Daniel Stern Lighting

Relays: WHY AND HOW TO UPGRADE YOUR HEADLAMP CIRCUIT

By Daniel Stern with special assistance from Steve Lacker and David Hueppchen

COMMON SENSE REQUIRED BEYOND THIS POINT

The success or failure of your lighting upgrade efforts rides on the quality of your parts and the quality of your work. It matters how carefully you route wires to avoid chafing insulation. It matters how well you solder connections (crimps and sloppy or 'cold' solder joints corrode and die). It matters how well you shield added wiring from road spray. It matters that you use fuses in the new wiring to protect against vehicle damage due to a new or old electrical fault. It matters that you use high-quality parts that are designed to stand up to the rigors of automotive usage. Such components must be resistant to a wide range of temperatures, road splash, fumes found under the hood of every car, severe and prolonged vibration, etc. It will pay you to select only the products of companies with well established reputations for quality and durability; your $2.25 bargain no-name relay could easily kill you when it fails on a dark road somewhere, leaving you with no lights. Do not purchase vehicle components based solely on price!

The techniques described in this article will yield excellent results only if the work is carried out carefully and to a high standard, with quality parts and materials and without corner-cutting or sloppy work.

I personally wouldn't perform this upgrade on a really collectible car without taking care to hide all the new wiring. Actually, there's probably not much need to go to high-powered Cibie (or other European-specification) headlamps on a true collector car that is not driven at night. But on a hard-working daily (and nightly) driver like mine, powerful headlights are a real blessing, and keeping the wiring out in the open where it can be seen and inspected helps avoid failures!! Also keep in mind that this article focusses on the general principle behind headlamp wiring. There are many variations in original-equipment headlamp circuit design, and it will be worth your while to examine your vehicle's setup thoroughly, preferably with the aid of wiring diagrams applicable to your specific vehicle.

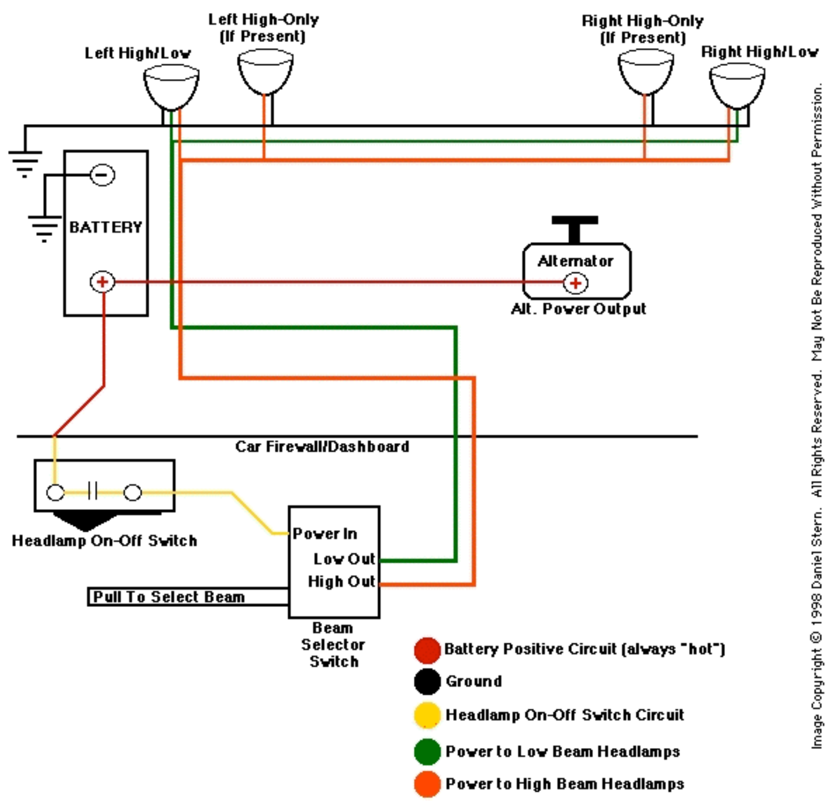
WHY USE RELAYS?

Power for the headlights is controlled by a switch on the dash. This is *not* a great place to tap into the system, for two reasons: The headlamp switch uses tiny, high-resistance contacts to complete circuits, and the wire lengths required to run from the battery to the dashboard and all the way out to the headlamps creates excessive resistive voltage drop, especially with the thin wires used in most factory installations.

