CONVERGING SYSTEMS

# TechNotes

**Revision 10/18/2022**

# Circadian Lighting

## Converging Systems LED Lighting Controller Systems

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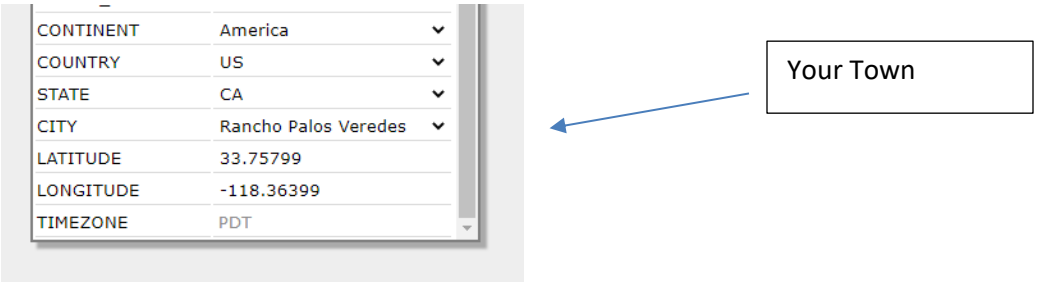
## 1. e-Node 4000/4100 overview

Converging Systems has developed the e-Node 4000/4100 with a number of additional features related to Circadian lighting (see below for information on Circadian Lighting).

During setup of the e-Node 4000/4100, all you have to do is select a location available from a pull-down box (or simply enter your latitude/longitude), and the built-in sophisticated 32-bit microprocessor performs all the calculations to enable automated circadian lighting for your location! As an enhancement over traditional Circadian systems, the device recognizes that various users as well as 3rd party automation and/or lighting control platforms may have different concepts of what exactly circadian lighting really is and how light output should be controlled.

The e-Node 4000/4100 platform offers the ability to follow (mimic) existing Circadian (Daylight) scenarios or to adapt to expanded Circadian lighting requirements evolving in the marketplace today.




## 2. Circadian Lighting

Circadian Lighting is a corollary to human circadian rhythm. Circadian rhythm is a 24-hour clock controlled by the hypothalamus, an area of the brain, that controls each person's circadian rhythm by receiving stimuli from the eyes and signaling when it is daytime and nighttime. Cooler temperatures are used in spaces when it is appropriate to promote alertness and attention. Warmer temperatures (seen when the sun is rising or setting) are used when people are waking up or falling asleep. The concept of using light to influence human circadian rhythm is a relatively new idea in the lighting industry and research continues to provide new findings. Converging Systems has mapped the chromaticity values of the sun on the Big Island of Hawaii (where the atmospheric interference is often less intense and/or impacted by pollution/cloud cover) over a course of a week from total darkness to mid-day sun and then all the wall back to darkness over a number of successive days. (This is one of the reasons the Mauna Kea observatory was built at that location). Converging Systems then mapped those values along with proprietary algorithms into a number of our own ILC-xx0 controllers leveraging off of the e-Node 4000 family's most powerful front-end processor which enables the feature set documented within this Tech Note.

In order to understand the significance of these advancements, the following short section (not mandatory reading) has been put created to explain the range of Circadian Lighting output choices available. The built-in intelligence and the user-entered geographical location is all that is required to trigger accurate Circadian lighting capability within this environment. Please note that for simplicity the following description relates to pre-dawn to mid-day sun events (but the concepts are equally applicable-yet reversed for pre-sunset through dusk to total darkness).

## 3. Note On Color Spectrum and Accuracy of 3rd party products

Mapping of CCT and Pseudo color among disparate luminaries is a complex process. Initial measurement of the luminaires (LEDs) requires sophisticated equipment while maintaining tight control of a number of environmental variables (length of time an LED is turned on, its ambient temperature, varying binning, etc.). Converging Systems manufactures its own FLLA ™ linear elements and also supports its recognized third-party partner's products (jointly referred to as

"CSI Calibrated LEDs) as accurately as possible. Although the CSI Circadian technology is also built into the e-Node/dmx 4100, but given that Converging Systems does not manufacture any DMX fixtures or control those products' LED component selection including binning or tolerances (but only supports DMX devices through its e-Node/gateway device), there can be no assurance that the precise Circadian lighting schemes obtainable from such 3rd devices will match CSI Calibrated LEDs (that have been specified, calibrated controlled with customer profiles).

