



NLC MINI recessed downlight seen from behind: one finned aluminium heatsink per LED module.

NLC Academy | Episode 20

You buy the lumens.
The metal decides how long you keep them.

Most of the power an LED draws leaves as heat, and that heat has exactly one way out: through the metal you bolted the LED to. This episode follows it from the junction to the outside air, and ends at the one number worth asking every supplier for.

The energy

Most of what you pay for **leaves as heat.**



■ Light output **over 40%**

- 1 Cree states white XLamp LEDs are over 40 percent efficient, with roughly 50 to 60 percent of input power leaving as heat. For SIZING a heatsink Cree recommends the conservative assumption: 25 percent light, 75 percent heat. [1]

■ Heat **50 to 60%**

- 2 Not all of it appears at the junction. Part of the heat is released in the phosphor by Stokes loss during down-conversion, so the package thermal path matters, not only cooling the die. [2]

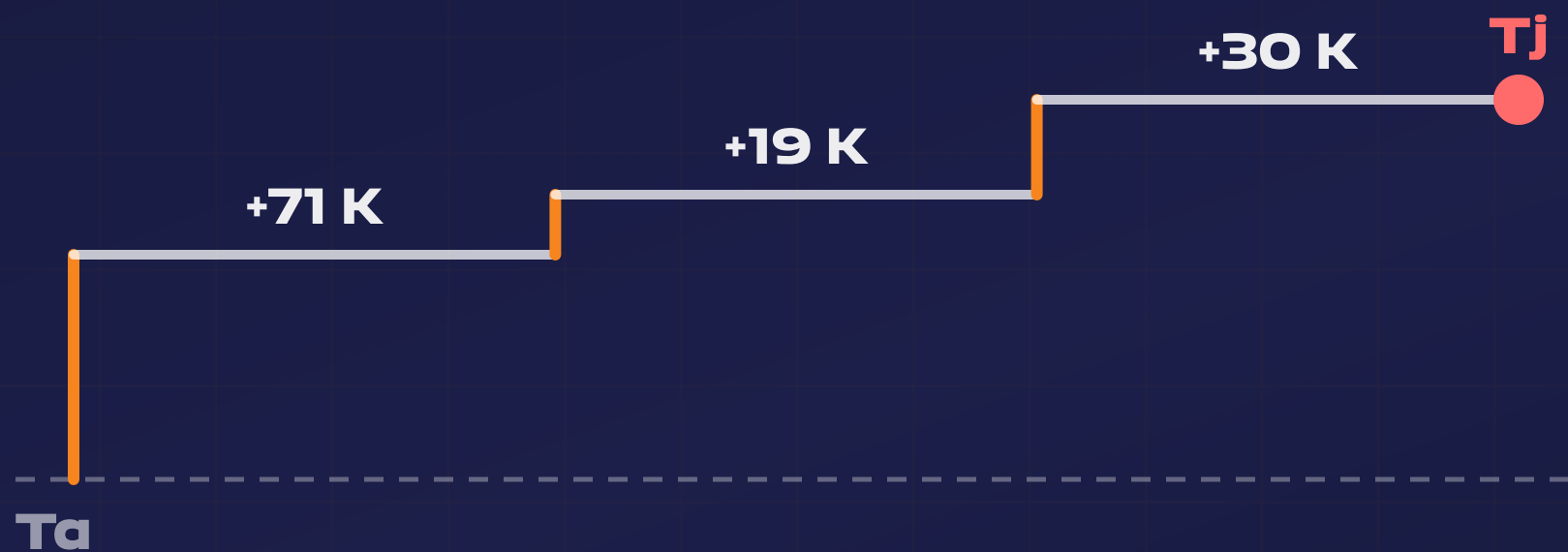
Radiant efficiency (optical watts out per electrical watt in) is not luminous efficacy in lm/W. Always quote the divisor: a 165 lm/W warm-white package (DOE 2020, 25 °C) is about 51 percent of the 323 lm/W LER of a typical 3000 K, 80 CRI phosphor-converted white, but about 40 percent of the 414 lm/W ceiling for an ideal colour-mixed white. [2]

