EDITION 1

Assembly Manual

TEMPERATURE CONTROLLER FOR SOLDERING IRON

K-3479

DICK SMITH ELECTRONICS PTY LTD

KIT

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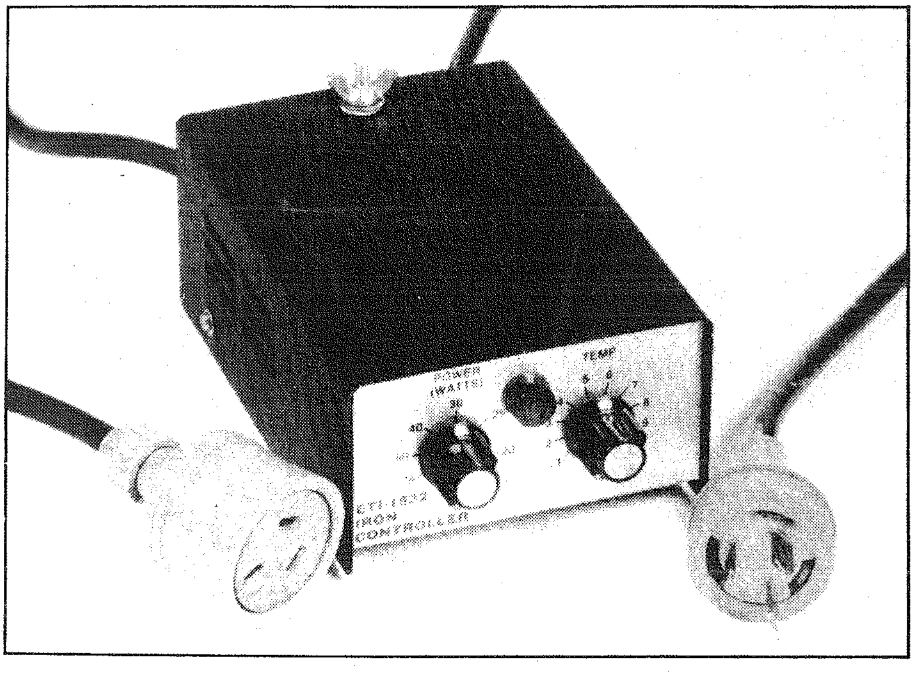
If you have put off buying a temperature controlled soldering iron because they are so expensive, your problems are solved with this low cost soldering iron temperature controller. However, a substitute problem: how to solder the solderer?



WHILE THIS TEMPERATURE controller may not have all the features of a soldering station, it provides fully regulated, adjustable temperature control over a reasonably wide temperature range. And there is no need to discard the soldering iron that you have now. This temperature controller will work with just about any conventional 240 V soldering iron rated from 20 W to 75 W, and can easily be adapted for use with higher powered soldering irons.

