DCC and the HO Layout

Part 1*

Ralph James
June 15, 2023

* Hmm. Lots to talk about. . .

First Let's Build a Base of Understanding

- Brief History of Multi-Train Control
- Communications Bus
- Signal Encoding and Noise
- Advantages of DCC
- DCC Components
- DCC track waveform and messages

Then Cover a Few Practical Topics

DC Support – Zero Stretching

Message Sequencing

The Locomotive Slot Table and Importance of Dispatching

And Save Some Topics for Another Day

- Power Districts and Circuit Breakers
- Reversing and the Wye
- The Bus Rewiring Project and the New Extension
- Troubleshooting

- Java Model Railroad Interface (JMRI)
- Decoders (need a speaker for this one)

Multi-Train Control History, Communications Buses and Noise

Astrack, 1964

- Analog, 5 locomotives
- Up to five radio signals send on the rails, one per loco (100kHz to 255kHz)
- Radio frequency FM shifts controlled speed and direction
- AC track voltage was used to turn off drive SCR’s in the decoders

AUTOMATIC SIMULTANEOUS TRAIN CONTROLS (ASTRAC)

GIANT STEP FORWARD MODEL RAILROADING

erates up to 5 trains on one electrically ntinuous track, no insulated rail joiners
ll voltage on track at all times—lights stay full brilliance even when train is stopped
mbines amazingly slow creep-speed with ll power
laptable to all model trains, any track rout
minates complicated wiring—accessories n now be wired to nearest track terminal int
ock-proof, collision-proof, completely safe
sy to install
warm-up time

General Electric's new ASTRAC System can add a new, exciting realism to your model train installations. Easy to install and operate, ASTRAC units can control up to five trains on the same electrically continuous track — all independent of each other.

The ASTRAC System maintains full voltage on the track at all times, regardless of the speed or direction of the trains. Accessories requiring constant power — station lights, etc. — can be connected directly to the nearest track terminals. What's more, you always have full power for and head lamp brilliance, even when the train is stopped. ASTRAC eliminates jackrabbit starts, too, with a creep speed so slow you can barely see the wheels turn.

ASTRAC consists of a transmitter and micro-receivers placed in engines or accessories. The Models K-2 and K-4 control units are capable of controlling two trains running simultaneously. Model K-5 can selectively control any one of five trains on the same electrically continuous track.

Model No. K-2 (Channels 1 and 5)
Model No. K-4 (Channel 2 and 4)

DUAL CONTROL UNIT

Controls two trains on the same track both independently and simultaneously, using two G-E Micro-Receivers. Model K-2 controls channels 1 and 5; Model K-4 controls channels 2 and 4. Separate speed controls and separate forward/reverse switches are provided for each train. Control unit contains 4 transistors, 6 diodes and printed circuit. Indicator light tells when system is on. To install the K-2 or K-4 Dual Control unit, simply connect two leads from the transformer accessory terminals to the terminal board on the back of the control unit, and attach the K-2 or K-4 leads to the tracks. A Micro-Receiver is placed in each engine with a lead connected to each of two pick-up wheels. The third lead is attached to the motor. Then plug the six-foot cord into the 110-volt outlet and you're ready to go.

Transmitter size: 12½" x 4½" x 3½".
Carton size: 14" x 8" x 4". Packed one set per carton.
Micro-Receivers:
Approx. Ship. Wt. 3 lbs. Retail price about $64.95.

Model No. K-5

5-CHANNEL CONTROL UNIT

Selectively controls any one of five trains on the same electrically continuous track. Completely assembled and ready to mount in your control panel. Model K-5 has a speed control, a forward/reverse switch, and a five-channel selector switch. Control unit is completely transistorized with printed circuit and transformer. By simply switching channels, you can control any one of five trains independently through a G-E Micro-Receiver installed in each train. Operates from 110-125 volts AC, 50-60 cycles, 4 watts. Transmitter size: 8½" x 2½" x 3".

Carton size: 10" x 5" x 5". Packed one per carton.
Approx. Ship. Wt. 2 lbs. Retail price about $34.95.

Models: K-10, 20, 30, 40, 50

MICRO-RECEIVERS

Encased in clear General Electric silicone rubber, G-E Micro-Receivers are shock-proof, moisture-proof, collision-proof, heat-resistant, and short-proof. A micro-electronic device using two General Electric Silicon-Controlled Rectifiers, these receivers are designed for H-O, OO, O and S gauge equipment. Each receiver can handle up to 1.6 amperes, 15 amperes one cycle, or a 48-watt load at 30 volts. They operate from 6 to 30 volts, 25-60 cycles. Only three connections need be made to each receiver: one wire to each of two pick-up wheels, and one to the motor. Complete instructions included.

Receiver size: 1½" x 1½" x ¾".
Models and channels are as follows:

K-10	Channel 1	100KC
K-20	Channel 2	140KC
K-30	Channel 3	180KC
K-40	Channel 4	220KC
K-50	Channel 5	255KC

Carton size: 3" x 2" x 1½". Packed 5 per carton (K-10 [illegible]
Approx. Ship. Wt. 1½ lbs. Retail price about $9.95.
Also available in single units.

RADIO RECEIVER DEPARTMENT • UTICA, NEW YORK GENERAL ELEC

CTC-16, 1979

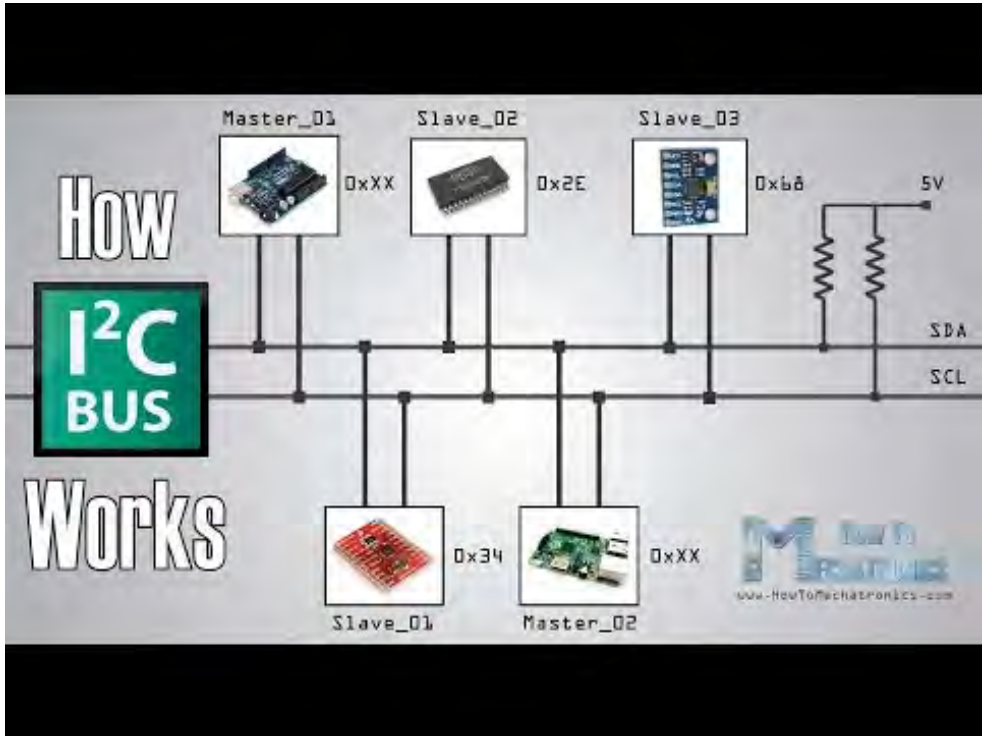
- Analog, 16 locomotives
- A repeating sequence of 16 four volt pulses was superimposed on the track base voltage
- Varying pulse width set loco speed and direction
- Similar to early R/C airplane “digital proportional” coding

More trains, please!

We are going to need a more sophisticated approach. . .

Try a Communications Bus

- Connect devices to a common electrical, optical, radio, etc. transmission medium
- Devices send messages of 1’s and 0’s over the bus
- Each device has a unique digital bus address
- Messages typically contain a synch sequence, followed by a destination address followed by some content



- Used for:
  - Computer backplanes
  - Peripherals (USB)
  - Network routing

Lionel TMCC, 1995

- FM Digital bus, 99 locos
- Can control consists, sound, lights, switches and routes, and accessories
- Digital messages are coded as an FM radio signal sent over the track along with the constant AC track voltage
- There are many similar systems including MTH's DCS

General command format

Bit order

MSB															LSB
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Note: Bits transmitted / received in descending order, i.e. bit 15 first.

Switch commands

0	1	A	A	A	A	A	A	A	C	C	D	D	D	D	D

Route commands

1	1	0	1	A	A	A	A	A	C	C	D	D	D	D	D

Engine commands

0	0	A	A	A	A	A	A	A	C	C	D	D	D	D	D

Train commands

1	1	0	0	1	A	A	A	A	C	C	D	D	D	D	D

Accessory commands

1	0	A	A	A	A	A	A	A	C	C	D	D	D	D	D

Group commands (several accessories activated together)

1	1	0	0	0	A	A	A	A	C	C	D	D	D	D	D

Definitions

A—*Address field:* the address for the object (switch, route, engine, etc.) receiving the command.

