User's Guide
DRV8316xEVM Evaluation Module

TEXAS INSTRUMENTS

ABSTRACT

This document is provided with the DRV8316xEVM customer evaluation module (EVM) as a supplement to the DRV8316 data sheet (DRV8316 4.5-V to 35-V Three-Phase Smart Gate Driver). This user's guide details the hardware implementation of the EVM and how to setup and power the board.

Note

The EVM is populated and configured for the DRV8316R (SPI variant) device by default. To configure the EVM for the DRV8316T (Hardware variant), please see Section 4.1.1.

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Trademarks

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1 Cautions and Warnings

Observe the following cautions and warnings as printed on the EVM board.

HOT SURFACE:

Caution Hot Surface! Contact may cause burns. Do not touch. Please take the proper precautions when operating.

2 Introduction

The DRV8316 is an 4.5-V to 40-V, 8-A peak integrated three-phase gate driver IC for motor drive applications. It provides three accurately trimmed and temperature compensated half-bridges capable of directly driving a three-phase brushless-DC motor. Both the SPI variant (DRV8316R) and hardware interface variant (DRV8316T) integrates an adjustable buck regulator, flexible parameter settings such slew rate control, and protection features, and both are compatible with the DRV8316xEVM. See Table 2-1.

Table 2-1. DRV8316 variants

Device Name	Variant
DRV8316R	Buck regulator and SPI
DRV8316T	Buck regulator and Hardware

Along with the hardware of the DRV8316xEVM, the TMS320F280049C microcontroller on the LAUNCHXL-F280049C LaunchPad™ has reference software that provides the algorithm to the DRV8316 to control the BLDC motor.

This document serves as a startup guide to supplement the DRV8316xEVM + LAUNCHXL-F280049C BLDC motor control demonstration kit. It also is intended for engineers to design, implement, and validate reference hardware and software for the LaunchPad™ MCU and DRV8316R. For step-by-step details on connecting the LAUNCHXL-F280049C + DRV8316xEVM, installing software, and running the project to spin a motor, refer to Section 5 *Hardware Setup*.
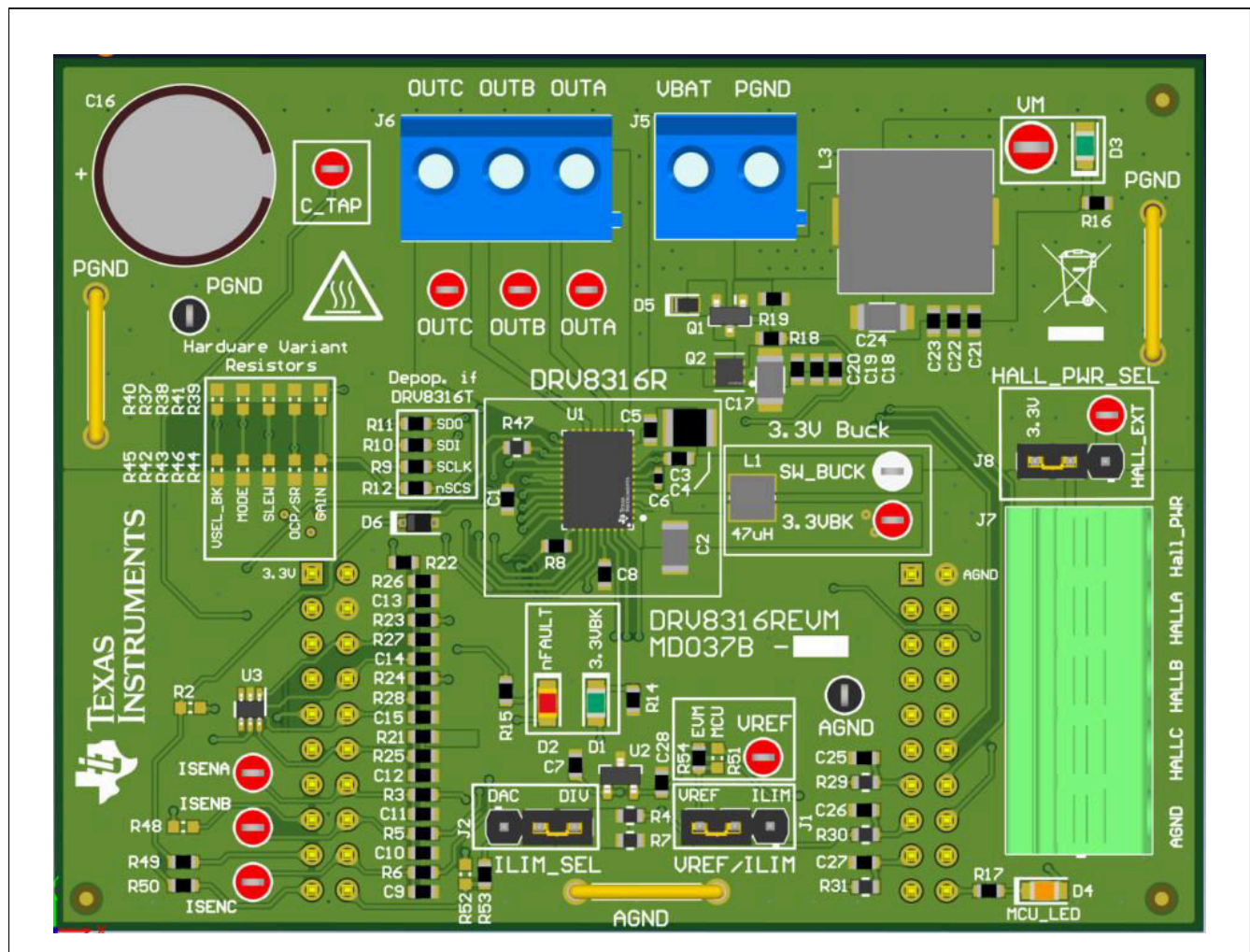
Figure 2-1. DRV8316xEVM PCB Layout

