

Abstract:

The goal of this circuit is to provide a reliable rectifier/voltage regulator for small engines. The circuit that was presented in the VREG.PDF file worked but it did have a few deficiencies. These problems were:

-As the battery would wear out, the trip point of the shunt regulators would need to change to handle the higher ESR

-There was a high ripple current on the battery. This tended to evaporate the electrolyte. The battery would tend to last only about 2 years of commuter service. The battery should last much longer than this.

-There was no provision for battery maintenance in the off season.

Notes on rev 4 board (in the previous VREG2 package):

-There were 4 component errors on the circuit board. The changes from revision 4 are

R108 should be removed

C108 should be 100nF not 47pF. Converter may not recharge battery and just whistle. The output voltage rises too fast for the current control loop and the safety current limit is tripped.

R115 should be replaced with a wire jumper. This resolves an issue where the safety overcurrent will sometimes trip at a current less than the current control loop.

Add 470 ohm resistor in series with C113

-There were circuit board changes to improve the current handling of the board. Problematic traces are the SCR high power traces. The engine coils were capable of more than the expected current which would cause the traces to open disabling the shunt regulator. The bulk storage caps would then pop making a mess. These traces should be reinforced.

How to identify if this circuit will work on your engine:

There are 2 main types of voltage regulation system used in engines today. The first one is where the generator/alternator has a set of stationary windings (stator windings) and a set of windings wound around the center armature. The magnetic field created by the windings in the armature control how much current is induced into the stator windings. This circuit will not work with this type of regulation system.

The second type of voltage regulation system uses a permanent magnet in the armature to create the magnetic field. For this reason, the amount of current generated in the stator windings is close to constant. In this type of system, the voltage is regulated by shorting out windings when the output voltage gets too high. The shorting needs to be done before the rectifiers to prevent the regulator from shorting out the battery.

Specifications

Output voltage: 12VDC to 15VDC

Output current: Up to 20A

Over current protection: Fold back current limit and over current followed by soft start limit.

Charging voltage: 15VDC to 20VDC. External current limit required.

Physical dimensions: 4.6inches x 2inches x 1.25inches

How does the circuit work:

The first part of the circuit is a simple rectifier pack. I used a couple of bridge rectifiers. The GS400 engine has 3 phases on it. A lower voltage can probably be used but since there is no cost savings, I went with the higher voltage. This will just rectify the AC coming back from the stator windings.

To perform the action of shorting out the windings, each of the windings is connected to an SCR (Q101, Q102 and Q103) that will short the winding to ground. The rectifier pack will have the ground being the lowest voltage of each of the windings so it is not necessary to directly across each winding, just from the

winding to ground. The SCR's used were 25A 100V devices. The current rating of the SCR will depend on the amount of current your engine will produce. It is possible to do a short test where all the phases are connected together and the current on each phase measured. The other way to guess based on the electrical load on the system. Some systems do not need to have an SCR on each phase. They are OK with only 1 or 2 phases having an SCR. The systems that do not need tight regulation usually have a large static load on them (such as headlights, tail lights, etc).

The output of the bridge is connected to C101, C102, C103. When the voltage on these capacitors gets over 24V, D106 will fire the SCRs shorting the windings out and limiting the voltage on the capacitors. On the earlier versions of the regulator (both OEM and the VREG.PDF), this node was connected to the battery. The high ripple current was due to the problem that when the SCRs were firing, the battery was supplying all of the power to operate the vehicle. When the SCRs were not firing, the battery would need to charge up to make up for the drain. In this circuit, the energy storage devices were changed to capacitors that can handle the ripple current without problems.

The next part of the circuit is a DCDC converter to take the 24VDC and brings it down to the 13.6V needed to float charge the battery and power the accessories. The converter is based on the Texas Instruments UC3578. The data sheet which explains the device is included in the datasheets subdirectory in the .zip file.

The main changes from the typical application circuit in the data sheets are:

- There is an output rectifier added to the circuit. This is to prevent current from the battery going backwards through Q105 to charge the big storage capacitors. This was done to prevent a big current spike through Q105 when connecting the battery and to reduce leakage current when the engine is off.
- There is a fold back current limiting circuit added. This prevents excessive current from charging the battery too fast (or destructively if there is a shorted cell).