C—*Command field:*

00—action
01—Extended
10—Relative speed
11—Absolute speed

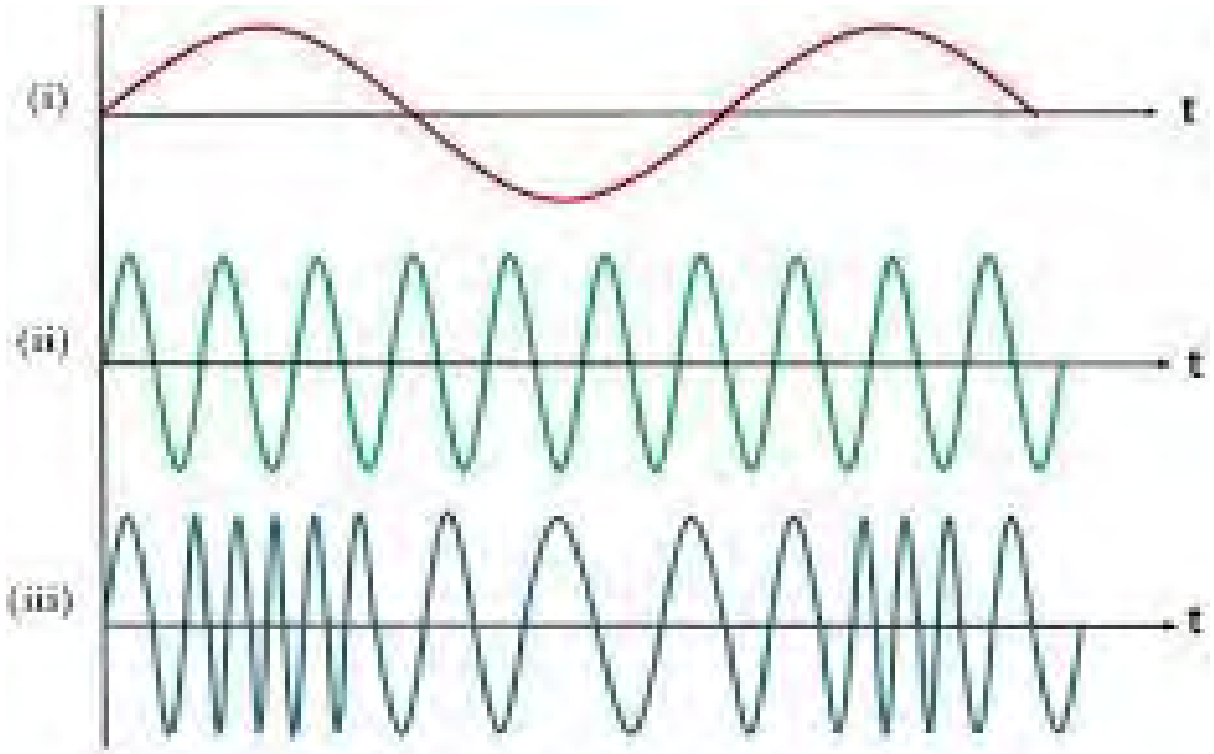
D—*Data field:* the data being sent to the addressed object.

The Noise Problem and why DCC is So ~~Weird~~ Different

FM encoding

- Recall FM means frequency modulation of a carrier frequency

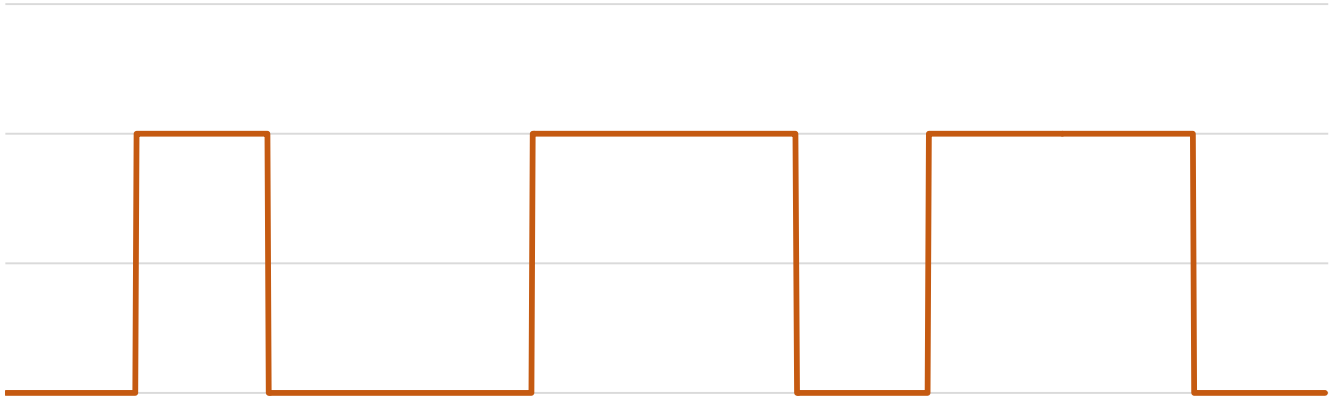
- Here is a sine wave encoded as an FM signal



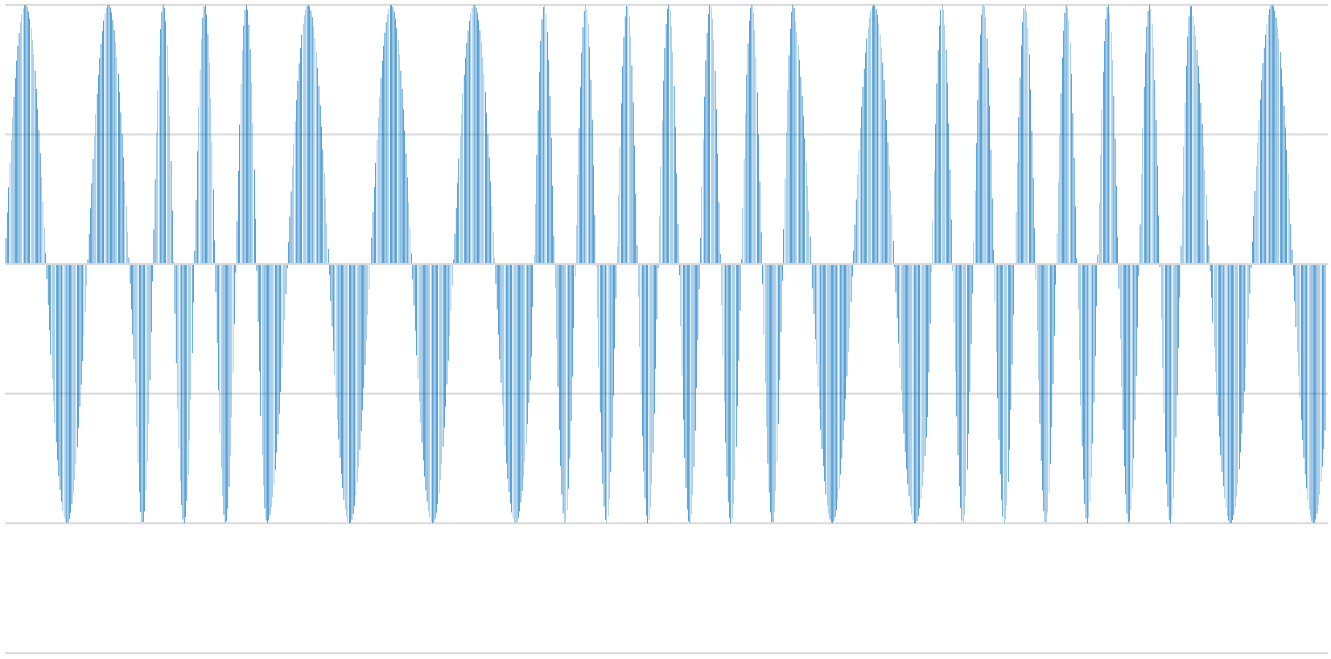
(i) Modulating signal
(ii) Carrier waveform
(iii) Frequency modulated signal

FM Encoded Binary

- Here is a binary sequence

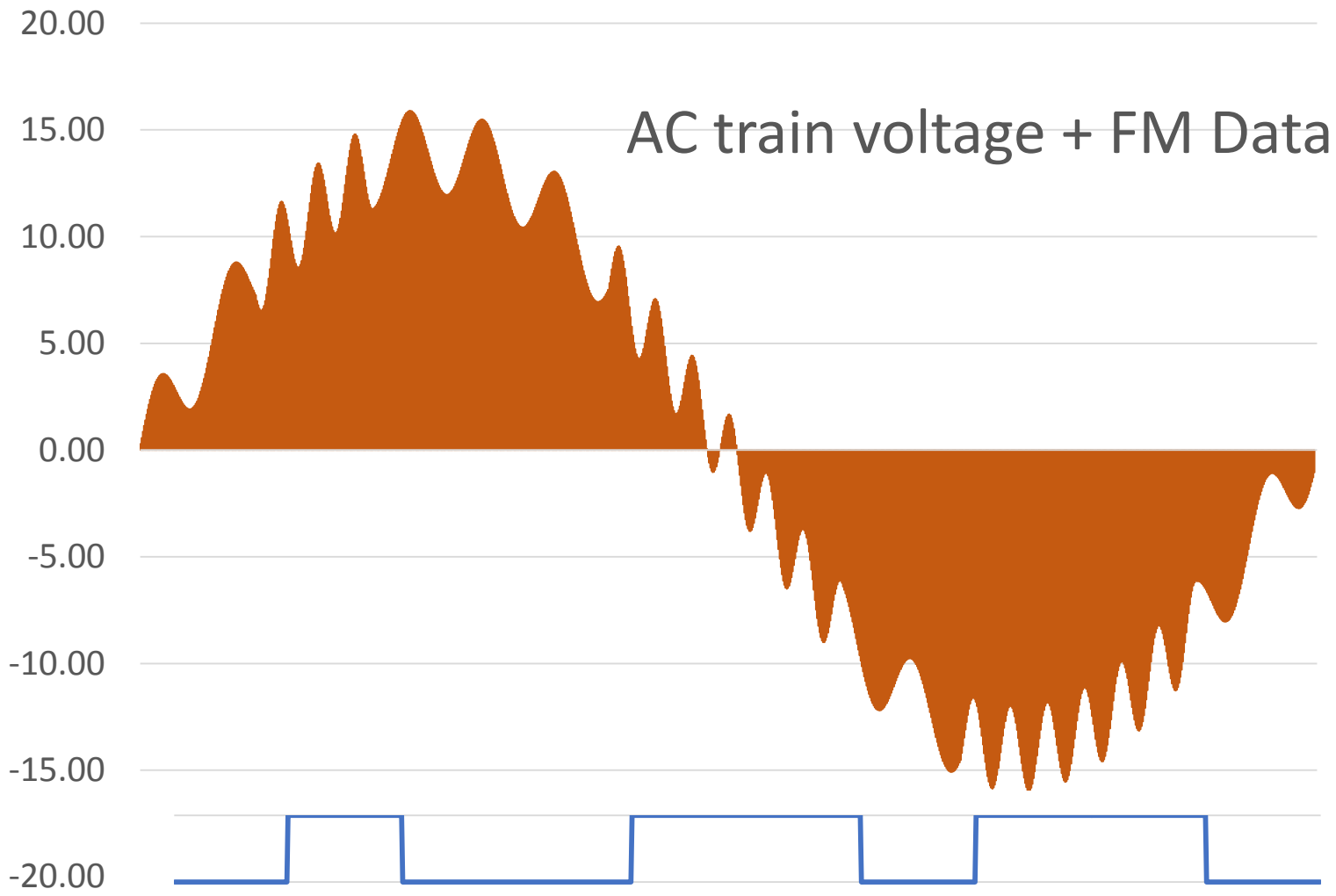


- FM encoded carrier (sine) wave will be placed onto the track at a nominal level of 2 volts



