2 Speed and Direction Control

2.1 General

Before dealing with speed and direction control it will be useful to look briefly at the characteristics of the motors used for powering model locomotives. The subject is dealt with in greater depth in Part 3, Section 2, Traction Motors, but summarising - speed is proportional to voltage and torque is proportional to current.

As voltage is applied to a motor the current rises until sufficient tractive effort to overcome friction is produced and the train begins to move. As it accelerates the voltage must be gradually increased in order to maintain the current, and hence the tractive effort, substantially constant until the train is running at the desired speed.

It must be appreciated that it is almost impossible to obtain smooth slow running and acceleration if friction in the bearings and gears of the locomotive and train is continually varying, as is also the case if the contact resistance of the current pickup system fluctuates. Consequently time spent in reducing friction and ensuring stable electrical contact is well worth while.

2.2 Speed Control

Speed is controlled by varying the voltage supplied to the motor by means of either a rheostat or some form of electronic circuit, the choice between the rugged simplicity of a rheostat and the more sophisticated electronic controller being a matter of personal preference. If the resistance value and wattage are correctly matched to the duty the former will provide excellent high and low speed control for all types of motor. However, because modern electrical systems make great use of electronic controls, heavy duty rheostats of the type illustrated in Photo 2.1 are becoming more difficult to obtain on the retail market and are no longer available as 'ready to run' mains or low voltage fed units.

Electronic controllers, on the other hand, are readily obtainable from the local model shop and are less affected by differing motor characteristics than rheostats wired as either series resistances or potentiometers. They are available as mains fed units, as low voltage controllers and as what are termed 'walk around' units using a hand-held control connected to a main unit by a long cable. The latest versions of the latter eliminate the cable by using either a radio link or an infra-red transmitter not unlike a TV remote control. Low power units primarily intended for the smaller gauges are usually available off the shelf and many model shops stock the heavier versions or can obtain them to order fairly quickly. In addition to the simple direct drive units there are ones having various inertia effects, speed compensation, etc., should these be considered desirable. (The writer once incorporated a speed compensation unit into a controller which if turned up too far caused the locomotive to increase speed up a gradient and lose speed going down; which is not exactly a realistic way to operate).

Compiled by K. Sheale, Technical Committee
Drawn by R Emerson, Photos T. Hughes

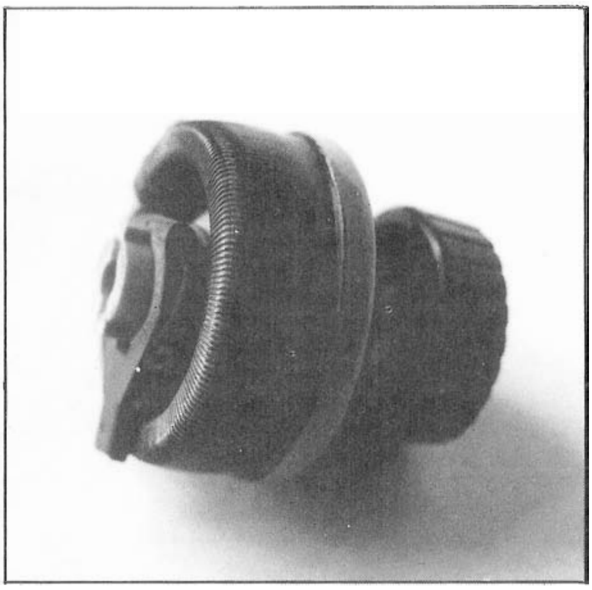


Photo 2.1 A 50 ohm, 50 watt rheostat used for speed control for about 25 years at Derby Museum, and probably good for another 25 years.

To sum up, although there is little to choose between operation of the two systems, the ready availability of electronic controllers now makes them the normal choice of modellers who do not wish to build their own equipment. However, in making this choice it is essential to ensure that the chosen controller is suitable for the heavier duty of a Gauge O system compared with that of the smaller gauges.

2.2.1 Rheostat control

Photo 2.1 shows a 50 ohm 50 watt rheostat that was used for a number of years on the Derby Museum layout. It was connected to the track and hence to the locomotive motor in the series mode as shown in Figure 2-1. The characteristic of the motors used on the layout was such that although current was passing through them when the controllers were in the off position the tractive effort developed was insufficient to cause movement.

Note: To prevent current passing when in the 'off' position in the series mode it is recommended that a thin piece of insulation is inserted to lift the slider off the wire at that position.

