BUILD THE AUTODIM

for automatic light dimming

Here is a light dimmer with a difference. Called the "Autodim" it provides smooth, "snap on" free light dimming and can also automatically fade lights up or down with adjustable rate and range. The basic unit uses just one CMOS IC and can control loads up to 2kW.

by RON DE JONG

Light dimmers are very popular these days especially the small architrave-mounting dimmers. But one function these simple dimmers cannot perform is automatic dimming. This particularly useful feature was included in our three previous Autodim circuits, the last of which we published in 1976. Because of the continuing popularity of these projects we have come up with a new design offering all the features of previous circuits, but using readily available components.

Since the Autodim also functions as a normal light dimmer it can provide soft lighting for parties, watching television, listening to music and other more private activities upon which the Editor will not allow me to elaborate. With the "autodimming" feature as well, the Autodim can automatically dim lights at an adjustable rate and to an adjustable level, all at the flick of a switch.

In fact, the automatic dimming feature makes the Autodim ideal for use as a night light for young children, where the almost imperceptible dimming provided by the fade function creates a relaxing "sunset" effect while the child is falling asleep. The steady and controlled dimming rate could also be used to advantage in theatrical work, where slow "fade up" and "fade down" can make for a really professional performance.

Other possible applications are in photographic studios for producing special lighting effects; in industrial applications where heat or light must be applied at a controlled rate; and in applications where expensive high power lamps, such as projector lights, must be operated on a "soft start" basis to minimise surge failure and prolong life.

One very important feature of the Autodim is that, unlike many commercial dimmers, it provides electromagnetic interference (EMI) suppression. EMI can be particularly annoying in city areas, so effective suppression is a worthwhile feature. In addition, the dim control on the Autodim has no "snap-on" effect as found in some commercial dimmers.

To explain further, "snap-on" is an effect whereby the dimmer control has to be turned through (typically) 30-40% of its rotation before the lamp begins to glow. At this initial setting the lamp will be quite bright, although it can be dimmed by now rotating the control back in the opposite direction. The Autodim eliminates this problem completely.

CONTROLS

Three controls are provided on the Autodim, viz "rate", "dim" and a function switch which has three settings; either "Fast On", "Variable" (Var), or "Off". When the function switch is in the variable position the dimming level is set by the dim control, just as in a normal dimmer. The rate at which the dimming level changes is controlled by the rate control, which provides a range in dimming time from around two seconds to three minutes.

The "fast-on" and "off" positions of the function selector are provided for extra convenience. In the fast-on position the light dimmer turns full on immediately while in the off position the dimmer will dim down to off from a set dimming level at a rate set by the rate control.

Just to round things out we also have a "Fade" function which is selected by turning the rate control to the off position. The fade function causes the light to dim down very slowly with a fixed dimming time of 30 minutes from full brightness.

All of the features described above are achieved with just one standard CMOS IC at the heart of a Triac power control circuit. A Triac is a bidirectional switching device which is universally used in AC power control applications such as dimmers, motor speed controllers, heat controllers etc. Since it is bidirectional it has no anode or cathode as such, but has two terminals called T1 and T2 plus a control terminal called a gate. When a brief trigger pulse is applied to the gate the Triac turns fully on and remains on until the load current drops to zero, ie at the end of each mains half cycle.

