

Topic 2

LED Driver Case Temperature (Tc) vs Ambient Temperature (Ta) Analysis

This document explains the mathematical relationship between LED driver Case Temperature (Tc) and Ambient Temperature (Ta), incorporating the thermal resistance (Rθ) model and power loss formulas to illustrate risks in high-temperature industrial environments.

1. Fundamental Thermal Equations

Tc can be decomposed into the sum of ambient temperature Ta and two heating contributions:

$$T_c = T_a + \Delta T_{\text{enclosure}} + \Delta T_{\text{self-heat}}$$

Where:

- $\Delta T_{\text{enclosure}}$ = temperature rise due to enclosure/fixture effects (typically +10 ~ +25 °C / 18 ~ 45 °F)
- $\Delta T_{\text{self-heat}}$ = temperature rise due to the driver's own power dissipation

$\Delta T_{\text{self-heat}}$ can be estimated by:

$$\Delta T_{\text{self-heat}} = R_{\theta}(\text{case} \rightarrow \text{air}) \times P_{\text{loss}}$$

And power loss is given by:

$$P_{\text{loss}} \approx P_{\text{out}} \times (1/\eta - 1)$$

Where η is driver efficiency (90–96%), and P_{out} is the output power.

2. Example Calculations

Example 1: 100 W LED Driver, $\eta = 94\%$

$$P_{\text{loss}} \approx 100 \times (1/0.94 - 1) \approx 6.4 \text{ W}$$

$$R_{\theta} = 3 \text{ }^{\circ}\text{C/W}$$

$$\Delta T_{\text{enclosure}} = +15 \text{ }^{\circ}\text{C} (27 \text{ }^{\circ}\text{F})$$

$$T_a = 65 \text{ }^{\circ}\text{C} (149 \text{ }^{\circ}\text{F})$$

$$T_c = 65 + 15 + (3 \times 6.4) \approx 99 \text{ }^{\circ}\text{C} (210 \text{ }^{\circ}\text{F})$$

At this point Tc is near the upper limit of many drivers (85–105 °C / 185–221 °F).

Example 2: 200 W LED Driver, $\eta = 92\%$

$$P_{\text{loss}} \approx 200 \times (1/0.92 - 1) \approx 17.4 \text{ W}$$

$$R_{\theta} = 3 \text{ }^{\circ}\text{C/W}$$

$$\Delta T_{\text{enclosure}} = +20 \text{ }^{\circ}\text{C} (36 \text{ }^{\circ}\text{F})$$

$$T_a = 65 \text{ }^\circ\text{C} (149 \text{ }^\circ\text{F})$$

$$T_c = 65 + 20 + (3 \times 17.4) \approx 137 \text{ }^\circ\text{C} (279 \text{ }^\circ\text{F})$$

At this point T_c far exceeds $105 \text{ }^\circ\text{C}$, causing dramatic lifetime reduction and creating high failure and fire risk.

3. Lifetime and Arrhenius Law

The lifetime of electrolytic capacitors can be estimated using the Arrhenius law:

$$\text{Life}(T_c) \approx \text{Life}(T_{\text{ref}}) \times 2^{((T_{\text{ref}} - T_c) / 10)}$$

Assuming $T_{\text{ref}} = 55 \text{ }^\circ\text{C} (131 \text{ }^\circ\text{F})$ with $\text{Life} = 50,000 \text{ h}$:

$$T_c = 95 \text{ }^\circ\text{C} (203 \text{ }^\circ\text{F}) \rightarrow \text{Life} \approx 50,000 \div 2^4 \approx 3,100 \text{ h} (\sim 4 \text{ months})$$

This shows that when T_c reaches $90\text{--}100 \text{ }^\circ\text{C} (194\text{--}212 \text{ }^\circ\text{F})$, the driver's lifetime drops to only a few thousand hours.

4. Conclusion

- T_c is always higher than T_a , determined by $\Delta T_{\text{enclosure}}$ and $\Delta T_{\text{self-heat}}$.
- In high-temperature industrial environments with $T_a \geq 65 \text{ }^\circ\text{C} (149 \text{ }^\circ\text{F})$, T_c often exceeds $95\text{--}100 \text{ }^\circ\text{C} (203\text{--}212 \text{ }^\circ\text{F})$, leading to lifetimes of only a few thousand hours and increasing fire risk.
- Remote driver placement can reduce T_c but introduces issues of DC voltage drop, energy loss, higher installation costs, and safety concerns.
- The best solution is driverless solid-state architecture (e.g., ACCOB), capable of sustaining $T_c \geq 115\text{--}145 \text{ }^\circ\text{C} (239\text{--}293 \text{ }^\circ\text{F})$ for long-term reliable operation.



