TI Designs
Driving Three-Phase Stepper Motor With BLDC Motor Driver Reference Design

TEXAS INSTRUMENTS

Description

The TIDA-01362 reference design demonstrates how to drive a three-phase stepper motor using the same hardware structure of a brushless DC (BLDC) driver. By regulating the pulse-width modulation (PWM) signal schemes, the design achieves a smooth sinusoidal-output current. The DRV8313 device is used for the implementation of this design.

Resources

TIDA-01362	Design Folder
DRV8313	Product Folder
MSP430G2553	Product Folder
DRV8313EVM	Product Folder

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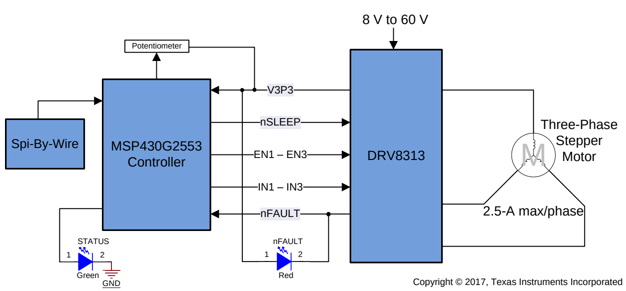
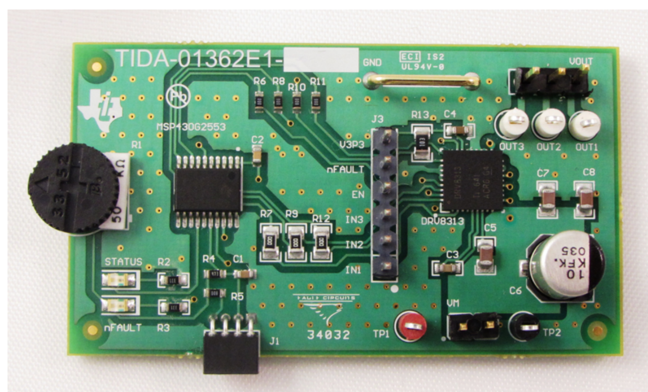
Features

- Smooth Current
- Low Noise Operation
- Compact Design
- Open Loop; No Current Feedback Required
- Can Be Driven With Most TI BLDC Driver
- Very Low to Zero Vibrations

Applications

- Textile Equipment
- Dome Cameras
- Gimbals
- Analytical and Medical Instruments
- Robotics





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1 System Overview

1.1 System Description

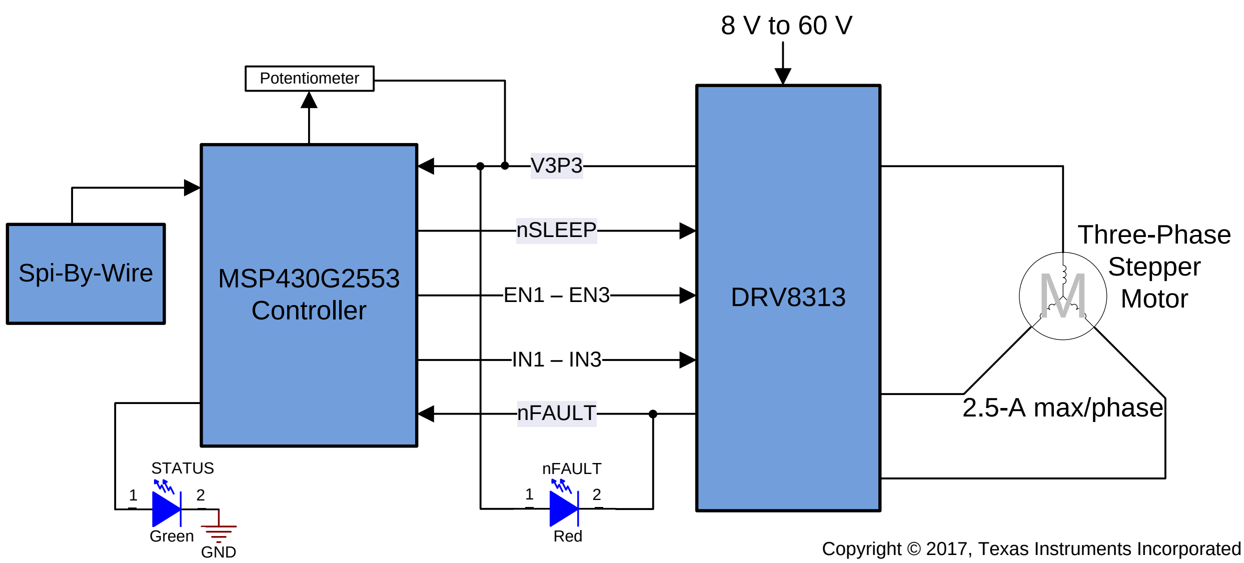
This TIDA-01362 TI Design achieves a three-phase, high-resolution, micro-stepping module using Texas Instruments DRV8313 brushless DC (BLDC) motor driver. This design demonstrates how to create a PWM signal sequence to control the three-phase currents, sinusoidal, and 120º of phase shift.

1.2 Key System Specifications

Table 1. Key System Specifications

PARAMETER	DESCRIPTION	VALUE
Voltage	Input voltage for motor	10 V to 18 V
Current	Maximum motor phase current	3.5 A
Resistance	Motor winding resistance	4.5 Ω
Inductance	Motor winding inductance	20 mH
Frequency	Microcontroller PWM signal frequency	20 kHz

1.3 Block Diagram



1.4 Highlighted Products

1.4.1 DRV8313

The DRV8313 provides three individually-controllable, half-H-bridge drivers (see Figure 1). The device is intended to drive a three-phase BLDC motor, although it can also be used to drive solenoids or other loads. Each output driver channel consists of N-channel power MOSFETs configured in a ½-H-bridge configuration. Each ½-H-bridge driver has a dedicated ground terminal, which allows independent external current sensing.

An uncommitted comparator is integrated into the DRV8313, which allows for the construction of current-limit circuitry or other functions.

Internal protection functions are provided for undervoltage, charge pump faults, overcurrent, short circuits, and overtemperature. Fault conditions are indicated by the nFAULT pin.

