# Electronics

## THE MAPLIN MAGAZINE


14-Channel, 2-wire

# MODEL TRAIN CONTROLLER

**Full construction details inside**

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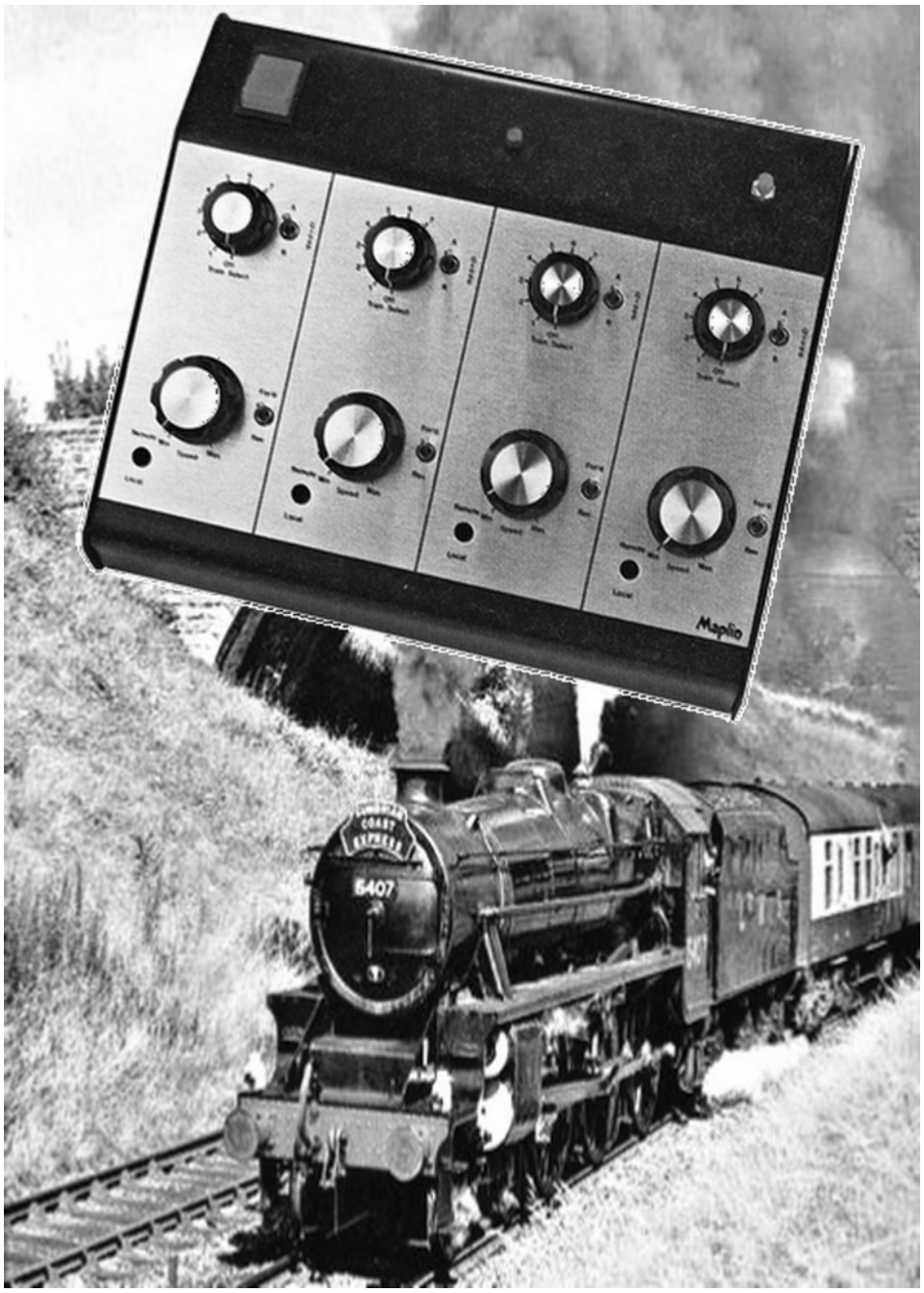
# DIGITAL MULTI – TRAIN CONTROLLER

by Robert Kirsch

- 14 locomotives individually controlled on the same track
- Any 4 locomotives controlled simultaneously
- Automatic short-circuit protection
- Supply always present for carriage lighting etc.
- Remote control and computer interfacing
- Low cost two wire system




Railway enthusiasts have for many years appreciated the need for a control system that enables trains to be driven as if the operator were in the driving cab of the locomotive. This not only means control of speed and direction of that locomotive, but also the ability to move anywhere on the layout without the need for track isolating or switching, thus making the wiring of the layout much simpler.

The system described in this article fulfils all these needs by producing a constant 18 volts DC on the track with digital information superimposed on it, to which only the selected train or trains will respond. The permanent track voltage also means that locomotive headlights, carriage lighting and many accessories may be used unaffected by the speed of the trains.

This system can control up to 14 locomotives all on the same track, and any four of these may be driven independently at one time. Provision is also made for any or all, of the four control units to be operated by a 7 bit digital input, thus enabling remote control either from hand-held units (using wire or radio) or from a home computer, giving full control of direction and speed.

Details of the remote control and computer interfacing will be described in later articles.

**Circuit Description**

Refer to Figures 1 to 5 when following the circuit description.

The most important consideration in the design of a system like this is to keep the receiver module as small as practical to enable it to fit in as many 2 locomotives as possible. This has been achieved by using a small 8 pin IC, the ML 926/7, IC1 as the receiver. Decoding and control is accomplished by IC2, a 40106 CMOS IC leaving two transistors, TR2 and TR3 as input amplifiers, the six transistors TR4 to TR9 for motor control and one transistor, TR1 as a voltage stabiliser.

The ML 926 and ML 927 are pulse position modulation (PPM) receivers with built-in error detection circuits. There are four outputs from each IC, three of which are decoded by IC2 to control one of the seven receivers. (000 is used as the all off condition.) The fourth output is used to control the direction of travel. A fifth bit is transmitted by the control unit to select either the ML 926 or the ML 927 ICs, thus giving fourteen channels.

As it is only possible to decode one signal at a time the receiver is addressed for one period out of four (called its time slot) and it retains the

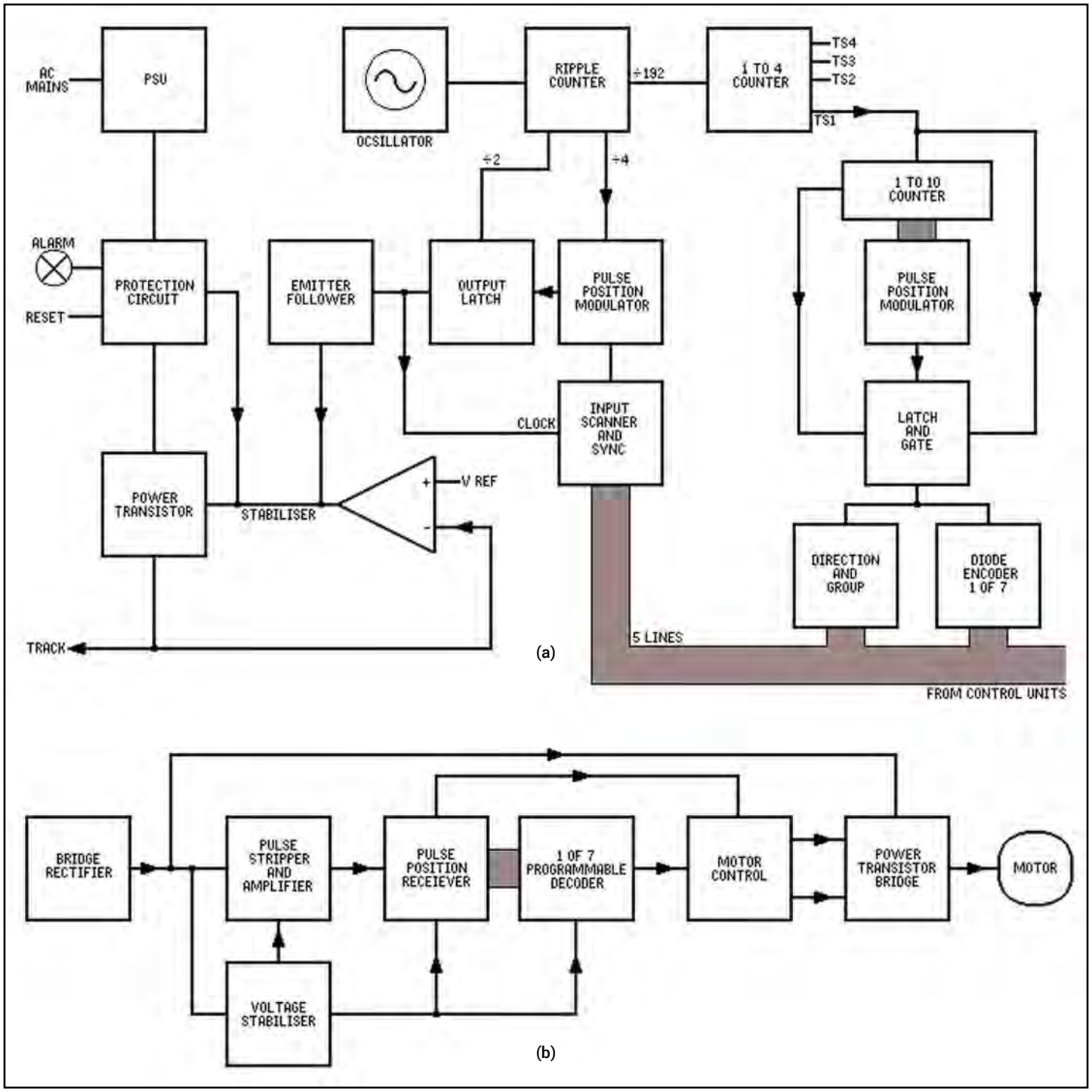



Figure 1. Block diagram (a) Common and control boards. (b) Receiver.

information received until the next address is due.

