DN0001

DFN2020-Packaged MOSFETs Benefit PoL DC-DC Applications

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DMT34M8LFDE DFN2020 MOSFET and AP6ACO5 Synchronous Buck Controller
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Summary

Across industrial and automotive products, electronic systems are becoming increasingly distributed. As a result, centralized power architectures suffer from reduced efficiency due to longer cable lengths and PCB traces, which lead to voltage drop and power losses. Point-of-load (PoL) converters are being used to address such inefficiencies by placing the DC-DC conversion close to the load, thus reducing losses in power distribution and improving overall system efficiency.

This design note explores a compact 12V-5V synchronous buck converter from Diodes Incorporated (Diodes), based on the DDB121R2 reference board. The solution uses an AP6ACO5 synchronous buck controller with the DFN2020-packaged 30V DMT34M8LFDE 4mΩ MOSFET. Devices packaged in DFN2020 achieve a junction-to-case thermal resistance ($R_{\theta JC}$) as low as 11°C/W, enabling superior performance when compared to SOT23 while being 40% smaller, and achieving high-efficiency PoL conversion with minimal footprint.

Design Approach

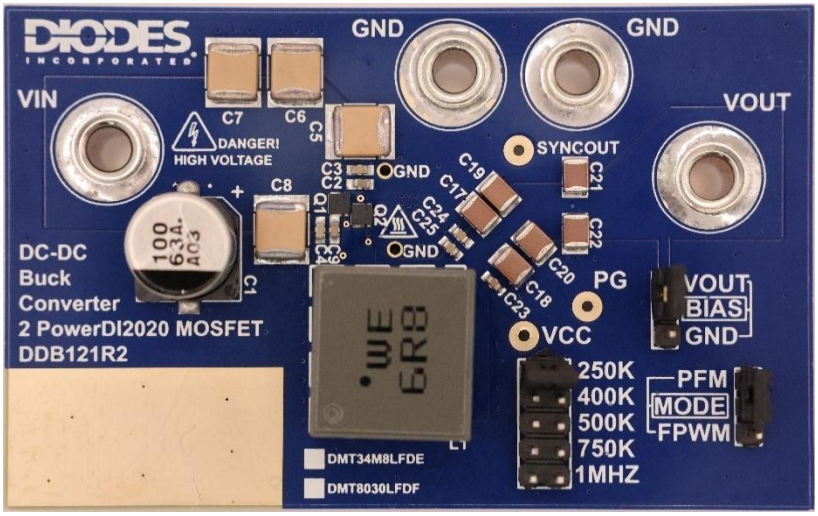


Figure 1: DDB121R2 PoL 12V-5V DC-DC Synchronous Buck Converter

Centralized architectures, wherein a single, high-power buck converter supplies power to multiple loads, result in space constraints, parasitics, and voltage drops due to long cable lengths. The solution is to use a decentralized architecture with the assistance of PoL converters, which are essentially DC-DC step down converters, located at or near the load that requires power. By reducing the length of cable required to reach the load, the user significantly reduces voltage drops and power losses.

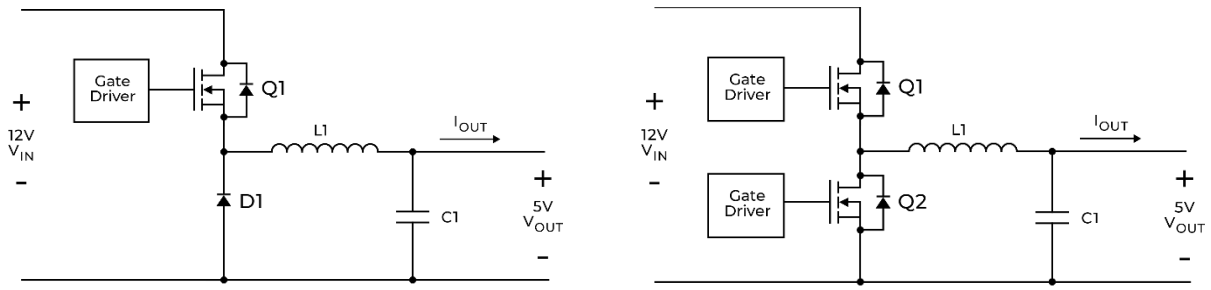


Figure 2: a) Asynchronous b) Synchronous Buck Converter Circuit Diagram

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At its core, an asynchronous (Figure 2a) step-down DC-DC converter uses a MOSFET, inductor, capacitor, and diode to step down voltages to a pre-determined level. When the MOSFET is switched OFF, the inductor releases stored energy, maintaining current flow to the load. The freewheeling diode provides a path for this current flow when the MOSFET is OFF. A synchronous step-down DC-DC converter replaces the freewheeling diode with MOSFET Q2 (Figure 2b), improving overall efficiency. The diode's forward voltage drop is replaced with a much smaller voltage drop determined by the MOSFET's drain-source on-resistance ($R_{DS(ON)}$), which can be calculated using Ohm's law ($V = I * R_{DS(ON)}$).

