TI Designs

Single-Layer, Brushless-DC Motor Drive Reference Design for Pedestal Fans

Description

The TIDA-01223 is a BLDC motor sinusoidal drive reference design using the DRV10983 motor driver. This design specifically targets pedestal fans. By using this design, the designer has access to proprietary sensorless control and the ability to tune the motor parameters to achieve an optimal performance for the end application.

Resources

TIDA-01223	Design Folder
DRV10983	Product Folder

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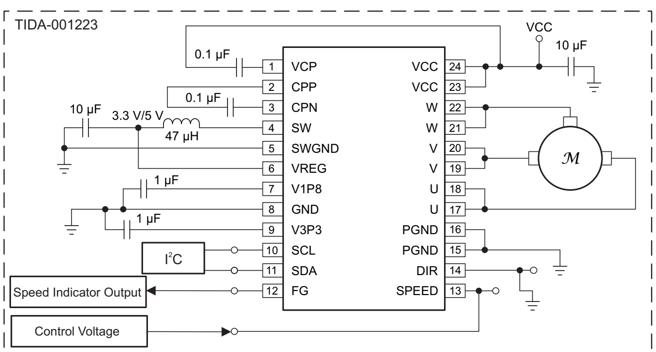
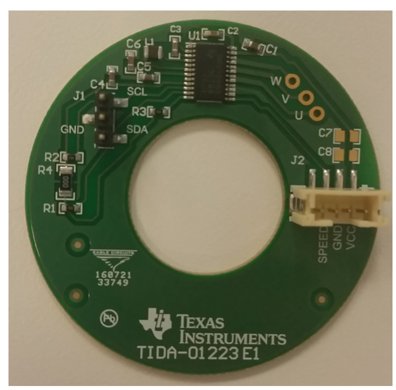
Features

- 24-V Drive Capable of Driving Brushless DC (BLDC) Motors With Sinusoidal Commutation
- Single-Layer Design Reduces Manufacturing Cost
- Uses DRV10983 Three-Phase Sensorless Motor Driver With Integrated Power MOSFETs to Provide Continuous Drive Current up to 2 A_{RMS} (3-A Peak)
- DRV10983 Uses Proprietary Sensorless Control Scheme to Provide Continuous Sinusoidal Drive, Significantly Reducing Pure Tone Acoustics (Typically Occurring as Result of Commutation)
- Integrated Buck and Linear Regulator Efficiently Steps Down Supply Voltage to 3.3 V to Power Both Internal and External Circuits
- I^2C Interface Allows User to Reprogram Specific Motor Parameters in Registers and Program EEPROM to Optimize Application Performance
- Extensive Protection and Fault Detection Mechanisms Ensure Reliable Operation

Applications

- Pedestal Fans





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1 System Overview

1.1 System Description

The TIDA-01223 reference design is a cost-effective, small-form-factor (SFF), single-layer, three-phase sinusoidal motor drive for brushless DC (BLDC) motors. The board accepts the 24 V at the input and provides the three motor outputs to drive the BLDC motor sinusoidally. A connector from the pedestal fan provides the control voltage that will go into the speed pin as well as the supply voltage of 24 V that moves into the VCC pin.

The DRV10983 device has a SPEED pin that accepts either an analog or pulse width modulation (PWM) input. The DRV10983 device provides speed information on the frequency generator (FG) output or I^2C. The I^2C interface is also available as a header where an external graphical user interface (GUI) can also be used for programming the DRV10983 device.

The integrated buck converter of the DRV10983 has been configured for a 3.3-V output, which is capable of powering both internal and external circuits. The optimum motor spin-up profile can be achieved by tuning all of the applicable configuration parameters inside the EEPROM of the DRV10983 device.

A pedestal fan is a common household item which functions to cool the air in a closed environment. Pedestal fans are available in multiple sizes, various power levels, and control levels. The DRV10983 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.

At the time of this publication, permanent magnet BLDC motors continue to gain importance because of their high efficiency, low maintenance, high reliability, low rotor inertia, and low noise as compared to their brushed motor counterpart. A permanent magnet BLDC motor has a wound stator, which is a permanent magnet rotor assembly. These motors generally use internal or external devices to sense the rotor position. The sensing devices provide logic signals for electronically switching the stator windings in the proper sequence to maintain rotation of the magnet assembly. The DRV10983 device is an electronic drive that uses sinusoidal control to drive the BLDC motor.

