LUTRON

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Color Tuning with Lutron Controls

Purpose

Color tuning is the concept of changing the color of LED lighting for a variety of purposes such as presentations, comfort and well-being. Color tuning has evolved significantly with the development of LEDs (or solid state lighting – SSL) and is being designed into both residential and commercial applications. In these applications, the color of the light being controlled can be modified to create a variety of environments.

This application note focuses on the three predominant color tuning techniques, methods, and solutions on how to achieve them with Lutron controls and systems.

1. **Dim to warm** is the capability of reducing the color temperature of a light source in proportion to the intensity. This mimics the color shift of incandescent lamps as they are dimmed to a lower intensity (warmer color temperature at lower light levels, cooler color temperature at higher light levels).
2. **Tunable white** is the capability of achieving any color temperature at any intensity of a light source, within specified parameters.
3. **Full color tuning** is the capability to change the relative mixture of multiple independent base colors (such as red, green, and blue) within a single source of a fixture.

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Background

Similar to the way white paint comes in different shades, white light has its own variations known as color temperature. **Color temperature** is defined as the light emitted by a black body radiator at different temperatures, and is measured in degrees Kelvin (K). Lower color temperature (red/orange) light is described as "warm" (for example 2200 K) and higher color temperature (blue/white) light is described as "cool" (for example 5000 K).
Figure 1 depicts a heated piece of iron, a black body radiator. Depending on the temperature of the piece of iron, different color temperature light is emitted. Incandescent lamps are also black body radiators and emit light at different color temperatures depending on their intensity. Although neither fluorescent nor LEDs are black body radiators, we still refer to their light output as having a color temperature. Therefore, the term correlated color temperature (CCT) is used to correlate a non-black body radiator to the color temperature emitted by an equivalent black body radiator. Figure 3 depicts a color temperature curve for an incandescent lamp over different intensity values.

The **visible color spectrum** describes all of the colors in the portion of the electromagnetic spectrum that are visible to the human eye. These include primary colors such as red, green and blue as well as all of the possible colors that result when these colors are mixed. However, white light can also be achieved by mixing select colors together (such as red, green and blue). The ratio of how the colors are mixed determines the color temperature. Figure 2 depicts a chromaticity space with an overlay for the black body locus and lines of constant color temperature (T_C).

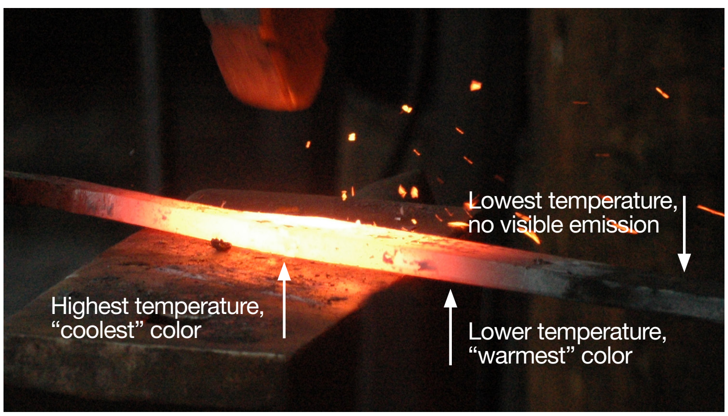


Figure 1: Heated piece of iron showing the black body color temperatures.

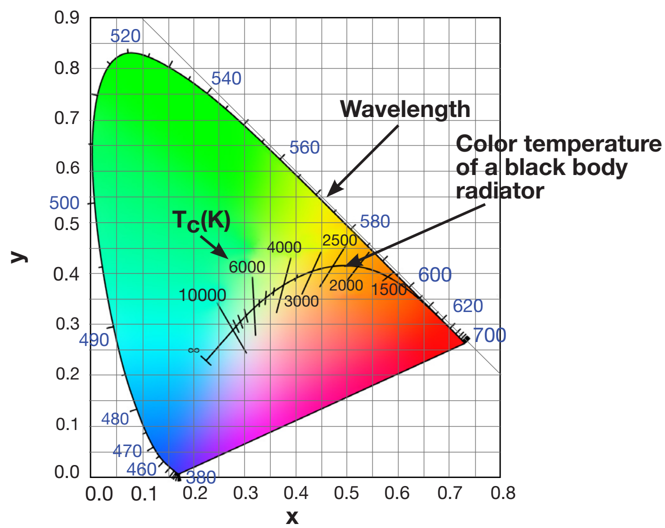


Figure 2: Color space with black body locus and lines of constant color temperature (T_c).

Dim-to-Warm

When turned on at full output, the filament of an incandescent lamp glows white hot, the color temperature of which varies from about 2700 K to 3000 K, depending on the lamp. Dimming a filament naturally cools the filament, moving it back to yellow then red the further you dim. This gives a "warmer" light at lower levels, preferred for intimate settings and producing a calming feeling. People are familiar with this behavior and expect it, especially in residences, restaurants and similar spaces. To mimic the behavior of incandescent lamps, LED light sources capable of dim-to-warm dimming will mix two or more LEDs of different colors in an attempt to emulate the color temperature of an incandescent lamp throughout its dimming curve. Figure 3 depicts CCT curves for an incandescent lamp and USAI Lighting's fixtures equipped with their Warm Glow® Dimming technology.

LEDs capable of dim-to-warm require only one control input. The LED driver translates the control input into the appropriate intensity and color temperature. For LED lamps (i.e. screw-based LEDs with integral drivers), the control input is typically forward- or reverse-phase line-voltage control.

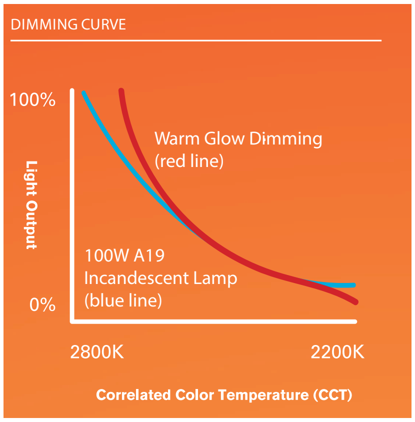


Figure 3: CCT curves for incandescent lamp and USAI Lighting luminaire with Warm Glow® Dimming technology.

Example Dim-to-Warm Implementation #1: Phase Control Lamps

Figure 4 shows an example of a Lutron Diva LED+ dimmer controlling Philips DimTone® LED. Compatibility testing was performed by Lutron's LED Control Center of Excellence to ensure high quality dimming between the Diva LED+ dimmer and Philips DimTone® lamps.

Visit Lutron's LED Control Center of Excellence (www.lutron.com/leds or 1-877-346-5338) for more dimmer options and compatible LED lamps.

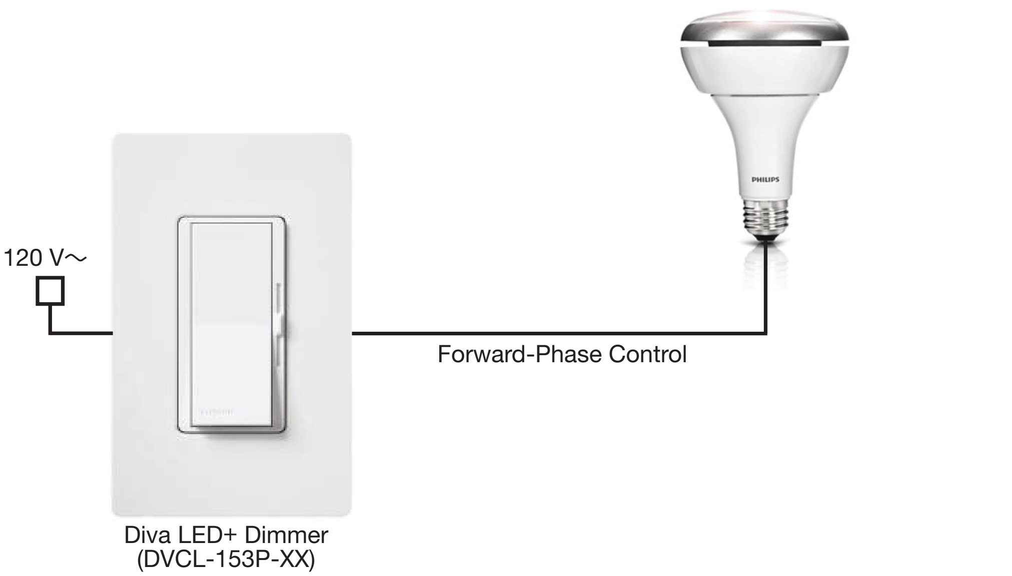


Figure 4: Lutron Diva LED+ dimmer controlling Philips DimTone® LED.

Example Dim-to-Warm Implementation #2: Fixtures

For LED fixtures where the LED light engine and driver are separate, the control input can include phase control as well as 0-10V or digital inputs (such as Lutron EcoSystem, DALI®, or DMX512). Figure 5 depicts a Lutron GRAFIK Eye QS with EcoSystem controlling Lutron Ivalo Finiré Prime with Warm Dimming installed with a Lutron EcoSystem LED driver. The benefit to using a digital control scheme like EcoSystem is that the power and control wiring can be run separate and the fixtures can be grouped and zoned through software without needing to change line-voltage wiring.