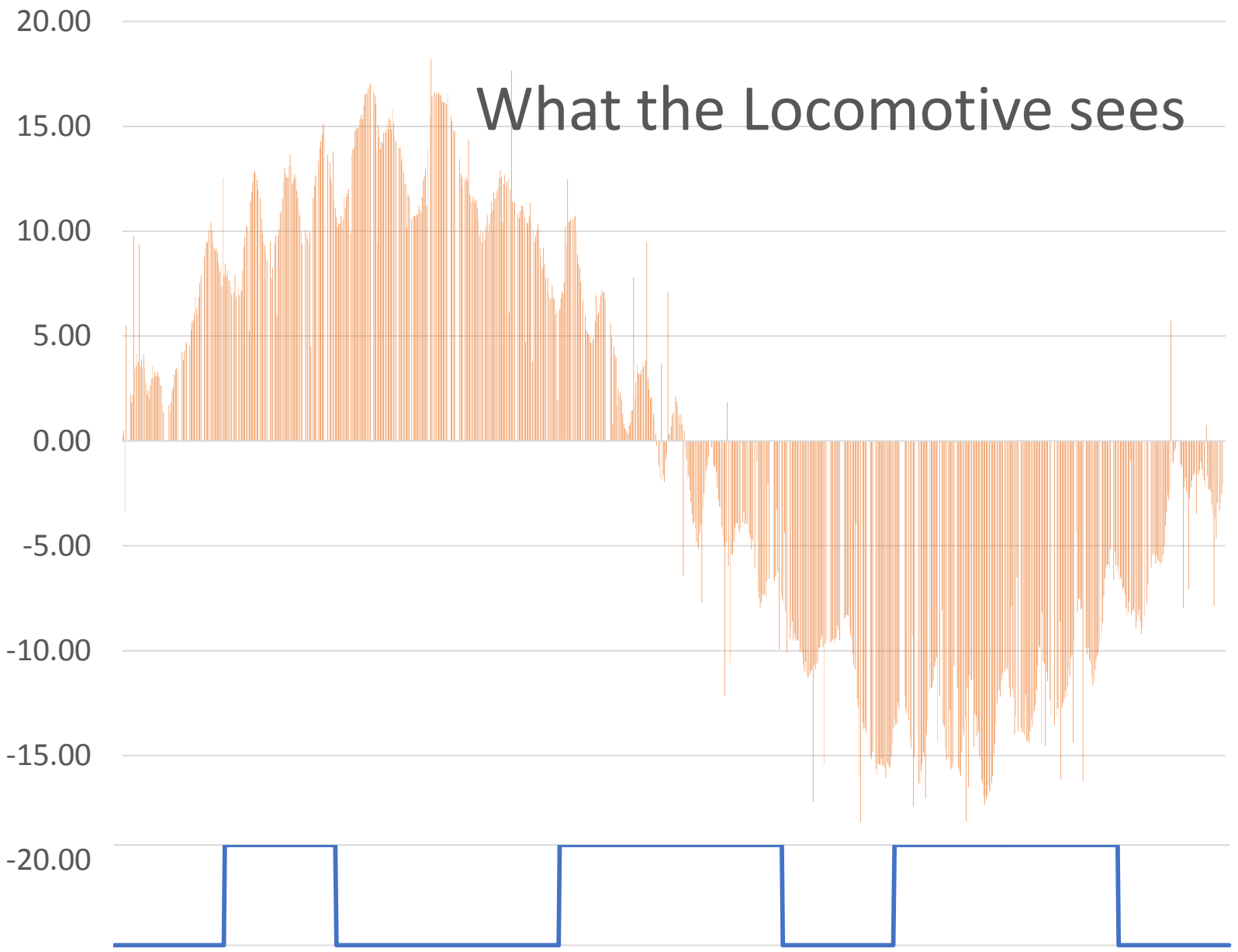
FM signal on Track

18 volts AC runs the trains. The FM signal is added to that



With noise, dropouts and sparks.

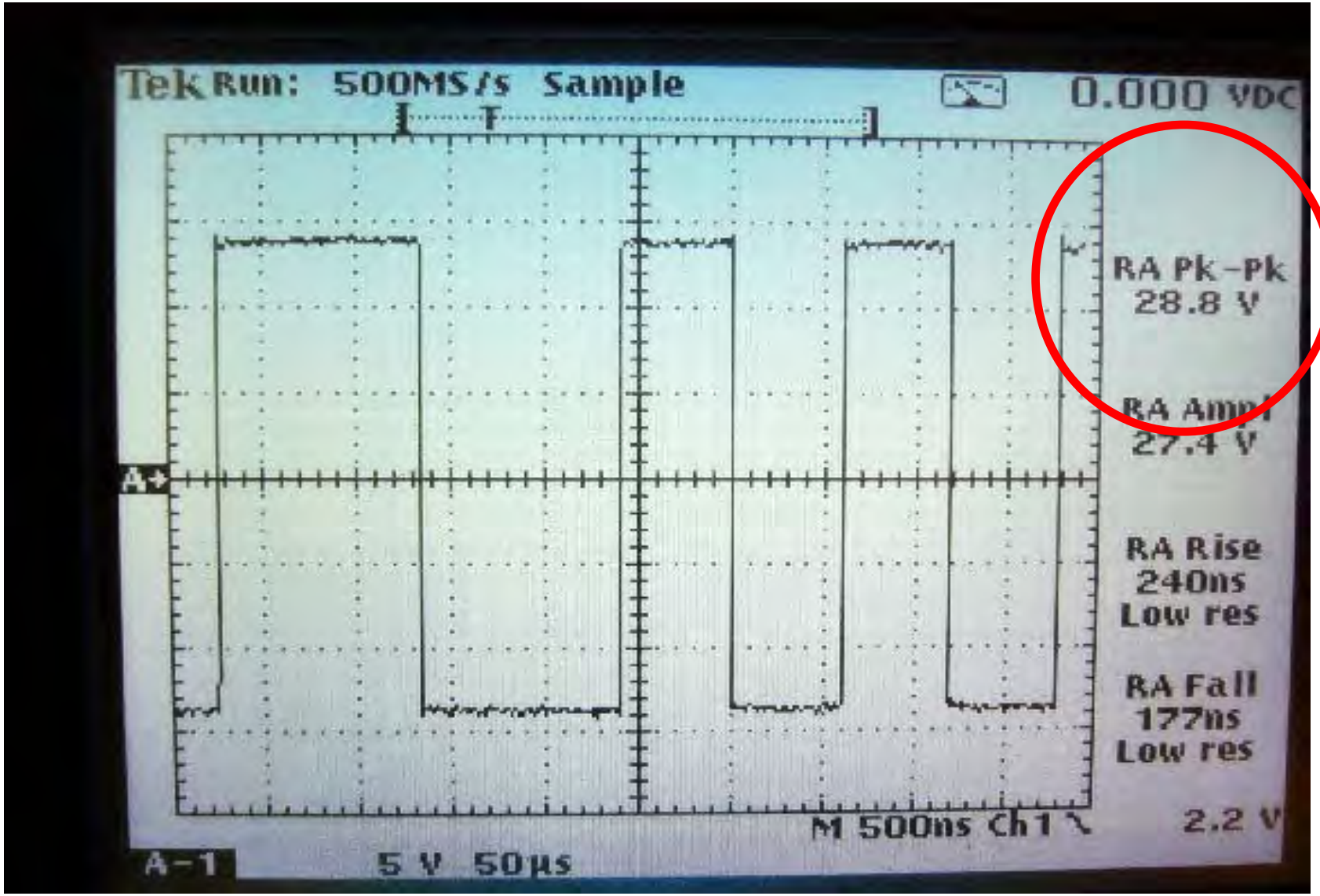
Yes, the messages are digital, but the bits are encoded in an *analog waveform* that can be noisy



DCC uses a pure, 100% Digital Encoding

DCC inverts the *entire track voltage* thousands of time a second to transmit ones and zeros!

This approach is revolutionary among multi-train control systems



Advantages of DCC

- Improves message signal-to-noise ratio
- Is a cross-vendor standard by the NMRA, started in 1990
- Supports variable address and message lengths for extensibility
- Leaves a lot of flexibility in throttle connection and communication
- Allows operation of one DC locomotive on same track as DCC

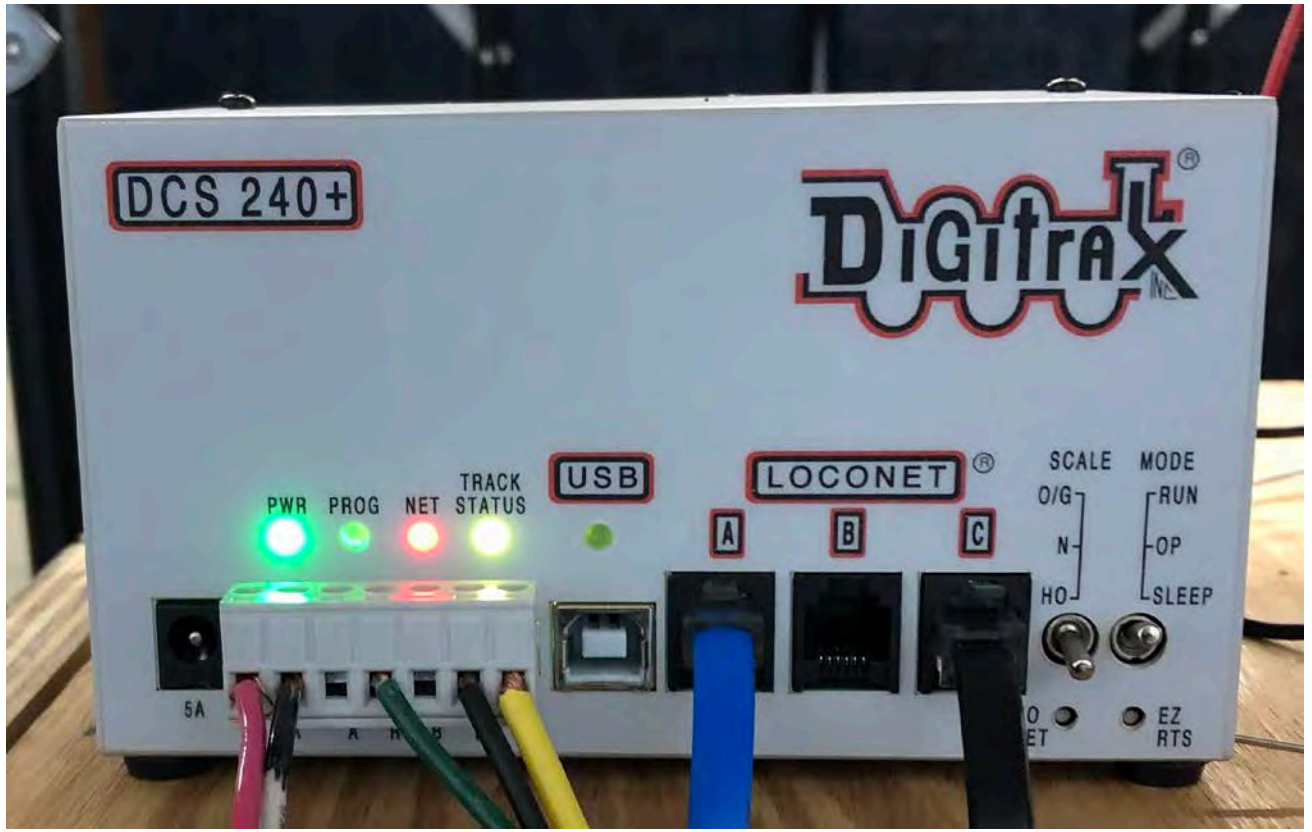
- Following original work by Marklin and Lentz in 1988