3 Quick Start Guide

The DRV8316xEVM requires a power-supply source, which has a recommended operating range from 4.5 V to 35 V. To setup and power the EVM, use the following sequence:

1. Connect the power supply ground to PGND of the two-pin power connector J5 and the voltage pin to the VBAT pin. Ensure R13 on the bottom layer is not populated and that jumpers J1-J3 of the LAUNCHXL-F280049C are populated (USB powers LaunchPad).
2. Connect the motor phases to OUTA, OUTB, and OUTC. If using the Hall sensors, connect them to five-pin connector J7 as Figure 4-6 shows. Select 3.3 V or HALL_EXT_PWR on jumper J8 to select Hall power source.
3. Mate the DRV8316xEVM onto the top half of the LAUNCHXL-F280049C (Launchpad Headers J1/J3 and J2/J4) as Figure 4-7 shows. The motor and power connectors should face the same direction as the Micro-USB connector on the LaunchPad.
4. Power on the DRV8316xEVM.
5. Connect a Micro-USB cable from the computer into the Micro USB connector on the top of the LAUNCHXL-F280049C.

4 Hardware and Software Overview

4.1 LEDs, Switches, and Jumpers

There are LED indicators on both the LAUNCHXL-F280049C and DRV8316xEVM when power is provided.

The LAUNCHXL-F280049 LaunchPad LEDs power up when the Micro-USB cable is plugged in and their functionalities are not modified upon powering the board.

The DRV8316xEVM has four status LEDs implemented on the board. By default, the VM and 3.3-VBK LEDs will light up when the board is powered and the MCU LED (tied to GPIO59) can be used for debugging and validation. Table 4-3 shows LED descriptions including those that are on during power up in bold and Figure 4-1 shows the locations of the LEDs.

Table 4-1. Description of DRV8316xEVM LEDs (default Upon powerup in bold)

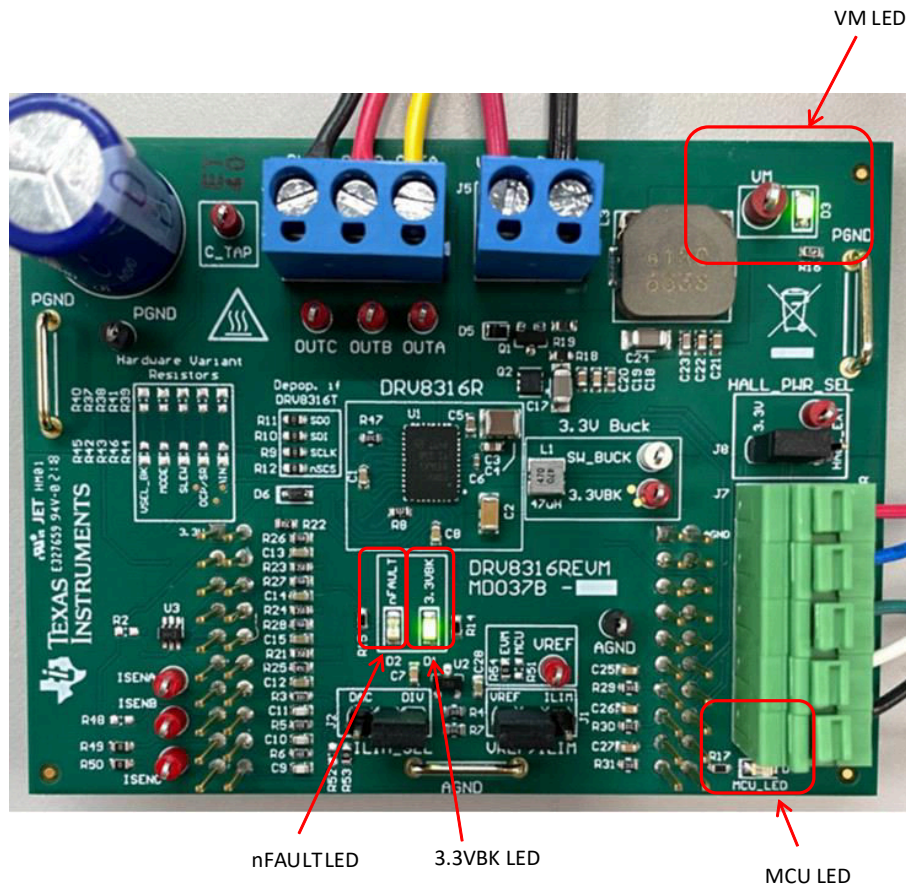| Designator	Name	Color	Description
D1	**3.3VBK**	**Green**	**Internal buck regulator is outputting 3.3 V**
D2	nFAULT	Red	Lights up when fault condition has occurred on DRV8316
D3	**VM**	**Green**	**Power is supplied to the board**
D4	MCU_LED	Orange	MCU debugging

Figure 4-1. DRV8316xEVM LEDs

The DRV8316xEVM includes a variety of user-selectable jumpers and unpopulated components on the bottom and top layers of the PCB to choose user settings and evaluate the DRV8316 device. A summary of those selectable settings are listed in Table 4-2 (defaults in bold) and can be seen on the board in Figure 4-2 and Figure 4-3.

Table 4-2. Description of User Selectable Settings on DRV8316xEVM (default in bold)

