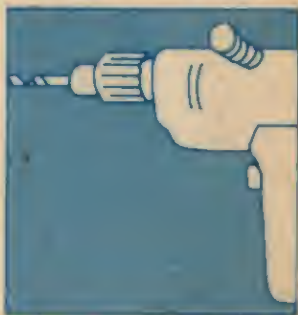
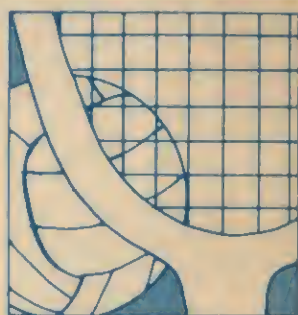
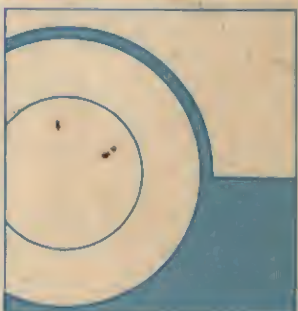
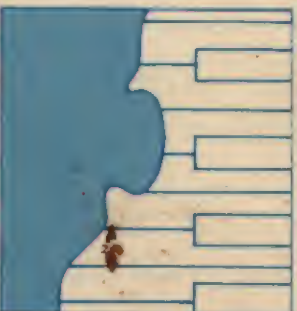
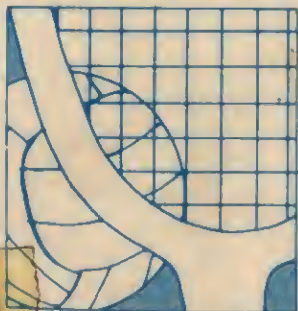


Electronic Projects in the Workshop



R A Penfold

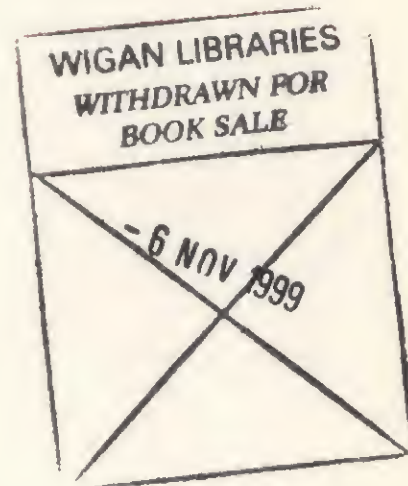


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Preface

The purpose of this book is to provide a number of useful and interesting electronic constructional projects for use in and around the workshop. The projects will have considerable appeal to the home handyman and will find use in the average 'Do It Yourself' workshop. Many of the circuits are very versatile, and could easily be adapted to perform different functions.

All the projects are reasonably simple and have been designed so that they are not beyond the constructional capabilities of anyone who is reasonably practical, and many are suitable for beginners at electronics construction.

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1

Rain/Water Level Alarm

This simple device (Fig. 1.1) may be used as a rain alarm, to indicate that it's time to rush out and bring in the washing, but it may also be used in other domestic situations, e.g. to give an audio indication that the bath water has reached the right level, or to give an alarm when

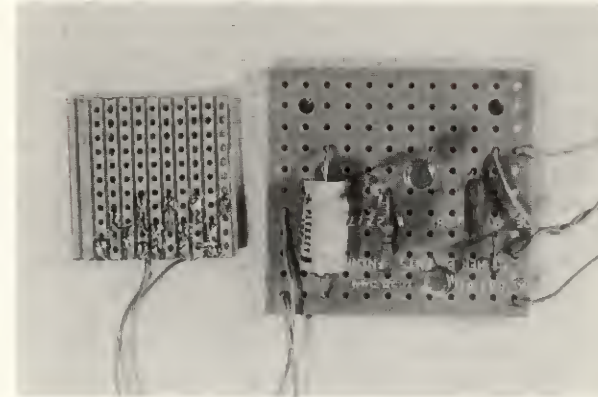


Figure 1.1

The rain/water level alarm

water gets into premises that are prone to flooding. Units of this type also have uses outside the home environment, e.g. in yachting, where there are obvious uses. In fact circuits of this type are extremely useful and versatile despite their simplicity.

The circuit

The operation relies on the fact that, although pure water is an insulator, water which contains even quite small amounts of dissolved impurities

will conduct sufficiently well for the current to be easily detected by an electronic circuit and a simple sensor. In practice, any water which the unit is likely to be used to detect will contain significant amounts of dissolved impurities, and even rainwater, which might be expected to be almost pure water, can be readily detected by this circuit.

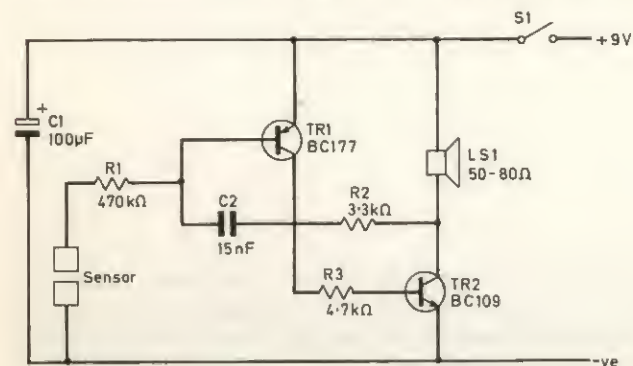


Figure 1.2
The circuit of the alarm

The circuit diagram of the rain/water level alarm is provided in Fig. 1.2. Basically the unit is just a simple audio oscillator with the output fed to a loudspeaker. However, bias resistor R1 is not connected direct to the negative supply rail as it would normally be, but is connected via a simple sensor. The sensor simply consists of two pieces of metal which are mounted close to each other, but not in direct contact. Therefore, under quiescent conditions TR1 receives no base bias current and is cut off. TR2 receives only leakage currents via TR1 and R3 into its base circuit, and as these are only minute TR2 is also cut off. This gives the circuit a standby current consumption which is negligible, and this makes it suitable for battery operation even if it will need to be used for very long periods.

When the two pieces of metal forming the sensor are bridged by water, a small bias current will flow into TR1 base, and TR1 will switch on. TR2 will then be switched on by the base current it receives from TR1, and a negative going pulse will be fed to TR1 base from the collector of TR2 by way of R2 and C2. This causes TR1 to conduct more heavily which in turn results in TR2 conducting more readily and supplying a stronger negative signal via C2 and R2. This regenerative action continues until TR2 is saturated, and can no longer supply a negative going signal to TR1 base.

In the absence of a further signal from TR2, TR1 will start to conduct less heavily and will reduce the base current to TR2. This

causes TR2 to start to turn off, and the positive-going signal at TR2 collector is fed to TR1 base by R2 and C2. This causes TR1 to conduct still less heavily, and a regenerative action occurs once again with TR2 becoming cut off as a result.

The original regenerative action then commences once again, and the circuit continuously oscillates in this way. Of course, the circuit actually oscillates very rapidly, and several hundred pulses of current are fed to the loudspeaker (which forms the collector load for TR2) each second. A tone of several hundred hertz is therefore emitted from the loudspeaker when the sensor is bridged by water. The unit produces quite a loud sound and has a current consumption of about 50mA when operating the alarm.

The three resistors are needed to protect the transistors against passing excessive base or collector currents, and C1 is merely a supply decoupling capacitor. S1 is the on/off switch.

Construction

All the small components are mounted on a 0.15in matrix stripboard panel which has 11 copper strips by 12 holes. Details of this panel are provided in Fig. 1.3. When a panel of the required size has been cut out

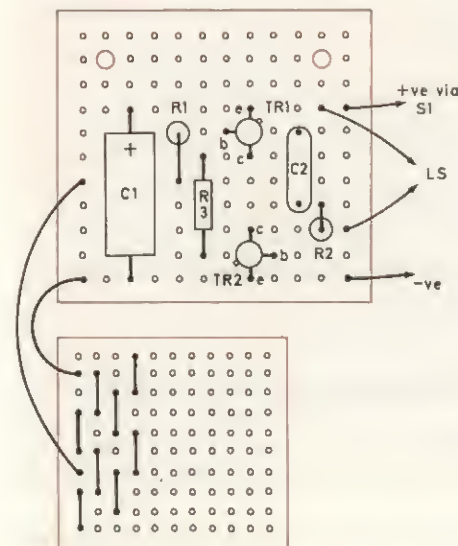


Figure 1.3
The circuit board of the alarm

and the two mounting holes have been drilled, the components can be soldered into circuit. There are no breaks in any of the copper strips.

Mechanically the construction of the unit is quite straightforward except for the mounting of the loudspeaker on the front panel. This requires a cutout of slightly less than the loudspeaker diameter to be made in the front panel, and this can be accomplished using either a fretsaw or a miniature round file. A piece of loudspeaker fret or cloth is then glued in position behind the cutout and the loudspeaker is carefully glued into place over this. A minimal amount of a high quality adhesive such as an epoxy type should be used so that the loudspeaker is firmly mounted, but there is little risk of adhesive getting onto the diaphragm and possibly impeding it. An alternative to the cutout and speaker fret is simply to drill a matrix of small holes in the panel, although it is more difficult to make a good job of this than one might think.

Components list for the rain/water level alarm

Resistors (all miniature ¼W 5%)

| | |
|----|-------|
| R1 | 470kΩ |
| R2 | 3.3kΩ |
| R3 | 4.7kΩ |

Capacitors

| | |
|----|----------------|
| C1 | 100μF 10V |
| C2 | 15nF type C280 |

Semiconductors

| | |
|-----|-------|
| TR1 | BC177 |
| TR2 | BC109 |

Switch

| | |
|----|----------------------|
| S1 | S.P.S.T. toggle type |
|----|----------------------|

Loudspeaker

| | |
|-----|--|
| LS1 | miniature loudspeaker with an impedance in the range 50 to 80Ω |
|-----|--|

Miscellaneous

Case, and speaker fret or cloth
0.15in matrix stripboard for component panel and 0.1in stripboard for sensor
PP3 battery and connector to suit
Connecting wire, solder, etc.

S1 is also mounted on the front panel, and either a hole for the lead to the sensor must be made in the case, or the leads from the sensor should be terminated in a 3.5mm jack plug, and those from the main circuit should be terminated in a 3.5mm jack socket, the latter being

mounted at any convenient place on the case. When all the wiring has been completed the component panel can be bolted into position.

A sensor for the unit can consist of a piece of 0.1in pitch stripboard (this is preferable to 0.15in matrix board which has a wider strip spacing) with alternate strips bridged by link wires, as shown in Fig. 1.3. For many applications, a short piece of board having two copper strips will be quite adequate, but for a rain alarm the sensor should be as large as possible so that there is a good chance of a raindrop being detected almost immediately raindrops start to fall. Of course, there are many other possible ways of producing a suitable sensor, and there is plenty of scope for using one's initiative here.

Once the alarm has been activated it can be silenced simply by switching the unit off. Before the unit is ready for use again it may be necessary to wipe any moisture from the sensor. Unless the sensor is made from a non-corrosive metal it will be necessary to inspect it periodically to check that it is not badly corroded. If necessary it must be cleaned with metal polish, otherwise it is possible that the alarm will fail to operate.

2

Flat Battery Warning Light

Many items of electronic equipment, particularly test gear, are battery operated and have a regulated supply voltage. A problem which can easily arise here is that of the battery voltage falling to a level which is inadequate to drive the regulator circuitry properly. This can result in the unit providing erroneous results.

Some such pieces of equipment have an integral battery check facility of some form or another, but it is an easy matter to add this feature to apparatus which is not already equipped in this way. One very simple form of battery check device is a circuit which turns on a warning light if the supply voltage falls below some predetermined level, and it is a simple unit of this type which is described here.

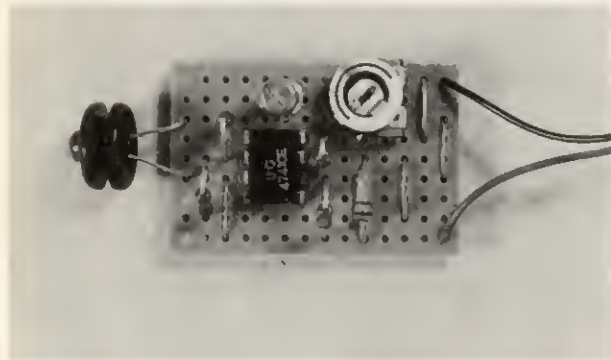


Figure 2.1
Flat battery warning light board

The unit (Fig. 2.1) can be used to monitor equipment other than test gear, of course, and can be used wherever it is necessary to ensure that a battery voltage does not fall below a certain critical level. It can

also be used in cars, boats, etc., to provide warning of a nearly discharged battery. Another application is in battery powered equipment which is used infrequently, or in alarm systems (such as the one described in the previous project) where the equipment is left switched on for prolonged periods and draws no significant current. In either of these cases it is very easy to neglect the battery and let it deteriorate to the point where it begins to leak. This can cause severe damage to the equipment owing to the highly corrosive nature of the leaking substance. This can be avoided by fitting to the equipment a circuit of the type described here, and using it to check the battery condition periodically.

The unit can be used with a minimum supply voltage of a little under 7V and it is advisable to keep the maximum supply voltage to no more than about 20V or so.

The circuit

The circuit is based on an operational amplifier i.c. which is used here as a comparator. The circuit diagram of the unit appears in Fig. 2.2 and IC1 is the operational amplifier.

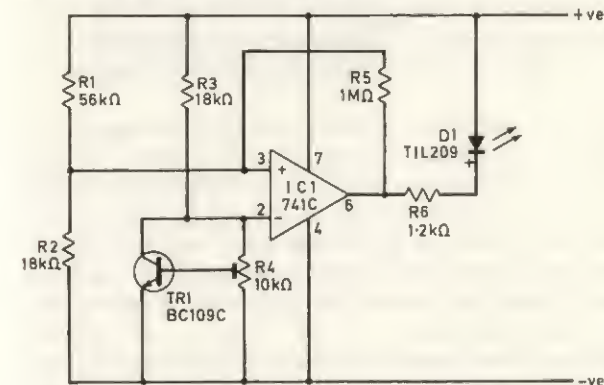


Figure 2.2
Circuit diagram of the indicator

The output of IC1 drives a light emitting diode indicator (D1) via current limiting resistor R6. When the output of IC1 is low (at virtually the negative supply rail potential), current will be supplied to D1 and it will light up. When the output of IC1 is high (at virtually the full positive supply rail potential) D1 will not be supplied with any significant current and will not light up.

Which output state the i.c. assumes depends upon the comparative input voltages. If the non-inverting (+) input is at a higher voltage than

the inverting (–) input, the output goes high. If the comparative input levels are reversed, then the output goes to the low state. The non-inverting input is given a small positive bias voltage by the potential divider R1 and R2. The exact voltage at the non-inverting input obviously depends to a large extent on the supply voltage.

A simple voltage stabiliser circuit is used to provide a regulated potential at the inverting input of IC1. The regulator circuit consists of R3, TR1, and R4, with TR1 being used as what is often termed an amplified diode. This type of regulator relies upon the fact that a high gain silicon transistor such as TR1 will not begin to conduct until its base–emitter voltage reaches a level of about 0.6V, but a voltage only fractionally higher than this is sufficient to saturate the transistor. Therefore, if the slider of R4 is set a quarter of the way up its track, for instance, a current will flow through R3 and R4 and the voltage at TR1 base will rise to about 0.6V. It cannot rise much above this level as this causes TR1 to turn on and divert some of the current from R3 through its collector–emitter circuit. The voltage at TR1 base is thus stabilised at about 0.6V, and by a simple potential divider action the voltage at TR1 collector must be four times this level, or 2.4V in other words.

