Wally 100 Alternator Controller for charging LiFePO4 and Lead-Acid batteries on boats.

Introduction

Many boaties face the problem that after installation of new LiFePO4 batteries, their existing alternator setup for lead-acid batteries turns out to be unsuitable for charging the new batteries.

Due to the low internal resistance of LFP batteries, very high currents are experienced during most of the charging process that exceed the limit of what the alternator can handle. This can easily result in an overheated alternator which can subsequently burn out completely.

One solution can be to install an expensive high capacity "hot rated" alternator with external voltage regulator, but there is no guarantee that this solves the problem. The problem is that most "smart" alternator regulators measure and regulate Voltage, not current (Amps).

Another solution promoted by some manufacturers is to install a DC-DC converter as a "current limiter". Now the alternator is not overloaded, but the LFP batteries are charged inefficiently and usually at a much slower rate than they can accept**. Having high capacity batteries which can be efficiently**

charged in a short time is often the very reason for installing LFP, so this "solution" can be rather unsatisfactory.

The Wally100 Alternator Controller solves the problem in an elegant way. It can be set up for charging the LFP batteries in the fastest possible manner by an existing alternator. If it is decided to install a higher capacity alternator as a better match for the new high capacity batteries, the new alternator does not necessarily have to be "hot rated". The Wally100 can be set up to safely charge LFP batteries from any alternator, no matter what the capacity is.
The charge current is measured and limited to what the alternator can handle without becoming overheated. The charge process is controlled by the measured current, voltage of the batteries, temperature of the alternator and alternator RPM.

Method

Key to the way the Wally100 does its job is measuring the charge current, as opposed to voltage only by most other alternator regulators. For this purpose a shunt is connected in the heavy gauge cable between the alternator and the battery (bank).

The alternator output is controlled by a current from the alternator controller through the alternator field winding (rotor). By varying this field current, aka excitation current, the alternator output can be increased or decreased to match the set Amperage value. This is what sometimes is referred to as "Constant Current" (CC) charging, but can be more accurately described as Current Limiting. The field current is only a few Amperes strong and is generated by the Wally100 using PWM (Pulse Width Modulation). Changing the duty cycle (pulse width) of the PWM signal changes the field current.

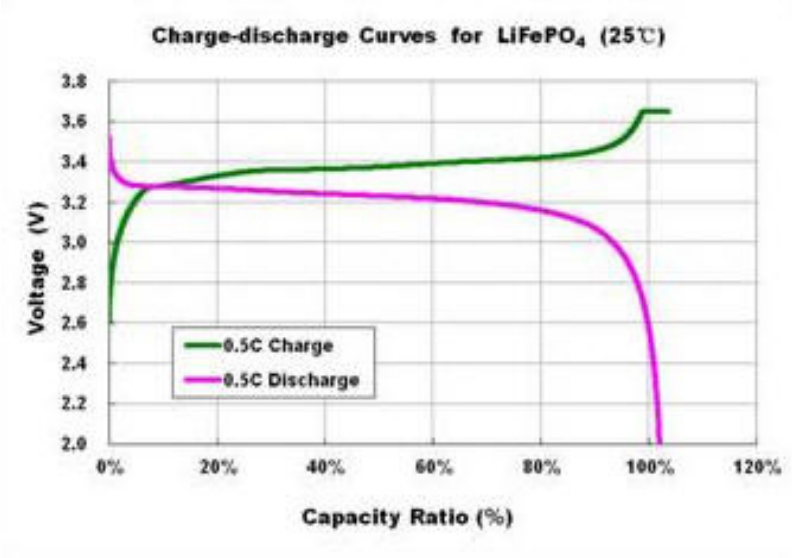
Charging always commences with a "Soft start". The field current is stepped up once per second until the maximum allowed current is reached. This avoids sudden mechanical loads when the engine is cold.

The maximum current is set as a parameter when the alternator controller is configured, but can also be adjusted during the charge process, if necessary. In fact, there are 3 maximum current parameters, each of which is for a certain

alternator RPM. The reason for this is that at low RPMs, the alternator has less cooling due to the cooling fan turning slower. To avoid temperature rising unacceptably high during low RPM, the maximum Amps has to be set lower. There are 3 settings: For alternator RPM 2000, 3500 and 5000.
At a pulley ratio of 1:2, this translates to engine RPMs 1000 (high idle), 1750 (slow cruising) and 2500 (max cruising). The Wally100 interpolates to determine max. Amp values in between these RPMs.

