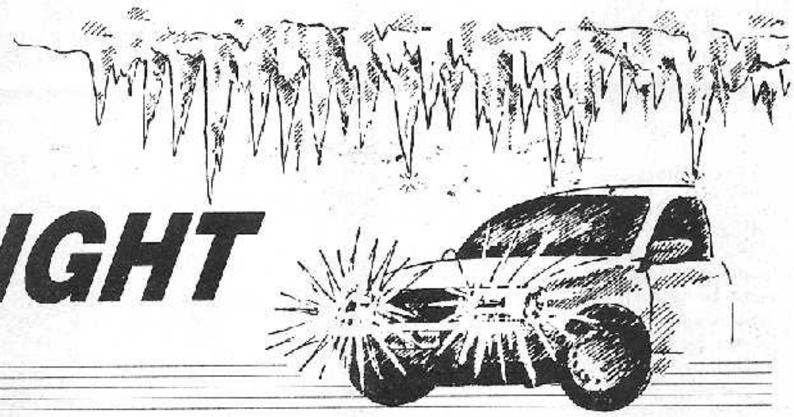


AUTO GARAGE LIGHT

A. R. WINSTANLEY

No more fumbling around in the dark when parking the car in the garage at night. The headlights trigger the garage light for a preset time period – daytime overide included.

Winter is upon us at the time of writing, which highlights the inconvenience that the author experiences when garaging the car at night after a hard day's work at the office. After parking the car at night, it can be quite a job to fumble around in the dark garage in search of briefcase, coat and house keys, and so this project was designed in order to throw a little light on the matter (literally).

This garage light control unit will automatically operate the garage's electric light for a pre-set period, and is activated by the car's headlamps as the vehicle enters the garage. It is also automatic in that it will only operate during the night-time hours, once ambient light levels have dropped below a pre-determined level.

The Auto Garage Light has been designed to be versatile to allow simple installation in several configurations, as shall be seen. The device is a mains-operated project and may require some experience or knowledge of domestic wiring, but installation is quite straightforward and involves minimal interference with existing wiring.

HOW IT WORKS

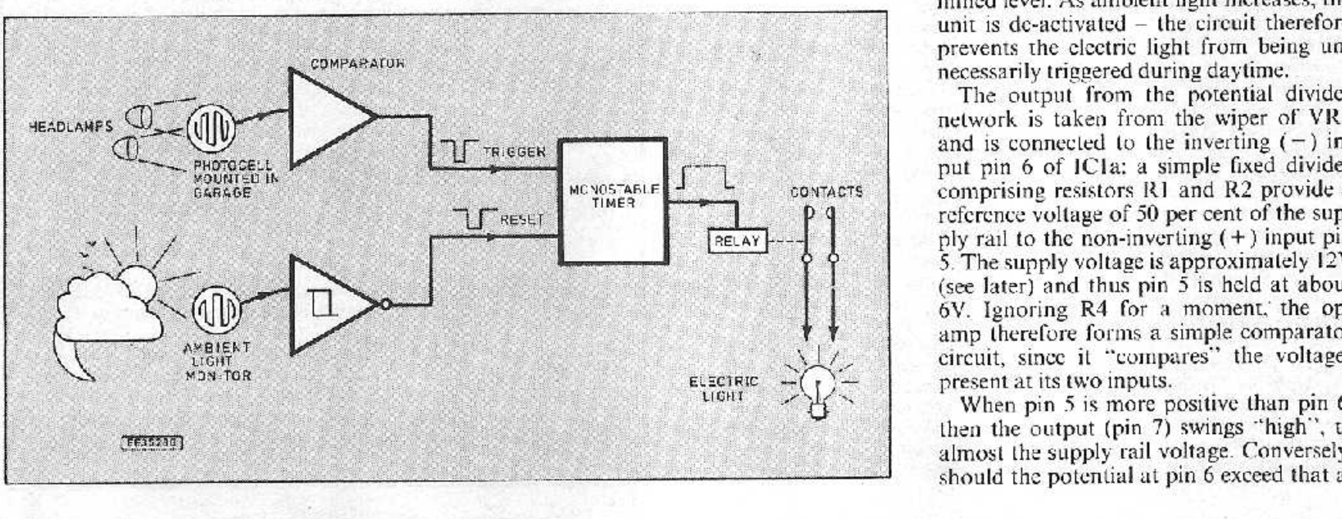
The unit to be described incorporates several distinct sections as detailed in Fig. 1. To outline the principles of operation, when the car is driven into the garage, the light from the headlamps falls upon a photo-sensitive device mounted inside the garage. This sends a triggering signal to a monostable ("one-shot") timer which starts timing for a period of up to about five minutes or so.

The timer is connected to a mains-rated relay, the contacts of which are in parallel with the existing light switch. Hence, the electric light in the garage will illuminate for a preset time period (the monostable period), long enough to get one's coat etc. out of the car and to lock up with the convenience of actually being able to see what you are doing for a change!

Precautions have to be taken to ensure that the system is not "fooled" by daylight, which would cause the device to mistake sunlight for the car headlamps and trigger the electric light.

