TI Designs: TIDA-01496
単層、12V、プログラマブル三相BLDCモータ・ドライバ、速度レギュレーション付きのリファレンス・デザイン

概要

これは、DRV10983-Q1モータ・ドライバとMSP430G2553マイクロコントローラ(MCU)を使用するセンサレスBLDCモータ正弦波駆動のリファレンス・デザインです。MCUは速度制御用のみに使用し、DRVデバイスがFET内蔵のメイン・モータ・ドライバとしてモータを駆動します。小型のモータ・モジュール向けで、特にファンに適しています。独自のセンサレス制御を採用したり、モータ・パラメータを調整して最終用途に性能を最適化することができます。

リソース

TIDA-01496	デザイン・フォルダ
DRV10983-Q1	プロダクト・フォルダ
MSP430G2553-Q1	プロダクト・フォルダ
DRV10xxソフトウェア	ソフトウェア ・ダウンロード

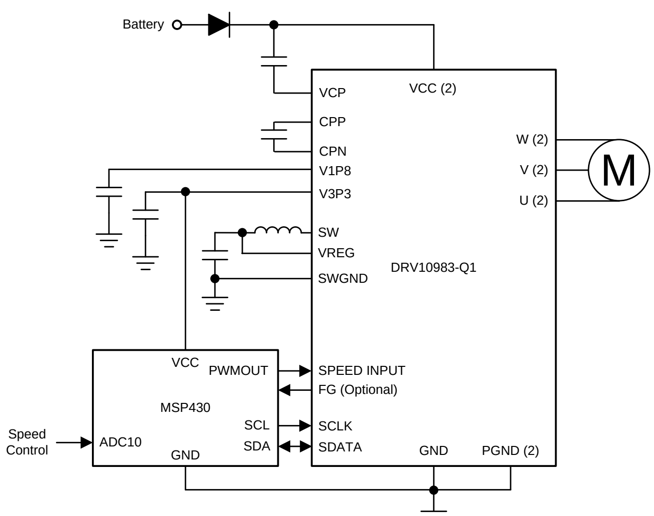
TI E2E™ Community　E2E™エキスパートに質問

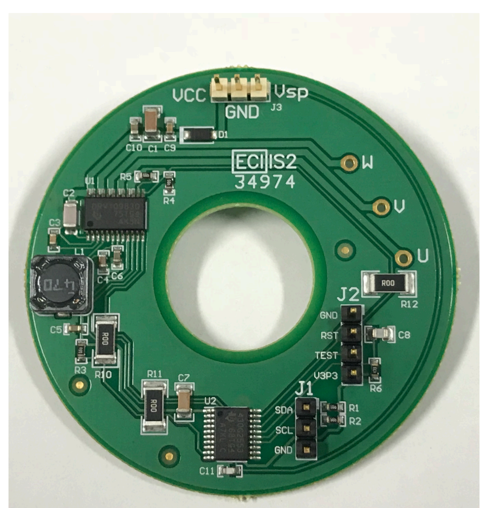
特長

- 12V動作VBAT、最大45Vの負荷ダンプ状態に対応する三相ブラシレスDC (BLDC)モータ駆動ソリューションをDRV10983-Q1で実現
- 単層設計により製造コストを削減
- DRV10983-Q1は独自のセンサレス制御方式を採用して、連続正弦波駆動を実現しているため、純音の音響効果が大幅に低減
- MSP430G2553 MCUが速度入力、制御ループを処理し、モータ・パラメータをプログラミング
- パワーMOSFETを内蔵したDRV10983-Q1三相センサレス・モータ・ドライバにより、最大2Aの連続駆動電流(ピーク3A)を供給
- DRV10983-Q1により出力スルーレートと周波数を構成可能なため、EMC耐性を調整する柔軟性が向上
- 統合された降圧レギュレータにより、電源電圧を5.0Vまたは3.3Vまで効率的に降圧して内部回路と外部回路の両方に給電

アプリケーション

- 全装備シート
- 暖/冷シート





TIDUDD8 翻訳版 — 最新の英語版資料 http://www-s.ti.com/sc/techlit/TIDUDD8

1 System Description

This 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 12 V at input and provides the three motor phase outputs to drive the BLDC motor sinusoidally. The board consists of the DRV10983-Q1 motor driver and MSP430G2553 MCU. The DRV10983-Q1 delivers 3.3 V to the MCU through its V3P3 LDO regulator.

The board also has a speed pin input, which is connected to the ADC10 of the MSP430™ MCU. The ADC10 takes an input voltage from 0 to 3.3 V and converts it to a digital 10-bit value. This value controls the percentage duty cycle for the output PWM signal. The MSP430 MCU creates a pulse width modulation (PWM) signal output, which connects to the DRV10983-Q1 SPEED input pin. The DRV10983-Q1 then uses this input to control the speed of the motor.

The SPEED pin in the DRV10983-Q1 accepts either an analog or PWM input. The DRV10983-Q1 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 for programming the DRV10983-Q1 device. For this reference design, the GUI can be used to configure and tune the motor parameters.

The MSP430G2553 MCU uses the speed measurement feedback to implement a speed control loop. The MSP430G2553 also programs the motor parameter registers into the DRV10983-Q1 without the need of a GUI. The DRV10983-Q1 device is specifically designed for cost-sensitive, low-noise, low-external-component count, small-motor applications. This reference design shows the application of an automotive seat blower fan. The DRV10983-Q1 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.

1.1 Key System Specifications

表 1. Key System Specifications

PARAMETER	SPECIFICATIONS
DC input voltage	8 to 16 V
Current	1.0 A continuous
Power level	Thermal design for 8- to 16-W operation
Control method	Integrated 180° sinusoidal control
Analog speed input	0 to 3.3 V
Protection circuits	Overcurrent, lock detection, voltage surge protection, UVLO protection, thermal shutdown
Operating ambient	–40°C to +125°C

2 System Overview

2.1 Block Diagram

図 1 shows the system block diagram for this reference design. The system is supplied with a motor supply voltage of 12 V, which goes to the DRV10983-Q1 device. The DRV10983-Q1 driver's P3V3 LDO regulator supplies 3.3 V to power the MSP430 MCU. Speed control voltage ranging from 0 to 3.3 V is input to the MSP430 MCU, which drives the PWM duty cycle into the DRV10983-Q1, which drives the speed of the motor. I²C connections are used to program the registers onto the DRV10983-Q1 as well as provide speed feedback data for the speed control loop.

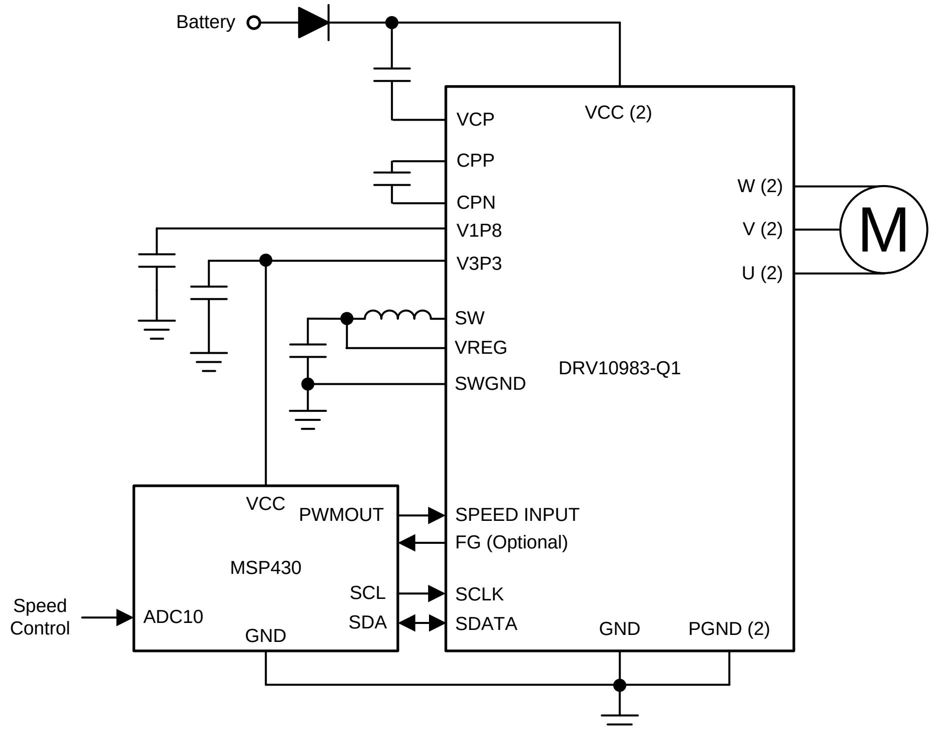


図 1. System Block Diagram

The DRV10983 driver can be configured through I²C using the external GUI with the header available onboard. The user can also implement the MSP430 MCU using a JTAG interface if additional features such as speed loop are required.

2.2 Highlighted Products

2.2.1 DRV10983-Q1

The DRV10983-Q1 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 DRV10983-Q1 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 DRV10983-Q1 circuitry. This function is able to handle a load dump condition up to 45 V.

表 2 highlights the different versions of the DRV10983-Q1: sleep version and standby version. The DRV10983-Q1 enters either sleep or standby to conserve energy. For more information, see *DRV10983-Q1 Automotive, Three-Phase, Sensorless BLDC Motor Driver*.

表 2. Device Options for DRV10983-Q1

DEVICE OPTION	DESCRIPTION	PACKAGE	BODY SIZE (NOM)
DRV10983Q	Sleep version	HTSSOP (24)	7.80 × 6.40 mm
DRV10983SQ	Standby version	HTSSOP (24)	7.80 × 6.40 mm

The DRV10983-Q1 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 DRV10983-Q1 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 may 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 (DRV10983SQ) leaves the regulator running and the sleep mode (48 µA) version (DRV10983Q) shuts off the regulator. Use the standby mode version in applications where the regulator is used to power an external microcontroller. Throughout this datasheet, the DRV10983-Q1 is used for both devices [DRV10983Q (sleep version) and DRV10983SQ (standby version)], except for specific discussions of sleep versus standby functionality.

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 DRV10983-Q1 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.

2.2.2 MSP430G2553

The Texas Instruments MSP430 family of ultra-low-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 1 µs.

