4

Auto Turn On/Off Switch

Light operated switches are amongst the most useful and versatile of electronic circuits. The circuit described here may be used in a number of applications, such as in the role of an automatic porch light where the unit automatically switches the light on at dusk and off again at dawn. It may also be used as a deterrent to burglars when one's house is to be left empty for a long period. By automatically operating a hall or porch light the unit gives the impression that the house is occupied.

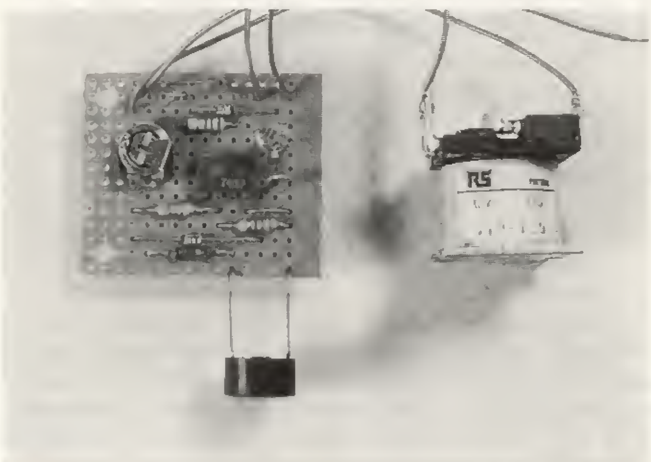


Figure 4.1

The auto turn off switch

Circuits of this type are also popular for use as automatic parking lights for cars and can be used in similar applications by yachtsmen. The load is controlled via a relay so that the unit can control any electrical equipment provided the relay has enough contacts of the right type and of adequate rating. This also enables the unit to switch the load off at the onset of darkness and switch it on again when it becomes light again. To do it is merely necessary to use normally closed relay contacts instead of normally open contacts.

The circuit

Fig. 4.2 shows the complete circuit diagram of the unit which is based on an operational amplifier i.c. which feeds a single transistor relay

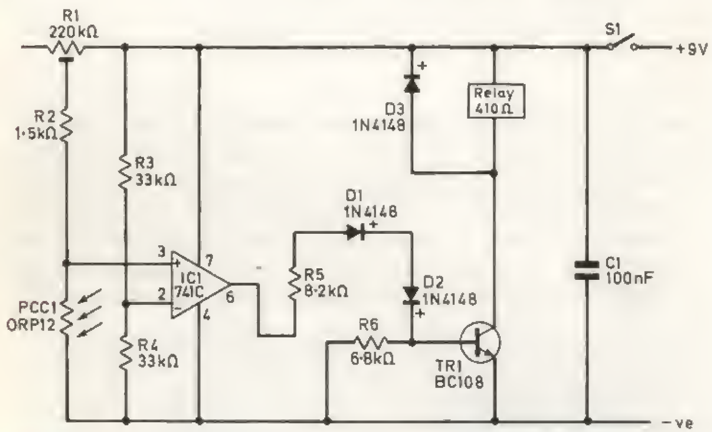


Figure 4.2
Circuit diagram of the switch

driver stage. The circuit is somewhat similar to the 'flat battery warning light' circuit which was described earlier, and as was the case then, the i.c. is used as a comparator.

If the non-inverting (+) input is at a higher potential than the inverting (−) input, the output of the i.c. will go to virtually the full positive supply rail potential. This will result in a strong base current being fed to TR1 through D1, D2, and current limiting resistor R5. This results in TR1 being switched hard on and a large current is supplied to the relay coil, thus causing the relay to be switched on as well.

If the non-inverting input goes to a lower voltage than the inverting input, the output of IC1 will swing to quite a low level, probably about 2V or a little less. Because of the shunting effect of R6 on the base – emitter junction of TR1 plus the 1.2V or so dropped across D1 and D2, this voltage is not sufficient to switch TR1 on, and it passes no significant collector current. Therefore the relay is not energised.

The inverting input of IC1 is held at about half the supply rail potential by R3 and R4. The non-inverting input connects to a potential divider circuit which consists of R1, R2 and PCC1. PCC1 is a cadmium sulphide photoresistor, and its resistance varies greatly with changes in the level of light falling on its sensitive surface. When subjected to very bright light its resistance will only be a few tens of ohms, but in total darkness this figure will rise to in excess of 10MΩ.

If PCC1 is brightly illuminated, the voltage at the non-inverting input will be only very small, and the relay will not be energised. If, on the other hand, PCC1 is subjected to fairly dull conditions, the voltage at the non-inverting input will be comparatively high and the relay will be energised. The light threshold level at which the circuit switches from one state to the other can be varied over very wide limits by adjusting R1.

Circuits of this general type often incorporate built in triggering to ensure that the circuit is always fully switched on or off and that it does not assume some intermediate state. This is not necessary in this case though as relay control is used, and this component can be only on or off, even if the electronic control circuit is in an intermediate state.

