DDB099R1
EVB User Guide

Quick Start:

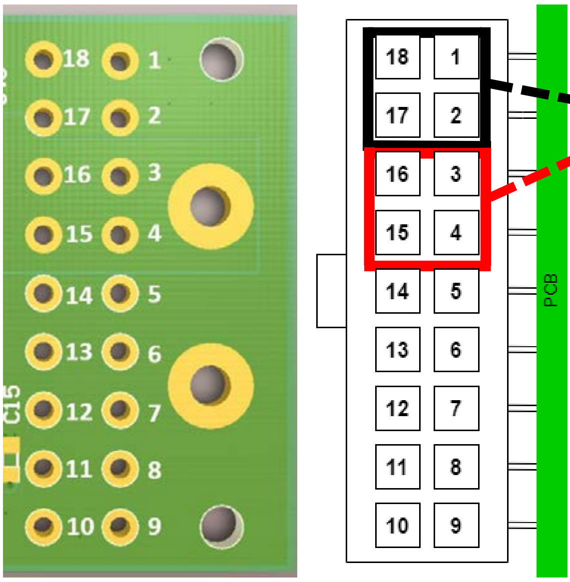


Figure 1: DDB099R1 Connector and Pin Number

Pin	Description
1, 2, 17, 18	Ground 0V
3, 4, 15, 16	Voltage Input, Vin (see table 2)
5	High-side Phase 1 input (SW1)
6	Low-side Phase 1 input (SW2)
8	Low-side Phase 2 input (SW4)
9	Gate driver supply Voltage VCC, Max = 14V
10	Low-side Phase 3 input (SW6)
11	High-side Phase 3 input (SW5)
12	Current sense output 3
13	Current sense output 2
14	Current sense output 1

Table 1: PCB Pin Legend

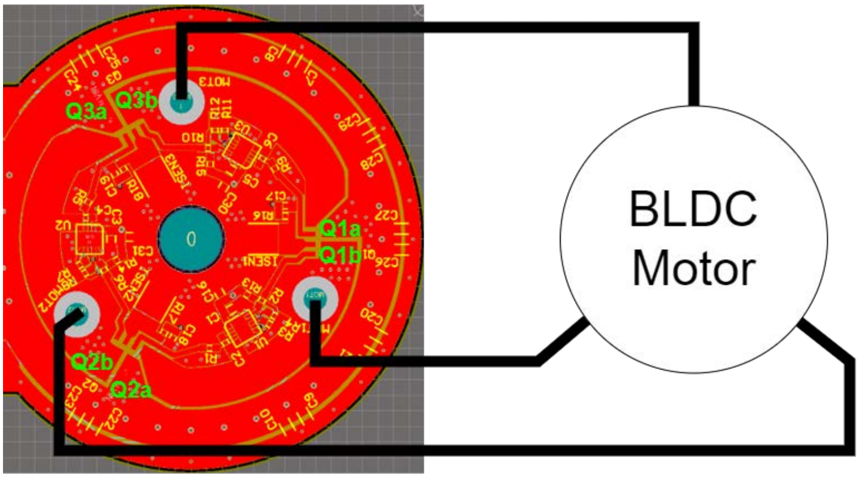


Figure 1: Motor Output Connections

1. Set channel 1 of the PSU to 12/24/48V (see table 2) and the current limit to 20A.
2. Set channel 2 of the PSU to 12V and the current limit to 0.3A.
3. Connect channel 1 to pins 3, 4, 15, 16 (Vin).
4. Connect channel 2 to pin 9 (Vcc).
5. Connect GND to pins 1, 2, 17, 18 and connect the ground of the PSUs together.
6. Pins 5, 6, 7, 8, 10, 11 are inputs from the microcontroller to drive the phases. The current sense pins (12, 13, 14) need to be connected to an analog input pin on the microcontroller. Ensure the MCU and the board have a common ground.
7. Connect the MOT1-MOT3 outputs to phases 1-3 of the motor respectively.

