

DCC for large scale: a beginner's guide





DCCfor LARGE SCALE SARDEN RAILMANS PROJECT SFGINNE



Introduction to basic components and configuration variables

by Kevin Strong | Centennial, Colorado | Photos and illustrations by the author



DCC in large scale is more than the conventional track-powered DCC systems common to the smaller scales. While traditional (track powered) DCC systems are also common in large scale, there are wireless battery-powered variants in use as well. At the core, though, these systems share many common features and controls, offering modelers in both battery and track-powered environments an ever-increasing amount of customization and control over motors, sounds, lights, and other functions.



ore often these days we see the letters "DCC" pop up in large scale. Some locomotives come equipped with DCC decoders already installed on board, while some are marketed as "DCC ready." If you're involved in the small scales, you've seen the inroads that DCC has made into those arenas. I can hardly find a smallscale club or modular group that isn't using DCC on their displays. While slower to gain ground in large scale, more manufacturers are embracing DCC technology, or at least making it easy for the modeler to use it with their products.

What's a dyed in the wool, battery-R/C guy like me doing playing with DCC? That stuff's only for track power, right? Yes and no. The majority of DCC systems use the rails to send electrons and signals to their trains, but large scale is different. We have a history of wireless battery power for our trains, so it's only natural that we're beginning to see more products take advantage of that, eschewing the traditional "through the rails" interface in favor of an on-board wireless model.

Regardless of how the power and signals are delivered, though, the fundamentals are the same. As DCC technology becomes more ingrained in the hobby, a basic understanding of how it works becomes necessary, not only for those looking specifically for advanced control systems, but also for new consumers about to buy their first locomotives.

What is DCC?

DCC stands for "Digital Command Control." Command control is a system where each individual locomotive has an onboard decoder that looks for signals sent specifically to it, to instruct it what to do. This allows independent control of multiple locomotives all operating on the same rails. Command control comes in many varieties, as I've discussed in previous "Garden railway basics" columns



(April, June, and August 2010 issues).

DCC is a specific variety of command control. It gets so much attention over the others because it's an open-source system. DCC standards are in the public domain, available for any manufacturer to incorporate into their products. That's its key strength. Multiple manufacturers can provide a lot of flexibility for the user.

In most cases, it would make sense to begin a series like this by describing the components that make up a typical DCC system. I'll hold off on that aspect since, in large scale, "typical" isn't what it used to be. Instead, I'm going to start by examining how the DCC protocol itself works to control the things it does and, in later parts, look at the various components used to make it function.

How it works

With DCC, a controller or throttle, connected to a central command center, sends instruction signals (called data or bit packets) to individual decoders (**figure 1**). These packets are embedded in the track voltage that's sent through the rails. The signal sent through the rails is a special form of AC (alternating current), where the frequency of the modulation varies based on the commands being sent. (This does not mean the locomotives are running on AC power. The decoders convert

Related reading

"An introduction to Digital Command Control," June 2005 *Garden Railways* "Basic DCC installation," April 2007 *GR Basic DCC Wiring For Your Model Railroad* by Mike Polsgrove, Kalmbach books

To order call 800-533-6644 or visit www.GardenRailways.com and click "Shop."



the AC into DC for motors, lights, and accessories.) Each command has a specific decoder address associated with it.

The decoder then reads these data packets and responds only to those with its unique address. It reads those instructions and acts accordingly (**figure 2**). Those commands are virtually limitless in what they can do. They can make the motor run faster, slower, stop, change direction; they can turn lights on and off; control smoke units and motors for things like animated figures. . .you're limited only by your imagination and the functionality of the specific decoder you're using. (I'll discuss that in a future installment.)

When a manufacturer advertises a locomotive as "DCC-equipped," that means it comes with a DCC decoder already installed. The locomotive will still run on a "traditional" DC-powered railroad, but it will also run on a DCCpowered one without additional effort on the modeler's part.

"DCC-ready" means the manufacturer has provided a simple means of installing a DCC decoder into the locomotive (often in the form of a plug-in socket or screw terminals). However, the decoder is



Table 1: Basic CV valuesand their definitions

CV1: Locomotive address (short). This is a number between 1 and 127, called the "short address," which sets the unique ID for the specific decoder. Most people use the road number of the locomotive to make identifying things simple. Some references cap this value at 99 instead of 127 to avoid confusion with the "extended address" (see CV17, 18).

CV2: Start voltage (Vstart). This is the voltage needed to get the motor turning. You would set this so that, as soon as you move the throttle up to its first notch, the locomotive begins to crawl (**figure A**).

CV3: Acceleration rate. This controls the rate at which the locomotive accelerates between lower and higher throttle settings. The higher the value, the longer it takes for the locomotive to change speeds. This simulates the inertia of a train, often called "momentum."

CV4: Deceleration rate. This controls the rate at which the locomotive decelerates between higher and lower throttle settings.

CV5: Top speed (Vhigh). This one allows you to set a maximum speed you want your locomotive to run. DCC requires a fixed-voltage source but, since locomotives are geared differently, they will run at different speeds at a given voltage. This setting allows you to set all of your locomotives to run at the same maximum speed (figure B). CV6: Speed curve (Vmid). This CV adjusts the middle voltage or mid-point speed. The default value of this CV is usually 50% of the top speed (CV5) so the locomotive accelerates linearly. By adjusting CV6 along with CV2 (start voltage) and CV5 (top speed) it's possible to set a custom speed curve with finer control at lower speeds or higher speeds, depending on the value of CV6 (figure C).

Many decoders include pre-programmed (internal) speed curves, allowing modelers to adjust a locomotive's performance without having to program CVs 5 and 6. These internal speed curves are selected using CV25, and the characteristics of each curve is usually described in the decoder's user manual.

CV17 and CV18: Locomotive address (extended). Use these CVs to program your decoder with a four-digit address instead of the two-digit "short" address. This is handy for those who run locomotives with three- and four-digit numbers,





Internal: CV6 sets the speed curve at a point midway through the speed steps. A lower value means finer control at lower speeds.

Figure C—Speed curves



External: CV6 is ignored, and the decoder uses a series of 28 CV values corresponding to 28 speed steps. The user can program these values to specific levels, creating a custom curve.

Speed curves are used for a number of reasons. They can be used to give the operator finer control over the motor speeds in a given speed range, such as slow speed for switching. They can also be used to match the speeds of multiple locomotives operating as a group (consist), so they all run at the same speed throughout the throttle range. Speed curves can also be used to compensate for a motor whose rotation speed may not be linear in proportion to the voltage, so that each speed step results in the same increase in actual speed.

and want to use the entire number as the locomotive address.

