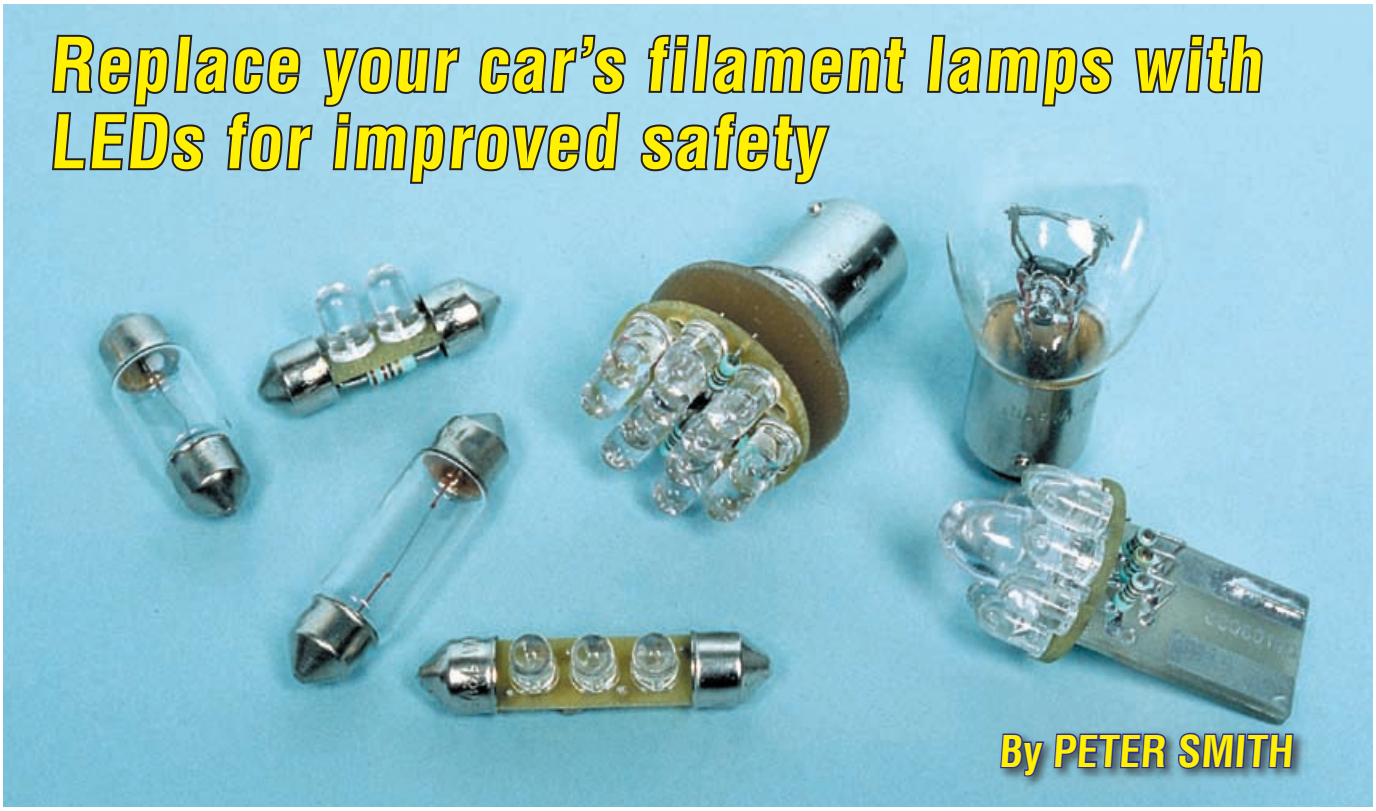
Replace your car's filament lamps with LEDs for improved safety



By PETER SMITH

LED Lighting For Your Car

INCREDIBLY BRIGHT Light Emitting Diodes (LEDs) are now available in standard 5mm packages – bright enough, to rival incandescent bulbs in some applications.

This month, we present five simple and easy-to-build modules based on these, ultra-bright LEDs. These modules can be used to replace or supplement a variety of existing automotive lights to improve safety.

Safer, huh?

Do you know why the centre high-mount stop lights of some vehicles use LEDs rather than conventional filament lamps? For the "high-tech" look, perhaps?

Maybe, but there's a much more important reason; LEDs reduce the incidence and severity of rear-end collisions!

So how is this possible? The answer is based on the fact that filament lamps typically take between 120ms and 250ms to 'light up' when you hit the brakes. If that doesn't sound like much, then consider the distance travelled in 200ms at 70mph/6·8yds (approx. 6·3m):

70mph x 1/3600 x 200ms x 1760 = 6·3m

Convert These to LEDs

- High-mount stop lights
- Trailer lights
- Breakdown lights
- Interior (festoon) lights
- Bayonet lamps
- Wedge lamps
- Almost anything!

Those 6·3 metres could make all the difference in an emergency braking situation – a serious accident or none at all!

The good news is that you can get that distance back with LED-based stop lamps, because LEDs 'light up' almost instantaneously. Not only that but the fast turn-on of LEDs makes them more conspicuous; they have greater attention-getting power.

LEDs have a number of other advantages over filament lamps, too. They load vehicle electrical systems by at least one third less, generate little heat, require *less* space and have a very long service life.

With all these positives, it seems ludicrous that new vehicles still aren't fitted with the latest high-brightness LED technology even in the centre high-mount stop light (CHMSL).

You can now convert your old-technology CHMSL to the latest and greatest with the aid of our LED CHMSL module and a few simple tools.

This particular module consists of a single, 150mm-long PC board strip carrying 16 high-intensity red LEDs, four resistors and two diodes. It should fit inside most CHMSL housings without too much difficulty, replacing the standard 21W filament lamp. But before we describe how that's done, let's take a look at how it works.

How the modules work.

All modules are of the simplest design possible. They consist of one or more strings of LEDs, current limiting resistor(s) and in most cases a diode or two as well.

Referring to the circuit diagram for the CHMSL module (Fig.1), you can see than the LEDs are arranged in four strings. Each string consists of four LEDs in series with a current limiting resistor. The resistor sets the current through the string, as follows:

$$I = V/R$$
$$= V_{BATT} - V_{DIODE} - (4 \times V_{LED}) / R$$
$$= 12{\cdot}8V - 0{\cdot}7V - (4 \times 2{\cdot}0V) / 150\Omega$$
$$= 27{\cdot}3mA$$

V_{LED} is the forward voltage of the LEDs at the intended current, in our case about 27mA. This value will vary between LED types, so you may need to adjust your resistor values for optimum results.

Although the high-brightness red LEDs we've specified can be driven at much higher current levels (up to 50mA), we recommend derating to a maximum of 30mA to allow for the high temperatures found in automotive interiors. If you're using different LEDs, then derate even further to 25mA.

