

About our DCC columnist



Bruce Petrarca is a well-known expert on all things DCC.

[Click here](#) to learn more about Bruce.

Photos by author unless otherwise noted.

DCC Impulses: And now, LIGHTS – LED style!

Getting the light you want!

Now that your decoder is installed, let there be light ...

I love using LEDs to light my locos, cars and buildings! There are several reasons. Let me count the ways ...

Life: Properly installed, modern LEDs will have a life of tens of thousands of power-on hours. Just think – 20,000 power-on hours is 8 hours a day, 5 days a week, 52 weeks a year for almost a decade! Probably longer than you'll run your equipment!

Colors: Colored LEDs are a pure, single-frequency color.

“White” LEDs are now available in many different shades, ranging from almost Xenon blue-white to a very good representation of a warm white incandescent bulb.

Refer to the SMD LEDs video in the sidebar on [page 41](#). I show a technique that lets you adjust the color value of a white LED away from cool white and toward warm white. While the video focuses on SMD LEDs, the technique also works on packaged LEDs.

For headlight use, I'm partial to Richmond Controls' sunny-white and golden-white LEDs. Golden-white

devices are better for emulating incandescent lamps, but need to be recessed into the loco so the orange bodies cannot be seen.

Temperature: No more melted shells. Unlike relatively high-temperature incandescent lamps, even the 1.5 volt bulbs, neither the LEDs nor their dropping resistors get warm enough to deform plastic shells or building walls.

Power: The heat being generated by an incandescent lamp could be running a loco for you! If you have enough high-current lamps lit at once, you might need to add another DCC booster.

Size: LED sizes range from packaged devices in excess of 5 mm (1/4-inch)

in diameter down tiny (0.04 x 0.02 inch) surface mount devices (SMD). You can almost certainly fit an SMD LED in a really tight spot.

Cost: LEDs can be very cost-effective. I just purchased a bunch of SMD LEDs with an SMD resistor for each of them for a total cost per light of under 10 cents.

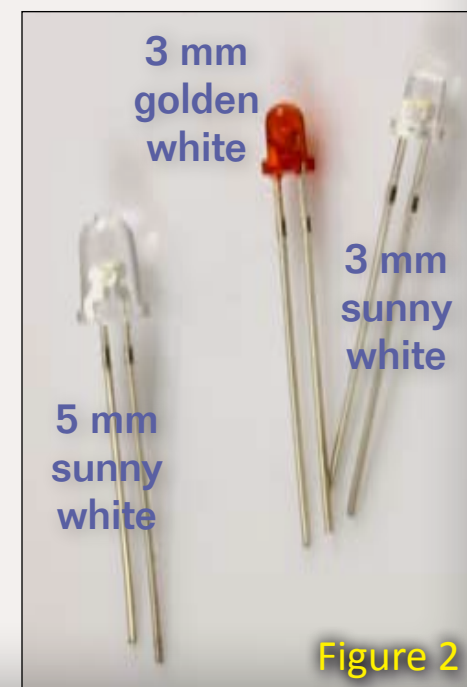
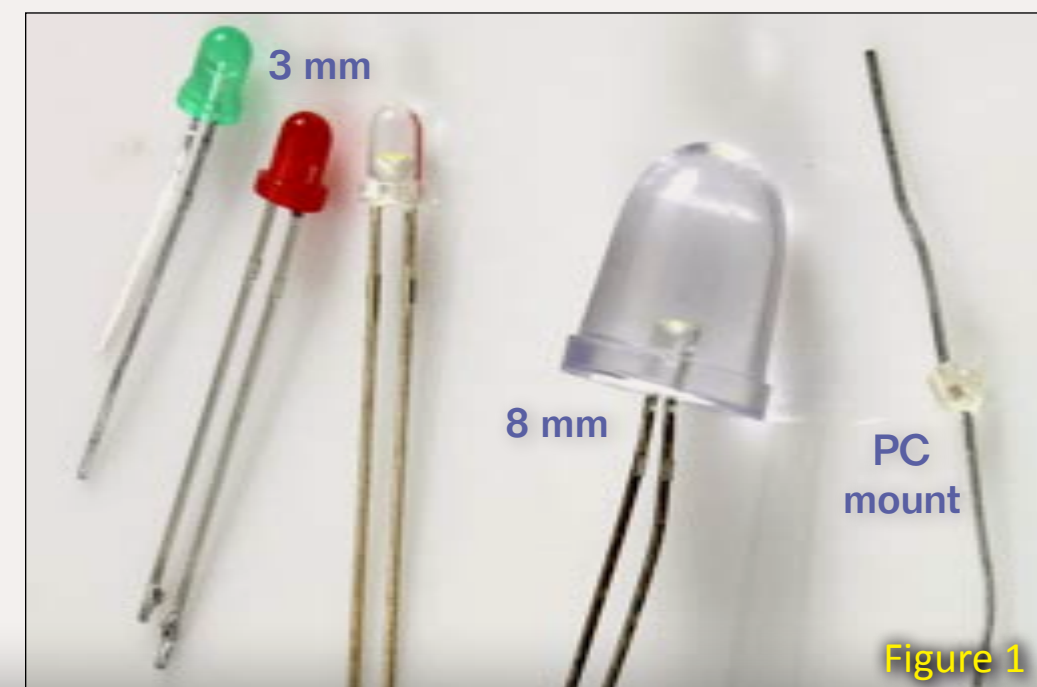
LEDs and Your Layout

