Top-Side Cool Package (TCPAK1012) Development and Applications

AND90411/D

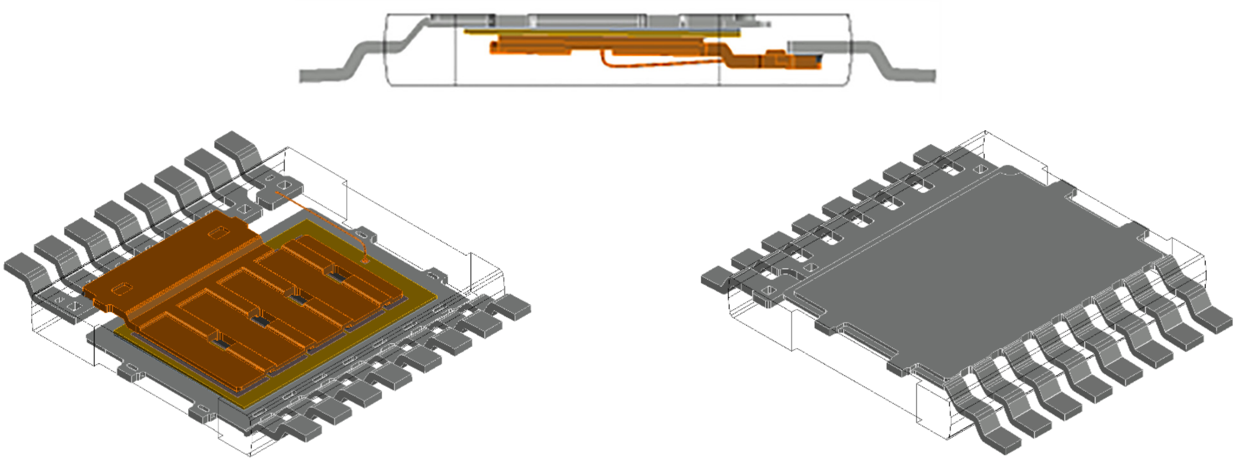
The Top-Side Cool package was created to overcome the thermal limitations of traditional PCB-based cooling in power semiconductors. Conventional bottom-cooled MOSFETs rely on the PCB for heat dissipation, which has low thermal conductivity and often requires thermal vias and complex layouts. This increases design complexity and limits power density.

Top-Side Cool technology solves these issues by exposing the drain pad on the top of the package, enabling direct heat transfer to a heatsink instead of the PCB. This approach significantly reduces thermal resistance, improves current handling, and enhances reliability under high-power conditions. It also frees PCB space, allowing more flexible component placement and simplified thermal management.

In automotive systems, such as EV traction inverters and onboard chargers, Top-Side Cool MOSFETs can be mounted under liquid-cooled heatsinks for superior thermal performance. This results in lower junction temperatures, extended component life, and higher current capability without increasing PCB size.

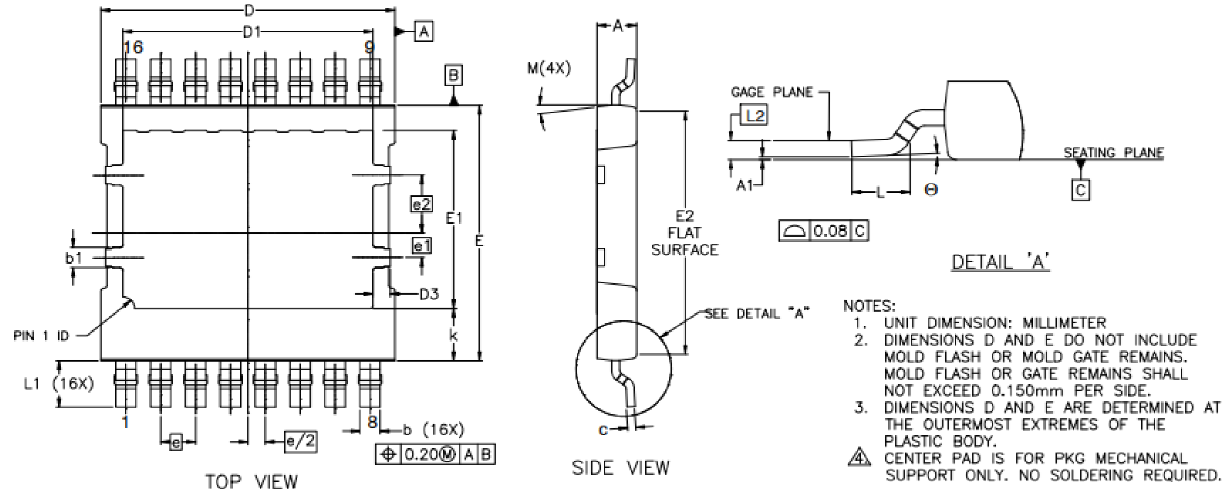
Beyond automotive, Top-Side Cool packaging is also ideal for industrial markets where high power density and efficient thermal management are critical. By enabling direct heatsink integration, it provides a robust solution for next-generation power electronics across multiple sectors.