In many cases, the thin factory wires are inadequate even for the stock headlamp equipment. Headlamp bulb light output is severely compromised with decreased voltage. For example, normal engine-running voltage in a "12-volt" automotive electrical system is around 13.5 volts. At approximately this voltage, halogen headlamp bulbs achieve 100 percent of their design luminous output. When operating voltage drops to 95 percent (12.825v), headlamp bulbs produce only 83 percent of their rated light output. When voltage drops to 90 percent (12.15v), bulb output is only 67 percent of what it should be. And when voltage drops to 85 percent (11.475v), bulb output is a paltry 53 percent of normal! [Source: Hella KG Hueck AG, Germany]. It is much more common than you might think for factory headlamp wiring/switch setups to produce this kind of voltage drop, especially once they're no longer brand new and the connections have accumulated some corrosion and dirt.

From the headlamp on-off switch, a single wire runs to the beam selector (high/low) switch. Two wires run from the dimmer to the front of the car: one for high beams, one for low.

Here's what we have to start with:



Those are long lengths of thin wire between the battery and the headlamps! Typically we find 16 gauge wire (1.5 mm2) at best, more commonly 18 gauge (1.0 mm2) and in some cases even 20 gauge (0.5 mm2). Most such circuits produce unacceptable voltage drop.

HOW TO MEASURE YOUR VOLTAGE DROP

This test must be made with the lamps switched on and all bulbs connected, so you may have to work to get access to the correct bulb terminal. In some cases, it may be easiest to remove the bulb from the headlamp and (carefully) operate it outside the headlamp with your voltmeter connected.

Connect the positive (red) test lead of a voltmeter to the car battery positive (+) terminal, and the negative (black) test lead to the + terminal of whichever headlamp filament (beam) you're testing -- use the bulb farthest away from the battery. Your voltmeter will give a direct reading of the voltage drop. Write it down.

Then, connect the positive (red) voltmeter lead to the ground terminal of the headlamp bulb, and the negative voltmeter lead to the negative (-) terminal of the battery. Your voltmeter will again give a direct reading of the voltage drop. Write it down. Add the two voltage drop figures obtained, and this is the total circuit voltage drop.

HOW TO SOLVE VOLTAGE DROP

To bring full power from the electricity producer--the battery or alternator Positive (+) terminal--to the electricity consumer--the headlamps--we must minimize the length of the power path between the producer and the consumer, and we must maximize the electrical current carrying capacity, or wire gauge, of that power path. But we still want to be able to control the headlamps remotely (from the driving seat), so how do we do that? Install relays!

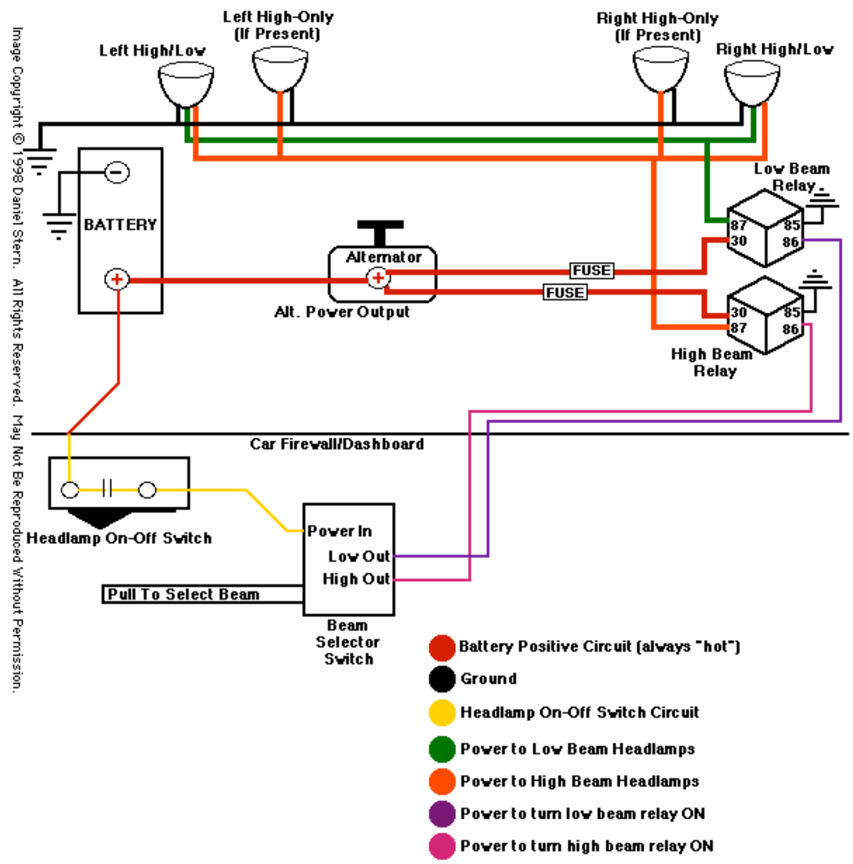
A switch is a device that completes or breaks a circuit, sending or interrupting current to whatever device we wish to control. A relay is simply an electrically-operated switch. When we send power to the relay with the headlamp switch, the relay completes a circuit between the the battery or alternator Positive (+) terminal and the headlamps. Unlike headlamps, relays require only a tiny amount of power to operate, so the thin wires that are inadequate to power headlamps are more than sufficient to power relays. We will simply use the existing headlamp wires to switch the relays on and off, and let the relays do the big job of sending or interrupting current to the headlamps. We use relays with plenty of current carrying capacity, which enables us to use heavy-gauge wiring that also has plenty of current carrying capacity. This way, we can bring full current to the headlamps, with virtually no voltage drop, even if we choose to install power-hungry overwattage headlamp bulbs.