## 4. Understanding Night to Mid-day Sun Events (or Mid-day Sun to Night Events)

Note there are three major Periods (i.e., Astronomical Twilight (AT), Nautical Twilight (NT) and Civil Twilight (CT)) leading up to traditional DayLight (DL) sun. During each of these periods there are mid-to-wide variations in the chromaticity (**H**ue and **S**aturation) as well as **B**rightness levels perceived by an optical receiver (electronic equipment or the human eye). With proper replication of these variations within each Period, a lighting system can be used to provide a good approximation in many regards (but not all) to the target Sun's output. These periods and their associated light output are quite relevant to replicating Circadian cycles for health, comfort, marketing, or particular product differentiation needs. These Periods are described in the following section.

Figure 1 below should be used a reference when reading the following section.

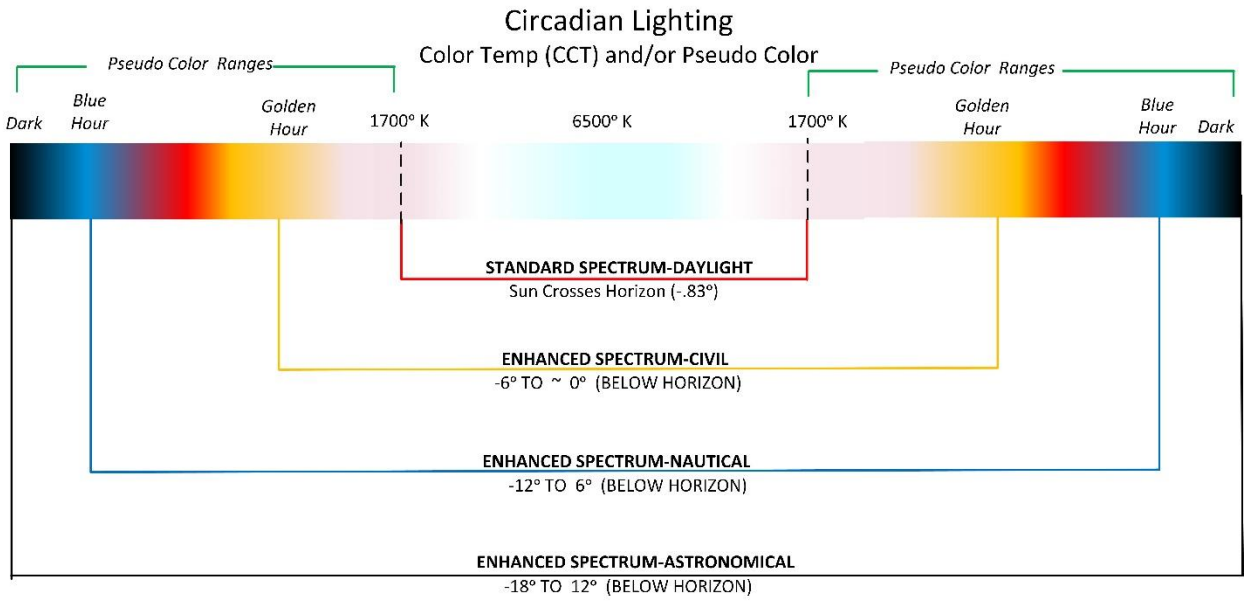



**Figure 1**

- (**AD/AT**) The first period occurs when the sun first generates its first sign of illumination (after Night or darkness) and when the sun's geometric center crosses -18 ° (below) the

horizon—quite some distance before it actually crosses the horizon. This exact moment of crossing is referred to as "**Astronomical Dawn"** and the ensuing period until the sun crosses -12° (below) the horizon is referred to as "**Astronomical Twilight**." During this period, more subtle dark/deeper blues are emitted. The start time and duration of this Astronomical Twilight period is dependent upon both the latitude and the season of the observer.