| Id.	Setting Name	Description	Layer	Position	Function
A	3.3-V buck inductor	User populates L1, L2, or R1 to choose switching component for buck regulator	Top	**L1 = 47 µH Inductor**	**Inductor Mode**
			Bottom	L2 = 22 µH	Inductor Mode
			Top	R1 = 22 Ω	Resistor Mode
B	VREF/ILIM	Select between using onboard VREF or ILIM reference circuitry	Top	**J1 = Left**	**VREF**
				J1 = Right	ILIM
C	ILIM_SEL	Selects ILIM voltage reference for cycle-by-cycle current limit	Top	J2 = Left	ILIM comes from MCU DAC (R53 must be populated)
				J2 = Right	**ILIM comes from R4/R7 voltage divider**
D	HALL_PWR_SEL	Selects Hall power voltage	Top	**J8 = Left**	**Hall power comes from 3.3VBK**
				J8 = Right	Hall power is provided externally
E	VREF select	Selects VREF source	Top	**R54 pop., R51 DNP**	**VREF = 3 V from EVM**
				R54 DNP, R51 pop.	VREF comes from MCU
F	Rev. pol. Bypass	Bypasses reverse polarity protection and pi filter	Bottom	R20 is populated	Bypass RPP and pi filter
				R20 is DNP	**RPP and pi filter is used**
G	3.3 V from LaunchPad	Connects buck voltage to LaunchPad 3.3 V	Bottom	R13 is populated	Connects 3.3VBK and LaunchPad 3.3 V
				R13 is DNP	**No connection between 3.3VBK and LaunchPad 3.3 V**
H	Center Tap	Used to measure center tap voltage of motor (R52 must be populated)	Bottom	R33, R34, and R35 are populated	Center tap voltage of motor can be measured through C_TAP test point
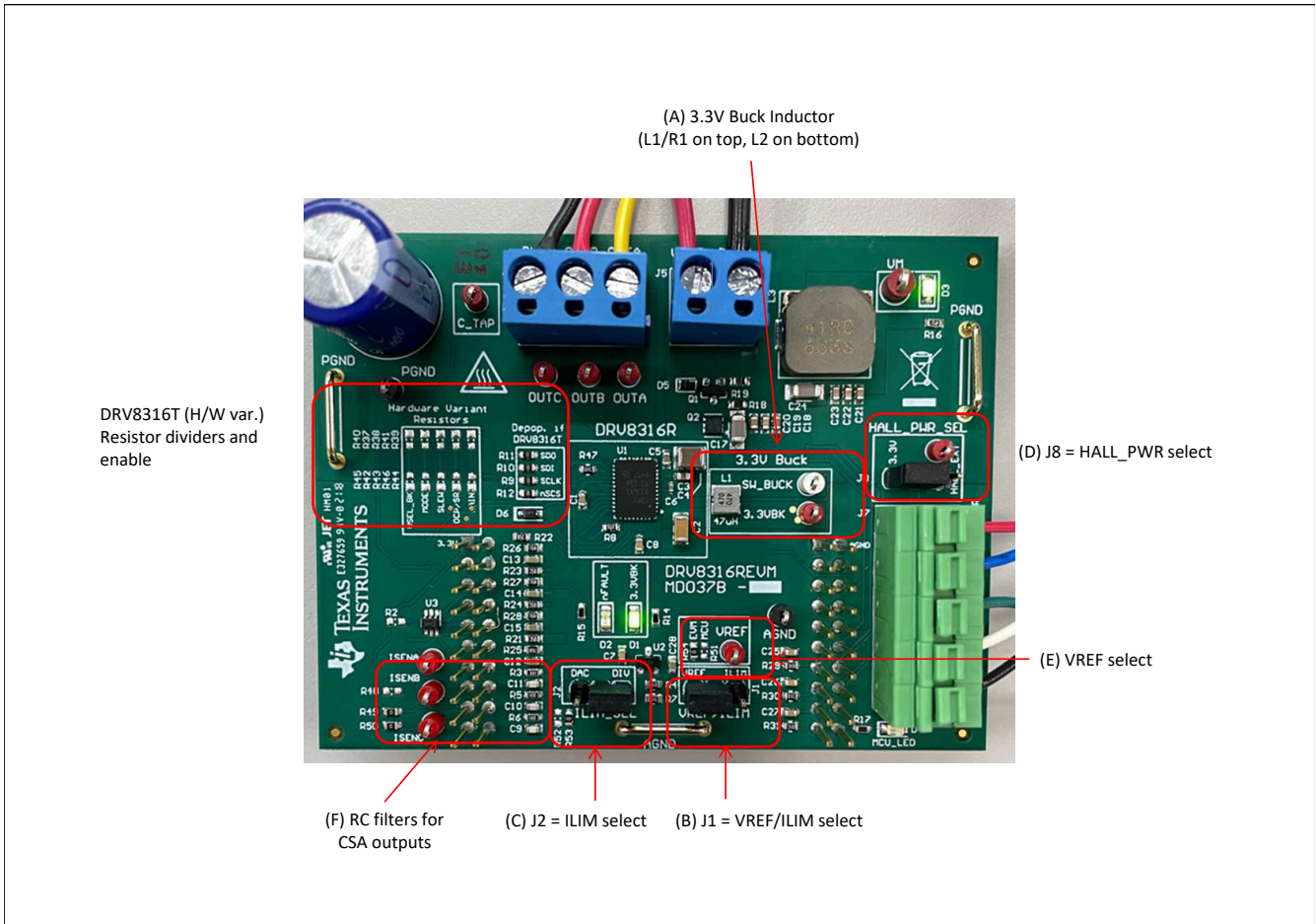
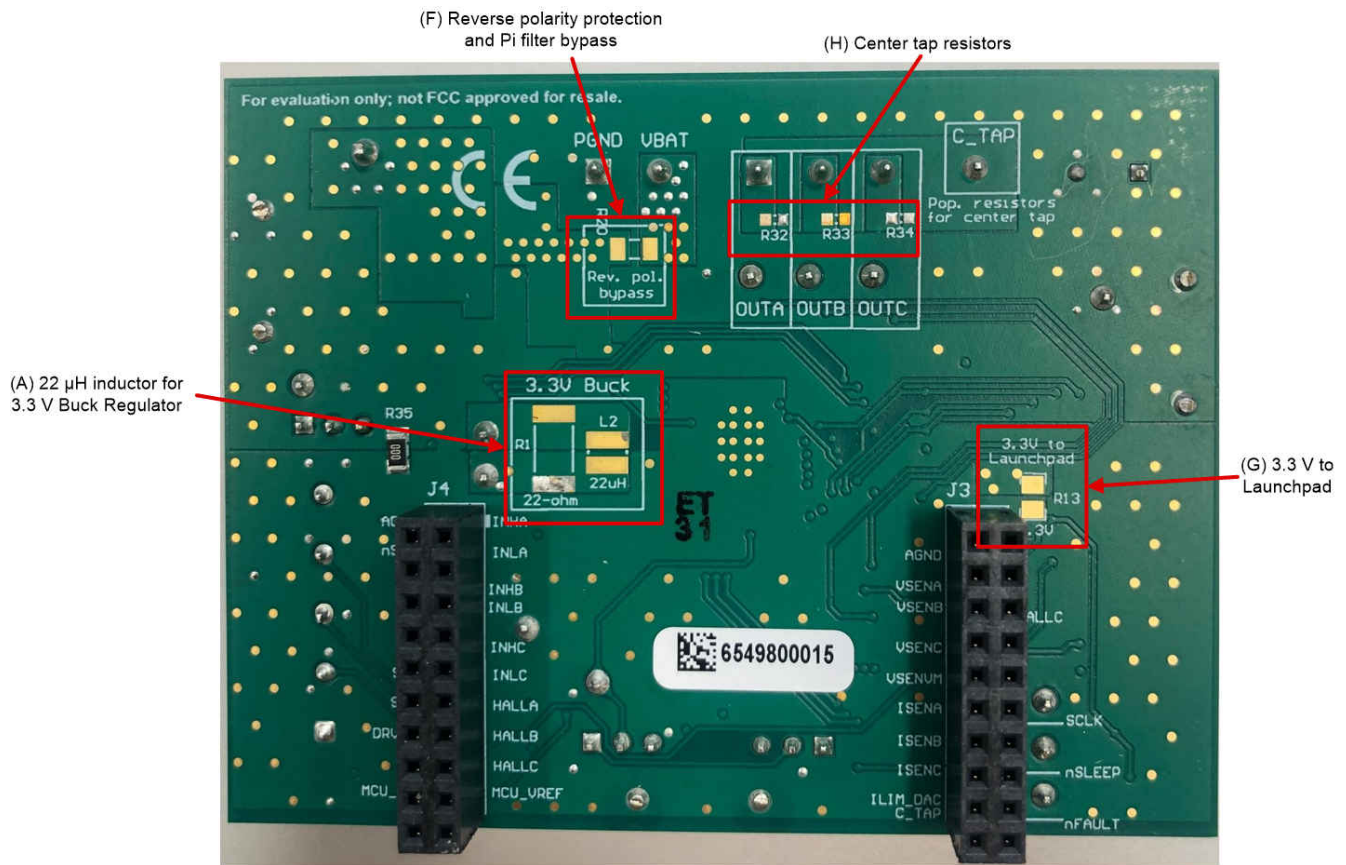**Figure 4-2. User-Selectable Jumpers and DNP Components on Top Side of DRV8316xEVM**

