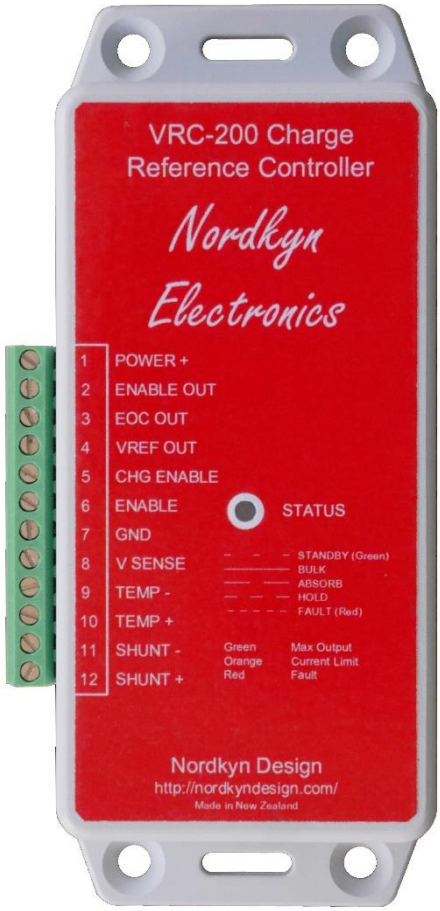


NORDKYN ELECTRONICS VRC-200 CHARGE REFERENCE CONTROLLER

Installation & Setup Manual

Advanced Charge Controller for Externally Sensed Alternators and Chargers

A Charge Reference Controller enables programming a charge profile for externally-sensed alternators and chargers without replacing their internal regulator.

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Introduction

The VRC-200 voltage reference controller is the successor of the VRC-100 manufactured between 2015 and 2018. It provides greater functionality as well as compatibility with 24V systems in a smaller footprint. These controllers were specifically designed to operate in conjunction with modern stock marine alternators featuring a voltage regulation sensing input to achieve a flexible and configurable charge profile. They can also be used with a variety of chargers and charge controllers as long as they feature remote battery voltage sensing.

Externally referenced (or remote sensed) alternators have become very common since the release of the *Volvo Penta Compact D-Series* marine diesel engines which are fitted with Mitsubishi alternators, so if you happen to own one of them, this controller is the solution of choice to implement advanced alternator control and charge regulation. Some older *Volvo Penta MD-series* engines were equipped with Valeo alternators also compatible with the VRC-200 controller. It can of course be used with many other externally-sensed alternators, such as the *Delco Si*, *Bosch LHX* and *Eco-Tech* alternators to name just a few, which meet the electrical compatibility specifications provided in this document.

In the case of alternators, it is worth pointing out that piloting the alternator's own regulator allows the factory thermal protection to keep the alternator within its thermal envelope *without* the use of an additional alternator temperature sensor. This is in stark contrast with external regulators, which *require* a temperature sensor to prevent the alternator from burning out at high load. Locating this sensor correctly is often problematic, because the heat is generated within the stator windings and rectifier assembly.

The VRC-200 controller was designed to correctly charge all battery technologies and chemistries, ranging from lead-acid batteries to lithium cells, by integrating battery voltage, charge current and temperature measurements in its algorithm. This allows determining the true state of the charge of the battery without relying on assumptions or a myriad of "user-defined parameters".

Applicability

This document is applicable to VRC-200 controllers using:

Hardware Revision 6 (PCB Rev6) and later

Firmware Revision 3.7 (FW) and later

Refer to Figure 6 in this document to identify the revision numbers if necessary.

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Overview

Key Features and Benefits

When associated with an alternator, this controller has many advantages over so-called alternator "smart regulators":

- Designed to control stock alternators: no need to disassemble the alternator and remove the existing built-in regulator, losing its thermal protection in the process.
- Charge control based on current as well as voltage, not just voltage.
- Fastest charge rates, without ever overcharging.
- Designed for charging all types of batteries and chemistries, including lithium cells.
- True charge absorption termination on residual current.
- True current limiting.
- Thermal management of the alternator.
- Simple adjustment with a multimeter and a screwdriver.
- Compatible with 12V and 24V DC electrical systems.
- Seamless integration in mixed 12/24V systems.
- External charge control with battery management system (BMS) possible.
- No integration issues with engine electronic monitoring systems.

Operation

Concept and Principle of Operation

A standard alternator regulates its own output according to its built-in regulator, as shown in Figure 1. Not only the charging characteristics depend entirely on the internal regulator, but, when the charging current is high, the battery voltage falls below the regulation point present at the alternator due to voltage losses along the cables. This extends the charging time.

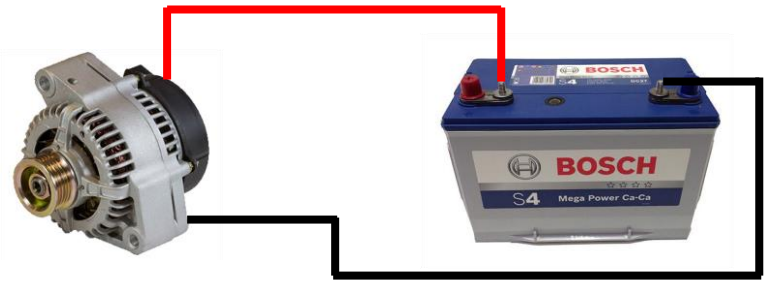


Figure 1 - Standard alternator cabling. The voltage is regulated by the alternator at the alternator output. The battery voltage drops as the current increases.

Externally-sensed alternators and chargers have an additional input to measure the battery voltage *at the battery terminals*, rather than regulating their own output, as shown in Figure 2. This feature ensures that the battery voltage reaches its target by compensating for the voltage drop between the charger or alternator and the battery. This leads to increased charging efficiency. Amongst other advantages, it also allows the seamless and trouble-free integration of charge splitters or blocking diodes as the voltage loss they introduce is taken into account. However, the charging profile is still entirely determined by the internal regulator and may not suit the application.

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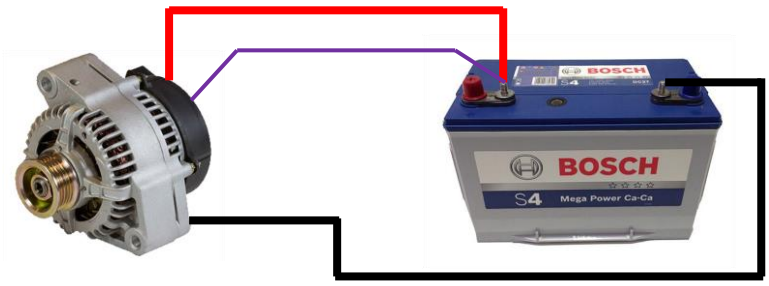


Figure 2 – Externally-sensed alternator cabling. The battery voltage is regulated by the alternator using the voltage obtained from the purple wire. As this wire carries no current, the voltage is accurate.

In Figure 3, a *voltage reference controller* is introduced to manage the alternator by generating the external voltage signal used by the built-in regulator: the controller can make the battery voltage appear either higher or lower than it actually is in order to obtain the desired charging profile. The characteristics of the alternator's built-in regulator are now irrelevant and the charging solution has become entirely programmable.

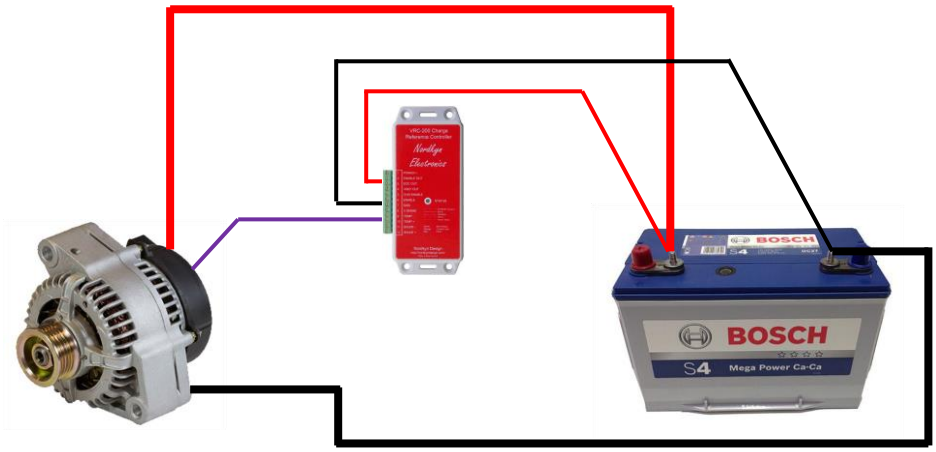


Figure 3 – Externally-sensed alternator cabling. The voltage is regulated by the alternator using the value supplied by the controller through the purple wire. This makes the alternator completely programmable without any alterations.

Using a voltage reference controller and an externally-sensed alternator eliminates the need to dismantle the alternator and remove the built-in regulator. The field polarity is irrelevant, the alternator over-temperature factory protection feature is preserved and it causes no integration problems with the engine's own wiring harness. Should the alternator ever fail, it can be directly replaced with a factory unit without requiring custom alterations before it can be put into service. The VRC-200 controller was designed for an extremely long service life and is much more robust and reliable than a great many of the after-market alternator field current controllers.

When used with chargers or other DC power sources, the VRC-200 controller can create a complete compliant charging solution even with charging devices that cannot be configured to achieve a suitable charge profile. This is often the case with chargers that can only be set for a few preconfigured battery chemistries.

When charging lithium batteries with equipment designed for lead-acid systems, the controller is capable of accurately determining when the battery is full by tracking both the battery voltage and the absorption current. It then creates a charge termination by raising the apparent battery voltage

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and causes the chargers to cut out. The voltage reference signal produced by the VRC-200 can be shared across several charge controllers and/or alternators if desired as long as they all charge the same battery bank.

Charge Control

The VRC-200 controller has two external control inputs: ENABLE and CHG ENABLE. Each input is activated by applying a voltage greater than about 6V to it. The ENABLE input wakes up the controller from standby and the CHG ENABLE input must be active to enable multi-stage charging.

The controller is programmed using five adjustable control parameters listed in Table 1, including separate voltage setpoint for the absorption phase and the holding phase. Note that the use of the term "float" following absorption goes back to the switching regulators days and is incorrect. Modern regulators provide tight regulation and the voltage is no longer allowed to "float".

Parameter	Description	Range Minimum	Range Maximum
V ABSORB	Absorption voltage setpoint	12.0V (24.0V) [1]	15.0V (30.0V) [1]
V HOLD [2]	Holding voltage setpoint	12.0V (24.0V) [1]	15.0V (30.0V) [1]
I TERMINATE	Charge termination current	Zero [3]	(See note 3)
I LIMIT	Current limit	Zero	No limit (disabled)
T ABSORB	Absorption time limit	Zero [4]	12 hours

Table 1 - Adjustable control parameters.

