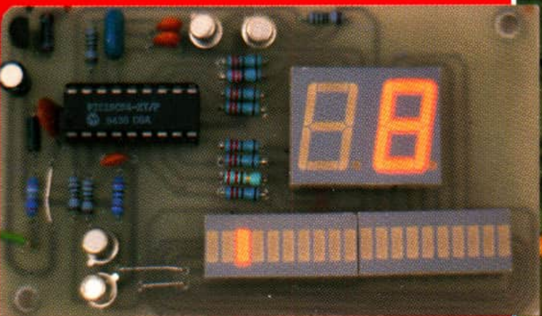
Vari-Colour Christmas Lights

Red to Green to Yellow and off in a pseudo random pattern

PIC D/A Tachometer

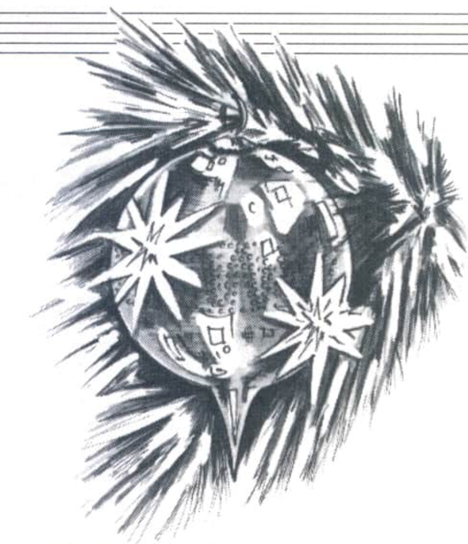
Digital and Analogue Readout of R.P.M.



Stereo Cassette Recorder

Easy to build record/replay p.c.b. project

EPE Elysian



VARI-COLOUR CHRISTMAS TREE LIGHTS

ROBERT PENFOLD

Light-up your tree with ever – changing colours this festive season.

THE electronically controlled Christmas tree lights featured here consist of a string of ten or twelve tri-colour light emitting diodes (l.e.d.s). A range of colourful effects can be produced, and standard flashing Christmas tree lights simply do not bear comparison to this system. The basic effect is for the lights to be cycled through red, green, yellow and off in a pseudo random fashion.

A tri-colour l.e.d. is basically just a green l.e.d. and a red type housed in the same case, with their light output directed at a single diffuser. As one would expect, red or green light is produced if one or other of the l.e.d.s is switched on. If both l.e.d.s are switched on at once, their light output mixes to produce yellow/orange light. By altering the relative strengths of the two l.e.d.s, the exact colour of the light can be varied from a very red-orange through to a green-yellow colour.

LIGHT FANTASTIC

The electronics at the heart of this "lights show" is basically just two low frequency triangular oscillators, one driving the red l.e.d.s and the other driving the green ones. A triangular waveform gives a steady variation from zero to full brightness and back again.

One of the oscillators operates at a fixed frequency of about one Hertz, but the other has an adjustable output frequency. Its approximate frequency range is one cycle every 2·5 seconds to a little over four Hertz.

Example output waveforms for the oscillators are shown in Fig. 1. In this case the oscillator driving the green l.e.d.s is operating at three times the frequency of the one controlling the red l.e.d.s.

The colours produced at various points in the sequence are also shown in Fig. 1. Even with one oscillator operating at a frequency which is an exact multiple of the other oscillator's frequency, and a convenient phase relationship between the two, the sequence of colour changes is quite involved.

Results are best if the oscillators are set at frequencies which do not have such a convenient mathematical relationship. This gives a display which varies in brightness at a rate which is controlled by the higher frequency oscillator, but the colour variations are apparently rather random.

In truth the colour patterns will always repeat, but over a long period of time, giving an apparent randomness to the display. The effect is hard to describe, but the complex and continuous variations in colour make a simple flashing light display look rather pedestrian by comparison.

CIRCUIT DESCRIPTION

The main circuit diagram for the Vari-Colour Christmas Tree Lights appears in Fig. 2, and the mains power supply circuit is shown separately in Fig. 3.