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Figure 4-3. User-Selectable Jumpers and DNP Components on Bottom Side DRV8316xEVM

4.1.1 DRV8316T Compatibility

The DRV8316xEVM is compatible with the DRV8316T (H/W variant) as the featured motor driver IC to spin a three-phase Brushless-DC motor. The DRV8316T replaces the SPI settings with five specific pin settings (MODE, SLEW, OCP/SR, GAIN, and VSEL_BK) that can be adjusted through resistor dividers.

When using the DRV8316T, the SPI enable resistors in the "Depop. if DRV8316T" silk screen box are to be depopulated (R9-R12) and the resistor dividers in the "Hardware Variant Resistors" silk screen box are to be populated (R37-R46) with the desired settings. Figure 4-4 shows this setup.

Table 4-3 shows the status of populated and DNP resistors for the two compatible DRV8316x variants. Table 4-4 shows the user-adjustable resistor divider settings when using the DRV8316T. R37-R41 resistors tie to AVDD and R42-R46 tie to AGND. The defaults of the two tables are in bold.

Table 4-3. Status of Resistors for DRV8316R and DRV8316T Variants (defaults in bold)

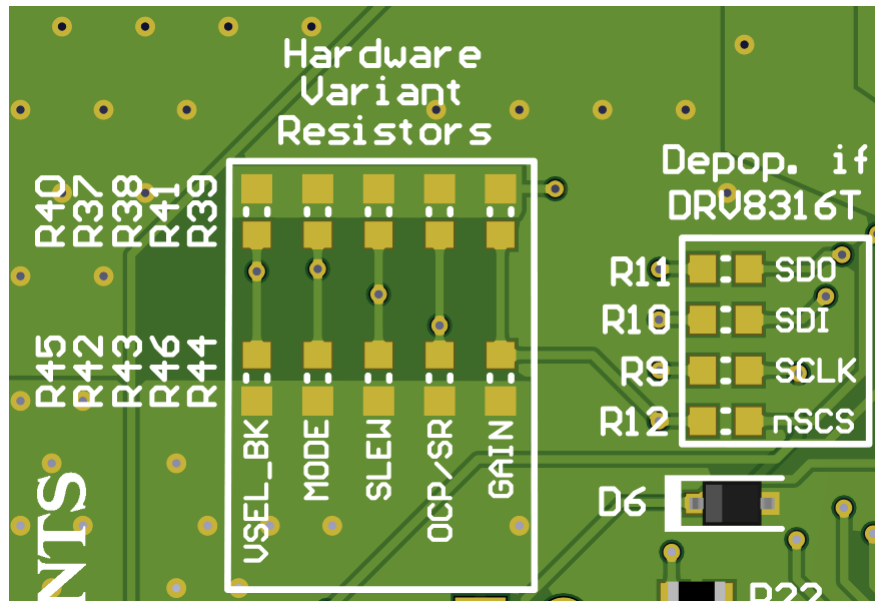| Device	Variant	R9-R12 Status	R37-R46 Status
DRV8316R	**SPI**	**Populated**	**DNP**
DRV8316T	Hardware	DNP	User adjustable

Figure 4-4. Resistor Divider Settings (R37-R46) and Resistors to Disable SPI (R9-R12)

Table 4-4. User-Adjustable Resistor Divider Settings for DRV8316T Variant (defaults in bold)

