heating controller

It is generally accepted that — in the interests of reduced fuel bills and increased night sleep — it is advisable to reduce the temperature setting of one's heating system before retiring. Many systems are however provided with only a single thermostat, so that one has to turn the knob down a few degrees every evening and then back up again in the morning. The circuit about to be described will carry out both resetting functions at pre-programmed times.

Twiddling the knob of a heating thermostat is not a job for an electronic slave — stepper motors and all that kind of thing — so this circuit switches between two separate thermostats. One unit (Te2) is set to the 'day' temperature and the other (Te1) to the 'night' temperature; the circuit determines which of the two has control of the system. Figure 1 shows the principle of the switchover. Since the 'day' temperature will normally be set higher than the 'night' temperature, a single-pole-single-throw switch (S1) will enable the 'day' thermostat to take over. This arrangement is not only simple; it is also 'fail safe' — the system will always be set to at least the 'night' temperature in the event of an electronic failure.

The switch S1 is operated by a flip-flop that in turn is controlled by a 24-bit shift register. The clock input of this register receives one pulse per hour, so that the '1' steps through the register at the rate of one bit per hour.

Switches S2a and S2b interconnect the set- and reset-inputs of the flip-flop with shift register bit outputs. This means that the switching times, in hours, can be selected by means of S2a (set flip-flop) and S2b (reset flip-flop). The actual time of day at which the action occurs will of course depend on the time at which the shift register is reset, during setting up.

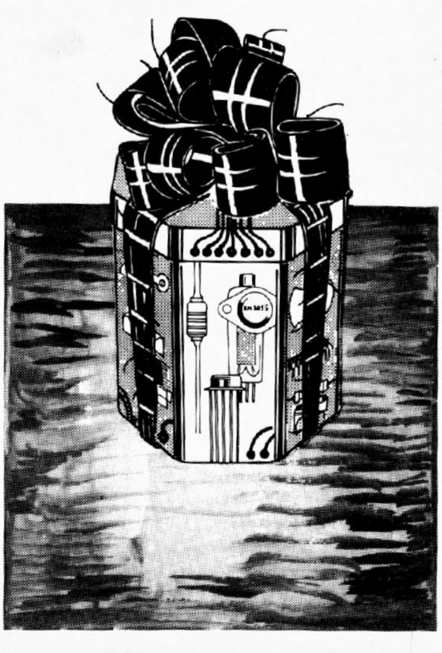
Timer circuit

Figure 2 gives the circuit diagram of the timer section. Input C is fed with a 50 Hz reference signal. The pulse shaper using N6 and N7 turns this reference into a neat clocking waveform that is fed to the divider. The circuit around IC5 and IC6 divides by 180000, so that the output of N9 (point D) will deliver one impulse per hour. This hour-pulse is in turn fed to the 24-bit shift register IC7 . . . IC9. To make the process continuous, the arrival of a '1' at the last bit output is arranged to reset the register, by means of monostable N17/N18.

Various outputs of the shift register can be fed, via the DIL-switches S4 and S5, to the set- and reset-inputs of flip-flop N15/N16. The 'on' and 'off' periods of the flip-flop can therefore be programmed using S4 and S5. If, for example, the shift register was reset at 18.00 hours (by means of S1 in figure 3), then the switches S4a . . . S4h will select a time between 20.00 and 02.30 hours and S5a . . . S5h will select a time between 03.00 and 09.30 hours. Note that the half-hour impulse is taken separately from the main divider. Other ranges of programming can obviously be obtained by resetting the shift register at a different time, or by selecting other shift-register outputs.

The flip-flop N15/N16 is also provided with a 'manual override' in the form of S2 and S3.

The information stored in the flip-flop is used to bring the second thermostat into circuit when the higher room temperature is required.



Controller

Figure 3 shows how the second ('day') thermostat Te2 is switched in and out of circuit by the triac Tri1. To minimise the drive dissipation in the triac, this is driven via T2 from an oscillator (N1 . . N3) that produces a 4 kHz signal with a 10% duty cycle. The oscillator is started and stopped by commands from the flip-flop N15/N16.