CV29: Decoder configuration. This controls how the decoder behaves. There are four parameters it looks at. **Motor direction** controls which way the motor runs relative to which direction is indicated on the controller. **Analog DC operation:** Many decoders have the ability to operate on "analog" DC, meaning that they'll run just as a "normal" locomotive will when powered with analog DC power. You can turn this feature on and off depending on your needs. **"Internal"** or **"External" speed tables:** You can choose between the speed curves set by CVs 2, 5, and 6 (internal) or user-defined speed tables (external). The advantage of the user-defined speed tables is that you can really customize the performance of your locomotive to fit your operational preferences. **Extended or short address** selects which address the decoder uses as its unique identification. not included with the engine.

With DCC, the decoder in the engine converts the high-frequency DCC track power to a DC-equivalent voltage for the motor. This voltage is provided in "speed steps" based on the setting of the throttle. With DCC, you have a choice of 14, 28, or 128 "speeds." The advantage of more speed steps is that you have finer control over the speed (**figure 3**).

A nice thing about DCC is that you can customize the throttle settings to match the motor of a specific locomotive. For instance, if you have a locomotive with a motor that doesn't start moving until it gets 5 volts, you can program the decoder so that as soon as you move the throttle to speed-step 1, the voltage jumps to 5V and the motor begins to move. You can also program the top speed and adjust the curve to give you the most control in the speed ranges where you want it, and you can easily match the speeds of two locomotives that might run together in a consist. You can use a pre-programmed speed curve (called "internal") or you can program a custom motor voltage for each and every speed step along the way ("external" speed curve). You can also dial varying degrees of momentum into the motor control to give you smooth starts and stops, and to simulate the weight of a long train.

Configuration variables

DCC uses a series of controls called "configuration variables" (CVs for short) to define how the decoder reacts to the commands it receives from the throttle. These are user-programmable values, meaning that the modeler can adjust these parameters to customize the performance of the locomotive to his/her satisfaction. CVs are in 8-bit binary code. These codes can either be taken as a whole to control a range of values (such as a top speed or volume), or each individual bit can be an on/off switch for a specific function, with the resulting decimal equivalent being assigned to a specific state (figure 4). There are a core number of these CVs that are defined by the open-source standard that all manufacturers must use. (See
Table 1 for a list of the basic CVs.)

Beyond the core CVs, individual manufacturers can add their own CVs to control decoder-specific functions. If you're interested in what each specific CV does, I CVs are an 8-bit binary number. These individual bits can be either 1s or 0s. (Think of a 1 as being "on" and a 0 as being "off.") To convert to decimal values, you only add the bits that have a value of "1."

Decimal value for each bit									
	128	64	32	16	8	4	2	1	
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit O	010
	1	1	0	1	1	0	1	0	= 218 Decimal
Ringry Rit String									, equivalent

Example 1: On some CVs, the bit string is taken as a whole, controlling a function like motor voltage, volume, light intensity, or similar function that would have a range from "off" to "full." In an 8-bit binary world, that gives you a decimal equivalent range from 0 to 255. The value here (218) is 85% of the full range so, if this were controlling the top speed of the locomotive, it would run no faster than 85% of the voltage available to it.

Example 2: On other CVs, each bit has a unique meaning which works together to define how the decoder behaves. For example, CV 29 (below) is the "decoder configuration" CV.



Bit 7 (off) indicates this is not an accessory decoder, but a locomotive decoder

- Bit 5 tells the decoder whether it should use the short or extended address. In this case, it's set to 0, so the decoder will use the short address.
- Bit 4 tells the decoder whether to use the internal or external speed table to control how the motor responds to the throttle
- **Bit 3** is ignored
- **Bit 2** tells the decoder to run normally on an analog DC railroad.
- Bit 1 determines whether the decoder will run in only 14 speed steps, or recognize up to 128 steps
- Bit O determines whether the loco's motor will turn one direction or the other, realitive to the direction indicated on the controller.

The user would put 1s in each of the parameters to be turned on, then the corresponding decimal equivalent number would be programmed into the decoder for that CV.

Figure 4 — CV bit strings

refer you to the NMRA's website: www. nmra.org (found under "Standards & Conformance").

Each decoder is shipped with a factory default setting for each CV that has been chosen for what the manufacturers consider optimal performance. Because of this default setting, you can run a DCCequipped locomotive right out of the box, without ever having to program a CV. You just can't run two out-of-the-box locomotives independently on the same track, because the default address is usually 3. Most manufacturers publish their manuals online, giving you ready access to their CVs for programming.

Some manufacturers use "indexed" CVs, where the first number is the primary CV, and the second, or even third, number is a further index within the first (**figure 5**). Think of this as file folders on your computer's hard drive. The

Bit 6 is ignored



Main CV — The overall group of features that this CV controls. This could be things like lights, sounds, motor-control features, or the like.

Primary index — The particular feature that is being controlled, such as a headlight or whistle.

Secondary index — The attribute of that particular feature that is being programmed, such as brightness or volume.

Figure 5-CV indexes

first number is the main folder and subsequent numbers (indexes) are subfolders. This allows the user to really dial in the performance of individual features of the decoder to their exact tastes.

The more options the decoder offers the user, the more complex is the array of CVs used to control it. Understanding CVs and how to program them is probably the most daunting aspect of running DCC but the manuals are usually a big help and, eventually, it begins to make sense.

If you're scratching your head over CVs, binary, and all that, you're not alone. Understanding CVs is probably the most difficult aspect of DCC for new users to grasp. Fortunately, this hasn't been lost on the manufacturers. Over the years, they've improved the programming interfaces for many of the common user-defined CVs (locomotive ID, speed steps, etc.) so that they are largely transparent to the user setting up the decoder in a locomotive.

The intent is to make programming more intuitive, more "plain English." For instance, it might ask you to program the "top speed" for the locomotive instead of prompting you to program CV5. For something more complex, like the locomotive ID, it might ask you to enter the road number of your locomotive. The software in the controller then takes care of determining whether it needs to use the "short" or "extended" address for that number, then programs the corresponding CVs with the appropriate values automatically. An increasing number of manufacturers are also offering PC-based software to assist in programming their decoders, and there are freeware programming interfaces like DecoderPro (*www.jmri.sourceforge.net*) that allow you to do that as well.

In "Part 2" in the next issue, I'll look at the components that make up a "traditional" DCC installation and discuss how wiring that to your railroad differs from wiring an analog DC railroad. I'll also look at some of the wireless and non-traditional means of running DCC in the garden. Then, we'll examine the decoder side of the equation; examine features, programming, and accessory control.