A daylight override is therefore included in this design. This takes the simple form of a second photocell which is mounted near the window, for example, or if the garage does not have one, outside where it can watch for dusk and dawn. This second photocell sends a "reset" signal to the timer to prevent it from operating during daylight hours and will automatically activate the circuit again when the ambient light has dropped to a preset level.

Fig. 1. Block diagram of the Auto Garage Light.



Variable controls are incorporated to permit adjustment of the timer period, sensitivity to the headlights and dusk/dawn switching point. A further feature permits the provision of an extra electric lamp output, in case a light is not already fitted in the garage.

The Auto Garage Light was designed to plug directly into a mains socket, although skilled and experienced constructors will be able to wire directly to a fusebox, or a spur, for example. Obviously, such installation work *MUST* be carried out by a competent electrician if any doubts exist. To simplify construction, all components are mounted on a single p.c.b. which includes most mains interwiring for added safety and ease of assembly.

CIRCUIT DESCRIPTION

The circuit diagram of the Auto Garage Light is shown in Fig. 2 where the various sections can be seen. The circuit is centred around a twin operational amplifier chip type LM358 although other pin-compatible chips have been proven to function equally well.

As indicated earlier, this circuit utilises two economical photo-conductive cells or light-dependent resistors (l.d.r.s) similar to the ORP12 type. The first l.d.r., R3, can be considered as a "daylight/night-time detector" and is connected to form a potential divider with preset resistor VR1. It is located in a position where it can monitor ambient light levels.

The "Day/Night" sensor, which detects when dusk is approaching, is formed by IC1a and associated components and will activate the Auto Garage Light circuit when the light has fallen to a predetermined level. As ambient light increases, the unit is de-activated – the circuit therefore prevents the electric light from being unnecessarily triggered during daytime.

The output from the potential divider network is taken from the wiper of VR1 and is connected to the inverting (−) input pin 6 of IC1a: a simple fixed divider comprising resistors R1 and R2 provide a reference voltage of 50 per cent of the supply rail to the non-inverting (+) input pin 5. The supply voltage is approximately 12V (see later) and thus pin 5 is held at about 6V. Ignoring R4 for a moment, the op-amp therefore forms a simple comparator circuit, since it "compares" the voltages present at its two inputs.

When pin 5 is more positive than pin 6, then the output (pin 7) swings "high", to almost the supply rail voltage. Conversely, should the potential at pin 6 exceed that at pin 5, then the output will swing "low", to approximately one volt or so.

Since the resistance of l.d.r. R3 changes inversely to incident light levels, the voltage at pin 6 will fall when the ambient light level increases, and rise when light upon it reduces. Thus, the output of IC1a can be made to switch high or low by the change of light level which is monitored by l.d.r. R3, such that in darkness (R3 resistance high) pin 7 is low, and vice versa.

The exact point at which the switch-over from high to low takes place can be determined by the setting of preset VR1. This can be trimmed so that each installation can be individually tuned to prevailing conditions.

Of course, the gradual onset of darkness is a very slow change over several hours. The gain of the op-amp is so high that, in comparator mode, only a tiny fraction of a voltage difference need exist between the approaching the triggering level (itself set by VR1).

Resistor R4 introduces an additional side-effect in the operation of the Schmitt trigger. When the output switches either high or low, this effectively places R4 parallel with resistors R1 or R2 respectively. This can be considered as altering the values of R1 and R2 (to roughly 7.6k), and has an important effect upon the reference voltage at pin 5.

When IC1a output is low, resistor R4 can be considered as parallel with R2. By voltage divider action, the output voltage from the divider connected to pin 5 is:-

$$V_{ref} = \frac{\text{(combined value of R2 and R4 in ||)}}{\text{(total resistance of voltage divider)}} \times \text{Supply Voltage}$$

R2 and R4 in parallel are 7.6k and thus the reference voltage at pin 5 is now not 6V but 5.18V i.e. (7.6k ÷ 17.6k) x 12.

Alternatively, when pin 7 is high, R4 is now in parallel with R1, and the reference voltage becomes:-

