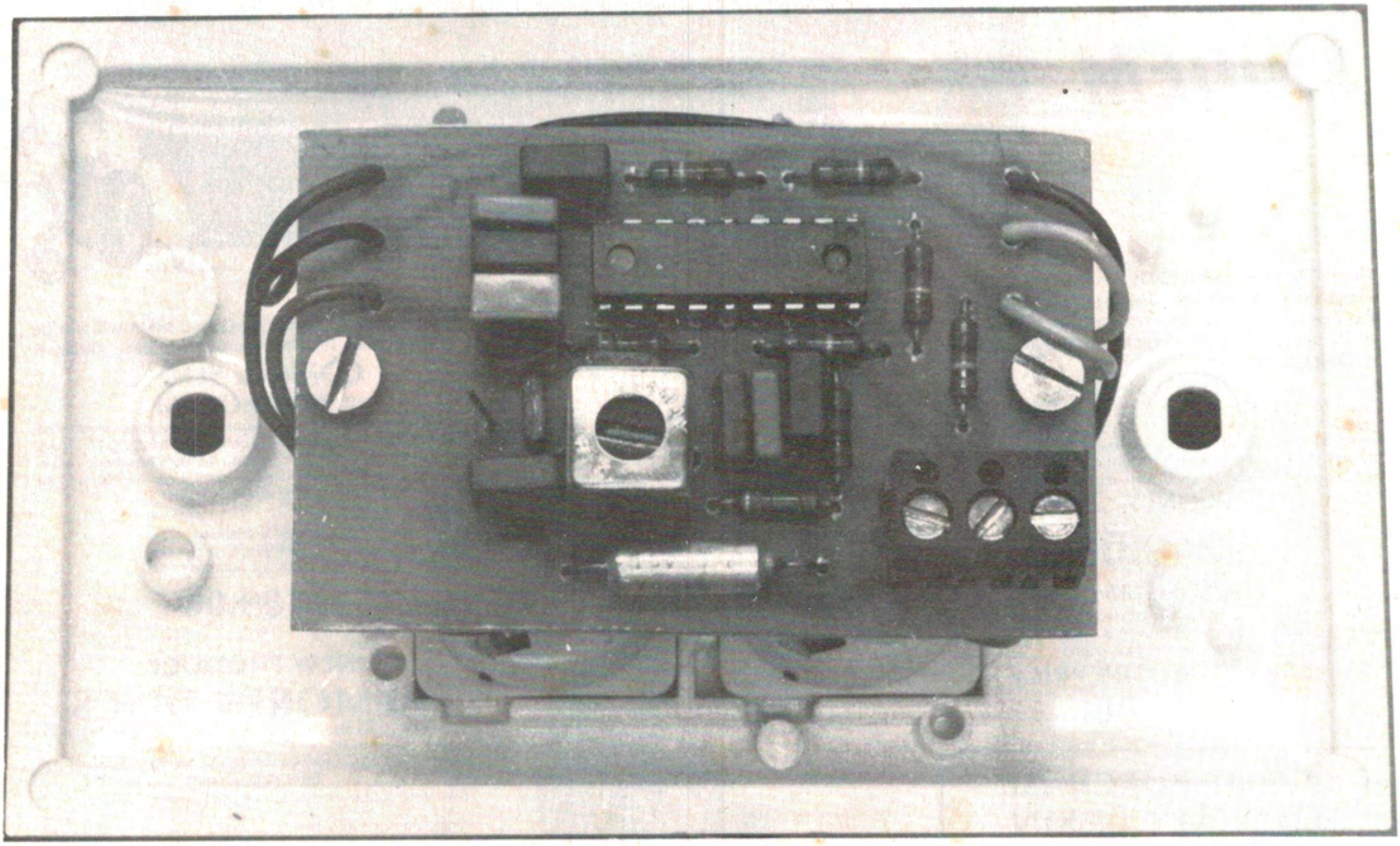


Control up to four room lights over a twin-wire cable

Here are the full construction and setup details for our room lights controller.

