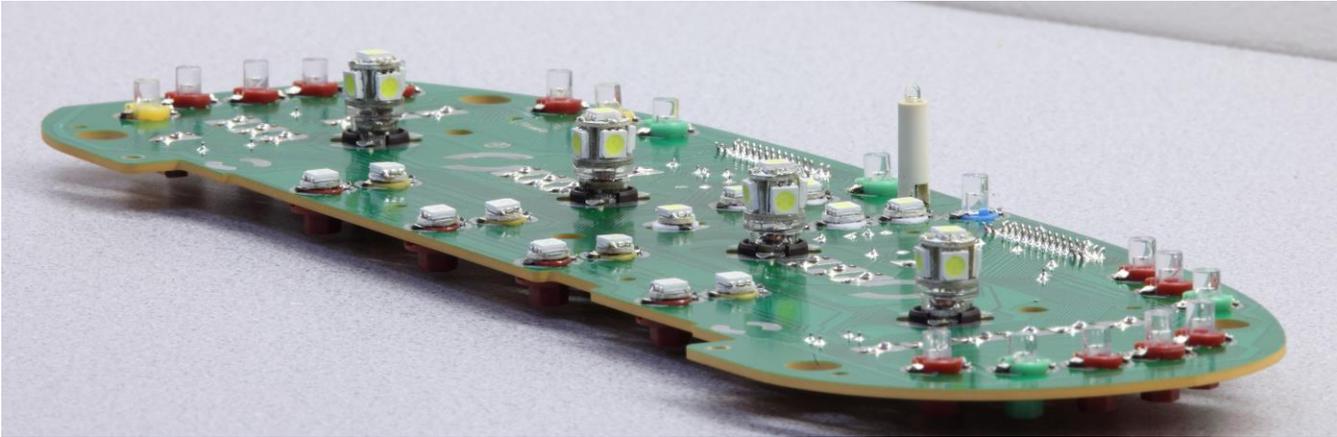


Converting Porsche 928 Interior Lighting to LEDs

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Introduction

This document is intended to provide guidance to those who would like to upgrade their Porsche 928 to use LEDs rather than incandescent lamps for interior lighting. While some of the interior lighting (such as the courtesy lights) are quite simple to upgrade to LEDs, other items such as the instrument cluster and central console (climate control head, etc.) are quite a bit more challenging.

Scope and Limitations

This document is based on my experiences of upgrading a 1990 Porsche 928 S4. It is likely that this guide will apply to 1989 and later 928s; earlier models, however, had significantly different instrument clusters. Models prior to 1987 are even more different and even less of this guide will apply.

Requirements

As I was carrying out my interior lighting upgrades from incandescent lighting to LED lighting, I had the following requirements (or at least preferences):

- Replace *every* incandescent bulb with an LED bulb.
- Increase overall brightness of instrumentation lighting (both backlighting and indicators).
- For any socketed bulb, find replacement LED lamps with identical bases if possible (i.e., no filing or other modification of bulb base or socket).
- Attempt to achieve uniform brightness of indicators, i.e., don't have any indicators arbitrarily brighter than others (e.g., the central locking button always struck me as being *way* too bright when fully illuminated relative to the other indicators).
- Retain functionality of the instrument illumination control using the original rheostat.

Caveats

In a few cases, results were short of what I would consider ideal. These were—in my opinion—acceptable, but still noteworthy. Rather than listing those items here, I have noted them in sidebars.

Terminology

“Owner’s Manual” terminology is used when appropriate. For example, the speedometer and tachometer (among many other instruments and lights) are part of the *instrument cluster*, which also contains the *park brake warning light*, the *air bag warning light*, the *high beam indicator light*, etc.

The S.I. system of units is used.

How to View Photos at Higher Resolution

If you are viewing this document using Adobe Reader (or any other PDF viewer that supports links), the photos in this document are links; if you click a photo, your viewer application should take you to a substantially higher-resolution image on Picasa Web.

Note that when viewing a photo in a web browser, many web browsers (such as Microsoft Internet Explorer) will scale the photo so it will fit within the viewable area of the browser window. You can typically click the image to re-expand it to its full resolution, and then you can scroll around in the image using the browser's horizontal and vertical scroll bars.

Warnings

⚠ Always disconnect the car's battery ground strap before performing significant work on the car's electrical system unless you are *absolutely* sure that the circuit you are working on is not live (e.g., you're *sure* that you've removed a fuse that provides power to the circuit). This isn't necessary for minor items (such as pulling the knob off a pod switch and replacing the bulb). But for complex devices such as the instrument cluster, there are so many signals from so many sources that it is not wise to attempt to work on it (or disconnect/connect it) "hot."

⚠ [more warnings TBA]

Credits

I would like to acknowledge the trailblazing work related to interior lighting of three people:

- Keith Widom (Rennlist handle "928ntslow"), whose "[Interior LED Changeover \(uhm...Looooong\)](#)" thread on the Rennlist 928 Forum provided the inspiration for diving into the instrument cluster and some of the other lighting. In fact, I regard my write-up as a more comprehensive and updated version of Keith's write-up.
- (Rennlist handle) "Schocki", whose "[15 minute instrument pod removal update and instrument light bulbs for an OK price](#)" thread on the Rennlist 928 Forum provided key information on how to remove the instrument cluster without removing the steering wheel. Those who doubt that you can remove the instrument cluster in fifteen minutes... well, (with the knee protector trim already removed) I timed myself and got mine out in six minutes. Once you've done it at least once, it's really easy. Getting in back in takes a little longer (at least it does for me ☺).
- "Wojtek", whose "My 1987 Porsche 928 S4, 5 speed: [Instruments Illumination](#)" provided some very good ideas about instrument illumination, particularly related to the climate control head (I wound up doing something like what he did for backlighting the fan speed control knob).

Parts, Tools, and Techniques

Necessary (or Just Useful) Items

- soldering iron suitable for use on small-gauge wires and PC boards (you might find that you'll want a flat tip for some tasks and a conical tip for other tasks)
- solder
- solder sucker and/or wick for de-soldering
- clip-on heat sink (for dissipating heat from heat-sensitive components when soldering)
- wire cutters
- needle-nose pliers
- assortment of heat-shrinkable tubing
- bench power supply
- multimeter
- test leads terminated with alligator clips, test clips (I really like the little "hook" style), banana plugs; various terminations are used for attaching to power supply, multimeter, circuit under test/being powered, etc.



Working with LEDs

LED Types

There are two main types of LEDs you will be working with in the applications covered by this document:

- *12 V LED lamps*: these are one or more discrete LEDs (see next item) packaged along with a diode (sometimes four diodes in a bridge rectifier configuration, which allows the bulb to be non-polarized, i.e., works when inserted into the socket "either way") and current limiting resistor wired in series such that the LED(s) are protected against reverse voltage (by the diode) and such that their drive currents are regulated by the resistor so they are operating with safe power dissipation when a +12 V voltage is applied across the lamps' terminals. These LED lamps are generally easy to work with and unlikely to be damaged as long as you don't exceed 14 V when powering them.
- *Discrete LEDs (also known as component LEDs)*: these are just "raw LEDs" that rely on external circuitry to limit their drive current. They should not be reverse biased, i.e., they should not have



a higher voltage at their cathode than their anode. Discrete LEDs should be used with care, as they can be easily destroyed in two ways: reverse biasing them or exceeding their rated maximum drive current.

- ⚠ Applying current from a typical power supply or battery directly to a discrete LED *without* using a current-limiting resistor in series with the LED is likely to destroy the LED.

LED Polarity

- With the exception of non-polarized LED bulbs (which are fairly uncommon, but becoming more common for festoon bulbs), it is important that you get the polarity correct on LED bulbs when inserting them into a circuit. LEDs have an anode (“positive side”) and cathode (“negative side”). In an automotive application, the anode is typically connected to some positive voltage (usually a +12 V source or some other smaller positive voltage) and the cathode is typically connected to ground. Some LED bulbs are diode-protected so that if you insert them with reversed polarity, it will do no harm, but (again, with the exception of non-polarized LED bulbs) *a diode-protected LED bulb inserted with inverted polarity will not light*.
- The polarity on some LED bulbs that have internal reverse voltage protection is often not marked. It is best to bench test your LED bulbs and, while you’re at it, mark the polarity. I mark the cathode side (that will connect to the ground/low/negative side of the PC board) with a black marker. Likewise, the sockets for the bulbs—since they were typically intended for use with incandescent bulbs (non-polarized)—should be marked; a black mark on the ground side should suffice.
- On the most common discrete LEDs, the cylindrical/dome-shaped 3 mm or 5 mm diameter ones, the cathode is indicated by the flat side of the flange on the plastic package as well as the shorter of the two leads.
- A discrete LED will likely be destroyed almost instantaneously if you reverse bias it (i.e., apply a higher voltage to its cathode than its anode). Actually, you can get away with some reverse bias (as long as you don’t exceed the LEDs *reverse bias breakdown voltage*), but it’s best to just avoid *ever* applying reverse polarity when working with discrete LEDs.



Choosing Current-Limiting Resistors for Discrete LEDs

If you are using discrete LEDs to replace incandescent bulbs (i.e., in the absence of existing LED driving circuitry), you will need to add a current-limiting resistor (and optionally, a reverse polarity protection diode).



To determine the resistance needed, consult the specifications of the LED; look for the “continuous forward current” parameter. Then, given the voltage (14 V if you want to be conservative, knowing that in automotive

On-Line LED Current-Limiting Resistor Calculators

There are on-line calculators that, given a few of the parameters of an LED, will provide you with the minimum acceptable current-limiting resistor.

For example, the “LED Calculator” at <http://ledcalculator.net/> given the values from Example #1 (see main text on left) provides the following schematic:



applications, the voltage is often higher than 12 V and sometimes as high as 14 V), apply Ohm's law: $V = I \times R$, i.e., voltage equals current times resistance. Use a resistor of *at least* the calculated value (the higher the resistance, the less current will flow through the LED, making it dimmer, but also making it run cooler and last longer).

Example #1: given a LED with continuous forward current of 50 mA, then $R = 14 \text{ V} \div 0.05 \text{ A} = 280 \Omega$. So... you would use a resistor of *at least* 280 Ω . In this case, I'd experiment with resistors certainly no less than 280 Ω , but perhaps as high as 1.5 k Ω , choosing one that provides an acceptable light intensity (remembering that a higher resistance means less current, less heat, and longer LED lifetime).

5%, ¼ W or ½ W carbon film resistors are usually acceptable for most discrete LED current limiting applications. To determine whether to use a ¼ W or ½ W resistor, you can check how much power the resistor will be dissipating using $P = I \times V$, i.e., power equals current times voltage (actually, the LED dissipates some of the power, too, but we can be conservative and ignore that and assume that the resistor dissipates all the power). Note that you can substitute a ½ W resistor where a ¼ W resistor would suffice, but not (in general) vice-versa.

Example #2: Let's assume a 14 V voltage source and a 1 k Ω resistor wired in series with an LED. The resistor would dissipate no more than $P = I \times V = (V \div R) \times V = V^2 \div R = (14 \text{ V})^2 \div 1000 \Omega = 0.196 \text{ W}$. Since this is less than 0.25 W, a ¼ W resistor would suffice.

5%, ¼ W and 5%, ½ W carbon film resistors in a wide range of resistances are readily available from both on-line sources as well as local sources. Radio Shack carries a wide variety.

Selecting the Best LED Color

With few exceptions, it's best to choose an LED color that is well matched to whatever color filter is in front of it.

For example, the turn signal indicator was originally a "white" incandescent bulb behind a green filter to make the indicator "green". Use a green LED for this application.