1.2 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS
DC input voltage	12 V to 24 V
Phase current rating	2-A_{RMS} (3-A Peak)
Analog speed input	1.23 V to 3.69 V
Operating ambient temperature	–40°C to 125°C
Protections	Overcurrent protection, motor lock detect, voltage surge, overtemperature protection, and undervoltage lockout

1.3 Block Diagram

Figure 1 shows the block diagram of the TIDA-01223 system. The system is supplied with a motor supply voltage of 24 V and a control voltage that varies with the speed setting (from the pedestal fan through an onboard connector), and the DRV10983 device is used to drive the BLDC motor. If applying voltage to VCC and SPEED externally using a power supply, the user must solder wires to the appropriate pins of the male receptacle.

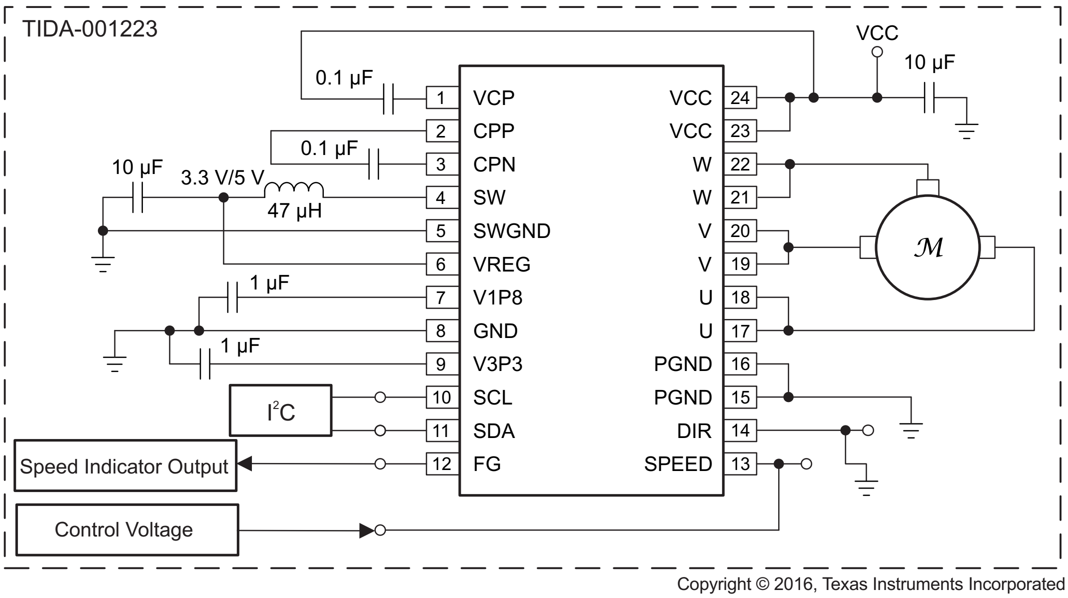

Figure 1. TIDA-01223 Block Diagram

The DRV10983 driver can also be configured through the external GUI with the header available onboard.

1.4 Highlighted Products

The key features of the highlighted device is available in its respective data sheet. The following subsection details the highlighted product used in the reference design.

1.4.1 DRV10983

The DRV10983 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, and low external-component count applications.

The DRV10983 driver 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 has been designed to be simple and flexible. The motor can be controlled directly through the PWM input, analog input, or I^2C inputs. The motor speed feedback is available through either the FG pin or I^2C interface.

The DRV10983 driver features an integrated buck and linear regulator to efficiently step down the supply voltage to either 5 V or 3.3 V for powering both internal and 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 (3-mA) version leaves the regulator running and the sleep mode (180-µA) version shuts it off. Use the standby mode version in applications where the regulator is used to power an external microcontroller (MCU).

An I^2C interface allows the user to reprogram specific motor parameters in registers and program the EEPROM to help optimize the performance for a given application. The DRV10983 is available in a thermally-efficient HTSSOP, 24-pin package with an exposed thermal pad. The operating temperature is specified from –40°C to 125°C.

2 System Design Theory

The block diagram in the preceding Figure 1 shows the complete system and its major sections.

2.1 Motor Drive Section

Figure 2 shows the motor drive section for the DRV10983.

