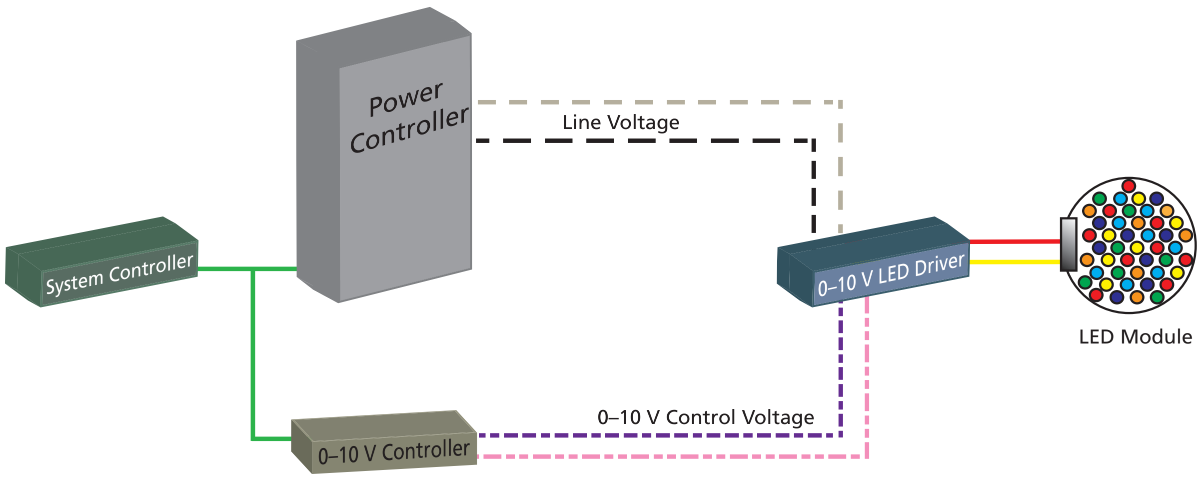
White Paper
Understanding 0–10 V LED Drivers

How LED Fixtures Dim

This document describes the different components that may be required to control an LED fixture using 0–10 V control, how the components are wired, and how these components work together to control an LED fixture. Depending on the application, some or all of these components may be combined into an “all-in-one” approach.



Component	Function	Example ETC Products
System Controller	Sends level information to the power controller and 0–10 V controllers via DMX or other data control protocol	• Unison Architectural Control Processors • Unison Mosaic Controllers • Eos Family Consoles
Power Controller	Receives line voltage (120–277 VAC) and feeds that to the 0–10 V LED driver	• Unison DRd • Echo/Elaho Relay Panel, Sensor IQ • Echo/Elaho Zone/Room Controllers • Unison Foundry Zone/Room Controllers
0–10 V Controller	Sets the control voltage on the line to the 0–10 V LED driver to set an output level for the LED fixture	• Unison DRd 0–10 V Control Option Card • ERP, ERP-FT, Sensor IQ 0–10 V Option Card • Response 0–10 V Gateway
0–10 V LED Driver	Requires four input conductors: • Two for line power that are used to energize an internal processor • Two for control voltage that are used to determine the intensity of the output	
LED Module	The LEDs and other optical and electronic components that emit and guide the light	

Note: *Typically the manufacturer of the power controller is not the provider of the LED driver. Drivers and LED modules may be specified independently of each other as well.*

Take care to confirm compatibility between the power controller, the LED driver, and the LED module prior to installation.

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Protocols

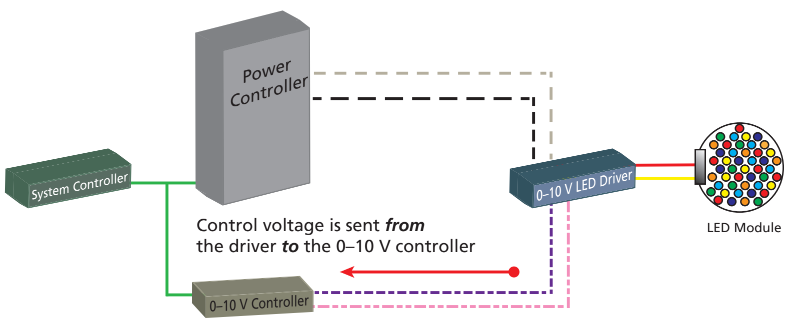
0–10 V drivers use one of two 0–10 V protocols: sink control or source control. With either protocol, the driver needs a switched source of line voltage separate from the control lines.