The speed of a locomotive is control led by al lowing any number of coded time slots (from 1 to 10) to be transmitted during a period of 10 time slots (TS), thus controlling the on to off ratio of pulses fed to the motor. Minimum speed is with one TS pulse and nine blank periods, half speed is with five TS pulses and five blank periods and full speed is with a continuous string of TS pulses being sent thus keeping the motor driven at full power.

The transmitter IC normally used with the ML 926/7 is the SL490 but several of the built in features of that IC make it undesirable to use in this application.

The PPM system uses a frame of six pulses followed by a sync period. Digital information is transmitted by varying the time between two consecutive pulses in the following ratio: DATA 1 = 2, DATA 0 = 3, SYNC = 6.

The pulse timing is controlled by resetting a counter IC4 after 2, 3 or 6 clock pulses have been received depending on whether the data to be sent is 1,0 or sync. In order to transmit each one of the five data bits in their correct order another counter, IC8 scans the five AND gates IC3c and IC7 in turn and then at the sixth count causes the sync period to be sent at the same time resetting the counter for the next scan. The timing point of the pulse to be transmitted is detected by monitoring the resetting point of this counter. This causes the latch IC3d to be triggered which allows a pulse of twice the clock period to be sent.

The ripple counter, IC5 provides all timing pulses required by the controller. It is fed by the CMOS relaxation oscillator formed by IC6 a,b,c and d. This oscillator is divided by 192 by IC5 to produce a TS trigger pulse approximately every 850µs. Each frame of data takes about 380µs, so that two

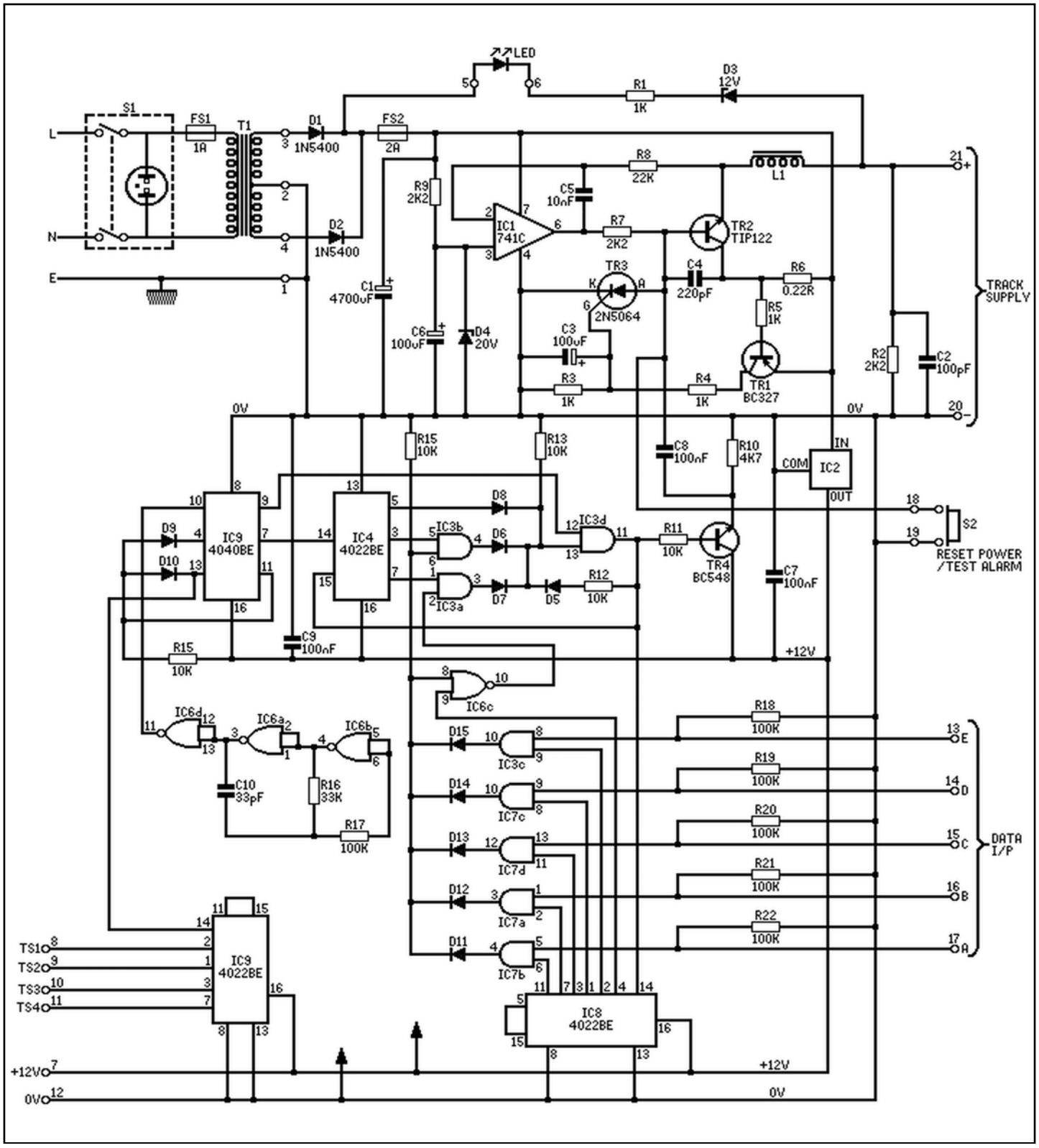
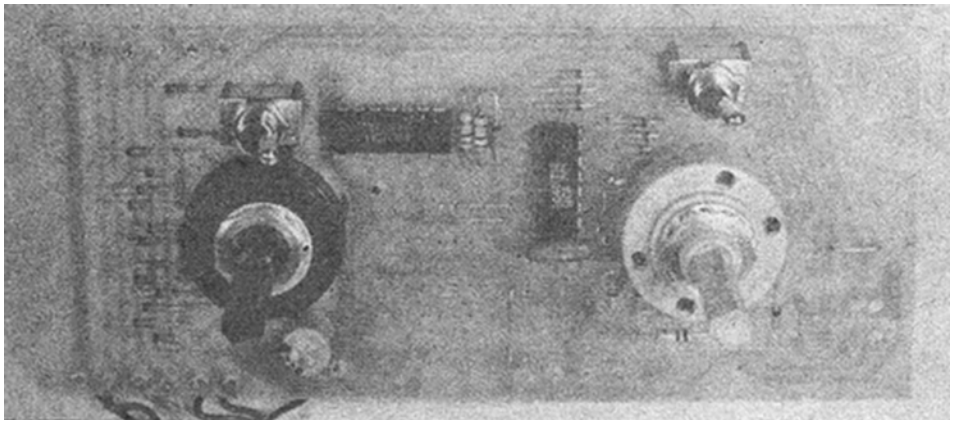



Figure 2. Common board. PSU circuit diagram.



Completed control PCB.

complete frames can be sent in one TS period.

The trigger pulse denoted above is used to clock the counter IC9 and produce four separate, consecutive output pulses, TS1-4 each approximately 850µs long. Each of the four control boards is fed with one of these TS pulses and this pulse is used to step the counter IC1 (control board). The counter steps from one to ten and then resets itself for the next count. The first output from the counter sets the

