Model Trolley Car Wiring by Richard Kerr

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Part 1: The Basics

Surprisingly little information has been published about model trolley car wiring. Depending on the wishes of the model builder, this is a simple task or a sophisticated undertaking. To begin, let’s start with the basics, and then we can confuse ourselves from there.

Direct Wiring

At its simplest, car wiring is fundamental. There is a positive overhead wire, a negative return through the running rails, and a permanent magnet motor with two wire leads. Connect one lead to the trolley pole (or other current collector), and connect the other lead to the wheels, and away the car goes (Figure 1).

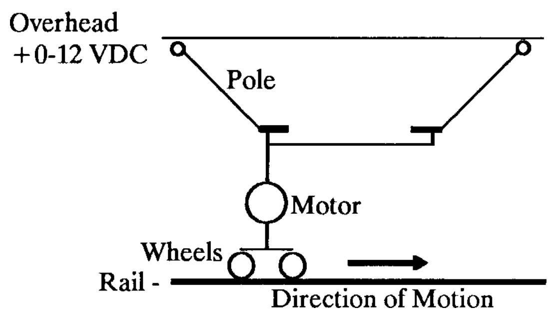

Figure 1 - Basic Direct Wiring Overhead

Pole Reverse Wiring

The first twist in this simple scheme is the concept of pole reverse. In this variation, each motor lead is connected to a trolley pole (assuming there are two poles). The pole hooks, which hold the leading pole down to the roof, are made part of the circuit by connecting them to the wheels. Raise one pole to the overhead, hook the other pole down, and away the car goes (Figure 2).

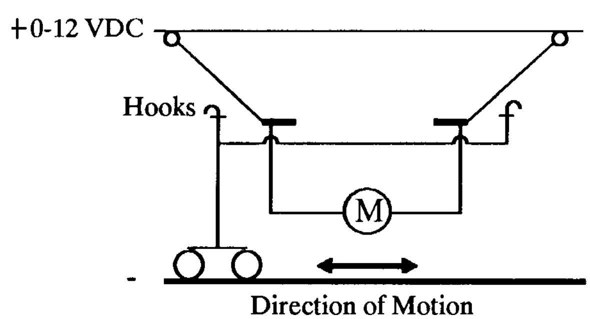

Figure 2 - Basic Pole Reverse Wiring

Which Method is Better?

The answer to this question depends on whom you ask, but let's look at some particulars so you can decide for yourself. Both arrangements will be shown in subsequent chapters.

The advantage of pole reverse wiring is that changing ends (raising one pole and lowering the other) changes which motor lead is positive and which is negative, automatically reversing the car. Instead of throwing a direction switch on a control panel, the operator is using the trolley poles, thrown in unison, as a double-pole, double-throw switch. The end result is basically the same.

If you operate any point-to-point routes with no loops, or a point-to-loop route, direct wiring can make it difficult to operate and to remember which way different cars are facing. The NMRA standard requires a car to move "forward" with a positive overhead, but if your car is double ended, which end is forward? This is not just an academic issue. On a large layout or module setup, many cars can be operated simultaneously with one control. Would you like to put your car on the track or start it up without worrying about which end of your car is "forward"? Would you like to be able to run it with either end forward (for example, baggage or coach end)? Would you like to reverse a car into a trailing-switch siding or crossover, while all other cars continue forward uninterrupted? Pole reverse offers these advantages.

Pole reverse wiring has its disadvantages, too. For one thing, the modeller must electrically insulate the poles, which is sometimes difficult to do on a metal roof (Walthers offers insulated bushings). The pole hooks have to be wired, which may also be difficult on a particular commercial model. Pole reverse is hard to engineer on a car with only one pole or with pantographs. Having a mixed fleet of direct-wired and pole reverse cars can make operations confusing! Some modelers also argue that pole reverse wiring involves more wires inside the confines of the carbody than direct wiring, and requires more connections between the carbody and the roof or floor, whichever is removable for maintenance. These points would appear to be true, based on the two figures shown above. Remembering that the motor is usually in a power truck, it looks like three connections are needed (two motor leads and the ground wire), while the direct-wired car seems to need only one connection. As we shall see in a future installment, this is not really the case if you also want operating lights. With the lights factored in, the wiring added for pole reversal is minimal. Let's clear up another misconception, while we're at it. The pole reverse wiring scheme does not prohibit an operator from backing a car "against the pole." Just throw that old direction switch on the control panel, the same as always.