DCC Components:

Command Station: Maintains a table of throttle-to-locomotive associations. Sorts and priorities messages coming in from the throttles into a continuous, sequential stream of messages for the booster

Booster: Rapidly flips track polarity back and forth to encode bits as track voltage

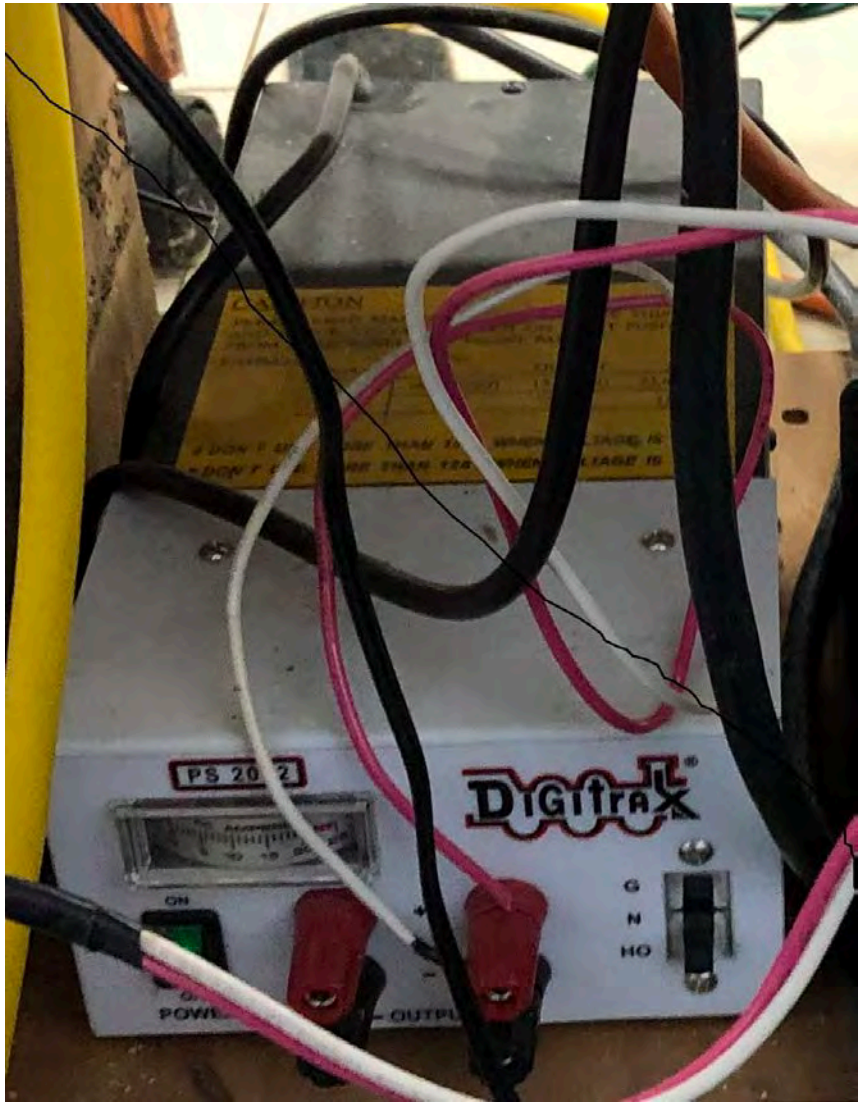
Our Digitrax DCS240 is a combined Command Station and Booster



DCC Components:

Power Supply: Supplies power for the Booster.

Ours can supply up to 20 amps at 18 volts, which easily supports two boosters



DCC Components:

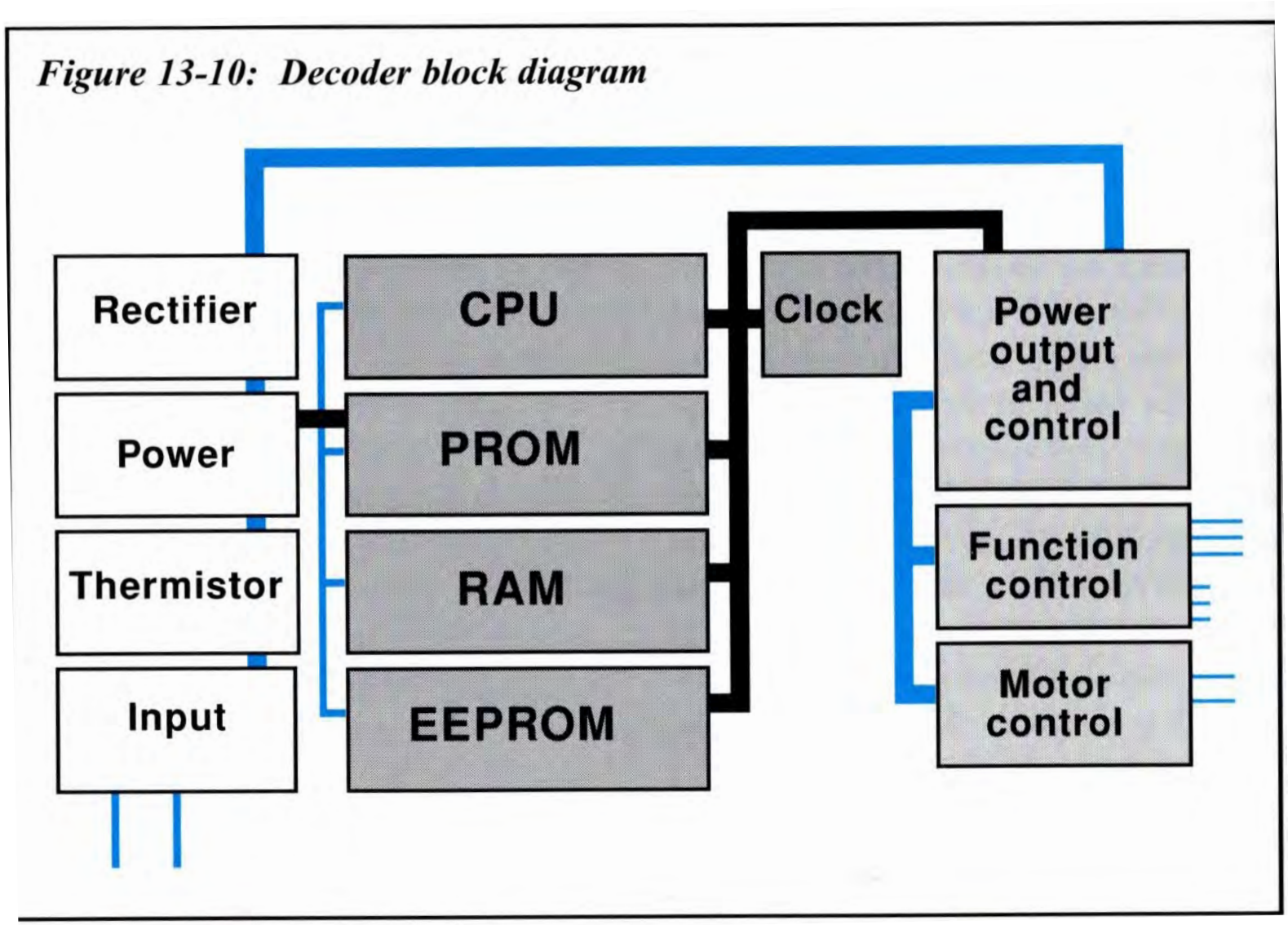
Throttle: Generates locomotive commands

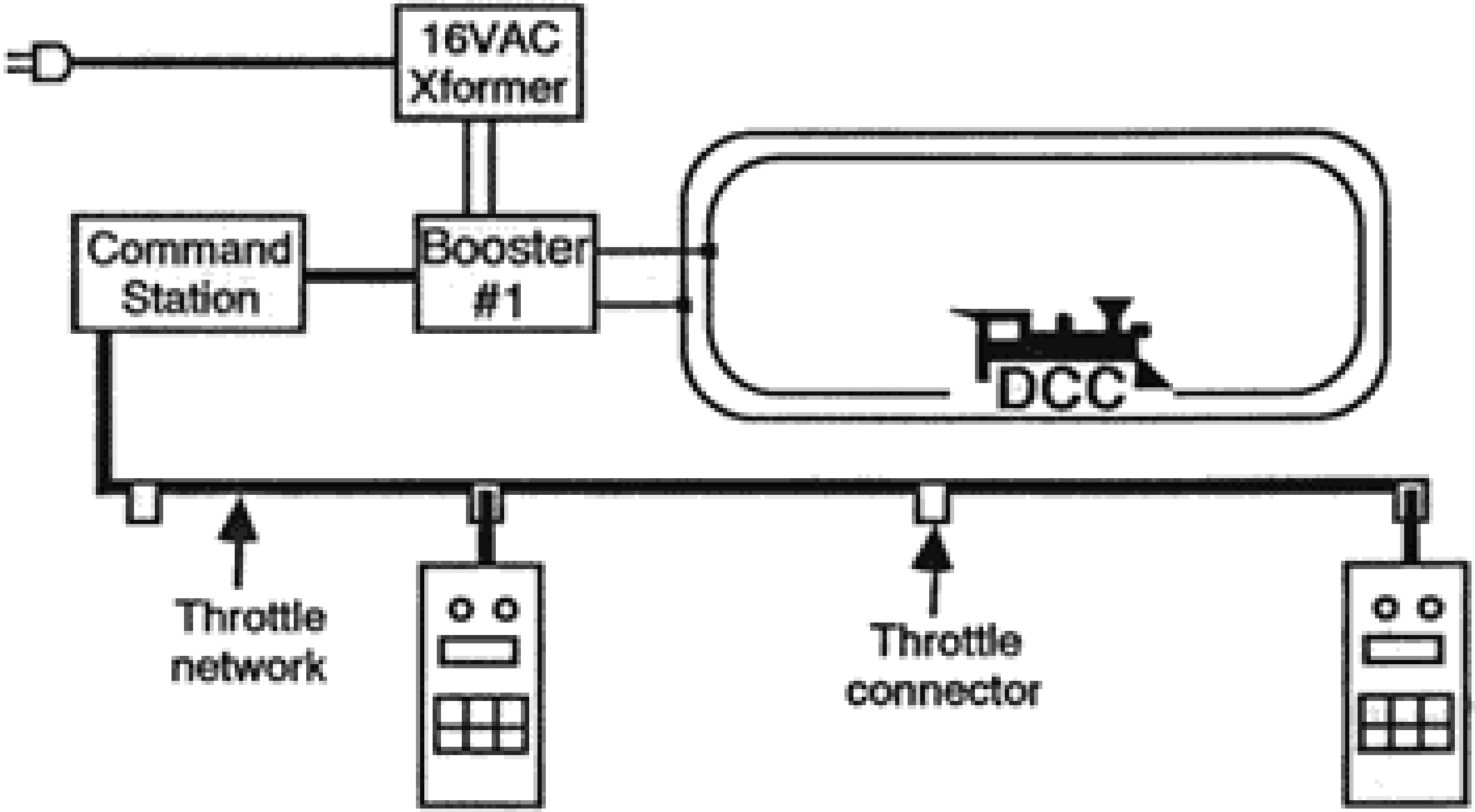
Throttle Bus (LocoNet): Provides a bi-directional, Ethernet-like bus to bring throttle commands to the Command Station.