D3 is a protective diode used to suppress the high voltage spike which would otherwise be developed across the relay coil as it de-energised. C1 is a supply decoupling capacitor and S1 is the on/off switch. The circuit has a current consumption of less than 1mA from a 9V supply when the relay is not energised, but the current consumption greatly increases when the relay is switched on. The exact current consumption with the relay turned on will depend upon the coil resistance of the relay employed in the unit, and a relay having a high coil resistance is necessary if a low current consumption is desired.

Construction

Apart from the relay and on/off switch, all the components are accommodated on a 0.1in pitch stripboard panel which has 15 copper strips by 14 holes. Details of the component layout are provided in Fig. 4.3.

A hole about 12mm in diamater must be drilled in the case to provide a suitable entrance point for the light to operate PCC1. The component panel must be mounted in a position which brings the photosensitive surface of PCC1 just behind this hole. The sensitive surface of an ORP12 cell is the one opposite the leadout wires.

The method of mounting the relay will depend upon the exact type which is used. Some types are suitable for direct chassis mounting and others can be mounted on a chassis via a separate base into which

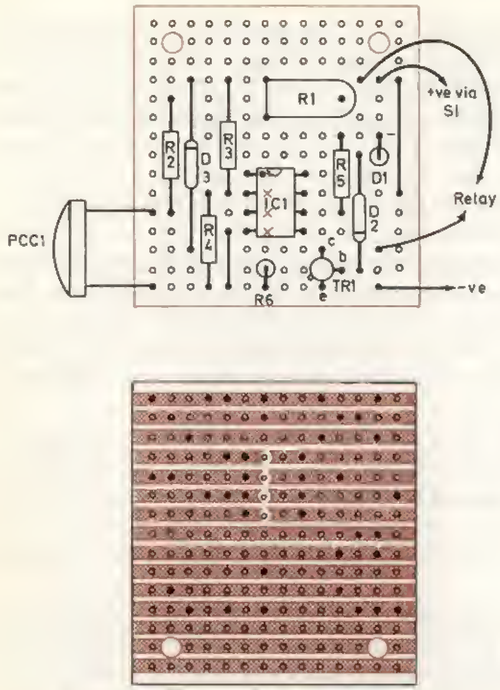


Figure 4.3

Details of the 0.1 in pitch strip board

the relay may be plugged. In either case it will probably be necessary to construct a simple aluminium mounting bracket. The relay used with the prototype is a p.c.b. mounting type, and this can be mounted on a piece of stripboard which is then bolted to the case.

Adjustment

If it is necessary for the circuit to switch the load on at some particular light level, then the unit should be placed in such a light level and R1 adjusted as far in a clockwise direction as possible without the relay switching off. In many applications however, the precise light level at which the unit turns on the load will be uncritical, and virtually any setting of R1 will give satisfactory results if this is the case.

If the unit is used to control a light it is essential that the unit is positioned where the photocell will not receive a significant amount of light from the controlled lamp. Otherwise it is likely that positive feedback will be applied to the circuit via the lamp and photocell, and this will result in the lamp being continually flashed on and off!

Components list for the auto turn on/off switch

Resistors (all are miniature ¼W, 5% except R1)

R1	220kΩ sub-miniature (0.1W) horizontal preset
R2	1.5kΩ
R3	33kΩ
R4	33kΩ
R5	8.2kΩ
R6	6.8kΩ

Capacitor

C1	100nF type C280

Semiconductors

TR1	BC108
IC1	741C
D1	1N4148
D2	1N4148
D3	1N4148

Photocell

PCC1	CRP12

Relay

Any type having coil resistance of about 200Ω or more for 6V operation and adequate contacts of correct type and adequate rating (RS 6V 410Ω open P.C. type used with prototype)

Switch

S1	S.P.S.T. toggle type

Miscellaneous

Case
0.1in pitch stripboard panel
9V battery and connector or suitable mains power supply
Wire, solder, etc.

5

Timer Unit with Audio Alarm

Like the previous project, this has numerous applications in a number of fields. Projects of this type are often put forward ostensibly as electronic egg timers, but they are actually suitable for a great variety of uses in the kitchen, workshop and elsewhere. For instance, timers of this sort are popular as aids to various games where each player has only a limited time in which to make his or her move. In fact, it is surprising how often a unit of this type can be put to good use.

