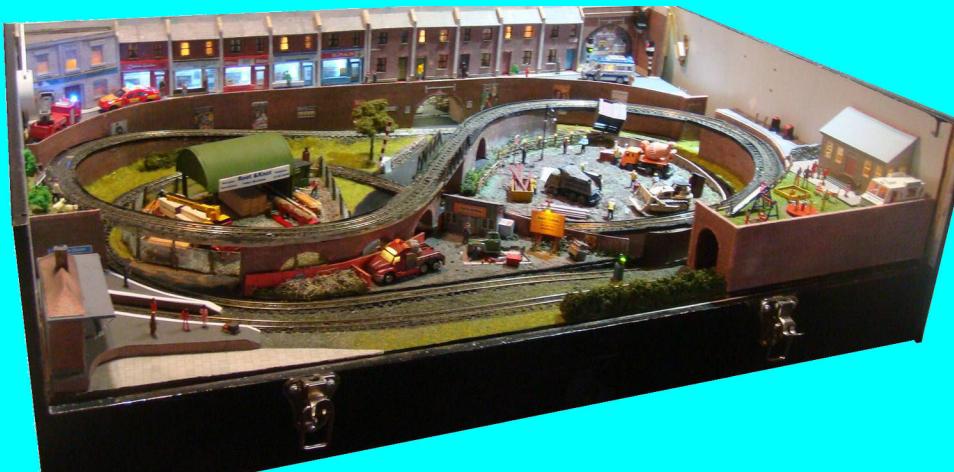


Electronics for Model Railways



Chapter 9

Digital Command Control

By Davy Dick

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In memory of Margaret



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DCC - Digital Command Control

For many years, model railway systems ran on DC. You varied the DC voltage to the track and the loco slowed down or speeded up.

Modellers observed that things worked differently in the real world. The voltage supplied to electrified railway systems or underground systems did not vary their voltage. The overhead lines or rail tracks were supplied at a constant rate; the varying of the voltage to the electric motors took place within individual locos. That observation started the development of DCC, notably by Bernd Lenz, which has now become widespread in model railways.

DCC Features

With DCC, the loco is always provided with full track voltage and it is up to the operator to control how much of it is provided to the motor. This is explained in more detail later but the main thing to recognise is that:

- All sections of track are live at all times.
- The electronic devices (known as '*DCC decoders*') that can be connected to the locos or to the track provide great flexibility.

These provide a great many benefits to model railway enthusiasts, such as:

Simplified wiring

- DCC does not require any complex wiring systems for normal operation.
- A single power bus can feed the entire layout, connecting to every piece of track.
- A DCC layout does not need block/section switches or relays.
- A DCC layout, with less complicated wiring, results in fewer wiring problems.
- A DCC control panel has a cleaner look, with far fewer switches.
- A DCC layout need have no control panel at all, running everything from a handset.
- Wiring reversing loops, wyes and turntables are simplified.

Simplified working

- With all sections live at all times, there is no need to remember what sections are live or dead and there is no block switching.
- You can run multiple locos on the same section of track, at the same time.
- You can run '*consists*' (one or more locos pulling a train).

Improved running

- Non-polarised rails attract less dirt.
- DCC locos use PWM, with its benefits of improved slow running and less stalling.
- DCC decoders can use back EMF to improve running.
- Given its constant high voltage track supply, it is less troubled by voltage drops in cables.
- Each loco can be set to have a constant stopping distance.
- Loco sounds are readily available.

Motor tuning

- You can set the loco's minimum working voltage, so that the motor is fed with this voltage as soon as the operator advances the speed control to the very first notch.
- You can set the loco's maximum voltage. So, for example, a shunter will be prevented from racing round the yard.
- You can set the rate of acceleration for an individual loco.
- You can set the rate of deceleration for an individual loco.
- You can set bemf (see earlier) for maximum performance.
- You can tweak the reverse running to be identical to forward running.
- You can match the performance of multiple locos, to allow smooth-running consists.
- Each loco's electronics has its own individual settings that you set up and it remembers.

More than loco motors

DCC offers more than running motors. It is designed to handle a range of accessories, both in the train and at the trackside.

Loco features

Since there is power available to all locos on any section of track, at any time, even when they are stationary, the loco decoder can be configured to switch off and on various loco features such as:

- Sound (horns, whistles, bells, diesel engine and steam engine effects, brakes, etc.).
- Lights (headlights, beacons, Mars lights, firebox flicker, ditch lights, etc.)
- Uncouplers
- Cranes

Lineside features

There are two types of DCC decoders- those intended for handling loco motors and those intended for handling accessories. Accessory decoders obtain their power (and their instructions) from the track and are used for:

- Points.
- Signals.
- Crossing and barrier gates.
- Uncouplers

Simplified computer control

Computer control of DC layouts is perfectly possible, with the computer turning relays on and off to switch the power to various track sections on and off. This is in addition to controlling the track voltage levels for speed control.

Computer control is made easier with DCC, as the computer only has to tell a loco's DCC decoder to start or stop the motor, or change the motor's speed. There is no elaborate and complicated track power switching to worry about.

Each loco has to have its own electronics board fitted – called a DCC loco decoder. The trackside decoders are known as '*Accessory Decoders*'. They don't have the electronics for controlling the loco's motor, but provide switchable outputs for signals, lights, etc. Most of these provide 4 or 8 switchable outputs on the one decoder. Other decoders are designed to drive servos for point operations; others handle stall point motors or capacitive discharge point motors.

Downsides

As usual, benefits come with downsides namely:

Cost

- The cheapest decoder costs around £12 and can be as much as £70 for large gauge locos that require higher current. To equip a sizeable fleet of locos would be an expensive undertaking.
- While a bottom of the range DCC command station costs little more than a good DC controller, the top of the range command station could cost around £600.
- A DCC sound decoder can costs anywhere from £30 to over £120.
- Railroad & Co Train Controller Gold is at the top end of computer automation software and sells for \$800 US. (fortunately, there are cheaper versions – including free programs).

Complexity

- You can only run one loco straight out of the box. Each loco decoder has to be allocated a unique identification number. So, if you bought two locos with pre-fitted decoders, they would both be supplied with the same default address. You would have to change one decoder's address to get both working on the same layout. Similarly, if you bought decoders to fit to locos, you have to ensure that they have different address numbers before trying to run them both at the same time.
- Decoders can be awkward to fit, especially in smaller gauges.
- All decoders require some initial tweaking to get the best from them. This is covered in a later chapter.
- DCC decoders don't make poorly running loco run much better. If your motor and mechanism is dirty, sticky, or badly adjusted, the electronics inside the decoder cannot compensate for the lack of basic maintenance.

DCC shopping list

If you are considering starting a DCC layout, here are the items to look for.

Minimum

- A DCC command station. The image shows a budget model – the Bachmann E-Z Command.
- A separate power supply, if one is not built into or supplied with the command station.
- A decoder for each loco.



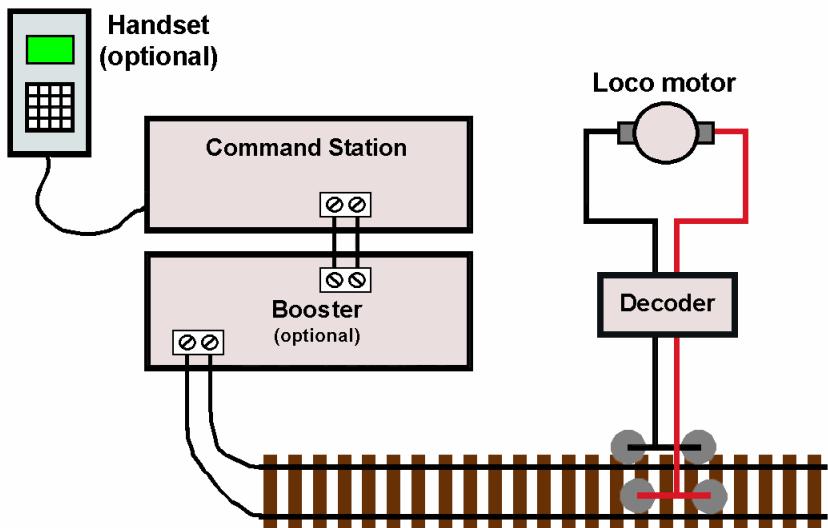
Additions

- A booster unit, if you need to run more locos than your command station can cope with at any one time.
- DCC function decoders, if you want to operate points and accessories via DCC.
- A hand held cab controller, if you want to walk around the layout while operating locos, etc. These can be wired to the layout via a plug and socket, or can use a wireless system.

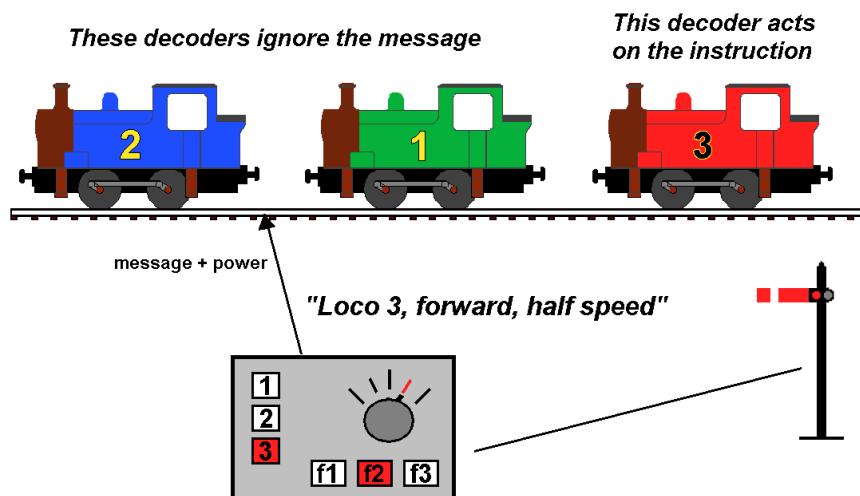
How DCC works

Unlike DC, which varies the voltage to the track to control motor speed, DCC has the track powered at full voltage all of the time. Altering the voltage to the electric motors takes place within each individual loco. This is achieved by fitting a little circuit board, called a '*DCC decoder*', between the motor connections and the loco's wheel pickups.

A DC controller only sends out the power to the track. A DCC controller, called a '*Command Station*', also sends out the power. Additionally, it sends out commands to the various decoders that are connected to the track. Usually the decoders are fitted to the locos but others can be fitted at the trackside, to control points, lights, signals, etc.



These commands are sent on to the track as part of the power supply to the track.



The illustration shows three locos on the same section of track, being operated from a single command station. Although they are shown next to each other, they can, of course, be anywhere on the layout, since all the track is regarded as a single piece.

Each loco is fitted with its own decoder. In the example, the decoders have been given the unique addresses of 1, 2 and 3. There can be no two locos with the same decoder address on the layout at the same time.

Decoders only respond to messages that are sent to its unique address, ignoring all other messages. When a message is received that matches its address, the instruction from the command station is acted upon. The message could be to go faster, go slower, stop, reverse, etc.

In the example, the operator wants loco 3 to drive forward at half speed, so he/she selects loco 3 on the command station and turns the speed control to half way forward. The command station converts this setting of the speed control into an electronic message that is sent out along the track.

Although the message is received by all the loco decoders, only the decoder with address 3 will act on the message.

A similar process takes place when the operator wants to move a point or operate a signal. The accessory decoder for that point will also have its own unique address. In this case, the message is not picked up from the loco's wheels and pickups. The decoder is permanently wired across the track near where it is to be used. Although the decoder will be receiving messages via the track, it will require additional power for running the accessories it is attached to.

In the example, the command station has a set of function buttons and pressing function 2 operates a semaphore signal.

Comparison of DC and DCC systems

	With DC	With DCC
Track voltage	Varies from 0V to max (12V?).	Always at max voltage.
Power availability	Only on sections that are switched.	All track powered at all times.
Multiple trains on same track at the same time	No	Yes
Need to split track into blocks	Yes, for anything but the simplest layout.	No, unless you want a track occupancy system, or a very large layout.
Multiple operators	Each operator needs own power controller.	Entire layout controlled by a single command station. Each operator has their own CAB controller that links to the command station.
Run consists	Only with some difficulty.	Yes
PWM running	Depends on controller used.	Yes
Changes to loco	None.	Need to fit decoder in each loco.
Voltage drops	Can be a problem.	Less of a problem.
Handles bemf	Depends on the controller used.	Depends on the decoder used.
Motor tuning	No	Yes
Points and accessories	Need separate wiring.	Can use DCC accessory decoders.
Computer control	Generally complicated.	Easier.
Locos run straight from the box	Yes	Needs to be given a unique number.