The MSP430G2x13 and MSP430G2x53 series are ultra-low-power mixed signal microcontrollers with built-in 16-bit timers, up to 24 I/O capacitive-touch enabled pins, a versatile analog comparator, and built-in communication capability using the universal serial communication interface. In addition, the MSP430G2x53 family members have a 10-bit analog-to-digital (A/D) converter.

Typical applications include low-cost sensor systems that capture analog signals, convert them to digital values, and then process the data for display or for transmission to a host system.

2.3 Design Considerations

表 3 shows the recommended components for the DRV10983-Q1 device to function. In addition to these components, a Schottky diode is added at VCC for reverse voltage protection as well as an addition capacitor in parallel with C_{VCC}. JTAG pin headers are used for MSP430 programming and 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. Additional layout guidelines are found in *DRV10983-Q1 Automotive, Three-Phase, Sensorless BLDC Motor Driver*.

表 3. External Components

COMPONENT	PIN 1	PIN 2	RECOMMENDED
C1	VCC	GND	10-µF ceramic capacitor rated for VCC
C2	VCP	VCC	0.1-µF ceramic capacitor rated for 10 V
C3	CPP	CPN	10-nF ceramic capacitor rated for VCC × 2
C4	VREG	GND	10-µF ceramic capacitor rated for 10 V
C5	V3P3	GND	1-µF ceramic capacitor rated for 5 V
C6	V1P8	GND	1-µF ceramic capacitor rated for 5 V
C7	DVCC	GND	0.1-µF ceramic capacitor
C8	RST	GND	2200-pF ceramic capacitor
C10	VCC	GND	(DNP) 10-µF ceramic capacitor rated for VCC
C11	P1.1	GND	470-pF ceramic capacitor
C9	VCC	GND	0.1-µF ceramic capacitor rated for VCC
D1	VSource	VCC	Schottky diode rated for 30 V, 2 A
L1	SW	VREG	47-µH ferrite rated for 1.15 A (inductive mode)
R1	FG	V3P3	4.75-kΩ pullup to V3P3
R2	SDA	V3P3	4.75-kΩ pullup to V3P3
R3	SCL	V3P3	4.75-kΩ pullup to V3P3
R4	SPEED	GND	4.75-kΩ pulldown
R5	DIR	GND	4.75-kΩ pulldown
R6	DVCC	RST	47 kΩ
R10	FG	FG	Jumper

2.4 System Design Theory

2.4.1 PI Speed Loop Implementation

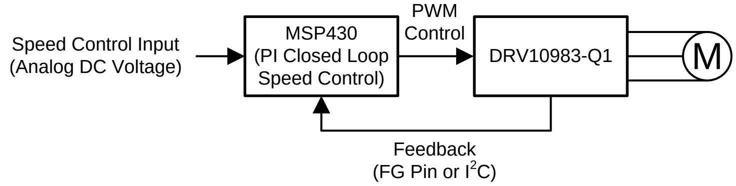


図 2. High-Level System Block Diagram With Speed Loop

The system design includes two main device components, the MSP430G2553 and DRV10983-Q1. The MSP430 MCU takes in a voltage input through its ADC10 and converts it to a 10-bit number. This number determines the percentage duty cycle of the PWM output to the DRV10983-Q1. The MSP430G2553 also programs the motor parameters into the DRV10983-Q1 EEPROM registers through I^2C. The DRV10983-Q1 drives the motor and at the same time send motor speed feedback information through I^2C or FG pin. This feedback goes back to the MSP430 MCU, which processes the proportional integrator (PI) speed control loop.

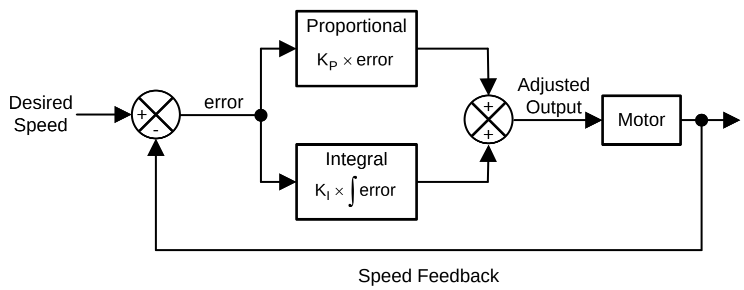


図 3. PI Loop Implementation

A PI controller is made up of two separate controller terms, the proportional term and the integral term. The system takes in the desired input and compares it to the current feedback from the output system. The difference between these two values is the error term. This calculated error term is the input to the controller. The proportional term is calculated by taking the proportion gain, K_P, and multiplying it by the magnitude of the error term. The integral of the error is also calculated and multiplied by the integral gain, K_I. These two values are then added to each other and output the new speed command to the motor. The motor takes this command and turn while at the same time providing feedback to the PI controller. The gains of the proportional and integral terms determine the overshoot and settling time.

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 V_{BAT} input and controlled using the V_{SP} input. Specifically, V_{SP} refers to the analog voltage used by the MCU that generates the PWM signals necessary 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 is used for I^2C communication with the motor driver and MCU while J2 is used for the JTAG interface with the MCU. While the DRV10983-Q1 can drive the motor without the use of an MCU, the design uses the MCU for implementing the speed loop functionality and providing the PWM speed signal for motor drive.

To set up the system, connect a power supply capable of providing 12 to 28 V and 3 A using V_{BAT}. 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 V_{SP}. It is recommended to use a USB2ANY and the DRV10x Software GUI when communicating with the DRV10983-Q1 using I^2C. For pins 1 through 3 of the J1, see the SDA, SCL, and GND connections needed for I^2C communication. See 図 4 for more information when connecting to the system through I^2C.

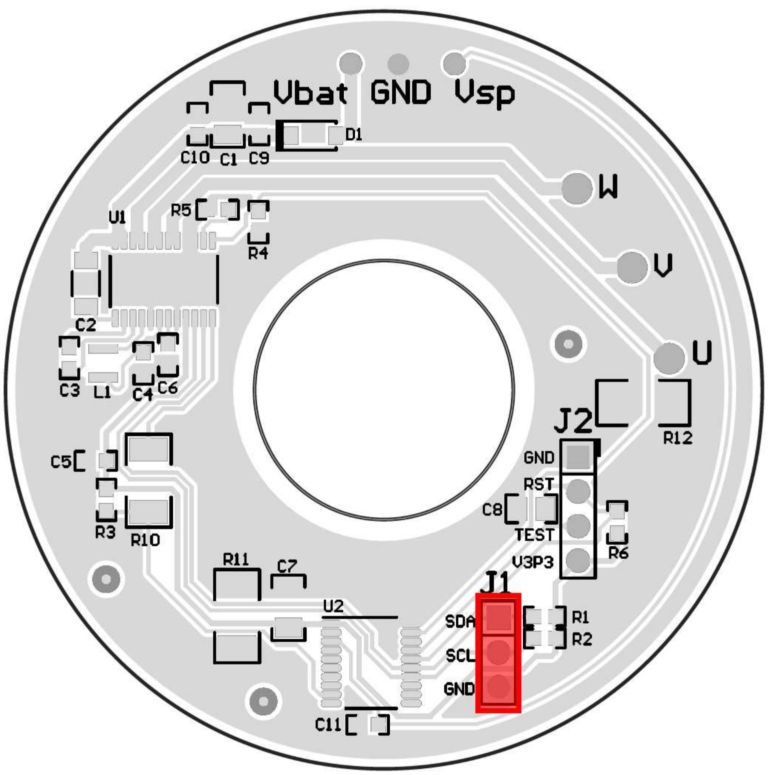


図 4. Hardware Setup for I^2C Communication

It is also recommended to use a JTAG emulator like the one found through the MSP430 LaunchPad™ Value Line Development Kit (MSP-EXP430G2) to interact with the MSP430G2553. See 図 5 for more information when connecting to the system using the JTAG interface. For pins 1 through 4 of J2, see the GND, RESET, TEST, and V3P3 required for the JTAG interface. For more information about I²C and the JTAG interface, see 3.1.2.

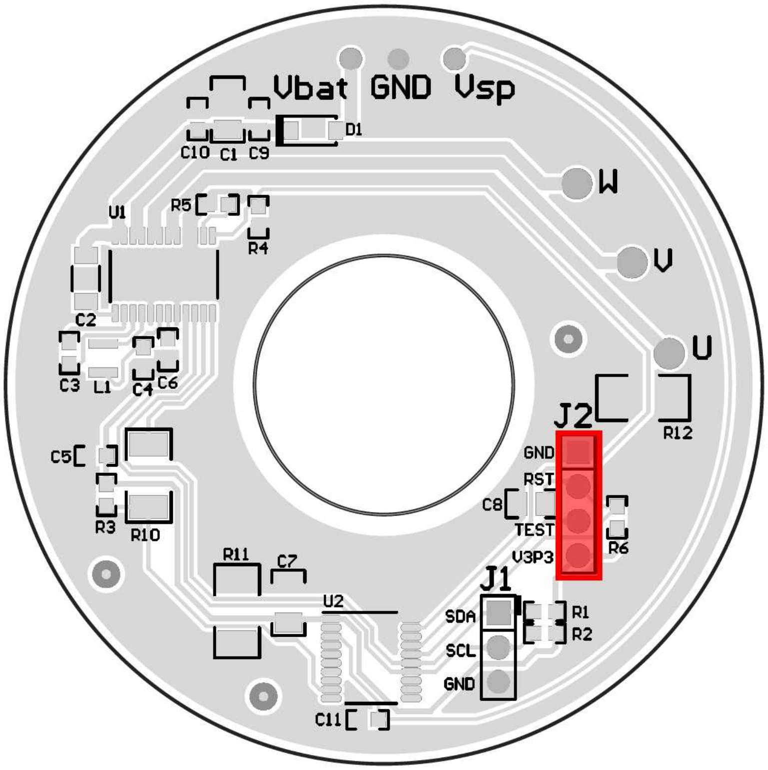


図 5. Hardware Setup for JTAG Interface and Communication With MSP430 MCU

Once the MCU has been programmed and the DRV10983-Q1's EEPROM settings have been tuned, the user only needs to power on the system and control the speed voltage to operate the design.

3.1.2 Software

The firmware is written for the onboard MSP430 controller. The existing firmware serves two major functionalities:

- The firmware can configure the DRV10983-Q1 device. This firmware is usually a one-time configuration unless the user wants to modify parameters runtime of the configuration.
- The firmware processes the input speed using the ADC10 of the MSP430 MCU and implements a PI speed control system using feedback from the DRV10983-Q1 from either I²C or FG.

