LIGHT-OPERATED SWITCH

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Let dusk and dawn control your spruced-up Santa lights, or anything else that needs nocturnal enlightenment.

LIGHT operated switches are not new ideas, but neither are they the easiest items to purchase ready-made. Originally, this unit was built to switch on the author's outside Christmas lights when it became dark. No doubt readers will have other uses in mind. One such might be as a security porch light controller.

Up to 500W of lighting can be controlled by this Light-Operated Switch. However, the load must be resistive, i.e. normal lamps. Lights containing transformers are not suitable. The load is switched at the mains zero-crossing point, to minimize radio interference.

The light level required for the unit to switch on or off is fixed, but since the trigger point is set by a single resistor value it can easily be altered. A degree of hysteresis is included to reduce the chance of the unit being affected by the light it is controlling. Reasonably careful siting, though, will still be necessary to prevent the controlled light from directly illuminating the sensor.

The printed circuit board (p.c.b.) is designed to fit behind a single electrical blanking plate, with a hole to allow light to reach the photocell. This plate can be fitted to a single 25mm surface box, giving a cheap and tidy wall mounting case.

For the original purpose, the unit was placed on a window sill with the photocell facing outwards. If the unit is to be used outdoors or exposed to moisture, a sealed waterproof case will be needed.

WARNING

This circuit operates at potentially lethal mains voltages. If you are in any doubt about your ability to construct it safely, obtain advice from a suitably qualified or experienced person. Although the construction is straightforward, THIS PROJECT IS NOT SUITABLE FOR BEGINNERS.

CIRCUIT OPERATION

The complete circuit diagram for the Light-Operated Switch is shown in Fig. 1. Low voltage power is derived from the mains supply without isolation. The a.c. input is clamped to −15V and +0·6V relative to Neutral by Zener diode D1. The remaining voltage is dropped by capacitor C1. A capacitor is used because it dissipates virtually no power (unlike a resistor) due to the 90 degree phase shift between voltage and current. The negative-going cycles are rectified by diode D2 and smoothed by capacitor C2 to give a steady −15V supply rail.

Capacitor C1 must be a Class X component rated for continuous connection directly across the mains. These devices are normally sold as suppression components. A normal high voltage capacitor is NOT suitable and MUST NOT BE USED.

Resistor R1 is a surge limiting component which reduces the in-rush current if the unit is powered up when the mains cycle is near a peak. A wirewound resistor should be used as it has better surge handling than carbon or metal film.

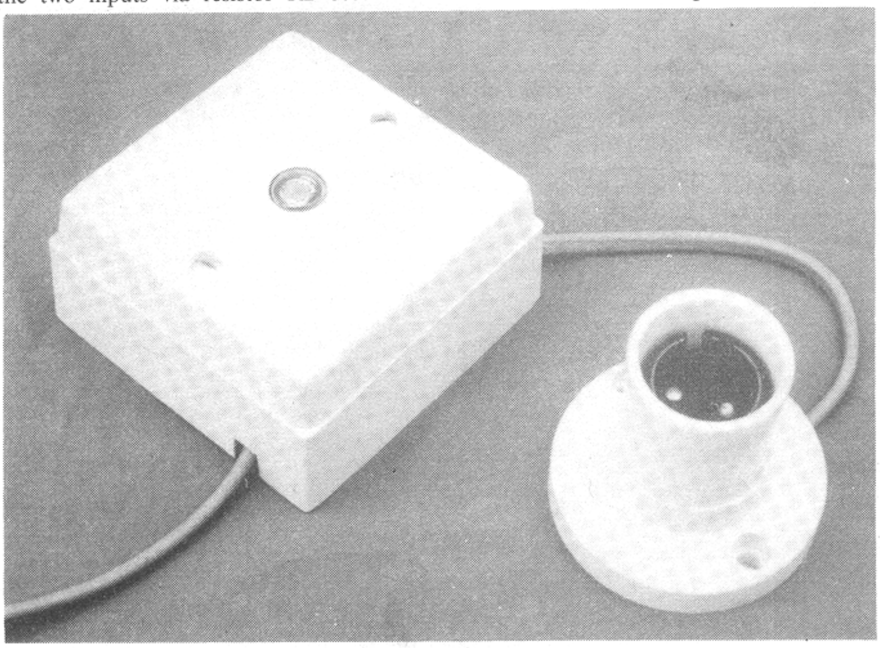
Schmitt NAND-gates IC1a, IC1b and their associated components produce the zero-crossing pulses, waveforms for which are shown in Fig. 2. The inputs of IC1a, pins 1 and 2, are normally held low by resistor R3, causing a high output at pin 3. When the mains cycle (waveform A) rises above about +40V, the voltage fed to the two inputs via resistor R2 becomes sufficient for the gate to be triggered and its output go low. When the mains voltage falls below +40V near the end of the positive half cycle, the output of IC1a goes high again (waveform B). Diodes D3 and D4 clamp the waveform to the d.c. supply rail, protecting IC1 from excessive input voltages. The Schmitt trigger inputs of IC1 ensure reliable switching.

