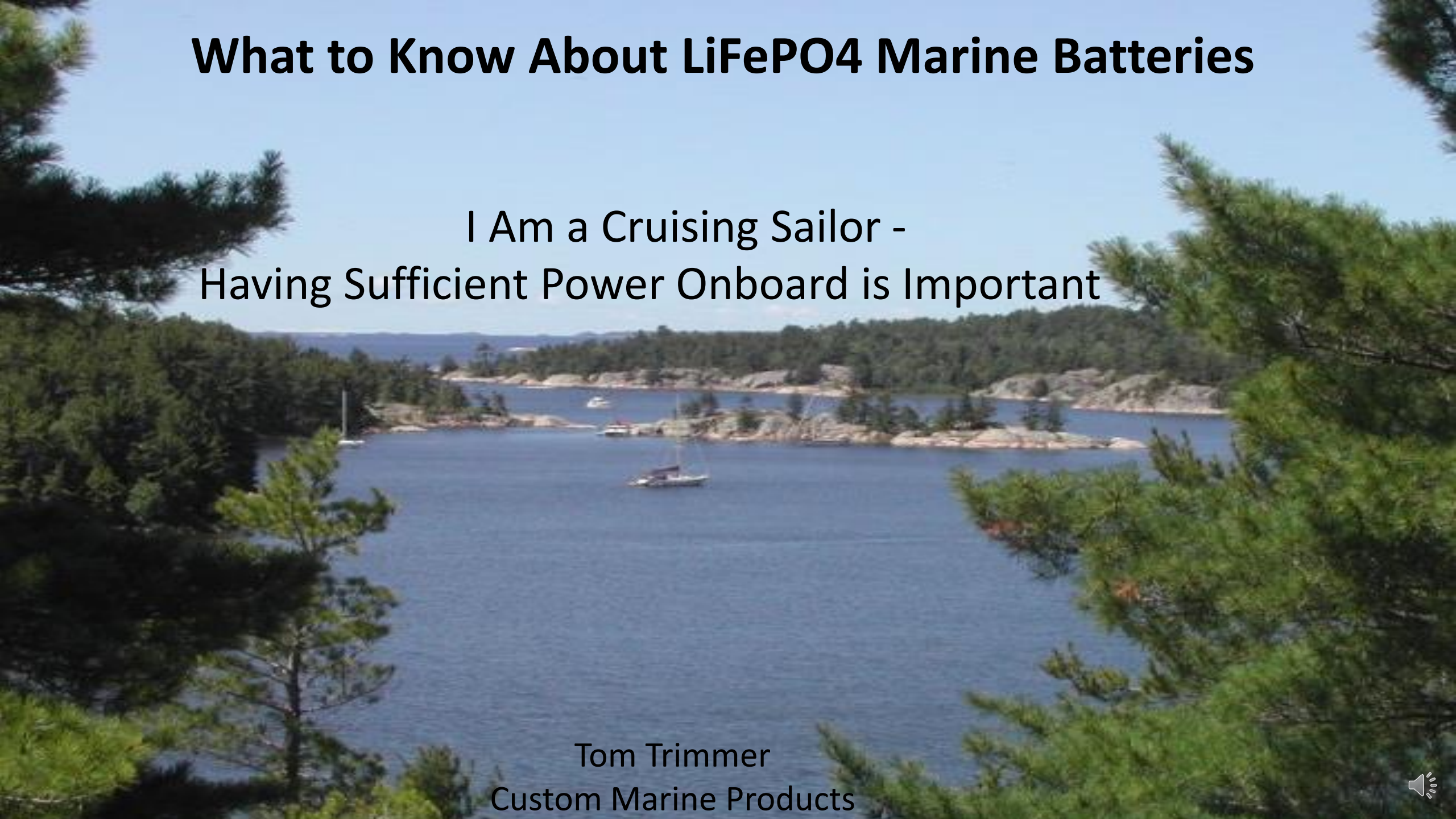
What to Know About LiFePO4 Marine Batteries



I Am a Cruising Sailor -
Having Sufficient Power Onboard is Important

Tom Trimmer
Custom Marine Products

What to Know About LiFePO4 Marine Batteries

- Overview of LiFePO4 battery technology
- LiFePO4 performance characteristics
- Comparison – lead acid and LiFePO4
- Designing a LiFePO4 battery bank for your boat
- Installation considerations
- Summary

Slides are available for reference at
custommarineproducts.com

Tom Trimmer
Custom Marine Products
248 705-8337

What is a LiFePO4 Lithium Iron Phosphate Battery?

Li Fe PO

LiFePO Cells (LFP)

+

Battery Management System (BMS)

+

Sealed Case

=

LiFePO4 Battery

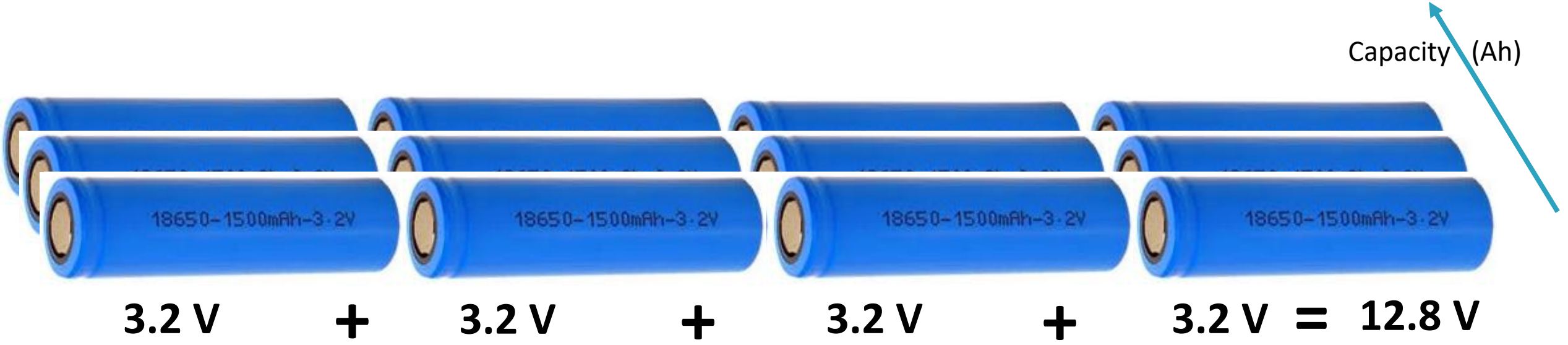
Lithium Iron Phosphate (LFP) is a lithium chemistry that has excellent thermal and structural stability and excellent power density.

What to Know About LiFePO (LFP) Cells

LiFePO – Lithium Iron Phosphate also referred to as LFP

- LFP is a lithium chemistry that has many advantages
  - High thermal and chemical stability – won't catch on fire
  - Long cycle life - >2,000 charge cycles
  - Near constant discharge voltage – full power until discharged
  - High energy density – double lead acid (power stored/weight)
  - Low discharge rate – limited power loss in storage
  - Rapid and efficient charging – >20% more efficient than lead acid
- Disadvantages
  - Should not be charged or discharged below -4 F, -20 C
  - High initial investment
- Commonly used cell models
  - 26650, 32700

Construction of a LiFePO4 battery



Four groups of cells wired in series = 12.8 Volts

LiFePO4 is a chemical formula. A single molecule of Lithium Ferro-Phosphate is made up of one Lithium atom, one Iron atom, one Phosphorus atom, and four Oxygen atoms.
A Phosphate ion is made up of one Phosphorus atom and **four** Oxygen atoms.

Cylindrical

Prismatic

What is a BMS – Battery Management System?

The BMS regulates the power charge and discharge of the battery and protects the cells from being damaged.

- Power regulation for cell protection
  - Over and under voltage monitoring for charge and discharge
  - Low and high temperature during charge and discharge
  - Maximum current draw
  - Short circuit cut off
- Keeps all cells in balance
  - Regulates cell charging so all cells maintain the same charge level
- Enables “drop in” replacement for lead acid and AGM batteries
- Monitors and reports battery functions
  - Some BMS’s report battery State of Charge through a meter or Bluetooth app.

