Model Train Controller

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THE circuit outlined below was evolved to provide a model railway enthusiast with a "foolproof" means of controlling an electric train. Besides providing complete protection against overloads, the circuit gives good overall performance and a high degree of control.

OVERLOAD PROTECTION

Let us consider first the performance of a shunt connected d.c. motor; that is one with the field winding in parallel with the armature winding. If the motor is stationary, then, when the supply is switched on the current through it will initially be very high, limited only by the low armature resistance. Once the motor armature starts turning, a voltage is induced in its winding due the the dynamo effect; the winding rotates in the motor field. This back e.m.f. tends to oppose the applied voltage, and hence reduce the supply current.

If unloaded, the motor will run up to some speed such that the armature opposing voltage plus the voltage due to the product of armature current and resistance, is equal to the supply voltage. If the motor is mechanically loaded, the speed falls, and the armature current will increase to maintain the relationship. Conversely if the motor is to be speeded up for a given load, the supply voltage must be increased; the motor will then run faster and draw more current.

There are two possible ways of controlling the motor, firstly by supplying it from a constant voltage supply, and secondly from a constant current supply. In both instances control being affected by altering either the supply terminal voltage or current as appropriate.

In this instance a constant current control was decided upon since it offered the following features:

(a) Maximum current limitation could be readily built in, thus protecting the power supply against short circuits caused by metal objects being placed across the rails;

(b) If the train is overloaded and refuses to start, the current could not rise to a value sufficiently high to damage the motor;

(c) Such a controller will give constant acceleration of the train up to the required speed.

CONTROLLER THEORY

The theoretical circuit diagram is shown in Fig. 1. The a.c. mains supply is stepped down to 20 volts by the transformer T1, then rectified by the diodes D1 and D2, giving a d.c. output smoothed by the large electrolytic capacitor C1. A stabilised voltage of 6·2V is established across R2 and VR1 by the Zener diode D3. Any proportion of this voltage can be applied to the base of transistor TR1 by adjustment of the wiper of potentiometer VR1.

Suppose now that the wiper of VR1 is at the "grounded" end of the track; no voltage is applied to the base of TR1, which is cut off. Thus no current passes through R3, so there is no drive voltage to the base of TR2, which is also cut off. Similarly TR3 is also cut off and no current flows through the load.

If the wiper of VR1 is moved to some other position, a voltage is applied to the base of TR1 causing it to conduct. Its collector current produces a voltage across R3, which drives TR2 on and hence drives TR3 on. Current through the load and R8 builds up until the voltage across R8 almost equals that picked off VR1.

When this state is reached the current remains constant at that value. It is seen that the current through the load is independent of the load resistance.

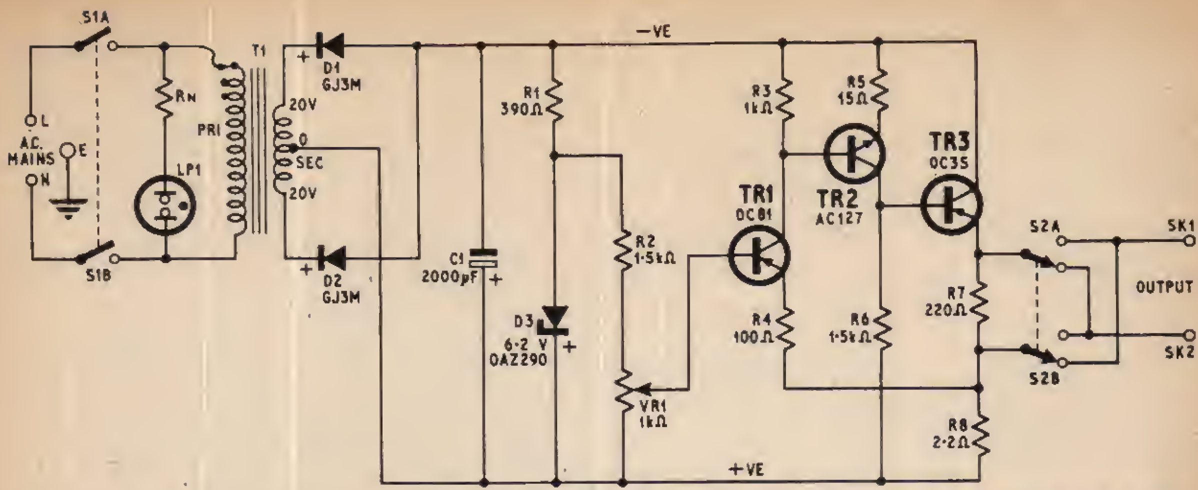

Fig. 1. Circuit diagram of the model train controller. VR1 is the speed control and S2 is the forward/reverse control

If the load becomes effectively a short circuit, then the current through it cannot rise above the value determined by the setting of VR1.