Naturally the Wally100 has sensors for RPM and temperature of the alternator to enable the above described functionality.

Battery Voltage monitoring by the Wally100 is of crucial importance. During most of the charging process, the Voltage of LFP batteries remains relatively constant (compared to lead acid). It creeps up somewhat from 3.3V to 3.4V per cell (13.2V-13.6V for 4-cell battery), but rises more sharply towards the end of the charge process (see figure).



When the maximum Voltage, aka “absorption point”, is reached, the absorption (acceptance) charging stage commences. This stage is not absolutely necessary for LiFePO4 batteries, but to charge to full 100% SoC (State of Charge), the last 5% are charged in this step. Also, this allows for cell balancing, if necessary. Voltage is regulated to not exceed the absorption voltage setting and the charge current is monitored as it tapers off. When it drops to a certain value, which depends on the absorption Voltage setting, charging stops to avoid over-charging. The Wally100 minimizes the field current to the alternator. A small field current is maintained to keep a signal on the W connection of the alternator for the rev counter. The absorption stage is also timed and cannot exceed a set time (in minutes). When charging of the LFP batteries stops, the Wally100 enters a Voltage monitoring loop. When the LFP Voltage has dropped to a set value, charging resumes.

Important to know is that it is better for LFP batteries not to keep them topped up at all times and at every opportunity, like lead-acid batteries.

Alternator temperature is also monitored by the Wally100. If the maximum set temperature is reached, charging stops and a timer (in minutes) starts for a cool-off period. When the set time has elapsed, charging resumes. This is intended as a safety mechanism. The maximum Amps parameters should be set to such values that the maximum temperature is never reached. The maximum Amp values should be adjusted if the maximum temperature is reached regularly.

Charging LiFePO4 house batteries and Lead-Acid start battery

The Wally100 alternator controller also supports 3-stage Lead-Acid battery charging (bulk-absorption-float). Although the marine engine can be started with the LiFePO4 battery (bank), many boaties wish to retain their lead-acid start battery, not only for starting but also as an emergency power source for radio, GPS etc.

As the charging method of lead-acid and LiFePO4 batteries are different, parallel charging is not ideal. During LifePO4 charging, the Voltage is 13.4 - 13.6 for much of the charge process. This is insufficient Voltage to top-up the start battery quickly. A full start battery is important if the boat's engine has to be started several times in a short period of time. On the other hand, if the start battery is mainly used for starting the engine, it only needs a short charge period but at a higher voltage, say 14.2V, to be topped up completely immediately after starting.

The Wally alternator controller can be set up in a very simple way for charging of the lead-acid battery for a short time after starting the engine, e.g. 5 minutes, before it switches to charging the LiFePO4 battery (bank). It has 2 low-voltage outputs that can be used to switch relays to either connect the start- or the LFP battery to the alternator output. Switching the alternator output can be dangerous, as the rectifying diodes can be damaged. To avoid this, the controller first cuts the alternator field (rotor) current, checks if the output is 0 Amps and only then swithes the relays.

So after power-up of the Wally100 controller the relay that connects the start battery to the alternator output is closed and lead-acid charging begins. After the set time (Vreg time) is elapsed, lead-acid CC charging is terminated. The field current is stopped by setting the PWM pulse width to 0, charge Amps are checked for 0 and if so, the relay is opened and the relay for the LFP batteries is closed. LFP charging now commences with soft-start.

Charging of the LiFePO4 batteries stops when the set Voltage, e.g. 14.00V (cell voltage 3.5), has been reached. The Wally100 terminates the field current by changing the PWM pulse width to 0. The alternator is now running without load. At this point one of the above mentioned relay control outputs is reset, for

disconnecting the LiFePO4 batteries from from the alternator. Again, the controller first checks if no charge current is running before doing so. After disconnection of the LFP batteries, the second relay control output is activated, that switches the lead-acid batteries back to the alternator output. This is not strictly necessary if the lead-acid battery is small and is only used for starting, but it can be useful to maintain a float voltage on this battery, especially if it is a marine battery that doubles as an emergency house battery. During this L-A battery charging, the absorption stage will be reached fairly quickly in most cases and the float charge stage will start if the charge current falls below a minimum.

