Speed plant propagation with this . . .

Triac-controlled soil heating unit

by A. B. HOLLEBON

Have you ever wondered why those garden cuttings which you so carefully prepared take so long to show some sign of life? A little heat applied to the soil using this device may just do the trick.

Most plants show optimum growth at some particular soil temperature and, for many common garden types, this is generally at about 22°C. If the potting mix or other growing medium in a cutting bed is maintained at this temperature for 24 hours a day, a spectacular increase in the rate of root and leaf growth occurs compared to that which is obtained under normal conditions, particularly during the cooler parts of the year.

A satisfactory method of heating the growing medium is to place a heating element in the bottom of a wooden cutting box containing a bed of potting mix about 25-30cm deep. The element must be placed as low as possible in the bed so that developing roots on the cuttings do not reach it. In order to achieve uniform heating over the whole area of the box it is necessary to use a distributed heating element similar to those used in electric blankets.

*18 Wendron St, Cloverdale 6105, Western Australia.

Since this unit is operated in an environment which is fairly moist and in which water is present it is necessary for safety to use an element which operates at low voltage and which is adequately insulated.

Experiments have shown that a power input of about 100 watts is required to maintain the bed of potting mix in a box with an area of about half of a square metre at about 20°C above the ambient temperature (ie, when temperature drops to around 0°C). If the transformer which feeds the heater has a secondary voltage of 18 volts, the resistance of the element necessary to generate 100 watts of heat will be approximately 3Ω.

The prototype was built on stripboard and housed in a water-tight plastic case. It speeds plant growth by maintaining the soil temperature at about 22°C.

An element with the required characteristics consists of about 50 metres of 10/0.2mm PVC insulated hook-up wire. If the cutting box is about 70cm square, the 50 metres of wire will just cover the bottom if it is laid out in parallel lines spaced 1cm apart. The wire should be firmly held in place by threading it through holes spaced 1cm apart in two pieces of light timber (70cm long) which are screwed to the floor of the box at opposite ends.

Temperature control

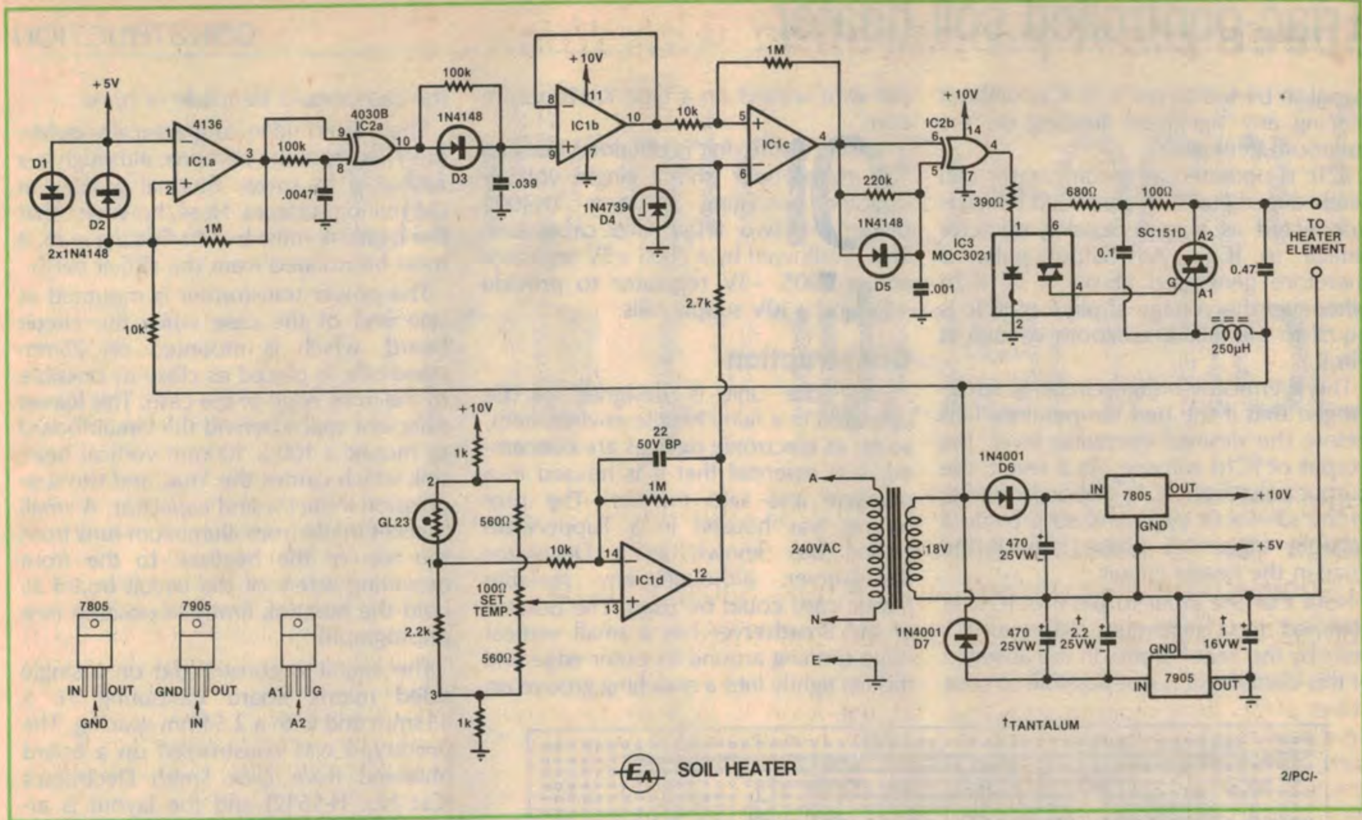
The cutting bed temperature is monitored by a thermistor sensor mounted in a probe which is placed in the bed at about the same depth as the bottom of the cuttings. Since there is a significant distance between the heating element and the thermistor, there is a long time lag between the application of power to the element and the arrival of heat at the sensor.

