How to Install and Maintain your Lithium House Batteries

Noel Swanson
Feb 2018

The author may be contacted through his blog at http://LifePart2.info

Disclaimer

The information in this document is based on the author's personal experience and is offered in good faith that it will be of interest and use to the reader. The reader is warned that some of the strategies presented below are advanced strategies that have the potential to damage your alternators, batteries, or other electrical equipment. Any modifications that you make to your own setup are done at your own risk. If you are not confident in what you are doing, seek the help of a professional.

Table of Contents

Disclaimer....2

The Benefits of Lithium over Lead....4

The Ins and Outs of Lithium Cells....5

Step 1: Buy Your LiFePO4 Cells....8

Step 2. First-Time Charge....10

Step 3. Put Together Your Charging System....11

The Junsi's....13

The Smoke Detector....15

The Relay....15

The Self Locking Timer Relay....16

How it all Works....17

Programming the Junsi's....18

Programming the Timer Relay....19

Step 4. Controlling your Charging Inputs....22

Controlling your Wind Generator....22

Controlling Your Alternators....24

Strategy One: Regulate the Regulator....30

Strategy Two: Advanced Regulator Replacement....30

Controlling Your Solar Panels....34

MPPT Controller....34

Basic or No Regulator....35

Charging Multiple Batteries....35

Step 5. Fine Tuning Your Setup....36

Step 1: Set up the Logging....37

Step 2. Start the Logging....37

To View the Data....37

Download the Data....37

Now, what to do with this data?....38

Long Term Maintenance and Storage....41

Conclusion....41

Shopping List....42

Shameless Plug..42

How to Install and Maintain Your Lithium House Batteries

There seems to be a lot of confusion and misinformation about how to set up Lithium (LiFePO4) batteries as a replacement for the old lead acid ones. Indeed, the thread on the subject at CruisersForum.org runs to several hundred posts.

Yet, once you understand how these batteries work, their set up and maintenance is actually very simple and even easier than the old lead acid. In this article I will give you step by step instructions on how to set up your own system.

The Benefits of Lithium over Lead

Without spending too long on the topic, I thought I should briefly cover the reasons why you would want to switch over to Lithium. Note that we are talking about LiFePO4 (and also LiFeYtPO4), which are NOT the same as the lithium cells in your laptop and phone.

- Longer life. Lithium cells typical have a life span of 5,000 to 7,000+ cycles. Assuming a typical once-a -day charging regime that gives you about 15 to 20 years of life. That is probably longer than you will keep your boat! Compare this with about 600 cycles for a good AGM that is cycled down to 60% state of charge (SOC).
- More efficient charging. As we shall see, Lithium cells have a pretty flat charging curve. What that means is that they can continue to accept high charging currents even when they are almost fully charged. On Life Part 2, with our old AGM batteries at 90% state of charge (SOC) we could charge them up at about 8 amps from our alternator. In contrast, with the Lithium cells in place, we would be charging at over 25 amps with the same alternator under the same conditions. That translates to less time running engines or generators, and also greater likelihood of achieving a full SOC when using just solar and/or wind.
- Consistent voltage (about 13v) throughout the discharge curve. This means that your electronics and electrical appliances will run better.
- Smaller size and weight. A replacement bank of lithium cells takes up about a third of the space and a quarter of the weight of lead acid batteries.

- Greater safety. Lithium cells do not release any noxious gases, won't leak acid if punctured, and won't explode.
- Simpler charging regimes. Without the need for complex regulators, you can tweak your charging systems so as to produce greater output, and thus quicker charge times - again reducing the time spent running engines or generators.
- No maintenance. Like AGM and gel batteries, but unlike lead acid wet cells, there is no maintenance. You don't need to check electrolyte levels etc. Nor do you need to periodically run an equalization charge.
- No gradual fading of capacity cause by sulphation of the lead plates, and no 'memory' effects such as occurs with NiCad and NiMH cells.
- Similar price to high quality AGM batteries.

As you can see, with all these benefits, if your current lead acid batteries (of any description - wet cell, AGM or gel) are approaching their end of life you should have zero hesitation about switching.

The Ins and Outs of Lithium Cells

As you will have noticed, when it comes to Lithium we normally talk about cell voltage rather than battery voltage. The reason for this is that there are four important numbers that you need to know (the number in brackets is the combined voltage for a 4-cell battery). These numbers are for Winston cells. Other manufacturers have slightly different numbers. Make sure you read their specification sheet before you start.

Maximum voltage 4 V (16 V). The cell is damaged if the voltage exceeds this voltage.

Safe charging voltage 3.6 V. (14.4 V). This is the recommended charge voltage for most applications. This is about 95% state of charge.

Safe discharge voltage 2.8V (11.2 V). Stop discharge when this voltage level is reached. This is 20% state of charge.

The minimum voltage is 2.5V (10 V). The cell may be destroyed when voltage drops below this voltage.

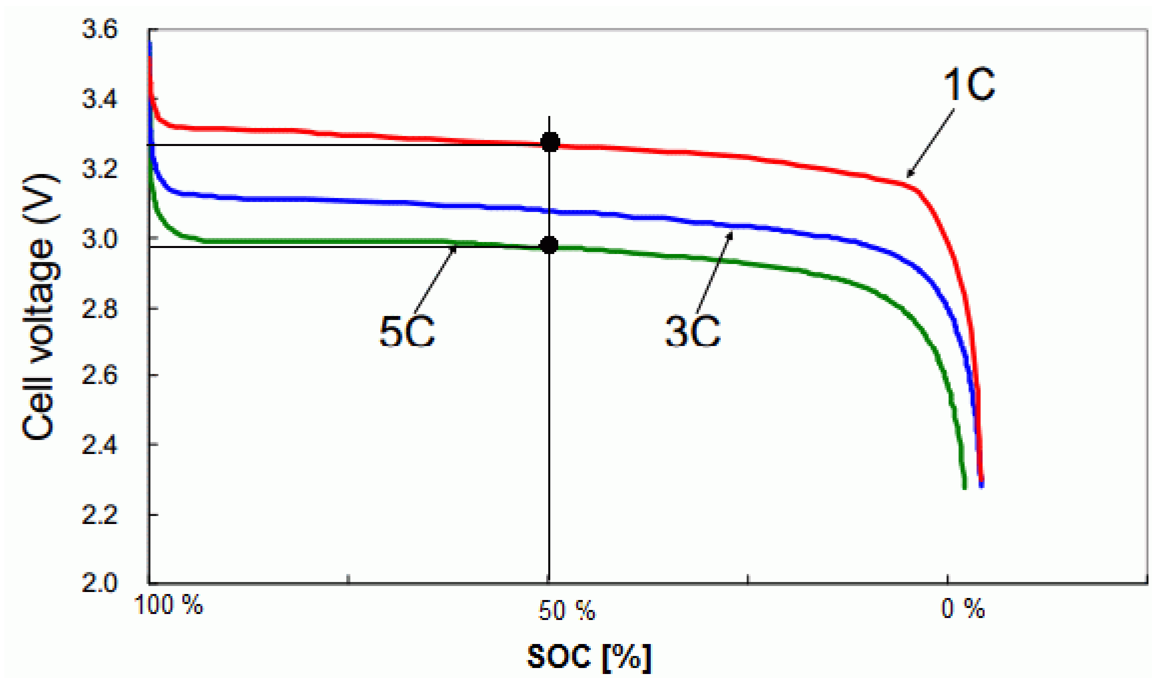
And one more number that you should check:

Optimal charge and discharge current: <0.5 C (where C represents the cell capacity in amp hours. Thus for a 300 aH setup, 0.5C would equal 150 amps. The cells can actually handle 5 times that for short periods, but aim to keep your general usage at that level or less). If your boat is going to need higher current levels than this for more that 10 or 15 minutes at a time, then you should increase your total battery capacity accordingly.

If you research how to charge lithium cells on the internet you will come a across a lot of confusing information about ideal voltages and charge currents and so forth. The reason for this, is that the people who are discussing this are using their lithium cells for two applications: either electrical powered vehicles, or radio controlled airplanes. In both applications the user is concerned with getting the absolute maximum capacity out of their batteries. In other words they want to make sure they charge the all the way up to 100% (without damaging them), and then deeply discharge them as low as they dare, again without damaging them.

The problem is that the cell voltage depends on the current that is going into or out of it.

The diagram below shows a typical discharge curve for a lithium cell. A charging curve looks similar, but mirror image - the curve (voltage) goes up, as the cell is charged up.



Suppose you were to measure the cell voltage and found it to be 3.0V. So, is the cell pretty much fully charged? Or almost empty? As you can see from the graph, it depends on the current. If you are drawing 5C from the cell (i.e. 1500 amps for a 300 aH system - not unusual for an electric car), then 3.0 V means you are still pretty full. But if you are drawing just 1C (i.e. 300 amps for a 300 aH system - way more than your boat would use), then that same 3.0V means your battery is almost dead. And how accurately can you measure that 3.0V? I have four different meters for measuring voltage. Using them to measure my battery voltage I get a range of 13.05V to 13.2V. Which one is correct?

So how do you know when you are fully discharged or fully charged? But if you are trying to extract (or charge) to the max, you *need* to know, as you risk destroying your cells if you get it wrong. Hence all the discussions.

As a cruiser, none of this matters to you for several reason:

1) Except for very brief periods of time, such as when turning over the engine to start it, or operating a windlass or bow thruster, your current is going to be low. Most likely, your discharge current is going to be in the region of 10-15 amps maximum (= 0.05 C on a 300 aH setup), and your charging current will probably be below 100 amp (=0.3 C on 300 aH setup). That means you only need to be concerned about the top curve in the graph. But, don't worry, as you shall soon see, it gets even simpler.

2) On a boat you are not concerned about maximal performance. You are more concerned about reliability and economy. All you need to be able to do is make it comfortably from the end of today's charging session (whether that be solar or generator) to the beginning of tomorrow's charging session. For those reasons you have no need to push the charging envelope all the way to 100%. 97%, or even 95% is plenty. After all, the difference of 5% is only 15 amp hours - about one or two hours use. Similarly, going down to, say 30%, is more than enough. In fact, on Life Part 2 we mostly operate between about 95% and 70% - so even if there is not sun or wind we can go as much as three days without having to charge the batteries.

Once you accept those limits, then it all becomes easy. Look again at the discharge curve. You will see there are three phases. An initial steep curve between 100% SOC and about 97%. Then a relatively flat section, all the way down to about 10% SOC, and then another sharp drop down to fully discharged.

Your goal, as a cruiser, is to keep your cells in that flat section. Do that, and they will probably last forever.

Using the system I describe below will keep you within that flat section AND does not depend on the accuracy of your voltage meters.

So, without further ado, let's get on with making the switch.

Step 1: Buy Your LiFePO4 Cells

When you buy a lead acid battery, you actually buy a factory-built package of 6 lead acid cells, each producing 2.1 V, that are wired in series. You CAN do the same with Lithium, but that is the more expensive route. Far simpler is to buy the individual lithium cells. Each cell has a nominal voltage of 3.2v so to replace a 12 V battery you will need 4 cells.

Each cell has a specific capacity, e.g. 300 amp hours. Note that his is 300 aH at 3.2 V, not at 12 V. So when you put together four of these cells, you still have 300 aH, but now it is at 12 V.

So, what size do you need?

Lead Acid batteries suffer from a process called sulphation. Simply stated, the lead plates get gummed up and less efficient each time they are discharged. The deeper you discharge them, the more this happens. The process can be partly reversed by briefly overcharging the batteries with an 'equalisation' charge but, even so, the bottom line is that the more you run down the batteries, the more they get damaged.

For this reason most cruisers will not allow their lead acid batteries to fall below a 50% state of charge - and preferably above 60%. This provides the maximum number of amp hours delivered over the life of the battery.

In contrast, Lithium cells are quite happy to be discharged to as low as 20% with no damage and minimal voltage drop.

At the other end of the scale, bringing lead acid batteries up to 100% charge is a slow process of trickle charging. That is fine when you have solar doing the job, though on many days you may not reach the full 100%. But when running engines or generators, most people will call it a day at about 80% SOC, as trying to get higher than that just takes too long, and burns too much fuel.

Lithium cells, as you will see, have not such limitations and can be happily and quickly charged to 95% or more.

Putting the two together, for lead acid you have a useable range of 90% to 60%, i.e. 30%, whereas for Lithium you have 95% to 20%, i.e. 75%.

