Fluorescent Dimming Systems
Technical Guide

LUTRON®

save energy with Lutron™ ®

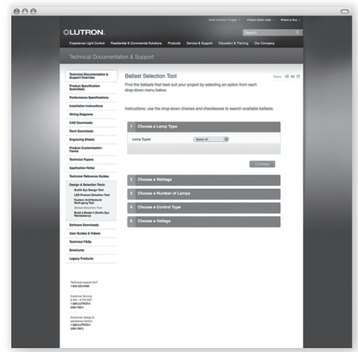
Innovation and quality from the world leader in lighting controls

Lutron invented the world's first electronic dimming ballast over 30 years ago. Lutron continues to lead the industry with innovative and energy-saving fluorescent dimming options, offering an extensive selection of ballasts and controls, and providing complete fluorescent dimming solutions.

This guide is designed to be a complete resource for all technical aspects of Lutron fluorescent dimming systems. The technical guide will review the basics of fluorescent lamps and dimming ballasts, including functional principles, lamp varieties, ballast factor, and lifetime expectations. Installation topics such as ballast mounting, grounding, lamp mounting height, wiring schemes, and troubleshooting will also be covered in detail.

Fluorescent Dimming Systems Technical Guide

For ballast model numbers and control selections, please see P/N 366-002.



To search online for the ballast that best fits your project, visit the updated Ballast Selection Tool at www.lutron.com/BallastTool

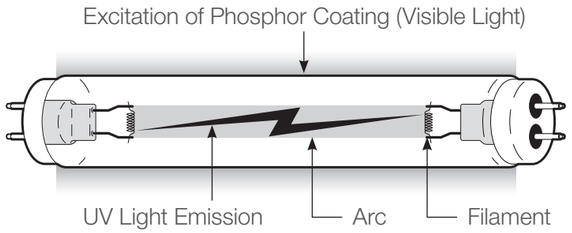
Lutron Fluorescent Dimming Ballasts

For a complete listing of model numbers, see the Fluorescent Ballasts and LED Drivers Selection Guide or consult product pages on www.lutron.com.

Fluorescent ballasts	Compatible Lamp Types and Wattages	Input Voltage	Control Options	Available Case Types	Dimming range	Integral Sensor Connections
EcoSystem® H-Series ballasts 	• T8 linear and U-bent: 32W • T5 HO linear: 54W • T5 linear: 28W	• UNV: 120V, 220/240V and 277V @ 50/60Hz • 347V @ 60Hz	• EcoSystem® digital link	 C-case  G-case  M-case	• 0.7% for T8 • 1% for T5 and T5 HO	No
Hi-lume® 3D ballasts 	• T8 linear and U-bent: 17W, 25W, 32W, 40W • T5 HO linear: 24W, 39W, 54W, 80W • T5 linear: 14W, 21W, 28W • T5 twin-tube: 36W, 40W, 50W	• UNV: 120V, 220/240V and 277V @ 50/60Hz	• EcoSystem digital link • 3-wire	 C-case  G-case	• 100% to 0.7% for T8 • 1% for T5 and T5 HO • 5% for T5 twin-tube and T5 HO 80W	No
EcoSystem ballasts 	• T8 linear and U-bent: 17W, 25W 32W • T8 linear reduced-wattage: 25W, 28W, 30W • T5 HO linear: 24W, 39W, 54W • T5 linear: 14W, 21W, 28W, 35W • T5 twin-tube: 36W, 39W, 40W, 50W, 55W	• UNV: 120V, 220/240V and 277V @ 50/60Hz	• EcoSystem digital link • 3-wire control • Low-voltage wallbox controls occupancy and daylight sensors	 J-case  G-case	• 100% to 10%	Yes
EcoSystem compact ballast 	• T4 4-pin quad-tube CFL: 18W, 26W • T4 4-pin triple-tube CFL: 26W, 32W, 42W	• UNV: 120V, 220/240V and 277V @ 50/60Hz	• EcoSystem digital link • 3-wire	 K-case	• 100% to 5%	No
Hi-lume ballasts 	• T5 HO linear: 24W, 39W, 54W • T4 4-pin triple-tube CFL: 26W, 32W	• 120V or 277V @ 60Hz	• 3-wire	 A-case  C-case	• 100% to 1%	No
Compact SE™ ballasts 	• T5 twin-tube: 36W, 39W, 40W, 50W • T4 4-pin quad-tube CFL: 18W, 26W • T4 4-pin triple-tube CFL: 18W, 26W, 32W	• UNV: 120V, 220/240V and 277V @ 50/60Hz (T5 twin tube only) • 120V or 277V @ 60Mhz (T4 4-pin lamps)	• 3-wire	 A-case  G-case	• 100% to 5%	No
Eco-10® ballasts 	• T8 linear and U-bent: 17W, 25W, 32W • T5 HO linear: 24W, 39W, 54W • T5 linear: 14W, 21W, 28W	• 120V or 277V @ 60Hz (T5 and T5 HO only) • UNV: 120V, 220/240V and 277V @ 50/60Hz (T8 only)	• 3-wire	 C-case  G-case	• 100% to 10%	No
Tu-Wire® ballasts 	• T8 linear and U-bent: 25W, 32W • T4 4-pin quad-tube CFL: 18W, 26W • T4 4-pin triple-tube CFL: 18W, 26W, 32W	• 120V @ 60Hz	• Tu-Wire® (fluorescent)	 A-case  B-case  C-case	• 100% to 5%	No

How do fluorescent lamps work?

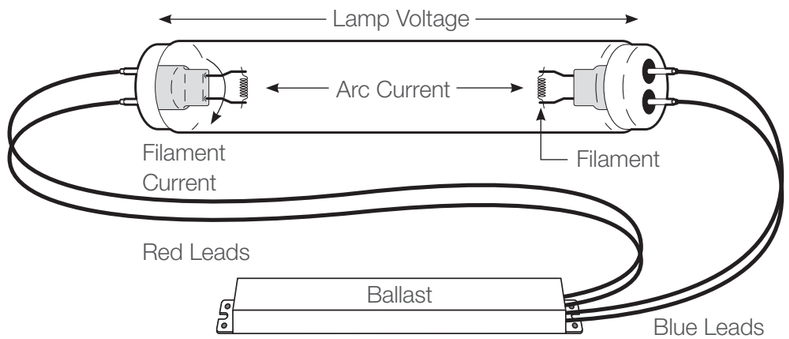
A linear fluorescent lamp consists of a glass tube containing low pressure mercury vapor with a tungsten filament at each end. Ultraviolet (UV) light is produced by striking an arc across the lamp from one filament to the other, causing the gas to glow. The amount of current passing through the lamp determines the light output. The UV light is converted to visible light by a thin coating of phosphor on the inside of the glass. U-bent, twin tube and compact fluorescent lamps are simply linear lamps with a varying number of bends.



How does Lutron dim fluorescent lamps?

Lutron ballasts adjust the current passing through the lamp to allow the user to control the light level. As part of the dimming process, it is important to keep the filaments heated by passing a current through them. Instant-start ballasts do not provide heat to these filaments and therefore can use sockets that connect the two filament pins together.

All Lutron ballasts are rapid-start-type, which provide supplemental heat to the filaments. It is therefore important that these two pins are not shorted together in the socket. Rapid-start sockets which keep these pin connections separate, must be used with Lutron ballasts. Using instant-start sockets with a Lutron ballast may cause permanent damage to the ballast, and will prevent proper operation.



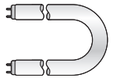
Lamp type

Lutron offers dimming ballasts for every popular lamp type:

Linear

Linear lamps are straight lamps with pins at both ends. Lutron dimming ballasts work only with rapid-start lamps, which will have two pins at either end.

U-Bent



U-bent lamps have many of the same properties as linear lamps and are usually offered in the same sizes, except they are bent in a “U” shape. Lutron dimming ballasts for linear lamps will often control a U-bent of the same size and wattage.

Reduced Wattage

Reduced wattage lamps are designed to save energy through simply relamping from their standard wattage equivalents. Lutron offers dimming ballasts specifically designed to work with some reduced wattage lamps.

Compact

Lutron dimming ballasts for compact lamps are offered in quad tube and triple tube. Quad tube lamps appear to have two or four tubes, while triple tube lamps appear to have three. They mount in 4-pin rapid-start sockets.

