# Lights & Illumination

**by Michael Link**


*The operation of the headlights on the UK Stag is different from that of U.S. Federal Stags*

When we turn on the Stag's lights at night, most of them are for other drivers, whom we hope and trust are paying enough attention to see us. One of the few lights for ourselves, as drivers, are our headlights. These are for us, to illuminate the path forward as we make our way wherever it is that we are headed. Headlights work by reflecting light off of whatever is in their path, back to our eyes. The brighter the headlights, the better we see because of the greater amount of reflected light.

Modern cars pretty much do everything better than our classic cars, except perhaps in the enjoyment/fun-to-drive category. The Stag's older systems, such as brakes with their longer stopping distance, means that we benefit from better headlight illumination. When the subject is seeing and stopping in a world illuminated mostly from our headlights, driving after dark is safer with brighter headlights; as drivers we see better and have more distance to react and avoid trouble.

One very effective way to improve the headlight illumination is to upgrade them from the original spec to a halogen or HID (high intensity discharge) system. However, most of us know of classic car owners who have replaced their headlights with halogen units and been disappointed with the result. There should be nearly a 50% improvement in light output from such a change. Yet many see little improvement, some even find their headlights to be dimmer; both are understandably disappointed with the results. Why is this, and how do we get a better result, closer to the promise of dramatic improvement?

## Why Does It Matter So Much?

The answer lies in the wiring. Headlights, in fact any and all incandescent lights, are sensitive to voltage level, becoming significantly dimmer as the voltage drops lower. DC circuitry is very sensitive to the length of the wire: voltage drops over the wire's length due to its resistance to conducting electricity. Wire size, or gauge, is also a factor in voltage loss with a larger wire adding less resistance than a smaller wire. The longer the wire length, the more it benefits from a larger gauge wire to minimize its voltage loss. Resistance due to corrosion in the connections within the wiring harness add significantly to voltage loss in the circuit.

As voltage is reduced to a light or lamp, two things occur. One is the brightness becomes reduced. How much does the headlight brightness reduce from how much of a voltage reduction? The answer may surprise you. If a headlight has a 1.5 volt drop, its brightness is reduced to 62% of its rated wattage output. At 2 volts lost, or a 10 volt supply to a light, the bulb has only 48% of its rated output. Think about the significance of these numbers not only in terms of dimmer headlights, but also in terms of the lack of visibility of your brake lights, tail lights, and so forth—those very lights you're depending on for other drivers to be able to see you. All your Stag's lights may well be producing less than half as much light as they are designed to—and that you may think they output.

The other effect of reduced voltage is the light output shifts towards the red end of the light spectrum. This matters because the eye is only about one tenth as sensitive at this end of the light spectrum as it is in the green-yellow part of the spectrum. The cells in your retinas that see at night are not sensitive to red, only the cells for seeing in the daylight are. You can see this difference when you encounter traffic signals, notice that the traffic lights for yellow and green appear brighter than do the red lights. This matters because we see from our headlights by reflected light, the redder the headlights become the less effective they are. Add this effect to the overall dimmer light they produce and it makes for a significant reduction in headlight effectiveness from the reduced headlight voltage.

## A Long Run with Resistance

Stag headlight power comes from the battery in the front right of the car, travels to the firewall, crosses over to the driver's side on the left and up the steering column to the main light switch. From there it goes to the turn signal switch, then back down the column and crosses to the right to the fuse box. Here the circuits become fused and then the wires travel back to the left side of the car, turn frontwards and travel to the front of the car inside the left fender, where they end up at the front left headlight, then on across the front of the car, finally terminating at the front right headlight. Before making too many Lucas jokes, bear in mind the wiring is not unusual for cars of its era.

Another old car way of doing electricity is the connections in the wiring harness. Likely most people reading this have seen the many, many connectors all over the car in its wiring harness. That's the way it was done, and is a big part of the causes of electrical gremlins in vehicle electrical systems. Modern cars have few if any connections in their wiring, because connections give trouble and have been designed out of today's cars. Most of the trouble comes from corrosion in the connectors, which add resistance to the passage of electricity. The corrosion can be enough to block or nearly block the current.