R4 can obviously adjust the potential at TR1 collector over quite wide limits, since taking the slider of R4 further down its track will increase the voltage required at TR1 collector in order to produce 0.6V at TR1 base. Taking R4 slider higher up its track will have the opposite effect.

In practice, R4 is adjusted to produce the same voltage at the inverting input of IC1 as appears at the non-inverting input when the supply voltage is at the minimum acceptable level. If the supply voltage is above the critical level, then the output of IC1 will be high and the LED indicator will not come on. If, on the other hand, the supply voltage falls below the critical level, the voltage at the non-inverting input will be below that at the inverting input, and D1 will be switched on as the output of IC1 will go low.

One slight problem with the circuit is that with very small voltage differences across the inputs, say a few hundred microvolts or less, the output can take up an intermediate state and produce an indecisive output from D1. This is overcome by the inclusion of R5. If the output of IC1 starts to go negative the current through R5 takes the non-inverting input more negative, which in turn takes the output more negative. This regenerative action continues until the output is fully negative, and in this way intermediate output states are eliminated.

Construction

All the components can be accommodated on a small 0.1in matrix stripboard panel which has 9 copper strips by 14 holes. Full details of

this panel are given in Fig. 2.3. Construction is quite straightforward, but be careful not to omit any of the four link wires or the five breaks in the copper strips. Also be careful not to bridge any copper strips with small blobs of excess solder, as this is easily done on this compact 0.1in matrix stripboard, particularly when soldering in the i.c. It is a good idea to check the completed board with a continuity tester to ensure that no short circuits of this type are present.

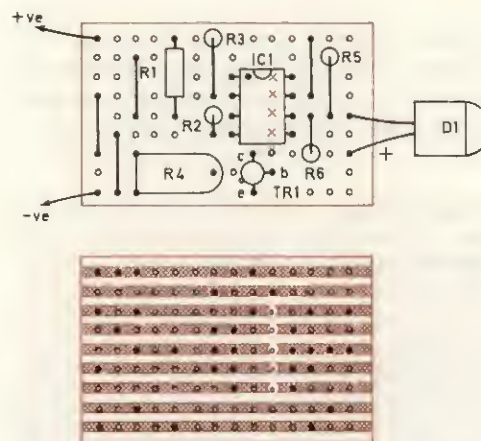


Figure 2.3

Constructional details of the board

If the leadout wires of D1 are bent at right angles it will then be possible to mount this component in an ordinary LED panel clip. As the component panel is quite small and light, this also provides an adequate mounting for the panel, but the leads of D1 must be kept quite short in order to provide a reasonably firm mounting. Owing to the small size of the unit, it will not normally be too difficult to fit it into a piece of equipment, although it may always be built as a separate unit in its own case where integration is not feasible. If this approach is adopted it will be necessary to bring the monitored supply rails out to a socket mounted at some convenient point on the main equipment. The input lead of the indicator circuit would then be terminated in a suitable plug so that it could be connected to the main equipment whenever necessary.

The unit has a current consumption of only about 1mA from a 9V supply, and so it will not normally reduce battery life to any great extent. However, it could do so under certain circumstances, and if this should be the case a push-to-make non-locking pushbutton switch

can be connected in series with the positive supply rail. The unit will then draw no standby current, but it will be necessary to operate the pushbutton switch in order to check the battery condition, of course. The current consumption with the indicator lamp on is about 8mA from a 9V supply.

Adjustment

To enable the unit to be adjusted correctly it must be connected to a supply potential which is equal to the minimum acceptable battery voltage. R4 is then adjusted as far in a clockwise direction as possible without the indicator lamp coming on. The unit is then ready for use.

Components list for the flat battery indicator

Resistors (miniature 1/4W, 5% except where noted otherwise)

| | |
|----|---|
| R1 | 56k Ω |
| R2 | 18k Ω |
| R3 | 18k Ω |
| R4 | 10k Ω sub-miniature (0.1W) horizontal preset |
| R5 | 1M Ω |
| R6 | 1.2k Ω |

Semiconductors

| | |
|-----|--|
| TR1 | BC109C |
| IC1 | 741C |
| D1 | TIL209 or any small panel mounting LED with holder |

Miscellaneous

0.1in matrix stripboard
Wire, solder, etc.

3

Thermometer

An electronic thermometer (Fig. 3.1) makes an extremely interesting constructional project and has uses in a number of fields. Although a unit of this type does have certain disadvantages over a more conventional thermometer, such as the need for a power source, there is the advantage of being able to locate the temperature sensing element

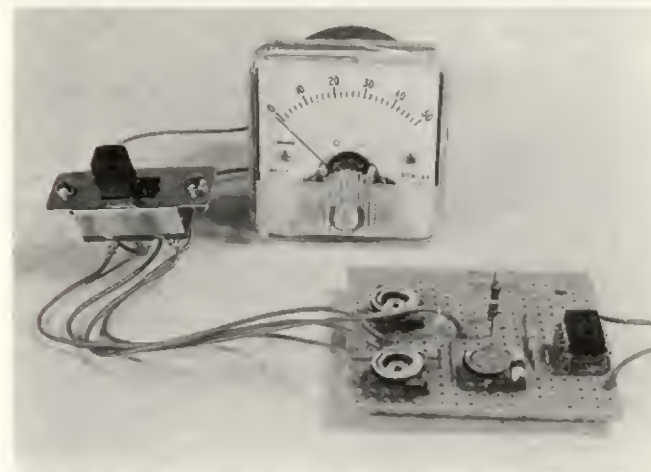


Figure 3.1
Electronic thermometer

remotely from the rest of the circuitry. Thus, for example, it is possible to monitor the temperature in an outbuilding such as a greenhouse from inside one's house.

The unit is also suitable for use in many other applications such as in photography, in heat experiments in schools, as a room temperature

thermometer, etc. It has the advantage over most mercury and alcohol thermometers of having a large easy-to-read scale. A range of 0 to 50 degrees Celsius is covered, and the temperature is displayed on a $50\mu\text{A}$ meter. The scaling is linear.

A special purpose integrated circuit is used as the basis of the unit, and this provides a very high level of performance despite the apparently simplicity.

The circuit

Fig. 3.2 shows the complete circuit diagram of the electronic thermometer, and the only active device employed in the unit is an LM3911N integrated circuit; very few discrete components are required.

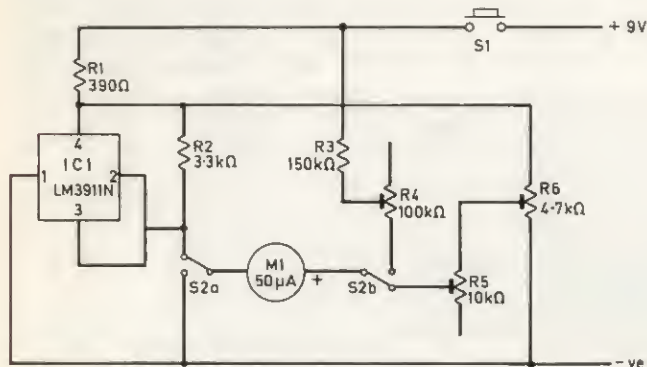


Figure 3.2
Circuit diagram

A stabilised power supply is required for the unit, and the necessary zener diode is connected between pins 1 and 4 of the LM3911N. In conjunction with R1 this provides a simple shunt stabiliser action which gives a highly stable voltage having a nominal potential of 6.8V.

The circuit is really deceptively simple as the LM3911N has quite a sophisticated internal circuit which includes a temperature sensing section. This operates by virtue of the fact that the voltage across a forward biased silicon diode reduces with increasing temperature by a couple of millivolts or so per degree Celsius. Actually the diode is the base emitter junction of a transistor, and there are two sensing circuits operating at different currents. The two outputs are compared and the

differential voltage is amplified to produce an output voltage change of 10mV per degree C. The i.c. operates over a temperature range of -25 to $+85^\circ\text{C}$ with a tracking linearity of 0.5%.

An operational amplifier is incorporated in the device and the non-inverting input of this connects to the output of the temperature sensing circuit. The inverting input and output of the operational amplifier are available at pins 2 and 3 of the device, but in this case these are simply wired together so that the operational amplifier provides unity gain buffering. No voltage amplification is required since over a range of 0 to 50 degrees Celsius the LM3911N will provide an output voltage swing of 500mV (50 degrees \times 10mV per degree) which is more than adequate to produce full scale deflection of any normal $50\mu\text{A}$ meter. The internal operational amplifier of the i.c. has an open collector output and so an external load resistor must be provided. This is R2.

R6 is adjusted so that the voltage at its slider is the same as the voltage produced at the output of the i.c. when it is at a temperature of zero $^\circ\text{C}$. There is then no voltage developed across the meter circuit and the meter reads zero in consequence. R5 is adjusted to give the meter circuit a sensitivity of 500mV f.s.d. Therefore, if the i.c. is raised to a temperature of 50°C , the voltage at the output will decrease by 500mV. This will cause a voltage of 500mV to be developed across the meter circuit and will produce a reading of 50 on the meter. Intermediate temperatures will give intermediate readings on the meter.

Of course, although the meter scale is marked in terms of micro-amperes, the number indicated by the meter also corresponds to the temperature of the i.c. sensing circuit in degrees Celsius, and there is no need to recalibrate the meter. S2 enables the meter to be used as a 0 to 10 voltmeter with which the battery voltage can be checked. It is important that the unit should not be used with a battery having a voltage which has fallen to much less than 8V. If this is done there may be insufficient supply voltage to operate the stabilisation circuit properly, and only a minute drop in this voltage is needed to produce wildly inaccurate readings. R4 enables the sensitivity of the voltmeter circuit to be varied so that the unit can be accurately calibrated against a multimeter.

A pushbutton switch of the non-locking type is used to provide on/off switching as presumably in most applications the unit will not be needed to provide continuous monitoring. With this method S1 is operated when a reading is required, and then released once a reading has been taken. In this way there is a minimum of battery drain. S1 can be replaced by an ordinary slider or toggle switch if preferred. The current consumption of the unit is approximately 6mA from a 9V supply, but the current consumption varies greatly with changes in supply potential owing to the use of a shunt regulator circuit.

Construction

A suitable 0.1in matrix stripboard layout for the unit is provided in Fig. 3.3. The panel has 17 copper strips by 19 holes and once a suitable board has been cut out, the two 3.2mm diameter mounting holes and the five link breaks in the copper strips are made. The components and the two link wires can then be soldered into position.

Construction should be quite straightforward mechanically, apart, perhaps, from the mounting of the meter. This usually requires a large

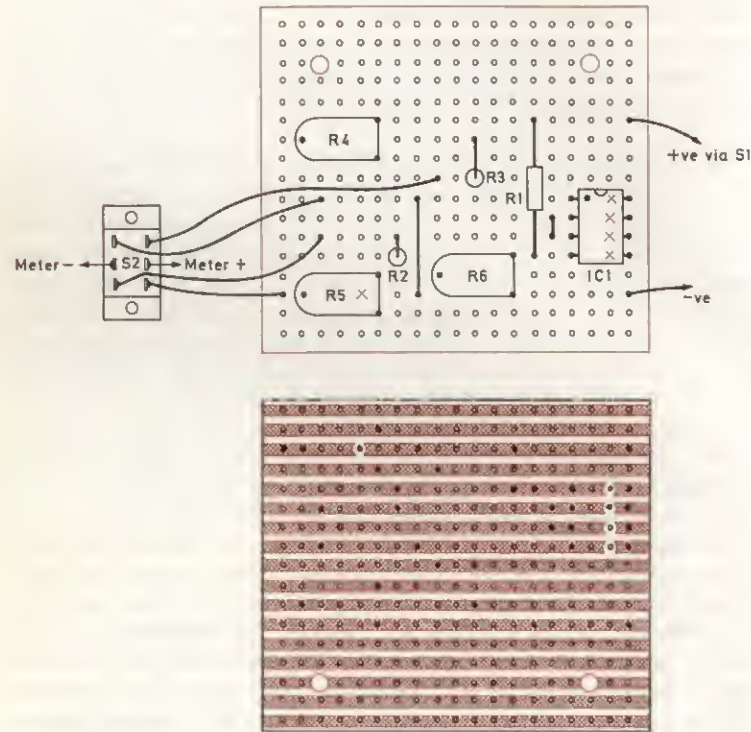


Figure 3.3

Top and underside views of the board

central cutout and four small holes for the threaded rods which take the mounting nuts. It is probably easiest to make the large cutout first using either a fretsaw or a small round file, and then locate the positions of the smaller holes using the meter as a sort of template. The four holes can then be drilled and the meter mounted in position.

The unit will work using any normal 50 μ A moving coil meter, and the accuracy of the unit fully justifies the use of a large meter.

Adjustment

Ideally the unit should be calibrated by bringing the temperature of the i.c. to 0°C and then adjusting R6 to zero the meter. The i.c. should then be raised to a temperature of 50°C or some other known temperature which represents something approaching f.s.d. of the meter, and then R5 is adjusted to produce the appropriate reading on the meter. The procedure should be repeated once or twice to check that the calibration is accurate.

In practice this may not be easy to carry out unless the i.c. is housed in a waterproof probe of some kind. This is quite feasible, and there is no need to mount the i.c. on the component panel. It can be mounted in a probe and connected to the component panel via a 3-way cable. This cable may be quite long if necessary, but if it is more than a few metres long it would probably be best to use twin screened cable (with twin or common screening) with the negative supply line connecting to the outer braiding(s) and the positive supply line and output being carried by the inner conductors.

A suitable probe can consist simply of a small test tube, or something similar, into which the i.c. is fitted. It is advisable to use silicon grease or a substitute to fill the gaps around the i.c. so that there is a good thermal contact between the outside of the test tube and the temperature sensing circuit inside the i.c.

With the i.c. mounted in a probe it is an easy matter to bring the i.c. to 0°C. If some ice cubes are stirred into some water until no more will dissolve, the water will be at almost exactly the right temperature (any error will be too small to be of significance). Some warmed water of known temperature can be used to provide the higher calibration point.

If the i.c. is not mounted in a probe, then the same basic method can be used. Two environments of significantly different temperature are required, and their precise temperatures must be known. First the unit is placed in the colder environment and allowed to adjust to its temperature, then R6 is adjusted to produce the appropriate reading on the meter. Next the unit is placed in the warmer environment and after it has adjusted to the new conditions, R5 is adjusted to produce the correct reading on the meter. This procedure is repeated until no further adjustment is necessary.

It is a good idea to solder a heat fin onto pins 5 to 8 of the i.c. as it is these pins which conduct the outside temperature to the sensing circuit. A heatfin will help to pick-up the heat in the outside environment and conduct it to the chip, or pick up the small amount

of heat generated by the chip and disperse it, as appropriate. This will provide more reliable readings and will help the unit to respond more rapidly to temperature changes. A heatfin can simply consist of a small piece of copper plate or copper laminate board.

Components list for the electronic thermometer

Resistors

| | |
|----|---|
| R1 | 390 Ω miniature $\frac{1}{4}$ W, 5% |
| R2 | 3.3k Ω miniature $\frac{1}{4}$ W, 5% |
| R3 | 150k Ω miniature $\frac{1}{4}$ W, 5% |
| R4 | 100k Ω subminiature (0.1W) horizontal preset |
| R5 | 10k Ω subminiature (0.1W) horizontal preset |
| R6 | 4.7k Ω subminiature (0.1W) horizontal preset |

Semiconductor

| | |
|-----|-----------------------------|
| IC1 | LM3911N (8 pin D1L package) |
|-----|-----------------------------|

Switches

| | |
|----|---|
| S1 | push-to-make release-to-break pushbutton type |
| S2 | D.P.D.T. slider switch |

Meter

| | |
|----|---|
| M1 | 50 μ A moving coil panel meter (any desired size) |
|----|---|

Miscellaneous

0.1in matrix stripboard panel
Metal or plastics case
PP3 battery and connector to suit
Wire, solder, etc.