All ETC 0–10 V control products use 0–10 V sink control protocol. This document does not cover source control in detail because source control is uncommon outside of specialist applications.

0–10 V Sink Control

This is the predominant protocol in the commercial lighting industry. The 0–10 V sink control protocol is defined in the ANSI/NEMA standard C137.1 and Annex E of the IEC60929 specification.

0–10 V sink control is also known as passive control, 4-wire control, or 1–10 V control.



The driver measures the voltage drop on the control line to determine the output to the LED module.

The 0–10 V controller selectively sinks between 0 V and 10 V in order to adjust the control level of the driver.

Tip: *0–10 V Sink Control*

Sink control refers to voltage provided by the ***driver*** *and absorbed by the controller to set light output.*

Drivers maintain max level output at or above 10 V and minimum level output at or below 1 V.

Key Points:

- When energized with control lines disconnected (lines are open), drivers output their maximum level.
- When energized with control lines shorted, the input drops below 1 V and the driver outputs its minimum level.
- On/off switching is controlled via line voltage to the driver.
- Dimming control is provided by **sinking** voltage from the driver to the controller.
- Drivers are labeled with their minimum light level. Typically this is 1%, 5%, or 10%.
  - Minimum light level refers to light output as measured by a light meter in reference to maximum output and may not have any relation to power output or control level.
- The maximum available control current **per driver** should be no greater than 2 mA and no less than 10 μA, typically 0.5 mA.
- A typical ETC control circuit can sink up to 100 mA of 0–10 V control, which can support 50 drivers at 2 mA per driver or 10,000 drivers at 10 μA per driver.

Note: *If constant power is used instead of a switched power controller, the LED will dim to its minimum level but may not turn off completely.*

Common North American Wiring Practices

The LED driver is connected to the power controller via a pair of line-voltage conductors (typically a black and white wire pair in North America) and to the 0–10 V controller via a pair of low-voltage wires (typically a violet and pink wire pair). The low-voltage wiring may be run as Class 1 or Class 2. The US National Electrical Code (NEC) defines some standards for signal wiring.

Class 1 Wiring	Class 2 Wiring
• No limits on voltage or current. • Consider it similar to a "mains" connection. • Typically requires conduit. • When control wiring and line-voltage wiring are run in the same conduit, insulation of control conductors must be rated for line voltage.	• Strict limits on the amount of available energy (voltage and current). • It is possible to touch Class 2 wiring without injury. • Class 2 wiring can be short-circuited without resulting in a fire. • Typically can be run without conduit (exposed). • Cannot be run in the same containment (conduit or raceway) as line-voltage conductors unless separated by a nonconductive barrier.

Since the LED driver is the device which sources the voltage, the construction of the driver determines whether the signal wiring should be considered Class 1 or Class 2. Consult the manufacturer and the datasheets for your drivers to determine the type of wiring.

ETC control products are able to handle either a Class 1 or Class 2 wiring method for 0–10 V. You can decide which method to use. Follow all national and local codes for appropriate wiring techniques.

Reclassification of Class 2 to Class 1

If you have a circuit that is Class 2 but want to run it as Class 1 wiring (for example, to allow a 0–10 V circuit to run in the same conduit as power circuits), you can do that through reclassification following this section of the NEC:

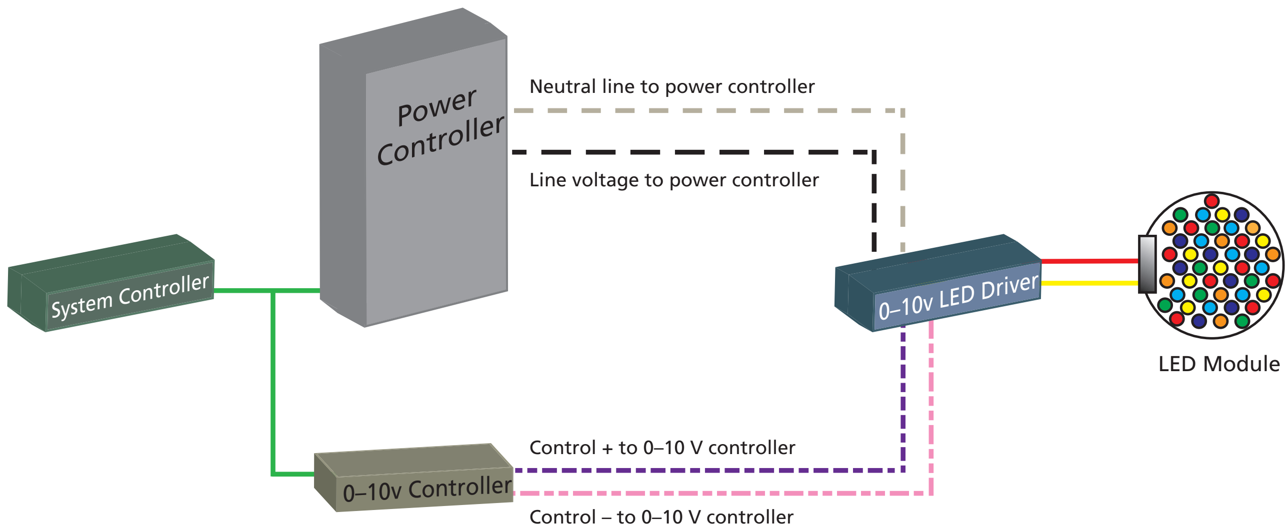
> *725.130 exception #2: Class 2 [..] circuits shall be permitted to be reclassified and installed as Class 1 circuits if the Class 2 [..] markings [..] are eliminated and the entire circuit is installed using the wiring methods and materials in accordance with Part II, Class 1 circuits.*

Note: *If you reclassify a circuit from Class 2 to Class 1, any markings stating Class 2 must be eliminated for all devices on the circuit and the circuit must be run with Class 1 wiring methods along its entire length.*

Wiring a Single Driver to a Controller

Line-voltage wires are run to a switching circuit providing on/off switching for the LED driver.

Low-voltage control lines run to positive and negative points on the controller.



Note: *If the 0–10 V controller is in the same device as the switching circuit, make sure to terminate control wires in the correct terminals so they match up to the circuit address.*

Connecting Multiple Drivers to a Single Controller

Note: *When connecting multiple drivers together to be controlled as a single circuit, be sure to keep wires connected by color/type throughout the entire set of connected drivers.*

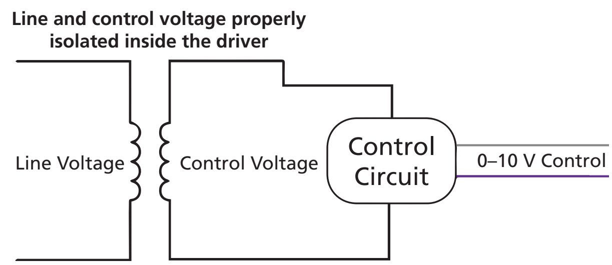
- Connect line-voltage drivers together in parallel to the same branch circuit so switching is provided to all drivers simultaneously.
- Connect low voltage.
    - Connect drivers together in parallel so they are controlled as a single zone from the same position in the 0–10 V controller.
    - Run the control lines (typically violet wire for positive and pink wire for negative) to the termination points of the 0–10 V controller.

Note: *Control wires are polarity dependent. Crossing the positive and negative wires while combining drivers will result in improper performance such as flickering or not dimming.*

0–10 V Control Line Isolation from Mains Voltage

Isolation Inside Drivers

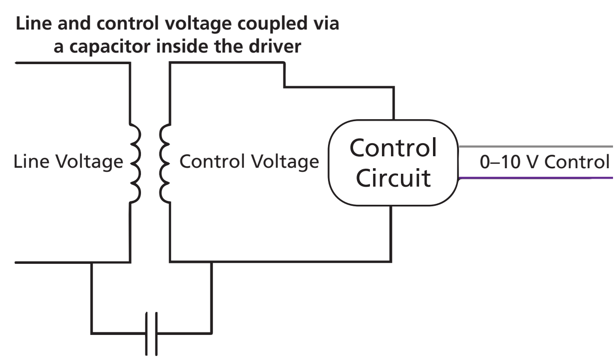
In addition to isolating wiring between devices, the ideal installation completely isolates control wiring from line voltage *inside* the driver via a transformer or switch-mode power supply. This guarantees that there is no excess voltage leaking from mains to the control circuit. There is no path for line voltage to flow to other systems, so there is no shock hazard.