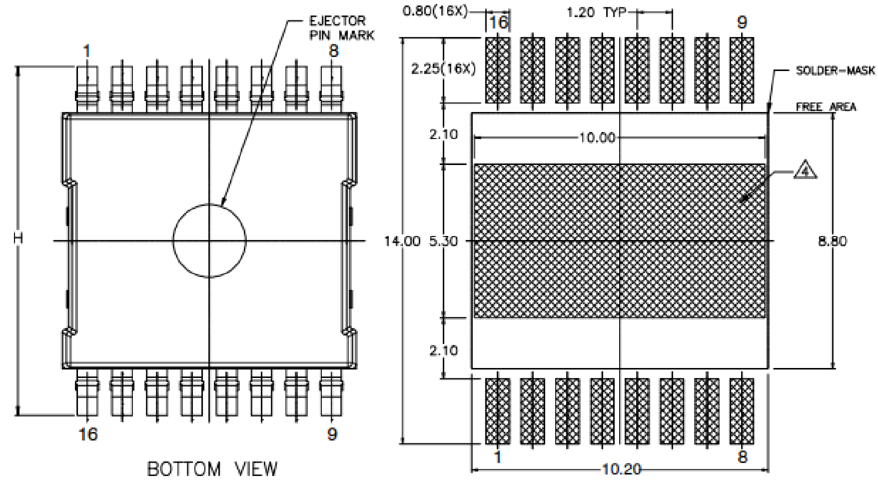
Package & Mechanical Structure Overview



The *Top-Side Cool package* is designed with an exposed drain pad on the top surface, enabling direct heatsink attachment for efficient thermal management. Its internal structure uses an optimized lead frame and robust molding to ensure mechanical strength against vibration and thermal cycling, making it suitable for harsh environments. Compared to the *TOLL package*, which relies on bottom-side cooling through the PCB, Top-Side Cool offers superior design flexibility by reducing PCB thermal load and freeing space for other components. While TOLL is ideal for very high-current modules in heavy-duty automotive or industrial drives, Top-Side Cool delivers high power density in a smaller form factor, making it an excellent choice for applications like EV inverters, onboard chargers, and industrial power supplies where space and thermal efficiency are critical.

Package Drawing





MILLIMETERS			
DIM	MIN	NOM	MAX
A	1.30	1.35	1.40
A1	0.00	0.05	0.10
b	0.67	0.72	0.77
b1	0.65	0.70	0.75
c	0.21	0.26	0.31
D	10.00	10.10	10.20
D1	8.50	8.60	8.70
D3	0.55	0.60	0.75
E	8.70	8.80	8.90
E1	6.04	6.14	6.24
E2	---	---	8.70
e	1.20 BSC		
e/2	0.60 BSC		
e1	0.85 BSC		
e2	2.00 BSC		
k	1.70	1.80	1.90
H	11.80	12.00	12.20
L	0.80	1.00	1.20
L1	1.40	1.60	1.80
L2	0.30 BSC		
Θ	–	2.5°	5°

The Top-Side Cool package features an exposed drain pad on the top surface for direct heatsink attachment, enabling efficient thermal management without relying on PCB copper planes. Its compact footprint (approximately 10 mm x 12 mm) and low profile height (1.3–1.4 mm) make it ideal for space-constrained designs. A key mechanical advantage is its negative standoff design, which ensures consistent and stable mounting height when soldered to the PCB, improving assembly accuracy and reliability. The bottom center pad provides mechanical support only, with no soldering required. This design delivers superior thermal performance and high power density for automotive and industrial applications.

