Save money on incandescent lamps

Build this Lamp Saver for spotlights

Does your house eat lamps? Does it seem that you are always having to replace expensive spotlights, ornamental lamps or bulbs in inaccessible places? The solution to these problems is the Lamp Saver which will greatly extend the life of any 240VAC incandescent lamp.

by COLIN DAWSON & LEO SIMPSON

In recent years there has been a considerable reaction against the use of fluorescent lighting in homes apart from in utility areas such as the laundry, garage and workshop. For all other areas of the home, the trend to incandescent lighting has been overwhelming and so now there are a multitude of special purpose light fittings designed, often as not, to take special lamps.

The most popular of these are the spotlight and downlight fittings which take Edison-screw lamps rated at around 75 to 100 watts. Now while these work well they can be quite expensive to replace and generally cost between $5 and $7 or more. Moreover, they tend to have a fairly short life because they have a relatively small bulb to begin with and they are used in fittings which are poorly ventilated. As a result, the lamps overheat and fail prematurely.

If you have several of these fittings in your home you can count yourself lucky if you do not have to replace each of these lamps several times a year. It can add up to quite a lot of money over a period.

So that is the purpose of the Lamp Saver; to protect and extend the life of these more expensive lamps. It is not intended to be used with ordinary domestic light bulbs which are dirt cheap. At around 60 cents for an ordinary light bulb, it would be hard to justify the cost of the Lamp Saver. But if you have a lamp in a particularly inaccessible spot, such as right up high on a "cathedral" ceiling, the Lamp Saver could be justified, even if it was used with an ordinary light bulb.

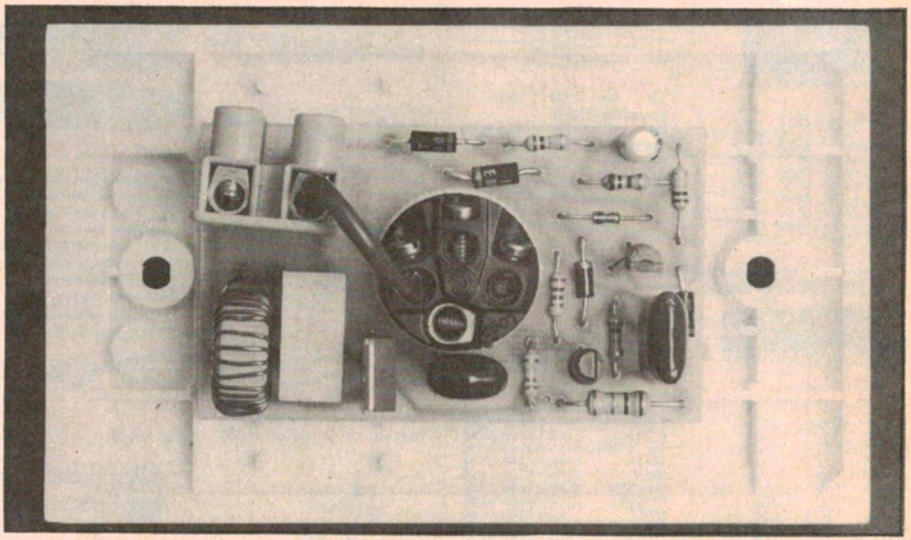
So what is the Lamp Saver? It's a simple, inexpensive circuit that incorporates three-way protection for a lamp. It is designed to fit on the back of a standard switch plate, thereafter never to be seen or thought of again. It combines three proven methods of lamp protection: soft-start, derating and over-voltage protection.

