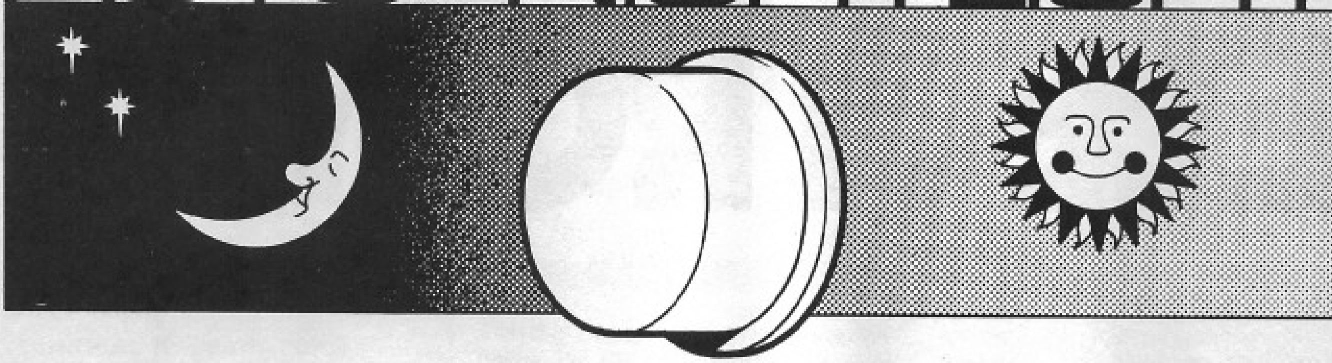
AUTO NIGHTLIGHT



By A. R. Winstanley

THIS device was designed to switch on a low-powered nightlight in a child's room. It is completely automatic so that it will switch on the lamp when darkness has reached a preset level. Although the system is quite simple, it performs very well, providing as it does a comforting glow.

The circuit employs a well-known i.c. in a popular and important configuration.

COMPARATOR

The circuit, it will be seen, consists of five "blocks", the most important one of which is the "comparator." This is the electronic brain of the system, for, having been given certain electronic information, it decides whether the nightlight should be alight or switched off. The comparator is fed by two reference voltages. One of these, V_{ref}, is fixed at half of the supply rail voltage; the other reference V_{sense} is determined by the ambient light level falling onto an electronic "eye"—in other words it is light-dependent.

The output of the comparator drives a solid-state transistor switch (for high reliability and noiseless operation) which applies power to the actual lamp.

If the reference voltage (V_{ref}) is greater than the sense voltage (V_{sense}) then the nightlight is off; similarly if the sense voltage is greater than the reference voltage then the nightlight switches on.

SAFETY FIRST

The following points are detailed separately for emphasis.

1. *It is most advisable that a metal case is used for the main unit because of R1 which gets warm during normal operation. There is a very remote chance that if a plastics case were used, it could soften or even melt if the resistor were placed close to the case. With the metal case specified in the text, the heat dissipated by R1 is totally unnoticeable and it is quite safe.*
2. *Concerning the use of an aerosol top for a lamp diffuser, it would be most unwise to use either: a smaller aerosol top than that detailed in Fig. 5 (a) or a lamp of a wattage in excess of 2·2W. Whilst the prototype lamp unit gets barely warm in use, and is therefore safe, it is possible that the polythene could soften if a smaller diffuser and/or higher power bulb was employed.*

If the text is followed carefully then no problems at all should be experienced.

CIRCUIT DESCRIPTION

The circuit diagram of the Electronic Nightlight appears in Fig. 1. It has been divided into sections to correspond with the block diagram.

The circuit is centred around IC1, an μA741C operational amplifier integrated circuit (normally abbreviated just to "741"). This device is used in its comparator mode, for it compares two signals.

