Electronics for Dummies

Like scenery building, electronics appear to be an aspect of the hobby that many try to sidestep. To be sure, it's straight out of Physics class and seems difficult to grasp. Most of the *cognoscenti* are professionals in the field, and it is perhaps difficult things for any expert to simplify his knowledge so it can be understood by a rank beginner. We all must pick up some electronic knowledge if we want our electric trains to run and are structures to light up at night, and if taken a little at a time, what we need to know is not all that complicated. There are trade-offs in all engineering applications. A gain in one property will usually cause a loss in another. There is never a single perfect way to implement any design. Each problem requires its own solution.

As to my background, I studied and worked in fine arts for pretty much all of my life, and found myself completely befuddled by high school Algebra. Taking Physics was out of the question. I managed to fulfill my high school science requirements by taking Biology and "majoring in language, which was not my forte either. Faced with a possible career change in my late thirties, I did complete a year in a community college electronics technician program. Being older helped, and I grasped more from their job-oriented curriculum.

Unless you use this information daily, it will be impossible to remember it all, let alone apply it. If there is a worthwhile purpose for this clinic, it is to make you less afraid of the unknown, and provide you with an outline of how to use electricity for the model railroading hobby. There are many, many internet resources that delve into all of this in far greater detail.

Basic Electricity

All light waves are a form of energy. And **Electricity** is an invisible light wave that we harness as an energy source. Water analogies are often used to used to describe the properties of electricity. In any technical subject, it is important to understand the terms and abbreviations.

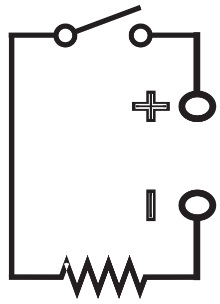
VOLTS (V) are compared to water pressure or how much energy is available? Sometimes known as **Potential,** which is the pressure available at the reservoir relative to the pressure available at the faucet. Voltage is often expressed with the abbreviation **E** (energy).

CURRENT (I) is the rate of flow or how far is the faucet opened? Current is most often expressed in **Amperes (A).** Current is often expressed with the abbreviation **I** (impetus).

WATTS (W) is a measurement for how much water is flowing at what pressure. This term is commonly used for household electricity power consumption.

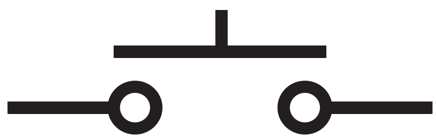
To be useful, electricity must flow from

To be useful, electricity must flow from a **power source**, through an obstacle or **resistance (R)** and then return to the source**.** Also known as a Load, the obstacle (resistance) is often the device the circuit operates such as a lamp, a soldering iron, or a television**.** This is the purpose of an electrical circuit.A **switch** can interrupt the flow. Current usually flows through a wire. Wire size must be matched to the current load. There are many tables that provide that information.



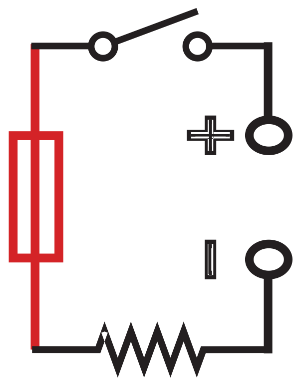
A schematic drawing of this simple circuit is shown at right. It is good to get used to reading these drawings since they are very useful in working with electricity.

Current flows through a **closed circuit**.



Current does NOT flow through an **OPEN CIRCUIT**.

> If there is insufficient resistance, flows uncontrollably, causing a **SHORT CIRCUIT**. The unimpeded current flow can cause dangerous heat build up. Placing an inline **FUSE** or **CIRCUIT BREAKER** will protect against fire. Use a fuse rated a little above the desired current flow.



Direct Current (DC) flows in one direction from plus (+) to minus (-). DC is most often used in scale model railroading and in most solid state electronic circuits. Automobiles operate on direct current. **Alternating Current (AC)** flows in one direction then the other. AC is most often used in tinplate model railroading and most household lighting and appliances. Home electronics convert an AC input to DC.

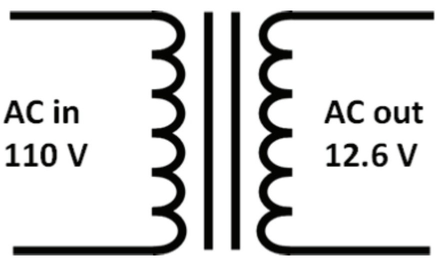
In DC circuits, after the current leaves the load, the minus (-) side of multiple circuits may be tied together, even with different voltages and current ratings. This common connection is best seen in a prototype automobile, where the minus sides of all circuits return via the metal frame.