If a simple on/off thermostat switch was used to control the power there is the possibility that the system would go into oscillation with the temperature at the bed surface swinging alternately above and below the mean temperature by several degrees. It is therefore necessary to use a proportional control system where the rate at which heat is supplied by the element is proportional to the amount by which the bed temperature is below the required value. This ensures that the system approaches the correct operating temperature with no significant overshoot.

Control circuit

The circuit uses a GL23 thermistor to measure the bed temperature. The thermistor is operated in a bridge circuit and the bridge arms are such that the bridge is balanced when the bed is at the desired temperature. The bridge output is fed to IC1d which is connected as a differential amplifier with a nominal gain of 100.

Since the line from the thermistor probe to the control unit may be one or two metres long and may run close to the heating element, a significant 50Hz signal



The circuit uses a thermistor to monitor soil temperature and a Triac to provide phase control of the heater circuit.

may be present at the input of IC1d. In order to remove this unwanted component a 22μF non-polarised electrolytic capacitor is connected across the amplifier feedback resistor. The DC output from IC1d then goes to the inverting input of comparator IC1c via a 2.7kΩ resistor. Zener diode D4 clamps the input of IC1c to a maximum value of 9.1V.

The heater control circuit uses a phase-controlled Triac operating in a system which was fully described in "Electronics Australia" in November 1981 (Slide Cross-Fader and Auto-Advance Unit). For a detailed description of the mode of operation of this circuit it is suggested that the original article should be consulted. For those who do not have access to the November 1981 issue, the following brief description gives an outline of the system.

The 50Hz output from the power transformer secondary is clipped by two back-to-back diodes (D1 and D2) and fed to the squaring amplifier IC1a. The 50Hz square wave output from IC1a is then fed to exclusive-OR (XOR) gate IC2a with the signal going directly to pin 9 and also to pin 8 via an RC delay network. This gives a brief positive pulse at the output of IC2a each time the square wave output from IC1a passes through zero. The output of IC2a is thus a continuous stream of short positive pulses at a rate of 100 per second.

The voltage pulses from IC2a pass through diode D3 to charge a 0.039μF capacitor. During the time between pulses the capacitor discharges through a 100kΩ resistor which is connected in parallel with the diode. The input to pin 9 of IC1b is therefore a sawtooth wave with a frequency of 100Hz. IC1b is connected as a high impedance voltage follower which allows the sawtooth

PARTS LIST

- 1 stripboard, 76 x 153mm, Dick Smith Cat. No. H-5612
- 1 18V, 6A power transformer, Dick Smith Cat. No. M-2000 or equivalent
- 1 RM10 ferrite core, Radiospares Stock No. 228-258
- 1 GL23 thermistor, Radiospares Stock No. 151-029
- 1 case to suit (see text)
- 1 finned aluminium headsink, 100 x 100mm
- 50 metres of 10/0.2mm insulated wire
- 1 mains cord clamp
- 1 3-way terminal block
- 1 6-way terminal block