A pair of anti-parallel diodes, D1 and D2, is connected in series with the 'night' thermostat. This derives the 50 Hz reference signal that has to be fed to point C of the timer section (figure 3).

Power supply

The starting point for the design of this controller was that it had to be suitable for direct connection into a heating system, at the position of the existing single thermostat (points A and B). This causes some complication with regard to the power supply. When the system is *not* operating, the full 24 V AC is present between points A and B. This voltage is used, see figure 3, to charge a nickel-cadmium accumulator. D3 and D4 operate as a half-wave rectifier and T1 and D5 provide voltage regulation. R1 sets the maximum charging current, depending on the ratings of the accumulator — and on the amount of current 'thievery' that the control box will (im)passively tolerate!

-15V (i.e. so that the end of the track approached by clockwise rotation of the wiper is connected to ground).
A multimeter set to the 100 μA range is connected between the wiper of the potentiometer and the junction of R10 and R33, an input signal is provided to the VCF from a sinewave generator or from the VCO, and the Bandpass output is monitored on a oscilloscope. The test then proceeds as follows:
1. Set the Q-factor of the filter to maximum (wiper of P5 turned towards R19).
2. By means of the 100k log potentiometer set the control current to 50 μA on the meter.
3. Slowly increase the generator frequency from about 300 Hz to 1500 Hz; somewhere in this range the VCF output should peak as its resonant frequency is reached (i.e. there will be a sharp increase in output at a particular frequency with a fall-off on each side). Note the frequency at which resonance occurs.
4. Increase the control current to 100 μA and check that resonance now occurs at twice the previously noted frequency.
Note. Tests 2 to 4 are intended to check the linearity of the filter frequency v. control current characteristic. The tolerance in the absolute value of filter frequency for a given control current is due to OTA tolerances and is unimportant provided linearity is maintained i.e. the filter frequency doubles for each doubling of control current.
5. Set the generator to about 50 Hz and check that it is possible to obtain resonance at this frequency by varying the control current with the 100 k potentiometer. Repeat this test at 15 kHz.
The exponential converter can now be tested after inserting IC1 and removing IC4 and IC5. A multimeter set to the 100 μA range is connected from the bottom end of R10 to -15V and the wiper voltage of P1 is monitored with a voltmeter.
The test and adjustment now proceed as follows:
1. Set P8 to its mid-position, and turn P1 fully anticlockwise so that its wiper voltage is zero. Adjust P7 until the mircroammeter reading is 50 μA.
2. Turn P1 clockwise until its wiper voltage is 1V, then adjust P8 until the microammeter reads 100 μA.
3. Repeat the procedure for 2V, 3V, 4V etc. on the wiper of P1, checking that the exponentiator output current doubles for every 1V increase.

Offset adjustment

Now that the two sections of the VCF have been checked, IC4 and IC5 can be re-inserted so that the entire VCF can be checked as a functional unit, as follows:
1. A squarewave with 50% duty-cycle at a frequency of about 500 Hz is fed to one of the filter inputs. P1 is turned fully clockwise and P7 is turned anticlockwise.
2. The lowpass output of the VCF is monitored on an oscilloscope, and at this stage should appear at the output without degradation.
3. If the wiper of P7 is now turned slowly clockwise the leading edge of the squarewave will start to be rounded off as the turnover point of the filter is reduced. To carry out the offset adjustment with P7 its wiper is turned as far clockwise as is possible without significantly degrading the square waveform (just a slight rounding of the top corner is acceptable, but this adjustment does not have to be particularly precise).

