DCC Wiring – A Practical Guide Updated

April 2003 ver. 02

July 2004 ver. 03

October 2020 ver. 05

(057)

A Little Background

- *1993 NMRA DCC Standards Announcement*

Model Railroader October 1993

New standards proposed for command control

Highlights of the digital command control standard being considered by the National Model Railroad Association

BY STAN AMES AND RUTGER FRIBERG

What will a National Model Railroad Association digital command control standard do for you? It will make buying and installing multitrain control equipment as easy as buying and setting up a new television. Because of standards you don't have to worry about what kind of signal or voltage a television needs. The proposed NMRA command control standard can offer the same ease for purchasing and using command control equipment, and could make command control more affordable.

We want to introduce you to the proposed command control standard and show how it can make your model railroading more enjoyable.

Developing the standard

We're in the middle of a microprocessor technology revolution. Small, single-chip microcontrollers are being used on everything from toasters to automobiles because they're inexpensive and reliable. Microcontrollers often replace hundreds of components with one chip. They can also be "personalized" with custom software to control a variety of devices so the same microcontroller that runs a toaster can also be used to make a greeting card sing "Happy Birthday."

Using microcontrollers as the basis of a command control receiver lets a manufacturer develop products that can control a locomotive or accessory precisely the way the modeler wishes. Any changes needed to respond to market demands can be done with software instead of having to redesign all the hardware. The key to this is standardizing the information transmitted between the command station and the digital decoder (receiver).

A standard communications protocol that covers both the electrical characteristics (voltage and current) and the data formats (signals) will allow different manufacturers to build components with different capabilities in different price and performance ranges, yet these products will still be compatible with other firms' systems.

The first and most important part of the proposed NMRA standard covers the information transmitted through the rails. In creating a standard for communications through the rails, we don't care about the style, design, or implementation of the command station or receiver. Different manufacturers will likely offer different components using different kinds of hardware. Technology will change, and these components will be constantly evolving. What will stay constant is the method for communicating between devices.

To find the best communication method, the NMRA Command Control Working Group evaluated a large number of existing and proposed command control and computer control systems. We eventually settled on the transmission technique developed by Lenz Electronics of Germany. Lenz-based systems are used widely in Europe and they estimate that more than 150,000 receivers are currently in use.

Lenz-based systems offer many desirable features at the track communications level. Among these are the strength of the signal, the flexibility of the communications protocol, and the ability for the receiver to determine the type of power source, allowing a locomotive equipped with a command control receiver to be operated on both command control and conventional DC track power.

While the Lenz communication protocol is excellent, the NMRA Working Group desires to create the best system possible for the model railroad community. Therefore, we developed several improvements, including a significant extension of the instructions that can be sent to the locomotives and more flexibility in the signal shape.

Since the NMRA doesn't endorse or standardize proprietary products, one of our prime requirements was that any standard generated must not contain proprietary, patented, or copyrighted components. Lenz Electronics has agreed to the NMRA request to release all rights to this technology for sale outside Germany.

Technical details

Now that you know what the standard is supposed to do and where it's

Fig. 1 PACKET CONTROL SIGNAL

1 bit

0 bit

-5 to 20V*

*Amplitude of signal determined by scale to be powered

104 OCTOBER 1993

- *But 10 years later: NMRA Bulletin March 2003 p 37!*

> Most people just hear the word DCC and cringe—if they would only give it a chance they would probably be pleasantly suprised.

- *Early version of this clinic at NMRA PSX Convention 2004 - Available on 4D Website.*
- *2004 Clinic Theme: DCC Really is Less Complicated (than DC Cab Control Wiring)*
- *2020 AP Electrical still includes Cab Control and "Electronic Throttles" as legacy items.*
- *This clinic update assumes that at least a basic DCC understanding is now widespread.*

From: DCC Made Easy, Lionel Strang, Kalmbach 2003.

