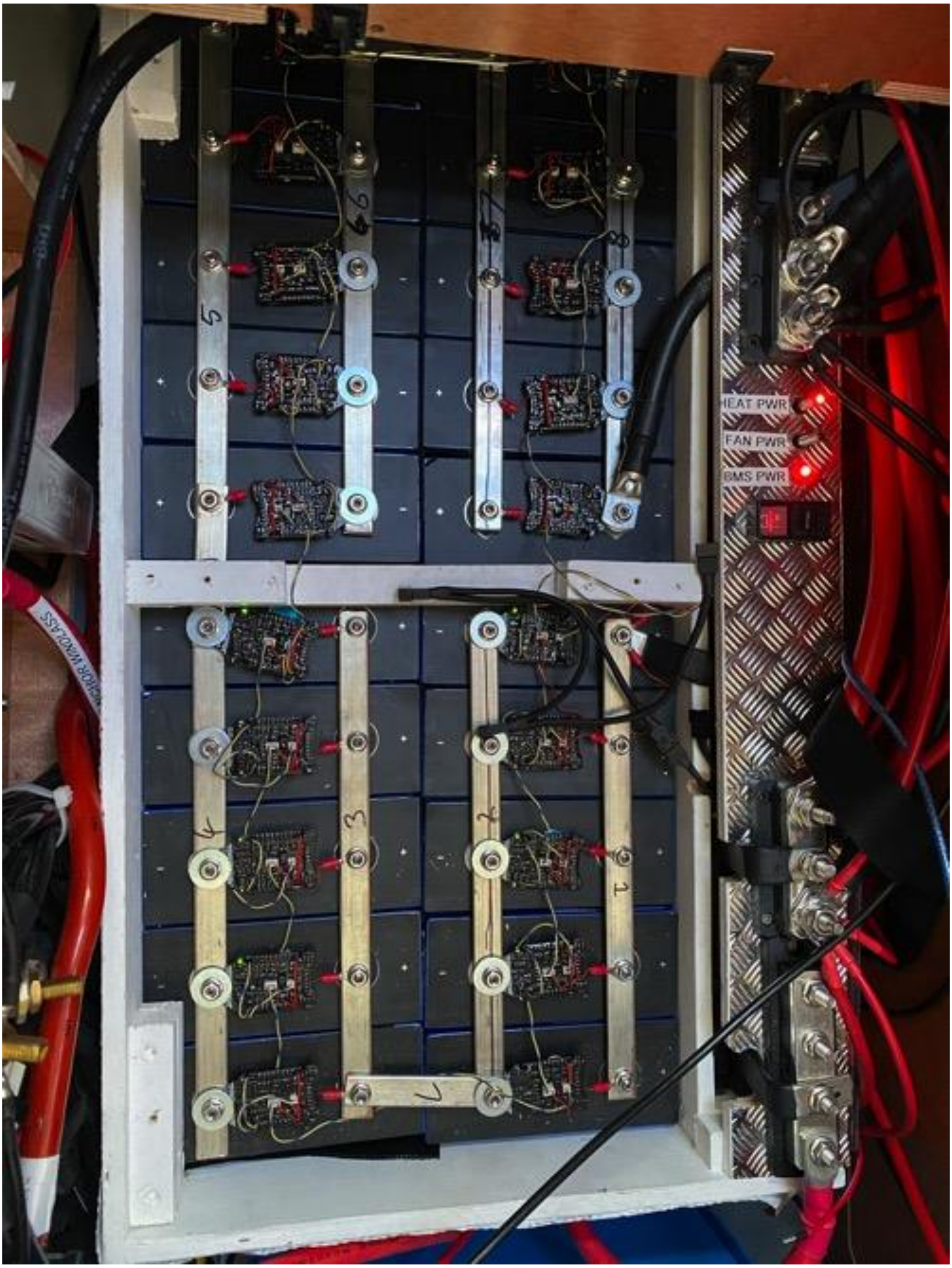
WHITE PAPER

MARINE ELECTRONICS

Lithium Charging myths and basics.

CONTENTS

Contents 2
Introduction 4
Lithium Ion Batteries are at least 6 different chemistries. 5
Are lithium batteries safe 6
Battery Chemistry and charging 7
What do I need to know about battery charging to move to lithium? 10
Key Findings 12
Conclusion 13
Contact details: 13


HEAT PWR
FAN PWR
BMS PWR

INTRODUCTION

If you trawl along on the internet looking for advice on charging lithium batteries there are 101 different things you will hear.