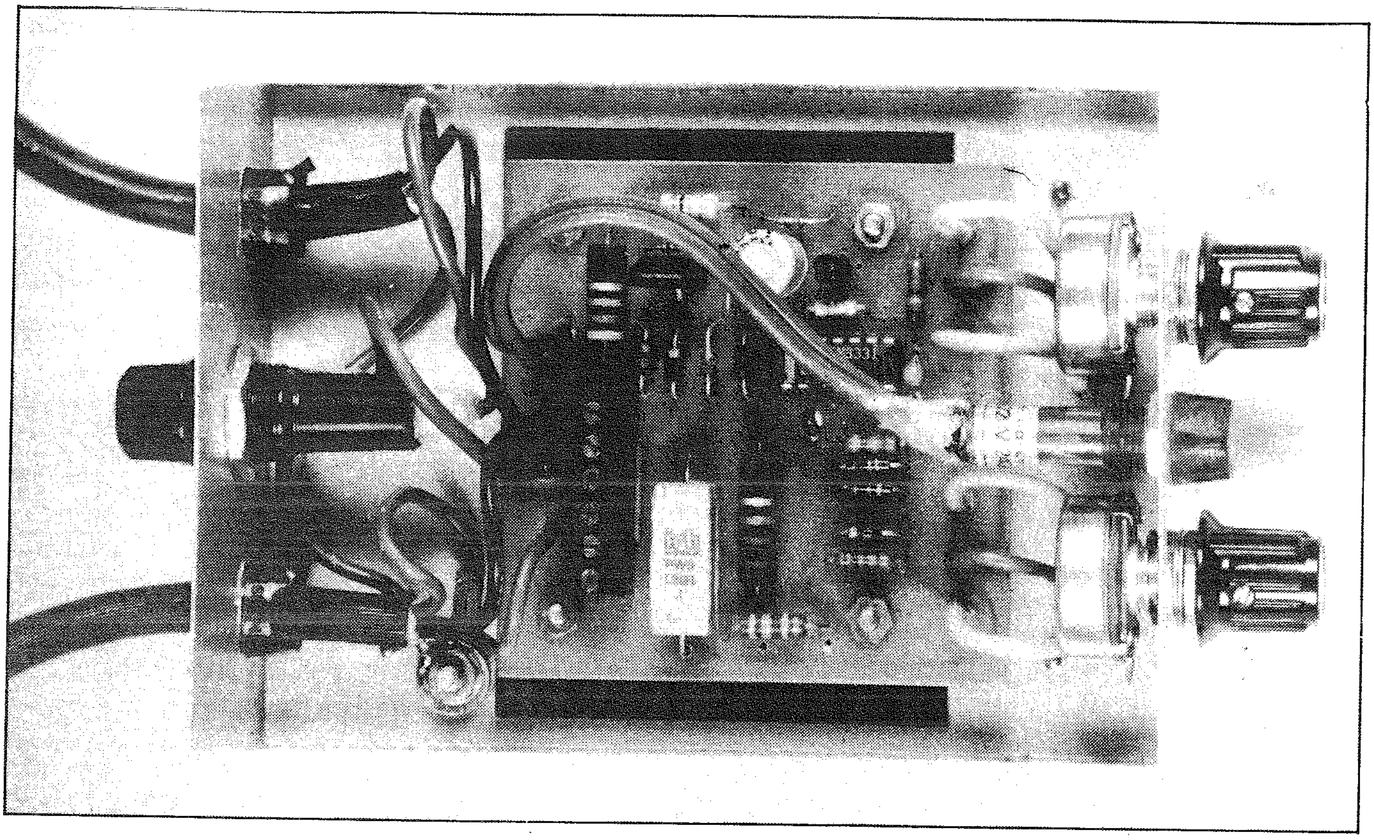
Why temperature control?

An important factor in good soldering technique is the correct choice of soldering iron temperature. Experience suggests that there is an optimum temperature for every soldering job and that this should be adhered to as closely as possible. Excessively high or low temperatures should definitely be avoided. Too high a temperature during soldering may obviously result in such nasties like damage to sensitive electronic components, tracks lifting off pc boards and the like. Too low a temperature, on the other hand, makes soldering difficult and increases the time required — which might also result in damaged components. Not only that, use of too low a temperature may lead to dry joints, an almost certain recipe for future circuit problems.

Where operating temperature is concerned, conventional (non-temperature controlled) soldering irons are anything but ideal. The two major problems with a conventional iron are that its temperature is not adjustable, and that its operating temperature is dependent on external factors such as the heat absorbing capacity of the components being soldered, and on variations in the supply voltage. A variation of ±10% in the supply voltage, for example, will result in approximately 20% variation in the heating power of the iron, all things being equal.

The power rating of an iron directly relates its suitability to any particular application. A typical iron intended for electronics work would be rated at around 20 W, which would be just adequate for average pc board work. But try to solder a large component, such as an electrolytic capacitor in a power supply with a 20 W iron and you might find yourself getting stuck (literally) because a lot of heat is being absorbed by the component, and the iron doesn't have enough reserve power to keep the solder above melting point. In such cases a higher power rated iron (eg, a 25 W or 30 W iron) is necessary. However, higher power means a higher temperature, especially when the iron sits idle in its stand or if it is only used for light work. There is then a greater risk of damaging components and the iron may be uncomfortable to work with.