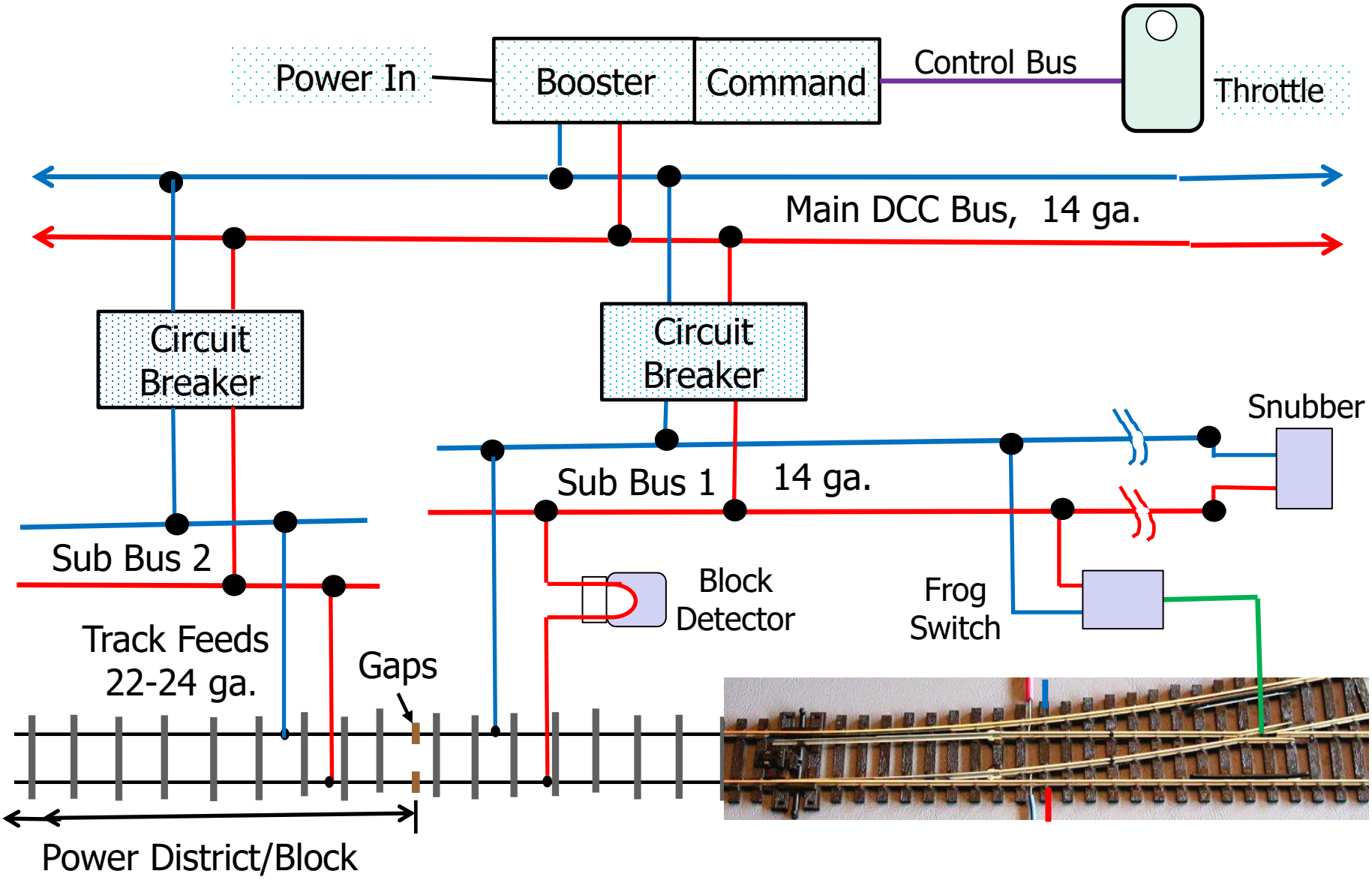
What This Clinic Will Cover

- Refresher on Requirements and Installation of DCC Wiring
  - Basic power and track wiring
  - Materials and tools.
  - Handling common track features.
- Points of confusion (and sometimes controversy)
- Some Recommendations.