V_{DIODE} is the forward voltage of the 1N4004 diode. The purpose of this diode is to protect the LEDs from the large negative voltage transients (up to 400V) often present in automotive electrical systems.

Typical LED reverse breakdown voltage is somewhere in the region of 5 to 6V, so with four LEDs in series the best we could hope to "stand off" without the additional diode would be about 24V.

In cases where there are less than three LEDs in a string, the 1N4004 also provides reverse polarity protection. Without protection, accidental lead reversal could cause your LED bank to glow brighter than the Sun for a few milliseconds!

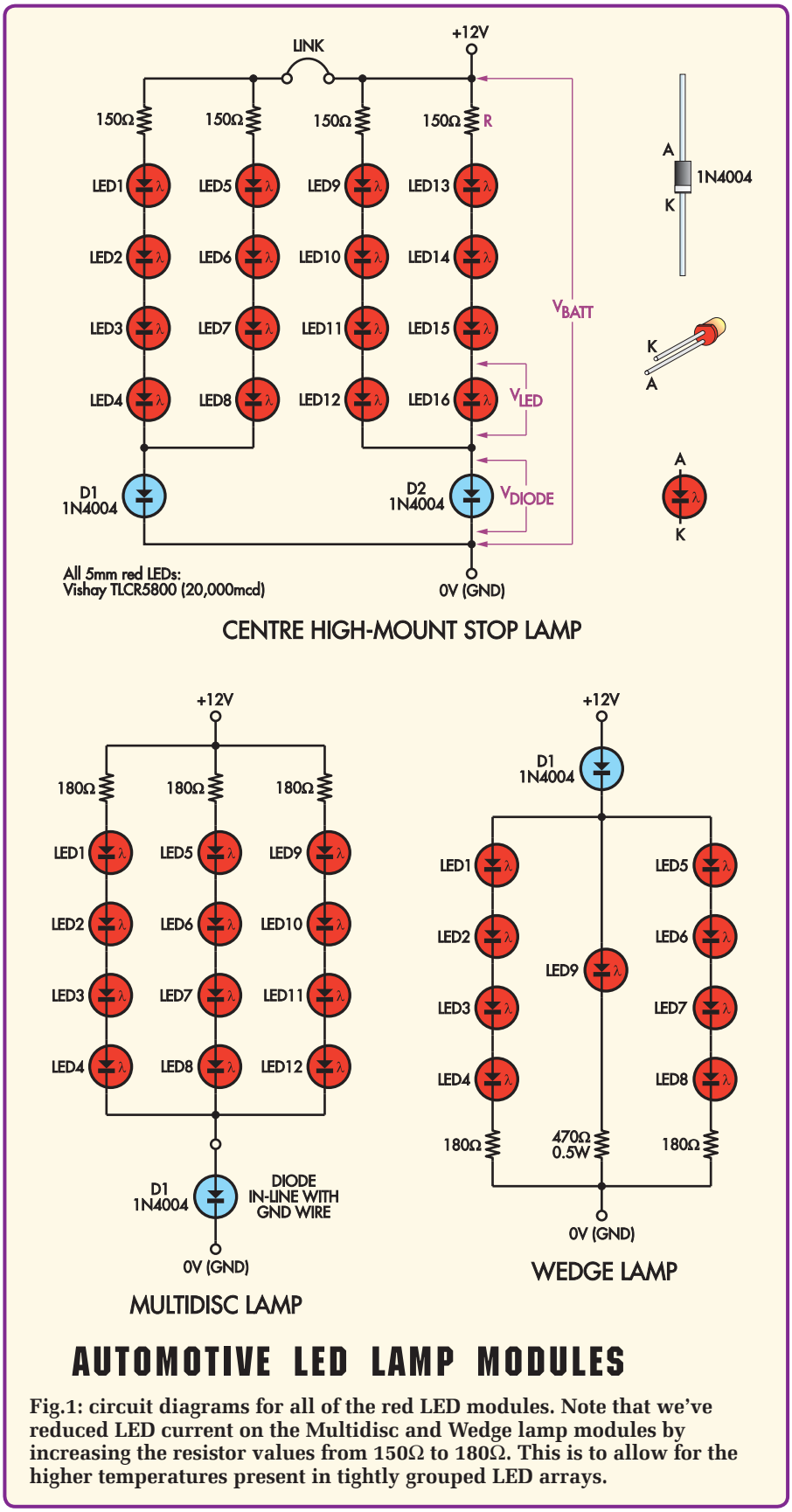


Fig.1: circuit diagrams for all of the red LED modules. Note that we've reduced LED current on the Multidisc and Wedge lamp modules by increasing the resistor values from 150Ω to 180Ω. This is to allow for the higher temperatures present in tightly grouped LED arrays.

An example

Let's look at an example. Suppose you're using different LEDs to those

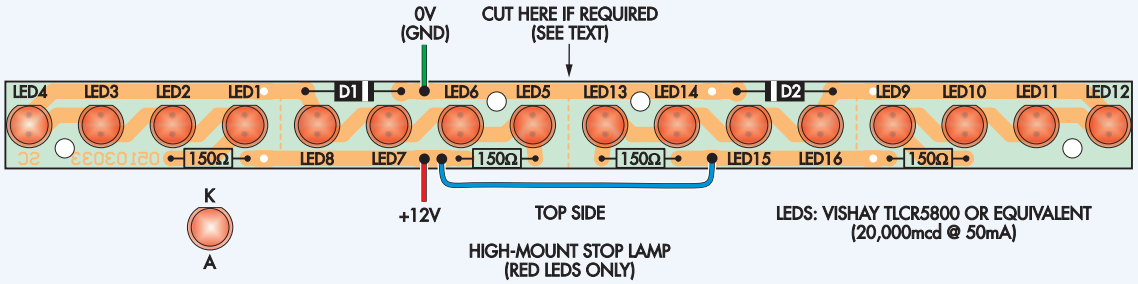
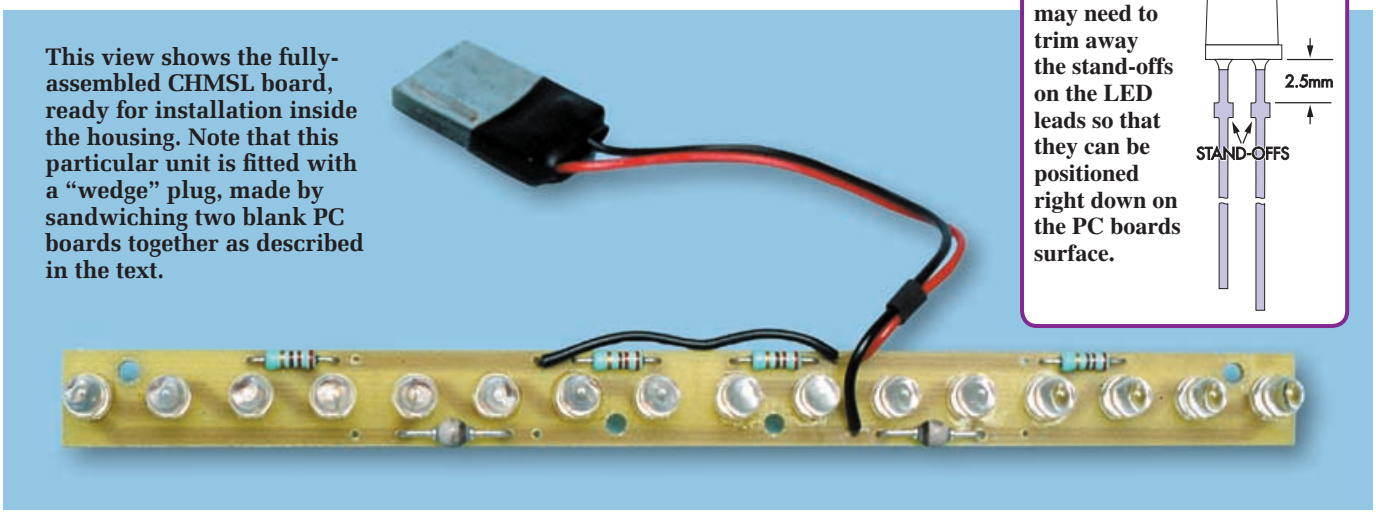


