DCC Wiring for model railroads

using Digitrax components

because that's what I know

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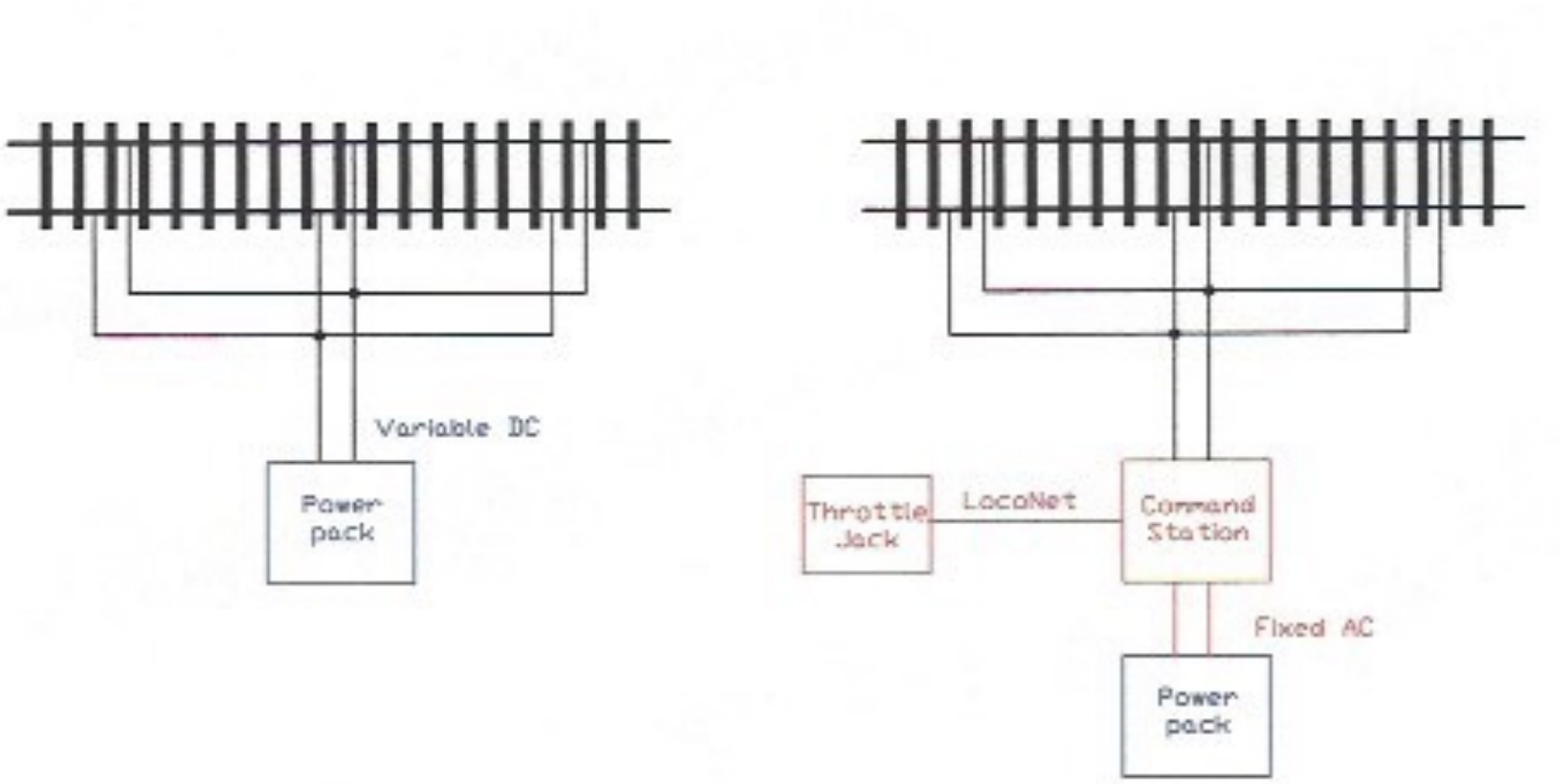
Converting A DC Layout to DCC



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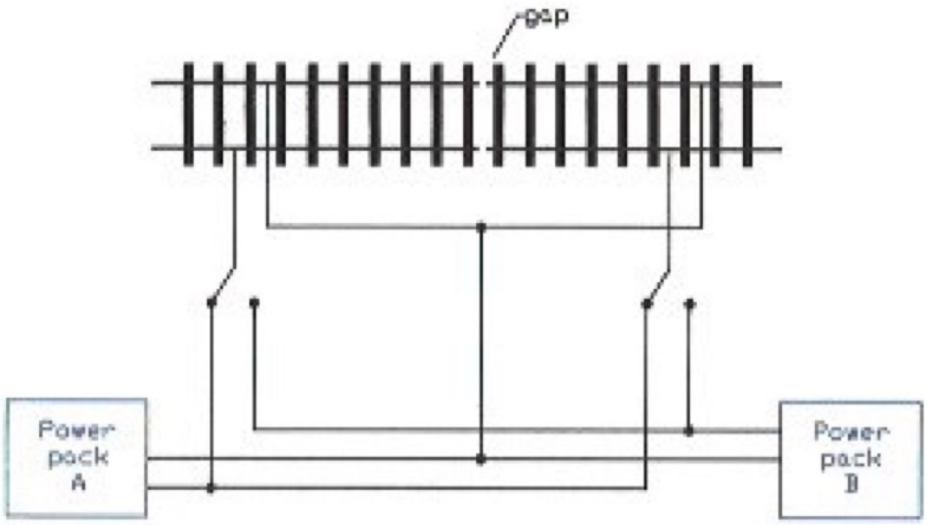

