Permlight "101"

July 2017

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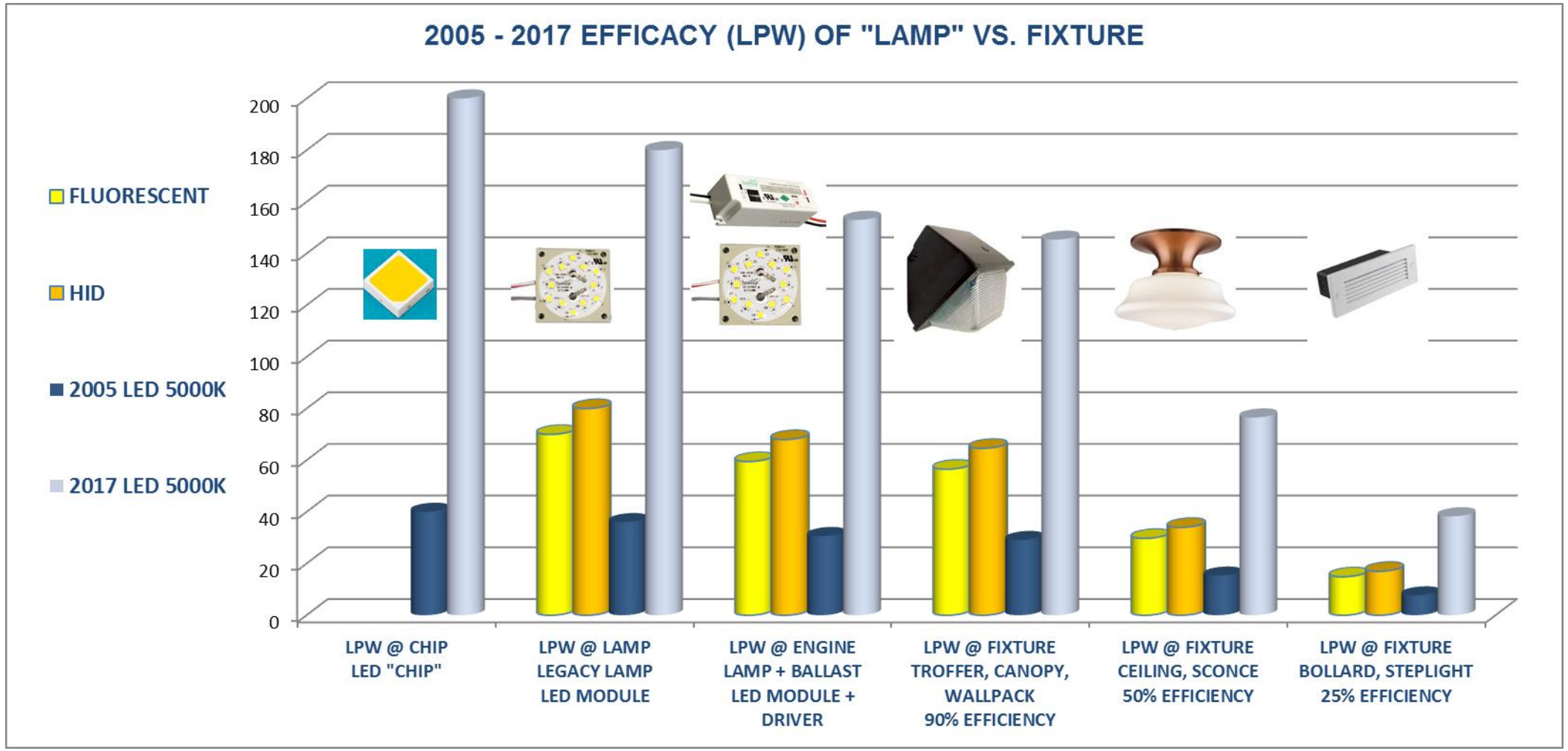
LED Efficacy, LPW in Various Fixtures

5000K/80CRI LED = 200 LPW (July 2017), technology has 240 LPW theoretical limit



Rule of Thumb:

LED replaces fluorescent or HID with about 35% of power

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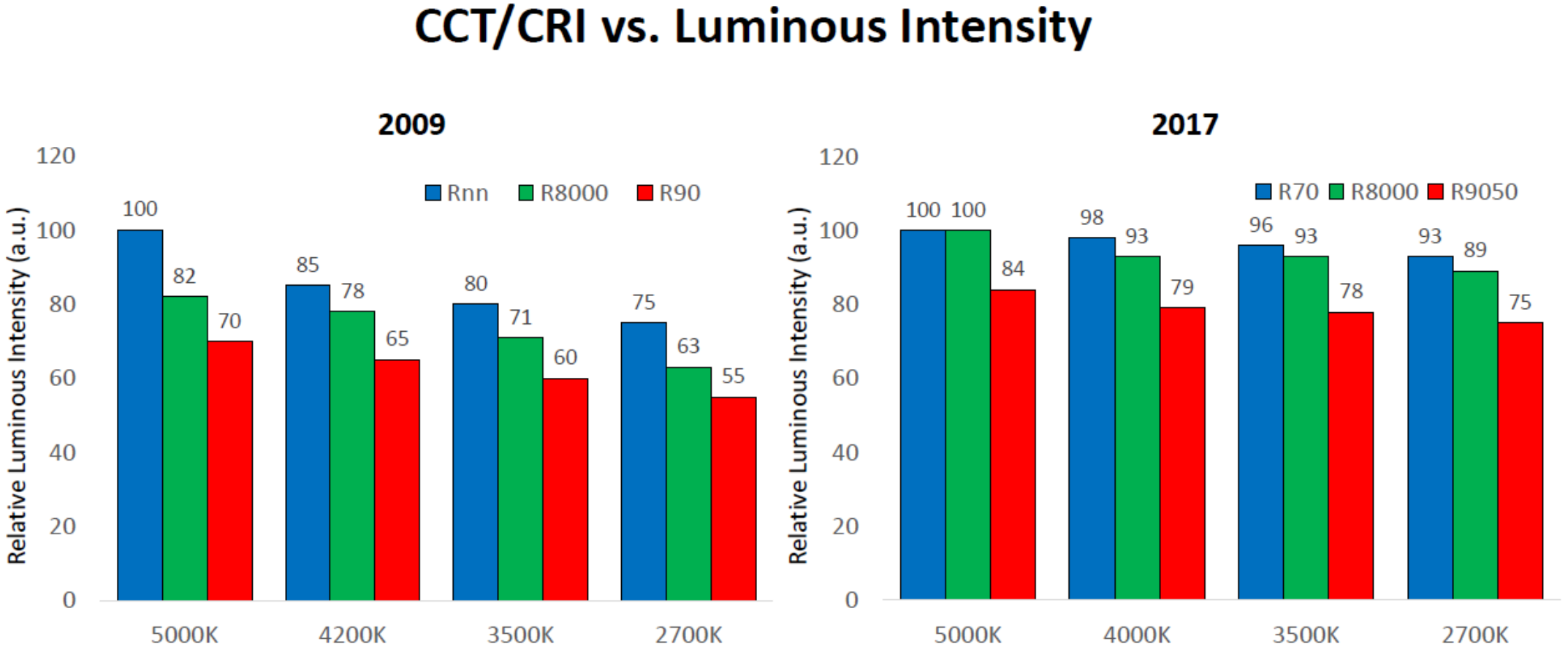
CRI, Color Rendering Index



- Low CCT and high CRI require more light from phosphor.
- Luminous Intensity is down due to Stokes loss

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Services Provided

- No Cost Collaborative Engineering
  - Luminaire prototype and retrofit, thermal and power consumption test
  - In-house 60" Integrating Sphere: total lumens, CCT, CRI (NOT = IES file)
  - Assistance with UL/CSA/ETL, ENERGY STAR, DLC, LM-80, TM-21
  - Consultation and testing of drivers and dimming controls for compatibility

- Terms of warranty to meet 5 year requirement, DLC requirement
  - OEM must follow datasheet thermal and warranty guidelines
  - When in doubt Permlight can test fixture at no cost to verify

- Stock SKUs and normal lead times
  - PCB, LED in popular CCT, and drivers are stocked
  - Permlight builds modules and engines to order, too many varieties
    - 1-4 weeks for popular SKU, CCT dependent
  - Drivers typically stock, 8 weeks if no stock, alternatives recommended

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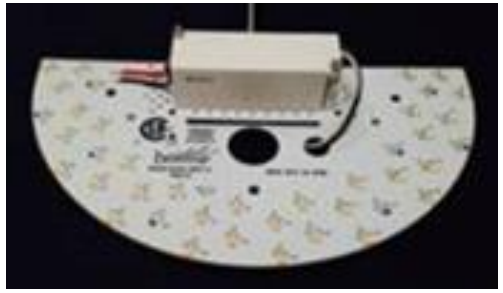
Permlight Part Number Key