Values of VR1, R2, R8, and the Zener diode D3 are chosen such that the maximum value of voltage which can be applied to the base of TR1 is 2·5V, and hence no more than 1A, producing a 2·2V drop across R8, can flow through the load. The circuit is thus protected against short-circuits across the output terminals. If the engine is overloaded and refuses to start, the maximum current through it cannot exceed 1A

If, however, 1A is considered too much current for safe control, R2 can be increased to reduce the maximum voltage that can be applied to the base of TR1, and hence reducing the maximum current that can flow through R8 and the engine.

PRACTICAL POINTS

There are a few practical points to watch. The final transistor TR3 is a power transistor dissipating, at most, about 6 watts. It *must* be mounted on a heat sink; a suitable one is shown in Fig. 2a. The transistor should be insulated from it by using the customary mica washer, and clamping it on with nylon screws. All holes should be carefully deburred and smoothed so that no damage is inflicted on the mica washer. The mounting face of the transistor and the corresponding area of the heat sink should be smeared with silicon grease to improve thermal conductivity.

Transistor TR2 should be mounted in a copper heat clip, see Fig. 2b. It is quite permissible to leave this free standing as shown in the layout diagram Fig. 3, but it may of course be attached to the chassis or front panel, provided that the case is isolated from the collector of the transistor.

For a power supply of this kind it is essential that the winding resistances of the transformer are low, otherwise there will be a large voltage drop in the windings. The d.c. voltage across C1, at full power output, may fall to a value too low to maintain the Zener diode current. Should this be the case, there will be large changes in load current for variations in the load. Normally large changes in the load should not produce more than small, about 5 per cent, changes in the current through it.

A suggested layout for the components on printed wiring board is shown in Figs. 3 and 5. The Zener diode and its associated resistor R1 should be mounted clear of the board since they can get quite warm. The Zener diode should in this case be mounted on a heat sink.

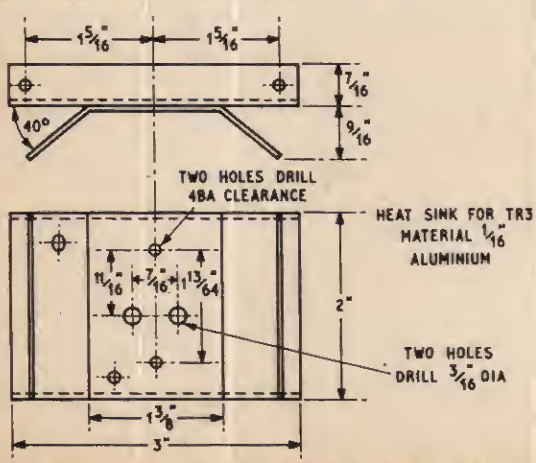

Fig. 2a. Construction of the heat sink for TR3

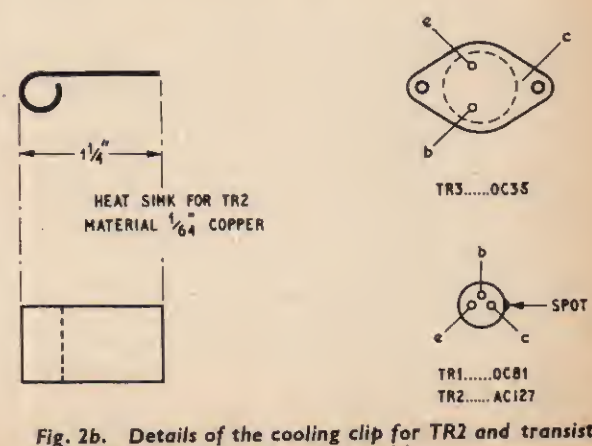

Fig. 2b. Details of the cooling clip for TR2 and transistor connections (looking at the wire ends)