Before temperature controlled irons became generally available, it was sometimes necessary to have several different irons on hand so that the most suitable one for the job could be used. However, apart from the cost of having several irons, this approach is not very convenient. A temperature controlled iron does away with this inconvenience. In essence, a temperature controlled iron is one which is automatically switched off when it reaches operating temperature and switches on again (automatically) when it drops below operating temperature. This switching action provides for an iron with



plenty of reserve power for those 'difficult' jobs without the danger of overheating. The benefits include constant temperature and adjustable temperature, consistent soldering quality, and use of a single iron for light and heavy work. Another advantage is that temperature controlled irons generally reach operating temperature much more quickly than conventional irons.

Typically, if you wanted the advantages of a temperature controlled soldering iron, you had to buy a soldering station which comes with a special, low voltage iron and inbuilt temperature sensor, or an iron with inbuilt temperature controlled switching. Now you can build one yourself.

Design considerations

Let's look at some of the ways in which the temperature of a soldering iron might be controlled. One method might be to use a rheostat in series with the soldering iron heating element. But this method is very inefficient because a lot of power would be dissipated in the rheostat, and besides, a rheostat capable of dissipating such power would be expensive and probably difficult to obtain.

Alternatively, the rheostat may be replaced by a diode. With ac power applied, the diode conducts during alternate half cycles, so that the soldering iron operates at half power. Short out the diode with a switch and the soldering iron operates at full power. This method is highly efficient because very little power is dissipated in the diode. But although simple and cheap to build, a diode controller is of very limited usefulness because only two control settings are possible. A better method would be to control the average power going to the soldering iron using an SCR or triac controller, such as in an ordinary light dimmer. However, SCR and triac switching circuits tend to generate considerable amounts of rfi (radio frequency interference) unless zero crossing switch techniques are used.

Each of the methods mentioned suffers from the serious drawback of poor temperature regulation. This means that the temperature of the soldering iron is influenced by external factors, such as variations in power supply voltage and the nature of the soldering work. This characteristic is undesirable and rules out these methods as such for a fully regulated temperature control system. To overcome this drawback negative feedback must be used. This requires the use of a temperature transducer of some kind to monitor the temperature of the soldering iron, and a switch responsive to the output of the temperature transducer to maintain the power to the soldering iron for the required constant temperature.

However, as soon as you start to talk about temperature transducers in this kind of application you run into all sorts of problems. Because of the high temperatures involved, devices like ordinary thermistors and silicon diodes won't do. Special devices rated for high temperatures are required. The most likely choices are thermocouples and 'high temperature' thermistors. These are not too difficult to get in lots of, say, 1000 or more but just try to get one from your local electronics supermarket or the distributors. Not very likely!

