LUTRON

Application Note #591
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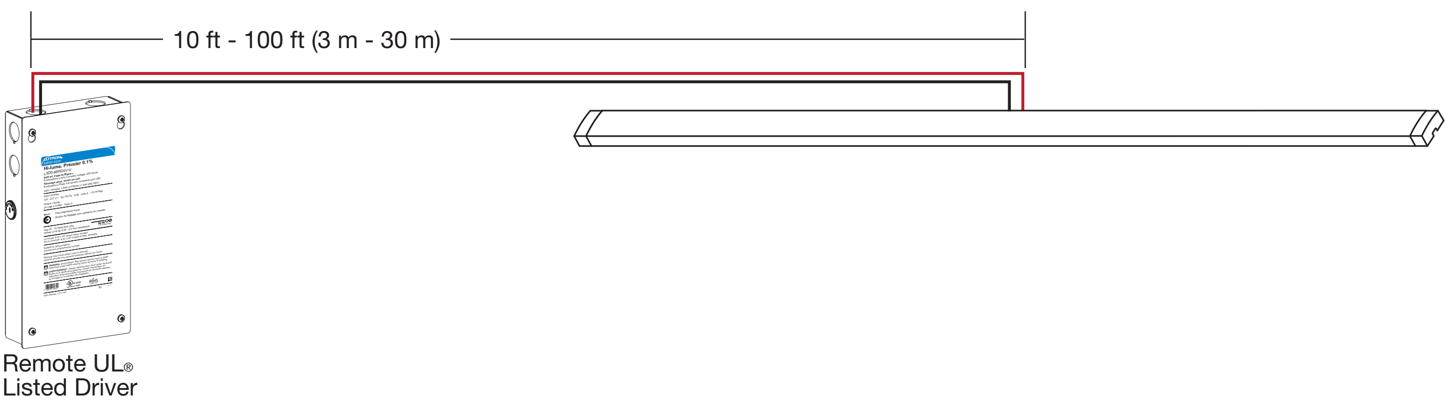
Best Practices for Voltage Drivers

Introduction

Constant-voltage loads present an opportunity for relatively quick and simple LED lighting installations. While these loads come in a variety of shapes and sizes, the market is dominated by 12 V⎓ and 24 V⎓ compatible strips of LEDs. This document will focus on 24 V⎓ loads for use with the Lutron Hi-lume Premier 0.1% Voltage Driver, but the recommendations and lessons learned can be applied to other Pulse Width Modulation (PWM) voltage drivers and their loads. This includes Hi-lume 1% voltage drivers and PWM voltage drivers from other manufacturers.

Linear LED strips designed for DC constant-voltage control are commonly used in accent applications such as under cabinets, cove ceilings, pathway lighting, and/or decorative fixtures. They are also increasingly being applied to general illumination in the form of thin linear pendants and recessed fixtures. To reduce the overall feature size of the fixture, most linear LED applications are powered by an LED driver that is installed remotely from the fixture. A typical installation is illustrated below.

Figure 1. Typical Voltage Driver Installation



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Best Practices Summary

1. Keep the driver as close to the load as possible.
2. Make all wire runs the same length.
3. Use the largest wire size available.
4. For loads that must be split at the end of a run, split the loads evenly.
5. Minimize connections between the driver and the load.
6. Use high-quality, low-resistance connections and splices.
7. Please see the specific product installation guide at www.lutron.com for other troubleshooting tips.

Quick Fix Guide

Solutions to common installation issues.

Problem 1: When using one driver with several homeruns, one load is dimmer than the other at low-end.

Answer: If you are using one driver with multiple loads on it, you should review the installation best practices on **Page 7** and ensure your installation is optimized.

Problem 2: When dimmed to low-end on multiple drivers, one driver seems to be dimmer than the other.

Answer: For Hi-lume Premier 0.1% drivers, locate the dimmest driver and turn the field adjustment knob clockwise until the light output matches the low-end light output of the brightest driver. Repeat for all drivers except the brightest.

For other drivers, equalize the lead length and load wattage among the drivers or increase the low-end trim on the control.

Problem 3: I am using a digital control and the Soft-on, Fade-to-Black feature no longer appears to work.

Answer: For Hi-lume Premier 0.1% drivers, ensure the field adjustment knob is fully turned counter-clockwise or properly adjusted per **Problem 2**.

Problem 4: I am dimming two drivers on the same 3-wire control and one of them has dead travel at low-end.

Answer: Set the low-end trim **of the dimmer** to the point where both drivers are responding at low-end. Then, use the field adjustment knob on the drivers to ensure that the light intensity matches at low-end.

Problem 5: When operating below high-end, the LED load has an audible buzz.

Answer: Check the load for capacitors as illustrated in the section on **Load Selection**. Fixtures with extra capacitance will often exhibit an audible buzz. In some instances, LED fixtures installed with magnets close to the LED tape can result in audible buzzing. If this occurs, please contact the fixture manufacturer for alternate mounting methods.

Load Selection

In remote driver applications, the installer must often choose the combination of driver and LED loads to be used. This is different than in the traditional line-voltage powered fixture application and therefore presents an opportunity for problems. The electrical characteristics of the LED load must be considered along with more traditional characteristics: lumen output, light quality, etc.