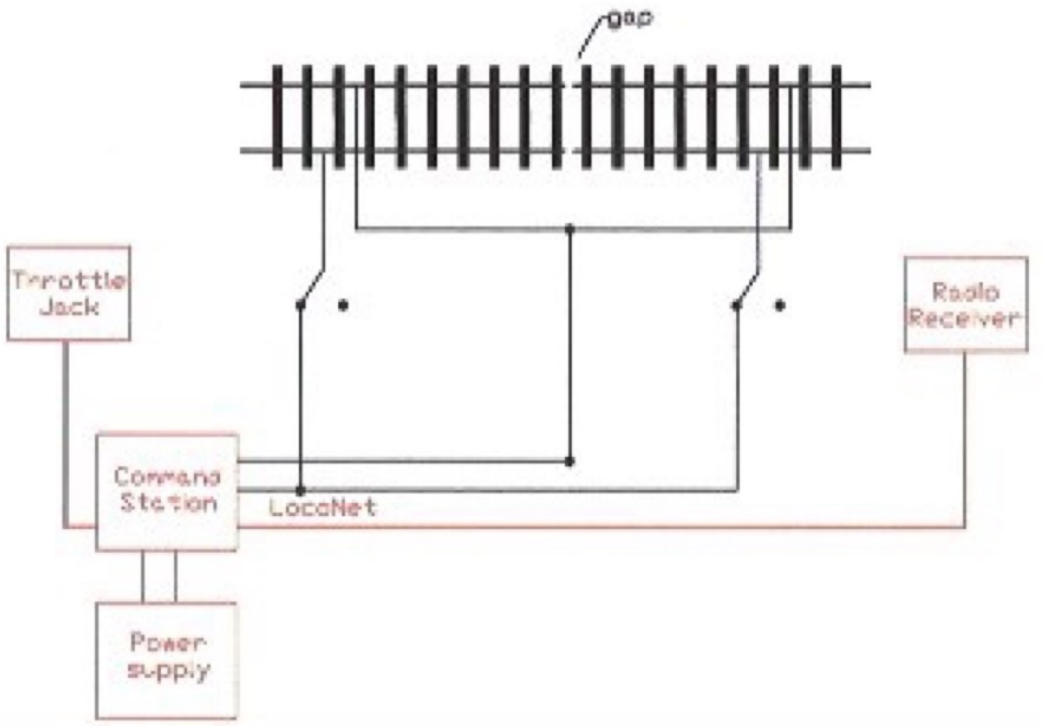

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