Part 2

Ian Thomas

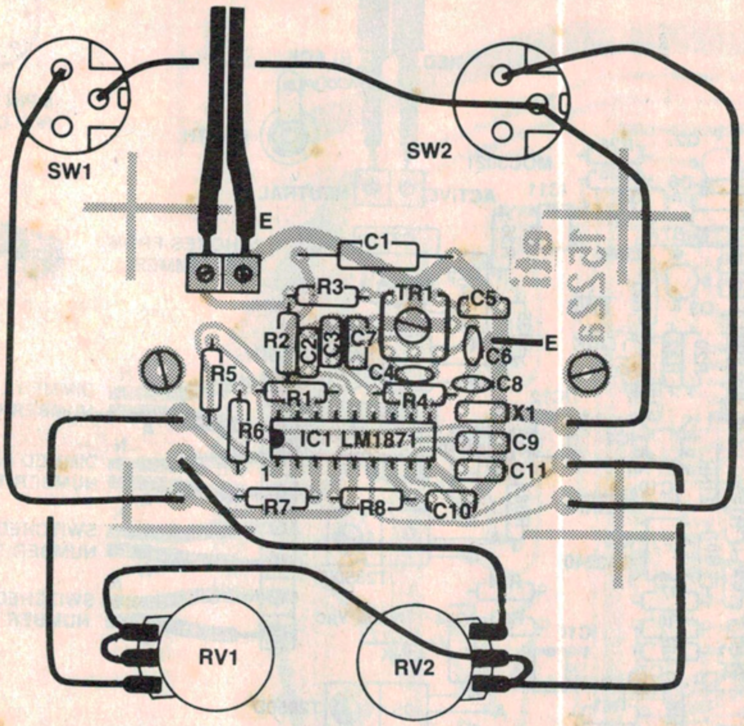
THE SIMPLEST AND EASIEST part to build is the transmitter end which is finally the actual light switch on the wall. The printed circuit board itself is quite straightforward. You need only take care that the integrated circuit is in the right way and that the power supply filter capacitor, C1, has the correct polarity. The correct transformer to use in the oscillator from the pack supplied by Dick Smith (and others) is the one marked "OSC" and has a red tuning slug.

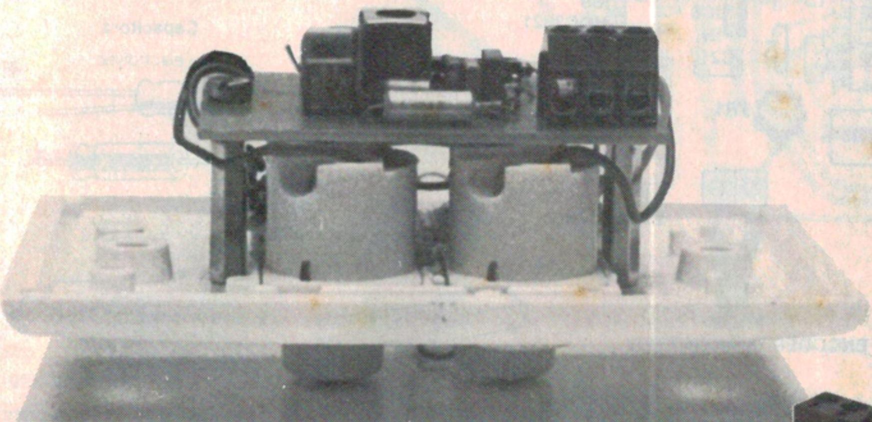
Before mounting any switches on the four-way "HPM" mounting plate it is a good idea to use the printed circuit board as a template to mark where the two mounting screw holes should go. Drill the two mounting holes in the plate to 5/64" (to clear 4 BA) and, if necessary, drill out the printed circuit board itself to the same size. Before mounting any spacers on the printed board or front panel it is necessary to assemble the front panel itself.

The first step is to completely strip down the two "HPM Cat. No. 500 VA" light dimmers. The two switches may be directly inserted in the four way panel as shown in the photo. In order to remove the dimmers from the two-way mounting panel in which they came, first pull off the knob (they're a straight pull with no clamping screws). The dimmers can then be removed from their front panels (once again, there's no magic — just muscle). The next step is to remove the rear cover of the dimmer body itself. Here it is easy to slip a small screwdriver under where the tongue catches in the slot and lever off the rear cover. The whole works of the light dimmer can then be slid from the outer plastic case by pressing on the potentiometer shaft.