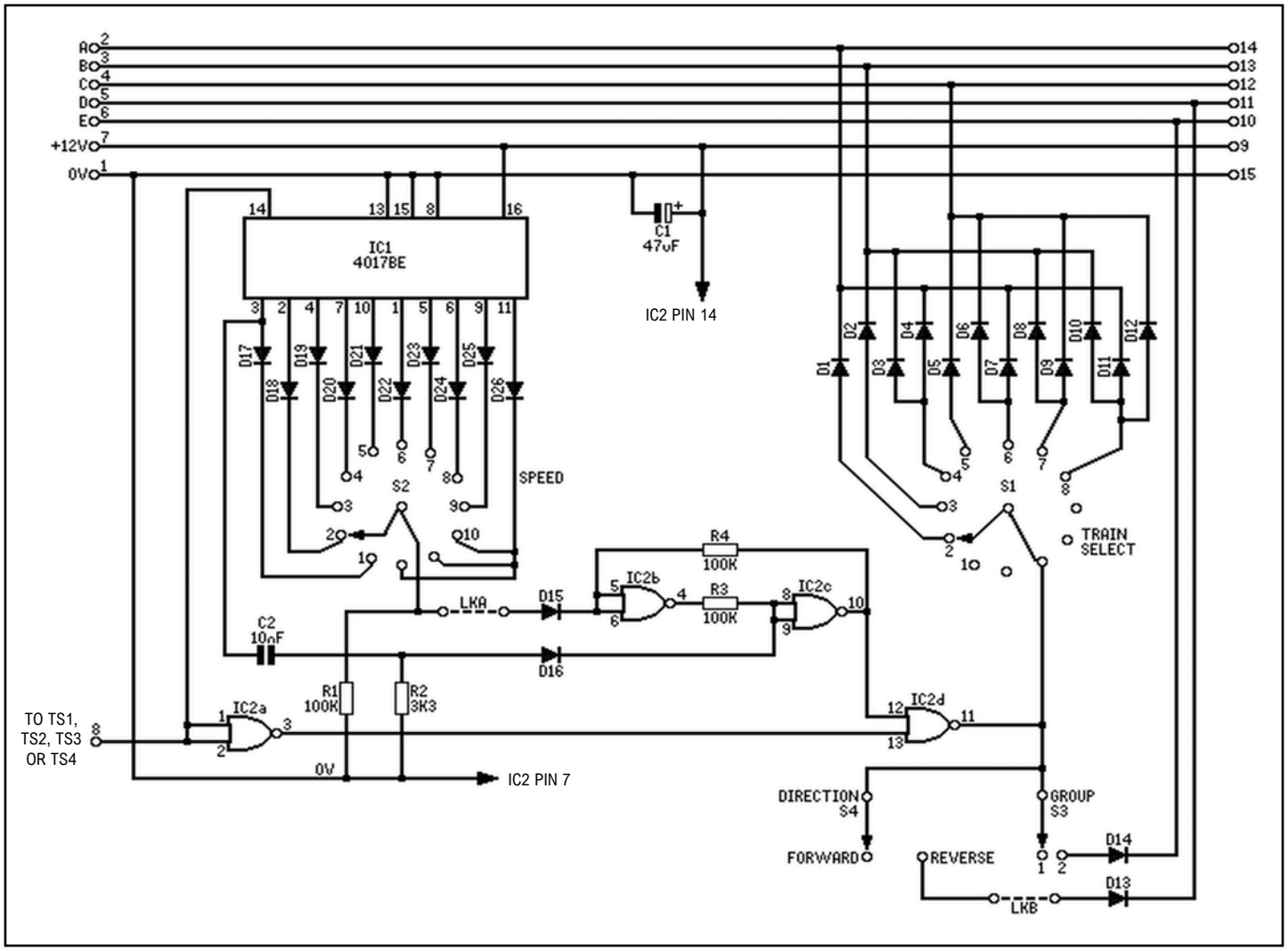



Figure 3. Control board circuit diagram.

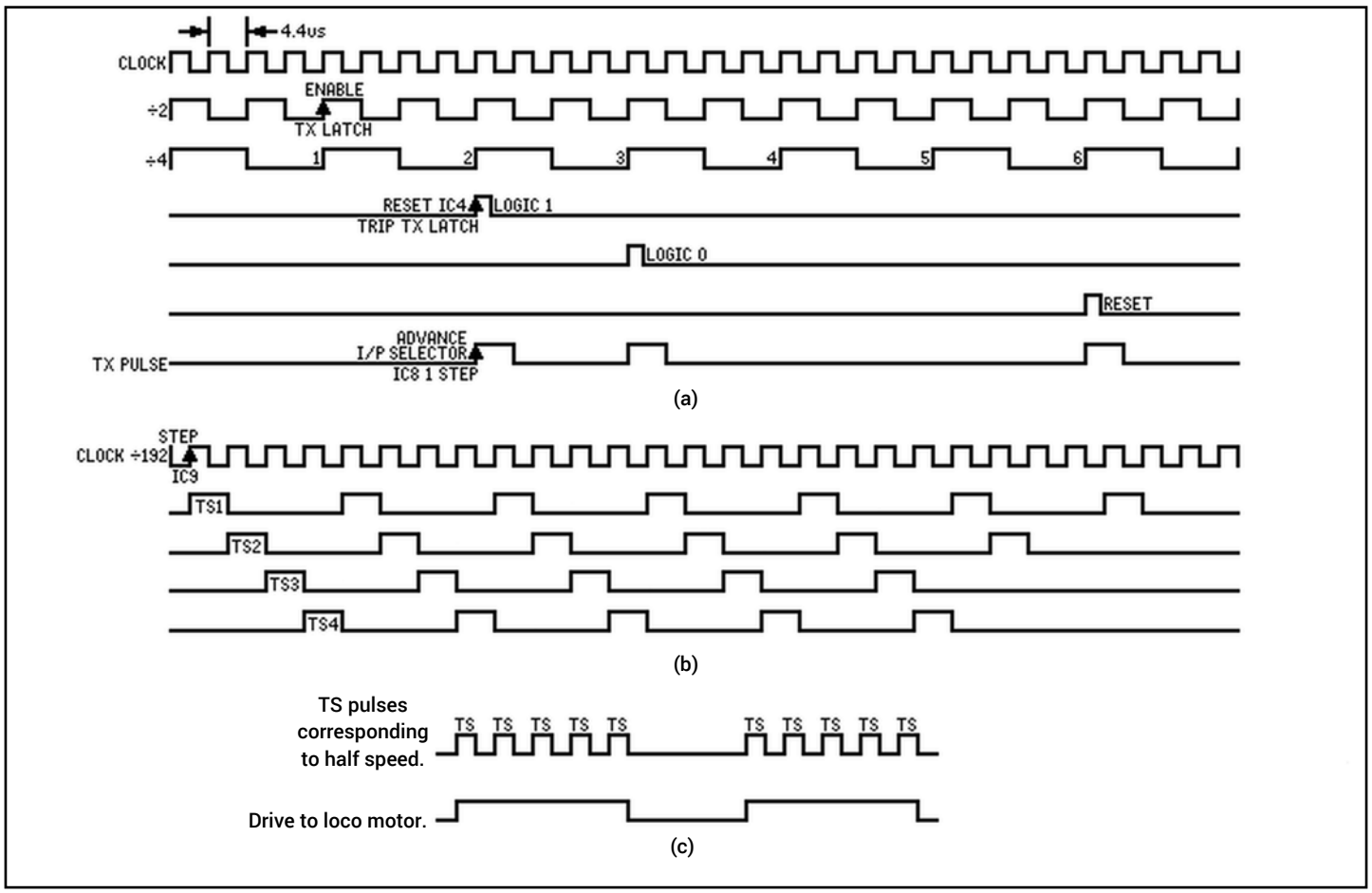



Figure 4. Timing diagram.