Most of which are incorrect, some of which are misleading and some of which is brilliant advice.

So which is which and how do you tell the difference. Well; First look for evidence and explanation of why their suggestions are correct.

In this whitepaper we'll cover off how you can charge a lithium battery bank and how you should not. We will almost entirely focus on Lithium Iron Phosphate (LifePo4 or LFP for short).

LITHIUM BATTERIES ARE AT LEAST 6 DIFFERENT CHEMISTRIES.

Not all Lithium batteries are the same. There are many different chemical make ups and also very different charge rates and responses. There are also very different safety criteria and responsibilities for each chemistry. So first thing we need to understand is what is Lithium Ion Batteries?

Lithium Ion Cobalt ($LiCoO_2$):

You will often see in laptops, cellphones etc. They have a high energy density, which is saying per kilo they can store a lot of energy. They have a Cobalt oxide Cathode and a graphite carbon Anode.

They are not particularly safe as chemistry goes and can cause fires if overcharged and/or damaged physically.

They also have a relatively short lifespan (500-1000 cycles) compared to some other chemistries.

Lithium Manganese Oxide ($LiMn_2O_4$):

You may find these in medical equipment and things that need a high temperature tolerance. They are a particularly safe chemistry and also rather inexpensive.

Being particularly new chemistry they are seen as a even safer replacement for LifePo4 batteries.

There lifespan is quite short though (300-700 cycles) so not entirely suitable for Boat battery banks.

Lithium Nickel Manganese Cobalt Oxide (CoLiMnNiO+):

Having a relatively high specific density they are often found in automobile battery banks for electric vehicles.

They are not as safe as some other chemistries but safer than LCO and have a longer life than LCO at cheaper cost.

Lithium Nickel Cobalt Aluminum Oxide ($LiNi_{0,84}Co_{0,12}Al_{0,04}O_2$.):

They have a high energy density and a long lifespan , but are not as safe as other chemistries and are rather expensive.

You do see this chemistry being used in electric automobiles.

Lithium Titanate (Li2TiO3):

These batteries most benefit from very fast charging and a high safety. They might appear perfect for electric automobiles other than the range issues (weight vs power) brought about by the density.

They have a long life also but are rather expensive.

Lithium Iron Phosphate (LifePo4):

LifePo4 (LFP) batteries are very robust and have a long life, being able to exceed 2000 cycles if well looked after. They are quite tolerant and very safe as a chemistry.

They will hold a charge for long periods of time with very little loss.

They also have a nominal resting voltage of 3.2v per cell which means 4 in series is a perfect match for existing 12v (nominal) systems, such as our boats.

Thermal runaway threshold is extremely high, meaning you can put an axe through a fully charge battery and although you will cause a short and much heat to be developed the battery will most likely NOT ignite and cause a fire. This means they are very safe for overcharging and physical damage.

They have a reasonably energy density, but not as high as some other chemistries.

ARE LITHIUM BATTERIES SAFE

Reading from above, you will understand that Lithium batteries is a general term and some are safe whilst other are more volatile. LifePo4 is used for boat battery banks because of its safety parameters putting it in very much the same ball park as FLA (Flooded Lead Acid, your normal lead battery).

I WOULD NOT EVER PUT LITHIUM BATTERIES INTO MY BOAT THAT WERE NOT LIFEPO4 CHEMISTRY.

I make this statement because LifePo4 (Lithium (Li) Iron (fe) Phosphate) batteries are as safe if not safer than Lead Acid batteries.

But don't' take my word for it, a picture is worth a thousand words, look at https://www.youtube.com/watch?v=Qzt9RZ0FQyM .

From real world experience, I personally have woken in the middle of the night to the smell of smoke and found one of my starter batteries (Lead Acid) had developed an internal short and was heating up to the "could cause a fire" point. Even after a day of sitting on the dock it was still too hot to touch. A friend had his brand-new car catch fire whilst driving and the car burnt to the ground, fortunately after he and his family had exited. The cause, a faulty starter battery (FLA). Lesson: Lead Acid is not completely safe either.

But why might Lifepo4 batteries be safer than Lead Acid? The answer is 'C Rating'.

The Charge/Discharge rating of a battery is limited by the internal resistance of that battery and therefore the heat that is generated through charging/discharging. C ratings are given to batteries chemistries based on the safe heat generation that a given C rating creates.