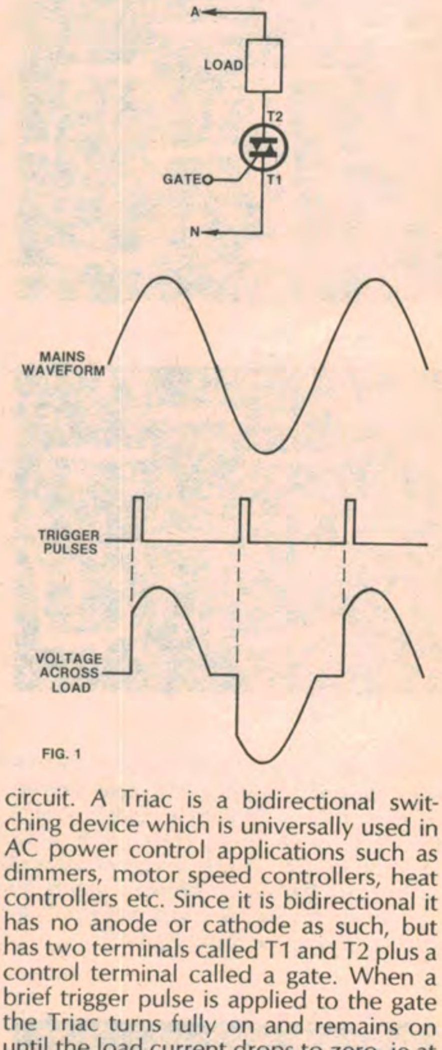
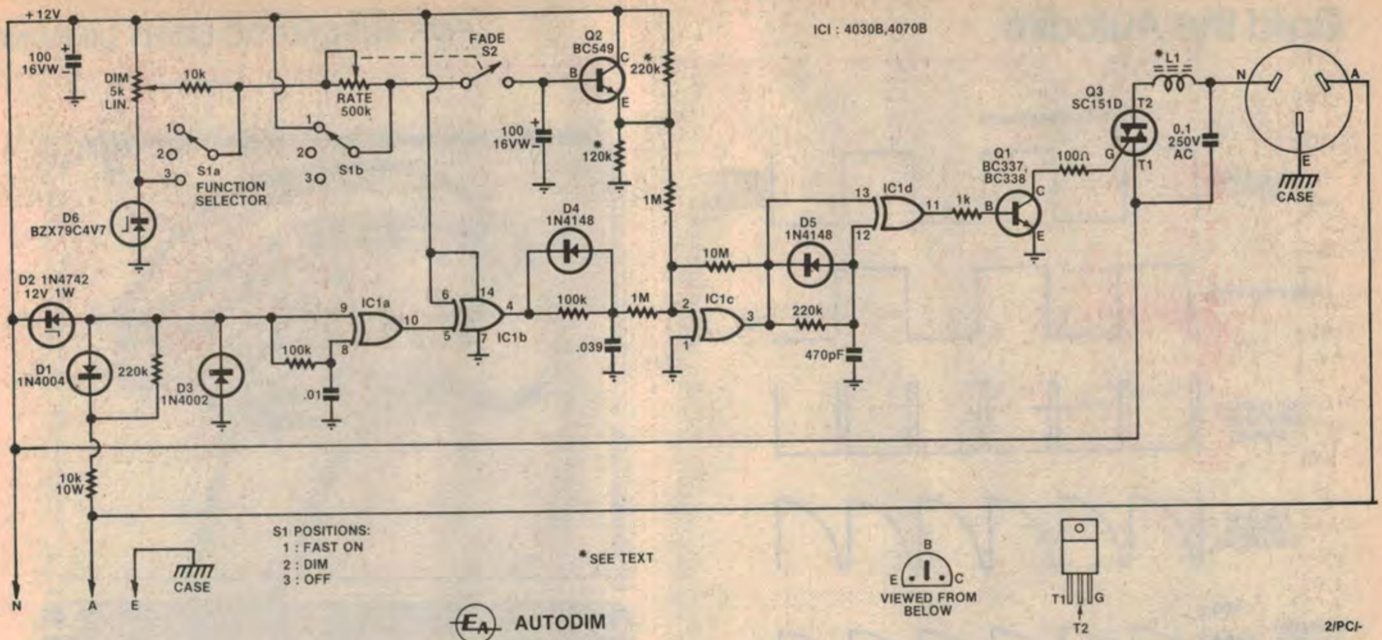


FIG. 1

Power control can thus be achieved by "firing" the Triac at a set time or "firing angle" after the start of each mains half cycle. This is referred to as phase control and is illustrated in Fig. 1 which shows a Triac connected to a load, together with typical trigger and load voltage waveforms. Note that power is delivered to the load only after the Triac has fired, and can be varied simply by altering the firing angle of the trigger pulses.



