DESCRIPTION

Lotus Thermal Guides (LTG) from Lotus Microsystems are thermally conductive yet electrically isolated, silicon-based thermal jumpers.

These devices are designed to guide heat away from hot electronic components, toward heat sinks or cooler areas (such as ground planes), without establishing an electrical connection.

LTGs significantly enhance thermal conductivity, particularly in scenarios with limited or no direct access to a ground plane or heat sink, such as high-side switches in a half-bridge configuration.

The silicon-based substrate used in LTG devices provides a cost-effective alternative to traditional ceramic materials, offering high thermal conductivity, excellent thermo-mechanical properties, and reliable processing. By improving thermal management, LTG devices help reduce component temperatures, supporting greater circuit reliability and a longer service life.

FEATURES

- High thermal conductivity, up to 140 W/(m K)
- High electrical isolation resistance
- Low parasitics
- High-precision standard package dimensions
- Low coefficient of thermal expansion (CTE)
- RoHS compliant

APPLICATIONS

- High-power LEDs
- PIN and laser diodes
- Power converters and amplifiers
- xPU and FPGA boards
- Semiconductor packages
- Optical transceivers

Abstract

This application note quantifies the thermal-management improvement achieved by integrating 26 LTG0402 thermal jumpers into an aluminium EVB with nine high-power LEDs, compared with an equivalent EVB without the LTGs. The evaluation follows three complementary experiments.

Experiment 1 establishes the relationship between $V_{\text{F,board}}$ and junction temperature, providing the calibration required to determine the LED junction temperature from the forward voltage.
Experiment 2 uses this relationship to compare LED junction heating after continuous operation at $I_{\text{F}} = 350\,\text{mA}$. The EVB with the LTGs shows a 6.03 °C lower junction temperature and a 26.4 % reduction in temperature rise compared with the EVB without the LTGs.
Experiment 3 uses thermal images to compare the maximum LED surface temperature at $I_{\text{F}} = 350\,\text{mA}$, 550 mA and 750 mA. The images show steady-state LED surface temperature reductions of 9.7 °C, 14.2 °C and 19.0 °C, respectively, for the EVB with LTGs.

The increasing improvement demonstrates that the benefit of the LTGs grows with thermal load. By lowering the LED junction and surface temperatures, the LTGs reduce thermal stress and can support optical stability, efficiency, reliability, and operating life.

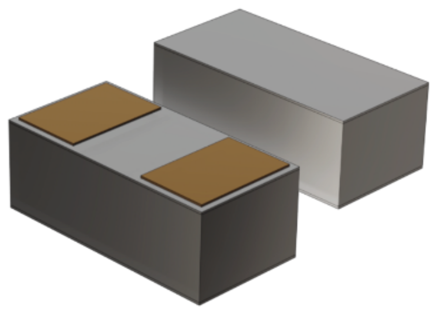


Figure 1: LTG package representation.

Contents

1 Application Description

High-power LEDs generate considerable heat during operation, causing the LED junction temperature to rise. If this heat is not dissipated effectively, the resulting elevated junction temperature can reduce luminous efficiency, accelerate ageing, alter optical characteristics, and shorten the LED operating life.

Thermal management becomes particularly challenging when space constraints, electrical isolation requirements, or the construction of the application limit the use of conventional heat-transfer solutions. In these situations, an additional localized thermal path can help transfer heat from the LED region toward a cooler area of the system.

LTG devices from Lotus Microsystems are thermally conductive yet electrically isolated, silicon-based thermal jumpers. By thermally coupling electrical nodes with limited local copper area to larger copper regions, LTGs can reduce thermal bottlenecks and improve heat spreading while maintaining electrical isolation between the regions.

The objective of this application note is to quantify the thermal-management improvement achieved by integrating 26 LTG0402 thermal jumpers into an aluminium evaluation board (EVB) with nine high-power LEDs, compared with an equivalent EVB without the LTGs.

2 Operating Principle

2.1 LED forward voltage as a junction-temperature indicator

The LED forward voltage, V_{F}, depends on both forward current (I_{F}) and its junction temperature, T_{j}. When I_{F} is held constant, V_{F} decreases as the LED junction temperature increases. This behavior originates from the temperature-dependent electrical properties of the semiconductor junction and allows V_{F} to be used as an LED junction temperature indicator. Real LEDs also exhibit series resistance and device-specific non-ideal behavior; consequently, the actual V_{F}-temperature coefficient must be established by measurement.

Over a limited temperature range and at a fixed I_{F}, the relationship can be approximated as in Equation 1, where $V_{\mathrm{F,ref}}$ is the LED V_{F} at the reference junction temperature $T_{\mathrm{j,ref}}$, and K_V is the V_{F}-temperature coefficient at the selected I_{F}. The coefficient is expected to be negative, but its value depends on the LED devices, selected I_{F}, and measurement conditions and must therefore be determined experimentally. An idealized representation of the V_{F}-T_{j} characteristic is shown in Figure 2.

$$V_{\mathrm{F}}(T_{\mathrm{j}}) \approx V_{\mathrm{F,ref}} + K_V \left(T_{\mathrm{j}} - T_{\mathrm{j,ref}}\right) \tag{1}$$