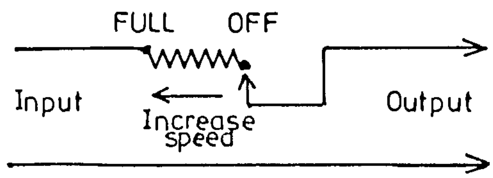


FIGURE 2-1
Rheostat in series mode.

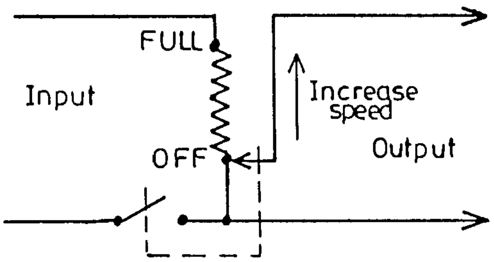


FIGURE 2-2
Rheostat in potentiometer mode.

Most commercially available rheostats are wired as potentiometers. Figure 2-2 shows the circuit. In this mode the motor voltage is zero when the rheostat is in the minimum position and rises gradually to the supply value as the handle is advanced. The potentiometer connection draws a constant current from the supply in the zero voltage position but if desired this can be eliminated by fitting a micro switch to open at the minimum position as shown in Figure 2-2. A 50 ohm, 100 watt rheostat is suitable for most 12 volt applications and 100 ohm, 100 watt for 24 volt systems. If all the motors to be controlled are high efficiency low current types the resistance values should be doubled and the wattage halved.

The range of motors that can be controlled by a given resistance value can be extended by providing a switch to select operation in the series mode for higher current types and in the potentiometer mode for the lower current ones. See Figure 2-3.

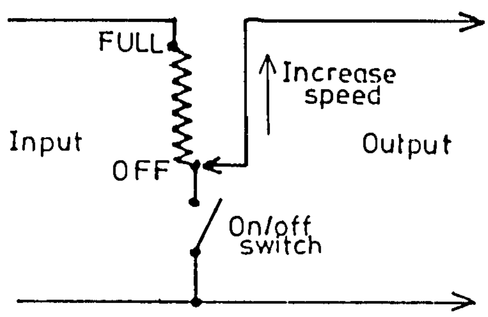


FIGURE 2-3
On/off switch added to rheostat to give a choice between series and potentiometer mode

Whilst not as effective as changing to the potentiometer mode, an alternative method of controlling low current motors as well as higher current ones by series resistance is to increase the overall current drawn by connecting a resistance in parallel with the motor.

A 47 ohm, 7 watt resistance, which is a standard value obtainable from suppliers of electronic equipment, is suitable for this purpose on a 12 volt system and can either be fitted to each locomotive or switched in at the controller when required. For 24 volt systems the resistance should be increased to 100 ohms.

A further development of this method for a 12 volt system is to connect a switched parallel circuit consisting of two 12 volt, 5 watt motor car lamps in series across the controller output. This has the advantage that the increase in lamp resistance with temperature reduces the increase in the parallel circuit current as the series resistance is reduced.

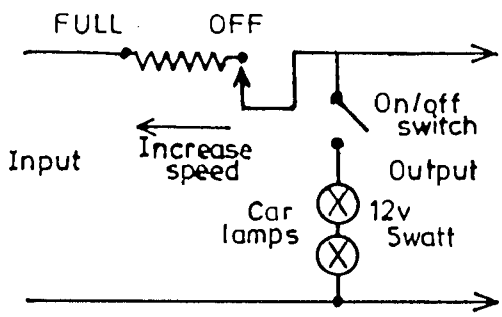


FIGURE 2-4
Two car bulbs added to the rheostat output to improve control of low current motors.

For a 24 volt supply use three or four lamps in series. (see Figure 2-4 and the article by Lewcock and Moxon, December 1990 *Gazette* page 159).

The main advantage of rheostat control is its simplicity. Additionally, in the event of loss of contact due to, say, dirty track, with the rheostat in the series mode the full system voltage appears across the break, thus helping to restore contact. (The explanation is quite simple, if no current flows there is no voltage drop in the rheostat and the full voltage, 12 or 24 volts depending on the operating voltage, appears across the 'high spot'. The instant the current flow is re-established voltage is dropped in the rheostat and the appropriate voltage restored to the motor terminals).