If your current house bank is sized at, say, 600 aH, then your daily useable cycle would be about 180aH. To produce the same useable cycle with Lithium you would thus need a battery capacity of 240aH. I would suggest rounding this up to an even 300 aH - i.e. half of your current battery size. You will find that the price of such cells will be pretty similar to the price of 600 aH of high quality AGM batteries.

The cells are available in several different physical sizes, so you should be able to find some that fit into the same battery compartment. There is little, if any, difference between the different brands. They are all made in China, and all seem to have the same characteristics. The one possible exception are the Winston cells that have an additional element, Yttrium, added to them which, they claim, gives them some better performance. For our purposes as cruisers that benefit would probably be invisible, so choose whichever are the cheaper (calculated as dollars per amp hour) and the right physical size. You can even choose them by color if you like - blue versus yellow!

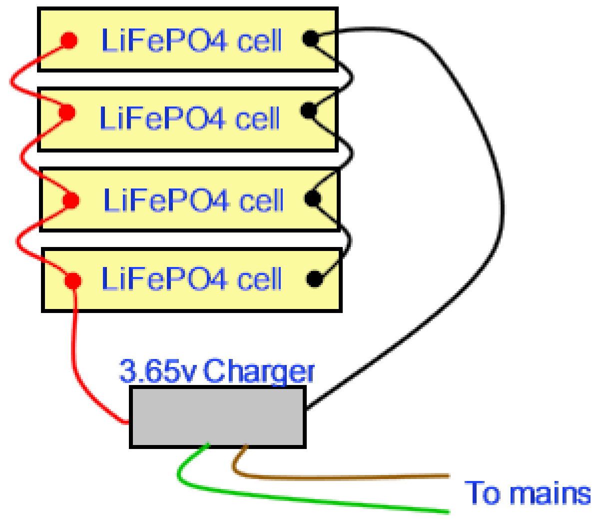
When you buy them insist that all four cells come from the same manufacturing batch. You want these cells to be as identical as possible so, like matching paint colors, it is best if they all come from the same lot.

You will also need to buy a 3.65v single-cell charger, and 5 terminal links.

You will also need to buy some other items, but I will discuss these in the sections that describe their use. The full shopping list is included at the end, as is a list of suppliers.

Step 2. First-Time Charge

When the cells are delivered to you, they will be at approximately a 50% state of charge. Your first task is to fully charge them. Unlike future charging cycles, this first charge is done with the cells wired in **parallel**. The reason for this is that you want to charge them all up to exactly the same state of charge.

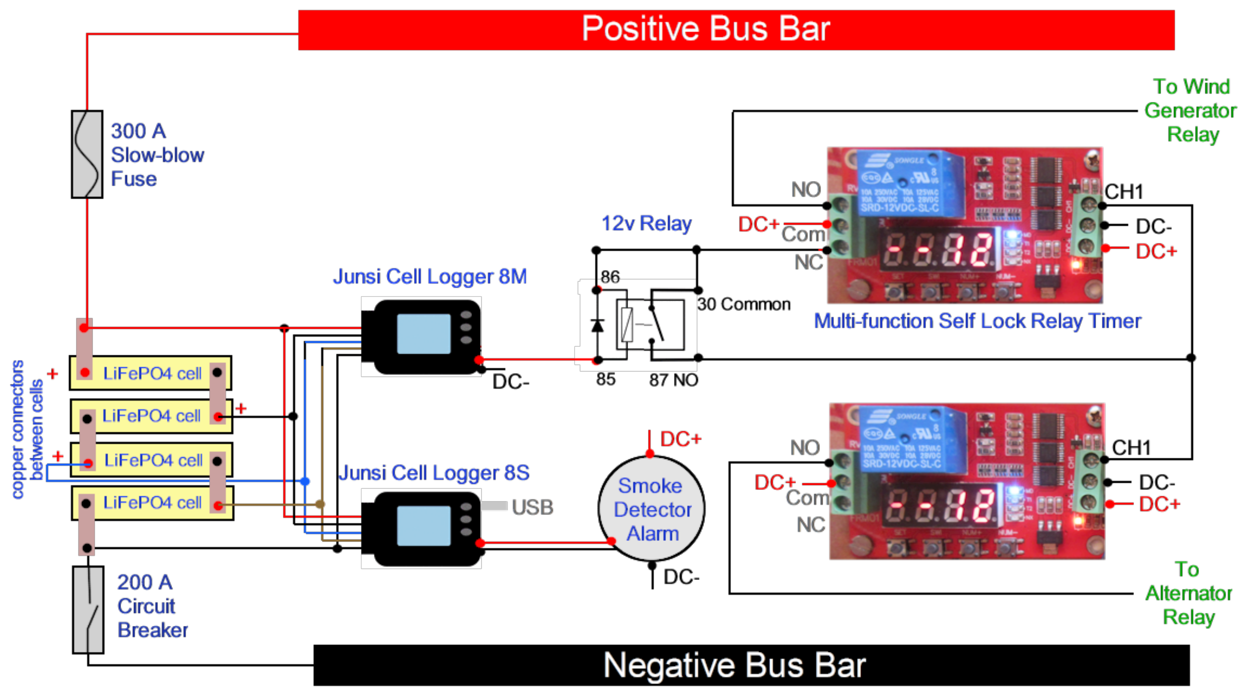


To do this, connect the cells together as shown below and then connect them to your 3.65v single cell charger (note how the charger is connected to the front and back cell). Leave them to charge. This will probably take several days as it just trickle charges them. At the end the charger will show them as fully charged and, as they are wired in parallel, they will all be at identical voltage.

Step 3. Put Together Your Charging System

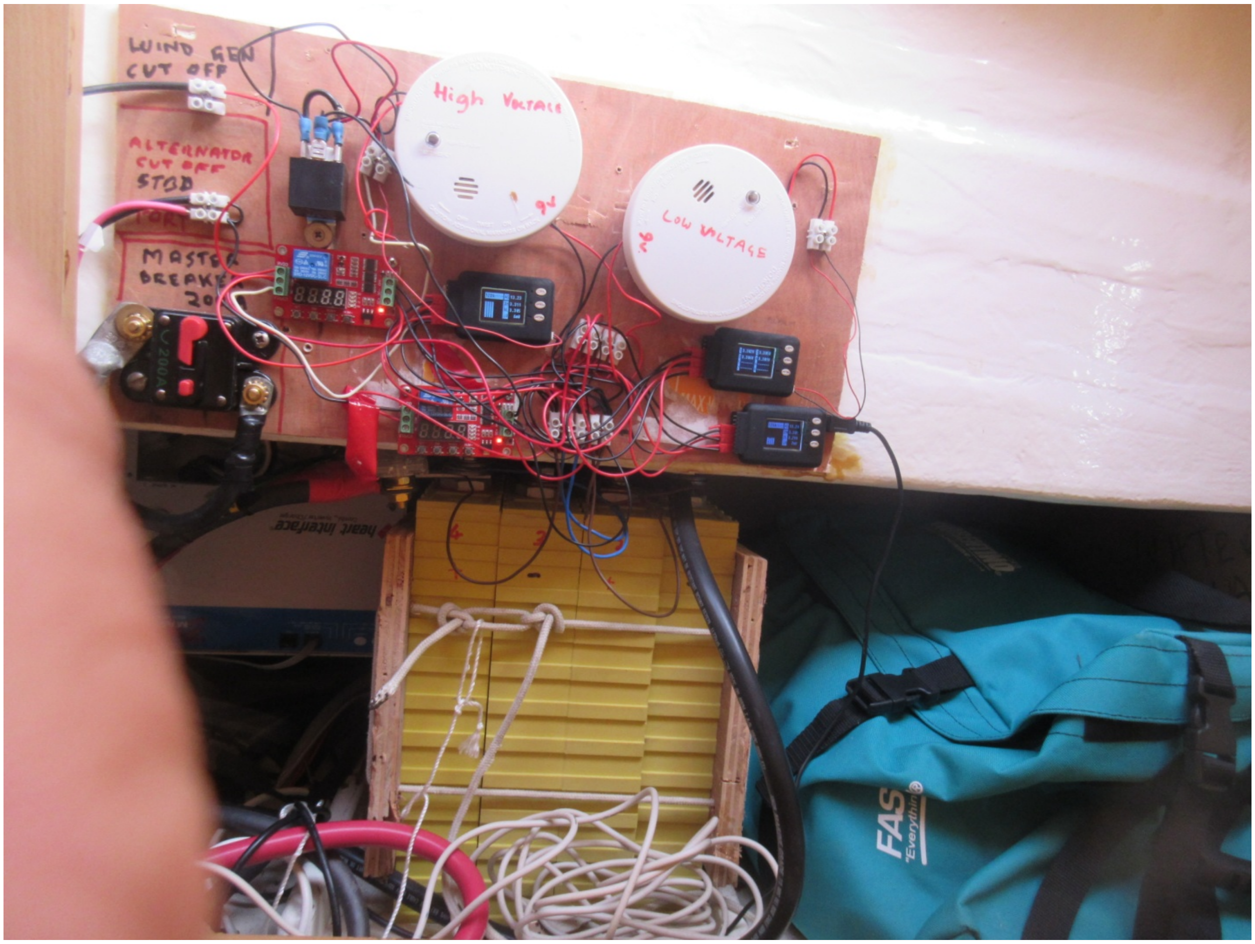
While the cells are charging, you can construct your charging control system. The goal of this is to maximise your charge rate, while keeping you safely within the flat section of the charge curve AND have it all automated so that you can get one with cruising instead of monitoring your batteries.

The circuit diagram is below:



I suggest that you assemble all this by attaching the various components onto a piece of plywood that you can then mount near your battery. All the terminals marked with DC+ or DC- should be connected directly to the positive and negative bus bars respectively. Double check all your polarities before you hook up the cells and make it all live.

Below is how it looks on Life Part 2. Our setup is a little bit more cluttered, as it was developed through several iterations. We also have a third Junsi, because I burnt out the alarm on the 8S (see the warning below), so I replaced it with a cheaper 8M which does not have the logging, and I use the burnt out one for just logging. I also have two smoke detector alarms, but one of them is disconnected and no longer in use; again, the result of a previous iteration. With the above circuit diagram you can make a much neater installation. The yellow blocks are our lithium cells. The blue bag is our para-anchor. Previously this entire locker was filled with our three AGM batteries.

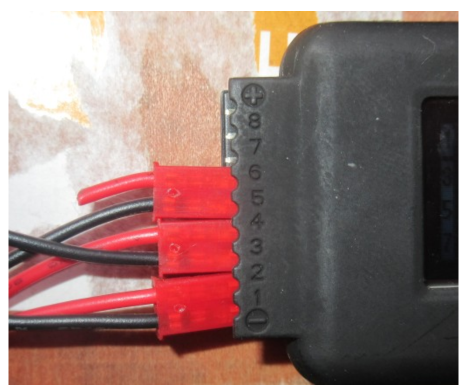


So, let's go through the circuit diagram piece by piece.

On the left are the four lithium cells (if you are doing a 24 V setup, then you would use eight, and you will have to make the other appropriate adjustments as you go along.)

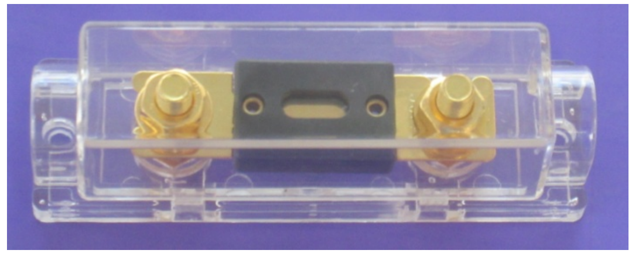
Unlike your first charge, the cells are now connected in series using the copper connectors, i.e. the positive terminal on one cell goes to the negative terminal of the next.

There are thus five terminals - the negative for the whole pack, the positive for the whole pack, and three connectors in the middle. Take a small wire from each of the five terminals to a terminal strip. Then take a small wire from each of the terminals to the first five input ports on the Junsi. Make sure you have the connected in the right order to the correct input ports. You will need to buy a pack of little connectors for this.

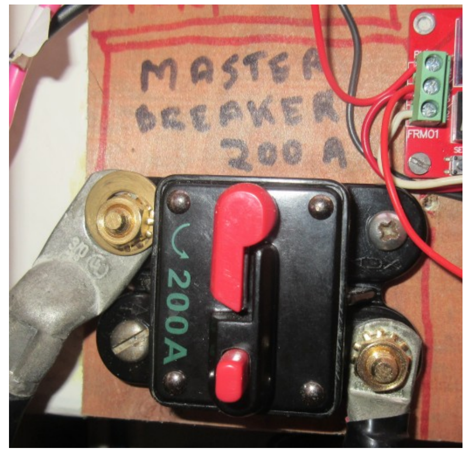


Now use another couple of terminal strips to create a positive and negative bus bar.