SEMICONDUCTORS

- 1 4136 quad operational amplifier
- 1 4030B quad exclusive OR gate
- 1 MOC3021 optically-coupled Triac driver
- 1 7805 3-terminal regulator
- 1 7905 3-terminal regulator
- 1 SC151D 15A Triac
- 4 1N4148 silicon diodes
- 2 1N4002 silicon diodes
- 1 1N4739 zener diode

CAPACITORS

- 2 470μF/25VW PC electolytics
- 1 22μF/50VW bipolar
- 1 2.2μF/25VW tantalum
- 1 1μF/16VW tantalum
- 1 0.47μF metallised polyester (greencap)
- 1 0.1μF metallised polyester
- 1 .039μF metallised polyester
- 1 .0047μF metallised polyester
- 1 .001μF metallised polyester

RESISTORS (½W, 5%)

3 x 1MΩ, 1 x 220kΩ, 2 x 100kΩ, 3 x 10kΩ, 1 x 2.7kΩ, 1 x 2.2kΩ, 2 x 1kΩ, 1 x 680Ω, 2 x 560Ω, 1 x 390Ω, 1 x 100Ω, 1 x 100Ω wire-wound potentiometer.

MISCELLANEOUS

Hook-up wire, machine screws and nuts, scrap aluminium, epoxy adhesive, silicone sealant, solder, etc.

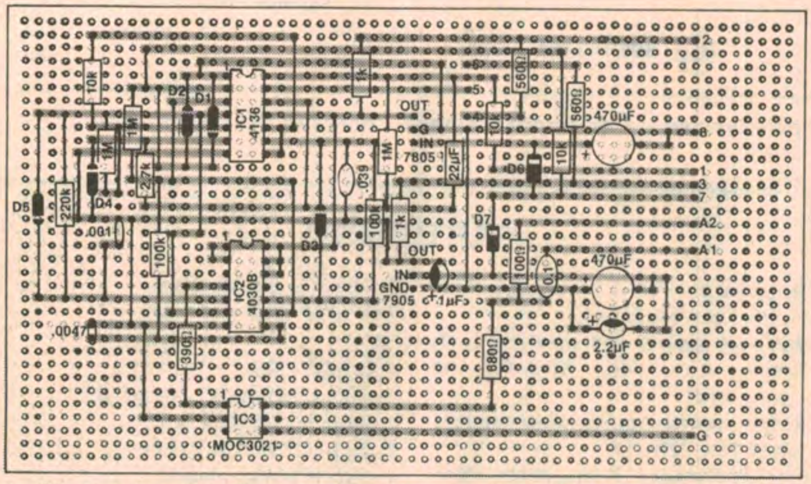
The GL23 thermistor and RM10 ferrite core are available from Radiospares Components, PO Box 281, Subiaco 6008, Western Australia.

signal to be fed to pin 5 of IC1c without placing any significant loading on the sawtooth generator.

IC1c is operated as a comparator and feeds directly to XOR gate IC2b which is connected as a zero-crossing detector similar to IC2a. An output pulse is therefore generated at pin 4 of IC2b whenever the voltage at pin 6 of IC1c is equal to the falling sawtooth voltage at pin 5.

The thermistor bridge circuit is so arranged that if the bed temperature falls below the desired operating level, the output of IC1d will rise. As a result, the output pulse from IC2b will occur earlier in the sawtooth cycle and so provide a suitable trigger to phase control the Triac in the heater circuit.

Note that the input to pin 6 of IC1c is clamped to a maximum value of 9.1 volts by the zener diode. In the absence of this clamping it is not possible to start



Follow this parts location diagram when wiring up the soil heater. Cuts in the copper pattern are easily made by hand twisting an oversize drill bit.

up the heater if the bed temperature is very low since the input to pin 6 of IC1c would be higher than the peak sawtooth voltage. Under these conditions no trigger pulse can be generated by IC2b and therefore no heating can occur.

The output pulses from IC2b are fed directly to IC3 which is an opto-coupled Triac driver.

All phase-controlled Triac systems are potential sources of radio frequency interference and this unit is no exception. In fact, since it is constructed in an unshielded plastic housing and uses a 50-metre long heating element, it must be considered as a fairly effective interference generator. Fortunately, this problem is largely overcome by including a 250μH inductor and a 0.47μF capacitor in the Triac circuit. The inductor is required to carry the full 6 amps which flows in the heater circuit and consists of 25 turns of 1mm enamelled copper wire wound on a type RM10 ferrite core.

Power for the unit is obtained from an 18V transformer and a single voltage doubler consisting of two 1N4002 diodes and two 470μF filter capacitors. This is followed by a 7805 +5V regulator and a 7905 −5V regulator to provide +5V and +10V supply rails.