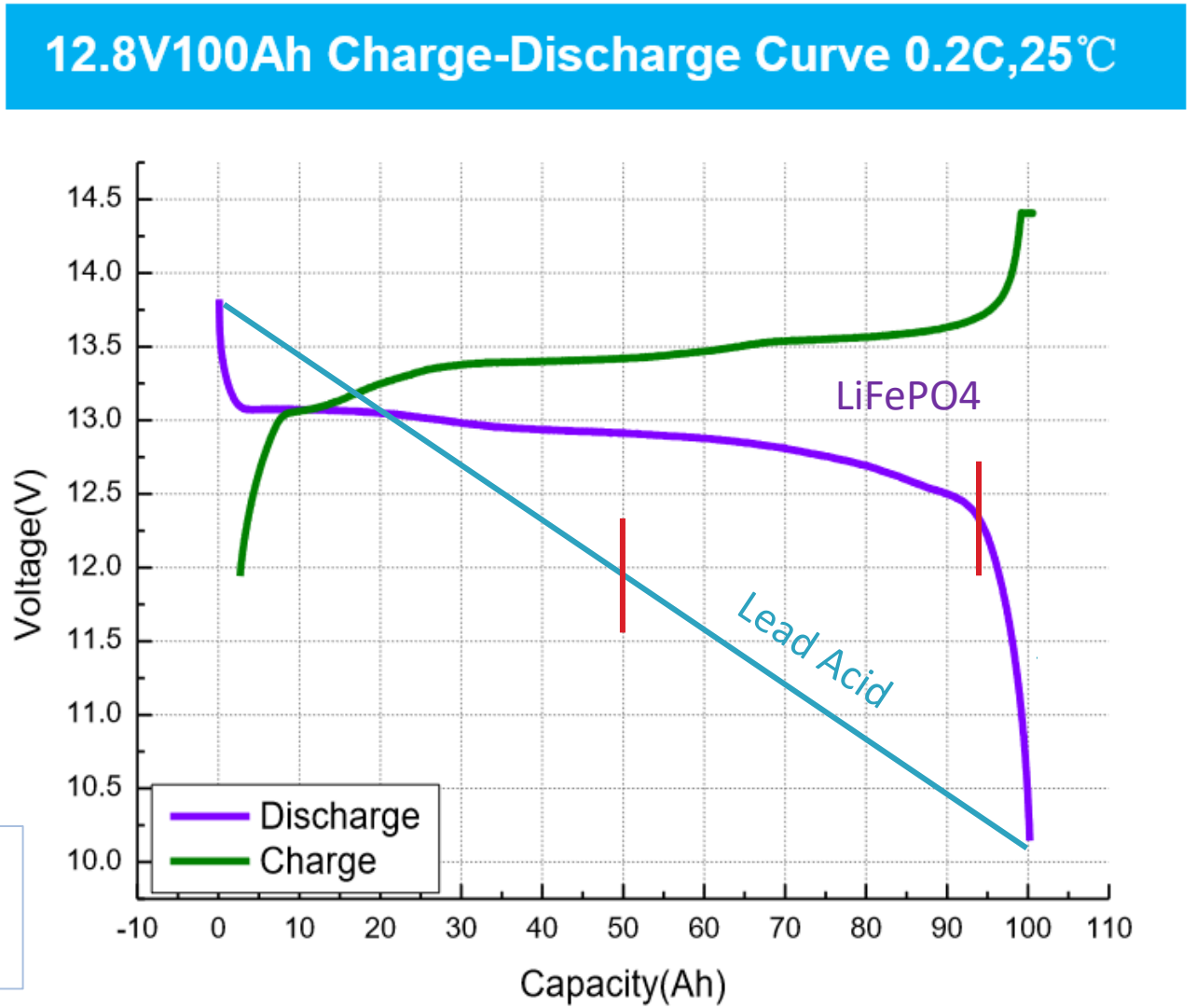
State of Charge (SoC) – Percentage of power remaining in the battery.

LiFePO4 Battery Discharge Curve

Flat rate of discharge:

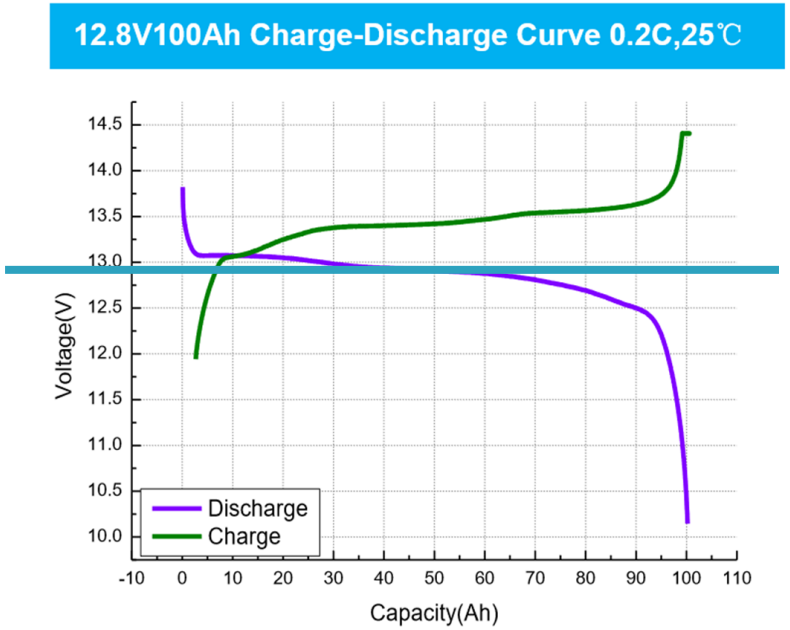
- Appliances run more efficiently
- 95%+ of rated capacity is usable capacity
- Volt meter does not accurately indicate State of Charge (SoC)

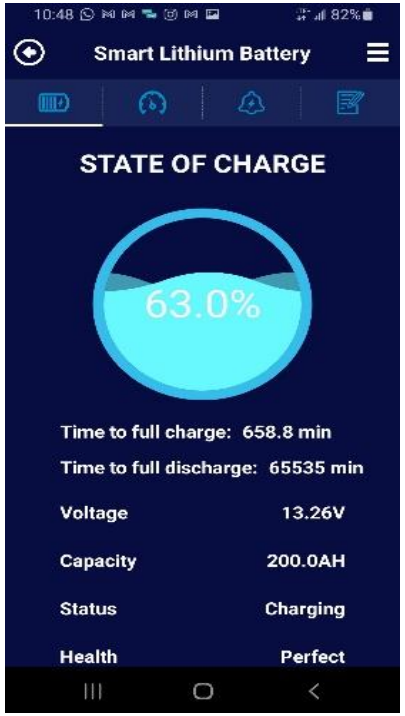
‘**C**’ is the rated amp hour (Ah) capacity of the battery

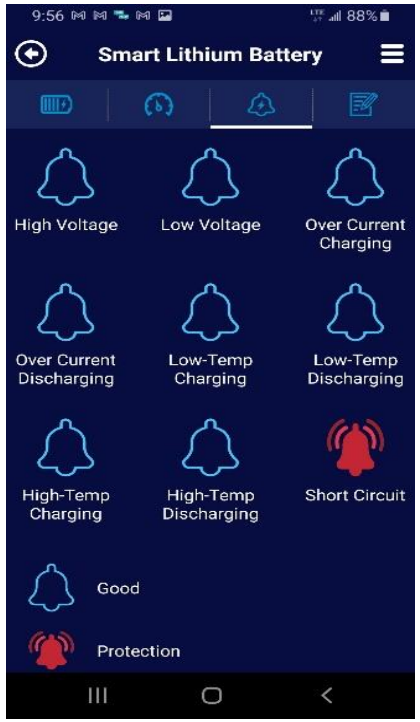


Why is a Bluetooth Battery Monitor Important?

A volt meter is not accurate because the discharge voltage is nearly constant.







An app connected directly to the BMS provides better accuracy than external measuring systems.

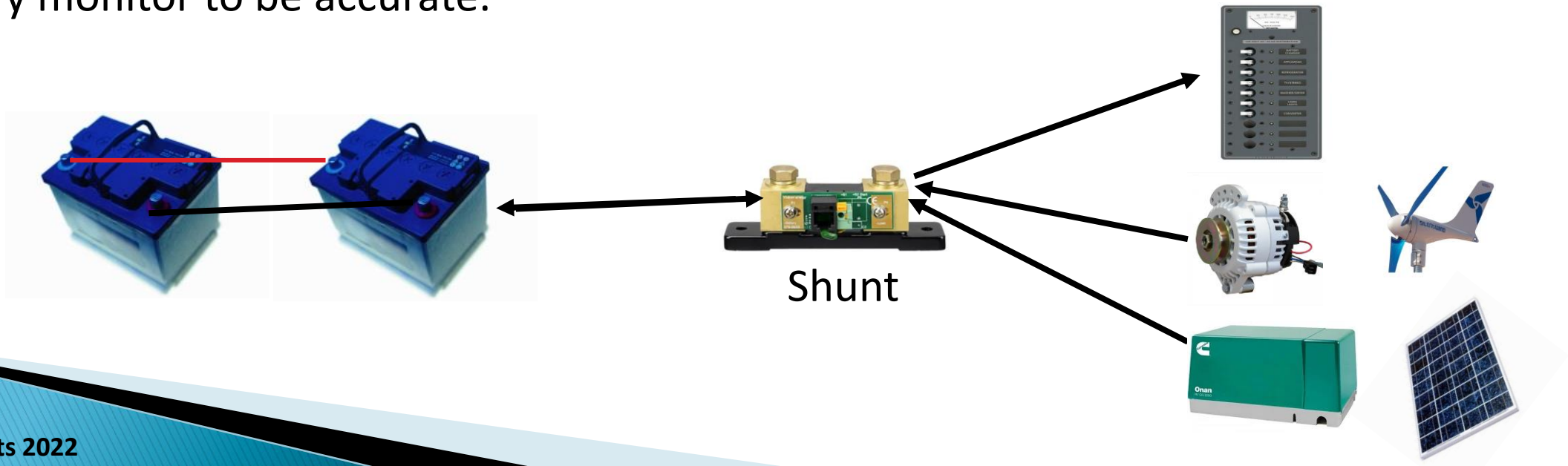
Will a Traditional Battery Monitor Report an Accurate SoC?

Yes - close, with a bit of reprogramming

- Battery monitors compute the SoC of a battery bank by measuring the electrical energy (coulombs) crossing over a shunt (bridge).