R4 is given the correct adjustment by first carefully measuring the supply voltage using a multimeter, then switching S2 to the battery check position, and finally adjusting R4 for the correct meter reading. S1 should be depressed when measuring the supply voltage using the multimeter and while adjusting R4.

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.

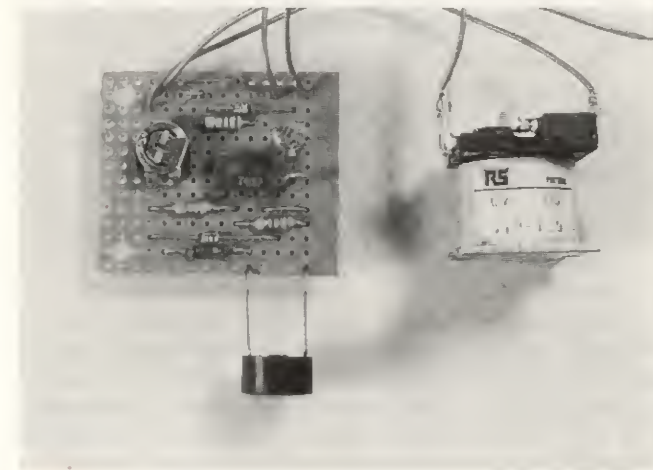


Figure 4.1

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

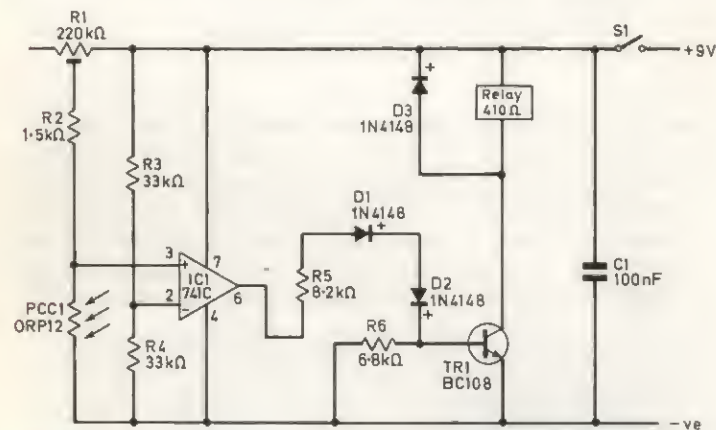


Figure 4.2
Circuit diagram of the switch

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 diameter 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

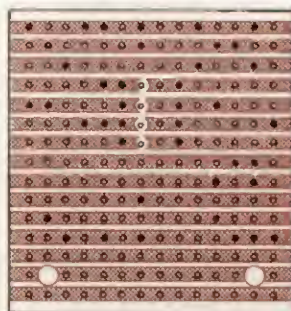
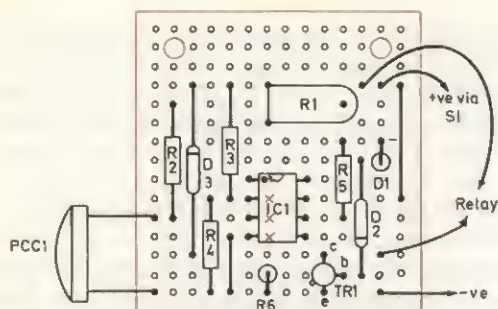


Figure 4.3
Details of the 0.1 in pitch strip board

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.

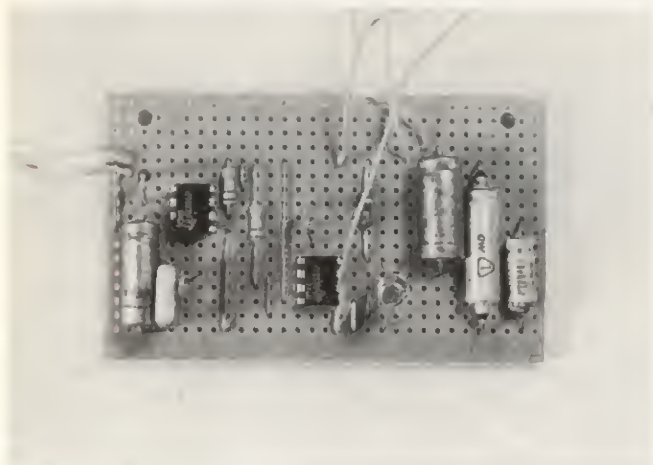


Figure 5.1

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.

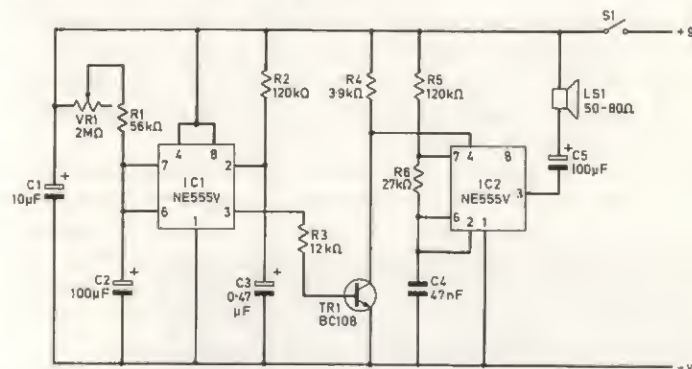


Figure 5.2

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 $3\frac{1}{2}$ 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

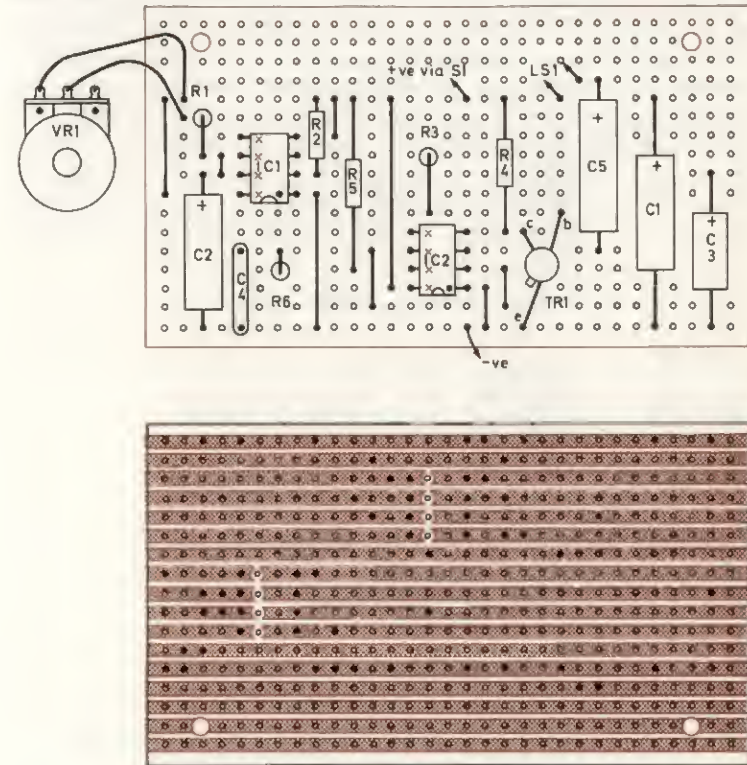


Figure 5.3
Board layout

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

Components list for the timer unit with audio alarm

Resistors (all miniature 1/4W, 5%)

| | |
|-----|---|
| R1 | 56k Ω |
| R2 | 120k Ω |
| R3 | 12k Ω |
| R4 | 3.9k Ω |
| R5 | 120k Ω |
| R6 | 27k Ω |
| VR1 | 2M Ω (or 2.2M Ω) lin. carbon |

Capacitors

| | |
|----|------------------|
| C1 | 10 μ F 10V |
| C2 | 100 μ F 10V |
| C3 | 0.47 μ F 10V |
| C4 | 47nF type C280 |
| C5 | 100 μ F 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 80 Ω impedance |
|-----|--|

Miscellaneous

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

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

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.

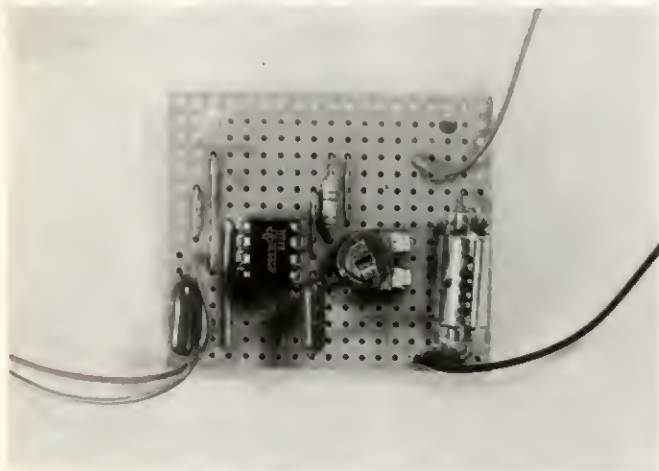


Figure 6.1
Ultrasonic transmitter

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

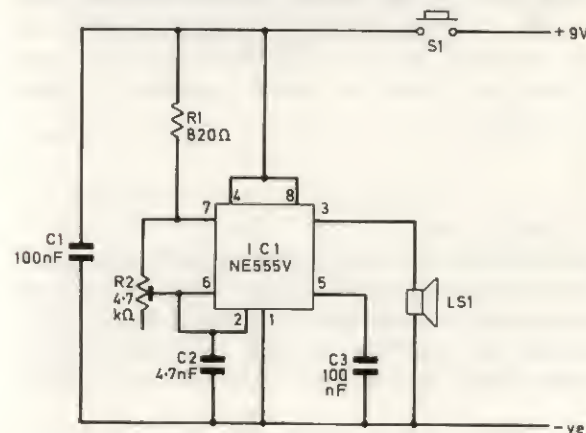


Figure 6.2
Circuit schematic

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

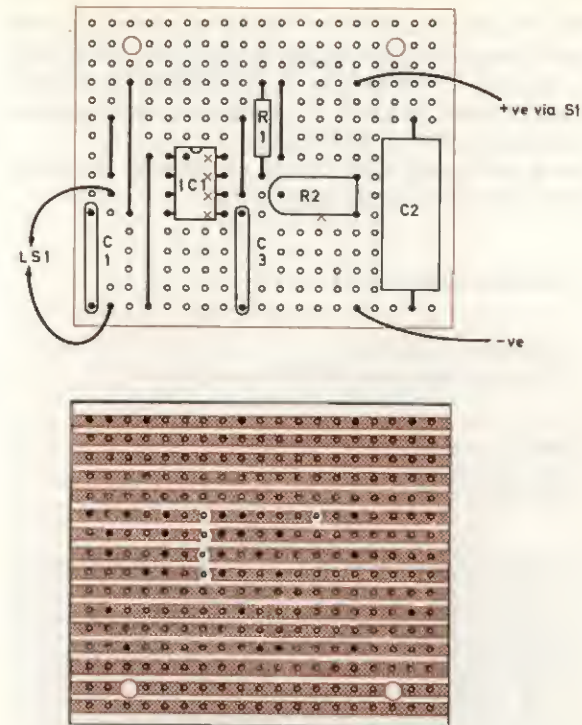


Figure 6.3

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 | 820 Ω miniature 1/4W, 5% |
| R2 | 4.7k Ω 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

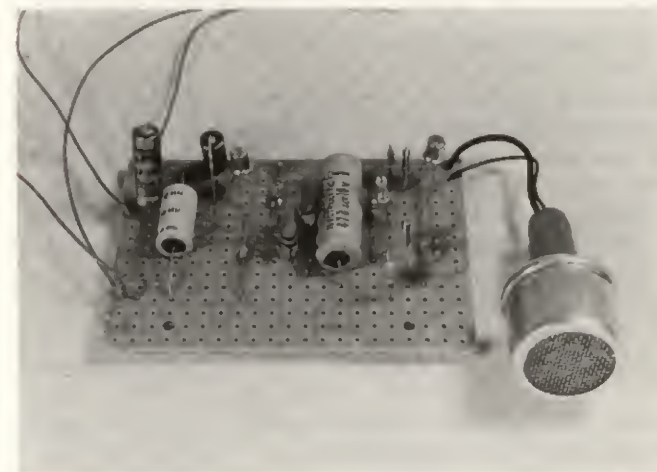


Figure 7.1
Ultrasonic receiver

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

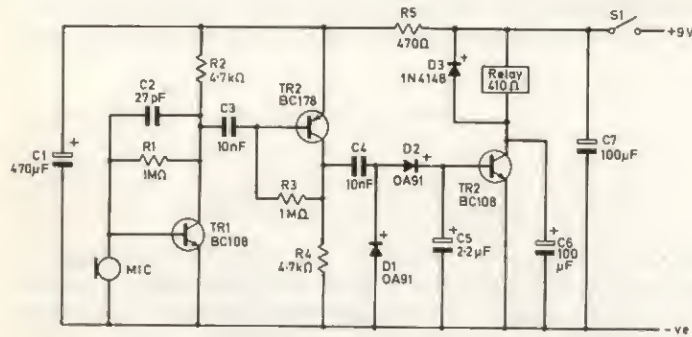


Figure 7.2
Circuit schematic for the ultrasonic receiver

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

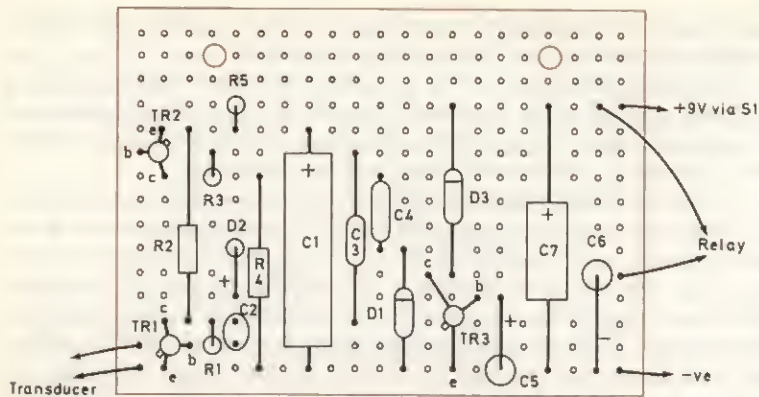


Figure 7.3

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.

8

Telephone Repeater

This is a project which, although of general use around the house, is especially useful to have in a workshop. It is a device which will pick up the sound of a telephone ringing and relay it to some remote part of a house or to an outbuilding. This avoids the telephone call being missed because one happens to be well away from the telephone, or in a fairly noisy environment. Since many workshops are situated in outbuildings and tend to have fairly high ambient noise levels, a unit of this type is especially useful.

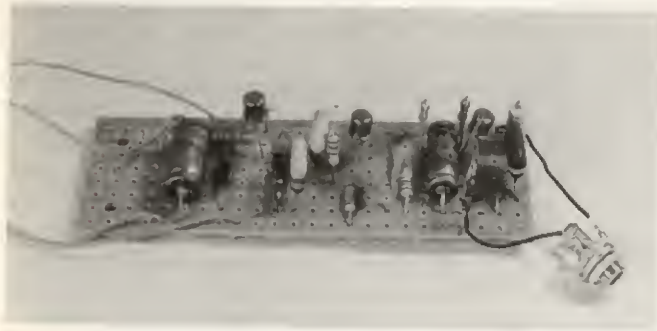


Figure 8.1
Telephone repeater

The unit may also be of great benefit to someone who is hard of hearing, and could easily not hear the sound of a telephone ringing.

