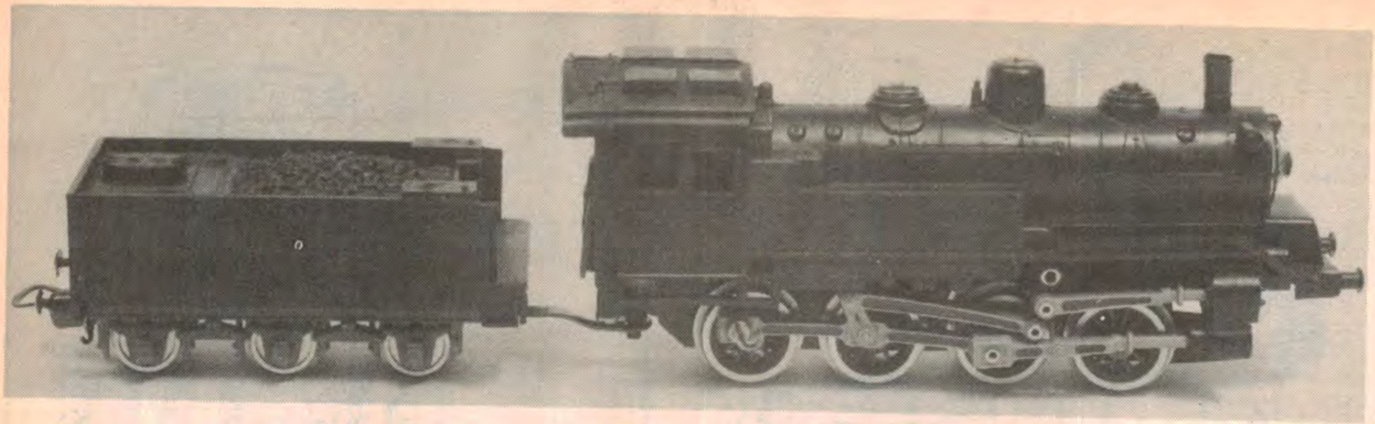


Low-cost bipolar model train controller

Here is a simple model train control for those enthusiasts who desire something better than the usual rheostat control. It provides much improved low speed performance and is fully overload protected, yet contains relatively few components. Best of all, you don't need to be an electronic genius to construct it.

by JOHN CLARKE

It's Christmas again (almost) and, within a few weeks, there will be quite a number of new model train sets in action. Most will suffer from one major disadvantage – a low-cost rheostat control unit that provides barely adequate performance. Worse still, many of the simpler sets will be powered by batteries alone with just a simple reversing switch.

A rheostat controller simply consists of a variable resistor in series with the supply voltage. This provides continuous control of the armature current and hence of motor torque. The main advantage of this scheme is that it is the easiest and cheapest method of control, which is precisely why it is used by the train set manufacturers.

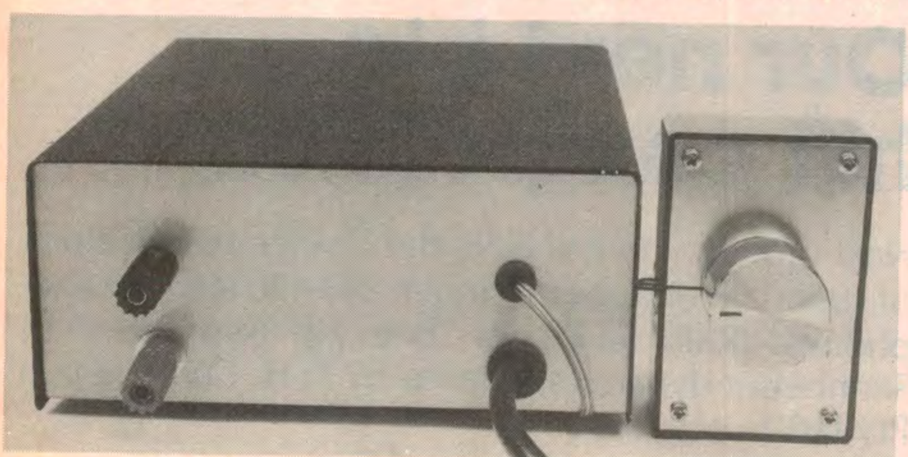
Admittedly, a rheostat controller provides acceptable control at high running speeds since the circuit resistance, consisting of the armature resistance and the control resistance, is quite small. In this situation, the back EMF of the motor is the major factor determining armature current and the speed of the train will be substantially independent of load variations.