The heatsink is not trim. **It is the only exit the heat has.**

The path

Junction to air: a chain of resistances.

i Illustrative chain, scaled from Cree's split



Heat sink to air

7.1 K/W

Board and attach

1.9 K/W

LED package

3.0 K/W

R_{th} , also written R_{θ} , is quoted per link. Add the links to get $R_{th\ j-a}$, then $T_j = T_a + R_{th\ j-a} \times P$. [4] The proportions follow Cree's XP-E star-board test on a metal-core board, board and heatsink measured, package from the datasheet: about 25 percent package, 16 percent board and attach, 59 percent heat sink. [3]

The junction does not run hot by nature. **It runs wherever the chain puts it.**

The metal

Not all aluminium conducts alike.

Copper C11000 ETP, reference		391
1100 sheet, O temper		222
6063 extruded, T6		201
6061 machined, T6		167
B390 die cast		134
A413 die cast		121
A360 die cast		113
A380 die cast		96

Typical values near room temperature, W/m·K. Kaiser [5] and CDA [23] state their data at 20 °C; the NADCA die-cast rows [6] are as-cast typical values with no test temperature printed. Conductivity depends on TEMPER as well as alloy, so every row names its condition. Across the aluminium rows the spread is about 2.3 times, not five.

The extruded fin conducts about **2.1 times what the die-cast shell does**. Same metal, different alloy.

The process

The shape you need **picks the alloy for you.**

Extrusion

Wrought 6xxx alloys



Typical alloy 6063-T6:
201 W/m·K

One constant cross-section pushed through a die. The alloy can stay lean, so conductivity stays high, and fins can run long. It cannot close its own ends: a sealed shell needs machining, end caps or another process. [5][24]

Pressure die casting

Silicon-rich casting alloys



Typical alloy A380: 96 W/m·K

Molten metal forced into a complex cavity. Thin sections fill best with the high-silicon alloys, and every alloying element (silicon, copper, zinc, iron) scatters the electrons that carry heat. You buy the shape and pay for it in W/m·K. [6][25][26]

A die-cast housing is not a cheaper heatsink. **It is a different engineering trade.**

The geometry

More fins is not more cooling.

 Computed for the assumptions below



Relative array dissipation vs fin spacing, mm. Shaded: the channels choke.

L = 150 mm

dT = 40 K

vertical

Bar-Cohen & Rohsenow [18]

- 1 Crowd the fins and the channels choke: boundary layers merge, the buoyant flow slows, and total dissipation falls even though total fin AREA went up. Lumileds puts the optimum at 6 to 10 mm of free space; below that the airflow is obstructed. [7][8]
- 2 Fin HEIGHT is capped by fin efficiency and a falling fin coefficient: beyond a point more fin adds nothing. [8] The payback is sublinear: Mehrtash and Tari's fin-array data scale as about $H^{0.68}$, so doubling height buys about 60 percent more, not 100. [9]

Publish a band, not a number: **6 to 10 mm for vertical channels 100 to 300 mm long, about 8 mm by default.**
 Unsure? Go wider: the penalty past the optimum is gentle.

The board

The board under the LED is part of the heatsink.



FR-4 with thermal vias

1.6 mm board, 14 plated vias, 4 oz copper

Board plus mounting interface, measured. Lower is better.

8.40 °C/W

Not automatically hopeless. In a separate TI study (TIDA030) a thin 0.84 mm FR-4 board was estimated at 3.76 °C/W against 4.23 °C/W for an IMS build with a thicker-than-needed dielectric. Different product and method, not this chart. [10]



Metal-core board (MCPCB)

Thin dielectric on an aluminium base

Board plus mounting interface, measured. Lower is better.