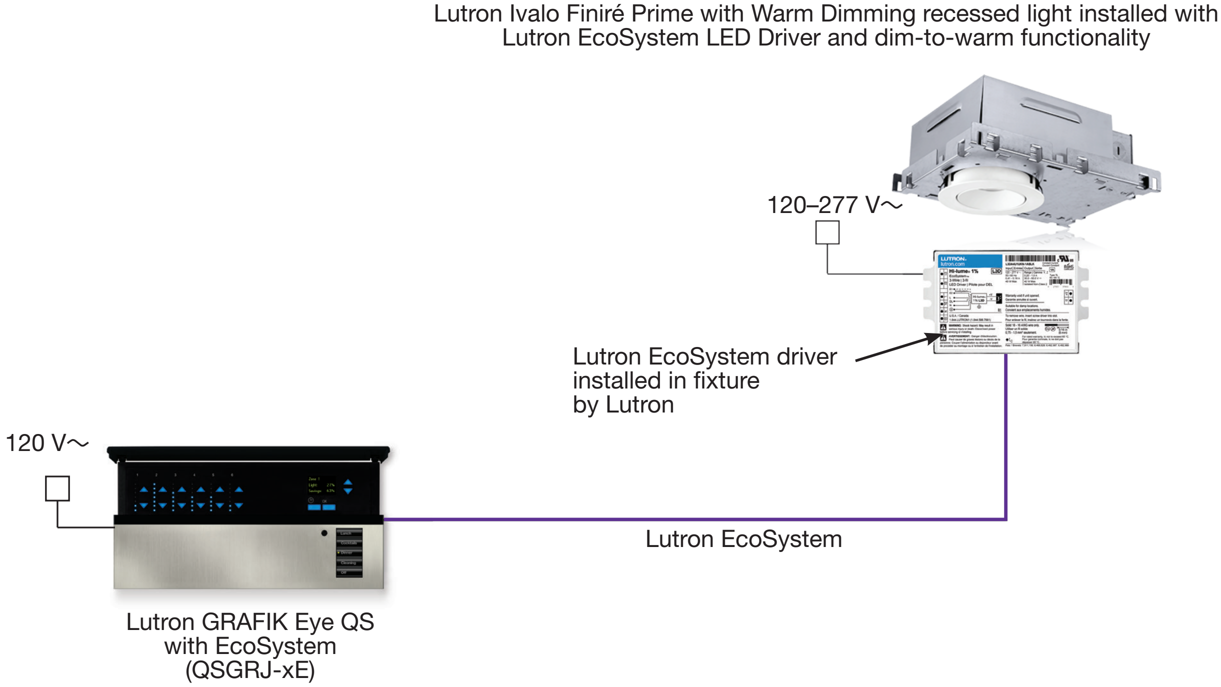


Figure 5: Lutron GRAFIK Eye QS unit controlling Lutron Ivalo Finiré Prime with Warm Dimming recessed light installed with Lutron EcoSystem LED driver.

Example Dim-to-warm Implementation #3: Ketra

Using an integral multi-channel LED chip, Ketra lamps can easily be configured to dim-to-warm. As the intensity of the fixtures change, its color temperature will automatically be adjusted to match the desired light source. Control of intensity can come from any controllers within the HomeWorks or Athena systems.

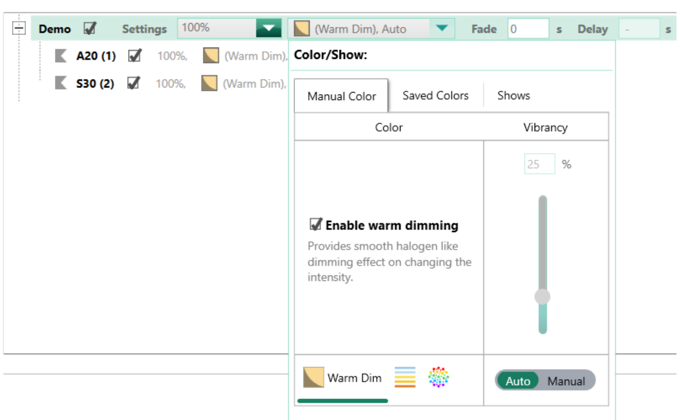


Figure 6: Available dim-to-warm emulations available with Ketra lamps.

Considerations when specifying Lutron controls with dim-to-warm applications:

1. Ensure the LED lamp or fixture is capable of dim-to-warm dimming.
2. Understand the control technology required to control the lamp or fixture (e.g. forward-phase control, reverse-phase control, 0-10V, Clear Connect-Type X, etc.). This is typically found in the lamp or fixture spec sheet.
3. Select a control that utilizes the appropriate control technology, and confirm compatibility of the control with the LED lamp or fixture by checking with the control and LED manufacturer. Lutron's LED Control Center of Excellence (www.lutron.com/ledtool) tests for compatibility between Lutron controls and phase-control LED lamps and fixtures and provides compatibility report cards to ensure solutions are specified correctly and the highest quality dimming is achieved. Additionally, Lutron's High Performance Fixture List tool (www.lutron.com/findafixture) is designed to help you find fixtures available with Lutron LED drivers.
4. Ensure that factors such as inrush currents and repetitive peak currents have been taken into account such that the minimum and maximum number of loads are correctly specified. A compatibility report card, such as those available from Lutron's LED Control Center of Excellence, should provide this. Additionally, look for controls and LED drivers that have been tested to comply with NEMA 410, which defines a maximum expected inrush current.
5. Be aware that the simulated warm dimming behavior of LED light sources may not exactly match that of existing incandescent lamps and may show variations from one manufacturer to the other.

Tunable White

Light sources have historically been purchased with a specific color temperature. This is particularly true for fluorescent lamps, which have been the primary commercial light source for decades. However, there are emerging studies on the health, comfort and productivity benefits of being able to change, or tune, the color temperature of a light source. Tunable white applications use more sophisticated LED drivers and light engines to independently control both the color temperature and the intensity of a fixture.

Tunable white is primarily a technique available in LED fixtures and not for screw-in lamps, although more sophisticated LED screw-in lamps, such as those controlled wirelessly, may offer it as a feature. There are two primary types of tunable white lighting products: Fixtures with separate control inputs for warm intensity and cool intensity and fixtures with separate control inputs for intensity and color temperature.

NOT RECOMMENDED: Separate control inputs for warm and cool intensity (warm / cool)

The first method for achieving tunable white consists of controlling the intensity of two different color temperature LED loads (e.g. 3000 K and 5000 K). The relative intensity of the two loads determines the resulting color temperature of the system as well as the intensity. The color temperature of the fixture can be tuned within the bounds set by the individual LED color temperatures. This can be achieved with two dimmable LED drivers, each with a separate control input. The control input can be phase control, 0-10V or digital. Figure 7 depicts a Lutron 0-10V Energi Savr Node unit controlling a fixture with two independent 0-10V drivers with different CCT LED light engines. In this example, a Lutron seeTouch QS keypad is used to select specific color temperatures for the fixture by setting the appropriate intensity for the two LED drivers.

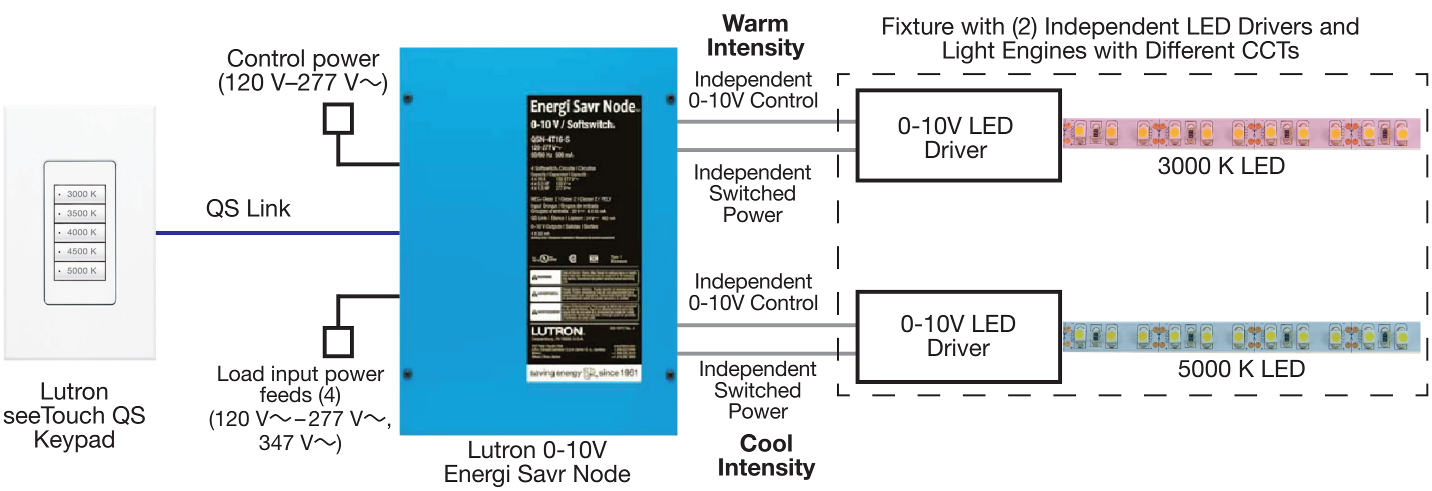
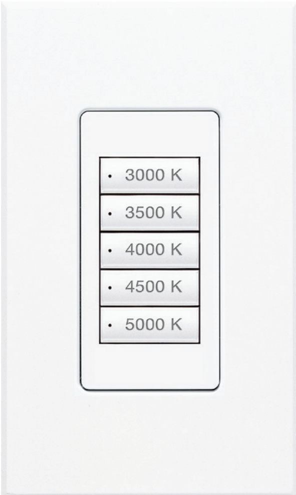


