LEDr Lamps – A Look Back and a Look Forward

Bill O’Connell, LC, LEED® AP
A Quick bit about Bill

• Optical Engineer by training
• 19 years in lighting
• 5 years in current job
• Focusing on
  – Lighting Specification
  – Lighting Education
  – Commercial Utility Incentives
Agenda

- Can you believe we tried to sell THAT
  - Historic Performance #’s & Odd Products
- The Stuff Just Launched
  - What we have now
- Dimming
  - {Hum first bars of Theme to Jaws here}
- The Future
  - What to look for next
LED Lamps: A-line (Circa 2009)

Product Features & Benefits

Replacements for incandescent - High R9 & R13, closely matches halogen color (non-dimmable applications)

Lamp  | LED  | INC
--- | --- | ---
Wattage | 8 W | 40W
Light Output | 350 lm | 390 lm
Lifetime L<sub>70</sub> | 25K hrs | 3K hrs
CCT | 3000K | 2700K
CRI | 82 | 95

80% energy savings and 8x longer life than incandescent
LED A-Line (Circa 2010)

- LED high quality replacement for 40W A-line incandescent lamps
  - Dimmable
- 80% energy savings and 33x longer lifetime with ULTRA Gen 2
- High CRI

<table>
<thead>
<tr>
<th>A-Line Lamp</th>
<th>LED A-Line Gen 1</th>
<th>INC</th>
<th>LED A-Line 78642</th>
<th>INC</th>
<th>LED A-Line Gen 1</th>
<th>INC</th>
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<tbody>
<tr>
<td>Wattage</td>
<td>8 W</td>
<td>40 W</td>
<td>8 W</td>
<td>60 W</td>
<td>8 W</td>
<td>60 W</td>
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<tr>
<td>Rated Life</td>
<td>25K hrs (L_{70})</td>
<td>1500 hrs</td>
<td>50K hrs (L_{70})</td>
<td>1500 hrs</td>
<td>50K hrs (L_{70})</td>
<td>1500 hrs</td>
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<td>Lumen Output</td>
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<td>470</td>
<td>430</td>
<td>770-850</td>
<td>430</td>
<td>770-850</td>
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<tr>
<td>Efficacy</td>
<td>44 LPW</td>
<td>11.75 LPW</td>
<td>54 LPW</td>
<td>12.8 - 14 LPW</td>
<td>85</td>
<td>100</td>
</tr>
<tr>
<td>CRI</td>
<td>82</td>
<td>100</td>
<td>85</td>
<td>100</td>
<td>85</td>
<td>100</td>
</tr>
<tr>
<td>CCT</td>
<td>3000 K</td>
<td>2700 K</td>
<td>3000 K</td>
<td>2700 K</td>
<td>3000 K</td>
<td>2700 K</td>
</tr>
</tbody>
</table>

1 Average Rated Life (L_{70}): Mean time to 70% initial lumen output, in hours when operated at nominal lamp voltage, current and temperature. Higher ambient operating cycles will affect life.
LED A-Line 810 Lumen (Circa 2010)

- LED high quality replacement for 60W A-line incandescent lamps
  - Dimmable
  - 80% energy savings and 12x longer lifetime
  - High CRI

<table>
<thead>
<tr>
<th>A-Line Lamp</th>
<th>LED A-Line</th>
<th>INC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td>8 W</td>
<td>60 W</td>
</tr>
<tr>
<td>Rated Life</td>
<td>25K hrs ($L_{70}$)(^1)</td>
<td>2K hrs</td>
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<tr>
<td>Lumen Output</td>
<td>810</td>
<td>770-850</td>
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<tr>
<td>Efficacy</td>
<td>67 LPW</td>
<td>12.8 - 14 LPW</td>
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<td>CRI</td>
<td>90</td>
<td>100</td>
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<tr>
<td>CCT</td>
<td>2700 K</td>
<td>2700 K</td>
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</table>

**Target Launch – Fall 2010**

\(^1\) Average Rated Life ($L_{70}$): Mean time to 70% initial lumen output, in hours when operated at nominal lamp voltage, current and temperature. Higher ambient operating cycles will affect life.
ULTRA LED A19 Lamps (Circa 2011)

Quality, Omni-directional light

Features
40W, 60W & 75W incandescent equivalents
Dimmable & non-dimmable versions
Life: 25,000 hours (L70)
CCT: 2700K

Benefits
- Light distribution similar to incandescent A19
- Energy Savings: 77% - 82% incandescent
- Longer Life: Up to 25X longer than incandescent
- RoHS compliant
- UL Listed

Applications:
- Table lamps
- Downlights
- Track
- Suitable for residential, hospitality, restaurants, retail

Target Launch Date: July 2011 (40W & 60W) & Sept (75W)

