VSR SYSTEMS

ALTERNATOR REGULATOR

AN OPEN-SOURCE INTELLIGENT ALTERNATOR REGULATOR

Reference Manual

v1.3.1 - July 22, 2018
For use with Source Code v1.3.0 and later

Acknowledgments

Special thank you to those who assisted debugging, correcting code, making suggestions for enchantments, documents, and many other ways of help. The Alternator Regulator is better thanks to their contribution.

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Yachtdynamics

And Many Others. . . .

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THE ALTERNATOR REGULATOR

"House Batteries" are common on RVs, boats, remote cabin / houses. These battery banks often represent investments in the hundreds if not thousands of dollars, so it is well worth the effort to take care of them.

The use of an external alternator regulator is a well-known way to improve over standard 'auto' internal regulators. With accurate measurement of battery voltage, and then control of the alternators field to adjust its output, these often provide several important features such as soft staring to save belts, multi-stage charging to assure faster and more complete recharging, even temperature sampling of the battery to adjust target voltages as needed. But with almost universal exception, all currently available external chargers are lacking one key ability: the ability to monitor current as well as voltage.

Sampling the specific gravity of the Acid is often the preferred way to determine the true SOC of a battery. Another approach recommended by many battery manufacturers is to monitor the amount of current a battery is accepting[1] while recharging. By continuing to hold a battery in the Acceptance Phase until these manufacturers recommended thresholds are meet we can assure a battery is indeed fully recharged. Without the ability to measure current, most common regulators revert to another approach for determining if a battery is fully recharged: they guess.

The Alternator Regulator includes the ability to monitor current in addition to voltage and temperatures. It also provides the ability to limit alternator output to protect the alternator, battery and/or engine (depending on how it is configured). And it is able to support batteries and alternators from 12v to 48v, and both P type as well as N type alternators.

During installation, an Amp Shunt is placed on the house battery to monitor current into and out of the battery. You may already have such a shunt already installed, for example if you use a battery monitor along the lines of the Link-10. In this case, simply reuse the same amp shunt, though do make sure the regulator is correctly configured (default is 500A / 50mV) with the shunt proprieties – refer to the $SCA: command for more details.

Another way to utilize the Alternator Regulator is to place the amp Shunt on the Alternator, as opposed to locating it at the battery. With this configuration, the Amps monitored can more closely focus on the Alternator and one is able to configure the Regulator to limit the amount of Amps produced, and hence the load the alternator places on the engine. This can be useful in cases of building a DC generator where the Alternator is much larger than the engine is able to support. By capping the amount of power the Alternator is allowed to produce, you can match its demands to the capability of the engine. A downside to this approach is one loses true visibility into the House battery state of charge; other loads on the system can cause confusion – e.g., if there is a 'house load' to power instruments, navigating equipment, and such, this confuses slightly the true status of the battery's state of charge. One can compensate for this by either adjusting the Charge Profiles, slightly raising the Amp Exit Thresholds to account for an expected average house-amp draw, or the ASCII command $EOA: can be used by an external all-charging source cordoning device to inform the Alternator Regulator of any adjustments to the measured Amps that are appropriate.

[1] Example, see: "Exide Battery Charging & Storage Guidelines 5_9_13" -- www.exide.com/Media/files/Downloads/TransAmer/Battery Care and Maintenance/Battery Charging & Storage Guidelines 05_9_13.pdf

The Alternator Regulator may also be used in conventional Voltage Only mode[2] by simply not connecting the Amp Shunt (place a small wire across the Amp Shunt terminals to remove the chance of any electrical noise fooling the regulator). The Regulator will fall back to time-only charge profiles, though with very accurate measurement of voltages. In addition, Acceptance Phase will utilize an 'adaptive' time based formula; it will remain in Acceptance for 5x the duration the regulator was in Bulk mode, OR the configured maximum amount of time contained in the CPE – whichever is less. In this way, the battery gains more protection from over charging when the regulator is unable to measure the amps.

[2] Voltage Only mode is detected when the Alternator Regulator is unable to measure current in excess of +5A at any point in time. Under this case the code will ASSUME the Amp Shunt is either not connected, or damaged and will fall back to time-only exit criteria. (i.e., all the CPE Amp values will be assumed set = 0 (disabled). See source code "#define USE_AMPS_THRESHOLD" to control this capability.

THE ALTERNATOR REGULATOR FAMILY

There are three members in the Alternator Regulator family. All members share common characteristics as noted above, including: flexible 12v-48v support, ability to use acceptance amps to properly charge a battery, and tight voltage regulation. But there are some slight differences between each version:

1st Generation: (RETIRED)
Original development design.
Based on the ATmega328 CPU, PCB version 0.0.x - this design is retired and not supported.

2nd Generation: (ACTIVE)
Through-Hole components.
Continuing to use the ATmega328P CPU, PCB versions 0.1.x.
Features optional Bluetooth.
Made available as blank PCB - v0.1.4 being the most common.

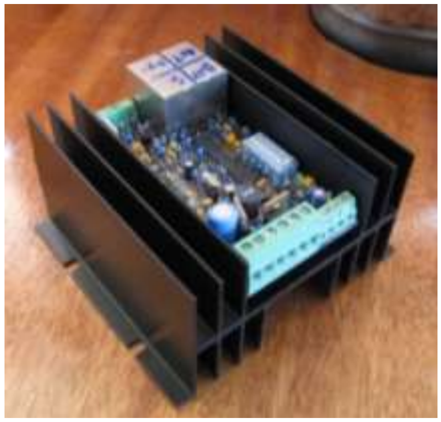

Figure 2 - First Generation Design

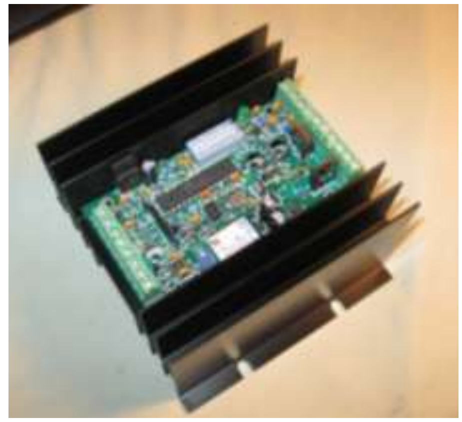

Figure 1 - Second Generation Design

3rd Generation: (ACTIVE) Newest version - SMT based design. Utilizes the ATmega64M1 CPU, PCB version 0.3.x it features CAN subsystem. Available as both blank PCBs as well as partially/fully assembled regulator beginning with v0.3.5 of the PCB

A slight variation called 3B is designed to be installed in a small plastic or metal project box such as the Hammond 1591XXBSFLBK

Figure 3 - Third Generation Design

WHAT IS A 'SYSTEMS' APPROACH TO BATTERY MANAGEMENT?

Even the most basic DC battery and an associated battery is a `System', it is only a question of how well the system works. Voltage-only regulators have only one channel of communications: voltage. Though very important, it leaves no ability to communicate any other information, hence the addition of additional sensors: temperature probes, current shunts, etc. But even with added sensors there is still only one channel of communications: Voltage. And having only one channel of communication can be restrictive and starts to introduce compromises. Trying to get Solar panel controllers to cooperate with alternator is one example.

Communications between different nodes in a system is a long know challenge, with many proven and reliable solutions. Beginning with the 3rd generation of the VSR Alternator Regulator a CAN (Control Area Network) port is added to provide for a robust proven communications path between devices connected to and surrounding the battery. Built upon truly open standards, the added communications capability allows for coordination of charging sources. Battery Monitors are able to determine the true needs of the battery and inform charging sources, twin engine alternators are able to balance with each other without any extra 'Balancer' hardware being added. Solar is able to be used to its fullest capability in conjunction with other charging sources; while also prioritizing – allowing Solar to finish the final stages of recharging with the alternator pulling back. Meeting the needs of the battery in ways impossible to obtain with a single (e.g. voltage-only) communications channel.

CAN (Control Area Network) is a mature communications hardware standard which has been in existence for several decades. Reliable, fault resistant, it has seen millions and millions of applications ranging from transportation, industrial, heavy equipment, to agriculture and marine. Just to name a few. The VSR Alternator Regulator builds upon this robust base again using proven and open standards. SAE's J1939 (a core part of NMEA-2000) combined with the open standard RV-C makes up the software protocol which is the basis for OSEnergy (Open Systems Energy). OSEnergy is an open architectural specification who's aim is to provide a framework for the design, deployment, and operation of charging sources associated with a DC battery, and whose goals are to protect, optimize, and simplify the installation, operation and maintenance of DC systems.

Installation can be greatly simplified by utilizing the Remote Instrumentation capability of OSEnergy spec – reducing cabling from a multitude of wires from each charging device individually to the battery to a single CAT-5 cable. High Availability installations mesh-type sensing systems are also possible, allowing for one or more component / wiring failures.

CONNECTIONS

The following illustrates connection terminals on the alternator regulators. See the following table for a description of each connection, as well as suggested min size. Example deployments follow the table.

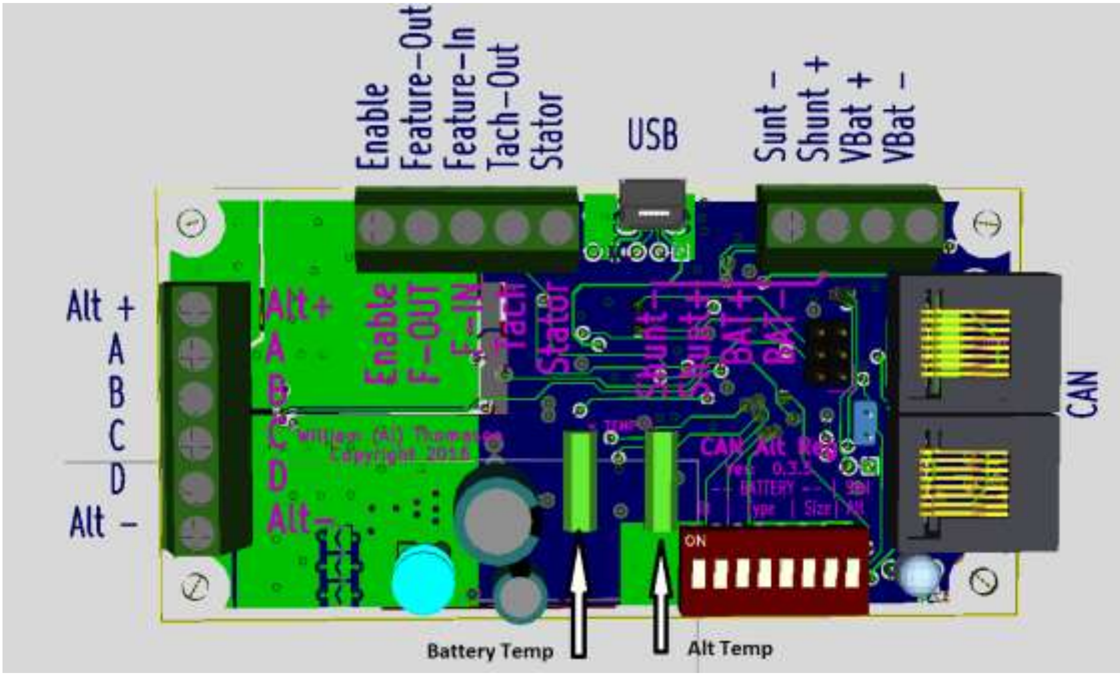

Figure 4: 3rd Generation connections

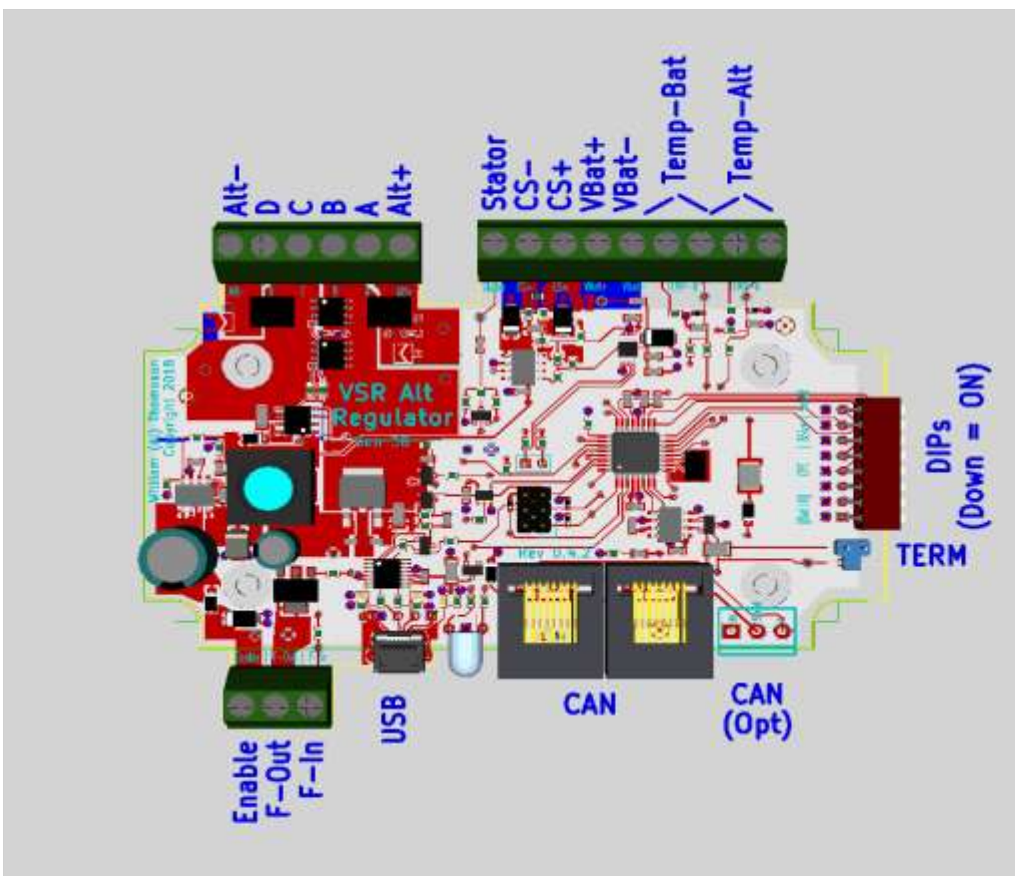

Figure 5: 3rd Generation Connections (Ver 3B)

VBat+, VBat - Connect ***directly*** to the battery via 14AWG wire protected with a 2A fuse located at the battery. (Do not connect after any busses, shunts, etc..)

Alternatively, on Gen 3 regulators, these may be connected locally to the alternator if the regulator will remotely receive battery voltage via the CAN bus. Refer to "Integrated System Samples" on page 22

Enable: Connect to VBat+ to 'turn on' the regulator. Use min 14AWG wire and a 2A fuse.

Current Shunt + ,
Current Shunt -: (optional) Connect to the Current Shunt using twisted pair 16AWG or larger wire. The Current Shunt maybe installed in either a ground wire (low shunt), or in the + voltage wire (High Shunt). Do not exceed 80mV difference between CS+ and CS-, nor exceed connect to a shunt more than 72v above ground. If the Current Shunt is not being used, it is suggested to place a wire between these two terminals to avoid any electrical noise confusing the regulator. If the VSR Alternator Regulator is participating in an Integrated System where battery voltage, current and temperature is being measured using a remote battery monitor or BMS, the local Current Shunt may optionally be connected to a shunt located in the ALT+ output to allow direct amperage measurement of the alternator.

Feature In: (optional) Connect to VBat (6-72v) to enable features (see FEATURE IN section).

Feature Out: (optional) Open Collector driver, connect to external Alternator LAMP at dash. 0.5A *max* current sink capability. See Source Code to enable other optional capabilities.

Alternator +: Connect to + (Bat) terminal of Alternator. Use wire sized to match your expected maximum Field current draw and protected by an appropriate fuse. (typically 4-12A, depending on alternator size) (Min 14AWG – use 12AWG or 10AWG for large frame alternators)

Alternator -: Connect to the – (gnd) terminal of Alternator using appropriate wire. (Min 14g)

Stator (optional) Connect to an Alternator Stator pole via 2A fuse and 16AWG wire.
Used to increase battery voltage measurement accuracy, as well as enable several battery and alternator protection features in the regulator.

A, B, C, D: Connect to the field per the following table depending on the configuration of your alternator:

	Jumper	**Alternator Field**
High Drive (P / B-type)	**A - B**	**Field: C**
Low Drive (N / A-type)	**C - D**	**Field: B**

Use wire of sufficient gauge to carry the expected current, up to 32A (connector limit) (Min 14AWG).

Bat Temp, Alt Temp:	(Optional) Appropriate NTC temperature sender. Note that Alt Temp may be OPTIONALLY shorted to enable half-power mode.
Service / USB:	Used to initialize and debug the regulator. Generation 3 and greater contain a built in USB connector while Generation 2 requires the use of an external USB ← → TTL adapter.
CAN:	(3rd Generation) Allows communication of regulators status via NMEA-2000 and/or OSEnergy protocols. Provides for remote sensing of battery and charger coordination / prioritization with other OSEnergy compliant devices. Utilize CAT-5 cables if regulator is populated with RJ-45 connectors, otherwise use 120 Ohm twisted pair wire to the CAN terminal block.

CONNECTION AND FEATURES ENABLED

The VSR Alternator Regulator minimal installation needs only 6 wires to be connected (See " Example 1: Minimal (Voltage Only) Installation" on page 21) and will operate as a highly capable multi-step voltage regulator, where charging decisions are based on time. Adding sensing wires unlocks additional features. The following table highlights a few of these capabilities and connections needed.

Connection / **Feature**	**Minimum Required**	**Additional Connections** *(Connected separately, or in combination)*				
	VBAt+, VBat- Alt+, Alt- Field Enable	Stator	Battery Temperature	Alternator Temperature	Current Shunt	CAN / CAT-5
High Accuracy voltage regulation	✓					
Adaptive Idle		✓				
Battery Temperature Compensation			✓			
Alternator Overheating protection				✓		
Battery measurement based charging decisions					✓	
System charging coordination						✓
Status reporting (NMEA2000™, etc.)						✓

Table 1: Connections and Features Enabled

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Table 1 above is not exhaustive, only illustrates some of the main capabilities of the VSR Alternator Regulator.

WHY DO WE NEED A STATOR WIRE?

The VSR Alternator Regulator includes a wire to be connected to one of the Status terminals on your alternator. Though optional, attaching this wire will improve the accuracy of voltage measurements, and enable several protection features.

- Improved Voltage Measurement by synchronizing the sampling of battery voltage with the stator. This is a 'best Practice' for measuring battery voltage as it allows us to see the true 'high point' of the alternators output each time we measure battery voltage. It also reduces external noise and other issues if the voltage samples were at random times. Battery voltage to a resolution of 1.25mV (a bit more than 0.001 volt), it is capable of very accurate sampling. By using the Stator wire we are able to maximize this accuracy.

- Connecting the Stator wire is also needed to facilitate Tach Mode. And if you then set the appropriate calibration values (pulley size, alternator poles, etc), you will be able to measure the engine RPM via the ASCII status strings (assuming no belt slip).

- Stator Sample allows for Adaptive Idle pullback, where the alternator load is reduced as the engine approaches idle. This can be helpful with small engines to prevent stalling, or sluggish performance near idle while still allowing for full current output at higher RPMs. (See $SCA: command 'PFB' – Pull Back Factor)

- Stator Sample also enables a few protection features. Example, if at some time we see SOME stator pulses, and then they disappear, we assume the engine has stopped. In this condition we reduce the Field PWM drive greatly. Without the stator wire we have no idea this has happened (remember, OTHER sources might be charging the same battery, so looking for a drop in VBat is no use). This prevents the regulator from continuing to apply field current and heating up the alternator.

Special note: If your existing installation has additional lamps, resistors, diodes etc. connected to the Stator field, or perhaps a Diode Trio (part of the dash lamp) or 'exciter' connection on the alternator, it is advisable to remove these. You can reconnect the dash lamp to the Feature-out connector. Leaving existing resistors, diodes, or other connections from the old installation have been known to cause issues with RPM measurements and other features of the VSR Alternator Regulator.

WHY DO WE NEED A CURRENT SHUNT?

The VSR Alternator Regulator is fully capable of operating using only battery voltage sensing, and in fact this is a fail-over mode in the case of a missing or broken current sensing probe. In Voltage Only mode charging decisions are based on times values, either pre-determined, or at times calculated based on prior phase changes. However, with very few exception, battery manufactures preferred charging guidelines call for the monitoring of charge acceptance current as a critical factor in making charger mode decisions, specifically when to end Acceptance phase. As a battery is held in Acceptance Phase the amount of current being accepted by the battery has a direct correlation to a batteries SOC (State of Charge). Monitoring acceptance current allows the regulator to make better decisions and safer charge profiles: using a lower acceptance voltage set point while still allowing for the complete recharging of a battery. LiFeP04 and related battery technologies greatly benefit by this 'lower stress' charging approach of a proper acceptance phase vs. to be held long enough to assure a fully charged battery, and no more. Reducing battery stress as a result of overchaging.

