Topic 3

LED Driver Tc–Ta Relationship in Junction Box Environments

In many industrial applications, LED drivers are often installed inside metal junction boxes to protect them from dust, moisture, and corrosive agents—especially in hazardous locations or explosion-proof areas. While this enclosure provides protection, it significantly restricts heat dissipation, causing the driver's Case Temperature (Tc) to rise far above the Ambient Temperature (Ta).

1. Definitions

• Ta (Ambient Temperature): The external environmental temperature at the installation site.
• Ta_in (Internal Air Temperature): The air temperature inside the junction box, typically higher than Ta due to restricted airflow.
• Tc (Case Temperature): The driver's case temperature measured at the designated Tc test point; always ≥ Ta_in.

2. Thermal Equations

In a junction box environment, Tc can be expressed as:

$$Tc = Ta + \Delta T_{box} + R\theta(case \rightarrow air) \times P_{loss}$$

Where:
• ΔT_{box} = additional heating caused by the sealed junction box enclosure, typically +10 ~ +25 °C (18 ~ 45 °F).
• $R\theta(case \rightarrow air)$ = thermal resistance from driver case to surrounding air (°C/W).
• $P_{loss} \approx P_{out} \times (1/\eta - 1)$, where η is driver efficiency (90–96%) and P_{out} is output power.

3. Example Calculations

Example A: 100 W Driver, η = 94%
$P_{loss} \approx 100 \times (1/0.94 - 1) \approx 6.4$ W
$R\theta$ = 3 °C/W
ΔT_{box} = +15 °C (27 °F)
Ta = 55 °C (131 °F)

$Tc = 55 + 15 + (3 \times 6.4) \approx 88$ °C (190 °F)
➞ Approaches typical driver Tc_max of 90–95 °C (194–203 °F).

Example B: 200 W Driver, η = 92%
$P_{loss} \approx 200 \times (1/0.92 - 1) \approx 17.4$ W
$R\theta$ = 3 °C/W
ΔT_{box} = +20 °C (36 °F)
Ta = 65 °C (149 °F)

Tc = 65 + 20 + (3 × 17.4) ≈ 130 °C (266 °F)
➞ Far exceeds 105 °C (221 °F), causing severe lifetime reduction and fire risk.

4. Lifetime and Arrhenius Law

The lifetime of electrolytic capacitors follows the Arrhenius empirical law:

Life(Tc) ≈ Life(Tref) × 2^((Tref - Tc) / 10)

If Tref = 55 °C (131 °F) with Life = 50,000 h:
Tc = 95 °C (203 °F) → Life ≈ 50,000 ÷ 2^4 ≈ 3,100 h (~4 months).

This shows that when Tc reaches 90–100 °C (194–212 °F), the driver lifetime drops to only a few thousand hours.

5. Safety Implications of Junction Box Enclosures

• The metal junction box effectively contains any flame, so even if the driver ignites internally, there is no direct open-flame hazard to the factory environment.
• However, internal short-circuits within the driver can still trigger surges and cascading failures in the factory's power distribution system, potentially damaging other equipment.
• In hazardous or explosion-proof areas, such faults may cause fuse trips, system-wide outages, and even disputes with insurance claims.

6. Conclusions and Recommendations

• In sealed junction box environments, Tc can exceed Ta by 20–40 °C (36–72 °F).
• At Ta ≥ 65 °C (149 °F), Tc almost always surpasses 100 °C (212 °F), far beyond typical driver design limits.
• Remote driver placement can mitigate Tc but introduces DC voltage drop, energy loss, and high installation cost.
• The most reliable solution is adopting driverless solid-state architecture (e.g., ACCOB), capable of sustaining Tc ≥ 115–145 °C (239–293 °F) for long-term stable operation, while avoiding system-wide risks caused by driver short-circuits.