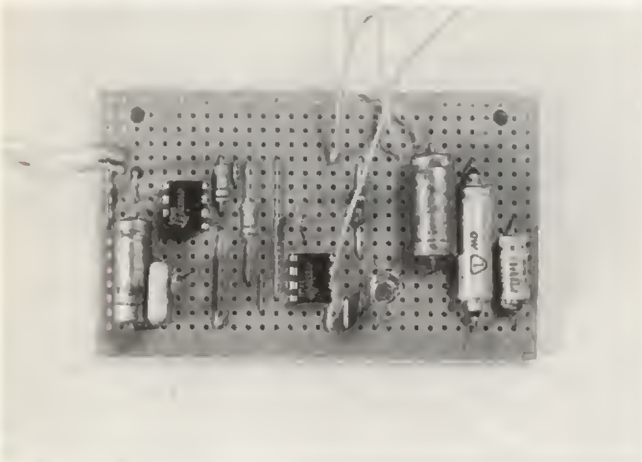


Figure 5.1

Timer unit with audio alarm

The timer described here (Fig. 5.1) has a range of approximately 6 seconds to 3½ minutes, but this can easily be altered to suit individual needs if necessary, as described later. The unit is very simple to operate

as it has just two controls. The first is a control knob which has a dial calibrated in minutes and seconds, and this is adjusted to set the required timing period. The second control is a switch which is thrown when it is desired that the timing period should start. After the appropriate length of time an audio alarm sounds, and this can be silenced by setting the switch back to its original position. The unit is then ready to commence operation once again.

The circuit

The complete circuit diagram of the timer unit is shown in Fig. 5.2, and this is based on two NE555V timing i.c.s. One is used in the timer circuit proper and is used to control the other device which is used to generate the audio alarm signal.

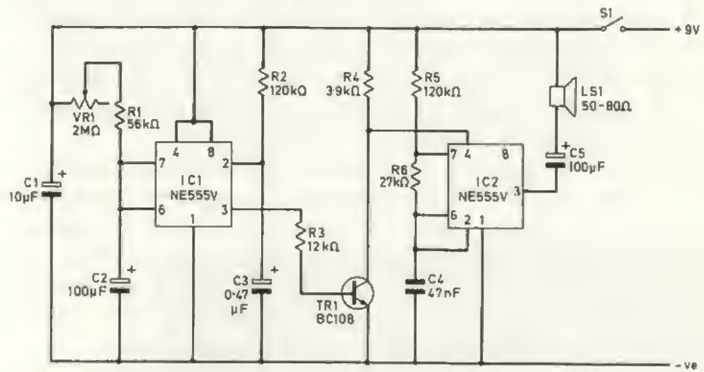


Figure 5.2

The circuit diagram of the timer

IC1 is used as the timer, and this device is connected in the monostable mode. The output of IC1 (pin 3) is normally low (at virtually the negative supply rail voltage) but can be made to go high (to almost the positive supply rail voltage) by momentarily taking pin 2 low. Pin 2 must not be taken low continuously as this would block the operation of IC1. It is therefore taken to an R–C network which consists of R2 and C3. When S1 is closed and the supply is connected to the circuit, pin 2 of IC1 will initially be taken to the negative supply rail potential and the timer circuit will be triggered into operation. C3 will quickly charge up to the positive supply rail voltage via R2 though, so that IC1 pin 2 is taken high and does not block the operation of the timer at the end of the timing period.

C2 is normally short circuited by an internal transistor of the i.c., but this transistor is switched off once the circuit has been triggered, and this enables C2 to charge up via VR1 and R1. C2 continues to charge up until the voltage developed across it becomes two thirds of the supply rail voltage. The circuit then reverts to its original state with C2 being discharged through the internal transistor of IC1 and the output of IC1 returning to the high state.

The time for which the output of IC1 goes into the high state depends upon the time constant of VR1 plus R1 and C2. The timing period is actually equal to 1.1 *CR* (with *C* in microfarads and *R* in megohms), which gives times of roughly 6 seconds with VR1 at minimum resistance, and 3½ minutes with it at maximum. However, it should be borne in mind that the components used in the timing network have quite high tolerances, and the range of actual units built to this design can vary considerably from the range quoted above. This is a problem which is common to any simple timer circuit of this general type.

IC2 is connected in the astable mode, but it does not begin to oscillate when the supply is initially connected. This is because IC1 is triggered the moment the supply is connected, and this causes its output to go high. This switches on TR1 which earths the reset pin of IC2 (pin 4) and blocks the operation of the astable circuit.

When pin 3 of IC1 goes low at the end of the timing period TR1 is switched off and pin 4 of IC2 is connected to the positive supply rail through R4. This enables the tone generator circuit to operate normally, and it oscillates at a frequency of a few hundred hertz. The output at pin 3 of IC2 is connected to a high impedance loudspeaker by d.c. blocking capacitor C5. The output waveform is a series of fairly short pulses and this produces quite a penetrating alarm sound.