Figure 7: Lutron 0-10V Energi Savr Node unit controlling two independent LED drivers in a tunable white application (**NOT RECOMMENDED**)

The color temperature and intensity of the fixture are not completely independent. In order to achieve a specific color temperature, the LEDs must be set to distinct intensities which will dictate the overall lumen output of the fixture. This method reduces flexibility for end users, due to the following limitations:

- Independent control of intensity and color temperature is not possible.
- This option does not allow for manual raise/lower of intensity or color temperature. Loads can be adjusted strictly via scene-based control to achieve pre-determined "mixes" of the warm and cool LEDs.
- Since intensity raise / lower is not supported, daylighting or load-shed of intensity is also not supported.
- Any timeclock events must be used only to select scenes.
- Intensity and color temperature cannot be guaranteed when fading from one scene to another. Undesired color temperatures or intensities may occur when going from one scene to another, which means timeclock-based scene selection will not provide a good experience.
- Manual overrides cannot revert to a previous level or to a fade. Manual overrides can ONLY revert to a static scene.
- Changing programming (color temperature or intensity of a scene) is an extremely difficult process requiring measurements or table lookups, and will be nearly impossible for an end-user to change without support.
- The lighting designer at the job must specify exact percentages for the warm and cool outputs for each scene to achieve desired color temperature and intensity, such as the example shown in Figure 8. Lutron's design, programming, and commissioning services do not include determining the required mix to achieve a desired intensity and color temperature.



Fixture Manufactuer		Brand XYZ	
Fixture Model		Model 123	
Desired Color Temperature	LED #1 Intensity	LED #2 Intensity	Lumen Output
3000 K	100%	0%	4500
3500 K	78%	27%	4650
4000 K	52%	46%	4470
4500 K	27%	70%	4410
5000 K	0%	100%	4570

Figure 8: Sample keypad engraving and manufacturer-specific table defining color temperature based on relative LED intensity.

Some additional items to consider when specifying this type of tunable white solution:

1. With digital control, all LED drivers communicate on a single low-voltage link as opposed to running independent line-voltage or low-voltage control signals. Digital control schemes, such as Lutron EcoSystem, can reduce design complexities and wiring material and labor as compared to an analog control scheme.
2. The minimum and maximum color temperature achievable is limited by color temperature of the LED light engines used. In the example shown in Figure 8, the minimum and maximum color temperature achievable will be 3000 K (at 4500 lumens) and 5000 K (at 4570 lumens) respectively.
3. Because the black body curve is not a straight line (refer to Figure 9), using this application to fade from one color temperature to another will not produce fading along the black body curve.

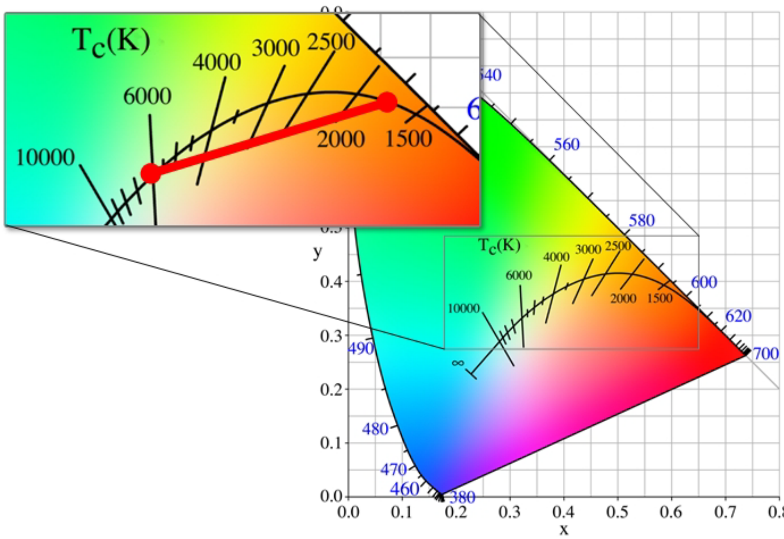


Figure 9: Using single colors (warm and cool) to achieve color tuning will cause colors in between the two extremes to deviate from the black body locus.

RECOMMENDED: Fixtures with separate control inputs for intensity and color temperature (intensity/CCT)

The second type of tunable white fixture uses one control input for intensity and the other for color temperature. The control inputs for these fixtures are typically digital or 0-10V control. Implementation of this method requires a driver which has the capability of dynamically mixing its output (using two or more colors) to generate the requested intensity and color.

Unlike solutions with warm/cool control inputs, loads that provide separate intensity and CCT inputs like Lutron T-Series and the Lumenetix® araya5® logic module (ALM) are much more flexible. Users can easily set an override of the intensity at any color temperature. For example, a scheduled event can be used to vary the CCT throughout the day, while allowing for intensity overrides by occupants. This method also allows the users the flexibility to have presets for CCT and a raise/lower for intensity. This could be in the form of a four-button keypad (for example 6000 K, 5000 K, 4000 K, and 3000 K) with a raise/lower control at the same location for intensity as shown in Figure 10 (Quantum 3.4 and above) and Figure 11 (Athena and HomeWorks). All common sequences of operation can be supported in the same way as in non-color-tuning situations (daylighting, load shed, etc.). The Athena system, HomeWorks system, and versions of Quantum starting at 3.4 will support direct entry and control of CCT values, as supported by the fixture's capabilities. All other Lutron systems will only support CCT values in a range of 0% (minimum CCT supported by the fixture) to 100% (maximum CCT supported by the fixture). Intuitive physical buttons or software-based sliders are available as shown in Figure 12. CCT and intensity control may be through a variety of typical means (0-10V, EcoSystem, T-Series, DMX, or Ketra).

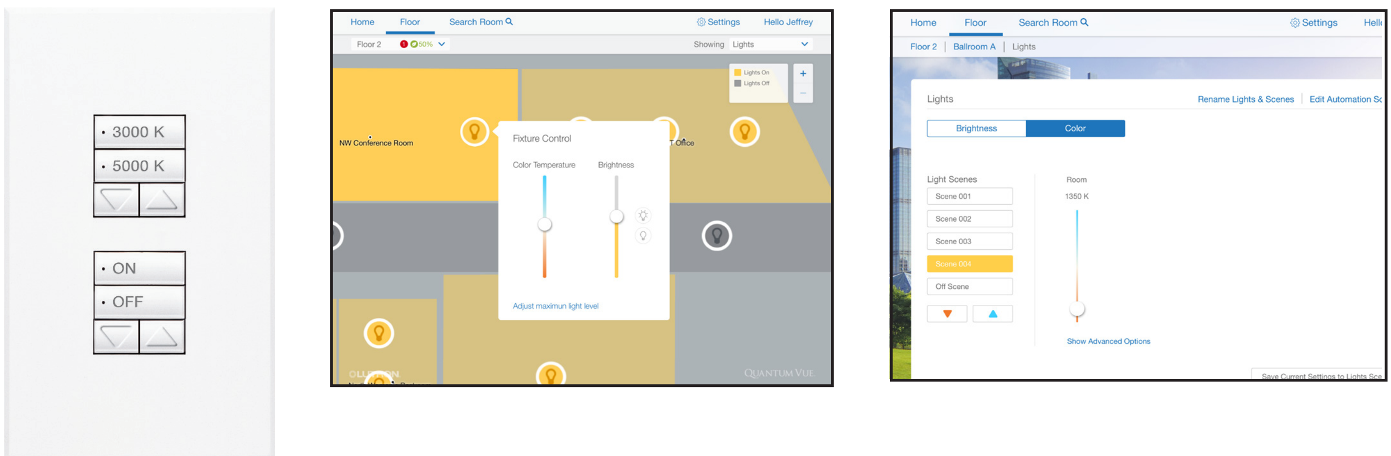


Figure 10: seeTouch QS keypad with custom engraving for tunable white applications and Quantum Vue user interface for tunable white applications. Available in Quantum systems.