A dual operational amplifier, IC1, is utilized in a conventional triangular/squarewave oscillator. IC1a acts as the integrator and provides the triangular output signal, while IC1b is used as the trigger and provides a squarewave signal. In this case it is only the triangular waveform that is needed, and the output signal of IC1b is unused.

Maximum efficiency is usually obtained by driving large numbers of l.e.d.s in series. Unfortunately, in this case *series* connection is *not* an option.

Tri-colour l.e.d.s invariably seem to have either a common cathode (k) or a common anode (a) connection, and the l.e.d.s used in this design are of the common cathode variety. Series connection is only possible if the anode and cathode terminals are individually accessible.

DRIVING FORCE

The l.e.d.s must therefore be driven in *parallel*, which inevitably means that quite high output currents are involved. A drive current of about 20 milliamps per l.e.d. is needed in order to give really good brightness, which gives a total drive current of 200 milliamps (200mA) for a bank of ten l.e.d.s.

This current is far higher than IC1a can supply, and the l.e.d.s (D1a to D10a) are therefore driven via transistor TR1, which

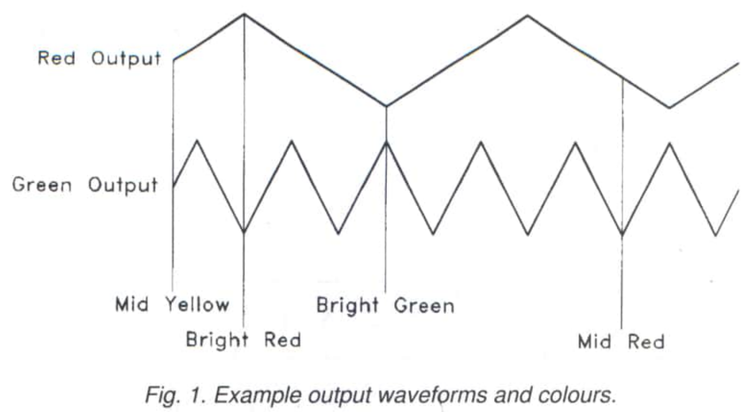


Fig. 1. Example output waveforms and colours.

operates as an emitter follower buffer stage. Transistor TR1 is actually a power Darlington device which can easily supply output currents of 200mA or so, even though IC1a can provide an output current of only a few milliamps.

Ideally, each l.e.d. would be driven via its own current limiting resistor. This is impractical as it would require each l.e.d. to be fed from the controller via a separate lead.

In order to avoid a complete "rats nest" of wires it is necessary to use a method of connection that enables the l.e.d.s to be interconnected via a single cable that runs from one light to the next. Experiments showed that there was no problem if the l.e.d.s are fed via a common current limiting resistor (R6) provided they are *all* of the same type.

The circuit seems to regulate itself so that the current through each l.e.d. is more or less the same, and there is no obvious difference in the brightness of the lights.

VARIABLE FREQUENCY

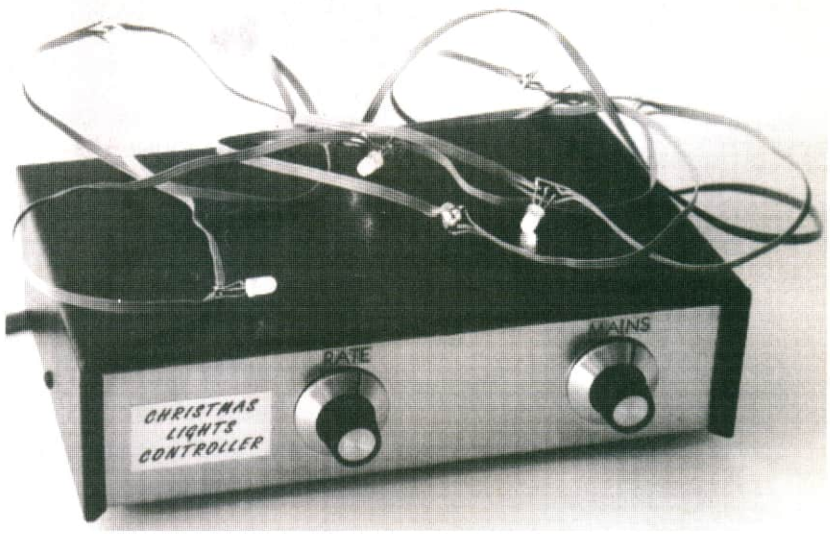
The other sections of the l.e.d.s (D1b to D10b) are driven from another triangular/squarewave oscillator and buffer amplifier, but this circuit has a variable output frequency. This is achieved by using a rotary potentiometer VR1, wired as a variable resistor, as part of the timing resistance.