<table>
<thead>
<tr>
<th>Incandescent Replacement</th>
<th>LED Lamp Wattage</th>
<th>Dimmable</th>
<th>Lumens</th>
<th>LPW</th>
<th>CCT</th>
<th>CRI</th>
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</thead>
<tbody>
<tr>
<td>40W A19</td>
<td>8</td>
<td>No</td>
<td>480</td>
<td>60</td>
<td>2700K</td>
<td>85</td>
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<tr>
<td>40W A19</td>
<td>8</td>
<td>Yes</td>
<td>450</td>
<td>56</td>
<td>2700K</td>
<td>85</td>
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<tr>
<td>60W A19</td>
<td>13.5</td>
<td>No</td>
<td>825</td>
<td>60</td>
<td>2700K</td>
<td>85</td>
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<tr>
<td>60W A19</td>
<td>13.5</td>
<td>Yes</td>
<td>800</td>
<td>60</td>
<td>2700K</td>
<td>85</td>
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<tr>
<td>75W A19</td>
<td>13</td>
<td>Yes</td>
<td>1100</td>
<td>84</td>
<td>2700K</td>
<td>83</td>
</tr>
</tbody>
</table>

Preliminary Specifications
ULTRA LED A19 – “2011 Show Special”

**Features**
- 15W
- Dimmable
- Medium Base
- High CRI
- Life: 25,000 hours ($L_{70}$)

**Benefits**
- 85% Energy Savings
  - Compared to 100W Incandescent
- Longer Life - 25X longer than incandescent
- RoHS compliant

**Applications:**
- Table lamps, Down lights, Track
- Suitable for residential, hospitality, restaurants, retail

**Preliminary Specifications**

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Wattage</th>
<th>Dimmable</th>
<th>Lumens</th>
<th>LPW</th>
<th>CCT</th>
<th>CRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED A19</td>
<td>15</td>
<td>Yes</td>
<td>1500</td>
<td>100</td>
<td>2700K</td>
<td>80+</td>
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<tr>
<td>Inc 100W</td>
<td>100</td>
<td>Yes</td>
<td>1530</td>
<td>15</td>
<td>2700K</td>
<td>100</td>
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</tbody>
</table>
ULTRA LED A-line Omnidirectional Lamps - 2012

Energy saving, quality LED light

Energy saving LED replacements for 40, 60, 75 & 100W incandescent lamps

- Light distribution and quality similar to incandescent lamps
- Environmentally preferred products
- Long life, no mercury or other hazardous materials
- No UV or IR; no fading of materials
- Reduces maintenance and lamp replacement costs due to their long life

Applications
- Downlights
- Pendant fixtures
- Table lamps
- Track lights
- Wall sconces

<table>
<thead>
<tr>
<th>Product Overview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulb Shape</td>
</tr>
<tr>
<td>--------------</td>
</tr>
<tr>
<td>A19</td>
</tr>
<tr>
<td>A21</td>
</tr>
</tbody>
</table>

目標推出:
8W, 12W – March 2012
14W – April 2012
20W – July 2012

Industry First
100W Equivalent!

2011 WINNER
### LED PAR Lamps (Circa 2009)

#### Product Features & Benefits

**Replacements for Halogen PAR** – High R9 & R13, closely matches halogen color (non-dimmable applications)

#### Lamp Specifications

<table>
<thead>
<tr>
<th>Feature</th>
<th>LED</th>
<th>HAL</th>
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</thead>
<tbody>
<tr>
<td>Wattage</td>
<td>16 W</td>
<td>60W</td>
</tr>
<tr>
<td>Beam Angle</td>
<td>30°</td>
<td>30°</td>
</tr>
<tr>
<td>Center Beam Candle Power</td>
<td>2350 cd</td>
<td>2500 cd</td>
</tr>
<tr>
<td>Lifetime L&lt;sub&gt;70&lt;/sub&gt;</td>
<td>25K hrs</td>
<td>3K hrs</td>
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<tr>
<td>CCT</td>
<td>3000K</td>
<td>2875K</td>
</tr>
<tr>
<td>CRI</td>
<td>87</td>
<td>95</td>
</tr>
</tbody>
</table>

#### Product Features & Benefits

**PAR38**

- **June**

**PAR30LN**

- **Available Now**

<table>
<thead>
<tr>
<th>Feature</th>
<th>LED</th>
<th>HAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td>13 W</td>
<td>50W</td>
</tr>
<tr>
<td>Beam Angle</td>
<td>30°</td>
<td>30°</td>
</tr>
<tr>
<td>Center Beam Candle Power</td>
<td>1350 cd</td>
<td>1850 cd</td>
</tr>
<tr>
<td>Lifetime L&lt;sub&gt;70&lt;/sub&gt;</td>
<td>50K hrs</td>
<td>2.5K hrs</td>
</tr>
<tr>
<td>CCT</td>
<td>3000K/3500K</td>
<td>2850K</td>
</tr>
<tr>
<td>CRI</td>
<td>82/85</td>
<td>95</td>
</tr>
</tbody>
</table>

