P R O J E C T

Auto Light

A simple unit that will provide emergency lighting or an automatic night light.

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This project is designed to switch on a small, low voltage lamp automatically when the light level sensed by a Light Dependent Resistor (LDR) falls below a set level.

This is an interesting circuit in its own right and has a number of useful applications. These can include an automatic night light for use with a child or an emergency lighting system to take over illuminating a strategic area in the event of a power failure. The main active device in the project is the light dependent resistor. Light dependent resistors operate in the same way as variable resistors in so far that the actual resistance of the component can be made to vary.

In the case of a variable resistor or potentiometer you can manually alter the resistance by operating the rotating control of the component. With a light dependent resistor the amount of light falling upon the photo-sensitive area of the device governs the actual resistance of the component. In general when more light is shining on the LDR the resistance of the component is low and when very little light falls on it the resistance is high.

Circuit Description

The circuit diagram for the Autolight project appears in Fig. 1. Resistors R1 and R2 form a *fixed* (reference) voltage divider to produce a steady voltage of approximately 0.8V at the inverting input, pin 2 of IC1. Preset VR1 and LDR1 form a similar voltage dividing network which produces a *variable* voltage, dependent upon the amount of light falling upon the LDR, which is connected to the non- inverting input (pin 3) of IC1. The preset control is included so that the operating light level of the circuit may be accurately set.

IC1 is a CA3140 op amp which is configured in this circuit as a comparator. An operational amplifier is designed to amplify the difference between the two inputs by a factor which is determined by the ratio of the resistance between the signal and the inverting input and a similar resistance connected between the output and the inverting input.

When the op amp is set up as a comparator these two resistors are omitted and as a result the op amp has virtually an infinite gain. This is, in practice, limited by being restricted to the power supply rail voltages.

Under these circumstances the output state is determined by the voltages present at the two inputs. If the voltage at the non-inverting input (pin 3) is greater than the voltage present at the inverting input (pin 2) then the output at pin 6 will be the battery voltage.

If the conditions are reversed so that the voltage at pin 2 is greater than the voltage at pin 3 then the output at pin 6 will be 0 volts. The circuit is in fact very sensitive and a very small fluctuation of the input voltages will cause a complete swing of the output voltage at pin 6 from 0V to 9V.

Transistor Power Switch

The operational amplifier has a very low current output. As a result it is not possible for this device to directly switch the lamp on and off so a simple, single stage, transistor output switching amplifier, consisting of resistor R3 and transistor TR1 is used to carry out this task.

In this sort of application the transistor is used as a simple switch so that a small current flowing through the base/emitter junction is used to control a much larger current flowing through the collector/emitter circuit. When a very small current flows through the base emit-

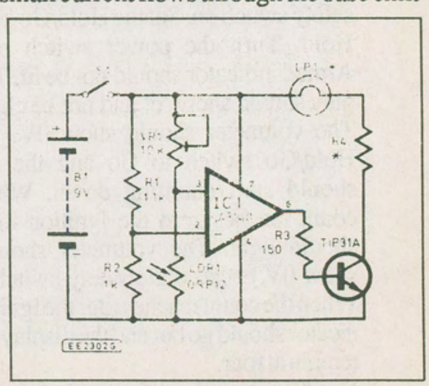

Fig. 1. The complete circuit of the Autolight.

Parts List

Resistors

R1 ....10k
R2 ....1k
R3 150
R4 ....150 0.5W (see text)
All 0.25W 5% carbon film

Potentiometer

VR1 ....10k horiz. trim

Semiconductors

TR1 .... TIP31A *npn* power
IC1 ....CA3140 op amp

Miscellaneous

LDR1 light dependent resistor such as Philips 600-94001, ORP12, or photocell with 1000 ohms or less on-resistance.
S1 .... SPST toggle switch
LP1 ....6.5V, 0.15A bulb (see text)
B1 ....9V battery
JK1 Min. jack connector to suit power supply (optional).

Perfboard, 38 holes x 18 holes; wire; bulb holder; 8-pin IC socket; battery connector; plastic case to suit.

ter circuit this allows a large current to flow through the collector/emitter circuit.

As soon as the current through the base/emitter ceases to flow then the current through the collector/emitter circuit is also prevented from flowing. The current will flow through the base/emitter as long as the voltage between the base and the emitter of the transistor exceeds 0.7V.

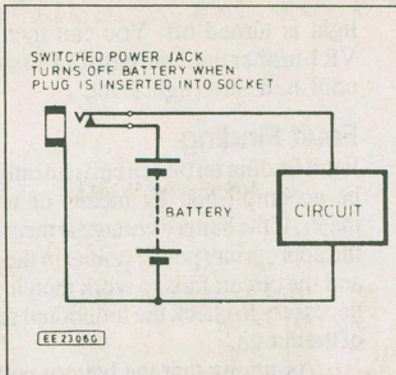

Fig. 2. Using a battery eliminator.

