AN1178

DDB094R2 and DDB099 Demo Boards

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The automotive industry is undergoing unprecedented change, with the move to electrification and ongoing development in safety devices and autonomous vehicles resulting in an increased demand for semiconductors. DC motors are experiencing exponential growth in areas ranging from simple, low-power brushed versions to high-power brushless DC motors (BLDC). According to Allied Market Research, the Brushless DC motors industry will reach $72.24 Bn by 2030, compared to $33.15 Bn in 2020. This in turn increases the requirement for a variety of motor driver solutions.

Diodes Incorporated (Diodes) has developed two demo boards featuring its automotive ‘Q’ MOSFET and portfolio of gate driver ICs to target BLDC Motor applications in the automotive sector.

The DDB094R2 board has three dual N-Channel MOSFETs (DMN3032LFDBQ), with a 30V rating and 30mΩ $R_{DS(ON)}$. Each device comes in a space-saving U-DFN2020-6 package measuring only 2mm x 2mm.

The dimensions of the board itself are only 60mm x 38mm in a circular design which makes it ideal for mounting directly onto a motor. It has two layers and includes the gate drivers and current sense resistors required for it to interface directly with a microcontroller.

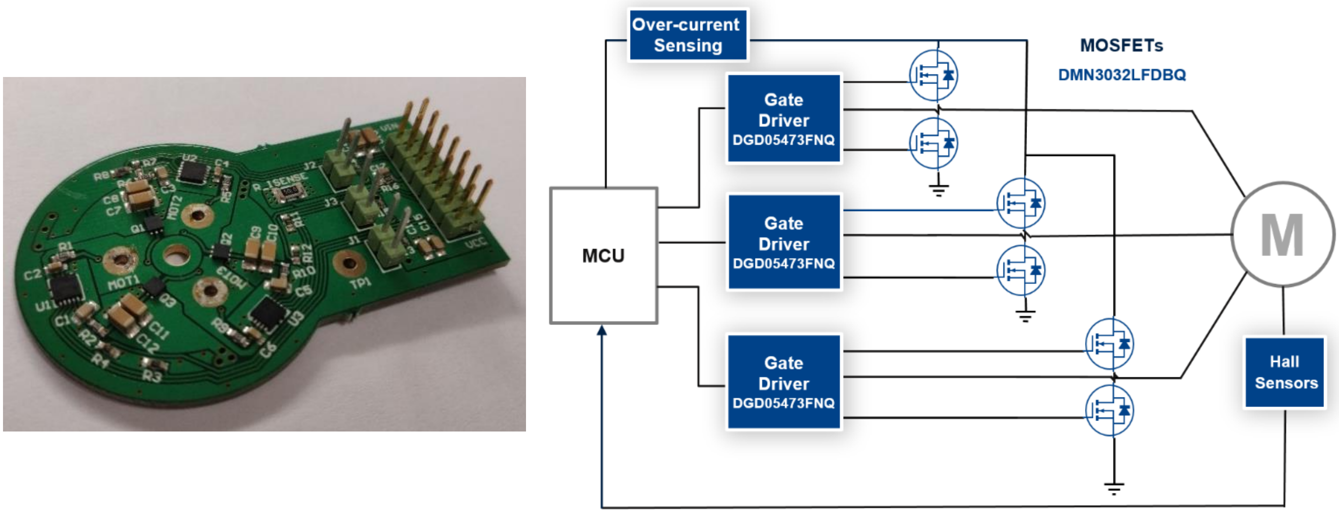

Figure 1. DDB094R2 Demo Board and Typical Block Diagram.

The DDB099 board has a larger form factor and includes the DMTH6010LPDQ MOSFETs. These are 60V dual N-Channel and 11mΩ $R_{DS(ON)}$ in the 5mm x 6mm PowerDI5060 package. The board itself measures 100mm x 60mm and it has four layers. It also includes three current sense resistors to measure current in each of the three phases independently, thus enabling sensorless commutation schemes to be implemented.

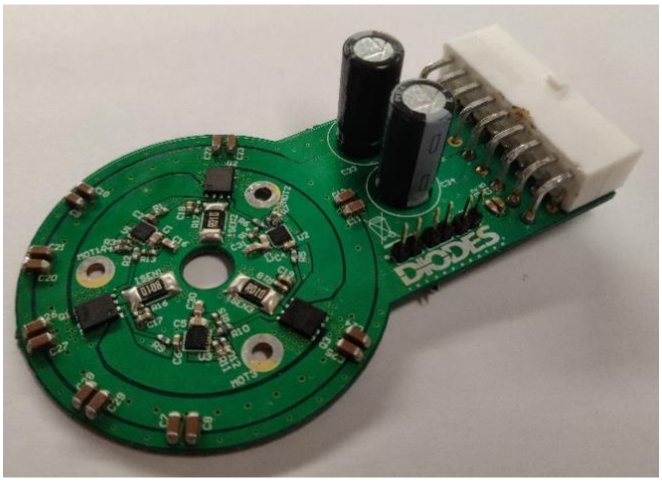

Figure 2. DDB099R1 Demo Board.

