Lighting Structures with LEDs

Lighting up the night!

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by Ken Ferguson

Figure 1: Even with a significant amount of ambient light present, the LED lighting in 'Spud's Bar' is bright enough to illuminate the sidewalk.

LEDs are bright, run cool, have great energy efficiency, and last nearly forever.

I believe I have found the ultimate lighting device for model structures – the LED or Light Emitting Diode. Until a few years ago, LEDs were limited to the utilitarian task of indicating that your TV, stereo, or throttle was powered on. Early LEDs were limited to red, yellow or green. Today LEDs are available in virtually every color of the spectrum (including white and a warm white), plus you can easily control where and how much illumination is delivered.

By definition, an LED is a solid state device, a special diode that emits light when energized with a low voltage electric current. The heart of the device is a semiconductor that is encased in a clear epoxy cover with two power leads. When LEDs are on they produce virtually no heat and draw very little current. This means you can use very small gauge wire inside your buildings.

The Project

As a demonstration project for myself, I chose to build a turn-of-the-century structure dubbed - SPUD's Pool Hall & Bar. It's an off-the-shelf kit similar to DPM's "Skip's Chicken & Ribs" (figure 2).

My challenge was to provide controlled lighting in a gentlemen's bar decorated with several paintings and a mirrored wall. Showcasing the seamier side of the establishment, there is a long corridor leading to the pool hall in the back, where a green glow reflects off the felted tables. The second floor was to be a group of rooms for boarders, some of which were rented for as little as an hour at a time. The shadow on the window shade would tell only part of the story.

Construction

I used bright LEDs in this project - I mean really bright. You will be surprised at output of an LED versus a grain-of-wheat or other incandescent lamp. Before assembling the building, I gave the interior walls a paint job. The paint becomes a light block, preventing a "translucent glow" through the walls.


Figure 2

Figure 2: The future Spud's bar.


Figure 3

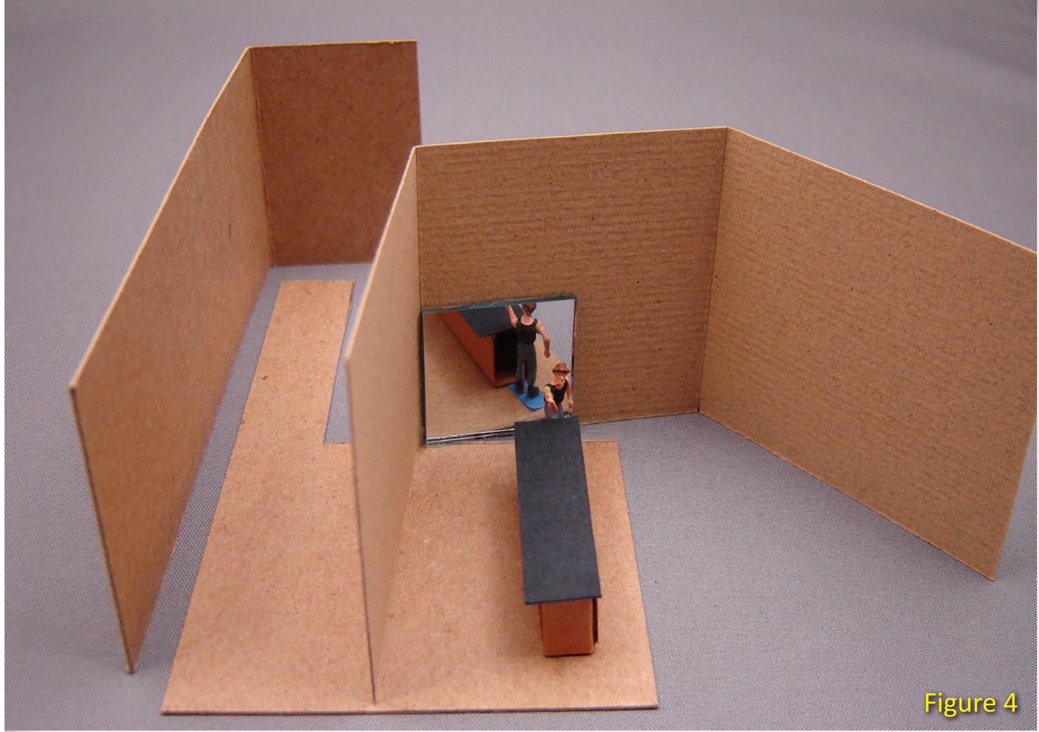
Figure 3: Matte board floor, cutting template, and interior paint