Variable light dimming is achieved by means of a phase-controlled Triac power control circuit.

THE CIRCUIT

Refer now to the circuit diagram to see how these trigger pulses are generated.

The first step is to derive a suitable synchronisation signal so that the trigger pulses will remain in phase with the mains. In this circuit, sync is obtained from the power supply which consists of a 10k/10W resistor, diodes D1 and D3, 12V zener diode D2, and a 100uF capacitor. This produces a nominal 12V across the 100uF capacitor (which is actually 0.6V less than the zener clipping voltage due to the voltage drop across D1 when it conducts).

The sync signal is taken from the junction of diodes D2 and D3 where the signal is a square wave version of the mains, clipped to 0V by the zener diode on negative half cycles and to +2V by the zener and the 220kΩ pull up resistor across D1 on positive half cycles. The positive transitions of the square wave mark the zero crossing points for the positive half cycles while the negative transitions mark the zero crossing points for the negative half cycles. What we now need to do is convert this square wave signal to a series of brief pulses marking each transition.

The way in which this is achieved is best understood by reference to the waveforms of Fig. 2. First, the square wave signal is fed to one input of IC1a, an exclusive-OR (XOR) gate, and to the other input via a simple RC delay network consisting of a 100kΩ resistor and a .01μF capacitor. Since the output of an XOR gate is high only when its two inputs are at different logic levels, brief pulses will be generated at the zero-crossing points with a pulse width equal to the time delay introduced by the RC circuit (ie about 1ms).

So far, we have a synchronisation signal consisting of brief pulses generated at each zero crossing. Now we have to provide variable delay of these sync pulses so as to obtain variable firing angle and hence controlled light dimming.

If we wanted a simple light dimmer, this could be readily achieved with another RC delay circuit consisting of a potentiometer and a capacitor. However, because we want the delay to increase or decrease automatically, we need a voltage controlled delay circuit. A potentiometer and a capacitor can then be used to provide a gradually increasing or decreasing control voltage to provide the automatic dimming function.

The voltage controlled delay circuit used consists of IC1b and IC1c plus associated components. IC1b is connected as an inverter and drives an RC circuit consisting a 100kΩ resistor and .039μF capacitor, together with D4. The output of IC1b is an inverted version of the sync signal so it is low for 1ms at the beginning of each half cycle and high for the remainder.

Thus, at the beginning of each half cycle D4 is forward biased and the .039μF capacitor is discharged. Following the pulse, the voltage across the capacitor rises slowly as it is charged via the 100kΩ resistor, generating the sawtooth waveform shown in Fig. 2.

This voltage is then applied to one input of IC1c via a 1MΩ resistor. Another

The Autodim can function as a conventional light dimmer, and can be used to automatically fade lights up or down. It can accommodate loads up to 2kW.