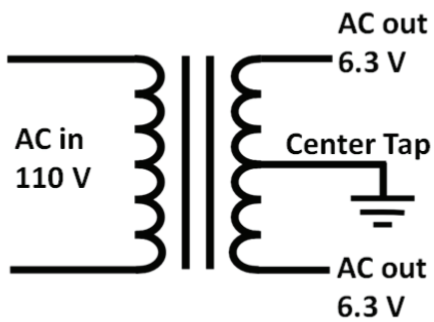
Known as **Ground**, it symbolized thus: 

Power Supplies

Household power supplies typically operate at 110V AC. This voltage is far too great for model railroad circuits which typically operate at or below 18V DC.

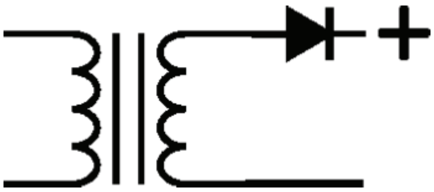
Batteries provide the correct current at suitable voltages but are expensive and require frequent replacement. Adapters are also expensive and usually provide very limited current output. Inexpensive electronic power supplies are readily available in suitable voltage and current ratings from electronics suppliers like Allied, Mauser, and Udoit. But commercial supplies are too large for small projects, and do it yourself is fun and can save money. Inexpensive step-down transformers are also widely available. Building your own also gives a greater understanding of the principles.



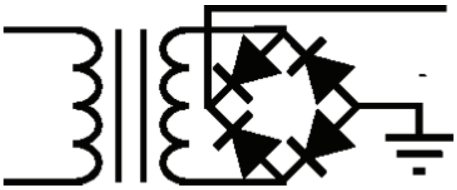


Household voltages are "stepped down" to a safe and useful range for hobby use (eg. 12.6 V). Transformers are available In a wide variety of current ratings. A center tap transformer takes half the voltage from each end and can be used at half voltage (e. 6.3 V). Ends can not be tied together unless "rectified" To DC. Input and output terminals are clearly marked.

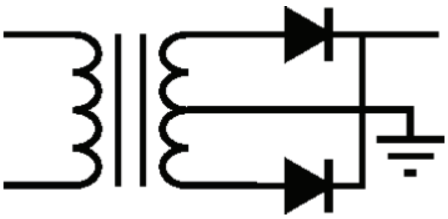
A Diode converts AC to DC by blocking current flow in one direction. The band indicates the direction of current flow. Make certain the diode exceeds the voltage and current rating of the power supply.



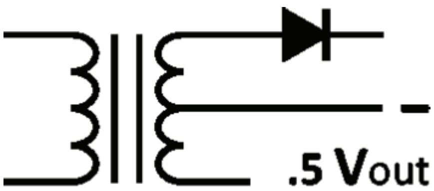
A single diode will convert (Rectify) a transformer's output to **D**irect **C**urrent. Known as Half Wave Current.



A Diode Bridge Rectifier will do the same but the Full- Wave current will be smoother, often important. Bridge rectifiers are sold with the four diodes combined in one package.

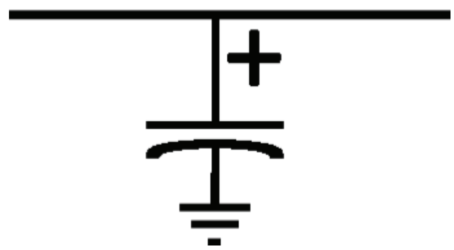


A full wave circuit using a center tap transformer.



Only one end of the center tap transformer is used, cutting the output voltage in half.

A Capacitor is a componet that can store an elevtric charge. They have many uses, but in the csae of power supplies they are used to smooth the wavform of an electric current. This is important for solid state electronics.



Power supplies should operate at about one half their rated output for cool running and long life.

Household electric service operates in POTENTIALLY LETHAL ranges. Always turn power off and use extreme caution when working with electricity.

If uncertain, seek **QUALIFIED HELP.**

Ohm's Law

E=IR; I=E/R; R=E/I

E (Energy) = Volts
I (Impetus) = Current (Amperes.)
R (Resistance) = Load

P=IE; I=P/E; E=P/I

PIE

P (Power) = Watts
I = Current
E = Volts

Ohm's Law states the relationship between the three main properties of electrical energy. Using algebra even I can understand, if any of the two values are known, it is possible to calculate the third.
With Ohm's Law, we can put our theoretical knowledge to practical use. Smartphone apps can perform the calculations automatically.

Not to be confused with Pi (a geometry term), **PIE** shows the relationship between Wattage, Voltage, and Current. Since we are often given wattage as a value, it is necessary to be able to convert the terms so we can apply Ohm's Law.

Practical Examples

We want to use an old power pack is rated at 30 Watts (Volt Amps) for structure lighting. Large and small GOW lamps draws .050 Amps. and .030 Amps. How many lamps can we safely light?

Output is commonly 12 Volts. PIE: 30 W / 12 V = 2.5 A. 2.5/.050 = 50 large lamps. 2.5/.030 = 83 small lamps. Best to operate about half that number.

