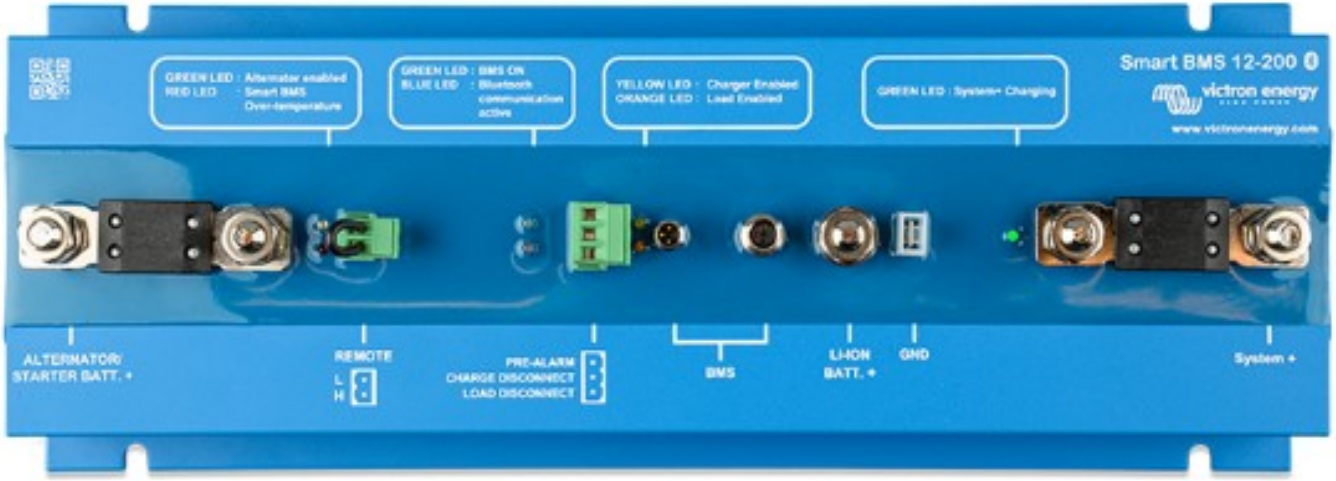
EXTERNAL relay, Bluetooth, 16 series cells max, 150ma passive balancing, 4 outputs, logging, recommended but very expensive $450-$650+,

REC Active BMS

Perfect solution for substituting 12 V lead batteries with lithium cells. Covering all necessary protections REC Active BMS is the first of its kind on the market with active cell balancing.

EXTERNAL relay, 2a active balancing, 4 outputs, 4S cells max, alarm, Wifi, logging, recommended but expensive $330-$560 US,

Victron Internal Control
Smart BMS 12/100-200

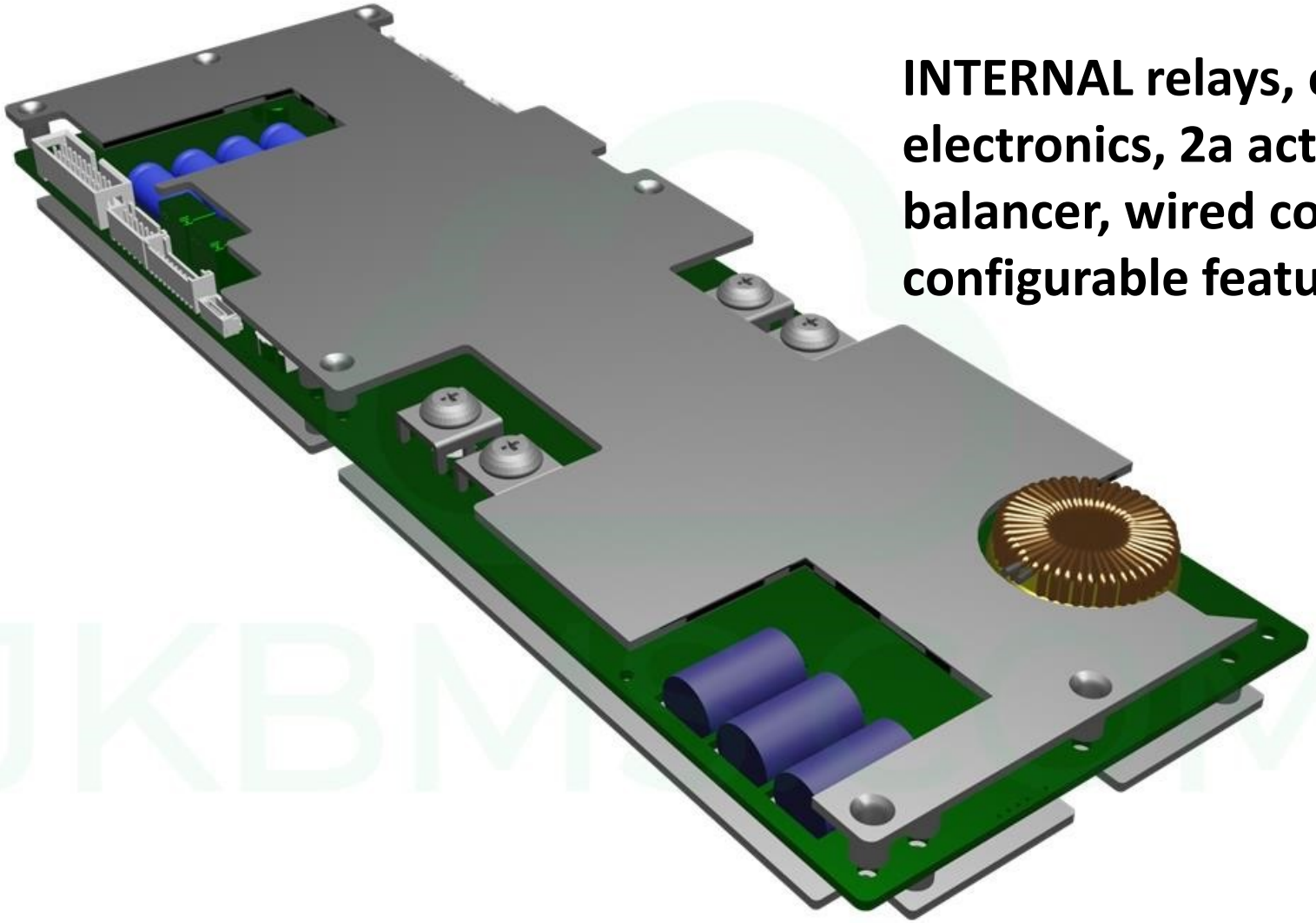


BMS for Victron PA batts, INTERNAL relay, Bluetooth, pre-disconnect alarm, alt current limiting & control, start batt control, remote, quality $175-245+

BMS 123 Smart Gen 3

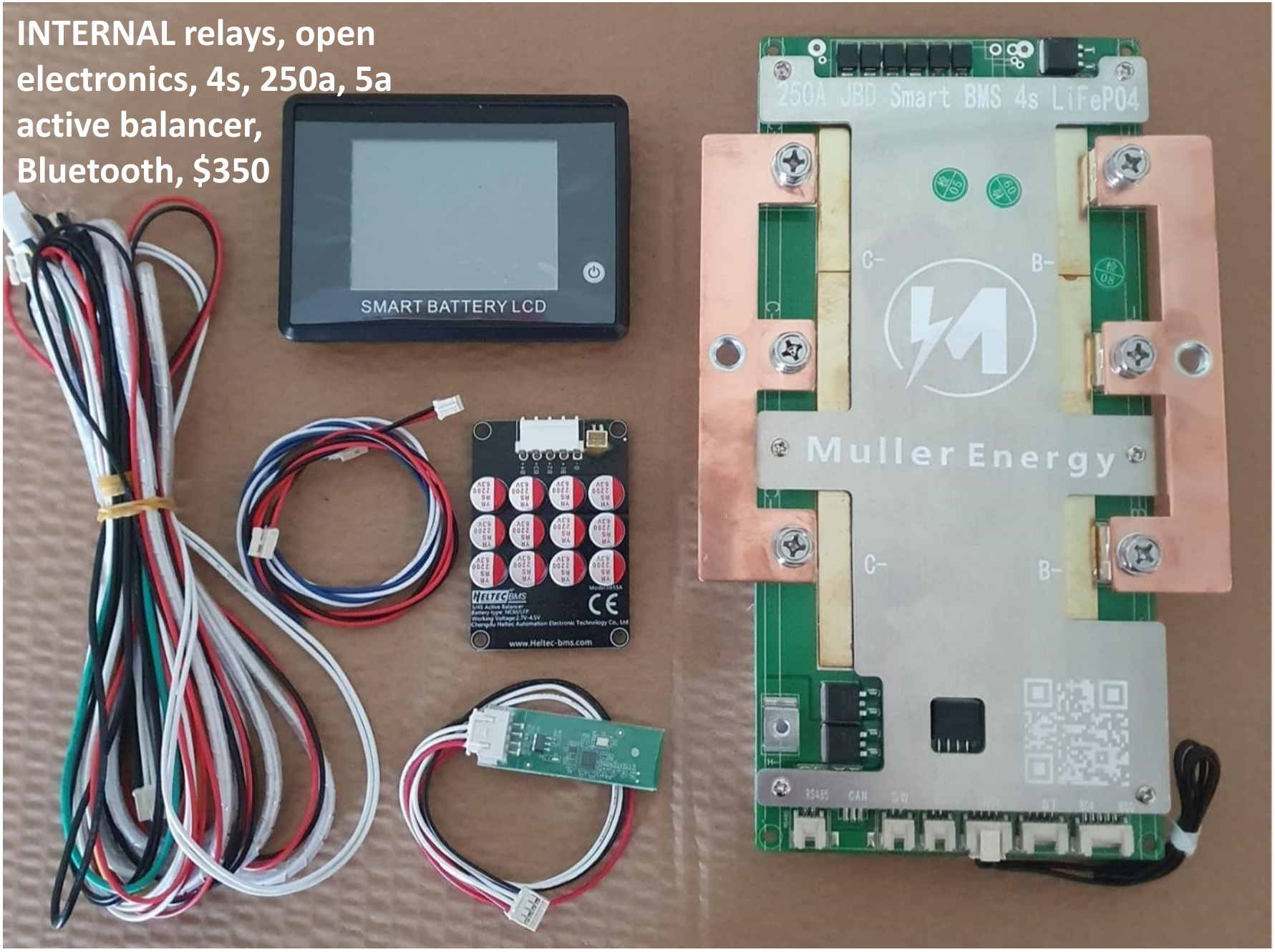
INTERNAL relays, multiple open electronic boards, a negative issue in salt air