Input pin 6 of IC1b is connected similarly, but is normally held high by resistor R5. The gate therefore operates on the negative half cycles. The differing values of R3 and R5 are due to the fact that one gate is biased to Neutral and the other is biased to 15V below Neutral. The other input of IC1b, pin 5, is connected to the output of IC1a, so that this second gate sums the two half cycles, outputting from its pin 4 the zero crossing waveform shown in Fig. 2c. This is inverted by transistor TR1, giving a signal which pulses high around the zero crossing points.

A two input AND gate is formed by IC1c and IC1d. One input (pin 9) is driven by the previously mentioned zero-crossing pulses. The output (pin 11) will follow this only if the level on the other input (pin 8) is above 50 per cent of the supply voltage. The voltage here is determined by the light level reaching the light sensor R13.

LIGHT LEVEL

Light is sensed by the light dependent resistor (l.d.r.) R13. The resistance of this device decreases as the light level increases.



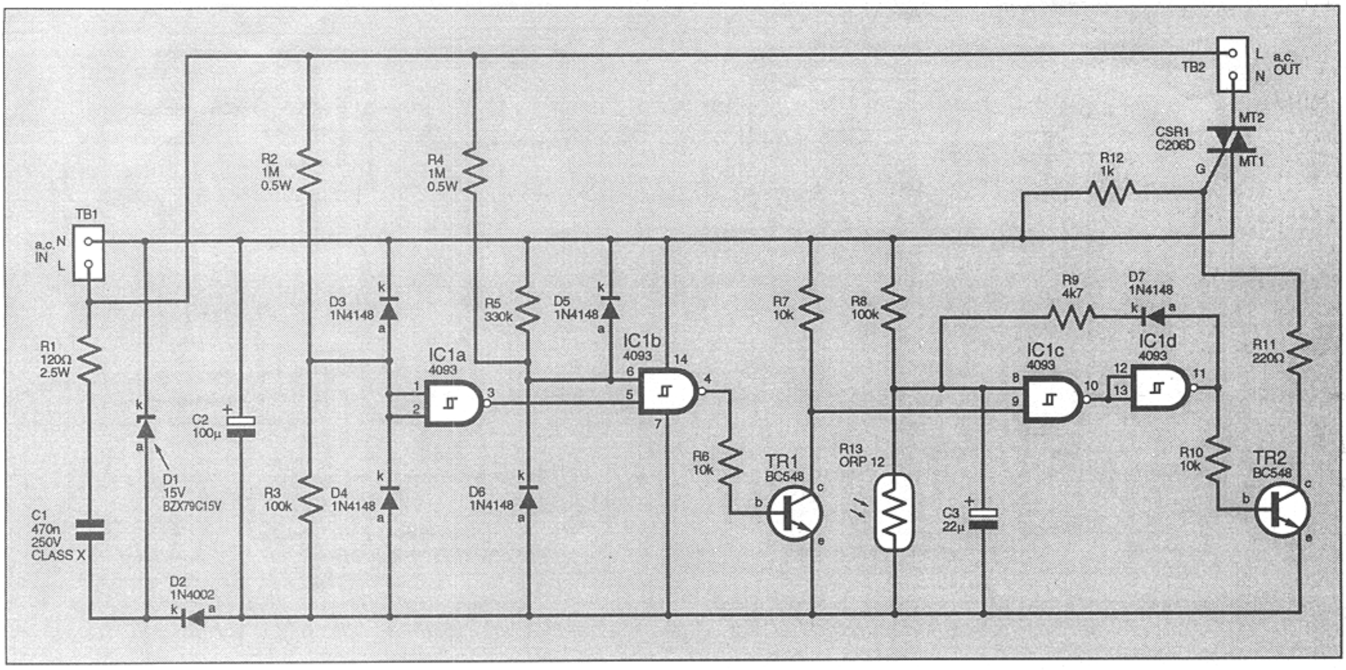


Fig. 1. Complete circuit diagram for the Light Operated Switch.

In bright light the resistance can be as low as 100 ohms, while in darkness it may exceed 10 megohms. In this circuit R13 is half of a potential divider, the other half being resistor R8. The switching point occurs when the resistance of l.d.r. R13 is about equal to R8.

The value of R8 can be varied to change the threshold level if preferred. A preset could be fitted, but this must **NEVER** be adjusted with the power on.

The voltage from the potential divider is damped by C3, to reduce the chances of the unit being triggered by rapid fluctuations in the light level, such as shadows caused by people or animals passing.

When the light level is low enough to cause the unit to switch on, positive-going pulses at the output of IC1d are coupled back to the potential divider by diode D7 and resistor R9. These are smoothed by capacitor C3, causing a voltage increase on IC1c pin 8. This gives the circuit hysteresis: the light level required for the unit to switch off again is now set higher than the level that caused it to switch on.