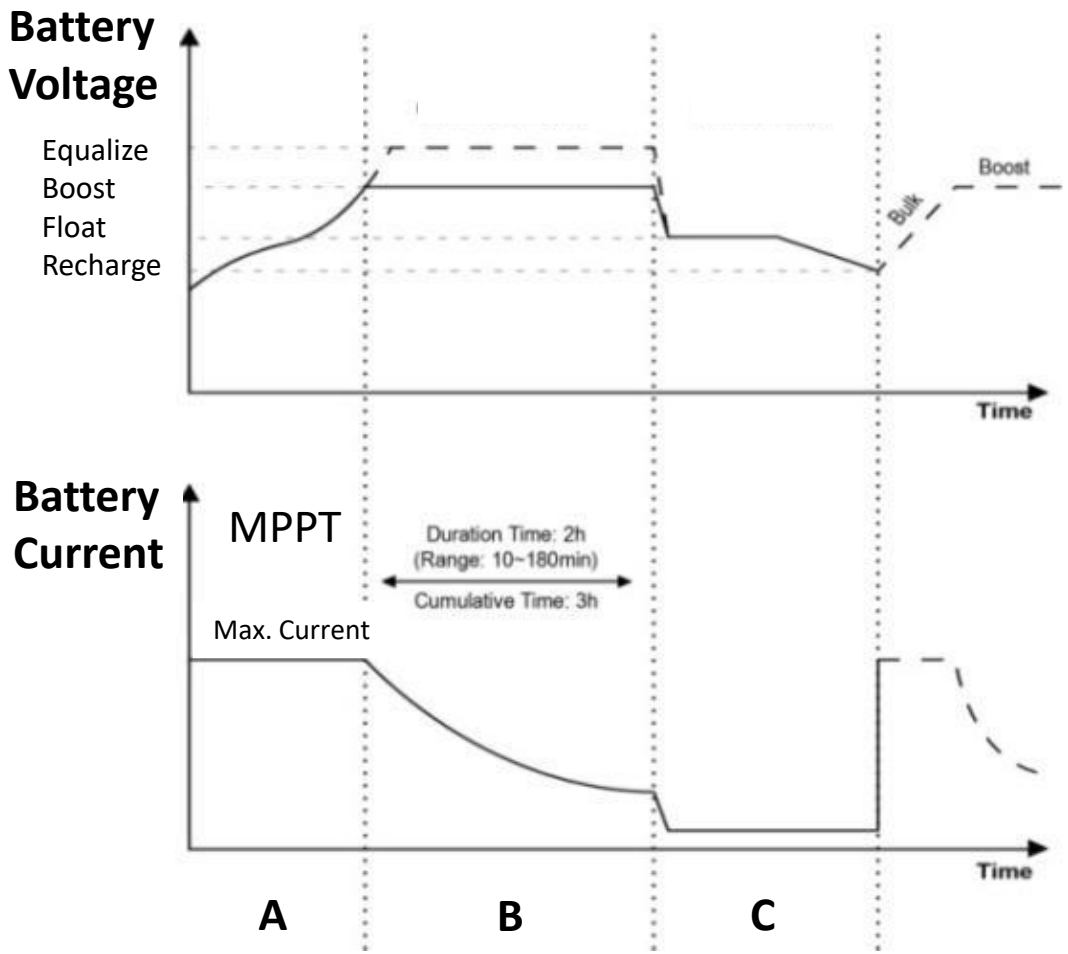
- Most battery monitors are designed for monitoring lead acid and AGM batteries. They use a Peukert coefficient to compensate for battery charge/discharge inefficiency.

- The Peukert coefficient must be changed from the default (1.2 – 1.5) to 1.04 (ish) for the battery monitor to be accurate.



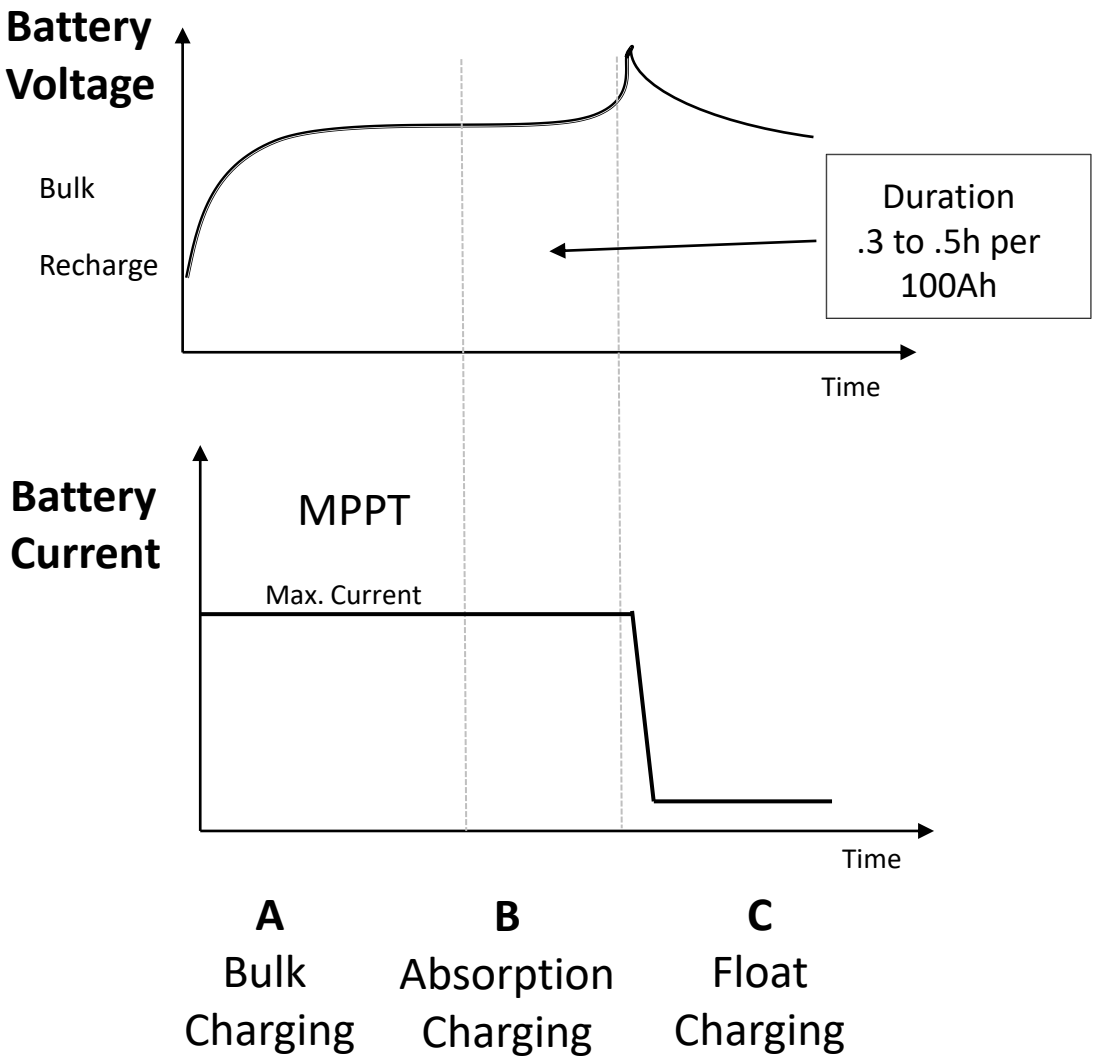
Battery Charging Curves

Lead Acid



EP Solar

LiFePO4



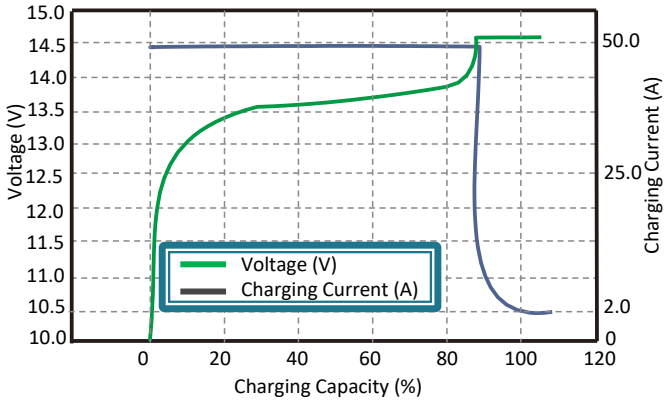
CMPower

LiFePO4 Battery Performance Characteristics

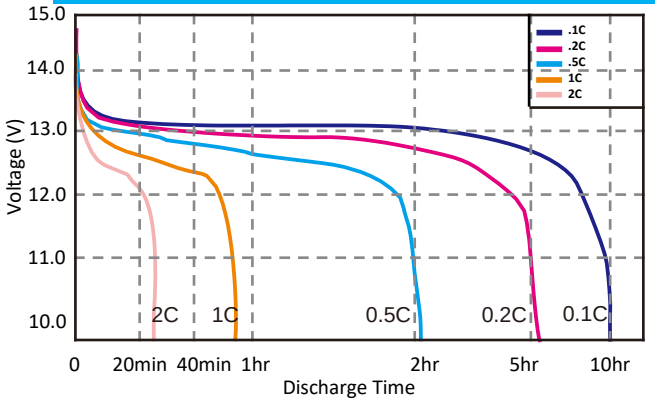
12.8 V 100 Ah LiFePO4 Battery

Capacity (% rated)

