Early systems

General Electric's Astrac, introduced in the early 1960s, is the grandfather of command-control systems. With Astrac, no longer did you have to fiddle with a bunch of toggle switches to run your train around the layout. Instead, receivers installed in locomotives responded to signals sent through the rails, **1**.

Astrac was an analog system with control channels for five locomotives. It was a state-of-the-art system in the 1960s, using discrete solid-state parts. Expansion to additional channels was planned, but GE discontinued the system before this happened. Although short-lived, operationally limited, and expensive, Astrac was important as it gave model railroaders a taste of the future of locomotive and layout control.

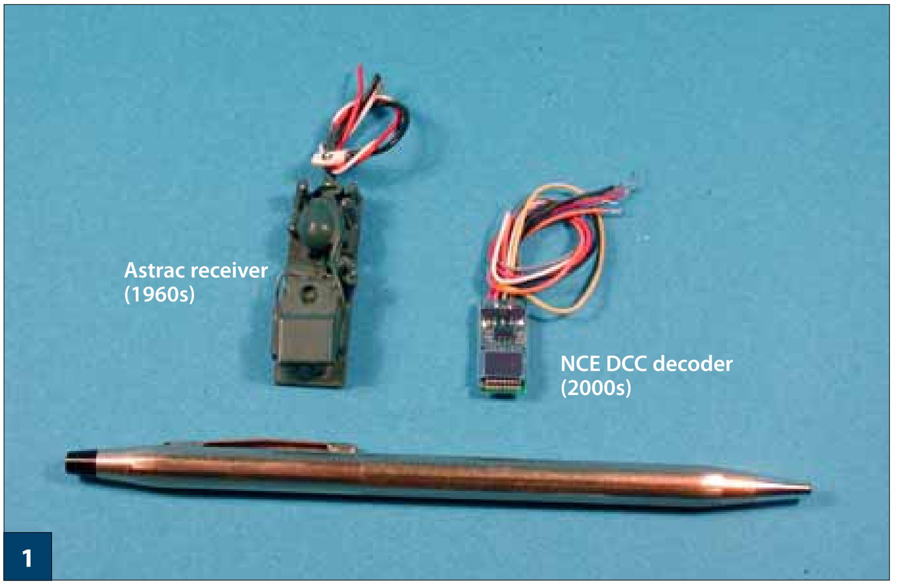
Other analog command-control systems eventually appeared, including CTC-16, CTC-80, Dynatrol, and Onboard. In the 1980s, the Onboard system offered a new dimension to command control: sound! Newer systems packed more functions into smaller receivers by using integrated circuits (ICs), **2**.

Early analog systems suffered from a combination of problems, including operational malfunctions due to heat, a limited number of channels (addresses), and a reliance on proprietary components.

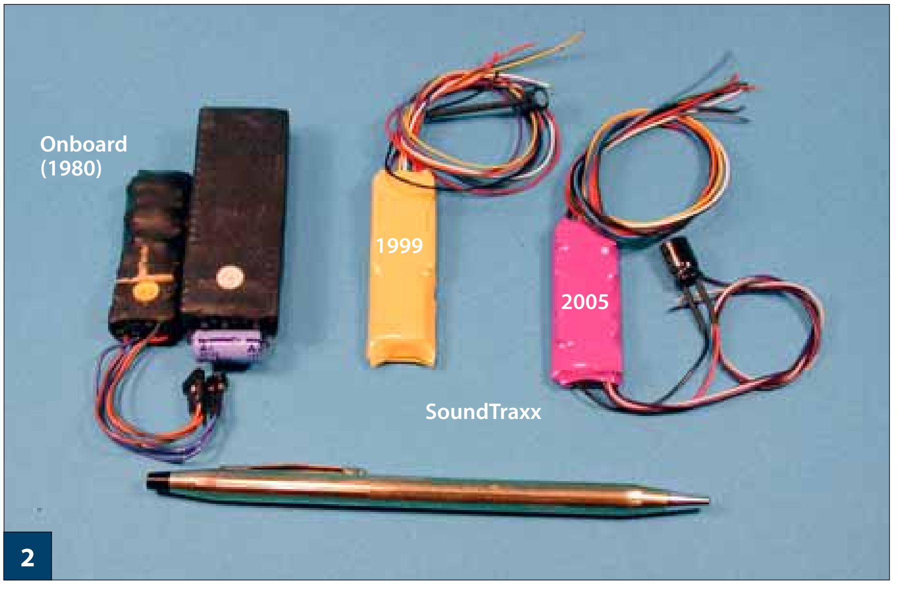
The modular group I worked with in the 1980s used an analog system. When running the layout at shows, operators would often lose control of their locomotives in the afternoon after they had operated for a long time. When the engines were turned off and allowed to cool, they were OK. These heat-related problems disappeared when the group switched to DCC.