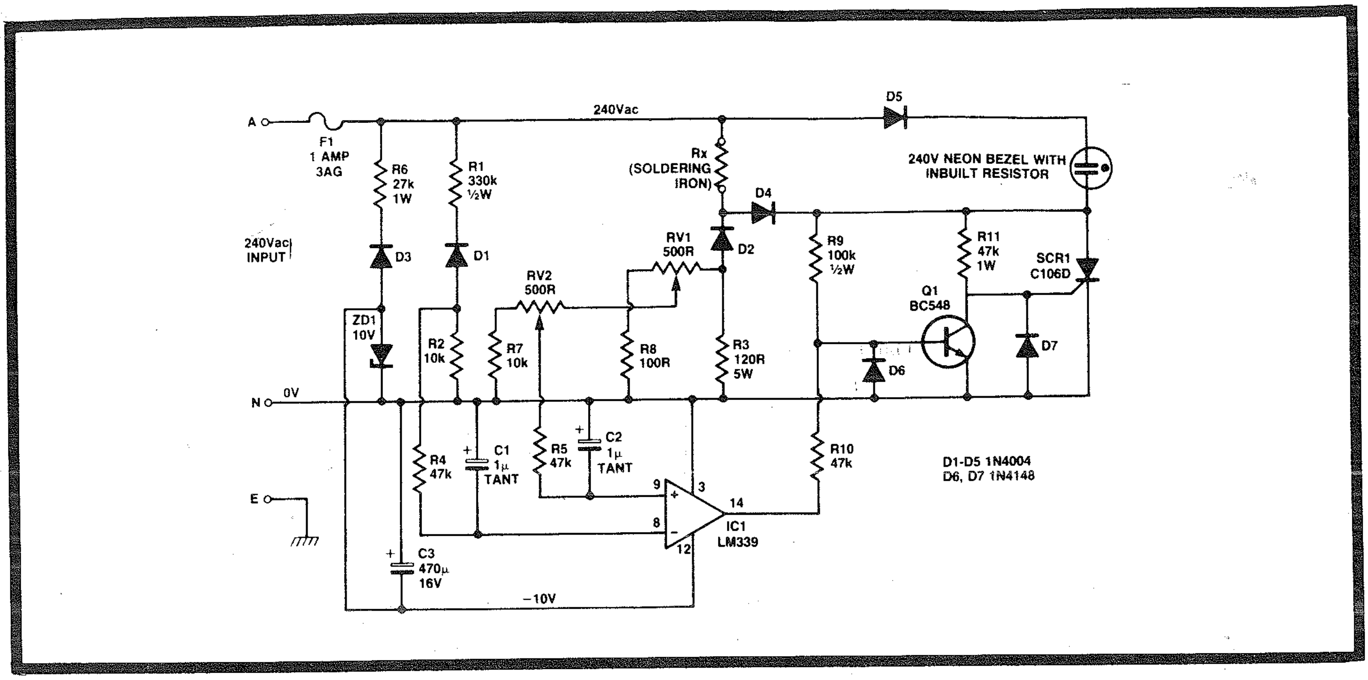
Nevertheless, assuming that this problem has been overcome, there is the second problem of mounting the transducer onto (or inside) the soldering iron. There would also have to be (presumably) at least one wire going from the transducer to the control circuitry as well as the usual power supply and earth wires. All of which suggests a somewhat drastic modification of a conventional soldering iron. These may not be insurmountable problems to a manufacturer who is prepared to set up a production line for temperature controlled soldering irons, but they are clearly serious objections for a hobbyist.

At this point you may be thinking that there is no practical way of using feedback to control the temperature of a soldering iron without modifying the iron. But despair not, there is a solution.

The basic problem is what to use as the temperature transducer. As it happens, we already have one right there inside the soldering iron itself. The heating element in a typical soldering iron is essentially nothing more than a wirewound power resistor. Now, it is the usual characteristic of a resistor that its resistance changes with temperature. The temperature coefficient (proportional change in resistance per degree change in temperature) may vary with the type of resistance wire used by the manufacturer, but all practical resistors exhibit some change in resistance with temperature. If then the resistance of a soldering iron heating element could be measured on a continual basis while the soldering iron is being used, it would be the ideal transducer for temperature control.

Circuit details

The soldering iron temperature controller is designed to be connected between a 240 Vac mains outlet and a soldering iron. The circuit works directly off the mains and derives a low voltage dc supply for the electronics via a straightforward resistor zener diode network (R6, ZD1). Two front panel controls are provided. A coarse adjustment pot RV1, labelled POWER, is calibrated approximately in terms of the nominal power rating of the soldering iron being used (from 20 W to 75 W). A fine adjust-



ment pot RV2, labelled TEMP, is used to set the operating temperature of the soldering iron. Ideally RV2 could be calibrated in degrees centigrade. However, this project was designed as a general purpose device and, since different soldering irons are likely to differ in their temperature/resistance characteristics, a single calibration would not necessarily be valid for different irons. For that reason, in the case of the prototype, RV2 was simply given an arbitrary calibration from 1 to 10. A neon lamp which lights up when SCR1 conducts provides a useful indicator for setting up and adjustment of the front panel controls.

With the component values shown in the schematic, the range of adjustment available is limited for use with soldering irons rated from 20 W to 75 W (approximately). For irons rated less than 20 W, the benefits of temperature control are marginal at best, since these irons have barely enough power for most jobs anyway. If you want to use the soldering iron temperature controller for irons rated above 75 W, replace R3 with a lower valued resistor. In fact, by suitable choice of R3 and R8 the range of adjustment can be optimised for a particular iron. Table 1 gives some suggested resistor values for different irons. These figures have not been verified by experiment so you may have to alter the values slightly if you do not get the range of adjustment that you need.