T5 Twin Tube

Lutron also offers ballasts for the T5 twin tube lamps. T5 twin tube lamps use a locking-type 4-pin rapid-start twin tube socket.

For selection information on our entire line of ballasts and controls for different lamp types, please see the Fluorescent Dimming Systems Selection Guide (P/N 366-002), visit www.lutron.com/ballast, or contact the toll-free Lutron Technical Support Center at 1.800.523.9466.

Lamp seasoning and lifetime

Lamp life of fluorescent lamps is defined as the time for which the lamp can operate within its performance specification, i.e. produce the specified light output and strike within specification. Dimming fluorescent lamps without seasoning can reduce performance and lamp lifetime.

Contact the lamp manufacturer for their recommendations on lamp seasoning. As a general guideline, NEMA recommends 12 hours of operation at full intensity before dimming.

See NEMA LSD 23-2010 “Recommended Practice—Lamp Seasoning for Fluorescent Dimming Systems.”

Why keep the lamps at full intensity before dimming?

New fluorescent lamps can have impurities in them that lamp manufacturers cannot eliminate completely.

Ways to Obtain Seasoned Lamps

- Operate new lamps continuously (time period might include a weekend or holiday)
- Remove lamps with over 100 hours of use from another (non-dimmed) area; re-install in dimming area
- Use a lamp burn-in station to build an inventory of properly seasoned lamps

Ballast Factor

Overview

Ballast factor (BF), also referred to as relative light output (RLO), is a measure of the light output of a fluorescent lamp on a particular ballast expressed as a percentage of its light output on a standard reference ballast. BF is not a measure of ballast efficiency, since there are ballasts that produce both lower and higher outputs than reference ballasts.

Actual Lumen Output =
Reference Lumen Output × Ballast Factor

BF is sometimes thought to reflect the energy efficiency of the ballast. That is incorrect because BF only describes the relative light output of a lamp-ballast combination and does not consider the power that the ballast is consuming. Hence if **Ballast A** and **Ballast B** have the same BF but **Ballast A** has a higher power consumption, then it is less efficient than **Ballast B**.

Example:

Actual lumen output
= 2,400 lm × 0.9
= **2,160 lm**

Range of BF
In the electronic fluorescent ballast industry, BF ranges from 0.7–1.2. Therefore for any lamp, there are ballasts available that are designed to provide anywhere from 70% to 120% light output of a reference. Ballast factors of all Lutron ballasts are indicated on the respective specification sheets.

Need for BF data
BF is important for fluorescent lighting design and specification as it helps to calculate the total lumen output of the lamps.

When doing lumens per watt (lm/W) calculations to comply with watts per square foot (W/ft^2) requirements in a region, the appropriate method to compare ballast efficiency is by using Ballast Efficacy Factor (BEF).

BF of Lutron dimming ballasts
The ballast factor of Lutron linear fluorescent dimming ballasts is 0.85 or greater and for compact fluorescent dimming ballasts it is 0.95 or greater. See ballast specification sheet for available ballast factors for a given lamp.

Selecting CBF
Lutron enables customers to order ballasts with a custom ballast factor (CBF): factory-tuned ballasts with reduced ballast factors that achieve greater energy savings, meet lumen/ft^2 specifications, and/or qualify for the highest levels for LEED.

CBF is an option for all Lutron ballasts with EcoSystem control capability including: Hi-lume 3D, EcoSystem, and EcoSystem H-Series, and can be selected by utilizing the Ballast Selection Tool: www.lutron.com/BallastTool

Ballast Efficacy Factor

Overview

Ballast efficacy factor (BEF) is the ratio of BF to the input power being supplied to the ballast. BEF considers both light output and correlated power consumption of a lamp-ballast system, allowing an effective comparison between different ballasts.

$$\textbf{BEF} = \frac{\text{Ballast Factor (\%)}}{\text{Input Power (W)}}$$

BEF is the only objective method to compare the performance between different ballasts. BF is the relative light output of a lamp on the ballast and the input power in watts is the ballast energy consumption. Therefore BEF is a quantity that relates the lamp light output to the ballast power usage. BEF can then be used to calculate the lumens per watt (lm/W) of the lighting system.

Typical installation
Consider two 1 lamp ballasts for F32T8 lamps. If the BF of the first is 0.90 and the BF of the second is 1.0, the second ballast is not necessarily more efficient in producing light. Let the input power to the first lamp-ballast combination be 34W. Let the input to the second lamp-ballast combination be 38W.

Example:

First ballast BEF
$= \frac{0.9\,\text{BF} \times 100}{34\,\text{W}}$
= **2.65 BEF**

Second ballast BEF
$= \frac{1.0\,\text{BF} \times 100}{38\,\text{W}}$
= **2.63 BEF**

This illustrates that the ballast with the lower BF may have greater efficacy and is therefore a lower energy usage product.

Power Factor

Overview

Power factor measures how efficiently an electrical device operates. In electronic ballasts, the input power is used to operate the ballast and provide power to the lamps. Power factor compares the input power to the power actually made available to the ballast and lamps.

$$\textbf{Power Factor} = \frac{\text{Input Power}}{\text{Line Voltage} \times \text{Line Current}}$$

Power factor is always a value less than one.

The electrical design of a device determines whether the input current and voltage are converted to maximum power within the unit. If the current draw is in-phase with the voltage, the power utilization is maximized. When the two are out of phase, some amount of power cannot be efficiently converted. Ballast Power Factor does not directly indicate the current supplied through the lamps, or how efficiently the lamps produce light when operated on a particular ballast.

Example:

$$\text{Power Factor} = \frac{34.8}{277\,\text{V} \times 0.13\,\text{A}} = \textbf{0.96}$$

Range of ballast power factor

High power factor products are rated greater than 0.9. Lutron electronic dimming ballasts achieve greater than 0.95 power factor by efficient design and use of high-quality components. Utility companies discourage low power factor devices because of their high device losses.

Power factor correction

Inductive loads generally have low power factors and present day designs add sophisticated circuitry to achieve a power factor close to 1. The solution is called power factor correction (pfc) and ensures more efficient power.

Total Harmonic Distortion

Overview

Total harmonic distortion (THD) is a measure of the magnitude of all the harmonics (distortions) of the input current expressed as a percentage of the fundamental frequency current of 60Hz. THD is an important consideration for electrical safety, but lighting typically accounts for less than 30% of total building load and 10% of a building's overall THD.

Line current is supplied to electrical equipment at a fundamental frequency of 60Hz. Harmonics to the fundamental current are integer multiples of the fundamental frequency—the 2nd harmonic is at 120Hz, and the 3rd harmonic is at 180Hz, etc. Depending on the electrical design of the equipment, it can distort the input sine wave of the fundamental frequency and introduce harmonics on the power line.

Why high THD is detrimental

Significant harmonics are put back on the line if the load type is not linear and draws current from the line in short pulses. Harmonic currents do not provide any power to the load, and flow in the neutral wire in a 3-phase system. Harmonics up to 33% are allowed by ANSI.

When line harmonics are present, the total current is the summation of the fundamental frequency current and the harmonic current. If the THD of an electrical device is 20%, it introduces 20% of the magnitude of its input current back on the line as harmonics. If this device constitutes 10% of the total electric load in a building, then it contributes only 2% to the total building THD. Codes and regulations require that total building THD not exceed 33%.

THD may be a concern for 2-wire line-voltage dimming ballasts as the power wires carry the phase control dimming signal to the ballast. The current drawn by the 2-wire dimming ballast mimics the phase-control dimming signal and will result in higher THD when dimmed.

THD regulations

In the early 1980s when there did not exist a standard for THD of electronics, some dimming ballasts would produce up to 100% THD when dimmed down to low light levels. There have been many design improvements since, and ANSI C82.11-1993 now specifies maximum 33% THD for electronic ballasts.

All Lutron ballasts have a THD rating of 20% or less. Hi-lume, Hi-lume 3D, and EcoSystem H-Series ballasts all have a THD rating under 10%.

Overview

The lifetime of a ballast is defined as the actual number of operating hours that can be achieved using specified lamps operating within their specifications. Maximum lifetime is achieved not only by using long-life components, but also by not approaching the operating limits of those components. Ballast life is strongly correlated with the lifetime of the electrolytic capacitors, whose lifetime can be maximized by operating them at lower temperatures. Lutron ballasts are designed to operate for their rated lifetime under worst-case conditions; however, external factors such as dimming level and fixture mounting can help the ballast run cooler and last longer.