Thus, if some light from the lamp being controlled reaches the l.d.r., the unit will hopefully not switch off again. There is a limit to this effect, however, for if the controlled light shines directly onto the l.d.r., the lamp will probably start flashing.

The positive pulses on the output of IC1d switch on transistor TR2, which in turn triggers the triac CSR1. The triac is therefore driven only briefly at around the zero crossing points of the mains supply voltage.

Once the triac is triggered it will remain on until the current passing through it drops below a minimum value. This will occur as the mains cycle reaches the next zero crossing point. If the lamp still needs to be lit, as sensed by the l.d.r. (R13), the triac will be triggered again at this point.

The synchronised pulsing arrangement used ensures that the lamp is not switched on near the peak of a mains cycle. If this were to happen the surge could cause momentary radio interference, although this would not be a major problem with a unit that switches so infrequently.

Another advantage of applying only brief drive pulses to the triac is that the average current consumption from the low voltage supply is much lower. This enables the simple power supply arrangement described earlier to be used.

However, this zero-crossing arrangement will not work correctly with inductive loads as the current passing will be out of phase with the voltage.

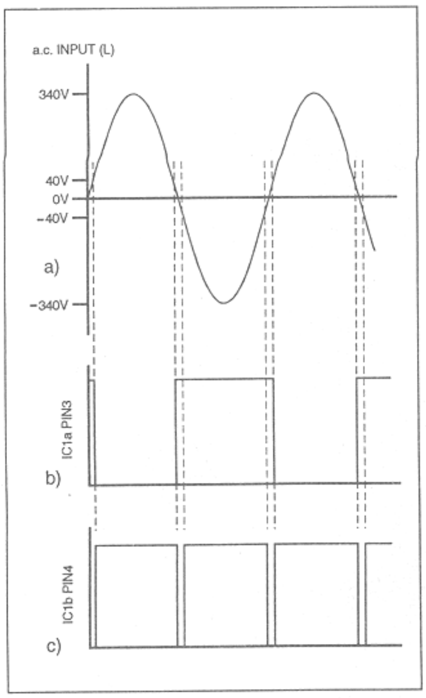


Fig. 2. Waveforms associated with IC1a and IC1b.

CONSTRUCTION

Construction is very straight-forward if the recommended printed circuit board (p.c.b.) is used. The component overlay and track layout for this board are shown in Fig. 3. The board is available form the *EPE PCB Service* code 966.

Assemble the components in any order with which you feel comfortable. It is preferable to use a socket for IC1, fitting the i.c. only after everything has been checked. Discharge static electricity from yourself as usual before handling CMOS devices.