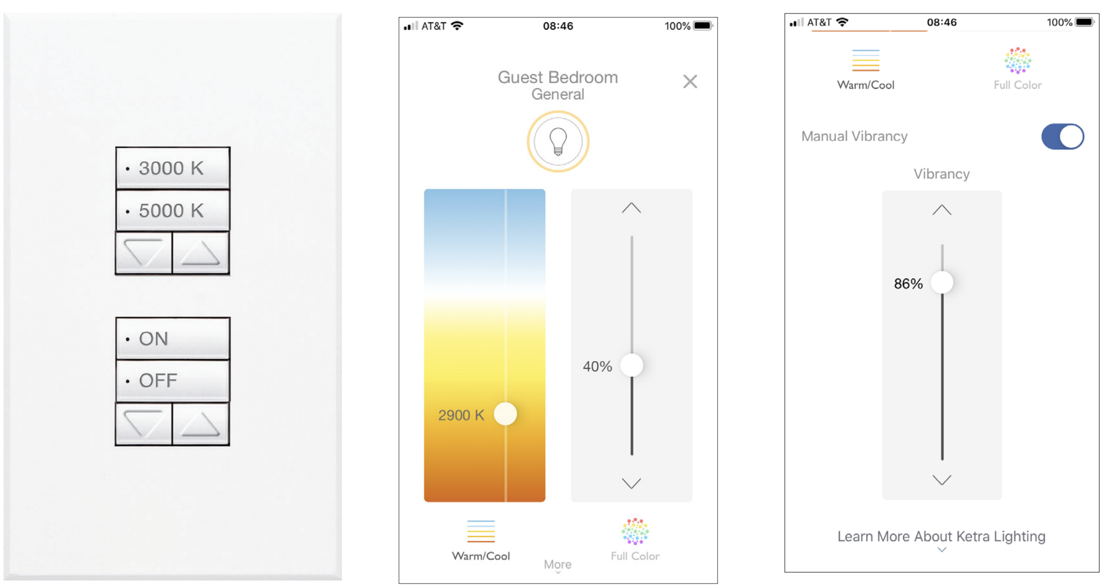


Figure 11: seeTouch QS keypad with custom engraving for tunable white applications and the Lutron App user interface for tunable white applications. Available in Athena and HomeWorks systems.

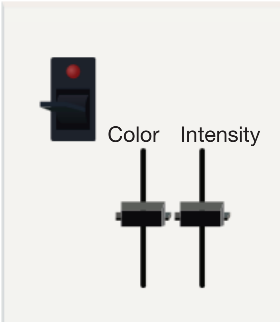


Figure 12: QS Slider control with custom engraving. Available in select Lutron QS-based systems.

The following examples show various implementations of the recommended intensity and CCT control using different control types, including Lutron T-Series, 0-10V, Lutron EcoSystem, DMX, DALI, and Ketra.

Example Tunable White Implementation #1: Lutron T-Series

Lutron T-Series provides high performance tunable white dimming for human centric applications. The T-Series solution includes a Lutron T-Series Energi Savr Node and a fixture with an integral Lutron T-Series driver, providing smooth, flicker-free dimming from 100% down to 1%. An example of this is shown in Figure 13.

Each T-Series driver has 2 channels of control available on the 2-wire digital communication link, which allows control of intensity and CCT. The T-Series driver intelligently determines how to drive the LED light engine to achieve the desired intensity and color temperature.

The T-Series digital communication link can be wired up to 32 drivers.

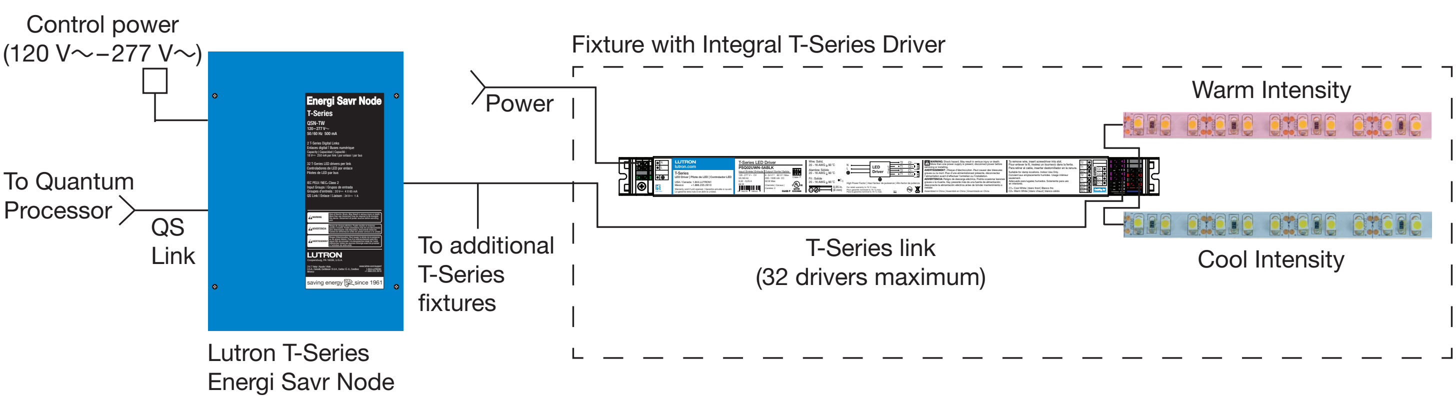


Figure 13: Lutron T-Series control and driver providing independent control of intensity and color temperature.

Example Tunable White Implementation #2: 0-10V Control

The two diagrams below show how 0-10V control technology can be used to control a fixture with Lumenetix® araya5® Logic Module (ALM). In both cases, one control is used to provide a 0-10V intensity signal while the other provides a 0-10V CCT signal to the ALM controller for color temperature control. The color mixing module from Lumenetix® interprets the 0-10V signals and sets the LED light engine to the correct color temperature.

Analog control, such as 0-10V, requires substantially more wires for tunable white than digital control, such as Lutron T-Series or Lutron EcoSystem. Because of this, digital control is recommended for tunable white applications. For example, a single zone of 0-10V tunable white requires five wires to be run between the controls and the driver – one for switched hot, two for 0-10V color temperature control, and two for 0-10V intensity control. A single zone of T-Series tunable white requires just two wires. As more zones of control are added, more wires need to be run for 0-10V control. Digital control allows each driver to be controlled individually over a single wire run.

Figure 14 depicts two Lutron Nova T☆ slide dimmers, and Figure 15 depicts two Vive 0-10V PowPak modules.

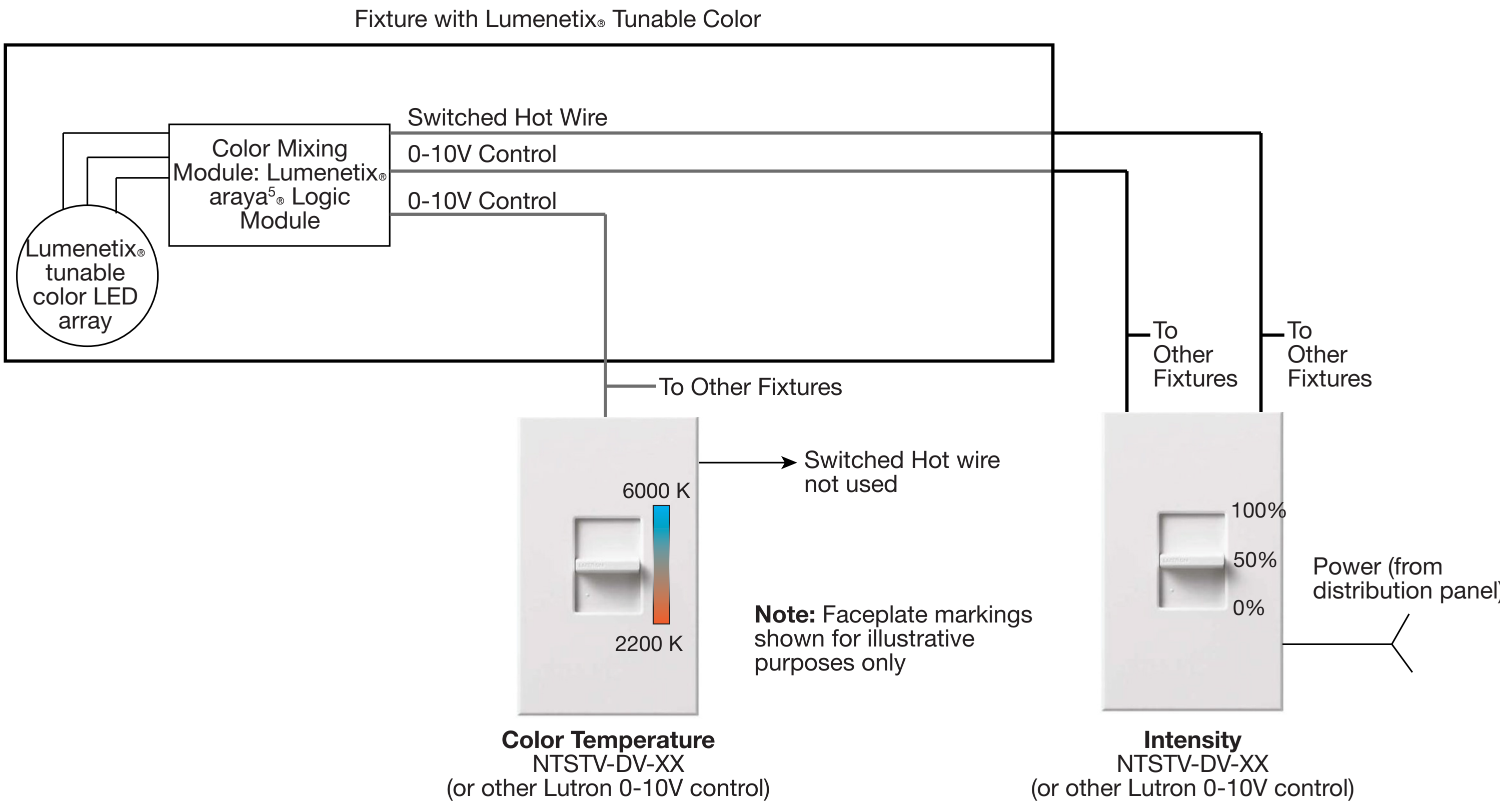


Figure 14: Lutron Nova T☆ slide dimmers providing independent control of intensity and color temperature of a Lumenetix® fixture with a tunable color LED array fixture inside.