Whereas incandescent bulbs emit light with a fairly wide range of frequencies in the color spectrum (generally rather "yellowish white"), LEDs emit light at a very specific frequency; they emit a more "pure" color, e.g., "pure green." Using a white LED behind a colored filter generally won't give results as appealing (the color won't be as saturated) as putting the same color LED behind the filter as the filter color.

In a few cases (such as the automatic-transmission-equipped car's "selector lever position indicator"), a compromise must be made, as the same lamp shines through multiple filter colors (white and red or white and green); a white LED is appropriate in such a case, but the result will appear somewhat washed out.

Instrument Cluster

Instrument Cluster Lamp Summary

Main Gauge Backlighting

Bulb Socket	twist-lock, with contacts for W2.1x9.5d base bulb
Original Bulb Type	W3W-12V with T3-1/4 glass with base W2.1x9.5d (10 mm diameter, 26 mm long wedge base; same base as #168 and #194)
Recommended LED Replacement Bulb Type	Super Bright LEDs WLED-WHP5
Notes	<ul style="list-style-type: none"> • Retain twist-lock base; just replace bulb. • Absolute maximum size bulb that will fit is 12.3 mm diameter, 30 mm long (note that a Super Bright LEDs WLED-WHP9-T <i>will not</i> fit).

Information System Display Backlighting

Bulb Socket	twist-lock integrated with bulb (not designed to be separated)
Original Bulb Type	[TBD] with B8.4d twist base
Recommended LED Replacement Bulb Type	<ul style="list-style-type: none"> • Super Bright LEDs B8.4D-AHP (amber) for the upper four “LCD white” lamp positions • Super Bright LEDs B8.4D-RHP (red) for the lower four “LCD red” lamp positions
Notes	Order extra LED bulbs and bench test to obtain sets of four LED bulbs with good color and brightness match (variations can be visible).

Indicator and Warning Lights

Bulb Socket	twist-lock integrated with bulb (not designed to be separated)
Original Bulb Type	W1.5W-12V with T1-3/4 glass with base W2.1x4.9d or B8.4d twist base (all the originally yellow-base bulbs); W1.2W-12V with T1-3/4 glass with base W2.1x4.9d or B8.4d twist base (all the originally blue-base bulbs)
Recommended LED Replacement Bulb Type	Super Bright LEDs B8.4D-xHP for the A/T selector lever position indicators; B8.4D-x for all other indicator and warning lights (where x is: R=red, A=amber, W=white, G=green, B=blue)
Notes	

Tools for Use Working With the Instrument Cluster

- i** A ¼ inch and/or 6 mm socket make excellent tools for removing the B8.4D twist lock bulb bases. You can use a flat-tip screwdriver in the slot, but the plastic base is rather soft and tends to deform fairly easily.
- i** “Vice Grips” (or equivalent) are useful for adjusting the electrical contacts on the B8.4d bulbs.
- i** A permanent black marker (Sharpie or equivalent) is appropriate for marking polarities of LED bulbs and the bulb positions on the PC board.

Instrument Cluster Removal

- ⚠** As the instrument cluster has four connectors with numerous signals, I’d strongly recommend disconnecting the battery (and not just trying to pull a fuse or two) when removing the instrument cluster.

To remove the instrument cluster, follow the instructions at [“15 minute instrument pod removal update and instrument light bulbs for an OK price”](http://forums.rennlist.com/rennforums/928-forum/372301-15-minute-instrument-pod-removal-update-and-instrument-light-bulbs-for-an-ok-price.html) (<http://forums.rennlist.com/rennforums/928-forum/372301-15-minute-instrument-pod-removal-update-and-instrument-light-bulbs-for-an-ok-price.html>).

To remove the instrument pod, you will first need to remove (using a 5 mm Allen wrench) five socket head cap screws, as shown in Figure 2.

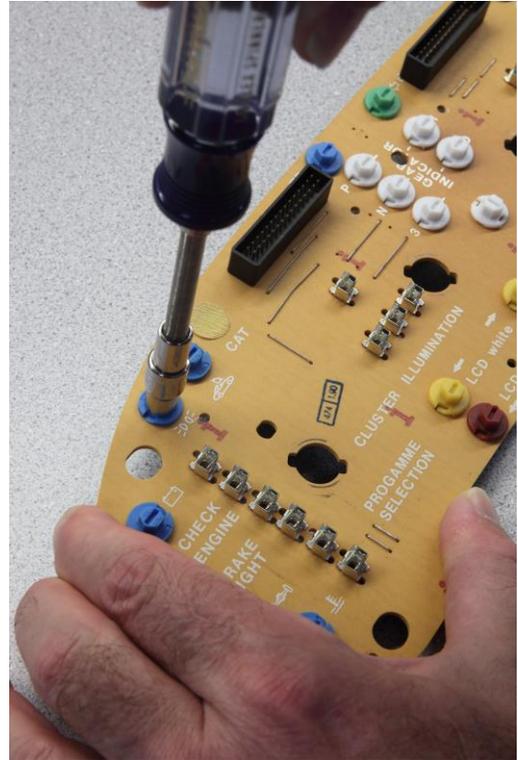


Figure 1: Optimal tool for B8.4d bulb removal and insertion

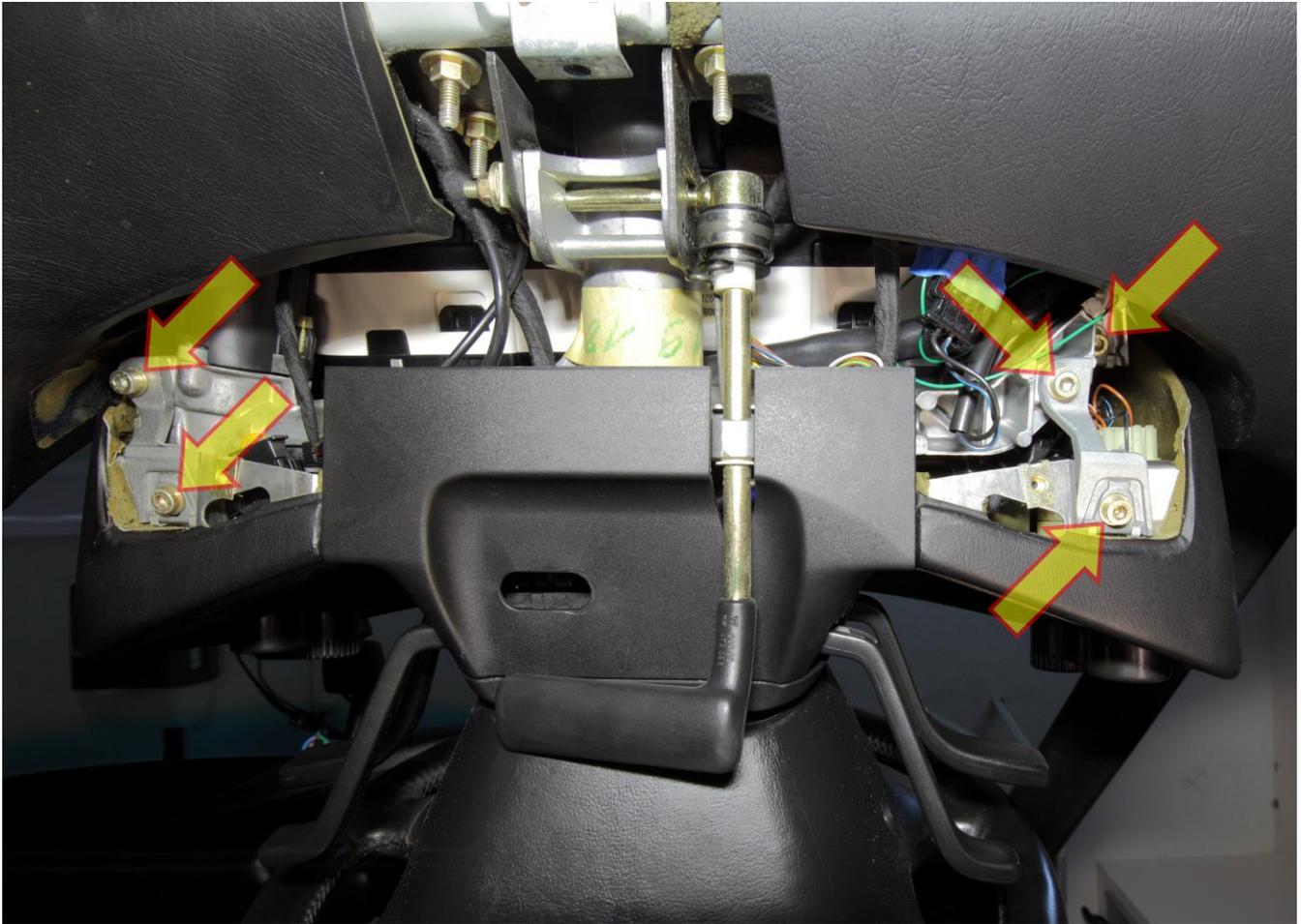


Figure 2: Looking up at the bottom of the instrument pod and the five screws that secure it

You might find that disconnecting the four cables to the instrument cluster is a little challenging if you haven't done it before. Be very careful when unlocking the four connectors. The two little locking levers on each connector are fairly strong, but you can break them if you don't understand how they work. Study the next photo to assist in your understanding of how the locking levers function.



When working with these connectors:

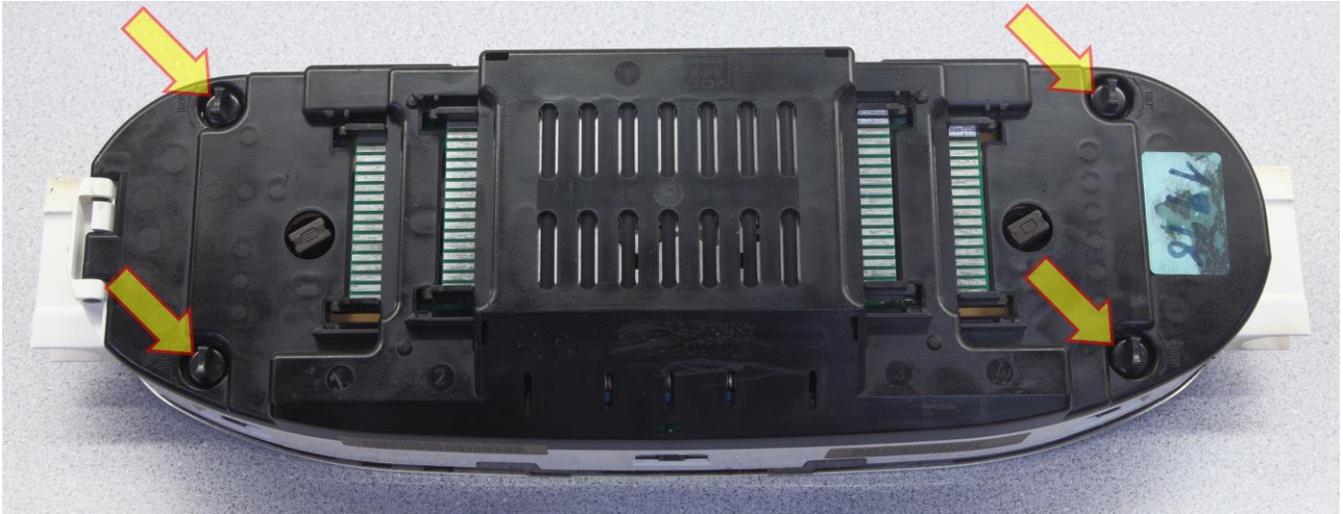
- Move the locking levers slightly away (perpendicular from what appears to be their main direction of travel) from the connector (bend them a little) to allow them to move. This is necessary because there are little slots on the connector and little "pins" on the locking levers that lock them into position either fully closed or fully open.
- Operate both of the levers at the same time if you can; you probably cannot fully unlock one lever while the other one is still locked (this is because as you move the levers to unlock, it also pushes the connector away from the PC board, but it can't do this if the other lever is still locked and if you're not careful and try to force it, you'll likely break the locking lever).
- Consider improving the labeling, since it is likely you'll be plugging/unplugging them more than once and you'll want to be confident you're working with the right connectors (mine had hand-written labels on the connector, but the corresponding labels on the cluster itself were black-on-black and very hard to see). See photos below for improved labeling.