For a working DCC system, as we have seen, we need a command station to send out the commands and a decoder that will act on these commands.

So, let's start by looking at decoders in some more detail.

DCC decoders

Locos draw different amounts of current depending on their size.

An N gauge motor may only consume a quarter of an Amp, while large scale motors may consume a number of Amps.

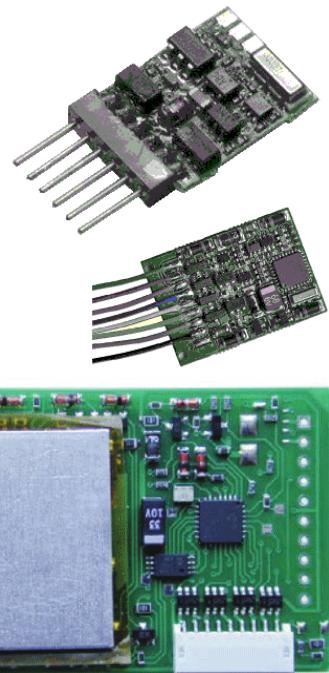
Accordingly, DCC decoders are produced with different current handling capabilities, at different prices.

For example, the Lenz Silver Mini decoder only handles 0.5A, while the Lenz Gold + decoder handles 1A and the Digitrax DG583S DCC decoder handles 5A.

Remember to choose a decoder that can handle the loco's stall current, not just its running current.

As expected, the decoders that handle larger currents are also bigger in size.

The Lenz Silver Mini is only 10.6mm x 7.5mm. The DG583S, shown here, is 56mm x 37mm.



8-pin screw terminal pin out

BLACK (left track) Pin 1
GRAY (motor -) Pin 2
Not Used
BLUE (+Common) Pin 4
GROUND Pin 5
Not Used
ORANGE (motor +) Pin 7
RED (right track) Pin 8

A basic loco decoder is able to control the speed and direction of the motor. Most also have function outputs – connections to switch lights on headlights or lights in the cabin.

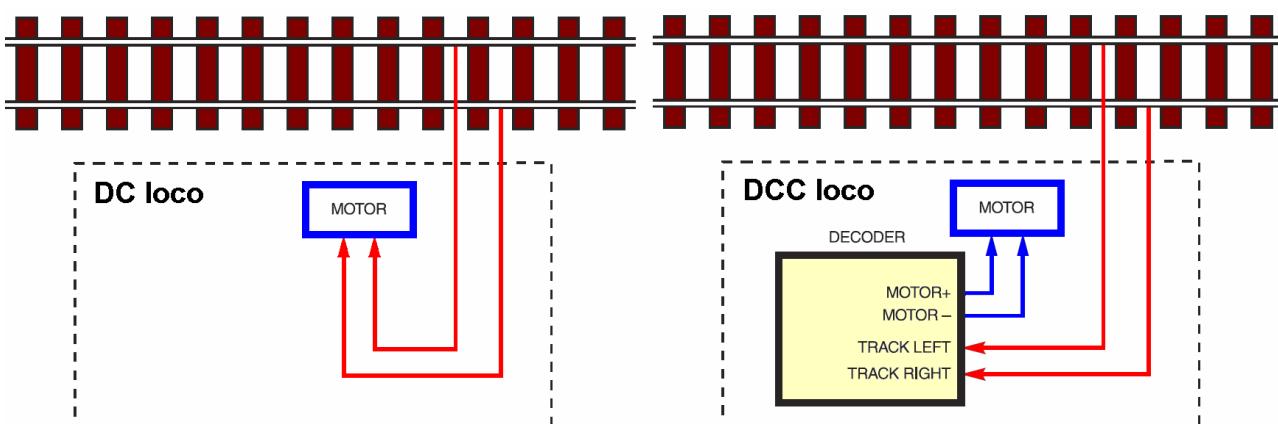
Wiring decoders to locos

You can buy locos with decoders already installed in them. There is nothing inside the loco that you need to touch, although you might want to tweak the decoder to maximise performance (this is carried out externally - see later).

DC locos can be converted to DCC working by installing a decoder.

If you are wary about tackling the conversion, or have a difficult installation (e.g. a loco with a non-isolated frame), you can use a fitting service to do the job for you. Of course, this adds more expense to the conversion.

This illustration shows what is involved in upgrading a DC loco to DCC.



The left hand drawing shows a DC loco with the power from the track being wired directly to the motor. The right hand drawing shows the track power only reaching the motor through the electronics on board the decoder. This is the electronics that controls the motor speed and direction.

There are three types of decoder connection, and you can see two of the images at the top of the previous page.

- Wired – You have to solder the wires yourself.
- Plug – The end of the decoder has connection pins that plug into a socket.
- Harness – Like the plug version, only with a wire extension (as in this image).



Installing Wired Decoders

If you can solder, you can fit your own decoders. There are only a few things to watch out for:

Space

Finding space inside a loco body can be a problem, especially for smaller gauges. While there is often sufficient room inside a large diesel, an N gauge 0-4-0 poses a bigger challenge. Fortunately, smaller gauge locos use motors that draw less current and can use the smaller decoders. In extreme cases, the decoder can be fitted inside the loco's coal tender or a following coach/wagon.

Isolation

Some, especially older, locos had a split chassis. The left and right hand sides of the chassis were isolated from each other, one or both of which were used to carry current from the wheels to the motor. A quick test with a multimeter will determine whether your loco uses a split chassis and requires alterations to isolate the motor from the chassis.

To ensure isolation from the chassis, any direct connection between wheel/chassis/motor tag has to be interrupted to allow the decoder to be wired in.

Following colour codes

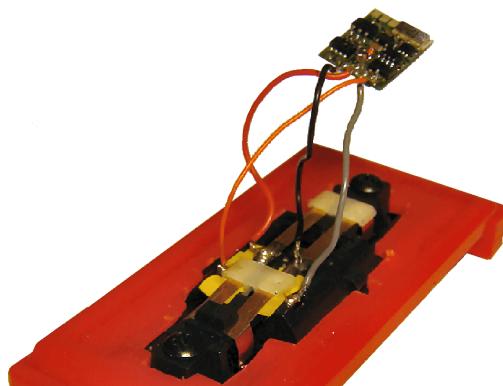
The wires that emerge from a decoder follow an agreed code, as laid out in the NMRA Recommended Practice RP9.1.1.

This means that whichever decoder you buy, you should be confident that the main connections are identical with other decoders.

The four main wires, available on all decoders, are:

Red		Goes to the loco's power pickup from the right hand track rail, when in forward travel.
Black		Goes to the loco's power pickup from the left hand track rail, when in forward travel.
Orange		Goes to the motor's positive brush.
Grey		Goes to the motor's negative brush.

The image shows a decoder wired to a Kato chassis. In some locos, the motor is fitted in a chassis in such a way that the orange and grey leads need to be reversed, otherwise the loco would run backwards. Alternatively, the decoder's CV can be altered, as discussed later.



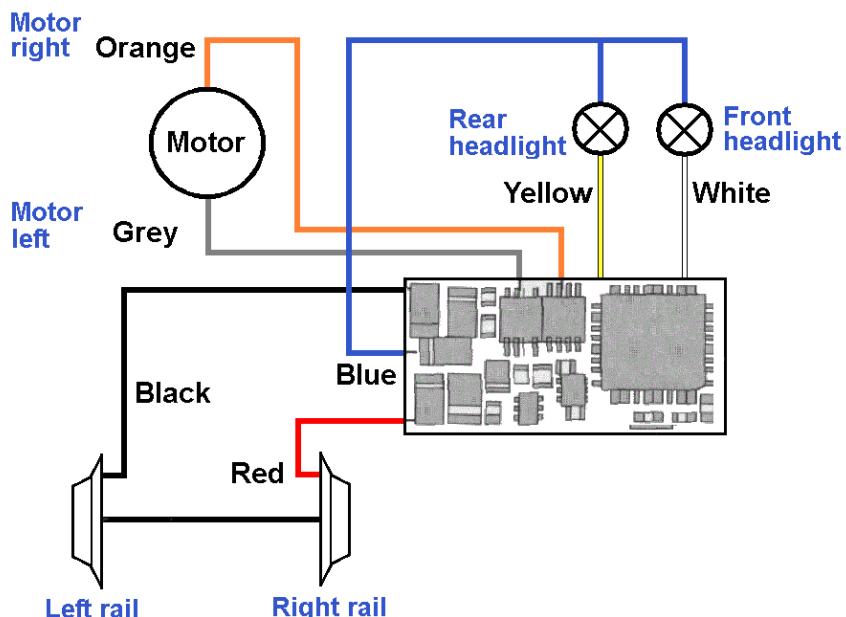
Note

Take great care to avoid the red and black wires shorting to the orange or grey wires, as this will almost certainly blow the decoder's main chip.

The other decoder wires may include:

- White  Goes to the forward headlight.
- Yellow  Goes to the rear headlight.
- Blue  This is always positive and is the common return for the lights and any other functions. Not provided on a 6-pin socket; available on 8-pin sockets.
- Green  Provides an extra function output (if the decoder supports it). Not provided on a 6-pin socket; available on 8-pin sockets.

Here is the wiring diagram for a decoder that provides basic motor and headlight functions.



Plug-and-play decoders

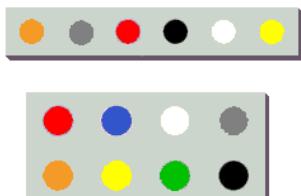
The decoders that have pins or harnesses are used in '*DCC Ready*' locos.

A DCC ready loco is one that has the wires from the track pickups, the motor and the lights all connected to a socket. The illustrations show two popular socket types – the 6-pin and the 8-pin.

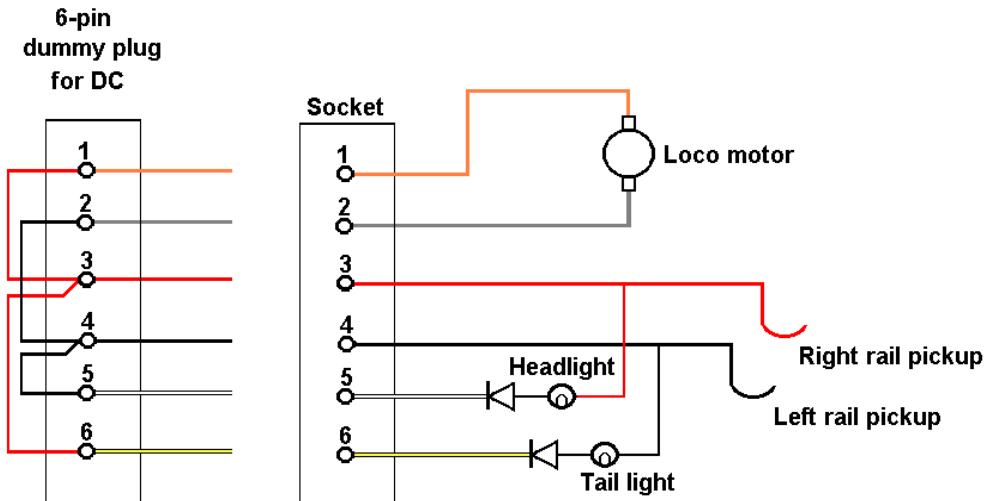
The 6-pin socket is designed for N gauge motors and is rated at 500mA continuous (750mA peak).

The 8-pin socket is rated at 1.5A continuous (3A peak).

Not all decoders match this specification, so check before buying.



In DC mode, a 'dummy plug' sits in the socket, as shown in the following diagram.



This allows the loco to function as a normal DC loco. If you trace the wires, you will see that the motor and lights are simply wired in parallel across the track pickups.

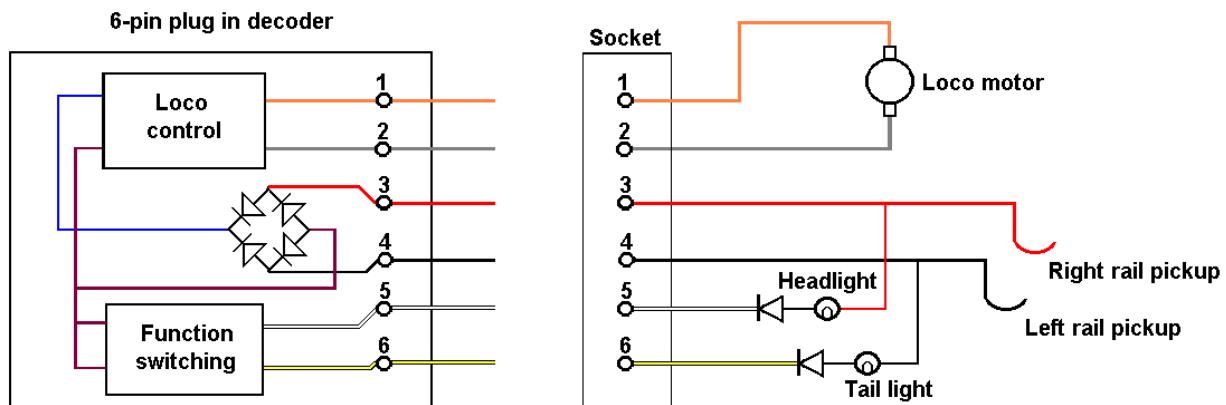
For conversion to DCC running, the dummy plug is removed and the decoder's pins or harness is plugged directly into the socket.