The maximum frequency of about four Hertz is achieved with VR1 set at minimum resistance, running through to the minimum frequency of around 0·4Hz with VR1 at maximum resistance.

POWER SUPPLY

The mains power supply circuit (Fig. 3) is of conventional design. Mains transformer T1 provides a voltage step-down and isolation from the dangerous mains supply. Full-wave bridge rectification is provided by rectifier diodes D11 to D14, and the supply is smoothed by the high value electrolytic capacitor C4.

A monolithic voltage regulator, IC3, stabilises the output potential at eight volts. The supply current to the main circuit varies from about 10mA with all the lights switched off, to a little over 400mA with both sections of all ten lights at maximum brightness.



Completed controller with "lights" chain.

CONSTRUCTION

A stripboard having 52 holes by 26 copper strips accommodates most of the components. This is not a standard size in which the board is sold, and a larger piece must be trimmed to the correct size using a hacksaw.

The circuit board topside component layout and interwiring details are given in Fig. 4. Also included is an underside view showing the positioning of the 34 breaks required in the copper strips.

Start construction by drilling the two mounting holes, which should be about 3·3mm in diameter. Three holes of the same size are also needed where TR1, TR2, and IC3 will eventually be bolted to the board.

Next the numerous breaks should be made in the copper strips, using either a special track-cutting tool or a hand-held twist drill bit of about five millimetres in diameter. Make sure that each break covers the full width of the strip, but try to avoid cutting too deeply into the board (which could weaken it significantly).

The board is now ready for the components and 14 link-wires to be fitted. It is best to work methodically across the board, being careful not to omit anything.

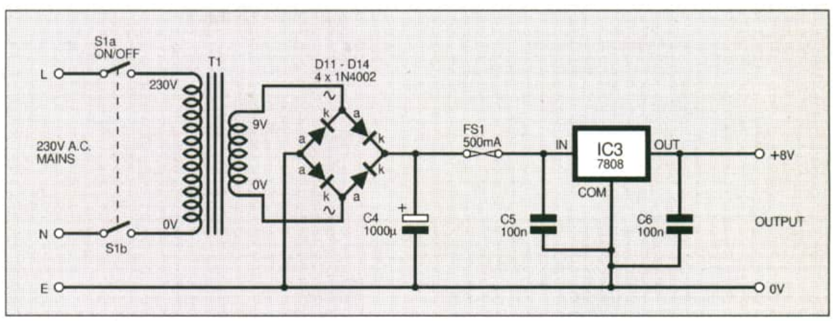


Fig. 3. Circuit diagram for the 8V mains power supply.