Note 1: The values in parentheses are applicable to operation in 24V nominal systems. Settings outside the permitted voltage range will cause a Setpoint Fault, see section "Fault ".

Note 2: If V HOLD is configured above V ABSORB, its effective value is taken as equal to V ABSORB and the controller effectively operates in two stages only, bulk and absorption/hold at constant voltage.

Note 3: A termination current setpoint of zero means that absorption finishes only when the current becomes non-measurable (shunt voltage falling below 0.15mV) or when the time limit T ABSORB is reached. Conversely, setting the termination current setpoint too high can result in aborting the absorption phase.

Note 4: Setting the absorption time limit to zero results in skipping the absorption phase.

The controller follows a 3-stage charging profile with bulk and absorption before stepping down to a holding voltage, as shown in Figure 4. The stages are detailed in Table 2.

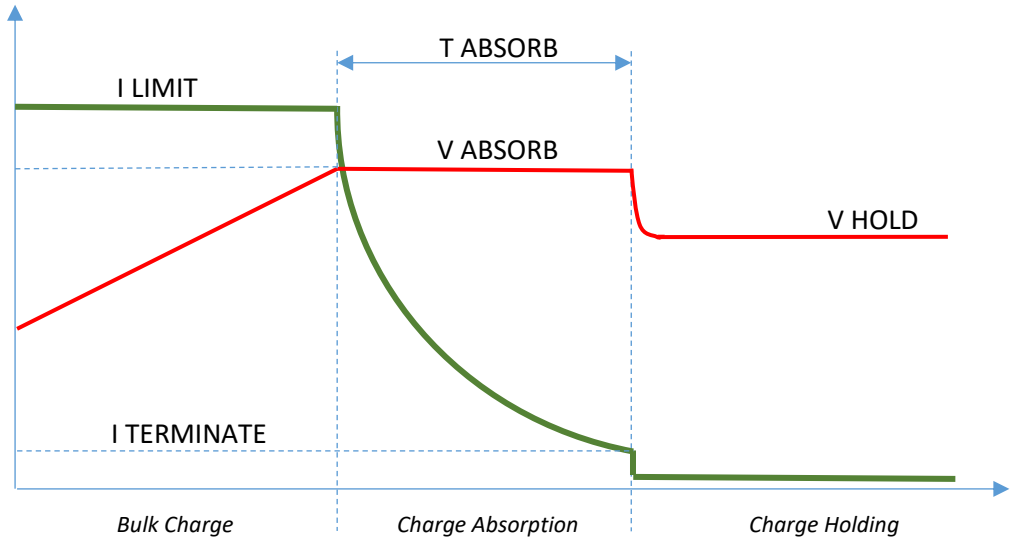


Figure 4 - Charging cycle.

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Charging Stage	Voltage Control	Current Control
Bulk	The battery voltage is allowed to rise until it reaches the absorption limit V ABSORB. The measured current is kept at the maximum allowed or achievable and the voltage depends on the state of charge of the battery. Bulk terminates immediately if the CHG ENABLE input is disabled.	The current is limited by the I LIMIT setting if applicable, to prevent overheating.
Absorption	The controller operates as a voltage limiter at the V ABSORB setpoint. The battery voltage is limited not to exceed V ABSORB until: • The maximum absorption time has elapsed; **or** • The charging current has reduced down to the termination limit, whichever happens first. This condition must be met for at least 30 seconds before it is acted upon to prevent false charge terminations. Absorption terminates immediately if the CHG ENABLE input is disabled.	The controller gradually reduces the current in order to maintain a constant absorption voltage. The current limit remains active if required. If the absorption voltage cannot be maintained with the available current, the controller returns into Bulk.
Hold	The battery voltage is stepped down to the V HOLD setting. If this setpoint is low enough, charging can stop entirely. The controller operates as a voltage limiter at the V HOLD setpoint.	The current is normally very low, but the current limit remains active.

Table 2 - Charging stages.

Charge absorption completes whenever the current reaches I TERMINATE or the T ABSORB duration has elapsed. Both Bulk and Absorption can finish early if the CHG ENABLE input is disabled by external action, see section “Slave Operation with Battery Management Systems (BMS)”.

A new charge cycle is initiated if:

- The battery voltage drops below 12.8V on a 12V nominal system and 25.6V on a 24V nominal system for at least 10 minutes, and the battery voltage is also below the Holding voltage setpoint; or
- If the CHG ENABLE input is switched from inactive to active.

True Alternator Current Limiting

Unlike the many so-called alternator “smart regulators” on the market, the VRC-200 controller is capable of measuring the actual alternator output current and implement true current limiting, independently of the engine speed. This allows true de-rating of stock alternators for continuous operation at high output without overheating issues.

Optimal Charge Termination

Due to its ability to sense battery current, the VRC-200 controller is also capable of terminating the absorption charge once the ability of the battery to accept current has reduced below a configurable

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limit, rather than following a fixed-time absorption period. This feature ensures that batteries are charged as efficiently as possible and never overcharged.

If no connection to a current sensor is provided, or if the absorption time exceeds the maximum duration configured, the absorption phase is terminated at the end of the configured period to prevent damage to the batteries.

Battery Temperature Sensing and Compensation

The optional battery temperature sensor is exclusively intended for use with lead-acid batteries and provides a charging voltage compensation of -20mV/°C for 12V nominal systems and -40mV/°C for 24V nominal systems.

A battery temperature sensor must not be used in conjunction with lithium battery cells as it will result in excessive charging voltages in cold temperatures.

Recharging Deeply Discharged Batteries

A deeply discharged battery can cause the battery voltage to read abnormally low, or even zero, at the start of the charge. The controller cannot distinguish a flat battery from a broken or missing voltage sensing wire, so it must initiate charging even if the battery voltage is not reading to allow recovering from a flat battery. It will however enter a fault state if the battery voltage hasn't reached a minimum of 6V (12V for 24V installations) *within 1 minute of the controller being enabled* in order to protect against charging without a valid battery voltage reading. The controller ENABLE signal must be turned off and on again to clear the fault.

Slave Operation with Battery Management Systems (BMS)

An external battery management solution can, for a number of reasons, decide to disallow battery charging. The CHG ENABLE input is provided for such a purpose. A signal of at least 6V is required for the controller to charge. In the absence of this signal, it will control the battery voltage to the Holding setpoint.

This feature is primarily of interest with lithium battery systems.

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Installation

Controller Overview

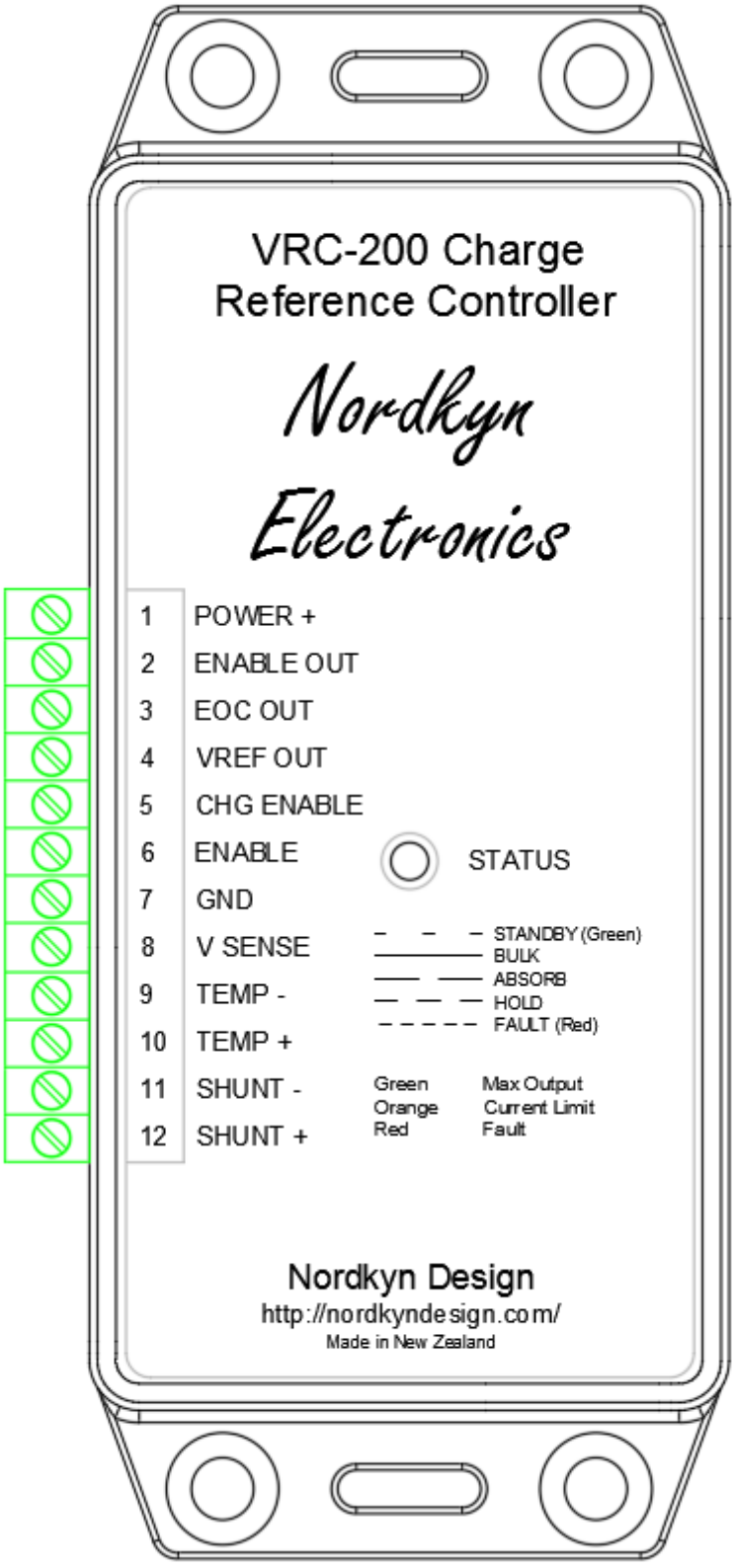


Figure 5 - Controller layout and connection terminals for hardware revision 5 and later (earlier versions have terminal #1 located at the bottom)

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Selecting a Location for the Controller

The controller should be installed in a clean location away from extreme heat, vibrations, moisture, oil and dust. The engine compartment itself is not in general the best environment for electronics, even when fully encapsulated, because they can suffer from the heat and encapsulation makes circuits unrepairable by definition.

Access for in-place adjustment can be useful after installation and the wiring should be led in such a way that the housing can be unfastened. This is easily achieved as all the connections are made on the same side of the enclosure.

Requirements

Common Negative System

Whenever the electrical system contains more than a single battery bank, including banks at different voltages, **there must be a common negative** (or ground) between all the batteries involved in the electrical system associated with the controller. On marine vessels, this typically includes the engine starting battery and engine electrical system and the main battery bank sensed and charged by the controller. In this situation, the controller ENABLE signal typically comes from the starting battery through the engine ignition circuit, while the battery reference voltage originates from the main battery bank.

