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This guide provides suggestions for the use of color coded wires to help document and clarify a model railroad's electrical installation. To our knowledge, there are no established standards, so this should be considered as a list of recommendations.

TERMS USED

Railroads typically have a "standard direction" of travel. On some railroads, or divisions of a railroad, trains are said to be "west bound" or "east bound"; on other railroads, trains are said to be "north bound" or "south bound". These four terms are often abbreviated "WB", "EB", "NB" and "SB".

These are conventions chosen by the railroad for its convenience. Some prototype railroads used EB/WB on some divisions and NB/SB on other divisions.

For EB/WB territory, the "north rail" is the right hand rail when facing forward in the cab and moving WB; the "south rail" is the left hand rail.

For NB/SB territory, the "east rail" is the right hand rail when facing forward in the cab and moving NB; the "west rail" is the left hand rail.

Since many model railroads are continuous loops of track, Linn Westcott suggested that we think of the NORTH POLE as being in the center of the loop. Then, when moving clockwise around the north pole, a train is moving WB and the right hand rail is the "north rail" (closest to the north pole). Obviously, the other rail is the "south rail".

For the rest of this guide, we will assume that the railroad uses WB/EB directions of travel, will have north and south rails. If you have an NB/SB railroad, simply make the obvious direction and word substitutions.

Layouts controlled by direct current were often wired using an electrical technique called "common rail" wiring. With this technique, one rail is picked as the "common rail", and all common rails were connected together. It doesn't matter whether the common rail is the north rail or south rail. You can make the choice on your layout by flipping a coin, consulting with a psychic, or whatever. What does matter is that the same rail must be common in all blocks. If the south rail is the common rail in one block, it must be the common rail in all of the other blocks as well. The other rail is often called the "power rail".

For reversing blocks in wyes or other reversing sections, the common and power rails electrically change sides depending on the direction setting of the block. This means that the choice for the common and power rails of the reversing block must always match the rails of the non-reversing block that the train is moving in to or out of. That's why there will always be an extra DPDT toggle switch somewhere in the layout wiring for DC or AC controlled layouts whenever there is a reversing section.

With DCC, automatic polarity control can be used. The extra "reversing switch" is still present, but it's often an electronic circuit within a booster or other device.

When a layout uses common rail wiring, the electrical point where all the common rails connect is called "layout common". This is often called a “ground” connection, but it doesn’t have to be connected to a buried water pipe or copper stake driven into the ground. It is simply a voltage reference level, thought of a zero volts. Other voltages within the layout are measured with reference to the layout common or ground.

All the block common rails are connected to that point, and one output of each cab is also connected to that point. The "point" is usually a relatively heavy "bus wire" that is routed everywhere beneath the layout. That way, it's close to every block and can easily be connected using a somewhat lighter gauge wire to the block's common rail. The reason the layout common is a heavy gauge wire is that it carries the current of all trains. Lighter gauge wire can be used for the power rails since it only carries the current for the one train that's in its block.

Trains are often detected by using an electronic circuit that monitors the electrical current going to a block. If there's no current, there's no train present, and the block is vacant. If there's any current, there is a train present, and the block is occupied. This is called “current detection”, and has the advantage that it can detect a train anywhere within a block. Other forms of detection, such as optical or magnetic, can only “see” the train when it’s physical at the detector. To “see” a train everywhere in a block, you need many such detectors, spaced closer together than the length of the shortest car or engine you operate. Optical or magnetic detectors are very handy to see if a train is at a specific location, such as at the end of a hidden siding or just before the fouling point of a hidden switch. We won’t be considering optical or magnetic detectors further in this guide.

Current detection circuits are wired between the layout common connection and each detected block's common rail. In such cases, the common rail for a block may also be called the "detection rail".

Note also that, for DCC controlled layouts, BOTH rails are really "common rails" in that one rail of each block is connected to the "RAIL A" output of the booster, and the other rail of each block is connected to the "RAIL B" output of the booster. For DCC layouts, the terms "layout common", "common rail" or "detection rail" don't change. You will still pick either the north rail or the south rail as the "common rail" or "detection rail", and can connect it to either the "RAIL A" or "RAIL B" booster output.