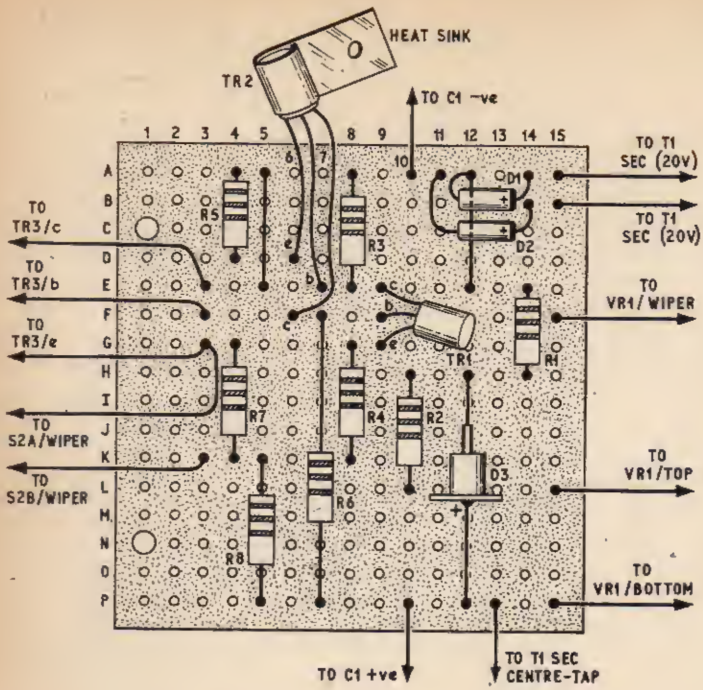

Fig. 3a. Layout of components on the board

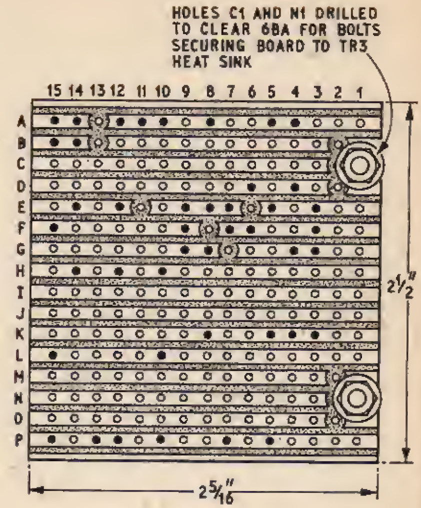

Fig. 3b. Connections and breaks on the copper strip side of the board

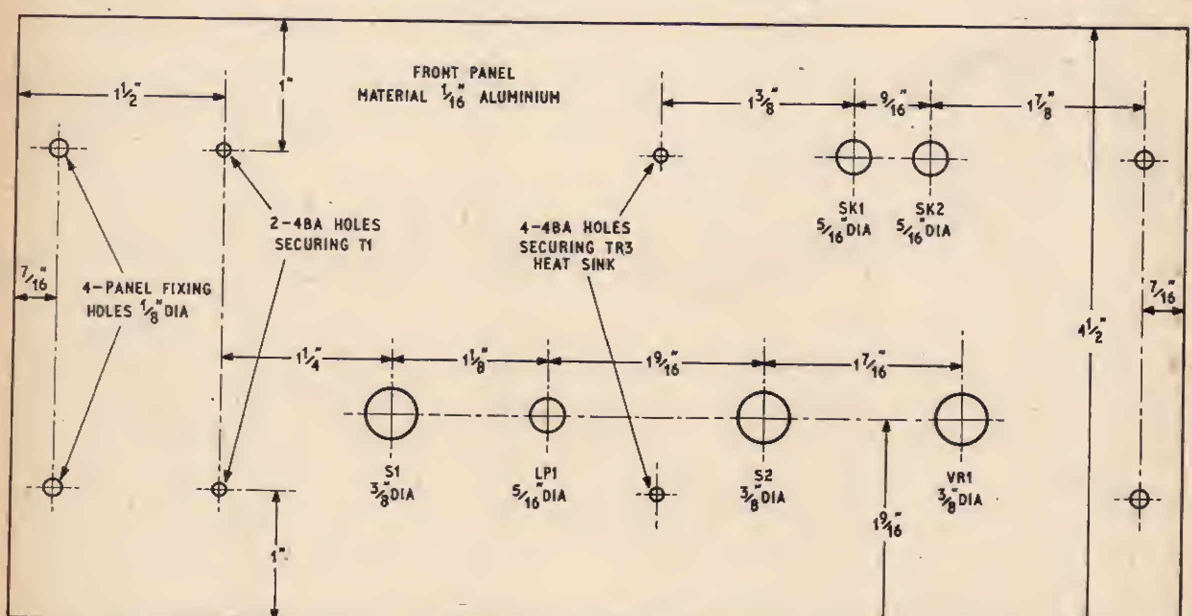

Fig. 4. Drilling details of the front panel

COMPONENTS . . .

