TI Designs: TIDA-01493
Thermally Optimized, Two-Layer, 60-W Sensorless BLDC Motor Drive Reference Design

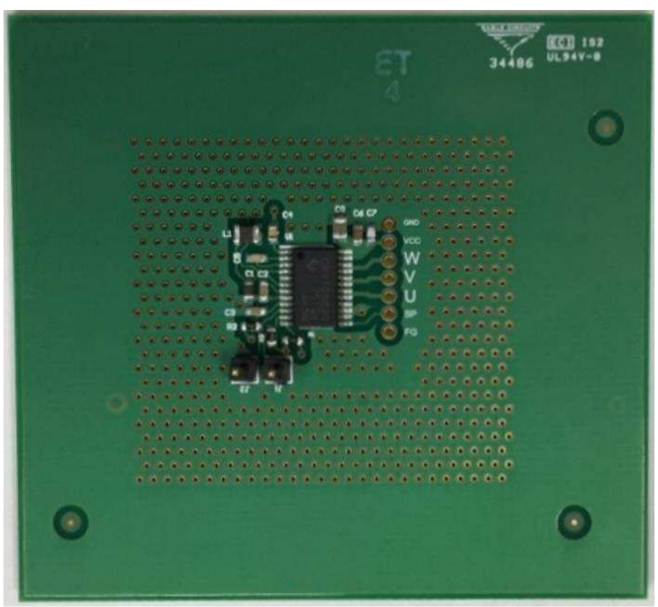
Description

This reference design is a sensorless brushless DC (BLDC) motor sinusoidal drive using the DRV10987 motor driver. The PCB is designed to lower the temperature of the DRV10987. The design targets cases that can over heat the DRV10987 or cases that need a low-case temperature due to material such as waterproofing on the case of the DRV10987. The end equipments that require this could be dryer fans, drain pumps, or air purifiers.

Resources

TIDA-01493	Design Folder
DRV10987	Product Folder
GUI	Software

TI E2E™ Community — ASK Our E2E™ Experts

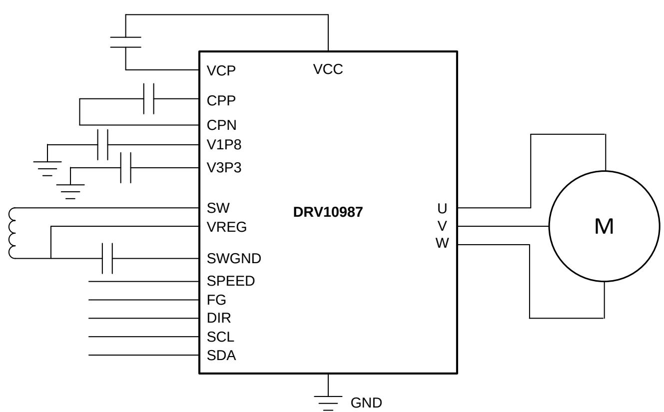


Features

- 12- to 24-V Drive Capable of Driving BLDC Motors With Sinusoidal Commutation
- Uses DRV10987 Three-Phase Sensorless Motor Driver With Integrated Power MOSFETs to Provide Continuous Drive Current up to 2.5 A (3-A Peak)
- DRV10987 Uses Proprietary Sensorless Control Scheme to Provide Continuous Sinusoidal Drive, Significantly Reducing Pure Tone Acoustics
- Integrated Buck Regulator Efficiently Step-Down Supply Voltage to Either 5.0 V or 3.3 V to Power Both Internal and External Circuits
- Board has Improved Thermal Characteristics, Allowing for Higher Ambient Temperature Operation
- Board Allows for Increased Efficiency of Driving Motors with DRV10987
- Programmable Motor Parameter Registers in EEPROM Using I^2C Interface With GUI

Applications

- Dryer Fans
- Drain Pumps
- Air Purifiers
- Pedestal Fans
- Ceiling Fans



1 System Description

This reference design is a thermally optimized, three-phase sinusoidal motor drive for brushless DC (BLDC) motors. The board accepts 12 to 24 V as input and provides the three motor phase outputs to drive the BLDC motor sinusoidally.

The PCB consists of two-sided copper with each having a thickness of 2 oz. The board dimensions are 2.5 inches by 2.3 inches with many thermal vias to effectively connect the two sides of the board.

