Constructional Project

TIME DELAY TOUCH SWITCH

BART TREPAK

Automatically turns off lights after a preset period

GLOBAL warming in relation to our use of energy is a subject that is heavily debated. A major use of energy is the consumption of electricity in our homes and industries. Perhaps the most obvious waste of electricity in our homes (although certainly not the largest) is caused by lights being left on in areas when the occupants have left. Nowhere, perhaps, is this more common than in halls and stairways.

Fitting switches which turn off automatically after a preset time in these locations can reduce the electricity consumed quite significantly. A single 100W bulb left burning all night (say eight hours) would consume 800W/hrs. The same bulb fitted with a switch which turned off automatically after say five minutes would consume only 83W/hrs, even in the unlikely event that it were to be activated ten times during this period.

MECHANICAL DELAYS

Commercial time delay switches for stairs and halls are generally mechanical devices which work on the basis of a leaky cylinder. When the button is pressed, air is expelled from the cylinder and a contact is made, so switching on the light. A spring now slowly pushes the cylinder back to its rest position at the limited rate at which air can re-enter the cylinder, eventually causing the contact to be broken and turning off the light.

Although simple enough, being a mechanical system it has many drawbacks. With repeated use, the components making up its valve can become worn allowing air into the cylinder faster, thus reducing the time delay. Additionally, dust and dirt can find their way into the switch, causing it to stick and preventing it from switching off.

Furthermore, the delay also depends on the depth to which the button is pressed, which determines how much air is expelled from the cylinder. As some force is required to do this fully, it can be difficult for elderly or infirm persons. Consequently, those who require the most time to make it up the stairs can end up with the least!

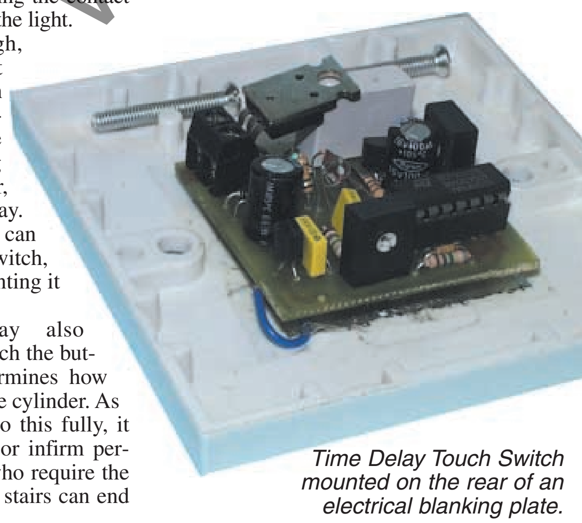
This circuit overcomes these problems by having no moving parts. It is activated by touch and has the added bonus of a small neon light which enables it to be easily located in the dark. The finished unit is mounted on a standard electrical blanking plate and can replace any conventional light switch.

Although intended primarily for conventional incandescent light bulbs, the circuit has also been found to work with low energy fluorescent types.

TRIAC CONTROL

There are two major problems to solve when designing a touch switch to replace a conventional mechanical light switch and these concern the power supply and noise immunity.

The main switching element used to control the light is a triac, a semiconductor a.c. switch. This is normally in its off or non-conducting state but can be switched into conduction by means of a small trigger current fed to its gate terminal. Once triggered it will remain conducting until the current through it drops below a certain value (known as the holding current). This occurs normally on a.c. supplies when the voltage drops to zero at the end of every mains half-cycle, and the triac must be re-triggered again if the light is to remain on.



Time Delay Touch Switch mounted on the rear of an electrical blanking plate.

As with any switch, the voltage across a triac when it is in its off state will be the supply voltage (in this case 230V a.c.). When the triac is on, the voltage across it will be around 1V a.c., depending on the current. The triac therefore dissipates very little power so no heatsink is required.

With normal house wiring, only the Live wire and its feed to the lamp are accessible at the wall-mounted light switch. The Neutral wire from the lamp is left inaccessible in the ceiling. Thus it is not possible to simply reduce and rectify the mains to provide a d.c. voltage for the triac control circuit, which must therefore be powered "through" the lamp, i.e. from the voltage across the triac.

An adequate d.c. voltage can be derived by delaying the point at which the triac is triggered in a mains half-cycle. This allows a higher voltage to develop across it which can be rectified and used to power the rest of the circuit.