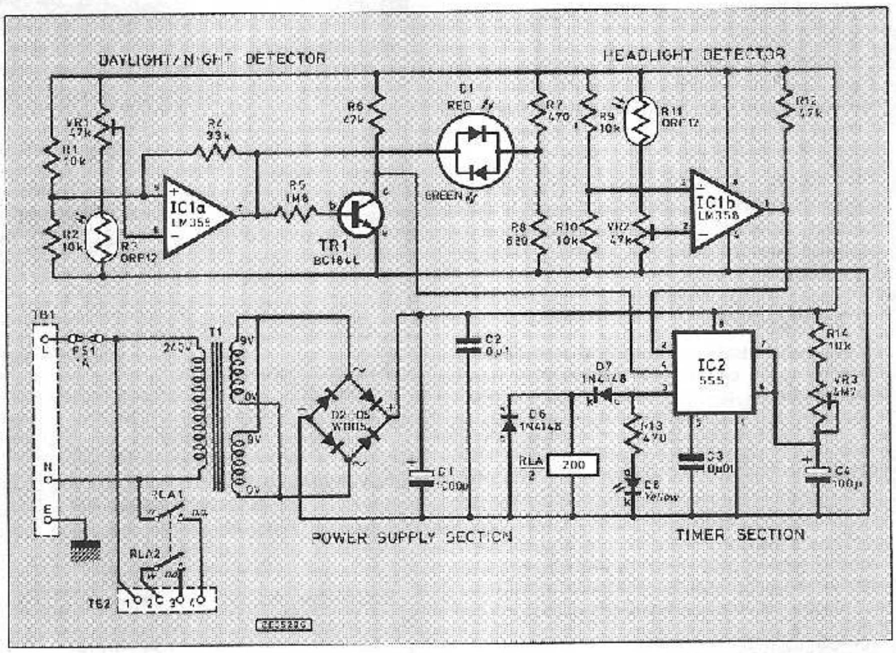
$$V_{ref} = \frac{\text{R2}}{\text{R2 Plus (value of R1 and R4 in ||)}} \times \text{Supply Voltage}$$

Hence the reference voltage is now about 6.8V: (10k ÷ 17.6k) x 12.

Note: to calculate the value of two resistors in parallel, the formula is:

$$R\,\text{total} = \text{Ra} \times \text{Rb}/(\text{Ra} + \text{Rb})$$

There is now a difference between the point at which the circuit can switch high and the point when it must switch low, because the reference voltage at pin 5 (against which the signal voltage from l.d.r. R3 is compared) is changed by the inclusion of R4. This difference in switching points is called "hysteresis" and is a fundamental characteristic of Schmitt triggers.



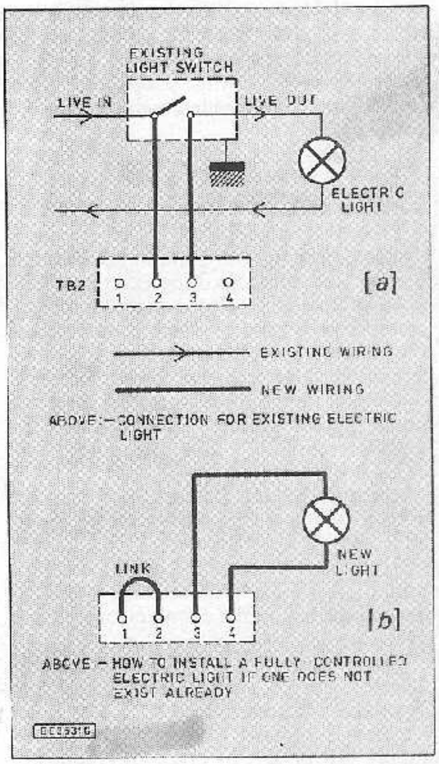


Fig. 2. Complete circuit diagram for the Auto Garage Light. The installation of the unit in an existing garage light circuit is shown in (a) and how to install a light if one does not exist is shown in (b).

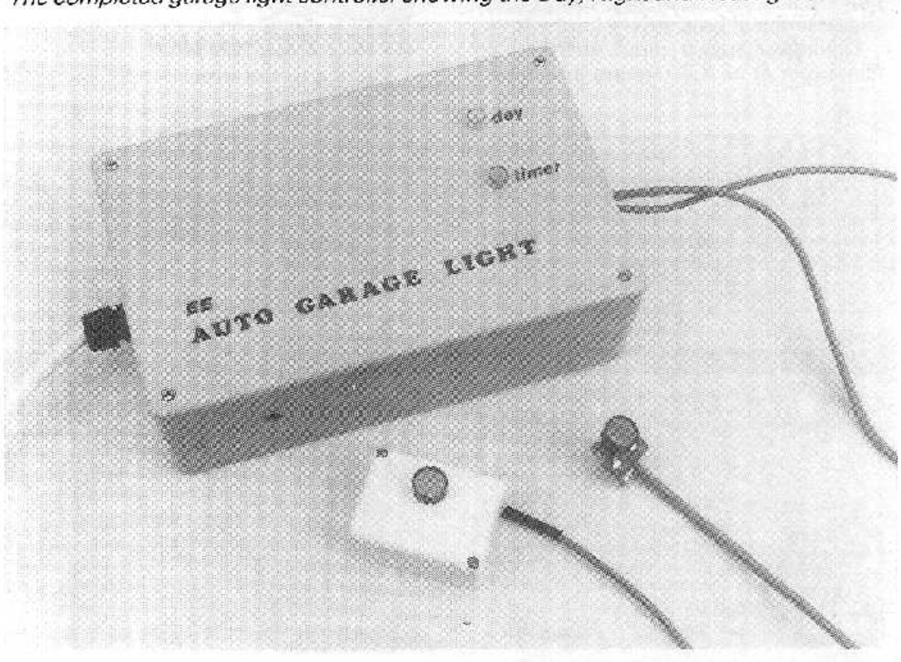
non-inverting (+) and inverting (−) inputs of IC1a and the device will amplify this and switch over the state of the output. Without any feedback between the output and inputs, the amplification factor or "open loop gain" of the LM358 is up to 100,000 and so the i.c. will multiply the difference between the two inputs by this factor, making the circuit very sensitive to differences between the inputs.

