Mick Moignard's Digital Topics – updated from ScaleFour News articles

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Forewords

Jim Summers, onetime editor of Scalefour News.

Mick Moignard was demonstrating DCC things at the Scaleforum show a few years ago, but I wasn't really in the market for going over to DCC. So it was his D&RGW narrow gauge loco, which caused me to pause: that line is an old passion of mine. The loco made steam engine type noises, and I began to concentrate. "Of course, there is nothing like the old PFM sound system", I insisted to Mick, being rather proud of my prowess on that control system on the famous Castle Rackrent layout (now nearly 40 years old, good grief). "You can shut off the steam and coast to a stand, just like the real thing", I pronounced, "and you can't do that with your modern DCC stuff". Mick didn't argue – he is far too nice – he just made the D&RGW loco speak for itself, if you follow me. And it made more sounds than just chuffs. It was getting serious. This chap knew what he was talking about and moreover, could explain it patiently to a sceptical soul like me. But could he explain it to my wife, I wondered.

So, swiftly donning my Scalefour News Editor's hat, I asked him to write about the wonders of DCC for the members of the Scalefour Society. Not only did he not say "no", he went on to produce a series of articles which aroused enormous interest. His objective and informative overviews of the various aspects of DCC became well thumbed in my house certainly. Now, I can't claim my wife read every word, but she did say that I had better get one of those DCC sets. A good man, that Mick Moignard.

Nigel Cliffe, Chairman 2mm Scale Association

I first came across Mick Moignard somewhere on the internet in a discussion about DCC. A few years later, just after I had started experimenting with DCC, his series of articles appeared in Scalefour News. I read them and found lots of ideas and concepts to start researching.

Sometime around the beginning of 2009, I was asked to recommend a book to someone who was considering DCC. I couldn't think of one. I had Mick's articles, which were passed to this person. They were what was needed, and another modeller started in DCC with confidence in what he was doing rather than guessing at where to start.

A little while later, I asked Mick if the articles could be made available for other readers. A few chats were held by email and in person, and the result is this document. There were a few details which were updated to reflect changes in what is available commercially, though the vast majority of Mick’s words from a couple of years ago accurately describe how DCC works, what it can do for the modeller, how to install for reliable running and what to consider before making any purchases; be it an expensive system or a single decoder. Along the way, it knocks a few myths on the head.

Like much model making, what is possible with a DCC system is down to the modeller making use of things in intelligent and imaginative ways; you just need a few clues on where to start.

Preface

What you're reading now all started when I was asked by John Chambers of the Scalefour Society if I would do a lecture at Scaleforum 2004, talking about Getting Started in DCC. That must have gone down reasonably well, because I was asked again to speak at Scaleforum 2005, and to join the gang of demonstrators there. Given that I'm not a P4/S4 modeller, I felt both flattered and honoured to be invited. It was after the 2005 show, when Jim Summers, then the editor of Scalefour News asked me to write for him, I started to feel almost like an imposter. But both Jim and his successor, John Bateson, made me so very welcome, and the resulting series of articles ran in Scalefour News from issue 146 in February 2006 to number 158 in July 2008.

Much more recently – indeed at Warley 2009, Nigel Cliffe asked me whether the articles could be made more widely available. His reasoning was that there aren't many decent books available in the UK on the DCC, particularly recent ones. I'm pleased to say that Scalefour News were more than happy to see these articles reproduced, and I thank them for that, but rather than just reprise them, I've taken the liberty of a little re-editing, and doing some updates. The first article was written over four years ago now; DCC hasn't stood still in that time. Indeed, in the period since the series started, DCC has clearly moved from specialist tool fully into the mainstream of railway modelling. Even the ready-to-run manufacturers have moved from ignoring it to embracing it, to recognizing that they got it wrong first time round, to their second generation of systems and decoders. What's needed now is to see more DCC layouts on the exhibition circuit, to show off all the advantages that DCC has, not just for exhibition layouts but also for home layouts. Now I can speak from direct experience here, being part of the team behind Parsons Lumber Company, Camp 93, an On30 US logging layout that's been shown since late 2005 – do come and say hello - as well as my home layout, built since 2000 as a DCC-powered layout.

So, here with some updating and re-editing, is the ScaleFour News series, all in the one place. I sincerely wish, and fervently hope, that you get as much fun from reading them as I got writing them, and that they inspire you towards better operation, better operating, simpler to build, and more realistic layouts as a result.

Acknowledgements

This set of articles didn't happen just because of my efforts. There's a number of people who've been involved along the way and who have in one way or another influenced me, and I'd like this opportunity to thank them.

I've been modelling the Denver and Rio Grande Western 3-foot gauge lines in HO scale (HOn3) since the late 1970s, but until 2000, with no layout. One of the reasons for that was my memory of how complicated DC wiring became to be able to operate more than one loco. I'd seen and looked at some of the old carrier control systems, but could not see how to get the receivers into HOn3 locos. I'd been following for some years, though, and by 2000, started to conclude that it was then mature enough to do what I wanted to do. I also realised that if I purchased a system, it would spur me on to start to build the layout. I now had the space that I'd been lacking previously, so that barrier had been removed. So I contacted my local DCC dealer, Sunningwell Command Control, which then as now, is operated by Ted Smale. He set me on the right lines by letting me play with his Digitrax-controlled HO layout, showing me the system components and assuring me that DZ121 decoders would go into HOn3 locos, which they did. Ted, then as now, was always patient, caring and knowledgeable with all the questions that I had.

From that time onward there was no stopping me. I guess I probably bored a few fellow members of the Risborough and District Model Railway Club pretty much rigid over the next few years – that is, until they saw the DCC light themselves, of course. Now most of the members are also confirmed DCC users, and that's given me strength.

David Lane, a fellow member of the RDMRC, is a leading light in the ScaleFour society. It was he who put John Chambers in touch, which led to my lectures at Scaleforum and spawned the idea for the original articles. And of course my Scalefour News editors, Jim Summers and John Bateson, who agreed a series outline and kept me on the path and my deadlines while the articles were being written.

Richard Turner, co-owner and leader of the Camp 93 layout project plays a part,. He's pushed and encouraged use and knowledge of DCC as we built and extended the layout. We planned Camp 93 right from the start not just to be completely DCC operated but also intended that we would only operate fully sound-equipped locos. We intended right from the start to use it to showcase what DCC can do, from a simple and practical standpoint, using locos and rolling stock that are openly available. As we operate from the front, we've had innumerable conversations with the show audiences about DCC, and I'm sure we've both learned greatly from these. If you see us at a show, do come and

say hello.

Finally, to Nigel Cliffe, who cornered me at the 2009 Warley show, and asked me to mke these articles available again. Nigel's been a key part of many of the updates since 2006. I thank him for his input, encouragement and suggestions, particularly in the updates to the comparison table of systems that appears at the end of chapter 2.

Updates Log

November 2010: Updated the system comparison table in section 2 to replace the Digitrax Zephyr with the new Zephyr Xtra. This supports 29 (F0-F28) functions on the keypad – up from 10 (F0-F9), 20 extra throttles, has 20 slots, and is now a 3-amp system supplied with a PS314 multivoltage transformer.

1. What is DCC, and Why?

DCC is now a part of mainstream, serious railway modelling. More and more layouts seen at exhibitions or which are written up in various magazines use DCC, yet to many DCC is still a mystery. What I'm hoping to do in this series of articles is open your eyes to what DCC can do, and explain why I think DCC should be a part of every new layout. I'm going to discuss various aspects of choosing and buying DCC systems and products, how to install them and use them, drawing on my experiences of over five years of using DCC. That five years is mainly from building and running my room-sized HOn3 (HO scale, 3foot gauge prototype, 10.5mm gauge model) layout but also includes experiences in OO, HO standard gauge, O scale standard and narrow gauge and a little in P4.

Command control (the "CC" of DCC) is not a new concept. There have been many command control systems marketed in the past, Hornby's Zero-1 springs rapidly to mind, and in the US, Keller OnBoard and Dynatrol were two of the leading brands. Strictly, most of these were Carrier Control systems, but the main principles and objectives were the same.

Command or carrier control differs from conventional control in that it moves the actual motor controller from the line side into the locomotive itself. The reasons for wanting to do that have always included the following:

- The fact that the system has a constant voltage on the track at all times, with the control signals somehow overlaid upon that. The constant voltage means that pick-up issues are eased, particularly at low speed, because there is full voltage available all the time.
- Layout wiring is simplified, because there is no need for any block wiring or any block control panels. That improves layout reliability, too, because there is less to go wrong. .
- Placing the motor control close to the motor (often within an inch or two) means that the low voltages and current draws used to turn motors slowly are not attenuated by yards and yards of wiring, connectors and rails. Again, more reliability.
- Lastly, because each locomotive carries its own command receiver, called a decoder, it is possible to tune each one to more closely match the motor, rather than as with conventional DC control, having one controller to operate all the different motor types that appear on the layout. And you have the ability to operate additional functions on the locos, such as lights, firebox glows, and so on. Even carriage lighting that you can switch on and off becomes completely practical.

Older command control systems had a number of problems, however. There was the issue of compatibility - or rather, complete lack of. A locomotive fitted with one system could not be used on another, or, in most cases, on a standard DC layout either. And unfitted locomotives could also not be used on a command control layout. Then there was the matter of the size of the locomotive receivers. Most were so big that they could only be fitted into O scale locos or in 4mm or HO, large diesels where there was plenty of open body space. 4mm and HO steam, narrow gauge and anything in 2mm scale or N-gauge were pretty much ruled out. There was also the matter of cost - these systems were not cheap, and of the fact that these systems were quite limited in the number of locos that could be handled. This meant that few people used such systems, because they offered little real advantage over standard DC control.

DCC has changed all of this. Firstly the D bit of DCC: it stands for Digital, unlike the older systems which used analogue signals on the rails. These days we are surrounded by digital electronics, not just computers, but television, mobile phones, cameras and so on. Digital electronic components are smaller, use less power, are more reliable and infinitely more capable, and of course, cheaper, and getting even cheaper almost by the day. Such things have fed into DCC, and all helped to move it from a minority specialisation into the mainstream of modern railway modelling.

Next, DCC is standardised. Bernd Lenz, a pioneer of DCC, made his technology available to the US National Model Railroad Association (NMRA). The NMRA published the standards and encouraged other manufacturers to sign up and produce equipment to match. The standard, by the way, is all about the signals on the rails, how the DCC system must feed the signals into the rails, and how the decoders interpret those signals and run the motors, lights and other effects on the locomotive. It also covers accessory decoders for driving point motors, signals and other line side pieces of equipment. It does not describe how the control parts of the system interface with each other, and it is not restrictive either. So long as a decoder implements the NMRA functionality, the manufacturers are free to add extra functionality to distinguish their products from others. The value of the standard is that decoders from any manufacturer can be used with any other manufacturer's DCC system. That means that the manufacturers compete with each other for our modelling money by delivering what we ask for; high-quality systems and decoders that are cheap, work well, are reliable, have good functionality, and are easy to use.

But still there is the question of why use DCC at all. Well, the best answer I ever had was from the HOn3 Yahoo Group, from an American called Scott McLeod. I'm sure he won't mind me quoting him: "I've had two layouts in my life. Both were walk around representations of the Rio Grande Southern [a 162-mile 3-foot road in south-western Colorado]. My first layout used block control and a command system. It was set up for four cabs. I found that you spent 75% of your time dealing with the block system versus running and watching your train.

On my current layout that is equipped with Easy DCC [A brand of DCC system], I find that you spend maybe 5% of your time programming the decoders and setting up the locomotives. The rest of the time you spend running and watching your trains. I have six cabs on this layout. There is simply no comparison if you are talking about multiple operators." My experience mirrors this; with DCC you run trains. You are not operating control panels and block switches. You are running trains.

A DCC system consists of three main components. The heart of the system is the Command Station. This takes the inputs from the next piece, the controllers, usually called Throttles, and converts them into the standard DCC signals. Lastly there is a device called a Booster which amplifies the DCC signal by adding the power (voltage and current draw capability) required to operate the layout, and also transmits those signals to the rails. In most DCC systems the Command Station is combined with a booster in one box, and in some (ESU's Ecos, ZTC's 511, Digitrax's Zephyr, Hornby's Elite) all three, throttle included, are combined. NCE's PowerCab is also, for all intents and purposes, in this list, as you can't unplug the handset, as it contains the command station. For larger layouts, extra boosters may be added to ensure that enough power is available to run all the trains required, all driven from one command station. Most systems have a network or bus system that allows extra throttles, almost always hand-helds, to be plugged in. Many of these network/bus systems also provide for other devices to be added, such as accessory decoders that report back what they are up to, computers, and so on. Nearly all DCC systems allow you to start at a simple level and grow the system as your needs change, and of course it is always easy to move the system from one layout to the next.

So, these three components combine to take the throttle commands, and get them onto the track as a DCC signal. There it is picked up by the last component, the decoder. The signal on the track is frequency-modulated AC, with a square wave form - the fact that the net voltage is zero also helps to reduce the collection of dirt on the rails. The amplitude of the wave, which, depending on the system and its configuration, is somewhere between 12-17 volts, provides the power. The digital information is carried by the timing of the phase changes. A phase change in less than61microseconds is a 1-bit (actually it should be between 55 and 61microseconds). Zero bits can be much longer, and as we shall see later, are also used (Zero-stretching) to drive a DC loco on a DCC layout. Not that, apart from some side-effects of using zero-stretching, the average modeller needs to know any of those details.

These digital signals carry both control and power to the decoder. The decoder interprets them and acts upon them, powering the motor and other functions such as lights, smoke and sound. So, if the command station sends a signal that says "locomotive 71, proceed in reverse at step 20, with function 0 turned on", then the locomotive whose decoder has been set to number 71 will start to move in reverse, and quite possibly will also have its headlight turned on, depending on exactly how the decoder has been installed and programmed. No other loco will move, even though it might be sitting right next to loco 71.

The last, but by no means least, component of a DCC system, is the power supply. Unlike an analogue layout, a DCC layout is wired such that all the track is live, all the time. All the locomotives sitting on the track are listening for commands, and depending on the system in use, may be moving, or just sitting still with some lights on. The layout needs to have enough power for all this to happen. Consider a conventional, medium sized, double-track oval exhibition layout. This might have six cabs; one for each main line in the visible section, two in the fiddle yards - one in each direction, and a goods yard and loco shed each with a cab. If those six cabs each are able to power a locomotive with possible maximum 1-amp total draw, then 6 amps of power supply is required. Most conventional power packs put out around 12va to 18VA, which means 12-18 volts can be supplied at one amp. We don't often draw all that, but what it does mean is that the potential is there. And so with DCC - the one booster needs to be able to do all of that, and so rather than a number of small 1 to 1.5 amp transformers, we need one large one of considerably higher capacity to run the system. A 5-amp DCC system - most high-end systems are 5-amp capacity or more - needs a 5-amp capable power supply.

In later instalments of this series we will explore many of these facets of DCC further. Next time we'll explore choosing and buying a DCC system. We'll explore the key features of DCC systems and which ones I think are important, and present a comparison of some systems. Just remember that the DCC standard means that "There's no right DCC system, just the right one for you".

2. Choosing and Buying a DCC System

Buying a DCC system is likely to be one of the larger purchases you make for your railway. That means that you need to get it right. There are a lot of DCC systems on the market, ranging from what are to be honest, toy train controllers, through to full function and fully expandable systems. Because of the expense involved and the time investment that you do need to make to get the best from DCC, you need to make an informed choice. As I said last time, there is no right DCC system, but there is the right one for you.

So let's look at some of the things that you should take into account in making a system choice. Here I'm looking at what the system itself will do; I'm not discussing decoders at all in this article. That's because all decoders will work with all systems, because the DCC signal on the track is a standard. That's not to say that every feature of every decoder will work with every system, for example you need Digitrax transponder detectors to work with Digitrax transponding decoders. But by and large, you buy the system that meets your needs and the decoders that meet your needs from the manufacturers that offer you your best choice.

Support.
This is one of the most important parts of your choice. You've got the boxes home. You've opened them up, set up a piece of track on the dining room table, and something isn't right. You don't know if it's because you've done something wrong, something wrong with the system, or what. You need some help. First off is the documentation that comes in the box. And as most vendors post their documentation for free on the web, download it and read it before you make your purchase. If you don't like the documentation before you make the purchase, you might not like it afterwards, either. Once you make the purchase, read the stuff, again, too. You've paid for it, and unless you do read it, you won't get the best from the system.

You'll get most of your initial support from the dealer. Your dealer should be prepared to help you make the best of this purchase, especially if you are thinking of buying a mid or top-range system. In fact, if the dealer cannot explain these products to you and let you play with them, then I, for one, would go elsewhere. It is worth paying a little bit extra to buy from a local dealer, one who is himself a modeller and user of the system, than it is to buy from a discount box-shifter who has little or no product knowledge and no incentive to share what he knows with you. I ended up counting my DCC dealer as a firm friend, and I operate on his home layout from time to time.

Use your friends, too. If you know someone who likes or dislikes a particular system, use that recommendation as you make your choice. Remember, too, that if you have the same system as someone else, you'll be able to operate their layout really easily, and them yours - just remember to take a throttle with you when you go.

Finally, most systems/manufacturers have a committed chat group on Yahoo or elsewhere. These are absolute gold mines, and not just for novice users. Here you are likely to find someone who has already seen and solved the problem you have, and who will help get you moving. You will read all manner of gripes too. Just take them with a reasonable pinch of salt.

Now let's start looking at some functional aspects of a DCC system, and how these can affect your choice.

2 or 4 Digit Addressing

Each locomotive decoder is given an address. You select that address on the throttle to operate the loco. All DCC systems can do 2-digit addressing. All middle and all top-end systems can also do 4-digit. Most DCC users use the number painted on the side of the loco as the address; it's simple and pretty foolproof. With a two-digit system, just use the last two digits of the number. After all, there are 99 to choose from, right? Yes, true, but in my case, I have locos 361 and 461, and 278 and 478. Ok, so use the first two digits - but then what about 490, 494 and 499? You need to keep it simple, and the last thing you want to keep a crib-sheet of which loco has what address, though I have seen that used. A 4-digit system gives you more space to play with. Now, I know that BR steam and diesels mostly have 5-digit numbers. Modern-image DCC users I know work with the convention of using the class number and the last two digits, so avoid owning 37005 and 37605! With most BR regional steam, you are safe dropping the first digit.

Do be aware that some cheap systems, such a Bachmann's EZ-command, and also some not so cheap systems, may hide the addresses that are given to locos from you, too. EZ-command gives you 10 buttons, and you assign a loco to each. What you don't know is what address it has given the loco. If you take it to another DCC layout, how will you know what address it has?

I recommend a 4-digit system. It may cost a little more initially, but you will save in the long run.

Programming Modes

DCC systems need to be able to program decoders as well as operate trains. You use the programming mode of the system to set the loco address, and then to set everything else up in the decoder. I'm not going into programming in any detail here, suffice it to say now that it is not a complex process with most DCC systems; simpler than setting up many video-recorders.

There are two main methods of programming decoders: Service mode, which uses a dedicated programming track, and Operations mode, which works while the loco is running on the layout.

Service mode, with the programming track, has to be used to set locomotive addresses. It can and usually is used to make all the other settings, too. These are stored in the decoder in Configuration Variables, or Cvs - we'll go into detail about these later. For mostly historical reasons, there are three sub-modes of service mode programming, called Paged, Direct and Register mode. I'm not going to go into the details of these, but you do need to be aware that not all DCC systems can do all of these three modes, and not all decoders can be programmed in all of them. Register mode (also called Physical Register mode) is the oldest, and can only be used for a small number of variables. Most modern decoders can do both Page and Direct mode, but not all - for example, CT decoders from Austria cannot be programmed in Page mode. It's a good idea to make sure that the system you buy supports both Page and Direct modes.

As to connecting a program track, all top-range and many mid-range systems have a separate program track output. Many cheaper ones do what is called Broadcast Write programming. That means that the Service mode programming track outputs are the same as the layout is connected to. It is up to you to connect the layout when running, and the program track when programming - via a DPDT switch, for example. I very strongly recommend that you avoid Broadcast Write systems, because it's all too easy to program everything on the layout at once, by forgetting to flick the switch. Everyone I know who has one tells me that they done just that on at least one occasion, and often more than once.