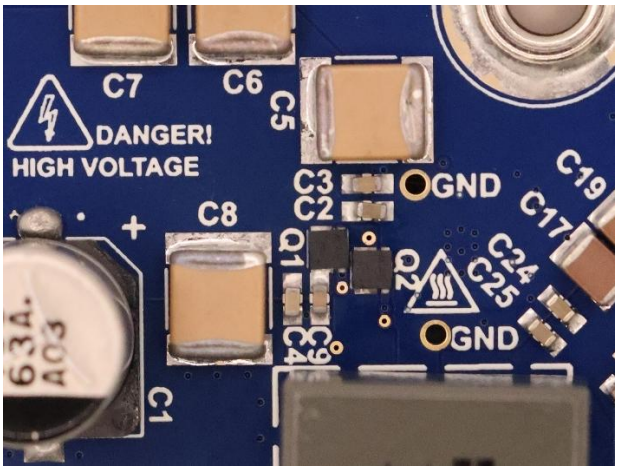


Figure 3: Q2 Low-Side MOSFET Replaces Diode

The DDB121R2 synchronous buck converter shown in Figure 1 and 3 uses the DMT34M8LFDE DFN2020 MOSFET as both the high-side switch and low-side synchronous rectifier (Q1 and Q2). The DFN2020 is a compact 2mm x 2mm package that enables efficient thermal performance and high-current capability, all in a small footprint.

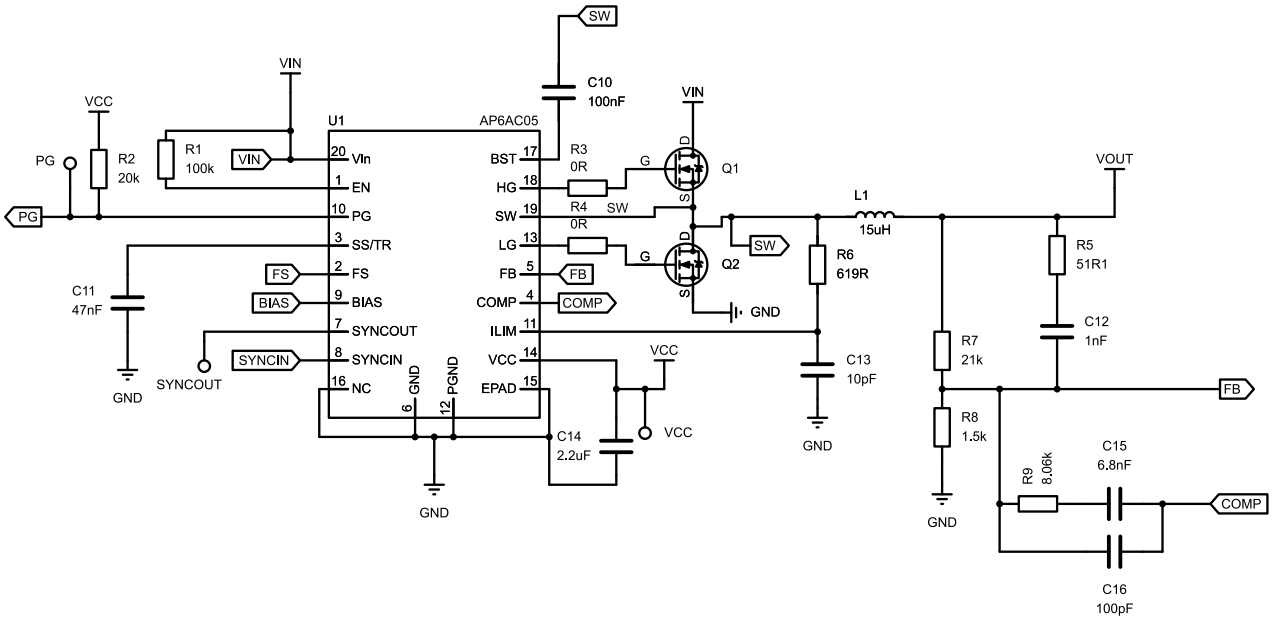


Figure 4: DDB121R2 PoL 12V to 5V DC-DC Synchronous Buck Converter Schematic

In DC-DC converters, the high and low-side MOSFETs typically switch at frequencies ranging from hundreds of kHz to several MHz, thus requiring a low gate charge to combat switching losses. At V_{GS} = 10V, Diodes' DFN2020-packaged DMT34M8LFDE 30V MOSFET has an on-state resistance of 4mΩ and gate charge of 15.4nC. Figure 4 shows the schematic of the DDB121R2, where the AP6ACO5 synchronous buck controller manages the switching of both MOSFETs, regulating the duty cycle to ensure a stable 5V output. The AP6ACO5 is intended for step-down conversions from 12V, 24V, 48V, 60V, and 72V in unregulated, semi-regulated, or fully regulated supply rails.