Problems occur at low speed settings, however. Here the large amount of series resistance in the supply circuit makes the rheostat controller behave as a "constant current" source, negating the beneficial effect of reduced back EMF. Normally, when a motor slows down, the back EMF generated by the motor falls and armature current rises, increasing the torque; conversely, when a motor speeds up, the back EMF rises and armature current falls, reducing the torque.

With the rheostat controller, however, the armature current (and hence the torque) is limited at low speed settings by the large amount of resistance in circuit. What's more, because the supply has a constant current characteristic, the ability of the motor to vary its torque according to back EMF is quite limited and the model becomes quite sensitive to load variations. The loco will slow noticeably on gradients and curves, and in some instances may even stall.

In addition, the supply voltage to the train is poorly regulated with a rheostat controller. Whenever additional current is drawn to cope with an increased load, the voltage drop across the resistance increases and the track voltage falls. Again, this has as an adverse affect on low-speed performance and the loco's ability to cope with load variations.

Another objectionable feature of the simple rheostat controller is its poor starting characteristics. It's almost impossible to start a train without having it take off like a rocket, no matter how skillfully the control knob is handled. The reason for this is that a very much larger armature



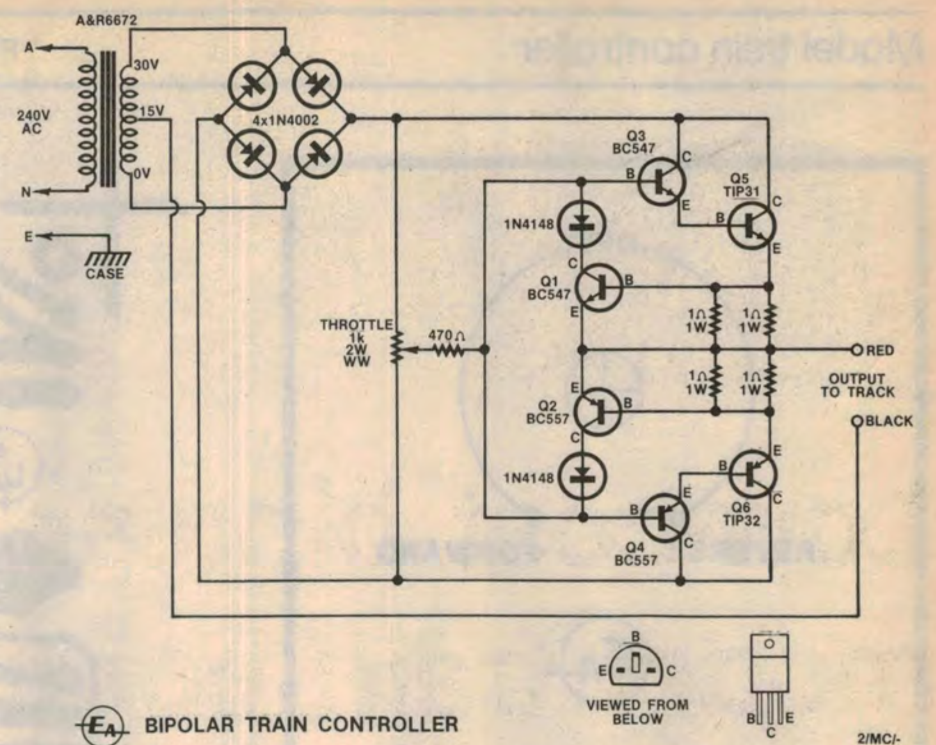
Here is the completed control unit, built into a standard metal case. A separate hand-held plastic case is used to house the speed control potentiometer.

current (torque) is needed to start the motor than to keep it running.

