Become an LED Lighting and Controls Expert

Ethan Biery
Lutron Electronics
September 12, 2014
8:00am – 9:30am
Agenda

- Background
- Challenges of controlling LEDs
- Lutron product solutions
- Tools and resources
- Questions
So what’s the problem?

LEDs are like a box of chocolates…

…you never know what you’re going to get!
Why do customers want LEDs?

• Saves energy
• Long lasting
• Environmentally friendly
• Elegant form factors
• New functionality (color!)
• “Everybody’s doing it”
Why are LEDs “hard”? 

- New market players
- Technology is changing rapidly
- Products are more complicated
- Compatibility is not assured
- LED lamps are different than incandescent lamps!
Terms: Color rendering index (CRI)

- CRI describes how well (accurately) a light source shows color compared to a known reference light source.
- Tested against a standardized color swatch set.
- Higher is better, 100 is best.
  - LEDs: typically >80 (>95 is available).
  - Sunlight / incandescent lamps: 100 (maximum).

**Fair**
- 50-60 CRI
  - Standard Fluorescent
  - 60-70 CRI
  - Premium HPS
  - Standard Metal Halide

**Better**
- 70-80 CRI
  - Thin-coat Tri-Phospher Fluorescent

**Best**
- 80-90 CRI
  - White HPS
  - Warm Metal Halide
  - Thick-Coat Tri-Phospher Fluorescent
- 90-100 CRI
  - High CRI Fluorescent
  - Incandescent and Halogen

Photo: Javier Ten, RPI Lighting Research Center
Terms: Correlated color temperature (CCT)

- The color emitted from a heated “black body” radiator
- Higher temperature = cooler color (bluer)
- Low temperature = warmer color (redder)
- Measured in degrees Kelvin (K)
  - LEDs: 2200K - 6000K+
  - All tungsten: 2700K*
  - All halogen: 3000K*

* Warms (lower CCT) when dimmed
Anatomy of an LED system: Fixture

- **Dimmer**: Determines compatibility and ergonomics
- **Driver**: Determines compatibility AND best possible dimming performance
- **Optics**: Determines beam spread
- **LED Module**: Determines light quality
Anatomy of an LED system: Lamp

Dimmer
Determines compatibility and ergonomics

Driver
Determines compatibility AND best possible dimming performance

Optics
Determines beam spread

LED Module
Determines light quality
**Why drivers matter**

If you only remember two things…

1. **The LED driver design determines the best possible dimming performance**
   - Dimming range (non-dim, 20%, 10%, 1%...)
   - Dimming curve (linear, logarithmic, monotonic...)
   - Dimming smoothness

2. **The compatibility between the LED driver and the control determines to what degree the driver can deliver upon its designed performance**
   - The wrong dimmer will make a great driver dim poorly
   - Even a perfect dimmer can’t make up for a bad driver

**Having a reliable driver will eliminate the common concerns of LED lighting (flicker, loading, dimming performance...)**
Steps to a successful LED dimming installation

_Ideally:_
1. Determine the dimming range needed by the application
2. Select whether an LED lamp or LED fixture is appropriate
3. Choose the appropriate control type
4. Confirm maximum/minimum number of loads on the control
5. Adjust trims and load types as necessary
1. Determine the dimming range needed

**Measured vs. Perceived**

- **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

**Example**: 20% measured = 45% perceived

- Different applications have different low-end needs
- Different LEDs have different low end light levels

**Formula**: Perceived Light (%) = 100 x \( \frac{\text{Measured Light} \text{ (%)}}{100} \)

2. Select an LED lamp or LED fixture

**LED Lamps (LEDIs)**
- Designed to replace/retrofit standard incandescent or screw-in CFL bulbs
- Standard Edison (E26) base sockets, as well as candelabra & MR16
- Integral drivers determine dimming performance (if dimmable)
- Easy to install, generally lowest cost

**LED Fixtures**
- Variable in purpose (cove lights, down lights, 2x2, etc.)
- Usually have an external driver, selected by the OEM and mounted as part of the fixture housing
- OEMs may offer different control technologies (dim vs. non-dim, 0-10V vs. DALI)
- Sleek and elegant, precise optical control
3. Choose the appropriate control type

- Control type refers to the signal and wiring between the wall control and fixture / lamp
  - Lamps generally use only forward/reverse phase control
  - Fixtures can use any method
  - The LED and control MUST be of the same control type!

