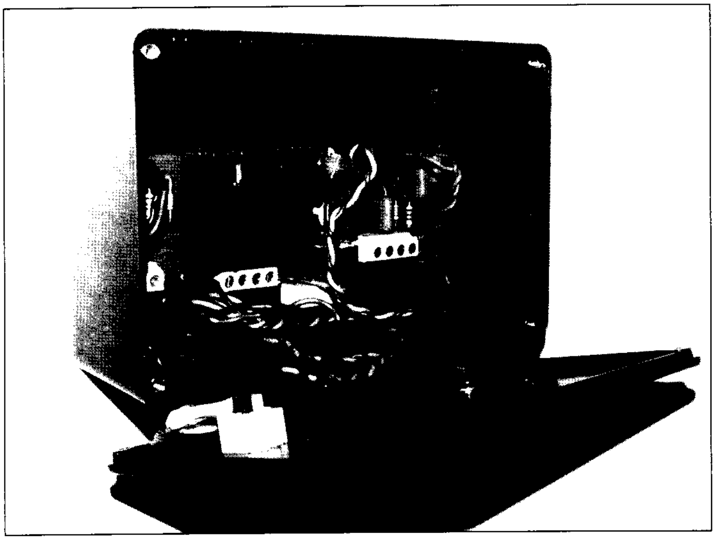
The Solar Controller



Why use a controller?

A solar water heating controller is a gadget used in conjunction with a solar water heating panel array to supply hot water to your taps. In the simplest systems, water circulates by itself. However, if you install a pump it means greater choice over where you position the panel, plus improved thermal efficiency. The controller is a simple thermostat that only switches on your pump to carry water from the heater when it's hot enough to be of use. This section tells you how to make and install one from standard electrical components.

The controller we describe can be used for most solar heated water systems. Let's look first at how it works and then at

LIST OF COMPONENTS

Resistors	Value	Colour code
R1,R2	4K7 (two)	yellow, violet, red
R3,R13	100R (two)	brown, black, brown
R4,R5,R6	2K2 (three)	red, red, red
R7,R8	10K (two)	brown, black, orange
R9	4M7 (see note)	yellow, violet, green
R10	1K5	brown, green, red
R11	33OR	orange, orange, brown
R12,R14	2K2, 0.5Watt	red, red, red
R15	1K 1Watt	brown, black, red
VR1	100R cermet preset	

Capacitors	
C1	470nF capacitor polyester 100V
C2,C3	100nF capacitor polyester 100V (two)
C4	330uF capacitor radial electrolytic 40V
C5	100nF suppression capacitor

Diodes	
D1	8V2 zener diode
D2,D3,D4	1N4148 (three)
D5,D6	1N4002 or 1N4007 (two)
D7	green LED (with clip)
D8	red LED (with clip)

Others	
TR1	BC182L transistor
IC1	LM741 op-amp
RLA	10A single pole changeover relay, 24V coil
T1	3 VA transformer, 240V primary, 20-0-20V secondary
S1	d.p.s.t. rocker switch, 240V AC 4A
S2	s.p.s.t. toggle switch, 30V DC1A
FS1	1 amp fuse

3 way terminal block
4 way terminal block (two)
p.c.b. terminal pins (ten)
fuse clips (two)
plastic case
rubber grommets (three)
printed circuit board
twin 7/0.25mm cable
epoxy putty and (maybe) silicone sealant

making the control box, fitting the sensors, choosing the temperature difference, testing procedure, installation, and some additional technical detail.

How it works

Two sensors are mounted, on the hot water tank and on the solar panel. They measure the difference in temperature between the two. When the panel is sufficiently hotter, they tell the controller automatically to switch on the pump. When the tank has heated up it will switch the pump off. There is also a manual override switch.

Building the control box

Most of the components are fitted on to a printed circuit board. This is shown in Figures 15 & 16 on the next page. Figure 14 shows the circuit diagram. The board was designed to fit inside a plastic case measuring 150mm by 80mm by 50mm, although any reasonable size may be used; you could adapt something or build it out of wood. It should be possible to solder together and construct the controller, and put it in the case, with careful reference to the diagrams and photograph. However the following points are offered to avoid some of the mistakes that might occur.