Before we jump into the details, let's think about what is possible with LEDs.

- Loco lights, including head and rear lights, marker lights, cab lights, step lights, and ditch lights, are an obvious place to start.

Figure 1: Packaged LEDs come in many colors, sizes and styles.

Figure 2: Richmond Controls' LEDs – golden-white version has an orange body – shown are 5 mm sunny-white and both versions in 3 mm.



 **Reader Feedback**
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Video 1: LED lighting effects.

- Caboose lights, including marker lights and interior lights.
- Passenger car lighting and markers.

Let your imagination run wild!

How about covered wagons with nose lights: white going forward and red in reverse? A white/red bi-color LED is indicated. Decoders can simulate a Mars light if your prototype had them.

Modern decoders allow great effects with LEDs as well as incandescent bulbs. Usually there is a CV setting to tell the decoder which is attached.

Video 1 demonstrates how changing decoder CV settings allows LEDs to

simulate lighting effects. LEDs react to changes in voltage and current differently than a light bulb. See how enabling a decoder's LED mode dramatically improves the appearance of a Mars light effect.

LED safety

LEDs are somewhat sensitive to electrostatic discharge (static electricity). Touch something metal (preferably grounded) before touching them to discharge any static charge you're carrying.

This is a DCC column, so I'm going to discuss putting LEDs on the function outputs of decoders, which require no special care to insure their safety.

If you are wiring them to the track or a power supply, there may or may not be other steps you need to take to assure their safety. More about this can be found on my website (www.mrdccu.com/curriculum/Lighting/LED.htm).

LED Anatomy

- Packaged LEDs include a small die (the actual device) packaged into an epoxy housing with external leads as shown in figure 3.
- Surface mount LEDs eliminate the epoxy housing and have the die mounted on a small ceramic holder with connection points on two sides as shown in figure 4.