In terms of the over current protection that UC3578 provides, it is still in the circuit but it is set to a higher current limit than the fold back current limiting. This is in case there is a transient on the output (such as a short to ground in the electrical system). If the current goes up faster than the fold back current limiting can handle, the UC3578 current limit will trip forcing a soft start of the circuit.

Construction

Caution – This circuit is not for beginners. The board is surface mount and can be difficult to solder.

Equipment required:

Variable power supply (0 to 30V, 2A limit minimum)

Multimeter

Oscilloscope is really handy for debugging.

2 pcs of 15 ohm 10W resistor.

Construction

Install all components except for Q105. Make sure to use insulators on D109 and D107.

Heat sink grease should be used on all TO-220 packages.

Testing

Starting with the circuit completely built up except Q105 is removed perform the following tests:

Rectifier/regulator test

1. Connect 2 of the resistors in series with the power supply positive. Connect the ground of the supply to the circuit ground. Connect the resistor to the phase input.
2. Measure the voltage on the phase input.
3. Ramp the supply from 0V up to 30V. The voltage on the meter should follow the up to approx 24V where the SCRs fire. The voltage should then drop to less than 2V at the phase input.
4. Turn off the supply and test the other phases.

DCDC converter test

1. Disconnect the supply.
2. Discharge the internal caps (or wait for them to discharge).
3. Install Q105
4. Remove the resistors from the previous test. Set the supply for 20VDC and connect it directly to one of the phase inputs.
5. Connect one of the 15 ohm resistors between the output and ground.
6. Turn on the power supply.
7. Adjust R106 for 13.6V across the output resistor. Watch out, the resistor might be hot.
8. Listen for any instability squeals or check the switching waveform on the source of Q105. The waveform should be a steady pulse train without a lot of modulation of the pulse width.

Note: This converter will not run and regulate if there is no output load.

DCDC converter current test

This test is good to do, but may be difficult without the correct equipment. You will need enough resistors to load the output beyond the desired output current and an input power supply with enough output current to perform this test.

Set the output current limit as described in the installation instructions (or set it to a lower point if equipment limitations are present).

1. Connect the supply set for 20V to the RECT pin on the connector.

2. Connect one resistor to the output terminal
3. Power up the board.
4. The output voltage should be 13.6V
5. Disconnect the power
6. Increase the load and apply power again
7. The output voltage should stay at 13.6V until the current limit is exceeded. Above the current limit, the circuit will follow a constant power function.
8. Once the output voltage drops below 10V, the test is complete.

Note: At full current with no air flow the heat sink will get rather hot.

Installation

There are few items that need to be set on the regulator before the regulator can be put into service.

Current limits

R106 controls both the UC3578 current limit and the fold back current limit. The fold back current limit is set to limit when there is 0.2V across this resistor. $R106=0.2V/I_{max}$. The maximum current should be set to a few amps higher than the current consumption of the electrical system. This will allow some margin to charge the battery.

Voltage limit

This is set by R114. Before connecting

Charging Current Limit

This limit is for the off season battery maintenance charger. This circuit will not draw the voltage on the RECT pin below approx 15VDC so the maximum current from the battery maintenance charger can be set using a resistor. $R_{series}=(V_{maintenance}-10V)/I_{max}$.

$V_{maintenance}$ is the voltage of the maintenance supply (typically 18 to 20VDC)

I_{max} is the maximum current of the maintenance supply.

This resistor will dissipate the following power under the worst case fault conditions:

$P_{series}=(V_{maintenance}-10V)/I_{max}$.

What will happen when using the maintenance supply and the battery voltage is low is the voltage on the RECT pin will vary between 10 and 12V with the output current of the circuit pulsing on and off. The output current pulses will be at the limit set in the current limits.

If the battery has some charge and is between 10 and 13.6V, the RECT pin will sit at about 1.6V above the battery voltage. The duty cycle of the converter will be at 90%.

If the battery is charged and at 13.6V, the duty cycle will drop down low and possibly pulse. The current on the RECT pin may rise as high as the maintenance supply as the battery current decreases.