Construction

Since this unit is designed to be operated in a fairly hostile environment, so far as electronic devices are concerned, it is essential that it is housed in a practical and safe manner. The prototype was housed in a Tupperware plastic box known as a Decorator Breadserver, although any sealable plastic case could be used. The bottom of the Breadserver has a small vertical ridge running around its outer edge and this fits tightly into a matching groove on the lower edge of the cover to provide a watertight seal.

Even if a hose is played directly on the case no water penetrates the seal. The main power lead, the lead to the temperature probe, and the heater leads are all brought out through the floor of the case and these exit points should also be made watertight. A silicone sealing compound from your local hardware store can be used for this job.

Since the Tupperware plastic case tends to distort slightly under the weight of the power transformer it is necessary to run two lengths of 12.5mm aluminium angle along below the bottom of the case to provide sufficient rigidity. Four rubber feet about 25-30mm high are also attached to the bottom of the case to allow sufficient clearance for the leads which come down through the floor. In order to reduce corrosion problems, all screws which pass through the floor of the case should be made of brass.

There is no need to electrically isolate the Triac from the heatsink, although it is advisable to smear thermal grease on the mating surfaces. Note, however, that the heatsink must be left floating – ie, it must be isolated from the circuit earth.

The power transformer is mounted at one end of the case while the circuit board, which is mounted on 25mm stand-offs, is placed as close as possible to the front edge of the case. This leaves sufficient space behind the circuit board to mount a 100 x 100mm vertical heatsink which carries the Triac and the suppression inductor and capacitor. A small bracket made from aluminium runs from the top of the heatsink to the front mounting screw of the circuit board to hold the heatsink firmly in position (see photograph).

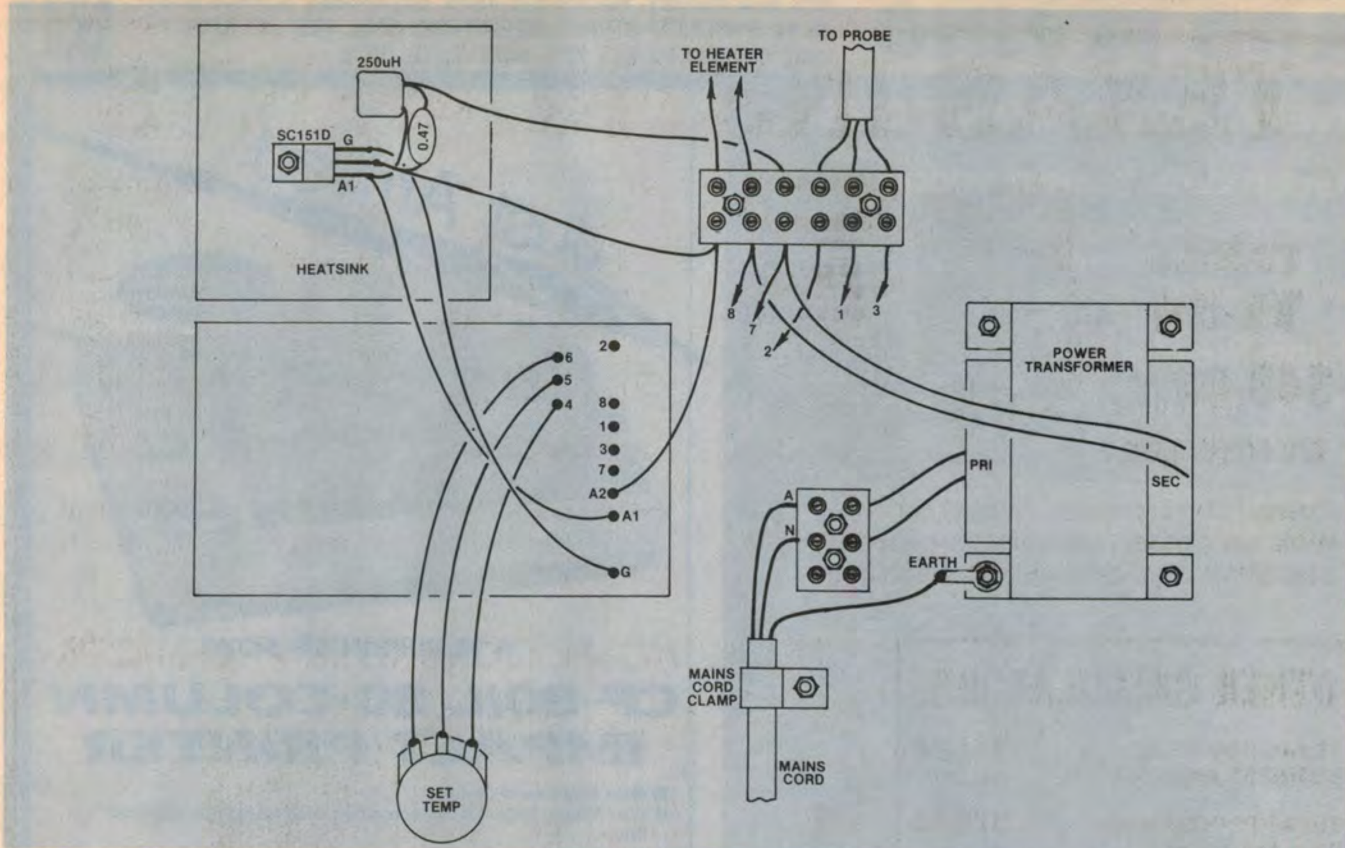
The circuit is constructed on a single sided matrix board measuring 76 x 153mm and with a 2.54mm spacing. The prototype was constructed on a board obtained from Dick Smith Electronics (Cat No. H-5612) and the layout is arranged to fit around the two small undrilled areas in this board.