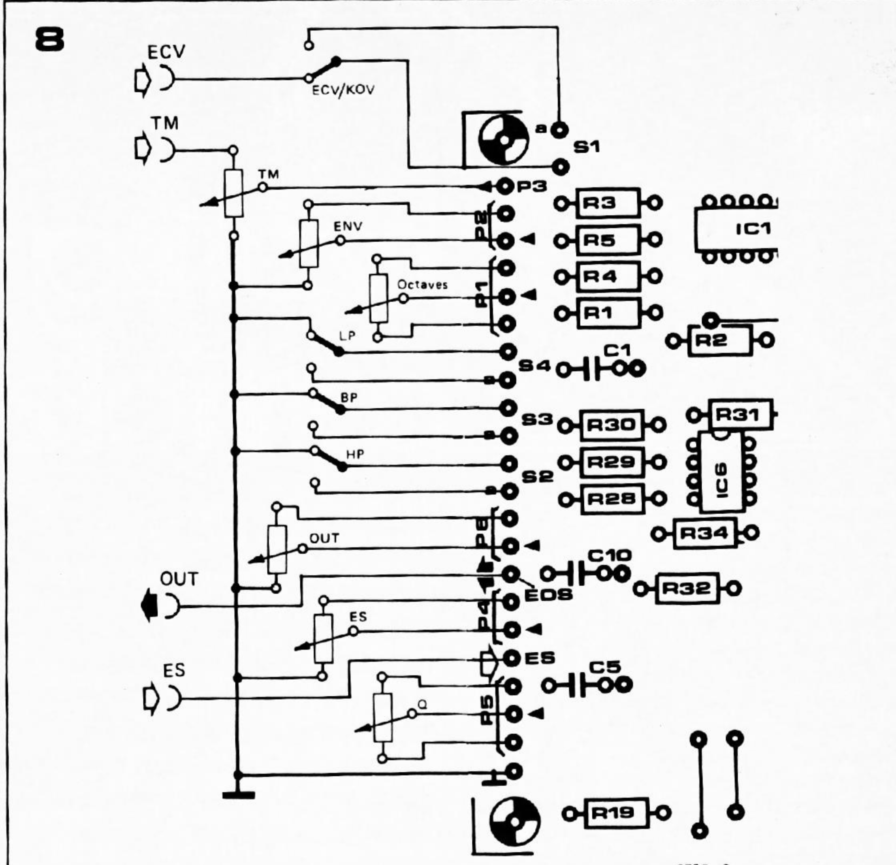


Figure 8. Wiring diagram for the panel mounted components.

Octaves/Volt adjustment

The octave/V characteristic of the VCF can be adjusted by seeing how well it tracks against a previously calibrated VCO. To do this, the KOV input is connected to the VCO and the VCF, and the sine output of the VCO is connected to the VCF input. The adjustment procedure is as follows:
1. Switch off the main tuning of the keyboard, depress top C of the keyboard and use the octaves control of the VCO to set its frequency to about 500 Hz.
2. Set the Q control, P5, of the VCF to maximum, monitor the bandpass output of the VCF and adjust P1 until the VCF output peaks. As the filter is easily overloaded at high Q-factors it may be necessary to reduce the VCO output voltage.
3. Depress the key two octaves lower and adjust P8 until the VCF output again peaks.
4. Depress top C again and if necessary readjust P1 so that the output peaks.
5. Repeat 3 and 4 until no further readjustment is necessary for the output to peak when changing from one note to the other.
6. The offset adjustment may have been disturbed, so check this and if necessary readjust P7 as described in the offset adjustment procedure.
7. Repeat 3 onwards until no further improvement can be obtained.

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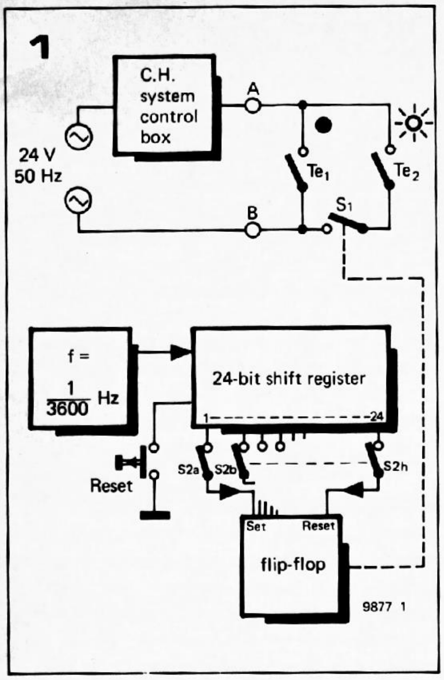

Figure 1. Block diagram of the heating controller. Two thermostats are used, one of which is connected permanently to the central heating control unit. The other is switched in and out of circuit at predetermined times.