About the series

October 2013: Command stations and wireless control December 2013: On-board decoders and programming February 2014: Accessories and automation



The basic components



by Kevin Strong | Centennial, Colorado | Photos and illustrations by the author



The necessary components of a DCC system (left to right): Handheld controller (with wireless receiver, near its upper-right corner, though the controller is shown tethered), command station, and power supply.

ost of us are familiar with the traditional track-powered setup; a power supply feeds a throttle (often housed in the same case), which feeds power to the track. If you want to run more than one train, you need two such units, and you also need to divide your railroad into multiple separate sections, called "blocks." These blocks can be separate loops, or separate sections of a continuous loop (**figure 1**). You would have a separate control throttle for each block, and each block could run one locomotive individually (or two or more locomotives together as a consist, provided they run at nearly the same speed at a given voltage).

Traditional DCC runs on a different model. With DCC, you still have the power supply—that doesn't change, as you have to convert power coming from the wall socket to something we can use to run our trains. But all that fancy block wiring—the things that allow you to run more than one train on the same track at one time—go away. With DCC, instead of a throttle that feeds variable DC voltage to the rails, the rails provide a constant AC voltage. The throttle sends commands to an electronic "decoder" located in the locomotive, which determines the amount of voltage to supply to the engine's motor.

The hand-held controller (**photos 1** and **2**) is not limited to controlling just one locomotive. Rather, each locomotive has its own unique decoder "address," which you select via the controller (**figure 2**). This controller is tied to a central command station that sends the DCC signals through the rails, so the individual decoders can receive them and respond to the operator's commands. You can also group multiple decoder addresses and have them act as one, as in a consist.

The power supply

Most DCC control systems come as complete sets, with three key components: the power supply, the command station, and the handheld controller. Decoders for the locomotives are sold separately, or are included with some models. The power supply converts the 120V coming from the wall to, typically, 12–25V, either AC or DC, depending on the power supply. (However, at the rails, the power is AC on a DCC railroad.) Each command station will be different in terms of what it prefers, and many DCC sets come matched with the manufacturer's recommended supply. Those that don't will have specifications as to what they can handle. As long as you don't exceed this, your power supply will be adequate.

It's recommended that you get a "regulated" power supply. This isn't necessary, but it has advantages. As the name implies, a regulated power supply puts out a constant voltage regardless of the load placed upon it (up to the limits of the supply, of course).

About the series

August 2013: Introduction and configuration variables December 2013: On-board decoders and programming February 2014: Accessories and automation



Figure 1: Traditional block control for multiple trains on the same track

The railroad is divided up into individual blocks, each block having its own dedicated throttle. This throttle can control just one locomotive at a time. The throttle for that particular block controls whichever locomotive is running in that block.





That means if you've got a 24V/10-amp power supply, it will supply a solid 24V whether the trains are drawing half an amp or all 10. A simple transformer will suffice but, under high current draw, the voltage to the track might drop below what you're used to getting, and the trains will slow down.

The command station

The command station (**photo 3**) is the "brain" of the DCC system; essentially, it's a small computer. It is usually compact, because it doesn't have knobs or direction switches or any other gizmos that take up space on traditional train controllers. On the command-station box, you'll have some kind of power input from the power supply and an output to the track. You'll also have a receptacle into which to plug the hand-held controller, or built-in controls, like on Digitrax Zephyr or NCE's Twin. Depending on the particular system you're using, there may be a USB computer user interface; visual readouts for voltage, current draw, and other status reports; and/or a dedicated output to "boosters" (more on those later). Overall, these are "little black boxes" designed to quietly do their job, while the stars—the hand-held controller and decoders—get all the glory.

The hand-held throttle

That brings us to the most interactive part of these systems: the hand-held controller. The power supply provides the muscle, the command station the brains, but the hand-held controller is the heart of the system. This is the user interface, where your thoughts get translated, via the buttons and dials on the controller, into commands the locomotives respond to. If the throttle is confusing to operate or program, clunky, or uncomfortable to



1. Controllers come in a variety of sizes and capabilities. Clockwise from left: MRC and Piko's wired, handheld controllers (both of which also have wireless options), with different function shortcuts and programming buttons in addition to the basic controls; Bachmann's E-Z Command control (not inherently designed to be handheld) and — just to illustrate how simple the user interface can be an older-model Airwire controller. The controller user interface is one of the most important aspects of choosing a system. It should be simple to understand but functional enough for you to run your trains any way you choose.

handle, you're not going to have an enjoyable experience.

The majority of manufacturers offer their hand-held controllers as either tethered to ports or to the command station, or as wireless controllers (wireless is almost always at added cost). In the garden, wireless is virtually imperative. Few garden railroaders operate their railroads from just one position and, given the distances involved, a 50' tether is just not practical. Wired throttles are fine indoors, where you're never more than a few feet

Figure 3: Simple DCC booster installation

In this example, the booster is being used to feed the DCC signal to the track in lieu of the command station. This would be done in cases where the output of the command station itself is insufficient to power your trains, such as using a command station with a lower-voltage power supply than what the trains required. The booster has its own power supply and will provide whatever voltage that particular power supply outputs.





2. Graphic displays on handheld controllers are a tremendous benefit. Here, you see the name of the locomotive being controlled, a pictograph of the locomotive, direction indicators, throttle settings, list of functions that are currently triggered, as well as the current being drawn by the locomotive.

DCC system voltages

Different DCC systems provide different levels of voltage to the track. Some systems allow you to adjust this, some do not. Some systems' output voltage is dependent on what you feed into it (up to a limit). Often, though, you'll see systems designed primarily for the smaller scales running at 15–18V, while systems designed with large-scale modelers in mind will run in the 20–24V range. The question is, how much do you need? Does the large-scale modeler inherently need to limit his choices to the large-scale-centric systems? The answer depends on the kinds of trains you want to run.

The constant voltage supplied to the rails is a measure of potential speed for the motors. The more voltage you can supply, the faster your trains have the potential to travel at full throttle. If you're going to be running mainlinespeed passenger and fast freight, then, yes, you'll probably want the full 24V to the rails. If not, then there's no advantage in doing so. You're free to use lower-voltage systems because they'll still run your trains fast enough. For instance, I primarily run narrow-gauge trains that seldom exceed 20 scale miles per hour. Most of my locomotives reach that speed at around 8-12V. So, for my purposes, a lower-voltage system would be well suited to my operations. In fact, I use one such system from MRC, rated at 15 volts, 3.5 amps, to test and program my decoder installations prior to hooking up the batteries and wireless receivers. The amperage of this particular unit is low for a large-scale system running multiple locomotives but, with

boosters (or MRC's 10-amp version of this system), it would be fine.

