Application Brief

Punch Above Your Weight – How TI's QFN High-Side Switches Deliver Heavy-Hitting Value

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Introduction

The release of TI's first QFN-packaged automotive high-side switches represent a long-awaited inflection point not only for TI's high-side switch portfolio, but also more broadly for power switching within automotive power distribution nets. They are an answer to a challenge that perennially besets chipmakers and hardware engineers alike: deliver more with less. This document briefly reviews how TI's latest QFN high-side switches, listed in Table 1, rise to the challenge of delivering more along different vectors, namely through construction and internal protection mechanisms, without sacrificing in reliability or impeding the design process. The qualities described below give these QFN high-side switches an advantage in space-constrained automotive applications.

Table 1. TI's QFN-packaged Automotive High-Side Switches

Part Number	Description
TPS1HC04-Q1	Automotive, 4.8mΩ, 15A single-channel smart high-side switch
TPS1HC08-Q1	Automotive, 9.7mΩ, 10A single-channel smart high-side switch
TPS2HC08-Q1	Automotive, 9.7mΩ, 7.5A dual-channel smart high-side switch
TPS2HC16-Q1	Automotive, 18.5mΩ, 5A dual-channel smart high-side switch

Optimized Construction

The most visible area of advancement TI's QFN high-side switches showcase is its form factor. As shown in Figure 1, the overall size of a device at a specific on-resistance and channel count is over 70% less than other solutions on the market. This is achieved via the intersection of two new technologies. First, TI's silicon process has shrunk, allowing for the use of a smaller FET while still meeting the nominal current expectations at a given on-resistance.

Figure 1 shows TI's new QFN package compared to its high-side switch SOP package (left) and TI's QFN package compared to the common SOP package found on the market (right).

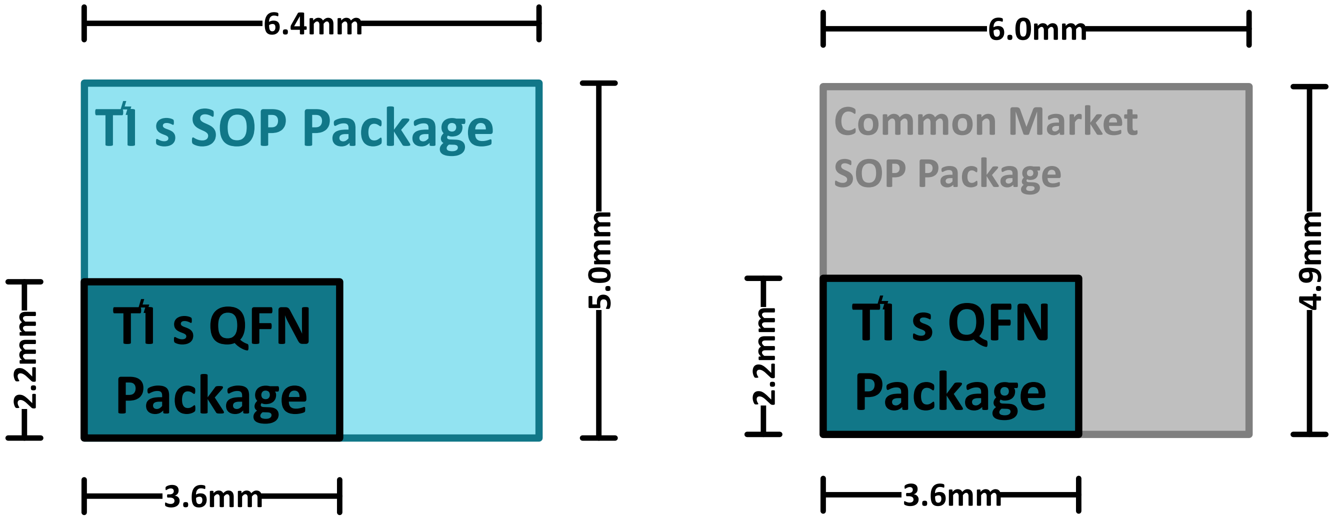

Figure 1. Package Comparison

Second, and of greater consequence, the construction and assembly of the device have been greatly optimized. As shown in Figure 2, a cross section of the high-side switch, TI has moved to QFN packages where the chip is placed directly on the copper posts of the lead-frame. This delivers a three-fold advantage:

1. Thermals are superior to a similar device electrically attached to the lead-frame through bond-wires as direct placement on the copper posts provides better heat sinking.
2. Electrical characteristics are stronger since the copper posts have lower parasitic impedance than bond-wires.
3. Reliability is improved as the removal of bond-wires reduces the number of failure points.