The SPEED pin in the DRV10987 accepts either an analog or PWM input. The DRV10987 device provides motor speed measurement information on the frequency generator (FG) output or I^2C, which can be used to implement the speed control loop. The I^2C interface is also available as a header where an external graphical user interface (GUI) can be used to program the DRV10987 device. For this reference design, the GUI can be used to configure and tune the motor parameters.

The DRV10987 device is specifically designed for cost-sensitive, low-noise, low-external-component-count small motor applications. The DRV10987 device uses a proprietary sensorless control scheme to provide continuous sinusoidal drive, which significantly reduces the pure tone acoustics that typically occur as a result of commutation.

In applications such as drain pumps, air purifiers, and dryer fans, the PCB that drives these motors are typically covered in a sealant to protect the devices from being damaged in case of leakage or moisture accumulation. The sealant has a melting point that the case temperature of the device cannot exceed without making the board vulnerable. This reference design helps prevent the device from reaching that melting temperature through thermal optimization.

1.1 Key System Specifications

Table 1 lists the key system specifications for the DRV10987 device.

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS
DC input voltage	12 V to 24 V
Current	2.5-A continuous
Power level	Thermal design for up to 60 W
Control method	Integrated 180° sinusoidal control
Protection circuits	Overcurrent, lock detection, voltage surge protection, undervoltage lockout (UVLO) protection, thermal shutdown
Operating ambient	–40°C to +125°C

2 System Overview

2.1 Block Diagram

Figure 1 shows the system block diagram for this reference design. The system is supplied with a motor supply voltage of 12 V to 24 V, which goes to the DRV10987 device. The SPEED pin controls the speed of the motor through a voltage input. The speed input can be an analog voltage between 0 V and 3.3 V or a PWM signal. I²C connections are used to program the registers onto the DRV10987 and tune the motor settings.

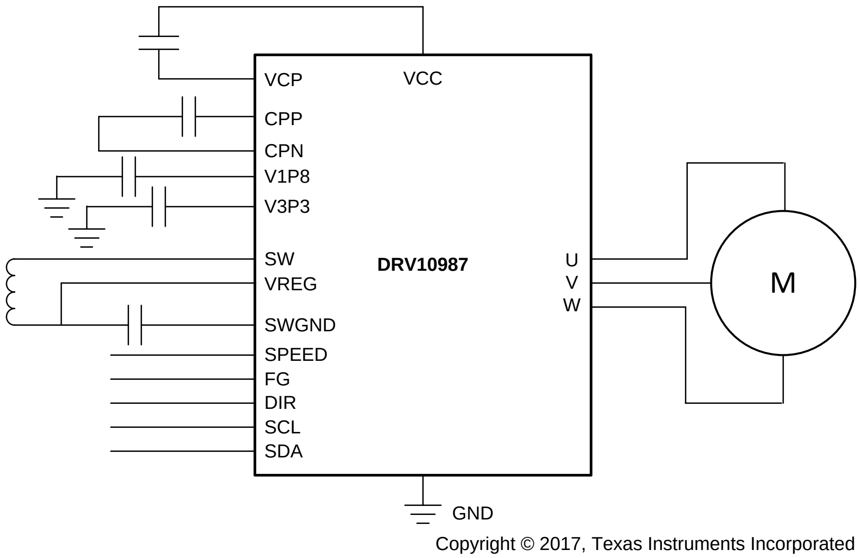


Figure 1. Block Diagram of TIDA-01493

The DRV10987 driver can be configured through the external GUI with the header available onboard.

2.2 Design Considerations

Table 2 shows the recommended components for the DRV10987 device to function as well as an addition capacitor in parallel with C_{VCC}. There are I^2C headers are used for GUI connection and EEPROM register programming. For compact board layouts, it is sufficient to use a smaller inductor for the buck regulator to minimize board footprint. Figure 2 and Figure 3 shows the design schematic and layout. Additional layout guidelines can be found on the DRV10987 datasheet.