- (**ND/NT**) The second period occurs when the geometric center of the crosses -12° (below) the horizon and continues until it crosses -6° (below) the horizon. The exact moment of crossing -12° (below) the horizon is referred to as "**Nautical Dawn**" and the period until the end of this period is "**Nautical Twilight**." During this period lighter blues can be seen. As with Astronomical Twilight, the start time and duration of this Nautical Twilight Period is dependent upon both the latitude and the season of the observer. (In clear weather conditions, many of the brighter stars can be seen, making it possible to use the position of the stars and the horizon to navigate-hence "Nautical.")
- (**CD/CT**) The third period occurs when the geometric center of the sun crosses -6° (below) the horizon and continues until it crosses the horizon (~0°). The exact moment of crossing -6° (below) the horizon is referred to as "**Civil Dawn**" and the period until the end of this period at Sunrise is "**Civil Twilight**." During this period (sometimes referred to as the "Golden Hour") rich reds, and oranges can be seen. As with Astronomical Twilight and Nautical Twilight, the start time and duration of this Civil Twilight Period is dependent upon both the latitude and the season of the observer.
- (**DA/DS**) The most obvious lighting period (and typically the only presented choice with some Circadian Systems) occurs when the geometric center of the sun crosses the horizon (~0° ) and continues until the sun reaches its high position in the sky. During this period two well understand metrics called (i) **Correlated Color Temperature** (CCT) and (ii) **Brightness** (B) or **INT** (Intensity) can accurately represent the colorimetric measurements of the Sun during this period (only). And as well as with the above three Periods, the start time and the duration of Daylight are dependent upon both the latitude and the season of the observer. At higher latitudes and during the equinoxes (i.e., at Olso, Norway and the northern most tip of Antarctica), it takes about 60 minutes from the beginning of NT until the sun rises, while at the equator (i.e., Tanzania or Quito) and during the equinoxes, the same process occurs within a much shorter period of time. Also, of note that within the polar circles, the Sun does not set at all in the summer, so there is no twilight during that period, but during the winter, the sun may only reach an angle of -6° to -18° (**below**)the horizon around noon yielding only a short period of AT and NT only during these periods!

The below figure represents various types of Circadian cycles

| Case | Methodologies | Color Range Possible (for legend see above) |
|---|---|---|
| 1 | Traditional Circadian Control (**CCT + INT**)<br>-CCT from 1700°K (warm) to 6500°K (mid-day sun)<br>  <br>-Brightness from 0 to 100% (INT)<br>  | <br>*Daylight(DL)* |
| 2 | "Civil" Enhanced/expanded daylight into the Golden Hour (**CCT + INT + GH**)<br>Same as above but with some enhancements to the sub 1700°K CCT range into the "Golden" (GH) pre-sunrise and post sunset colors |  <br>*Expanded into "Golden Hour"*<br>Note: dotted vertical lines represent the subset of "Daylight" within this expanded color range. |
| 3 | "Nautical Enhanced/expanded daylight into the Blue Hour (**CCT + INT + GH + BH)**<br>Same as above but with some enhancements to the sub 1700°K CCT range into the "Golden" (GH) pre-sunrise and post sunset colors |  <br>*Expanded into "Blue Hour"*<br>Note: dotted vertical lines represent the subset of "Daylight" within this expanded color range |
| 4 | "Astronomical" Enhanced /expanded in to Darkness (**CCT + INT + GH + BH + DK**)<br>Same as above but with some additional enhancements to the Golden Hour range to include the various Blue Hour (light blues and dark blues) to Astronomical Dawn (or Astronomical Dusk) |  <br>*Expanded to Full Darkness*<br>Note: dotted vertical lines represent the subset of "Daylight" within this expanded color range |

Typically for most ILC-xx0 controllers, a simple firmware upgrade will enable all of the above Circadian Modalities to be functionally surfaced. Consult on-line documentation on how to upgrade ILC-xx0 controllers.

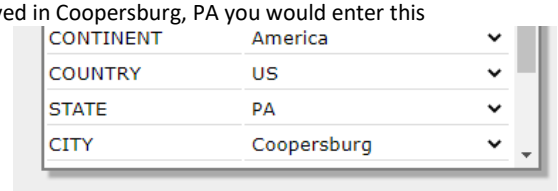
We have created this Tech Note for installers interested in experimenting and implementing Circadian Lighting on either a standalone basis or in conjunction with third-party platforms.