Fig.2: follow this diagram when assembling your centre high-mount stop lamp board.



This view shows the fully-assembled CHMSL board, ready for installation inside the housing. Note that this particular unit is fitted with a "wedge" plug, made by sandwiching two blank PC boards together as described in the text.

Fig.3: you may need to trim away the stand-offs on the LED leads so that they can be positioned right down on the PC boards surface.

shown in the parts list and you've determined that they drop about 1·8V at 25mA (the forward voltage can be determined from the LED data sheets or by trial and error). What value resistors would you use on the CHMSL module?

R = V/I
= 12·8V – 0·7V – (4 x 1·8V) / 25mA
= 196Ω

The closest readily available value to 196Ω is 200Ω, so that would be your final choice. A 0·25W power rating is sufficient in most cases.

So far, we've only talked about the CHMSL module but there is little difference in operation between the five modules. Some have less LEDs per string, some have just one (the 10mm LED on the wedge lamp, for example) and one requires the diode to be fitted externally.

Note, however, that we've listed LED colours with each module. This is because white and blue LEDs have a significantly higher forward voltage than red (and other colours) and therefore will not work on modules that have four LEDs in series.

Likewise, reds (and other colours) cannot easily be used on the modules specified for white and blue without considering the increased resistor power dissipation requirements.

CHMSL module assembly

Referring to the overlay diagram in Fig.2, begin by installing the two diodes and four resistors. Take care with diode orientation, noting that D1 and D2 go in different ways around.

Next, install all 16 LEDs, aligning the side with the 'flat' (the cathode) as indicated. This should also be the side with the shorter lead. We mention this because some 10mm LEDs we received were incorrectly polarised; the flat side was next to the anode (longer lead). If you're not sure, use your multimeter on "diode test" to verify polarity.

The LEDs should be seated right down on the PC board surface. Some LEDs have large standoffs formed into their leads, making this impossible. If you have this problem, then measure between the underside of the LED and the start of the standoffs (see Fig.3). If you measure 2·5mm or more, then you can cut the leads off right at the edge of the standoffs, as there will be sufficient length remaining for soldering. Try just one LED first, though!

If the standoffs are closer than 2·5mm to the body, then shorten the leads to about 4mm and using a fine-edged pair of electronics side-cutters, carefully snip away the shoulders of the standoffs (see Fig.3).

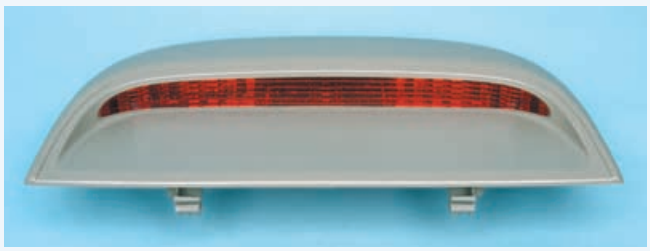
WARNING

If you have a recent-model car, it may have a lamp failure detector in the brake lamp circuit. If you convert just the CHMSL to LED operation, it is unlikely to be affected. However, if you also convert the stop lamps to LED operation, the lamp failure detector will almost certainly operate each time you press the brake pedal. The fault may even be recorded in the computer's diagnostic memory.

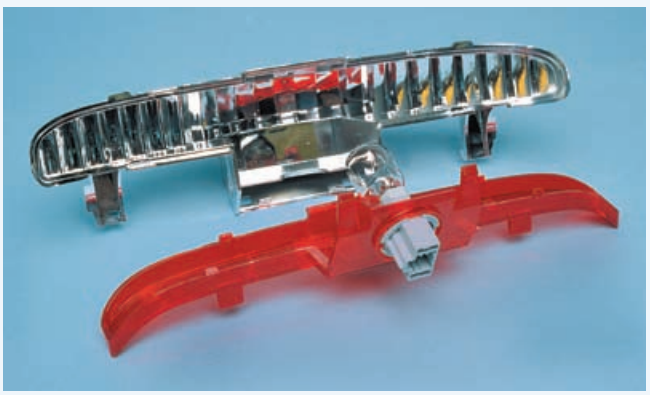
In some older prestige cars, such as some Lexus models, the CHMSL also has a lamp failure detector and it will "detect" a lamp failure if the LED conversion is present. At present, we have no solution for this problem.

Converting A High-Mount Stop Light To LEDs

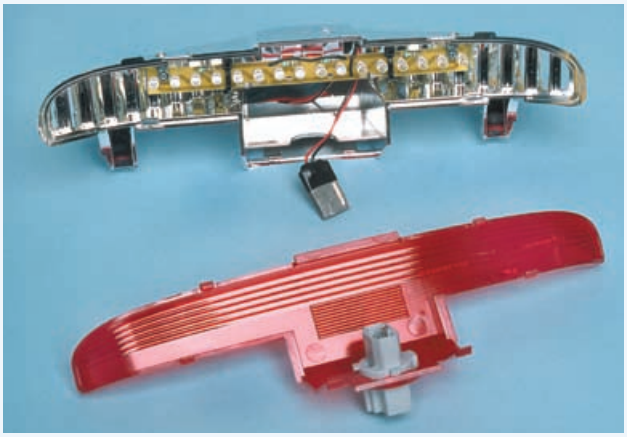
Fitting the CHMSL module (shown at left) to an existing housing can be achieved with a little ingenuity. Here's how we did the job on a Honda Accord.