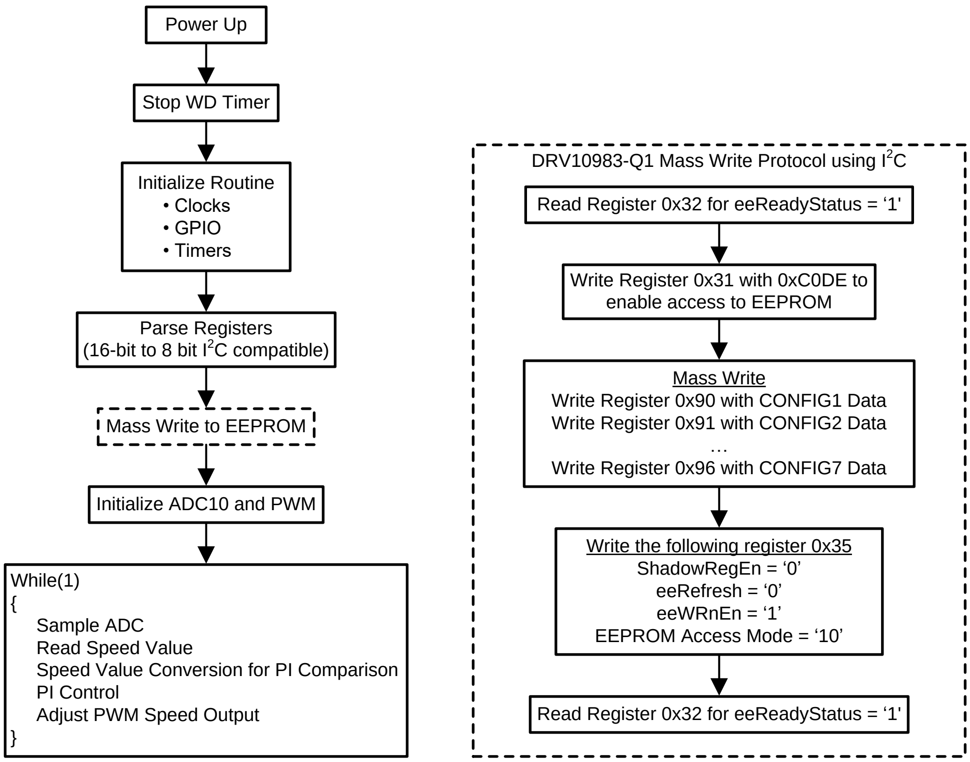


図 6. Software System Block Diagram

3.1.2.1 Using Software to Configure DRV10983-Q1

Configuring the DRV10983-Q1 refers to programming the tuning parameters, which are written to the EEPROM. These settings contain intrinsic motor parameters unique to the motor, such as Kt and Phase Resistance, and tuning parameters just as the acceleration coefficients and open to closed loop threshold. Consult the *DRV10983-Q1 Tuning Guide* for more information.

Ideally, the motor parameters can be obtained by using I^2C to communicate with the motor driver. Download the *DRV10xx Software GUI*. (1) to easily implement EEPROM settings and monitor motor faults during operation. A guide for installing the GUI software is found in "Appendix A GUI Installation and Overview" of the *DRV10983-Q1 Evaluation Module User's Guide*.

When interfacing with the MSP430G2553, download the latest version of *Code Composer Studio™ (CCS)* to easily implement the provided code. By simply importing the project or copying and pasting the code, the MCU can be programmed to implement EEPROM settings, the speed loop, and the PWM signals.

It is highly recommended to make all the connections first before turning on the voltage supply. Once the connections are made, the voltage supply can be turned on. A common error can occur during programming: "MSP430: Error initializing emulator: Could not find MSP-FET430UIF on specified COM port". Usually this error can be remedied by turning off the power supply, disconnecting the LaunchPad from the computer, reconnecting the LaunchPad first, and then turning on the power supply again.

Follow these instructions to program the MSP430 MCU:

1. Import the "TIDA-01496-ExampleSoftware" project using TI's CCS software.
2. Connect the LaunchPad programmer to the TIDA-01496 board, as shown in 図 5.
3. Build the project by clicking the Build button (hammer icon), which if run successfully, appears as shown in 図 7.
4. Click the Debug button (bug icon) as 図 7 shows.

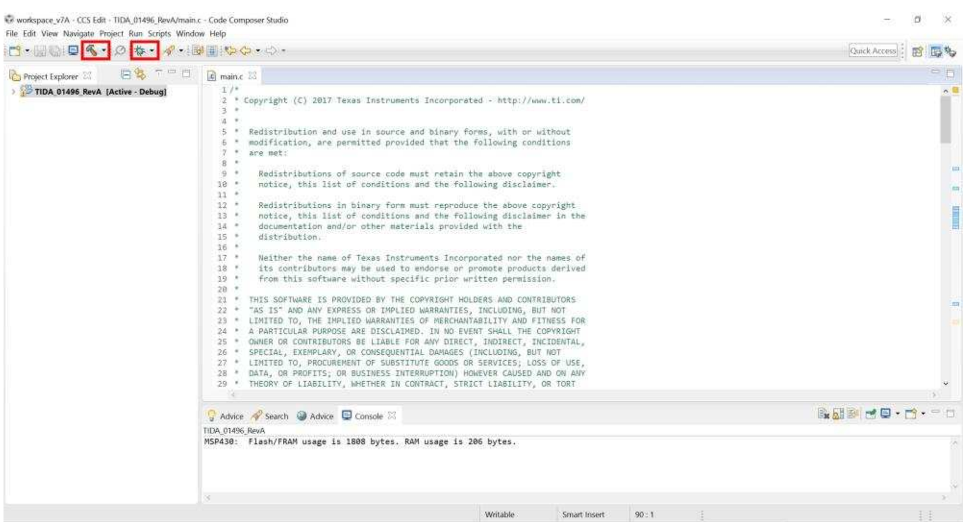


図 7. Building and Debugging Project in CCS

(1) This requires a TI.com login

Follow these instructions to program the motor parameter registers into the MSP430 software:

1. Find the optimum motor parameter settings using the GUI. For help tuning the motor, see the *DRV10983-Q1 Tuning Guide*.
2. Save the motor configurations using the GUI. This action saves the seven CONFIG registers as a .csv file as shown in 図 8.

図 8. How to Save a Motor Configuration File in DRV10x GUI

3. Open the .csv file with Notepad. These registers are now implemented in the reference design CCS as shown in 図 9.

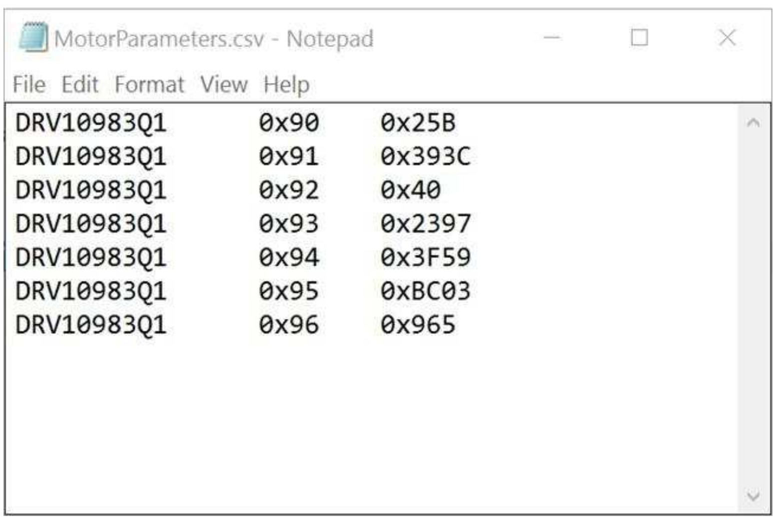


図 9. Example Motor Configuration File in .csv Format

4. Open the RegisterValues.h header file and place the CONFIG values in their corresponding registers as shown in 図 10.

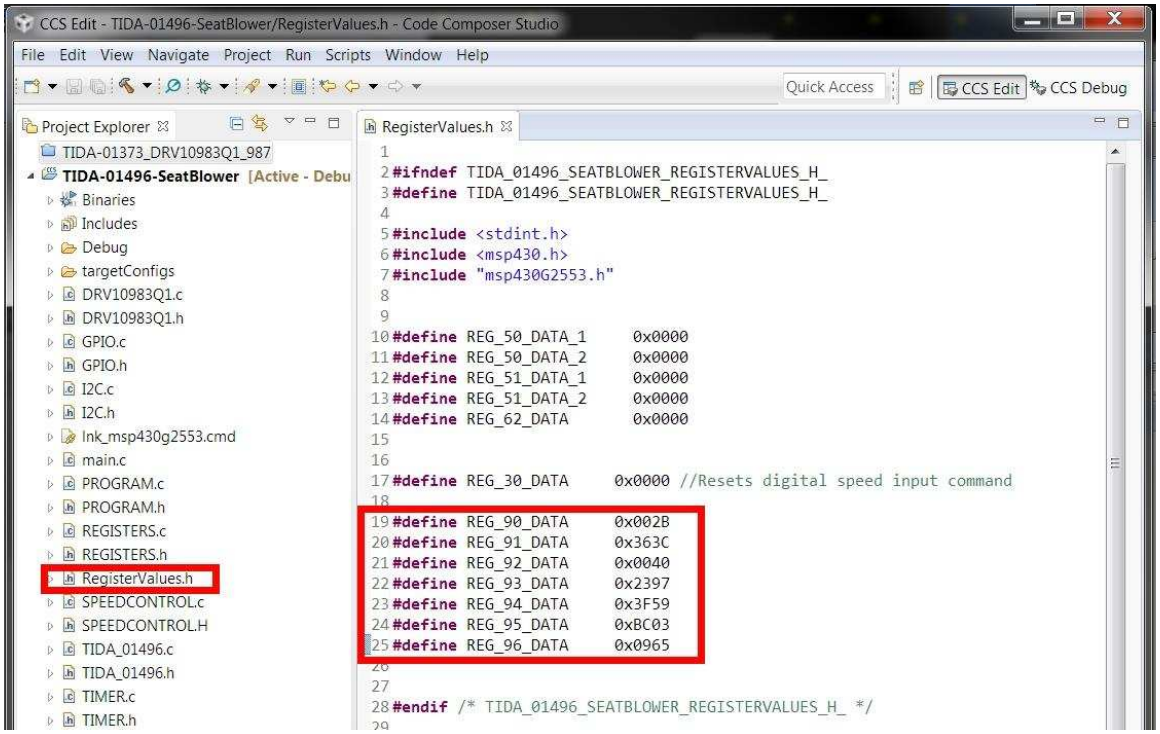


図 10. Adding Motor Configuration Settings into RegisterValues.h

5. Save the project and rebuild.
6. Optional: Program other registers the seven CONFIG registers if needed:
   a. Define the new register value in the RegisterValues.h header file.
   b. Define the number of total registers in the REGISTERS.h header file as shown in 図 11.

