

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

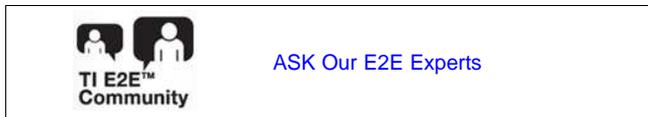


Description

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

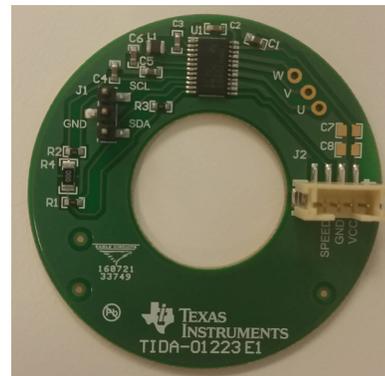
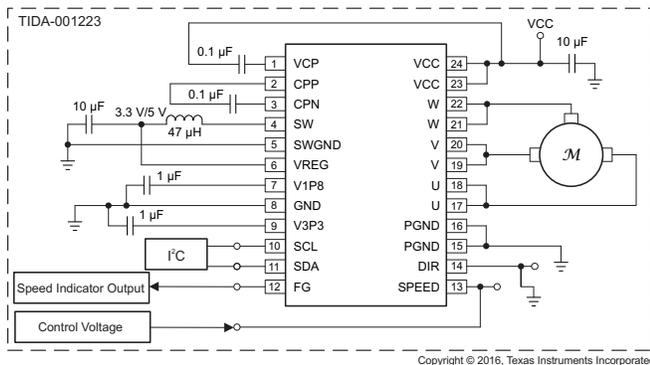


Features

- 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
- I²C 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



An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.

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 I²C. The I²C 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.

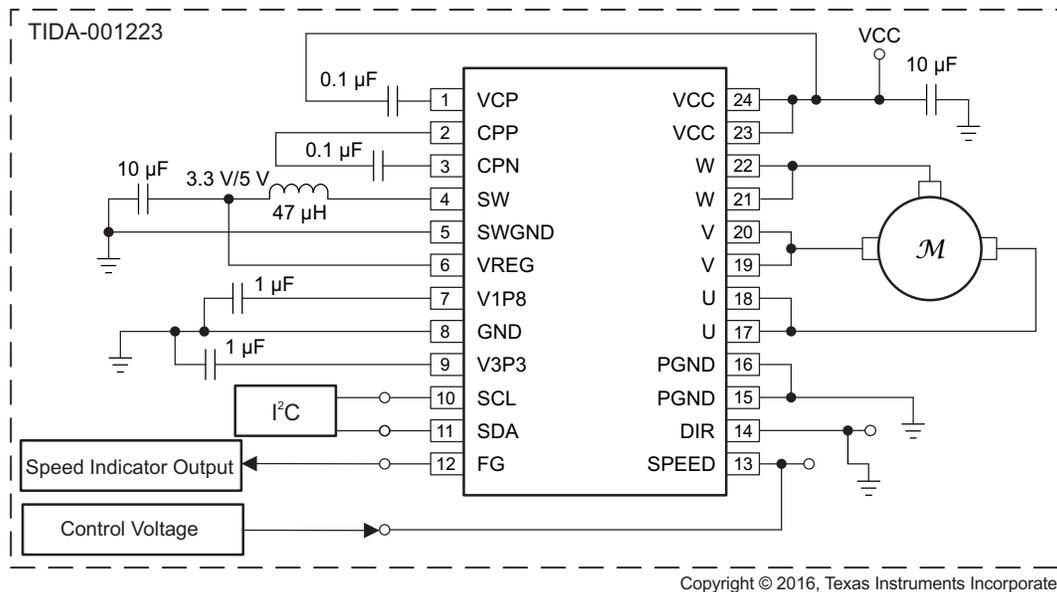


Figure 1. TIDA-01223 Block Diagram

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 I²C inputs. The motor speed feedback is available through either the FG pin or I²C 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 I²C 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.