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Performance Highlights

The buck converter was tested at frequencies of 250kHz and 100MHz, which are the minimum and maximum the controller can be set at, with MOSFETs driven at V_{GS} = 10V. The tests were conducted up to and including a 9A output current.

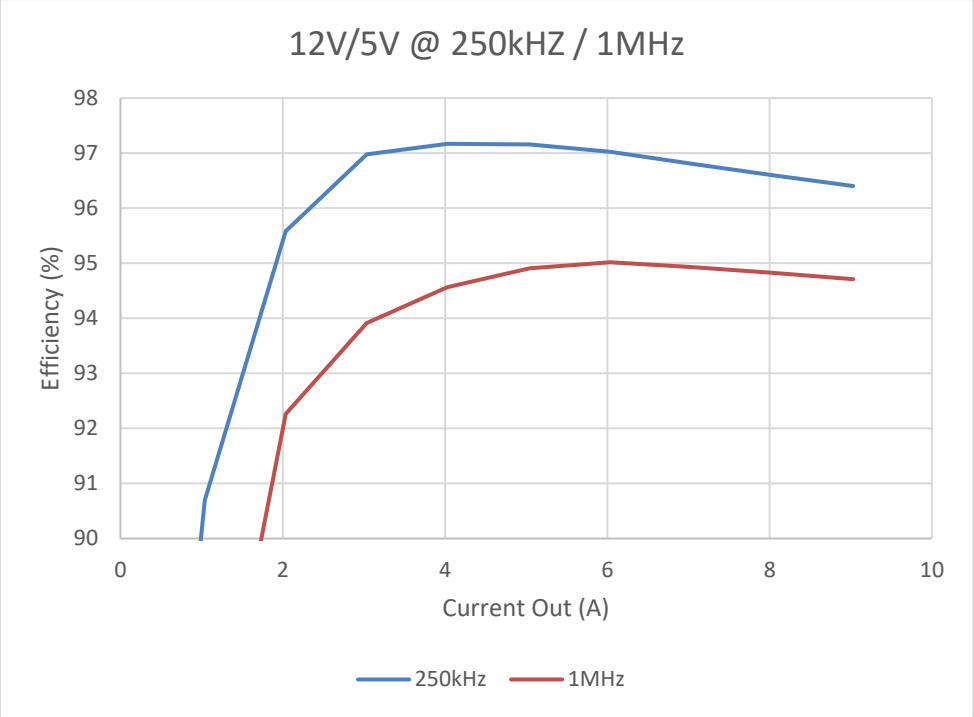


Figure 5: Graph Showing DFN2020-Packaged MOSFETs 12V-5V, Efficiency vs. Current Out

The results in Figure 5 show that the DDB121R2 performed better at a 250kHz frequency, achieving a peak efficiency of 97.2% at 4A, compared to 95% peak at 6A when operating at 1MHz. This reduced efficiency at higher frequencies is to be expected, considering at 1MHz the MOSFETs must now switch four times more often. This not only increases switching losses but also gate driver losses.

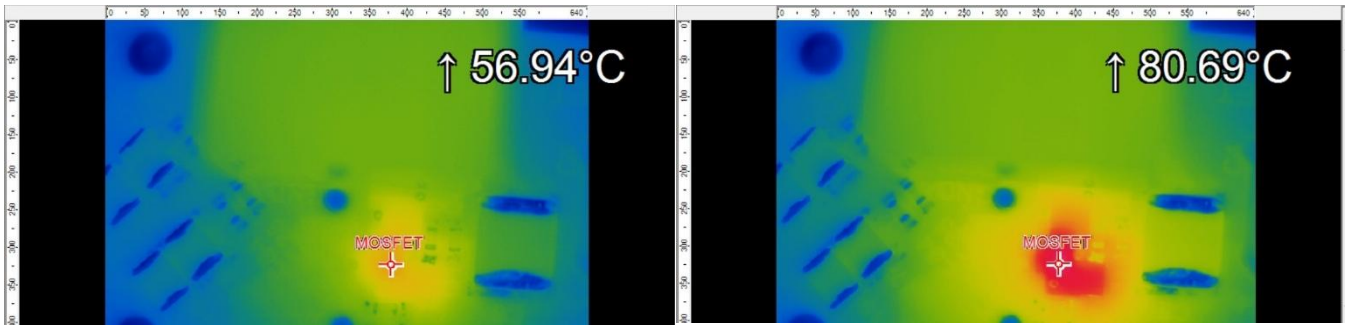


Figure 6: DFN2020 MOSFETs 12V-5V 9A Out, Tamb = 25°C, No Airflow a) 250kHz b) 1MHz

Figure 6a and 6b show the thermal images of the DMT34M8LFDE MOSFET operating at a 9A output current at 250kHz and 1MHz, respectively. Temperatures of 57°C and 80.7°C were recorded, highlighting the impact of increasing switching frequency on thermal performance. While 1MHz operation increases gate drive and switching losses, the DMT34M8LFDE maintains a junction temperature well within its operating range, showcasing the effectiveness of the silicon and DFN2020 package. The results show that despite a mere 2mm x 2mm footprint, the MOSFET safely handles a 9A output at high frequencies.