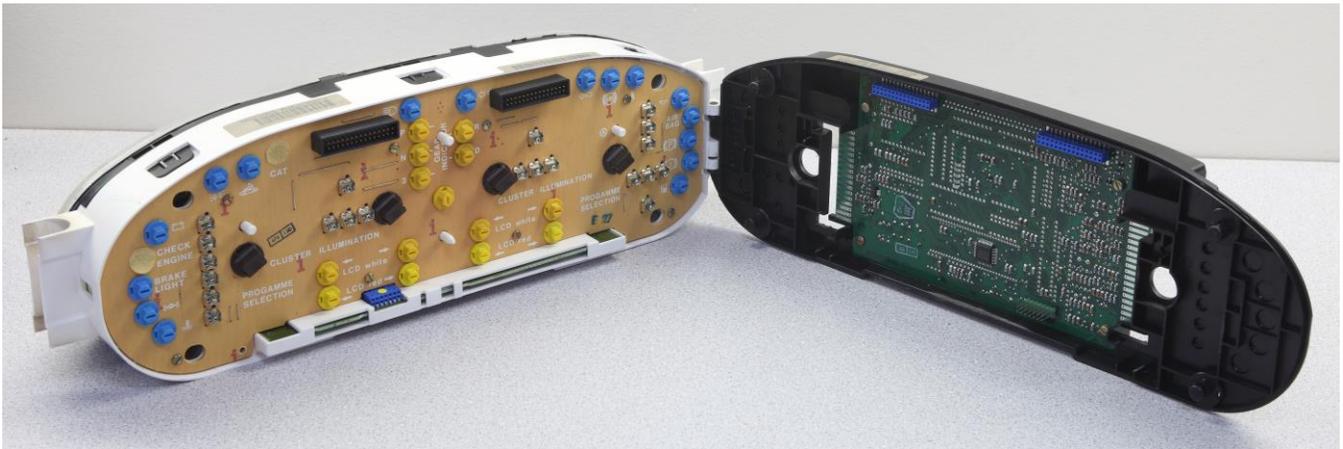
Instrument Cluster Disassembly

To get to the instrument backlighting bulbs, information display backlighting bulbs, and various indicator and warning bulbs, you will first need to separate the rear-most black part of the cluster from the white intermediate part. To do this, rotate each of the four black knobs (see arrows in photo below) on the back of the cluster 180° counter-(anti-)clockwise. You can see the “180°” label near each one of those knobs if you look carefully. Note that these knobs may be difficult to turn if they haven’t been operated for some time; mine were, so I lubricated them with some light, general-purpose oil after I got the back off so they’d subsequently be easier to operate.

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This unlocks the black rear part; you can then open it up like a door:



If you open them up all the way (about 90°) as shown in the above photo, the two pieces will completely separate at the hinge when you move the white half up and the black half down.

At this point, you can familiarize yourself with the main PC board for the instrument backlighting and indicator/warning lamps.



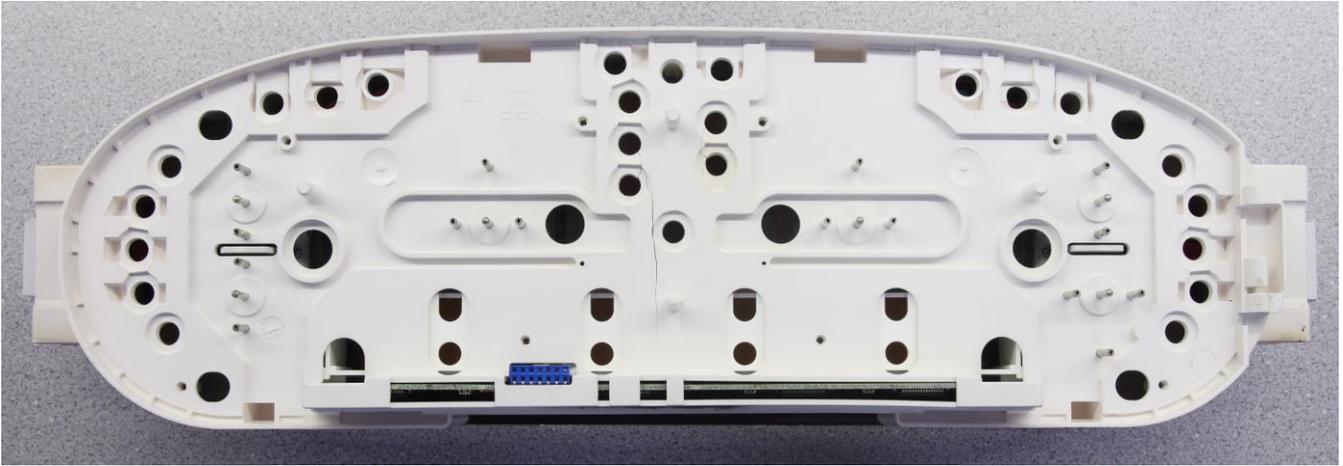
What you'll see (mostly nicely labeled):

- eight screws holding the PC board to the white plastic enclosure;
- twenty-one silver sockets with containing pins; these are the electrical connections for the various analog gauges (they'll come unplugged if/when the PC board is pried off);
- four backlighting bulbs for the analog gauges (brown twist-lock bases) (labeled "CLUSTER ILLUMINATION"); and
- lots of other bulbs in B8.4d twist-lock bases; the lower eight yellow ones are for the LCD information display backlighting (labeled "LCD white" and "LCD red"); the rest are for various indicator and warning lamps and are all nicely labeled.

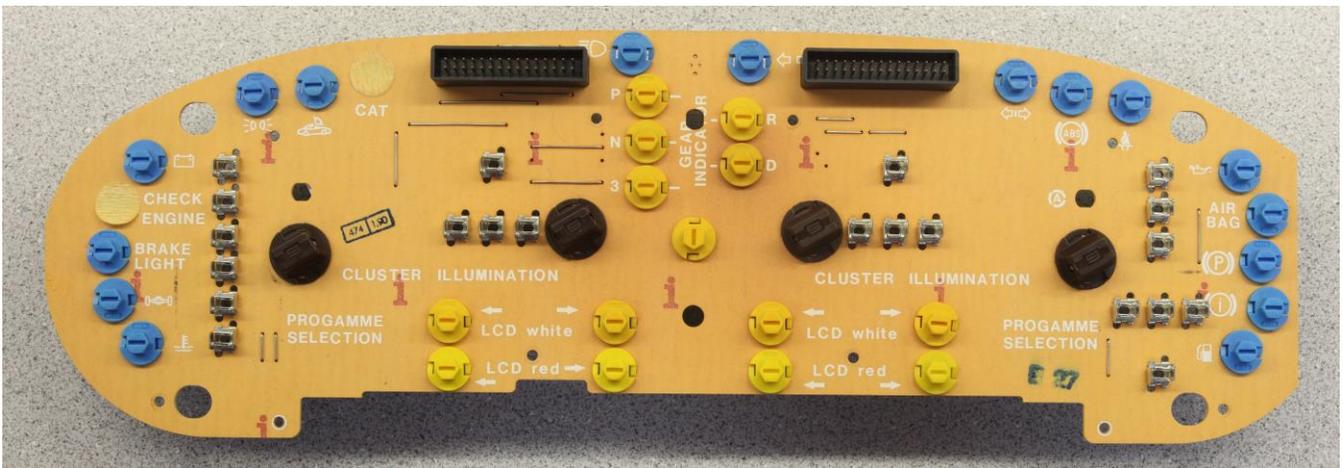
If you were just replacing a small number of bulbs with identical incandescent bulbs, you could probably just do that now, but as you will be doing more substantial modifications, you should remove the eight screws and carefully pull/pry off the PC board. With the eight screws removed, the only things holding the PC board are the analog gauge connectors; they'll separate as you pry/lift the PC board.

Once you've separated them, you'll be left with this:

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and this:



You'll probably get all excited and flip the PC board over so you can see all the bulbs:



At this point, you've got access to all the parts you'll need to replace and work on for the LED upgrade of the cluster.

Instrument Cluster Lamp Replacement

Beveling Holes in PC Board for B8.4d Bulbs



Figure 3: B8.4-XHP bulb; note base spread causing increased diameter near top of base

If you use the recommended B8.4d bulbs, you may find that they are a very tight fit into the instrument cluster PC board. This is especially true for the regular (B8.4-X, non-SMD) bulbs that are pictured in Figure 3; the B8.4-XHP (SMD high-intensity) do not seem to suffer from this problem as much. Note that the plastic base for the bulb is spread out a bit at the top; this makes it a little larger than the hole in the instrument cluster PC board. This slight size mismatch along with the sharp edge of the hole in the PC board makes it difficult if not impossible to insert the bulb. Also, the metal contacts may not fit through the “ears” in the holes; the next section discusses how to address that problem.

You can try squeezing the plastic base near the top of the base with pliers to try to make it fit, but it will likely still be difficult to insert.

Beveling the holes in the instrument cluster PC board solves the problem.

You can either use a round file, as shown in Figure 4, or a Dremel with an appropriate grinding stone (e.g., Dremel #941). A hole beveled as shown in Figure 5 will readily accept a B8.4d (like the one shown in Figure 3).

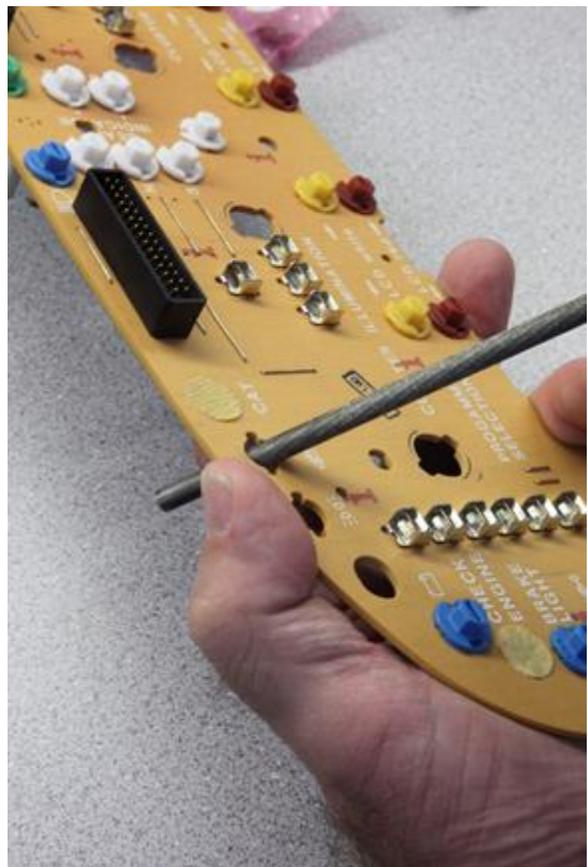


Figure 4: Using a round file to bevel the hole for a B8.4d bulb



Figure 5: Unmodified (left) vs. beveled (right) bulb hole

Dealing with Twist-Lock Contact Shape and Unreliability

Refer to the photo of the B8.4d bulb in Figure 3 and note that there are metal electrical contacts. The upper part (the part nearer the top of the photo) is the part that will actually make electrical contact with the copper trace on the PC board. There are two of these (the one visible in the photo and the one directly across from it on the back that you can't see in the photo).