Table 2. External Components

COMPONENT	PIN 1	PIN 2	RECOMMENDED
C1	VREG	GND	10-µF ceramic capacitor rated for 10 V
C2	V1P8	GND	1-µF ceramic capacitor rated for 5 V
C3	V3P3	GND	1-µF ceramic capacitor rated for 5 V
C4	VCP	V_{CC}	0.1-µF ceramic capacitor rated for 10 V
C5	CPP	CPN	10-nF ceramic capacitor rated for VCC ×2
C6	V_{CC}	GND	10-µF ceramic capacitor rated for VCC
C7	V_{CC}	GND	(DNP) 100-pF ceramic capacitor rated for VCC
C8	V_{CC}	GND	10-µF ceramic capacitor rated for VCC
R1	FG	V3P3	4.75-kΩ pullup to V3P3
R2	SCL	V3P3	4.75-kΩ pullup to V3P3
R3	SDA	V3P3	4.75-kΩ pullup to V3P3
L1	SW	VREG	47-µH ferrite rated for 1.15 A (inductive mode)

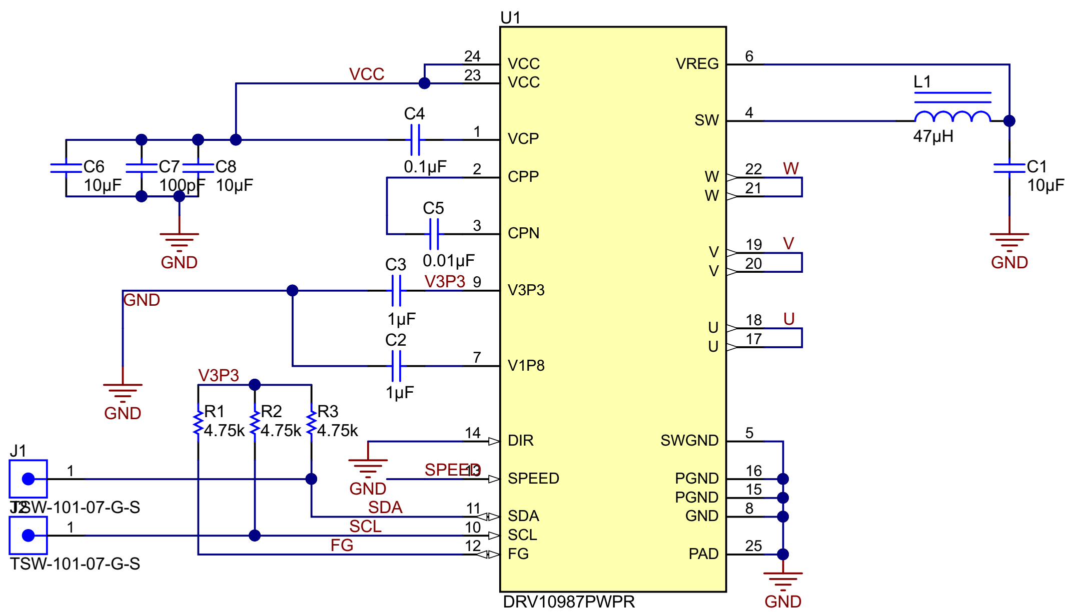


Figure 2. Reference Design Schematic

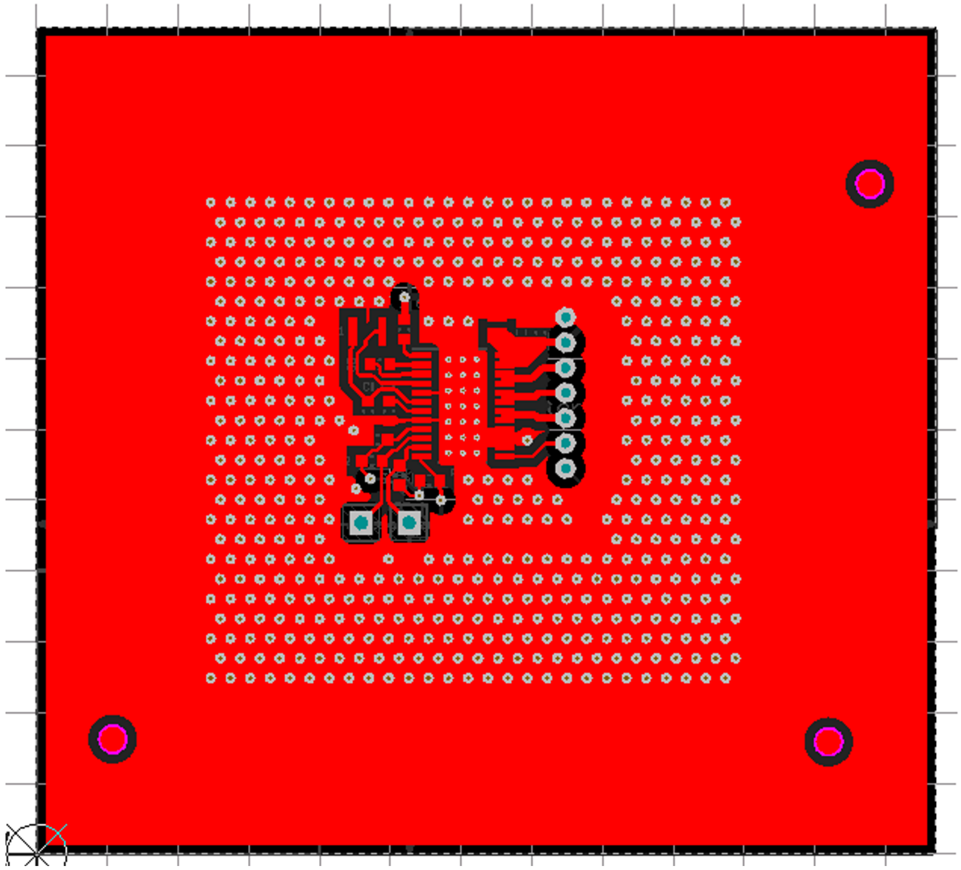


Figure 3. Reference PCB Layout

2.3 Highlighted Products

2.3.1 DRV10987

The DRV10987 device is a three-phase sensorless motor driver with integrated power MOSFETs, which can provide continuous drive current up to 2 A. The device is specifically designed for cost-sensitive, low-noise, low-external-component-count fan and pump applications.

The DRV10987 device preserves register setting down to 4.5 V and delivers current to the motor with supply voltage as low as 6.2 V. If the power supply voltage is higher than 28 V, the device stops driving the motor and protects the DRV10987 circuitry. This function is able to handle a load dump condition up to 45 V.

Device options include:

- DRV10987D: Sleep version
- DRV10987S: Standby version

The DRV10987 device uses a proprietary sensorless control scheme to provide continuous sinusoidal drive, which significantly reduces the pure tone acoustics that typically occur as a result of commutation. The interface to the device is designed to be simple and flexible. The motor can be controlled directly through PWM, analog, or I^2C inputs. Motor speed feedback is available through both the FG pin and the I^2C interface simultaneously.

