

# L.E.D. STROBOSCOPE

**ROBERT PENFOLD**

*Freeze the action with the second of our low-cost, easy-build practical starter projects.*

**T**HESE days the word stroboscope probably conjures up images of high power flashing lights at a disco rather than a scientific instrument. However, the old style stroboscope still lives on, and units of this type can produce some fascinating results

As many readers will no doubt be aware, the scientific purpose of a stroboscope is to "freeze" moving machinery. The basic idea is to synchronise the flashing light of the stroboscope with the machine so that the light flashes at precisely the same point in each cycle of the machine.

The flash of light must be much brighter than the ambient light level so that any onlookers only see the machine during the pulses of light. Because they only see the machine at the same point in each cycle it seems to be stationary.

In fact, things become more interesting if the stroboscope and the machine are slightly out of synchronisation. With the light flashing slightly later in each cycle the machine appears as though it is operating in slow motion. A lack of synchronisation in the opposite direction makes it seem as though the machine is going slowly in reverse!

By carefully adjusting the flash-rate it is therefore possible to move to any point in the operating cycle of the machine, and to effectively make the machine operate at the desired speed in either direction. This makes it possible to closely analyse the action and see precisely how everything operates.

## BRIGHT L.E.D.S

In order to "freeze" large pieces of machinery it is necessary to use a high power stroboscope. Such a device is not necessarily very complicated, but it requires the use of relatively expensive flash tubes that need high operating voltages. Not a project that is usually considered suitable for beginners.

However, as the title suggests, the L.E.D. Stroboscope featured here is based on ultra-bright l.e.d.s that provide comparatively small light levels and is a low-budget project that is ideal for the newcomer to electronics. Consequently this unit must be used in a darkened room and it will only illuminate a small area.

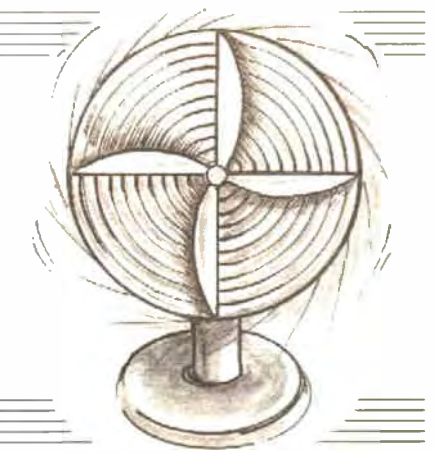
It is adequate for use with things such as watches, small engines, or any small mechanisms that have a repeating action. The use of l.e.d.s keeps the cost to a minimum, enables an extremely simple circuit to be used, and permits safe operation from a low voltage battery supply.

## DESIGN CONSIDERATIONS

On the face of it, this application requires nothing more than a low frequency oscillator driving one or more l.e.d.s. In practice the oscillator must provide very brief output pulses if the desired action is to be provided. To be more precise, it is the ratio of the on time of the l.e.d.s to the off time that is of importance.

If the l.e.d.s were simply to be switched on for 50 per cent of the time the machine would go through half a cycle during the course of each flash of light, providing a very blurred image to the users. Practical experiments suggest that an off to on ratio of at least 100 to 1 is needed in order to obtain a reasonably sharp "frozen" image.

This brings a second problem, which is a lack of brightness from the l.e.d.s when they are only switched on for one per cent of the time. A modern ultra-bright l.e.d. will provide good brightness from a current of about 20mA, but pulsing it at this current for one per cent



of the time this gives an average drive current of only about 0.2mA. This gives nothing more than a faint glow from even the most efficient of l.e.d.s.

In order to overcome this, the l.e.d.s must be pulsed at a much higher current than normal, and should ideally be pulsed at about two amps (2000 milliamps). This gives an average current of 20mA and good brightness.