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Increasing the switching frequency may seem counterintuitive; however, this is dependent on design requirements. As switching frequency increases, the amount of energy stored and transferred during each cycle is reduced, enabling smaller inductors and capacitors. Thus, an engineer can shrink the size of their buck converter design as the components are physically smaller. Despite its lower efficiency, a switching frequency of 1MHz is useful in applications where a compact solution is required. In contrast, a lower frequency such as 250kHz should be used when maximizing efficiency is the priority.

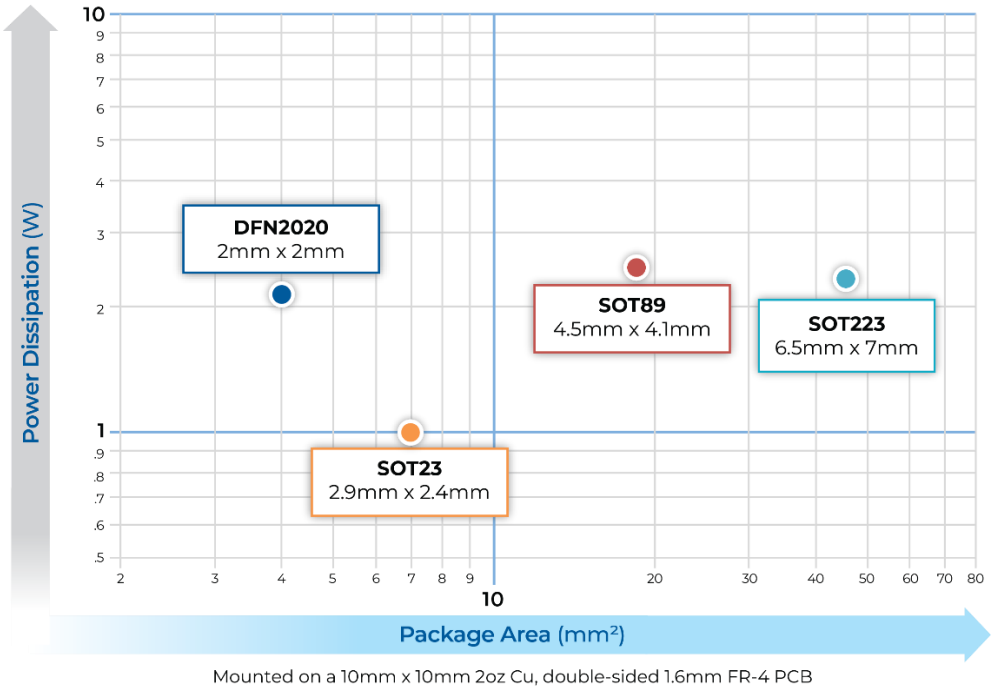


Figure 7: Graph Showing Power Dissipation vs. Package Area of Various Packages

Figure 7 shows the DFN2020's power dissipation capability against packages of various sizes. Despite having the smallest footprint, the DFN2020 can dissipate similar power against the likes of SOT89 and SOT223, which are more than four times its size.

Conclusion

Point-of-load converters are at the forefront of distributed power architectures to reduce power losses, voltage drops, and wiring constraints. MOSFET selection plays a crucial role in determining both power density and efficiency.

At 1MHz, the DDB121R2 delivered a peak efficiency of 95%, whereas at a lower frequency of 250kHz, tests showed a 97.2% peak efficiency. While efficiency slightly decreases with increasing frequency, the DFN2020-packaged DMT34M8LFDE MOSFET supports high frequencies and output currents while maintaining excellent efficiency due to its ultra-low gate charge and $R_{DS(ON)}$. This demonstrates its effectiveness across a wide operating range in PoL applications and enables designers the flexibility to either reduce solution size for compact applications, or maximize efficiency.

Thermal imaging gives further evidence of the DFN2020 package's capability to deliver high current density in a compact footprint. The DMT34M8LFDE maintained a safe operating temperature at both tested frequencies, combining efficiency, thermal performance, and power density, making it an ideal solution for next-generation point-of-load applications.

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Revision History

Design Note Revision History: V1.0, 2026-09	
Previous Version:	
All	**Initial release**

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