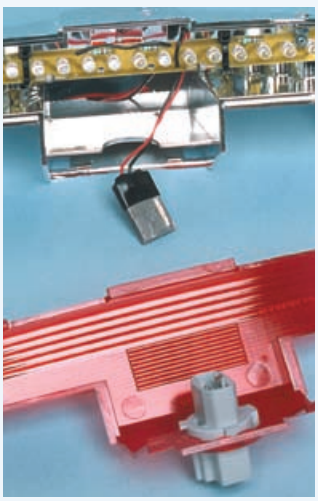
(1). The Accord's CHMSL sits on the parcel shelf and is retained with two clips accessible from within the boot space. The entire assembly came away in less than 10 seconds!



(2). Once we had the assembly on the bench, it was a simple matter to separate the red lens from the reflector to get to the insides. Be careful with the clips that hold these parts together, as the plastic is very brittle.



(3). In our case, the replacement LED module was just the right length for the job. We made a couple of small right-angle brackets to hold the board and screwed these to the top of the reflector. Many other mounting methods are possible, depending on shape and available space; eg, nylon standoffs, cable ties, M2.5 screws, silicone sealant, etc. Make sure that the rear of the PC board cannot contact anything metallic, though.



(4). We didn't want to modify the vehicle's wiring, so we powered the LED module directly from the old filament lamp socket. A suitable plug can be fashioned from two pieces of PC board, some glue and a length of tinned copper wire (see wedge lamp details). Be sure to tin all bare copper areas to prevent corrosion.

To finish, install the +12V link and two 150mm flying leads for the +12V and 0V connections. Any light duty multistrand hook-up wire will do.

CHMSL module installation

We chose a Honda Accord for our prototype installation – see photos. We didn't hack off any "unnecessary" bits along the way, thus allowing return to the standard filament lamp configuration if need be. Adapt our methods to suit your particular vehicle.

If the module is too long for your housing but there is plenty of vertical space, then you can cut it in half and mount one section directly above the other. This is possible because we've designed the two sides of the board in "mirror image". These smaller sections could be useful for other applications as well.

Multidisc module assembly

As the name suggests, the Multidisc module has multiple uses, some of which will require the PC board to be circular in shape see Fig.4.

Install the LEDs, aligning all cathodes (flat sides) towards the centre of the board. The LEDs must be mounted right down on the PC board surface. If your LEDs have large standoffs that prevent this, then refer to the assembly instructions for the CHMSL module for the solution.

Install the three resistors next. Now turn the board over to the copper side and install an insulated wire link as shown on the overlay diagram (Fig.4). Finally, solder two lengths of light duty hook-up wire to the +12V (+) and 0V (-) points and pass the ends through the cable hole.

Unlike the other modules, this one doesn't have a diode in series with the supply. We recommend installing a 1N4004 diode in series with either the positive or negative lead and insulating it with heatshrink tubing.

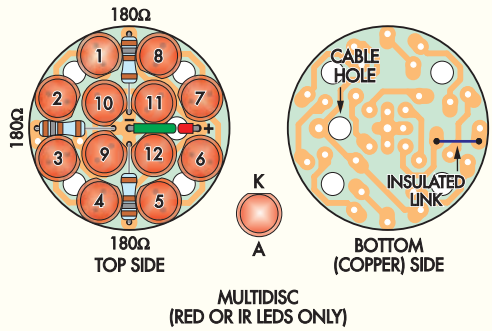


Fig.4: the overlay diagram for the Multidisc module. Form the leads of each resistor so that its body sits directly between adjacent LEDs.

Bayonet lamp assembly

Below are the instructions for the bayonet lamp assembly, presented in a step-by-step format to help make the job easier – see Figs.5 & 6.

(1). Remove the glass bulb and filament from a standard 21W automotive bayonet lamp. Clean the glue from around rim of base and several millimetres into the interior. Polish the area with a fine scouring pad or ink rubber and clean with alcohol.

(2). Remove solder from the tip.

(3). Cut a standard 14·5mm outside diameter copper water pipe joiner in half and chamfer one end with a file. Polish the tube with a fine scouring pad or ink rubber and clean with alcohol. Insert the tube 2 to 3mm into the base rim and solder in place.

(4). Centre the Platform PC board over the end of the tube and solder in place. Apply your iron to the copper tube rather than the PC board so as not to overheat the latter.

(5). Trial fit an assembled Multidisc module on the Platform board to determine the required lead length. Trim the +12V wire to length and strip and tin the end. Pass it through the centre hole in the Platform board and solder it to the base tip, building up the solder as needed to get a nicely curved "bump".

(6). Pass the 0V (GND) wire through the outer board hole and trim to 10 to 15mm in length. Strip and tin the end.

(7). Trim both leads of a 1N4004 diode to about 6mm in length and solder the anode end to the 0V (GND) wire. Slip a length of heatshrink tubing over the diode to insulate the connection. Solder the other (cathode) end of the diode to the underside of the Platform PC board.

(8). Attach the Multidisc assembly to the Platform board using small cable ties, or for a more permanent job, use several 'blobs' of silicone sealant.

Wedge lamp "skeleton" assembly (Fig.7)

(1). Prepare the blank (non-copper) sides of two wedge PC boards so that all edges are free of burrs and the surfaces are completely smooth and clean.

(2). Bond the blank sides together (copper sides facing out) using a very thin smear of cyanoacrylate-based adhesive. Pay particular attention to alignment; the boards must be exactly aligned, such that they appear to be one single unit after bonding.

(3). Touch up the sides with a fine file to bring the edges into perfect alignment. Also, file the shoulders if necessary to ensure that they are horizontal and in-line.

(4). Trial fit the assembly to a wedge lamp socket. A small chamfer on the leading edges of the wedge assembly may make insertion easier.

(5). As supplied, the Disc PC board may have a series of three holes rather than a slot in the middle. You'll need to file a slot that is just large enough to accept the head of the wedge assembly. Make the fit as firm as possible. You may also need to cut and/or file the board outline into a circular shape.

(6). Assemble the boards, making sure that the shoulders of the wedge assembly firmly contact the underside of the Disc board. Solder the three pads on the wedge assembly to the pads on the underside of the Disc board. Repeat for the second side. If the Disc board is double-sided (has copper on both sides), then repeat on the top side.

(7). Mount all components as per the overlay diagrams in Fig.8 and the text that follows.