POSITIVE FEEDBACK

However, it was decided to further improve the switching characteristics of the circuit by including resistor R4 to introduce positive feedback. The i.c. then forms a Schmitt trigger, a circuit which is excellent for converting a very slowly-moving signal (l.d.r. output) into a very rapid on-off switching action.

Basically, once the output starts to switch high, R4 transmits a positive-going signal back to the non-inverting input (pin 5) of the op-amp, which accelerates the positive-going tendency of the output even more. This removes any tendency for the comparator to "jitter" in an intermediate state where the l.d.r. R3 resistance is just

The completed garage light controller showing the Day/Night and Headlight sensors.



A graphical summary of operation of this Schmitt trigger is shown in Fig. 3 which plots output against the input from the l.d.r. R3, and is a classical characteristic of this type of circuit. In practice the circuit will trigger when the ambient light level has fallen to a certain level but the light must increase back beyond that level before the circuit switches back again.

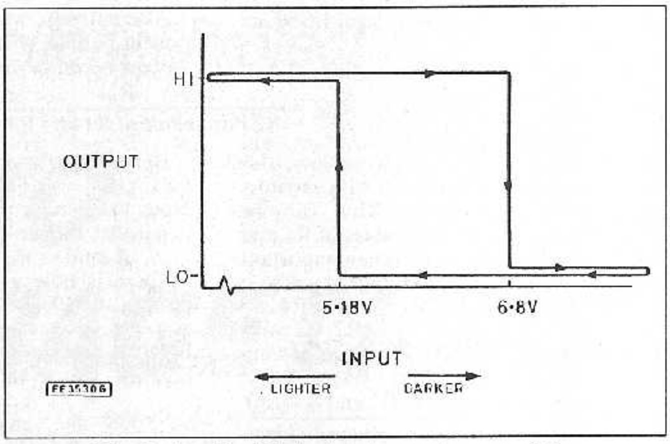


Fig. 3. Graph of Schmitt trigger characteristics.

Connected to the output of IC1a is a bi-colour l.e.d. D1 and this will glow red when the op-amp output is high (daylight conditions) to indicate that the circuit is disabled, and green when the op-amp output is low (circuit operational). This will prove especially useful during setting up. Resistors R7 and R8 provide a voltage drop for each l.e.d. chip.

HEADLIGHTS DETECTOR

The other op-amp, IC1b, is also connected as a comparator circuit but this time it was not considered necessary to add positive feedback. R11 is another photoconductive cell (l.d.r.) which is mounted in the garage at a spot where the car's headlamps will shine on it. This time, when light falls upon the photo-resistor, the inverting input (pin 2) will be forced towards the positive supply rail and the output will swing low.

Resistors R9 and R10 set up a reference voltage at pin 3 (the non-inverting input) and VR2 is another preset which controls the sensitivity of the circuit, i.e. how brightly R11 must be illuminated by the car headlamps before the comparator switches over.

The output from IC1b ("headlights detector") drives the trigger terminal (pin 2) of the 555 timer chip, IC2. The timer requires a voltage of two-thirds of the supply rail or less in order to commence timing, and so the 555 is triggered when l.d.r. R11 detects the car headlights, the trigger terminal being driven low by IC1b.

Unlike the trigger input, the reset terminal (pin 4) of IC2 requires a voltage of 0.7V maximum for the device to reset. The output of IC1a can be well over one volt when "low" and so a transistor switch TR1 was included which also inverts the output signal from pin 7.

Therefore, when IC1a output goes high (daytime conditions), transistor TR1 saturates and the collector falls to about 100mV or so. This provides a suitable reset signal for the timer chip, with the result that during daylight hours, the timer is disabled (reset pin held low by TR1) and cannot operate; this will override any signals present at the timer's trigger terminal.

TIMER

The timer itself is a standard monostable arrangement which will generate a fixed period delay when triggered at pin 2, unless the reset pin 4 is low. The period is determined by resistor R14, preset VR3 and capacitor C4 and is about eight minutes maximum. VR3 can be trimmed to change the period as required.

The output of the timer, pin 3, goes high during timing and this will illuminate l.e.d. D8 – a useful indicator during initial installation. The relay RLA is also energised during timing, diode D7 preventing latching up or relay chatter which sometimes occurs, and D6 shunts away any reverse voltage ("back e.m.f.") generated by the relay coil when it de-energises.

POWER SUPPLY/MAINS SWITCHING

Turning to the power supply and mains switching section, mains input voltage is applied to a three-way terminal block TB1, via protective fuse FS1 and is stepped down by transformer T1 to 9V a.c. and both secondary windings are in parallel. This is then full-wave rectified by the bridge rectifier D2-D5; this is smoothed by the reservoir capacitor C1, C2 helping to decouple any noise and spikes. The result is a d.c. unregulated supply of approximately 12V-13V which is the main supply rail for the circuit.

