Connected:
How Networked Control Systems
(and codes and standards!)
Will Drive LED Adoption

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CLTC’s Mission

To accelerate the development and commercialization of energy-efficient lighting and daylighting technologies in partnership with utilities, manufacturers, end users, builders, designers, researchers, academics, and governmental agencies.

MISSION-DRIVEN ACTIVITIES:
• Research & Development
• Demonstration & Outreach
• Education & Training
### FOUNDING ORGANIZATIONS

- UC DAVIS
- pilar
- NEMA
- [Logo]

### UTILITIES

- Pacific Gas and Electric Company
- Southern California Edison
- SDG&E
- SMUD
- Los Angeles Department of Water & Power
- City of Roseville
- Silicon Valley Power
- BC hydro

### MANUFACTURERS

- Acuity Brands
- 
- Cooper Lighting

### LARGE END-USERS

- DGS
- Department of General Services
- The California State University
- LACCD
- Walmart
Lighting & Energy Efficiency

Luminous Efficacy
– **One time, long duration change**
– **Reduction of baseline**
  • Light Source Efficacy
  • Luminaire Efficacy
  • Application Efficacy

Lighting Controls
– **Continuous, real-time change**
– **Fluctuations from base line**
  • Occupancy / Vacancy
  • Daylighting
  • Demand Response
  • Tuning
  • Personal Control
Adaptive Lighting Systems…

automatically adjust their light output…
  – Total Luminous Flux
  – Spectral Power Distribution
  – Candle Power Distribution

based on sensor input from the space they serve…
  – Occupancy / Vacancy
  – Daylight
  – DR Signals

to optimize space and building performance.
  – Comfort
  – Energy Savings
  – Peak Demand Reduction
Select the Appropriate

Source + Luminaire + Controls
(for the application)
The California Context:
2013 Building Energy Efficiency Standards
Lighting Controls Requirements
Title 24, Part 6 2013 start date: July 1, 2014
### Luminaire alterations

**TABLE 141.0-E Requirements for Luminaire Alterations**

<table>
<thead>
<tr>
<th>Quantity of existing affected luminaires per Enclosed Space</th>
<th>Resulting Lighting Power for Each Enclosed Space</th>
<th>Applicable Mandatory Control Provisions for Each Enclosed Space</th>
<th>Multi-level Lighting Control Requirements for Each Altered Luminaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum total &lt; 10% of existing luminaires</td>
<td>Existing lighting power is permitted</td>
<td>Existing provisions are permitted</td>
<td>Existing controls are permitted</td>
</tr>
<tr>
<td>Sum total ≥ 10% of existing luminaires</td>
<td>$\leq 85%$ of allowed lighting power per Section 140.6 Area Category Method</td>
<td>§130.1(a), (c)</td>
<td>Two level lighting control $^2$ or §130.1(b)</td>
</tr>
<tr>
<td></td>
<td>$&gt; 85%$ of allowed lighting power per Section 140.6 Area Category Method</td>
<td>§130.1(a), (c), (d) $^3$</td>
<td>§130.1(b)</td>
</tr>
</tbody>
</table>

**Alterations that change the area of the enclosed space or the space type or increase the lighting power in the enclosed space**

| Any number                                              | Comply with Section 140.6                         | §130.0(d) $^3$, §130.1(a), (c), (d) $^3$, (e)                  | §130.1(b)                                                        |

1. Affected luminaires include any luminaire that is changed, replaced, removed, relocated; or, connected to, altered or revised wiring, except as permitted by EXCEPTIONS 1 and 2 to Section 141.0(b)2iii:

2. Two level lighting control shall have at least one control step between 30 and 70% of design lighting power in a manner providing reasonably uniform illuminations

3. Daylight controls in accordance with Section 130.0(d) are required only for luminaires that are altered.
Lighting controls requirements

Indoor

130.1 (a) = area controls
130.1 (b) = multi-level lighting controls
130.1 (c) = shut off controls
130.1 (d) = daylighting
130.1 (e) = demand response

Outdoor

130.2 (c)
Multi-level lighting control: 130.1 (b)

Changes from 2008:

• Areas with LPD greater than $0.5 \text{ W/ft}^2$ now, was $0.8 \text{ W/ft}^2$

• Requirements based on source type, was only one control step between 30% and 70% of full output

• Additional control strategy required, previously no additional requirements

• There are some exceptions
Table 130.1-A

Any area ≥ 100 ft\(^2\) with a connected lighting load > 0.5 W/ft\(^2\) must meet the control and uniformity requirements in Table 130.1-A, with each luminaire controlled by at least one of the following control strategies:

- Manual dimming
- Lumen maintenance
- Tuning
- Automatic daylighting
- Demand response

<table>
<thead>
<tr>
<th>Luminaire Type</th>
<th>Minimum Required Control Steps (Percent of Full Rated Power)</th>
<th>Uniform Level of Illuminance Shall Be Achieved by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line-voltage sockets except GU-24</td>
<td></td>
<td>Continuous dimming 10–100%</td>
</tr>
<tr>
<td>Low-voltage incandescent systems</td>
<td></td>
<td>Continuous dimming 10–100%</td>
</tr>
<tr>
<td>LED luminaires and LED source systems</td>
<td></td>
<td>Continuous dimming 10–100%</td>
</tr>
<tr>
<td>GU-24 rated for LED</td>
<td></td>
<td>Continuous dimming 10–100%</td>
</tr>
<tr>
<td>GU-24 sockets rated for fluorescent &gt; 20 W</td>
<td></td>
<td>Continuous dimming 20–100%</td>
</tr>
<tr>
<td>Pin-based compact fluorescent &gt; 20 W</td>
<td>Minimum one step between 30–70%</td>
<td>• Stepped dimming or Continuous dimming or Switching alternate lamps in a luminaire</td>
</tr>
<tr>
<td>GU-24 sockets rated for fluorescent ≤ 20 W</td>
<td>Minimum one step in each range:</td>
<td>• Stepped dimming or Continuous dimming or Switching alternate lamps in each luminaire, having a minimum of 4 lamps per luminaire, illuminating the same area and in the same manner</td>
</tr>
<tr>
<td>Pin-based compact fluorescent ≤ 20 W</td>
<td>Minimum one step between 30–70%</td>
<td>• Step dimming or Continuous dimming or Separately switching circuits in multi-circuit track with a minimum of two circuits</td>
</tr>
<tr>
<td>Linear fluorescent and U-bent fluorescent ≤ 13 W</td>
<td>Minimum one step between 30–70%</td>
<td>• Stepped dimming or Continuous dimming or Switching alternate lamps in each luminaire, having a minimum of 2 lamps per luminaire, illuminating the same area and in the same manner</td>
</tr>
<tr>
<td>Linear fluorescent and U-bent fluorescent &gt;13 W</td>
<td>Minimum one step between 30–70%</td>
<td>• Step dimming or Continuous dimming or Separately switching circuits in multi-circuit track with a minimum of two circuits</td>
</tr>
<tr>
<td>Track lighting</td>
<td>Minimum one step between 30–70%</td>
<td>• Stepped dimming or Continuous dimming or Switching alternate lamps in each luminaire, having a minimum of 2 lamps per luminaire, illuminating the same area and in the same manner</td>
</tr>
<tr>
<td>HID &gt;20 W</td>
<td>Minimum one step between 50–70%</td>
<td>• Stepped dimming or Continuous dimming or Switching alternate lamps in each luminaire, having a minimum of 2 lamps per luminaire, illuminating the same area and in the same manner</td>
</tr>
<tr>
<td>Induction &gt;25 W</td>
<td>Minimum one step between 50–70%</td>
<td>• Stepped dimming or Continuous dimming or Switching alternate lamps in each luminaire, having a minimum of 2 lamps per luminaire, illuminating the same area and in the same manner</td>
</tr>
<tr>
<td>Other light sources</td>
<td>Minimum one step between 50–70%</td>
<td>• Stepped dimming or Continuous dimming or Switching alternate lamps in each luminaire, having a minimum of 2 lamps per luminaire, illuminating the same area and in the same manner</td>
</tr>
</tbody>
</table>
Adaptive Lighting in Transitional Spaces

