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PIR LIGHT CHECKER
by TERRY DE VAUX-BALBIRNIE

Be trigger happy with your outdoor security light system

Passive infrared (PIR) lamps, of the type that may be bought in any DIY store, are now very popular with householders. Mounted on an outside wall, they may be used to improve security or simply to illuminate dark areas when a member of the family passes by.

JUST PASSING THROUGH

These lamps are designed to switch on for a certain time when someone walks in the detection field. This extends fan-shaped from a "window" in the front of the detector. In simple units, the operating time is fixed at manufacture. However, it is more usual to provide a control, which may be used to adjust it over a certain range.

Normally, the lamps operate only when the ambient light falls below a certain level so that they will not switch on during daylight hours. Again, the point at which this happens is often adjustable using a control on the unit.

The working part of a PIR lamp is a sensor, which detects the infrared radiation that is naturally emitted by a warm body. The detector may be contained in a separate unit connected remotely to the lamp. In most DIY units, however, it is attached to the lamp itself because this makes for simpler installation.

When a warm object moves in the sensitive zone, a signal is given which, after processing, operates a relay and switches

on a filament bulb. In the larger security-type lamp, the bulb will be a halogen unit of some 150W to 500W rating. Smaller PIR lamps use an ordinary 60W household bulb.

BLOWING IN THE WIND

When the PIR unit is properly installed, the lamp does its job well and rarely causes problems. However, when it is not properly set up it may be activated by animals such as dogs and cats passing by.

Any warm object moving in (and especially across) the detection field is likely to cause the unit to trigger – even warm air from a nearby central heating flue. Tree branches and other objects moving in the wind sometimes activate it – presumably because they reflect infrared from somewhere else.

Any cause of false triggering may be difficult to track down. It can occur even when the user has taken every precaution detailed in the installation guide. After supposedly "correct" setting-up, there is often a tendency towards occasional false triggering. This will require further adjustment on a "trial and error" basis to eliminate it completely.

Most PIR lamps have a "test" facility, which enables them to operate in daylight and this helps with the initial adjustment process. However, it will miss any false triggering

which happens only occasionally. There could be considerable difficulty when the lamp is mounted in a position that cannot be seen from the house.

Normally, the only way to check for correct operation would be to stand outside and watch it for a long period of time! Unnecessary operation of the lamp can be a nuisance to neighbors as well as wasting electricity and reducing the life of the bulb. With this *PIR Light Checker*, however, you can leave the monitoring to automatic electronics!

CLOCKED

This self-contained battery-operated unit will automatically monitor a PIR lamp over a period of several hours overnight. A LED (light-emitting diode) display registers the number of times it has been triggered, up to nine. If the count exceeds this, the display will return to zero but the decimal point will light up. This shows the "overflow" – that is, a number greater than nine. When the unit is switched off then on again, the count is reset to zero, ready for a further test.

By adjusting the aim and sensitivity control on the lamp (if one exists), re-siting and cutting away foliage as necessary, any improvement can be easily monitored. Multiple causes of false triggering may then be eliminated one by one over a period of a few days. Note that if the unit is used to monitor the lamp overnight, it will record an extra count at dawn and this will need to be subtracted from the total.

This circuit is only suitable for use at
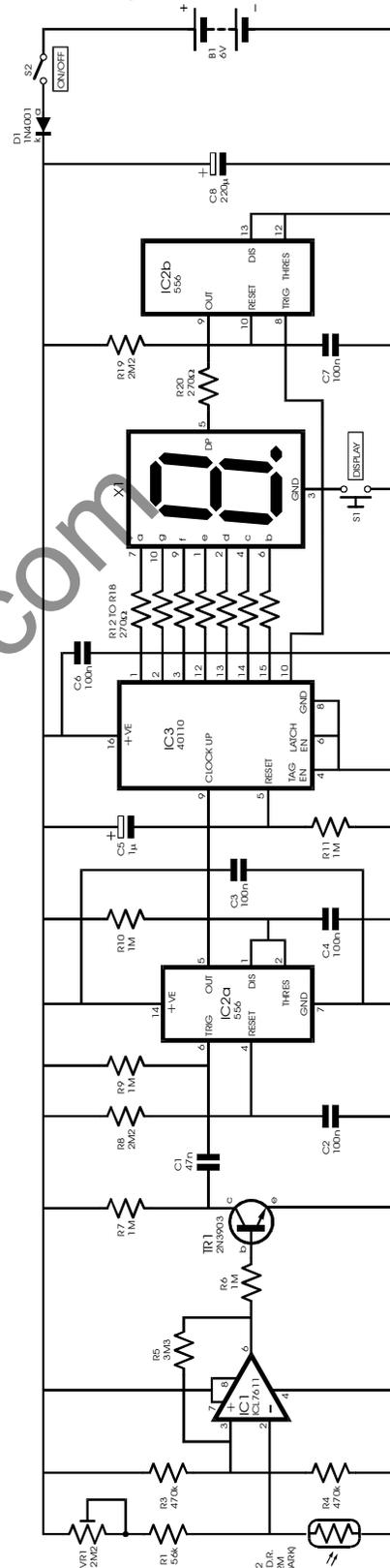
Fig.1. Complete circuit diagram for the PIR Light