Most l.e.d.s are rated to take continuous currents of up to 20mA or 50mA, but they can withstand much higher currents provided they are supplied for short periods and the average current consumption is within the permitted maximum current. The required high current pulsed operation is therefore acceptable provided the minimum frequency is not made too low, which would leave the l.e.d.s switched on for too long during each pulse.

## CIRCUIT OPERATION

The full circuit diagram for the L.E.D. Stroboscope appears in Fig.1. The basis of the circuit is a (more or less) conventional oscillator circuit based on IC1. This is a form of relaxation oscillator and it operates by first charging capacitor C2, and then discharging it.

Integrated circuit IC1 is an operational amplifier (op.amp), but it is used here as a voltage comparator. Its output (pin 6) goes high when the inverting input (pin 2) is at a lower voltage than the non-inverting input (pin 3). Reversing the relative states of the two inputs results in the output going low.

Resistors R1 and R2 form a potential divider that biases the non-inverting input of IC1 to half the



supply potential, but the coupling through resistor R3 and potentiometer VR1 to the output of IC1 modifies this potential. When the output of IC1 is high the bias potential is pulled higher, and when it is low the bias is taken lower. The amount of change depends on the setting of VR1, and becomes greater as the resistance of VR1 is reduced.

Initially there is no charge on capacitor C2 and the output of IC1 goes high. Capacitor C2 then charges from the output of IC1 via resistor R5 and the much lower

This is the purpose of potentiometer VR1, which is shown configured as a variable resistor.

Conventionally the frequency of an R-C oscillator is controlled by varying the resistance in the timing circuit, but that would be difficult in this case as there are two resistors in the timing circuit (R4 and R5). Simply varying the value of R5 would produce substantial changes in the mark-space ratio of the output signal. Altering the value of the positive feedback resistance gives the required changes in

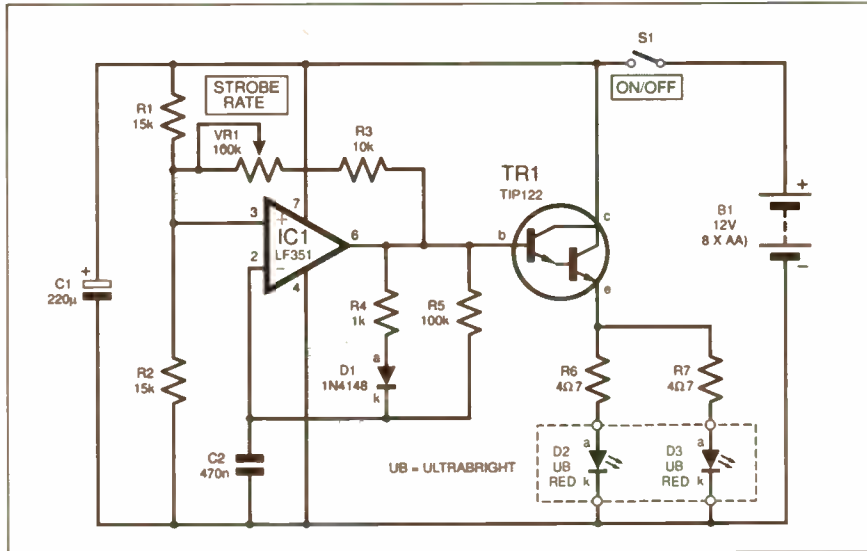


Fig.1. Complete circuit diagram for the L.E.D. Stroboscope. The two "strobe light" l.e.d.s can be housed remotely from the main unit - see photograph.

resistance path provided by R4 and diode D1. The low resistance of R4 results in a rapid increase in the charge potential until it goes above the bias voltage at the non-inverting input. The output of IC1 then goes low, and capacitor C2 starts to discharge via resistor R5.

There is no discharge path through resistor R4 and diode D1 because D1 blocks any flow of current in this direction. Capacitor C2 therefore discharges at a relatively slow rate through R5 alone.