Note: *If run as a Class 2 circuit, the NEC requires physically separating the 0–10 V control wiring from the power input wiring to prevent a shock hazard.*

Capacitive Coupling

Some driver manufacturers have introduced drivers with capacitive coupling between the line-voltage and control-voltage components. This is done to reduce the amount of radio emissions, but can have an unintended consequence.



Consequences of Capacitive Coupling

Capacitive coupling inside an LED driver allows a small amount of line voltage to “leak” through the capacitor from the mains voltage components and onto the 0–10 V control lines. This means that 0–10 V control lines may have a high potential voltage relative to ground. As long as this voltage only sources a very low current, no shock hazard is created.

UL8750 Supplement SF is the standard that covers wired control circuit used in LED lighting equipment. This standard dictates that the **total** leakage current on a control circuit **may not exceed 3.5 mA**.

Therefore, in order for an LED driver with a 0–10 V control circuit to be UL Listed it cannot generate more than 3.5 mA of leakage current on the control circuit. However, it is an extremely common practice to connect multiple luminaires in parallel on a single control circuit, which can increase the amount of leakage current on the control circuit exponentially. To address this potential safety hazard, UL8750 Supplement SF, clause SF8.5 states that an "LED equipment instruction sheet shall include...e) The manufacturer's recommendation to assure a cumulative leakage current of less than 3.5 mA on the control circuit."

Very few, if any, LED driver manufacturers comply with this requirement, making it virtually impossible for specifiers and installers to know how many drivers can be placed on a single control circuit before exceeding the standard for safe leakage current. As a result, most use the current draw specification of the driver to determine the maximum number of drivers on a line power circuit and connect them to control circuits accordingly. The end result is that exceeding the allowed leakage current on a 0–10 V control circuit connected to multiple LED luminaires has become an industry norm.

Most manufacturers of 0–10 V controllers, including ETC, have responded by engineering their products to withstand excess voltage to avoid damage to the controllers. However, most 0–10 V controllers achieve this by "floating" the excess voltage on the control circuit by having no connection to ground. Devices are available that take in the control circuit and filter out the AC voltage, only passing along the DC control signal voltage. The use of these devices decreased significantly as manufacturers of 0–10 V controllers improved their designs to better handle the excess AC voltage.

WARNING: RISK OF DEATH OR INJURY BY ELECTRIC SHOCK! Hazardous voltage on 0–10 V control lines that results from capacitive coupling creates a dangerous situation for an installer. Do not assume that 0–10V wiring is safe to touch, even when run as an NEC Class 2 signal. Have a licensed electrician test for AC voltage to ground.

Identifying Isolated Drivers

If you are unsure if your LED drivers provide proper isolation, you can measure the potential between the 0–10 V control lines and ground.

Note: *Use a meter with a manual range setting such as a Fluke 114, 116, 117, or equivalent. An auto-ranging meter may make it difficult to read the voltage on wires with both AC & DC voltage because the display will change rapidly.*

WARNING: RISK OF DEATH OR INJURY BY ELECTRIC SHOCK! 0–10 V wiring may not be fully isolated from high voltage AC power. Do not assume that 0–10 V wiring is safe to touch, even when run as NEC Class 2 wiring.

Consult a suitably skilled and qualified electrician.

CAUTION: ***Even drivers that claim to be isolated can leak enough voltage to damage 0–10 V control electronics, especially when many drivers are wired in series.***

1. Using a digital voltmeter (DVM) on a manual range setting (not an auto-ranging setting), measure the AC voltage between the 0–10 V control wires and between the control wires and ground.
   a. Measure between the positive control wire (typically violet) and earth ground.
   b. Measure between the negative control wire (typically pink) and earth ground.
   c. Measure between the positive and negative control wires.
2. Switch the voltmeter to DC mode on a manual range setting (not an auto-ranging setting).
3. Measure the DC voltage between the positive and negative control wires.

WARNING: RISK OF DEATH OR INJURY BY ELECTRIC SHOCK! If any measurement exceeds 20 V, the driver may not be fully isolated and you should treat the control wiring as potentially live. Check whether you may be detecting ghost voltage. See ***Making Accurate Voltage Measurements on 0–10 Volt Control Wires on the next page*** **and** ***What Are Ghost Voltages? on the next page*****.**

Making Accurate Voltage Measurements on 0–10 Volt Control Wires

Making accurate measurements of voltage created by capacitive coupling on control wires requires use of a meter with a low-impedance (“low-Z”) input, typically 3 kΩ (kiloohm). Many modern digital multimeters provide a selectable low-Z setting. Examples of such meters are the Fluke 114, 116, and 117.