COMPONENTS

Resistors

R1	56k
R2	sub-miniature light-dependent resistor (LDR), dark resistance 5M ohms approximately (see text)
R3, R4	470k (2 off)
R5	3M3
R6, R7, R9 to R11	1M (5 off)
R8, R19	2M2 (2 off)
R12 to R18, R20	270 ohms (8 off)

All 0.25W 5% carbon film

Potentiometer

VR1	2M2 miniature enclosed carbon preset, horizontal

Capacitors

C1	47n metallised polyester, 2.5mm pitch
C2	100n metalised polyester, 2.5mm pitch
C3, C4, C6, C7	100n metalised polyester, 5mm pitch (4 off)
C5	1u radial electrolytic, 63V
C8	220u radial electrolytic, 10V

Semiconductors

D1	1N4001 1A 50V rectifier diode
TR1	2N3903 *npn* transistor
IC1	ICL7611 micropower opamp
IC2	ICM75561PD dual CMOS timer
IC3	40110B decade up/down counter

Miscellaneous

X1	7-segment, common cathode LED display, 12.7mm
S1	miniature s.p.s.t. push-to-make or biased toggle switch
S2	miniature s.p.s.t. toggle switch

PCB available from the *EPE Online Store*, code 7000263 (**www.epemag.com**); 8-pin DIL socket; 14-pin DIL socket; 16-pin DIL socket; 1.5V AA-size alkaline cell (4 off) and holder; plastic case, size 138mm x 76mm x 38mm internal; PCB supports (2 off); connecting wire; solder, etc.

See also the SHOP TALK Page!

Approx. Cost Guidance Only (excl. battery pack) **$32**

night with the PIR lamp in "normal" mode. There must be no other bright sources of light nearby which could result in false counts.

BATTERY SAVING

The circuit is housed in a small plastic box. This has a seven-segment LED display showing through a hole in the lid. There are also two switches (see photograph). One of these is simply an on-off switch while the other activates the display. This latter switch is operated only when a reading needs to be taken and so saves battery power. A hole in the side of the box allows light from the lamp being monitored to reach a sensor on the printed circuit board (PCB) inside.

The unit draws power from a 6V battery pack consisting of four AA-size alkaline cells. Under standby conditions, the current requirement of the prototype unit is some 400uA.

When the display is operated, the current rises to a value that depends on the number being displayed. This is because each digit is formed by lighting up the appropriate segments in the display. The most current-hungry case is when the number "8" is involved (since this uses all seven segments) together with the "over-flow" decimal point.

Since each segment and the decimal point require 12mA approximately, the total current will be about 100mA. However, this will only be needed for a few seconds during each test and, as stated earlier, it is the "worst" case. In practice, the battery pack should last for at least a year under normal conditions.

HOW IT WORKS

The full circuit diagram for the *PIR Light Checker* is shown in Fig.1. Power is derived from a 6V battery pack (4 x 1·5V cell) B1 via on-off switch S2 and diode D1. The diode prevents possible damage if the supply were to be connected in the opposite sense. If this were done, the diode would be reverse-biased so no current would flow.

It will be found that the actual nominal supply voltage is 5·3V taking into account the forward voltage drop of the diode (0·7V approximately). Capacitor C8 charges up almost instantly and helps to provide a smooth and stable supply.

The light-sensing section of the circuit is centered on IC1 and associated components. The light detector itself is a light-dependent resistor (LDR), R2. The resistance of this device rises as the illumination of its sensitive surface falls.

The LDR works in conjunction with fixed resistor R1 and preset potentiometer VR1 to form a potential divider connected across the supply. Thus, as the resistance of the LDR increases, the voltage across it will rise. This voltage will therefore be greater when the LDR is dark than when it is illuminated. The actual "dark" and "light" voltages can be varied within certain limits by adjusting VR1. The voltage appearing across the LDR is applied to the inverting input (pin 2) of operational amplifier (opamp) IC1. The non-inverting input (pin 3) is connected to the mid-point of a further potential divider consisting of fixed resistors R3 and R4. Since these have the same value, the voltage here will be equal to one-half that of the supply – that is, 2·6V approximately.