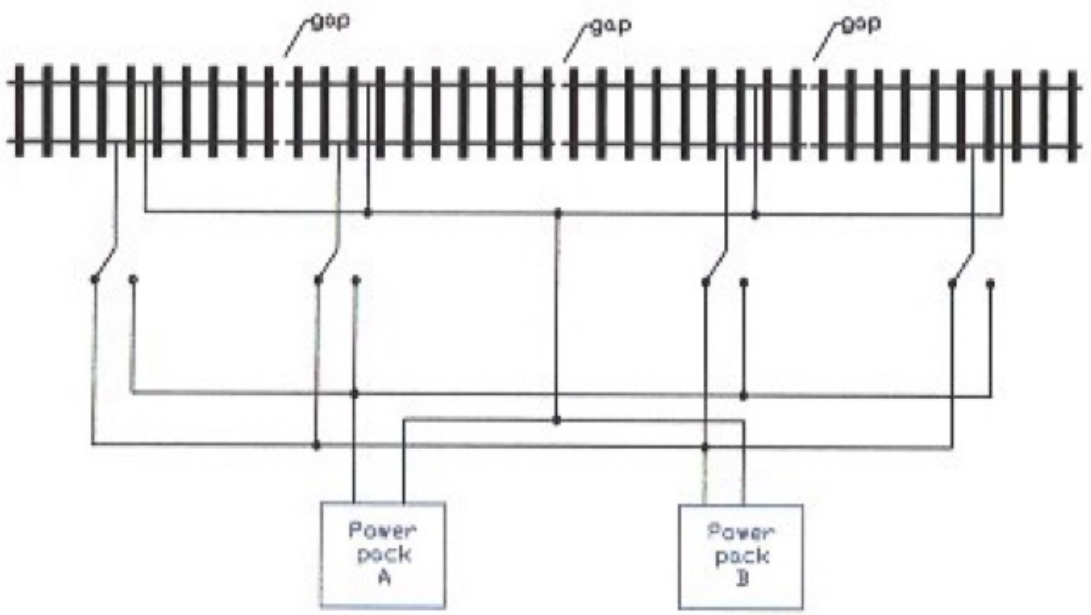
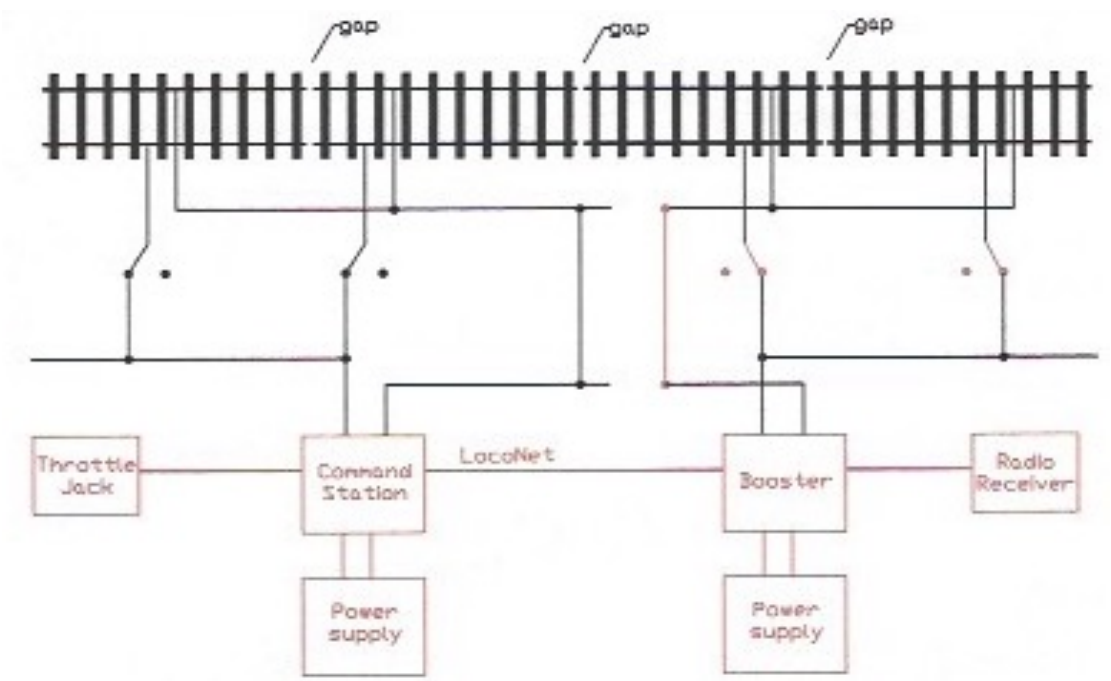
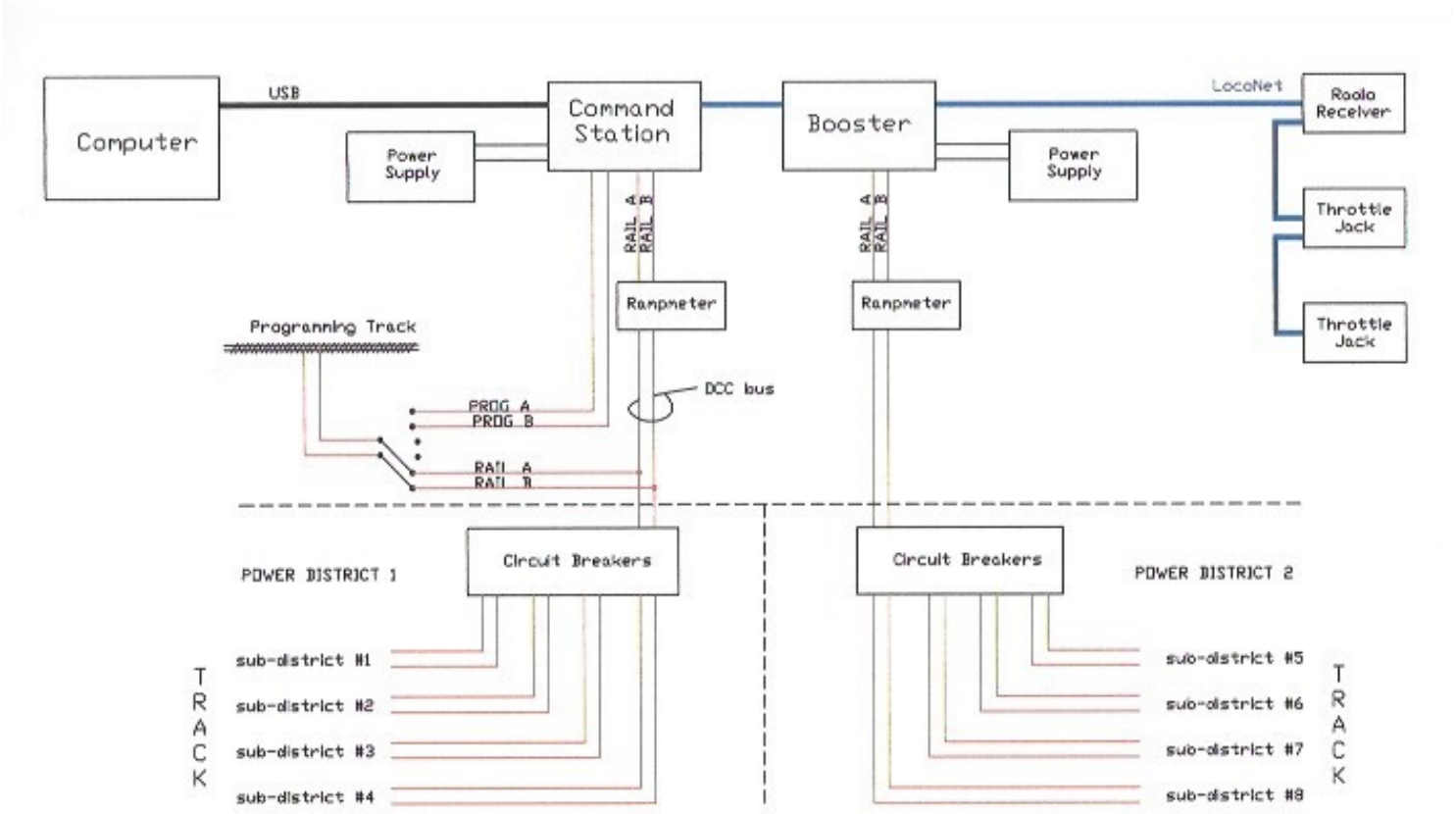