Construction

For this project, we chose a metal cabinet to house the 'works' rather than a plastic one because a plastic one would be all too easily damaged by accidental contact with a hot soldering iron. Because of the metal construction and because of the presence of dangerous voltages on the board, there are several precautions which the constructor MUST be aware of. First of all, the metal cabinet and all exposed metal parts, such as knobs, pot shafts, etc. MUST be securely earthed. Although human contact with mains neutral or a short circuit between neutral and earth will not have serious consequences, *assume that all components on the PC Board are or could be at a potentially dangerous live voltage.* Therefore at every stage of construction check that there is no weak point at which any of the components could make contact with each other or the metal cabinet.

Construction may begin with the pc board on which most of the components apart from RV1, RV2, fuse holder and neon bezel are mounted. Before soldering components, check the board carefully to make sure that there are no bridges between tracks or breaks in any of the tracks. The components may now be soldered to the board in any convenient order, but I would suggest that you start with the smaller components and leave the larger components, such as the electrolytic capacitor and terminal block till last.

If you wish, you can use an IC socket for IC1. After all of the on-board components have been soldered in check that all polarised components, which include IC1, Q1, SCR1, the diodes and capacitors, have been correctly mounted. Incidentally, reversing the polarity of any of these will most certainly cause problems later on.

Now connect up the potentiometers RV1 and RV2 with approximately 50 mm of hookup wire to each terminal (use only insulated wire rated at 240 V/250 V for all connections). Be particularly careful when soldering the wires to the pot terminals because these could easily bend and make accidental contact with the metal case if the connections are not carefully made. Also,

ETI-1532 — HOW IT WORKS

The soldering iron Rx, together with resistors R1, R2 and R3 and diodes D1 and D2, form a bridge which is connected across the ac mains power supply. The voltage at the junction of D1 and R2 is taken to the negative input of comparator IC1 via R4. Similarly, the voltage at the junction of D2 and R3 is divided down by potentiometers RV1 and RV2 and taken to the negative input of IC1 via R5. Components R4, C1 and R5, and C2 form low pass filters to reduce ac ripple at the comparator inputs. The output of comparator IC1 controls transistor Q1 which, in turn, controls SCR1.

Assume that RV1 (coarse adjustment) and RV2 (fine adjustment) have been set for a desired operating temperature. Initially, the soldering iron has a relatively low resistance. The output of IC1 is low, causing Q1 to turn off and SCR1 to turn on. Full power flows into the soldering iron and it heats up quickly. When the soldering iron has reached the set temperature, the output of IC1 goes high, turning on Q1 and turning off SCR1. The current then flows through the soldering iron only during negative half cycles via D2 and the power drops to half. The temperature will then start to fall below the set temperature and the cycle is repeated. Thus, the soldering iron is maintained at a relatively constant average temperature.

Diode D4 isolates the bridge from the SCR and associated drive circuitry which might otherwise load the bridge during negative half cycles and upset operation. A negative dc supply for the comparator is derived directly from the ac mains via a voltage dropping resistor, R6, and limited by zener diode, ZD1.

During operation, a neon indicator lights up when SCR1 conducts. When the soldering iron is either above or below the set operating temperature, the neon indicator is either fully off or fully on, as the case may be. The neon indicator flashes when the soldering iron is at operating temperature.

A feature of this circuit is that SCR1 is turned on only near zero crossings of the ac voltage waveform, thereby minimising rfi (radio frequency interference).

Here's how it works. Assume that the output of IC1 is low. At the beginning of a positive half cycle, the voltage across resistors R9 and R10 is relatively low and transistor Q1 is prevented from turning on by the low output of IC1. Current therefore flows into the gate of SCR1 via resistor R11 and, being a sensitive gate device, the SCR turns on early in the half cycle. Suppose, however, that the output of IC1 happens to go low in the middle of a positive half cycle, when the voltage across resistors R9 and R10 is fairly high. These resistors form a potential divider with the base of transistor Q1 connected to the junction. In this case, Q1 is turned on despite the low output of IC1, thereby shorting out the gate current of SCR1 and preventing it from turning on.