Discard all the small bits of grey insulating material around the aluminium triac heatsink. Next, unsolder the three potentiometer leads from the printed circuit board and remove the pot. The plastic main body of the dimmer must next be prepared by cutting it off about 1-2 mm from the step in the body where it locks into the front panel.

Finally, Araldite the potentiometer into the cut-down plastic body so it is located exactly as it was in the original dimmer. *Take exquisite care not to get any Araldite on the pot shaft or in the pot itself.*





Encoder/transmitter. At top is the overlay and wiring diagram, beneath it a view of the switch plate assembly. Note that the twin-wire line to the receiver/triac driver board is polarised. The cable already in the wall will likely have a red and a black wire — use the black one for the line marked 'E' on each board.

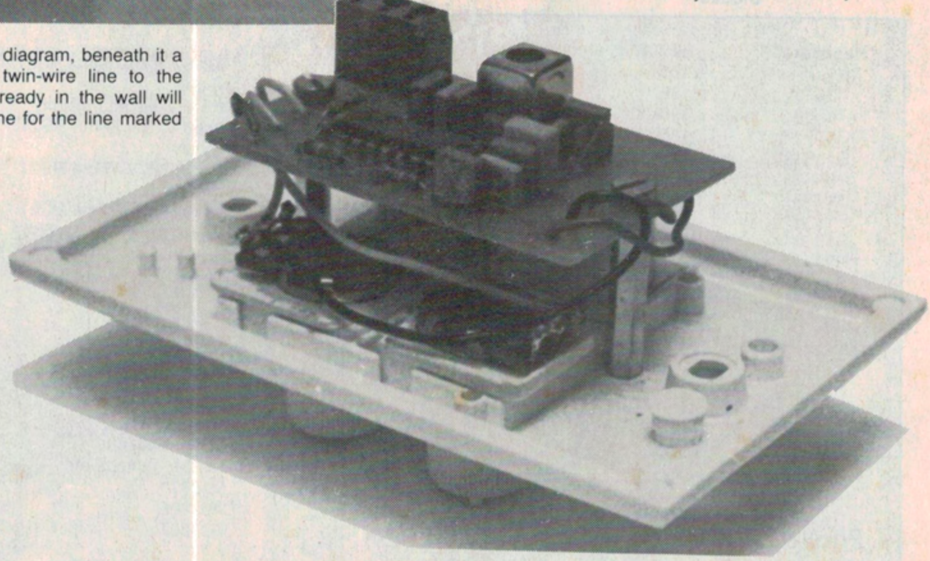
PARTS LIST — ETI-1522A

Resistors	all ¼W, 5% unless noted
R1	150k, 2% metal film
R2	100R
R3	470R
R4	47k
R5	150k, 2% metal film
R6, R7	220k
R8	120k, 2% metal film
RV1, RV2	500k, see text
Capacitors	
C1	22µ/16 V radial lead electro.
C2, 5, 9, 10	100n/63 V Wima type RS21 or equiv.
C3	2n2/100 V Wima type PR2 or equiv.
C4	390p ERO type KP1835 or equiv.
C6	1n ERO type KP1835 or equiv.
C7	10n/63 V Wima type RS21 or equiv.
C8	100p ceramic (NP0)
C11	3n3/100 V Wima type PR2 or equiv.
Semiconductors	
IC1	LM1871
Miscellaneous	
SW1, SW2	from HPM switch/dimmer module, see text.
TR1	local oscillator coil from 455 kHz IF set, DSE cat. no. L-0260, or equivalent.
X1	Murata CSB455E Ceralock ceramic resonator, or Tandy cat. no. 272-1303.

ETI-1522A pc board; HPM dual switch/dimmer module wall plate Series P.774/VH (see text); 3-way pc mount terminal strip; 2 x 25 mm fibre standoffs with 2 x c/s bolts and 2 x cheesehead bolts; hookup wire, etc.