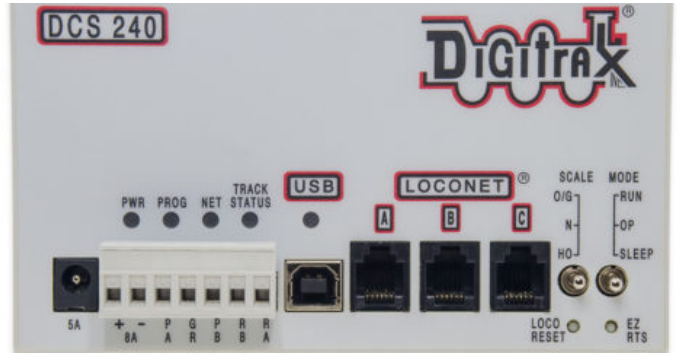


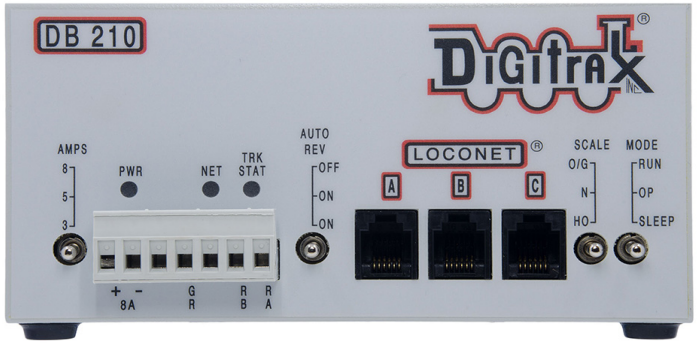
DCC Architecture



Command Station and Boosters

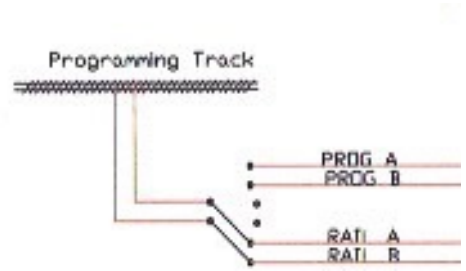
- Command station is the brains of the system
- Boosters amplify the command station DCC signal and send it to the track
- Older Digitrax DCS 200, DB150
  - 12 – 28 v (AC or DC) – use 15v as a minimum
  - 5A max
- Newer Digitrax DCS 240, DB210
  - 13 – 24vdc **(dc only)**, recommend power that is 3v more than your track voltage
  - 8A max
- Connections
  - Power In (from power supply)
  - RAIL A and RAIL B (to track)
  - PROG A and PROG B (to programming track)
  - LocoNet
  - Computer (via USB port or RR-CirKits Loco Buffer)
- Different track voltages available for N (12v), HO (15v) and O(20v)
- Use a fan to cool the heat sink on the back of the unit
- Connect ground between devices and to the house ground
  - Connect to the wall plate screw on any outlet

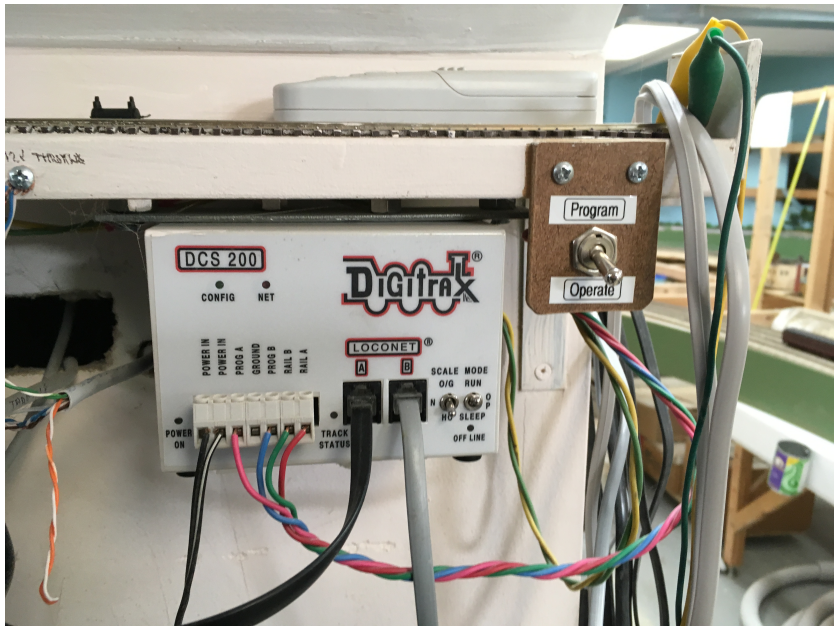




Programming Track

- Short section of track (3’) used to address and program engines
  - Recommend placing stand alone track above work area
  - Can be a siding or section of mainline on your layout
    - Must be double-gapped at both ends
- Install a **center-off** DPDT toggle switch to select either programming or operations
  - Programming mode used to address engines
    - Connect from PROG A and PROG B
    - No sound available while in programming mode
  - Operations mode used to program and test engines
    - Connect from RAIL A and RAIL B