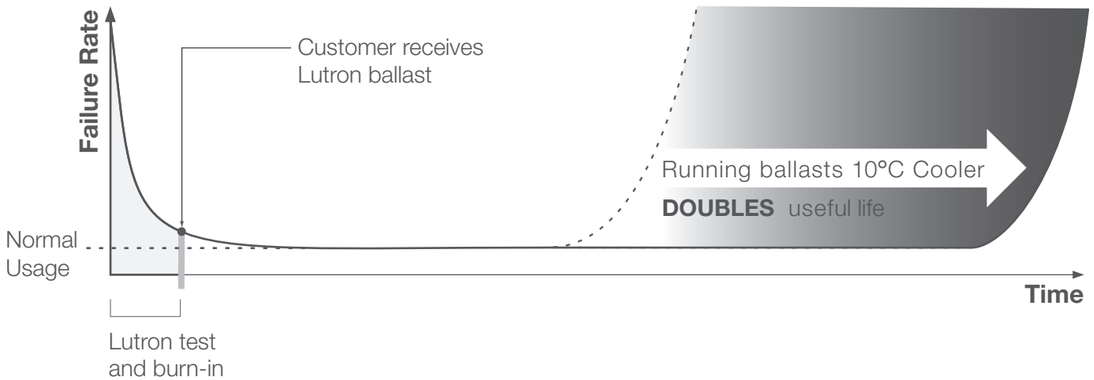
When fluorescent fixtures are dimmed down to 80% of their maximum light output, the ballast has to drive less current through the lamp. On average, dimming fluorescent lamps by 20% reduces the ballast case temperature by up to 10ºC. Every 10ºC reduction in ballast temperature doubles the lifetime of the electrolytic capacitors, and hence the ballast.

The operating temperature of a ballast can also be dramatically influenced by proper installation. Fixtures that mount a ballast to a metal surface and ensure full contact between the ballast and a conductive surface allow for proper heat sinking of the ballast, and therefore lower operating temperatures and longer life.

This should be verified by measuring the calibration point in the intended fixture during fixture design.

Calibration point temperature not to exceed 65ºC. Maximum case temperature 75ºC.

Lutron product reliability curve



Ballast mounting

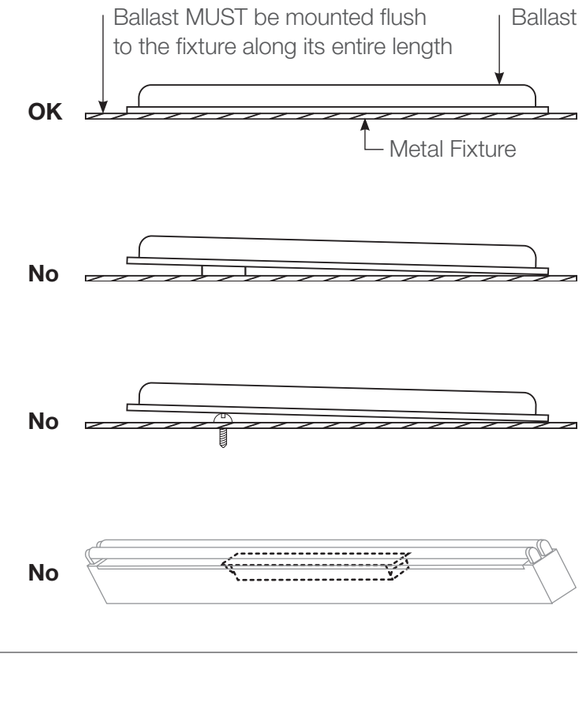
Notes:

1 Ballasts generate heat and MUST have a means to dissipate it.

2 Ballasts MUST be mounted flush to the fixture in order to provide the best heat transfer.

3 Screws, knockouts, dimples, or features that raise the ballast off the fixture (even slightly) are not acceptable as these will impair the ballast's ability to dissipate heat.

4 Avoid mounting the ballast on the fixture cover plate that holds the lamps. This mounting location is often the hottest point on the fixture.

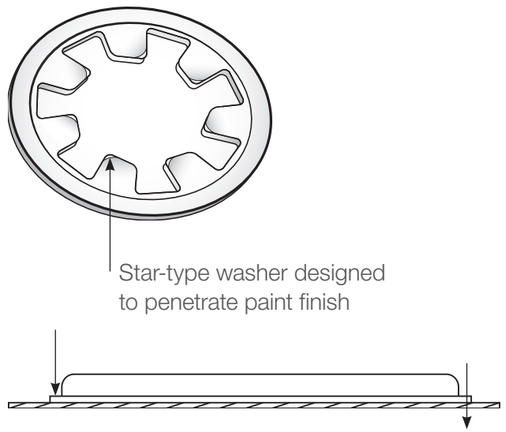


Grounding

Both the ballast and the fixture must be connected to earth ground. Grounding the ballast to the fixture requires "star-type" screws, washers or nuts in order to penetrate the paint finish on the ballast. To ensure safety and performance, proper grounding is essential.

Both ends of the ballast must be attached to the fixture to ensure proper grounding.

UL and NEC require that the ballast and all parts of the luminaire be electronically grounded.



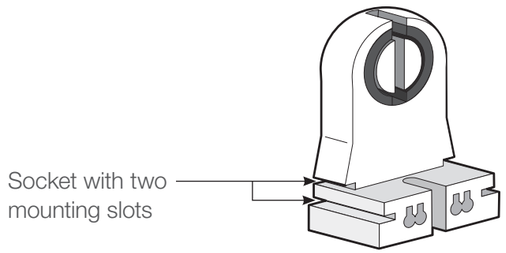
Lamp mounting height

Lamp Type	Distance from grounded surface
T8 Linear	0.125" – 0.75" (3.2 mm – 19.1 mm)
T5 Linear	0.125" – 0.50" (3.2 mm – 12.7 mm)
T5 Twin Tube	0.125" – 0.50" (3.2 mm – 12.7 mm)

Mounting a fluorescent lamp too close to the grounded metal will make the minimum intensity too low and may reduce lamp life. Lamps should never touch metal surfaces. Mounting a fluorescent lamp too far away from the grounded metal may make the lamp flicker or not turn on at all.

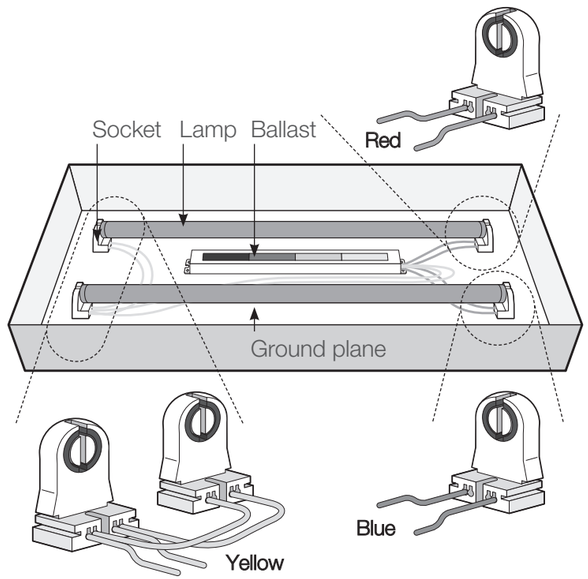
The listed mounting height ranges ensure that dimming performance and lamp life is maintained. It is important to make sure that in installed fixtures these spacings do not change over time.

Note: If using Eco-10 ballasts, T5 Twin-Tube lamps can be mounted as close as 0.03125" (0.79 mm) and linear T5 and T8 lamps can be mounted at 0.0625" (1.59 mm).



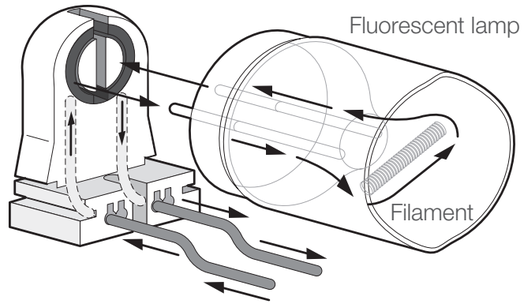
Typical fixture mounted and wired ballasts

Typical 2-lamp linear fixture with ballast mounted in center trough



Why are sockets important?