For DCC layouts with multiple boosters, two different wiring approaches can be used. The most common is to have the track territory powered by a booster totally isolated from all other booster territories. Within each booster territory, there is a “common rail” and a “power rail”, but these rails do not connect to corresponding rails in other booster territories. Boosters connected this way have a special common connection, independent of the rail connections that must be tied together.

The other approach is to connect one output of every booster together and create a layout wide “common rail”, just as is done with DC wired layouts. Boosters connected this way must have internal optical isolation from the control bus that connects them to the command station. The only permitted booster-to-booster connection is the common rail connections on the booster outputs.

TRACK WIRING - train detection not used	
Connection	Color
POWER RAIL	RED
COMMON RAIL	GREEN

TRACK WIRING - train detection used	
POWER RAIL	RED
LAYOUT COMMON	GREEN
COMMON RAIL	BLACK (connected directly to layout common)
DETECTION RAIL	BROWN (connected from detection rail to detector circuit)

SIGNAL WIRING

This covers wires between the signal controller circuit board and the physical signal itself. Any single signal head normally displays three aspects: clear (green), approach (yellow) and stop (red). Obviously, for position light signal heads that only use yellow lamps or LED's, you can associate each combination of lights with one of the 'normal' aspects. There are five basic types of signal heads used in north America: color light (CL), position light (PL), color position light (CPL), searchlight (SL), and semaphore.

Position light and color position light signal heads can sometimes display a fourth aspect for which the upper left, center and lower right lamps are lit. We will call this fourth aspect "lunar" for lack of a better term.

Whether these aspects are continuously on or flashing is not important for our purposes here. That's a function determined by the signal controller circuit.

Signal heads normally require very little current, especially when LED's are used. This makes it very convenient to use 4-conductor modular phone cord to make the connections between the signal head and control board. I'm refering to the "flat" modular cord, not the round phone cord. The flat cord is much easier to use.

For signal heads that display four aspects, I recommend 6-conductor modular phone cord. One of the six wires will be a spare.

All of the signal heads I've used have one "common" wire, and one additional wire per aspect. Depending on brand, the common connection will either connect to a positive voltage such as +5 or +12 volts DC, or will connect to the circuit common (ground). The aspect wires will connect to the opposite level. The choice here depends on brand of signal; the signal controller board must also be able to handle the signal head. Some signal controllers can only operate common ground heads; others can only handle positive common heads. The Signaling Solution Master Signal Controller (MSC) can handle either type.

The above relates specifically to color light, position light and color position light signals. Searchlight signal heads are different, and there are two different types of searchlight heads.

The first type of searchlight head is constructed using a LED with two electrical connections (pins). With this type of LED, there are, internally, two separate LED's, one RED and the other GREEN. They are wired in parallel, but opposite polarity. Current flows to the head through one wire, and returns to the controller board through the other. The color displayed depends on which wire carries current to the head (positive) and which returns current from the head (negative). The controller circuit does what is necessary electronically to control the direction of current. These two directions of current flow will cause the LED to display 'red' in one case, and 'green' in the other. To display 'yellow', the controller circuit will alternate rapidly between 'red' and 'green'. The human eye-brain combination will see this as 'yellow'.

This type of head requires only two wires. Because of the low cost, I still recommend using the flat modular phone cord, even though 2 wires will be spares. Or, if it's convenient, the second pair of wires could be used to operate another signal head.

The second type of searchlight head is constructed using three electrical connections (pins). With this type of LED, there are two separate LED's internally, with their cathodes (negative) connections tied together. Their anode (positive) connections are brought out to separate pins. Three wires are needed for this type of head. Once connects the cathodes to the circuit common (ground) of the controller board; the red and green pins each connect to separate positive going outputs on the controller board. The controller displays red or green by sending current out through the proper anode wire, and receiving the return current on the common (cathode) wire. To display yellow, the controller will generally turn on the green output continuously, and rapidly turn the red output on and off, with the percentage of on-time controlling the shade of yellow. Again, the human eye-brain will see this as 'yellow'.

For semaphore signals, a bit more is required. First, there is a motor drive mechanism, often a Tortoise™ switch machine wired to be able to select three physical positions. Second, there is a single bulb or LED the illuminates the selected roundel on the semaphore blade itself. Depending on which of the three positions the blade is in, either the red, yellow or green roundel will be positioned in front of the light. Thus, the color displayed and the position of the arm display the aspect in two different ways. The light was used to allow the signal to be seen at night; the arm position was easier to see during the day.