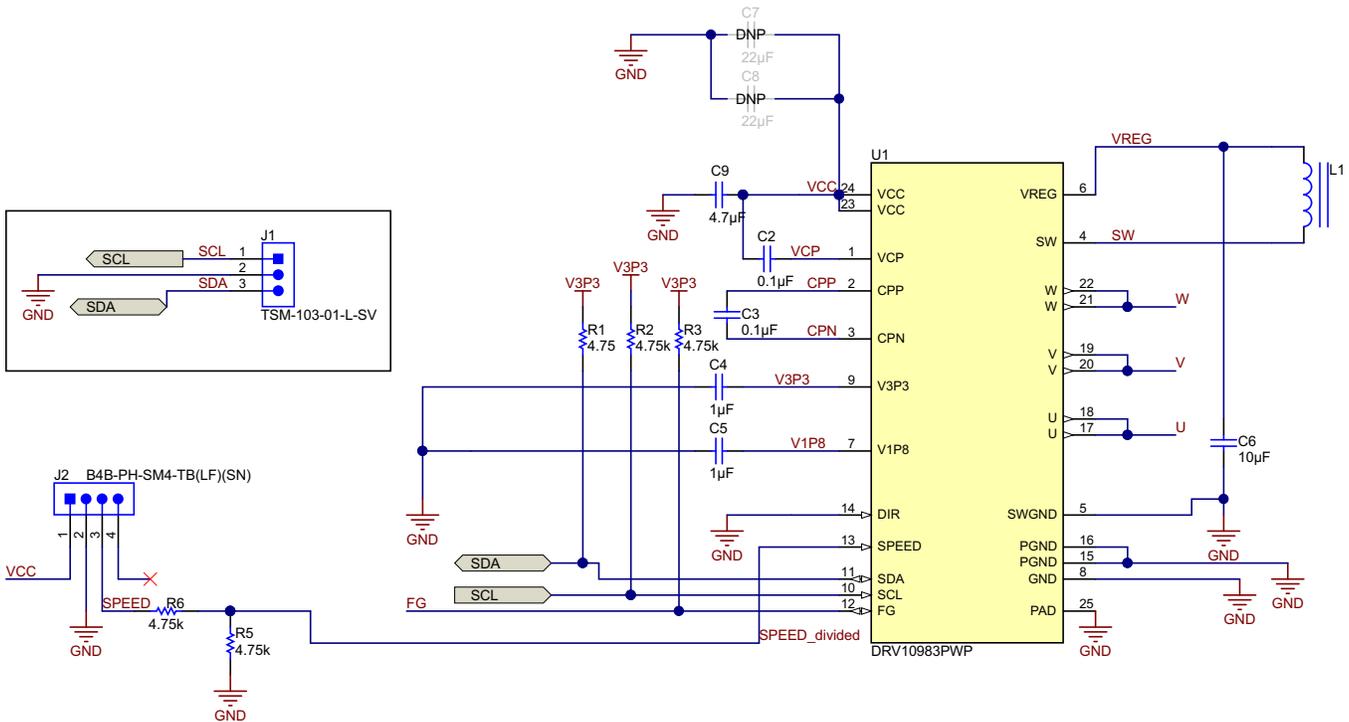


Figure 2. DRV10983 Motor Drive Schematic

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.