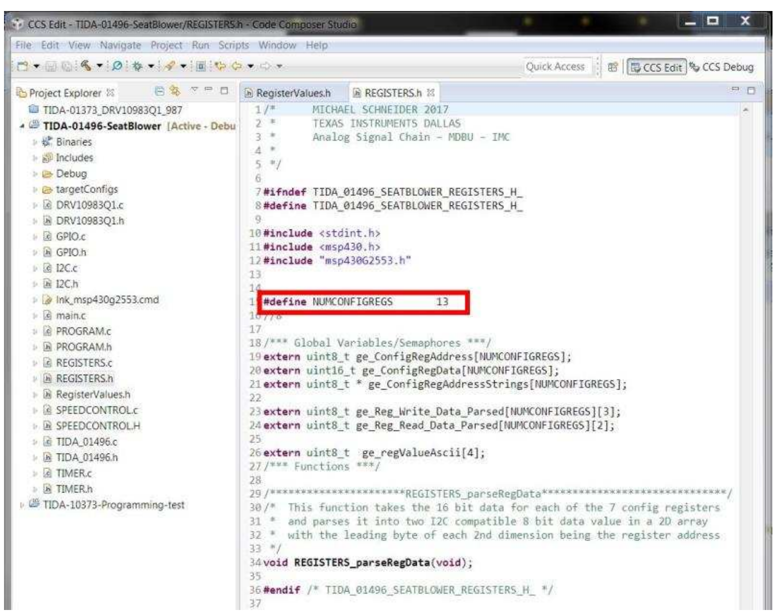


図 11. How to Change Total Number of Registers Used in Project

c. Define the register address in the REGISTERS.c source file in both corresponding arrays as shown in 図 12.

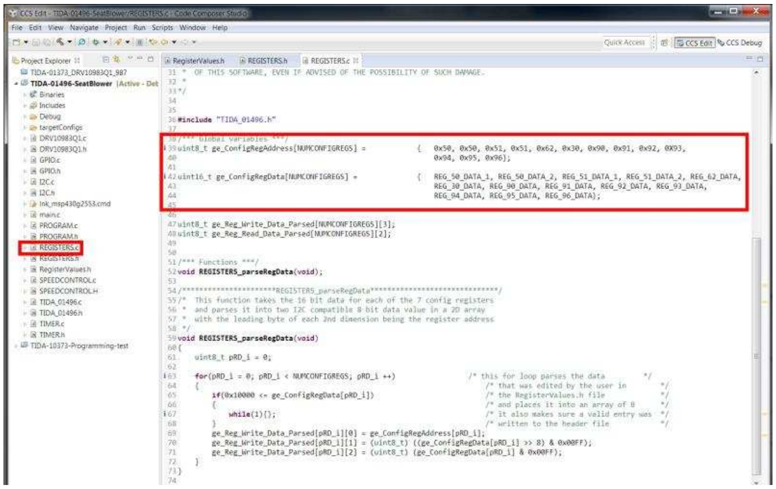


図 12. How to Change Array of Registers Used in Project

3.1.2.2 Flow for Using ADC10 of MSP430 to Implement PI Speed Control System

As shown in 図 6, after initialization, the program stays in the while loop continually running the SPEEDCONTROL function. The SPEEDCONTROL function flows by the following process:

1. ADC samples voltage of MCU and translates into a bit value defined by *ADC_Value*.
2. Using this bit value, a speed level is assigned (that is, 0 to 5) defined by *Speed_Level*.
3. The speed level determines the target speed of the electrical cycle (Hz), defined by *SPEED_INPUT*, and scale value, defined by *Scale*.
4. The current speed of the electrical cycle speed is read through I^2C from the DRV10983-Q1 defined by *SPEED_MEASURED*.
5. The difference between the target speed and current speed is defined by *Error*.
6. The PI loop operation calculates the error and adjustments needed to reach the target speed defined by *OutPreSat*.
7. An if statement is used to bound the error and adjustments if the error is too large defined by *Out* (Hz).
8. The error for the next cycle used by the PI loop is determined by *SatError*.
9. The PWM signal uses the error and adjustments. This is defined by *CCR1* (Hz).

3.1.2.3 Tuning Speed Levels

Each motor has its own specific speed curve and parameters. This requires tuning for the speed levels and PI loop. Any speed levels can be set for the device depending on the application of the system. The easiest method is to run the firmware with one simple modification. In the SPEEDCONTROL.c file, change:

```
CCR1 = NEW_SPEED;
```
to
```
CCR1 = ADC_Value;
```

This change is shown in 図 13.

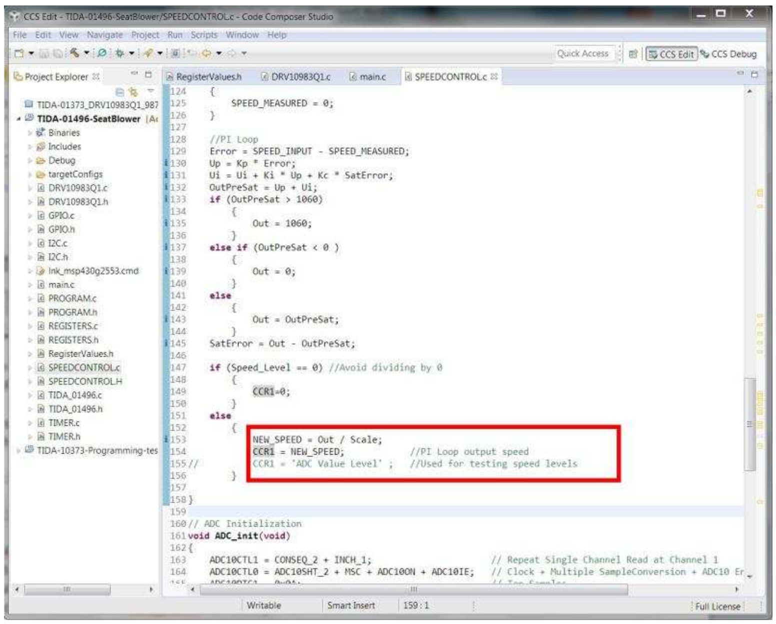


図 13. Example of Changing SPEEDCONTROL.c File for Testing

The ADC_Value is the value read by the ADC10 ranging from 0 to 1023. There needs to be a one-to-one relationship between the ADC_Value and the PWM output, meaning an ADC_Value of 1023 is 100% PWM and an ADC_Value of 511 is 50% PWM. Under ideal conditions, choose the required speed levels and convert them to an ADC_Value. See 表 4 for an example:

表 4. Translating Speed Levels, PWM Duty Cycles, and ADC_Value

SPEED LEVEL	PWM DUTY	ADC_Value (1023×DUTY)
0	0%	0
1	20%	205
2	40%	409
3	60%	614
4	80%	818
5	100%	1023

Now set the ADC_Value ranges in the SPEEDCOMMAND.c file to correspond with these specified levels:

```
if (ADC_Value <= 50) {Speed_Level = 0;}
else if (ADC_Value > 50 && ADC_Value <=205)  {Speed_Level = 1;}
else if (ADC_Value >205 && ADC_Value <=409)  {Speed_Level = 2;}
else if (ADC_Value >409 && ADC_Value <=614)  {Speed_Level = 3;}
else if (ADC_Value >614 && ADC_Value <=818)  {Speed_Level = 4;}
```

```
else if (ADC_Value >818 && ADC_Value <=1023) {Speed_Level = 5;}
else {Speed_Level = 5;}
```

3.1.2.4 Finding Appropriate Scale for Each Speed Level

Usually, the ADC_Value input, and by extension the SPEED_INPUT, will be compared to the SPEED_MEASURED and put through the PI loop. Setting the CCR1 value will manually determine the PWM duty cycle and ignore the effects of the PI loop. This is important because unique motor parameters will cause different speeds at 100% duty cycle. Determining the max speed will determine the scale between the PWM duty cycle and the SPEED_INPUT.

To determine the scale, observe the PWM duty cycle and SPEED_MEASURED for each CCR1 value and determine the scale value by dividing the CCR1 value by the SPEED_MEASURED. This is implemented in 図 14 and listed in 表 5.

To manually set CCR1, implement the following code:

```
CCR1 = 1060;
```

Each time a speed is set, run the motor and check the SPEED_MEASURED variable. To do this, run the debugger and add SPEED_MEASURED to the expressions table by right clicking the table and selecting "add global variable". Pause the debugger while the motor is running in closed loop to observe the speed value measured by the DRV10983-Q1 using I^2C.

表 5. Example of Tuning SPEED_INPUT(1) Using Scale Functionality

SPEED LEVEL	EXAMPLE PWM DUTY	EXAMPLE CCR1 Value	EXAMPLE MEASURED (SPEED_MEASURED)	EXAMPLE SCALE (CCR1/SPEED_MEASURED)
0	0%	0	0	—
1	20%	205	31	6.61
2	40%	409	63	6.49
3	60%	614	94	6.53
4	80%	818	126	6.49
5	100%	1060	163	6.5

(1) SPEED_INPUT is motor specific

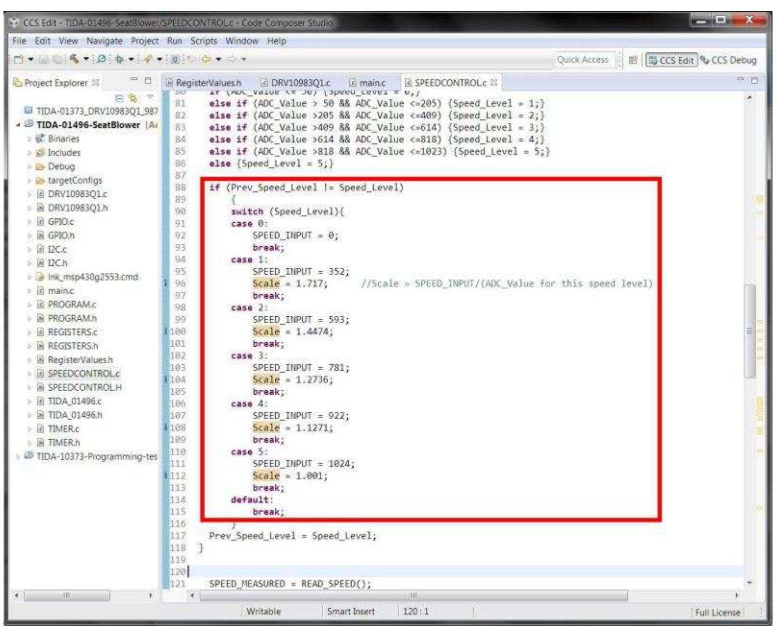


図 14. Example Implementation of Scaled SPEED_INPUT in CCS Project

These speed levels may or may not be linear. This case is for a non-linear relationship between the input command and output speed due to the motor's inherent load properties. For a more linear motor, a constant scale can be set for any input without using speed levels and these calculations can be simplified.