Both boards use the DGD05473FNQ, a high-frequency high-side/low-side gate driver. This device is housed in a 3mm x 3mm U-DFN3030-10 package which is rated up to 50V and has logic inputs that can operate down to 3.3V for easy microcontroller interfacing.

To drive the motor, a bridge configuration of six MOSFETs in three dual packages is used (Figure 3). To rotate the motor, each phase must be energized in sequence, and this is achieved through high-side and low-side switching of each phase.

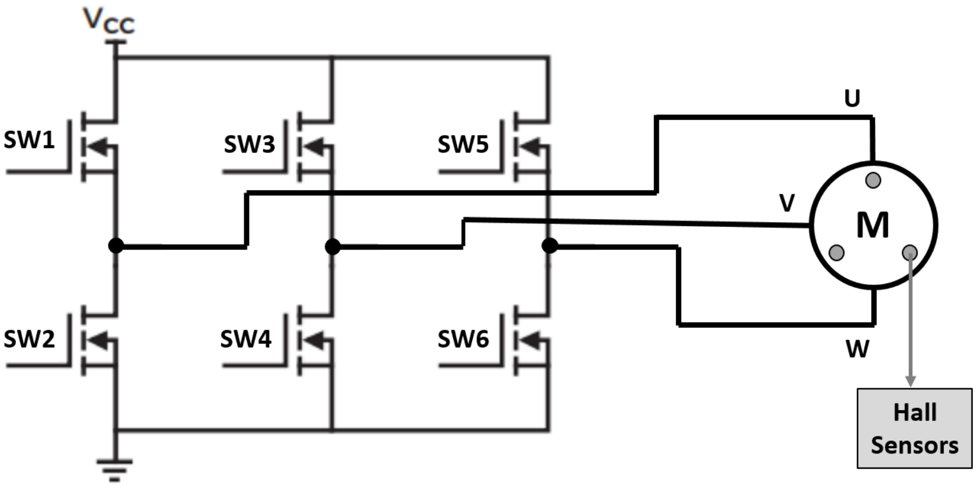

Figure 3. Three-phase BLDC Bridge Configuration.

Commutation of the motor is managed by a microcontroller that controls MOSFET switching. Speed control is performed using a pulse width modulation (PWM) switching scheme, which can be applied to either:

- all six MOSFETs (both low and high sides),
- the low side (the three MOSFETs switching with respect to ground),
- the high side (the three MOSFETs switching with the input voltage). This is the most common approach.

To make the motor rotate, a PWM signal is first applied to SW1 while a logic high DC voltage is applied to SW4. This creates a path for current to flow into the motor phases U and V. Repeating this process in the appropriate order for each of the other pairs produces the desired spin.

One of the key differences between brushed and brushless motors is that BLDC motors require a microcontroller to achieve commutation by energizing each of the respective coils at the right time. To do this requires a means of being able to detect the position of the rotor as it spins. This can be done using either Hall Effect or current sense resistors. The DDB099 has three current sense resistors (one per phase), which means either method can be used. However, the DDB094R2 has one resistor (which is included for safety purposes), which means it cannot use current sensing for position detection. The more common approach is to place Hall Effect sensors inside the motor, each separated by 120°. These devices produce a digital signal (low or high) when the pole is in position and using three allows multiple binary combinations to be produced and stored. Having knowledge of these combinations then allows the MCU to switch the MOSFETs in the correct sequence.