## 4. Theory of Operation-Circadian Server

Once the Circadian Server is turned on for a particular lighting controller with a defined **Z**one/**Gr**oup/**N**ode address and with a supplied peak brightness, the internal lighting computer will read the geographical location for the installation and adjust the light levels progressively during the entire active period. If at any time there is user intervention such as a user selection of a Recall or a command for a particular HSB or CCT level, the Circadian Server will be suspended for the duration of the day (only) and the user selected state will be remain intact. However, if there is no reactivation command invoked later the same day (after the initial intervention that stopped the Circadian auto-sequencing), the fixture will remain set to the user-adjusted level but will once again (automatically) start and sequence through the normal Circadian sequence the next day. It should be understood that a manual user reactivation does not start the Circadian Sequence at its normal starting level (i.e., **Astronomical Dawn)** but rather and more precisely automatically "rejoins" the Circadian (virtual) sequence in progress at precisely the same time and chromaticity and brightness levels **as it were never paused**.

Now let's get started.

## 6. Programming Quick Steps

| Step # | Task | Detail |
|---|---|---|
| 1 | Within the e-Node 4000/4100 **Settings** tab, enter your city or city close to your location or alternatively your Latitude/Longitude (negative sign for West or South entries).<br><br>**Note**: This feature requires that you are initially connected to the internet to access the pre-programmed database of cities and time zones After the initial setup, it is often not necessary to be internet-connected for proper operation. | If you lived in Coopersburg, PA you would enter this<br>  <br>**Note**: Since there is a vast set of cities throughout the world accessible and selectable through the scroll down menu within this setup feature, if your city is not listed, it is generally sufficient only to select the closet city to your location (provided it is within the same time zone as your location). |
| 2a | Invoke the Circadian Server ***on non-Lutron platforms*** | **More information on some non-Lutron platforms can be found here (see bottom of linked page).**<br><br>The following is presented for platforms where more detailed information is not currently available.<br><br>Other than through a direct connection to a supported Lutron platform (see Step 2b below), this new feature requires a new command to be supported by our compatible drivers. Depending upon the lighting/automation platform, this new command may be able to be transmitted directly currently (i.e., through a RAW command in RTI for |

<table>
<tr>
<td></td>
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<td>instance, or through a slight modification to the Crestron driver by the Crestron programmer). For other platforms, refer to the Converging Systems website for new drivers supporting this feature that will be posted.<br><br>EXAMPLE 1. This is an example of a command that is required to invoke the Circadian Server for a lighting controller with a Z.G.N of 2.1.1 and a peak brightness of 100% (referring to the maximum brightness of the Circadian cycle's when the sun is at its highest apogee).<br>Note: The range for the Circadian Cycle maximum brightness level can range from >0 to 240 which equates to >0 to 100%--therefore, a value of "240" means 100% brightness at the cycle's midpoint.<br><br>String: #2.1.1.LED=SOLAR,240;<cr><br><br>Detail: This above string will trigger a LED controller with a Zone/Group/Node address of 2.1.1. that includes (i) the trigger command name (SOLAR) to invoke the Circadian Server and (ii) the peak brightness value of 240 (i.e., 100% at mid-day peak) for the circadian cycle.<br><br>EXAMPLE 2:<br>If you wanted to adjust the maximum brightness intensity (for mid-day sun to 75% of the available brightness) for your luminaries you would enter:<br><br>String: #2.1.1.LED=SOLAR,180;<cr> (since "180" is 75% of 240)<br><br>Note: Different fixtures can have their own level of brightness<br><br>See here for platform specific Tech notes (see bottom of linked page).
<table>
<tr><td colspan="2">Driver Availability</td></tr>
<tr><td>Platform</td><td>Driver Availability</td></tr>
<tr><td>Control4</td><td>Available 4th qtr 2021 from CSI</td></tr>
<tr><td>Crestron</td><td>Must manually add to drive</td></tr>
<tr><td>Elan</td><td>Available 4th qtr 2021 from CSI</td></tr>
<tr><td>Lutron</td><td>Available now</td></tr>
<tr><td>RTI</td><td>Use Raw command to create</td></tr>
<tr><td>Savant</td><td>Available 4th qtr. 2021 from CSI</td></tr>
<tr><td>Other platforms</td><td>Contact CSI</td></tr>
</table>
<br>Now proceed to step 3b</td>
</tr>
<tr>
<td>2b</td>
<td>Invoke the Circadian Server on supported Lutron platforms</td>
<td>More information on Lutron platforms can be found here.</td>
</tr>
<tr>
<td>3a</td>
<td>For non-Lutron control platforms--If the Circadian cycle has been interrupted by a user intervention (i.e., turning a light to a certain HSV or CCT value or simply turning the device OFF), it is possible to "rejoin" the Circadian cycle by following this procedure.</td>
<td>(By control through Lutron platforms, follow Step 3b instead.)<br><br>More information on some non-Lutron platforms can be found here (see bottom of linked page).<br><br>The following is presented for platforms where more detailed information is not currently available for a specific platform.</td>
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</table>