So in order to provide enough current to start the motor, the control knob must be advanced well up the scale. The result is inevitable: once the motor does start it quickly gathers speed and the train "blasts off".

This is where the controller described here scores. Basically, it is a variable power supply with a low output impedance. At any given setting it behaves as a constant voltage source, allowing the current to vary according to the motor's requirements and as dictated by the back EMF. As a result, low speed torque is considerably improved, leading in turn to much improved starting and low-speed running characteristics.

Other features of our new "Bipolar Train Controller" include overload protection and bi-directional control using a single control potentiometer. The unit can supply positive and negative output voltages variable from 0V to 20V peak (or around 13.5V average) and is easy to operate, with the control pot mounted in a small hand-held plastic case.



The circuit is based on complementary Darlington transistor pair output stages. Transistors Q1 and Q2 form the overload protection circuitry.

THE CIRCUIT

Let's take a look at the circuit and find out how it works.

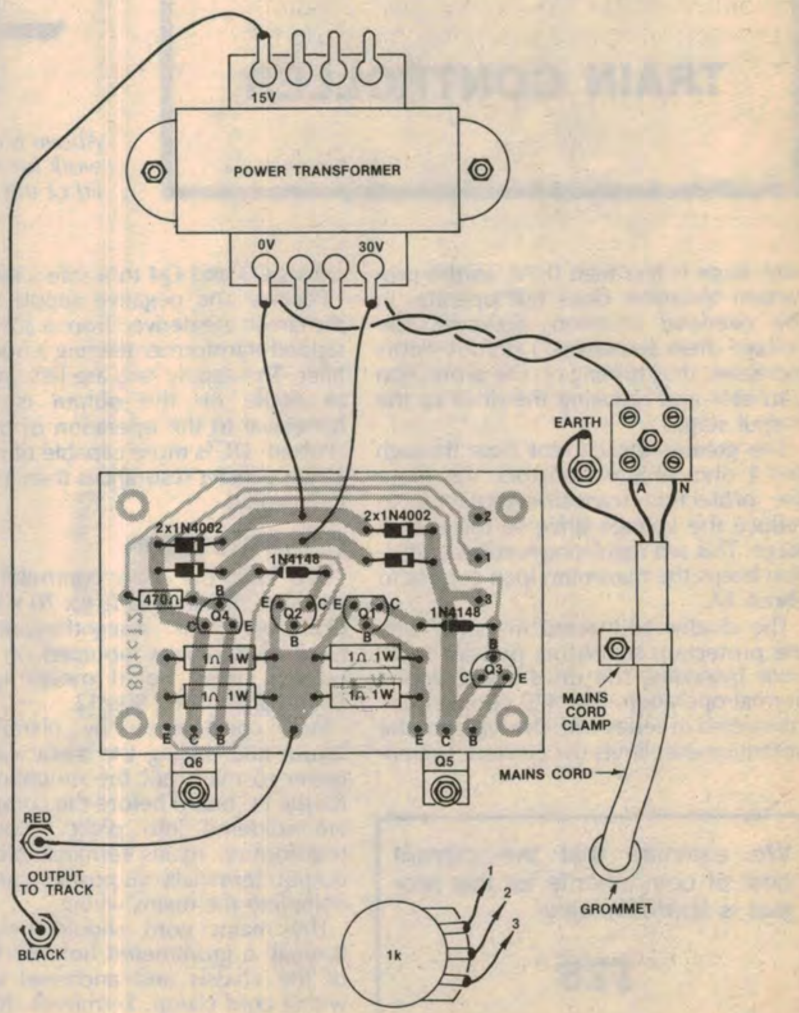
The circuit is based on complementary Darlington transistor pair output stages, to which we have added protection circuitry. Transistors Q3 and Q5 make up one Darlington transistor pair, while Q4 and Q6 form the other pair.