Two methods can be used to create this light block (figure 3):

- Craft-acrylic, black paint applied with a brush works just fine. Two or three coats will be necessary. I use this technique when there are a lot of windows and doors because it gives me better control of where the paint goes.
- Generic black automotive primer (in a spray can) works too. I use this method when there are a lot of surfaces with few doors or windows that might get an unintentional coat of paint from over spray. Again, I apply multiple coats to insure complete opaqueness.

At this point, I assembled and painted the exterior walls, sashes, and window sills before adding the window glazing on the interior.

Next, I traced the interior of the building on a scrap piece of matte board. This makes a mechanically solid floor for the building. When cutting the matte board floor, I intentionally left a void in the rear of the building. It occupies the space that will be the pool room and serves as a place for the



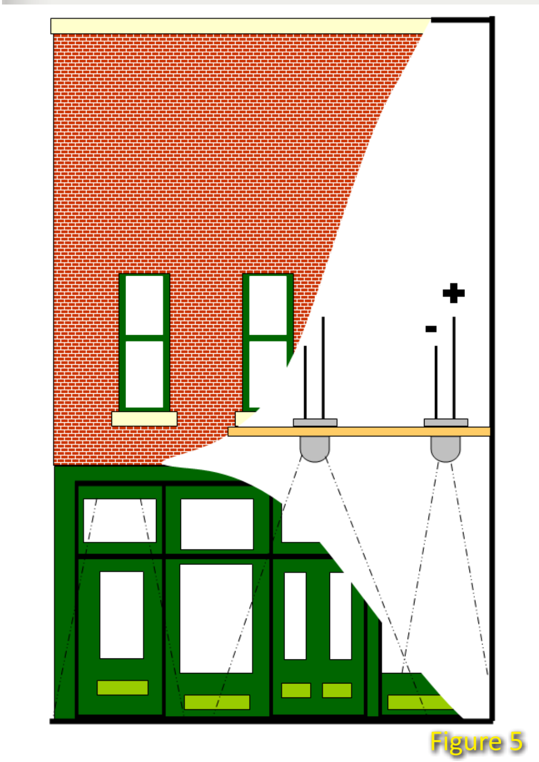


Figure 4: Textured paper floor, walls and bar.

Figure 5: Cut-away view of the matte-board upper floor with the LEDs installed.

Figure 6: The 'set' with patrons, paintings, mirror, and door installed.

wiring to enter the building. I saved a template of the floor as a pattern for when I'm cutting out the second floor and roof. Then I glued the first floor into the building. The seam between the walls and the floor needs a liberal coat of paint to prevent light leaks under the sides of the structure. Think of this as a form of caulking.

With those steps complete, I got to work on the "scene." When I was in college, I spent time in the theater group, so it was natural for me to construct the interior of the model as a miniature set.

I used the template to cut a piece of textured paper to size for the floor covering. I used heavy textured paper for the walls too. The wall height is critical for a couple of reasons.

- I didn't want the observer to see the lighting "instruments," so I made the ceiling as high as possible.
- To take full advantage of the characteristics of LEDs, I needed to have some distance between them and the objects below.

I chose an interior wall height that aligns with the bottom of the second floor window frames. The front wall of the building hides the LEDs.

Then, I positioned the bar, the paintings, and the people in the main room(figure 6). When I was satisfied with the arrangement, I glued the whole assembly together as a single unit, and glued it to the sub-floor.

