

SEALITHIUM ALTERNATOR CHARGE REFERENCE CONTROLLER MANUAL

Installation & Setup Manual

Advanced Charge Controller for Externally Sensed Alternators

The use of a Charge Reference Controller eliminates the need to disassemble and modify the alternator as it pilots the unit's built-in regulator instead of replacing it.

Nordkyn Design, New Zealand
support@nordkyndesign.com

Table of Contents

Introduction 4
Overview 4
Key Features and Benefits 4
Principle of Operation 4
Advanced Features 4
True Current Limiting 4
Optimal Charge Termination 5
Alternator Temperature Sensing 5
Battery Temperature Sensing 5
Operation 5
Charge Control 5
Control Parameters 6
Installation 7
Controller Overview 7
Prerequisites 8
Common Negative System 8
Alternator 8
Selecting a Location for the Controller 8
Electrical Connections 9
Description of the Terminals 10
Ancillary Devices 11
Safe Alternator Shutdown Relay 11
Current Sensor 11
Battery Temperature Sensor 12
Alternator Temperature Sensor 12
Configuration and Adjustment 12
Pre-Adjustment Procedures 14
Minimum Wiring 14
Measurements 14
Absorption and Holding Voltages 14
Absorption Time 14
Current Limit and Charge Termination Current 14
Recommended In-Place Adjustment Sequence 15
Default Settings 16
Status Display 16

© 2015-2019 Eric Bretscher, Nordkyn Design

Power-Up 16
Controller Enable – Self-Test 16
Charging 17
Fault States 17
Troubleshooting 17
General 17
The controller appears unresponsive 17
The controller enters a fault state immediately after ignition power is applied 17
The controller doesn't appear to operate correctly 18
The alternator has no output in Bulk stage or won't exit Standby after the engine has started 19
The alternator has no output in Charge Absorption or Charge Holding stage 19
The voltage remains high after the end of the absorption phase 19
Current Sensor 20
The current sensor appears not to be working 20
Temperature Sensor 20
Electrical Specifications 21
Appendix A - Instructions for Connection to Mitsubishi A003TR0093ZT Alternators 22
Alternator Connection 22
Voltage Reference Terminal 22
Appendix B - Instructions for Integration in Volvo Penta EVC Engine Monitoring Systems 23
Controller Charge Enable Input Signal (B8) 23
Preferred Option 23
Alternative Option 24
Controller Power Supply (A2) 24
Regulation Voltages 24

© 2015-2019 Eric Bretscher, Nordkyn Design

Introduction

This controller was specifically designed to operate in conjunction with modern stock marine alternators featuring a voltage regulation sensing input.

Those have become very common with the release of the Volvo Penta Compact Series of marine diesel engines, so if you happen to own one of them, this controller is the solution of choice to implement advanced alternator control and charge regulation.

It can of course be used with other externally-sensed alternators, as long as they meet the electrical compatibility specification provided in this document.

While this controller was intently designed for charging lithium battery cells, it can equally well charge all types of lead-acid batteries: flooded, SLA, AGM or gel.

Overview

Key Features and Benefits

This controller has many advantages over so-called alternator "smart regulators":

- Works with a stock alternator: no need to disassemble the alternator and no need to remove the existing built-in regulator
- No spurious alarms and integration issues with the engine electronic monitoring system
- Fastest charge rates, without ever overcharging
- Designed for charging lithium cells as well as all types of lead-acid batteries
- Capable of monitoring battery charge current as well as voltage
- True charge absorption termination on low current
- True current limiting
- Thermal management of the alternator
- No computer or complex instrumentation needed for setup

Principle of Operation

Externally-sensed alternators use an additional input terminal to measure true battery voltage, rather than regulating their own output.

This feature is very beneficial as it allows to compensate for voltage drop between the alternator and the battery. Amongst other advantages, it allows the seamless and trouble-free integration of charge splitters or blocking diodes.

A *charge reference controller* manages the alternator by altering this voltage signal used by the alternator's built-in regulator. As a result, there is no need to dismantle the alternator and remove the built-in regulator, no need to deal with field polarity issues and no integration problems with the engine's own wiring harness.

Should the alternator ever need to be replaced, it can be directly replaced with a factory unit without requiring custom alterations before it can be put into service.

Advanced Features

True Current Limiting

Unlike the many so-called alternator "smart regulators" on the market, this controller is capable of measuring the actual current and implement true current limiting, independently of the engine speed.

© 2015-2019 Eric Bretscher, Nordkyn Design

This allows true de-rating of stock alternators for continuous operation at high output without overheating issues.

Optimal Charge Termination

The controller is also capable of terminating the absorption charge once the ability of the battery to accept current has reduced below a configurable limit, rather than blindly following a fixed-time absorption period. This feature ensures that batteries are charged as efficiently as possible and never overcharged.

If no current sensor connection is provided, or if the absorption time reaches its preset maximum duration, absorption is terminated to prevent possible damage to the batteries.

Alternator Temperature Sensing

The optional installation of an alternator temperature sensor can allow the controller to reduce the alternator output to improve cooling above a temperature threshold of 120°C (250°F). It is primarily of interest with lithium batteries when no current sensor is available; setting the current limit to match the continuous rating of the alternator is a usually better pathway as it also stabilises the output.

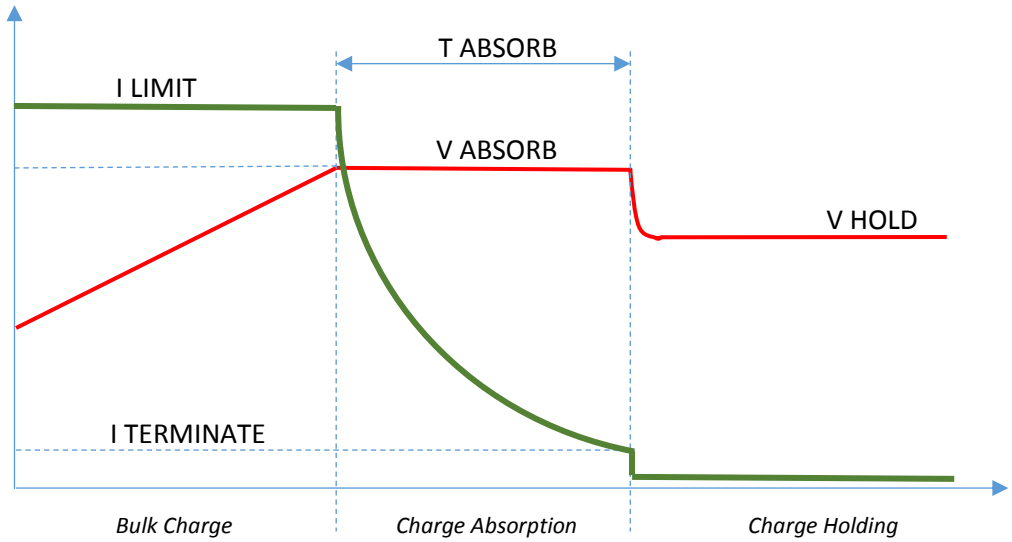
Battery Temperature Sensing

The optional battery temperature sensor is exclusively intended for use with lead-acid batteries and provides a charging voltage compensation of -20mV/°C. Fitting a temperature sensor to a lithium battery will result in damaging it in cold temperatures.