Some loads are generally incompatible with Pulse Width Modulation (PWM)* dimming DC voltage drivers. Their use can result in poor dimming performance, high acoustic noise, and/or reduced load/driver lifetime. For instance, some low-voltage loads are designed for use with ELV and MLV transformers. They may have the same 12 V or 24 V rating, but are designed for an AC input instead of DC.

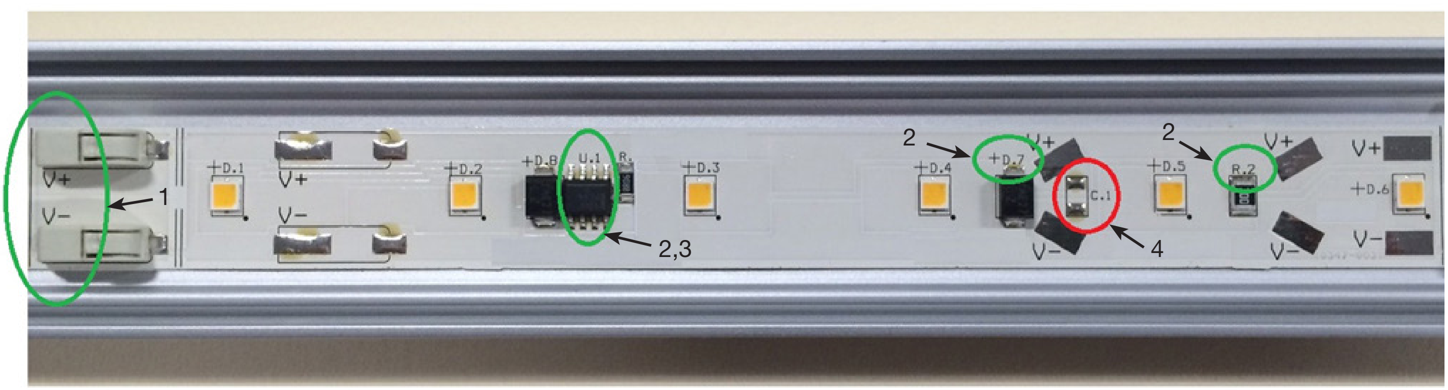
For use with Lutron voltage drivers, please ensure that the load meets the following minimum criteria:

1. Proper nominal voltage which matches the V_{out} or U_{out} rating on the driver label. Typically “24 V” or “12 V”.
2. DC voltage rated. Typically “Vdc”, “VDC”, or “V⎓”.
3. PWM Dimmable

Within loads that are generally compatible with PWM dimming DC voltage drivers, there are variations that may affect the performance that is achieved. Some loads will be more resilient to installations that differ from the recommendations explained in this guide. In general, linear regulator based loads will provide the most uniform light output.

Below are the general classes of low-voltage DC LED loads with their defining characteristics. Problematic characteristics are identified in red. These are general guidelines for making informed decisions regarding loads. As with most LED applications, it is always best to test the entire application before permanent installation.

Figure 2. 24 V⎓ Linear Regulator LED Load (Preferred)



Key Characteristics (Green):
1. Only two input terminals (e.g. V+, V-)
2. Ususally have only one IC per section (e.g. U1)
3. Reference Designators tend to only be “U” (ICs), “D” (Diodes), or “R” (Resistors)

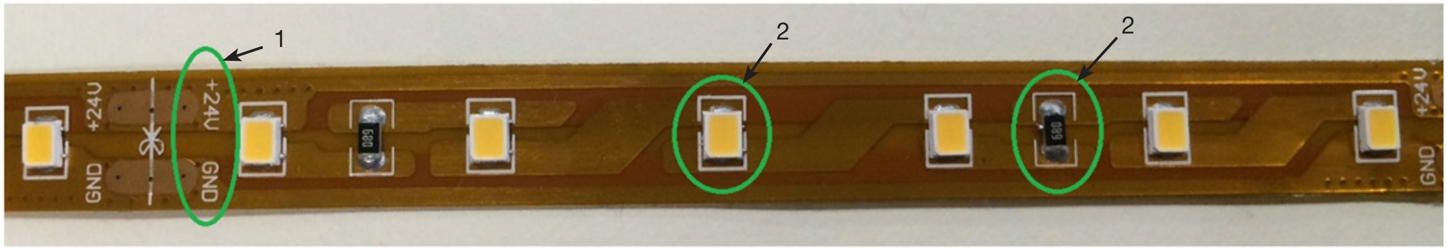
What to Watch Out For (Red):

4. Ensure there are no capacitors (e.g. if C.1 were placed)

* See Application Note #360 (P/N 048360) at www.lutron.com for more information on PWM drivers.