Now the real fun began as I became the Lighting Director! I visualized the scene with both entrances having fairly strong warm light, to attract patrons. On the bar side, I wanted to highlight the "Ingres Odalisque" canvas (a painting that is so bad that art students actually study it for what NOT to do when painting the human form) behind the bar, and let the light get dimmer farther away from the bar for some privacy. The hall leading to the pool room would get progressively darker moving toward the back, with a very soft green glow at the end. The shades on the second floor would have a yellow incandescent blush.

The question now is, what LEDs would produce this mix of lighting effects?

Types of LEDs

Search the web and you'll find numerous LEDs available from a variety of vendors. I purchased mine from Super Bright LEDs www.superbrightleds.com. Their website has all of the information any modeler will need to select appropriate devices, plus a lot more information about LEDs in general.

There are five attributes that need consideration before placing an order: Size, color, lens color, luminous intensity, and viewing angle.

- SIZE - LEDs are manufactured in a variety of sizes and shapes for many different applications. For this project, I limited my choices to the 5mm (diameter) devices. A modeler in N scale might want to consider the smaller 3mm LED, but the selection is not as extensive.
- COLOR - Rather than go into a detailed technical explanation on color temperature and wave lengths, simply put, a white LED emits a brilliant white light that has a very slight violet overtone. A warm white LED emits a light that leans toward a very pale peach color. The rest of the color spectrum available includes a vivid blue, green, aqua, red, yellow, orange, and violet. On this project, I went with warm whites for the entrances, white for the painting, green for the pool hall, and yellow for the second floor.
- LENS - There are two options here - clear or diffused. The effect on the light output is analogous to a table lamp with a bare bulb, and the same lamp with a lamp shade on it. The diffused lens puts out soft omnidirectional light. With the exception of the green light in the pool hall, all of the other LEDs I used for this project have clear lenses and project beams.
- LUMINOUS INTENSITY - This is equivalent to the "wattage" of an ordinary bulb. Intensity is measured in millicandela (1/1000th of a candela, abbreviated mcd). The definition according to the Super Bright LEDs web site is, "Candelas are used to measure how much light is produced at the light source. The candela is the Luminous Intensity, in a given direction, of a source of monochromatic radiation of frequency 540 × 1012 hertz, that has a radiant intensity in that direction of 1/683 watt per steradian." More simply put, the more mcds, the brighter the light. But before making a decision based solely on output, the viewing angle must be considered. The desired lighting effect will be a combination of these two specifications.
- VIEWING ANGLE - Choices here range from 15° to 120°. A 360° viewing angle LED is also offered in another section of the web site, but all of the lenses are diffused, and color selection is limited to white, blue, green and red. How the viewing angle affects the light intensity is straightforward. In the LED manufacturing process, tiny reflectors are mounted behind the solid state junction that produces the light. Variations here determine how wide the emitted light beam will be. If you have a Maglite® flash light, you know that you can adjust the beam width by turning the barrel. The narrower the beam, the brighter the light looks. But, that is not really the case. The output of the bulb is the same regardless of the beam width - the perceived brightness is a function of how much area the light beam is covering. More area with the same light will appear dimmer.

In figure 7, the LED on the left is a white, 1500 mcd, 120° device. The one in the middle is a white, 2500 mcd, 45°, and the one on the right is a white, 6000 mcd, 18°. This demonstration shows the variations in intensity and beam spread. At a distance of 2", the narrow 18° device casts a beam that is about 3/4" in diameter. The medium 45° unit spreads out to about 1 1/2", and the 120° device casts a soft glow over 3" in diameter.

There were no options for intensity or angle with the warm white LEDs on my project. I did have several possibilities

Figure 7: LED comparison.

