Smiths Voltage Stabilizers

Rev.02

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What is covered:

The following document discusses the operation of the basic Smiths voltage stabilizer as used to operate electrical gauges on British vehicles. Methods of replacement and testing are also discussed.

Though discussed, methods of adjustment are not known to be accurate.

Glossary:

(Refer to Figure 1)

"E" terminal. The "E" terminal (if marked) is the electrical connection common to the chassis of the vehicle (ground or **E**arth). It may be positive or negative depending on which battery terminal is connected to the body of the vehicle. The stabilizer's case (even if unmarked) is also terminal "E"

Contact Points. These are electrical contacts inside the stabilizer. The points act as a switch.

"B" terminal. This is the **B**attery connection to the voltage stabilizer. It is typically a switched connection that is "hot" only when the ignition switch is on.

"I" terminal. This is the **I**nstrument or gauge connection to the voltage stabilizer.

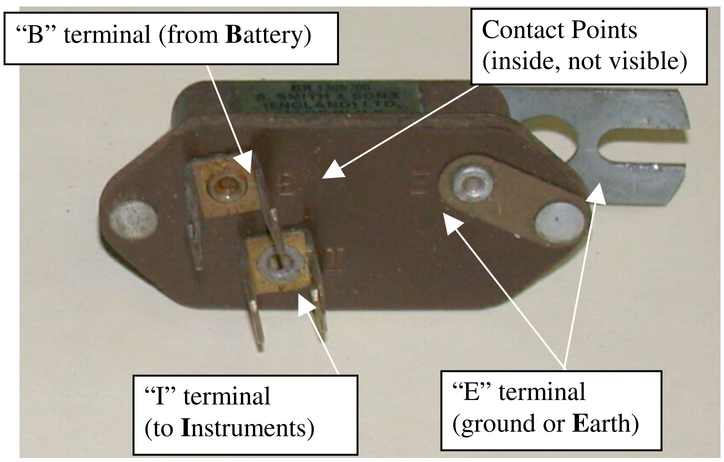


Figure 1 – Voltage Stabilizer Terminals

Theory of Operation:

Early British cars (prior to the mid-1960s) did not always utilize a voltage stabilizer and their instruments operated at full battery potential. The voltage of the car's electrical system would change according to the operation of the charging system and what loads were put on it. This changing voltage allowed the instruments to behave erratically or inaccurately.

The Smiths voltage stabilizer is a mechanical voltage regulator that reduces and maintains the instrument operating voltage at 10v dc. Inside the stabilizer is a bimetallic strip, an insulated heating wire coil, and contact points. (See Figure 2a & 2b)

1) The contact points are located inside the stabilizer housing. One side of the points is on the "B" terminal, the other side is on one end of the bimetallic strip attached to the "I" terminal.
2) The bimetallic strip carries current between the contact points and the "I" terminal.
3) The heating wire coil is wound around the bimetallic strip. It is connected between the contact point on the bimetallic strip and chassis ground.