Because LifePo4 batteries have a C rating 5X higher than a Lead acid battery they produce far less heat and are much more within their safe parameters during use as a House Battery where the loads can be high and lengthy.

NOTE: Lead Acid starter batteries often have what is called a CCA which is very high. (Cold Cranking Amps) but this is a momentary delivery of discharge and reading the fine print will inform you that full CCA should never be maintained for more than a few seconds at a time. This is to allow the battery to dissipate the heat generated by that load.

BATTERY CHEMISTRY AND CHARGING

Different batteries require different charging strategies for the long-term health of the battery and also safety. This is NOT a negotiable fact. Please understand that Lithium batteries require different charging than FLA.

So some very strong statements, then I will back them up:

Can you charge a Lithium (LFP) battery with a lead Acid charger: **Yes**
Will it damage the battery: **Yes**
Will it blow up: **No**
Will it shorten the life: **Yes**
"Should" you charge an LFP battery with a FLA charger: **NO definitely NOT**.

Can connecting a Lithium battery to an engine alternator charge the battery: **Yes**
Can it damage the Alternator: **Yes**
Can it cause a fire: **Yes**
Will it always: **No**
Can I get away with it for a while: **Perhaps, perhaps not**.
"Should" I charge from an alternator without modifying/checking: **NO definitely NOT**.

FLA battery charging requirements:

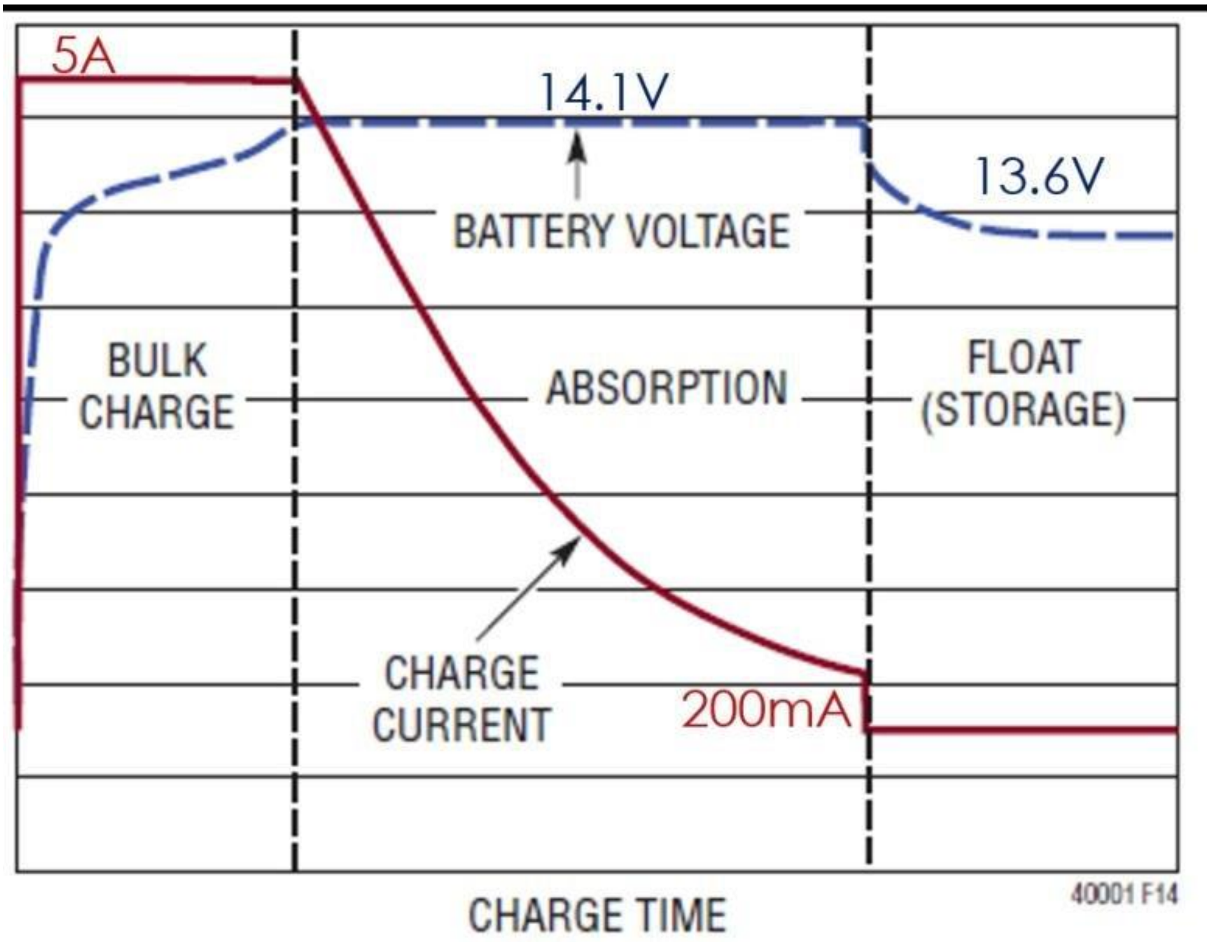
Let's start with the Charging requirements for a Flooded Lead Acid battery. Because we tend to discuss Lithium as if its something very strange and difficult, whereas if fact FLA is more difficult and strange, we are just used to it and our systems are designed for it.