The disadvantage is that it gives rise to EMI (electromagnetic interference) which can interfere with radio reception and computer systems. As a result, bulky and expensive chokes and capacitors have to be fitted to suppress it. This is unavoidable in light *dimmers* where we *have* to delay the triggering so that the power to the lamp can be controlled. For an on/off control, though, triggering should occur as early as possible so that full power is available to the lamp and without interference being generated.

IN CONTROL

In this circuit, a small Zener diode is connected in series with the triac. This causes sufficient voltage drop so that after rectification a 3V to 4V d.c. supply is available for the control circuits. The Zener has the load (light) current flowing through it during operation and therefore dissipates power, but for the kind of currents used in lighting this only amounts to a few hundred milliwatts, a value well within the ratings of small wire-ended Zener diodes.

The circuit provides sufficient current to enable the triac to be triggered by d.c. pulses instead of the short a.c. trigger pulses normally used. As a result, the triac does not turn off between half-cycles, and so does not cause interference to the mains supply. This point is important as it also enables the circuit is to be used with low power fluorescent lamps if required.

TOUCH CONTROL

Touch control circuits, by their very nature, tend to be prone to spurious switching in response to the many glitches and pulses which normally occur on the mains supply due to other equipment being switched on or off. This is often difficult to overcome, but it can be very much reduced by building a delay into the circuit so that short pulses, which characterise most of the interference, are ignored and the circuit only responds to longer inputs.

By fitting a delay of a few hundred milliseconds, users will not notice any delay in switching, and interference, which rarely lasts for more than a few tens of milliseconds, will be largely ignored by the circuit. This is not a complete solution to the problem, but in this case there is also the advantage that even if the circuit should switch on accidentally, it will only remain on for a few minutes anyway.

of a standard light switch blanking plate. The foil forms one plate of a capacitor. When it is approached by a hand, which becomes the other plate, the capacitor formed effectively connects the base of transistor TR1 to earth. (The human body is a fairly good conductor and exhibits a capacitance to earth of around 100pF, depending on size and area!)

Since the emitter circuit of *npn* transistor TR1 is connected via resistor R2 to the Live rail, which is at 230V a.c. with respect to earth, this is equivalent to a 230V input to the base of TR1 via the combined capacitance of the body plus that the hand and foil.

Not surprisingly, transistor TR1 turns on when the input polarity is correct and charges capacitor C1. Resistor R1 and preset resistor VR1 set the sensitivity of the circuit, allowing it to be activated by placing one finger or the whole hand on the plate. Resistor R2 discharges the capacitor when the hand is removed.

When the input threshold of gate IC1a is exceeded, the output switches low causing

time for which the triac remains triggered and the lamp turned on.

With the components specified, the turn-on time can be made variable from around 20 seconds to 2¼ minutes. This may be increased if required by increasing either R4 or C3, or both.

COMPONENTS

Resistors

R1, R3	2M2 (2 off)
R2	680k
R4	330k
R5	390Ω
R6	1k
R7	150k

All 0·25W carbon film

See SHOP TALK page

Potentiometers

VR1, VR2	2M2, min preset, vertical (2 off)

