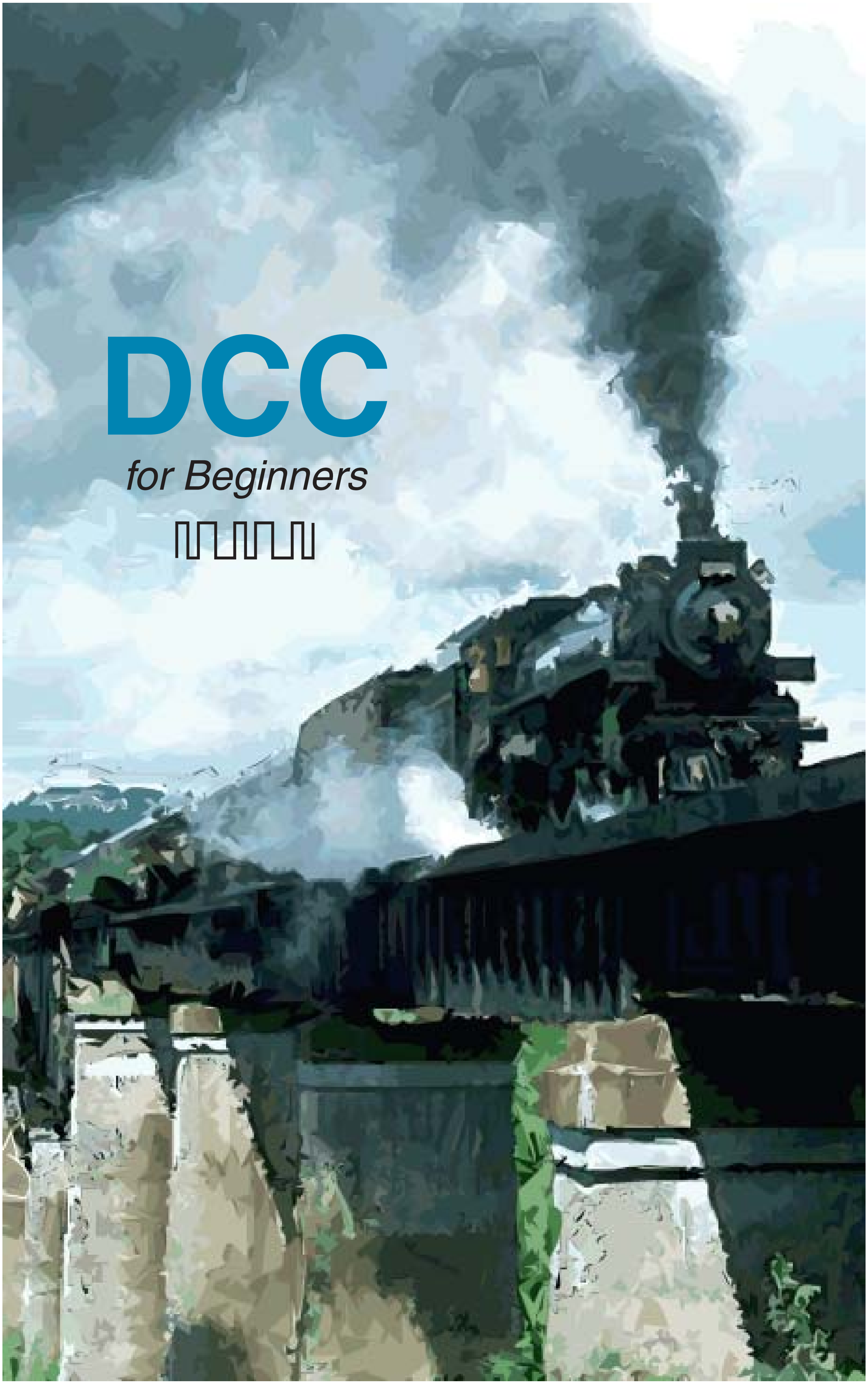

DCC
for Beginners

Credits

The text in this section has been adapted from the following sources:

"Digital Command Control - the comprehensive guide to DCC", by Stan Ames, Rutger Friberg, Ed Loizeaux.

"Digital Command Control: The Wave of the Future", by Zana and A.J. Ireland.

"DCC for Novices", by Stefano Curtarolo.

"DCC Made Easy", by Lionel Strang, with permission of Kalmbach Publishing Co.

"The Digitrax Big Book of DCC"

We would like to extend our gratitude to the model railroading enthusiasts and authors for their contributions or permissions to use their text.

Content

DCC Introduction

Conventional DC Operations

Multiple Train Control Using Conventional Blocking

With conventional blocking, train operation depends on track wiring which can be extremely complex. Each block is powered and wired separately to allow more than one train to move around the layout. Trains move one block at a time by using insulated blocks and toggle switches to control power routing. This requires a lot of time and expense to wire and debug before you are up and running. Once you have it wired, you have to learn to “play the piano” and remember the rules to keep the trains moving.

What Is DCC?

Digital Command Control allows you to operate multiple locomotives independent of each other at the same time with varying speeds and directions on the same electrically controlled section of track.

DCC Origin

The origins of DCC can be traced back to 1940s when Lionel Trains introduced a commercial two-channel system using frequency control. An oscillator generated different frequencies, depending on which button an operator might press. Then a tuned circuit and relay in each engine controlled the direction of the train.

GE, in the early sixties, introduced a five-channel commercial carrier control system called ASTRAC (Automatic Simultaneous Train Control), which could control more than one train per block.

Systems such as Dynatrol’s CTC-16 from late 1970s were popular but suffered from lack of compatibility among competing systems. This is partly why National Model Railroad Association (NMRA) introduced standards for Digital Command Control based on proposal by Lenz. All manufacturers have to abide by this standard in order to receive NMRA conformance approval.

As a result of NMRA conformance standards, a digital signal from a command station can be received by any number of commercially available decoders.

How Is DCC Different from DC?

Multiple Train Control Using Digital Command Control

With DCC, train operation depends on the decoder installed in the locomotive. The track is powered by a command station and/or booster connected to a transformer. Each locomotive operates independently over the track. Several locomotives can be moving at different speeds and in either direction at any time on the same electrical section of track. Blocking is not required for train control. It’s easy to move engines around in the yards and park them close to one another without worrying about where the insulated sections are. It’s easier to operate trains in the wide open spaces, too! DCC lets you run your trains instead of running your track.

Digital Command Control will revolutionize the way you run your railroad and it doesn’t have to cost an arm and a leg. Whether you have an existing railroad or are starting a new one, DCC can work for you and let you run your trains the way you’ve always wanted!

Why DCC Is Better?

- Simpler wiring.
- Control 9999 engines with only 2 wires.
- DCC voltage always present on the track to feed lights, functions, accessories.
- Turnouts/signals can be controlled with the track.

NMRA Standard

The NMRA Digital Command Control Standard defines the basic communications structure at the track level for digital control signals via the rails. The standards specify a communication protocol between transmitter and decoder without specifying transmitter and decoder hardware. The data needed to operate each decoder is transmitted in packet format on the rails in the form of a balanced square wave. This baseline packet format allows for interoperability among equipment made by different companies that support the standard.

Interoperability is the most important advantage of the standard. Interoperability means that if you have a DCC compatible decoder, you can run it with any DCC compatible command station. This is very important since the major part of your investment in any DCC system is in the decoders. We have all heard the horror stories: “I have a fortune invested in this equipment and now I can’t even get spare parts any more much less expand my system!!!” Any system that is available from more than one source is not as likely to disappear and leave its users stranded. Also, having equipment available from multiple suppliers creates competition in price and features to the benefit of the end user.

The standard does not cover the actual command stations or control equipment used to operate the decoders or the features they offer. You can buy a full-featured DCC command station or a basic DCC command station. You can spend more money or less money. There is a place in the market for both low end and high-end equipment. You decide what makes sense for you and your railroad.

Because of the DCC standard we have already seen the cost of Digital Command Control systems drop dramatically. In the early days, a “starter” system ran about $1000 and decoders were $95 each. Today a system that does much more than those early systems costs about $325 and decoders can be purchased for less than $30.00.

Today’s NMRA DCC Standard provides a framework for interoperability without precluding manufacturer innovation. Some innovations we have seen that are not required or covered by the standard include: automatic reversing boosters and devices, 128 speed step control, analog locomotive operation, various cab bus systems, a network for layout operation, cost effective decoder harnesses, block detection systems, sound decoders, system upgradability, new “painless” ways of installing decoders and much more to come. The standard is just the starting point!

Recommended Practices (RP’s) are adopted from time to time to give manufacturers additional guidelines for interoperability. Several RP’s have already been adopted to cover the NMRA recommended locomotive plugs, the extended packet format that allows for decoders to receive and process more information, the programming RP and the “fail-safe” RP. The NMRA DCC working group is continuing to work on additional RP’s and refinements to the standard. Once new RP’s are adopted manufacturers will begin to incorporate the ones that make sense in the marketplace. Hopefully, these new RP’s and changes to the standard can be incorporated in a way that will be backwardly compatible with existing equipment.

What does the “DCC symbol” mean? How is it different from an NMRA “Conformance Seal”?

Manufacturers that build interoperable DCC equipment compatible with the NMRA’s DCC Standard use the DCC logo to let customers know that they support the NMRA's standards effort by producing compatible equipment. Various groups who support the DCC effort, including the DCC working group and the DCC SIG also use the logo. This symbol is not a conformance seal.

The NMRA conformance & inspection program covers all aspects of model railroading interchange, not just DCC. Many people who have heard a lot about the NMRA DCC standard are surprised to learn that the NMRA actually has standards covering couplers, track gauge, wheels and much more. The NMRA conformance and inspection program was relatively inactive until 3 or 4 years ago. Now, the NMRA is working to revive this program. To that end, the NMRA has established a conformance testing program for DCC equipment and for other model railroad products as well. The NMRA is now issuing conformance seals based on the tests they are performing. Let's briefly review the conformance seals that have been issued for equipment manufactured by DCC companies and "non-DCC" companies. (Since locomotives must conform to more non-DCC than DCC standards & RP's we have not counted the ones that follow the NMRA plug RP as DCC products.) In 1996 (the first year of the C&I revitalization), 9 seals were issued (8 for products made by DCC manufacturers and 1 for other products). In 1997, 13 conformance seals were issued (2 for DCC and 11 for others). Through June of 1998, 51 conformance seals have been issued (none for DCC specific products although some previous seals were updated). As you can see, the C&I program has grown beyond just DCC.