Figure 2. The timing and drive circuit, consisting of the clock generator, 24-bit shift register and flip-flop.

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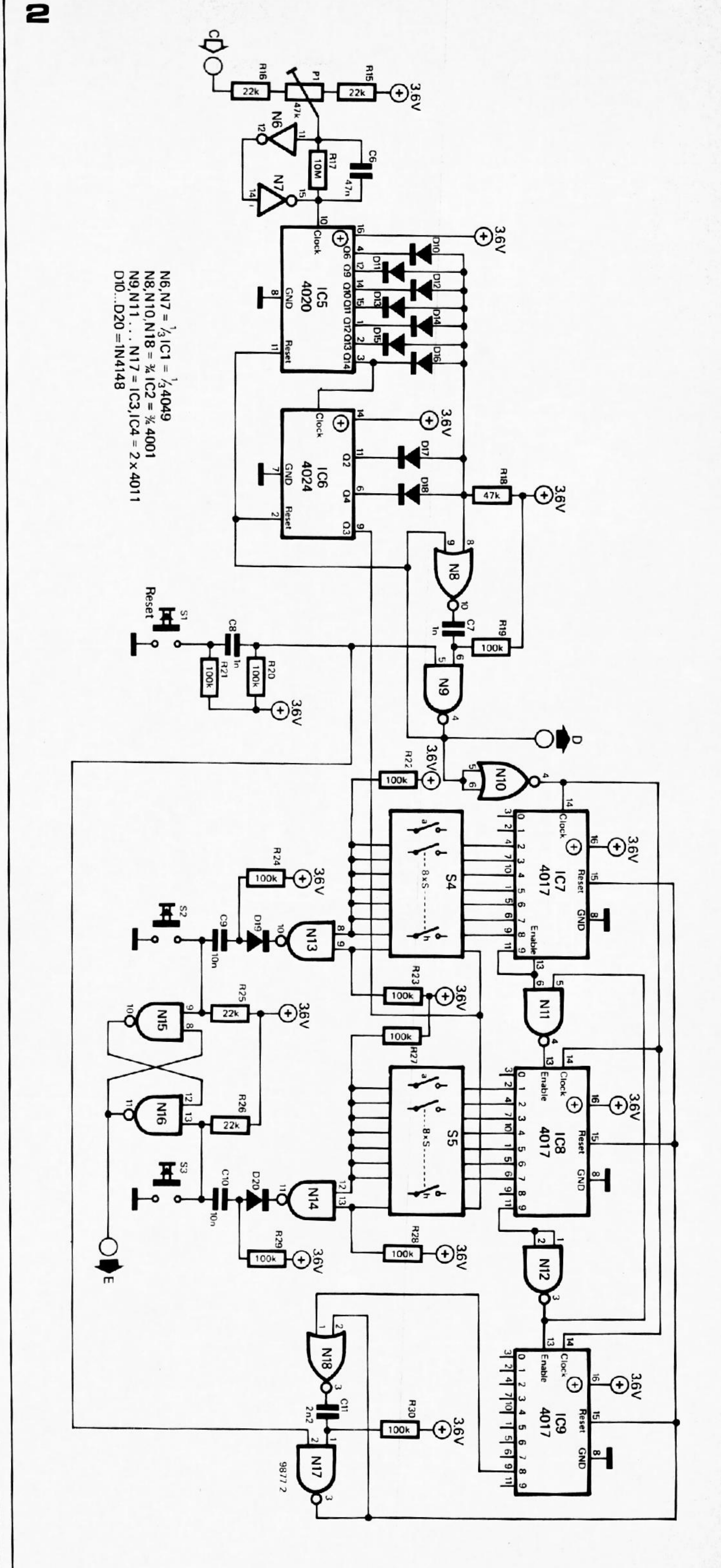
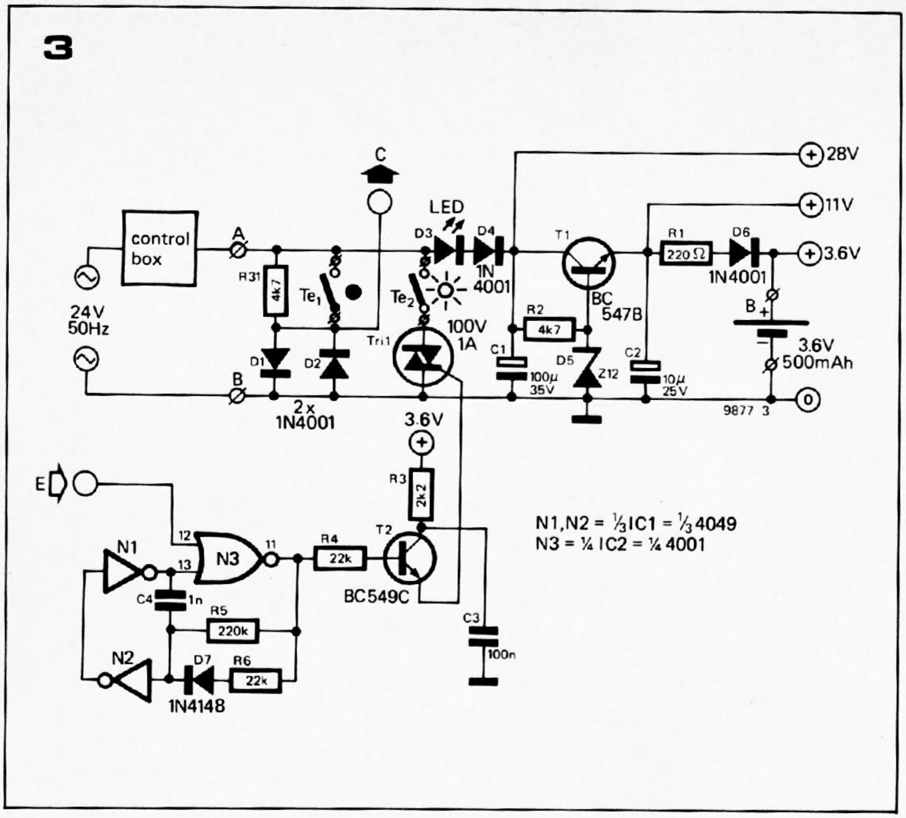
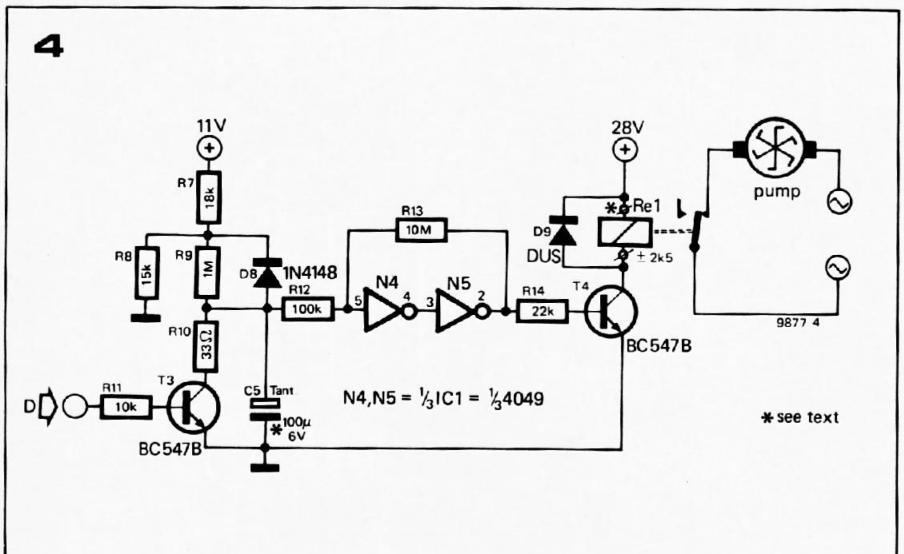