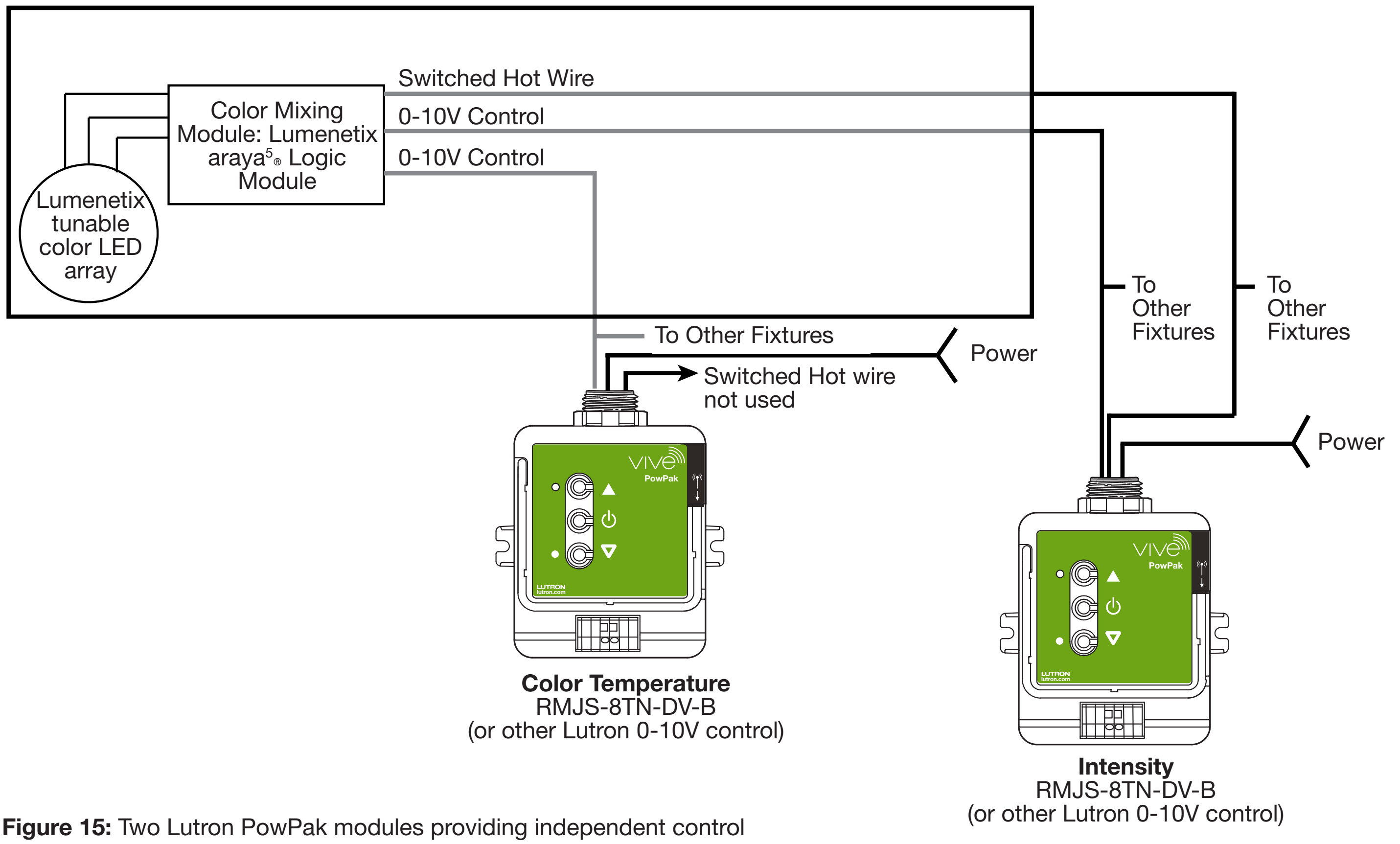


Figure 15: Two Lutron PowPak modules providing independent control of intensity and color temperature.

Example Tunable White Implementation #3: EcoSystem Control

Figure 16 depicts an alternate implementation for separate control of intensity and color temperature. An EcoSystem-compatible control system (such as Quantum, Athena, HomeWorks, or QS Standalone) is used with a fixture that controls an integral Lumenetix® araya5® Logic Module (ALM) with EcoSystem control and an araya5® Tunable Color round or linear LED array. The Lumenetix® color mixing module determines the proper color temperature provided by the EcoSystem Link.

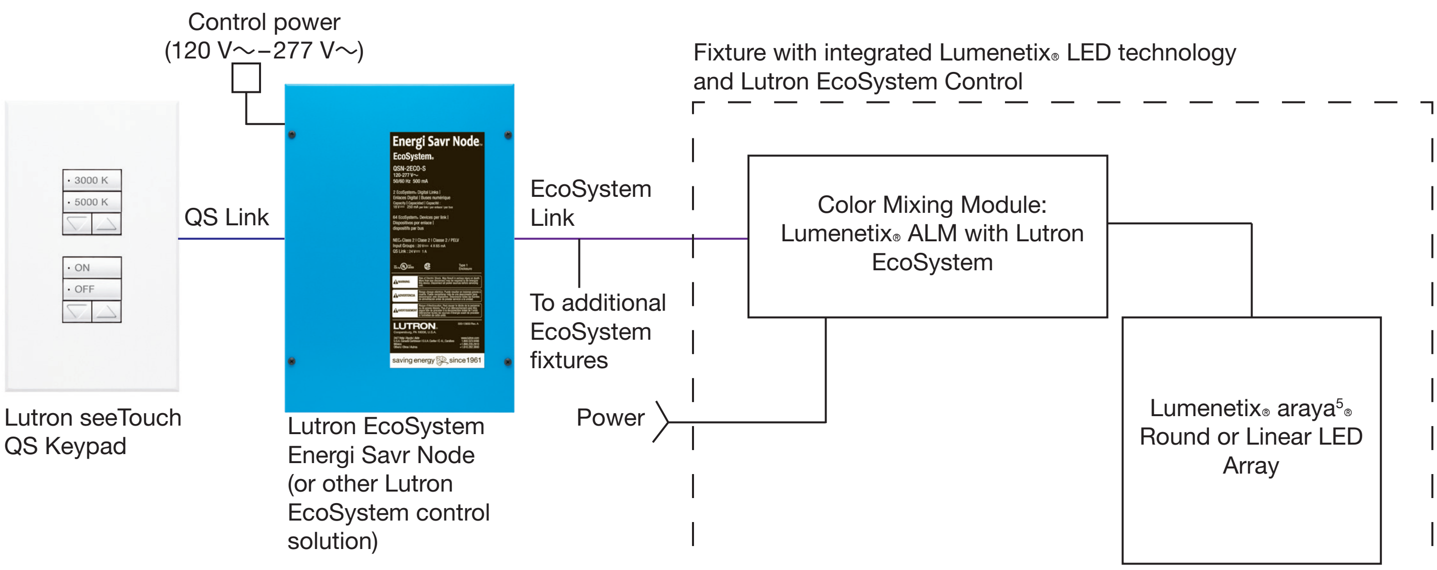


Figure 16: Lutron EcoSystem providing independent control of intensity and color temperature.

Example Tunable White Implementation #4: DMX Control

Figure 17 depicts an implementation for separate control of intensity and color temperature using a DMX protocol. A DMX interface to the Lutron control system (such as the QSE-CI-DMX) is used with a fixture that contains a DMX-compatible color-mixing interface and DMX multi-channel driver. One example of this would be the eldoLED® DUALdrive™ with lightshape® capability. In this case, the color-mixing interface and multi-channel DMX driver are integrated together as part of the driver. A different example of a separate driver and color-mixing interface is the Finelite® FineTune™ system, where the Power Control Center (PCC) acts as the color-mixing interface, and the Finelite® LED driver is the multi-channel DMX driver.