Next we will look at more complicated circuits with interior lights, headlights, and taillights. A more practical wiring diagram method will be introduced. Beyond that, we will drift into relatively new, not classic, wiring methods. We will review the so-called constant voltage lighting, light-emitting diodes (LED's), can-style motors, and other subjects.

Part 2: The Classics

Operating Lights (and Diodes)

Many modellers add working lights to model trolleys. In the classic method (Figure 3 shows direct wiring), 12 volt bulbs are wired in parallel to the motor. They see the same varying voltage that the motor sees, glowing dimly as the car runs slowly and brightly as the car runs quickly. Two bulbs of the same type in a row (in series), like those marked “IL*” in Figure 3, will split the available voltage, produce a softer glow, and last longer.

Diodes can provide directional control of headlights, taillights, or marker lamps. Diodes act as one-way valves for electricity, passing current flowing from the positive to negative in the direction of the diode’s schematic arrowhead, but blocking current in the other direction. Today, diodes are “classic,” since many quarter-century old trolley models contain vintage rectifiers for headlights.

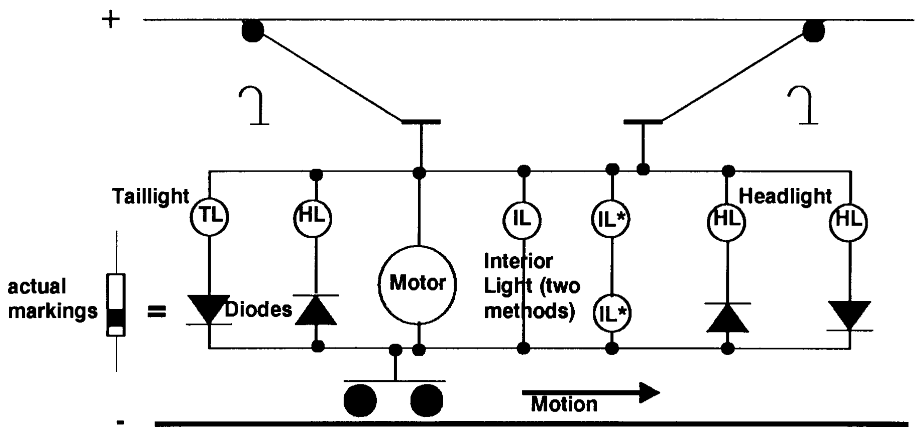

Figure 3 - Direct Wiring

Diodes can also be used in a pole reverse wiring scheme, but Figure 4’s clever wiring is more elegant. Here the poles, not the direction of travel, reverse the headlights and taillights. Backing “against the pole” will not reverse the lights. This wiring method creates an interesting feature. If the car is parked with both poles up, all headlights and taillights will light up, while the motor and any interior lights remain off. Some modellers like the effect of a carbarn or yard full of illuminated cars. The interior light marked “IL*” in Figure 4 shows an alternative wiring method that keeps the interior lights on during poles-up parking, but off when the car is backed “against the pole.”

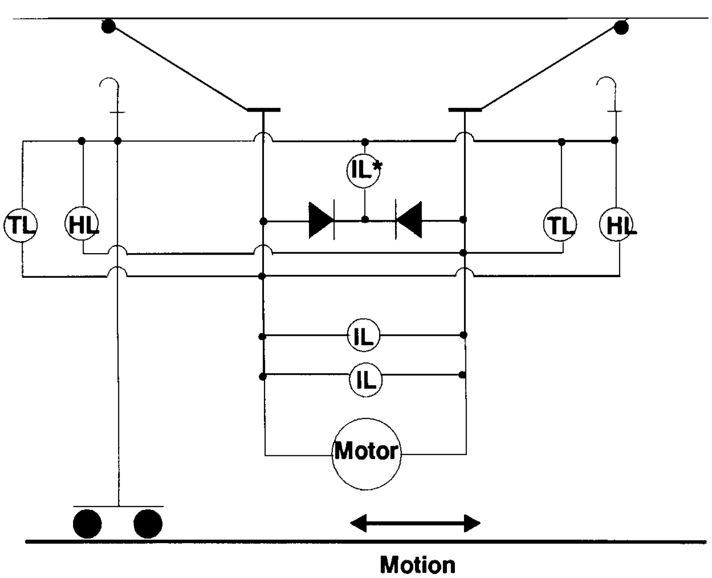

Figure 4 - Classic Pole Reverse w/lights

A More Practical Wiring Diagram

So far this article uses a fairly common style of wiring diagram, drawn to simplify understanding the circuit. The wiring, when done, will be different. Let's introduce another way of drawing circuits, showing the actual wiring for a model with a removable floor. Making the floor removable, instead of the roof, makes it easy to hide the mating seams and fasteners and keeps the wiring for lights in the roof and ends together. Figures 5 and 6 show the same wiring as Figures 3 and 4, but laid out on the underside of a car roof. If you prefer removable-roof models, you can draw your own sketches to suit.