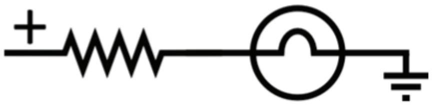
A lamp will light at 1.5 V and .025 A. we have a 6V power supply. What value resistor do we need to drop the voltage to a safe level?

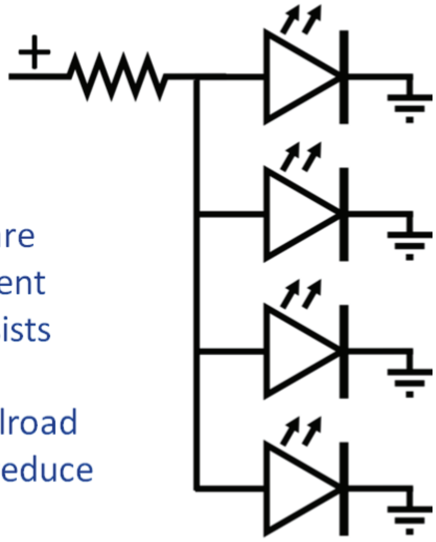
R=E/I 6/.025 = 240. 240 OHM resistor.
*.025 A*1.5 =.0375 Watts power consumption.*
.25 W/.0375 W = 6. A ¼ watt resistor can "drop" six lamps.

Four LEDs (3V @ .020 A) are to be supplied by a 15 volt power source. Do we need a resistor in the circuit? What current rating?

.02A*4 =.080A. 15V/.08A = 187 ohms. Nearest larger resistor is 220 ohms.
.08A*3=.240A. Close enough to ¼ watt to either use a ½ watt resistor or split into two circuits.

Schematics for Example Circuits

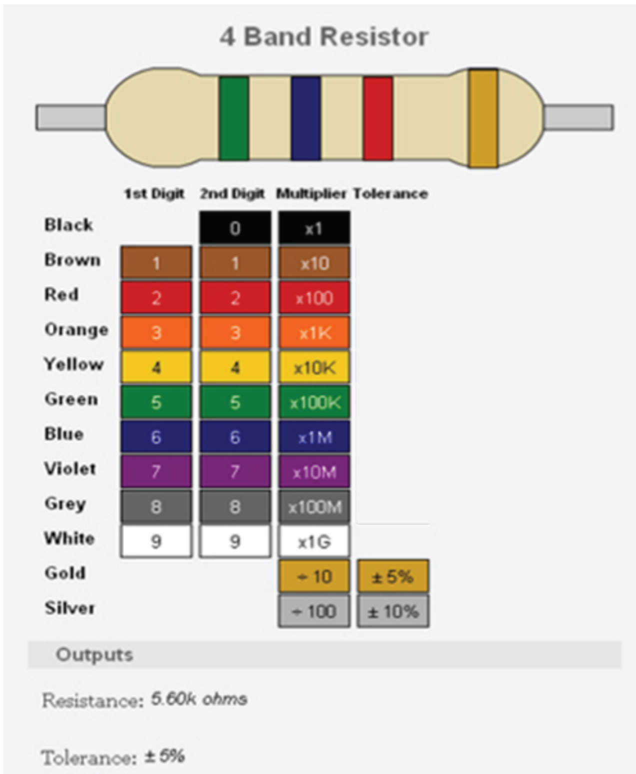




Although all electrical loads are resistances and thereby prevent short circuits, a **RESISTOR** resists the flow of electric current.
In most home built model railroad circuits, a resistor is used to reduce the input voltage.

Resistors are available in a very wide range of values (ohms) and current ratings. The smaller ¼ and ½ watt resistors are most often used for model railroad circuits. Universal color bands denote the value of the resistor. Tolerance is not a factor in most of our applications.

Ω Resistance is measured In **Ohms.** The Omega (Ω) is its symbol.