Features:

- Triple ½-H-bridge driver IC
  - Three-phase BLDC motors
- High Current-drive capability: 2.5-A peak
- Low MOSFET ON-resistance
- Independent ½-H-bridge control
- Uncommitted comparator can be used for current limit or other functions
- Built-in 3.3-V, 10-mA low-dropout (LDO) regulator
- 8-V to 60-V operating supply-voltage range
- Sleep mode for standby operation
- Small package and footprint
  - 28-Pin HTSSOP (PowerPAD™ integrated circuit package)
  - 36-Pin VQFN

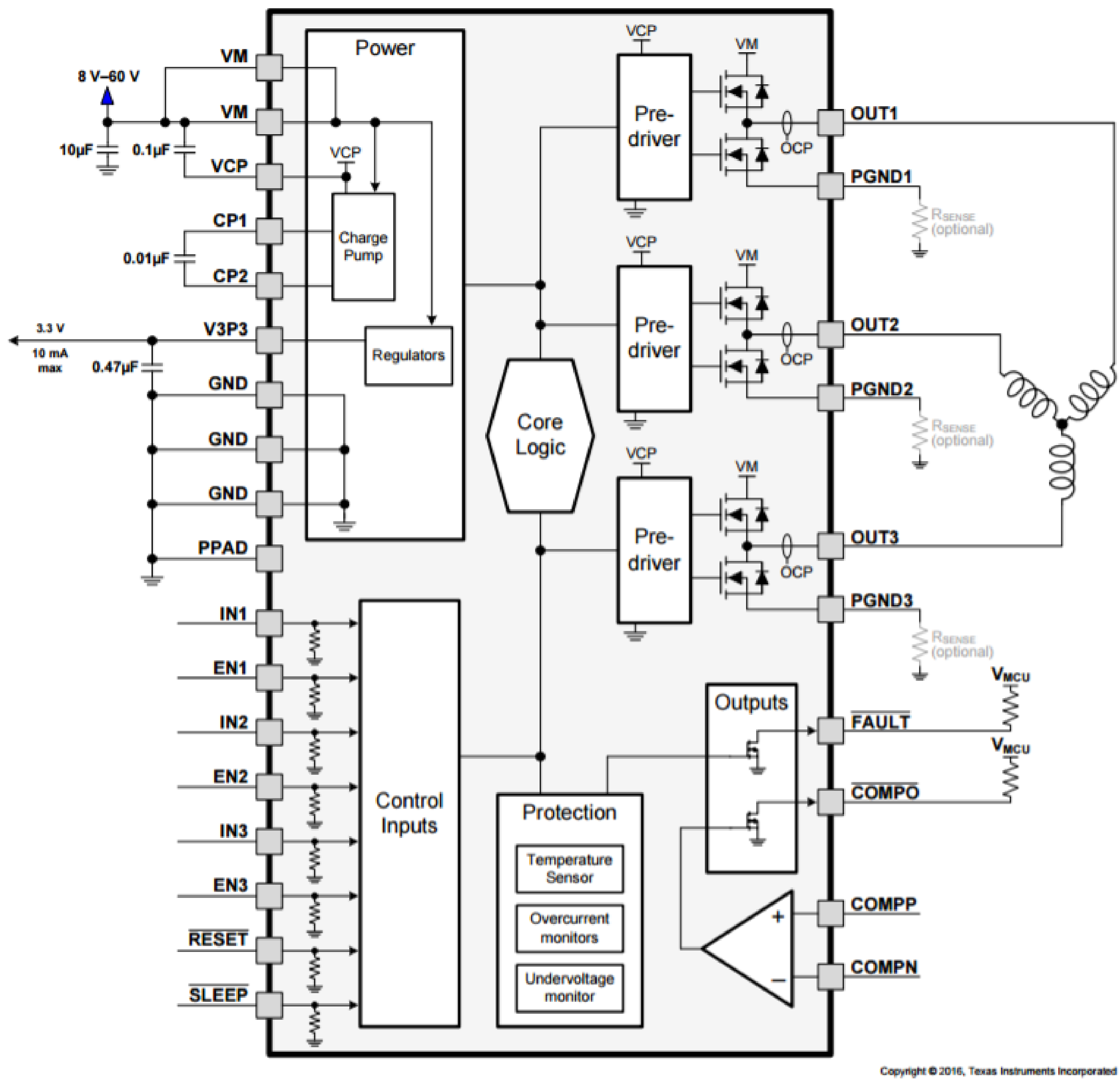


Figure 1. DRV8313 Block Diagram

1.4.2 MSP430G2533

The Texas Instruments MSP430™ family of ultra-low-power microcontrollers (MCUs) 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 reduced instruction set computing (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 MCUs 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 (see Figure 2). In addition, the devices in the MSP430G2x53 family have a 10-bit analog-to-digital (ADC) converter.

Features:
- Low supply-voltage range: 1.8 V to 3.6 V
- Ultra-low-power consumption
  - Active mode: 230 µA at 1 MHz, 2.2 V
  - Standby mode: 0.5 µA
  - Off mode (RAM retention): 0.1 µA
- Five power-saving modes
- Ultra-fast wake-up from standby mode in less than 1 µs
- 16-bit RISC architecture, 62.5-ns instruction cycle time
- Basic clock module configurations
  - Internal frequencies up to 16 MHz with four calibrated frequency
  - Internal very-low-power low-frequency (LF) oscillator
  - 32-kHz crystal
  - External digital clock source
- Two 16-bit Timer_A with three capture/compare registers
- Up to 24 capacitive-touch enabled I/O pins
- Universal serial communication interface (USCI)
  - Enhanced universal asynchronous receiver/transmitter (UART) supporting auto baudrate detection (LIN)
  - IrDA encoder and decoder
  - Synchronous serial peripheral interface (SPI)
  - I^2C
- On-chip comparator for analog signal compare function or slope analog-to-digital conversion
- 10-bit 200-ksps ADC with internal reference, sample-and-hold, and autoscan
- Brownout detector
- Serial onboard programming, no external programming voltage required, programmable code protection by security fuse
- On-chip emulation logic with Spy-Bi-Wire interface