Most middle and top-end systems can interrogate decoders while on the program track, and tell you how CVs are set, a process called Decoder read-back. Some cannot. If you plan to use a computer and a program such as DecoderPro to help with decoder programming, don't buy a system that cannot do decoder readback. It is very frustrating to be that blind. If you make a programming mistake without decoder readback, you are likely to have to reset the whole decoder and start again - but can you remember all the other CVs that you'd programmed?

Lastly, OPS mode, also called Programming on the Main. This is probably something that you don't see the value of, until you use it. With it, you can set CVs in a loco while it is on the main track, and see the effect straight away. You do need to use decoders that support OPS mode, but virtually all modern decoders do. Without OPS mode, you have to put the loco on the program track, set the CV in question, put it back on the layout and test it. OK, for lights, you could do this on a yard of track on your workbench and flick a switch, but if what you want to do is speed match one loco with another, with both running, there is no substitute for OPS mode. To my mind, OPS mode is one of the absolute must-haves in system choice.

In summary, then, you need to have:

- both service and ops mode programming.
  Here I'm afraid that we have to rule out ZTC, as they do not support OPS mode in their systems.
- paged and direct mode program-track programming. Register mode isn't really important any more.
- decoder readback
- separate program track output - no Broadcast Write.
  That rules out the Digitrax's DB150, as used in their Empire Builder range of starter sets, and also Zimo's MX1ec command station.

Programming support is one of the situations where buying a cheap system can really be a false economy. Many cheap systems just do not properly support all the decoder programming capabilities that you may well need, to do such things as motor and back-EMF tuning, and setting up lights. I mean, just how annoying would it be to buy a new sound decoder and then find that your system can't program it? Which also means that if you do make a mistake and buy too simple a system to start with, you may not be able to relegate it to the workbench, either, because that's where you will need some of these programming capabilities.

Consists

One of the great things about DCC is the total freedom to be able to operate several locos at once, and it won't be long before you start playing with that. Not only can you double-head, but you can also couple up to and then move "dead" locos around the engine shed. To do that, you need a system with the ability to do double-heading, called Consisting in DCC-speak. You do need to use locos that are reasonably well speed-matched to get the best from consisting.

As a Digitrax user I can operate two locos simultaneously merely because the standard DT402 Digitrax hand-held actually has two throttles on it. But DCC actually offers three consisting modes. All systems can do basic consisting, where the locos to be consisted actually have the same address and the system itself knows nothing about what's going on. Each loco with the same address responds to the commands sent. Simple, but not very flexible.

Next is Advanced or Decoder-Assisted consisting, which uses a consist address in the affected locos, and which requires OPS mode programming or a trip to the program track to set up. Both these are of most use when locos are semi-permanently coupled, such as a class 20 diesel pairing. Advanced consisting also allows you to set up how the locomotive will respond to function keys when it's consisted, both as the lead locomotive or as a secondary one. That makes a difference with lights and sound, where you want the lead locomotive only to respond, while you may want other functions such as brakes or shunt speed settings to apply to all the locomotives in the consist. Some systems - NCE for example - make setting up and breaking advanced consists very simple.

Then there is command-station consisting, also called Universal consisting. Here only the command station knows about a consist. It sends the same command to all locos in the consist (actually, only speed and direction commands; other commands for lights and sound still have independent per-loco control), and in most cases, the command station also takes account of which physical direction the locos are facing. With my Digitrax system, Universal consists are made and broken up with two keypresses, and adding third and fourth locos are little more effort. It can operate Universal consists of nose to nose or tail to tail locos as well as those facing the same way (note that not all systems can do that; ZTC's 511 requires the locos to face the same way).

Whichever method you use, the end result is that once the consist is set up, you drive with one throttle knob, and all the locos respond and move together. As well as the conventional use of double-headers, I use consists to manage rear-end helpers that are marshalled inside the caboose, and also to allow one locomotive to move other (apparently) dead locos around in my engine shed area - with the sound on the dead engine muted, this is very attractive.

Slots and Power

The number of available slots in the system is the maximum number of locos that the DCC system can keep track of. To be completely accurate, it is the number of decoders that the system is refreshing all the time. You might say that you only need to run four trains at once on your layout, but given the freedom that a DCC system will bring, should you consider more? And, if you consist locos, you may in fact have more locos active on the layout than that. Then, consider that as the whole layout is powered, all the locos are listening for commands. Now add coach lights to that (did I mention that DCC not only operates superb constant coach lighting, but you can use function-only decoders to enable you to turn the lights on and off in them?). You soon end up with 10 or 20 decoders being refreshed all the time. And each different address occupies a slot in the system.

Simple systems support maybe 10 slots. You are likely to be able to reach that limit quite easily, even on a small layout - 10 locos. Larger systems support many more - such as the Digitrax Chief at 120, or Lenz's Set-90 and Set-100 which can support 256 slots. Do not fall in to the trap that as you only have three locos now that you might not want more in the not too distant future. Consider a 10-slot system as an absolute minimum, and think about going for more.

Allied with the number of slots is the amount of available power. We've already noted that every loco on the layout will be alive; I grant you that if it is not moving and has no lights on, its draw is minimal, less so if it has sound too. In 4mm scale, a moving loco is unlikely to consume more than 0.5 amps if it has a modern coreless or can motor. Older RTR-based locos may consume up to an amp or so. If you are a Modern traction fan, you will want to add some lights to that, too. So an HO or 4mm loco needs to be considered at between a half and one amp, with O-scale locos being towards or even over the one-amp level. Now, with the freedom that DCC gives, you'll start to find that you have more locos moving than you did on DC. It's quite possible even on a small layout to have two or three locos on the move at once - with a combined draw which could be in the two amp region.

Or look at it another way. Many conventional DC exhibition layouts have three or more cabs; each with a one or one-and-a-half amp supply. That's 3 to 4 amps supplied by conventional controllers. Why should a DCC layout be any different? The only difference with DCC is that all the power is supplied at one place. Which is why most larger DCC systems supply 5 amps or more to the layout to ensure that there is enough power to do the job properly. So, if you are thinking anything beyond a really quite small layout, you should look at a system that delivers at least 2.5 - 3 amps and preferably 5 or more. Don't forget that you will also need a suitable transformer for this. You cannot run a 5-amp DCC system from the auxiliary outputs of an old 1-amp transformer - well, you can, but it is not safe to do so. The DCC system won't see a short until its rated current is being drawn. If the power supply cannot deliver it, then it won't shut down. The continuous draw risks damage to models, to wiring, and in extreme - or even not so extreme - cases, starting a fire from the electrical overheating. We'll come back in a later article to the simple rules of layout wiring and testing to deal with this risk.

The Throttle

DCC throttles come in two flavours, just as analogue controllers do. There are fixed-point controllers, which tend to be throttle and command station all in one box, and there are hand-held throttles. Most, but not all, of these are memory walkround types which can be unplugged and plugged back in again without affecting running trains. Many manufacturers of larger DCC systems offer more than one throttle type, too, You'll find that every system has a throttle or base unit that will do everything the system can do. Most ranges have simpler (and cheaper) throttles that can just run trains, and not do any programming, and some have add full-function units.

First consider whether you want a fixed location or hand-held throttles. Most low-end systems are the all-in-one box type, and often have little more control capability than old DC throttles. Most train-set controllers like Hornby's Elite or Select are like this.

Further up are full-function systems that are still tied down to a fixed location. ZTC's 511 and 505 are like this, as is Digitrax's Zephyr and ESU's Ecos system. All these allow with extra hand-held throttles, as do some lower end systems. Remember though, that low and middle-range systems, as we have seen, tend to be limited in power output and number of slots, so you won't get very far in terms of running trains by adding more throttles.

There are also a small number of systems where there is one hand-held throttle that acts as the command station, and which cannot be unplugged. The most commonly seen system like this on the current market is NCE's PowerCab system; though Uhlenbrock's Daisy is also configured this way.

At the top are systems which only have hand-helds. Digitrax's Chief, with the two-knob DT400 throttle is one of these, as are Lenz's Set-90 with its single-knob handheld, or the Set-100 with an all-pushbutton throttle. NCE's ProCab system has a large handheld, and so does Gaugemaster's (re-badged MRC) system. Bachmann's Dynamis is also in this family, but unlike the others, the handset connects to the base station by Infra-red, not via a cable (think rechargeable batteries here). It's soon to be joined by Digitrax's new Duplex radio system, which offers the choice of plugging in or unplugged operation. There are also a number of European systems that are now offering radio - Roco's Multimaus, ESU's Ecos, and the venerable (and some say useless) Lenz solution that uses a digital cordless phone as a handset. While we mention radio, don't fall into the trap of thinking that the radio DCC system you can buy in the US will be OK to use here - it's very likely to be illegal, operating on 900Mhz or other frequencies not available here. Check carefully before buying.

Choose carefully here, because what looks attractive at first meet may turn out to be awkward to use when you get acquainted to it. Ask other users what they think, try to get a chance to operate a layout with different systems, and choose from some personal experience. If the shop won't let you touch and feel the throttle, or better, operate a layout with it, look elsewhere. You may feel somewhat bewildered first time you see a Digitrax DT400 or NCE PowerCab, but believe me, you will be able to operate the key functions quite quickly just by feel.

By and large you cannot intermix throttles from one system with throttles from another, unless they use the same bus system (and not always then). Each manufacturer has their own system, so interoperability is limited. Lenz systems use their XPressNet bus system, which is also used by ZTC, Bachmann and Atlas (which is, after all, just re-badged Lenz gear). It's possible to use a Lenz throttle with a ZTC system, and also the other way round - indeed, using a ZTC511 as a throttle with Lenz command stations is a common way round some of ZTC's notorious failings. Digitrax's LocoNet network is used by Uhlenbrock and some other manufacturers, so there's interchangeability there. NCE users are somewhat stuck with the NCE system, as are Zimo users with Zimo systems. What DCC system do your friends have? Get what they have, because then, when you get an invite over to operate, you just take your throttle with you.

I have to say here that there is one big differentiator in throttles. The Digitrax DT400 has two throttles on the one handheld - it's the only throttle on the market to do so. That means that you can simultaneously control two locomotives at once; just consider starting a banked train on a grade, and dropping the banker off at the top, all while on the move. Easy with a DT400, very hard with other throttles. Lenz's and NCE's throttles allow you to switch from one loco to another quite quickly, but it isn't really the same. That Digitrax capability was what sold me on my Digitrax system, and I've never regretted it.

Before we leave the subject of throttles, also consider the number of functions supported by the throttle and the system. What we might call train-set systems now commonly support up to F8. Most if not all advanced, full function systems support 13 functions; that's F0 forward and reverse, and F1 to F12. Some - Digitrax's Super Chief Extra supports 29 functions, as does the Bachmann Dynamis. You may be thinking - what do I need all of those for? My steam locos don't need any functions. Well, maybe they don't now, because on DC, you don't really have a choice. But then consider a fully-kitted Bulleid Pacific. Five electric lights at the front. Five on the back of the tender, and you'll want to be able to light each one individually for the correct headcode. Add a flickering firebox, and the lights under the edge of the casing to light the wheels for maintenance. 12 Functions. Or consider something simpler. A Turbostar DMU from Bachmann, and add day and night running lights at each end, and tail lights, all individually controlled. 6 Functions. Then sound: Soundtraxx's Tsunami decoder has four light outputs, each offering various effects including three modes of flickering firebox, and then uses all the rest of my DT400's 12 function keys for sound effects. So before you decide that only two functions is all you will ever need, spend just a moment thinking ahead. Want to be able to operate the pantograph on your class 87 electric? I think that a system that supports up to F12 is a reaslistic minimum, and you should also pay attention as to how many of the functions can be reached from a single pushbutton. Here, Digitrax DT402 has single buttons for all of F0 to F12, while the NCE Procab throttle requires a shift-key press for F10 and above - indeed, nearly all systems require two or more buttons to be pressed to access functions above F9. And why does that matter? Well, on my Soundtraxx Tsunami-equipped locos, there's a brake function on F11. You really need to be able to press and release that with one button, and not two.

Expandability

At the point that you are buying a DCC system expandability is probably not very high on your priority list - you're spending quite a bit as it is, and the thought of more is too much. But you should think a little here. You may well want to use the system on another layout, or you may have two layouts, or be making a choice on behalf of a club. Apart from just running trains, what else can the system do, and how big can it get?

Quite a number of simple DCC systems cannot operate accessory decoders. Accessory decoders are things that most commonly are used to drive point motors. These have a separate address range from mobile decoders, so that point 1 and loco 1 can co-exist. The question here is whether you might want to have DCC point operation in the future, maybe via computer assistance. Many larger DCC systems also enable you to set up routes, so you can switch several points in one go.

Then there is the ability of the system to handle more throttles, or other more esoteric devices, and the ability to use a computer with the system. We'll explore computers in more detail in a later article, but let me say that the use of programs like DecoderPro with a computer when setting up complex lighting effects or sound decoders is very valuable, as is the then storing the entire set-up of the loco.

Price

Ah, price. Cheap is cheap, and more expensive is more expensive, right? Well, no. You see, buying a cheap DCC system may actually cost you more than you expect, because by the time you've played with the cheap and simple system for a week or two, and added decoders to a couple of locos, you find that you want more - 4-digit addressing, more functions, or more power. Or worse, you find that the system you bought actually won't do all the things that you thought it would. Then you have to go out and buy another, more functional system, and also new power supply. If you are lucky, you'll find that the cheap system you started with can be used as a throttle or as a booster on the new one, or you might be unlucky. You might even not be able to use that old one as a workbench programming tool, because it can't do - can't program - all the things you now need to do.

There's also looking around for the cheapest price. Yes, you can buy grey imports from US dealers, or from elsewhere in the Euro-zone. A great deal and usually a fast response you'll get, but what about support? Your local dealer won't be too keen on supporting you - why should he, if you've spent no money with him? So you have to go back to the US based dealer, and while some of them will give great support by phone and by email, it's not the same as being able to take the loco or your wiring diagram to the dealer and ask him what's wrong and what should you do next. And of course, if you don't support your local hobby shop, it won't be there to support you.

Conclusions

Before you make your DCC choice, spend a little time working out what you need, and also what you want. I'd suggest that you avoid pure bottom-end train-set controllers straight off - things like the Bachmann Ez-Command, and the Hornby Select systems for example. Look at products from the DCC manufacturers - those whose main or only product line is DCC equipment, and who have a dealer network. Check their web sites and any available chat lists. Download the manufacturer's documentation, and use that to understand what each system has to offer, and what it will mean to you. Ask friends what they use, and whether the system does everything you want, and even better, go and play. I can assure you that a good DCC system will be the best single modelling purchase that you are ever likely to make, but one that is not suited to your needs will just be a waste of money, so plan your purchase well, and be prepared to enjoy it, because you will. I bought a Digitrax Chief in May 2000, and I can honestly say that it has revolutionised my interest in the hobby. Your DCC system will do that for you too.

Here's a table that compares a number of systems available in the UK, from Bachmann's Dynamis, Hornby's Elite and the Roco Multimaus - reasonably sophisticated train-set systems - up to the top-end systems from DCC specialist manufacturers such as Lenz, Digitrax and NCE.

I've changed this table from that published in Scalefour news back in 2006, because things have moved on so much - some systems have been removed, some updated, and new ones added. I've not included Zimo's offerings either - mostly because they don't have an easily identifiable boxed starter system as such, and the information isn't completely available on their web site. They do sell a large range of throttles and command stations, and you make your system up from these. Great reputation, but great (as in large) prices to match.

Next time we will look at layout wiring for DCC, both for new layouts and for existing ones.

Comparing DCC systems

	Bachmann Dynamis	Roco Multimaus /10764 Command station	Hornby Elite	ESU ECOS 50200	Digitrax Zephyr Xtra	NCE Powercab	MRC/Gaugemaster Prodigy Advanced	Lenz LZV 90	Lenz LZV 100	NCE Powerhouse Pro	Digitrax Super Chief Xtra
Maximum # of cabs	1 (4 with Pro box)	?	8	Up to 128 devices	20	2	99	31	31	63	120
# of slots	40	10?	10	?	20	12	25	256	256	250	120
2 or 4 digit addresses	2 or 4	2 or 4	2 or 4	2 or 4	2 or 4	2 or 4	2 or 4	2 or 4	2 or 4	2 or 4	2 or 4
MU capability?	Yes (not sure how)	?	Yes	Yes	Basic. Advanced, Universal	Basic. Advanced, Universal	Basic. Advanced, Universal	Basic Advanced	Basic. Advanced, Universal	Basic, Advanced, Universal	Basic. Advanced, Universal
Speed controls	Joystick	Knob	2 Knobs	2 Knobs	1 knob & brake lever	1 Wheel and keypad	1 knob and keypad	1 knob	1 keypad	1 wheel and keypad	2 knobs (two throttles) & keypad
Maximum current (amps)	2.5	3.2	3 (track, requires 4 amp input)	4 amp	3	2.5	3.5	5	5	5	5
Service mode prog	Yes (Pro Box recommended)	Yes (in 10764)	Yes	Yes	Paged, Direct, Register	Paged, Direct, Register	Paged, Direct, Register	Paged, Direct, Register	Paged, Direct, Register	Paged, Direct, Register	Paged, Direct, Register
Decoder read-back	Pro box only	No (10764). Yes if other command stations are used	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OPS mode Prog	Yes (Limited)	Yes	Yes	yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of functions supported	21 (F0 - F20)	20 (F0 - F19)	13 (F0 - F12)	20 (F0 - F19)	29 (F0 - F28)	13 (F0 - F12)	20 (F0 - F19)	9 (F0 - F8)	13 (F0 - F12)	13 (F0-F12)	29 (F0 - F28)
Functions on single keypress	F0 - F9	F0-F10	F0 - F9	F0-F9	F0-F9	F0-F9	F0 - F9	F0 - F4	F0 - F8	F0 - F9	F0-F12
Supports sound decoders?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Walkaround capability?	Yes (Infra-red only)	Tethered	Add-ons	Add-ons	Add-on throttles	1st cab is Tethered.	Yes	Yes	Yes	Yes	Yes
Operate Accessory Decoders	100	Yes	255	2048	999	2044	20	999	1024	2044	999

3. Wiring a DCC layout

Wiring a layout for DCC is, in reality, not that much different from wiring a layout for DC, just a good deal simpler. Indeed, the simplicity of wiring a layout for DCC was one of the drivers that led me to DCC in the first place. The major difference between DC and DCC wiring is the lack of block switches, which is the main reason that the wiring is so much simpler. There are also a number of urban myths circulating about wiring a layout for DCC which I hope I can dispel.

The most important thing about a DCC layout is that it is wired so that all the track is powered, all of the time. This is because there are no separate cabs and no separate block wiring setups. Just as with a DC layout, you do still have to provide for switching the polarity of point frogs, and we'll come on to this later. The command station/booster powers all of the layout, and the selection of what engines move, and when, is up to the operators selecting locos from the throttles and is not controlled by whether a piece of track is live or not, Having the whole thing powered is important, particularly when you have sound and lights in locos and trains. You don't want a loco held at a signal for a conflicting move to go silent, just because it's not moving. The only exception to this rule tends to be in hidden storage/staging yards, where you might want to be able to turn off the power to individual sidings to ensure that you can't accidentally move a train, and also to silence sound decoders.

All that means that instead of wiring each section of track back to a block-switch on a control panel, all that is required is for it to be wired to the nearest piece of rail or bus wire that is at the same polarity (actually, as the DCC track voltage is AC, we should say "the same phase", but essentially it means the same thing, and I'll use both interchangeably) And that, basically, is all there is to it.

Of course, life is just a wee bit more complicated than this, but not too much. Let's explore a few things that you need to be aware of.

Power Districts

Firstly, while it is entirely possible for a large layout to be all wired together as a single block, it's better to divide it into what are called power districts, and feed these through separate short circuit protectors. This is so that should you have a derailment, or even run through a mis-set point, the resulting short-circuit won't shut down the whole layout, just a part of it.