At first sight it might seem to be a better idea to simply connect a tone generator or bell direct to the telephone, rather than go to the bother of using a microphone to pick up the sound of the bell and feed an amplifier and speaker combination. Indeed, this is the case, but it must be borne in mind that it is an offence to make any unauthorised

connection to a Post Office telephone, and so the system used here must be adopted.

One slight advantage of this system is that it is convenient to use and set up due to the fact that there is no need to make a direct connection to the telephone. Also, the unit can be used to simultaneously monitor a doorbell and a telephone provided the two are situated reasonably close together.

The circuit

The complete circuit diagram of the Telephone Repeater appears in Fig. 8.2. Basically this consists of a high gain amplifier which drives a loudspeaker. However, the unit is designed to have only a very low

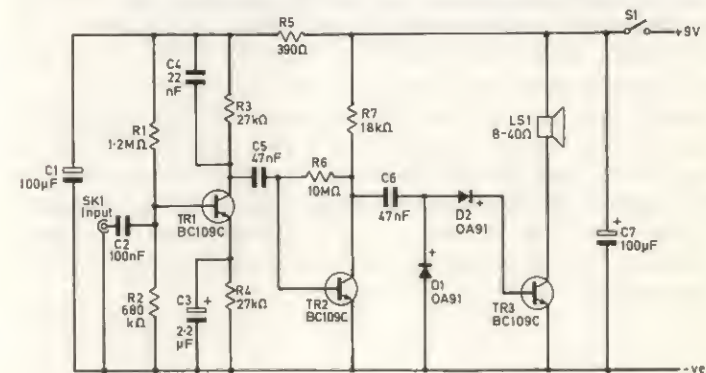


Figure 8.2
Circuit of the telephone repeater

quiescent current consumption so that it may be run economically from batteries, despite the fact that in practice it is likely to be left switched on for quite long periods.

TR1 is the active device employed in the preamplifier stage and this transistor is used in the common emitter mode. Base biasing is provided by R1 and R2 while R4 and C3 are the emitter bias resistor and bypass capacitor respectively. R3 is the collector load for TR1. This stage operates at a low collector current of only about $100\mu\text{A}$, and this is done in order to provide a low noise level and to minimise battery drain. C4 is an r.f. filter capacitor which is needed in order to prevent problems due to radio interference and breakthrough. C2 provides d.c. blocking at the input.

The output from TR1 is fed to a second common emitter amplifier via C5. TR2 is used as the basis of the second amplifier stage, and R7 acts as its collector load and R6 as its bias resistor. This stage operates at a slightly higher collector current than TR1, the actual operating current being something in the region of $500\mu\text{A}$. This is necessary to produce higher gain and a greater output drive capability.

In order to provide a low quiescent current a class B output stage is obviously called for as the high standby current of a class A stage makes it totally unsuitable. A normal complementary output stage would be the obvious type to use, but a more simple method can be used. High fidelity amplification is not needed here as the purpose of the unit is simply to provide an audio signal of some kind. Therefore a simple single transistor class B output stage may be used, and the fact that the signal from the loudspeaker will be rectified and greatly distorted is of no consequence in this instance.

The output from TR2 is fed to a rectifier circuit by C6, and the positive going pulses produced by D1 and D2 are used to switch on TR1 and produce pulses of current in its collector circuit. These are applied to the loudspeaker and an audio output signal is produced.

The supply lines need to be well decoupled and this function is carried out by C1, R5 and C7. S1 is the on/off switch. Although in theory no current flows through the output transistor under quiescent conditions, in practice a small current may flow here due to noise and stray pick up by the microphone causing TR3 to be turned on to some extent. However, the total quiescent current consumption of the unit is typically less than 1mA from a 9V supply.

Construction

All the small components are accommodated on a small 0.15in pitch stripboard panel and are positioned as detailed in Fig. 8.3. Begin by cutting out a board having 8 copper strips by 24 holes and then drill the two 3.2mm diameter mounting holes and make the ten breaks in the copper strips. The components are then soldered into position.

S1, SK1 and the loudspeaker are all mounted on the front panel at any convenient points which provide a reasonably neat and tidy appearance. SK1 can conveniently be a 3.5mm jack socket, but any preferred type (DIN, phono, etc.), should also be suitable. Loudspeaker mounting has been described in earlier projects, and will not be repeated here.

Once the components for front panel mounting have been installed in the case the point to point wiring can be completed and then the component panel is mounted inside the case using M3 or 6BA mounting screws and nuts. Although the input of the unit is very sensitive it is not

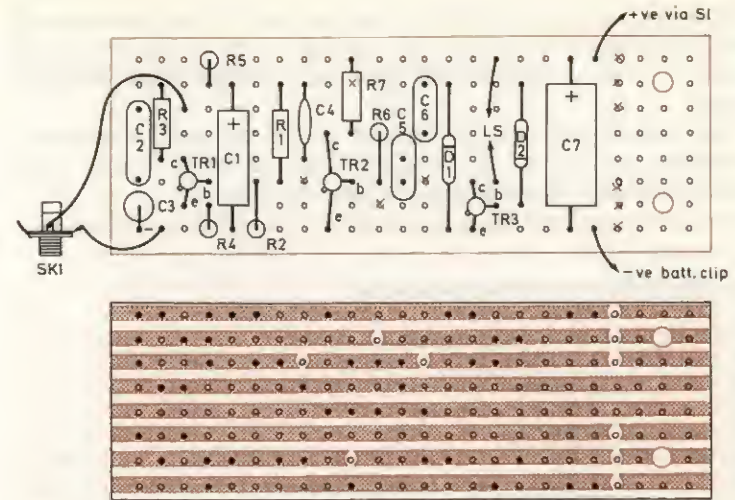


Figure 8.3
Strip board layout

necessary to use a screened cable to connect SK1 to the component panel.

Using the unit

A low impedance dynamic microphone can be used with the unit, and an inexpensive type (such as those used with cheaper cassette recorders) is perfectly adequate. Some of these have two plugs, a 3.5mm one and a 2.5mm one. Both will need to be cut off so that the microphone can be connected to an extension cable. The wiring to the 2.5mm jack plug, if fitted, is concerned with the remote control switch on the microphone and this wiring may be ignored. The extension cable can be several metres long if necessary, but it must be made from screened lead. The outer braiding connects to the negative supply rail of the repeater circuit and the inner connector goes to C2.

The circuit is very sensitive and it should be possible to obtain good results even with the microphone a metre or two away from the telephone.

Low, medium and high impedance loudspeakers seem to work quite well as the microphone for this unit, but these provide lower sensitivity than a proper microphone, particularly low impedance loudspeakers. However, they provide a perfectly adequate output level provided they

are placed on or very close to the telephone, and if a low impedance (2 to 8 Ω) loudspeaker is used it is not necessary to use a screened cable to connect the microphone to the main unit. Ordinary bell wire will suffice.

Note that the unit may be unstable if it is switched on without a microphone connected to SK1, but the instability should cease completely when a microphone is connected to the unit.

Note: A crystal microphone is unsuitable for use with this device.

Components list for the telephone repeater

Resistors (all miniature 1/4W, 5 or 10%)

| | |
|----|---------------|
| R1 | 1.2M Ω |
| R2 | 680k Ω |
| R3 | 27k Ω |
| R4 | 27k Ω |
| R5 | 390 Ω |
| R6 | 10M Ω |
| R7 | 18k Ω |

Capacitors

| | |
|----|---------------------|
| C1 | 100 μ F, 10V |
| C2 | 100nF type C280 |
| C3 | 2.2 μ F, 10V |
| C4 | 22nF, ceramic plate |
| C5 | 47nF, type C280 |
| C6 | 47nF, type C280 |
| C7 | 100 μ F, 10V |

Semiconductors

| | |
|-----|--------|
| TR1 | BC109C |
| TR2 | BC109C |
| TR3 | BC109C |
| D1 | OA91 |
| D2 | OA91 |

Switch

| | |
|----|----------------------|
| S1 | S.P.S.T. toggle type |
|----|----------------------|

Loudspeaker

| | |
|-----|---|
| LS1 | Miniature loudspeaker having an impedance of about 8 to 40 Ω |
|-----|---|

Miscellaneous

Case, speaker fret, etc.
 0.15in matrix stripboard panel
 3.5mm jack socket (SK1)
 PP3 battery and connector to suit
 Low impedance dynamic microphone (cassette type)
 Wire, solder, etc.

9

Telephone Amplifier

A telephone amplifier can provide very worthwhile advantages, the main one being that it enables more than one person to hear the conversation. Another advantage is the added volume which it provides and which can make a poor connection much more easily understood.

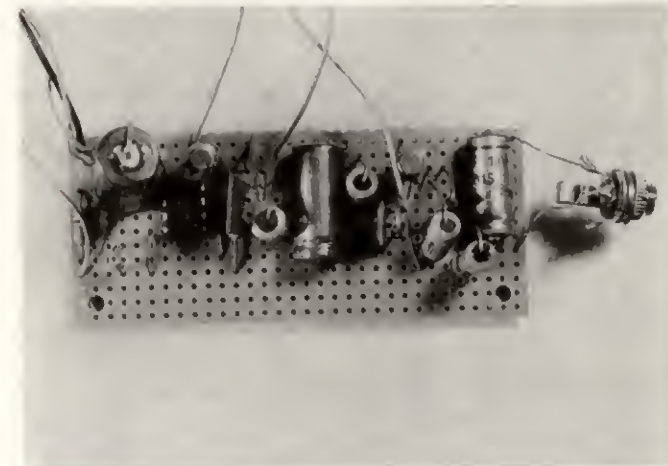


Figure 9.1
Telephone amplifier layout

Extra volume can also be of advantage if the telephone is situated in a noisy environment, such as a factory or workshop.

As was mentioned in the previous section of this book, it is illegal to make a direct unauthorised connection to a Post Office telephone, and this obviously makes it rather difficult to obtain a suitable signal for a telephone amplifier. The obvious method would be to place a

microphone close to the earpiece of the telephone, and then amplify this signal. However, this is likely to produce a rather poor quality output and would probably be rather inconvenient to use in practice.

The more usual way of obtaining a signal is to use an inductor placed near the base part of the telephone. Normal telephones contain inductive components which radiate the signal in the form of magnetic waves. These will induce small electrical signals into any coil which is placed near the telephone, and in this way it is possible to obtain a suitable signal.

Of course, a considerable amount of amplification is needed to boost the small signals from the pick up coil to a sufficiently high level to drive a loudspeaker, but the necessary gain can be achieved reasonably simply using modern components and circuitry.

The circuit

The complete circuit diagram of the Telephone Amplifier appears in Fig. 9.2.

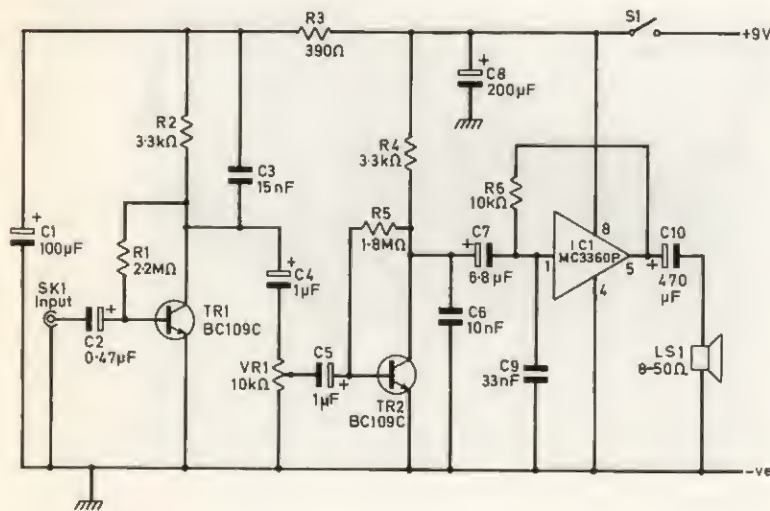


Figure 9.2

Circuit diagram of the telephone amplifier

The input signal is applied to the base of TR1 via d.c. blocking capacitor C2. TR1 is used as a high gain common emitter amplifier which has R2 as its collector load resistor and R1 as the base bias resistor. C3 provides high frequency attenuation and this helps to

maintain the stability of the circuit and attenuates any r.f. signals which are induced into the pick up coil and fed into the amplifier.

C4 couples the output from TR1 to volume control VR1. From here the signal is fed to a second high gain common emitter amplifier by way of C5. This stage is basically the same as the first stage of amplification, and its output is fed to the i.c. audio power amplifier.

The latter is based on IC1, and this is quite a simple audio power amplifier i.c. It consists of a common emitter driver stage followed by a complementary emitter follower output stage. The necessary circuitry to provide a small quiescent current through the output transistors (to minimise cross over distortion) is incorporated in the i.c., but overall biasing of the amplifier is not, this is provided by discrete resistor R6. C7 and C10 provide d.c. blocking at the input and output respectively. C6 and C9 are used to reduce the high frequency response of the circuit in order to ensure good stability and minimise breakthrough of strong radio signals.

Supply decoupling is provided by C1, R3 and C8. S1 is the on/off switch and this can be ganged with VR1 if desired. The quiescent current consumption is typically only a little in excess of 5mA from a 9V supply, but the MC3360P i.c. has a class B output stage and the current consumption rises to about 40mA or so at high volume levels. Ideally the loudspeaker should have an impedance of 16Ω, and the maximum available output power is then about 300mW.

Unfortunately, 16Ω loudspeakers are not very widely available, but in practice the circuit will work well using an 8Ω speaker. Higher impedance loudspeakers are also quite suitable, but their use will result in a loss of maximum available output power. It is not advisable to use a loudspeaker having an impedance of less than 8 ohms.

Construction

All the small components are wired up on a 0.1in pitch stripboard panel which has 13 copper strips by 32 holes using the component layout illustrated in Fig. 9.3. After cutting out a panel of the specified size, the two 3.2mm diameter mounting holes are drilled and the eight breaks in the copper strips are made. The latter can be made using a small drill bit, say about 4mm in diameter, held in the hand, if the special spot face cutter tool is not to hand. The various components and the three link wires are then soldered into position. As the layout is quite compact it is necessary to take great care not to bridge adjacent copper strips with minute blobs of excess solder, and it is a good idea to check the finished board for such short circuits using a continuity tester.

SK1 is a 3.5mm jack socket and this is mounted on the front panel of the case together with S1, VR1 and LS1. The remaining wiring can

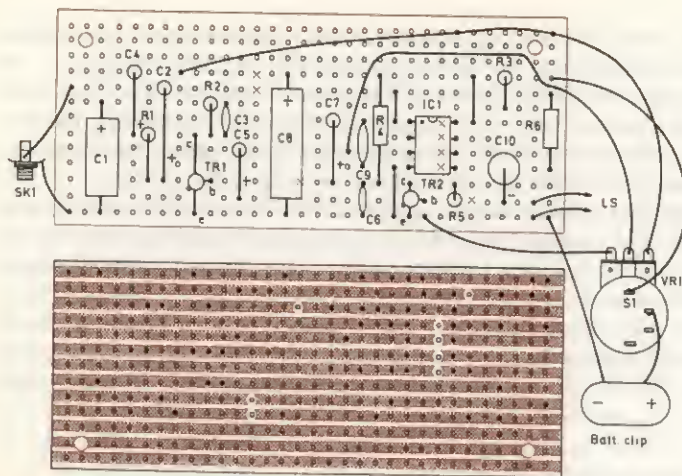


Figure 9.3
Strip board layout of the amplifier

then be completed and finally the component panel is mounted in the case using M3 or 6BA nuts and screws.