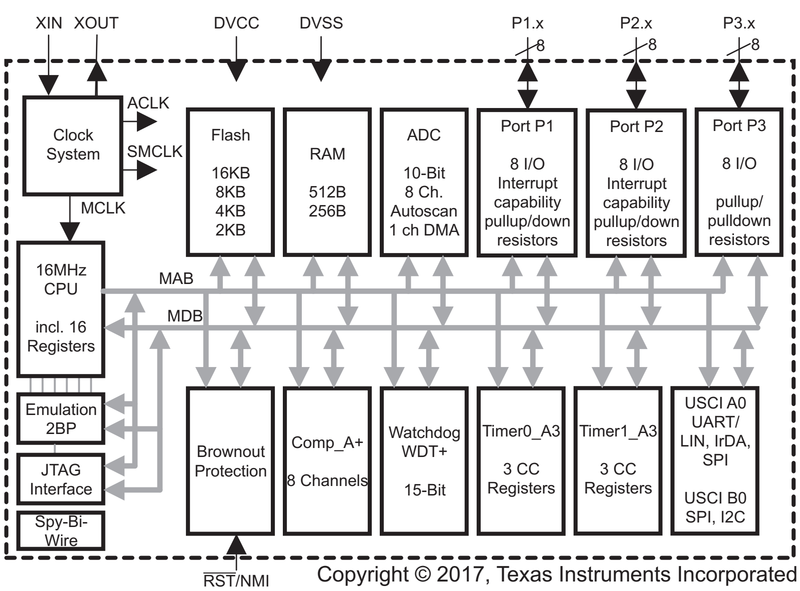


Figure 2. MSP430G2553 Functional Block Diagram

2 System Design Theory

Three-phase stepper motors are useful in applications that require very-high resolution (micro-stepping) as well as minimal noise and vibration. This TIDA-01362 design achieves all of these requirements by driving a three-phase stepper motor using Texas Instruments DRV8313 brushless DC (BLDC) motor driver. The three half-bridges of the BLDC device drive the three phases of the stepper motor in an open-loop system. Any TI BLDC device can be used to drive a three-phase stepper motor; for practicality, the DRV8313 device has been selected for its compact design because it offers integrated power MOSFETs.

Driving the three-phase stepper motor is achieved by implementing and controlling the duty cycle of PWM signals of the MCU. The modulated signal controls the ON and OFF time of the power MOSFETs in the half-bridges, which in turn controls the output current and voltage supplied to the windings of the three-phase stepper motor.

The three phases of the motor are driven by the three outputs of the DRV8313, as Figure 3 shows.

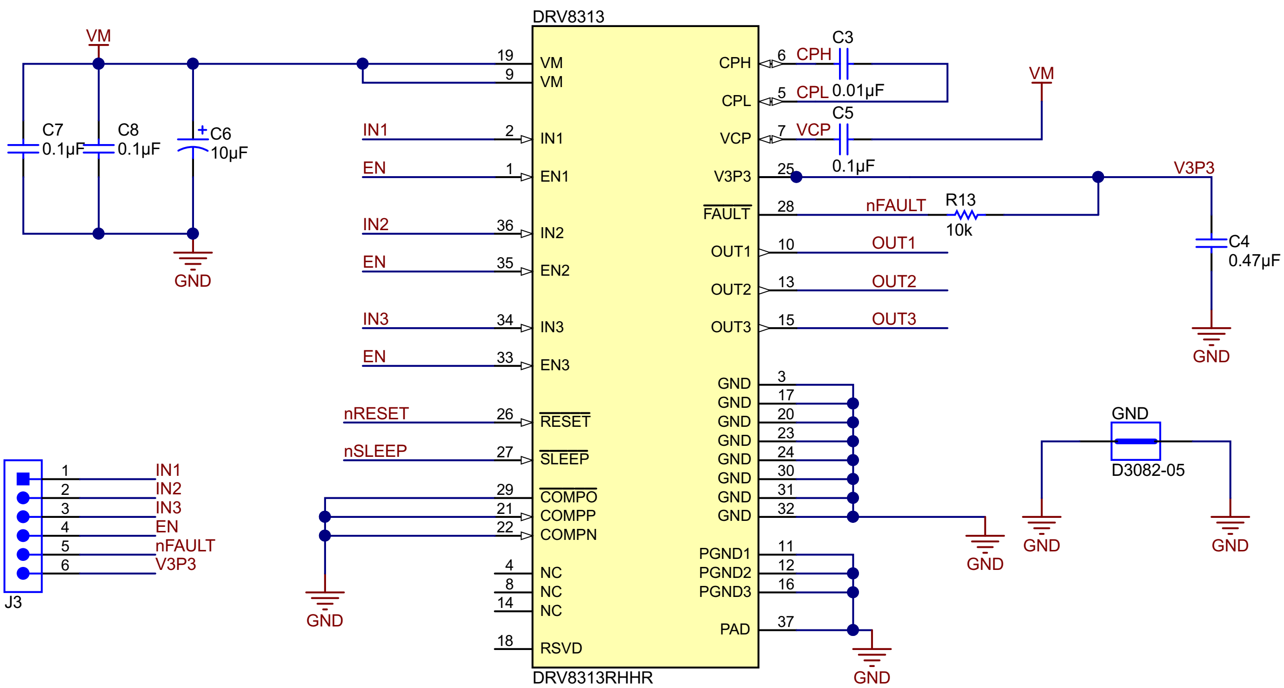


Figure 3. DRV8313

Pins IN1, IN2, and IN3 are the three PWM inputs from the microcontroller into the DRV8313 (see Figure 4). Also, the enable pin, EN, is driven from the MCU. The EN1, EN2, and EN3 input pins in the DRV8313, enable or disable the outputs of the driver OUT1, OUT2, and OUT3, respectively. For this design, the three EN pins always remain high because the implementation only depends on the PWM signals.