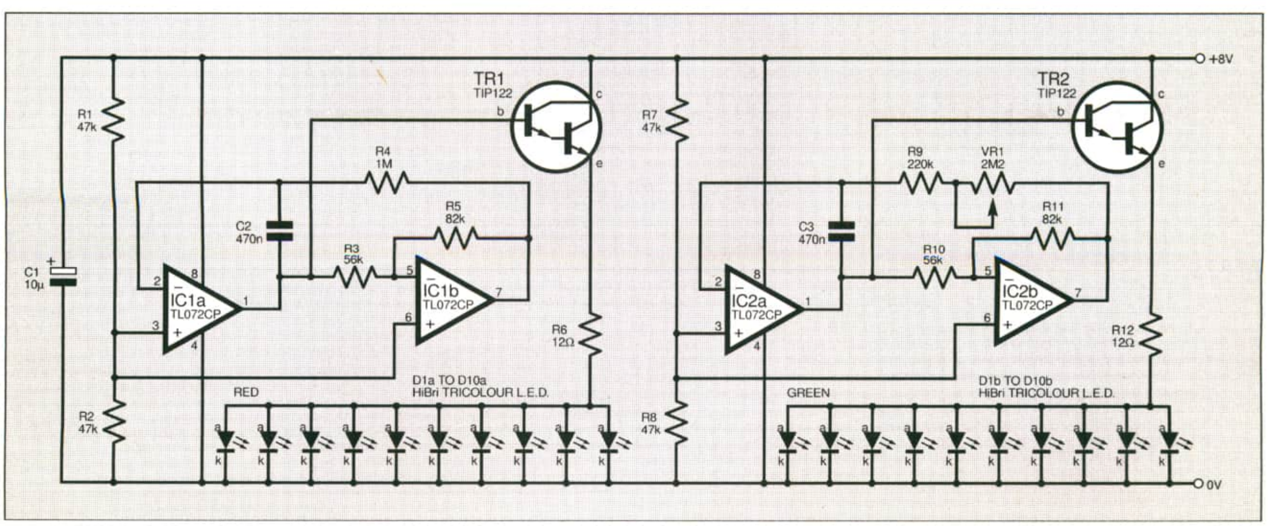


Fig. 2. Main controller circuit diagram for the Vari-Colour Christmas Tree Lights.

Op.amps IC1 and IC2 are not MOS devices and do not require any special handling precautions, but it is still advisable to fit them to the board via d.i.l. holders. Capacitors C2 and C3 must be miniature printed circuit mounting types having 7·5mm (0·3 inch) lead spacing if they are to fit neatly into this component layout.

Be careful to fit the electrolytic capacitors C1 and C4 the right way round as a mistake here could result in the incorrectly fitted component being destroyed (probably in spectacular fashion). For the same reason, double check that diodes D11 to D14 are all fitted correctly. The link-wires can be made from 22s.w.g. or 24s.w.g. tinned copper wire, or trimmings from the resistor leadout wires might suffice.

The amount of power dissipated by TR1, TR2, and IC3 is not very large, but it is advisable to fit them with small bolt-on heatsinks. The heatsinks used on the prototype are somewhat larger than necessary, and the smallest of ready-made heatsinks for TO220 cased devices should be perfectly adequate. The screws which hold the heatsinks in place are also used to secure the components to the circuit board.

To complete the circuit board, fit single-sided solder pins at the points where connections VR1, T1, etc. will be made. "Tin" the tops of the solder pins with plenty of solder, as this will make it easier to produce reliable connections to them.

CASE

For reasons of safety this project must be housed in a ***metal*** case which has a screw fitting lid, and not one that simply clips on and unclips. The case *must* be reliably "earthed" to the mains Earth lead.

A mains powered project such as this is not suitable for beginners unless they are closely supervised by someone who is suitably experienced at electronic project construction.

A metal instrument case is probably the best choice for this project, and one about 200mm (8in.) or so wide should comfortably accommodate everything. Switch S1 is mounted well towards the left-hand end of the front panel (rear view), and potentiometer VR1 is fitted at any desired

