

## Designers Light Forum

### **Session 0216:** *Why "Compatibility" is the Magic Word in controlling LEDs?*

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March 2018



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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.



# Learning Objectives

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At the end of the this course, participants will be able to:

Objective #1: Understand the “compatibility” of components in an LED Lighting System

Objective #2: Understand the “compatibility” of LED switching/dimming/sensor/controls/  
interconnecting wiring

Objective #3: Understand the “compatibility” of vocabulary and customer expectations

Objective #4: Understand the full challenges of getting 100% compatibility  
Be the best – sweat the small stuff

## Learning Objectives

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At the end of the this course, participants will be able to:

**Objective #1: Understand the “compatibility” of components in an LED Lighting System, i.e. the “fixture” aka the “lighting solution”**

The lighting “fixture” spec sheet now decides it all - what used to be a bulb, a fixture and a dimmer are now LED Modules, housings and LED drivers...and a dimmer!

Specifiers have had a lot of experience choosing the housings!  
Everyone has to now learn enough to also choose the right LED modules and the LED drivers...to get their expected results!



# MATCH THE DRIVER OUTPUT TO THE LED

Rated Lumens	Current	Forward Voltage			Power	Flux	Efficacy
	mA	Min	Typ	Max	(W)	Lm	Lm/W
700	700	12.3	13.6	15.0	9.5	700	74
	500	12.0	13.2	14.3	6.6	550	83
	350	11.7	12.9	14.3	4.5	400	89

The same LED Module can be run at different mA Current for different lumen output

The fixture manufacturer spec sheet allows specifiers to choose CCT and Lumen Output

<b>CCT MULTIPLIER</b>	<b>2700K</b>	<b>3000K</b>	<b>3500K</b>	<b>4000K</b>
Color Rendering Index	80+ CRI	80+ CRI	80+ CRI	80+ CRI
Multiplier for Lumen Output	1.00	1.00	1.08	1.08

# LED MANUFACTURER OPTIONS

ENGINE CODE	COLOR	HOUSING TYPE	SELECT ONE VOLTAGE	DIMMING DRIVER OPTIONS	ACCESSORIES
- <b>M2</b> -	-	-	-	-	-
<b>M2</b>	<b>27KS</b> 2700K, 80+ CRI <b>30KS</b> 3000K, 80+ CRI <b>35KS</b> 3500K, 80+ CRI <b>40KS</b> 4000K, 80+ CRI  2 Step MacAdam ellipse is standard for all	<b>NCSM</b> New Construction, Narrow Width <b>IC</b> Insulation-Contact Rated / Airtight <sup>2</sup> <b>CP</b> Chicago Plenum <sup>2</sup>  <sup>2</sup> N/A with EM	<b>120V</b> <b>277V</b>	<u>For use with 120V or 277V</u> <b>DIML2</b> 0-10V dim, 10% (provided standard) <b>DIML4E</b> 5 ECO, 5% <b>DIML4H</b> H ECO, 1% Fade <b>DIML6A</b> 0-10V, 0.1%, logarithmic <b>DIML6B</b> 0-10V Linear, 0.1%, linear controls <b>DIML6E</b> 0-10V, 1%, logarithmic, <b>DIML6F</b> 0-10V, 1%, linear controls <b>DIML7</b> DALI, 0.1%	<b>CB27</b> 27" C-Channel Bars <b>CB52</b> 52" C-Channel Bars <b>EML</b> Emergency battery <sup>3</sup> <b>EMLW</b> Emergency battery, wet location <sup>3</sup> <b>TZ</b> 6" TechZone ceiling compatible N/A with 01 or 02 flange finishes <sup>4</sup>  <sup>3</sup> NCSM housings require above ceiling access. Not for use with IC or CP housings. <sup>4</sup> With NCSM housing only
			<b>120V</b>	<u>For use with 120V only</u> <b>DIML3</b> A 2-wire, 1% 120V only <b>DIML19</b> Phase 2-wire dimming, 1% 120V only	

Same LED Engine – different options for CCT & Drivers

## Learning Objectives

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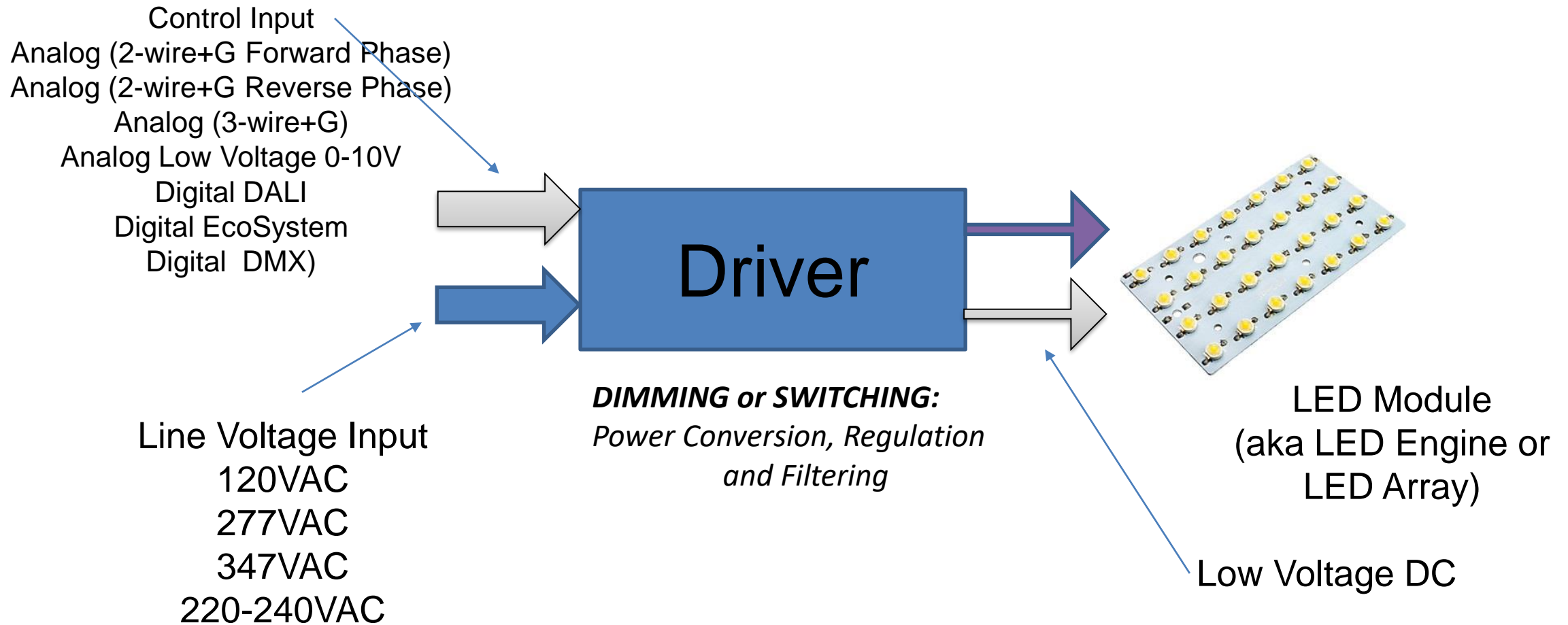
At the end of the this course, participants will be able to:

**Objective #2: Understand the “compatibility” of LED switching/dimming/sensor/ controls/ interconnecting wiring**

Once you’ve chosen the driver option, you’ve also chosen:

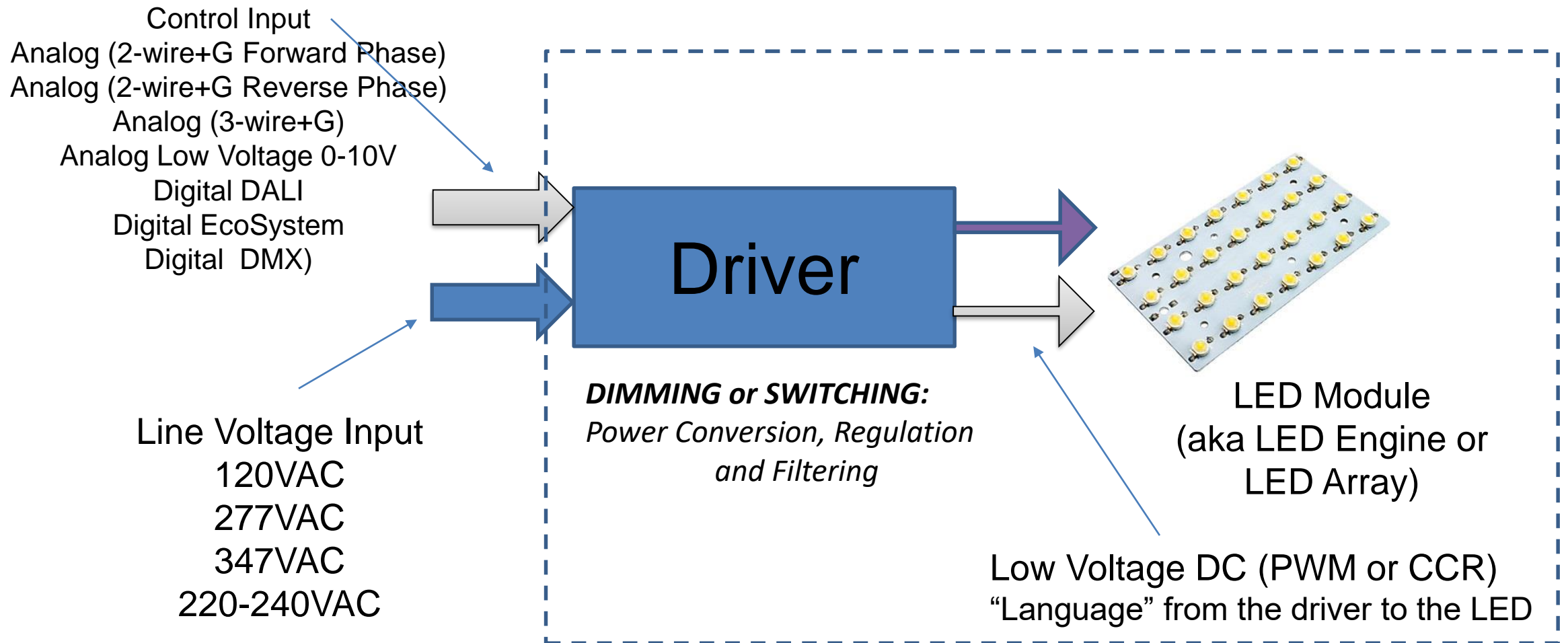
- 1) the low-end of the LED dimming, i.e. 0%, 0.1%, 0.1% SoftOn/FadeToBlack, 1.0%, 5%, 10%
- 2) the wiring back to the switch, dimmer, dimmer system and/or the Circuit Breaker Panel
- 3) the switch, dimmer or dimmer system

# What does an LED Driver do?...it does the dimming!





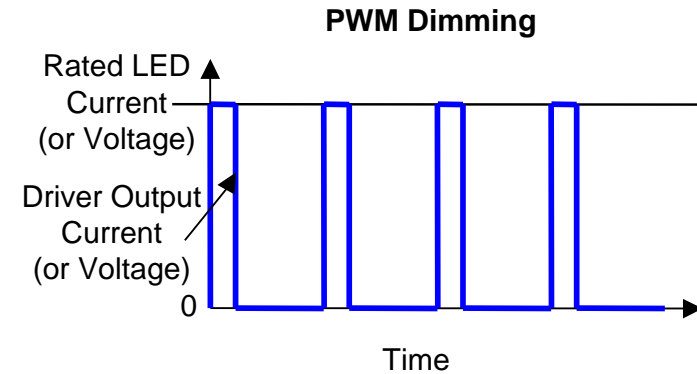
# What is an LED Driver?...it determines the dimming