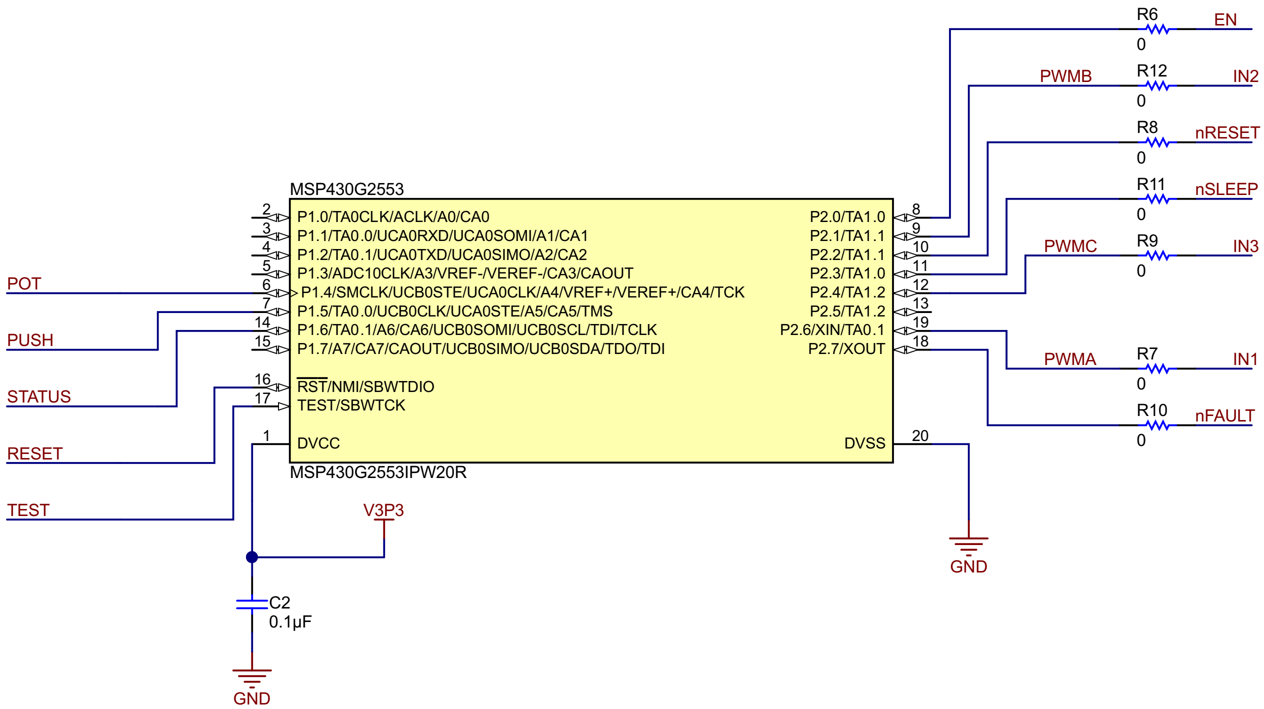


Figure 4. MSP430G2553

The three PWM signals implemented from the MSP430G2553 MCU follow a sine-wave scheme. For each output phase of the stepper motor, the same scheme is executed with a 120° phase shift.

The duty cycle of the modulated signals are set to change between 10% to 90% duty cycle. These ON and OFF time variations create the sine waves required to drive the stepper motor.

The following Figure 5 shows the PWM scheme to produce the microstepping-sine waveform output.

As Figure 5 shows, the three PWM signals from the MCU create the three current waves. The sequence starts at 50% duty cycle and increases to maximum, which represents the peak of the sine wave. Then, the duty cycle starts decreasing down to 50% all the way to the minimum, which is the valley of the wave. This commutation is the same for all three phases with the 120º delay.

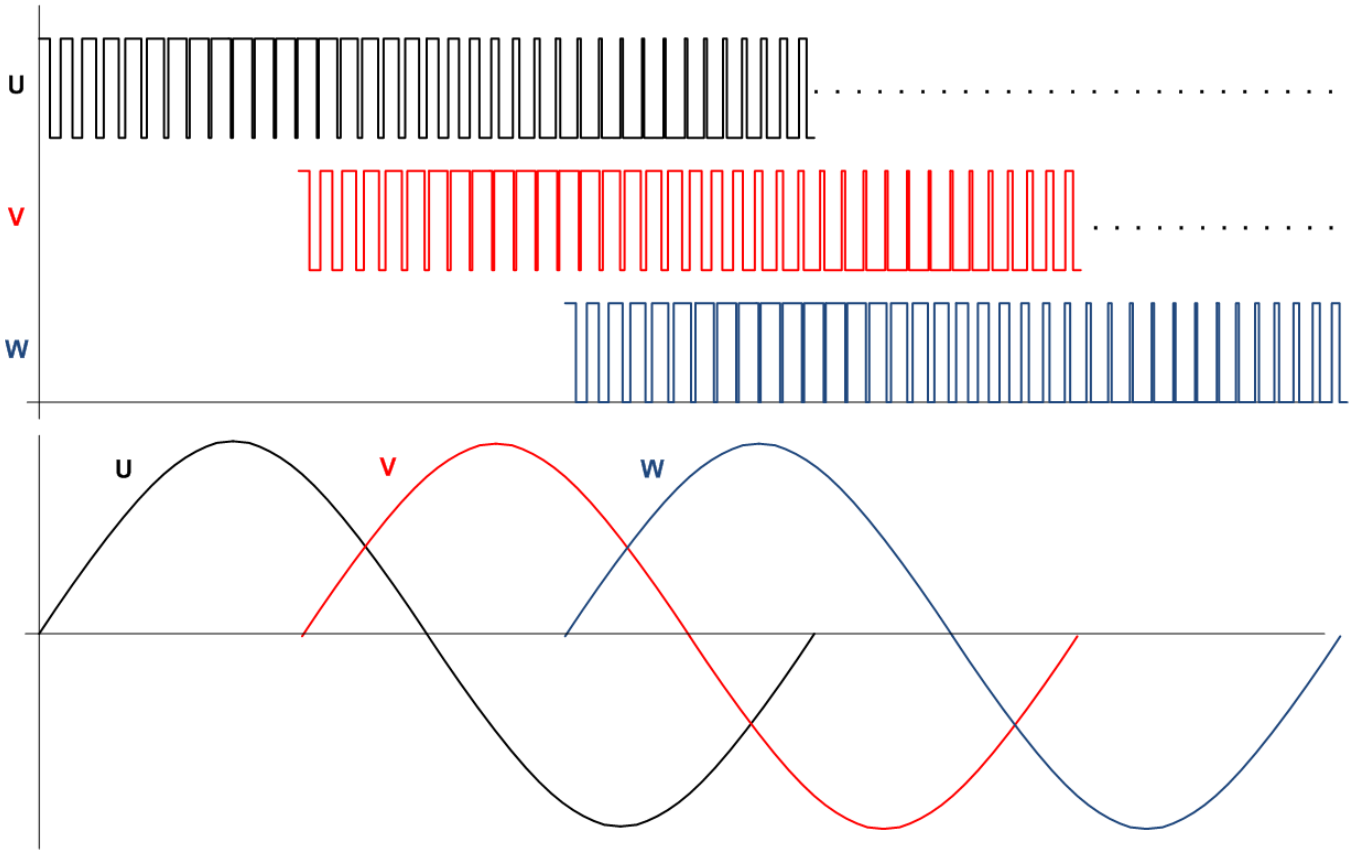


Figure 5. PWM Scheme for Sine Waveform Output

3 Getting Started Hardware

3.1 Hardware

The VM pin headers are the input voltage supply for the board. The output to the three-phase stepper motor is through the VOUT pin header connectors, as Figure 6 shows.

