PHILIPS

sense and simplicity

LED System Solutions

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The Illumination Space…

Power & Voltage

<table>
<thead>
<tr>
<th>Power &amp; Voltage</th>
<th>LV</th>
<th>MV</th>
<th>HV</th>
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<tbody>
<tr>
<td>LV</td>
<td>¼ W</td>
<td></td>
<td></td>
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<tr>
<td>LV MV HV</td>
<td>½ W</td>
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<td></td>
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<tr>
<td>LV MV HV</td>
<td>2 W</td>
<td></td>
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<td>4-8 W</td>
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<td>Arrays</td>
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Directional

Cons

Prof

Medium power less suitable

Non Directional

Cons

Prof

Traditional Power LED, - Luxeon Rebel, ES; Cree XPG, XPE; Nichia 219; Golden Dragon

Typically Level 2 Solutions - COB, Beamers, Outdoor, Hi Bay

Typically Multi Die Emitters - Spots, Floods, Hi Bay, Outdoor

The Battle Ground
Medium vs. High Power LEDs

Assumptions:

- Mid-power LEDs lag high-power in lm/W
  - The last 2 years have clearly proven that this is no longer a safe assumption.
  - Assume existence of general equivalence among main players in omnidirectional solutions
- At optimum drive currents, mid-power LEDs lag high-power in lm/$
  - This continues to be true: drive current limitations in medium power packages means that high power LEDs driven at 2-3W can provide superior emitter lm/$
  - However, system limitations can significantly limit this advantage
- Mid-power LEDs lag high-power in system lm/$
  - Too general a statement – the relative system value is much less clear and heavily design dependant
System Value

Mid-Power

– Uniformity
  • Sources can be spread around particularly for TLED etc…

– String Voltage
  • Driver compatibility

– Redundancy
  • Relative ease of providing redundancy compensates for lower reliability

– Simplicity of Use
  • Cheap level-2, even COB

– Mitigations
  • Smaller packages/COB

  • Improved reliability

High-Power

– Compact
  • Small footprint for tight spaces

– High Flux
  • Higher Lumen packages easier to realize with power LED

– Reliability
  • Higher reliability

  • Lumen Maintenance

– High Directionality & Punch

– Mitigations
  • String voltage: multi junction solutions

  • Smaller die sizes

  • Improved reliability
Other Applications

• **Display (Mid-power)**
  – A lost cause for hi-power?

• **Flash (High-power)**
  – High surface brightness and punch requirements make this a very directional solution, therefore unsuitable for today’s mid-power solutions

• **Automotive Exterior Lighting (High-power)**
  – High surface brightness and punch requirements make these very directional solutions, therefore unsuitable for today’s mid-power solutions
Test & Measurement

- Problem: Cost of 100% electro-optical testing has not kept pace with other mfg cost reductions
  - Testing is necessary, but does not add value
  - Electrical test very cheap, but optical adds complexity & cost
- Desired solutions:
  - Better test equipment to enable cheaper testing, especially hot test
  - Better algorithms to avoid 100% test & binning
  - Tighter process control of color, flux, voltage distributions to enable test simplification
  - Simpler methodology for calibration, both individual tester and across fleet
  - Optical test capability on-par with state-of-art electrical testing
Flexible Packaging

• Today, package form/fit is designed around LED chip architecture
  – Asia mfgs: mid-power, lateral die 5-sided emitters → PLCC cups
  – USA mfgs: high-power, surface emitters → die on ceramic, others
• Common (standardized) packages will inevitably serve some die architectures better than others
  – PLCC footprints serve mid-power (Asia) well, disadvantageous to high-power (USA)
  – Array packaging accommodating to either mid- or high-power
• How do we get packaging standards that work for high-power?
  – Need more affordable materials that don’t sacrifice reliability or performance
  – Less material leads to lower cost

Nichia 157, 757
Samsung MP56L
LUXEON Rebel ES
Nichia 119
Cree XP-G
Phosphor Solutions

• **Problem**: Phosphor solutions are a significant portion of packaging cost
  – Phosphor & matrix materials; application technology and process control
  – Mid-power has cheap solution (goopinacup), but not suitable for high-flux, tight binning

• **Need**: Low-cost phosphor solutions for high-power LEDs
  – Phosphor materials may not dominate phosphor system cost
  – Tight control of thickness & volume (tight binning) are required

• **High-power tradeoffs**
  – Flux density vs. material volume, CE (direct vs. remote phosphor solutions)
  – Material cost vs. reliability, CE, temperature performance
Conclusion

• In the non-directional battleground for high volume illumination, very low cost mid-power LEDs offer an excellent proposition, in particular where a distributed light source is desired (e.g., TLED)

• In space-constrained applications, high-power LEDs offer form factors which are difficult to meet with mid-power solutions (especially high-lumen packages)

• In the mass A-type bulb space, considerations over system design, including phosphor strategy, heat sink design, and driver create a space which can be addressed by either solution and, thus, is where the lines are most blurred

• Disruptive factors include: regulation (*Energy Star specs, etc*…), excess display capacity dumped into illumination, use of hybrid white LEDs (white + red), and remote phosphor designs