

VOLTAGE REGULATOR 101

by Bob Jeffers

I get a lot of questions that tend to indicate that a lot of British car aficionados don't really understand much about how a voltage regulator is supposed to work. They seem to know that it should keep the battery fully charged. But how it does it and what are the signs that it is doing it properly? Hopefully this little blurb will enlighten many of the readers. The descriptions are for either positive or negative ground systems. Where there could be confusion I have tried to phrase it such a way that it will be clear.

First let's talk about the standard Lucas Regulator that our cars came equipped with. It is a relay type, as were all regulators from the period before transistors were invented. The two relays are; a cutout relay whose function is to open the circuit between the battery and the dynamo when the dynamo is not turning fast enough to charge the battery and a regulator relay. The cutout relay has a voltage coil and a current coil. The current coil is wound with large diameter wire, the voltage coil is wound with very small diameter wire and has a resistance of about 140 ohms. The voltage coil is connected across the dynamo. When the voltage output of the dynamo increases enough, the magnetic field becomes strong enough to overcome the air gap and spring tension holding the relay open. When this voltage is reached the relay closes and the dynamo is now able to charge the battery. After the relay closes, as current starts to flow from the dynamo to the battery, it passes through the current coil. This coil is wound and connected in such a way that the current flowing into the battery pulls the armature down harder which causes the contacts to make a better low resistance path from the dynamo to the battery. This prevents heating of the contacts and lengthens their life. Also when the dynamo slows down the current will flow through the current coil in the reverse direction which will help the spring open the relay and stop the flow of current from the battery to the dynamo. Now as the dynamo turns faster it will generate more voltage and put more current through the battery. This is fine up to a point. But if allowed to go too far it will cause the battery to boil and evaporate water from the electrolyte eventually exposing the plates to the atmosphere which will destroy them. To prevent this, the second relay is used.

This second or regulator relay has its contacts normally closed. Connected across the contacts is a large (physically) resistor that connects the field coil to the output terminal of the dynamo. When the voltage is below the desired point, this arrangement insures maximum output of the dynamo. When the voltage reaches the desired point the relay opens putting the resistor in series with the field coils and reduces the output to a very nominal level. Also when the points open the magnetic field of the coils collapses creating a large voltage (this is how the high voltage in a spark coil is generated). The resistor absorbs this voltage surge to prevent excessive arcing and sparking at the contacts of the regulator relay. So the resistor serves two purposes, absorbing the voltage surge and setting the low nominal level of output. Now, of course, when the relay opens and the dynamo reduces output the regulator relay contacts will close again and the cycle repeats. On these original regulators I have measured the cycling of the regulator relay at between 50 and 60 cycles per second. Adjustments for the spring tension are provided on each of the relays so that the point at which they operate may be set where desired. As you can see there are a lot of variables, spring tension, air gap etc., besides their age, that will effect the point at which these relays operate.

Now with the miracle of modern solid state electronics we can have much more precise control over when and how the operations described above occur as, for instance, with the relay type regulator a reverse current of up to 8 Amps can flow from the battery to the dynamo when the dynamo is not turning fast enough. This not only discharges the battery but it heats up the dynamo which is not a good thing. With solid state we use a diode as the cutout. When the output of the dynamo is higher than the battery voltage, current can flow from the dynamo to the battery. When the battery voltage is higher than the dynamo output, nothing. No reverse current can flow at all! To establish the voltage set point we can use an integrated circuit which produces a precise, temperature compensated, voltage and compare the voltage across the battery to it. We can amplify the difference and control the charging voltage with the amplified output. To limit the current we can concentrate the magnetic field that exists around the wire carrying the output of the dynamo in a ferrite toroid. Then apply that magnetic field to an integrated circuit. The output of the integrated circuit can then be used to control the dynamo output so that it's rated current is never exceeded. This makes it almost impossible to burn out the dynamo.

Now we said that the voltage set point was derived from a precise, temperature compensated integrated circuit. Fine, but since the 1930s the voltage set point has been made variable according to the ambient temperature because the battery wants to be charged by a slightly higher voltage in the cold weather and by a slightly lower voltage when the ambient temperature is higher. Nowadays we can get resistors that vary their value according to the temperature. These resistors can be incorporated into the voltage set point circuit such that we can achieve almost any degree of change desired with temperature.

What we did not yet explain is how with the relay type regulator we get anything but full output or next to no output. That is done by the time that the relay spends open vs. the time it spends closed. These pulses of full output are averaged to the value we need by the timing of the "ON" pulses. If they are 100% ON then we get full output. If they are ON 50% of the time then we get 1/2 output. Well in the solid-state circuit we do the same thing only more precisely since, among other things, we don't have that big resistor limiting the lower charging rate. The rate of the full output pulses is constant in the electronic version, the early versions running at about 130 pulses per second. Later versions will run at about 500 pulses per second. The width of the pulses is changed to effect the variation in averaged output required. Even the early versions were fast enough to nearly eliminate the flicker in the ammeter by the fuel pump pulsing.

This conversion has been designed so that no changes to the wiring harness are required and the appearance of the regulator is unchanged (it's a stealth conversion). Any British car using a Lucas regulator can use one of these conversions. By means of jumpers on the printed circuit board we can set it up for positive ground, negative ground, 6 volt, 12 volt, "hot" field or grounded field. We only need to know the system voltage, polarity and the current rating and field circuit of the dynamo it will be used with.

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