Analog systems offered a limited number of addresses, and it was a hassle to keep track of which channel number matched which locomotive. DCC fixed this with a range of 9999 addresses, allowing the locomotive number to be the address.

A lack of standards also plagued analog systems. Each system was different, with no cross-compatibility. If you bought a system and needed to expand it, there was only one source for components. If a manufacturer went out of business, you were out of luck unless you could find used equipment of the same brand.



Compare the pioneering Astrac receiver (which was available with five pre-set addresses) at left to the much smaller NCE DCC decoder, which can be programmed with more than 10,000 addresses and control forward and reverse lights.



The circa-1980 Onboard system used high-frequency tones added to the 12-volt track power for control and selection. The Onboard receiver has two parts: one for control and the other for sound. In the late 1990s, SoundTraxx introduced its line of DCC sound decoders. The device at right is the new Tsunami 16-bit sound decoder.

NMRA DCC Standards

The National Model Railroad Association (NMRA) realized the need for a standardized command control system and in the 1980s began looking for a solution. A basic method of combining power and data on the rails was needed, and the approach that looked most promising was a digital system developed by Lenz in Germany. The NMRA obtained permission to use the Lenz digital method, leading to the NMRA releasing its DCC specifications in the mid-1990s.

The NMRA divides its specifications into two basic parts: standards (indicated by an S) and recommended practices (RPs), with DCC specs fall-

Programming step-by-step

There are two basic methods of programming a decoder: Using the program track or using program-on-the-main (POM) or on-the-fly programming.

Here's a step-by-step description of programming a decoder on the programming track using an NCE Power Cab (other systems will vary – check the manual for specifics).

Place the engine on the programming track. With power on, press the PROG/ESC key four times until you see:

SEL MODE XX:XXAM
USE PROGRAM TRK

Press ENTER. You should then see:

PROG TRK
1=STD 2=CV 3=REG

Press 2 for CV programing and the display will be:

PROG CV
PROG CV NUM:

Enter the CV number to be programmed – for example, 1 for the short address:

PROG CV
-----WAIT------

The response after the wait will be either the value in CV 1 or:

PROG CV
CAN NOT READ CV

Sometimes sound decoders have difficulty reading back the value on the program track. If it read OK, the display will show:

PROG CV
CV VALUE = XX

Press ENTER and then

PROG CV
CV NUM 001 = XX

Press ENTER, and the number will be programmed into CV1. The display will come back asking for the next CV to be programed:

PROG CV
PROG CV NUM:

When you are finished, press ESC/PROG to get out of the programming mode.

Program-on-the-main, or on-the-fly programming, lets you program CV settings while the engine is in use on the layout (not on the programming track). With this method, it's not possible to read back CV values. Also, unlike program-track programming, you *must* use the address of the locomotive to be programmed.

Here's an example, again using the NCE Power Cab.

Press ESC/PROG once and the screen shows:

SEL MODE XX:XXXM
PROGRAM ON THE MAIN

Press ENTER and you'll see:

OPS PROG XX:XXXM
PROG LOCO: 1234

Be sure that the proper loco number is selected, or you may program the wrong one!

Press ENTER and the display is:

LOC:1234 XX:XXXM
1=ADR 2=CV 3=CFG

There are other options if you press ENTER, or if you know the option number, just press the number key. There are nine options. Option 9 allows you to set individual bits in a CV. The screen looks like this for option 9:

CV: 00X 76543210
BITS 00000000

Type the number of the bit to change, and it will change to a 1; type the same number (1, 0) again to toggle it back to a 0. Press ENTER to program the CV and more CVs, or ESC/PROG to return to standard operation.

For the 2=CV mode simply press 2, then the CV number, and then the value. ENTER to program and return to normal operations.