The loco is now a DCC loco, with no soldering involved.

You will have noticed that the 6-pin socket has no blue or green connections.

Since the blue wire is used as a common return for the headlights, this method is not available. Instead, the lights are taken to the track pickups. That's OK for DC, but for DCC they only work on half wave. This reduces the light's brightness which some overcome by reducing the value of the LED's series resistor.

This illustration shows how a 6-pin decoder interfaces with the loco wiring.



The DCC power from the track pickups are connected to a bridge rectifier in the decoder, which provides a DC voltage for the decoder's circuitry. The decoder shown has circuitry for controlling the loco speed and direction, along with additional circuitry to switch headlights.

An 8-pin version would use its blue connection to carry a positive voltage across from the decoder into the socket, where it would act as a common return for the two headlights.

Note

DCC sockets and dummy plugs are available as separate items for purchase. You can buy a socket and wire it yourself, to create a DCC Ready loco. That way, you can use the loco on a DCC layout or a DC layout by simply swapping the decoder and the dummy plug.

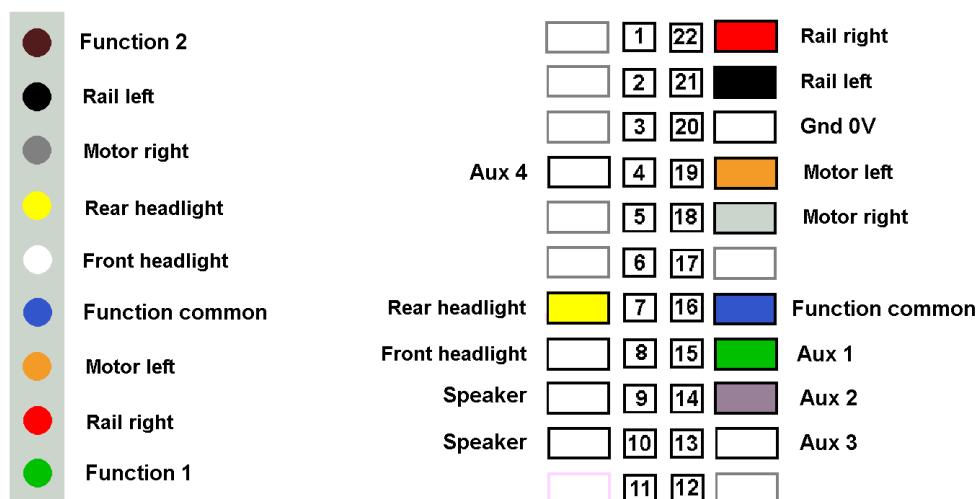
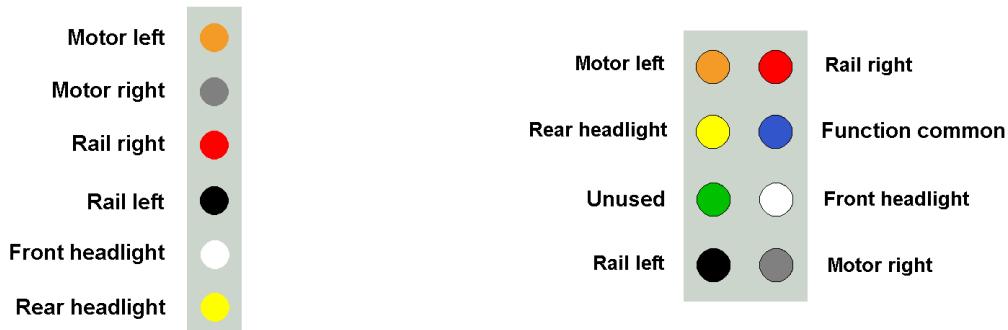
DCC plugs and sockets

When it comes to plug-and-play decoders, there is a range of decoder plugs and sockets. Early decoders, such as the Hornby shown here, only had four connections.



- Two wires taking power and DCC signals from the track.
- Two wires controlling the motor's speed and direction.

As decoders became more sophisticated, extra connections were added to control lights, sounds, servos, etc.



The top left image shows the very common 6-pin NEM 651 connector, while the top right image shows the 8-pin NEM 652 connector. The two extra connections allowed the DCC controller to switch front and rear loco lights on and off.

The 9-pin adds two function outputs and is used by some NCE, TCS and DigiTrax decoders.

The bottom right image shows the 21-pin connector ('pin 11' has no connection and is used as an index pin). The extra pin connections support multiple function outputs and also sound decoders.

This connector is used by Lenz, ESU, Bachmann, etc. In fact, any decoder advertised as 21-pin uses this interface.



If your new loco has a 21-pin connector and you only have a decoder with an 8-pin connector, you can buy an adaptor like the one shown here.

Next18

This connector is small and is intended for fitting in TT and N scale locos.

Track right					Track right
Motor +					Rear light
Aux 1					Aux 5
Aux 3					DC+
Gnd 0V					Gnd 0V
DC+					Aux 4
Aux 6					Aux 2
Front light					Motor -
Track left					Track left

etc. Here is a Lenz Silver Next18 decoder and you can see just how small the connector socket is.

Although it has 18 pins, it only has 14 separate connections as four pins are paired.

The connector matches the NEM 662 standard.

There is sound version of the connector, called the Next18S. It uses Aux 5 and Aux 6 as speaker connections.



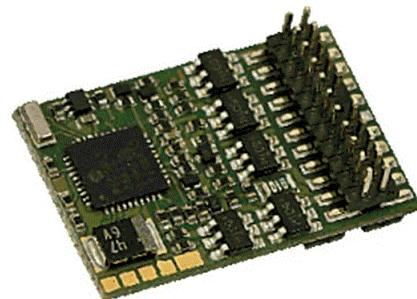
Plux

This is a family of connectors. The PLUX22 also has an index pin to ensure correct insertion. It supports sound decoders and a range of auxiliary outputs.

The connector matches the NEM 658 standard. and is used by Bachman, Tilig, Piko, etc.

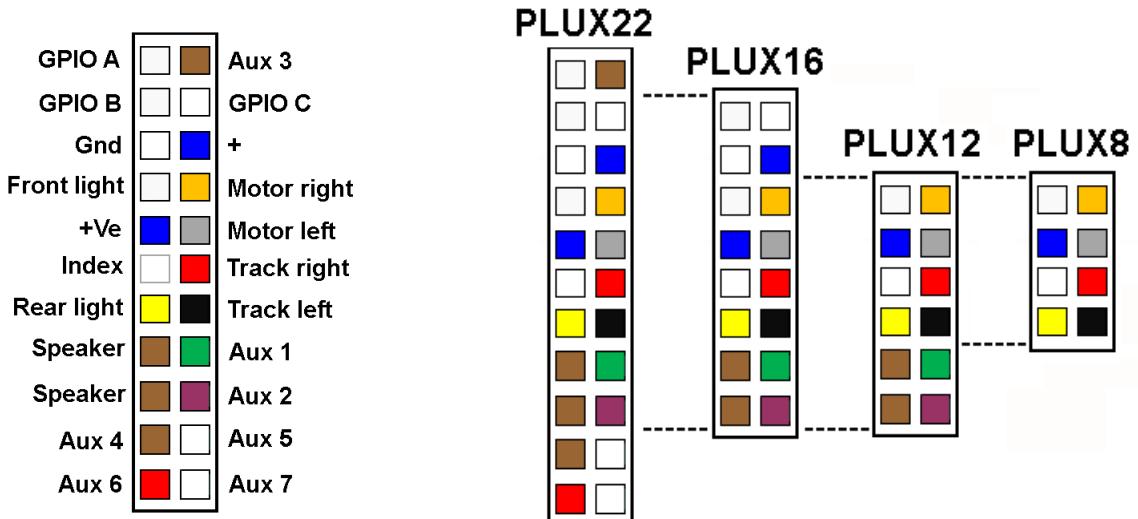
This is a Bachmann PLUX22 decoder.

The PLUX range has 8-pin, 12-pin, 16-pin and 22-pin versions.



As the illustrations show, the PLUX16 connector uses a subset of the PLUX22 pins.

Similarly, the PLUX12 is a subset of PLUX16 and PLUX8 is a subset of PLUX12.



They all share the same core set of connections for track power, motor control and front and rear lights.

Stay-alives

You can never guarantee that a loco will always get the power it needs from the track, without any losses whatsoever. Problems caused by dirty track, dirty wheels, dirty pickups, insulfrogs, short wheelbases, etc. can lead to power glitches. In extreme cases, the loco just comes to a halt. Temporary power dropouts can lead to the loco lurching or a sound decoder's sound dropping out or starting to repeat from the beginning.

Gradually, more decoders provide for the additional of an on-board power store. This stores power during normal running and powers the decoder and loco during short track power glitches. A common demonstration shows a loco running over a length of track that is covered with an insulating material. Check out:

<https://www.youtube.com/watch?v=QBcZmILS3vw>

to see an OO gauge loco fitted with a DCCconcepts Super High-Power Stay Alive running over a 2m section of unpowered track.

A heavy OO gauge 16-wheeled diesel, with its large wheels and multiple power pickups can span across dirty track sections or a point frog. On the other hand, an light N gauge 0-4-0 with its much shorter wheelbase, smaller wheels and fewer pickups would benefit the most from fitting stay-alives.

Commercial versions

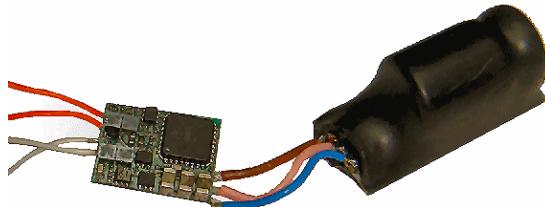
In some cases, the stay-alives are sold as optional extras, while others are sold as a matched pair.

The image shows a Lenz Gold Mini fitted with its optional stay alive, known as a 'Power 1'. An effective, although expensive, combination.

Alternatives are the TCS KAT24, the ESU Powerpackk add-on and the DigiTrax Power Xtender.

Bear in mind that commercial stay-alives have different storage abilities, with some providing much shorter support. Check before you buy.

Zimo decoders allow you to buy and add your own capacitors, rather than having users tied to branded storage products.



DIY

If you have the experience, the skills and the confidence, you can make and fit your own stay-alives and save money. The website at:

www.members.optusnet.com.au/mainnorth/alive.htm

provides details on how to tackle a range of different manufacturers' decoders.

A Google search for “*dcc decoder hacking*” also provides details on this.

Remember, this will almost certainly invalidate your decoder warranty.

There is a bit of a predicament here; the smaller locos are the ones to most benefit from stay-alives, yet they are the ones with the least space to house them.

While it is usually possible to install a decoder inside a small loco's body, the stay-alives are much larger.

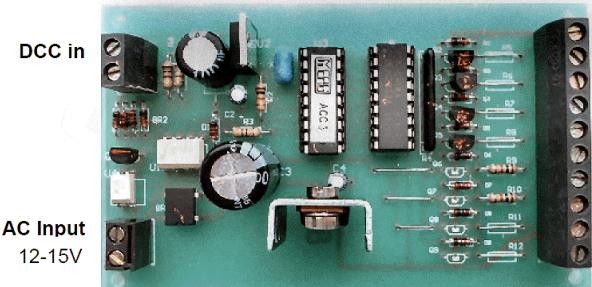
The image shows a decoder and stay-alive installed inside a coach, with wire links between the coach and the loco. This works but means that the coach must always be attached to the loco.



Accessory decoders

Accessory decoders also connect across the track and get their instructions from the command station (e.g. put a light on, switch a point, move a semaphore arm). Some accessory decoder outputs can handle lights or Tortoise motors directly, using the power derived from the DCC on the track. For more power-hungry devices (e.g. solenoid motors), the decoder would need a separate power supply.

This image shows the MERG Steady State Accessory Decoder kit that has 8 outputs. These outputs can control low power devices such as LEDs and Tortoise-type point motors (when used in pairs).



Examples of commercial versions are the DAC20 from CML Electronics, the Lenz LS100, the Zimo MX820X, the Digitrax DS64, the ESU SwitchPilot V2.