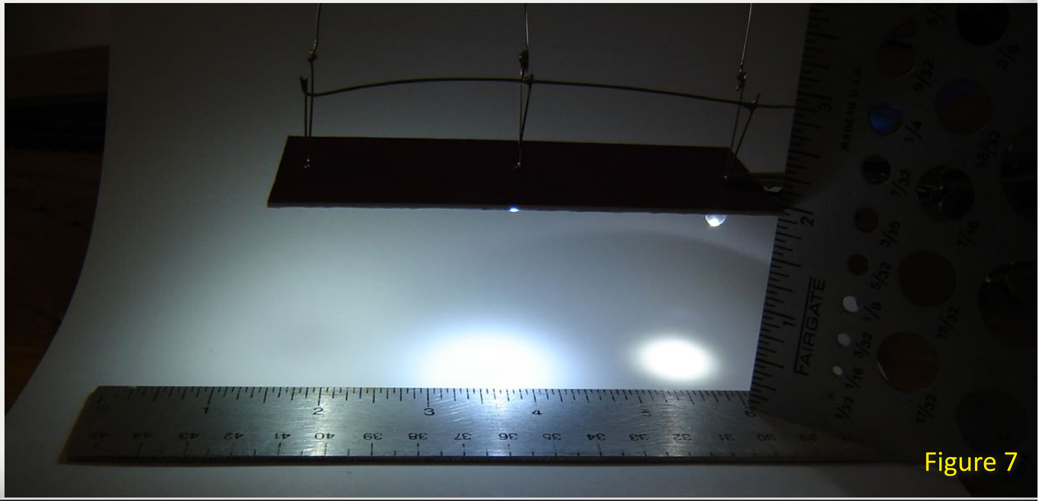


Figure 7

for the focused light on the painting behind the bar and I went with the 6000/18° device. The pool hall light is a diffused 2000/360° green. The lights on the second floor needed to be strong enough and tight enough to cast a hard shadow on the shade, but not so intense that they overpowered the ambiance on the ground floor. That selection was two yellow 3500/45° units.

So with shopping list in hand, I went online and placed an order. Super Bright LEDs shipped my order promptly. I liked that there was no minimum purchase. If an item is out of stock, it's not listed on their web site.

While waiting for the mail to arrive, it was time for me to return to construction mode. Using the template from the ground floor, I cut a full sheet of matte board without the wiring void in the ceiling. The piece should be tight enough that friction will hold it in place. Do not glue this in place as you WILL be taking this part in and out of the model several more times as the project progresses.

Next, I used a pencil to mark the LED location, on the underside of first floor's ceiling. I used a 4mm bit to drill the LED mounting holes. With a 5mm unit and a 4mm hole, the LEDs will fit snuggly into place without gluing.

I took a trip to Radio Shack to purchase a power supply and current limiting resistors. I opted to power my LEDs with a 12vdc source. LEDs will light with as little as 3.3 volts, but I chose a higher voltage supply to avoid issues of voltage drop in the wiring around the layout, as I planned to use the power supply for multiple buildings. I picked out a 1000ma, 1.5-12 VDC Universal AC Adapter (p/n 273-316) for about $19 from Radio Shack. This single unit will light a lot of LEDs, considering that each LED will typically draw about 20ma @ 12vdc.

My second purchase was a bulk pack of resistors. Generally, a 470 ohm resistor will work with most LEDs. But since this project entailed some experimentation, I selected the 100 piece, 1/4 watt fixed resistor assortment (p/n 271-308) for about $7.

Resistors have colored bands. Three indicate their resistance in ohms. A fourth band specifies tolerance (how close the component guaranteed to be to the specified resistance). The color code cipher is on the back of the pack.

For example, the color codes yellow, violet, brown, silver, means a resistance value of 470 ohms plus or minus 10% (423 ohms to 517 ohms).

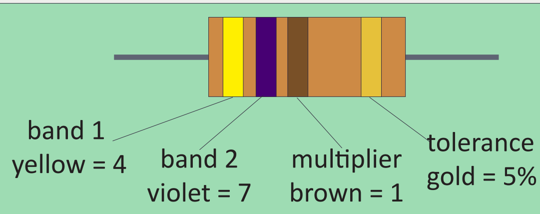
Back at home, I cut the plug off the output side of the power adapter and attached alligator clips to the wires. This makes testing the LEDs much easier.