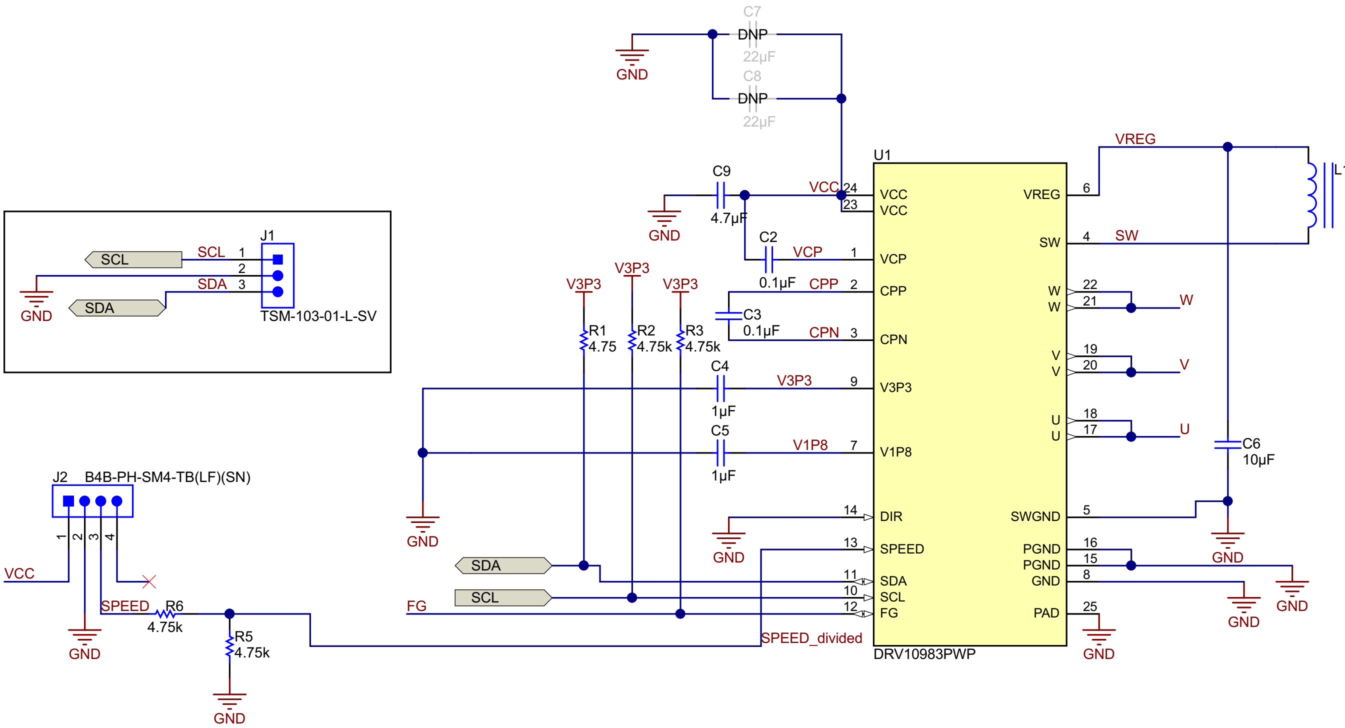

Figure 2. DRV10983 Motor Drive Schematic

J1 is the header where the user can connect the GUI to configure the DRV10983 EEPROM. J2 is the input connector that receives the input bus voltage as well as the control voltage.

Capacitors C7 and C8 are designated as do not place (DNP) so that the designer can solder their choice of the bypass capacitor to shunt noise and ripple from the power supply. Note that if the ripple is more than 200 mV, TI recommends the designer to add bulk capacitance (package reference 0805) in addition to the local decoupling capacitors. If a bulk capacitor has been used, the local ceramic capacitor can be reduced to 1 µF.

The direction pin is tied to ground; however, the motor direction can still be changed by switching the phase wires. Three pullup resistors are present for the SDA, SCL, and FG signals for the purpose of limiting current. The VCC, GND, U, V, and W pins require thick traces in the layout because high current passes through them. The capacitor between VCC and GND, in addition to the capacitor between CPP and CPN (charge pump), must be placed as close as possible to the pins of the IC. The GND, PGND, and SWGND pins are connected under the thermal pad.

2.2 Thermal Design

Proper thermal design is crucial for the safe and reliable operation of semiconductors. The operation of a semiconductor at a higher operating temperature leads to a reduction in the safe operating area and can result in failure or reduce the life of the device.