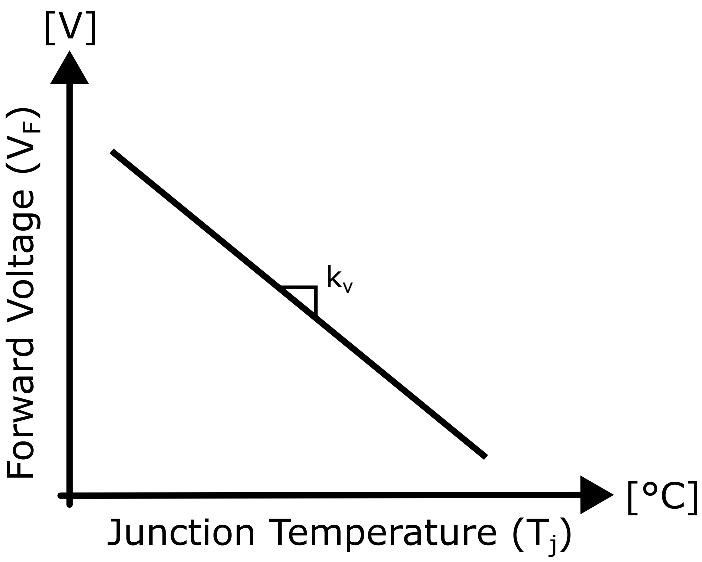


Figure 2: Idealized representation of the V_{F}-T_{j} curve at constant I_{F}.

2.2 Thermal characterization of the evaluation boards

The relationship between the board forward voltage ($V_{\text{F,board}}$) and LEDs junction temperature (T_{j}) is determined at a sufficiently low, constant I_{F} to minimize LED self-heating. By minimizing self-heating and allowing the board to reach thermal equilibrium in a temperature-controlled chamber, the LED junction temperature can be assumed to be approximately equal to the stabilized chamber temperature (T_{chamber}), as expressed in Equation 2:

$$T_{\text{j}} \approx T_{\text{chamber}}. \tag{2}$$

By measuring $V_{\text{F,board}}$ simultaneously at several stabilized ambient temperatures, a set of operating points is obtained from which the board-specific $V_{\text{F,board}}$-T_{j} characteristic can be constructed.

Since $V_{\text{F,board}}$ depends on both T_{j} and I_{F}, this characteristic is valid only at the I_{F} used during characterization and cannot be applied directly to $V_{\text{F,board}}$ obtained at higher I_{F}. It can, however, be used to estimate and compare junction temperatures when each EVB is evaluated at the characterization I_{F} using its own characteristic.

2.3 Expected thermal improvement with LTGs

Under the same test conditions, LTGs are expected to reduce the LED junction temperature. This reduction cannot be inferred from a direct comparison of $V_{\text{F,board}}$ between different EVBs because their reference values may differ. Instead, the $V_{\text{F,board}}$ obtained for each EVB at the common I_{F} must be converted using its board-specific characteristic.

The $V_{\text{F,board}}$-based estimate is complementary to thermal images. Thermal images show the temperature of the accessible LED surface and are influenced by emissivity, viewing geometry, and the thermal path between the junction and the LED surface. $V_{\text{F,board}}$, by contrast, originates from the nine LED junctions and is therefore sensitive to their junction temperature. It remains an indirect estimate and depends on a controlled I_{F}, a valid characterization, and controlled measurement timing.

3 Evaluation Method

Based on the principles described in Section 2, the evaluation is organized into three linked experiments.

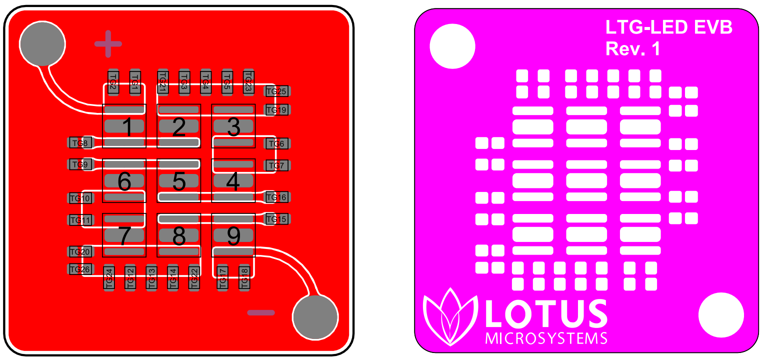
- Experiment 1 thermally characterizes both EVBs in a climate chamber to establish their board-specific $V_{\mathrm{F,board}}$-T_{j} relationships at a low sensing I_{F}.
- Experiment 2 operates each EVB at $I_{\mathrm{F}} = 350$ mA, returns it rapidly to the sensing I_{F}, and measures $V_{\mathrm{F,board}}$ to estimate the post-transition LED junction temperature.
- Experiment 3 uses thermal images to compare the maximum LED surface temperature at $I_{\mathrm{F}} =$ 350 mA, 550 mA and 750 mA.

The same board mounting and controlled ambient conditions are used for the paired comparisons. The $V_{\mathrm{F,board}}$-based estimates and the measurements extracted from thermal images are reported separately because they describe different thermal quantities: the former estimates LED junction temperature after the I_{F} transition, whereas the latter measures the maximum accessible LED surface temperature during operation at high I_{F}.

3.1 Evaluation Board

The designed EVB is a 16 mm × 16 mm single-layer aluminium PCB with a thermal conductivity of 8 W/(m K).

The assembly, top-copper and solder-paste layers are shown in Figure 3a and the solder-mask layer is shown in Figure 3b.



(a) Top copper layer. (b) Solder-mask layer.

Figure 3: Layers of the designed EVB.