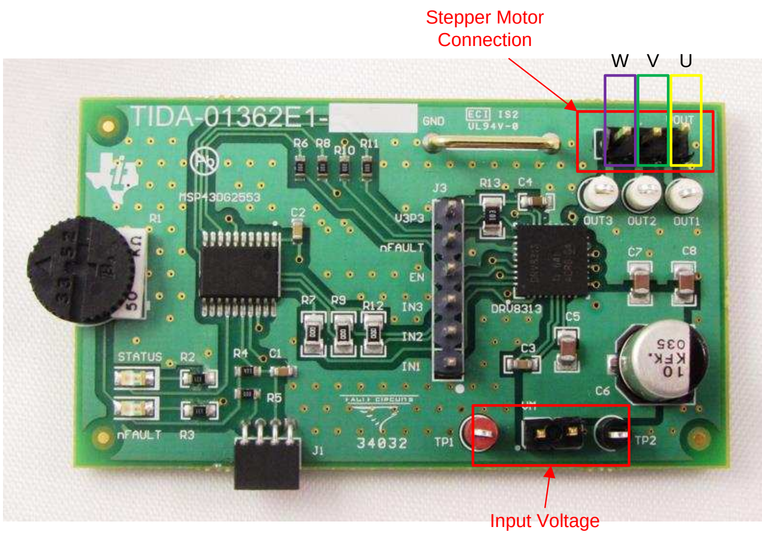


Figure 6. Input and Output Connections

The board has two light-emitting diodes (LEDs), the status LED (green) to acknowledge a functional board and the nFAULT LED (red) when a fault occurs in the DRV8313 driver. The board also has a potentiomenter for speed, direction input control, or both, and a Spy-Bi-Wire connector to program the MCU of the board, MSP430G2553. Figure 7 shows the board hardware.

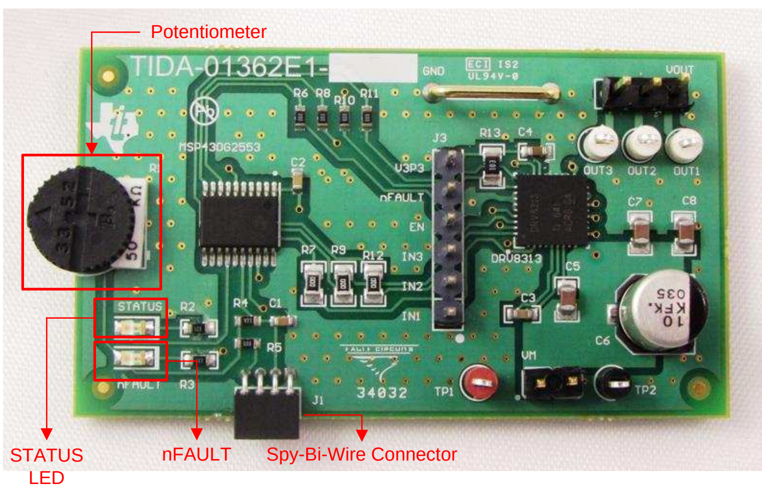


Figure 7. Board Hardware

3.2 Software

The firmware for this TI Design was developed using the TI Code Composer Studio™ software version 6.1.3. The code uploaded to the MSP430G2553 MCU was programmed through Spy-Bi-Wire protocol (two-wire Joint Test Action Group (JTAG)).

This firmware can be downloaded from the TIDA-01362 design folder (see Section 6). The high-level description implemented in the design is as follows.

1. Define the pins used in the MCU then set the PWM frequency.
2. Create a sine look-up table for the stepper motor
3. Configure the clock and timers. TA0CCR1 is used for phase U, TA1CCR1 is used for phase V, and TA1CCR2 is used for phase W.
4. Set the timer interrupt and update the values for each phase according to the sine look-up table values.

Although firmware for the speed control and direction feature is not implemented in the code provided with the reference design, it can easily be implemented to reproduce a typical stepper motor application by setting the ADC feature of the MCU (see Figure 8).

