

0-10V Dimming: A Technical Guide

Overview

0-10V dimming is the most widely used dimming protocol for commercial lighting installations. The systems are predictable and reliable and generally require minimal maintenance. A complete 0-10V dimming control system includes a control interface, one or more light fixtures that support 0-10V dimming and a dedicated control wire pair that connects the 0-10V dimmer controller to the light fixtures. Power control to the fixtures may either be integrated into the dimmer itself or be managed by a separate power control system.

This article explores the basics of how a 0-10V dimming circuit works in a source/sink relationship, the overall system including driver and dimmer and a basic understanding of dimming curve characteristics. It also covers application considerations for implementing 0-10V dimming, and common problems encountered in 0-10V dimming applications.

0-10V Dimming Operation

Within a lighting fixture, the 0-10V dimming control of the fixture is a result of the LED driver and its 0-10V control leads connected to an external 0-10V dimmer. The dimmer can be either a wall 0-10V dimmer switch or a lighting panel control system and the connection is made using an additional pair of wires that connect to the driver. The 0-10V dimming leads are color-coded violet and pink (+DIM and -DIM, respectively). Earlier implementations may have a gray wire for the -DIM lead.

The need for dedicated control lines is one of the main reasons why 0-10V dimming is uncommon in residential applications, which typically only have 120V connections to wall box dimmers and light fixtures.

For general illumination applications, 0-10V dimming control is defined in ANSI C137.1, which describes a current source/sink relationship. The LED driver in the fixture is defined as the device that supplies the current (current source) and the dimming control device is defined as the current sink, meaning the LED driver provides current to the 0-10V dimming control.

Simplified 0-10V Dimming Circuit

Since the current is sourced by the LED driver, a circuit is designed into the driver to source the appropriate amount of current. The circuit can be designed in many different ways including using both discrete components or utilizing integrated circuits designed specifically for 0-10V LED driver dimming applications.

Figure 1 is an illustration of a simplified 0-10V dimming current source circuit in the driver and its connection to a 0-10V wall dimmer. In the system shown in Figure 1 the driver is the source of current in the dimming loop, as a 10K ohm pull-up resistor connects +DIM to 12V which is produced in the circuit of the LED driver. Current then flows from the driver through the 0-10V dimmer. POT can be thought of as the slider on the dimmer.

The voltage produced at +DIM is sensed by a circuit component, such as U1 and the output current of the driver into the fixture's LED load is proportional to voltage V_{+DIM} . If +DIM is disconnected from the dimmer (or POT is set to a maximum) then the load voltage sensed by U1 will be at a maximum, and if +DIM is shorted to -DIM (or POT is set to a minimum), the voltage sensed at U1 will be a minimum. This particular circuit produces a maximum of 1.2mA when the dimming lines are shorted.

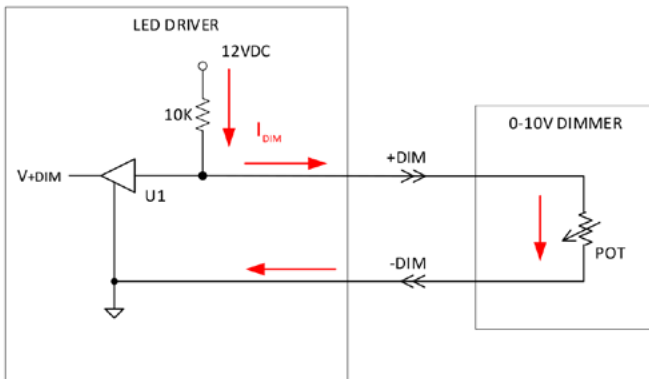


Figure 1 Basic 0-10V Dimming System

0-10V Dimming Curves

A typical LED driver's output current vs 0-10V dimming voltage can be seen in Figure 2. The reference curve is for a 1.05A constant current LED driver. In this implementation, the relationship between the +DIM voltage and the fixture's LED driver output current is linearly proportional. The LED driver's output current reaches a maximum near 10V (near the maximum +DIM voltage and a proportionally high dimmer resistance). Likewise, the driver's output current is at a minimum when the voltage at +DIM is near 1V, which occurs with a very low dimmer impedance.