A (settable) LiFePO4 charge restart timer is started and when it times out (e.g. after 30 mins), L-A mode charging is terminated and LFP charging is started again.

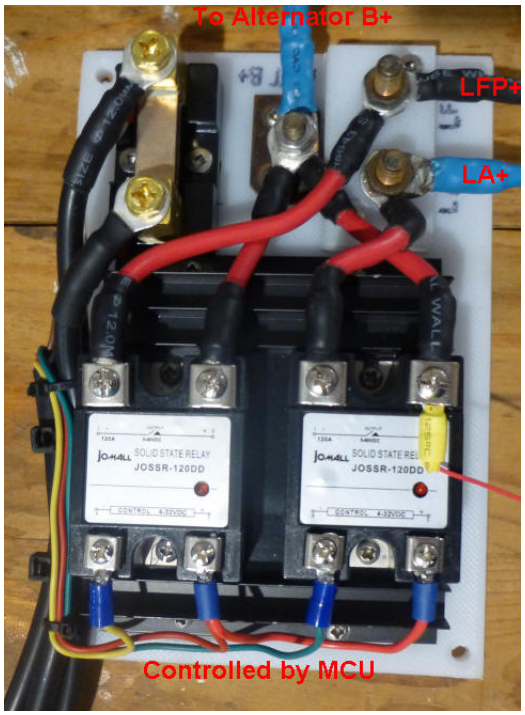
The Wallyt100 can be configured for 3 main charging modes:
Alternating, **Dedicated LiFePO4** or **Dedicated Lead-Acid.** In Alternating mode the Wally100 switches between LiFePO4 and Lead-Acid charging, as described above. If the Wally100 is only used for LiFePO4 charging, the mode is set to Dedicated LiFePO4 and no switching by the relay control outputs will take place. The LFP batteries can be connected directly to the alternator output without relay. For dedicated conventional lead-acid battery charging, the mode has to be set to Lead-Acid (see configuration screens below).

In summary:

1. Mode set to LiFePO4: LiFePO4 charging only, no relays necessary.
2. Mode set to Alternating: LiFePO4 charging, but after engine starts first lead-acid charging to top up start battery. Furthermore, after LiFePO4 charging terminates, lead-acid charging is continued for a set time.
3. Mode set to Lead-Acid: Dedicated Lead-Acid charging (bulk-absorption-float), no LiFePO4 charging at all. No relays necessary.

This system ensures that Lead-Acid and LiFePO4 batteries are never switched in parallel and are both most efficiently charged in the shortest possible time.

The picture below shows an example of a relays setup for sequential charging of lead-acid start and LiFePO4 batteries.



N*ote: To avoid the need for the switching relays, as an alternative a small inexpensive DC-DC (buck-boost) charger can be used for charging the start battery. Input would be from the LiFePO4 battery pack and output Voltage can be set to a suitable Voltage, e.g. 14.2. to fully charge the start battery. Charging of the start battery will generally be quick if it is only used for starting the engine. Charge current will quickly taper down.*

The LCD and push button.

The 2x16 alphanumeric display with backlighting is used to display charge Amps, maximum Amps, Battery Voltage, Alternator RPM and Alternator Temperature. It is also used for setting the various operating parameters. A number of different "screens" have been defined which can be displayed one by one in a cyclic way by short-pressing the push button under the display. The first 6 screens are for displaying information only:

Screen 1

Short press the button for next screen:

Screen 2

A: Amperes charging
Vbat: Volts battery
T: Temperature of alternator in degrees Celcius
RPM: RPM alternator

Short press for next screen:

Screen 3

A: Amperes charging
Amax: Maximum Amperage for this RPM (interpolated between Max Amps for 2000 and 3500 RPM). As can be seen, the charge Amperage is regulated to the maximum Amps for this RPM.
T: Temperature alternator in degrees Celcius
RPM: RPM alternator

Short press for next screen:

Screen 4:

Amps and Temperature.

Short press for next screen:

Screen 5:

Battery Voltage and alternator RPM

Short press for next screen:

Screen 6:

Another **short press** completes the cycle and will return to screen 1.