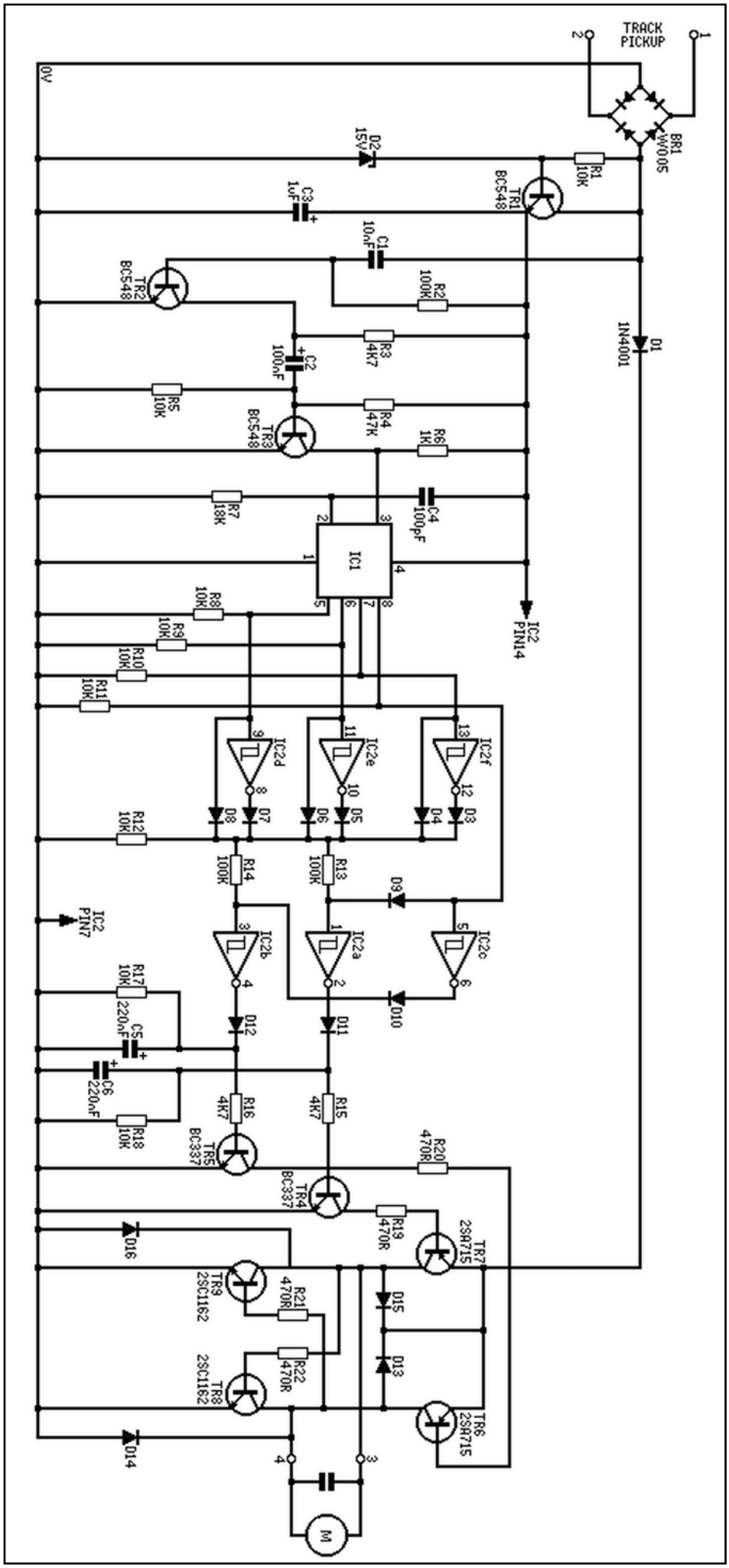



Figure 5. Receiver circuit diagram.

latch IC2b and c which is reset when the counter reaches the number set by the speed control thus holding the latch open for one to ten pulses. The latch gates TS pulses which are fed to the diode encoder. The pulses are connected onto one or more of the three data lines depending on the code of the receiver being addressed. If the reverse switch is operated or group 2 is selected the TS pulse is switched onto the appropriate data lines.

The DC supply fed to the track is stabilised by IC1 (common board) at about 18 volts and data signals from the emitter follower TR4 are superimposed on it and used to control the power Darlington transistor, TR8 which supplies current to the track. In order to protect the controller from damage due to accidental short circuiting of the track the current flowing through R6 is monitored by TR1. When this current exceeds the preset limit the transistor conducts and fires the SCR TR3 thus removing the drive to TR2 and turning off the supply to the track.

The SCR remains latched until it is reset by shorting it with S2. If the fault is still present the circuit will trip immediately and cause no damage.

When the track supply falls more than 12 volts below the power units output, either due to the protection circuit being tripped or due to a fuse failure the indicator LED 1 will light. Provision is also made for a buzzer to be fitted if an audible indication of track supply failure is required. A timer may be used to reset the protection circuit automatically after a short delay and this will be described in a later article.

**Construction**

Build all PCBs referring to legends and parts list.

**Common Board**

The track layout and component overlay for the common board are shown in Figure 6. Fit Veropins and PCB mounting fuse holders and solder. Insert and solder all resistors, diodes, capacitors and the choke. Insert the two plastic transistors, regulator and SCR into their correct positions. Push the leads of the power transistor TR2 through the PCB just far enough to allow it to be soldered and bend the leads as shown in Figure 7. Finally, insert and solder all ICs observing the usual CMOS precautions and making sure that they are the correct way round.

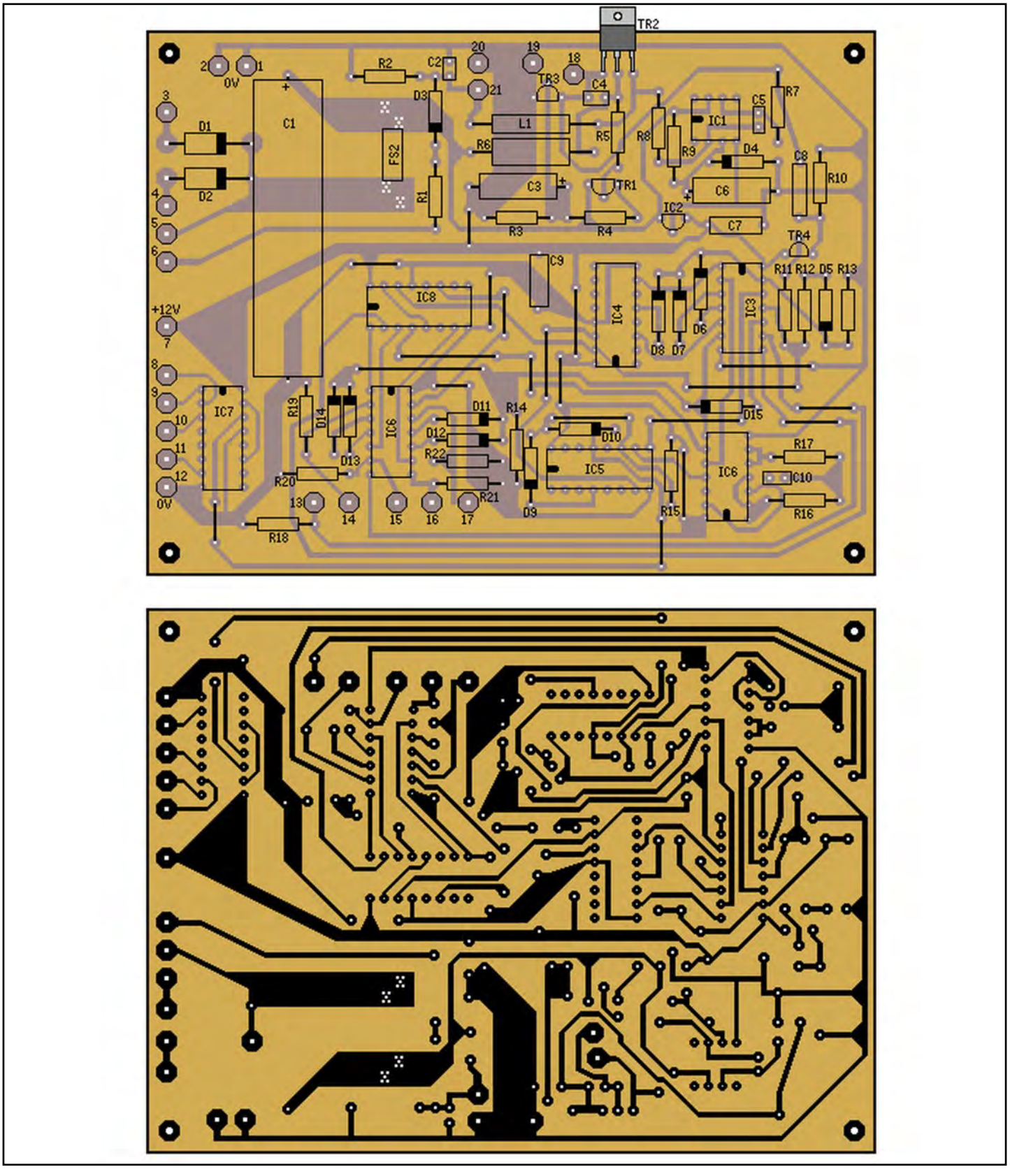
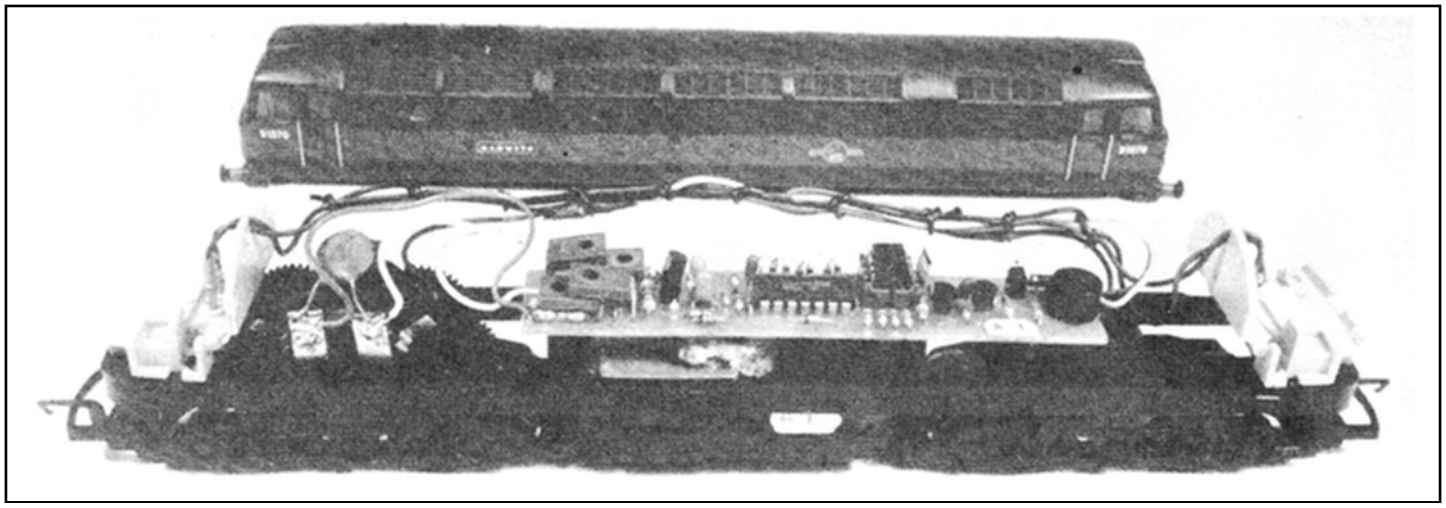
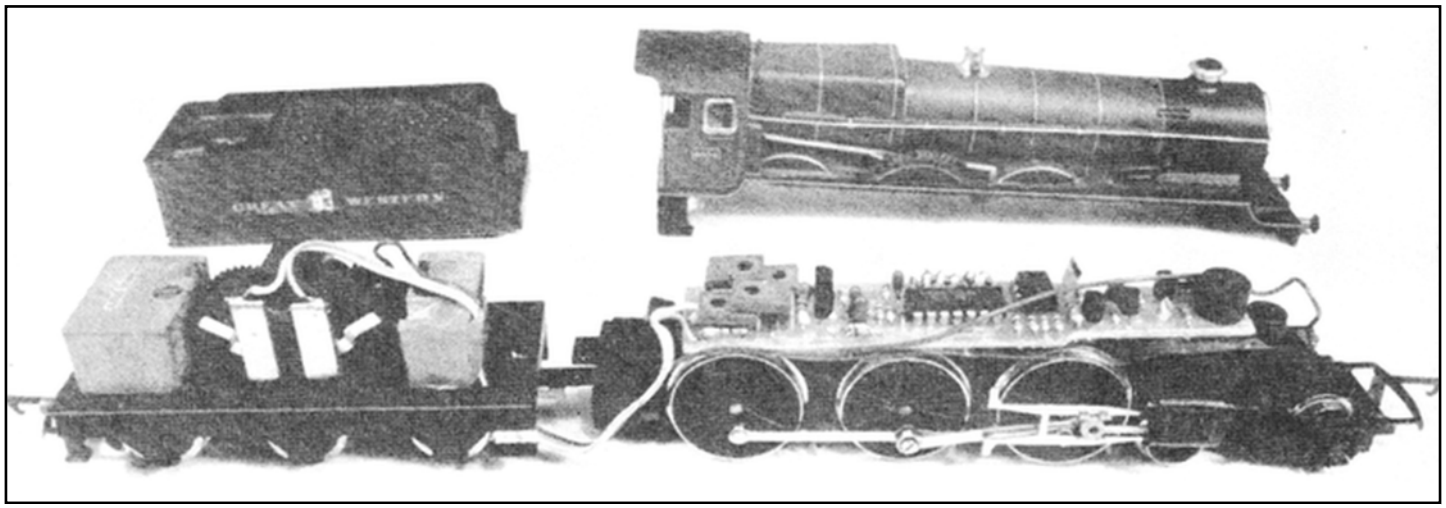