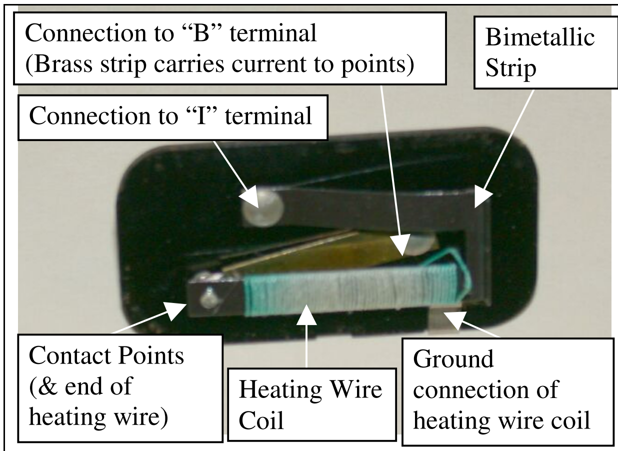


Figure 2a – Inside the Stabilizer

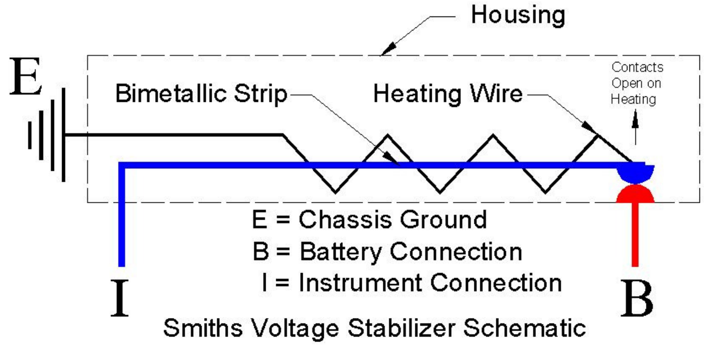


Figure 2b – Stabilizer Schematic

When the ignition switch is turned on, the "B" terminal sees full battery voltage. Initially the stabilizer points are closed. Current is carried across the contact points, through the bimetallic strip, and provided to the "I" terminal. Thus, when the ignition is first turned on, full battery voltage appears on the "I" terminal of the stabilizer. Remember that one end of the heating wire is also attached to the contact point on the bimetallic strip. Thus, when the ignition is switched on, current also begins to flow through the heating wire to chassis ground. The resulting heat causes the bimetallic strip to change shape and "open" the points. This breaks the current flowing to the "I" terminal and through the heating wire. The voltage on the "I" terminal drops to zero (0) volts when the points open and the heating wire cools. Without heat the bimetallic strip returns to its original shape closing the points. This restores current flow to the "I" terminal and the heating wire. The cycle repeats several times a second.

The result of this on-off cycling produces a reduced "average" voltage on the "I" terminal. The voltage is not a steady 10v, but switching occurs with a frequency that approximates 10v. Because of this fast switching, it is virtually impossible to measure the operating voltage of a stabilizer directly using a volt-ohm meter.

Troubleshooting:

Vehicles with Smiths voltage stabilizers can easily be identified. If the fuel gauge needle "jumps" off the empty position when the ignition is switched on, the vehicle is NOT equipped with a voltage stabilizer. Fast responding gas gauges are based on the "balance magnet" principle and do not require the voltage stabilizer. If, however, the fuel or temperature gauges slowly drift up when the ignition is switched on, the car uses a voltage stabilizer and gauges based on bimetallic heating elements. The voltage stabilizer can be mounted any number of places. Consult your service manual to determine its location.

If you suspect there are problems with a vehicle known to have a voltage stabilizer there are a few quick tests that can be made to determine the source of problems.

High Gauge Readings:

1) While the stabilizer is in the vehicle, remove the wires from the "I" terminal and connect a volt meter between the "I" terminal and chassis ground.
2) Switch on the ignition. If you measure full battery voltage AND it remains there without changing for more than 20 seconds it is likely that the points in the stabilizer are not opening. Failure of the points to open does not necessarily mean the stabilizer has failed.
3) Remove the stabilizer, clean all its spade lug terminals AND clean its mounting tab. Remove any rust and corrosion on the stabilizer AND where it mounts to the vehicle. If the ground or earth contact is poor the stabilizer points will never "open".
4) Remount the stabilizer, connect the "B" wire(s) and repeat the test. If the voltage is still high consider replacing the stabilizer.

Low Gauge Readings:

1) Consistently low gauge readings can be the result of bad sending units, bad ground connections, or a failed stabilizer. First confirm that low readings are not the result of disconnected wires or an empty gas tank.
2) Disconnect the "hot" lead from the fuel sending unit (typically this is the green/black wire on the sender).
3) Switch on the ignition and have an assistant touch the "hot" lead to a good, clean, bare metal point on chassis ground.
4) If the fuel gauge climbs to full, the problem is in the sending unit or its ground connection.
5) If the fuel gauge reading is still low, this could indicate low output voltage from the stabilizer or a defective wire (See "No Gauge Readings" below).
6) Before replacing the stabilizer clean all of its spade terminals, its mounting tab, and its mounting spot on the car. After cleaning, repeat the test above and if there is no improvement replace the stabilizer.