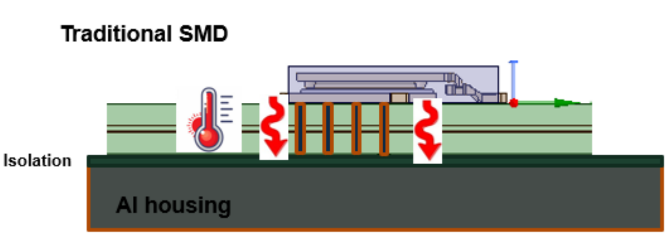


Figure 1. Typical SMD-type Device

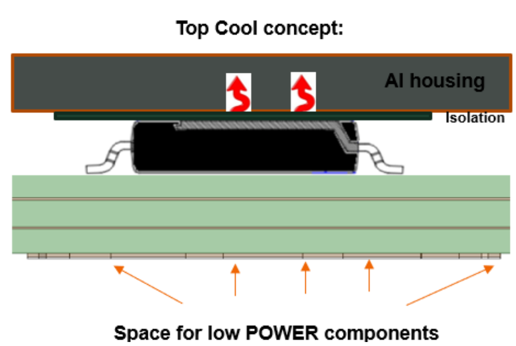


Figure 2. Top-Side Cool Package

In a typical SMD-type device, as shown in Figure 1, the component is soldered onto the PCB surface, and therefore the generated heat is primarily transferred through the PCB. To guide the heat efficiently from the device to the bottom side of the PCB, a design incorporating a large number of thermal vias is commonly used. The bottom side of the PCB is then connected to a heatsink through a Thermal Interface Material (TIM), enabling the final dissipation of heat to the external environment.

However, because this structure forces heat to pass through the PCB material (e.g., FR-4), which generally has low thermal conductivity and thermal capacity, a limitation arises in the device's maximum power-handling capability.

In contrast, the Top-Side Cool Package, shown in Figure 2, features a fundamentally different thermal path. In this package, the leadframe is directly connected to the heatsink through TIM, without passing through the PCB. This direct-contact structure provides the shortest and most efficient path for heat to travel from the leadframe to the heatsink.

This approach offers several key benefits:

- Maximized thermal conductivity: The high thermal conductivity of the leadframe can be utilized directly.
- Minimized thermal resistance: The PCB is no longer part of the heat-transfer path, eliminating unnecessary thermal resistance.
- Improved maximum power-handling capability: Faster heat transfer to the heatsink helps reduce temperature rise within the device.

As a result, the Top-Side Cool Package delivers significantly enhanced thermal performance compared to conventional SMD structures, making it especially suitable for high-power applications.

Comparative Analysis: TCPAK1012 vs. TOLL

The thermal impedance (Zthja) data of TCPAK1012 and TOLL measured using the T3ster with a heat sink attached are shown below. Both packages exhibited similar characteristics up to 300 ms; however, beyond that point, TCPAK1012 showed a significantly lower thermal resistance. Under DC conditions, the difference was approximately 60%. The heat sink and TIM materials used for the measurement are listed below. The two devices evaluated had the same die size (22 mm^2).

- 4 Layer PCB 122 mm x 87 mm x 1.6 mm mounted to heatsink
- Gap filler 4.5 W/mK, 100 μm thickness
- 23 °C initial temp. Aluminum heatsink 144 mm x 107 mm x 20 mm

In this test, the water-jacket-based liquid cooling system can exhibit different heat-transfer characteristics depending on the coolant flow rate, which may cause structural temperature variations or unstable steady-state conditions during measurement.

To minimize these sources of error, the water jacket was used only during the initial temperature-setting stage to align the sample to the desired starting temperature. For the actual power dissipation measurement, data were acquired in a stationary state with the coolant flow stopped.

This approach ensures that changes in thermal resistance caused by fluid flow do not affect the measurement results.