JK BMS

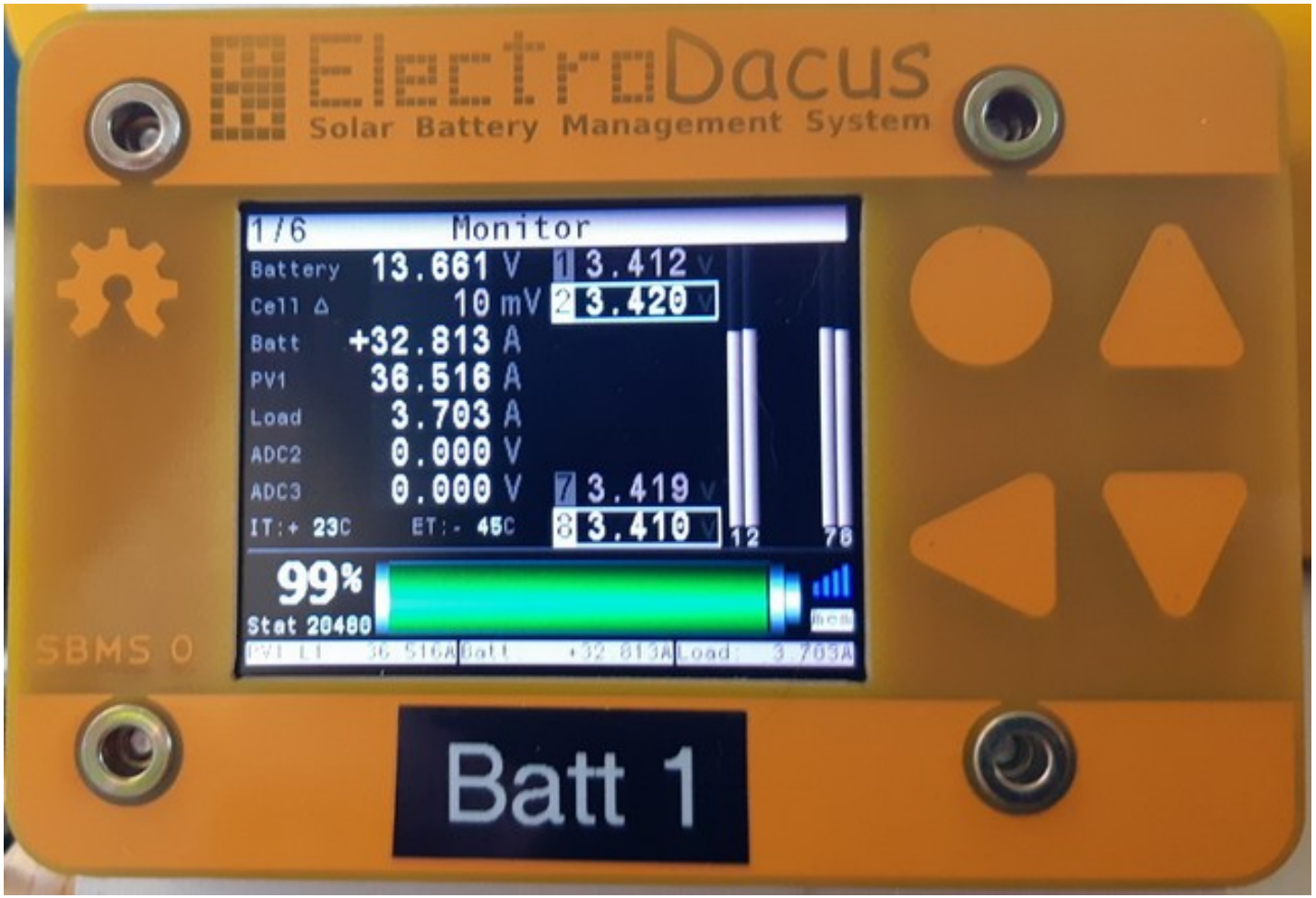


INTERNAL relays, open electronics, 2a active balancer, wired comms, configurable features

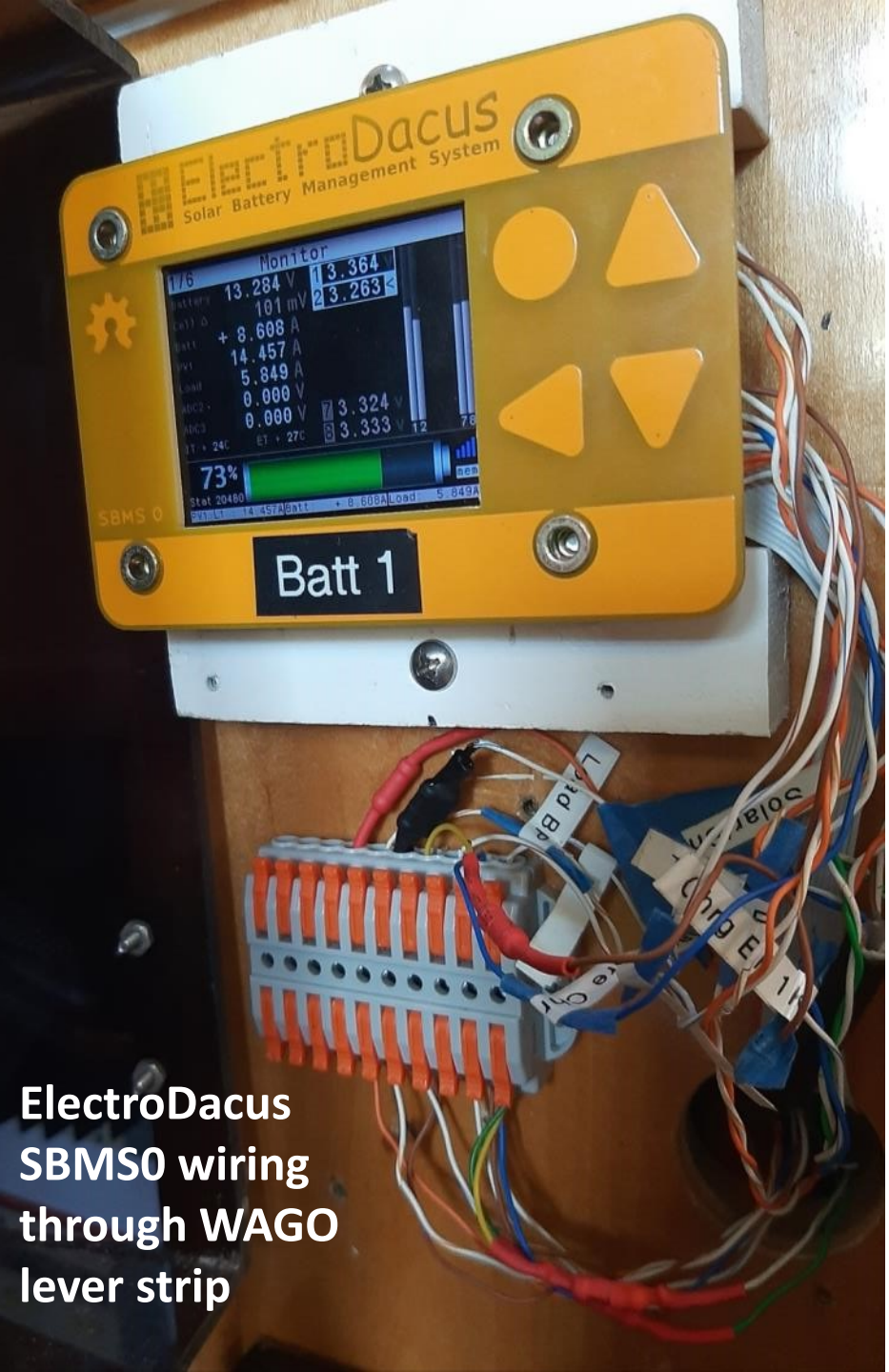
Muller/Jiabada/JBD BMS



ElectroDacus SBMS0 BMS



EXTERNAL relay, 4 outputs, 200ma passive balancer, Wifi, extensive logging, good but small display, small Canadian company, great forum, forever warranty, quality SPaws choice ~$150



ElectroDacus SBMS0 wiring through WAGO lever strip

Mounted in acrylic box

Solar

- **Tropics cruising should be primary charge source**
- **~$4 US a watt in 2000, now ~$.50 US per watt**
- **Minimum for tropics cruising buy 5x daily ahr usage in watts, 150 ahrs/day = 750 watts min solar**
- **Soft panels- relatively short service life, vibration issues, less efficient & more expensive**
- **Wire PVs in parallel not series if chance of shading**
- Consider 24v vs 12v nominal voltage
- Mount lengthwise for best shading avoidance
- Strong rail mounts best for high wind protection
- Mount flat no shade

Solar Panels

Cat mounting:

4 x 200w 24v
-total 800w, 50a,
- >200ahr/day
-no shading!
-on rail mounts
-wired in parallel
-oriented fore/aft
-60a MPPT
-easy on a cat

Monohull panel mounting options- 650 watts

Arch rotating panel mounting

DIY stern railing mount

Solar Controllers

- **If 12v system & 24v panels:**
  - **need MPPT for voltage conversion**
  - **MPPT efficiency better than PWM**
- **If hard shading possible:**
  - **multiple MPPTs best for multiple panels**
  - **wire panels in parallel not series**
- **Buy only fully programmable MPPTs including absorption duration**
- Morningstar, Victron, Outback, Midnight & many others LFP acceptable
- If 12v panels & 12v system can use without controller