Contrast this to time based decision criteria which uses fixed or perhaps a calculated time basis for determining the batteries needs; perhaps adding a bit of extra time just to make sure. While time based decisions can be estimated in the lab, they are often confounded by real world imitations. Battery age, temperature, model, and more all impact the amount of time needed to properly complete an Acceptance Phase. Adding extra time may potential result in a more complete battery SOC recharge, however care must be taken with this approach as some battery are less forgiving to over-charging then others. FLA (Flooded Lead-Acid) batteries might just use more water, while some GEL/AGM and any Li based battery technology could be damaged. The alternative of a short acceptance phase has it owns issues; chronic under charging has a very detrimental impact on the lifespan of many battery technologies. Not to mentioned the underutilization of the fill (but paid for) capacity in the battery bank. Another mitigating approach is to monitor the field drive and use that to help augment charging decisions. However field drive decisions have no idea where the alternator output is actually being consumed and can be tricked to either over or under charge. One example is by simply running a concurrent load while charging. If a washer/dryer is being powered via an inverter, field drive decisions will never see a reduced field drive and can easily overcharge the battery.

MAXIMUM LIMITATIONS

The following table documents maximum allowed values during the operation. Exceeding any of these values may cause unpredictable operation and/or damage. All voltages are referenced to VBat- unless otherwise noted. Note that some regulators are configured to support only 12..24 systems, while other are able to support 12 through 48v systems.   Take care to assure which configuration your regulator is!

Item	Min	Max	Symbol
VBat+		32	Volts
Enable	8.5	32	Volts
CS+	-0.5	32	Volts
CS-	-0.5	32	Volts
CS+ vs. CS-	-80	80	mVolts
Feature-In	-0.5	32	Volts
Feature-out		32	Volts
		0.5	Amps
Alt+		32	Volts
Field (B or C) current		32	Amps
Ambient Temperature	-40	100	Celsius

Table 2 – Maximum Limitations 12-24v regulators

Item	Min	Max	Symbol
VBat+		65	Volts
Enable	8.5	65	Volts
CS+	-0.5	65	Volts
CS-	-0.5	65	Volts
CS+ vs. CS-	-80	80	mVolts
Feature-In	-0.5	65	Volts
Feature-out		65	Volts
		0.5	Amps
Alt+		65	Volts
Field (B or C) current		32	Amps
Ambient Temperature	-40	100	Celsius

Table 3 – Maximum Limitations 12-48v regulators

Special care should be noted of the Current Shunt lower voltage limitations. If the current shunt is located in the ground line and a distance from the battery (example at the alternator), too small of a ground wire between the shunt and the battery could easily exceed the limits and create a ground-loop. Increasing the size of the ground cable, and/or relocating the Amp Shunt to the Alternator + wire are potential solutions.

Alternator Temperature Probe Location

In most cases the diode pack is the critical limitation in alternators and the best point of reference for measurement – however it is best to consult your alternator manufactures for recommended placement - as well as for allowable operation limits. Figure 6 below shows the recommended location for the alternator temperature probe from Leece Neville / Prestotolite -- on the diode pack.

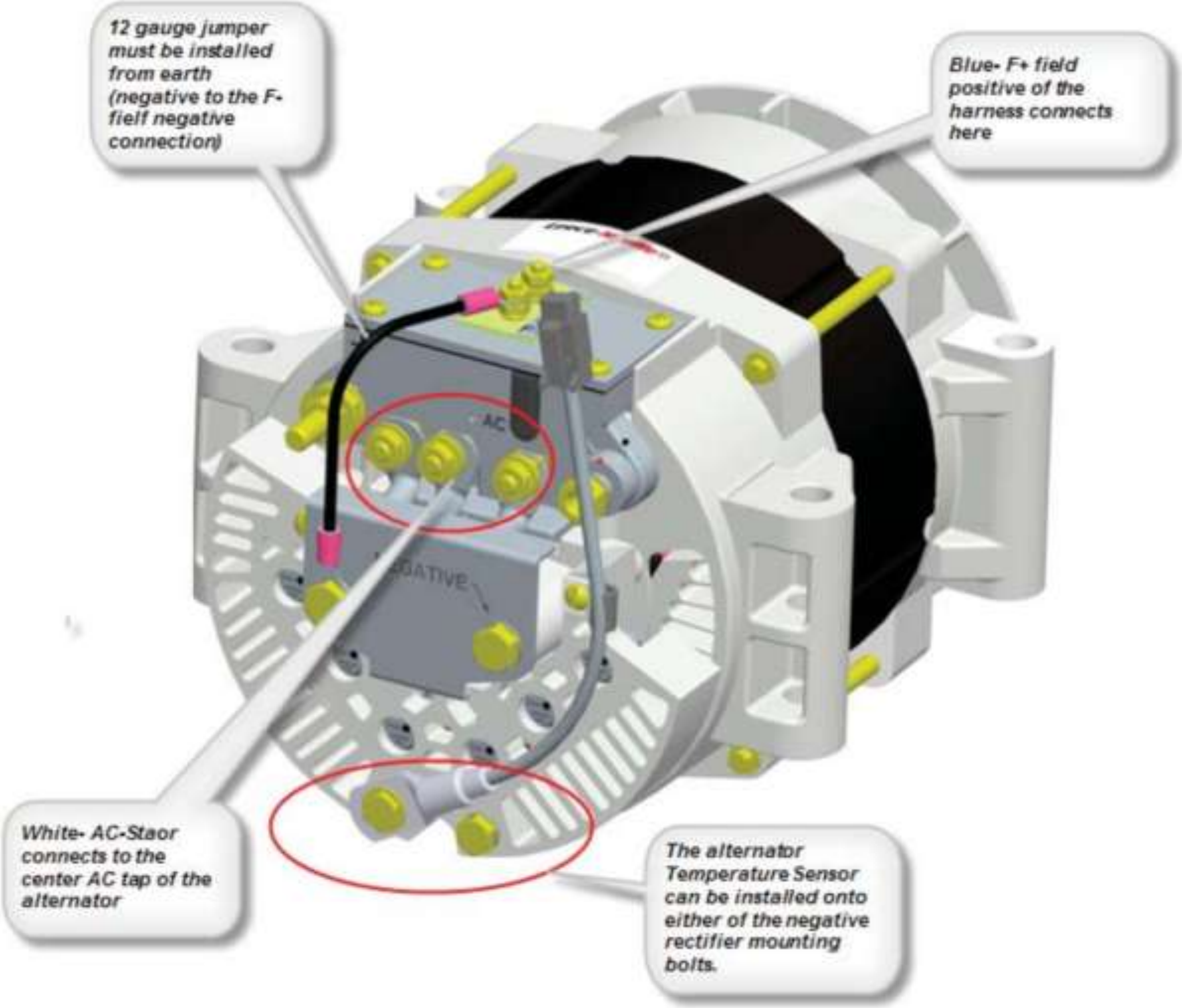


Figure 6 - Example Alt Temperature probe location

ACCESSORIES – PROBES, CASES, SHUNTS, ETC.

To install your regulator you may need some or all of the following. There are many ways to purchase these, and the examples given are only one option.

Temperature probes:

The VSR Alternator Regulator uses NTC temperature probes to optionally monitor battery and/or alternator temperature. There are several sources for NTC probes, do make sure to get ones with these specifications:

- Resistance: 10K Ohms
- Beta: 3950

(Note: It is possible to alter these values (to some extent) by making changes to the Source Code)

There are positions for two sensors, A and B – typically used for Alternator and Battery respectively. Gen 2 regulators use screw connectors, while Gen 3 uses a common JST XH2.54 2P connector. When sourcing for sensors you should be able to find many probes which already have the connector installed.

Searching Ebay or Amazon for "NTC 10K waterproof 3950" will quickly bring up a wide range of suppliers, with cable lengths from 0.5m to 5m. Here is a photo of one bundle of 5x sensors – with attached JST connectors:

Fuse Holders:

It is recommended to install fuses in the locations indicated in the Example Installations. Chose a fuse of appropriate rating (See `Connections' above) Use a good quality water resistant fuse holder and fuses which you are able to secure easily and locally. Remember, Fuses are primarily intended to protect wires, not the device – with one exception: the Field fuse will also help protect the Alternators Regulators field drive circuit – choose a fuse about 50% higher than you expected maximum field draw. For smaller alternators, a 10A fuse should be sufficient, while larger units may need a 15A fuse. If you are driving multiple alternators in parallel from one VSR Alternator Regulator, adjust the fuse size accursedly, but do not exceed 32A as that is the terminal strips maximum rating.

Current Shunts:

Many installations already have a battery current shunt installed, often as part of an existing battery meter. If so, simply attach the Current Shunt leads to that existing shunt. The shunt may be located in the + or the – wire with no adjustments needed for your regulator. Do pay attention to the + and – connections (refer to example installation diagrams on page: 17). You can verify the shunt is working correctly by connecting a computer to the Serial/USB port (see page: 47) and monitoring the AST; status strings (page: **Error! Bookmark not defined.**). If you find you have the shunt installed backwards, correct the wiring or use the $SCA: command (page: **Error! Bookmark not defined.**) to indicate the 'shunt is reversed'.

By default the regulator is configured for a 500A/50mV shunt (Common on many battery monitors). If you are using a different shunt, use the $SCA: command to inform the regulator of the shunt value.

CAUTION: Do not use a shunt who's voltage exceeds 80mV, or inaccurate results will occur as well as a potential for damage.

Shunts are known for being less then accurate, and if you find the calibration of the VSR Alternator Regulator is off, you may use the $SCA: command to adjust for any error.

Enclosure:

Gen 2 VSR Alternator Regulator was designed to fit inside its heat-sink, largely for protection – though there is a little heat which must be dissipated. Aside from protective heat sinks, die-cast aluminum box would be another suitable choice, just make sure that the driver FETS as well as the voltage regulator (Q1 and U1) are solidly attached to the case. (Make sure to use appropriate electrical isolation for any heat-sinked component)

Gen 3 dissipates very little heat and no heat-sink is needed – just air flow around the components (PCB standoffs are sufficient). Plastic boxes are suitable for this release of the regulator. NEMA 4x 'Water-proof' boxes available at electrical supplies and/or building supply houses can be an attractive low cost option; especially when combined with water-tight bulkhead glands around the cables in and out of the box. Some examples:

Figure 7 - E989PPJ 5" X 5" X 2"Junction Box

Figure 8 - Uxcell® Waterproof Box 200x120x75mm

Also check the blog / mailing list / github for any updates as well as potentially for custom 3D-printed cases which others may have designed.

Both Gen 2 and Gen 3 regulator PCBs have 3mm mounting holes in the corners. These holes can be taped using a 6-32 tap, allowing gentle screwing up from the bottom of the case into the PCB. Make sure to use nylon spacers to provide air circulation to the bottom of the PCB.

Here is an example of the gen 2 design so mounted, notice the screw on the right coming up through the heatsink to the PCB and the white nylon spacer.

CAT-5 Cable

Used only on the Gen 3 (CAN enabled) regulator, CAT-5 cable is used to connect the VSR Alternator Regulator with other OSEnergy compliant devices to allow monitoring and coordination of a DC System. Any CAT-5 or CAT-5e cable will work, as well as CAT-6 cable. Connect the CAT-5 cable from each OSEnergy compliant device in a daisy-chain fashion, making sure the 'Terminator' is enabled on each end of the daily chain (remove the terminator from any nodes not on the end).

Waterproofing:

There are a verity of options for doing installations in a water resistant way, from simply installing in a protected area, to using cable glands and/or waterproof bulkhead connectors, to even potting the entire regulator in a sealed unit. Each of these options comes with a cost. Perhaps the most likely approach is to use a case with sufficient size to allow for the wires to exit the bottom, providing some level of splash resistance. Another option is to use sealed box and "Liquid tight / strain relief" cable glands such as these (Often available at home building centers):

And/or dedicated waterproof bulkhead connectors for the options you wish to bring out, such as:

Combined with matching cable covers.

USBasp / USB ←→ Serial converters & USB cable:

Generation 2 VSR Alternator Regulators will need access to an ISCP adapters (such as a USBasp device) in order to burn in the boot-loader into the CPU. A Serial to USB adapter will also be needed if you wish to monitor the regulators status and/or configure the regulator via ASCII commands. One of these devices will also be needed in order to load the firmware. Please see the Blog for more details:

http://arduinoalternatorregulator.blogspot.com/2010/06/assembly-and-programming.html

as well as `*Communicating with the VSR Alternator* Regulator' on page 47

Neither of these devices is needed for the 3rd generation VSR Alternator Regulator, as it comes pre-assembled with both the bootloader and the current firmware flashed in. (Unless you purchased a blank PCB). For the Generation 3 VSR Alternator Regulator a simple Micro USB cable is needed to allow communication and configuration as well as firmware updates.

Note that when attaching a USB cable, or Serial cable to the service port, the logic portion of the regulator will be powered via the attached cable. This allows for pre-configuration 'on the bench' before physical installing the regulator. Do keep this feature in mind if you wish to do long-term connection to the USB/service port for ongoing status monitoring – as the regulator will continue to 'operate' even if the ENABLE wire is not powered on. You may disable this feature on Gen 2 of the regulator by not connecting pin #6 of the Service connector; and on Gen 3 regulators by either by modifying the USB cable cutting the +5 wire, or by removing D12 from the PCB. If you do use long-term connections, be aware of a potential for substantial ground-currents, especial with large alternators. Upwards of 2-300mV ground voltage delta is not uncommon…

REGULATOR INSTALLATION

The VSR Alternator Regulator is a very versatile device with several installation options depending on your goals and objectives. In it s simplest form, the Enable, Alt+, Alt- and Field wires are all that are needed to connect, and in this mode the regulator will behave as many voltage-only regulators, abet with a high level of precision. Adding additional sensing capabilities will unlock additional capabilities of the VSR Alternator Regulator, up to and including a fully integrated Systems deployment.

The following will give an overview of how to connect and configure the regulator in different situations. The first section will illustrate typical installations, from simple to more involved; while the second section showcases some alternative installations for unique deployments, such as DC generators or high-reliability integrated systems.

REGULATOR PLACEMENT

Place the near the alternator – keeping the Alt+, Alt- and Field wires as short as reasonably practical. Take into consideration ambient temperature as well as any potential for water splashing and consider augmenting the case as needed. The regulator is very efficient and does not need much cooling beyond what is typically found in engine room compartments, but that is not to say one should test its limits!

BATTERY-CENTRIC VS. ALTERNATOR-CENTRIC INSTALLATIONS

Throughout the examples it is helpful to keep in mind there are two distinct ways the VSR Alternator Regulator may be configured and installed in a system, depending on where the Amp Shunt is placed. If the shunt is placed at the battery the installation is known as a 'Battery Centric' installation, allowing for accurately monitor the SOC (State of Charge) of the battery and use that to determine when it should change charging phases. (e.g., from Acceptance to Float). This is the default deployment model for the regulator.

Alternatively, the amp shunt can be placed at the Alternator in what is referred to as an 'Alternator Centric' configuration. This is useful to either further protect a smaller alternator, or perhaps to allow a very large alternator to be placed on a small engine (for example in a DC Generator). Alternator Centric configurations are also used when integrating into an OSEnergy compliant 'system' where another device is able to monitor battery current (ala, a Battery Monitor or full BMS) and provide that information remotely.

CAUTIONARY NOTE: OVERSTRESSING SMALL-FRAME ALTERNATORS

The most common alternator found will be a small frame unit, especially if it is the OEM alternator on a motor. These alternators are good reliable units, but may not be up to the demands of delivering large amounts of current over a long period of time. Overstressing alternators can result in damage from burnt out diodes and/or internal heat stress related damage and failures. Such stress conditions are exacerbated by high acceptance battery banks (ala, Lithium, AGM/GEL, or even large capacity standard wet-cell FLA batteries).

The best way to protect a small-frame alternator is to install an alternator temperature sensor, ideally located near or on the Diode pack. This will allow the VSR Alternator Regulator to monitor the alternator and reduce output as its safe temperature limit is approached. . (side note: it is not unknown to see an '80A' alternator restrained to as low as 30A in order to prevent alternator overheating…). In addition it is recommended to select 'Small-Alt Mode' via DIP switch to provide an overall capping of alternator loading. After some run time experience has been had, you can consider turning off Small-Alt mode and see if the alternator is able to handle your specific installation.

Special Considerations for 32v/36v, and 42v systems

The VSR Alternator Regulator self-adjusts for battery voltage, applying an appropriate multiplier to the CPE entries. For example, if deployed with a 24v battery all the CPE voltage values will be doubled, ala VBat Target would go from 14.4v to 28.8v. (The multiplier factor being used is reported out in the $SST ASCII status string.)

In Auto-select mode (default) the battery voltage is sampled at each startup and used decide what the most likely system battery voltage is. Battery voltages of 12v, 24v, and 48v may be auto selected in this way. If you have a different system voltage (e.g., 32v) you will need to manually configure the regulator via the $SCO command setting the battery voltage multiplier to 2.667 – likewise a 42v system can be configured for using a multiplier of 3.5

'Auto-select' may be bypassed, forcing the voltage multiplier even for common 12/24/48v systems via the $SCO: command – this could be considered a high-reliability configuration step to preclude any chance of false auto-detects.

Note: Beginning with release 1.0.3 of firmware, the 'Favor 32v' option has been removed as well as auto-select for 32v systems. Use the $SCO command to set the voltage multiplier as noted above.

Other Considerations:

Diode based battery isolators: These are often installed when one alternator is asked to charge two or more batteries. The Isolator prevents any loads on one battery from discharging the other battery when the engine is turned off. These present a problem for the VSR Alternator Regulator, as it is attempting to decide when the battery is full – which battery does it look at? If you have a battery Diode battery isolator it is might be better to replace it with an automatic battery switch/combiner (following). However, if you do install the regulator in a system with a Diode battery isolator it is suggested you pick the battery you with to focus on – place the Battery Amp Shunt on that battery, and attach the battery voltage sensing wires to that same battery. The regulator will then control the Alternator to meet the needs of THAT battery. There is a risk of overcharging the 2nd battery, but that risk existed well before installing the VSR Alternator Regulator.

Automatic Battery Combiner: Another way to connect a 2nd battery to the main one is to use an Automatic Battery Switch. These will sense the voltage of both batteries, and when the time is right, connect them together. If you install in a system with one of these, connect the VSR Alternator Regulator to the primary battery, placing the Battery Shunt on that main battery and connecting the Battery + and Battery – sensing wires to that battery. The VSR Alternator Regulator will focus on that main battery and let the Automatic Battery Combiner deal with the needs of the 2nd battery. A couple of notes:

- Make sure to connect the 2nd battery on the Alternator side of the Battery Amp Shunt – it is important that the Amy Shunt ONLY measure the current needs of the battery we are focusing on.
- There is a #define FEATURE_OUT_COMBINER option in the source code that can be enabled to allow a simple external high current relay to be used for a battery combiner. See the section on Feature-out options.

Standalone Installations

The first set of examples illustrate how the VSR Alternator Regulator may be installed as an independent (not systems integrated) regulator. In this mode the regulator will make independent decisions for charging and mode transitions, and is applicable to both Generation 2 and Generation 3 regulators. With each example additional wires and sensors are connected to the regulator allowing smarter management. Examples shown include:

Example 1: Minimal (Voltage Only) Installation Though simple to install, it is not suggested to use this configuration as many of the capabilities of the VSR Alternator Regulator will be disabled. If you do select this installation option take great care with the configuration options (Alternator output capping / limitations, CPE selection of voltages and transition times among a few) to best match your typical operations and assure limited risks due to battery incomplete charging and/or alternator over-stress situations.

Even with these risks it is helpful to understand this simplest installation as if any of the regulators sensors fail it will `fall-back' to simpler modes of operation, thereby allowing continued operation, though perhaps in a less efferent manner.

- Example 2: Basic Stand-alone Installation   (Most common single engine installation)
- Example 3: Twin engine Installation

Integrated System Samples

Following that are examples which feature the benefits of the Generation 3 VSR Alternator Regulator CAN based communications to help coordinate charging sources as well as potential provide a higher level of reliability / failure mode recovery.

- Example 4: Basic System Installation   (Utilizing remote battery sensor)
- Example 5: System Installation w/Alternator Current Measurement
- Example 6: Dual (or more) Engine System installation
- Example 7: High Reliability System Installation

Special Examples

The final group of examples shows some special or alternative way to install the VSR Alternator Regulator. For example, using the regulator in a DC generator in an 'Alternator Centric' deployment.