Setting	Name	Description	Resistors (AVDD/ AGND)	Hardware	Setting
VSEL_BK	V_{BK}	Buck regulator average voltage (L_{BK} = 47 or 22 µH, C_{BK} = 22 µF)	R40/R45	Tied to AGND	3.3 V
				Hi-Z	**5.0 V**
				47 kΩ to AVDD	4.0 V
				Tied to AVDD	5.7 V
MODE	PWM Control Mode	Selects the PWM control mode type	R37/R42	Tied to AGND	6 × PWM
				Hi-Z	**6 × PWM with Current Limit**
				47 kΩ to AVDD	3 × PWM
				Tied to AVDD	6× PWM with Current Limit
SLEW	Slew rate	Phase pin slew rate switching low to high (10-90%) and high to low (90-10%)	R38/R43	Tied to AGND	25 V/µs
				Hi-Z	**50 V/µs**
				47 kΩ to AVDD	125 V/µs
				Tied to AVDD	200 V/µs

Table 4-4. User-Adjustable Resistor Divider Settings for DRV8316T Variant (defaults in bold) (continued)

Setting	Name	Description	Resistors (AVDD/ AGND)	Hardware	Setting
OCP/SR	Overcurrent Protection / Smart Rectification	Selects the Mode for Overcurrent and Smart Rectification Settings (ASR = Automatic Synchronous Rectification; AAR = Automatic Asynchronous Rectification)	R41/R46	Tied to AGND	OCP = 10 A ASR and AAR Disabled
				22 kΩ to AGND	OCP = 15 A ASR and AAR Disabled
				100 kΩ to AGND	OCP = 10 A ASR Enabled
				Hi-Z	**OCP = 10 A ASR and AAR Enabled**
				100 kΩ to AVDD	OCP = 15 A ASR Enabled
				22 kΩ to AVDD	OCP = 15 A ASR and AAR Enabled
				Tied to AVDD	OCP = 15 A ASR and AAR Enabled
GAIN	G_{CSA}	Current sense gain	R39/R44	Tied to AGND	0.15 V/A
				Hi-Z	**0.3 V/A**
				47 kΩ to AVDD	0.6 V/A
				Tied to AVDD	1.2 V/A

4.2 Hardware Connections Overview – DRV8316xEVM + LAUNCHXL-F280049C

Figure 4-5 shows the major blocks of DRV8316xEVM plugin module that mounts to the J1/J3 and J2/J4 headers of the LAUNCHXL-F280049C LaunchPad development kit. The DRV8316xEVM is designed for an input supply from 4.5-V to 35-V and up to 8-A drive current. The DRV8316 includes three integrated half-bridges that can drive 8-A peak current and can be used in systems implementing sensored, sensorless, or field-oriented control. The 3.3-V supply to the Hall sensors is derived by the buck converter integrated in the DRV8316.
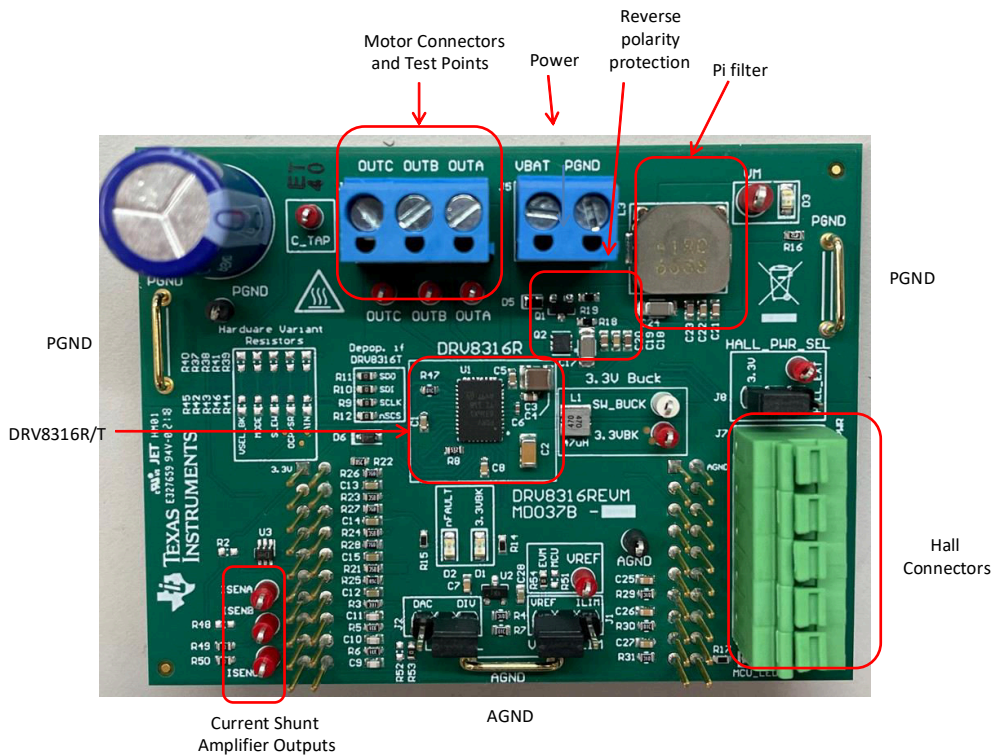
Figure 4-5. Major DRV8316xEVM Hardware Blocks

4.3 Connection Details

Figure 4-6 shows the connections made to the DRV8316xEVM to spin a three-phase sensored Brushless-DC motor.

An 4.5-V to 35-V power supply or battery is connected to the VBAT and PGND terminals. There is a reverse polarity protection implemented on the VBAT and PGND terminals. To bypass the reverse polarity protection and pi filter implementation, R20 can be populated on the bottom of the board.

The three phases of the BLDC motor connect directly to the OUTA, OUTB, and OUTC terminals of the screw terminal provided on the DRV8316xEVM.