- Control options
  - Forward Phase
  - Reverse Phase
  - 3 Wire
  - DMX 512
  - 0-10V
  - EcoSystem
Control type summary

- **Forward Phase**
  - Most common dimming method (150 million dimmers in use)
  - Designed for resistive (incandescent, halogen) or magnetic low-voltage (MLV) loads; not originally intended for LEDs
  - Performance issues possible on existing dimmers

<table>
<thead>
<tr>
<th>Applicable LED-rated Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caseta</td>
</tr>
<tr>
<td>PD-6WCL, PD-3PCL</td>
</tr>
<tr>
<td>RadioRA 2</td>
</tr>
<tr>
<td>RRT-G25LW, RRD-6NA, RRD-6CL, RRD-10ND</td>
</tr>
<tr>
<td>HomeWorks QS</td>
</tr>
<tr>
<td>HWQS-6NA, HWQS-6CL, HWQS-10ND</td>
</tr>
</tbody>
</table>
Control type summary

- Reverse Phase
  - Typically used for ELV loads, sometimes perform better with LEDs (or select LEDs may require reverse-phase)
  - Smaller installed base, always require a neutral wire

<table>
<thead>
<tr>
<th>Applicable LED-rated Controls</th>
<th>Caseta</th>
<th>RadioRA 2</th>
<th>HomeWorks QS</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>RRD-6NA</td>
<td>HWQS-6NA, 4A Panel Module</td>
<td></td>
</tr>
</tbody>
</table>
Control type summary

- **3 Wire**
  - Fluorescent standard, control signal carried separate from power
  - Precise, less prone to noise, but requires a third line voltage wire

### Applicable LED-rated Controls

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Caseta</td>
<td>N/A</td>
</tr>
<tr>
<td>RadioRA 2</td>
<td>RRD-F6AN</td>
</tr>
<tr>
<td>HomeWorks QS</td>
<td>HWV-FDB-8A</td>
</tr>
</tbody>
</table>

AC Power

Switched Hot (power)

Dimmed Hot (signal)

Load

Hot

Neutral
Control type summary

• DMX-512
  – Popular in theater applications & RGB LED control
  – Multiple channels for individual color control
  – Possible to use for single color general applications
  – Complicated wiring for general illumination
  – Often requires an interface and more complex programming and installation

<table>
<thead>
<tr>
<th>Applicable LED-rated Controls</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Caseta</td>
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<tr>
<td>RadioRA 2</td>
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</tr>
<tr>
<td>HomeWorks QS</td>
<td>LUT-DMX</td>
</tr>
</tbody>
</table>
Control type summary

- **0-10V**
  - Analog control standard, low voltage (simplified wiring)
  - IEC standard exists for general illumination, not always followed (alternate incompatible standard also exists)
  - Requires low voltage output AND line voltage switching
  - Often require an interface

### Applicable LED-rated Controls

<table>
<thead>
<tr>
<th></th>
<th>GRX-TVI Interface</th>
<th>GRX-TVI Interface, 0-10V PowPak</th>
<th>GRX-TVI Interface, 0-10V PowPak, TVM2 Panel Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caseta</td>
<td>GRX-TVI Interface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RadioRA 2</td>
<td>GRX-TVI Interface, 0-10V PowPak</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HomeWorks QS</td>
<td>GRX-TVI Interface, 0-10V PowPak, TVM2 Panel Module</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Typical 0-10V system architecture