Finally, make sure you have a good solid terminal at each end of the pack as this will be where you connect your big fat house battery cables. Make sure that, when you do so, you also include a 300 amp ANL ignition-protected slow-blow fuse and perhaps also a 200 amp circuit breaker.



These lithium batteries can produce a lot of power. If ever a cable comes loose, or a tool falls across some terminals and you end up with a short across the battery you could easily have 3000 amps running very quickly. That will make something very hot, and might well sink your boat with a fire. The ANL fuses take about 10 seconds to blow - so no nuisance blowing - and won't arc even if there is 6000 amps running. They are a lot cheaper than the cost of having a fire. Use one.



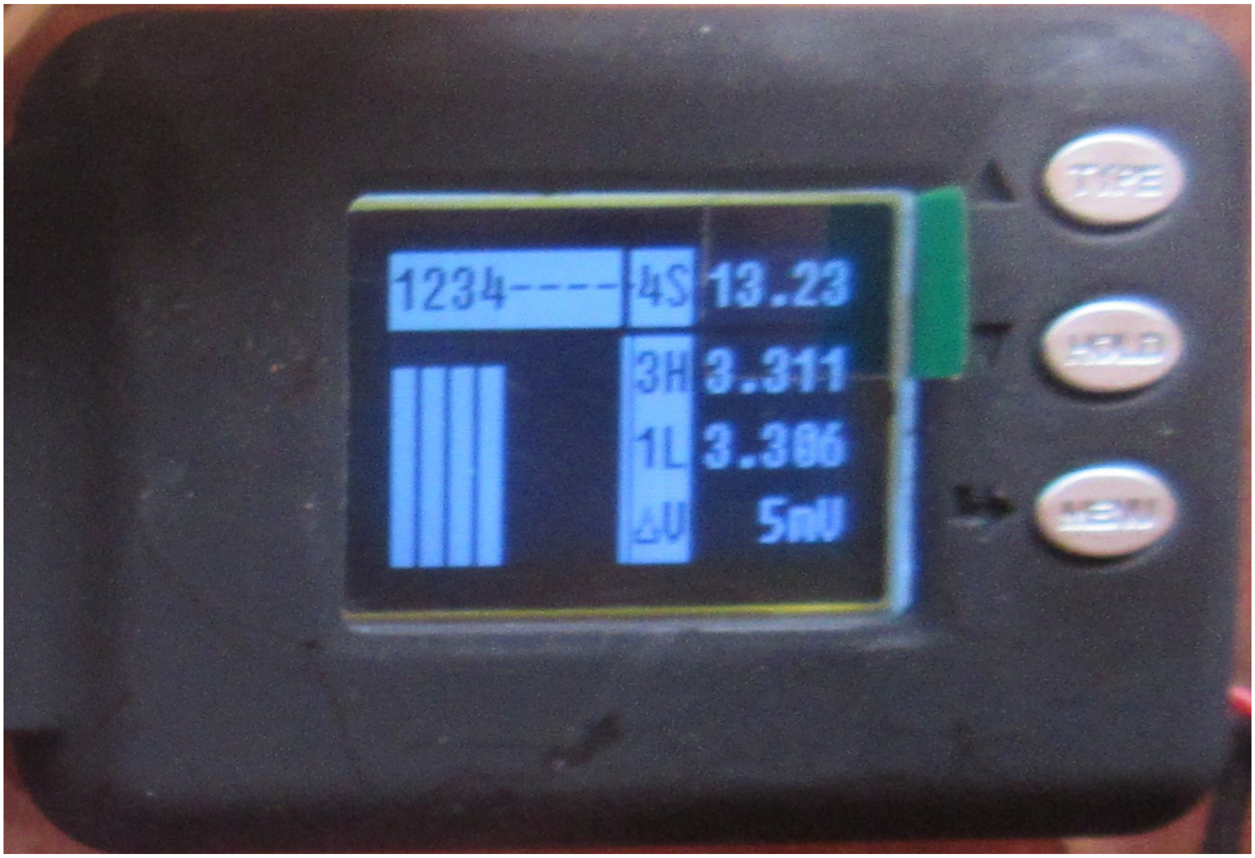
I also installed a 200 amp circuit breaker. This will blow before the ANL fuse blows. It did go once on Life Part 2 when Ceu turned her hair dryer onto full power. It is easily reset. But it is not rated to interrupt a huge current of several thousand amps, and would likely arc. For that I need the proper fuse as described above.

WARNING: On Life Part 2 the breaker shown in the picture started to trip at much lower currents than 200 amps. In fact, it started to trip when the windlass was operating, even before the 100 amp breaker that I have on the windlass circuit. When this battery isolation breaker trips, it disconnects the battery from the boat's electrics, that is, after all, what it is supposed to do. However, there are other sources of electricity for the boats electrics, i.e. the solar panels and wind generator. Without the battery in line to soak up the power output from these sources, their output voltage can start to fluctuate wildly. The solar regulator can probably handled that. However, if you have removed the regulator from the wind generator, as described below, the wind generator may now produce un-regulated voltages, even up to 16v or higher. This, in turn, may damage your electrics if it continues unchecked. The solution? Either do without the circuit breaker above, or make sure that whenever it does trip, it is immediately recognised, and reset. Do not leave the battery disconnected from the other electrics while you still have solar and wind turned on. Likewise, if you even need to disconnect the battery for some reason, make sure you first turn off the wind, solar, engines, and any other sources of charging.

The Junsi's

These two little gadgets are the secret to this setup. Each unit accepts up to 9 inputs on the left. Each pair of inputs measures the voltage of one cell, and so each unit can handle up to 8 cells for a 24 V system. For a 12 V system you will be using just the first 5 inputs.

On the display below you can see that I have four cells connected in series for a total voltage of 13.23 V. Of these four cells, cell number 3 has the highest individual voltage, at 3.311 V, while cell number 1 is the lowest, at 3.306 V for a total difference between them of 5 mV.



Notice that we are talking here about measuring milliVolts - that is a thousandth of a volt - and that the cells are so closely matched to each other that they differ by merely a few milliVolts. In this system we will be using 2 of these Junsi Cell Loggers, and you will find that they agree with each other to a tolerance of a few milliVolts. However, while my two Junsi's are displaying a voltage of 13.23V, my Blue Sky Solar Charge controller shows 13.1 V and my handheld digital multi-meter says 13.05 V. Which is correct? I suspect the Junsi, but without going to a reference lab to get them properly calibrated, I don't know for sure. As you will see, however, that does not matter.

There are two versions of the Junsi Cell Logger. The more expensive one, the 8S, has a USB port that allows you to connect it to your laptop. It will record and save the voltage for each of your cells at regular user-defined intervals. You can then download this mass of data and view it on a graph.

The cheaper version, the 8M, does not have this logging memory function, and so only displays the voltage in real time. You will need one of each. Connect them up as shown in the diagram.

Both versions have an alarm function. We will set this up so that it triggers an alarm when certain voltage conditions exist. It is this that will prevent you from having to constantly check and monitor your batteries. We will set it up in a minute.

To the bottom right of the three silver buttons is an alarm output. To connect to this you will need a special little plug with red and black wires attached. This is normally supplied with the Junsi.

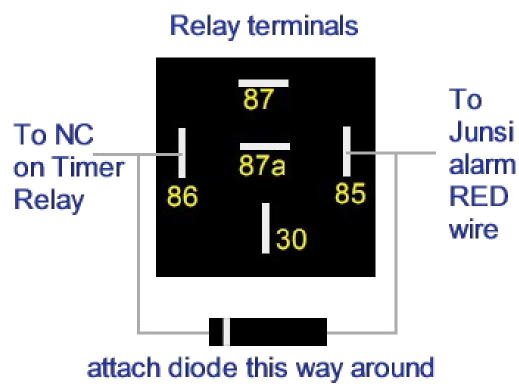
The Smoke Detector

We are using a smoke detector alarm as it is the easiest and cheapest way of setting up a nice loud alarm. All you need is a very basic battery operated smoke detector. It should have a button on the face that says 'Test'. With a battery in place, pressing this button should cause the alarm to sound.

Open up the case of the smoke detector so that you can see the circuit board inside it. Locate the push button 'Test' switch. Now what you want to do is to solder a small wire to each side of the switch and bring it outside the casing. Connect these two wires to the two outputs from the alarm port on one of your Junsi's.

Take out the battery from the smoke detector and find the connections to the battery. Take these to your positive and negative bus bars. The smoke detector probably runs on a 9V battery, but it will manage quite well with the 12 V from your house battery. The 'Test' Button should still work, so try it.

The Relay



Next is the relay. This is a standard automotive cube relay. If you can, buy one with an integral LED light that tells you when the relay is active. However, to protect your new Junsi, you do need to make a small addition to it. You are going to use the alarm function on the Junsi to turn on the relay which will, in turn, regulate your alternators and wind generator. But, to protect your Junsi, we need to put a diode across the relay. The reason for this is that when the relay turns off it can generate a brief spike of voltage in the opposite direction. To prevent this from flowing through and damaging the Junsi, we provide an alternative short circuit, through the diode. Diodes, you will recall, are like a one-way valve that allows the electric current to flow in only one direction.

For this you need a power diode. These are available from electronic shops or else you can salvage one from an old transformer-type mains to DC power adaptor such as your laptop or camera might use. Cut open the case, and inside you will find 4 or 5 suitable diodes. Normally they are a black cylinder with a white or silver band around one end, and a wire poking out each end. The end with the band on it is the end that corresponds with the black bar on the symbol for a diode in a circuit diagram. You will need to disconnect them from the circuit board which will probably require a soldering iron.

Take one such diode and solder a short piece of wire to it. Then solder one end to a female spade connector and the other end to another spade connector. Add a wire to each connector. So now you should have two wires ending in female spade connectors, with a diode joining them together.

Now look at the bottom of your relay. You should see two pins, one label with 85 and the other with 86. Attach the diode assembly to these two pins, making absolutely sure that the end of the diode with the white band on it goes on the terminal labelled 86. Then attach this same wire to the port labelled NC on the relay timer. **This is crucial. Get this the wrong way around, and you will fry your Junsi.** And then you will have to buy another one, like I did.

The other relay terminal, 85, and the end of the diode without the white band on it, is connected to the red wire coming from the Junsi alarm output.

The black wire from the Junsi alarm output goes to the negative bus bar.

Now unplug the little plug from the Junsi alarm output.

WARNING. Do NOT go any further until you are absolutely sure you have connected the diode the right way around.

Now connect the terminal on the relay labelled 30 to that same port labelled NC on the relay timer.

Finally connect the remaining terminal, 87, to the ports labelled CH1 on the two timer relays. Terminal 87a is not used, and some relays don't even have it.

The Self Locking Timer Relay

Connect the two timer relays as per the diagram.

The relay is powered by the two DC inputs. Connect these to your positive and negative bus bars.

Also connect the terminal marked 'Com' (for common) to the positive bus bar.

CH1 should already be connected to the car relay terminal 87, and NC should be connected to the other relay terminals 30 and 86 (the one with the banded end of the diode).

NO will be connected by a long stretch of wire to the alternator and wind generator controls, to be discussed later.

The three terminals marked Com, NC and NO together make a two pole switch.

NC means 'normally closed', which means that when at rest the switch connects Com and NC together.

When the relay is activated, then the switch flips to the other side, disconnecting NC and, instead, connecting together NO ('Normally Open') and Com.

The relay is activated by means of a positive voltage arriving at CH1. It is programmable so that it stays activated for a user-defined period of time before then self de-activating, and returning to its normal resting state, with NC closed and NO open.

How it all Works

To start with, the relay timer is at rest. That means that NC is closed, which means there is a positive voltage flowing through the Com to NC and onwards to through relay (terminals 85 and 86) and into the red wire on the Junsi alarm output.

At this point, however, it can go no further, as the alarm circuit is not active.

This means that the relay stays inactive, which means that terminals 30 and 87 are not closed, which means that there is no voltage reaching 87, and thus no voltage reaching CH1. So the timer stays inactive.