## Low Voltage DC - PWM or CCR “Language” from the driver to the LED

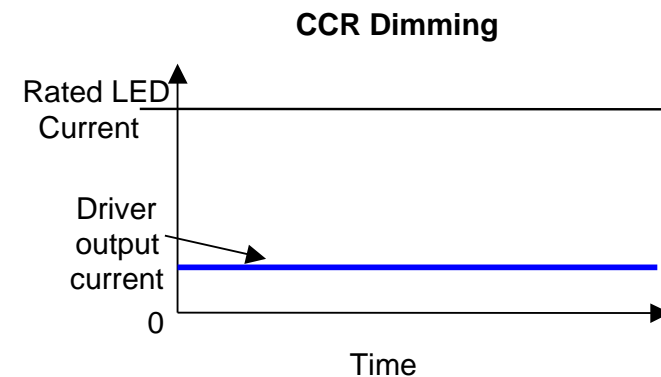
- **Pulse Width Modulation (PWM)**

- Available in both Constant Current and Constant Voltage drivers
- PWM cycles the LED on and off (500 - 2,500 Hz)
- Benefits:
  - Prevents color shift
  - Provides more precise control for shared loads



- **Constant Current Reduction (CCR)**

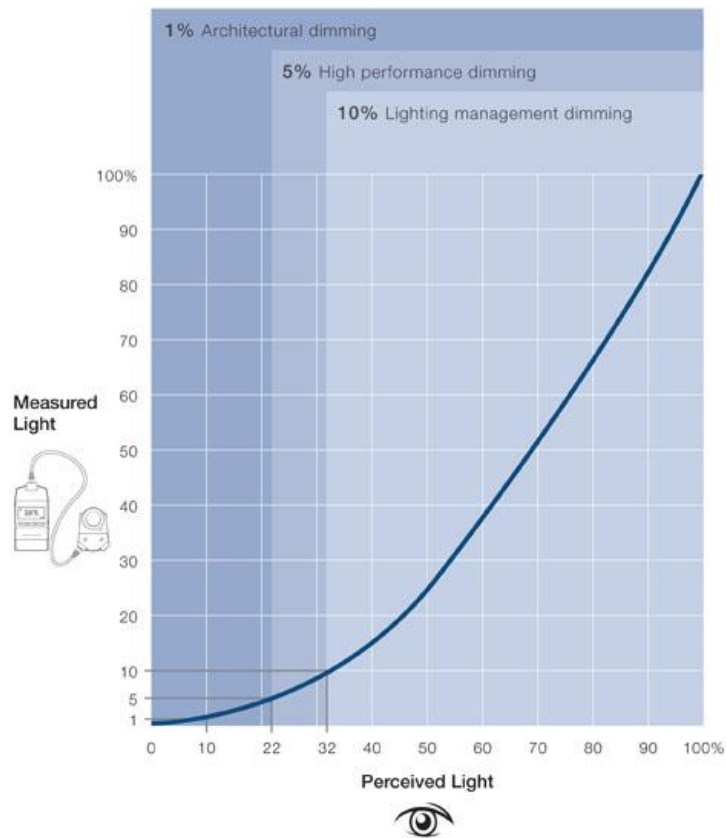
- Available only for Constant Current drivers
- CCR reduces current supplied to the LEDs
- Benefits:
  - Class 2 UL requirements allow more output voltage with CCR
  - Minimal EMI produced - No stroboscopic effects
  - Superior performance with long wire runs



Again...when you select the LED Driver...it determines everything:

- Dimming vs. Non-Dim
  - Smart Controls vs. Code Compliance
  - Dimming may...may not have a premium price
- Control Type and wiring required, i.e. the “Language” between dimmer/control and driver:
  - Phase Control (Forward or Reverse), 3-wire
  - Analog 0-10V
  - DIGITAL: DALI, EcoSystem, DMX
- Dimming range suitable for application
  - 10% dimming: lobbies, open office, atriums, and...
  - 1% dimming: restaurants, hospitality, conference room, and...
  - 0.1% dimming: residential, AV spaces, and....





Formula:  $\text{Perceived Light (\%)} = 100 \times \sqrt{\frac{\text{Measured Light (\%)}}{100}}$

Source: IESNA Lighting Handbook, 9th Edition, (New York: IESNA, 2000), 27-4.

- Difference between measured and perceived light

- **Measured light:** the amount of light as shown on a light meter
- **Perceived light:** the amount of light that your eye interprets due to dilation
- **20% measured = 45% perceived**
- **10% measured = 32% perceived**
- **1% measured = 8% perceived**
- **0.1% measured = 3% perceived**

## Control Types and Wiring “Language”

**Analog Control** – Requires:

- 1) Point-to-Point wiring for each fixture in any one control zone;
- 2) Dedicated Occ/Vac and/or Daylight sensors for each zone; and,
- 3) Limited driver quantities per switch/dimmer and 16A circuit

TYPICAL OF:

- Analog 2-wire+G (Forward Phase, MLV, Triac, Leading Edge, Incandescent)
- Analog 2-wire+G (Reverse Phase, ELV, Trailing Edge)
- Analog 3-wire+G (Dimmed Hot/Switched Hot/Neutral)
- Analog Low Voltage 0-10V (4-wire: 120/277V Hot, Neutral+G and 2 x LV for 0-10V control) aka 1-10V and 10-0V

### Digital Control – Provides:

- 1) No wiring requirements to assign control zones; each driver/fixture is addressed individually;
- 2) Shared sensor outputs on LV data link (64 drivers); and,
- 3) Full power load on 120V/277V 16A circuit - no driver limits per switch/dimmer
- 4) LV Data Link can be wired Class 1 or Class 2 & no polarity issues

### TYPICAL OF:

- Digital DALI (Hot, Neutral+G, 2 x LV Data Link)
- Digital EcoSystem(Hot, Neutral+G, 2 x LV Data Link)
- Digital DMX(Hot, Neutral+G, 2 x LV Data Link)



# Sensor Controls and Code Compliance

## Occupancy/Vacancy Sensors

- Save up to 90% of lighting energy by turning off the lights in unoccupied rooms - depending on the space
- Models available for ceiling mount (varied ceiling heights, wall mount, corner mount and hallway mount)
- Indoor & Outdoor Applications
- Wired and Wireless options available