To connect Hall sensor outputs to the Hall connector on the DRV8316xEVM, push down on the respective terminals to open the sockets and insert the Hall sensor connections.
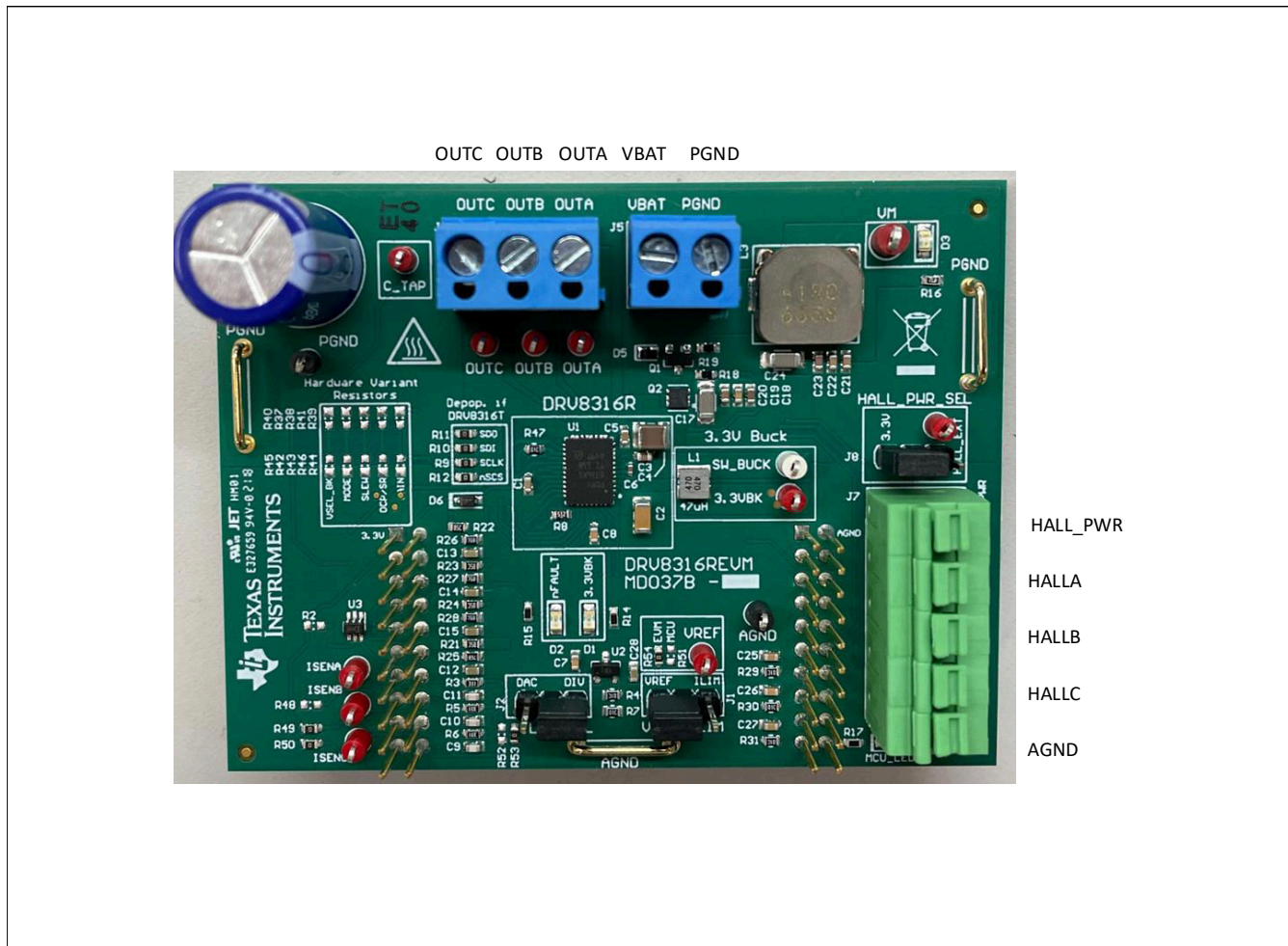
Figure 4-6. Connections From Motor to DRV8316xEVM