This is uncommon. Most DMX LED drivers map a DMX channel to a single color of LEDs, such as red, green, and blue. Most DMX LED drivers are NOT capable of receiving an intensity and CCT input; they need to explicitly be described as capable of receiving intensity and CCT values via a DMX control signal. Also be aware of the limitations of DMX systems:

1. DMX wiring must be daisy-chained using special cable and terminations, Class 2 rules apply
2. One zone of lighting control is mapped to 1 channel of DMX
3. A DMX wire run typically supports 32 DMX fixtures; adding additional fixtures requires the use of additional hardware
4. A DMX fixture may have multiple channels per fixture
5. Daylight control of a DMX zone is not currently implemented in Quantum, Athena, HomeWorks, GRAFIK Eye QS, or Energi Savr Node systems

For more information on Lutron's DMX solutions, see the "Lutron Solutions for DMX" application note (P/N 048592) on www.lutron.com

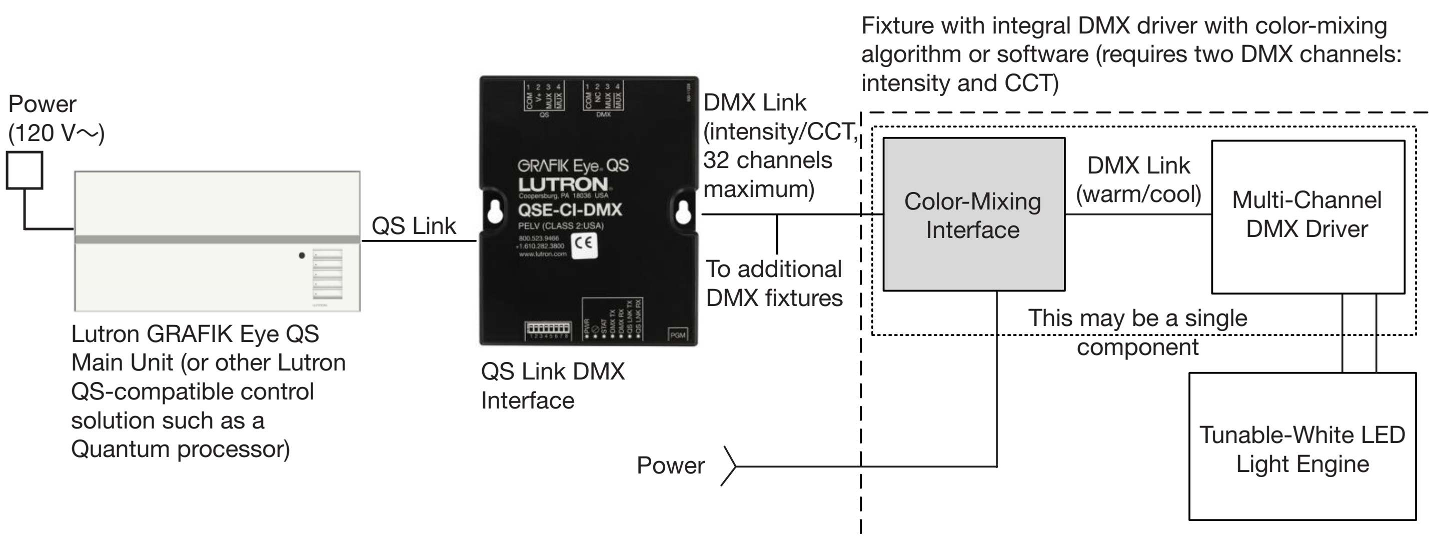


Figure 17: DMX providing independent control of intensity and color temperature.

Example Tunable White Implementation #5a: DALI Control (DALI Type 6)

Figure 18 depicts an implementation for separate control of intensity and color temperature using a DALI protocol. Note that this implementation utilizes DALI Type 6 (intensity-only) commands, and is NOT the same as using the color-specific commands of DALI Type 8, which is explained in the next section. Rather, this method uses a multi-channel DALI driver that has been configured to listen to two DALI addresses — one for intensity, and one for CCT. It then uses these two values to determine how to mix together the warm and cool LEDs connected to its output to achieve the desired intensity and CCT levels. An example of this application would be certain eldoLED® DUALdrive™ LED drivers with internal lightshape® software. Most standard DALI drivers do not offer this functionality, so please confirm that it is explicitly stated.

–Note the following systems and DALI Type 6 compatibility:

Quantum:
- U.S.A./Canada: QSN-2DAL-S-CPN6916
- All other countries: QSNE-2DAL-D

Athena:
- All countries: QSN-2DALUNV-D or QSN-2DALUNV-S

Standalone QS:
- U.S.A./Canada: Not available
- All other countries: QSNE-2DAL-D

When considering the applications where such a scenario would be used, be aware that the DALI protocol only supports fade times up to 90 seconds (newer versions of the DALI protocol, which are not universally supported by all hardware, allow fade times up to 16 minutes). This makes it difficult to fade from one color temperature to another over a long period of time, such as when you're trying to simulate natural daylight. These sort of applications require fade times of tens of minutes, or even hours, to mimic how the light changes outside. Due to the short fade times available in DALI, you would need to create many small steps, each one lasting only a few minutes, to properly simulate the changes of daylight. This is expensive to program and impractical to maintain over the life of a system. **For this reason, DALI drivers are not recommended for tunable-white applications that are meant to mimic daylight.**

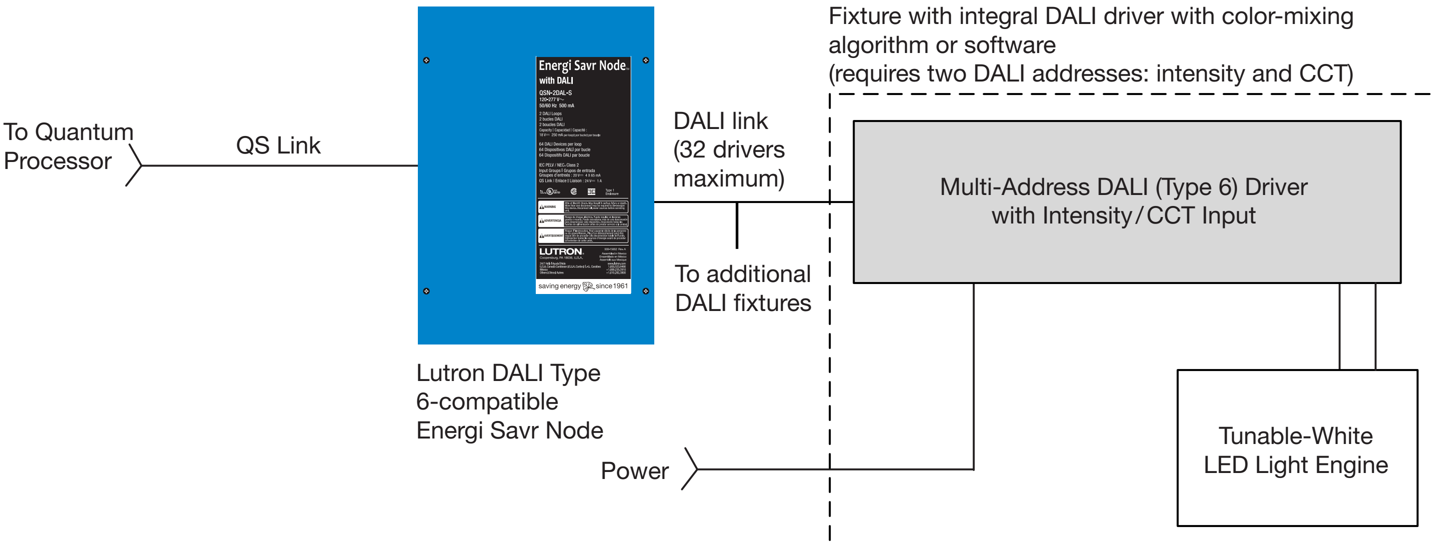


Figure 18: DALI Type 6 implementation providing independent control of intensity and color temperature.

Example Tunable White Implementation #5b: DALI Control (DALI Type 8)

Figure 19 depicts an implementation for separate control of intensity and color temperature using a DALI protocol, utilizing the DALI Type 8 extensions for color-specific commands. Note that this implementation is different than the previous DALI Type 6 example. This method requires a multi-channel DALI Type 8-compatible driver which listens to a single DALI address. Commands sent to that single address can then be used to change both intensity and CCT, and the driver does the mixing of the warm and cool loads to achieve the desired result. An example of this application would be select eldoLED® DUALdrive® LED driver with DALI Type 8 capability.

–Note the following Lutron DALI Type 8 systems and compatibility:

Athena:
- All countries: QSN-2DALUNV-D or QSN-2DALUNV-S

Using the model numbers listed above provides additional benefits beyond what is supported through the standard DALI protocol. One particularly useful feature in color tuning applications is support for fade times of up to four hours, rather than the 90 seconds supported by DALI. This allows for color and intensity fades over long periods of time, which can emulate the natural changes of light throughout the day.