- **75% energy savings and 8x longer lifetime**

- **74% energy savings and 16x longer lifetime**
LED PAR38 (Circa 2010)

- LED high quality replacement for 60 and 75W PAR38 halogen lamps
  - Dimmable
  - Outdoor Rated
- Up to 76% energy savings and 16x longer lifetime with ULTRA Gen 2
- Very high CRI

<table>
<thead>
<tr>
<th>PAR38 Lamp</th>
<th>LED Gen 1</th>
<th>HALOGEN</th>
<th>LED</th>
<th>HALOGEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td>15 W</td>
<td>60 W</td>
<td>18 W</td>
<td>75W</td>
</tr>
<tr>
<td>Rated Life</td>
<td>25K hrs (L_{70})</td>
<td>3K hrs</td>
<td>50K hrs (L_{70})</td>
<td>2.5K hrs</td>
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<tr>
<td>CBCP²</td>
<td>2350 cd</td>
<td>3700 cd</td>
<td>3100 cd</td>
<td>3150 cd</td>
</tr>
<tr>
<td>Beam Angle (@50% CBCP)</td>
<td>30°</td>
<td>25°</td>
<td>25°</td>
<td>30°</td>
</tr>
<tr>
<td>Lumens</td>
<td>550</td>
<td>850</td>
<td>900</td>
<td>1060</td>
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<td>CRI</td>
<td>88</td>
<td>100</td>
<td>87</td>
<td>100</td>
</tr>
<tr>
<td>CCT</td>
<td>3000K</td>
<td>2875K</td>
<td>3000K</td>
<td>2900K</td>
</tr>
</tbody>
</table>

1 Average Rated Life (L_{70}): Mean time to 70% initial lumen output, in hours when operated at nominal lamp voltage, current and temperature. Higher ambient operating cycles will affect life.
2 CBCP: center beam candlepower, measured in candela.
Spec Grade LED PAR30/38 (2010)

- LED replacement for 50W and 60W halogen PAR30 and PAR38
  - PAR30 Dimmable
  - Medium base
- Various Beam Angles
- High CRI: 87 (>85), R9 (53), R13 (93)
- CCT: 3000K & 2700K
- Lifetime L-70: 50K hours at max ambient temperature 40°C

<table>
<thead>
<tr>
<th>LED PAR38</th>
<th>Nominal Wattage</th>
<th>CCT</th>
<th>Nominal CRI</th>
<th>Lamp Lumen</th>
<th>7 Degree</th>
<th>10 Degree</th>
<th>12 Degree</th>
<th>15 Degree</th>
<th>25 Degree</th>
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<tbody>
<tr>
<td>LED PAR38</td>
<td>16W</td>
<td>3000K</td>
<td>87</td>
<td>660</td>
<td>25,000</td>
<td>12,500</td>
<td>11,000</td>
<td>5,000</td>
<td>3,000</td>
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<tr>
<td>LED PAR38</td>
<td>16W</td>
<td>2700K</td>
<td>87</td>
<td>620</td>
<td>22,800</td>
<td>11,400</td>
<td>10,000</td>
<td>4,500</td>
<td>2,730</td>
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<tr>
<td>LED PAR38</td>
<td>10W</td>
<td>3000K</td>
<td>87</td>
<td>480</td>
<td>20,000</td>
<td>10,000</td>
<td>8,000</td>
<td>3,600</td>
<td>2,200</td>
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</table>
## MUSICLITES®
### A Symphony of Light and Sound

### SYSTEM COMPONENTS

- **MusicLites®**
  - Source dependent transmitters with remote control
    (Source Dependant; iPod, iPhone, USB, Headphone Jack, etc)
- **Audio Signal:** Proprietary 2.4 Wireless Transceiver
- **Dimensions:** 3.8” x 5.2” (Equivalent to BR30)
- **Weight:** 1 Lb
- **Light Can Compatibility:** 4”, 5”, 6”

### LIGHT SPECIFICATIONS

- **Size:** Medium Based
- **Life Span:** 25,000 Hours
- **Lumens:** 500
- **Color Temperature:** 3000º K
- **Color Rendering:** 80+
- **Beam Angle:** 80º
- **Dimmable:** With existing dimmers and remote

### AUDIO SPECIFICATIONS

#### Loudspeaker
- **Driver Complement:** 2.75” High Fidelity Loudspeaker
- **Frequency Response:** 80 Hz – 20 kHz
- **Sensitivity:** 85dB @ 2.83 Volts, 1 Meter
- **Maximum System Output:** 96dB SPL
- **Enclosure Type:** Sealed Cabinet
- **Cabinet / Finish:** White Aluminum

