DATA SHEET

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Sheet #:	**D7l**
Title:	**WIRING**
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INTRODUCTION

This group of pages deals with wire size, type and color, and factors relating to their selection; and planning and installation of wiring. Review of Data Sheet D7p, "Common Return Systems"**,** is important to the complete understanding of this material.

WIRING DIAGRAMS

These are graphic representations of electrical circuits, using lines to represent wires and cables, and conventional signs and symbols to represent such components as relays, lamps, LED's, motors, switches, etc. The best construction or wiring installation is done from good clear diagrams. Diagrams usually come with a switch machine or other pieces of equipment to give the model railroader some ideas as how to use the device. **ALL** wiring diagrams should be kept in a 3 ring binder and updated when any changes are made. Without this the model railroader faces a nightmare when trying to maintenance or trouble shoot the wiring.

A very important part of wiring is to keep good records. When the model railroader uses terminal strips on the layout, it's important to keep a log book for each terminal on the terminal strip. This log should state the terminal number and destination of the wire that is hooked to that terminal.

For uniformity and clarity the symbols in NMRA Recommended Practice RP 41 should be used. If a symbol for a particular element is not included in this practice, it should be added to the wiring diagram with an explanation on the diagram. Wiring diagrams can be simplified using various suggestions from various data sheets. Repetitive circuits offer another means of simplifying wiring diagrams. For example, if all the switch machines on a layout are wired the same, one diagram with an explanation is all that is necessary. Block wiring can be treated in the same manner. Wiring diagrams should show each circuit in detail at least once. Color coding of wire is another important aspect in the completion of the wiring diagram. If different size wire is used it should be stated on the diagram as well.

Drawings may be prepared on 8½"x11" sheets. They fit nicely in a 3 ring binder. Diagrams can be placed in clear acetate page protectors. Any investment made in the wiring diagram log or roster, is repaid in very short order.

WIRING DESIGNATIONS

It is important to use wire designation numbers in wiring documentation. Each individual or club tends to develop a system; many are used and they can be quite complicated. There must be a definition sheet in the book to let a person know what system is being used. The preferred principle to use is the "KISS " principle. This means "keep it simple, stupid." Numbers are usually assigned in blocks. 1 to 99 could be used for mainline blocks or feeder wires. 100 to 199 could be used for switch machines. Others could be assigned for other functions such as freight yards, passenger terminals, engine and service facilities, branch lines, etc.

Model railroads usually choose arbitrarily the beginning and end and the "compass direction" of the railroad. East to west is most chosen. For instance East blocks would be low numbers and West blocks would be large numbers. A,B,C, can also be used.

WIRING DESIGNATIONS - continued

All conductors can be numbered or identified in some manner. Numbering systems are available at the local discount house in the electrical department. Switch machines could be designated as SM, signals designed as SS, track feeders as TF, etc. There are other items available to make the wiring diagram simple. Check at the local discount house or electronics store.

COLOR

Coding of wires by color of insulation can speed circuit tracing and maintenance. The code must be planned in advance to be orderly and understandable. Color codes are usually so arranged that no two conductors of the same color are connected to the same circuit component.

Electrical suppliers' open stock is usually limited to ten solid colors: Black, brown, red, orange, yellow, green, blue, violet, gray and white. With striped insulation, often available on special order, as many as thirty options may be available. Most wiring is done with the solid colors. White wire should be reserved for the common return system, although this conductor is frequently a bare one for easy tapping.

In planning the color code, one should consider two - conductor lamp cord (zip cord) as discussed later in this data sheet. The cost of this wire outweighs the disadvantages of connecting two conductors of like color to the same component. Using a meter or buzzer to ring out the wire eliminates this problem. This cord is available in different colors.

WIRE SIZE AND VOLTAGE DROP

Wire diameter (and cross-sectional area) increases as gage number decreases; see sheet D1c. Resistance decreases with the decrease in gage number. With every change of three integers in gage number, resistance halves or doubles. Resistance of #18 wire would be twice that of #14, but only half that of #20. No. 10 wire, used bare for common return conductors on some O scale layouts, has a resistance of 1.0 ohms per thousand feet.

Distances on most model railroads are short and conductors rarely exceed 25 feet in length. Table 1 is based on 25-foot lengths. As current flows through a conductor, a certain amount of pressure is lost, a condition called ***voltage drop.*** Voltage drop is the product of resistance and current (ohms multiplied by amperes). The average current in HO scale may be figured at 1.0 amperes, at which value voltage drop exactly equals resistance of wire. Increasing the current or the length of the conductor increases voltage drop.