Figure 4-7 shows where the Micro-USB cable is plugged into the LAUNCHXL-F280049C to provide communication between the LaunchPad firmware and GUI as well as the correct installment of the DRV8316xEVM to the J1/J3 and J2/J4 headers of the LaunchPad.
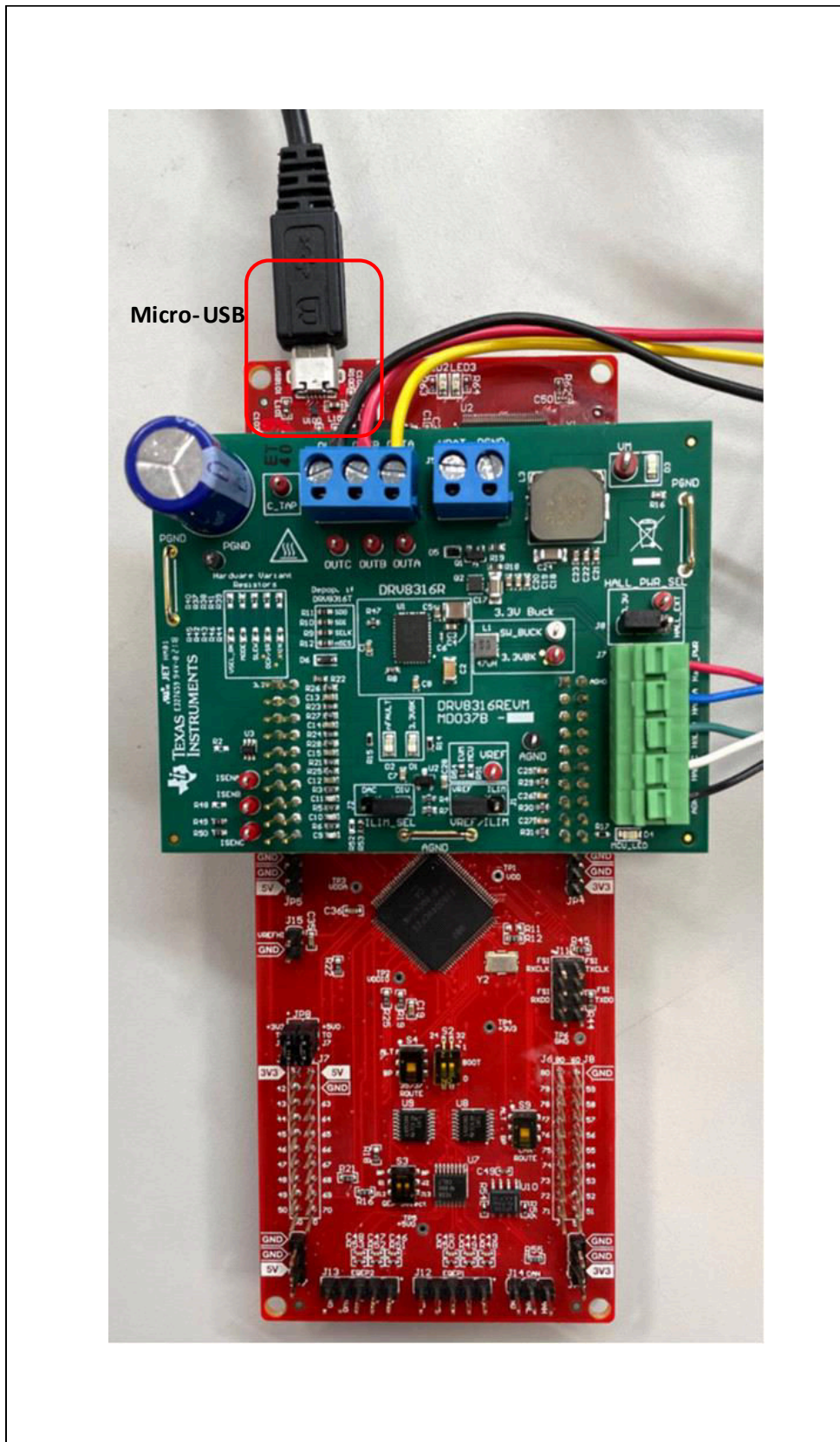
Figure 4-7. DRV8316xEVM on Headers J1/J3 and J2/J4 of LaunchPad™ and Micro-USB Plugged Into LaunchPad™

4.4 Interfacing DRV8316xEVM and LAUNCHXL-F280049C LaunchPad™

The DRV8316xEVM has 40 pins with different functions. These pins are interfaced with the LAUNCHXL-F280049C LaunchPad development kit and are mapped appropriately to receive the functionalities of the DRV8316R device. These 40 pins are grouped into 4 ports in respect to the LAUNCHXL-F280049C (J1 to J4). Table 4-5 and Table 4-6 list the interfacing of these ports of the DRV8316xEVM headers J3 and J4.

Table 4-5. Connections for Header J3 on DRV8316xEVM (DNP in bold)

J3 Pin Number	DRV8316xEVM Function	LAUNCHXL-F280049C Function	Description
1	**3.3VBK (DNP)**	3.3 V	3.3-V LaunchPad supply
2	Not used	5 V	5-V LaunchPad supply
3	Not used	PGA1/3/5_GND	Not used
4	AGND	GND	GND connection
5	Not used	GPIO13/SCIBRX	Not used
6	VSENA	ADCINA5	Phase A Voltage Sense
7	Not used	GPIO40/SCIBTX	Not used
8	VSENB	ADCINB0	Phase B voltage sense
9	**nSLEEP (DNP)**	NC	For internal use only
10	VSENC	ADCINC2	Phase C voltage sense
11	Not used	ADCINB3/VDAC	Not used
12	VSENVM	ADCINB1	VM Bus voltage sense
13	SCLK	SPIACLK	SPI clock (DRV8316R only)
14	ISENA	ADCINB2	Phase A current sense
15	**nFAULT (DNP)**	ADCINC4	For internal use only
16	ISENB	ADCINC0	Phase B current sense
17	nSLEEP	GPIO37	Active-low output sleep pin
18	ISENC	ADCINA9	Phase C current sense
19	nFAULT	GPIO35	Active-low input fault pin
20	C_TAP/ILIM_DAC (populate only R52 or R53, not both)	ADCINA1/DACB_OUT	ADC for center tap sensing / DAC for ILIM voltage reference

Table 4-6. Connections for Header J4 on DRV8316xEVM

J4 Pin Number	DRV8316xEVM Function	LAUNCHXL-F280049C Function	Description
1	INHA	GPIO10/PWM6A	PWM used to switch Phase A high-side FET
2	AGND	GND	GND connection
3	INLA	GPIO11/PWM6B	PWM used to switch Phase A low-side FET
4	nSCS	SPIASTE	SPI active-low chip select (DRV8316R only)
5	INHB	GPIO8/PWM5A	PWM used to switch Phase B high-side FET
6	Not used	NC	Not used
7	INLB	GPIO9/PWM5B	PWM used to switch Phase B low-side FET
8	Not used	NC	Not used
9	INHC	GPIO4/PWM3A	PWM used to switch Phase C high-side FET
10	Not used	XRSn	Not used
11	INLC	GPIO5/PWM3B	PWM used to switch Phase C low-side FET

Table 4-6. Connections for Header J4 on DRV8316xEVM (continued)

J4 Pin Number	DRV8316xEVM Function	LAUNCHXL-F280049C Function	Description
12	SDI	SPIASIMO	SPI data input (DRV8316R only)
13	HALLA	GPIO58	HALL sensor A from motor
14	SDO	SPIASOMI	SPI data output (DRV8316R only)
15	HALLB	GPIO30	HALL sensor B from motor
16	DRVOFF	GPIO39	Active-high output to disable gate drivers
17	HALLC	GPIO18*/XCLKOUT	HALL sensor C from motor
18	Not used	GPIO23/LED4	LED reserved on LaunchPad
19	**VREF (DNP)**	GPIO25	For internal use only
20	MCU_LED	GPIO59	Visual feedback for LaunchPad connection

