Lighting Consumer’s Conundrum
Dimming LED’s
Agenda

• LED Lamp Technology
• LED Dimming Methods
• Challenges and Solutions
• Resources and Tools
Successful LED Dimming:

LED LAMP TECHNOLOGY
LED Lamps consist of an LED Array and Driver

- LED arrays, within a lamp, come in many shapes and sizes
- A driver is required to power the Array,
  - It converts the line voltage power to what the array needs
LED Lamps produce Heat

• Heat is created
  – By the LED Array
  – Components in the driver
• A heat “sink’ is required to dissipate the heat
• As LED’s become more efficient, heat sinks can be reduced in size
• Dimming reduces the amount of heat produced

Heat Sink
LED Drivers are Key

• Compatibility
  • Between the LED driver and the LED array is critical
  • It determines to what degree the Lamp can deliver upon its desired performance

• The LED driver design determines the dimming performance
  • Non-dim vs. Dimmable
  • Dimming range
    • Minimum Level - 20%, 10%, 1%
  • Dimming curve
  • Dimming smoothness
Understanding Dimming Range

• Dimming range varies greatly
  – Some LED lamps only dim to 50%, others to 1%

• Required dimming range – application dependent
  – 20% minimum level: suitable for a lobby, atrium, office
  – 1% minimum level: needed for restaurant, media room

Lobby or Atrium:

Residences and Restaurants:
Successful LED Dimming:

LED LAMPS –
DIMMING METHODS
LED Lamp Dimming

Line Voltage Dimmers

- Used to control LED lamps

![Diagram of Line Voltage Dimmer and LED Lamp](image.png)
LED Lamp Dimming

• Two Types of Dimmers
  – Forward Phase (Leading Edge, Triac)
    • Most Common Dimming Method
    • 150 million dimmers in use
    • Not originally intended for use with LEDs
    • Performance issues is what concerns people
  – Reverse Phase (Trailing Edge, ELV)
    • Traditionally used for Electronic Low Voltage (ELV) Lighting (track lights etc.)
    • Provides improved performance of LED lamps
    • Much smaller installed base
LED Lamp Dimming

- **Forward Phase (Leading Edge/Triac)**
  - Designed for incandescent/halogen lamps and magnetic low-voltage (MLV) loads
LED Lamp Dimming

• Reverse Phase (Trailing Edge, ELV)
  – Designed for Electronic Low Voltage Lighting
  – Requires a neutral wire connection
Successful LED Dimming:

LED DIMMING CHALLENGES
LED Dimming Challenges

- **Controls compatibility**
  - Not all LEDs are dimmable
  - “Dimmable” Lamps may have unknown or poor performance

- **Color consistency**
  - Color shift in LED light output can occur over time
  - LED color doesn’t get “warm” as they are dimmed
LED Dimming Challenges

- **Flicker**
  - The unexpected modulation of light level that is visible to the human eye
- **Pop-on**
  - The lamp flashes on when the dimmer is turned up
- **Drop-out**
  - The Lamp suddenly goes out as dimmer is turned down
- **No Off state**
  - The lamp SHOULD turn off when the dimmer is off
LED Dimming Challenges

- **Dead-travel**
  - As dimmer is adjusted there is no corresponding change in light level

- **Audible Noise**
  - From control or lamp

- **Popcorn**
  - Multiple lamps on the same dimmer turn on at different times
LED Dimming Challenges

• Dimming Low Voltage (MR-16) Lamps
  – MR-16 Lamps need a low-voltage transformer
    • Reduces the Line voltage to 12V
  – Compatibility required:
    • Between the dimmer and transformer
    • PLUS the transformer and lamp
  – There are many lamp/transformer combinations
    • But few good solutions for dimming LED MR16 lamps
LED Dimming Challenges

- Dimming Low Voltage (MR-16) Lamps
  - Dimmers and transformers have minimum load requirements
  - The dimmer type must match the transformer type
    - MLV or ELV

compatibility requirements both here and here
Successful LED Dimming:

LED DIMMING SOLUTIONS
LED Dimming Solutions

- Dimmers designed for LED Lamps
- New designs specifically for **dimmable** LED Lamps
  - UL listed with LED lamps
  - Also dim incandescent and halogen lamps
- LED Lamps designed for dimming
  - Improved driver electronics
LED Dimming Solutions