Both conductors must be considered when calculating length (hence resistance and voltage drop). If a suitably constructed common-return system is used, the drop in this portion of the circuit is nil. Common-return is of low initial resistance, and the wire carries only the difference between currents of opposite polarity. Because the voltage loss would be only the result of this difference, the common-return can be ignored in resistance calculations.

Five percent voltage drop in the conductor is acceptable in circuits in which voltage control is important -- propulsion, detection and, sometimes, lighting. Voltage drop on switch machine and

WIRE SIZE AND VOLTAGE DROP - continued

other auxiliary circuits can be much greater without causing problems. In these instances, the only criterion is that there be enough voltage available at the device that it may function properly. Current ratings of conductors should not be exceeded except when used for control of intermittent devices.

TABLE 1: WIRE GAGES AND RATINGS

WIRE GAGE	OUTSIDE DIAMETER (INCHES)	OHMS PER 25' LENGTH	VOLTAGE DROP 25' LENGTH AT 1.0 AMP	CURRENT RATING OF PLASTIC COVERED WIRE*
14	0.0640	0.06	0.06	15 AMP
16	0.0508	0.10	0.10	6 AMP
18	0.0403	0.16	0.16	4 AMP
20	0.0319	0.25	0.25	2.4 AMP

** Bare conductors as used in common return systems or to interconnect closely adjoining terminals, may safely carry several times their rated amperage since the heat will more easily dissipate.*

Long power feeders originating at central locations and connecting to a number of cabs or other points of operation about the layout may be treated as loop feeders. A loop feeder runs from the power supply terminal, around the layout beneath track subbase, and direct to the starting terminal where both ends are connected. The effects of looping the conductor are a 50% reduction in resistance and a doubling of the current-carrying capacity of this wire. This method is generally used in conjunction with common return systems and power supplies for switch machines, relays, lighting and auxiliaries. Looped systems are usually cabled separately from other wires to increase accessibility.

TABLE 2: CURRENT RATINGS FOR COMMONLY USED DEVICES

DEVICE	TYPE	CURRENT RATING	REMARKS
Switch Machines	Most common types Heavy duty types	1.0 amps 3.0 amps max	
Propulsion Motors	HO and smaller O permag types Can motors	0.5 to 0.9 amps Approximately 2.5 amps < 0.25 amps	Wide variations found
Lamps		Estimate at 0.25 amps	See Data Sheet D7i
Relays		From below 0.03 to above 0.25 amps	Wide variations found; consult mfr specifications

RECOMMENDED TYPES AND USES

#14: Excellent for heavy current and particularly-long conductors. Especially suited for common return conductors, switch machine power feeders, pilot and decoration lamp feeders, and other applications in which ample capacity is needed. Wide range of colors available.

#18: ("Fixture Wire") Almost all wiring within its current range (to 4.0 amp). Well suited to "loop" system wiring mentioned above. Full color range. Available at most discount stores and hardware stores.

Lamp cord, twin-conductor: Applicable for any device requiring only two conductors. Suggested for switch-machine control DC feeds, from power pack to control panel, reversing sections and block feeds. With common rail, needing only one control feeder per block, this wire may be used to feed like-numbered blocks of adjacent double tracks. Size #18 most popular, and adapted to most uses, but #16 and #14 also available. Most houses stock three conductor (SJ or SO) lamp cord.

#20: Useful within control panels where space is generally restricted, and for short lengths where current range is not exceeded. Bare, tinned #20 wire ideal for bonding ground rail joiners.

Thermostat wire: Any application requiring several parallel conductors of moderate capacity available with two, three, four or more conductors. Jacketed type is available.

There are many other types of cabled wiring available at your local electronics store or through mail order warehouses. Be careful of the application that this is being used for. The conductors in these cables are generally size 20 or smaller. They do not work well for power or heavy load applications. Be sure to purchase copper wire. Some come in solid, and also stranded. Either can be used. Stranded has a little more flexibility in the case where the wire or connections are subject to movement.

Bell wire: Application similar to above: Only plastic insulated copper wire recommended.

Solid wire is more satisfactory at screw and solder terminals.

Stranded wire on terminal boards has a tendency to allow strands of wire to migrate between terminals causing shorts. The use of a terminal connector on stranded wire will correct this situation.