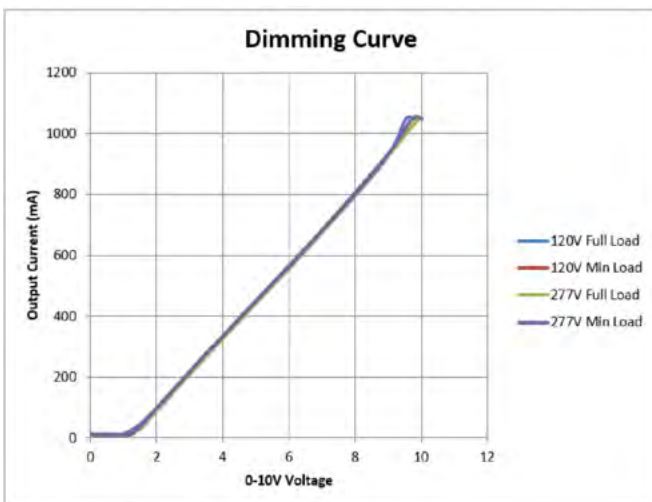


Figure 2 Typical 0-10V Dimming Curve

In addition to a linear dimming profile, some programmable drivers also include the ability to install a logarithmic dimming profile instead. Since the human eye is much more sensitive at lower light levels this is designed to 'linearize' the human perception with respect to the dimming device. This type of dimming curve can be seen in Figure 3.

One problem encountered in 0-10V dimming applications is when drivers on the same dimming circuit have different programmed settings. For example, one driver may have a 10% minimum output current while other drivers may have 1% minimum output. It is important that the programmed parameters are the same for all drivers on the same dimming circuit.

Many drivers have multiple programmable set points for establishing their dimming curves including setting the dimming voltage where maximum and minimum output currents occur and setting the minimum and maximum output current. Some drivers continue to operate even though there is no LED current/no light. This is known as standby mode or 'DIM-TO-OFF'. The only way to 'turn off' the ballast or driver is to disconnect mains from the fixture,

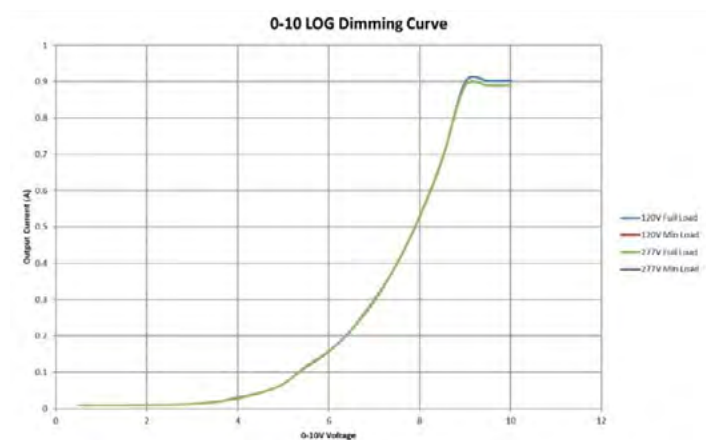


Figure 3 0-10V Logarithmic Dimming Curve

typically via a wall switch, a 0-10V dimmer that includes a mains switch, or a separate power controller. ANSI C137.1 defines this DIM-TO-OFF condition.

Figure 4 and Figure 5 illustrate the difference in dimming curves for drivers with and without standby mode.

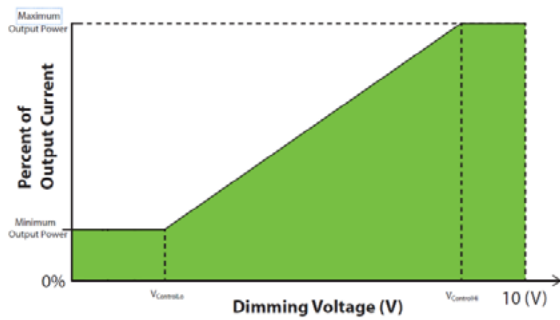


Figure 4 LED Driver Without Optional Standby Mode

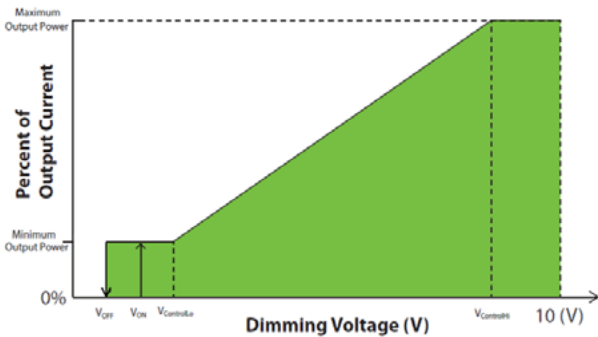


Figure 5 LED Driver With Optional Standby Mode

Application Considerations

When considering the use of 0-10V dimming during an installation there are several factors to keep in mind.