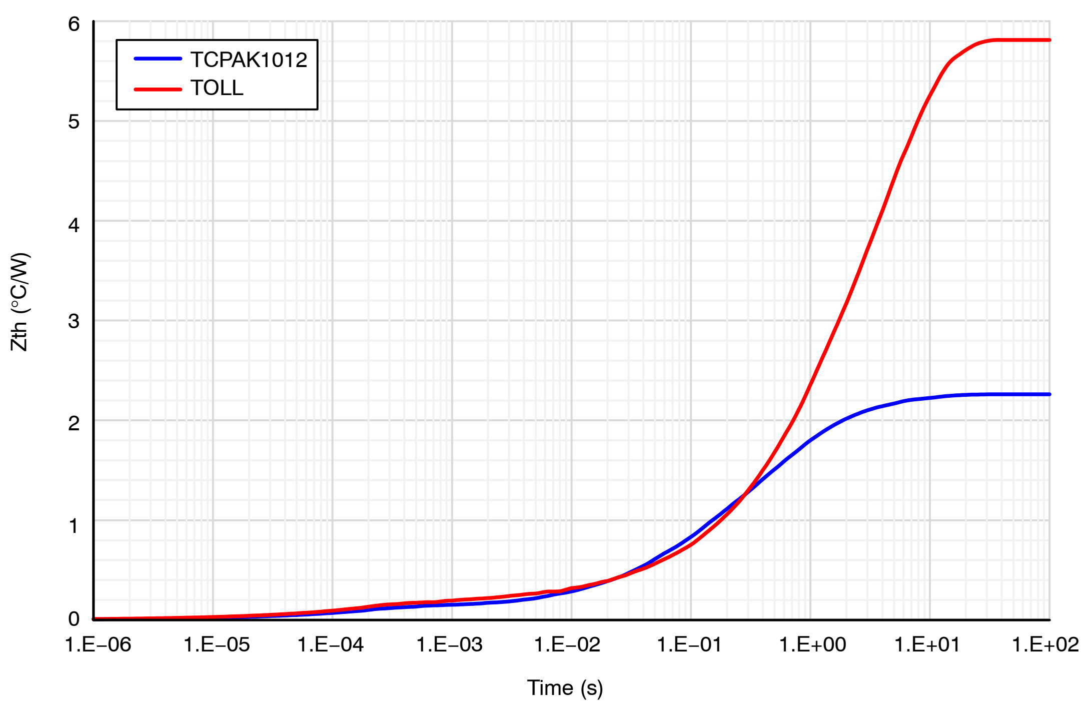


Figure 3. Transient Thermal Impedance (Zthja)

The following thermal impedance curve (Zthjc) was obtained through FEM simulation using 3D models. The same die and package were applied, and under DC conditions, the TCPAK1012 shows approximately 25% lower Rthjc compared to the TOLL package.

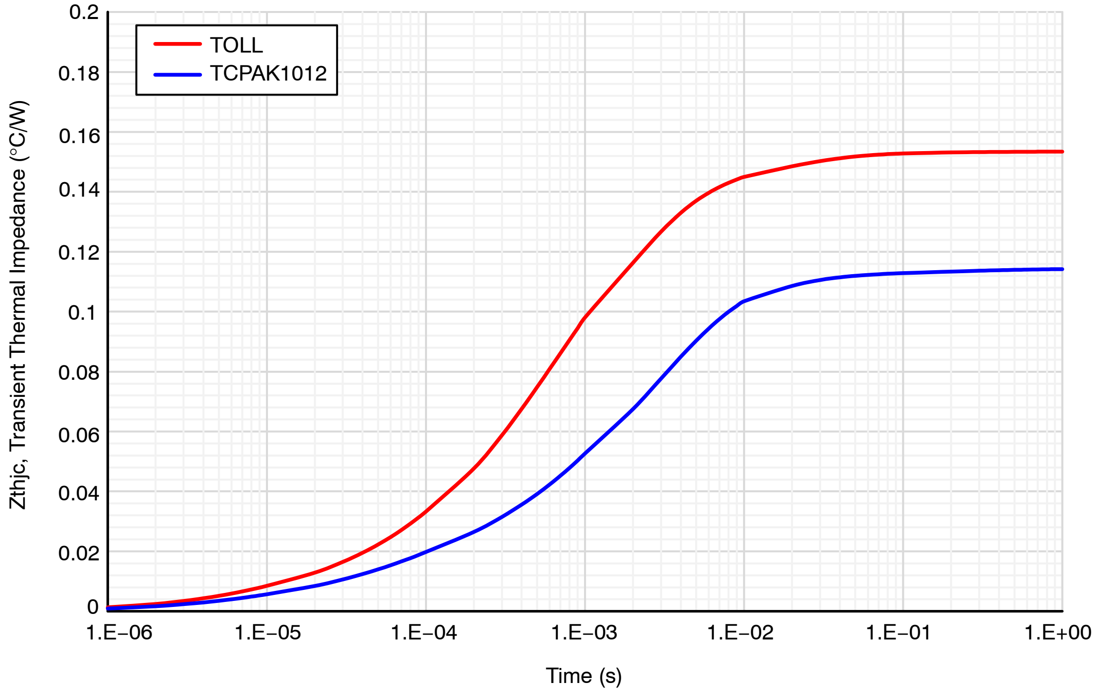
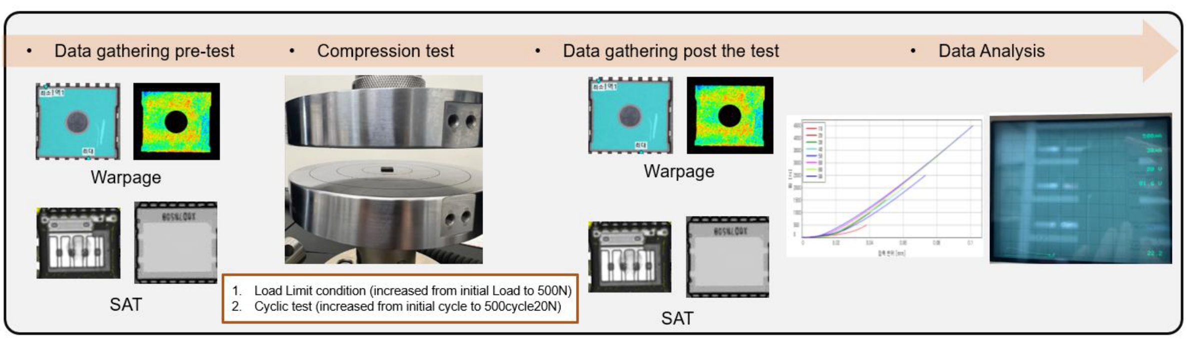