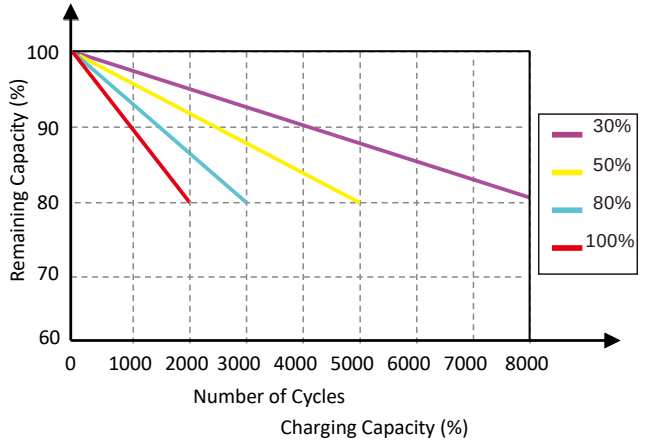
Charging Characteristics @ 0.5 C 25°C



Rate of Discharge Curves @ 25°C

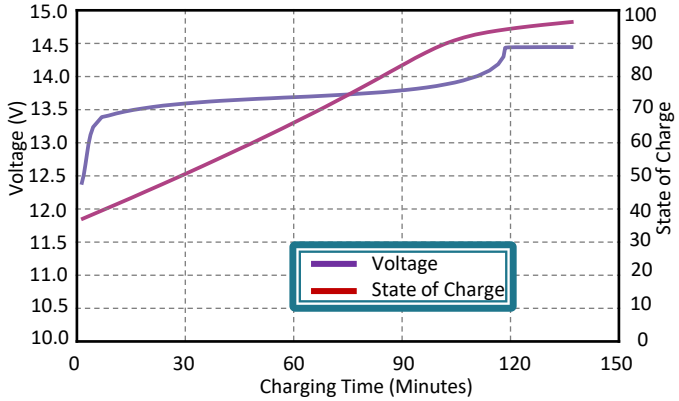


Depth of Discharge Cycle Life @ 1C

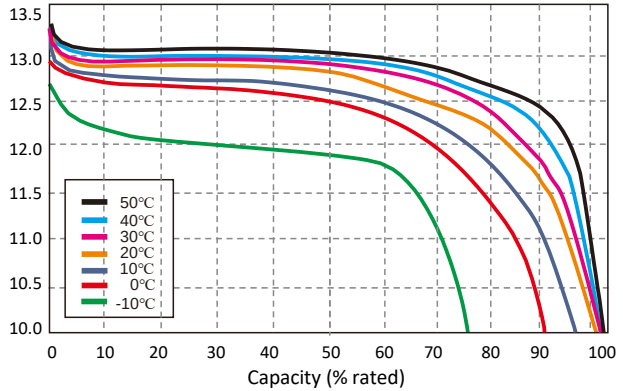


Charging Capacity (%)

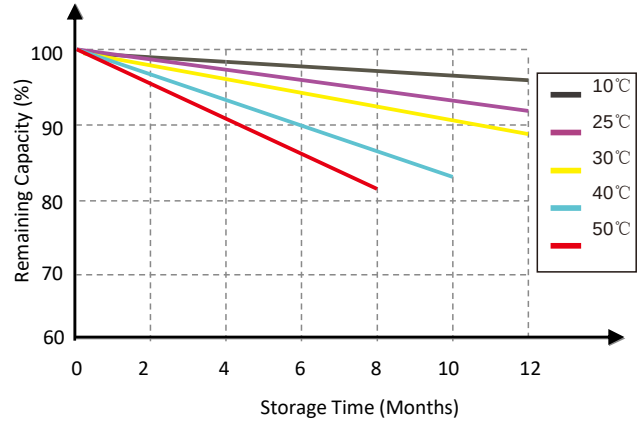
State of Charge @ 0.5 C 25°C



Temperature Discharge Curves @ 0.5C



Temperature - Self Discharge



‘**C**’ is the rated amp hour (Ah) capacity of the battery

Temperature Impact on Battery Life

Cycling at high charge/discharge rates at extreme temperatures will reduce the number of life cycles, especially at low temperatures.

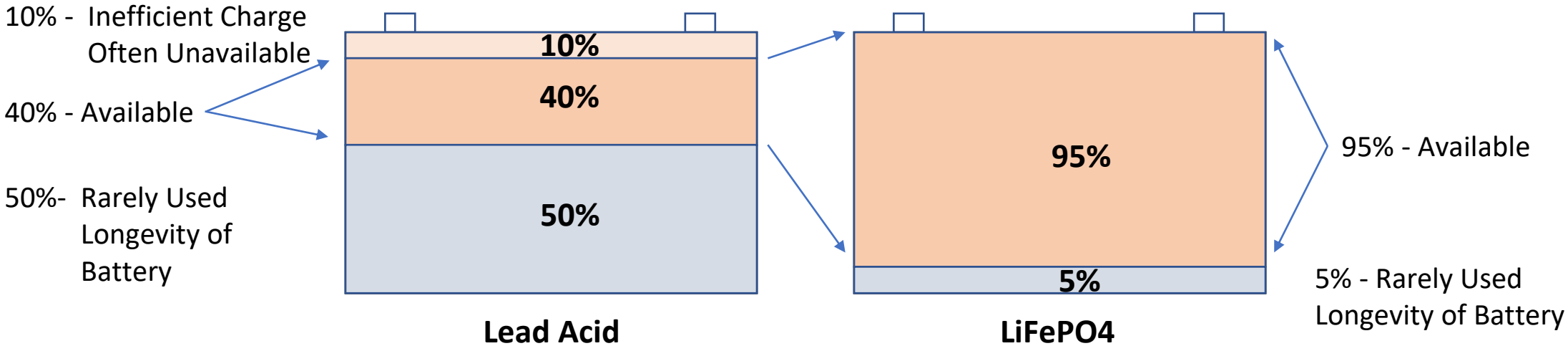
Charge Temperature	32°F to 113°F	0°C to 45°C	
Discharge Temperature	-4°F to 140°F	-20°C to 60°C	
Storage Temperature	-10°F to 104°F	-25°C to 40°C	

Charging and discharging a LiFePO4 battery does not generate significant heat within the battery.

Example of LiFePO4 Battery Specifications – 100 Ah 12.8 V

Electrical Characteristics	Nominal Voltage	12.8V
	Nominal Capacity	100Ah
	Energy	1,280 Wh
	Internal Resistance	≤20mΩ
	Cycle Life	>2000 cycles @1C 100% DOD, >3000 cycles @1C 80% DOD
	Months Self Discharge	<3%
	Efficiency of Charge	100% @0.5C
	Efficiency of Discharge	96~99% @1C
Standard Charge	Charge Voltage	14.4±0.1V
	Charge Mode	0.2C to 14.4V, then 14.4V,charge current to 0.02C (CC/CV)
	Charge Current	20-50A
	Max Charge Current	100A
	Charge Cut-off Voltage	14.6V±0.1V
Standard Discharge	Continuous Current	150A
	Max. Pulse Current	300A(<3s)
	Discharge Cut-off Voltage	10V
Environmental	Charge Temperature	0 ℃ to 45 ℃ (32F to 113F) @60±25% Relative Humidity
	Discharge Temperature	-20 ℃ to 60 ℃ (-4F to 140F) @60±25% Relative Humidity
	Storage Temperature	0 ℃ to 40 ℃ (32F to 104F) @60±25% Relative Humidity
	Water Dust Resistance	IP56
Mechanical	Cell & Method	32700 6000mAH
	Plastic Case	ABS+PC UL V-0 flame resistant
	Dimensions (mm./in.)	L340*W170*H210mm / L13.4*W6.7*H8.3 in.
	Weight (kg./lbs.)	14kgs/31lbs.
	Terminal	M8
	Features	Bluetooth battery monitor app

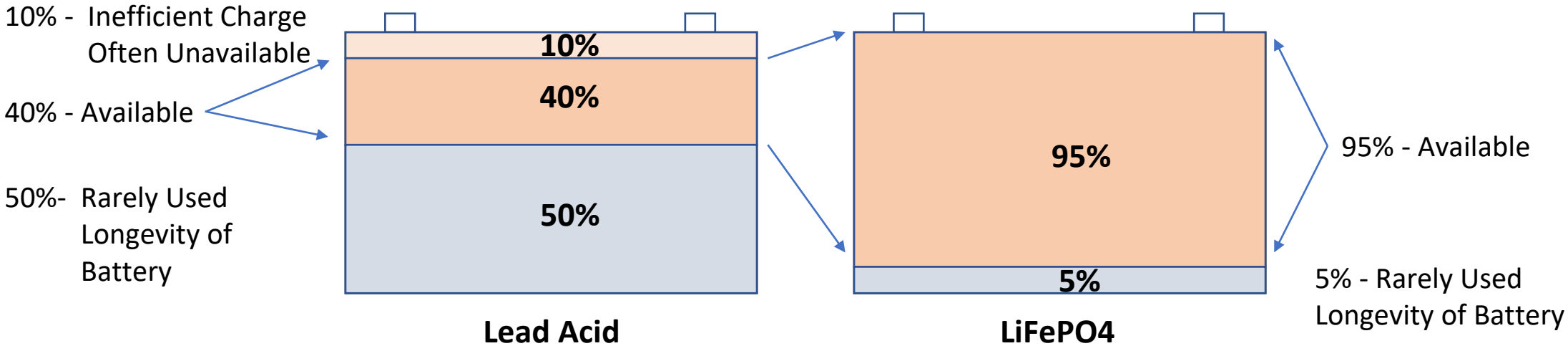
Comparison of Lead Acid vs. LiFePO4 - 100Ah Battery



Useable Amp Hours	**40-50 Ah**	**90 - 95 Ah**

Ah - Amp hours

Comparison of Lead Acid vs. LiFePO4 - 100Ah Battery



Useable Amp Hours	40-50 Ah	90 - 95 Ah
Weight	**65 lbs.**	**31 lbs.**

lbs. - pounds

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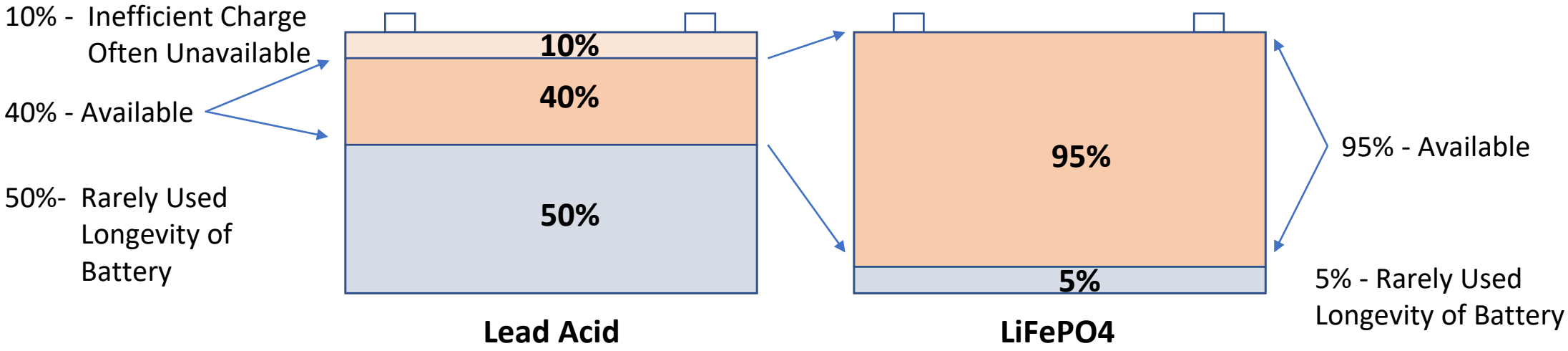