Another source of resistance in the wiring is the electrical switches. In the original wiring, the main light switch and the turn signal switch each carry the full electrical load that all the Stag's lights draw. This causes an electrical arc every time the switch is used. Think of the arc when you unplug something inside your house when it has an electrical load (vacuum running, lamp turned on, etc.); that is what happens every time your headlights are turned on or off, since the switches carry the full electrical load. Over time, those electrical arcs cause carbon to build on the contacts, adding resistance to the circuit.

Why all the discussion space spent on electrical resistance from wiring length, connections and switches? Because resistance is why headlights and all the other vehicle lights become dim, and why so many efforts to upgrade the headlights becomes an exercise in disappointment and frustration.

## The Solution

The solution to issues in classic car lights is to ensure they receive full voltage, that they are as bright as the chosen bulbs can be. For headlights, this means halogen lights which are 20% to 50% brighter than the same wattage in a regular bulb, with the wiring modernized to reduce the resistance from the obsolete wiring design.

The best way to do this is to add relays to your Stag's headlight system. A relay is nothing more than a switch that is operated electrically. Best of all, with both relays and halogen bulbs there can be a brightness increase of more than double. Adding higher powered halogen lights without adding relays can be counterproductive—the higher current rating draws more on the old wiring through its resistance points which can result in an even larger current drop.

Modern vehicles use relays to minimize the voltage loss from eventual corrosion in the electrical system, and to reduce the length of the wiring runs that bring the power to the lights. Remember, the size of the wire and its length matter in a DC circuit. Resistance is less in a larger size wire, and the shorter the wire, the less resistance in it when compared to the same size wire in a longer run. Relays route power directly to the lights without the voltage loss from being run to the switches inside the car; only the minimal power to trigger the relay has to run to the car's interior.

Relays use only about 0.15 amps to operate, so they can be connected to the original wiring to be operated, while new heavy gauge wires with shorter runs can be used to bring the power to the lamps for illumination. The small current used to operate the relays will not load the original wires or shorten the life of the switches. It is an easy project to add relays to your Stag, the original switches and features remain and the relays can be hidden if that is desired. With relays you get full brightness headlights with an almost eliminated load on your original harness and its components.

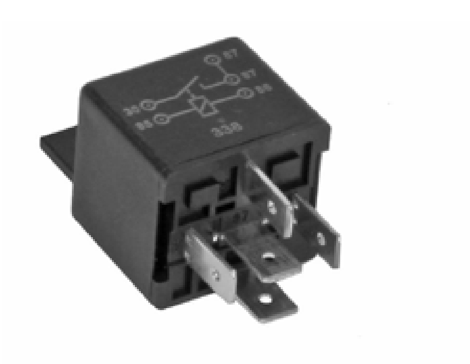
There are relay kits sold for British cars (such as from Moss Motors) that are prewired with the correct color coded wires, along with instructions (Moss has an online video for their relay kit) on how to add them to the vehicle. This is a great way to go, but a word of caution is in order here. Most British cars have a two-headlamp system, whereas our Stags have a four headlamp system. The directions, wire gauges and the relays themselves are sufficient, but the included fuse is not. The relay kits sold by British suppliers are for Stags with different headlight wiring, and some will not work especially well for our North American spec, and again their included fuse is inadequate because of the difference between non-American wiring and our North American Spec Stags.

## Fuse Selection

What was that about inadequate fuses? The formula is volts (V) x amps (A) = watts (W). Therefore, watts divided by volts equals amps. If you select 60/55 watt bulbs for the

outer headlamps, and 55-watt inner high beam bulbs, then… your system will consume 230 W when high beams are selected. Fuses (and circuit breakers) are thermal devices and not exact, blowing when heated from too much current. Manufacturers recommend a 25% allowance for a circuit when selecting the size of the fuse (or circuit breaker) to protect it. This is to allow for voltage spikes and power surges within the car's electrical system, imprecision in the fuse itself, and that fuses lose some of their rating over time.

230W divided by 12V equals 19.17 A, which is what you can expect your system to draw for its ongoing current consumption after the initial current surge when the lamps first get power. But, the relay systems sold include a 20A fuse, which will blow if you use your high beams and have to dim them a few times. So, to choose the correct fuse size, don't divide the wattage by 12V, instead divide by 9V to allow the 25% margin required. 230W divided by 9 equals 25.56 A, which is the minimum fuse size you can use without having it blow. Then, round the fuse size up to the next higher available rate: a 26A fuse if you can find it, otherwise more likely a 30A fuse.