A relay only needs a watt or two of power to activate it. On the other hand, even many old-fashioned sealed beam headlamp systems' total power is over 100W on low beam (even more on high beam), which means they need over 10 amps of current. Remember, Power (in Watts) equals current (in Amps) squared times the resistance (in Ohms). So if the headlamp switch or beam selector switch has a resistance of only 1 ohm due to aging, that means 100 watts worth of heating in the switch. Ever put your hand on a 100W light bulb? Remember that these switches can't dissipate heat very well, so they'll get really hot. You can solder with as little as a 15 watt soldering iron!

So what does the headlamp circuit look like when we install relays?

There are several things to notice in this diagram:

<u>Upgraded Headlamp Circuit With Relays, Fuses, Heavy-Gauge Wire</u>



Those seemingly random numbers on relays and sockets are universal (by Bosch decree...) terminal designators. On relays, we have:

86 is the relay switching (control) circuit input.

85 is the relay switching (control) circuit output.

30 is the power circuit input.

87 is the power circuit output.

The best relays to use in setting up a headlamp circuit have dual 87 terminals. That lets you use one 87 terminal to power the left filament, and the other 87 terminal to power the right filament in whatever circuit you're building (low beam, high beam, fog lamp, etc.). Note that a terminal labelled 87a is not the same as an 87 terminal.

On headlamp sockets, the terminal designations are as follows (not shown in diagram):

56a is the high beam feed.

56b is the low beam feed.

31 is ground.

WHERE TO RUN THE WIRES

Next, you need to choose a place to draw the power for the headlamps. The two most common choices are the alternator output (B+, BAT) terminal, or the battery positive post. Some cars with remote-mounted batteries or underhood fuse panels have underhood power points, and these can be a good selection as well. So, which is the best power point?

On cars with full-current ammeters (mostly pre-1976 Chrysler products) it is best to take power from the alternator output terminal, rather than at the battery Positive (+) terminal. This so that when everything is in its 'normal' state (ie, engine running, battery charged) then the power for the headlamps doesn't go thru the car's existing wiring at all. This is the wise way to do it on cars with full-current ammeters, because such gauges must carry *all* current for the entire car. Keeping heavy current loads out of this area reduces stress on the entire wiring system, and eliminates much voltage drop on the charging side of the wiring.

The vast majority of cars, however, do not have full-current ammeters, which makes it OK to take your choice, based on access and convenience, of the alternator or battery positive terminal (or power point terminals, on cars so equipped). These points are all electrically common, and any of them will serve equally well.

You may have heard that it's not good to take headlamp power from the alternator output because of "voltage spikes"; this is a myth. No voltage spikes are present in an electrical system with good voltage regulation, and any spikes that are present in a system with bad voltage regulation are present in equal magnitude across the entire system. If your charging system is "spiky", indicated by vehicle lamps that flash brighter and dimmer with the engine running at a steady speed, then you need to fix the problem that is causing the spikes!

Another consideration when tapping at the battery is the potential for corrosion. Keep those terminals clean-clean-clean, and once you've added the power wire to the positive battery cable, usually via a ring terminal, be sure to overspray the terminals with plastic-based spray made for the purpose.

Note: The illustrations below use the alternator as the power takeoff point.