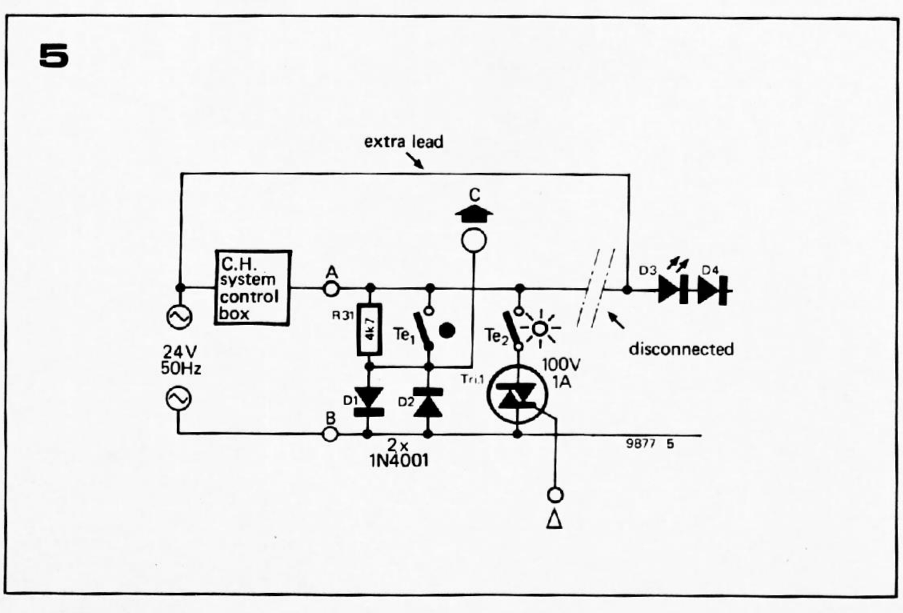
The inclusion of the LED D3 gives an indication of the circuit operation; the LED lights when the boiler is *out*. Since the entire timer circuit is built up with MOS devices, the load on the power supply is only a few mA. It is nonetheless possible, in a case of high duty-cycle of the system (high temperature desired, low outside temperature, boiler capacity marginally sufficient), that the shut-down periods of the system will be too short for the accumulator to charge sufficiently to maintain the supply during the 'on' periods. In this case the power supply will pack up after a while. There will then be nothing else for it but to install a separate supply.

Pump starter

Some heating systems practice the dubious economy of turning off the circulating pump when the boiler is shut down. This has the objection that floating particles can sink, leading in the long run to blocked pipes. The repair bill will then exceed several years of electricity supply for the pump. It is possible, in this case, to both have one's cake and eat it. Figure 4 gives a circuit that will start and run the pump intermittently during boiler-off periods.







The circuit is triggered by the hour-impulse from the timer. The impulse causes the discharge of C5 and therefore the release of the relay. The pump connected to break-contacts of the relay will now start to run. C5 will start to charge through R9, so that the relay will pull in after a few minutes, turning off the pump.

The power supply for this circuit is also obtained from the figure 3 supply section. This has the extra effect of starting the pump when the boiler turn-on causes the rectified AC to fail. The pump-relay must of course have a low pull-in current (about 10 mA) to prevent inadvertant operation of the boiler.