INSULATION -- TYPE AND REMOVAL

The insulation on wiring purchased at the local discount warehouse or electronics store is generally suitable for model railroad usage. Do not purchase enamel coated wire (used to rewind motors). This wire does not lend itself to usage on the model railroad.

Be careful in removing the insulation from the wire. It will nick quite easily and this is the point where the wire will break. If this happens in a bundle or on a terminal board it may be hard to find. There are several types of wire strippers on the market to do this job.

INSULATION - TYPE AND REMOVAL - continued

Use a wire stripper, not a knife. These strippers can get expensive. There are ones on the market for ten dollars or less.

RUNWAYS AND HANGERS

Common return conductors are discussed in sheet D7p. Other conductors should be installed in supports which permit easy installation and maintenance while discouraging accidental removal. Some arrangement is usually made to permit cables and conductors to follow closely the lines of trackage which they serve.

There are different types of runways on the market. Some are quite expensive. It depends on how much a person wants to spend and how elaborate they want to get. An easy method to use is to drill holes in cross members of the layout bench work (open bench work) and thread the wires through these holes. Pieces of 1½" PVC (plastic conduit) can be cut in 2 in lengths. Cut a slit along one side of the pipe to allow the wires to be inserted. Drill two mounting holes at 90 degrees of the slit. This side of the pipe goes next to the mounting surface. Drill two additional larger holes directly opposite to allow for the insertion of a screwdriver for mounting. There are additional clamping units available at the discount warehouse and the electronics store. All work well. Do not use any clamps or other devices with sharp edges. This will cut the insulation on the wires and cause some mighty nice short circuits. It is important after all the wires have been run to their final locations to bundle the wires together with tie wraps. These are available in various sizes. This makes your wiring job look professional and neat.

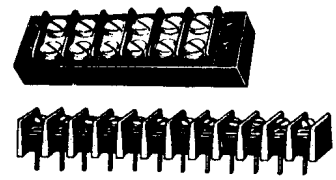
The preferred way to run the wiring is around the edge of the layout and not in every which direction. It takes more wire, but the results are worth the extra expense.

IDENTIFICATION OF COMPONENTS AND FEEDERS

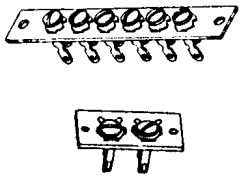
A practice frequently overlooked is that of marking the under-side of the roadbed as to ends and numbers of blocks. Each switch machine, relay and other electrical device also should be clearly identified, as should all block and track feeders. Both installation and maintenance will be simplified if this practice is followed. A convenient tool for sub-table marking is the felt tipped marking pen known by various trade names ("Magic Marker," etc.).

These pens come in various colors for better identification. Each terminal board should be labeled and placed in a log book identifying each terminal and the wire on that terminal.

"Peg Board" (1/8" hardboard with 1/8" holes drilled in it) can be used to make your own terminal boards. 8-32 brass machine screws, nuts, and washers can be used to create these terminal boards. This can get expensive if you need a lot of them. Use alternate rows to create the terminal board. The additional holes allow wires to come into the terminal board at the rear and eliminate some of the wiring on the front of the board.



BARRIER TERMINAL BLOCKS



SCREW TERMINAL

INTERLOCKING
SCREW-CLAMP STRIPS

TERMINAL STRIPS

Good wiring practice calls for the wires from each component or group of components to be connected to a suitable terminal strip. Some of the various types are illustrated above.

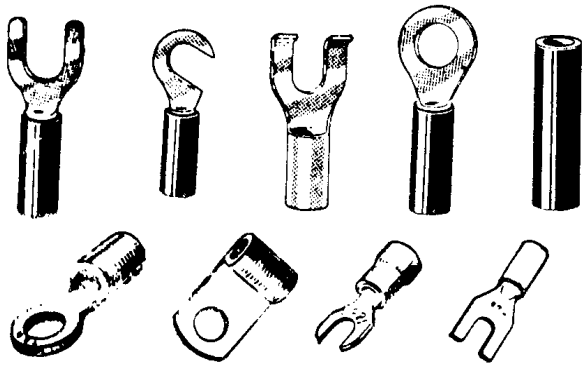
The barrier type, with raised barriers between connected pairs of screws, is best and most costly. It permits easy opening of connections for additions or circuit tracing.