To figure out how much voltage you need, run your train at the fastest desired speed while you measure the power going to the rails. You'll need at least that much.

There is one advantage to going with the lower-voltage systems, if you can get away with it. Not all decoders are created equal. While published DCC standards say a decoder meant for large scale should be able to handle 27V, not all of them actually do and there are instances where you will be using decoders designed for smaller scales, which may or may not be able to handle these voltages. Always check the manufacturer's specs for the decoder you're buying to make sure it will handle the voltage on your system.

from your train and can plug into various ports along the side of the railroad.

Boosters

The command station/controller relationship is the only truly proprietary relationship in DCC. Decoders communicate by a standard protocol (as long as they are NMRA compliant; see part 1 of this series in the August issue), but one hand-held controller cannot be used with another manufacturer's command station.

That's all you need for a basic DCC control set-up for large scale. But what is "basic?" For the most part, most commercial DCC systems will deliver between 5 and 10 amps of power. That sounds like plenty, but it's not uncommon for one locomotive pulling a heavy train to draw 3 or 4 amps (or more). So what good is DCC in terms of running multiple locomotives at once if it's still only got the capacity to handle two or three locomotives? The answer is "boosters," mentioned earlier. Boosters are what enable DCC in large scale pretty much unlimited capacity in terms of the number of trains that can be run at the same time. A booster (**photo 4**) is a repeater. It's a "brainless" command station. It has its own dedicated power supply and track output but it reads the DCC command signals from the command center via a dedicated cable user interface (**figure 3**). All DCC systems come with a booster, usually encased in the command station. Adding more boosters, or a more powerful booster, increases the range of the system.

Each booster feeds its own specific power district (**figure 4**). You might lay these power districts out similarly to how you'd lay out blocks on a traditional DC railroad, but the overall idea is to lay them out in such a way that there's never a draw in any one district that exceeds the capacity of the booster supplying it. An

Figure 4: DCC booster installation for "power-hungry" railroads

The railroad is divided up into power districts, each district having its own dedicated booster. Locomotives may cross from one power district to another without issue. In this example, the command station feeds one of the power districts directly. The voltage going to each district should be the same.





3. DCC command stations are typically fairly small, designed to be tucked away inconspicuously. The front panel of this unit from MRC gives the operator a reading of the voltage being supplied and the current being drawn. Along the bottom is a clock, which can be programmed as a "fast clock" for prototypical operations. The time would also be displayed on all the handheld controllers.



4. Boosters are an important aspect of larger DCC systems, where you may be drawing more current than just the command station can supply. This booster from Bachmann allows you to select the voltage you want it to feed to the tracks; either 14V or 18V, depending on the size of the trains. Boosters need to be fed a DCC signal from the command station. While the signal is universal, the form the user interface takes is unique to each manufacturer so, while it is possible to use boosters from multiple manufacturers, it's easier to stick with one to make the user interface easier.



5. Not all DCC systems are through-the-rails systems. This Bachmann Climax has a QSI decoder installed in the tender but it's being controlled wirelessly through the receiver plugged into it via the white ribbon cable. This allows DCC to be used with battery power. The board on the left is an Airwire G3 receiver/throttle board, where the wireless receiver and motor-control decoder are combined onto one board. Just hook up your batteries and your motor, and you're off and running. Sound boards can be connected to this as well.

advantage of power districts on a large railroads is that a short is easy to locate, and it doesn't disrupt the entire railroad.

The communication protocol between the command station and the booster is universal. Any manufacturer's command station should be able to talk to any other manufacturer's booster. There's a catch, though: while the protocol is standard, the specific user interface is not. You'll have to build or buy adapter cables to go from brand A to brand B.

Variations on a theme: DCC lite

Not all DCC systems are inherently full fledged, full-featured systems. There are a few systems on the market that use DCC protocols but limit them, to one degree or another, to keep things simple for the modeler. LGB's MTS system is one such system. There are different "classes" of MTS, which add higher and higher levels of functionality, bringing each level closer to full DCC. Any DCC decoder will run with an MTS controller, but not all MTS controllers can control all functions of a DCC decoder.

Likewise, Bachmann's "EZ DCC" system is a stripped-down version of a full DCC system. At 18V and 5 amps, it's capable of handling several large-scale trains, but it only recognizes DCC-locomotive addresses 1 through 9. It also does not allow programming of configuration variables (CVs) beyond the locomotive address. The system also doubles as an analog DC controller, so it's really geared for the modeler who might have a small handful of DCC-equipped locomotives but who still runs the "old fashioned way" as well.

Non-track-powered systems

So far, I've talked about through-the-rails DCC. There are also non-track-powered systems that take advantage of DCC protocols and technology, but implement them in a slightly different way that doesn't rely on rails to carry the signals to the decoders.

For non-track-powered operations, there's no central command station that talks to multiple decoders. In this system, each decoder has its own wireless command-station receiver connected directly to it (**photo 5**). The transmitter broadcasts to as many receivers as are within range, and each receiver waits to hear instructions for the specific decoder it's attached to before sending the instructions (**figure 5**).

There are currently two ways of doing this. First, there's a combined receiver and decoder, all on one circuit board, such as Airwire's G3 receiver. This board has the command station and motor-control decoder combined; you don't need anything else

Figure 5: Wireless, onboard DCC

Each locomotive has a receiver combined with an onboard command station that communicates directly with the onboard decoder. Onboard batteries take the place of the power supply and the hand-held controller communicates wirelessly with the command station.



to run. (The Airwire board also has a DCC output, to which you can attach a DCC-compatible sound system.)

The second way involves a wireless command station that has an output that can feed a separate DCC motor (or motor/sound) decoder. This type of user interface is just now coming into being. Both QSI and Airwire make boards that fall into this category, though the QSI board is largely a proprietary user interface with QSI's large-scale decoders. Airwire's "converter" board is universal but is limited to 2.3 amps continuous output, which may be low for bigger large-scale locomotives. (The good news—at least for these two examples—is that the wireless transmitters are compatible with each others' receivers.) One or two other DCC manufacturers have floated such on-board wireless receivers/command stations but none have come to market yet.