Only one control device supported per zone

All light sources receive the same control signal
Control type summary

- **EcoSystem**
  - Allows digital addressing of individual fixtures and status feedback
  - Allows assignment to occupancy sensors, timeclocks and controls to one or many fixtures without added wiring
  - Based off of DALI IEC standard (with some manufacturer-specific extensions)

<table>
<thead>
<tr>
<th>Applicable LED-rated Controls</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Caseta</td>
<td>N/A</td>
</tr>
<tr>
<td>RadioRA 2</td>
<td>N/A</td>
</tr>
<tr>
<td>HomeWorks QS</td>
<td>Grafik Eye QS, DIN Rail Power Module</td>
</tr>
</tbody>
</table>
# 0-10V vs. EcoSystem

<table>
<thead>
<tr>
<th>Feature</th>
<th>Lutron EcoSystem</th>
<th>0-10V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re-zoning ability</td>
<td>Simple reprogramming</td>
<td>Re-circuiting and re-wiring</td>
</tr>
<tr>
<td>Polarity and topology free wiring</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Lights track together</td>
<td>Yes</td>
<td>May not over long wire runs</td>
</tr>
<tr>
<td>Automatic ballast replacement</td>
<td>Yes</td>
<td>N/A</td>
</tr>
<tr>
<td>Guaranteed compatibility controls + drivers</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Load feedback</td>
<td>Extensive</td>
<td>No</td>
</tr>
<tr>
<td>BMS integration</td>
<td>Fixture by fixture information</td>
<td>Generally circuit level information (depends on amount of control interfaces)</td>
</tr>
</tbody>
</table>
Special case: MR16 lamps

- Huge issue for very popular MR16 lamps
- Two compatibility requirements
  - LED lamp and step-down transformer
  - Step-down transformer and dimmer
- Step-down transformer characteristics are often not known (and not locatable) for retrofits
- Both magnetic and electronic transformers designed for LV systems were typically designed for halogen (not LED) loads
  - Simply pairing an MLV dimmer with a magnetic transformer or ELV dimmer with an electronic transformer does not guarantee success with LED loads
Special case: MR16 lamps

- Both dimmer and step-down transformer (ELV or MLV) may have minimum loading requirements

Minimum load and compatibility requirements both here and here

The right dimmer type (MLV/ELV) must be used AND compatibility confirmed!
# Control quick comparison

<table>
<thead>
<tr>
<th>Control Technology</th>
<th>Type</th>
<th>Wiring</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward Phase</td>
<td>Analog line voltage</td>
<td>2: Hot / Dimmed Hot</td>
<td>Most common type of dimmer installed</td>
</tr>
<tr>
<td>Reverse Phase</td>
<td>Analog line voltage</td>
<td>2: Hot / Dimmed Hot</td>
<td>Typically requires a neutral wire</td>
</tr>
<tr>
<td>3-wire</td>
<td>Analog line voltage</td>
<td>3: Hot / Switched Hot / Dimmed Hot</td>
<td>Originally developed for high-performance fluorescent dimming</td>
</tr>
<tr>
<td>EcoSystem</td>
<td>Digital low voltage</td>
<td>2: E1 / E2</td>
<td>Allows easy programming and zoning changes after installation</td>
</tr>
<tr>
<td>DALI</td>
<td>Digital low voltage</td>
<td>2: D+ / D-</td>
<td>Open standard, not always compatible</td>
</tr>
<tr>
<td>0-10V</td>
<td>Analog low voltage</td>
<td>2: +/-</td>
<td>Open standard, performance difficult to predict</td>
</tr>
<tr>
<td>DMX</td>
<td>Digital low voltage</td>
<td>2: D1 / D2</td>
<td>Often used with theatrical or color-changing fixtures</td>
</tr>
<tr>
<td>ClearConnect</td>
<td>Wireless</td>
<td>N/A</td>
<td>Available in limited products so far</td>
</tr>
</tbody>
</table>
4. Determine maximum & minimum loads

- Most new Lutron dimmers have LED-specific load ratings and ratings for mixed loads
- LED load power ratings are LOWER than incandescent ratings
- LED dimmers have low minimum loads (e.g., 10W or one lamp)