Figure 6. Common board track layout and component overlay.



Receiver board 1 installed in a diesel locomotive.



Receiver board 1 installed in a tender drive locomotive.

**Control Board**

The track layout and component overlay for the Control Board are shown in Figure 8. Fit and solder all components in order as described above but in this case fit the Veropins from the component side of the PCB to enable ease of wiring when the boards are fitted to the front panel. The rotary switch without the click stops is mounted next to IC1. Note the unused component positions on the board are for the remote control option which may be added later.

**Assembly**

Mount the transformer, mains switch, fuse holder, LED, push button and terminals on the case. Fit the common board and control boards. (Note that only one control board need be fitted initially.) The self-adhesive penal legend may be used as a template for drilling the front panel.

Wire all boards and components together referring to Figure 13. Insert the fuses noting that the 1 amp antisurge fuse is fitted in the panel fuse holder.

**Receiver board**

There are initially two receiver boards available to fit varying size locomotives. See Figures 10 and 11. The dimensions of these boards are shown in Figure 9. Fit and solder all capacitors and resistors noting that some resistors do not lay flat on the board. Insert and solder all diodes other than D3 to D8 and fit all transistors taking special care with the positioning of TR6, 7, 8 and 9 as shown in Figures 10b and 11b. Insert and solder IC2.

Decide which channel the receiver is to use and insert the appropriate diodes referring to Figure 12. If the receiver is to be group A then insert an ML 926, if group B an ML 927. Carefully check all soldering and positioning of components before testing.

**Testing Procedure**

**Controller**

Switch on power with nothing connected to the output terminals. The neon indicator in the mains switch should now be illuminated. Using a meter set to 20 volts DC or above check that there is approximately 18 volts at the output terminals.

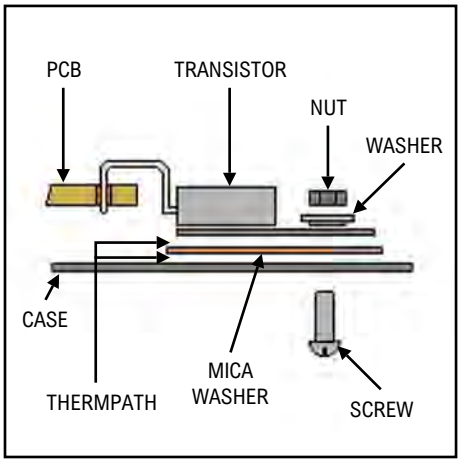



Figure 7. Power transistor mounting

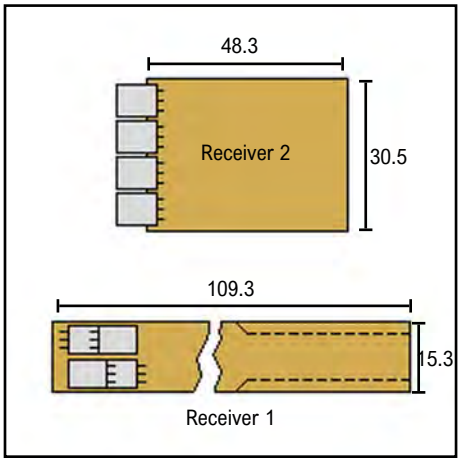



Figure 9. Receiver board dimensions.

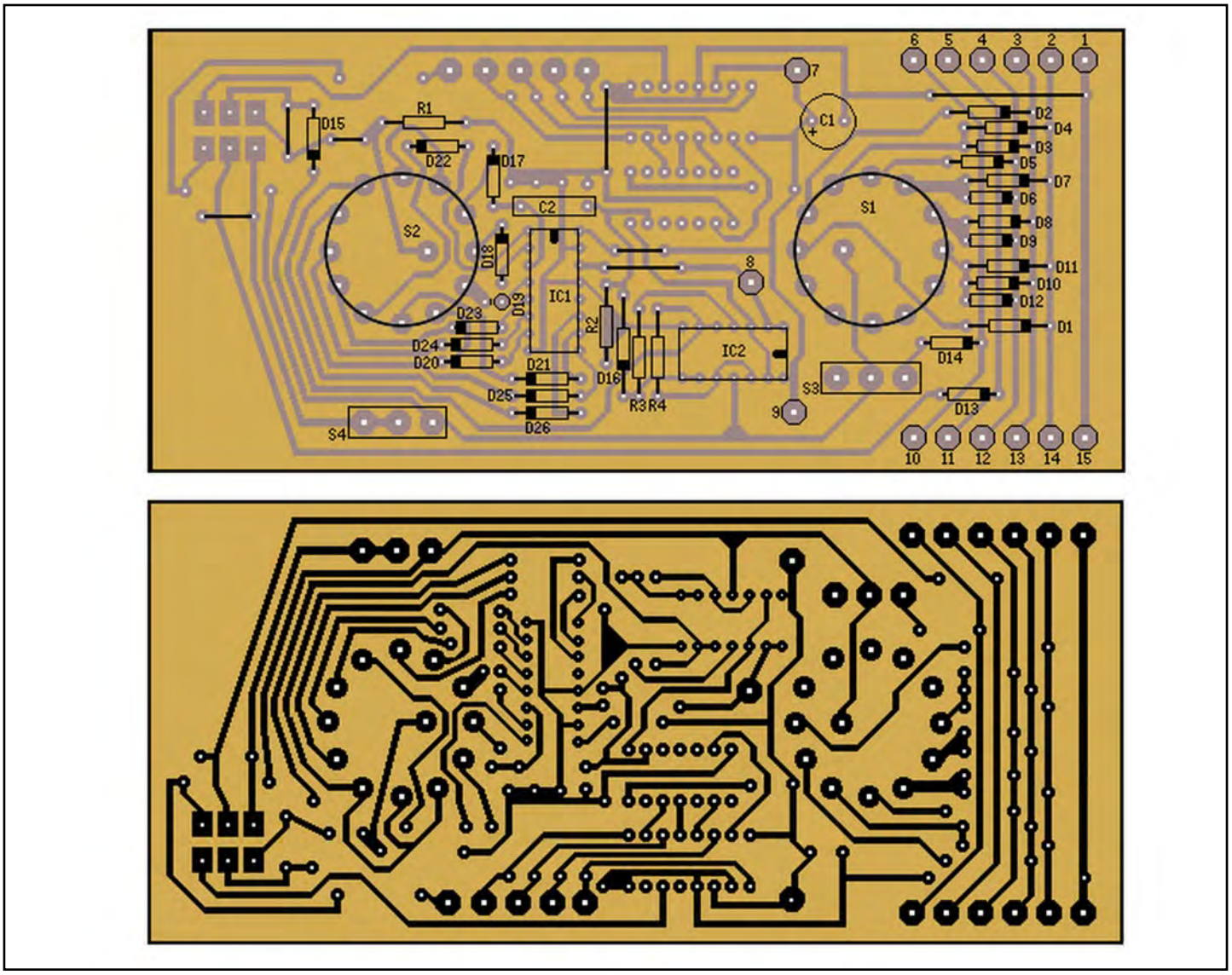
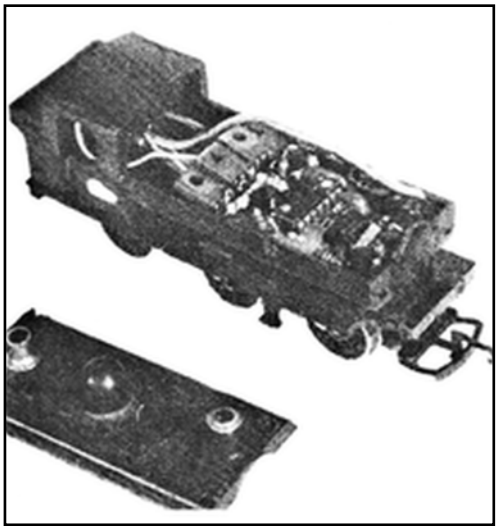