Failure to establish a common negative can result in unexpected behaviour and operation.

Charging Devices

Typical charging devices used with the VRC-200 controller are alternators, battery chargers and other charge controllers like solar and wind chargers. All charging devices must meet three conditions to be compatible:

1. They must have a battery voltage reference input.
2. They must not draw significant current through the voltage reference input. This condition is nearly always satisfied, because drawing current from the sensing wire would skew the voltage reading and defeat the purpose of having a sensing input.
3. They must stop charging at a voltage no higher than 15.0V (30.0V for 24V nominal systems). This condition is also normally satisfied as such a voltage would damage all common battery types.

An excessive load on the voltage reference output can reduce the reference voltage and, while not damaging to the controller, this condition is detected as an output overload by the controller and can cause it to enter a fault state. Refer to the section “Specifications” for limiting values and measure the current flowing into the voltage reference input with a multimeter if necessary. See also the sections “Status Display” and “Troubleshooting”.

VRC-200 controllers with hardware revision level up to 6 (PCB Rev6) can raise the alternator or charger built-in regulation voltage by a maximum of 0.6V, which is normally sufficient with most fixed setpoint alternators and chargers. Should this be deemed insufficient, this value can be increased to 1.2V by adding a series diode on the voltage reference signal output (VREF OUT).

VRC-200 controllers with hardware revision level 7 and above (PCB Rev7+) can raise the regulation voltage up to 3V above the alternator built-in regulation voltage. This feature was introduced to assist with charging some of the latest lead-acid chemistry variants which can require absorption at higher voltages, charging at very low temperatures and operation at 24V where more voltage headroom is required.

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Alternators

Alternators with built-in regulators and external sensing fall into two broad categories:

1. The regulator delivers a constant voltage. This voltage must be conservative to allow operation over long periods without damaging the battery and the type of battery must also be selected accordingly. This reduces charging efficiency, because the voltage is not as high as it could be during absorption and it may also reduce battery life because the voltage is also higher than it should be once absorption is complete.
2. The regulator implements a simple 2-stage algorithm where a higher voltage is produced for a short period of time after starting, followed by a step-down. These alternators are intended for automotive systems where battery charging is not the primary objective. It is impossible to achieve good charging performance with such alternators alone, because the bulk/absorption phase is too short for charging large banks.

Both types of alternators are perfectly suitable for operation with the VRC-200 controller.

Note: Some internally-sensed alternators can be altered to expose the regulator's voltage reference input. The wiring of the internal regulator varies considerably between alternator models and is beyond the scope of this document, but as long as the regulator uses separate wires to sense the output voltage and source power for the field coil, it is normally possible to extract the voltage reference input and connect it to the VRC-200. An internal regulator must have at least 4 electrical connections (B+, D+, Field and Ground) to be potentially compatible for use with the VRC-200 and the sensing input is then found connected to the B+ terminal.

Battery Chargers and Other Charge Controllers

The VRC-200 controller expects the charger to be capable of maintaining a stable battery voltage. On/off charge control is not suitable for operation with a voltage reference controller; Pulse Width Modulation (PWM) is acceptable.

Battery chargers and other charge controllers must not perform automatic battery equalisation cycles. Many chargers do not perform equalisation. The ones capable of equalising normally require it to be enabled manually because it raises the battery voltage considerably and the process must be supervised, but it is important to ascertain this.

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Electrical Connections

The maximum recommended size for all wiring is 0.75mm^2 (18AWG) tinned wire and the connections must be made tightly. This is a low-power device and heavy cabling not only won't fit in the terminal block, but would also increase prospective fault currents.

The minimum connections required by the regulator depend on the application and are detailed in the table below. Mandatory connections are required for the controller to operate correctly.

Term.	Name	Function	Lead-Acid Battery	Lithium Battery
1	POWER+	Power In +	○ [1]	○ [1]
2	ENABLE OUT	Enable Output		○ [2]
3	EOC OUT	End of Charge Out		
4	VREF OUT	Voltage Ref Out	●	●
5	CHG ENABLE	Charge Enable In	● [3]	●
6	ENABLE	Enable Input	● [3]	●
7	GND	Reference Ground	●	●
8	V SENSE	Battery V Sense +	●	●
9	TEMP-	Temperature -	○	x
10	TEMP+	Temperature +	○	x
11	SHUNT-	Current Shunt -		● [4]
12	SHUNT+	Current Shunt +		● [4]

Table 3 - Minimum required connections by application.

Legend: ● Mandatory connection ○ Recommended connection x Do not use

Note 1: The controller can operate without this connection if ENABLE OUT (2) and EOC OUT (3) are *both unused*, but it will indicate a Power Fault each time when enabled. POWER+ (1) must never be linked to V SENSE (8) if either ENABLE OUT (2) or EOC OUT (3) is used. On engine and alternator systems with a separate starting battery, POWER+ typically comes from the engine electrical system and is *necessary* for operation if V SENSE happens to be connected to a flat battery.

Note 2: This output should cause the charging device to be disabled when not powered.

Note 3: Normally wired together in lead-acid systems.

Note 4: Required to achieve charge termination, unless provided externally through CHG ENABLE (5).

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Description of the Terminals

The following table provides the electrical description of each termination.

Term.	Function	Description
1	**POWER+** Power In +12V or +24V	Main power supply for the controller. This terminal specifically supplies ENABLE OUT (2) and EOC OUT (3). The standby consumption is about 3mA and the maximum current depends on the combined loads on output terminals 2 and 3, but is limited at 1.8A internally by a self-resetting thermal fuse. If left unpowered, the controller will source about 3mA from V SENSE (8) instead. **Connect this supply to a clean, stable power source. Do NOT switch it in conjunction with auxiliary loads.**
2	**ENABLE OUT** Enable Output	This is an output at the voltage supplied to POWER+ (1), active whenever the regulator is functioning normally. It is intended to control a relay enabling the charger or alternator. The combined load on terminals 2 and 3 cannot exceed 1.8A.
3	**EOC OUT** End of Charge Output	This is an output signal typically 0.6V below the controller supply voltage (1) that is active whenever the controller is in the Holding stage. It is short-circuit and reverse-current protected and capable of driving loads of up to 0.7A, including relay coils. The combined load on terminals 2 and 3 cannot exceed 1.8A.
4	**VREF OUT** Voltage Reference Output	This is the variable reference voltage output for the alternator or charger. This terminal directly reflects the battery voltage (bypass) when the controller is inactive. The design load on this output is 5mA and it is protected by a 50mA self-resetting thermal fuse; excessive loading can cause the controller to stop with a Boost Fault. When the controller is inactive, the voltage on this output follows the voltage present on V SENSE (8).
5	**CHG ENABLE** Charge Enable Input	This signal is required to enable 3-stage charging. In most cases, it can be linked with ENABLE (6). A minimum of 6 volts is required to activate it and the load is about 0.2mA. The controller will enter and stay in Holding mode if is this input is not active. It initiates a new charging cycle each time it is activated. This feature is intended for achieving slave operation in conjunction with lithium battery management systems, but can also be used to manually prevent charging or reduce the load on the charging system.
6	**ENABLE** Controller Enable Input	This is the controller activation signal. A minimum of 6 volts is required to take the controller out of standby. It is normally fed by a signal indicating that the power source is enabled (i.e. ignition switch power for example). The load is about 0.2mA. **Operating the alternator or charger without this signal being active will usually lead to the charger or alternator regulating at its own built-in setpoint if it is not being disabled by the ENABLE OUTPUT terminal (2).**
7	**GND** Reference Ground	Reference negative for measuring battery voltage. It must be permanently tied to the negative of the battery being charged. **A good ground connection on GND is essential for reliable operation. Do NOT connect any other wires to this terminal.**

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Term.	Function	Description
8	**V SENSE** Battery Sense +	Battery voltage sensing connection. It should be permanently and directly tied to the positive of the battery being charged. This terminal is the supply for VREF OUT (4). Do NOT connect any other wires to this terminal. This terminal also acts as a backup power supply for the processor and sensing circuitry.
9	**TEMP –** Temperature -	Temperature sensor measurement input. Leave disconnected in the absence of temperature sensor. This terminal is internally connected to GND (7).
10	**TEMP+** Temperature +	Temperature sensor measurement input. Leave disconnected in the absence of temperature sensor. **Do NOT ever apply an external voltage to this terminal as it would likely damage the controller.**
11	**SHUNT –** Current Shunt -	Current measurement shunt negative (charging current "out") connection. It can operate with a high- or low-side shunt.
12	**SHUNT +** Current Shunt +	Current measurement shunt positive (charging current "in") connection. It can operate with a high- or low-side shunt.

Table 4 - Description of the terminals

Current Measurement Shunt

The controller is designed to operate with a current measurement shunt producing a maximum differential voltage signal of 150mV; higher values will not damage the controller, but will be interpreted as equal to 150mV. The recommended shunt sensitivity ranges from 1mV/A down to 0.1mV/A. The reaction time of the current control loop is shorter when a more sensitive shunt is used, but this is normally of little concern as the primary objective is limiting the average current. If the rating of the shunt is unknown, its sensitivity can be measured, refer to the section Instrumented Shunts below. Hall-effect current sensors produce a signal that is incompatible with the current measurement input of the VRC-200.

The controller is capable of reading either a high-side (positive) or a low-side (negative) shunt. Either way, the polarity of the connections is important. The SHUNT+ (12) input must be connected to the side where the current flows *into the shunt during charging*.

Many marine electrical installations already include such a shunt for tracking the state of charge of the battery. Alternatively, a new dedicated shunt for measuring the alternator output can be installed.

The shunt must produce a signal of 0.15mV or more continuously for at least 2 seconds after the controller ENABLE (6) input becomes active in order to be detected as present and used for control. If no current information is going to be provided to the controller, the shunt input terminals 11 and 12 can either be left disconnected or shorted together with a small wire.

Instrumented Shunts

Some systems use so-called "smart" shunts equipped with a signal amplifier and sometimes Bluetooth connectivity. The controller cannot use an amplified output signal; the inputs must be connected to each side of the high-current pass-through element. If the sensing terminals (Kelvin connection) are not accessible, connecting the controller inputs together with the high-current cables will work, but the accuracy may be slightly degraded.

The sensitivity of the shunt element used in such devices is not always published by the manufacturer; In this case it can be measured. For best accuracy, this should be done when the current is high and stable. The sensitivity S of the shunt is defined as the ratio of the shunt voltage signal V_{SHUNT} divided by the current I_{SHUNT} flowing through it.