This is just a sample using one DCC system. The Bachmann E-Z Command and Digitrax Super Empire Builder don't have provisions for program track operation, instead relying on POM for programming decoders.

for deceleration.

Some decoders now have a switching speed option activated with a function key. When activated, the speed is reduced by half, and the acceleration and deceleration are also reduced. This is very handy when using a road locomotive as a switcher.

Simplified decoder programming

It's sometimes difficult to determine which CV controls what feature. If you get lost in the translation from CV to function, help is available. Computer programs like JMRI's Decoder Pro can help by putting the function name on the screen and then letting you enter a number or move a slider with a mouse to change a CV value. Decoder Pro is updated frequently and is free over the internet (jmri.sourceforge.net).

Accessory decoder programming

Accessory decoders use a different address range than mobile decoders: from 1 to 2044 (but not all DCC systems use the full range).

Programming an accessory decoder can be different than programming a mobile decoder. Instead of using a programming track, they are set to program mode with a programming jumper, wire, or push button. When in the program mode, the decoder waits until the command station sends an accessory packet, then it stores the address in the decoder. The temporary jumper is removed, and the decoder retains the address information.

There are many variations on programming stationary decoders, so always check the decoder's manual for the correct procedure.

Jim Forbes

CHAPTER FIVE

Selecting a System

You'll make the best decision about buying a Digital Command Control system if you first consider your needs. Think about the size and scale of your layout, number of operators, and the features that are important to you. In this chapter we will explore the various factors for researching the purchase a DCC system.

Systems from various manufacturers have differing features and displays. The entry-level Digitrax Zephyr (center) includes a cab on the control station; others, such as the MRC Prodigy Advance² and NCE Power Pro, rely on handheld cabs.

E: Stationary decoder and switch machine compatibility	Digitrax			Lenz		DCC Specialties		NCE			Team Digital	CVP	
Decoder Switch Type	DS44	DS52	DS64	LS 100	LS 150	Hare	Wabbit	Switch-it	Snap-it	Switch-Kat	SMD2 SMD8	AD4MC	AD4H
Switch motor Type A1	Yes	Yes	Yes	OK[1]	Poor[2]	Tortoise Only	Tortoise Only	Yes	No	No	Poor	Yes	No
Switch motor Type A2	No	Yes	Yes	No	Yes	No	No	No	No	No	No	?	No
Twin-coil Type B1	No	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	No	Yes
Twin-coil Type B2	No	Yes	No	Yes	No	No	No	No	Yes[3]	No	Yes	No	Yes
Kato or LGB	No	Yes	Yes	No	Yes	No	No	No	No	Yes	No	Yes	No
Number of outputs	4	4	4	4	6	1	2	2	1	1	2/8	4/8	4

[1]LA 010 Required for this output. [2]Output not continuous. [3]May need to add a capacitor for high-current machines.

Accessory decoders with multiple outputs can control several switch machines at once. This is especially handy in staging and other yards, where a single command can align all the turnouts for a yard track.

Many multiple-output accessory decoders order the outputs so only one turnout is thrown at a time. This is more typical of capacitor-discharge decoders where the timing allows the capacitor to recharge.

The Hare and its bigger brother, the Wabbit, are intelligent accessory decoders that can be wired to automatically throw a turnout if a train approaches with the turnout set the wrong way. This eliminates a possible short circuit. The Hare also lets you feed back the switch position to the command station. You can also use these decoders to program routes, whereby the decoder will tell other Hares and Wabbits which turnout to set. This is helpful if your DCC system doesn't offer macro or route-control features.

Accessory decoders

Accessory (also called stationary) decoders are normally mounted under a layout where their size in not important. The important consideration in selecting an accessory decoder is the type of switch machine or motor that you are using – not the scale, **13**, **14**.

There are two basic types of switch machines: the coil or solenoid, which snaps the points into place; and the slow-motion stall-motor type. Both of these can be divided into two more categories, high-current and low-current.

Some stationary decoders are designed to drive a particular type of switch machine, and others are programmable and can drive many types of machines, **E**, **F**.

Power for accessory decoders and switch machines can come from the DCC signal/power bus that feeds the rails or from a separate power source. With some stationary decoders, the choice of the power source is optional.