Using the unit

When the unit is switched on and VR1 is advanced, there should be quite a high background noise level. If there is not, switch off at once and thoroughly check all the wiring. If a multimeter is available, this can be used to locate the faulty stage or stages. With the unit switched on once again there should be approximately half the supply voltage at TR1 collector, TR2 collector, and IC1 pin 5. Any great departure from such a voltage indicates that there is an error in the wiring to the appropriate stage.

There should be a large reduction in the background noise level when the pickup coil is plugged into SK1. Specially made pickup coils may be obtained, although they are not widely available. These have a rubber sucker which enables them to be secured to the base of the telephone.

An alternative is a ferrite cored r.f. choke having a value of about 5 to 10mH; the exact value is not critical, but should not be much less than about 5mH. This is connected to the telephone amplifier by a piece of screened cable about 1 metre long which is terminated in a 3.5mm jack plug. Make sure the connections to the jack plug are the right way round, with the outer braiding of the cable connecting to the

negative supply rail of the amplifier. For neatness the pickup choke may be mounted in a small plastics (not metal) box.

The pickup must be placed in the position which provides the best signal, and this can only be found with a little experimentation. With an ordinary telephone of the type currently fitted by the Post Office the best pickup point for the coil will probably be somewhere along the

Components list for the telephone amplifier

Resistors (all miniature ¼W, 5 or 10%)

| | |
|-----|---|
| R1 | 2.2M Ω |
| R2 | 3.3k Ω |
| R3 | 390 Ω |
| R4 | 3.3k Ω |
| R5 | 1.8 Ω |
| R6 | 10k Ω |
| VR1 | 10k Ω log (may be ganged with switch S1) |

Capacitors

| | |
|-----|------------------------------------|
| C1 | 100 μ F, 10V |
| C2 | 0.47 μ F, 10V |
| C3 | 15nF, ceramic plate |
| C4 | 1 μ F, 10V |
| C5 | 1 μ F, 10V |
| C6 | 10nF, ceramic plate |
| C7 | 6.8 μ F, 10V |
| C8 | 200 μ F, (or 220 μ F), 10V |
| C9 | 33nF, ceramic plate |
| C10 | 470 μ F, 10V |

Semiconductors

| | |
|-----|---------|
| TR1 | BC109C |
| TR2 | BC109C |
| IC1 | MC3360P |

Loudspeaker

Miniature type having an impedance of about 8 to 50 Ω

Miscellaneous

Case, speaker fret, etc.
Control knob
0.1in matrix stripboard panel
PP6 battery and connector to suit
3.5mm jack socket (SK1)
Telephone pickup coil (see text)
Wire, solder etc.

right hand side of the telephone base. For a Trimphone the best position for the pickup coil is towards the rear of the telephone base on the left hand side.

The equipment is sensitive to any a.f. magnetic field, and so there may be a certain amount of stray pick-up from mains wiring. If this

should occur to a significant degree it should be possible to minimise it by altering the orientation of the pickup coil and (or) the position of the telephone base.

It is quite likely that a howling sound will be produced if the volume control is fully advanced with the telephone handset at all close to the loudspeaker. This is due to acoustic feedback between the loudspeaker in the amplifier unit and the microphone in the handset, and can be avoided by keeping the two reasonably far apart.

It is worth noting that a sensitive amplifier of this type is suitable for uses other than as a telephone amplifier. It can, for example, be used as a baby alarm if a low impedance dynamic microphone (the type used with cassette recorders) is connected to SK1 instead of the pickup coil.

10

NiCad Battery Charger

Ordinary dry cell batteries can be rather expensive for long term use in equipment which has a fairly high current consumption, such as portable cassette recorders and electronic flashguns, and there is also the bother of frequently having to replace exhausted batteries. Nickel cadmium (NiCad) cells have a rather high initial cost, but they are

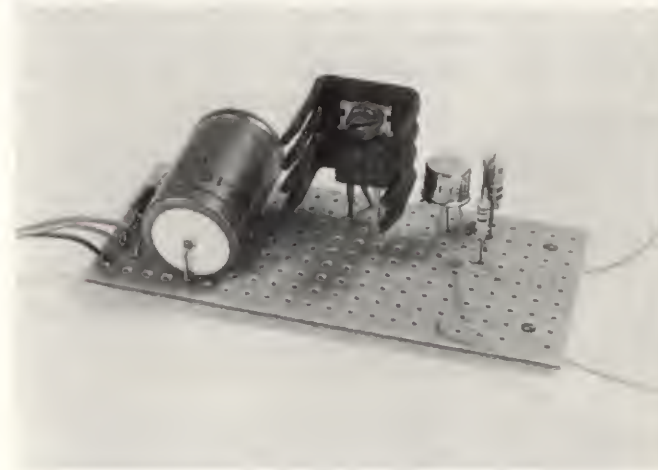


Figure 10.1
NiCad battery charger

rechargeable and have an extremely long lifespan. This makes them economically quite attractive in the long term, especially if one builds one's own charger unit at low cost.

The charger described here is designed for charging up to about six AA size NiCad cells (these are equivalent to HP7 cells in size). However,

it can easily be modified to charge other sizes of battery, as will be explained more fully later on.

NiCad cells have a rather low internal resistance which is an advantage in that it enables them to supply quite high currents, but is a disadvantage in that it slightly complicates the recharging of these cells. Due to the low cell impedance the charger needs to have only a slightly higher output voltage than the cells in order to produce a very high charge current. Usually NiCad cells must not be charged at high currents as this would result in a greatly reduced life. AA size cells have a recommended charge current of about 50mA and require a charge time of about 15 hours in order to recharge a cell that has become completely discharged. The precise figures actually vary slightly from one cell manufacturer to another, but are not really critical.

The circuit

The complete circuit diagram of the NiCad Battery Charger is provided in Fig. 10.2. The mains supply is connected direct to the primary of mains isolation and step down transformer T1, and no on/off switch

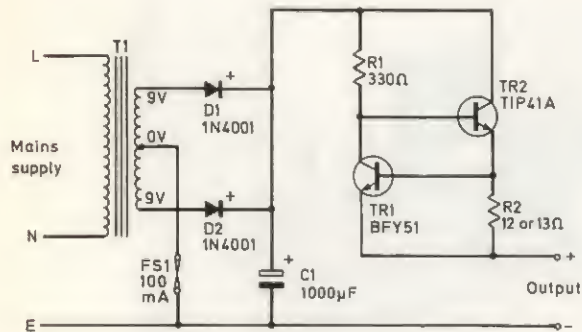


Figure 10.2
Battery charger circuit

is used as the unit will presumably be disconnected from the mains when it is not in use. The output from the secondary of T1 is fullwave rectified by D1 and D2 and the resultant rough d.c. is smoothed to some degree by C1.

A current limiter circuit of quite conventional design is connected in series with the output and ensures that the output current is approximately the required level. The current limiter employs TR1, TR2, R1 and R2, and it works in the following manner.

TR2 is used in the emitter follower mode and is biased hard on by R1. With a battery connected across the output a fairly high output current therefore attempts to flow from the charger. This current develops a voltage across R2 as this component is connected in series with the output, but the voltage across this component will rise only to about 0.65V. When this voltage is reached, TR1 is turned on and it taps off some of the base current of TR2 down to the negative supply rail through the load.

Even if a short circuit is placed on the output, the voltage across R2 will not exceed more than about 0.65V as the base of TR2 would be virtually short circuited to earth through TR1, and the output voltage would be little more than zero.

From Ohm's law it is easy to see that the output current is equal to 0.65V divided by R2 in ohms. A 13Ω resistor in the R2 position gives the required current of 50mA (in theory anyway), and the more readily available value of 12Ω gives a theoretical current of just over 54mA, which should also be perfectly suitable in practice. Of course, due to component tolerances etc. the actual output current of a circuit built to this design may be as much as several per cent different to the calculated output current, but this is of no real consequence as the charge currents of NiCad cells are not highly critical.

Fuse FS1 protects the charger and NiCad cells against passing an excessive output current if the current limit circuit should fail for any reason.

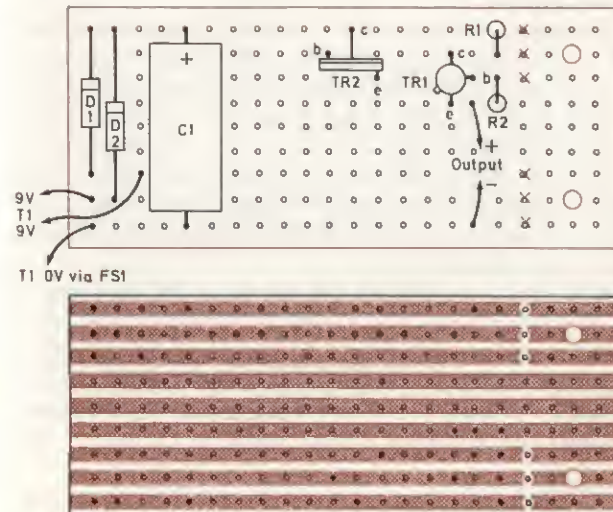


Figure 10.3
0.15 in strip board layout

Construction

A suitable 0.15in matrix stripboard layout for the unit is shown in Fig. 10.3. This accommodates all the components except T1 and FS1. The latter is mounted in a chassis fixing fuse holder which is bolted to the bottom of the case. T1 is also bolted to the base of the case. The output sockets, which may be wander types, are mounted on the front panel of the case and a hole for the mains lead must be made in the rear of the case. This hole should be fitted with a grommet to protect the lead if a metal or hard plastics case is used.

The point to point wiring is then completed before the component panel is finally mounted at the bottom of the cabinet. The mains earth lead connects to the negative output socket, and if a metal case is used this must also be earthed.

Using the charger

Battery clip leads to fit AA type cells are not available, but suitable battery holders are. These holders are available for various numbers of cells, and they are fitted with a battery clip of the same type and size used on PP3 and PP6 batteries. By mounting the cells in such a holder it is therefore possible to make the connection between the charger and the cells using a PP3 type battery connector having its leadout wires terminated in wander plugs.

If a holder for the appropriate number of cells is not available either unused positions in the holder can be bypassed using a shorting lead, or a couple of holders may be connected in series, whichever the situation dictates. Make absolutely certain that the charger is connected to the cells with the correct polarity (positive to positive and negative to negative). Also make sure that the cells are not forgotten and accidentally charged for much longer than is necessary, since the charger will continue to force current into the cells once they have become fully charged, and this is best avoided.

It is an easy matter to modify the unit to provide a different charge current, and the principal change is to the value of R2. The theoretical value of this component is equal to 0.65 divided by the required charge current in amperes, and this gives the answer in ohms. The theoretical value will not always coincide with a preferred value, and it is then necessary to choose the preferred value which is closest to the calculated one.

A few other points must be kept in mind if the unit is being used to provide a charge current of much more than about 50mA, or is being used to charge a large number of cells. T1 must have a rating which enables it to provide at least the required charge current, and it must

be capable of producing a loaded voltage which is two or three volts more than that of the fully charged cells in series (when charging more than one cell they are always connected in series and not in parallel). The rating of FS1 must be suitably increased for charge currents of more than 100mA.

If the unit is used to charge fairly large cells such as the C (HP11) or D (HP2) types, the higher charge currents required will result in increased dissipation in TR2. This will probably necessitate the fitting of a small commercial bolt-on type heatsink, and the component panel has been designed to accommodate such a heatsink. If the transformer supplies a loaded voltage which is considerably higher than the total cell voltage it may even be necessary to mount TR2 away from the component panel on a more substantial heatsink in order to prevent this device from overheating.

Components list for the Ni-Cad battery charger

Resistors (both ½W, 5%)

| | |
|----|----------------------|
| R1 | 330Ω |
| R2 | 12 or 13Ω (see text) |

Capacitor

| | |
|----|-------------|
| C1 | 1000μF, 16V |
|----|-------------|

Semiconductors

| | |
|-----|--------|
| TR1 | BFY51 |
| TR2 | TIP41A |
| D1 | 1N4001 |
| D2 | 1N4001 |

Fuse

| | |
|-----|------------------|
| FS1 | 100mA, 20mm fuse |
|-----|------------------|

Transformer

| | |
|----|--|
| T1 | Standard mains primary, 9 – 0 – 9V at 100mA secondary (see text) |
|----|--|

Miscellaneous

Case
0.15in pitch stripboard panel
Heatsink for TR2
Chassis mounting 20mm fuseholder
Output sockets and connecting leads
Mains lead, plug, wire, solder, etc.

Mains/9 Volt Adapter

In the previous section of this book a charger for NiCad cells was described, and together with the appropriate batteries this can provide a low cost method of powering battery operated equipment in the long term. However, if portability is not of prime importance, a much cheaper method of powering battery operated equipment is via a mains adaptor.

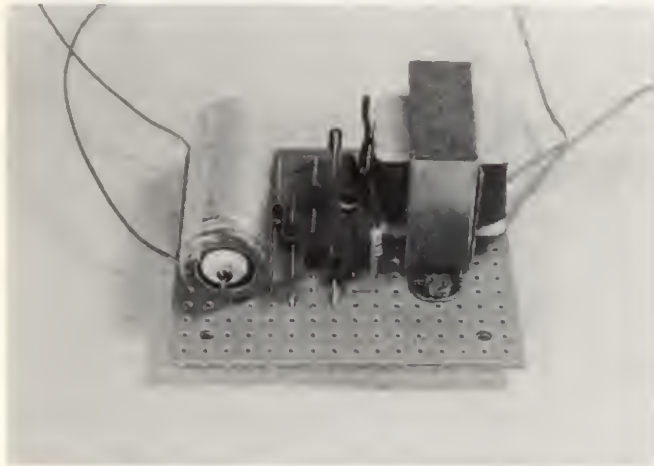


Figure 11.1
Mains/9V adapter

Units of this type consume only about 1W of power and thus have a negligible running cost of only about 1p per 400 hours use. The initial component cost is not very high and is soon recouped in saved battery costs.

This adapter can be constructed either as a separate unit which plugs into the main equipment, or as a compact assembly which fits inside the battery compartment of the powered equipment. The second method is only really practicable if the equipment takes a fairly large battery such as a PP9, but is the more convenient solution. In either case there is no loss of portability in that the equipment can still be battery powered if this should be desired at some future time.

The unit supplies a well smoothed and regulated 9V supply at a maximum current of 100mA. It is suitable for powering most 9V battery equipment such as transistor radios, signal generators, etc. There are several projects in this book which it could be used to power, such as the 'Auto Turn On/Off Switch' and the 'Rain/Water Level Alarm'. It is not suitable for powering cassette recorders and other items of equipment which have a fairly high current consumption.

A unit of this type is very useful to have around an electronics workshop when building or testing small battery operated apparatus.

The circuit

The circuit diagram of the Mains/9 Volt Adapter is given in Fig. 11.2. The mains supply is fed to the primary winding of T1 by way of on/off switch S1. T1 provides both voltage step down and safety isolation, and

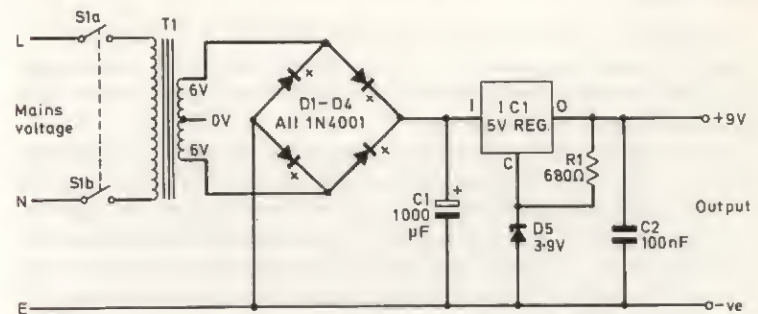


Figure 11.2
Circuit diagram of the adapter

its output is fullwave rectified by the bridge rectifier formed by D1 to D4. The pulsating d.c. output from the rectifier network is smoothed by C1.