Opening S1 removes the power from the circuit and obviously cuts off the alarm. C3 quickly discharges through R2 into the supply lines, whereupon the circuit is ready to start once again from the beginning when S1 is closed once again. C1 is merely a supply decoupling component, and this helps to give good volume from the alarm when the battery voltage drops due to ageing. Note that the timer circuit is not significantly affected by changes in supply rail voltage, as the time taken for the charge on C2 to reach two thirds of the supply rail potential is, theoretically (and very nearly in practice), totally unaffected by what the supply rail voltage actually is.

Construction

With the exceptions of VR1, S1 and LS1, all the components are assembled on a 0.1in matrix stripboard panel. This has 17 copper strips by 31 holes and uses the component layout shown in Fig. 5.3. Make quite sure that both i.c.s are connected the right way round and be

careful not to omit any of the eight link wires or eight breaks in the copper strips.

A cutout for the loudspeaker must be made in one side of the front panel for the case, and this is most easily produced using a fretsaw. An alternative is to use a miniature round file, or failing that, a ring of small closely spaced holes can be made just inside the periphery of the required cutout. The piece of material at the centre of the required cutout can then be broken out, and the rough edges smoothed up using

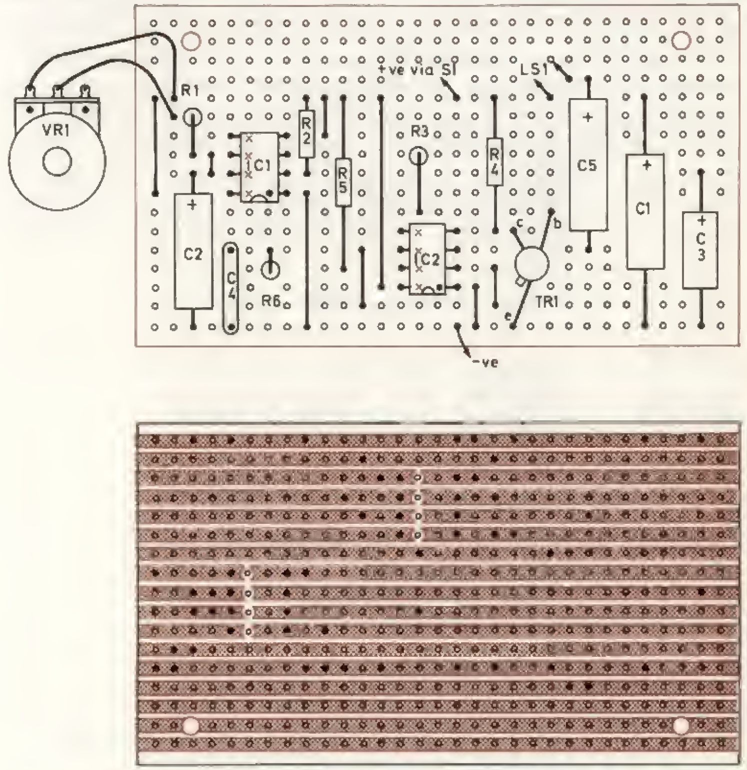


Figure 5.3

Board layout

a large half round file. A piece of speaker fret or cloth is next glued in place behind the cutout, after which the speaker should be carefully glued in position.

VR1 and S1 are also mounted on the front panel, and VR1 should preferably be fitted with a large pointer knob so that a large calibrated scale can be marked around this. Next the point to point wiring is completed and finally the component panel is mounted in position using short M3 or 6BA bolts with nuts.

Calibration

When first testing the unit it is advisable to have VR1 set for the shortest possible time (adjusted fully anticlockwise), and the alarm should then sound within about 10 seconds of the unit being switched on. If it fails to sound, disconnect one end of R3 and switch the unit on again. This should result in the alarm sounding immediately; if it fails to do so there is probably a fault in the wiring around IC2. If the alarm does operate, the fault almost certainly exists in the wiring associated

Components list for the timer unit with audio alarm

Resistors (all miniature ¼W, 5%)	
R1	56kΩ
R2	120kΩ
R3	12kΩ
R4	3.9kΩ
R5	120kΩ
R6	27kΩ
VR1	2MΩ (or 2.2MΩ) lin. carbon
Capacitors	
C1	10μF 10V
C2	100μF 10V
C3	0.47μF 10V
C4	47nF type C280
C5	100μF 10V
Semiconductors	
TR1	BC108
IC1	NE555V (or equivalent)
IC2	NE555V (or equivalent)
Switch	
S1	S.P.S.T. toggle type
Loudspeaker	
LS1	Miniature moving coil loudspeaker of about 50 to 80Ω impedance

Miscellaneous
Case, speaker fret, etc.
Control knob
0.1in pitch stripboard panel
PP3 battery and connector to suit
Wire, solder, etc.

with IC1. If the unit works correctly over short timing periods, but does not when set for longer times (or if longer periods are considerably longer than they should be), this suggests that C2 has an excessive leakage current and it should be replaced.

Marking the dial around the control knob of VR1 is quite a time consuming business, but there is no short cut to this. Finding the chosen calibration points is simply a matter of trial and error.