Figure 4. Transient Thermal Impedance (Zthjc)

Mechanical Compression Robustness and Its Impact on Thermal Interface Consistency

- Overview

TCPAK1012 utilizes a clip-based structure that provides uniform mechanical load distribution across the die and leadframe. To assess the mechanical stability of this structure, a compression test was performed by applying increasing downward force on the package to evaluate deformation and structural robustness.



- Compression Test Result Summary

The package demonstrated minimal deformation under the compression load range typically encountered during assembly processes (e.g., socket clamping, heatsink mounting, fixture pressure). The clip and mold compound interface maintained structural integrity without noticeable warpage or cracking within the tested load conditions.

- Relevance to Thermal Performance

Although the compression test is primarily a mechanical robustness evaluation, its findings have indirect implications for thermal performance.

- Stable Interface Pressure

Limited package deformation ensures that the contact pressure between the package surface and the thermal interface material (TIM) remains consistent. This contributes to maintaining predictable thermal resistance during system integration.

- Reduced Variability in RθJC/RθCA

By minimizing warpage or tilt under mechanical load, the package helps prevent localized air gaps or uneven interface thickness, both of which can increase thermal resistance variability.

- Enhanced Reliability Under Real Asssembly Conditions

Systems that apply mechanical clamping—such as heatsink attachment or module-level pressure frames—benefit from the package's structural robustness. TCPAK1012's resistance to deformation supports stable long-term thermal performance, especially in applications with vibration or repeated pressure cycles.

- Summary

While the compression test itself is not a direct thermal characterization, the mechanical stability demonstrated by TCPAK1012 helps maintain consistent thermal contact conditions during real-world assembly. This robustness contributes indirectly to reliable thermal performance and supports the thermal comparison data presented in earlier sections.

Conclusion

The TCPAK1012 Top Side Cool package provides a fundamentally improved thermal architecture by enabling direct heat transfer to a heatsink rather than relying on PCB based dissipation. Through both measurement and simulation, the package demonstrated substantially lower thermal impedance compared to traditional bottom cooled packages such as TOLL, particularly under steady state conditions. Mechanical compression testing further confirmed the structural robustness of the package, supporting consistent thermal interface conditions during real system assembly.

Key system level benefits include:

- Significant reduction in junction-to-ambient and junction-to-case thermal impedance
- Simultaneous reduction of conduction and switching losses when paired with low Rds(on) / low Qg MOSFETs, improving overall system efficiency
- Support for platform miniaturization through reduced PCB thermal burden and higher power density
- Enhanced long term thermal reliability and extended device lifetime
- Higher pulse and peak current capability enabled by improved thermal headroom

Together, these characteristics establish the TCPAK1012 as a highly effective solution for next generation automotive and industrial power systems requiring compact form factors and superior thermal performance.

REVISION HISTORY

Revision	Description of Changes	Date
0	Initial document release.	3/9/2026

ADDITIONAL INFORMATION

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Technical Library: www.onsemi.com/design/resources/technical−documentation
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