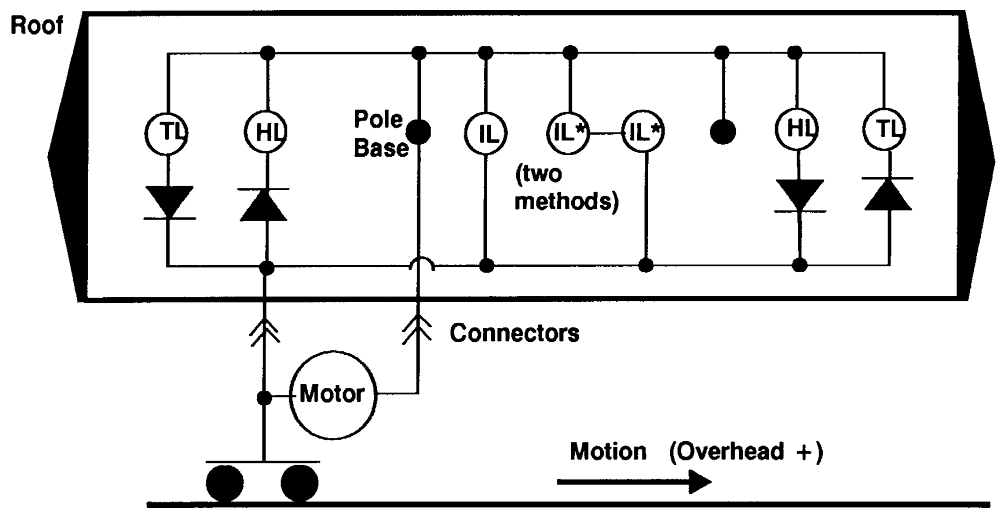

Figure 5 - Classic Direct Wiring w/Lights

One construction trick is to use stiff brass strip or wire shape (held by homemade brass wire staples), instead of electrical wire, along the length of the roof. Then you can solder light bulbs to these bus lines at any location. The diagrams show connectors, which simplify disassembly and maintenance later. They can be real electrical mini-connectors, small dress snaps from the sewing department, tack-soldered wire ends, or the floor fastening screws.

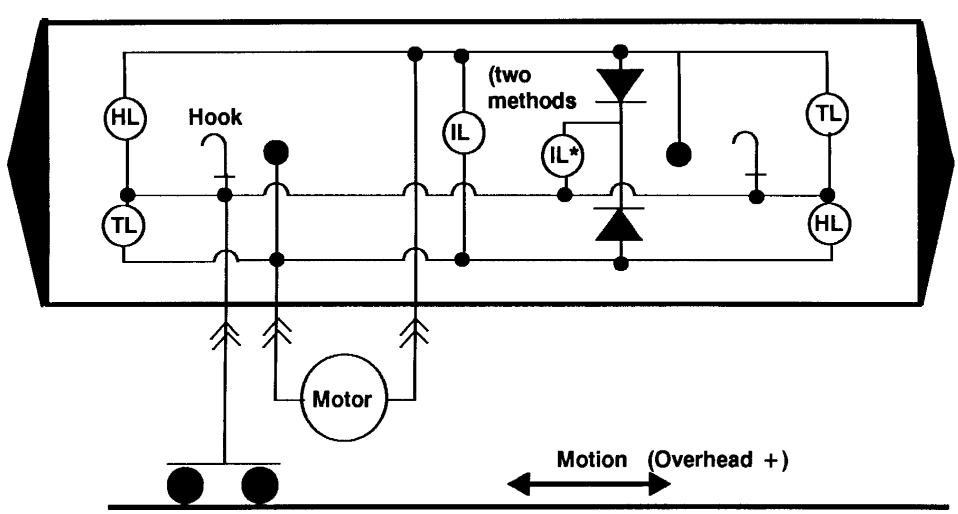

Figure 6 - Classic Pole revers w/Lights

The previous section we stated that pole reverse wiring adds only slight complexity in an iiluminated car model. Comparing Figure 6 to Figure 5 shows three roof-length bus wires and connectors instead of two, and the elimination of all four headlight/taillight control diodes.