The Signaling Solution MSC can also control semaphore signals. Six conductor flat modular phone cord is used. Four wires control the Tortoise(tm) or other motor drive; two wires power the bulb or LED.

The following are the recommended colors for signal head wires.

COLOR LIGHT SIGNAL HEAD	
Aspect (connection)	Wire Color
COMMON	Black
RED LIGHT	Red
YELLOW LIGHT	Yellow
GREEN LIGHT	Green

POSITION LIGHT SIGNAL HEAD	
Aspect (connection)	Wire Color
COMMON	Black
HORIZONTAL (red)	Red
UPPER DIAGONAL (yellow)	Yellow
VERTICAL (green)	Green
LOWER DIAGONAL (lunar)	White (if four aspect head is used)

COLOR POSITION LIGHT SIGNAL HEAD	
Aspect (connection)	Wire Color
COMMON	Black
HORIZONTAL (red)	Red
UPPER DIAGONAL (yellow)	Yellow
VERTICAL (green)	Green
LOWER DIAGONAL (lunar)	White (if four aspect head is used)

SEARCHLIGH SIGNAL HEAD - 2-PIN LED	
Aspect (connection)	Wire Color
RED (1st head)	Red (positive for RED, negative for GREEN)
GREEN (1st head)	Green (positive for GREEN, negative for RED)
RED (2nd head)	Yellow (positive for RED, negative for GREEN)
GREEN (2nd head)	Black (positive for GREEN, negative for RED)
RED (3rd head)	White (positive for RED, negative for GREEN)
GREEN (3rd head)	Blue (positive for GREEN, negative for RED)

SEARCHLIGH SIGNAL HEAD - 3-PIN LED	
Aspect (connection)	Wire Color
COMMON	Black
RED (1st head)	Red (positive for RED)
GREEN (1st head)	Green (positive for GREEN)
RED (2nd head)	White (positive for RED)
GREEN (2nd head)	Blue (positive for GREEN)

SEMAPHORE SIGNAL HEAD (drive motor & bulb or LED)	
Aspect (connection)	Wire Color
Bulb or LED anode	White
Bulb or LED cathode	Blue
Remaining wires (red, green, yellow, black) are used to control the motor to have 3 positions for the arm. Various circuits are recommended by motor drive vendors. With multiple head semaphore signals, very low voltage (1.5v) bulbs may be series connected, while high voltage bulbs (12v) should be parallel connected. Because LED's are low voltage (~2.3v) devices, they should probably be series connected.	

SIGNAL CONTROL WIRING

Signal control wiring is used to connect the train detection circuit board outputs to the signal control board inputs. In most cases, the detection boards will have a 'common connection' that is tied to the layout common, and is also tied to the signal control board common connections. This common connection can share the layout common wire, typically a heavy GREEN wire.

The detector board 'occupied' outputs connect to appropriate signal controller board inputs. I recommend using ORANGE wires for this purpose. Since 'occupied' is normally thought of as 'red', and red wires go from the control board to the signals, orange seems to be a good choice, indicative of the 'red' block status condition that it carries.

Signal controller boards also often have inputs from turnout contacts so the controller can change signal aspects based on turnout positions. At least for the Signaling Solution MSC, a contact on the turnout operating mechanism is electrically 'open' when the turnout is in the 'safe' position, which usually means aligned for the main line. The contact closes when the turnout is in the 'unsafe' position, which typically means aligned for a siding or diverging route. The closed contact connects an MSC input to the layout common wire.

I recommend a light gauge black wire from the layout common to one of the switch connections, and a grey wire from the other switch contact to the appropriate MSC input. Since the current carried by these wires is less than a milliamp, very small wires, such as 26 or 28 gauge, are perfectly ok.

OTHER WIRING

This can be a very broad topic, since there is virtually no limit to the possibilities. Attempting to list them here is impossible. Let me simply suggest that, where possible, colors other than the ones above be chosen.

Also, you can often take advantage of multi-conductor cable of various types. We discussed using flat modular phone cord for connections between signal controller boards and signal heads. I've purchased this wire with both grey and white sheath colors. If the current demands for the particular situation allow, you might want to use grey sheath modular cord for the signal head connections, and white sheath modular cord for groups of other low current connections.