COMPONENTS

Resistors

R1	120Ω 2·5W wirewound
R2, R4	1M 0·5W (2 off)
R3, R8	100k (2 off)
R5	330k
R6, R7, R10	10k (3 off)
R9	4k7
R11	220Ω
R12	1k
R13	ORP12 light dependent resistor

All 0·25W 5% or better unless stated.

See SHOP TALK Page

Capacitors

C1	470n 250V a.c. Class X
C2	100μ axial elect., 25V
C3	22μ axial elect., 25V

Semiconductors

D1	BZX79C15 15V Zener diode
D2	1N4002 rectifier diode
D3 to D7	1N4148 signal diode (5 off)
TR1, TR2	BC548 *npn* transistor (2 off)
CSR1	C206D triac
IC1	4093 CMOS quad 2-input *Schmitt NAND Gate*

Miscellaneous

TB1, TB2 2-way p.c.b. mounting mains rated terminal block (2 off); printed circuit board, available from the *EPE PCB Service,* code 966; 14-pin d.i.l. socket; single electrical blanking plate; single 25mm electrical surface box; self-adhesive p.c.b. stand-offs (4 off); 13A plug with 3A fuse; cable etc. as required for installation; solder.

Approx cost guidance only **£15**

Do not forget to insert the single link wire near TR1. A number of holes are provided for capacitors C1 and C2 to enable various sizes to be accommodated. The triac, CSR1, should be bolted to the p.c.b. with an M3 nut and bolt. TB1 and TB2 are p.c.b. mounting terminal blocks and should be fitted with the cable entries facing outwards.

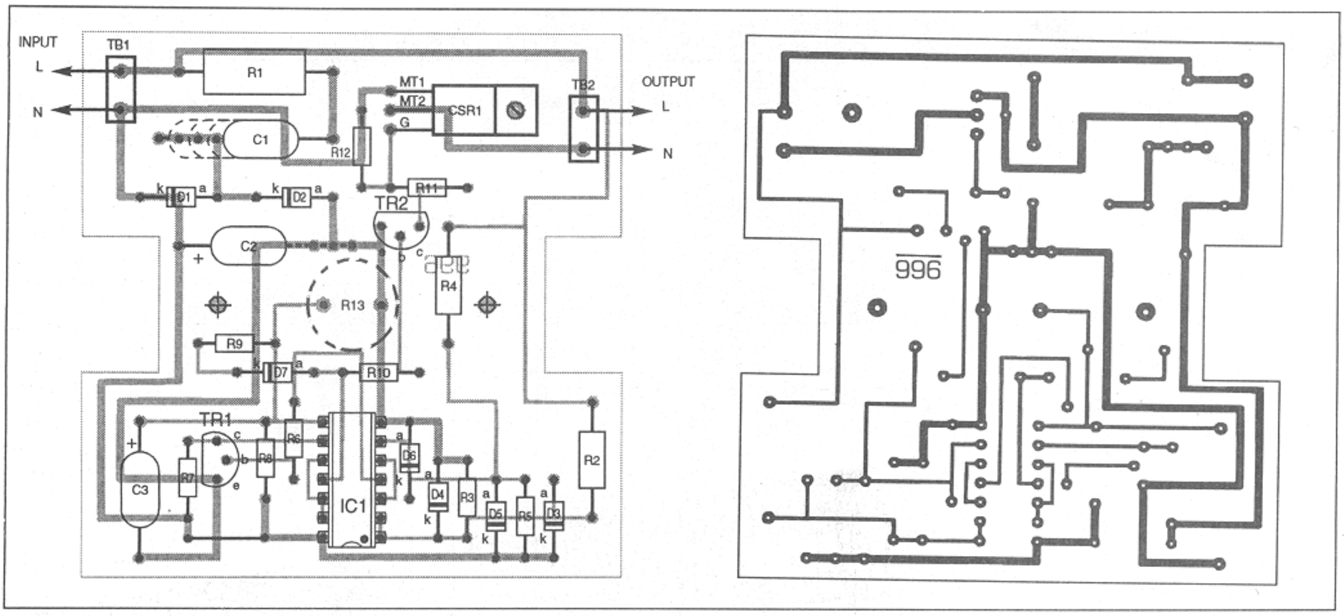


Fig. 3. Printed circuit board component layout and full size copper foil track details. Note the l.d.r. (R13) should be mounted on the track side.