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Shunt Configuration 1: Battery Current Sensing

A shunt installed on the battery side (locations A or C on the reference wiring diagrams) measures the battery current, which is not automatically equal to the alternator/charger output, unless no other charging sources or loads contribute or consume current. In this configuration, the controller can limit the maximum battery charging current, but it can't strictly limit the alternator or charger output to a maximum value. It can however accurately terminate charge absorption when the battery gets full and the residual charging current drops below the configured limit.

Most battery monitors rely on a shunt in location A. Such an existing shunt can be shared with the alternator controller without issues.

Shunt Configuration 2: Alternator Output Sensing

A shunt installed in the alternator or charger output cable (location B) provides an accurate measurement of the output current in all circumstances, but this doesn't automatically reflect true battery current because loads may consume some of the measured current. In this configuration, the controller is able to effectively limit the alternator or charger current, but it can't reliably detect the end of absorption current threshold and terminate the charge.

Selecting the Shunt Location

On **single alternator, single battery charging systems**, either configuration can be used. Configuration 1 is usually the most desirable as it provides the best charging characteristics and limits the alternator current while charging, but allows maximum output at times.

Systems with multiple alternators charging the same bank, including twin-engine installations, must use configuration 2 if the goal is limiting alternator current at all. If configuration 1 is instead used to obtain accurate charge termination and maximum alternator current is a concern, the alternator(s) may need to be de-rated using a different method. The simplest way of de-rating an alternator and improve its cooling-to-output ratio is inserting a low-value power resistor into its field circuit.

Battery Temperature Sensor

The optional battery temperature sensor should be used for charging lead-acid cells only. In the absence of sensor, no temperature compensation is performed. The sensor has no polarity.

The battery temperature sensor option must not be used with lithium battery cells as it would result in charging voltages harmful to the battery in cold weather.

Charger Enable Output (ENABLE OUT)

The controller attempts to trigger a safe shutdown by powering off the ENABLE OUT output if the battery voltage escapes control or a fault condition is present. In addition to this, it also attempts to raise the VREF OUT output to approximately 15.5V on 12V nominal systems and 31V on 24V nominal systems to cause the charging device(s) to cut out; this is possible as long as the output is not being overloaded or short-circuited.

In the case of alternators, disconnecting the external voltage reference signal can disable charging on some models. This feature can be exploited by using a small relay controlled by the ENABLE OUT (2) output to first make this connection to enable the alternator. If the application requires protection against severe alternator failures, then the relay should instead be used to interrupt the alternator field circuit as this only can guarantee shutdown in all circumstances.

Wiring to allow safe shutdown is good practice with lead-acid batteries to protect both the charger and the batteries in case of failure. It is usually essential when charging lithium battery cells in order to protect against the risk of overcharging, overheating and fire. The relay is normally also connected to the battery management system (BMS) on its negative side. This way the controller can shut down

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the charger/alternator if a malfunction is detected and the BMS can do the same if an unsafe condition is detected at the battery.

End of Charge Output (EOC OUT)

At the end of the charge, or whenever the CHG ENABLE (5) input is inactive, the controller limits the battery voltage to the Holding voltage setpoint and activates EOC OUT (3).

This output is capable of supplying up to 0.7A at the supply voltage present on POWER+ (1) to a load and can be used for a variety of purposes, from shutting down a generator to diverting current to discretionary loads at the end of the charging cycle.

Installation in Mixed 12/24V Systems

There are no issues with integration of the VRC-200 controllers in systems featuring both 12V and 24V battery banks, but **they must share a common negative**. The following aspects are of interest:

- The VRC-200 controller sources power for its own control circuitry either from POWER+ (1) or V SENSE (8). If the voltages are significantly different, the higher voltage source present is used as supply.
- POWER+ (1) supplies ENABLE OUT (2) and EOC OUT (3), so these terminals always operate at the same voltage.
- The voltage on V SENSE (8) is transferred out to VREF OUT (4). This circuit is completely independent of the supply voltage on POWER+ (1), so the voltages do no need to match.
- The activation threshold of the control inputs ENABLE (6) and CHG ENABLE (5) is about 6V regardless of any other considerations. As a result, the VRC-200 can operate with a control voltage different than its configured charging voltage, either higher or lower.

Installation with Electrically Isolated Marine Engines

An electrically isolated engine is one where the engine block is not connected to, or can be disconnected from, the common electrical negative. If a negative cable links the battery to the engine block at all times, as in most installations, the engine is not electrically isolated and this section is not relevant.

The engine can only be fully isolated if its electrical system is connected to the starting battery through a *2-pole isolating switch*, or if a *negative disconnect relay* is used. This type of wiring is typically found on aluminium-hulled vessels only. In this case, care must be taken to ensure that the reference voltage supplied to the alternator doesn't affect the electrical potential of the engine block. This can happen if:

a) The alternator negative is not isolated (common to the alternator body); and
b) The alternator body is also electrically bonded to the engine block.

In this situation, the reference voltage will pass through the alternator regulator to the negative body of the alternator and from there to the engine block.

If a significant voltage can be measured between the batteries common negative and the engine block when the engine is isolated from the starting battery, and this voltage disappears when the alternator voltage reference terminal is disconnected from the battery or the VRC-200, then there is an isolation issue with the alternator negative or between the alternator body and the engine block.

If the negative connection between the engine block and/or alternator and the batteries is not permanent, then the alternator reference voltage input should also be disconnected whenever the negative is disconnected in order to eliminate the possibility of current leakage. This is best achieved by using a small relay powered by the engine electrical system "ignition" signal. The reference voltage is then passed through the normally-open relay contacts. On Volvo Penta EVC engines, the auxiliary

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relay kit Part No. 3594745 can be used to this effect (see also Appendix B - Instructions for Integration in Volvo Penta EVC Engine Monitoring Systems).

Configuration and Adjustment

Adjustment of the control parameters of the unit requires lifting the cover to expose the circuit board after removing the four machine screws holding it in place from underneath. A digital multimeter of reasonable accuracy is necessary.

There are no dangerous voltages or hazards on the board, but components can be physically or electrostatically damaged by contact. Do not interact with it other than for adjusting the setpoint potentiometers.

The controller uses a precision voltage reference and the setpoints can be pre-adjusted on a bench prior to installation by establishing the following connections:

- Terminal GND (7) must be wired to the ground of a 10-30VDC power source;
- Terminals ENABLE (6) and V SENSE (8) must be connected together to the positive supply to power up and enable the controller to allow the adjustment of the setpoints.

Alternatively, the same adjustments can be made with the controller wired in place in its final configuration, see the section “In-Place Adjustments”.

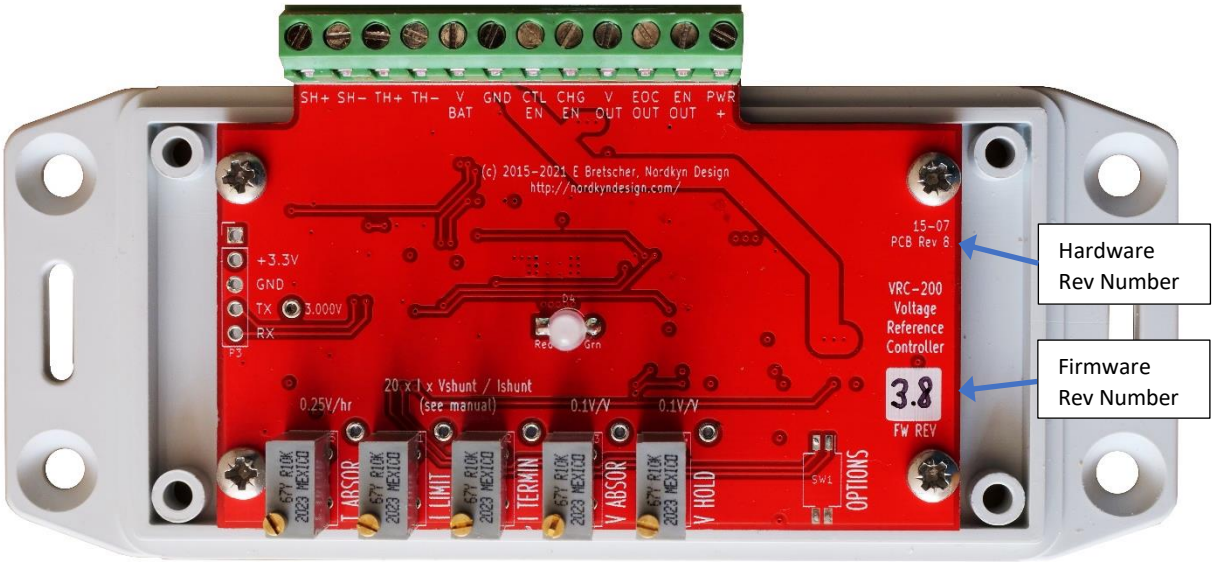


Figure 6 - Internal layout. The five adjustment potentiometers (grey) are visible along the bottom edge of the board.

There are five multi-turn potentiometers for setpoint adjustments on the circuit board and each has a corresponding measurement point located near its upper right corner as shown in Figure 7.

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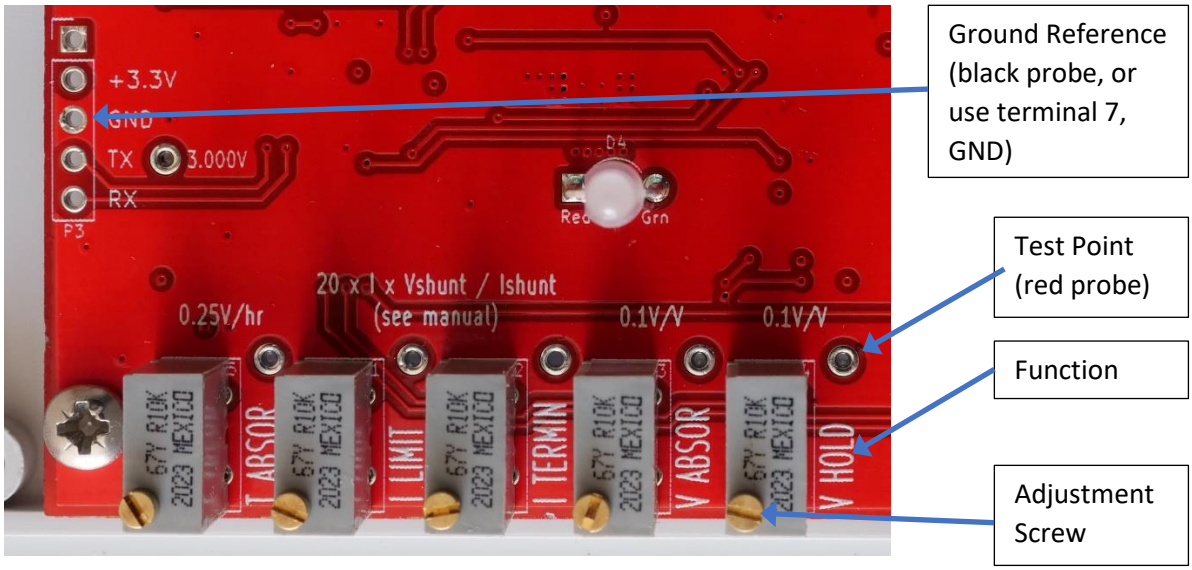


Figure 7 - Setpoint adjustment and measurement points.