The waveform produced across C2 is a form of sawtooth wave (Fig.2a). More importantly, the output of IC1 produces brief positive pulses, as in Fig.2b. In fact, the pulses are even more brief than those shown in Fig.2b due to the massive difference in the values of R4 and R5. This gives the required mark-space ratio of about 1 to 100.

### STROBE RATE

For a stroboscope to be of any practical value it must be possible to vary the output frequency over a reasonable span.

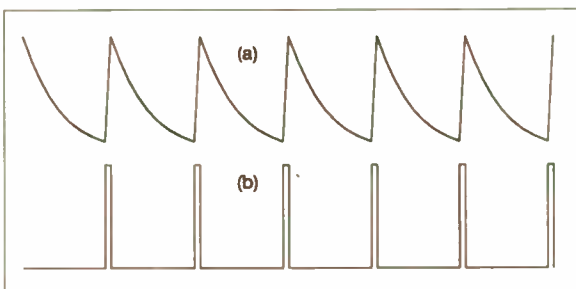
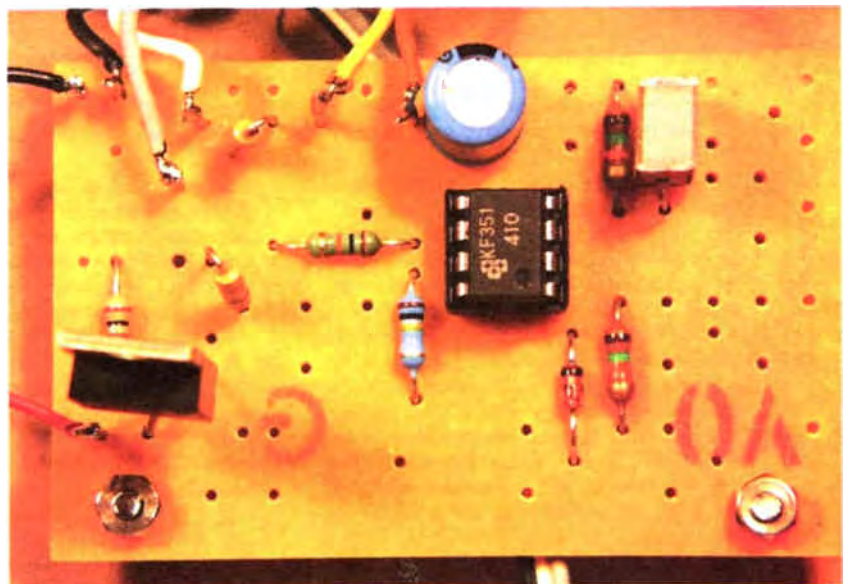


Fig.2. (a) Example waveform at pin 2 of IC1 and (b) at pin 6 of IC1.

frequency without significantly altering the output waveform.

With VR1 at a high value there is little change in the bias potential at the non-inverting input when IC1's output changes state. The charge on capacitor C2 therefore has to change by only a small amount to move from one threshold to the other, and this takes relatively little time.

With VR1 set at minimum resistance the charge and discharge threshold voltages are pulled several volts apart, greatly lengthening the charge/discharge cycle. The flash rate can be varied from approximately 17 to 100 per second. This corresponds to rotation speeds from about 1000 r.p.m. to 6000 r.p.m.



Component layout on the multi-project p.c.b.

## COMPONENTS

### Resistors

|                          |              |
|--------------------------|--------------|
| R1, R2                   | 15k (2 off)  |
| R3                       | 10k          |
| R4                       | 1k           |
| R5                       | 100k         |
| R6, R7                   | 4.7k (2 off) |
| All 0.25W 5% carbon film |              |

See  
**SHOP  
TALK**  
page

### Potentiometer

|     |                          |
|-----|--------------------------|
| VR1 | 100k rotary carbon, lin. |
|-----|--------------------------|