3.1.2.5 Tuning the PI Loop

Tuning the PI loop consists of simply modifying the proportional and integral constants in the SPEEDCONTROL.c file.

The PI controller is implemented within a while loop, which runs continuously. First, the error is calculated between the desired speed and the feedback speed. The error is multiplied by the proportional gain and the output of the proportional term is stored in the $U_p$term. The integral output is calculated by adding together the previous integral output, the product of the integral gain and proportional output, and the product of the integral gain factor and the saturated error. The pre-saturated value is the sum of the integral and proportional outputs, U_i and U_p. The saturated error is calculated between the output after saturation and the pre-saturation output and applied to the integral output. A PI loop is an essential controller method when closing the speed loop within a motor. The loop allows motors to work across different voltages and different loads while maintaining the same desired speed input. To learn more about the PI loop theory, see 2.4.1.

Tuning a PI loop is required to make the system stable and responsive while minimizing overshoot. The last two objectives often conflict with each other, and a compromise must be met to achieve the best results. Tuning a PI loop for a system with a fast response such as for this motor application must have a low P-gain. Set the P-gain low and the I-gain to near zero and run the motor to see if oscillations occur. Once oscillations occur, halve the P-gain value. Next, set a very small integral value. Slowly increase and run the motor until oscillations occur more than half the integral value. 図 15 demonstrates the effects of increasing the proportional and integral terms on overshoot and setting time.

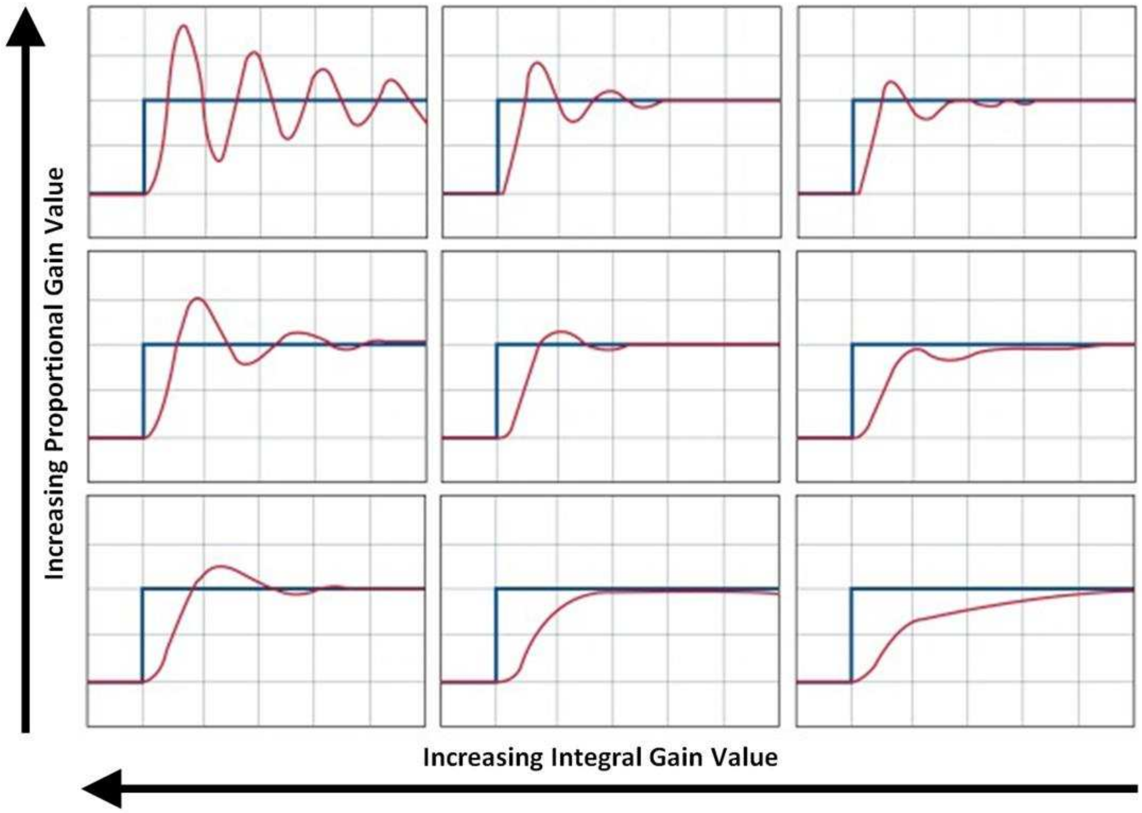


図 15. Effects of Tuning PI Controller Gains

3.2 Testing and Results

3.2.1 Test Setup

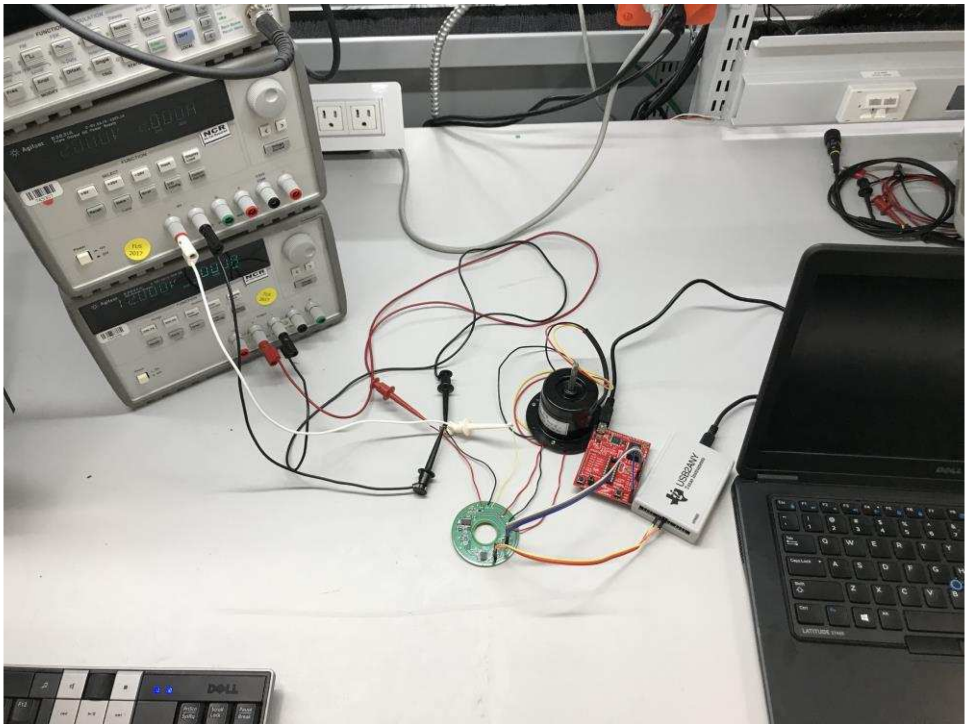


図 16. Example Bench Setup

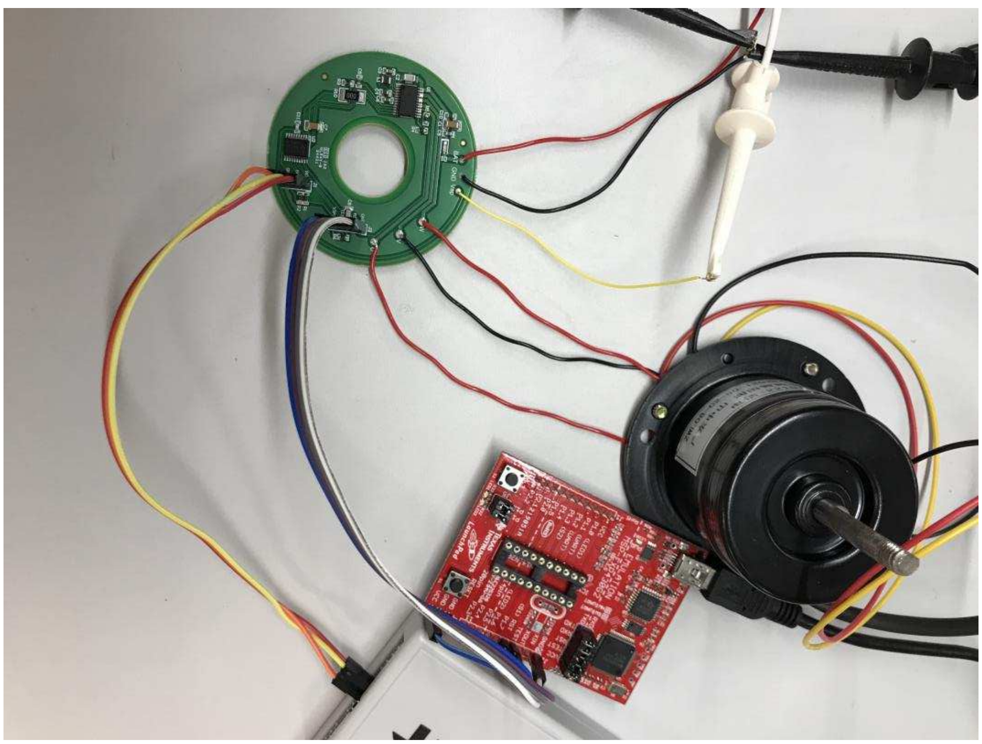


図 17. Closeup of Connections

3.2.2 Functional Test

The functional test refers to basic programming and start up using both the DRV10xx Software GUI through I^2C and the MSP430 MCU using CCS and JTAG. The MSP430 MCU specifically is tested with a low- and high-voltage start-up of 8 V and 16 V, respectively.