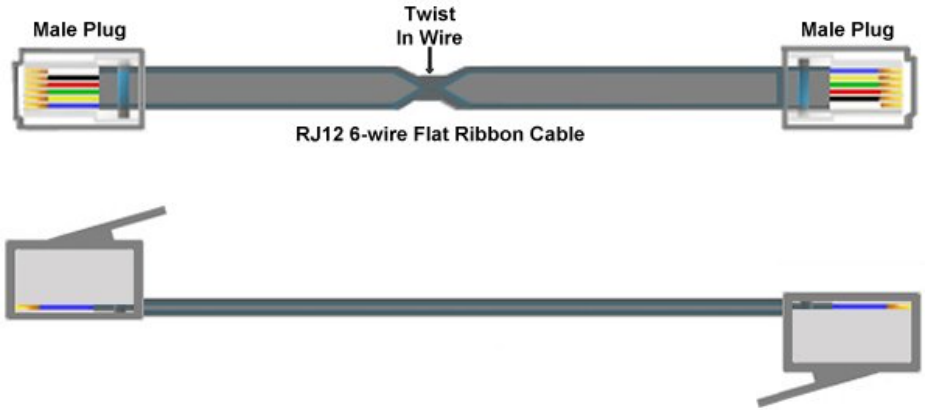




Command Bus (LocoNet)

- Used to communicate between DCC devices
  - Ground – 2 wires
  - Rail Sync (command station to boosters) – 2 wires
  - LocoNet (command station to throttles and accessories) – 2 wires
- Wire and Plugs
  - You can buy 6 conductor phone cable with connectors attached
  - Or, make or modify your own
    - Flat 6 conductor phone cable
    - or Cat 3/5 eight conductor cable (two wires unused)
    - Crimp on 6 pin modular phone type connector (RJ12)
    - Buy a 6pin/8pin crimping tool
  - Use LT1 tester to confirm wiring - **easy to get it wrong**
  - 9 beeps from booster indicates wrong wiring

With tab up, white is right



Command Bus (LocoNet)

- Jacks
  - Digitrax UP-5
    - 3 LocoNet jacks – one for branch
      - third one has limits (see manual)
    - Provides track status and connector for 12v throttle power

  - Wall plates for 6 wire phone jacks
    - Less expensive but must hook up the bus's 6 individual wires
    - Order from on-line electronic stores

Command Station, Booster Arrangement

- Don’t centrally locate the boosters with the command station
- Place boosters so that track (DCC) buses are short while running longer command buses (LocoNet) back to command station
- It’s better to have a longer command bus (LocoNet) and a shorter track power (DCC) bus
  - Track buses longer than 25’ begin to be effected by inductance which can destroy decoders
  - Longer track buses need bigger wire to avoid voltage drop
  - Might even make sense to not use the booster in the command station depending on its location

Power Supplies for Command Stations and Boosters

- Types
  - Train set power pack - use fixed 17VAC
  - Wall wart
  - 5A, 8A or 20A power supply
- Command stations and booster have current limits
- When selecting a power supply -
  - The scale of the train doesn’t really matter; it’s the amount of power you need

How Much Power?

Running loco's can draw anywhere between 20mA and 5A, sound adds more

- Assume 50mA for standing locomotives with sound
- Assume for running locomotives
  - N gauge 300mA
  - HO gauge 600mA
  - O gauge 2A
- Or, measure current using a Rampmeter

Current – Loco running at mod to full speed
-- Current – No Locos on track
Current drawn by Loco

Lighted passenger cars and cabooses

- Bulbs 50mA
- LED's 15mA

Other accessories using track power – find current requirement on specs or the internet

Add these up and multiply expected current draw by 1.2 (limit use of power supply to 80%)

How Much Power - Example

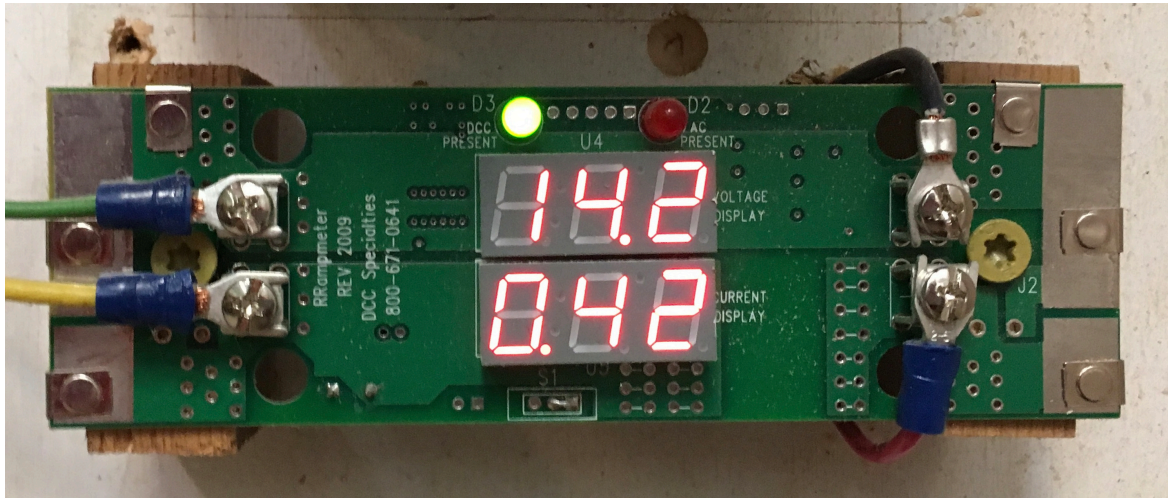
- Let's say you have 12 HO loco's
  - At most, 8 will be running at one time, 4 will be idling
- Your lighted passenger train has 6 cars with 2 bulbs in each