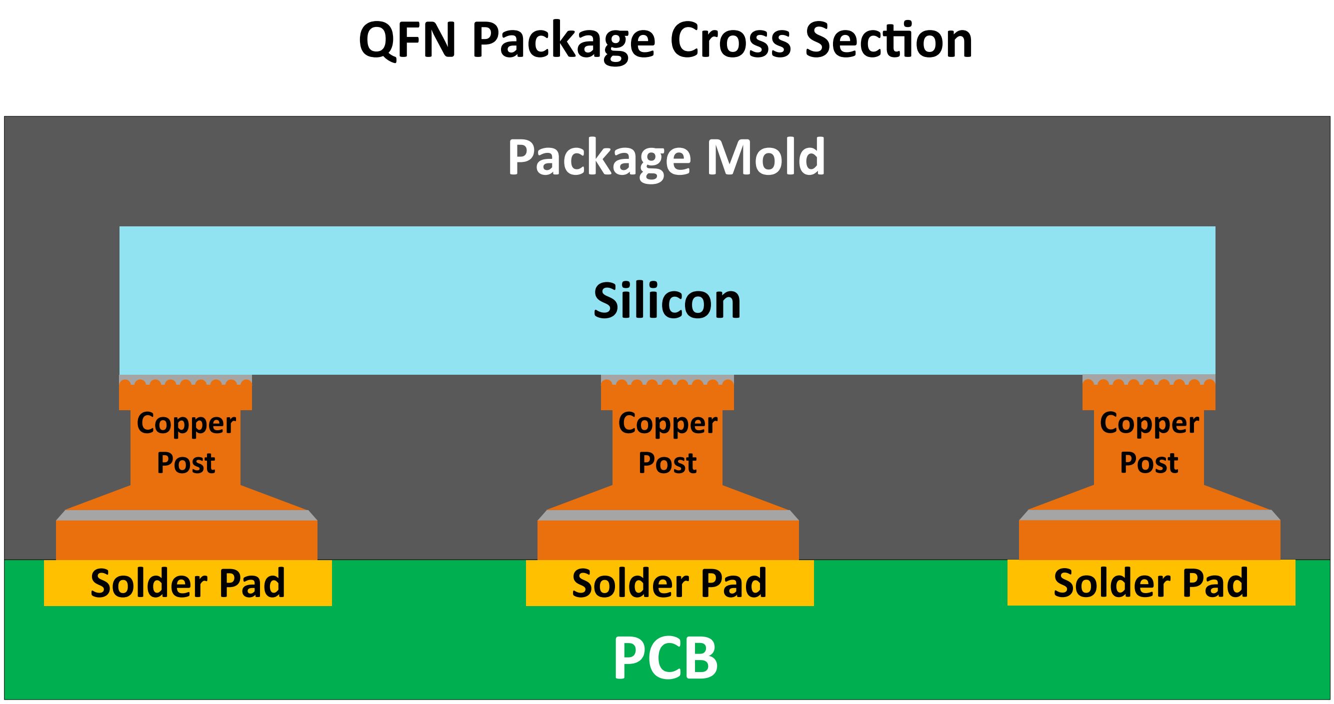

Figure 2. A Cross Section of the QFN High-Side Switch

Advanced Integrated Thermal Management Mechanisms

Common to power switch devices across markets and applications is some form of current limitation. TI's high-side switches feature either a current limit clamp, where the device holds the current at the programmed limit once the threshold is reached (as shown in Figure 3a), or an immediate shutdown response, where once the programmed current limit threshold is reached, the switch disables. Both current limiting schemes have advantages for different applications. However, in the QFN-packaged high-sides switches, a more advanced current limit scheme is implemented.

The QFN high-side switches feature a dynamic and self-regulated current clamping scheme called thermal regulation as illustrated in the figure below on the right. Using the internal temperature monitors within the device, the gate of the FET is actively controlled in response to thermal fluctuations when driving the load. The key benefit of this scheme comes when driving capacitive loads. In previous generations of high-side switches that only clamped the current at one level, it may have taken several tries before the input capacitance of the load was fully charged. With this new scheme, the capacitive load can be fully charged without the switch disabling. The benefit of this is that the device has higher thermal consciousness, allowing it to charge larger capacitive loads and endure longer charge cycles.