- Example 8: Using regulator with a small DC generator (Advanced)

Example 1: Minimal (Voltage Only) Installation

This example shows the very minimal connections needed when installing the VSR Alternator Regulator; only 4 wires and a few jumpers. In this very basic installation the VSR Alternator Regulator will function in a like way to most Voltage-only regulators, relying on battery voltage and timers to make charge decisions; and with that also brings the same limitations and risks of a voltage/timer regulator.

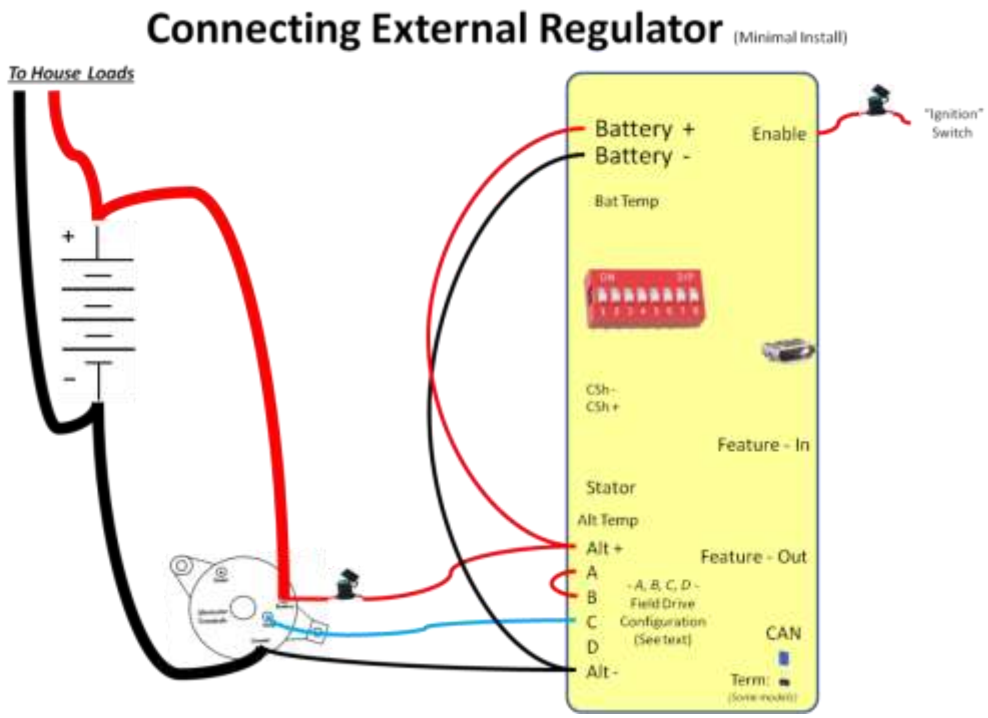


Figure 9 - Minimal Install

Though simple to install, it is not suggested to use this configuration as many of the capabilities of the VSR Alternator Regulator will be disabled. If you do select this installation option take great care with the configuration options (Alternator output capping / limitations, CPE selection of voltages and transition times among a few) to best match your typical operations and assure limited risks due to battery incomplete charging and/or alternator over-stress situations.

Even with these risks it is helpful to understand this simplest installation as if any of the regulators sensors fail it will `fall-back' to simpler modes of operation, thereby allowing continued operation, though perhaps in a less efferent manner.

Example 2: Basic Stand-alone Installation (Most common single engine installation)

This is the recommended basic installation of the VSR Alternator Regulator is in a stand-alone configuration. With this configuration the regulator monitors a current shunt located at the battery as well as battery temperature and voltage to allow for accurate and safe charging. By sensing an amp shunt at the battery the VSR Alternator Regulator is able to account for all other charging sources, as well as potential house loads, when making decisions about charge state transitions – to give a true indication of the status of the battery's needs. Alternator temperature sensing protects the alternator from overheating / overstressing.

Installing the battery voltage sensing wires (Battery+ and Battery -) DIRECTLY to the battery! Do not attach the wires after a battery switch, dual alternator diode separator, the Battery Amp Shunt, or a common 'bus bar'. Instead connect directly to the batteries for best results.

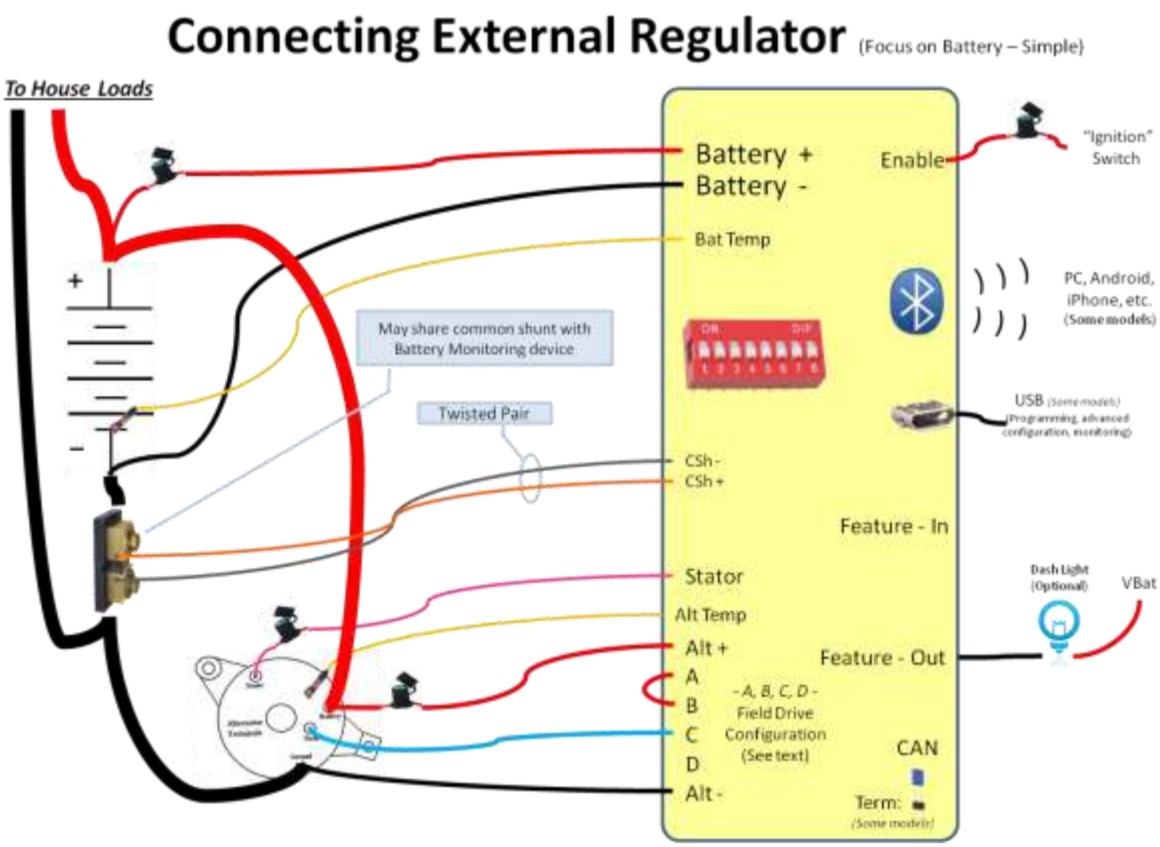


Figure 10 - Basic install, shunt LOW

The shunt may be located on either the ground side of the battery as shown above or positive side of the battery as shown on the next page. It is suggested to use twisted pairs of wires from the shunt to the regulator. If you already have a shunt installed (perhaps for an Amp meter, or an existing battery monitor system) there is no need to install a 2nd shunt, just use the one already in place – the VSR Alternator Regulator is able to share existing shunts. By default, the regulator is calibrated for a 500A/50mV shunt (commonly used on battery monitors) ; if your shunt has a different rating adjust the system configuration using the $SCV command. Any shunt may be used as long as the maximum sensing voltage does not exceed 80mV.

Connecting External Regulator (Focus on Battery – Simple)

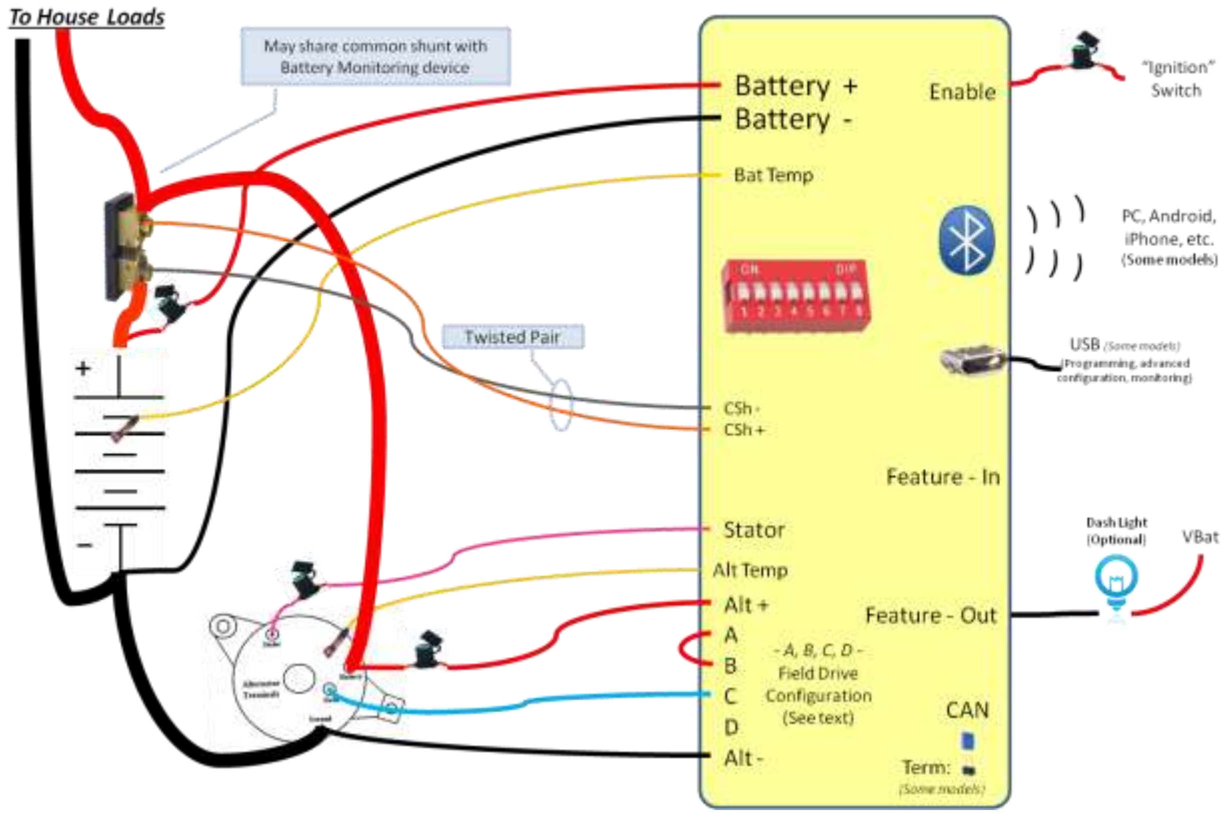


Figure 11 - Basic install, shunt HIGH

EXAMPLE 3: TWIN ENGINE INSTALLATION

It is common for many marine applications to have two engines, each with an alternator to charge the batteries. In this case, simply install a regulator on each engine as you would for a single engine installation. Configure the two regulators the same and connect the Enable wire to each respective engine. You may share the same battery current shunt between both regulators. It is best if each regulator has its own Battery + and Battery – sensing wires, and the temperature sensors *cannot* be shared, each will need its own.

Connect a common CAT-5 cable between the two regulators allowing them to communicate and coordinate their charging: balancing the loads between the two engines and working towards the same charging goals as opposed to fighting each other.

If you give each regulator a unique name (e.g., Port and Starboard) it will aid in those models featuring Bluetooth connectivity or CAN enabled regulators when communicating status. Use the $NPC: command to set each regulators name.

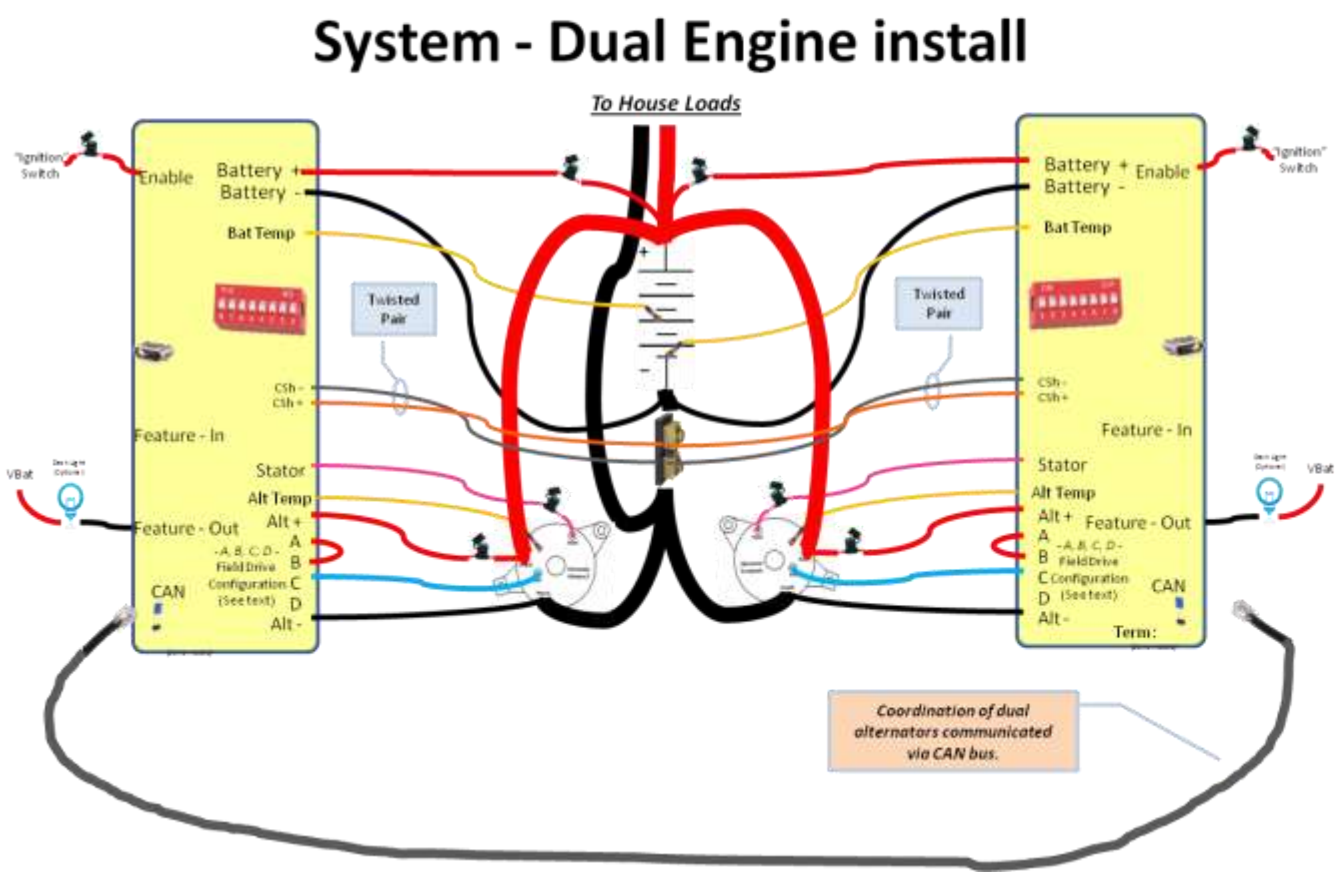


Figure 12 - Duel engine install with communications

EXAMPLE 4: BASIC SYSTEM INSTALLATION (UTILIZING REMOTE BATTERY SENSOR)

When installing the VSR Alternator Regulator in a 'system' one of the benefits is simplified wiring. Rather than routing individual sensing wires to the battery for voltage, current, and temperature, that information may be delivered over the CAN bus using a technique of remote-instrumentation.

Remote-instrumentation is a very reliable and long used method for reducing the wiring needs in many industrial and transportation applications. By having a device located at the battery sensing the voltage/current/temperature of the battery and sending that information via the CAN bus to the VSR Alternator Regulator, the wiring burden is reduced to one CAN cable as opposed to several discreet wires. If the installation has more than one charging source (say, twin engines, or an alternator and solar) this reduced wiring benefit becomes even greater.

To take advantage of remote-instrumentation you will first need an OSEnergy compliant monitoring device at the battery which senses battery voltage/current/temperature. Then when installing the VSR Alternator Regulator, you only need to connect sensing wires locally to the alternator saving long wires back to the battery.

At minimum, you need to connect the VBat + and Vbat – wires to the local alternator + and – output. Adding Alternator Temperature sensing and stator sampling allows the VSR Alternator Regulator to fully protect your alternator.

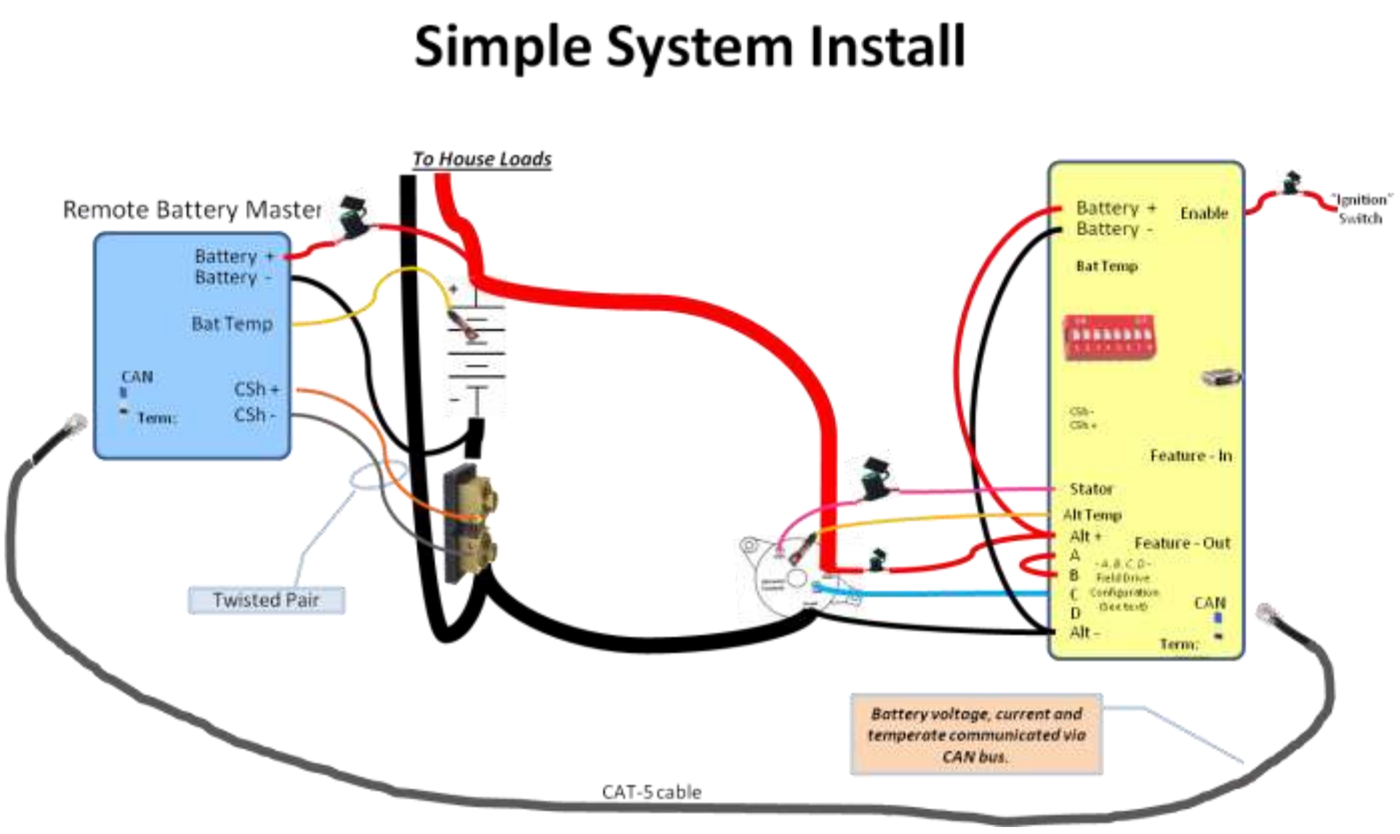


Figure 13 - Simple System Install

Example 5: System Installation w/Alternator Current Measurement

By taking advantage of remote instrumentation as shown in the example above, we can then use the remaining VSR Alternator Regulator ports to monitor the alternator its self, using the wiring as shown in Figure 14.

