Dimming LED Fixtures

Perspective of Fixture Manufacturer
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Learning Objectives

Understand different classes of dimmers

Deep dive into how phase-cut dimmers work

Understand how a dimming driver operate

Learn to recognize potential conflicts before they happen

Best practices for matching controls, fixture types and applications
COMMON PROBLEMS

Flickering: What is it? What causes it? How do we avoid it?

Min - max loads on dimmers: What is an ‘LED’ dimmer? In-rush current?

Dimmer compatibility lists: Why are they so long? Does it really matter? What can I do if my preferred control is not on the list?

Mixing different luminaire types on the same control.
WHAT IS DIMMING & WHY DO WE DIM?

Dimming is Intentional reduction in light output from a luminaire
Simple with incandescent sources

Reduce the power, reduce the radiation (heat + light)
WHAT IS DIMMING

& WHY DO WE DIM?

We Dim Because

Mood and ambiance
Meeting rooms. Residential applications

Energy savings
Code requirement – vacancy/occupancy sensors. Daylight harvesting

We just want to – OK?!
ARE LEDs DIMMABLE?

Short answer: YES

• LED chips and integrated Chip arrays (COB) are dimmable

• Supply less current and they will reduce luminous flux
ARE LEDs DIMMABLE?

Long answer: YES, BUT…

- Outside of the OEM level the chip or chip package is nearly irrelevant
- What is important is the complete LED luminaire
- LED luminaire consists of: Power supply, Driver, LED Chip, Optical Control, Thermal management
ARE LEDs DIMMABLE?

Long answer: YES, BUT…

• Both LED ‘bulbs’ and ‘fixtures’ are complete luminaires
• Are they dimmable?
  • It depends
  • Only if they are designed to be dimmed
  • Must be dimmed in accordance with manufacturers specifications
HOW DO LEDs DIM?

Reduction in Power supplied to the Chip

\[ P = VA \]

Watts = Volts x Amps

Reduction in amperage corresponds to reduction in light-output

\[
\begin{align*}
1000\text{mA} & \times 18\text{v} = 18\text{w}, 1000\text{lm} \\
500\text{mA} & \times 18\text{v} = 9\text{w}, 500\text{lm}
\end{align*}
\]

Using the 18-V CXA1512 LED as an example, at steady-state operation of \( T_c = 105 \degree \text{C}, I_f = 600 \text{ mA} \), the relative luminous flux ratio is 80\% in the chart below. A CXA1512 LED that measures 1200 \text{ lm} during binning will deliver 960 \text{ lm} (1200 \times 0.8) at steady-state operation of \( T_c = 105 \degree \text{C}, I_f = 600 \text{ mA} \).
HOW DO WE CONTROL POWER TO THE CHIP?

The LED **Driver**: Power supply. Driver Chip

Usually integrated into a single device

Can be separate components. Constant Voltage applications

In all scenarios a dimmable driver takes an input signal and modifies the power output in accordance with that signal
TWO METHODS

Constant Current supplies a fixed DC current directly to an LED.

- Dimming is relatively straightforward. Reduce current output and reduce flux.
- This is used when a fixed LED load is on a circuit. The current is evenly divided among all the LED loads.

Constant Voltage supplies a fixed voltage, eg, 12v 24v.

- The current is allowed to rise and fall with the number of loads.
- This is used when the final load is unknown or flexible, eg, length of tape light, number of pucks.
- Dimming is very complicated due to certain patents and technical challenges with not infringing.

The role of the LED driver + Power supply is to provide the appropriate amount of power (current x amperage) to the led chip(s).
WHAT ARE DIMMERS?

Dimmers are controls that send a signal to a luminaire.
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2 CLASSES

Phase-Cut
Forward Phase
Reverse Phase
Adaptive Phase
AC vs DC POWER

A QUICK REFRESHER

• AC = Alternating Current
• Kayak strokes are Left / Right but they add up to forward motion
• Pass through a 0 phase with no power, motion does not stop
Phase Cut Dimming

A dimmer reduces power by increasing the amount of time the power is “off”

Forward Phase, Leading Edge or TRIAC dimmers cut off the first part of the cycle

Reverse Phase, Trailing Edge or ELV dimmers Cut off the second part of the cycle
The sine wave on and off switch is correlated as a percentage of power. By measuring the amount of time that the power is in the 0 state we can modify the output to match the required light levels.

Flickering can be caused in Leading Edge if the trigger signal is shorter than the amount of time until the next cycle.