Part 3: Goodbye Plain Wiring, Hello Electronics

At this point we have covered the most rudimentary motor wiring, and the enhancements of pole reversal and working lights. Even at this level, we managed to sneak in diodes and the concepts of series and parallel wiring of electrical components. Now it's time for a smattering of electrical formulas (in plain English) before we move onward.

The following facts will be useful in looking at total circuit designs and in sizing components to be adequate. Components wired in series share the same current and split the power supply voltage. Components wired in parallel share the power supply voltage and their separate current loads add up to the total load on the power supply. Mr. Ohm figured out that voltage equals amperage multiplied by resistance. Power wattage is amperage multiplied by voltage. For example, a diode used to make a 12 volt headlight operate directionally must handle the current drawn by the bulb. A typical grain of wheat bulb draws 0.1 amps at 12 volts. It therefore has a resistance when lit of 12 divided by 0.1 or 120 ohms, and it consumes 12 times 0.1 or 1.2 watts maximum. A typical 50 volt, 1 amp diode is more than up to the job, and could easily handle two taillight bulbs wired in parallel, drawing 0.2 amps.

Another Property of Diodes: Voltage Drop

We know that ordinary diodes conduct electricity in one direction only. The atomic properties of the materials in the diode require a certain voltage across the diode to be reached before the electrons break free and flow as electrical current. For older germanium diodes, this voltage was 0.3 volts, and for today's silicon diodes it is 0.7 volts. This voltage is "lost" in the diode. If you have 12 volts in your overhead, a diode-controlled headlight in your model will only get 11.3 volts; at six volts, the light will only get 5.3 volts. This is no big deal.

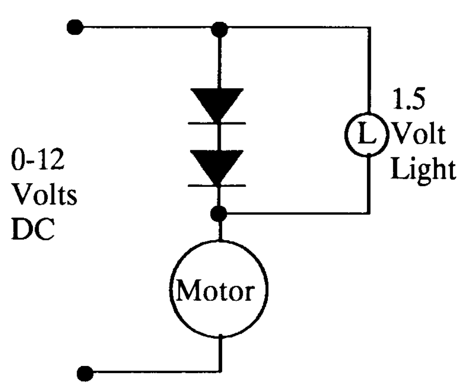

Figure 7 - Diode Drop

The big deal is that the voltage drop across the diode stays at this constant value, regardless of the supplied voltage going up and down. Some clever modeller years ago saw the diode not as a one-way control valve for electricity, but, in a totally different use of the device, as a source of constant voltage. Look at Figure 7. Two diodes, each losing 0.7 volts, are placed in series in a model trolley's motor circuit, for a total drop of 1.4 volts. The rest of the supplied voltage goes to the motor. The current drawn by the motor is split by the diodes and a 1.5 volt bulb placed across the diodes. No matter how much the controller is cranked up, the bulb sees 1.4 volts. As a result, the lighting levels stay relatively constant, not getting dim and bright with car speed. Micro-sized 1.5 volt bulbs are now commonly available to modellers.

However, don't wire a model like Figure 7! Throwing the control panel reverse switch will make the diodes block the reversed power. The total motor current will then detour through the little 1.5 volt bulb until it goes poof. Notice that the motor in Figure 7 sees a voltage 1.4 volts below what it used to see. The car will start later and have a lower top speed. This can be an improvement, not a problem. Running cars equipped with commercial power trucks and constant voltage lighting, the author finds that the controller voltage he sees for reasonable speeds range at most between 3 and 7 volts.

Bridge Rectifiers

Figure 8(a) shows a usable constant lighting circuit. The two pairs of diodes allow current to flow properly in both directions. (A single diode in one path would provide a bright/dim light reversal, like many steam locomotives had.) A neater installation than using four separate diodes is to use a single bridge rectifier package. As Figure 8(b) illustrates, a bridge rectifier is a four-diode setup commonly used to convert AC power to full-wave DC power. The positive current from a household electrical source will switch between the "AC" terminals of the bridge 120 times every second, but will always be directed to the " + " output terminals of the diodes. We are not using the bridge to rectify AC power here, just as a handy package of four diodes. By shunting the "+" and the "-" terminals (carefully soldering them together— always use a small, hot iron to quickly solder diodes), we create Figure 8(c), which is equivalent to Figure 8(a). Radio Shack part 276-1161 is a small 50 volt, 1 amp bridge rectifier that is just dandy for this application. The lights supplied by the shunted bridge rectifier will come on before the car starts to move. A minimum controller voltage of about 2 volts lets the car sit motionless with their lights on.