The output voltage is determined by the setting of the 1k potentiometer, which forms the loco speed and direction control. When the control is centred, there is no output voltage, and the loco remains stationary. When it is rotated clockwise, the output voltage increases, driving the train in one direction, while anti-clockwise rotation produces movement in the opposite direction.

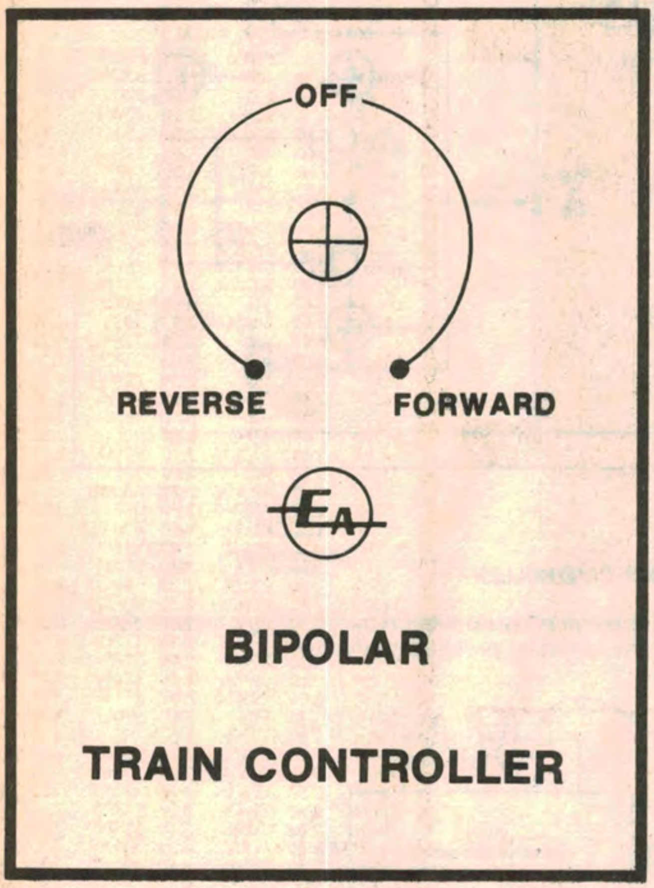
Operation of the circuit is as follows: the voltage at the wiper of the potentiometer is passed to the bases of the Darlington transistor pairs via the 470 ohm resistor. Depending upon the setting of the potentiometer, this will forward bias one Darlington pair, and reverse bias the other.

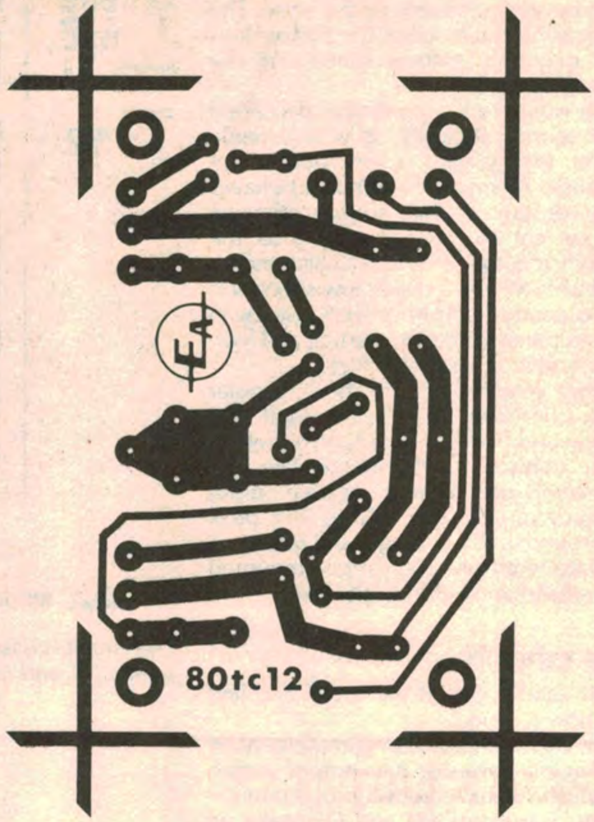
The forward biased stage operates as an emitter follower and supplies current to the load (in this case the loco) via two parallel 1 ohm emitter resistors. The emitter-follower action applies local negative feedback, and tends to keep the voltage applied to the train constant, irrespective of the load current. So the loco tends to have improved "pulling power", even at low speeds.