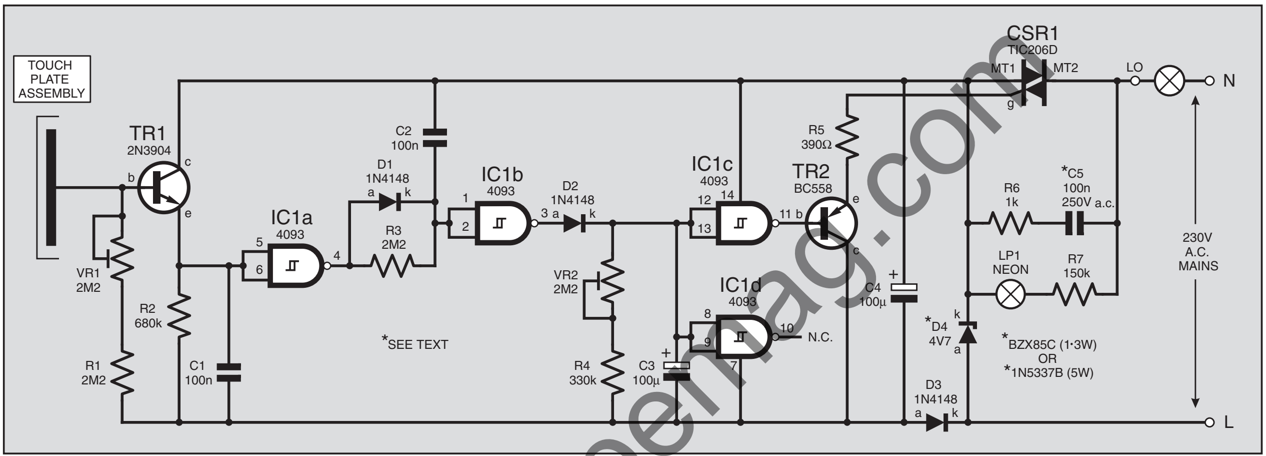


Fig.1. Complete circuit diagram for the Time Delay Touch Switch.

CIRCUIT DESCRIPTION

The circuit diagram for the Time Delay Touch Switch is shown in Fig.1. Triac CSR1 and Zener diode D4 are connected in series with the lamp as previously discussed. The voltage appearing across the Zener is rectified and smoothed by diode D3 and capacitor C4 to provide a d.c. supply of around 4V.

As this voltage only appears when the triac is on, capacitor C5 is connected as a capacitive mains dropper to provide a small current to the Zener to maintain the d.c. supply when the triac is off. Resistor R6 is included to limit the Zener current should the circuit be powered when the capacitor is discharged (very likely) and also to limit the discharge current which could destroy the triac when it switches on (also very likely).

The rest of the circuit is quite conventional and is based on a quad CMOS Schmitt trigger NAND gate, although the gates are used as logic inverters by having both inputs connected together. This type of gate has the advantage of switching cleanly once the input threshold voltage has been exceeded.

The input sensor is formed by placing a conducting foil *behind* the insulating front

capacitor C2 to charge via resistor R3, which introduces the switch-on delay required to improve the noise immunity of the circuit. Should the output of IC1a go high again because TR1 turned on for only a short period due to noise, C2 would be quickly discharged via diode D1 so that the input of IC1b would not have time to go low.

Assuming a moderately long input period during which the output of IC1a remains low, however, IC1b's input will also become low, causing its output to go high, so quickly charging capacitor C3 via diode D2. This, of course, causes the output of IC1c to go low and allow gate current to flow to the triac via *pnp* transistor TR2 and resistor R5. In turn, this causes the triac to be triggered and so switch on the lamp.

Note that the circuit uses negative triggering (i.e. a current flows *out of* the triac gate rather than into it) because triacs are generally more sensitive in this mode and require less gate current to ensure triggering.

When the hand is removed from the touch plate, diode D2 will become reverse biased and capacitor C3 will only be able to discharge via resistor R4 and preset VR2. These two components, together with C3, therefore determine the length of

Capacitors

C1, C2	100n ceramic, 5mm pitch (2 off)
C3, C4	100µ radial elect, 16V (2 off)
C5	100n class X2, 250V a.c. (see text)

Semiconductors

D1 to D3	1N4148 signal diode (3 off)
D4	4V7 BZX85, or 1N5337 Zener diode (see text)
CSR1	TIC206D 400V 4A triac
TR1	2N3904 *npn* transistor
TR2	BC558 *pnp* transistor
IC1	4093 quad Schmitt trigger NAND gate

Miscellaneous

LP1	neon, wire-ended

Printed circuit board, available from the *EPE PCB Service*, code 331; 2-way p.c.b.-mounting terminal block; plastic electrical blanking plate; aluminium foil; insulating materials; connecting wire; solder, etc.

Approx. Cost Guidance Only* £9 *excluding elec. plate

Note also that the time can easily be extended by touching the plate during the on period. This will recharge C3 so that if you stop on the stairs for a chat, you need not be plunged into darkness half way through the conversation!

In any event, even if this should happen, with the triac turned off 230V a.c. will appear across it and the small neon lamp LP1 will light. This is arranged to shine through a hole in the printed circuit board, illuminating the touch area so that it should be an easy matter to find the switch in the dark. Resistor R7 limits the current through the neon, which generally strikes at about 90V.