According to the NMRA, an NMRA Conformance Seal is not an endorsement or guarantee by the NMRA. It is merely a statement that a particular product passes a particular test to determine whether, in the opinion of NMRA volunteers, it conforms to a particular NMRA Standard. It is important to remember that the NMRA conformance tests are administered and defined by dedicated NMRA volunteers who are working very hard to turn the C&I program into a useful tool for NMRA members.

DCC Advantages

Operation is far more exciting with each train running independently. You can create more lash-ups (consists, MUs) and match the speeds of locomotives from different manufacturers. You can program realistic acceleration and deceleration rates, or limit the top speed of a locomotive.

DCC has advantages for everyone from the beginner to the advanced modeler and for every layout from the smallest to the largest. For beginning and intermediate modelers (most modelers classify themselves at this skill level) the advantages of reasonably priced simple command stations and simple layout wiring are very important. Start with a relatively low cost command station and add components as your interest grows. If you decide you want more advanced features and functions from your command station or if you want to add a computer, it's an easy transition from basic to full-featured command stations. The equipment you already own moves on with you as you add more features to your system. Your largest investment in time and money is in the decoders you install in the locos. These are upwardly compatible as you expand and add to your system. By simply adding components you can grow into a more advanced system at your own pace and as your budget allows.

Most home layouts are small or medium sized. They typically have a limited amount track available for block control. DCC has a real advantage in these situations. Since blocking is not required you can operate more locos in a smaller area.

For the large home or club layout DCC offers truly prototypical operation and minimum wiring hassle.

Modular layouts running with DCC can operate more than 2 or 3 trains at a time. Let's face it, the outside loop running clockwise and the inside loop running counterclockwise all day isn't very exciting. The ease of wiring makes modular hook up simple and lets you get operating sessions up and running more quickly.

DCC Limitations

The only big limitation is the one-way communication from system to decoder. Lenz (Railcom) and Digitrax (Transponding) have developed solutions fro two-way communications that are inexpensive and compatible with existing products.

Future of DCC

- Two way communication
- One decoder in every engine and car
- Car/engine "finder" - where is the car on the layout?
- Automatic train routing and advanced signal system
- Smaller and smoother decoders
- Car detection accessories for yard database

Basic Principles - How Does It Work?

SHORT SUMMARY

With Digital Command Control (DCC) you use a handheld throttle to send information to a command station telling it what you want train X to do. The command station then takes this information, transforms it into a stream of digital packets and sends it to the booster. The booster will add power to the packets, and broadcast the combined signal to the rails.

- DCC system sends commands
- Loco decoders receive and act

PACKET BROADCAST

The decoder-equipped locomotives on the railroad constantly listen to the 'packet' broadcast. Each information packet has an address component to it which should match the address of one of the decoders.

The decoder which is not the intended recipient of the packet simply ignores the data and its locomotive keeps on doing whatever it is doing - running forward, backward, lights on etc.

The decoder, to which the data packet IS addressed, will translate the packet into command for the locomotive such as 'slow down', 'stop', 'reverse direction', and the locomotive will behave accordingly.

BASIC PRINCIPLES

- The power on the tracks is alternating current (AC), and not DC or direct current.
- Full power is running through the tracks at all times while the system is turned on. Voltage is sent by pulses to a decoder in a locomotive which controls the locomotive's speed.
- The polarity of electricity on the rail does not control locomotive direction. The decoder in each locomotive converts AC current to DC and controls the voltage and polarity that travel through the electric motor. When the decoder receives the digital signal sent from the command station, the decoder applies the appropriate amount of voltage and polarity to the motor based on the speed and direction in which you want the locomotive to travel.

DCC Systems Components

DCC Systems Components

All DCC systems are made up of various components that are connected by a command bus. Generally, DCC decoders and boosters are interoperable and DCC command stations are not interoperable. This is because each DCC manufacturer uses its own command bus structure.

The way communications are handled by any given system are very important to overall system performance and to system expandability. When you are making your decision about which system to choose we recommend that you look carefully at what each manufacturer of bus structure has to offer. Some factors to consider are ease of hookup, ability to run multiple devices without slower response times, future expansion capabilities and overall system architecture.

Digitrax's LocoNet is a collision sense multiple access bus with carrier detect. Lenz's X-bus and Xpress Net are "polled" buses. Wangrow/ NorthCoast bus is similar to X-bus. As other manufacturers enter the market they are adopting their own communications structures.

To create a DCC system you will need each of the following:

- One or more Power Supplies to convert 120 VAC to power your DCC components
- One Command Station to generate the command signal
- One or more Boosters to combine the signal with the power and put them on the track
- One or more Throttles to send your commands to the system
- One or more Mobile Decoders to decode the signal and control the locomotives

Most DCC manufacturers provide everything you need (except for the input power supply) in starter sets. Optional equipment:

- Automatic Reversing Devices and Power District Circuit Breakers (see PowerShield products)
- Accessory Decoders for turnout and other accessory control
- Programming Devices
- Signaling
- Transponding and Detection Devices
- Sound and other specialty decoders

Power Supply

All DCC systems require an external power supply. Power Supply (also Transformer) converts 120 VAC to provide the power for your DCC components.

Follow the manufacturer's recommendations to get the best performance from your system.

Command Station

Basic Command Stations

Control speed and direction of a limited number of trains. Some allow programming, others do not. These stations usually cost between $200 and $400.

Full Featured Command Stations

Control speed and direction of up to 127 trains. Can access between 99 and 9,999 locomotive addresses. Control accessory decoders. Control limited throttles. Allow programming of decoders. These stations offer a wide variety of options and features. They cost between $350 and $800.

Computer Control Command Stations

Control the layout from your PC or MAC. Software prices range from "Freeware" to over $100. Some packages require command stations to generate the DCC packets others use boosters and the computer directly generates the packets.

Multi-Format Command Stations

Can generate command control signals for DCC along with command control signals for other command control systems at the same time on the same track. For example, DCC decoders and Marklin "Motorola" format decoders can run on the same set of track with a multi-format command station.

Booster

Boosters (also called Power Boosters, Power Stations) take the DCC signal generated by the DCC Command Station and electrical power generated by the Power Supply (also called Transformer) and combines them to provide the power with the encoded digital packet signal to drive the rails.

Standard Boosters simply boost the DCC signal and Auto Reversers allow for complete automation of reverse loops. Boosters come with current ratings from 2.5 amps to 8 amps (the maximum legal limit). Boosters range in price from the NMRA F9 "build it yourself" to around $300.

Throttle

Most DCC Throttles (also knows as Cabs) are different from any conventional throttle you have ever used. This is because DCC gives you many more options than you had with conventional throttles.

DCC throttles have the traditional throttle & direction control. In addition, these units might also access locomotive functions such as turning lights on and off and activating sounds. Some of these throttles even let you run more than one train at the time!

Some customers want simpler DCC throttles or throttles that are more like throttles on an older system they ran before DCC. Simple DCC throttles are available but they don't give you access to all the possibilities of DCC. If you are worried about complex throttles, think back to the first time you read about block control and how complicated it all seemed then. If you are worried about how to explain these newfangled doo dads to your operators, consider the "joys" of explaining how to run your present blocked system to them.

Converting to DCC does involve a learning curve but the rewards of prototypical operation are worth it!

Full Featured Throttles

Can access addresses for locomotives on the layout. Can set up consists of locomotives. Some Full Featured Throttles can assign trains to limited throttles and control locomotive functions and control accessory decoders on the layout.

Limited Throttles

Throttles that are used as input devices with Full Featured and Computer controlled Command Stations.

Wireless Throttles

Radio and IR Throttles that are used as input devices to radio and/or infrared receivers. These receivers relay the input information to the command station.

Mobile Decoder

These are the "chips" that go in the locomotives :)

Sometimes they are called receivers but they are really more that just receivers. Decoders decode the DCC signal and control the engine's speed and direction.

There are many different decoder choices available.

- Decoders let you program locomotive characteristics like acceleration, deceleration and, starting and mid-point voltages.
- Some may have built in light and function controls as well.

- Some can simulate lighting effects like Mars lights, ditch lights, Gyra lites, rotating beacons & other special effects.
- There are other decoders that include sound and motion control in a single unit.
- Mobile decoders cost between $20 and $200 depending on the manufacturer and the features you choose.
- You can even build decoders yourself from a kit.
- Standard DCC decoders typically have an address range from 1 to 127 and Extended Packet Format (EPF) decoders have addresses from 1 to 9,999.
- Some DCC decoders can be used to run Hi-rail locomotives like Lionel and American Flyer and three rail AC Marklin Locomotives. Check with the manufacturers on this one!

With most DCC systems you can run one analog locomotive (without a decoder) along with the digital ones. This lets you convert your fleet gradually. You may also have some locomotives are too small or too valuable as collector's items to be converted but you still want to run them on your DCC layout.

If one of your friends brings his unconverted locomotives over to run on your layout, your DCC system can probably handle it. And it goes the other way too, if you want to run your DCC equipped locomotive on a regular DC layout, many DCC decoders automatically convert to DC operation if there is no DCC signal present. Check with your manufacturer about the availability of this feature.

Analog locomotives tend to "sing" when sitting still on DCC layouts. This noise decreases as the analog locomotive accelerates and runs. The noise is caused by the DCC track signal. This noise can be significantly reduced by using conductive brush lubricants such as Aero-Car Technology's "Conducta" and by assuring that there is no vibration inside the locomotive that will add to the noise generated.

It is best to park your analog locomotive on an un-powered section of track when it is not running to cut down on heat build up inside the engine.

Locomotive Speed Controls

Because DCC is a digital system, discrete speed steps define locomotive speeds. The DCC standard calls for 14 forward and reverse steps for speed control. Some decoders offer advanced 28-step operation to give you even more speed control. And if that's not enough, how about 128 step operation.