It is virtually essential to incorporate a regulator circuit in equipment of this type since the output voltage varies over quite wide limits between no load and maximum load if no such circuit is employed. This could easily result in either an excessive voltage being

applied to the powered circuit under low load conditions, or an inadequate voltage being supplied under high load conditions, depending upon the nominal output voltage chosen.

In this circuit a monolithic i.c. voltage regulator is used, and this provides a high degree of regulation. It also provides electronic smoothing of the output which has an extremely low ripple content in consequence. The regulator incorporates output current limiting and thermal overload protection circuitry, and so the unit is not easily damaged by output short circuits.

A regulator for an output potential of 9V is not readily available and so a 5V type in a suitably modified circuit configuration is used. I.C. monolithic voltage regulators are three-terminal devices: input, output, and a common terminal. By raising the common terminal 4V above the negative supply rail potential an output of 9V can be obtained.

In this circuit the common terminal of the regulator i.c. is connected to a simple zener shunt stabiliser circuit which uses R1 and D5 and produces a potential of 3.9V. This gives a nominal output voltage of 8.9 volts, which is sufficiently close to the required figure of 9V.

C2 helps to give the circuit a good transient response and also aids its stability.

Construction

A 0 15in pitch stripboard panel which has 16 holes by 15 copper strips is used as the constructional basis of the project, and all the components are mounted on this except for the on/off switch. Fig. 11.3 shows the component layout for this panel.

T1 is mounted on the panel using a couple of short M3 or 6BA bolts with nuts. The centre tap on the secondary of T1 is unused in this particular application and so this leadout wire is cut short and is otherwise ignored. The other components are next soldered into position and care must be taken to ensure that the rectifiers, zener diode, and i.c. are all connected with the correct polarity. Also be careful not to omit the three breaks in the copper strips as this could produce a short circuit across the unregulated supply lines.

If the unit is to be constructed as a separate unit from the main equipment it can be housed in any case of adequate dimensions. The front panel is drilled to accept S1, and a hole for the output lead must be made here as well. If a metal or hard plastics case is used it is advisable to fit this hole with a grommet. A hole for the mains lead is drilled in the rear panel, and the same point also applies to this hole. If a metal case is used it should be connected to the mains earth lead for reasons of safety. The negative supply rail must also be connected to the mains earth, as shown in Fig. 11.3.

Some pieces of equipment have a power socket so that they can be connected to a battery eliminator. If this is the case, the output lead from the adapter should be fitted with a power plug of the appropriate type. If a power socket is not fitted to the equipment it should not be too difficult to add one. In either case it is essential to ensure that the adapter is connected to the main equipment with the correct polarity.

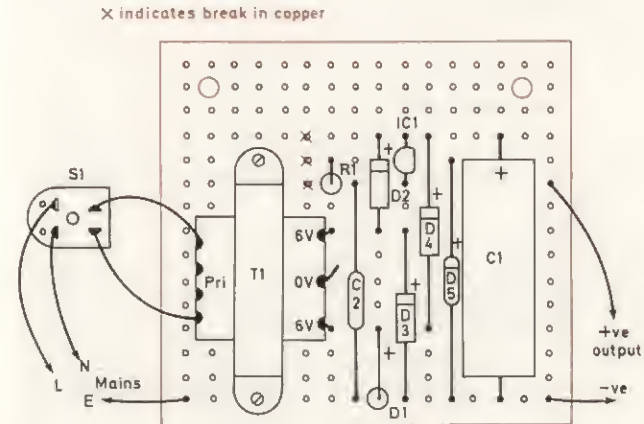


Figure 11.3
Component layout on the board

If the unit is to be fitted into the battery compartment of the main equipment it will be necessary to use one's initiative. S1 must be omitted and the L and N mains leads can be connected to the primary leads of T1 via a connector block. These are sold in 12 way lengths and a 2 way block must be cut from one of these using a sharp knife. It is recommended that the connector block is covered with several layers of insulation tape so that no mains wiring is exposed. The unit can either be switched on and off by simply plugging and unplugging it into the mains, or a better alternative is to use a switch inserted in the mains lead. Suitable switches are available from electrical shops.

It will probably be necessary to make a rough casing for the unit from hardboard, thin plywood, or sheet plastic material in order to ensure that none of the wiring comes into contact with the wiring of the main equipment, and to make the unit a reasonably good fit into the battery compartment. The output lead can be a battery connector of the same type as fitted to the main equipment, but remember that the positive battery connector lead connects to the negative output of the adapter, and vice versa. This is because the two positive battery connectors are of the same physical type, as are the two negative ones.

The two connectors therefore connect positive to negative, and so the leads connecting to the adapter must be the wrong way round, as it were, in order to correct this.

Components list for the mains/9 volt adapter

| | |
|-----------------------|--|
| <i>Resistor</i> | |
| R1 | 680Ω ¼W, 5% |
| <i>Capacitors</i> | |
| C1 | 1000μF, 25V |
| C2 | 100nF, type C280 |
| <i>Semiconductors</i> | |
| IC1 | μA78L05WC (or similar 5V 100mA regulator in TO92 case) |
| D1 | 1N4001 |
| D2 | 1N4001 |
| D3 | 1N4001 |
| D4 | 1N4001 |
| D5 | BZY88C3V9 (3.9V, 400mW, zener) |
| <i>Transformer</i> | |
| T1 | Standard mains primary, 6 – 0 – 6V 100mA, secondary |
| <i>Switch</i> | |
| S1 | Two pole rotary mains switch |
| <i>Miscellaneous</i> | |
| Case | 0.15in pitch stripboard panel |
| | Mains lead and plug |
| | Control knob |
| | Wire, solder, etc. |

12

Lamp Dimmer

This unit uses a conventional diac–triac lamp dimmer type circuit and it can provide anything from zero to virtually full power to the controlled lamp. Of course, this type of power controller can be used with many other types of load, such as an electric drill. It cannot be used with a fluorescent tube though.

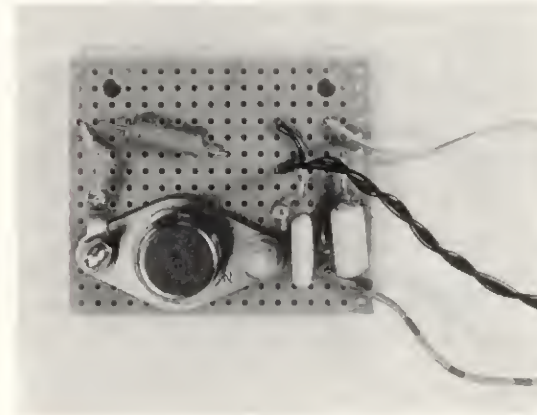


Figure 12.1
Lamp dimmer

The unit is capable of handling a maximum continuous power of about 250W or so, but this can be increased somewhat if the load is only supplied intermittently. The power handling capability of the circuit can be considerably increased if the triac is fitted with a suitable heatsink.

It must be pointed out that, although this circuit is much simpler than most of those featured earlier, in some ways this project is more difficult from the constructional point of view. This stems from the fact that not only does the unit obtain its operating power from the mains, it does so directly without any mains isolation transformer. There is no point in using such a transformer as the unit has to be connected directly to the mains anyway in order to control the load. This makes it necessary to take certain safety precautions when constructing the unit, as detailed later. These precautions must be strictly followed, and it is advisable for a complete beginner not to undertake this project until he or she has obtained some constructional experience with battery operated devices.

The circuit

The very simple circuit of the Lamp Dimmer appears in Fig. 12.2. This type of circuit does not control the power fed to the load by using some form of variable resistance in series with the power source, but uses a switching action. When controlling fairly high powers the variable

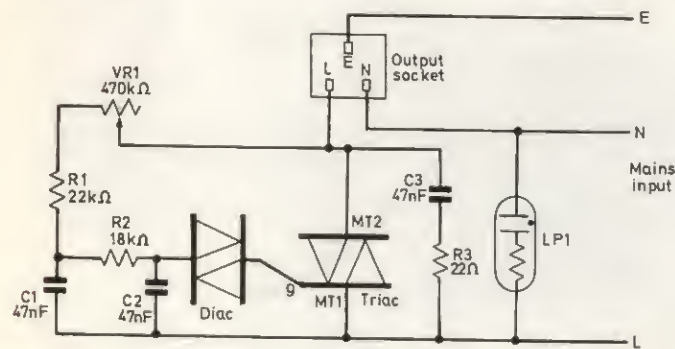


Figure 12.2

The lamp dimmer circuit

resistance approach has the disadvantage of producing a considerable amount of heat which has to be dissipated, and a considerable amount of power is wasted to produce this heat.

A switching type power controller of the type described here operates by switching on the load only for part of each mains half cycle. For example, in order to apply half power to the load the unit would not switch on until half way through each mains half cycle. In order to

provide the load with one third power the unit would not switch on until two thirds of the way through each half cycle.

Little heat is generated in the control device as, when it is switched off, no significant current is passed and so little power is developed across the device. When it is switched on there is a large current flow, but little voltage is dropped across the device which should theoretically have zero impedance. Practical devices such as triacs actually have a voltage drop of about 1V or so when they are switched to the on state and so a certain amount of power is produced in the device, but only a comparatively small amount.

Considering the practical circuit of Fig. 12.2 now, the triac is normally in the off state, but it will be switched on when the voltage across the diac reaches the trigger voltage of this component. When this happens the diac, which normally has an extremely high impedance, avalanches almost immediately to produce a low impedance path to the gate terminal of the triac. C1 and C2 then rapidly discharge into the gate circuit of the triac, and in doing so they switch this component on. The triac is connected in series with the load and so once it has switched on, power is supplied to the load.

The voltage across the diac is zero at the beginning of each mains half cycle, as the mains voltage is also zero. As each half cycle progresses, C1 and C2 charge up via VR1, R1, and R2. If VR1 is adjusted for zero resistance, the voltage across C2 will be virtually equal to the mains voltage, and the trigger voltage of the diac will be quickly reached. Thus the triac will be triggered very early in each half cycle, and almost full power will be applied to the load. There is actually some loss of power, but this is not really significant as the missing part of the waveform is very short and is in a low voltage part of the wave. The power loss will not be noticeable.

If VR1 is adjusted for increased resistance this results in the voltage across C2 significantly lagging behind the mains potential, and the triac is not switched on until later in each half cycle. With VR1 at about maximum resistance, the delay will be so long that the diac trigger voltage will not be achieved, and zero power will be supplied to the load.

When the triac switches on, it effectively short circuits the triggering circuit so that it is ready to start each half cycle with no significant charge on either C1 and C2. The triac may be switched off by reducing the current flowing through it to a very low level. This obviously happens at the end of each half cycle when the mains voltage reaches zero, and so this component too is ready to start afresh on each mains half cycle.

Circuits of this type tend to produce a certain amount of radio frequency interference due to the high speed at which the switching takes place, and C3 and R3 help to attenuate this interference. LP1 is simply an on/off indicator lamp, and this must be a type which has an integral series resistor for normal mains voltage use.

Construction

A suitable 0.1in matrix stripboard layout for the unit is given in Fig. 12.3. Make quite sure that there are no accidental short circuits between any copper strips as this could easily result in some of the components being damaged. The triac may be any type which has a voltage rating of 400V or more and has a TO66 type encapsulation. The type used in the prototype was an RCA T2700D device, but triacs are often sold by voltage/current/encapsulation rather than by a specific type number.

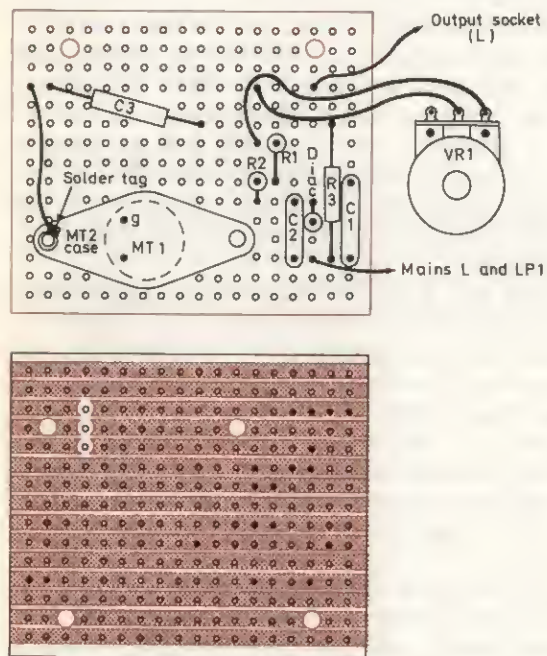


Figure 12.3

The 0.1in matrix stripboard layout for the lamp dimmer

Some triacs have a built in diac, and a component of this type can be used if the discrete diac is replaced by a link wire. Note that the diac is bidirectional and may be connected into circuit either way round.

C3 must be capable of handling mains voltage, and capacitor operating voltages are often specified in d.c. rather than a.c., so any type capable of operating on 500 volts d.c. or more should be suitable.

The connection to the MT2 terminal of the triac, which is its metal casing, is made via a solder tag which is mounted on one of the 6BA or M3 mounting bolts, as shown in the diagram (Fig. 12.3). The other

mounting bolt (the one nearer to R2, C2, etc.) must be a nylon type as it could otherwise short circuit the copper strips which connect to the gate and MT1 terminals of the triac. Alternatively, this mounting bolt can simply be omitted as the other bolt and the soldered connections to the gate and MT1 terminals will hold this component quite firmly in position.

A double size surface mounting plastic switch box makes a good housing for the project. This has a mains outlet socket mounted on one side (this is the output socket) and a blanking plate mounted on the other side. The blanking plate is drilled to take VR1, and the latter should be a type having a plastic spindle. It should be fitted with a plastic control knob having a built in nut cover. LP1 can be mounted on the left hand side panel of the case. The component panel is mounted on the base of the case beneath the blanking plate preferably using nylon bolts. If metal bolts are used they must be earthed, as must any

Components list for the lamp dimmer

Resistors (all miniature ¼ watt 5%)

| | |
|-----|--------------------------------------|
| R1 | 22k Ω |
| R2 | 18k Ω |
| R3 | 22 Ω |
| VR1 | 470k Ω lin. (plastic spindle) |

Capacitors

| | |
|----|--------------------------------|
| C1 | 47nF, type C280 |
| C2 | 47nF, type C280 |
| C3 | 4.7nF, high voltage (see text) |

Semiconductors

| | |
|-------|--|
| Triac | Any type rated at 400V or more in a TO66 encapsulation |
| Diac | BR100 or similar, if needed (see text) |

Indicator

| | |
|-----|--|
| LP1 | Panel mounting neon indicator with integral series resistor for normal mains use |
|-----|--|

Miscellaneous

| | |
|--|------------|
| Mains outlet socket and other parts for case | (see text) |
| 0.1in matrix stripboard panel | |
| Plastic control knob | |
| Nylon mounting nuts and bolts | |
| Mains lead, plug, connecting wire, etc. | |

exposed metal, apart from the mounting bolts for the mains socket and blanking plate.