For leading-edge dimmers, once triggered, a triac or thyristor relies on the current flowing through the device to keep it conducting. If the current falls below the device’s threshold level (i.e., the zero crossings of the AC waveform), it will turn off and stop conducting. However, with an inductive load, the current lags behind the voltage so it’s possible that the current through the triac will not reach the triac’s threshold level before the trigger pulse ends. This results in unacceptable dimming performance. To avoid this issue, dimmers designed for use with wire-wound transformer loads use a triggering technique known as a “hard firing.” This ensures the trigger pulse is maintained for a long enough period of time to make certain that the current reaches the device’s threshold level.
INCANDESCENT ARE A RESISTIVE LOAD.
Need High initial ‘voltage’ then taper off. Current and voltage are in unison.

LED POWER SUPPLIES ARE A CAPACITIVE LOAD.
The current leads the voltage. Results in a very high peak to average voltage ratio.
WHAT IT LOOKS LIKE IN THE REAL WORLD

**Forward Phase With Incandescent Load**
Voltage and Current wave forms are in unity

**Forward Phase With LED Load**
Voltage and Current peaks are out of sync. Peak Inrush current is very high compared to average current

**Reverse Phase With LED Load**
Voltage and Current are out of Sync. Current is much lower and more organized than forward phase
WHY USE FORWARD PHASE AT ALL?

• Dimming LEDs with forward phase controls is like putting a motor inside a horse carriage
• It’s better than a horse…but it’s a stop-gap technology
• For new construction or significant re-work they should not be used at all
• Commercial work should be 0-10v or other dedicated dimming signal
• Residential should use a purpose built reverse phase
FLICKERING...

Percent flicker is a measure of the depth of modulation of flicker and is calculated using the following formula:

Percent Flicker = 100% x (max - min)/(max + min)

Flicker index is a lesser known metric that accounts for the different shapes or duty cycles that the periodic waveforms of AC lighting can have. It is calculated using the following formula with reference to the figure on the right.

Flicker index = Area above Mean / Total Area
               = Area 1 / (Area 1 + Area 2)

WHAT CAUSES IT?

Flicker Type: Mid-range Flicker

LED power supplies convert AC power to DC Power

A dramatic change in the AC waveform causes oscillation in the DC power supplied to the LED
HOW CAN WE AVOID IT?

Confirm that the driver is in fact dimmable, and that the appropriate system is being used

Avoid interrupting the sine wave by using a separate dimming circuit

Use reverse phase dimmers since the peak to average current is much lower

Confirm a dimmer is on OEM compatibility list. Note special minimum and maximum loading
FLICKER
TYPE: LOW END

If the trigger signal is longer than the AC wave, low-end flicker will be the result.

Solution: Use Trim wheel on dimmer to reduce bottom end of dimming range.
A NOTE ON FIXTURE SELECTION

- Flicker is caused by power supplies that insufficiently protect the output current from noise on the input side.
- Trigger signals that are not of sufficient fidelity.
- A better quality driver will reduce flickering.
- Size of the driver is often limited by form factor limitations.
- In general higher quality drivers will be physically larger.
- Avoid using LED lamps, internal driver components are comprised by necessity of form factor.
- A dedicated LED driver will handle flicker control much better than an integrated one.
MIXING FIXTURES
ON SAME CONTROL

• There is a wide variety of signals coming from phase-cut dimmers
• There is a wider variety of methods for interpreting those signals and converting them to a stable constant current DC output
• It is unlikely that:
  • different fixtures
  • different power levels
  • different drivers
  • different LED arrays
  • will dim to the same power output on the same signal
• What’s worse, is that different fixtures will have different types of distortion and when mixed on the same line may cause flickering in otherwise perfectly functioning fixtures
  • Distortion may also be caused by mixing inductive loads or even sharing a common
WHAT DOES THIS MEAN TO ME?

• High load commercial applications (more than 100w) should use dedicated dimming circuit whenever possible.

• Reverse phase dimmers offer better low end control without flickering.

• Due to peak in-rush current – LED loads should be sized approximately 10x average load for Forward Phase dimmers eg. 50w of LED should be treated like 500w of incandescent.

• Choose fixtures with dedicated drivers rather than LED lamps or integrated modules.
WHAT DOES THIS MEAN TO ME?

- Forward phase dimmers should be limited to applications where:
  - Neutral wire is not available
  - Dedicated dimming circuit is not practical
  - Cost is the only concern
- Don’t mix fixture types on the same control without testing first
Dimming LED Fixtures
Perspective of Fixture Manufacturer

THANK YOU!
QUESTIONS?