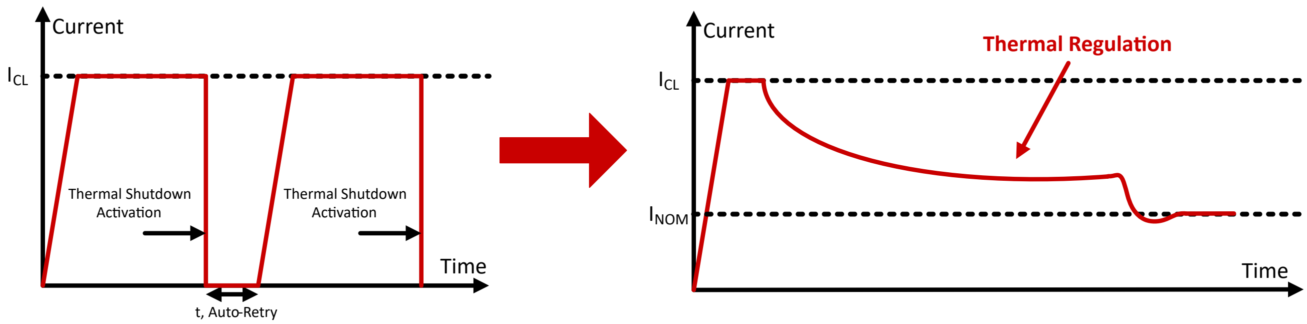

Figure 3. Current Limit Clamping Types: Static Current Clamp (Left) and Thermally Regulated Clamp (Right)

A second protective feature newly introduced with this family of QFN high-side switches is a form of voltage monitoring called current limit foldback. As the voltage across the internal FET increases, the device automatically folds back, or reduces the current limit to prevent damage to the device. Based on the configuration of the adjustable current limit (I_{CL}) in regards the device's circuit breaker threshold (I_{CB}), the current limit will experience foldback as voltage increase following the scenarios described below and represented visually in Figure 4:

- Scenario A (blue line): The current limit is set higher than half the circuit breaker threshold (I_{CB}). This limit will be reduced to $I_{CB}/2$ then $I_{CB}/3$ as voltage increases.
- Scenario B (red line): The current limit is set between $I_{CB}/2$ and $I_{CB}/3$. This limit will be reduced once the second voltage threshold is reached.
- Scenario C (green line): The current limit is set below $I_{CB}/3$. This current limit will not be folded back.

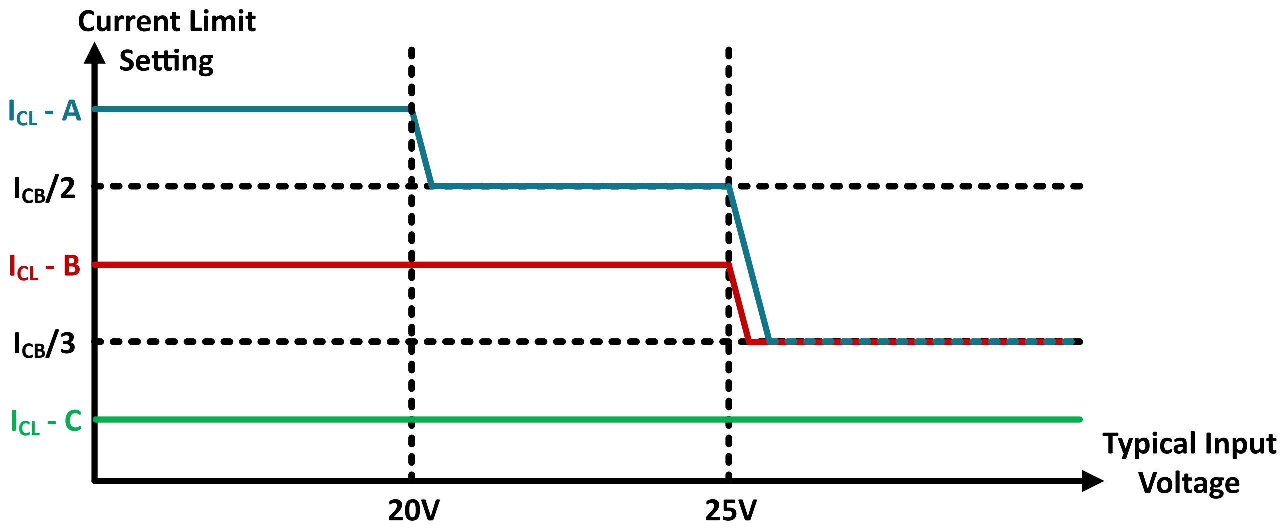

Figure 4. Current Limit Foldback Based on the Current Limit Setting

Together, thermal regulation and current limit foldback maximize the safe operating area usage of the internal FET of the device through voltage and current control.