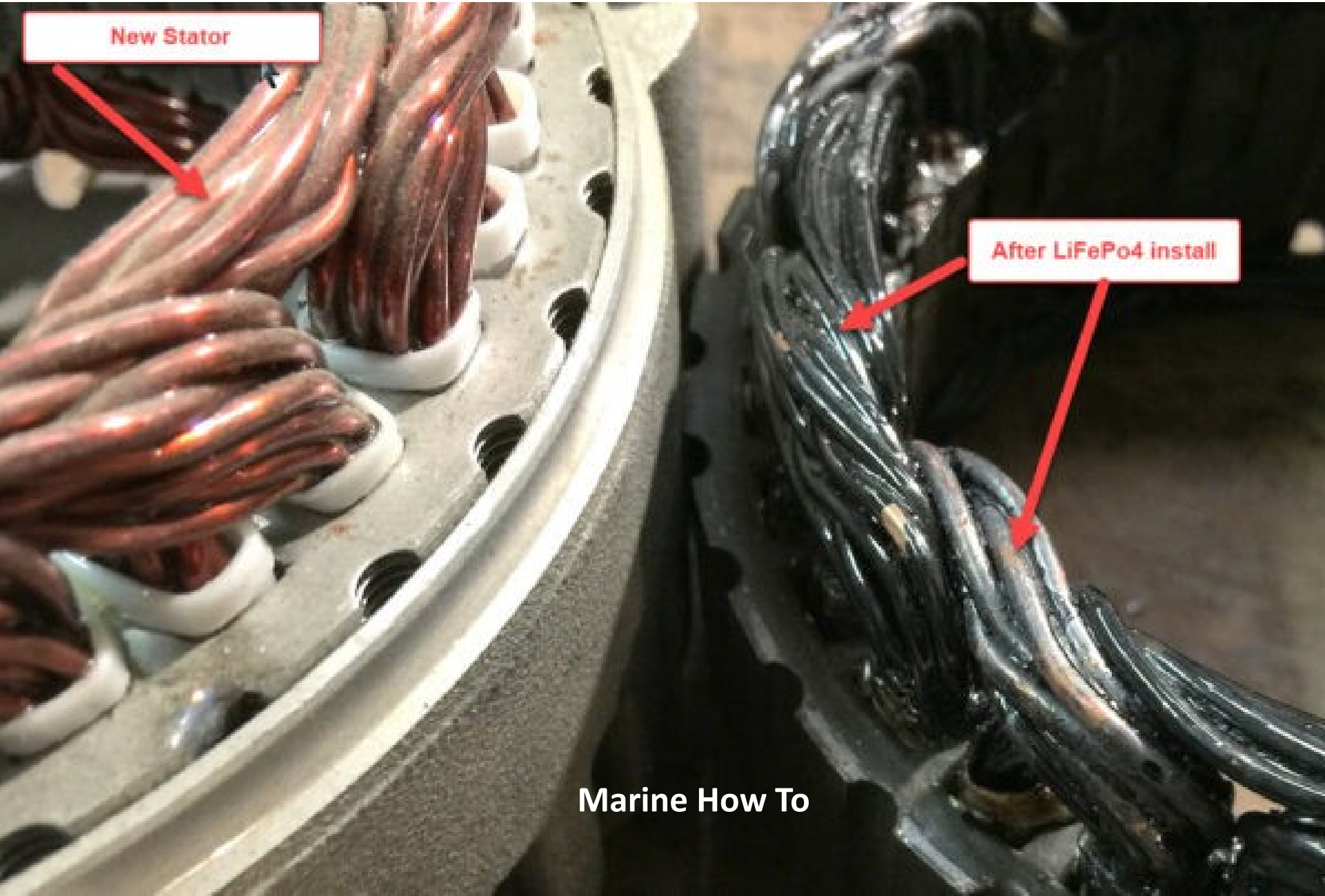
Morningstar TriStar 60a MPPT controller

Excellent, robust and fully programmable, US solar company, remote ~$700

Alternators & Regulators

- **Very INEFFICIENT charging compared to solar (50x cost of solar charging)**
- **External regulator much better than internal, especially for cruising using LFP**
- **Regulator must be fully programmable including absorption duration, WakeSpeed 500, Balmar 614/618 or Zeus (or other older regs?)**
- **Three important issues:**
  - **Need way to reduce max alternator output or LFP batteries will damage most alts- programmable external regulator**
  - **Protection from sudden load dump/batt disconnect- Balmar or Sterling Alternator Protection Module (APM)**
  - **Must have way to charge house and start batts separately**
- Dual or serpentine alt belts needed if output over 100a
- Alts over 90a use larger diodes

Alternator stator damage from high output over heating



WS500 external regulator alternator.

Fully adjustable, not cheap, but best there is ~$500+, VSR predecessor discount

Latest Balmar MC-618 external regulator, also 614 & ARS-5

Less expensive & good value, but worth comparing features with Wakespeed ~$350

May be programmable for LFP, Contact Balmar ~$250

New Arco Zeus Alternator Regulator

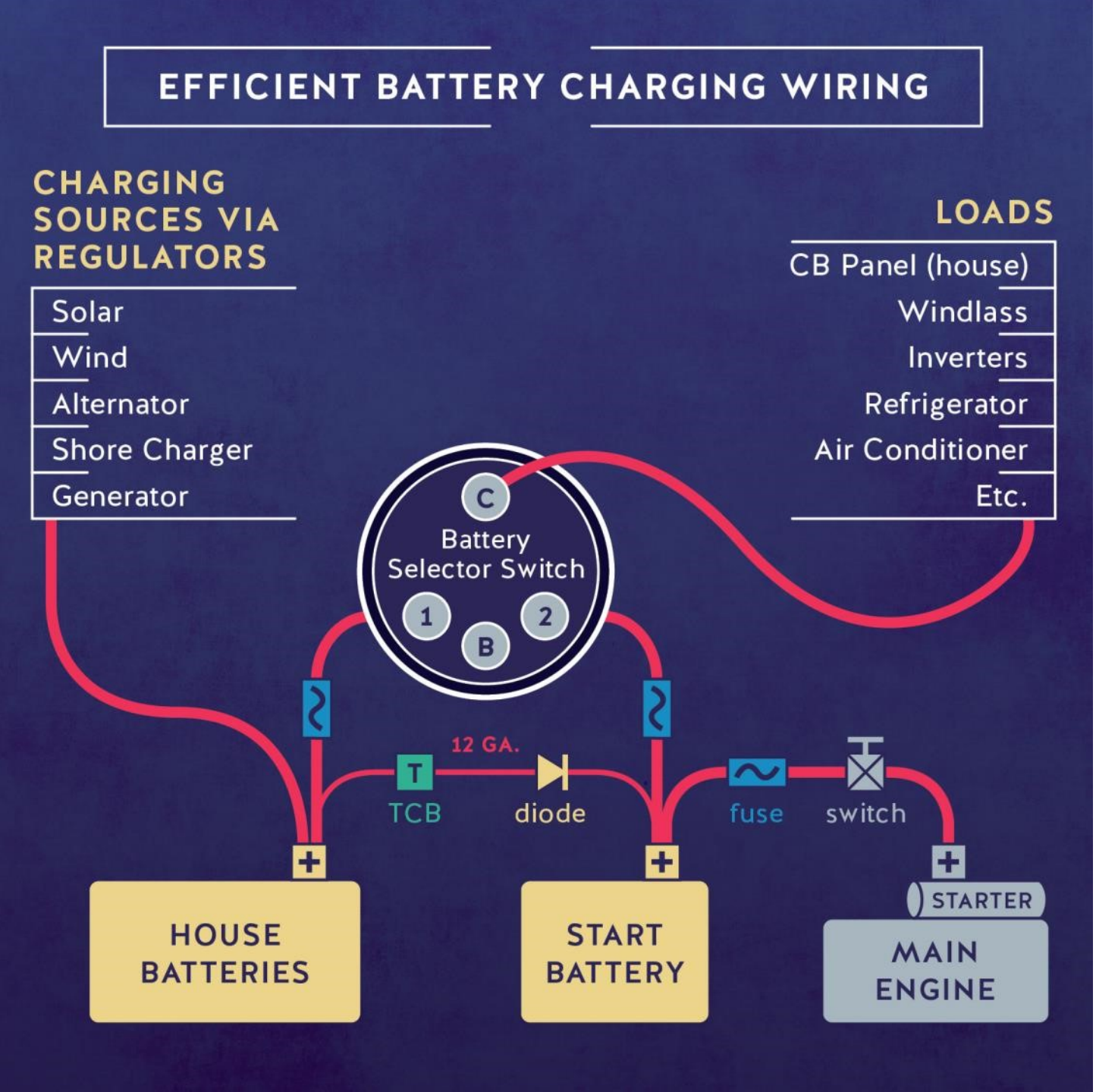
New this year, external regulator, 'high energy', Bluetooth, fully programmable, $800!

Alternator Protection Module/Device

Balmar APM
~$80

Sterling APD,
alarm circuit ~$80

Meets ISO 16750-2 for Load Dump Protection
Meets ISO 7637-2 for Surge Protection



Charging a LA starter battery

-Trickle charge LA starter batt off LFP house bank
-Diode, TCB, 12ga wire
-No need for costly and inefficient DC to DC charger or expensive electronics!
-See SPaws SSCA CW article.