C1 shows V_{BAT}, C2 shows the Frequency Generate (FG) pin on the DRV10983-Q1, and C3 shows the current of the U phase of the motor.

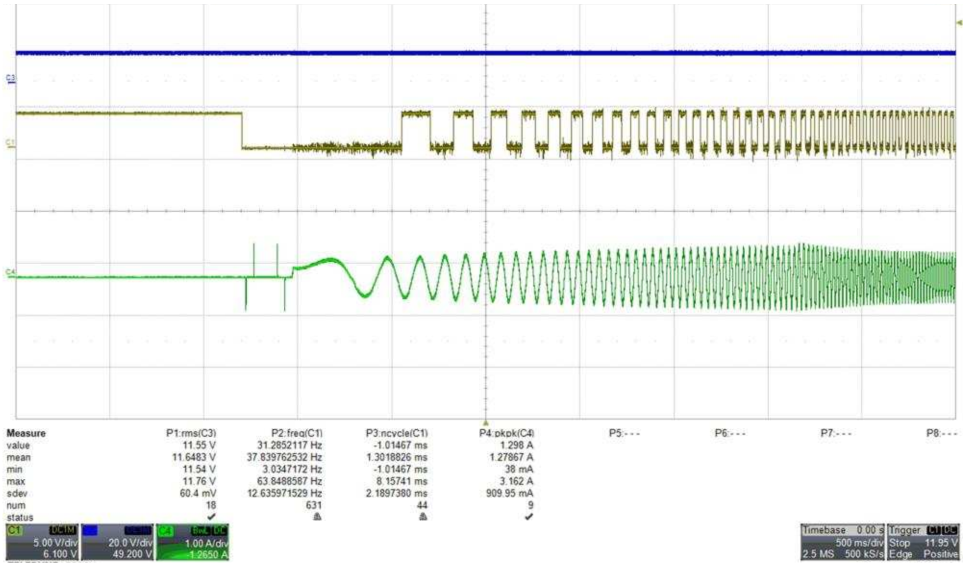


図 18. Startup Profile, GUI Control, 12 V, 50% Speed

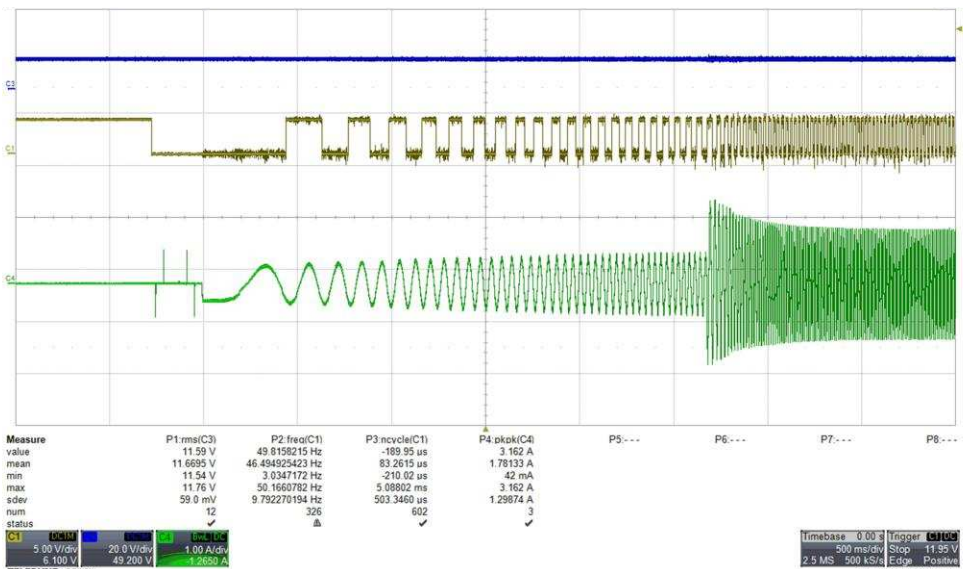


図 19. Startup Profile, GUI Control, 12 V, 100% Speed

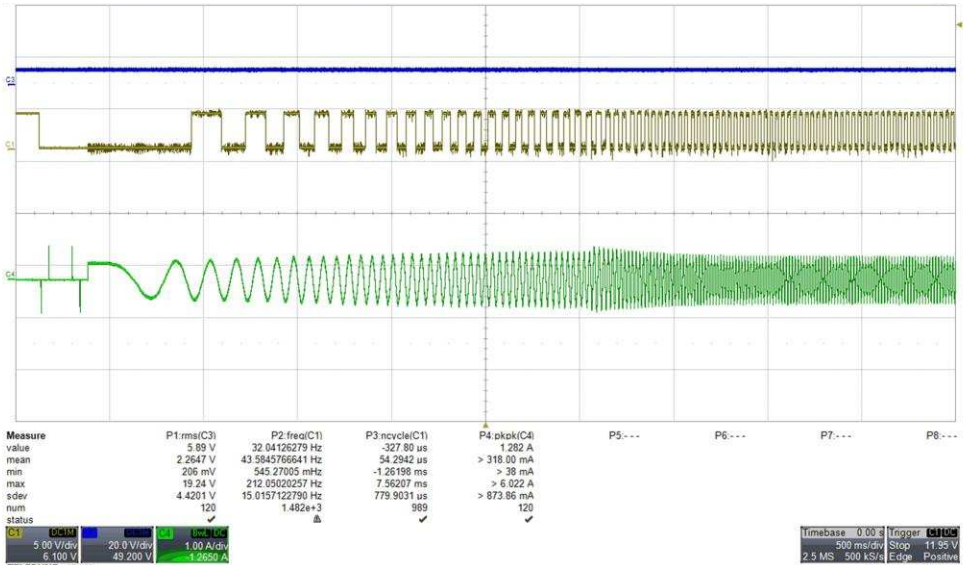


図 20. Startup Profile, MSP430 Speed Control, 8 V, 100% Speed

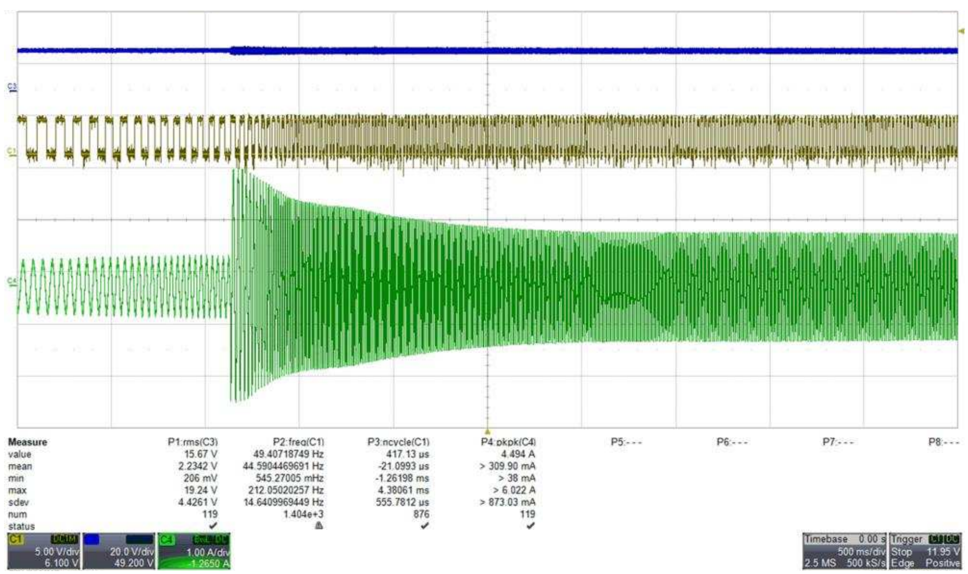


図 21. Startup Profile, MSP430 Control, 16 V, 100% Speed

3.2.3 Speed Loop Regulation Test

Five motor specific speed levels are programmed. Each speed level is tested for voltage ranging from 8 to 16 V in 2-V increments. Measurements are taken in Hz but converted to RPM. For more information, see 表 6 and 図 22.

表 6. Output Speeds versus Input Speed Commands and Input Voltage Ranges

VOLTAGE INPUT	SPEED INPUT = 1000 RPM	SPEED INPUT = 1692 RPM	SPEED INPUT = 2236 RPM	SPEED INPUT = 2636 RPM	SPEED INPUT = 2956 RPM
8 V	1001	1691	2041	2210	2314
10 V	1000	1691	2236	2559	2686
12 V	1000	1691	2236	2636	2956
14 V	1000	1691	2236	2640	2956
16 V	1001	1691	2236	2641	2956

図 22 compares the output speeds versus input speed commands and input voltage ranges.

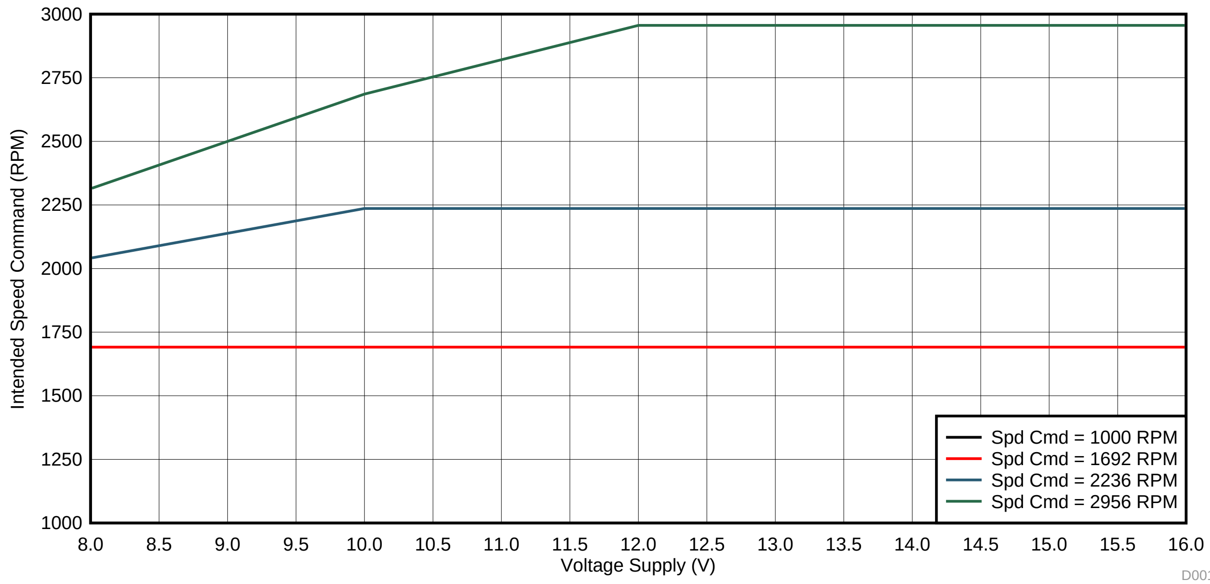


図 22. Speed Regulation: Speed (RPM) versus Voltage Input

3.2.4 Load Dump Test

The recommended operation voltage of the DRV10983-Q1 device is from 6.2 V to 28 V. The device is able to drive the motor within this V_{CC} range. In the load dump condition, V_{CC} can rise up to 45 V. Once the DRV10983-Q1 device detects that V_{CC} is higher than VOV_R3 , it stops driving the motor and protects its own circuitry. Find more information in 表 7.