The 741 has two inputs, these being designated the inverting input (negative symbol) and non-inverting input (positive symbol). The entire principle of operation of the nightlight is this: if the voltage at the inverting input exceeds that at the non-inverting input, then the output of the IC2 is low —near zero volts. However, if the potential at the non-inverting input happens to be greater than that at

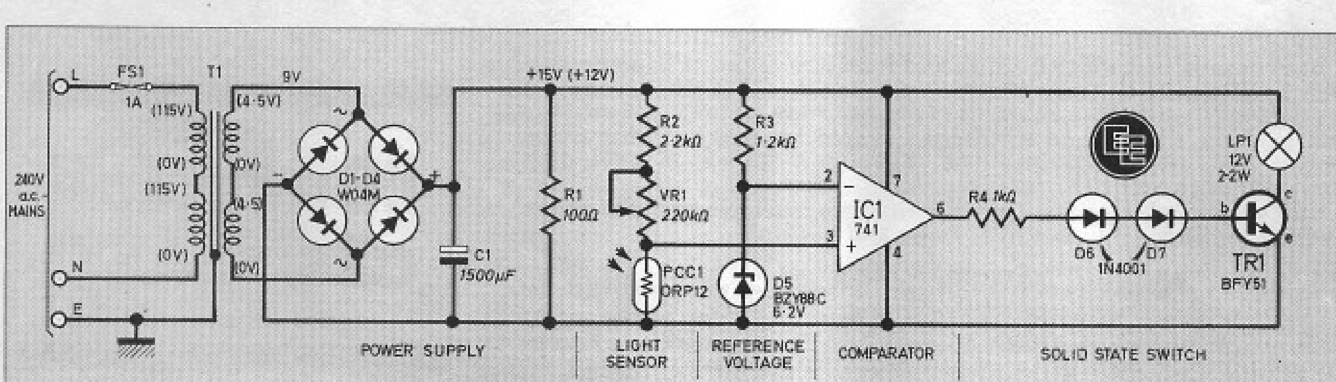


Fig. 1. Circuit of the Auto Nightlight.

the inverting input, then the output swings high, almost to the voltage of the supply rail.

If the voltages at the two inputs should be the same, then the output remains low. But it only takes a difference of a few millivolts to exist between the two inputs and the high gain of the i.c. will amplify this so much that the output will swing to either high or low (depending of course on its previous state) in a very short time.

The inverting input in this design is permanently clamped to a potential of 6·2V (±5 per cent) by means of a Zener diode D5 and its associate current-limiting resistor R3. The current flowing through the Zener is 5mA and so it dissipates 30mW.

The voltage at the other input, however, depends on the level of light being received by PCC1, an ORP12 light-dependent resistor—the "electric eye" of the system.

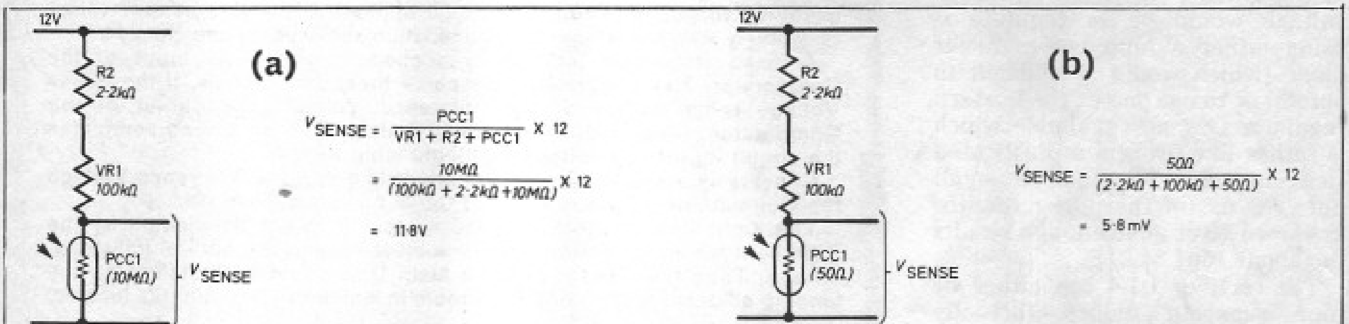


Fig. 2. How the sense voltage is derived. (a) no light falling on PCC1. (b) large amount of light on PCC1.

POTENTIAL DIVIDER

R2, VR1 and PCC1 form a potential divider, they split up the supply rail into a series of lesser voltages. It can, to make things easier, be assumed that VR1 is set to halfway, and can therefore be replaced by a fixed resistor of about 100 kilohms.