Operation

Charge Control

The controller can deliver a charging profile including up to 3 stages.



Charge absorption completes whenever the current reaches I TERMINATE or T ABSORB has elapsed.

© 2015-2019 Eric Bretscher, Nordkyn Design

Charging Stage	Voltage Control	Current Control
Bulk	The battery voltage is allowed to rise until it reaches the absorption limit V ABSORB. The alternator output is kept at the maximum allowed or achievable and the voltage depends on the state of charge of the battery. The controller only acts as a limiter.	The current can be limited by the I LIMIT setting, or by the alternator temperature sensor, if present, to prevent overheating.
Absorption	The battery voltage is maintained constant at V ABSORB until: • The maximum absorption time has elapsed; **or** • The charging current has reduced down to the termination limit, whichever happens first. The controller operates as a voltage limiter.	The controller gradually tapers the current down in order to maintain the absorption voltage. The current and alternator temperature limits remain active if required.
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 regulator.	The current is normally very low, but current and alternator temperature limits remain active.

Control Parameters

The following five control parameters are available to define the operation of the controller:

Parameter	Description	Range min	Range Max
V HOLD	Holding voltage setpoint	Zero (see note 1)	V ABSORB (limited)
V ABSORB	Absorption voltage setpoint	Zero (see note 1)	Alternator reg + 0.6V
I TERMINATE	Charge termination current	Zero (see note 2)	(See note 3)
I LIMIT	Current limit	Zero (see note 4)	No limit
T ABSORB	Absorption time limit	Zero (see note 5)	180 minutes (3 hours)

Note 1: the controller is able to lower the alternator's built-in regulation voltage by about 3 volts. Too low a setting will cause a fault.

Note 2: A termination current setpoint of zero means that absorption finishes when the time limit T ABSORB is reached.

Note 3: Setting the termination current setpoint too high can result in aborting the absorption phase.

Note 4: An unrealistically low current limit value (such as a few amps only) can cause fluctuations in the alternator output as the sensitivity to voltage becomes too high.

Note 5: Setting the absorption time to zero results in skipping the absorption phase.

© 2015-2019 Eric Bretscher, Nordkyn Design

Installation

Controller Overview

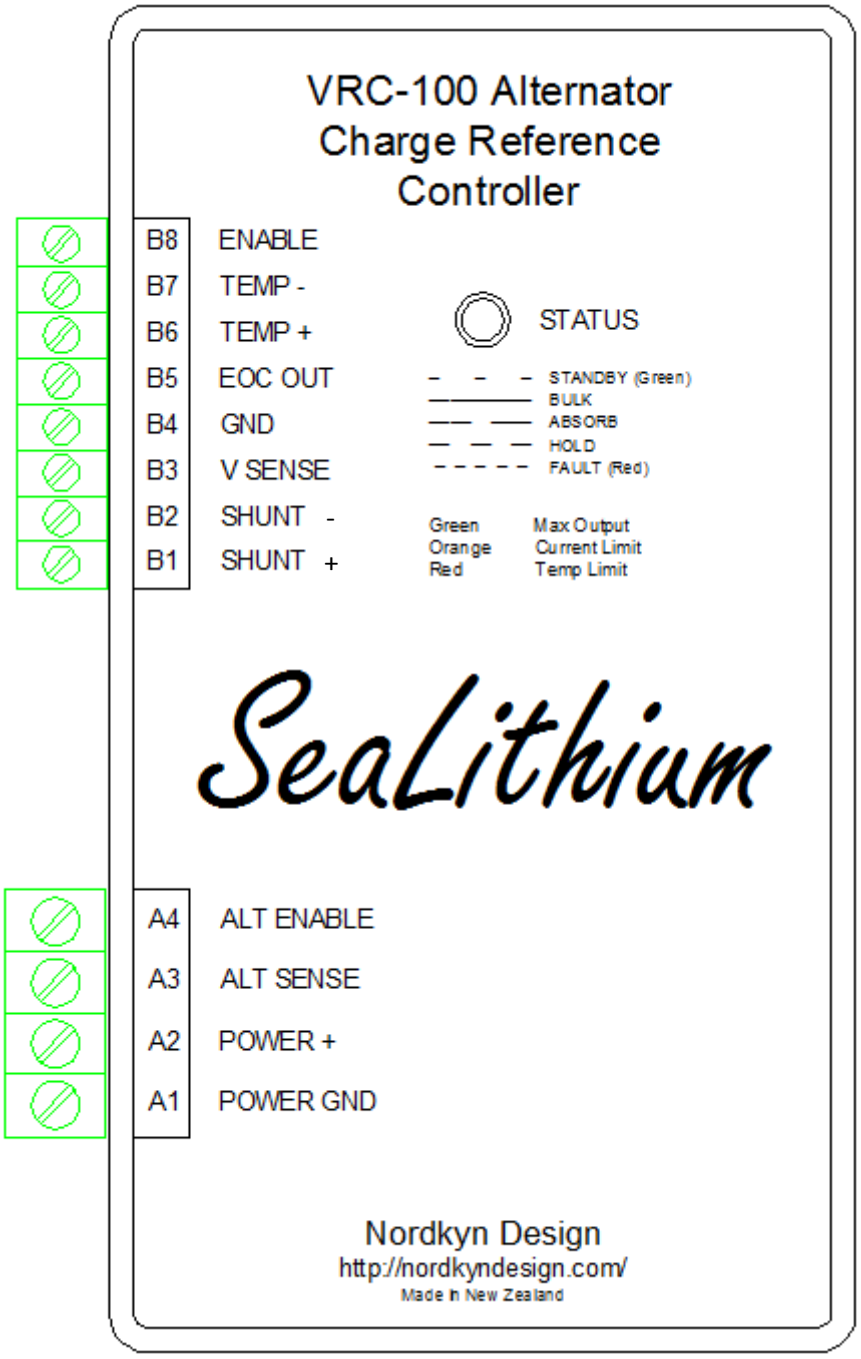


Figure 1 - Controller layout and connection terminals

© 2015-2019 Eric Bretscher, Nordkyn Design

Prerequisites

Common Negative System

Whenever the electrical system includes more than a single battery bank, **there must be a common ground** (or negative) between the engine starting battery and electrical system and the battery bank sensed and charged by the controller.