The DRV10987 device features an integrated buck regulator to step down the supply voltage efficiently to 5 V for powering both internal and external circuits. The 3.3-V LDO also can be used to provide power for external circuits. The device is available in either a sleep mode or a standby mode version to conserve power when the motor is not running. The standby mode (8.5 mA) version (DRV10987S) leaves the regulator running and the sleep mode (48 µA) version (DRV10987D) shuts off the regulator. Use the standby mode version in applications where the regulator is used to power an external microcontroller.

An I^2C interface allows the user to reprogram specific motor parameters in registers and to program the EEPROM to help optimize the performance for a given application. The DRV10987 device is available in a thermally-efficient HTSSOP, 24-pin package with an exposed thermal pad. The operating ambient temperature is specified from –40°C to +125°C.

2.4 System Design Theory

The system design consists of only the DRV10987. The board is designed to maximize the heat dissipation of the device. The board is designed with 2-oz copper thickness and two layers. The board also uses thermal vias to effectively connect the GND planes and transfer heat between the layers.

Equation 1 shows how to calculate θ_{JA}, which is the constant the board tries to minimize through good layout techniques and thicker copper layers.

$$\theta JA = TJUNCTION-TAMBIENTPower\ Dissipation \tag{1}$$

Figure 4 shows the thermal resistance model for a typical PCB. This reference design is designed to minimize these resistances in the model above by using 2-oz copper as well as thermal vias. Another way to minimize these thermal resistances is to make sure traces are parallel to the flow of heat as to not block the flow of heat. Heat will flow radially from the heat source. For this design the heat source will be the pins and power pad of the DRV10987. Traces from the pins should go in the same direction as the pins and should not make sharp turns. From the power pad you should have thermal vias underneath that flow through the layers of board.