Thermal CB & Diode- <$20

No need for expensive electronic Combiners, Isolators, Eliminators, DC to DC chargers, etc

Heat activated circuit breaker

One way & current limiting device

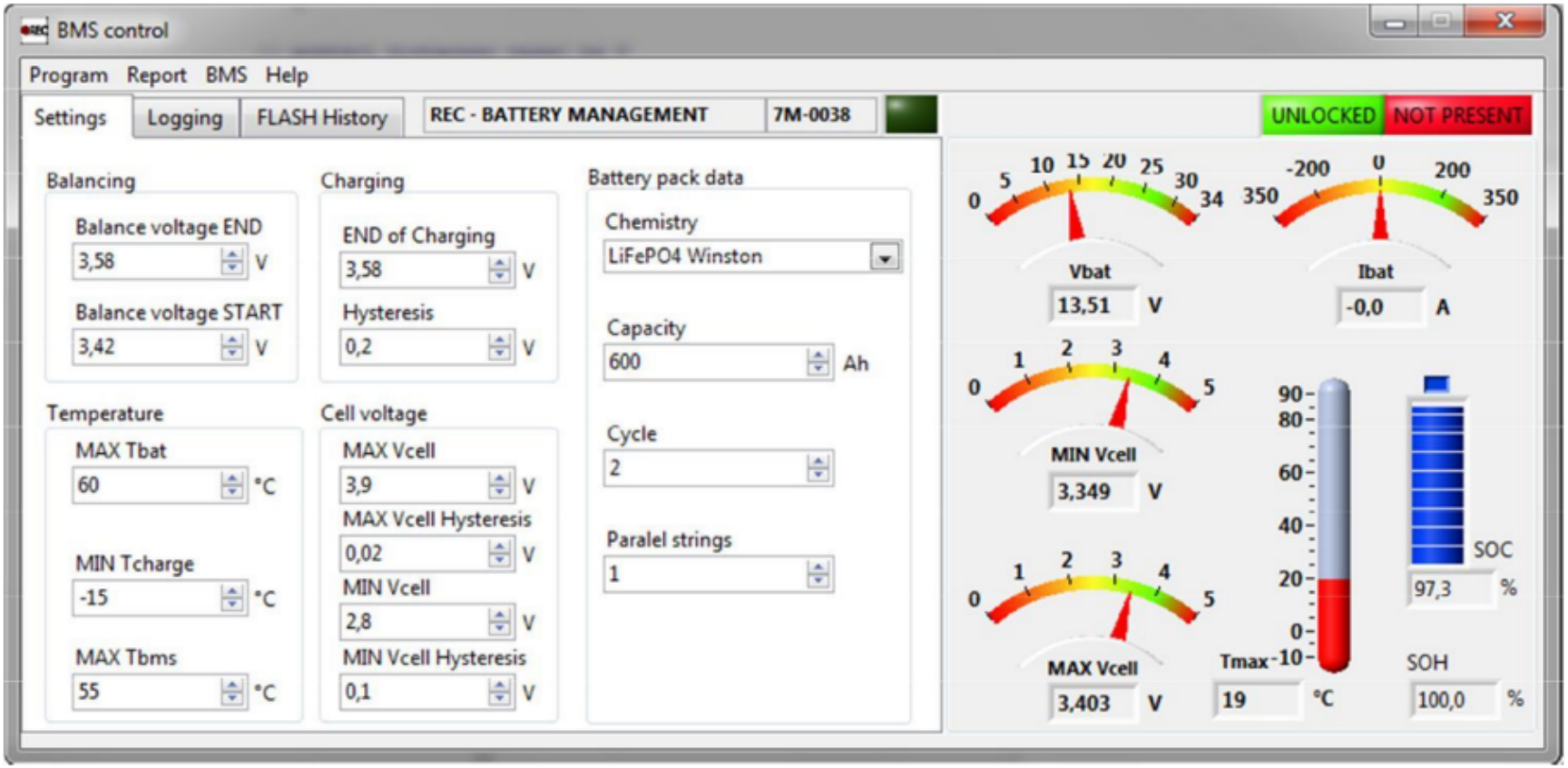
Monitors & Displays

- BMS must accurately transmit all parameters and log historical info
- View all CELL, not just total BATT, parameters
- 3 BMS comms options:
    - WiFi- visible onboard navigation computer screen AND internet worldwide remotely
    - Bluetooth- visible only on nearby devices like cell phones
    - Hard wired onboard to monitor

Monitors

Our old LA Link 2000 batt display, monitors only TOTAL BATT, not BMS or CELLS info, now backup

REC BMS LFP Display

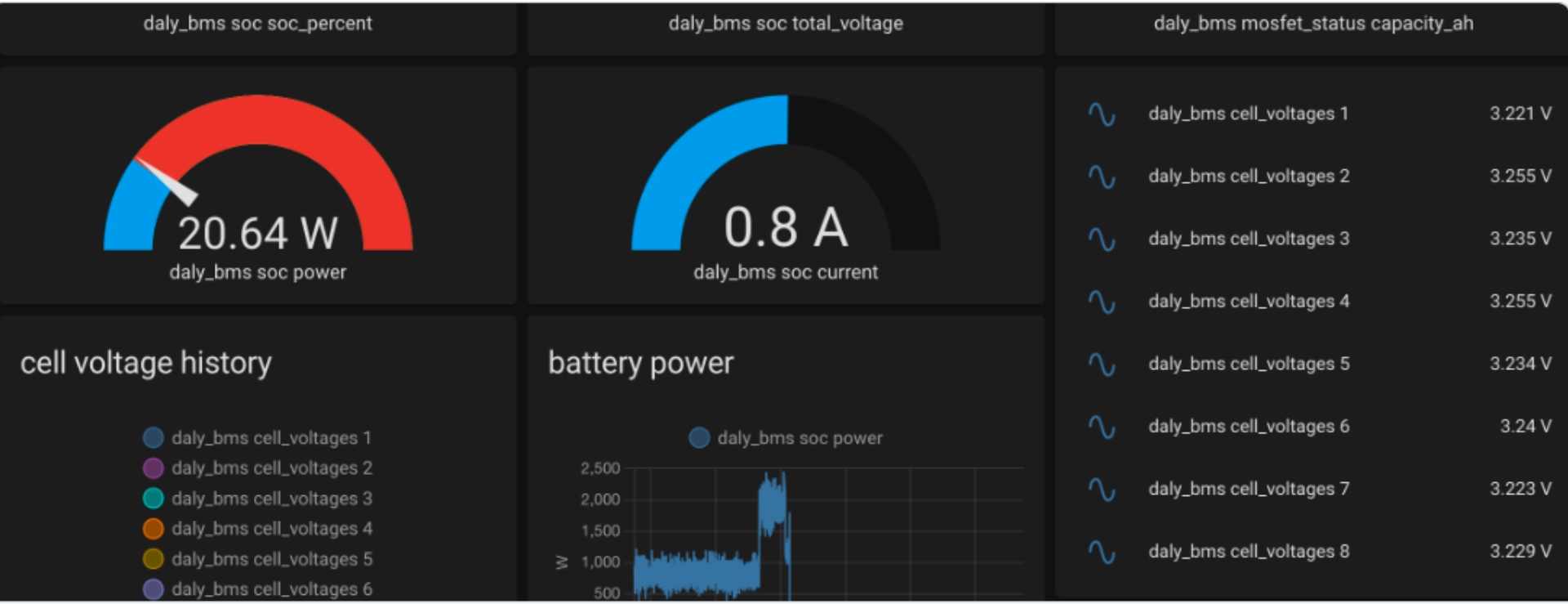


Better, but a bit busy, min & max cell volts, speedo gages

Orion Jr BlueTooth Display Unit

No graphs and an additional $119

JK/Daly BMS Display

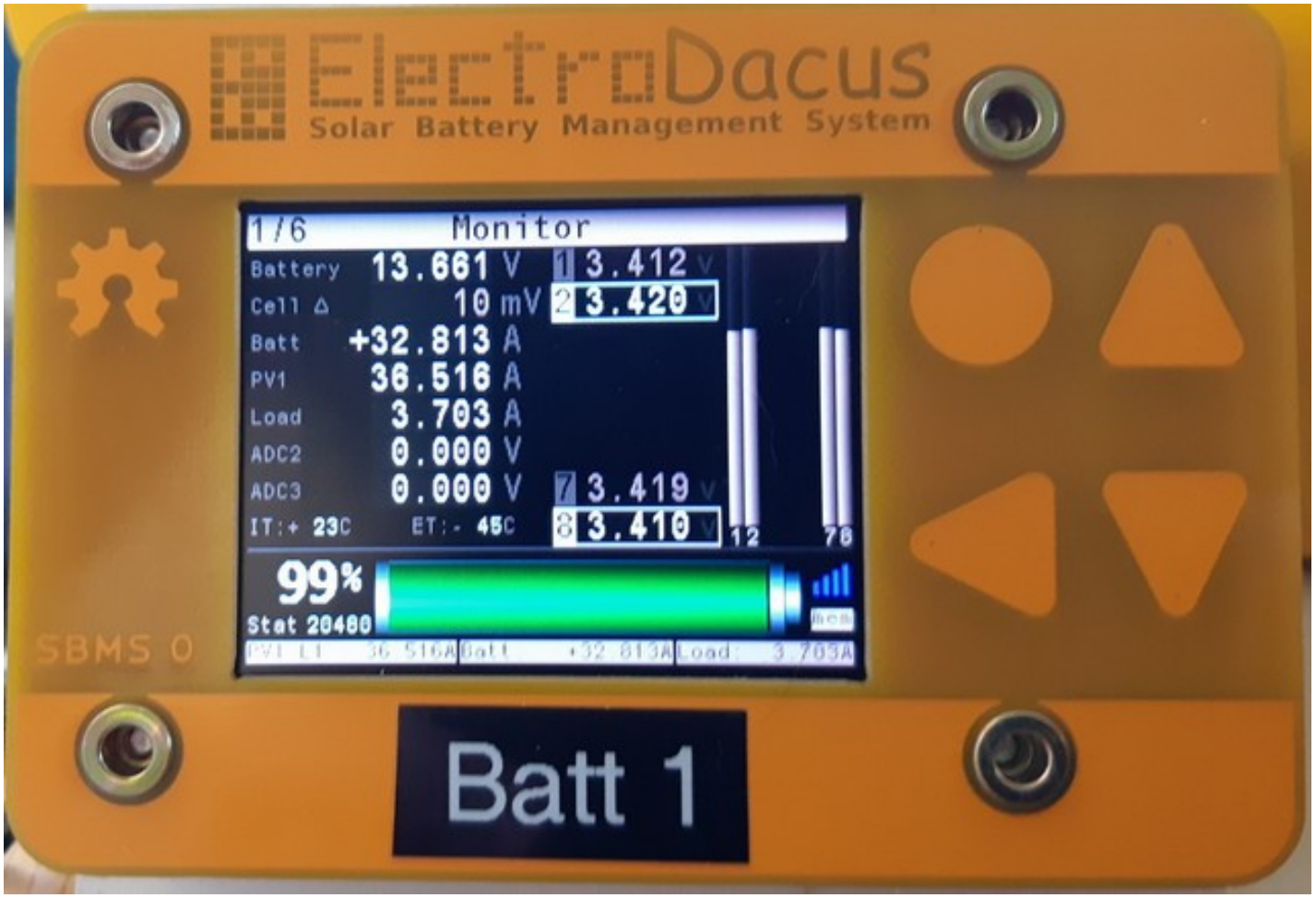


Not much info, not very intuitive or user friendly

JBD Display Module

Wired, separate display module

ElectroDacus SBMS0 BMS Display



Small display with most useful parameters on home page.
Details and parameter adjustments on additional pages.