This will give you the most benefit from your VSR Alternator Regulator as it most closely follows a fundamental concept of OSEnergy 'Systems': Manage and control your local device – in this case we are managing the alternator. Such an installation is helpful if you wish to fully monitor the output of your alternator, perhaps for display on a NMEA2000 compatible monitor, or as a feed into Signal-K.

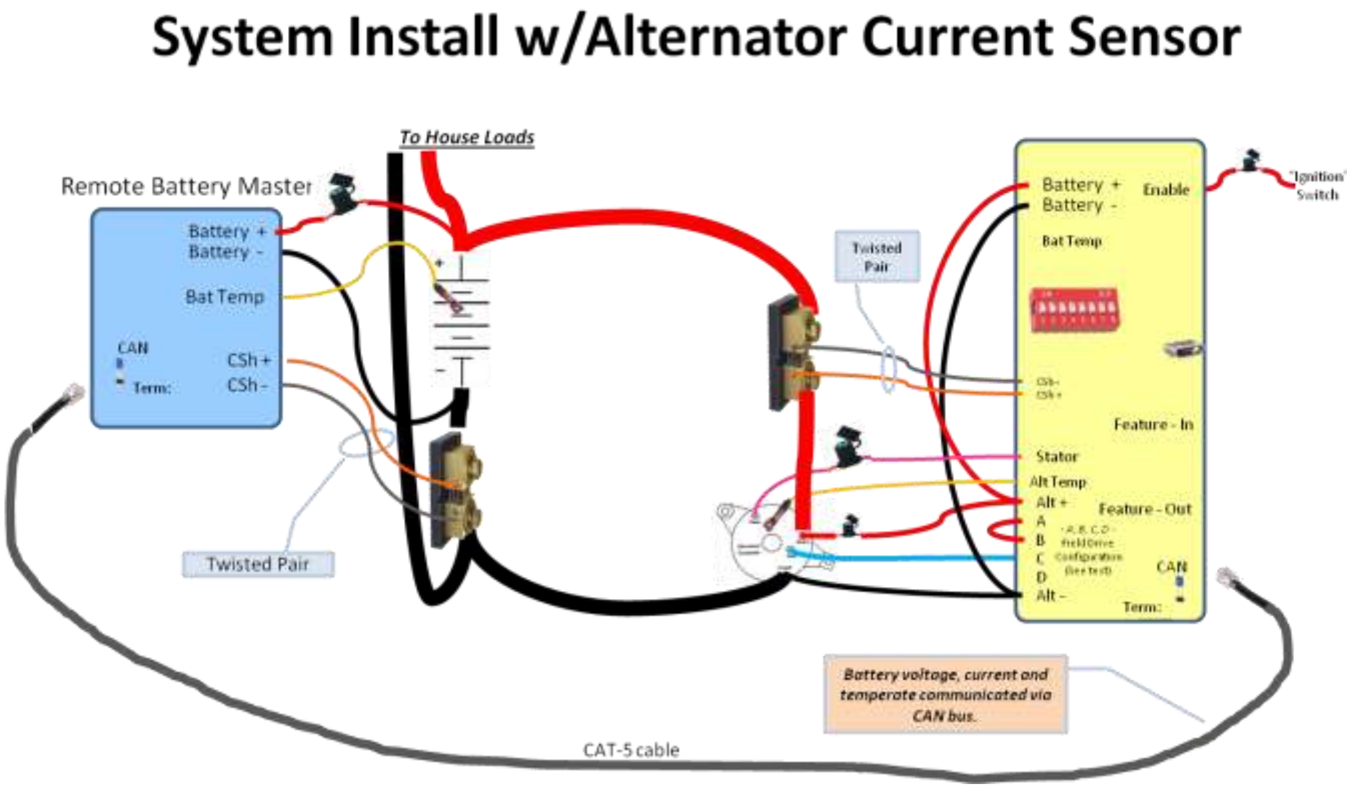


Figure 14 - System Install w/alternator current measurement

EXAMPLE 6: DUAL (OR MORE) ENGINE SYSTEM INSTALLATION

Extending the examples shown above, as more OSEnergy compliant charging sources are added to your system, you can simple configure them and extend the CAT-5 cable, connecting them daisy-chain fashion. Make sure the terminator is installed on the two end devices in the chain, and not on any of the ones in the middle.

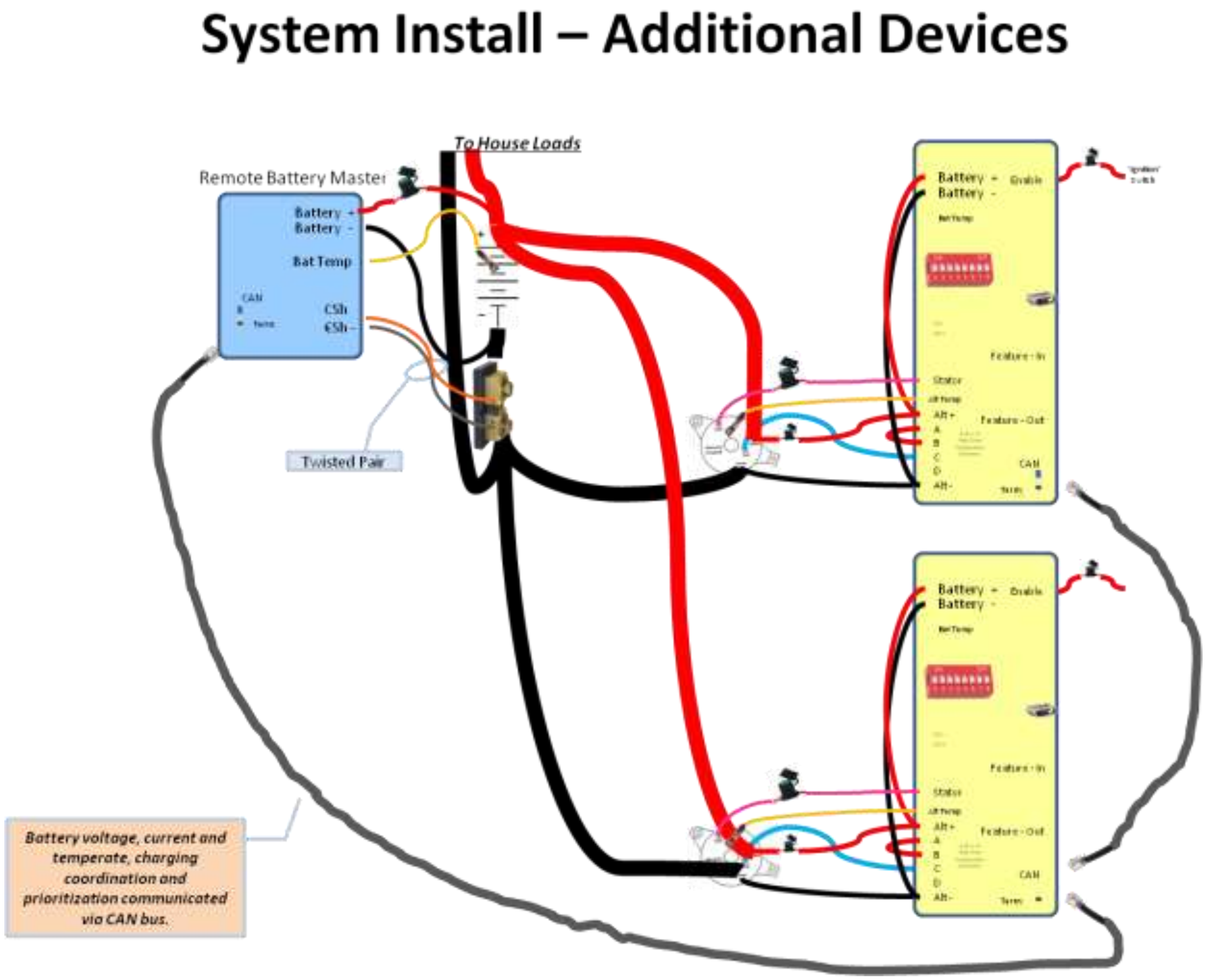


Figure 15 - Multiple charging sources in a coordinated system

The integrated system view shown in Figure 15 is extendable to other VSR Alternator Regulators as well as other devices, such as Solar MPPT controllers, DC Generators, any device which support the OSEnergy protocol. All will work cooperatively in a well coordinated and prioritized manner.

Example 7: High Reliability System Installation

In this example the VSR Alternator Regulators sensing wires are routed to the battery in addition to the remote sensing supplied over the CAT-5 CAN cable. This configuration provides an additional level of reliability in case of a failure somewhere, and even allows for the VSR Alternator Regulator to assume the role of Remote Battery Sensor if needed. It does however increase wiring complexity requiring additional wires and sensors back to the battery.

Typically this type of installation is only seen in larger DC designs, where there are multiple charging sources and a desire to provide a level of redundancy in case of a system failure.

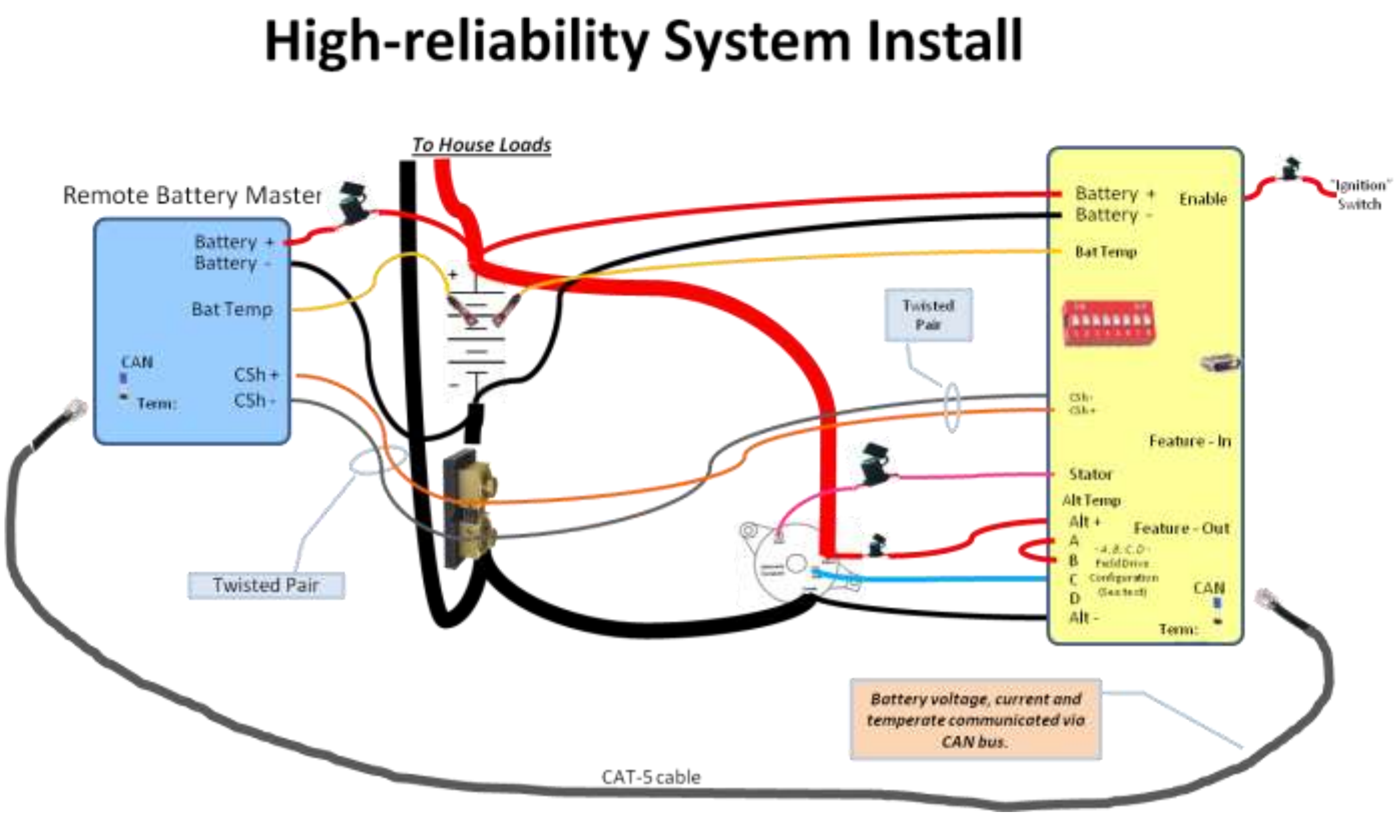


Figure 16 - High-Reliability system deployment with redundant sensing

If this configuration is selected, review carefully the CAN configuration ($CCN:) to assure both the 'Allow RMB' and the 'Shunt-at-battery' flags are set true. This will allow the VSR Alternator Regulator to offer to assume the role of Remote Battery Master in case of a system failure.

Example 8: Using regulator with a small DC generator (Advanced)

Another way to deploy the VSR Alternator Regulator is to focus more on the Engine and Alternator (though not totally ignoring the battery). An example would be a DC generator where the Alternator is so large that it can easily stall the engine; we need to rein it in some.

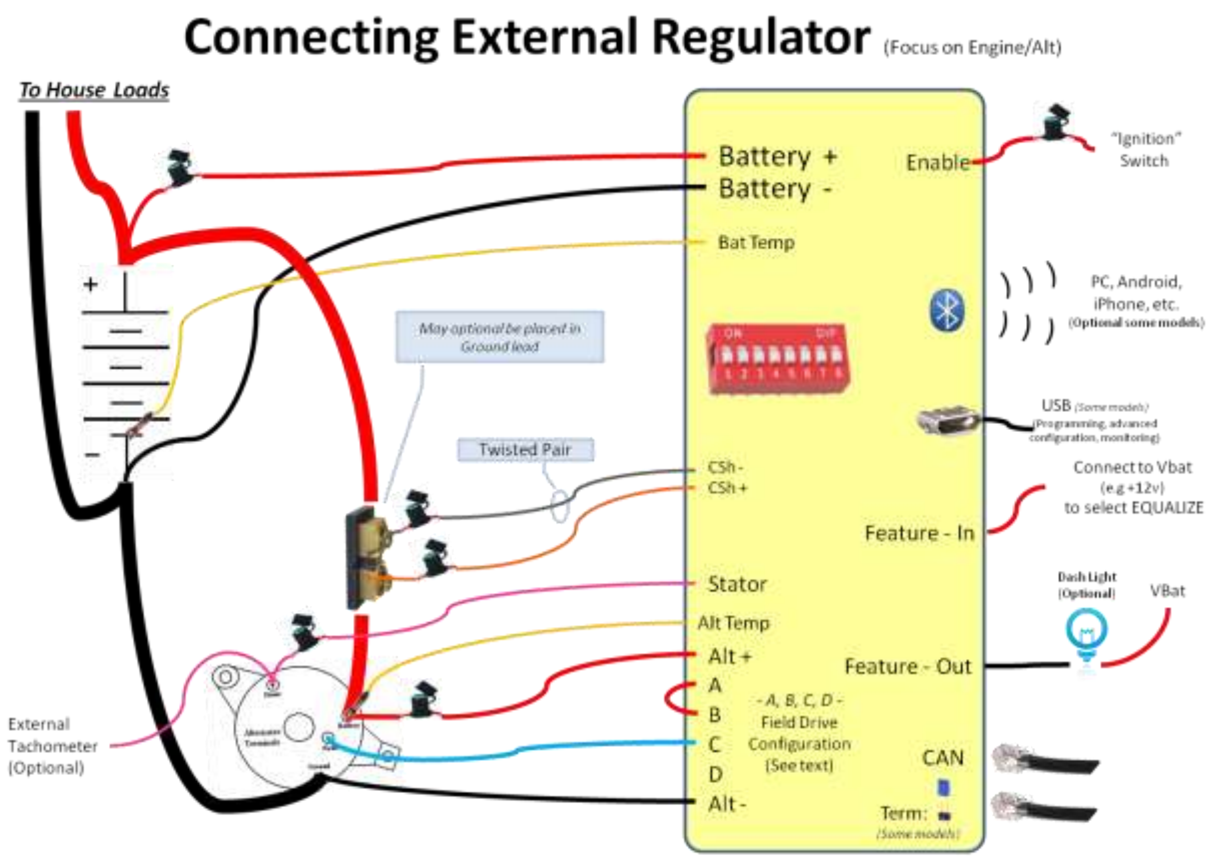


Figure 17: Wiring Diagram (Engine/Alt Priority)

By monitoring the number of amps being produced by the alternator, and configuring the regulator (via the $SCV command) to the maximum number of Watts we wish to be placed on the engine, the max engine load can be controlled. You may also want to adjust other parameters, such as exit amp criteria, and perhaps even set up Amp limits for the Alternator.

A feature of the VSR Alternator Regulator when deployed in this way is the ability to protect the Alternator a bit more. It will limit the amount of Amps produced via the $SCV command. Both an Amp limit and the Watt limit may either be defined, or you can configure the regulator to automatically determine the capabilities. Then limits can be made via the DIP Switch #7 (Use Small Alternator Mode) to configure the regulator to 'take it easy' on a smaller alternator. The specific limits can be changed by the derating values in the $SCV command.

There are a couple of new challenges with this deployment when trying to decide if it is time to exit Acceptance Phase:

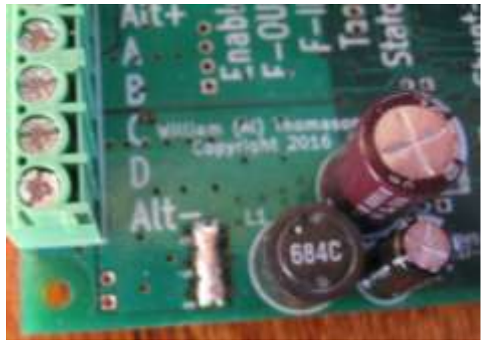
- Other charging sources supplying current to the battery,
- Account of house loads that are being served by the Alternator in addition to recharging the battery.

In simpler deployments, such as when this is the only charging source, or perhaps when any house load is limited or relatively consistent, accommodations can be made by increasing the exit Amp criteria for Acceptance Phase. Using the CAN port (Gen 3 only) allows full participation in an integrated system, regaining not only the ability to remotely monitor battery voltage, current, and temperature, but also coordinating with other charging sources.

Another option is to change how the FEATURE-OUT port functions, using it to signal to stop the engine when the DC generator is no longer needed. Uncomment the `#define FEATURE_OUT_ENGINE_STOP ' flag in the source code to enable this capability.

PCB ONBOARD VOLTAGE SENSING OPTION (ADVANCED OPTION)

An option for the VSR Alternator Regulator is to make the connection for VBat+ and VBat- internally, as opposed to needing external wires as shown in the examples above. 'Solder Bridging' PCB jumpers J1 on the back side of the PCB as well as J8, J9, and J10 on the front as shown in the photos below. Doing so will pick up VBat+ from the Current Shunt+ connection (J1), and VBat- from the Alt- connection (J8..J10).



--- CAUTION: With this option you <u>MUST</u> connect the Shunt+ wire and the shunt MUST be located in the Positive power lead. ---

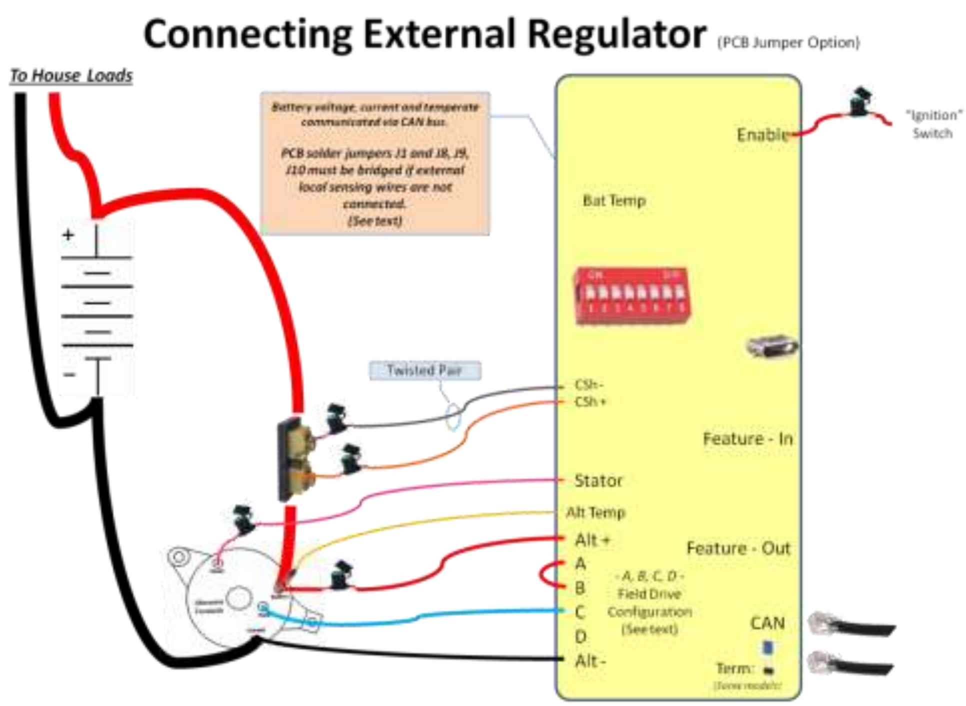


Figure 18 - PCB jumper options, onboard voltage sensing.