Occupancy/vacancy

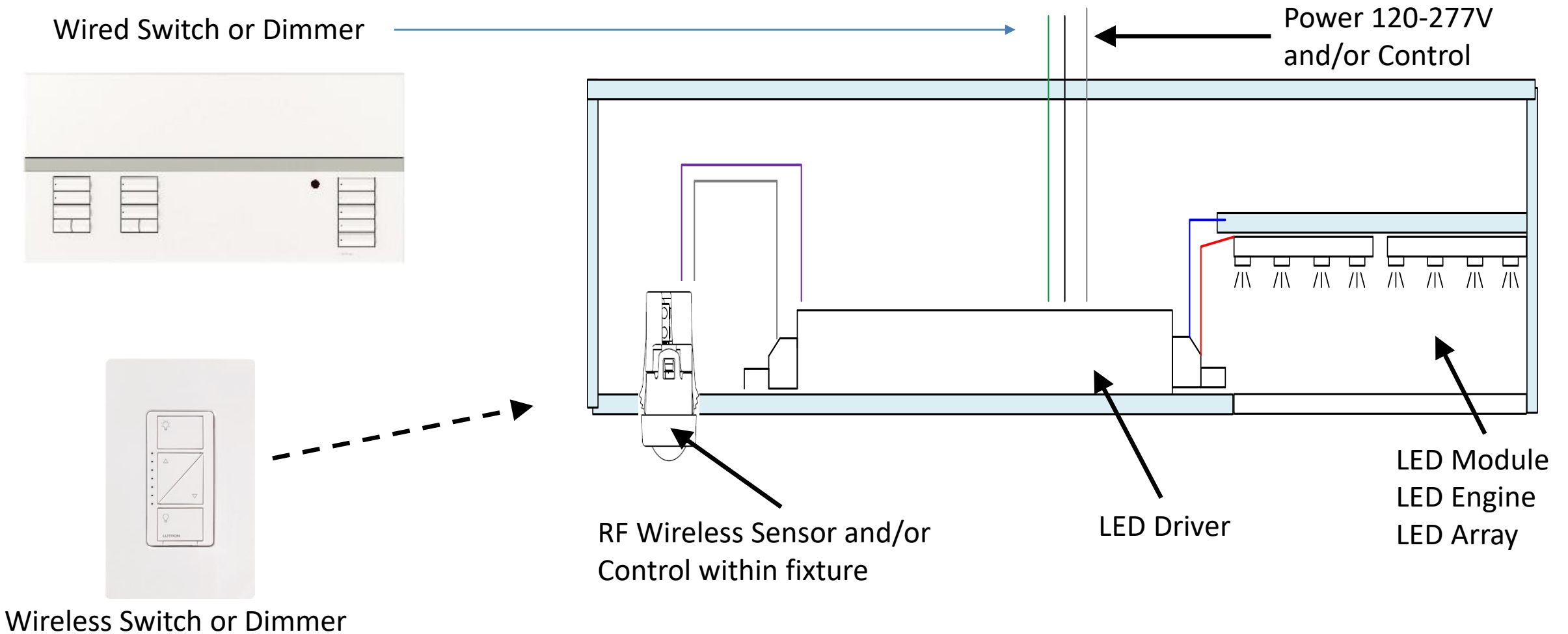


Daylight

## Daylight Sensors

- Save up to 25% of lighting energy by reducing electric light in the presence of abundant daylight
- Can be integrated with Shading Systems to minimize glare while maximizing Daylight Harvesting
- Can be used to maximize Human Centric Lighting response to the changing CCT of the Sun sunrise to sunset
- Indoor & Outdoor Applications
- Wired and Wireless options available

# What Does “In-Fixture Sensor Technology” Mean?





# Learning Objectives

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At the end of the this course, participants will be able to:

Objective #3: Understand the “compatibility” of vocabulary and customer expectations

Clients have mostly experienced Incandescent Dimming and created their visual expectations:

- 1) Any dimmer will dim and lamp/bulb – NOT TRUE FOR LEDs
- 2) Dimming will be smooth, continuous and flicker-free down to OFF – NOT TRUE FOR ALL LEDs
- 3) Dimming “warmed” the output of Incandescent as it dimmed – available from special LED fixtures
- 4) Fluorescent/Neon/Cold Cathode/Metal Halide were all fixed, i.e. static white sources

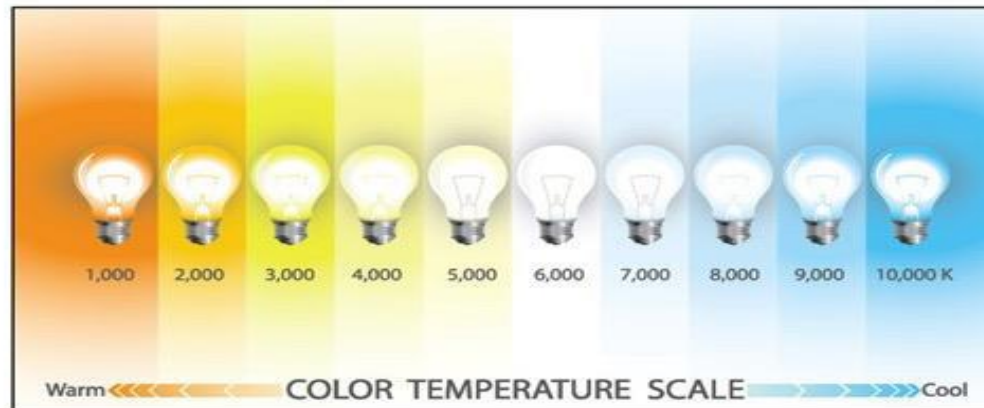
LEDs give us the opportunity for “White Tuning”, i.e. to change colors as no other light source did – that can create as many problems as it solves