Two characteristics of these contacts are very important and may need adjustment:

- *The curvature and width of the upper contacts:* the upper contact is bent into a “V” shape to allow it ride over the back edge of the “ear” part of the hole in the PC board and then make contact with the copper trace on the PC board. However, if it is not bent enough, it will not pass through the ear part of the holes. Adjust as needed by bending into more of a “V” shape. “Vice Grip” style pliers can be a good tool for this, as they can be adjusted so they won't over-compress the contact.
- *The spacing between the upper and lower part of each contact:* The spacing between the upper and lower parts of each electrical contact must be slightly less than the thickness of the PC board. If this spacing is too small, the contact will not turn after you've inserted the bulb in the hole in the PC board. If this spacing is too large, the contact will not make electrical contact with the copper trace on the PC board. Most of the bulbs come with the contacts spaced properly, but they bend easily, and the spacing can change when you insert the bulb if everything doesn't line up just right. Adjust with pliers as necessary.

The Mysterious CHECK ENGINE and CAT Warnings

Did you notice that there are two bulb positions labeled CHECK ENGINE and CAT that weren't filled in with bulbs?

It's not clear why these were unused, but I chose to put LED lamps in these positions.

And... interestingly enough, they turn on during the “lamp check” period when the ignition is first switched on.

Whether or not they'll ever actually illuminate to warn about anything, I don't yet know.

Marking Polarity on the B8.4d LED Bulbs

The B8.4d LED bulbs are polarized; they will only light if inserted with their anode connected to the “positive” contact on the PC board and their cathode connected to the “negative” contact on the PC board.

To assure that all bulbs are inserted into the PC board with correct polarity (especially considering that you may be removing them and reinserting them or replacement bulbs for a variety of reasons (testing reveals contact problems, failed bulbs, etc.), it is wise to mark them with their polarity since, unfortunately, this isn't done by the manufacturer.

You can determine polarity with a diode tester (a feature sometimes found on digital multimeters) or by just applying a voltage (from a bench power supply or just a 9 V rectangular battery).

Once you have determined polarity, mark the cathode (negative) side with a black mark.

Deciding on a Color Scheme for the A/T Gear Indicator Bulbs

Most of the photos included in this document show the gear indicator bulbs all using white B8.4d LED bulbs. An alternative choice you may want to consider is shown in Figure 7: green bulbs for '2', '3', and 'D', white for 'N', yellow for 'R', and red for 'P'.

Installing the B8.4d LED Bulbs

Figure 21 shows the polarities of the holes for each of the bulb positions (holes for the twist-lock bulbs) on the PC board.

Insert each bulb through the hole such that when you twist 90°, the polarities will be correct, i.e., that your black mark on the LED will match up with the black marks on the PC board as shown in Figure 21. You may find that a socket screwdriver is the best tool: it can be turned and jiggled gently to work the bulb through the hole and then twist 90° to seat it.

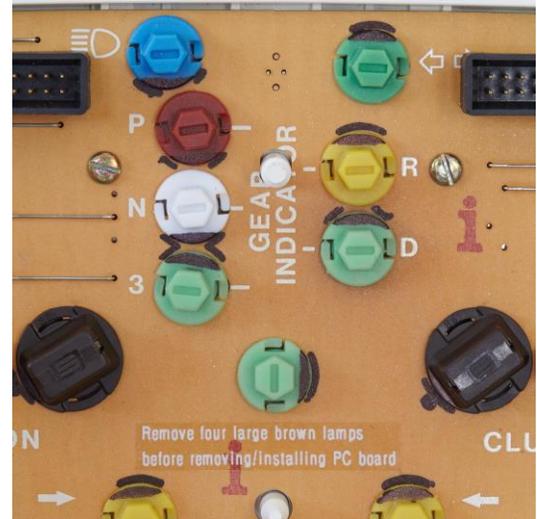


Figure 6: Alternative A/T bulb color scheme

Installing the Four #168/#194-Style Backlighting Bulbs

The four main analog gauge backlighting bulbs are also twist-lock bulbs, but they are easily removable from their brown plastic bases. After removing the original bulbs, you can just insert the replacement LED bulbs into the original twist-lock bases.



While you may want to insert the new LED bulbs along with their twist-lock bases into the instrument cluster PC board and test them, you may find that it is best to temporarily remove them prior to screwing the PC board back into the instrument cluster—the LED bulbs are big enough where it is difficult to insert the PC board into the rest of the instrument cluster assembly with the four main backlighting LED bulbs installed. When the PC board is screwed into position in the instrument cluster assembly, you can then easily install each of the four bulbs, jiggling them down and then twisting them 90° into place.

Marking the Bulb Polarities on the PC Board

At some point, you should mark the polarities of each bulb position on the PC board as shown in Figure 21.

Testing the B8.4d Lamps after Installation

Once you have installed the B8.4d LED bulbs, but before you reinstall the PC board into the rest of the instrument cluster assembly, it is prudent to test the bulbs. You can perform this test “in circuit”.

You should apply 12 V from a bench power supply (or even 9 V from a 9 V rectangular battery) to the traces near each bulb as shown in Figure 7.

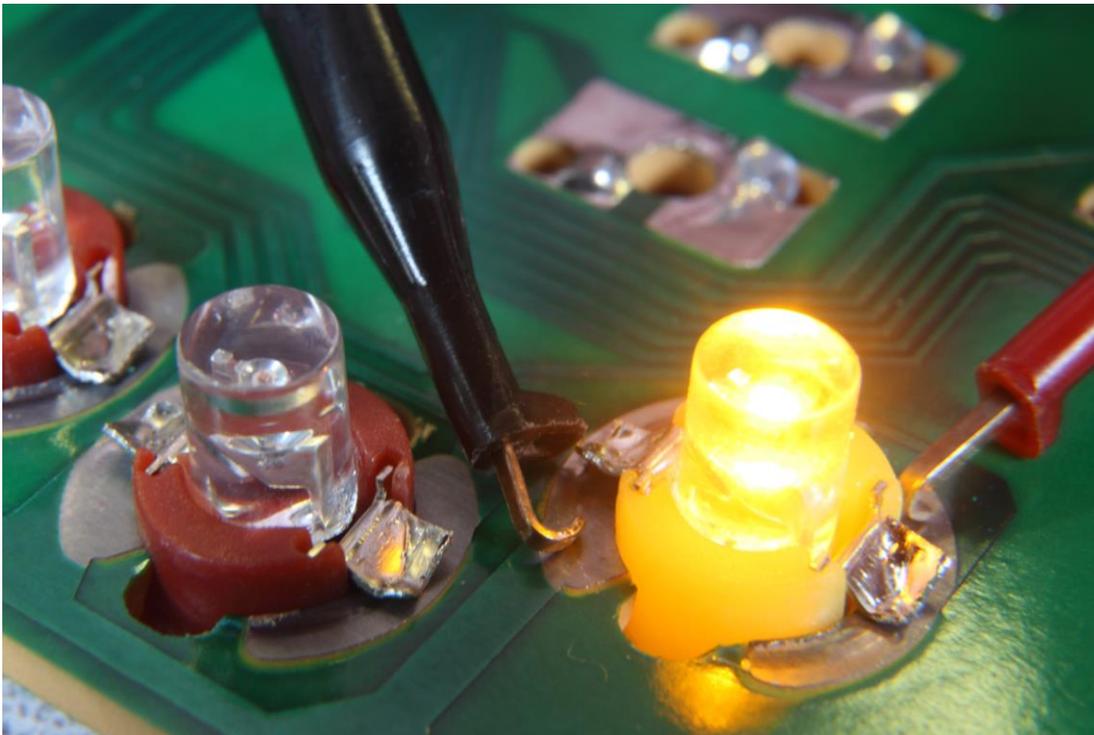


Figure 7: Testing B8.4d LED lamp “in-circuit”

It is important that:

- you observe the correct polarity as you have marked on each bulb and as shown in Figure 21;
 - you apply the test current to the PC board traces near the contacts, *not the LED bulb contacts*! If you were to apply the test current to the LED bulb contacts, you’re missing a key part of the test: to assure that the LED bulb contact is actually electrically connected to the PC board trace.
- i** Note that ordinarily, it would not be wise to apply power to a PC board in this fashion. It is safe in this particular case because this PC board (when removed from the rest of the instrument cluster assembly) is nothing more than a collection of electrical connections from the various connectors to the various bulb positions—there are no active electronic components at all on this board.

Testing the Four #168/#194-Style Backlighting Bulbs after Installation

You can test the four analog instrument backlighting bulbs *after* you reinstall the PC board into the rest of the instrument cluster assembly; the metal contacts are accessible on the edges of the twist-lock knob. Applying 12 V to one of the four twist-lock bulb bases will illuminate and test all four of them. Remember to observe the correct polarity on the bulb.

If the bulb in the base to which you are applying current lights but the other three do not, then that base to which you are applying current is probably not making a proper connection to the PC board (or all three of the other bulb bases are not making a proper contact, but that is much less likely). If any of the bulbs fails to light, you might also have incorrect polarity on those bulbs.

Anticipating and Preparing for Bulb Failures

It is quite possible that you will discover one or more failed bulbs. The sooner this discovery is made—ideally, before you reinstall the instrument cluster into your car—the better.

To reduce the impact of failed bulbs:

- Keep some spare bulbs on hand. This is especially true for the SMD-LED-based bulbs (of the recommended bulbs that go into the instrument cluster, the B8.4D-xHP bulbs and the WLED-WHP5 bulbs are SMD-LED-based). This will at least avoid delays in obtaining replacement parts should they become necessary.
- Remember to mark polarities on each bulb position on the PC board. This will make it easier to replace a failed bulb and getting its polarity correct.

To reduce the likelihood of installing a marginal bulb that is destined to fail sooner than normal, you might consider “burning in your bulbs” for a few hours; many LED bulbs “fail fast”. If a bulb makes it through a few hours of testing, it will likely continue to work.

Heat makes LED bulbs fail faster.

Improving Light Intensity and Reducing Unwanted Errant Light on A/T Selector Lever Position Indicators

A little bit of further disassembly of the instrument cluster is required for this step.

- ⚠ Be careful when separating the last few pieces of the instrument cluster; if the pieces separate in an uncontrolled fashion, you might damage the fragile needles on the gauges.
- ⚠ Separate the front and center parts of the instrument cluster with the cluster *face down* on a soft cloth.

You will need to, one at a time, depress the center of one of the five tabs shown in Figure 8 and Figure 9 (three on top of the cluster, two on the bottom) while simultaneously inserting a flat-tip screwdriver into the closest end slot shown in Figure 10 and pry the white center part of the assembly away from the front part underneath. You'll need to start on one of the ends and work your way around. Until you release all five tabs, you should only

Converting Porsche 928 Interior Lighting to LEDs

pry the parts apart a little bit. Once all five tabs have released, you can pry at both ends simultaneously or just go back and forth from end to end a few times.

(Figure 8 and Figure 9 show the back of the cluster still attached; yours is probably removed at this point.)