<table>
<thead>
<tr>
<th>Total CFL/LED Wattage Installed (Watts per bulb x # of bulbs)</th>
<th>Maximum Allowable Incandescent/Halogen Wattage*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ne sides removed</td>
</tr>
<tr>
<td>0 W</td>
<td>+</td>
</tr>
<tr>
<td>1 W – 25 W</td>
<td>+</td>
</tr>
<tr>
<td>26 W – 50 W</td>
<td>+</td>
</tr>
<tr>
<td>51 W – 75 W</td>
<td>+</td>
</tr>
<tr>
<td>76 W – 100 W</td>
<td>+</td>
</tr>
<tr>
<td>101 W – 125 W</td>
<td>+</td>
</tr>
</tbody>
</table>

2 load ratings
5. Set load type and trim settings

- Default (incandescent) settings may not provide smooth dimming performance on LED loads
  - Low end too low: dead travel, flicker, drop-out
  - High end too high: dead travel
- Incorrect load type (for adaptive dimmers) may provide unreliable operation
  - Loads may operate differently on forward vs. reverse phase
- See individual control instructions for setting trim and load type
- See LED load specifications or compatibility tables for recommended settings
Risk mitigation and best practices

- Understand product dimming performance in advance
  - “Dims from 100%-0%” (what’s just before 0%?)
- Follow recommendations from fixture and/or control manufacturer
  - Beware: they may vary!
- Do mock-ups
  - Use real amounts of load in real applications
- Develop trusted sources
  - Who will support you if things don’t go as expected?
- Understand that installed legacy dimmers weren’t designed for new LED loads – always use dimmers rated for LEDs
- System “tuning” may be needed
  - Load type setting
  - Low end / high end trim adjustment
Fixing dimming problems

• Often there are no good solutions once products are installed

• Common “fixes”
  – Change the LED load
  – Use a different driver (if possible)
  – Use a different control (with neutral?)
  – Add incandescent or dummy load
  – Add additional wires and/or interface devices and/or minimum load box

• Who is responsible? Who pays?

• Compatibility must be determined BEFORE products are ordered and installed!
Product Solutions
## Summary of different LED Product Solutions

<table>
<thead>
<tr>
<th>Solution</th>
<th>Product</th>
<th>Caseta</th>
<th>RA 2</th>
<th>HW QS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixtures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finiré</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Lumaris</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Aliante, L’ale, Rotare</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Drivers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hi-lume A-Series</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>EcoSystem 5-Series</td>
<td></td>
<td>✔</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td><strong>Phase Control Dimmers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.L Dimmer</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Phase Adaptive Dimmer</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Grafik T</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Panel Dimming Modules</td>
<td></td>
<td>✔</td>
<td></td>
<td>✔</td>
</tr>
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</table>
Finiré by Ivalo LED Recessed Lighting

- 4” downlight, wall wash, and adjustable luminaires
- Flicker-free dimming down to 1% with Lutron Hi-lume A-Series LED Driver
- Guaranteed performance and compatibility of fixture, driver, & control
- Options include 2700K, 3000K, or 3500K CCT; trim or trim-less; IC rated or standard
- Industry best color consistency and available 98 CRI
  - Standard offering is 83 CRI
- Industry best 5 year warranty on fixture, driver, and LED color consistency

www.lutron.com/finire
Lumaris by Ivalo LED Linear Lighting

- Sleek LED system that provides high-quality, uninterrupted lines of LED illumination
- Flicker-free dimming down to 0% via UL-listed Hi-lume A-Series LED driver
  - Driver can be remote mounted up to 180’ away
- Now available in brown, silver or black with clear or frosted lens
- 30° and 60° bracket options available
- 95 CRI; 2700K or 3500K options
- Industry best 5 year warranty on fixture, driver, and LED color consistency

www.lutron.com/lumaris
LED pendant and sconces by Ivalo

- High-end pendant and sconce fixtures now available in LEDs
- Flicker-free dimming down to 1% with Lutron Hi-lume A-Series LED Driver
- Guaranteed performance and compatibility of fixture, driver, & control
- 95 CRI; 2700K or 3500K options
- Industry best 5 year warranty on fixture, driver, and LED color consistency
C•L Controls