All DCC manufacturers sell short circuit protectors. There are some available from DCC add-on suppliers, too. Some are single-cell breakers, and others will protect up to four power districts off one device. Some even provide reverse-loop management, which we'll also touch on later. The breaker must be set to operate faster than the booster's own short-circuit protector, so that the district with the short shuts down before the booster shuts the whole layout down.

Your power divisions can be much larger than the conventional blocks used on DC layouts, and may be arranged totally differently. The commonest way to divide a double-track layout is to have each track as a separate division. You may then have extra divisions for any sizeable yard or engine shed area, or branch lines. Basically a division for each part of the layout that is normally under the control of a single operator. Both rails are gapped at the point where you run into another division, but there is no hesitation as the train moves from one division to another, and no special provisions are made.

With a travelling layout, another way to divide the layout would be to add a breaker to each baseboard, which means that you don't have to carry wires for several divisions between boards; less to go wrong and fewer connections between boards required. You just feed the two wires of the main DCC bus feed into the board, and then any short on that board affects that board only. All you need to ensure is that the rails on all divisions are at the same DCC polarity or phase. We'll see how you make that easy to do later.

Should you, in the initial design, or later, plan also to use DCC accessory decoders to control the point motors, you should also power these either from a separate booster, or take them off the DCC main feed bus on the booster side of the breaker protecting the track. In that way, a short in the track won't stop you from changing any points. After all, the most common cause of a DCC short is running over a point that's not set correctly, and you need to be able to move the point to clear the short.

Adding power districts to a DCC layout is easily possible after the event, but to be honest, it is something best planned for as you design the layout. Clever design of power districts can reduce the amount of wiring and significantly increase reliability and operability, and well as reducing the time taken to troubleshoot any problems.

Reverse Loops

Reverse loops have always been a problem with any sort of two-rail wiring, because they connect the left rail to the right, if you see what I mean. Any DC powered train has to stop and have its polarity reversed, so that it can then travel in the opposite direction as it rounds the loop.

Now, a DCC train's direction of operation is not controlled by the track polarity (strictly, phase, because the track power is actually AC), but by the direction that the loco faces; forwards is of course forwards with DCC. So all you need to do on a DCC reverse loop is to reverse the track phase while the train is in the loop.

You double gap the rails at each end of the loop (that means a gap in each rail, opposite each other). You then power the rails via a reversing switch of some sort. A DPDT (double-pole/double-throw) switch will work fine. You throw it as the train is in the loop - and even while it is moving will be OK. If you don't, then you'll get a short as it reaches the end of the loop and bridges the gap. Or you get the short as the train starts into the loop, depending on where the switch is.

Now, you can do this with a DPDT switch, as I've just described, but a better way is to use a DCC auto-reverser. This is connected instead of the DPDT switch, and does exactly the same thing, but automatically. It just detects the short that happens when the train bridges the gap at whichever end of the loop has the rails electrically out of phase, and reverses the track phase inside the loop. It needs to do this very quickly, faster than the breaker or the system reacts to the short, and fast enough that the decoder in the loco doesn't notice either. Add a spring-point to the loop, and you can make the thing completely automatic. The only thing you need to ensure is that the double-gapped area of the loop is longer than your longest train.

Auto-reversers can also be used to power the bridge of a turntable, which means that powering the rails is much simpler. My turntable has one rail powered from the ring-rail, and the other via the motor shaft, and no gaps in the ring-rail. In my case, rather than then switching via an auto-reverser, I have an NYRS PTC-III turntable system that, among other things, reverses the track power at a specific point in the circle. The PTC-III uses a step-motor to drive the bridge, and indexes the tracks by counting steps, but that's another story.

Wire
Premium DCC systems can deliver 5 amps or more to the layout to operate it. This means that you need to ensure that the wiring is capable of carrying the load, and more importantly, doesn't have so much resistance that the booster or any breakers can't actually see shorts and so fail to shut down. Even if you start with a small DCC system, wire the layout for a more powerful one.

I suggest that you wire the layout with a single DCC bus per power district. You might want an extra bus for DCC-powered accessory decoders, too. These buses should be of decent sized wire, with some sort of terminal every few feet around the layout to attach local feeds to. 5-amp two-core mains cable is perfect for this; designed for 5 amps at 240 volts, it will be able to handle 5 amps at 12-15 volts with no trouble at all.

You then wire the track from this bus, using short lengths of smaller wire; the kind of wire sold in model shops for layout wiring is fine for this. There have been a large number of discussions all over the Web as to what wire sizes should be used. Suffice it to say that if the 10p test delivers a short properly, then the wire you have used is adequate. More important is the resistance of nickel-silver, or even steel, rail. This is much greater than the resistance of copper wire, so you should plan to have a feed to each rail every 6-10 feet or so, and you should also ensure that if power is carried across rail joiners that such joints are soldered. Many people nowadays ensure that every discrete piece of rail is separately powered.

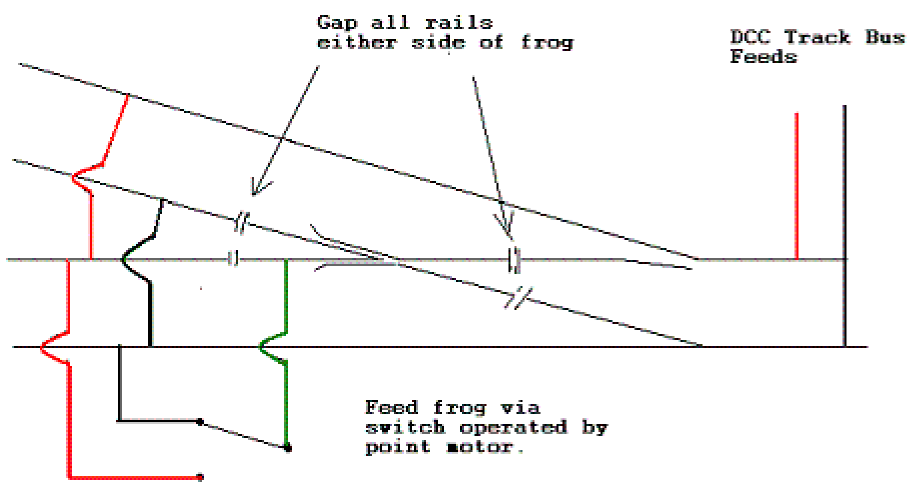
I'd suggest here that you wire the track with red and black wire. Make a standard of wiring the front rail with red wire connected to the brown wire of the bus cable, and the rear rail with black wire to the bus blue wire. And use these colours when wiring the track feed wires to the point-motor polarity switches. I then wire point frogs to the frog-polarity switches with green wire, because, to quote Tony Koester, "frogs are green". Use other wire colours for other wires; such as yellow and blue for the power feeds to switchmotors. Then, when troubleshooting anything under the layout, you always know what any wire is supposed to be doing.

The 10p Test

You must wire the layout with thick enough wire to be sure that the short-circuit protection works, quickly and efficiently. You do not want the DCC system trying to push 5 amps through a single part of your layout at any time, do you? As you wire the layout, you should use what the Americans call the "quarter test" - place a quarter dollar coin across the rails and check that the breaker breaks - in the UK, a 10p coin is just fine, as is, of course, anything metal. Whether you use additional breakers or have a single power division and use the booster's own breaker, you must do this test, every couple of feet or so, and on every point frog. Listen for the breaker's clicks or beeps, depending on the breaker. If you have a silent breaker, then you should check with a 12v LED that the power does indeed go off when you short the track - you may well also be able to hear the brief buzz-ping noise that happens at the point of the short. I have heard of one modeller who, when he gets a short, uses a cardboard tube as an ear trumpet to find the short quickly, just by listening for the ping noise. I added an LED to a piece of double-sided PCB that can be placed on the rails and shows if there is power present. If the breaker does not break and the system leaves power flowing through the coin, remember that you may have the best part of 5 amps in the coin. At 12 volts, 5 amps is 60 watts, so you'd then expect the coin, and the rails around it, to warm up a bit. Or possibly quite a lot, and fairly quickly too. Which explains why you need to do the test, and if the breaker doesn't cut the power, why you need to fix the problem. You don't want your nice new etched brass locomotive to be the generator of the 60watts of heat - you might just get the kit back!

I actually go further than this testing. I tend to wire track as I lay it, and test it as I go, with the track power turned on as I do it. Whatever you do, I strongly recommend that you at least wire the track with the power on. This means that if you generate a short as you wire, you'll detect it instantly, and it saves you all the hassle of finding it later when you come to test things out. After all, if you generate a short, your breaker will catch it, and if you don't when you should, then you know that you have a dry joint or are using wire that is too small, and can fix it there and then.

DCC friendly pointwork.
This is a subject that has evoked much comment in all sorts of places. Because of the sensitivity of DCC systems, and also the amount of power they command, a brief brush of the back of a flange against an open point blade of the opposite potential will always cause a short. Such a touch on a DC system nearly always goes unnoticed. DCC friendly points avoid this problem, because they are arranged with the blades at the same potential, or phase, as the adjacent stock rail. Something that in P4 is a requirement anyway, because of the tight clearances.



In such a point, each of the four rails leading to the frog are gapped close to the frog, as the diagram shows. The frog is powered from the switchmotor's auxiliary contacts, or from some other polarity-switching device, via, remember, the green wire. Then each closure rail and blade are bonded to the adjacent stock rail, and the rails behind the point also powered by short jumpers to the nearest convenient powered rail or bus wire terminal. I recommend that the gap after the frog is close to the frog, rather than being close to the clearance point beyond the frog; too close to the clearance point and you'll have extra shorts as and when people overrun the clearance point.   Keep the gap as close to the frog as you can.

By the way, while we mention rail gaps: I recommend that instead of cutting rail gaps with a cut-off wheel in a mini-drill, do it instead with a piercing saw before the track is actually laid. Then press a sliver of 10-thou plastic (black, preferably) into the gap and secure with superglue, trimming when hard.   This gives a much smaller gap, but the plastic stops it closing up and being the source of hard-to-find shorts.

You'll notice that I've talked about gapping the rails behind the frog as well as in front. You'll always need to do this if the diverging tracks lead to the trailing end of other points, and you will have done this for DC wiring. For sidings, normally DC wiring would have the siding powered from the frog, without gaps. Then both rails are at the same polarity when the point is against them, and nothing runs in that siding.   DCC custom and practice is always to gap behind every point, and power the diverging rails behind the point, even if it leads to a siding. There is no reason why a DCC layout can't be wired like a DC one, though. Just remember that if you do, then a loco left on a siding is unpowered, and so cannot have lights or sound active. You may say that this doesn't bother you, but as soon as you have one loco with sound, or a brakevan with internal lights, it will!

Auxiliary Contacts on Point Motors

You may have wondered how the auxiliary switches on your point motors are going to cope with the 5 amps of a DCC system? Well, you don't need to worry. Here's why. Even though the contacts themselves are probably rated by the manufacturer to be 1 or 2 amps, at the most, there is only a draw through the contacts at the moment that the loco is crossing the frog, and only then if that side of the loco is only picking up from the frog and not from other rails as well. Now a normal P4 or even O-scale loco rarely draws more than 1 amp, and most of the time, considerably less. So even though 5 amps are available at the DCC system, it's not normally drawn through the switch-machine contacts.

But then, the most common short on a DCC system is running against a mis-set point, and then the whole 5 amps will be drawn from the frog and through the switchmotor contacts. But only momentarily, as either the booster or your breakers will disconnect almost instantly.   And indeed will disconnect well before there is any heating effect at the contacts, or anywhere else. So the contacts are not handling any load in this circumstance for any more than a few milliseconds. Always assuming, of course, that you have successfully done the 10p test on the point-frog itself - you must do this to ensure that you can't overload the contacts.

For final peace of mind, here is a quote, via Don Crano's web site (http://home.neo.rr.com/mrwithdcc) from Steve Worack, President of Circuitron, Inc, who are the makers of the Tortoise switchmotor: "As to the contact rating, we rate the contacts for 1 amp switching. They will safely carry 4-5 amps, and the short circuit protection of DCC systems makes contact or circuit board "frying" a fairly remote possibility. In truth, with over 3/4 million Tortoises in the field, I have never gotten one back with burned up contacts. And many of these are being used for Hi-rail and G scale."

Converting an existing layout to DCC

Converting an existing DC layout to DCC can be as simple as wiring the DCC system to one of the cabs, and then switching all the sections to that cab. You must then do the 10p test over all of the track, to ensure that there is not too much resistance in the existing wiring to run DCC properly and safely. Then run trains. And for quite a number of layouts, that will be all that you need do.

But you may well not get the best from your DCC system or your layout if you leave it at that. Particularly, one cab may not be able to reach all of the layout, and you may feel that you need to wire the DCC system in place of more than one cab. Again, mostly that won't be a problem, but you may run into the odd place where you have sections adjacent to each other that have different polarity, and you'll get shorts from this that will be very hard to find. So in the end, you could well end up finding that some rewiring will be necessary, and then you'll quickly find that you are unwiring more than rewiring. You'll be removing all the wires back to the control panels, and merely wiring the track droppers back to the new DCC bus that you'll have installed. You'll probably also find that you need to add more gaps behind point frogs and extra droppers to wire in some sidings. But in the end, you'll end up with less wire than you started with and many fewer switches.

In the end, wiring a layout for DCC is common sense, and is simpler than for DC. No cabs, no control panels, no block wiring. You do need to add a power breaker or two (my HOn3 room-sized layout has just two power districts), and you do need to ensure that all track is positively powered, with enough feeds of sufficient wire thickness to enable all the track to pass the 10p test, but that's all.

Next episode, we'll look at locomotive decoders, what they can do, and discuss some of the factors that will affect your choice of decoder.

4. Choosing Mobile decoders.

Enjoyment of any model railway, DCC equipped or not, is pretty much dependant on how well the trains run. How smoothly they start and accelerate, and how responsive they are to the controls. In the DCC world, the choice of decoder and how you set the decoder up plays a big part in that enjoyment. In this part of our series, we'll look at decoder features, and discuss how to make the best choice.

Price

First, price. While price matters, use it only as a way to differentiate decoders with the same feature set that you are interested in. Don't use price as the prime choice factor. My experience is that cheap decoders, are, in fact, expensive decoders. Most cheap decoders have such poor motor control and feature sets that you will end up replacing them very quickly with a better one, the one you should have bought first time around. So the entire cost of the cheap one will have been wasted. But hopefully you'll probably only make that mistake once.

Note that as DCC is a standard, you can use any manufacturer's decoders with any DCC system, which means the choice of decoder is as open as your original choice of system. There are some very advanced features in some DCC systems that require the use of specific decoders, often the same manufacturer, but by and large, you don't need to worry about who makes them.

Motor Control

The main reason for installing a decoder is to make the locomotive run. So let's discuss the basic motor control functions of the decoder next, and how to make those work for us. We'll then work outwards from there to lights and other more specialised features, but I'm not discussing sound this time around - that will be in a later episode.

Decoders work by switching the motor on and off in short cycles, a technique called Pulse Width Modulation (PWM). The bigger the fraction of time that the motor is on rather than off, the faster it goes. This is the same technique as is used in most modern analogue controllers, too, especially those that have feedback or back-EMF circuits. These days, nearly all decoders are high-frequency, operating at upwards of 19khz. Some head towards 30khz, and quite a few even allow the PWM frequency to be tuned. These are often described as as Silent Drive, Quiet Drive, or Supersonic decoders.

Older decoders tend to be non-supersonic, low-frequency, working down at around 200hz or so. This tends to make motors very noisy at low speeds. Low-frequency decoders sometime do help with old and very crude motors like some of the flat, 3-pole pancake motors that used to be used by some RTR manufacturers, where noise isn't really an issue - there being so much of it already. These old motors have such large mechanical starting resistance that the crude pulses of low-frequency decoders are sometimes the only way to make them run. Coreless motors, and indeed any decent modern motor should not be used with low-frequency decoders at all. Coreless motors have very little rotating mass, and so little inertia, and lose speed rapidly between relatively infrequent pulses. Each infrequent pulse changes the speed markedly, leading to vibration, noise and brush damage.

Which leads to one problem with high-frequency decoders. It is to do with the fact that the short and frequent pulses, coupled with the inductance of the motor, make the motor appear to be smaller than it really is at low speed - and that results, in some cases, of a reasonably significant loss of low-speed torque. That leads to poor starting as the pulse width widens, torque rises, and suddenly there is enough power input to get it all moving in a big jerk. I should also say that such low-speed torque loss will happen with any high-frequency DC PWM control, too, and not just with DCC.

Most decoders have some sort of compensation for this low-speed torque loss, however. Some rely solely on back-EMF to do this, which in my experience works well. Most non-back-EMF decoders use other, passive ways to deal with it. Digitrax offer Torque Compensation. It mixes random, larger pulses in with the small ones, and reducing these as the throttle is increased. It isn't adjustable, but can be switched off. It works well with decent mechanisms. TCS have their Dither feature which works the same way, but which is tunable both in the size of the pulses and in the frequency of them.

Unlike analogue control, which offers a pretty much seamless increase in power as the controller is advanced, DCC systems have a number of discrete speed steps. When a DCC command station sends a speed and direction command to the decoder, the speed is expressed as a number, 0 being stop. Early DCC systems had only 14 speed steps up to full speed, and the jump from step to step was often visible. Later systems decoders extended that to 28 steps, and now the accepted standards is 128 steps, and nobody can detect the tiny jumps between speed steps. Indeed, many modern decoders internally operate in even higher numbers of steps- Soundtraxx's Tsunami has 2048 internal steps, and passes through these as consecutive 128-step commands are sent by the command station.

Most command stations these days are 128-step, and nearly all decoders are 128-step too. But there are a few 28-step decoders still on the market - Bachmann's factory fitted decoders for example (and these are also low-frequency). These are OK as simple train-set decoders, but you'll want better for your models.

Back-EMF
Most premium decoders offer back-EMF. Unlike the torque compensation systems that are used to overcome the high-frequency torque loss, back-EMF, or BEMF, is an active system. The armature coils turning in the magnetic field act as a generator, producing a voltage that's in the reverse direction to that being applied to turn the motor. In between power pulses, the decoder reads that generated force - it's an electro-motive force, or EMF - and uses it to determine if the motor is running faster or slower than it should be. The decoder then adds or subtracts power to adjust the speed of the motor. In the best decoders you get to be able to adjust all three parameters of the BEMF control. There is the droop, which specifies how far away from the expected speed the motor can get before the decoder starts to try to adjust it. Second is the amount of adjustment made - how much throttle to add or take away, and thirdly how fast the throttle adjustments are made. Some decoders - Digitrax, Zimo and Soundtraxx's Tsunami, for example, allow you to adjust all these parameters and tune the loco exactly. Some, like Lenz's Silver and Gold ranges, offer you five "motor types" and you try all of them to see which works best. I prefer the more adjustable ones to the Lenz model, personally.

Where BEMF really scores is in slow running and assured starting, because the decoder watches the motor, and grabs on to it and makes it do what is required. The adjustability enables you to tune the motor-decoder pairing until you get exactly what you want - and doing this with OPS mode programming is quick and pretty simple. Indeed any such tuning exercise, including setting up TCS's Dither, cannot really be done in any other way than with OPS mode.

If you do go for BEMF, then you don't need to add a flywheel to the motor. Indeed flywheels can actually mask the effects of BEMF, because they don't allow the decoder to see what the motor loading really is. As a flywheel that is going to be effective enough to be of any real use is actually too big to get into many locos, BEMF is actually a better bet, particularly at slow speeds where flywheels really don't help at all.

A number of decoders have a switchable shunting-speed setting. The Digitrax version is selected by setting CV54 to 1, and then it operates from F6 (and is not remappable to another F-key). When F6 is pressed, it halves the loco's top speed, and significantly reduces the effects of momentum that you may have programmed into CVs 3 and 4. Press F6 again and the loco goes back to normal. Lenz Silver/Gold and Zimo decoders have an essentially similar feature, as do many others. Is this a useful feature for you?

Nearly all decoders offer the ability to set and manage the acceleration and deceleration rates, and also the ability to customise speed versus throttle setting.