With 128 step operation you have extremely fine speed control. You can really make those locomotives crawl! The ability to take advantage of more speed steps depends on the throttle you are using. The number of speed steps a particular decoder can use is determined by the manufacturer, some systems use CV29 to set up which mode the decoder will operate in.

Back EMF

This is cruise control for your locomotives. Some decoders have this feature that lets you set a speed for your locomotive and have it run at that speed "up hill and down dale." It is also called load compensation. This is particularly useful for low speed operation when 128-speed step control is not available. Decoders that offer scalable speed stabilization let you select how much of this effect your system will implement with any given locomotive. This type of speed stabilization let's you avoid the problem of the "pushy pusher" that was inherent with non-scalable versions of back emf decoders. In this scenario, because the stabilization is constant, speed stabilized rear end helpers would often create the "concertina" effect with trains moving up grades.

Acceleration and Deceleration Rates

Acceleration is the rate at which the decoder increases speed from one speed step to the next in response to a new increase speed command. The acceleration rate (CV03) can be set to simulate train weight. Deceleration is the rate at which the decoder decreases speed from one speed step to the next in response to a new decrease speed command. The deceleration rate (CV04) can be used to simulate inertia. Just like the prototype, you can set your locomotives to get off to a slow start because of a heavy load and to take a long time to come to a stop because of the inertia of the train once it is moving.

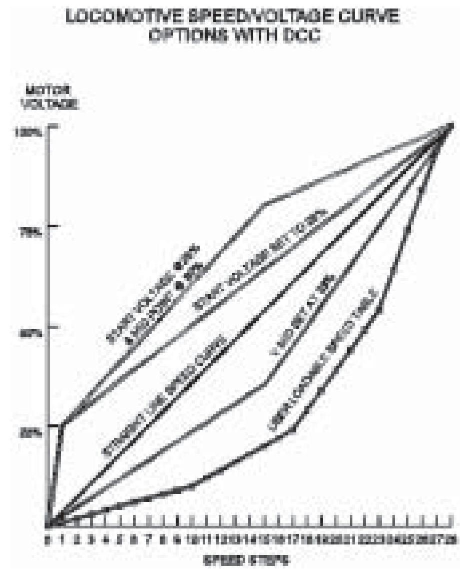
Adjusting The Throttle Response Curve

It's easy to confuse the throttle response curve with acceleration & deceleration. The throttle response curve is the relationship of the motor voltage (throttle setting) to the speed step command sent by the command station. Acceleration and deceleration are the rate of change from one speed step to the next up or down.

The Graph below shows the various curves that can be created using V-start and V-Mid adjustments or by programming the user loadable speed table for each discrete speed step.

Adjusting the Loco's Throttle Response Curve

The default motor voltage/speed curve is a straight line from stop to maximum speed. However, since locomotives don't really accelerate this way, DCC decoders let you alter this speed curve to simulate prototypical train motion. Let's look at the different ways to control locomotive speed and motion that are available with DCC. The chart above shows the default speed curve and how you can modify it by using V-start, V-mid & V-max.



Discrete Speed Steps

Because the signal is digital, the throttle response curve has 14, 28 or 128 discrete speed steps.

Start Voltage

You can set the start voltage by using CV02. The higher the start voltage, the higher the locomotive's initial speed when started. This adjustment is used to trim the locomotive to compensate for its motor efficiency. If you have a locomotive that takes a lot of voltage to get started, this adjustment can be helpful.

Mid Point Voltage

The mid-point voltage adjustment allows the motor speed curve to be altered at step 15, the midpoint of the motor voltage curve by using CV06.

Max Voltage

The maximum voltage adjustment lets you set the maximum voltage to be applied at the top speed step. Use the maximum voltage CV05 to limit the top speed of your locomotives.

Start voltage, mid point voltage and maximum voltage can be used to quickly and effectively set your locomotive's throttle response curve to simulate the prototype.

Loadable Speed Tables

If you wish to be more precise in setting your throttle response curve, loadable speed tables let you define each individual speed step for a locomotive. Once you have defined the speed curve you like, you can use the forward and reverse multiplier to move the curve up or down in speed.

Setting up a loadable speed table involves setting many CV's since you will set a value for each of 28 speed steps. Many DCC users find that using a computer based programmer makes this process much easier. When you use a computer, you can even save the speed tables you like and load them into other decoders quickly and easily via the computer.

Consisting - Can I MU Locomotives?

DCC systems offer three choices for consist control:

The Basic Consisting method is to reprogram all the locomotives in a consist to the same address and run them on one throttle. In this case all the locomotives must be headed in the same direction, head to tail, head to tail, head to tail.

Advanced Consisting stores the consist information in each decoder. The locomotives can be added to and deleted from the consist in any orientation head to head or tail to tail. This method requires that all locomotives in the consist be equipped with decoders that support this feature. This method allows you to set up a consist that will be "transportable" from one DCC layout to another but you must be sure to always put the locomotives back on the track in the same order and orientation you programmed them for or you can get some unexpected results.

"Universal" Consisting stores the consist information in the command station and allows you to consist locomotives with any DCC decoder as well as an analog locomotive. The locomotives can be added to and deleted from the consist in any orientation head to head or tail to tail.

The number of locomotives you can consist varies widely from system to system.

Special Effects

Loco Lighting and Other Features of DCC Mobile Decoders

In addition to address and motion characteristics, most DCC decoders control constant directional lighting and in some cases offer additional function outputs.

DCC decoders usually have at least 2 functions available (sometimes these are set up as directional lights so that your headlights go on and off automatically when you reverse the engine). Large-scale decoders have as many as 8 functions available.

Some decoders have special effects lighting built in so that you can activate additional locomotive lighting like Mars lights, ditch lights, cab lights, etc. Additional functions can be used for smoke units for steam locomotives, sound units, and much more. These extra locomotive functions are accessible from full-featured command stations. Some DCC decoders include a mobile decoder and sound decoder in one unit.

Programming Decoders, Wiring Pgm Track

By programming a decoder you create a value in a specific memory location called a CV (Configuration Variable) that controls an aspect of a decoder's performance. Write programming is a creating a value in a CV. Read programming is a reading back the value from a CV.

TYPICAL CVs

- Locomotive Address - 2 digits (CV1), 4 digits (CV17, 18)
- Momentum - acceleration and deceleration rates (CV3, 4)
- Voltage to the motor - MIN, MID, MAX (CV2, 5, 6)
- Consist Address (CV19)
- Configuration - 14/28 speeds, brake on DC (CV29)
- Speed tables (CV67-94)
- Manufacturer and version (CV8, 7)
- Extra lights effects (depends on manufacturer)
- Load compensation (depends on manufacturer)
- PWM period/frequency (high numbers, low frequency, CV9)

There are several ways to program your decoders. Most DCC Command Stations have built in programmers that send programming information as a broadcast message to any decoder that is listening. This means that you could reprogram all the locomotives on the track with one simple keystroke. To prevent this, it is useful to add an isolated programming track to your layout and program decoders as follows:

1. Run the decoder-equipped locomotive you want to program onto the programming track.
2. Throw the switch to disable the rest of the layout.
3. Switch your command station to program mode and follow the manufacturer's instructions for programming the decoder.
4. Switch the layout back on and drive away.

Some DCC Command Stations offer a separate programming output so that you can program decoders without shutting down the rest of the layout as described above. Also some systems offer operations mode programming which allows you to send programming information to a specific decoder on the layout. Another programming option is a stand-alone programmer or a computer based programmer.

Decoder Installation

Because every engine is different we will cover only the basic concepts involved in decoder installation.

Is Decoder Installation Difficult?

- New HO and bigger engines do have NMRA plug for fast and easy installation.
- Atlas engines come with Dual Mode Decoder for DC and DCC.
- New N engines "might" be DCC ready or "easy". Lenz has very small decoders.
- Most importantly - READ INSTRUCTIONS!

Now that DCC has been around for a few years, locomotive manufacturers are beginning to build locomotives that are more "decoder friendly." This makes installation much simpler than it used to be! Many new HO locomotives are equipped with the NMRA standard medium plug. DCC manufacturers also build decoders that replace the factory-installed circuit board for many HO locos. If you have one of those, it's just a matter of plugging in your decoder and programming it. Most other HO locomotives allow relatively easy decoder installation. Do the easy ones like Atlas/Kato Diesels and Athearns first. Then as your skill increases, tackle the more difficult engines like Rivarossi Steam engines and small yard engines.

N-scale & narrow gauge installations are more difficult because of the limited space available for the decoders. N-scale locomotive manufacturers are working on making their future releases decoder friendly. Kato's C44W-9 has a light board that can be removed and replaced by a clip in decoder made especially for that locomotive. There are decoders that replace the light boards in the Kato PA's and E8's. Still another N scale DCC decoder is made for the Atlas GP40-2 and U25B's. If you are using other Atlas or Kato engines in N scale, it's probably a good idea to start with locomotives that have replacement frames available. These make N-scale installations easy because you don't have to make room for the decoder or the wires, you simply replace the frame and solder in the decoder. Other N-scale locomotives don't require replacement frames but you will need to modify the weights to fit the decoders inside.

Since almost all narrow gauge installations are in steam locomotives, space is tight! You'll want to consider installing the decoders in your tenders where there is usually more room. Sound is another issue that many narrow gaugers want to incorporate in their operation and this requires even more room inside the locomotive because of the need to install a speaker, too.

Sound Decoders

- Speakers need a lot of space
- The right engine-decoder-speaker match
- Plastic cones sound better than paper cones
- Speakers move air, therefore smaller speaker with longer cone displacement might be louder than bigger speaker.
- Sound in N scale is possible!

In G-scale locomotives, there is almost always plenty of room inside to install DCC decoders and sound units, too. It is usually easy to see where the wires to and this makes large-scale installation easy. Beware that large scale locomotive manufacturers don't follow any wire color conventions when they build the locomotives so, it will be important for you to closely examine your locomotive and determine "which wire does what" before you start your installation. Unfortunately, many large-scale locomotives were not made to be taken apart so, getting the locomotive disassembled is often the biggest challenge you will face in large-scale installations.