Wire Length

In general wire length should only be an issue for sites with many fixtures on a branch circuit. Since 0-10V dimming is a linear DC voltage protocol effects on wire length can be easily calculated using a wire resistance model. This is illustrated in Figure 6 by using the previous simplified 0-10V dimming circuit inside the driver. Observing that R1A and R1B represent the DC resistance of the +DIM and -DIM leads that connect the dimmer to the driver, the effect of the wire length can be found using the following formula:

$$V_{+DIM} = V_{R1A} + V_{R1B} + V_{DIMMER};$$

Assume the 0-10V dimmer is set to a minimum (shorted);

$$V_{DIMMER} = 0;$$

$$\text{Therefore } V_{+DIM} = V_{R1A} + V_{R1B} = (R1A + R1B) * I_{DIM}$$

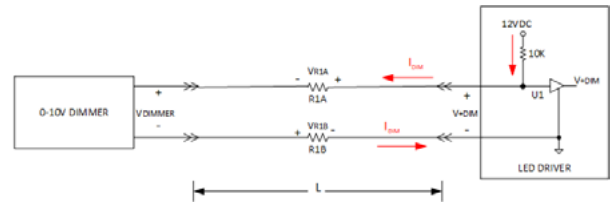


Figure 6. Control Wire Length

This calculates the actual voltage drop in the dimming leads alone and represents the minimum dimmer voltage that can be developed.

R1A and R1B represent the total wire resistance for each leg of the control wire. All that is required to complete the calculation for R1A and R1B is the distance L and the ohmic loss/ft of the wire, which is gage dependent. Tables exist that provide the resistance per foot based on gage. For the example calculation assume 24AWG for control wires, which has a resistance of 0.026 ohms/foot and it is 300' between the dimmer and driver. Thus, for a system that has a driver max source current of 1.2mA the minimum dimming voltage can be calculated:

$$V_{+DIM} = (R1A + R1B) * 0.0012 = ((0.026 \text{ ohms/ft} * 300 \text{ feet}) + (0.026 \text{ ohms/ft} * 300 \text{ feet})) * 0.0012 = 0.019 \text{ V}$$

To determine the minimum dimming voltage on a group of fixtures, simply multiply the total number of drivers on the control circuit by the voltage loss for a single driver, assuming identical fixtures.

It should also be obvious that even though this calculation was done for a driver that produces a maximum dimmer current of 1.2mA, many drivers now use dimming circuits that reduce the dimming circuit current per driver to 120uA. This serves not only to reduce the voltage drop on wiring thereby enabling more fixtures to be on the same control circuit but also to reduce the total amount of current that the dimmer will be subjected to, since the total current the dimmer will need to conduct is directly proportional to the number of fixtures sourcing dimming current.

Another factor to consider with respect to control wire length is RF noise. Control wire leads can act as an antenna in environments where RF noise is prevalent. Depending on the circuit design in the LED driver, this can introduce noise into the driver which can affect output current stability, especially at low dimming levels. A straightforward and common way to reduce the impact of this is to use twisted pair dimming control leads, especially in applications that require longer control wires between the dimmer and drivers. If wires are not shielded or twisted pair, consider placing them away from other devices to prevent cross-coupling into the 0-10V wiring. Sources of interference may include transformers, electric motors, high-frequency drives, neon fixtures, HID fixtures, and fluorescent lighting.

Leakage Current

Leakage current is a measure of how much electrical energy can be coupled from the LED driver itself to earth ground. This is a standard test requirement in UL8750 and this measurement is defined in UL8750 section 8.9. It is a safety issue, as leakage current can elevate isolated low voltage Class 2 circuits such as dimming control lines to a common-mode voltage that can easily be measured and sometimes exceed allowable Class 2 limits. This is typically a result of EMI reductions techniques inside the driver. To reduce conducted emissions from the driver, y-class, or safety capacitors, are often used to shunt EMI noise emitted by the driver from the mains input leads to earth ground.

Leakage current can also be caused by leakage inductance in the driver transformer design. Leakage current caused by transformer leakage inductance can be minimized by using certain winding techniques. These can be both design and process dependent.

0-10V Isolation

The 0-10V circuit isolation in an LED driver is an important area to understand both from an installation and a performance standpoint.