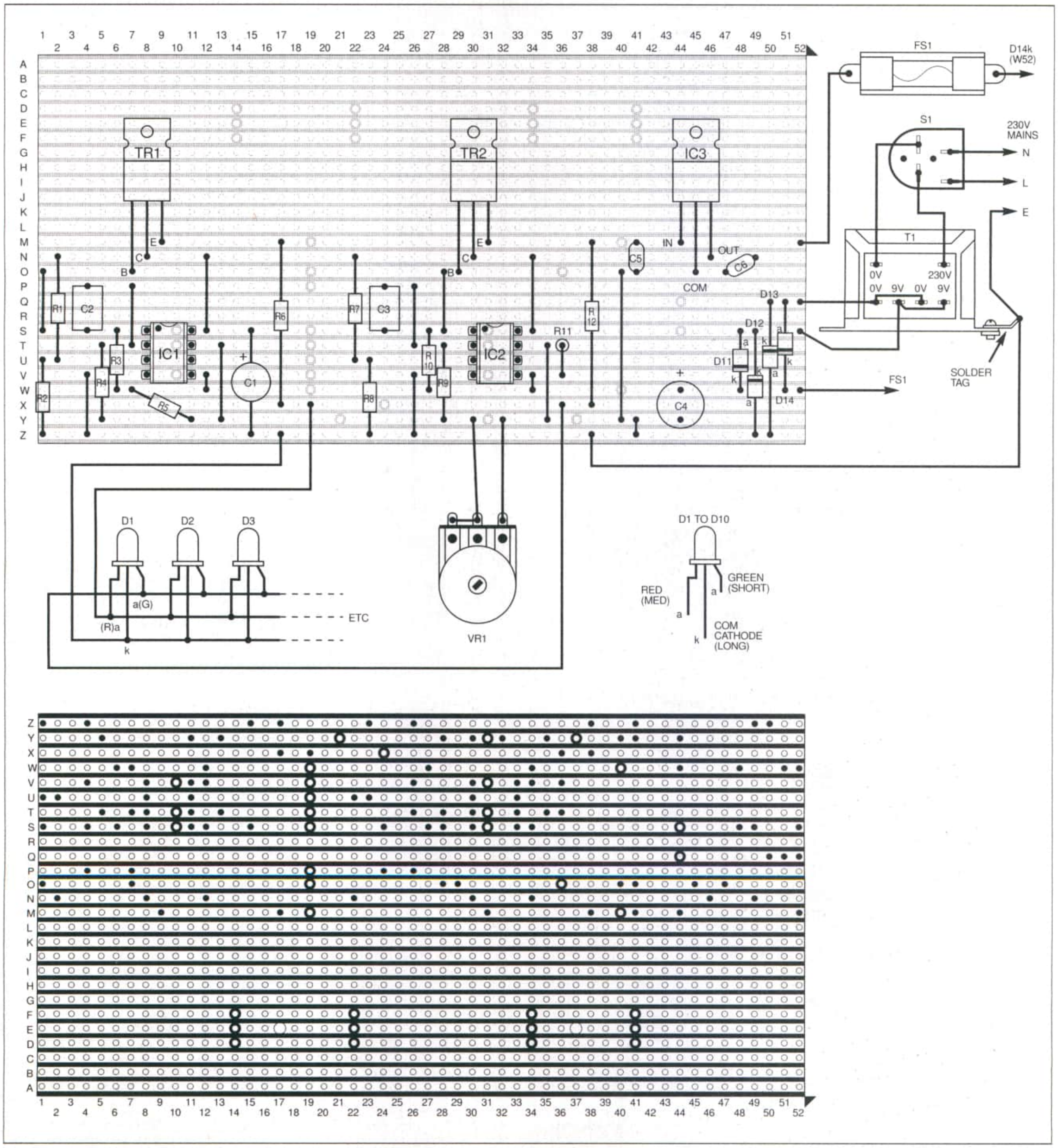
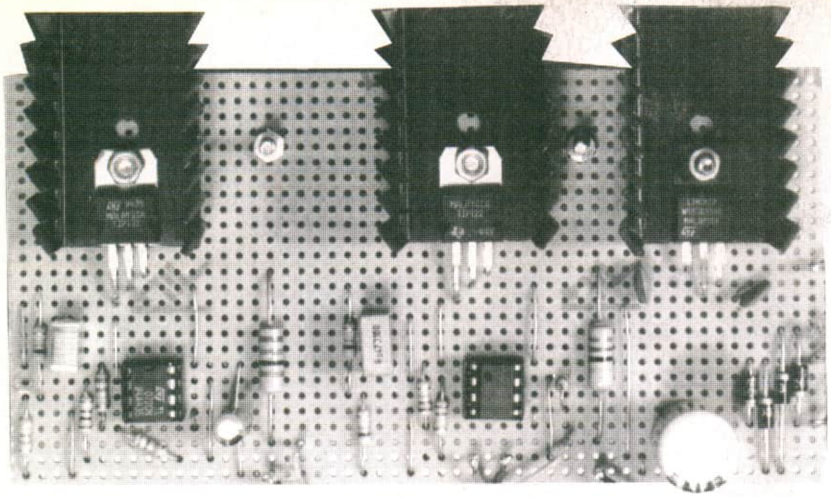