When your batteries are charging the cell voltages, as monitored by the two Junsi's, will gradually rise. When they reach a critical value (e.g. 3.5 V), the upper Junsi will activate its 'alarm output'. Actually, what it does is to close the switch, inside the Junsi, that then connects the little red and black wires together. Doing so allows the current from the relay to complete the circuit through the Junsi black wire and down to the negative bus bar.

We now have a complete circuit flowing through the relay, and so the relay becomes active. Terminals 30 and 87 now become connected. Voltage flows through to CH1 on the timer.

This now activates the timer. It switches NC off and NO on and it starts to count down the prescribed amount of minutes.

NC is now no longer live, and so the car relay (terminal 86) no longer has power entering into it, so it goes back to its inactive resting state. This prevents the relay from constantly clicking on and off. The relay switch turns off, voltage no longer reaches CH1, and the timer is no longer activated. HOWEVER, it is still counting down. So until it reaches zero it does not make any changes to NC and NO.

NO is now live, and that activates your alternator and wind generator controls, telling them to stop charging the battery as we have already reached the target voltage. The reason I have two relay timers is so that I can program a different duration for the alternator (3 hours) and wind generator (2 hours) controls. The connection between NC and the relay should be made on the timer with the shorter duration (probably the wind generator one).

After the prescribed amount of time, the timer will deactivate by switching NC back on again, and disconnecting NO. There is now no current going to the wind generator and alternator controls, and so they are now permitted to start charging again. Presumably, by now, the battery has been discharged a bit, so that is fine. If it is still fully charged, the voltage will quickly go back up to target, and the whole relay sequence will happen again.

if, for some reason, the above sequence fails, or for some reason the battery continues to be charged further, then the cell voltages will continue to rise. This is where the second Junsi kicks in. Should the voltage reach a critical level - either too high (e.g. 3.6 V) or too low (e.g.. 3.0 V), or should the cells go too far out of balance with each other (e.g. a difference between the cells of more than 50mV) then this Junsi will close the alarm switch, and the smoke detector alarm will sound.

This is your wake-up call. If you hear the alarm take a quick look at the voltage. If it is high, turn off whatever is charging the battery too much. If it is too low, immediately turn on an engine or generator to start to recharge the battery. Fail to take these measures and you risk destroying your battery. This is a fail-safe backup. In normal use you should never hear this alarm.

If the cells are out of balance then it will require more investigation, but is unlikely to be an emergency like the high or low voltage. One possibility is that one of the cells has failed. That will be obvious from the cell voltages. If that is the case, remove the dead cell, and try to limp along on three cells (9v) as best you can until you can get a replacement. However, this is extremely unlikely to happen.

On the other hand, over a long period of time the cells may just drift out of balance. In that case, disconnect all the cells and do a fresh 'First-time' charge (see Step 2) to bring them all up to exactly the same voltage again. This will require access to mains voltage for a while.

Programming the Junsi's

So now we come to setting the Junsi alarm parameters.

The Junsi is programmed using the three silver buttons. Note that in the following instructions **PRESS** means press the button briefly. **HOLD** means press and hold it for 3 seconds. The programming is well described in the manual that comes with the device.

When at rest, the Junsi displays one of four monitoring screens. You can toggle between these by pressing the TYPE button. All the programming instructions assume you are starting from any one of these screens (e.g. the one shown to the right).

First we need to set the Alarm mode to be 'Normally Open' (NO): Do this for both Junsi's.

1. Hold the MENU (Enter) button till the MAIN MENU screen appears
2. Press the HOLD (Down) button once to reach System
3. Press the MENU (Enter) button
4. Press the HOLD (Down) button 2 times to reach ALM Output
5. Press the MENU (Enter) button
6. Press the HOLD (Down) button once to reach NO
7. Press the MENU (Enter) button to select NO
8. Hold the MENU (Enter) button 3 times till the normal monitoring screen appears

Next we set the Cell High Voltage:

1. Hold the TYPE (Up) button till the SELECT TYPE screen appears
2. Press the HOLD (Down) button as many times as necessary to reach the type of battery you are testing. I set this to LiFe, though I don't think it actually makes any difference to the functioning.
3. Press the MENU (Enter) button to select the label
4. Press the HOLD (Down) button 2 times to reach Alarm

5. Press the MENU (Enter) button

6. Press the TYPE (Up) and HOLD (Down) button as required to reach Cell Voltage. Press MENU (Enter) to select this.

Set the upper voltage limit HV, lower voltage limit LV and maximum cell voltage difference ΔV for the cells for each Junsi as per the tables on the right. Pressing MENU (Enter) moves from one to another. TYPE (Up) and HOLD (Down) increases or decreases the value. Holding the MENU (Enter) button saves the value and returns to the previous screen.

Junsi 1 (Charge control) Alarm Settings	
Cell High Voltage	3.5V
Cell Low Voltage	any
Delta	any

We will use only the alarms for cell voltage, not for overall pack voltage.

Junsi 2 (Audible Alarm) Alarm Settings	
Cell High Voltage	3.6V
Cell Low Voltage	3.0V
Delta	50mV

7. Hold the MENU (Enter) button as many times as required till the SELECT TYPE screen appears. Choose the battery type you are configuring and press the MENU (Enter) button.

8. Press the HOLD (Down) button twice, then the MENU (Enter) button to get to the ALARM SETTING screen.

9. Press the HOLD (Down) button three times, then the MENU (Enter) button to get to the ALARM TRIGGER screen.

10. Press the TYPE (Up) and HOLD (Down) button as required then press the MENU (Enter) button to toggle on or off which alarm conditions you want to use as per the table on the right.

Junsi Alarm Triggers	
Junsi 1 (Charge control)	Cell HV
Junsi 2 (Audible Alarm)	Cell HV, LV & ΔV

Hold the MENU (Enter) button as many times as needed until you get back to the normal monitoring screen.

Programming the Timer Relay

This nifty unit has 18 different programs from which to choose. We shall be using Program 12. With this program the unit stays at rest until a voltage is applied to the CH1 input port. You will recall that this happens when the Junsi 1 alarm is triggered. When that happens, the timer relay starts a timer and switches the outputs so that NC becomes open and NO becomes closed, and it holds them in that position until the timer reaches zero, at which point it all goes back to the resting state.

The programming is achieved with just four buttons, and it also has 4 blue LED's that show you what mode you are in. It is somewhat confusingly described in the manual that comes with the unit.

We need to set this up in two ways: First we need to select program 12. Then we need to define for how long we want the timer to run.

To Select the Program:

1. Hold the SET button to enter into [Parameter setting mode].

2. Press SET as many times as needed until the blue LED shows MD.

3. The digital display will now show the program number. Press SW to select which digit needs to be changed, and then press NUM+ and NUM- to alter that digit up or down. Do this so that the readout shows 0012 on the four digits.

4. Hold SET to save and return you to the top level.

Do this for both Junsi's.

To Define the Timeout:

The timeout is defined with two parameters. The first is the units. This is defined in the NX function and can range from 1 to 99 seconds. The second is the number of units. This is defined in the T1 function, and can range from 1 to 9999. There is also a second timeout, T2, that is used by some of the programs but is irrelevant to our use of program 12. Accordingly NX can be set to different numbers for T1 and T2.

So, if NX (for T1) is set to 60, that means the units are 60 seconds, i.e. one minute.

If T1 is then set to 120, that means the timer will run for 120 units which, in this case, would be 120 minutes.

To set these parameters:

1. Hold the SET button to enter into [Parameter setting mode].

2. Press SET as many times as needed until the blue LED shows NX.

3. The digital display will now show four digits. The two to the left are the units for T1, the two to the right are the units for T2. We only care about T1. Press SW to select which digit needs to be changed, and then press NUM+ and NUM- to alter that digit up or down. Do this so that the readout shows 60 for the left two digits. This will set the units for T1 to be 60 seconds.

4. Hold SET to save and return you to the top level.

Now repeat this process, but this time adjust the T1 parameter:

1. Hold the SET button to enter into [Parameter setting mode].

2. Press SET as many times as needed until the blue LED shows T1.

3. The digital display will now show four digits. Set this to your desired number of minutes ranging from 1 to 9999. Remember that the total timeout will be this number times the number of seconds you defined for NX.

For my Junsi 1. which controls my wind generator, I have this set to 120 (i.e. two hours total), and I have my Junsi 2 set to 180 (three hours). The rationale for this is as follows:

As soon as the voltage alarm is triggered, the charging process will be stopped, and the batteries will now start to discharge through normal usage (although they may still receive charge from the solar panels - see later). Since the wind generator does not produce a lot of power, I don't want my batteries going too low before the wind generator starts to top them up again.

In contrast, if I am running my engines I don't need to be constantly topping up the battery. After all, doing so does actually consume fuel, and there is a chance that when I turn the engines off I may still receive enough power from wind and solar to fill the batteries. So why do it unnecessarily with fossil fuel? On the other hand, if I am using a lot of power (e.g.. with the autohelm and instruments at night) I don't want to run my battery down too far before the engine charging kicks in again. Somewhere around 3-4 hours seems to work well for me.

4. Hold SET to save and return you to the top level.

Step 4. Controlling your Charging Inputs

Ok, at this point your setup is almost complete. You can automatically monitor the cell voltages. If it gets too low and is at risk of damaging your cells (with a good margin of safety), it will sound an alarm. You could, if you wanted to, also have it trigger a huge relay to totally disconnect your battery so it cannot discharge any further, but that would turn off your navigation, your lights, and everything else. I think a manual approach at this point is preferable.

If it gets too high (again, with a good margin of safety) it will first turn off your alternator and wind charging and, if that fails and the voltage goes higher still, it will sound an alarm.

Finally, if the cells go too far out of balance it will again sound an alarm.

All that is left is to actually control your alternators and wind generator. Here is how:

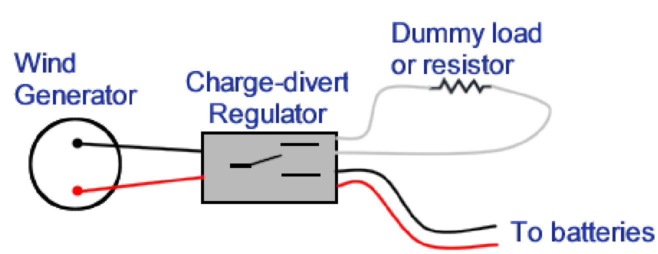
Controlling your Wind Generator

There are a number of different brands of wind generator out there, and they use different methods for controlling their output so that they don't overcharge your batteries. You will need to look at your own system to see which type you have.

One issue with all the regulators described below is that they measure the battery voltage where they are, and not at the actual battery terminal. Because of voltage drop along the cables, and possibly through isolation diodes, this can lead to undercharging. Careful setup is required - or else the use of our system as above where we measure the actual voltage at the battery terminals.

Also be careful to convert battery voltages to cell voltages when you work out what settings to use!

Charge Divert Regulation.

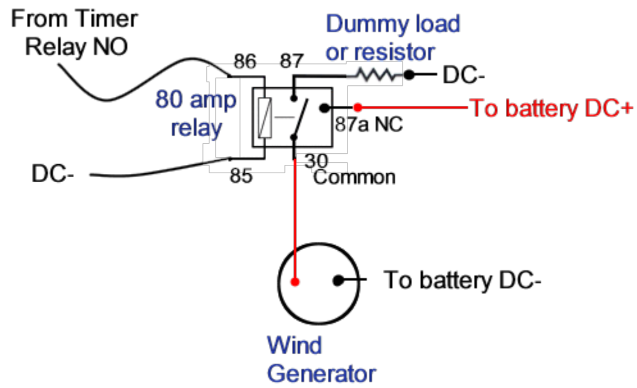


This is the simplest, and the easiest to adapt for our purposes. It is the method used by the 6TB regulator for the Eclectic Energy D400 wind generator, which is the one we have. The regulator can be coarsely adjusted to a set voltage (e.g. 14.1 V). When the output from the generator rises and hits that threshold, the regulator stops sending the current to the batteries and, instead, sends it to a set of big resistors or some other kind of dummy load.

In essence it is just a big relay switch.

This would be perfect except that it is impossible to finely adjust the cut-off voltage so as to maximise the output without then overcharging.

So we will simply replace it with our own relay switch, controlled by the system described above. To do so, we re-wire as shown here. The negative from the wind generator goes straight to battery negative. The positive from the wind generator goes to terminal 30 on a relay. Then terminal 87 (NO) goes to the dummy load, and 87a (NC) goes to the battery positive.



Terminal 85 also goes to battery negative.

