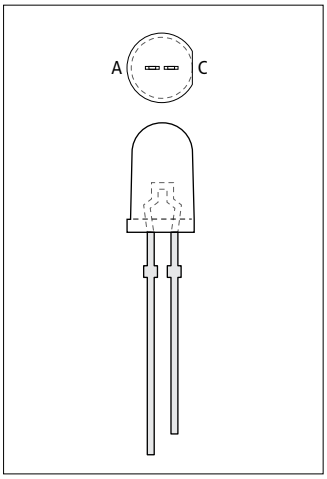
Shining light on light-emitting diodes

1 Left to right: NCE (ncedcc.com) WWLEDx20 Warm White, SoundTraxx (soundtraxx.com) No. 810133 Sunny White, and SoundTraxx No. 810134 Golden White. Allan Gartner put a 1,000 ohm resistor in series with each of the LEDs shown here. You can change the resistor value to control the LED's brightness. The LED from NCE is more "point source" than the "diffuse" LEDs from Soundtraxx.

Now that light-emitting diodes (LEDs) are illuminating our homes, it's hard to not know something about them. While the kind of LEDs that light our homes have additional circuitry that allow them to run off of 120 volts, all LEDs are efficient and run much cooler than their incandescent predecessors. Most last virtually forever.



2 The flat side and corresponding short lead is the cathode on an LED. This goes to the negative power source, like the function lead from a decoder. The long lead is the anode and goes to your positive power source, like the blue function lead. Don't forget a series resistor.

Those of us who grew up using incandescent light bulbs (contains a filament and gets hot) are used to "white" lights having a "warm" tone to them. Fluorescent lights have long come in various shades of white, but were not used for headlights in locomotives or automobiles. Since the demise of incandescent light bulbs, LEDs and other technology lights have become available in various shades of white known as color temperature.

To avoid specifying color temperature, some hobby suppliers try to give the shade of white a name. While well intended, I haven't found the names to give me a good idea of what shade of white I'm getting. There's nothing like seeing the actual LED lit up. I have provided a photo comparing several different LEDs to give you an idea of they look like 1.

What color temperature do you want? If you're modeling the steam era, you want a warm white LED for the headlight, cab light, marker lights, and number boxes.

Modern diesels likely use something other than incandescent lights. If you're fortunate to live somewhere where you can see your favorite railroad in action, you can compare headlights, ditch lights, and number boards with LEDs that you can buy.

Bipolar LEDs come in two configurations and are typically red/green. Some have two leads and light red when current flows in one direction and green when the current is reversed. Some bipolar LEDs have three leads where one is a common, one for red, and the third for green. The two-lead bipolar is commonly used for slow motion switch machine position indicators.

All LEDs only light when the power is flowing through them in one direction. Equally important is that all LEDs need a series current limiting resistor. Usually, you want to limit to a maximum of 20 milliamps (mA). Often 10 mA is fairly bright for modern LEDs. For the tiny ones used in signals and marker lamps, 3 mA is plenty.

If you want the equation to calculate the size resistor you need, see the sidebar on the next page.

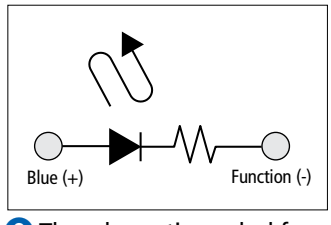
Trying different resistor values until you achieve the brightness you're after is probably the easier approach for most modelers. Start with 1,000 to 2,200 ohms and work up or down from there.

You can purchase resistors from All Electronics (allelectronics.com), Jameco Electronics (jameco.com), eBay, and other outlets. Jameco also sells assortment sets. Resistor selector boxes are available, but they're not inexpensive. Unless you always keep your brain engaged, you could accidentally select a value that's too low, thereby letting the smoke out of your DCC electronics. Once you figure what you want, you can buy resistors by the hundred for a few dollars. Just make sure you buy resistors with leads on them.

If you have never worked with LEDs before, here are a few tips. It used to be that LEDs could be wired backwards and they simply wouldn't work. Turn the LED around and you were good. But newer LEDs, particularly the white ones, can only tolerate a few volts when hooked up backwards before being damaged. Therefore, it's wise to make sure you wire them up correctly the first time.

Round LEDs with leads generally have two ways to determine which lead is which. One, there's a flat side to the rim of the LED. Two, one lead is shorter than the other. 2 For the 3mm ones discussed here, look for the short lead. The short lead is the cathode, or negative, lead. In a schematic, it's the end with the line that the arrow is pointing to it 3.

The positive end, called the anode, goes to your positive power source. Usually, that will be the blue lead of a decoder. Unless you are using a decoder that has a built-in resistor (examples include the NCE Light-It and the NixTrainz Decoder Buddy motherboard for 21-pin decoders), you'll need to add a resistor. Consult your



3 The schematic symbol for an LED with a series, current-limiting resistor. Hook it up to a function lead as shown. The end with the arrow pointing to it is the cathode, or negative, lead.