#### Amplifier
- **Amplifier Power:** 25 Watt RMS, 95% Efficiency
- **Amplifier Type:** Class D
- **Signal Processing:** Digital Equalization with Bass Enhancement down to 50 Hz
### Clarity Thru Technology

#### Features
- High CRI
- Dimmable
- Outdoor rated
- Life: 25,000 Hours \((L_{70})\)
- Increase lumens
  - 90 watt equivalent
- Beam Angle 30°

#### Benefits
- High color quality
- 78% Energy savings
  - Compared to 90W Halogen
- Longer life – 10X longer than halogen
- RoHS compliant
- ETL listed
- Assembled in the USA

### Applications:
- Recessed down lights
- Accent/Display
- Track
- Suitable for art galleries, hospitality, offices, residential, restaurants, retail

### Preliminary Specifications

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Wattage</th>
<th>Beam Angle</th>
<th>CBCP</th>
<th>Lumens</th>
<th>LPW</th>
<th>CCT</th>
<th>CRI</th>
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<tbody>
<tr>
<td>LED PAR38</td>
<td>21</td>
<td>30°</td>
<td>3200</td>
<td>1100</td>
<td>50</td>
<td>3000K</td>
<td>95</td>
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<tr>
<td>90PAR38 Halogen</td>
<td>90</td>
<td>30°</td>
<td>3500</td>
<td>1310</td>
<td>15</td>
<td>2925K</td>
<td>100</td>
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**Target Launch Date: June 2011**
## ULTRA LED PAR38 Lamps
### High Performance Series (2011)

### Product Offering

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Wattage</th>
<th>Beam Angle</th>
<th>CBCP 2700K</th>
<th>CBCP 3000K</th>
<th>Replaces Halogen PAR</th>
<th>Life (L70)*</th>
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<tbody>
<tr>
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<td>10W</td>
<td>15°</td>
<td>-</td>
<td>6,900</td>
<td>60W PAR38</td>
<td>25,000</td>
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<tr>
<td></td>
<td>15W</td>
<td>10°</td>
<td>15,000</td>
<td>16,000</td>
<td>50W or 60W PAR38</td>
<td>25,000</td>
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<tr>
<td></td>
<td></td>
<td>15°</td>
<td>7,000</td>
<td>7,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18W *</td>
<td>25°</td>
<td>3,680</td>
<td>3,100</td>
<td>75W PAR38</td>
<td>50,000</td>
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<tr>
<td></td>
<td></td>
<td>40°</td>
<td>1,150</td>
<td>1,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>24W **</td>
<td>25°</td>
<td>-</td>
<td>3,850</td>
<td>90W PAR38</td>
<td>25,000</td>
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<tr>
<td></td>
<td></td>
<td>40°</td>
<td>-</td>
<td>1,750</td>
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</tbody>
</table>

- 50K life @ 6000 hr Energy Star *
- 24W – preliminary specifications **

**Preliminary Specifications for 24W**

**Target Launch Date for 24W : July 2011**

**Assembled in USA**

**Assembled in NAFTA & China**
ULTRA LED PAR38 – “2011 Show Special”

Features
High CRI
Dimmable
Medium Base
Life: 25,000 Hours ($L_{70}$)
Beam Angle 30°

Benefits
• 80% Energy Savings
  • Compared to 120W Halogen
• Longer Life - 10X longer than Halogen
• RoHS compliant

Applications:
• Recessed down lights, Wall washers, Track
• Suitable for retail, museum & gallery lighting

Preliminary Specifications

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Wattage</th>
<th>Beam Angle</th>
<th>CBCP</th>
<th>Lumens</th>
<th>LPW</th>
<th>CCT</th>
<th>CRI</th>
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</thead>
<tbody>
<tr>
<td>LED PAR38</td>
<td>24</td>
<td>30°</td>
<td>5000</td>
<td>1650</td>
<td>70</td>
<td>3000K</td>
<td>92</td>
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<tr>
<td>120W PAR38</td>
<td>120</td>
<td>30°</td>
<td>4600</td>
<td>1800</td>
<td>15</td>
<td>3000K</td>
<td>100</td>
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<tr>
<td>Halogen</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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</table>
LED Lamps: B10 (Circa 2009)

Product Features & Benefits

Replacements for incandescent - High R9 & R13, closely matches halogen color (non-dimmable applications)