Description:

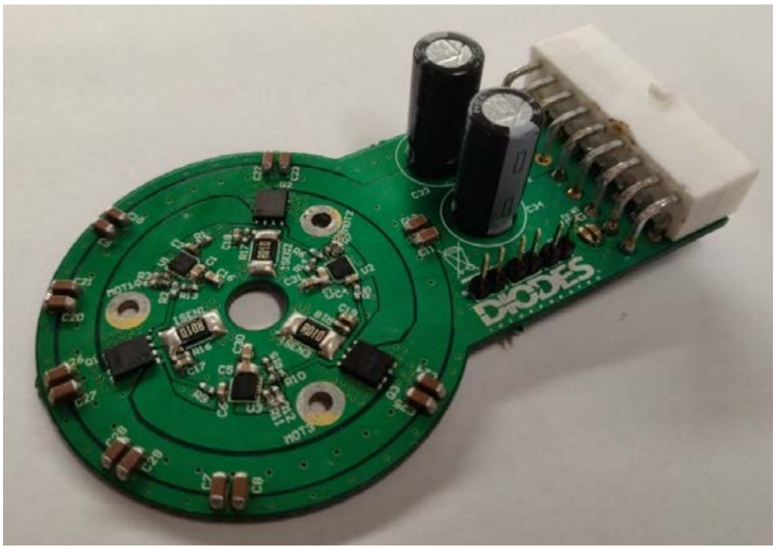


Figure 2: DDB099R1 Demo Board

The DDB099R1 demo board is a three-phase motor driver board with three high-side/low-side gate drivers and three dual N-channel MOSFETs in the PowerDI®5060 package. It is designed for driving three-phase brushless DC motors (BLDC motors) by taking input controls from a microcontroller or motor control IC. The PCB offers good thermal performance and can drive more than 20A maximum continuous current. See Table 2 for build variants for different voltage applications.

The dual N-channel MOSFETs come in the PowerDI5060 package, only 5mmx6mmx1mm. They offer remarkable power density, able to handle high continuous currents. The high- and low-side MOSFETs of each phase are driven by high-frequency high- and low-side gate drivers for N-channel MOSFETs. These devices can source 1.5A and sink 2.5A to ensure rapid and therefore efficient switching of the output devices and provides output gate drive voltage up to 14V to ensure that the MOSFETs are fully enhanced. Additionally, the internal logic prevents the high and low outputs being on at the same time. The logic inputs are MCU compatible.

The connector J4 provides access to power and input/output connections between the board, external microcontroller, and power source. J1-J3 headers can be used to disable the gate drivers. They are enabled by default and can be disabled by shorting the header pins.

The DDB099R1 demo boards are suitable for an input voltage range from 12V-48V depending on the components used and their ratings, which are shown in the table below:

Board Voltage Rating*	Suggested Automotive Use Input Voltage	Gate Driver	MOSFETs
40V	12V	DGD05473FNQ	DMTH45M5LPDWQ
60V	12/24V		DMTH6010LPDQ
100V	12/24/48V	DGD0579UFNQ	DMTH10H017LPDQ

Table 1: DDB099R1 Driver Board Component Legend for Different Input Voltages

*Note: 40V and 60V builds use 50V capacitors.

From here on, the boards will be referred to by their maximum voltage rating.

Description (continued):

The theoretical maximum continuous current the MOSFETs can conduct based on their $R_{DS(ON)MAX}$. The maximum power dissipation mentioned in their datasheets is shown in Table 3 and was calculated with the following formula:

$$I_{MAXCont} = \sqrt{\frac{P_{MAX}}{R_{DS(ON)MAX}}}$$

MOSFET	$R_{DS(ON)MAX}$	Maximum Power dissipation	$I_{MAXcont}$
DMTH45M5LPDWQ	5.5mΩ	3W	23.35A
DMTH6010LPDQ	11mΩ	2.8W	15.95A
DMTH10H017LPDQ	17.4mΩ	2.6W	12.22A

Table 2: Maximum Theoretical Current Rating

Figure 4 shows the layout of the switches in the three-phase half-bridge, which device each switch is part of, and the switching sequence required to drive a BLDC. Each device has two switches, and each switch is ON one third of the switching cycle. If each switch conducts the $I_{MAXcont}$ current value given in Table 3, during one rotation cycle the power dissipated in the device will average out at two thirds of the rated power of the device. This means that the MOSFETs can conduct higher than $I_{MAXcont}$ currents.

