Wally 100 Alternator Controller for alternatingly 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).

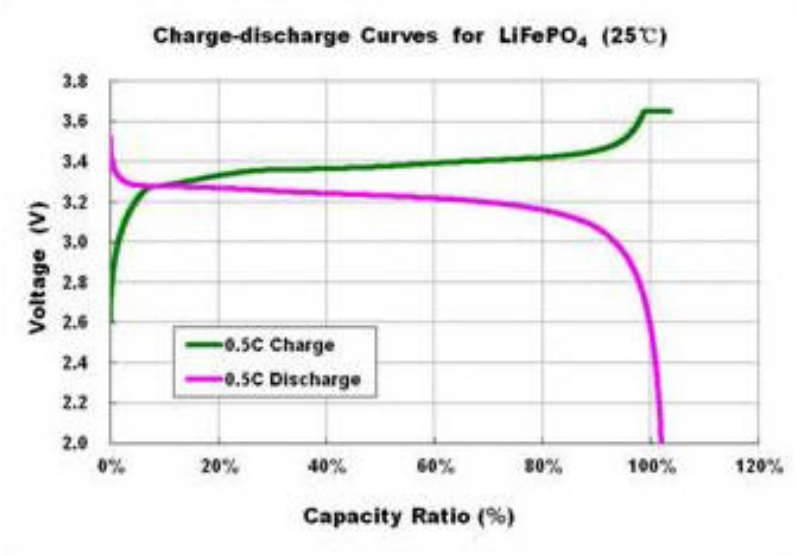
The alternator output is controlled by a current from the alternator controller through the alternator field winding (rotor). By varying this field current, aka excitation current, the alternator output can be increased or decreased to match the set Amperage value. This is what sometimes is referred 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 is reached, charging stops to avoid over-charging. The Wally100 stops the field current to the alternator. LFP batteries do not need an absorption or float charge stage. When charging stops, a timer (in minutes) is started. When timed out, the Wally100 starts charging again. The timeout is a configuration parameter and setting depends on circumstances. If there are not many users, it can be set high, e.g. 120mins. A shorter time may be more appropriate if users include a fridge, freezer, heater or other high electricity users. The time can be short-cut or increased at all times, if necessary.

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 during 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 needs only 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 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 always first cuts the alternator field (rotor) current, checks if the output current is 0 Amps and only then switches the relays.

So after power-up of the Wally100 controller (when power of the engine control panel is switched on), 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 commences with soft-start.

Charging of the LiFePO4 batteries stops when the set Voltage, e.g. 13.8V, 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 the above mentioned relay control output for charging the LiFePO4 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.

The earlier described LiFePO4 charge restart timer, which is started when the LiFePO4 charging stops, still runs during lead-acid charging and when the set time-out is reached (e.g. after 60 mins), L-A mode charging is terminated and LFP charging is started again. If

not much capacity has been used, the LFP max charge voltage will be reached soon and the controller switches back to lead-acid mode.