Instructions, Planning

Each manufacturer provides instructions with decoders. Read them! Take a close look at the operation of the locomotive you want to convert when it is running on regular DC. Installing DCC decoders will not improve the mechanical operation of your equipment! Prior to installing the decoder is a good time to audit the mechanisms and give them a good tune up (since you already have the shell off). Be very careful when you take you locomotive apart, don't lose any of the little parts that tend to fly off in every direction. If you decide not to install a decoder in a given engine but plan to run it on a DCC layout do the tune up anyway. If you are working with Athearn diesels, the November 1993 issue of Model Railroader (Page 106) has an excellent article on tuning up these engines.

The mechanical placement of the decoder is important and may involve sculpting plastic and or metal parts to allow enough room for installation. Decoders from different manufacturers have different form factors. You should choose the one that has a current rating appropriate for your locomotive and that fits best in your locomotive. Try to locate the decoder in the coolest part of the body. Your decoders will provide more power to your motors if they are installed away from heat sources inside the locomotive body like motors and lamps. Try to put them where they can shed as much heat as possible.

Obviously, the scale you model will have a bearing on the ease or difficulty of decoder installation. In G scale, there is usually lots of room inside for decoder installation, the trick is removing the shell. Even though decoders are smaller today than ever, it is still a tough job to get them into many N-scale engines. The small size of the HO decoders has made installation possible in most diesels and steam engines. Some of the smaller switchers still present a challenge and some modelers use the smaller N-scale decoders in these with no problems. For N-scale modelers replacement frames really simplify decoder installation.

Choosing Decoder

Check if there is any plug and play decoder available. Plan in advance the capabilities you want - load compensation, lighting / sound effects. Measure the stall current. If the motor's stall current exceeds the decoder's rating you are sure to have problems down the road so, start by using the following procedure to check the stall current of your motor.

1. Put the locomotive without the shell on a regular DC track.
2. Attach a DC current meter (ammeter) in series with one of the track feeds. Some power packs that have ammeters are really ideal for this test.
3. Apply 12V DC power to the track for N or HO. (16V for G)
4. Hold the flywheel or drive shafts to stop the motor from rotating for a couple of seconds.
5. While the motor is stalled, measure the current that the unit is drawing from the power pack. Be sure that while you are taking the measurement that the power to the track remains at 12V to get an accurate measurement.
6. Use the manufacturers' recommendations to choose the appropriate decoder for your application.

Generally speaking, N-scale engines with can motors draw about one amp, HO engines with can motors draw about one amp. Older Athearns with open frame motors and Bowers with Pittman motors draw around 1 3/4 amps. Large scale engines (O, S & G) vary in current draw and some even have two motors, those with can motors may draw less than 2 amps but each should be tested individually to determine which decoder to use.

Test The Decoder

Test your DCC decoders before installation by following the manufacturers' recommendations.

Some manufacturers include basic test kits with starter sets; you can easily build your own decoder tester or purchase one of the commercially available models. You can save yourself a lot of troubleshooting time if you perform this test first to be sure that the decoder you are installing is working before you put it in your locomotive. You can do this test for new decoders and for ones that you are moving from one locomotive to another.

You will need a test lamp and a protection resistor to perform the test. Instead of using an actual motor, locomotive lights and functions, use a test lamp to be sure the decoder is functioning properly. Use a protection resistor to avoid any damage to the decoder caused by wiring errors.

If you are a first time installer, this procedure will have the added benefit of familiarizing you with the decoder wiring before you do the installation.

Decoder Diagram

Once you have chosen the right decoder and tested it, it's time to check the installation instructions once more. Pay particular attention to the decoder wiring diagram provided.

Be sure you know the purpose of each wire and can identify where it should be soldered to the locomotive. In general decoders follow the NMRA DCC standard recommended wiring colors, but it's always best to check just to be sure.

Note that several different types of light bulbs are used in locomotives and some lamp installations may require that you use current setting resistors to prevent the bulbs from burning out.

Be sure to follow the manufacturers' instructions concerning light installations.

Isolate The Motor

For DC permanent magnet powered locomotives, the decoder must be electrically inserted between the track power pickups and the motor brushes. The most important part of any successful locomotive conversion is proper electrical isolation of the motor brush connections, so that they are driven exclusively by the decoder circuitry.

Note: Failure to isolate the motor will damage the decoder. Once the motor is isolated, you can proceed to follow the manufacturer's wiring diagram for installing the decoder.

Testing Your Installation

Once you have completed the installation, test the locomotive with decoder installed to be sure it runs properly on DC (if available on your system) and DCC. Address the locomotive, run it in both directions, turn the lights on and off and try out any other functions you installed.

Stationary Decoder

Stationary (or Accessory) Decoder controls stationary accessory devices such as switches and building lights.

Stationary decoders cost between $50 and $85. Some control more than one accessory and some allow you to use either slow motion (Tortoise type) switch machines or solenoid (Atlas Snap type) switches.

If you want to build these yourself, printed circuit boards and instructions are available from the DCC Working Group.

Other Devices

The possibilities with DCC are nearly endless. New products are being developed at a rapid pace so if there is something you wish your layout could do, there will probably be a way to do it with DCC before long.

Today there are several computer based decoder programmers, automatic reversing devices, power management devices and block detection devices. In the future we will see signaling systems, sound systems and more.

With the adoption of the DCC standard there is a variety of different equipment available. You have lots of choices of features and price ranges. Since the market is changing so rapidly, it's best to contact the equipment manufacturer, importer or dealer to get the latest information on any system you are considering.

Special interoperability note: DCC decoders and boosters are generally interoperable but command stations are not. For example, you can use Digitrax decoders with Lenz command stations or Lenz decoders with Digitrax command stations. You can use Digitrax and Lenz decoders together with either command station. Note that some systems use components produced by a common manufacturer and have a common command bus structure that does allow some throttle interoperability.

Track Wiring Considerations

It is very important for you to consider your layout power wiring, your command bus or network wiring and in some cases separate feedback bus wiring.

With DCC the signal and the power go hand in hand so your locomotive must have good conductivity to insure reliable train control. DCC is more tolerant of dirty track than some other command control systems because of the fact that DCC commands are sent over and over to the decoders. Nevertheless, periodic track cleaning will still be needed.

Track Wiring

Early proponents of DCC touted the fact that you can hook up your railroad with just two wires. While this is technically correct, there are some issues that need clarification.

If you are wiring a new HO layout it is a good idea to use at least 12 gauge wire with feeders to EACH rail every 10 feet or so as a power bus. If you have an existing layout, the general rule is that if you can run regular DC engine around the layout, the wiring should be able to run DCC without problems.

Unless you need to section your layout for added power, the only gaps you need are for hard shorts such as reverse loops and un-insulated frogs. If you are already wired for block control, you probably don't need to rewire to use DCC. Just open all your blocks so that the entire track has power and you are ready to go. If you are using common rail wiring and you wish to section your layout, you will need double gaps to separate the sections.

Remember, no matter how you control your trains, you should always use safe wiring practices.

Dividing Your Layout Into Sections

Even though blocking is not required for train operation with DCC, sectioning the layout has two advantages:

1. To provide additional power to operate more locomotives than one power supply can handle.

For example a 4 Amp booster and power supply will operate between 6 and 10 average N-scale locomotives, between 4 and 6 HO locomotives and 2 to 4 G scale locomotives. You can run more equipment by sectioning the layout and adding additional boosters and power supplies.

For large-scale operations you can use higher current boosters to deliver more power to individual sections if needed to run more trains.

A note about boosters and current ratings: most DCC boosters will require an external fan in order to output the stated maximum current for extended periods of time. This is not an issue for most modelers but if you experience booster shutdown, you should consider adding fans to increase heat-sinking capability.

2. To prevent total layout shutdown when shorts occur in any given section.

If a short occurs in one section, only that section shuts down, the rest of the layout keeps operating. The reason for this is that all of the boosters are linked to the command station and will continue to receive the DCC signal and output it to their own section of track.

You can avoid purchasing additional boosters and still section your layout by using Power Shield DCC Circuit Breakers and Reversers.

Wiring the Command Bus or Network & Feedback Bus

Follow your system manufacturer's instructions for wiring your DCC Command Bus or Network and Feedback Bus.

Digitrax LocoNet requires a 6 conductor phone wire network phone jack type outlets. These outlets can be daisy chained around the layout. This system is topologically similar to an Ethernet type computer network. LocoNet does not require a separate feedback bus.

Lenz's X-bus and X-press Net require a 5-conductor command bus with DIN jacks. This system requires a separate feedback bus.

The Wangrow / North Coast cab bus is similar to the Lenz X-bus.

Throttle Connectors

There are several different connectors in use by different manufacturers for plugging throttles in to the command bus or network. You may prefer a different plug in connector for your throttles than the one your manufacturer ships with their throttles.

Generally, you can rewire any throttle to use any plug arrangement that you prefer as long as you use correct pin-out. So, if the system you like uses DIN5s and you would rather have stereo jacks or RJ12s, ask the manufacturer for throttle rewiring instructions.

Reverse Loop

You can operate reverse loops manually or automatically using DCC. You must double gap (completely isolate) both ends of the reversing section.

If you choose manual operation you will power the reverse section separately and use a switch or relay to handle the polarity change as the locomotive enters and leaves the reversing section.

If you use an auto reversing strategy you will power the reverse section separately and use an auto reversing booster or other auto reversing device to handle the polarity change.

Note that when the polarity change occurs DCC equipped locomotives will continue at the speed and in the direction commanded but any analog engines running will reverse direction because they “see” the polarity change and respond to it.

If you choose the auto reversing booster strategy, you will need at least two boosters. One will be the system reference booster and the second will be the auto reverser. The good news is that you can run more than one reversing section on a single auto-reversing booster.

Note that some auto reversing devices require that you make changes to locomotive wiring where the pickups are not “side by side” on the locomotive. This is an issue in many steam locomotives where one power pickup is on the locomotive and the other is on the tender.

Protecting Against Short Circuits

Electrical short circuits are one of the major concerns when operating with Digital Command Control.