In the December issue, we'll look at the array of decoders available for large-scale locomotives, and talk about times when you may be able to "go cheap" with smaller-scale decoders.

a beginner's guide

D C for LARGE

by Kevin Strong | Centennial, Colorado | Photos and illustrations by the author unless otherwise noted



DCC decoders come in a variety of shapes, sizes, capacities, and functions. From left to right: TCS FL4 4-function (lights or similar) decoder; Soundtraxx 1-amp Tsunami (motor, lights, sound); QSI Titan plug-nplay interface (6-amp, motor, lights, sound); MRC-1817 (3 amps, motor, lights, sound); Piko American Steam (3 amps, motor, light, sound); Massoth eMOTION XXL (10 amps, motor, lights, wired to plug-n-play adapter board); Airwire G2 Wireless receiver (3 amps, motor, lights); Phoenix P5 (sound only).

o far, we've talked about the principles of DCC and examined the parts of the control system that tell the on-board decoders what to do. Now, we get to the decoder itself. If the command station is the brains of the operation, the decoder is the muscle. The decoder is what makes the motors turn, lights illuminate, the smoke units puff,

the whistles blow, etc.

The variety of functions available on decoders seems to grow almost daily. Today's decoders run the gamut, from basic motor control to boards that fully integrate motor, sound, lights, and even exhaust, for an ever-increasing sense of realism for our models. It's important to remember, though, that even though the

About the series

August 2013: Introduction and configuration variables October 2013: The basic components February 2014: Accessories and automation

ROEN RAILWAY



Some locomotives, like this Piko 0-6-0, come factory-equipped with DCC already installed.

super-whizbang decoders can do great things, the modeler is under no obligation to use all of the features. All decoders come programmed with factory-default settings that are designed to give basic control without any tweaking.

There is no point for me to list here specifically which decoders do what, as that list would likely be obsolete by the time the article gets into print. Instead, I'll highlight some of the basic features of decoders, then leave it to you to visit the various manufacturers' websites to see what products might suit your needs.





Figure 1: Pulse-width modulation

(Part 4 of this series in the December issue will offer a list of DCC manufacturers and their contact information.)

Motor decoders

The most basic decoder is a motor-only decoder. I say "motor only," but chances are you won't find one that controls just the motor and nothing else. More likely, you'll get motor control and basic directional lighting.

But I digress. In terms of how decoders actually control the motor, there are similarities and differences among decoders. All of the DCC motor controllers I'm familiar with use pulse width modulation (PWM) to control the motor (**figure 1**). This is where the motor is fed the "full" voltage in short pulses. The longer the pulses, the faster the motor turns. PWM is good but it can still be hard to control locomotives at low speeds. To improve upon that, many DCC decoders use what's called "back electro-motive force" or BEMF. Without getting too technical, this is something the motor creates as it's turning (**figure 2**). The decoder can detect this and change how it controls the motor in response to what it's detecting. This allows for precise speed control, and even "cruise control," where the speed of the train is kept more-or-less constant regardless of the change in grades, curve, and other things that might otherwise affect its speed.

The decoder does this through a feedback process called "PID," or sometimes just "PI."The hows and whys of PID lie outside the scope of this series. You may never need to worry about changing the factory-default settings for these, but know that you *can* change them to a varying degree with many decoders in the event your locomotive exhibits erratic performance. Once properly set, consistent speeds down to one scale mile per hour can be attained.

While on the subject of motors, let's discuss the current capacity of the decoders. Decoders designed for use in most



As a motor turns, it creates "back electro-motive force" (back EMF or BEMF), which the DCC decoder can read to better control the motor.

Figure 2: Back EMF



DCC decoders can be installed in a locomotive or piece of rolling stock in parallel. As long as they all have the same DCC address, they'll work together.

Figure 3: Piggybacking decoders

large-scale trains should have a continuous current-handling capacity of between 3 and 5 amps. That's not to say your locomotive will draw that much, but it's a safe range in which to operate, knowing that you're not going to overtax the decoder during operation. However, there will be times when you're not going to need something with that much oomph behind it. Small "critter" type locomotives, like Galloping Geese or a streetcar, might be well-served by a 1-amp-capacity decoder designed primarily for smaller scales.



Inside the tender are the "guts" of the DCC installation.



Other locomotives, like this Bachmann 2-6-6-2, have built-in "plug-n-play" sockets so that a variety of plug-in decoders can be easily installed.



Small critters, like this Rio Grande Southern Galloping Goose, draw little current and can use decoders designed for smaller scales. Here, a 1-amp Soundtraxx Tsunami (purple) is installed next to an Airwire "Convertr" wireless receiver so that the Goose can run on battery power. The battery will go on the deck of the Goose but all the control electronics are safely tucked away under the frame, out of sight.

These vehicles don't draw that much current and, because of their small size, can benefit from using a smaller decoder.

More and more, we're seeing decoders with multiple lighting outputs that can control any number of prototypical lights: cab lights, firebox flicker, class lamps, ditch lights, even specialty lights, like roof beacons, strobes, or Mars lights. These lighting effects can typically be customized via CVs specific to each function. Things like brightness, rate of flashing, even the ability to simulate the way an incandescent light doesn't instantly come to full brightness or shut completely off can be programmed to varying degrees, depending on the specific decoder. In most cases, these are generally low-current outputs designed for small grain-of-wheat incandescent bulbs or LEDs. However, you can get creative and use them to power small motors and similar things, via relays and the like, to add some animation to your locomotive-a prototypically ringing bell or a fireman shoveling coal, for instance. Some decoders also can control a fan-driven smoke unit to give you more

realistic engine exhaust. You may also be able to control servo motors that will operate couplers or raise and lower pantographs.

I said earlier that "motor only" decoders are the most basic decoders. However, there are "function-only" decoders that just do lights and things of that nature. These are ideal for passenger cars or cabooses, or you can piggy-back them in a locomotive whose motor decoder may not have the lighting functions you want. (More on multiple decoders later.)

Controlling sound

One of the most attractive features of DCC is the ability to control sound. There are two types of sound decoders; sound only and sound/motor. Sound-only decoders are just that. They solely provide (literally) the bells and whistles of our trains. Probably the most popular soundonly decoder for large scale is made by Phoenix. (Note: Phoenix boards are also compatible with non-DCC control systems but have the most functionality under DCC control.) The specific sounds on these boards are controlled by the 28 function buttons on the controller. There may also be some "automatic" sounds that play at certain points, or the sound may change in response to speed changes. For instance, the chuff may get quieter as you decrease the power, simulating the engineer closing the throttle so the locomotive slows down.