F: Switch machine brands

Motor-driven		Twin-coil	
Stall (Type A1)	Power cut-off (Type A2)	Low- to medium-current (Type B1)	High-current (Type B2)
Micro-Mark, Tortoise, and SwitchMaster	PFM/Fulgerex and Scale Shops[1]	Atlas and Peco	Rix, NJI, and Tenshodo

[1]May need series lamp or resistor to reduce voltage.

Check the manual for each decoder (usually available on the manufacturer's Web site).

Most stationary decoders can be controlled by either a DCC command or push button switches. Some of the simple cabs and throttles will operate locomotives, but can't issue accessory decoder commands. If your operators have only basic cabs, push buttons will be needed for turnout operation.

Programming accessory decoders

Most accessory decoders use a jumper or wire connection for programming (not the programming track). Set the programming mode on the decoder, turn on the DCC power, then issue the accessory address commands. With a Digitrax system, turn on the system *before* connecting the decoder to be programmed. Some Digitrax systems send out a few packets when first turned on, which can cause incorrect programming.

Turn the power off, put the accessory decoder back into run mode, and the accessory decoder will respond to the programmed address.

Don Fiehmann

CHAPTER EIGHT

Lighting

This F7A has two headlights and two lamps in the number boards. The top light is a Mars light, and the lower one is a standard headlight. All are under DCC control. With key mapping, all three function outputs can be turned on with the same function key.

Lighting has always been important in the appearance of an operating locomotive. With DCC, constant lighting with controllable front and rear headlights is almost a standard. DCC makes many other lighting effects easy to add and remotely control, including simulated Mars (rotating) lights, strobe and warning beacons, ditch lights, firebox flicker, and dimmed headlights.

The locomotive headlight on the left is a lamp, the one in the middle is an older bluish-tint white LED, and the model at right has a Yeloglo LED that gives off a color more like an incandescent lamp.

Lamps vs. LEDs

Light-emitting diodes (LEDs) have been replacing lamps (bulbs) in models for some time, and many new locomotive models use LEDs. There are some good reasons for this. Incandescent lamps and LEDs both produce light, but they have significantly different electrical characteristics. Also, although LEDs were once expensive, they are now comparable in price to the lamps they replace. Here are some key differences.

Power consumption. Lamps require a short warmup time, and electrical resistance changes significantly as the lamp heats up. A cold lamp has about a tenth of the resistance of an operating lamp. Miniature lamps are available in a range of voltages from 1.5 to 16 volts, with current ratings of 15 to 100 milliamps. Lamps act like a resistor, and current can flow both ways through them.

An LED comes on instantly when power is applied, and its resistance remains constant. LEDs normally operate on just a few volts and less than 20 milliamps. Since LEDs are diodes, current flows through them in only one direction, so LEDs must be wired with the correct polarity.

Low-voltage lamps and LEDs require a series resistor to match their low operating voltage to the output voltage of a decoder. The value of the series resistor used with a lamp is critical.

LEDs begin producing light at a very low current. This light remains fairly constant, not growing much brighter from about 5 milliamps to the maximum of 20 milliamps. The value of a series resistor for LEDs is not critical. A 1K ohm (1000-ohm) to 2K ohm (2000-ohm) resistor works fine most of the time.

Heat. Heat can be a problem with lamps. One modeler told me his experience of using two lamps for the front headlight of a diesel. After leaving the lights on for some time, the lamps melted part of the plastic shell.

Light pattern. Lamps emit light in all directions, while an LED's light is directional, like a flashlight.

Life expectancy: Lamps have a life expectancy in terms of hours, while the life of an LED is rated in years.

Color: Real locomotive headlights are white with a slightly yellowish appearance. More recent LEDs (such as Sunny-White or Yeloglo), produce a color that closely resembles that of an incandescent lamp, **1**. Older "white" LEDs have a bluish look; they can be tinted with a yellow or amber paint wash or a felt-tip pen to improve the color.

Size: Lamps and LEDs are both available in small sizes, **2**. Common LED sizes are 3mm, 5mm, and 1.5mm. Surface-mount LEDs are extremely small, **3**. These will fit into the smallest locomotives and are mounted on PC boards in many new locomotives. They will easily fit into an N scale headlight or HO marker lantern.

Cost: Most colored LEDs are comparible to – and sometimes cheaper than – lamps. White LEDs cost about $1 each. A properly installed LED will outlast its locomotive, and the LED cost is certainly cheaper than your time in replacing a burned out lamp.

