Electrical Solutions for Model Railways

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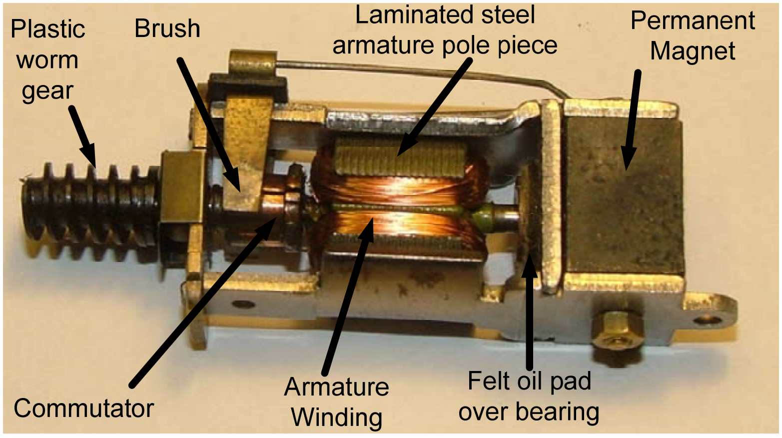
Electric Motors and layout wiring.

Some of the problems we experience in operating our model locomotives are deteriorating performance and reliability. How often have we noticed that the loco starts operating erratically? How often does it seem to lack the pulling power that it used to have? Why does it slow down at certain points on your layout? Why won't it go at all? In this article I attempt to explain what happens and why. If one understands how things work then one can analyse the problem, fix it and take precautions to prevent it happening again. Does the phrase "routine maintenance" sound familiar?

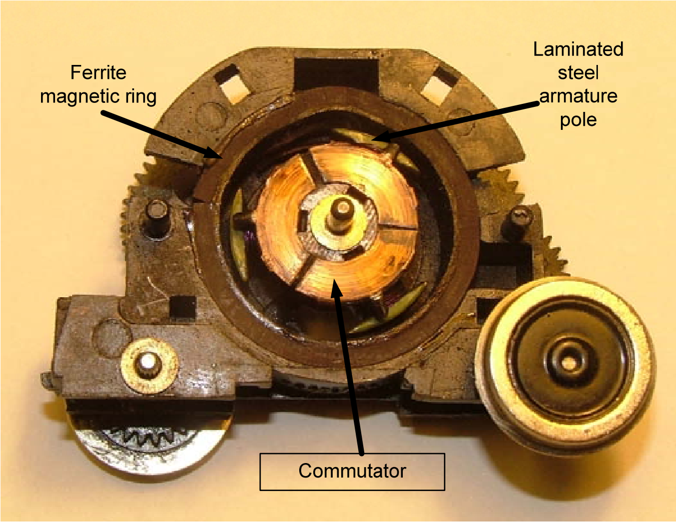
So how does an electric motor work? The basis of a motor and generator is the movement of wires through a magnetic field. This generates voltage in that wire and if connected to a load, like a small bulb, a current will flow and the bulb will light up a little bit. Electrical rotating machines use this phenomenon. Many turns of wire are wound onto the armature and are connected to the commutator of a DC machine. (An AC machine does not have a commutator). This is mounted in a magnetic field which in the case of model trains is created by a permanent magnet. If one were to spin the armature a voltage can be measured on the brushes which run on the commutator. What is a commutator and armature I hear you say? The armature is the bit that rotates and usually has a worm gear on the shaft, and the commutator is the copper segments to which the winding wires are connected/soldered. The brushes collect the voltage from the wires via the commutator.

Below are a couple of photos of a simple Hornby motors.



This is a Hornby X03 motor as was used in their 1960 vintage locos. It has a plastic worm and phosphor bronze bearings that should have oil pads to keep them well lubricated. The many wires can be seen wound round the armature poles and the black square permanent magnet on the right hand end of the motor, with the brass bolt through it. The brushes are soldered onto the brass arm that is kept in pressure onto the commutator by the spring wire "hairpin", one side of which is insulated.