• 8 running loco's x 600mA =		4.8A
• 4 standing loco's x 50mA =		.2A
• 6 passenger cars x 2 bulbs x 50mA =		.6A
• Expected current draw =		5.6A
• Multiplier	x	1.2
• Power required =		6.7A

- You need a command station (5A) and another booster (5A)
- Or, one 8A command station

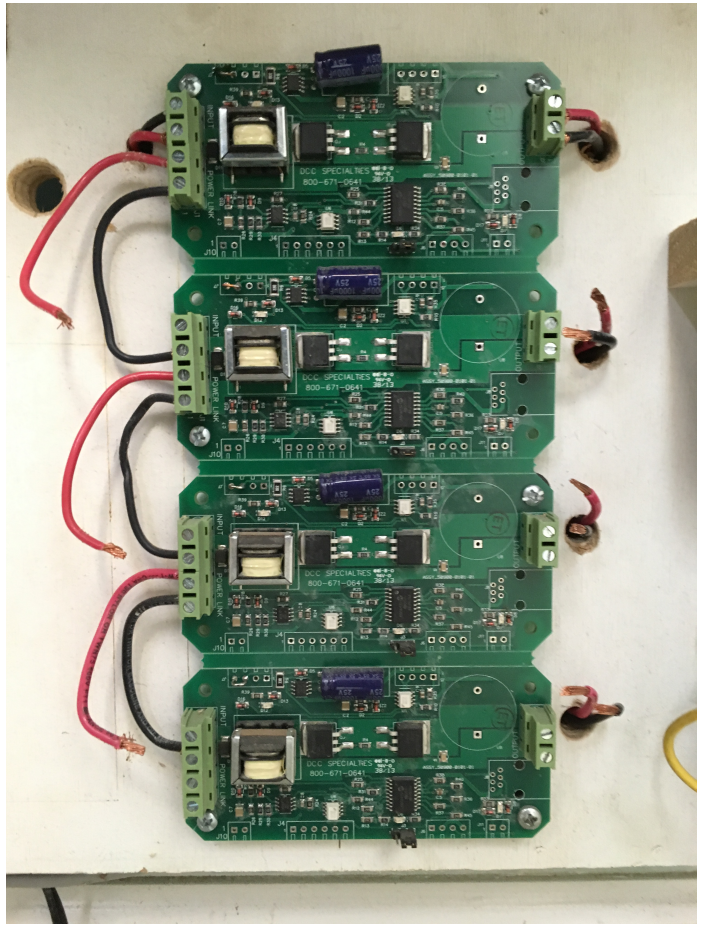
Rampmeter from Tony's Train Exchange

- Displays booster's voltage and current
  - 14.2 VAC and .42A shown here
- Connect to the output of each booster
  - Or, keep as a portable unit
- Helpful when troubleshooting
  - Can be set on track to check voltage when searching for dead spots
  - Can be used to determine current drawn by locos
  - Can be used to determine if track current is to high



Circuit Breakers

- Tony's Train Exchange Power Series
  - PSX1, PSX2, PSX4, PSX-AR
- Provides another way to detect/shut-off current to a short circuit
  - Automatically resets
- Accommodates the in rush of current on start-up of sound locomotives
  - Boosters may interpret in rush of current as a short and shut down
- Use to divide layout into power sub-districts
  - Limits effected area of short circuit
  - Reduces size of area to troubleshoot



Power Districts, Sub-districts and Blocks

- Power district
  - Isolated section of layout **controlled by one booster**
  - Based on booster capacity
  - Double gap track between districts
  - Examples: engine terminal isolated from layout proper
- Sub-district
  - Isolated sections of layout **controlled by one circuit breaker**
  - Based on troubleshooting strategy
    - Easier to find short circuits or other wiring problems (less real estate to search)
    - Avoid shutting down entire layout for one derailment
  - Double gap track between sub-districts
  - Examples: separate mainlines, branches and yards
    - Separate completed sections from sections under construction
- Block
  - Isolated track sections **for detection, signaling and engine management**
    - Blocks for occupancy detection
    - Signaling blocks - coincident with block occupancy sections
    - Track sections with power on/off switches for storing engines
  - Single gap track sections