The l.d.r. (R13) should be fitted to the track side of the p.c.b., but do not solder this until you know precisely where in the case the board will be mounted.

Double check the p.c.b. assembly when you have finished, particularly around C1, R1, D1, D2 and TR3. Mistakes on a mains powered circuit like this can cause a horrible mess when the power is applied!

PANEL AND CASE

The front of the case is a single electrical blanking panel. The panel may be carefully drilled using a hand drill or a SLOW electric drill. A normal DIY power drill will be too fast.

Note, though, that the plastic used for the blanking panels is very brittle. Take it VERY gently when you near the point of breaking through. A WorkMate is useful to hold the panel while drilling, as is having a piece of wood firmly in contact with the underside of the panel.

Try to get a panel that is plain on the inside, some have extra moldings and bits which may get in the way.

For safety reasons it is recommended that the p.c.b. is not secured with screws and spacers, unless nylon spacers with a threaded insert at each end are used. A much better method is to use two or more self-adhesive p.c.b. stand-offs to provide steady support.

The rear of the case is a 25mm (socket depth) single electrical surface box. Before buying this, make sure it has only two threaded holes for the front panel screws. Some boxes have four of these, one on each edge – the top and bottom ones will foul on the p.c.b. It will be necessary to remove one or two knock-outs on the side or back for the cables to enter.

TESTING

Since there is nothing to adjust, testing simply involves seeing if the unit works. ***Remember that the whole p.c.b. is at mains voltage and is therefore potentially lethal.***

Fit the p.c.b. into the case before switching on. Connect one end of a length of two-core mains cable to the TB1 terminals (Live nearest to edge of p.c.b.) and connect the other end to a 13A plug fitted with a 3A fuse.

Connect another length (at least one metre) of two-core cable between the TB2 terminals (Live to edge of p.c.b. again) and a lampholder. Fit a 60W lamp into the holder. Position the lamp holder about a metre away from the l.d.r.

Connect the unit to the mains, preferably via an Earth leakage or residual current circuit breaker (the type intended for power tools). Switch on. Hopefully nothing dramatic happened!

Place your hand over the l.d.r. After a couple of seconds the lamp should come on. Move your hand away and it should go off again. That's all there is to it. Hopefully your unit worked fine – there isn't much to go wrong!

INSTALLATION

Installation will depend upon what the unit is to be used for. The prototype was mounted on a piece of wood next to a single 13A socket. Three-core mains cable was used, the Live and Neutral passing through the unit, and the Earth connecting directly to the socket. The other cable end terminates in a 13A plug with a 3A fuse.

It is important to use three-core cable if the unit is being used to control a load via a 13A socket, even if the load does not need an Earth. At some future point someone may plug a load that *does* need an Earth into the unit.

The prototype was sited indoors on a window sill, with the lead to the outside Christmas lights passing through a hole in the window frame. It can be more permanently installed if required. However, it is not suitable for permanent connection to household wiring. This is due to wiring regulations, not a fault with this unit.

Do not assume that a load is safe if it is switched off by this unit. It is the Neutral line being switched by the unit, not the Live. This reduces the potential difference between the circuit and Earth. Also, there is sufficient leakage through an untriggered triac to give a fatal electric shock.

When working on the unit, or a load connected to it, the power **MUST** be properly isolated (Live and Neutral disconnected).

Take care to position the unit so that light from the lamp it is controlling does not fall directly on the l.d.r. It may be possible to mount it on a different side of the building to the lamp, for example. Street lamps have the light sensor mounted on the top, above the lamp which shines downwards.

If mounting the unit outdoors it will need a suitably waterproof case. The suggested case is suitable for indoor use only. It is imperative that the circuit cannot get wet. The area where the light gets to the l.d.r. may be difficult to seal effectively. A sealed plastic case (to IP65) with a clear lid would be a satisfactory solution.

Use sealed cable glands for the cable entries. Drill a small (2mm) breather hole at the lowest point in the case, to prevent condensation and let out any moisture which might get in despite your efforts. □