Two EVB configurations are used: with and without LTGs. Both EVBs contain nine L1C1-AMB1000000000 LEDs connected in series. The EVB with LTGs contains 26 LTG0402 devices that thermally connect the electrical nodes of the LEDs to a larger copper plane used to spread and dissipate heat. As shown in Figure 4, the LTG footprints remain unpopulated on the EVB without LTGs, while the 26 LTG0402 are assembled around the LEDs on the EVB with the LTGs.

(a) EVB without LTGs. (b) EVB with LTGs.

Figure 4: Nine-LED EVBs used for the comparative thermal measurements.

Consequently, $V_{\mathrm{F,board}}$, measured at the EVB terminals, is the sum of the individual LED V_{F} values, as expressed in Equation 3.

$$V_{\mathrm{F,board}} = \sum_{n=1}^{9} V_{\mathrm{F},n} \tag{3}$$

The measured temperature coefficient is likewise the combined response of all nine LEDs. The resulting characterization therefore represents the electrical and thermal response of the complete set of LEDs rather than that of one individual device.

However, because the LEDs are connected in series and carry the same I_{F}, the average V_{F} and temperature coefficient per LED can be estimated by dividing the board-level values by nine, as expressed in Equation 4.

$$V_{\mathrm{F,avg}} = \frac{V_{\mathrm{F,board}}}{9} \qquad K_{V,\mathrm{avg}} = \frac{K_{V,\mathrm{board}}}{9} \tag{4}$$

These values represent averages across the nine LEDs and do not account for device-to-device variation.

3.2 Experimental procedure

The procedure comprises thermal characterization of the two EVBs, an electrical junction-temperature assessment at $I_{\mathrm{F}} =$ 350 mA, and an LED surface temperature assessment using thermal images at three increasingly demanding operating points. Experiment 1 establishes the required board-specific characteristics; Experiments 2 and 3 then apply two complementary methods to compare the EVBs with and without LTGs.

3.2.1 Experiment 1: Thermal characterization of the evaluation boards

The EVBs with and without LTGs are characterized separately using the same temperature profile. A BINDER MKF 115 climate chamber controls the ambient temperature, while a Source Measure Unit (SMU) Aim-TTi SMU4201 applies a constant I_{F} and simultaneously measures $V_{\mathrm{F,board}}$.

For each temperature step, the chamber temperature is polled every 5 s. A setpoint is considered stable only after the measured chamber temperature has remained within $\pm$0.1 °C of the target for 30 s continuously. The SMU is enabled after the first temperature step has stabilized and remains enabled throughout the subsequent steps. During a 10 min soak period at each temperature, the measured chamber temperature and $V_{\mathrm{F,board}}$ are recorded simultaneously every 10 s.

Table 1 summarizes the operating and acquisition conditions for the characterization.

Table 1: Operating and acquisition conditions for the thermal characterization of the evaluation boards.

Parameter	Symbol	Value	Definition
Applied I_{F}	I_{F}	20 mA	Constant I_{F}
Voltage limit	V_{limit}	24 V	SMU voltage limit
Temperature setpoints	$T_{\mathrm{ch,set}}$	25 °C, 40 °C, 50 °C, 60 °C, 70 °C, 80 °C and 90 °C	Programmed chamber-temperature setpoint sequence
Stability criterion	$\Delta T_{\mathrm{tol}},\ t_{\mathrm{stable}}$	$\pm$0.1 °C, 30 s	Temperature must remain within tolerance continuously
Soak duration	t_{soak}	10 min	Applied at each temperature step after stabilization
Acquisition interval	Δt_{acq}	10 s	Synchronous acquisition during the soak period
Recorded quantities	$T_{\mathrm{chamber}},\ V_{\mathrm{F,board}}$	–	Chamber temperature and $V_{\mathrm{F,board}}$

For the characterization, one representative point is calculated from the final ten samples of every complete soak period. A linear least-squares fit is then applied over the common 25 °C to 90 °C range.

Because $V_{\text{F,board}}$ depends on I_{F}, the obtained characteristics cannot be applied directly to $V_{\text{F,board}}$ obtained at a higher I_{F}. They can, however, be applied after returning the EVB to the same sensing I_{F} used during Experiment 1.

3.2.2 Experiment 2: LED junction temperature from the thermal characterization

In Experiment 2, the EVB-specific $V_{\text{F,board}}$-T_{j} characteristics obtained in Experiment 1 are used to estimate the LED junction temperature. Each EVB is first stabilized at $I_{\text{F}} = 20$ mA to establish its baseline $V_{\text{F,board}}$ ($V_{\text{F,board,base}}$) and baseline temperature (T_{base}). Subsequently, the EVB is operated at a higher I_{F} and returned directly to $I_{\text{F}} = 20$ mA. $V_{\text{F,board}}$ is then measured as quickly as the instrumentation allows.

For each EVB, the baseline-referenced junction temperature is calculated using its own measured temperature coefficient, as expressed in Equation 5:

$$T_{\text{j}}(t) = T_{\text{base}} + \frac{V_{\text{F,board,base}} - V_{\text{F,board}}(t)}{|K_{V,\text{board}}|}. \tag{5}$$

Because the I_{F} transition and $V_{\text{F,board}}$ acquisition are not instantaneous, some cooling occurs before the first $V_{\text{F,board}}$ measurement. The result is therefore a post-transition estimate of T_{j}, rather than the exact junction temperature at the end of the heating interval.

Table 2 summarizes the operating and acquisition conditions used for this assessment.