Bi-Color LEDs

Observe how LEDs are built in figures 3 and 4. The die (the part that emits



Figure 3

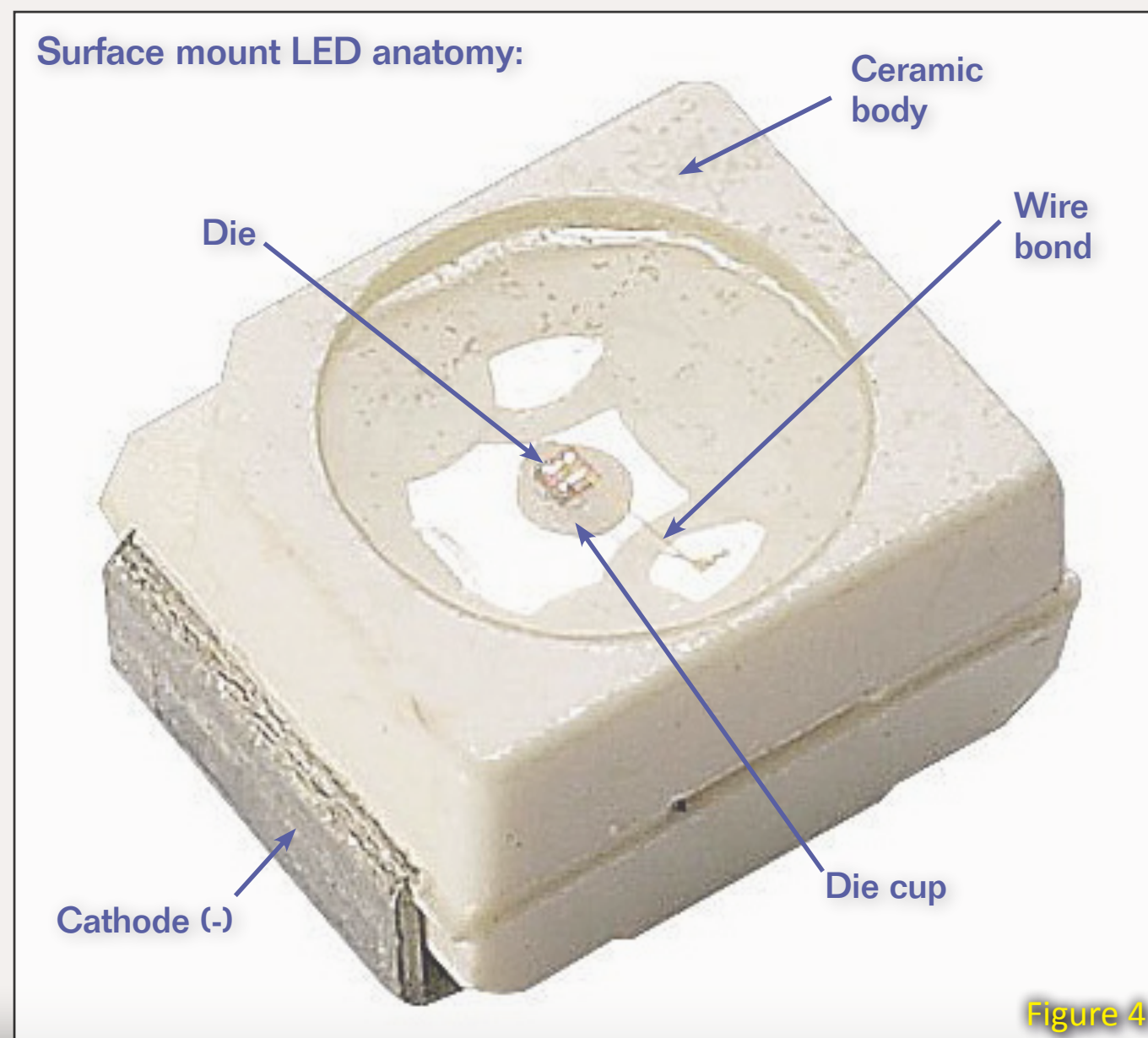


Figure 4

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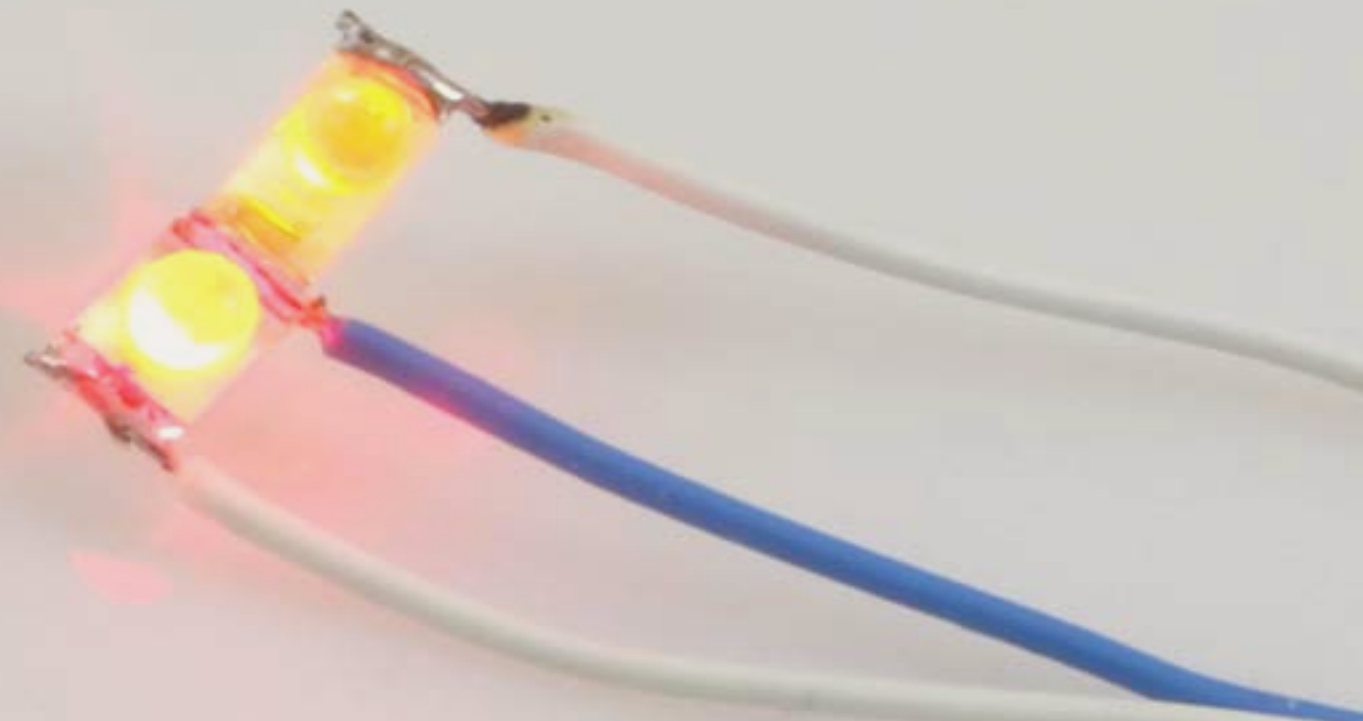


Figure 5

Figure 5: Common-anode LED made out of two SMD LEDs – lower (brighter) red and upper (dimmer) orange.

the light) sits in the (cathode) die cup. Common cathode is the simplest way to manufacture an LED with two colors. Two dies that emit different colors are placed in the same cup and connected to different anodes.

That's a problem for DCC installations because the decoder function outputs are connected to the cathode of an LED, not the anodes. To work with a decoder, a common-anode LED is required.

There are a few common anode LEDs, but they are rare. However, you can make your own by connecting the anodes of two SMD LEDs of different colors, as shown in figure 5. This is made of a red (lower) and an orange (upper) LED. Why would you want this

combination? I don't know! They were just colors that I had with similar packages in my stash! But this shows the concept.

As you can see in the photo, the two LEDs have different light levels when driven with the same (10 mA) current. Use different value resistors in series with each LED in the cathode (white) leads to compensate for this.

Polarity

You'll need to identify the polarity of your LED in order to wire it correctly.

The lead that connects to the DIE CUP is the cathode and should be connected to the negative voltage. With packaged devices or wired SMD units, this is traditionally the short wire. This

Text continues on page 41

LED Theory

Okay, let's get the boring part over. You may skip over this section for now, but I'll bet you'll be back here later to get a question answered.

1. LEDs are current-based devices. The light they generate depends on the current passing through them. They are NOT a linear device. An LED rated for 10 mA may produce 90% of its light at 5 mA. The amount of light you desire may be produced at 2 or 3 mA.

Control the current by placing a resistor in series with EVERY LED! See the body of the article on how to select resistor values.

2. LEDs are diodes. That means that current only flows through them in one direction. If you hook one up backward, it probably won't be damaged, but it isn't going to light up.

3. LEDs don't have large reverse voltage ratings. Don't use an LED as a rectifier.

4. Although the light produced by an LED depends on the current, an LED won't start conducting current and producing light until a certain voltage (called the "firing" voltage) is reached. Less voltage than that and you get no light. More voltage and they quickly go over-current and fail.

Each color has its own firing voltage ranging from about 2 volts for red to about 4 volts for ultraviolet. White LEDs usually need about 3 volts but that can vary, based on their design.