T8 rapid-start socket



Flow of electricity for filament heating

Dimming ballasts must connect to both lamp pins to heat the lamp filaments—without heating, the lamp ends will become black and fail prematurely (may take anywhere from a few days to several weeks). Additionally, poor lamp to socket connections will result in poor dimming or lamp striking.

When installing Lutron ballasts, good lamp pin-to-socket contact and correct wiring are required to produce flicker-free dimming and ensure long lamp life. For best filament contact, use only recommended sockets.

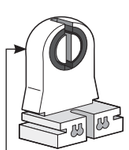
High quality electrical lampholder connections are critical, especially in dimming fixture assemblies. Both Lutron and NEMA strongly encourage the use of IEC 60400 compliant sockets, which greatly reduces lampholder related issues in the field. Lampholders that meet IEC 60400 specifications are of superior quality and will deliver the most reliable connections throughout the lifetime of the fixture.

See Appendix A (based on Lutron Application Note 122) and NEMA Publication LSD 34-2006.

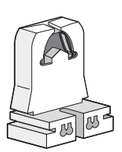
Identifying rapid-start sockets

Rapid-start sockets are necessary because each socket must be able to accept two separate wires from the ballast, and in some cases, two additional wires from another socket. High quality rapid-start sockets have a good grip on lamp pins and make reliable connections with all wires. The backing material of the socket should be the same as the rest of the socket body, and should not deform with over-insertion of wires or repeated lamp changes.

See Appendix A (based on Lutron Application Note 122) and NEMA Publication LSD 34-2006.

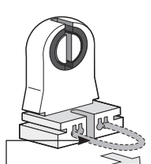


Rapid Start
(Rotary Locking Variety)



Rapid Start
(Slide-In Variety)

The back must NOT be made out of flexible material (i.e. cardboard or paper)



Rapid Start
(Rotary Locking Variety)

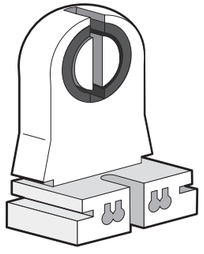
Instant Start
(do not use)

A **jumper** may have been installed for instant-start applications. This jumper must be removed.

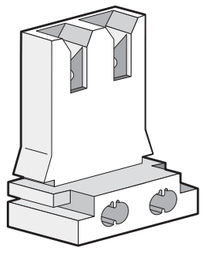
WARNING: Using Lutron ballasts with instant-start sockets may damage the ballasts.

Linear fluorescent lamps

Sockets for T8 Linear Lamps
The sockets should be rotary locking type, with metal contacts that make good, firm contact with the lamp pins. The sockets may also be slide-in or knife-edge variety. The fixture must have a grounded metal surface near the lamp (see pg. 11). The sockets MUST be rapid-start type.

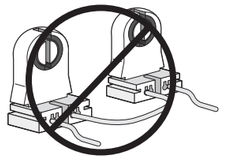


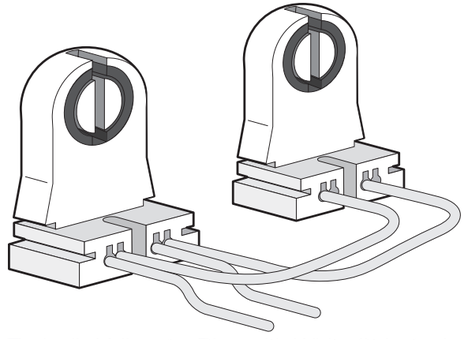
T8 Linear



T8 U-Bent

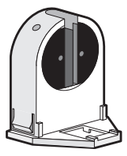
Socket wiring for T8 Linear
For ballasts that control more than one lamp, sockets wired to the yellow or blue-with-white stripe leads of the ballast MUST be wired in parallel, not in series.





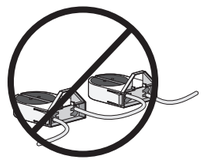
Typically Yellow (or Blue with White Stripe) wires
Note: Yellows wired in parallel

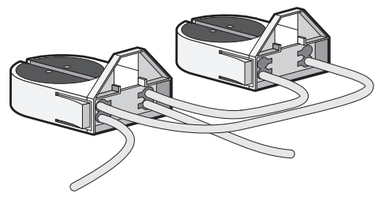
Sockets for T5 Lamps
The sockets should be of the rotary locking type. The fixture must have a grounded metal surface near the lamp (see pg. 11). The sockets MUST be rapid-start type.



T5 Linear

Socket wiring for T5 linear
For ballasts that control more than one lamp, sockets wired to the yellow or blue-with-white stripe leads of the ballast MUST be wired in parallel, not in series.

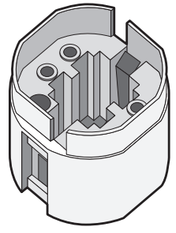




Note: Yellow wired in parallel

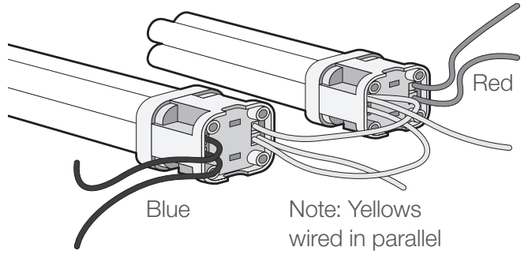
Compact fluorescent lamps

Sockets for T4 Compact Lamps
T4 compact sockets must be the 4-pin type and must be used with 4-pin compact lamps. Instant-start sockets with 2-pin connections can only accept 2 wires and will not work. Sockets MUST be 4-pin rapid-start type.

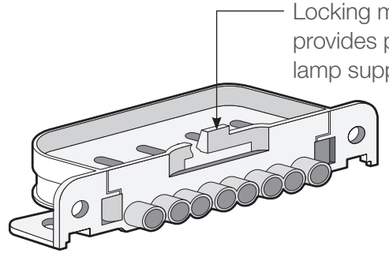


T4 Compact 4-Pin

Socket wiring for T4 Compact 4-Pin
Typical 2-lamp installation

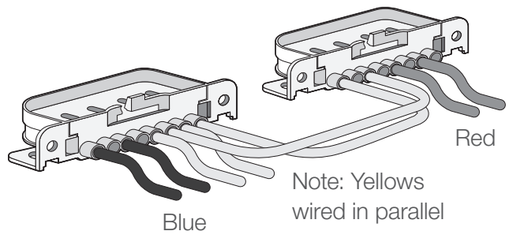


Sockets for T5 Twin Tube Lamps
Use only 4-pin “locking” sockets that hold the lamp in place. T5 twin tube lamps require proper lamp support at the opposite end from the lamp base, to hold lamp pins in full contact with socket. The sockets MUST be rapid-start type.

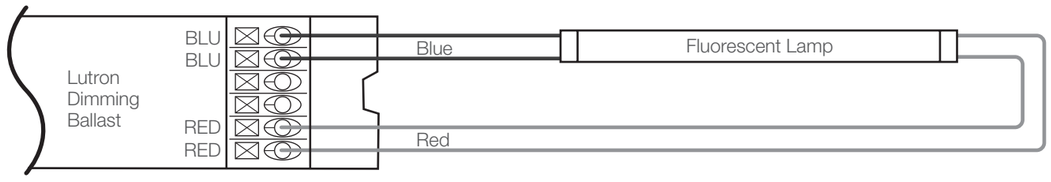


T5 Twin Tube

Socket Wiring for T5 Twin Tube
Typical 2-lamp installation

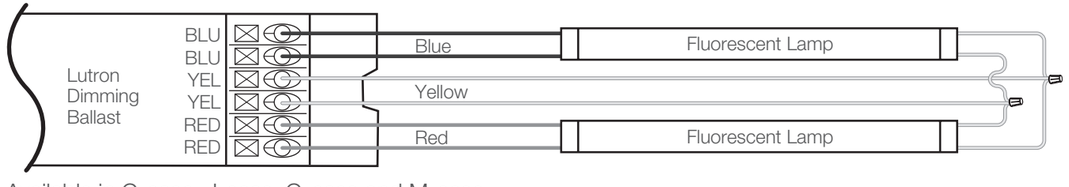


Linear 1-Lamp



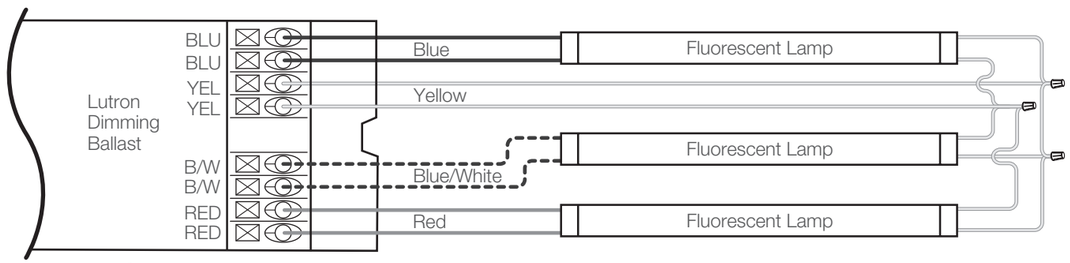
Available in C-case, J-case, G-case and M-case