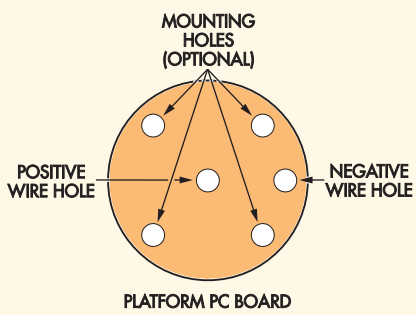


Fig.5: the Platform PC board is unetched (blank copper). To make one, cut the 26·5mm disc from blank circuit board material and drill six 2·5mm holes as show here. The Multidisc PC board can be used as a template.

Wedge lamp assembly

With the wedge lamp "skeleton" complete, it's time to mount all the components. Begin with the eight 5mm LEDs on the Disc board, aligning the cathode (flat) sides towards the centre of the board.

Fit the 10mm (centre) LED last. The flat (cathode) side must be aligned towards the "dot" side of the board. The "dot" side is marked with a small copper dot (pad without a hole) on the underside. Form the leads as shown in Fig.7 and push the LED down until it makes contact with the head of the wedge board assembly.

Bayonet Lamp Assembly Details

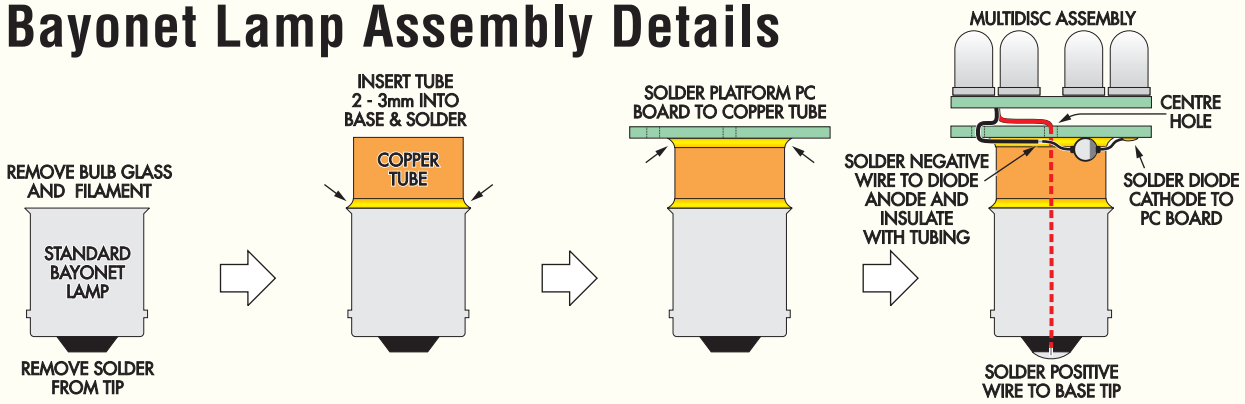
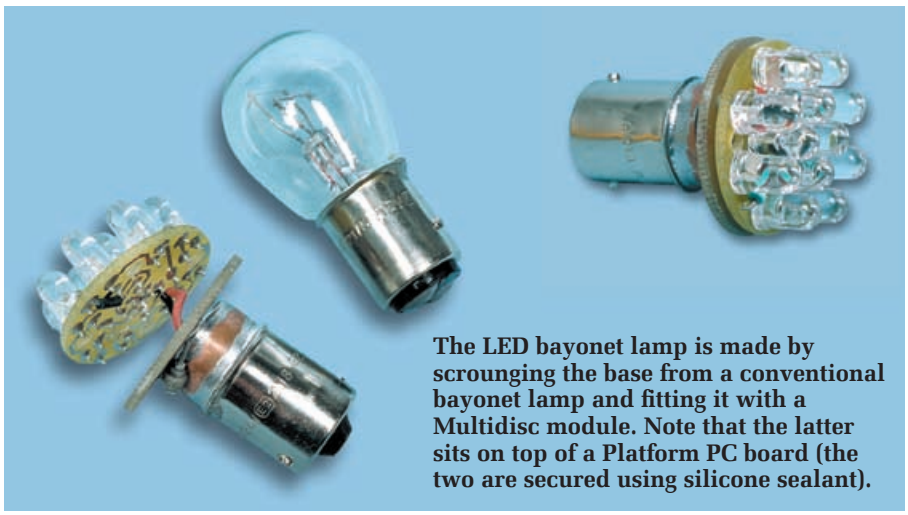


Fig.6: follow this diagram and the step-by-step instructions in the text to make the Bayonet lamp assembly. The Multidisc assembly can be fixed in place with silicone sealant.

The three resistors and the 1N4004 diode can go in next (see Fig.8). Note that it is vital that these components go on the right sides of the wedge assembly. As shown in Fig.7, the resistors mount on the "dot" side and the diode on the other.

Component mounting is unconventional in that the leads should not pass through both PC boards and protrude from the opposite side. The PC board holes have been deliberately offset to prevent this from happening. You'll need to bend the leads of each component and trial fit it in place, trimming back lead lengths just enough so that they enter their respective holes before soldering in place.

Finally, solder lengths of tinned copper along the tracks exactly as shown in Fig.8. The vertical lengths at the bottom take the place of the filament lead-outs on the base of a wedge lamp and need to be positioned so that they mate with the contacts in the wedge socket. The horizontal lengths replace the "bump" on the wedge bulb base that is captured by

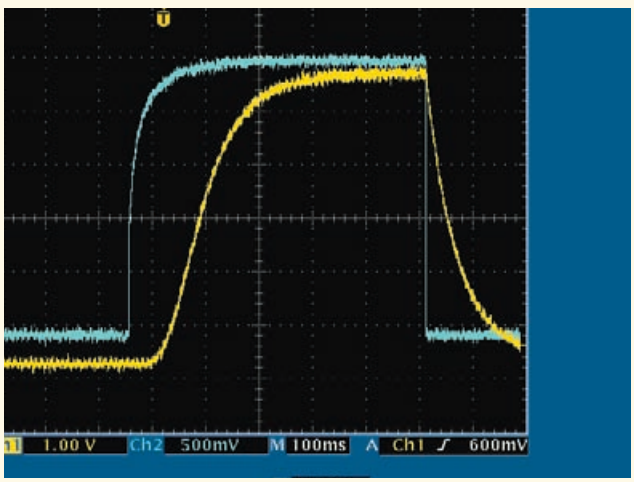


The LED bayonet lamp is made by scrounging the base from a conventional bayonet lamp and fitting it with a Multidisc module. Note that the latter sits on top of a Platform PC board (the two are secured using silicone sealant).