WARNING: Failure to establish a common negative can result in malfunction or damage to the controller not covered by the warranty!

Alternator

The alternator must have a built-in regulator featuring an external voltage sensing input in order to be compatible with this unit. Some internally-sensed alternators can be altered to expose the regulator's reference input. This varies considerably between alternator models and is beyond the scope of this document.

In order to operate properly with this unit, the alternator may not draw significant current from its voltage reference input. Excessive load is treated as a fault by the controller. Refer to the section Electrical Specifications for limit values.

By design, the controller can only raise the alternator's built-in regulation voltage by 0.6V, which is normally sufficient for most fixed setpoint alternators and provides a natural secondary protection level for the battery.

In the unlikely situation that this would prove insufficient, contact the manufacturer for instructions to increase this value.

The maximum charging voltage *reduction* the controller can provide is about 16V minus the internal regulator's setpoint value.

Always assess the characteristics and operation of an unknown alternator before using it.

Selecting a Location for the Controller

The controller should be installed in a clean location away from extreme vibrations, moisture, oil, dust and the heat of the engine.

The engine compartment itself is not in general a good environment for electronics unless fully encapsulated, in which case they still suffer from the heat and become by definition unrepairable.

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

© 2015-2019 Eric Bretscher, Nordkyn Design

Electrical Connections

We recommend using tinned wire for all wiring and all connections must be made tightly.

The connections required by the regulator depend on the application and are detailed in the table below. Mandatory connections must always be established, either to ensure correct operation, prevent damage to the regulator or provide the safety level required.

- Basic functionality represents the minimum configuration for safe operation
- Extended functionality adds useful application-dependent features

		Lead-Acid Battery		Lithium Battery	
Term.	Function	Basic functionality	Extended functionality	Basic functionality	Extended functionality
A1	Power Ground	●	●	●	●
A2	Power In +12V	●	●	●	●
A3	Alt Sense Out	●	●	●	●
A4	Alt Enable Out	○	○	●	●
B1	Current Shunt +		○	○	○
B2	Current Shunt -		○	○	○
B3	Battery Sense +	●	●	●	●
B4	Logic Ground	●	●	●	●
B5	End of Charge Out				
B6	Temperature +		○		○
B7	Temperature -		○		○
B8	Charge Enable In	●	●	●	●

Legend: ● Mandatory connection ○ Recommended connection

© 2015-2019 Eric Bretscher, Nordkyn Design

Description of the Terminals

The following table provides the electrical description of each termination.

Term.	Function	Description
A1	Power Ground	Negative connection for the power section of the controller. It must be connected to the electrical system's common negative whenever there is power to the engine electrical system. It can be disconnected when the engine battery switch is off.
A2	Power In +12V	Main power supply for the controller. It must be connected to a +12V supply whenever there is power to the engine electrical system, such as ignition power. It is however acceptable to connect it to the engine starting battery switch. The standby current is about 1mA, and consumption is about 40mA in operation.
A3	Alt Sense Output	This is the variable reference voltage output for the alternator. There is no voltage on this terminal when the controller is inactive. The design load on this output is 5mA; excessive loads can cause the controller to fault and stop.
A4	Alt Enable Output	This is a +12V output, active whenever the regulator is functioning normally. It is intended to power a field connection relay, which is a critical safety feature if charging lithium cells. It is intended to supply no more than 2A and overload-protected internally.
B1	Current Shunt +	Current measurement shunt positive (charge current "in") connection. It can operate with a high- or low-side shunt.
B2	Current Shunt -	Current measurement shunt negative (charge current "out") connection. It can operate with a high- or low-side shunt.
B3	Battery Sense +	Battery voltage sensing connection. It should be permanently tied to the positive of the battery being charged. The maximum load is about 1mA.
B4	Logic Ground	Reference negative for measuring battery voltage. It must be permanently tied to the negative of the battery being charged. A good ground connection at B4 is essential for reliable operation. Do not connect B4 to A1.
B5	End of Charge Output	This is a "3.3V logic level" output signal that becomes active after the controller reaches Hold stage. It has an impedance of about 100Ω. This signal is intended to control approved devices only. It is short-circuit protected, but not immune to excessive input currents and must never be connected to any supply. It can directly drive a bare indicator LED against ground.
B6	Temperature +	Temperature sensor supply. Leave disconnected in the absence of temperature sensor. This terminal must never be connected to any supply or the controller is likely to be destroyed.
B7	Temperature -	Temperature sensor voltage sensing input. Leave disconnected in the absence of temperature sensor. This terminal must never be connected to any supply or the controller is likely to be destroyed.
B8	Charge Enable Input	This is the controller activation signal. It must be connected to a supply of at least 4 volts whenever the engine electrical system is live (i.e. ignition switch power). The load is about 0.2mA. **Running the engine without this signal being active can lead to battery overvoltage if no field disconnect relay has been installed.**

© 2015-2019 Eric Bretscher, Nordkyn Design

Ancillary Devices

Safe Alternator Shutdown Relay

Inserting a relay in the alternator field circuit is recommended as it guarantees shutdown even in the event of a severe alternator failure.

The controller triggers a safe shutdown if the battery voltage escapes control. Wiring to allow safe shutdown is recommended with lead-acid batteries to protect both the alternator and the batteries in case of alternator failure.

It is usually essential when charging lithium battery cells in order to protect against the risk of overheating and fire if the alternator fails. The relay is normally also connected to the battery management system (BMS) on its negative side.

Safe shutdown operates by interrupting the power supply to the external relay and opening the alternator field circuit.

Current Sensor

The controller is designed to read a current measurement shunt. Many marine electrical installations feature 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 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 + input must be connected to the side where the current flows *into the shunt during charging*.

If no current information is going to be provided to the controller, terminals B1 and B2 can either be left disconnected or shorted together with a small wire.