Major electrical distributors such as Allied Electronics or Newark Electronics, as well as many others, often stock or can special order other forms of multi-conductor cable. A wide variety of wire gauges and wire counts per cable are available. Typically, there is a round outer sheath, and a number of individual wires, or a number of wires twisted into pairs contained within the sheath.

If your application has a lot of wires used as pairs, such as loudspeaker wires or turnout motor wires, the paired cable is suggested; if your application just needs a lot of wires connected between two locations, the individual wire form is suggested. While such cables may appear to be costly, they are actually only a little more expensive than the same number of wires run individually. They really pay off in that your layout wiring will be neater and much better organized that with huge numbers of individual wires.

OTHER TIPS

For those of us who have not had career experience teach us how to do things right, this will mean that we must learn some new skills and techniques. Getting started may not seem to be that enjoyable or interesting, and we may have to “bite down on a stick” while reading material on good wiring practices, but we will be rewarded by years of reliable operation with minimum amounts of time spent doing trouble-shooting and making repairs. Each operating session that comes off without an electrical hitch will be our reward for paying proper attention to the electrical details.

Color coding our wires is a step that helps us do the work correctly. When you're doing the installation, an error is immediately obvious if you see a red wire connected to a place that should only get an orange wire. True, you may have connected the wrong orange wire, but at least some of the possible problems are easy to see.

Later, when trouble-shooting a problem that just came up, you may know which wires to start checking simply by checking the color. For example, if a signal was working, but the yellow LED no longer lights, you know that you begin by checking the yellow wire from the signal controller board to the signal. That may not be the problem, but it's the first place to look.

We recommend that you keep a log book for your electrical system. Document every circuit or device you install, perhaps even include a sketch showing how the wires are routed beneath the benchwork. Label the figure in the log book, and put the same label at each end of a cable or wire. Record the wire gauge and colors used. This way, you can easily find the log book figure that has the complete picture of the circuitry you're testing, and identify precisely which wire is which.

Use strain relief devices to make sure that a tug on a wire doesn't destroy something fragile. The wires that run up a signal mast, especially for N-scale signals, are very small. The most gentile tug on a wire will pull them out or break them. For LED based signals, we recommend you use our signal mounting adapters. They are low-cost kits that include all the resistors and diodes you will need to connect the signal, and come with circuit boards to hold all the parts and provide the necessary strain relief. Best of all, the signal mounting adapter and signal can be assembled as a unit at your workbench. There, you have plenty of light, clamps to hold everything in position while you work, and no hot solder dropping on your face!

Solder lug terminal strips with various numbers of connections are manufactured by Keystone at very low cost, and are available through many electronic distributors. I use these wherever two wires join. For example, I make connections to the track by dropping a short, say 6 inch, length of bare, tinned copper wire, called "bus bar", through a small hole drilled right next to a rail. One end is soldered to the rail, and the other is connected to a lug on terminal strip right below. The feed wire, to the booster, block detector, cab select switch or layout common bus is soldered to the same lug and is then run to wherever it goes. A label in installed at the terminal strip, marked with the block identity (e.g., block 123) and rail identity (CR, DR, PR or whatever).

These same terminal strips can be used to join building light wires to the relatively heavy lighting power bus that runs from the power supply to each building. They make good strain reliefs, and provide a convenient place to connect a voltmeter to see check for voltage. And, with the wires securely soldered to lugs, you won't have to worry about bare wires being pushed around and shorting out.

The NMRA has published a data sheet that describes good soldering practices. If this is not your favorite thing, read the data sheet and practice with terminal strips attached to a piece of scrap wood. Get a little instruction from a friend who's not electrically challenged.

SUMMARY

The long-term, reliable operation of our layouts is very important to us. The more time we MUST spend making repairs, the less time we have to operate the layout or create new models. If the maintenance time gets too large, the layout ceases to be fun, and we will either have to replace the layout or abandon the hobby.

Neither choice is welcome. For these reasons, I strongly recommend that modelers make every effort to do their electrical work RIGHT the first time, even if they have to spend what seems to be extra money to do so. Long term, the benefits cannot be overestimated. We can always buy our next engine next month or next year; this year, let's spend the money to make our electrical system bullet-proof.

The most important thing to remember is that the electrical success or failure of your layout is your responsibility. Learning how to do this phase of the hobby well is just as important to good operations as is a smooth running mechanism and good trackwork.

Enjoy.