DCC boosters provide 1st line of defence against shorts. When a short circuit occurs, it will draw more Amps than typically needed. This will be sensed by the booster which in turn will trip the breaker.

Most boosters will reset automatically in a second or two. But the part of layout where a short has occurred will stop operating until the short has been corrected. To avoid having the entire layout shut down, divide it into sections.

Why Shorts Happen?

1. Poor Wiring

The short caused by poor wiring may be nearly impossible to find. The best, but seemingly drastic, solution is to rewire the entire layout and doing it carefully.

2. Driving a Train Into A Block of Track Where a

Turnout's Points Are Set Against It.
3. Freight Car or Locomotive Whose Metal Wheels are Out Of Gauge (or derailed)
4. Coming into contact with the point rails when they pass through a turnout.

Turnouts With Non-Insulated Frog

The frog with non-insulated turnouts should be fabricated from rail and connected to all adjoining rails.

The most common form of short circuit happens when train enters the turnout from the frog and is driven past tan electrical gap. If the turnout's points are set against the direction on which the train is traveling, the loco will "bridge the gap" between the electrical block it is leaving and the electrical block it's entering. The locomotive becomes "confused" because one set of wheels is receiving power differently than the other set.

As a result, every train in the booster's district will stop. Until the train is moved away from the turnout or the turnout is thrown so the points are in correct position, a short will occur.

Turnouts With An Insulated Frog

Insulated frog turnout means that the frog is plastic or cast metal completely insulated from all adjoining rails.

A short will happen when a train enters a turnout from the frog end and the points are set against the direction in which the train is traveling. The train will continue until it gets to the points, eventually derailing and fouling the turnout.

As a result, every train in the power district will stop.

Controlling Short Circuits

You will never be able to completely eliminate short circuits. The only really effective way to reduce the effect of shorts circuits on your railroad is to divide it into power districts. Dividing your layout into power districts by adding more boosters is the simplest way to control the effect of a short circuit on the rest of the layout. More boosters will also ensure that each power district has enough amperage to control all the locomotives, switch machines, and other accessories.

You can avoid purchasing additional boosters and still section your layout by using Power Shield DCC Circuit Breakers and Reversers.

F.A.Q.

How Many Trains Can I Operate?

The actual number of trains you can run is determined by several factors. Seriously, how much room do you really have to run trains? For most people the answer is - “Not Enough!”.

To figure out how many trains you can run with DCC you'll need to know the address range supported by your system and your decoders, how much power you will need to run a given number of locomotives and how many throttles your system will support.

Address Range

DCC systems can access anywhere from 6 to over 9,000 addresses. This is the number of addresses you can assign to your decoders, not necessarily the number of locomotives you can run at a time. Some decoders can only use “2-digit addressing” others can use both “2 digit” and “4 digit addressing”. The advantage to 2 digit addressing is that it is much simpler to use. The advantage of 4 digit addressing is that you can assign the number painted on the side of the locomotive as its address. Most DCC systems can run both types of decoders on the same layout.

Power Requirements

The maximum number of trains you can actually run will ultimately be determined by the amount of power you supply to your layout. Each DCC booster is rated for between 3 and 8 Amps. This means that you can run as many locomotives as your booster can power. To run more locomotives, you'll need to add more boosters.

How Many Throttles Can Your System Support?

Another factor that determines how many trains you can run is the number of throttles your system will support. DCC systems support from 4 to over 200 throttles. Check with your manufacturer if you are planning to have a lot of operators.

ALWAYS check the Voltage on the track to avoid destroying decoders. Check the amps you use to avoid overloading the booster.

How Can I Customize Each Loco’s Performance?

Each decoder installed in your locomotives can be programmed to have its own unique personality.

When you program DCC decoders, the command station sends programming information to decoders and the decoders store that information for future use. You do not have to open up the locomotive to program decoders. Just press a few keys and you are ready to go. Each decoder can have a different personality and it “remembers” its programming until you change it. We use configuration variables or “CV's” to set up various operating characteristics in our decoders.

DCC decoders have a wide variety of features. Not all features are important to everyone so you will find decoders available in a wide variety of feature combinations and price ranges. The following is an outline of most of the features available in today's decoders. Check with your manufacturer to be sure whether the decoder you are buying has the features that are important to you. Remember that DCC decoders are interoperable and you don't have to put the same decoder in every locomotive.

Locomotive Address

The locomotive address is a two digit (CV01) or four digit number (CV17 & 18) assigned to a certain decoder. This is the number you will use to access the locomotive in your system. Some systems use color designations instead of numbers but in reality, these colors correspond to numbers.

Locomotive Speed Controls

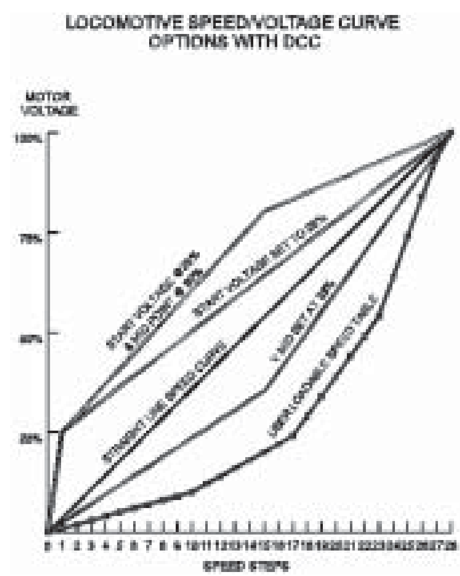
Because DCC is a digital system, discrete speed steps define locomotive speeds. The DCC standard calls for 14 forward and reverse steps for speed control. Some decoders offer advanced 28-step operation to give you even more speed control. And if that's not enough, how about 128 step operation. With 128 step operation you have extremely fine speed control. You can really make those locos crawl! The ability to take advantage of more speed steps depends on the throttle you are using. The number of speed steps a certain decoder can use is determined by the manufacturer. Some systems use CV29 to set up which mode the decoder will operate in.

Speed Stabilization or Back EMF Speed Control

This is cruise control for your locomotives. Some decoders have this feature that lets you set a speed for your locomotive and have it run at that speed “up hill and down dale.” It is also called load compensation. This is particularly useful for low speed operation when 128-speed step control is not available. Decoders that offer scalable speed stabilization let you select how much of this effect your system will implement with any given locomotive. This type of speed stabilization let's you avoid the problem of the “pushy pusher” that was inherent with non-scalable versions of back emf decoders. In this scenario, because the stabilization is constant, speed stabilized rear end helpers would often create the “concertina” effect with trains moving up grades.

Acceleration & Deceleration

Acceleration is the rate at which the decoder increases speed from one speed step to the next in response to a new increase speed command. The acceleration rate (CV03) can be set to simulate train weight. Deceleration is the rate at which the decoder decreases speed from one speed step to the next in response to a new decrease speed command. The deceleration rate (CV04) can be used to simulate inertia. Just like the prototype, you can set your locomotives to get off to a slow start because of a heavy load and to take a long time to come to a stop because of the inertia of the train once it is moving.



Throttle Response Curve

It's easy to confuse the throttle response curve with acceleration & deceleration. The throttle response curve is the relationship of the motor voltage (throttle setting) to the speed step command sent by the command station. Acceleration and deceleration are the rate of change from one speed step to the next up or down.

The Graph shows the various curves that can be created using V-start and V-Mid adjustments or by programming the user loadable speed table for each discrete speed step.

Adjusting the Loco’s TRC

The default motor voltage/speed curve is a straight line from stop to maximum speed. However, since locomotives don't really accelerate this way, DCC decoders let you alter this speed curve to simulate prototypical train motion. Let's look at the different ways to control locomotive speed and motion that are available with DCC. The chart above shows the default speed curve and how you can modify it by using V-start, V-mid & V-max.

Discrete Speed Steps

Because the signal is digital, the throttle response curve has 14, 28 or 128 discrete speed steps.

Start Voltage

You can set the start voltage by using CV02. The higher the start voltage, the higher the locomotive's initial speed when started. This adjustment is used to trim the locomotive to compensate for its motor efficiency. If you have a locomotive that takes a lot of voltage to get started, this adjustment can be helpful.

Mid Point Voltage

The mid-point voltage adjustment allows the motor speed curve to be altered at step 15, the midpoint of the motor voltage curve by using CV06.

Max Voltage

The maximum voltage adjustment lets you set the maximum voltage to be applied at the top speed step. Use the maximum voltage CV05 to limit the top speed of your locomotives.

Start voltage, mid point voltage and maximum voltage can be used to quickly and effectively set your locomotive's throttle response curve to simulate the prototype.

Loadable Speed Tables

If you wish to be more precise in setting your throttle response curve, loadable speed tables let you define each individual speed step for a locomotive. Once you have defined the speed curve you like, you can use the forward and reverse multiplier to move the curve up or down in speed.

Setting up a loadable speed table involves setting many CV's since you will set a value for each of 28 speed steps. Many DCC users find that using a computer based programmer makes this process much easier. When you use a computer, you can even save the speed tables you like and load them into other decoders quickly and easily via the computer.

Can I MU Locomotives?

DCC systems offer three choices for consist control:

The Basic Consisting method is to reprogram all the locomotives in a consist to the same address and run them on one throttle. In this case all the locomotives must be headed in the same direction, head to tail, head to tail, head to tail.

Advanced Consisting stores the consist information in each decoder. The locomotives can be added to and deleted from the consist in any orientation head to head or tail to tail. This method requires that all locomotives in the consist be equipped with decoders that support this feature. This method allows you to set up a consist that will be "transportable" from one DCC layout to another but you must be sure to always put the locomotives back on the track in the same order and orientation you programmed them for or you can get some unexpected results.

"Universal" Consisting stores the consist information in the command station and allows you to consist locomotives with any DCC decoder as well as an analog locomotive. The locomotives can be added to and deleted from the consist in any orientation head to head or tail to tail.

The number of locomotives you can consist varies widely from system to system.

Glossary

A

Accessory decoder
A decoder that is not intended to be installed in a locomotive, but remains in a fixed location and controls accessories such as signals or track switches/turnouts. Also known as "stationary" decoder.