Price estimate: $38-$42

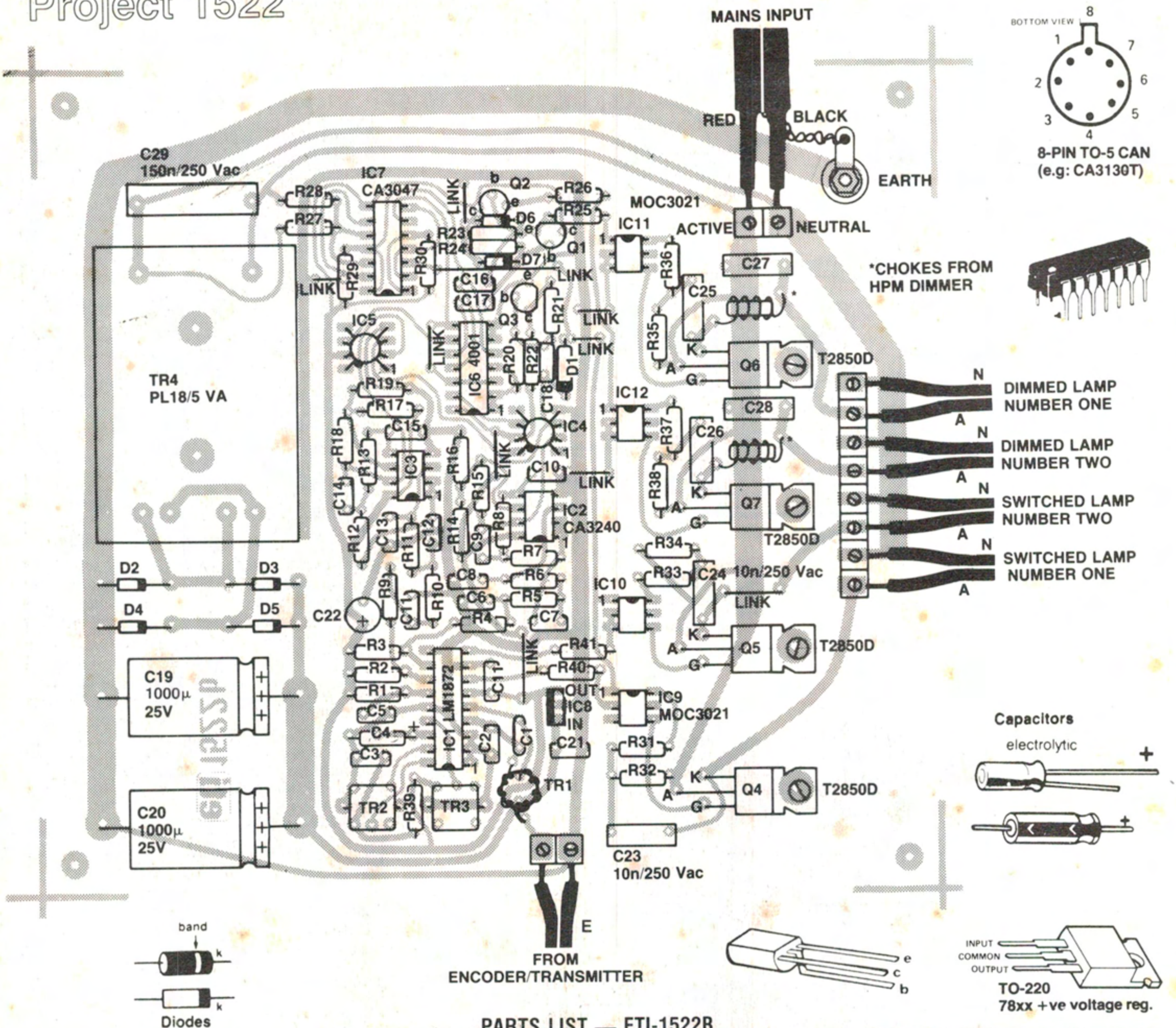
Below. Angled view of the switch plate showing the pots and the board mounting more clearly. Note that the board mounting pillars may be epoxied in place to avoid drilling screw holes through the front of the switch plate. The three-way terminal block was used only because that's what I had on-hand! The overlay shows a two-way block.