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Weight	65 lbs.	31 lbs.
Energy Density	**9 Wh/lb.**	**39 Wh/lb.**

Wh – Watt hours

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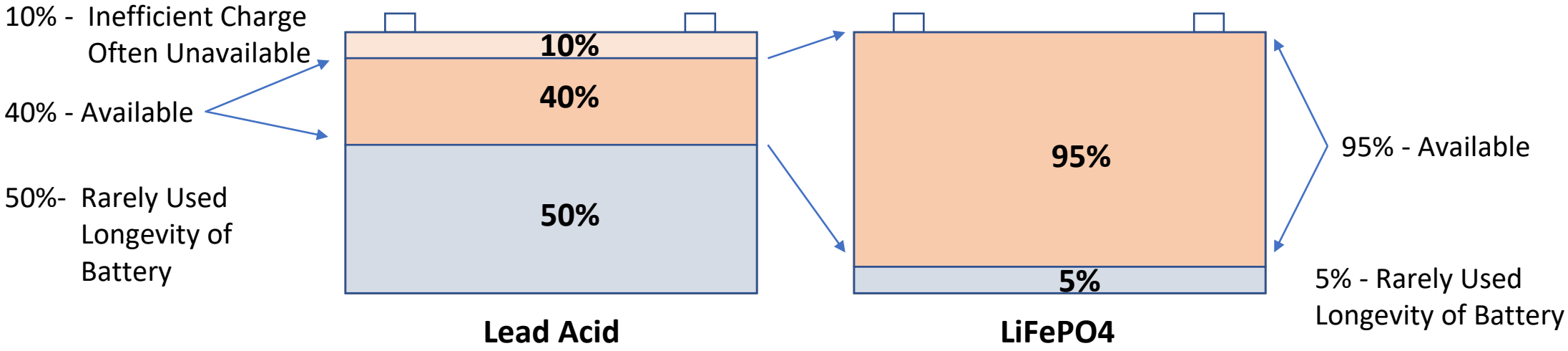
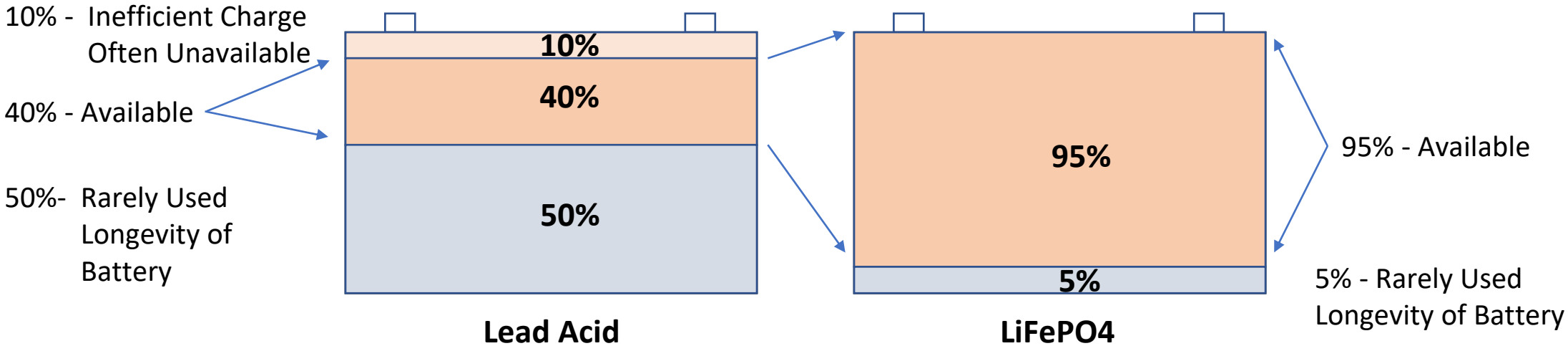


	Lead Acid	LiFePO4
Useable Amp Hours	40-50 Ah	90 - 95 Ah
Weight	65 lbs.	31 lbs.
Energy Density	9 Wh/lb.	39 Wh/lb.
Charge/discharge Cycles	**<400**	**>2,000**

Cost per charge cycle: SLA $1 LiFePO4 $.15

Comparison of Lead Acid vs. LiFePO4 - 100Ah Battery



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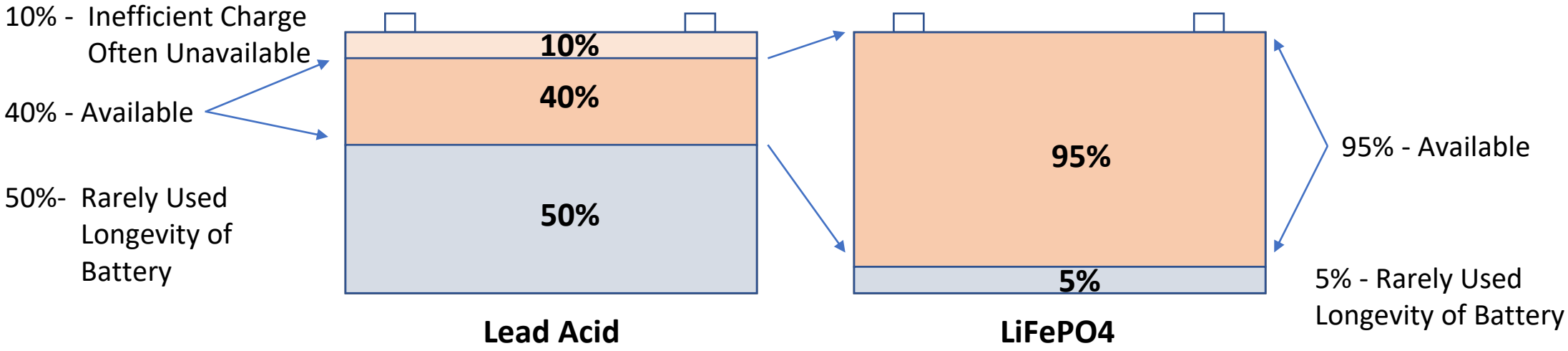
Useable Amp Hours	40-50 Ah	90 - 95 Ah
Weight	65 lbs.	31 lbs.
Energy Density	9 Wh/lb.	39 Wh/lb.
Charge/discharge Cycles	<400	>2,000
Charge Efficiency	**70-80%**	**99%**

A 20% greater charge efficiency means 20% more power is stored.
Example: 100 Ah charge: 80% efficient = 80 Ah stored, 99% efficient = 99 Ah stored

Comparison of Lead Acid vs. LiFePO4 - 100Ah Battery



	Lead Acid	LiFePO4
Useable Amp Hours	40-50 Ah	90 - 95 Ah
Weight	65 lbs.	31 lbs.
Energy Density	9 Wh/lb.	39 Wh/lb.
Charge/discharge Cycles	<400	>2,000
Charge Efficiency	70-80%	98%
Self Discharge	**up to 20% / mon.**	**<3% / mon.**

Summary of LiFePO4 Battery Advantages

- **Bluetooth Battery Monitor:** Built in real time monitoring of battery State-of-Charge
- **Longer Cycle Life:** Up to 10 times longer cycle life and 5 times longer calendar life than lead acid batteries.
- **Lighter Weight:** Up to 50% lighter than a comparable lead acid battery. Up to 4 times more power per pound than lead acid batteries.
- **Efficient charging and discharging:** Up to 20% more efficient. Store 20% more generated charging power.
- **Superior Safety:** LiFePO4 chemistry eliminates the risk of combustion due to overcharging, short circuit, high impact.
- **Increased Flexibility:** Modular design enables deployment of up to 4 batteries in series and up to 10 batteries in parallel.
- **Compatibility:** The built in BMS (Battery Management System) compensates for various charging profiles and protects the LiFePO cells.

The Case of the Listing Oyster 66

Rolls Surrette Lead Acid
12V 210 Ah
2-series, 5 sets in parallel

CMPower
24V 150 Ah
4 in parallel

Useable Amp Hours @ 24V	525 Ah	600 Ah	**+75 Ah**
Weight	1,250 lbs.	320 lbs.	**-930 lbs.**

What was the extra space in the battery compartment used for?