<table>
<thead>
<tr>
<th>Lamp</th>
<th>LED</th>
<th>INC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td>6 W</td>
<td>15W</td>
</tr>
<tr>
<td>Light Output</td>
<td>150 lm</td>
<td>120 lm</td>
</tr>
<tr>
<td>Lifetime L_{70}</td>
<td>25K hrs</td>
<td>1.5K hrs</td>
</tr>
<tr>
<td>CCT</td>
<td>2700K</td>
<td>2700K</td>
</tr>
<tr>
<td>CRI</td>
<td>83</td>
<td>95</td>
</tr>
</tbody>
</table>

16x longer life than incandescent B10 bulb
ULTRA LED B10 (2011)

Features
- Dimmable
- High lumen output
- Candelabra and Medium base
- Bent and blunt tip
- Life: 15,000 hours (L70)

Benefits
- 86% Energy savings
  - Compared to 25W incandescent
- Longer life - 5x longer than incandescent
- RoHS compliant

Applications:
- Chandeliers, Wall Sconce, Decorative Lighting Fixtures
- Residential, Hospitality, Restaurant, Retail

Preliminary Specifications

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Wattage</th>
<th>Dimmable</th>
<th>Lumens</th>
<th>LPW</th>
<th>CCT</th>
<th>CRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED B10</td>
<td>3.5</td>
<td>Yes</td>
<td>150</td>
<td>43</td>
<td>2700K</td>
<td>85</td>
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<tr>
<td>Inc B10</td>
<td>25</td>
<td>Yes</td>
<td>150</td>
<td>6</td>
<td>2850K</td>
<td>100</td>
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</table>
**OVERVIEW – FEATURES & BENEFITS**

**ULTRA LED B12 Lamp (Circa 2012)**

- Energy saving LED replacements for 40W incandescent B12 lamps
- Light pipe diffuses light to add special sparkle
- Medium (E26) and Candelabra base (E12)
- Bent and Blunt Tip
- Dimmable to 10% - Control energy usage and light output
- Damp location rated
- Environmentally preferred products
  - Long life, no mercury or other hazardous materials
  - No UV or IR; no fading of materials
- Reduces maintenance and lamp replacement costs due to their long life

**Applications**
- Chandeliers
- Decorative lighting
- Wall sconces

<table>
<thead>
<tr>
<th>Product Comparison</th>
<th>Wattage</th>
<th>Lumens</th>
<th>LPW</th>
<th>Life</th>
<th>CCT</th>
<th>Energy savings</th>
<th>Life benefit</th>
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<tbody>
<tr>
<td>LED B12</td>
<td>6W</td>
<td>350</td>
<td>58</td>
<td>15,000</td>
<td>2700K</td>
<td>85%</td>
<td>10X</td>
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<tr>
<td>Incandescent B10</td>
<td>40W</td>
<td>360</td>
<td>7.5</td>
<td>1,500</td>
<td>2850K</td>
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**Preliminary Data**
LED MR16 Lamps (Circa 2009)

Product Features & Benefits

- Replacement for 20W Halogen MR16 (non-dimmable applications)
- 60% energy savings and 16x longer lifetime
- High CRI - high R9 & R13, closely matches halogen color

<table>
<thead>
<tr>
<th>Lamp</th>
<th>LED</th>
<th>HAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td>8 W</td>
<td>20W</td>
</tr>
<tr>
<td>Beam Angle</td>
<td>35°</td>
<td>35°</td>
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<tr>
<td>Light Output</td>
<td>220 lm</td>
<td>220 lm</td>
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<tr>
<td>Lifetime L_{70}</td>
<td>50K hrs</td>
<td>3K hrs</td>
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<tr>
<td>CCT</td>
<td>3000K</td>
<td>3000K</td>
</tr>
<tr>
<td>CRI</td>
<td>82</td>
<td>95</td>
</tr>
</tbody>
</table>
LED MR16 (Circa 2010)

- LED replacement for 20W halogen MR16 (12V, GU5.3 bi-pin base)
  - Dimmable
- Up to 70% energy savings and 17X longer lifetime with ULTRA Gen 2
- High CRI

<table>
<thead>
<tr>
<th>Lamp</th>
<th>LED</th>
<th>HAL</th>
<th>LED</th>
<th>HAL</th>
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<tbody>
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<td>Wattage</td>
<td>8W</td>
<td>20W</td>
<td>6W</td>
<td>35W</td>
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<tr>
<td>Rated Life</td>
<td>50K hrs (L_{70}) (^1)</td>
<td>2000 hrs</td>
<td><strong>35K hrs (L_{70}) (^1)</strong></td>
<td>3000 hrs</td>
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<tr>
<td>CBCP (^2)</td>
<td>430 cd</td>
<td>510 cd</td>
<td><strong>860 cd</strong></td>
<td>2000 cd</td>
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<td>Beam Angle (@50% CBCP)</td>
<td>25°</td>
<td>35°</td>
<td><strong>25°</strong></td>
<td>25°</td>
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<tr>
<td>Lumens</td>
<td>220</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>CCT</td>
<td>3000K</td>
<td>3000K</td>
<td><strong>3000K</strong></td>
<td>3000K</td>
</tr>
<tr>
<td>CRI</td>
<td>82</td>
<td>100</td>
<td><strong>87</strong></td>
<td>100</td>
</tr>
</tbody>
</table>

\(^1\) Average Rated Life (L_{70}): Mean time to 70% initial lumen output, in hours when operated at nominal lamp voltage, current and temperature. Higher ambient operating cycles will affect life.