Load dump protection is effectively enabled by the device when the 45-V pulse is injected from the supply. The device shuts down to protect its circuitry and then turns back on again.

C1 shows the voltage on the Frequency Generator (FG) pin of the DRV10983-Q1, C2 shows the voltage on the U phase of the motor, C3 shows the current on the U phase of the motor, and C4 shows the voltage of V_{BAT}.

表 7. Load Dump Protection Specifications

LOAD DUMP PROTECTION	DESCRIPTION	MIN	TYP	MAX	UNIT
V_{OV_R}	Load dump protection mode entry on rising V_{CC} threshold	28.5	29.2	30	V
V_{OV_F}	Load dump protection mode entry on falling V_{CC} threshold	27.7	28.2	28.8	V
V_{OV_HYS}	Load dump protection mode hysteresis	0.73	1	1.1	V

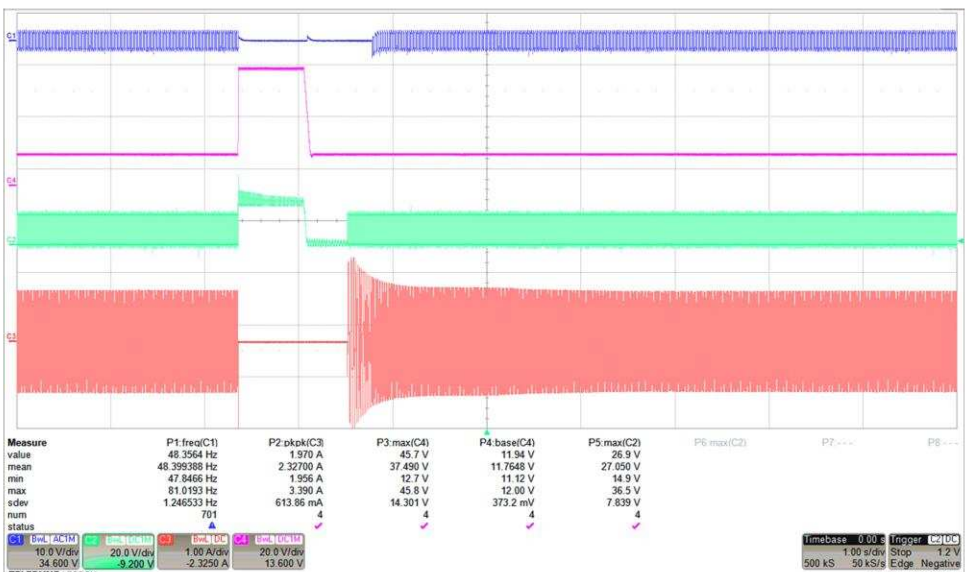


図 23. Load Dump Protection Waveforms After Injecting 45-V Pulses

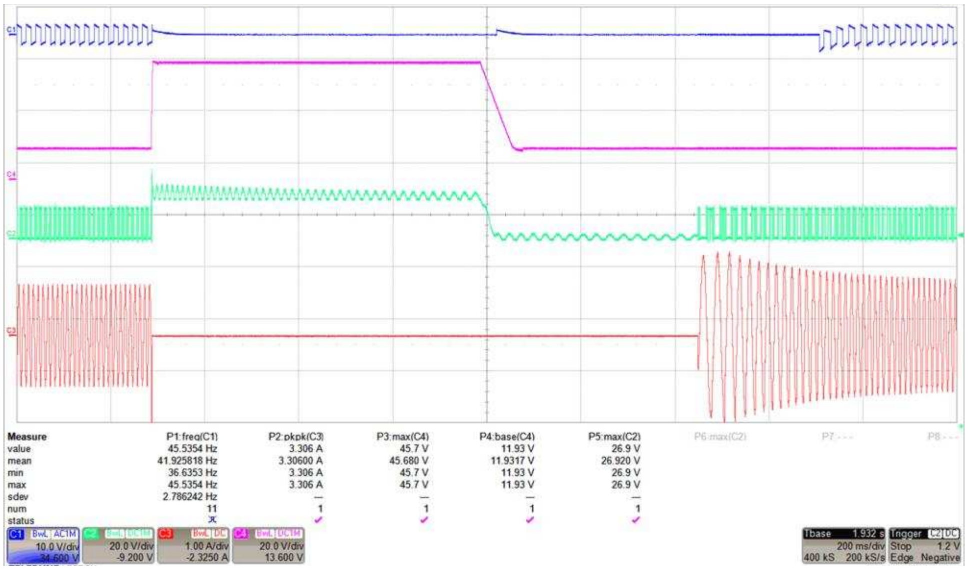


図 24. Load Dump Protection Zoomed Waveforms After Injecting 45-V Pulses

The load dump voltage signal is created using the sequence outlined in 表 8.

表 8. Sequence for Creating Load Dump Signal

SEQUENCE	DURATION (s)	SLEW RATE (V/ms)	VOLTAGE (V)
1	5.5	0.001	12
2	0.3	10	45
3	0.4	0.001	45
4	0.3	10	12
5	5.5	0.001	12

3.2.5 Thermal Test

Thermal testing is conducted for a range of temperatures. The device operated and spun the motor at all temperatures. The device operated on average 20°C higher than the ambient temperature, which remained consistent in all the results.

注: The numbers shown in the following images are in degrees Celsius.