FLA has a very high internal resistance and more importantly the resistance climbs quite quickly as the battery charges.

Overcharging, forcing to much voltage into a FLA battery will cause heat and rapidly shorten the life of the battery, it can cause a fire if really excessive.

For this reason FLA batteries DO NOT LIKE TO BE RAPIDLY CHARGED TO FULL CAPACITY.

They prefer to be charge rapidly to less then 80% capacity and then slow charged after that point. An FLA Charge curve looks like this (The Red Line):



This means that FLA chargers are designed to charge at full amps and then drop down to an "Absorption" phase and eventually to a "Float" stage.

The "Float" Stage is because FLA batteries LIKE to be kept charged and keeping them "topped" off works well for their lifespan.

This makes them particularly suited for vehicle starter batteries where an alternator will constantly keep them charged and their off charge use will be limited. FLA's like this very much and will live a long time.

They also do not like being discharged too deeply, i.e. beyond 50%.

Lithium Battery Charging Requirements:

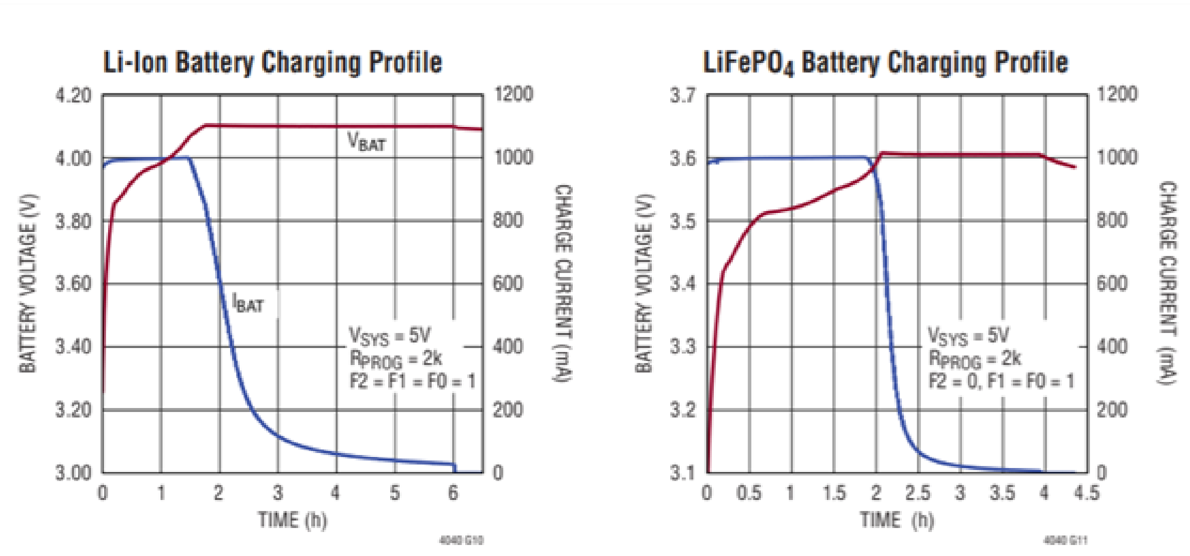
Lithium batteries have a very low internal resistance and this does not change dramatically during their charging cycle.

They like to be charged as fast as the chemistry will allow, but mostly 1C or better right up to full capacity and then for charging to stop. This stop can be quite sudden with LFP.