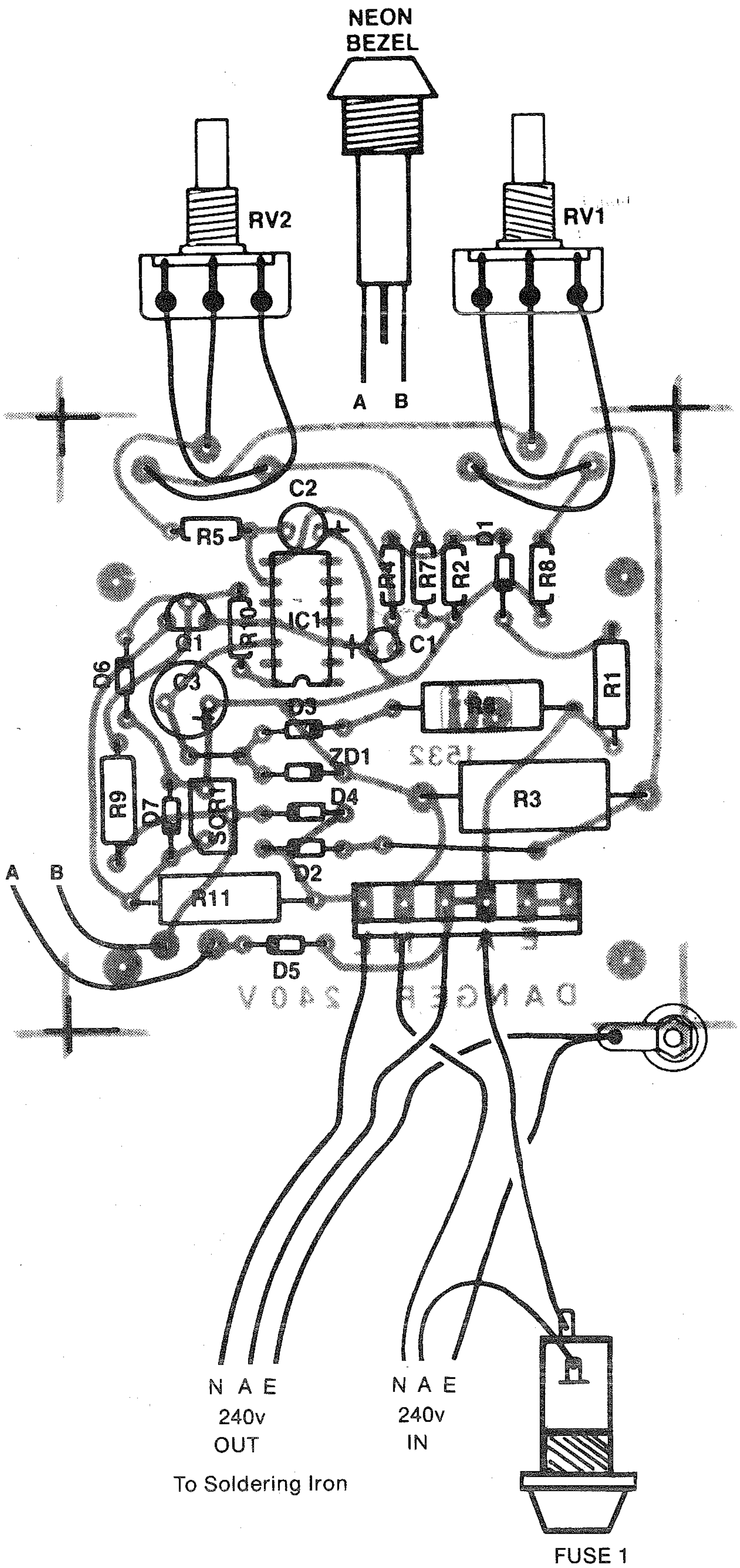
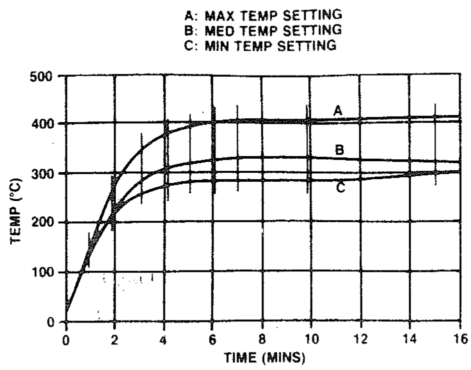

NEON
BEZEL
RV2
RV1
A B
C2
R5
R4
R7
R2
D1
R8
IC1
C1
Q1
R10
D6
C3
R1
D3
ZD1
R3
R9
D7
SCR1
D4
D2
A B
R11
D5
N A E
240v
OUT
To Soldering Iron
N A E
240v
IN
FUSE 1

TABLE 1. SUGGESTED COMPONENT VALUES FOR DIFFERENT RANGES (see text).