5. Don't connect LEDs in parallel. The firing voltage varies slightly between even identical devices. Placing multiple LEDs in parallel using a single current limiting resistor is a bad idea. The LED with the lowest firing voltage in the group will hog most of the current. Some LEDs with higher firing voltages may not even fire. Excess current will shorten the life of the lowest voltage LED. When it burns out (assuming it does not short in the process) the next lowest LED takes an even larger amount of current. You get the idea.

6 - LEDs emit a narrow band of wavelengths (color). Because white is a smorgasbord of colors, a single-wavelength device can never be white. Instead, the single-wavelength LED die is coated with a fluorescent material. When the LED shines on it, the coating lights up like a fluorescent lamp. The chemical makeup of the coating determines the color emitted.

The composition of the coating and the wavelength of the impinging light work together to set the color value. Since the firing voltage relates to the wavelength, white LEDs may operate anywhere from 2.8 to 4 volts.

Lots more theory is on my website (www.mrdccu.com/curriculum/Lighting/LED.htm).

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connects to the decoder function output (white wire, for example).

The other lead (usually longer) is the anode and connects to the positive voltage (blue decoder wire).

If you have an LED but can't tell which lead is the cathode or anode (often a problem with tiny SMD packages), there's hope. Connect a 2700 ohm resistor in series with a 9-volt battery or use the buzzer I mentioned in prior columns. Probe the LED with both polarities.

When the LED lights up, connect the pad or lead that is in contact with the positive side of the 9-volt battery to the blue decoder lead. The SMD LED video in the sidebar talks further about LED polarity.

Connecting LEDs

Connecting an LED with reversed polarity results in no light. Omitting a series (current limiting) resistor is likely to result in a very bright light, but only for a second or two. Either way, you put your LED at risk and may damage a decoder's function output. Do it right the first time and prevent damaged components.

The simplest way to limit the current flowing through an LED is to include a resistor in series with it. It makes no difference if the resistor is connected to the cathode or to the anode.

Folks have good reasons for putting a single resistor in the decoder's blue wire or a function wire. I've even seen

Hint for soldering tiny parts:

I refer to "tinning" in the LED wiring videos. This is a process where a bit of heat and solder are applied to a terminal or wire (or the soldering iron) to coat a surface with a thin layer of solder. A tinned surface is easy to join to another tinned surface. Just add heat.

installations where one resistor (smaller value) was placed in each wire. My preference, absent any other considerations, is to put a single resistor in the blue (positive) wire. But there is nothing magic in this, it's just my preference.

Use one resistor for each LED. Putting multiple LEDs in parallel connected through a single series resistor is not a good idea. See the LED Theory sidebar.

If you want several LEDs activated by the same function, and they all need the same current to achieve the brightness you desire, you may put them in series (until the total voltage drop gets close to the voltage output of the decoder) and calculate the resistor value with Ohm's law. This is an advanced technique for experienced installers. More about this can be found on my website (www.mrdccu.com/curriculum/Lighting/LED.htm).

What resistor to use?

The total resistance needed in series with a single LED can be calculated. However, I've created a table of total resistance (sum of all resistors in series with a single LED) vs. current flow for

A video showing how I add resistors to my standard bodied LEDs and apply shrink tubing to them.



This video shows wiring SMD LEDs and using Tamiya paint to adjust their color. Don't expect 100% success when working with these tiny parts – I always lose some physically and electrically. It's cheap insurance to buy extras.



Resistor Picking Table

Resistance	Current
750 ohms	11 mA
1000 ohms	8.5 mA
1500 ohms	6 mA
2100 ohms	4 mA
2700 ohms	3 mA
4700 ohms	2 mA

Table 1: Resistances vs current limiting, assuming a 14 volt DCC waveform.

a 4-volt LED, assuming a 14 volt DCC track voltage. Higher DCC voltage or lower LED voltage will increase the current slightly – just use one size larger resistor value from the table.

As you can see, 1000 to 1500 ohms will get you going with less than 10 mA current. With modern 10 mA rated LEDs, this resistor value will probably give enough light for your needs and keep LED operating life up in the tens of thousands of hours.

Resistors have no polarity, so it doesn't matter which lead is connected to the LED or the decoder. Power dissipation is low enough in all cases that 1/8-watt or SMD resistors are adequate.