An absorption phase is very bad for a lithium battery because low current charging can encourage the formation of “tendrils” lithium formations on the cathodes that extend into the battery and cause an internal short. FLA batteries also suffer from this problem but mostly when overly discharged rather than the charging current.

For the same reason LFP batteries do not like “Float” charging and “Float” should not be allowed to happen whilst charging an LFP battery.

Below is a chart comparing Li-ion (lithium) to LifePo4 (LFP, Lithium). You can see they like to be getting full current right up to fully charged and then will sag to resting voltage. This graph is for a cell, rather than a 12v battery so the numbers (3.6) refers to volts for a cell. Multiply by 4 to get 12V battery equivalents (i.e. 3.6 = 14.4v). The sag to 13.6 is what is called resting voltage, i.e. charging has stopped at 14.1 or 14.2 and battery voltage will sag to rest at 13.6.



Battery voltage the full story:

When we talk about a 12V system we are describing the “Nominal” voltage of that system. By agreement this means a system that will work somewhere between the boundaries of 10VDC and 13.7VDC.

This does not BTW, mean that everything will accept the lower end or higher end, but it does mean that a 12V DC battery may in fact be 13.7V fully charged or indeed in the case of LFP 13.6 resting and 14.2V at the fully charged point.

A 12V FLA battery is fully charged at 13.7VDC and will drop to resting of 12.5 approximately.

A 12V LFP battery is fully charged at 14.2VDC and will drop rapidly to 13.6 resting.

Immediately you can see there is a problem if you have a FLA charger because it will expect the battery to be fully charged and in “Float” well below the full voltage required for a LFP battery. Despite, absorption phase and float it will never get to a high enough voltage to charge correctly.

WHAT DO I NEED TO KNOW ABOUT BATTERY CHARGING TO MOVE TO LITHIUM?

There are some things you need to understand. I should point out that the only reason you think you don't need to know these for Lead Acid is that you already have a well-designed (one would hope) lead acid environment that you have not had to consider.

Moving to Lithium the rules change, you get bigger C ratings for a start, and they require a slightly different supporting environment to Lead Acid batteries.

Can I just buy "Drop in Lithium" batteries and be done with it

The answer is no, any more than you could if we were going in the other direction, from a Lithium battery environment and adding Lead Acid. Batteries fit into a supporting environment, and it all needs to line up.

So unfortunately to move to lithium you need to understand how you must adjust your environment to fit the new batteries requirements or things can go wrong.

What changes with Lithium compared to Lead Acid?

The two most important changes are:

- Charge/Discharge rates i.e., internal resistance of the batteries
- Charge Profile (style if you like) of the different chemistries.

The second one is important because Lead Acid and Lithium require slightly different charging techniques.

You might not be aware, but your battery chargers currently are charging your batteries according to a pattern that is best for your Lead Acid batteries. This is not good for your Lithium batteries in the long term and will slow down their charging greatly in the short term.

So, either your chargers will be able to be re-programmed (presuming you are not keeping any Lead Acid batteries around) or you might need new chargers.

If you get this wrong, the whole thing won't blow up, it just won't last as long or take advantage of one of the benefits of Lithium, which is fast charging.

Things can go *bang* if you don't understand

The C rating (Charge/Discharge rate) is a much more important factor to consider.

Lead Acid batteries have a much higher internal resistance, and therefore their charging rate is much lower.

Some of the components of your electrical system may well depend on this fact to protect them. Your alternators on your engines for instance; if they are not regulated and many perhaps most, are not, then they will attempt to provide as much current as the battery demands.

They can get away with this because they are designed to work with the maximum C rating of a lead acid battery, but if you suddenly put a Lithium battery in there and it now demands 5 X the current from the alternator, if it doesn't have some external regulator, it will simply get too hot and burn out.

Again, a picture is worth a thousand words, so take a look at https://www.youtube.com/watch?v=jgoIocPgOug kindly provided by Victron to educate us.

This is the reason that putting "Drop In Lithium" batteries is not such a good idea.