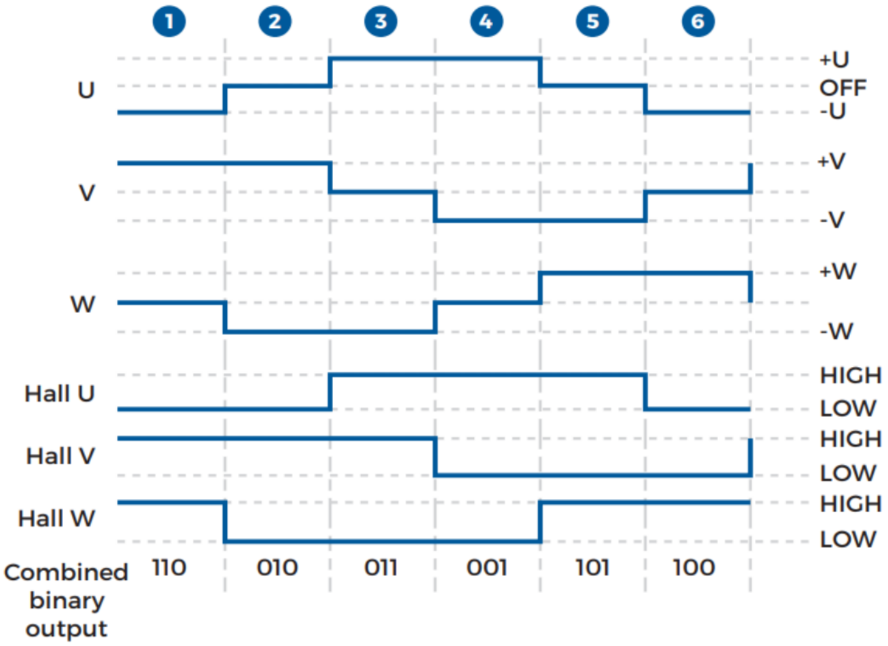

Figure 4. Hall Effect Sensors and Phases Truth Table.

In each combination, one phase should be high, one low while the third is floating.

To evaluate the thermal behavior of the boards, a thermal camera was used to measure the surface temperature of the MOSFETs and the heat dissipated in the PCB at room temperature (25°C). The DDB094R2 was attached to a 77W input power BLDC motor (24V, 3.2A) and, as can be seen in Figure 5, the surface of the MOSFETs reached 75°C. There is a significant margin between this value and the maximum allowable operating temperature of 150°C. The other component which reaches a high temperature during operation is the current sense resistor (shown in the upper right area of the image).

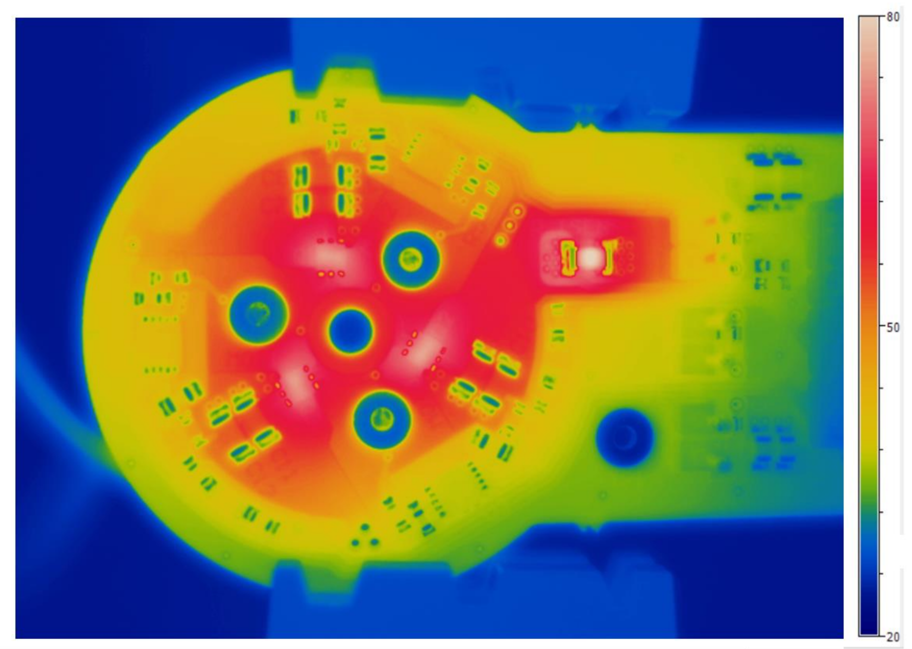

Figure 5. DDB094R2 Thermal Image.

As expected, the performance of the larger DDB099 was even better. When tested under the same conditions (Figure 6) using the same 77W input power level, the surface of the MOSFETs only reached 33°C, just 8°C above room temperature and far below the 175°C limit.