Linear 2-Lamp



Available in C-case, J-case, G-case and M-case

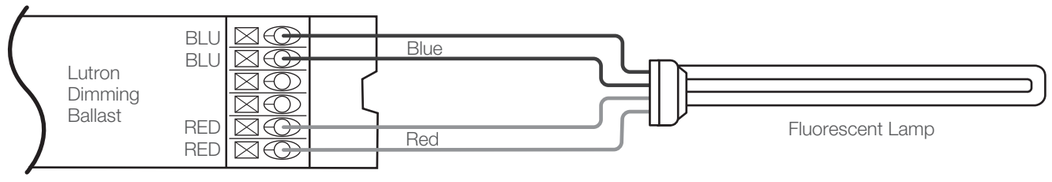
Linear 3-Lamp



Available in G-case

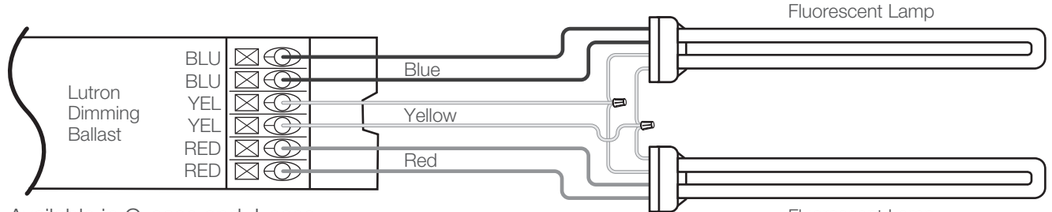
Note: Lamp terminals accept only one 18 AWG wire. Ballast-to-lamp wire lead lengths must not exceed 7 ft (2 m) for all wiring scenarios shown above.

T5 twin tube 1-lamp



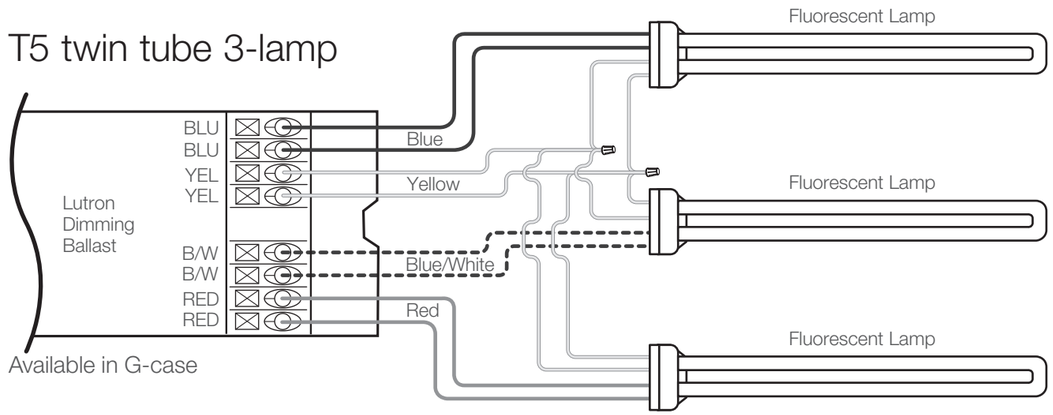
Available in G-case and J-case

T5 twin tube 2-lamp



Available in G-case and J-case

T5 twin tube 3-lamp

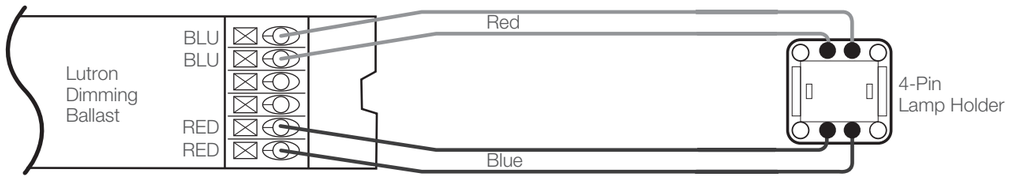


Available in G-case

Note: Lamp terminals accept only one 18 AWG wire. Ballast-to-lamp wire lead lengths must not exceed 3 ft (1 m) for all wiring scenarios shown above.

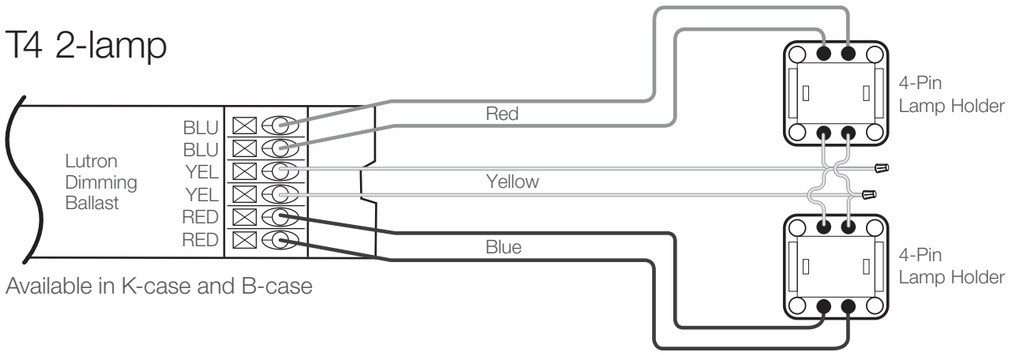
Lamp Wiring Diagrams

T4 1-lamp



Available in K-case and A-case

T4 2-lamp

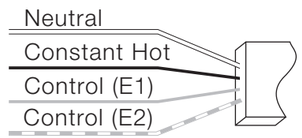


Available in K-case and B-case

Note: Lamp terminals accept only one 18 AWG wire. Ballast-to-lamp wire lead lengths must not exceed 3 ft (1 m) for all wiring scenarios shown above.

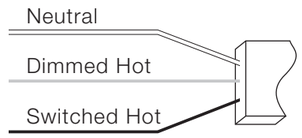
Ballast Control Types

In addition to offering ballasts with different low-end dimming levels, Lutron offers dimming ballasts with a variety of control options.



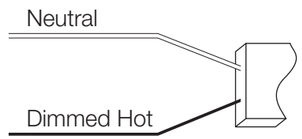
EcoSystem® digital link

Models available: EcoSystem H-Series, EcoSystem, and Hi-lume® 3D ballasts
Dimming levels available: 1%, 5% and 10%
The EcoSystem digital link is a wired communication technology that facilitates individual ballast addressing, connection of multiple control devices, and control of ballasts individually or in groups. The digital communication wires are polarity insensitive and may be wired in any topology. They may be run with the line-voltage wiring (Class 1) or separately from the line-voltage wiring (Class 2). The EcoSystem digital link allows for the quick connection of devices and re-configurability.



3-wire

Models available: EcoSystem, Hi-lume, Hi-lume 3D, Compact SE™, and Eco-10® ballasts
Dimming levels available: 1%, 5% and 10%
3-wire control is a line-voltage phase-control dimming method. Along with Hot and Neutral, the dimming signal is communicated via a third wire called Dimmed Hot. All three wires are rated Class 1 and can be run within the same conduit. 3-wire control is stable over long wire runs, allows for maximum circuit loading, and is very easy to wire.



2-wire

Models available: Tu-Wire® ballasts
Dimming levels available: 5%
2-wire control is a line-voltage phase-control dimming method. The ballast receives the dimming signal through the Dimmed Hot wire. Intended for small-scale retrofit applications, the 2-wire control method is often the easiest way to implement dimming in existing fluorescent fixtures.