Three rubber grommets are fitted to cable holes in the lid of the case, and the LEDs and switches are fitted in the lid. Take care to position these lid-mounted parts so that there's enough clearance space when the case is put together. When fitting the diodes and the capacitor C4, make sure that their polarity is correct and that the integrated circuit IC1 is the right way round. Similarly, when completing the interwiring between the components, pay careful attention to the polarity of the LEDs, to make sure they are connected the right way round.

Check the wiring of switch S1 since this will carry mains voltage. When the components of the board are all securely soldered in place, lower the board into the case you have made and connect a three core mains cable to the three way terminal block. The cable should be fitted with a 3 amp fused plug.

Installing the sensors

First, make up the two sensor leads, one for the solar panel and one for the hot water tank. Use twin core 7/0.25mm cable. The type with one side marked with a coloured stripe or ribbing is ideal. At this stage each lead may be about 2 metres long. If necessary, extend them with more cable later; or calculate first the distance you want to position the controller from the panel and tank.

The sensors themselves are 1N4148 diodes. Simply solder them to the end of each lead as shown in Figure 17. Seal the bare wire and joints with epoxy putty against water. This will harden in a few minutes.

Thread the two sensor leads through the grommet on the end of your box and connect them into the terminal block as shown in Figure 16.

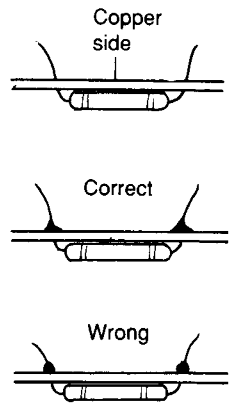
Choosing the temperature difference

The size of the temperature difference between the tank and the panel that switches the pump on or off is controlled by the component called R9. This is a feedback resistor of the 741 amplifier. You can choose its specification to give a temperature difference as shown below:

SPECIFICATION	TEMPERATURE DIFFERENCE
3M3	10°C
4M7	7°C
10M	3.5°C

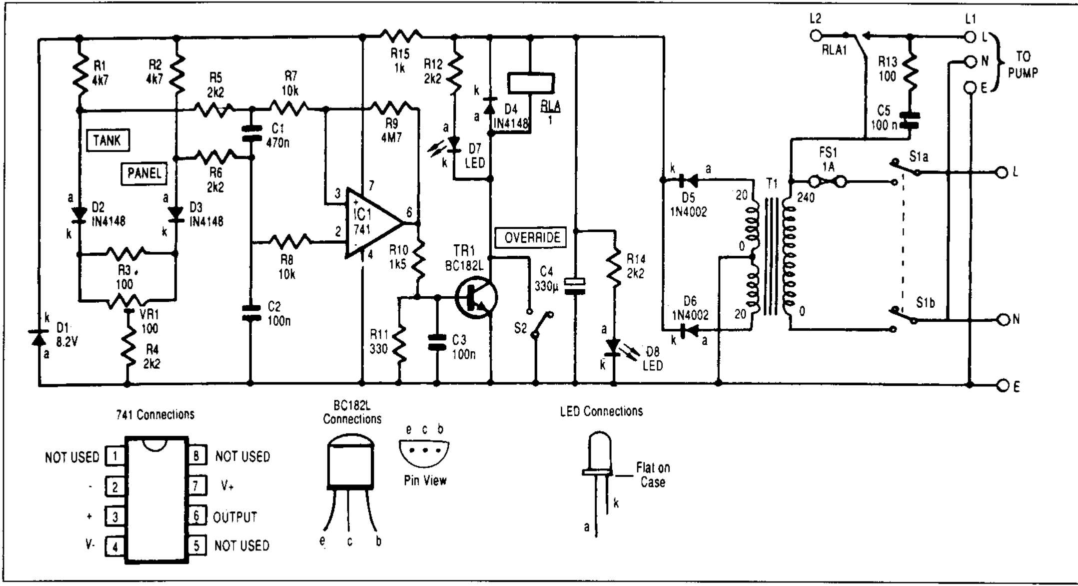
You may wish to experiment with installing different resistors at different values to find the one that works best for your conditions. Alternatively you could fit a variable resistor, and having found the optimum position, leave it there.

Hints on soldering



If you've never done any soldering before, you may find these notes useful.