Response Times: LEDs Versus Conventional Filament Lamps

After upgrading the Honda's CHMSL to LEDs, we decided to "get technical" and actually measure the difference in response between the old and the new. We made up a couple of phototransistor-based sensors and positioned one behind the CHMSL and the other behind one of the stop lights. Our Tektronix scope captured the waveforms at right when we tapped the brake pedal.

As you'd expect, the blue trace represents the LED CHMSL light output whereas the yellow represents the conventional stop light. A rough estimate shows the filament lamp to be about 150ms behind the LEDs, with full brilliance at least 200ms later. The rounding on the leading edge of the LED waveform is caused by voltage drop in the wiring loom, a result of the stop lamps' cold filament current, which momentarily exceeds about 40A.



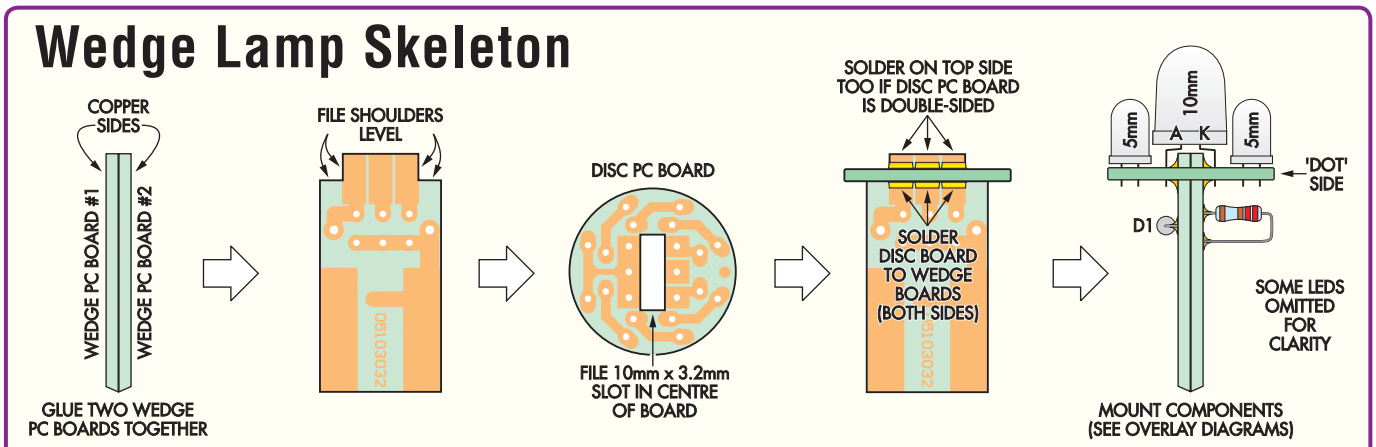


Fig.7: here's how to put together the Wedge lamp "skeleton". After soldering the Wedge and Disc boards together, inspect your work for potential solder bridges between pads. This is only important on the "dot" side, as all pads on the opposite side will be connected with a wire link anyway (see Fig.8).

a spring clip in the socket in order to retain the bulb.

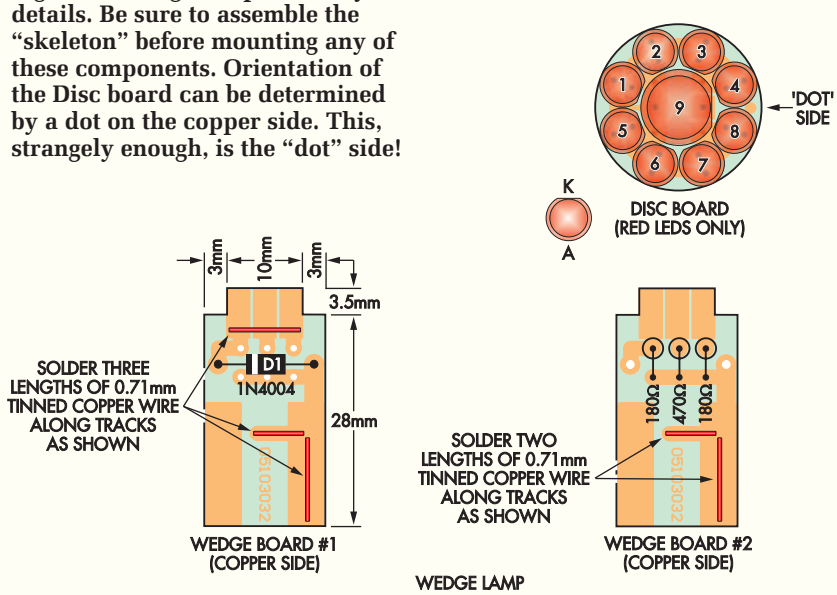
Festoon lamp assembly

This LED equivalent of the festoon (interior) lamp can be built in either a 31mm (2 LED) or 41mm (3 LED) version. As mentioned previously, you have the choice of using either white or blue LEDs.

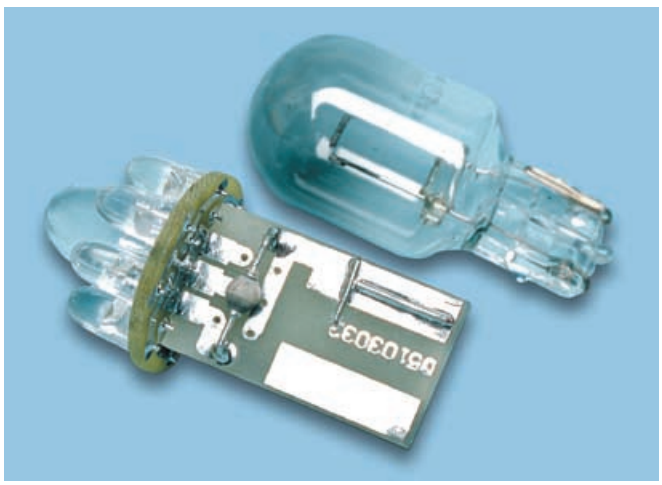
Referring to Fig.10, begin by installing the LEDs, aligning the flat (cathode) sides as shown. Be sure that you have the PC board oriented as shown on the overlay; the positive side must be on the left. The "+" and "-" symbols on the copper side allow you to determine correct polarity.

Now flip the board over and install the resistor and diode on the copper side. Both of these components should be insulated with heatshrink tubing to prevent short circuits. However, only

Fig.8: the Wedge lamp assembly details. Be sure to assemble the "skeleton" before mounting any of these components. Orientation of the Disc board can be determined by a dot on the copper side. This, strangely enough, is the "dot" side!



The wedge lamp is made up using the Disc board and two identical Wedge boards. It all goes together as shown in Figs.7 & 8.



The LED-powered wedge lamp can be used to replace a conventional filament lamp in some situations and will generate much less heat.