Electrodacus 5/5/2021, 11:27:27 AM

13.67 Volts -0.1 Ah

99 % SOC Temp 80 F

Cell 1 3.416 V
Cell 2 3.421 V
Cell 3 3.416 V
Cell 4 3.413 V
Cell Delta 8 mV

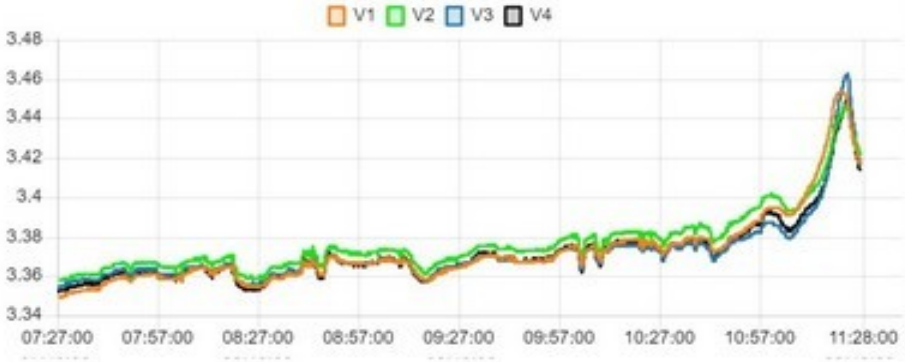
Charge 0 Amps
Battery -2.65 Amps
Load 2.65 Amps

SBMS Temp°F 76

LED's

Charge Enable			Loads Enable
End of Charge			LV Warn
Over Voltage			Under Voltage
OV Lock			UV Lock
			Low V Cutoff

Cells (V)



Delta Chart

Daily Highs and Lows

Highest Battery **13.37 V**

Lowest Battery **13.05 V**

Highest SOC **70 %**

Lowest SOC **68 %**

Highest Cell **3.419 V**

Lowest Cell **3.179 V**

Max Ah **-174.5 Ah**

Max PV Output **30.771 Amps**

Max Load **14.268 Amps**

Amps

Alternator Status

Stbd Alt State Off

Port Alt State Off

Solar State **MPPT**

Solar V Setpoint **13.80**

Solar V **13.39**

Solar Amps **21.3**

Solar Faults **None**

Solar Alarms **None**

Open Source Node Red custom computer display- by Sherry


Electrodacus
4/30/2023, 6:09:08 PM
Battery
13.29 Volts
-7.6 Ah
98 % SOC
Temp 79 F
Cells
Cell 1
3.325 V
Cell 2
3.327 V
Cell 3
3.323 V
Cell 4
3.318 V
Cell Delta
9 mV
Cell Voltages
LED's
Charge Enable
Loads Enable
End of Charge
LV Warn
Over Voltage
Under Voltage
OV Lock
UV Lock
Low V Cutoff
Cells (V)
Current Flows
Charge
1.69 Amps
Battery
-2.49 Amps
Load
-4.18 Amps
SBMS Temp°F 70
Delta Chart
Daily Highs and Lows
Highest Battery 13.78 V
Lowest Battery 13.26 V
Highest SOC 100 %
Amps
Charging Status
Stbd Alt State Off
Port Alt State Off
Solar State Float
xantrex
Link 2000
Battery
Control
Setup
Volts
Amps
A hrs
Time
Equalize
Status: AC In Charge Accept Float
vesperMarine
NMEA
AIS + GPS
Computer
Our new Mini PC N5105 nav computer ~$170, display ~$75, & keyboard/mouse. Windows 11, low amp draw, 12v adaptable.

More Equipment Options

- Inverters
- Shore Chargers
- Relays
- Shunts
- Fuses & CBs
- Balancers
- Switches
- Wire and terminals
- Tools

Inverters

- **Best to buy Pure Sine Wave not Modified Sine Wave**
- **For LFP buy SEPARATE Inverter and Shore Charger so can turn off separately**
- **Consider installing small inverter (5-600 watt) for daily electronics charging, on 24 hours**
- **Less expensive quality options besides marine**
- Display & remote nice features
- Ensure on/off switch can be wired for HVD
- Buy quality- Giandel, Victron, many others
- Read reviews and watch Utubes for relative quality
- **SPaws inverter article on Ocean Navigator & our website under Articles**


Giandel 2200w PSW Inverter
POWER
POWER
FAULT
Input(v)
Output(kw)
Output(w)
Full
14V
13V
12V
11V
GEL
LEAD
ACID
USB
Remote On/Off
Power
Display, remote, solar
controller, excellent
quality, reasonable price,
recommended ~$350

600w PSW inverter- for daily use device charging ~$100

Our Sterling ProCharge Ultra Shore Charger

-International capable

-Not LFP friendly

-Can’t be adjusted for less than one hour absorption!

-Little used now

~$600

Relays, Circuit Breakers & Shunts

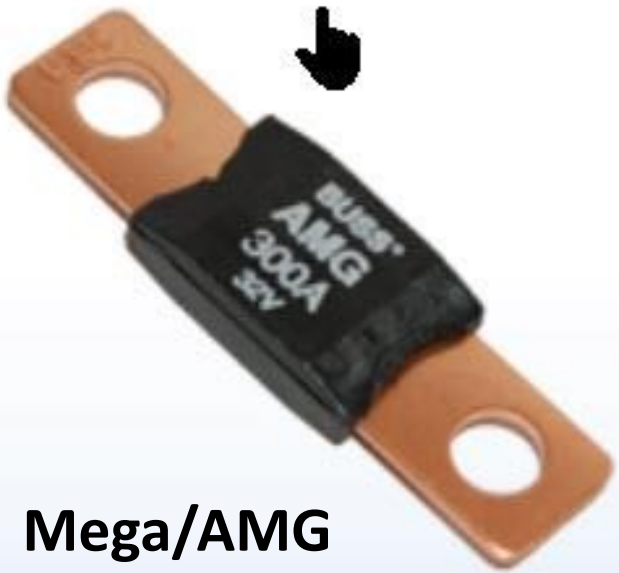
FOTEK charge relay, 5ma draw

Blue Seas 500a buss relay, switch, remote, 7ma

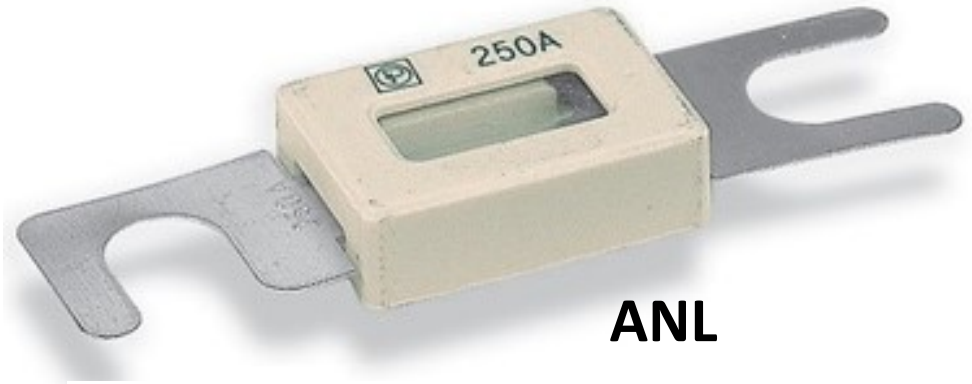
Reidon shunts 100mv, 200a

Blue Seas surface mount thermal CB, switch 25-150a

High Amp Fuses



Mega/AMG



ANL

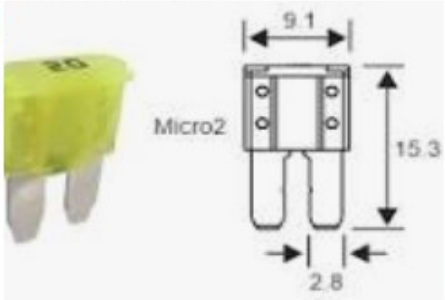
Class T main battery fuse, 20,000a AIC!