The simple way is to use CVs2, 5 and 6 which control start speed, top speed and mid-point speed, respectively. My experience is that these suffice in nearly every case. More extensive work on a custom acceleration/deceleration curve can be made by the use of a 28-step speed table, offered in pretty much every up to date decoder. I'd suggest that programming of 28-step speed table is something that's best done with a computer program such as DecoderPro, which we will cover in a later installment.

Motor Control Summary
So, what does all that leave us? Well, firstly you should choose only high-frequency decoders that operate at 128 steps. Then you need to decide on whether you need BEMF. For a loco that is just to pass through the scene at a reasonable speed, and which won't be called upon to pull long or difficult trains, then BEMF is not an absolute requirement. But if you don't specify BEMF, then you do need a decoder with some sort of low-speed torque compensation and the ability to set the start speed with CV2. For a shunting loco, or a freight loco that is required to pull well at low speed, and to be able to do smooth starts and stops with a heavy load, I think that BEMF is an absolute must. You'll probably want to have the shunting speed setting for such a loco, too.

Now, what else should you think about?

Nearly all decoders will run the loco on DC, given a DC controller that provides reasonably pure DC. Indeed, because the decoder is still involved in controlling the motor, many will run better on DC with a decoder installed than they did without. So if you plan to operate your locos occasionally on DC, make sure the decoder will do it. You really don't want to be switching the decoder out to do that. But beware too, that some sound decoders don't work at all on DC, and may even be damaged by it. Do also note operating a decoder-equipped loco with some more advanced and complex DC controllers – particularly those using PWM and back-EMF - may result in quite poor running as the decoder and the controller start to second-guess each other. Pentrollers spring to mind here.

You need a decoder that will have enough power-handling capacity to drive the motor and all the chosen functions, and be able to cope with the unexpected. You should always do what's called a stall-test on a motor, to determine the highest power draw that it can handle. You do this with a DC controller, with an ammeter in the circuit - an old H&M or trainset controller here is all you need, so long is it has enough power - 1.5 amps will be fine. You then put it on full throttle, and stall the motor by grabbing the flywheel or pressing the loco on to the track till the wheels stop, and check the current draw with the motor stalled. Do it in both directions (and discard the motor if the readings in the two directions are significantly different). You need a decoder that can handle that draw; so that should something go wrong, such as the valve gear become detached or a piece of ballast jam the gears, the motor current draw won't blow the decoder. Remember most decoders, even cheap ones, cost more than many motors. Measure also the steady-state running current draw if you can, before the motor stalls.

Most motors - Mashimas, Buhlers, Faulhabers, and so on, as used in the better 4mm or HO models draw somewhere between 0.2 and 0.5 amp in normal use, and stall at between 0.3 and 1 amp. In all these cases, a decoder with a 1.25amp peak will be more than fine, and you'll find that many decoders have a higher peak that they can handle for short periods. But beware that some small decoders, Lenz Minis for example, have continuous ratings of as little as 0.5amp, and any decoder driven continuously near its peak will get hot. Note also that such ratings include lighting functions, so if you add four 30ma bulbs to a decoder, that's 120ma, 0.12 amps, that needs to be added to the motor's peak draw.

Decoders come in different sizes. It's pretty obvious that you need space for the decoder, but you also need to take into account space for the wires at the end of the decoder, and that some decoders have a bulky plug/socket on the end. Paradoxically, there's usually more space in kit-built locos than there is in modern RTR, especially steam. Many RTR steam locos are completely full of cast weights. You also need to be aware that some decoders get more than a bit warm - Lenz ones in particular, and many sound deccoders. Lenz decoders are also not covered in heat-shrink, so you need to be sure that they aren't going to get in contact with anything metal. Such contact is normally fatal to the decoder.

Whether you buy a decoder with bare wires or a plug really depends on the target locomotive. If it has a socket, you can fit a plug-in decoder. But even these days, there are a surprising number of locos out there fitted with sockets where the socket doesn't work properly; either shorting against the chassis, or just plain not working properly with modern decoders. It's often better to strip out the manufacturer's circuit board and hard-wire the decoder in to the loco, an operation that can quite often save a lot of space, too. Bare-wire decoders often come with more wire, too, which gives you more choice in exactly where to squirrel away the decoder.

Functions

Now, lights and functions. Many modellers, particularly those modelling steam, disregard DCC functions, and some will even base their decoder choice on the number of functions offered, or rather the number not offered. I think that's a mistake. Quite a number of the more expensive decoders appear to be more expensive because they have more functions, while in reality it's because they have better motor control. Discarding better motor control just because you don't want to pay for functions you won't be using is not the best way to choose a decoder. Remember what I said at the start about cheap decoders being expensive decoders, when you end up replacing them because they're no good.

Diesel and electric modellers, particularly those modelling the current scene, will be interested in decoder functions, and often the more the better. The choice here is to do with function power and effects. Many decoders can cope with quite high power drains on the first two - white and yellow - functions, not just enough for large bulbs, but often capable of 100ma or more which can be used to drive a smoke unit. But remember again, the decoder's maximum capacity includes the draw of all the switched-on functions, as well as the motor.

You also need to decide whether you will want to use bulbs or LEDs. LEDs have the advantage of lower current draw, but you do need to search for LEDs that offer the more yellow colour of steam-era lighting from them. Look here for Golden White or Sunny White LEDs. Small bulbs are usually 1.5v, and so will need resistors to reduce the decoder output to a safe level. LEDs also require protection, but here you have more leeway in the resistor choice, as we'll see next time. Bulbs will often reproduce the special effects from decoders - strobes and rotating beacons, better than LEDs, though, because they switch on and off more slowly. You'll need to explore the effects you want against what the decoder offers. Nearly all decoders will offer a steam locomotive random firebox flicker, and quite a few more offer a variety of US-oriented lighting effects. All this means that you can add a glow in the cab as well as headlights to both steam and diesel locos.

Some decoders, particularly European ones such as ESU, Zimo and CT, and to a lesser extent, Lenz, have other facilities. Some Zimo decoders have 5v outputs (call logic-level, because they come direct from the electronics, which operate at 5v) as well as 12v functions - these can be used to operate other electronic devices in locos. Zimo again has functions that can operate pre-programmed sets of outputs - such as operating onboard uncoupling, where a single function cab be programmed to move the loco as well as opening the coupler. Then there are functions such as pre-programmed braking. If these sorts of things attract you, you'll need to do some searching and reading to see who offers what. But remember, you don't need to stick with one manufacturer's decoders - you can choose the best, regardless of manufacturer (well, almost), for what you need. Just be sure that the DCC system you have has enough functions and capability to be able to program and operate your decoder choice. What I mean here is, for example, don't buy decoders that require the use of F12 if your system only goes up to F9.

Now, much of the detail of lighting effects and other functionality needs to be dealt with when the decoder is installed, which we will cover next time.

5. Installing Mobile Decoders

Installing DCC decoders is not often difficult. These days a fair number of RTR locos come with DCC sockets ready in place, and mostly these days the sockets work, properly, too. But for older RTR and kit or scratchbuilt locos, the decoder has to be "hard-wired" in place, which is also, by and large, a simple operation.

Sockets

Let's consider locos with DCC sockets first. In 4mm and HO scale, far and away the most common is the NMRA standard 8-pin one. There's a not entirely happy history with the RTR manufacturer's early sockets; it took Hornby three attempts on their Class 50 diesel to get the circuit board correct so that the loco and the lights would all work and at the correct ends. Heljan's early 47 had a habit of frying decoders when the lights were turned on, because the decoder plug pins could go all the way through the socket and touch the chassis. Fortunately, things have improved, and by now the hardest part of many a plug-in decoder install is either getting the loco apart to get at the socket, or putting it back together again afterwards, with no damage.

But before you start adding a decoder, though, make sure that the loco works properly. If it's a new one, run it in a little, on DC, if you still have a DC power pack. Make sure there are no binds and that it runs without getting hot. If it's an older loco, give it a service - clean out all the fluff, clean the wheels and pickups, and make sure that it is properly and sparsely lubricated.
If the loco has a DCC socket, all you need to know is how to get it apart and then how much space is available inside. Quite a few early DCC-ready locos had very little space for decoders, but thankfully that's starting to change, particularly as the RTR manufacturers are now starting to sell locos already fitted with decoders. What is still sometimes a problem, particularly in steam locos, is that the socket is mounted fore-and-aft, when the wires on most decoder plugs come out of the side, meaning that a 90-degree bend is required to get the decoder in; easier to do if the wires are thin and flexible.

So, having got the loco apart, just pull the dummy plug out of the socket, and then locate pin 1 of the socket (or pin 8, if that's the one that's marked). Carefully press the decoder plug in, with the orange wire to pin 1, or grey to pin 8. It won't do any harm if you plug the decoder in backwards - the wire layout in the plug is specifically designed so that no damage occurs. All that will happen is that the loco will run backwards, and any lights won't work. If that happens, just unplug and turn it round.

In N-scale, many European locos come with a 6-pin socket, and these are starting to be found in US-prototype models, especially steam, too. Again, you find pin-1 on the decoder and the loco, and carefully press the decoder home after removing the blanking plug. If you get this one the wring way round, hope that nothing goes wrong; unlike the 8-pin, this one isn't completely foolproof. And now, quite a number of HO and larger locos are being fitted with 21-pin plugs, which connect directly to a socket on the decoder. That one cannot be installed the wrong way round.

Once the decoder is installed, put the chassis on your program track, or connect the program track to the loco pickups with clip leads. Then read the decoder address, and be sure that your system sees the address as 3. If that happens, OK, you can be sure that you have power connected to the decoder, and the decoder connected to the motor. The motor should pulse, too, as the address is read, and in the forward direction. If you don't get the address read back correctly (you do have a system with decoder read-back, don't you?), then check and double-check that the decoder is properly installed. This check has saved many a decoder from faulty installation.

Now test it, on address 3. If you are lucky, which you will be nearly all of the time, the loco will work just fine. There will be space to get the decoder into the body shell, and you can reassemble it with no problems. And apart from some programming, that's the job done. But sometimes, your favourite decoder makes the loco run horribly badly, or you may even find it won't run at all.

The most common reason for this is that the inbuilt circuit board and the various interference suppression components on it are confusing the decoder - either they are damaging the DCC signal before it reaches the decoder, or, especially in the case of back-EMF decoders, interfering with the signals between the decoder and the motor, so the decoder doesn't know what to do for the best. If this happens, you should first try resetting the decoder to factory settings, just in case. Also make sure that the decoder and the DCC system are both running at 128 steps - you'll need to consult the decoder and system manuals for this. If that doesn't solve the problem, you're either going to need to try a different decoder, or you need to remove the factory electronics completely and hard-wire the decoder. This is of course easiest with steam locos where there isn't a lot of lighting to worry about.

Hardwiring decoders

So, to hardwiring DCC decoders. This is a great deal less intimidating than it might appear. Get hold of the decoder, and check the wires from it. All NMRA-compliant decoders use the same wire colours, which you will rapidly learn. First find the red and black wires. These will go to the track pickups just as your non-DCC motor wires did. Don't connect them yet, though. Orange and grey go to the motor. Blue is the function common wire, and is always positive and live. Then white, yellow and the rest of the colours, green and violet come next, are the function negative wires. These are off when the function is off, and on when it is on.

Now, very important, you must make sure that the motor brush connections on the loco are not grounded to the chassis or track. If the motor is a modern can motor, you'll just have two terminals on the end of the motor, or two short wires coming out of it. No problem here. But if you have an old RTR loco, or an old open-frame motor, it may be grounded. You must isolate both brushes before you go any further. You really must do this, at best it won't work, and at worst, you'll fry the decoder.

You also need to work out where the decoder will go. It helps to put it close to the motor. You don't want lots of wires between loco and tender, but with some more modern RTR locos that are all full of cast blobs, that can be hard to avoid. But at least most new models now have some space for the decoder. One thing you should avoid, though, is taping the decoder to the side of the motor, especially if you use Lenz decoders - these tend to be more heat-sensitive than other brands. One way of finding out whether there is enough space is to put a blob of Blu-Tack in the space and put the chassis back in the body. Take it off again, and look at the blob. Bigger than the decoder, or not?

Now, you're ready to start with the decoder. You may be going to join wires together, depending on the loco, and you'll need to insulate these joins. It's OK to use insulating tape, but heatshrink tubing is much better and much neater. All Components carry a decent line of the stuff, as do other electronics stores such as Maplins. A range of sizes is good to have, the 1.6mm is probably the most useful. Also you'll need a way to strip insulation (decent fingernails are a start here), rosin-cored solder and a small iron. I actually use a 50w, and turn the temperature down a bit, but a 25w or even 12w will work just fine.

For your first install, do it once without shortening the leads, just to get the feel of doing it. But once you've done that, you should shorten the leads so that the decoder goes in to the chosen place without masses of wires about. If there are any function wires you aren't going to use, trim them off to about 1 cm - this allows you to change your mind later. If you feel particularly virtuous, dip the cut ends of those wires in a little nail varnish to insulate them, just in case (I usually don't bother).

Now, add the red and black wires to the pickups. It doesn't matter too much which way round, but convention is that the red wire is to the right rail when facing forward. The reason it doesn't matter is that the decoder will always spin the motor the same way for forward regardless of which way round the loco sits on the track - if you turn the loco round, the red wire is on the other rail, but the loco still goes forwards, unlike analog operation. Now, if you are going to use advanced features such as Asymmetric braking, then it actually does matter that you connect the red wire to the right rail, so it does makes good sense to get this one right.

Add the orange and grey wires to the motor. Here it does matter which way round these go, and it's worth getting it right. Orange is usually connected to the motor terminal that was connected to the right rail, but that may depend on the number of direction reversals in the gearbox. So tack the grey and orange wires, and get ready for a test. What we want to check is that the loco runs forwards when the throttle is set to forward.

First, put the loco chassis, and tender if needed for pickup, on your program track, and read back the decoder address. You did buy a system with decoder readback, didn't you? If not, then try setting the address to 3 (the decoder default). If you get a jerk from the motor and a readback of the address (usually 3), then you have a connection through to the decoder, and it will be safe to try the loco with full track power. Check the jerk of the motor - it will always be "forwards" - if not, reverse the orange and grey wires. I often do this test with some croc clip leads as I do installs. This means that should you run the loco on an old fashioned DC layout, it will run in the conventional direction. For DCC only, it doesn't actually matter which way round the wires are attached, because you can reset the normal direction of travel with CV29, as we will see, next time - however, as with the track wires, it makes sense to get them right first time and not later.

Now that you have the orange and grey wires the right way round, you can shorten them and reattach them. Worth checking again, once you've done that. And if you are not adding any lights, that's about it, and all you need to do now is reassemble the loco and program it. Or program it and then reassemble, it mostly doesn't matter which.

Lights and Functions
If you are adding lights, though, now you need to start on that. First question is whether you are using LEDs or bulbs. They both have advantages and disadvantages. Bulbs tend to have a shorter life, but this can be helped by using resistors to dim them slightly, and bulbs make a better representation of older, steam era, lights, even when compared to Golden White LEDs such as those from Richmond Controls (http://www.richmondcontrols.com). But they generate heat, and that might not be very desirable in plastic-bodied locos. LEDs have a longer life - almost infinite if treated properly - but are not as good as bulbs at special effects such as flickering firebox lights or strobe lights, and are more difficult to dim, if you want dimmable lights. But they do have the advantage that they don't generate any heat.

Look also at the size of bulbs and LEDs. 1.5v bulbs or 12v bulbs? 1.5v bulbs are smaller, and if properly protected by resistors, will last for a long time. I use 1.5v 15ma Miniatronics bulbs in my HOn3 loco headlights. With a proper resistor, I've never had one fail. LEDs come in various sizes right down to surface mount versions, but then the leads can be a bit of an issue to hide.

Secondly, look at where the bulbs and LEDs go, and how you'll get them into place. Every loco is different, so this really is up to you. Lastly, look at how you will get the wiring back to the decoder. Will you need to plan for miniature plugs and sockets to be able to get it all apart for maintenance? Fortunately, not many British steam locos ran with illuminated lamps in daylight, so for the steam modellers, lighting is something that you can mostly ignore. And for diesel modellers, space is not often too much of a problem, except when fiddling wiring round cab interior detail. A good starting point for DCC lighting in an RTR diesel is to explore the products of Express Models at http://www.expressmodels.co.uk.

You'll need to work out what resistor sizes to use - and for bulbs, you need to get the resistor right. Ohms law states: r=v/a. V here is the voltage you need to "get rid of"; Function voltage minus Bulb voltage. You can measure the output of your DCC system to get the track voltage. Subtract around 1.5v to account for the decoder's rectifier losses, or instead, measure the decoder function output. DCC Track voltage is AC, so use an AC-capable meter to measure it (or use a DC meter and measure each rail to ground, and add the results together). Decoder function output is DC, with the blue wire positive (note when testing and installing LEDs that they are polarity sensitive). My Digitrax system, running on its N-scale setting, puts 12v on the track, which gives around 10.5v decoder function output. Many DCC systems put a fair bit more on the track, up to 17v in some cases, so be sure to measure it.

So:

r=(function volts - bulb volts)/ bulb current

says that for a 1.5v 15ma bulb with 10.5v function output, r = (10.5-1.5)/.015 = 600 ohms. I commonly use 580ohm resistors here, and 330ohm for 30ma bulbs. You must use a separate resistor for each bulb. Do not attempt to share resistors between more than one bulb – good practice is to put the resistor in the function wire rather than the blue common wire – and of course, if the function drives more than one bulb, use separate resistors in parallel, one for each. If you don't follow this advice, you've been warned. When one bulb fails, then all others on the same resistor will get too much voltage, and will fail shortly afterwards – like after about a second or so.

LEDs work on around 3.5v. You need to use a resistor to protect them from the full function voltage, but beyond that, adding more resistance just dims the LED - most LEDs are way too bright for steam-era lighting, and are pretty bright for diesels, too. I tend to use 1k or even 9k resistors with LEDs in steam models, and these are just fine – as well as prolonging the already lengthy life of the LED. They're also, unlike bulbs, when protected by a largeish resistor value, not affected by different track voltages from different DCC systems, either.

Lastly you need to work out what wires you will use. Convention is that the headlight is on the white wire and the tail light on yellow, and for two-function decoders, that's all you'll have. But if you want more, and you are also adding sound, you may to be able to operate lights on F4 or above. To do that you must check the decoder documentation to check which colour wire to use. Most decoders allow you to re-map output wires to another function, but you will find often that white, yellow and green can often not be mapped to a function higher than F3. You will also find advice that explains that you don't have to use the blue wire at all, and can ground the bulbs straight to the chassis or to one rail, and indeed the European NEM six-pin decoder socket commonly used in N-scale does not use the blue wire. This is OK if you don't use address zero to run an analog loco, but if you do, any lights in any loco wired without using the blue wire will dim as the throttle is wound up on address zero.

Again, like we did for the motor, hook the lights up temporarily without shortening any wires. Check that it all works, and the lights are bright enough. You can at this point do any function re-map programming, set up effects that you want, and check that they all work too. Then you just have to install it all in the loco, slowly and carefully, and check that it all works there too. Don't forget to use heatshrink tubing in all wiring joints for insulation. If you use plugs and sockets in the wires to enable the body with lights to be removed from the chassis, don't forget to add the socket to the decoder and the plug to the other wire - then if it comes open, you don't have a loose, live, pin looking for a chunk of chassis to ground against and blow the decoder.
Lastly, tidy up the wires; fold them around, and tape them to the loco motor or chassis, and if need be, shorten a little more. You need enough wiring length to be able to move the decoder about to get it back in to the loco, but no more. Even keep wires that have plugs and sockets as short as is practical. Put the loco back together carefully, and check that there are no wires getting into any of the gears or rubbing on flywheels. Run it slowly with clip leads, to be sure.

I'd suggest that at this point you make a few records as to what you have done. Make a note of what the decoder in the loco is, what address you have, or will, set it to, and where the wires go, even down to which motor terminal has the orange wire. These notes will be very useful in the future - not just for troubleshooting if the loco stops working - but also if you get another similar loco, you know what works (or what doesn't), and what you did last time, without dismantling it to see. Even take a digital photo or two of the installation, if it was particularly tricky.