It is not essential to use the specified case, of course, but it is inexpensive and well suited to this application, and the parts should be

readily available from a local electrical shop. If a metal case is used, make quite sure this is earthed and that adequate insulation is used where necessary (such as between the case and component panel).

The mains earth lead must be connected to the earth terminal of the output socket so that any appliance having an earth connection is in fact earthed when it is plugged into the dimmer. A 3A fuse should be fitted in the mains plug.

Check all the wiring very thoroughly a couple of times before testing the unit. Do not work on any of the wiring or even just touch it while the unit is plugged into the mains. Doing so could easily result in a severe electric shock being obtained.

13

Multimeter Sensitivity Booster

Although a multimeter is undoubtedly the most useful piece of electronic test equipment for normal amateur requirements, such instruments are not without their drawbacks. Unless one has an electronic multimeter, the main drawback is the current drawn by the multimeter from the equipment under test when making d.c. voltage tests. Most multimeters incorporate a $50\mu\text{A}$ meter movement, and so a current of $50\mu\text{A}$ must be taken from the test circuit when making a voltage measurement which will produce full scale deflection (f.s.d.) of the meter. Lower readings draw a correspondingly lower current.

The problem is that in parts of many electronic circuits there are voltages of a reasonable magnitude, but only extremely small current flows. In other words there are high resistances and impedances present which severely limit the available current. Testing such a high impedance circuit with an ordinary multimeter will often produce very misleading results.

What happens here is that, when the multimeter is connected to the circuit, it affects the circuit conditions as the resistance across the test prods is low in comparison to the resistances in the test circuit. The multimeter thus shunts and significantly reduces in value any resistance path in the test circuit which it is connected across. This causes a reduction in the test voltage, and the meter registers this artificially low reading. The reading is correct in the sense that the voltage indicated is indeed the voltage present while the meter is connected to the circuit, but it is misleading as a completely different voltage is present when the meter is disconnected.

Electronic voltmeters and multimeters overcome this problem by using an amplifier ahead of the meter in order to reduce the current drawn by the unit. Units of this type typically require an input current of less than $1\mu\text{A}$ in order to produce f.s.d. of the meter. Virtually any electronic circuit one is likely to encounter will be capable of supplying

such a low current, and so reliable readings are almost invariably obtained using such an instrument.

The unit described here (Fig. 13.1) is a very simple device which can be added ahead of an ordinary multimeter switched to the $50\mu\text{A}$ range

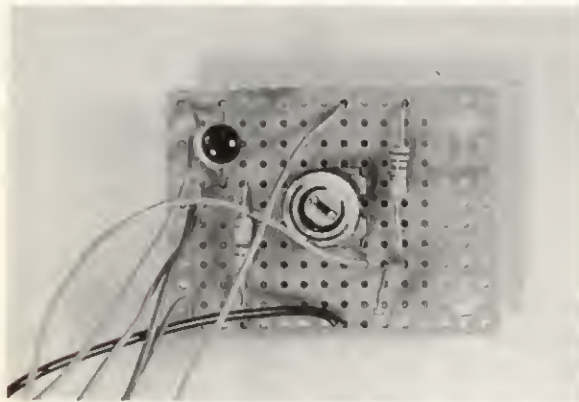


Figure 13.1

High impedance multimeter adapter

to convert it to an electronic voltmeter. The unit has three voltage ranges which are 1, 10 and 100V f.s.d., or if preferred, the unit can be adjusted to produce ranges of 0.5, 5 and 50V instead. Of course, the circuit can be used in conjunction with a $50\mu\text{A}$ panel meter if a completely self-contained electronic voltmeter is required.

The circuit

The complete circuit diagram of the Multimeter Sensitivity Booster is given in Fig. 13.2. This is based on a single transistor of the junction gate field effect (jufet) type.

Unlike an ordinary bipolar transistor, a jufet will conduct quite heavily unless it is reverse-biased. The normal method of achieving this is to connect a resistor in the source circuit of the device and connect the gate to earth via a second resistor. The current which flows in the source circuit causes a voltage to be produced across the source resistor, thus taking the source positive of the gate terminal which is at a very high impedance and effectively shorted to earth via its bias resistor. In this way the device is reverse-biased and brought onto a part of its transfer characteristic which is suitable for linear amplification.

This is basically the arrangement used here, with R5 acting as the source bias resistor and R1 and R3 providing the gate biasing. However, the gate biasing connects to the slider of VR1 rather than to the negative supply rail, and the reason for this will be explained shortly.

R6 and R7 form a potential divider across the supply lines, and about half the supply rail potential is produced at the junction of these two components. The meter is connected between this point and the source terminal of TR1 by way of R4, the latter forming a simple voltmeter circuit in conjunction with the meter. R4 is adjusted to give this voltmeter circuit a sensitivity of 1V f.s.d.

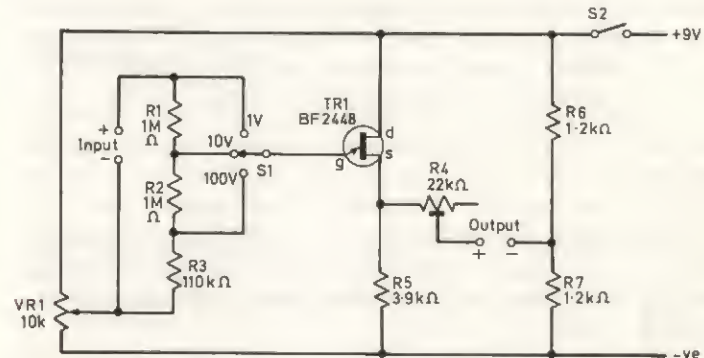


Figure 13.2

The circuit diagram of the multimeter sensitivity booster

With the slider of VR1 at the bottom of its track only about 1V is produced at TR1 source, whereas there is about 4.5V at the junction of R6 and R7. This is obviously unsatisfactory as it results in a reverse potential of about 3.5V being produced across the voltmeter circuit! The problem can be overcome by taking the slider of VR1 up its track until it is at a potential of about 3.5V. TR1 is connected in the source follower mode and therefore has a voltage gain of almost exactly unity. The voltage at TR1 source is thus equal to the gate voltage plus the source bias voltage, or about 4.5V in this case. In this way VR1 can be used to balance the voltages at either end of the voltmeter circuit, and so produce zero deflection of the meter under quiescent conditions.

With S1 in the 1V position the input voltage is connected direct into the gate of TR1, and the gate potential will be increased by an amount equal to the input voltage. As TR1 has a voltage gain of unity, the voltage at TR1 source rises by an almost identical amount and causes a positive deflection of the meter. Obviously an input level of 1V will produce 1V across the meter circuit and will give f.s.d. of the meter.

TR1 has an input impedance of about $1000M\Omega$ and draws no significant input current. The input impedance of the circuit is thus almost entirely governed by resistors R1 and R3. These set the input impedance at a little over $11M\Omega$. Apart from providing gate biasing for TR1, these resistors also form a simple attenuator network and reduce the f.s.d. sensitivity of the circuit by the appropriate amounts when S1 is in the 10V and 100V positions. The sensitivity of the circuit when expressed in terms of ohms per volt varies from a little over $11M\Omega$ per volt on the 1V range, to slightly in excess of $110k\Omega$ per volt on the 100V range. This is considerably better than the $20k\Omega$ per volt of an ordinary multimeter.

S2 is a straight forward on/off switch. The current consumption of the unit is approximately 4mA, and this is economically obtained from a PP3 size 9V battery. There is no need to stabilise the supply as the gain of TR1 is largely unaffected by variations in supply voltage.

Construction

Some of the components are assembled on a 0.1in pitch stripboard panel which has 12 copper strips by 16 holes, but R1 and R3 are mounted on S1. Details of the component panel and wiring of the unit are shown in Fig. 13.3.

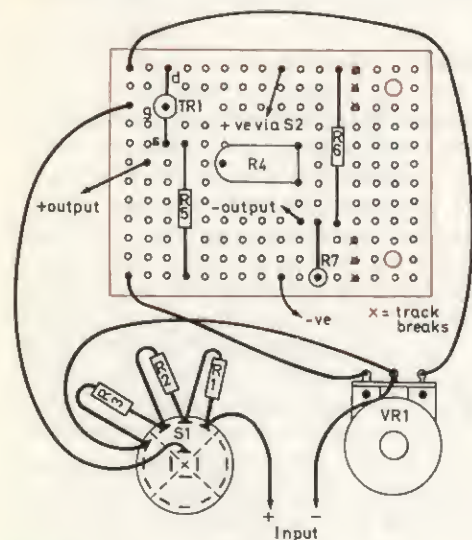


Figure 13.3
Constructional details of the multimeter sensitivity booster

Commence construction by carefully cutting out a stripboard panel of the correct size using a hacksaw. Then file up any rough edges to a smooth finish, make the six breaks in the copper strips, and drill the two 3.2mm diameter mounting holes. Next the various components are soldered into position.

The three controls are mounted on the front panel of the case, as are the input and output sockets which can conveniently be wander types. The remaining wiring can then be completed before the component panel is mounted inside the case. The panel can be mounted using either M3 or 6BA mounting nuts and screws, and the panel must be spaced well clear of the case if the latter is of metal construction.

Adjustment and use

At the outset both VR1 and R4 should be adjusted fully anticlockwise. Before connecting the multimeter to the unit, set it to a low volts range (say 5 or 10V f.s.d.) and measure the voltage at the junction of R6 and R7. Then connect the multimeter to monitor the voltage at TR1 source, and adjust VR1 to increase this voltage to fractionally above the voltage at the junction of R6 and R7.

The multimeter is then switched to the $50\mu A$ range and connected to the output of the sensitivity booster. The two connections can be made using a couple of short leads, each having a crocodile clip at one end and a wander plug at the other end. The wander plugs fit into the output sockets of the booster and the crocodile clips connect to the test prods of the multimeter. Ensure that the meter is connected with the correct polarity.

There should be a small positive deflection of the meter, but it should be possible to zero the meter using VR1. From time to time it will probably be necessary to readjust VR1, but frequent adjustment should not be necessary.

The unit is calibrated by connecting a known voltage to the input with S1 switched to a suitable range. R4 is then adjusted to produce the appropriate reading on the meter. The calibration voltage should be one which will produce something approaching f.s.d. of the meter on whatever range the unit is calibrated on. A suitable calibration voltage could be a 9V battery, the multimeter being used to measure the exact battery voltage prior to the unit being calibrated. The unit could then be calibrated on the 10V range.

R4 can be adjusted to provide ranges of 0.5, 5 and 50V if desired, and this is obviously preferable if the unit is used in conjunction with a panel meter as a self contained voltmeter, since the meter will not have a scale which is ideally suited to 1, 10 and 100V ranges. The same might apply to some multimeters as well.

Components list for the multimeter sensitivity booster

Resistors (all $\frac{1}{4}$ or $\frac{1}{2}$ W, 5% tolerance unless otherwise noted)

| | |
|-----|---|
| R1 | 10M Ω , 5% or better |
| R2 | 1M Ω , 5% or better |
| R3 | 110k Ω 5% or better |
| R4 | 22k Ω sub-miniature (0.1W) horizontal preset |
| R5 | 3.9k Ω |
| R6 | 1.2k Ω |
| R7 | 1.2k Ω |
| VR1 | 10k Ω lin. carbon |

Semiconductor

TR1 BF244B

Switches

S1 3-way 4-pole rotary type (only one pole used)
S2 S.P.S.T. toggle or miniature toggle type

Miscellaneous

Metal instrument case
PP3 battery and connector to suit
0.1in pitch stripboard panel
Input sockets, test prods and leads
Output sockets
Two control knobs
Wire, solder, etc.

14

Capacitance Bridge

A standard multimeter can be used to accurately measure resistor values, and can provide quick checks on other components such as diodes, transistors, and high value capacitors. The one major type of component which most multimeters are not equipped to test is low and medium value capacitors, say from a few picofarads to a few microfarads. Apart from checking for short circuits, an ordinary multimeter cannot check this type of component at all.

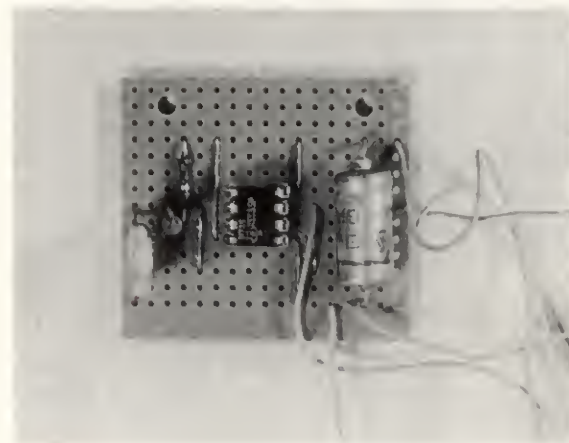


Figure 14.1
Capacitance bridge

This can be quite a serious drawback as capacitors form a substantial part of most constructional projects and sooner or later the constructor is likely to be faced with checking a doubtful capacitor, or measuring the value of one which has lost its value markings. A unit for measuring

capacitance can also be invaluable when sorting through the popular bargain packs of assorted capacitors.

Some piece of capacitance measuring test gear is therefore a valuable addition to an electronics workshop, and probably the most simple way of obtaining accurate capacitance measurements is to use a capacitance bridge. A simple unit of this type is shown in Fig. 14.1. It has three ranges which provide coverage from 10pF to 10 μ F.

The circuit

The complete circuit diagram of the capacitance bridge is shown in Fig. 14.2. A bridge circuit is simply two potential divider circuits fed from a common signal source, and the output is taken from across the outputs of the potential dividers. This general arrangement is much used in electronics, and bridge circuits were employed in the multi-meter sensitivity booster, flat battery warning light and thermometer projects which have already been featured.

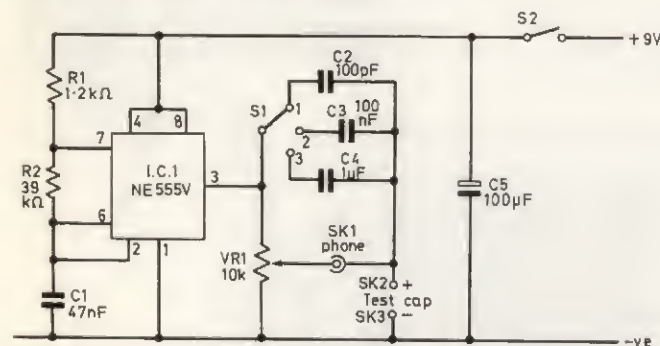


Figure 14.2

The circuit diagram of the capacitance bridge

In this circuit VR1 forms one side of the bridge and the other side is comprised of C2, C3 or C4 (according to the position of S1) and the capacitor under test. The input of the bridge is fed with an audio tone which is generated by the 555 timer i.c. (IC1) which is connected in the astable mode. The signal at the output of the bridge can be monitored using a crystal earpiece.

With S1 in the position shown, and a 100pF test capacitor connected to the circuit, at most settings of VR1 the audio tone will be produced from the earphone. However, with the slider of VR1 at about the centre of its track it will be possible to locate a setting where the tone is nulled.

The reason for this is quite simple: C2 and the test capacitor form a simple potential divider, and as they are of equal value, half the input signal voltage is produced at the output of this circuit. When the slider of VR1 is at the centre of its track it too produces an output equal to half the input signal voltage. Therefore, the voltage developed across the earphone must be zero since the two voltages to which it is connected rise and fall in unison. If the setting of VR1 is altered the bridge circuit will be unbalanced and there will be a higher voltage at one side of the bridge than appears at the other. This will cause a voltage to be developed across the earphone and the tone will be audible.