\(^2\) CBCP: center beam candlepower, measured in candela.
ULTRA LED MR16 Lamp

- Energy saving LED MR16 replacements for 50W halogen MR16
- Passive cooling
  - No fan
- ANSI Spec size
- Dimmable down to 10% - Control energy usage and light output
- GU5.3 base
- For indoor use only
- Environmentally preferred products
  - Long life, no mercury or other hazardous materials
  - No UV or IR; no fading of materials
- Reduces maintenance and lamp replacement costs due to their long life

<table>
<thead>
<tr>
<th>Applications</th>
<th></th>
<th></th>
<th></th>
<th></th>
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<td>Recessed Downlights</td>
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<tr>
<td>Wall Washer</td>
<td></td>
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<table>
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<tr>
<th>Product Comparison</th>
<th>Wattage</th>
<th>Lumens</th>
<th>Beam angle</th>
<th>CBCP</th>
<th>Rated life L70 (hrs)</th>
<th>Color CCT</th>
<th>CRI</th>
<th>Energy savings</th>
<th>Life Benefit</th>
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<tr>
<td>LED MR16</td>
<td>8W</td>
<td>540</td>
<td>25°</td>
<td>2323</td>
<td>25,000</td>
<td>3000K</td>
<td>80</td>
<td>82%</td>
<td>6.25X</td>
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<td>Halogen MR16</td>
<td>50W</td>
<td>650</td>
<td>25°</td>
<td>4400</td>
<td>4,000</td>
<td>3000K</td>
<td>80</td>
<td>-</td>
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</table>

Preliminary Data
Agenda

• Can you believe we tried to sell THAT
  — Historic Performance #'s & Odd Products

• The Stuff Just Launched
  — What we have now

• Dimming
  — {Hum first bars of Theme to Jaws here}

• The Future
  — What to look for next
ULTRA iQ LED Lamp Family

Wirelessly controlled intelligent lighting

- Integrated wireless control
  - On/Off, Dims, Set Scenes
  - Controls unlimited number of lamps wirelessly
  - Zigbee platform ZHA (Home Automation)
- Controllable via smart device
  - Easily control light levels and set scenes
- Dimming 100% - 5%
  - No external dimmer required
  - Eliminates issues of interfacing with incandescent dimmers
- Three to five year warranty

### Applications
- Recessed downlights
- Wall Wash

### Product Description

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Wattage</th>
<th>Lumens</th>
<th>LPW</th>
<th>Life</th>
<th>CCT</th>
<th>CRI</th>
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</thead>
<tbody>
<tr>
<td>LED iQ RT6</td>
<td>11</td>
<td>700</td>
<td>63</td>
<td>35,000</td>
<td>3000K</td>
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<tr>
<td>LED iQ BR30</td>
<td>11</td>
<td>650</td>
<td>59</td>
<td>25,000</td>
<td>2700K</td>
<td>80</td>
</tr>
</tbody>
</table>
ULTRA Sunset Effect LED Lamp Family

Color temperature shifts from 3000K to 2000K as lamp dims

- Create ambiance with incandescent-like dimming
  - Phase cut dimmable to 10%
- Energy savings up to 78% over the incandescent and halogen lamps they replace
- Long life reduces maintenance cost
  - RT6 35,000 hours (L70)
  - Others 25,000 hours (L70)

<table>
<thead>
<tr>
<th>Bulb Shape</th>
<th>Wattage</th>
<th>Lumens</th>
<th>LPW</th>
</tr>
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<tr>
<td>PAR38 FL 30°</td>
<td>16</td>
<td>950</td>
<td>56</td>
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<tr>
<td>PAR30LN NFL 25°</td>
<td>14</td>
<td>725</td>
<td>52</td>
</tr>
<tr>
<td>A19</td>
<td>13</td>
<td>800</td>
<td>62</td>
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<tr>
<td>RT6</td>
<td>10</td>
<td>700</td>
<td>70</td>
</tr>
<tr>
<td>BR30</td>
<td>13</td>
<td>750</td>
<td>57</td>
</tr>
<tr>
<td>BR40</td>
<td>17</td>
<td>950</td>
<td>55</td>
</tr>
<tr>
<td>R20</td>
<td>8</td>
<td>450</td>
<td>56</td>
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</table>
ULTRA 25 LED Lamp Family