### Capacitors

|    |                                   |
|----|-----------------------------------|
| C1 | 220µ radial elect. 16V            |
| C2 | 470n polyester, 10mm lead spacing |

### Semiconductors

|        |  |
|--------|--|
| D1     | 1N4148 signal diode                              |
| D2, D3 | ultra-bright red l.e.d. - see text (2 off)       |
| TR1    | TIP121 or TIP122 npn power Darlington transistor |
| IC1    | LF351N bifet op.amp                              |

### Miscellaneous

|    |  |
|----|--|
| S1 | s.p.s.t. min. toggle switch                  |
| B1 | 12V battery pack (8xAA size cells in holder) |

Multi-project printed circuit board, available from the EPE PCB Service, code 932; medium size metal or plastic case, size to choice (see text); small box for l.e.d.s (optional); control knob; battery clip (PP3 type); 8-pin d.i.l. socket; multistrand connecting wire; solder pins; solder, etc.

Approx. Cost  
Guidance Only

**£9.50**  
excluding batts & case

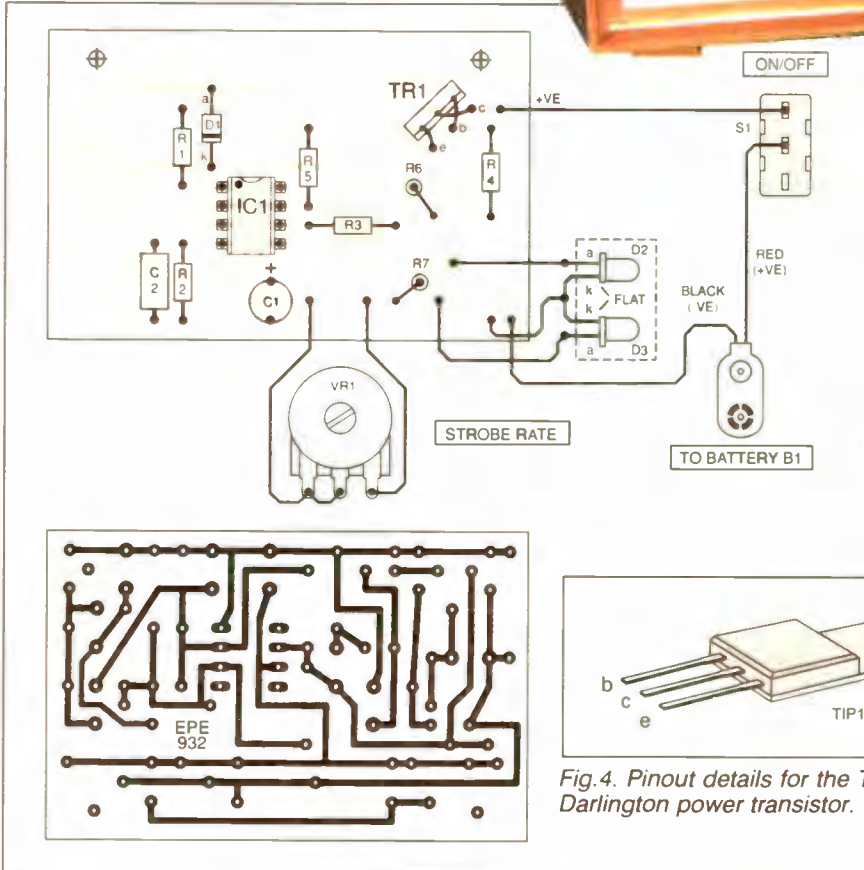
## CURRENT DRIVER

Only output currents of a few milliamps can be provided by IC1, and a large amount of amplification is needed to provide the l.e.d.s (D2 and D3) with suitably high drive currents. This is provided by TR1, which is a Darlington power transistor used as an emitter follower buffer stage.

A Darlington transistor is really two transistors connected so that the output current of one device drives the input of the second.