If the range of the unit is far from the quoted limits, this is probably due to the high tolerance of the timing components, and C2 in particular. One way around this is to try replacing C2 in the hope of finding a more suitable component. Of course, in many applications the precise range of the unit will not be too important, provided it encompasses the required times. With the aid of the formula provided earlier it is possible to obtain virtually any required maximum and minimum times by altering the values of R1 and C2. However, it should be noted that very long timing periods, say a few hours or more, are really impracticable with a simple timer of this type.

6

Ultrasonic Transmitter

Ultrasonic remote control systems are used in a number of applications, the most well known example probably being in TV remote control units. However, they can also be used in the remote control of model cars and boats, or virtually any other electrical or electronic equipment for that matter. They can be used in simple signalling, say between the house and a workshop in an outbuilding, and with a little ingenuity this type of system can also be made to operate as a broken beam type burglar alarm.

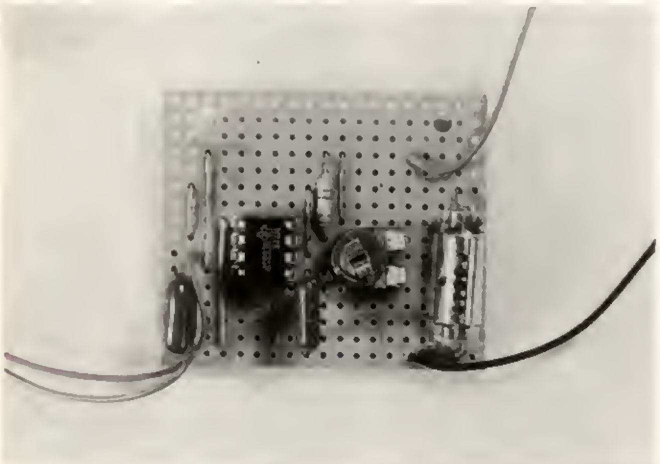


Figure 6.1

Ultrasonic transmitter

As described here, the system consists of a transmitter having a pushbutton switch and a receiver (described in the following section) which has a relay at the output. Operating the switch on the transmitter

causes the receiver's relay contacts to close. However, the unit can be made to latch or provide a stepping action by using a suitable relay or actuator.

Systems of this type have only a relatively limited range, the actual figure being 10 metres or so for this system, although the maximum range which can be obtained depends to some extent on the environments in which the units are used. The range is usually greater indoors than it is out of doors as indoors the system is usually aided by the sound which reflects off the floor, walls, ceiling and objects in the room. This occurs to only a very limited extent out of doors.

A Home Office licence is not needed to use this system legally and, in fact, no licence whatever is required, because ultrasonic systems use soundwaves and not radio waves.

The circuit

The transmitter consists simply of a high frequency oscillator which drives a special type of transducer. The circuit diagram of the transmitter is given in Fig. 6.2.

The oscillator is based on an NE555V timer i.c. which is used in the astable mode. When used in this configuration, timing capacitor C2 charges up to two thirds of the supply rail voltage via R1 and R2, and

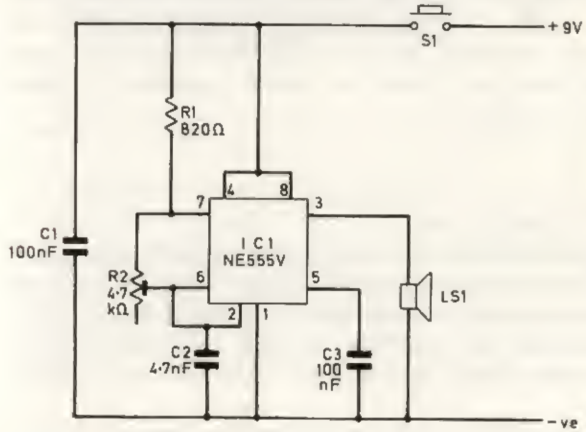


Figure 6.2

Circuit schematic

is then discharged into pin 7 of the i.c. until the potential across it is one third of the supply rail potential. C2 then charges up to two thirds of the supply rail voltage, is partially discharged again, and the circuit continuously oscillates in this manner.

R2 controls the discharge time of C2, and it also controls the charge time to a large extent. It thus controls the operating frequency of the oscillator and it is adjusted to a nominal operating frequency of 40kHz. This is the frequency at which the transmitting transducer is most efficient. The transducer is fed from the output (pin 3) of IC1, and this terminal goes high when C2 is charging and low when C2 is discharging. A signal voltage of several volts peak to peak is therefore fed to the transducer.

S1 is the pushbutton on/off switch, while C1 and C3 are decoupling components.