Table 2: Operating and acquisition conditions for the electrical junction-temperature assessment.

Parameter	Symbol	Value	Definition
Chamber setpoint	$T_{\text{ch,set}}$	25 °C	Controlled ambient condition
Sensing I_{F}	$I_{\text{F,sense}}$	20 mA	Baseline and post-heating I_{F}
Heating I_{F}	$I_{\text{F,heat}}$	350 mA	Constant I_{F} during heating
Voltage limit	V_{limit}	24 V	SMU voltage limit
Heating duration	t_{heat}	25 min	Time at the heating I_{F}
Rapid samples	N_{rapid}	100	Post-transition $V_{\text{F,board}}$ measurements
Nominal interval	Δt_{rapid}	50 ms	Target spacing between rapid measurements

3.2.3 Experiment 3: LED surface temperature from thermal images

Thermal images acquired in Experiment 3 provide independent evidence that reinforces the thermal advantage identified by the junction-temperature measurements in Experiment 2. They also extend the assessment to progressively higher I_{F} and thermal loads. At every operating point, the EVBs with and without LTGs are tested under the same electrical, ambient, mounting, and measurement conditions. Thermal-image acquisition position, measurement geometry, and board mounting remain unchanged between each paired comparison.

Table 3 presents the three operating points assessed during Experiment 3.

Table 3: Operating points for Experiment 3.

Operating point	EVBs compared	I_{F} (mA)	Chamber setpoint (°C)	Emissivity ε	Duration (min)
1	With / without LTGs	350	25	0.95	25
2	With / without LTGs	550	25	0.95	25
3	With / without LTGs	750	25	0.95	25

Experiment 2 provides a junction-sensitive comparison at $I_\mathsf{F} = 350\,\mathrm{mA}$. The LED surface temperature extracted from the thermal images complements that result and extends the assessment to $I_\mathsf{F} = 550\,\mathrm{mA}$ and 750 mA.

For steady-state analysis, the data processing applies a 60 s moving average to each curve. A curve is considered stable from the earliest time at which this moving average varies by no more than 1.0 °C in every complete 5 min window through the end of the test. Two EVBs (with and without LTGs) are tested at the same time, and it is considered that the steady state is reached when both curves satisfy the explained criterion.

The *steady-state temperature difference* is the mean absolute difference between the paired curves from this time through the final sample. Each point in a curve is the maximum LED surface temperature measured at that sampling time. The *complete-test average* for one EVB is the arithmetic average of all 148 points in its curve. The *maximum temperature difference* is the largest absolute difference between the paired curves at a common sampling time.

4 Experimental Results

4.1 Experiment 1: Thermal characterization of the evaluation boards

Figure 5 presents the characterization of the LEDs on both EVBs at low I_F. Both configurations show the expected approximately linear reduction in $V_{F,board}$ as the controlled temperature increases.

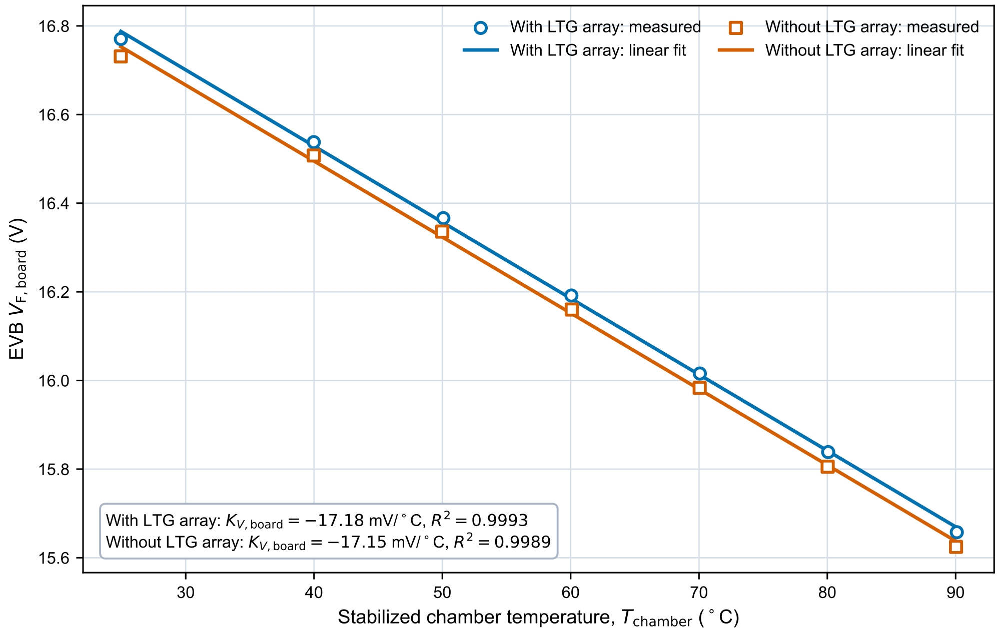


Figure 5: Measured $V_{F,board}$-T_j characteristics of the LEDs on both EVBs at $I_F = 20$ mA. Each point represents the final ten samples of a complete soak period.

Table 4: Measured LED characterization results for both EVBs over 25 °C to 90 °C.