Fig. 2 shows how the sense voltage (i.e. the voltage at the non-inverting input) varies by potential divider action as the light level changes.

In Fig. 2a there is no light falling on the l.d.r. and so its resistance is in the order of 10 megohms. Therefore, because the supply rail is at 12V, the output of the potential divider is about 11V, as the calculation in the diagram shows.

Similarly, in Fig. 2b a large amount of light is falling on the l.d.r. and so its resistance is about 50 ohms, giving an output of about 6mV.

Hence when it is light, the voltage at the inverting input is 6·2V but the non-inverting input is at less than 10mV—therefore the output of IC1 is low and the lamp is off (but see later).

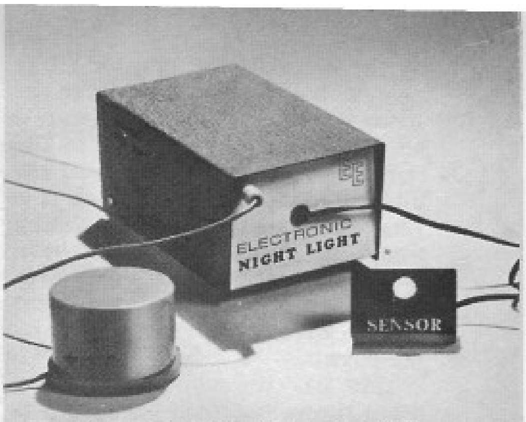
When the ambient light level falls, the resistance of the l.d.r. increases so that the potential at the non-inverting input eventually equals and then exceeds the 6·2V reference voltage at the inverting input, so that the output of IC1 swings high.

Because the resistance of the l.d.r. changes very slowly in this application, the output of IC1 does not rapidly switch from low to high, in practise it takes from about 30 seconds to one minute for the lamp to reach full brightness.

TRANSISTOR SWITCH

The output of IC1 drives a simple medium power transistor switch (TR1) which allows current to flow through LP1, which is the lamp forming the nightlight. The lamp is rated at 12V 0·18A, and so has a low power of about 2·2W. This may seem to be insufficient but proves to be, if anything, a little too bright for some rooms.

The transistor switch design is very flexible, and so the lamp may be replaced by a 12V 0·1A type without modification. If on the other hand the lamp is not bright enough, then a second 12V 0·18A lamp may be added directly in parallel with LP1, again without modification. (No harm will result from drawing too much current from the i.c. because the output of IC1 is short-circuit proof, and current-limits at about 20mA.



The completed Auto Nightlight showing the control unit, sensor and light housing.

Unfortunately, when the output is described as "low" it is not quite at zero volts—in fact it still has a potential of over one volt. This would be enough to switch on the transistor, as only 0·65V is required to turn the transistor hard on, illuminating the lamp. Indeed, in practise the lamp would remain on all the time!

To overcome this problem, two silicon diodes D6 and D7 have been included in the circuit. When they are carrying current, the diodes each drop 0·6V across themselves; so that together they will drop about 1·2 volts, and so removing any drive to the transistor when IC1 output is "low".

POWER SUPPLY

The circuit operates from a 12V d.c. rail, and draws a maximum of 200 mA. Therefore battery operation is really out of the question, and so the rail is derived from a mains power supply.

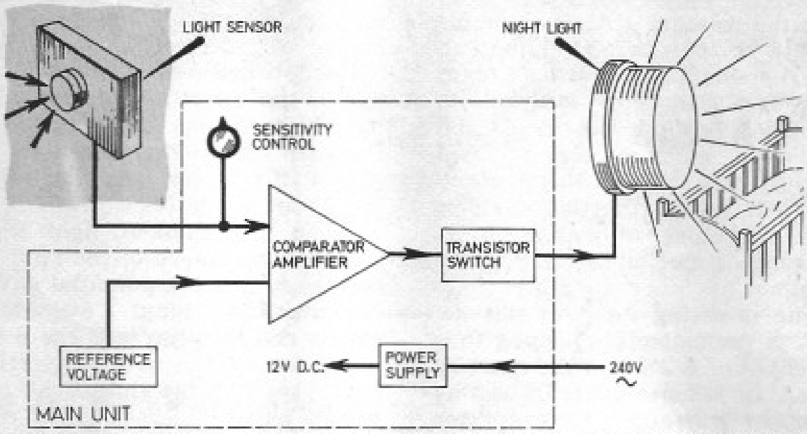
Mains voltage is "stepped down" by T1, the secondary of which is wired to give 9V a.c. at 670mA. This alternating voltage is rectified by D1-D4 to give a d.c. voltage which contains a very high a.c. ripple content. This is smoothed out by the electrolytic capacitor C1 to give an unregulated voltage of some 16-17V d.c. when the lamp is off. This comes quite close to the maximum operating voltage of the integrated circuit, and though it is very unlikely that this rating would be exceeded, R1 has been placed directly across the power supply to increase the quiescent (or "tickover") current drawn by the circuit.