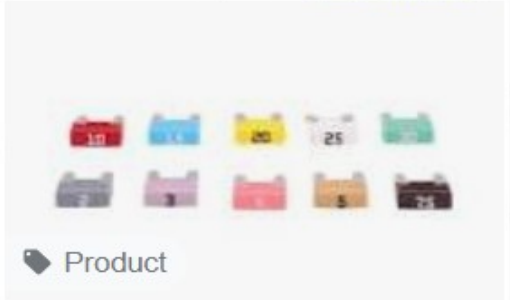
MRBF

Small fuses

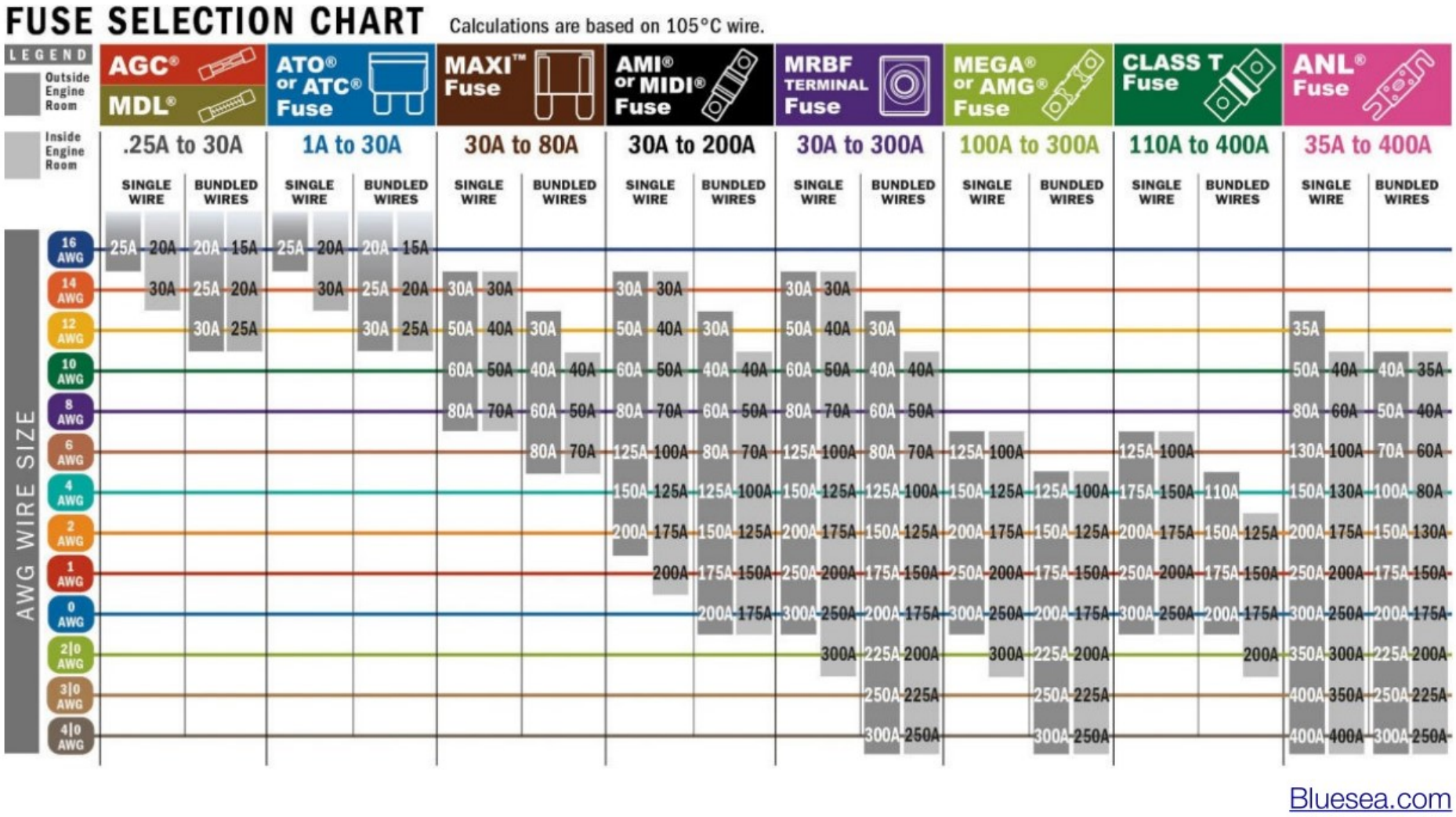
many types, sizes and holders, carry spares

micro | low profile | blade | car | fuse box | 10 amp





Fuse Selection by Type & Wire Size



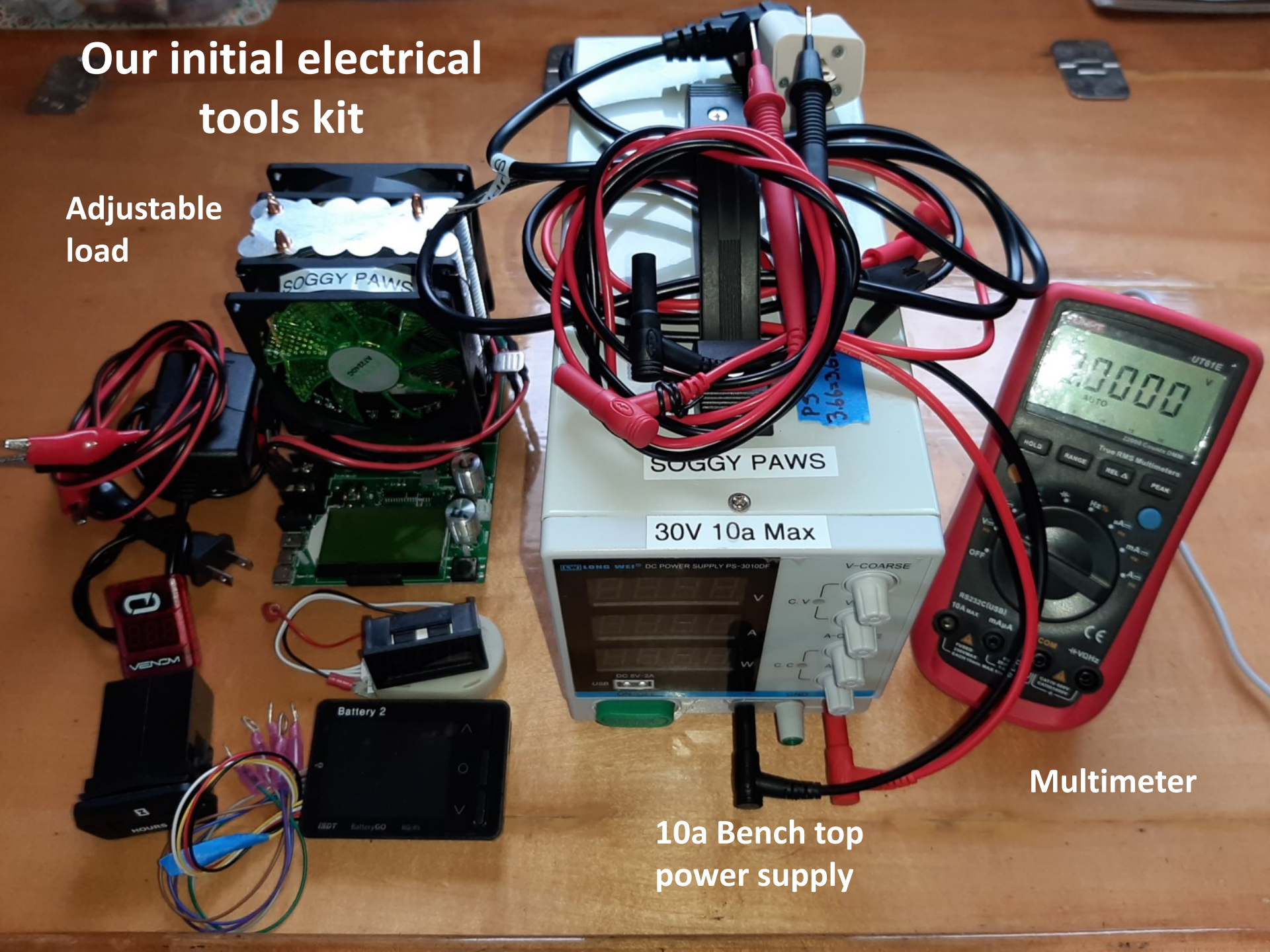
Bluesea.com

Quality marine Anchor wire end connectors, terminals & lugs, don’t use automotive grade!

Tools & Spares List

- **Cruisers can never have too many tools!**
- **UNI-T UT61E very accurate multimeter**
- **40a ZKETECH battery tester & load for capacity testing and top balancing**
- **Shanghai Fossi TR1035+ resistance tester**
- Wire crimper & stripper for 12-24 gage wire
- Crimper for large wire terminals to 2/0
- Spare cells, BMS, other components if remote cruise
- UNI-T UT210E clamp multimeter
- Various size quality wire terminals & heat shrink tubing
- Tinned wire of various sizes 2/0-24 ga
- **More complete list on SPaws website Workshop**

Our initial electrical tools kit



UNI-T UT61E very accurate multimeter

Accurate to one MV, true RMS, 22000 counts*, logging function, good option to expensive Flukes, about $75

***counts = max value displayed- higher = wider range, better resolution**

Klein MM4400 Multimeter

Good quality, accuracy? $50


Bolt cutter
and stripper
Bolt cutter
and stripper
Wire nipper
Stripper
Useful LFP install
pliers, buy quality,
but no need to buy
pro/expensive
models
Cable cutter
Crimper