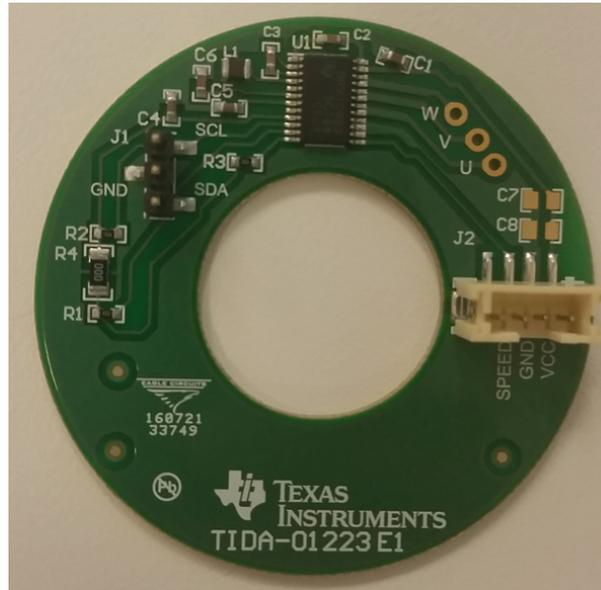


Figure 3. Assembled TIDA-01223 Rev E1 Board

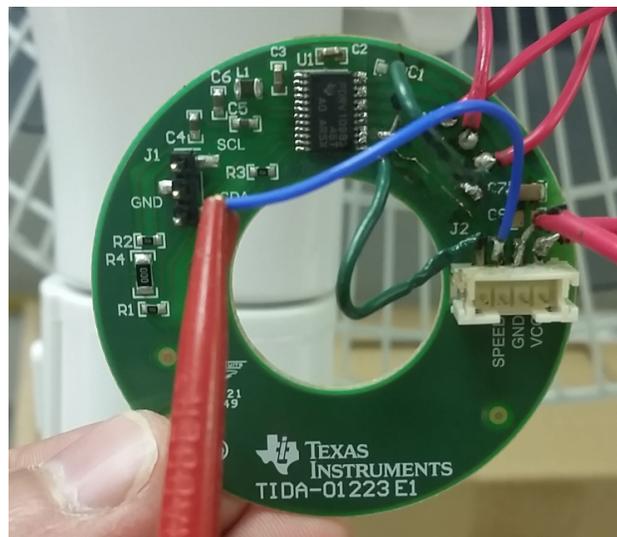


Figure 4. Test Setup

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):

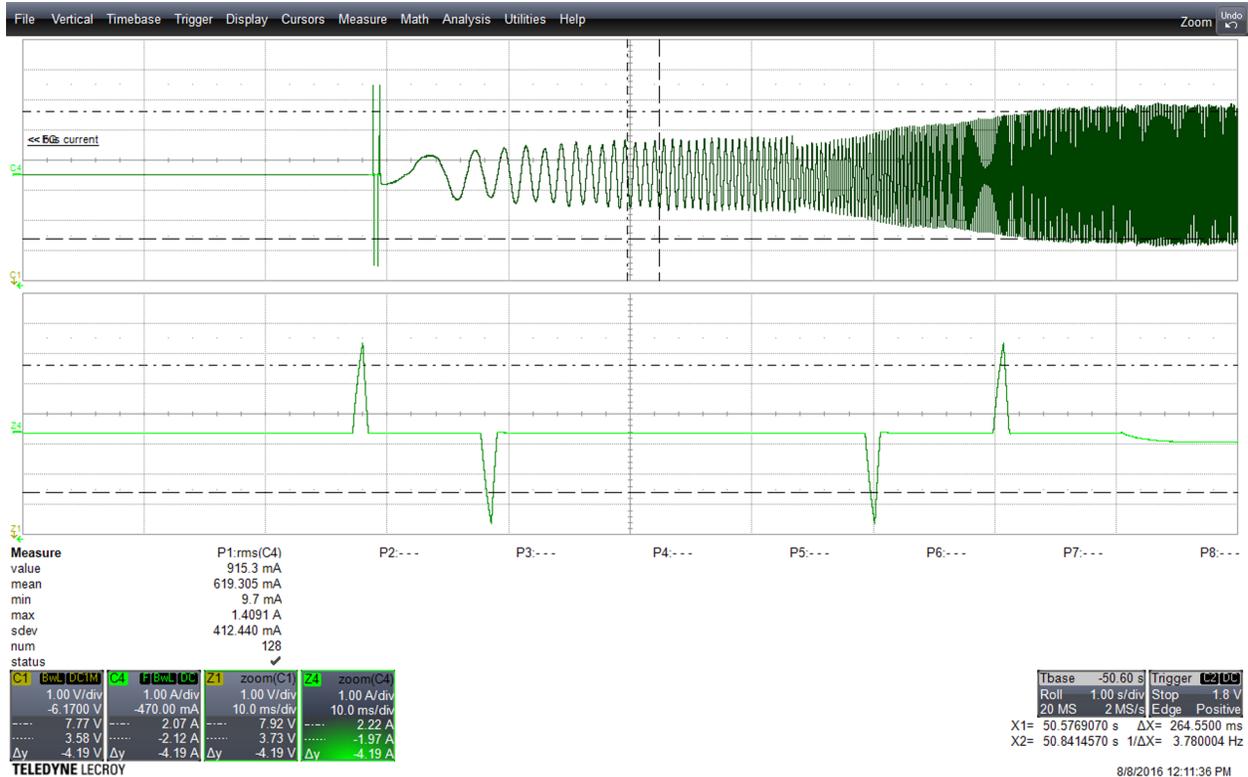


Figure 5. Start-up Profile

Run time:

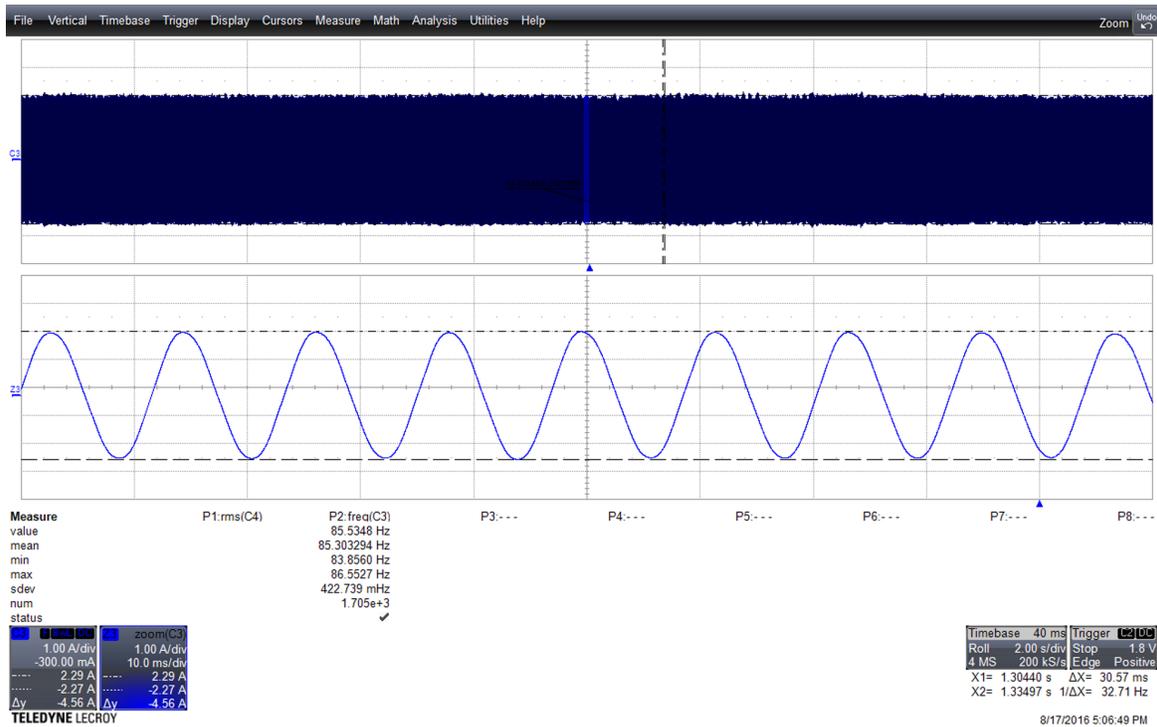


Figure 6. Run Time at 24 V, Speed 86 Hz

Acceleration:

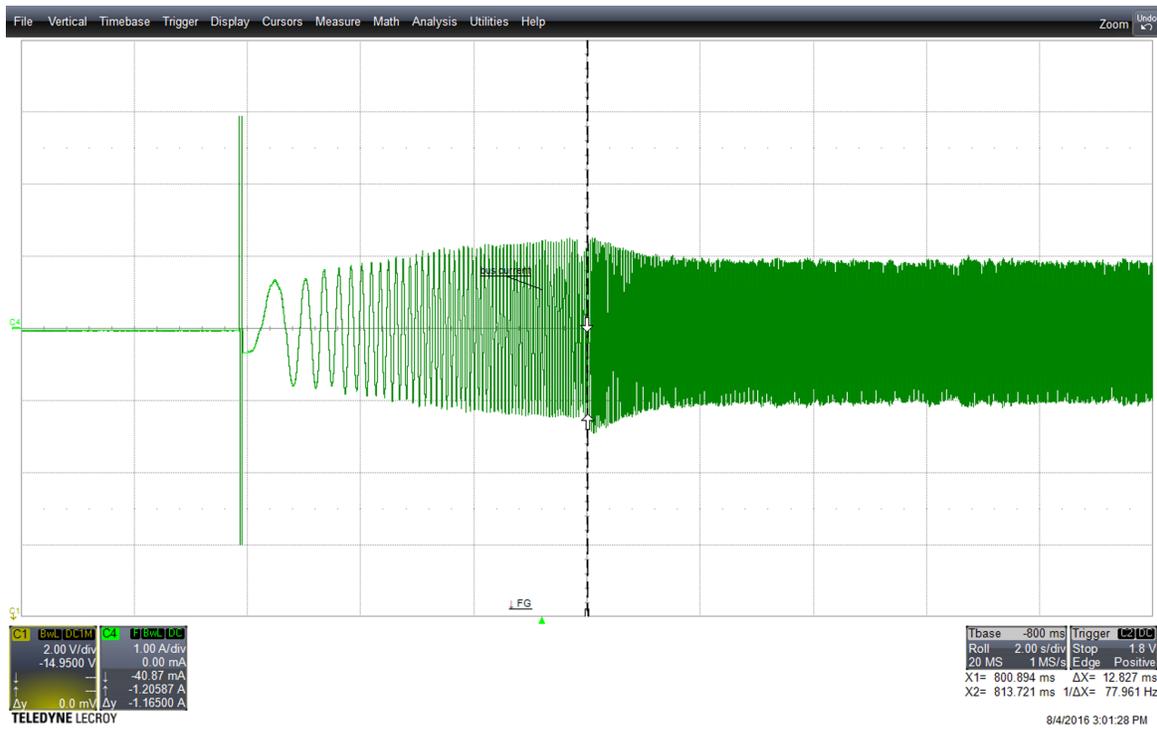


Figure 7. Acceleration

Deceleration:

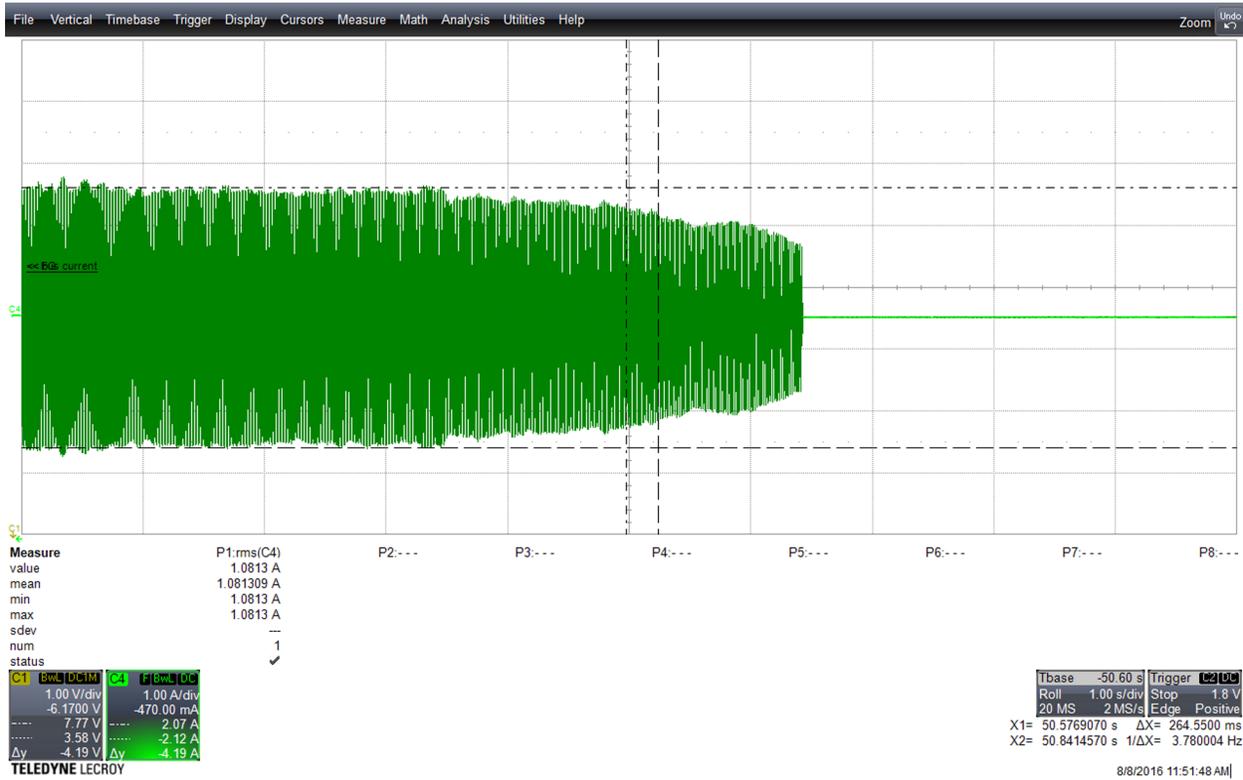


Figure 8. Deceleration

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

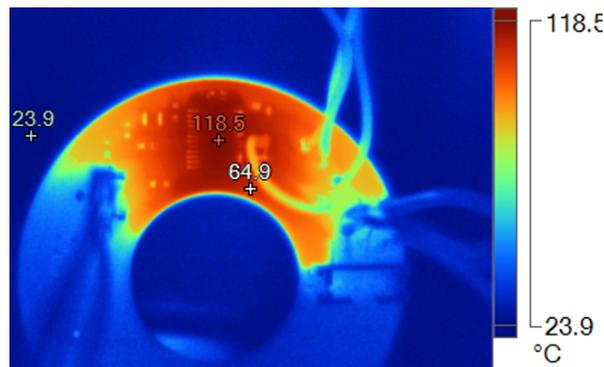


Figure 9. Thermal Image—Top Side

4.3 Speed Control Test

The PWM duty is modified after reading the speed from the DRV10983 device over I²C. 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.

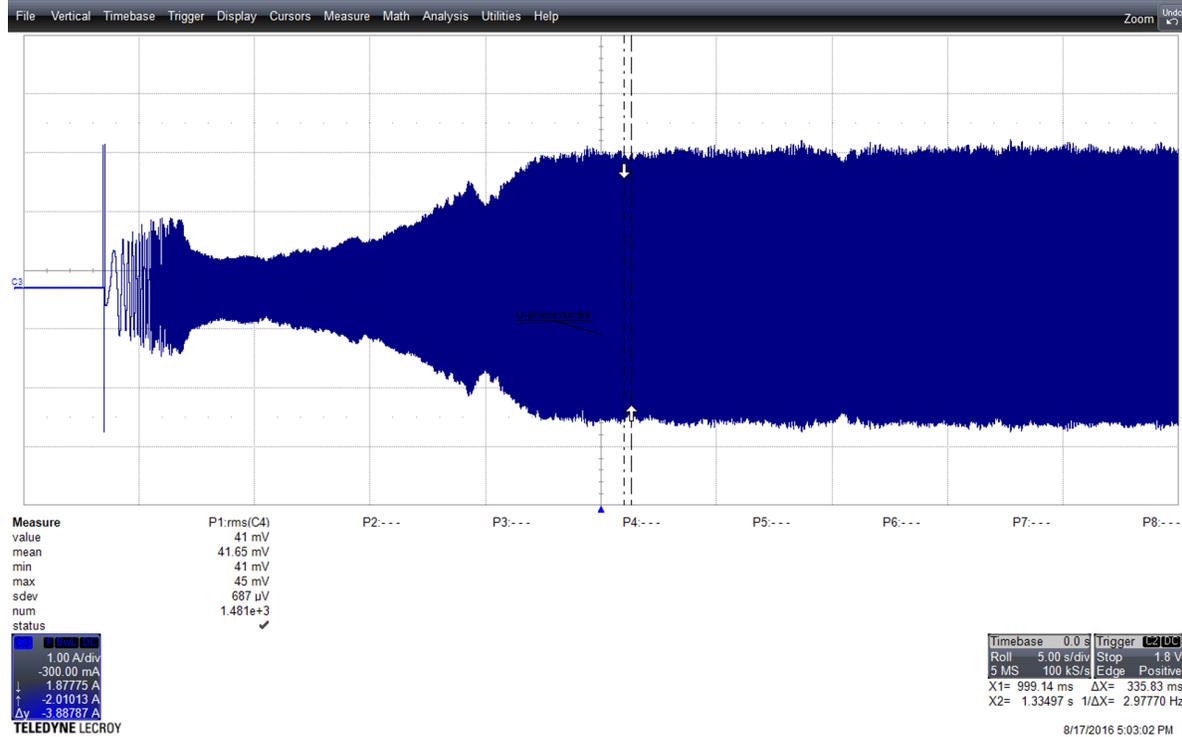


Figure 10. Speed Regulation With Respect to Input Control Voltage (VSP)

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.