Balance Voltage between Power Districts

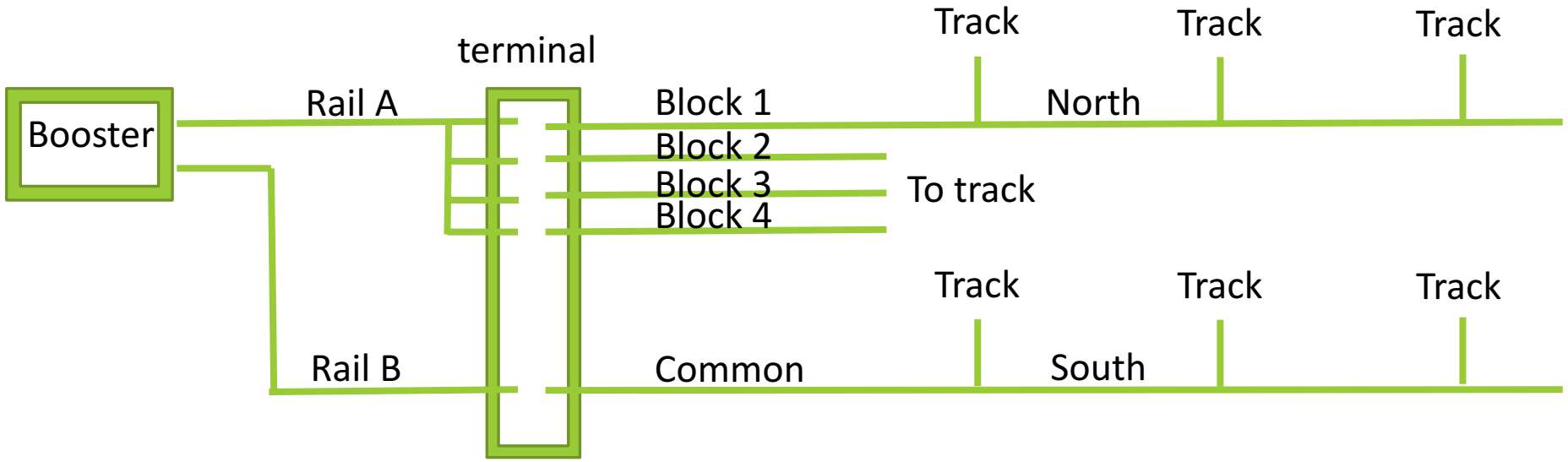
- Minimize voltage difference between power districts
  - Use voltmeter or Rampmeter to measure voltage from RAIL A to RAIL A and from RAIL B to RAIL B
  - I was able to reduce mine to about .2 volts
- Voltage differences cause unrestricted current flow when rail gaps are shorted
  - Especially problematic when metal wheel is parked on gap
  - I measured 4+ amps on my Rampmeter when this occurred on my layout
- See Digitrax manual for instructions
  - Easy to do
  - Two person job

Wiring the Layout – DESIGN IT

- Don’t underestimate its value
  - You won’t remember what you did after 6 months of working on something else
  - Absolutely mandatory if your friends will be working on your wiring
  - Needed for NMRA electrical AP certificate
- If done before you lay roadbed, you can drill holes and run wires while the bench work is open
- Can be hand drawn or created with design software
- Start with a drawing of your layout - make several copies
  - Show your DCC architecture and where the components are located
  - Show where your LocoNet goes on your layout and what devices are connected (in proper order)
  - Show your layout with power districts and sub-districts
  - Show your terminal blocks and what they are for
  - Show where your track buses run on the layout and their identifying marks or colors
  - Show your layout blocks
  - Show other wiring (i.e. 5v, 12v)

Track Power Wiring - the DCC bus

- Bus wires carry DCC signal from boosters to track - RAIL A and RAIL B
- Use terminal blocks to distribute wire (not soldered clumps of wire)
  - Or use: screws into bench work or wire nuts
  - Easier to separate when troubleshooting
- Track drops every 6 – 10 feet (22AWG solid wire)



Track power wiring – Do’s and Don'ts

- Ensure Rail A from each booster goes to the same track rail (i.e. – North)
  - Failure to do so causes the track in each district to be out-of-phase
- Gap both rails between power districts and sub-districts
  - Both track bus wires return to booster or circuit breaker
  - Don’t connect a common bus wire or have a common rail between boosters (common rail wiring)
- Gap one rail between blocks
  - Block bus wires return to terminal strip for connection to booster
  - Common rail between blocks is OK
  - Plan ahead for blocks even if you don’t use them initially – run a separate wire for each potential block
- Avoid inductance effects which can damage decoders
  - significant in track power wires run parallel to each other and longer than 25’
  - Run 2 conductor cables such as speaker wire or lamp cord (Parts Express SKRL-12-100 or SKRL-14-100)
  - Twist discrete wires (6 – 8 twists per foot)

Track Power Wiring – Do’s and Don'ts

- Don’t rely on rail joiners for electrical connectivity – connection deteriorates over time
  - Solder joints between every other 3’ track section
    - One track feeder for each “solid” 6’ section of rail
    - Leaving every other joint loose (unsoldered) allows for expansion and contraction of layout
  - Solder joints on curves
    - Soldering joints on curves avoids track kinks
    - Solder while track is straight before forming the curve
  - Avoid pressing down on rail joiner while soldering or a ”vertical kink” will form at the joint
- Don’t rely on turnout points to power rails
  - Solder feeders to these rails instead
- Use resistance soldering unit to solder rail joiners and track drops
  - Prolonged heat melts plastic ties

Voltage Drop – from Tony's tips: Digitrax DCC Hints and Tips, Simpson

Limit voltage drop to 1v total (1/2v out + 1/2v back)

- Loss of train speed
- Dimming of lights
- Booster can't detect short circuits

The quarter test - short the rails with a quarter

- Failure of DCC to shut down is caused by voltage drops
  - Too small wire
  - Not enough feeders – resistance in rail too high
  - Poor connections – rail joiners??