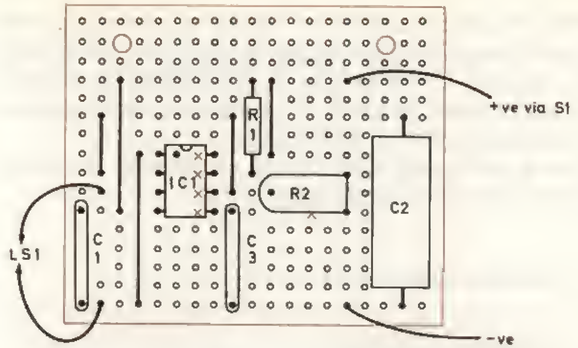
It should perhaps be explained that the transducer is nothing like an ordinary loudspeaker, and it is not an electromagnetic device at all. It is what is known as a piezoelectric device, and has characteristics which are similar to both a quartz crystal and a crystal earpiece. Like an earpiece, if it is fed with an electrical signal it converts this to its equivalent sound signal. It is very inefficient at ordinary audio frequencies though, and becomes more effective at frequencies a little above the audio range. In common with a quartz crystal unit, the ultrasonic transducer has a resonant frequency, and for the unit used in this design the resonant frequency is at a nominal figure of 40kHz. At this frequency the efficiency of the transducer reaches a sharp peak, and this is why the oscillator is adjusted to this particular frequency.

The ultrasonic transducers are sold in pairs, one for the transmitter and one for the receiver. The type number OAB40K is used in the transmitter, and the RAB40K unit is used in the receiver, although the system should work well using any similar transducers if these should happen to be to hand.

Construction

The components are assembled on a 0.1in pitch stripboard panel which has 17 by 19 holes with the copper strips running lengthwise along the panel. Details of this panel are provided in Fig. 6.3. Construction of this is quite straightforward, but note that R2 must be a sub-miniature horizontal type preset resistor if it is going to fit into the available space.

Assuming the transmitter is to be constructed as a hand held unit, a small plastics box should be used as the housing for the unit. S1 and the transducer should be mounted on the case so that S1 is at the top and the transducer is at the front when the box is held in the hand. One way of mounting the transducer is to drill a hole about 10mm or so at the appropriate point in the case and then glue the transducer in place on the outside of the case. The hole is needed to accommodate the phono socket at the rear of the transducer. The connection between



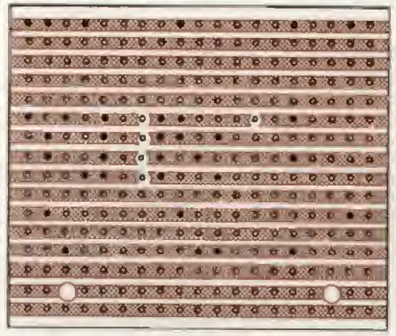


Figure 6.3

Views of the board for the ultrasonic transmitter

the component panel and the transducer is made via a short lead which is terminated in a phono plug, the latter plugging into the socket on the transducer. An alternative method of mounting the transducer is to drill a somewhat larger hole in the case, say about 20mm in diameter, and then glue the transducer in position on the inside of the case.

The remaining wiring can then be completed after which the component panel is bolted into place inside the case.

Adjustment

R2 cannot really be given the correct adjustment until the receiver has been constructed. It is then simply a matter of trying this component at various settings in an attempt to find the one which gives the greatest range.

If an audio millivoltmeter is available a slightly more accurate and quicker method can be used. The millivoltmeter is used to monitor the signal level at TR1 collector of the receiver, the transmitter is switched on and directed at the receiver, and then R2 is adjusted for maximum signal strength as indicated by the millivoltmeter.

Unless the system is to be used at something approaching maximum range the setting of R2 will not be particularly critical.

Components list for the ultrasonic transmitter

Resistors	
R1	820Ω miniature ¼W, 5%
R2	4.7kΩ sub-miniature (0.1W) horizontal preset
Capacitors	
C1	100nF type C280
C2	4.7nF polystyrene
C3	100nF type C280
Integrated circuit	
IC1	NE555V (or equivalent)
Transducer	
LS1	40kHz ultrasonic transducer*
Switch	
S1	Push to make non-locking pushbutton type
Miscellaneous	
Case	
0.1in pitch stripboard panel	
PP3 battery and connector to suit, phono socket, wire, solder, etc.	

*Ultrasonic transducers are available from Arrow Electronics Ltd., Leader House, Coptfold Road, Brentwood, Essex. They are sold only in pairs (one for transmitter, one for receiver) and have the order code RL400PP. Suitable transducers are also available from Ace Mailtronix, Tootal Street, Wakefield, W. Yorks, WF1 5JR. Transducers can also be obtained from many advertisers in electronics magazines.