*The best way to maximize voltage is to add relays to your Stag's headlight system and ensure you use the correct gauge wiring*

Lights work from having their filament heat and produce light. The filament when cool does not have much resistance, being fairly close to a direct short circuit. As current flows through the filament, it heats and as it does it greatly increases its resistance, reducing its current draw. When you dim and re-illuminate your high beams, you have quite a current surge every time as the headlights draw power before the filaments heat and reduce their load on the system. This is in part why the 20A fuse in the example would not work if one must dim the high beams, which is to be expected.

For our four headlamp systems, you can use the available relay kits sold by suppliers such as Moss, but be sure to provide a different fuse. If you would rather not, then another solution would be to purchase two of their relay kits and wire one for each side of the Stag so that each only operates two headlamps. You could also buy relays from an auto parts supplier such as NAPA or Amazon and make your own set-up.

## Final Thoughts, Some Numbers and Sources

I'd suggest that a good starting point would be to remove the outer right side headlight and measure the voltage to its socket, compare that value to the voltage at the battery. Do the same for the tail lights and brake lights. Then, depending on how much voltage loss you find, decide what, if anything, you will do to remedy the loss of light voltage. For the headlights, add halogen lamps and relays, use a correct size fuse and heavy gauge (10 or 12 AWG) wire to bring them power.

A good place to get power for the headlights is to run a 10 AWG wire from the starter solenoid (using a ring terminal on the post with the main battery cable) to the front of the Stag for the relay power supply. Run the wire along where the inner fender and the firewall meet, next to a section of original harness already there. Put a fuse or circuit breaker somewhere near the brake master cylinder where it would be easy to find and reach, write down its size and location in your repair manual. Then fish the 10 AWG wire through the inner fender cavity to the front of the Stag to power the headlight relays. It would be good to use a correct color code wire for this, or at least choose something that has a logical relationship to the Lucas wire color codes. For mine, I chose brown with a blue tracer, and decided to hide the relays—mounting them outboard of the horns behind the left-most headlight. For any holes you may drill to mount the relays or anything else, be sure to take steps to treat the bare metal hole to prevent it becoming a future rust generating opportunity.

Depending on what the voltage is at the tail lights, you might consider LED bulbs where you'll get the brightness output so long as the voltage requirements are met. LEDs draw very little power and will be bright even with low voltage so long as their voltage range includes what you measure at the socket. Stag tail lights use the same bulbs as a TR6, you can use that when searching on LED bulb websites such as Super Bright LED's (superbrightleds.com), LiteZupp (litezupp.com), and Classic and Vintage Bulbs (classicandvintagebulbs.com).

A source for correct color coded wire supply that I use and rather like is British Wiring (britishwiring.com); for heat shrink tubing, modern connectors, and nice crimping tools I use West Marine (westmarine.com). If you would like to replace the headlamp pigtails, British Wiring sells them already made with correct wiring, sockets and seals for the TR6 which are the same for the Stag; just get four of them, they fit nicely into the headlamp bowls of the Stag too. When selecting wire gauge, be sure to consider its length as well as its current carrying capacity with less voltage loss in larger wire over its length.

The maximum recommended regular current load for various wire gauges: 10 AWG – 32 amps, 12 AWG – 24amps, 14 AWG – 20 amps, 16 AWG – 15 amps, 18 AWG – 13 amps. For AWG wire ratings, doubling the area of conductive surface in wire decreases the AWG gauge by three, 12 AWG wire has double the conductive surface of 15 AWG, though you're more likely to find either 14 or 16 AWG wire available for purchase. The point is the mathematical relationship in AWG wire gauge numbers.

The original headlight and light systems are challenged due to their age and the natural degradation of electrical connections. Many older vehicles have less than 50% brightness of their lamps, and their owners don't realize it. It isn't difficult or expensive to make the Stag safer, more visible to other drivers and to provide better illumination for ourselves. Measure the voltage at the headlamps and tail lamps and brake lamps, compare that value to the battery voltage measurement, then see how much power is lost throughout the system. You may be very surprised. **SN**

*Michael placed the relays controlling his headlights adjacent to the horns, hidden behind the left outer headlight. Another part of Michael's electrical project was to add a relay to the relay panel so that the headlights only have power when the key is turned on. The gold resistor visible just above the lower horn is for daytime running lights.*