Resistors
R1 390Ω 1·5W R4 100Ω R7 220Ω 1W
R2 1·5kΩ R5 15Ω R8 2·2Ω 5W
R3 1kΩ R6 1·5kΩ
All 10%, ¼W carbon except where otherwise stated

Potentiometer
VR1 1kΩ linear carbon

Capacitor
C1 2,000μF elect. 50V

Transistors
TR1 OC81 TR2 AC127 TR3 OC35 (Mullard)

Diodes
D1, D2 GJ3M or ZR11 (2 off)
D3 OAZ290 (6·2V 7W Zener)

Transformer
T1 Mains transformer. Pri: 0–205, 225, 245V; Sec. 20–12–0–12–20V r.m.s., 0·7A (d.c. rating) (Radiospares)

Switches
S1 Double pole on/off toggle switch
S2 Double pole change over toggle switch

Lamp
LP1 Neon indicator with series resistor R_X mounted in holder

Miscellaneous
Veroboard 0·15in square hole matrix, 2½in × 2 5/16 in
Aluminium sheet 16 s.w.g., 8½in × 4½in, and 3in × 3in
Copper cooling clip for TR2
Plywood for box 8½in × 4½in × 2½in
Mounting clip for capacitor C1
Mica washer, nylon screws, silicon grease for TR3
SK1 and SK2 output sockets

The whole can be mounted on the front panel (Figs. 4 and 5) fitted with mains switch S1, neon warning light LP1, and a reversing switch SW2.

Before putting into service the following electrical checks should be made. Check that the collector (case) of TR3 is insulated from the heat sink. With the mains supply connected and switched on, check that the voltage across R7 varies with adjustment of VR1. Connect a 15 ohm 15W resistor across the output terminals, and set VR1 to maximum output voltage. Monitor the voltage across R8, which should be about 2·2V (current 1A). Short circuit the output terminals and check that the voltage across R8 changes by not more than about 5 per cent.

The unit is now ready for service. It is not advisable to provide full output to the train immediately otherwise a derailment may result. Careful operation of the control, by increasing the output slowly, is quite adequate to give the desired realistic effect. Similarly, always slow down the train, using VR1, before reversing direction. These points are common knowledge to most model railway operators but do tend to be overlooked by some. ★

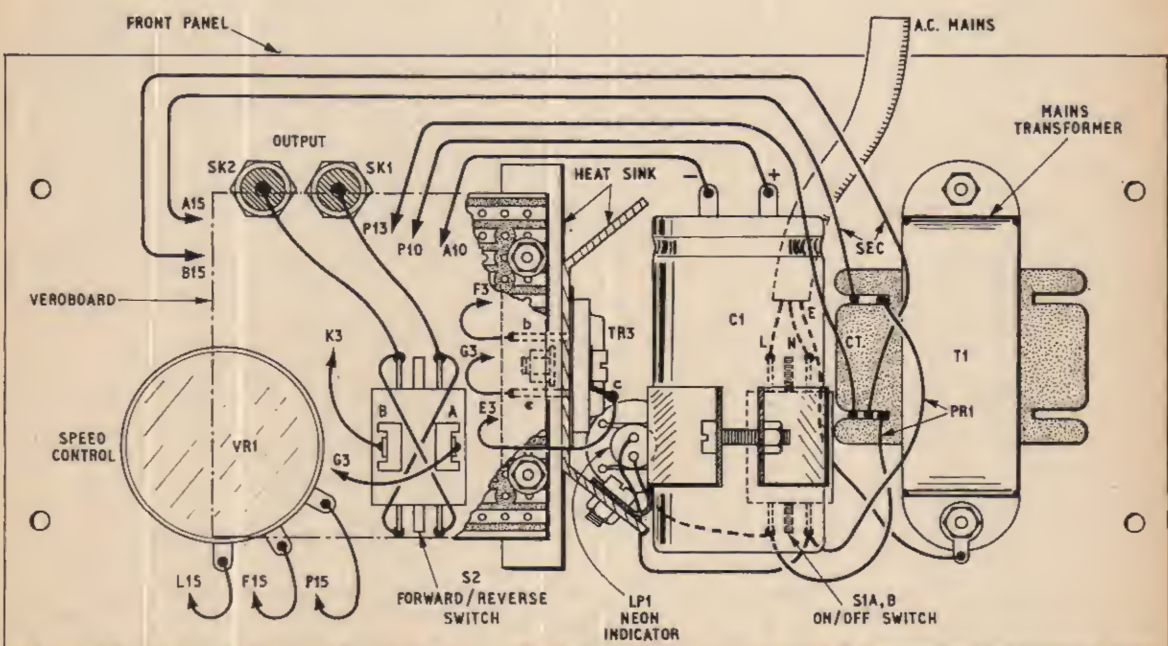

Fig. 5. Panel mounted components and their connections to the component board