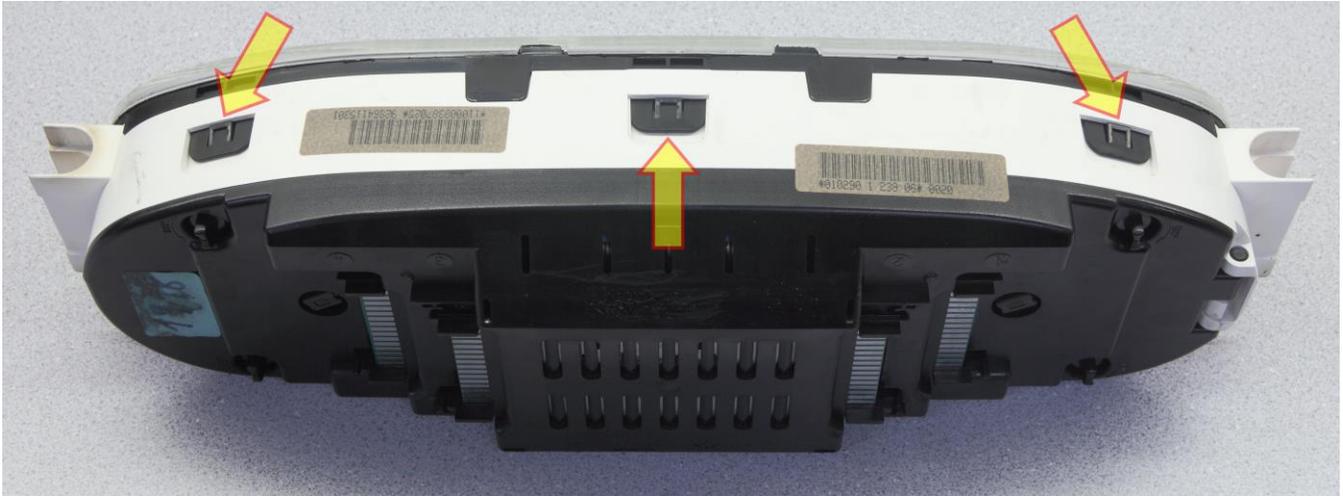


Figure 8: Three front-part-to-center-part-of-cluster latching fastening tabs on the top of the cluster



Figure 9: Two front-part-to-center-part-of-cluster latching fastening tabs on the bottom of the cluster

Converting Porsche 928 Interior Lighting to LEDs



Figure 10: Slot to use for prying the front part from the center part of the cluster

The separated parts will then look like this:



Figure 11: Front part of instrument cluster (be careful with this: it is fragile and will further separate into two pieces very easily!)

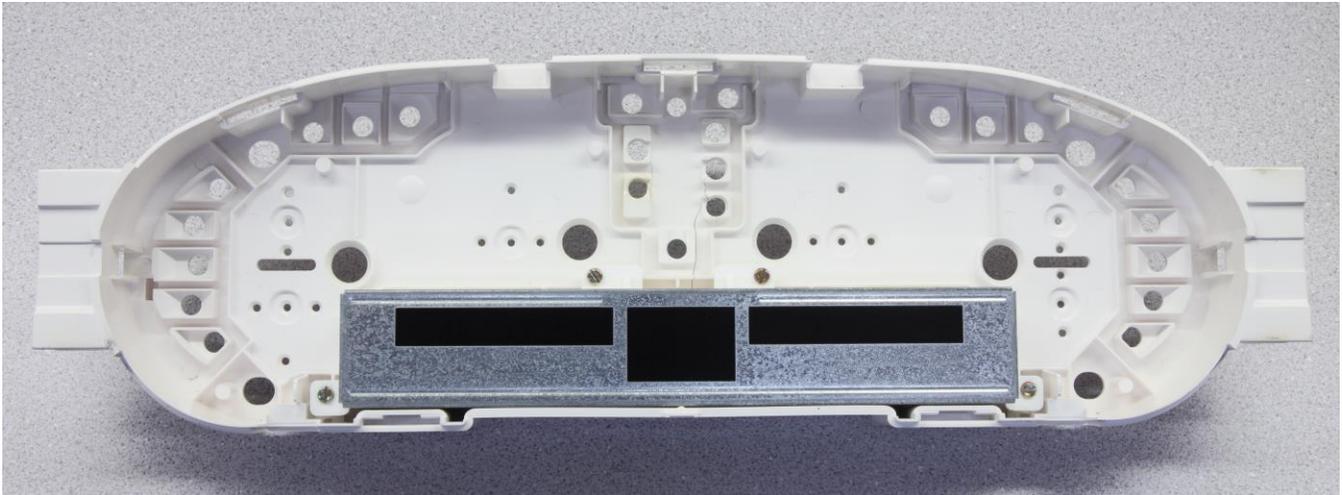


Figure 12: Center part of instrument cluster

The A/T selector lever position indicator bulbs are enclosed in a molded plastic piece that has likely become discolored with age and the heat of the original incandescent lamps. You might get slightly improved light intensity from the replacement LED bulbs if you cover at least some of the discolored surfaces with white or silver metallic tape as shown in Figure 13 and Figure 14.

Again, be very careful when working with this front part of the instrument cluster; it can still separate into two pieces very easily, and if it does when you're not expecting it, you can easily damage the fragile analog gauge needles!

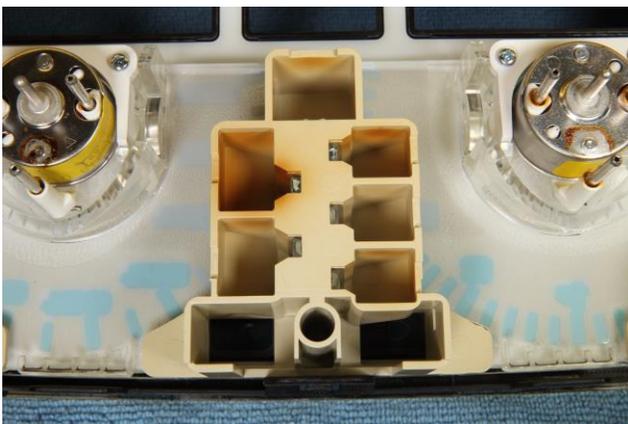


Figure 13: A/T selector lever position indicator bulb housings before modification

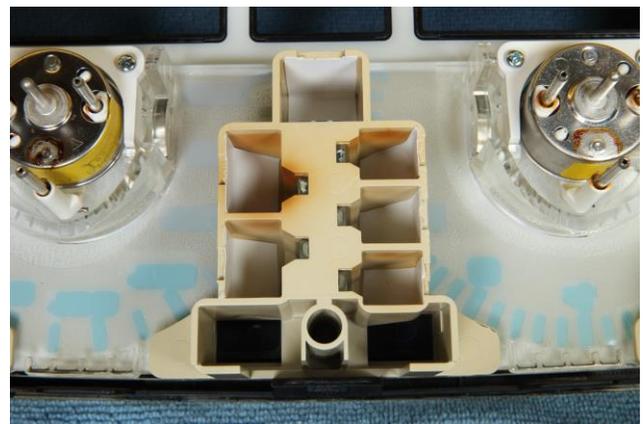


Figure 14: A/T selector lever position indicator bulb housings after white tape added to improve reflectivity

You can also add some black electrical tape as shown in Figure 16 and Figure 17 to mask some areas around the A/T selector lever position indicator bulb housings to help prevent light bleeding through from the very intense analog gauge backlighting.



Figure 15: Black tape added to help prevent analog gauge backlighting from bleeding into A/T selector lever position indicators

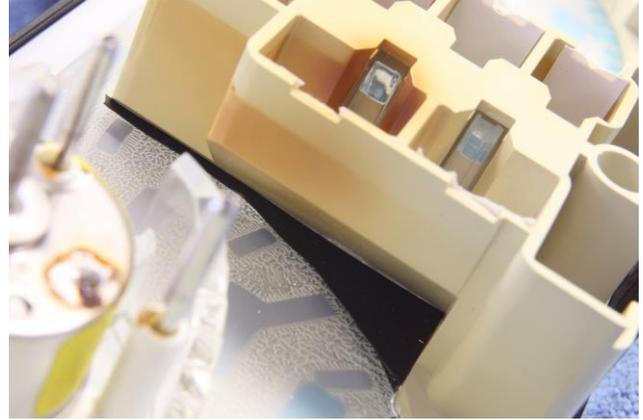


Figure 16: Black tape added to help prevent analog gauge backlighting from bleeding into A/T selector lever position indicators

Cleaning the Front of the Instrument Cluster as Needed

If there is any cleaning you want to do to the front side of the cluster (analog gauges, etc.) or for any other reason, you want to access that part of the cluster, you can easily further disassemble the front part of the instrument cluster (the part shown in Figure 11).

Assuming the front part is still safely placed on a soft cloth face down, just carefully lift up at both ends, grasping at the ivory-colored plastic (the bulb housings for various indicator/warning lights). The whole piece consisting of analog gauges and all the ivory-colored parts should easily lift off of the clear plastic window. Flip this part over (*absolutely do not just set it down face down anywhere!*) and you'll see the front part of the analog gauges, as shown in Figure 17.

At this point, you can perform any maintenance on the exposed parts.



Figure 17: Analog gauges, freed from their housing

Adding Resistor in Parallel to Air Bag LED Lamp

Due to a small amount of electrical current being present even when the Air Bag warning indicator is “off”, it is necessary to add a $390\ \Omega$, $\frac{1}{2}\text{ W}$ loading resistor in parallel with the air bag LED lamp. If you do not do this, that warning indicator will stay dimly lit even when it should be off.

The resistor can be added at the location shown in Figure 18, and wired to the back of the connector shown in Figure 19.



Figure 18: Added 390 Ω , 1/2 W loading resistor in parallel to air bag LED lamp

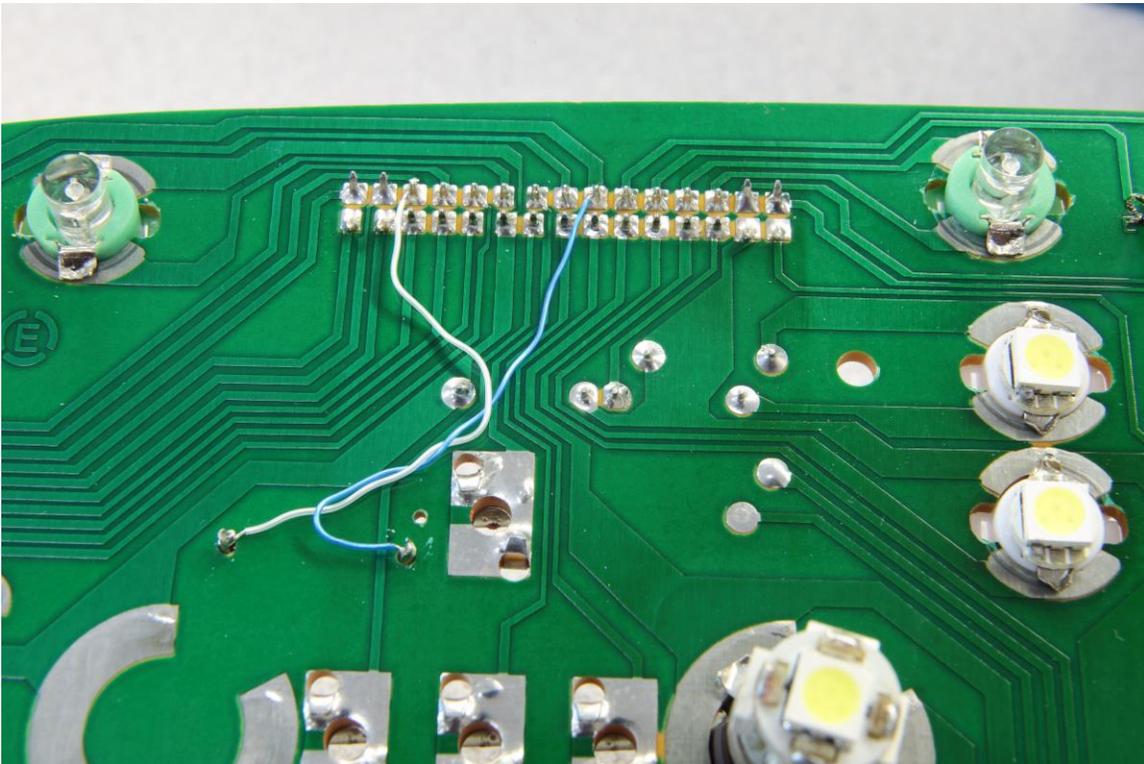


Figure 19: Connections for air bag LED loading resistor; solder wires as shown

Instrument Cluster Reinstallation

Generally, instrument cluster reinstallation is the reverse of removal.