Configuration 1: Battery Current Sensing

A shunt installed on the battery side (locations A or C on the reference wiring diagram) measures the battery current, which is not automatically equal to the alternator output unless no other charging sources or loads contribute or consume current. In this configuration, the controller can only limit the alternator output not to exceed a maximum battery charging current, but it can't strictly limit the alternator 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.

This is the most common configuration as it is used by battery monitors with a shunt found in location A. Such an existing shunt can be shared with the alternator controller without issues.

Configuration 2: Alternator Output Sensing

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

Selecting the Most Suitable 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. The use of an alternator temperature sensor provides additional current control capability in the event of occasional peak (like running a heavy load while also charging at maximum current).

© 2015-2019 Eric Bretscher, Nordkyn Design

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, the alternator(s) may need to be de-rated using a different method. The use of an alternator temperature sensor can be useful to keep the alternator within an acceptable operating envelope, but this does not provide the level of regulation obtained with current sensing and should not be used as the primary mechanism for reducing the alternator output.

The best way of de-rating an alternator and improve its cooling-to-output ratio is inserting a 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.

Connection of a battery temperature sensor with a lithium battery would result in damaging the battery in cold weather.

The sensor has no polarity. It is electrically different than the alternator temperature sensor and the controller recognises which sensor is connected.

Alternator Temperature Sensor

The optional alternator temperature sensor is primarily intended to be used when charging lithium cells. An alternator temperature sensor is most useful if no battery current sensor is available, the current limit is not configured not to exceed the continuous output capability of the alternator, or if the current shunt can't always measure the full alternator output (shunt installed in battery current sensing configuration).

The sensor has no polarity. It is electrically different than the battery temperature sensor and the controller recognises which sensor is connected.

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 needed for setting up the controller.

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.

© 2015-2019 Eric Bretscher, Nordkyn Design

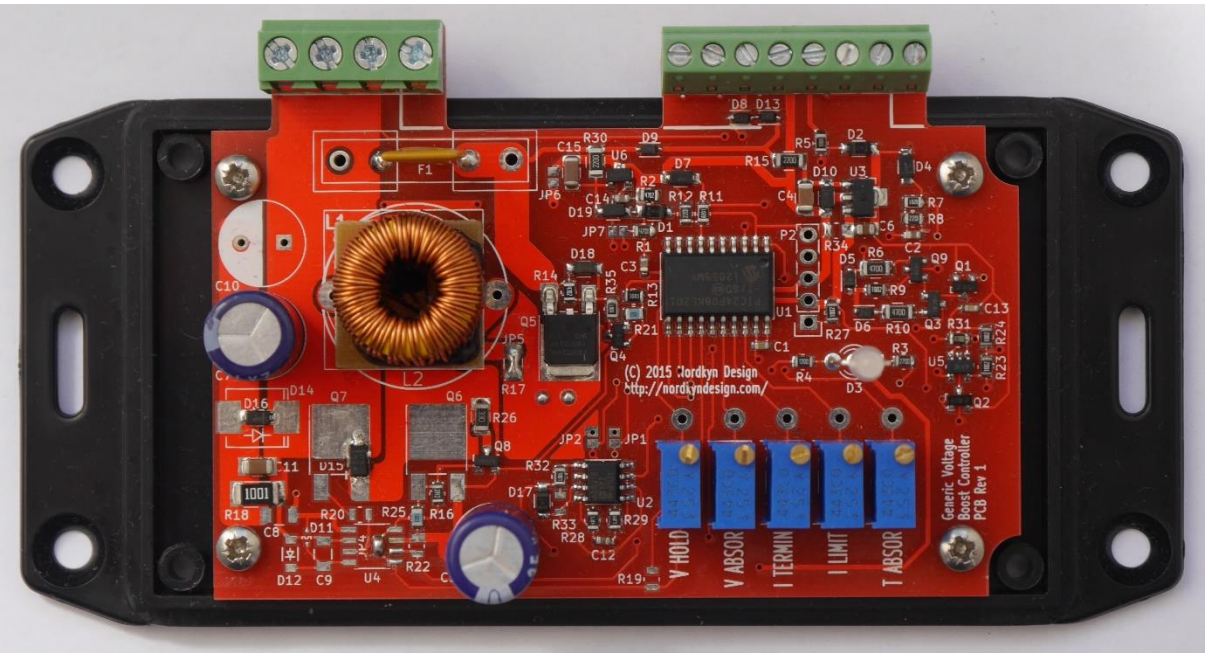
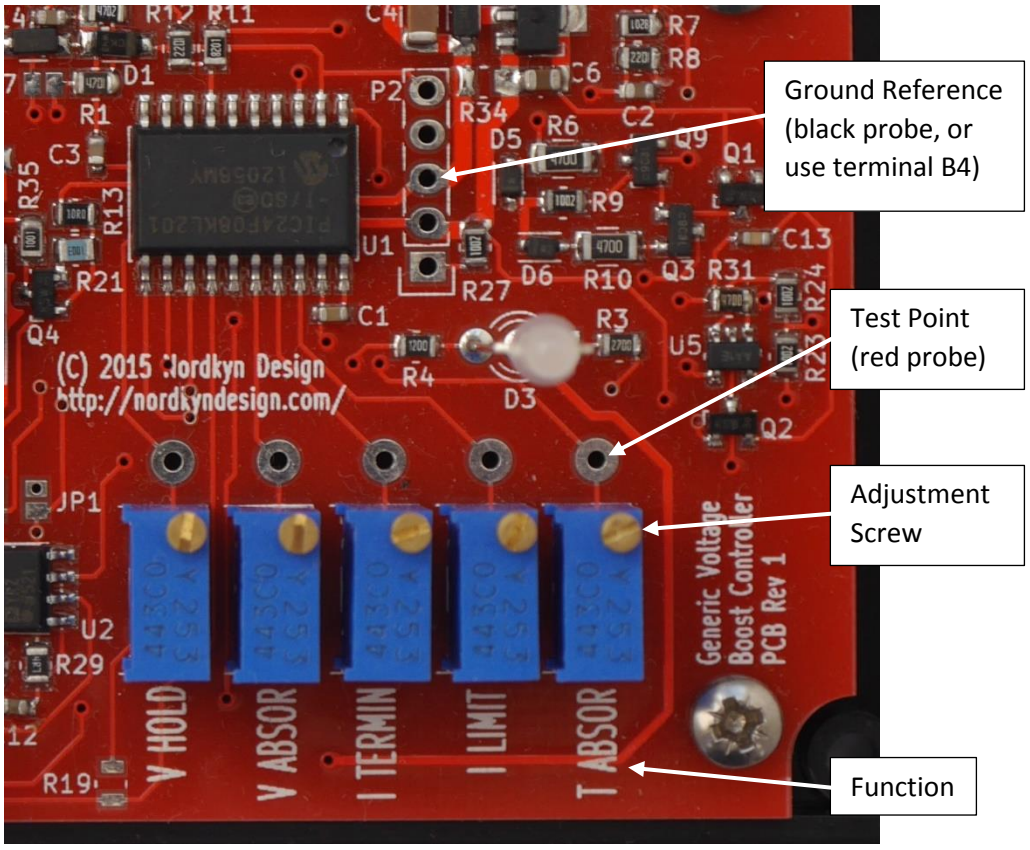