Changes from Original (August 2016) to A Revision	Page
• Changed title from <i>24-V, 50-V BLDC Motor Sinusoidal Drive Reference Design for Pedestal Fans</i> to <i>Single-Layer, Brushless-DC Motor Drive Reference Design for Pedestal Fans</i>	1
• Deleted "50-W" from "50-W, 24-V Drive Capable of Driving Brushless DC (BLDC) Motors With Sinusoidal Commutation" in <i>Features</i>	1
• Added "Single-Layer Design Reduces Manufacturing Cost" to <i>Features</i>	1
• Changed "Uses DRV10983 Three-Phase Sensorless Motor Driver With Integrated Power MOSFETs to Provide Continuous Drive Current up to 2 A" to "Uses DRV10983 Three-Phase Sensorless Motor Driver With Integrated Power MOSFETs to Provide Continuous Drive Current up to 2 A _{RMS} (3-A Peak)" in <i>Features</i>	1
• Added "single-layer" to "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"	2
• Deleted " motors up to a power of 50 W at 24 V" from "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"	2
• Deleted paragraph "This reference design provides a ready platform to use a 50-W inverter drive for a BLDC motor-based pedestal fan."	2
• Changed the specification for the "DC input voltage" parameter from "22 V to 24 V" to "12 V to 24 V"	2
• Changed "Rated power capacity" parameter to "Phase current rating"	2
• Changed the specification for the "Phase current rating" (formerly "Rated power capacity") from "50 W" to "2-A _{RMS} (3-A Peak)"	2
• Changed specifications for the "Protections" parameter from "Overcurrent, overtemperature, motor lock, short circuit, undervoltage, and voltage surge" to "Overcurrent protection, motor lock detect, voltage surge, overtemperature protection, and undervoltage lockout".....	2
• Changed DRV10983 Motor Drive Schematic to updated image	4
• Added subsection <i>Single-Layer PCB Design</i>	5

IMPORTANT NOTICE FOR TI REFERENCE DESIGNS

Texas Instruments Incorporated ("TI") reference designs are solely intended to assist designers ("Designer(s)") who are developing systems that incorporate TI products. TI has not conducted any testing other than that specifically described in the published documentation for a particular reference design.

TI's provision of reference designs and any other technical, applications or design advice, quality characterization, reliability data or other information or services does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such reference designs or other items.

TI reserves the right to make corrections, enhancements, improvements and other changes to its reference designs and other items.

Designer understands and agrees that Designer remains responsible for using its independent analysis, evaluation and judgment in designing Designer's systems and products, and has full and exclusive responsibility to assure the safety of its products and compliance of its products (and of all TI products used in or for such Designer's products) with all applicable regulations, laws and other applicable requirements. Designer represents that, with respect to its applications, it has all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. Designer agrees that prior to using or distributing any systems that include TI products, Designer will thoroughly test such systems and the functionality of such TI products as used in such systems. Designer may not use any TI products in life-critical medical equipment unless authorized officers of the parties have executed a special contract specifically governing such use. Life-critical medical equipment is medical equipment where failure of such equipment would cause serious bodily injury or death (e.g., life support, pacemakers, defibrillators, heart pumps, neurostimulators, and implantables). Such equipment includes, without limitation, all medical devices identified by the U.S. Food and Drug Administration as Class III devices and equivalent classifications outside the U.S.

Designers are authorized to use, copy and modify any individual TI reference design only in connection with the development of end products that include the TI product(s) identified in that reference design. HOWEVER, NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of the reference design or other items described above may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI REFERENCE DESIGNS AND OTHER ITEMS DESCRIBED ABOVE ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING THE REFERENCE DESIGNS OR USE OF THE REFERENCE DESIGNS, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY DESIGNERS AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS AS DESCRIBED IN A TI REFERENCE DESIGN OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE REFERENCE DESIGNS OR USE OF THE REFERENCE DESIGNS, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

TI's standard terms of sale for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>) apply to the sale of packaged integrated circuit products. Additional terms may apply to the use or sale of other types of TI products and services.

Designer will fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of Designer's non-compliance with the terms and provisions of this Notice.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2016, Texas Instruments Incorporated