And that's it. Next time we'll look at programming the decoder, and how to be sure that you are getting the best performance that you can from it.

6. Programming Mobile Decoders

Now that your decoder is installed, you need to do some programming to make it actually useful. At the very least you need to set the address, or loco number, that the loco will be known by to the DCC system. If you don't do that, every loco will be loco number 3, as that is the address that nearly all decoders are shipped with. If all your locos were set to address 3, chaos would result.

Before we get into any specifics, let me just explain what decoder programming actually is. While a decoder is basically a computer, programming it is not like computer programming. Decoder programming is just the setting of values in internal slots, called Configuration Variables or CVs, that the decoder uses to vary its operation. The decoder then remembers these values for ever, and uses them to vary how it operates the motor and the function outputs. As well as telling it what DCC packets to execute,and which to ignore (it ignores all those that aren't for its designated address).

Now what I'm not going to do here is discuss the details of how to do decoder programming with any specific DCC system. I use Digitrax with a DT400 throttle, and the mechanics of programming with this are different to, say, using a Lenz Set-100 or a Gaugemaster/MRC system. So for the details of how to do your programming, you are just going to have to read the manual that came with your system. And in many cases you'll also need to read the decoder manual that covers your decoder, so that you know how to set up the various decoder functions. What I am going to do is discuss some of the common CVs and also some of the thought strategies that help when determining what CVs to set to what values.

Now, there are a number of CVs that perform the same function in every decoder. First one of these is the address. Most, but sadly, not all decoders support both short (2-digit) address, and long, 4 digit addresses. 2 digit addresses are stored in CV1, and range (usually) from 1 to 127. Yes, 127 is 3 digits, but as we said, decoders are computers, and work in bits and bytes - the 2 digits referred to are hexadecimal, base 16 digits.

Binary and Hexadecimal

Let's have a quick digression of what that all means, and try to make it as simple as possible. CVs are stored as single bytes inside the decoders - a byte being 8 bits. Each bit is a single binary digit, valued as 1 or zero, on or off. So with 8 bits in each byte, the CV can store

- 8 individual on-off switches. This is often called a bit-mapped CV. CV29 works like that and we'll explore CV29 in a minute.
- two 4-bit numbers, each with a value ranging from 0 to 2^4-1, or 15.

Some Digitrax CVs work like that to control light effects.

- one 8-bit number, each with a value ranging from 0 to 2^8-1, or 255. Most CVs are used like this.

So you can see that a CV value can always be referred to as just a number between 1 and 255, and that's pretty simple.

For those CVs that use the two half-bytes separately, often the easiest way to refer to them is to use hexadecimal notation. This uses the numbers 0-9, followed by letters A-F, to represent the values in each half, and make it obvious that the two halves of the CV are separate. So, using a Digitrax decoder, you might set CV51 to x'21', to set the light effect on the green wire to a non-directional firebox flicker. The first half, the "2", is the non-directional part, and the second half, "1", is the flicker effect. Each is a choice of 15 values - 0 through F. The x denotes that the number following is in hexadecimal as opposed to decimal format.

So now that we're rather confused, let me say that the first time you successfully work it out for real will be followed by an "ah-hah" moment, and all will become clear.

Addresses and CV29.
So let's move on to discuss addresses and some common motor-control CVs in more detail.

Addresses, again. Two or 4 digit. Hopefully, following my advice in earlier installments, you have a 4-digit system in use. I'd recommend, very strongly indeed, that you follow the convention of using the engine number as the address; after all, it's painted on the side of the cab. If you do only have a 2-digit system, convention is to use the last two digits, and try to avoid duplicates (I have locos 278 and 478, also 361 and 461, so you can see the value of a 4-digit system). I have also seen class numbers used for DMUs - so if you only have one class 165 DMU, 165 might be quite a decent choice of address.

BR numbering and TOPS diesels, I hear you say? Convention here is to drop the middle number, so A4 Sir Nigel Gresley in BR days would be address 6007, for example (or 4498 in LNER days). And if you model the GWR, it all stays nice and simple.

Four digit addresses are stored in CVs 17 and 18, with some complex arithmetic used to determine the two values. Just about every DCC system that can handle 4-digit addresses will work all this out for you; you just program the number, and you're almost ready to go.

Almost. Before you are, you'll need to explore and set CV29. This CV is a bit-mapped one, and requires a little bit of work to use. It has five bits in it that you need to pay attention to. Now, conventionally, the bits in each byte are numbered right to left, zero to 7. Lenz number them from 1 to 8, but the end result is the same. And all decoders use CV29 in the same way, because it is part of the NMRA standard.

- bit zero is used to turn the normal direction of travel round. If you wired the motor backwards (that's the orange and grey wires), you can reverse the direction of the locos here so that forward is forward. A value of 1 does that. Bit zero has a total value in the CV of zero or 1.
- bit one defines whether the decoder is to listen for 14-step packets or 28/128 step packets. When turned on, it's in 28/128 step mode, and that's the normal setting. If this is to be turned on, you add 2 to the CV setting.
- bit two defines whether the loco is to run on DC as well as DCC. 0 is DC off. If you want it on, you add 4 to the CV value.
- bit three is used to enable Railcom, for decoders using it.
- bit four is speed tables enabled. In total value, 0 is off, 16 is on. We'll mention speed tables in a while.
- bit 5 is two or 4 digit addresses. 0 is two digit. Add 32 for 4 digit.
- bits 6 and seven are not used.

From this we can see that the commonest values are 6 and 38. Value 6 means 28/128 step, DC enabled (2+4). A value of 38 is 28/128 step, DC enabled, 4 digit address: 2 + 4 + 32. And again, many systems, as you enter a two or 4 digit address, will do all this detail for you. And until you get into complex lighting setups, this is by far the most challenging part of decoder programming there is.

Nigel Cliffe pointed out to me that there is a CV29 calculator on the 2mm Scale Association website, at http://www.2mm.org.uk/articles/cv29%20calculator.htm, and this page also contains a long-address calculator, should your system not do it for you.

Motor Control

Now let's look at motor control. We'll start with CVs 3 and 4. These control acceleration and deceleration, providing some momentum to the locomotive and making it behave rather more like the tons of steel, brass and copper that you want it to represent, rather than the few ounces of mazac, brass and plastic that it really is. CV3 controls acceleration, CV4 deceleration. The standard is that each point in the CV adds a tenth of a second to the time it takes the decoder to step from one speed step to the next. A value of 5 means that the decoder will accelerate or decelerate the motor at around half a second per step, or take 5 seconds to go from speed 10 to speed 20. The extreme is that a value of 255 means nearly 4 minutes from stop to full speed! Start with a value of 5 in each, and adjust to suit the loco. Using CVs 3 and 4 carefully should mean the end of jackrabbit starts, and sudden stops, and a jerky response to changes in the throttle setting.

Personally, I tend to adjust these things using OPS mode - programming on the main. Then you get an instantaneous visual feedback of the effect of the change you've just made. And that's important when you start to use the next three CVs that we'll discuss.

CVs 2, 5 and 6 control the start point, top speed and mid point speed. You'll often find them referred to as start volts, max volts and mid point volts, but they don't actually cut the voltage supplied to the motor - they actually adjust the relevant settings of the pulse-width modulation to set the appropriate average voltage at the relevant throttle position. You can't use CV5 to enable you to use a 6v motor! There are also a few decoders (CT, Zimo, among others) which enable the track reference voltage to be set as an alternative way to manage the speed range. Soundtraxx's Tsunami has a no load reference for use when the back-EMF is switched off, so that it can check motor load, to manage sound levels for different loads.

Now, I use back-EMF decoders almost exclusively, and such decoders don't tend to require that CV2 is set to anything other than zero. That's because the bEMF system watches the motor and ensures that it is running, just, at step 1. If you use non-bEMF decoders, you'll likely need to set CV2 to get a good starting point low down in the throttle range. And when I set CV2, I do it in a few easy steps, using OPS mode.

First run the loco for a few moments to ensure that it is warm. The main use of CV2 is that it helps to overcome motor and chassis stiction, and we need to set it for warm usage, not cold. By the way, it's best to do this work with CVs 3 and 4 set to zero. Put the loco on the layout, with at least six feet or so of space that it can run up and down. Start by setting the throttle to speed step 2, or just off the bottom, and go to OPS mode. Set CV 2 to, say, 50, and see if the loco then starts. If it does, reduce CV2, say by 10; increase if the loco does not start. Find a value that is just below the point at which the loco starts. Now go back to throttle mode, and you should be able to see the loco start, and stop, right down at the bottom of the throttle range.

Similarly, setting CVs 5 and 6 is easiest in OPS mode. CV5 reduces top speed; use this to curb locos that run like slot cars, and also use it to slow down the faster of two locos that you want to double-head together. Just as we set CV2, the best way to set CV is to run the loco at full throttle, and reduce the value of CV from 255, to get the top speed you want. Try starting at 175, and go up and down in steps of 25, then smaller, until you get what you need. Now, use CV6 to adjust the midpoint speed if need be, to make a three-point speed curve effect. Once you've done all of that, turn CVs 3 and 4 back to the values you chose earlier, and you'll find you have a much more realistic locomotive response.

By the way, you did note that values that you set in these CVs, didn't you? If you didn't, then you should. Always write down all CV settings you make in every locomotive, so that you have a reference. One day, you'll want to experiment with the CVs, and having done that, want to get back to where they were. Or you want to set up a similar loco the same way. Or the decoder fails and you have to replace it. Or, heaven forbid, you use a broadcast write system and have just re-set every locomotive on the layout to the same settings.

One set of CVs that you really want to write down your settings for are the 28 CVs that are used to make a speed table. CVs, 67 to 94, that define speed settings at a set of points across the whole speed range. You'll tend to use these to match closely two locos that cannot be matched with just CVs 2, 5 and 6, or to generate specific acceleration/deceleration curves, say for a shunter that accelerates rapidly at low speed but then less so as it gets faster. I have to say right now that the best way to deal with a speed table, by far, its to use a computer program like DecoderPro. Doing speed tables by hand is really quite tricky and error-prone. I've heard of people who have used them who say that it's too easy to get one setting way out of line, and then have peculiar loco effects (like the loco stops at a specific throttle setting because that entry is set to zero). Note also that you need to set bit 4 of CV29 to tell the decoder to use the speed table – just add 16 to CV29's current value. And equally, subtract 16 from CV29 to stop using the speed table. Note, too, that you can't use the speed table and CVs 2, 5 and 6 together; it's one or the other.

What else is there? Depending on the decoder, you may be able to switch on a shunting speed mode. Digitrax decoders use CV54 to set this; when set to 1, F6 then halves the top speed of the loco and reduces the CV3/4 effects markedly, making shunting a little easier. Lenz Silver and Gold decoders use CV58 to set up their shunting mode.

Most decoders that have back-EMF enable you to tune it - normally there are three CVs for that. One controls how strong the back-EMF effect is to be, another controls how much throttle is to be added or subtracted when the loco speed strays away from the throttle setting, and the third controls how fast that throttle change is to be made. You'll also find a number of other motor control CVs in various different decoders: Lenz's CV50 motor type control, TCS's Dither settings, various braking distance settings, and more. To get the best from these, you need to read the manufacturer's documentation,. Digitrax and Soundtraxx have quite good descriptions for setting up Back-EMF in their

decoders, Lenz's CV50 documentation is much less useful.
Here's a detailed description for setting up Digitrax back-EMF that I found some years back on the web. The URL I used then, doesn't work now, so I'm including the whole article, rather than the URL, and corrected the worst typos in it.

Back EMF- Digitrax Scalable Speed Stablization

CV57 "The speed monitor"

CV57 is basically the loco speed monitor. It is the CV that keeps an eye on the speed of the loco and will determine when it's time to do something about the speed loss or gain. CV57 can have a value of 0 to 15. 0 is BEMF turned off, while a value of 15 is BEMF turned on to maximum.

Lets consider a loco running a 40mph. If CV57 is set to 0 the decoder will do nothing about the speed loss as the loco encounters a gradient. The loco will just keep slowing until it gets to a point where the motor can hold and make the top of the gradient or stall if it can't. If CV57 is set to 15 (max) then as soon as the decoder detects the loco is losing even a fraction of speed it will apply more throttle to maintain the current speed, (current speed being what you have set on your throttle). At such a high setting, as far as the decoder is concerned, the loco must not drop below or go above 40mph and will do everything it is allowed, based on the values in CV55 and CV56, to make sure it doesn't.

If CV57 is set to a more mild setting of maybe 6 then the decoder will allow the loco to lose a certain amount of speed before it does anything about it. Our 40mph loco starts to slow as it hits the gradient but the decoder won't bother to do anything about it until the loco drops to maybe 30mph, then the decoder will apply more throttle to hold the loco at 30mph. It will be your personal preference as to what value you put in CV57. It all depends on how you like to run your trains. Naturally a train loses speed on the hills, with CV57 you can set it to how much speed it loses.

Just a note with CV57 when it comes to consisting. CV57 has a 2 digit setting. The first digit is for when the loco is running alone, the second digit is for when the loco is running as part of a lash-up or consist with other locos.

For example: a value in CV 57 of "60" says that while alone use a value of 6 for speed monitoring and the 0 means turn BEMF "Off " when the loco is added to a consist. A value of 63 says gentle "6" speed adjustments for running alone and even more gentle "3" when running in a consist.

The reason for this is so you can stop the consisted locos from fighting each other. If the two locos consisted together have a BEMF setting that is too aggressive, and the lead loco is pulling a little harder than the second, the second loco will attempt to slow the train down, but then the first loco detects that the train is slowing too much and tries to pull even harder. With a mild BEMF the locos will be less over-reactive and thus provide a smoother run. I tend to use a value of 66 in CV57. It all depends on the quality of the locos.

A value of "66" for CV57 is a good start point. That's 6 for running alone and 6 for when running in a consist.

CV55 "The throttle adjuster"

CV55 determines how much throttle to apply when CV57 detects speed loss.

If the loco starts to slow and gets to a point where CV57 does something about it, and CV55 is set to 0 then then there will be no extra throttle applied and the loco will just keep losing speed. If CV55 is set to 255 (max) and the loco starts to lose speed, the throttle will put over to maximum to compensate.

Note though that because of the sudden increase in throttle, CV57 will detect that there is now too much speed, and CV55 will pull the throttle all the way back to 0. The loco will lose speed and CV55 will give it max power again.

This is not a pretty sight for our locos as they lurch and jump start down the track. CV55 needs to be set so it doesn't apply too much throttle, but maybe only add another 20% to compensate for the speed loss. Or if the train is running too fast, only reduce the throttle by 20% to slow it down.

A value of 50 in CV55 is a good start point.

CV56 "The throttle application speed"

CV56 determines how quickly the throttle is moved up or down as the BEMF tries to compensate for speed loss or gain.

When the loco starts to slow and CV57 does something about it, and CV56 is set to 0, then it will take for ever to move the throttle up to CV55's allowed amount. In fact a setting of "0" will never move up the throttle. However if CV56 is set to a max of 255 the throttle will be slammed up to CV55's setting instantly. The loco lurches off and CV56 slams the throttle back to down instantly. Again this offers a very erratic movement. With a more subtle value in CV56 the throttle will be adjusted slowly until it reaches the value set in CV55.

Again a value of 50 is a good start point for CV56.

Let see what happens with all 3 CVs combined

Lets say you have CV57 set to a maximumof 15, so the moment the loco starts losing speed the decoder takes action, and both CV55 and CV56 are set to their maximums of 255. Our loco hits the gradient at 40 and begins losing speed. The decoder gets on the case instantly, and because CV55 is set to max the decoder rams the throttle to full speed and it does so instantly because CV56 is also set to max. However, because the throttle is shoved to full the loco leaps off like a jack rabbit. Now the decoder detects that the loco is going too fast so pulls the throttle all the way back to stop and does so instantly. The loco comes to a stop and the decoder detects the drop in speed and rams the throtlle to full again. This is what causes the loco to stop start stop start in a jerking fashion along the track.

What the decoder is doing is getting on the "speed loss" case to quickly, applying way too much throttle and applying it way too quickly. Our crew vomits all over the cab floor and never mind the rest of the train, we smashed the first coupler way back.

Lets put CV57 back to 66 (allow some drop in speed before doing anything about it, both running alone and while in a consist.) Set CV55 to 50 (only apply a small amount of throttle) and CV56 to 50 (add throttle slowly).

Now our 40mph loco begins to lose speed on the gradient. The decoder doesn't worry about it until the speed drops to 30mph. At this point the decoder applies a small amount of throttle and applies it gently until the loco is back to speed. If the load is too heavy on the gradient and the loco is still losing speed, the decoder will give up trying any harder, it's doing the best it can on the settings you have set. For the loco to do any better you will need to add more throttle yourself on the controller or adjust the CV's to be more aggressive.

The loco makes it over the top of the gradient and begins gaining speed and does so until it reaches 40-50mph at which point the decoder eases the throttle back gently. All this happens many times a second in the decoder.

While you may feel you would rather adjust the throttle of the loco yourself, as do I, you can set up the BEMF of your decoder to only be semi automatic leaving the rest for you do, especially on "mainline". Note also though that BEMF is also very good at getting more out of an otherwise sluggish loco. If a particular loco struggles a bit on tighter curves etc, you can use a more agressive BEMF setup to coax a more powerful and smoother run out of it. Setup any loco with BEMF, run it slowly with your finger holding it back slightly and use the F5 key to turn on and off the BEMF function and you will notice the difference. The loco will push harder with BEMF on.

You can find yet more details on Back-EMF and the Proportional-Integral-Derivative formula, and a summary of how it's used by various manufacturers, at http://www.tonystrains.com/technews/introto_bemf_pid.htm.

Lighting and Other Effects
All decoders have Lighting Effect CVs and Function Mapping CVs. And, not implemented by some decoders, but arguably the most important of all, the Factory Reset CV. This is the one that allows you to start again when it's all gone wrong. Most modern decoders have it, and in most, it's accomplished by setting CV8 to 8, but do check your documentation here – for example to reset a Lenz Gold, set CV8 to 33.

I mentioned Function Mapping when we discussed installing decoders, because you need to have worked out what you want to do before you install the decoder. For example, the white and yellow wires are normally used to power lights at opposing ends of the loco, white at the front, yellow at the rear, and with most decoders, by default, white and yellow reverse as the loco is reversed. But let's assume that you want to have the headlight as non-reversing, on F0, and the backup light, also non-reversing, on F4. Then you want to make F3 control a firebox glow in a steam locomotive. This needs at least 3 functions. Let's explore how we'd set this up for a Digitrax DZ143 decoder, which is a 4-function device with white, yellow, violet and green wires. (Any other 4 function decoder will have the same four colour wires).

Here's part of the function mapping tables for Digitrax Series 3 decoders. The * shows the default value.

Functions F0 to F3:

	Wire colour	White	Yellow	Green	Violet	Brown	
	Add to CV	01	02	4	8	16	
Function	Mapping CV						Default value
F0F	33	*					1
F0R	34		*				2
F1	35			*			4
F2	36				*		8
F3	37					*	16

And Functions F4 to F6:

	Wire colour	Violet	Brown	White/Yellow	White/Green	White/Blue	
	Add to CV	01	02	4	8	16	
Function	Mapping CV						Default value
F4	38			*			4
F5	39				*		8
F6	40					*	16

This shows two things. Firstly, that we cannot map the yellow or green wires to F4 with this decoder. So to use F4 for a light, we need to use the violet or brown wires. The DZ143 doesn't have a brown wire, so we'll wire the tail light to violet. And we'll use the green for the firebox, leaving yellow unused.

To get the non-directional headlight, we set CV34 = 1. That maps F0R to the white wire. F0 is the only function that is directionally sensitive, and the two directions are known as F0Forward - F0F, and F0Reverse - F0R. Then to make F4 operate the brown wire, we set CV38, which controls what F4 does, to 2.