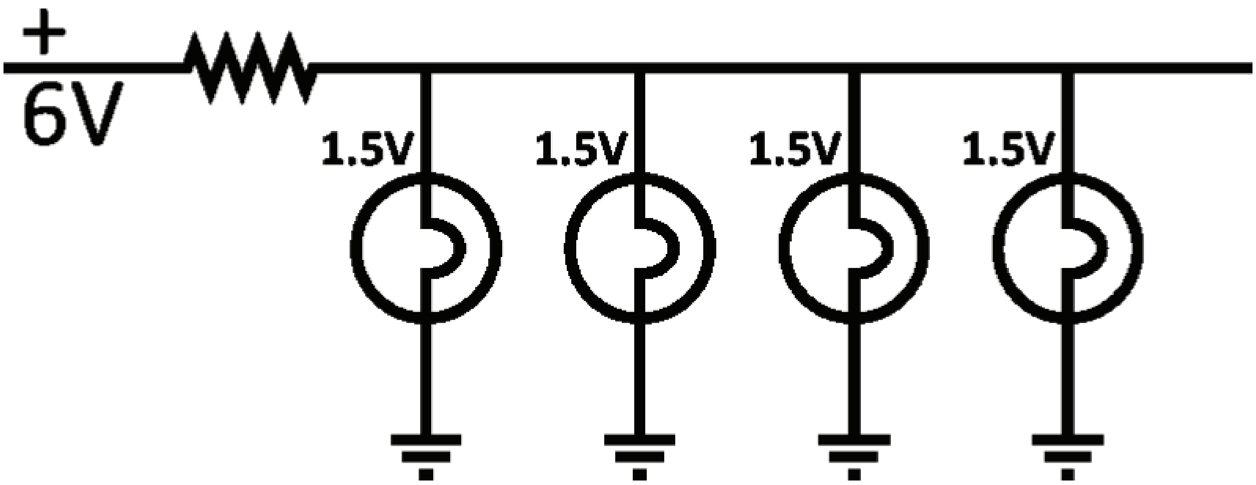


Bad **B**oys **R**ape **O**ur **Y**oung **G**irls
Beneath **V**ictory **G**arden **W**alls
(**B**ut **V**iolet **G**ives **W**illingly)

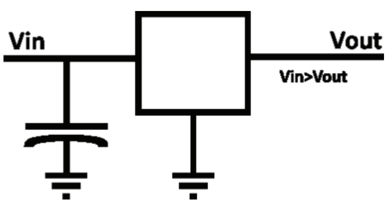
Series and Parallel Circuits

Series Circuits place the components in line with each other. Since current passes through each lamp in the circuit, four lamps will drop the 6V input to a safe 1.5V. This is the infamous circuit used with for old style Christmas tree lights; if one lamps burns out the other lamps will also go out. AInce it is usually a simple matter to match power supply voltage to that of lamps, series circuits are now rarely used for lighting model railroad lamps. Since LEDs tend to have an infinite life span series circuits are practical for dropping voltages for the correct number of LEDs.

Parallel Circuits connect each component separately to a feeder bus, so each lamp is independent and will remain lit if another burns out. Recommended for model railroad lamp lighting and suitable for LED lighting, each lamp would pass the full 6V and would thus burn out. A resistor is indicated as a voltage drop, but better solutions might be to match the power transformer to the necessary voltage or use a voltage or current regulator.



Voltage regulators are simple **integrated circuits** (a group of components combined in one package) that will change the output voltage from a power supply. They are available in many values and current ratings. See wiring instructions for each. For higher currents a metal **HEAT SINK** is necessary. Small single piece limiters are available for use with LEDs. Follow manufacturer's instructions.



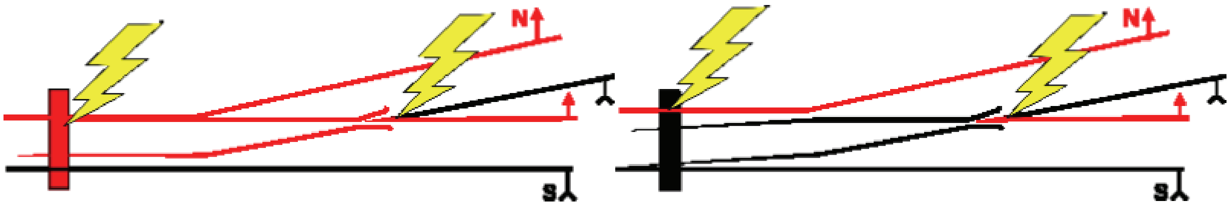
Lighting

Lamps (bulbs) are **analog** devices (output varies with input) and have been around since Thomas Edison. Any voltage at or below the rated voltage will light them. This property can be very useful- operating a lamp at one half to three quarters the rated voltage causing it to glow more dimly, providing a very realistic warm illumination and increasing life of the lamp up to 400 times, making them likely to last a lifetime. Leads are bidirectional and lamps will operate using either AC or DC power. The smallest lamps are rather large for fine scale modeling. Lamps are best used in parallel circuits so good lamps will light if one burns out. Since replacement is difficult at best, I often use several lamps in building interiors for redundancy in case of failure. Soldering is a good choice for assembling circuits. Heat shrink tubing is a dependable material for preventing short circuits at joints.