This has the effect of pulling down the voltage rail because it is unregulated, and in fact it is reduced to 15V when the lamp is off and comes down even further to 12V when the lamp is illuminated. R1 dissipates $(15^2/100)=2{\cdot}25$W; therefore a power resistor is called for here, and not the usual half-watt device.

As a matter of interest, the only other satisfactory method of providing a more stable power supply voltage would be to regulate it using either a high power Zener diode (which would be difficult to obtain) or to use one of the modern regulator i.c.s. now available, which is rather like using a sophisticated sledgehammer to crack a small nut. The use of the power resistor as shown gives good enough results for about 15p!

The rectifier D1-4 can either be four separate diodes (actually rectifiers), or a device called a "bridge rectifier" in which four rectifiers are encapsulated into one small package. The latter is more convenient to use, but is twice as expensive as four separate rectifiers.

HOW IT WORKS



The Light Sensor is a light-dependent resistor (l.d.r.). Together with the Sensitivity Control VR1 it forms a potential divider across the 12V supply. Voltage is tapped off this divider and applied to one input of the Comparator Amplifier.

When exposed to ambient light, e.g. in the day time, the resistance of the l.d.r. is low, but when no light falls upon this device its resistance becomes very high. Thus the voltage applied to the Comparator varies conversely with the amount of illumination received by the Sensor.

A fixed Reference Voltage is applied to the other input of the Comparator. The Comparator compares these two signals. If the Sense Voltage is in excess of the Reference Voltage, the output of the Comparator swings high, drives the transistor TR1 on and so completes the circuit for the low voltage Nightlight lamp LP1.

Conversely, when the Sense Voltage falls below the Reference Voltage the Comparator output is low and the lamp is switched off.

The Light Sensor must be sited so that it is not illuminated by the Nightlight which it controls, but is subject only to the natural light conditions. Thus the Sensor and the Main Unit could be installed on the landing adjacent to the child's bedroom in which the Nightlight is located.

START HERE FOR CONSTRUCTION

CIRCUIT BOARD

The main unit is built in an R.S. Type 11 instrument case. The lamp and photocell are connected by flying leads to the main unit.

Construction may commence with the component panel (see Fig. 3) which is 0·1in matrix stripboard size 24 strips by 36 holes. Start by drilling a $\frac{5}{16}$in hole in each corner to take a 4BA self-tapping screw. Make all of the breaks in the copper strip using either the proper spot face cutter or a hand held twist drill.

SOLDERING

Insert all of the solder pins (9 in all) and then solder the i.c. socket into place. The six strip-interconnection wires may now be soldered in: they consist of solid "bus wire" which should be insulated with 1mm p.v.c. sleeving where there is a danger of them touching other component leads.

Proceed to solder in all of the components. Particularly ensure that C1, D5 and the bridge rectifier are connected the right way round. An error here could have dramatic results.

The transistor, bridge rectifier, Zener diode and i.c. output diodes are of course semiconductors, and as such should not be heated for more than about four seconds when soldering them.

For those who are inexperienced in soldering semiconductors, it is advised that a special heatshunt which is available is used. This is clipped onto the wires being soldered, and serves to dissipate any excess heat, thus preventing damage occuring to the device.

TR1 should be soldered in last of all. It is fitted with a small "crinkled" TO-5 heatsink, and this should be fixed on *before* the transistor is soldered in. When this is in position the small identification tag on the case of the transistor will not be easily visible, therefore pay particular attention to see that the device is inserted the correct way round before fitting the heatsink.