Figure 8. Control board track layout and component overlay.



Receiver board 2 installed in a tank locomotive.

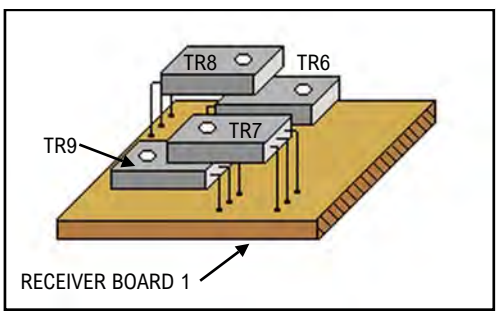



Figure 10(b). Receiver board 1 transistor mounting.

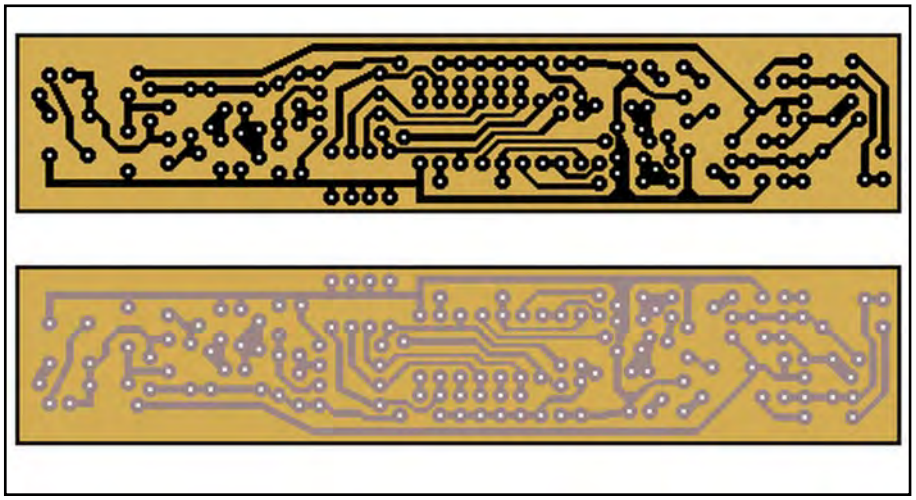
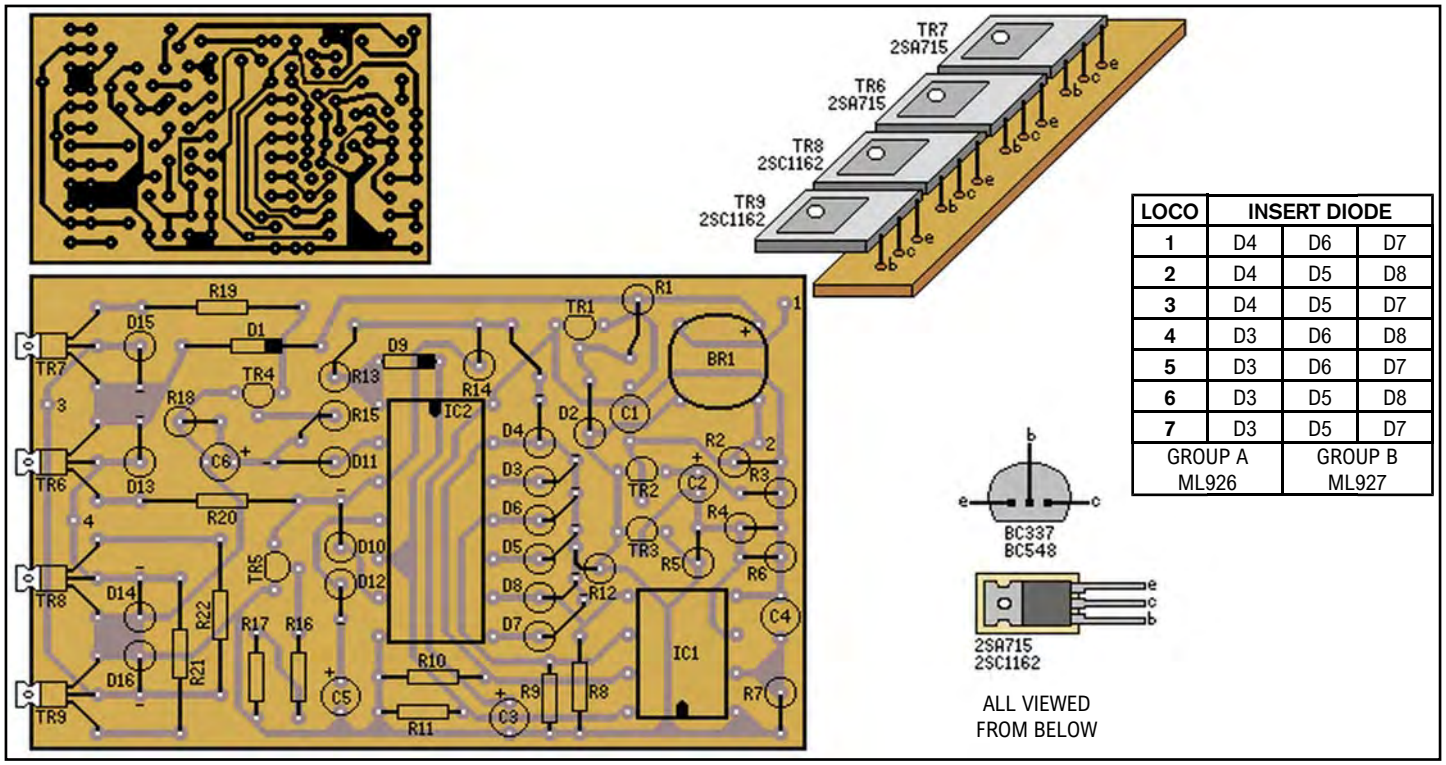


Figure 10(a). Receiver board 1 track layout and component overlay.




| LOCO | INSERT DIODE | | |
|---|---|---|---|
| 1 | D4 | D6 | D7 |
| 2 | D4 | D5 | D8 |
| 3 | D4 | D5 | D7 |
| 4 | D3 | D6 | D8 |
| 5 | D3 | D6 | D7 |
| 6 | D3 | D5 | D8 |
| 7 | D3 | D5 | D7 |
| GROUP A ML926 | | GROUP B ML927 | |

Figure 11(a). Receiver board 2 track layout and component overlay. (b). Receiver board 2 transistor mounting.