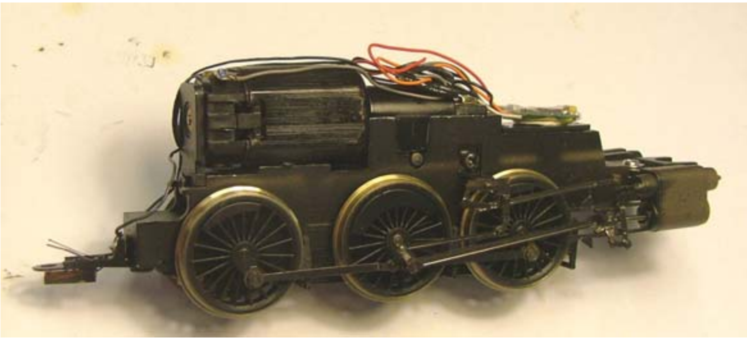
Although of simple but robust design these little motors took a lot of abuse and for their time were good workhorses. The weakness was the bearings. Unless the felt oil ring was kept wet the bearings wore quickly and then the motor vibrated and caused the steam engines to sound like ropey old diesels. My Ivatt 2-6-0 is a classic noisy beast.



This is the guts of an early Hornby ring field motor. For what it is it was a good motor and had good power output. The brush gear support plate with outer bearing is removed so that the armature can be seen.

Basically the construction is the same, a permanent magnetic field and 3 pole armature. Modern motors have 5 or more poles. Lima, Jouef and other manufacturers all made ring field motors for their models and all worked well.

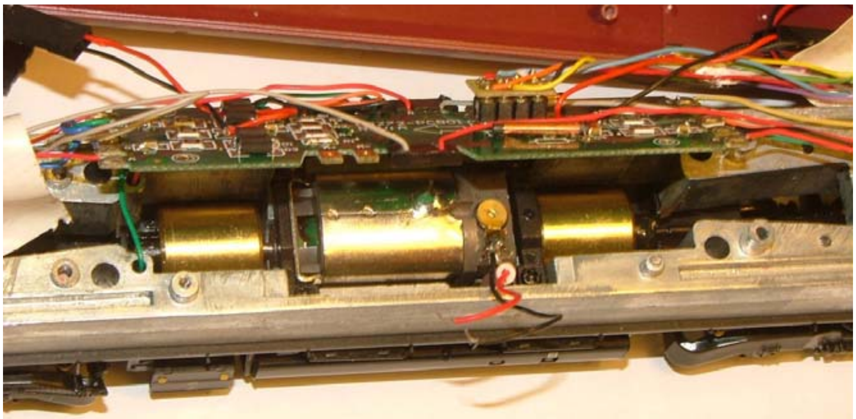
Almost all modern Hornby, Bachman, Atlas and most if not all other manufacturers use "can" motors as in the locos shown below. Being sealed units the inside is not visible but they contain the same components but of much better design and quality.



The picture above is that of a Hornby Black 5 clearly showing the "can" motor, the bunch of wires are those connecting to the DCC decoder, Actually only 4 are used, 2 to the motor and 2 to the rails. No lights bells or whistles on this loco.

Lubrication points are shown, motor bearing, gear shafts and of course the conrod big ends and valve gear, slide bars etc. Only a SMALL drop is required.

Note the electrical connection "fingers" that connect through to the tender. Hornby fit collectors to at least 4 if not 6 tender wheels for extra pick up so this loco has 6 wheels on each side to pick up current. This results in a loco with excellent performance over points and rough track.