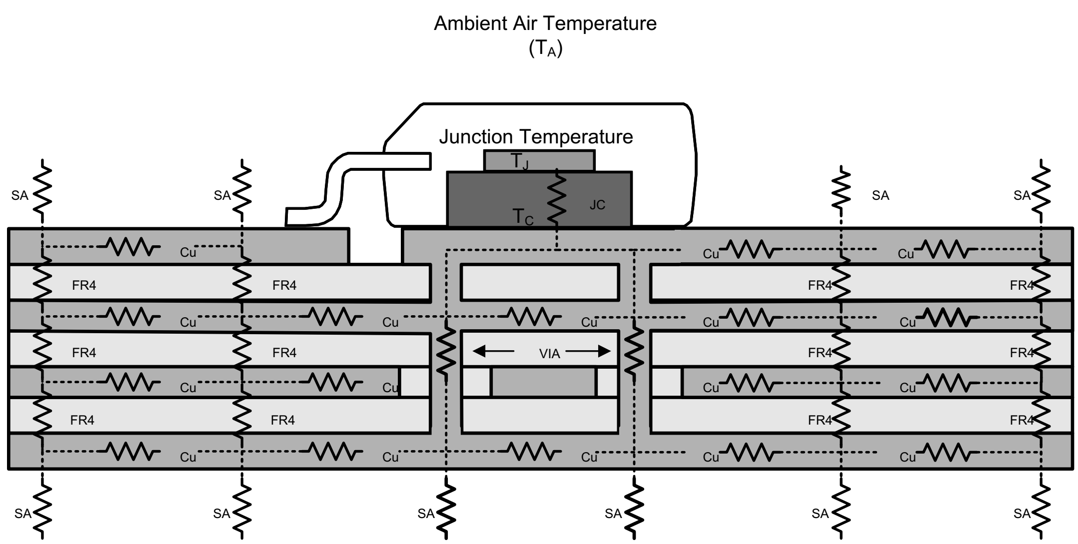


Figure 4. Thermal Model

[Figure 5](#) shows examples of three different PCBs with either no breaks in the thermal path, traces cut perpendicular to the heat flow, and traces cut parallel to the heat flow. If there are no breaks in the thermal path, the PCB has a more even heat distribution, leading to a better heat dissipation than the other two PCBs. If the traces are cut perpendicular to the heat flow, the PCB has a less even heat distribution than the first case, leading to a reduced heat dissipation. If the traces are cut parallel to the flow of heat, the PCB has worse heat distribution than the first example but better than the second example, leading to heat dissipation that falls between the two. This reference design uses thermal vias to allow paths around traces that run perpendicular to the flow of heat.

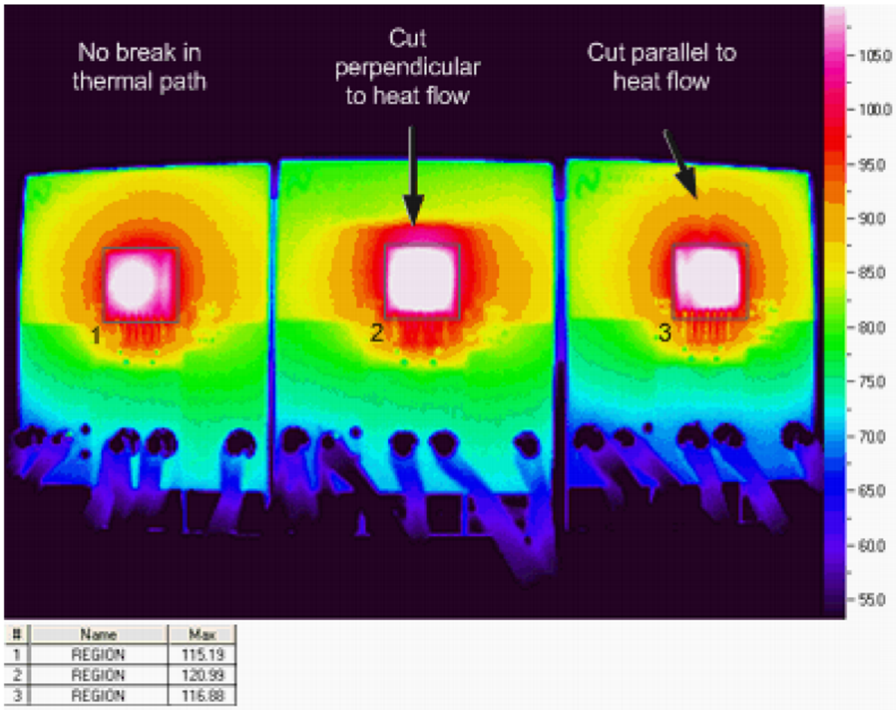


Figure 5. Effects of Blocked Thermal Path

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Required Hardware and Software

3.1.1 Hardware

This reference design is powered through the VCC input via and controlled using the SP input via. The SP pin refers to the SPEED pin that accepts either an analog or PWM input to control the speed of the motor. The vias marked U, V, and W refer to the phase winding inputs of a three-phase BLDC motor. J1 (SCL) and J2 (SDA) are used for I^2C communication with the motor driver.