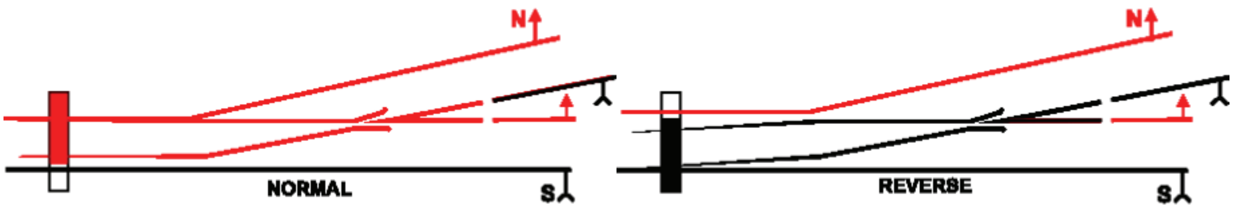
LEDs (Light emitting diodes) are digital devices (output either full on or off) and are a recent development in solid state electronics. They operate at precise voltage and current ratings. Unless the correct input voltage is available, voltages must be dropped using resistors or current limiters calculated with Ohm's Law. They are available in many bright colors (including cool and warm white) in many sizes, some so small as to provide scale sized light sources. Although electronic dimming circuits are available, lights tend to be overly bright. They are well suited to signaling. LEDs operate only on DC and current must be applied to correct lead. Once installed properly, they have a virtually infinite life expectancy so they are equally practical in series or parallel circuits and redundancy is unnecessary. LEDs draw significantly less current then lamps, making lighter wires and smaller power supplies possible than with lamps. Heat buildup is negligible. The short leads are prone to damage from the heat of soldering irons, so wire wrap (a solderless connection system involving inexpensive tools and wire) is a good choice for fabricating circuits.

Since each lighting application is individual, there is no best choice for the best lighting medium or circuit choice. There will often be advantages and disadvantage to different approaches. It is our hope that we have helped provide the tools and knowledge to understand manufacturer's instructions and make intelligent choices with basic electronic components and circuitry.

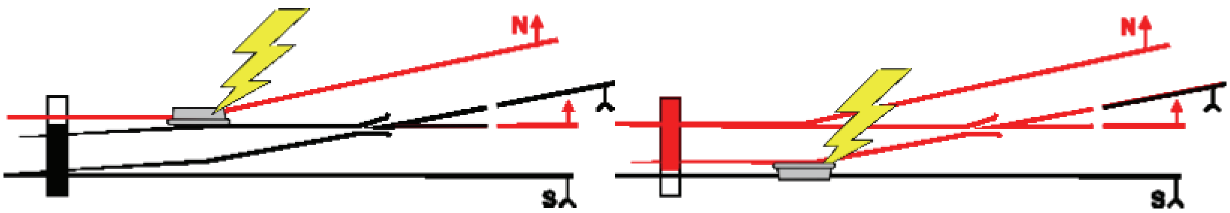
DCC Friendly Switches



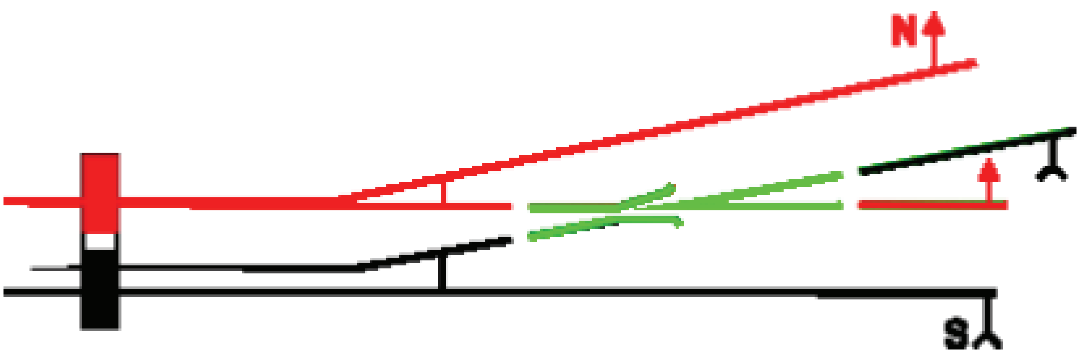
A **Short Circuit results** when the **North** and **South** rails connect at the switch frog and may also connect if a conductive throw bar is used.



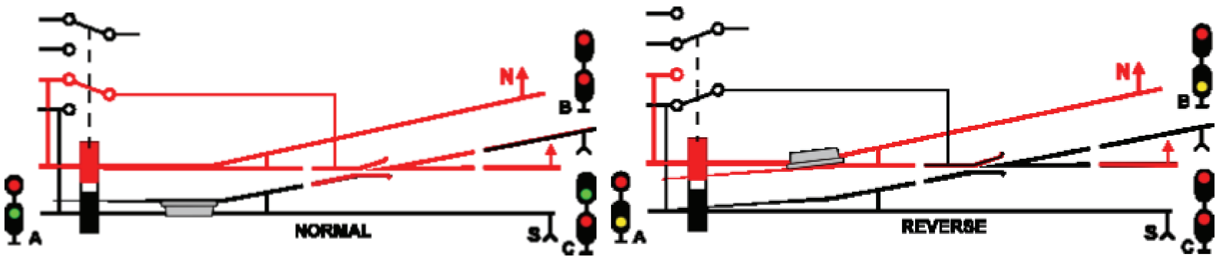
Insulating rail gaps at the frog and throwbar solve this problem.