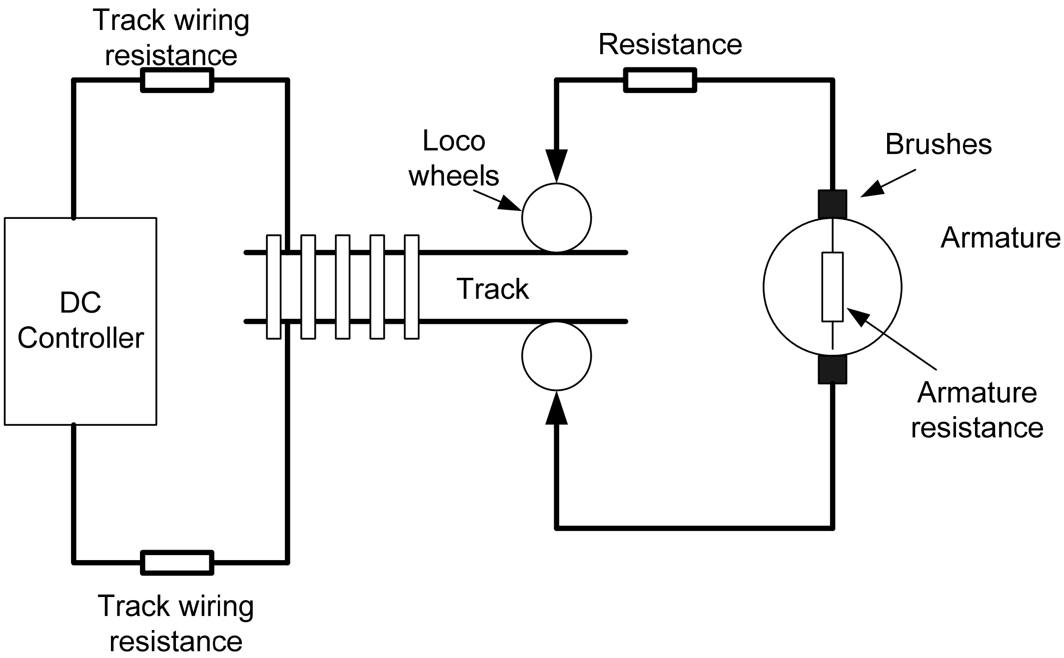
Above is a photo of a can motor inside the Bachman Branch line class 66 with the two large flywheels on each end of the motor shafts. These flywheels are about the same size as the armature itself and make a huge difference the performance of the loco. The large inertia prevents jerky motion and enables to loco to run over intermittent loss of power from the track.

So the motors in our model trains are of similar construction to one of the above. To keep them operating well they need lots of TLC and some maintenance.

Properties of the motors.

We all know that if a DC voltage is applied to the motor it will go round. But what actually causes this phenomena. The application of a voltage causes a current to flow in the circuit including the brushes and the armature. If it is a loco sitting on the rails then the wiring from the controller to the track, along the track to where the loco is and then through the wheels and pick ups to the armature are all in circuit and have an effect. The amount of current flowing is determined by the applied voltage and the total resistance from controller to armature. This is OHMS law, I=V/R. The greater the resistance the less the current will be. Now it is the current that causes the motor to rotate, it is the reaction between the current in the armature wires and the magnetic field that creates torque in the armature causing it to rotate.

However before the motor rotates it has to overcome static stiction, and then the rolling resistance of the loco and all its motions, and the rolling resistance of the coupled train. So the motor needs a fair amount of current before it actually starts to go. This is why you have to turn up the volts considerably before the train moves. Then to make it go faster more volts are required, i.e. more torque is needed, so more current hence more volts.



This is a circuit from the controller to the armature of our loco. All parts have resistance including the controller itself, the wiring to the track, the track and the fish plate/rail joiners, the wheel to track resistance, the pick up from the wheels and the armature. All of these affect the amount of current flow in the motor and hence how much torque it produces. It is torque that produces tractive effort and hence how the train behaves.

So if you have dirty wheels, dirty track, poor fish plate /rail joiners, thin wiring, a poor controller then the current to the motor will be erratic, dither, slow down or it will not go at all and generally be unacceptable. So good maintenance is necessary on loco and track and all connections.

All the above apply to analogue DC and Digital Command Control. DCC can have other problems in that the commands do not get to the onboard decoder properly. But DCC locos with back emf speed control can appear to behave better as they compensate for gradually changing resistance as they go round the loop, but they will still stall on bad connections.

Maintenance.

The open frame motors should be kept clean and free of dust and bits of metal. Because of the permanent magnet they can pick up bits of metal such as staples and iron filings that can cause the armature to jam solid or cause a high spot. Bearings must be oiled about every six months or longer, depending on their use. Use an oil that does not attack plastics, the best is that supplied by PECO, it is expensive and is in fact Electrolube, an electrical contact lubricant. Do not use 3 – in-1, it is a mineral oil and does eat some forms of plastic.