Other accessory decoders are designed to control servos. For example, the ESU SwitchPilot Servo module and the Team Digital SMC4 module both control up to 4 servos.

The LDT TT-DEC-B kit is specifically designed for controlling a turntable.

CML sell the MSC Scenery Animator, shown in this image. It can control a mix of devices including motors, servos and lights. It also supports creating sequences and 'flicker' effects.

All the accessory decoders have one thing in common- they all are controlled by the messages issued from the DCC command station.

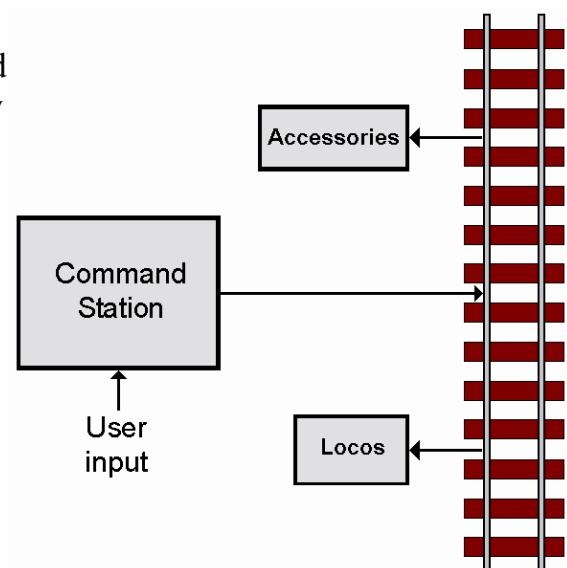
Wiring for DCC

The chapter on '*Layout wiring options*' explained that DC layouts split the track into multiple sections/blocks using lots of cuts in the track. Each section has to be individually powered using switches (or sometimes relays).

The chapter also explained that for a one-operator DCC layout running a few trains, there was no need for track sections. The layout could be reasonably large and complex and still be run with a simple wiring scheme. That scheme involved running power round the entire layout, to every bit of track, allowing locos to go anywhere on layout without any section switching.

This illustration shows how a simple DCC layout operates. The whole layout is controlled by a single command station. Its output is permanently wired to every piece of track on the layout.

The locos get their power and operating instructions from the track.



Commercial command stations

Command stations are also called DCC controllers, DCC control units and DCC throttles by various manufacturers.

They are available from many manufacturers including Digitrax, ESU, Hornby, Lenz, NCE, Viessmann and Zimo. These offer a range of facilities and cover a wide price range

At the lower end of the price range is the Hornby Digital Select, shown in this image. It is an entry level command station and comes with a separate power supply that provides 1A to the track. Locos are selected using the keypad and speed is controlled using the central knob. The direction of the loco is selected by pressing one of the arrow keys on the keypad. It provides basic functions such as setting a loco's unique address, its acceleration and deceleration. It can control up to 10 locos simultaneously, although the 1A maximum clearly limits the number (without extra power being added).

A similar product is the Digitrax Zephyr Starter Set, with a maximum output of 3A.



At the other end of the price range is the ESU ECOS 50200. It can control up to 16384 locos simultaneously, as well as 2048 points.

It has a 7" touch colour screen display and the operator can use it like a mimic panel. The user's layout is displayed on the screen and points can be changed by touching them with a stylus.

Without any additions, it only provides 4A, which is

not a lot at the price being asked.

The Viessmann Commander uses a similar approach with the user's layout displayed on a 7" colour touch screen.

Both of the above expect the user to operate from wherever the command station is sited. For those who prefer the flexibility of moving around a layout while operating, manufacturers provide handheld controllers. These may plug into an existing command station or be matched with a less glamorous box containing the power unit.

The image shows an example of this – the Lenz Start Set 100, which has an output of 5A.

Other similar products include the modestly-named Digitrax Super Empire Builder and the Super Chief, both working at 5A. The NCE Power Pro 10A Large Scale Set, as the name suggests, is intended for O Gauge and above.



For even more flexibility, some command stations get round the restrictions of having a handheld tied to the layout by a cable – by providing wireless communication between the handset and the power unit. The operator is free to move anywhere round the layout without having to find a socket to plug in the hand controller.

Example are the Digitrax EVOD Evolution Advanced 8A system which uses infra-red communication (perhaps not the best choice for a link) and the Zimo MX 31 12A system based on a radio link.

MERG command station

MERG has two kits that provide a cheaper alternative to the commercial offerings.

The image on the right shows the CANCMD kit. This command station module provides up to 1A but can be connected to a booster for extra power. It connects to MERG's CBUS system (see the next chapter), which allows it to be controlled either by a suitable handheld controller or by a computer. It provides the power and the instruction messages to the track.



This image shows the CANCAB kit, a handheld controller that connects to the CANCMD.

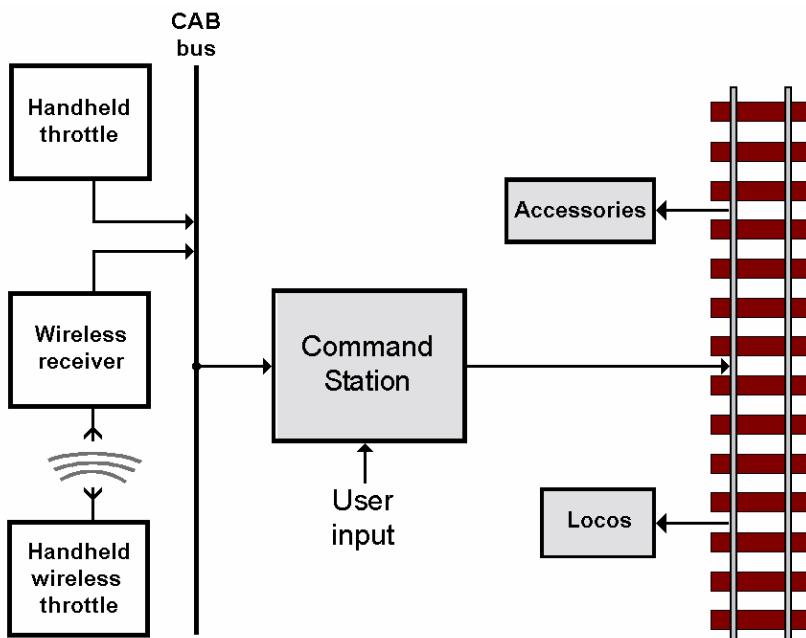
It can control up to 32 locos simultaneously, along with points and accessories.

Locos are selected using the keypad and speed is controlled using the thumb-operated knob on the top-left of the case. The direction of the loco is selected by pressing a button and LEDs indicate the current loco direction.

Pressing the STOP button once, stops the loco that is currently being controlled. Pressing the button a second time stops all locos on the layout.

Multiple operators

There may be circumstances when you want more than one person to be operating a layout. Examples are club layouts, large home layouts, or the grandkids coming round. Fortunately, many command stations allow you to connect more than one hand controller. The illustration shows three operators sharing a command station. One is using the command station controls, while the others use a wired throttle and a wireless throttle.



Although there are multiple operators, there is still only a single DCC command station which controls the entire layout. The operators press their buttons, etc. and these actions are sent as messages to the command station. The command station translates these messages into the instructions that are sent to the track.

The connection between the handheld controls and the command station is known as the '*CAB Bus*' or '*Throttle Bus*'. The way the bus is wired is often specific to a particular commercial DCC system, as there is no NMRA standard for CAB buses. Most manufacturer's modules are not interchangeable (e.g. CabBus/NCE, LocoNet/DigitTrax). Some use Expressnet (e.g. Lenz, Atlas, ZTC, Hornby, Roco – although they call theirs RocoNet).

To allow the maximum flexibility of operation, it is common to wire the CAB Bus round the edges of a layout, with sockets at strategic points. The operator can then plug a handheld controller into the nearest socket, while moving round the layout.

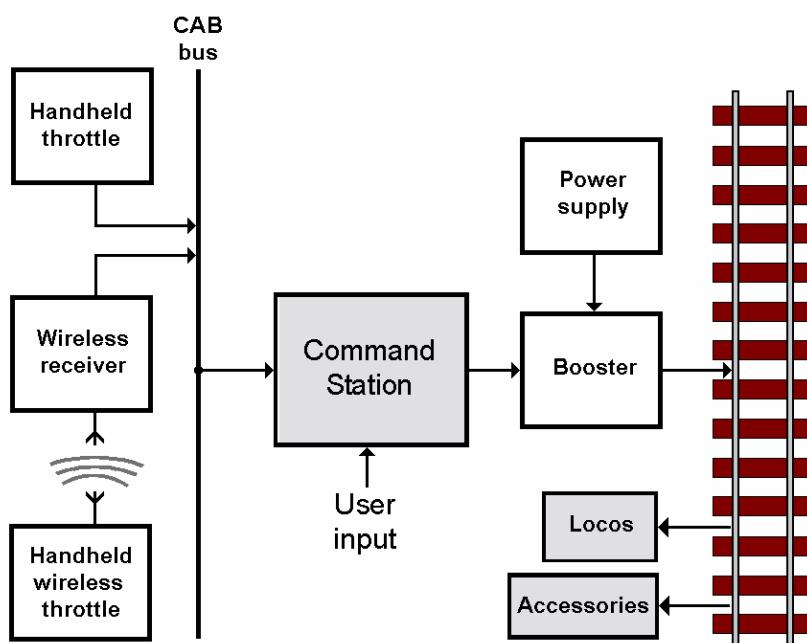
CAB cables commonly terminate in an RJ12/RJ25 plug or a RJ45 plug. The RJ25 plug, shown on the left looks like a plug you find on the end of a telephone, but it is different. The wires are straight-through (no inversions) and it has six contacts. These are found on Lenz, Hornby, NCE, XpressNet/Loconet Atlas, Roco, etc. handhelds. The RJ45 plug is the type used for Cat 5 Ethernet cabling. It uses duplicate connections for increased reliability. Used by MRC and Gaugemaster handsets.



Although not shown in the illustration, the CAB bus can also be used as a means of controlling a layout using a computer or a control panel.

Handling high currents

As your layout grows, you may find that the 1A or 3A command station you own is not sufficient to meet the current demands of your expanding fleet of locos and accessories. If you are working in larger gauges, or running multiple locos, you can expand the capabilities of your existing command station by adding a '*power booster*', sometimes also known as a '*power station*'. Many command stations provide for this improvement.



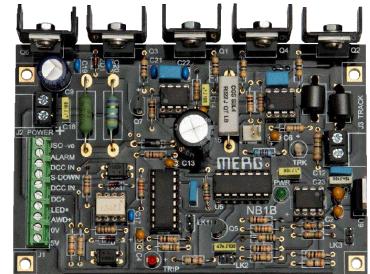
The illustration shows that the booster provides the track power and requires a beefed-up power supply to provide the higher amperage. The booster also receives the messages from the command station and send them out on the track.

In all other respects, the setup runs as before.

Locos still move freely throughout the layout without any block or block switches.

A power booster unit is usually housed in a plain case, as can be seen in the earlier image of the Lenz Starter Set. Digitrax sell 5A and 8A boosters, while NCE have a Powerhouse 10A version.

The image shows the MERG NB1B Booster, which can provide an output of 5A or 10A depending upon the components that are used. It connects to the MERG CANCMD command station.



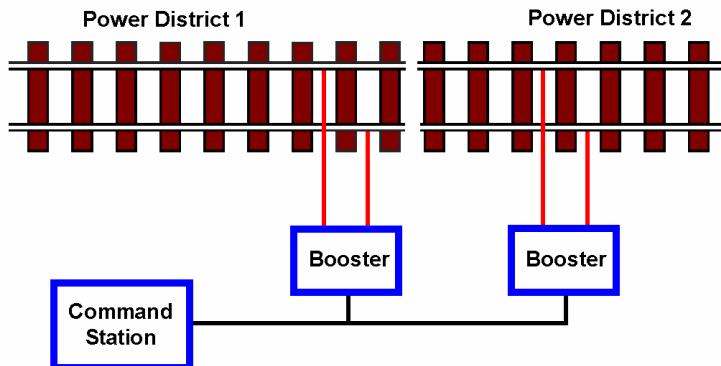
Large scale DCC

When we look at *really* big layouts, the ones with many large power-hungry locos running at the same time, they need even more power than a 10A booster can handle.

The answer is to use extra boosters. Unfortunately, it is not that easy, as multiple boosters can't be wired in parallel with each other.

The answer still lies in using multiple boosters – but with each booster providing power to a *part* of the layout.

For the first time, we have to break the layout up into independently powered blocks, known as '*power districts*'.