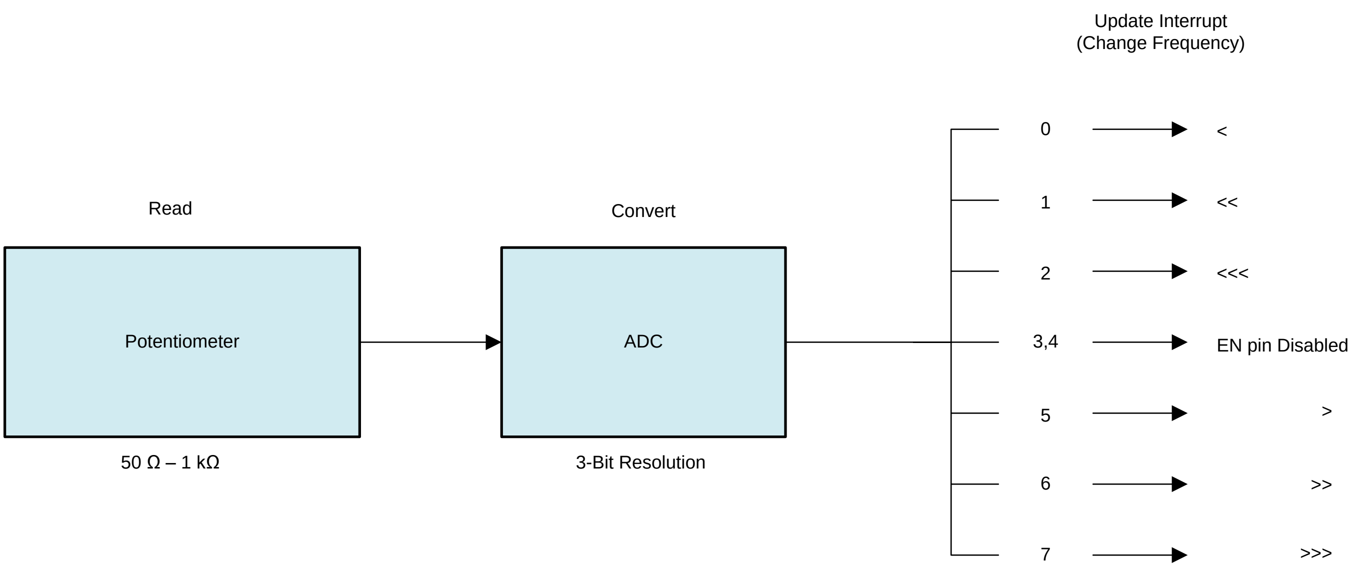
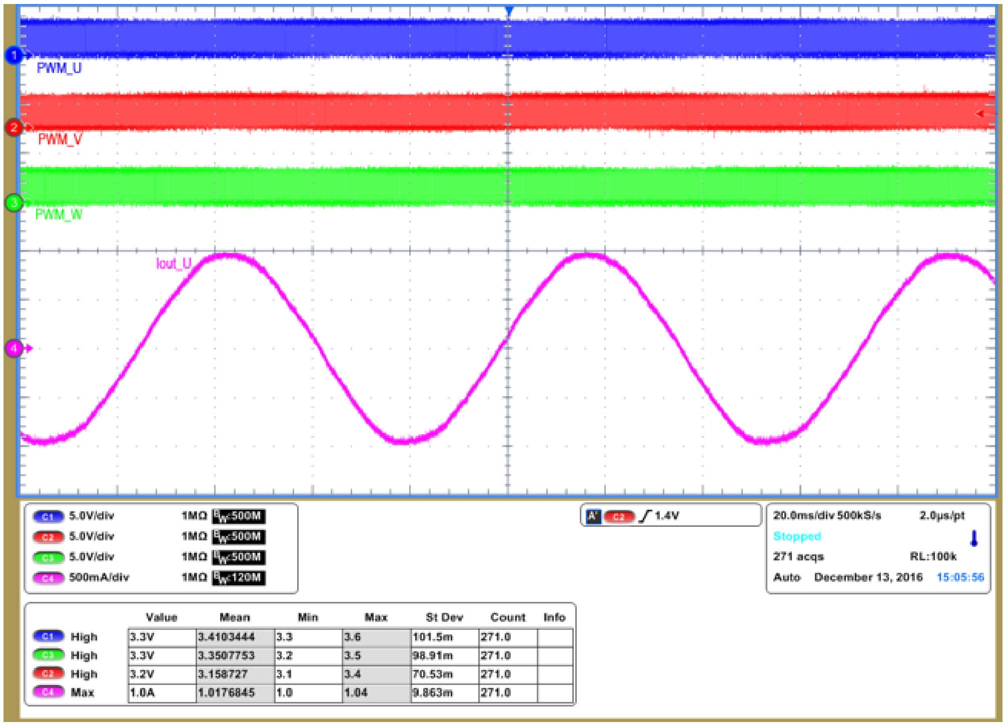


Figure 8. Speed and Direction Implementation

4 Testing and Results

Two different type of motors are tested with this design, the first being a Nema 34 and the second a Nema 17 stepper motor. The captures in Figure 9 through Figure 13 have been generated while running the Nema 34 stepper motor at 10 V. Motor specificaitions are listed on Table 1



	Value	Mean	Min	Max	St Dev	Count	Info
C1 High	3.3V	3.4103444	3.3	3.6	101.5m	271.0	
C3 High	3.3V	3.3507753	3.2	3.5	98.91m	271.0	
C2 High	3.2V	3.158727	3.1	3.4	70.53m	271.0	
C4 Max	1.0A	1.0176845	1.0	1.04	9.863m	271.0	