Load Selection *(continued)*

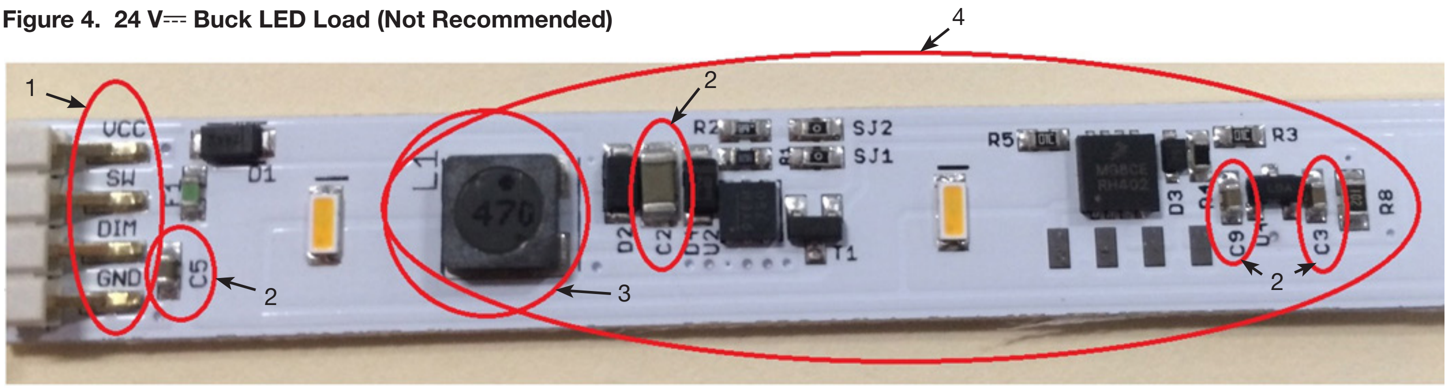
Figure 3. 24 V⎓ Resistor Ballasted LED Load (Acceptable)



Key Characteristics (Green):

1. Only two input terminals (e.g. +24V, GND)
2. Only LEDs and Resistors

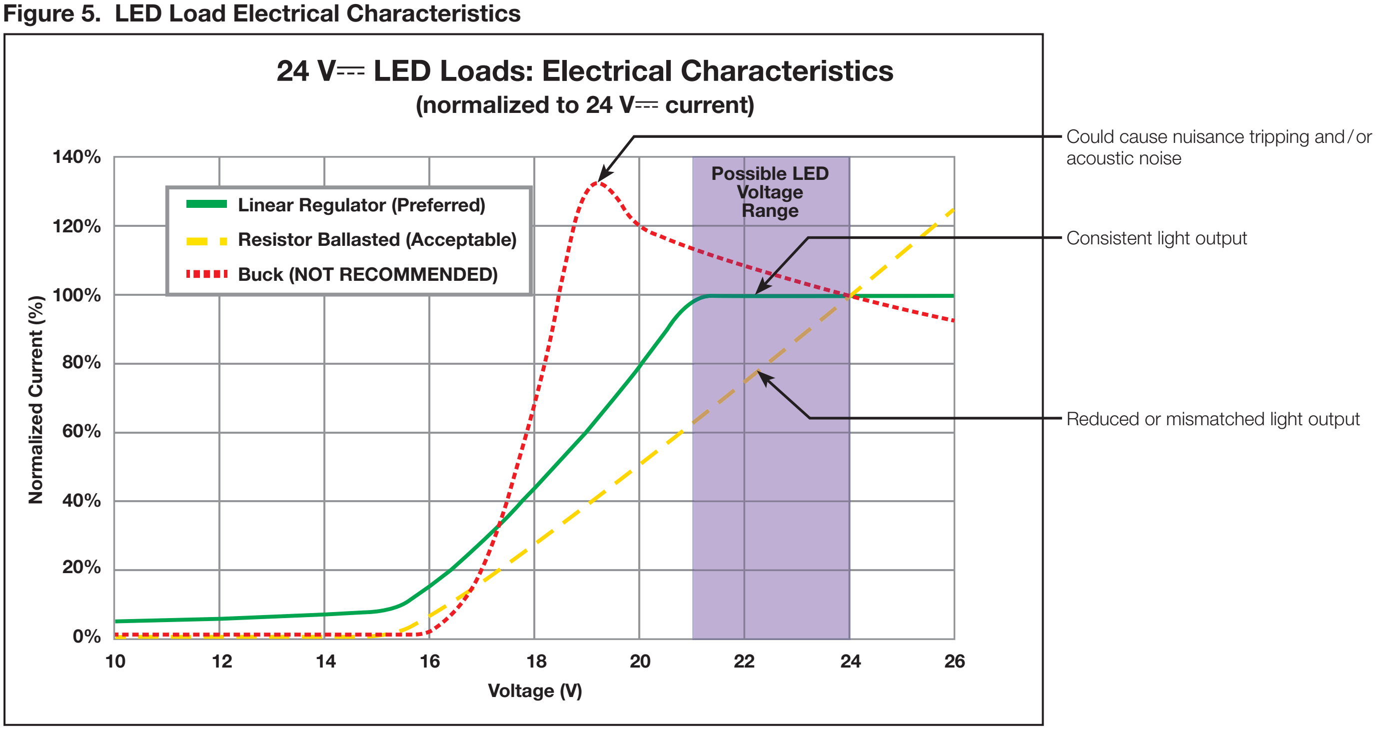
Figure 4. 24 V⎓ Buck LED Load (Not Recommended)