So far, so good. In fact, all we have left is to make the green wire into a firebox flicker. And from the function effects table in the Digitrax manual, we'd find that CV51 controls the effects on the green wire. CV51 is one of those CVs that use the left half of the CV to control the direction the effect works on, and the right half to control the effect. A value of X'21' specifies that the effect is non-directional (the "2") and the "1" in the right half is the firebox flicker. Or you can work it out as:

- add 0 for forward only, 16 for reverse only, 32 for both directions
- 1 for firebox flicker (0 for no effect, 2 for Mars light, 3 for flashing, 4 for strobe and so on)

making 33 in total. X'21' = decimal 33.

One last thing; if you have two throttles, and your DCC system will enable you to select the same loco on both, you can make this whole process quick and much more fun. All you do is use OPS mode programming on one throttle to do the programming, and instantly use the other one to test the effects. And of course, write it all down!

Next time, we'll move away from the mechanics of DCC and talk a little about life with a DCC layout, and show just how DCC enables you to move, easily, far beyond what's possible with a DC layout.

7. Using DCC: The addition of extra realism.

The previous articles in this series have all dealt with the mechanics and the hardware of DCC. This time we're going to change tack, and talk about how your DCC system will improve the operation and flexibility of your layout. But before we start on that, let's just go back a little and explore again some of the impacts that choosing DCC will have on the layout as you build it.

Planning and Building the Layout
The first one comes as you plan the layout, and plan the operations on it. With a DC-powered layout, a big part of the design is the block and cab system, the need to divide the layout up into electrical blocks to match the anticipated operating regime, so that when there are multiple locos on scene, they are isolated from each other electrically to enable the various movements of each loco to be made. As the layout gets more complex, this becomes quite a significant design headache. And if course it makes the layout itself operationally rather inflexible, because the only movements that can be made tend to be those that were planned at the design stage. But as the layout comes together and operations start, it's more than likely that you'll want to make different movements, and find they are hard to do with the original electrical block design.

And of course there is the added task of actually constructing the block wiring system - bad enough on a fixed layout, but on a travelling exhibition layout, it all adds electrical complexity which needs to be robust enough to stand up to the erection and dismantling and also easy to maintain. Quite a few DC layouts have a modest-sized copper mine underneath, all of which has to be constructed, and then maintained.

That's not to say that a DC layout isn't interesting and fun to build and operate, far from it. It's just that the freedom and flexibility that DCC brings to a model railway starts at the design and construction phase, and the benefits start there too. If you elect to operate points and signals via the DCC system, then operations can be done entirely with the DCC hand-held throttle. So you can start running trains properly on the layout pretty much as soon as the track is laid and the switchmotors wired, without waiting for any control panels to be built, which in itself means that operational potentials and deficiencies are discovered early on, before any investment of time or money is made in control panels and so on.

But it is when you start running the layout for real that the magic of DCC will really show itself. This is the realisation that you are operating a specific locomotive, and not just what happens to be on the piece of track connected to your controller. That, and the fact that with all the track being live, so that you can go anywhere where the points are correctly set, changes the way that the layout is used and how you run the trains.

First you realise that you are the locomotive driver, just as if you were in the cab. You are in full control of it, and the only thing that can stop you is a trailing point set against you, because when you reach it, you'll get a short and shut down the power district - and all the other operators will know you've done it, too. So, you need to pay attention to the signals, if there are any (my Colorado narrow gauge layout in HOn3 doesn't have any signals). Which in itself may mean that you will need to make the signals work, and potentially, interlock them with the points. Even go to the extent of having a signalman to operate the signals. You may say that isn't really all that different from a conventional set of block wires, but it is. With block wiring, especially those setups where it is interlocked with signals, mean that it's just not possible to move a loco unless the block switches and signals are set; but the real railway doesn't work like that. The driver and the signalman have to work together and cooperate on a DCC layout, just as on the real thing. The drivers trust the signalman to be signalling them safely, and the signalman trusts the drivers to obey the signals.

You can set momentum - acceleration and deceleration rates - into the locos, as we noted when we discussed programming decoders. So your models of 100-ton locos start to behave like 100-ton locos; they accelerate gently, and they don't stop instantly. You have to start to drive them differently - anticipate your stops, particularly when backing down on to a rake of coaches waiting for departure. You don't want to spill anyone's drink, after all. You really do have to do what the proptotype does: approach, stop, and then inch backwards to make the coupling. You can also, with many decoders, also switch on shunting speed control, which slows down the loco and reduces the momentum effect, ideal for such situations. Add to that the use of OPS mode programming, allowing you to re-program decoder CVs on the fly, even as the train is moving. Consider how that helps make operations more realistic. Try adjusting CVs 3 and 4 - acceleration and deceleration - to suit what the loco is currently doing. When a freight loco is moving off shed to pick up a train, it will accelerate and decelerate pretty smartly - say with CVs 3 and 4 both set to around 5. Once coupled to the train, you can simulate the effect of that train merely by resetting both to, say, 20. Then the loco will accelerate the train quite gently, and, more realistically, it will take a great deal more care, and more space, to stop it - just as stopping a real unfitted freight was an action that took forward planning on the part of the engine crew (try setting CV4 to 75, on your long, unfitted freight, and then experience how hard it was for the real world drivers to stop such a thing!).

Then there is the freedom to move locos closely together, such as in a loco depot. Hostling operations, for example the depot crew using one loco to shift a whole row of dead locos just as if they were shunting wagons are easy; you merely couple the locos together, consist the whole lot on to one throttle, remembering to mute the sound on any of the "dead" ones, and then move the whole row. So the whole operation in a crowded shed, getting locos ready for their next shift becomes a simple and reliable process, which cannot be marred by mis-setting block switches. It is even possible, with two throttles, to simulate dead locos that really don't want to be moved, and forcing the shunting engine to slip under the load.

Then there's terminal station operations. DCC makes it easy to run a train into a platform road, and follow it in with an empty stock shunter. Couple that up, and pull out the empty stock as the train engine drifts up the platform, behind the departing stock, to the shunt signal at the platform end, with both locos under independent control. Or you can bring the empty stock of an outbound train into the platform, then back the train engine down and couple up. And when the right-away is given, the empty stock shunter, now uncoupled, can give the main train a shove, and then follow up to the end of the platform.

Banking operations are also easy with DCC. You've the choice of foot of incline operations or top of grade - or both, if you have the luxury of enough space. Imagine a loaded freight train, with a loco that's able to pull it on the level, but would need help on the hill. You can either stop, and attach a helper or banker, or, as used to happen at Tebay, run through on the fly, and catch the train up with the banker. At the top of the hill, if the banker is not coupled, it can drop gently off the train - get this really correct, and you can slacken off the couplings gently before the banker actually drops clear of the brakevan.

Then there's the added functionality that DCC brings. Lights, sound, and other functions - try operating sliding doors on a DMU, or lowering pantographs on an electric loco. Your operations get more prototypical, particularly in the modern era, with ensuring that the correct lights are shown at the front of the train, and tail-lights to match. Or switching lights in coaches on or off. Sound, in particular, adds a great deal to steam and diesel layouts; the trains actually sound as though they are working, and proper whistle and horn signals can be given. And you'll also find that sound, particularly in steam locos, will make you operate at more prototypical speeds - shunting happens just a little bit more quickly, in most cases, while mainline trains will tend to move a little more slowly. And they are so much more exciting to watch, too, as the sound responds to load and to throttle opening.

But in the main, it's the ease of operation and the extra fluidity that DCC brings. In the US, there are many large layouts which host complete operating sessions where the layout is operated as a proper transport system. That's a new but growing trend in the UK; for example, read Dave Bradwell's article about using

US-style card and waybill operations on his P4 layout, and how he says it's transformed the way the layout is used (Model Railway Journal #195, December 2009, page 303). I operate on an HO scale US prototype layout in the Oxford area, using this system too: around 10 scale miles of track, 8 or 10 towns each with several on-line industries to switch, and where the dispatcher - controller - is elsewhere in the house, and contacted by radio. Yet operation is straightforward and simple; the dispatcher gives crews clearance to proceed. The crews report in when they reach the end of their allowed section, having switching operations at the towns they've passed as per the waybills for the cars in the train and those awaiting pickup. Again, all this can be done with a DC layout, but owners of such large operations-oriented layouts all report that switching to DCC means that in a given session more trains get run, with fewer problems, and more enjoyment, and far less maintenance.

What it all means is that you spend time on a DCC layout running trains, obeying signals, and actually operating a miniature transport system, rather than operating the layout control system. Watch DCC layouts at exhibitions, and note not just how well they tend to run, but also how much more fluid many of the operations are. That's the real magic of DCC - after all, all the hardware that we've discussed so far is actually the means to an end - that end being a better running and more usable model railway.

Next time we'll talk about Accessory Decoders, and how you can use these to add the DCC magic to points and signals.

8. Accessory Decoders

So far in this series we have concentrated on operating trains with DCC - talking about DCC systems and installing and setting up mobile decoders. As I'm sure you'll have gathered, you can also use your DCC system with Accessory Decoders to operate points, signals, crossing gates and indeed pretty much any other electrically operated device. While the use of accessory decoders is entirely optional - you can operate points and signals on a DCC layout exactly as you would on a DC layout, I believe that they make a great contribution to the entire DCC experience.

Accessory decoders come in a great variety of types and capabilities, and like mobile decoders, the DCC standard ensures that you can mix and match accessory decoders from almost any manufacturer with almost any DCC system. The standard specifies the signals that are sent to the accessory decoders, and that they have a different address range to mobile decoders. This different address range means that you can have loco number 24 and point number 24; the system sees them as separate entities, and operates them accordingly. Actually you do need to be aware that there are one or two manufacturers, down at the toy-trains end of the DCC spectrum, who have been a little loose in how they have interpreted the standards - which means that there are one or two train-set accessory decoders that actually use mobile decoder addresses. But we'll ignore those, and hopefully you will too.

Operation of an accessory decoder is really pretty simple. It has an address, and two operational states, which as they come from US point operation parlance, are called closed and thrown. You can think of these equally as on or off, left or right, clear and danger, depending on what you are operating with it. You connect the decoder's inputs to the DCC system's track outputs, which provides the input DCC signals, and may also power the device all in one go. You connect the relevant outputs to what you want to operate, noting that these outputs will normally be a volt or two below the DCC track input, or somewhere around 12v.

Apart from that, though, pretty much everything else is down to the individual decoder. The DCC standard only mandates one CV for accessory decoders, and that's the address. Unlike the mobile decoder's wire colour standards, there are no standards for wiring and none for how the decoder is programmed. Which means that a little research is required to be sure that the accessory decoders you choose are compatible with the system you have, and that the combination will deliver the functionality that you need.

What do you want to do?

Let's discuss a few characteristics of accessory decoders, because the wide variety of functions and packaging make choice somewhat complex.

First there is what you actually want to drive with the decoder. Most commonly used accessory decoders are used to drive point motors, and most but by no means all accessory decoders can operate both slow-motion and snap action - solenoid - switch motors. Indeed, most, if not all, decoders that can drive snap-action motors also have a capacitor discharge system built in. All accessory decoders that are specifically sold to drive slow-motion motors produce DC at the output, reversing the DC polarity between closed and thrown. There are a few accessory decoders that only produce AC at their outputs. That will by and large drive a snap-action motor OK, but will need diodes added to enable it to drive a slo-mo motor. You should check the manufacturer's documentation, just in case. Some newer accessory decoders are designed with servo-motors in mind, too.

Decoders driving slow-motion motors can get all of their power needs from the DCC track inputs, because the power consumption of the motors is quite small. But charging a capacitor from the DCC circuit brings the risk of voltage sag on the track and a slow charge cycle of the capacitors. Worse, the current in-rush all at once from several decoders at startup could even be seen by the system as a short. Which means that if you use snap-action motors, you'll need to arrange a separate power supply to the decoder, which it will use in favour of the DCC signal, and that also gives faster capacitor charging. Such decoders will always have auxiliary power inputs. You can use these too with slow-mos, but it's less necessary - but can nevertheless be quite a good idea. You'll even find that some accessory decoders, like Digitrax's DS64, can have a startup delay set, so that any initial charge-up of capacitors is delayed from when the DCC signal appears. If you have a dozen of the things, that could be quite a load if they all tried to charge-up at once.

Most accessory decoders come these days as a closed box with screw terminals. There are a few that come as bare cards that plug into a multi-pin (and I mean multi-pin - 44 is common) socket, and even one or two that look like mobile decoders - Digitrax's DS44 is one of those. Conventional wisdom says that you mount the decoder close to the points that it operates, to keep wiring lengths down. This is particularly good advice on an exhibition layout, because then the only point-operation wiring to the baseboard is the DCC supply and possibly auxiliary power - apart from any local-input wiring that we'll cover in a little while. You won't have the actual wiring that operates the points going across board joints, and that means fewer wires and plugs to go wrong.

Next is how many outputs there are - which equates to how many points the decoder can operate. For example, Digitrax's DS44 and DS64, both drive 4 points, but the DS44 can only drive slow-mos. Their DS52 operates two. CML's DAC10 drives 8 motors, while Lenz's LS150 will operate 6. This can affect choice on a portable layout, because commonly you'll mount the accessory decoders close to the points or signals that they operate. For a baseboard with only one point on it, a 6-output decoder is a relatively expensive way to go.

Quite a number of accessory decoders also allow you to program exactly how the output is to operate. Digitrax's DS64, when running in snap-action mode, allows you to set the length of the output pulse between 200 ms and 3 seconds, so that you can tune it to match the needs of your specific switchmotors. Or you can set it into Crossing-Gate mode, which oscillates the polarity of the outputs back and forth - which, with LEDS, simulates two red lights flashing alternately. You can then set the blink rate. If you use slow-mo motors with internal off-switches, such as the Fulgurex or Lemaco, you can tell the DS64 to turn off its outputs after 16 seconds. For Tortoise use, you leave the output on all the time. Some accessory decoders - here again the DS64 is an example - require that all outputs are slow-mo or all are snap-action, while others, such as CVPs AD4, allows you to select the output type per individual cell.

Local Inputs enable you to control an accessory decoder separately from the DCC system. Most local inputs toggle the decoder output as the input is turned on, so the simplest way to provide such an input is a cheap pushbutton, probably mounted on a small, local control panel on the fascia of the layout. You can then operate the points from there, or from the DCC system itself. More extensively, these inputs can also be provided by other accessory decoders, so, for example, you can use this to set up routes, too, but as we'll see, there can be better ways to do that.

Now, this local input functionality starts to look quite interesting from an operational point of view. You can create what is in effect a ground-frame for some points - which a train-crew on the ground operates switches manually - but leave others have to be operated by the DCC system only. And if you send out your train crews with simple throttles that cannot operate the switches - such as Digitrax's UT4 - that then leaves mainline points and signals operable only by the signalman, just as the real thing.

Quite a few accessory decoders will generate system feedback; the exact details of what and how is to be specific to a given DCC system, or at least, to the feedback system. In the Digitrax case, their Loconet system provides the connectivity between throttles, accessory decoders and the system itself. There are a number of accessory decoders available, not just from Digitrax, that will send Loconet messages back and forth. Lenz's XpressNet system provides similar functionality with appropriate accessory decoders. Feedback signals can be used either to generate commands for other decoders, or to inform a computer or even the throttle itself of what is going on. Feedback to a computer can not only be used to drive switch position on an on-screen layout mimic diagram, but could also be used by the computer software to clear signals, lock other routes, or even send commands to start and stop train movements - a software throttle, if you will.

A number of accessory decoders support routes. Some DCC systems, like Digitrax's DCS100/Chief also support routes in the command station. Route capability enables you to send a single point command, and actually have a number of turnouts respond, one after another, to set the route. Imagine you have an 8-track storage yard - you can assign each track a route command - say from 1 to 8, and when selected, know that all the switches that need to be moved to set the route will move, all from that one single command.

Special Purpose Accessory Decoders
Beyond general-purpose accessory decoders that we have so far discussed, there is a growing number of special-purpose accessory decoders, specific to given applications. One that has generated quite some heat, particularly in the US, is the Hare, from DCC Specialities. This is a Tortoise-specific device, which actually plugs on to the connector strip on the Tortoise itself. Not only does it support the usual facilities of switching the point, it supports local inputs, it has turnout-positioning outputs specifically for driving LEDs, it has a second output to drive a second motor for, say a crossover, supports routes when used with other Hares, and can do all sorts of other things too. You even can wire it and set it to switch the point automatically if a loco approaches the frog against the set of the switchblades, and also tell it what to do as the layout powers up. There are feedback versions which support Digitrax Loconet or Lenz XPressnet, too. The Hare is relatively expensive, but the added functionality and installation simplicity does have a great deal going for it. DCC Specialities also have the Wabbit, which is a two-turnout version of the Hare.

Just on the market is Circuitron's own DCC-equipped version of the Tortoise, called the Smail. It's so new, as I write, that I have not been able to get hold of any detailed documentation, but from what I have seen, it looks just like a Tortoise, but with more connections, supporting local inputs and other functions. Also just appearing on the market is a device called the Flea, which is a tiny DCC decoder and motor-driven switchmotor factory mounted underneath the tiebar of Shinohara HO switches; not yet interesting for S4 modellers, but a strong indication of trends to come.

There's also CML Electronics Towermaster product, strictly not an accessory decoder. This is a Digitrax-only device that takes control panel inputs from pushbutton switches, and generates accessory decoder commands on Loconet as though they had been sent from a throttle. You build your panel with one or more Towermaster boards - one controls up to 30 points - and connect this panel back to the DCC system with a piece of Loconet cable, and provide power. So you end up with a portable control panel for some or all of the points on the layout, and connecting it to the layout itself is done with just the one Loconet cable, and you also need to provide power. With all the detail wiring inside the panel, this gives enormous operational flexibility, as you can even carry the control panel around with you.

CML and other manufacturers also make signal controllers, which a provide the same functions as the prototype Automatic Block Signals. As the trains move, block detectors - now there's another set of components - tell the signal controllers where trains are, and the signal controllers operate the signals. All the train driver, you, has to do, is pay attention to the signals. How much more prototypical can you get?

Team Digital have an accessory decoder - the SMC4 -that's specifically designed for use with two-position and proportional servers, as used in radio control model aircraft. While a two-position servo is little different from a conventional slo-motion switchmotor such as the Tortoise, the proportional servo gives new capabilities. As used in model aircraft, these operate the control surfaces, and can be moved back and forth small amounts - the servo has a position sensor device in it, and the controller uses that to position the servo as required. In model railway applications, we can use that for such things as 3-way stub points, or 3-position semaphore signals. And what's been seen as one of the holy grails of UK modelling, the bounce return of signal arms. See http://www.borg-rail.com/servos.html for more on this.

If all of this starts to look a little complex and maybe somewhat forbidding, remember that it is easy to start simple and then move forward as you need. Simply wiring accessory decoders to the DCC signals - track power - allows you to operate the points from your throttle. Adding local control panels can come later, and for many people, that's as far as they'll go. But you know that as you move forward, with the right system and the right components, you can add more and more capability as you need it. What that does mean is, of course, that you need to start with a system that will operate accessory decoders, and which has the extensibility that you'll later need. In part 3 of this series, I presented a table of system capabilities, and that showed that all the systems listed can operate accessory decoders. I'd suggest going beyond the simpler systems, because 99 switches, for example, can easily be eaten up faster than you might think. This again is one area where buying an economy DCC system can actually prove rather expensive - when you find that you grow out of it quite quickly and then have to buy the system you should have bought in the first place.

When it actually comes to installing, wiring and programming for accessory decoders, you do need to do a little planning; where to put the decoders, how to power them, and how to number them. Each accessory decoder will have what's called a Board ID, and for many decoders, that sets the accessory addresses of the things that it operates. With CVPs' AD4, for example, board number 1 operates switches 1 to 4; board 2, switches 5 to 8 and so on. Other decoders, such as Digitrax's DS44 and DS64 allow you set a different switch address for each output, which is less restrictive. You can use this ability to have more than one decoder respond to the same switch address - imagine that you have a crossover spread across two baseboards, separate accessory decoders in each baseboard, but you want the two points to operate together from the same command, and so need two decoders to respond to the same address. I would also suggest that you number according to location, too. If you have multiple stations or junctions on your layout, use switches 1 to 99 in one station, 100 to 199 in the next, and so on, rather than allowing the numbers to get mixed up. You do not need to use all the available switch numbers in sequence, gaps are just fine (so long as your system can cope with the higher numbers that you end up using). Do also note that some accessory decoders need to be programmed in part or in total on a programming track, which means that you may have to program them before you install them - which in itself means that you should place them where you can get at them if need be, or be able to remove them easily. And of course document what you have done, so that should you want to change it, or need to replace a decoder, you can do it quickly and easily. Do note that by and large there is no decoder readback on accessory decoders, so writing down how you have set them up may be easier than working it out again from the manuals.