Terminal 86 receives the long wire from NO on our timer relay.

When the timer relay activates, that wire becomes live, terminal 86 receives voltage, the relay activates, and it switches the wind generator output from 87a (the battery) to 87 (the dummy load).

It stays like that until the timer counts to zero, and then it all resets itself.

The big advantage with this system is that we can accurately set the cut-off voltage, which is impossible with the charge-divert regulator.

IMPORTANT: This relay will be carrying all the current from your wind generator. Use a good quality heavy duty relay rated for 80amps so that you don't melt it! The small cube relays designed for cars will NOT do they job. Even if they say 80 amps on them, they will melt under the continuous output from your wind generator – even if it is only around 10 – 15 amps.

REMEMBER also to use fat cables to carry the current from the wind generator to the battery. Your wind generator manual will probably guide you on the minimum sizes for your cabling so that it can carry the load and not lose too much voltage drop.

Shunt Regulation

This is essentially a sophisticated version of the charge-divert regulation described above. Instead of an all-or-nothing switch between the battery and the dummy load, it will do a partial diversion, sending some to the battery and some to the load in an attempt to optimize the charging of the battery, much like your alternator regulator does. In this case the dummy load is usually the regulator itself, mounted on some heat sinks so as to get rid of the heat produced.

The problem from the perspective of lithium batteries is you don't want that, as it will be lowering the charging current unnecessarily. You do really want maximum current until the end. And then you want it to switch off. Also, you do not want it to continue to trickle charge the batteries at the final voltage (e.g. 14.1 V = 3.55 V per cell) which could happen if you are anchored in sustained fresh winds.

If your setup uses this type of regulator AND it is externally connected, then just remove and replace with the above setup.

If it is internal to your wind generator, then you have two options:

a) either open up the casing, find the regulator, and replace it with the above wiring - but this will probably void your warranty, or

b) leave it as it is, and accept that you won't get as much charging as you might - though it will probably still be better than it was with the old lead acid battery.

Either way, check to see if the wind generator has a cut-off switch by which you can manually turn off its output. If it does, make sure that it is ok to use this switch for extended periods of time in high winds (if the coils are not specifically designed for prolonged use like this, they will probably burn out from the high temperature that can be generated in a good blow). If there is such a switch, then you can use the relay as above to switch off the wind generator when it reaches the critical voltage.

Alternatively, and as a fail-safe to the regulator failing, you can pass the regulated output from the wind generator through the relay as shown above. The relay will then either send it to the battery (the default position) or to a dummy load to prevent over charging. This will prevent it from trickle charging your batteries at too high a voltage.

Do not use the relay to simply disconnect the wind generator, leaving it with an open circuit, as this can lead to dangerously high blade speeds.

Short-Circuit Regulation

Instead of sending the excess current to a dummy load, this regulator simply short circuits the generator, causing it to use itself as the dummy load. The power produced acts on the generator itself as a brake, thus slowing it down and reducing the output. This is done when a cut-off voltage is reached, which for the Air-X is factory set at 14.1 V but can be adjusted by the user. Depending on how accurate their calibration is, this might be fine. Run it straight to your battery, and if it triggers the audible alarm, then see if you can lower the voltage.

Normally, when the cut-off voltage is reached and the brake is applied, it will remain in this state until the battery voltage falls to a predetermined level, at which point it all gets switched on again. This is exactly the behaviour you want, so provided you can set the cut-off voltage to the right level, this setup is perfect as it is.

Controlling Your Alternators

This is where you can dramatically increase the charging current produced by your alternators (as in more than double it!) , but it does require a bit of tinkering in your alternator. Follow these instructions ***carefully*** and you will not have any problems but be aware that this will void your alternator warranty.

We need to start with **a very quick primer on how alternators work**.

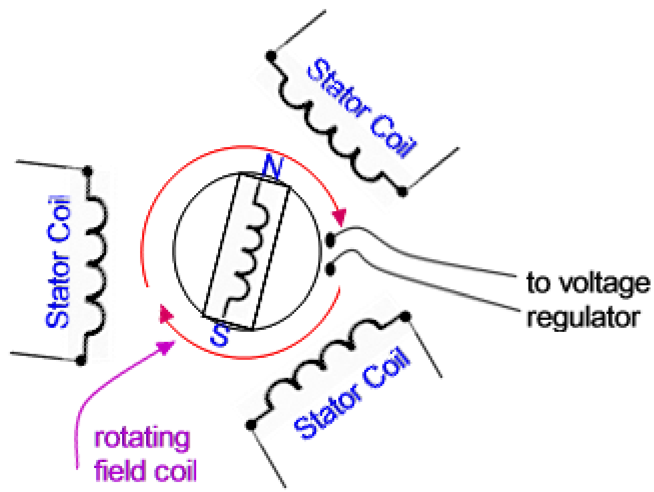
If you set up a magnetic field and then physically move a wire through that field (or else move the magnetic field over the wire), electromagnetic physics dictates that this will induce a current into that wire. In other words, you can make electricity just by passing a wire through a magnetic field. Which is basically what an alternator does. If you coil that wire so that multiple strands of it pass through the magnetic field, then you get more electricity.

That magnetic field can be produced by a permanent magnet (just like those horseshoe shaped magnets you played with in school). This is what is used in wind generators.

Or you can actually create the magnetic field by passing a current through a separate coil of wire. This is what is done in an alternators.

So, you pass a current through a coil to set up a magnetic field. This is then called the field coil. And then you move that field over a different wire coil to generate more electricity. Since the latter coil is stationary we call it that stator coil. How much electricity you create depends on how strong that magnetic field is, how many turns are in the stator coil, and how fast the two move relative to each other. And that, in turn, depends on how much current you send through that field coil.

An alternator is built by rotating the field coil around the stator coil. The speed depends on the speed of the engine and the fan belt pulley ratio. The number of turns in the stator coil is fixed. That leaves the current flowing through the field coil as a variable. Adjust that, and you can adjust how much electricity is produced.



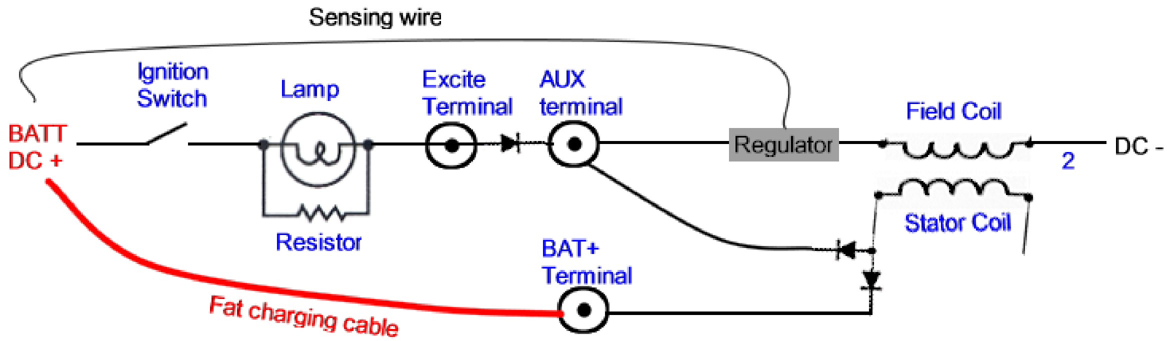
Basic Alternator Construction

If you apply the full battery voltage, 13-14 V, across the alternator field coil, you will maximise the magnetic field, and you will get the maximum available electricity from that alternator. That is the situation in the image to the right. In this situation (which can also occur if your regulator fails) the alternator output will typically rise to 15 V and, if you leave it too long like this, you will soon be destroying your batteries - whether they be lithium or lead acid.

Turn off the field coil voltage, and you will get zero electricity.

Adjust the voltage to somewhere between the two, and you will get a middling amount of electricity. That is what the regulator does. The regulator senses the current battery voltage, and then adjusts the output of the alternator so as to drive maximum current to the battery if the voltage is low, or minimizes the current if the battery voltage is high so as to prevent overcharging. To do this, it either takes a lead from the positive end of the stators or, preferably, it has an external terminal to which you connect a wire that is, in turn, connected to the positive terminal of the battery that you are wanting to charge.

Finally, the alternator can produce current only if there is current flowing through the rotor field coil. That current is usually taken from the output of the alternator. But if there is no alternator output, there is then no field current and so nothing gets started. To 'jump start' the alternator, and external current is supplied to the field through the excitation lead. This is connected to the ignition switch.



Basic excitation circuit with P-type regulator. For N-type the regulator would be in position 2 instead. In some cases there may be no Excite terminal. In others the AUX terminal might be hidden internally.

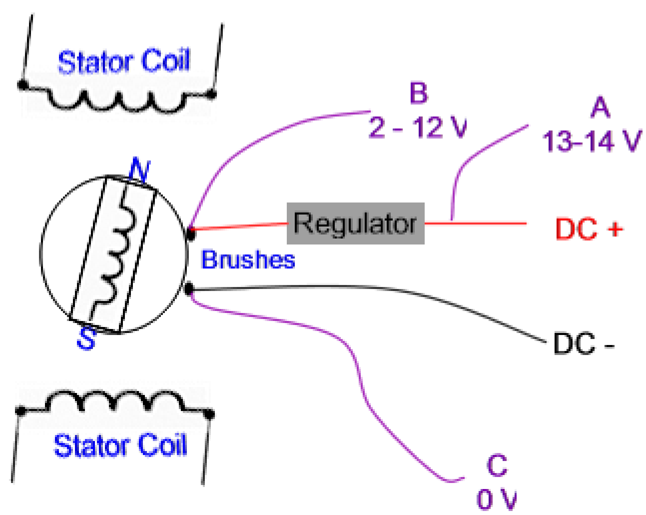
The regulator, therefore, is placed between the battery and the field coil. It can be put either on the positive side or the negative side. Both work equally well, but you need to know which type you have if you want to make the following adjustments.

The AUX terminal is similar to the BAT+ terminal - it gets the full output from the stator coils. However, it is isolated from the BAT+ terminal by diodes, so current cannot flow directly between the two.

Now that the excitation current provides current through the field coil, the alternator starts to generate its own current. This arrives at the AUX and BAT+ terminals. Since AUX is now at the alternator's output voltage, it will now be a slightly higher voltage than the battery you are wanting to charge. Thus current now flows through the lamp and resistor in the other direction. The voltage difference (maybe 2 volts or so) is not enough to keep the lamp shining, The resistor is there so the excitation still works even if the bulb gets burned out while making sure that this thin wire does not become the main battery charging cable. If there is a diode in place, that also does the job.

Note that the some alternators and regulators provide an AUX terminal. Others may, instead, just provide an Excite terminal. Such a terminal would be protected by a diode (as shown above) so that it cannot be used as an AUX output. The regulator would then, internally, connect the Excite input to the AUX and Field coil. If the regulator is externally mounted you may, or may not, see its connection to the AUX

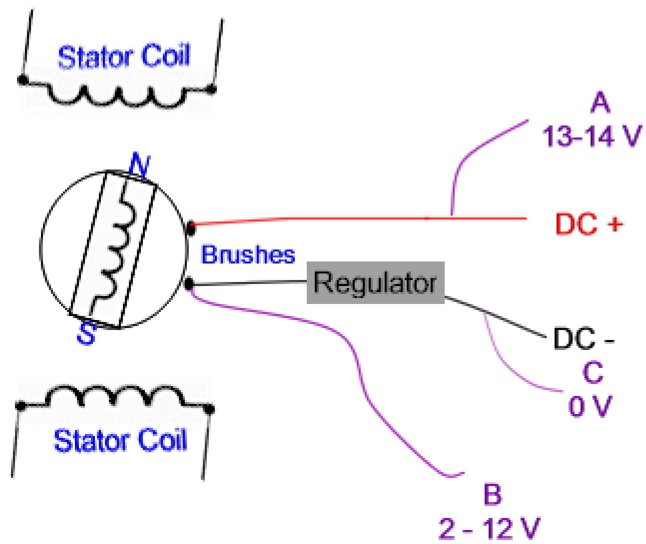
Since the regulator uses power itself, it can never provide a fully open or fully closed circuit.



Positive Field Control

If the regulator is on the positive side (Positive Field Control), it will deliver between 2 - 12V to the positive end of the field coil. I.e. at the brush - point B in the diagram to the right.

The negative end (point C) will be at Zero volts. Since it is the difference in voltage between the two ends of the field coil the determines the strength of the magnetic field, when the positive end is at 12V, the alternator will be at maximum power. When it is at 2V, then it will be at minimum. This is the most common arrangement with North American alternators.