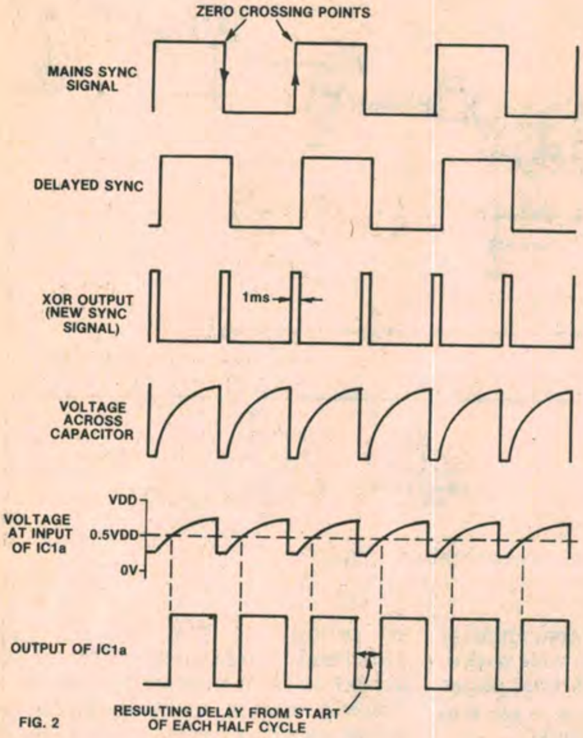
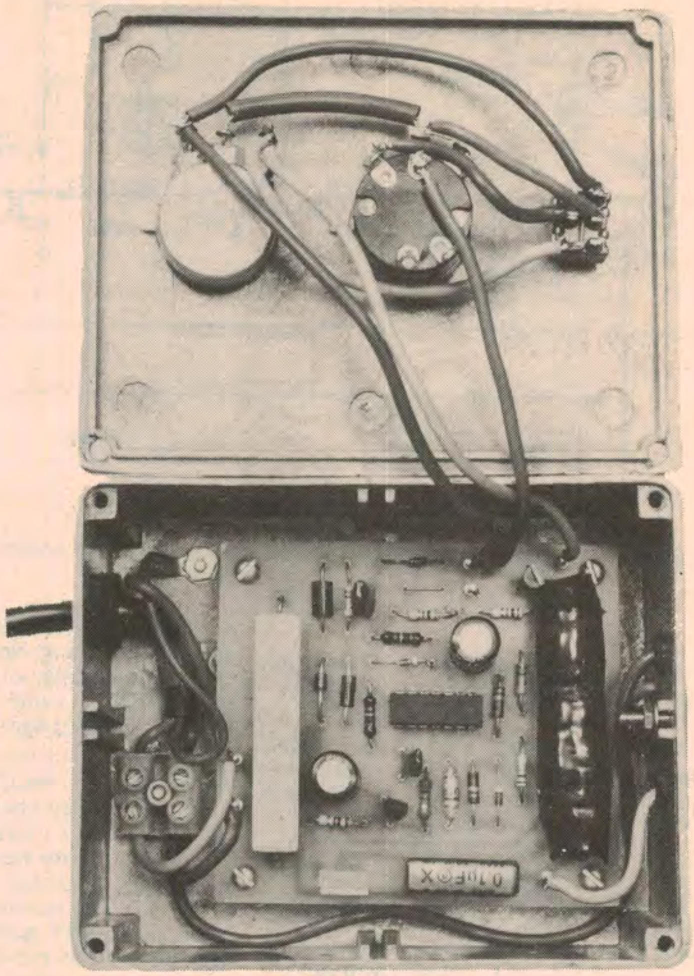


FIG. 2



RIGHT: Inside the completed Autodim. Keep all mains wiring neat and tidy. ▶

1MΩ resistor is also connected to this point and supplies what is in effect a bias voltage from transistor Q2. Since the transition voltage for CMOS is ½Vcc – ie below ½Vcc is a logical low and above it is high – the output of IC1c will go high the instant that the voltages summed together at its input reaches ½Vcc.

By varying the bias voltage from Q2, the transition point can be varied during each charging cycle, and the output of IC1c will go high sooner or later as required.

A 10MΩ resistor is included between output and input of IC1c to provide positive feedback to ensure reliable comparator action. This is necessary because at the transition point, the gate functions as a high gain amplifier and would otherwise become quite unstable with a slowly rising input signal.

Now, as mentioned earlier, we require an RC circuit to provide us with a slowly changing voltage. The RC circuit we have used consists of the 100μF capacitor and 500kΩ potentiometer connected to the base of Q2. Disregarding switches S1 and S2 for the moment the 500kΩ pot acts as a "Rate" control since, by changing its resistance, we can vary the rate at which the 100μF capacitor charges and hence the rate at which the light dims (or brightens).