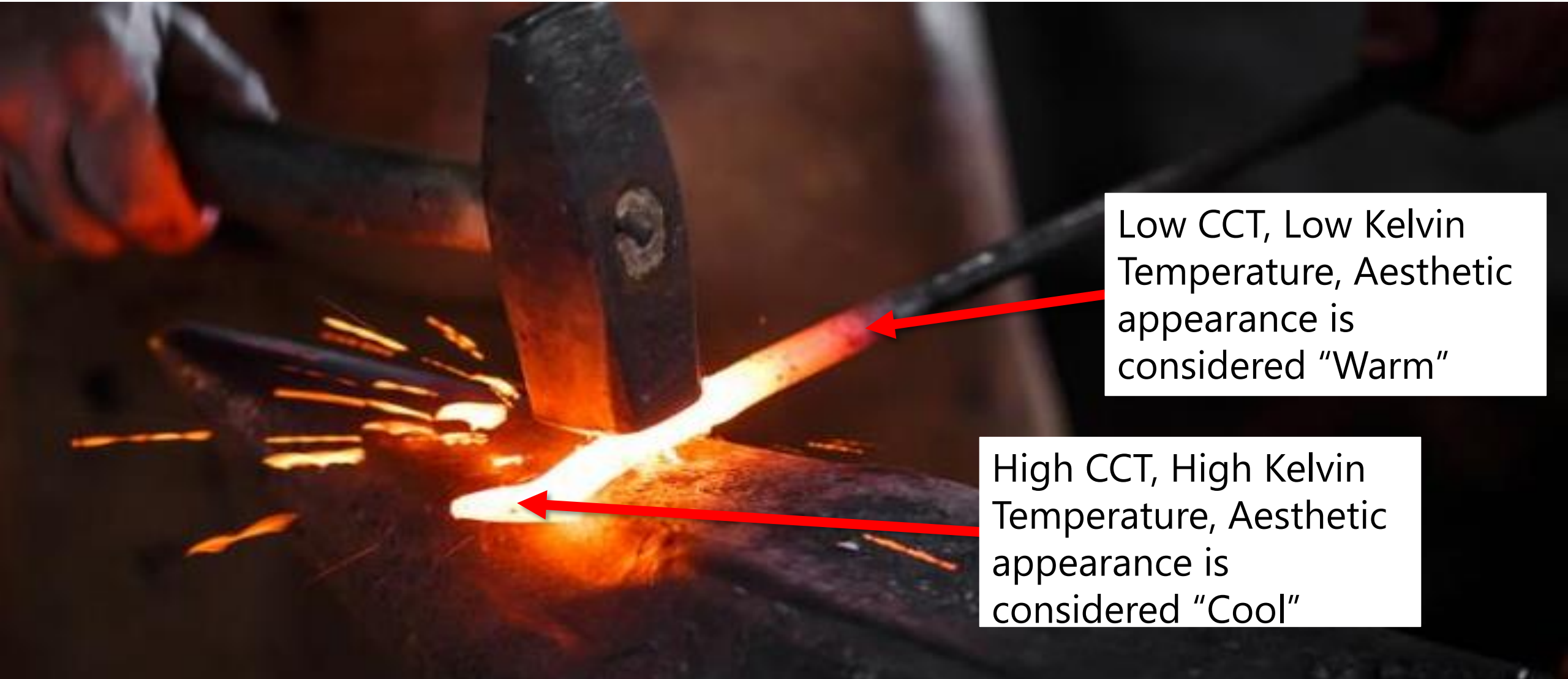
Clients have experienced Incandescent Dimming and created their visual expectations to avoid:

- **Flicker**: The unexpected modulation of light level
- **Shimmer**: The unexpected low intensity, high frequency modulation of light, e.g. Christmas tree lights
- **Pop-on**: The level the light is at when it is turned off...especially low levels...is the level it should return to when it is turned back on...without first jumping to a higher level
- **Drop-out**: Light should turn full-off when the switch/dimmer/power is turned off
- **Dead Travel**: Adjusting the control with no change in light level
- **Audible Noise**: From driver or dimmer control
- **Popcorning**: Mismatched start times

## Correlated Color Temperature (CCT)

- Measure of how cool or warm the light source color appears
- Measured in degrees kelvin (K)
- Referenced on the black body curve





Low CCT, Low Kelvin Temperature, Aesthetic appearance is considered "Warm"

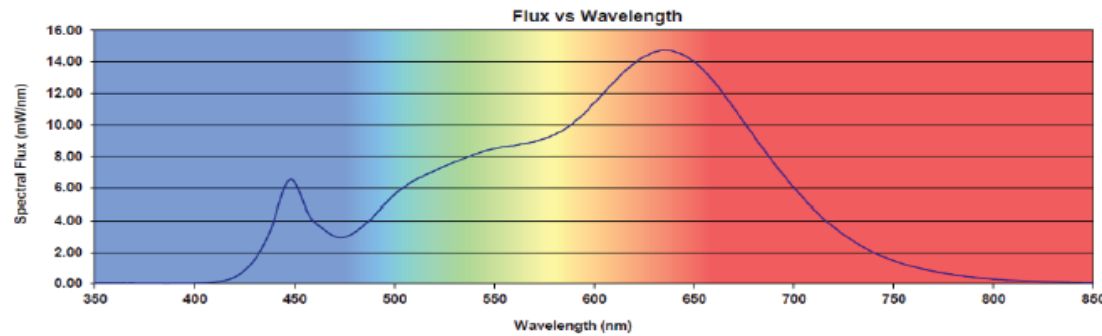
High CCT, High Kelvin Temperature, Aesthetic appearance is considered "Cool"

# Color Rendering Index (CRI)

## CRI Comparison

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- 95+ CRI is industry leading
- R9 is also important (not counted in CRI)
  - > 90 is industry leading
  - Often times is a very low value



Color Rendering Index Detail

Ra (CRI)	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
96.4	95.8	98.5	95.6	93.3	95.9	96.6	97.8	97.6	97.2	98.4	90	95.2	96.1	96.5

## Color Rendering – TM-30-15

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- New measurement system released fall 2015
- Uses 99 color samples
- More uniform color space
- 3 outputs
  - Fidelity ( $R_f$ ) - similar to CRI
  - Gamut ( $R_g$ ) - saturation
  - Color Vector Graphic



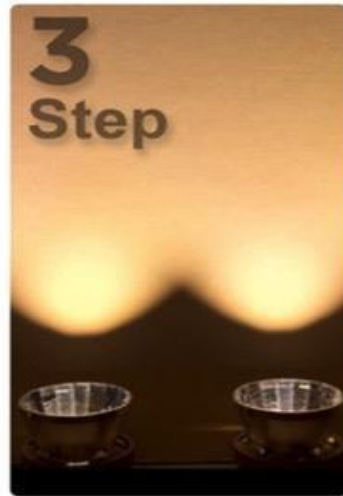
From IES Method for Evaluating Light Source Color Rendition (TM-30-15) with permission from the Illuminating Engineering Society.