The inductor is constructed by winding 25 turns of 1mm (18 gauge B&S) enamelled copper wire on the bobbin of a type RM10 ferrite core assembly. After assembly of the completed unit it is advisable to run epoxy adhesive around the windings and into the space between the windings and the two ferrite core sections. This ensures that the whole assembly does not vibrate noisily when the unit is delivering full power to the heating element.

All connections between the various sections of the unit and the external lines are made through two terminal blocks located on the floor of the case below the circuit board. In order to avoid any problems due to the presence of water, no plugs and sockets or other types of connectors are used in the heating element circuit.

Since the element only operates at a very low temperature it is quite practical to terminate it at the terminal block inside the case. There is then a continuous unbroken cover of PVC over the whole element system and there is no possibility of any short circuits or other circuit malfunction. For the same reason, the unit should be fitted with a long power cord so that the power connection will be made at a point which is well away from the area where water is likely to be present.

The thermistor probe contains the thermistor and the 2.2kΩ resistor which together form one half of the bridge circuit. The thermistor is mounted inside a



The Triac can be bolted directly to the heatsink provided the heatsink is not earthed. Keep mains wiring neat and tidy.

25mm length of 6mm copper or stainless steel tubing. The end of the thermistor should be located just inside the end of the tubing with the leads projecting from the opposite end. The tube should then be filled with epoxy adhesive to ensure that no water can reach the thermistor.

The 2.2kΩ resistor and the connecting cable are connected to the thermistor leads with short lengths of spaghetti tubing being used to provide insulation of each lead. The whole assembly is then slid into the end of a piece of 10mm tubing about 20cm long so that the thermistor mount projects about 6mm from the end of the larger tube. Epoxy adhesive is again used to make a seal between the two tubes so that no water can enter.

A length of light three core cable should be used to connect the probe to the control unit and a silicone sealant should be used to make a flexible waterproof seal where the cable leaves the end of the probe tube.

In order to provide for a range of operating temperatures a 100Ω potentiometer is included in the bridge circuit. This potentiometer is mounted on a small aluminum bracket about 20mm above the circuit board and connected by flying leads to the points marked 4, 5 and 6 on the circuit board. The bracket is held in place by the two circuit board mounting screws at the end of the board nearest to the power transformer.

Calibration

Due to the long time delay between the application of the power to the element and the arrival of heat at the thermistor sensor, it is not possible to carry out a quick calibration of the temperature setting potentiometer under actual working conditions. The most practical way to carry out the calibration is to roll the element into a coil and place it in a bucket containing about three litres of water. Place the thermistor probe in the water together with a thermometer and switch on the unit.

The equilibrium temperature will then be reached fairly quickly and, for a given potentiometer setting, the temperature should not vary by more than about half a degree over the whole 24 hours (provided, of course, that the ambient temperature is always less than the set point).

Note: There will be a significant energy cost in using this unit. We estimate that during winter on the east coast of Australia the energy consumption is likely to be about one kilowatt-hour in a 24-hour period. This means that the likely cost of running the unit continuously over a three-month period would be about $5 to $7.

> We estimate that the current cost of parts for this project is approximately
>
> **$70**
>
> This includes sales tax.