Fig. 4. Vari-Colour Christmas Tree Lights stripboard component layout, underside showing breaks in copper strips and interwiring to off-board components. The pinout details for the tri-colour l.e.d. is shown inset.



Completed circuit board showing the Darlington transistors bolted to heatsinks.

position on the right-hand section of the panel (rear view). The circuit board is mounted well towards the right-hand side of the case, which should leave ample space for transformer T1 to its left (as viewed in the internal photograph).

Mount the circuit board on the base panel using 6BA or metric M3 screws, using spacers about 12mm long to hold the board well clear of the case. This should ensure that there is no danger of the fixing screws for the outer casing damaging or "short circuiting" the board.

Also be careful to position the mains transformer T1 where it will not be damaged by these screws. A solder tag is fitted on one of T1's mounting bolts, and this acts as an Earth connection point for the case.

A hole for the mains lead is made in the rear panel of the case, roughly opposite mains on/ff switch S1. This hole ***must*** be fitted with a "strain relief" type grommet and the connecting leads securely anchored to protect the mains cable from young prying fingers, particularly at this seasonal time of year.

Fuse FS1 is fitted in a chassis mounting fuseholder which is bolted to the base panel of the case to the rear of T1. Alternatively, a panel mounting fuseholder can be mounted on the rear panel of the case, next to the entrance hole for the mains lead.

The output of the unit can be connected to the l.e.d. "light chain" via a three-way socket fitted on the rear panel, but direct connection is used on the prototype. This requires a hole for the output lead in the rear panel, and this hole should also be fitted with a grommet to protect the cable.

INTERWIRING

The "hard wiring", apart from the connections to the l.e.d.s, is also shown in Fig. 4. The wiring is very straightforward, but it is essential to take ***extra care*** with

COMPONENTS

See SHOP TALK Page

Resistors

R1, R2, R7, R8	47k (4 off)
R3, R10	56k (2 off)
R4	1M
R5, R11	82k (2 off)
R6, R12	12Ω 0·5W (2 off)
R9	220k

All 0·25W 5% carbon film, unless stated

Potentiometer

VR1	2M2 rotary carbon, lin

Capacitors

C1	10µ radial elect. 25V
C2, C3	470n polyester, 7·5mm lead spacing (2 off)
C4	1000µ radial elect. 25V
C5, C6	100n disc ceramic