Figure 9. Three PWM Input Signals and Current Output Phase U

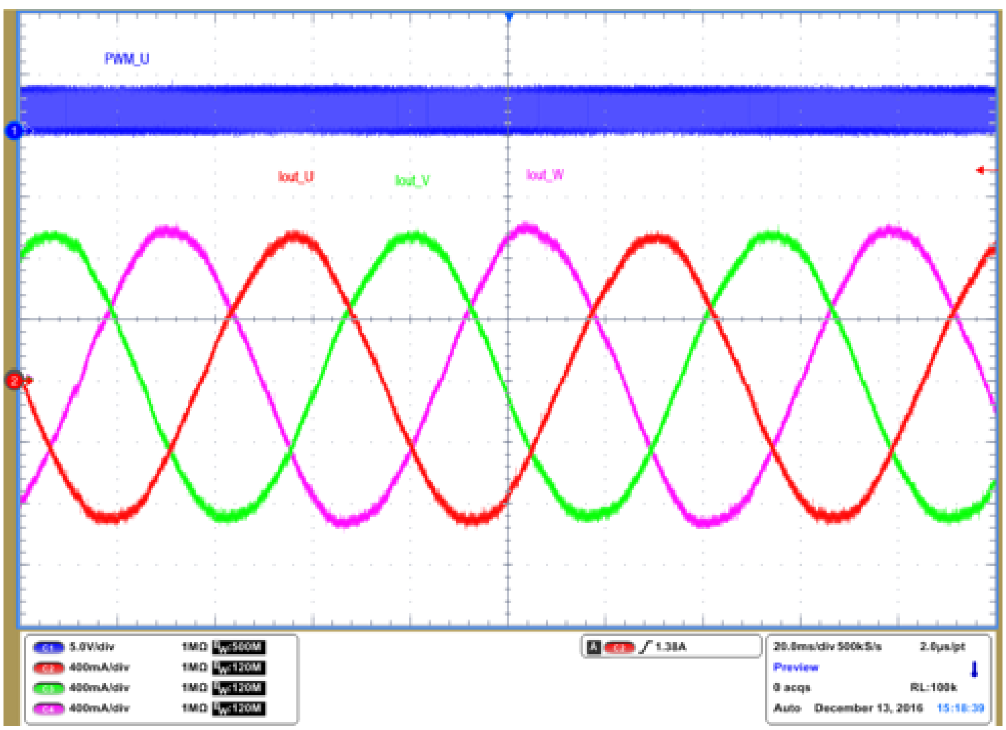


Figure 10. Output Currents of Three-Phase Stepper Motor

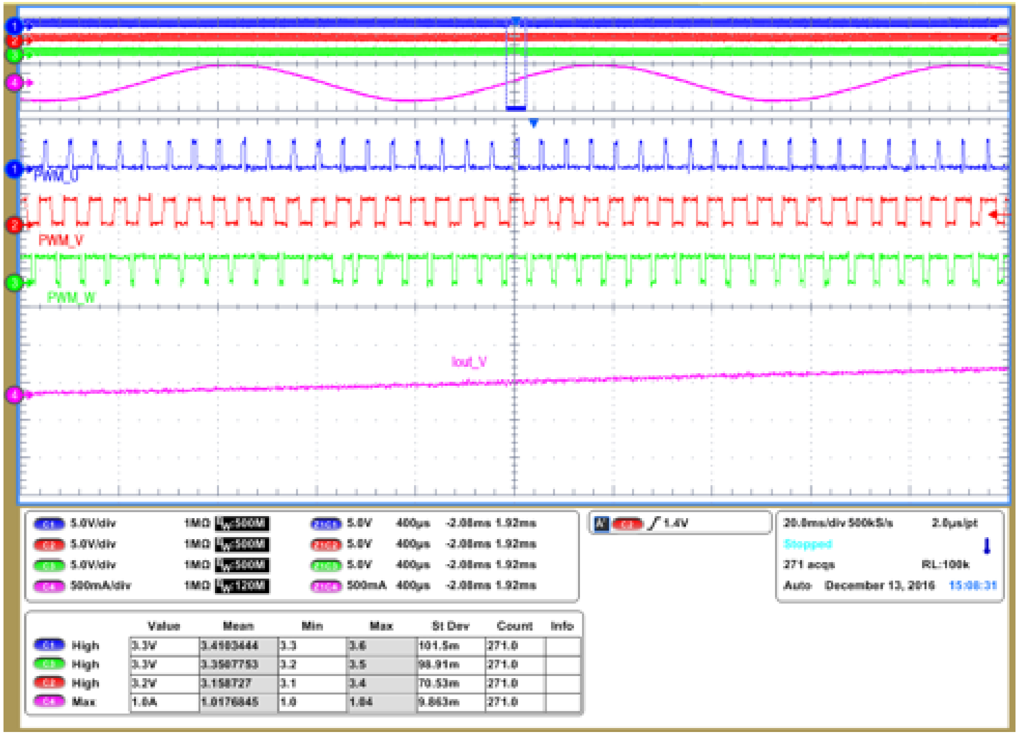


Figure 11. IN2 (PWM_V) 50% DC, Output Phase V at 0º

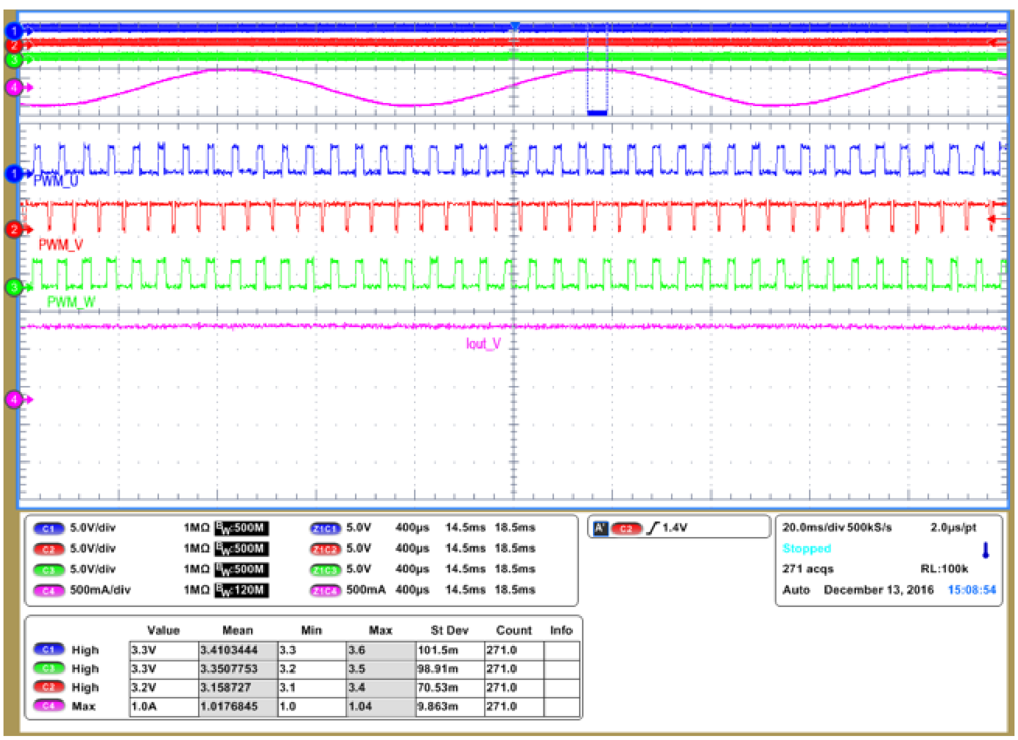
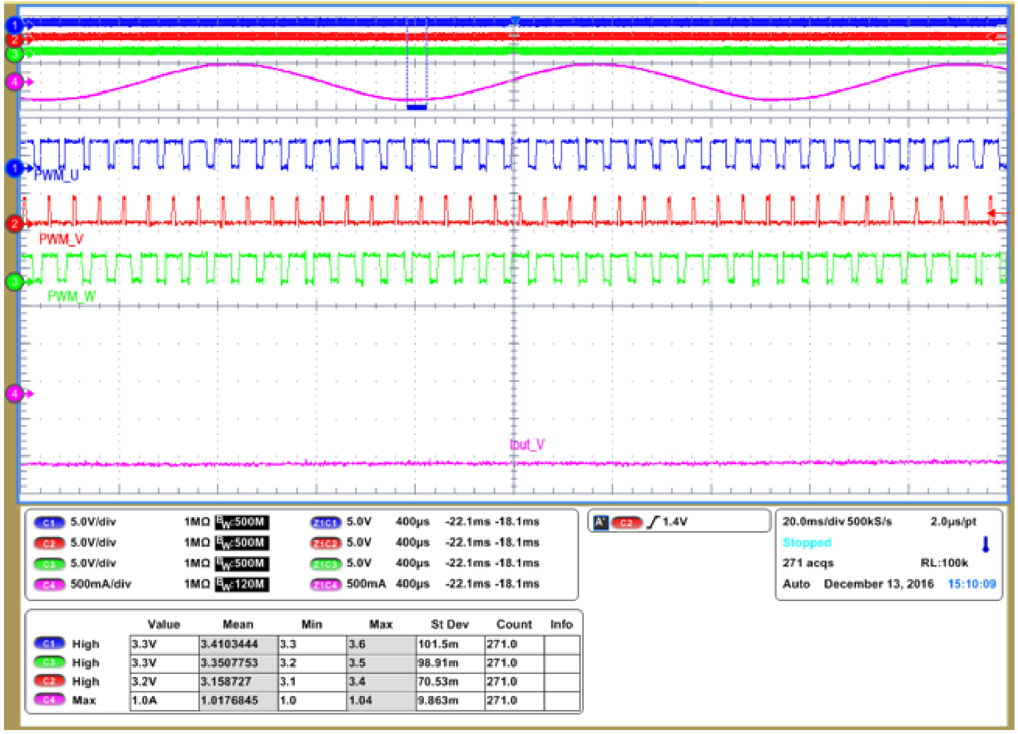