Turning the potentiometers clockwise increases the setpoints and anticlockwise reduces them. They slip when reaching the end of their travel, the adjustment screw doesn't stop.

Measurements

Test points for voltage measurements are provided immediately to the right of each one of the five multi-turn potentiometers on the board (positive probe). Measurements must always be made between GND (7) (ground, negative probe) and each of the test points with a multimeter in DC Volts mode on a range able to read values up to 3V. The test voltages are not present until the controller is powered up (terminals 7 and 8) and enabled (terminal 6).

At the maximum of each range, an accurately calibrated multimeter should read 3.000V ±0.1% (2.997V to 3.003V). A test point labelled "3.000V" is also provided for this reference voltage and can be used to check the calibration of the multimeter when the controller is powered and enabled.

Absorption and Holding Voltages

The voltage setpoints configured must be within the valid range of 12-15V for 12V nominal systems and 24-30V for 24V systems, or the controller will display a Setpoint Fault. Note that, by definition, V ABSORB should always be higher than V HOLD; V HOLD will otherwise be taken as equal to V ABSORB by the controller software.

The controller determines whether the installation nominal voltage is 12V or 24V purely based on the values of the charge control setpoints.

The voltage at the corresponding test points should be set to read 1/10th of the desired voltage:

$$V_{TEST} = \frac{V_{SETPOINT}}{10}$$

Examples:

Standard 12V lead-acid battery

Desired absorption voltage 14.4V @ 25°C and holding voltage 13.8V @ 25°C: set V_{ABSORB} test voltage to 14.4 / 10 = 1.440V and V_{HOLD} test voltage to 13.8 / 10 = 1.380V.

Standard 24V lead-acid battery bank

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Desired absorption voltage 28.8V @ 25°C and holding voltage 27.6V @ 25°C: set V_{ABSORB} test voltage to 28.8 / 10 = 2.880V and V_{HOLD} test voltage to 27.6 / 10 = 2.760V.

4-Cell lithium iron phosphate battery

Desired absorption voltage 14.0V and holding voltage 13.3V: set V_{ABSORB} test voltage to 14.0 / 10 = 1.400V and V_{HOLD} test voltage to 13.3 / 10 = 1.330V.

When a battery temperature sensor is connected on terminals TEMP- (9) and TEMP+ (10), the charging voltage setpoints correspond to a nominal temperature of 25°C (77°F). The effective voltage regulation level is lower above this temperature and higher below. The temperature correction is -20mV/°C on 12V nominal installations and -40mV/°C on 24V nominal systems.

Absorption Time Limit

The absorption time limit must be set as 0.25 volts per hour of maximum absorption time:

$$V_{TEST} = \frac{T_{ABSORPTION(HOURS)}}{4} = \frac{T_{ABSORPTION(MIN)}}{240}$$

Example:

30-minute desired maximum absorption time: set T_{ABSORB} test voltage to 30 / 240 = 0.125V.

Current Limit and Charge Termination Current

These settings are dependent on the characteristics of the current measurement shunt. Shunts are rated in terms of maximum current and voltage drop.

Examples:

1. A shunt block stamped 450A and 50mV will produce a measurable signal of 50mV for a current of 450A, or 1mV for a current of 9A flowing through.
2. A smaller shunt rated 200A and 200mV will generate 1mV for each ampere flowing through.

We will refer to these values as I_MAX_{SHUNT} and V_MAX_{SHUNT} below.

The current-related setpoints can be preset using the following relation:

$$V_{TEST} = \frac{20 \times I_{TARGET} \times V_MAX_{SHUNT}}{I_MAX_{SHUNT}}$$

The result is expressed in the same units as the maximum shunt voltage, i.e. either volts or millivolts typically.

Example:

A 200A/50mV shunt block is used to implement a 90A current limit and 8A charge current termination limit: the test voltage for I LIMIT is 20 x 90 x 50 / 200 = 450mV = 0.45V and the test voltage for I TERMINATE is 20 x 8 x 50 / 200 = 40mV = 0.04V.

If the rating of the shunt is unknown, its sensitivity S can be determined from experimental measurements as described in the section *Instrumented Shunts* and the above setpoint formula becomes:

$$V_{TEST} = 20 \times I_{TARGET} \times S$$

If no current measurement shunt is connected, configure I LIMIT to its maximum value of 3.000V and I TERMINATE to its minimum value of 0.000V. These settings can also be used to disable any of the

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limits. The shunt must first produce a value of 0.15mV at the input for at least 2 seconds before the controller begins to use its signal.

In-Place Adjustments

It is possible to adjust the setpoints when the controller is installed and in operation, provided some consideration is given to possible interference from other charging sources. It is also best to carry in-place adjustments with a battery that requires charging, so the operation of the controller is not influenced by the residual current charge termination condition.

The initial setpoints for voltage and current must be established as described in the previous sections "Absorption and Holding Voltages" and "Current Limit and Charge Termination Current".

It must also be remembered that regulation voltages are influenced by temperature when a battery temperature sensor is connected. Momentarily disconnecting the temperature sensor can help with adjusting the regulation voltages for a nominal battery temperature of 25°C. Alternatively, take the actual battery temperature into account.

1. Disconnect all competing charging sources (such as solar panels), so external charging doesn't influence the behaviour of the controller during adjustment.
2. Power up the system to activate the controller.
3. Set the T ABSORB potentiometer to obtain a test voltage reading of 25mV = 0.025V. This will limit the absorption time to about 6 minutes at first.
4. Start the engine or power up the charger and watch the battery voltage climb. It is possible to fine tune the current limit for as long as the LED is solid. When current limiting is active, the LED changes from green to orange.
5. Once the controller enters absorption, the LED goes from solid to blinking slowly and V ABSORB can be fine-tuned as required while measuring the battery voltage.
6. Wait until absorption times out or wind back T ABSORB until the LED begins to blink faster as the controller enters Holding mode.
7. Fine-tune V HOLD as required while measuring the battery voltage. The alternator or charger must be delivering some current in order for V HOLD to be able to be adjusted meaningfully; turning on a moderate electrical load can help.
8. Reset the maximum absorption time T ABSORB to the desired value.
9. Verify operation before reconnecting any external charging sources.

Default Settings

For testing purposes or in order to reset a unit to factory state and a consistent configuration, the following parameters can be used:

Parameter	Test Voltage	Setting
V HOLD	1.330 volts	Holding at 13.3 volts
V ABSORB	1.420 volts	Absorbing at 14.2 volts
I TERMINATE	0.000 volts	No termination current
I LIMIT	3.000 volts (maximum)	No current limit
T ABSORB	0.250 volts	1-hour absorption

Table 5 - Default configuration settings for 12V nominal systems.

Parameter	Test Voltage	Setting
V HOLD	2.660 volts	Holding at 26.6 volts
V ABSORB	2.840 volts	Absorbing at 28.4 volts
I TERMINATE	0.000 volts (minimum)	No termination current
I LIMIT	3.000 volts (maximum)	No current limit
T ABSORB	0.250 volts	1-hour absorption

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Table 6 - Default configuration settings for 24V nominal systems.

These settings are provided for testing purposes or as a starting point prior to further adjustment as they may not be suitable with all types of batteries.

Status Display

Power-Up and Self-Test

The status LED displays the following sequence upon initial power-up only:

1. Green flash, 0.5s – unit is booting up.
2. Temperature sensor diagnostics. Either of the following:
    a. One red flash – no temperature sensor found.
    b. One brief orange flash – battery temperature sensor found.
3. Power supply / ENABLE OUT diagnostics. Either of the following:
    a. Green flash – ENABLE OUT can be controlled.
    b. Red flash – No power on POWER+ or ENABLE OUT is shorted or can't be turned off.
4. Voltage reference output test. The LED turns:
    a. Orange if VREF OUT is close to V SENSE while the controller is passing the battery voltage through; or
    b. Red if VREF OUT appears low, as when an abnormal load is placed on the output.
5. Voltage reference boost test. Either way, the controller then attempts to raise VREF OUT up to about 3V above V SENSE while the LED is on. At the end of the test, the LED turns off and the result is indicated by one flash:
    a. Green flash – The controller was able to boost VREF OUT.
    b. Red flash – The controller failed to boost VREF OUT. If there is no battery voltage present on V SENSE, the test can only fail.

The controller then enters Standby and the status LED remains off until the controller is enabled by supplying voltage to ENABLE.

Controller Enable – Short Test

The controller is normally enabled for operation each time the engine ignition power or the charger is turned on by powering the ENABLE (6) input. The controller begins with performing a short self-test and displays either one of the following diagnostics in this order of priority:

a. Orange flash – VREF OUT output may be overloaded.
b. Red flash – ENABLE OUT cannot be controlled.
c. Green flash – No issues.

Regardless of the result, the controller continues and waits for the voltage to rise on V SENSE. Depending on the initial battery voltage, the status LED can display:

a. Green flash every 3 seconds – battery voltage is detected on V SENSE, waiting for charging to start and the battery voltage to rise.
b. Red flash every 3 seconds – no battery voltage or too low, waiting for charging to start and the battery voltage to rise. If this conditions lasts more than 1 minute, the controller enters a fault state because it is not possible or safe to charge without a valid battery voltage.
c. LED goes directly into a charging mode – the battery voltage is already high (due to prior charging or other charging sources typically).

Charging

During charging, the status LED follows the sequence below according to the charging stages:

1. **Bulk Charge** - LED on, solid.

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2. **Charge Absorption** – long flash, 4s on, 0.5s off.
3. **Charge Holding** – flashing 0.5s on, 0.5s off.

Note that stages can be skipped depending on battery voltage and controller settings. The controller can also return into Bulk from Absorption if the current reduces and the absorption voltage can no longer be maintained.

The colour of the status LED during charging reflects the following information:

- **Green** – normal, maximum output.
- **Orange** – output reduced not to exceed the current limit setpoint.

Fault Codes

The controller can enter a fault state and display a fault code at any time once enabled. Fault codes are characterised by a sequence of red flashes followed by a 2-second pause:

- **2 Red Flashes – Setpoint Fault**. The voltage setpoints are out of range or inconsistent.
- **3 Red Flashes** – **Battery Voltage Fault**. The battery voltage is not reading on V SENSE, failed to rise above a minimum of 6V (12V for 24V installations) within 1 minute of the controller being enabled or failed during charging.
- **4 Red Flashes** – **Boost Fault.** The controller appears unable to reduce the alternator or charger output. The control output VREF OUT (4) appears overloaded.

See the section “Troubleshooting, Fault States” for additional information.