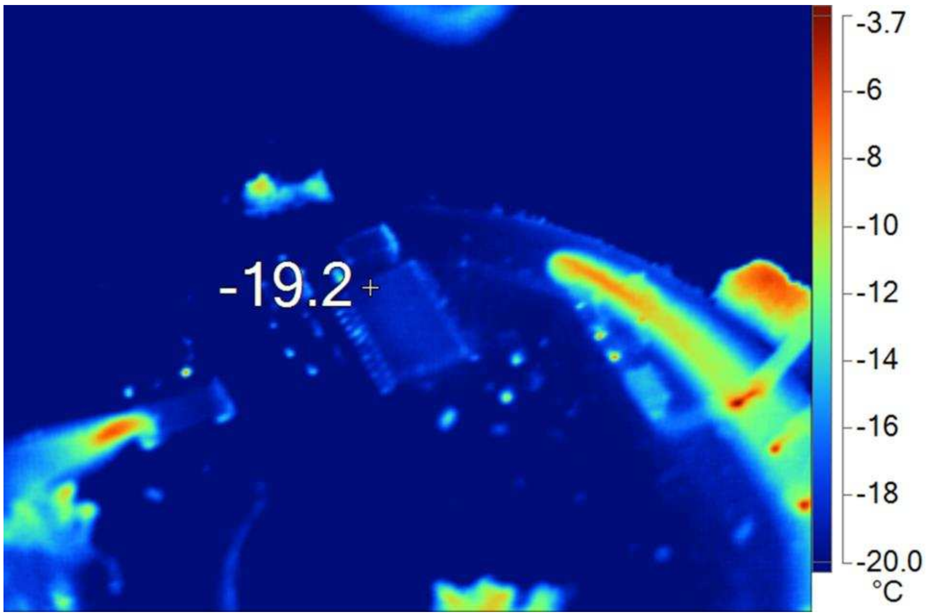


図 25. Thermal Image After 3 Hours at 12 W, –40°C Ambient

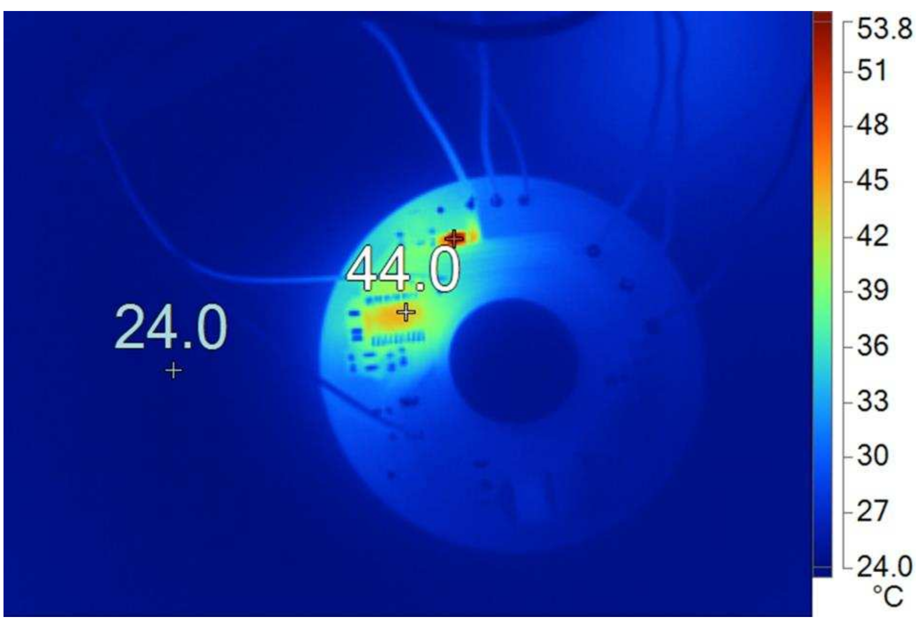


図 26. Thermal Image After 15 Hours at 12 W, –40°C Ambient

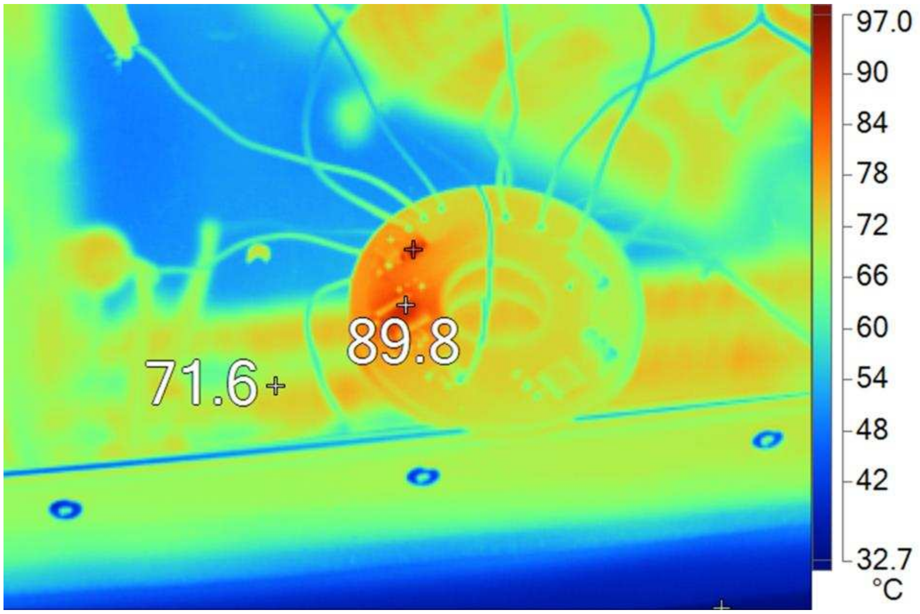


図 27. Thermal Image After 15 Hours at 12 W, 70°C Ambient

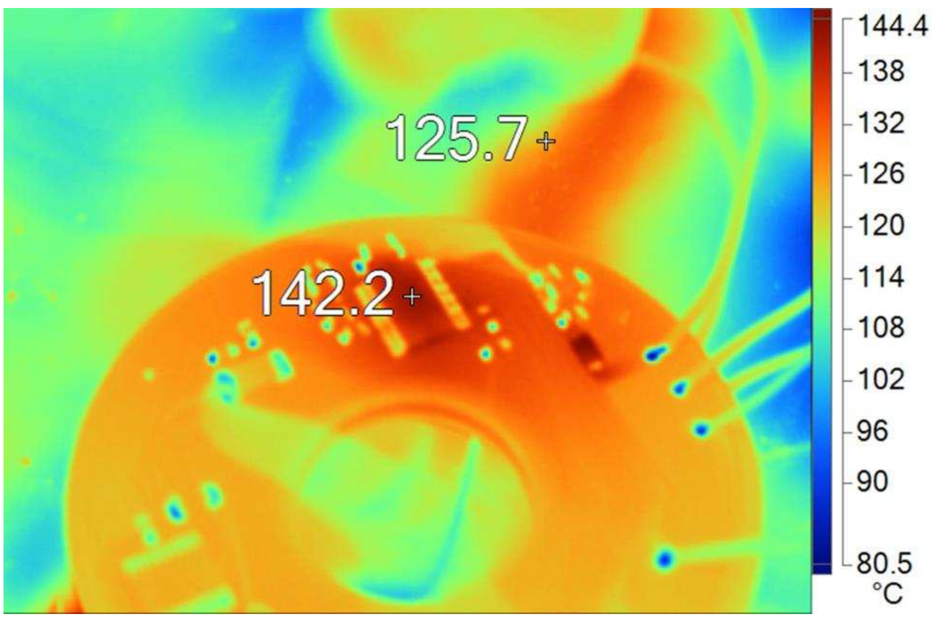


図 28. Thermal Image After 15 Hours at 12 W, 125°C Ambient

4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDA-01496.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01496.

4.3 PCB Layout Recommendations

- Place the VCC, GND, U, V, and W pins with thick traces because high current passes through these traces.
- Place the 10-µF capacitor between VCC and GND, and as close to the VCC and GND pins as possible.
- Place the capacitor between CPP and CPN, and as close to the CPP and CPN pins as possible.
- Connect the GND, PGND, and SWGND under the thermal pad.
- Keep the thermal pad connection as large as possible, on both the bottom side and top sides. The connection must be one piece of copper without any gaps.
- Single-layer boards often suffer in optimal thermal and GND loop designs. Layout can be supplemented using 0-Ω resistors to connect isolated GND planes.

4.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-01496.

4.4 Altium Project

To download the Altium project files, see the design files at TIDA-01496.

4.5 Gerber Files

To download the Gerber files, see the design files at TIDA-01496.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-01496.

5 Software Files

To download the software files, see the design files at TIDA-01496.

注: The software files of this reference design require a TI login to access.

6 Related Documentation

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

6.1 商標

E2E, MSP430, LaunchPad, Code Composer Studio are trademarks of Texas Instruments.
すべての商標および登録商標はそれぞれの所有者に帰属します。

7 Terminology

BLDC — Brushless DC motor

ESD— Electrostatic discharge

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

IGBT— Insulated gate bipolar transistor

IPD— Initial position detection

OCP— Overcurrent protection

OTP— Overtemperature protection

PWM— Pulse width modulation

RPM— Revolutions per minute

RMS— Root mean square

UVLO— Undervoltage lockout

8 About the Authors

COLE MACIAS is an applications engineer at Texas Instruments, where he is responsible for supporting customers and customer issues for the DRV10x family of products. These include 3-phase BLDC motor drive solutions in a wide range of applications. Cole obtained his BSEE at Arizona State University.

MOSTAFA SHUBBAR is a product marketing engineer at Texas Instruments currently working in the Integrated Motor Controller group. He completed his BSEE at the University of Texas at Dallas and is currently pursuing an MSEE at UTD.

TIDUDD8 翻訳版 — 最新の英語版資料 http://www-s.ti.com/sc/techlit/TIDUDD8

TIの設計情報およびリソースに関する重要な注意事項

Texas Instruments Incorporated ("TI")の技術、アプリケーションその他設計に関する助言、サービスまたは情報は、TI製品を組み込んだアプリケーションを開発する設計者に役立つことを目的として提供するものです。これにはリファレンス設計や、評価モジュールに関係する資料が含まれますが、これらに限られません。以下、これらを総称して「TIリソース」と呼びます。いかなる方法であっても、TIリソースのいずれかをダウンロード、アクセス、または使用した場合、お客様(個人、または会社を代表している場合にはお客様の会社)は、これらのリソースをここに記載された目的にのみ使用し、この注意事項の条項に従うことに合意したものとします。

TIによるTIリソースの提供は、TI製品に対する該当の発行済み保証事項または免責事項を拡張またはいかなる形でも変更するものではなく、これらのTIリソースを提供することによって、TIにはいかなる追加義務も責任も発生しないものとします。TIは、自社のTIリソースに訂正、拡張、改良、およびその他の変更を加える権利を留保します。

お客様は、自らのアプリケーションの設計において、ご自身が独自に分析、評価、判断を行う責任がお客様にあり、お客様のアプリケーション(および、お客様のアプリケーションに使用されるすべてのTI製品)の安全性、および該当するすべての規制、法、その他適用される要件への遵守を保証するすべての責任をお客様のみが負うことを理解し、合意するものとします。お客様は、自身のアプリケーションに関して、(1) 故障による危険な結果を予測し、(2) 障害とその結果を監視し、および、(3) 損害を引き起こす障害の可能性を減らし、適切な対策を行う目的での、安全策を開発し実装するために必要な、すべての技術を保持していることを表明するものとします。お客様は、TI製品を含むアプリケーションを使用または配布する前に、それらのアプリケーション、およびアプリケーションに使用されているTI製品の機能性を完全にテストすることに合意するものとします。TIは、特定のTIリソース用に発行されたドキュメントで明示的に記載されているもの以外のテストを実行していません。

お客様は、個別のTIリソースにつき、当該TIリソースに記載されているTI製品を含むアプリケーションの開発に関連する目的でのみ、使用、コピー、変更することが許可されています。明示的または黙示的を問わず、禁反言の法理その他どのような理由でも、他のTIの知的所有権に対するその他のライセンスは付与されません。また、TIまたは他のいかなる第三者のテクノロジまたは知的所有権についても、いかなるライセンスも付与されるものではありません。付与されないものには、TI製品またはサービスが使用される組み合わせ、機械、プロセスに関連する特許権、著作権、回路配置利用権、その他の知的所有権が含まれますが、これらに限られません。第三者の製品やサービスに関する、またはそれらを参照する情報は、そのような製品またはサービスを利用するライセンスを構成するものではなく、それらに対する保証または推奨を意味するものでもありません。TIリソースを使用するため、第三者の特許または他の知的所有権に基づく第三者からのライセンス、もしくは、TIの特許または他の知的所有権に基づくTIからのライセンスが必要な場合があります。

TIのリソースは、それに含まれるあらゆる欠陥も含めて、「現状のまま」提供されます。TIは、TIリソースまたはその仕様に関して、明示的か暗黙的かにかかわらず、他のいかなる保証または表明も行いません。これには、正確性または完全性、権原、続発性の障害に関する保証、および商品性、特定目的への適合性、第三者の知的所有権の非侵害に対する黙示の保証が含まれますが、これらに限られません。

TIは、いかなる苦情に対しても、お客様への弁護または補償を行う義務はなく、行わないものとします。これには、任意の製品の組み合わせに関連する、またはそれらに基づく侵害の請求も含まれますが、これらに限られず、またその事実についてTIリソースまたは他の場所に記載されているか否かを問わないものとします。いかなる場合も、TIリソースまたはその使用に関連して、またはそれらにより発生した、実際的、直接的、特別、付随的、間接的、懲罰的、偶発的、または、結果的な損害について、そのような損害の可能性についてTIが知らされていたかどうかにかかわらず、TIは責任を負わないものとします。

お客様は、この注意事項の条件および条項に従わなかったために発生した、いかなる損害、コスト、損失、責任からも、TIおよびその代表者を完全に免責するものとします。

この注意事項はTIリソースに適用されます。特定の種類の資料、TI製品、およびサービスの使用および購入については、追加条項が適用されます。これには、半導体製品(http://www.ti.com/sc/docs/stdterms.htm)、評価モジュール、およびサンプル(http://www.ti.com/sc/docs/sampterms.htm)についてのTIの標準条項が含まれますが、これらに限られません。