No Gauge Readings:

1) Mark and disconnect all the wires going to the voltage stabilizer so you can replace them later.
2) Clean all the terminals on the wires connected to the stabilizer.
3) Connect a volt meter between chassis ground and the <u>wire(s)</u> that <u>were</u> on the "B" terminal. Switch on the ignition and observe the volt meter reading.
4) If the reading is not the same as battery voltage, look for a fault in the supply wire to the stabilizer.
5) If full battery voltage is measure on the "B" wires, switch off the ignition and use the use the volt-ohm meter to measure the resistance of each wire (that was connected to the "I" terminal) from end to end. If the wires show more than a few ohm of resistance there is a fault in the wiring.
6) If no problems are found with the wires <u>and</u> if the problem is with the fuel gauge, reconnect the voltage stabilizer. Repeat the "Low Gauge Reading" test above where the "hot" wire on the fuel sender is shorted to ground. If the gauge shows "full" with the ignition on, carefully check the ground connection of the sending unit AND the resistance of the sending unit itself.

   (Reference: With a volt-ohm meter connected directly across the fuel sending unit terminals (no wires attached) the sender should measure between 0-20 ohms full (float up) and near 270 ohms when empty (float down))

Stabilizer Recalibration/Replacement:

There are many reports of "brand new" voltage stabilizers being defective or inoperable when installed. Apart from trying multiple units until a serviceable one is found there are only a couple of options available.

Recalibration:

Some voltage stabilizers have an external adjustment screw for factory setting the points and adjusting the voltage stabilizer output level. (See Figure 3) The author does not know the method used by Smiths to calibrate these devices but speculates the method involves connecting the stabilizer in series with a calibrated gauge and a known, accurate series resistance (to simulate a sending unit). If the reader has access to an accurate, steady 10v power source (and resistors) calibration can be attempted.

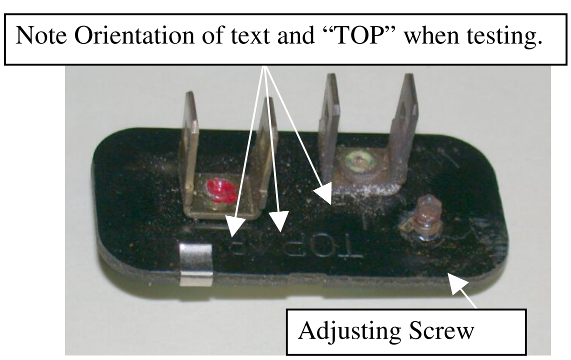


Figure 3 – Voltage Stabilizer
(Removed from housing.)

NOTE: For any tests or calibration attempted on a mechanical voltage stabilizer, the unit MUST be mounted properly. This includes proper vertical/horizontal orientation. Some units are marked “TOP” to clarify this. The units are generally mounted horizontally.

FIRST, construct a circuit using a known resistance (a fixed 50 ohm resistor) in series with a gauge (say a fuel gauge.) The sending unit must not be in the circuit at this time (the series resistance acts as the sending unit). (See Figure 4) Supply the circuit with a constant, accurate 10 volts (from a solid-state power supply) and allow the system to stabilize over several minutes. Place tape on the gauge face and mark the needle position on the tape. (See Figure 5a)

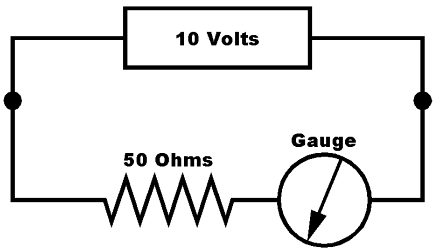


Figure 4 – Calibration Schematic.

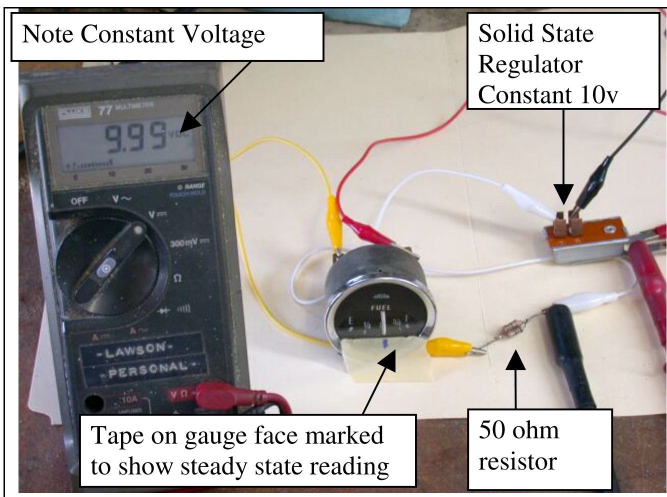


Figure 5a – Calibration with Accurate 10v Source.