Cable Lug Terminal Crimpers: need #8-2/0 capable

Greenlee K05 Synchro ~$250

HYCLAT hydraulic lug crimper ~$50

Hammer lug crimper- NOT recommended

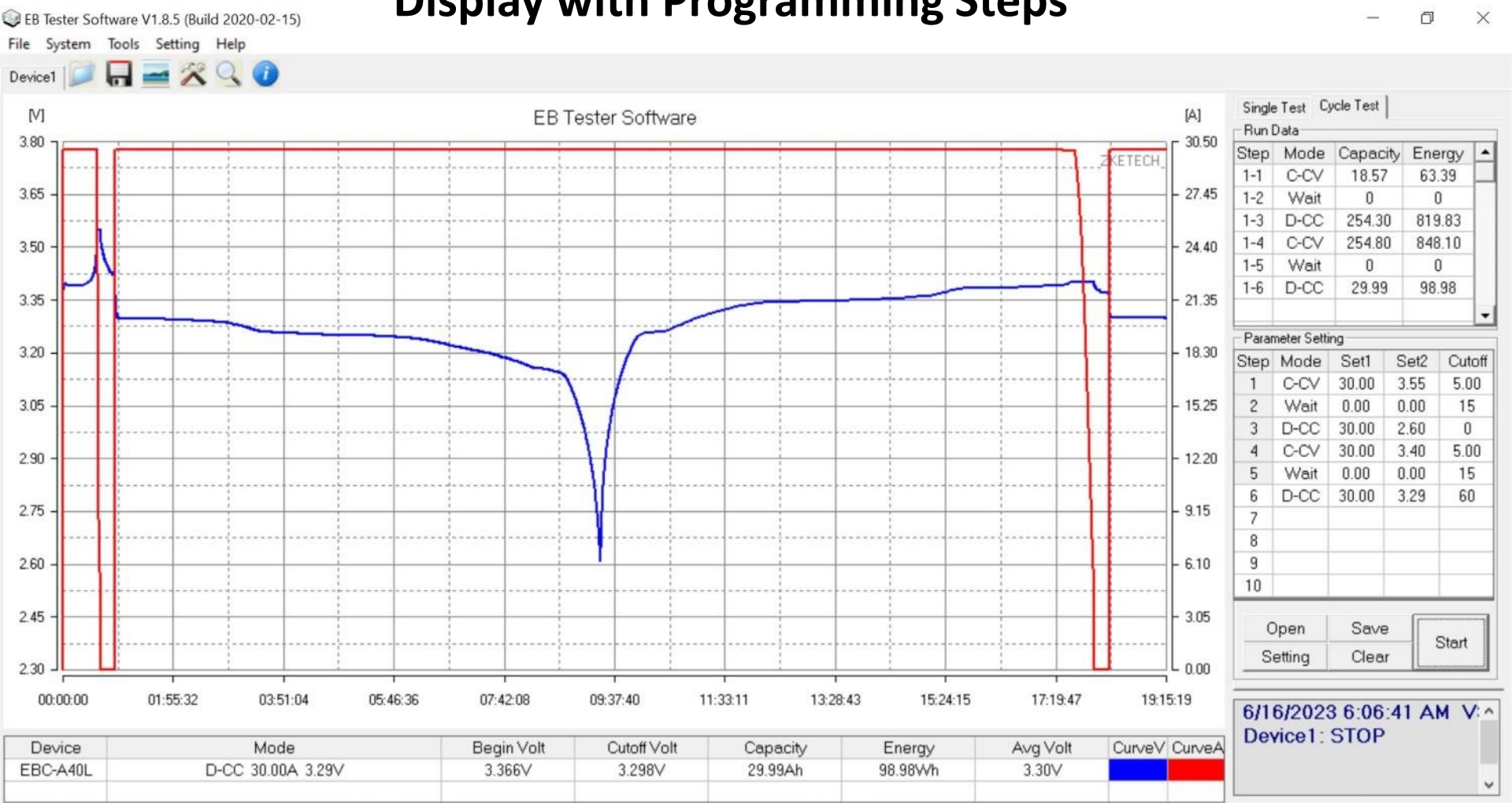
Rotating dies type, ~$30-50

Combo battery tester load tester, cell charger

- Good quality, reasonable price
- Top balance and capacity testing
- 5v x 40a max
- USB to computer
- Programmable
- Multiple work steps
- Voltage sensing
- Excellent!
- About $120 US

ZKETECH Voltage & Amp Graph

Display with Programming Steps



New Battery Internal Resistance Tester

TR1035 resistance tester- test cell IR & connection resistance, very useful, ~$30

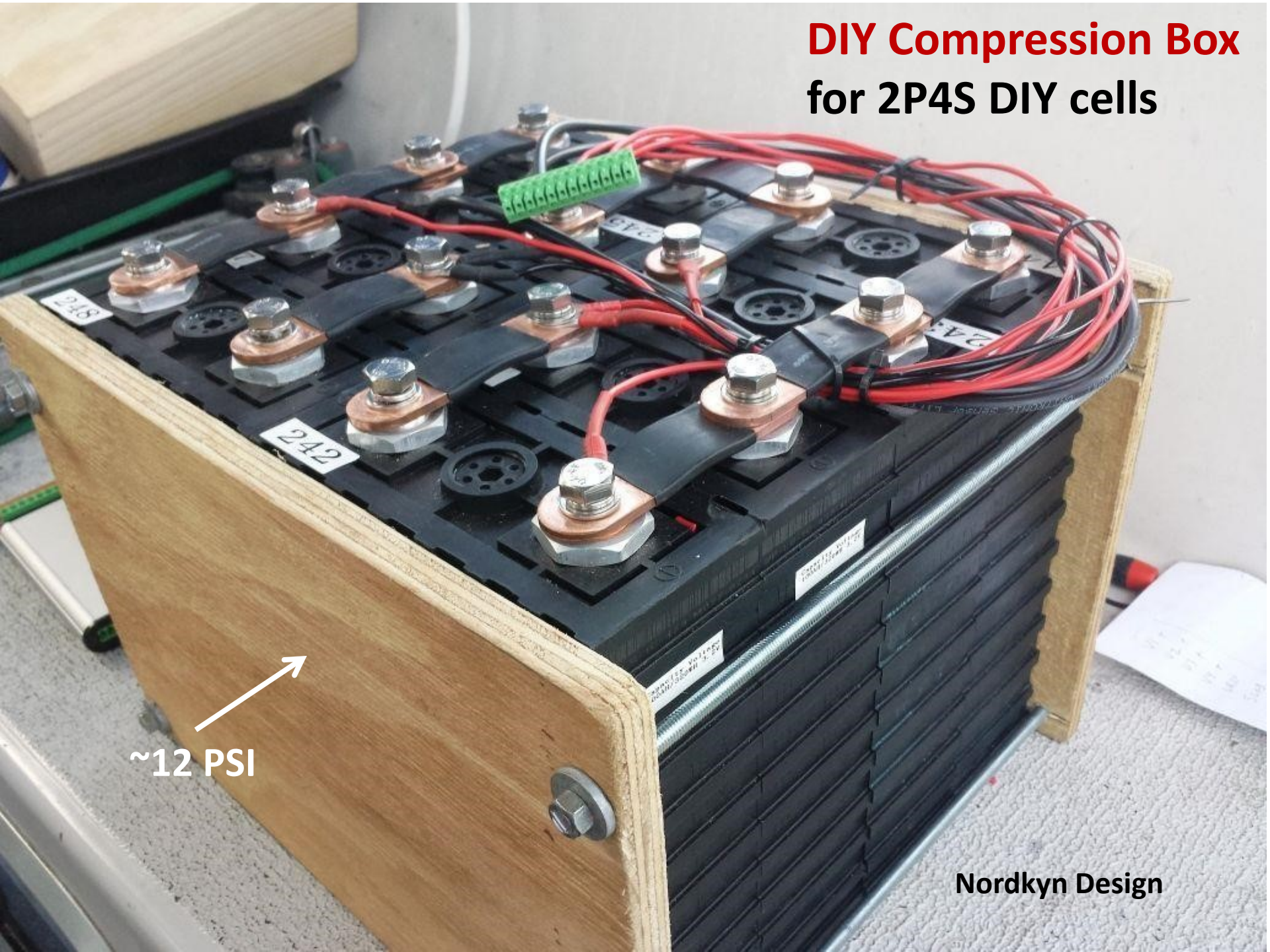
Corrosion Protection

Corrosion inhibitor penetrant for electrical components and circuit boards. Wet.

Moisture, thermal and electrical protective coating applied to circuit boards and components. Dries.

Enhances electrical and thermal conductivity for battery terminal connections, not dielectric

Insulates and protects from moisture small electrical crimps, liquid but dries


DIY Compression Box
for 2P4S DIY cells
~12 PSI
Nordkyn Design

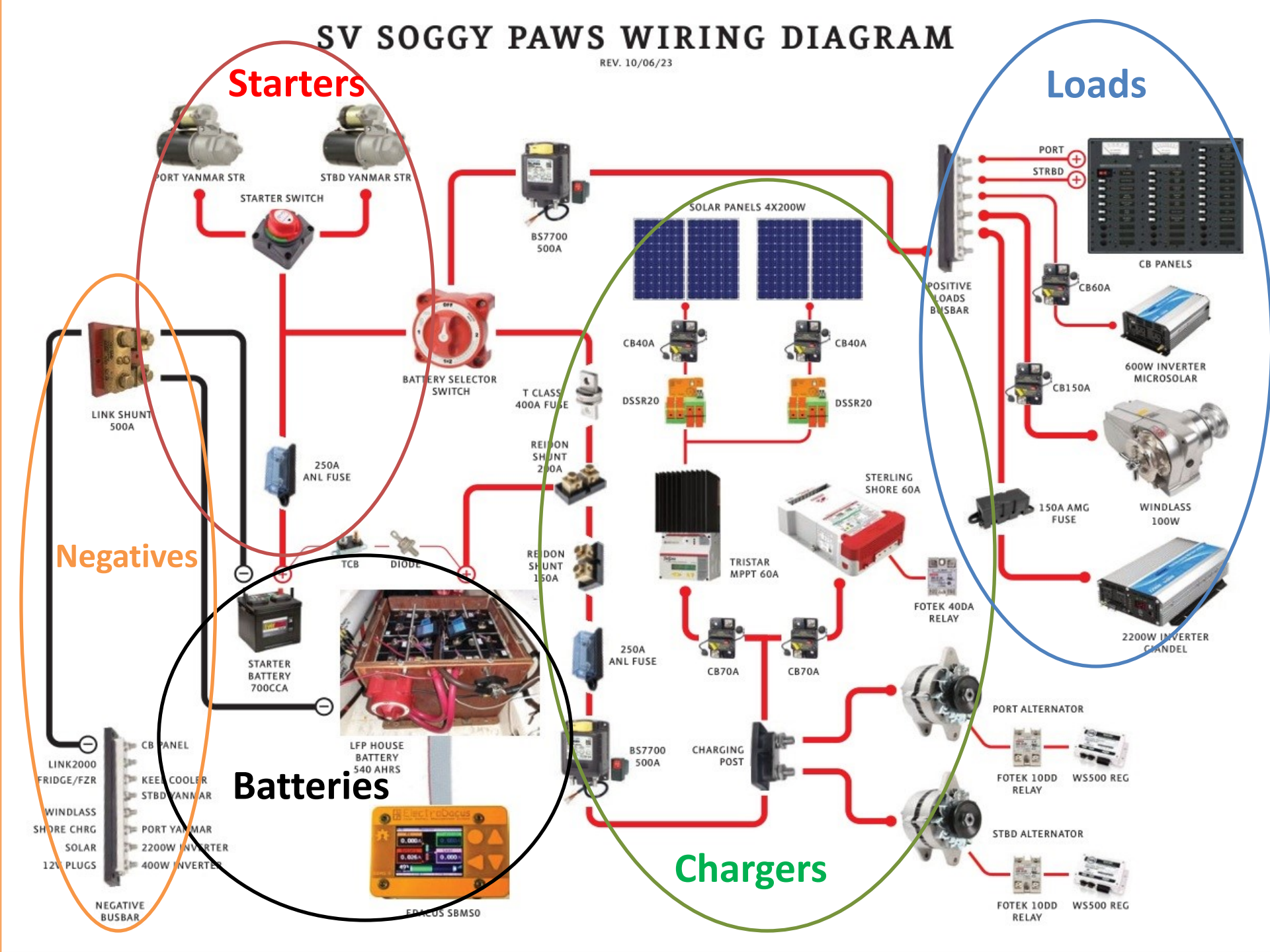
LFP bulging aluminum case cell

Marine
How To


Even Winston
plastic case cells
need compression
ElectroDacus

SV SOGGY PAWS WIRING DIAGRAM

REV. 10/06/23



Dave's Initial Prep Advice

- Study, Research & Plan before starting
- Read trusted resources, watch Utubes, Google questions
- If DIY study carefully & take your time to learn how
- Evaluate your existing layout/eqpt for LFP suitability
    - 2 busses, solar, alternators, chargers, inverters, monitor, space
- Acquire electrical skills- NOT ROCKET SCIENCE!
- If paid help be very careful:
  - Typical US labor cost $100-150+/hr, $150 x 8 hrs = $1200/day!!
  - Once underway lithium help hard to find!
  - 'Professional' means paid labor not 'expert'
  - How much LFP training, knowledge, experience?
  - Not all paid installers know LFP, ABYC requires only 1 hour course!
  - Ask what LFP equipment to be used?
  - Get firm quote for eqpt and labor
- Lots of ways to do LFP install, lots of opinions, be careful who you trust!
- Best plan is to study so you can make your own decisions.