This effectively gives a super high gain transistor having a current gain equal to the product of the current gains of the individual transistors. The current gain of TR1 is typically several thousand, and this enables it to provide output currents of a few amps.

A current of a little over one amp is driven through each l.e.d., which produces an average current of about 10mA per l.e.d. This is high enough to give good brightness but low enough to avoid operating the l.e.d.s close to the point where they are in serious danger of being destroyed. The average current consumption of the circuit as a whole is about 23mA.



consisting of eight AA size cells is fairly bulky. Remember to allow for this factor when selecting the case. Mount the printed circuit board on the base panel of the case using either plastic stand-offs or 6BA bolts plus spacers.

The two "strobe" l.e.d.s can be mounted on the front panel of the main case, but the unit is easier to use if they are fitted in a separate much smaller case. The l.e.d.s are then connected to the main unit via a piece of three-way cable about 0.5 to two metres long.

The current flow to the l.e.d.s is not sufficient to warrant any form of heavy-duty cable. Twin-screened cable or a three-way lead peeled from a piece of ribbon cable will suffice. The rear panels of both cases must be drilled with holes to take the cable, and if metal cases are used the holes should be fitted with p.v.c. grommets to protect the cable.

Practically any ultra-bright l.e.d.s should work well in this circuit, and the higher their efficiency the brighter the pulses of light produced. However, evenness of illumination is also important in this application, and it is worth experimenting with a few l.e.d.s to find the ones that give the best results.

In general, larger l.e.d.s seem to give more even beams of light, but the latest 5mm diameter types give the highest light levels. The 3mm types do not seem to give high enough light output levels to be of use in this application.

Fig.3. Printed circuit board component layout copper foil master and interwiring details. Check component positions as not all holes are used.

Fig.4. Pinout details for the TIP121/122 Darlington power transistor.

### CONSTRUCTION

The EPE multi-project printed circuit board (p.c.b.) forms the basis of this project, and it utilizes the component layout, copper foil master and wiring shown in Fig.3. This board is available from the EPE PCB Service, code 932.

Although this project is extremely simple the usual warnings about the multi-project p.c.b. have to be repeated here. Unlike an ordinary custom printed circuit board the multi-board has numerous "leftover" holes that tend to confuse things slightly when fitting the components. Take extra care to avoid misplaced components when building this board and double-check the completed board very carefully for errors.

In all other respects construction of the board is largely straightforward. The LF351N used for IC1 is not static-sensitive, but it is still advisable to use a holder for this device.

Fitting TR1 is slightly awkward because the leadouts of the device do not match up properly with the board layout. Things

would be much easier if the base (b) and collector (c) terminals of the Darlington transistor were the other way round. In order to fit the device into this layout it is necessary to cross over the base and collector leads, but this is not difficult provided TR1 is given the orientation shown in Fig.3.

The pinout wires of TR1 can be fitted with short pieces of p.v.c. sleeving to ensure that there are no accidental short-circuits. Fig.4 shows the leadout configuration for TR1, and should help you to avoid errors when connecting this component.

Although the TIP122 is a power transistor it only operates at very low average power levels in this circuit, and so no heatsink is required. A TIP122 is used for TR1 on the prototype, but some suppliers stock the TIP121 instead, and this is equally suitable.

### L.E.D.S

Virtually any medium size plastic or metal box should accommodate this project, but bear in mind that the battery pack

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## TESTING

Once the small amount of hard wiring has been added the unit is ready for testing. It is essential to thoroughly check the finished unit before connecting the battery and switching on because mistakes could easily result in the l.e.d.s being fed continuously with a high current. This would destroy them in a fraction of a second.

When initially testing the circuit it is not a bad idea to connect a 220 ohm resistor in the cathode (k) connection to the l.e.d.s. This will limit the current to a safe level in the event of a fault.