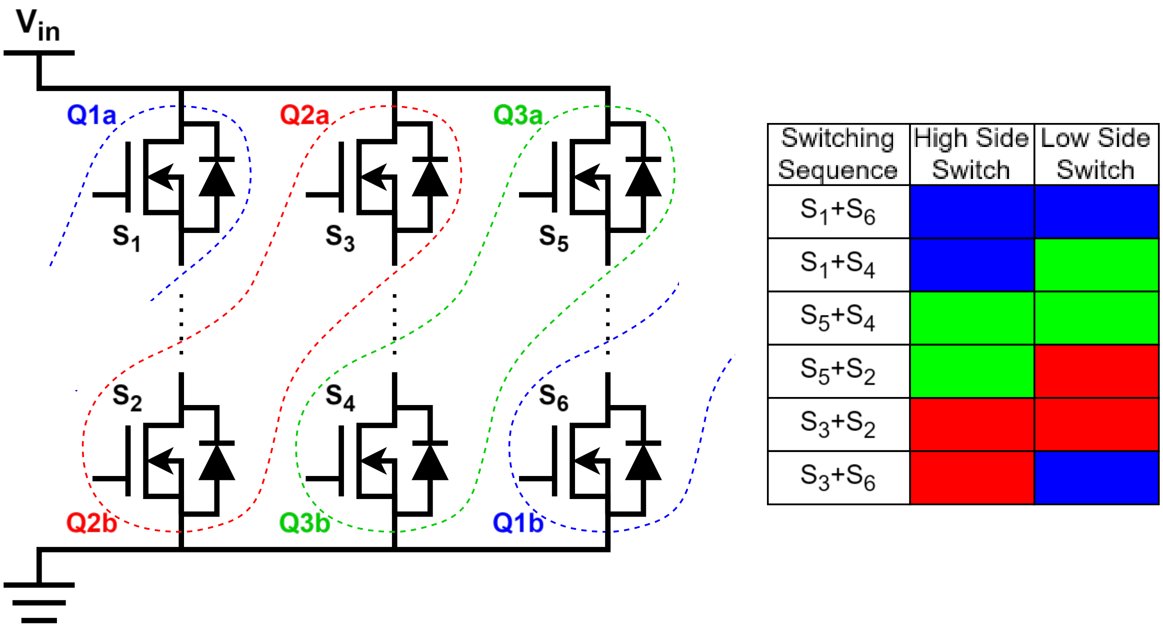


Figure 3: Component layout in the three-phase half-bridge and BLDC switching sequence

The MOSFETs' gate resistors were chosen accordingly to get the best performance. The gate resistance was selected to be 10Ω to optimise switching without excessive ringing.

Description (continued):

The gate voltage was measured during switching and the waveform obtained can be seen in Figure 5. Commutation and dead time control is handled by the external microprocessor.

Figure 4: MOSFET gate voltage

Thermal Performance:

Test Setup

The board was set up as detailed in the **Quick Start** part of this document for its thermal performance analysis.

Two MY1020D 48V, 5600 max RPM motors with Hall sensors and concentrated windings were used for the analysis: one of them was used as the actuator and the other as the load. The actuator and load motors were fixed to a metal base and their axles were linked together through a chain. The load that the actuating motor was driving could be adjusted by modifying the phase resistance on the load motor side and connecting them to a star point as shown in Figure 6. The inputs of the DDB099R1 demo board were connected to the power supply unit and an Arduino Mega 2560 that generates three PWM trapezoidal waveforms using the actuator motor's Hall effect sensor outputs as feedback. The outputs of the demo board were connected to the corresponding phases of the motor. A thermal camera was placed right above the demo board which allowed for the constant monitoring of the demo board's temperature.

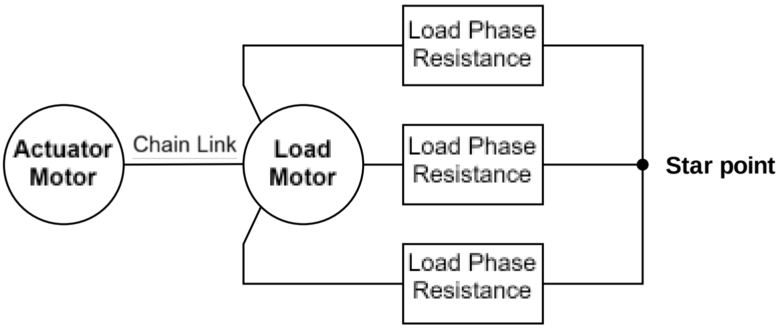


Figure 5: Actuator Load Representation

This setup was used to test the demo board configurations mentioned in Table 2. The 40V, 60V and 100V boards were tested at an input voltage of 12V, 24V and 48V respectively. To find the current rating of each board the load resistance had to be adjusted accordingly.

Thermal Performance (continued):

Test Procedure

The speed of the motor was increased to achieve an increase of the input current in increments of 1A every 2 minutes for the MOSFETs to reach a steady-state temperature which was then measured. By the time the maximum current was achieved the demo board would reach a steady-state maximum temperature. This test method is intended to show the reliability of the MOSFETs in extended continuous use. At every increment the following were measured: power supply unit input current $I_{in}(A)$ and temperature difference between warmest MOSFET and ambient temperature $\Delta T(°C)$. The relationship between ΔT and input current and ΔT power dissipated per MOSFET were plotted in Figure 7 and Figure 8 respectively using the recorded measurements.