Partial ON/OFF control: 130.1 (c)
Partial ON/OFF control: 130.1 (c)

Specific requirements for partial ON/OFF occupancy sensors;

*none required in 2008*

- Parking garages
- Other indoor parking areas
- Indoor loading and unloading zones
- Library book stacks*
- Stairwells and corridors*
- Warehouse aisle ways and open areas*

* in addition to automatic time switch controls
Reduce on vacancy, then off at COB

Areas where partial ON/OFF occupant sensing controls are required in addition to full automatic shut-off at COB:

- Stairwells
- Corridors
- Aisle ways and open areas in warehouses
- Library book stack aisles, 10 feet or longer

Reduce by 50% power on vacancy, increase when occupied
Reduce on vacancy, rather than off

Areas where partial ON/OFF occupant sensing controls are required instead of full automatic shut-off at COB:

- Stairwells and common area corridors in high-rise residential buildings and hotel/motels
  - ≥ 50% reduction

- Indoor parking and loading/unloading areas
  - One step between 20-50%
  - Control ≤ 500W per zone
Daylighting Controls: 130.1 (d)

- **Automatic controls** now required, manual option removed
- Calculation method for daylit zones = simplified!
- Area size exemptions removed
- Parking garages are now included; previously exempt
**TABLE 140.6-A   LIGHTING POWER DENSITY ADJUSTMENT FACTORS (PAF)**

<table>
<thead>
<tr>
<th>TYPE OF CONTROL</th>
<th>TYPE OF AREA</th>
<th>FACTOR</th>
</tr>
</thead>
</table>
| a. To qualify for any of the Power Adjustment Factors in this table, the installation shall comply with the applicable requirements in Section 140.6(a)2  
b. Only one PAF may be used for each qualifying luminaire unless combined below.  
c. Lighting controls that are required for compliance with Part 6 shall not be eligible for a PAF | | |
| 1. Partial-ON Occupant Sensing Control              | Any area ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, conference or waiting room | 0.20    |
| 2. Occupant Sensing Controls in Large Open Plan Offices | In open plan offices > 250 square feet: One sensor controlling an area that is:  
                          | No larger than 125 square feet                                            | 0.40    |
|                                                     | From 126 to 250 square feet                                               | 0.30    |
|                                                     | From 251 to 500 square feet                                               | 0.20    |
| 3. Dimming System                                   | Manual Dimming                                                             | 0.10    |
|                                                     | Multiscene Programmable                                                   | 0.20    |
| 4. Demand Responsive Control                        | Hotels/motels, restaurants, auditoriums, theaters                         |         |
| 5. Combined Manual Dimming plus Partial-ON Occupant Sensing Control | Any area ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, conference or waiting room | 0.25    |
Certified Lighting Controls ATT

- Conducted by certified field technicians
- Verifies installation requirements are met
- Ensures installed equipment and systems operate properly
  - Automatic Daylighting Controls
  - Automatic Time Switch Controls
  - Occupancy Sensor
  - Demand Response Controls
  - Outdoor Lighting Shut-off Controls
  - Outdoor Motion Sensor

CALCTP
www.calctp.org
Outdoor controls: 130.2 (c)

Lighting mounted ≤ 24 ft above the ground, motion controls required:

• Auto-ON when the areas become occupied
• Automatic step-dimming or continuous dimming when areas are vacant
• No more than 1,500 W of lighting with a mounting height of 24 ft and under may be controlled together
WHAT’S NEW IN THE 2013 CODE?
Changes to mandatory Title 24 lighting requirements

California’s new Building Energy Efficiency Standards take effect in 2014. They improve the energy efficiency of homes by 25 percent and make nonresidential buildings 30 percent more efficient than the previous 2008 standards. This brief guide offers an overview of important requirements and major updates to the lighting code.

New requirements for lighting controls constitute one of the biggest changes to Title 24 standards. The latest version of the standards also includes more stringent requirements for the testing and certification of controls commissioning.

All lighting control systems with two or more components—in both residential and nonresidential spaces—must meet the requirements of 2013 Title 24 standards. Section 110.9. Both stand-alone and luminaire-integrated lighting controls, such as vacancy sensors and photocells, must now comply with Title 20 regulations.