What to Watch Out For (Red):

1. More than two input terminals (e.g. SW, DIM)
2. SMT Capacitors (e.g. C5, C2, C9, C3)
3. SMT Inductors (e.g L1)
4. Generally more parts and complexity

Figure 5. LED Load Electrical Characteristics

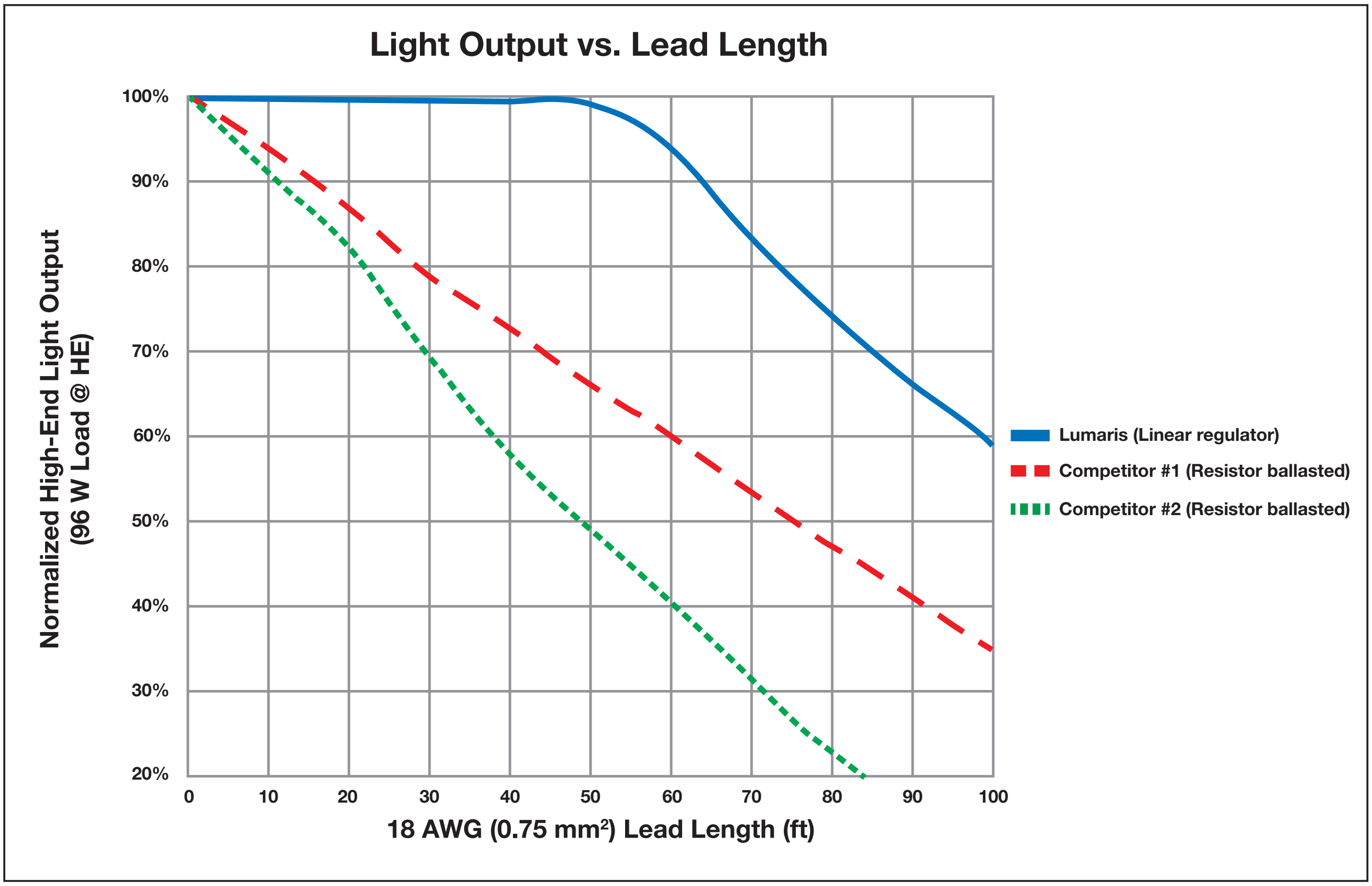


Installation Challenges

Remote installation of the driver creates a number of challenges that can be addressed through careful installation and wiring practices. One of these challenges is mismatched light output caused by long wire runs between the driver and the fixture.

The graph below shows the normalized light output per linear foot of the Ivalo Lumaris fixture as well as two competing products. The graph shows that as the lead length is increased there is a change in maximum light output. It also shows that each load responds differently to the increased lead length. This non-ideal situation can create unwanted aesthetic results, such as reduced or mismatched light output, if not considered carefully during the planning phase. For best performance, careful planning of the installation and space layout must be completed.