Designing a LiFePO4 battery bank for your boat

Designing a LiFePO4 Battery Bank for Your Boat

1. Determine power usage for a day

1 AH - Amp Hours - Amps of current consumed in one hour

2 Windlass is often not considered because the engine alternator is running when used

Note:

1,100 watts / 13 volts x 1.2 inverter inefficiency factor

Appliance DC	Amps	Hours At Anchor	Hours On Passage	Daily AH *1* At Anchor	Daily AH On Passage
Refrigeration	5	10	10	50	50
Radar	4		4	0	16
Computer - Laptop	4	1	10	4	40
Autopilot	4		10	0	40
Cabin Lights (LED)	1	4		4	0
Nav/Anchor Lights	0.2	10	10	2	2
Stereo	1	3	3	3	3
VHF Radio	0.5	10	10	5	5
Instruments	1		8	0	8
Pressure Water	6	0.25	0.1	1.5	0.6
Phone Charger	1	2	2	2	2
Other				0	0
Other				0	0
Windlass *2*				0	0
Total Amp Hours				**71.5**	**166.6**
AC - Equipment powered by an Inverter (Watts)					
Microwave (Watts)	1100	0.1	0.1	10.2	10.2
Other				0.0	0.0
Other				0.0	0.0
Total Amp Hours				**10.2**	**10.2**
Total Amp Hours Consumed per Day				**81.7**	**176.8**
Battery Charging Voltage			13		
Total Watt Hours Consumed per Day				**1,061.5**	**2,297.8**
2. Alternative Power Sources					
Alternator	30		4	0	120
Generator				0	0
Other				0	0
Total Amp Hours				0	120
Total Watt Hours Produced per Day				**0**	**1560**
Net Watt Hours per Day Consumed or Produced				**1,061.50**	**737.80**

Designing a LiFePO4 Battery Bank for Your Boat

2. Estimate the days of reserve capacity desired
3. Determine optimal useable battery capacity
4. Determine the capacity of the batteries to be used
5. Calculate the number of batteries needed

Net Watt Hours per Day Consumed or Produced		1,061.50	737.80

LiFePO4

		At Anchor	On Passage
Number of Days of Reserve Battery Capacity	2		
% of Battery Capacity Useable	90%		
Rated Battery Capacity Required (AH)		181.5	392.8
Rated Battery Capacity (Ah)	120		
Number of Batteries Required (in parallel)		1.5	3.3

2 4

Lead Acid

		At Anchor	On Passage
Number of Days of Reserve Battery Capacity	2		
% of Battery Capacity Useable	50%		
Rated Battery Capacity Required (AH)		326.6	707.0
Rated Battery Capacity (Ah)	120		
Number of Batteries Required (in parallel)		2.7	5.9

3 6

Designing a Marine Power System – Application of the Worksheet Assumptions

3

1,061.5 Wh / 5h X 1.2 = **254.8W**

Avg. sun hours per day

Panel Inefficiency When Hot

Watts of Solar To Meet Demand (Full Sun)

At Anchor

LiFePO4 91.3Ah X 2days / 95% = **192.2Ah**

SLA 91.3Ah X 2days / 50% = **365.2 Ah**

Usable Power as a % Of Rated Capacity

Rated Battery Capacity To Meet 2 Day Demand

4

10.2 Ah DC

Inverter

AC

Appliances

110 Wh AC

1100Wh / 13V *.1Hr*80%= **10.2Ah**

Inverter Inefficiency

DC amps to Meet AC Demand

1

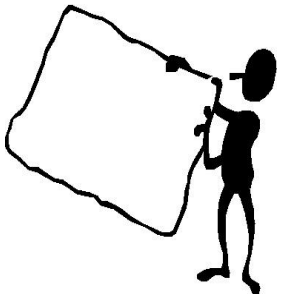
71.5 Ah DC

DC

Appliances

71.5 Ah

2



Designing a Marine Power System – Application of the Worksheet Assumptions

On Passage

3

(10.2Ah + 166.6Ah – 120Ah) X 13V = 737.8 Wh

737.8 Wh / 5h X 1.2 = **177.1W**

Avg. sun hours per day

Panel Inefficiency When Hot

Watts of Solar To Meet Demand (Full Sun)

LiFePO4 41.5Ah X 2days / 95% = **87.4 Ah**

SLA 41.5Ah X 2days / 50% = **166 Ah**

Usable Power as a % Of Rated Capacity

Rated Battery Capacity To Meet 2 Day Demand

4

10.2 Ah DC

Inverter

AC

Appliances

110 Wh AC

1100Wh / 13V *.1Hr*80%= **10.2Ah**

Inverter Inefficiency

DC amps to Meet AC Demand

1

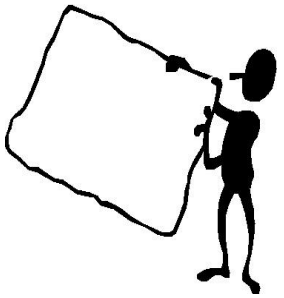
166.6 Ah DC

DC

Appliances

166.6Ah

2

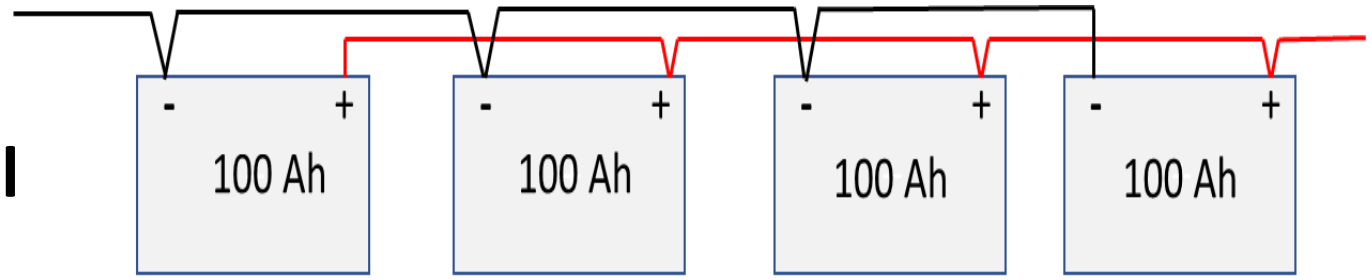


Wiring a Battery Bank

Battery Specifications

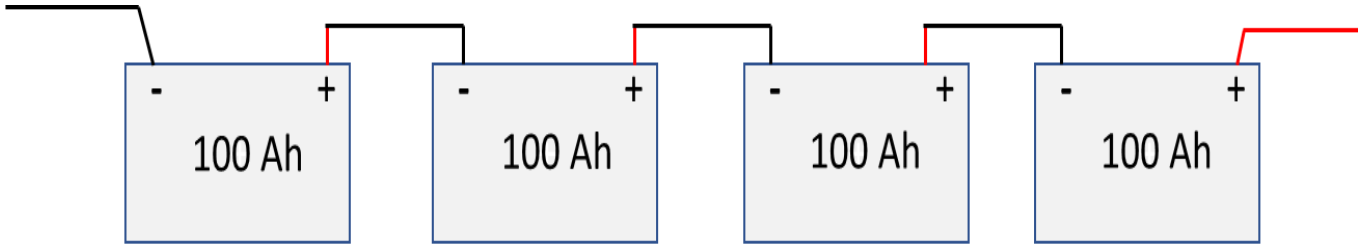
Capacity	100 Ah
Voltage	12 V
Continuous Current	100 A

Parallel



12V **400 A** Continuous Current - 360 Ah Capacity at 90%

Series



48V **100 A** Continuous Current - 90 Ah Capacity at 90%

The ***CMPower*** BMS will support 10 batteries in parallel and 4 batteries in series.

Wire batteries together only when their SoC is within 5% for each battery.

The Dilemma of Multiple Battery Types Onboard

?

?

Combiners/Isolators

?

Start
(Lead Acid)

House
(LiFePO4)

Thruster
Generator Start
(Lead Acid, AGM)

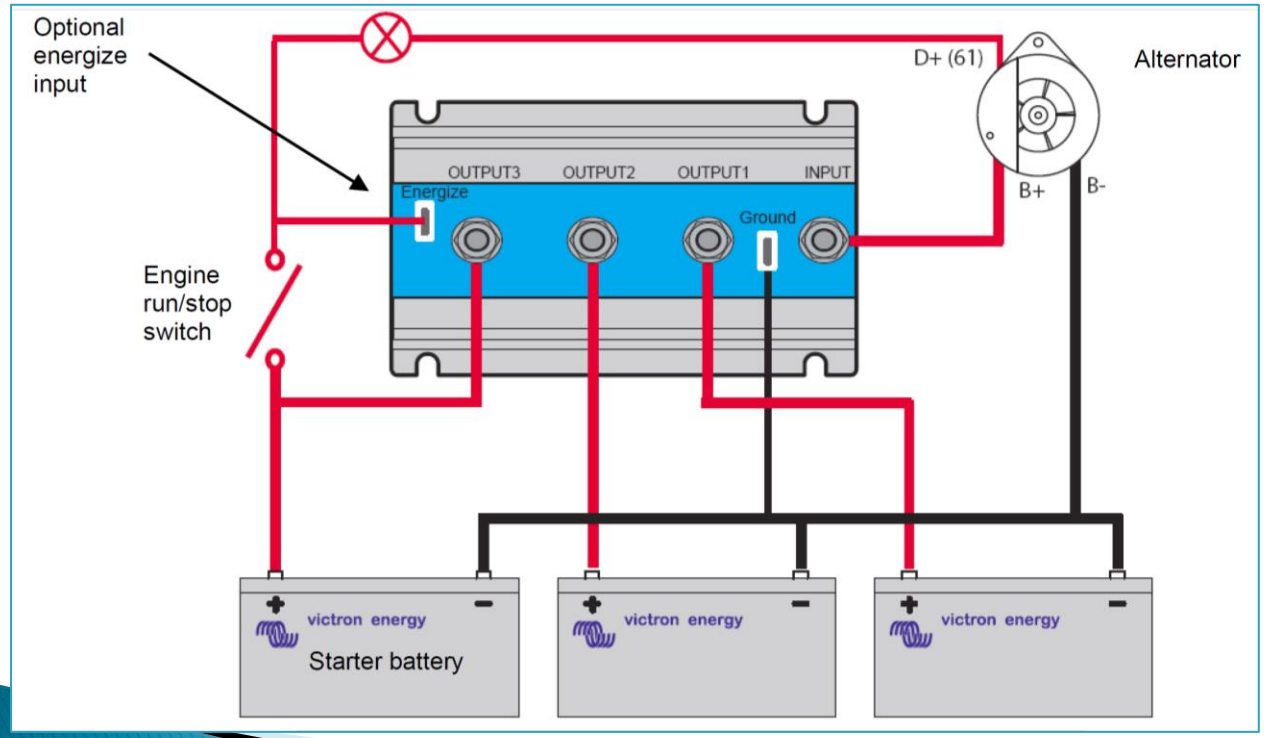
Never combine different types or sizes of batteries.