31mm & 41mm Festoon Lamp Assemblies

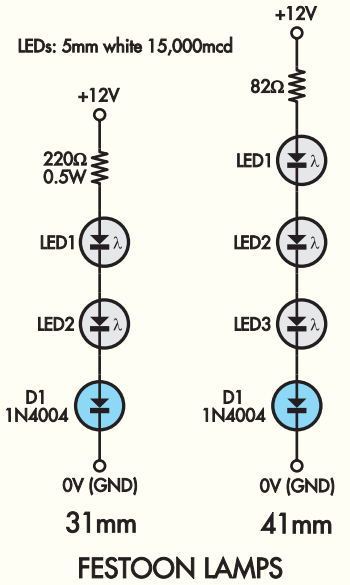


Fig.9: the circuit details for the 41mm & 31mm festoon lamps.

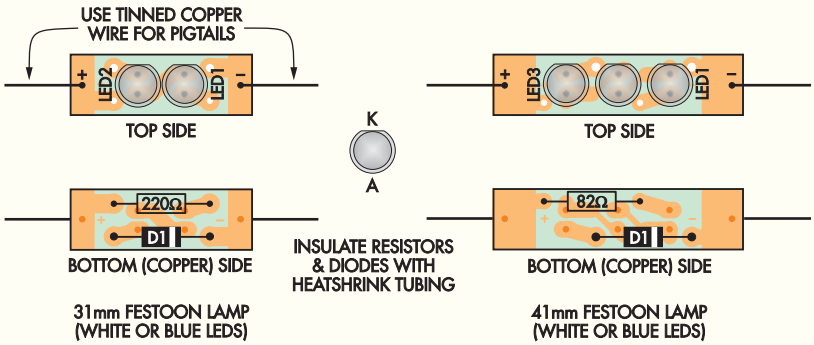
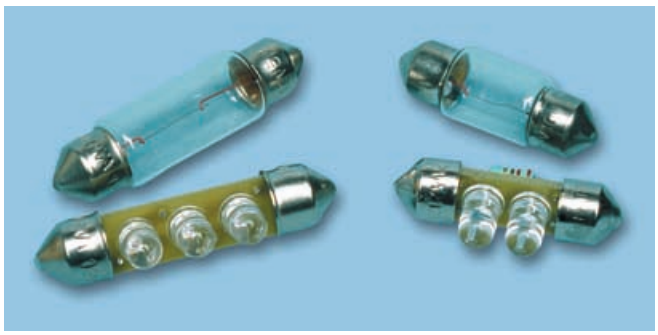
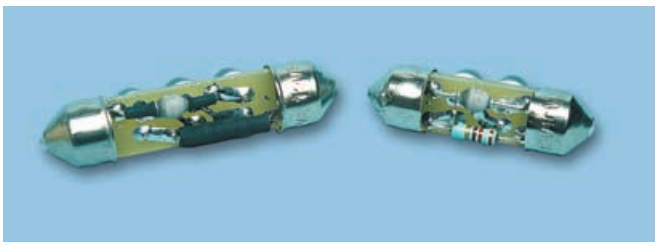


Fig.10: the assembly details for the 31mm (left) & 41mm (right) festoon lamp modules. The end caps are soldered to the PC boards after the parts have been installed.





The completed festoon lamp assemblies can be plugged straight into a conventional festoon lamp holder but must be oriented with the LEDs facing outwards.

the leads of the resistor should be insulated (not the body), otherwise heat dissipation will be impaired.

Next, solder 10mm lengths of 0·71mm tinned copper wire to each end of the board, forming axial "pigtails". These wires will make the connections to the end caps.

With the board assembly complete, the next step is to fit the end caps. Begin by removing the glass cylinder and filament from a standard festoon lamp. Take care to remove all glass fragments from inside the caps.

Desolder the holes in the cap peaks and then slip them over the pigtails. Push the PC board as far as it will go into each end cap. The assembled size should be close to the 31mm (or 41mm) mark. Snip the wires off so that they only just protrude through the cap peaks. Now solder in place and smooth off with fine glasspaper or similar.

Check that your completed lamp works in-situ and, assuming all is well, fill the end caps with 5-minute epoxy glue to make the job permanent.

The three current-limiting resistors are mounted vertically on the wedge assembly and can be insulated with heatshrink tubing if desired.

The diode goes on the other side of the wedge assembly. The three long pads on both wedge boards are soldered to matching pads on the disc board.

Automotive lamps vs. LEDs

The extremely narrow emission angle of these ultra-bright LEDs (4°) makes them well suited for use in high-mount stop lights. However, in the case of conventional tail, stop

Parts List

High-Mount Stop Lamp (HMSL) Module

1 PC board, 11·45mm x 149·2mm
16 5mm 20,000mcd red LEDs (LEDs1-16) (Vishay TLCR5800 or similar)
2 1N4004 diodes (D1, D2)
4 150Ω 0·25W 1% resistors
200mm length of red light-duty hookup wire
150mm length of black light-duty hookup wire

Multidisc Module

1 PC board, 26·5mm diameter
12 5mm 20,000mcd red LEDs (LED1 - LED12) (Vishay TLCR5800 or similar)
1 1N4004 diode (D1)
3 180Ω 0.25W 1% resistors
10mm length of 0·71mm tinned copper wire
20mm length of 5mm-diameter heatshrink tubing
150mm length of red light-duty hookup wire
150mm length of black light-duty hookup wire

Wedge Lamp

1 PC board, 22mm diameter (Disc)
2 PC boards, 31·5mm x 16mm (Wedge)
8 5mm 20,000mcd red LEDs (LEDs1-8) (Vishay TLCR5800)
1 10mm 6,000mcd (min.) red LED (LED9)
1 1N4004 diode (D1)
1 470Ω 0·5W 1% resistor
2 180Ω 0·25W 1% resistors
60mm length of 0·71mm tinned copper wire
Cyanoacrylate-based adhesive (super glue)

Bayonet Lamp

1 assembled Multidisc module
1 PC board, 26·5mm diameter (Platform)
1 14·5mm outside diameter copper water pipe joiner
1 12V 21W single filament automotive bayonet lamp

31mm Festoon Lamp

1 PC board, 8mm x 24mm
2 5mm 15,000mcd white LEDs (LED1, LED2)
1 1N4004 diode (D1)
1 220Ω 0·5W 1% resistor
1 31mm automotive festoon lamp
20mm length of 0·71mm tinned copper wire
35mm length of 5mm diameter heatshrink tubing
5-minute epoxy

41mm Festoon Lamp

1 PC board, 8mm x 33mm
3 5mm 15,000mcd white LEDs (LED1 - LED3)
1 1N4004 diode (D1)
1 82Ω 0·25W 1% resistor
1 41mm automotive festoon lamp
20mm length of 0·71mm tinned copper wire
35mm length of 5mm-diameter heatshrink tubing
5-minute epoxy

and turn indicators, there are some potential visibility issues.