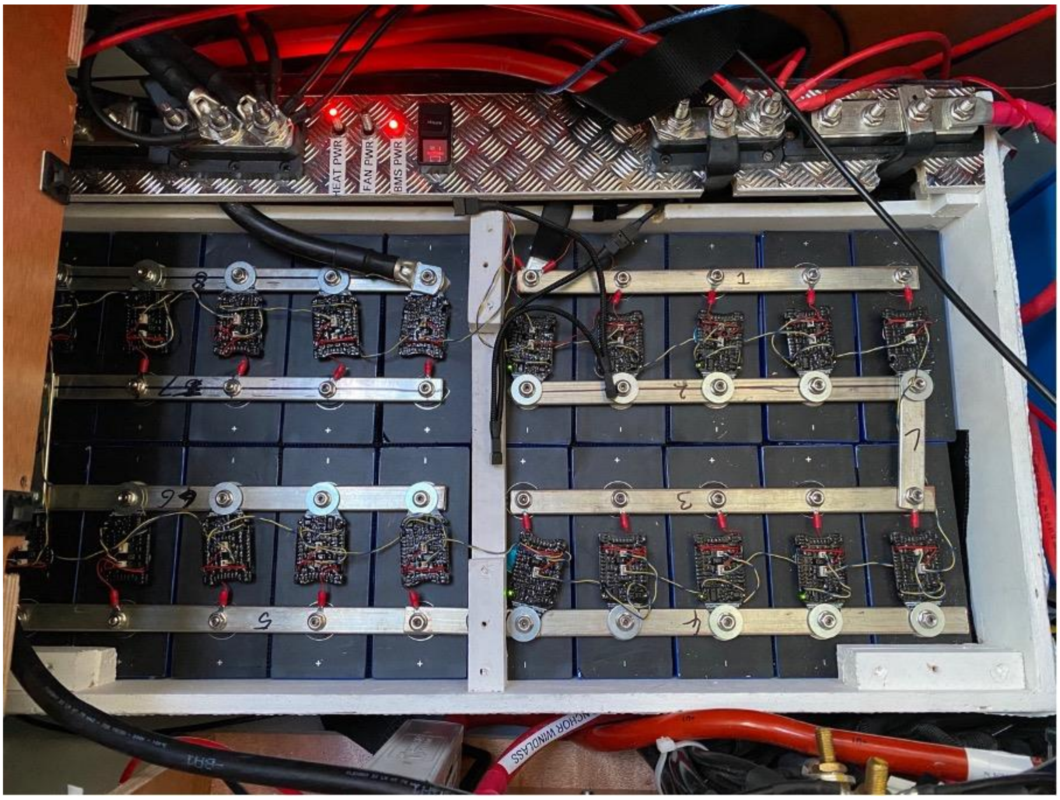
If you want to geek out, or learn a little bit, consider this….

> *A Lead Acid battery bank can only be charged at 0.2 C until it approaches 80% charged. Then the internal resistance will reduce the rate at which the batteries can be charged because of the increasing internal resistance.*
>
> *So, a 125Amp alternator would be at maximum capacity if the battery bank had 625AH of free space left before it got to 80%. This would mean that the battery bank because you should not discharge below 50% for Lead Acid, would have to be over 1500AH and almost fully drained to draw 125A from the alternator.*
>
> *But a Lithium battery, which could accept 1C of charge right up to 100% would only need a battery of 125AH that was partially drained (just a little) to draw the same current. Imagine how much a slightly empty 600AH battery would try to draw from that 125A alternator (600A would be the answer).*

In Conclusion

You cannot "just drop in" a Drop in Lithium battery because you need to consider what impact your chargers might have on it and what impact it might have on components in your system, like your alternators.

KEY FINDINGS



- You CAN charge Lithium (*LFP) with a FLA charger but you will damage the battery eventually.
- If you can turn off Absorption phase and Float phases and raise the charging voltage appropriately it will also work, manufacturers call this Lithium charging profiles!!!.
- “Drop In” replacement batteries are a bit misleading and can work but perhaps you need to think about your charging requirements.
- You do need to ensure you understand how your electrical environment needs to change to fit Lithium. It’s not hard, just different and may come with hidden costs.

CONCLUSION

Lithium Iron Phosphate are excellent batteries BUT they are NOT Flooded Lead Acid. They are very very different.

Do not believe people who tell you you can just drop them in and all will be well or you can charge them with FLA chargers (even Gel battery chargers!!). You can't safely, but its not hard to adjust a few things to make it all work.

I would highly recommend that you investigate Lithium (LifePo4) for Household Battery requirements, where they really do shine.

CONTACT DETAILS:

Feel free to contact me on GREG@ABBISS.CO.NZ or WhatsApp +447495739753

Good luck with your future boat projects.