LED Light Engine is defined by IES:

LED **module** + LED **driver** + **heatsink**, **example shown**



BB = **B**asic **B**oard, technically LED **module**

BEP = **B**asic **E**ngine **P**roduct, technically LED **Light Engine**

BB40HR = **HR module** (only) = **always 9.25" half round**

BEP40HR = **HR engine** (module + driver) = **always 9.25" half round, example shown**

KEY information is the **two digits after the numbers**, example **"HR"**

BEP**40** = Number (**40**) of **LEDs**, determines watts/lumens, **but does NOT specify 9.25" PCB**

BEP40HR-**27** = **2700K CCT** (color temp, warm/cool), -50 for 5000K, etc.

BEP40HR-27-**80** = **80 CRI** (color rendering index), -90 for 90 CRI, etc.

PS12-350C-DIM = **P**ower **S**upply, **12** watts, **350**mA, Constant **C**urrent, **DIM**able

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Perfect Pairs, LINE Voltage

- Driver and module engineered for compatibility and warranty
- Available in **point source, linear and rectangular**
- 4W, 120V, ELV dim, 400 lumens
  - Replaces 60W incandescent
  - **Point source** PS3 + FK

- 12W, 120V/UNV, triac dim/non-dim, 1600 lumens
  - Replaces 200W incandescent
  - **Linear source** PS18 + DQ

- 25-50W, UNV, 0-10V dim, 6000 lumens
  - Replaces 150W metal halide
  - **Rectangular source** PS50 + WC

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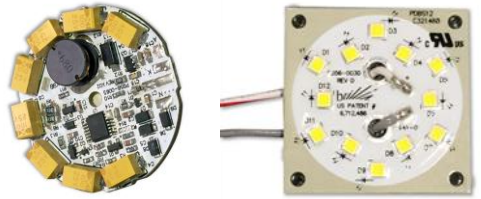
Perfect Pairs, LOW Voltage

- Driver and module engineered for compatibility and warranty
- Available in **point source, linear and rectangular**
- 1-4W, 8-18V LVM dim (landscape), 50-700 lumens
  - Replaces 20-50W MR11/16 halogen
    - **Point source** PS7 + FK

- 13W, ~25V LVM dim (track), 900-1600 lumens
  - Replaces 90-150W incandescent
  - **No known US competitor with MLV dimming**
    - **Point source** PS13 + RD



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Surface (Shallow) Engines, Even Illumination

- "Plug and play" with diffused/soft appearance over entire lens surface
- Ideal for flat "pan" luminaire such as ADA
- Integrated white driver eliminates j-box mounting, reduces shadows
- No heatsink required for interior applications to 40°C
  - Remote driver(s) and proper heatsink doubles power/lumens
- Scalable 28-88 LEDs, 9–26WAC, 800–4000 lumens

- Available in various sizes
  - Rectangle 4x6" (JR) or without driver (JT)
  - Square 6" (JSR), 8" (MSR) and 11" (GSR)
    - JSR and MSR have round or square LED pattern
  - Round 7" (JL) and 9" (GL)
  - Half Round 9.25" (HR)

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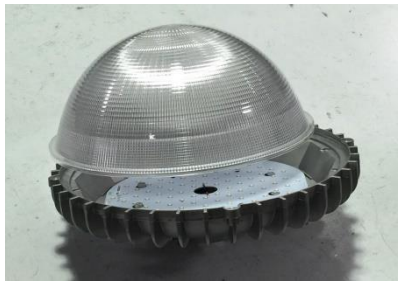
Point Source Engines

- For classic luminaire such as downlight, pendant, sconce, garage
- Remote driver and heatsink required
  - PS12, 18, 50, 120, 150, etc.
- Wide range of power and CCT/CRI
- Thermadjust™ (some models) protects engine from overheating
- Scalable power by number LEDs, 6-150WDC, 600-19,500 lumens

- Available in various sizes
  - 1.38" square (VK), replaces Bridgelux Vero18 COB
  - 1.6" square (RD, RE)
  - 1.9" square (VS), replaces Bridgelux Vero29 COB
  - 2.17" square, 0.41" center hole for shafts (RC)
  - 3.5" round, 1.25" center hole for shafts (UP)
  - 8" round (DH, HB) for garage or high bay



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Linear Engines

- Remote driver and heatsink required
  - PS12, 18, 50, 120, 150, etc.
- Wide range of power and CCT/CRI

- Bollards and small exterior luminaires such as step lights
  - HG, TW, TB Flagship building blocks
    - Skinny filament appearance "looks like" metal halide

- Wall Packs
  - WA, WB, WC
    - Designed for QSSI/Grandlite housings, split circuit
    - Designed for PS50 driver

- Linear Architectural and High/Low Bays
  - DQ, FE, SK, FQ, FP, FN, TL, TM, TN, TO
    - 0.5" and 0.75" wide, 11" through 23.5" long, 44" coming soon...