*Warm incandescent like glow*

- Specially designed color temperature for hospitality applications
  - Warm 2500K color temperature
- Creates a warm feeling environment without dimming
  - Light color similar to a 60% dimmed incandescent lamp
- Energy efficient replacements for traditional incandescent/halogen lamps

**Applications:**
- Accent and ambient lighting
- Chandeliers
- Recessed downlights
- Wall sconces
- Wall Wash

<table>
<thead>
<tr>
<th>Bulb Shape</th>
<th>Wattage</th>
<th>Lumens</th>
<th>Beam Angle</th>
<th>Rated Life L70 (hrs)</th>
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</thead>
<tbody>
<tr>
<td>BR40</td>
<td>16</td>
<td>1000</td>
<td>NA</td>
<td>25,000</td>
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<tr>
<td>PAR30</td>
<td>10</td>
<td>675</td>
<td>25°</td>
<td>25,000</td>
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<td>PAR20</td>
<td>10</td>
<td>550</td>
<td>20°</td>
<td>25,000</td>
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<tr>
<td>MR16</td>
<td>7</td>
<td>500</td>
<td>25°</td>
<td>35,000</td>
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<tr>
<td>B13</td>
<td>6</td>
<td>330</td>
<td>NA</td>
<td>15,000</td>
</tr>
<tr>
<td>B10</td>
<td>4</td>
<td>200</td>
<td>NA</td>
<td>15,000</td>
</tr>
</tbody>
</table>
PAR38 – Free Form Factors

*Creative decorative shapes and colors for unique look*

- Lamps available in fun shapes and colors
  - Used to add design, ambience, or brand to a store or hospitality space.
- Equivalent to 90W halogen
  - 81% energy savings
- High CRI
  - Excellent color quality
- High R9
  - Highlights reds, oranges, wood grains, skin tones

<table>
<thead>
<tr>
<th>Bulb Shape</th>
<th>Wattage</th>
<th>Lumens</th>
<th>LPW</th>
<th>Beam Angle</th>
<th>CBCP</th>
<th>CCT</th>
<th>CRI</th>
<th>Rated life (L70)</th>
<th>R9</th>
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<td>PAR38</td>
<td>17W</td>
<td>1150</td>
<td>67</td>
<td>40°</td>
<td>3000</td>
<td>3000K</td>
<td>90+</td>
<td>25,000</td>
<td>50</td>
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</table>
Agenda

• Can you believe we tried to sell THAT
  — Historic Performance #'s & Odd Products

• The Stuff Just Launched
  — What we have now

• Dimming
  — {Hum first bars of Theme to Jaws here}

• The Future
  — What to look for next
Where are we now?

Two approaches to dimming

• Coincident AC power and control signal
  • Reduce amplitude of AC sine wave
  • Phase-cut AC sine wave

• Separate AC power and control signal
  • Wiring requirements
  • Degree of device-level control
  • One or two-way communication
Common dimming technologies

• Coincident AC power and control signal
  – Sine wave (long obsolete)
  – Phase-Cut
    • Forward phase or reverse phase
    • 2-Wire or 3-Wire

• Separate AC power and control signal
  – Fluorescent 3-Wire
  – 0-10V
  – DALI
  – DMX512
Forward Phase Dimming

Most common dimming method

• Largest (by far) installed base
• Designed for resistive (incandescent, halogen) or magnetic low-voltage (MLV) loads

• Low cost, simple designs
Incandescent sources are simple loads

- Incandescent sources electrically behave like resistors (unlike pretty much every other lighting technology)

- Incandescent sources effectively only care about $V_{\text{rms}}$ (Voltage Root Mean Square)
  - Constant $R$ at steady state
  - $R$ is a function of filament temperature

- Incandescent sources are bidirectional
  - Applying $\pm V_{\text{rms}}$ results in the same $I_{\text{rms}}$
  - $I_{\text{rms}} = \frac{1}{R} \times |V_{\text{rms}}|$

- Important caveat: thermal persistence
  - If $I(t>0) \approx 0$ in incandescent source, light output continues
Controlling incandescent light output

- `V_{rms} = 120V`
- `V_{rms} = 120V`
- `V_{rms} = 120V`
- `V_{rms} = 120V`

Same (average) light output

High performance
Inexpensive
`V_{rms}` adjuster
Determines dimming performance

- `V_{rms} = 60V`

50% light output
LEDs are complex loads

• LEDs are non-linear devices
  – Different current-voltage relationships in different regions of operation
  – Small change in voltage can equal large change in current
  – (Average) current must (typically) be controlled

• LEDs are unidirectional
  – (Forward) current only flows in one direction
  – Light output only produced for forward current

• Important caveat: fast response
  – Careful attention to time where I≈0
Controlling LED light output

- $V_{rms} = 120V$
- $V_{rms} = 120V$
- $V_{rms} = 120V$
- $V_{rms} = 120V$

Different (average) light output

- $V_{rms} = 120V$
- $V_{rms} = 60V$

High performance
Inexpensive
$V_{rms}$ adjuster

Black Box

Controls current to LED
Determines dimming
performance!
Shouldn’t LED dimming be easy?