Negative Field Control

If the regulator is on the negative side (most common on European and Asian alternators), then the positive end of the field coil (Point A) gets the full 13-14V from the battery positive, and the regulator delivers between 2 and 12 V to the negative end of the field coil. (Point B). With the positive end at 14V and the negative end at 2V, you will get maximum alternator output. With the negative end at 12V you will get minimal output.

In either case, as you can see, you will never get the same amount of power as you would if there were no regulator at all. Likewise, the regulator will never totally shut down the charging, which means that it will continue to deliver current at the final output voltage (whatever the regulator is set to - typically 14.2 V) for as long as the alternator is spinning. This is not ideal with Lithium, as it can overcharge, and thus damage, your cells.

So, what we want is maximal output until the battery is fully charged (or at least 95% charged) and then zero after that so we don't over charge.

There are, theoretically, three ways to achieve this, but one of them will blow the diodes in your alternator and render it useless, so don't do that. Here are the three ways:

1) you could use a relay to simply interrupt (disconnect) the connection from the alternator positive to battery positive. **DO NOT DO THIS - IT WILL KILL YOUR ALTERNATOR.** I mention it here specifically so you don't come up with the idea yourself.

2) You could use a relay to interrupt the connection between the regulator and the field coil. This works well - you will then have either the normal regulated output or zero output from the alternator. Doing this will NOT damage your alternator.

3) You could just remove the regulator completely, and use a relay to deliver either full battery voltage or zero voltage to the field coil. You will then have either maximum or zero output from your alternator. **NOTE: if you do this one, you will probably DOUBLE the amount of charging current your alternator**

delivers. Literally. On Life Part 2 our charging current with the batteries at 50% SOC increased from 35 amps to 65 amps - and stayed there right until the battery was full, at which point it shut off. That cuts the total charging time to half or even a third of the normal amount. In other words, we can bring our battery from 35% SOC to 95% SOC (that's 60% = 180 amp hours), in under three hours! Try doing that with your current setup.

And then the alternator burned out and we had to replace it. At that point we discovered that a brand new Delco 24SI 160 amp hot-rated high-output alternator was only $140. Far simpler to just buy a new high output alternator than to go through this process. Or else try this process and then be ready to buy a new alternator when this destroys your existing one. You have been warned!

But we are getting ahead of ourselves. The first step is to do the no-risk regulator cut-off. Then, if you are crazy enough, you can proceed with the high-risk alternator bump-up.

Either way, the initial process is the same:

The first step is to determine which type of field control your alternator is using. For this you will need either a multi-meter, or just a 12V light bulb connected to a couple of wires. Follow these steps exactly.

1. First you need to find a connection to the field coil terminal. The goal is to connect a temporary wire to the field brush or field terminal so that you can make some measurements. There are three possibilities:
   a. the alternator has NO regulator attached - there is merely one that is wired to a terminal on the casing that is marked as FLD, DF or F. That is the field terminal. This type are almost always P-type regulators.
   Connect a wire to this terminal.
   b. the alternator has an external regulator that is bolted to the back of the alternator case (and thus you might think it is an integral part of the alternator). Unscrew the bolts that hold this regulator to the case and gently prise the two apart. Inside you should find as many as four wires. Identify what connections you can see:
      i. One of these will go directly from the regulator to the field brush.
      ii. A connection to an Excitation or AUX terminal.
      iii. A connection to a Sensing wire input.
      iv. A connection to the other field terminal. This would mostly be the case with an N-Type regulator that has an Excitation terminal, as it has to pass that excitation input through to the positive end of the field terminal.
      v. There may also be a connection to ground.
   Your goal is to find the field wire that connects the regulator to one of the field brushes. If the regulator seems to be connected to both field brushes, then attach a wire to each, and bring them both outside the case. Otherwise, just bring a wire from the one field terminal outside the case. Disconnect the regulator from the field brush terminal(s).
   c. the alternator has a completely internal regulator. On some of these there is no obvious wiring. However, you may be able to get access to the actual brushes (since these should be replaceable). If you can, then attach a wire to each brush, and bring it outside of the alternator casing. If there is no access to anything, and there is no outside terminal marked as FLD, DF or F, then we cannot proceed any further.

2.

a. PROCEEDURE FOR A SINGLE FIELD TERMINAL

Make sure you have disconnected the regulator from the terminal. Turn off your battery isolation switch. Turn off the ignition switch. Set your multi-meter to the Ohms function, at the lowest setting (e.g. 0-20 ohm, or R x 1). Now measure the resistance between the field brush, and the casing (ground, battery negative).

If the reading is low, e.g. 2-6 ohms, then the field terminal you are testing is the positive terminal and you are measuring the resistance of the field coil itself, the other end of the field coil being earthed. In this case your regulator is a P-type that is connected (and currently disconnected) to the positive field terminal.

If the reading is high, infinite, or 'open circuit' your regulator is N-type.

Write the type down in your Engine Maintenance Book (if you don't have one, then start one),

b. PROCEEDURE FOR TWO FIELD TERMINALS

If the regulator appears to be connected to both field terminals, then most likely the regulator is supplying the excite current to one terminal, and the regulator current to the other one. Your job is to determine which is which.

This is done by connecting a short wire to each of the field terminals and leaving the regulator connected. Bring these two wires outside the alternator casing, and then reassemble and re-attach the alternator. Then you will measure the voltage at each wire *with the engine running and the alternator working.* **SAFETY: Before you start up the engine, make sure that the alternator is firmly attached, that there is nothing loose and dangling that could get caught in the fan belt, and that you can get safe access to the wires with your multi-meter without exposing yourself to danger from the moving parts.**

i. Start up the engine. Make sure the alternator is producing power as normal. If the alternator is not working normally, then you have disturbed something. Turn off the engine, fix the connection, and try again. Do not proceed until the alternator is working normally.

ii. Measure the voltage between one wire and ground, and then between the other wire and ground.

    One of these should read between 2V to 12V - i.e. not zero, and not full battery voltage. This is the field terminal that is being regulated.

    The other wire should be at either zero or 13+V (i.e. full battery voltage). If it is zero, then your regulator is P-type. if it is 13+V, then your regulator is N-type. Write this down in your Engine Maintenance Book (if you don't have one, then start one), and label the two wires. Use some white electrical tape on which you can write with a fine marker pen.

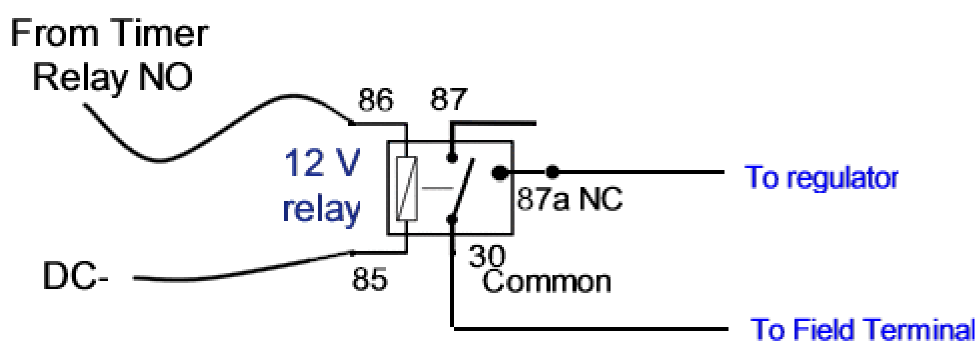
Now you know what type of regulator you have.

Strategy One: Regulate the Regulator

The goal of this strategy is to have the regulator produce as much output as it can until your Junsi determines the batteries are full, at which point the connection between regulator and field terminal is interrupted, and output goes to zero. This is the no-risk strategy and will not damage your alternator.

The method for doing this is the same whether you have a N-type or P-type regulator:

Having identified the field terminal that is being used for regulation, disconnect the regulator from the field terminal. Take a wire from the field terminal, to terminal 30 on a relay, and take another wire from the regulator to terminal 87a (the center one) on a relay. Connect relay terminal 86 to the wire coming from NO on the timer relay, and terminal 87 to ground.



WARNING

The tweaks that are described for bumping the output from your alternator are an advanced strategy and should not be attempted unless you understand what you are doing.

In particular, these tweaks may have any or all of the following consequences, for which I can accept no liability. Proceed at your own risk:

1. Since rotor current will be higher than normal it is possible to burn out the rotor winding. You should protect the ignition/excite circuit with a 10 amp fuse.
2. Since alternator output will be higher than normal, ensure that attached charging cables, relays, diodes and other components can handle the higher currents. Ensure that you have adequate fuses in place.
3. High charging current will eventually overcharge and destroy your batteries. Do NOT make these modifications unless you have also set up the various overcharge protection systems as described previously.
4. Many alternators are not designed for continuous use at high outputs. Using them in that manner **will PROBABLY BURN OUT the diodes, the bearings or the stator coils.** Or all three. This is because the alternator will likely overheat, this will then break down the insulation on the windings, and that will then burn out your alternator. Use an alternator that is specifically designed for such heavy use and can withstand high temperatures. Likewise for the fan belt.
5. Ensure that the existing regulator is completely disconnected so that it does not become damaged.

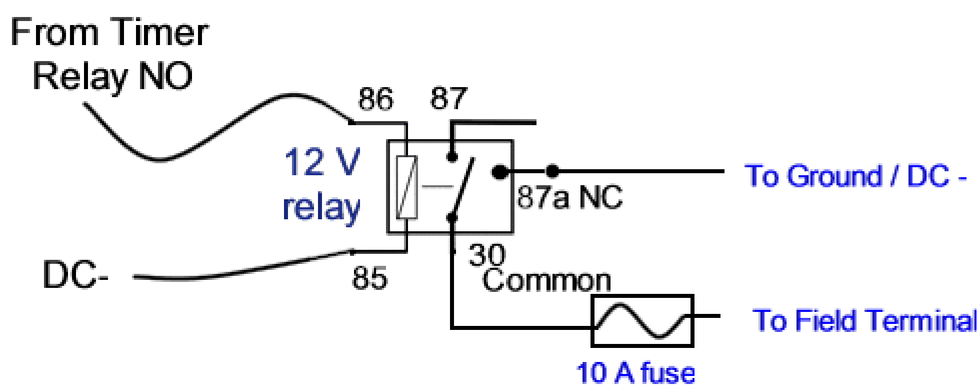
Make sure you have a spare working regulator to replace this one when you destroy it, ;-)

First read the warning box above. You will probably destroy your alternator if you attempt this. I include this here just in case you come up with this bright idea yourself. You would probably be better advised to just buy a higher output alternator. They are not expensive.

Determine if you have a heavy duty alternator, and associated components, that can cope with the increased output.

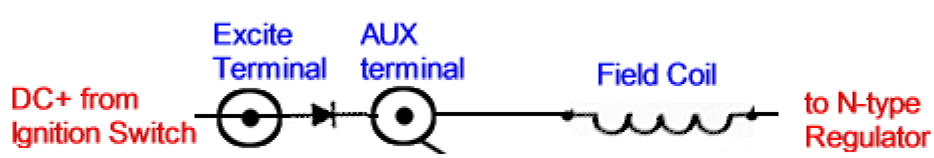
For N-type Alternator

Disconnect the regulator from the field wire. Then connect the field wire through the relay to ground, as shown below. Use a fuse.



Regulator replacement for N-Type Regulator

Now check that you have excitation to the positive field terminal. If your regulator has a separate connection to the positive field terminal, disconnect that and also disconnect the excitation wire from the Excite terminal on the regulator. Then connect that positive field terminal to the incoming Excitation wire. You will also need to connect that same wire to the AUX terminal. You should also put a diode into the sequence, as shown below, so that current cannot flow up from the AUX to the ignition switch. I was able to simply crimp the two ends of a diode (that I had salvaged from an old power supply) into male and female spade connectors. Then I just plugged it in between the excitation wire and the wire I had installed and led out of the casing out from the positive field brush terminal.