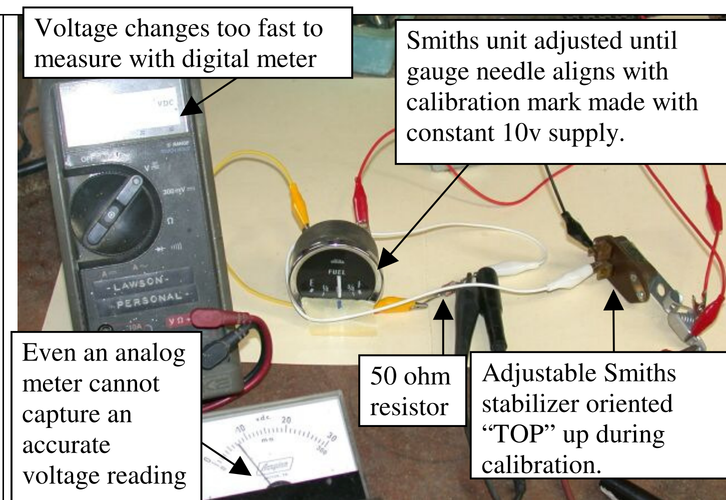


Figure 5b – Calibration of Adjustable Smiths Voltage Regulator

SECOND, replace the accurate 10v supply with the Smiths voltage stabilizer. Connect 12v power to the stabilizer and allow the system to reach a steady reading. Turn the adjusting screw on the Smiths unit in small increments and wait several minutes for the system to stabilize. Keep adjusting the screw in or out until the needle position on the gauge matches that marked on the tape. **NOTE: During calibration and use, the Smiths stabilizer must be oriented correctly (generally horizontally).**

Replacement (Solid-State Regulators):

Modern vehicles use solid-state voltage regulators to operate their gauges. Unlike the mechanical Smiths units these devices deliver a constant 10v. They are also polarity specific, meaning that the device must be designed to operate uniquely with either negative or positive ground. A solid-state voltage regulator may be substituted for the mechanical components inside a Smiths stabilizer.

Positive Ground:

For older positive ground vehicles the insides of the Smiths stabilizer may be replaced with either a u7910 fixed -10v regulator or an LM337T adjustable, negative regulator. (See Figure 6) The LM337T will require additional feedback resistors to achieve the desired -10v. The u7910 is <u>not</u> readily available.

Negative Ground:
For newer negative ground vehicles the insides of the stabilizer may be replaced with either a u7810 fixed +10v regulator or an LM317T adjustable, positive regulator. The LM317T will require additional feedback resistors to achieve the desired +10v but is more readily available than the u7810 chip. The LM317T is available at Radio Shack®.

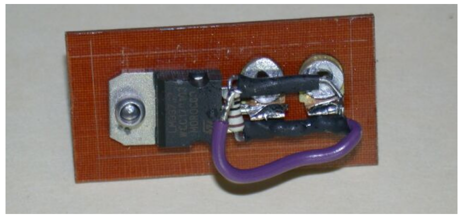


Figure 6 – LM337
(Positive ground regulator, with feedback resistors for -10v. The purple wire will connect to chassis ground inside the stabilizer housing)

Solid-state regulators and detailed schematics for their use as power supplies are available through the internet. Simple schematics are provided below. Regardless of which chip you select, purchase the TO-220 package style (shown in Figure 6) as these have higher (1.5 Amp) current ratings and can be riveted for mounting. **NOTE: Only the u7810 chip may be riveted to the metal housing of the stabilizer. The LM317 and LM337 must be electrically isolated from chassis ground. For all these chips, limit the number of attached gauges to three or fewer to minimize the heat generated in the regulator**.