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Troubleshooting

Defect Codes

The controller can indicate two types of defects when enabled for operation through the ENABLE (6) input. The defect code consists of a single LED flash, which is green if no issues are detected.

Output Overload – Orange Flash

If the control output voltage on VREF OUT (4) is about 0.3V or less than the reference voltage supplied on V SENSE (8) while in standby, the controller indicates an output overload. If the overload is modest, the controller may be able to overcome it when increasing the voltage and still control the charging process. If not, it may result in a Boost Fault later and trigger a shutdown.

The charging devices connected to the VREF OUT output should not draw any meaningful current while sensing the voltage. The output is capable of supplying a lot more current than normally required, but the voltage will sag or even collapse completely if it is overloaded.

Proceed by elimination to identify the culprit if necessary.

Power Fault – Red Flash

A Power Fault indicates that the ENABLE OUT (2) output is not responding as expected. The most common scenario is when it cannot be powered up (open-circuit fault) and it has two possible root causes:

- The supply voltage on POWER+ (1) is absent or below about 8V. Remediate as relevant.
- ENABLE OUT is shorted or overloaded. The output is designed to supply no more than 0.7A. Disconnect the load and address the issue.

A Power Fault can also arise if the controller is unable to turn the output off when POWER+ (1) is powered (short-circuit fault). This fault can be caused by supplying power externally into ENABLE OUT (2). If it occurs while ENABLE OUT is disconnected, it suggests a failure of the switch “U9” on the board.

If ENABLE OUT is used by the installation, a Power Fault can either prevent charging altogether (open-circuit fault, fail-safe), or represent a liability in the sense that the controller may not be able to disable the charging device (short-circuit fault). When the controller is in operation and disables ENABLE OUT, it also simultaneously raises VREF OUT to also shut down charging and provide the best mitigation for this risk.

Fault States

The controller can enter three different fault states. While a defect code is only an indication and the controller will attempt to operate anyway afterwards, once in a fault state, it attempts to disable the charging device(s) by simultaneously:

- Turning off the ENABLE OUT (2) output; and
- Raising the VREF OUT voltage to about 15.5V on a 12V nominal system and 31V on a 24V nominal system.

Fault states are characterised by a sequence of two or more red flashes, see “Status Display, Fault ”.

Setpoint Fault

A Setpoint Fault is caused by misconfiguration of the V ABSORD and/or V HOLD setpoints. Both setpoints must lie within the valid range of 12-15V for a 12V nominal installation, or 24-30V for a 24V nominal installation. Refer to the section “Installation with Electrically Isolated Marine Engines

An electrically isolated engine is one where the engine block is not connected to, or can be disconnected from, the common electrical negative. If a negative cable links the battery to the engine

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block at all times, as in most installations, the engine is not electrically isolated and this section is not relevant.

The engine can only be fully isolated if its electrical system is connected to the starting battery through a *2-pole isolating switch*, or if a *negative disconnect relay* is used. This type of wiring is typically found on aluminium-hulled vessels only. In this case, care must be taken to ensure that the reference voltage supplied to the alternator doesn't affect the electrical potential of the engine block. This can happen if:

- The alternator negative is not isolated (common to the alternator body); and
- The alternator body is also electrically bonded to the engine block.

In this situation, the reference voltage will pass through the alternator regulator to the negative body of the alternator and from there to the engine block.

If a significant voltage can be measured between the batteries common negative and the engine block when the engine is isolated from the starting battery, and this voltage disappears when the alternator voltage reference terminal is disconnected from the battery or the VRC-200, then there is an isolation issue with the alternator negative or between the alternator body and the engine block.

If the negative connection between the engine block and/or alternator and the batteries is not permanent, then the alternator reference voltage input should also be disconnected whenever the negative is disconnected in order to eliminate the possibility of current leakage. This is best achieved by using a small relay powered by the engine electrical system "ignition" signal. The reference voltage is then passed through the normally-open relay contacts. On Volvo Penta EVC engines, the auxiliary relay kit Part No. 3594745 can be used to this effect (see also Appendix B - Instructions for Integration in Volvo Penta EVC Engine Monitoring Systems).

Configuration and Adjustment, Absorption and Holding Voltages" for remediation.

In order for a Setpoint Fault to clear, it must disappear for a full minute regardless of its prior duration. Alternatively, disable and re-enable the controller to clear the fault immediately after adjustment.

Battery Voltage Fault

The controller senses the battery voltage by measuring between V SENSE (8) and GND (7). Good, direct connections to the battery being charged are essential for this reason. A Battery Voltage Fault is characterised by a voltage between V SENSE and GND below 6V on a 12V nominal system, or below 12V on a 24V nominal system.

A Battery Voltage Fault is critical because the controller has no means of controlling the process without this information. However, as a low battery voltage can also simply reflect a flat battery and it must be possible to recover from it, the controller behaves differently if the fault is present when it is enabled (possible flat battery), or appears later during charging (broken wire):

- In the presence of a low or absent battery voltage when enabled, the controller enables the charging device and displays one red flash every 3 seconds for 1 minute while waiting for the fault condition to clear. If the battery voltage is still low after this delay, the fault state is entered.
- If the battery voltage becomes invalid for longer than 2 seconds during charging, the controller enters the fault state. The delay ensures that it can ride over short transients such as caused by heavy loads being turned on.

If the condition clears, the controller recovers automatically after a 1-minute delay by returning to Bulk if CHG ENABLE (5) is enabled, or Holding if not.

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Boost Fault

In order to control the charging process, the controller relies on its ability to increase the output voltage on VREF OUT (4) to cause the charging device(s) to cut back or stop. A Boost Fault occurs if the voltage on VREF OUT cannot rise as required and the charging process escapes control. As long as VREF OUT is able to reach its maximum value, the controller does not trigger a Boost Fault. This allow normal operation if another charger takes the battery outside the limits configured for the VRC-200.

The most typical cause of Boost Faults is overloading of the control output VREF OUT (4). The controller should only be supplying a few milliamps at the most into the voltage reference circuit. A persistent Boost Fault when the output is connected suggests a device drawing too much current on its voltage reference input, a short-circuit in the wiring or a failure of the charger/alternator built-in regulator leading to the same outcome.

The integrity of the voltage boosting circuitry can be tested by causing the controller to reboot after disconnecting VREF OUT, see the section “Full Diagnostics”.

A Boost Fault only clears after one minute if the voltage on VREF OUT is able to rise to its target maximum, or at least 3V above V SENSE, or if the battery voltage on V SENSE drops below the recharge threshold of 12.8V on a 12V nominal system and 25.6V on a 24V nominal system, as well as below the Holding voltage setpoint. In this case, ENABLE OUT can be powered up again even if a problem exists on VREF OUT as some charging is preferable to eventually losing all power or the battery.

Note that VREF OUT is protected by a self-resetting thermal fuse which requires time to fully return to normal if tripped. The fuse normally resets within seconds, but a Boost Fault caused by an overload is more likely to repeat itself once it has occurred in the preceding few hours.

Short Diagnostics

Each time each time the controller is activated through its ENABLE (6) input, it completes the short test sequence described under “Status Display, Controller Enable – Short Test”. Powering up ENABLE should immediately produce a green LED flash. An orange flash indicates a possible overload of the control output VREF OUT; refer to the section “Defect Codes, Output Overload”. A red flash indicates an issue with the ENABLE OUT output; refer to the section “Defect Codes, Power Fault”.

Full Diagnostics

The controller executes a more extensive set of diagnostics when booting up. This only happens when first powered up, by opposition with only being enabled for operation through the ENABLE (6) input.

The VRC-200 controller can be forced to reboot by performing the following steps:

1. Disconnect POWER+ (1).
2. Disconnect V SENSE (8).
3. Wait at least 30 seconds.
4. Reconnect V SENSE only to power up the controller again.

Refer to the section “Status Display, Power-Up and Self-Test” for a description of the sequence and diagnostic indications.

Controller Unresponsive

1. Turn the engine ignition on without starting the engine or power up the charger circuit to enable the controller.
2. Check that battery voltage is present between POWER+ (1), or at least V SENSE (8), and GND (7).
3. Check that battery voltage is present between ENABLE (6) and GND (7).

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Remediate if any power supply issues are present, otherwise continue as follow:

1. Check that all batteries involved in the operation of the controller share a common negative connection (see wiring diagrams).
2. Disconnect both POWER+ (1) and V SENSE (8).
3. **Wait at least 30 seconds.**
4. Reconnect either POWER+ (1) or V SENSE (8) cleanly to a 10-30VDC supply and watch the controller boot up. Refer to the section "Status Display, Power-Up and Self-Test" for diagnostics. A poor power-up with transients can prevent the controller from booting up properly. V SENSE (8) should normally remain powered at all times.

Control Stability Issues

Control stability issues, where the current and voltage vary rapidly and fail to stabilise, are typically caused by current and/or voltage measurement problems.

- Disconnect ENABLE (6) and start charging.

If the system is not stable even when the controller is disabled, the issue is mostly related to voltage sensing or the charging system itself and must be rectified:

- Check that all batteries involved in the operation of the controller share a common negative connection (see wiring diagrams).
- Make sure that GND (7) and V SENSE (8) originate from the battery being charged.
- Make sure the nominal battery voltage and the charger/alternator voltage are indeed compatible.

The charging system must operate in a stable manner before it can be controlled by the VRC-200. If the system is stable when the controller is turned off, continue as follow:

- Reconnect ENABLE (6).
- Make sure the voltage regulation setpoints are correct for the voltage of the equipment used.
- Make sure the ENABLE (6) and CHG ENABLE (5) inputs are receiving stable signals.
- Disconnect the shunt input if it is used.
- Start charging.

If the controller becomes unstable only when the shunt is connected, check the sensitivity of the shunt and the setpoints used. It is not feasible for the controller to limit the current down to small values if the shunt is not capable of measuring small currents with some accuracy.

Voltage Control and Operation Issues

The controller stops with a Battery Voltage Fault after 1 minute

- Check that the battery voltage is reading correctly on V SENSE (8), and remediate as required.

The controller enters Holding mode and won't charge

- Check that battery voltage is available between CHG ENABLE (5) and GND (7).
- Check that the battery voltage is below the V ABSORB setpoint.

If either condition is not met, the controller will not initiate charging.

The controller won't stay in Absorption

If the controller appears to operate normally, but switches to Holding mode too early and fails to stay in the absorption phase:

- Check that the T ABSORB setpoint is not too low or near zero.

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- Check that the polarity of the current measurement shunt is not inverted at the SHUNT+ (12) and SHUNT- (11) terminals. Incorrect polarity causes the charging current to read as zero and the battery is then considered as fully absorbed.
- If no shunt is connected, linking the shunt input terminals with a small wire can resolve the issue if the environment contains intense electrical interference.

The controller doesn't appear to operate correctly

- Check that the controller is not being influenced by other charging sources. Other regulators using different voltage settings can cause the controller to skip some charging stages by holding the battery voltage high.
- Check that all batteries involved in the operation of the controller share a common ground connection (see wiring diagrams).