Range	R3	R8
20 ~ 30 W	100R	680R
30 ~ 40 W	68R	820R
40 ~ 60 W	47R	680R
60 ~ 75 W	33R	1k
75 ~ 100 W	27R	820R
100 ~ 120 W	18R	1k8
120 ~ 150 W	15R	1k5

Results with 'Lotring' iron



break the lug off the SCR as this is not needed. Now, solder two lengths of hookup wire, about 75 to 100 mm each on the board for the neon bezel but do not as yet solder the ends to the neon bezel.

Leaving aside the pc board for the time being, drill holes in the front panel if this has not already been done for pots RV1, RV2 and the neon bezel. A photocopy of the front panel artwork could be used conveniently, as a template for this operation. In addition, holes will also have to be drilled in the base for the pc board mounting screws and in the rear panel for input and output cables and for the fuse holder. Ream or file away any burrs and rough edges. Carefully apply the Scotchcal label to the front panel, making sure that the hole positions on the label are exactly aligned with the holes in the front panel, then cut out the holes from the label. Drill a hole in the cover to receive a bolt for fixing a spring-type soldering iron holder, if desired. (This is note included in kit)

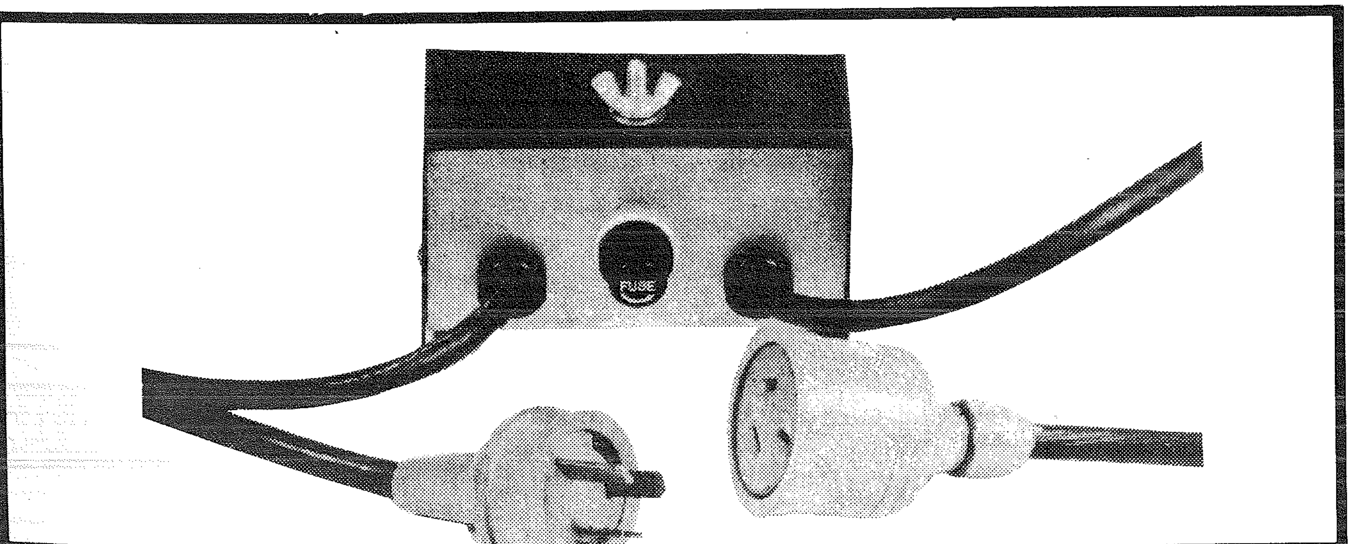
Now you can mount the PC Board in the cabinet using machine screws and plastic spacers. It is also recommended that, when mounting RV1 and RV2 to the front panel, spacers such as washers or nuts be used between the pots and the front panel so that the metal cases of these pots are not mounted too closely to the panel. The reason for this is to leave a wide gap between the soldered pot terminals and the metal panel so as to lessen the risk of accidental contact between them. If you wish, you could lay a piece of plastic (say, about 0.5mm or 1mm thick) over the inside face of the front panel so as to prevent any chance of such contact. Last you can mount the input and output cables as per the overlay. Note when wiring the fuse and the bezel it is recommended that some Heatshrink tubing be used for extra insulation.