Sound/motor decoders control both sound and motor-control functions. This saves the modeler the need to piggyback a sound decoder on top of a motor-only decoder. Beyond consolidating two boards into one, the biggest advantage of having both features on one board is that the sound can be better integrated into what the decoder is actually doing, relative to the motor. With a sound-only decoder,



Some decoders have identical CV numbers that control different things. In order to program just the specific decoder you want to program, it's advisable to install an on-off power switch for each individual decoder. Turn off all decoders except the one you wish to program.

Figure 4 Programming individual decoders

the sound decoder may respond to voltage or polarity, but that's about it.

By integrating sound and motor, you can also change sounds based on the load of the motor (how hard it's working). For instance, if your locomotive encounters an uphill grade and slows down, drawing more current, the decoder may increase the volume of the chuff or diesel motor to simulate the engine working harder to get up the grade. It does this by sensing changes in BEMF and/or changes in the current being drawn. There are also decoders that can read chuff-trigger input and synchronize a fan-driven smoke unit in conjunction with the chuff trigger. The list of available features seems to grow daily as technology improves and manufacturers compete with each other.

In the case of most sound decoders (both sound only and sound/motor), you can tweak various aspects of the sound itself. Individual sound volumes can be programmed relative to one another, so



Piko sells their on-board decoder separately as well. Components from left to right: speaker, DCC decoder, volume-control board, magnetic-trigger board (which gets mounted on the tender truck to trigger the whistle and bell via track magnets).

you can hear certain sounds over others. Some manufacturers allow you to adjust the equalization (like on a stereo) to get the most favorable sound out of the speaker in the locomotive. QSI's new Titan decoder offers two-channel output for multiple speakers, so you can program certain sounds to come from one speaker or the other, or blended between the two.

The sounds themselves can also be changed. Many manufacturers program multiple whistles onto their boards so you can select from a variety to find one that suits you. Also, some manufacturers offer computer interfaces so you can download new sounds from their websites and program the decoders. I could spend an entire article just talking about ways to tweak sounds for maximum realism. There's a lot you can do.

I mentioned piggybacking decoders earlier. With DCC, you can put as many independent decoders in a locomotive or piece of rolling stock as you'd like. Each picks up the DCC signal from the track and responds in kind (figure 3). As long as all the decoders in a given locomotive are programmed to the same address, they'll work together. That's the good news. The flip side is that you have to be careful when programming these decoders. While some CVs are universal, others are manufacturerspecific. For instance, CV52 may control lights on one decoder but may control the volume of a particular sound on another. If both decoders are on the track when you program CV52, the programming will change the value on both decoders to that new number. To counter this, it's wise to put a toggle switch in line with the DCC signal going to each decoder so that you can isolate just the decoder you wish to program and leave the rest alone (figure 4).

Programming decoders

Programming these decoders is typically done via the handheld throttle. However, more manufacturers are moving toward proprietary PC-based programming to interface with their decoders. There's also free software that you can download to program decoders, such as Decoder Pro from JMRI (*http://jmri.sourceforge.net*). Decoder Pro is compiled by a network of volunteers operating independently from any manufacturer. The fruits of their labors give you the ability to use the computer to program a number of decoders

Decoder installation

In an analog DC locomotive, power from the rails feeds the motor directly. As the voltage on the rails increases, the motor speeds up. Depending on the locomotive, there may or may not be a centralized circuit board through which all the power runs. If a locomotive is advertised as "DCC equipped," then the locomotive already has a DCC decoder installed. As yet, this isn't nearly as common in large scale as it is in the smaller scales. If a locomotive is advertised as "DCC ready," then it has a simple means of installing a DCC decoder. Most Aristo-Craft and Bachmann locomotives come equipped with a "plug-and-play" socket that allows for this. Other manufacturers haven't adopted that yet, but some offer similar arrangements (screw terminals, plugs, etc.) that make installing advanced control products easier.

Regardless of whether the locomotive has such a socket or not, to install a DCC decoder into the locomotive, you must interrupt the power feed from the rails to the motor (**figure A**). The power from the rails (which includes the DCC signal) is then fed to the decoder, which converts the AC to DC and feeds the appropriate voltage to the lights, motor, etc., based on the commands it receives. Many DCC decoders are "dual mode," in that they'll work on DCC, but will also allow you to run your train on traditional track power.



With traditional analog DC operation, power comes directly from the rails to the motor, lights, and smoke unit.



With DCC operation, no power goes directly from the track to the motor. Instead, power comes in from the rails to the decoder. This decoder distributes power as dictated by the hand-held controller. All locomotive functions are controlled by the decoder, including motor, lights, smoke, sound, etc.

Figure A: Decoder function

for which the manufacturers do not offer PC-based programming. Having said that, though, it's generally best to use the manufacturer-specific software whenever possible, for the highest level of compatibility. There are some things that JMRI simply cannot do for certain decoders.

There's a lot to think about when choosing the decoder for your particular locomotive and, with so much competition, you've got lots of choices. Choose the one that's right for the level of simplicity/ complexity that you want. That's the beauty of DCC; it's open-source, so any decoder will work. Pick one manufacturer for one installation, another for the next. You can tailor your choice to the specific needs of the project at hand.

MARC HOROVITZ

In the final installment of this series, I'll cover some of the cool things you can do with DCC in terms of automation, as well as look at some ways of combating dirty track. I'll also go over accessory decoders that you can use to throw switches and control various trackside elements on your railroad.

Differ LARGE for Scale a beginner's guide Part 4: Accessories and automation

by Kevin Strong Centennial, Colorado PHOTOS & ILLUSTRATIONS BY THE AUTHOR EXCEPT AS NOTED



Automated DCC control keeps the trains on D.A. Burtram's railroad in Denver running smoothly. FRED HUGHES

n the last issue, I looked at the decoders that make our locomotives run. turn on lights, and activate the sound systems. These decoders are the bread and butter of why people use DCC. The trains are paramount, but locomotives aren't the only things that DCC can control. That's where "accessory" decoders come into play. As the name implies, accessory decoders control things that supplement the operation of our railroads: switches, signals, lights in stations-typically, things that don't run on the rails. Like their mobile counterparts, these come in a variety of flavors and function levels, from dead simple to quite complex.

Accessory decoders are similar to locomotive decoders in that they're governed by the same CVs. However, they operate as a different "class" of decoder than locomotive decoders. In part 1 of this series, I discussed CV29. One of the bits in that CV determines whether the decoder responds as a locomotive decoder or an accessory decoder. That's the key differentiation between the two classes. It may sound confusing at first, but it's a good thing.