Final notes

It is conceivable that, if the original control unit is sufficiently sensitive, the central heating may never turn off – the current consumption of the circuit being sufficient to simulate a closed thermostat. In this (unlikely) event, the circuit can be modified as shown in figure 5. The output from the control unit is only connected to the thermostats; power to the rest of the circuit is derived from the 24 V input to the control unit. The disadvantage of this system is, of course, that a third wire must be run from the control box on the boiler to the room thermostats.

A printed circuit board for the 'heating controller' is shown in figures 6 and 7. ◀

Figure 3. Thermostat switching and power supply section.

Figure 4. Extension circuit for switching the pump on periodically in order to prevent blocking of pipes and/or pump.

Figure 5. This modified circuit can be used if the central heating control unit proves to be too sensitive, or if the shut-down periods of the boiler are too short to charge the accumulator sufficiently.

Figures 6 and 7. Printed circuit board and component layout for the central heating controller (EPS 9877).

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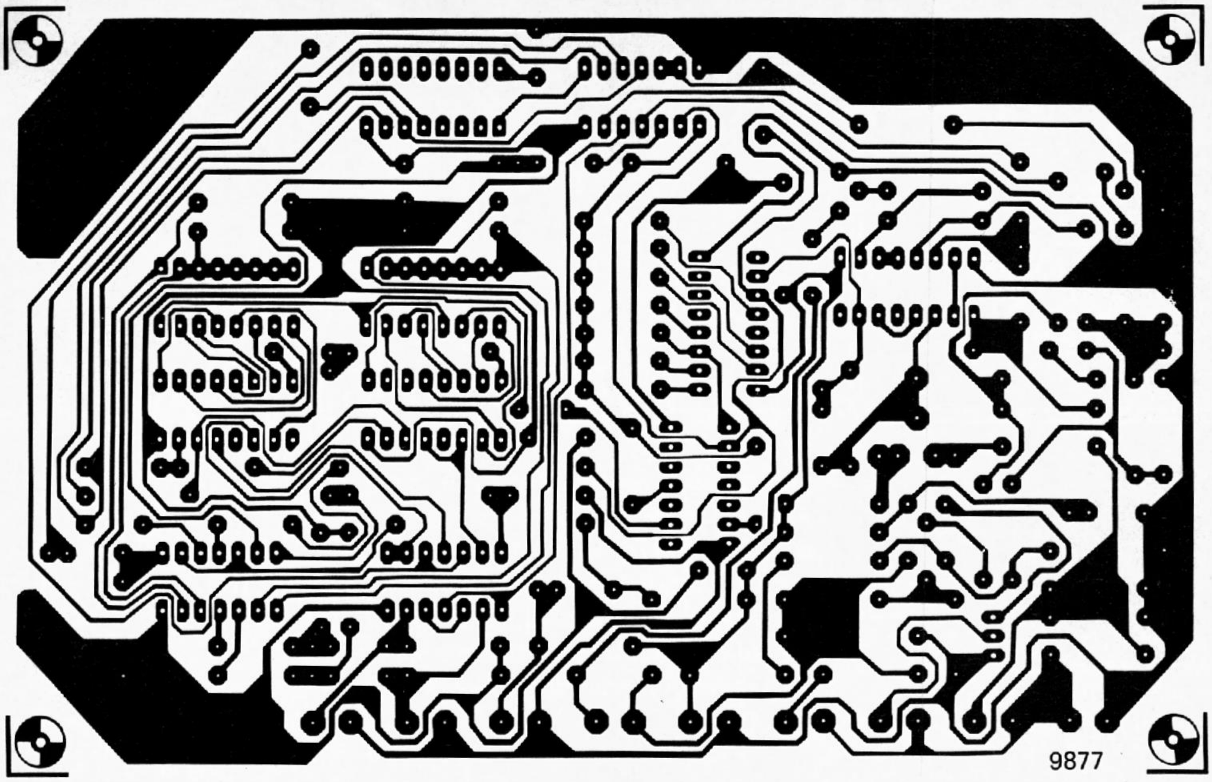