The specified relay RLA has two sets of changeover contacts, of which the normally-open contacts are employed to switch the electric light. In fact, the circuit has been arranged to be more versatile, and will permit not only an *existing* lamp to be operated, but also enables the constructor

COMPONENTS

Resistors

R1, R2	10k (2 off)	
R3, R11	ORP12 light dependent resistor (2 off)	
R4	33k	**See SHOP TALK Page**
R5	1M8	
R6	47k	
R7	470	
R8	680	
R9, R10	10k (2 off)	
R12	47k	
R13	470	
R14	10k	

All 0.25W 5% carbon film

Potentiometers

VR1, VR2	47k min. preset, horizontal
VR3	4M7 min. preset, horizontal

Capacitors

C1	1000µ axial elect., 25V
C2	0µ1 polyester
C3	0µ01 polyester
C4	100µ axial elect., 25V

Semiconductors

D1	bi-colour l.e.d.
D2-D5	W005 50V 1.5A bridge rect.
D6, D7	1N4148 signal diode (2 off)
D8	yellow l.e.d.
TR1	BC184L *npn* silicon transistor
IC1	LM358 or 1458 or TL082CP twin op-amp
IC2	NE555 bipolar timer

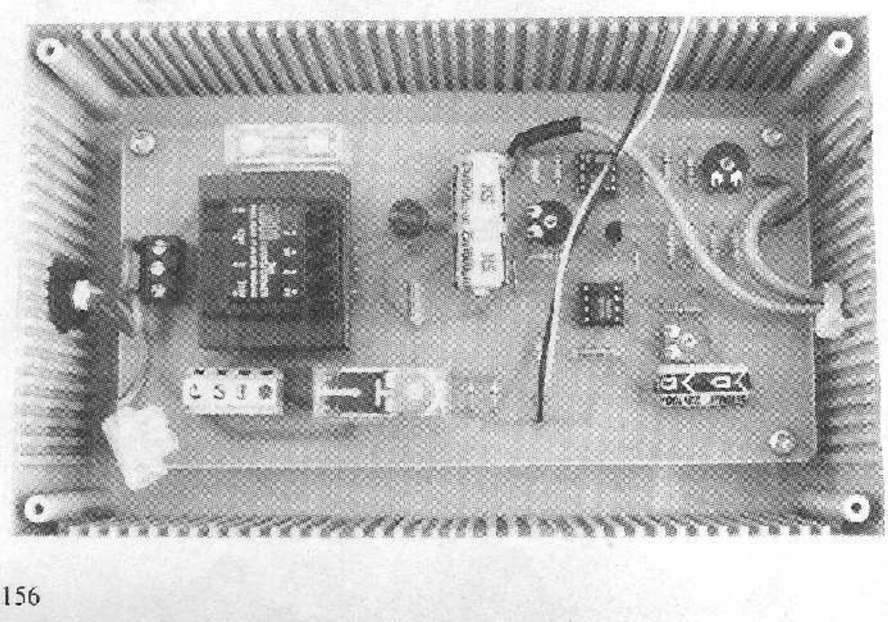
Miscellaneous

T1	Mains transformer: 240V primary; twin 9V 3VA secondaries (6VA total)
FS1	20mm p.c.b. mounting fuseholder c/w 1A fuse
RLA	Min. p.c.b. mounting 12V 200ohm coil relay, with d.p.d.t. mains rated (240V a.c. 5A) contacts
TB1	3-way mains rated p.c.b. mounting screw terminal block
TB2	4-way mains rated p.c.b. mounting screw terminal block

Plastic box, size 115mm x 185mm x 62mm; insulated p.c.b. mounting pillars (4 off); l.e.d lens-clips, 1 clear, 1 yellow; 1.00mm² twin-core and Earth wire; cable, solder etc.

Printed circuit board available from *EE PCB Service*, code EE786.

Approx cost guidance only **£19** *plus case*



to connect a light to the unit if the garage does not already have lighting installed.

The electric light is connected to the four-way terminal block TB2. To automate an existing light, simply connect terminals TB2/2 and TB2/3 in parallel across the light switch. Contacts RLA2 will then close when IC2 is timing, and this will in effect short out the light switch to illuminate the electric light.

If however no light and/or light switch exists, then a link wire can be inserted between terminals TB2/1 and TB2/2 which connects the live (L) supply to RLA2. The live output is taken from terminal TB2/3 to a new light which can be installed by the constructor in the garage. The circuit returns to terminal TB2/4 where it is connected to neutral (N) through relay contacts RLA1.

The mains supply can be taken from a fused 13A outlet (as in the case of the prototype) or experienced constructors will be able to take a suitable supply from the domestic fusebox. In its basic configuration using the existing light switch, installation is kept very straightforward and the modifications to any existing electrical wiring are very simple, but this depends on whether a 240V supply already exists in the garage.