Note that above 2100 ohms it takes significant increases in resistance to effect much change in LED current.

Some ultra-efficient LEDs are rated at 2 mA. With these LEDs, 4700 ohms would be a MINIMUM value.

Blue-box Athearn (HO)

One of my favorite LED installations is a blue-box Athearn diesel. Last month, I showed how to isolate the motor from the frame. Now for the lights. Refer to figure 6.

The LED is mounted “periscope” style above the rear power tab. The anode (long lead) connects to the track power through the tab. The cathode (short lead) connects through the dropping resistor to the yellow decoder lead. The LED leads and resistor are covered with heat-shrink tubing.

Connected this way, the LED is off for about half the time, due to the nature of the DCC waveform. You may want to use one value smaller resistor from Table 1 to restore brightness.

I used a 5 mm LED for this locomotive – it is the same price as a 3 mm, but it throws a wider beam.

I carefully adjust the LED height so that it is in line with the lens on the Athearn shell. Point it toward the rear when the truck is straight. The LED pivots a bit as the loco goes around corners, but not enough to show much light variation through the lens. Because of the distance between the LED and the lens, a golden-white LED works fine and gives good color rendition.

Atlas C-424 – sound (HO)

In figure 7, you get a look at a sound decoder installation in an Atlas C-424. The speaker takes a bit of the room normally used for the rear light.

So an LED assembly, built as shown in the LED wiring video, is taped on top of the speaker to shine through the rear lens. In this case, I used a 3 mm sunny-white LED, the customer's preference.

Atlas RS-1 – sound (HO)

Figure 8 gives you a peek at how I handled a sound installation in an Atlas RS-1.

In order to get the speaker in the rear of the loco, I needed to remove the Atlas light pipes which direct light to the end lights and the number boards. It was deemed a good tradeoff to forego the number board lights in order to have good sound in the loco.

A sunny-white 5 mm LED was glued into the shell in place of the light pipe, using the Faller Expert cement discussed in a prior column. The Faller Expert gives a nice optical surface instead of crazing the LED lens, as many styrene cements do.

The number boards could be illuminated by gluing SMD LEDs to them. Wire each front LED in series with an appropriate resistor and connect both resistors to a function output. Connect the rear LEDs to a different function output.

The loco used in the LED lighting effects video was done similarly to the one in figure 8.

Figure 6: Golden-white LED in an Athearn blue-box locomotive.

Figure 7: Atlas C-424 sound installation.



Figure 6



Figure 7



Figure 8

Figure 8: 5 mm LED as part of an Atlas RS-1 sound installation.

Figure 9: Kato RS-2 light pipe replacement.