A **long press** while this screen is displayed will turn Configuration mode on:

Screen 6

Another **long press** while this screen is displayed will turn Configuration mode off again.

A **short press** with Configuation mode on will display the first configuration screen (see below).

Notes:

1. A **short press** is about 1 sec.
2. A long press is about 2 sec. The word "SET" is displayed and the button should then be released.
3. A **long press** while any of the data screens 1-6 above is displayed stores the screen number in eprom as the first screen that will be displayed when the Wally100 is powered on. Screen 2 will be most useful in most cases and is recommended.

Configuration

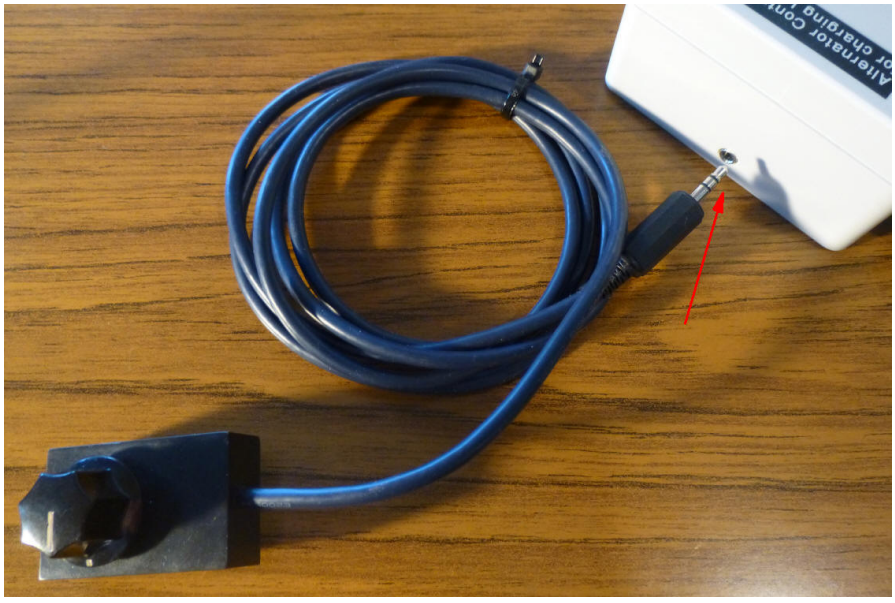
Configuration screens follow the data display screens if Config is "ON" by short pressing the pushbutton, see Screen 6 above.

Configuration mode is always off at power-on time of the controller. Configuration can be carried out with or without the engine running.

If the controller is currently in lead-acid charge state (mode=LiFePO4 and Vreg time non-zero), the first character of any of the configuration screens is blinking.

The first configuration screen shows the present (default) charge mode.
A **long press** changes the charge mode to lead-acid. The Wally 100 has been specifically designed for LiFePO4 charging, but lead-acid mode is available in case a lead-acid start or back-up battery needs fast charging. Refer to "Lead Acid mode" later in this document for details.

Important:
For all following configuration screens, values have to be entered if the present parameter setting has to be changed. For this purpose a separate module with turning knob has to be plugged in the side of the Wally100 unit (see figure).



All configuration screens have in common that the present setting of the parameter is displayed on the left hand side of the second line of the LCD and the value on the right hand side can be altered by turning the knob. Ignore the initial value on the right because the turning knob can be in any random position.
Turn the knob until the required new parameter value is displayed.
Then **long press** the button under the LCD. The word **SET** will be displayed, followed by the the same configuration screen with the new parameter value now displayed on the left as the present setting.

After the Mode screen, **Short press** for the next configuration screen:

"Set maximum Amps for 2000 alternator RPM."
This also applies to alternator RPM below 2000. With a pulley ratio of 1:2, this corresponds with engine RPM 1000.
Maximum Amps for RPMs between 2000 and 3500 are interpolated.

If the present setting on the left has to be changed, turn the knob to set the number on the right to the required value and **long press** the button.

Short press for the next configuration screen:

"Set maximum Amps for 3500 alternator RPM."
With a pulley ratio of 1:2, this corresponds with engine RPM 1750.
Maximum Amps for RPM between 2000 and 3500 and between 3500 and 5000 are interpolated.