R1 is not mounted flush to the board in the usual way. It dissipates a fair amount of heat, and so the resistor body is allowed to overhang the stripboard where it can

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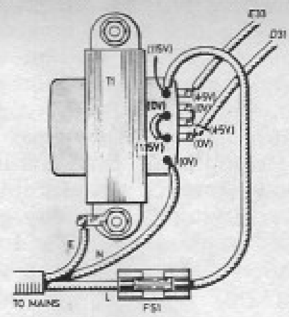


Fig. 4. Mains transformer T1 wiring details.

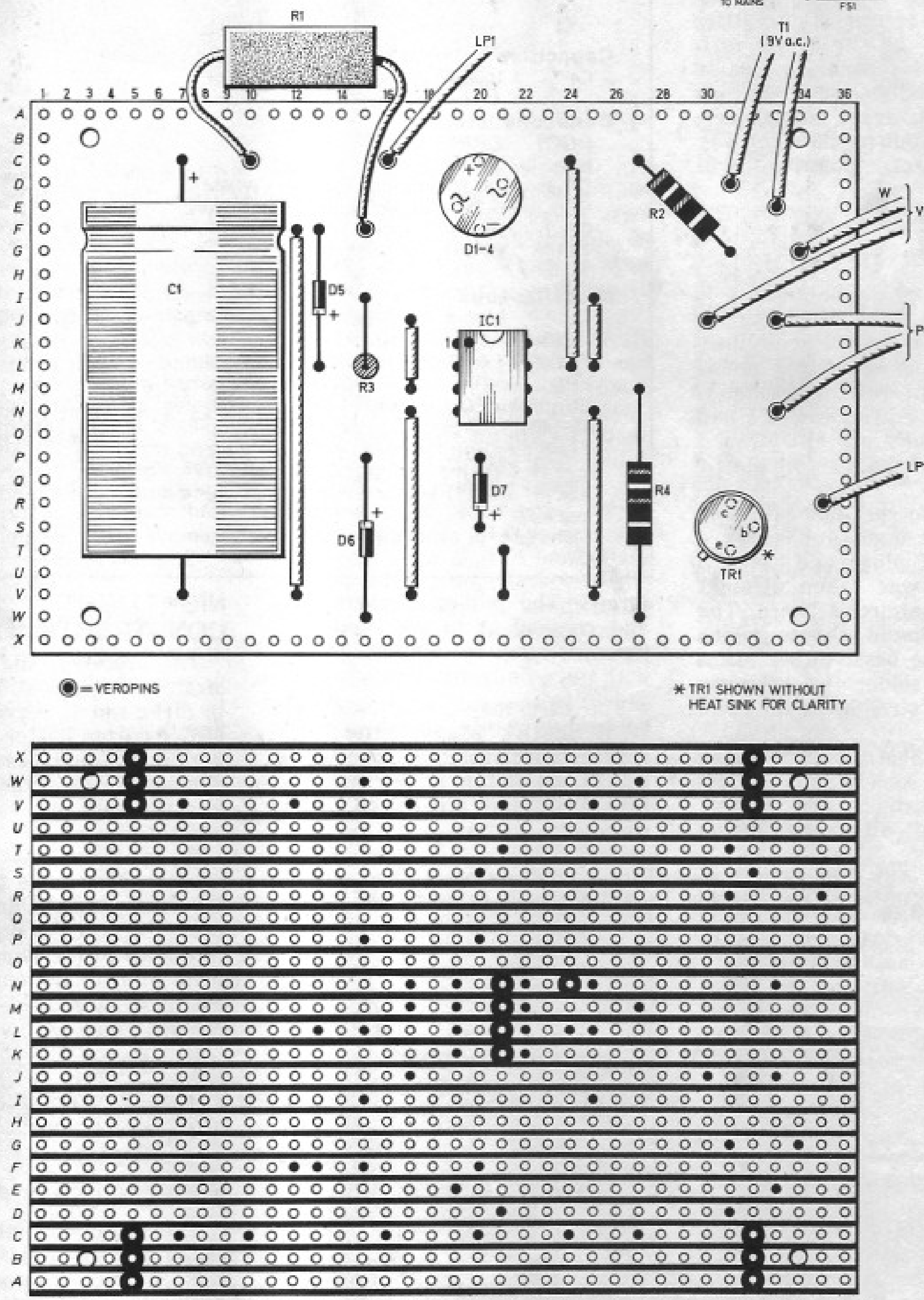


Fig. 3. The component board. Breaks in the copper strips must be made before components are mounted on the other (plain) side of the 0.1 in matrix stripboard. Note that the TR1 heatsink must be fitted before this component is soldered in position.

radiate its heat without affecting nearby components. It will be seen that the slightly longer leadout of the resistor needs to be insulated with p.v.c. sleeving to prevent it shorting to a nearby solderpin.

Having completed the circuit board, now inspect (preferably with a magnifying glass) each of the soldered joints, looking out for "dry" connections or whiskers of solder bridging adjacent copper strips. The underside of the stripboard could be sprayed with printed circuit lacquer if this is available. Finally insert the i.c. into its socket, again making certain that it is put in the right way round—incorrect polarity will destroy it.

MECHANICAL DETAILS

The next part to be tackled is the metalwork. The chassis has to be drilled to take T1, the fuse, VR1, the circuit board, the mains cable entry (fit with a grommet) and the cable entries for LP1 and PCC1. Four holes are also needed in the base to take a set of plastic cabinet feet.

On the prototype, LP1 was connected to the main unit using a 2·5mm jack plug and socket, whilst PCC1 was taken straight through to the circuit board. The constructor should choose which method will be best: either use a connector or solder the interconnecting wires straight to the component panel.

