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Introduction, ICE-R LED light engine

Introduction to this guide
Thank you for choosing the Licon ICE-R LED light engine system. In this guide you will find the information required to design the ICE-R into a luminaire.

Information and support
For technical support, visit www.dwlicon.com/support or call 1-408-213-6200.

Features and benefits
The ICE-R light engine module operates directly from nominal AC line input voltages of 120Vrms or 220Vrms at power levels of 5, 10, 15 and 20Watts. Three standard color temperatures are available, warm (3000K), neutral (4000K) and cool (5700K) at a color rendering index > 80. (Contact Licon for special CCT and CRI requests.) It has a diameter of 50mm and a height of 10.9mm. These dimensions provide ease of installation on numerous lamp and luminaire heat sinks without the need for separate power supply mounts. The ICE light engine module fully integrates the LED power driver, the LED array, the color temperature dome, and thermal heat sink mounting plate.

The ICE-R light engine is UL certified for use in either dry or damp locations.

Part Numbering Scheme
(Subject to change)
Example part number:
ICE120R24VF-5W-XX

<table>
<thead>
<tr>
<th>ICE</th>
<th>Voltage</th>
<th>R</th>
<th>LED Voltage</th>
<th>F – EMI type</th>
<th>S</th>
<th>W - power</th>
<th>XX</th>
<th>Color</th>
<th>color bin option</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>120Vrms</td>
<td>Regulated</td>
<td>24V or 46V</td>
<td>F=EMI filter</td>
<td>5 Watts</td>
<td>Warm</td>
<td>XX</td>
<td>color bin option</td>
<td></td>
</tr>
</tbody>
</table>
Technical Lighting Design
(This section is in process, refer to the product specification or contact Licon for further information.)

CRI values for each product in the matrix, optional diffusers, and guides on:
Color rendering values
Beam Performance
Diffusers
Reflectors

### Heat Sinks

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Description</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuventix</td>
<td>Universal Lighting Heat Sink</td>
<td>HP30S-CALBL-00</td>
</tr>
<tr>
<td>Nuventix</td>
<td>HEATSINK 60W SPOT CONFIG BLACK</td>
<td>NX300100</td>
</tr>
</tbody>
</table>

### Optical Clips

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Description</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>TE Connectivity AMP</td>
<td>Z50 Optic Clip Type 1</td>
<td>2213194-1</td>
</tr>
</tbody>
</table>

### Reflectors

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Description</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ledil</td>
<td>LED Lighting Reflector</td>
<td>G13379_Angela-S</td>
</tr>
</tbody>
</table>

### Thermal Adhesive

<table>
<thead>
<tr>
<th>Manufacturer(s)</th>
<th>Description</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M™</td>
<td>Thermally Conductive Adhesive Transfer Tape (TIM)</td>
<td>8805 or 8810</td>
</tr>
<tr>
<td>Laird Technologies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Bergquist Company</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Link to data sheet: [http://www.adafruit.com/datasheets/3m8810.PDF](http://www.adafruit.com/datasheets/3m8810.PDF)
Laird Technologies ([http://www.lairdtech.com](http://www.lairdtech.com))
The Bergquist Company ([www.bergquistcompany.com](http://www.bergquistcompany.com))
Mechanical Mounting
An enclosure shall be provided in the end use. The cover provided serves as an electrical enclosure and accessibility barrier.

Module dimension drawings

Mechanical attachment points
(Link to CAD files is in process.)

Mounting torque
(Section in process)
Torque or load required assuring adequate heat transfer to heat sink
Adhesive requirement when using adhesive TIM material.
Electrical Design

General
All ICE-R light engines are mounted on an electrically isolated anodized aluminum base plate. The primary function of the base plate is for thermal heat transfer, and not for electrical safety or electrical grounding use.

While the ICE-R meets certain electrical safety standards per the compliance section of this document, compliance of the final integrated product is the customer’s responsibility.

General information on wiring and grounding can be found below and in the following drawings. (In Process)

Voltage ranges
ICE-R will self regulate over a wide input voltage range, as follows.

ICE-120 has a 120Vrms nominal input voltage, and a guaranteed operating range of 100Vrms to 140Vrms.

ICE-220 has a 220V nominal input voltage, and a guaranteed operating range of 180Vrms to 240Vrms.

ICE-230 has a 230V nominal input voltage, and a guaranteed operating range of 180Vrms to 240Vrms.

Fuse protection
ICE-R have an internal 1.5Amp time delay fuse, rated to 250V.

Surge protection
ICE-R products have built in surge protection, utilizing Y type safety filter capacitors from line to ground, as well as a 350V, 600W TVS surge diode.

Inrush current
(Data being collected.)

Dimming compatibility
Unsuitable for Line-Voltage Dimming.