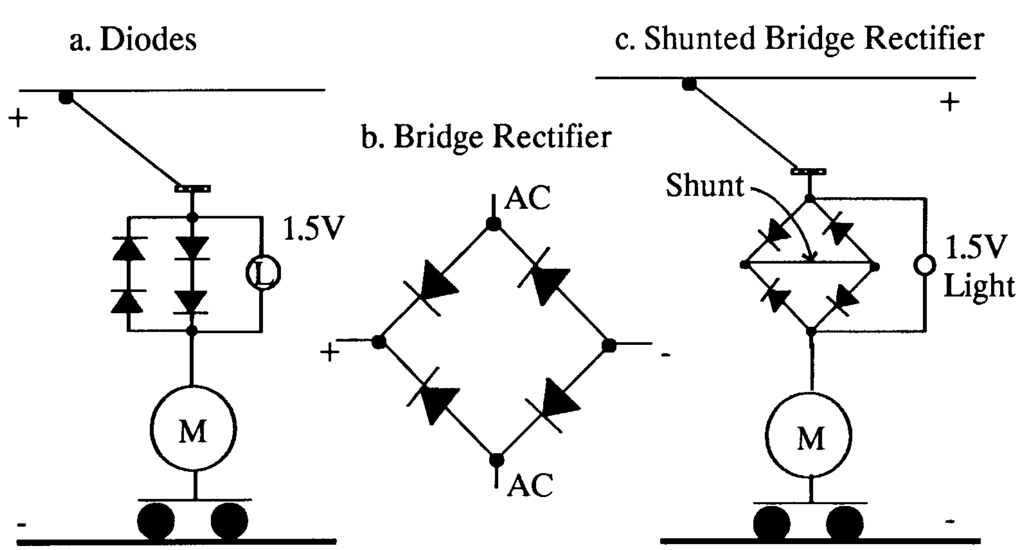

Figure 8 - Constant-Voltage Lighting Circuits.

Part 4: Constant-Voltage Lighting Schematics

Light-Emitting Diodes

Before examining complete schematics, let's look at one more useful device, the light-emitting diode (LED). We have already used diodes as electrical one-way valves and as a convenient source of constant voltage drop to operate low-voltage light bulbs. The LED is a more exotic diode which emits light when it conducts. LED's are easily and inexpensively available in a variety of sizes, and in red, green or amber colors. The light they provide tends to be very directional, meaning you won't see much of it from the side of the LED. (Low-voltage light bulbs work better for lighting models of old-fashioned marker lanterns with multiple lenses.) An LED's light level varies only a little as the supplied voltage varies. LED's provide light with little or no heat generation, and they last a long time; these are both advantages in modeling.

LED's are a light and a control diode all in one. When the voltage is reversed, they do not conduct and do not light. What could be better for taillights? A resistor is needed in series with an LED to limit current. A typical LED might handle 20 milliamps (0.020 amps) safely and need about 2 volts across it to operate. LED's differ, so it's best to calculate the resistance needed in each application. To do this, take the maximum voltage being supplied, and subtract from it the LED's specified voltage requirement to calculate the voltage left for the resistor to handle. Using Ohm's Law, divide this remaining voltage by the LED's current rating to determine the resistance value that is needed. Finally, round the resistance up to the next highest commercially available value. Rounding upward reduces the current, adding a margin of safety. Not all throttle power supplies stop at 12 volts, so it's best to be conservative (high) in choosing your resistance value. Here's an example: 15 volts maximum supply minus 2 volts across the LED leaves 13 volts across the resistor. The resistance to pass only 0.020 amperes at 13 volts is 13 divided by 0.020, or 650 ohms. Most model railroading articles advise a 1000 ohm, half-watt resistor for a typical LED.

Constant-Voltage Lighting Schematics

The classic model trolley wiring schemes, using 12-volt bulbs, have already been presented. Now we can put together constant-voltage schemes (also called constant brightness or constant intensity). Figure 9 shows a direct wiring scheme and Figure 10 is its pole-reverse counterpart. You should recognize in them the various building blocks we've learned about: directional control diodes, voltage-drop diodes, a shunted bridge rectifier, low-voltage light bulbs, and LED's. Notice that the LED's happen to be fed from the voltage-dropping diodes and not from the full track voltage. This is an attempt to keep their brightness very constant, and also to reduce unnecessary wattage being turned into heat by their protection resistors.