The circuit board is fixed to the chassis using special P.C. pillars see photo) which are simply secured using 4BA self-tapping screws. The pillars are very easy and convenient to use, and save tiresome and frustrating fiddling with nuts, bolts and spacers.

The case may be lettered with W. H. Smith's "Magic Letters" and sprayed with protective lacquer. Of course, all of this is best done before any items are bolted to the case.

COMPONENTS

FOR GUIDANCE ONLY

ESTIMATED COST OF COMPONENTS £8.00

excluding case

Resistors

R1	100Ω 4W	
R2	2·2kΩ	¼W ± 5%
R3	1·2kΩ	¼W ± 5%
R4	1kΩ	¼W ± 5%

Potentiometer

VRI 220kΩ linear

Capacitors

C1 1500μF 25V elect. (axial leads)

Semiconductors

PCC1	ORP12 l.d.r.
IC1	741 8-pin d.i.l.
D1-4	1A 50V bridge rectifier (W04M)
D5	6·2V 400mW Zener. BZY88C6V2
D6, 7	IN4001 (2 off)
TR1	BFY51 silicon *npn*

See **Shop Talk** page 547

Miscellaneous

T1 Mains transformer: Sec. 0–4·5V + 0–4·5V, 0·67A (Doram 66–110–4)
FS1 1A 20mm fuse with chassis holder
LP1 12V 2·2W M.E.S. lamp, and batten holder
Stripboard: 0·1 matrix, 24 strips × 36 holes; metal case type 11 (Doram 68–140–7); 8-pin d.i.l. socket; P.C. pillars (4 off—Doram 69–611–7); TO–5 push-on heatsink; 4BA self-tapping screws (8 off); knob; cabinet feet (4 off); mains input cable (6A 250V); lightweight inter-connecting, cable; solder; solder pins. 2·5mm plugs and sockets (2 off)—optional see text.
Materials for sensor and nightlight assemblies.

NIGHTLIGHT CONSTRUCTION

The prototype nightlight is illustrated in Fig. 5(a). It is very easy to make but is very effective. The M.E.S. batten holder is mounted on a thin plywood base, which is of dimensions to make it a snap-fit into the base of a large polythene aerosol top.