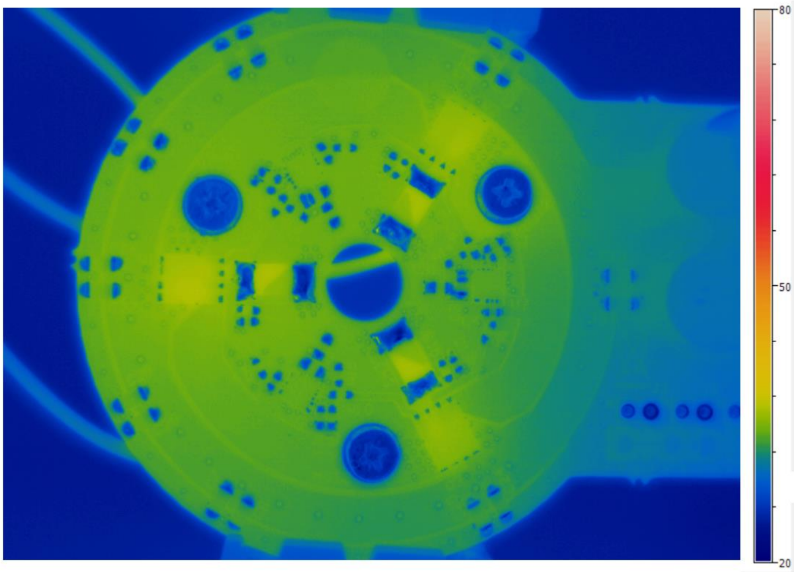

Figure 6. DDB099 Thermal Image with 77W Input Power

Even when the input power was increased further to 120W (24V, 5A) the surface temperature of the MOSFET was only 40°C (15°C above ambient), as shown in Figure 7.

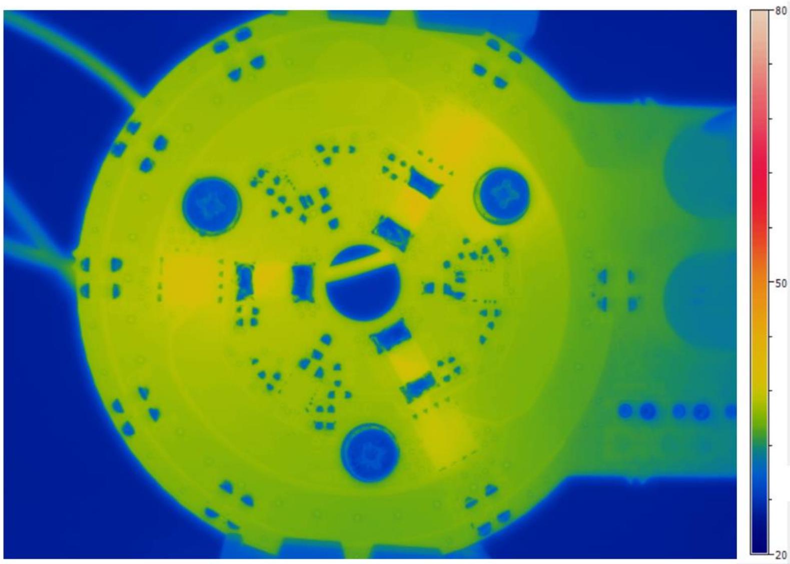

Figure 7. DDB099 Thermal Image with 120W input power

This improved thermal performance can be explained by the DDB099 having larger MOSFETs and a bigger PCB with four layers. The board layout takes advantage of the dual MOSFET package to allow for a compact design with large solid copper areas to provide good thermal performance. This design also minimizes loop areas and short switching nets also help to reduce EMI.