A simplified LED driver schematic is seen in Figure 7. Underwriters Laboratories (UL) typically draws a distinction between Class 1 and Class 2 circuits as a matter of safety and associated test and evaluation requirements. Class 1 circuits are typically on the input side (mains) and are considered as 'hazardous' while Class 2 circuits are typically low voltage/low energy. For safety reasons UL requires that the circuit grounds

between the two be isolated. This is typically done using an isolation transformer. An earth ground E is associated with input mains while an isolated signal ground is connected to the Class 2 side of the transformer.

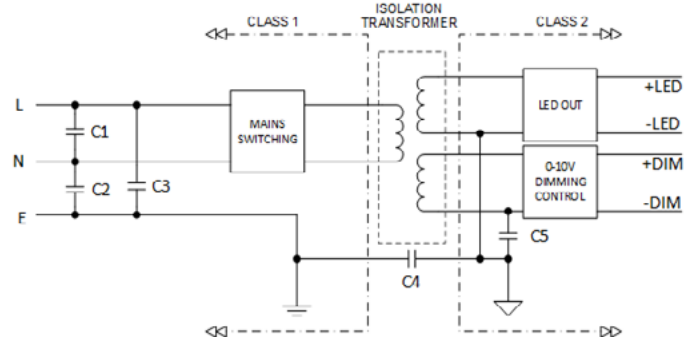


Figure 7 Simplified Driver Schematic

It can also be seen that even though both the LED output circuit and the dimming control circuit are on the Class 2 side of the transformer, there is isolation between them via capacitor C5. Depending on the LED output circuit topology this can help to improve dimming performance by shunting circuit noise produced by the LED output circuitry to signal ground. Some circuit topologies such as PWM are more susceptible to this issue and this is exacerbated at low dimming levels.

Note also that even though there is isolation between the Class 1 and Class 2 sides of the circuit (separate grounds), capacitor C4 connects the Class 1 earth ground to the Class 2 signal ground. This helps to couple high frequency noise produced by the output stage in the driver to earth ground. This is an approved EMI suppression technique by UL but this also incurs the consequence of introducing leakage current into the ground of the Class 2 side from noise produced by other equipment on the same branch circuit. See Figure 8. Equipment that is upstream of the fixture and on the same branch circuit produces cumulative ground noise. This noise can then be inadvertently coupled back to the Class 2 side of the LED driver, as seen in Figure 9, effectively elevating the common-mode voltage of the Class 2 circuit. This can result in an elevation of the dimming signal lines sometimes as high as 50V or more with respect to earth ground. Even though this voltage can be detected with a high impedance multimeter it is typically such a low energy level that it poses no safety risk. UL specifies a maximum cumulative leakage current of 3.5mA on any control circuit for this reason but no specific leakage current requirement is levied on an individual driver.