The primary advantage of having two "classes" or registers of decoders is that you can address them more easily. Locomotive decoder addresses can be any number between 1 and 9999. Accessory decoders are somewhat more limited

1. Handheld controllers are all different in how they handle accessory decoders. The MRC and Airwire controllers (left and right) have "ACCY" buttons that allow you to directly enter the address of the accessory decoder you wish to control. The Piko controller (center) uses one of the three menu buttons below the display screen to scroll to the accessorydecoder input.

About the series

August 2013: Introduction and configuration variables October 2013: Learn the basic components December 2013: On-board decoders and programming

but can be any number between 1 and 2048. Because these addresses are in different registers, they can overlap. You can have a locomotive and accessory decoder with the same address, and they'll work without confusion.

There is a button on most handheld controllers that selects which type of decoder you want to control (**photo 1**). To select an accessory decoder, you simply press the "Accessory" button, then enter the address. At that point, you're controlling that particular accessory decoder. If the accessory happens to have the same address as a locomotive currently running, the locomotive will ignore any commands being sent to that address, as it knows they're being sent to an accessory



BEGINNER

© 2013 Kalmbach Publishing Co. This material may not be reproduced in any form without permission from the publisher. www.GardenRailways.com



2. Accessory-control decoders are fairly simple affairs. This one, by Piko, can control up to four switches, lights, or signals. Other decoders may also give the user the option of electrically throwing the switches from a central control panel in addition to using the handheld controller.

decoder. Accessory decoders are most commonly used to control switches, lights, and signals, but can also be used for controlling turntables and other animated features on the railroad.

With locomotive (function) decoders, each physical decoder can be programmed to one specific address. They're designed to be installed into a specific mobile locomotive (or caboose, etc.). For instance, a four-function lighting decoder will have one unique DCC address that then controls four separate outputs or functions (figure 1). You'd select the decoder by its address, then control each of the four outputs by pressing one of four individual function keys to turn the lights on and off. An accessory decoder with four outputs (photo 2) assigns a unique DCC address for each output but, typically, those outputs have only one of two states-"open" or "closed" (off/on).

Controlling switches

Controlling switches (turnouts) is probably the most common use for accessory decoders. Switch decoders are designed to control the electric switch motors used to move the points. These motors come in three common varieties; slow-motion, twin coil, and bipolar DC. A slow-motion switch motor uses a motor and gears to slowly move the points from one position to the other. In large scale, Train-Li-USA offers slow-motion switch motors (and Aristo-Craft used to). These are controlled by powering the motor for a few seconds while it turns the gears that move the points.

Twin coil and bipolar DC are the other common switch motors, though, in large scale, twin-coil machines have largely been replaced by bipolar DC motors. Their operation is nearly identical so, for the most part, the controllers treat them much the





On an accessory decoder, each individual output has its own specific DCC address.

Figure 1 Function vs. accessory decoder

same way. These motors are actuated by a quick pulse of electricity (on the order of 100 milliseconds or so), which will throw the mechanism one way or the other.

By and large, switch-control decoders can handle both varieties of switch motors, though, typically, all the outputs of the individual decoder must be programmed for one type or the other. Most people tend to use the same kind of switch motors on all their switches, so that shouldn't be a problem. These decoders can handle multiple switches per decoder, though four per box seems to be fairly common.

Some controllers may allow for "local" control of switches. This refers to the ability to use a push button or electrical switch on a control panel to throw the switch in addition to addressing each switch via the handheld controller. While it's unusual to have local control panels at each town on an outdoor railroad, as is common on indoor pikes, it's not unheard of, so it's certainly something to consider when looking at accessory decoders.

Switch controls may also be grouped into "routes." This allows for control of multiple switches at once, and comes in



The module passes the DCC from the command station to the track until sensor #2 is triggered. When that occurs, the output of the module is switched to a "Speed = 0" data packet generated by the module. The locomotive will stop, and not resume operation until sensor #1 is triggered, and the data packet coming from the command station restored.

Figure 3 - "Set speed = 0" command module

handy when you want to control switches in yards or at crossovers (**figure 2**). Instead of addressing each individual switch by its DCC address, you assign groups of these switches to pre-programmed "routes." When selecting a particular route, the decoder throws all the necessary switches to their appropriate positions to get the train to the desired track.

Some switch decoders can also be used to control lights and motors for buildings and animation. You might also be able to use a standard lighting-function decoder for some of these tasks but they'd not be in the "accessory" register of addresses.

Controlling signals

Another common accessory decoder controls signals. Some of these work in conjunction with throwing switches so that signals change with switch position. Others work with various block-detection schemes (which is outside the scope of this series) to indicate the presence of a train in a particular section of the railroad. This level of signaling and train detection is uncommon on outdoor railroads but, again, not unheard of.

Some accessory decoders draw their power for lights and motors directly from the track, while others require separate power supplies. The advantage of using a separate power supply for these decoders is that you're not drawing from the overall power available for the trains. The accessories receive their control signals through the track but the motors and lights draw from that second power supply.

DCC and automated train control

It's natural, given the level of control available with DCC, to think about how you can use it to automatically control the trains on your railroad. You can do quite a lot with DCC, from simple out-and-back to operating multiple trains over multiple routes. Photo 3 shows the automation controls for D.A. Bertram's garden railway. When I wrote my series on automation for regular track power, it took six installments to cover the various scenarios one could come up with (August 2012-June 2013 issues). With DCC, all of those and more are possible, so it would be impossible for me to adequately cover the scope of all the possibilities in half of one article. I refer you to that series to get your creative juices flowing, and assure you that pretty much everything I discussed there can be done with DCC controls. Here, instead, I'll focus on how DCC decoders make that task different and, in many ways, easier. (Note: The automation discussed here works only with traditional through-the-rails DCC. It will not work with battery-powered [Airwire or similar] DCC installations discussed in previous installments.)

Automation with DCC control relies largely on breaking up the railroad into blocks, then controlling each block with a circuit that can either pass the DCC signal



3. The automation controls for D.A. Burtram's railroad hang on the wall in a nearby shed. These are from DCC BitSwitch.

from the command station to the track or switch to an alternate signal (figure 2). One basic means of controlling automation is to simply send the locomotive a "stop" (also called "set speed = 0") command. A trigger (photo 4) would detect the presence of a locomotive on that section of track, which would then change the output of the block-control circuit from the command station to this "stop" command. A second trigger (activated by another train or by a timer of some sort) would then set the output of the blockcontrol board back to the output of the command station, and the locomotive would resume its speed (figure 3). The

Further reading

The DCC Guide Don Feihmann Kalmbach Publishing \$19.95

Basic DCC Wiring for your Model Railroad Mike Polsgrove Kalmbach Publishing \$15.95

DCC Projects and Applications (vols. 1 and 2)

Mike Polsgrove Kalmbach Publishing \$19.95 each



4. Magnetic reed switches are commonly used to trigger automation. This one fits neatly and inconspicuously underneath the tie of a section of large-scale track.

time it takes to speed up from and slow down to a stop is determined by the acceleration and deceleration CVs programmed on the locomotive's decoder (CVs 3 and 4, respectively.)