I would always place accessory decoders close to the points that they operate, particularly with snap-actions, to keep the wiring runs short and minimise voltage drop. Yes, that might lengthen the wiring for local inputs, but as that is carrying electronic signalling load and not loads for actually switching the points, it's less important - and also not a disaster if it one doesn't work, because the switches can always be operated from a throttle. With a transportable layout, I'd ensure that each baseboard has its accessory decoders mounted on it, so that all the wiring is as self-contained as possible. And if you use a Towermaster with a Digitrax system, or a computer to act as a control panel, you then don't need any local input wiring on the board either, which further reduces wiring complexity and the number of connections between baseboards.

Also consider how you power them - we already noted that if you drive snap-actions, you are likely to need auxiliary power as well as the track power inputs. I would always supply the DCC inputs to accessory decoders, even if it is just providing the DCC signal and not operational power, from a separate power division to the real track power. That's because should you have a short on the track - for which the most common cause is running over the frog-end of a point that's set the other way - you will still be able to send switch commands to the accessory decoder and operate the errant point. Indeed, on my own layout, I actually use a separate Digitrax DB150 booster to drive the switchmotor/accessory decoder circuits. In that way, the 40-odd Tortoise motors are not drawing their power from the same booster as the track, and I am assured that there will be enough power for everything.

Next time we'll look at adding a computer to your DCC system, both to make decoder programming easier, and enhance your layout operations.

9. Adding a Computer

Given that the D of DCC stands for Digital, it seems almost inevitable to try to couple a computer to a DCC system. While there's no need to involve a computer, there's no doubt that connecting a computer to your DCC increases the value, and it's also fair to say that DCC is by far the easiest way to interface a computer to a model railway. Once connected to DCC, there are two distinct ways to make use of the computer. Firstly, in the programming of DCC decoders, and secondly, in actually operating the layout.

But before that, the computer has to be connected to your DCC system. Fortunately with all the mainstream full-function DCC systems that's not a difficult problem - some systems - NCE, Zimo, and ESU's ECOS for example, have a computer interface built in, so all that's needed is a cable. Digitrax, the various systems that use Lenz's Xpressnet, and quite a few others require a hardware adapter that connects the computer to the system's bus or network. With my Digitrax system, I use a Locobuffer-USB, which is a USB to Loconet connection box. That makes the computer look like another Loconet device as far as the Digitrax system is concerned, able to send Loconet traffic and to read and potentially act upon any packets received. While other system connections are different in the details, essentially they provide the same set of abilities: the computer can issue commands to the system, and can receive feedback and status from it. However, you would be well advised to do a little research on exactly what is available with your system and what specific functionality it can bring - a good place to start is the DecoderPro hardware page on the web. We'll get to DecoderPro in a moment.

One exception to this is the SPROG device, now the SPROG II. This is a stand-alone DCC Programming device. Connected to your computer's USB port, it generates DCC programming packets under the control of the computer, and may also be able to provide enough track power to test the programmed locomotive - but it cannot run a layout beyond the smallest, because it only outputs 1 amp at the most to the track. As they say on their web site (www.sprog-dcc.co.uk), it allows you to program decoders from your computer without taking the computer to the layout or vice-versa. It can be of enormous value, too, if your DCC system does not have a computer interface.

DecoderPro

Programming decoders with a computer, whether you use a SPROG or connect the computer to the DCC system, is best done with a free program called DecoderPro - indeed, I don't see any need to go beyond DecoderPro, unless you have an MRC/Gaugemaster system – their computer interface only supports their own software, and won't work with DecoderPro any other non-MRC software. DecoderPro can be found at jmri.sourceforge.net. It differs from commercial products in that it is an "open-source" project, built by hobbyists, and not for profit. It's system-independent and is updated pretty frequently, with new functions and, more importantly, new decoder definitions - this means that it knows what the decoder you are using can do and what programming it requires. It also presents all decoders in a similar way, making it easier to find your way around. You'd have to buy a very newly produced decoder, one that is completely different from its predecessors, to be struggling to program it with DecoderPro.

DecoderPro does require that your computer has Java installed. If you don't have that, there are links on the DecoderPro site to get to Sun Microsystems's Java.com download site. Java is another free download, and you just need to follow the links and the instructions to install it. This all may seem like quite a bit of work to get it going, but it's actually pretty simple and straightforward - and I'm sure that you'll be able to find someone who will help you should you feel the need.

Once you have DecoderPro installed and your connection to the DCC system or your SPROG set up, you tell DecoderPro what hardware interface and what system you are using, and you are away. It's best to start with a loco on your programming track. DecoderPro can read CVs 7 and 8 in the loco to find out what the decoder is, or you can select it manually. DecoderPro will then display a set of tabbed pages that leads you through all the Decoder functions, with their default settings which you change, or not, as you please. DecoderPro can then write the changes back to the decoder, and your loco is ready to go. Assuming that you are using a DCC system that supports decoder readback - or a SPROG - you can also read back the entire settings from the decoder, display it all on the screen, and save it all on the computer, too. That makes the chore of recording all the settings very easy, and also means that you can copy settings from one loco to another with minimum hassle.

DecoderPro can also do OPS mode - main-track - programming, if your system supports it. That means that you can program and test loco settings all from the computer, and that makes things such as Back-EMF setup, speedmatching locos and setting sound volumes much less stressful. Depending on the system you use, DecoderPro can also put a virtual throttle on the screen, which you can then use to select a loco and operate it - though using a mouse on a slider bar as the throttle itself does take a little getting used to.

I personally think that DecoderPro is a pretty much essential tool, if you have a loco fleet of any size, and you do more than the most basic of programming. Once you start into complex lighting setups or sound, it really does become hard to deal with locos without it.

Layout Functions

However that's not all that DecoderPro can do. With the connection to the layout made, the computer can issue any command to the DCC system that the system can understand, not just programming commands. DecoderPro has the ability to display information from your system - if the system makes such information available. With my Digitrax system, I can display all the loco slots in the system - that means that I can see what locos are being refreshed, which are selected, and to which throttle, what functions are turned on, and what speed and direction they are going in. It can even show all the DCC packets being sent around the Loconet - which if you are setting up point feedback or block detection, can be a useful troubleshooting tool. It will do similar things for other DCC systems, too - depending, of course, on the exact capabilities of your system.

Once you are able to send commands and receive confirmations on actions and feedback from the system, it seems logical that the next step is to use the computer to provide some more meaningful interface to the layout and take part in actually operating it. This does mean that the layout needs to be operated by and interface to the DCC system more completely. To do that requires that the points and signals should be operated from the DCC system via accessory decoders, so that they can be controlled from the computer.

A very simple start is to use PanelPro, which comes along with DecoderPro. PanelPro lets you draw signalbox trackplan schematics in a variety of styles. You can include signals as well. You then click on the diagram to operate the points, and the display shows, by moving the point display or altering signal aspects, what commands have been sent to the system.

But if you want to, you can go quite a bit further than this. Once you have points and signals operated by DCC accessory decoders, you might want to start looking a block detection. We covered the use of accessory decoders last time, but we've not mentioned block detection yet. This is something that has no fixed standards in the DCC world, yet. All the main manufacturers can offer block-detection - which tells you, like track-circuiting on the real railway, what blocks are occupied. Some systems are even able to tell you what decoders are detected in each block - like Digitrax's Transponding, and the upcoming NMRA Railcom-based feedback standard. I think that you'd need to match your use of block-detection to your prototype - so that if your 1920s prototype only used a small amount of track-circuiting to display occupancy of sections that are out of sight of the signalman, then you can do the same, while a modern-image layout might call for complete block-detection on all stretches of main line, passing loops and siding entrances. Or you might want to use it just to help manage large and hidden storage sidings, showing which roads are occupied and which are free - and then go on to getting the system to switch the points to vacant tracks ready for inbound trains.

PanelPro is quite simple, and that's what it's meant to be, though it does interface with some block-detection systems - Digitrax Transponding, and has an RFID interface. There are also far more complex programs available, for purchase, that will take you in a variety of directions. One way is towards more complex panel displays, complete with occupancy and transponder reporting. Another is towards layout automation, for which block detection is pretty much a mandatory requirement. Here's a list of a few of these more complex programs - none of which I have any personal experience with, so there's no endorsement here.

The CATS system is a free download at http://home.comcast.net/~kb0oys/ . It adds on to the JMRI/DecoderPro suite. It's US-based, but that's not to say that it won't be useful. It will display and operate centralised point and signal panels and helps a dispatcher manage the operation of trains on the layout and be able issue instructions - train orders - to crews.

Digitoys, another American company have a number of products at http://www.digitoys-systems.com/PC_Software_e.htm, most of which are biassed towards use of a Digitrax system, but their classic WinLok will work with just about any DCC setup. Like CATS, it enables the development of on-screen layout panels, and also offers layout automation facilities.

Railroad and Co from Germany, at http://www.freiwald.com extends this kind of functionality even further and also claims to support pretty much every DCC system on the market, including Hornby.

SSI is an Australian/British software company that among other things offers a railway control system at http://www.gppsoftware.com/ssi/ssi.asp. This is limited to a few DCC systems, but does appear to be more British-oriented than the others.

Finally at the MERG site, you will find a set of links to these and other sites that offer computer enhancements to DCC.
http://www.merg.org.uk/links.htm#COMPUTER

In all cases, you need to do your research before buying. I'd suggest that you consider what you'd like to be able to do, and then research these and other web sites. Understand the connectivity options with your system, download manuals and see what the products do, and how they do it. Look at the underlying philosophy - some will be oriented towards prototype, particularly US prototype operational practices of traincrews operating with waybills and switchlists under the control of a dispatcher, while others will be more towards providing layout automation. Certainly one thing you could do, after having played with DecoderPro and PanelPro, is download CATS and try that out before you spend any money on other software, but beware, it's not instantly intuitive, and does require some basic computer knowledge to get it up and running.

Next time, we'll look at Sound decoders, what's available, what the issues with fitting them are, and learn just how addictive sound can be.

10. Sound

If there's anything more addictive than DCC itself, it has to be the addition of sound. DCC sound today has moved far beyond the sound effects of yesterday's toys into accurate and believable re-creations of the ambience of hard-working locomotives. Depending on exactly what you model, you can now listen to your Brush 4 lean into its train and get it on the move, or hear a pair of 8Fs slogging slowly uphill, exhausts going in and out of sync, followed by the pop of safety valves as they come to rest at the top. Once you've operated a sound-equipped layout, you'll find it hard to go back to silence.

Adding sound to your own locos is really not difficult to achieve. Let's explore what's required.

Functions

Firstly, you do need a DCC system with enough functions to get the best from sound decoders. Given that the accepted standards for sound functions include F8 as the mute key, I'd say that a system that goes up to F8 is the barest minimum, and F12 or more is better. While nearly all sound decoders have an array of automatic sounds, there are quite a number of manually triggered sounds that you'll want to use. F2 is almost always used for the whistle or horn, F4 or F5 is often a steam hiss or diesel dynamic brake fan sounds, and F7 is often used for dimming lights on US-spec locos to meet rule 17 (lights are dimmed when waiting for opposing trains or when standing in a station). You'll certainly be able to operate sound locos with less functions, but it won't be the same. And should you be wanting to operate modern British diesels, then you have to consider four or six functions worth of lights, too, making an 8-function only system seem a bit sparse. Note that the NMRA - the US National Model Railroad Association, who own the standards that govern DCC - has worked on extending the standard to include 28-function systems and decoders - and since the first writing of this piece, systems offering 20 or more functions are now on the market; Digitrax going right up to F28 on its DT402 series thottles.

There's another thing you need to be aware of, too. Sound decoders often have attached to them what are called Keep-Alive capacitors, which are intended to keep the decoder working across a blip in the track pick-up - and we'll cover these in a bit more detail, later. When the track power is applied, or restarted after a short, these capacitors all start to charge at once. The so called inrush current of a number of these can overwhelm lower-powered DCC systems. I occasionally have problems in recovering from shorts when I have more than 15 or 17 Soundtraxx Tsunami decoders in a single power district with my Digitrax PM42 circuit breaker, but the Chief itself can handle upwards of 30 simultaneously. Some decoders, particularly early QSI ones - as fitted to a number of US-prototypes - are known to cause the inrush current draw issue. So if you haven't yet bought a DCC system, and intend to go for sound, buy a 5-amp system as a minimum, and be prepared to wire the layout with a number of power districts.

Next, of course, you need a sound decoder and speaker. Sound decoders come in a number of varieties.

Sound Decoders

Firstly, there's sound-only decoders. These are ones that do not contain a motor-decoder, and in many cases, don't operate lights either. Soundtraxx have their DSX range - which is pretty much all US-prototypes. These are pretty old technology now, but the richness and flexibility of the sound they make is still pretty good. ZTC used to offer a badged version of the DSX with GWR 2-cylinder sounds, but at the most appalling price - the newly revived (end 2009) ZTC may or may not offer these again. Separate decoders are also available from Digitrax, ESU, CT and others. You'd use a sound-only decoder often where space or practicality means that you cannot use a single decoder. An example might be a steam loco that has enough space in the boiler for a motion decoder, but not enough for sound, so you'd then need to put the sound decoder in the tender. But that would mean that you'd need several wires across the loco-tender coupling, and you'd rather not do that. Two decoder installations can be very flexible, but they do have the disadvantage that the two decoders are not connected together electronically, so that the sound decoder doesn't actually know what the motor decoder is doing. SUSI is an attempt to get over this; it's supported by Lenz, Zimo and Dietz, and enables a back-EMF decoder to tell a sound decoder how hard the motor is working, and so have the sound affected by that.

Then there are decoders whose sounds are user-loadable. Indeed, these days, the majority of available sound decoder ranges are reloadable, but a word of caution here: making up a good sound set is not for the faint-hearted. It takes decent recording gear, time to make clear and clean recordings with no background noise, and then a great deal of digital editing to make the sounds acceptable, in terms of pitch, matched volumes and generally working together. Just consider: to make a whistle sound that plays as long as F2 is depressed takes 3 snippets of sound: the start of the whistle, the end, and a piece in the middle that can be played over and over, which when played is not just seamless when connected to the start and end sounds, but also to itself to allow it to be looped. The same goes for steam chuff sounds. With diesels, the challenge is to make the different pieces of sound that make the different engine speeds properly blend into each other as the loco speeds up, slows down, or as load or throttle settings change. ESU's Loksound range, Zimo's sound decoders, Digitrax's sound-only decoders, and Austrian manufacturer CT's decoders are all capable, with their own sound loading systems, of be user loaded. This, by the way, is not the same as programming decoder CVs, which, by and large, can be done on any DCC system. We'll discuss programming sound decoders later.

Soundtraxx's decoders, along with MRC's, come with fixed sounds in them. DSX's are fixed to a single loco, and apart from the ZTC-badged one we mentioned earlier, the British interest is somewhat limited. There's a British L1 tank engine which has a great LNER whistle, and I'm told that the Norfolk & Western A class 2-6-6-2 whistle sounds just like an LMS Stanier Hooter. Soundtraxx's Tsunami, which is by far and away the best steam sound decoder currently available, comes in several steam varieties, each with half-a-dozen whistles, sadly few if any of which sound at all British. That's a great pity, because not only does the Tsunami have good motor control, but the sound is connected to the back-EMF and to the throttle setting in such a way that you get sharp barks on acceleration, quieting as the loco reaches the set speed, mild breathing of a just-cracked regulator with lots of rod clank as the train coasts, and braking to a stand with brake squeal as F11 is pressed to apply the brakes, all of these with separate volume controls. Soundtraxx do a number of DSX diesel decoders, and a large range of diesel Tsunamis, of which the only one that probably has any serious British usage is the Rio Grande Southern Galloping Goose, a 4-cylinder petrol engine object with a 4-speed manual crash gearbox; not bad for small industrial shunters even if it's a bit more petrol than diesel.

So, what's the choice for UK modellers here, then? SouthWestern Digital (http://www.southwestdigital.co.uk/) have a large range of sounds, mostly diesel, in ESU LokSound decoders. I've heard a number of these, and apart from the fact that the UK diesel two-tone horn cannot be played in both tones, they sound pretty good. Howes Models at http://www.howesmodels.co.uk also use ESU LokSounds for a number of diesels too, and some steam - for example, LMS Black 5 and 8F, GW Castle, Bulleid West Country/BB and a Standard 4-6-0. Then Digitrax have a number of British sounds - a class 108 DMU, 04 diesel shunter, class 33, and some steam, all of which SCC (www.scc4dcc.co.uk) can load into a Digitrax decoder as you buy it from them. Bachmann are already selling their class 66 among others with ready with an ESU sound installation, using, I believe, SouthWestern's sound. Hornby have a few locos with sound: LMS Duchess in steam and class 60 diesels for example. I think Hornby also use ESU Loksound decoders. Zimo have a large range of sounds available for theiur decoders - some are free, some need to be paid for, but as yet, none are British sounds.

Even if your favourite steam loco is not yet available, don't despair. While a diesel really needs to be accurate - with the right prime mover sounds, what really matters with steam is the whistle. Get that reasonably right, and you'll probably be happy. If not, and the loco is preserved, someone someday will record it and blow it into a Digitrax or ESU decoder. And if it's not been preserved, and isn't on one of Peter Handford's recordings either, then who knows what it sounded like for sure? Do you know what a Highland 4-4-0 sounded like? If you do, and you have a decent, clear recording of all the pieces that you need, you can assemble these as WAV files, and download them into downloadable decoders. Now, while that might sound simple, it actually isn't. First, you need clear recordings. Whistles with no birdsong, car horns or crew chatter, and so on. Then you need to match up the start and end of sounds. For example, a whistle has a start, middle and end. When you press F2, the decoder plays the start piece. If, when it's done playing that, F2 is still pressed, it plays the middle piece, over and over again until you let F2 go. Then it plays the end piece. So, you can see that the start piece's end has to match the start of the middle piece, which has to match the end of the middle piece as well as the start of the end piece, so that it can play start-end, start-middle-end, or start-middle-middle-middle-end without you noticing the joins. Similarly, the start and end of a chuff need to be properly silent, so that two chuffs can be separated, or blended into each other. And then you need all the other sounds, all set up so that the decoder can vary them as the speed and load changes. All of that is why good sound projects, like the Tsunami, or the SWD or Howes ones in Loksounds, are quite expensive.

Installing Sound Decoders

Once you've chosen your decoder, installing it is pretty much the same as installing a non-sound decoder, except for the speaker, and for steam locos, the option of a chuff synchronisation cam. Both of these need care and attention to get the best results.

Let's start with chuff cams first. There's a variety of different ones, but in essence, fitted to one of the driving axles, most of them short the decoder's cam lead to one of the rails - it doesn't matter which - if the loco was turned round, it would be the other rail anyway. I use Grizzly Mountain Engineering cams from the USA (http://www.g-m-e.com), mainly using the slotted variety that can be fitted to an axle without removing the wheels. These aren't actually cams as such; they're circular disks around 3mm wide, brass centred, and a number of brass lands at the circumference separated by insulation. For two-cylinder and most 4-cylinder locos a 4-pointer is required, giving 4 chuffs per revolution. GME also offer 6, 8 and other varieties for 3 cylinder locos, geared locos and other strangenesses. Soundtraxx offer cams made of thin PCB that are added to the back of a wheel, and there are also magnetic reed-switch synchronisers sold by EDM models (http://www.ngtrains.com) - these don't require the axle they're mounted on to be grounded to one rail, but I find them picky to set up, and they're badly affected by under-track magnetic uncouplers. Zimo decoders can output a "pulse train" that's apparently derived from the back-EMF circuitry in the decoder, which could then be fed into a sound decoder. I guess Zimo also use that internally in their own sound decoders for the chuff timing, too.