Better method: measure voltage drop with a Rampmeter under load

- Lamp attached to end of Rampmeter creates the load
  - #1156 equivalent to 2 amp load
  - #1141 equivalent to 1.5 amp load
  - #912 equivalent to 1 amp load
- Measure voltage right out of booster and at end of wire run then calculate the difference

Voltage drop versus wire length

At 1 Amp	10 ft.	20 ft.	30 ft.	40 ft.	50 ft.	60 ft.
12 gauge	0.01 v	0.03 v	0.05 v	0.06 v	0.08 v	0.10 v
14 gauge	0.02 v	0.05 v	0.07 v	0.09 v	0.11 v	0.14 v
16 gauge	0.04 v	0.08 v	0.12 v	0.16 v	0.20 v	0.24 v
18 gauge	0.06 v	0.13 v	0.19 v	0.26 v	0.32 v	0.38 v
20 gauge	0.10 v	0.20 v	0.30 v	0.41 v	0.51 v	0.61 v
22 gauge	0.15 v	0.32 v	0.48 v	0.65 v	0.81 v	0.97 v
At 5 Amp	**10 ft.**	**20 ft.**	**30 ft.**	**40 ft.**	**50 ft.**	**60 ft.**
12 gauge	0.08 v	0.16 v	0.24 v	0.32 v	0.40 v	0.48 v
14 gauge	0.11 v	0.22 v	0.34 v	0.45 v	0.56 v	0.66 v
16 gauge	0.20 v	0.40 v	0.60 v	0.80 v	1.0 v	1.2 v
18 gauge	0.32 v	0.64 v	0.96 v	1.3 v	1.6 v	1.9 v
20 gauge	0.50 v	1.0 v	1.5 v	2.0 v	2.5 v	3.0 v
22 gauge	0.81 v	1.6 v	2.4 v	3.2 v	4.0 v	4.8 v

More Do’s and Don'ts

- Use stranded wire
  - Won’t break when flexed
  - Easier to pull through bench work
- Exceptions:
  - Use solid wire between track power bus and rail (22 gauge)
    - Easier to solder to rail
  - Use sold wire for small circuit board connectors
- Keep it neat
  - Group and contain wires: use plumbing pipe holders or drill holes in bench work
  - Avoid wire ties (at least until you’re sure there are no more wiring problems or additions)
    - hard to troubleshoot
- Leave a little slack for possible adjustments, but not overly loose (keep it neat)
- Separate certain types of wiring
  - Separate command bus (LocoNet) and track bus (DCC) from 120v wiring – because of potential interference
  - Separate low voltage wiring (<50v) from 120v wiring– code requirement for safety reasons
    - Recommend using electrical conduit to house 120v wiring for its protection

More Do’s and Don'ts

- Use different colored wire for different voltages or uses
  - Don’t splice wires of two different colors together
  - Don’t use all one color for everything
  - Do have a different color for each voltage and its ground
- For Example, different voltages

DCC north rail	**12 v**	**5 v**
DCC south rail	12v ground	5 v ground

- For example, different uses

DCC north – main #1	**DCC north - main #2**	**DDC north – branch**
DCC south rail	DCC south rail	DCC south rail

- Label wires if colors are not enough
  - For example, block #1 on main #1, block #2 on main #1, etc.

Troubleshooting Tips

- Don’t make any mistakes to begin with!
  - Test as you go (Don’t wire the whole layout and then turn it on!!!)
- Construction
  - Divide the layout into power districts and/or sub-districts
  - Then divide districts into blocks
    - Allows the problem to be isolated
  - Think of everything as a component, including wires
    - Make every component removable (or dis-connectable)
    - Use terminal blocks or simple screws and wire nuts for connections
    - Avoid soldered connections between components
  - Use colored wire and labels to help when troubleshooting
  - Keep wiring neat and organized
  - Connect track leads **with the power on** so that a short is obvious immediately
  - Use insulated rail joiners or fill gaps in track with styrene
    - Won’t allow gaps to close when track expands

Troubleshooting Tips

- Shorts
  - They sing! Find the diva
  - What's the last thing (or things) you did - if it worked before, then it didn't break itself
  - Remove all engines
  - Check for cars on gaps
  - Have all gaps been cut that are suppose to be (hand-laid turnouts, sidings, PC board ties)
  - Has a gap closed due to track expansion
  - Did you connect north and south leads to the track backwards
  - Remove block leads one at a time to further isolate section of track with short
- Update your design drawings as you make changes or find things you didn't expect
- Keep a record of problems, symptoms and how you fixed them for future reference
  - Create a Layout Problem Report form and make copies for easy recording of problems
  - Group them by kind of problem (i.e. shorts, LocoNet, device malfunction, etc.)

The End

- Questions?
  - Thanks to Larry Maier and Tony's Train Exchange for their information

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