A BIT DIM

With preset VR1 suitably adjusted, under dim conditions the voltage at the opamp inverting input will exceed that at the non-inverting one, so the device will be off with the output (pin 6) low. When the LDR is sufficiently illuminated, the conditions will reverse with the inverting input voltage falling below the non-inverting one. The opamp will then switch on and output pin 6 will go high. Resistor R5 applies some positive feedback to the system, which sharpens the switching action at the critical light level.

Transistor TR1 inverts the output state of the opamp. When the output is high, current flows into TR1 base (b) through current-limiting resistor R6. This switches the transistor on and its collector (c) goes low. When the opamp output is low, no current will enter the base and the transistor will remain off. The collector will then take on a high logic state via load resistor R7. The state of the collector is therefore in the opposite sense to that of the opamp output.

MONOSTABLE

Transistor TR1's collector is connected to the trigger input (pin 6) of a monostable based on IC2a, which is one half of dual integrated circuit timer, IC2.

When TR1 collector goes from high to low (that is, the LDR is illuminated), the trigger input receives a low pulse through capacitor C1. The monostable output (pin 5) then goes high for a time dependent on the values of resistor R10 and capacitor C4. With the values specified, the timed period is 0·1s, approximately.

While the opamp output
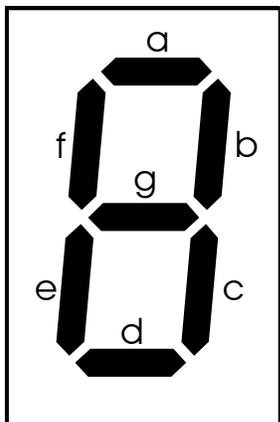
Fig.2. The seven segments of the display are identified by letters (a to g)

remains low (the LDR dimly illuminated), the high state of TR1's collector has no effect. In fact, in the absence of a low pulse, IC2a trigger input is kept high through resistor R9 and this prevents possible false triggering. Capacitor C3 decouples this section of the circuit.

At the instant of powering-up, capacitor C2 keeps IC2a reset input (pin 4) low and this disables the monostable. The capacitor soon charges up through resistor R8, pin 4 goes high and the monostable then functions normally. The purpose of this is to allow time for the power supply to settle down to a steady state since, otherwise, the monostable could self-trigger and a false count would be registered.

COUNTING PULSES

When the monostable outputs a pulse, this is transferred to the "clock up" input (pin 9) of counter and 7-segment driver IC3. This registers the number of pulses received and decodes the result into a form which will directly drive the 7-segment LED display X1.

The seven segments of the LED display are identified by letters **a** to **g** as shown in Fig.2. Note that the unit used in this circuit is a common cathode type. In this, all the LED cathodes (including that of the decimal point) are connected together and taken to pin 3 (GND).

Each segment requires a current-limiting resistor (R12 to R18) as with a conventional LED. With the value specified, each one will draw 12mA approximately when using a new battery.

The display, however, will do nothing until push-to-make "Display" switch S1 is operated. This allows current to flow through any active segments and complete the circuit via pin 3 to the 0V line. With S1 in the off state, no current is drawn by the display.

At the instant of switching on, IC3's reset input (pin 5) is maintained in a high state while capacitor C5 charges up through R11. During this time, the counter is reset so the display will always begin at zero. After a short time, C5 will charge sufficiently, pin 5 will go low and the counter will function normally. Capacitor C6 decouples this section of the circuit.