CONSTRUCTION

As this circuit is always live at mains voltage, its construction should only be undertaken by those who are suitably experienced or qualified.

The circuit *should not be constructed on stripboard*, and ***it must not be earthed***, either intentionally or accidentally as this will cause the instant destruction of many of the components.

The recommended printed circuit board (p.c.b.) component and tracking layouts are shown in Fig.2, together with the triac and transistor pinouts in Fig.3. This board is available from the *EPE PCB Service,* code 331.

Care should be taken to ensure that the correct orientation of all polarity-conscious components is observed. The use of a socket is recommended for IC1, which is a CMOS device, and you should discharge static electricity from your body before handling it.

The neon should be mounted slightly above the p.c.b. to enable it to be bent to lie directly above the central hole. Insulating sleeving should be fitted over the leads to prevent them touching other components.

The triac should be a 400V a.c. sensitive-gate device and the type specified has a maximum gate current requirement of 5mA. Any substitute should have a similar specification.

Zener diode D4 will dissipate about 1W with a 100W lamp so a 1·3W type, such as the BZX85 series, should suffice. For higher lamp powers a 5W device such as the 1N5337B should be used.

The choice of capacitor for C5 is **very important** as this device *must* be rated for connection across the mains. On the face of it, a 400V rating would appear suitable but this is not usually the case as this is often a d.c. rating and many such capacitors have only a 200V a.c. specification. It is *essential* that a Class X2 type should be used as these are guaranteed for operation up to 275V a.c.

TESTING

Before testing, ensure that there are no solder splashes or short circuits on the board and the soldering is of a good standard.

As the circuit operates at mains potential, do not touch any part of the p.c.b. when it is powered and ensure that the mains supply is off when fitting or adjusting it. Under no circumstances should any part of it be connected to earth.

Having said that, the circuit is safe to use once it is mounted in its wall box. There is, however, the problem of testing it safely

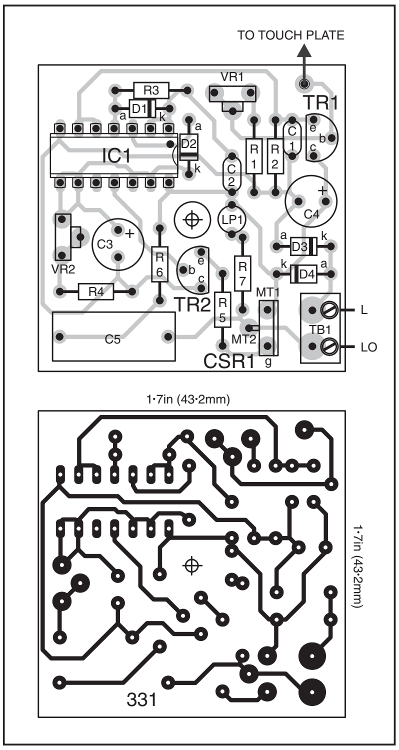


Fig.2. Printed circuit board component layout and full-size copper foil master. Note, a small "window" is cut in the centre of the p.c.b. for the neon light to shine through.

and to do this it is best to use a temporary d.c. supply and not fit the triac at this stage. For this testing an l.e.d. should be connected between the two holes adjacent to the terminal block where the triac will be mounted, with the l.e.d. cathode (*k*, usually denoted by a shorter lead) nearest the edge of the board.

Solder a temporary lead to the junction of components C5 and R6 and connect this to the positive terminal of a 9V d.c. power supply or battery. Secure another lead to the L terminal and connect this to the negative terminal of the power supply. The circuit can now be tested at low voltage and should work as described.

It will probably not be possible to switch the circuit on by touching the plastic front panel but it should switch when the transistor base is touched directly. If not, a 1MΩ resistor connected from the supply positive to the transistor base should cause the l.e.d. to light.

The operation of the circuit can easily be followed by monitoring the outputs of the gates with a multimeter or oscilloscope and the status of the triac will be displayed by the l.e.d. In this

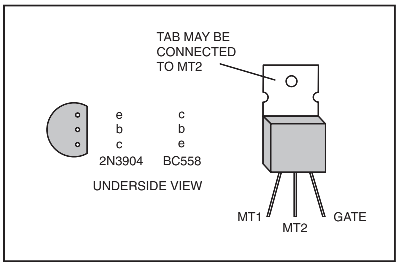


Fig.3. Pinout connection details for the transistors and triac.

way the time delay, and to a certain extent the sensitivity, can be set up by adjusting presets VR2 and VR1, respectively.