In actual fact, no matter what voltage is available at the base of the transistor the transistor will actually prevent the voltage between the base and the emitter exceeding 0.7V. Any excess voltage is converted to heat by the transistor and could cause serious damage to the transistor. In order to restrict the current flowing through the base/emitter circuit of the transistor to a safe level resistor R3 has been included in the circuit as a base protection resistor.

Lamp

The selection of the lamp operated by this circuit (LP1) presents a difficulty, since it appears that no suppliers have 9V bulbs available in their catalogues. The solution is to therefore use a lower voltage bulb and to adjust the voltage flowing through it by means of a series resistor (R4).

Although the values given in the component list will work quite happily they are by no means the only suitable combination. There are such a large number of bulbs available that the best strategy is for you to select a bulb and then select the appropriate value for R4 to suit your bulb using the formula:

R4 = (Vss - Vbulb)\Ibulb

Where Vss = the battery voltage, bulb = the voltage of the bulb and Ibulb = the current taken by the bulb.

Battery Eliminator

If you intend to operate this circuit as a child's night light, or in some similar situation where it must operate for a long period of time, you will probably find that normal 9V batteries are insufficient to keep the bulb burning for a prolonged period. However, it is possible to operate this circuit from a mains driven power pack of the type that is sold at component stores.

In order to connect a battery eliminator into the circuit you will need to use a low voltage input connector socket, of the type suitable for the output from your power supply, which switches off the

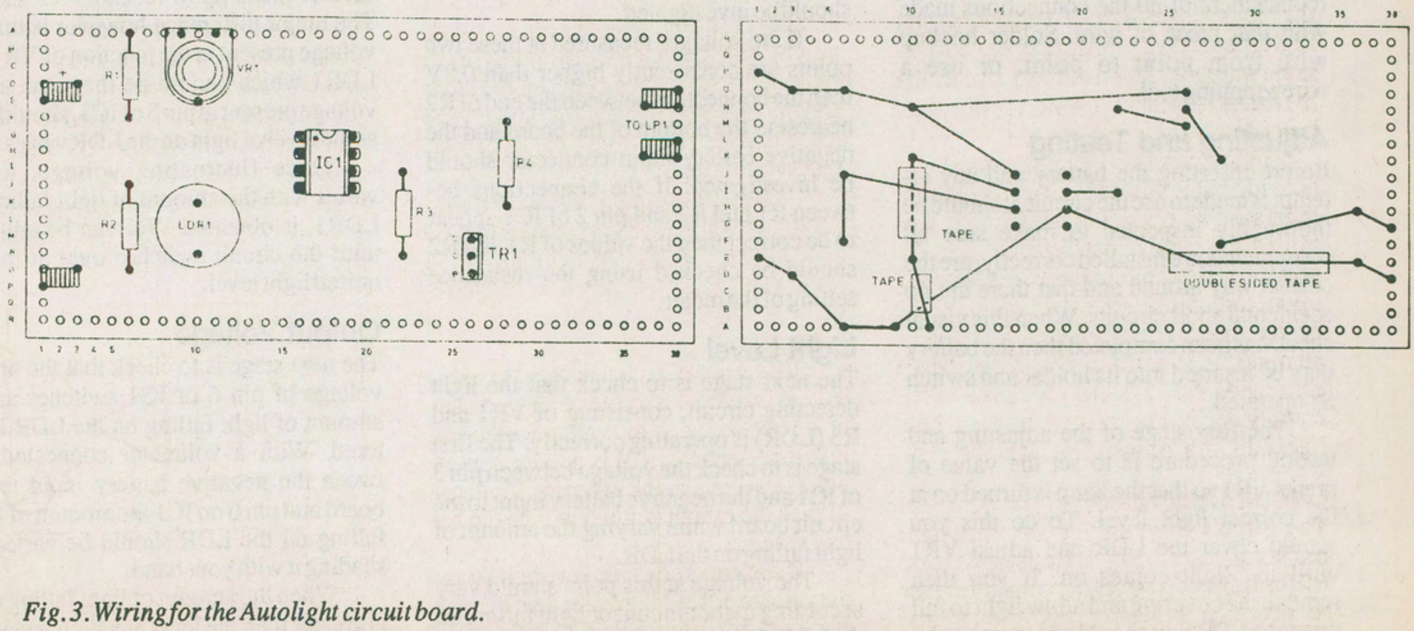

Fig. 3. Wiring for the Autolight circuit board.

internal battery when the external power supply is connected. This should be wired up as shown in Fig. 2.