Special effects: For a headlight or strobe, either lamps or LEDs can be used. However, for special effects like headlight dimming and Mars lights, there's a difference in response time and current sensitivity. These effects are controlled by pulse-width modulation (PWM), the same method used to control motor speed.

Some decoders use a bit in the lighting-control CV to change the characteristic of the function output to better match an LED for special effects. Before using an LED for special lighting, check to see whether your decoder supports LEDs.

To determine the PWM difference between an LED and a lamp, I connected an oscilloscope to a decoder's lighting function output. To dim a lamp, the function output was on 37 percent of the time. However, to make an LED appear to dim, the output was on for only 6 percent of the time.

Decoder manuals

The decoder's manual should be your first reference when wiring lamps and LEDs. Some decoders use built-in resistors or voltage regulators to reduce the output voltage/power to match low-voltage lamps and LEDs.

Check existing lights when installing a decoder in a DCC-ready locomotive. Many of these models use diodes to reduce the voltage to the lamps, and connecting the existing lamps to a decoder may burn out the bulbs. Check the locomotive's instruction sheet or manual to determine if the lamps need to be replaced.

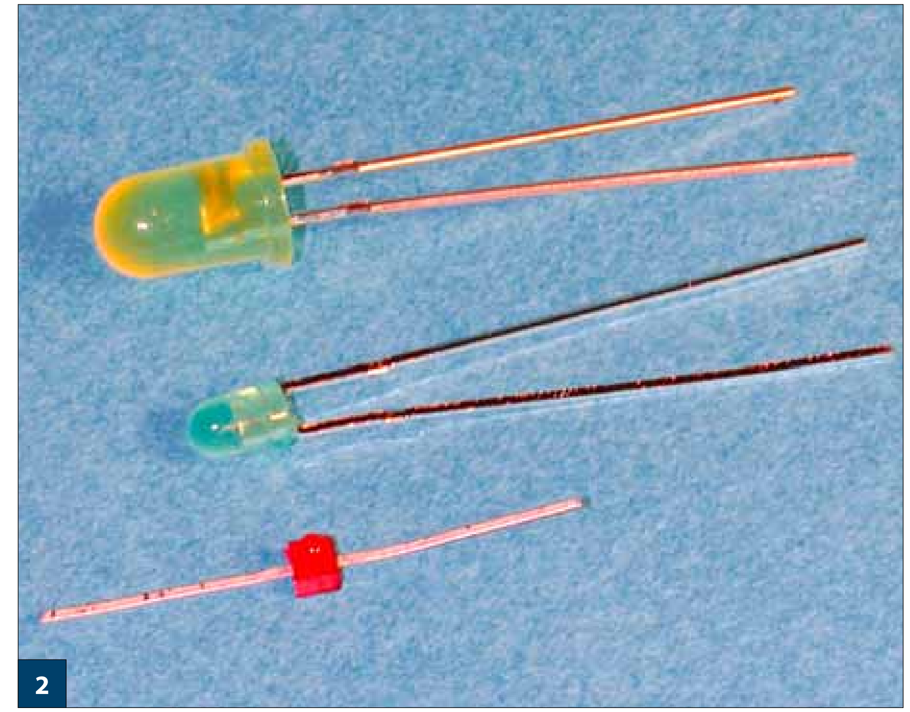
If you're unsure of a lamp's voltage, test it with a 1.5-volt battery. If it lights brightly, it's a 1.5-volt bulb. If it doesn't light, then either it's a higher-rated bulb or burned out – check it using a higher voltage.

Wiring

Lights and LEDs are normally wired from the blue (common) wire on the decoder to one of the function outputs. The blue wire is the positive (+) connection, and the function outputs are the negative (-) connections. Lamps and LEDs can be connected to the same decoder; for example, a lamp for the headlight and an LED for a roof-top strobe.

Lamps are not polarity sensitive, but LEDs require a resistor, and the cathode of the LED must be connected to the function output. The cathode is the lead next to the flat side of the LED, **A**.

Insulate all connections to lamps, LEDs, and resistors to prevent short



Three common LED sizes are (from top) 5mm, 3mm, and 1.5mm. LEDs come in many different colors, including white.

This very small LED, soldered to two pieces of magnet wire, is a Surface Mount Technology (SMT) device.