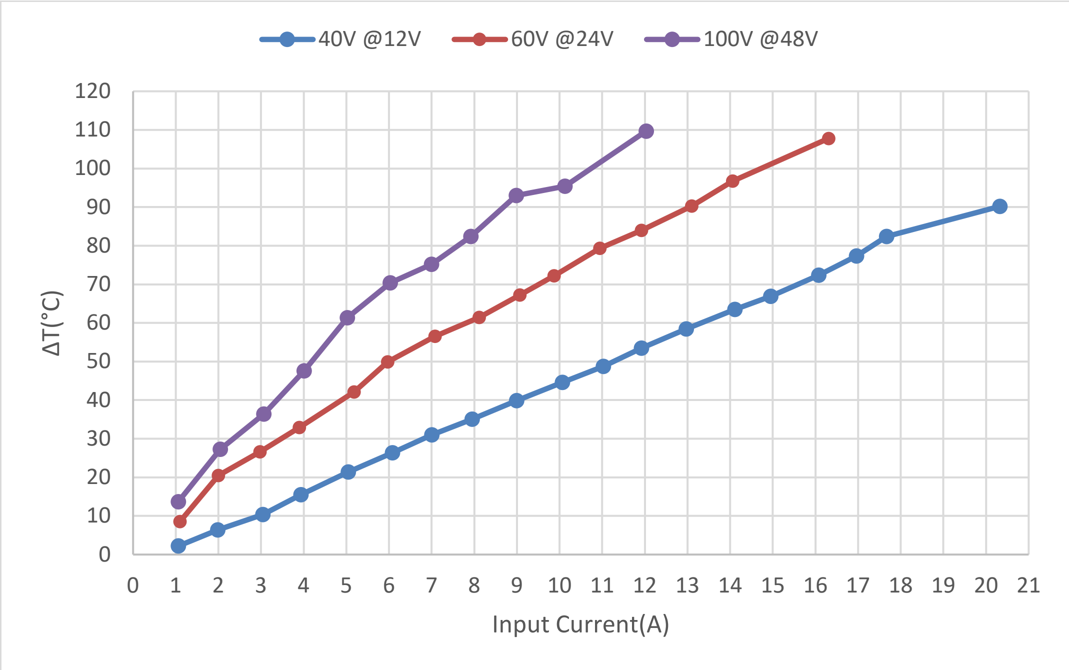


Figure 6: ΔT vs. Input current

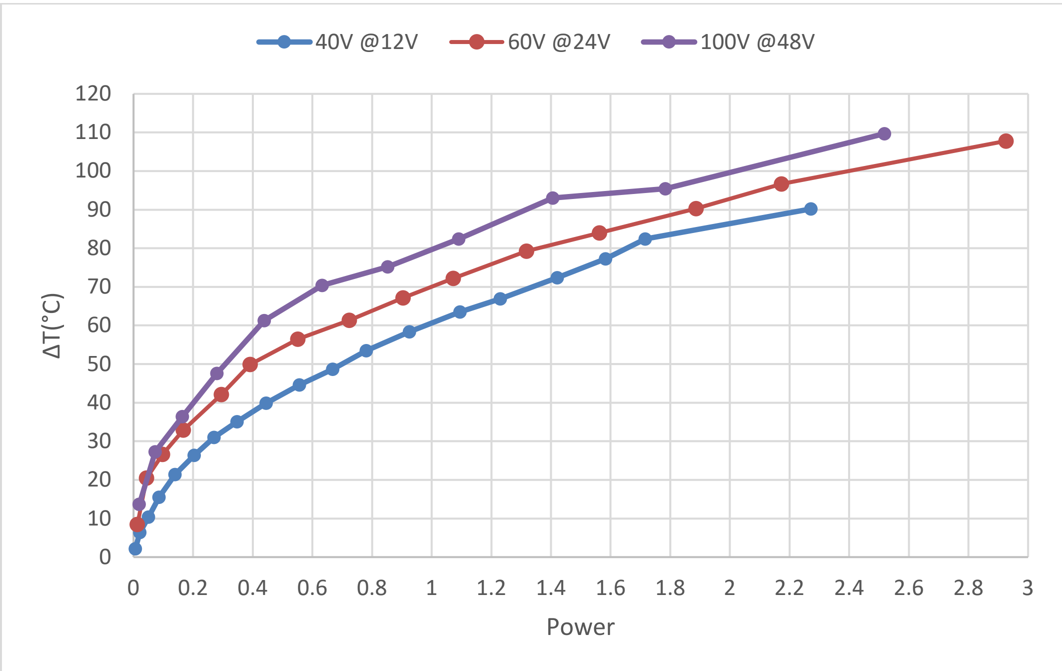


Figure 7: ΔT Vs Power dissipated per MOSFET

Thermal Performance (continued):