3.81 °C/W

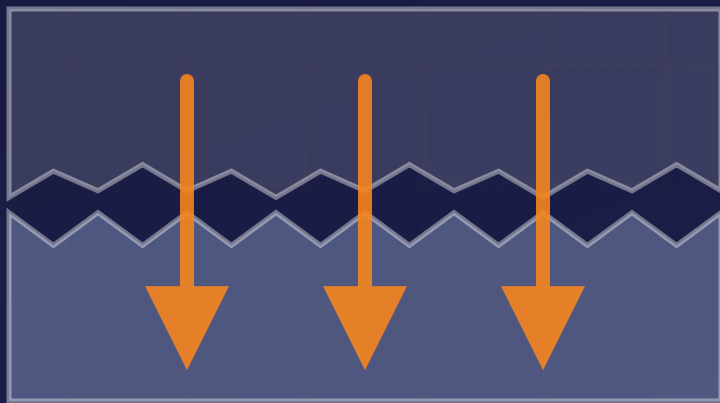
A thin filled dielectric over solid metal, and the hidden link: 76 μm at 0.58 °C·cm²/W against a 1.6 mm aluminium base: the dielectric alone is about five to seven times the resistance of the base. [11]

Bars: Cree's MEASURED board plus mounting-interface resistance, 1.6 mm FR-4, XP-E at 0.7 A. Lower is better; the metal-core board wins. Vias capped at 5 W per LED. [3]

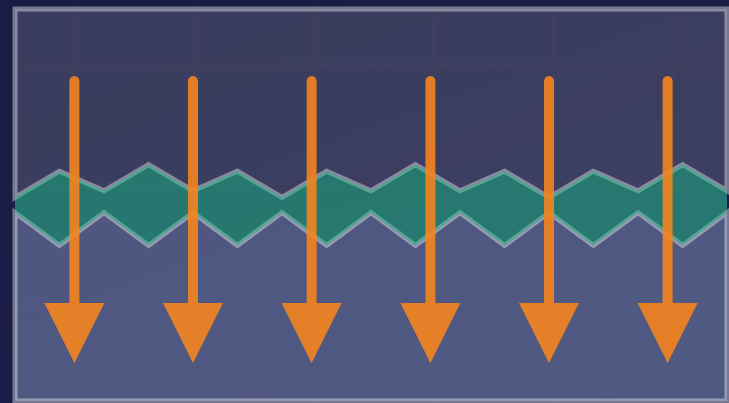
In natural convection the **heatsink still dominates: 31.8 of 39.1 °C/W** in TI's IMS build. Fix the biggest link first. [10]

The joint

Two flat faces are never flat.



Bare joint: air fills the gaps, heat squeezes through a few contact points



Filled joint: the TIM displaces the air, heat crosses the whole area

- 1 Two machined faces touch only at their high points; the rest of the nominal area is air. In one bench test a dry joint measured $2.9\text{ }^{\circ}\text{C}/\text{W}$ case to sink against $0.9\text{ }^{\circ}\text{C}/\text{W}$ with grease, taking the whole junction-to-ambient path up by 22 percent. [12]
- 2 Bulk $\text{W}/\text{m}\cdot\text{K}$ is the wrong criterion. A $5\text{ W}/\text{m}\cdot\text{K}$ elastomer clamped at low pressure measured twice the resistance of a grease because under inspection less than 30 percent of it actually touched. Specify resistance at a stated bond line and mounting pressure. [12][13]

A TIM figure with no AREA is meaningless. **Quote $^{\circ}\text{C}\cdot\text{cm}^2/\text{W}$, then divide by the real contact area.**

The finish

Radiation is not a rounding error.

Emissivity, 0 to 1

Bare

aluminium,
handbook

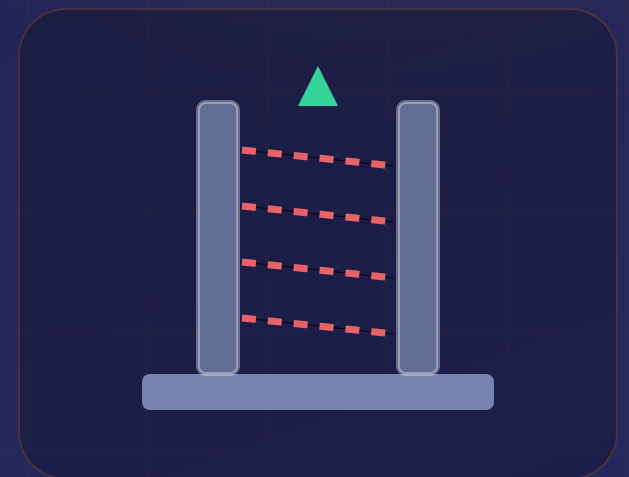


0.09

Anodised



0.85



1 A real sulfuric anodic film of normal thickness takes emissivity to about 0.83 to 0.86, and the oxide does it, not the dye: measured clear anodising radiates nearly as well as black, 0.76 to 0.84 against 0.82 to 0.86. [14][27][28]