Dave's Initial Install & Layout Advice

- Layout- make rough schematic
  - Cell arrangement P vs S, 12v = 4s or max 2P4S
  - Place all components on plan
  - See recent SPaws detailed wiring layout
- Order cells, equipment & tools
- Prep for Top Balance and Capacity test
- Build compression box & padding
- Wire for separate Charge and Load busses
- Check all charging equipment for adjustable bulk/absorb/float voltages
- How to charge start battery?
  - Trickle charge vs B to B and isolator, combiner, etc
- How to protect alternator?
  - Wire HVD to relay on ignition or field wire
  - Install a APD on alternator
  - Detune alternator output with external regulator

Dave's Solar & House Bank Capacity Advice

- **How much total capacity do you need?**
- **If no sun, need 3+ days holdover (3x daily usage)**
- **Example, if use 100 ahrs/day:**
  - **Need 300 ahrs useable +15% safety**
  - **Buy ~ 350 ahrs total capacity**
- **Solar minimum 5x daily usage in watts**
- Assumptions:
  - Our experience over 15 years in tropics
  - Desire to use only solar for charging
  - Alternator or generator backups only, no wind/water
  - MPPT solar controller
  - Minimum solar shading

Dave's Installation Advice Summary

- Use only accessible/replacable grade A cells, no PA batts
- Use one House bank batt instead of two or more
- Perform initial capacity test and top balance on all cells
- Make careful clean & tight cell connections
- Separate non LFP Start batt from House bank with Batt Selector Switch
- Long term store all LFP batts at mid SOC in relatively cool location
- Install all batts and BMS in cool location, not engine room
- Use quality external relay BMS like Electrodacus, Orion, Victron or REC:
  - Charge termination parameters fully adjustable
  - Wifi or BT display & logging capability
  - Customer support with forum & tech advice
  - Full minimum 1 year warranty
  - High/low temp disconnect
- Use quality reliable relays like Victron or Blue Seas for HVD/LVD buss control
- Use a cell compression box
- Install proper wiring size and fuse/CB protection
- If full time overseas cruising, carry substantial spares & tools
- Make all charging & load equipment controllable by BMS
- Use external regulator capable alternator controllable by BMS, less than 100 amp preferable so can use one belt & 30 a diodes
- Use proper quality tools for wiring and testing

Dave's Charge Parameter Advice

- **Some LA charge sources will have problems with LFP**
  - Charge termination should be based on V & A
  - BMS control can be viable solution, but not best solution
- **Bulk V**
  - Charge termination**13.8v**/3.45vpc - **14.2v**/3.55vpc, **14.0v**/3.5vpc ideal
  - Max 14.6v/3.65vpc, not desirable, cell damage above this
- **Charge & Absorb Amps**
  - **Charge daily at .2-.3C max**, occasional max 1C
  - **No/less absorb normally is better for cells**
  - Max absorb depends on voltage & current at charge termination
  - Chg term- 13.8v: max absorb (7.5a), 14.0v: max absorb (12.5a)
- **Float V**
  - **Goal: minimize time near 100% SOC,** but maximize capacity
  - **About 13.3v or less** so net PM amps keeps up with load
  - Above 13.6v/3.4vpc potential to reach 100% SOC & over charge

Dave's Misc Charging Advice 1

- **Storage or long inactivity**
  - Store at low ~60% SOC, ~12.8v/3.2vpc charge term, low temp
  - Bulk only, no absorb time needed
  - Set float at 12.8/3.2vpc will maintain loads with no cell impact
- **Balancing**
  - One cell will always go high early at upper end knee
  - Goal is to minimize delta and how soon cells spread
  - Persistent over charging balance problem is an indication of a failing cell
  - Most BMSs balance only during charging
  - Start ~13.6v/3.4vpc & over ~10mv delta
- **Memory effect**
  - Incomplete charge absorption followed by rest or little discharge
  - Must charge to 3.4-3.65vpc and residual current absorption condition met at full SOC periodically to remove memory effect
- **Multiple charge sources at the same time**
  - Not optimum because of sensing issues
  - Confusion due to surface voltage issues
  - Need individual V & A shunt sensing or BMS as master control

Dave's Misc Charging Advice 2

- **Charge LFP to 100% SOC daily?**
  - Minimize time at 100% SOC
  - OK charging to only ~80-90% SOC
  - Store around 50% SOC, cool area
- **Chargers terminate charge**
  - Let charger terminate charge at total batt voltage, minimal absorb
  - Set BMS to turn off charger at HVD if cell goes over voltage
- **Knees**
  - Very few ahrs in knees so stopping charge/discharge early OK
  - Charge/discharge moves very rapidly in knees
  - VPC delta increases rapidly in knees
- **Alternators**
  - Use only external regulators
  - Must detune most alternators to .5-.75C output if charging LFP
  - Sudden batt disconnect from alt will damage alt diodes, use APM
  - Wire HVD relay in ignition wire to regulator

ABYC E-13 Standards

- **American Boat & Yacht Council, Inc**
- **E-13 Standards for Lithium Batteries System design and installation including BMS published 2023**
- **Future may become standard for insurance underwriter coverage requirements**
- **Most BMS Best Practices/install descriptions comply except for pre-disconnect alarm requirement**
- Consensus of govt, industry & public experts
- Guide for manufacturers & marine community
- Design, construction equipage and maintenance of small craft
- Relies heavily on battery/cell manufacturer installation requirements
- Thermal runaway description & prevention

ABYC LFP Combustion Hazard

- **Under certain fault conditions LI batteries can enter a condition known as thermal runaway (TR)**
- **TR results in rapid internal pressure and temperature rise and venting**
- **Given only thermal runaway, LFP electrolyte will not normally reach high enough temps to self ignite**
- If electrical arcing, flames or other heat sources does ignite electrolyte fire it is difficult to extinguish
- Typically best method to extinguish is to remove heat by flooding or water sprinkler extinguishers
- Battery compartment design and construction must comply with battery manufacturer's specifications

Pantaenius Insurance

- **Must adhere to ASNZ (similar to ABYC/ISO) standards**
- **Must use only LiFePO4 batts**
- **Must have BMS to monitor & control to cell level**
- **BMS must disconnect charge sources at HVD & loads at LVD**
- **Batts must be installed so temp limits not exceeded**
- **BMS must disconnect batt if temp exceeded**
- **BMS must have visible & audible alarm before disconnect event**
- **Be careful disconnecting charging sources**
- **Cell phones, tablets, computers, water toys etc fires not covered!!**
- **Don't charge non LFP batts if off the boat**

Pantaenius Insurance Requirements 1

- **Please note that Pantaenius Australia can only offer cover for lithium ion batteries when installed in accordance with the Australian and New Zealand standards (ASNZ). Please find the standards here:**
- ***AS/NZS 3004.2 (2014) Lithium Battery requirements:***
- If you are thinking about a lithium battery on your boat, you should consider only a modern lithium iron phosphate battery, where the danger of thermal runaway does not exist at all. But even then, before changing the battery in any way, check the wiring with the dealer or manufacturer whether the wiring, including the cable cross-sections, fuses and charging technology, are suitable for the new battery. If you are planning to change over, you should take advantage of the situation to thoroughly check your on-board electrics, because this is one of the most frequent causes of total loss due to fire.

Pantaenius Insurance Requirements 2

- *Lithium ion batteries shall be installed in locations that ensure the battery manufacturer's specified operating temperature limits cannot be exceeded.*
- *Each lithium ion battery shall be provided with a battery management safety system. The BMS shall continuously monitor the voltage and temperature of each cell in the battery.*
- *All charging sources shall be automatically disconnected by the BMS when voltage exceeds the manufacturer's recommended maximum.*
- *All connected load shall be automatically disconnected by the BMS when the voltage falls below the manufacturer's recommended minimum.*
- *The battery shall be automatically disconnected by the BMS from all connected load and all charging sources when temperature exceeds the manufacturer's specified maximum.*
- *The BMS shall provide an audible and visual alarm at the normal vessel operating position before a disconnection event occurs.*
- *Lithium ion battery ventilation air flows shall be in accordance with the manufacturer's requirements. Care must be exercised when disabling charging sources to avoid the risk of elevated voltages that may damage the equipment."*

OCC Member Recent LFP Comments

- **Don't under estimate how much rewiring you may need to do to accommodate lithium.**
- **There is no such thing as a drop in replacement battery.**
- **Stay clear of cheap lithium batteries.**
- It is far better to build your own with cells from a known source and a good BMS than buy something in a sealed box that you know nothing about.
- **The cost of building your own battery is about half the cost of a cheap drop in lithium battery.**
- Building your own battery also allows you to install the battery in a ventilated battery box. The BMS Mosfets make considerable heat when charging and particularly discharging. This heat cannot escape a sealed box.
- **Lithium and solar were made for each other. Maximize your solar install.**
- **Speak to your insurance company. Mine were happy for me to install lithium.**

LFP Article: ***svsoggypaws.com -> Workshop -> Electrical***
Presentation: ***svsoggypaws.com/presentations.htm***

Questions/Comments?