Since we are working with DC, we'll need to determine which wire is positive and which is negative. This can be done with a voltmeter. If you don't have one, there is a simple work-around (figure 8). Take a 470 ohm or and clip it to one lead of the power source, and connect the remaining clip to either of the leads on the LED. Plug the adapter into an outlet. Touch the lead from the resistor to the unused lead on the LED. If it lights, you know that you have the correct polarity. Mark the alligator clip that ultimately connects to the LED's long lead as positive. Mark the alligator clip connected to the LED's short lead as negative.

My order finally arrived with my LEDs. I was pleasantly surprised that the variety of LEDs I purchased were individually packaged and labeled with the color, mcd, and viewing angle. This is a good thing because most LEDs look identical with no external markings.

Resistor Color Codes

0 - black	5 - green
1 - brown	6 - blue
2 - red	7 - violet
3 - orange	8 - gray
4 - yellow	9 - white
10% - silver	2% - red
5% - gold	1% - brown



Value = (band 1, band 2) * 10 $^{\text{multiplier}}$

$47 * 10^1 = 470$ ohms +/- 5%

NEVER connect a LED directly to a power supply without a dropping resistor - it will instantly burn out . . .

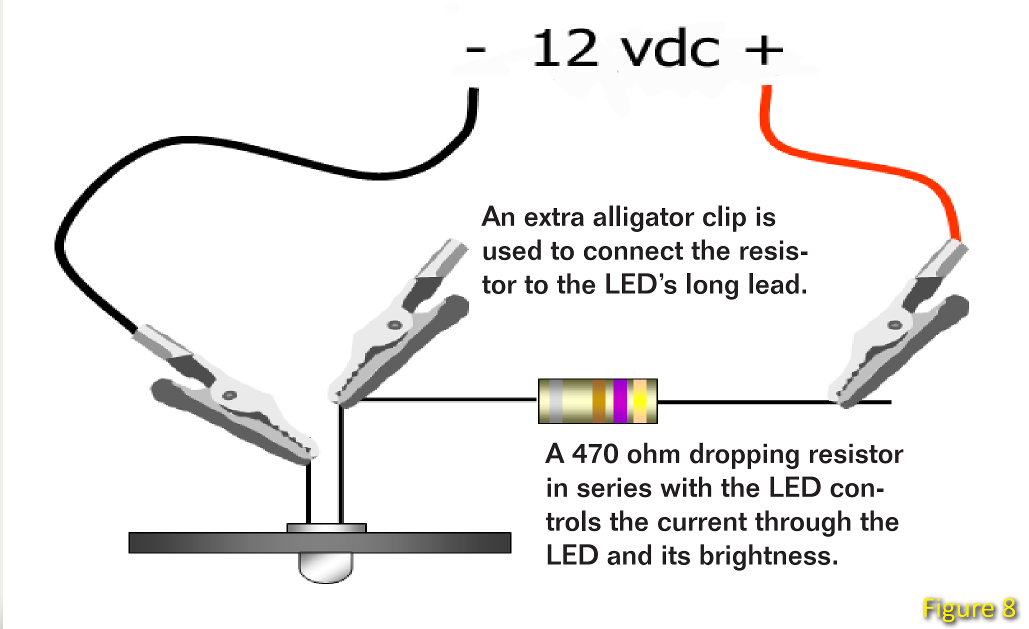


Figure 8: LED testing setup.