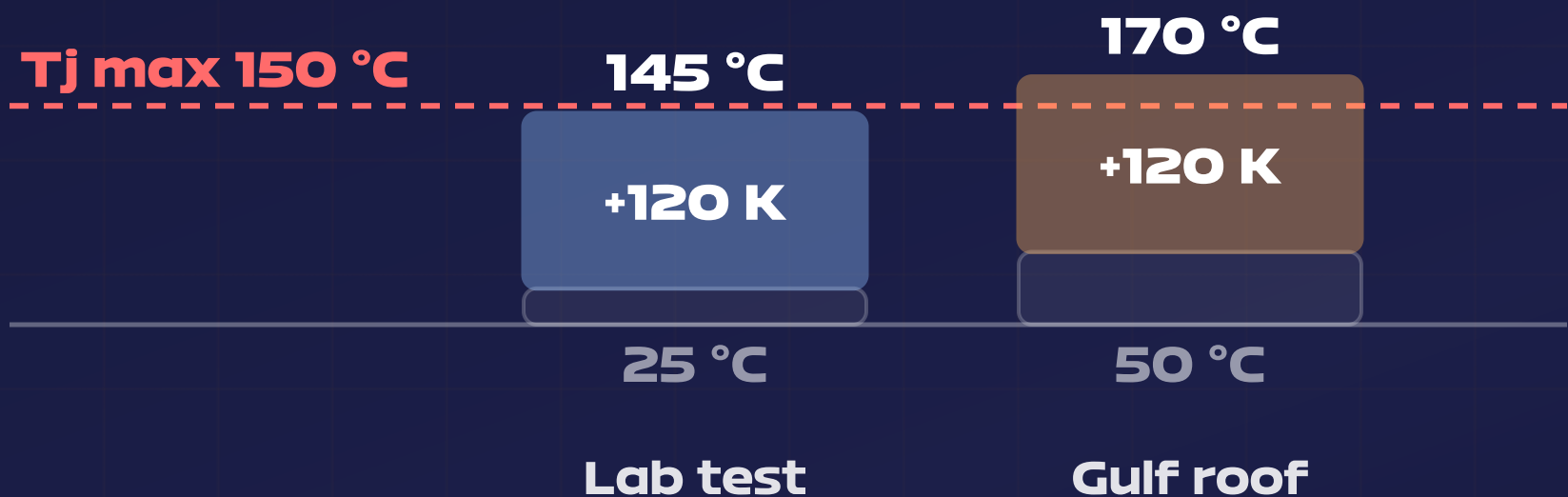
2 On a small natural-convection heatsink with an emissivity 0.85 finish, radiation carried 28 to 30 percent of the total across 5 to 25 W, and going bare cost close to 30 °C in that worked example. [15]

Bare aluminium is not one number: a fresh extrusion measured 0.02 in one study [14], handbooks put commercial sheet near 0.09 [15], highly polished is 0.04 to 0.06 [28]. And deep, closely spaced fins largely radiate at each other, so radiative output follows the channel view factor, not total fin area. [29][30]

Outdoors, specify a **high-emittance, light-coloured finish**: clear or light anodise, or a light powder coat. Never bare or mirror-polished, and a dark finish adds solar load. [16]

The ambient

Every thermal number **is quoted at an ambient.**



Environmental chamber: the fixture runs at rated current while the chamber holds a set ambient, which is how a maximum ambient is demonstrated rather than assumed.