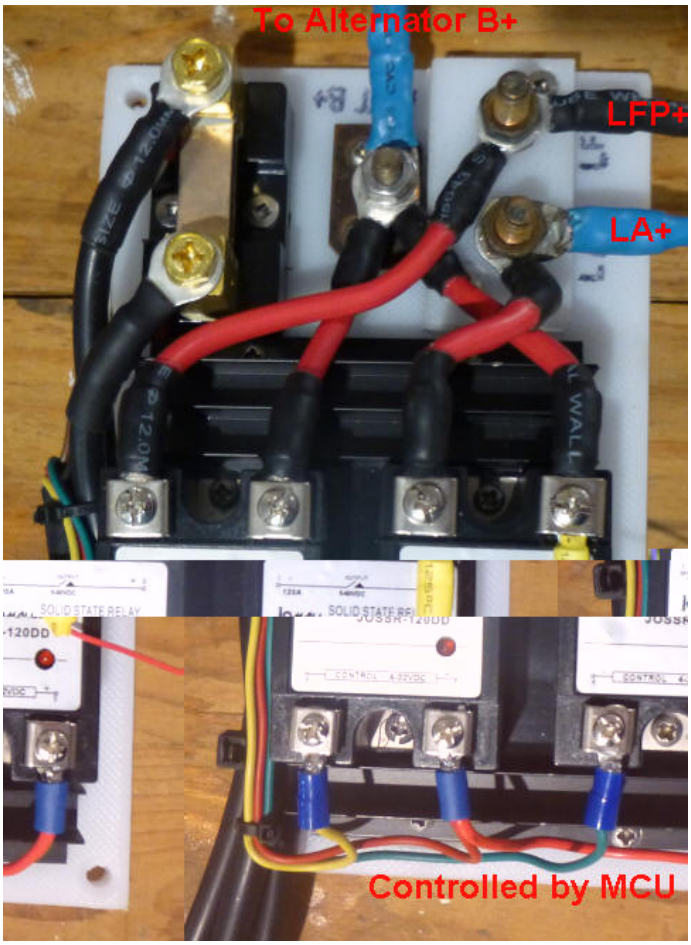
This system ensures that Lead-Acid and LiFePO4 batteries are never switched in parallel and are both most efficiently charged in the shortest possible time.

Wally100 charge modes

Three selectable charge-modes are available:

1. Alternate mode.
   In this mode the Wally100 alternates between LiFePO4 and Lead-Acid charging as described above.
2. Dedicated LiFePO4 mode.
   The Wally100 only charges in LiFePO4 mode. No switching relays are necessary. When the maximum charge voltage is reached charging stops and voltage is monitored until it drops to the charge restart voltage. When reached, the LiFePO4 charge process starts again.
3. Dedicated Lead-Acid mode.
   The Wally100 acts like a conventional 3-stage lead acid charge controller. (Bulk, Absorption, Float). No switching relays are necessary.

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



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. In most cases screen 2 will be set as the default screen, as the most important data is displayed here.

If configuration is required, a long press of the push button while the Config on/off screen is displayed will make a number of extra screens available for setting the various parameters. Please refer to Wally100 Configuration below for details.

The last position of the second line of the LCD is used for indicating the current charge mode, no matter which information or configuration screen is currently being displayed.

The one-letter codes for charge mode/phase are:

A – Alternate mode, currently charging LiFePO4 (CC mode)
V – Alternate mode, currently charging Lead-Acid (CV mode, timed)
T – Alternate mode, currently charging Lead-Acid after LiFePO4 full (CV mode, timed)
L – Dedicated LiFePO4 (CC) mode
W- Dedicated LiFePO4 mode, waiting for Voltage to fall to restart Voltage. (not charging)
P – Dedicated Lead-Acid mode (bulk, absorption, float)
C – Cooling alternator after max alternator temp has been reached. (not charging, timed)

Information screens

Screen 1

Short press the button for next screen:

Screen 2 (Usually set as default)

A: Amperes charging
Vb: Volts battery. If the code for charge mode/phase on the last position of the 2nd line of the LCD is A, L or W, this is the Voltage of the LiFePO4 battery(ies). If V, T or P, this is the Voltage of the lead-acid battery(ies).
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:

Vb: Volts battery. If the code for charge mode/phase on the last position of the 2nd line of the LCD is A, L or W, this is the Voltage of the LiFePO4 battery(ies). If V, T or P, this is the Voltage of the lead-acid battery(ies).