Semiconductors

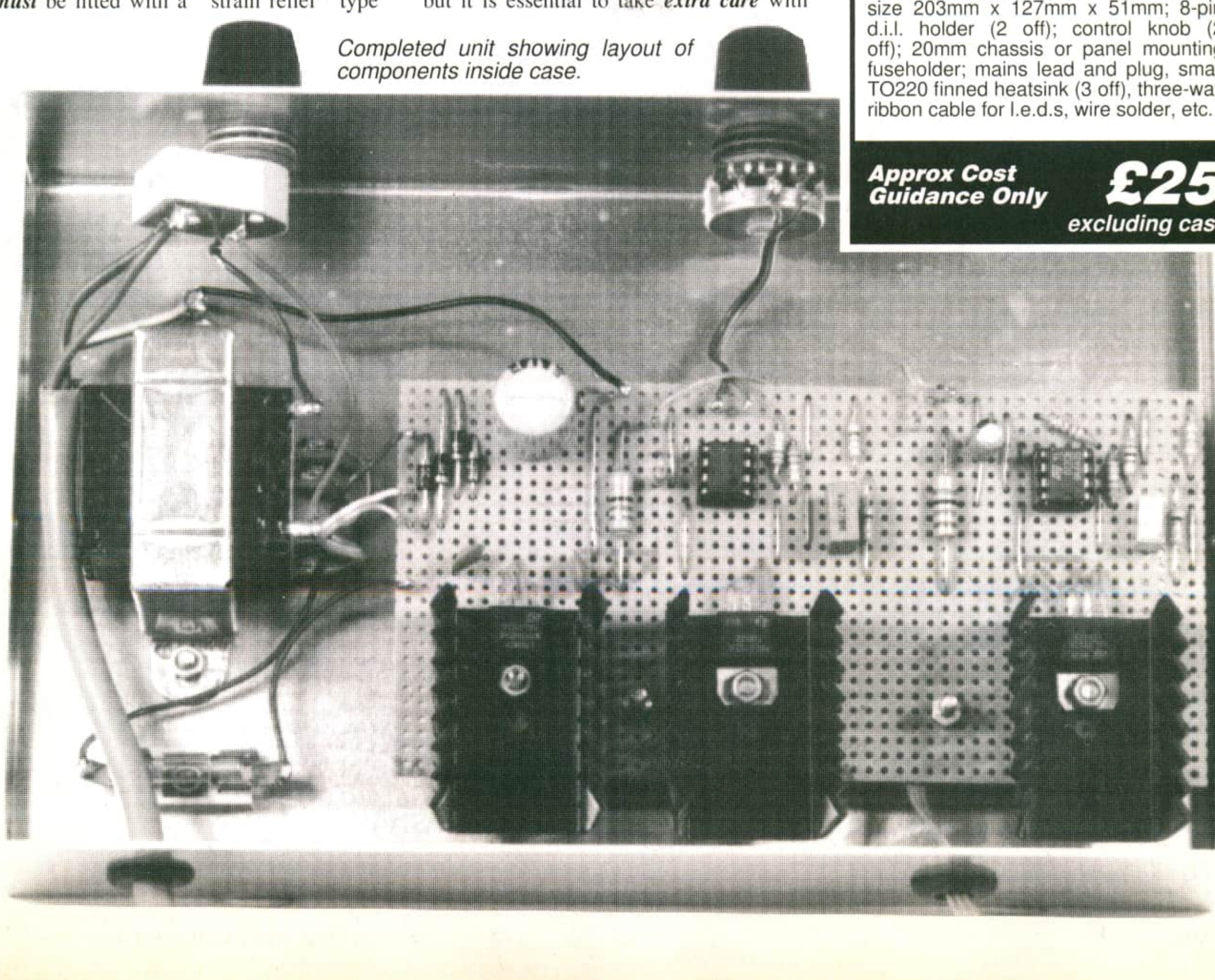
D1 to D10	5mm common cathode, high brightness, tri-colour l.e.d. (10 off)
D11 to D14	1N4002 100V 1A rectifier diode (4 off)
TR1, TR2	TIP122 or TIP 121 *npn* power Darlington (2 off)
IC1, IC2	TL072CP bifet dual low-noise op.amp (2 off)
IC3	µA7808 8V 1A positive regulator

Miscellaneous

T1	standard mains primary, 9V 666mA secondary (see text)
S1	rotary mains switch
FS1	500mA 20mm "quick-blow" fuse

Stripboard 0·1 inch matrix, size 52 holes x 26 strips; metal instrument case, size 203mm x 127mm x 51mm; 8-pin d.i.l. holder (2 off); control knob (2 off); 20mm chassis or panel mounting fuseholder; mains lead and plug, small TO220 finned heatsink (3 off), three-way ribbon cable for l.e.d.s, wire solder, etc.