ICE-R LED engines are somewhat compatible with some triac type dimmers. Dimming results may vary based on the type, brand or model of dimmer. There is no provision for 0=10V, DALI, or DMX dimming.

Grounding
Grounding may or may not be required depending on the final product configuration. The green lead is ground path for EMI purposes. It does not provide ground to any other part of this construction.
and is considered an optional connection. Suitability of the supply leads to be determined in the end use.

**Electromagnetic interference filter options**
There are two EMI filter ordering options, filtered or unfiltered.

EMI Filtered option parts pass compliance per tests specified in the compliance section of this guide. If additional filtering is required, it may be possible to add external filters to the AC input wiring of the ICE-R in order to meet more stringent EMI criteria.

Unfiltered option products have no EMI filtering and have not been certified to pass any EMI compliance tests. This option is for customers who will be integrating ICE-R products along with custom designed external EMI filters.

**Thermal Management and Heat Sink Design**

**General**

All ICE-R light engines are mounted on an electrically isolated and thermally conductive anodized aluminum base plate. The ICE-R engine dissipates heat primarily through thermal conduction to an external heat sink of the user's choosing.

Proper heat sinking shall be provided in the end use. A properly specified heat sink is required to meet lifetime and luminance specifications. Good thermal connection to the heat sink is required, and a thermal pad or thermal grease is recommended. Heat sink manufacturers have numerous additional guides for the proper specification of both heat sink and thermal pad.

During temperature testing the following are the maximum limits:
- a) TC point on PCB - 90°C
- b) Plastic Case - 84°C
- c) Leads – as marked

The suitability of the thermal shut down feature has not been determined. The suitability of the mounting means is to be determined in the end use. The aluminum-mounting surface of this module shall be electrically insulated from the end product mounting surface.

**Thermal measurement points**

Product lifetime and luminance specifications require that the temperatures do not exceed those shown at the thermal test points. The critical point is under the LED, which must not exceed 70°C at the thermal interface point. To verify the temperature, a small hole or groove can be made in the heat sink such that a thermocouple can be inserted next to the ICR-R mounding plate.

The optional temperature test point on the outside of the ICE-R printed circuit board is for quick testing, not for heat transfer calculations. This optional test point will be about 50°C when the primary temperature test point is at 70°C.

Drawing with thermal points and max operating temperatures - (TBD)
Temperature v. performance

**ICE-R, 20Watt**

<table>
<thead>
<tr>
<th>LED main test point temperature, Deg C</th>
<th>Lumen output, relative</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>0.995</td>
</tr>
<tr>
<td>45</td>
<td>0.99</td>
</tr>
<tr>
<td>50</td>
<td>0.985</td>
</tr>
<tr>
<td>55</td>
<td>0.98</td>
</tr>
<tr>
<td>60</td>
<td>0.975</td>
</tr>
<tr>
<td>65</td>
<td>0.97</td>
</tr>
<tr>
<td>70</td>
<td>0.965</td>
</tr>
</tbody>
</table>

**Thermal interface materials (TIM)**

The function of a TIM is to reduce thermal impedance between the LED module and the heat sink. The thermal interface material replaces air, which is a thermal insulator, by filling the gaps with material that has better thermal conductivity.

The working principle of thermal interface material (TIM)
In general:
- Thermal paste performs better than thermal pads.
- The lower the thermal impedance the better.
- The thinner the TIM the better.

The following are suggestions for thermal interface material products that can be used with the ICE-R light engine.

- 3M 8805 and 8810 thermal pad adhesive bonding material recommended
- Laird Technologies (http://www.lairdtech.com)
- The Bergquist Company (www.bergquistcompany.com)

**Heat sink design guidelines**

Electrical and thermal analogy
Standard static thermal situations can be modeled using ‘thermal resistances’. These resistances behave like electrical resistances. The analogy between electrical and thermal resistances is explained in the figure below. The electrical units are shown on the left, while the thermal equivalents are given on the right.

With a known voltage difference at a certain current it is possible to calculate the electrical resistance using Ohm’s law. The same applies for a thermal resistance. If the temperature difference and the thermal power are known, the thermal resistance can be calculated using the thermal Ohm’s law.

![Electrical and thermal analogy diagram](image)

For example: we want to keep a 10Watt luminaire at the specified 70°C, in a 40°C environment.

\[ T = 70°C - 40°C = 30°C \]

**Maximum thermal resistance** \[ R_{th} = 30°C / 10Watts = 3° Deg C / Watt \]

A heat sink and thermal pad combination must have an \( R_{th} \) less than 3°C / Watt

\[ R_{th \ heat \ sink} + R_{th \ thermal \ pad} < 3°C / Watt \]

**Heat sink fin design notes**

Heat sink thermal resistance, as outlined in the previous section, is a function of fin area, fin spacing, heat sink width vs. length, and material emissivity. Briefly, the guidelines are covered below.
Emissivity
In the temperature range and conditions that ICE products operate, emissivity is contributing less than 25% to the thermal resistance of the heat sink. In general, black anodized Aluminum is the best choice. A very thin coating of black enamel over Aluminum is also good, however care must be taken to keep the enamel coating as thin as possible.