Address
The numeric identification code by which a decoder recognizes commands directed specifically to it. It is also the identifier that a transponder broadcasts. The address is usually unique for each decoder, but this is not a requirement.

Address 00
The special address used to send speed and direction commands which the command station uses to operate conventional, non-decoder equipped locos. Conventional non-decoder equipped locos are sometimes called analog locos.

Advanced consisting
Operating and controlling several locomotives as if they were a single entity by sending speed and direction commands to a common address. Also called decoder assisted consisting. See also "Consist".

Aliasing/aliased addressing
The method used by a command station to run trains with a 2 or 4 digit addresses stored in the command station when the decoder has its own separate 2 digit address. This feature is not part of the Standard or RPs.

Alias roster
A list of alias addresses and their associated decoder addresses stored in a command station.

All live turnout
A turnout where throwing the turnout does not change the rail polarity. This type of turnout is also called a non-power routing turnout.

Ampere (also Amp, A)
A measure of the amount of electrical current used or required by a device. This is a flow measurement.

Amplitude
The height of a wave function.

Analog
A term used to describe conventional DC control where the loco responds to the magnitude of the track voltage.

Analog control
Conventional track voltage (NMRA Standard S-9) typically varying between zero and twelve volts for speed control and polarity reversal for direction control.

Analog mode conversion
It is how most DCC decoders can run on layouts that use conventional control.

Analog signals
Voltages and/or frequencies which convey information and are not digital.

Architecture (or system architecture)
Arrangement of components and/or the method used by a DCC or other computer based system for communication among the various components connected to the system. System architecture is determined by each individual DCC manufacturer.

Armature
Rotating frame which supports the field coils of a motor. In common usage the term applies to the entire rotating part of the motor.

Aspect
A combination of lights or positions on a signal which has a defined meaning. This meaning is the signal's indication.

Automatic analog mode conversion
It is when the decoder handles this change automatically when there is no DCC signal present. Some decoders must be programmed to address 00 for this to take effect. This feature is not part of the Standards.

Automatic polarity reversing
Control circuits which sense opposite polarities at rail gaps and automatically reverse the polarity of the rails to allow smooth continuation of the motive power. Applications include: reversing loops; wyes; and turntables.

Automatic reversing booster (ARB)
Booster connected to a reversing section that is configured to handle automatic reversing. ARBs are always used in conjunction with another booster connected to the remainder of the layout that is configured to run as a normal booster. Automatic reversing can also be implemented on DC layouts.

Automatic reversing device (ARD)
An electronic device which is connected between the power bus and a reversing section to perform automatic reversing.

Automatic train control
The process by which sensors, receivers and coded pulses sent through the track enforce the speed restrictions of signal indications in the prototype. (Sounds a lot like command control, doesn't it?)

Automatic train stop
The process by which a train is stopped automatically if it fails to obey a restrictive signal indication.

B

Back-EMF
Some locomotive decoders can sense the rotational speed of the motor and automatically adjust future digital pulses to the motor to maintain a desired speed. Also called load-compensating decoders. Back emf is the voltage developed by the spinning motor armature as it acts as a generator. EMF is short for electromotive force. Back emf measurements are used for speed stabilization.

Bandwidth
The amount of information that can be transmitted between the command station and decoder(s) (or another communication link) in a certain amount of time.

Basic consisting
Operating and controlling several locomotives as if they were a single entity by sending discrete speed and direction commands to each locomotive in the consist. See also "Consist".

Baud
Measurement of bits per second transmitted or received.

Binary
The base two number system. All binary numbers are described by the two digits, 0 and 1.

Bipolar
A wave function which goes from positive to negative and back. The DCC signal is a bipolar wave form.

Bipolar signal
The electrical waveform of digital packets transmitted along the rails is known as a hi-polar signal. Positive pulses followed by mirror image negative pulses are the key characterization.

Bit
A logical value, a binary digit, that can be either a one or a zero.

Booster
Booster is the electronic device that combines and amplifies the DCC commands generated by the command station with power from the power supply. The booster sends the DCC commands as electronic signals along with the track power to the decoders to deliver both power and DCC signals to the DCC devices on the layout. A DCC system may have more than one booster. Boosters are also sometimes called power boosters or power stations. Also known as "Power stations" or "Power Boosters".

Braking sections
Track segments where the power supply is set up so that DCC trains stop automatically.

Broadcast packet
A specially encoded digital packet that will be acted upon by all decoders that receive the packet. Commonly used in service mode programming and for stopping a locomotive in front of a red signal.

Bus
A set of wires that serves as a conduit for electrical signals and distributes them around the layout.

Byte
Byte is a group of eight bits.

C

Cab
A device used by model railroad engineers (operators) to control motive power and accessories by sending electrical or electronic instructions to the locomotive (via the DCC command station).

Cab bus
The bus used for cab-to-command station communication, and vice-versa.

Carrier Sense Multiple Access with Collision Detection (CSMAICD)
A signal and message handling system used by networks such as Ethernet and LocoNet.

Cascaded route
Operation of one or more turnouts by a function cell when it sends a request for the command station to initiate the required action.

Client/Server
Network architecture used to manage communications among devices on a network. It usually uses event driven communications. LocoNet uses this type of architecture.

Closed
The state of a turnout or the decoder which controls it, where the routing is through the straight leg or set for the main line.

Command Station
The command station receives electrical signals (operator instructions) from the cab. The command station then creates NMRA DCC digital packets in accordance with NMRA specifications to achieve the desired results and transmits these packets to the power station(s).

Common
A decoder status, used by Digitrax, which means that, although the decoder is active, it can be selected by any throttle.

Common rail wiring
Method of wiring conventional layouts. The track feeds for one rail are connected together to one output of the power pack. The other rail is gapped and the track feeds are connected to the power pack through block control switches.

Commutator
The rotating contact on the armature which transfers power from the motor brushes to the field coils.

Compatibility
A claim made by a manufacturer that their product will generally work with other compatible devices in areas where both devices support a given function.

Compliant
Same as conformance. A compliant product is one that has passed NMRA tests and earned an NMRA Conformance Warrant.

Configuration register
Configuration variable (CV) 29. The configuration register soft switches control some of the most basic aspects of decoder operation. These are normal direction of travel or NDOT, 14/28 or 128 speed steps, analog conversion on or off, speed table on or off and two or four digit addressing.

Configuration variable (CV)
Memory location in the decoder that contains information that controls the decoder's characteristics. A defined piece of information used by the decoder to adjust its operation. This information is permanently stored inside the decoder until the user wishes to change its value.

Conformance
Products that have passed the NMRA's extensive testing procedures are eligible for a Conformance Warrant if the manufacturer also agrees to fix any discrepancies that might become apparent in the future. Conformance seal is awarded by NMRA for products passing the Conformance and Inspection program for particular NMRA Standards.

Conformance Warrant
An official document awarded by the NMRA to a manufacturer for a specific product that has demonstrated conformance to NMRA Standards and applicable Recommended Practices by virtue of passing all appropriate tests as performed by the NMRA.

Consist
Operating and controlling several locomotives as if they were a single entity. For example, several diesels might be connected together to provide more power for a steep grade. Also called multiple unit lashup, "MUing", multiunit consist, or lashup. There are three types of consisting: (1) Basic consisting is where all locomotive decoders in the lash-up have the same address. (2) Advanced consisting is where the consist information is stored in CV19 in the decoder. (3) Universal consisting is where the consist information is stored in the command station.

Control Bus
The bus used for transmitting digital packets from the command stations to power station.
Control Digital Packets
A digital packet is a defined sequence of bits that instruct the decoder how to respond. See also bit and byte.

Conventional control (or analog or block control)
This method of model train control uses extensive wiring to control the power delivered to the locos through the rails. It is a system of running the track, not the trains.

Current
The flow of electricity in a circuit.

Current Draw
The amount of electrical flow required by an operating device.

D

Daisy chain topology
Network wiring plan where each new device connects to the previous device and through the chain of devices to the controller.

DCC
Stands for Digital Command Control. One of several methods of controlling and/or operating a model railroad layout. The control information is provided in the form of a digital signal instead of a standard analog (DC or AC) power, overlaid with control information. NMRA DCC is a specific form of Digital Command Control specified by the NMRA as a nonproprietary international specification and is implemented by a significant number of manufacturers worldwide. On the most basic level, DCC encompasses systems and products that are interoperable with the basic NMRA DCC Standards and RPs. In addition, DCC includes other related technologies that are designed to enhance and extend the basic capabilities outlined by the NMRA.

Decoder
Electronic device that receives the DCC signal from the command station through the track, decodes it and tells the locomotive, turnout or other equipment, it is controlling, what to do. Decoders come in a variety of sizes and specifications. See also "Accessory decoder", "Locomotive decoder", "Mobile decoder", "Stationary decoder", and "Slave decoder".
- Mobile decoders are installed in locomotives to control their movement and, in some cases, other functions such as lights or sound.
- Function-only decoders are installed in equipment that moves, but function only decoders do not control movement. Rather, they control other functions like lights, sound, smoke or animation.
- Stationary decoders control fixed equipment like turnouts, lights, signals, sound and other immobile animation devices. These are sometimes called accessory decoders.
- Terminology note on decoders:
- Sometimes decoders are referred to as throttles or receivers. This comes from carrier control terminology. DCC manufacturers use the term throttle for the handheld that to sends input commands to the system. The term receiver is not used because a decoder does more than simply receive a signal, it actually decodes the signal and determines what actions are needed.

Detection section
A section of track gapped on one or both rails and connected to an occupancy detector.

Digital Command
See "DCC"

Direct home wiring
Method of wiring layouts where each power district and its booster is electrically isolated. The track within each power district may use common rail wiring for detection or power management.

Direct CV programming
A high performance form of service mode programming for manipulating the values of a decoder's CVs.

Direct programming
Form of service mode programming defined by the RPs.

Ditch lights
Lights mounted on a loco's pilot or low on the hood to illuminate each side of the track just in front of the loco. When the horn is sounded they flash alternately increasing the visibility of the loco, especially at grade crossings.