• Dimmers designed for LED Lamps
• Advanced dimming circuitry
• Voltage compensation to reduce flicker issues
• Improved minimum load requirement
• Added low-end adjustment dial
  - Set the bottom (low end) of the dimming range
• Mixed load type rating
  - Allows end-user to gradually replace incandescent lamps with LEDs

Adjustment Dial
LED Dimming Solutions

• Minimum number of lamps on a Dimmer
  – Performance may suffer with too little load
  – Incandescent dimmers require a 25 – 40 watt load
  – New dimmers only require 5 to 10 Watt load
LED Dimming Solutions

- Maximum number of lamps on a dimmer
  - A 10 Watt LED is similar to a 100W incandescent in terms of dimmer stress
  - Start-up inrush and repetitive current create stress on the dimmer
LED Dimming Solutions

- A new standard, NEMA SSL-7A
- Helps provide compatible solutions
- SSL-7A is an interface standard:
  - it specifies the interaction between LED lamps and dimmers
- Allows different manufacturers to provide compatible products
SSL-7A Adoption agents

- Manufacturers
- Retailers
- Zhaga
- EPA ENERGYSTAR
  - Lamps Specification
  - Luminaire Specification
- California Energy Commission
Successful LED Dimming:

RESOURCES AND TOOLS
**Resources and Tools**

- Compatible LED Lamp Lists
  - Many manufacturers
  - Specific Lamp Model No’s.

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### Compatible LED Lamp Lists

<table>
<thead>
<tr>
<th>Brand</th>
<th>Model</th>
<th>Wattage</th>
<th>Bulb Description</th>
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<tbody>
<tr>
<td>Cree</td>
<td>C9R</td>
<td>9.0W</td>
<td>9.0W Downlight</td>
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<tr>
<td></td>
<td>C9R-GL24</td>
<td>10.5W</td>
<td>10.5W Downlight</td>
</tr>
<tr>
<td></td>
<td>L9E</td>
<td>10.5W</td>
<td>10.5W Downlight Module</td>
</tr>
<tr>
<td>ecosmart</td>
<td>ML106802</td>
<td>13.8W</td>
<td>2&quot; Module</td>
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<tr>
<td>Halo</td>
<td>DFN 19-CW 120</td>
<td>6W</td>
<td>A19, Cool White, 4000K</td>
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<tr>
<td></td>
<td>DFN 19-NW 120</td>
<td>6W</td>
<td>A19, Neutral White, 4300K</td>
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<tr>
<td></td>
<td>DFN 19-W27 120</td>
<td>6W</td>
<td>A19, Warm White, 2700K</td>
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<tr>
<td></td>
<td>DFN 19-WW 120</td>
<td>6W</td>
<td>A19, Warm White, 3000K</td>
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<td>DFN 20-CW 120</td>
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<td>DFN 20-NW 120</td>
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<td>A19, Neutral White, 4300K</td>
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<td>DFN 20-W27 120</td>
<td>6W</td>
<td>A19, Warm White, 2700K</td>
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<tr>
<td></td>
<td>DFN 20-WW 120</td>
<td>6W</td>
<td>A19, Warm White, 3000K</td>
</tr>
<tr>
<td></td>
<td>DFN 25-CW 120</td>
<td>6W</td>
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<td>DFN 25-120</td>
<td>6W</td>
<td>A19, Warm White, 3000K</td>
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<tr>
<td></td>
<td>2E27BA11</td>
<td>9W</td>
<td>A19, Candelabra, Bent Tip</td>
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<tr>
<td></td>
<td>3E13B11-1E</td>
<td>9W</td>
<td>A19, Candelabra, Bent Tip</td>
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<td>6E26010</td>
<td>6W</td>
<td>A19, Tubular</td>
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<tr>
<td>Philips</td>
<td>T3/930</td>
<td>7W</td>
<td>A19</td>
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<td>T3/940</td>
<td>7W</td>
<td>A19</td>
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<td>T3/940-E</td>
<td>7W</td>
<td>A19</td>
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<td>1252646</td>
<td>12W</td>
<td>A19</td>
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</table>
Resources and Tools

- LED Product Selection Tool
- Lamp type/ Manufacturer / Control type Compatibility

LED Product Selection Tool

While LEDs have shown great potential within the lighting industry, they – like all lights – benefit from the proper control. Use the dropdown choices to search for tested LED solutions that will ensure compatibility between controls and drivers with other LED products.