Overview

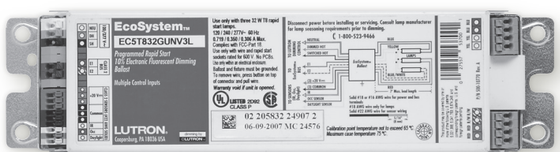
Lutron EcoSystem lighting control systems start with one simple, but essential building block, the EcoSystem dimming ballast. EcoSystem digitally addressable dimming ballasts employ revolutionary technology allowing each device to listen, think, decide, remember, and react to its environment. A variety of sensors or wallstations can connect directly to the ballast to create an efficient lighting control system, whether the system contains only one ballast or up to 64 ballasts connected together. Sensors and wallstations can also be connected to the system through sensor modules and control panels to allow for maximum flexibility. EcoSystem redefines fluorescent lighting control as a cost-effective solution that is easy to design, install and maintain.

EcoSystem ballasts are available for many voltages and lamp types. If a ballast is not available for direct control via the EcoSystem Bus, a Lutron 3-wire dimming ballast can be connected using a Ballast Module. The system provides continuous, flicker-free dimming from 100% to 10%, 5% or 1% depending on lamp type. Lamps can be turned on at any dimmed level without first flashing to full brightness. The digital link control allows for re-zoning without rewiring, and miswire protection is included in the EcoSystem link. Components are 100% performance tested including burn-in before shipping, and include a 5-year limited warranty with field service commissioning (3-year warranty standard).

Connecting Sensors and Wallstations

To connect a daylight sensor, occupant sensor, wallstation and/or infrared receiver, refer to the instruction sheets provided with the devices. Diagrams for the Class 2 Sensor/Wallstation terminals are shown below.

NOTE: The ballast accepts only one infrared input connection from a daylight sensor, IR sensor or wallstation.

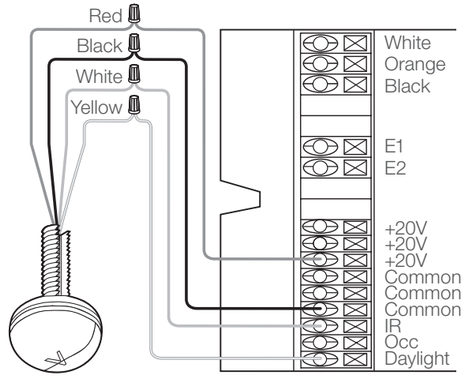


G-case Class 2 Sensor Terminals

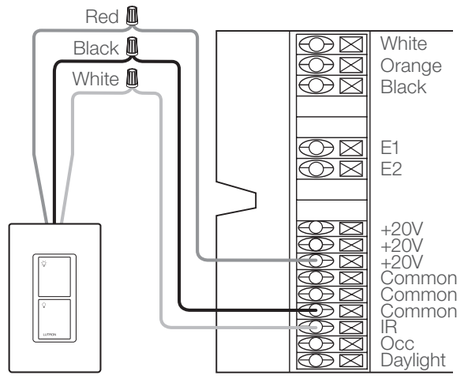
J-case Class 2 Sensor Terminals

Example: Sensor Wiring Connections

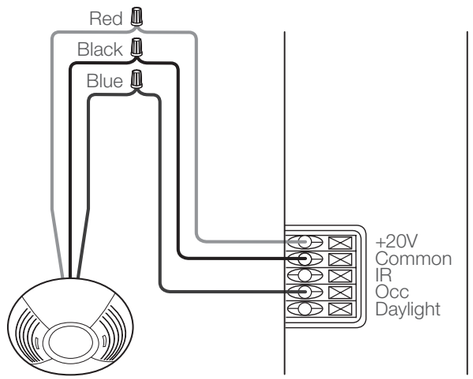
G–case with daylight and IR sensor



G–case with wallstation



J–case with occupancy sensor

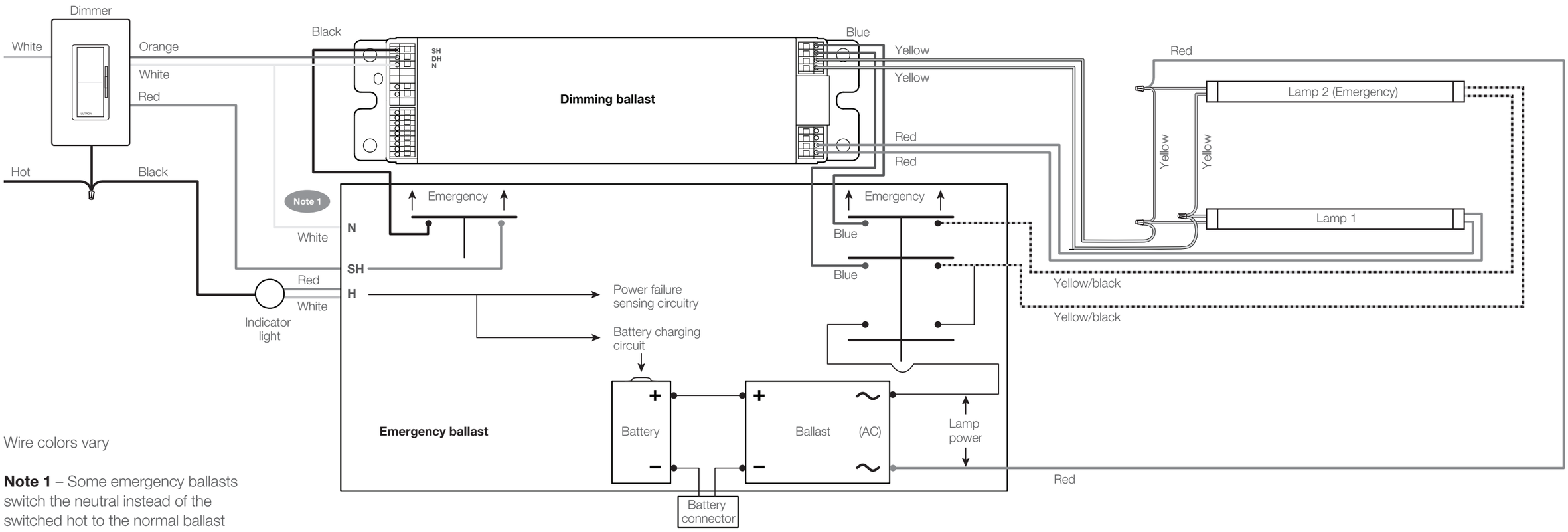


Overview

In commercial fluorescent applications, battery backup ballasts are sometimes used for required emergency and egress lighting. Battery backup ballasts provide one solution for addressing emergency lighting. These ballasts provide light on a temporary basis when normal power has been interrupted. Some of the major manufacturers are Bodine Emergency Lighting, Exide Technologies and Iota Engineering.

Emergency Ballast Recommendations
Lutron fluorescent ballasts are designed to provide lamps with a precise amount of voltage to ensure long lamp life, flicker-free performance and lamp balance. The addition of an emergency ballast can affect the amount of voltage delivered to the lamps. It is imperative that any emergency ballast should not significantly alter the amount of voltage that is delivered to the lamp and filaments. We recommend choosing emergency ballasts from manufacturers who take these considerations into account. Please refer to the emergency ballast manufacturer for compatibility.

Typical Wiring Diagram



Wire colors vary

Note 1 – Some emergency ballasts switch the neutral instead of the switched hot to the normal ballast

Emergency Backup Ballast

Wiring Recommendations
While the wiring method may change for each manufacturer, the main function is to illuminate one lamp or two lamps within the chosen fixture in an emergency condition. There are several guidelines for using this technology with Lutron dimming ballasts.

- Always keep the lamp wires as short as possible. The total lamp wire length for Lutron fluorescent ballasts includes the wire length of the backup device. Please see Lutron ballast specifications for maximum allowable lamp wire length.
- Depending on the fixture layout there may be a slight imbalance of illumination on a multi-lamp ballast during normal operation.
- Contact Lutron Technical Support for further information.

The below diagram is an example emergency ballast wiring diagram showing single lamp emergency operation. Wiring varies by manufacturer.