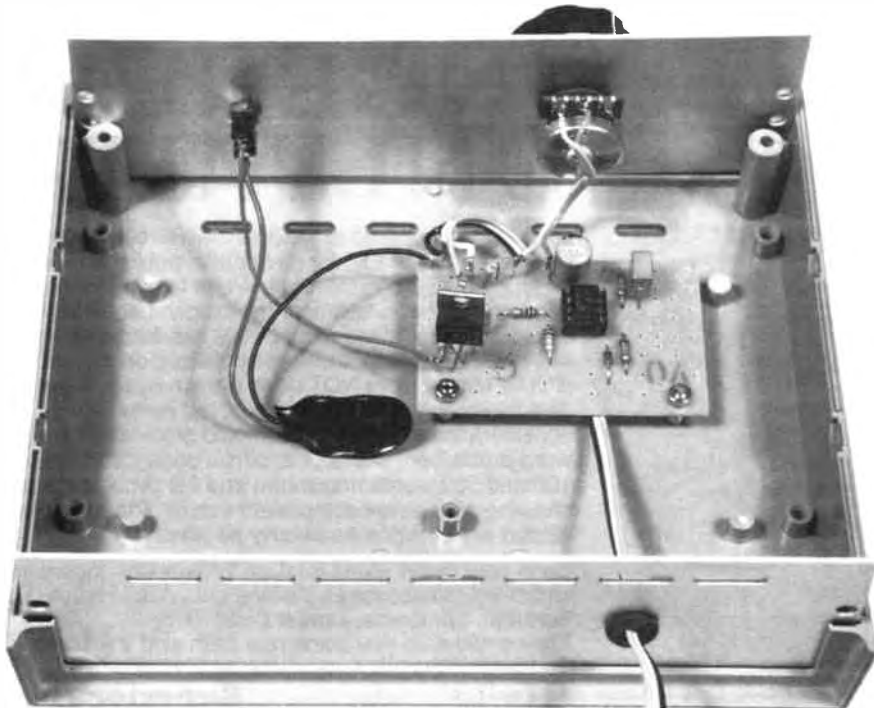
With control VR1 set at maximum resistance (fully counter-clockwise) the l.e.d.s should flash at a low enough rate for the pulsing action to be seen. Advancing VR1 in a clockwise direction will soon increase the operating frequency to the point where the flashing is too fast to be perceived.

A quick way of checking that the l.e.d.s are still strobing is to simply wave the l.e.d.s around in the air. This should draw a sort of dotted line of light in the air.

## IN USE

Although this unit is only suitable for use with small items of machinery it is still essential to use it with due care so that accidents are avoided. Most ultra-bright l.e.d.s produce fairly tight beams of light, so it should not be necessary to use the unit at very close ranges.

Finding the right setting for frequency control VR1 is largely a matter of trial and error. If the required "freezing" is obtained, but with the machine in two or



Suggested layout of components inside the case. Allow plenty of room for the 8-cell AA size battery pack.

more positions simultaneously, the flash rate is too high resulting in more than one flash per cycle of the machine. The "freezing" effect will be obtained if the stroboscope is set to flash on every other cycle, every third cycle, etc., but the "frozen" image will be rather blurred. Optimum results are produced at the highest flash rate that gives a single "frozen" image.

The maximum rate of 100Hz (6000 r.p.m.) might not be sufficient for some small pieces of machinery. The maximum output frequency can be increased to about 300Hz (18000 r.p.m.) by increasing the value of VR1 to 220 kilohms, but accurate adjustment of the flash rate will then be more tricky. Using a value higher than 220k is not recommended as it could result in the oscillator stalling. □

## SHOP TALK

with David Barrington

### EPE Mood PICKer

Reading between the lines, the conclusion to be drawn regarding the use of the choke version of the inductor for the *EPE Mood PICKer* is – don't! Apart from being an extremely messy operation to produce an air-cored coil from it, the cost is about three times greater than the alternative coil.