To set up the system, connect a power supply capable of providing 12 to 28 V and 3 A using VCC. Note to turn on the power supply only when all connections are finalized. Then, connect another voltage source capable of providing 3.3 V using the SP pin. It is recommended to use a USB2ANY and the DRV10x Software GUI when communicating with the DRV10987 using I^2C. See Figure 6 and Figure 7 for more information when connecting to the system through I^2C.

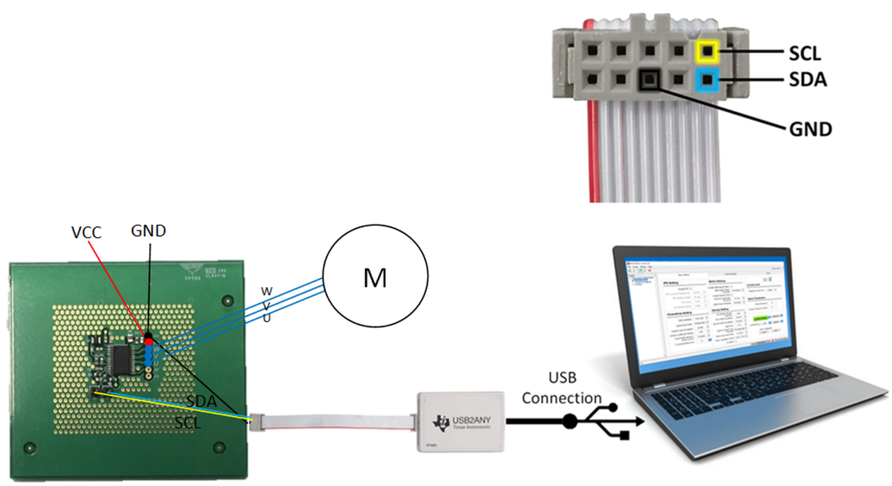


Figure 6. Setup for GUI—DRV10987 Programming

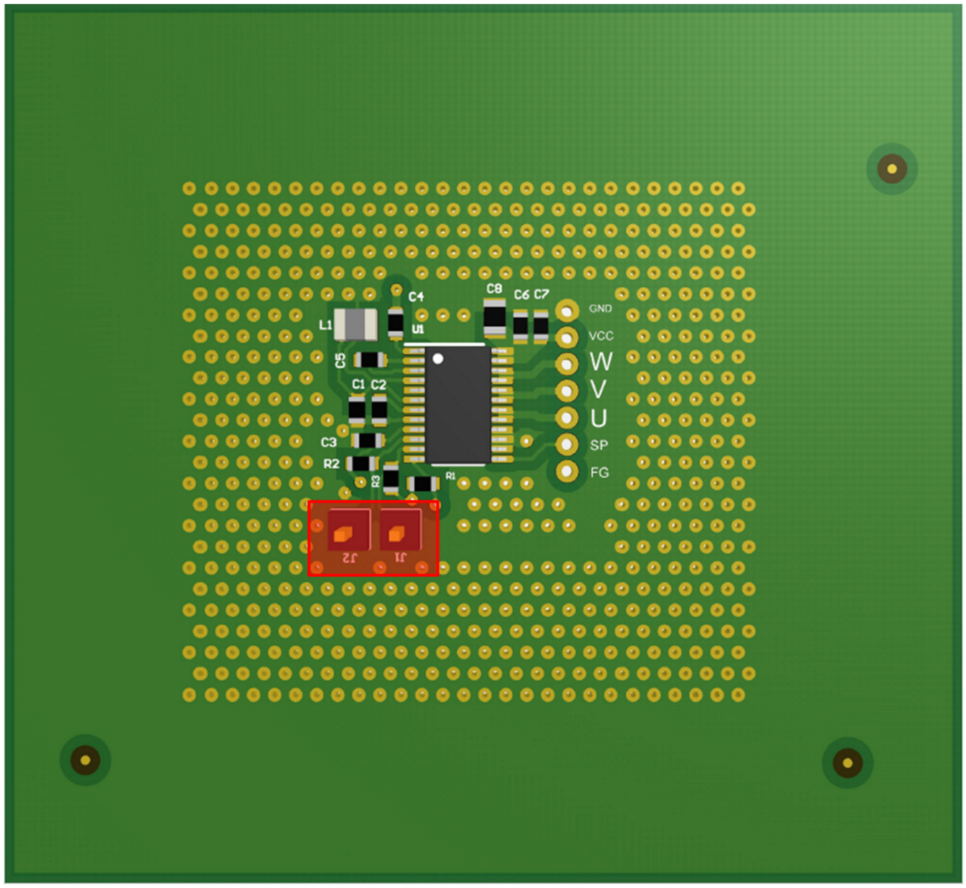


Figure 7. Hardware Setup for I ²C Communication

3.1.2 Software

The DRV10983-Q1 GUI was developed to communicate with the device to configure different registers within the device, and to understand the response based on the configurations. See the *DRV10983-Q1 Evaluation Module User's Guide* [2] for installation and available feature configurations.