What This Clinic Will NOT Cover:

- DCC Basic Theory
- Installing decoders.
- Programming Decoders – Use JMRI https://www.jmri.org/
- Competitive Equipment Comparisons
- Requests to wire your layout not accompanied by generous rewards.
- Fixing Problems if you already wired it or messed with it. (for any rewards no matter how generous).

DCC Wiring Structure - Medium Sized Layout



Minimal Needed Wiring

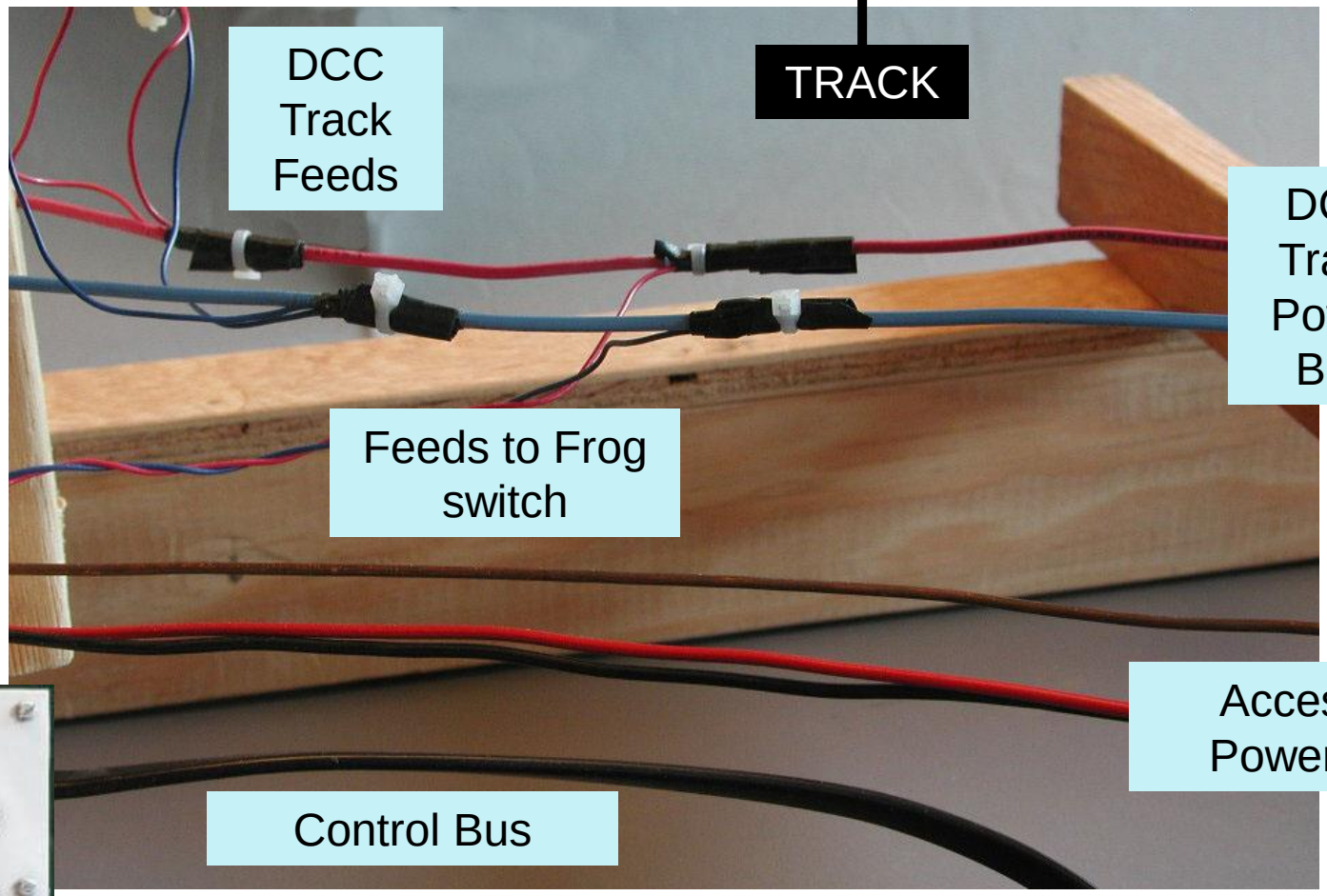
- Track Power Bus
  - Same regardless of Manufacturer (Thanks to NMRA Standards)
  - Power Blocking or Districts on all but the smallest layouts.
  - Automatic Reversing Switch for Return Loops /Turntables/Wyes
  - Programming Track (Separate from main!)
- Control Bus
  - Links multiple outlets for plug in cabs/radio transceivers
  - Synchronizing multiple boosters.
  - Varies depending on Manufacturer. CAT 3 commonly used.
- DCC Controlled or Powered Accessories - turnouts etc.
  - At least a circuit breaker isolated separate sub bus for these
  - Larger layouts – separate booster.
- Other Accessory Power (optional but recommended)
  - +/- 9 to 12 volts DC for (local control) turnouts, lights, signals