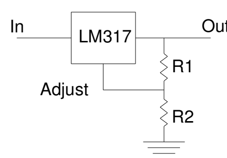
NOTE: Over the years I have been contacted by several electrical engineers who feel very strongly that capacitors must be used on the input and output sides of the regulator circuit. I do not present the capacitors below. The reader is advised that if they wish to add capacitors to the regulator circuit they should follow the datasheet for the chip they select and use.

Solid State Circuits To Replace Smiths Voltage Stabilizers

Smiths Voltage Stabilizer Wiring: B = In, I = Out, Ground = Chassis

Negative Ground

LM317
Negative Ground Adjustable Voltage Regulator

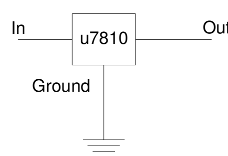


Pin#	Function
1	Adjust (Feedback)
2	Output (Mounting tab also Output)
3	Input

Vout = 1.25 * (1+ R2/R1)
Suggest R1 be 240 Ohm
NOTE: DO NOT ground the mounting tab as it is the output.

or

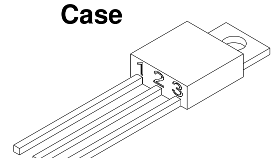
u7810
Negative Ground Fixed 10 Volt Regulator



Pin#	Function
1	Input
2	Ground (Mounting tab also Ground)
3	Output

NOTE: Mounting tab MAY be grounded.

TO-220 Case



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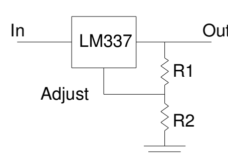
Positive Ground

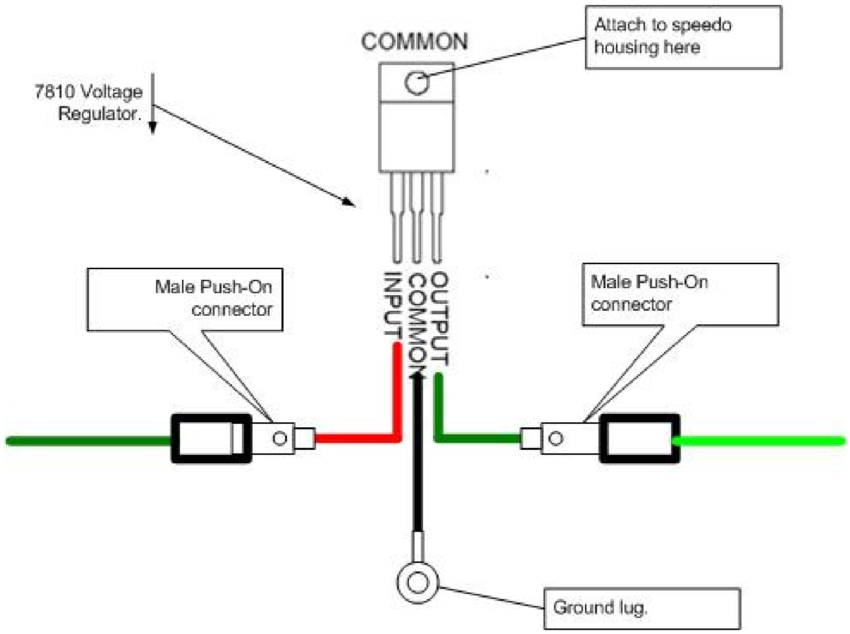
LM337
Positive Ground Adjustable Voltage Regulator



Pin#	Function
1	Adjust (Feedback)
2	Input (Mounting tab also Input)
3	Output

Vout = 1.25 * (1+ R2/R1)
Suggest R1 be 240 Ohm

NOTE: DO NOT ground the mounting tab as it is the input.



The schematic above is a greatly simplified negative ground application routinely implemented by my friend Wes. Wires with crimp terminals are soldered directly to the chip for connection to the power supply and the gauges.

The process of replacing the internals of the Smiths voltage stabilizer is fairly simple and is outlined here.