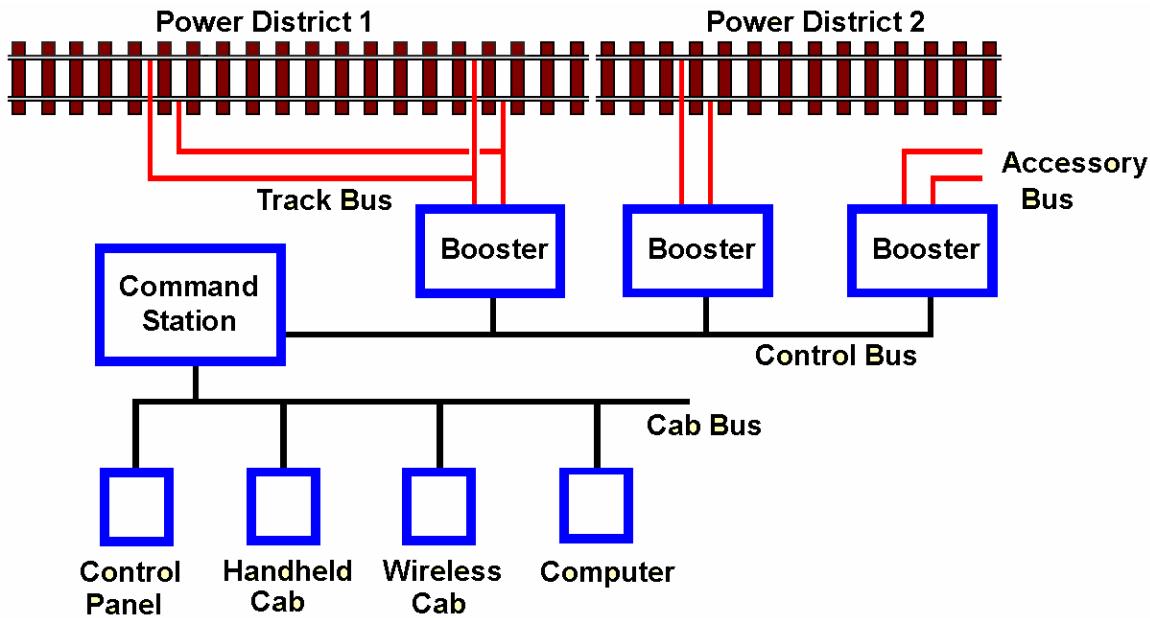


This is different from DC block working in a number of important respects;

- All pieces of track are still powered at all times.
- There is still a single command station that controls the entire layout. The instructions from the command station are fed to all boosters and from them to all power districts.
- Locos can still move freely between districts, without the need for switches or relays.

It makes sense to separate a layout into distinct work areas (e.g. goods depot, marshalling yard, mainline station, etc.) with an operator in charge of the loco operations within each work area. Since each work area can expect heavy traffic, it is allocated its own power booster. That way, power districts match the main activities of the layout and the command station and its wiring does not have to carry the total current of the entire layout. Power districts result in more complex wiring. On the other hand, having separate identifiable sections can help in tracing layout faults.

Here is a possible configuration for a large layout.



In this example, the layout's DCC accessories require too much power to connect them to the track. In such a case, a separate cable can be taken from a booster and fed directly to the accessory modules. This is known as an '*Accessory Bus*'.

Bear in mind that power districts are not required for most layouts – although there is still a case for creating independent track sections for feedback purposes (see the chapter on track occupancy detectors).

Handling shorts

Despite our best efforts, short circuits are a common occurrence on model railways, mostly caused by loco derailments. Short circuit protection is an absolute must to protect the layout and to avoid the serious risk of fire.

You may have wondered why we bothered to have multiple power boosters instead of one giant power booster. We could, of course, build a 50A booster, instead of using five 10A power districts. Now, consider what would happen if there was a short with a booster running at 20V. Power, you will know by now, is voltage times current. So the power that would be dissipated in event of a short would be:

$$P = I \times V$$

$$P = 50 \times 20 = 1\text{KW}$$

In other words, a short would produce the same heating effect as a single-bar electric fire!

No wonder, then, that command stations and boosters provide:

- Short circuit protection – closing down the power when an excessive current is detected.
- Thermal protection – closing down the power when the components inside the command station or booster are detected as overheating.

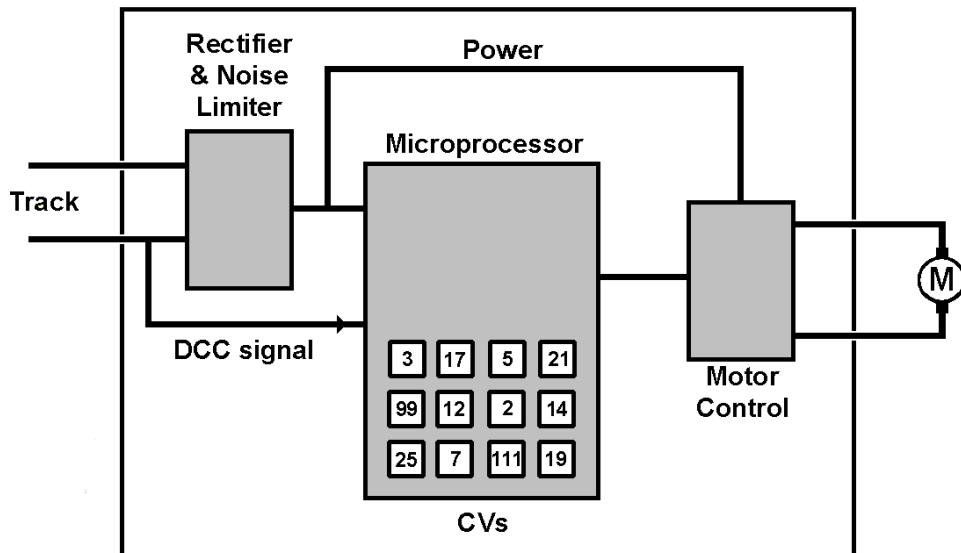
Most cutouts spring into effect after about 50mS. They then test every 0.5 secs to see whether the short is removed and power can be restored.

The chapter on '*Power supplies and cutouts*' looked in detail at DC and DCC overload protection.

Setting up decoders

A decoder is supplied with some default settings. For example, the unique address is always set to 3. If you want to run other DCC locos on your layout then the decoders have to be given new addresses. This is called 'programming the decoder'.

Apart from addresses, decoders can store all kinds of details regarding the loco's performance – minimum and maximum motor voltage, acceleration, deceleration, lights, and much more. All these performance factors are stored inside the decoder and can be altered by the user. These values are known as CVs (Configuration Variables). This illustration shows some of the internal workings of a decoder.



The loco's motor, lights, functions, etc. are all controlled by a microprocessor on the decoder. The chip contains a number of separate memory locations, each one able to store details of the way that particular loco is configured.

They are called 'variables' because they are alterable and may well be different for different locos (each decoder would certainly have to store a different address). By altering the values stored in the CVs, you can tweak each loco for maximum performance.

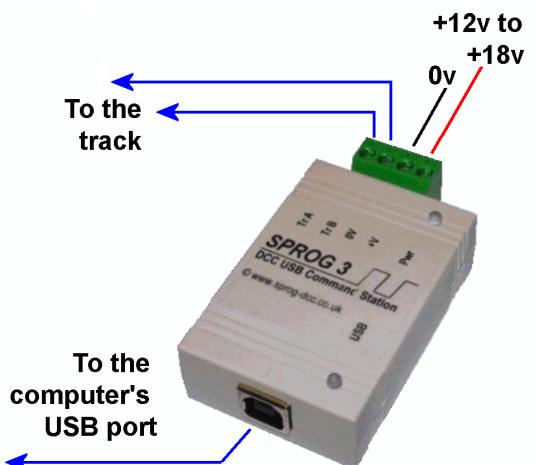
Programming hardware

Most command stations can program the contents of a decoder, although it can often be a laborious process requiring multiple button presses and some knowledge of all the CV numbers and their options. Command stations may have two outputs, with a separate output for Service Mode programming (see next).

A popular alternative is to use the SPROG DCC decoder programmer, as shown in this image. You connect a power supply and the track to the terminal block and use a USB cable to connect the unit to a computer.

For more details on the SPROG, check out:

www.sprog-dcc.co.uk



Wiring for programming

There are three ways that you can connect your programmer and decoder.

Ops Mode

This is often referred to POM (Programming on the Main).

The output of the command station or programmer is fed to the main layout track.

This means that a loco can be anywhere on the layout and still be programmed.

Even better, the alterations can be carried out while the loco is moving. So, you can check the effects of altering loco parameters (e.g. max speed, matching locos for consists, adjusting sound levels, etc.).

This mode works by specifically sending the new data to a specified loco address.

An example Ops Mode instruction could be considered as

“Loco 7, change your acceleration momentum to 109”

All the decoders in other locos should ignore the instruction and carry on as before.

Note

The programming hardware, the decoder and the software must all support Ops Mode for this to work. Older command stations (Lenz Compact, Atlas Commander, Digitrax UT4 Throttle) and older decoders may not support POM. Check before using POM. Unless you are absolutely sure, consider Service Mode programming (see below).

A couple of other limitations:

- You cannot read and examine the existing stored CV values while in Ops Mode; you need to be in Service Mode.
- Some systems don't allow you change the unique address while in Ops Mode.

Service Mode

The output of the command station or programmer is fed to a length of '*programming track*' that is electrically isolated from the rest of the layout. This could be an unused siding, a length of track in the fiddle yard, or even a piece of track sitting on your workbench. The programming track must not connect to the layout track in any way.

An example Service Mode instruction could be considered as

“Change your acceleration momentum to 109”.

This is called '*broadcast programming*', as the instruction is not specific to any one decoder address. Since no loco address is specified, all locos on a programming track would have their decoder CVs programmed at the same time.

Your command station may have separate outputs for the main layout and for a programming track.

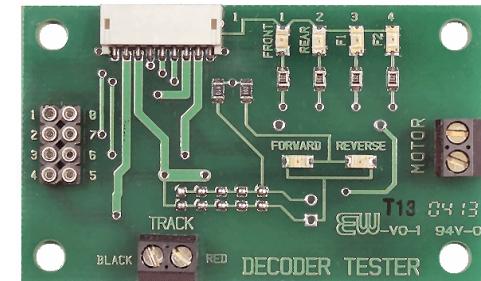
Although this mode loses the benefit of altering CVs while the loco is in motion, it provides other benefits:

- You are guaranteed not to program other decoders by mistake.
- You can change the decoder's address.
- You can read existing CVs values stored in the decoder. You can only read one decoder at a time, so disconnect the sound decoder to read the loco decoder – and vice versa.
- You can reset a decoder back to its factory defaults (see manuals) if you get totally muddled or get unexpected results.

DCC Test Rig

Some users prefer to use a 'test rig' for their decoders. This is a board with all the connections to a spare motor, lights, DCC power etc. The decoder is either plugged in or wired to these connections. It has similar benefits to working on a programming track. However, the decoder can be programmed and tested *before* fitting it into a loco. That way, you know everything works prior to the fitting.

The image shows a commercial tester, the NCE DTK Decoder Tester, available from Bromsgrove Models, Digitrains, etc. It has connections for both wired and plugin decoders, plus connection to the DCC power (via the track) and a connection for an external test motor.



Once wired up, it can test for motor control including direction, plus four functions. The ESU 51900 is similar but has a motor mounted on the board.

If preferred, a homebuilt version is easily made up from a piece of stripboard, some LEDs with resistors, and various connectors.

This is available as a MERG kit.

Programming software

You can download a very useful software application called '*DecoderPro*' which makes the process of setting up a decoder much more user friendly. DecoderPro works with Windows, Linux, Macintosh (OS 8.6 through 9.2 and MacOS X), and OS/2. For a detailed tour and guide to DecoderPro, check out:

<https://www.jmri.org/help/en/html/apps/DecoderPro/>

or look at tutorial videos at:

http://model-railroad-hobbyist.com/mrht_decoderpro

The examples that follow are from DecoderPro.

Decoder standards

Before looking at programming a decoder, we should be aware of the standards expected from a decoder. The NMRA (National Model Railroad Association) presents itself as the lead body on helping to set standards with the model railway industry.

In fact, the NMRA produce both '*Standards*' and '*Recommended Practices*' in relation to many electrical and electronic issues – including DCC decoders.

Standards are mandatory, if a manufacturer wants to claim NMRA compliance for their products. For example Standard S-9.1 describes the electrical standards for DCC (e.g. pulse amplitude, length, etc.) while S-9.2 describes how instruction packets are coded. For a mine of information, check out:

www.nmra.org/standards/sandrp/consist.html

Recommended Practices cover decoder abilities but, as the title implies, not all its proposals are mandatory.