Worked example, electrical-power convention: 10 W into a 12.0 K/W chain adds 120 K whatever the ambient; the 150 °C line is the Cree XLamp limit, mid-power emitters are often 125 °C.

Riyadh's ASHRAE 2025 design dry bulb (0.4 percent) is 45.0 °C and a fixture on a sunlit roof runs hotter than the air, hence the 50 °C column; 25 °C is the IEC 60598-1 default for unmarked luminaires, not a Gulf ambient. [17][19]

A fixture qualified at 25 °C **is not qualified for a Gulf roof.**

From the NLC range

Four housings, **four published ambients.**



CONTRAST

In-ground,
96 W (48×2 W)

+45 °C

Housing: Extruded
Aluminum + 316
Stainless Steel



CENTURY

Linear pendant,
36-54 W

-30 to +50 °C

Housing: Extruded
Aluminum



COMET

Street light,
50-300 W

-40 to +55 °C

Housing: Die-Cast
Aluminum



DIAMOND PRO

High bay,
100-240 W

-30 to +60 °C

Housing: Die-Cast
Aluminum

Housing and working-temperature rows from each NLC product page, housing wording normalised. IEC 60598-1 requires the ta mark only when ta is other than 25 °C, so a luminaire rated exactly 25 °C carries no ta marking at all, and a missing marking is not a missing rating. [19]

The published maximum ambient is **the fastest thermal question you can ask.**

Before you sign

Five questions that **keep the metal honest.**

- ☐ Ask for the **published maximum ambient** (t_a) and compare it with the real installed location. A missing t_a marking means 25°C , not "any ambient". [19][22]
- ☐ Ask for the **in-situ measured temperature** per ANSI/IES LM-98-24 at the hottest LED's measurement point, at rated current and your design ambient. Then the matching LM-80-21 report: flux and colour maintenance at set case temperatures, not the temperature reached in your luminaire. [20][21]
- ☐ Ask which **alloy and temper** the housing uses. [5] An eddy-current meter (%IACS, ASTM E1004) screens a casting without damage, read against the declared value with a hardness check. [31]
- ☐ Ask for the board's **thermal resistance**, and for the interface material's **resistance at a stated pressure and area**, never bulk $\text{W/m}\cdot\text{K}$ on its own. [10][13]
- ☐ Our practice: **avoid modifying the enclosure** where possible. If the test method requires an access hole, keep it minimal, reseal and document it; do not infer IP compliance from a modified sample.

The sources

Every number on these slides, sourced.

- [1] Cree, XLamp thermal management · [2] US DOE, 2022 SSL R&D ·
[3] Cree, XLamp PCB thermal
[4] JEDEC JESD51-14 · [5] Kaiser Aluminum, alloy data · [6] NADCA,
die-cast alloy data
[7] Lumileds WP31, heat sink design · [8] Bar-Cohen, Iyengar & Kraus
2003 · [9] Mehrtash & Tari 2013
[10] TI TIDA030, FR-4 vs IMS · [11] Bergquist MP-06503 TDS ·
[12] deSorgo 1996, TIM
[13] Blazej 2003, TIM · [14] Gustavsen & Berdahl ·
[15] HeatSinkCalculator, radiation
[16] LBNL cool roofs · [17] ASHRAE 2025, Riyadh KKIA · [18] Bar-Cohen &
Rohsenow 1984
[19] IEC 60598-1:2024 · [20] ANSI/IES LM-98-24 ·
[21] ANSI/IES LM-80-21 · [22] IEC 62722-2-1:2023
[23] CDA, C11000 · [24] AAC, Extrusions Manual · [25] Zhang 2022, Al-Si ·
[26] Luo 2022, Al-Si
[27] ATS Qpedia, anodising · [28] Design1st, emissivity table ·
[29] Lasance 2016
[30] Shabany 2008, fin radiation · [31] ASTM E1004-23, eddy current

Producer datasheets, standards and manufacturer-published measurements, each fetched and checked. Standards are cited in their current revisions. Full citations, URLs and access dates are on the episode page.

PRACTICAL LIGHTING ENGINEERING

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<https://nlc.com.sa/academy/metal-and-thermal-conductivity.html>



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