EVB configuration	$K_{V,board}$ (mV °C^{-1})	$K_{V,avg}$ (mV °C^{-1})	R^2	Setpoints
With LTGs	-17.18	-1.909	0.9993	7
Without LTGs	-17.15	-1.905	0.9989	7

The board-level coefficients differ by only 0.04 mV °C^{-1}, approximately 0.2 % of their mean magnitude. The approximately 30 mV to 33 mV $V_{F,board}$ offset observed between the EVBs from 40 °C to 90 °C is attributed to LED device-to-device electrical variation. This close agreement confirms that the LTGs do not produce a meaningful change in the electrical temperature coefficient of the board. However, absolute $V_{F,board}$ values from the two EVBs cannot be compared directly; each EVB requires its own characteristic.

The obtained characteristics and their inverse forms are given in Equations 6 and 7:

$$V_{F,board}^{\text{with LTGs}} = 17.2163\,\text{V} - 0.01718\,\text{V}\,°\text{C}^{-1} T_j, \qquad T_j^{\text{with LTGs}} \approx \frac{17.2163\,\text{V} - V_{F,board}}{0.01718\,\text{V}\,°\text{C}^{-1}} \quad (6)$$

$$V_{F,board}^{\text{without LTGs}} = 17.1810\,\text{V} - 0.01715\,\text{V}\,°\text{C}^{-1} T_j, \qquad T_j^{\text{without LTGs}} \approx \frac{17.1810\,\text{V} - V_{F,board}}{0.01715\,\text{V}\,°\text{C}^{-1}} \quad (7)$$

4.2 Experiment 2: LED junction temperature from the thermal characterization

Table 5 summarizes the baseline temperatures, first post-transition junction temperatures, and corresponding temperature rises for both EVBs. Before the transition to the sensing I_F, both EVBs had stabilized: during the final 5 min of heating, the $V_{F,board}$ spans were 2.7 mV without LTGs and 2.6 mV with them. The first valid $V_{F,board}$ measurements were acquired after 60 ms.

Table 5: First post-transition junction-temperature results after 25 min at $I_F = 350$ mA.

EVB configuration	T_{base} (°C)	First T_j (°C)	$T_j - T_{base}$ (°C)
Without LTGs	25.05	47.67	22.62
With LTGs	25.01	41.65	16.64

At the first available measurement, the EVB with LTGs is 6.03 °C cooler than the EVB without them. Relative to each EVB's pre-heating baseline, the measured temperature rise is reduced by 5.98 °C, or 26.4 %. These values are based on Equations 6 and 7; they do not depend on comparing the absolute $V_{F,board}$ values of the two EVBs.

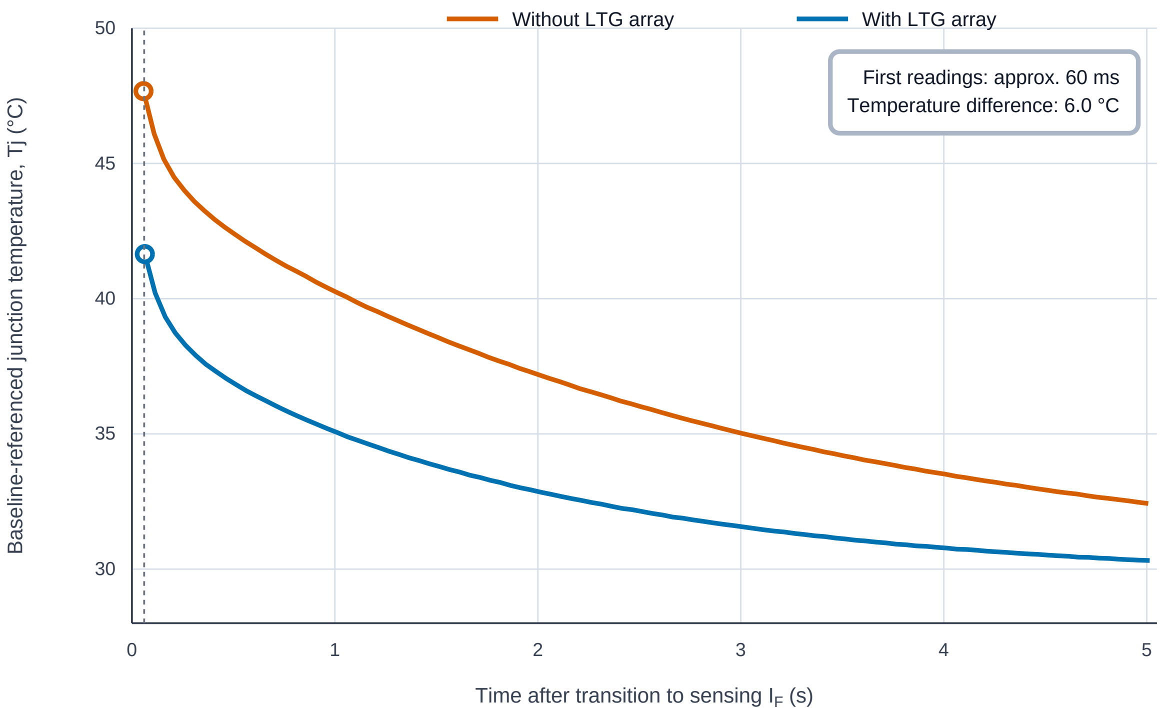


Figure 6: LED junction temperature during the first 5 s after the transition from $I_F = 350$ mA to $I_F = 20$ mA.

Figure 6 shows that the EVB without LTGs remains hotter. The temperature separation decreases from 6.03 °C at the first reading to approximately 2.1 °C after 5 s as both EVBs approach the controlled ambient temperature. Because some cooling occurs before the first $V_{F,board}$ measurement, the reported values should not be interpreted as the exact junction temperatures immediately before the I_F transition.