Proven Robustness Against External Stress

It is widely accepted that leaded packages are generally more robust against environmental stressors like heat and mechanical forces, particularly bending, torsion, and vibration. This is because the flexibility of the leads naturally gives higher solder joint reliability. Robustness of this sort is necessary as automotive systems are very often subject to temperature fluctuations, vibrations, and high accelerative shock. It is necessary that a QFN-packaged device proves robust against such stressors if it is to be used in automotive applications. As part of the qualification of TI's QFN high-side switches, units were subject to a variety of tests that simulated common environmental stressors. To pass, the units under test must not experience solder joint or functional failure under each test's conditions. To learn more about the details of each test, visit TI's quality, reliability & packaging data download page for tabulated test information for each part. The qualification summary includes information such as the test type, specification, and conditions.

Ease of Manufacturing

As technologies shrink in size, they require a proportionate increase in the precision of the tools that manufacture them. In favorable circumstances, a smaller and newly introduced technology would also offer something to bridge the precision gap to accelerate its adoption, thereby proliferating the technology. A bridge of this kind comes with TI's immersion tin, or Imm Sn for short, wettable flanks technology.

The following figure shows a cross section of a QFN package with TI's immersion tin wettable flank (left) and the 11-pin QFN package that carries the high-side switches (right).

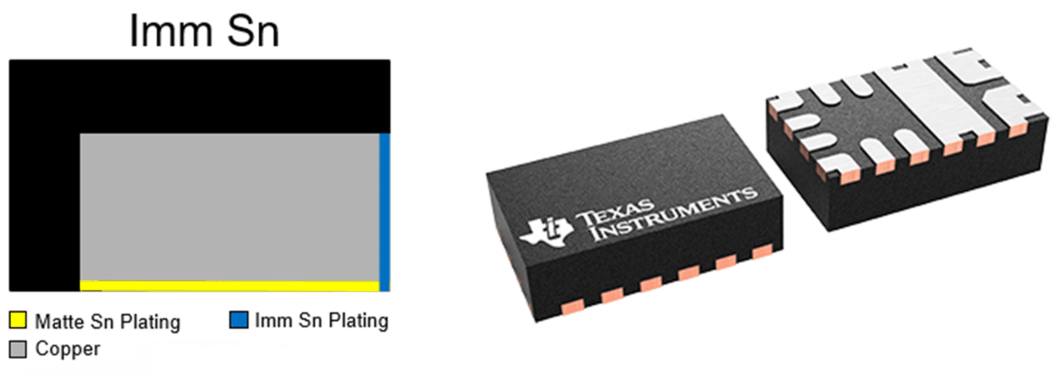

Figure 5. QFN Package

As shown in Figure 5, the packages feature an exposed flank, a portion of the lead frame, that provides surface area on the side of the package for solder to grasp. The tin plating itself is white in color, therefore providing a clear visual indication of solder coverage upon inspection. This wetting does not alter the package electrical characteristics or reliability performance, and it meets the industry requirement of 100 µm side-whetting, as shown in Figure 6.

The benefit of TI's immersion tin wettable flanks technology is clear. First, it allows for easy manufacturing as the immersion tin flanks serve as a backdrop for automated optical inspection. Second, it is more optimized than other flank technologies that require a cut or that use a higher cost plating like Nickel-Palladium-Gold (NiPdAu).

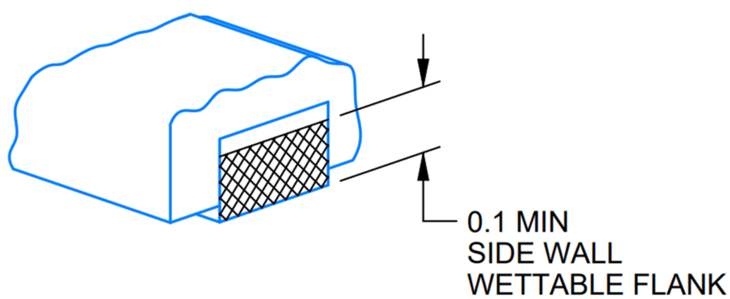

Figure 6. The 0.1mm Side-Whetting Industry Requirement

Conclusion

This application brief reviewed the advancements that have come together in TI's latest family of QFN packaged high-side switches. These devices are space conscious, thanks to a smaller die and over 70% reduction in package size and pin-to-pin compatibility with each other. These devices are more thermally intelligent than other high-side switches, featuring thermal regulation and current limit foldback. Lastly, the devices have proven reliability and features of the construction that aids in the manufacturing process. In summary, all these qualities together make these devices preferred for applications where space and budget are constrained, where these switches must deliver more with less.

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