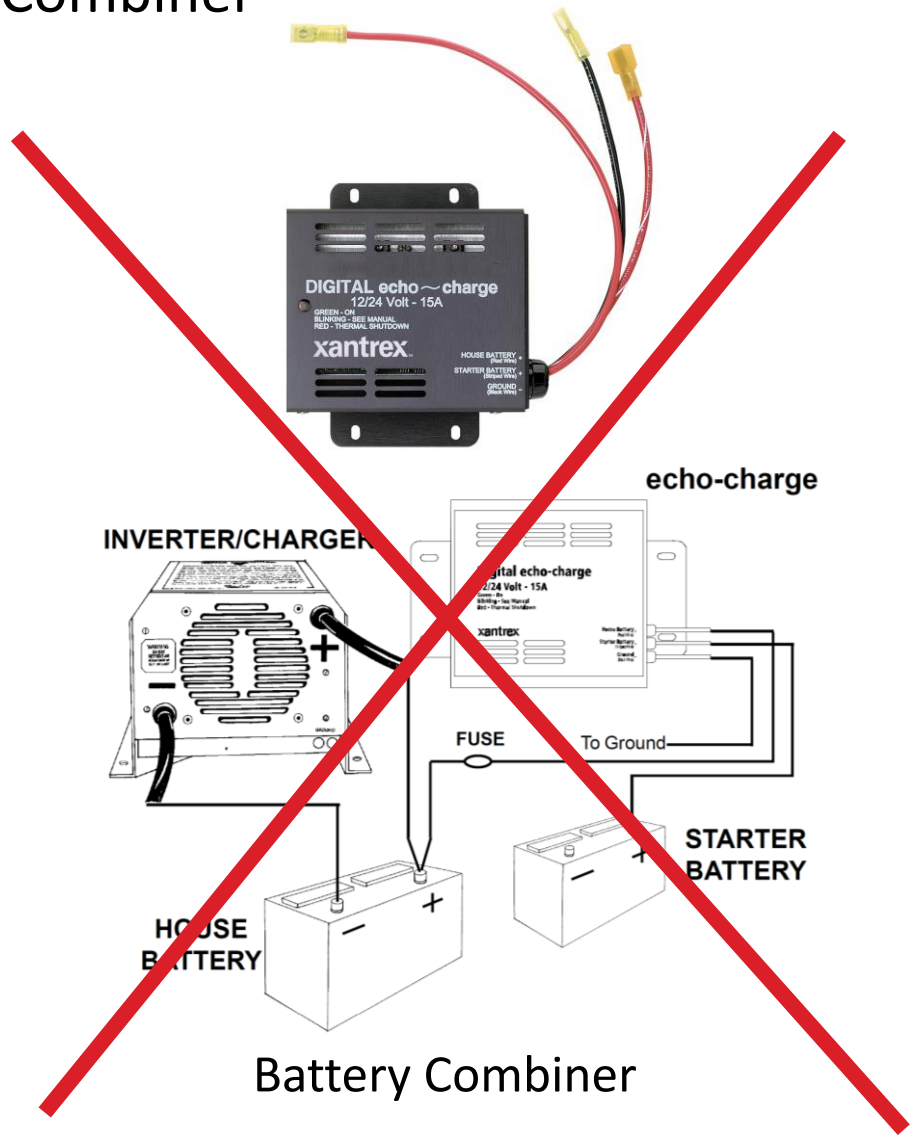
Multiple Battery Types Onboard – Wiring a Battery Isolator

Battery Isolator vs a Battery Combiner

Victron ARGO FET Battery Isolator

Advantage – multiple batteries can be charged independently.
Disadvantage – only one battery charging profile.



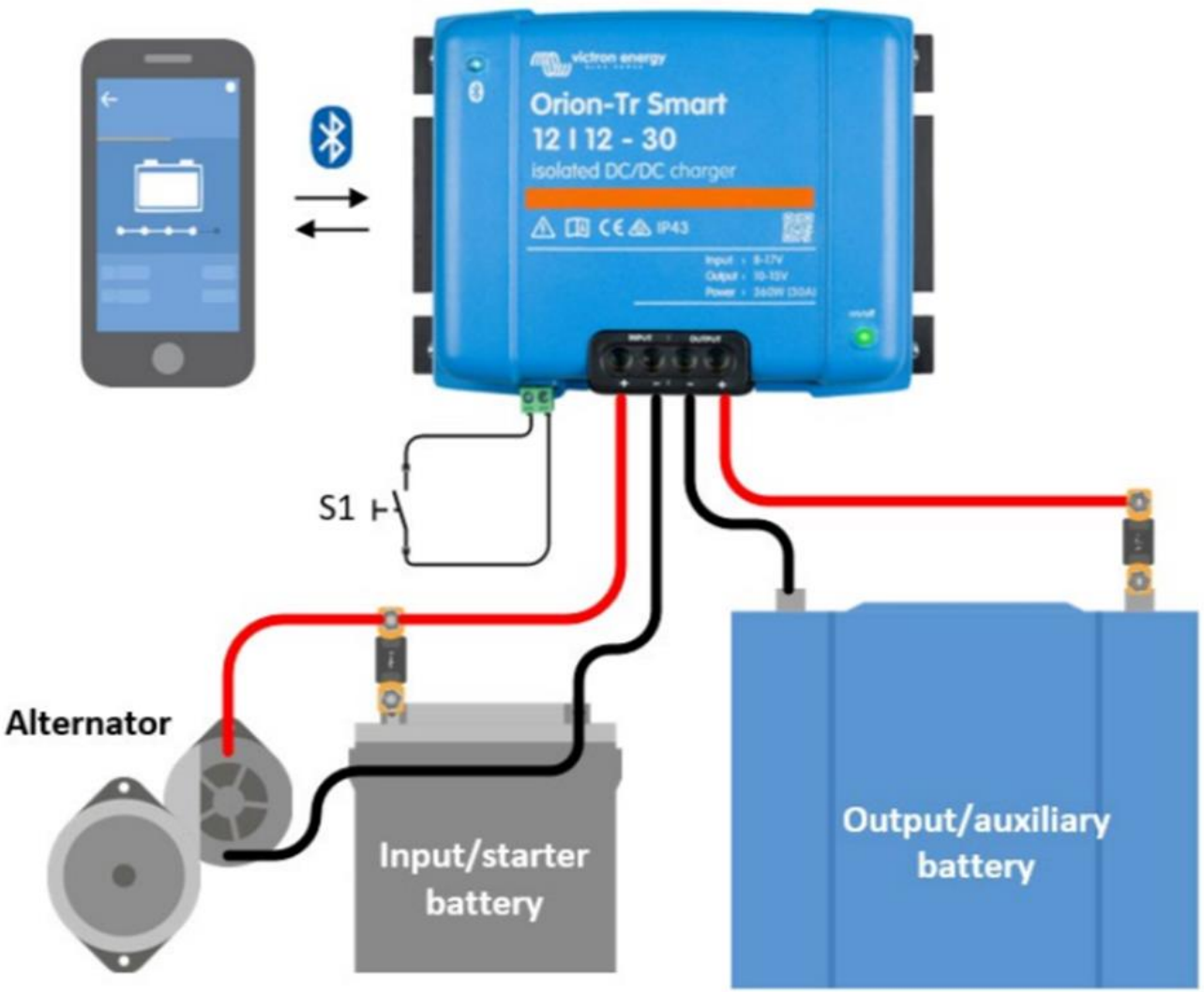


Battery Combiner

Never combine different types or sizes of batteries.

Multiple Battery Types Onboard – DC-DC Charger

For use in dual battery systems where the alternator and the start battery are used to charge the service/house battery bank.

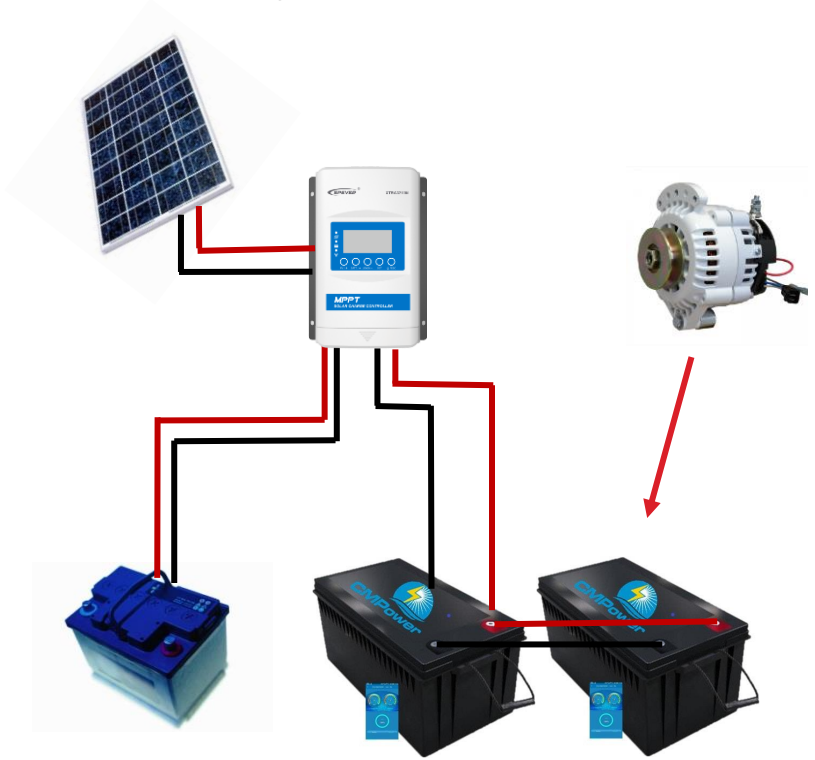


Advantages

– Multiple batteries can be charged independently.
– Multiple battery charging profiles.
– Easy to install and monitor
– Protects the alternator
– Multiple Orion units can be wired in parallel for higher power charging.