Figure 2 - Internal layout. The five adjustment potentiometers (blue) are visible in the lower right quadrant.

There are five adjustment potentiometers on the circuit board and each have a corresponding test point located immediately above.



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

© 2015-2019 Eric Bretscher, Nordkyn Design

Pre-Adjustment Procedures

Minimum Wiring

The controller can be preset while wired as per the installation instructions for the application considered; connection to the alternator is optional for pre-adjustment.

At the minimum, if the unit is being pre-adjusted on the bench, connections to the terminals A1, A2, B4 and B8 must be made: A1 and B4 must be wired together to the ground of a 12V power source; A2 and B8 must connected together to +12V approximately.

Measurements

Test points for voltage measurement are provided above each one of the five multi-turn potentiometers on the board (positive probe). Measurements must always be made between terminal B4 (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 3.5 volts. The test voltages are not valid until the controller is powered up and enabled for charging (terminal B8).

When pre-adjusting the unit on an actual engine installation, **do not use** terminal A1 (power ground) as measurement ground reference (negative probe) as this would lead to skewed readings.

Absorption and Holding Voltages

The voltage at the corresponding test points should be set to read:

$$V_{TEST} = \frac{V_{SETPOINT}}{4.848}$$

Examples:

Standard 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 / 4.848 = 2.970V and V_{HOLD} test voltage to 13.8 / 4.848 = 2.847V.

Lithium iron phosphate battery

Desired absorption voltage 14.0V and holding voltage 13.3V: set V_{ABSORB} test voltage to 14.0 / 4.848 = 2.888V and V_{HOLD} test voltage to 13.3 / 4.848 = 2.743V.

Absorption Time

The absorption time is best set by calculation:

$$V_{TEST} = \frac{T_{ABSORPTION(MIN)}}{60}$$

This simply equates to 1 volt per hour of absorption time.

Example:

30-minute desired absorption time: set T_{ABSORB} test voltage to 30 / 60 = 0.500V.

It is suggested to initially set the absorption time to a few minutes to facilitate final check and adjustment of the absorption and holding voltages. A test voltage of 50mV is normally adequate as initial preset before adjusting V HOLD.

Current Limit and Charge Termination Current

Those are dependent on the characteristics of the current measurement shunt. Shunt are rated in terms of maximum current and voltage drop.

© 2015-2019 Eric Bretscher, Nordkyn Design

Examples:

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

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

The current values 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.

Recommended In-Place Adjustment Sequence

In order to facilitate adjustment of the unit, the following process is recommended. It must be read in conjunction with the previous section covering pre-adjustment procedures.

It must be remembered that regulation voltages are influenced by temperature when a battery temperature sensor is connected. The effective regulation voltage is reduced by 0.02V for each 1°C temperature increase. Disconnect the temperature sensor if adjusting the regulation voltages for the nominal battery temperature of 25°C or take the battery temperature into account: for example, at 15°C, the regulation voltages would be 0.2V higher than configured.

1. Disconnect all competing charging sources (such as solar panels), so external charging doesn't influence the behaviour of the controller during adjustment.
2. Wind the I TERMINATE potentiometer to its minimum to disable residual current based charge termination.
3. If a current shunt is connected and current limiting is desired, set the I LIMIT potentiometer as per the pre-adjustment procedure. A good starting value is 80% of the alternator rating. If no shunt is connected or the alternator can be allowed to reach full output, set I LIMIT to its maximum value.
4. Set the T ABSORB potentiometer to obtain a test voltage reading of 80mV (see pre-adjustment procedures below). This will limit the absorption time to about 5 minutes at first.
5. Set V HOLD and V ABSORB as per the pre-adjustment procedures below. Note that, by definition, V ABSORB must always be higher than V HOLD, otherwise V HOLD will be taken as equal to V ABSORB by the controller software.
6. Start the engine and watch the battery voltage climb and stabilise close to the preset value for V ABSORB. At this point, the LED goes from solid to blinking slowly. Fine-tune V ABSORB as required while measuring the battery voltage.
7. Wait a few minutes or wind back T ABSORB until the LED begins to blink faster as absorption is terminated.
8. Turn a moderate electrical load on in order to bring the voltage back down to V HOLD more readily and maintain some alternator output.
9. Fine-tune V HOLD as required while measuring the battery voltage. The alternator must be producing some current in order for V HOLD to be able to be adjusted meaningfully.

© 2015-2019 Eric Bretscher, Nordkyn Design

10. Set the T ABSORB potentiometer as per the pre-adjustment procedure to obtain the desired absorption time.
11. If a current shunt is connected only, set I TERMINATE as per the pre-adjustment procedure to obtain charge termination at the desired current level.
12. 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	2.743 volts	Holding at 13.3 volts
V ABSORB	2.929 volts	Absorbing at 14.2 volts
I TERMINATE	0.000 volts	No termination current
I LIMIT	3.300 volts (maximum)	No current limit
T ABSORB	0.500 volts	30-minute absorption

These settings are provided for testing purposes or as a starting point prior to further adjustment as they may not be suitable with the type of battery being charged.

Status Display

Power-Up

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 brief orange flash – battery temperature sensor found
    b. Two brief orange flashes at 0.5s interval – alternator temperature sensor found
    c. One red flash – no temperature sensor found

The status LED remains off after power up until operation of the controller is enabled through terminal B8.

Controller Enable – Self-Test

The controller is normally enabled for operation each time the engine ignition power is turned on, before the engine is started.

The controller performs a self-test:

1. Orange flash, 0.75s – unit is running self-test
2. Self-test diagnostics. Either of the following:
    a. LED turns green for 0.25s – test passed.
    b. LED flashes a fault state in red (see further).