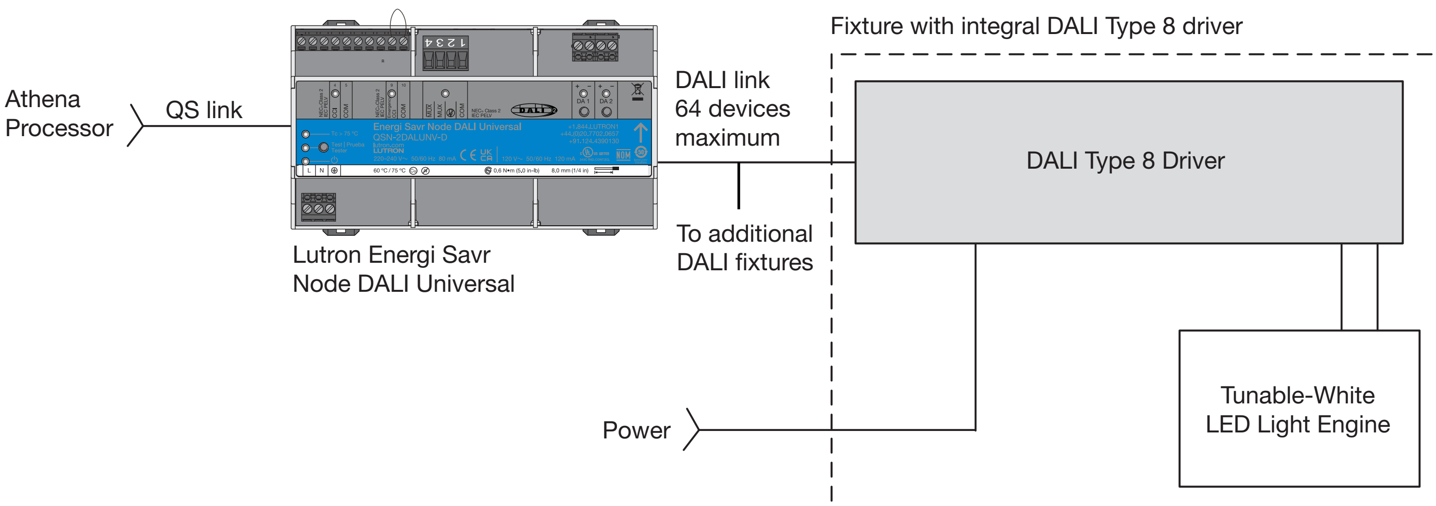


Figure 19: DALI Type 8 implementation providing independent control of intensity and color temperature

Example Tunable White Implementation #6: Ketra

Because of the RGBW source used inside of a Ketra LED light, it has the capabilities of maintaining a color temperature exactly on the black-body curve within one MacAdam Ellipse from 2700K to 5000K. Furthermore, if an application desires it, a Ketra light source can be intentionally adjusted to be off the black-body curve. This might be useful, for example, if the characteristics of a particular object are trying to be accentuated, such as the green of vegetables, the red of meats, the particular hue of a piece of clothing or artwork. This adjustment can be made in the Ketra's design software as shown in Figure 20 or from the Lutron App as shown in Figure 11, and programmed to be recalled at the touch of a button from other Lutron systems such as Athena and HomeWorks.

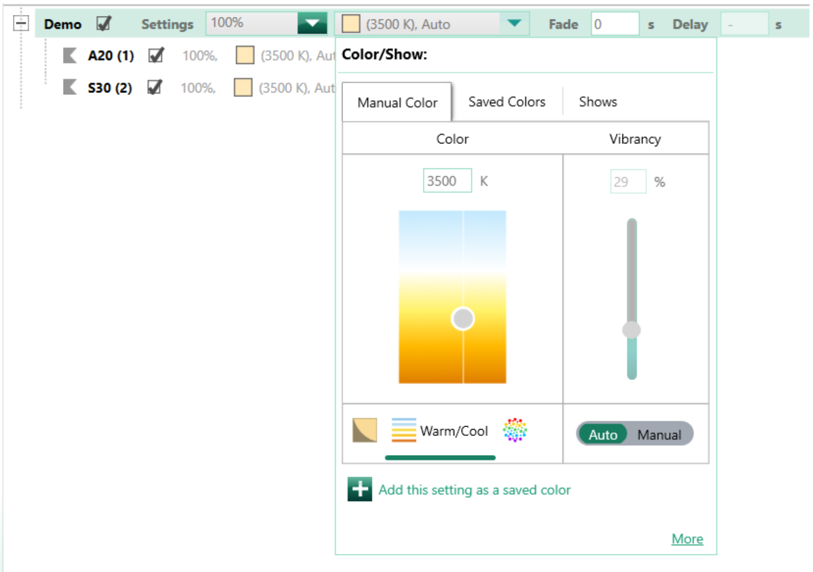


Figure 20: Ketra not only allows independent control of intensity and CCT, but also allows a user to adjust vibrancy (maintaining CCT while adjusting the spectral power density to manipulate color reflection in the space).

Some items to consider when specifying tunable white solutions:

1. With digital wired control, all LED drivers communicate on a single low-voltage link as opposed to running independent line-voltage or low-voltage control signals. Digital control schemes, such as Lutron T-Series and EcoSystem, can reduce design complexities, wiring material, and labor as compared to an analog control scheme.
2. Wireless control systems, such as Ketra with either the HomeWorks or Athena systems, eliminate the low-voltage cable altogether increasing design efficiency and flexibility and decreasing labor and complexity even further.
3. Tunable white control with intensity / CCT is necessary when daylight harvesting is also required, since color temperature can remain constant as intensity is adjusted.
4. When designing systems with tunable white control, specifiers should include language requiring control to be provided via separate channels of intensity and CCT. When bidding on projects where the control intent is unclear, manufacturers should include an RFI stating intensity / CCT control is assumed. The RFI should also state that deviations from this method of control will incur significant cost adders, and may not meet the desired sequence of operation.
5. Sequences of operation should explicitly call out intensity and color temperature values, as shown in Figure 21.
6. The Lutron High Performance LED Fixture List (www.lutron.com/findafixture) is designed to help find fixtures available with Lutron LED drivers and integrated Lutron control technology.

Space Type: Open Office			
		Color Temperature Control Input Level	Intensity Control Input Level
Keypad Buttons	3000 K	10%	Unaffected
	5000 K	90%	Unaffected
	Color Raise / Lower	Raise / Lower	Unaffected
	ON	Unaffected	100%
	OFF	Unaffected	0%
	Intensity Raise / Lower	Unaffected	Raise / Lower
Occupancy	Occupied Action	50%	90%
	Un-occupied Action	Unaffected	0%
Daylighting		Unaffected	Enable (2) daylighting rows to mantain 50 fc

Figure 21: Sample of sequence of operations for tunable white applications.

Full Color Tuning

An early use of LEDs for lighting was in theatrical applications where their ability to change color output to any mix of red, green, and blue had considerable stage value. This ability to change colors was soon adopted beyond the stage to create similar effects in commercial and residential spaces. Designers can now highlight different areas within a space or provide accents to walls and other architectural features to create the perfect appearance.

This type of color changing lighting or color modification is different than tunable white and dim to warm because it is not based only on maintaining white light. It is meant to produce a color output anywhere within the visible color spectrum. This is most commonly accomplished through the mixing of several base color LEDs as depicted in Figure 22. A common example is red / green / blue or RGB color control. A wide variety of colors can be produced by mixing these three colors in varying intensities. To provide finer range of color control or better color qualities additional color LEDs are included such as amber (RGBA) or white (RGBW).

Some architectural uses for color changing lighting include tuning one set of LED products in a space to match other sources in the space, tuning for preferred appearance of retail products (like fruit) or creative appearance of space (3500 K at one work station, pool of reddish light in corridor, wash of purplish light on lobby wall).

This method is often used in very dynamic color changing applications and involves advanced controllers that interpret digital control signals and regulate the current to individual LEDs.

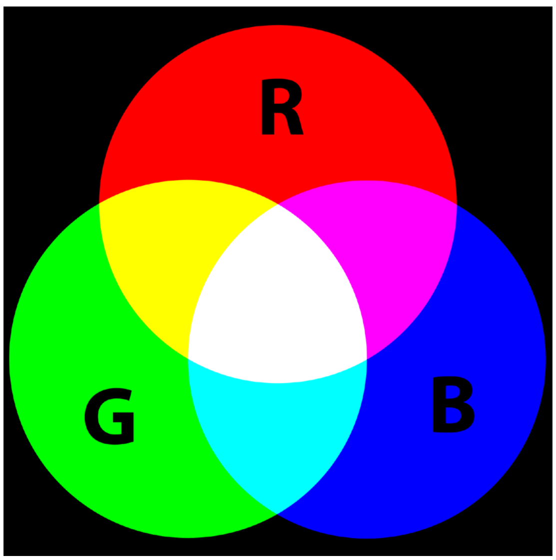


Figure 22: RGB additive color mixing.

Example Full Color Tuning Implementation #1: DMX

One such control type is theatrical show controllers that use the DMX512 protocol. Figure 23 depicts a Lutron GRAFIK Eye QS unit controlling Philips® Color Kinetics™ fixtures through the use of DMX control interfaces. This method can be used to control a variety of different DMX fixtures or controllers.