## Color Consistency

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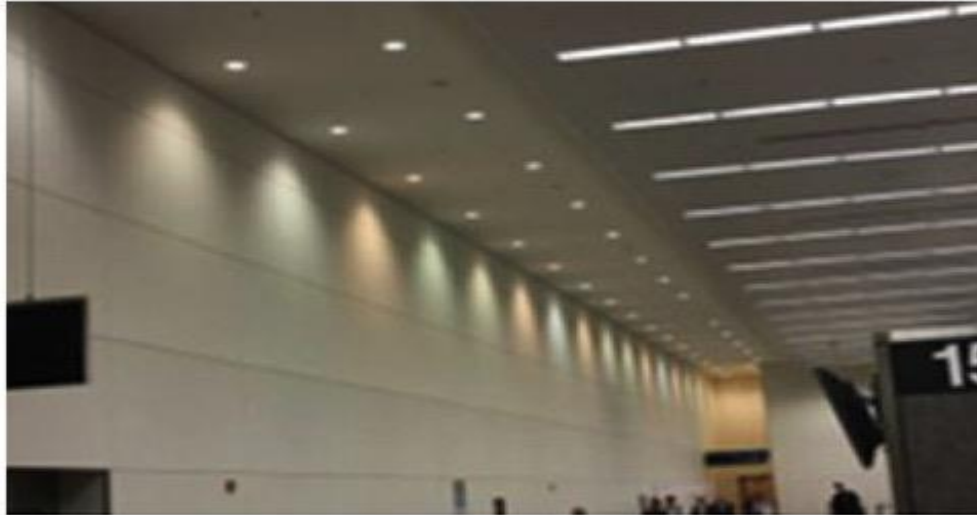
The average amount of variation in chromaticity among a batch of supposedly identical lamp samples at time of manufacture



## Color Shift/Stability

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- Describes a change in color over time
- Usually related to phosphor degradation in the LED
  - Heat is the primary cause of this degradation





## White Tuning

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- The concept of a light source having the ability to shift in CCT
- Offers flexibility both in specification as well as in use
- 3 approaches to use:
  - Warm Dimming
  - Tunable White
  - Spectral Tuning



# Warm Dimming

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As the intensity decreases, the CCT gets warmer