Following a successful test, the controller waits for the engine to start. Depending on the battery voltage, the status LED can display:

1. Green flash every 3 seconds – waiting for the engine to start and the battery voltage to rise.
2. LED goes directly into a charge mode – the battery voltage is already high (due to prior charging or other charging sources typically).

© 2015-2019 Eric Bretscher, Nordkyn Design

Charging

During charging, the status LED follows the sequence below according to the charging stages. Note that stages can be skipped depending on battery voltage and controller settings:

1. **Bulk Charge** - LED on, solid.
2. **Charge Absorption** – long flash, 4s on, 0.5s off while voltage limiting, otherwise LED on solid.
3. **Charge Holding** – flashing 0.5s on, 0.5s off.

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.
- **Red** – limiting output current to control overheating.

Fault States

The controller can jump into a fault state at any time once enabled for charging:

- **Power Fault** – LED red, slow blink 2s on, 0.1s off. There is no power to operate the controller on A2, or the alternator enable output A4 is overloaded.
- **Boost fault** – LED red, fast blink 0.5s on, 0.1s off. The control voltage signal supplied to the alternator is too low, the alternator control output A3 appears overloaded.

Fault states only clear once the controller is disabled. This normally requires turning the engine ignition power off and on again.

Troubleshooting

General

The controller appears unresponsive

- Turn the engine ignition circuit on without starting the engine.
- Check that battery voltage is present between A1 and A2.
- Check that battery voltage is present between B4 and B3.

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

- Check that all batteries involved in the operation of the controller share a common negative connection (see wiring diagrams).
- Disconnect the outputs A3 and A4, the temperature sensor (B6 and B7) and current sensor (B1 and B2), the Controller Enable signal B8 and the output B5 (if used), in order to rule out any external disturbances.
- Disconnect the power supply input A2 and voltage sensing input B3 to power down the unit completely. *This leaves only the ground connections on A1 and B4 attached to the unit.*
- Wait 30 seconds.
- Reconnect A2 sharply to a good 12V battery voltage supply and watch the controller boot up. Refer to the section Status Display, Power-Up for diagnostics. A poor power-up with transients can prevent the controller from starting properly. The first power supplied to the unit through either A2 or B3 must be switched on cleanly and power on B3 should normally remain available at all times.

The controller enters a fault state immediately after ignition power is applied

- Check that power is available between A1 and A2 at least as soon as the engine ignition circuit is turned on.

© 2015-2019 Eric Bretscher, Nordkyn Design

Remediate if necessary. If the problem persists:

- Turn the engine ignition circuit off.
- Disconnect terminals A3 and A4.
- Turn the engine ignition circuit back on and watch the self-test sequence. Refer to the section Status Display, Controller Enable – Self-Test for diagnostics.
- If the controller passes its self-test, there must be a short circuit or overload on either output A3 or A4.

Power Fault

A power fault indicates that no voltage can be found on terminal A4.

- Power must be supplied from terminal A2 in order to be able to be transferred to terminal A4, so battery voltage must be present between A1 and A2.
- A short-circuit or overload on terminal A4 is a cause for a power fault.

Loads present on terminal A4 should not exceed 1A.

Boost Fault

The most common cause of boost faults is overloading of the alternator control output A3. The controller should only be supplying a few milliamps into the voltage reference circuit.

A persistent boost fault when the alternator is connected can indicate an alternator drawing too much current on its voltage reference input, a short-circuit in the wiring to the alternator or a failure of the alternator built-in regulator leading to the same outcome.

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).
- Turn the engine ignition circuit on without starting the engine.
- Check that battery voltage is present between A1 and A2 (power supply).
- Check that battery voltage is present between B4 and B3 (voltage sensing)
- Check that battery voltage is available between B4 and B8 (controller enable).

Check all voltage settings and if needed, reset to the values provided in section Configuration and Adjustment, Recommended In-Place Adjustment Sequence

In order to facilitate adjustment of the unit, the following process is recommended. It must be read in conjunction with the previous section covering pre-adjustment procedures.

It must be remembered that regulation voltages are influenced by temperature when a battery temperature sensor is connected. The effective regulation voltage is reduced by 0.02V for each 1°C temperature increase. Disconnect the temperature sensor if adjusting the regulation voltages for the nominal battery temperature of 25°C or take the battery temperature into account: for example, at 15°C, the regulation voltages would be 0.2V higher than configured.

13. Disconnect all competing charging sources (such as solar panels), so external charging doesn't influence the behaviour of the controller during adjustment.
14. Wind the I TERMINATE potentiometer to its minimum to disable residual current based charge termination.

© 2015-2019 Eric Bretscher, Nordkyn Design

15. If a current shunt is connected and current limiting is desired, set the I LIMIT potentiometer as per the pre-adjustment procedure. A good starting value is 80% of the alternator rating. If no shunt is connected or the alternator can be allowed to reach full output, set I LIMIT to its maximum value.
16. Set the T ABSORB potentiometer to obtain a test voltage reading of 80mV (see pre-adjustment procedures below). This will limit the absorption time to about 5 minutes at first.
17. Set V HOLD and V ABSORB as per the pre-adjustment procedures below. Note that, by definition, V ABSORB must always be higher than V HOLD, otherwise V HOLD will be taken as equal to V ABSORB by the controller software.
18. Start the engine and watch the battery voltage climb and stabilise close to the preset value for V ABSORB. At this point, the LED goes from solid to blinking slowly. Fine-tune V ABSORB as required while measuring the battery voltage.
19. Wait a few minutes or wind back T ABSORB until the LED begins to blink faster as absorption is terminated.
20. Turn a moderate electrical load on in order to bring the voltage back down to V HOLD more readily and maintain some alternator output.
21. Fine-tune V HOLD as required while measuring the battery voltage. The alternator must be producing some current in order for V HOLD to be able to be adjusted meaningfully.
22. Set the T ABSORB potentiometer as per the pre-adjustment procedure to obtain the desired absorption time.
23. If a current shunt is connected only, set I TERMINATE as per the pre-adjustment procedure to obtain charge termination at the desired current level.
24. Verify operation before reconnecting any external charging sources.

- Default Settings. Inconsistent values can cause unexpected behaviour.

The alternator has no output in Bulk stage or won't exit Standby after the engine has started

- Check that the controller hasn't entered a fault mode.
- Check that the alternator field circuit is closed 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 A3.