A few tips:

- When refastening the five socket head cap screws (see Figure 2), you may find it difficult to get the three longer ones to thread into its corresponding nut. It may require some jiggling of the whole pod.
- Do not fully tighten all five socket head cap screws until all five are at partially threaded; this will allow pod movement, allowing remaining screws to threaded. You may find that a long screwdriver with a tip smaller than the nut for each screw can be used to position screw hole properly over the nut.
- The middle (and long) socket head cap screw on the side of the cluster held by three screws, if pushed up very hard without engaging the nut, can push the nut out of its holder. You might want to locate the nut so you're prepared to prevent this; it is possible to get a finger on top of it to prevent it from being pushed upward. Alternatively, you can just be very gentle when threading that screw.



Figure 20: Taping the spacers, bushings, and washer

- As shown in Figure 21, use some tape to attach the aluminum spacers, plastic/rubber bushings, and the washer for the left end of the instrument cluster. This holds those components together, reducing the likelihood that you will have problems with this part of reassembly.

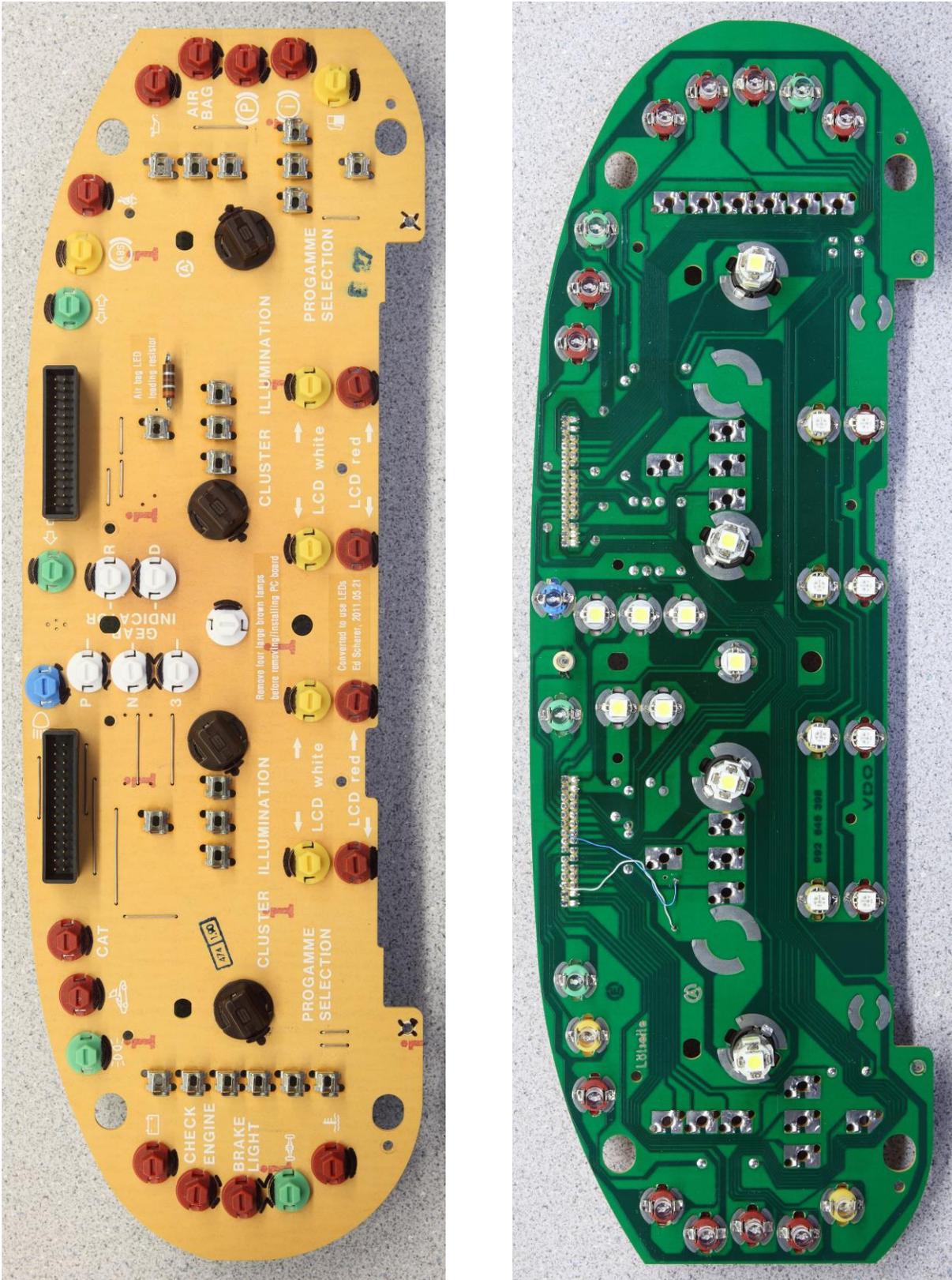


Figure 21: Back and front of PC board after LED replacement; black marks Indicate LED cathode (low/ground) side

Additional Labeling on PC Board

In Figure 21, you'll note some additional labels and markings (beyond the polarity markings at each bulb position, already recommended in an earlier section of this document) that have been added to the PC board:

- White-on-clear label "Remove four large brown lamps before removing/installing PC board": this label provides a reminder that may be helpful during any future maintenance involving PC board removal and reinstallation.
- White-on-clear label "Air bag LED loading resistor": this label explains the purpose of the added resistor.
- White-on-clear label "Converted to use LEDs...": this label provides a record of the significant modification to LEDs that has been performed on the PC board.
- Black "X" marks over the two lower-most holes (that, other than the white circle around them, look like the other screw holes) to clearly indicate that those holes are not used when refastening the PC board to the white plastic part of the instrument cluster assembly.

Instrument Cluster Anomalies

The following minor imperfections were noted with the instrument cluster after performing the LED upgrades as described in this document:

- The air bag warning light illuminates very briefly (probably just a few milliseconds; barely noticeable) at regular intervals approximately every three seconds when the system is operating normally.
- After shutting off the ignition, the park brake warning light (if the park brake is applied) and the ABS warning light are illuminated very dimly as long as the information system display remains backlit.

Further tweaks (like loading resistors in parallel with the corresponding LEDs) might eliminate these anomalies; I didn't believe that it was worth the additional circuitry.

Pod Switches

Pod Switch Lamp Summary

Large Cylindrical Switch Knob Backlighting (5 Switches)

Bulb Socket	W2x4.6d
Original Bulb Type	W1.2W-12V with T1-1/2 glass (4.8 mm diameter, 18 mm long wedge base; slightly smaller than #74)
Recommended LED Replacement Bulb Type	<ul style="list-style-type: none"> • for light switch knob and fog light switch knob: Autolumination “#74 Super High Power 1 Watt Super-Charged LED Bulb”, green • for zero button: Autolumination “#74 Super High Power 1 Watt Super-Charged LED Bulb”, white • for rear window defogger switch knob: Autolumination “#74 Super High Power 1 Watt Super-Charged LED Bulb”, amber • for emergency flasher switch knob: Autolumination “#74 Super High Power 1 Watt Super-Charged LED Bulb”, red
Notes	<ul style="list-style-type: none"> • Wrap thin layer of tape around base as necessary to make snug fit between bulb and socket, preventing bulb from popping out of socket.

Intensive Cleaning Switch Backlighting

Bulb Socket	none; through-hole
Original Bulb Type	3 mm discrete LED
Recommended LED Replacement Bulb Type	Super Bright LEDs RL3-W6045
Notes	Only necessary if you want to change an existing yellow LED to white.

Normal Pod Switch Backlighting Behavior

The normal behavior of the pod switch knob backlighting (in case you never noticed it, or have burned out bulbs, etc.) is:

- The lights switch knob is *always* fully lit; this is probably so it can be found in the dark, regardless of whether or not the lights are on.
- For the fog lights switch, rear window defogger switch, and emergency flasher switch, the knob is:
 - unlit if the lights are off and the switch’s corresponding function is inactive (switched off);

Converting Porsche 928 Interior Lighting to LEDs

- dimly lit (with dimming level set by the instrument illumination control) if the lights are on and the switch's corresponding function is inactive (switched off); and
- fully lit if the switch's corresponding function is active (switched on).
- The zero button knob is unlit if the lights are off and lit (with dimming level set by the instrument illumination control) if the lights are on

Tools for Use Working With the Large Cylindrical Pod Switches

- An IC removal tool (available from many electronic parts and tools vendors, e.g., [Jameco 16838](#)) makes it very easy to remove the large cylindrical pod switches from the pod.
- A small piece of ¼ inch clear vinyl tubing makes a good tool for removing the original pod switch bulbs (it fits over the end of the bulb and makes it much easier to get a grip on the bulb).

Large Cylindrical Pod Switch Removal

While you do not need to remove the pod switches to replace the bulbs, you will need to remove three of them (the fog light switch, the rear window defogger switch, and the emergency flasher switch) to get to the socket wiring to install the current-limiting resistors to make the LED bulbs dimmer when the switch is "off".

The knobs are friction-fit and just pull off the switches (and are just pushed back on to reinstall).

To remove a pod switch from the pod, use the IC removal tool (or equivalent) to grab the pod switch by the "ear tabs", compress the ear tabs, and pull. The photos below show the how the IC extractor tool is used to grab a pod switch (which normally would still be in the pod).

Removing Porsche 928 Instrument Pod Switches: The Video

The YouTube® video "[Removing Porsche 928 instrument pod switches](#)" demonstrates the use of the IC extractor tool to remove a pod switch.



Replacing the Original Incandescent Bulbs with LED Bulbs

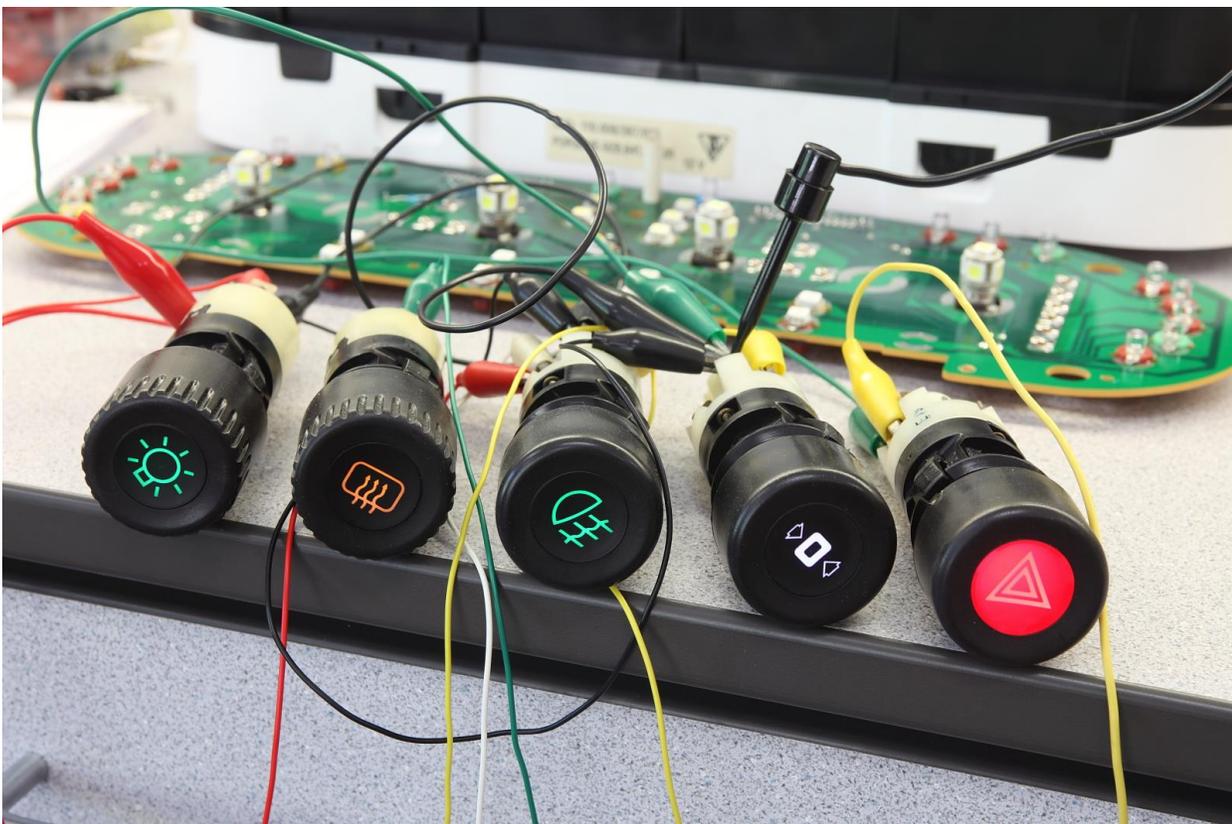
Bulb replacement is trivial; just:

1. Remove the original incandescent bulb (using a piece of vinyl tubing to get a grip on the bulb if necessary);
2. Wrap a thin piece of tape around the base of the recommended replacement LED bulb and push it into place. Adjust the amount of tape as necessary to get a snug fit. Test that the bulb stays in place by reinstalling the switch's knob. For some of the switches, you'll note that when reinstalling the knob, the center portion of the switch that holds the bulb will snap outward and may eject the bulb; if this happens, you'll need to add a little more tape to the base of the bulb.

Repeat the procedure for each of the five large cylindrical pod switches:

- Light switch and fog light switch (green bulbs);
- Zero button (white bulb);
- Rear window defogger switch (amber bulb);
- Emergency flasher switch (red bulb).

When fully lit, the switch backlighting looks like this:



Adding Resistors to Set Maximum “Dim” Level

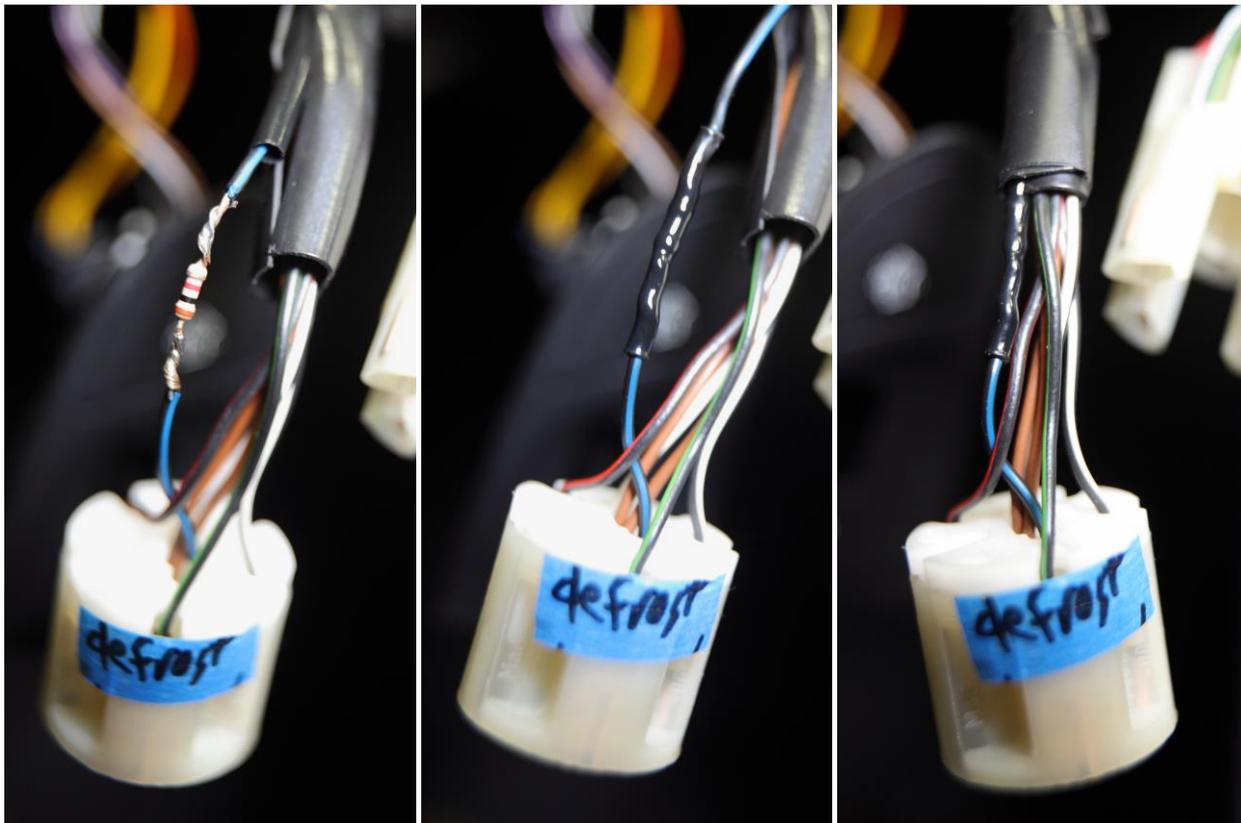
To preserve the original behavior of the backlighting, three of the large cylindrical pod switches (fog lights, rear window defogger, and emergency flasher) need to have resistors added so they will dim appropriately when the switch is off. Likewise, you need to add a resistor for the zero button (even though it doesn't have a separate on/off brightness); otherwise it is too bright.

This modification is necessary because of the reduced power demands of the LED bulbs (more resistance is needed to dim the LED bulbs than was originally used to dim the incandescent bulbs).

The recommended resistor values (assuming the recommended LED bulbs have been used) are:

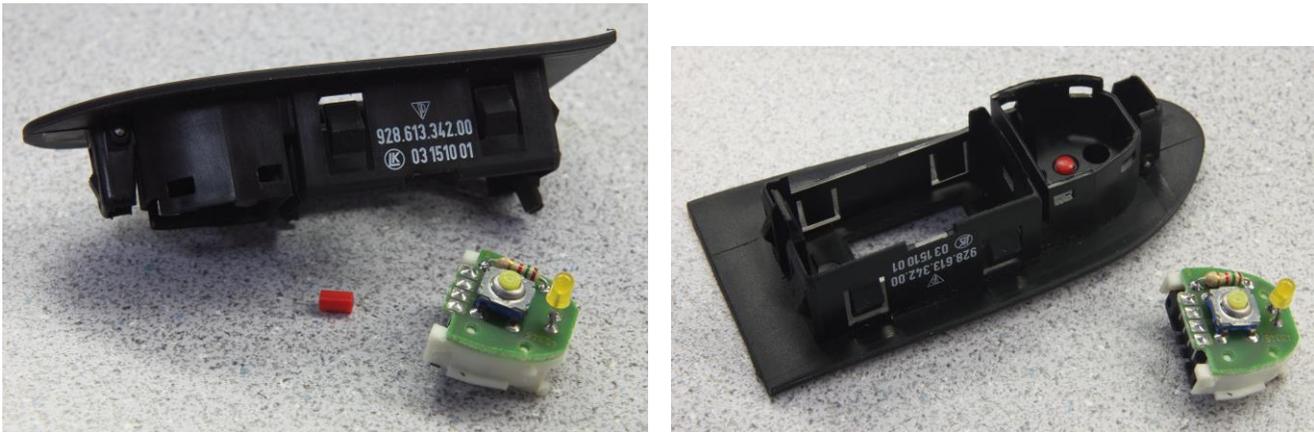
- 1.8 k Ω , ½ W (or ¼ W) carbon film resistor for fog lights switch, emergency flasher switch, and zero button;
- 1 k Ω , ½ W (or ¼ W) carbon film resistor for the rear defogger switch.

In each case, you will need to cut the BK/BL (black wire with blue stripe) leading to the switch's socket and solder or crimp in the resistor. Cover the solder joints and resistor with heat shrinkable tubing (remember to thread the heat shrinkable tubing onto the wire before soldering the resistor in!)



Intensive Windshield Cleaning Switch

The intensive windshield switch may have a yellow LED backlight. If you wish to replace this with a white LED, you'll need to remove the entire switch assembly. Then *very carefully* (to avoid breaking the brittle plastic), use one or two very small screwdrivers to pry the little switch/LED/resistor module out of the black housing. Watch out for the small red plastic cylinder; you need to make sure it's reinstalled as shown or else pressing the black plastic switch cover won't activate the small PC-board-mounted switch underneath.



If you wish to bench test the LED backlighting, just apply 12 V to the terminals (the top two in the photo) as shown in Figure 22.

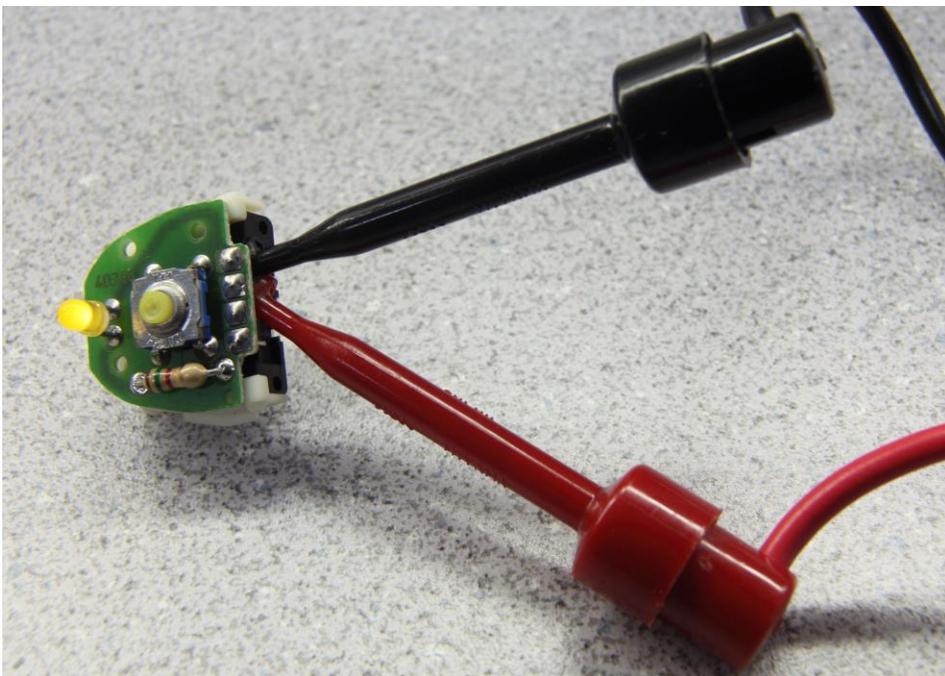


Figure 22: Terminals for testing intensive windshield washer switch backlighting

Converting Porsche 928 Interior Lighting to LEDs

To replace the LED, desolder the old one (a solder sucker and/or solder wick are helpful) and then solder in the new one, making sure to orient it the same way as the original one (especially with respect to the polarity). Solder quickly and/or use a heat sink as shown to reduce the likelihood of damaging the heat-sensitive LED.