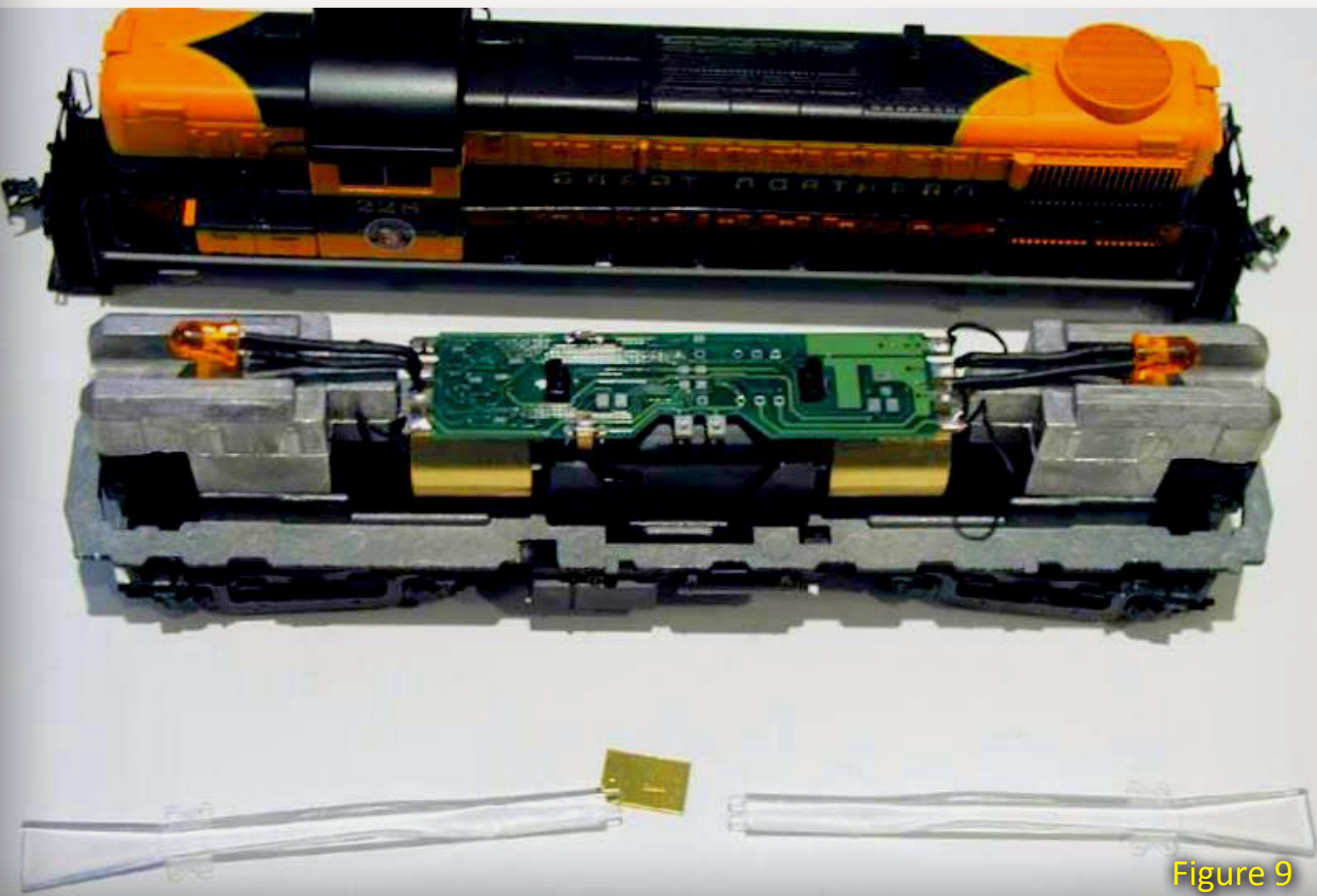


Figure 9

Early Kato diesel (HO)

The early Kato diesels had a gray light board with a bulb in the middle of the loco and light pipes to each end.

Here's an easy way to install directional lighting in them.

Remove the light pipes from the shell. If they are needed for lenses, cut them short and cover the end with Faller Expert cement to give an optical finish.

Install an Atlas light board style decoder. Now for the LEDs.

If you use a decoder like the TCS A4X or A6X, that have 1000-ohm resistors built-in, you can hook the LED to the correct terminals on the board. Observe polarity when connecting the LEDs and cover the leads with heat shrink tubing.

For decoders with track-voltage light outputs, (the majority of decoders fall into this category), follow the directions in the sidebar video to prepare an LED with a resistor. Stop before cutting the resistor or LED lead or installing shrink tubing. Position the LED where you want it to be in the final installation and then cut the LED lead to length. Cover it with shrink tubing and solder it to the decoder circuit board. Then cut the resistor lead to length, insulate it with heat shrink tubing and solder it in place.

Figure 9 shows the resulting installation in an RS-2, using golden-white LEDs.

Many LEDs in a shell

Earlier we talked about putting lots of LEDs in your locos. SP fans will want to take notice here – SP never seemed to meet a light it didn't like!

How do you keep the fuss to a minimum when you are operating lots of LEDs in the shell?

Steve Gill of Ulrich Models has come to your rescue. He offers a board for well under \$10 that can connect up to eight LEDs through resistors to the function outputs from your decoder. As you can see in figure 10, there are pads to connect to up to 8 functions and the blue wire at the top (inputs). The bottom

Figure 10: Ulrich Models' LED resistor boards.