The other side of the "Rate" pot goes to a voltage divider consisting of a 5kΩ linear pot and zener diode D6. Since the 100μF capacitor will eventually charge to the voltage set by the 5kΩ pot, and hence to a set dimming level, the pot is called the "Dim" pot. Zener D6 sets a convenient lower limit to the voltage range of the pot.

Function selector switch S1 also controls the operation of the circuit, and has three positions labelled "Fast On", "Dim" and "Off". In the "Dim" position the circuit functions as described above, while in the "Fast On" position S1b pulls the 100μF capacitor straight up to the supply voltage, immediately turning the lamp on to full brilliance. In the "Off" position, S1a switches the charging circuit to the minimum voltage, and the 100μF capacitor slowly discharges to this voltage (ie the lamp fades to off) at a rate set by the "Rate" pot.

The "Fade" function is obtained by switching S2, the switch on the back of the Rate potentiometer, off. The 100μF capacitor is then disconnected from the charging circuit and will very slowly discharge via the base of transistor Q2, resulting in a dimming time from full on to off of 30 minutes.

To remove any loading effects on the RC charging circuit we have connected a buffering stage between it and the voltage controlled delay stage. The buffer consists of transistor Q2 connected as an emitter follower with a 120kΩ/220kΩ voltage divider as the load. The purpose of the voltage divider is to set the minimum bias voltage and hence maximum delay in the firing angle: if the minium bias is too high the lamp will not compeltely extinguish, and if it is too low the trigger pulses will be delayed right into the next half cycle, causing the light to flicker.

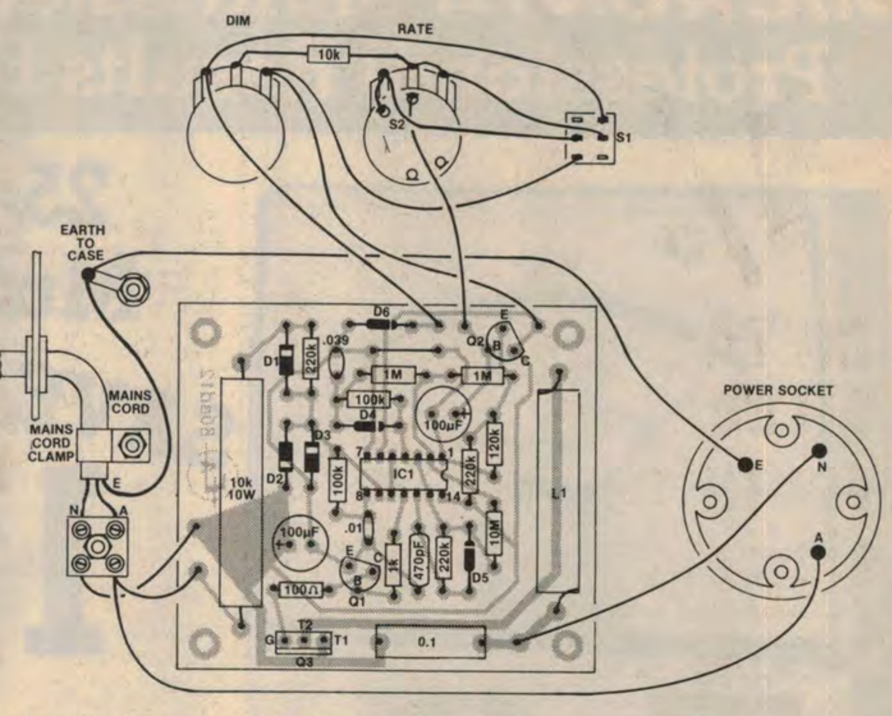
Due to component variations the minimum bias value may have to be adjusted by altering the 120kΩ and 220kΩ resistor values. The bias level must be set so as not to cause flicker when the lamp is almost completely dimmed out. If the resistors are altered, the 120kΩ resistor should not be changed to less than 100k.