DCC Components:

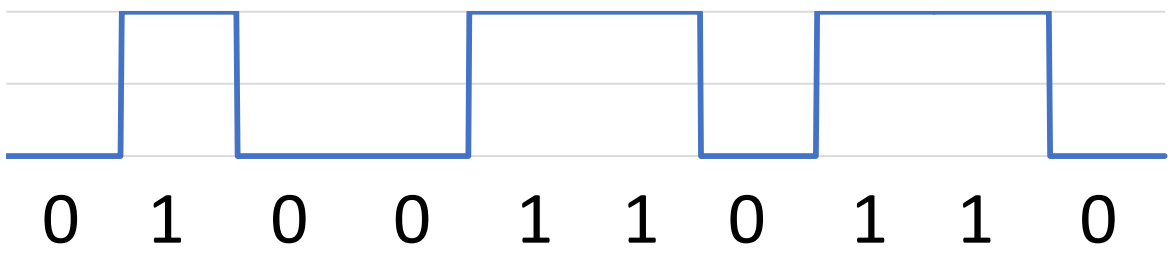
Decoder: Recognizes commands intended for this locomotive, decodes them, and takes action.

Decoders must also rectify the track voltage into pure DC to run the loco motor and onboard electronics




16VAC
Xformer
Command
Station
Booster
#1
DCC
Throttle
network
Throttle
connector

DCC Waveform

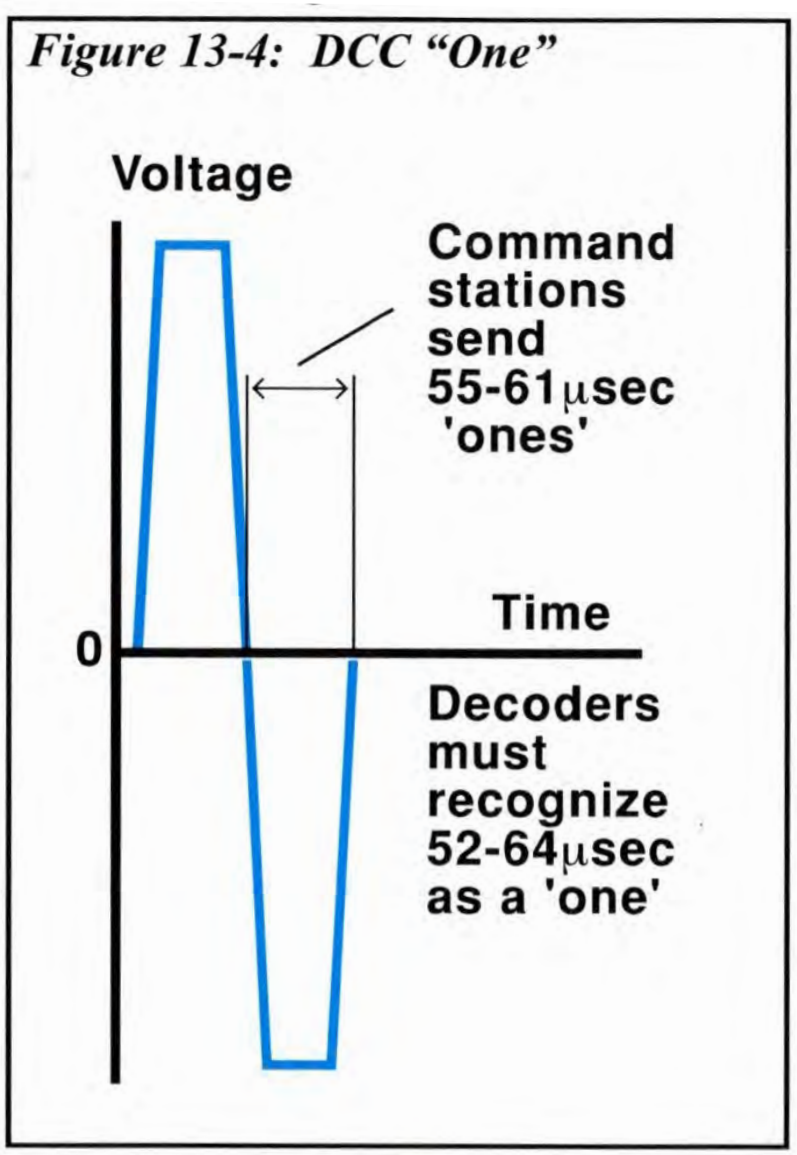


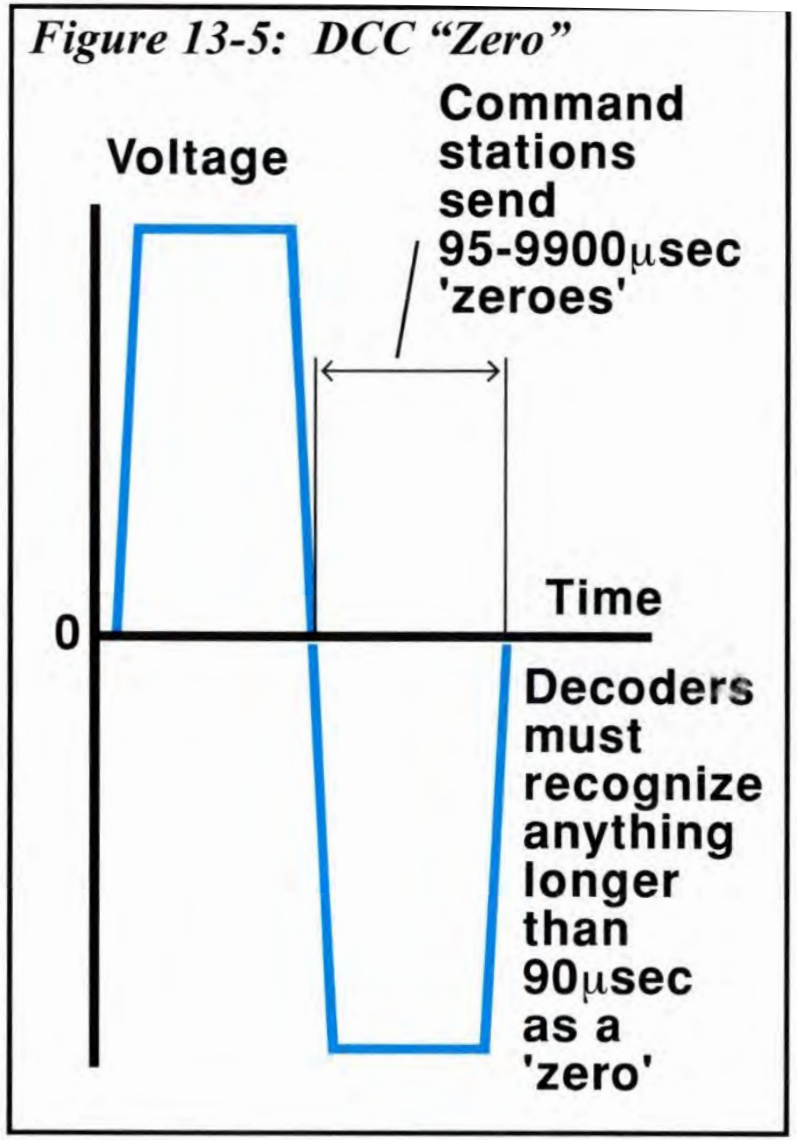
DCC Track voltage is not really flipped in polarity such that one direction represents zero 1 and the other represents 0.

The resulting *average* voltage would vary based on the instantaneous ratio of 1's and 0's. Instead. . .

Instead, both logical 1 and 0 use a full cycle wave, with an average value of zero volts.

The difference between 1 and 0 is encoded via the time it takes to complete a full cycle.





DCC Message

Figure 13-6: Sample DCC packet commanding decoders with address 71 to go in reverse at speed step 4 in 14 speed step mode.