Testing and calibration

When construction is completed and everything checked, plug in a soldering iron and switch on. Turn the POWER knob from the fully anticlockwise to the fully clockwise position. If all is well, the neon indicator will light up when the setting corresponding approximately to the rated power of the soldering iron is reached. If the neon lamp doesn't light up or is constantly on regardless of the knob position, switch off power and check for faults.

Assuming everything is OK, adjust the TEMP pot to about mid-position and allow the iron to heat up to full operating temperature. Now, turn the POWER knob (RV1) till the neon lamp is just on the point of going out. The neon lamp will begin to flicker, a sign that the circuit is working, and the soldering iron is ready for use. If desired, you can then make fine adjustments to the soldering iron temperature using the TEMP control. If you want to calibrate the unit in terms of actual temperature, this can be easily done using a soldering iron temperature meter. (I purchased a low cost meter from Jaycar not very long ago for this purpose; such meters may still be available from there and possibly some of the other retailers.) Note, that the calibration will change if the POWER select knob is moved and that the calibration may not be the same for a different iron, even if of the same power rating due to slight variations between irons.

If the temperature controller doesn't work, the first things to check are the power supply connections and that all of the components have been soldered in the right way around. *Under no circumstances start prodding around the circuitry with the power switched on.* If the fault still can't be found you might try checking all the resistors, since the circuit may not work if resistors of incorrect value have been used or if the tolerances of critical resistors are way out. The critical resistors are R1, R2 and R3. Also, don't discount the possibility of a short circuit between tracks, for example due to solder bridges or a break in one or more tracks. Generally, these are readily checked using a high power magnifying glass. As a last resort, you may have to check if individual components have failed, although this is not very likely if care has been taken during soldering.



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PARTS LIST

RESISTORS

- 1 x 330K 1/2 Watt Resistor (R1) ☐
- 2 x 10K 1/4 Watt Resistor (R2,R7) ☐
- 1 x 120R 5 Watt Resistor (R3) ☐
- 3 x 47K 1/4 Watt Resistor (R4,R5,R10) ☐
- 1 x 27K 1 Watt Resistor (R6) ☐
- 1 x 100R 1/4 Watt Resistor (R8) ☐
- 1 x 100K 1/2 Watt Resistor (R9) ☐
- 1 x 47K 1 Watt Resistor (R11) ☐
- 2 x 500R Potentiometer (RV1,RV2) ☐

COMPONENTS

- 2 x 1uF Tantalum Cap (C1,C2) ☐
- 1 x 470uF 16v Electro Cap (C3) ☐
- 5 x IN4004 Diode (D1,D2,D3,D4,D5) ☐
- 2 x IN4148/IN914 Diode (D6,D7) ☐
- 1 x BC548 Transistor (Q1) ☐
- 1 x LM339 IC (IC1) ☐
- 1 x C106D Rectifier (SCR1) ☐
- 1 x 1 Watt Zener IN4740 (ZD1) ☐

MISCELLANEOUS

P.C.B.Board, 150mm x 61mm x 103mm Metal Case, Scotchal Front Panel, 1A 3AG Fuse, Fuse Holder, 6 Way Terminal Block, 240v Neon Bezel, 2 x cable Clamp Grommets, Mains Cable, Plastic Spacers, Screws, Nuts, Washer, Solderlugs, Knobs, Mains Hook Up Wire, Solder, Heatshrink and Inline Socket

NOTES AND ERRATA

NIL

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