- Variation in LED system architecture, driver design matter
  - LED lighting is still very much an emerging technology
  - Significant market variation today
  - Lagging focus on dimmability (dimmable or designed to dim?)

- Variation in dimmer architecture, circuit design matter
  - Existing infrastructure was predominantly designed to dim incandescent sources
  - Cost, expectation barrier to replacing dimming controls

- No standards for ensuring LED dimming compatibility or predictable performance
  - Standard measurement procedures or metrics for dimming compatibility or dimming performance have never existed
  - Some existing standards are not as “standard” as one would expect or desire
Phase-cut dimming user problems

Dimming range
Dead travel
Pop-on
Drop-out
Popcorn
Ghosting
Flashing/Strobing
Induced Flicker
Audible noise

Dimming smoothness
Dimming monotonicity
Dimming up/down symmetry
Dimmer loading
LED load -dimmer inoperability
Premature failure of dimmer and/or LED load
Main problems

• Drop-out
  – No light output at the bottom of the dimming range
  – The light source turns off when the switch is still on

• Popcorn
  – Different turn-on times for different light sources on a dimmed circuit

• Ghosting
  – The light source is at a low-level on state when it should be off

• Flashing/Strobing
  – The light source is intermittently on when it should be off
LED load inrush current

• Created by connection to power
• Occurs once per power-up
LED load repetitive peak current

- Created by forward phase-cut, occurs every half-cycle
- Commonly 5-10x \( I_{\text{rms}} \); can be much higher
LED load repetitive peak current

• Varies significantly across LED products
• Often major factor determining maximum dimmer loading
• Major contributor to audible noise in light sources and controls
• Major contributor to RFI noise and interference with other electronics
• Major contributor to potentially reduced control lifetime
Dimmer timing element requirements

• The timing element for phase-cut dimmers without neutral are designed to operate through the load, and expect “resistive” load characteristics.

• LED load input impedance characteristics are typically not resistive, and may change as it is dimmed.

![Dimmer Timing Circuit Diagram]
Dimmer timing element requirements

• Timing element problems cause the switching element to turn on or off at the wrong time, a periodically (not at consistent intervals), or both

• Any change in the switching element behavior directly affects light output
  – Turning on or off at wrong time will raise or lower light level
  – Turning on or off a periodically causes the light level to change from cycle to cycle, likely resulting in objectionable flicker
Dimmer “advanced features” requirements

- Dimmers without neutral need to use LED load for return path to keep “advanced features” circuitry running

- Most LED loads can not pass standby current required by dimmers with advanced features
Neutral benefits

Dimmers with neutral have a path other than through the load for timing circuit or “advanced features” current.
**Dimmer operating current requirements**

- Can lead to LED source flashing/strobing
  - LED source accepts enough current to start, but not maintain operation

- Can lead to LED source ghosting
  - LED source gets/accepts enough current to start, and maintain (low light level operation)

- Can lead to dimmer inoperability or malfunction
  - LED source does not accept enough current to maintain proper operation of the dimmer control
  - Most problematic for advanced dimmers
Agenda

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NEMA SSL 7A-2013:
LED Lamp and Dimmer Compatibility Standard

NEMA SSL 7A-2013
Phase Cut Dimming for Solid State Lighting: Basic Compatibility

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LEDr Price Degradation

<table>
<thead>
<tr>
<th>Date</th>
<th>LEDr Retail Price</th>
<th>LEDr Brand Retail Price</th>
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<td>1-Mar-13</td>
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<td>1-Jun-13</td>
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NEMA Total LEDr AUP

Source: NEMA

Source: OSRAM Internal Research & Estimates
Bill’s Other Thoughts on ‘The Future’

- Next couple of Generations of lamps will focus on $$$ not performance
  - Generations occur ~ 12 to 18 months
- LEDr lamps may become (or try to become) part of the ‘Internet of Things’
  - First products are on the market now
  - Another solution to dimming problem
- Integration with other solid state products will keep being tried until it succeeds
  - Sound
  - Cameras
  - Who knows what else?
- The current rule of thumb on performance vs. cost is:
  - Every decade, LED costs down by factor of 10
  - Every decade, LED light output up by a factor of 20
Thank you for your attention.