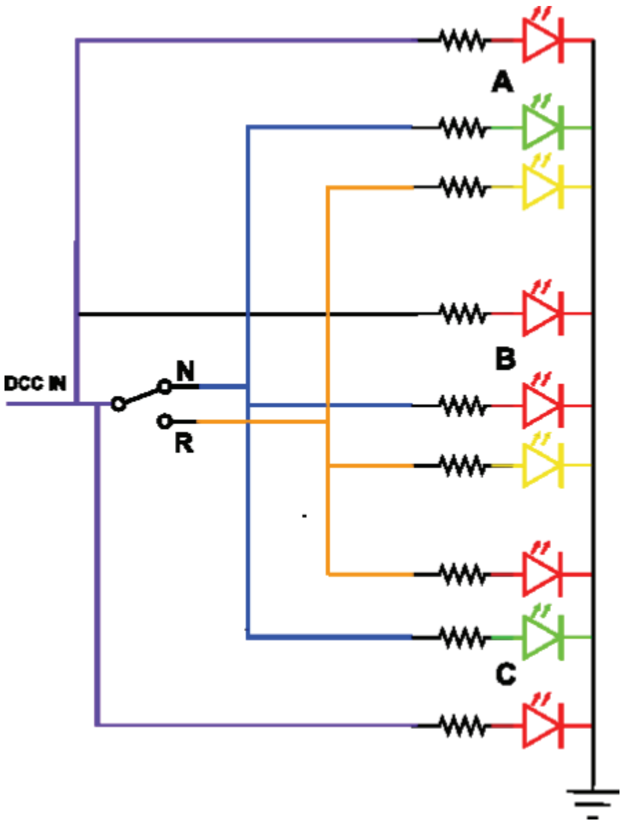
Unfortunately, a Short Circuit can be caused when a metal wheel connects the running rail to the point rail.



The frog is electrically isolated. Additional gaps have been cut so power can be connected to the point rail from the adjacent stock rail. **Short circuits** are prevented but short engines can stall on the electrically dead frog. Throwbar is gapped and jumper wires insure continuity.

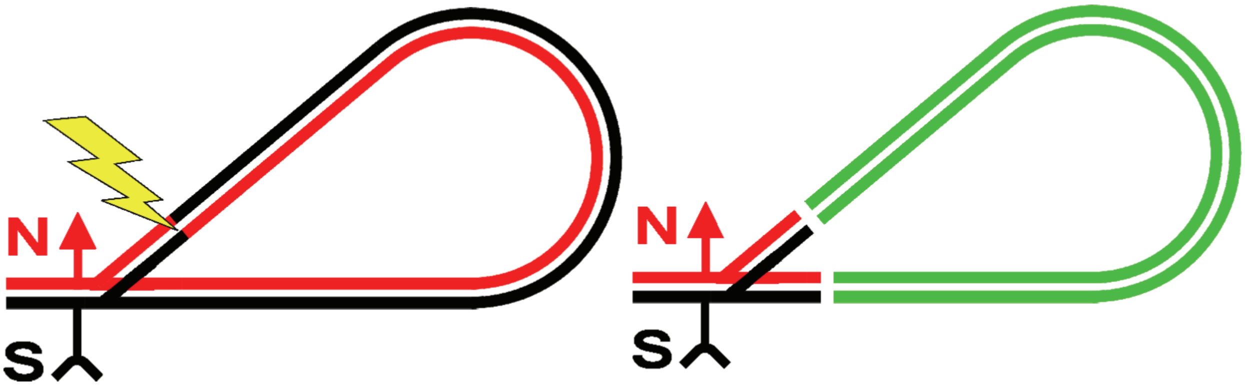


Always the best way to configure a switch, the frog is electrically connected to the correct rail by movable contacts connected to the switch throw mechanism. Additional contacts may be used to operate wayside and panel signals; a simplified version of an interlocking plant is shown here.