## Benefits

- Familiar

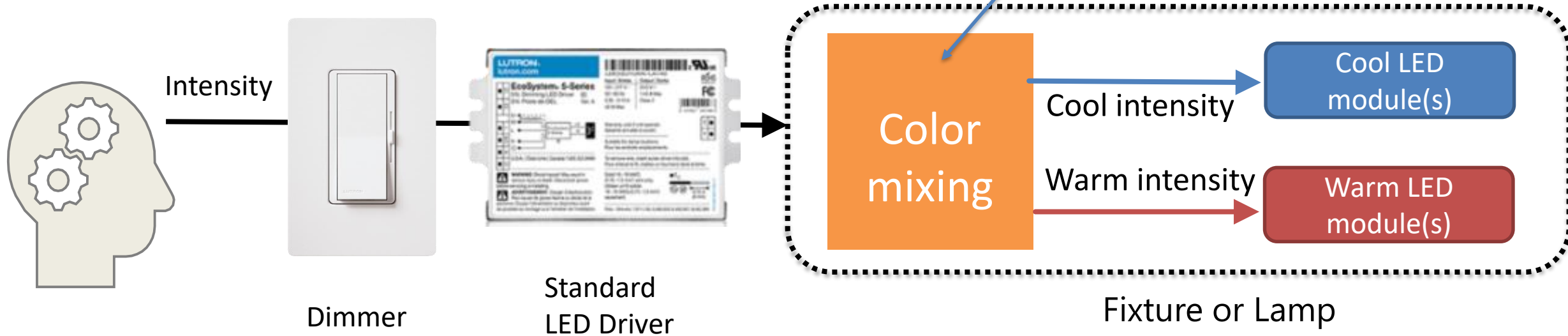
## Concerns

- Inflexible
- Perpetuates experience



# Warm Dimming

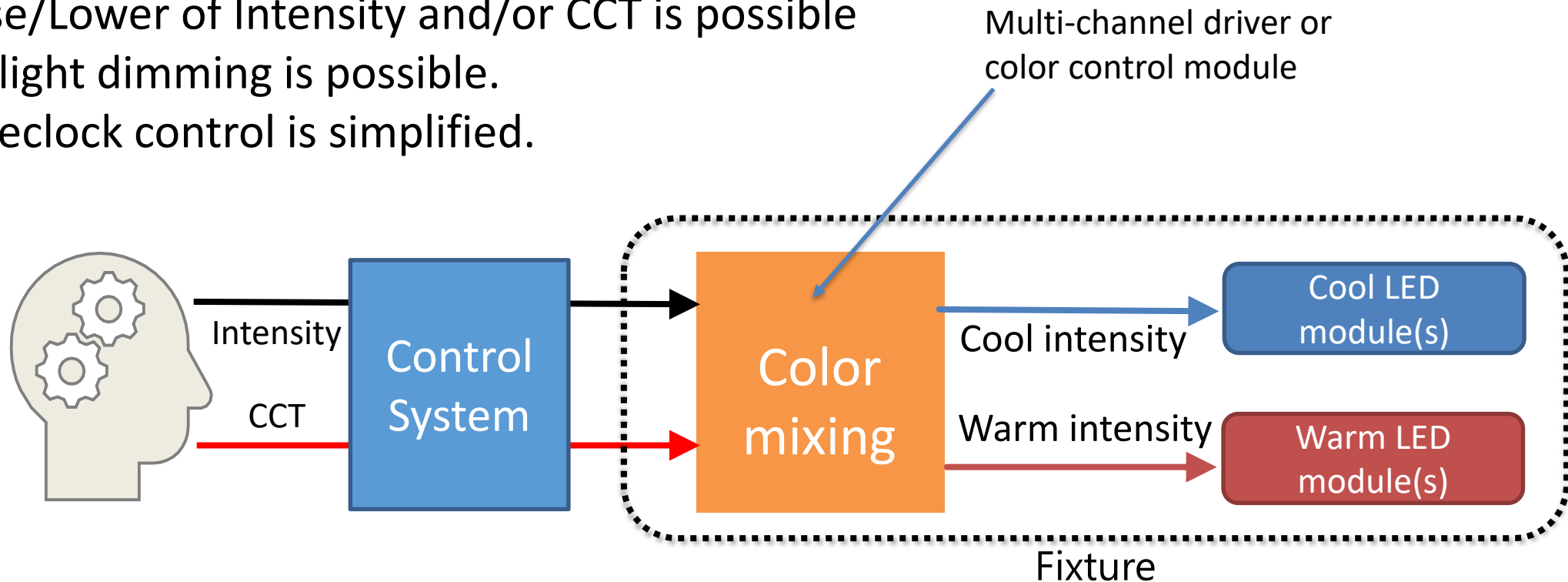
Intensity & CCT are linked  
One dimming input is used  
Proprietary circuitry on the LED light engine  
determines the mix/CCT range while dimming



# Tunable White – what is it?

A method that allows for independent control of intensity and CCT

- Raise/Lower of Intensity and/or CCT is possible
- Daylight dimming is possible.
- Timeclock control is simplified.



# LEDucation Tunable White –why is it?

- 1) Use the color of white light to optimize the task being performed (potentially improve productivity, increase attentiveness, hasten healing)
- 2) An on-site control to create the right environment - adjust the CCT after material installation and address unforeseen issues with FFT and finishes
- 3) Adapt the space over time while giving end-users more personal control

Kelvin Color Temperature	2700K	3000K	3500K	4100K	5000K	6500K
Associated Effects and Moods	Ambiant Intimate Personal	Calm Warm	Friendly Inviting	Precise Clean Efficient	Daylight Vibrant	Daylight Alert

**Applications: Offices, Classroom, Patient Rooms and...**

Source: Vivianne C. Smith and Joel Pokorny, **Color Matching and Color Discrimination**, Departments of Ophthalmology & Visual Science and Psychology, University of Chicago

# White Tuning with RGB/W/Y/A and DMX Controls

## Spectral Tuning

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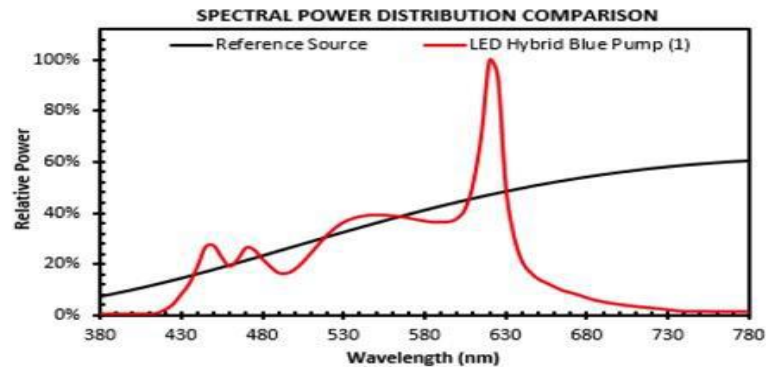
Separate channels allowing for wavelength manipulation

### Benefits

- Complete flexibility
- Adjust the light for any application

### Concerns

- Requires complicated mixing algorithm
- Requires extensive commissioning



# ASID headquarters – 1<sup>st</sup> WELL Platinum & LEED Platinum building - uses Tunable White

- <http://www.ecmag.com/section/safety/take-your-construction-vitamins-well-certification-and-healthy-building-design>
- The American Society of Interior Designers (ASID) opened its new Washington, D.C., headquarters in May 2016, calling it “a living laboratory.” Designed with optimum sustainability in mind, it earned Leadership in Energy and Environmental Design (LEED) Platinum certification. Occupant health is an equal concern as ASID hopes to also achieve WELL Platinum. [P]  
[SEP]
- “The 8,500-square-foot office includes biophilic design (engaging nature through natural light, vegetation, and organic forms and materials) to reduce stress and promote health; enhanced air quality; stringent water quality standards; and a lighting system that is both efficient [and] helps to regulate the body’s circadian rhythms,” said Ken Wilson, principal in Perkins+Will’s Washington, D.C., office. [P]  
[SEP]
- David Cordell, senior associate and senior technical coordinator, Perkins+Will, served on the project and navigated his deep understanding of LEED with his new WELL-AP training.

## Learning Objectives

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At the end of the this course, participants will be able to:

**Objective #4: Understand the full challenges of getting 100% compatibility:**

**Be the best – sweat the small stuff**

**First: Is the LED a “retrofit” bulb or an LED Module/Driver in a fixture?**

**Second: Pick the LED module/driver with the lumens, low-end and CCT you need**

**Third: Think about controls at the same time – do you need dimming? Sensors?**

**Fourth: Wall-box dimmers? Preset dimming system? Smart dimming system?**

**Fifth: What else is in the space needs to interface – AV? BMS? HVAC?**



## IS THE LED A “RETROFIT” BULB OR AN LED MODULE/DRIVER IN A REPLACEMENT FIXTURE?

Is the LED Retrofit Bulb replacing:

Incandescent? Are there optics issues? Heat dissipation issues?