| | | |
|---|---|---|
| | | For non-Lutron platforms, if a fixture's Circadian cycle had been suspended, it can be triggered to resume its real-time Circadian tracking by receiving the following command:<br><br>**#2.1.1.LED=SOLAR;<cr>** *no value specified*<br>*Or*<br><br>**#2.1.1.LED=SOLAR;1<cr>**<br><br>Therefore, create a button event for your supported third-party platform to transmit the above command to the targeted device. |
| 3b | **For Lutron control platforms—**If the Circadian cycle has been interrupted by a user intervention (i.e., turning a light to a certain HSV or CCT value or simply turning the device OFF), it is possible to "rejoin" the Circadian cycle by following this procedure. | **More information on Lutron platforms can be found here.** |

## Schedule

The fixture can be restricted to specific days by sending

| Step # | Task | Detail |
|---|---|---|
| 1 | Set schedule or specific days to the week. | Just weekdays<br>**#2.1.1.LED=SOLAR; MoTuWeThFr;<cr>** |
| 2 | Set schedule to specific weekend days. | Just weekend days<br>**#2.1.1.LED=SOLAR;SaSur;<cr>** |
| | | |

**Appendix 1**

How to sync up with Lutron Natural Show (see Case 1 above)

Lutron's new Homeworks™ QSX platform provides direct support for Lutron's innovative Ketra™ fixtures which are programmed using a single Lutron programming platform--Lutron's Designer™ software. An innovative feature available from Lutron' offering is its ability to provide Circadian output from Ketra fixtures based on a combination of CCT (color temperature) and INT (intensity) values from sunrise to sunset -- Lutron's tradename for this feature is the "Natural Show."

Although Lutron dealers can modify the standard Natural Show for demonstration or alternative purposes (with alternative start times, starting CCT & INT levels and ending CCT & INT levels), the Natural Show if set to track the default astronomical events of sunrise through sunset, can be tracked by Converging Systems' Circadian Server during the course of the day to complement the Ketra-fixture offerings with those luminaries supported by Converging Systems (such as our FLLA ™ family of linear luminaries) in order to expand the range of luminaries able to be controlled from the QSX platform.

Using the e-Node 4000/4100 Lutron/Table SLIM programming platform (available through e-Node web server feature), several options are available:

- A Lutron Ketra load (actual load) could be tracked by the e-Node 4000/4100—in effect the CSI supported luminaire would "track" the Lutron Ketra fixture, and/or
- A Lutron button press could trigger a phantom Ketra Load which would in effect appear to the e-Node 4000/4100 as another "Ketra" load that it could "track"

Although the e-Node 4000/4100 can provide 3 enhanced versions of standard Circadian lighting (Case 2, Case 3 and Case 4), the feature set described within Case 1 (spectrum pictured below) best matches the Lutron Natural Show and should therefore be selected when attempting to extend the Lutron system.

Please follow the directions below to begin.

| Step # | Task | Detail |
|---|---|---|
| A1-1 | | |
| A1-2 | | |
| A1-3 | | |
| A1-4 | | |
| A1-5 | | |

## Appendix 2 (additional topics)

-How to simulate a show for tradeshow purposes or sales demo
-How to change the ramps timing and length
-How to change the peak CCT though commands