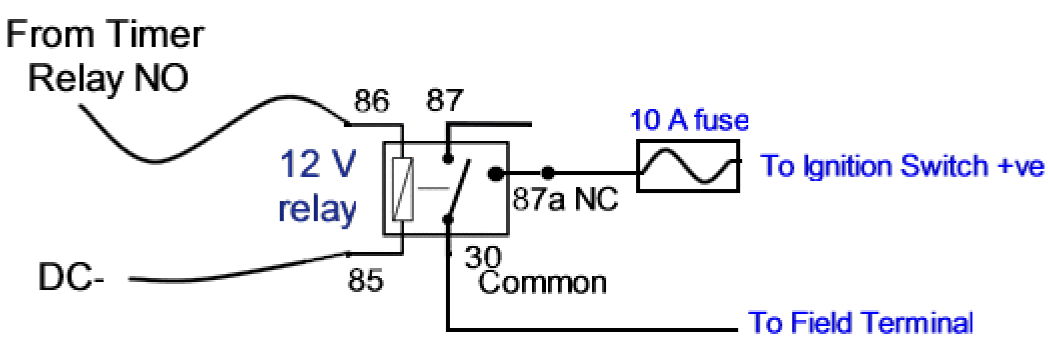


If there is no obvious connection from regulator to positive field terminal, then the excitation must be getting supplied elsewhere (e.g. through an AUX terminal), in which case no further adjustment should be necessary. To double check this, switch on the ignition switch, but don't start the engine. Use the multi-meter to confirm that the positive field terminal is now at battery +ve voltage (e.g. 13V). Start the engine, and the ignition buzzer and/or charge light should go off.

For P-Type Regulator

In this case we have to find the other end of the regulator. One end, as you have already determined, is attached to the positive field terminal. Disconnect that end, and connect the field terminal to terminal 30 on the relay.

The other end of the regulator must be connected to a positive input somewhere. Quite likely this is the Excite terminal. Or there may be another positive terminal. Either way, disconnect the regulator from there, and take that connection to the relay. The goal is to connect the other relay terminal to a positive input the gets switched OFF when the ignition switch is off - otherwise you will have a constant connection between your battery through the field coil to ground, which will rapidly run down your battery and may eventually burn out the rotor field coil.



Regulator replacement for P-Type Regulator

Once again we have to make sure that there is a connection between the positive field terminal and the AUX terminal. Turn on the ignition, and check you have voltage reaching the field terminal. Confirm that the voltage stops when you turn off the ignition switch. If you have access to both the AUX terminal and the excitation lead, with the ignition switch off, use your multi-meter to test that there is a diode to prevent current flowing FROM AUX to Excite. If not, then install one, as described above for the N-type regulator.

Now fire up the engine and make sure the ignition buzzer and/or light go off. If it doesn't, then there must be another connection in the regulator somewhere.

Fire Up and Test

Fire up the engine and check all is working. Your alternator should be producing maximum output until your Junsi says the batteries are charged at which point the output will go to zero. Make sure that the fan belt is not slipping, as there will be extra force on that. Check that your battery cables and other components are not overheating.

At any time you can revert to your original regulated setup by reversing the wiring changes.

Troubleshooting

If you are getting no alternator output, first check that the timer relay isn't active! If you use relays with an LED light in them, the light should be OFF. If it is on, then the relay is active, and the connection between the field and ground (or field and positive) has been broken. That means the system is doing its job in protecting your batteries.

Assuming that the relay is not triggered, check that the relay has not failed. If it fails in the resting position, your alternator will never switch off, the voltage will rise, and eventually the Junsi audible alarm will sound. If that happens, disable the alternator just by removing the field connection from the relay.

On the other hand, if the relay fails in its active position, then the field connection is open, the field is getting no current, and so the alternator can produce no output.

In either of these two scenarios, simply replace the relay with a better quality one.

If that fails, and there is still not output, check that the ignition circuit is providing excitation voltage to the positive field terminal. If the fuse has blown, it probably means that you are getting current from the AUX into the ignition switch. Install a diode to prevent this.

If there is still no output, it is possible that there is a problem with the alternator itself. It may be that the diodes have failed - either open circuit (in which case you may get a reduced output from the alternator) - or short circuit. With everything switched off, check the voltage at the AUX terminal or the positive field terminal (but at the alternator end of any diode you might have installed in the excitation line). The voltage at AUX compared to ground should, with everything switched off, be zero. If it matches your battery voltage, then one or more diodes have short circuited, and the positive voltage from the BAT terminal is leaking backwards to the AUX terminal. Replace the alternator with your spare, and have it professionally repaired with higher-rated components.

Keep a close eye on the temperature of your alternator. Make sure there is good ventilation to the engine compartment, as alternators are air cooled, and it doesn't help if the air in there is hot! It is heat that destroys the alternators, by cooking the diodes, by breaking down the insulation on the windings, or by just burning out the stator or rotor windings.

Controlling Your Solar Panels

MPPT Controller

If you have MPPT (maximum power point tracking) regulation on your panels then all that is needed is to adjust the charging parameters. This is most likely the case if you have solar panels that output at a much higher voltage than your battery, and you have a fancy control panel. These regulators are normally set up as three stage charging:

first a 'bulk' charge, in which the regulator sends as much current as it can to your batteries. Since this is going to be way less than the 0.3C maximum (e.g. 100 amps for a 300 amp hour battery), no change is needed.

Once the voltage rises to a certain point, the charging is switched to the 'Absorb' phase. Now the voltage is constrained to that absorb voltage, and so the current starts to decrease. Set the absorb voltage to 14 volts (3.5V per cell).

MPPT Charging Parameters	
Absorb Voltage	3.5V per cell
Absorb cut-off time	2 hours
Absorb cut-off current	0.03 C
Float Voltage	3.2V per cell
Float Current	0.03C

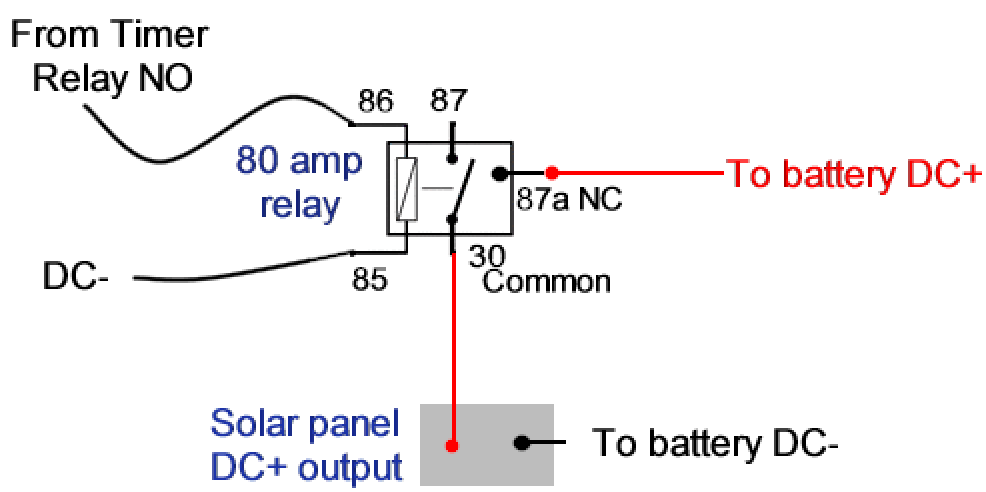
This Constant Voltage phase will be continues until either a certain time passes (I suggest setting this to 2 hours) or else the current drops to a certain level (I suggest setting this to 0.03 C (for a 300 amp Hour battery, this would be 9 amps).

At this point, the regulator switches to Float mode, where it sends the maximum voltage to a lower level, and also sets a maximum current. I suggest setting this to a float voltage of 3.2V per cell (12.8V) and a float current of 0.03 C (for a 300 amp Hour battery, this would be 9 amps). This will effectively turn off your float charging, which you don't really want anyway.

These parameters will keep your cells safe.

Basic or No Regulator

If your solar panels' output is a similar voltage to your batteries then it is quite likely that you do not have any regulation in place. The only thing you need to do in this case, therefore, is to have a relay cut off the charging if the voltage goes too high. This is the same setup as for the Wind Generator, except that in the case of solar panels there is no problem with having an open circuit. Simply install a heavy duty relay on the output lead of the solar panel so that the connection is on until the relay is triggered by the timer.

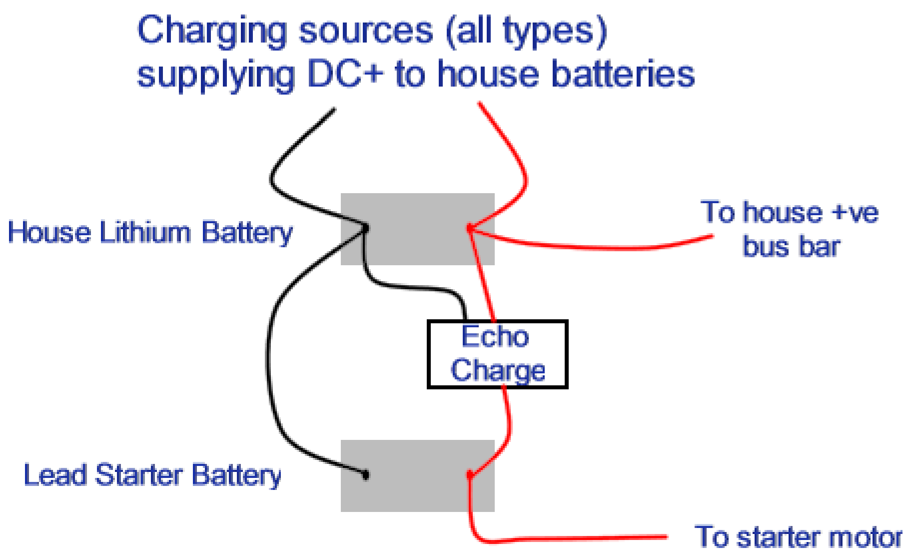


Controlling solar output without a MPPT regulator

Charging Multiple Batteries

So far we have considered only charging up your house batteries. But most boats also have one or two batteries dedicated to starting the engine(s), and these are likely to be lead-acid starter batteries. So how do we keep these charged as well?

As you now realise, the charging parameters for lead and lithium are quite different. The typical arrangement of using isolation diodes to set up a split charging system is far from ideal in this situation. My strong recommendation is that you use the system shown below:



The Echo Charge is a device produced by Xantrex that will keep your starter battery topped up at all times. Essentially it just siphons off some charge from your house batteries, provided that your house batteries are themselves sufficiently charged. If they are not, then it does not draw off any more current.

The charging parameters for the starter battery are those for lead. The charge current is less than 15 amps, so it is basically just trickle charging the battery, which is all that you need, since all you need to do is replenish the small amount that was used to start up your engine.

Your windlass and bow thruster should come from the house battery, which will get charged up much more quickly. By wiring them this way, you don't run the risk for flattening your starter battery if you have a tough time getting your anchor up or manoeuvring into a tight corner.

With this set up the two batteries are isolated, so if you have a disaster with one, the other is still working, and you can jury rig for yourself a solution to get you home.

If you have two starter batteries, as on a catamaran, then just add another Echo Charge in parallel with the first one. There are other similar devices made by other manufacturers.

Step 5. Fine Tuning Your Setup

At the beginning I promised you that it did not matter whether your various voltage meters were accurate. The reason for that, is that we can fine tune our charging parameters according to the charging curve of our own setup to ensure that we stay on the flat portion of the curve.

The way we do that is to monitor and graph the voltage of each cell, over time, as it charges and discharges. This is done by the logging function of the Junsi Cellog 8S. The data is then output by USB to your laptop, where you can view it as a graph.

Step 1: Set up the Logging

On the 8S Junsi,

1. Hold the MENU button for 3 seconds
2. Use the UP and Down buttons to select Log File
3. Press the MENU button
4. Select LogFile1. If there is no LogFile1 listed, hold the TYPE (Up)Button for 3 seconds to create a new file.
5. Hold the Menu button for 3 seconds to save and return to the top screen.

Step 2. Start the Logging

From the initial info screen, Hold the HOLD (Down) button for 3 seconds to start logging.

To View the Data

First install the USB drivers: Just follow the instructions on page 16 of the Cellog 8S manual, which should be on the CD that comes with the unit.

You will need to install the LogView program that comes with the Junsi Cellog 8S on a small CD. There is a new version of this, called Log View Studio that you can download, but I still haven't figured out how to use that version, so I am still using the LogView version 2.7 that came with the Junsi on the CD. It is in German, so although you can select English when you install it, some of it remains in German.

The instructions for installing LogView are on page 17 of the manual. Follow that through to the end, where it says to press the button that says "Start Recording". Unfortunately at that point the instructions come to an end!

