# Thermal Resistance Values for LED Lamps

## Application Brief I-002

### Change in T-1, T-1¾, and Rectangular Lamp Lead Frame Material

Avago Technologies has changed the metal in the lead frames for T-1, T-1¾, and rectangular LED lamp products from a copper-iron alloy to 5005 mild steel. This change was implemented to keep these LED lamp products an attractive, cost effective solution for front panel indicator, backlighting, and emitter applications. These mild steel lead frames are solder dipped, meeting the solderability requirements of Test Method 2026 per MIL-STD-750. Since the thermal conductivity of mild steel is less than that of copper, the LED junction-to-lead thermal resistance values, $R\theta_{J\text{-}PIN}$, are higher than the values shown for copper-iron alloy leads.

### The HLMP-6XXX/-PXXX Series Subminiature Lamp Lead Frame

The lead frame for the HLMP-6XXX/-PXXX series subminiature lamps has been redesigned to a cross-link configuration to provide enhanced reliability. This cross-link lead frame has a different thermal resistance than the older standard lead frame design. The copper-iron alloy metal for lead frame has not been changed. The lead frame surface finish was converted from silver plating to 85% Sn/15% Pb solder plate about mid year 1982, meeting the solderability requirements of Test Method 2026 per MIL-STD-750.

This application brief discusses these new thermal resistance values.

### Thermal Resistance Values

Table 1 lists the lamp thermal resistance values, $R\theta_{J\text{-}PIN}$, for T-1, T-1¾, rectangular, and sub-miniature LED lamps. These $R\theta_{J\text{-}PIN}$ values are independent of the LED chip technology used in the various lamp package configurations.

### Using The New Lead Frame $R\theta_{J\text{-}PIN}$ Values to Determine LED Chip Junction Temperature, $T_J$(LED)

There are two basic methods to determining LED junction temperature, $T_J$(LED). The first method assumes the cathode lead temperature (anode lead temperature for TS AlGaAs lamps), $T_{PIN}$, is known. The LED chip temperature rise is calculated using $R\theta_{J\text{-}PIN}$ and is added to this known cathode (or anode) pin temperature to determine $T_J$(LED). The second method requires knowing the LED lamp pin-to-ambient thermal resistance through the pc board mounting assembly, $R\theta_{PC\text{-}A}$. The LED lamp and pc board thermal resistances are added together to form the thermal resistance LED junction-to-ambient, $R\theta_{J\text{-}A}$. In this case, the LED junction temperature rise above ambient is calculated using the $R\theta_{J\text{-}A}$ value and then added to the ambient air temperature, $T_A$, to obtain $T_J$(LED).

**Table 1. $R\theta_{J\text{-}PIN}$ LED Junction-to-Lead Thermal Resistance Values for LED Lamps.**

| LED Lamp and Lead Frame | $R\theta_{J\text{-}PIN}$ |
|---|---|
| T-1 Lamp, Steel Lead Frame, 0.45 mm (0.018 in.) Square | 290° C/W |
| T-1¾ Lamp, Steel Lead Frame, 0.45 mm (0.018 in.) Square | 260° C/W |
| T-1¾ Lamp, Steel Lead Frame, 0.51 mm (0.020 in.) Square | 237° C/W |
| T-1¾ Lamp, Steel Lead Frame, 0.64 mm (0.025 in.) Square | 210° C/W |
| Rectangular Lamp, Steel Lead Frame, 0.45 mm (0.018 in.) Sq. | 260° C/W |
| Subminiature Lamp, Copper Alloy, Cross-Link Lead Frame | 170° C/W |

**Method 1, the LED lead temperature is known:** The cathode lead (or anode lead for TS AlGaAs) temperature, $T_{PIN}$, is carefully measured with a temperature probe. In a pc board assembly, the $T_{PIN}$ is measured at the lead-to-board solder connection, preferably on the component side of the pc board. For a lamp that is mounted to a front panel assembly by a clip and ring mount, $T_{PIN}$ is carefully measured at the base of the lamp package (plastic dome).