You can now assemble the complete four way panel and wire it up as shown in the photo. Finally, mount the printed circuit board on 1″ (25 mm) spacers and the control unit is complete.

The receiver and triac driver is the larger part of the project and I found it easiest (and safest) to assemble and test it in sections.

First, assemble the power supply starting from the mains input connector, mains transformer, TR4, diode bridge D2 to D5, filter capacitors C19, 20 and 21, and finally, the 5 V regulator, IC8. ▶



PARTS LIST — ETI-1522B

Resistors	all ¼W, 5% unless noted
R1	100k
R2, R3	18k
R4, R9	390k, 2%
R5, 6, 10, 11	180k, 2%
R7, R12	160k, 2%
R8, R13	100k, 2%
R14, R17	10k, 2%
R15, R18	7k5, 2%
R16, R19	1k1, 2%
R20	300k, 2%
R21	1k
R22	56k
R23, R24	10k
R25, R26	150R
R27, 28, 29	220k
R30	56R
R31, 33, 36, 37	330R
R32, 34, 35, 38	470R
R39, 40, 41	100R
Capacitors	
C1	390p poly, ERO type KP1835 or sim.
C2, 3, 6, 7, 10, 11, 12, 15, 21	100n/63 V, 5% Wima RS21 or equiv.
C4	1µ/6 V axial lead electro.
C5, C18	47n/63 V, 5% Wima RS21 or equiv.
C8, 13, 16, 17	10n/63 V, 5% Wima RS21 or equiv.
C9, C14	22n/63 V, 5% Wima RS21
C19, C20	1000µ/25 V axial lead electros
C22	100µ/10 V radial lead electro.
C23, 24, 25, 26, 27, 28	10n/250 Vac mains suppression caps
C29	150n/250 Vac mains supp. cap.
Semiconductors	
D1, 6, 7	1N914, 1N4148
D2, 3, 4, 5	1N4001, 1N4002 etc
IC1	LM1872
IC2, IC3	CA3240E
IC4, IC5	CA3130T
IC6	4001B
IC7	CA3046
IC8	7805
IC9, 10, 11, 12	MOC3021
Q1, 2, 3	BC549, BC109 etc
Q4, 5, 6, 7	T2850D RCA triacs
Miscellaneous	
TR1	Philips toroid, 9 mm O.D. by 3 mm thick, 3H1 material; or Neosid toroid 6.35 mm O.D. by 1.52 mm thick, F9 material.
TR2, TR3	IF/DET. transformers from 455 kHz IF set, DSE cat. no. L-0260, or equivalent.
TR4	Ferguson PL18/5VA or equiv.

ETI-1522B pc board; housing to suit (see text); four 12 mm standoffs with bolts and washers; pc mount screw terminal strips (1 x 8-way, 2 x 2-way); 0.4 mm enamelled copper wire; tinned copper wire for links; 4 BA bolt, nuts & solder lug (earth terminal); 4 x 4 BA bolts and nuts; six clamp-type grommets or similar, etc.

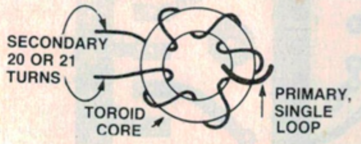
Price estimate: $90-$100

Next, cover all tracks that carry mains voltages with insulating tape so that when the printed circuit board is being tested your good health and longevity is not at risk (joking aside this is a *very* good idea as if you try to build the board up and get it running without taking any precautions you will get bitten at the very least!)

Power-up the board with only the power supply assembled and check that the output from the voltage regulator is 5 V ± 0.4 V. (It is exasperating beyond belief to assemble a large board only to see it all destroyed because the voltage regulator was faulty or, more likely, there was a solder short).

If all is well, turn off the power *and pull out the plug* as the bloke who wired up your house wouldn't be the first to get active and neutral reversed.