Soft start

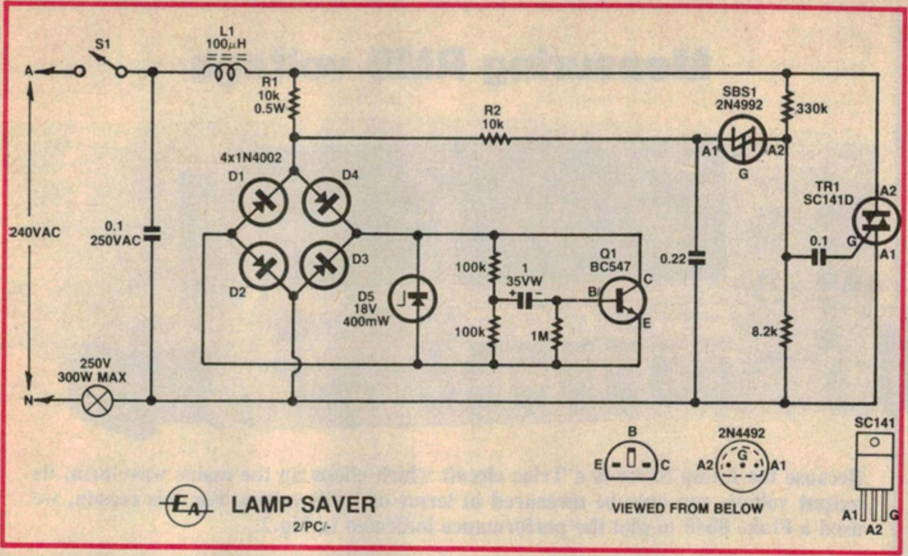
One of the problems with incandescent lamps is their "cold resistance". If you measure the filament of a 240VAC lamp rated at 100 watts you might expect to find that its resistance would be around 570Ω (or exactly 576Ω, by calculation from Ohm's Law). In reality, the filament resistance when measured by a multimeter is likely to be around 50Ω or less. Measurements taken in this way give the "cold" resistance of the filament whereas when it is operating it presents a much higher "hot" resistance to the AC mains supply.

When power is first applied to the lamp, the fact that its filament is cold means that a very high surge current will flow until the filament heats up. This initial surge current will be ten to 15 times the normal operating current and flows for the first ten milliseconds or so after switch-on. As short as this surge period is, it can blow the lamp as the very high current causes a high magnetic field which literally shakes the filament apart.

So next time you hear the dreaded



The circuit board assembly is mounted on the back of a standard switch plate.



The final circuit incorporates soft-starting, derating and over-voltage protection.

"plink" as another lamp fails at switch-on you'll know that initial surge current has claimed another victim.

Protecting lamps against the initial surge current is a simple matter of having a soft turn-on. By letting the initial voltage across the filament build up gradually over half a second or so, there will be virtually no switch-on surge and no high filament stresses.

Over-voltage protection

Another factor which kills incandescent lamps is over-voltage. In simple terms, operating an incandescent lamp at 10 percent more than its rated voltage will halve its expected life. Even a 5% increase in applied voltage means a significant reduction in lamp life. Accordingly, our circuit has a clamp action which prevents the voltage across the lamp filament from going much over 240VAC, regardless of how high the mains voltage may go.

An extension of this concept is to derate the lamp. If a small increase in applied voltage means a considerable reduction in lamp life, then a slight decrease in voltage will give a considerable increase in lamp life. The drawback is that if the voltage is reduced by more than a small amount, there will be a noticeable decrease in lamp brilliance which may be undesirable.

Circuit description

The circuit is similar in principle to a typical light dimmer. It uses a phase controlled Triac to control the voltage applied to the lamp. A Triac controls the amount of power it feeds to its load by turning on earlier or later in each mains half cycle. And when it turns on, it stays on until the voltage across it drops to zero, at the end of each half-cycle.

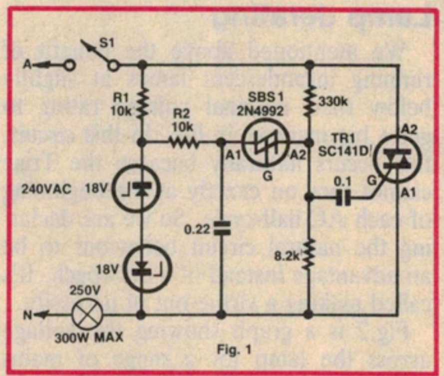


Fig.1: a phase-controlled Triac is used to control the voltage applied to the lamp.