Now when oiling the motor ONLY A SMALL DROP OF OIL is required, not a flood! To apply a small drop is very easy, take a short piece of solid wire, or a pin and dip it onto the oil about 6 mm. When withdrawn from the oil you will see a SMALL drop on the end, touch this onto the shaft/bearing and the oil will run into the bearing. That is enough. When too much oil is applied it can run onto the armature and brushes which can go soft and wear out quickly.

Brushes do wear down with time and could need replacing, but it takes a lot of running to wear out the brushes. Commutators can look a bit ragged and scored but should be a shiny copper coloured. When they appear black and dirty it is usually because they have “been oiled” or severely overloaded. Cleaning them needs some care and maybe removal from the magnet frame.

However do not remove the armature from the magnet frame unless you have a magnetic keeper. If the magnetic loop is left open then the strength of the magnet will deteriorate. So use a keeper. Remember that horseshoe magnets we had as kids, with a small metal bar that was kept over the open end of the horseshoe? Okay, do not take the armature out of the magnetic frame unless you have a “keeper”.

Remember above we stated that the torque produced by the motor was proportional to the armature current and the magnetic strength. So if the magnet looses its magnetism the loco will loose its pulling power.

Maintenance is mostly common sense, keep it clean and lightly oiled. The track, rail joiners and points/switches all need some TLC if you want reliable running.

In Circuit Resistance.

As shown above there are many sources of resistance that can cause poor performance. Unfortunately we cannot control that of the controller or the loco wiring, brushes and armature but we can do something about the track wiring, connections from controller to and in the track. It is these resistances that can cause poor performance. I am not going into the maths or typical values as there are so many variables but I will demonstrate that good thick wiring is a must. Below is a table of wire parameters.

Cross Sectional Area mm²	Nominal Current rating Amps in air at 25°C	Resistance per 1000 metres	Volt Drop per amp per 5 metre,	Short Circuit Current at 12 Volts per 5 metre run	Short Circuit Current at 12 Volts per 50 metre run
0.22	2	91	0.45	26.6	2.66
0.5	6	41	0.205	58.5	5.85
0.75	10	26.8	0.134	89.6	8.96
1.00	15	20.1	0.1005	119	11.9
1.5	22	13.4	0.067	180	18
2.5	30	8.01	0.041	293	29.3
4	40	5.01	0.025	480	48.0

So what is the significance of this data? Most locos draw less than an amp at full speed so the smallest wire will do for at least 2 locos running at the same time. Fine. But if the furthest part of the track is 5 metres from the controller than the resistance of the wire will cause a volt drop of half a volt. If the train was running at half speed then the controller voltage would be a bit over 6 volts, but now the voltage getting to the train would be reduced by the 0.45 volt so it will have slowed down by about 7 percent. On the club layout with its 85 metre loop the volt drop would be more like 7.5 volts. Your train would have stopped!! Another problem that could arise is the short circuit current would not be enough to cause the controller to trip, it will just sit there delivering current until something in your loco burns out.

So the message is to use the largest size wire practical. On the EMRIG layout the standard is to use 1 mm^2. Forget the rating of the controllers and the current drawn by say 3 locos at once, the volt drop will now be insignificant, approx 0.3 volts at the point furthest away if the train was pulling 300 mA. But this is still 5% volt drop. Short circuit current will be at least 5 amps if the controller voltage was set at 6 volts.

The same applies to DCC control. It is ore important that the short circuit current is over 5 amps otherwise the power booster will not trip but supply 5 amps until something else burns out. The supply voltage in the DCC booster is 15 volts so the short circuit current will be about 15 amps.

The above does not take into account the imperfections of the wiring connectors and other bad joints so the results could be as much as 50% worse than I have indicated. But the bottom line is use the largest wire size practical. My layout at home uses 1.5 and 2.5mm^2 with little short lengths of telephone (26swg) droppers onto the rails every 2 – 3 metres. My only problem now is some of these wretched points that switch the current, another subject for another day.

Okay so that's it. Any questions please ask.

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