7

Ultrasonic Receiver

The signal produced by the ultrasonic transducer at the receiver is extremely small, perhaps being little more than 1mV when the system is used over a short range, and considerably less than this over distances approaching maximum range. Therefore, considerable amplification of

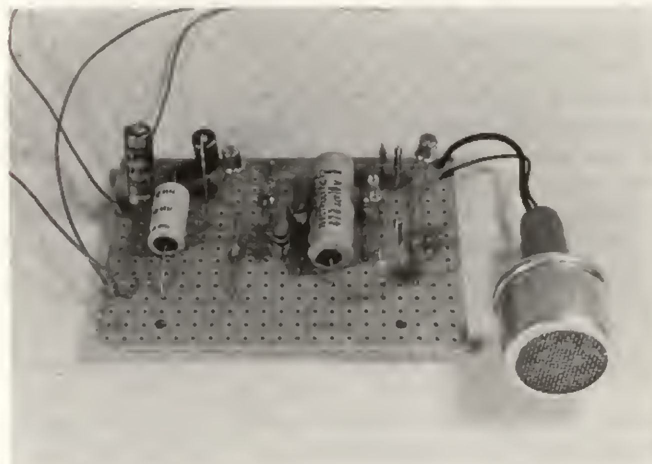


Figure 7.1
Ultrasonic receiver

the signal is needed to bring the signal to a sufficient level to drive a relay.

The circuit

The complete circuit diagram of the ultrasonic receiver is shown in Fig. 7.2 and although this does not have the extreme simplicity of the transmitter circuit, it requires only three active devices.

Like the transducer at the transmitter, the receiver transducer is a piezoelectric device, and has a resonant frequency of 40kHz. Unlike the transmitter transducer though, it is designed to produce an electrical signal from a sound signal, rather than the other way round. It is rather like a crystal microphone, in fact, but it is very inefficient at

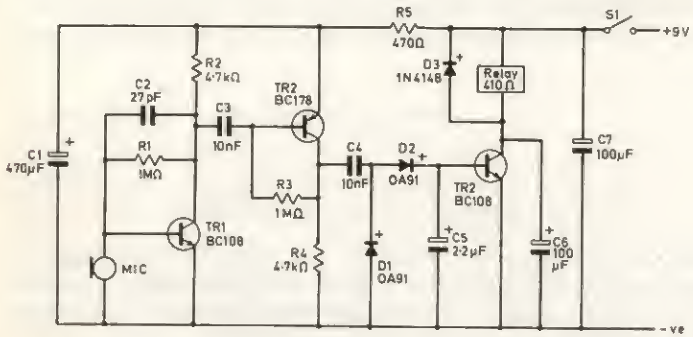


Figure 7.2

Circuit schematic for the ultrasonic receiver

audio frequencies. It is more effective at frequencies just above the audio range, and its efficiency peaks at the resonant frequency of 40kHz. Thus the transducer effectively picks out the signal from the transmitter but rejects other sounds which might otherwise cause spurious operation of the unit.

TR1 is used as a high gain common emitter amplifier having R2 as its collector load and base biasing provided by R1. The transducer is coupled direct to TR1 base, and this is acceptable as the transducer has an extremely high resistance and will not significantly affect the biasing of TR1. Neither will the small voltage at TR1 have any detrimental effect on the transducer. C2 rolls off the gain of TR1 at radio frequencies, and this helps to prevent spurious operation due to instability or pick-up of strong radio signals.

The output from TR1 is coupled to a second high gain common emitter amplifier via C3, the latter being purposely given a fairly low value so that the 40kHz signal is effectively coupled, but audio signals are rejected to a large extent. Apart from the fact that the second amplifier stage uses a *pnp* device and has no high frequency roll off capacitor, it is basically the same as the first stage.

In order to drive a relay, the signal at TR2 collector must be rectified and smoothed to a d.c. bias and then further amplified. C4 couples the signal to the rectifier circuit which consists of D1 and D2, and C5 smoothes the pulsed d.c. output of the rectifier network. If a signal of sufficient amplitude is present at TR2 collector, the d.c.

bias that is produced will be adequate to switch on TR3, and the relay in the collector circuit of TR3 will be activated.

Of course, the relay will be activated only while the transducer is receiving a signal from the transmitter, and so when the pushbutton on the transmitter is depressed the relay will be switched on, and when the pushbutton is released the relay will be deactivated.

D3 is the usual protective diode which is needed in to eliminate the high reverse voltage spike that would otherwise be generated across the relay coil as it de-energises. C6 is used to slightly slow up the time taken by the circuit to respond to the commencement and ending of the input signal. This was found to be necessary as acoustic feedback between the relay and the transducer otherwise caused slight instability, but this component may not be necessary in every case. It depends to a large extent on the characteristics of the relay used and on the physical layout of the unit. C1, R5 and C7 are supply decoupling components, and with the high gain and fairly high output current of the circuit, the high level of decoupling that these provide is fully justified. S1 is the on/off switch. The quiescent current consumption of the device is only about 2mA, but it is considerably higher than this when the relay is switched on, the actual figure depending upon the coil resistance of the particular relay used. If a low level of current consumption is important (as it will be if the unit is battery operated, for instance), a relay having a fairly high coil resistance is to be preferred. Any relay suitable for operation on 6V and having a coil resistance of about 200Ω or more will work in the circuit, but it is essential to ensure that the relay has an adequate number of contacts of the right type and suitable rating for the application in which the unit is to be utilised.