Lampholders and lampholder installation

Overview

When fluorescent lamps are dimmed, they require continuous electrical current to heat the lamp filaments. Lamps fail prematurely if this filament heat is absent. This type of failure is characterized by extreme darkening of the ends of the lamp. The common cause for lamp failures is either poor connection between the lamp pins and the lampholder, poor connection between the lampholder and the ballast, or incorrect wiring of the ballast to the lampholder. It is important that high quality lampholders are used and installed correctly in fixtures to provide reliable and trouble-free lamp operation. This specification recommends which lampholders to use and best practices for installing the lamp and lampholders.

Specification

I. Lampholder Requirements

1. Lampholders shall be UL listed, and meet IEC-604001, "International Standard: Lampholders for tubular fluorescent lamps and startholders." *The IEC specification already lists many design requirements that are essential for fluorescent dimming. Some of them are repeated below for emphasis.*

a. The wire/lampholder connection shall meet IEC 60400 section 9.5. *The force to remove wires from the lampholder must significantly exceed the force applied to the wire during shipping, installation, and normal use. IEC 60400 sec. 9.5 requires wires support a force of 50 N in the least favorable direction.*

b. Lampholder shall meet IEC 60400 sections 10 and 13, which specify contact force and endurance of the mechanical connection between lamp and lampholder. *Contacts and lamp clips in the lampholder shall have sufficient spring force such that after repeated insertion of lamp the metal does not yield. Otherwise a poor connection will result.*

c. Lampholder shall meet IEC 60400 sections 13 and 18, which specify impedance and endurance of electrical connection between lamp and lampholder. *Metal parts shall resist corrosion, e.g. phosphor bronze. A metal contact that corrodes increases the resistance of the connection, which reduces the power delivered to lamp filaments and results in premature lamp failure.*

d. Lampholder material shall be rated per IEC 60400 sections 17, 18, and 15.6, which specify mechanical resistance to heat, stress, and corrosion. *Lampholders shall not deform due to operating temperatures expected under normal use and luminaire design. Deformation of the lampholder could result in a broken electrical connection, resulting in poor dimming performance and premature lamp failure.*

2. Lampholder housing shall not deform due to wire or lamp insertion. *Cardboard backing can deform during wire insertion, which could allow the wire to be over-inserted, resulting in poor contact with lampholder.*

II. Lampholder wiring

1. Rapid-start sockets shall be used with dimming ballasts. Instant-start sockets can not be used. *Instant start sockets short out the pins of the lamp, so the ballast cannot provide supplemental heat to the filament.*

2. Wiring between ballast and lamp sockets shall follow diagram provided by ballast manufacturer. *Some manufacturers wire "yellow" filaments in parallel, other manufacturers wire "yellow" filaments in series. The ballast design provides the correct filament heat only if the lamps are wired according to the diagram.*

3. Lampholders shall provide a separate channel for each wire that connects to a lamp pin, and accommodate a specified range of wire diameters. *Insertion of a second wire into the lampholder must not compromise electrical connection of the first. Therefore the socket should have a separate locking mechanism for each wire. Inserting wires of different sizes must not compromise the electrical connection.*

III. Lamp installation

1. Lampholder design shall have obvious indication that lamp installation is correct. *If lamps are partially inserted, intermittent contact may result in arcing. Example, rotate-and-lock sockets for T5 and T8 linear lamps. Correct installation should be visibly obvious to someone with minimal experience installing lamps.*

2. Lampholders shall be mounted according to recommendations of lampholder manufacturers. Secure mounting of the lampholder is required to prevent pivoting or other movement. *Socket to socket spacing is important for linear fluorescent lamps as lamp dimensions may vary, and intermittent contact between lamp and socket may result.*

3. Lampholder shall be mounted to the fixture so as to provide the correct spacing between the lamp and the grounded fixture. *The distance between the lamp wall and ground plane for proper dimming function varies depending on the lamp type. See pg. 12 for Lutron recommended distances. (The recommended lamp heights are for lamps dimmed from 100% down to 1%. For lamps that are only dimmed from 100% down to 10%, the minimum distances can be further reduced to the following: T8 linear: 0.80 mm (0.031"); T5 linear and T5 twin-tube: 1.6 mm (0.062").*

4. Fixture design and packaging shall ensure lampholders meet this specification after shipping and installation. *Lampholders must be mounted rigidly. Fixture design and packaging must prevent deformation during shipping, installation, and/or usage that would cause lamps to make poor contact with lampholders.*

IV. Provisions for twin-tube and U-bent lamps

1. Fixtures for twin-tube lamps shall have mechanical support for the end opposite the cap. *Otherwise the weight of the lamp may cause intermittent connections between the lamp pins and the lampholder.*

2. The mechanical support for the twin-tube end opposite the cap shall be thermally isolated from the fixture. *Lamp should not be thermally connected to fixture, otherwise a secondary cold-spot will result in uneven wearing of the lamp.*

3. Twin-tube support shall withstand conditions of operation, including but not limited to temperature, UV exposure, and vibration. *Years of exposure to heat and lamp UV causes some plastics to become brittle. Insertion of a lamp into an embrittled support may then cause the support to break, resulting in intermittent contact between the lamp and the lampholder.*

4. Lampholder should be supported in the fixture to withstand insertion force of the lamp. *Repeated insertions and removals should not compromise lamp-pin-to-holder contact.*

EcoSystem® Bus Class 1 and Class 2 Listing

Overview
EcoSystem digital fluorescent dimming ballasts are connected together by a 2-wire low voltage bus. The bus is designed for both Class 1 or Class 2 installations. This application note explains how the bus is installed in either type of configuration. Steps required by fixture manufacturers and electrical contractors to meet the National Electrical Code are detailed as well.

Wiring Details: EcoSystem Bus wired Class 2
In the configuration diagrammed below the EcoSystem bus is wired Class 2.

I. For factory installed wiring, as per UL1598 section 6.17.1: *Factory-installed power limited wiring and branch circuit wiring that come in random contact within the luminaire shall have insulation rated for the maximum voltage that exists in any of the circuits.* As long as the properly rated insulation is used, no spacing or separation is required, regardless of the circuit conductor voltage.

II. Class 2 wiring methods follow the NEC Requirement 725.136(D) (references to Class 3 eliminated): *Class 2 circuit conductors in compartments enclosures, device boxes, outlet boxes, or similar fittings shall be permitted to be installed with electric light, power, Class 1, … circuits where they are introduced solely to connect the equipment connected to Class 2 circuits, and where (**1**) or (**2**) applies:*

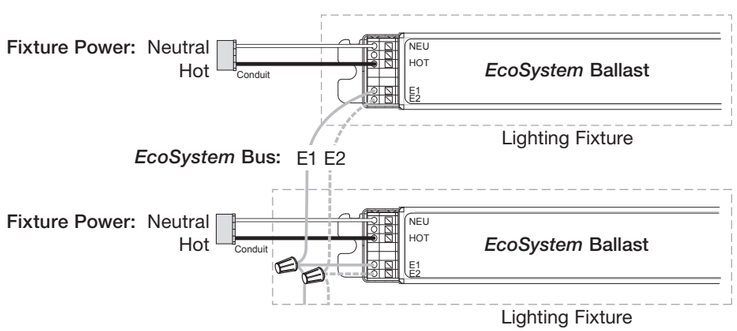
1. The electric light, power, Class 1, …circuit conductors are routed to maintain a minimum of 6 mm (.25 in) separation from the conductors and cables of Class 2.

2. The circuit conductors operate at 150 volts or less to ground and also comply with one of the following:

A. The Class 2 circuits are installed using Type CL3, CL3R, or CL3P or permitted substitute cables provided these Class 3 cable conductors extending beyond the jacket are separated by a minimum of .25 in (6 mm) or by a nonconductive sleeve or nonconductive barrier from all other conductors.

B. The Class 2 circuit conductors are installed as a Class 1 circuit [see below]

III. EcoSystem Ballasts have a minimum of .25 in spacing between line voltage and EcoSystem Bus terminals (E1 and E2) for Class 2 installations. Terminals read “Class 2 Bus”



For more detail on Class 2 wiring and additional Class 2 wiring requirements see the National Electrical Code Article 725.

Appendix B: Application Note

Wiring Details: EcoSystem Bus wired Class 1
In the configuration diagrammed below the EcoSystem bus is wired Class 1.