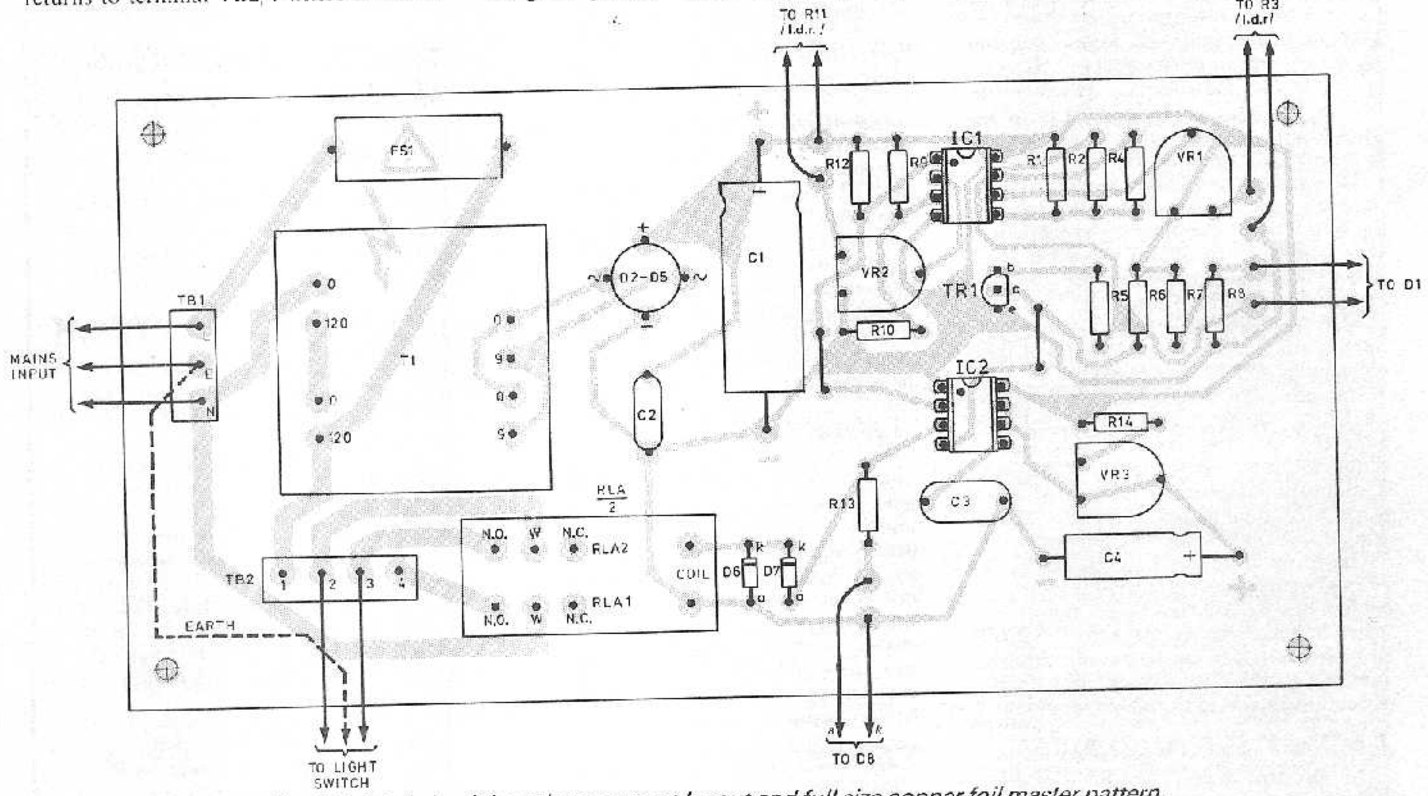
CONSTRUCTION

The whole of the circuit for the Auto Garage Light is constructed on a specially designed printed circuit board (p.c.b.). This includes all mains interwiring which simplifies assembly.

However, due to the presence of mains voltages, extreme care must be taken when finally installing and setting up the unit. The board should be tested using the low voltage method outlined under the "Testing" heading.