In order to have the necessary heat capacity to supply short term loads in excess of their continuous current capacity, rheostats for model railway controllers must be of the heavy duty ceramic insulated type illustrated. The cheaper open wire type is not suitable for this application.

2.2.2 Electronic control

Although the number of electronic control designs appear to equal the number of electronic design engineers, in general terms they fall into two main categories commonly referred to as 'smooth' and 'pulsed' output controllers. The components used for the majority of commercial electronic controllers are

Photo 2.2 A mains fed controller. This one by AGW is rated at 14V 10VA and while satisfactory for 00 scale motors is only suitable for light current motors in O gauge

usually more than adequate for the duty they are required to perform. Often identical circuits are used for controllers having different current capacities; the difference lying in the size of the heat sink provided for the output stage transistors. The casing of a controller rated at 1 or 2 amps could act as a heat sink and keep the output transistors within prescribed temperature limits whereas a controller rated at 4 or 5 amps would require a finned aluminium heat sink. (See Photos 2.2, 2.3 and 2.4).

Smooth output controllers

Smooth output electronic controllers vary the output voltage from zero to maximum in the same way that a rheostat does when working in the series mode. Changes in motor current requirements, e.g. climbing a gradient, normally require the controller output to be altered to maintain speed but some units have compensation circuits built in which alter the output electronically. Speed control units of this type are readily available commercially and are suitable for all types of motors.

Pulsed output controllers

In this type the output consists of a series of full voltage pulses of varying duration. When the controller is 'off' there is no output from the control circuit but as it is turned 'on' an internal circuit commences to switch the output full on and then off again in a series of pulses. Initially the 'on' period is very small compared with the 'off' period and the average voltage supplied to the motor is just sufficient to pass the current needed to start the train moving.

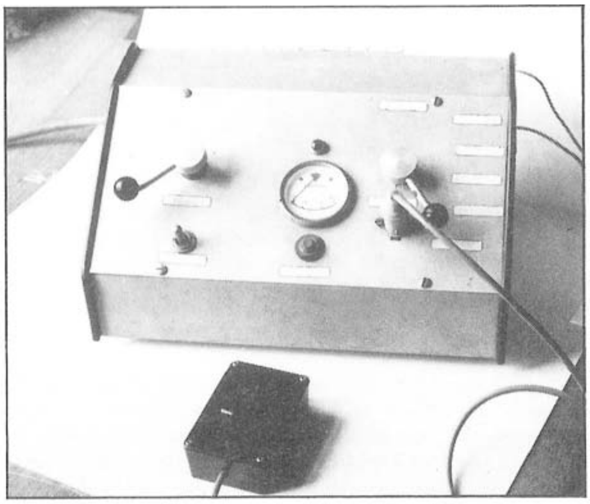


Photo 2.3 A heavy duty mains fed controller. This unit is home made and can deliver 5 amps at 24 volts. It is used as a test bed and has been fitted with a brake simulator and a socket for a 'walk around' control box.

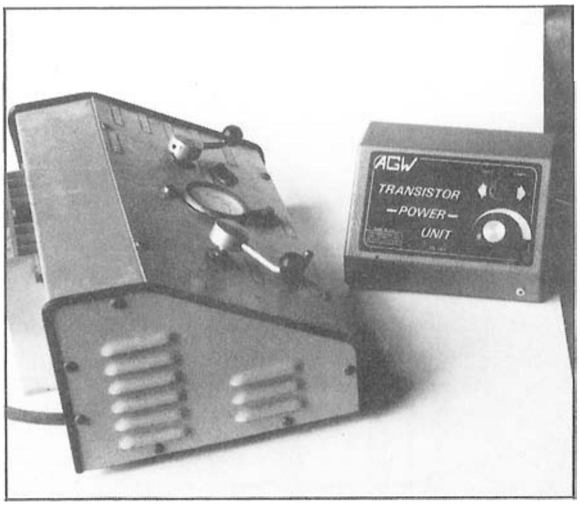


Photo 2.4 The AGW and home made units side by side. Note the size of the finned heat sink provided for the heavy unit which under fault conditions may need to dissipate up to 120 watts to prevent the output transistors overheating.

As the length of the on period increases and the off period decreases, the average voltage increases and thus raises the motor speed until the output is on continuously and full speed is reached. Figure 2-5 shows the various pulse stages from stopped to full speed.