If the present setting on the left has to be changed, turn the knob to set the number on the right to the required value and **long press** the button.

Short press for the next configuration screen:

"Set maximum Amps for 5000 alternator RPM."
This also applies to alternator RPMs above 5000. Maximum Amps for RPMs between 3500 and 5000 are interpolated. With a pulley ratio of 1:2, this corresponds with engine RPM 2500.

If the present setting on the left has to be changed, turn the knob to set the number on the right to the required value and **long press** the button.

Short press for the next configuration screen:

"Set the maximum Voltage" (= the Voltage that charging should stop)
In units of Volts x 10), e.g. 140 means 14.0 Volts.

If the present setting on the left has to be changed, turn the knob to set the number on the right to the required value and **long press** the button.

Short press for the next configuration screen:

"Set the maximum allowed temperature of the alternator in degrees Celcius".
Charging will stop if this temperature is reached and a cool-off period will start.

If the present setting on the left has to be changed, turn the knob to set the number on the right to the required value and **long press** the button.

Short press for the next configuration screen:

"Set the time (in minutes) charging has to start again after the set Voltage has been reached and charging has stopped.

Short press for the next configuration screen:

"Set the time (in minutes) charging has to start again after the set Temperature has been reached and charging has stopped, i.e. this is the length of the cool-off period.

Short press for the next configuration screen:

"Set the absorption voltage for lead-acid mode charging"

Short press for the next configuration screen:

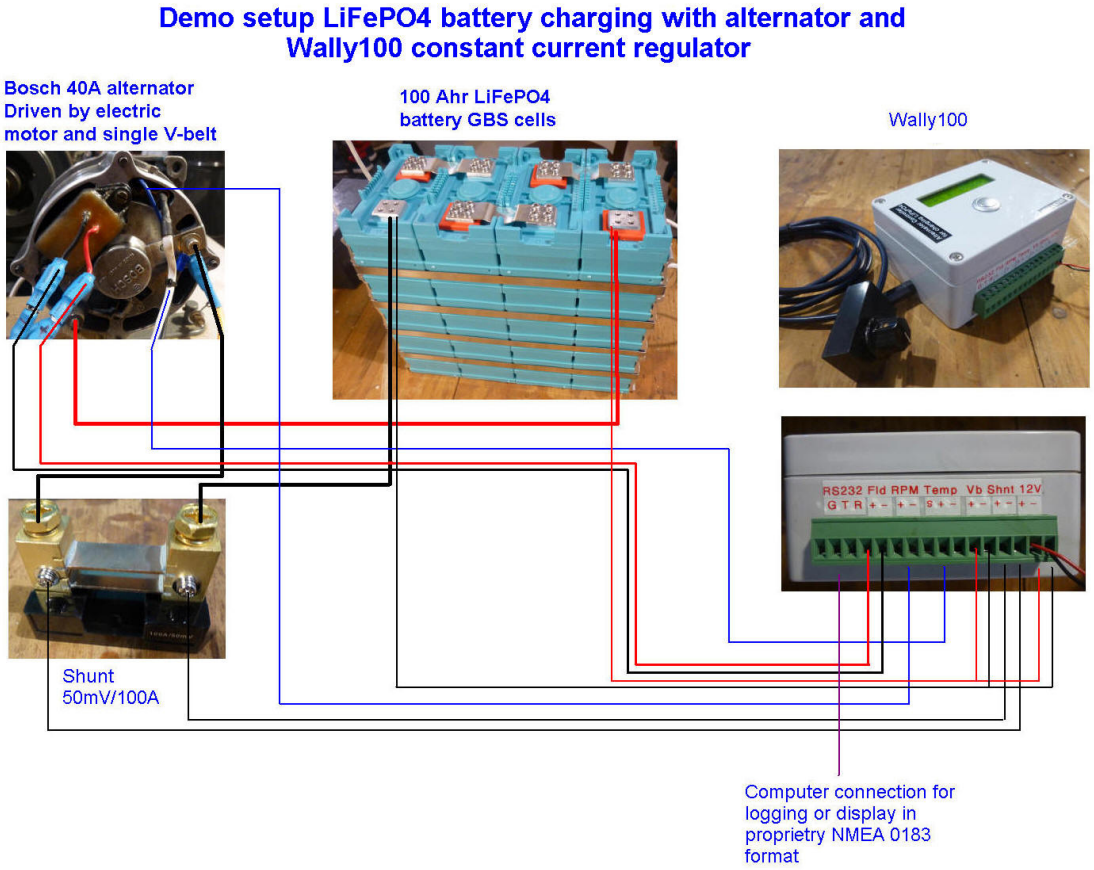
"Set the time the charge time in lead-acid mode (usually the start battery) after the engine has started, before LiFePO4 charging begins.
The alternator controller has outputs for switching relays to connect either to the lead-acid battery or the LiFePO4 battery (bank).