As an alternative to this "stop" command generator, you can program the decoders to "stop on DC." While DCC decoders can be programmed to run on analog DC voltage, you can also program the decoder not to do so, called "Stop on DC." As the name implies, the locomotive will come to a stop when it encounters a section of track that has DC power, as opposed to the bipolar AC/DCC signal. So if you want the locomotive to come to a stop in front of a station or siding, you would control that block of track with a block-control module that switches between DCC and DC (figure 4). When triggered, the block control would switch the voltage going to the rails to DC and the locomotive would come to a stop (subject to the deceleration programmed into CV4). The control would then switch



The module passes the DCC from the command station to the track until sensor #2 is triggered. When that occurs, the output of the module is switched to a linear DC output generated by the module. The decoder reads the linear DC voltage, slows down, and stops. When sensor #1 is triggered (either by a second train, timer, or pushbutton), the module switches back to passing the DCC signal to the track, the decoder reads this, and continues on its way.

Figure 4 - "Stop on DC" command module

back to the DCC signal coming from the command station, and the train would resume its journey.

The disadvantage of using the "stop on DC" feature is that you lose the ability to send DCC commands to the locomotive while on the DC-powered section of track. The solution to this is what's called "asymmetrical DCC" to control the automation (figure 5). A DCC signal is a bipolar square wave centered around a zero voltage. When the wave is symmetrical, both sides are the same distance from that zero point. An asymmetrical wave is unbalanced—one side is shorter than the other. This can be achieved by running one feeder wire through a series of diodes to lower the voltage on one side of the bipolar wave (photo 5). The decoder is still getting the

Is and 0s of the DCC signal so it can respond accordingly to commands, but it detects the imbalance, which acts as a trigger to get the decoder to follow the steps it's programmed to do, such as stop for a period of time, reverse, etc.

The key advantage of using asymmetrical DCC is that no external block-control boards are needed to create the automation. The automation is controlled solely by the decoder onboard the locomotive. The decoder determines what happens when the asymmetrical DCC signals are encountered. Only some decoders currently offer this function, and what they can be programmed to do upon encountering these asymmetrical signals varies. These decoders could be used to do timed station stops, auto-



Standard DCC bipolar wave (gray line): poles are equidistant from 0.

Asymmetrical DCC wave (black line): one pole is longer than the other. (Difference exaggerated for clarity.)

Figure 5—Asymmetrical DCC



5. Diode arrays carry power from one side of this insulated rail joiner to the other, creating an asymmetrical DCC signal that certain decoders can use for automation.



6. This mini panel from NCE stores a series of DCC instructions that can be used for simple automation. It's programmed via the handheld controller and, once programmed, will send the instructions to the locomotive without user input.



When the locomotive passes over each trigger or sensor, it tells the mini panel to perform a pre-programmed sequence of instructions. These can be anything that can be done via the handheld throttle, such as stop, change direction, change speed, turn on lights, blow the whistle, etc.

When the locomotive passes over the next trigger, it sets in motion the subsequent sequence of instructions, and so on down the line. In this example, if steps 1 and 9 were "change direction," then the locomotive would run back and forth as a point-to-point operation.

Figure 6 - Automation via a "mini panel"

reverse (back-and-forth streetcar operation), and things of that nature.

A fourth method of automation involves what's called a "mini panel" (**photo 6**). This is essentially a microprocessor that's programmed to perform a set of instructions whenever sensors are triggered. You program it using your handheld controller, keying in a specific set of instructions for each individual trigger. Once set in motion, it will then execute that specific set of commands (**figure 6**). Mini panels can be used to control both locomotives and accessory decoders.

Basic automation can be done simply using any of the methods described, or you can combine systems or add multiple block-control circuits to create a highly automated railroad that can control multiple locomotives at once.

There's much more to DCC than can be covered in an introductory series like

DCC manufacturers

this, or even in one book for that matter. Kalmbach offers four books on the subject and there are many others. I hope this series has demystified a little of the technology and inspired you to see how it may fit into how you run your trains in the garden, be it via track power or battery. Technology is bringing a new level of realism to our models. It's there for the taking and is getting easier to use with each new product introduced on the market.

Bachmann Industries

1400 E. Erie Ave. Philadelphia PA 19124 215-533-1600 www.bachmanntrains.com

CVP (Airwire)

P.O. Box 835772 Richardson TX 75083-5772 972-238-9966 www.cvpusa.com

DCC BitSwitch

31190 Eagle Crest Ln. Evergreen CO 80439 303-674-3114 www.dccbitswitch.com

Digitrax

2443 Transmitter Rd. Panama City FL 32404 850-872-9890 www.digitrax.com

ESU/LokSound

477 Knopp Drive Muncy PA 17756 570-649-5048 www.loksound.com

Lenz

American Hobby Distributors (importer) 57 River Rd. Suite 1023 Essex Junction VT 05452 800-671-0641 www.lenzusa.com

LGB

Gebr. Märklin & Cie. GmbH Stuttgarter Straße 55-57 D-73033 Göppingen Germany +49 7161 608-0 www.lgb.de

Massoth

Frankensteiner Str. 28 64342 Seeheim-Malchen Germany +49 (0)6151 35077-0 www.massoth.com

Model Rectifier Corp.

(MRC) 80 Newfield Ave. Edison NJ 08837 732-225-2100 www.modelrectifier.com

NCE

82 E. Main St. Webster NY 14580 585-265-0230 www.ncedcc.com

Piko

4610 Alvarado Canyon Rd. San Diego CA 92120 619-280-2800 www.piko-america.com

QSI Solutions P.O. Box 967 Colchester VT 05446 802-448-9899 www.gsisolutions.com

Soundtraxx

210 Rock Point Drive Durango CO 81301 888-789-7637 www.soundtraxx.com

TCS

845 Blooming Glen Rd. Blooming Glen PA 18911 215-453-9145 www.tcsdcc.com

Zimo

Model Railroad Solutions (importer) 1195 Velrose Dr. Kelowna BC V1X-6R7 Canada 250-765-7017 www.mrsonline.net