When the count passes from 9 to 0, IC3's carry output, pin 10, goes low momentarily. This would normally be used to feed the clock input of a second counter/driver IC and a further display would provide a readout up to 99.
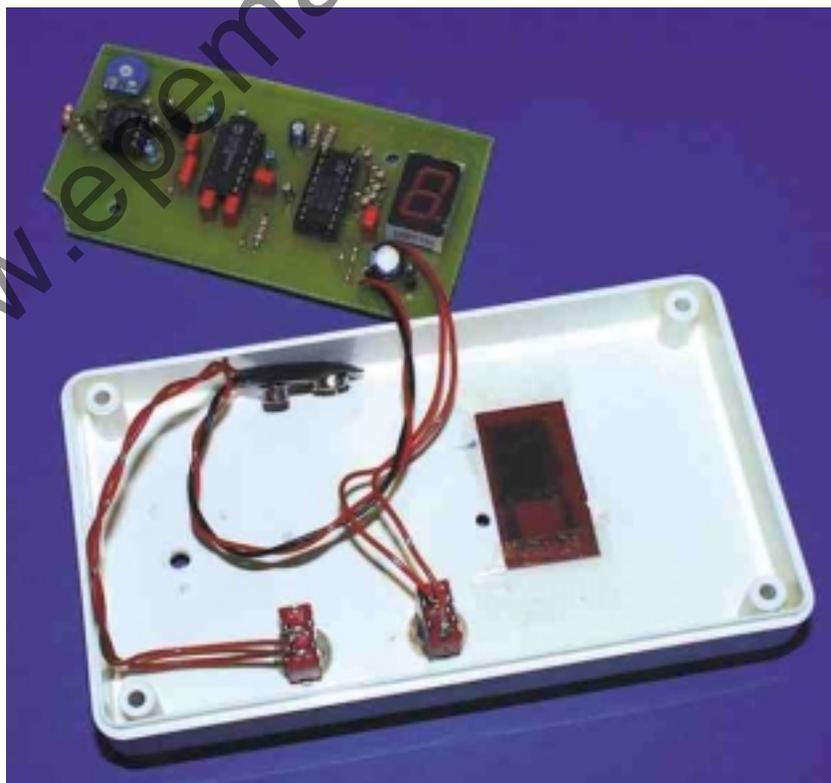
The PCB removed from the case lid to show wiring to the display and on/off toggle switches. The display switch needs to be a "biased" off type. Note the 7-segment display chip must be the highest component on the PCB.

Close-up of circuit board showing the leads of the LDR carefully bent at right-angles to the PCB to align with "light window" in side of case.

To save costs only one counter and display are used in this circuit. However, the low pulse provides the "overflow" indication by operating the decimal point. This uses IC2b (the second section of dual timer IC2). It is configured as a form of latch by making the threshold and discharge inputs (pin 12 and pin 13) low. Thus, once triggered by making pin 8 low for an instant, the output (pin 9) will go high and remain high until the supply is interrupted. The output feeds the decimal point via current-limiting resistor R20.

CONSTRUCTION

The *PIR Light Checker* circuit is built on a single-sided printed circuit board (PCB). The topside component layout and (approximately) full-size underside copper foil master pattern are shown in Fig.3. This board is available from the *EPE Online Store* (code 7000263) **www.epemag.com**

In the prototype, one corner of the PCB had to be cut off to avoid a bush in the box, see photograph. Begin construction by drilling the two fixing holes and soldering the three IC sockets and four link wires into place.

Fig.3. Printed circuit board component layout, (approximately) full-size underside copper foil master pattern, and wiring to the two off-board switches.

Omit display X1 for the moment. Note that it must end up as the highest component on the PCB. Checks should be made at intervals during the other assembly by inserting it into its holes in the PCB (but do not solder it yet).

Follow with all resistors (including preset VR1 but not LDR R2). Note that many of the resistors are mounted vertically (see photo).

Solder electrolytic capacitors C5 and C8 in position taking care over their polarity. If they are not of the sub-miniature type, it may be necessary to

mount them flat on the PCB so that they will not be higher than the display.

Cut the LDR leads to a length of about 10mm and solder them to the R2 position on the PCB. Bend them through right-angles so that the "window" points to the left. Note that the specified LDR is a sub-miniature type having a body diameter of 5mm approximately. If one of these is not readily available, it would be possible to use a standard ORP12 device, but some adjustment may be needed to the end leads to prevent the body getting in the
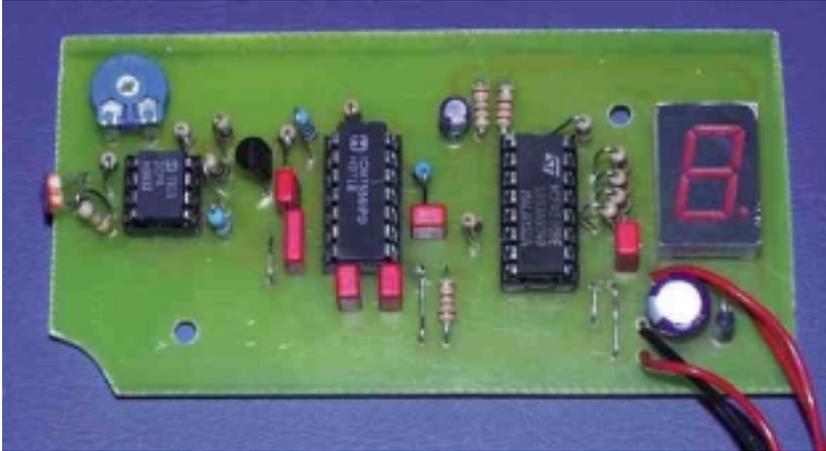
Layout of components on the completed circuit board. Note, one corner of the board has been trimmed off so it will fit in the case.

way of anything else.