The schematics are very similar. In both, power flows in series through a lighting circuit and then through the motor. The lighting circuit has 2.1 volts total drop. The interior lights use 1.4 volts of that total. So do the headlights, since their directional control diodes use up the other 0.7 volts. The entire 2.1 volts is available to meet the higher voltage needs of the LED taillights.

We're really getting someplace now, but don't use these schematics with a modern can motor. We'll see why in a future article.

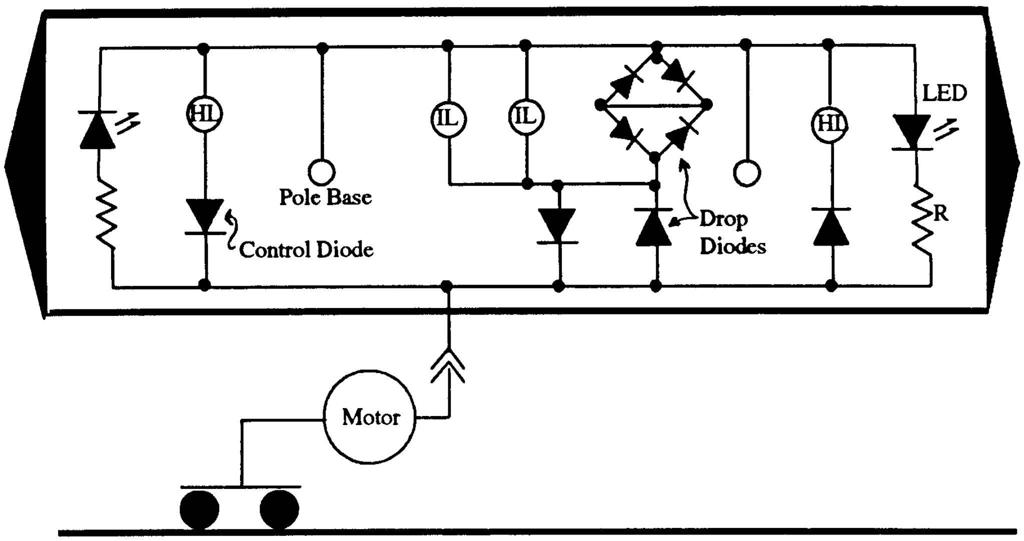

Figure 9 - Constant Lighting - Direct Wiring

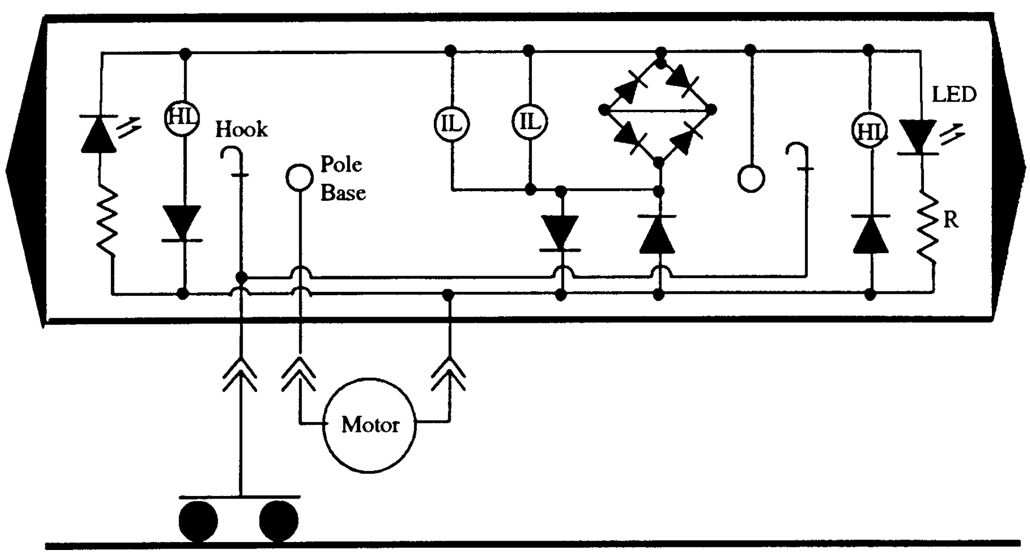

Figure 10 - Constant Lighting - Pole Reverse

Future Articles: Can motors and Fred Weigle's schematic, followed by a review of different lighting methods.

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