4.3 Experiment 3: LED surface temperature from thermal images

The maximum LED surface temperature curves extracted from the thermal images are presented below. All measurements in Experiment 3 were performed inside the climate chamber at a controlled ambient temperature of 25 °C. Table 6 summarizes the main results.

Table 6: Summary of measured thermal performance.

I_F (mA)	Complete-test average without LTGs (°C)	Complete-test average with LTGs (°C)	Maximum ΔT (°C)	Steady-state ΔT (°C)	Stable from (min)
350	57.2	47.3	11.3	9.7	8.0
550	75.3	60.8	16.5	14.2	9.3
750	94.4	74.9	22.2	19.0	15.5

4.3.1 Operating point 1: $I_F = 350$ mA

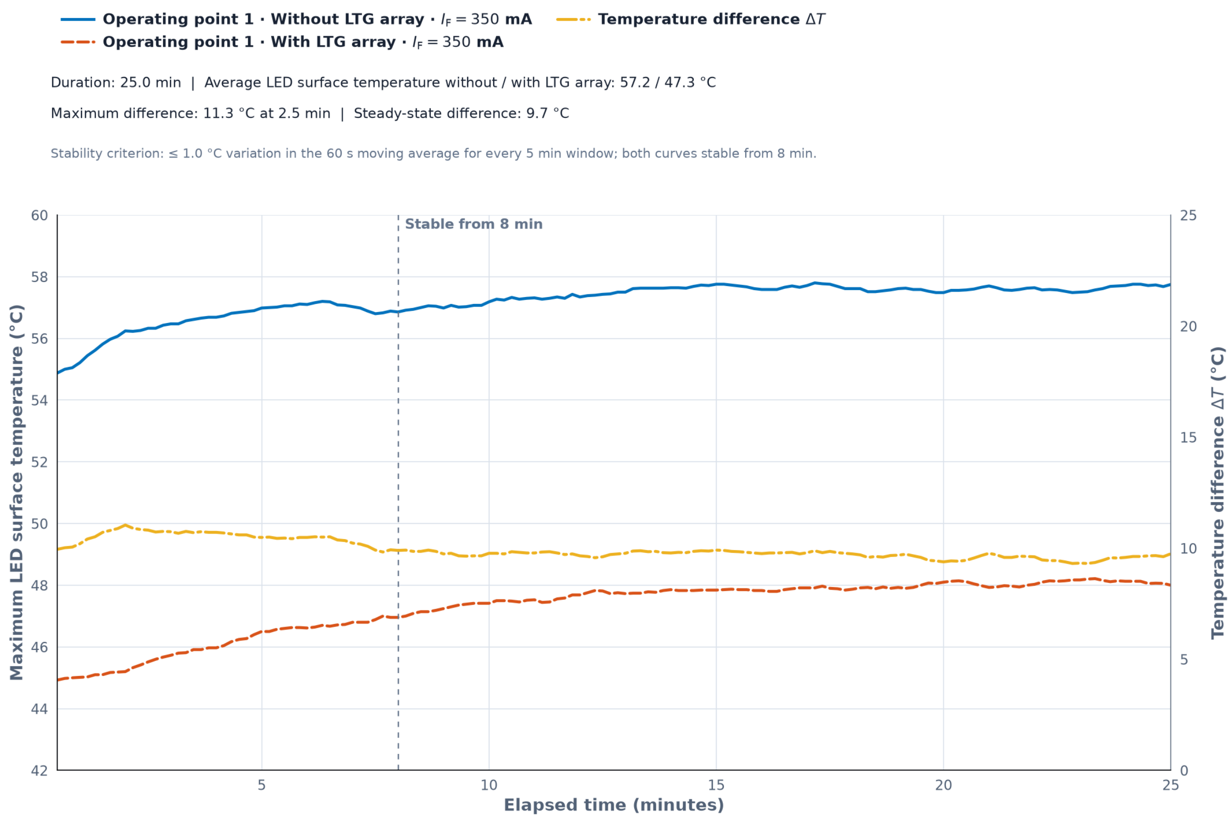


Figure 7: Maximum LED surface temperature with and without LTGs at $I_F = 350$ mA.

It can be seen in Figure 7 that the temperature separation is present since the initial transient and is maintained as both EVBs approach steady state. At the final sample, the maximum LED surface temperature is 57.4 °C without the LTGs and 47.7 °C with the LTGs. The paired response is stable from 8.0 min; the steady-state temperature difference is 9.7 °C, close to the separation observed at the end of the test. The maximum difference is 11.3 °C at 2.5 min.