Switching within the input socket SK1 works so that without the power plug inserted the contacts allow current from the battery to flow to the circuit in the normal way. When the power plug is inserted the internal switch mechanism disconnects the internal battery and powers the circuit from the circuit supplied by the power pack instead.

Under no circumstances should this project be connected to the mains EXCEPT through a SAFE low voltage power supply.

The on/off switch S1 is a simple, single pole, single throw switch which is included in the circuit so that it may be turned off when not required.

Construction

The layout of the components on the board together with the underside wiring is shown in Fig. 3. The components are simply inserted into the appropriate hole in the board from the side with the wider holes. When all of the components have been inserted into it, the board is turned over and the protruding component tails trimmed to a length of 3mm using a pair of side- cutters.

At this stage it is important to ensure that any polarity sensitive components are inserted into the board the correct way around. This should be double checked thoroughly before wiring the board up, since moving components after they have been wired tends to require the complete replacement of all the connections made with that piece of wire. Solder hookup wire from point to point, or use a wirewrapping tool.

Adjusting and Testing

Before inserting the battery and any attempt is made to use the circuit, it should be thoroughly inspected to make sure all components are installed correctly, are the correct way around and that there are no accidental short circuits. When this visual check has been completed then the battery may be inserted into its holder and switch S1 operated.

The first stage of the adjusting and testing procedure is to set the value of preset VR1 so that the lamp is turned on at the correct light level. To do this you should cover the LDR and adjust VR1 until the light comes on. If you then remove the covering and allow light to fall upon the LDR you should observe that the light is turned off. You can then adjust VR1 further until the bulb (LP1) switches on at the desired light level.

Fault Finding

Fault finding on this circuit can only really be accomplished by means of a multimeter. If the battery voltage is measured at the appropriate power points in the circuit and the circuit fails to work then it will be necessary to check the individual sections of the circuit.

Assuming that the battery voltage is available between pins 4 and 7 of IC1, the next stage is to check the voltages, with respect to the negative input to the board, at pins 2 and 3 of IC1. A voltage approximately 0.8V should be available at pin 2 and if this is not the case then the connections to the reference voltage divider, comprising resistors R1 and R2, should be checked.

With the meter, set to "volts", connected to the negative battery input the positive probe should be connected to the wire of R1 nearest to the top of the board. The battery voltage should be measurable at this point and if this is not the case then the connection between the positive power supply input and this point should be investigated.

The voltage at the other end of R1, at the junction with R2, should be approximately 0.8V. The voltage present at pin 2 of IC1 should also be checked and found to be the same as the voltage found at the junctions of R1 and R2. If this is not the case then the connection between the junction of R1 and R2 and pin 2 of IC1 should be investigated.

If the voltages measured at these two points are consistently higher than 0.8V then the connection between the end of R2 nearest to the bottom of the board and the negative battery input connector should be investigated. If the connections between R1 and R2 and pin 2 of IC1 appear to be correct then the values of R1 and R2 should be checked using the resistance setting of the meter.

Light Level

The next stage is to check that the light detecting circuit, consisting of VR1 and R3 (LDR) is operating correctly. The first stage is to check the voltage between pin 3 of IC1 and the negative battery input to the circuit board while varying the amount of light falling on the LDR.

The voltage at this point should vary according to the amount of light falling on the LDR. When very little light falls on the LDR then the voltage at pin 3 of IC1 should be between two volts and the battery voltage.

As the amount of light falling on it is increased by removing the shading between the source of the light and the LDR so the voltage at pin 3 should reduce to below the voltage measured at pin 2. If this is not the case then the connections in the vicinity of pin 3 of IC1 should be. If the voltage measures 0 volts, with respect to the negative supply voltage, then a check should be made between pin 3 and the positive battery input on the board.

If the battery voltage is measured between these two points then this would indicate either a wiring short circuit between pins 3, 4 or IC1 or a fault within IC1 itself. If no voltage is measured between either of the battery input connections and pin 3 then this would indicate that the fault lies with the interconnection between pin 3 of IC1 and the light sensing resistance chain (VR1/LDR1).

Another potential source of problems in the light sensing circuit is if VR1 is set so that there is very little resistance between the positive power supply rail and the connection of the wire of VR1 with the LDR then the variation of light levels on the LDR will have very little effect. A visual check should be made of the setting of VR1 and if necessary an adjustment of the setting VR1 made.