Note: *Why not measure with a low-Z meter all the time? A low-Z meter is less accurate because it loads the circuit with 3 kΩ added in parallel to the circuit reading, which can create a significant voltage drop across the circuit. For certain types of measurements, high-impedance meters provide greater accuracy because the meter itself does not load the circuit with an impedance lower than 1 MΩ (megaohm).*

However, this type of accuracy, sensitivity, and high impedance is generally not required on 0-10V lighting control circuits, and can actually result in inaccurate measurements (see What Are Ghost Voltages? below).

What Are Ghost Voltages?

When a 0–10 V circuit is run in the same conduit as a line-voltage circuit, especially over a long distance, a meter with a high-impedance input, typically 1 MΩ or greater, can produce an inaccurate abnormally high voltage caused by capacitive coupling of the control circuit and the line-voltage conductors. This is known as a “Ghost Voltage," which has little to no current and generally disappears when a low-Z meter is used to take the measurement.

Detecting a Ghost Voltage

Repeat the measurements at *Identifying Isolated Drivers on the previous page* with the meter on a low-Z setting.

- If voltages on the control circuit are greater than 20 volts when measured with a low-Z meter, there may be a poorly isolated or non-isolated driver connected to the control circuit, or there may be an excessive number of drivers connected to the control circuit. **Treat the control wiring as potentially live.**
- If voltages on the control circuit are less than 20 volts when measured with a low-Z meter, the voltage is a "Ghost Voltage" and is not a concern because there is little to no current.

Troubleshooting

The following are some general practices for troubleshooting systems; contact your control manufacturer for more details if required.

The first step in troubleshooting any problems is to make sure that all installed components are compatible. Engineering specifications and quality of 0–10 V drivers can vary greatly between manufacturers. ETC recommends that you request all documentation, including datasheets, technical specifications, wiring diagrams, and catalog/order numbers from the fixture manufacturers when troubleshooting a system.

Symptom	Solution
LED does not turn on	• Confirm that the LED is designed to dim. • Confirm that the driver and LED dimming type are compatible (constant voltage/constant current). • Confirm the system wiring. - Confirm the polarity of control wiring. • Confirm that the driver and LED module have the same voltage specification (12 V, 24 V).
LED turns on but will not dim	• Confirm that the LED is designed to dim. • Confirm that the controller is configured. • Check the location of the control wires inside the controller. **Are the control and power wires landed to the correct circuits?**
LED turns on and dims but will not turn off	• Make sure the driver is attached to a switching circuit and that when the control level goes to 0, the circuit switches off. **The minimum level of most drivers results in the output of some amount of light.**
There is a delay between setting control level to 0 and the LED turning off	• This can be normal in some drivers with small loads; test by increasing load on driver. **Check load rating of driver and do not to overload it.**
LED flashes to full Drops from full to zero Flickers quickly at multiple levels	• Check wiring for proper termination. - Check that each control wire is terminated to the correct circuit. • Confirm that the driver and LED fixture dimming type are compatible (constant voltage/constant current). • Confirm that the controller is configured. • Isolate drivers and test independently. **One bad driver can cause all drivers in line to flicker.**
LED flashes slowly	• Check load rating of driver. Overloaded drivers may auto-reset causing this behavior.
LED dims down to a certain point and then stops	• This may be normal depending on the rating of your driver. **For example, a 10% driver will dim from maximum output to 10% of maximum output and no further.**
With multiple drivers in line, LEDs do not turn on at the same time or go to consistent levels	• Depending on LED driver design, this may be a limitation of the driver. • Confirm that the driver and LED fixture dimming type are compatible (constant voltage/constant current). • Confirm that the driver and LED module have the same voltage specification (12 V, 24 V). • Confirm wiring polarity of control lines. • Confirm minimum output ratings of LEDs.

With multiple drivers in line, some LEDs dim and others do not, or no dimming occurs	• Check wiring for proper termination.
	  - Confirm the polarity of control wiring.
	  - Check that each control wire is terminated to the correct circuit.