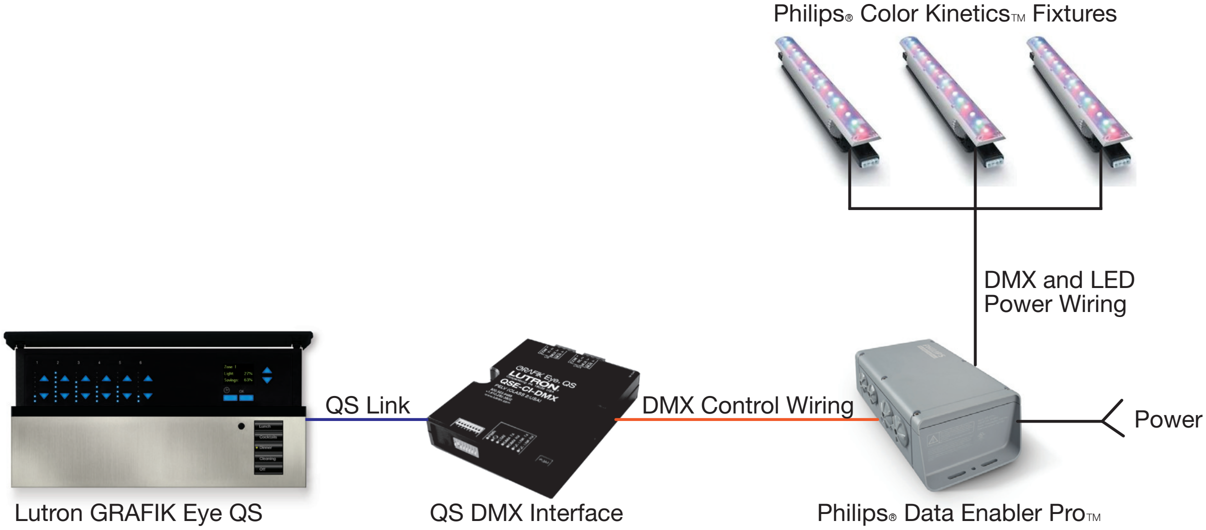


Figure 23: Lutron GRAFIK Eye QS unit controlling Philips® Color Kinetics™ fixtures through DMX control.

Example Full Color Tuning Implementation #2: Ketra

Ketra design software allows intuitive control of the RGBW module inside of every Ketra light source. For example, as shown in Figure 24, you can adjust the intensity (on the left) independent of the color. On the right, you can adjust the color via an intuitive touch palette for saturation on the x-axis (how rich or washed out the light color is) and hue on the y-axis (what color the light is). At time of commissioning, these colors can be designed as changing patterns using a sequence. Control of the color can be done via wired or wireless controls attached to a HomeWorks or Athena system, or directly through the Lutron app (as shown in Figure 24).

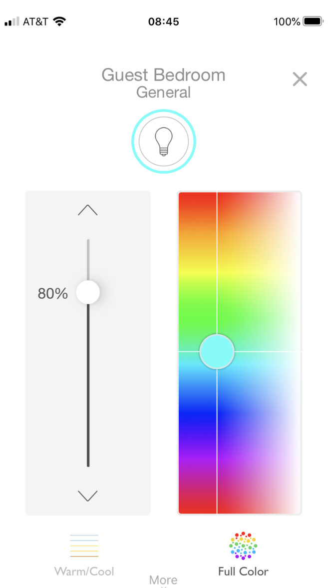


Figure 24: Full-Color tuning using saturation/hue is available via the Lutron App.

A few items to consider when specifying full color tuning solutions:

1. Full color changing applications tend to be the most complicated as they typically involve multiple control interfaces and require a well-documented sequence of operations in order to produce the desired effects for the space. These applications will require similar attention to detail during system startup. Strong communication between manufacturers, specifiers and end users is recommended. Plus, DMX wiring often involves more complicated and stringent wiring practices.
2. When defining specific colors that the lighting system must achieve, be sure to specify all components or channels that are required. For example, while full color tuning can be done by mixing red, green and blue LEDs, in order to achieve a specific color, a value for each individual LED channel must be specified. Lutron has several tools that help populate these values for specific colors. Figure 25 depicts the Color Table tool in the Quantum design software. By choosing a color from the palette, the three values for red, green and blue are automatically generated.
3. Be sure to consider any energy code requirements that may affect a color changing lighting scheme, as fixtures with multiple color options could significantly affect the lighting power density (watts per square foot) design intent of the space.

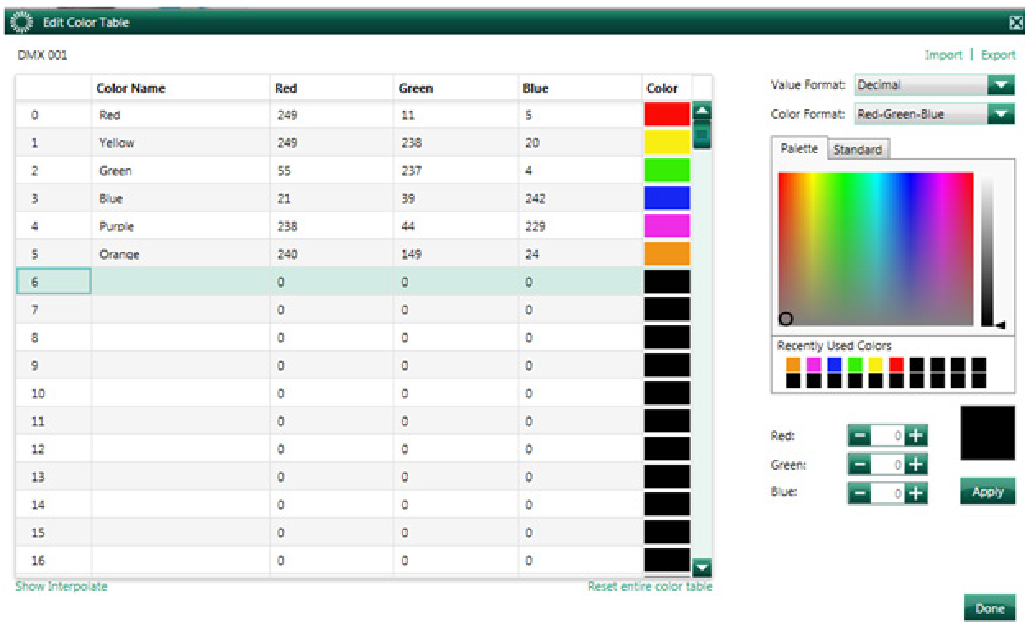


Figure 25: Color Table tool for DMX 3 channel lighting control packaged with Lutron Quantum design software.

Compatibility Matrix for Lutron Controls

When designing color tuning applications, there are usually many different control options available. These often need to be reconciled with other system requirements that may dictate one system type or another. The below table helps to outline the different control types available across all of Lutron's systems. In general, the following are the most common control types for color tuning applications:

Dim to Warm: Phase control / 0-10V / 3-Wire / Lutron EcoSystem / Ketra
Tunable White: 0-10V / Lutron EcoSystem / DALI / Lutron T-Series / DMX512 / Ketra
Full Color Tuning: DMX512 / Ketra

Control Types	Wallbox	Vive	GRAFIK Eye QS	Energi Savr Node	LCP128 & GRAFIK 4000	Quantum	Athena	Caséta Wireless	RadioRA 2	HomeWorks
Forward-phase	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Reverse-phase	✓	✓	✓[1]	✓	✓	✓	✓	✓	✓	✓
3-Wire	✓	✓	✓[1]	✓[1]	✓	✓	✓	✓[1]	✓	✓
0-10V	✓	✓	✓[1]	✓	✓	✓	✓	✓[1]	✓	✓
EcoSystem	✗	✓	✓	✓	✗	✓	✓	✗	✗	✓
T-Series	✗	✗	✗	✗[2]	✗	✓	✓	✗	✗	✗
DALI Type 6	✗	✓[3]	✓[3]	✓[3]	✗	✓	✓[3]	✗	✗	✓[3]
DALI Type 8	✗	✗	✗	✗	✗	✗	✓	✗	✗	✓[3]
DMX	✗	✗	✓[1]	✗	✗	✓	✓[1]	✗	✗	✓[1]
Ketra	✗	✗	✗	✗	✗	✗	✓	✗	✗	✓

[1] Interface required.
[2] The T-Series Energi Savr Node is only compatible with the Quantum and Athena systems. It cannot be used in a standalone Energi Savr Node system.
[3] While the system supports this control type, the system's user interfaces may not explicitly show a CCT slider. Check system documentation for details.

Application Considerations

When designing a color-tuning system, make sure you consider all the various sequences of operation that may apply to the system, and ensure that an intensity and CCT value is specified. For example, in the case of emergency lighting, what should the CCT of the lights be when normal power is lost? Warm? Cool? Kept at the previous level? Careful consideration early in the design cycle will ensure that no unexpected situations arise during system commissioning or usage. Refer to the "Tunable White Sequence of Operations Brochure" (Lutron part number 367-2835) to help guide you through key specification decisions that are needed.

Conclusion

Along with intelligent, automated control of lights and shades, the ability to control tunable white lighting has become a very important feature. Depending on the sequence of operations desired, it is critical to specify fixtures with separate intensity and color temperature inputs to minimize risk to designers, contractors, and owners. Lutron has a wide variety of solutions and resources to help specify these solutions. Our strong fixture OEM partnerships and broad product portfolio enable the specification of controls and luminaires that are tested together to provide the highest quality dimming and performance. Visit www.lutron.com/leds and www.lutron.com/findafixture to learn more about how Lutron controls and LED drivers can help with your projects featuring LED lighting. Contact your local Lutron representative or Lutron Customer Assistance for further assistance with your color tuning applications.

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