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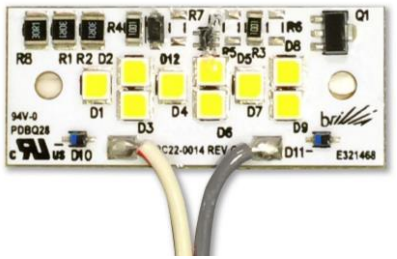
Unique Application Engines

- 2000K CCT Modules
  - Replaces HPS with same "warm" look
    - Cool white LED is "stark" and high glare
    - CRI 80 vs. 22
    - Solves issue "dude, where's my car?!"
  - Also great for decorative applications to simulate dimmed incandescent or candle color
  - Available on virtually all Permlight modules

- Thermadjust™ Modules (BA)
  - For exterior fixtures with limited heatsink
  - automatically dim if heatsink is insufficient "Air bags for LEDs" or "LEDs for dummies"
  - Constant Voltage 12VDC for easy driver sourcing and paralleling of multiple modules on one driver



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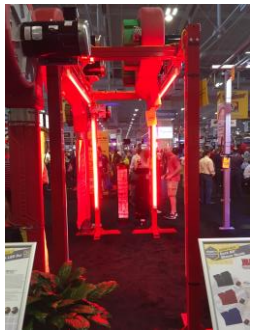
Monochromatic Engines

- Monochromatic colors available on most modules
  - Red 630nm, green 525nm, blue 470nm
  - LEDs can be mixed to create orange, purple, pink, etc.
  - Ideal for signs and specialty applications such as carwash
  - This is not RGB color changing, only fixed (single color)



- FWC turtle friendly amber available on some custom modules
  - Florida Wildlife Commission strict rules about intensity and wavelength under 600nm, no blue content, Nichia "amber" LED will fail test
  - Hawaii has similar rules, less than 2% blue content
  - Compared to white LED, 595 amber is 5x cost and 1/4 lumens but very long wavelength, example fog lights
  - For non-turtle friendly application, use 2000K which appears "amber"


- Horticultural for plant growth
  - High yield medicinal marijuana growth field proven with phosphor based LED mix SPD heavy red and blue to replicate HPS and MH

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Drivers, Power Supplies

- Stock of thousands of drivers, not just hundreds
- New driver design 8-16 weeks
- LED modules compatible with industry drivers if current/voltage ranges met
- Permlight can test other manufacturer's drivers for compatibility and warranty
- Dimming drivers are compatible with most dimmers and occupancy sensors
- No loss in LED or driver lifetime by repeated on/off cycling or dimming

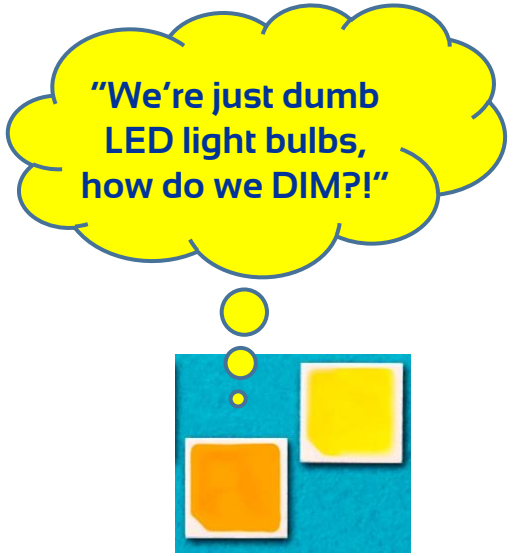
- Low voltage, constant current
  - PS7, PS11, 12VAC/DC, 7W, 125-700mA/10V, potted or un-potted landscape
  - PS13 Series, 12VAC only, 13W, 250-450mA/25V, frameless, optional leads