The potential divider circuit consisting of VR1 and LDR1 can be checked out in the same way as described for the checking of the fixed voltage potential divider made up of resistors R1 and R2. The major difference however is that the voltage present at the junction of VR1 and LDR1 which should be the same as the voltage present at pin 3 of IC1, should vary as the level of light on the LDR varies.

Once fluctuating voltage, which varies with the amount of light falling on LDR1, is obtained VR1 can be adjusted until the circuit switches over at the required light level.

Output Voltage

The next stage is to check that the output voltage of pin 6 of IC1 switches as the amount of light falling on the LDR is altered. With a voltmeter connected between the negative battery input to the board and pin 6 on IC1 the amount of light falling on the LDR should be varied by shading it with your hand.

When the amount of light falling on it is greater than the level at which you wish the circuit to switch then the output measured between pin 6 of IC1 and 0 volts should be virtually 0. As the light falling on the LDR is reduced, by shading it with your hand, so the voltage set at pin 3 should rise above the voltage set at pin 2 and the output voltage at pin 6 should, at this stage, rapidly switch from 0 volts to virtually the battery voltage.

If this does not happen and you have already checked that the voltage at pin 3 fluctuates above and below the voltage of pin 2 then you should check that there are no short circuits associated with pin 6 of IC1. If the voltage present at pin 6 of IC1 is permanently at the battery supply voltage then a check should also be made to ensure that there is not an accidental short circuit between pins 6 and 7 of IC1.

If this reveals no fault, or if the voltage pin 6 remains locked at 0 volts, then a check should be made that the battery voltage is present across pins 7 and 4 of IC1. If all other checks reveal nothing to be wrong then it must be suspected that IC1 is faulty and it should be replaced with a new one.

Output Circuit

Fault finding on the output circuit is relatively simple. The first stage is to check that bulb LP1 is firmly screwed into its lamp holder and that the connections are correctly made to the connectors on the board.

Once this has been done the next stage is to make a *temporary* short between the emitter and collector of transistor TR1. This should cause LP1 to light up. If LP1 does not illuminate when tested in this way then a careful check should be made of the lamp circuit from the battery positive connection to the board, through the under-board wiring to the positive side of LP1 and from LP1 through resistor R5 and the collector and emitter of TR1 to the negative battery connection. A break of any description along this chain will cause the lamp not to illuminate.

If the lamp illuminates when tested in this way when the short circuit between the collector and the emitter of TR1 should be removed and the voltage between the negative battery connector and the base of TR1 should be checked. When battery voltage is applied to the end of R4 which is connected to pin 6 of IC1 then approximately 0.7 volts should be measured between the base and emitter of TR1. This should cause LP1 to illuminate.

If no voltage is measurable between the base and emitter of TR1 when battery voltage is available at pin 6 of IC1 then the voltage present at the end of R3 nearest to the top of the board should also be measured. If the battery voltage is not present here but is present at pin 6 of IC1 then the connection between pin 6 IC1 and R3 should be investigated. If battery voltage is measurable at both ends of R3 then the connection between R3 and the base of TR1 should be investigated.

If all of the foregoing checks prove that there is nothing wrong on the circuit board then the voltage present between the emitter and the base of TR1 should be measured. If 0.7V or more is present at this point and the transistor still fails to cause LP1 to illuminate then it must be suspected that TR1 is defective and should be replaced.

Case

Before the project can be installed into a case a suitable sized case should be prepared. It is important to realize that the case layout should be designed so that the light from bulb LP1 does not shine onto the LDR and that the circuit board can be installed with the LDR exposed to the ambient light through a hole in the case.

In the prototype it was decided that LP1 would be mounted so as to protrude through the top of the case with the LDR mounted in what is effectively the front of the case (which is in fact the bottom of the case) furthest away from the removable lid. When suitable positions for these components and also for S1 and, if used, the input power supply jack socket JK1 have been formed the case should be carefully drilled with holes of the appropriate sizes to accommodate these components.

Because it is potentially difficult to assess the correct position of the LDR by holding the circuit board up to the case it will be necessary to find a position for the LDR by careful measurement. Once the hole to accommodate the LDR has been drilled in the case then the circuit board may be offered up to the case wall and the LDR accurately positioned.

In order to allow the LDR to be mounted as close as possible to the body of the case it will be necessary to carefully bend the body of transistor TR1 over so as to make it as close to the component board as possible. The mounting holes for the circuit board can then be marked and drilled.

Once these holes have been drilled and their edges cleaned up any lettering you may wish to use on the case may be applied.

In Use

This project is very simple to use. All that it is necessary to do is to set VR1 to give precisely the correct switching point and then turn the unit on.

It must be remembered that even when the lamp is not illuminated a current is being drawn from the battery, so when the unit is not required to be in use it should be turned off to conserve battery life. ■