<table>
<thead>
<tr>
<th>Fixture/Lamp Type</th>
<th>Manufacturer</th>
<th>Control Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select All</td>
<td>Cree</td>
<td>Select All</td>
</tr>
</tbody>
</table>

* Lutron Control *

* Hold Ctrl key for selecting multiple items

- Ariadni Dimmer
- C.L Dimmers

Input Voltage

- 120 V
- 120/277 V
- 240 V CE
- Low Voltage (12-24 volt)

Show only Lutron drivers (removes any non-Lutron driver options)

www.lutron.com/ledtool
Resources and Tools

- **LED Report Cards**
  - Detailed compatibility report

![Product Report Card](image-url)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model Number Tested</th>
<th>Other Model Numbers</th>
<th>Type of Device</th>
<th>Rated Output Voltage</th>
<th>Input Power</th>
<th>Input Current</th>
<th>Input Frequency</th>
<th>Control Type</th>
<th>Dimming Range</th>
<th>Output Power</th>
<th>Lumen Output</th>
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</thead>
<tbody>
<tr>
<td>Lutron</td>
<td>CR6</td>
<td>CR6-GL24</td>
<td>LED</td>
<td>120 V</td>
<td>11 W</td>
<td>Not Specified</td>
<td>60 Hz</td>
<td>Unspecified</td>
<td>100% - 5%</td>
<td>Not Specified</td>
<td>275 Lm</td>
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**Lutron Test Results**
- **Date Tested:** 26-Jul-10
- **Figure of Merit:** 0.10
- **Test Voltage:** 120 V
- **Test Notes:** None

**Lutron Recommended Compatible Products**

<table>
<thead>
<tr>
<th>Product</th>
<th>Model Number</th>
<th>Fixtures per Dimmer</th>
<th>Measured Dimming Range</th>
<th>Perceived Low End</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wallbox Dimmers</strong></td>
<td></td>
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<tr>
<td>Diva C-L</td>
<td>CR6</td>
<td>1</td>
<td>14</td>
<td>1%</td>
<td>99%</td>
</tr>
<tr>
<td>Skylark C-L</td>
<td>CR6</td>
<td>1</td>
<td>17</td>
<td>1%</td>
<td>99%</td>
</tr>
<tr>
<td>Luma C-L</td>
<td>CR6</td>
<td>1</td>
<td>7</td>
<td>1%</td>
<td>99%</td>
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</table>

**Commercial Systems**

<table>
<thead>
<tr>
<th>Category</th>
<th>Product</th>
<th>Model Number</th>
<th>Fixtures per Dimmer</th>
<th>Measured Dimming Range</th>
<th>Perceived Low End</th>
<th>Comments</th>
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<tbody>
<tr>
<td><strong>Drop Box</strong></td>
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<td>Lutron</td>
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<tr>
<td><strong>Residential Systems</strong></td>
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<tr>
<td>Panel Module</td>
<td>YB1L-P/IPEM</td>
<td>1</td>
<td>17</td>
<td>1%</td>
<td>99%</td>
<td>10%</td>
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<tr>
<td>Grafik C5</td>
<td>Grafik Eye Q5</td>
<td>1</td>
<td>7</td>
<td>1%</td>
<td>99%</td>
<td>10%</td>
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<tr>
<td>RadioRA 2</td>
<td>RRD-20NL</td>
<td>1</td>
<td>5</td>
<td>1%</td>
<td>92%</td>
<td>10%</td>
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<tr>
<td>RadioRA 2</td>
<td>RRD-3NA</td>
<td>1</td>
<td>6</td>
<td>1%</td>
<td>90%</td>
<td>10%</td>
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**Interfacing**

<table>
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<tr>
<th>Interface</th>
<th>Model Number</th>
<th>Fixtures per Dimmer</th>
<th>Measured Dimming Range</th>
<th>Perceived Low End</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>P1FM WBK with LVFR-103P</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>P1FM PA with Grafik Eye Q5</td>
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</tbody>
</table>

Notes: Measurements and fixtures are based on light output using the specified dimming control, and may not meet expectations of the fixture's full load capability.
COMMENTS AND QUESTIONS