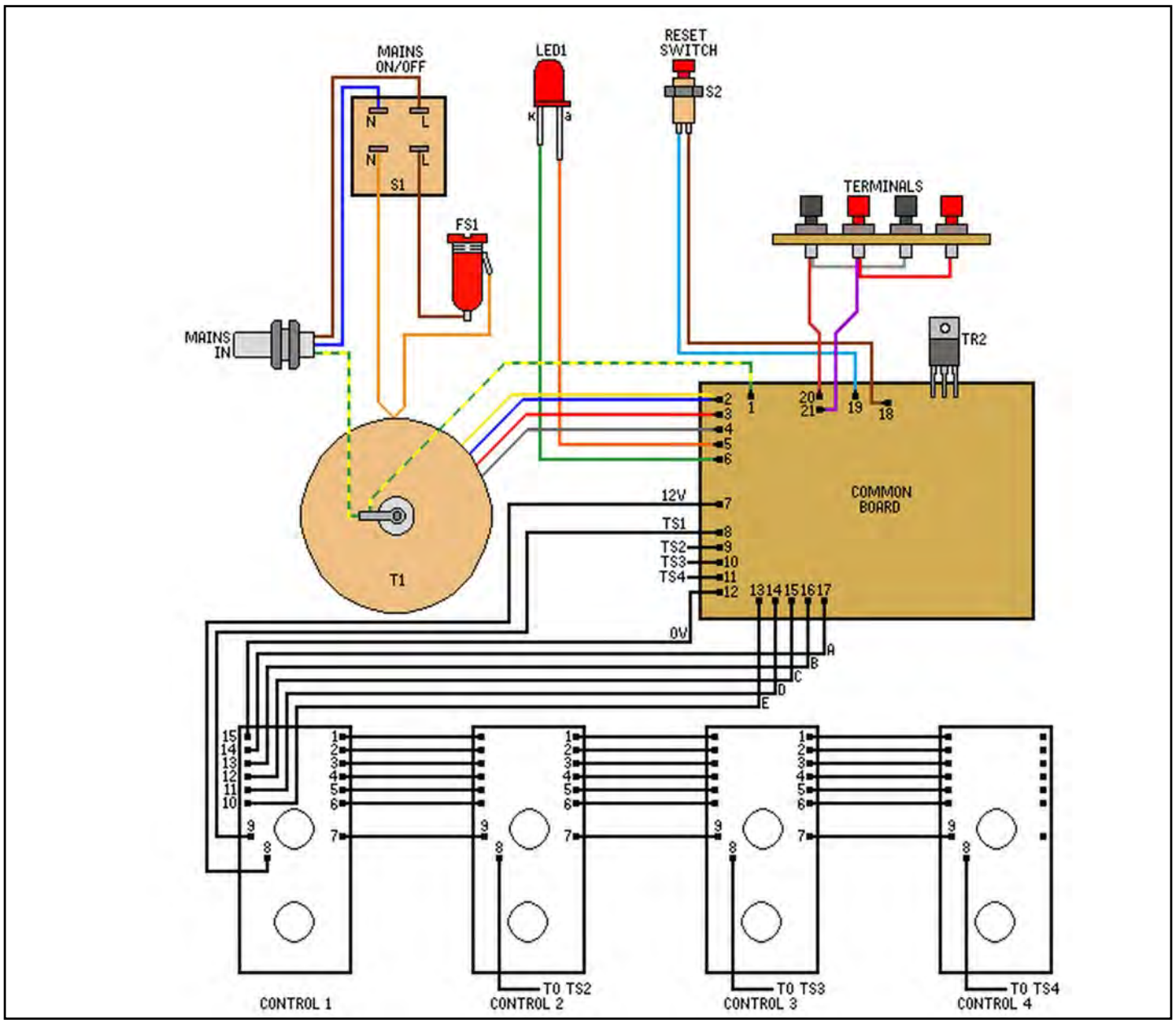



Figure 13. Controller wiring diagram.

Press the reset button and the "Track Supply Fail" LED should light and extinguish when the button is released. If this test is satisfactory, short circuit the output terminals and the LED should again light brightly while the short circuit is present and dimly when the short circuit is removed. Press the reset button. The LED should be extinguished and 18 volts restored to output terminals.

**Receiver**

Connect the receiver to the control unit as shown in Figure 14. Select the channel number and group of the receiver on a control unit and advance the speed control. One of the two lamps should light with its brightness depending upon the speed set. Switch over the reverse switch to the opposite position and repeat the test. In this case the other lamp should respond. Switch the control unit to the other channels and groups and ensure that the lights remain extinguished. If these tests are satisfactory the module is ready to be inserted in the locomotive.

**Installing Receivers in Locomotives**

All locomotives designed for use with conventional control systems have the two sides of the motor connected directly to the wheels on each side of the locomotive Figure 15. To install the receiver module, the motor must be completely isolated from the wheels. In many modern models this is accomplished by removing a wire link but in some of the older models there is a permanent connection from one side of the motor to the chassis. In all cases by careful modification this connection can be removed. Some examples are shown in Figure 16. It is most important to ensure that the motor is completely isolated and it is worth checking this with a meter set to ohms before installing the module.

In most cases there will be a wire coming from one of the pickups, this is connected to one input of the module and the other input is connected to the chassis at a suitable point as shown in Figure 17. After installation, if it is found that the locomotive travels in the wrong direction in relation to the controller switch, the wires to the motor should be reversed.

To ensure reliable operation of this system, as with any other, the locomotives should be in good condition, and it is often worth replacing brushes and cleaning wheels and pickups before use. The track needs to be kept fairly clean although the receiver will respond to signals as long as there is enough power to drive the motor.

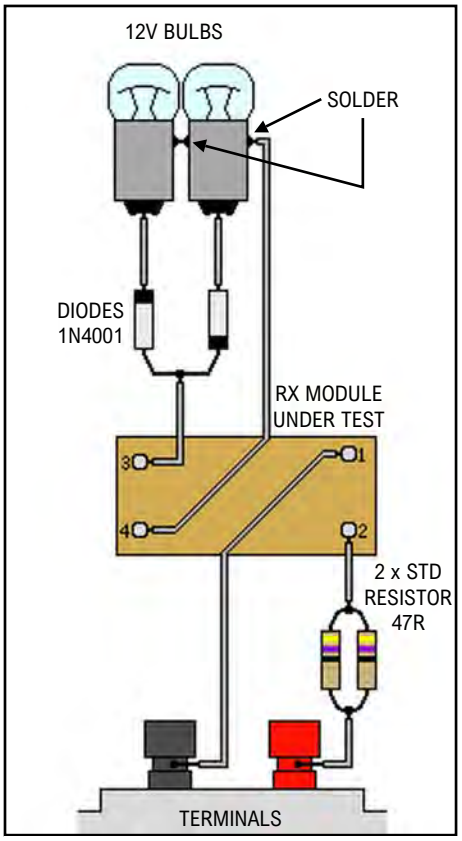
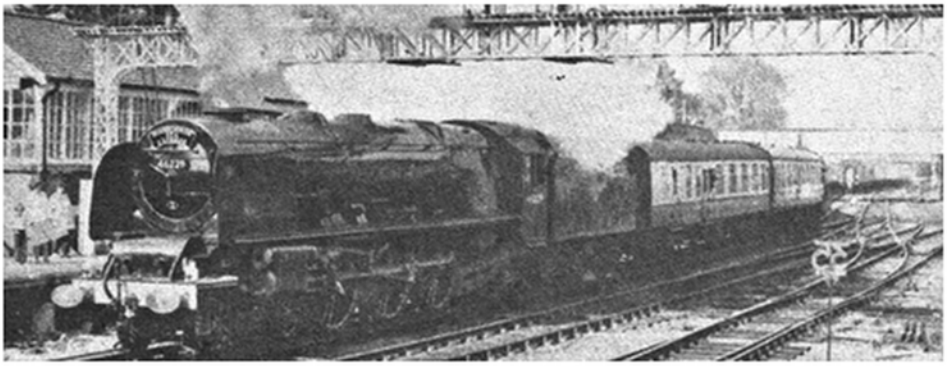



Figure 14. Receiver testing.



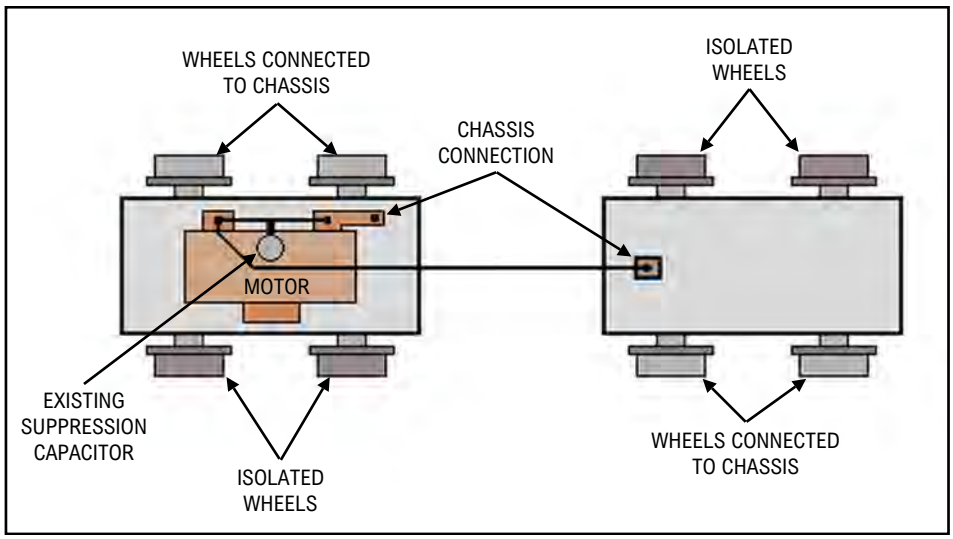



Figure 15. Wiring of a conventional locomotive.