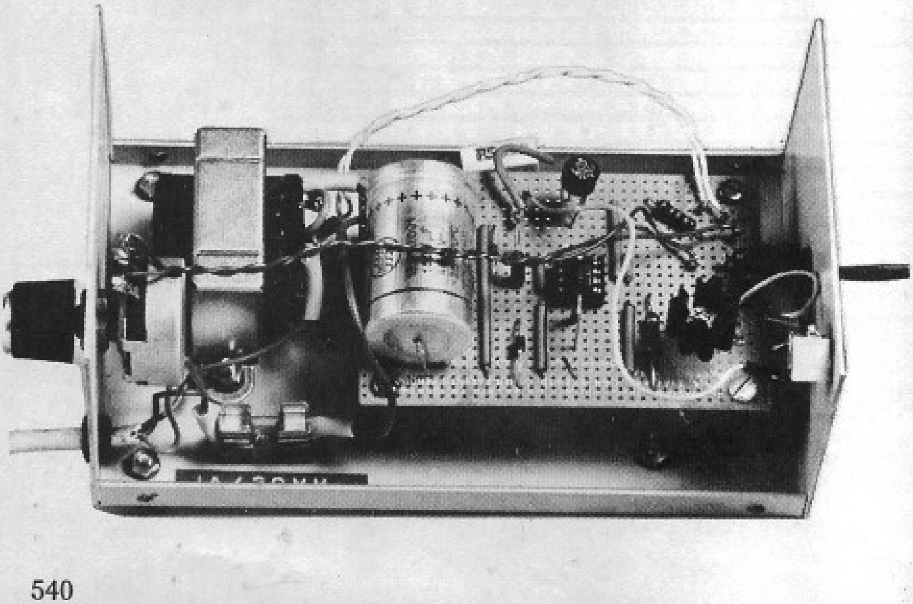
A small hole is made in the aerosol top to take the cable inlet for the lampholder. Twin-core cable is then taken from the terminals of the lampholder to the main unit. Cable length may be in excess of 10 metres, but about 4-5 metres should generally suffice.

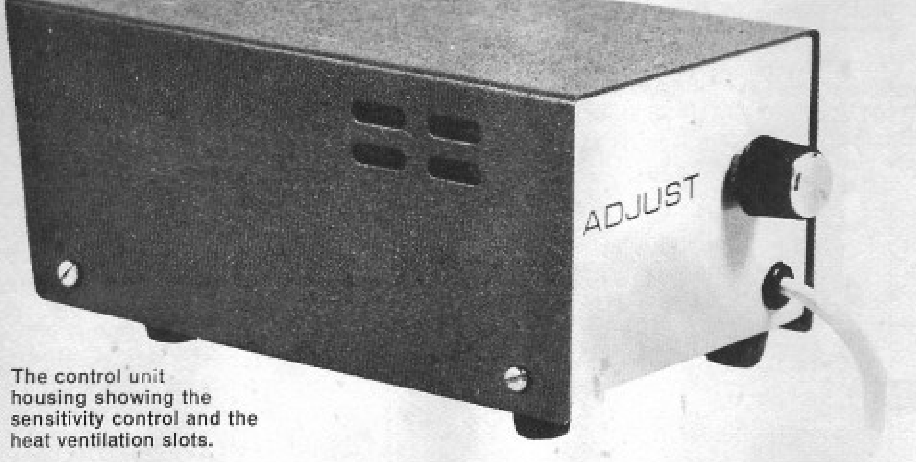
It will be found that the aerosol top idea works most effectively if a warm colour such as red or orange is chosen.

SENSOR CONSTRUCTION

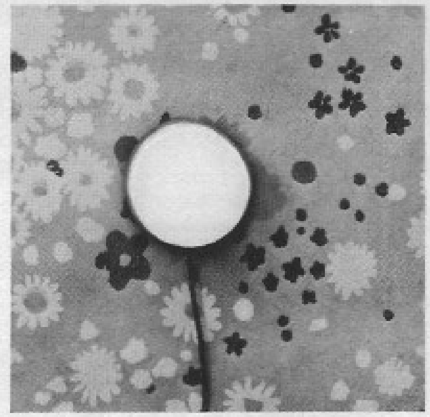
The prototype light sensor consisted of a small plastic box (which was actually from an old stylus package) onto which the ORP12 light dependent resistor was mounted (see Fig. 5(b)). The l.d.r.