1) Mark the wires going to the voltage stabilizer, disconnect them and remove the stabilizer from the vehicle.
2) On late model stabilizers use pliers to carefully fold back the formed sheet metal holding the circuit board inside the housing. On early stabilizers drill out the rivets securing the circuit board to the housing flanges.
3) Use cutters to remove all of the interior bits of the stabilizer, but leave the spade lugs riveted to the circuit board.
4) Use solder and flux to tin the rivets securing the spade lugs to the circuit board. Flow solder between the rivet and lug on the "outside" of the board, and tin the portion of the rivet that is on the "inside" surface of the board.
5) Construct the appropriate resistor feedback circuit if using LM317 or LM337 chips. (See above and internet sources for more details). Test your circuit on the bench BEFORE proceeding. Make sure you are producing 10v out of the chip. On adjustable regulators substitute alternate feedback resistors as necessary to obtain an output close to 10v.

NOTE: When soldering ANYTHING to chips be sure to use heat-sinks such as tweezers, needle-nose pliers, or hemostats to avoid overheating the chip.

6) Attach a short length of small gauge, insulated flexible wire to the circuit's ground connection.
7) Apply heat shrink tubing to the leads of the chips. (After the feedback resistors are installed if using adjustable regulators).
8) Solder the leads of the chip to the appropriate tinned rivets on the circuit board. **CAUTION:** It is imperative that heat-sinks are used during this step to prevent excess heat from damaging the chip.
9) Drill a hole in the circuit board and rivet the chip in place (if desired). In general, try and position the chip so that its metal mounting tab will NOT touch the metal stabilizer housing when the circuit is reinstalled. (The u7810 chip may be riveted to the stabilizer housing if desired, the LM317 & LM337 must not touch chassis ground.)
10) Solder the short length of flexible wire to the inside of the old stabilizer housing.
11) Thoroughly wash all of the flux and solder residue from the circuit board and housing and thoroughly dry before proceeding.
12) Carefully place the circuit board back into the housing. On late model stabilizers use pliers to gently fold the sheet metal back to secure it. On early stabilizers rivet (or use machine screws and nuts) to reattach the circuit board to the housing flanges. DO NOT allow the short wire to become pinched.
13) Test your work. Connect your vehicle's ground to the case of the stabilizer. Connect battery voltage to the "B" terminal. Connect a volt-ohm meter between the "I" terminal and chassis ground. If you do not observe 10v you will need to open the unit up and check the circuit again.
14) When working properly, mark the outside of the unit as positive or negative ground (as appropriate) and install in your vehicle.

Notes on solid-state voltage regulators:

Power is defined as the product of voltage and current. In the case of a solid state regulator for automotive gauges, the regulator delivers 10 volts when it is supplied with approximately 14 volts (while the engine is running.) Each gauge can draw as much as 100 mA under the right conditions. (Rev.02 – This was measured experimentally, not calculated… with additional current added as a safety factor to arrive at the 100 mA figure). Therefore, each gauge has the potential of causing the regulator to dissipate: (14 – 10) volts * 0.100 Amps = 4 Watts. If three gauges are connected to the regulator this can potentially produce 12 Watts of power, dissipated as heat, inside the stabilizer housing. For comparison, an incandescent night-light bulb is rated around 10 Watts. To prolong the life of your solid state regulator do not connect more than three gauges to a single chip. Remember that the regulator will become warm when in use.

Over the years I have been contacted by several electrical engineers, most advising the addition of capacitors to the chip to insure its proper operation and to provide a "clean", smooth voltage output from the regulator. An input capacitor can filter voltage spikes to prevent damage to the chip. Some engineers state that proper operation of the solid state regulator is not guaranteed if the output capacitor is omitted.

I do not question their expertise and the reader is advised that they may wish to add capacitors to the circuit. I will not provide information on capacitor selection or installation in this document. The reader is advised to follow the datasheet for the regulator they select if they wish to use capacitors in their application.

I have not used capacitors in my applications and have not experienced failures or problems.

Rev	Date	Changes
01	6/1/06	Changed R1 value to 240 Ohms on TO-220 components on advice of Dave Sherman
02	6/2/12	Added notes on capacitors to pages 5 & 7, added Wes' schematic to page 6.