4.3.2 Operating point 2: $I_F = 550\,\text{mA}$

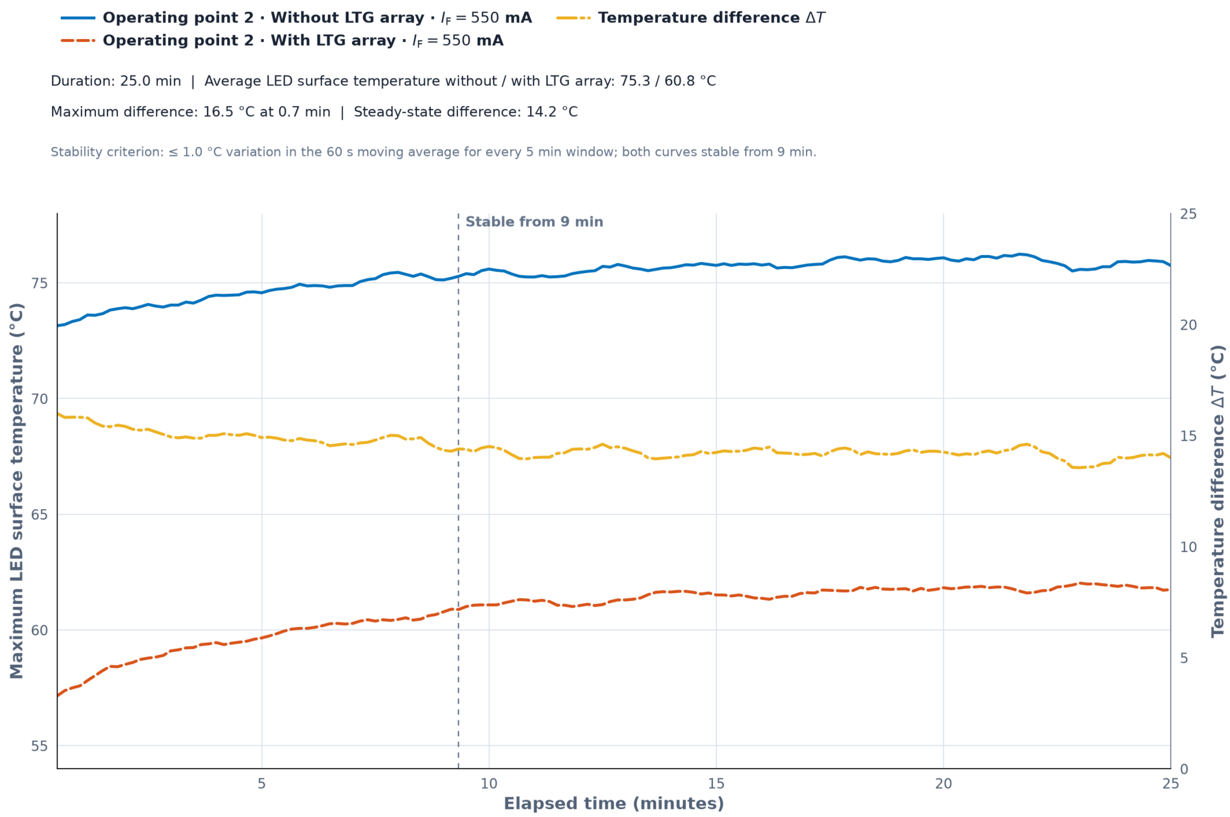


Figure 8: Maximum LED surface temperature with and without LTGs at $I_F = 550\,\text{mA}$.

Higher I_F values increase not only the LED surface temperature but also the temperature difference between the configurations with and without the LTGs. This demonstrates that the thermal benefit of incorporating LTGs becomes more pronounced at higher power levels. The EVB without LTGs rises rapidly to a higher temperature, while the EVB with the LTGs remains cooler throughout the operating point. The final maximum LED surface temperature is 75.7 °C without the LTGs and 62.2 °C with them. The paired response is stable from 9.3 min. The steady-state temperature difference is 14.2 °C, and the maximum difference is 16.5 °C at 0.7 min.