Fin Area and heat sink dimension consideration
First, consider the sketch below:

Source for reference design: [http://sound.westhost.com/heatsinks.htm - s3](http://sound.westhost.com/heatsinks.htm - s3)

Since the heat sink’s primary means of heat elimination is conduction to air from the airflow along the fins, the heat elimination will be less effective as the fin length is increased. As the length is increased, the air temperature on each fin is increased from inflow to outflow, which decreases the ability to conduct heat away from the fins. With this in mind, it is also clear that the fins need to be oriented reasonably vertical with no obstruction, so that air can flow into the bottom and out of the top.

Fin to fin spacing is also somewhat important. Too close of spacing allows heat to radiate from fin to fin, while reducing airflow at the same time. As a guideline, keeping fin spacing at a minimum of about 10% of the fin length will allow optimal conditions for ICE power and temperature ranges.

High altitude also reduces heat sink effectiveness, since the air is less dense. A 5000 Ft (1500m), the heat sink will be 90% as effective as a sea level.
A simple guideline for fin size

Keeping the above constraints in mind, a simple first order calculation of fin area can be used for ICE heat sinks:

Thermal resistance,  \( R_{th} := \frac{50}{\sqrt{\text{Fin area}}} \)

Where fin area is in cm\(^2\) (square centimeters) for Rth in Deg C/Watt

Solving for fin area, we can use

\[
\text{Fin area} := \left( \frac{50}{R_{th}} \right)^2
\]

Now, in our example of an ICE 10Watt module, we wanted a thermal resistance \( R_{th} = 3^\circ \text{C/W} \), so using the above formula for fin area, we get 278 cm\(^2\). Examples of calculations and performance measurements are shown in the “heat sink reference designs” section.

Heat sink reference designs

Using the calculation from the above example, we want a combined \( R_{th} \) of less than 3\(^\circ\)C/W. Using the Aavid heat sink estimator, we enter 3-inch length in to an example extrusion:

http://www.aavid.com/products/extrusion-heatsinks/6373

- **Height:** 2.25 in (57.15 mm)
- **Width:** 3.00 in (76.2 mm)
- **Weight:** 2.9 lb. per foot (4.32 kg per meter)
- **Perimeter:** 37.15 in
- **Material:** 6063-T5 Aluminum Extrusion Alloy

The Aavid on-line calculator shows that a 3" length of the above heat sink section will have a little better than 3\(^\circ\)C/W resistance, giving less than 30\(^\circ\)C rise at 10Watts. Combined with the \( R_{th} \) of the 3M 8805 pad at 0.5\(^\circ\)C / Watt, this heat sink and pad combination will meet the thermal design goal. With our simple formula of \( R_{th} = 50 / \sqrt{\text{Area}} \), the 3” section calculates to about 2.8\(^\circ\)C/W, which is pretty close to Aavid’s estimator at power input of 10 Watts.
From Digikey.com, another commercially available heat sink is Nuventix part number HP30S-CALBL-001, which is rated at 2.60°C / Watt at 10 Watts. Laboratory measurements were made using both a resistive heat source as well as an ICE light engine module. The results along with the comparison to theoretical temperature performance calculations are shown below.

**Resistive heat source calculations and measurements**

**Nuventix HP30S-CALBL-00**

**Calculations:**
Rth specification: 2.6°C / Watt at 10 Watts.
Fin area, as measured: 296 cm²
Simple calculation: Rth=50/√Area = 2.9°C/Watt
29°C estimated heat sink rise over ambient

**Lab measurements:**
10 Watts,
25°C ambient
  30°C heat sink rise over ambient
  3°C/Watt including TIM material
40°C ambient
  32.5°C rise over ambient
  3.25°C/Watt including TIM material

**Measurement method:**
The heat source was a flat-pack resistor bonded with 5mil thick 3M 8805 TIM in the center of the heat sink. Temperature rise was measured with a thermocouple placed underneath the resistor, as shown in the previous section“ location for primary temperature test point.”
ICE Light Engine measurements using Nuventix HP30S-CALBL-001

A 10 Watt ICE-R light engine part number ICE120R24VF-10N-XX was mounted using 3M 8805 TIM material to the Nuventix HP30S-CALBL-001 heat sink. A thermocouple was mounted at the primary thermal test point, under the metal backing plate, directly behind the LED array of the ICE light engine. The 3M TIM 8805 material was placed over the heatsink, holding the thermocouple to the aluminum backing plate. A groove was milled into the heatsink to allow the assembly to mount flush to the heat sink. Other thermocouples were mounted as shown, near the LED array and on the optional secondary temperature test point.