IC1d and transistor Q1 form a simple monostable which generates the actual triggering pulse used to fire the Triac.

This pulse is obtained as follows: when the output of IC1c goes low, both inputs of IC1d will pull down simultaneously and so its output will also be low. However, when the output of IC1c goes high, one signal input to IC1d will be delayed by the RC circuit comprised of the 220kΩ resistor and the 470pF capacitor. The resulting short positive pulse on the output of IC1d turns on transistor Q1, which in turn fires the Triac.

The duration of the trigger pulse is about 100μs which is quite long enough to reliably trigger the Triac. The 1kΩ resistor between IC1d and Q1 limits the current drawn from the gate, while the 100Ω resistor between the gate of the Triac and the collector of Q1 limits the trigger current to 100mA.

The only item not discussed so far is the EMI suppression circuit. This consists of RF choke L1 and a 0.1uF 250VAC capacitor acting together as an LC filter to effectively damp the rapid turn-on currents generated by the Triac. This circuit is optional but we have found that it virtually eliminates interference to AM tuners.



Follow this diagram carefully when wiring up the Autodim. Heatsinking must be provided for the Triac if the unit is to be used with loads greater than 300W.

CONSTRUCTION

We assembled our Autodim in a standard diecast aluminium case measuring 55 × 95 × 120mm (D × H × W). Of course it is not necessary to use exactly the same box, and some readers may wish to house the Autodim with other equipment, or build up a bank for use as stage light controls. Note, though, that the Autodim must be housed in a metal case which is securely earthed to guard against the possibility of electric shock.

Most of the components are mounted on a small PC board coded 80ad12 and measuring 84 x 74mm. An actual size artwork for the PC board is shown elsewhere in this article for those interested in making their own board. Alternatively, finished boards can be purchased from most kit suppliers.

Construction is best started by fitting all the hardware to the case. As can be seen from the accompanying photograph, the PC board, mains cord clamp and mains terminal block are all mounted on the base of the case, while the two control pots and the toggle switch are mounted on the case lid. The mains output socket is mounted on one end of the case, nearest the toggle switch.

Drill centres for the front panel can be obtained from the actual size front panel artwork included with this article.

Use a grommet for the mains cable entry hole and secure the cable with a clamp. The mains active and neutral conductors are terminated to the insulated terminal block, while the earth wire connects to a solder lug bolted securely to the base of the metal case. Don't forget to run an additional earth wire from the solder lug to the earth terminal on the mains output socket.

Note that these wiring details should be followed exactly for safety's sake. Again, in the interests of safety, the wires to the mains output socket should all pass through grommetted holes.

Next, mount the various components on the PC board following the overlay diagram provided. Pay particular attention to the orientation of polarised components and mount the 10k/10W resistor slightly above the board to allow air to circulate under it. Observe the usual precautions when soldering in the CMOS IC: do not handle the pins, connect, the barrel of your soldering iron to the PCB 0V pattern and solder in the two supply pins (pins 7 & 14) first.

PARTS LIST

1 diecast aluminium box, 120 x 95 x 55mm
1 surface mounting mains socket
1 PC board, 80ad12, 84 x 74mm
1 mains cord and plug
2 mains cable clamp
1 RF choke (see text)
3 small rubber grommets
1 large rubber grommet
1 5k potentiometer (1in)
1 500k switch potentiometer (lin)
1 DPDT centre position off toggle switch
1 2-way mains terminal strip
4 10mm brass spacers
2 knobs to suit potentiometers

SEMICONDUCTORS
1 SC151D Triac, plus mounting hardware if required.
1 4030B CMOS quad XOR gate
1 1N4002 diode
1 1N4004 diode
2 1N4148 diodes
1 1N4742 12V zener diode
1 BZX79C4V7 zener diode
1 BC337, BC338 NPN transistor
1 BC549 NPN transistor

CAPACITORS
2 100μF 16VW electrolytics
1 0.1μF 250VAC metallised dielectric
1 .039μF greencap (metallised polyester)
1 0.01μF greencap
1 470pF polystyrene or ceramic

RESISTORS (¼W 5% unless stated)
1 x 10MΩ, 2 x 1MΩ, 3 x 220kΩ, 2 x 100kΩ, 1 x 120kΩ, 1 x 10kΩ, 1 x 1kΩ, 1 x 100Ω, 1 x 10kΩ 10W.