Once the chosen cam is installed, a thin feeler of 10-thou phosphor bronze is added to run on the cam. When using the GME cams with a sprung or compensated loco, you should mount this to run vertically in front or behind the axle so that axle movement is not affected by the feeler, and also so that the chuff timing isn't altered by axle movement. This also means that the lands on the cam need to be lined up reasonably well with the crankpins on the same axle to get the chuffs at the end of the piston travel. With the Soundtraxx cam, the feeler presses sideways on to the cam, so should not be too heavily sprung otherwise the wheelset will be pushed sideways in the frame.

Cams are optional; all steam decoders have an autochuff facility that can be tuned to the wheel diameter. My experience is that these aren't perfect, especially with non-back-EMF decoders where the engine speed isn't linear with the throttle setting. Chuff sync matters most when starting and at low speeds, where non-BEMF decoders are at their worst. If you can fit a cam, you'll not regret the time and effort of doing it.

Speakers

Next thing you need to do is find space for the speaker, and fit it. You also need to ensure that the speaker is fully enclosed at the rear, too. To simplify the reasoning: when the cone moves to generate a sound wave, if the resulting pressure wave is merely able to get directly from the front of the speaker cone round to the back of the cone, very little sound volume will be generated because no net work is being done - just a small amount of air is being shuffled back and forth. There's a great deal of science and development attached to dealing with this in HiFi speakers, and to a lesser extent when developing sound-equipped RTR locos; QSI, for example, have available on their web site a document that describes the baffling (pun intended) process when designing speakers into model locomotives. Suffice here to say that so long as the speaker is in a reasonably airtight box, all will be well. The simplest airtight box is a steam locomotive tender, with the speaker sitting on the floor firing downward through holes in the floor, using the entire tender as the baffle. Just be sure that the speaker cone cannot touch the tender floor, because if it does, you'll get horrible, horrible distortion. You can use cardboard or styrene sheet to make a spacer. Smaller speakers across the diameter of a boiler, using the smokebox as the baffle box, also work well, as do side-tank mounted speakers firing into the motor space letting the sound come out around the wheels, using the sealed side-tank as baffle. You need to use the largest speaker that you can get in, to minimise distortion of transients and get the best bass response, but properly baffled, you will find that an 18mm round speaker, or an equivalent oval works pretty well in a home environment. Such a setup will generate enough sound to allow the decoder's amplifier volume to be set reasonably low, which leaves enough power to cope with transients and a decent whistle without distortion. Speakers in tenders with the decoder in the loco means two wires between loco and tender, optionally with a plug and socket. If the decoder has to go in the tender along with the speaker, then at least three wires will go to the loco (two motor wires and at least one track pick-up wire), and probably several more.

Do be sure when you choose speakers to ensure that you understand the resistance required by the decoder's amplifier; get this wrong and you risk damage to the decoder. Soundtraxx and Zimo decoders are all happy with 8-ohm speakers. Digitrax supply 32-ohm speakers with their decoders, but say that anything above 8-ohm is OK. Some CT decoders require 32-ohm speakers, while some others only need 8-ohm. Many ESU Loksounds require 100 ohms. You can add resistors in series with the speaker, but if you do, remember firstly that these resistors will get warm - which means they need ventilation - because of the power they are dissipating, and because they are dissipating power, the available volume at the speaker will be lower. Most sound decoders generate more than enough volume for home use for this not to be a problem, but sadly exhibition halls are noisy places and there, you need all the volume you can get.

Once it's installed, you'll want to test it out. Exercise a little caution, and do some programming first. All the sound decoders I've used, sound-only or combined, peep the speaker when programming on a program track. So if you read or write a CV on the program track, get a feedback to the system, and peeps from the speaker, then the chances are good that it's all connected properly. Programming sound decoders is exactly the same as programming non-sound ones, except that there's more CVs, and you will find that exploring these is worth while. Read the decoder documentation. SoundTraxx's documentation for the Tsunami range is the model that other manufacturers would do well to emulate - their Tsunami Steam Users Guide that's on their website is particularly good, but it is only relevant to the Tsunami. However, you will find that some sound decoders will not program with some systems very easily - to do with program track current limits. For example Soundtraxx Tsunamis are hard to program with Digitrax and some other systems, because the current draw they need when programming is more than these systems supply to the program track. For that reason, Soundtraxx offer a Program Track Booster to make life easier - and similar devices are available from other sources too.

Programming Sound Decoders

Here's some ideas to consider when programming sound decoders.

Firstly, use larger CV3 and CV4 values than you might otherwise. Try 30 for CV3 and 50 for CV4, and listen to how the sound changes as the loco accelerates and decelerates to match the throttle. Beware, however, that settings this large mean that you have to drive more carefully, and it will force you to use small throttle openings for careful coupling movements. But without such settings, you'll lose some of the ability for the decoder to vary sound levels and timbre depending on the loco loading, and on loco speed versus throttle setting.

Secondly, adjust volumes of different effects, where you can, in relationship to each other first. Make the whistle loud, make the exhaust a little less so, and make the other effects quieter still. When you have these volumes set, then adjust the master volume to what you are happy with at home - it's best if the loco is clearly audible from about 6 feet, but fading a little after that. If the loco is then to go to exhibitions, know how to change this CV to make it louder for the exhibition, and set it back to home levels afterwards, without affecting the overall balance of volume levels.

Most sound decoders also offer a "quiet" bit. This enables you to decide whether the loco stays quiet until it is selected and a command sent to it, or whether it is alive and making noise all the time. You'll often find that the quiet bit is also connected to another CV, which allows you to set how long the engine stays making sound when idle and not being addressed. You may well want to set that quite short - so that if you de-select the loco, the sound stops after 30 seconds or so. Diesels you might want to shut down even sooner than that.

Once you've got your first loco working, and working well, you'll start to see some changes in how you use your locos. Firstly, you'll tend to use the sound-equipped ones more, and the non-sound ones less. More importantly, you'll also notice a big change in how you run them. You will tend to run a good deal more slowly, savouring the sounds as the loco speeds up and slows down, and the fact that when stationary, it's still alive and making noises, just as the real thing. Then you'll use less abrupt throttle changes, and spend a little time stationary between shunting moves. There's also a fair chance that you'll add more CV3/4 momentum to the thing, possibly even more than I suggested above, and find yourself driving even more realistically, too. Then you'll start to use whistle and horn signals. And you'll start to realise exactly what you've been missing, and just how much the addition of proper loco-managed sound adds to your enjoyment of the whole layout and the time spent operating it.

But, of course, there are a few drawbacks. There's the cost issue, particularly if you started off with a simple DCC system that doesn't have enough functions to be able to reach all the sounds in your locos. Then there is the fact that sound decoders are more expensive than silent ones, but that is tempered by the fact that fewer sound-equipped locos will keep you going better than more but silent ones will, unless of course you have a truly enormous layout.

There's also one technical issue, particularly for travelling layouts, and that's loco pick-up and clean rails. A sound-equipped loco draws more current than a silent one, and of course is drawing current even when stationary, to run the sound system and the amplifier in the decoder. If you have a loco with lights, you may notice the lights flicker a little while the loco is running. If you have less than optimal pick-up with a sound decoder, you'll get some crackles in the speaker. Worse than that, should there be a mere momentary loss of pick-up, the decoder may stop completely; which, given lots of momentum and sound, means the loco stops, and then the sound system restarts - embarrassing particularly if the loco is a diesel with a 10-second startup sequence. You do need to keep track and wheels pretty clean when you use sound, and you are well advised to pick up track power from as many wheels as you can on every loco.

Most sound decoders these days have what are called keep-alive capacitors, which aim to help the decoder over momentary loss of power. Some - most - use the capacitor across the power input to the decoder so that it powers the whole thing. Some use the keep-alive to ensure that the microprocessor doesn't stop - which means that even if the sound and motor stop, the decoder will stay alive and not lose what it is doing. The snag here, particularly for small locos - which are the ones that need most help - is finding space for the capacitor - though as they are mounted on wires, this may not be too difficult. Best way to avoid all of this, however, is to ensure that you have as many wheels picking up power as possible, and keeping the rails and wheels clean.

Next time we'll look a little into possible futures for DCC, and wrap the whole series up.

11. Wrapup

The original series in Scalefour News ran for 13 issues over two years - and two ScaleFour news editors, too. A lot has happened in the DCC world in the 8 years since I started with DCC, and a fair amount of change happened as the series was being written, and has continued since. A larger number of you are either now using DCC or are seriously contemplating DCC for your current or next layout than were two years ago. I hope that this series has shown you not only that DCC is really quite easy to adopt, but also just how much more real, and lasting, value it brings to your enjoyment of this really rather wonderful hobby. I've had a few personal bonuses from writing the original series, too. I've made new contacts, some right out of the blue. I've learned things about DCC that I might not otherwise have come across. I've been asked to re-issue it - which is what you're reading now. And I used the set of articles as part of the collateral to earn my NMRA Achievement Program Model Railroad Author Certificate, too.

But what of the next few years in DCC? Well, DCC will become the norm, and DC operation the minority, on new and on existing British layouts, just as DCC is pretty much already the accepted standard for US-outline HO layouts. I really don't see many new exhibition layouts being built as DC layouts once the constructional and operational benefits that DCC brings are understood. The RTR manufacturers now offer pretty much all their new OO/4mm models with DCC sockets as standard, and most have started quite aggressively re-engineering older models with sockets too. Hornby and Bachmann, the UK market leaders, have moved forward from that, and are now installing decoders as standard in some of their ranges. OK, the decoders that they are offering aren't of the best quality, but they do the job adequately for their prime train-set market, and they work at least as well as would the loco in DC operation. They've also started selling DCC systems of their own. Indeed, Bachmann's new Dynamis system is their second-generation offering, within just a couple of years, and it is starting to push the user interface aspects away from the simple knobs and buttons with a one-or-two line display and towards new ideas for control. They've also provided it with an infra-red, cordless handset system, showing that they, at least, see that the fixed control position is a thing of the past. These train-set systems have not yet hit the full range of functionality that the DCC leaders have achieved, but they are snapping at their heels, and even leading some of the end-user operability ideas. Over the next few years I'd expect that we'll see new systems, or at least new throttle designs, from the likes of NCE, Digitrax, Zimo and Lenz, to maintain their premium position in this changing marketplace. Indeed, expect to see full duplex radio available from Digitrax this summer, fully legal for operation in the UK. I for one can hardly wait for this to become available.

All the time I've been writing this series, we've seen prices fall. No doubt for US-made systems, some of that has been because of exchange rate fluctuations favouring the pound over the dollar. I'm sure that the bulk of it is, though, because the manufacturers are seeing volumes rise, and competition, particularly at the lower end of the market, is adding to pressure on prices, functionality and reliability. We've seen this pressure most in decoder prices and specifications. Not many years ago, Digitrax offered the DZ123 decoder: small, two functions but with no Back-EMF at around £17 in the UK. Now, their new DZ125 is smaller still, now has Back-EMF, but still sells at about the same price, exchange rates willing. For smaller scale modellers, Digitrax are also doing the DZ125 in the 6-pin version NEM version as well as 8-pin and plain wired – and this was, when it came out, the first 6-pin NEM decoder for under £20. Prices from the other manufacturers of premium decoders have also fallen in similar ways – you can buy 6-pin NEM651 decoders for well under £20 now, but as ever, decoders at the cheaper end aren't always a good buy. But I do expect this trend to continue - decoders becoming smaller, more functional, and cheaper.

In terms of decoder functions, I'm expecting more and more decoders to offer back-EMF as standard, and with the ability to tune the back-EMF to the motor if you need to. TCS now have back-EMF in their decoders, and even some of Hornby's decoders, challenged though they may be in some ways, have back-EMF functionality in them. Sadly neither of these are tunable. My experience with back-EMF decoders shows that you do sometimes need the ability to tweak it for the best of slow-running and smooth starts and stops. Also expect to see more decoders offering onboard drives for 1.5v microbulbs, and better facilities for driving LEDs, particularly with advanced functions, as LEDs react differently than do bulbs to fluctuations in supply.

Then of course there is sound. I talked last time about SoundTraxx's Tsunami range, among others. The Tsunami in particular takes both steam and diesel sound to a whole new level of realism in the way that the sound generation interacts with what the loco is doing. (The old ZTC offered some Tsunamis with UK whistles in them. I hope that the new ZTC revise these whistles and some of the other changes they made, most of which didn't enhance the Tsunami at all). As we saw, sound really makes a big difference to the whole illusion. It completely changes, for the better, the way that you operate the models, too. Just two years ago, sound was a specialist thing, requiring custom installations in every locomotive. Now, there's plenty of choice of decoders with specific custom sound sets for given British locomotive classes, and available in a range of decoders from a number of manufacturers. Add to that, the locomotive manufacturers themselves are making it easier and easier to add sound. Bachmann's On30 range of locomotives led the way, with tenders and bunkers ready-drilled for speaker installations, followed by various diesels with space under fans or in the fuel tank for the speaker. Bachmann are now selling class 57 and 66 diesels with sound ready-installed, and Hornby are following suit with sound-equipped RTR steam and diesels.

The NMRA standards are showing signs of moving forward, too. 28 functions systems and decoders are the next step, with products now available. I can hear people saying what on earth do we need 28 functions for? Well, imagine a fully-equipped 2-car DMU. Imagine that it has been designed around a pair of decoders, one in each car, so that there aren't too many wires between the cars. Indeed, think about a magnetic coupling between the two, similar to the one Dapol use in their N-scale Voyager DMU, but carrying track power between the two cars. Now, what do I mean by fully-equipped? Start with a function for turning on and off shunting/slow running mode, and maybe one that also turns the back-EMF off, something that is sometimes helpful when double-heading, or in this case, consisting this DMU to another one. Then we have the ability to control lights in the passenger areas, the two cabs, the headcode panels, and the guards compartment. You're already at 7 functions. What about opening doors on a sliding-door unit? Another two functions, one for each side, and maybe another one for the sound of slam doors closing. As an aside, imagine a sound-equipped Mark 1 coach, with lights and door slam sounds, too. Back to the DMU: now add the horn, two functions to do both a short beep and the full two-tone blast. Then add the engine start sequence, engine stop, and the revving up to blow the brakes off while stationary, and there's a few more. What about a manual gear-change, one up-shift function and one down-shift? These decoders will have quite a few wires to run all these lights, and maybe also powering a fan-driven smoke unit. As the unit revs up to blow off the brakes, a good cloud of smoke is emitted. Fancy all of that? I'd like to think that there's a strong chance that such a DMU would be available as an RTR model in not too many years time – indeed, Roco have some of this (close doors, Guard's whistle, close Guard's door) available in some European models today. And while we mention 28 functions, DecoderPro's throttles, in the latest versions, as well as Digitrax's DT402 series throttles, one of MRC's systems, and a couple of MRC decoders, for example, already support 28 functions. Some other systems already support 28 functions with a suitable throttle - again, DecoderPro can be a way to test this with your system.

28 functions isn't all of it. How about the ability for decoders to be "loaded" with fuel levels and water levels? As the loco operates, these levels get depleted, to the point that if they run out, the decoder will stop the loco. You'll need to go to a water column, coal stage or fuel filling station and "top up" periodically to keep the loco running. Forthcoming feedback technology would also enable the locomotive to report fuel and water levels, if it were asked to do so.

I just mentioned feedback systems: Digitrax has had its proprietary transponding system for some years now, which can tell the system, and an attached computer, which decoder addresses are in which block, enabling train describer and signalbox panels to be built which will show not just which blocks are occupied, but what's occupying them. Lenz has been working on its RailCom system, which is set to become the NMRA feedback standard. But regardless of which system is used, future possibilities from decoder feedback would include not just using feedback to see locomotive fuel levels, but a lot more. How about technical issues like feeding back locomotive debugging information - decoder and motor current consumption and decoder temperature, which together would enable you to check that the decoder installation is working properly, or, if over time, the loco's current consumption rises, it might indicate a need for maintenance and servicing. The decoder could also feedback back-EMF operational parameters, showing how hard the loco is working and again whether there are binds in the mechanism. You can also look forward to CV value readback in OPS mode, as well as on the program track.

Don't expect that accessory decoders will stand still. When we covered them, I noted that Circuitron are doing a version of the Tortoise switchmotor with its own DCC decoder built-in - the Smail. Bachmann have points complete with motors and decoders now available in their HO Ez-Track line. Now, while I don't expect that we'll see such things as DCC-ready switches available for P4, I would not rule out someone coming out with a decodered switchmotor assembly with the P4 under-baseboard tiebar driver all in one package, especially if it's engineered so that the dropper wires can be spaced for EM and OO as well. And what about a signal motor assembly, complete with decoder, that actually implements a bounce characteristic? Operated by a small motor, I could see this providing a number of bounce "maps" via CV selection, and even variable throw distances, so that you can program in exactly how you want the signal arm to move as the signal is pulled off and returned. Maybe even add sound, so that you can get the twang of the signal wire and the clang of the levers returning in the box. Even add some temperature sensitivity in the decoder so that the signal arm droops when the ambient temperature rises. Flights of fancy, you say. Well, so was DCC itself not that many years ago. And indeed, apart from the sound, a servo-motor driven DCC controlled bounce mechanism has indeed been made available - see http://www.borg-rail.com/servos.html for more detail.

Really, all this means that DCC is here to stay. It's now a mature technology, and the core standards means that interoperability between systems and decoders is pretty much assured - though there will still be the occasional glitch, mostly when new manufacturers appear. There will be a few who will lament the fact that it doesn't suit them, who maybe have forgotten that the use of 12vDC to run trains was itself an emergent standard after different manufacturers offered all sorts of different ideas. 24vDC was quite common, as were AC-based systems with all sorts of fancy reversing mechanisms - like Märklin's current system. DCC brings so much more functionality to the layout, enabling far greater operational realism coupled with greater operational reliability as well as equipment reliability. Take a look at some exhibition layouts that are operated with DCC. One, that I'm very familiar with, the On30 Camp 93 layout, uses Digitrax DCC. The DT400 throttles are used to drive the sound-equipped locos, and to operate the points, and all that is done from the front of the layout, not from the rear. That means that not only do we enjoy the layout in the same way as the audience do, but the very ability to have conversations with the visitors adds so much to the whole exhibiting experience, particularly as we are not tied to any particular control panel location. Further to that, when the radio system comes out later this year, we expect to spend some of the time actually operating it from the audience side of the barriers, too. Now all of that is possible to do with DC controls, but is just so much easier to achieve with DCC. And so much more realistic, too.

DCC may be pretty mature now, but it won't be standing still. There are so many new ideas for DCC being worked on around the world. Some of them will be ready to become product, soon, and within the next months and years. Others are half-formed at best, with lots more development work to do. Some will be around extra functionality in locos. RTR electrics that can raise and lower their pantographs - now available from Roco. Operating doors in DMUs - available. Locos with controllable couplers - available. Operating windscreen wipers? Not yet. There will be yet more around motor control. We may even see a complete revolution in motor technology, maybe around ideas like Märklin's C-sine motor that has no commutator. So there will be changes to decoder technology to work these electronically-controlled motors, just as there were to accommodate coreless motors. I would not be too surprised if the greatest change that we'll see will be in the systems themselves, and in the way we interact with them. They'll become more computer-oriented - indeed ESU's Ecos system is a computer, running Linux under the covers, and with different user interfaces; hinted at by the Ecos and the Bachmann Dynamis, which is an ESU design. Or the whole thing may change in ways that we've not yet dreamed of. You can, to a greater or lesser extent, be a part of what happens next by joining some of the various chat groups that exist at Yahoo and other places on the internet. Be a part of the ongoing discussions of what should or may happen next, and also, if you'd like, join the NMRA and participate in the setting of the standards.

Not that any of that has to matter to you at all; the DCC system you use now will be working just fine in the years to come. You may just be using smaller, better and cheaper locomotive decoders. And should you decide that DCC is not for you, that's fine too, though I can't help but say how much you're missing out on. But ultimately, how we all enjoy this fabulous hobby is up to each of us individually. I improved my enjoyment and fascination with the hobby with DCC; I'm sure that you will, or already have, too.