Overload protection is provided by transistors Q1 and Q2 which reduce the drive to the output stages under conditions of excessive loading (ie when there is a short across the tracks). In normal operation, the voltage drop across the two parallel 1 ohm resistors in the rele-



Make sure that you orient the transistors and diodes correctly, and keep mains wiring neat and tidy. Note that Q5 and Q6 must be isolated from chassis.





Above is an actual size PC artwork while at left is a panel artwork for those who choose to mount the control pot on the lid of the standard metal case.

vant stage is less than 0.5V, so the protection transistor does not operate. In the overload situation, however, the voltage drop across the 1 ohm resistors increases, thus turning on the protection transistor and reducing the drive to the output stage.

The greater the current flow through the 1 ohm emitter resistors, the more the protection transistor turns on to reduce the voltage drive to the output stage. This self-regulating feedback situation keeps the maximum load current to about 1A.

The diodes connected in series with the protection transistors prevent them from bypassing the drive signal during normal operation. The 470 ohm resistor connected in series with the wiper of the potentiometer, limits the currrent to transistors Q3 and Q4 to a safe value.

Positive and negative supply rails for the circuit are derived from a 30V centre-tapped transformer feeding a bridge rectifier. The supply rails are left unfiltered, as ripple on the output is actually beneficial to the operation of the loco. "Pulsed" DC is more capable of breaking down contact resistances than a smooth DC supply.

We estimate that the current cost of components for this project is approximately

$26

This includes sales tax.

CONSTRUCTION

We built our train controller into a standard metal case 184 x 70 x 160mm. Construction is straightforward, with most components mounted on a small printed circuit board measuring 84 x 54mm and coded 80tc12.

Start construction by planning the layout and drilling the metal case. It is easier to mark out the mounting holes for the PC board before the components are soldered into place. Mount the transformer, mains terminal block and output terminals in position and then complete the mains wiring.

The mains cord should be passed through a grommeted hole in the front of the chassis and anchored securely with a cord clamp. Terminate the mains active and neutral to the terminal block and run the earth wire to an adjacent solder lug. It is a good idea to leave sufficient slack in the earth lead so that it will be the last to break in the event of undue strain on the mains cord.

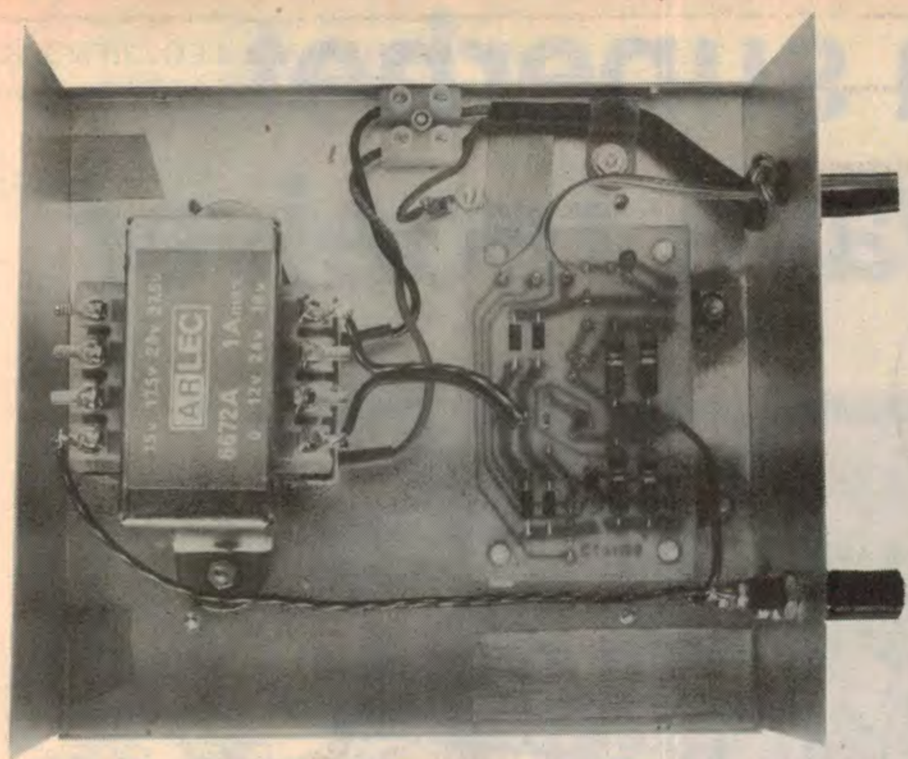
Assembly of the PC board can be tackled next. Make sure that the transistors and diodes are correctly oriented, and use PC stakes to facilitate external wiring to the board. This done, the PC board can be mounted in the case using 9mm Richco plastic supports, and the wiring completed.