If all is well the wires should be removed and the l.e.d. replaced by the triac. This will probably need to be mounted as shown in Fig.4. to ensure that its height does not exceed 1·5cm from the board. This is important if the unit is to be mounted in a plaster-depth wall-box but is not so vital if a deeper box is available.

The triac leads will need to be bent to suit and this should be carried out carefully by holding each lead in a pair of pliers at the point where the bend is required. Do not bend the leads too close to the body of the device or bend them repeatedly as they may break.

To stop the device from moving and placing a further strain on the leads, it may be a good idea to glue the triac tab to capacitor C5 with epoxy adhesive. Many triacs (including the device specified) have the heatsink tab internally connected to the centre pin and in these cases, **this must be insulated by means of insulating tape or suitable plastic sheet as shown to ensure that it cannot touch the wall box**.

TOUCH PLATE

The touch plate assembly is made by using a piece of aluminium kitchen foil about 4cm square stuck behind the centre of an electrical blanking plate, as shown in Fig.5.

Most blanking plates have a central area made of thinner plastic than the surrounding plate. This forms an ideal area for the

Completed circuit board. Note the neon has been bent over to lie directly over the centre hole in the p.c.b.

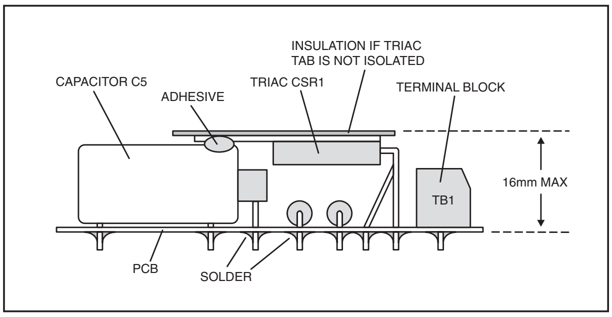


Fig.4. Suggested method of mounting the triac on the circuit board.

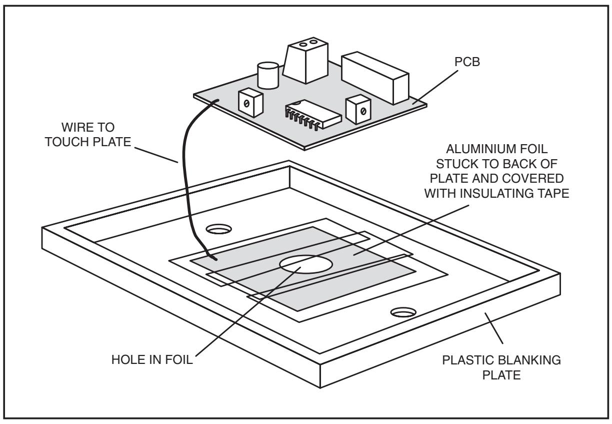
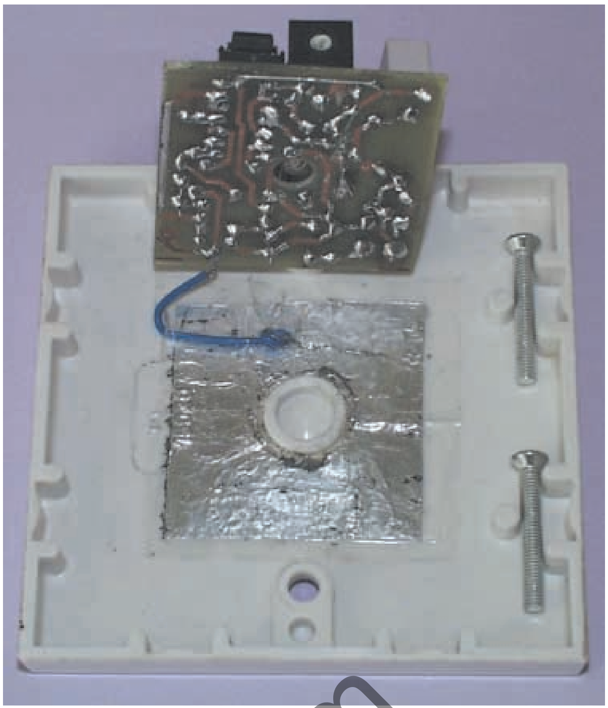


Fig.5. Suggested touch switch assembly.