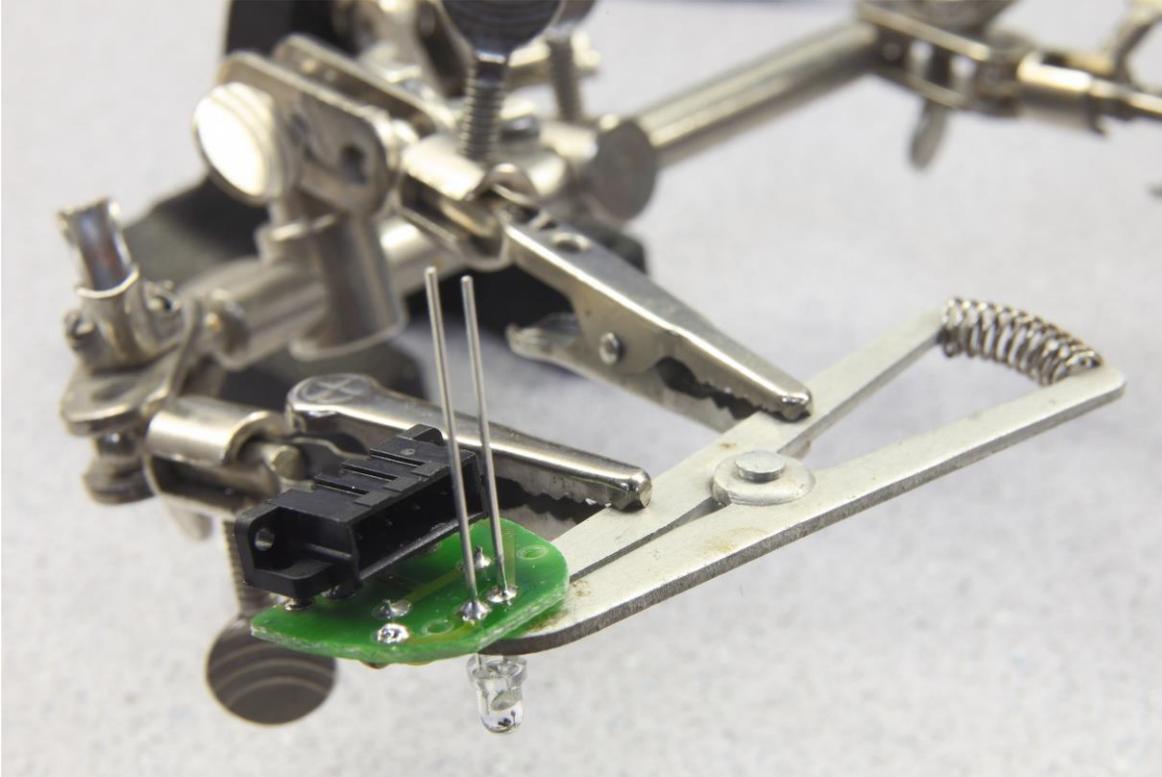
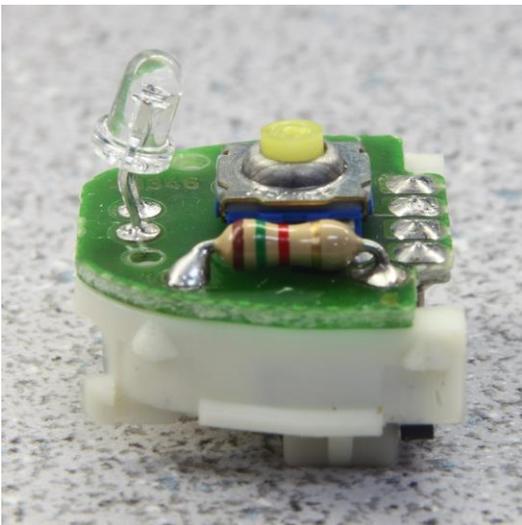


Figure 23: Soldering the replacement LED to the intensive windshield washer switch module (cathode on right)

Bend the leads of the LED so the beam fires slightly inward as shown.



Center Console Switches and Instrumentation

Automatic Climate Control

Central Door Locking Button

Clock

Cigarette Lighter / Ashtray

Courtesy Lighting

Footwell Lights in Lower Door Panels

Light in Headlining Near Front Visors

Light in Headlining Near Rear Visors

Luggage Compartment Light

Glove Box Light

Central Electric Panel Area Light

Restoring Dimming Functionality

The factory 928 instrument illumination control (a simple rheostat that adjusts current supplied to the instrument backlighting circuit) will not function with LED lights; it does no harm, but it provides little if any noticeable dimming.

After being unable to find an off-the-shelf solution to this problem, I developed a microcontroller- and PWM-based dimmer module that restores the dimming functionality using the existing dimmer control (rheostat) already present.

The solution wound up being effective enough that I decided to develop it into a nearly commercial-grade product, although its hand assembly will greatly limit the number of these I can produce.

For more information about this device, see [Protizmo AILD-1 Automotive Instrumentation Lighting Dimmer](#).



Part Summary

Order Extras!

Save yourself the trouble of having to place additional orders for replacement LED bulbs in case any fail or don't match in intensity or color with others. This is especially recommended for the information display backlighting LED bulbs and the analog gauge backlighting bulbs, which seem most prone to failure and matching issues.

Instrument Cluster

i For A/T clusters with the P/R/N/D/3/2 indicator bulbs, the below table assumes you are using all white bulbs. If you prefer to use the alternative color scheme shown in Figure 7, subtract five white B8.4D-WHP bulbs and add one red B8.4D-RHP bulb, one amber B8.4D-AHP bulb, and three B8.4D-GHP bulbs.

Qty	Part	Used For	Available From
11	B8.4d LED bulb, red	<ul style="list-style-type: none"> • brake fluid warning light • park brake warning light • air bag warning light • oil pressure warning light • safety belt warning light • catalytic converter warning light (optional) • tire pressure warning light • voltmeter warning light • check engine light (optional) • stop lamp warning light • coolant temperature warning light 	Super Bright LEDs B8.4D-R
4	B8.4d LED bulb, green	<ul style="list-style-type: none"> • trailer turn signal indicator light • turn signal indicator light • parking light indicator • PSD warning light 	Super Bright LEDs B8.4D-G
1	B8.4d LED bulb, blue	<ul style="list-style-type: none"> • high beam indicator light 	Super Bright LEDs B8.4D-B
2	B8.4d LED bulb, amber	<ul style="list-style-type: none"> • fuel level warning light • ABS warning light 	Super Bright LEDs B8.4D-A
6	B8.4d LED bulb, white, high-intensity	<ul style="list-style-type: none"> • selector lever position indicator (automatic transmission only) 	Super Bright LEDs B8.4D-WHP
4	B8.4d LED bulb, amber, high-intensity	<ul style="list-style-type: none"> • information display backlighting (normal display) 	Super Bright LEDs B8.4D-AHP
4	B8.4d LED bulb, red, high-intensity	<ul style="list-style-type: none"> • information display backlighting (fault display) 	Super Bright LEDs B8.4D-RHP

Qty	Part	Used For	Available From
4	#168/#194-style LED bulb with W2.1x9.5d base, white	<ul style="list-style-type: none"> analog gauge backlighting 	Super Bright LEDs WLED-WHP5
1	330 Ω, ½ W carbon film resistor	<ul style="list-style-type: none"> loading resistor for air bag warning light 	numerous sources (e.g., Radio Shack)

Pod Switches

i There are many #74 style bulbs available from various sources; the ones recommended below were chosen because (of various ones tested), they were appropriately bright, cool running, and had bases that didn't need to be filed to fit into the sockets in the pod switches (quite the contrary—it might take a little tape around the bases to keep them from popping out).

Qty	Part	Used For	Available From
2	#74-style LED bulb, green	<ul style="list-style-type: none"> light switch backlighting fog light switch backlighting 	Autolumination " #74 Super High Power 1 Watt Super-Charged LED Bulb ", green
1	#74-style LED bulb, white	<ul style="list-style-type: none"> zero button backlighting 	Autolumination " #74 Super High Power 1 Watt Super-Charged LED Bulb ", super white
1	#74-style LED bulb, amber	<ul style="list-style-type: none"> rear window defogger switch backlighting 	Autolumination " #74 Super High Power 1 Watt Super-Charged LED Bulb ", amber
1	#74-style LED bulb, red	<ul style="list-style-type: none"> emergency flasher switch backlighting 	Autolumination " #74 Super High Power 1 Watt Super-Charged LED Bulb ", red
1	3 mm, 45° discrete LED, white	<ul style="list-style-type: none"> intensive washer switch backlighting (optional: if was originally yellow LED and you want to replace it with white) 	Super Bright LEDs RL3-W6045
4	1.8 kΩ, ½ W (or ¼ W) carbon film resistor	<ul style="list-style-type: none"> current limiter to dim fog light switch backlighting when switched "off" current limiter to dim zero switch backlighting at all times (it's too bright otherwise) current limiter to dim emergency flasher switch backlighting when switched "off" 	numerous sources (e.g., Radio Shack)
1	1 kΩ, ½ W (or ¼ W) carbon film resistor	<ul style="list-style-type: none"> current limiter to dim rear window defogger switch backlighting when heating element is switched off 	numerous sources (e.g., Radio Shack)

Center Console Switches and Instrumentation

Qty	Part	Used For	Available From
1	5 mm, 15° discrete LED, white	<ul style="list-style-type: none"> climate control fan speed switch backlighting 	Super Bright LEDs RL5-W18015
1	1 kΩ, ½ W carbon film resistor	<ul style="list-style-type: none"> current limiting resistor for climate control fan speed switch backlighting LED 	numerous sources (e.g., Radio Shack)
1	1N4148 or 1N914 diode	<ul style="list-style-type: none"> reverse voltage protection for climate control fan speed switch backlighting LED (optional) 	numerous sources (e.g., Radio Shack)
1	#74-style top-and-side firing 5-SMD LED bulb	<ul style="list-style-type: none"> climate control head (including sliders) backlighting 	Autolumination “ #74 Matrix II, 5 LED 5x brighter ”, super white
1	#74-style LED bulb, high intensity	<ul style="list-style-type: none"> rectangular A/C button backlighting 	Super Bright LEDs 74-WHP
1	5 mm, 60° discrete LED, red	<ul style="list-style-type: none"> central door locking button backlighting 	Super Bright LEDs RL5-RD1560
1	1.8 kΩ, ½ W (or ¼ W) carbon film resistor	<ul style="list-style-type: none"> current limiting resistor for central door locking button backlighting when indicating “unlocked” (dim) 	numerous sources (e.g., Radio Shack)
1	680 Ω, ½ W (or ¼ W) carbon film resistor	<ul style="list-style-type: none"> current limiting resistor for central door locking button backlighting when indicating “locked” (bright) 	numerous sources (e.g., Radio Shack)
1	B8.5d LED bulb, white, high-intensity	<ul style="list-style-type: none"> clock backlighting 	Super Bright LEDs B8.5D-WHP
1	BA7s LED bulb, white	<ul style="list-style-type: none"> lighter backlighting 	Super Bright LEDs BA7S-W

Courtesy Lighting

Qty	Part	Used For	Available From
3	42 mm festoon-style LED bulb, front-firing, wide, white	<ul style="list-style-type: none"> footwell light in left door panel footwell light in right door panel overhead light in headlining near front visors 	Super Bright LEDs 4210-CWHP6
3	42 mm festoon-style LED bulb, front-firing, narrow, white	<ul style="list-style-type: none"> overhead light in headlining near rear visors luggage compartment/hatch light central electric panel area light 	Super Bright LEDs 4210-CWHP3
1	30 mm festoon-style LED bulb, front-firing, white	<ul style="list-style-type: none"> glove box light 	Super Bright LEDs 3022-W9

Converting Porsche 928 Interior Lighting to LEDs

[TBA: seat position memory switch backlighting]