NMRA do have a 'Baseline' standard for compliance, covering issues such as basic speed and direction, the need to offer up to 127 unique addresses, etc. All manufacturers have to meet this baseline to be able to describe their products as meeting NMRA conformance. The 'Extended Packet Format' (RP-9.2.1) covers additional features such as offering more than 127 addresses, functions, accessories, consists, etc. Since these are not mandatory, the list of facilities offered in a decoder varies between manufacturers and individual models.

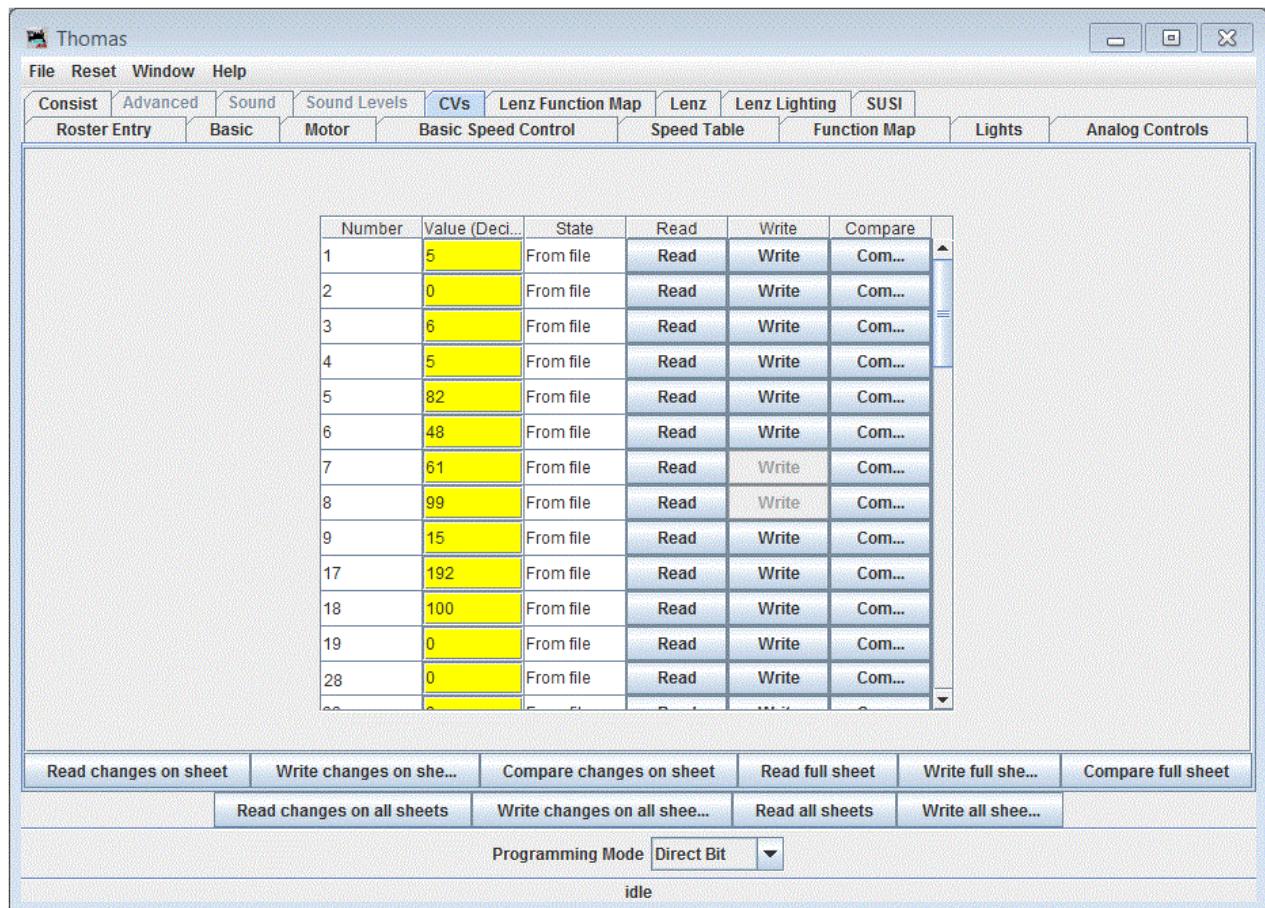
Decoder CVs

Here is a sobering thought - decoders CVs are so useful that there are hundreds of them! The NMRA standard CV definitions go up to 512, including some for future expansion. The Lenz Gold Mini, for example, stores 128 CV values.

Inside the decoder, the CV values are stored as a long table containing CV numbers and the values they are currently storing.

The hard way

This image shows only part of the long list of CVs, being viewed on a DecoderPro screen.



This screen can be used to alter the contents of any of the CVs as long as:

- You know what each CV number is used for
- You know the effect of any value you change.

Over a period of time, with regular usage, you might start to recognise the main CVs and their likely settings.

Fortunately, there is an easier way.

The easy way

This chapter does not include a tutorial on using DecoderPro, as there is a lot of material already available on that subject, including the links provided earlier.

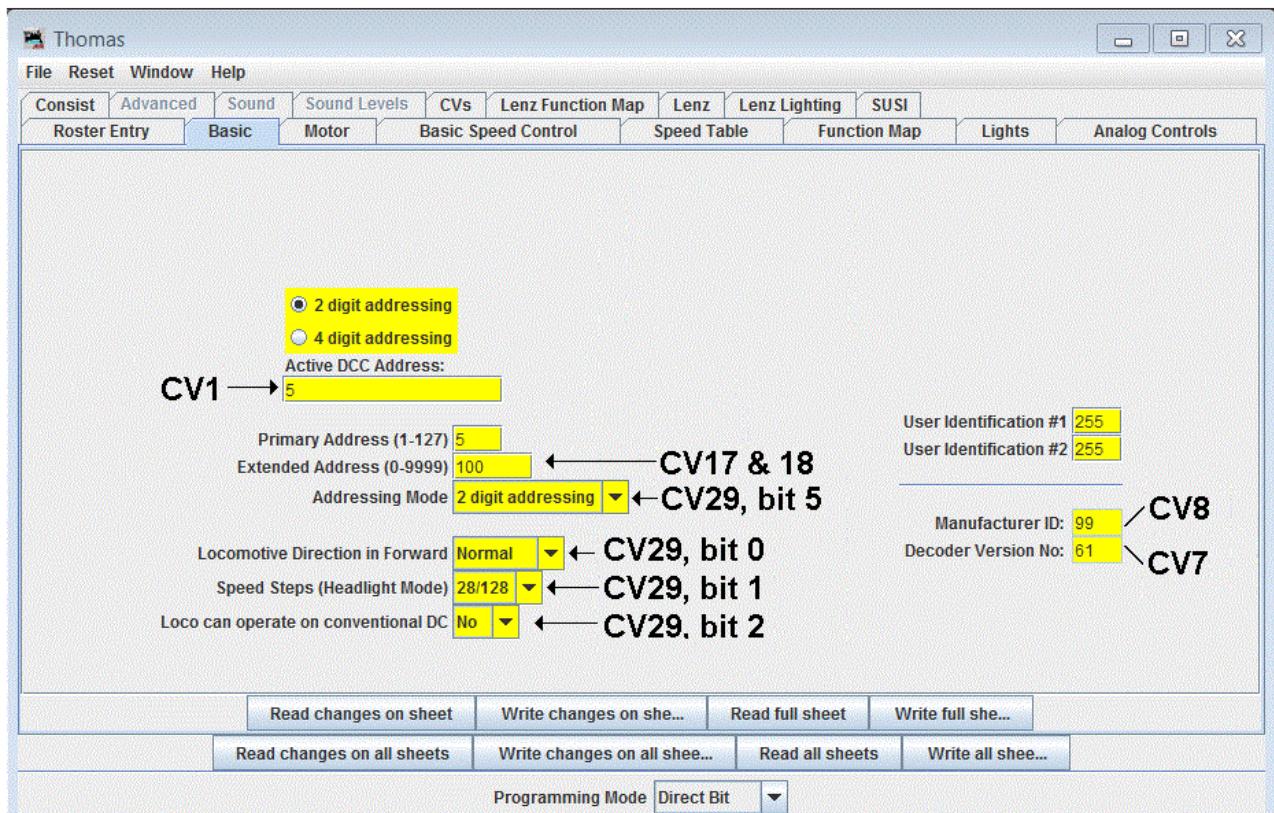
However, a number of screenshots from that package are shown to demonstrate some of main CVs that hobbyists alter or tweak.

So, if there are hundreds of possible CVs, how do you know which ones are usable with your particular decoder?

There are two ways to go:

- Look up the tables provided in the manual that come with the decoder. This will list the CVs supported by your decoder. The hard way.
- Let DecoderPro interrogate your decoder, find out what make and model it is, and only show you the CVs that you can view and alter. The easy way.

Here is a screenshot of a decoder, using the '*Basic*' tab.



You will notice that all the entries are in plain descriptive English; there is no mention of CV numbers. They are hidden from the user, so there is no need to know the CV that tweaks each parameter.

In fact, two of the CV locations (CV8 and CV7) store the make and model of the decoder. When DecoderPro reads these CVs, it knows what that particular decoder is capable of and only shows you its variables.

In the example, CV8's stored value is 99, which means that it was made by Lenz, while the value of 51 in CV7 means that it is a 4th generation model that is capable of handling BEMF. But you don't need to know this, as DecoderPro figures it out for you.

CV1

This stores the current unique address of the decoder. This is the one that is factory set to 3 when purchased and needs to be altered when using multiple locos.

You may have noticed that some CVs have a numeric value, while others are simply storing 'On' or 'Off'. Each CV can store a byte of data, which means values between 0 and 255. That is a waste for on/off values, so some CVs split the byte up into 8 separate bits. Each bit can then store a 1 for On and a 0 for Off. Again, this is all invisible to you.

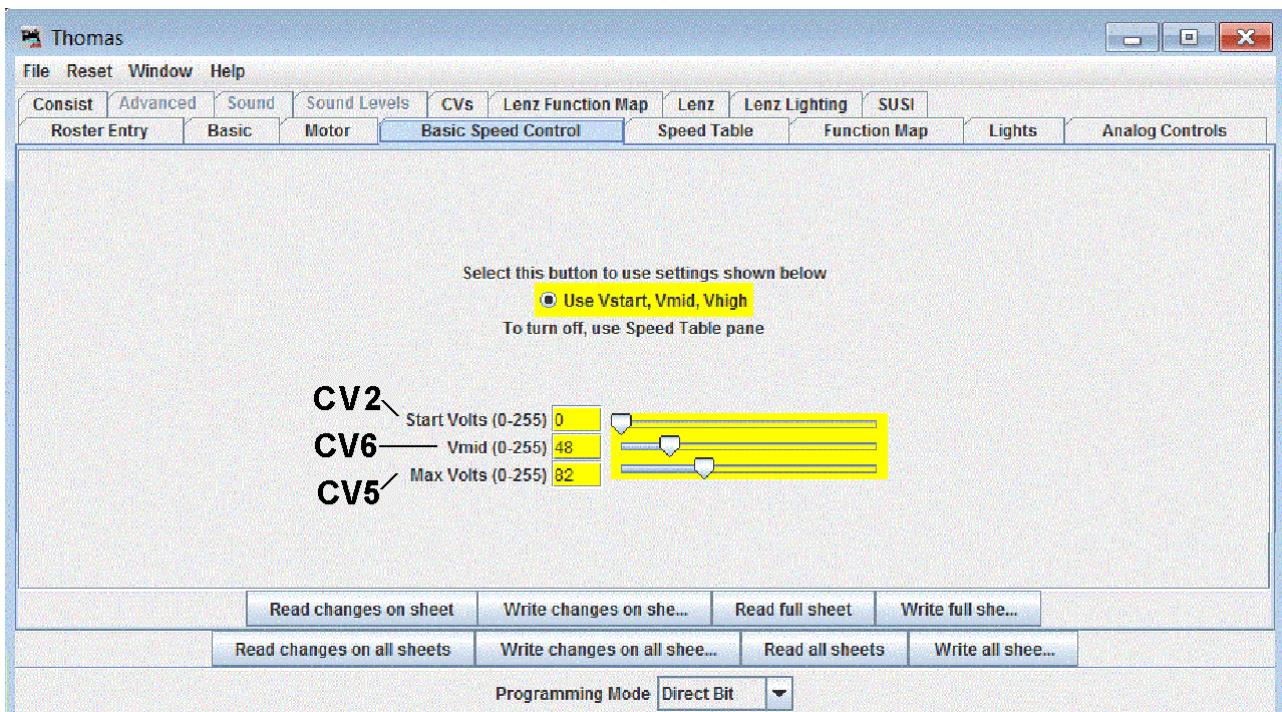
In the above example, CV1 CV7 and CV8 store values, while CV29 uses individual bits.