Figure 6. Light Output vs Lead Length

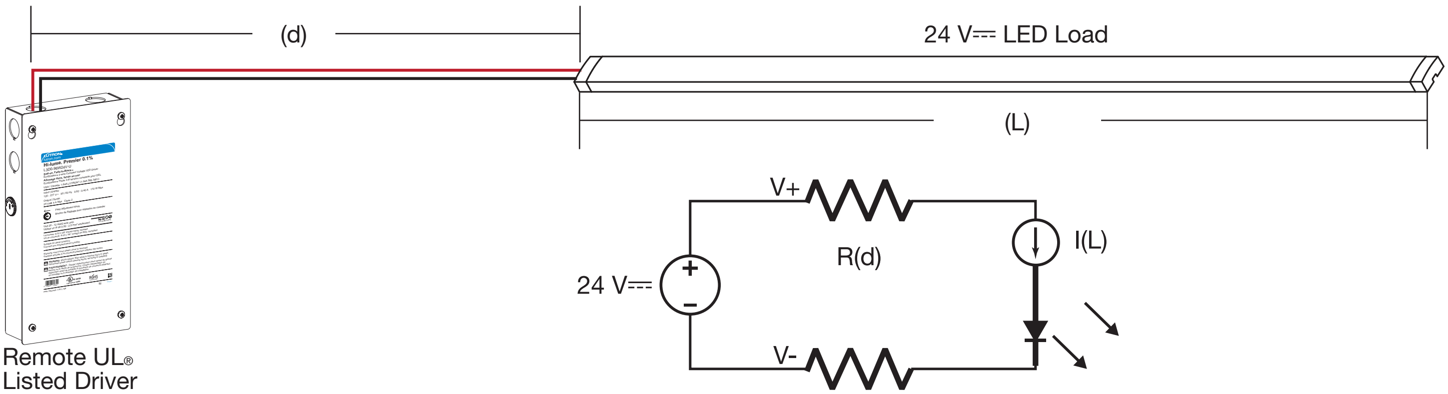


Mismatch Detail

To understand this behavior we must consider the system in a bit more detail. As a first order, the installation illustrated above can be modeled by a simple electrical circuit. In this circuit, the wire represents a resistor with a value that is a function of its length. As the lead length goes up, the resistance goes up and thus the more voltage will be dropped in the wire.

Mismatch Detail *(continued)*

Figure 7. Typical Voltage Driver Installation with a Simplified Circuit Model

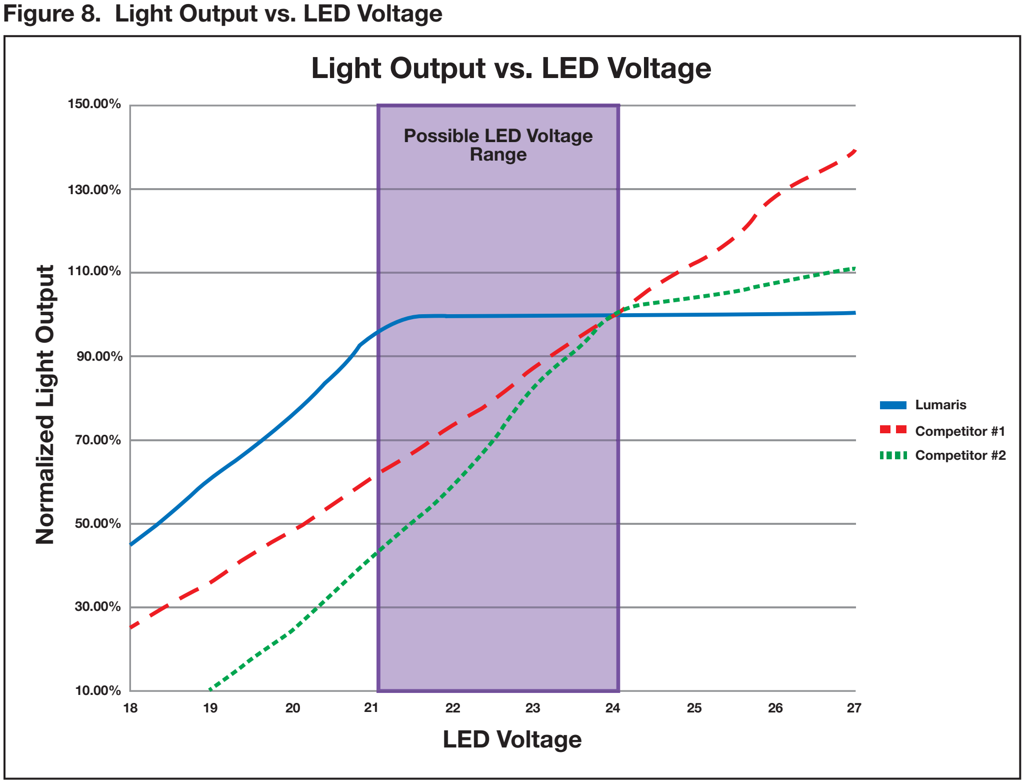


The voltage drop in the wire can impact the light output of the LEDs. LEDs are very sensitive to changes in voltage. This is shown in the graph below. The same three fixtures as before were compared with different voltages applied to their input. The highlighted purple area shows the range of voltages that are likely to be seen at the LED fixture due to voltage drops between the driver and LED fixture. The voltage dropped in the load wires is a function of three critical variables:

1. Lead Length (Longer Wires = More Voltage Drop = Less Light Output)
2. Load Wattage (Higher Wattage = More Voltage Drop = Less Light Output)
3. Wire Gauge (Smaller Wire = More Voltage Drop = Less Light Output)

In these low-voltage DC applications, the output current of the driver can be up to 4 A. In addition to the wiring lengths, it is important to consider all of the connections between the driver and the load. Minimize the number of spliced connections in the wiring, and only use high quality, low-resistance connections.