Figure 12. IN2 (PWM_V) 90% DC, Output Phase V at 90º



		Value	Mean	Min	Max	St Dev	Count	Info
C1	High	3.3V	3.4103444	3.3	3.6	101.5m	271.0	
C3	High	3.3V	3.3507753	3.2	3.5	98.91m	271.0	
C2	High	3.2V	3.158727	3.1	3.4	70.53m	271.0	
C4	Max	1.0A	1.0176845	1.0	1.04	9.863m	271.0	

Figure 13. IN2 (PWM_V) 10% DC, Output Phase V at 270º

5 Design Files

5.1 Schematics

To download the schematics, see the design files at TIDA-01362.

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01362.

5.3 PCB Layout Recommendations

Figure 14 shows a few layout guidelines for this design. The complete layout can be downloaded fro the design files at TIDA-01362.

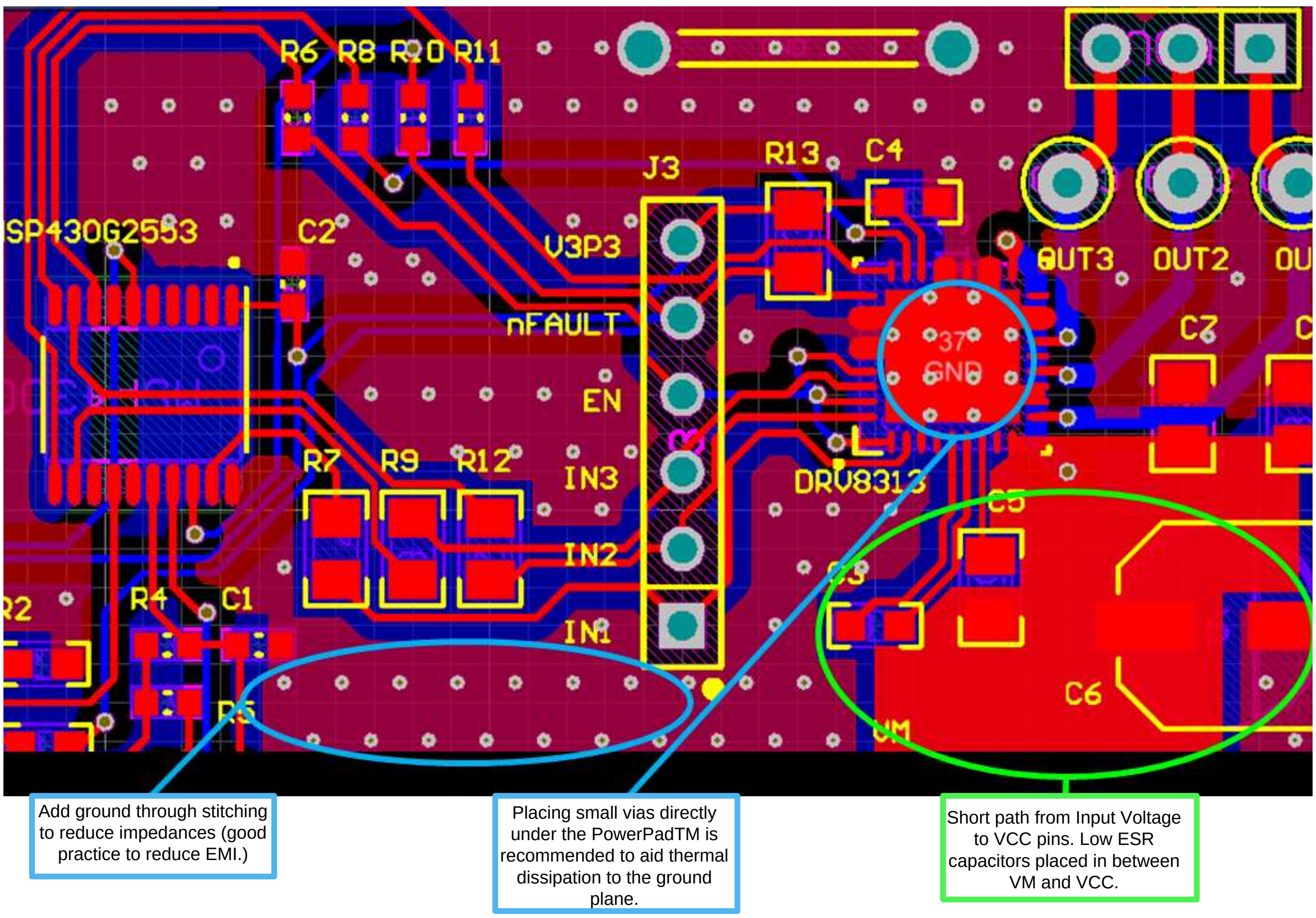


Figure 14. TIDA-01362 Layout Recommendations

5.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-01362.

5.4 Altium Project

To download the Altium project files, see the design files at TIDA-01362.

5.5 Gerber Files

To download the Gerber files, see the design files at TIDA-01362.

5.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-01362.

6 Software Files

To download the software files, see the design files at TIDA-01362.

7 Related Documentation

1. Texas Instruments, *DRV8313EVM User's Guide*, DRV8313EVM User's Guide (SLVU815)

7.1 Trademarks

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8 About the Author

LUIS RIVEROS-LUQUE is an applications engineer at Texas Instruments where he is currently part of the Applications Rotational Program. He supports a broad portfolio of motor drivers. Luis earned his bachelor's of science in electrical engineering from Virginia Tech in Blacksburg VA.