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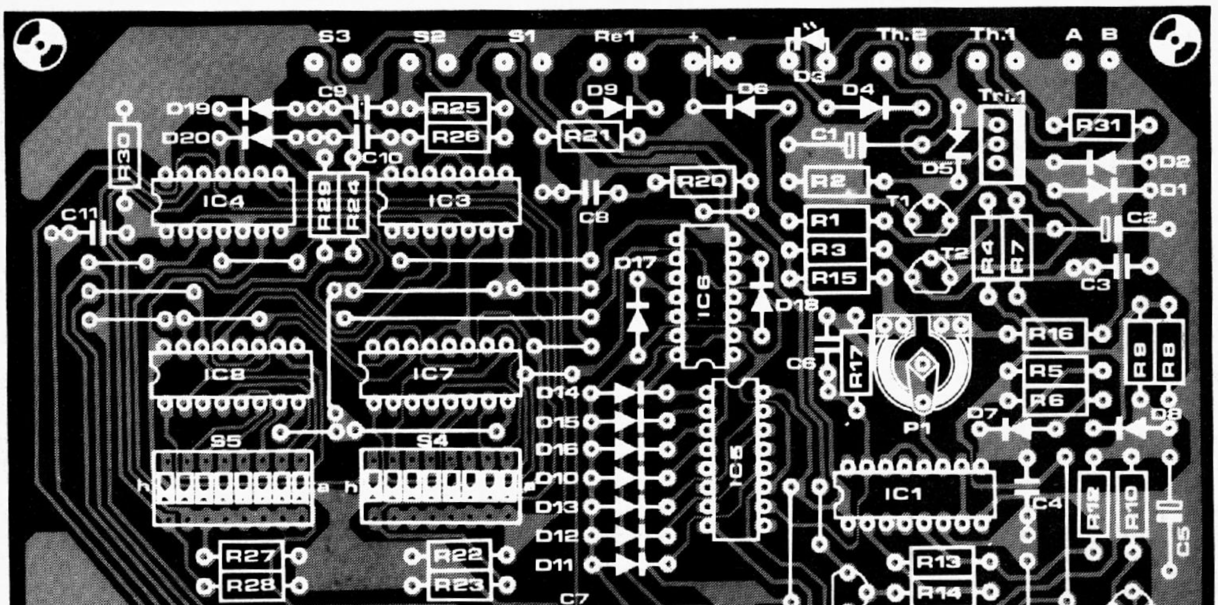

Resistors:

R1 = 220 Ω
R2,R31 = 4k7
R3 = 2k2
R4,R6,R14 . . . R16,
R24 . . . R26,R29 = 22 k
R5 = 220 k
R7 = 18 k
R8 = 15 k
R9,R13,R17 = 10 M
R10 = 33 Ω
R11 = 10 k
R12,R19,R20 . . . R23,R27,
R28,R30 = 100 k
R18 = 47 k
P1 = 47 k

Capacitors:

C1 = 100 µ/35 V
C2 = 10 µ/25 V
C3 = 100 n
C4,C7,C8 = 1 n
C5 = 100 µ/6 V tant.
C6 = 47 n
C9,C10 = 10 n
C11 = 2n2

Semiconductors:

T1,T3,T4 = BC 547B
T2 = BC 549C
D1,D2,D4,D6 = 1N4001
D3 = LED
D5 = 12 V/400 mW zener diode
D7,D8,D10 . . . D20 = 1N4148
Tri1 = 100 V/1 A or 400 V/4 A
IC1 = 4049
IC2 = 4001
IC3,IC4 = 4011
IC5 = 4020
IC6 = 4024
IC7 . . . IC9 = 4017

Miscellaneous:

S1 . . . S3 = pushbutton, SPST
S4,S5 = 8 section DIL switch
Te1 = existing room thermostat
Te2 = new thermostat, same type
Re1 = 15 V relay, one break contact
B = NiCd accumulator, 3.6 V/500 mAh (3 cells)