The goal of the thermal design is to limit the junction temperature of the switches inside the DRV10983 motor drive within the safe values. The data sheet specifies that the insulated-gate bipolar transistor (IGBT) has a maximum junction temperature rating of 150°C. This specification indicates that the user must design a heat dissipation area to account for this limit when operating at the full-load capacity.

2.3 Single-Layer PCB Design

The single-layer PCB has been designed with a small form factor to reduce manufacturing costs.

3 Getting Started Firmware

For GUI usage and tuning, refer to the *DRV10983 and DRV10975 Tuning Guide* (SLOU395).

4 Testing and Results

Figure 3 shows the top view of the TIDA-01223 Rev E1 board. Figure 4 shows the test setup image.

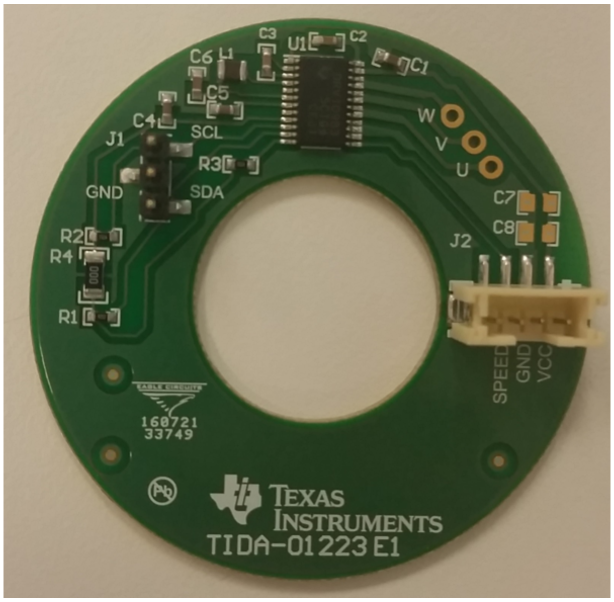

Figure 3. Assembled TIDA-01223 Rev E1 Board

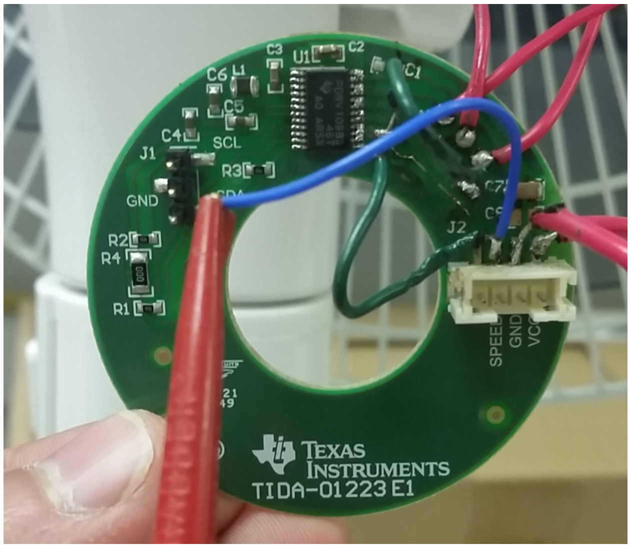

Figure 4. Test Setup

4.1 Functional Test—Spinning Pedestal Fan

For this test, the female connector from the pedestal fan that supplies VSP, GND, and VCC was connected to the male header on the reference design board. The power cord from the pedestal fan was then attached to the wall, which begins to supply the bus voltage of 24 V.

A GUI was used during functional testing of the board to configure the parameters for the DRV10983 devices to spin the specific motor.

The following images specify the configuration of parameters for the tested motor.

Start-up with initial position detection (IPD):