- Available in standalone, Caseta, RadioRA 2, and HomeWorks QS varieties
- 2-wire (non-neutral) high-efficacy load dimmer
- Controls dimmable CFL, LED, and INC/HAL/MLV loads designed for forward phase control
- Controls up to 150W of dimmable CFL/LED loads or 600W of INC/HAL/MLV
- 10W minimum load or 1 LED bulb
- Adjustable low end trim
Hi-lume A-Series LED driver family

- Flexible platform with many options offering smooth, continuous, addressable, 100%-1% dimming
- Versions available up to 53W maximum load
- Multiple dimmer control types
  - Phase control (Caseta, RA2, HWQS) or digital EcoSystem (HWQS) control options
- Various enclosure sizes, including UL Listed remote mountable (ideal for tape light)

www.lutron.com/hilumeled
EcoSystem 5-Series LED driver family

- Built on the EcoSystem platform (HomeWorks QS only)
- Provides smooth, flicker-free dimming from 100%-5%
- A low price solution for high quality LED dimming
- 50,000 hour lifetime at worst-case conditions
- Various current and power configurations for 5-75W fixtures
- Can be remote mounted up to 50ft away from fixture

www.lutron.com/ecosystem5series
Phase adaptive controls

- Available in RadioRA 2 and HomeWorks QS varieties
- Controls incandescent, halogen, MLV, ELV & LED lighting designed for forward or reverse phase control
- Up to 600W maximum load, requires a neutral wire
- Adjustable minimum load and default load type
- Minimum load: 5W or 1 LED bulb
Grafik T C•L dimmer

- Neutral-optional, high-efficacy load dimmer
- UL Listed to control:
  - Up to 250W of compatible CFL/LED loads
  - 600W of INC/HAL
  - 300 VA MLV
  - Up to 8 Lutron A-Series LED drivers
- Minimum load varies based on application (as low as 5W or 1 LED lamp)
- Adjustable low-end trim

www.lutron.com/GrafikT
Tools and Resources
<table>
<thead>
<tr>
<th>Tool</th>
<th>Description</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Performance Fixture List</td>
<td>List of fixtures available with Lutron drivers</td>
<td><a href="http://www.lutron.com/findafixture">www.lutron.com/findafixture</a></td>
</tr>
<tr>
<td>Compatibility Lists</td>
<td>List of loads compatible with a variety of controls</td>
<td><a href="http://www.lutron.com/dimcflled">www.lutron.com/dimcflled</a></td>
</tr>
<tr>
<td>LED Product Selection Tool</td>
<td>Report Cards on select LED loads with detailed compatibility information</td>
<td><a href="http://www.lutron.com/ledtool">www.lutron.com/ledtool</a></td>
</tr>
<tr>
<td>Whitepapers and resources</td>
<td>Background information and related links</td>
<td><a href="http://www.lutron.com/leds">www.lutron.com/leds</a></td>
</tr>
<tr>
<td>LED Center of Excellence</td>
<td>Specially trained tech support resources</td>
<td><a href="mailto:leds@lutron.com">leds@lutron.com</a> 877-DIM-LED8</td>
</tr>
</tbody>
</table>
RadioRA 2 and HomeWorks compatible controls

www.lutron.com/dimcflled
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.

View the LED Product Selection Overview Video

**Fixture/Lamp Type**
- A Lamp

**Control Technology**
- Forward Phase

**Lutron Control**
- Select All
- Ariadni Dimmer
- C.L Dimmers
- Caseta Dimmer

**Manufacturer**
- Select All
- Advance
- Aurora Lighting
- British Electrical Lamps
- Bulbrite Industries
- Color Kinetics/Philips
- Cooper/Halo

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

*Hold Ctrl key for selecting multiple items*

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

Search
Clear Form

View Lutron Qualified Partners | Learn more about all available control technologies.