Unless means of smoothing the pulsed output of the controller are incorporated in its design, this type of control increases the heating and mechanical stresses to which the motor is subjected in a similar way to half wave rectification. Consequently the manufacturer's data for some motors, particularly coreless ones, states that they are not suitable for pulse control. Unsmoothed pulsing can also cause vibration and overheating of more robust types of motor.

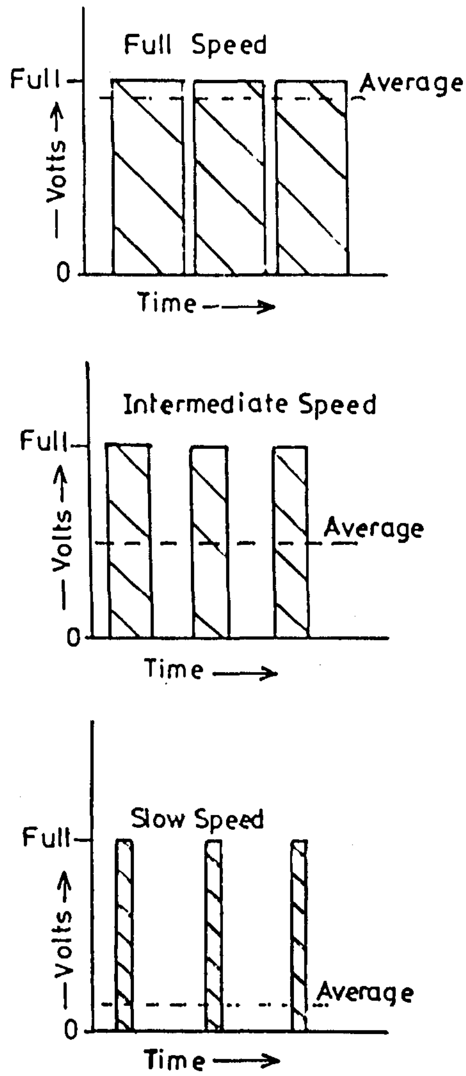


FIGURE 2.5

An illustration showing the increase in pulse length producing an increase in average voltage and hence increase in speed.

2.3 Direction Control

2.3.1 DC Permanent magnet motors

As the vast majority of model locomotives use dc permanent magnet motors, direction control consists of reversing the polarity of the low voltage output to the track.

Except for the split potential system this is achieved by supplying the track via a double pole double throw (DPDT) switch (Figure 2-6). On a split potential supply the reversing switch is situated before the speed controller and is a single pole double throw (SPDT) switch which connects the controller to either the positive or negative line. This

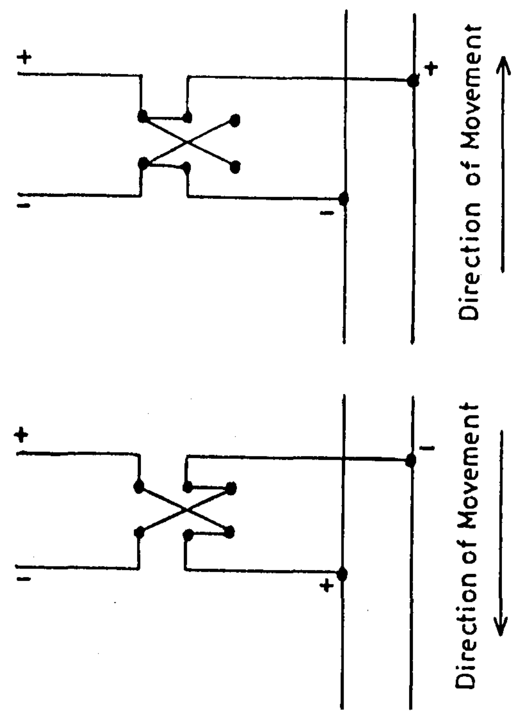


FIGURE 2-6

Action of two pole reversing switch. Also known as a double pole double throw (DPDT) switch.

is illustrated in Section 1 in Figures 1-4 and 1-5. (A selection of reversing switches is illustrated in Photo 2.5).