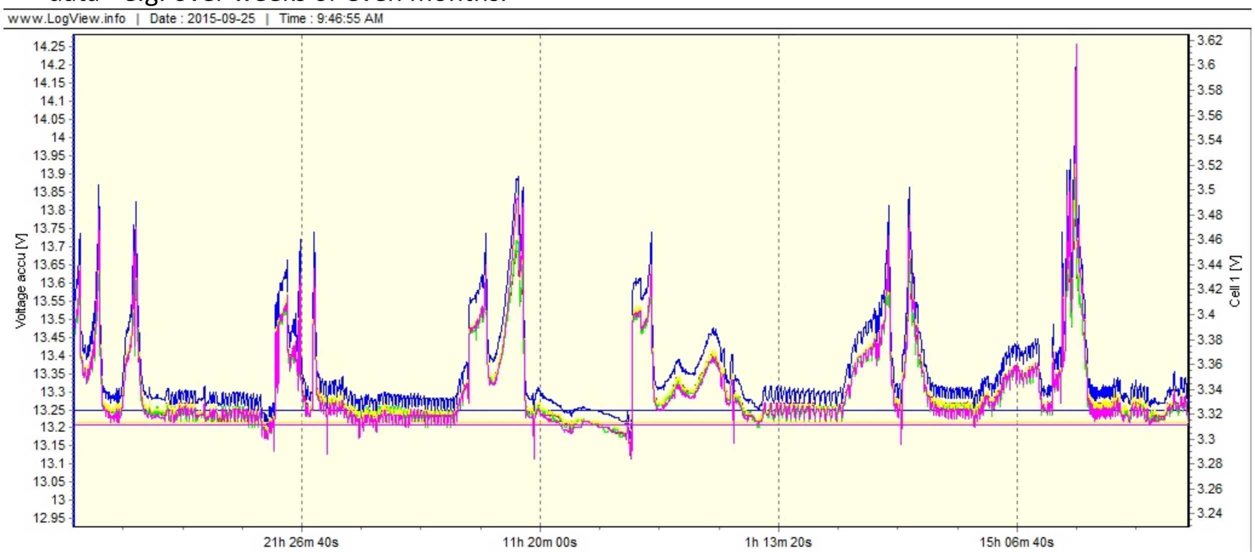
Download the Data

So, now go back to the Junsi.

From the top screen, hold the HOLD button for 3 seconds to Stop the Logging. You can now download the data onto your laptop to view it. To do this:

1. From the top screen, hold the MENU button for 3 seconds,

2. Select LogFile and press the MENU button,
3. You should now see an option that says "File Transmit". Use the up and down buttons to select this option, and then press the MENU button.
4. It should then say File Transfer, and start counting down. This process can take quite a while if the file is full.
5. When it has finally finished transmitting, you should now see a graph displayed on your laptop that looks something like the picture below.
6. don't forget to restart the logging once you are done. You can also change the logging interval, e.g.. to every half hour, say, if you want the device to be able to store a longer time period of data - e.g. over weeks or even months.



The times at the bottom, and the vertical dashed lines, don't make any sense to me, and seem to bear no relation to when the recording was made as, in this case, we have 6 separate days showing. If you have more days, you will see more peaks, and they will all be squashed together more. To zoom in, hold down your left mouse button and drag a rectangle over the area you are interested in, going from top left to bottom right. If you hold down the CTRL key while you do this, it will automatically select the full height (Y scale) and just zoom in on the X-axis. When you let go, it will zoom in to that portion.

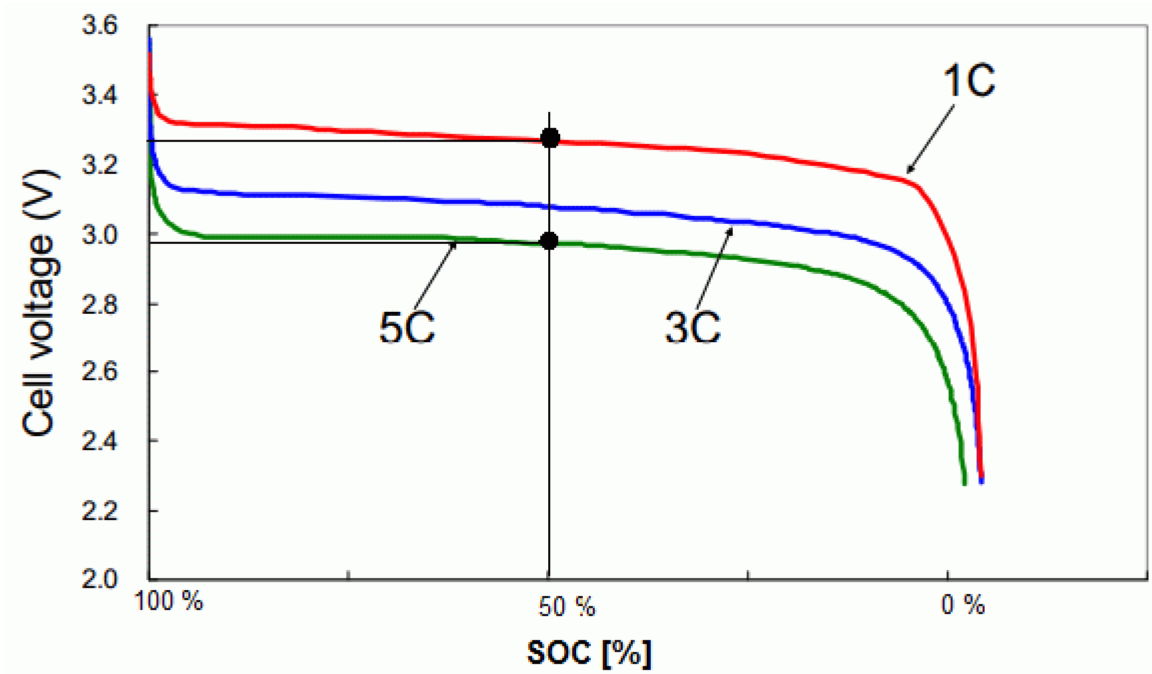
To revert to the full range, drag the rectangle again, but this time going from bottom right corner to top left corner. Or else press the button at the top with the magnifying glass and 1:1 written on it.

Now, what to do with this data?

First, on the LogView over on the left, you can select which cell voltages you want to see, as well as the overall battery voltage.

In the graph show above, you will see two peaks close together on many of the days, for instance, just before the time marked 1h 20m 00s. The first (left) of those two peaks comes from our engine running. As it charges the battery, the voltage goes up. It then hits the critical voltage, and the Junsi alarm and timer relay shut off the alternator charging. So the voltage drops back down.

However, we still have our solar panels charging. They charge slower than the alternator. As such, they don't run up the voltage so quickly. Remember the charging and discharging curves right at the beginning of this eBook? Here it is again:



The higher the current, whether that be charging or discharging, the sooner one hits the elbow in the graph. To read the graph as a charging curve, just go from right to left, and switch over the lines for 1C and 5C - more charge goes in, so the voltage goes up - and more so if the charging current is bigger. Bear in mind, also, that you will be charging at maybe at 0.05C for your solar panels, and less than 0.3C for your alternator, so your curves would actually be different again. So ignore the voltage numbers on the left. The absolute numbers don't mean much. What matters is the shape of the curve. Are you on the flat section, or a steep section?

So on my logging graph we can see that first the alternator hits the elbow, and the voltage quickly rises. The Junsi shuts it off, so the voltage drops. But now the solar panels continue to charge, and soon they too hit the elbow, and the voltage starts to rise rapidly again. Then they too hit the cut-off voltage that was programmed into the MPPT controller, and again the charging is terminated. Once the charging current is stopped, the cell voltage instantly reverts to its natural state, from which it then gradually decreases as the battery is discharged through the rest of the day and the night.

At this point, the batteries are as full as I want them to be - perhaps 95% or thereabouts.

This, then, is where you can do your own tweaking. What you are aiming to do is to have the charging switch off as you reach the elbow. If you push the charging too far, you run the risk of going into the steep part of the curve where you may lose control of the situation. As the final one or two percent of charged are forced into the cells, the resistance goes up, and the cells start to heat up. But the higher temperature lowers the resistance, and allows more current to flow. Go too far and they can go into thermal runaway with more and more current flowing until your cells are destroyed from over charging and overheating.

That you do not want.

So, start conservatively, watch your charging curve, get to know your own cells, and you will be able to fine tune the voltage setting on all your charging devices.

As you can see, your solar panel may say it is charging to 14 V, but the Junsi may say it is 14.2 V. And your voltmeter may say something different again. It doesn't matter. Adjust the voltages on your solar charger and your Junsi alarms according to the graph they produce, not the absolute number they show.

If your solar charger says it cuts off at 14V, but the Junsi shows the graph to be getting too steep, then back off the solar panel a little bit. You need only adjust by a tenth of a volt or less.

On the graph above I reached a maximum cell voltage (according to Junsi) of 3.62V. Even if the Junsi is a bit inaccurate (which I doubt, since all three units show very similar numbers), that is still well within the safety parameters as specified by Winston, my battery manufacturer. And it only hit that peak very briefly. Even so, the graph there is obviously getting into the steep section, so I probably backed down my voltages very slightly as a result.

You can also do the same tweaks on the way down, as you discharge your cells. Once again, make sure that you don't go so low that you enter into that steep decline at the end. Stay well within the flat section.

Long Term Maintenance and Storage

The only thing left to discuss is what to do when you pack your boat up for the winter.

If you are leaving her afloat, there isn't much option - you need to leave your batteries connected so that your bilge pumps will still work! But, apart from the very small current draw for the Junsi's themselves, plus maybe some other LED's on your control panels somewhere, your draw will be low.

My suggestion is that you simply lower slightly your cut-off voltage (Absorb voltage) on your MPPT solar charger - and the cut-off voltages for your wind generator. Maybe put the cut-off voltage down to 3.3V per cell (13.2V for the battery). Then you can leave those switched, secure in the knowledge that your batteries will be topped up, but never overcharged. Keeping them at maybe 80% seems reasonable.

If you are hauling out and storing on land, then either do the same, or disconnect everything and leave the battery to its own devices. It will discharge very slightly over time, but you can probably store it for a long time before that becomes a concern. If you connect the cells in parallel while you go away, you can give the cells the opportunity to balance themselves to exactly the same voltages again.

Conclusion

So that's it! I hope this was not to technical or intimidating. The goal is to keep it all simple. It will take a little bit of tweaking for the first few weeks, but after that, you will delight in how much quicker they charge, and how much easier their maintenance is. Just remember to not stress about getting that final 5% of charge into them, and don't discharge them beyond 20%, and they will probably last you the life of your boat.

Then get out and go sailing instead!

Shopping List

Listed below are some suppliers. They are by no means the only suppliers of the items in question, and you may well be able to find better prices or more convenient service. I list them only so you know what items I am describing. Click on the link to see the exact item. I have no financial relationship with any of the listings. I suggest that you buy spares of the cheaper items such as the relays.

Item needed	Quantity	Example supplier
Lithium Cells (LiFePO4)	4	EV-Power.eu
Battery terminals to match your cells	5	Ev-Power.eu
Single Cell charger	1	Charger-3-6V-18A-for-LiFePO4-cells
Junsi Cellog 8S and 8M	1 each	ProgressiveRC.com
Relay Timer	2	Multifunction-Self-lock-Relay-Cycle-Timer
80 amp 12V relay	4	Amazon
300 amp fuse	1	Ebay
Smoke alarm	1	Amazon
200 amp Circuit Breaker	1	Amazon
Wires with JST connector	1 pack	Amazon

Shameless Plug

Are your boat, your crew, and you equipped to survive a storm at sea?

No one wants to be in a storm, and with proper planning you can probably sail your whole life without getting caught. But, should it happen, how would you survive? And do you have the right equipment on board?

Probably the best equipment to have on board is a drag device of some sort - a sea anchor, drogue or similar. But what type? And how to actually use it in real life, given the type of boat that you have?

That was the reason that the Drag Device Data Base was developed. In it we have collected real-life accounts from real people caught in real storms. In other words, it is not just a bunch of theory from people who have never sailed out of sight of land.

From these accounts we can learn what works, what doesn't , and how best to use it.

You can read these reports online for free. Or you can download them to your Kindle or eReader for a very modest price. Knowledge is power, and this knowledge could potentially save your life one day.

Read it for FREE Today!

http://DragDeviceDB.com

Oh, and if ever you do find yourself caught in a storm like that, please submit your own report to be included in the database. The more we have, the more we can learn.

Fair winds, and smooth seas,

Noel Swanson