MISCELLANEOUS
Machine screws and nuts, mains rated hook-up wire, solder lug etc.

The Triac is mounted close to one edge of the board and should use the case as a heatsink if large loads are to be driven. Given this heatsinking, the Autodim can drive loads up to about 2kW, while loads up to about 300W can be handled without heatsinking.

Important note: the metal tab of the Triac is at mains potential and must be fully isolated from the case using mica washers and a plastic insulating bush. If you do decide to heatsink the Triac, we strongly recommend that you use two mica insulation washers (together with heatsink compound) to increase the breakdown voltage, and that you mount the device using a nylon screw and nut.

Inductor L1 is not available commercially but is quite easily made. A 50mm length of 10mm diameter ferrite rod is required, though if a longer length has been obtained it can be readily cut to size by filing a groove around the circumference and then snapping the rod as if it were glass.

Wind a layer or two of plastic insulation tape around the rod first, then close-wind a layer of 22B&S enamelled copper wire over the tape. The actual number of turns is not critical; use as many as will fit comfortably.

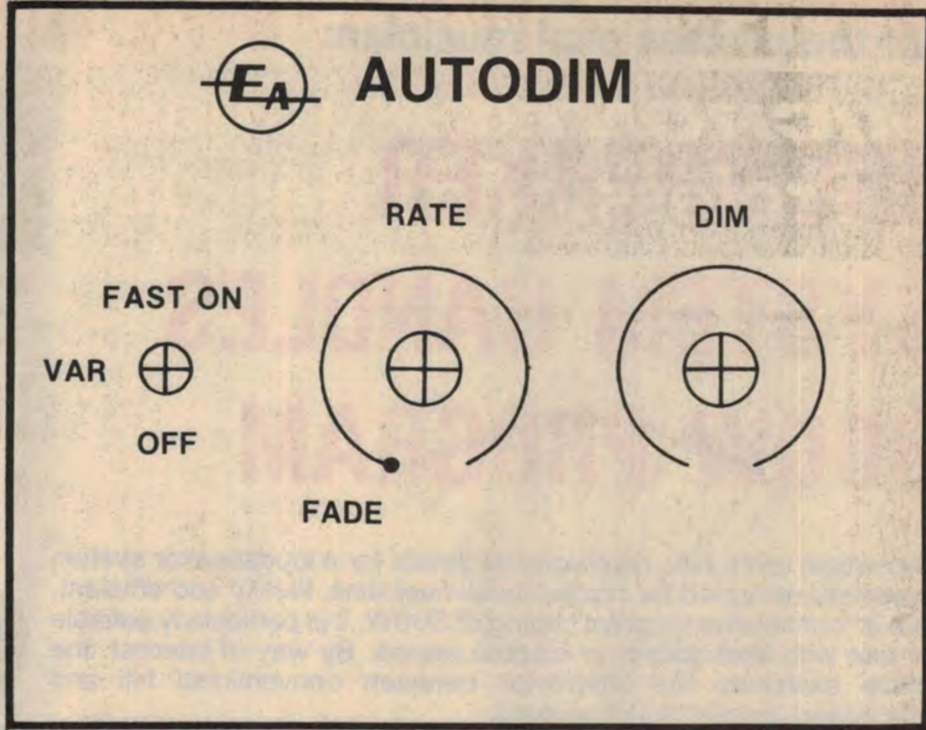
Next wind another layer of insulation tape around the coil making sure that the tape is wound firmly. If this is not done, the inductor will emit a buzzing sound due to the currents being switched by the Triac. The leads can now be scraped clean with a knife or razor blade, tinned, and the assembly soldered to the board.