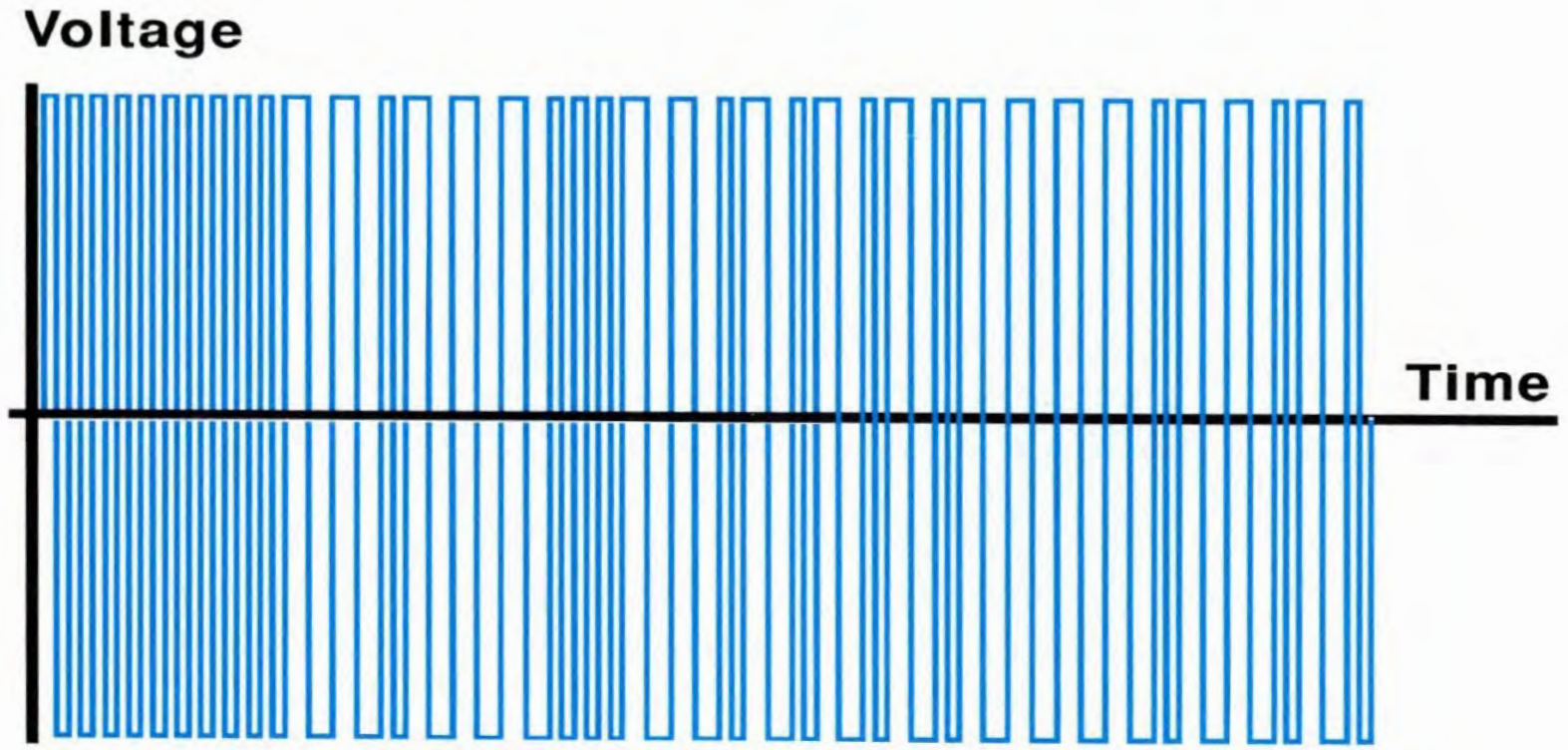
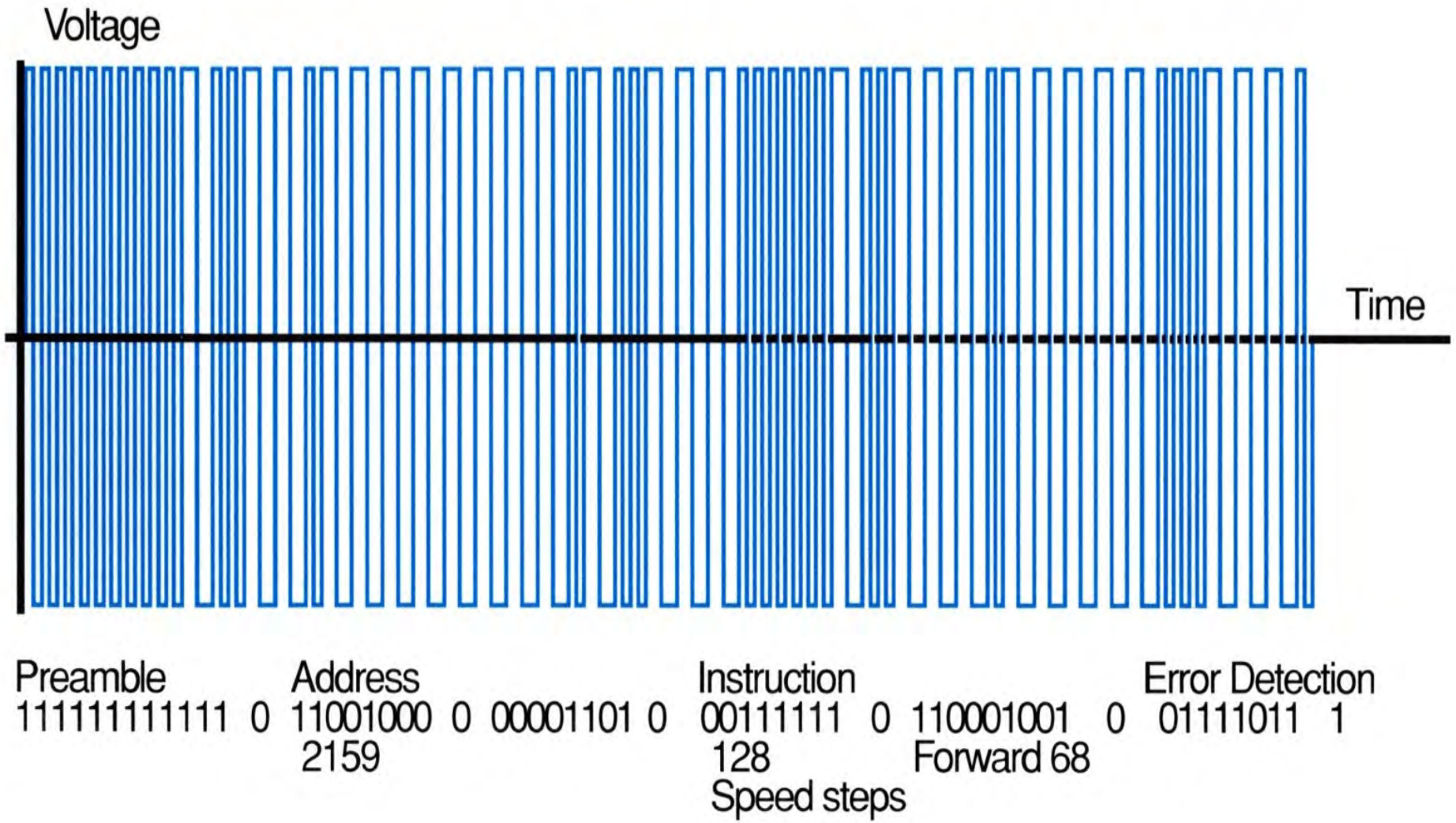


Figure 13-8: Sample DCC packet commanding decoders with four-digit address 2159 to proceed forward at speed step 68 in 128 speed step mode.



So. . . is DCC DC or AC?

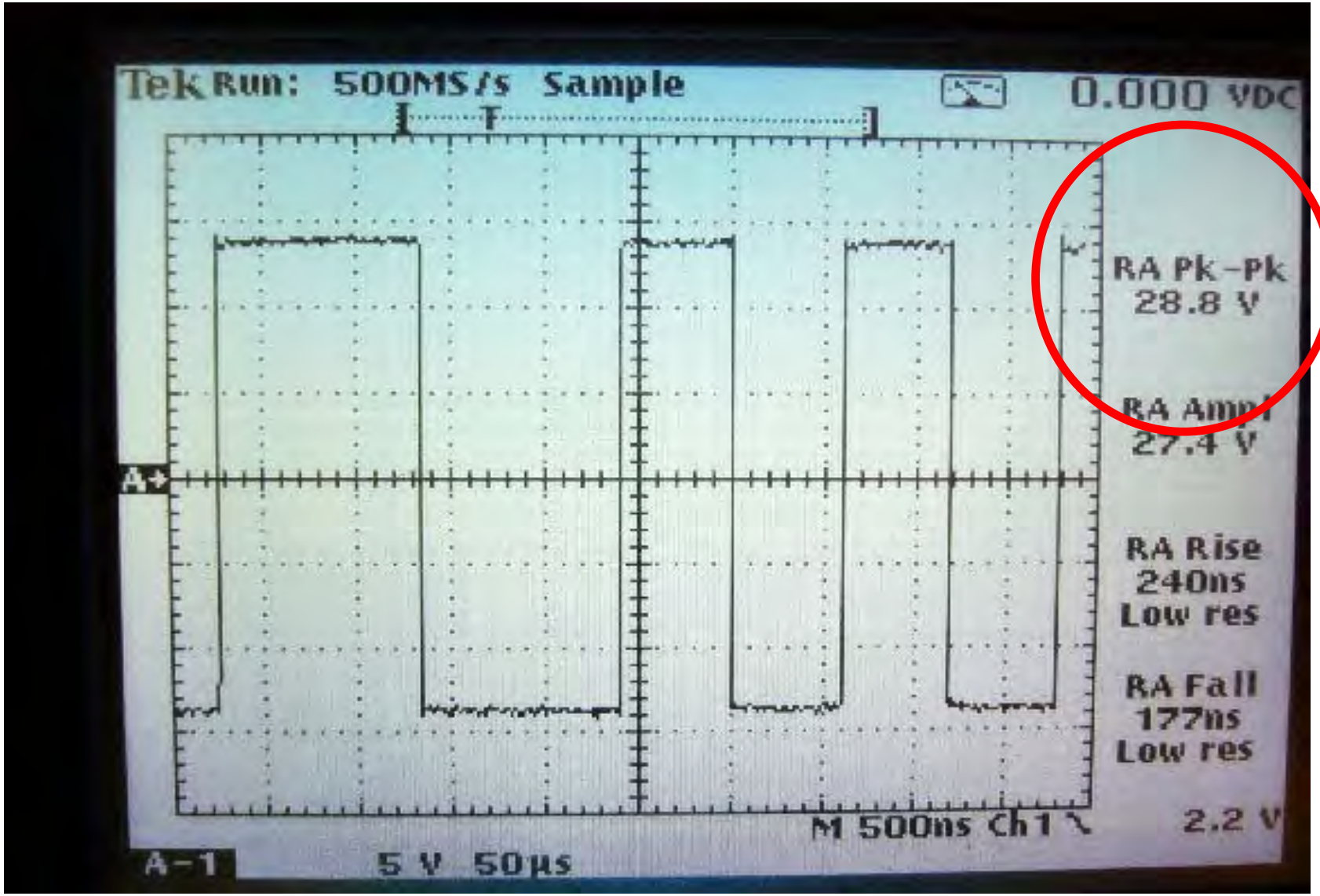
Neither!