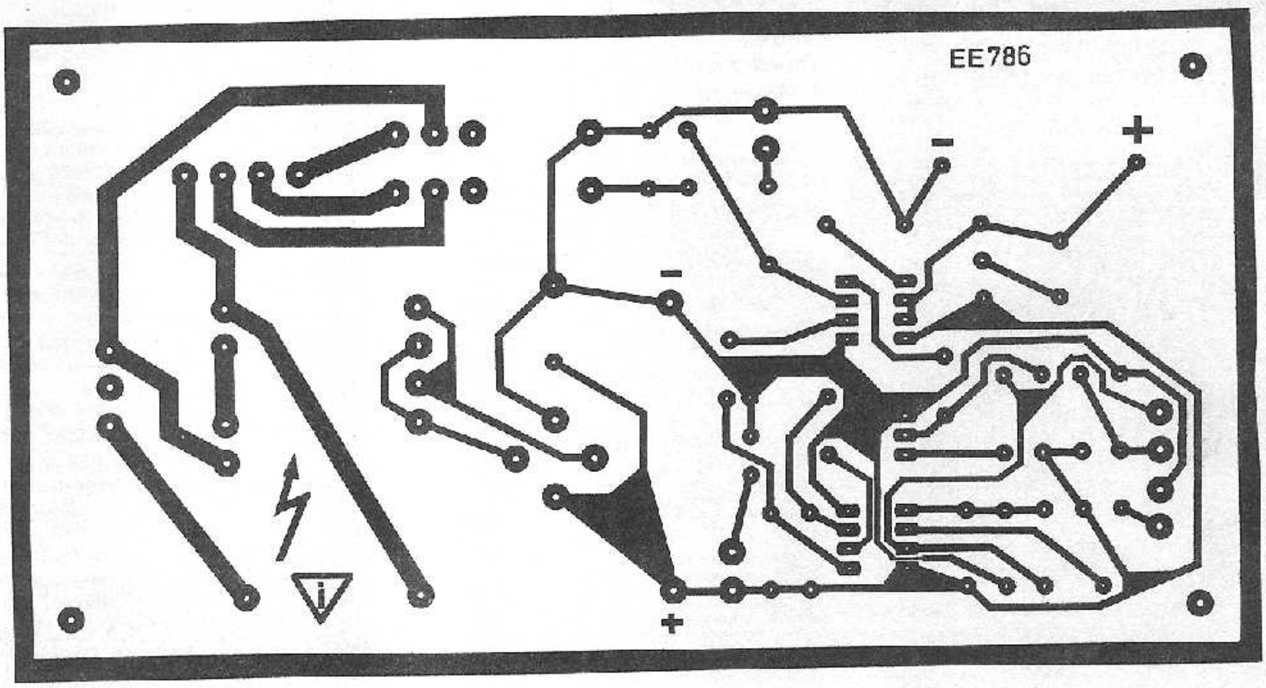
The printed circuit board component layout and full-size copper foil master pattern is shown in Fig. 4. This board is available from the *EE PCB Service*, code EE786.

The p.c.b. measures 160mm x 82mm and the prototype unit was housed in a plastic box of dimensions 185mm x 115mm x 62mm approximately. Before commencing work on the circuit board, simply use the empty p.c.b. as a template for drilling the p.c.b. mounting centres in the box.



EE35320

Fig. 4. Printed circuit board component layout and full size copper foil master pattern.



Assembly should start with soldering into position the smallest components first, see Fig. 4. The constructor may wish to utilise 8-pin d.i.l. sockets for IC1 and IC2. Continue by fitting the larger components, soldering the transformer in last of all. It is essential that the transistor, electrolytic capacitors, bridge rectifier and diodes are correctly polarised; also note the two link wires which need soldering into place.

It should be noted that the p.c.b. is designed to a 0.1in. pitch throughout, and it is therefore very important to purchase a transformer of the same pitch (5.08mm), as well as general pin configuration, to fit correctly on the circuit board. Metric pitch (5.00mm) transformers will not fit snugly on the p.c.b. and should not be used.

The same applies to the relay and two terminal blocks; again these are 5.08mm/0.1in. pitch and metric versions would not ensure an adequate fit. Bearing in mind that these items are at mains voltage, and the unit is designed to be left unattended, it is advisable to employ the recommended components.

After mounting all the components on the p.c.b., the board can be installed into the box. If a plastic housing is used, it is very important to mount the p.c.b. with *FULLY* insulated mounting pillars, such as p.v.c. stand-offs. These must be strong enough to carry the weight of the transformer and can be fixed into place with self-tapping screws at each end.

The use of a plastic box means that "Earthing" of the case is not required but none the less, any *exposed* metal screws should either be earthed or fully insulated from any mains circuitry inside – hence the plastic mounting pillars. If a metal case is used, this *MUST* be soundly Earthed.

The flying leads for the l.d.r. photocells and light-emitting diodes were soldered directly to the p.c.b. as per Fig. 5, though the mains connections are taken to the screw terminals. At this stage, do not connect anything to the 4-way block, and do not connect the board to the mains supply.

LIGHT SENSORS

On the prototype, l.d.r. R3 (Daylight detector) was mounted on a small tagstrip, with fixing lugs, and was located flush against the garage window; it was connected by a length of twin-core cable. The cable could be five metres long or more, if required.

It is obviously necessary that this photocell (R3) has an unobstructed view of ambient light levels. If no window is available, then it is very easy to construct an "outdoor" unit which could be mounted say on a door frame or near the eaves (if any). The suggested outdoor unit is built into a small plastic housing with a clip-on lid – an Aspirin container, for example.