CONSTRUCTION OF TR1



Core:	**9 mm O.D. Philips toroid, about 3 mm thick, of 3H1 material (A_L = 800), or 6.35 x 1.52 mm, F9 Neosid toroid (28-501-36).**
Wire:	**Light duty hookup wire.**
Primary:	**One turn.**
Secondary:	**20 turns (Philips toroid) or 21 turns (Neosid toroid).**

Now proceed to assemble all parts of the receiver section. The transformer that recovers the 455 kHz data from the transmitter power supply line has to be wound but is only 20 turns of about 22-26 gauge wire evenly distributed around a Philips 9 mm (O.D.) toroid of 3H1 ferrite. (These toroids are painted orange with one side of the toroid painted various other colours to indicate the permeability of the ferrite material — it doesn't matter what the permeability is). The secondary winding of TR1 is even easier; just one turn, which carries the +12 V to the transmitter section (and also holds down the toroid). Make sure that TR2 is the IF transformer with the yellow-painted tuning slug and TR3 has the white one. It is important that C22 be assembled at this stage.

After the receiver is assembled the transmitter and receiver can be tested and aligned to the same frequency. It is not all that important that the transmitter run at exactly 455.000 kHz, but merely that the receiver be tuned to the same frequency as that sent.

The first thing to do is set up the transmitter. Connect the transmitter to the receiver via the two printed circuit mounting terminals making sure you have the correct polarity (+12 V on the transmitter is nearest the corner and is nearest the IF transformers on the receiver). Then, disable the data transmission from the LM1871 by shorting pins 4 and 12 (I found it easiest to temporarily solder a short piece of wire between the two pins). Power up the combination and check that there is a continuous signal on the +12 V line. If you have a counter, measure the frequency of this signal and adjust TR1 of the transmitter until it is 455 kHz. If you don't have a counter then wind the adjusting slug all in (but gently! these things are not unbreakable) then come out about 1-1½ turns. The oscillator showed the characteristic that it could not be pulled much below 455 kHz but could be pulled until the ceramic resonator lost control completely on the high side. Adjusting this way will put you slightly below 455 kHz but not too far.

The receiver can now be aligned to the transmitter frequency by monitoring the agc voltage that appears on pin 16 of the LM1872. With the data still disabled on the transmitter, adjust first TR2 and TR3 so that the agc voltage is a *minimum*. This should set the passband of the receiver correctly as both transformers are only single tuned. If you have an oscilloscope then the tuning procedure is to monitor pin 17 and adjust TR2 for a maximum then monitor pin 15 and adjust TR3 for a maximum. If your oscilloscope does not have ÷ 10 low input capacitance probes, it is necessary to monitor the voltages through a 4.7 pF capacitor so probe loading does not pull the centre frequency.

Now that the transmitter and receiver are aligned, the short between pins 4 and 12 of the LM1871 can be removed and the two switches should work. Also if the pullup resistors R2 and R3 are in, pulses containing the analogue info should be visible on pins 11 and 12.

The rest of the analogue circuitry can now be assembled starting with the two active filters. Insert ICs 2 and 3 and all the resistors and capacitors associated with them. It will be necessary to insert the jumper near the 5 V regulator (see photo), but don't put in any of the other jumpers yet.

When the two active filters have been completely assembled that section of the receiver can be tested. Power up the system and monitor pin 7 of either IC2 or IC3. When the dimmer controls on the transmitter are varied (trial and error will show which control affects which output) the appropriate output should vary between 0 (actually about 50 mV — this is why it is essential to use an RCA CA3240E for ICs 2 & 3) and 3 volts. There should be no interaction whatsoever between the two controls or between the controls and the two switches. If there is, then there's something wrong.

The next part to do is the 50 Hz zero crossing detector and ramp generator with its associated comparators and gating. Assemble the rest of the circuit up to the optocouplers. When the circuit is powered up pulses about 50 µs wide and negative-going should be on IC6 pin 4, and positive-going on pin 3. The pulses are impedance transformed through three transistors in IC7 to give high current, positive-going pulses out of pin 3 of IC7. There should be a negative-sloping ramp of about 2½ V peak at pins 3 of ICs 5 and 6, which are the two comparators that compare the dc signals out of the filters with the mains synchronised ramp (see "How It Works"). Looking at IC6 pins 11 and 12, you should see square waves whose mark-space ratio is varied by the transmitter controls.