3.2 Testing and Results

3.2.1 Test Setup

- Functional test:
  – Uses the GUI to show the functioning device with the reference design
- Thermal test:
  – Compares thermal performance of this reference design to the EVM performance

3.2.2 Test Results

3.2.2.1 Functional Test

Figure 8 shows the functional test of the DRV10987 device on the reference design during start-up. Channel 2 shows the phase voltage of the device, Channel 3 shows the VCC that the device is set to, and Channel 4 shows the phase current of the device.

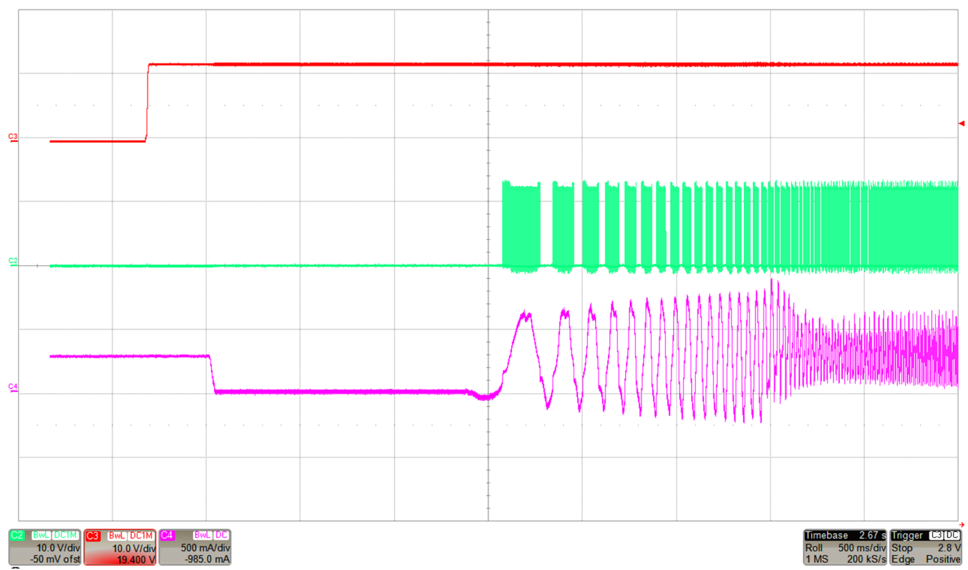


Figure 8. Driving Motor of TIDA-01493

3.2.2.2 Thermal Test

Figure 9, Figure 10, and Figure 11 show the thermal test results of the device running at 30 W, 32.5 W, and 50 W, respectively.