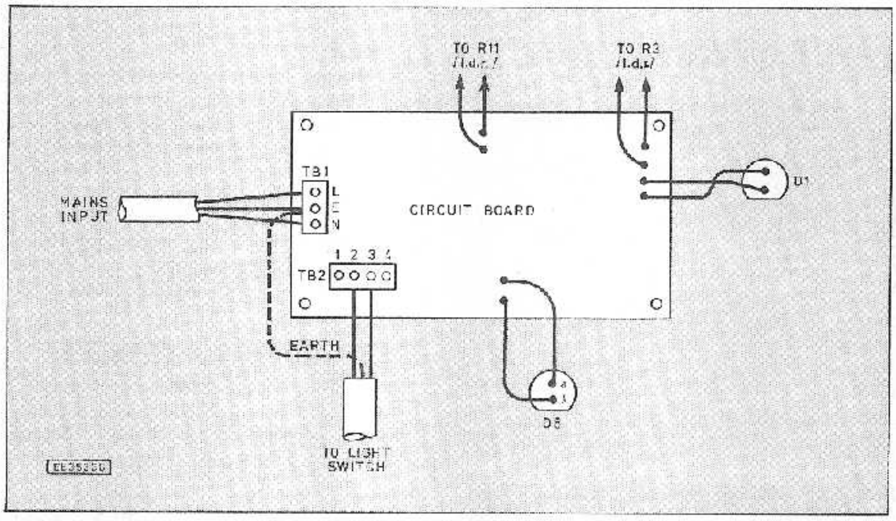


Fig. 5. Interwiring from the printed circuit board to the off-board components.

If the housing has thin enough walls, it will act as a weatherproof light diffuser for the photocell which is mounted within on a piece of tagstrip. The interconnecting cable is routed through into the garage to the Auto Garage Light. Obviously, there is plenty of room for improvisation using any materials to hand.

On the other hand, l.d.r. R11 must be mounted in the garage in a location where light from the car's headlamps will fall onto it. This photocell could be glued directly on a small plastic box as per the prototype, or indeed could be affixed to the box of the main unit itself if this is in a suitable position. Both photocells must be positioned where light from the electric light does not fall onto them to avoid feedback, and trial and error will determine the best location.

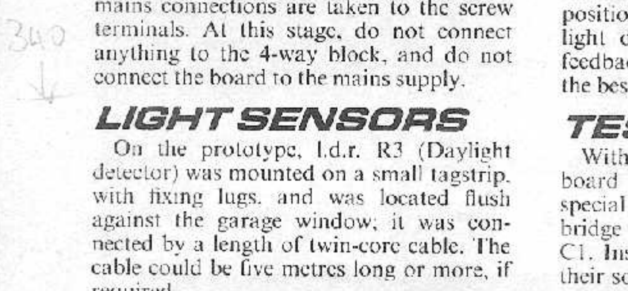
TESTING

With assembly now complete, inspect the board for any errors or omissions. Pay special attention to the polarity of the bridge rectifier and smoothing capacitor C1. Insert the two integrated circuits into their sockets, right way round, if you have not already done so.

Prior to operating the system, it might be an idea to keep the photocell assemblies to hand and not mount them permanently until the unit has been tested.

By far the best way of checking the unit before permanently installing it is to connect the board to a bench power supply if one is available. With the l.e.d.'s and photocells wired to the board ***(but not the mains)***, set presets VR1 and VR2 to midway, VR3 to nearly fully anti-clockwise, and clip a 12V d.c. supply across capacitor C1.

If the bicolour l.e.d., D1 is red ("daytime") then it should be possible to change the colour by covering up R3. This simulates night-time conditions, and preset VR1 might require adjustment to achieve this.



When the l.e.d. D1 turns green ("night-time"), temporarily exposing R11 to light will simulate car headlamps (adjust VR2 if necessary) and the relay should be heard to click into operation with the yellow l.e.d. D8 illuminating. After a period determined by preset VR3, the relay will switch out again.

The main thing to ensure at this stage is that if D1 is red then it should not be possible to activate the relay and D8 because the timer should be in a disabled state due to the resetting action of transistor TR1 upon IC1a.

If the board correctly operates as above, it can now be installed in the garage. Initially it would be better to run the board on the mains without connecting it to the light switch, so connect a 240V outlet via TB1. **It is extremely important to connect the Live, Neutral and Earth the right way round. Mains cables need to be secured with "P" clips or cable glands, for example,** so that they cannot be pulled out.

CAUTION! When the board is running from the mains, **certain components, notably the fuseholder, are live!**

FINAL INSTALLATION

Since no two garages are alike, installation is likely to be a matter of trial and error as far as the settings of the presets and locations of the two photocells are concerned. Testing of the prototype involved much flashing of headlights!

The link to the light switch can be effected with $1.00mm^2$ flat twin core and earth (TC&E) electrical cable of the required length, with cables firmly fixed to the wall using cable clips. A modern light switch may already be earthed and an Earth connection can be linked to the earth (E) terminal of TB1, for continuity. Carefully bend the TC&E wiring to shape so as to avoid undue strain on the 4-way terminal block.

Finally, if the constructor is using the unit to install a light where one does not already exist, then a short link wire (made from 6A wire) is fitted to join terminals TB2/1 and TB2/2 – see circuit diagram – and then an electric light can be wired in to terminals TB2/3 and TB2/4, again employing $1.00mm^2$ flat twin core. If required, an Earth can be taken from TB1 (middle terminal) to earth any additional light fittings or switches which may be installed by the constructor. □