Droop
The slope of the graph of speed vs. load for a locomotive. This is one of the variables that is used in scalable speed stabilization calculations by the decoder. Speed stabilization is used to manage the effects of load on loco speed.

Dynamic braking
Action of converting the mechanical energy and momentum of a moving train into electrical energy by using traction motors as generators. The electrical energy is dissipated as heat by arrays of resistors.

E

EEPROM
Electrically-Erasable Programmable Read-Only Memory. These computer memory devices are used to store data in a manner that is easily read, but that changes infrequently. Nonvolatile memory which is designed to be changed infrequently, and is used to hold the values programmed for the configuration variables that control the decoder's characteristics. Most decoders use EEPROM to store CV information.

EPROM
Erasable Programmable Read-Only Memory. These computer memory devices are used to store data in a manner that is easily read, but can only be erased and reprogrammed with special tools.

Event driven
Refers to a strategy of allocating communications resources on a network by sending traffic only when network devices need to communicate.

E unit
Originally an electromechanical device which was responsible for reversing locos using AC motors. The unit selects which field coils are used in the motor. Modem devices are usually solid state, but they are still called E units.

Exact feedback
Method of using a number of switches or sensors to determine the exact state of a device.

F

Fast clock
A clock set to run faster than real time to allow for operating sessions on a model railroad to be run in compressed time. The ratio between fast time and real time is typically 4:1, 6:1 or 8:1.

Feedback
The ability of a device to transmit information regarding its status back to the command station.

Forward trim
Scaling factor which is applied to all the speed step power values in a speed table for the forward direction of the loco.

FRED
Flashing Rear End Device, the light and logic box on the end of a modem train that replaces a manned caboose. Also known as end of train device (EOT or EOTD).

Frequency
The number of wave function cycles per second.

Function cell
A group of electronic components within a stationary decoder which controls the logic for a pair of decoder inputs and outputs.

Function mapping
The ability to specify (i.e. map) which function buttons on a cab activate which specific decoder function outputs. This defines which decoder wires are active for each user input.

Function output
A decoder controlled switch that can be turned on and off by a user's cab action.

H

Handheld (cab)
A portable cab used by the model railroad engineer (operator) to control one or more locomotives. Simple handhelds may have speed and direction controls only. Specialized cabs may also control accessory functions. Full-feature handheld cabs have further capabilities such as programming. See also “Cab”.

Hertz
Unit of frequency, cycles per second.

Hexadecimal
Base sixteen number system. The digits are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E and F.

Hostler
Railroad employee at an engine terminal who moves the engines from where they are stored to where the train crew picks them up. The hostler usually couples the locos to the outbound train.

I

Idle
Decoder status, used by Digitrax, when the decoder is not active and can be selected by any throttle.

In-use
Decoder status, used by Digitrax, when the decoder is active on a throttle and cannot be selected by another throttle.

Indexing
Process by which the turntable bridge is aligned with selected approach or stall tracks.

Indication
The meaning given to a signal aspect.

Interoperability
One of the most important features to look for in a command control system. This allows you to use your DCC compatible equipment with other DCC compatible equipment. Interoperability means that your DCC decoder made by DCC manufacturer A will work with a command station made by DCC manufacturer B.

Interrupt request
When computer's input or output device requests the computer to stop what it is doing and take care of that device's communication needs.

Ironless core motor
Small ultrahigh performance motor developed as a precision instrument or servo motor, but occasionally used in model railroad applications. These are sometimes called Micro-motors. Supersonic decoders or ballast lamps must be used when installing DCC decoders with this type of motor to prevent damage to the motor.

K

Kb/s
Kilobits per second (also kbps) refers to the speed of data transmission on various buses. For example 2.2kbps transmission passes data at 2200 bits per second. See also bus and byte.

Kick start
An entry in a speed table to regulate a burst of power sent to a motor when the decoder first commands it to start (at speed step 1).

L

LAN
Local Area Network is a computer term referring to the interconnections by which various computers and devices communicate with each other in a geographically small location, as opposed to a Wide Area Network (WAN) like the Internet.

LED
Light Emitting Diode, a solid state electronic device that conveils electricity to light, without heat.
Local route
The operation of a number of function cells within a single stationary decoder and without intervention from the command station.

LocoNet
Peer-to-peer local area network (LAN) system architecture used by Digitrax to carry DCC and other commands across Digitrax command control systems.

Locomotive decoder
A decoder intended for controlling a locomotive (or other similar device). See also decoder, and mobile decoder.

M

Macro
A sequence of user-definable commands, that is accomplished with a single button press.

Manual block system
Method of train control used by the prototype and run from block station to block station. Trains require explicit authority to enter each block. This is also used as the backstop method if an automated signaling system fails.

Master/Slave
A network architecture where a central controller manages access and communications to remote devices. It usually uses polled communications.

Maximum voltage (or Vmax)
Defined in configuration variable 05. It limits the maximum voltage sent by the decoder to the motor, effectively limiting top speed.

Microcontroller
A miniaturized, self-contained, computer on a single chip. The computer's operating instructions are also stored in this self-contained chip.

Microprocessor
A miniaturized, self-contained, computer on a single chip. The

computer's operating instructions are not stored in this self-contained chip, but instead are stored in an external device, usually an EPROM or PROM.

Microsecond
One millionth of a second. It is written as µsec.

Mid Point voltage (or Vmid)
Defined in configuration variable 06. It defines the power sent by the decoder to the motor at the middle speed step. This is step 7 of 14, step 15 of 28 or step 65 of 128.

Milliamperes
One thousandth of an ampere. One thousand milliamperes (mA) equals one ampere. See also ampere.

Millisecond
One thousandth of a second. One thousand milliseconds (ms) occur every second.

Mobile decoder
A decoder that is designed be able to properly work if installed in a device that moves around the layout using rotating wheels on tracks. See also decoder.

Momentum
Fundamental property of matter, the product of mass and velocity, which expresses an object's tendency to keep moving at its current speed and direction. Prototype trains have momentum.

Motorola trinary
Digital command control format used by Marklin AC digital HO and Marklin Maxi decoders. This format is different from the NMRA DCC Standards.

MU lashup
One way that the prototype refers to consists. This is a group of locomotives linked together by cables (MU cables) and controlled as one unit. MU means multi or multiple unit.

Muing
See "Consist".

N

Nested consist
A consist which is part of another consist.

Nested route
A route which is part of another route.

NMRA
The National Model Railroad Association is an organization of volunteers that, among other things, created the NMRA/DCC Standards and Recommended Practices. Founded in 1935, one of its purposes is to define and manage model railroad Standards related to interchange of equipment in North America. For membership information, call +1-423-892-2846 or check their web page located at www.nmra.org.

Non-retriggerable
A configuration of a stationary decoder function cell which requires it to complete its output action before it will accept new activation input.

Normal direction of travel (NDOT)
The direction a decoder sees as forward when the throttle is set for forward motion. Some diesels run long hood forward, others short hood forward.

NTRAK
The most widely used Standard for N scale modular layouts.

O

Occupancy detector
A device which senses and provides feedback for the presence of a train or specially equipped cars on a section of track. Also called a block occupancy detector on conventional layouts. Not covered by the DCC Standards or RPs.

Ohm(s)
Unit of measurement for the electrical resistance of an electronic component or device. This is a "friction" measurement. The kilo-ohm, or 1000 ohms, is more commonly used. An ohm is a small unit, like a cent. Ohms are represented by the Greek letter Omega.

Operating current
The current draw in amps used by a loco, including its motor, lights and other accessories, under normal continuous operation at full load.

Operation (Ops) mode programming
Programming method where programming information is sent to a specific decoder on the layout instead of on the programming track. This method of programming decoders does not interfere with the operation or settings of other decoders on the same track. A programming track is not used, the information sent is directed to a specific address. Not all decoders accept ops mode programming. This is sometimes called mainline programming or address directed programming.

P

Packet
Packet is the organization of bits and bytes into complete DCC commands. It consists of preamble, address, instruction and error detection information with bits to indicate the start and end of the components of the packet. The packet format is defined by the DCC Standards. See also digital packets.

Paged programming
A method used for programming of decoder CVs. It is a method of accessing the configuration variables, four variables at a time. Each set of four variables is called a page. See also Register Programming.

Peer-to-peer
Network communications scheme where messages between devices are not managed by a central controller or server. LocoNet uses event driven peer-to-peer communications.

Physical Register Programming
Another form of service mode programming defined by the RPs.

Polarity
The two directions of current flow, plus (+) and minus (-), or potential in an electrical circuit.

Polling
The process by which devices are interrogated sequentially, one after another in order, to see if they have information or commands to send to the system.

Positive feedback
Method of using a switch or sensor to determine one of the two possible states of a device.

Power Booster
Booster is the electronic device that combines and amplifies the DCC commands generated by the command station with power from the power supply. The booster sends the DCC commands as electronic signals along with the track power to the decoders to deliver both power and DCC signals to the DCC devices on the layout. A DCC system may have more than one booster. Boosters are also sometimes called power boosters or power stations. Also known as "Power stations" or "Boosters".

Power bus
Main wires that carry the power from the booster to provide power feeds to the power district.

Power district
The portion of a layout that is powered by a single power station. Power wiring, components and equipment attached to that wiring.

Power pack
A source of electrical power. Commercial power packs might also have controls for conventional analog (NMRA S-9) operation. See also transformer.

Power routing turnout
Turnout where only the route selected is live and the rail polarity changes when the turnout is thrown.

Power station
Booster is the electronic device that combines and amplifies the DCC commands generated by the command station with power from the power supply. The booster sends the DCC commands as electronic signals along with the track power to the decoders to deliver both power and DCC signals to the DCC devices on the layout. A DCC system may have more than one booster. Boosters are also sometimes called power boosters or power stations. Also known as "Boosters" or "Power Boosters".

Power subdistrict
Wiring, components and equipment that are controlled from both power bus wires by their own power management device, for example, a reversing section controlled by an automated reversing device.

Power supply
Transformer or power pack that provides electricity to the DCC system.

Programming
The action of setting the internal parameters of decoders and other control equipment. During programming, values are set for CVs to determine the personality of locomotives, stationary decoders and other programmable DCC devices.