4.3.3 Operating point 3: $I_F = 750\,\text{mA}$

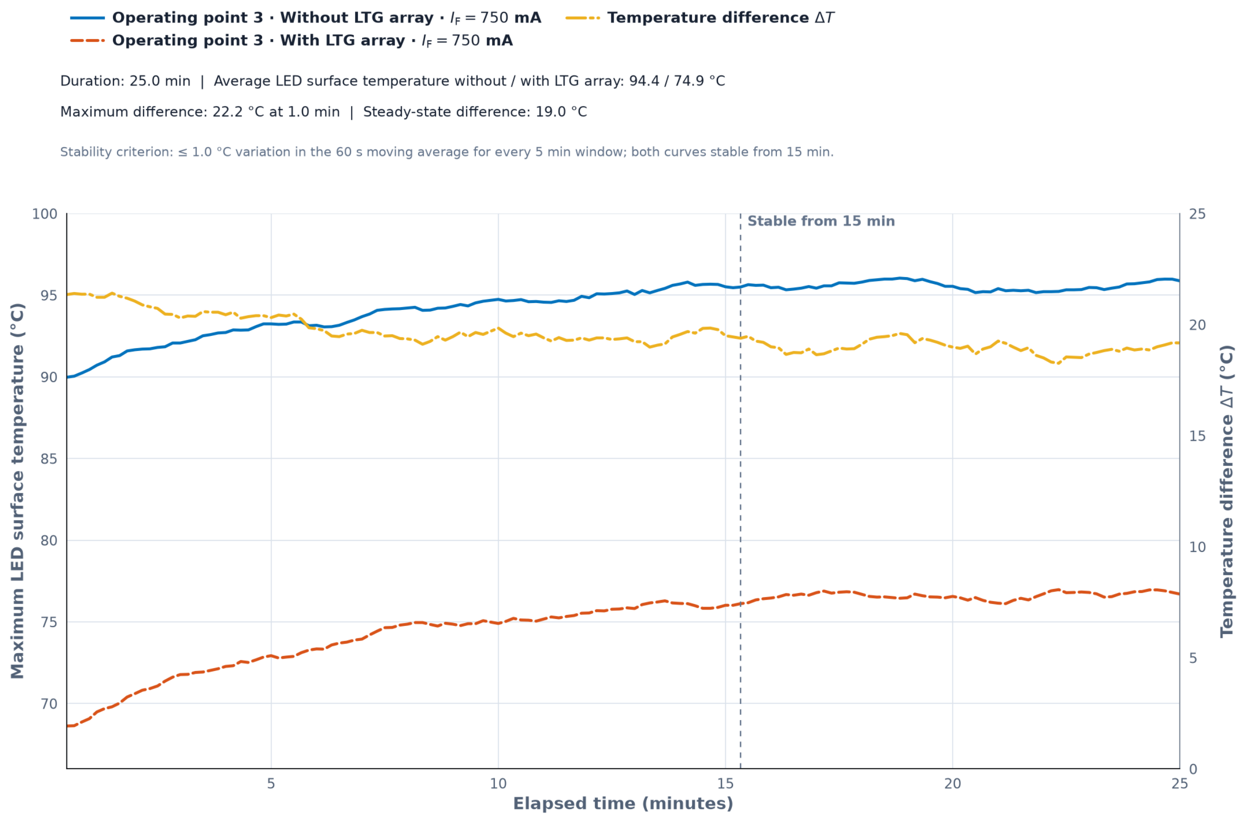


Figure 9: Maximum LED surface temperature with and without LTGs at $I_F = 750\,\text{mA}$.

Operating point 3 produces not only the highest LED surface temperature but also the largest temperature difference between the two configurations, confirming that the thermal benefit of having LTGs becomes more pronounced at higher power levels. The EVB without the LTGs approaches 96 °C, whereas the EVB with LTGs remains near 76 °C. At the final sample, the maximum LED surface temperature is 96.2 °C without LTGs and 76.1 °C with them. The paired response is stable from 15.5 min, reflecting the longer thermal transient at this operating point. The steady-state temperature difference remains 19.0 °C, confirming that the separation persists under the most demanding test condition. The maximum difference is 22.2 °C at 1.0 min.

5 Results Summary

The results demonstrate that LTGs substantially reduce LED operating temperatures, with greater improvements at higher thermal loads.

In Experiment 1, the two EVBs were characterized at low I_{F} to establish their board-specific $V_{\mathrm{F,board}}$-T_{j} characteristics. The LEDs on both EVBs showed a highly linear response and nearly identical temperature coefficients: −17.18 mV °C^{-1} with LTGs and −17.15 mV °C^{-1} without them. This close agreement establishes $V_{\mathrm{F,board}}$ as a consistent temperature-sensitive parameter for both EVBs and confirms that each EVB can be evaluated using its own measured characteristic.

In Experiment 2, these characteristics were used to determine the LED junction temperature after operation at high I_{F}. After each EVB had operated for 25 min at $I_{\mathrm{F}} = 350$ mA, I_{F} was reduced to $I_{\mathrm{F}} = 20$ mA and the first $V_{\mathrm{F,board}}$ measurement was converted to junction temperature. The resulting estimates were 47.67 °C without LTGs and 41.65 °C with them. The LTGs therefore reduced the first measured junction temperature by 6.03 °C and reduced the temperature rise above the respective pre-heating baseline from 22.62 °C to 16.64 °C, a 26.4 % improvement.

In Experiment 3, thermal images independently confirmed the thermal advantage under increasingly demanding operating conditions. The EVB with LTGs remained cooler throughout every operating point. The complete-test average was lower with LTGs by 9.9 °C at $I_{\mathrm{F}} = 350$ mA, 14.5 °C at $I_{\mathrm{F}} = 550$ mA, and 19.5 °C at $I_{\mathrm{F}} = 750$ mA. The steady-state temperature difference increased from 9.7 °C to 19.0 °C across the same I_{F} range, while the maximum pointwise difference reached 22.2 °C.

Together, the three experiments provide a consistent progression of evidence: the first establishes the electrical temperature characteristics, the second demonstrates a lower LED junction temperature with LTGs, and the third independently confirms the thermal advantage and shows that it becomes more pronounced as I_{F} and thermal load increase.

6 Conclusion

This application note quantifies the thermal-management improvement achieved by integrating 26 LTG0402 thermal jumpers into an aluminium EVB with nine high-power LEDs, compared with an equivalent EVB without the LTGs. The evaluation follows three complementary experiments.

Experiment 1 establishes the relationship between $V_{\mathrm{F,board}}$ and junction temperature, providing the calibration required to determine the LED junction temperature from the forward voltage.

Experiment 2 uses this relationship to compare LED junction heating after continuous operation at $I_{\mathrm{F}} = 350$ mA. The EVB with the LTGs shows a 6.03 °C lower junction temperature and a 26.4 % reduction in temperature rise compared with the EVB without the LTGs.

Experiment 3 uses thermal images to compare the maximum LED surface temperature at $I_{\mathrm{F}} = 350$ mA, 550 mA and 750 mA. The images show steady-state LED surface temperature reductions of 9.7 °C, 14.2 °C and 19.0 °C, respectively, for the EVB with LTGs.

The increasing improvement demonstrates that the benefit of the LTGs grows with thermal load. By lowering the LED junction and surface temperatures, the LTGs reduce thermal stress and can support optical stability, efficiency, reliability, and operating life.

7 Changelog

Revision Number	Revision Date	Description	Sections Changed
1.0	2026-08-06	Initial release	-
1.1	2026-08-06	Updated section	Section 4.2

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