PROTECTING THE CIRCUIT WITH FUSES

The system incorporates fuses in the power supply side of the headlamp power circuit, as close as possible to the power takeoff point (battery or alternator + terminal). This is very important! When you start tapping into places in the wiring harness that weren't tapped originally, you must properly protect the wiring system with fuses. In the case of tapping into the "battery" connection on the alternator, for example: suppose your new headlight wiring (or a portion of the old wiring after the relay) shorts to ground. Without a fuse, you will start a fire somewhere! The alternator can typically pump out 60 amps or more, and the battery can contribute another 80 to 100 amps before the vehicle main fuse or fusible link blows. Thats on the order of 130A flowing through your wires, which will heat them to orange-hot immediately. Not to mention that if you do blow the main fuse, you are now stranded as well. And if you own an old classic without any sort of main fuse or total-circuit protection, the entire wiring harness can be quick-fried to a crackling, crunchy crisp in a matter of seconds. I have seen/smelled/heard this happen, and it is not soon forgotten. (Incidentally--if you drive such a car, ADD A MAIN FUSE OR FUSIBLE LINK!)

Notice that in the diagram of the upgraded headlamp switch, the wires to the headlamps themselves are heavier. If you are going to the trouble of fixing inadequate factory headlamp wires, do a complete job and run good wires all the way to the headlamps. The necessary pieces and parts to facilitate such an improvement, such as fuse holders and headlamp sockets compatible with large-gauge wire, can be difficult to find locally. Parts stores tend to carry the same inadequately-small-gauge stuff your car originally came with. Packages containing all these necessary parts, dual-87 relays, and all the rest of the "juicy bits" are available here.

SELECTING WIRE SIZES FOR USE IN LAMP CIRCUITS

Use only stranded wire, never solid (household type) wire, in automotive applications.

Wire gauge selection is crucial to the success of a circuit upgrade. Wire that is too small will create the voltage drop we are trying to avoid. On the other hand, wire that is of too large a gauge can cause mechanical difficulties due to its stiffness, particularly in pop-up ("hidden") headlamp systems. The headlamp power circuit ought to use no less than 14-gauge (2.5 mm2) wire, with 12-gauge (4.0 mm2) being preferable. 10-gauge (5.2 mm2) can be used if bulbs of extremely high wattage are to be used, but it's usually overkill. Be sure to pick a kind that flexes easily if yours is a hidden-headlamp system. Do not fail to use the large wire size on both sides of the headlamp circuit! Voltage drop occurs due to inadequate grounding, too! you will only sabotage your efforts if you run nice, big wires to the feed side of each headlamp, and leave the weepy little factory ground wires in place. Most factory headlamp circuits run the too-thin ground wires to the car body. This is an acceptable ground--barely--on a new car. As a car ages, corrosion and dirt build up and dramatically increase resistance between the car body and the ground side of the vehicle's electrical system. It takes little extra effort to run the new, large ground wires directly to the battery Negative (-) terminal or to the metal housing of the alternator, and this assures proper ground.

WHERE TO MOUNT THE RELAYS

Relays are very compact--about 1 inch by 1.5 inches. Because they take up so little space, it is relatively easy to mount them in an optimal location. Because the main idea with this upgrade is to minimize the length of the headlamp power circuit in order to bring the producer and consumer as close together (electrically) as possible, it is best to mount the relays at the front of the car near the power source (alternator, battery or power point) and near the headlamps. Because you will need at least two relays--one for high beam, one for low beam--you will want to use relays that incorporate a snap-lock feature to create tidy relay banks that can be made to look like factory installations if the wiring is done neatly. These relays also use moulded terminal blocks so that all of the wires come together into one relay socket, which is preferable to having individual wires without a supporting plug. These are the relays included in the installation packages available here.