CV29, bit 0

This is handy if you have wired your decoder's motor wires incorrectly and the loco goes in reverse when you want it to go forward. You can either dismantle the loco and rewire the motor – or alter bit 0 so that the error is corrected in the decoder's electronics.

If you want the loco to be able to run on DC layouts as well as DCC tracks, you set CV29, bit 2 to Yes.

Here is DecoderPro's '*Basic Speed Control*' screen:



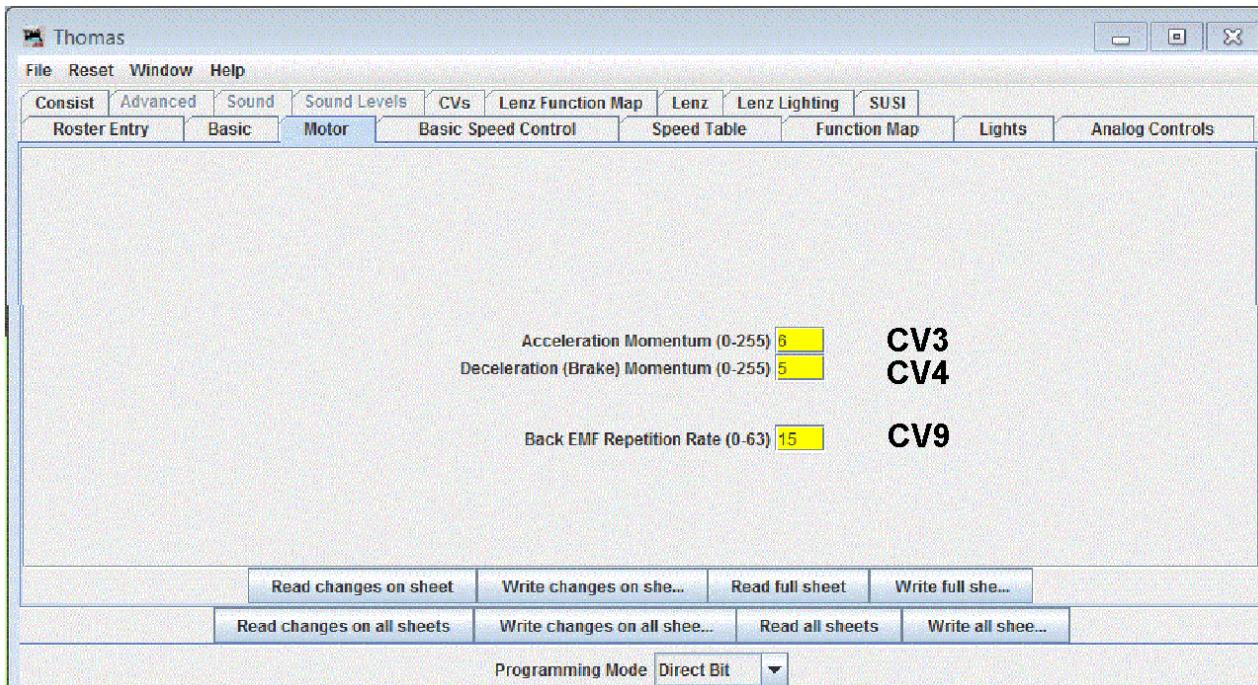
CV2

This sets the loco's minimum working voltage, so it stores a byte of data. The motor is supplied with this voltage as soon as the operator advances the speed control to the very first notch. There is no need to turn the speed knob part way round, just to get the loco moving.

CV5

This sets the loco's maximum voltage that will be supplied to the motor. So, for example, a shunter will be prevented from racing round the yard.

The screenshot of DecoderPro's '*Motor*' screen shows three options.



CV3

This sets the acceleration momentum. If you suddenly jerk the speed control higher, the loco will not take off like a bullet. Instead, it will gradually accelerate until it reaches the speed set by the command station. The rate of acceleration is controlled by the value stored in CV3 and may be different for different trains. For example, a small 0-4-0 pulling a long rake of coal wagons would be set to a slower than normal rate of acceleration.

CV4

This sets the deceleration rate. Having trains jerking to a halt is not very realistic, so CV4 lets you set the rate at which the train comes to a halt. Even if you suddenly reduce the controller's speed to zero, the train will slowly brake to a halt. Again, the value set will depend on the loco is an express train or a shunter.

CV5

This sets the BEMF repetition rate for maximum performance for that loco. See the chapter on Loco Controllers to remind you of how BEMF works. This option will not be present if your decoder does not support BEMF.

Here is a screenshot of DecoderPro's 'Speed Table' screen.



It is used for ultimate control over the speed of the loco for different setting of the command station's speed control. It is mostly used to match the performance of multiple locos, to allow smooth-running consists.

As you alter CV values, they are temporarily stored by the software. When you are finished altering values and setting, you write all the changes away to the decoder.

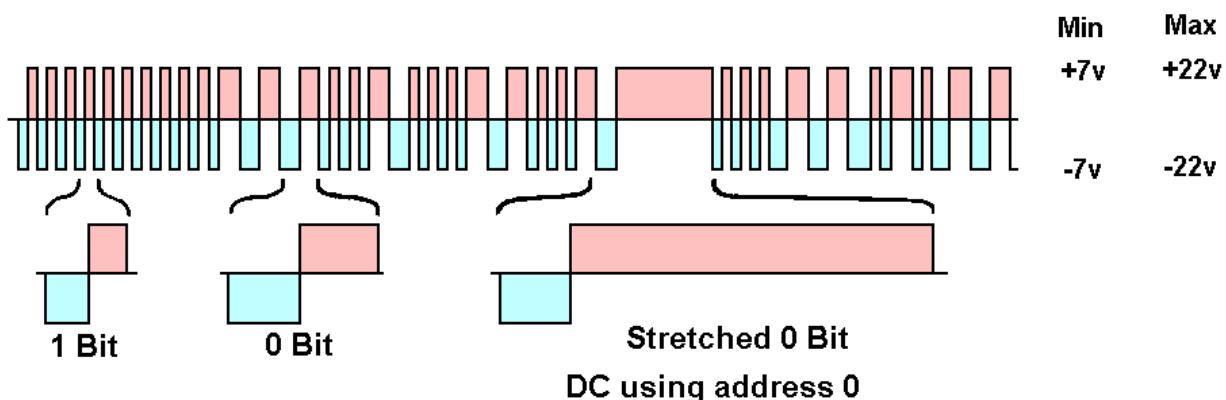
Remember, these are only samples to give you an idea of the process. Read the tutorials for more details.

The remainder of this chapter is for those who are curious about the inner workings of DCC. It is not required to use DCC, but it gives an insight into the way messages are constructed and handled.

Inside a DCC packet

A DCC command station sends both power and decoder instructions to the track – both at the same time.

The power is delivered as a continuous repetition of pulses, as shown in the illustration.



First it swings positive then negative, in what is described as '*bipolar DC*'. This is passed through a bridge rectifier in the decoder to obtain the DC power that the decoder, motor and lights use.

The decoder's specification calls for a minimum swing of 7V in each direction and a maximum of 22V. Here is a table of common voltages.

Common DCC track voltages, by gauge			
Z	N	OO/ HO/ O	Large scale
10V-12V	12V-14V	14V-16V	20V-22V

Since the voltage is constantly changing polarity, we can slightly alter the length of time it remains at any one polarity. In other words, we can alter the pulse width to introduce digital information on the signal.

In the above illustration, we can see that a shorter pulse represents a '1' logic while a longer pulse represents a '0' logic.

- A 1 bit last 58usecs (microseconds) positive and 58usecs negative – a total of 116usecs.
- A 0 bit last 100usecs positive and 100usecs negative – a total of 200usecs – although this can be increased to 9900usecs under certain circumstances.

This is the approximate equivalent to a 7kHz signal.

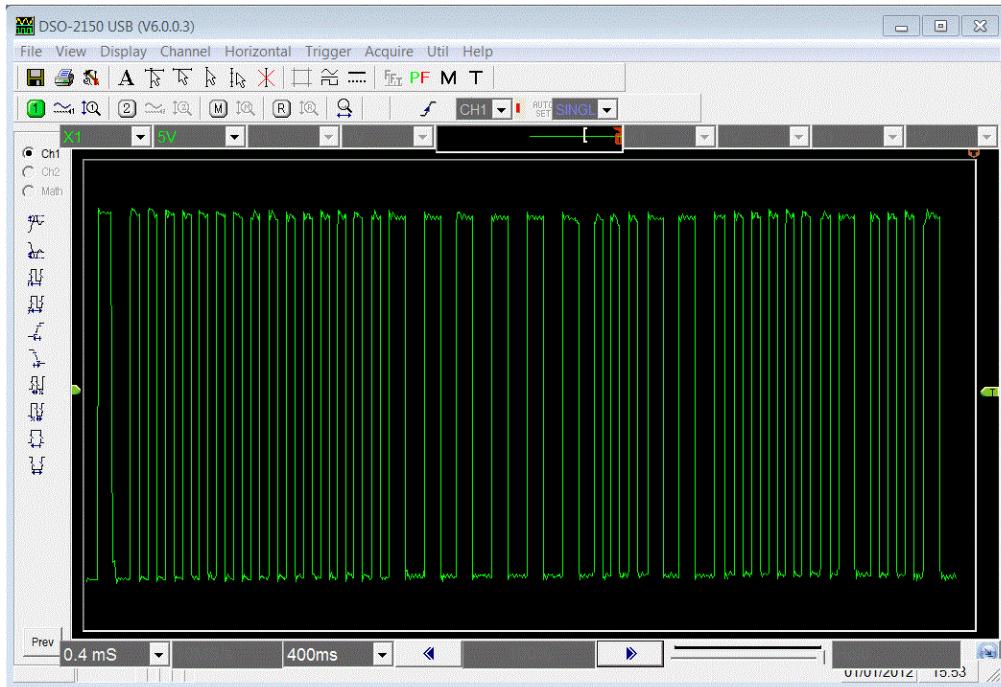
The command station's instructions to change speed, direction, etc. are encoded into a stream of 1 and 0 bits to send out with the DCC signal.

Note

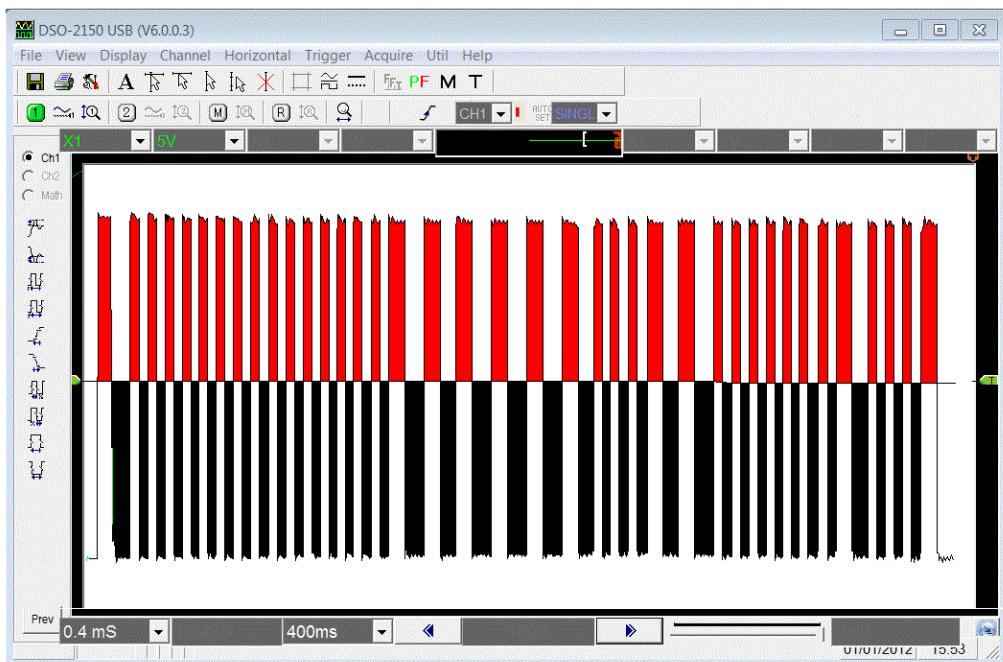
It is possible to run a single DC loco on a DCC layout, although not part of the official DCC specification. You set the command station to an address of zero and moving the speed control results in the 0 bit being stretched so that it appears more like a DC signal.

This image is an example of an actual DCC signal, as captured by an oscilloscope and shown unedited.

This is the signal that is sent out of the command station and this is what is received and processed by the DCC decoder.