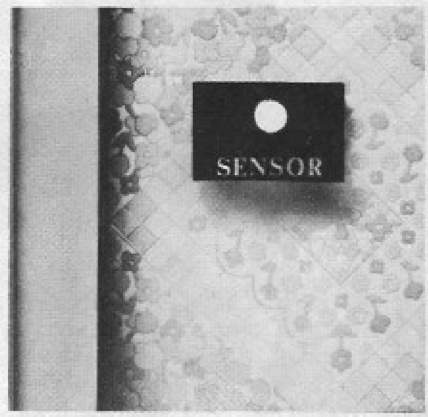
Layout of the components for the control unit. Note the position of the mains transformer, the heatsink for TR1 and the sleeving on resistor R1.





The control unit housing showing the sensitivity control and the heat ventilation slots.


The light mounted in a convenient position on a wall.



The sensor unit mounted in a convenient position in a room to monitor the ambient light.

was fixed to the top using a proprietary adhesive; two very small holes 9·5mm apart were drilled to take the photocell leadouts.

Twin-core flex was then soldered to the leadouts and then taken to the main unit where it passed through a hole in the case and was soldered directly to the stripboard.

Cable length should be kept as short as possible, although it can be up to about 5 metres.

Another idea possibly for sensor construction might be to use a white aerosol top as a diffuser with the ORP12 mounted inside, in a fashion similar to the nightlight.

COMPLETION OF WIRING

The rest of the wiring should now be completed to conform with Fig. 3. All joints which are at mains voltage should be of a good quality; they should not be dull or crystalline. Ensure that the windings of the mains transformer are connected together correctly (see Fig. 4). Finally, the earth wire of the mains input cable is soldered to a 4BA solder tag which is fixed underneath one of the transformer mounting bolts.

Check all of the wiring carefully and then plug in the nightlight and photocell if connectors are used. Set VR1 (the "sensitivity" control) to approximately its midway position and then plug in and switch on. The wirewound resistor R1 should start to get warm.

The nightlight may or may not illuminate, but if it is not alight then covering the photocell completely with, say, a small cardboard box should cause the nightlight to switch on. Now, removing the cover should result in the light going out. (This assumes of course that the initial testing is carried out in daylight!) (The unit is now complete.

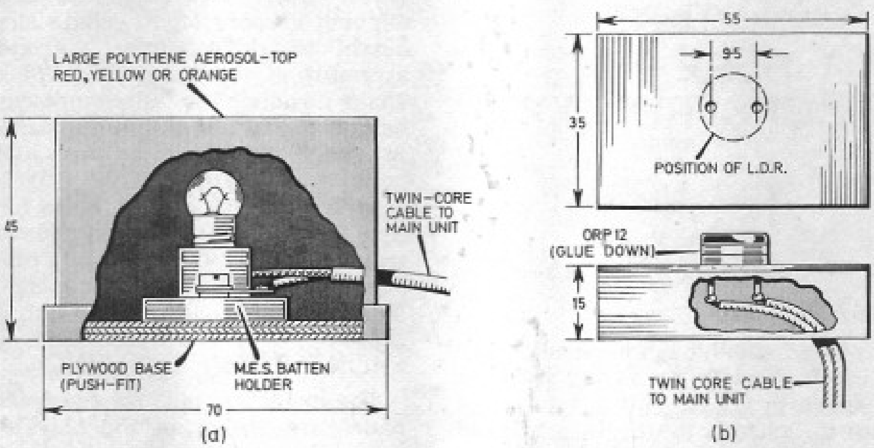


Fig. 5. Construction of the lamp unit (a) and the light sensor unit (b).

FINAL SITING

The system can now be installed in the room where it is to be used. It may take some experimenting with the position of the photocell to achieve the best results: initially the lamp might be coming on far too early, in which case reposition the ORP12 unit in a place where it receives more light. Alternatively adjust the sensitivity control to give the desired switching point. Light from the lamp should not be allowed to fall back onto the photocell.

Each set-up is bound to be different and so it is not really possible to generalise on the sensor position or sensitivity control adjustment which would give the desired operation of the unit. It is a case of "reposition and try again"—but the results should justify the trouble, because there is now one chore less to do last thing at night. Electronics does it for you. ⌑