RPM Alt: Alternator RPM

Short press for next screen:

Screen 6:

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

Notes:

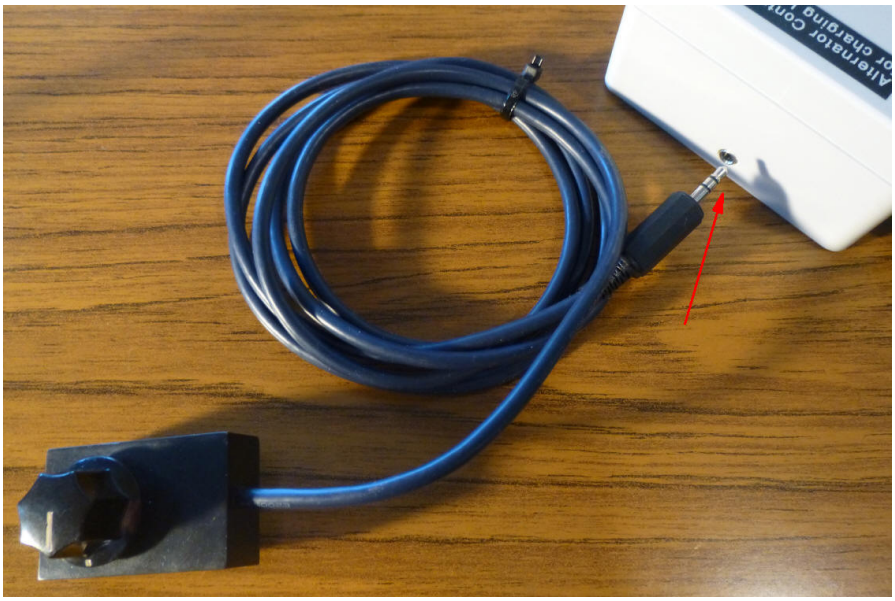
1. A **short press** is about 1 sec.
2. A long press is about 2 sec. The word "SET" is displayed and the button should then be released.
3. A **long press** while any of the data screens 1-6 above is displayed stores the screen number in eprom as the first screen that will be displayed when the Wally100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

Wally100 configuration

A **long press** while screen 6 is displayed will turn Configuration mode on.
Another **long press** while this screen is displayed will turn Configuration mode off again.

With “Config now ON” in screen 6, after a short press the first configuration screen is displayed.

Setting the various configuration parameters is done in a unique, easy way that does not require a computer, dip-switches or other complicated method.



A separate small module with turning knob is plugged into the small round socket on the side of the Wally100. Parameter values can be set by turning the knob until the required value for the parameter is displayed. Pressing the push-button then stores the displayed parameter value.

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

The first configuration screen shows the present (default) charge mode **Alternate**.
A **long press** changes the charge mode to dedicated LiFePO4, another **long press** sets the mode to **Dedicated LiFePO4** and another long press sets the mode to **Dedicated Lead-Acid.** A following long press returns the mode to Alternate again, etc.

A short press will show the next configuration screen.
Configuration screens are displayed independent of the current mode setting, e.g. even if the current mode setting is LiFePO4, parameters for Alternate and Lead-Acid mode can be set.

Most 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 same configuration screen with the new parameter value now displayed on the left as the present setting. The parameter has now also been saved to eprom.

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 where charging should stop) for LiFePO4 charging. Units are in 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) LiFePO4 charging has to restart after the set maximum LiFePO4 charge Voltage has been reached. In Alternate mode, the Wally100 switches to Lead-Acid charging after this LiFePO4 Voltage has been reached. During the lead-acid charging, the timer is constantly checked and the Wally100 switches back to LiFePO4 charging when the set time has elapsed.

Short press for the next configuration screen:

Set the time (in minutes) charging has to start again after the set maximum alternator 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).