Constructors are, therefore, recommended to stick with the "Eagle" LT44 driver transformer and modify it as outlined. The LT44 is sometimes listed by advertisers as a "transistor driver transformer" and should be widely available. If any difficulties are experienced in locating it try a **Maplin** store, quoting code HX82D. The same source was identified as stocking the AD8532 dual op.amp, code OA16S.

A ready-programmed PIC16F84 microcontroller is available (*mail order only*) from the author for the sum of £8 inclusive UK. Overseas readers should add £1 for postage and packing. Orders and payments should be made out to **Mr. A. Flind** and sent to: **Mr. A. Flind, 22 Holway Hill, Taunton, Somerset, TA1 2HB.**

For those readers who wish to program their own PICs, the software is available from the Editorial Offices on a 3.5in. PC-compatible disk, see *EPE PCB Service* page 540. If you are an Internet user, it can be downloaded *Free* from our FTP site: <ftp://ftp.epemag.wlmborne.co.uk/pubs/PICS/moodPICKer>.

### 12V Battery Tester

Most of the parts required for the *12V Battery Tester* are nearly all standard items and most of our components advertisers should be able to come up with the goods, or a suitable alternative. The extra flexible lead is usually sold as meter lead, but multistrand cable could prove to be just as reliable.

Some readers may experience difficulty in locating a suitable case, with probe, and the REF50Z 5V voltage reference chip. The probe case came from **Maplin** (☎ 01702 554000), code JX57M, and the REF50Z voltage reference from **Electromail** (☎ 01536 204555), code 283-851.

### L.E.D. Stroboscope

We do not expect any buying problems to arise when selecting components for the *L.E.D. Stroboscope*, this month's low-cost Starter Project. Both the specified TIP122 and TIP121 power

Darlington transistors should be stocked by the majority of our component advertisers.

Practically any of the ultra-bright l.e.d.s should operate well in this circuit, the higher their efficiency the brighter the pulses of light produced. The latest 5mm types appear to give the highest light levels. It is worth experimenting with several l.e.d.s to find ones that give a nice evenness of illumination. Forget the 3mm types, they lack the light output for this application!

The style of case is left to individual choice. Almost any medium size plastic or metal housing can be used, but bear in mind the bulk of the 8-cell battery pack when making your final choice.

If you intend to mount the strobe light l.e.d.s remote from the main unit, you could try adapting a probe type box or a small torch to give a handheld unit. A probe-case will cost about £2.

### Intruder Deterrent

Checking out components for the *Intruder Deterrent* project we came up against a minor problem in finding a source for the neat "plug-box", incorporating a mains outlet socket. We finally tracked it down as one being distributed by **BCL Distribution** and coded as PS13AS. Having contacted **BCL**, they put us onto **Harrogate Electronic Services** who, they suggested, might be willing to supply readers on a *mail order* basis.

Richard Page of Harrogate informs us that they are happy to supply the specified PS13AS case for the sum of £5.95 all inclusive. (Note that the pin arrangement is the UK three-pin standard.) Orders should be made out to: **Harrogate Electronic Services, 25 Regent Parade, Harrogate, N. Yorks, HG1 5AZ.** (☎ 01423 564353), quote code PS13AS.

The BP103B phototransistor also took some finding and was found listed by **Rapid Electronics** (☎ 01206 751166), code 58-490. It is most important that only a new **Class-X** capacitor rated for **direct** connection across the mains supply be used for C4. One can be purchased from **Electromail** (☎ 01536 204555), code 115-196 or 210-500.

### Practical Oscillator Designs

Investigating the "practical" circuits presented in the *Practical Oscillator Designs—1* feature we came across a Toko coil number that was alien to us. The one in question was the RHCS45328AC2 i.f. transformer and, referring back to the author, we were informed that it is a replacement for an earlier Toko IFT. It is currently listed by **Bonex Ltd** (☎ 01753 549502), code 355328. As far as we are aware, it is *not* listed or carried by **Cirkit**.

For this month's collection of printed circuit boards see page 541.