Add the diode and transistor to the PCB, taking care over their orientation. The flat face of transistor TR1 should face to the right as viewed in Fig.3.

Solder the display to the PCB (with the decimal point at bottom right, as shown in the photo) using minimum heat from the soldering iron to prevent possible damage.

Solder 10cm pieces of light-duty stranded connecting wire to the points labeled +6V and S1. Solder the negative (black) battery connector lead to the 0V point. Adjust VR1 to approximately mid-track position.

TESTING

Immediately before handling the pins of IC1, IC2 and IC3, touch something which is "earthed" (such as a metal water tap). This will remove any static charge, which may be present on the body. Insert the ICs in their sockets with the correct orientation.

Before mounting the PCB in its case, perform a basic check so that any minor problems may

be resolved more easily.

To do this, bare the end few millimeters of the wires for display switch S1 and connect them together. Similarly, bare the end of the +6V wire. Insert the cells for battery B1 into their holder and apply the connector. Twist the battery connector positive (red) wire to the +6V wire from the PCB.

The display should light up and read zero. The decimal

point should also be off. If it shows some other number, or the decimal point is on, the connection was probably not done "cleanly", so disconnect the battery, wait for 30 seconds and try again!

Cover the LDR with the hand then remove it to allow light to reach its window. The display should advance to a count of 1. If this does not work, it is likely that the LDR has not been properly covered. Try working in a dark cupboard and open the door slightly to give the flash of light. If this still does not work, re-adjust preset VR1 and try again.

By allowing repeated flashes of light to reach the LDR, the counter should increment to 9 and the next flash should return it to zero. However, the decimal point should now be seen to be lit up. If you wish to reset the display, you will need to wait for up to thirty seconds between disconnecting the battery and re-connecting it again.

Completed PIR Light Checker front panel layout. The display cutout has been backed with a piece of translucent filter material.

ENCLOSURE

If all is well, the PCB may now be mounted in the box. Note that when using the specified unit, everything may be attached to the lid section. This method places least strain on the battery connecting wires.

First, disconnect the positive supply wire and detach the battery connector. Decide on positions for the PCB, battery pack and switches, checking that there is sufficient space for everything to fit. Arrange for the LDR to lie between 5mm and 10mm from the side of the box.

In the prototype, a miniature toggle switch with "make" contacts was used for the on-off switch and a matching biased toggle switch was used for the display. A biased switch is one that springs back to the off position when pressure is removed from the actuating lever. It is best to use either a biased toggle switch or a push-to-make switch to activate the display so that it cannot be left on accidentally.

Mark through the PCB fixing holes. Measure the position of the display and mark around its outline. Mark also the position directly in line with the LDR

window and VR1 on the top. Mark the position of the switches. Remove the PCB and drill all these holes.

The hole for the LDR should have a diameter of approximately 4mm (about twice as large if the ORP12 type LDR is used). The hole above the preset VR1 position should be large enough to allow it to be adjusted using a thin screwdriver or trimming tool.

The easiest way to make the hole for the display is to drill small holes within its outline then remove the plastic using a small hacksaw blade, or sharp chisel. Finally, smooth the edges up to the line using a small file.

Attach the PCB temporarily using nylon fixings and with short plastic stand-off insulators on the bolt shanks. Adjust the length of the stand-off insulators so that the display will end up 1mm approximately below the inside face of the box. When satisfied, re-attach the PCB.

Check that the LDR window lies directly in line with the hole drilled for it. If not, adjust the position of its end leads so that it is. Attach the switches. Secure the battery pack using a small bracket or adhesive pads. Refer to Fig.3 and complete the

internal wiring.

In the prototype, a piece of red plastic filter was glued over the display hole on the inside of the box. This gives a professional appearance and also improves the contrast of the display. If a piece of real filter is not available, perhaps suitable material could be obtained from a sweet wrapper or something similar.

INTO SERVICE

With switch S2 off, connect the battery and attach the lid. Find a suitable place for the unit so that light from the PIR lamp will reach the LDR directly through the hole in the side of the box. The fact that the LDR is some distance behind the hole makes the response directional. This is useful because it tends to discriminate against other sources of light, which could result in false counting.

Make some tests at night. For initial trials, you may find it helpful to use an elastic band or PVC tape to hold the display switch (S1) on, so that the count may be observed over a period of time. Remember that this wastes the batteries so don't do it for too long.

Adjust preset VR1 for best effect. Remember to protect the unit against rain entering if this is a possibility.

No more disturbed neighbors with this "Trigger Happy" circuit!