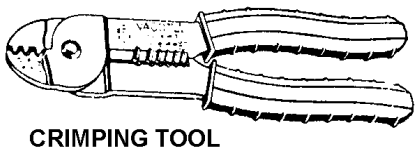
Only rarely are terminal strips used between feeder cables and rail connections. In such connections are needed to relieve rails and "drops" of the strain of supporting the cable. Spring-type terminals are not recommended for any model railroad wiring application. They should never be used in connection with common return systems, which require solid, reliable connections. Spring terminals do not hold wires securely, and severe maintenance problems may begin shortly after installation.

The barrier strips are available at surplus stores ranging from two terminals up to as many as twenty-four terminals.

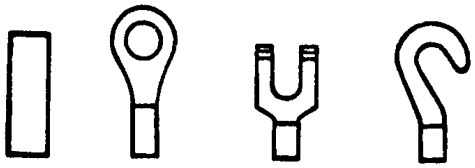
The interlocking screw clamp strips are mainly used on printed circuit boards. There may be an application on the layout for this type of terminal strip.

WIRE CONNECTIONS





CRIMPING TOOL



WIRE CONNECTIONS - continued

Soldering is the time-honored method of securing model railroad wiring. It ranks low in cost and high in freedom from trouble. Good mechanical connections, well-heated joints which do not carry "cold solder" and avoidance of any form of soldering acid are requisite. Bare connections should be properly insulated with tape or heat shrink tubing. Heat shrink tubing is inexpensive, available in various diameters and lengths.

Wires may be connected together by means of "wire nuts", conical connectors with sharp coil-spring threads inside them, designed to be twisted over a pigtail connection. Improperly installed wire nuts may loosen and drop off, however, reducing contact and making it possible for the bared ends of the wires to contact other circuits. Tubular "links" are also manufactured for lineal connection of wires. Some of these are designed to be soldered in place while others are intended to be crimped to the wires.

A wide variety of wire lugs may be had for use in connection with screw-type terminals as mentioned above. Like the links, they are designed for either solder or crimp attachment to wires.

The crimping tool is a pliers-like instrument designed for affixing lugs and links to wires. Some of the models marketed include insulation strippers in their construction.

COST AND PACKAGING

Wiring is one of the hidden costs of layout construction, and factory-fresh, insulated copper wire is not inexpensive. Each hundred feet of track may require 400' of wire or more.

Copper wire will vary in price depending on the size. The best way to purchase it is in rolls of 100, 250, 500, or 1000 feet. Multi wire cables can be purchased in various lengths or some even come in rolls. Check your local store for price and quantity.

CONTINUITY OF RAIL CIRCUIT

The actual rail circuit must be considered when designing a wiring system. Resistance of the rail itself, fairly difficult to calculate, is a factor in producing voltage drop which adversely affects engine performance. Most block wiring is done so that each block has but a single feed per rail, usually located in the approximate center of the block. Rail joiners are relied upon to connect the track into an electrical entity. In time, however, joiners become loose, oxidation reduces their conductivity, and poor operation results.

A set of parallel-to-rail conductors may be used to eliminate this problem. Each individual piece of rail, regardless of how short, may be connected to its respective parallel conductor. When employing rail smaller than Code 125 in O Scale, or Code 100 in HO Scale, the parallel conductor system may be essential because of reduced conductivity and greater resistance of the rail proper.

Bond wires offer an alternative, although less desirable solution. These bonds are soldered to the outside webs of the rails, by-passing all rail joiners in the block. Alternatively, they may be

CONTINUITY OF RAIL CIRCUIT - continued

passed through holes drilled clear through rail and track base, soldered in place, clipped short and neatly finished off. Regardless of which method is used, the block or section should be successfully operated before bonds or tie-ins are installed.

RAIL MATERIAL AND CONDITION

This used to be a real problem with the use of brass track. Today, nickel silver track is available and should be used. It requires less maintenance and will provide for much better operation. The track must be kept clean for equipment to run properly. Further discussion of different types of rails is carried on in other Data Sheets. If you are in one of the larger gauges and your layout is outside, use the recommended track for this purpose.

GAPS

Rail gaps are another important thing to consider. Rail tends to expand and contract depending on temperature and humidity conditions. This is a great place to create short circuits when a rail gap goes together. There are insulated rail joiners on the market for all scales. Use them and don't leave just a gap between two rail ends. They will sometime find their way together. Another method of insulating a gap is a piece of fairly thick styrene. This can be epoxied into the gap and later ground down using a small file or rotating sanding disk. Be sure to make this styrene fit the rail head exactly on the inside of the rail. If you don't you will have an instant derailment.