Construction

The components can be accommodated on a 0.15in pitch stripboard using the component layout illustrated in Fig. 7.3. The panel has 15 copper strips by 21 holes and there are no breaks in any of the strips. The relay is not mounted on the panel, and the method of mounting the relay will depend on the type used. It will almost certainly be necessary to construct some form of mounting bracket, and a little ingenuity must be used here. S1 and the transducer should be mounted on the front of the case, and methods of mounting the transducer were given in the section describing the transmitter. The connection to the transducer is made by way of a phono plug which is inserted into the socket at the back of the transducer. Provided the lead between the transducer and the component panel is fairly short, which it presumably will be, it is not necessary to use screened lead here. The unit can be

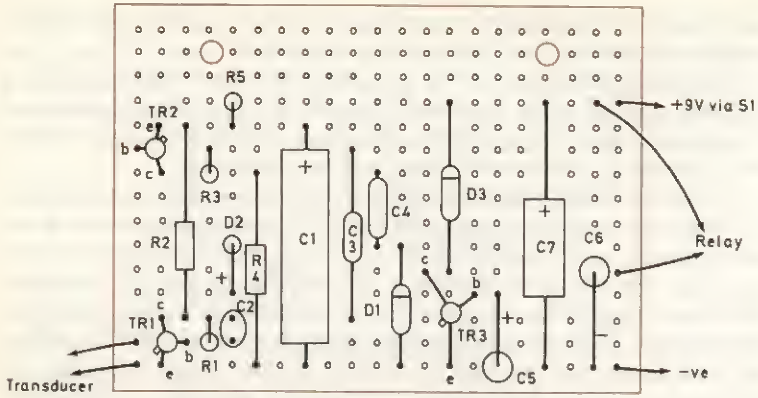


Figure 7.3
Details of the 0.15 in strip board

housed in a metal or non-metallic case, but a metal one is preferable as this can be earthed to the negative supply rail and it will then provide overall screening of the circuitry.

Using the system

Both the transmitting and receiving transducers are directional devices and in order to obtain optimum reliability and range it is necessary to aim the ultrasonic beam from the transmitter at the transducer on the receiver, rather as if one was shining a torch at the receiver. This effect is not always apparent when the unit is used indoors because of internal sound reflections, and it may even be possible to obtain reliable operation with the transmitter aimed completely in the wrong direction. Ultrasonic soundwaves will not readily travel through any object positioned between the transmitter and receiver, and so this is something which should be avoided if possible.

In some applications it may be necessary to arrange the circuit so that it latches in the on state once the signal from the transmitter has been picked up. A simple way of achieving this is to connect a pair of normally open relay contacts across the collector and emitter terminals of TR3. These contacts will close once the relay has been activated, and they provide a current for the relay coil even if TR3 should then switch off again.

In other applications, such as a broken beam burglar alarm, it will be necessary to arrange the circuit so that it will latch in the off state once the signal from the transmitter has temporarily ceased. This may be

achieved by connecting a pair of normally open relay contacts in series with the relay coil. With the relay normally activated, these contacts will usually connect the relay into circuit. However, if the beam is broken and the relay de-energises, the relay will be cut out of circuit and cannot be switched on again even if TR3 should start to conduct once again. A push-to-make non-locking pushbutton switch must be connected across the relay contacts so that the relay can be switched on when the circuit is initially set up.

Components list for the ultrasonic receiver

Resistors (all miniature ¼W, 5%)	
R1	1MΩ
R2	4.7kΩ
R3	1MΩ
R4	4.7kΩ
R5	470Ω
Capacitors	
C1	470μF, 10V
C2	27pF, ceramic plate
C3	10nF, type C280
C4	10nF, type C280
C5	2.2μF, 10V
C6	100μF, 10V
C7	100μF, 10V
Semiconductors	
TR1	BC108
TR2	BC178
TR3	BC108
D1	OA91
D2	OA91
D3	1N4148
Switch	
S1	S.P.S.T. toggle type

Relay
Any type having a coil resistance of about 200Ω or more for operation on 6V, and an adequate number of contacts of suitable rating (RS 6V 410Ω open P.C. mounting type used on prototype).

Miscellaneous
Case
0.15in matrix stripboard panel
Ultrasonic transducer (see previous project)
Large 9 volt battery and connector to suit (or mains P.S.U.)
Wire, solder, etc.