Low Voltage? 120V>12V or 277V>12V or 120V>24V Is there an MLV or ELV transformer to match?

Low Voltage MR-16? Is the new LED MR-16 designed for existing transformer?

Fluorescent ? Are the T-LEDs a 120V or 277V replacement? With existing ballasts? With a new LED driver?

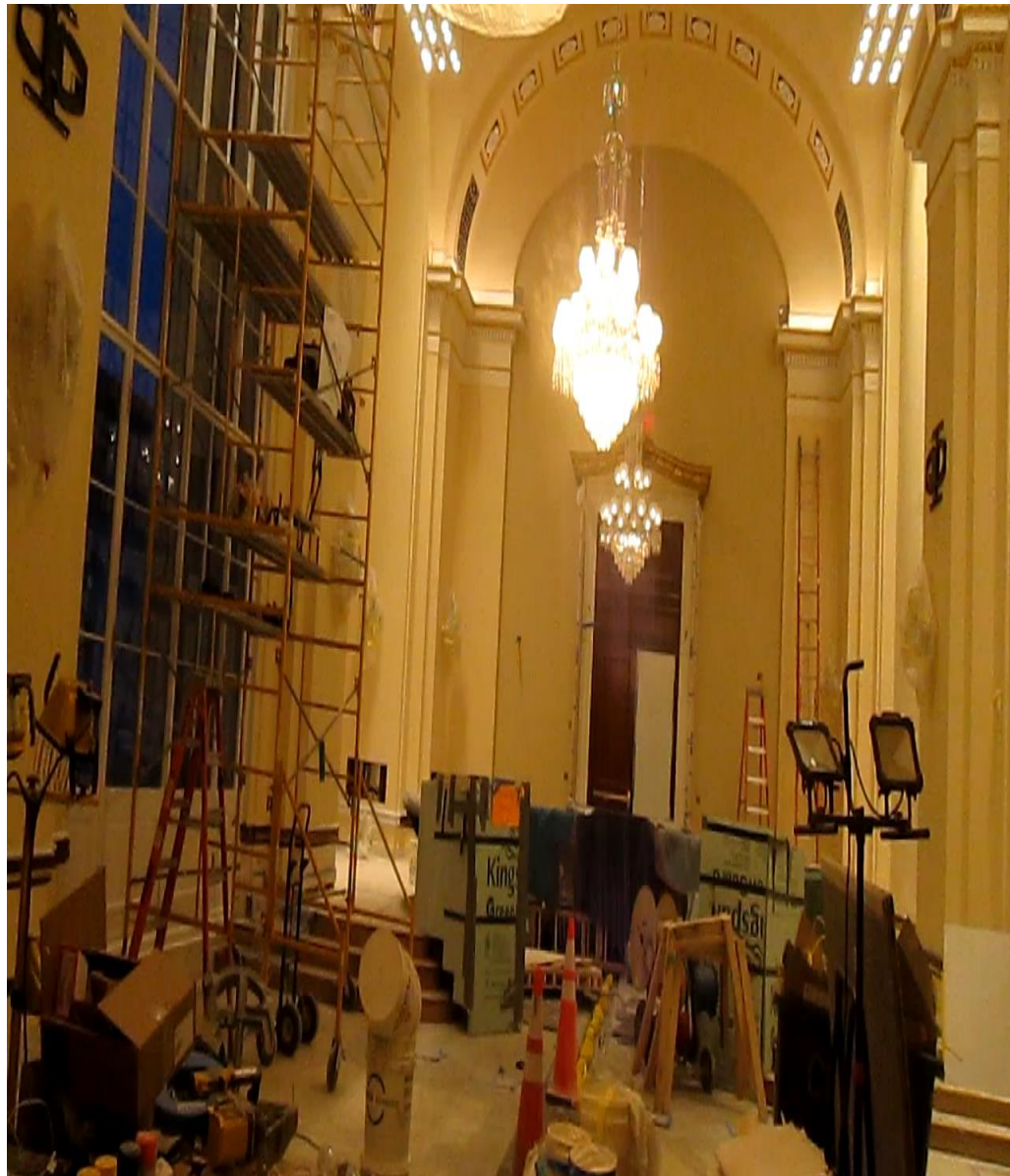
Is the NEW LED Retrofit fixture replacing:

Linear Cove Low Voltage Lighting? Are there remote Transformers to replace? How far?

Linear Cove Fluorescent Lighting? Can the new LED driver withstand ambient temperature within cove?

Track fixtures on Hot/Neutral Single circuit track? All fixtures will dim as one zone...is that OK?

Track fixtures on Hot/Hot/Neutral Two circuit track? Will “common neutral” be a problem?



Is the LED “retrofit” bulb or LED fixture in a space with AV or Broadcast requirements?

# Cheat Sheet: How to be an LED Dimming Pro

- 1) Think controls as you're designing the lighting
- 2) Decide the dimming scope needed for the job:
  - Are presets needed?
  - What Low-End needed?
- 3) Pick the LED driver as carefully as you pick the fixture
- 4) Driver control types for the fixture schedule must either:
  - All be the same control type, or
  - The Control System must be able to control multiple control types of all drivers used
  - ...and, the wiring shown on the RCP must reflect the control wiring types for each driver type
- 5) The Electrical Engineer must be aware of choices of analog drivers vs. digital drivers since they are power circuited in totally different ways
- 6) Make the Electrical Contractor responsible for any wiring/material changes in driver types/control types if making any fixture changes/substitutions
- 7) Make sure the commissioning is done to match design expectations, i.e. create and specify a Sequence of Operations

# Cheat Sheet: How to be an LED Dimming Pro

Always:

- When you pick the CCT (Color temperature) of LEDs to match the project environment...don't forget CRI (Color Rendering)
- Use reliable manufacturers who
  - Provide clear specification choices on product sheets
  - Will back you up on the project
- Encourage MOCK-UPS and TESTING!

This concludes The American Institute of Architects Continuing  
Education Systems Course