Figure 8. Light Output vs. LED Voltage



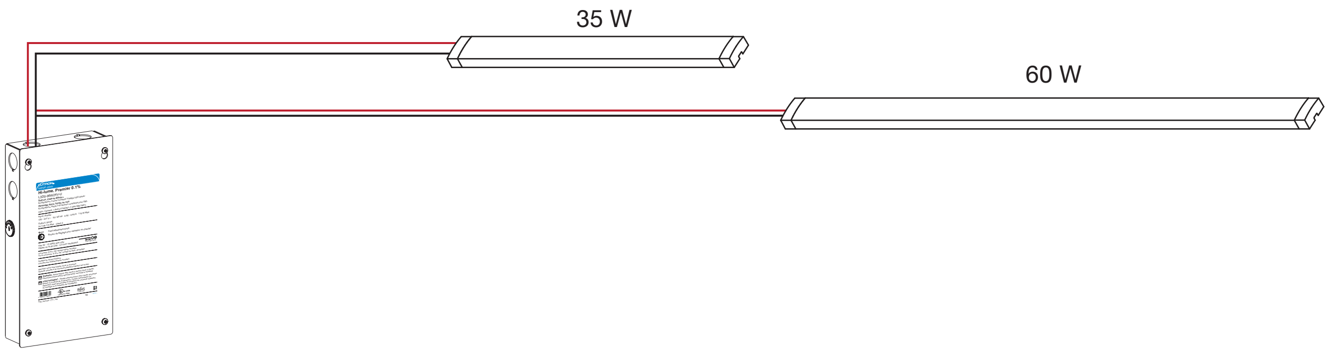
Best Practices

Installers should always refer to the fixture manufacturers recommended installation guide. However, here are a few general recommended practices.

1. Always attempt to minimize the length of the wire run.
2. Use the largest wire diameter (lowest wire gauge number) available.
3. Split the load into short matched segments.
4. Ensure the wire length between the driver and the load is the same for all load segments.
5. Minimize splices and connectors between the driver and load.
6. When necessary, use high quality, low resistance splices and connectors.

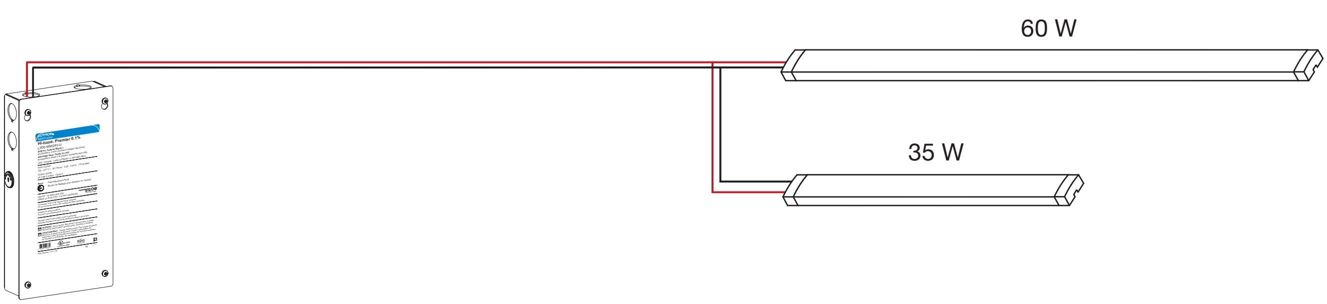
Worst Practice:

- Mismatched loads on mismatched lead lengths



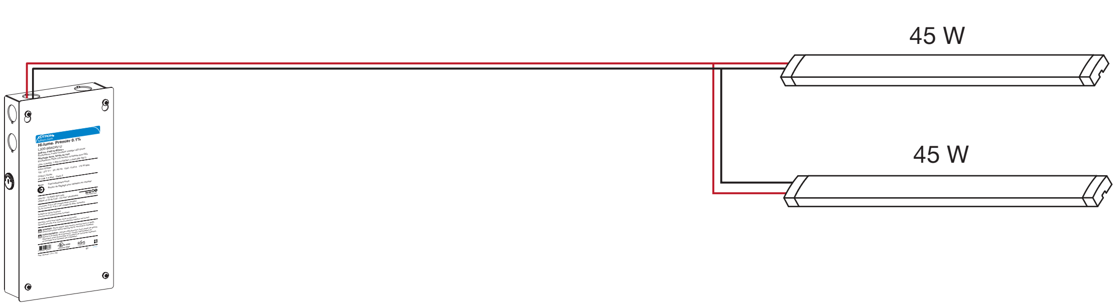
Bad Practice:

- Mismatched loads T-tapped off of a single home run



Better Practice:

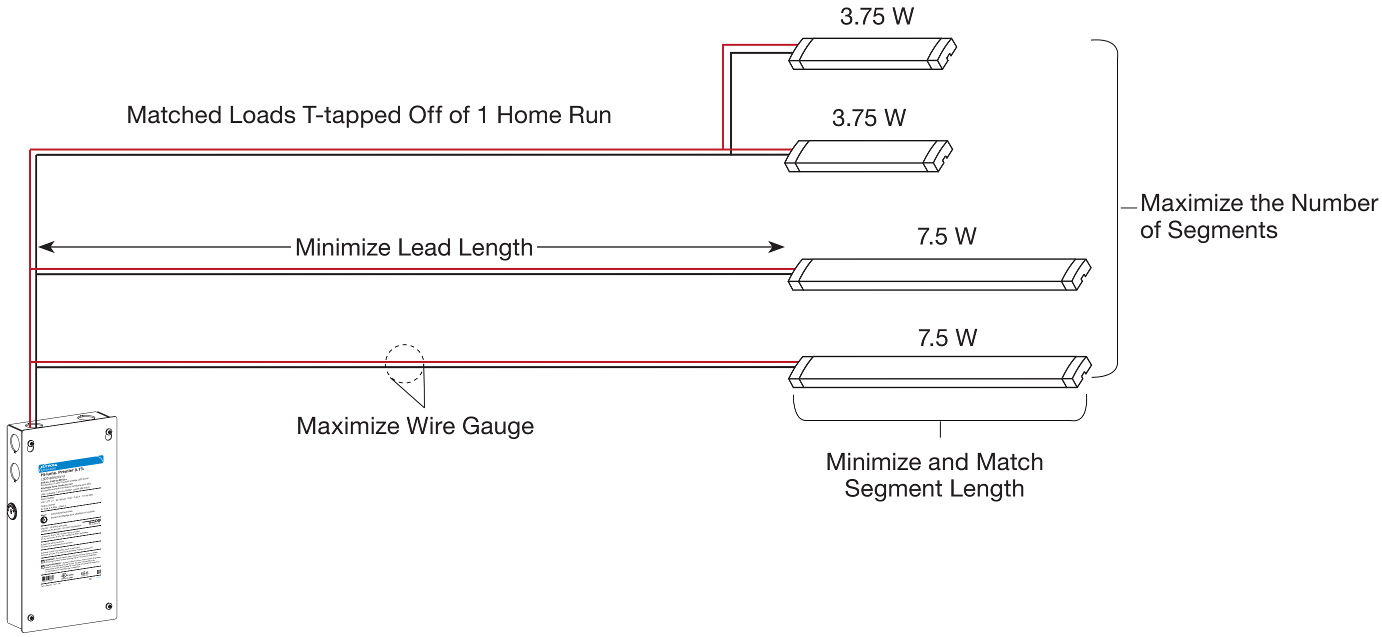
- Matched loads T-tapped off of a single home run



Best Practices *(continued)*

Best Practice:

- Use the shortest lead length possible
- Use the largest wire gauge possible
- Divide the load as equally as possible per home run
- Use as many home runs as possible (load should be equal)
- Keep the load length as short as possible to improve the light uniformity across the fixture
- Keep within the maximum continuous wire run spec of the chosen LED driver

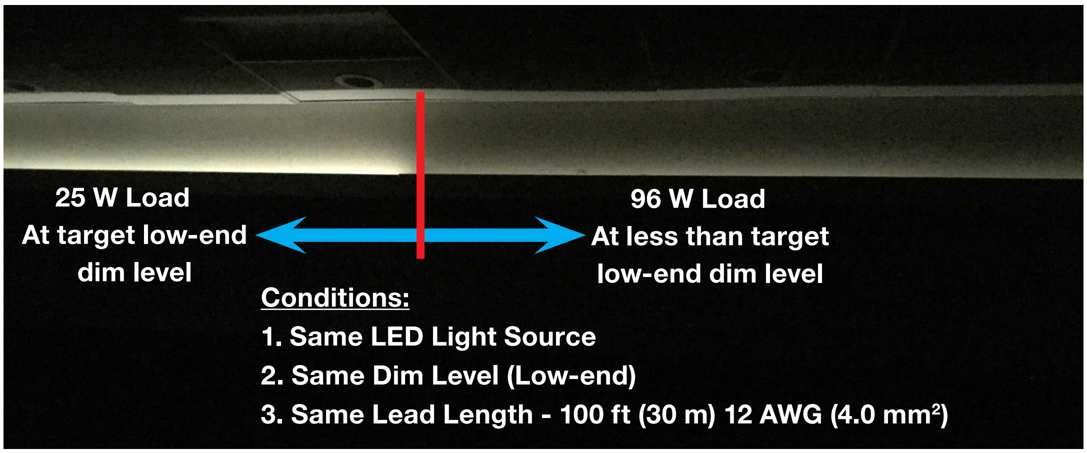


Multiple Driver Installations

In applications where multiple drivers are required for long runs of linear LEDs, additional considerations must be taken to optimize low-end performance. In many cases variations in loading and lead length cause the low-end light levels of multiple drivers to appear significantly different. This is shown in the photograph below. The recommended practices to minimize mismatch in this application are:

1. Divide the load up equally between each driver.
2. Use the same lead length of wire for each driver.
3. Use digital controls, such as EcoSystem controls, for optimal matching.