It is a bipolar digital logic signal

Voltmeter readings don’t tell you much

Voltmeter readings	VAC	VDC
From either rail to ground:	0	4.5
Across the two rails:	19.7	0.15
Half wave across rails:	-	13.9

DCC is a 28v peak-to-peak square wave pulse train

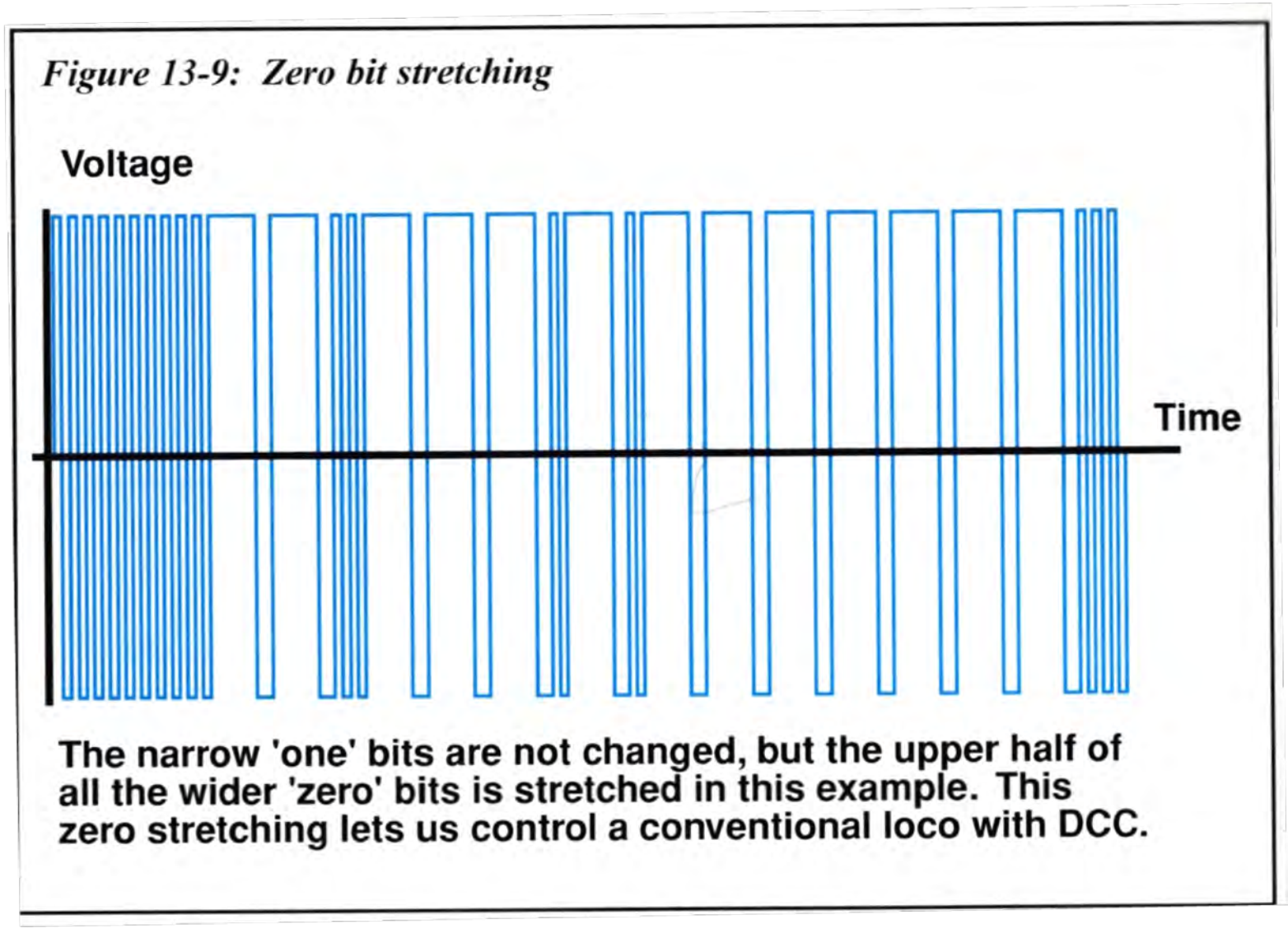


Enough Theory, Time for Practical Matters

- Support for DC locomotives (Zero Stretching)
- Message sequencing
- The Loco Slot Table and the Importance of Dispatching

Zero Stretching

Since any full cycle bit longer than 90 micro-seconds is considered a zero, it is ok to stretch any zeroes out



By stretching only one polarity, a DC offset is placed on the track

DC locos run as pseudo-address zero.

Zero stretching consumes more bus bandwidth than normal messaging

If there is little activity on the bus there won't be many zeros to stretch and DC locos may slow down

As the analog loco speeds up, it requires more power and this requires the command station to stretch the zero little more and more. This uses up bandwidth that would be available to decoders and reduces the number of commands that can be sent to other DCC devices. At full power, a Digitrax command station can stretch a zero bit to a maximum of about 1000µsec. Thus, an analog locomotive could use up a lot of bandwidth because the zeros are increased in length by ten times.

If your layout uses more than about 5 DCC locomotives at once, you may notice a slight delay in the throttle

Message Sequencing

Throttle messages arrive at the Command Station asynchronously from the active throttles (no polling)

The track command bus is sequential, so the Command Station sorts the pending messages by priority before sending them onto the Booster, one at a time

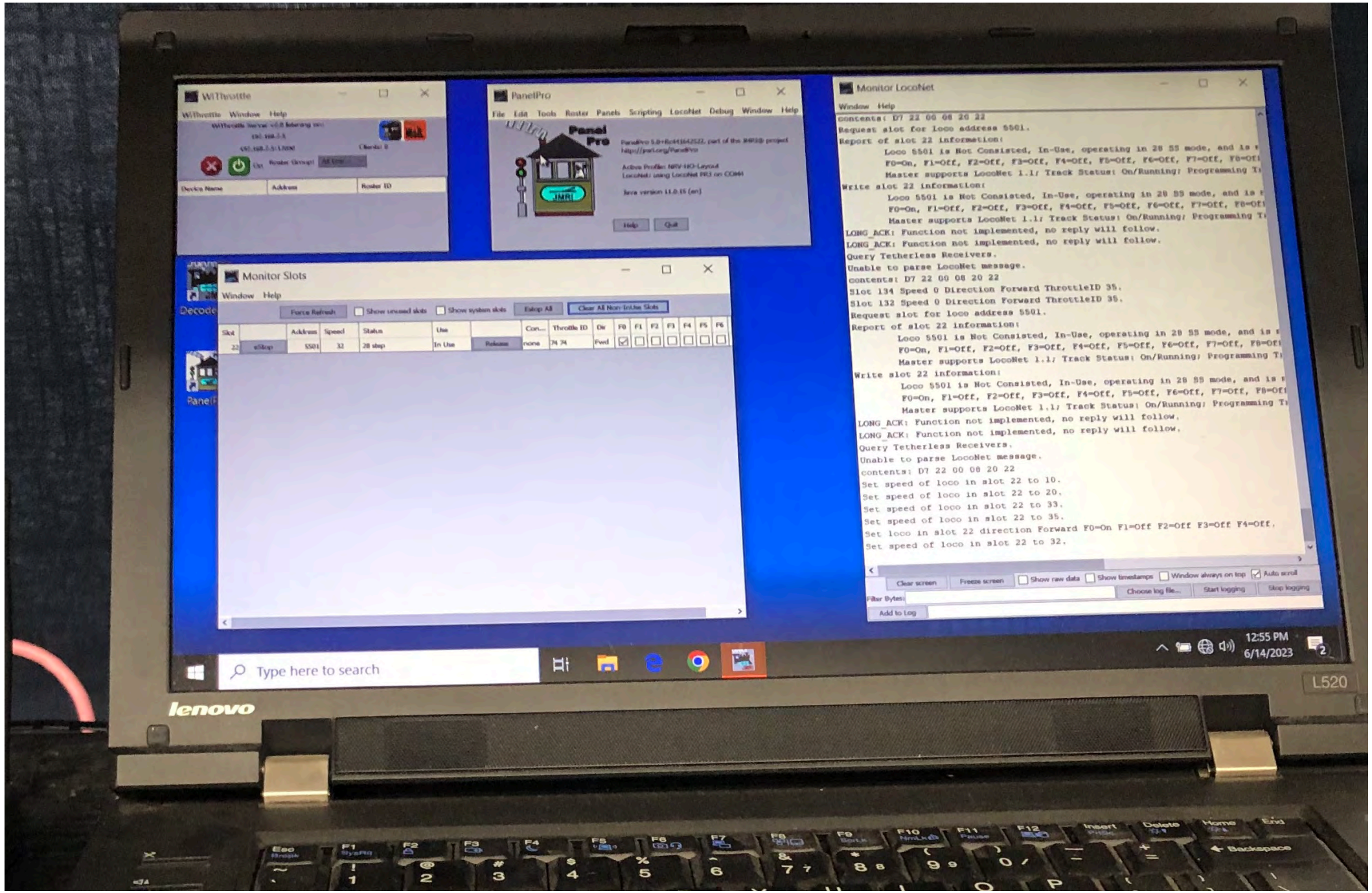
This is why sound and other low-priority messages may experience delays, especially on busy days or when Loco 0 is active

The Loco Slot Table

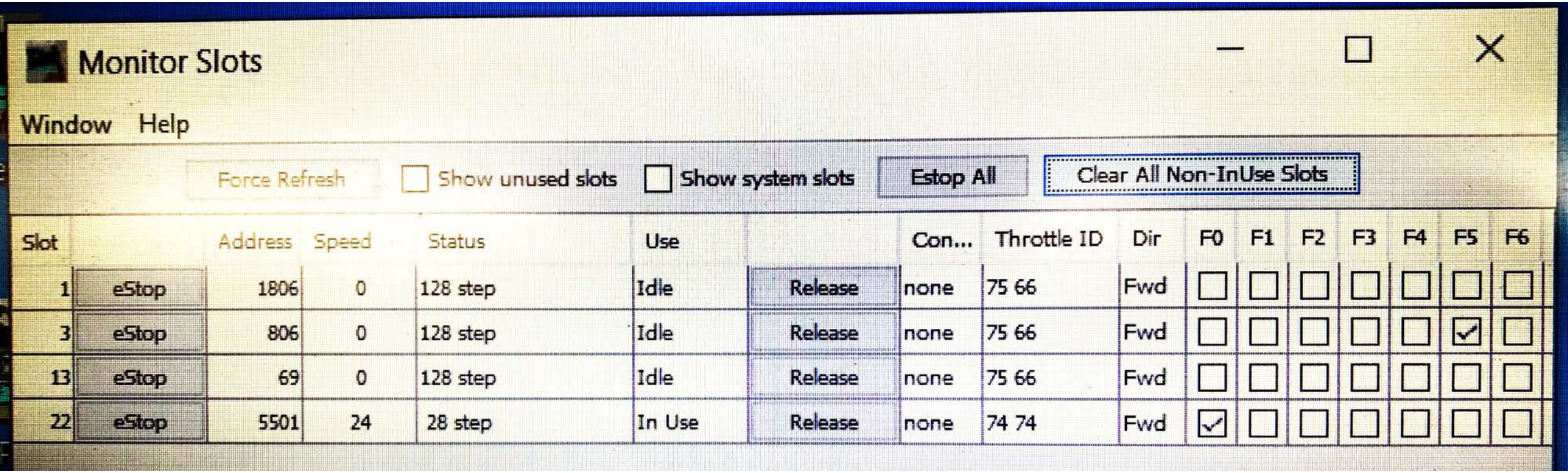
Assigning a locomotive to a throttle creates an entry in the Command Station's loco slot table