Results of ICE 10W thermal test:

<table>
<thead>
<tr>
<th>Temperature Readings</th>
<th>Locations</th>
<th>At 25°C ambient</th>
<th>Locations</th>
<th>At 40°C ambient</th>
</tr>
</thead>
<tbody>
<tr>
<td>59°C</td>
<td>LED top corner</td>
<td>LED top corner</td>
<td>71°C</td>
<td>LED top corner</td>
</tr>
<tr>
<td>54°C</td>
<td>Thermal interface</td>
<td>Thermal interface</td>
<td>65°C</td>
<td>Thermal interface</td>
</tr>
<tr>
<td>55°C</td>
<td>Thermal test point</td>
<td>Thermal test point</td>
<td>66°C</td>
<td>Thermal test point</td>
</tr>
<tr>
<td>3°C</td>
<td>Watt assembly thermal resistance</td>
<td>Watt assembly thermal resistance</td>
<td>3.1°C</td>
<td>Watt assembly thermal resistance</td>
</tr>
</tbody>
</table>

Thermal Reference Design Summary

A heat sink with a manufacturer’s nominal specification of 2.6°C/Watt kept the LED at the 70°C upper limit in a 40°C ambient environment, as our example reference design suggested. The thermal resistance as measured at 3°C/Watt to 3.25°C/Watt was within a few percent of the calculated measurements based upon the simple formula of $R_n = \frac{50}{\sqrt{\text{Area}}}$.
Heat sink thermal resistance and approximate fin area for ICE-R from 5~20 Watts

Total Thermal Resistance Reference Table

<table>
<thead>
<tr>
<th>ICE-R LED power</th>
<th>5 Watt</th>
<th>10 Watt</th>
<th>15 Watt</th>
<th>20 Watt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25°C</td>
<td>9.00</td>
<td>4.50</td>
<td>3.00</td>
<td>2.25</td>
</tr>
<tr>
<td>30°C</td>
<td>8.00</td>
<td>4.00</td>
<td>2.67</td>
<td>2.00</td>
</tr>
<tr>
<td>35°C</td>
<td>7.00</td>
<td>3.50</td>
<td>2.33</td>
<td>1.75</td>
</tr>
<tr>
<td>40°C</td>
<td>6.00</td>
<td>3.00</td>
<td>2.00</td>
<td>1.50</td>
</tr>
<tr>
<td>55°C</td>
<td>3.00</td>
<td>1.50</td>
<td>1.00</td>
<td>0.75</td>
</tr>
</tbody>
</table>

The above table gives the maximum allowable total thermal resistance, $R_{th \text{ heat sink}} + R_{th \text{ thermal pad}}$, in Deg. C / Watt for various LED power and ambient conditions. The results assume a 70°C max temperature at the primary temperature test point at the LED interface.

The chart below shows the simple estimated heat sink fin area in cm² for the thermal resistances shown in the above chart. These fin area estimates do not take all factors into account so they should be considered a starting reference point. These fin areas are for natural draft heat sink designs. If forced cooling is used the fin area can be greatly reduced.

For natural draft heat sinks (non-fan forced)

Approximate Fin Area in square centimeters at 25°C ambient

<table>
<thead>
<tr>
<th>ICE-R LED power</th>
<th>5 Watt</th>
<th>10 Watt</th>
<th>15 Watt</th>
<th>20 Watt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25°C</td>
<td>31</td>
<td>123</td>
<td>278</td>
<td>494</td>
</tr>
<tr>
<td>30°C</td>
<td>39</td>
<td>156</td>
<td>352</td>
<td>625</td>
</tr>
<tr>
<td>35°C</td>
<td>51</td>
<td>204</td>
<td>459</td>
<td>816</td>
</tr>
<tr>
<td>40°C</td>
<td>69</td>
<td>278</td>
<td>625</td>
<td>1111</td>
</tr>
<tr>
<td>55°C</td>
<td>278</td>
<td>1111</td>
<td>2500</td>
<td>4444</td>
</tr>
</tbody>
</table>

Compliance Information

General – UL File E464666, 2014-02-08

Compliance and approval marks: UL 8750, and CSA Standard for LED Equipment for Lighting Applications, C22.2 No 250.13.

Electromagnetic: FCC (TBA)

Environmental: Suitable for damp locations, up to 40°C ambient

Mechanical: Vibration and Shock (TBA)
Contact Information

Licon technical support
For technical support, visit www.dwlicon.com/support (Website under construction) or call 1-408-213-6200.