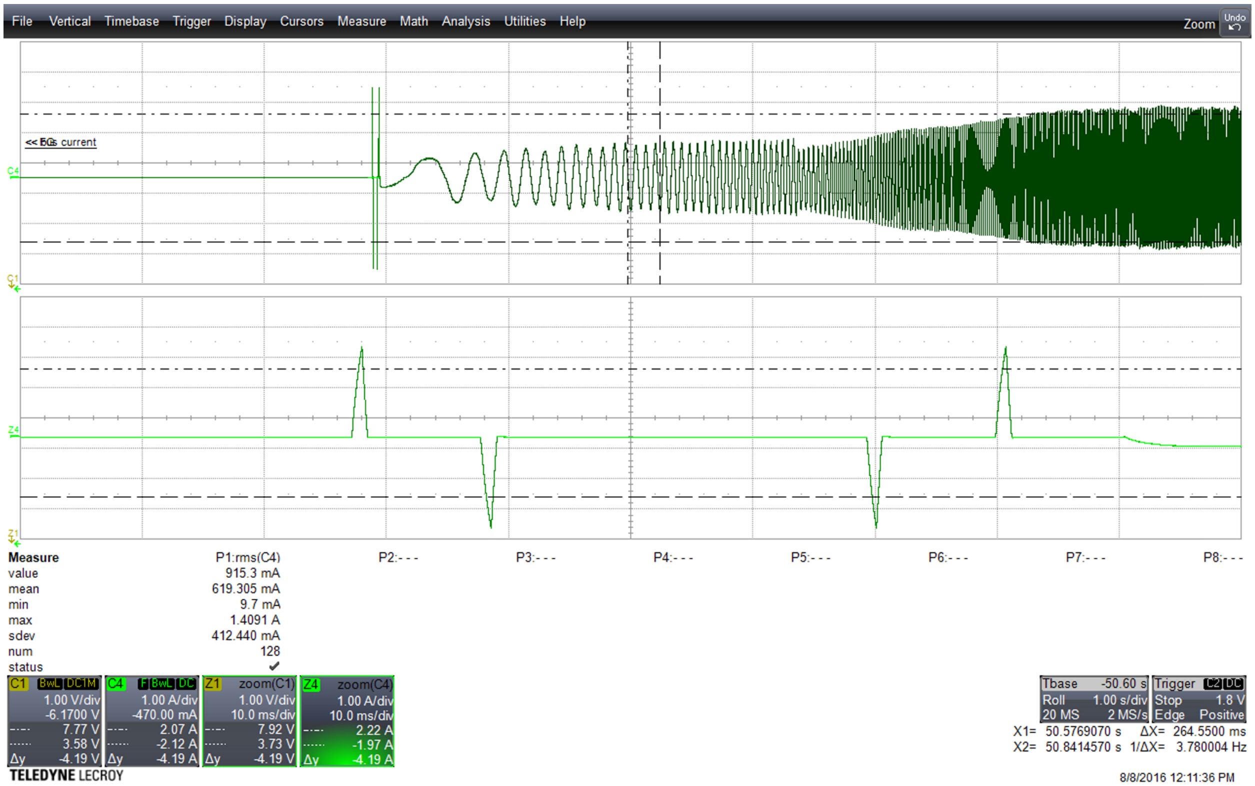

Figure 5. Start-up Profile

Run time:

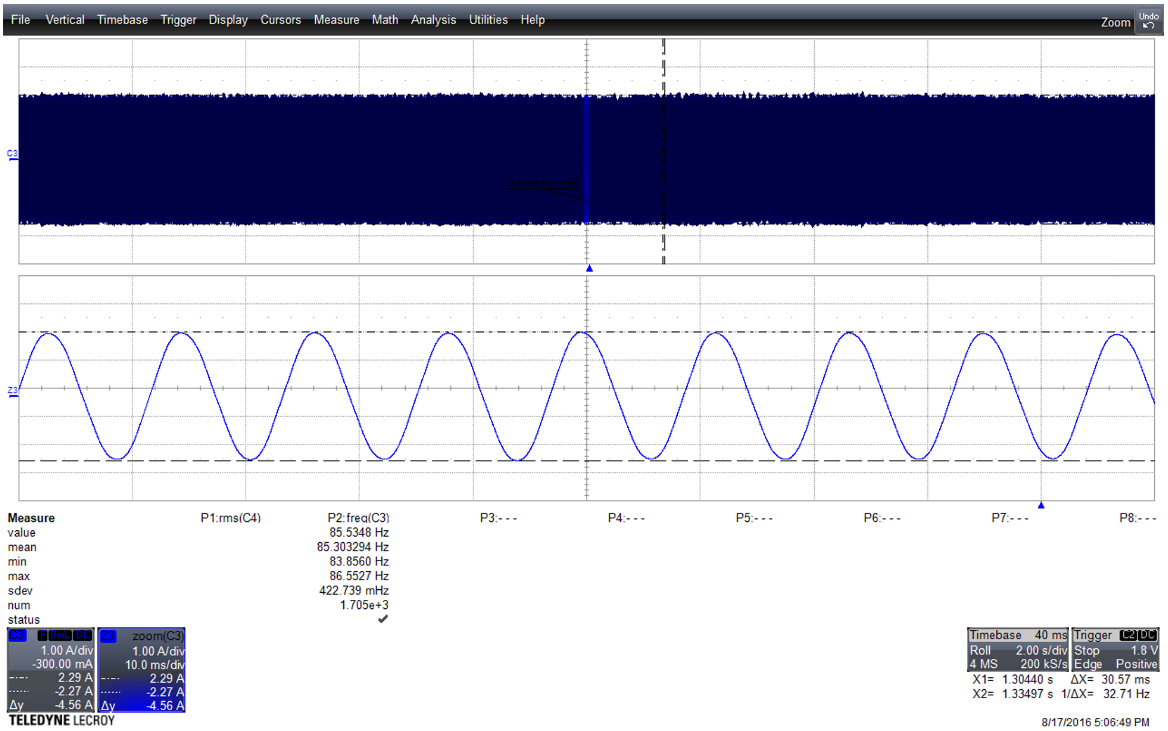

Figure 6. Run Time at 24 V, Speed 86 Hz

Acceleration:

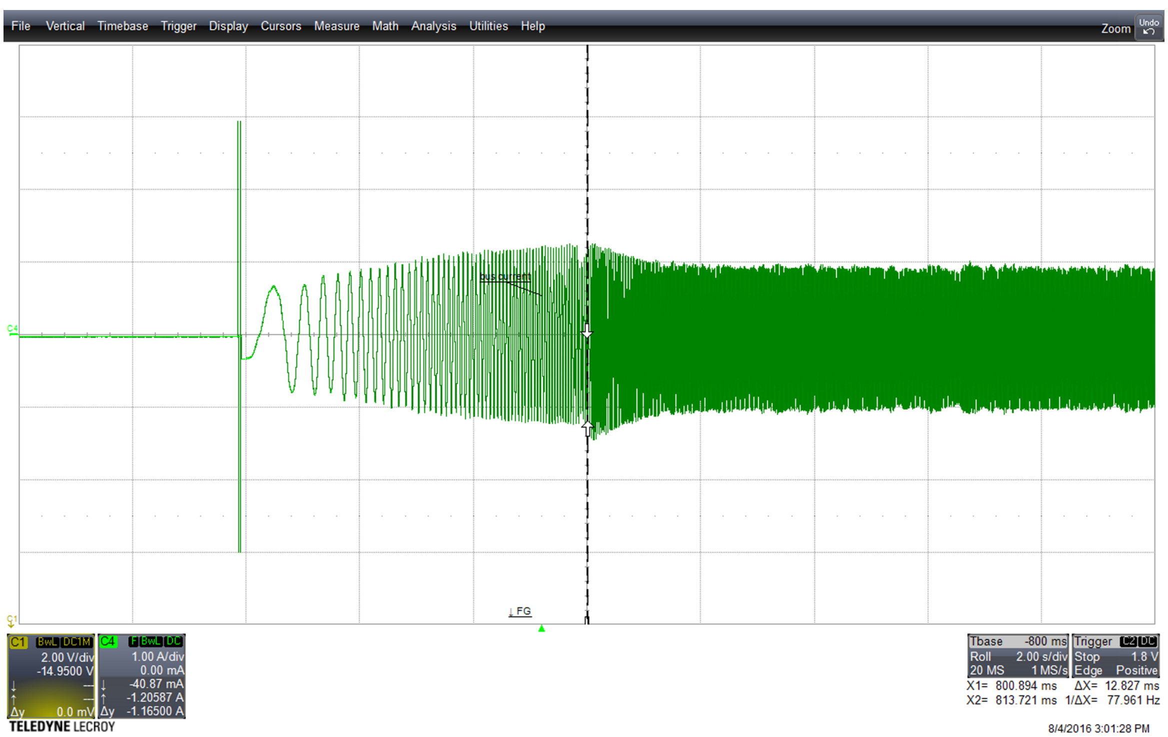

Figure 7. Acceleration

Deceleration:

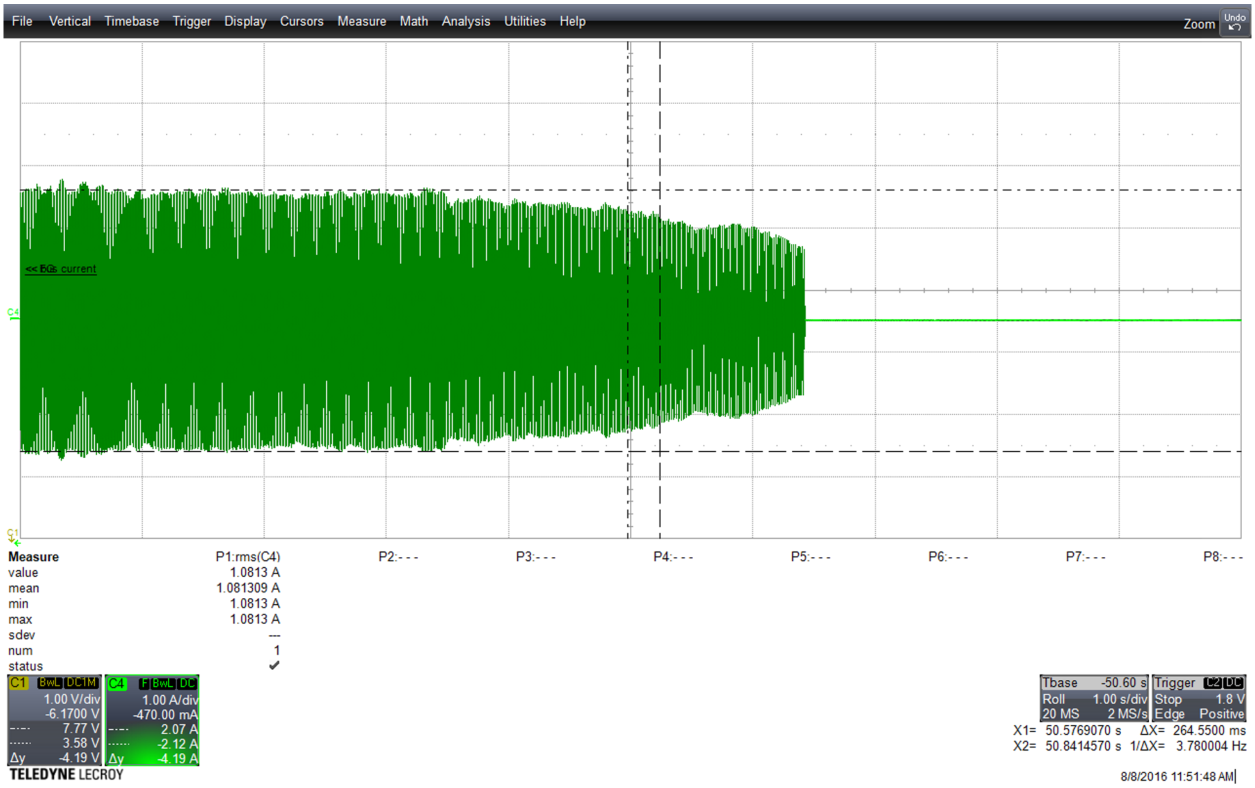

Figure 8. Deceleration

4.2 Thermal Test

Figure 9 shows the thermal characterization images of the TIDA-01223 board during the testing, which was conducted at full speed.

The test was conducted with the following specifications:

- Input voltage: 24 V
- Current drawn: 1.89 A_{RMS}
- Speed: 88 Hz
- Run time: 20 min
- Power consumption: 41 W

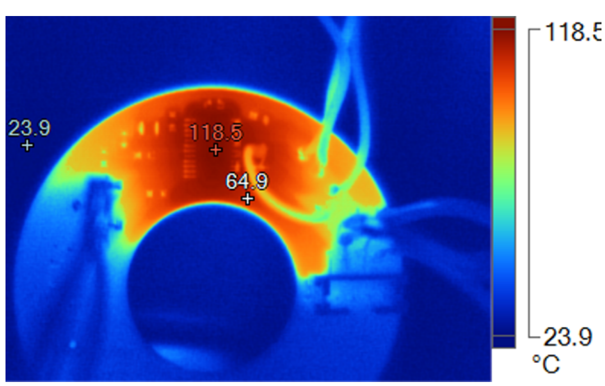

Figure 9. Thermal Image—Top Side

4.3 Speed Control Test

The PWM duty is modified after reading the speed from the DRV10983 device over I^2C. To check the speed regulation, the input control voltage was modulated from 1.23 V to 3.69 V and the speed was measured. The measurements in the following Figure 10 clearly show a quick ramp-up to the maximum speed.