Finally, assemble the optocouplers, *noting that pin 1 for the optocouplers is rotated 180° from all the other ICs*. Also, assemble all the dV/dt protection circuitry and the triacs themselves. The RCA T2850 triacs that I used have the wonderful advantage that the mounting tab is electrically isolated from the pins so you can do as you like with them. If the triacs are simply screwed down to the board it can handle up to about an amp or so without getting too hot.

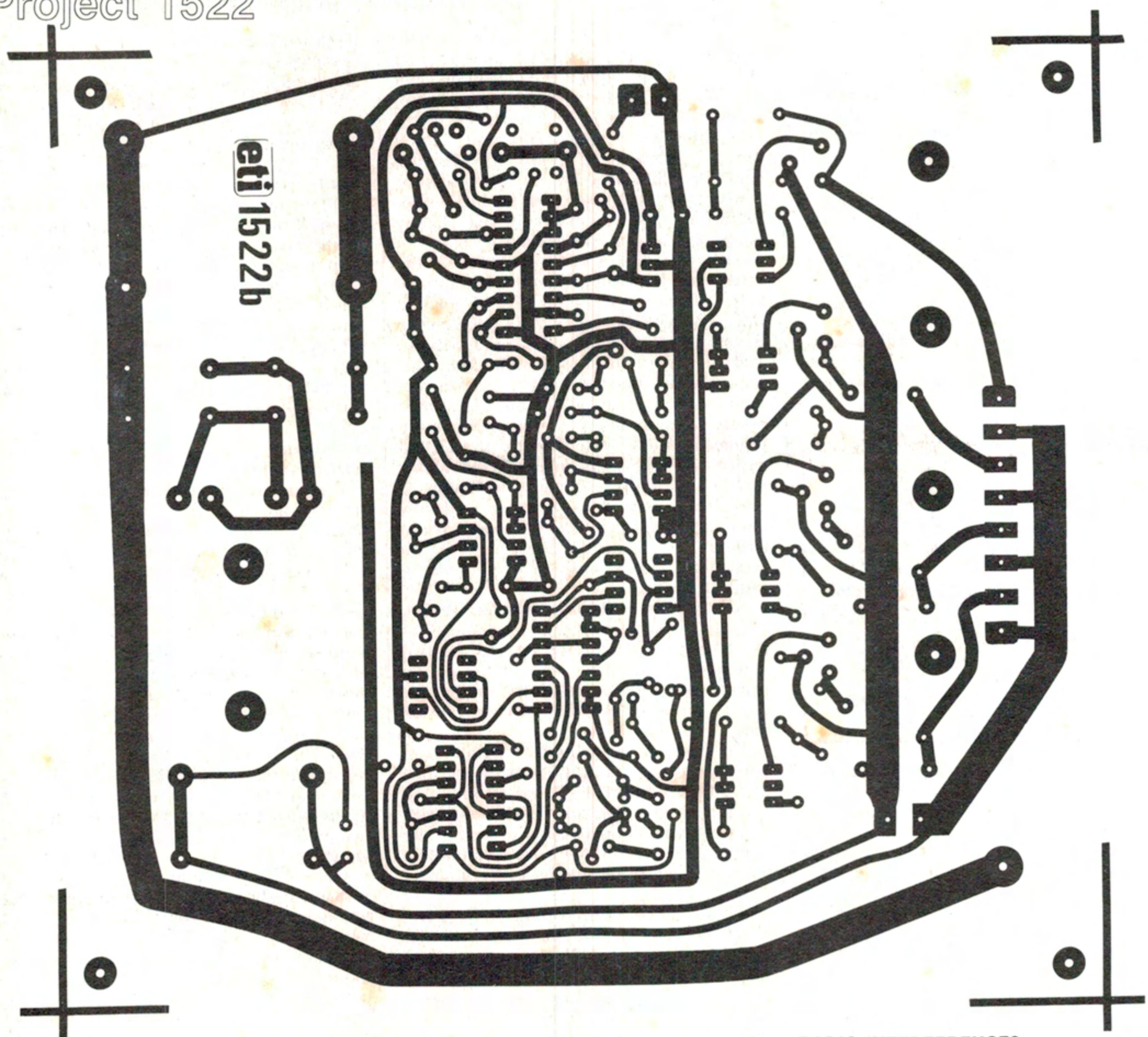
If you want one circuit to carry more than this it is quite easy to make up a right angle bracket to act as a heatsink. As the two on-off circuits are being switched on zero crossings they do not tend to generate RFI but the two that act as dimmers do and some form of filtering is necessary to suppress the edges if you don't want to drive your neighbours (and yourself) crazy with buzzing radios.