DCC Wiring Basics - Reminders

- With DC cab control the maximum current in a block ~1-2 Amps. Each wiring run needed to handle just one block current. 18 AWG was ample.
  - limited capacity of DC cabs prevented high currents in a short circuit. Usually recovered from transient problems. Often not noticed.
- With DCC all the current for all the trains comes from one source through the "bus" run. Booster capacity is typically 5 Amps. Wiring needs to handle this current level. 14 AWG is a minimum for (HO) track bus wire (except very small layouts/few locomotives)
  - An uncontrolled short has as much power as an old technology 60 watt bulb.
  - For protection the booster/circuit breakers must trip and shutdown very fast
    - This will stop everything in that power district - and reset sound.
    - But – it can also activate auto reversers, frog switching etc.
  - The overall electrical resistance must be low. A short must draw the trip current momentarily to make the protection work. (The famous "quarter test")
  - Really solid wiring connections are critical as well as adequate wire gauge.

Wiring Arrangement – Soldered Joints

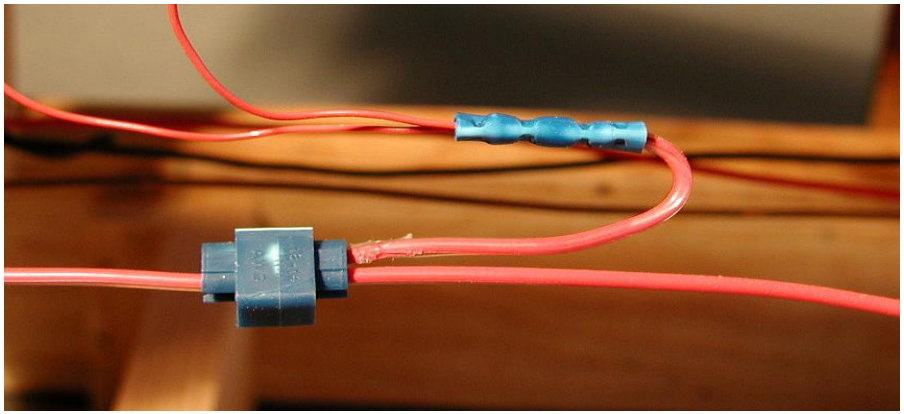
Solid and "gas tight"!



Tape the Joints! Secure the Tape! Finding stray connections later is very exasperating!

Wiring Arrangements – Solderless "One Time" Splices

- Solid and "gas tight"!



Do not fudge wire sizes on IDC (suitcase) splices! (Especially with stranded wire) Use a suitable tool ("gas pliers").

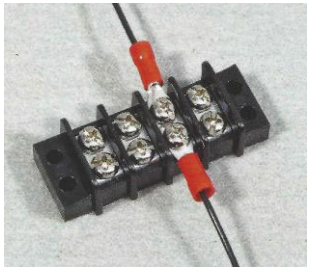
Wiring Arrangements – Other Connectors

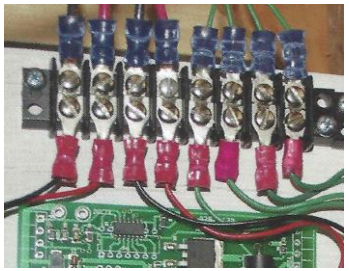
Solid and "gas tight"!