Table 4 shows the test conditions and their results:

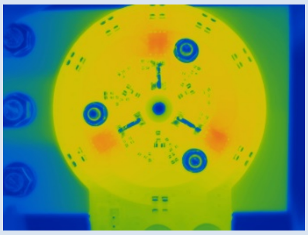
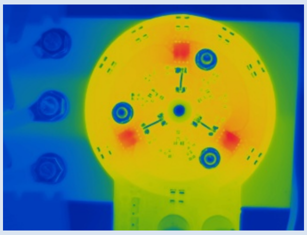
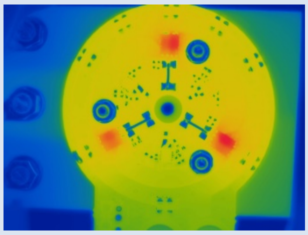
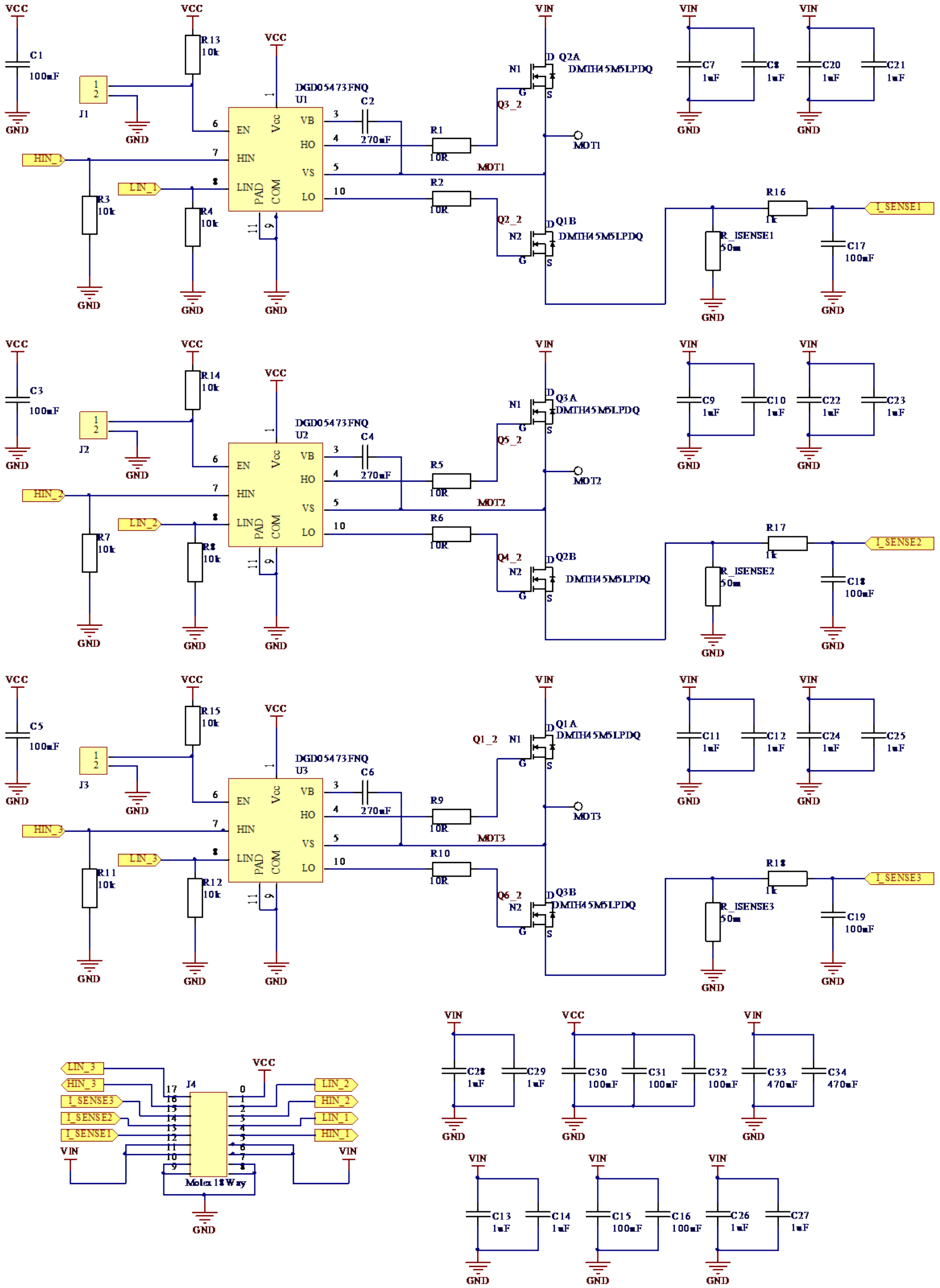
DDB099R1 Build	40V Board	60V Board	100V Board
Input Voltage	12V	24V	48V
Load Phase Resistance	0.3Ω	1Ω	5Ω
Cont. Current @T_A= 25°C	20.3A	16.31A	12A
T_{MAX}	115.2°C	129.8°C	129.7°C
Thermal Image After 15 minutes Continuous Running at Cont. Current			