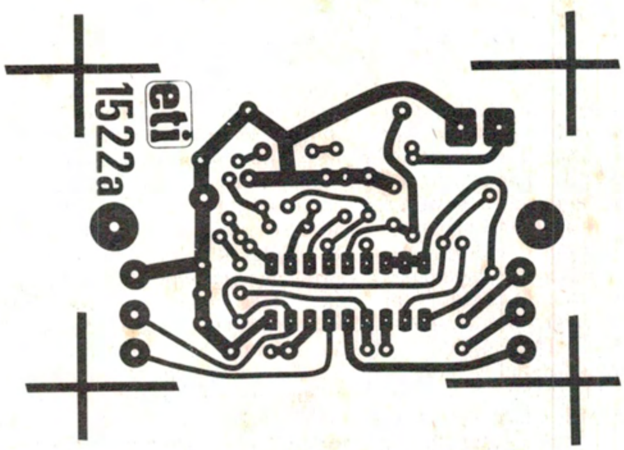
Fortunately, the filter inductors could be saved from the triac dimmers that were originally cannibalised to get the control pots. Unfortunately, HPM chose to use 1/32" thick printed circuit board material for the dimmers so most of the other components could not be salvaged, but by unwinding one turn from each end of the toroid winding, they can still be used. After soldering in the toroidal inductors, glue them down with a generous dob of Silastic or somesuch. Solder-in the output 8-way connector and your controller is ready for final test. The output terminals alternate between neutral and switched, with the two pairs nearest the receiver and away from the mains input being the on-off lines and the two pairs nearest the mains input being the 'dimmed' lines.

Connect a light bulb to each output in turn and ensure that the appropriate control works (at the same time you can establish which control operates which output).

Finally, the whole receiver board can be mounted in an insulated box. As the receiver is (presumably) to be left in the ceiling the size of the box doesn't matter so, as I always find it infuriating to have to work with tweezers and magnifying glass I chose a container of most generous proportions namely, a "Clipsal" adaptable box 300 mm x 200 mm x 150 mm, which gives plenty of space all around the receiver board.

Mount the board towards one end of the box with the 8-way terminal block away from the end of the box. This gives plenty of space for the four-wire pairs from the lights to connect to the board. Finally, cut holes with a hole saw opposite the three terminal blocks to allow cables into the box and you are ready to start having fun crawling around in the ceiling connecting everything up. Note that the wire pair to the wall switch is polarised. The line in the wall will likely have a black and a red wire. Connect the black to 'E' on each board. It only has the isolated 12 V on it now. By the time you cut and reconnect all the wires in the ceiling (or have a licensed electrician do it if you are not qualified to do so yourself), you will probably find that you need a few junction boxes and some spare lighting cable, so its a good idea to plan things out carefully first. ▶





RADIO INTERFERENCE?

As the 'carrier' for this system is on 455 kHz, the standard intermediate frequency (I.F.) for broadcast receivers, readers may be worried that some interference may be caused to radios in the room or house where this system is installed. Don't worry. We tried putting a sensitive portable transistor radio right next to the switch plate and the twin-wire cable. *Very* weak heterodynes ('whistles') can be heard on weak carriers between stations, but not on signals which can be clearly heard, though weak. On local stations there's *no effect whatever.* Once the receiver is moved a few centimetres away, no heterodynes at all can be detected.

The twin-wire cable between the encoder/transmitter and the receiver/triac driver acts as a low impedance transmission line, so radiation from it is very low in any case. The transmitter in the LM1871 is operated at a very low level, deliberately, because high levels are unnecessary, greatly reducing the possibility of interference — as our test showed.

As the line between the encoder/transmitter and receiver/triac driver boards is isolated from the mains by the power supply, mains-borne interference should not occur.