- Easy disconnect of sub buss feeds, track feeds etc. is important for layout changes and troubleshooting
- Soldering and IDC/suitcase connectors don't allow this.

Terminal blocks – very traditional

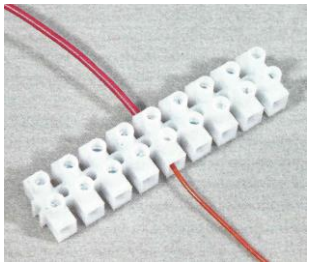
Use correct sized spade or ring crimp connectors on the wires.





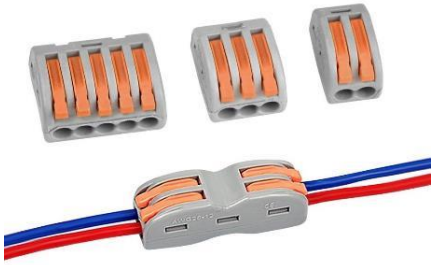
Screw blocks (aka "euro" connectors)

No wire preparation but use blocks with clamp tabs (on right)



Wago Connectors

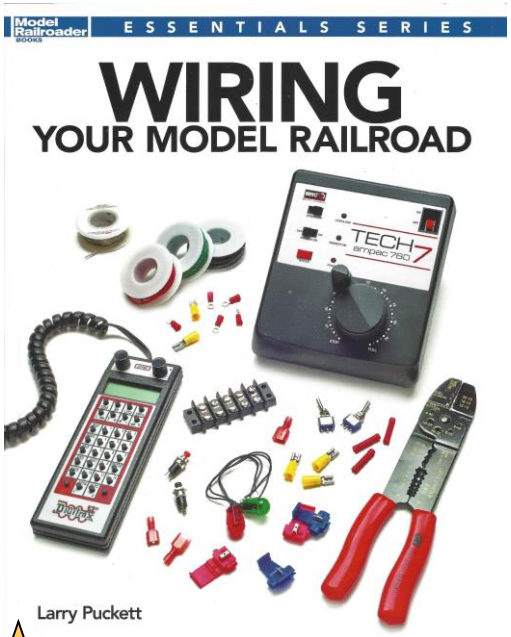
Lever action, no screws
Wide range of wire sizes
solid or stranded

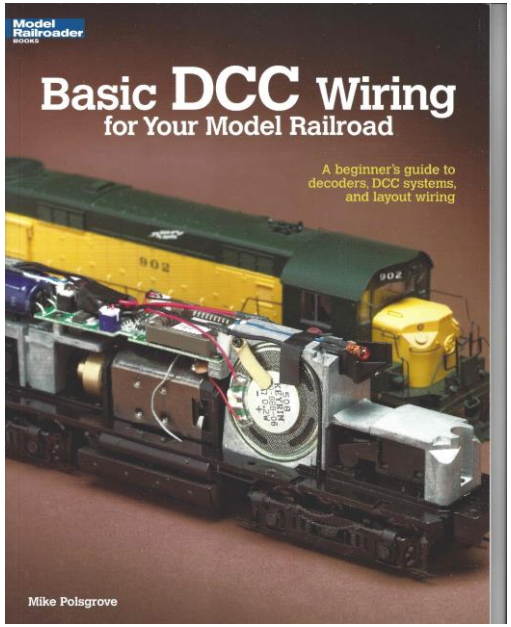


222-41x
28-12 ga.

For the Rest of the Details

- In the 2004 version of this clinic I had 12 more slides of fine detail on connectors, turnout wiring, DCC friendly (or other) arrangements, track gaps, reversing loops, programming tracks, soldering bus wires, etc.
- You can now get all this and more from books, magazines (including the NMRA Magazine - Mark Juett's series) and web sites.