The circuit board held clear of the electrical blanking plate to reveal the foil sensor. A centre hole is cut in the foil to allow light from the neon to be seen through the plate. The foil must be covered with several layers of insulating tape.

neon light to shine through. (***Do not make a hole in the blanking plate***.) The aluminium foil should be removed from this area as shown in Fig.5. The surface of the foil should then be covered with strips of insulating tape.

A short piece of wire with about 1cm of insulation removed should be trapped beneath the insulation to enable the foil to be connected to the transistor on the circuit board. A small knot tied in the wire under the insulating tape may help to prevent the wire from being pulled out during final assembly.

After soldering the other end of the wire to the base of transistor TR1, the p.c.b. should be mounted on the back of the touch plate. Double-sided self-adhesive pads are ideal for this but as these grip immediately on contact, care should be taken to ensure that the board is fitted to the centre of the plate. The position of the neon should be adjusted so that it shines directly over the central hole in the foil.

INSTALLATION

Once this has been completed, the unit can be mounted in the wall box. *The mains must be switched off before the existing switch is removed, and when making any adjustments*. The two cables inside the wall box should be connected to the terminal block on the unit. Because of the way the circuit operates, it is important that the Live wire is connected to the L terminal on the p.c.b. as shown in Fig.2.

This wire is normally coloured red but it may not be, depending on the installation. If you are not sure which of the two wires is the Live one, connect them either way around. If you have chosen the wrong one no damage will result but the circuit will not switch on and the

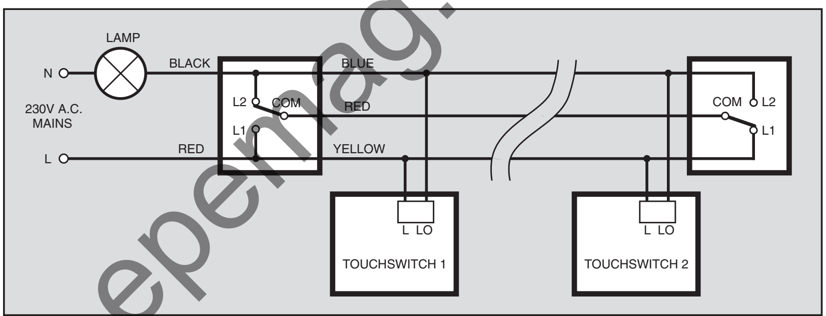


Fig.6. Two-way switching circuit. It is most important that the mains Live is connected to the correct touch switch terminal.

procedure will need to be repeated with the wires reversed.

Note that modern installations will also have an earth wire which is not connected to the switch terminals but is usually connected to a terminal on the wall box. This should be left in place and not disturbed.

Before fixing the switch, *make sure that none of the components on the board can touch any part of the box* and if there is any danger of this (especially if a shallow plaster depth box is involved) a piece of plastic sheet or a scrap piece of p.c.b. material should be fitted to the back of the box to prevent the components shorting to the (earthed) box.

Once this is done, the switch can be secured to the wall box and the mains switched on. Make sure that the light can be switched on when the plate is touched and ensure that it goes out at the end of the previously set time.

If the circuit cannot be switched on, increase the sensitivity of the circuit by turning VR1 clockwise (*switch off the mains before doing this*). If it is still impossible to switch the circuit on, turn the preset fully anticlockwise and reverse the wires to the terminal block before repeating the procedure.

Do not increase the sensitivity beyond the point at which it switches on easily as this can make it more susceptible to random switching, or even prevent the unit from switching off at the end of the preset period. The latter can be increased by turning VR2 clockwise.

Should you wish to use the unit with a two-way switching circuit, to enable the lights to be switched on and off from two locations, this can be done quite easily with no re-wiring being involved. Fig.6 shows a typical two-way switching arrangement and the new switches may be used to replace the existing switches as shown.

The wire colours stated in Fig.6 are those normally used although they may be different depending on the installer. In any event, one of the existing wires will not be required and the touch switches should be wired in parallel as shown. It is important to ensure that the mains Live is connected to the correct terminal on each switch. □