If you would like your product added to this list or you would like more information about our testing program, please e-mail LEDs@lutron.com

[www.lutron.com/ledtool](http://www.lutron.com/ledtool)
## LED Report Cards

### Residential Systems

<table>
<thead>
<tr>
<th>System Type</th>
<th>Model</th>
<th>Dimmer Type</th>
<th>Min.</th>
<th>Max.</th>
<th>Dimming</th>
<th>Efficiency</th>
<th>Compatibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>RadioRA 2</td>
<td>RRD-10ND</td>
<td>FF</td>
<td>1</td>
<td>18</td>
<td>7%</td>
<td>92%</td>
<td>28%</td>
</tr>
<tr>
<td>HomeWorks QS</td>
<td>HQRD-10ND</td>
<td>FF</td>
<td>1</td>
<td>18</td>
<td>7%</td>
<td>92%</td>
<td>20%</td>
</tr>
<tr>
<td>RadioRA 2</td>
<td>RRD-6NA</td>
<td>RP</td>
<td>1</td>
<td>18</td>
<td>7%</td>
<td>98%</td>
<td>27%</td>
</tr>
<tr>
<td>HomeWorks QS</td>
<td>HQRD-6NA</td>
<td>RP</td>
<td>1</td>
<td>18</td>
<td>7%</td>
<td>98%</td>
<td>27%</td>
</tr>
<tr>
<td>HomeWorks QS</td>
<td>HxO-5ND</td>
<td>FF</td>
<td>1</td>
<td>13</td>
<td>7% (15)</td>
<td>89% (99)</td>
<td>27%</td>
</tr>
<tr>
<td>Panel Module</td>
<td>HW/LP-RPM-4A-120</td>
<td>FF</td>
<td>1</td>
<td>89</td>
<td>7% (11)</td>
<td>96% (99)</td>
<td>28%</td>
</tr>
<tr>
<td>Grafik QS/ Wallbox Power Module</td>
<td>Grafik Eye GS Main Unit Family/ LQRJ-WPM-8P</td>
<td>FF</td>
<td>1 - 62</td>
<td>7% (16)</td>
<td>98% (99)</td>
<td>28%</td>
<td>Rating is per output, total quantity per Main Unit is 155.</td>
</tr>
<tr>
<td>Panel Module</td>
<td>GP (Harnier) Card</td>
<td>FF</td>
<td>1 - 44</td>
<td>8% (14)</td>
<td>97% (99)</td>
<td>27%</td>
<td>Rating is per output. Use load type 2-1.</td>
</tr>
<tr>
<td>Grafik Eye 3000/ HomeWorks</td>
<td>Grafik Eye 3000 Family/ HWI-WPM-5D-120</td>
<td>FF</td>
<td>1 - 62</td>
<td>7% (16)</td>
<td>98% (99)</td>
<td>26%</td>
<td>Rating is per output, total quantity per Main Unit is 93/118/155/155 for 2/3/4/6 Zone units, respectively.</td>
</tr>
<tr>
<td>RadioRA 2</td>
<td>RRD-6CL (R3)*</td>
<td>FF</td>
<td>1</td>
<td>18</td>
<td>20%</td>
<td>86%</td>
<td>44%</td>
</tr>
<tr>
<td>HomeWorks QS</td>
<td>HQRD-6CL (H2)*</td>
<td>FF</td>
<td>1</td>
<td>18</td>
<td>20%</td>
<td>88%</td>
<td>44%</td>
</tr>
</tbody>
</table>

### Interfaces

<table>
<thead>
<tr>
<th>Interface Description</th>
<th>Model</th>
<th>Dimmer Type</th>
<th>Min.</th>
<th>Max.</th>
<th>Dimming</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHPM-PA with Grafik Eye QS Main Unit</td>
<td>Rp</td>
<td>Rp</td>
<td>1</td>
<td>89</td>
<td>7% (15)</td>
<td>98% (96)</td>
</tr>
<tr>
<td>PHPM-WBX with 3-wire fluorescent control</td>
<td>Rp</td>
<td>Rp</td>
<td>1</td>
<td>89</td>
<td>7%</td>
<td>98%</td>
</tr>
</tbody>
</table>