The loco slot table associates throttle ID's with locomotive decoder ID's or consist ID's so that throttle input can be sent to the correct decoder(s)

The table also remembers the most recent speed, direction, and function settings for each slot


WiThrottle
Window Help
Device Name
Address
Roster ID
PanelPro
File Edit Tools Roster Panels Scripting LocoNet Debug Window Help
Panel Pro
Help
Quit
Monitor Slots
Window Help
Force Refresh
Show unused slots
Show system slots
Estop All
Clear All Non-Estop Slots
Slot
Address
Speed
Status
Use
Con...
Throttle ID
Dir
F0
F1
F2
F3
F4
F5
F6
Monitor LocoNet
Window Help
contents: D7 22 00 08 20 22
Request slot for loco address 5501.
Report of slot 22 information:
Loco 5501 is Not Consisted, In-Use, operating in 28 SS mode, and is
F0=On, F1=Off, F2=Off, F3=Off, F4=Off, F5=Off, F6=Off, F7=Off, F8=Off
Master supports LocoNet 1.1; Track Status: On/Running; Programming T
Write slot 22 information:
Loco 5501 is Not Consisted, In-Use, operating in 28 SS mode, and is
F0=On, F1=Off, F2=Off, F3=Off, F4=Off, F5=Off, F6=Off, F7=Off, F8=Off
Master supports LocoNet 1.1; Track Status: On/Running; Programming T
LONG_ACK: Function not implemented, no reply will follow.
LONG_ACK: Function not implemented, no reply will follow.
Query Tetherless Receivers.
Unable to parse LocoNet message.
contents: D7 22 00 08 20 22
Slot 134 Speed 0 Direction Forward ThrottleID 35.
Slot 132 Speed 0 Direction Forward ThrottleID 35.
Request slot for loco address 5501.
Report of slot 22 information:
Loco 5501 is Not Consisted, In-Use, operating in 28 SS mode, and is
F0=On, F1=Off, F2=Off, F3=Off, F4=Off, F5=Off, F6=Off, F7=Off, F8=Off
Master supports LocoNet 1.1; Track Status: On/Running; Programming T
Write slot 22 information:
Loco 5501 is Not Consisted, In-Use, operating in 28 SS mode, and is
F0=On, F1=Off, F2=Off, F3=Off, F4=Off, F5=Off, F6=Off, F7=Off, F8=Off
Master supports LocoNet 1.1; Track Status: On/Running; Programming T
LONG_ACK: Function not implemented, no reply will follow.
LONG_ACK: Function not implemented, no reply will follow.
Query Tetherless Receivers.
Unable to parse LocoNet message.
contents: D7 22 00 08 20 22
Set speed of loco in slot 22 to 10.
Set speed of loco in slot 22 to 20.
Set speed of loco in slot 22 to 33.
Set speed of loco in slot 22 to 35.
Set loco in slot 22 direction Forward F0=On F1=Off F2=Off F3=Off F4=Off.
Set speed of loco in slot 22 to 32.
Clear screen
Freeze screen
Show raw data
Show timestamps
Window always on top
Auto scroll
Choose log file...
Start logging
Stop logging
Filter Bytes:
Add to Log
Type here to search
12:55 PM
6/14/2023
lenovo
L520

JRMI Loco Slot Table Monitor Window



Slot		Address	Speed	Status	Use		Con...	Throttle ID	Dir	F0	F1	F2	F3	F4	F5	F6
1	eStop	1806	0	128 step	Idle	Release	none	75 66	Fwd	☐	☐	☐	☐	☐	☐	☐
3	eStop	806	0	128 step	Idle	Release	none	75 66	Fwd	☐	☐	☐	☐	☐	☑	☐
13	eStop	69	0	128 step	Idle	Release	none	75 66	Fwd	☐	☐	☐	☐	☐	☐	☐
22	eStop	5501	24	28 step	In Use	Release	none	74 74	Fwd	☑	☐	☐	☐	☐	☐	☐

Loco Slot Management

Slots with non-zero speed remain active when you unplug a throttle with the assumption that you are walking to a new throttle station

Even with your throttle disconnected, the Command Station will periodically refresh your loco's last known speed and direction from data saved in the loco table

After a period of at least 200 seconds at zero speed with throttle disconnected your slot *may* be reused

Loco Slot Management (continued)

Consists are never automatically removed from the table. You must break up the consist and dispatch the locos yourself. Otherwise the loco table will fill up (it has 160 slots).

Slots are only properly and fully released when you disassociate a consist and dispatch all locomotives

Actual NRV Problems Resulting from Careless Slot Management

A loco had one throttle controlling its speed, and another controlling its direction

A stopped loco suddenly starting up with no throttle input

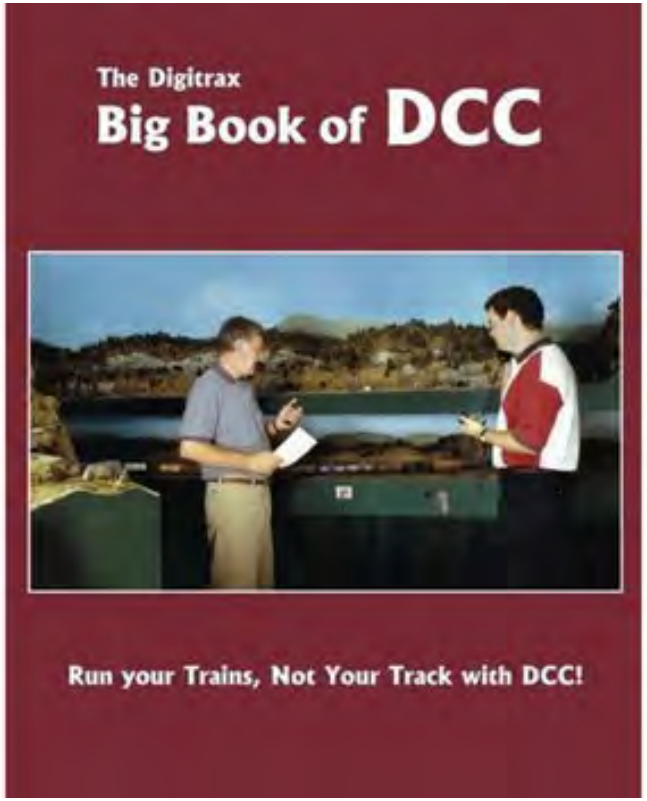
The loco table occasionally clogs to the point that no one can run

→ Please dispatch your consists and locomotives!

References

https://dccwiki.com

https://www.digitrax.com/

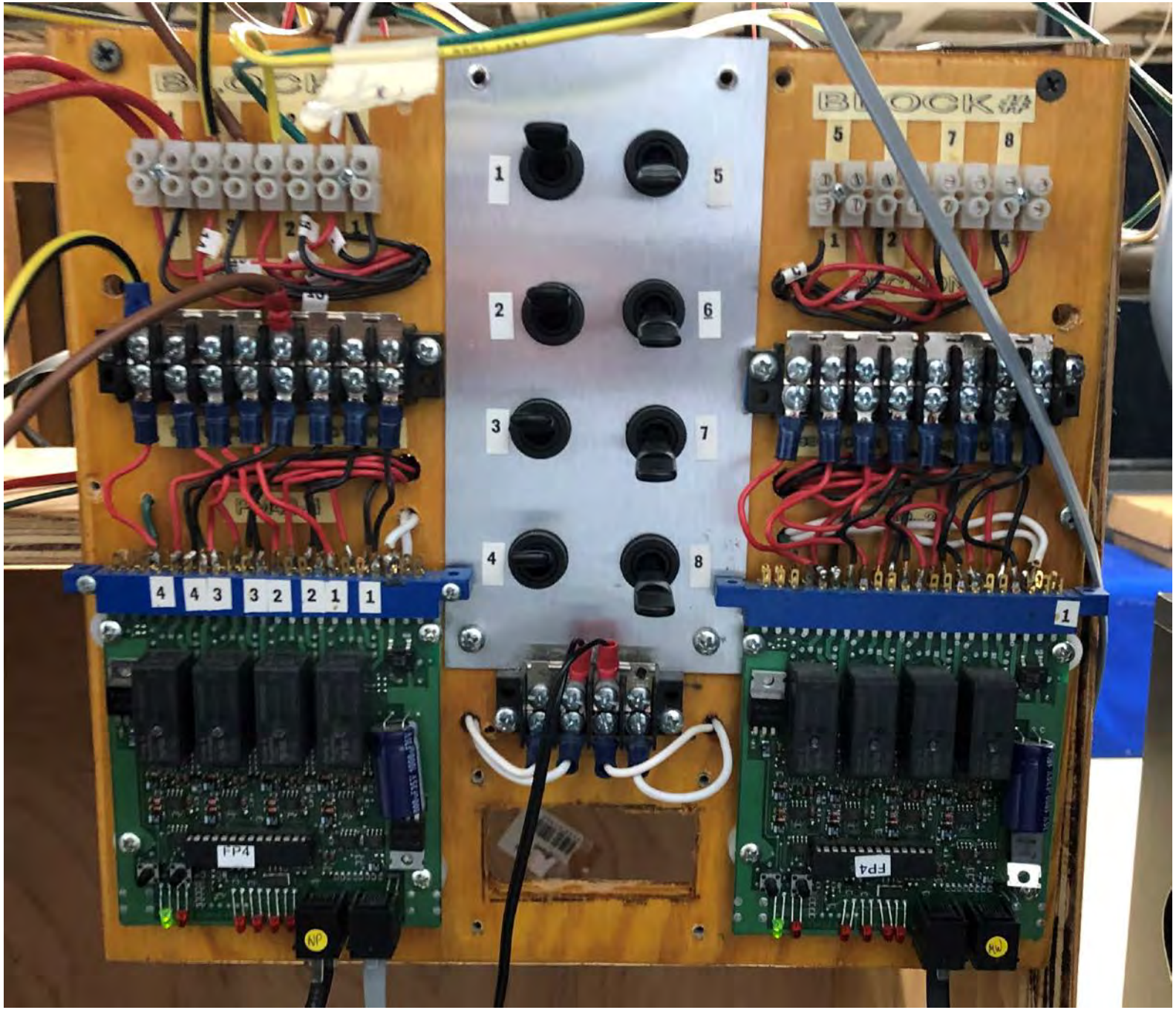


The Digitrax Big Book of DCC, in the NRV Library

Topics for Another Day

- Power Districts and Circuit Breakers
- Reversing and the Wye
- The Bus Rewiring Project and the New Extension
- Troubleshooting

- Java Model Railroad Interface (JMRI)
- Decoders (need a speaker for this one)


BLOCK
1
2
3
4
5
6
7
8
4 4 3 3 2 2 1 1
FP4
FP4