Note that heavy duty hook-up wire should be used for all connections to the transformer and to the output terminals. A 3-wire length of rainbow cable will suffice for linking the hand-held control unit to the PC board.

The TIP31 and TIP32 power transistors are bolted to the base of the chassis and their leads soldered to the underside of the PC board. It is necessary to insulate the metal heatsink tab on each transistor from the chassis using a mica washer and an insulating bush. A smear of heatsink compound on each mating surface is recommended to aid heat transfer.

Check the electrical insulation with an ohmmeter after the securing bolt for each transistor has been tightened.

Some constructors may prefer to dispense with the separate hand-held



Use heavy duty hook-up for all connections to the transformer and to the output terminals. The PC board is mounted using plastic standoffs.

PARTS LIST

- 1 PC board, 84 x 54mm, coded 80tc12
- 1 metal case, 184 x 70 x 160mm
- 1 plastic utility box, 83 x 54 x 28mm
- 1 1k 2W wire wound potentiometer
- 1 30V CT 1A mains transformer, A & R 6672, DSE M-6672, R6678
- 1 TIP31 NPN power transistor with mounting hardware
- 1 TIP32 PNP power transistor with mounting hardware
- 2 BC557 PNP transistors
- 2 BC547 NPN transistors
- 4 1N4002 1A rectifier diodes
- 2 1N4148 diodes
- 1 470 ohm ½W resistor
- 4 1 ohm 1W resistors
- 2 binding post terminals: 1 red, 1 black
- 1 knob
- 4 Richco CBS-6N plastic board supports
- 6 PC stakes
- 1 10A mains cord and plug
- 2 grommets; 1 large, 1 small
- 1 cord clamp and 2-way insulated terminal block
- 6 PC stakes

MISCELLANEOUS

Solder, hookup wire, solder lug, screws and nuts.

NOTE: Resistor wattage ratings are those used for our prototype. Components with higher ratings may generally be used provided they are physically compatible. Components with lower ratings must not be used.

controller and mount the potentiometer on the lid of the power supply case. If you do choose this option, we suggest that you also purchase a Scotchcal adhesive label to dress up the project. Scotchcal panels should be available from Radio Despatch Service (869 George St, Sydney) and from other suppliers by the time this article appears.

Once you have completed the unit, double check all wiring, and then switch on. Use a voltmeter to check that the output voltage can be controlled by the knob, and that both positive and negative output voltages can be obtained. Note that the meter will give the average value of the output voltage.

If all is OK, connect up to a train, and give the unit a practical test. If you have a suitable ammeter, connect it directly across the output, and check that the maximum output current is about 1A, in both directions.

Finally, it is quite normal for the control potentiometer to become warm during operation. This is because the pot is connected directly across the supply rails and continuously dissipates around 0.9W. Do not substitute a carbon potentiometer for the 2W wire wound type specified, as its rating (0.25W) will be inadequate.

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