LED Handling Precautions

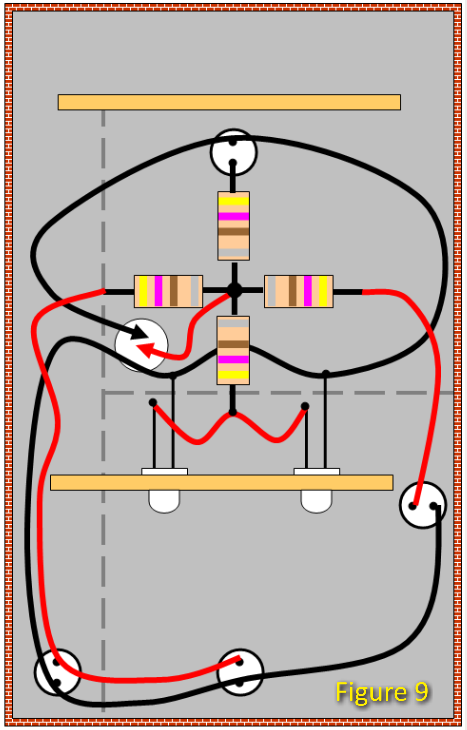
- **LEDs are static sensitive devices**. The static electricity shock you get when walking across a carpet and touching a door knob has a potential of several thousand volts. A mishandled LED may get fried. Pick up an LED by its shell, not by it's leads, if you're not grounded.
- **LEDs are heat sensitive**. When wiring the devices, solder for no longer than 3 seconds with 700° iron. Ignore this and your device becomes a burned out fuse.
- **LEDs are current and voltage sensitive**. ALWAYS use a resistor in series with an LED or LED array (more on this later.) Failure to do this can lead to the unintentional construction of a mini smoke generator on your pike.
- **LEDs are polarized devices**. Positive power to the positive lead, and negative to negative (through a resistor) produces light. With the power source leads reversed, the device remains very dark. The ANODE or positive contact is the longer of the two leads. The resistor in the circuit is not polarized so its orientation is not a concern.
- **LEDs can be mechanically abused**. If you need to form the leads, make the bend at least 3mm from the bottom of the LED.

I strongly suggest working with one color or beam width at a time.

Curb your desire to open any of the diode packs until you read and understand ***LED Handling Precautions***.

I started LED installation by removing the second floor from the building. I gently pressed the LEDs into the pre-drilled holes from the upper side of the floor/ceiling. LEDs have lips around their bases that will keep them from going completely through the hole. I oriented all of the negative leads (the shorter leg) toward

Figure 9: Wiring diagram. Red is positive, black is negative.



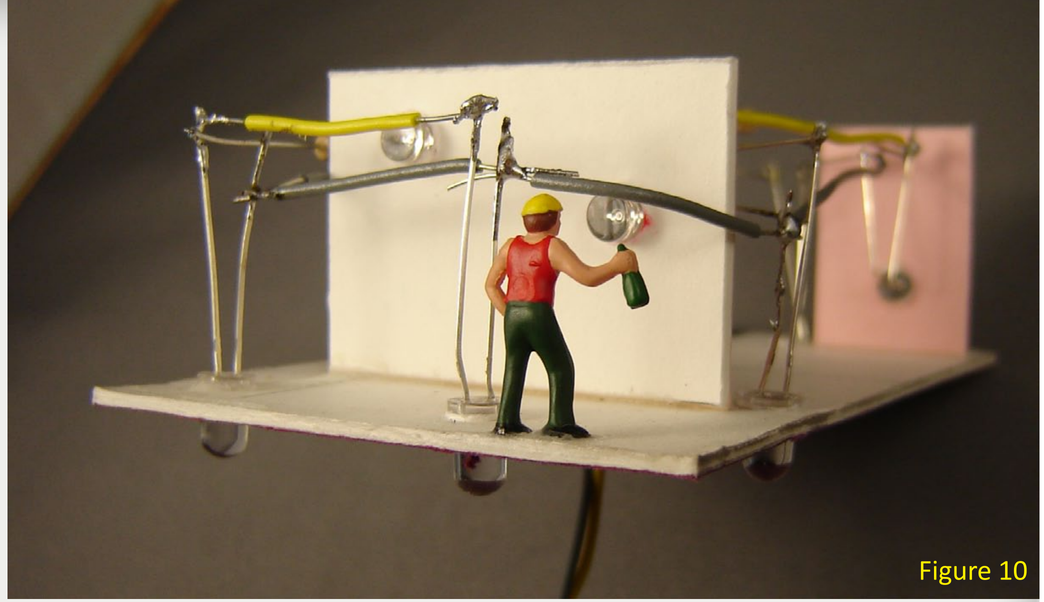


Figure 10: The figure that casts the 2nd floor shadow. The yellow LED is right in front of his face.

the exterior of the building. This will make wiring a bit easier (figure 9).