> We estimate that the current cost of parts for this project is about
>
> **$25**
>
> including sales tax.

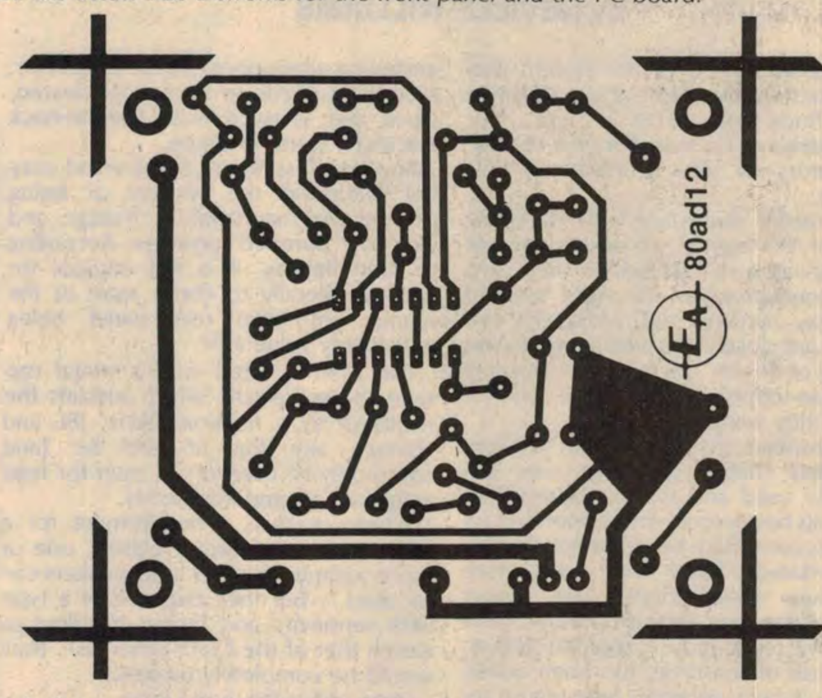
Now mount the PC board using 10mm spacers and complete the wiring to the PC board and to the front panel controls. Because the circuit operates at mains potential, all wiring should be run only in mains-rated cable.

The front panel for our prototype was made using "Scotchcal" photosensitive aluminium. You can either use the artwork provided to make your own front panel, or purchase a finished panel from the usual retail outlets.

Before switching on, make a final check of all wiring and the PC board assembly. Satisfied that all is correct, plug a 240V lamp into the unit, rotate the rate control to minimum, and test the various functions. First, switch the function switch to "Fast On" to test that the lamp comes on at full brilliance. Now switch to the "Var" position and rotate the Dim control — the unit should behave just like a normal light dimmer.



Here are actual size artworks for the front panel and the PC board.



Next, advance the "Rate" control and check that it controls the rate at which dimming levels change. The automatic slow fade function is checked by switching the "Rate" control to the "Fade" position.

Finally, a few words are in order concerning troubleshooting the Autodim. Because there is no isolation transformer, and because the circuit operates directly from the mains, most of the circuit can be at active potential. This means that servicing will be quite hazardous, so be very careful if you have any long term plans for staying alive!

If you do have to service the Autodim, we strongly recommend the use of an isolating transformer to minimise the danger of a fatal shock. You don't even have to use a transformer with a 240V secondary. A transformer with a secondary voltage down to 50V would be ideal for servicing although, naturally, the lamp brightness will be markedly reduced.

Note that where a low voltage isolation transformer is employed, the 10kΩ/10W resistor should be reduced accordingly. For example, if the transformer secondary is 120V, then the resistor value should be halved to 4.7kΩ (the nearest preferred value). If the transformer secondary is rated at 50V, then the resistor should be reduced to $10 \times 50/240 = 2.2k\Omega$.