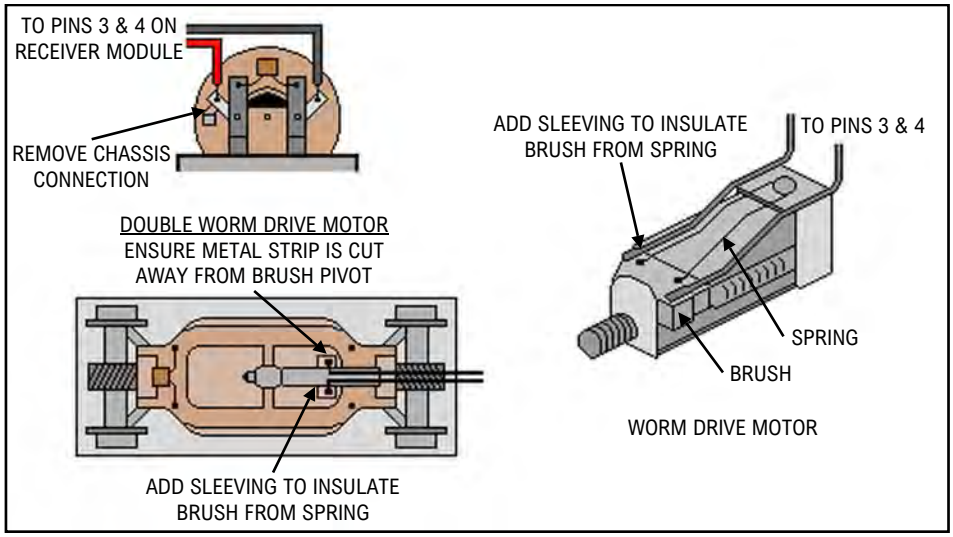



Figure 16. Modifications to various motors.

The next article in this series will describe the remote control facilities and computer interfacing.

Future articles will describe track circuiting (train position detection) point control and detection of position, interlocking and control of signals, automatic loop switching, and many other useful circuits as well as constructional hints for the railway modeller.

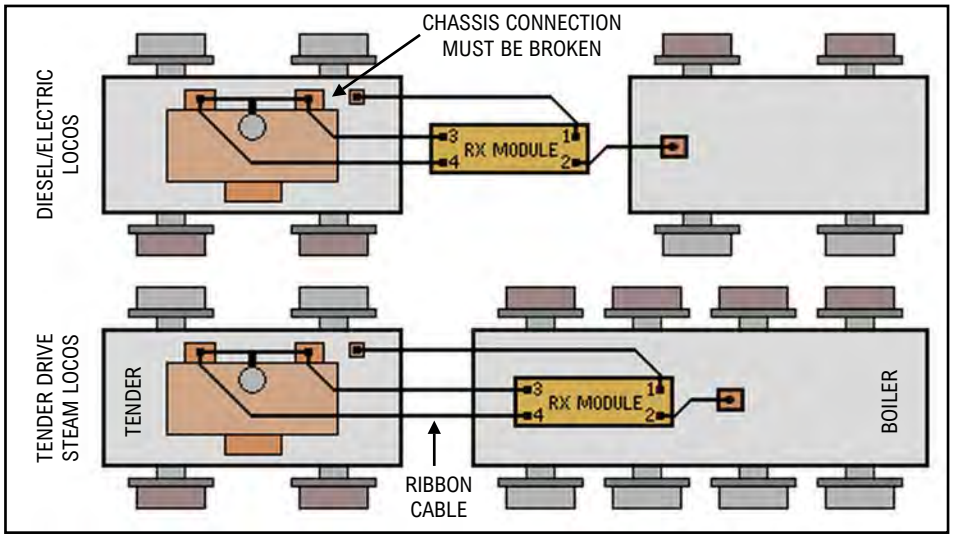



Figure 17. Installation of the receiver into the locomotive.

**TRAIN CONTROL MODULE PARTS LIST**

**Resistors** - All ½ watt 5% Metal Film

| | | | |
|---|---|---|---|
| R1, R3, R4 | 100k | Brown Black Yellow | 3 |
| R2 | 3K3 | Orange Orange Red | 1 |

**Capacitors**

| | | |
|---|---|---|
| C1 | 47µF 25V PC electrolytic | 1 |
| C2 | 10nF polyester | 1 |

**Semiconductors**

| | | |
|---|---|---|
| D1 to D26 | 1N4148 | 26 |
| IC1 | 4017BE | 1 |
| IC2 | 4001UBE | 1 |

**Miscellaneous**

| | | |
|---|---|---|
| S1 | Rotary switch 1 pole 12 way | 1 |
| S2 | Rotary switch 1 pole 12 way non-click stop | 1 |
| S3, S4 | Sub-miniature toggle switch | 2 |
| | Single-sided terminal pins | 15 |
| | Knob 23 mm x 16 mm (for S1) | 1 |
| | Knob 33 mm x 16 mm (for S3) | 1 |

**TRAIN COMMON/PSU PARTS LIST**

**Resistors** - all ¼ W 5% carbon unless specified

| | | | |
|---|---|---|---|
| R1, R3, R4, R5 | 1K | Brown Black Red | 4 |
| R2, R7, R9 | 2K2 | Red Red Red | 3 |
| R6 | 0.22R (3W) | wirewound | 1 |
| R8 | 22K | Red Red Orange | 1 |
| R10, R17 | 4K7 | Yellow Violet Red | 2 |
| R11, R12, R14, R15 | 10K | Brown Black Orange | 4 |
| R13, R17, R18 to R22 | 100K | Brown Black Yellow | 7 |
| R16 | 33K | Orange Orange Orange | 1 |

**Capacitors**

| | | |
|---|---|---|
| C1 | 4700µF 25V axial electrolytic | 1 |
| C2 | 100pF ceramic | 1 |
| C3 | 100µF 10V axial electrolytic | 1 |
| C4 | 220pF ceramic | 1 |
| C5 | 10nF ceramic | 1 |
| C6 | 10µF 25V axial electrolytic | 1 |
| C7, C8, C9 | 100nF polyester | 3 |
| C10 | 33pF ceramic | 1 |

**Semiconductors**

| | | |
|---|---|---|
| D1, D2 | IN5400 | 2 |
| D3 | BZX61C12 | 1 |
| D4 | BZY88C20 | 1 |
| D5 to D15 | 1N4148 | 11 |
| TR1 | BC327 | 1 |
| TR2 | TIP122 | 1 |
| TR3 | MCR102 Thyristor | 1 |
| TR4 | BC548 | 1 |
| IC1 | UA741C (8-pin) | 1 |
| IC2 | UA78L12 AWC | 1 |
| IC3, IC7 | 4081BE | 2 |
| IC4, IC8, IC9 | 4022BE | 3 |
| IC5 | 4040BE | 1 |
| IC6 | 4001BE | 1 |

**Miscellaneous**

| | | |
|---|---|---|
| L1 | RF suppressor choke 2A | 1 |
| T1 | Toroidal Transformer 80VA 18V | 1 |
| LED1 | LED red | 1 |
| FS1 | Fuse anti-surge 1 amp | 1 |
| FS2 | Fuse 20 mm 2 amp | 1 |
| S1 | Dual rocker switch with neon | 1 |
| S2 | Push switch | 1 |
| | PCB fuseholder 20 mm | 1 |
| | Fuse clip | 2 |
| | Strain relief grommet | 1 |
| | Single-sided terminal pins | 21 |
| | LED clip | 1 |
| | 4-way speaker terminals | 1 |
| | Mains lead 3 amp | 3 metre |
| | 10-way ribbon cable | 1 metre |
| | Equipment wire type 7/02 black | 1 metre |
| | Equipment wire type 7/02 red | 1 metre |
| | TO220 Transistor mounting kit | 1 |
| | Bolt 6BA x ½" | 7 |
| | Washer 6BA | 3 |
| | Spacer 6BA x 1/8" | 4 |
| | Nut 6BA | 7 |
| | Tag 2BA | 2 |
| | Heatsink compound | 1 tube |
| | Stick-on feet | 4 |

**TRAIN RECEIVER MODULE PARTS LIST**

**Resistors** - all ¼ watt 5% carbon

| | | | |
|---|---|---|---|
| R1, R5, R8 to R12 R17, R18 | 10K | Brown Black Orange | 9 |
| R2, R13, R14 | 100K | Brown Black Yellow | 3 |
| R3, R15, R16 | 4K7 | Yellow Violet Red | 3 |
| R4 | 47K | Yellow Violet Orange | 1 |
| R6 | 1K | Brown Black Red | 1 |
| R7 | 18K | Brown Grey Orange | 1 |
| R19, R20, R21, R22 | 470R | Yellow Violet Brown | 4 |

**Capacitors**

| | | |
|---|---|---|
| C1 | 10,000pF ceramic | 1 |
| C2 | 100nF 35V tantalum | 1 |
| C3 | 1µF 35V tantalum | 1 |
| C4 | 100pF ceramic | 1 |
| C5, C6 | 220nF 35V tantalum | 1 |

**Semiconductors**

| | | |
|---|---|---|
| D1 | 1N4001 | 1 |
| D2 | BZY88C15V | 1 |
| D3 to D16 | 1N4148 | 14 |
| BR1 | W005 | 1 |
| IC1 | ML926 (Group A) | 1 |
| | ML927 (Group B) | 1 |
| IC2 | 40106BE | 1 |
| TR1, TR2, TR3 | BC548 | 3 |
| TR4, TR5 | BC337 | 2 |
| TR6, TR7 | 2SA715 | 2 |
| TR8, TR9 | 2SC1162 | 2 |