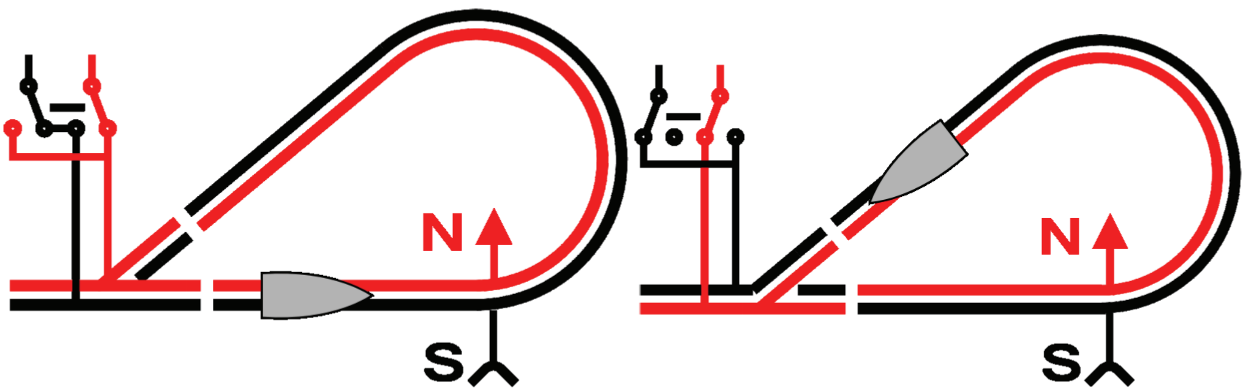


Schematic for the simplified interlocking circuit. Assuming a 12 Volt input and .020 LED Lights, each resistor would be 560 (600) ohms ¼ watt (.024W). Current draw for the circuit is .12A. Eight of these circuits could be operated from a 1A power supply but best to plan to operate five.

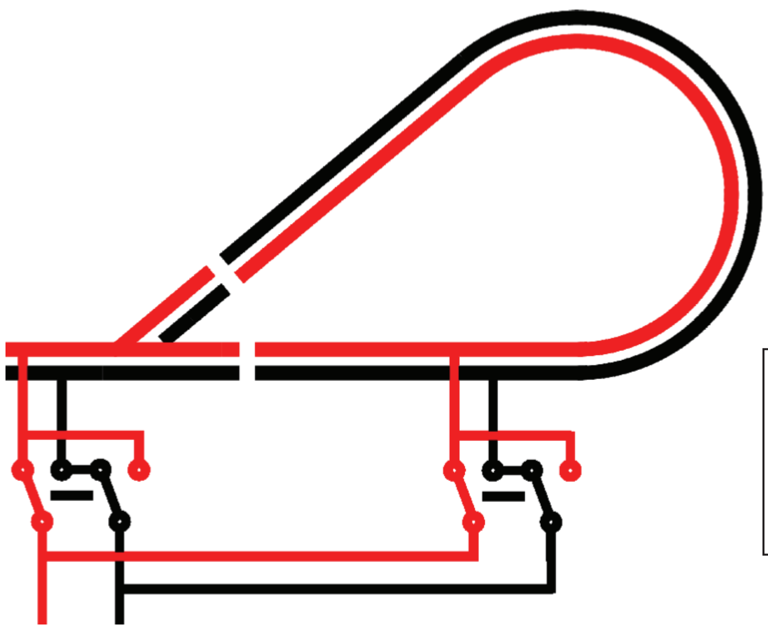
Reverse Loops and Wyes



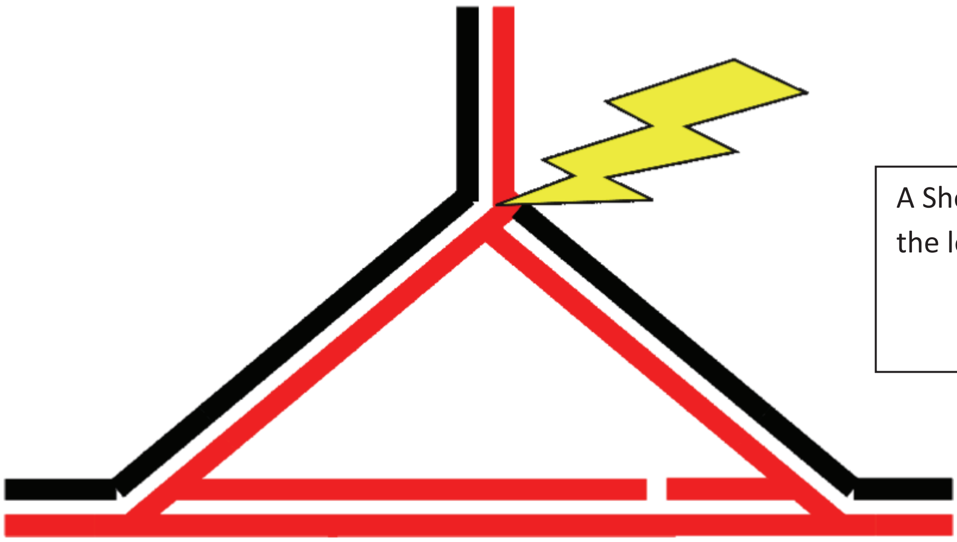
Reversing the direction of travel causes rails of opposite polarity to meet, resulting in a short circuit. Both rails of a reversing section must be isolated.