The general circuit concept of the Lamp Saver is depicted in Fig.1 which looks like a modified light dimmer. It works in the following way. A clipped version of the mains waveform from across the back-to-back zener diodes is used to charge the 0.22μF capacitor via a 10kΩ resistor.

As the voltage across the capacitor rises, the voltage across the 2N4992 silicon bilateral switch (SBS) will rise accordingly until the breakover voltage of the SBS is reached. At this point the SBS breaks down to a low resistance and delivers a pulse of current via the 0.1μF capacitor to the Triac gate, turning it on.

This sequence of events is repeated for each half cycle of the mains voltage and the circuit components are selected so that the Triac fires early in the half-cycle, therefore applying almost the maximum AC voltage to the lamp load.

So far so good but the circuit also includes some components which effectively limit how much voltage is applied to the lamp. These work as follows.

Consider that the breakover voltage of the 2N4992 SBS is reached when the voltage across it, ie, between its A1 and A2 terminals, is more than about 10V. Now if the A2 terminal of the SBS was connected directly to the gate of the Triac, the SBS would break down as soon as the voltage across the 0.22μF capacitor rose above 10V (or whatever the actual SBS breakover voltage was).

But note that the A2 end of the SBS is connected to the gate via a 0.1μF capacitor and tied to a potential above the Neutral line by the voltage divider consisting of the 330kΩ and 8.2kΩ resistors.

Now, the breakover condition can only exist when the timing capacitor charge exceeds the divider voltage by 10V. An increase in the AC mains voltage therefore increases the divider voltage and so the 0.22μF capacitor takes longer to reach the requisite charge and thus the Triac will fire later in the half cycle.

With correct component selection, the later firing angle will just compensate for the increased voltage. The power delivered to the load will be constant.

Ideally, this voltage limited effect should not interfere with power delivery to the load at all until 240VAC is reached. For any mains voltage above 240VAC, the output power should remain constant. The circuit only approximates this characteristic, but still, it is much better than having no limiting at all. We'll discuss the achieved characteristic later.

The soft starting characteristic could be added to the circuit simply by connecting a suitable NTC (negative temperature co-efficient) thermistor in series with R1. This would have the effect of reducing the voltage across the zener diodes D1 and D2 to a low level at switch-on and then allowing it to build up gradually. This would have the effect of initially allowing the Triac to fire only late in each half cycle and thus severely limit the power delivered to the lamp. Thus the lamp filament would be protected against initial surge current.

Well, we haven't used a thermistor. While a thermistor has the virtue of simplicity, they can be very hard to obtain. So we used a slightly more complicated circuit with readily available components. We now refer to the full circuit diagram of the Lamp Saver.

Instead of having two zener diodes D1 and D2 back to back in the circuit to clip the mains voltage we have used a bridge rectifier (diodes D1 to D4) and a single 18V zener diode D5. This func-

Lamp Saver to build

tions the same way as the back to back zeners but allows us to incorporate transistor Q1 and associated components into the circuit.

During normal operation, Q1, an NPN BC547, is biased off by the 1MΩ resistor connected from its base to the negative line from D1/D2. It is only during the period immediately after switch-on that current flowing through the 1μF capacitor biases Q1 on. The actual period for which Q1 is biased on is determined by the combination of the 1μF capacitor and the two 100kΩ resistors. It works out to be around 0.5s.

At the first instant after switch on, Q1 is biased fully on via the 1μF capacitor. Q1 virtually shorts the 10kΩ charging resistor R2 to the Neutral line, via the diode bridge. So the 0.22μF timing capacitor does not reach the SBS breakover voltage and the Triac remains untriggered.

Then the 1μF capacitor begins to charge which has the effect of turning Q1 off, which allows the voltage across zener D5 to rise to the full 18V. This allows the 0.22μF capacitor to charge more rapidly via R2. and thus turn on the Triac earlier in each AC half-cycle.

The net effect of this sequence is that the lamp comes up to operating brightness over a 0.5s period. This is barely noticeable unless you are looking for it but still much slower than the 50ms or so that it normally takes the bulb current to stabilise. Most importantly, the massive switch on surge current in the filament is avoided.