Approx Cost Guidance Only £25 *excluding case*

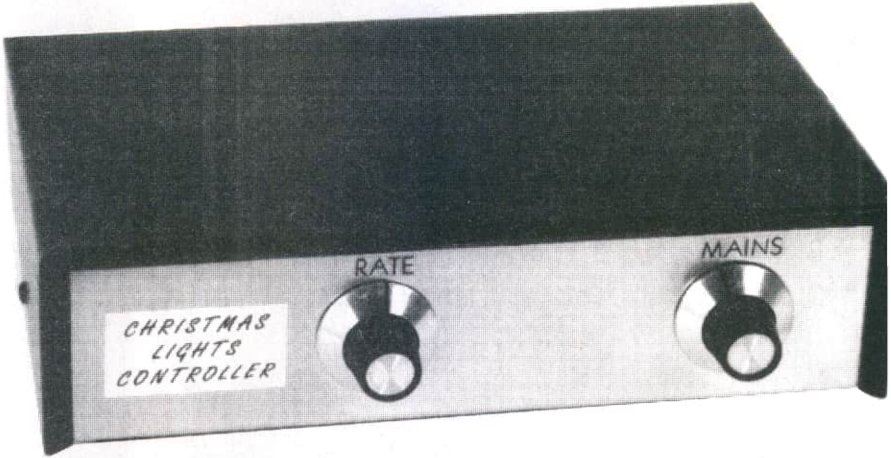


Completed unit showing layout of components inside case.

the wiring to the mains transformer T1 and on/off switch S1. Mistakes here could cause costly damage, and could also be very dangerous. Make quite sure that the connections to the Earth solder tag are reliable, and resolder the joint if it seems at all dubious.

A mains transformer having a 9V secondary winding rated at about 666mA is required. These days virtually all small mains transformers seem to have twin secondary windings.

The specified transformer has twin 9V 333mA secondary windings which are connected in parallel, as shown in Fig. 4. This effectively gives a single 9V 666mA winding. *Note that this method of connection must only be used with transformers that have accurately matched secondaries* ***that are designed for parallel connection.***



LIGHTING CHAIN

The l.e.d.s are wired together using a length of thin three-way cable. Grey ribbon cable is a good choice, and a three-way strip is easily peeled off a wider piece.

About 0·5m to one metre of cable is needed to connect the controller unit to the first l.e.d., and the l.e.d.s are then spaced at intervals of about 150mm to 250 millimetres. Fig. 4 also provides connection details for the chain of l.e.d.s.

In order to fit an l.e.d., the 3-way ribbon cable must first be split into three separate wires at the point where the l.e.d. is to be fitted/inserted. This is easily done using a modelling knife and a cutting mat, being careful to cut between the wires, and not into them. The wires should be separated over a length of about 20mm.

Wire strippers can then be used to cut through the insulation on each wire, so that it can be pulled apart to reveal a few millimetres of bare wire. This bare wire is "tinned" with solder, and there should then be no difficulty in connecting the l.e.d. to it.

The built-in current limiting of IC3 plus fuse FS1 should avoid disasters if accidental short circuits should occur in the l.e.d. wiring, but it is a good idea to use some Bostik "Blue-Tak" around the leads of each l.e.d. to keep them apart.

FINAL CHECKS

Give the finished unit a final check before plugging it in and switching on. If all is well the l.e.d.s should provide a psychedelic display as soon as the unit is switched on, and by adjusting the Rate control VR1 it should be possible to control the rate at which the colour change occurs.

If a simple red flashing display is produced, at least one of the l.e.d.s has its "red" and "green" anodes connected the wrong way round. The red sections have a lower turn-on voltage than the green sections, which makes it essential to have all the red sections driven from one output, and all the green sections driven from the other output.

Any attempt at mixed operation results in the red sections limiting the drive voltage to a level that is too low to switch on the green sections. Hence only the red half of each l.e.d. is activated.

Happy Christmas to all *EPE* readers! □