Configuring the VSR Alternator Regulator

The simplest way to configure your VSR Alternator Regulator is via the DIP switches. With these you can select one of the default Charge Profile Entries, as well as tell the regulator the size of the battery you have (needed to more accurately decide when the battery is full).

Using the DIP Switches

Many of the basic features of the VSR Alternator Regulator can be configured using the DIP switches. Advanced changes may be made using the ASCII serial commands (See: **Error! Reference source not found.**). The following table defines how the DIP switches are used:

Position	Meaning (Regulator Version 2 and earlier)
1	On – Supply power to Bluetooth adapter Off – Disable Bluetooth
2..4 <4> <3> <2> Off, Off, Off Off, Off, On Off, On, Off Off, On, On On, Off, Off On, Off, On On, On, Off On, On, On	Select Charge profile 1..8 1 = Default (Safe) & AGM #1 2 = Flooded Lead Acid #1 (Starter type , etc) 3 = Flooded Lead Acid #2 (HD - Storage type) 4 = AGM #2 (Higher charge voltages) 5 = GEL 6 = Reserved for Future Use 7 = Custom #1 (Changeable – Preconfigured HD Storage with Overcharge) 8 = Custom #2 (Changeable – Preconfigured: LiFeP04) *(See* Table 6 *for more details)*
5,6 <6><5> Off, Off Off, On On, Off On, On	Define Battery Capacity as: ** 1x, – 250Ah 2x, 250Ah – 500Ah 3x, 500Ah – 750Ah 4x. 750Ah and above
7	On – Use Small Alternator Mode Off – Use Large Alternator Mode Small Alternator Mode will restrict the maximum alternator output to 75% of its amperage capability. Large Alt mode limits output to 100%. See $SCA: command to change these values.
8	On – Tach Mode enabled Off – Disable Tach mode Some Diesel engines use the alternator to drive the tachometer. With these if the Alternator stops charging (say during Float mode), the tachometer can become sporadic or even stop working. Enabling Tach mode will cause the regulator to ALWAYS provide some small level of field drive, sufficient to provide a signal to the tachometer, but low enough to minimize Battery overcharge.

Table 4: DIP switch (2nd Generation Regulator)

*** Note: Begin with Firmware 1.2.0, Ah steps are in 250Ah increments. Prior versions were 500Ah steps.*

Position	Meaning (Regulator Version 3)
1..2 <1> <2> Off, Off On, Off Off, On On, On	Battery ID The ‘Battery ID’ this regulator is attached to. Used in CAN connected systems. Suggested settings: 1 = House Battery 2 = Main starter battery 3 = Secondary house battery 4 = Other
3..5 <3> <4> <5> Off, Off, Off On, Off, Off Off, On, Off On, On, Off Off, Off, On On, Off, On Off, On, On On, On, On	Select Charge profile 1..8 1 = Default (Safe) & AGM #1 2 = Flooded Lead Acid #1 (Starter type , etc) 3 = Flooded Lead Acid #2 (HD - Storage type) 4 = AGM #2 (Higher charge voltages) 5 = GEL 6 = Carbon Foam (Firefly) 7 = Custom #1 (Changeable – Preconfigured HD Storage with Overcharge) 8 = Custom #2 (Changeable – Preconfigured: LiFeP04) *(See* Table 6 *for more details)*
6,7 <6> <7> Off, Off On, Off Off, On On, On	Define Battery Capacity as: ** 1x, – 250Ah 2x, 250Ah – 500Ah 3x, 500Ah – 750Ah 4x. 750Ah and above
8	On – Use Small Alternator Mode Off – Use Large Alternator Mode Small Alternator Mode will restrict the maximum alternator output to 75% of its amperage capability. Large Alt mode limits output to 100%. See $SCA: command to change these values.

Table 5: DIP switch (3rd Generation Regulator)

Take special care in with the 3B regulators, not that the Switched are ‘ON’ when they are pressed DOWN!

*** Note: Begin with Firmware 1.2.0, Ah steps are in 250Ah increments. Prior versions were 500Ah steps.*

USING ASCII COMMANDS

In addition to the DIP switches, many parameters of the VSR Alternator Regulator can be customized by sending in a series of ASCII commands either via a Bluetooth connection (Version 2 board), or by using an attached USB ← → TTL adapter board attached to the Service Port (Generation 2 board), or via a USB cable (Generation 3 and later board).

Changes sent to the VSR Alternator Regulator are saved in FLASH memory on the CPU for use next time the regulator starts up. (See Sequence of Operation section below for more details). Because of this you will need to restart the regulator after you have finished sending it ASCII change commands. There are some exceptions, such as the $FRM Force Regulator Mode command, $EBA – External Battery Amps, and a few more. See details of each command below.

You can restart the VSR Alternator Regulator either by cycling the power, or sending a $RBT command to the regulator.

Special note for 2nd generation Alternator Regulators and command lockout.

With the ability to support an RF Bluetooth module there is a security risk that someone could remotely alter the configuration of your Alternator Regulator. In order to increase the level of security, ASCII commands are disabled by default until you change the regulators name and password/PIN at least once via the $SCN: command.

This is to protect you from someone inadvertently, or maliciously, altering the configuration of your regulator. See additional details in section 'Regulator Name & Password: need to Initialize' on page# 49

ALTERING SOURCE CODE

As a final configuration method, the source code may be directly modified, recompiled and then flashed into the VSR Alternator Regulator. This gives the ultimate flexibility, as well as the ultimate responsibility.

You will need to download the following:

- Arduino IDE: http://Arduino.cc
- 'Board Type' extensions to the Arduino IDE:
  - 2nd Generation: https://drive.google.com/drive/folders/0B5GiaoeXCQ3veFNFNWVSOHRUdkU
    - Select board-type: *"Smart Regulator (fixed Optiboot - 3.3V, 8 MHz) w/ ATmega328p"*
  - 3rd Generation: https://github.com/thomasonw/ATmegaxxM1-C1
    - Select board-type: *"ATmega64M1 (16Mhz - Xtal - Arduino)"*
- The source code & supporting libraries: https://github.com/AlternatorRegulator/alt-Source
  - It is suggested to use these version of supporting libraries, as other versions (including newer) may introduce errors and/or increase code size exceeding limits

If you purchased a blank PCB for your regulators, you will also need to install the boot-loader. For more details, refer to the blog: http://arduinoalternatorregulator.blogspot.com/2010/06/assembly-and-programming.html

Install the appropriate board type extensions following the directions in each link. Place the source code in your Arduino sketch working directory, and the libs in your Arduino working libraries directory, select the Board Type and do a trial compile of the source. Once you are able to compile without errors, connect your computer to the VSR Alternator Regulator using the directions in: 'Communicating with the VSR Alternator Regulator' on page# 47. Note that you *must* use the Service Port on 2nd generation regulators, Bluetooth cannot be used to update firmware. More so, you need to turn off the Bluetooth module via Dip #1 when attempting to update firmware.

There are several optional compile features in the VSR Alternator Regulators source code. These can enable special Debug detail outputs, battery combiner code, using Feature-out as an engine-stop signal when the battery is fully charged. Most of these capabilities are selected via #define statements in the `Config.h` file.

Built in Charge Profiles

Profile #	Battery Type	Bulk / Absorption Target Voltage	Exit Absorption when either:		Overcharge (Finish Charge)			Float		Equalize		Temperature Compensation (mV / 1c from 25c)
			Amps drop to	or Time exceeds	Target Amps	Exit Voltage	Max Time	Regulated Voltage	Regulated Amps	Target Voltage	Max Time	
#1	**Safe / AGM-1**	14.1v	15A	6 Hrs				13.4v				24mV
#2	**FLA 1** (Start)	14.8v	5A	3 Hrs				13.5v				30mV
#3	**FLA 2** (GC, L16+)	14.6v	5A	4.5 Hrs				13.2v		15.3v	3 Hrs	30mV
#4	**AGM-2**	14.7v	3A	4.5 Hrs				13.4v				24mv
#5	**Gel**	14.1v	5A	6 Hrs				13.5v				30mV
#5	**Firefly**	14.4v	6.5A	6 Hrs				13.4v		14.4v	3 Hrs	24mV
#7**	**FLA 3** (GC, L16+)	14.4v	15A	6.0 Hrs	15A	15.3v	3 Hrs	13.1v		15.3v	3 Hrs	30mV
#8**	**LiFePO4**	13.8v	15A	1.0 Hrs				13.36v	0A			n/a

Table 6: Default Charge Profiles

All values are normalized for 12v / 500Ah battery and assume the Amp shunt is installed at the battery. If the shunt is mounted at the alternator, adjust the Exit_amp values to account for house loads. (A suggestion is to add 5A to the values shown in the above table.) All Amperage exit values will automatically scale up by the Battery Capacity Dip switch and likely match larger batteries with larger 'house loads'.

Blank sections indicate that feature is disabled.

** Profile #7 and 8 may be modified via the Change Profile ASCII commands: *$CP_:n*

See Appendix A: Details of CPE (Charge Profile Entries) for more details.

CHARGING LIFEPO4 BATTERIES

As I write this section during the Summer of 2015, LiFeP04 batteries (and variations) are starting to see deployment in house-battery applications. There is a lot to be said for them: lighter, smaller, greater acceptance current capability (for shorter recharging times), and much wider usable discharge range then lead-acid based technology – combined with lower lifetime costs bring this new technology into a very viable candidate.

However, it is also true that most deployments of LiFeP04 technologies have been in Electric Vehicles – not house storage battery applications. And as such, what is 'known' these days are shaped largely by experience in a vastly different usage model.

- Vehicle usage = High Discharge rates, followed by long recharge cycle with little to no parasite loading.
- House usage = Moderate to low discharge rates, over a longer period of time. Recharging often occur concurrently while moderate to low 'house loads' are still present.

Vehicle usage focuses on a simple charge profile: Recharge until Vpc reaches a known threshold and then turn off all charging sources. However, such an approach is suboptimal for house usage. Specifically, it precludes the ability for a charging source to carry house loads after the battery had been fully recharged. Not allowing for this mode (Float if you will) can result in arriving at your destination or entering the night, with a less than a fully charged battery.

There is still a lot to learn (and with that, unlearn) as experiences with LiFeP04 technologies advances.

And this presents us with some options when deploying the VSR Alternator Regulator in conjunction with LiFeP04 batteries. Options imagined today may change as more is learned; fortunately, the great flexibility of this regulator allows for those changes to be easily deployed. The following are some concepts to consider when integrating the VSR Alternator Regulator into a LiFeP04 (or like chemistry) based system.

One of the first decisions is where the control point will be. Most LiFeP04 batteries are deployed in conjunction with a BMS, and many of these BMS devices have a signal that is indented to enable or disable charging sources. Other capabilities often include safety warnings and/or disconnects to prevent over chagrining, or over discharging; health of the battery, and even active cell balancing. There are perhaps two ways to enable communications between an external BMS and the VSR Alternator Regulator – both use the Feature-in port and CPE #8 where Feature-in is used to force the regulator into Float mode when active, and force it back into charging mode (Bulk) upon going inactive.

Consideration 1: BMS is the control point

- BMS makes all decisions as to whether the alternator should be charging or not.
- Regulator CPE #8 is adjusted to set its voltage points slightly outside the envelope the BMS uses to make charge / halt-charging decisions – but at levels less than the BMS disconnect voltage levels. Example, if a BMS has the following two voltage set points:
  - Charging Completed: 13.8v
  - Fault charging disconnect voltage 14.4v

  One might set the CPE's Bulk/Acceptance voltage level to 13.9v. In this way during normal operation the BMS can signal the alternator to go into Float mode at 13.8v, but if something happens to prevent that the regulator will itself transition at 13.9v before the BMS faults and disconnects charging sources.

- Likewise, voltage levels for Float_to_bulk can be set slightly lower than the BMS 'resume charging' level, but again slightly above any BMS disconnect for excessive discharge.

Consideration 2: VSR Alternator Regulator is control point:

- Much like the above, however in the case the basic roles are swapped, the regulator decides when to begin charging while the BMS is used as a backup.

Consideration 3: What to do about Float

- Much of the knowledge in existence today has been derived from EV (Electric Vehicle) usage profiles.
    - In EV usage a discharge cycle is followed by a complete recharge cycle – and once fully charged the battery's charging sources are turned off.
    - Until the EV is used again, very little current is drawn from the batteries – so this approach works well.
- However, in house battery usage there is often a noticeable 'static' load to power instruments, refrigeration, and communications gear. Perhaps pumps, computers, or any number of items.
- In this usage model, it would be desirable to allow any charging source to support those house loads while that charging source is available – preserving the charge in a full battery.
- This brings up the question of what to do about Float. Some ideas:
    1. Disable Float by setting the float target voltage very low, perhaps just above the BMS excessive discharge voltage trip point – again as a backup.
    2. Set float to a natural voltage level for idle cells, example 13.4v for a 4-cell ('12v') battery
    3. Utilize the Amps regulation capability (this required the Amp Shunt to be installed on the battery) and set the Float CPE to 'regulate' battery current to 0A – neither allowing discharging of the battery, nor allowing additional energy to enter it.
    4. Perhaps a combination of ii & iii
- The default CPE #8 uses approach ii & iii, setting VBat to 13.36v max and regulating current to 0A.

As more is learned about these deployments some of the above may be refined, and/or augmented. You can always check the Blog to for additional insight and/or join the mailing list.

http://arduinoalternatorregulator.blogspot.com/

https://groups.google.com/forum/#!forum/smart-alt

FEATURE-IN

Feature-in is enabled by connecting the Feature In pin to a voltage greater than 6v. Voltages as high as 72v are allowed. Feature-in serves several purposes. The function of feature-in can be altered using various #define compile options in the source, by default feature-in will behave as follows:

If CPE #1..7 is selected, Feature-in will:

- Master reset: To reset the controller to as-compiled (default) conditions set the DIP switches to select CPE select CPE#5, and all other switches turned ON. Connect FEATURE-IN pin to VBat before the power is applied. The regulator will fully reset to factory-configuration upon application of power – even overriding the LOCKOUT flag.

- With the Alternator Running, holding this line to VBat will enable EQUALIZE mode providing the CPE selected enabled Equalize mode. Once EQUALIZE mode is entered, the regulator will remain in the mode until one of three conditions are met:
    1. FEATURE-IN line is no longer connected to VBat
    2. Defined exit Amps have been met.
    3. Defined timeout has been met.

A comment on entering EQUALIZE mode: Equalize is considered a high-monitoring mode and there is a potential for damage to the batteries. As such, the Feature-in port must be in an inactive state (low) and then transition to HIGH in order for Equalize to be recognized. This is to prevent the possibility of someone acidently leaving the EQUALIZE switch turned on. Once equalize mode has been entered, the Feature-in port must remain connected to VBat and the LAMP light will blink-out the equalize status pattern.

If CPE #8 is selected Feature-in will behave slightly differently:

- If CPE #8 is selected (default LiFePO4), holding this line to VBat will prevent the regulator from entering one of the 'charging' modes (Bulk, Acceptance, Over-Charge). Instead only Float will be allowed. This capability is useful in conjunction with an external Battery management System (BMS), common on LiFePo4 batteries, that feature a High Voltage Cutout, or Charge Enable signal.

  It should be noted that as long as Feature-in is held active, the VSR Alternator Regulator will remain in Float mode – ignoring any of the normal exit criteria (e.g., timed exit, or accumulated Ah exit). And that when transitioning from Active to Inactive, the regulator may immediately enter Ramp/Bulk mode. See the section 'Charging LiFePO4 batteries' above for more details on using this option.

FEATURE-OUT

The Feature Out port is an open-collector driver and can be connected to a dash 'Alt' light - operating akin to a traditional ALT indicator light.

Options for Feature-out: In the source code there are several optional uses of the Feature-out connector. These are enabled via selecting different #define statements, recompiling the source, and reflashing the firmware. See the source code for details, but currently the following options are included in the source:

- #define FEATURE_OUT_LAMP - Enable LAMP / Fault driver – DEFAULT OPTION
- #define FEATURE_OUT_ENGINE_STOP - Active when we enter FLOAT mode.
- #define FEATURE_OUT_COMBINER - Allows sharing of charging source(s) between two batteries.

Feature Out is active Low and is limited to 0.5A on the Feature Out connector. This is not only due to the thermal limits of Q3, but also that the return line (battery -) is shared by the Feature-out and the VBat voltage sensing. Placing too much return current via the Feature out connector can impact the accuracy of measured battery voltages.

Feature Out Lamp (default option)

In this mode, the Feature Out port is useful for connecting to a dash mounted Alt lamp. The port will be disabled (lamp out), unless in one of the following conditions:

- Indication of no-charging status – lamp will be full on during this time. (e.g., during engine warm-up period)
- Fault status – lamp will blink-out the fault code (See status LED section)
- Controller resetting – Lamp will blink-out resetting LED pattern (See status LED section)
- Regulator is in EQUALIZE mode – Lamp will blink-out EQUALIZE LED pattern (See status LED section)

Feature Out Engine Stop

With this option selected, Feature Out will become active once the alternator enters Float or Post-Float mode. This can be used to signal an external generator that the battery is fully charged, and it is OK to stop.

Feature Out Battery Combiner Option

(The following description is for Source code v0.1.3 and beyond)

Many situations have more than one battery bank, but only one Alternator. Or they might have two batteries, each with their own alternator. An example might be a boat that has a large battery bank for the House battery, and a smaller battery used for the Starter, or a Bow Thruster. Using the Feature Out to drive a high-power relay is an inexpensive way to get a 'smart' battery combiner.

There are perhaps two common reasons for using a battery combiner:

1. Allow a 2nd charging source to 'help' recharge the large house battery during its Bulk phase
2. Recharging a 2nd battery which has no charging source of its own.

Because the VSR Alternator Regulator is designed to focus on the attached battery, and not the 'combined in', some assumptions and care must be made. We want to make sure we do not overload a 2nd alternator, or overcharge a 2nd battery. Some additional considerations which must be taken into account:

- Do not exceed the current limit of the Feature Out port (0.5a) with the coil draw of the external large relay.
- Use a length of medium size wire (e.g., 10' of 10g wire) to create a level of resistance between the two batteries. A minimum resistance of 5-10mΩ (milli-ohm) appears to be common.
- Monitor smaller alternators not managed by the VSR Alternator Regulator - watching for signs of overheating.

Situation #1: Using 2nd battery/alternator to 'help' the house battery during Bulk.

In this example, there are two fully independent battery and associated charging systems, perhaps the factory alternator and starter battery, and a house battery with its own alternator using the VSR Alternator Regulator. The starter battery will likely be quickly recharged after the engine starts, leaving a significant amount of unused capacity in the starter battery's alternator.