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

This can easily happen if the battery voltage happens to be higher than the controller setpoint: in this case the controller won't drive the alternator as the voltage is already higher than required. In this case, A3 (sensing voltage output) reads a high voltage, typically about 16V.

- 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 output can commonly drop down to zero when the controller transitions from absorption to holding voltage; at this point the battery voltage can take some time to drift down (see also next section).

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

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.

© 2015-2019 Eric Bretscher, Nordkyn Design

- Similarly, if the holding voltage is set below the level of a charged battery, the alternator can shut down until sufficient discharge has occurred and the voltage naturally remains above the V HOLD setpoint value.
- Check that other charge controllers are not holding the voltage up.
- If the V HOLD setpoint has been adjusted above the value of V ABSORB, the controller naturally maintains 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 if needed.
- The shunt block is not sensitive enough. The alternator current must be meaningful in relation with the measurement range of the shunt. Consider replacing the shunt or using a dedicated alternator output shunt.

Temperature Sensor

Two versions of temperature sensors can be used with this controller. The temperature sensor is detected at boot-up.

- Disconnect the voltage reference signal B3 and the power input A2 and wait for 10 seconds.
- Reconnect A2 and watch the unit boot up. Refer to the section Status Display, Power-Up for diagnostics. If the sensor is not detected, check the wiring and replace it if relevant.

© 2015-2019 Eric Bretscher, Nordkyn Design

Electrical Specifications

The following table contains absolute maximum ratings and electrical operating limits.

Parameter	Absolute Maximum	Operating Values
General		
Nominal system voltage		14VDC
Alternator		
Alternator internal regulation voltage (VREG)	14.6V	13.4-14.4V
Voltage regulation, minimum		2 x VREG – 16V
Voltage regulation, maximum		VREG + 0.6V
Controller		
Supply voltage (A1, A2)	30V continuous	10-15VDC
Battery voltage (B3)	30V continuous	10-15VDC
Charge Enable input (B8)	28V continuous	4-15VDC
Differential shunt voltage (B1, B2)	5V	0-165mV
Alternator Sense Output, current (A3)	1A	10mA
Alternator Enable Output, current (A4)	1.85A protected	1A
Standby power consumption (A1, A2)		1mA
Standby power consumption (B3, B4)		1mA
End-of-Charge Output, voltage (B5)	3.3V	3.3V
End-of-Charge Output, sinking (B5)	7V or 30mA	Not allowed
End-of-Charge Output, sourcing (protected, B5)	33mA continuous	20mA @ 1.2V
Temperature input TEMP +, output voltage (B6)	10V	3.3V
Temperature input TEMP -, voltage (B7)	0.3V	<10mV

© 2015-2019 Eric Bretscher, Nordkyn Design

Appendix A - Instructions for Connection to Mitsubishi A003TR0093ZT Alternators

Those externally-sensed alternators are specifically found on the new range of Volvo Penta D-Series diesel engines.

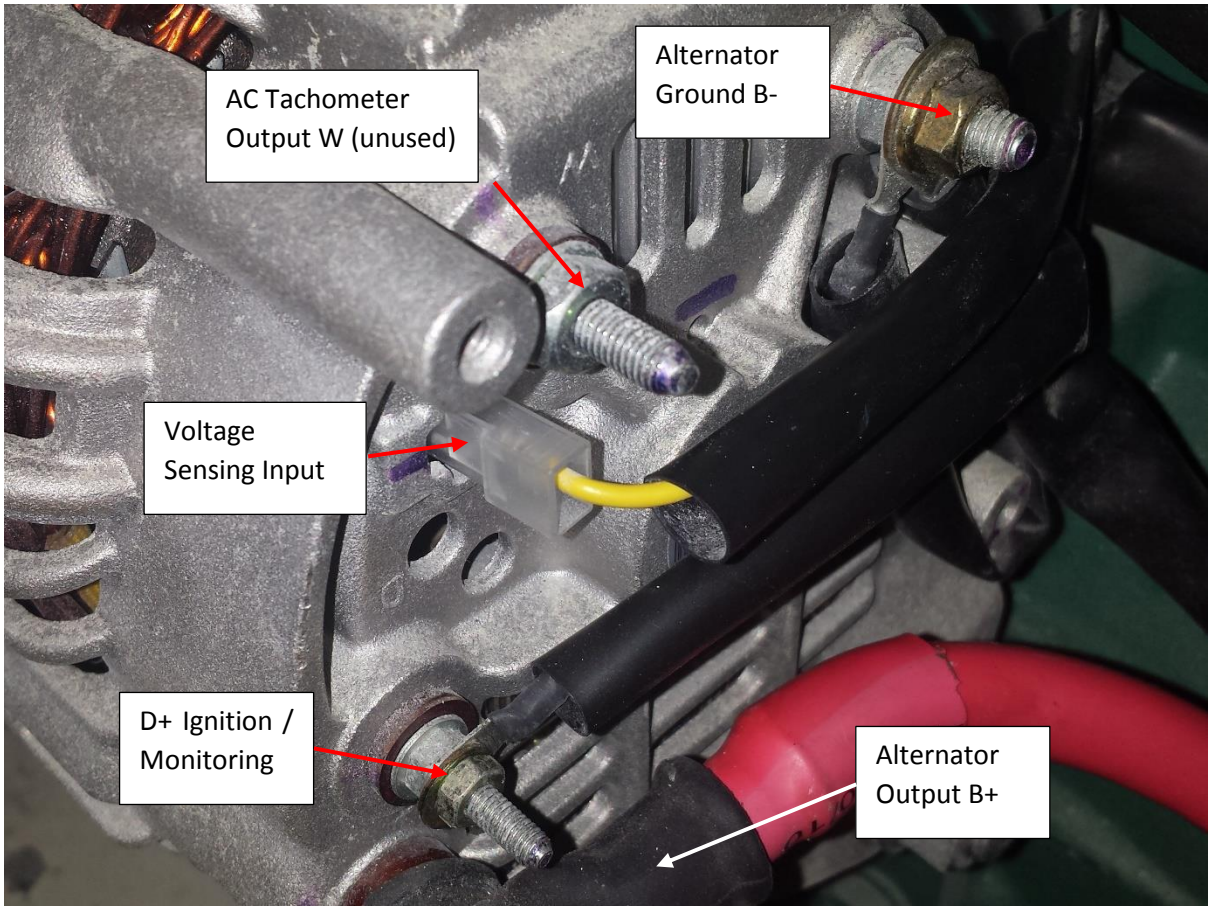


Figure 3 - Rear view of the Mitsubishi A003TR0093ZT on a Volvo Penta diesel engine

Alternator Connection

Voltage Reference Terminal

The rear of the alternator features a recessed ¼'' flat-blade terminal for voltage sensing. On Volvo engines, it is commonly factory-connected to a yellow wire equipped with an insulated push-on terminal coming from the starter 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 terminal A3 of the VRC-100 controller to this voltage sensing input at the back of the alternator. The original yellow wire can be either discarded or extended to feed terminal A2. In this case, a tidy solution is running a 2-core cable terminated with male and female ¼'' flat blade terminals from the alternator back to the VRC-100 controller.