Table 3: Thermal Testing Parameters and Results

Test Conclusions

The thermal images resulted from the tests show that the MOSFETs can easily handle the continuous current passing through them with some additional headroom up to the maximum rated temperature of the MOSFETs at 175°C. The 40V, 60V and 100V boards can now be determined to have conservative maximum current ratings of 20A, 15A and 10A respectively.

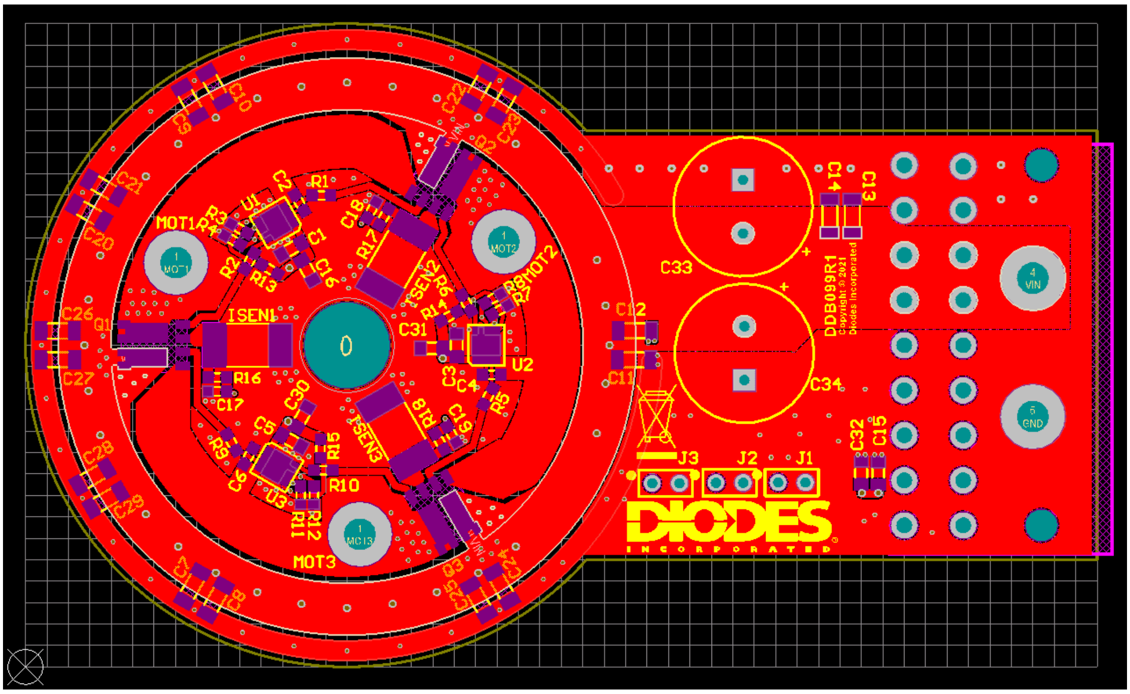
Schematic Diagram:



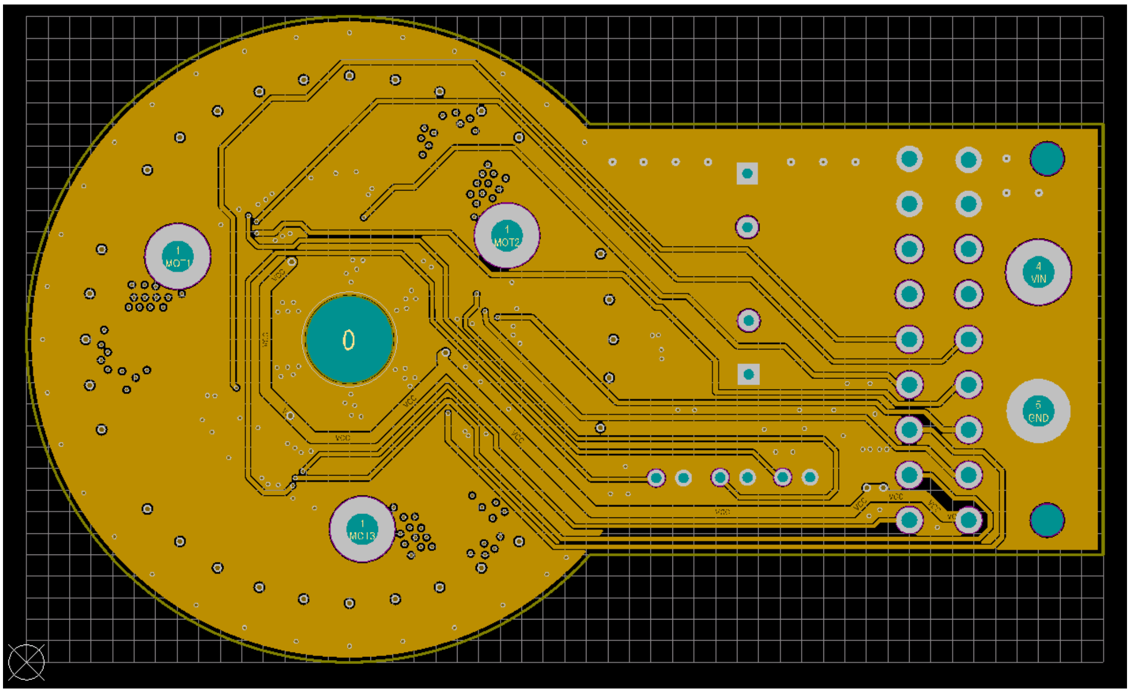
PCB Layout:

The DDB099R1 is a four-layer PCB on FR4.

Top layer:

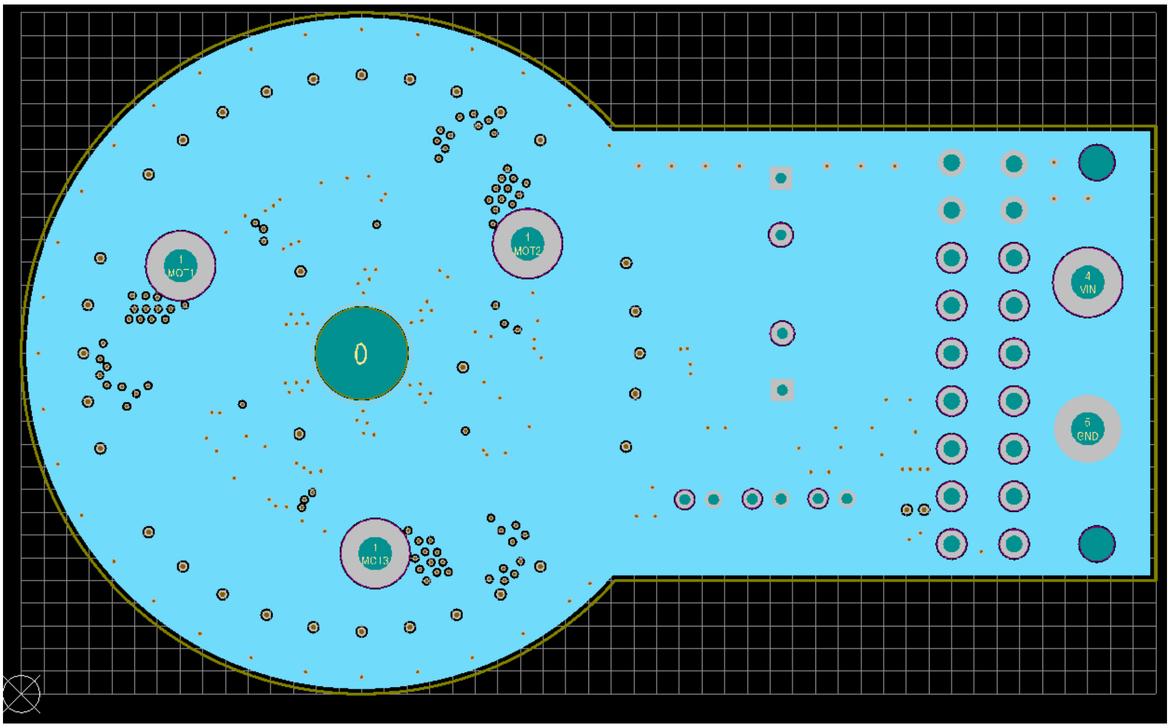


Mid layer 1:

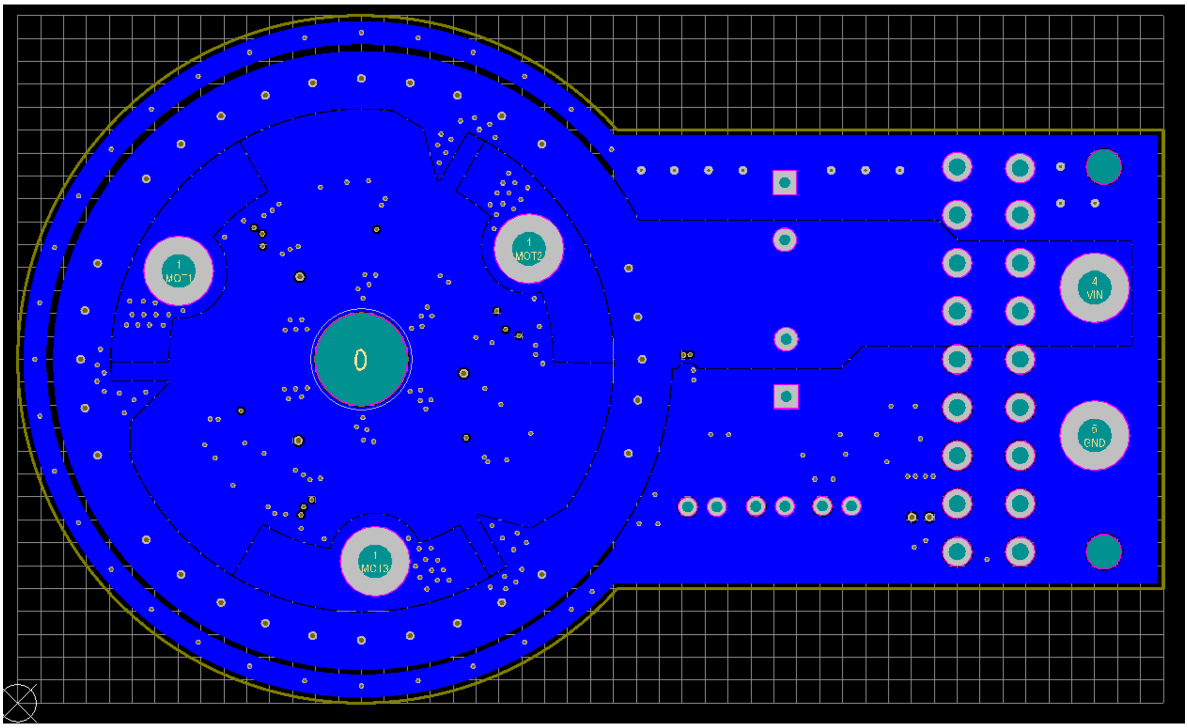


PCB Layout (continued):

Mid Layer 2:



Bottom Layer:



Bill of Materials:

Qty.	Indents	Description	Footprint
8	C1, C3, C5, C15, C16, C30, C31, C32	100nF X7R 50V(1) Ceramic SMD capacitor	0805
6	C2, C4, C6, C17, C18, C19	100nF X7R 50V(1) Ceramic SMD capacitor	0603
18	C7, C8, C9, C10, C11, C12, C13, C14, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29	1µF X7R 50V(1) Ceramic SMD capacitor	1206
2	C33, C34	470µF 50V(1) electrolytic capacitor	P5D13 ELEC
3	J1, J2, J3	2W Header	0.1" 2W
1	J4	Molex Type Header Connector	Molex_18_Way
3	Q1, Q2, Q3	DMTH45M5LPDWQ / DMTH6010LPDQ / DMTH10H17LPDQ	PowerDI5060
6	R1, R2, R5, R6, R9, R10	10R SMD Resistor	0603
9	R3, R4, R7, R8, R11, R12, R13, R14, R15	10k SMD Resistor	0603
3	R16, R17, R18	1k SMD Resistor	0603
3	R_ISENSE1, R_ISENSE2, R_ISENSE3	10m(2) SMD Resistor	2512
3	U1, U2, U3	DGD05473FNQ / DGD0579U	U-DFN3030-10

(1) Note: Capacitor voltage rating should be selected according to the application voltage
(2) Note: Current sense resistor should be selected based on application maximum current