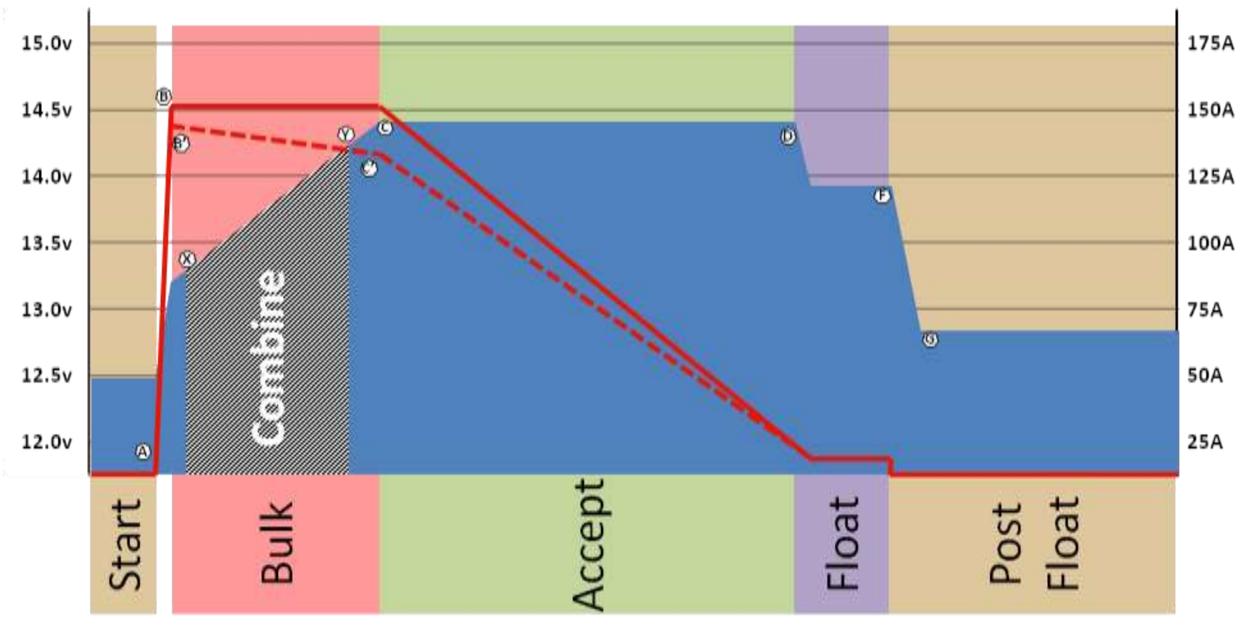


Figure 19: Receiving Help combiner profile (default)

In this mode, Figure 19 above illustrates when we want to combine the two systems (between points 'X' and 'Y'). Specifically during Bulk, we want to:

- Wait until the house battery reaches 13.2v before enabling the combiner. If we combined sooner there is a risk of pulling energy from the 2nd battery, as opposed to only asking the 2nd alternator to share its capacity. 13.2v will also reduce the voltage difference between the two batteries thereby minimizing initial surge current.
- Break the connection of the two batteries after 14.2v. With the assumption the 2nd battery has its own charging source that will handle all the recharging needs of that battery, we do not want to 'override' those decisions. 14.2v was selected under the assumption that many 'starter' batteries are connected to a default internally regulator fixed voltage alternator; those are often in the 13.8 to 14.2v range.

Situation #2: Recharging a 2nd battery which has no charging source of its own.

In this example, there are still two independent batteries, but only one charging source. A representative example would be a house battery / alternator being controlled by the VSR Alternator Regulator, and a 2nd battery used for engine starting or to power a bow-thruster. Unlike the case above where we are looking to gain assistance from the other battery/alternator, in this case the one alternator is being asked to be the charging source for the 2nd battery.

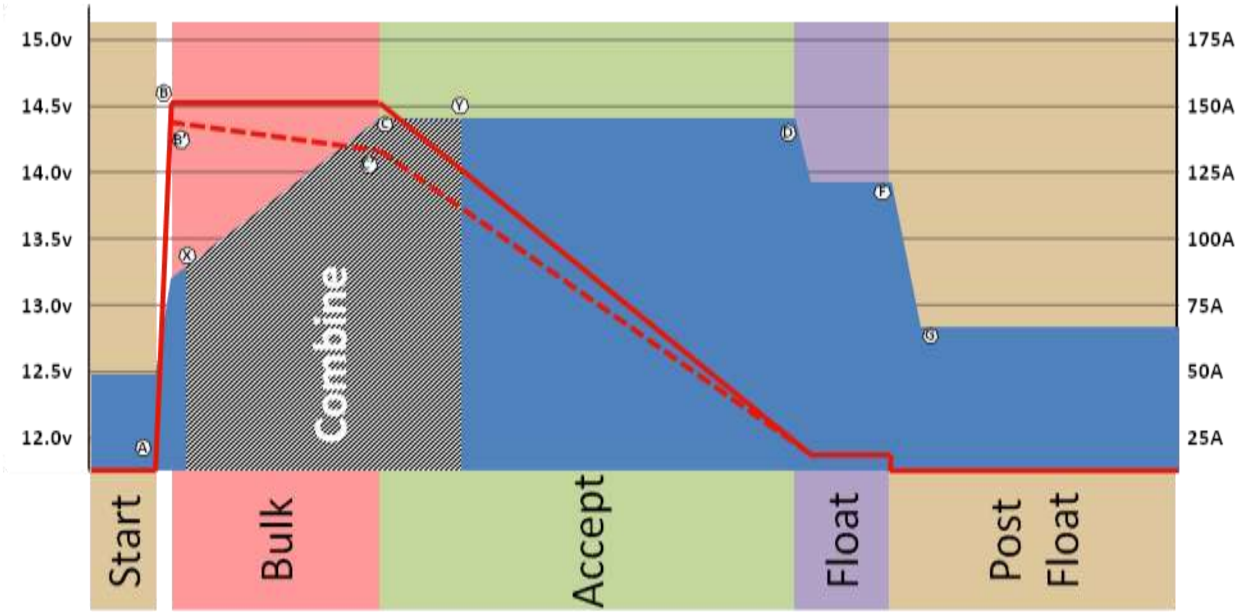


Figure 20: Charging 2nd battery combiner profile

Figure 20 illustrates the conditions when we want the combiner enabled. The idea is the 2nd battery parallels the charge profile of the main battery, and because we are not actively managing the 2nd battery we cut off the Acceptance phase after a relatively short time (Points 'C' to 'Y' above) to reduce the risk of overcharging the 2nd battery, in effect boiling it off.

Care must be taken in each of these situations to protect the 2nd battery and charging system; remember the VSR Alternator Regulator will focus on its battery and adjust things to its needs with NO regard to the other batteries needs - outside of the limited combiner configuration options.

Combiner Configuration Options

All options for configuring the Feature-out port as a combiner are made in the source code, there are no ASCII commands to modify these. The following variables in the source code:

```
#define     COMBINE_CUTIN_VOLTS          13.2
#define     COMBINE_HOLD_VOLTS           13.0
#define     COMBINE_DROPOUT_VOLTS        14.2
#define     COMBINE_ACCEPT_CARRYOVER     0.75*3600000UL  // ¾ an hour, 45 minutes.
```

COMBINE_CUTIN_VOLTS when the combiner is enabled (point 'X' below), along with COMBINE_HOLD_VOLTS. Once voltage raises to the CUTIN level (13.2 by default) the combiner will be enabled (via Feature-out), and will stay so even if the battery voltage temporarily dips – as long as it remains above the HOLD level (13.0v by default). However, if it drops too much and goes below the HOLD level, the combiner will be disabled.

As battery voltage rises, the combiner will be disabled by either rising above the DROPOUT level – point ‘Y’ shown in Figure 19 (14.2v by default), or after being in the accept phase for CARRYOVER duration – point ‘Y’ shown in Figure 20. Either point (along with low voltage) will cause the combiner to open.

Note that as with all Charge Profile Entries, voltages shown above are ‘normalized’ to a 12v battery and will automatically scale by the system voltage multiplier. (e.g., in a 48v system, the multiplier is 4, so the combine voltage becomes 4 * 13.2v, or 52.8v).

,

Communicating with the VSR Alternator Regulator

The VSR Alternator Regulator supports external communication of status and more advanced configuration changes than the DIP switched allow for. Communications is primarily via Serial ASCII strings, the formats of which are documented in the *"VSR Systems – Communications and Programming Guide"* The 3rd generation regulator adds support for Control Area Network (CAN) communications and support the OSEnergy protocol as well as limited NMEA2000TM compatible status messages.

Communications with the VSR Alternator Regulator is made using a USB attaché serial port. Gen 2 regulator needs either an external USB to Serial convert and/or the optional Bluetooth module installed while Gen 3 regulators and above have a built in USB connector. In addition, communications may also be made via the CAN connection on Generation 3 regulators.

Refer to the *"VSR Systems - Communications and Programming Guide"* for details on how to establish and utilize communications to the VSR Alternator Regulator.

Serial Port Connection on 2nd Generation Alternator Regulator:

Physical connection is made either via the SERVICE port located on the regulator, or wirelessly via the included Bluetooth module using SPP (Serial Port Protocol). Remember, changes will be blocked until the NAME and PIN code have been updated; see 'Need to Initialize' in the Bluetooth section on page 49 and the $SCN: command in Appendix B.

The Service port is a 6-pin female header located in line with a 2-pin expansion connector. Pin 1 of the service port is on the end of the female socket located next to the two male expansion pins. The Service port is defined as:

	Pin #	Purpose
■	6	+3.3v
■	5	GROUND
■	4	n/c
■	3	RX: Regulator Serial Receiving pin (Overrides Bluetooth module)
■	2	TX: Regulator Serial Transmission pin
■	1	~RESET: Resets regulator on falling edge
●	SLC	I2C Expansion (male pin - 3.3v)
●	SDA	I2C Expansion (male pin - 3.3v)

Figure 21: Service Port pin-out (Generation 2 regulator)

Service Port pin outs as used on the 2nd Gen regulator match a very select USB ←→ TTL adapter, and example of which is shown here:

Take careful note of the pinouts, there are a wide variety of 6-pin adapters. One that is known to work was found on EBay using the search: “CP2102 USB 2.0 to TTL UART Module 6Pin Serial Converter STC Replace FT232”. When verifying the pinouts, look closely at the 3.3v supply and the DTR signal in position 1 (used to drive ~RESET).

Serial communication is at 9600 Baud, 8-bit, no parity, 1 stop bit. **When the Serial port is attached it will have hardware priority – preventing any communications *received* via the Bluetooth from reaching the regulator.** You will still be able to monitor the VSR Alternator Regulator status via Bluetooth – just not send any commands via Bluetooth. The 3.3v pin can be used to supply limited power to an external expansion device, or optionally to power the VSR Alternator Regulator when it is not installed.

Remember that the 2nd generation regulator will lockout all ASCII commands until the NAME and PASSWORD has been updated from its default. See section ‘Regulator Name & Password: need to Initialize’ on page# 49.

Bluetooth Operation

Optional to the 2nd generation regulator, serial communications may be initiated with the VSR Alternator Regulator using Bluetooth. Attach an external computer, tablet, or smart-phone using the SPP (Serial Port Protocol). Then use a serial terminal to see the ASCII strings, or send commands to the regulator. The default NAME and PASSWORD for the Bluetooth connection is:

NAME: “ALTREG”

PASSWORD: “1234”

Regulator Name & Password: need to Initialize

Each VSR Alternator Regulator has a name associated with it. This name is used to help identify the regulator when communicating and is used for the Bluetooth ID, as well as the CAN identifier. Each regulator also contains a password which is primary used by the optional Bluetooth module. Both the NAME and PASSWORD may be any combination of alpha numeric character - with the exception of the comma (,), space ( ), or the '@' - up to 18 characters long.

After a master reset (or when 1st using the regulator) you will be able to view the VSR Alternator Regulator status via ASCII strings. However, due to the wireless nature of Bluetooth, and because the an incorrect change the configuration could potential harm your battery **the ability to SAVE any configuration changes is disabled in the 2nd generation regulators until the Name & Password has been updated via $SCN: command.** For additional security – the 1st time the Alternator's Name / Password is changed on the 2nd generation regulator you MUST use the Service Port, set the DIP Switch 1 = OFF (Bluetooth disabled) and DIP switch 2..8 = ON. The alternator must also not be charging (e.g., bench top configuration, or the engine is stopped) . Once the name/password has initially been updated you can then restore the DIP switches to the configuration needed for your system; and the name/password may be changed again without having to set the DIP switches as above. (Unless you do a master reset on the regulator – see *Restore to AS-Compiled (default) Status* on page 58)

Caution: The regulator will NOT check the validity of the strings, specifically that they do NOT contain a comma (,) space ( ) or '@' character. Be careful not to send these as the results might be unpredictable. If needed, perform a master reset to the regulator and start over.

On 2nd generation regulators, it is STRONGLY suggested you change BOTH the NAME and PASSWORD to something unique OR disable the Bluetooth via DIP-switch #1. And remember: no ASCII changes will be accepted until you do. Else you run the risk of someone near you accidentally, or maliciously, adjusting your Alternators configuration and potential damaging your system / batteries. (And this is why the ability to save configuration changes is disabled until the 1st $SCN: command has been received, and that can only happen if you set all the DIP switches as directed above.)

Operation Overview

The VSR Alternator Regulator has a wide range of flexibility and can be configured in three ways, ranging from Simple to Any-thing goes.

- Select among built-in (default) parameters via the DIP switches
- Modify many of the built-in parameters via sending ASCII commands over the Service port and/or the Bluetooth serial connection
- Modifying any or all built in parameters in the source code, recompile and re-flash to regulators firmware. (requires use of Service port and Arduino IDE, see http://arduino.cc/)

Startup Sequence:

When the VSR Alternator Regulator is first powered up it loads in the default Firmware and then looks to the DIP switches to see what the user has selected. It will then sample the system voltage to decide if it is installed in a 12v, 24v or 48v environment (and thereby setting the SysVolt multiplier, see SST: / System Status below for more details about this and how it is used). Finally, it will look at the saved FLASH memory in the CPU to see if any of the parameters have been modified or any of the DIP switches have been overridden by the user using ASCII commands.

Note that parameters saved to Flash are ONLY checked during startup; this is why after changing any parameters via an ASCII string command you need to reset the regulator (via the $RBT – ReBooT command) in order for any of those parameters to take effect. This is done this way so that the regulator does not start acting on changes part way through you making configuration changes. For example, if you are updating the CPE entry, you want to update and verify ALL parts of it before the regulator starts using the new values.

Ramp-up Sequence:

Next, the regulator will enter the Ramp-up phase. It first waits 30 seconds before doing anything (configurable) to give the engine time to start. Finally it will begin to slowly ramp up the alternator field over a period of about a minute before entering Bulk phase.

Charging the Battery:

Once the regulator has completed its startup and ramping sequence it enters the ‘charging’ phases. Each phase has limits (e.g., voltage, amps, etc.) as well as ‘exit’ criteria based on voltage, amps and/or time. A high degree of configurability allows each phase to be used, or bypassed as needed to meet the battery manufacturer’s recommended charging profile.   While in each of these phases the regulator will also monitor battery and alternator temperature, making adjustments as required. It will also look to see if the regulator has been configured with System limits and make sure none of those are exceeded.

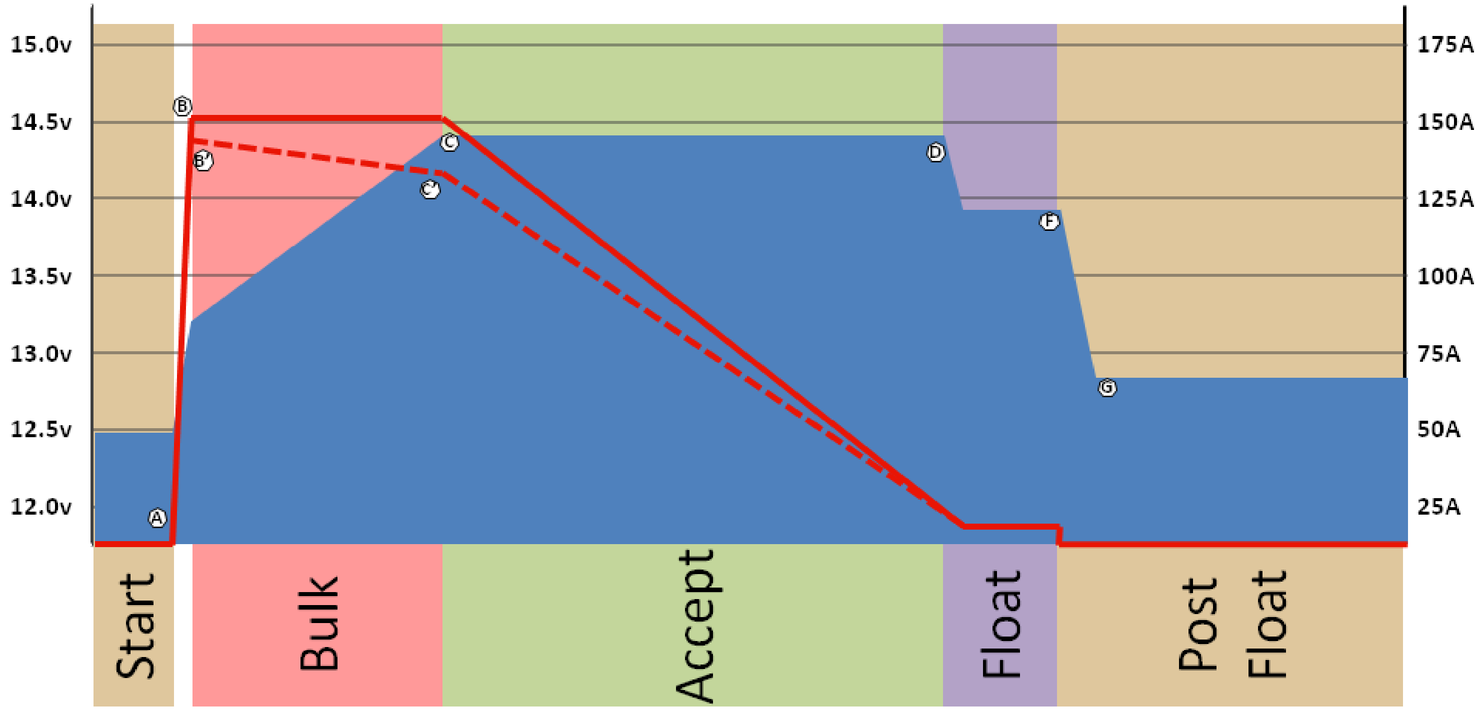


Figure 22: Example 3-stage Charge profile

Figure 22 above shows a typical 3-phase charge profile, consisting of the Bulk, Acceptance, and Float state. This is one of the simplest charge profiles, and very commonly seen in external regulators. The following table details each phase as well as the parameters in the source which can impact them.

Phase	Ref	Limiting Factor	Exit Criteria	Discussion	Key Source Variables
Start	-A	Time	30 second delay or Stator Signal.	Allows time for the engine to start and get up to speed before we apply a load to it. If Tach Mode is enabled, and the regulator has been configured with a fixed minimum PWM value via the *$SCT:* ASCII command (see: Tach Min Field), Start Phase will be extended past the 30 second initial delay until a value Stator signal is detected.	ENGINE_WARMUP_DURATION

Phase	Ref	Limiting Factor	Exit Criteria	Discussion	Key Source Variables
Ramp	A-B	Time	30 seconds Reaching target Voltage	Soft ramp of applied load. Normally this will exit via the Time variable, but if the battery is already well charged it will very quickly reach the target voltage set point, forcing an earlier exit of the Ramp(A-B) phase	PWM_RAMP_RATE ACPT_BAT_V_SETPOINT
Bulk	B-C	Alternator Capacity	Battery Voltage Time(optional)	**<u>Using default configuration (Battery Focused).</u>** During this phase, the majority of energy is returned to the battery, often touted as up to the 80% SOC point. The Alternator is run full out producing as much power is it is capable of producing. As the battery recharges voltage will raise until the set point is reached, which will trigger the exiting of Bulk. If Small-Alt mode is selected via the DIP switches, then the output of the Alternator will be managed to a lower level, to prevent overheating of small alternators that are unable to sustain continuous max amp output. Likewise, if Half-power mode is selected (via shorting the Alt Temp probes together), a more aggressive scale back will occur. This can be useful in installations where extra engine power is needed, perhaps to drive an additional pump, or perhaps allow for high speed / power mode (passing).	ACPT_BAT_V_SETPOINT ALT_AMP_DERATE_NORMAL ALT_AMP_DERATE_SMALL_MODE ALT_AMP_DERATE_HALF_POWER
Bulk’	B’-C’	System Capacity	Battery Voltage Time(optional)	**<u>An alternative configuration (Alternator Focused)</u>** to manage the system load at a lower level than the full capability of the Alternator. This is useful when powering a large alternator with a small engine, such as in a DC generator. All items discussed in Bulk above are still applicable in this configuration, with the additional system limit added. Notice in Figure 22 above: as the battery voltage increases – amps delivered are reduced, resulting in a constant wattage. Which translates to a constant load placed on the driving engine.	ALT_WATTS_LIMIT ALT_AMPS_LIMIT