Puckett: Kalmbach 2015 Polgrove: Kalmbach 2011

(Certain images from these books are used in this presentation)

- Wiring For DCC (since 1996)
  http://www.wiringfordcc.com/
  Website and chat group.
  All levels of understanding
- Mark Gurries (since 2011)
  https://sites.google.com/site/markgurries/home
  Mostly more advanced level
- Groups.io
  NCE and Digitrax chat groups
- FAQ's
  https://dccwiki.com/DCC_FAQ

Popular Questions and Confusions

- The chat groups and similar forums all have periodic outbreaks on a few choice topics.
- Mis-understandings, over-explanations and opinions are frequent and often expressed at length. Lots of anecdotes.
- There are several underlying causes for most of this.
  - Individual layouts are unique in construction, configuration, track arrangements and even more so in wiring and control.
  - Many current users are more into the "information layers" of DCC and layout control and less familiar with the underlying hardware.
  - There is still a significant number of people that remain "unconverted" and the technology barrier to entry gets higher every year.
- For the remainder of this Clinic I'll try to address some of the most common items.

Popular Topics – Bus Wiring

- Wire Size

  This was a bigger issue when many layouts were being converted from DC and had block by block "skinny" wiring in place.

- The basic needs are:

  a) less than about 5% voltage loss from booster to the most distant point on the track at the maximum operating current expected.

  b) be sure that if a short occurs the current flow will trip the booster or circuit breaker (or frog "juicer" or reversing loop switch)

  This is the more important requirement.

Wire Size	Resistance 60 feet*	Drop @ 2A (13v DCC)	Short circuit current **
12 gauge	0.10	0.2v / 1.5%	130 Amps
14 gauge	0.15	0.3v / 2.3%	87 Amps
16 gauge	0.24	0.5v /3.7%	54 Amps
22 gauge	0.05 (3ft)	0.1v / 0.7%	43 Amps***

* 30 ft out and back

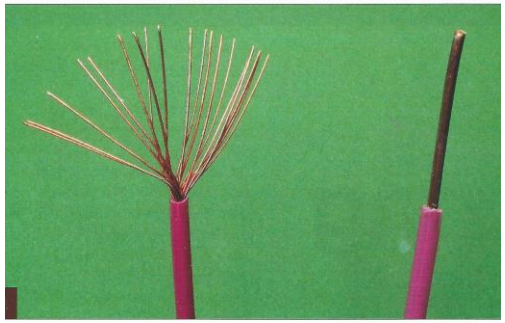
** Without cutout
Must be >> setting

*** 16 ga + 22 ga to rails

Popular Topics –Bus Wiring

- Wire Type

  This was a hot one for a while.
  - Solid wire?
  - Stranded wire?



e is either stranded (left) or solid. Stranded wire is more flexible than solid.

- Solid is readily available and less expensive, works with all types of connectors but is harder to string under the baseboard.
- Stranded is a little more expensive, better not used with "suitcase" connectors but is flexible.
- The confusion is over "skin effects".

  At higher frequencies (like DCC signal components) current tends to flow more in the outer part of a conductor thereby increasing the effective resistance. Stranded wire has (many) small conductors that individually are less affected - therefore its asserted that it will be better overall. However, combined in a stranded cable, this is true ONLY if they are also insulated from each other. (Litz wire aka audio "Monster cable")

- Don't fuss on this! Tight and solid connections are far more important.

Popular Topics –Bus Wiring

- <u>To Twist or Not to Twist.</u>

  A perennial topic.

- There is a solid basis for keeping the pair of wires forming a Main Bus or Sub Bus as close together as possible.

  - It reduces signal radiation from the bus that can affect the control bus, detection and signal arrangements – and AM radio reception.
  - It reduces the inductance of the bus which can help to maintain DCC signal integrity and reduce energy of voltage spikes from shorts.

- Tight twisting makes it a royal pain for attaching feeder wires to the track, circuit breakers and accessories.
- <u>A twist every foot or so is sufficient.</u>
  <u>- and keep other wires away.</u>
- Track in parallel makes a very non ideal configuration anyway.
- If you are making a longer run (10'+) with no taps make it a bit tighter.