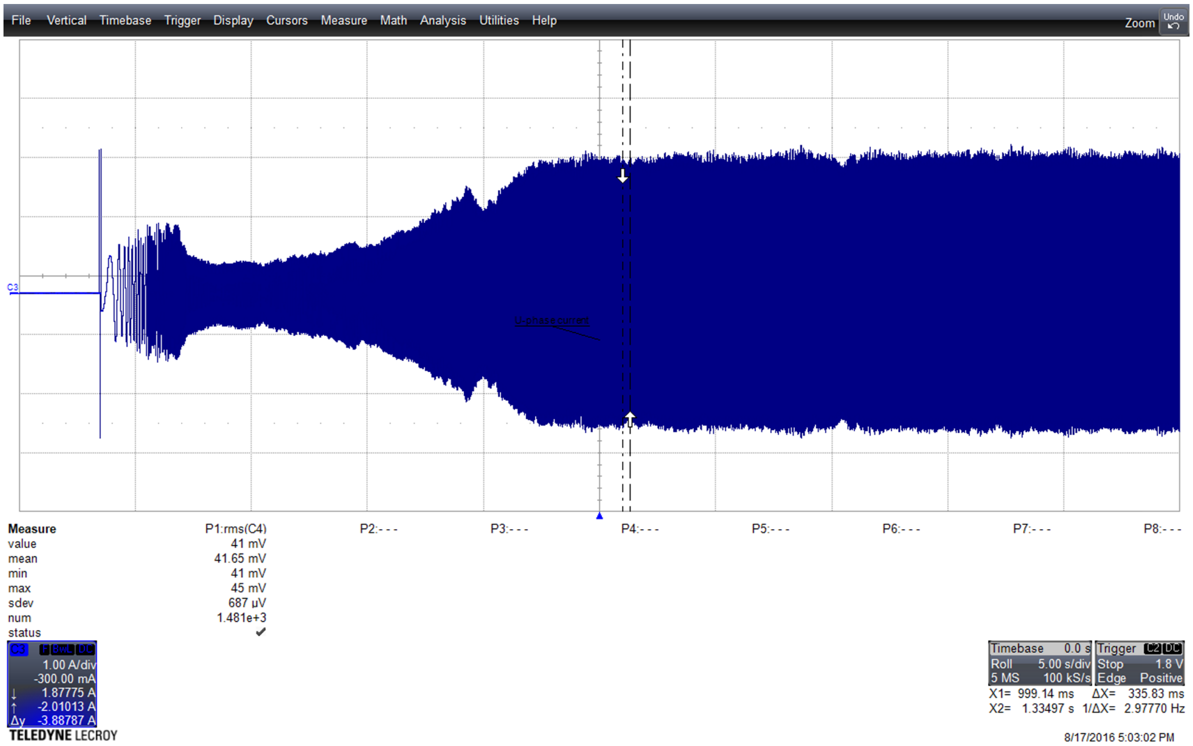

Figure 10. Speed Regulation With Respect to Input Control Voltage (VSP)

5 Design Files

5.1 Schematics

To download the schematics, see the design files at TIDA-01223.

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01223.

5.3 PCB Layout Recommendations

5.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-01223.

5.4 Altium Project

To download the Altium project files, see the design files at TIDA-01223.

5.5 Gerber Files

To download the Gerber files, see the design files at TIDA-01223.

5.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-01223.

6 References

1. Texas Instruments, *DRV10983 12- to 24-V, Three-Phase, Sensorless BLDC Motor Drive*, DRV10983 Data Sheet (SLVSCP6)
2. Texas Instruments, *24-V, 50-W BLDC Motor Sinusoidal Drive for Air Purifier Fans*, TIDA-00656 User's Guide (TIDUAJ0)

7 Terminology

BLDC— Brushless DC motor

ESD— Electrostatic discharge

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

IGBT— Insulated gate bipolar transistor

IPD— Initial position detection

PWM— Pulse width modulation

RPM— Rotation per minute

RMS— Root mean square

VSP— Input control voltage

8 About the Author

RUSHI DALAL is an applications engineer at Texas Instruments, where he is responsible for developing reference design solutions for motor control applications. He currently attends the University of Texas at Dallas.

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.