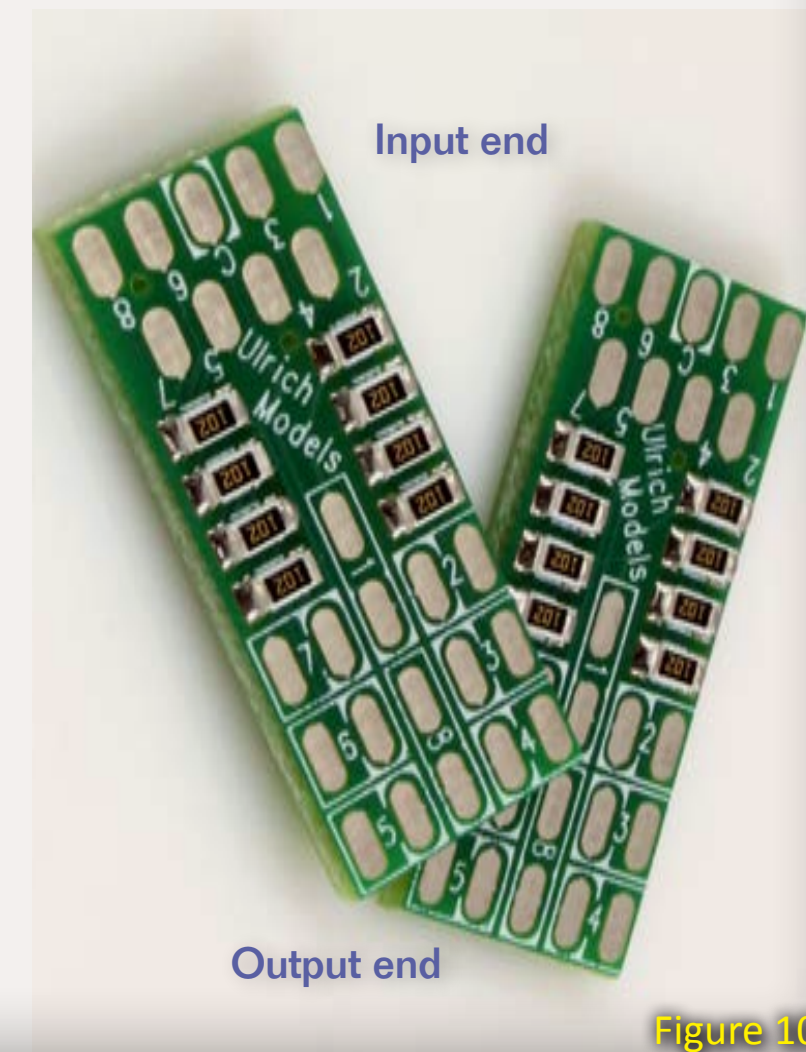


Figure 10

(outputs) connect to the LEDs. A single function can be connected to multiple inputs if you want several LEDs to be activated at once. Each LED will have its own series resistor.

The boards are available unpopulated, or populated with resistors of your choosing, for slightly more money.

See Steve's website (www.ulrich-models.biz/servlet/the-597/LED-Lighting-Resistor-Board/Detail) for more details and an installation photo.

Light pipes

What about the situation where you need to illuminate a light pipe with an LED? Figure 11 shows a light pipe for dual headlights with marker lights on each side of the loco. To illuminate all of these, a sunny-white LED is glued to the light pipe with Faller Expert cement.

Start by cutting the light pipe to the desired length.

Using a cutoff wheel in a Dremel tool, flatten the round nose of the LED. Don't

Figure 11: A LED glued to a light pipe with Faller Expert cement.

take off so much material that you get close to the die or wires inside the LED. Also flatten the end of the light pipe.

Cement them together with Faller Expert cement. Polishing the surfaces isn't required – the Faller cement creates an optical interface between the LED and light pipe.

After it dries, install it in your loco shell.

Summary

Okay, we've covered a lot of territory here, with a lot more on my website. You may need to go over this column several times, if this is new to you. If you are an old hand, perhaps you have seen something here or in the videos will that give you some new ideas or insight.

Let me know what you think of the videos – click on the [READER FEEDBACK](#) link and leave a message. Don't forget to register your vote for this column. Happy modeling!



Figure 11

Delrin to Styrene to Metal OH MY!



MicroBond Ultimate System Pack

Every adhesive you need to assemble the majority of kits with plastic/metal parts and etchings.

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[Contents](#)

[Index](#)