Calculating the initial value of a current limiting resistor

$$R = \frac{V_{PS} - V_L - V_D}{I_L}$$

$$W = I_L^2 \times R$$

Where:
V_{PS} is voltage provided by power source.
V_L is the voltage rating of the LED.
V_D is the forward voltage drop of a diode, if used.
I_L is the nominal current in amps for the LED.
R is the value found for the resistor in ohms.
W is the wattage value found for the resistor.
The term Vps is the output of your decoder, around 13V for HO, and not the track voltage. The term VD is 0.7V if you're using a series protection diode. Otherwise, it's 0V. The term IL is the nominal operating current in amps. If 20mA, then use 0.02. The term VL is the nominal operating voltage of the LED. The nominal operating voltage for my red and green LEDs is about 2V. The white LEDs are about 2.8V. – *Allan Gartner*

instruction manual to see if the resistor isn't needed. If you're not sure, try a resistor. If the LED light is very dim, then you will know that a resistor was already present.

The resistor can be attached to either of the LED's leads. I've shown it connected to the cathode end. Connect the other end of the resistor to the appropriate function lead, headlight (white wire), rear light (yellow wire) output, or one of the function outputs of your decoder.

The resistor should be between 470 and 3,300 ohms. The lower the value, the brighter the LED will be. Modern LEDs are efficient and bright. You'll probably find yourself using a resistor between 1,000 and 2,200 ohms. If you can manage working with tiny LEDs, you'll likely use a 2,200 ohm or higher resistor.

UNLESS YOU ALWAYS KEEP YOUR BRAIN ENGAGED, YOU COULD... LET THE SMOKE OUT OF YOUR DCC ELECTRONICS. – ALLAN

Electronics hobbyist suppliers like All Electronics and Jameco Electronics sell white LEDs, but there's no indication of what color temperature they are. I purchased all of Jameco's inexpensive white LEDs. None were warm white.

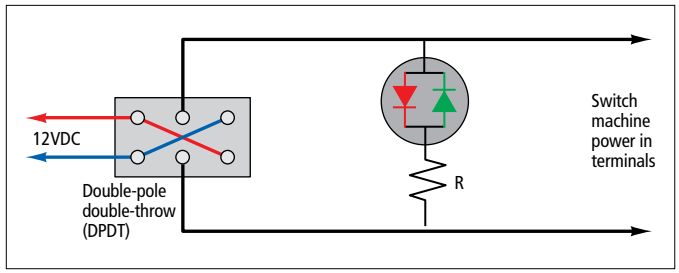
Hobby suppliers offer good prices, but I'm not confident that you'll get the same LED the next time you buy from them or even within the same order. I've seen that happen when buying from eBay. Big electronics distributors like Digi-Key (digikey.com) and Mouser (mouser.com) also carry a large selection of LEDs. You'll probably spend a lot of time determining which white LED will suit you at a price you are willing to pay.

All the LEDs that I compared for this column are 3mm (.118") diameter. Smaller LEDs are made, but soldering wires to them can be difficult. If you want to get a hole the correct size for the 3mm LED, Micro Mark sells metric drill bits. Otherwise, 7/64" is just a little small and 1/8" is just a little big.

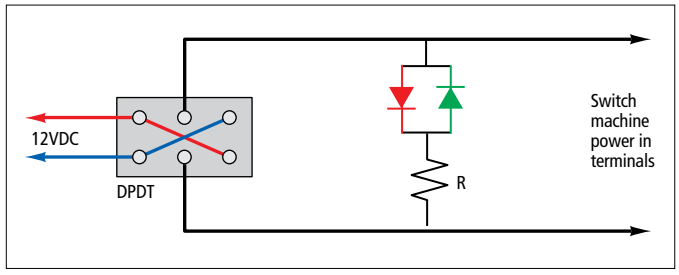
Many modelers like to have LEDs on their control panels to indicate turnout position. Control panels like this can take a fair amount of time to wire. Using one resistor saves a few cents, and more importantly, saves a few minutes per turnout control to wire. The more clutter you have in your control panel, the more crowded it becomes. Many modelers aren't overly concerned about the green LED being the same brightness as the red on their control panels. For completeness, I'm providing schematics for all options.

All the circuits shown can be used with the Walthers LCS, or any slow motion (stall motor) type switch machine like the Circuitron Tortoise.

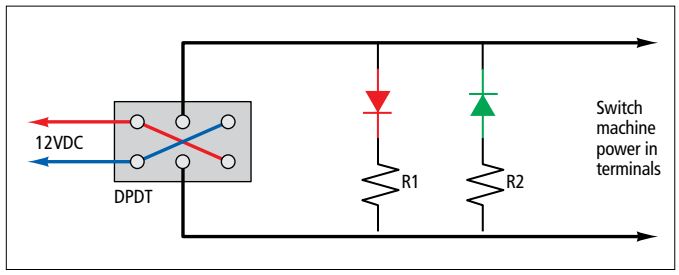
For the fewest parts, you can use one bipolar LED 4. If you want an LED for each track leaving a turnout, look at 5. If you want balanced brightness, look at 6. MR



4 A single bipolar LED provides for the fewest number of parts and the least amount of wiring. If the green and red aren't the same brightness, there's nothing that can be done to change that.



5 A single resistor with an LED for each track is satisfactory for many layout applications.



6 This diagram will yield LEDs with balanced brightness. Allan suggests that you determine the resistor value for the green LED first. Then determine the resistor for the red LED that produces matching brightness. You'll likely find that the resistor for the red LED will be a higher value.