- *Good quality soldering is essential for good connections and proper working of the circuit.*
- *First push the component lead through the board, then turn the board over and slightly splay the leads to stop the component dropping out.*
- *Place the tip of a fine-tipped soldering iron on to the joint so that it touches both the copper board and the lead.*
- *After a few seconds, when it is hot, run solder on to the joint and wait until it flows completely round the lead and on to the copper track.*
- *Remove the iron and check that the solder has spread evenly over the joint.*
- *Snip the leads off with small side cutters.*


R1 4k7
R2 4k7
R5 2k2
R7 10k
R15 1k
R12 2k2
L2
RLA1
L1
L
N
E
TO PUMP
R13 100
C5 100 n
TANK
PANEL
C1 470n
R9 4M7
D4 IN4148
RLA 1
D7 LED
R6 2k2
FS1 1A
S1a
T1
D5 1N4002
240
D2 IN4148
D3 IN4148
IC1 741
OVERRIDE
R8 10k
R10 1k5
TR1 BC182L
C4 330µ
R14 2k2
R3 100
VR1 100
D6 1N4002
S1b
D1 8.2V
R4 2k2
C2 100n
R11 330
C3 100n
S2
D8 LED
741 Connections
NOT USED
V+
OUTPUT
V-
BC182L Connections
e c b
Pin View
LED Connections
Flat on Case

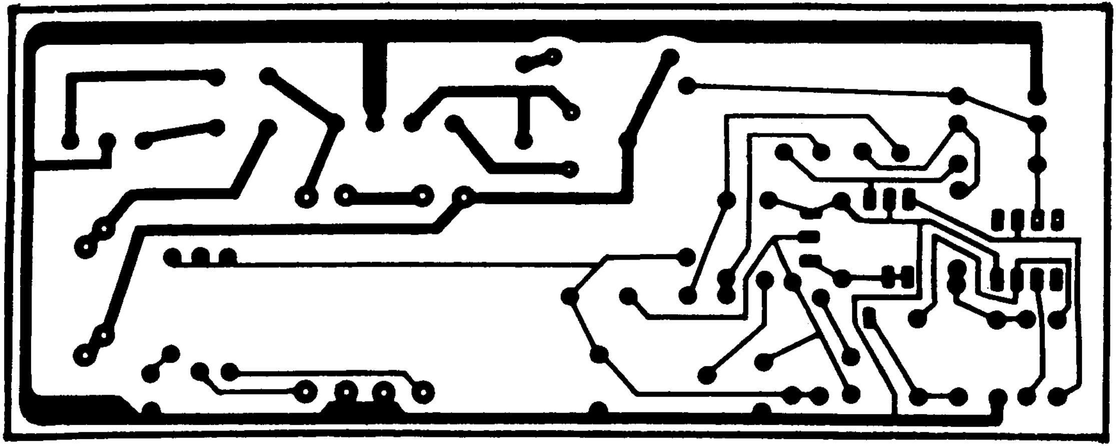
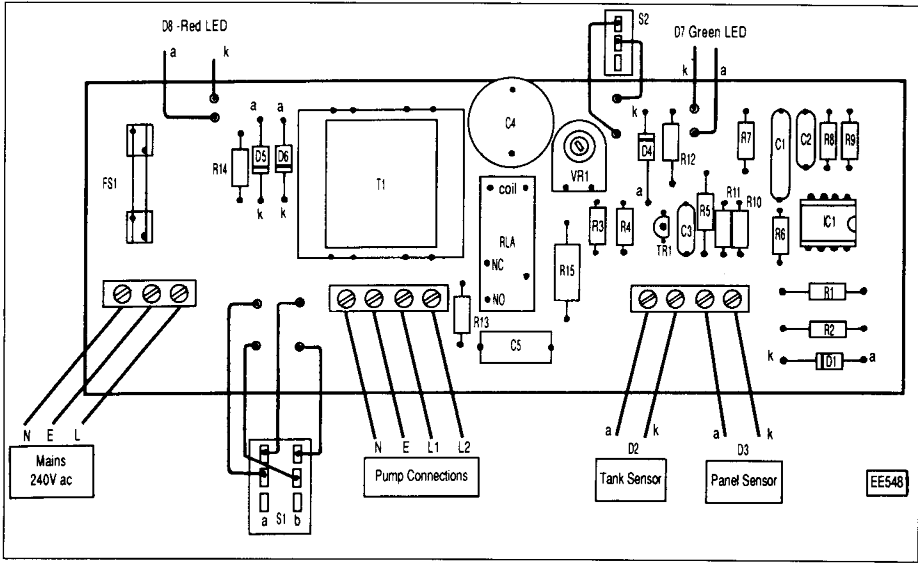


Fig. 13 (page 20): The completed box with the lid open demonstrating the circuit board and components

Fig. 14 (top): Complete circuit diagram.