When viewed on-axis, a tight grouping of these LEDs certainly appears to equal (or even surpass) the intensity of a 21W filament bulb. The bulb, however, emits light over a much larger area, resulting in good visibility over more than 180°.

Naturally, the reflector and diffuser in light housings is designed to take this into account, so if we were to simply switch the standard bulb for a bunch of LEDs, the resultant light pattern would be entirely different.

Simply put, direct replacement of filament lamps with LED lamps in existing automotive tail, stop and turn assemblies will not always be possible. This applies particularly to "wraparound" styles, which must provide light to both the rear and side of the vehicle. This problem is easily solved by designing the assemblies specifically for LEDs, a task best left to the experts.

Having said that, we believe that our modules have a multitude of highly practical uses. Here are just a few examples:

Where to use LED lamps

Why not add a centre-mount stop light to your trailer or caravan? The small size and shape of the Multidisc module will allow it to fit neatly within commonly available trailer stop light assemblies. Do you own a motorcycle? What about a truck? Get noticed!

Printed Circuit Boards

Due to the size of the PC boards used in these designs we have decided to make them available in sets in order to achieve a sensible price for them – individually they work out relatively expensive.

The set, code 568 – available from the *EPE PCB Service* comprises two sets of boards for the Wedge Lamp (six boards in all), one High Mount Stop Light board, two each of the 31mm and 41mm Festoon Lamp boards and two sets of boards (4 boards) for the Multidisc plus platform (Bayonet Lamp).

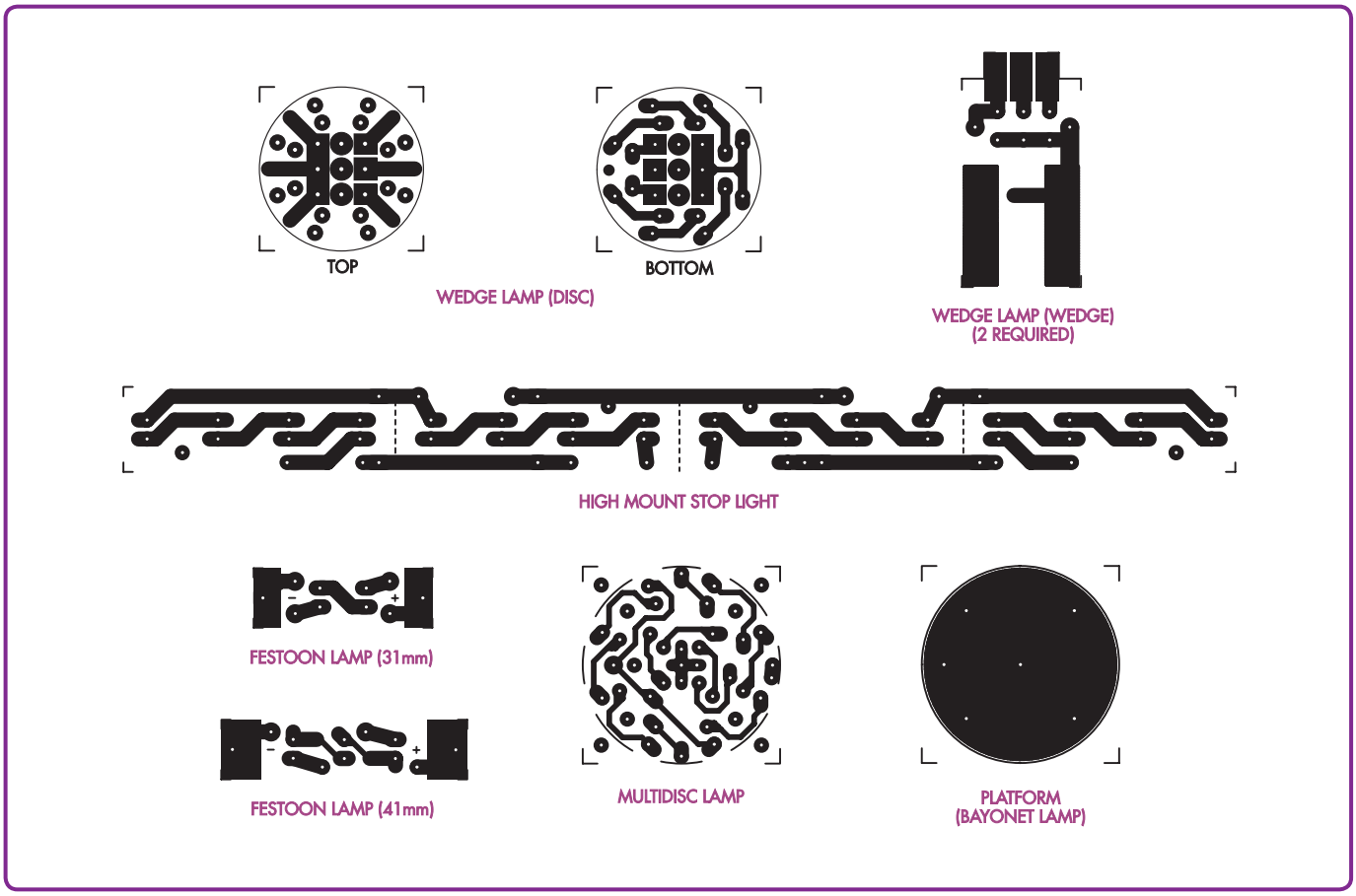


Fig.11: here are the full-size etching patterns for all the PC boards. Check your boards carefully for defects before installing any parts.

A couple of these hooked up to a simple flasher circuit and mounted under the boot lid or on a moveable panel would make the ultimate emergency beacon for late-night breakdowns. They will flash for days without running your battery flat!

In addition, the Multidisc module could be fitted with IR LEDs for use with CCD cameras and night viewers.

The LED festoon lamps don't put out as much light as the originals but they don't get hot and they won't run your battery flat in a hurry. Fit a couple under the hood, in the boot, along the floor line or in the door panels. For that high-tech look, try blue (or even true green) LEDs instead of white.

If you don't want to modify existing light housings, then the LED wedge or bayonet lamps are a good option. They're plug-in replacements for two popular auto lamp styles. If your vehicle uses different lamp styles, then you may be able to modify our designs to come up with something suitable.

Have fun! ***EPE***

Although not readily apparent from the photo, the modified high-mount stop lamp with the LEDs is brighter than the conventional left-hand & right-hand stop lamps. Its response time is quite a bit shorter as well (ie, it turns on much faster when the brakes are applied).