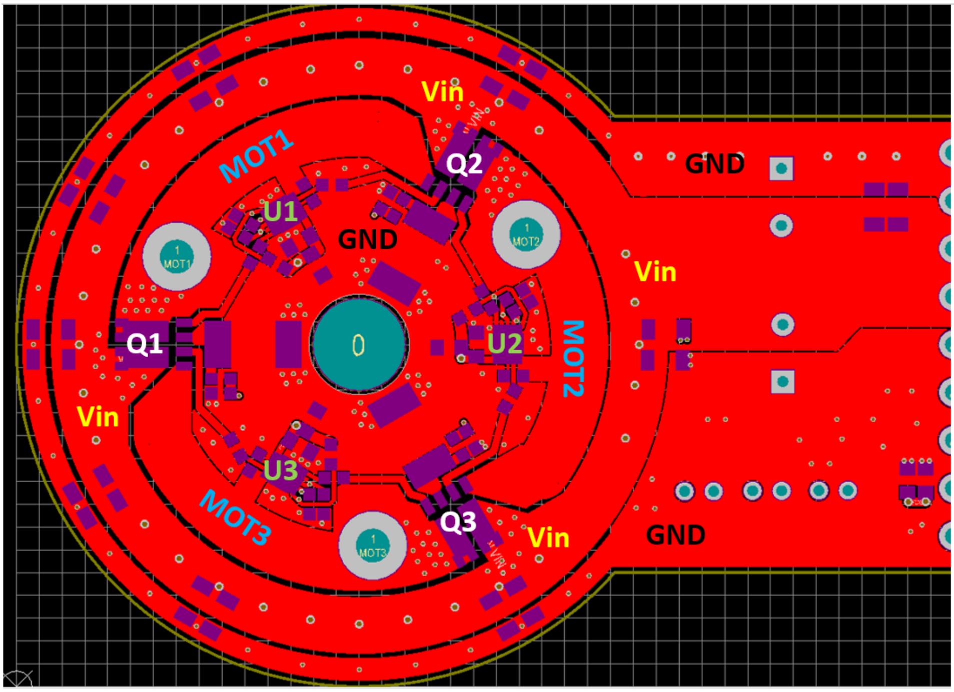

Figure 8. DDB099 Copper Areas Design.

The design of the copper areas with dual MOSFETs is shown in Figure 8. MOT1, MOT2, and MOT3 areas are shared between adjacent MOSFETs (i.e., MOT1 is Q2a and Q1b), simplifying the layout and enabling a larger copper area. This layout also provides shorter and neater routes to the gate drivers (U1, U2, U3). Following the circular pattern, V_{in} is arranged in a ring to connect to each of the MOSFETs in the same manner, and this is then surrounded by a ground line.

To improve EMC and thermal performance, the layout has a solid internal ground plane with additional power planes on the bottom layer. Another internal layer is used for signal routing and to provide grounding.

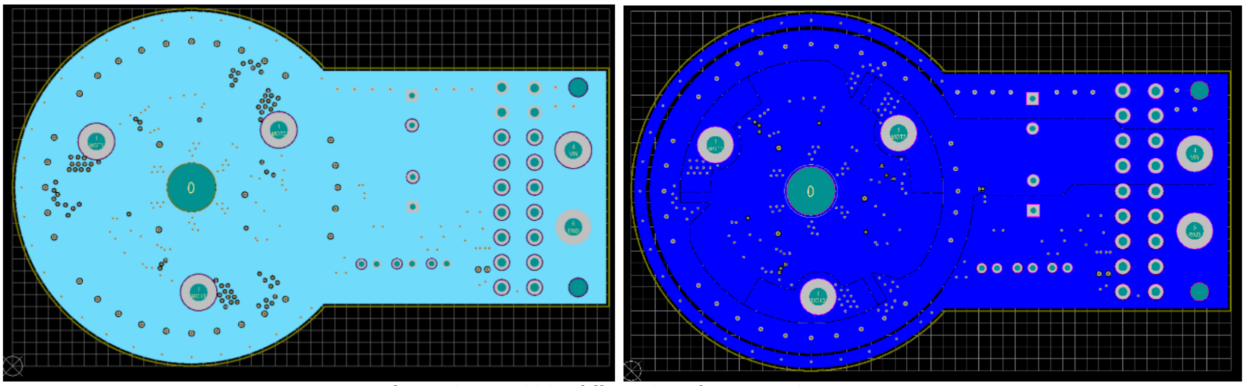

Figure 9. DDB099 Midlayer2 and Bottom Copper

The board layout also enables build flexibility, by allowing a choice of alternative MOSFETs and gate drivers according to the specific application requirements.

Input Voltage	**12V**	**24V**	**48V**
Gate Driver	DGD05473FNQ		DGD0579U
MOSFET	DMTH45M5LPDQ	DMTH6010LPDQ	DMTH10H017LPDQ

Conclusion

Diodes' dual MOSFETs and gate driver ICs are suitable for use with a wide range of DC motors of different sizes and power levels. The MOSFET packaging and PCB design offer optimized thermal dissipation, while the demo boards allow customers to evaluate the suitability of these devices for use in their own applications.

References

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Amar Chinchane, Onkar Sumant. *Brushless DC Motors Market by Rotor type (Inner Rotor, Outer Rotor), by Power range (0-750 W, 751 W-3 KW, More Than 3 KW), by Speed (Less Than 500 RPM, 501 To 2000 RPM, 2001 To 10, 000 RPM, More Than 10, 000 RPM), by End user (Industrial Machinery, Automotive, Healthcare, HVAC Industry, Power tools, Others): Global Opportunity Analysis and Industry Forecast, 2020-2030,* April 2022.

Link: https://www.alliedmarketresearch.com/brushless-dc-motors-market