The temperature rise, $\Delta T_J$(°C), is calculated by first determining the power being dissipated in the LED junction and then multiplying the power by the $R\theta_{J\text{-}PIN}$ value. The LED power dissipation, P(LED), is determined from the forward drive current and associated voltage drop across the LED and the on-time duty factor. Finally, $\Delta T_J$ is added to $T_{PIN}$ to obtain $T_J$(LED).

See Example 1.

**Method 2, the thermal resistance LED junction-to-ambient, $R\theta_{PC\text{-}A}$, is known:** The thermal resistance-to-ambient air from the lead solder connection through the pc board on a per lamp basis, $R\theta_{PC\text{-}A}$, is known. The ambient air temperature, $T_A$, is measured in close proximity to the LED lamp and pc board with a temperature probe. The LED temperature rise above ambient is calculated as the product of the power dissipated in the LED junction, P(LED), multiplied by $R\theta_{PC\text{-}A}$ and then added to the ambient air temperature, $T_A$, to obtain $T_J$(LED).

**Note:** For double sided pc boards with plated through holes and 20 mil wide traces, the $R\theta_{PC\text{-}A}$ value usually ranges between 100° C/W and 400° C/W on a per component basis depending upon the density of the trace metalization.

See Example 2.

In both of the above examples, the LED junction temperature of 78° C is well below the maximum allowed LED junction temperature, $T_J$(LED)MAX = 110° C.

**Example 1**

Example: An HLMP-D101, T-1¾, DH AS AlGaAs red lamp with a 0.45 mm (0.018 in.) square steel lead frame:

$I_F$ = forward current drive = 20 mA.
$V_F$(20 mA) = associated voltage drop across the LED = 1.8 V.
DF = on-time duty factor, here assumed to be 100% (lamp is DC driven).
$R\theta_{J\text{-}PIN}$ = thermal resistance LED chip to cathode lead = 260° C/W.
$T_{PIN}$ = measured cathode lead temperature at the pc board solder connection = 68.6° C.

$T_J(LED)(°C) = \Delta T_J(°C) + T_{PIN}$

Where: $\Delta T_J(°C) = P(LED) \cdot R\theta_{J\text{-}PIN}$

$T_J(LED)(°C) = [I_F\,(A) \cdot V_F\,(V) \cdot DF] \cdot R\theta_{J\text{-}PIN}\,(°C/W) + T_{PIN}\,(°C)$

$T_J(LED)(°C) = [(0.020\,A) \cdot (1.8\,V) \cdot (1.00)] \cdot 260°C/W + 68.6°\,C$

$T_J(LED)(°C) = 9.4°\,C + 68.6°\,C = 78°\,C$

**Example 2**

Example: An HLMP-D101, T-1¾, DH AS AlGaAs red lamp with a 0.45 mm (0.018 in.) square steel lead frame:

$I_F$ = forward current drive = 20 mA.
$V_F$(20 mA) = associated voltage drop across the LED = 1.8 V.
DF = on-time duty factor, here assumed to be 100% (lamp is DC driven).
$R\theta_{J\text{-}PIN}$ = thermal resistance LED chip to cathode lead = 260° C/W.
$R\theta_{PC\text{-}A}$ = 240° C/W per LED lamp.
$T_A$ = ambient air temperature around LED lamp and pc board = 60° C.

$T_J(LED)(°C) = P(LED) \cdot R\theta_{J\text{-}PIN} + T_A$

Where: $R\theta_{J\text{-}A} = R\theta_{J\text{-}PIN} + R\theta_{PC\text{-}A} = 260°\,C/W + 240°\,C/W = 500°\,C/W$

$T_J(LED)(°C) = [I_F\,(A) \cdot V_F\,(V) \cdot DF] \cdot R\theta_{J\text{-}PIN}\,(°C/W) + T_A\,(°C)$

$T_J(LED)(°C) = [(0.020\,A) \cdot (1.8\,V) \cdot (1.00)] \cdot 500°\,C/W + 60°\,C$

$T_J(LED)(°C) = 18°\,C + 60°\,C = 78°\,C$



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