- Line voltage, constant current
  - PS3, 120VAC ELV dim, 4W, 310mA/8-12V, small white case
  - PS12, PS18, 120V triac dim and UNV non-dim, 12-18W, 350mA/35-50V, white case
  - PS50, 52W, UNV, 0-10V dim, 1050mA/25-50V, TL listed reduces luminaire test

- Line voltage, constant voltage
  - PS25, UNV input non-dim, 25W, 48VDC/520mA
  - PS98, UNV input, <1% dimming 0-10VDC, 98W, 24VDC/4.1A

Dimming LED Modules

- Technically… **LEDs don't do the dimming**, the **DRIVER** does
- Residential
  - Triac, incandescent dimmer, leading edge
    - PS12 is industry leader in dimming quality
- Commercial low power
  - ELV, electronic low voltage, trailing edge
    - PS3 has no known competitor
- Landscape or track low voltage
  - LVM, low voltage magnetic dimmer, on AC side of magnetic transformer
    - PS7 is industry leader in regulation over input voltage
    - PS13 is industry leader in size/power and smooth dimming
- Commercial high power
  - 0-10V or DALI dimming
    - PS50 is TL and industry leader in performance
    - PS98 is industry leader in 24VDC constant voltage <1% dimming



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Selecting Constant Current Drivers

Step 1: Determine which module is best for application

Step 2: Ask Permlight which driver(s) are best for module(s) and application

- **CRITICAL!** Driver **DC OUTPUT VOLTAGE RANGE** must match module voltage
  - Incorrect driver will strobe or worse… shorten driver life without visual indication!
  - Module datasheets don't always specify voltage range, consult factory
  - Driver datasheets can be misleading, no ratings over temperature and load

- Drivers specified by **DC OUTPUT WATTS**, not power consumption
- Driver **DC OUTPUT CURRENT** must be less than or equal to rating of module
- Multiple modules should be run in SERIES, not PARALLEL
  - LED voltage variance can cause current non-sharing and premature failure

- Generally, AC input or dimming on driver has no detrimental affect on module

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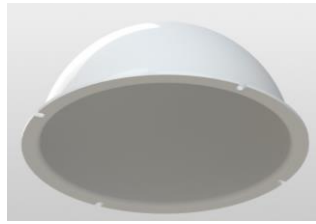
Optics

- Optics have dramatic effect on luminaire efficacy

- End users becoming increasingly concerned with reducing glare
  - Permlight optics can partially block, diffuse and/or spread LED intensity
  - Light transmission options from 50-90%
  - Available assistance with new designs

3" Dome

8" Dome



96" Linear
cut to length

- Some Permlight modules designed for use with off-the-shelf LEDIL optics
  - Designed for shaping and/or directing beam to achieve lighting targets
  - Available in wide flood, medium and narrow

Modules accepting
LEDIL optics

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Thermal and Handling

- Thermal recommendations
  - Heatsink must be in intimate contact (not a couple of screws) to outside air
  - Ideally, module should be mounted directly to fixture's aluminum housing
  - Recommend 8 sq. inches per watt of 16 gauge aluminum (0.060" thick)
  - Do NOT use thermal grease, can contaminate LED
  - Thin adhesive tape is better than mechanically attaching to heatsink (screws or rivets) that is not flat or has burrs
  - Air pockets have the worst thermal conductivity

- OEM handling recommendations that could void warranty
  - Don't touch or push down on LED or scratch top of PCB
  - Don't modify module, solder wires or cut wires close to PCB
  - Use torque values on datasheet and pan head screws if specified
    - Don't use flat head (cone shaped) screws, can cause short
  - For pre-taped modules, clean heatsink with alcohol only, no chemicals
  - Do not "hot swap": attach module to driver FIRST, THEN driver to AC

Miscellaneous FAQ

- What's the difference between constant voltage (CV) and constant current (CC)?
  - CV is best for long runs, illuminated sign or cove lighting, loses about 20% efficacy, completely scalable, multiple modules can be run in parallel
  - CC is best for a single fixture, highest efficacy, not always scalable, multiple modules can be run in series or share the current in parallel

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- Are your LED light engines wet listed?
  - OEM fixture must be wet listed, components do not have to be
  - Most drivers and modules are damp recognized
  - For exterior operation, a transparent conformal coating is used on modules to minimize corrosion in the event of moisture/condensation forming inside fixture. The material is high temperature, UV resistant, won't change color and doesn't trap heat of LED. It is not "waterproof", just "water resistant".
  - For landscape or submersed fixture, the engine can be encapsulated with a clear epoxy to be completely waterproof

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