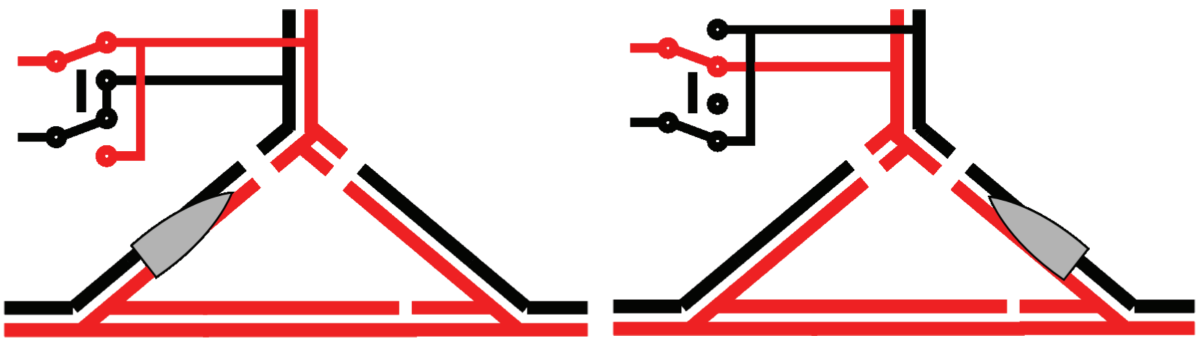
A DPDT switch reverses the polarity of the approach track while the train is in the loop. This circuit will work in one direction only.



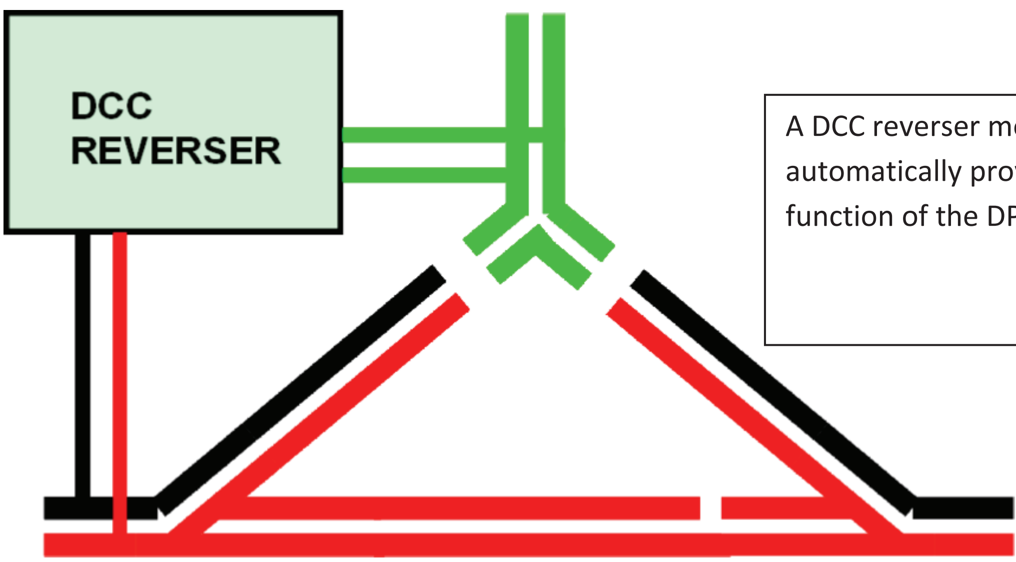
A second DPDT switch allows the loop to be entered in both directions.



A Short Circuit also results when the legs of a wye converge.



A DPDT switch reverses the polarity of the tail track.



A DCC reverser module automatically provides the function of the DPDT switch.

American Wire Gauge Chart

Sizes for common model railroad use. Most useful number is the maximum current rating for the wire. Voltage drop can be significant in very long runs, which can be possible on very large railroads. Using wire that is too large is an unnecessary expense and more difficult to work with. If visible it can be unsightly. Using wire that is too small will result in excessive heat buildup which can result in excessive heat buildup and possible fires. Always protect power supplies with a fuse or circuit breaker. **ALWAYS COLOR CODE wiring and KEEP DETAILED DOCUMENTATION of what is actually installed.**

AWG gauge	Conductor Diameter Inches	Conductor Diameter mm	Ohms per 1000 ft.	Maximum amps for chassis wiring
12	0.0808	2.05232	1.588	41
14	0.0641	1.62814	2.525	32
16	0.0508	1.29032	4.016	22
18	0.0403	1.02362	6.385	16
20	0.032	0.8128	10.15	11
22	0.0254	0.64516	16.14	7
24	0.0201	0.51054	25.67	3.5
26	0.0159	0.40386	40.81	2.2
28	0.0126	0.32004	64.9	1.4
30	0.01	0.254	103.2	0.86
32	0.008	0.2032	164.1	0.53

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Always turn power off and use extreme caution when working with electricity.

If uncertain, seek **QUALIFIED HELP**.

Michael Tylick

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