If the test capacitor has a higher value, say 1nF, then it will have a much lower impedance than C2 and the output from the right hand side of the bridge will be greatly reduced in consequence. The bridge can still be balanced of course, simply by taking the slider of VR1 down the track to the point where the two outputs match once again and the output tone is nulled.

A test capacitor of much lower value than C2, say 10pF, will have a much higher impedance than C2, and will cause a much increased output from the right hand section of the bridge. Again it is possible to balance the bridge, this time by taking the slider up towards the top of its track.

By marking the control knob of VR1 with a scale showing the positions at which various capacitance values balance the bridge, it is possible to use the unit to determine the value of an unmarked capacitor. It is merely necessary to connect the test capacitor, adjust VR1 for zero output from the earpiece, and then read the value off the scale. In theory the unit can be used to measure any capacitor, but in practice the values given in the example above represent the limits, as the scale would be excessively cramped outside these limits. However, the range of the unit can be extended by providing additional reference capacitors, and this is the purpose of C3 and C4. The unit has three measuring ranges which are as follows:

| | |
|---------|---------------------|
| Range 1 | 10pF to 1nF |
| Range 2 | 1nF to 100nF |
| Range 3 | 100nF to 10 μ F |

C5 provides supply decoupling and S2 is the on/off switch. The current consumption of the circuit is approximately 8mA.

Construction

Some of the components are mounted on a 0.1in pitch stripboard which has 14 copper strips by 17 holes, but C2 to C4 are mounted on S1, as shown in the wiring diagram of Fig. 14.3.

From the mechanical point of view construction should be perfectly straightforward, but it is recommended that a fairly large case constructed of a non-metallic material should be used. The large size is necessary to permit a large scale to be marked around the control knob of VR1.

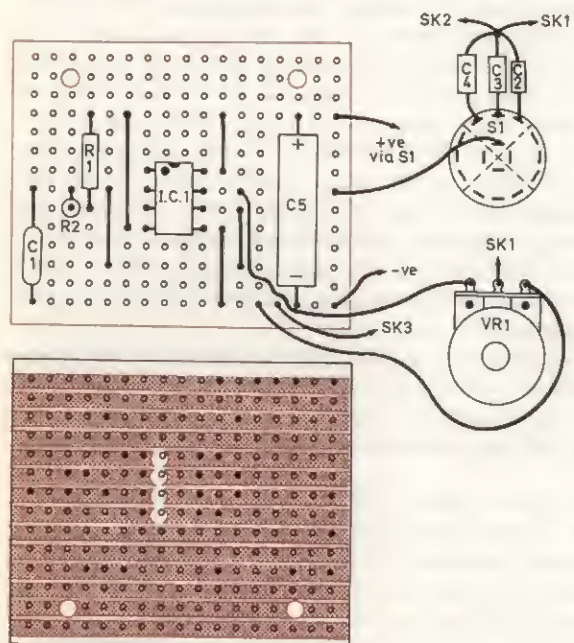


Figure 14.3

The 0.1in matrix stripboard layout and wiring of the capacitance bridge

Useful results can be obtained using a small scale, but this will place distinct limitations on the accuracy and resolution of the unit which is obviously far from ideal. A metal case should be avoided unless SK1 is either a socket of insulated construction, or steps are taken to insulate it from the case. No other wiring should be allowed to come into contact with the case. To do so could encourage stray capacitances and signal paths which could prevent a definite null from being obtained, particularly when measuring low value capacitors.

Calibration

In order to calibrate the unit it is necessary to have a number of capacitors of known value, and for optimum calibration accuracy these should all be close tolerance types. Provided C2 to C4 are all close tolerance

capacitors it is not necessary to mark an individual scale for each range. A single scale marked '1' at the low value end (VR1 set anticlockwise) to '100' at the high value end with '10' at the centre will be quite suitable. This is obviously correct in terms of nF on Range 2, and is easily converted into an actual capacitance value on the other two ranges.

The scale is calibrated by connecting a capacitor to the unit, setting S1 to the appropriate range, adjusting VR1 for minimum signal from the earphone, and then marking the scale with the correct number at the point indicated by the pointer of the control knob for VR1. For instance, a 10nF component would provide the '10' calibration point with S1 set to Range 2. 10pF and 1nF components would provide the '1' and '100' calibration points respectively with S1 in the Range 1 position. Of course, it is not just a matter of marking in the centre and limits of the scale, and it must be calibrated at all the preferred values in the E12 series (1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, etc.). This is quite a long process, but it is worth doing well as a unit of this type can provide a high degree of accuracy despite the simplicity of the circuit.

When measuring electrolytic capacitors ensure that they are connected with the correct polarity (other types are nonpolarised and can be connected either way round). Do not use electrolytic types for calibrating the unit as these often have tolerances as high as +100% and -50%!

Components list for the capacitance bridge

Resistors

| | |
|-----|--|
| R1 | 1.2k Ω miniature, $\frac{1}{4}$ W, 5 or 10% |
| R2 | 39k Ω miniature, $\frac{1}{4}$ W, 5 or 10% |
| VR1 | 10k Ω lin. wirewound |

Capacitors

| | |
|----|---------------------------|
| C1 | 47nF type C280 |
| C2 | 100pF close tolerance |
| C3 | 10nF close tolerance |
| C4 | 1 μ F close tolerance |
| C5 | 100 μ F, 10V |

Switches

| | |
|----|---|
| S1 | 3-way 4-pole rotary type (only one pole used) |
| S2 | S.P.S.T. toggle switch |

Integrated circuit

| | |
|-----|------------------------|
| IC1 | NE555V (or equivalent) |
|-----|------------------------|

Miscellaneous

0.1in matrix stripboard panel
 Case (preferably non-metallic, see text)
 3.5mm jack socket (SK1)
 Two wander sockets, one red and one black (SK2 and SK3)
 Crystal earpiece, control knob
 PP3 battery and connector to suit
 Wire, solder, etc.

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Bench Power Supply

A bench power supply is one of the most useful pieces of equipment for anyone interested in electronic project construction to have around the workshop, even if the supply is only a relatively simple affair, such as the unit described here.

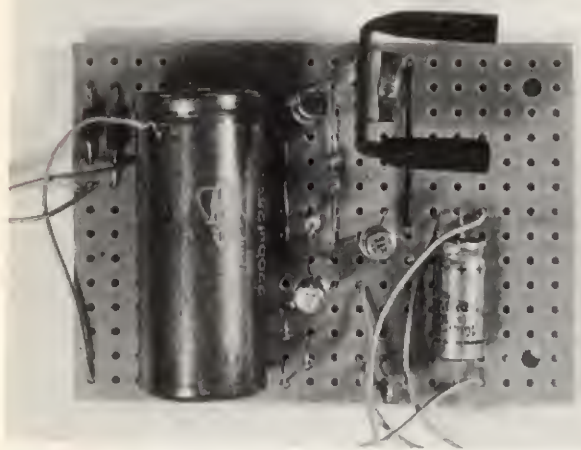


Figure 15.1
Bench power supply

This power supply has an output voltage which can be varied over a range of a little more than 3 to 12V and a maximum output current of 500mA can be provided. The output is very well smoothed and contains an insignificant ripple content. The supply is well regulated and there is little drop in output voltage between zero loading and full loading, especially at low voltages. Regulation efficiency falls away to some extent at higher voltages, but it is still good.

Output current limiting is incorporated in the circuit so that the unit is protected against damage in the event of an accidental short circuit on the supply lines, and the need for frequent replacement of blown fuses is avoided.

The circuit

The complete circuit diagram of the Bench Power Supply is shown in Fig. 15.2. It uses a basic circuit arrangement which, due to its relative simplicity and high performance, is frequently utilized in power supply designs.

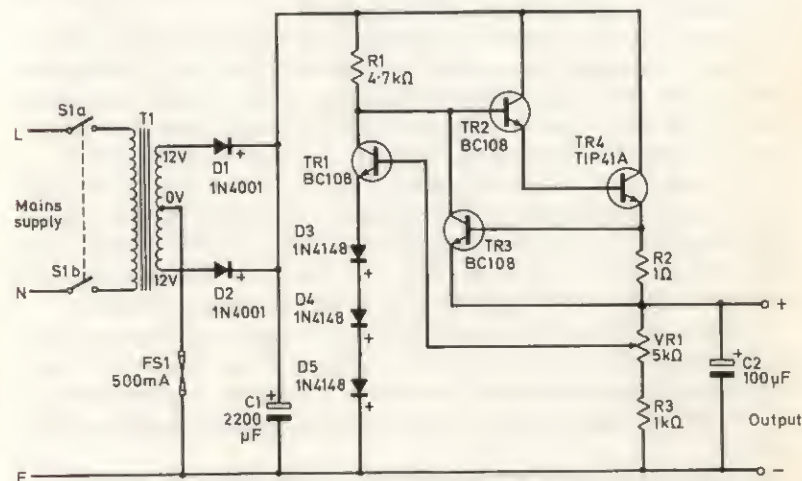


Figure 15.2
Complete circuit diagram

S1 is the on/off switch and T1 is the isolation and voltage step down transformer. The output from the secondary winding of T1 is fullwave rectified by D1 and D2 which are used in a push-pull type circuit. C1 provides considerable smoothing of the rough d.c. output from the rectifier network.

TR1, TR2, and TR4 are used in the regulator circuit, and TR1 is used as a feedback amplifier while TR2 and TR4 are merely used as a unity gain Darlington pair emitter follower output stage. With this type of circuit the output stage is biased on by a resistor (R1) and so the output tries to rise to the same level as the unregulated input, minus 1V or so which will be dropped across the output transistors. However, if we assume that the slider of VR1 is at the top of its track at present,

the base of TR1 is connected to the output, and will be switched on when the output reaches a certain potential. About 0.65V is needed across the base and emitter terminals of TR1 to switch this device on, but about 0.65V is developed across each of the three forward biased silicon diodes in the emitter circuit of TR1. Therefore about 2.6V is needed at TR1 base before this component will be biased into conduction.

When the output voltage reaches this figure and TR1 turns on, some of the base bias current for the output stage is diverted to earth through TR1 and D3 to D5. This effectively limits the output voltage to about 2.6V as any rise above this level simply causes TR1 to conduct more heavily and reduce the drive voltage to the output stage. This brings the output voltage back to its original level.

Similarly, if the output voltage should fall for some reason, due to increased loading on the output for instance, TR1 will conduct less heavily and will increase the drive voltage to the output transistors. This brings the output voltage back to its previous level once again. Thus the output potential is stabilised by a negative feedback action.

If the slider of VR1 is taken down its track, the feedback will still operate and stabilise the output voltage, but a higher output voltage will be needed in order to produce 2.6V at TR1 base. The further down the track of VR1 the slider is taken, the higher the output voltage will become. In this way VR1 may be used to vary the output voltage.

R2 and TR3 form the current limiting circuitry, and these limit the current to a maximum level of about 600mA or so. This circuitry will not be described in more detail as it works in precisely the same manner as the NiCad battery charger described in a previous section of this book.

C2 provides final smoothing of the output and FS1 protects the circuit in the event of a short circuit occurring ahead of the current limiting circuit, or if the latter should fail for some reason.

Construction

Most of the circuitry is wired up on a 0.15in matrix stripboard panel having 14 copper strips by 20 holes. Details of this panel are provided in Fig. 15.3. Be careful not to omit any of the seven breaks in the copper strips or either of the two link wires. In fact, great care should be taken not to make any wiring errors as this could very easily result in damage to some of the components.

S1, VR1 and the output sockets are mounted on the front panel of the case. The output sockets can be wander types, or terminal posts, which are ideal for this application, may be used.

T1 and the fuse holder for FS1 are mounted on the base panel of the case. The circuit will work quite well using a 12-0-12V 500mA component for T1, but for optimum results at output voltages of ten or more a component having a current rating of 1A is to be preferred as this will provide a more adequate loaded voltage. However, for normal amateur requirements a 500mA type will provide adequate results.

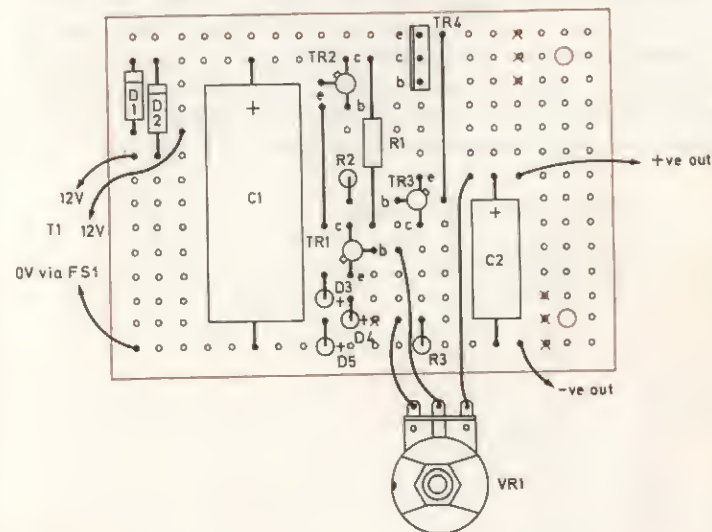


Figure 15.3

Strip board layout of the power supply

A hole for the mains lead is made in the rear panel of the case, and this should be fitted with a grommet. If a metal case is used, the mains earth lead should be connected to the case, and this connection can be achieved via a soldertag on one of the mounting bolts for T1. The mains earth lead also connects to the side of FS1 which connects to the negative rail of the component panel. The remaining wiring is then completed before the component panel is bolted in position on the base panel of the case.

Note that TR4 must be provided with a certain amount of heatsinking. A small commercially produced type was found to be just about adequate on the prototype.

Using the unit

It is recommended that a dial calibrated in output voltage should be provided around the control knob of VR1, and with the aid of a multi-meter this is very easily accomplished. If this is not done it will be

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necessary to set the output voltage to the required level with the aid of a multimeter each time the unit is used. Of course, an integral meter can be used to monitor the output voltage, and a current meter could also be added if desired, but panel meters are relatively expensive, and the added convenience of built in metering would result in the cost of the project being very considerably increased.

It is a good idea to check that the current limiting circuitry is working by connecting a 10Ω resistor and a multimeter set to read 1A f.s.d. in series across the output with the output voltage set to 7.5V. The meter should register a current flow of about 600mA or so, and if the reading is more in the region of 750mA, this indicates a fault and the relevant part of the circuit should be checked for errors.

Components list for the bench power supply

Resistors (all miniature $\frac{1}{4}W$, 5%)

| | |
|-----|-------------------------|
| R1 | 4.7k Ω |
| R2 | 1 Ω |
| R3 | 1k Ω |
| VR1 | 5k Ω lin. carbon |

Capacitors

| | |
|----|-------------------|
| C1 | 2200 μ F, 25V |
| C2 | 100 μ F, 16V |

Semiconductors

| | |
|-----|--------|
| TR1 | BC108 |
| TR2 | BC108 |
| TR3 | BC108 |
| TR4 | TIP41A |
| D1 | 1N4001 |
| D2 | 1N4001 |
| D3 | 1N4148 |
| D4 | 1N4148 |
| D5 | 1N4148 |

Transformer

| | |
|----|---|
| T1 | Standard mains primary, 12 - 0 - 12V, at 1A or 500mA secondary (see text) |
|----|---|

Switch

| | |
|----|------------------------------|
| S1 | Two pole rotary mains switch |
|----|------------------------------|

Miscellaneous

Metal instrument case
0.15in matrix stripboard panel
Heatsink for TR4
Two control knobs
Chassis mounting 20mm fuseholder with 500mA fuse (FS1)
Output sockets and leads
Mains lead, mains plug, connecting wire, solder, etc.

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