Fig. 15 (middle): Full sized printed circuit board master pattern.

Fig. 16 (below): Component layout and interwiring details.



Test procedure

You're ready to try it out. Plug in the unit and turn switch S1 on. If it's all connected properly, the red LEDs should light up. Now switch S2 into the auto position. Take care. The fuse clips and components near the 3-way terminal block are now live, as is the back of switch S1.

Next, ensure that the two sensors are near to each other, and therefore at the same temperature. Turning the preset dial [VR1] should cause the relay and the green LED to turn on and off. If it does, the next step is to find the correct point at which to set VR1. This is done by turning it until the relay just comes on. Then turn it back until it is just past the point at which the relay turns off. Five degrees of rotation past the turn off point is about right. Leave it there.

You're now ready to see if a temperature difference between the sensors turns on the switch. Find something hot like a soldering iron and hold it near or against the panel sensor. The relay should click on after a few seconds. If you then leave the sensor to cool down for a few minutes the relay should turn off. If it does all this you've succeeded so far. Now disconnect the unit from the mains. You may now to install it.

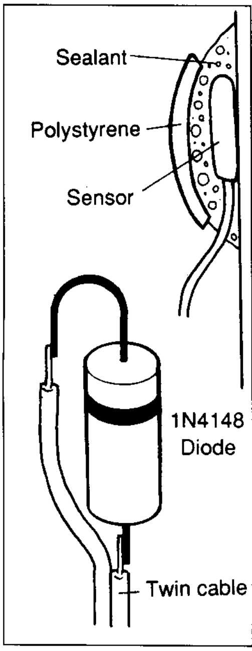


Fig. 17: Sensor construction and mounting

Installation

Have another look at Figure 2 on page 3, which shows a typical solar heated system. The solar energy collected by the panels is pumped to the pre-heat cylinder. The pump is switched on by the solar panel controller. This pre-heated water is then drawn through the existing hot water tank.

The pump is connected to your controller on the terminals marked L1, N and E on the controller's four way terminal block. Take note of the fact that terminal L2 is live when the green LED is off.

Now you can position the controller box. It should be in a visible and accessible position so the switching of the pump can be monitored. It should also be somewhere where the temperature won't vary widely. Don't put it in the attic.

It's now time to fix the sensors. If you don't get this right, the whole system won't work. Firstly, don't run the leads near mains leads, because they cause interferance. Fit the sensors in place with epoxy putty or silicone sealant and cover them with insulation, such as polystyrene. Figure 17 shows this arrangement. The tank sensor should be mounted on the pipe running from the pre-heat cylinder to the solar panels, and as near as possible to the tank. The actual connection flange is an ideal place.

The panel sensor goes on the outlet pipe inside the box of the last solar panel in the sequence. After the putty has dried, you're now ready to switch on, and the whole system should work.

For electronics buffs

This is for electronics buffs who wish to know the functions of each of the components in the circuit.

Diodes D2 and D3 act as sensors. A current is passed through each of them via resistors R1 and R2. One property of small signal diodes is that a change of temperature will cause their forward conduction of voltage to vary in a repeatable manner. This 'differential' voltage is applied to the inputs of the IC1, which is configured to act as a Schmitt trigger with positive feedback introduced by R9.

R3 and VR1 are used to balance the Schmitt trigger inputs initially so that a differential temperature change within the desired range will be detected.

If the solar panel diode, D3, becomes hotter than the tank diode, D2, the output voltage of the amplifier will rise. Resistor R9 ensures that the output switches cleanly between the supply rails. This turns on TR1 which activates the relay. The green LED, D7, indicates when this happens.

The power supply for the circuit comprises TR1, D5, D6 and C4, giving a full wave rectified and smoothed 30V nominal. This is then dropped through R15 and clamped by D1 at 8.2V to power the op-amp and provide a stable voltage drop across R1 and R2.

Capacitor C1 has been incorporated to reduce differential input noise. Any common mode noise is filtered by C2. C3 has been provided to reduce the effects of interference on switching transistor TR1.

C5 and R13 protect the relay contacts from the arcing that occurs when attempting to switch an inductive load. They also provide suppression of any outside electrical interference.