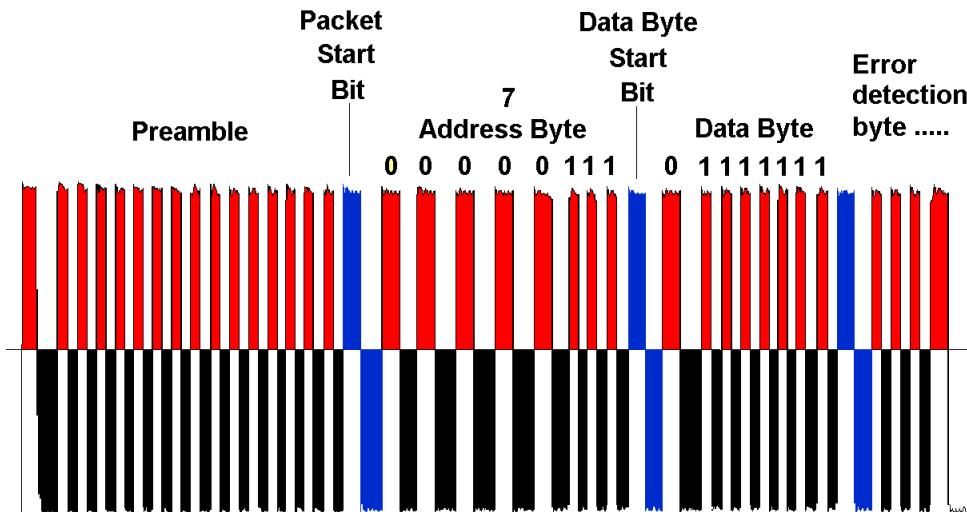


And here is the same image, edited so that the positive and negative transitions are more clearly identifiable.



Although it looks a bit of mess, it contains the DCC instructions, packaged in a way that does not get in the way of supplying the power to the decoder and motor.

This illustration shows how a baseline DCC packet is made up.



Both positive and negative transitions are used to provide power. From a packet point of view, the same information appears in both the positive and negative transitions. That is why the bottom section of the illustration is ignored.

The DCC packet is made up of several different parts:

The Preamble

This is a series of '1' bits that is used to alert decoders that a packet is about to be transmitted, allowing the decoder to synchronise its timings with the incoming signal. There is a degree of confusion on the number of bits required, with 10, 12 and 14 bits being stated from different sources. The answer lies in the NMRA Standard S-9.2:

"A digital decoder must not accept as valid, any preamble that has less than 10 complete one bits, or require for proper reception of a packet with more than 12 complete one bits. A command station must send a minimum of 14 full preamble bits."

The Packet Start Bit

This tells the decoder that the preamble is ended and the message data is about to begin. If the first bit of the message happened to be a '1' bit, the decoder would not know when the preamble ended and the message began. To prevent this, the preamble is always followed by a '0' start bit.

The Address Byte

This byte contains the address of the decoder that is to act on the instruction. All others with different addresses will ignore the rest of the packet. If the address is one byte, it is for decoders in the 1 to 127 range. For address above 127, there will be two address bytes.

The Data Start Bit

This informs the decoder that what follows is the instruction data.

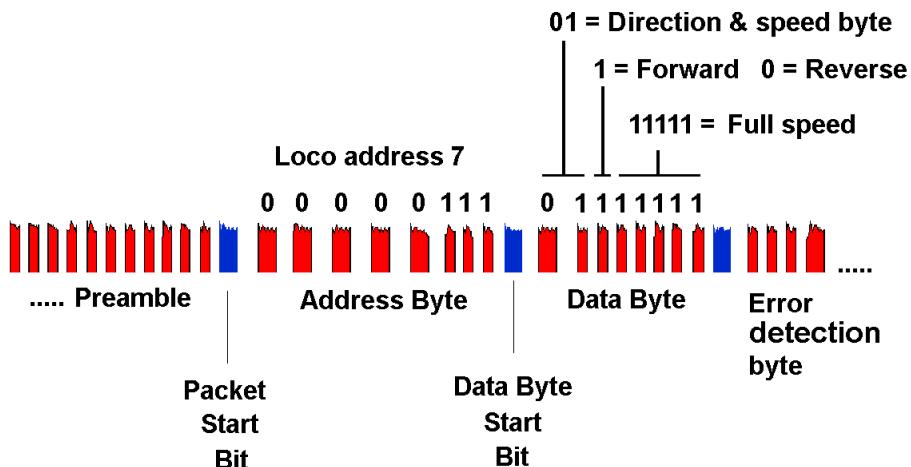
The Data Byte

For simple instructions, there will only be a single byte of data, with two bytes being used for more complex instructions.

The Error Detection Byte

There is the possibility of the incoming message being corrupted by electrical interference or interruption to the packet reception due to dirty track/pickups. To avoid acting on corrupted signals, the command station finishes the transmission of the packet with an error correction byte. This is a checksum on all the data sent in the packet. The decoder calculates its own checksum on the incoming data. If the two checksums are identical, the decoder knows that the packet is genuine; otherwise, it rejects the packet.

This illustration shows the actual message that was contained in the packet.



The Address Byte stored the eight bits 00000111. This is the binary number for 7, so the message was for the loco that is fitted with a decoder with the address of 7.

The Data Byte breaks up its 8 bits into three distinct groups of bits.

The first two bits stores 01 which indicates that what follows is loco direction and loco speed data. The next bit is a 1, indicating an instruction to go forward.

The remaining five bits are 11111, which indicates full speed (00000 being stop).

Handling errors

Not all the instruction packets arrive intact at the decoder end. Packets can get interrupted by dirt on the track or poor wheel pickups. Packets contents can also get distorted due to electrical interference. The error correction byte prevents incomplete or garbled messages from being acted on – but the packet is still lost.

In most circumstances, this is not a great problem, as the command station sends out the packets are repeatedly. So, if there was only one loco on the layout, all the packets would be directed at that decoder address. If there were three locos on the layout, each would receive their own packets on a time-sharing basis.

Given the pulse widths specified in the NMRA documents, a command station could issue up to 180 three-byte data packets per second. Where there is only a single loco on the layout, using a baseline working, it is capable of receiving 180 instruction messages per second. When there are 10 locos operating on a layout, they could expect to receive up to 18 instructions per second.

If the decoders are using extended packet formats, up to 110 five-byte packets can be sent every second.

Unless you are operating an extremely busy layout in a very harsh electrical environment, the loss of packets should not pose any problems.

Handling congestion

Although packet losses don't usually prevent decoders from eventually receiving their own messages, the lost packets represent loss of 'bandwidth' – every interrupted or corrupted packet is one less useable time slot. The command station can only issue between about 100 and 180 messages per second and every lost packet reduces the number of valid messages on the system.

Let us consider a bad case of congestion.

A layout is running 50 locos, each with an additional sound decoder.

The 100 decoders have to share the 110 packets per second, which mean that they might expect an average of 1.1 packets per second. If a decoder loses one of its packets, it has to wait about 2 seconds before receiving a duplicate message. For a speeding express, that might mean the difference between stopping and crashing into buffers or points, overshooting a platform, etc. This can be minimised using CV11, which is a packet time-out variable. This can be set to bring the loco to a halt if no commands are received after a preset time. Such drastic occurrences are not likely to happen on most layouts but designers have to consider the worst case.

There are a number of ways to combat congestion, with the main ones being queuing and prioritisation.

Once a decoder receives a command, it acts on and continues to act on that same instruction until it is given a new command. In theory, therefore, a single command should suffice.

In practice, as we have seen, periodic repetition of the command ensures that the packet arrives at the decoder.

At any one time, the command station is storing a list of all the packets that need to be sent out periodically. If there are too many additional incoming requests to the command station, there will not be sufficient time slots to send them all. The command station has to form a queue to allow all the packets to be sent eventually.

When there is a queue, the command station has to decide the order in which the packets will be sent out and this order could be constantly changing.

Decisions could include:

- Placing new packets ahead of older packets in the queue, since it is likely that the older packets have already been received by the decoder. This regards responding to changes in the system as more important than the repetition of older messages.
- Placing packets controlling sound and/or functions ahead of speed and direction messages. This recognises that the operator does not make rapid speed changes in any given time period (human movement being slow compared to the speed of the system).

If the system supports feedback, track occupancy sensors would be given a high priority, as they affect a loco's speed and position.

Advanced consisting, also called Decoder Assisted Consist, saves packet bandwidth by having a single command station packet controls all the locos in a consist.

With the use of congestion controls, several hundred locos can be run simultaneously – more than most operators could ever imagine

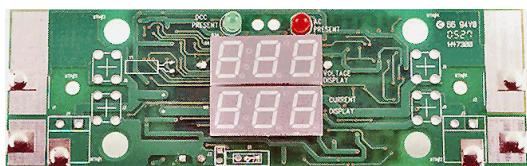
Measuring DCC voltage

Checking for the presence of a DCC signal is easy enough. You can use a car light bulb, a LED with a dropper resistor, or a multimeter set to the AC range. They will all tell you if DCC is available at the point you test. If you use the multimeter, it will also tell you if you are suffering from any voltage drop at any point, just by comparing the reading with that leaving the command station.

Getting an accurate measure of the DCC voltage is a little more complex than you might first imagine.

You can avoid any problems by using the RRampMeter by DCC Specialities, available from DCC supplies and Digitrains. Although expensive, it has a 2% accuracy.

Just connect the two left-hand terminals to the point to be tested, to get an accurate reading of the DCC voltage at that point. It is designed so that these terminals can be held across the track, making for a quick check on voltage presence and amplitude. It can be used as a hand-held tester or it can be permanently installed in a control panel. It can also read current, as described later.



Expensive models aside, most multimeters are unable to accurately read DCC voltages.

Multimeter on DC range

To measure DC, you just place a multimeter's leads across the controller's output terminals. However, DCC is more like AC, since its polarity constantly switches (hence its description of bipolar DC). So, every pulse of one polarity is followed by a pulse of the opposite polarity – cancelling each other out and producing no meter reading on DC.

The only exception to this is to set the command station to address 0. This places the output in DC compatibility mode and provides a reading, although not too accurate.

Multimeter on AC range

Most digital multimeters are designed to read voltages that are derived from the mains supply (i.e. either reading the mains voltage or the AC voltage output from a transformer). They expect AC readings at 50Hz (UK, Australia, etc.) or 60Hz (USA, Canada, etc.) and also expect the waveform to be a sine wave. The meter's electronics makes the necessary '*averaging*' processing prior to displaying the reading based on these expectations.

DCC though, operates at a much higher rate (approx 7kHz) and is not a sine wave. The meter cannot sample at a fast enough rate and this introduces readings that can be anywhere between 10% and 40% different from the true voltage. These readings are, at best, only a guide or can be used for comparison purposes.

Using a true RMS meter

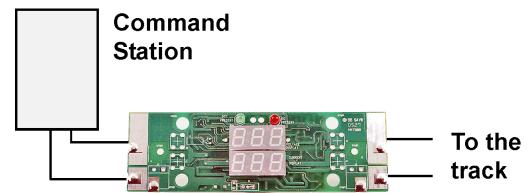
A meter than can accurately report voltages on waveforms that are not sinusoidal is known as a '*True RMS*' meter. A commercial example is the Fluke 115 for industry or the RRampMeter for model railways.

Unlike the cheaper average responding meters, true RMS meters can sample faster, process better and produce much more accurate readings.

If you know someone with a True RMS meter or a RRampMeter, you can compare the readings with your own meter, note the difference and use it in future meter readings.

Measuring DCC current

Like voltage, getting an accurate reading of DCC current requires using a True RMS meter. The illustration shows the RRampMeter connected between the command station's output and the track. Wired this way, it gives readings of both DCC voltage and current (assuming that there is a load on the track such as a loco to draw current). The meter can read up to 28V and 10A.



DIY projects

The RRampMeter, sells for over £70 at the time of writing, which is around the same starting price for industry's digital True-RMS meters.

If you are looking for a cheaper, homebuilt, alternative, try out the projects that are explained on these websites:

<http://www.wiringfordcc.com/track.htm#a4>

<http://www.circuitous.ca/DCCammeter10.html>

http://www.members.optusnet.com.au/nswmn2/DCC_Meters.htm#Ammeter

A DCC 'sniffer'

If you are adventurous and feel the need to examine the DCC packets, have a look at:

www.opendcc.de/elektronik/dcc_sniffer/dcc_sniffer_e.html

The module shown connects to the track and plugs into a computer's USB port.

The software description reads:

"This software allows for a complete tracking of all commands on the rails as well gives sophisticated trigger features to capture only special events. Local LEDs provide a quick overview of the status and the actual DCC commands."