Check the wiring of the control signals:

- Turn the engine ignition or charger circuit on.
- Check that a power supply is present between POWER + (1) and GND (7).
- Check that the battery sensing voltage is present between V SENSE (8) and GND (7).
- Check that the voltage between the enable input ENABLE (6) and GND (7) is at least 6V
- Check that the voltage between CHG ENABLE (5) and GND (7) is at least 6V.

Check all the setpoints and, if needed, reset to the values provided in the section "Configuration and Adjustment, Default Settings". Inconsistent values can cause undesired behaviour.

The alternator has no output in the Bulk stage or won't enter a charging mode after the engine has started

- Check that the controller hasn't entered a Fault Mode, see "Fault States".
- Check that the alternator field circuit is closed if relevant and that D+ (charging light circuit) is powered.
- Check the alternator and installation for failure and other faults by connecting the alternator voltage sensing input directly to the battery instead of VREF OUT (4) to eliminate the VRC-200 controller from the possible causes.

The alternator or charger has no output in Charge Absorption or Charge Holding stage

This can easily happen if the battery voltage is higher than the controller setpoint: in this case the controller won't drive the alternator or charger as the voltage is already higher than mandated. In this case, VREF OUT (4) reads a high voltage, typically 15.5V for 12V nominal systems and 31V for 24V nominal systems.

- Check that the absorption and holding voltage setpoints are not in fact lower than intended.
- Check that other charge controllers are not the cause of high battery voltage.

The alternator or charger output current commonly drop down to zero at the end of the charge when the controller transitions from the absorption to the holding voltage; at this point the battery voltage can take some time to drift down (see also next section "The voltage remains high after the end of the absorption phase").

If none of the above applies, check that the alternator field circuit is closed and that D+ (charging light circuit) is powered.

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The voltage remains high after the end of the absorption phase

- This easily happens with no fault from the controller as the battery voltage tends to float back down following charging up to the absorption voltage. Turning a moderate load on is normally enough to bring the voltage back down for testing purposes.
- Similarly, if the holding voltage is set below the level of a charged battery, the voltage naturally remains above the V HOLD setpoint value and the charger/alternator will shut down until sufficient discharge has taken place.
- Check that other charging sources are not holding the voltage up.
- If the V HOLD setpoint has been configured at or above the value of V ABSORB, the controller naturally regulates the voltage at V ABSORB indefinitely. This can be of interest in non-charging applications, but it is otherwise a misconfiguration and V HOLD should be reduced.

Current Sensor

The current sensor appears not to be working

- Check the polarity of the connection, swap the shunt input wires around on the SHUNT+ (12) and SHUNT- (11) connections if needed.
- The shunt block is not sensitive enough. The measured current must be meaningful in relation with the measurement range of the shunt. Consider replacing the shunt or using a dedicated alternator output shunt and remember that the shunt must produce a minimum of 0.15mV in order to be detected and then used for control.

Temperature Sensor

The temperature sensor is detected continuously during operation and its readings must remain valid at all times for the controller to use it.

In doubt, refer to the section “Full Diagnostics” to check the sensor. The sensor resistance can also be checked directly with a multimeter against the typical values below:

Temperature		**Resistance**
(°C)	**(°F)**	**(Ω)**
1.5	34.7	2996
4.8	40.6	2943
8.1	46.6	2884
11.4	52.5	2818
14.7	58.5	2746
18.0	64.4	2668
21.3	70.3	2583
24.6	76.3	2493
27.9	82.2	2397
31.2	88.2	2297
34.5	94.1	2193
37.8	100.0	2087
41.1	106.0	1978

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Specifications

Parameter	Value
Dimensions	
Length	125mm
Width, including terminal block	58mm
Height	25mm
Mass	
Stand-alone VRC-200	80g

The following table contains the electrical absolute maximum ratings and operating values for each terminal. Absolute maximum ratings only reflect limit values that will not cause damage.

Parameter	Absolute Maximum	Operating Values (12V Systems)	Operating Values (24V Systems)
General			
Nominal system voltage		12V	24V
Alternator / Charger			
Maximum built-in regulation voltage (VREG) [1]		15V	30V
Controller			
Voltage regulation, minimum [2]		12V	24V
Voltage regulation, maximum			
Rev 6 and earlier devices [3]		VREG + 0.5V	VREG + 0.5V
Rev 7 and later devices		VREG + 3.0V	VREG + 3.0V
Standby power consumption (1+8, 7)		3mA	3mA
POWER+ (1), voltage	45V	10-15V	10-30V
POWER+ (1), current	4.5A limited	0-3A	0-3A
V SENSE (8)	50V	0-15V	0-30V
CHG ENABLE (5)	70V	> 6V	> 6V
ENABLE (6)	70V	> 6V	> 6V
Differential shunt voltage (11, 12)	±80V	0-150mV	0-150mV
Common mode shunt voltage (11, 12)	-6V to 90V	-4 to 80V	-4 to 80V
VREF OUT (4), current	50mA protected	< 10mA	< 10mA
VREF OUT (4), voltage	33V clamped	0-15.5V	0-31V
ENABLE OUT (2), voltage	100V protected	POWER+	POWER+
ENABLE OUT (2), current	2.2A limited	1.5A	1.5A
EOC OUT (3), voltage	100V protected	(POWER+) - 0.5V	(POWER+) - 0.5V
EOC OUT (3), current	2.2A limited	1.5A	1.5A
TEMP+ (10), voltage			
Rev 6 and earlier devices	50V	3.3V	3.3V
Rev 7 and later devices	6V	3.3V	3.3V
TEMP- (9), current	100mA	<0.5mA	<0.5mA

Note 1: The 15V limit for 12V systems arises from the limit applied by the controller software on VREF OUT. Contact the manufacturer for special requirements.

Note 2: This limit is determined by the minimum configurable setpoints. Contact the manufacturer for special requirements.

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Note 3: This figure can be increased by another 0.5V by inserting a series diode in the VREF OUT output. This is permissible only as long as VREG < VREF OUT_{MAX} – 0.5V.

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Appendix A - Instructions for Connection to Mitsubishi A003TR0091ZT / A003TR0093ZT Alternators

These externally-sensed 14V/115A alternators are found on most of the current Volvo Penta D-Series diesel engines. They regulate at 14.3V with no step changes and include thermal protection by current fold-back.

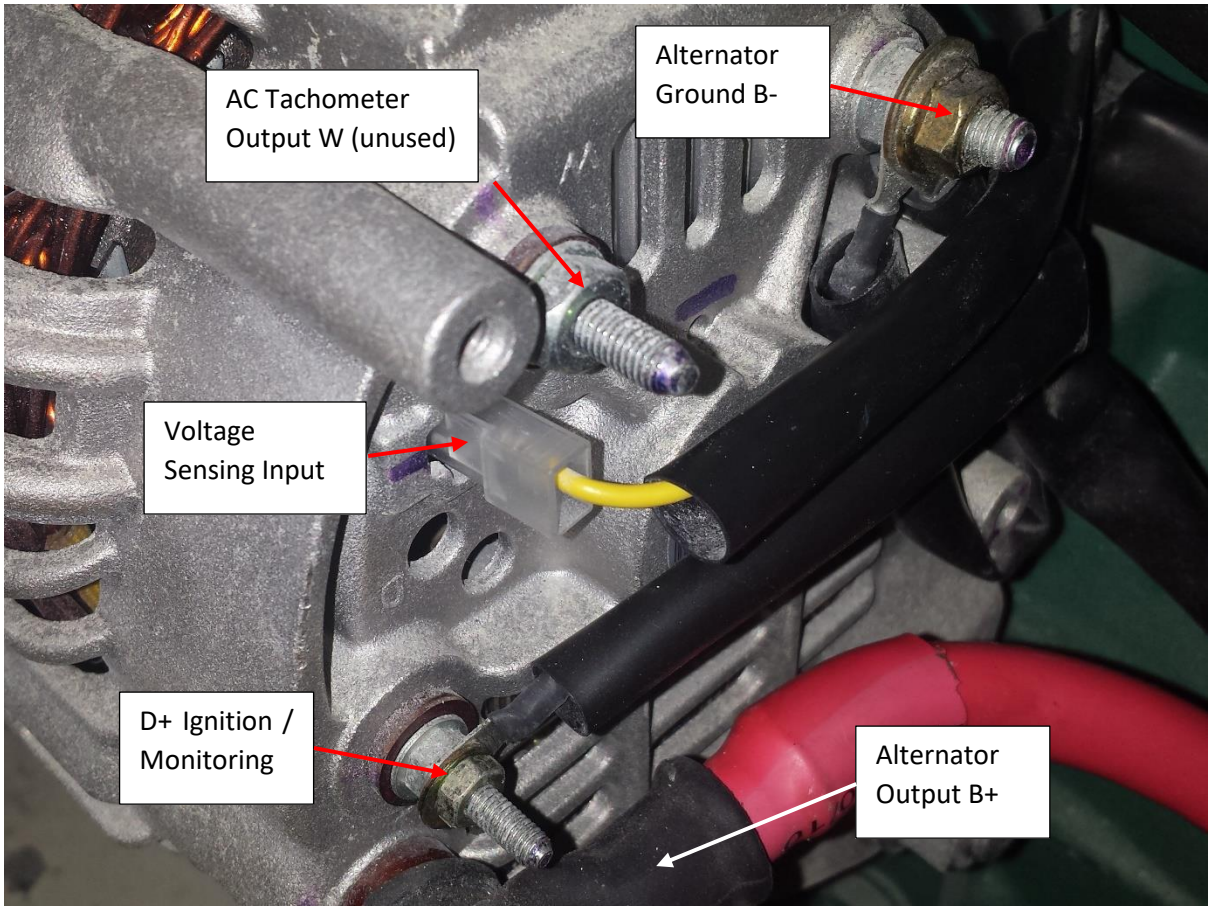


Figure 8 - Rear view of the Mitsubishi A003TR0091ZT on a standard Volvo Penta D-series diesel engine

Alternator Connection

Voltage Reference Terminal

The rear of the alternator features a recessed ¼'' flat-blade terminal for voltage sensing. On Volvo Penta engines, it is commonly factory-connected to a yellow wire equipped with an insulated push-on terminal coming from the starter motor solenoid positive supply post. This arrangement may be modified during engine installation to source the sensing voltage directly from the battery instead.

A new wire must be run from the VRC-200 controller VREF OUT (4) terminal to this voltage sensing input at the back of the alternator. The original yellow wire can be either discarded or extended to feed the POWER + (1) terminal. In this case, a tidy solution is running a 2-core cable from the alternator back to the VRC-200 controller, terminated with male and female ¼'' flat blade terminals at the alternator end. This way, POWER+ is fed by the engine electrical system and turned off altogether if the engine starting battery is isolated.