SPECIAL CONSIDERATIONS FOR GROUND-SWITCHED SYSTEMS

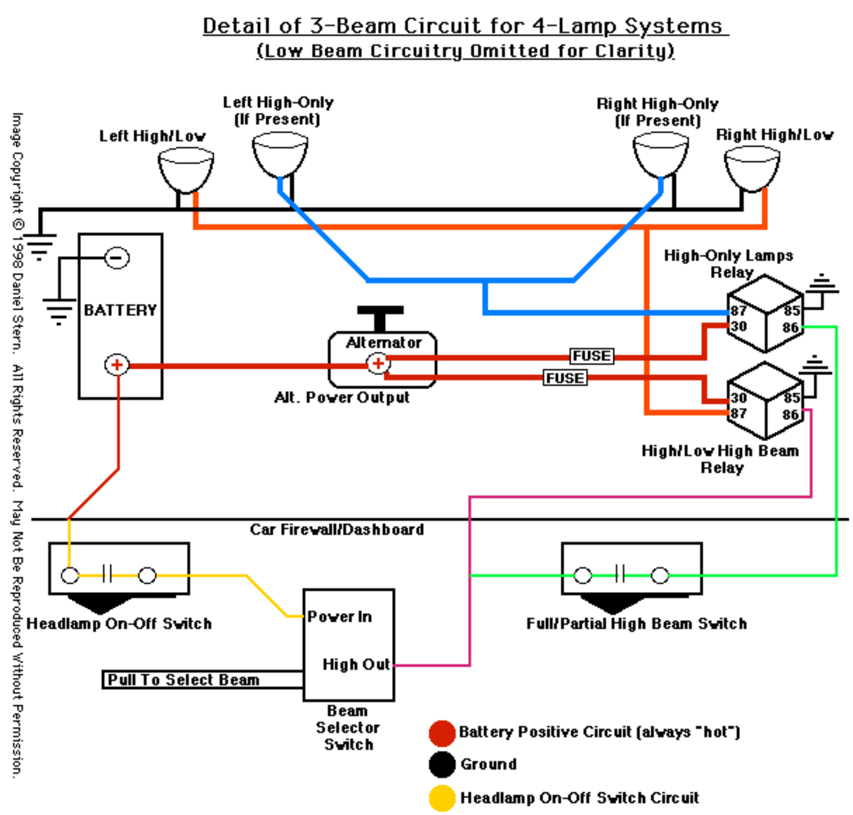
Many Japanese vehicles, as well as a few others, use a "ground-switched" headlamp circuit. In these circuits, the headlamp and beam selector switch break or complete the ground side of the headlamp circuit, rather than the feed side. On these systems, it's imperative to use both negative and positive existing headlamp wires to trigger the relays. It is tempting to run the existing headlamp feed wire to relay terminal 86 (trigger feed) and simply find a convenient ground for relay terminal 85 (trigger ground). However, this will not work with ground-switched systems. Run the vehicle's existing feed wire to terminal 86, and run the vehicle's existing ground wire to terminal85.

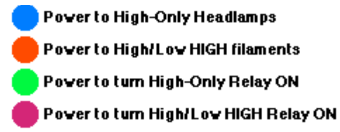
Now, what are we going to do now that we've used-up our one and only ground wire on the 85 terminal of the low beam relay, but we still have to install the high beam relay? Go to the other side of the car and you have another ground wire! Remember, the relay trigger circuits can be as long as you like, because they take insignificant power. So, you can extend the vehicle's existing headlamp wires to your relay mounting location. It is fine to use this method regardless of whether you have a ground-switched system or not, so go ahead and use it if you're not sure.

SPECIAL OPTION FOR 4-LAMP SYSTEMS

Here is a way to increase the flexibility and utility of your quad-beam headlamp system. This is applicable to systems that use a high/low and a high-beam lamp unit. Find a blank spot on the dashboard or the switch console of your car. Install a toggle switch and use a third relay to cut the inner high-only lamps in and out of the high beam circuit. This way, if you're cruising along with all four high beams blazing, and you see taillights way up ahead or headlamps off in the distance, you can throw the switch and deactivate the high-only lamps while keeping the outer lamps on high beam. That way you won't dazzle the far-off other motorist, but you don't have to putter-along on low beam for a mile. It makes for three, rather than two, beam distributions.

To accomplish this, the third relay's control circuit must be complete only when the high beam headlamps are aactivated and when your newly added dashboard switch is turned on. Here is a diagram of such a circuit:





Notice that the full/partial high beam switch is powered by the high beam feed from the beam selector switch. This circuit will change the operating mode of your high beam headlamps. With the full/partial high beam switch in the normal "ON" position, all four high beams will illuminate when you select high beam with the beam selector switch. If you turn the full/partial high beam switch "OFF", the high-only headlamps will turn off while the high/low beam headlamps continue to operate in High Beam mode. You still use the beam selector switch to shift from high to low beam, but the full/partial high beam switch allows to you adjust the reach of the high beams to get the maximum amount of light without dazzling far-off oncoming drivers.

IMPORTANT: Do not use high beam headlamps in traffic. This includes all high beam headlamps, even with the full/partial high beam switch in the "off" position. It is dangerous and obnoxious to use your lamps in a manner that creates glare for other drivers.

SPECIAL CONSIDERATIONS FOR CARS WITH LAMP-OUTAGE INDICATORS

Some cars have dashboard-mounted indicators to tell the driver when a headlamp has burned out. The function of such devices can be disrupted by the installation of headlamp relays. There are ways to maintain the function of a bulb-outage indicator while still using relays. On my own vehicles, I simply remove the bulb from the bulb-outage indicator...I will *notice* a burned-out headlamp!

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