Phase	Ref	Limiting Factor	Exit Criteria	Discussion	Key Source Variables
Accept	C-D	Battery Acceptance Rate	Battery Acceptance Current Time – Fixed Time - Adaptive	Acceptance carries recharging from 80% to 100% of the battery's capability. The preferred way to exit this phase is via measuring the current the battery is accepting; indicating its state of charge. Other ways to exiting include a fixed Max time, as well as a time ratio based on a multiplier of how long the battery was in the Bulk phase. Both of these can be useful for installations where the Amp shunt has not been installed, or it has failed.	ACPT_BAT_V_SETPOINT EXIT_ACPT_AMPS EXIT_ACPT_DURATION ADPT_ACPT_TIME_FACTOR
Float *Forced Float*	D-F	--	Pull back to Bulk Time(optional)	Float is a 'parking place' intended to maintain a fully charged battery. A slightly higher than rest voltage is maintained to overcome the batteries internal self-discharge. Further, the Alternator is maintained in a ready mode to supply current to any external load that might be requested. If the Alternator is unable to support this load and current is requested from the battery, we are pulled out of Float and back into a recharge cycle (back to Bulk). Another indication of this is if the battery volts start to drop. This can be helpful in situations where the Amp shunt is not installed, or has failed. Finally, the accumulated Amp Hours may be monitored and once a given amount has been removed from the battery – the regulator will revert to Bulk mode. Note: If CPE #8 is enabled, the FEATURE_IN pin may be used to force the regulator into Float mode. As such, none of the above exit criteria will be checked while FEATURE_IN is active.	FLOAT_BAT_V_SETPOINT EXIT_FLOAT_DURATION FLOAT_TO_BULK_AMPS FLOAT_TO_BULK_VOLTS FLOAT_TO_BULK_AHS <NONE – All exits bypassed>

Phase	Ref	Limiting Factor	Exit Criteria	Discussion	Key Source Variables
Post Float	F-G	--	Pull back to Bulk Time(optional)	Post Float is much like Float, except the alternator is turned off allowing the battery to sit on its own. Post Float will return to Float mode based on a timed exit value. Once this has been exceeded, the regulator will revert to FLOAT mode. Another way to exit Post Float is through the appearance of a large load which has been placed on the system. This can either be determined by battery voltage, or by monitoring the accumulated Amp Hours removed from the battery – much like Float above. Note however that when exiting via these conditions these two methods will cause the regulator to move back into Bulk mode - just like Float above.	EXIT_PF_DURATION PF_TO_BULK_VOLTS PF_TO_BULK_AHS

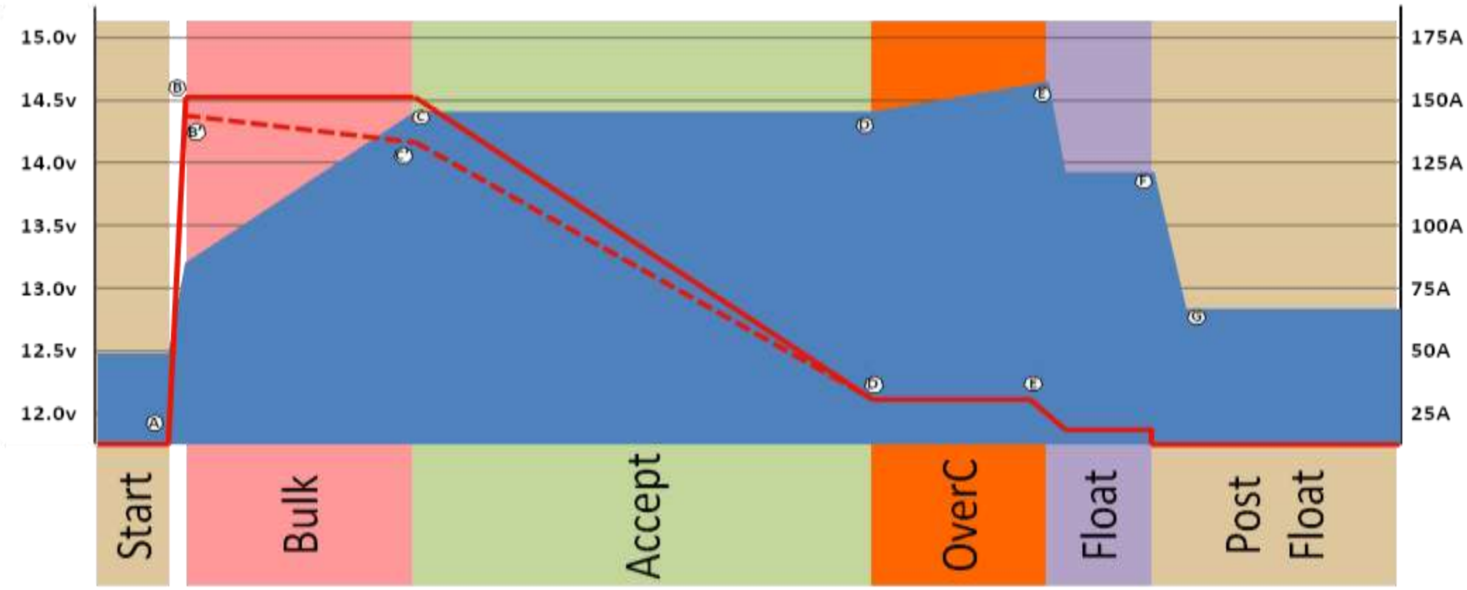


Figure 23: 4-stage Charge Profile

Some batteries ask for an additional charging phase after the Acceptance phase, one that provides a small constant current and allowed the voltage to raise. Referred to as a Finish Charge or an Over Charge, the purpose is to assure even chemical actions has occurred throughout the entire battery. For batteries which specify this 4th charge step, the above charge profile is used. Refer to the above table for stages other than Over Charge.

Phase	Ref	Limiting Factor	Exit Criteria	Discussion	Source Variables
Over Charge	D - E	Defined Amps	Battery Voltage Time(optional)	In this phase the alternator will be managed to maintain a consistent current into the battery, allowing battery voltage to raise (much like Bulk phase). Once battery voltage has reached the exit volts (Point E), or a max time has been exceeded, the regulator will move to the Float mode.	LIMIT_OC_AMPS EXIT_OC_VOLTS EXIT_OC_DURATION

Note how the VSR Alternator Regulator will move directly to Acceptance Phase if the battery voltage quickly rises. This, combined with the measurement of the Acceptance Current to determine if a battery is fully charged, handles the all too common situation of being plugged into shore-power and subsequently getting under way with the battery already fully charged. Traditional time-only based regulators might be stuck in the Acceptance phase for several hours until the fixed time limit is reached, overcharging the battery. With the VSR Alternator Regulator, the regulator will recognize quickly the battery is fully charged and move into float mode within seconds of starting the engine. This eliminates one of the major ways a less intelligent regulator can damage your batteries.

Each of the charge steps are fully configurable, and many can be bypassed (e.g., most charge profiles do not use the Overcharge step). As way of an example, the following two diagrams show two different approaches for charging a heavy duty 12v / 500Ah battery (e.g., two L-16 batteries). Both profiles are included in the default VSR Alternator Regulator as profile #3 and #6. Figure 24 shows the traditional 3-step charge profile (Bulk, Accept, and Float), while Figure 25 illustrates the flexibility to accommodate a 4-step charge profile (Bulk, Accept, Over-charge, then float). The diagrams provide an overview of each phase and represent a 180A alternator charging a 12v 500Ah battery.

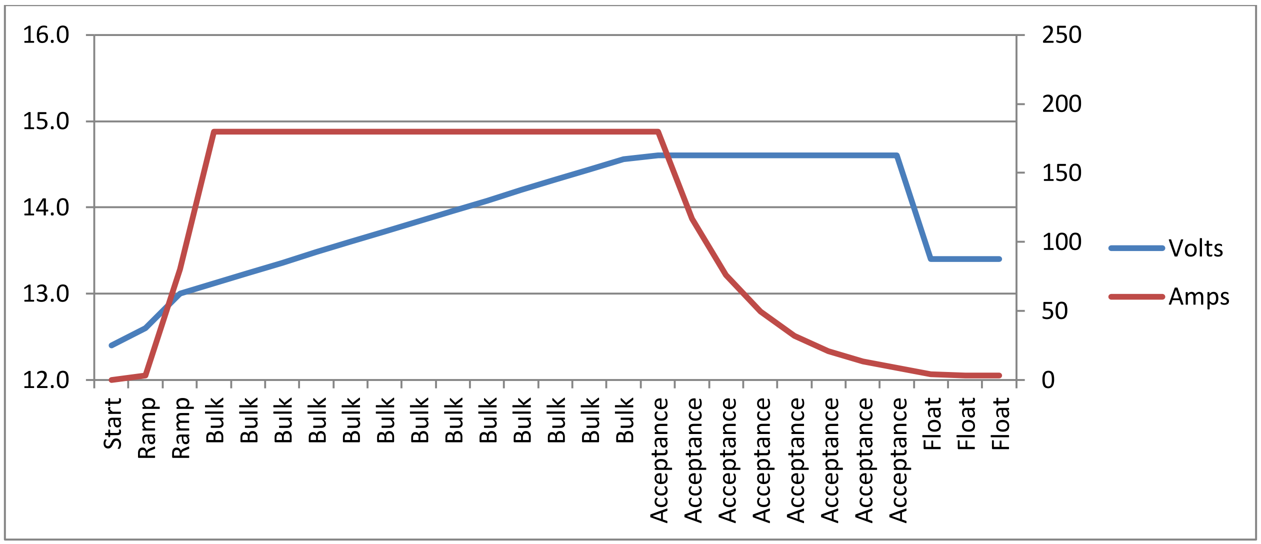


Figure 24 – Example Charge Profile #3 (HD FLA Storage battery)

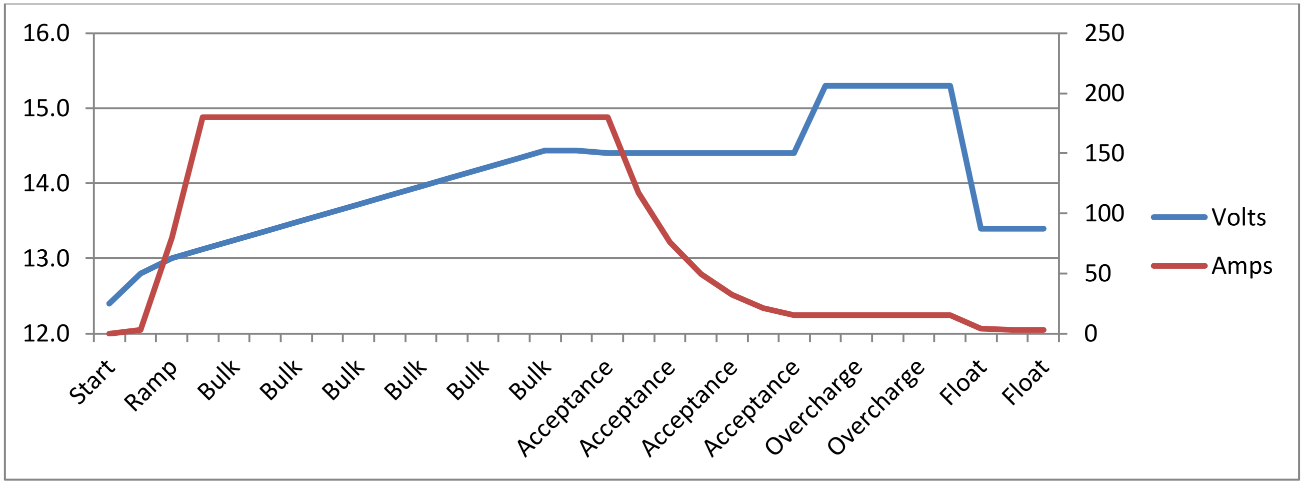


Figure 25 – Example Charge profile #6 (HD FLA - Alternative Charge Profile)

Restore to AS-Compiled (default) Status

Configurations (system and Charge parameters) which have been changed from the as-compiled default values may be restore in one of three ways:

- Individually by the $CPR:n , $SCR: and $CCR: commands.
- Collectively via the $MSR: command.
- Total system restore by connecting the FEATURE-IN to VBat before applying power to the regulator, and then applying power. This will restore ALL configurations to the default condition.
  - DIP switches must be set to select CPE #5 with ALL other DIP switches set = ON

If the regulator has been Locked Out via the $SCO command the only way to restore to the default configuration is via using the FEATURE-IN reset procedure, because none of the ASCII change commands will function once the regulator has been locked. You may also clear the locked flag by recompiling the firmware and reloading it. If you do this, you will need to make a change to the following defines in the source code to some other random value:

```
#define     SCS_ID1_K    0xFC3A
#define     SCS_ID2_K    0x69D3
```

These provide a validation token at the beginning of each saved block of data in the FLASH. If you do not change these values the CPU will read the existing FLASH and finding a match to the above keys will assume the saved parameters are valid. (Including the locked-out bit). So, in order to ‘clear’ the FLASH, you must change the tokens.

BENCH TESTING AND DIAGNOSTICS

Limited testing can be performed on the VSR Alternator Regulator using a simple test mockup, a voltage meter, power supply and a computer to monitor status out. If you suspect the regulator has been damaged, these steps can help you confirm basic functionality.

Simple Go / No-Go testing

The 1st test is to simply confirm the regulator is able to wake up and begin processing. This may be done with the regulator installed or removed on the bench. Connect a PC to the regulator via the Serial/USB port and open a terminal program. (See section: Communicating with the VSR Alternator Regulator on page: 47). You should see ASCII strings being sent out, much along the lines of this:

```
AST;,0.00, ,12.30,-39.3,0.0,-484, ,14.40,1000,15000,4, ,-99,18, ,0, ,12.30,15,-99,0
AST;,0.00, ,12.30,-39.3,0.0,-484, ,14.40,1000,15000,4, ,-99,18, ,0, ,12.30,15,-99,0
AST;,0.00, ,12.30,-39.2,0.0,-483, ,14.40,1000,15000,4, ,-99,18, ,0, ,12.30,15,-99,0
AST;,0.00, ,12.30,-39.3,0.0,-483, ,14.40,1000,15000,4, ,-99,18, ,0, ,12.30,15,-99,0
AST;,0.00, ,12.30,-39.3,0.0,-484, ,14.40,1000,15000,4, ,-99,18, ,0, ,12.30,15,-99,0
AST;,0.00, ,12.30,-39.3,0.0,-483, ,14.40,1000,15000,4, ,-99,62, ,0, ,12.30,15,-99,0
AST;,0.00, ,12.30,-39.3,0.0,-483, ,14.40,1000,15000,4, ,-99,18, ,0, ,12.30,15,-99,0
AST;,0.00, ,12.30,-39.3,0.0,-483, ,14.40,1000,15000,4, ,-99,18, ,0, ,12.30,15,-99,0
AST;,0.00, ,12.30,-39.2,0.0,-483, ,14.40,1000,15000,4, ,-99,18, ,0, ,12.30,15,-99,0
```

This means the basic CPU is operational. Please note that for bench testing the VSR Alternator Regulator is able to self-power from the Serial/USB port, so no other connection is needed – though this simple Go / No-Go test may also be performed with the regulator installed.

At the same time the LED should start flashing, about once a second. Both the flashing and the ASCII strings will continue for approximately 30 seconds at which time if the regulator is not installed (specifically, the Vbat sensing wires are not connected) it will fault-out with a low-voltage error. This is normal, as if the regulator cannot see a battery voltage that is reasonable it assumes something is wrong.

If you do not see strings such as above but the LED flashes, it means there may be a problem with your serial communications hardware/software. If you cannot see neither the flashing nor the strings it implies the regulator CPU is not functioning.

Good next steps would be to test the regulator using the Arduino IDE, making sure the firmware is flashed in.

Bench testing mockup

A simple test setup will allow you to verify major portions of the VSR Alternator Regulator are operational. Specifically testing the battery Voltage and Amperage sensing circuit and field driver FETs.

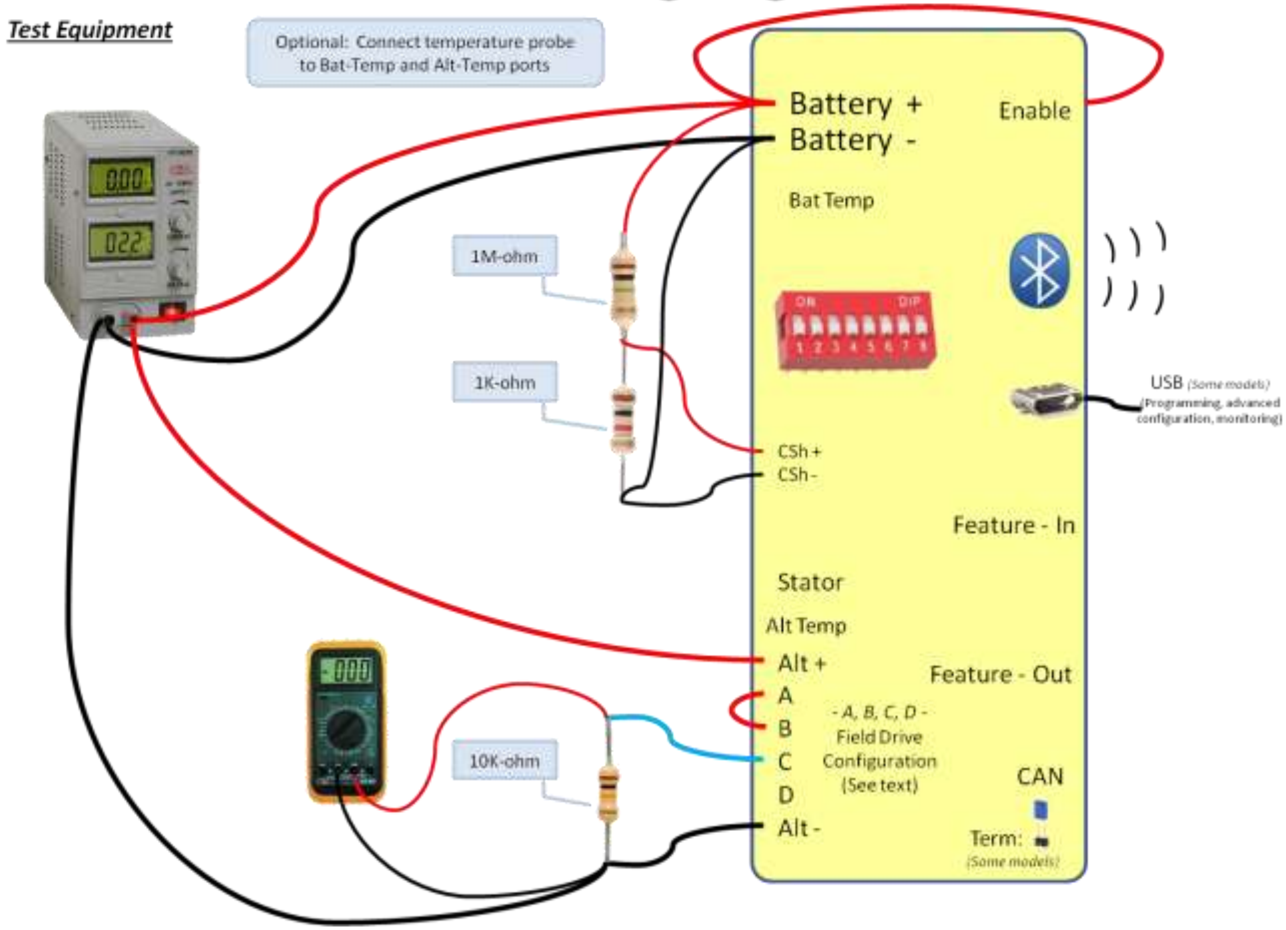
You will need the following test gear:

- Remove the regulator from the installation (do NOT attempt to do this test while the regulator is installed)

- A power supply of some type. To see complete operation a variable voltage supply is needed.
- Three resistors: 1M ohm, 10K ohm, and 1K ohm. Common 1/4W 5% or better resistors are ok.
- A DVM or VOM.
- A computer connected to the serial/USB port is helpful.
- 2x - 10k NTC temperature probes (optional)

Connect the power-supply, resistors and field as shown:

Basic Bench-testing Regulator



Verifying Voltage and Current sensing:

Turn on the power-supply and adjust it for approx 12.6v. Connect your terminal observe the AST; strings and you should see something along the lines of the example here. Note the reported Battery Voltage and Current (Marked in Yellow in the example below). It may take a few seconds for these values to be produced and your values may be slightly different (notable the current ones) if your regulator is configured with a different shunt ratio.

```
AST;,0.00, ,12.60,126.0,0.0,-483, ,14.40,1000,15000,4, ,-99,18, ,0, ,12.30,15,-99,0
```

Using your DVM/VOM, measure the actual voltage at the VBat+ and VBat- terminals on the regulator. They should be close to what the regulator reports. Depending on tolerances of regulator and meter, expect the results to be within 1% of each other. If not, there is a problem with the INA226 voltage sensing circuit.

Next measure the voltage across the *`Current_shunt+`* and *`Current_shunt-`* terminals. Also take note of the configured shunt value as reported by the $SCV; status string. Using the following formula, calculate the 'battery current':

```
Battery-current = (Measured-mV) * (SCV-Shunt-ratio)

Battery-current = (Measured-mV) * 10,000 ←If you are using the default shunt ratio
```

The resulting value should be close to what is reported by the $AST strings, if not there is something wrong with the INA226 and/or INA282 level shifter. Some areas to investigate include the 13v power supply (TP1 on the Gen3 regulator, pin #1 of U3 are accessible test points) – there should be around 11-14v at these points.