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Appendix B - Instructions for Integration in Volvo Penta EVC Engine Monitoring Systems

Volvo Penta D-Series engines feature the EVC engine management system, which monitors the operation of the alternator. The absence of an “ignition” power switch and the characteristics of the alternator management require following these specific guidelines for connection as well as to avoid spurious alternator failure alarms.

ENABLE / CHG ENABLE Input Connections

Ignition power for ENABLE (6), and commonly CHG ENABLE (5) as well, can be sourced from the engine electrical system one of several ways. The additional load placed on the engine electrical system by this connection is insignificant.

Wiring Option #1

A 6-core Volvo Multilink cable (Figure 11) connects the tachometer gauge to the engine monitoring/management module. Additional gauges are daisy-chained from the tachometer using a 3-wire interface, normally colour-coded red/blue/yellow, and sealed automotive connectors. The last, unused connector in the chain is capped.

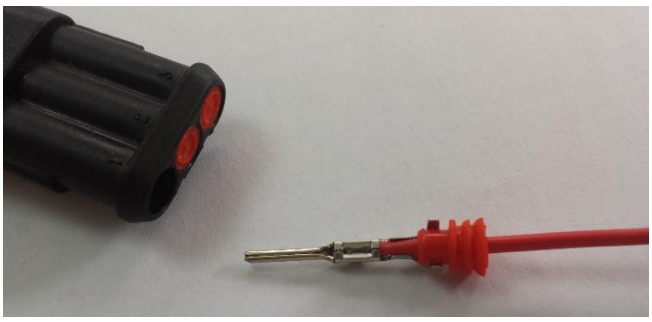


Figure 9 - End cap on Volvo Penta EVC gauge daisy chain wiring and installation of the new pin.

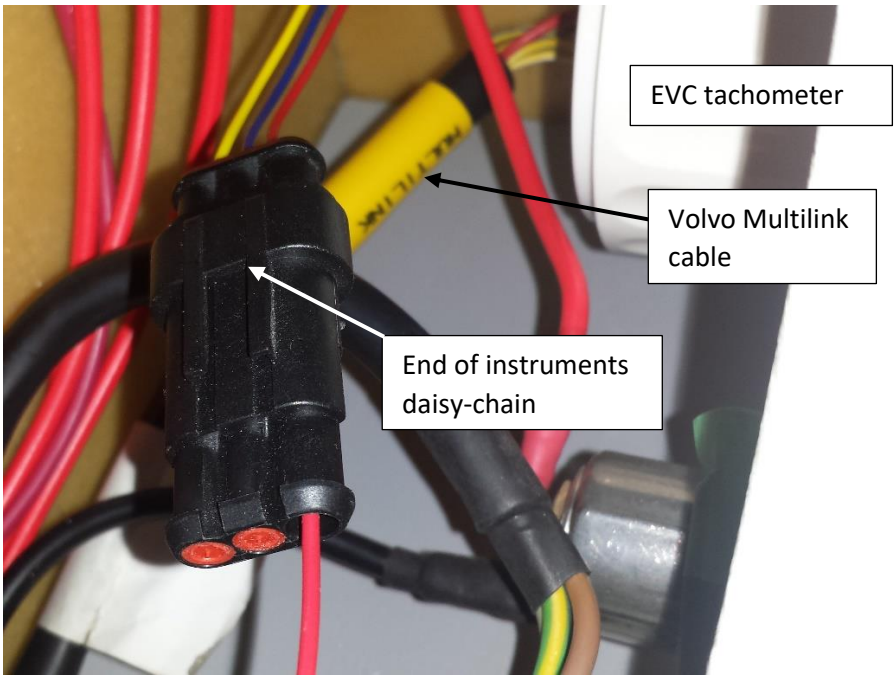


Figure 10 – Plugging into the end of the Volvo instruments daisy chain wiring.

A simple and tidy way of obtaining an “engine ignition” signal on these Volvo Penta EVC systems is plugging into the red core (pin #1) at the end of the gauges daisy-chain cabling. The cap is a 3-way TE-

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Connectivity AMP Superseal 1.5-Series male connector, which protects the last plug. It is only a matter of inserting a new pin into position #1 through the existing rubber wire seal (Figure 9 and Figure 10). The necessary pin is supplied with the controller. Sometimes the engine instrumentation can be located too far away to make this option attractive.

Wiring Option #2

Plug the Volvo Penta accessory relay kit Part No. 3594745 in the Multilink cable and use the relay contact to create a signal that is on when engine power is on. The relay coil is connected between pin #4 (negative) and pin #6 (engine power) of the Multilink plug.

Wiring Option #3

Tap directly into the 6-core Volvo Multilink cable between the engine monitoring/management module and the tachometer. “Ignition” power can be found on the red wire connected to pin #6 of the connectors whenever the engine electrical system is turned on. The pin reference numbers are embossed on the rear edges of the plugs.



Figure 11 – Tapping into the Multilink cable harness: splice into core #6 (red)

This requires splicing into the wire and insulating the connection afterwards. The Multilink cable contains the above red core, a black core (negative) and two yellow twisted pairs (CANbus data). The black outer cover of the cable is easily sliced open and then the red core can be cut and reconnected with an additional wire.

On some installations where the dash instrumentation is located far from the engine, this method keeps the controller installation local to the engine area without requiring running a new wire all the way back from the gauges.

POWER+ Connection

On conventional engine electrical hook-ups, the supply for POWER+ (1) can normally be sourced from the ignition circuit, with POWER+ (1) and ENABLE (6) being powered together.

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In the case of the Volvo Penta EVC systems where the controller ENABLE (6) signal has been sourced from the gauges supply, it is imperative to connect POWER+ (1) to the engine starting battery circuit breaker instead in order to avoid placing any additional load on the gauges circuit.

Regulation Voltage Considerations

On Volvo Penta EVC systems, the engine management module monitors the operation of the alternator by sensing the voltage available on the D+ terminal (see Figure 8). Alternator failure alarms can be experienced if the engine electrical system voltage falls below about 13.4V while the alternator is idle on early EVC systems. Some recent engines tolerate voltages down to 13.0V before alarming. The system also alarms if the engine system voltage reaches 15.0V or more.

On single-engine installations where the operation of the charge controller impacts the voltage of the engine starting battery, no spurious alarms due to low voltage will occur as long as the voltage regulation setpoints are configured at or above the threshold of the alternator failure alarm. This is not normally a restriction for charge control with lead-acid batteries. High charging voltage alarms can occur at high currents when the charging current is routed through

If the battery voltage in Holding mode needs to be regulated below the EVC alternator alarm threshold by the VRC-200 controller, two solutions exist:

1. Feed about 15V into the alternator D+ terminal whenever the controller is in Holding mode to fool the EVC in believing the alternator is under load. This is easily achieved by powering a small regulated DC/DC boost converter from the controller EOC OUT (3) terminal. EOC OUT is only enabled at the end of the charge and is protected both against overloads and current back-feeding. The converter should be able to handle up to 1A to ensure its rating exceeds the current capability of the EOC OUT output.
2. Use the EOC OUT output of the VRC-200 controller to start a small DC/DC charger operating from the main battery bank to the engine starting battery to keep its voltage up when the alternator is idle. This typically requires the use of a relay or solid state switch.

For dual-engine systems (i.e. catamarans for example) charging a common battery bank, refer also to the section “Dual-Engine Installations (Catamarans)”.

Cabling Considerations

On stock Volvo Penta engines, the alternator output terminal B+ is linked to the starter motor solenoid supply post with a short and relatively small red wire. As a result, the charging current reaches the starting battery through the starter motor cables. This can be undesirable for two reasons:

1. If the battery sensed and charged by the VRC-200 controller is not the starting battery, it is essential that the alternator output is fed to that battery as directly as possible.
2. An excessive voltage drop between the engine and the battery positive terminal can cause the EVC system to alarm on high voltage when charging batteries like AGMs with a high absorption setpoint using the VRC-200 controller.

For the reasons above, it is recommended to replace the original wire with a dedicated heavy cable running from the alternator B+ terminal to the battery sensed by the VRC-200 controller. It is also very important that the negative cable connecting the batteries to the engine block is heavy enough not to induce a meaningful voltage drop, as it needs to carry the alternator current. Alternatively, another dedicated cable can be run from the alternator B- post to the battery common negative.

In all other cases, the battery cables between the engine and the battery must be of a sufficient size not to induce a noticeable voltage drop when carrying the full alternator current of up to 115A.

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Voltage-Sensitive Relays (VSRs)

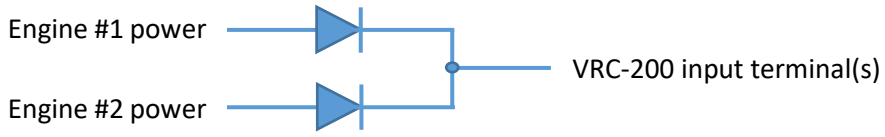
We recommend using charge splitters (diodes or FETs) rather than voltage-sensitive relays (VSRs). If any VSR is used at all, then the current charging the battery sensed by the VRC-200 controller must *not* flow from the engine starting battery through the VSR. VSRs commonly induce an undesirable additional voltage drop which can raise the engine system voltage enough to cause EVC high voltage alarms. If a VSR is present, it should always charge the engine starting battery *from* the bank sensed by the VRC-200 controller.

Dual-Engine Installations (Catamarans)

Dual-engine installations with Volvo Penta EVC engines are common in catamarans and require special attention due to the characteristics of the Volvo alternator management. A typical configuration is where each engine charges its own starting battery as well as a larger common battery bank using charge splitters (diodes or FETs) at the alternator outputs, or VSRs.

If one VRC-200 controller is used with each engine and alternator, matching the setpoints is very desirable, but one controller will still inevitably switch from Absorption to Holding mode before the other. The engine still charging will then finish the task with the side-effect of keeping the other engine's alternator idle for a time. This can result in the voltage on the engine no longer charging to sag below the alternator failure alarm threshold of the EVC monitoring system, because its battery is momentarily no longer being supplied any current. Several options are available to resolve the interaction problem between the alternators:

1. Split each alternator output 3-way, so each alternator charges both engine starting batteries as well as the main battery bank. This arrangement provides maximum redundancy as it can even tolerate an alternator failure without loss of functionality.
2. Share a common VRC-200 controller between both engines. In this case, the controller must be able to operate with either or both engines. To this effect, diodes must be used to supply POWER+ (1), ENABLE (6) and CHG ENABLE (5) (unless the latter comes from a BMS) while keeping each engine electrical system isolated from the other. A very common suitable diode for this purpose is type 1N4004, for currents of up to 1A. The VREF OUT (4) output connects directly to both alternator sensing inputs in parallel.



Note that if the Holding voltage setpoint is below the EVC alarming threshold, the considerations discussed under "Regulation Voltage Considerations" still apply because the EVC monitoring system will alarm once both alternators are operating in Holding mode and one of the mitigations offered will need to be implemented.

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