Short press for the next configuration screen:

Also see description of screen 6 above. After a short press, the first data screen is displayed and after the last data screen of the cycle, the first configuration screen is displayed, as config is still ON.
After a long press, Config is OFF and no configuration screens are displayed after the last data screen. Note that after power-off (engine has stopped and engine instrument power has been switched off) the config mode setting is not saved, so if configuration is required after power-on, it has to be turned on first.

Installation

Please note that the following figure only shows a demo setup for illustration purposes. Complete wiring schematics will be added later.



Connections

RS232
Used for logging purposes (proprietry format NMEA $PAXDR sentences. Data fields for: Amps, maximum Amps, Battery Voltage, Alternator RPM and Alternator Temperature. Frequency 1x per second. Baudrate 4800.
G - Ground
T - Transmit
R - Receive (N/C)

FLD
Field connection to alternator.
+ F terminal on alternator or equivalent.
- Ground
In case of isolated connections to rotator brushes, connect directly, not to ground.

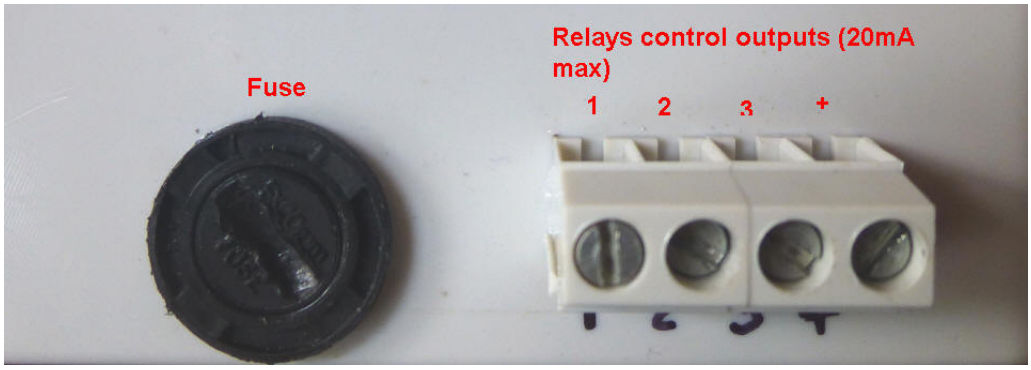
RPM
Alternator RPM connection.
+ W terminal on alternator or equivalent.

Temp
Alternator Temperature sensor connection (thermistor).
S Signal (input)
+ 5V output
- Ground

Vb
Battery Volts (Vbat)
+ Battery +
- Battery -

Shnt
Shunt connection for Amp sensing (standard 100A/50mV shunt)
+ High side
- Low side

12V
Power connection.
Normally to power connection of engine instrument panel. (10-16V)



Fuse
5A

Relays control outputs
Intended for solid state relays that require a small control current (max 20mA).
+ 5V output (at all times). To be connected to all relays + control connections.
1 - Connection. Switched. To be connected to relay 1 - control connection. Relay 1 (optional) can be used for switching engine room blowers, electric cooling circulation pump, etc. This will be activated (connected to ground to sink current) after the engine has been started and the alternator starts charging. By connecting the extras through a relay, the full start battery capacity is available for starting.
2 - Connection, switched. To be connected to relay 2 - control connection. Relay 2 is only required for sequential/alternating lead-acid and LiFePO4 charging and is used for switching the lead acid battery to the alternator.
3- - Connection, switched. To be connected to relay 3 - control connection. Relay 3 is only required for sequential/alternating lead-acid and LiFePO4 charging and is used for switching the LiFePO4 battery to the alternator.