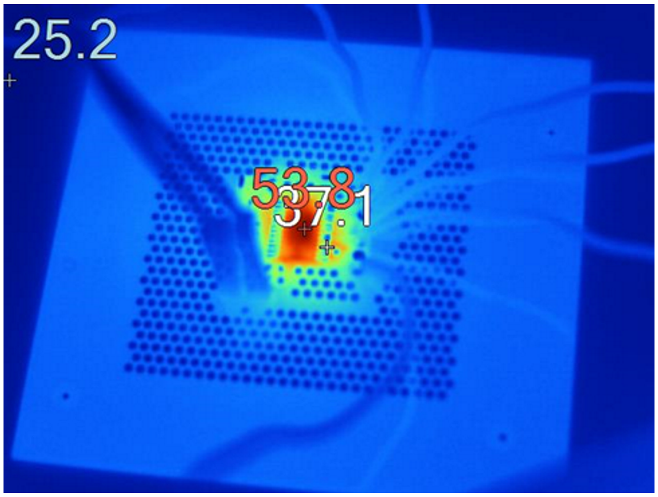


Figure 9. 53.8°C Top of Case Temperature Driving 30-W Load

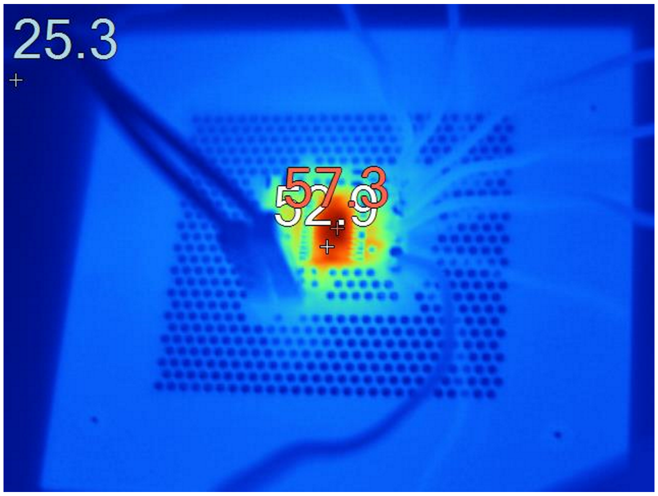


Figure 10. 57.3°C Top of Case Temperature Driving 32.5-W Load

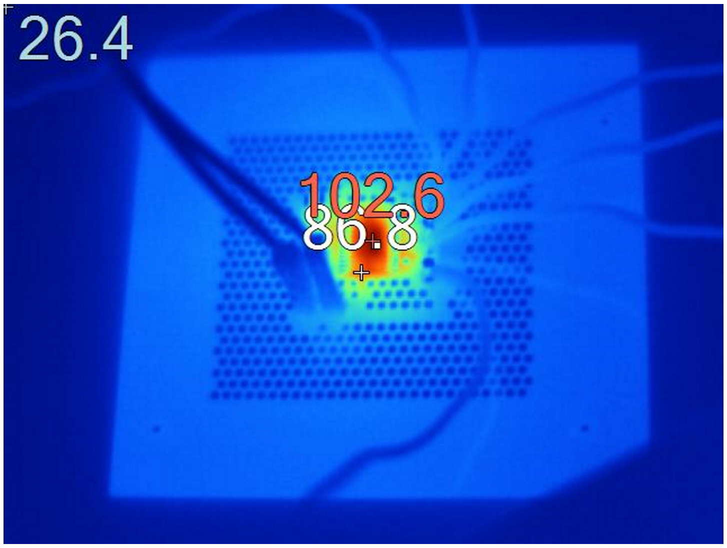


Figure 11. 102.6°C Top of Case Temperature Driving 50-W Load

Table 3 shows the thermal test results driving the motor at different speeds.

Table 3. Thermal Test Results

SPEED (RPM)	I RMS (A)	VOLTAGE (V)	TOP OF CASE TEMPERATURE (°C)	POWER (W)
6150	1.52	19.57	54.5	29.7464
6540	1.66	19.64	57.6	32.6024
6930	1.824	19.63	61.9	35.80512
7230	1.975	19.55	67.6	38.61125
7650	2.12	19.56	75.3	41.4672
8010	2.24	19.57	82	43.8368
8220	2.38	19.57	92.6	46.5766
8490	2.54	19.55	103.5	49.657
8820	2.65	19.5	116.5	51.675
9150	2.78	19.43	124.6	54.0154
9330	2.953	19.41	139.7	57.31773
9570	3.075	19.41	145.7	59.68575

4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDA-01493.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01493.

4.3 PCB Layout Recommendations

4.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-01493.

4.4 Altium Project

To download the Altium project files, see the design files at TIDA-01493.

4.5 Gerber Files

To download the Gerber files, see the design files at TIDA-01493.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-01493.

5 Software Files

To download the software files, see the design files at TIDA-01493.

6 Related Documentation

1. Texas Instruments, *DRV10983-Q1 Tuning Guide*
2. Texas Instruments, *DRV10983-Q1 Evaluation Module User's Guide*

6.1 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

7 Terminology

BLDC— Brushless DC

FETs, MOSFETs— Metal-oxide-semiconductor field-effect transistor

PWM— Pulse width modulation

UVLO— Undervoltage lockout

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