### Notes:

- *Identical model numbers with different compatibility codes may have different performance; () means there is no compatibility code assigned; contact technical support for additional information.
- (1) Control types of FF and RP represent Forward Phase and Reverse Phase, respectively. See product literature for details.
- (2) Maximum Fixtures per Dimmer value represents the maximum safe loading of the control.
- (3) Values are based on light output using the specified dimming control, and may not be an indication of the fixture’s full rated capability. Values are set to optimize performance, such as reducing dead travel, ensuring that fixtures turn on at low end, and trimming out instability. Softwaretrim values are indicated in parentheses when applicable.
- (4) Perceived light level percentage is the square root of the measured light level percentage, per IESNA Lighting Handbook.
- (5) Interfaces have been tested with the listed control; any compatible dimmer may be used instead, but high end/lowl end light levels may vary slightly.

### Test Comments:

Performance verified with up to 18 fixtures per control.
Limitations to recommendations

• Lutron recommendations are tested with up to 150W of load
• Only loads which perform well enough in most applications on multiple dimmers have Report Cards
  – For example, LEDs must dim to at least 20% measured light
• Only listed dimmers are approved; “similar” dimmers may have different performance
  – Check with the LED Center of Excellence with questions
• Lutron can only list solutions for products which are UL-approved for LED loads
High Performance LED Fixture Tool

- Lists fixtures from OEMs that contain Lutron drivers or EcoSystem technology
  - Updated regularly
- Guaranteed dimming performance and control compatibility
- Hundreds of fixtures listed:
  - Accent Lights
  - Coves
  - Downlights
  - Grazers
  - Pendants
  - Slots
  - Strips
  - Track
  - Linears
  - Sconces...

www.lutron.com/findafixture
## Summary of solutions

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>More</strong></td>
<td><strong>Untested products with drivers by others</strong>&lt;br&gt; Untested; dimming performance unknown or uncertain</td>
</tr>
<tr>
<td><strong>Load on Compatibility Lists or LED Product Report Cards</strong>&lt;br&gt;Lutron-tested compatibility and confirmed dimming performance</td>
<td></td>
</tr>
<tr>
<td><strong>Fixtures with Lutron drivers</strong>&lt;br&gt;Lutron-guaranteed compatibility and dimming performance</td>
<td></td>
</tr>
<tr>
<td><strong>Lvalo fixtures</strong>&lt;br&gt;Lutron-guaranteed light quality, compatibility, and dimming performance</td>
<td></td>
</tr>
</tbody>
</table>
LED Control Center of Excellence

• A resource for you and your customers to get answers on any LED control question, including:
  – Compatibility lists
  – Tested/non-tested products
  – Whitepapers and presentations
  – Educational information to share with customers

• Ways to reach us:
  – 1-877-DIM-LED8
  – LEDs@lutron.com
  – www.lutron.com/LED
Summary

• Using LED loads is not the same (not as easy!) as using previous technologies
• Successful projects depend on selecting the proper load and control early in the design process
• Understand that changing the load or the control may impact performance
• Fixing dimming compatibility “in the field” is costly and time consuming; LED-compatible controls should be selected for all designs today, regardless of the load type initially needed
Summary

• Lutron is the leader of controlling ANY light source, including LEDs:
  – Product innovation and performance
  – Customer education and support
  – Industry involvement and leadership

• Using Lutron products and resources simplifies the selection of LED lighting fixtures and controls
  – Use Lutron C•L products and drivers
  – Follow recommendations from the LED Center of Excellence

• Lutron’s LED fixture, driver, and control solutions are available to control hundreds of fixtures globally with known performance and compatibility
Further questions…?