This shows the track bus wires twisted in the foreground and separated from the cab bus cable toward the rear. To avoid electrical interference, don't route the track and cab bus wires through the same hole.

Popular Topics –Bus Wiring

- <u>To Terminate, Snub, High Frequency Filter etc.</u>

  A repeatedly controversial and little understood topic.

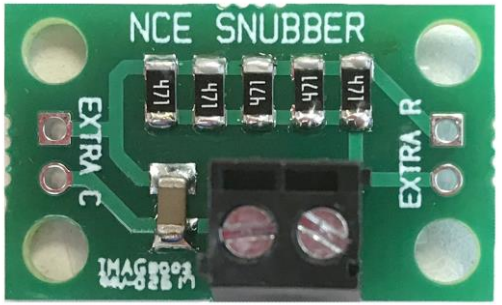
- Why add this little device at the end(s) of a bus run.?

  Imagine the steel balls are electrons carrying the DCC signal along a bus. The last ball at the far end flies off and comes crashing back sending a reversed message and interfering with new signals on the way. More balls, (longer path) it's worse. Now replace the end steel ball with a lead one. That's a "snubber".

- A electrical snubber acts to prevent electrical reflections that distort the DCC signal with voltage spikes and may result in loss of control.

- Why is this controversial.

  - Reflections are not usually an issue until the bus runs exceed about 30' Most users will never see symptoms.
  - NCE recommend use and sell snubbers in "two packs"
  - Digitrax claim their boosters control the bus signals so well that snubbers are never needed.



- <u>Snubbers work well and are recommended even for smaller layouts.</u>

See: NMRA "Scale Rails" Feb 2008, pp 17-20. Didrick Voss, (sidebar by MM) and Mark Gurries website.

Popular Topics – Track Voltage and Current

- <u>Why might you want to know?</u>

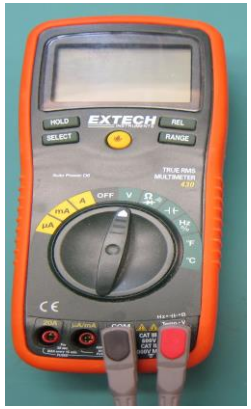
  - Locos slowing down/speeding up on different parts of the track.
  - Checking for dead spots in track
  - Matching DCC voltage levels of multiple boosters
  - Monitoring current load of locomotives on booster.

- <u>How accurately do these need to be measured.</u>

  - 99% of the time, not very –repeatable is more important than accurate

- The tool line-up:

RRampmeter
current & voltage
Cool Accessory!



True RMS meter
Good – but
over-rated

Harbor Freight
freebie
Quite useable

Harbor Freight
with DCC-DC
converter

Auto test lamp
Great for finding
dead spots.

Other Topics -Various

- Train Detection and Signaling
  - Split the power districts into smaller blocks fed via a current detector (Slide 6) Be careful of placement – "Juciers" etc. take current

- Live Frogs- Insulated Frogs
  - All-insulated frogs are something of a "train set" DC hangover
  - Live frogs do need to be switched to suit route.

- DCC Friendly - or otherwise (a "Wiring for DCC" site term)
  - Key Need: Turnout switch blades not electrically connected to each other..
  - If perfectly to gauge connected ones OK but a very transient short will trip a DCC breaker.
  - Old school turnouts (e.g. pre DCC Shinohara/Walthers) are not a good reuse for new DCC layouts.

- Reversing Loops, Wyes etc.
  - Thoroughly covered in the reference books.

A Rough Requirements Guide.