For most two rail systems a reversing switch on each controller is all that is required (reversing loops, etc. are dealt with later) but three rail systems may need additional switching mounted on the locomotives. As mentioned in Section 1.9 earlier, this applies to three rail multiple operator systems where trains pass from one control area to another without the receiving driver being able to see which way the locomotive is facing. The simplest way to overcome this operating difficulty is to have a standard track polarity setting for movements from one

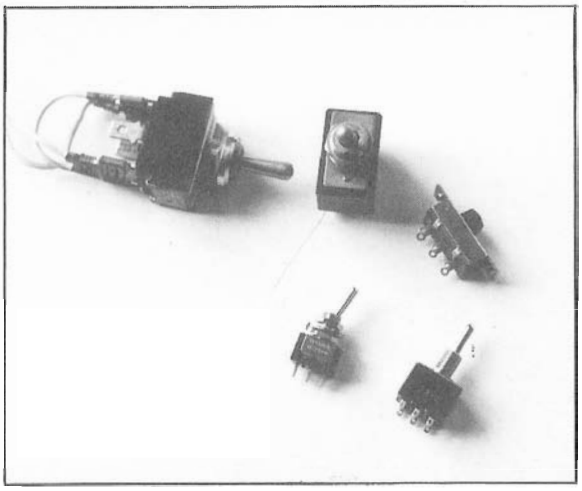


Photo 2.5 A selection of reversing switches. Clockwise: a DPDT centre-off switch rated at 10 amps, a toggle switch and a slider switch both DPDT and rated at 2 amps, a miniature DPDT switch with centre-off rated at 1 amp and suitable for mounting on a 3-rail locomotive, a single pole change-over swith.

area to another and to mount an unobtrusive double pole, double throw switch on the locomotive to set the standard polarity irrespective of which way it is facing. If the switch has a centre off position it also allows the locomotive to be isolated in positions that do not justify the provision of a separate isolating section.

2.3.2 Wound field motors

Wound field motors are normally only found on old Hornby, Maerklin and some Bassett-Lowke models. If the field coil is in series with the armature this type of motor will run on both ac and dc supplies and can be reversed by changing the polarity of the field windings in relation to the armature. If the track supply is ac this can only be done by using a DPDT switch on the locomotive which is either operated manually by a sequence reversing mechanism as used, for example, in old Hornby models or by imposing a reversal signal on the track supply. If the track supply is from a dc source it is possible to fit a bridge rectifier in the locomotive to perform a similar function but a motor so fitted will no longer work on ac. (See Part 3, Section 2.8, Reversal of wound field motors).

Rheostat control

To explain how rheostats work we need to briefly explain Ohms Law. Those with electrical knowledge can skip this panel; for those who find understanding it difficult the following may be useful.

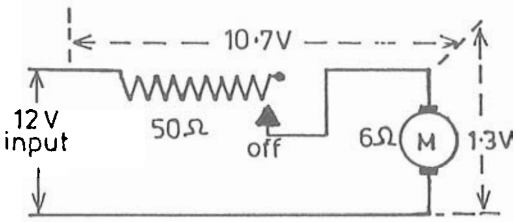
Ohms Law states that voltage equals current multiplied by resistance and is usually written as:

$$V = IR \text{ or } I = \frac{V}{R}$$

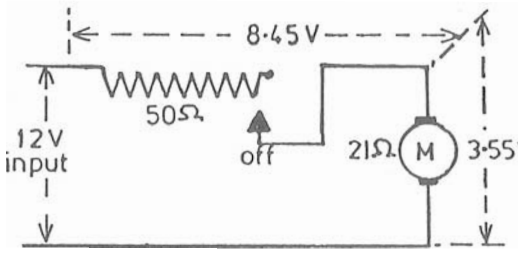
Taking the 50 ohm rheostat and a conventional motor with a resistance of 6 ohms the total circuit resistance is 56 ohms. When supplied with 12 volts the current flowing in the circuit is 12/56 = 0.21 amps. This would normally cause the the locomotive to remain stationary or to move slowly depending on the tractive effort developed.

Compared with an average of 6 ohms for a conventional motor most coreless ones have a resistance of between 18 and 24 ohms; the Escap motor used in the RG7 is typical with an armature resistance of 21 ohms. In this instance the total circuit resistance would be 71 ohms and when supplied with 12 volts the current flowing in the circuit would be 12/71 = 0.17 amps. As these high efficiency motors need a current of only a few milliamps to develop sufficient tractive effort to move a locomotive the resistance of 50 ohms is insufficient to provide acceptable low speed control.

By rearranging the connections to form a potentiometer, as in Figure 2-2, the voltage applied to the motor terminals when the controller is in the minimum position is zero and hence the locomotive will not move until the controller handle is slightly advanced.



Conventional motor with rheostat in series mode



High efficiency motor with rheostat in series mode

FIGURE 2.7

Voltage dropped in rheostat.