NON-RESIDENTIAL
INDOOR LIGHTING REQUIREMENTS

All interior luminaires in non-residential buildings must have manual on/off controls, and each area must be independently controlled. Dimmer switches must allow manual on/off functionality, with some exceptions such as public restrooms with two or more stalls, which do not need a publicly accessible switch.

MULTI-LEVEL LIGHTING CONTROLS
In areas larger than 100 ft², installed luminaires must:
- Incorporate multi-level lighting controls or continuous dimming, depending on the lamp type
- Meet the uniformity requirements in Table 130.1-A
- Have at least one of the following types of controls for each luminaire:
  - Manual continuous dimming and on/off control (Section 130.1(a))
  - Lumen maintenance (Section 100.1)
  - Tuning (Section 100.1)
  - Automatic daylighting controls (Section 130.1(d))
  - Demand response controls (Section 130.1(e))

Classrooms are one of the rare exceptions to the multi-level requirements. Instead, if they have a connected general lighting load < 0.7 W/ft², they must have at least one control step between 30% and 70% of full-rated power.
Adaptive Lighting: Case Studies
UC Davis: Bi-level Stairwells

UC Davis installed 999 LED units
Assumed 20% occupancy rate
22W high / 5W low
PIR sensor times out after 5 min
Estimated energy use reduction: 85%
  7,008 hours in standby mode
  1,752 hours in active mode
Campus Corridors Case Study: UCSF

- UCSF Medical Sciences building
- Total: 50 two-lamp T8 fluorescent fixtures addressed
- 20% of full lighting power during vacancy, 70% when occupied
- 3 different systems:
  - Lutron Energi TriPak
  - WattStopper Digital Lighting Management (DLM)
  - Enlighted
Campus Corridors Case Study: UCSF

Lutron Energi TriPak: 17 fixtures
- Occupancy rate: 12%
- Reduced lighting energy use: 62%
  - 260 kWh annual savings

WattStopper: 14 fixtures
- Occupancy rate: 16%
- Reduced energy use: 53%
  - 3,108 kWh annual savings

Enlighted: 19 fixtures
- Occupancy rate: 14%
- Reduced energy use: 68%
  - 5,396 kWh annual savings
Office Workspaces Case Study: UCSB

- Student Information Systems and Technology office
  - Three open office spaces with cubicles
- 58 2’x2’ 56W recessed fluorescent replaced by 58 dimmable LED
- Monitored from May to October 2013
- Occupancy rate: 28%
- Reduced energy use by 89%
  - Annual energy savings estimate: 11,500 kWh
  - Lifetime energy cost savings: $315 per fixture based on UCSB rate of $0.11/kWh
NETWORKED ADAPTIVE EXTERIOR LIGHTING
NorthBay VacaValley Hospital

Existing:
40 induction luminaires
13 HPS
7 metal halide luminaires

Project Partners:
Solution

- 57 LED luminaires, passive infrared (PIR) and microwave motion sensors, and a wireless radio frequency mesh network control system
- System components meet or exceed the IES’S best-practice photometric performance recommendations and the DLC’S criteria for its Qualified Products List
MWX: Microwave Sensor

MWX Sensor Detection Ranges
(one-way use)

- PIR Sensor Detection 50'
- Pedestrian 100'
- Small Vehicle 165'
- Full-Size SUV 200' +
- Truck/Bus 400' +

Lumewave’s MWX-LVE-80U-B Outdoor Microwave Lighting Controller
Demonstration Results

- Energy Savings: 66%
- Occupancy Rate: 35-55%
- Induction to LED luminaires reduced energy use 33.9%.
- Networked control system further reduced the energy use 49.2%
- Total annual savings for the demonstration: 29,020 kWh
- 2014 Lighting Energy Efficiency in Parking (LEEP) Award Winner: Best Use of Lighting Controls in a Single Facility
Next: Getting to Zero Net Energy

California Department of Public Health
Richmond, CA
Next: Customizable CCT and SPD
Next: Smart Cities, Connected Streetlighting
Connected: How Networked Control Systems (and codes and standards!) Will Drive LED Adoption

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