I. Class 1 wiring methods follow the NEC Requirement 725.48

1. Class 1 circuits shall be permitted to be installed with other circuits as specified in 725.48 (A) and (B)

A. *Class 1 circuits shall be permitted to occupy the same cable, cable tray, enclosure, or raceway without regard to whether the individual circuits are alternating or direct current, provided all conductors are insulated for the maximum voltage of any conductors in the cable, cable tray, enclosure or raceway.*

B. Class 1 circuits shall be permitted to be installed with power supply conductors as specified:

1. Class 1 and power supply circuits shall be permitted to occupy the same cable, enclosure, or raceway only when functionally associated.

II. Since the EcoSystem bus is designed for the more stringent requirements of a Class 2 installation, EcoSystem bus devices can be installed in a Class 1 manner when Class 2 markings are eliminated. The NEC allows the reclassification of Class 2 circuits provided:

1. *725.130 Exception No. 2: Class 2 and 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.*

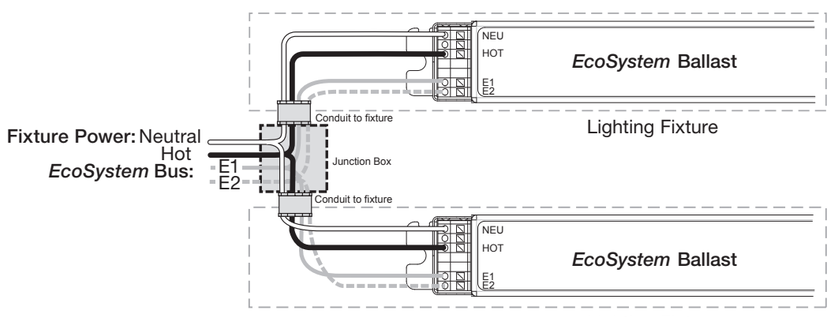
For more detail on Class 2 wiring and additional Class 2 wiring requirements see the National Electrical Code Article 725.

III. The EcoSystem bus is labeled “Class 2” rather than “Class 1 or Class 2” because the ballast is a sink of power, not a source. According to UL 935 SB12.3:

1. *When the ballast is the sink of a Class 2 limited power circuit, the circuit shall be identified as such with the words “Class 2 Circuit” to indicate that the ballast is intended for connection to a Class 2 circuit and that the controlling circuit is not affected by the presence of the ballast.* Since the ballast is not a source for this link, it is prohibited from being marked as “Class 1 or Class 2” even though it is allowed to be wired as Class 1 or Class 2.

Reference Information

- Code quotation, guidance, and wiring guides above are listed for reference only. Always follow local and national wiring requirements.
- NEC 2008 was used as a reference in this Application Note. More recent releases of the National Electrical Code should always be consulted.
- The National Electrical Code (NEC) is a registered trademark of the National Fire Protection Association, Quincy, MA.



In order to run power wires and EcoSystem bus in the same coduit, the wire used for the bus must be of a specific type permitted by the NEC for Class 1 circuit conductors. Refer to NEC code 725.48 (B) for more details.

Glossary

Ballast An electrical device used in fluorescent and HID fixtures. It furnishes the necessary circuit conditions (voltage, current, and waveform) for starting and operating a lamp.

Ballast Efficacy Factor (BEF) The ballast efficacy factor directly measures the efficiency of the ballast by illustrating that the higher the light output for a given power rating, the more efficiently the ballast will operate.

Ballast Factor A ballast's light output with respect to a reference ballast's light output. The reference ballast is a ballast which produces full light output as defined by the American National Standards Institute (ANSI). Ballast factor is expressed in percentage form (e.g., 0.95 or 95%).

CSA Certified Indicates that the product has been evaluated and undergoes continual assessment by CSA International to comply with safety standards established by the Canadian Standards Association.

Current Crest Factor The ratio of the peak value of lamp current to the root-mean-square (RMS) value of lamp current.

Filament In fluorescent lamps, the filaments are designed to emit electrons to sustain the arc.

Filter An electrical circuit (capacitor and inductor) intended to reduce radio frequency interference (RFI) and lamp buzz. Most Lutron ballasts and dimmers incorporate a filter circuit.

Fluorescent Lamp A low-pressure gas-filled electric discharge lamp in which a fluorescent coating (phosphor) transforms ultraviolet radiation into visible light.

Footcandle Defines the quantity of illumination on a surface or object, 1 footcandle = 1 lumen per square foot.

IEC Rated Indicates that the product has been certified by the International Electrotechnical Commission. Compliance with IEC's international standards propagates standardized design that is accepted in many countries around the world.

Incandescent Lamp An electric lamp in which a filament gives off light when heated by an electric current.

Inrush Current The current flow occurring at the instant of turn-on. (The level of inrush current depends on the load type and can be substantially higher than the normal operating current.) All Lutron ballasts incorporate inrush current limiting circuitry.

Instant-Start Lamp A class of fluorescent lamps which do not require filament preheating and can start instantly. Lutron dimming ballasts cannot be used with instant-start lamps.

Intensity The brightness of a lamp as a percentage of maximum brightness (e.g., 66% intensity describes a lamp dimmed to 2/3 of its maximum brightness).

KWH (Kilowatt hour) A unit of energy equal to one kilowatt of power expended for one hour.

Lamp A device for producing light (such as a bulb or tube).

LED Driver Auxiliary device(s) needed to operate and vary the intensity of light output from LED lamp source(s) by regulating the voltage and current powering the source. There are both dimming and non-dimming types.

Line Voltage The voltage between the lines of a supplying power system.

Load The device which a dimmer is controlling (i.e., incandescent lamp, ceiling fan, fluorescent lamp).

Glossary

Low-end Trim Adjustable setting on a dimmer that establishes its minimum output, therefore, establishing minimum light level.

Lumen The quantity of light that is emitted by a lamp, used in reference to efficacy (lumens per watt). Luminance describes the light emitted or reflected from a source or object in a particular direction. Luminance produces the sensation of brightness and is measured in candelas per square foot (or square meter) of a source or object surface area in the direction of viewing.

Luminous Efficacy The ratio of light emitted to power required for a light source or luminaire. Commonly used to measure energy efficiency, it is the lumens per watt from a light source (amount of light per watt of power).

Lux 1 lux = 1 lumen per square meter.

Phase Control A common method of dimming that removes part of the line cycle, therefore reducing the RMS voltage.

Power Factor Ratio of the average power delivered to the lamp ballast system to the product of voltage and current (the ratio of the average power to the VA). This shows how effectively available power is being used.

Radio Frequency Interference (RFI) Electrical noise that may be picked up by sensitive audio and radio equipment. Lutron builds filters into every control and ballast to reduce this noise. Also called electromagnetic interference (EMI). See Filter.

Rapid-Start Lamp A class of fluorescent lamps having filaments which must be constantly heated by an external circuit.

Relative System Efficacy (RSE) Relative system efficacy is a metric used to rank ballast and lamp efficacy. It is used almost exclusively to describe dimming ballast efficacy and uses lamp rated efficacy to normalize Ballast Efficacy Factor.

Source Refers to the type of lamp, (e.g., fluorescent, incandescent, low voltage, HID, etc.).

Square Law Dimming Dimming with a direct correlation between the position of the slider and the perceived light level (e.g., if the slider is halfway down the travel, the perceived light level is 50%). With Square Law Dimming, gradual movement of the linear slider results in a proportional change in the perceived light level– allowing for easy, precise adjustment of the light level setting.

T4 A fluorescent lamp which has a diameter of 1/2" (12.7 mm).

T5 A fluorescent lamp which has a diameter of 5/8" (15.9 mm).

T8 A fluorescent lamp which has a diameter of 1" (25.4 mm).

3-Way Dimming 3-way dimming control (as opposed to single-pole, multi-location, or Omnislide™ control) allows dimming from one location only (using a 3-way dimmer) and on/off switching from a second location (using a 3-way switch).

Total Harmonic Distortion (THD) The total amount of current at frequencies other than 60 Hz (the main frequency), expressed as a percent of the 60 Hz current. No power is delivered to the load by current at these other frequencies.

UL Listed Indicates that the product has been evaluated and undergoes continual assessment by Underwriters Laboratories Inc. to comply with safety standards established by Underwriters Laboratories Inc.

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Lutron Electronics Co., Inc.
7200 Suter Road
Coopersburg, PA 18036-1299

World Headquarters 1.610.282.3800
Technical Support Center 1.800.523.9466
Customer Service 1.888.LUTRON1

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