Verifying Field drive:

With the regulator still connected per above, connect your DVM/VOM to the Field terminal and monitor its voltage. While watching the AST; strings - looking at the field-drive% value (Highlighted in Yellow here)

```
AST;,0.01, ,12.49,124.9,48.2,602, ,14.40,1000,15000,5, ,-99,18, ,731, ,12.49,15,-99,58
AST;,0.01, ,12.50,125.0,46.1,577, ,14.40,1000,15000,5, ,-99,18, ,731, ,12.50,15,-99,60
AST;,0.01, ,12.51,125.1,48.3,604, ,14.40,1000,15000,5, ,-99,18, ,731, ,12.51,15,-99,62
```

As the regulator ramps up, and the field drive % increases, you should see a like increase in voltage indicated on your DVM/VOM, with the value being around the voltage of your power supply times the % field drive shown via the AST; string. Do note the field drive is a low PWM frequency (around 140hz), and many DVMs will be confused by this. If the DC setting does not work, try AC, or better – if you are able to locate an old-style VOM meter use it.

Failure to see increasing field drive voltage indices an issue with your power supply, the Enable source, the regulators 13v power supply (noted above), the FETs and/or the field drive. Depending on your meter you may try touching the input pun to the FET driver chip (marked FIELD-PWM in the schematics), and you should see a DC voltage increasing from 0 to 3.3v (for Gen 2) or 5.0v (Gen 3) regulator.

Once you have confirmed the field drive is working you can try varying the power-supply to voltage above and below the set point (14.40 in the above examples) and observe the field drive % ratio change.

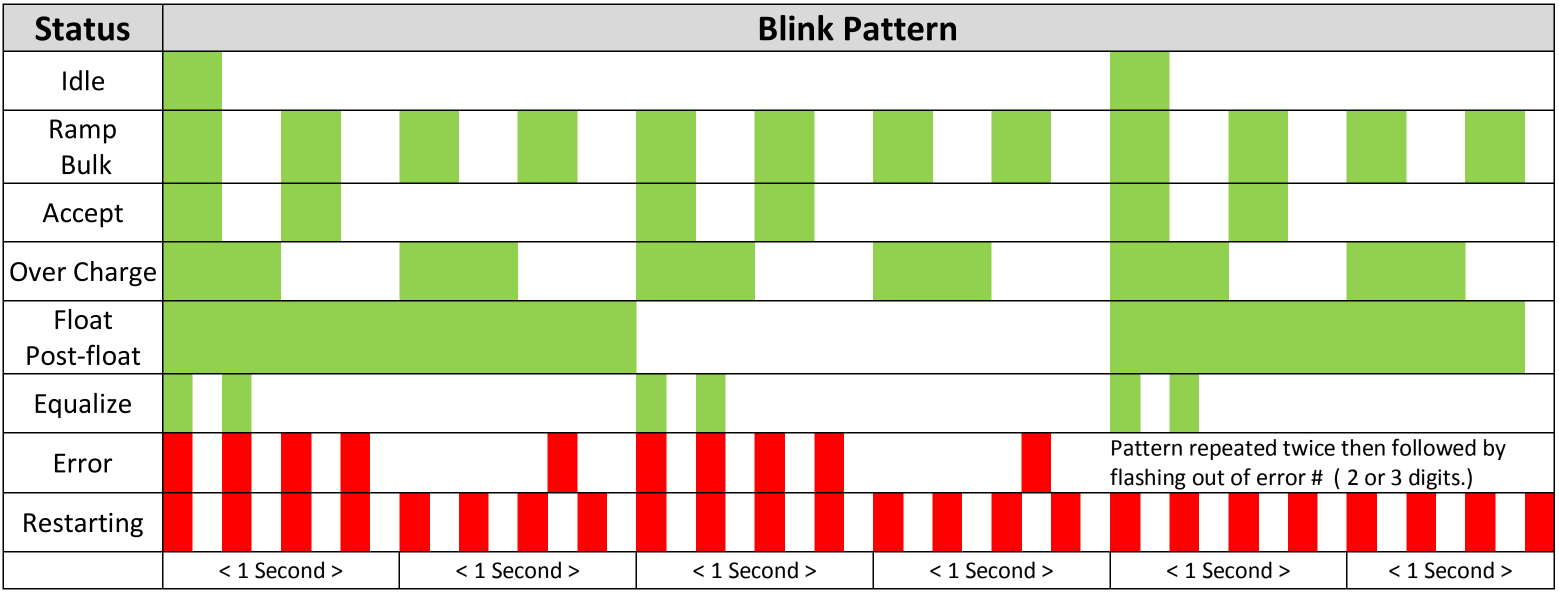
Verifying Temperature probes:

If you connect temperature probes you should see values close to room temperature. Note the FET temperature as well; it also should be close to room temperature. You can hold one of the probes in your fingers to observe a rise. Or place it on top of an ice-cube.

Other portions of the VSR Alternator Regulator will need to be tested using custom programs and more advanced diagnostic equipment. But the above will verify the core functionality.

LED Blink Patterns

The on-board LED will blink out patterns to inform the user of its current status, errors, and pending actions (e.g., about to restart). Patterns are made up by a combination of blink patterns, and the speed at which they blink. The following table describes the patterns.



Note: Generation 2 board only blinks GREEN.

If using the CAN enabled Systems Regulator (Version 3 or later), the LED will blink GREEN during normal operation. If the regulator is linked into a 'system' and being coordinated by a remote battery manager, the LED will blink YELLOW instead of Green. These colors can be used to quickly identify which device is currently acting as the battery master and that the system is configured correctly. It also allows quick visualization of which node has taken over in the case of a failed battery master. The LED will blink RED if there is a fault condition. Note also that if a Required Sensor is identified as not present (See the $SCA: command), the LED will blink out the normal mode patterns (Idle, Ramp, bulk, etc) except it will do so in RED indicating an issue.

APPENDIX A: DETAILS OF CPE (CHARGE PROFILE ENTRIES)

The following are excerpt from the CPE.H source code file to give more details on how each parameter impacts battery charging.

```
               //----- This structure defines a 'profile' for battery charging.  Each stage consist of 'modes', primarily:  Bulk, Acceptance,
               //      Overcharge, and Float.  Each mode has a max voltage set point, and criteria for exiting that phase (Exceeding a time limit,
               //      or Amps dropping below a given value).   Of special note is the entry Float and Post Float, which have additional criteria
               //      resuming charging.
               //
#define MAX_CPES        8                                      //  There are 8 different Charge profile Entries
#define CUSTOM_CPES     2                                      //  The last two of which are set aside as 'customizable' and are changeable via the ASCII
string commands.

typedef struct {                                               // Charging Profile Structure

   float          ACPT_BAT_V_SETPOINT;                         // Set point for Ramp, Bulk and Acceptance battery voltage.
                                                               // Alternator will transition from BULK mode into Accept Mode when this voltage is
                                                                  reached, and then start the Accept Duration counter.
   unsigned long  EXIT_ACPT_DURATION;                          // Stay in Accept mode no longer then duration in mS  (Set = 0 to disable Acceptance phase
                                                                  and move directly to OC or Float mode)
   int            EXIT_ACPT_AMPS;                              // If Amps being delivered falls to this level or below, exit Accept mode and go to next
                                                               //      Set ExitAcptAmps =  0 to disable Amps based transition and only rely on
                                                                  EXIT_ACPT_DURATION timeout.
                                                               //      Set ExitAcptAmps = -1 to disable Amps based transition and rely on
                                                                  EXIT_ACPT_DURATION timeout
                                                               //  or ADPT_ACPT_TIME_FACTOR adaptive duration.
                                                               // Set ExitAcptAmps = Same value used for LIMIT_OC_AMPS if Overcharge mode is to be used.
                                                               //
                                                               // FUTURE:  EXIT_ACPT_DVDT  Add dV/dt exit criteria for Acceptance mode, need to decide
                                                                  what it is :-)



                                                               // Overcharge mode is sometimes used with AGM batteries and occurs between Acceptance and
                                                                  Float phase.
   int            LIMIT_OC_AMPS;                               // During Overcharge phase, Amps are capped at this low value.  (Set this = 0 to disable
                                                                  OC mode.)
   float          EXIT_OC_VOLTS;                               // Overcharge will continue until the battery voltage reaches this level.
   unsigned long  EXIT_OC_DURATION;                            // Over Charge mode duration in mS.
                                                               // ( as a safety step, setting OC_VOLTS or DURATION = 0 will also disable OC mode..)
                                                               // FUTURE:  EXIT_OC_DVDT  Add dV/dt exit criteria for Overcharge mode, need to decide what
                                                                  it is :-)



   float          FLOAT_BAT_V_SETPOINT;                        // Set point for Float battery voltage, do not exceed this voltage.
```

```
int             LIMIT_FLOAT_AMPS;                               // During Float, manage system to keep Amps into Battery at or under this value.  Maybe =
                                                                   0, set = -1 to disable limit.
unsigned long   EXIT_FLOAT_DURATION;                            // Alternator will stay in Float mode this long (in mS) before entering Post-Float (no
                                                                   charging) mode.  Set = 0UL disable transition to Post-float mode.
int             FLOAT_TO_BULK_AMPS;                             // If Amps being delivered exceeds this value, we will assume a LARGE load has been placed
                                                                   on the battery and we need to re-enter
                                                                // BULK phase.   Set this = 0 to disable re-entering BULK phase feature
int             FLOAT_TO_BULK_AHS;                              // If the number of Ahs removed from the battery after 1st entering Float mode exceed this
                                                                   value, revert back to BULK.
                                                                // Note this will ONLY be usable if the Amp shunt is at the battery.  Set = 0 to disable
                                                                   this feature.
float           FLOAT_TO_BULK_VOLTS;                            // As with Amps, if the voltage drops below this threshold we will revert to Bulk.  Set =
                                                                   0 to disable.



unsigned long   EXIT_PF_DURATION;                               // Only stay in Post_float mode (no charging) this amount of time.  Set = 0UL to disable
                                                                   times based Post-float exiting and exit only on Voltage.
float           PF_TO_BULK_VOLTS;                               // If during Post-Float mode VBat drops below this voltage, re-enter FLOAT mode.
                                                                // Set = 0.0 to disable exiting of post-float mode based on voltage.
                                                                // Config note:  IF you configure the system to enter post-float mode from float-mode (by
                                                                   setting a time value EXIT_FLOAT_DURATION), AND you
                                                                //              set both EXIT_PT_DURATION and PF_TO_BULK_VOLTS = 0, the regulator will in
                                                                   effect turn off the alternator once charging is completed
                                                                //              and not restart a charge cycle until powered down and up again.  This can
                                                                   be useful if you truly want a one-time only charge.
                                                                //              You could also config the FEATURE-OUT port to indicate the complete
                                                                   charge cycle has finished, to say power-off the driving engine?
int             PF_TO_BULK_AHS;                                 // If the number of Ahs removed from the battery after 1st entering Post Float mode exceed
                                                                   this value, revert back to BULK.
                                                                // Note this will ONLY be usable if the Amp shunt is at the battery.  Set = 0 to disable
                                                                   this feature.


float          EQUAL_BAT_V_SETPOINT;                            // If Equalize mode is selected, this is the target voltage.  Set = 0 to prevent user from
                                                                   entering Equalization mode.
int            LIMIT_EQUAL_AMPS;                                // During equalization, system will limit Amps to this value.   Set = 0 to disable amp
                                                                   limits during Equalization Mode.
unsigned long EXIT_EQUAL_DURATION;                              // Regulator will not stay in Equalization any longer then this (in mS).  If set = 0, then
                                                                   Equalization mode will be disabled.
int            EXIT_EQUAL_AMPS;                                 // If Amps fall below this value during Equalization, then exit equalization.  Set = 0 to
                                                                   disable exit by Amps and use only time.



float          BAT_TEMP_1C_COMP;                                // Battery Temperature is compensated by this factor for every 1C temp change.  Note this
                                                                   is based off of BAT_TEMP_NOMINAL (25c)
int            MIN_TEMP_COMP_LIMIT;                             // If battery temperature falls below this value (in deg-c), limit temp compensation
                                                                   voltage rise to prevent overvoltage in very very cold places.
```

```
int           BAT_MIN_CHARGE_TEMP;                                // If Battery is below this temp (in deg-c), stop charging and force into Float Mode to
                                                                     protect it from under-temperature damage.
int           BAT_MAX_CHARGE_TEMP;                                // If Battery exceeds this temp (in deg-c),  stop charging and force into Float Mode to
                                                                     protect it from over-temperature damage.

} CPS;
```

Actual content of the CPE tables. Remember, all references are against a ‘normalized’ 12v / 500Ah battery.

```
const tCPS PROGMEM defaultCPS[MAX_CPES] = {

      //      Bulk/Accpt                 Overcharge                              Float                              Post Float              Equalization                    Temp Comp

      {14.1, 6.0*3600000UL, 15,       0,  0.0,   0*3600000UL,       13.4,  -1, 0*3600000UL, -10,  0, 12.8,    0*3600000UL, 0.0, 0,     0.0,  0,    0*3600000UL, 0,     0.004*6, -9, -45, 45},
      {14.8, 3.0*3600000UL,  5,       0,  0.0,   0*3600000UL,       13.5,  -1, 0*3600000UL, -10,  0, 12.8,    0*3600000UL, 0.0, 0,     0.0,  0,    0*3600000UL, 0,     0.005*6, -9, -45, 45},
      {14.6, 4.5*3600000UL,  5,       0,  0.0,   0*3600000UL,       13.2,  -1, 0*3600000UL, -10,  0, 12.8,    0*3600000UL, 0.0, 0,    15.3,  25, 3.0*3600000UL, 0,     0.005*6, -9, -45, 45},
      {14.7, 4.5*3600000UL,  3,       0,  0.0,   0*3600000UL,       13.4,  -1, 0*3600000UL, -10,  0, 12.8,    0*3600000UL, 0.0, 0,     0.0,  0,    0*3600000UL, 0,     0.004*6, -9, -45, 45},
      {14.1, 6.0*3600000UL,  5,       0,  0.0,   0*3600000UL,       13.5,  -1, 0*3600000UL, -10,  0, 12.8,    0*3600000UL, 0.0, 0,     0.0,  0,    0*3600000UL, 0,     0.005*6, -9, -45, 45},
      {14.4, 6.0*3600000UL,  7,       0,  0.0,   0*3600000UL,       13.4,  -1, 0*3600000UL, -20,  0, 12.0,    0*3600000UL, 0.0, 0,    14.4,  0,  3.0*3600000UL, 3,     0.024,  -20, -20, 50},},
      {14.4, 6.0*3600000UL, 15,      15, 15.3, 3.0*3600000UL,       13.1,  -1, 0*3600000UL, -10,  0, 12.8,    0*3600000UL, 0.0, 0,    15.3,  25, 3.0*3600000UL, 0,     0.005*6, -9, -45, 45},
      {13.8, 1.0*3600000UL, 15,       0,  0.0,   0*3600000UL,       13.36,  0, 0*3600000UL,   0,-50, 12.9,    0*3600000UL, 0.0, 0,     0.0,  0,    0*3600000UL, 0,     0.000*6,  0,   0, 40}
      };
```

```
const CPS PROGMEM defaultCPS[MAX_CPES] = {
               // #1 Default (safe) profile & AGM #1 (Low VOltage AGM).
               // #2 Standard FLA (e.g. Starter Battery, small storage)
               // #3 HD FLA (GC, L16, larger)
               // #4 AGM #2 (Higher Voltage AGM)
               // #5 GEL
               // #6 Firefly (Carbon Foam)
               // #7 4-stage HD LFA (+ Custom #1 changeable profile)
               // #8 LiFeP04        (+ Custom #2 changeable profile)
        };
```

APPENDIX : DEFAULT SYSTEM CONFIGURATION

The following documents default values (As Compiled) for the VSR Alternator Regulator's system configuration. It is configured assuming the Amp Shunt will be placed at the battery and that a 500A / 50mV shunt is being used. (This is the shunt used in the Link-10 battery meter as well as others).

```
SCS systemConfig = {
        false,                // .REVERSED_SHUNT              --> Assume shunt is not reversed.
        90,                   // .ALT_TEMP_SETPOINTc          --> Default Alternator temp - 90c  (Approx 195f)
        1.00,                 // .ALT_AMP_DERATE_NORMAL       --> Normal cap Alternator at 100% of demonstrated max Amp capability,
        0.75,                 // .ALT_AMP_DERATE_SMALL_MODE   --> Unless user has selected Small Alt Mode via DIP switch, then do 75% of its capability
        0.50,                 // .ALT_AMP_DERATE_HALF_POWER   --> User has shorted out the Alternator Temp NTC probe, indicating want 1/2 power mode.
        -1,                   // .ALT_PULLBACK_FACTOR         --> Used to pull-back Field Drive as we move towards Idle.
        0,                    // .ALT_IDLE_RPM                --> Used to pull-back Field Drive as we move towards idle.
                                                                  Set = 0 causes RPMs to be determined automatically during operation.
        0,                    // .ALT_AMPS_LIMIT              --> The regulator may OPTIONALLY be configured to limit the size of the alternator output
                              //                                  Set = 0 to disable Amps capping.  Set = -1 to auto-size Alternator during Ramp.
                                                                 (required Shunt on Alt, not Bat)
        0,                    // .ALT_WATTS_LIMIT             --> The regulator may OPTIONALLY be configured to limit the load placed on the engine via
                              //                                  the Alternator.
                              //                                  Set = 0 to disable, -1 to use auto-calc based on Alternator size.
                                                                    (Required Shunt on Alt, not Bat)
        12,                   // .ALTERNATOR_POLES            --> # of poles on alternator (Leece Neville 4800/4900 series are 12 pole alts)
       ((6.7 / 2.8) * 1.00),  // .ENGINE_ALT_DRIVE_RATIO      --> Engine pulley diameter / alternator diameter & fine tuning calibration ratio
 (int) ((500/0.050) * 1.00),  // .AMP_SHUNT_RATIO             --> Spec of amp shunt,  500A / 50mV shunt (Link10 default) and % calibrating error
                              //                                   CAUTION:  Do NOT exceed 80mV on the AMP Shunt input
        -1,                   // .FIELD_TACH_PWM              --> If user has selected Tach Mode, use this for MIN Field PWM.
                              //                                    Set = -1 to 'auto determine' the this value during RAMP phase
                              //                                    Set =  0 to in effect 'disable' tach mode, independent of the DIP switch.

        true,                 // .USE_BT                      --> Should we try to use the Bluetooth?
        "ALTREG",             // .BT_NAME                     --> Name of Bluetooth module.              MAX 18 CHARS LONG!  (see BT_NAME_LEN)
        "1234",               // .BT_PSWD                     --> Password to use for Bluetooth module.  MAX 18 CHARS LONG!  (see BT_PIN_LEN)
   DEFAULT_BT_CONFIG_CHANGED, // .BT_CONFIG_CHANGED           --> BT name and password are still the default.  Updates to configuration data is
                                                                  prevented until the name & password is changed.

         0,                   // .CP_INDEX_OVERRIDE           --> Use the DIP switch selected indexes
         0.0,                 // .BC_MULT_OVERRIDE            --> Use the DIP switch selected multiplier
         0.0,                 // .SV_OVERRIDE                 --> Enable Auto System voltage detection
         0 };                 // .CONFIG_LOCKOUT;             --> No lockouts at this time.
```

```
CCS canConfig = {
        0,                    // .BI_OVERRIDE            --> Battery Instance attached to.  0=use DIP switches, override with $CCN command
        1,                    // .DEVICE_INSTANCE        --> Default 'Charger' instance.  Override with $CCN
        70,                   // .DEVICE_PRIORITY        --> Default 'Device Ranking' - 70, Below AC powered chargers.  Override with $CCN command
        true,                 // .CONSIDER_MASTER        --> Default, is no one else steps up to the plate - shall we try to be master? Override with $CCN
        false,                // .SHUNT_AT_BAT           --> Until user explicitly tells us otherwise, we need to assume the shunt is NOT connected to the
                                                             battery when we are the RBM.
        RVCDCbt_Unknown,      // .BATTERY_TYPE           --> Default, we do not know unless the user tells us.
        true,                 // .ENABLE_OSE             --> Default, push out OSEnergy (RV-C) messages (This is NEEDED to support remote instrumentation,
                                                             prioritization, etc.)  Override with $CCN
        true,                 // .ENABLE_NMEA2000        --> Default, push out NMEA-2000 messages.  Override with $CCN
        false                 // .ENABLE_NMEA2000_RAT    --> Default, do not look for a NMEA2000 device to remotely supply battery amperage and
                                                             temperature - and we will send out PGN: 127506
    };
```

Note: not all struct entries shown here, see Source code for more details.