Programming track
An isolated track section used for programming decoder equipped locomotives or transponder equipped rolling stock.

PROM
Programmable Read-Only Memory. A computer chip which can be programmed only once. The contents of this memory are nonvolatile. Also OTPROM: One-Time PROM. These

computer memory devices are used to store data in a manner that is easily read, but can only be written at the factory before or during assembly. Many decoder manufacturers use PROMs to store the machine code instructions used to run the decoder since it allows them to put the most up-to-date code into the decoder during production.

Protocol
The definition of the "language" used between two devices. The agreed upon definitions of the packet's format and intended meaning is known as a protocol. The DCC protocol definition is contained in NMRA Standard S-9.2.

Pulse width modulation
The technique of controlling motor speed with voltage pulses of varying time duration (pulse width). The wider the pulse, the more power is provided to the motor, the faster the motor rotates. Also known as PWM.

Q

Queuing
The sequencing of items to be processed. A programming technique intended to insure that command stations transmit important digital packets first and less important packets later would be a priority queuing configuration. Use of priority queuing permits the bandwidth of a command station to be used most efficiently.

R

Recommended Practices (NMRA DCC RP)
A set of specifications that are only less mandatory than NMRA Standards by virtue of their slightly less critical subject matter. While the inclusion of features described by NMRA DCC Recommended Practices is optional in any given product, if a manufacturer chooses to include these feature(s) in a product, then the design must fully implement the feature as described in the pertinent RP in order to earn a Conformance Warrant.

RAM
This form of computer memory is used to store data in a manner that is easily read and written. Used in command stations and decoders to store information that frequently changes. This is volatile memory used as the working memory for the decoder.

Recommended practices (RP)
Established by the NMRA as an adjunct to the Standards. RPs are not mandatory but if a feature covered by an RP is implemented, it should follow the RP.

Receiver
Electronic device which performs a similar function to a decoder for a carrier control system. They are called receivers because the early systems used different frequencies for each channel.

Rectifier
An electronic device which converts a bipolar alternating current (AC) into direct current (DC).

Register programming
A basic method for accessing the eight most basic decoder CVs. See also paged programming, direct CV programming and operations mode programming.

Repeaters (power station)
This device cleans up the DCC signal timing and provides power to drive additional power stations.

Resistor wheel set
Set of model railroad wheels where the two metal wheels are not completely insulated from each other. The wheels are connected by a fairly large resistor, which allows a little current to flow. These wheel sets are made to trigger detection sections.

Retriggerable
One possible configuration of a stationary decoder function cell which allows it to accept new activation input and commence a new action before it completes the current output action in progress.

Reverse trim
Scaling factor which is applied to all of the speed step power values in a speed table for a loco in the reverse direction.

Reversing feature
Track geometry which allows a locomotive to enter and exit on the same rails with the same direction of motion. Examples are reversing loops, wyes and turntables. A loco enters traveling forward and leaves on the same rails still traveling forward. This geometry creates a polarity mismatch at one or the other end of the reversing section that must be corrected for the loco to continue moving no matter whether you use DCC or DC train control.

Reversing loop
Reversing feature which is made up of a turnback curve which connects to itself.

Reversing section
An isolated piece of track within a reversing feature which is set up to handle polarity conflicts either manually or automatically.

RJ12
Standard type of telephone style plug and socket used for six conductor cable.

ROM
Read-Only Memory. Also Mask Programmed ROM. These computer memory devices are used to store data in a manner that is easily read, but can only be written at the time the silicon chip is manufactured. This type of device is used for very large production runs to save production cost. See also PROM, EPROM, EEPROM.

Route
Stationary decoders linked together so that they operate on a single command. This is like consisting for stationary decoders.

Routing control
The act of specifying the desired route for a train and programming the DCC system to properly actuate all turnouts (track switches) automatically when the route is chosen. See also Macros.

Rule 17
A rule on many prototype railroads that specifies conditions for lighting and dimming the headlight. Rule 17 dimming requires locos waiting to be passed and in other circumstances to dim, but not extinguish their headlights.

S

Security element
The plant, including trackage, associated with any reporting, interlocking and/or signaling for that trackage. This is also simply called plant.

Service Mode Programming
This method is used when programming decoders on the programming track. It is characterized by using broadcast packets and a safe power level. It is programming information broadcast by the command station to all decoders on the rails. A programming track is used to isolate decoders for individual programming.

Slave Decoder
A special type of decoder that is intended to increase the power available from one conventional locomotive decoder. Slave decoders are quite inexpensive and are very useful in the larger scales. The output from each slave decoder then drives one motor. Slave decoders do not interpret digital packets from the command station, but simply repeat the output of a conventional decoder with additional power to the device being controlled.

Slot
Memory location in the command station which holds an active mobile decoder address.

Slot following
Mobile decoder under the control of two input devices simultaneously. This can be used for teaching operators or for a computer to override a throttle in a simulation of automatic train stop (ATS).

Slow motion (or stall motor)
Turnout motor that is operated by the stalling of a DC motor. Tortoise and Switchmaster turnout motors are examples of slow motion or stall motors.

Smph
Scale miles per hour, model speed converted into prototype terms. An HO loco traveling at about 1 foot per second is traveling at 60 smph. 60 mph is 88 feet per second and, HO scale is 1:87.2.

Soft switch
Memory location used to switch a feature or capability on or off.
Solenoid motor
Turnout motor that is operated by the magnetic effect of a coil. Atlas snap switches are one example of this.

Special Interest Group (NMRA DCC SIG)
The DCC SJG was established as a communications vehicle for exchanging DCC information amongst users. Membership is open to the public.

Speed stabilization
Use of back emf by the decoder to modify power to the motor to keep speed constant. Speed stabilization can be scaled to make this feature more useful.

Speed table
A list of 14 or 28 customized power settings for each speed step. The table also includes Kick start, forward trim and reverse trim values.

Speed Steps
Cab-controllable voltage increments which are used to control motor speed. With some decoders, the output power can be set for each speed step. A discrete power level provided by a decoder to the motor. The range from zero to full power is divided equally into 14, 28 or 128 speed steps.

Spring switch
Turnout which can be run through against the direction in which it is set. Afterwards a spring returns it to its original setting. These exist in the prototype as well as the model form.

Square wave
Wave form with vertical sides and a flat top.

Stall Current
The maximum current draw in amps that a locomotive is capable of when stalled. When a motor is prevented from rotating and its maximum rated voltage is applied, the current draw of the motor is known as its stall current. Typically, it is safest to insure that the stall current rating of a locomotive decoder exceeds the stall current of the motor being controlled. In case of a derailment or gear bind and subsequent motor stoppage, the decoder will not be damaged.

Standards (NMRA DCC S-9.x)
Referring to NMRA defined Standards which is to “provide the primary basis upon which Interchange between equipment and various North American scale model railroads is Founded.” The NMRA Standards cover many aspects of model railroading. NMRA Standards provide the primary basis upon which interchange between equipment and various North American scale model railroads is founded. Under this requirement NMRA Standards include only those factors that are considered vital to such interchange. All Standards must be complied with in order for a product to be awarded an NMRA Conformance Warrant. Over 90% of the NMRA membership voted in favor of adopting the DCC Standards in 1994.

Start voltage (or Vstart)
Defined in configuration variable (CV) 02. It controls the voltage sent by the decoder to the motor for the first speed step.

Stationary Decoder
See accessory decoder.

Stop packet
A digital packet that commands a locomotive decoder to stop.

Supersonic decoder
Decoder designed to power an ironless core motor at high pulse width modulation frequency (20 to 30 kHz) to avoid heating problems.

T

Task
What action a function cell performs when it receives a valid trigger.

Thermistor
An electronic device to switch power based on temperature.

Throttle
Electronic input device, often handheld, that is used to tell the command station what commands to send to the decoders. A DCC system may have many throttles and a single handheld throttle unit may include more than one control knob and be able to control more than one train at once. Throttles are sometimes called Cabs.

Thrown
The state of a turnout or the decoder which controls it where the routing is through the curved leg or set for the diverging route.

Track feed
The short sections of wire which connect the power bus with the track and supply power to that track.

Track Power Bus
The bus used for connecting power stations to track feeder wires.

Train order signal
Signal at a depot which lets the train crew know whether or not they must stop for train orders.

Transformer
A device used to convert house current to appropriate voltage levels suitable for model railroad equipment. In the USA typical house supply is 20 - 30 amps at 110 Volts. One or more transformers may be required to operate a layout and provide power to the DCC system, switch machines, lighting etc.

Transponder (or transponding device)
An electronic device which can be installed in any rolling stock and programmed with a transponder address. A transponder detector can receive the transponder address and, in some cases, other information which the transponder broadcasts. Transponding can be used to locate locos and rolling stock on the layout. Transponding is not covered by the DCC Standards and RPs.

Transponder detector
An electronic device which receives the address broadcast from a transponder. It also functions as an occupancy detector.

Trigger
Event brought to a function cell by one or more input leads and which can cause that function cell to execute a task.

V

Volt(s)
Unit of measurement for electrical potential required or provided by an electric device. This is a gradient or “pressure” measurement.

W

Watt(s)
Unit of measurement for power required or provided by a device. In electrical devices this is the product of the current and potential.

Whole layout common rail
Method of wiring layouts where power districts and their boosters are connected electrically by a common rail or common power bus return wire.

Word
Computer term for a group of 2, 4 or 8 bytes.

Working Group (NMRA DCC)
A group of DCC manufacturers and NMRA members who volunteer their time and expertise to create the many Standards and Recommended Practices that constitute the defining documents of digital packet command control systems.

X

X section
Segment of track on a conventionally controlled layout which can be linked temporarily to other electrical blocks. It is used so that a turnout can be used for switching without reserving a whole mainline block.

XOR (or eXclusive OR)
Logic function which compares two bits and generates a new value based on that comparison. If the two bits are the same, a 0 is generated; if they are different, a 1 is generated. It is used in DCC for calculating the error detection byte in a packet.

Z

Zero bit stretching
Process by which one half of the zero bit of the DCC signal, either the positive or negative part of the wave, is made longer to provide power to a conventional motor running on a DCC layout.