Multiple Battery Types Onboard

Dual Output Solar Controller



Start
(Lead Acid)

House
(LiFePO4)

Single Battery Bank

Features that enable single bank operation:

- 150A Continuous Draw BMS
- Bluetooth monitoring
- Low battery alarm

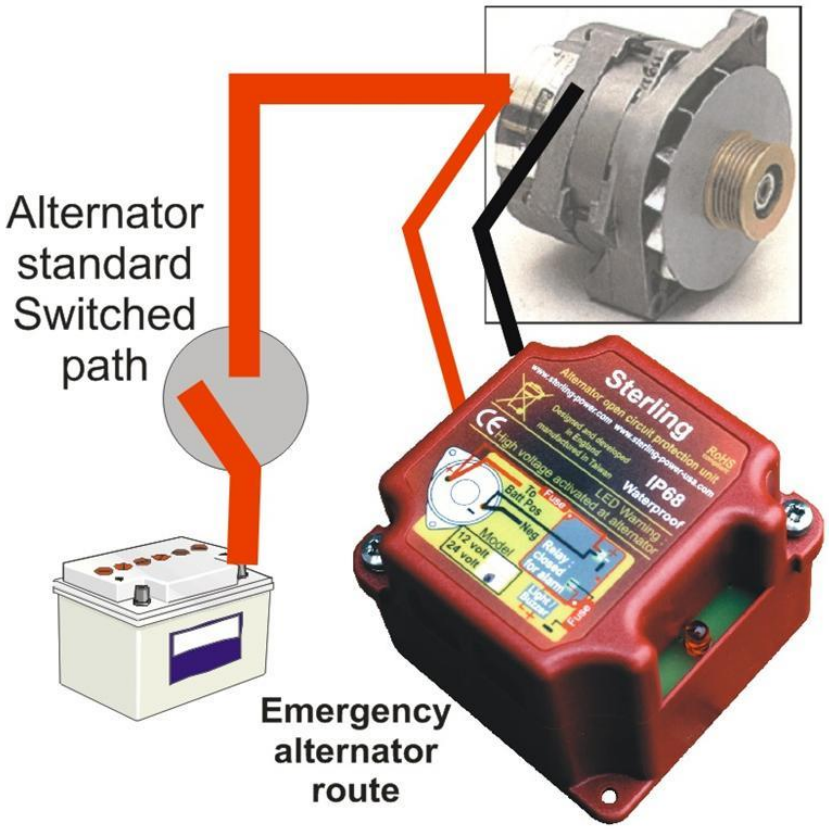
House & Start

Emergency Only

Never combine different types or sizes of batteries.

Alternator Protection

- Abrupt interruption of a load on the alternator can cause a voltage spike that could damage the alternator and possibly damage sensitive electronic equipment.
- Such an interruption could occur when the battery BMS shuts off from high voltage or during switching between battery banks.
- A Sterling Power Alternator Protection Device (APD) absorbs the voltage spike and protects the alternator. Cost <$90.
- Not all BMS's do abrupt cutoff. Batteries wired in parallel will likely have staggered high voltage cutoff mitigating the issue.



Installation Considerations

- Batteries can be mounted on bottom or any side.
- Batteries should be mounted in a moderate temperature environment.
  - not in the engine room unless well ventilated
- All positive wires should be fused near the battery bank per ABYC standards.
- All batteries should be within 5% State of Charge before connecting together.
  - All batteries at 100% SOC when connecting is ideal.
- Lead acid or AGM batteries should not be connected with LiFePO4 batteries.
- Battery monitor - Peukert constant should be set to 1.04 (1.25 for lead acid).
- Alternator loading – Efficient charging of LiFePO4 batteries may result in overheating of the alternator or additional strain on the alternator belt.
- Charging parameters for charging sources may need to be adjusted.
  - max voltage, min voltage cut off, etc.

Parameters for Charging LiFePO4 Batteries

If a “LiFePO4” setting is not available on your controller, use the “USER” function to program and set the following parameters:

- **Absorption voltage:** 14.0 volts (acceptable range is 13.6V to 14.4V, 28.0V to 28.8V)
- **Absorption Time:** The recommended setting is .3 to .5 hours per 100ah of LiFePO4 battery
  - (for example: for 2 -100ah batteries select .6 to 1 hour).
- **Float Voltage:** 13.5 volts (13.6 volts or lower is acceptable for LiFePO4 batteries although float is not necessary)
- **Equalization voltage: Do not** equalize LiFePO4, turn off the equalize function, but in case it ever runs a cycle or equalization can’t be turned off, set to 14.0 volts or less.
- **Temperature Compensation:** LiFePO4 batteries do not need temperature compensation.
- **Low Temperature cut-off:** -5 degrees C, 20 degrees F

Advantages of LiFePO4 Marine Batteries vs. Lead Acid Batteries

- Lighter than lead acid or AGM (half the weight - 4x energy density)
- Can be drawn down 95% vs 50% (double the usable power)
- Hold a steady voltage through 95% discharge (appliances run more efficiently)
- Generally plug compatible with lead acid chargers (easy installation)
- Charge more quickly than lead acid (less charging time)
- Charge more efficiently than lead acid (ideal for solar and wind generation)

Advantages of LiFePO4 Marine Batteries vs. Lead Acid Batteries

- Up to 10 times more charge cycles than lead acid (could last a lifetime +)
- Cost per charge cycle: SLA $1 LiFePO4 $.15
- Nontoxic and safe (very low fire risk, no fumes or acid)
- Low self-discharge (easy winter storage)
- Bluetooth battery monitor built in (accurate State of Charge data)
- Environmentally friendly (no toxic chemicals or heavy metals)

Disadvantages of LiFePO4 Marine Batteries

- Operating temperature range (lead acid can operate at lower temps)
  Discharging below -4F will reduce cycle life
- Some chargers are not compatible (additional equipment expense)
- Increased alternator loading
- Initial investment is higher than lead acid (advantages and longevity significant)
  (concept of a Battery Exchange)

Cost per charge cycle: SLA $1 LiFePO4 $.15

Things to Unlearn When Moving from Lead Acid to LiFePO4 Marine Batteries

- **Constant Voltage** - Voltage does not decrease significantly and battery power is used.
- **Battery Charging** – Charging to full is not necessary. 95% of power rating is available, not just top 50%.
- **Battery Charging** – Short absorption stage, no equalization, float stage is not necessary.
- **State of Charge** – 50% State of Charge is fine. 45% of power is still available.
- **Faster more efficient charging** – More power is stored faster.
- **Discharging** – Constant discharge voltage so appliances run more efficiently resulting in decreased power usage.
- **Maintenance** – No toxicity. No water level to check, no heat to be concerned about.
- **Easy Winter Storage** – Simply disconnect until next season.
- **Easy Monitoring** – Bluetooth app displays SoC and power remaining anytime from Smartphone or tablet.

What to Look for When Purchasing LiFePO4 Batteries

- Quality of the LFP cells (Lithium Iron Phosphate)
- Quality and functionality of the BMS (Battery Management System)
- Continuous Discharge Rate, peak discharge rate
  (minimum of 1C or 100A C - Ah capacity, we prefer 150A for marine)
- Determine how many batteries can be wired in series or parallel
- Battery monitor - Bluetooth or built in meter
- Compatibility with existing chargers and controllers
- Low battery alarm
- Warranty – battery exchange
- Support

CDR - how much power can be discharged (150A) How big is the pipe?

Specifications

Capacity

Ah - Amp Hours

V - Volts

Wh - Watt hours

Performance

A - Continuous discharge amps

Specifications

Model - Part Number	Voltage	Capacity Amp Hours	BMS Continuous Draw Amps	Size Inches	Weight lbs.
12 Volt					
CMP20501-L	12.8	10	10A	6x3.4x5.1	4
CMP20502-L	12.8	20	20A	7.1x3x6.7	6.2
CMP20505-L	12.8	50	100A	7.8x6.5x6.7	15
CMP20508-BL5	12.8	80	150A	12x6.7x8.3	28
CMP20510-BL1	12.8	100	100 A	13.4x6.7x8.3	31
CMP20510-BL5	12.8	100	150 A	13.0x6.7x8.3	31
CMP20512-BL5	12.8	120	150A	13.4x6.7x8.3	33
CMP20515-BL5	12.8	150	150A	18.9x6.7x9.5	45
CMP20518-BL5	12.8	180	150A	18.9x6.7x9.5	49
CMP20520-BG2	12.8	200	120A	20.5x9.2x8.7	59.3
24 Volt					
CMP20610-BL5	25.6	100	150A	20.7x9.2x8.7	80
CMP20615-BL2	25.6	150	120A	20.5x10.5x8.7	86
Starting					
CMP20510-SL	12.8	100	1,200 CCA	15.7x6.9x7.4	28.7

CMPower

Below is contact information should you have questions or comments.

Custom Marine Products
custommarineproducts.com
Tom Trimmer
tom@custommarineproducts.com
248 705 8337

CUSTOM MARINE PRODUCTS

Q & A