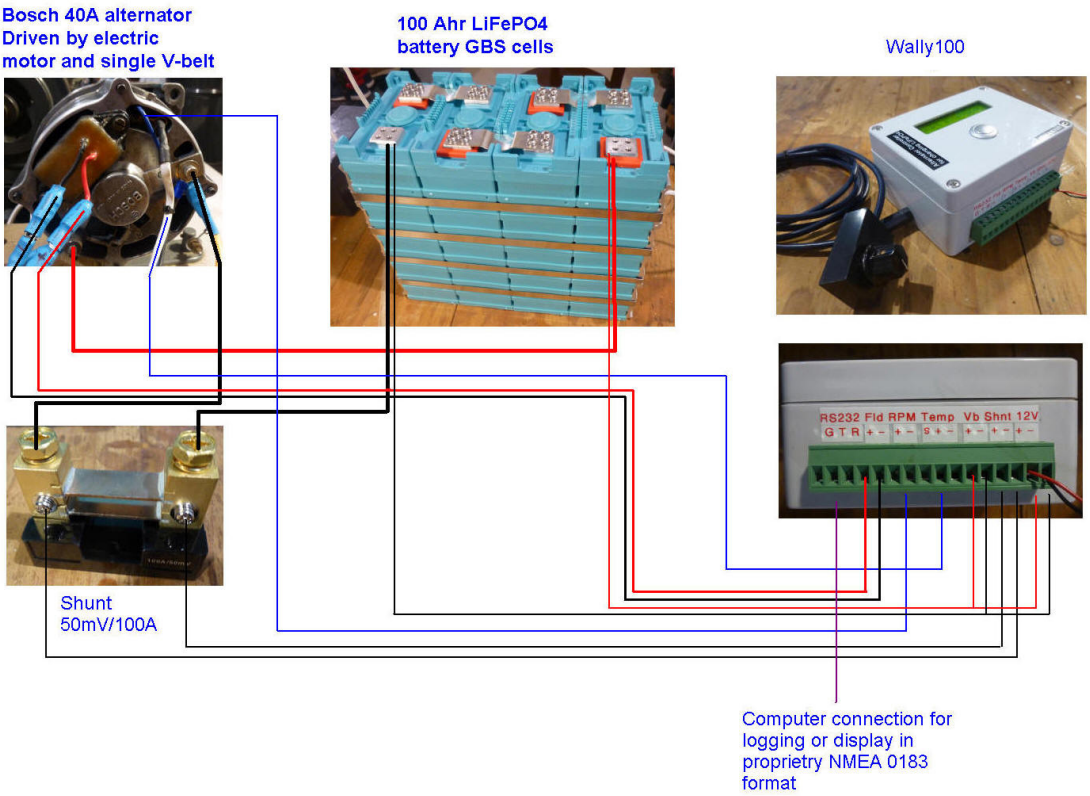
Short press for the next configuration screen:

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.

Demo setup LiFePO4 battery charging with alternator and Wally100 constant current regulator



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.

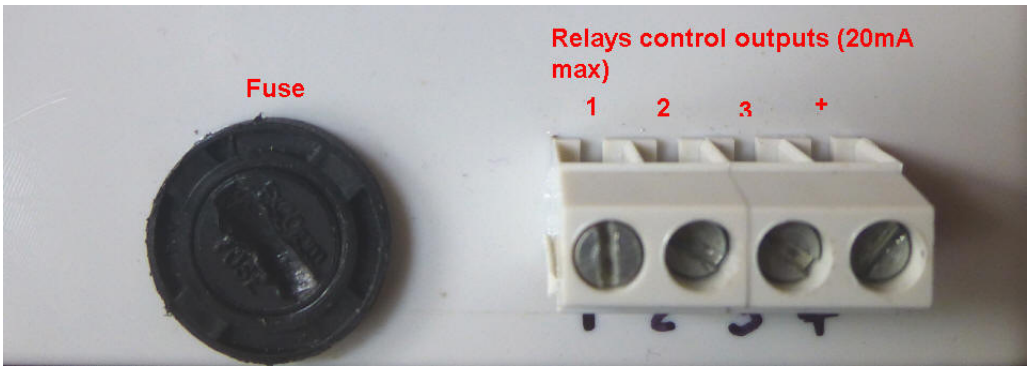
RPM
Alternator RPM connection.
+ W terminal on alternator or equivalent.

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.