© 2015-2019 Eric Bretscher, Nordkyn Design

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.

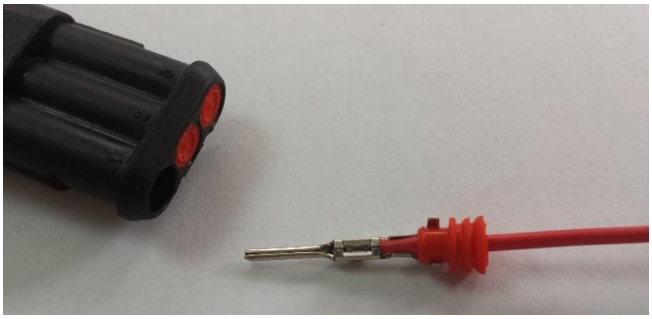
Controller Charge Enable Input Signal (B8)

Ignition power for terminal B8 can sourced from the engine electrical system in one of two ways. The source of the signal is the same each time. The additional load placed on the engine electrical system by this connection is insignificant.

Preferred Option

A 6-core Volvo Multilink cable connects the dash tachometer 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 automotive sealed connectors. The last, unused connector in the chain is normally capped.

The tidiest way of obtaining an "engine ignition" signal on 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-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. The necessary pin is supplied with the controller.



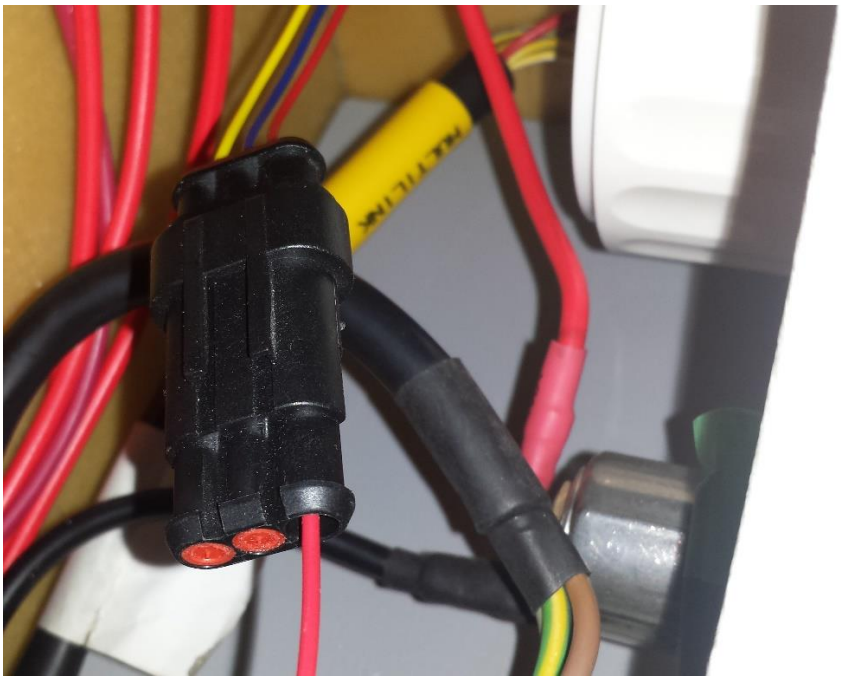


Figure 4 – Plugging into the end of the Volvo instruments daisy chain wiring

© 2015-2019 Eric Bretscher, Nordkyn Design

Alternative Option

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 wire (normally red) 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 5 – Tapping into the Multilink cable harness: splice into core #6 (red)

This requires splicing into the wire and insulating the connection afterwards.

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

Controller Power Supply (A2)

On conventional engine electrical hook-ups, power for A2 can normally be sourced from the ignition circuit, with A2 and B8 being powered together.

In the case of the Volvo Penta EVC systems, it is recommended that the main controller supply on terminal A2 is instead sourced from the engine starting battery circuit breaker in order to avoid placing an additional load on the gauges circuit.

Regulation Voltages

On Volvo Penta EVC systems, operation of the alternator is monitored by the engine management module. 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.

On installations where the operation of the charge controller impacts the voltage of the engine starting battery, the voltage regulation setpoints must be configured at or above the threshold of the alternator alarm. This is not normally a restriction for charge control.

© 2015-2019 Eric Bretscher, Nordkyn Design

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 battery through the starter motor cables. 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-100 controller. 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-100 controller.

For the same reason, it is 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 is also used by the alternator current. Alternatively, another dedicated cable can be run from the alternator B- post to the battery common negative.

Alternatively and 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.

Voltage-Sensitive Relays (VSRs)

We recommend using a charge splitter (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-100 controller should *not* flow from the engine starting battery through the VSR. The undesirable additional voltage drop it induces can raise the engine system voltage and cause alarms. Instead, the VSR should be used to charge the engine battery *from* the bank sensed by the VRC-100 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-100 controller is used with each engine and alternator, accurately matching the setpoints is important, but one controller will still inevitably switch from Absorption to Holding mode before the other. The charging engine will then finish the task, but in the process also keep the other engine's alternator idle for a time. At this point, the voltage on the engine no longer charging may sag below the alternator failure alarm threshold of the EVC monitoring system, because its battery is momentarily no longer being charged at all. There are a few options to prevent this situation from occurring:

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.
2. When the engine ignition circuit is on, enable a small DC/DC converter connected to the main battery bank to boost the engine starting battery to 13.8V for example. It will prevent the engine system voltage from sagging when the controller keeps the alternator idle.
3. Share a common VRC-100 controller between both engines. In this case, the controller must be able to operate with either engine. To this effect, diodes must be used to supply A2 and B8 and still keep each engine electrical system isolated from the other. The output A3 connects directly to both alternator sensing inputs in parallel.

© 2015-2019 Eric Bretscher, Nordkyn Design