Figure 9. Mismatched low-end light output due to not following best practices

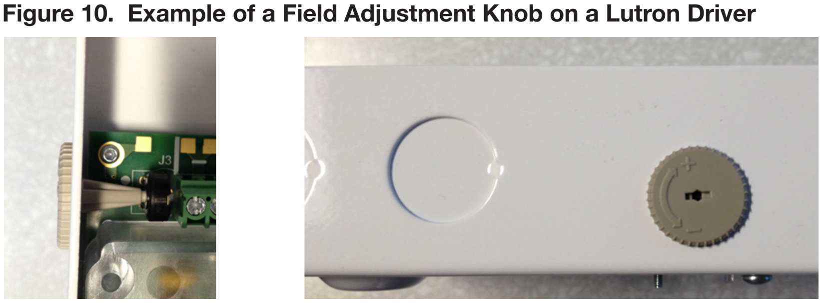


Drivers with a Field Adjustment Knob

If the above recommendations are not followed or are insufficient to resolve the light intensity mismatch at low-end, some drivers feature a field adjustment knob to allow installers to visually match the drivers at low-end. This knob is shown in the pictures below. The factory default is turned fully counter-clockwise. Rotating the knob clockwise will increase the low-end light level of the driver. To obtain best performance, please follow these steps:

1. Ensure knobs on all drivers are in the full counter-clockwise position.
2. Set the control to the lowest light level.
3. Turn knob clockwise to adjust the light output to match the brightest driver.
4. Repeat steps 2–3 for the remaining drivers.

Figure 10. Example of a Field Adjustment Knob on a Lutron Driver



NOTE: It is important to note that adjusting this knob too much or in installations where it is not needed can have undesired effects on the performance of the Soft-on, Fade-to-Black feature. Only use the knob as a compensation tool to increase light output up to the target low-end when the application has caused diminished light output. To trim the low-end above the rated low-end, use either the dimmer trim setting or the system low-end trim feature to increase the minimum light level.

3-Wire Control Installations

For 3-wire controls the trim setting of the dimmer must also be considered. To achieve the ideal performance, all recommended installation practices should be followed. Additionally, 3-wire controls should be tuned in a particular order.

1. Install the dimmer and all drivers to be controlled.
2. Set dimmer to low-end (LE).
3. Let the dimmer sit for 5 minutes (to reach thermal equilibrium).
4. Set the dimmer low-end trim to the point where all drivers are responsive to changes in the trim setting (see example of a dimmer low-end trim below).
5. Once the dead travel has been removed from all drivers, use the field adjustment knob to make each load match at low-end (Hi-lume Premier 0.1% drivers only).
6. **This process may result in the low-end of the driver being more than the minimum achievable light output of the driver.**
7. **Digital controls such as EcoSystem controls are the best way to guarantee low-end matching on multiple drivers on the same control.**

Figure 11. Example of a Dimmer LE Trim Wheel

LE Trim Wheel

Summary

Low-voltage LED installations provide an opportunity to illuminate spaces in new and unique ways not previously possible. By remotely locating the AC-to-DC LED driver, the fixture size can be greatly reduced. However, along with this flexibility comes increased risk of compatibility problems or installation problems. The best practices provide guidance for installations with Lutron voltage drivers. The wiring best practices are based on the physics of remote-mounted PWM voltage drivers, and are not unique to Lutron drivers.

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Lutron Contact Numbers

WORLD HEADQUARTERS
USA
Lutron Electronics Co., Inc.
7200 Suter Road
Coopersburg, PA 18036-1299
TEL: +1.610.282.3800
FAX: +1.610.282.1243

support@lutron.com

North & South America
Customer Assistance
USA, Canada, Caribbean:
1.844.LUTRON1 (1.844.588.7661)
Mexico:
+1.888.235.2910
Central/South America:
+1.610.282.6701

EUROPEAN HEADQUARTERS
United Kingdom
Lutron EA Ltd.
6 Sovereign Close
London, E1W 3JF United Kingdom
TEL: +44.(0)20.7702.0657
FAX: +44.(0)20.7480.6899
FREEPHONE (UK): 0800.282.107
Technical Support: +44.(0)20.7680.4481

lutronlondon@lutron.com

ASIAN HEADQUARTERS
Singapore
Lutron GL Ltd.
390 Havelock Road
#07-04 King's Centre
Singapore 169662
TEL: +65.6220.4666
FAX: +65.6220.4333
Technical Support: 800.120.4491

lutronsea@lutron.com

Asia Technical Hotlines
Northern China: 10.800.712.1536
Southern China: 10.800.120.1536
Hong Kong: 800.901.849
Indonesia: 001.803.011.3994
Japan: +81.3.5575.8411
Macau: 0800.401
Taiwan: 00.801.137.737
Thailand: 001.800.120.665853
Other Countries: +65.6220.4666

Lutron Electronics Co., Inc.
7200 Suter Road
Coopersburg, PA 18036-1299 U.S.A.
P/N 048591 Rev. C 11/2022