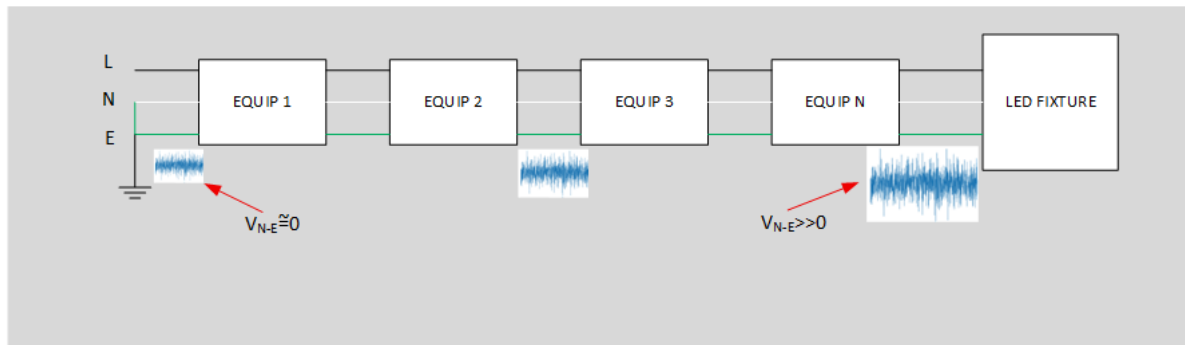


Figure 8 Branch Circuit Noise

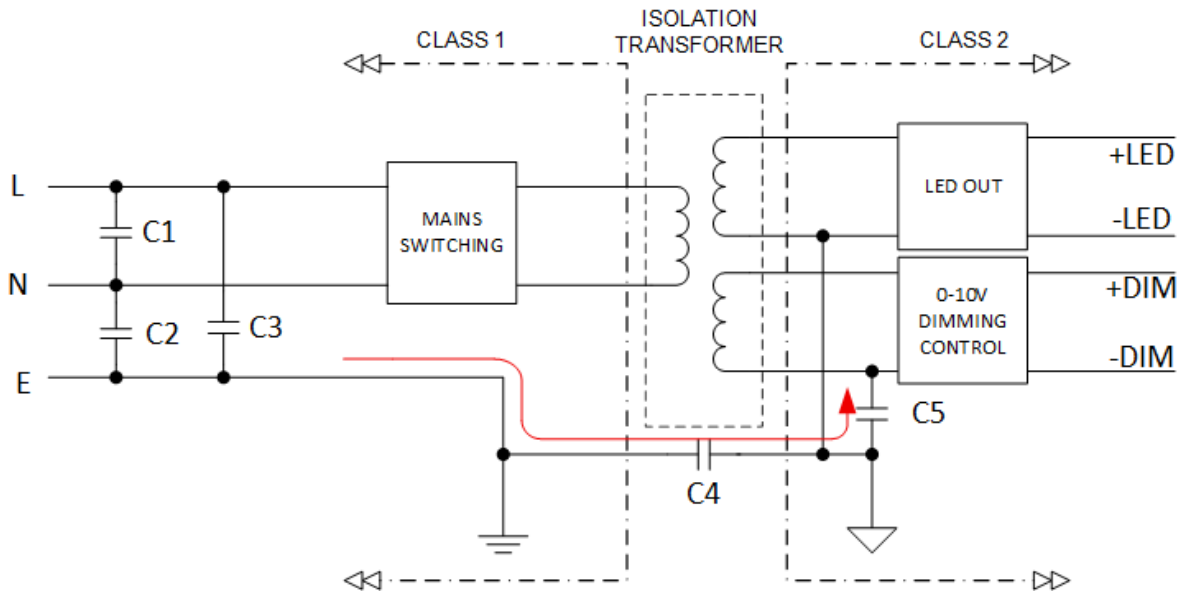


Figure 9 Ground Isolation in A LED Driver

Common Problems Associated with 0-10V Dimming

There are many factors that can affect lighting performance when using 0-10V dimming. The most important factor is that the drivers are the same model number and programmed to the same parameters. Inconsistent turn-on/turn-off points and dissimilar dimming profiles are common complaints when identical drivers with identical programming profiles are not used. This is a particularly common problem when LED driver field replacement is done.

Listed in Table 1 are common symptoms and root causes that are encountered when implementing 0-10V dimming lighting systems with identical drivers that have identical programming profiles.

Symptom	Possible Root Causes
Shimmering or flickering of one or more fixtures at low dim levels	Branch circuit equipment noise
Unpredictable operation such as flickering or incorrect dimming	
Greatly reduced lumen output	
Min dim or no light regardless of dimmer position	+DIM and -DIM leads reversed
Unpredictable operation such as flickering or incorrect dimming	
Inconsistent dimming between fixtures	Mismatched driver dimming Parameters
Inconsistent turn-on and turn-off dimming levels	
Unpredictable operation such as flickering or incorrect dimming	Damaged or pinched control wires
Inability to dim	
Unstable operation	Cross-coupling of noise from nearby wiring
Unpredictable operation such as flickering or incorrect dimming	

Table 1 Common 0-10V Symptoms and Root Causes

Recommendations

1. Be aware that different fixture types on the same branch circuits may have different LED drivers, which will likely affect the lumen output characteristics during dimming.
2. Ensure that identical fixtures that have programmable drivers have their 0-10V dimming characteristics programmed to identical settings. These include max/min output current, max/min dimming voltage levels and specific dimming curves.
3. Minimize 0-10V control wire distance, typically less than 300', between dimmer and fixture. Minimize distance between fixtures as much as possible. Maximize control wire gage for longer runs.
4. Consider using twisted pair for dimming control wires to eliminate possible RF noise introduction into the system.
5. Keep other equipment, especially motorized equipment, off branch circuits that include LED lighting.

Conclusion

While 0-10V dimming control is conceptually straightforward and reliable, it is important to understand the fundamental concepts of dimming 0-10V control when designing for this in a lighting fixture or application. This includes the basics of how a 0-10V dimming circuit works in a source/sink relationship, the overall system including driver and dimmer, a basic understanding of dimming curve characteristics and how noise can be introduced into the system, potentially affecting system performance.



To find out more about the [Foundation Series LED Drivers](#), call us at **813-288-8006**.