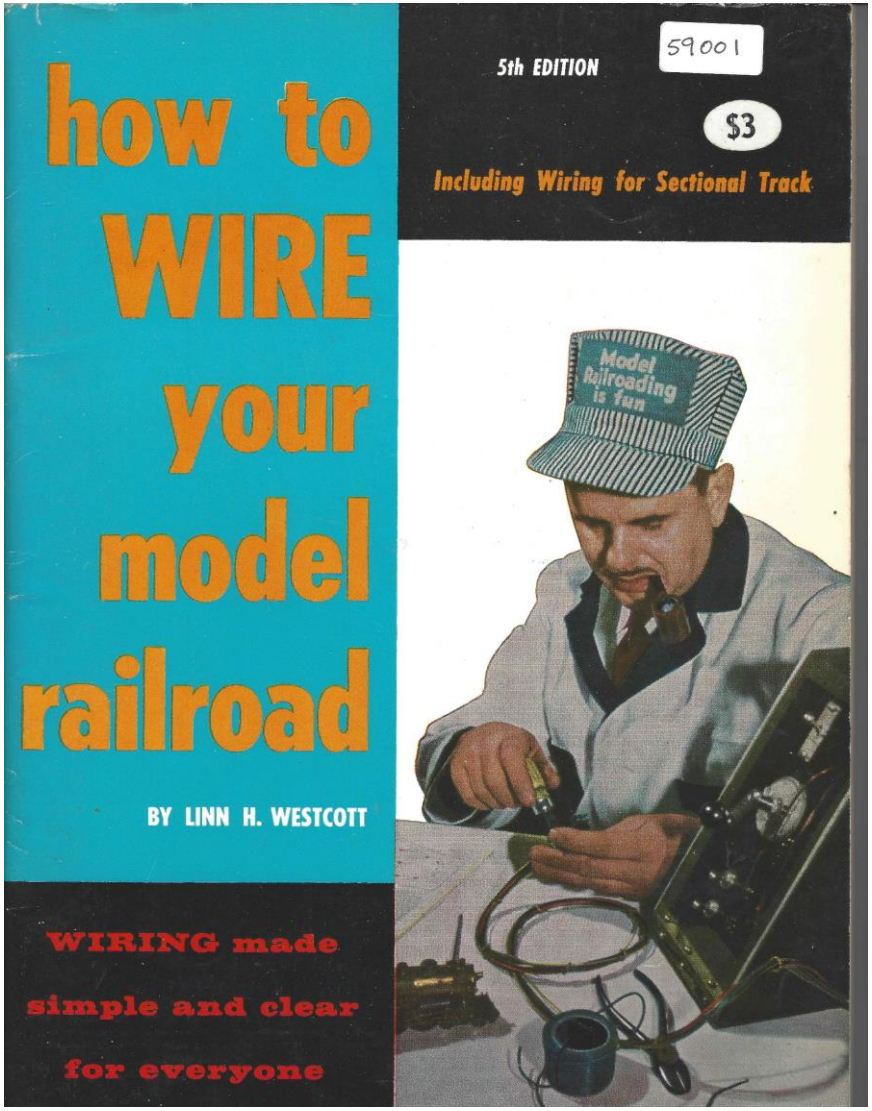
Layout Size (HO)	Area +/-	Maximum Bus Run*	Bus AWG	Number of Locos	Current Capacity	Boosters	Circuit Breakers	Snubbers
Small	<100 sq ft	< 30 ft	16	3-4	3-5 A	1	2	Desirable
Medium	100-250 sq ft	30 to 60 ft	14	5-10	5-8 A	1-2	4	Yes
Large	250-800 sq ft	60- 120 ft	12	10-25	16 A	3	6-8	Yes
Very large	>1000 sq ft	> 120 ft	10	> 30	24 A	>4	12+	Yes

- Area – typical estimate
- * Split into 2 bus runs for > 60 feet
- Number of active locos at any one time
- Current – locos with sound, accessories, turnouts etc.
- Boosters – add one more if many accessories

Summary (ex 2004 version)

- DCC wiring is different from DC blocks and cab control in consideration of wiring methods, but many of the same basic rules for electrical gaps etc. still apply.
- Higher currents = heavier power wiring, and overload protection must work.
- DCC wiring intolerant of sloppy workmanship and "make do" practices. Electrical joints must be soldered or properly crimped – gas tight
- Turnouts need certain attention for trouble free operation.
- Special devices drastically simplify reverse loops, wyes etc.

If in Doubt – the Originalist's Reference.



Linn H Wescott,
Kalmbach 1959.

First Published 1950

(Pipe no longer a required wiring accessory)