Measuring RMS voltage

Because the Lamp Saver is a Triac circuit which chops up the mains waveform, its output voltage can only be measured in terms of RMS values. For this reason, we used a Fluke 8840 to plot the performance indicated in Fig.2.

Lamp derating

We mentioned above the benefit of running incandescent lamps at slightly below their nominal voltage rating to get a big increase in life. In this circuit, this occurs naturally because the Triac cannot turn on exactly at the beginning of each AC half-cycle. So we are declaring the natural circuit behaviour to be an advantage instead of a drawback. It's called making a virtue out of necessity.

Fig.2 is a graph showing the voltage across the lamp for a range of mains voltages from 200VAC to 290VAC. Normally, if you applied a voltage much more above 260VAC to a typical lamp it would fail very quickly, if not immediately in the case of 290VAC. Our circuit progressively reduces the voltage so that at 280VAC there is actually less voltage across the lamp than with 220-VAC input. And note that with 250-VAC input the lamp voltage is about 239VAC which is a good operational compromise considering the mains voltage in most Australian towns and cities.

Also included in the circuit is an effective interference suppression circuit consisting of the 100μH choke in series with the Active supply to the Triac and the 0.1μF/250VAC capacitor. An essential factor in the effectiveness of this interference suppression filter is the use of a Neosid iron powder toroid, type 17-132-10.

Maximum lamp load for the circuit as presented is 300 watts which should be more than adequate for most domestic applications.

Construction

All of the circuit components mount on a PCB measuring 41 x 69mm and coded 86pc5. The board has a central 23mm diameter cutout which allows it

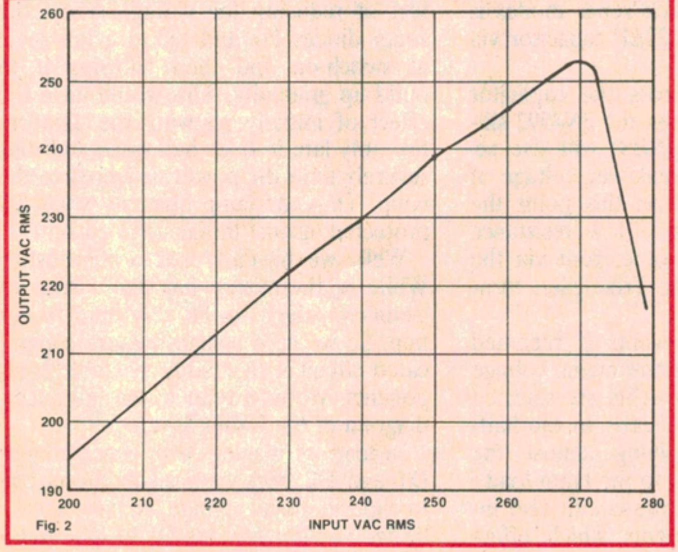
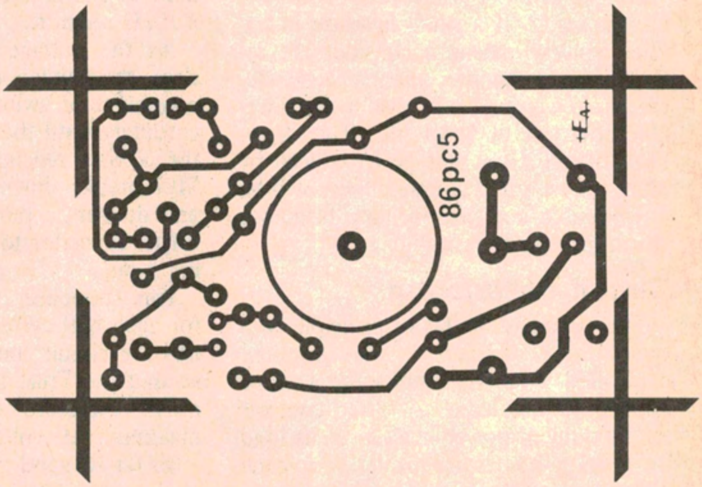
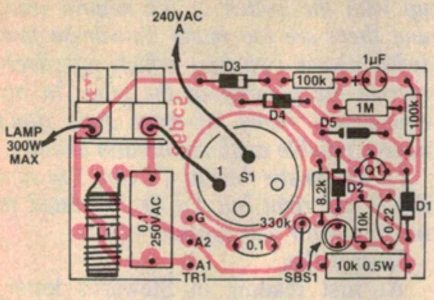