I began wiring by connecting LED's negative leads (short lead) together with #24 gauge black (for negative) wire. You could use wire as small as #30 gauge since the amount of current here is so low. I added one long black wire leading through the hole above the void on the ground floor for connection to the power supply.

Two or more LEDs can be connected in series (positive to positive) with a single resistor at the beginning of the chain. The Super Bright LEDs web site has a resistance calculator to help determine the resistor value for more than one LED in a circuit.

I used clip leads to connect a resistor between a LED (or set) and the positive power supply lead. Then I replaced the second floor and turned on the power.

If the light from those LEDs was too bright I increased the resistance and tried again until it seemed about right. When I'd picked appropriate resistors for each LED I soldered the resistors to the LED's positive (long leads) and connected the other ends of the resistors together and added a long red wire to connect to the positive power supply wire.

As you can see from figure 10, I glued two pre-drilled upright panels to the floor to hold the LEDs for the second floor windows. These panels also support the roof, so trim their heights accordingly.

The final step is to carefully cut a matte board roof and gently force fit it into place.

Figure 11 - Spud's in dimmed room lights. Note the different colors of light: green from the pool room, yellow upstairs, and white in the bar area.

Adjusting LED Brightness

Rather than having to substitute resistors for each LED in order to find the correct resistance for each LED's brightness, I'm building a 5 channel dimmer board (figure 12).

With this variable resistor bank, I can adjust each LED circuit independently by twisting the potentiometer (variable resistors) knobs. Once all the LEDs are brightness-balanced, I'll use a multi-meter (a device that measures voltage, current, and resistance) to measure the resistance across each potentiometer (and the common resistor!). Then I'll pick an appropriate fixed resistor to install permanently.

WARNING: The common resistor (shown in the lower left of figure 12) MUST be included. Otherwise if the resistors are twisted full off, that resistor will be connected directly across the power supply with no dropping resistor. Flash! Dead LED.

Wrap Up

Using LEDs for lighting really does offer an inexpensive way to make the interiors of all of your buildings "POP." The exciting part is that every modeler can become a budding Lighting Director, because now you can choose the colors and intensities of lighting to match the mood and themes of your layout.

Most buildings on a layout will not use as many colors, intensities, and beam widths as Spud's Bar. However, I have under construction I plan to light with LEDs. That will present some real challenges...flashing lights and more! ☑

By day Ken Feruson is an award-winning producer and director of TV commercials. He got started model railroading in 1954 when his dad brought home an HO Gilbert PRR switcher freight. He lives in northeast North Carolina with his wife Susan and has two grandkids who love his trains. His current layout is his third (and he claims his last).

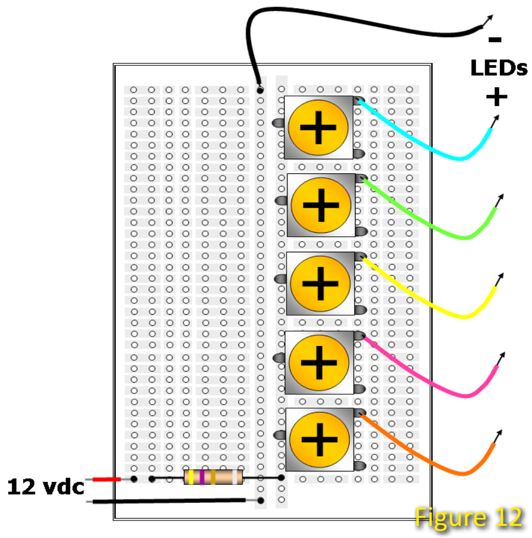


Figure 12 - Dimmer board example with five trim potentiometers used to set LED brightness.