Fig.2: lamp voltage as a function of mains input voltage.



Above: actual-size artwork for the PC board. Ready-etched boards are available from parts retailers.



Parts layout diagram for the Lamp Saver. Take care with mains wiring.

to mount directly over the switch barrel on a standard switch plate.

We assume that kitset suppliers will make the printed circuit board available with a ready-made cutout but if not, the cutout should be made before any component assembly begins.

It is most convenient to mount all of the small components, such as resistors and diodes, first. Follow the overlay diagram exactly for the diodes, transistor and electrolytic capacitor. The silicon bilateral switch may be mounted either way round since it is not polarity conscious.

Preferably, 1/4W resistors should be used throughout, except for R1 which is specified as a 1/2W type.

The two-way mains terminal block mounts vertically and is fixed to the board by means of two short wire "stubs" which can be made with 16-gauge tinned copper wire.

The toroidal inductor is prepared by winding on 37 turns of 0.5mm enamelled copper wire. The turns should be made tightly with each one touching the next on the inside of the core. When the winding is complete, use a razor blade to clean the enamel from the two ends of the winding and tin them ready for soldering into the board.

The inductor is held in place with a loop of wire through the PCB. Two pads are provided on the PCB for this purpose — solder one end of the loop to a pad, pass the other end through the toroid and spare PCB hole and pull the loop tight. Solder the free end to the pad.

Check your assembly and soldering very carefully before affixing the completed printed circuit board to the switch plate. The board can be secured to the rear of the switch-plate by a couple of spots of epoxy adhesive.

Installation

Only one wiring change will have to be made to a normal switch installation. This involves the wire from the switch to the lamp. This wire must be connected to the terminal block on the PCB. A link from the other PCB terminal to the switch then completes the circuit.

Most modern mains switches of the circular format have three enclosed terminals on the back although some have four. The fourth, where present, is only a "loop" terminal used to join two wires.

Of the three main terminals, only two are used in a typical installation. The third (marked "2") is used only for two-way switches. Of the remaining two, one is marked "1" (normally opened) and the other "C" (common). The mains active wire is connected to one of these terminals and the lamp to the other. It is the switch/lamp connection which is of interest. The wire must be disconnected from the switch and secured to the terminal on the PCB marked "lamp".

The other terminal (active) connects to the switch. A short insulated link must be used here. It is connected to whichever terminal was previously used for the switch/lamp connection.

PARTS LIST

1 PCB, 41 x 69mm, code 86pc5
1 standard 240VAC/10A switch plate, HPM series P 770 GF or equivalent
1 2-way mains terminal block
1 Neosid iron powder ring core, 17-132-10
1 2m length of 0.5mm enamelled copper wire
1 3cm length of 240VAC insulated hook-up wire

Semiconductors

1 SC141D, BT137 Triac
4 1N4002 diodes
1 2N4992 silicon bilateral switch
1 BC547 NPN transistor
1 18V 400mW zener diode

Capacitors

1 1µF 35VW PC electrolytic
1 0.22µF metallised polyester (greencap)
1 0.1µF/250VAC dual dielectric (Philips series MKT-P or equivalent)
1 0.1µF greencap

Resistors

(1/2W, 5% unless specified)
1 x 1MΩ, 1 x 330kΩ, 2 x 100kΩ, 1 x 10kΩ, 1 x 10kΩ 0.5W, 1 x 8.2kΩ

Miscellaneous

Epoxy adhesive, tinned copper wire, solder.