5 Hardware Setup

The hardware required to run the motor control is the LAUNCHXL-F280049C LaunchPad development kit, the DRV8316xEVM, a Micro-USB cable, and a power supply with a DC output from 8-V to 32-V. Follow these steps to start up the DRV8316xEVM:

1. Mate the DRV8316xEVM board to the top half of the LAUNCHXL-F280049C LaunchPad development kit (mates to J1/J3 and J2/J4 of the LaunchPad, as in Figure 4-7). Ensure resistor R13 is DNP on the bottom of board to separate buck voltage from the USB power supply voltage.
2. Connect the three phases from the brushless DC motor to the three-pin connector J4 on DRV8316xEVM. Phases OUTA, OUTB, and OUTC are labeled in white silkscreen on the PCB top layer. If using a sensored algorithm on the LaunchPad development kit, connect the Hall sensor to the five-pin connector J7.
3. Connect the DC power supply to header J5, ensuring the correct polarity of VBAT and PGND is applied.
4. Connect a Micro-USB cable to the LaunchPad development kit and computer.
5. Turn on the power supply and power up the PCB.
6. If using the DRV8316xEVM with an external microcontroller, make the logic-level connections needed on the male headers on the top of the board or female connectors on the bottom side of the board. The signal names are labeled on the bottom side of the board for convenience as Figure 5-1 shows.
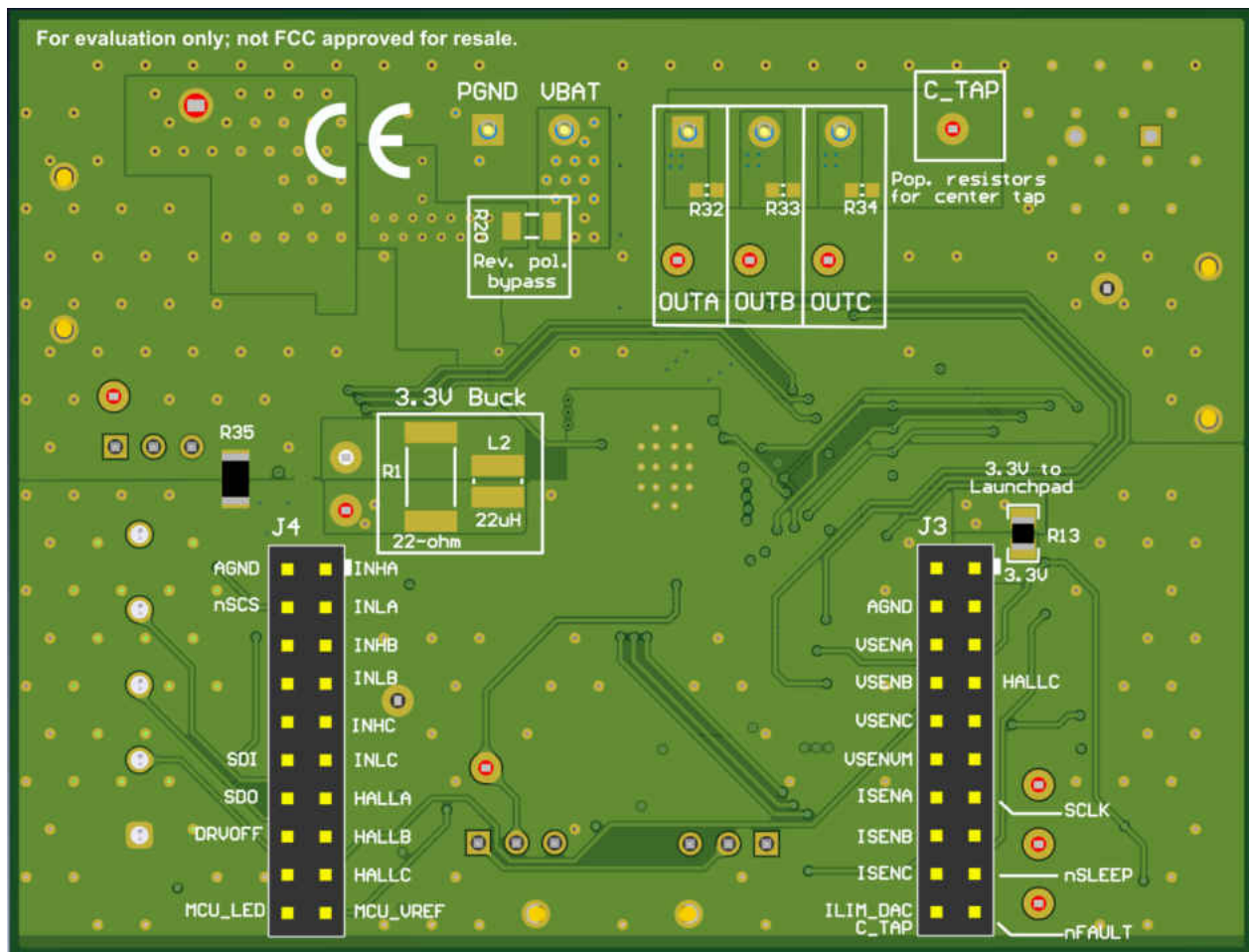
Figure 5-1. Bottom Silk Screen Shows Names of Pins When Using an External MCU

6 Firmware and GUI Application

The DRV8316xEVM can implement sensored, sensorless, or Field-oriented control for commutating a three-phase Brushless-DC motor. The supported firmware is a sensorless ield-oriented control algorithm adapted from Texas Instruments' MotorControl SDK Library of motor solutions. The algorithm includes motor identification and parameters, sensorless sinusoidal commutation, torque and speed control, and field weakening to maximize the performance of the motor. The firmware uses GUI Composer to run the algorithm and includes a tab to read/write to the DRV8316 SPI registers.

The following steps describe how to identify useful motor parameters, spin the motor using a sensorless sinusoidal profile, use the PI controller gain settings for torque and speed control, and communicate with the DRV8316 SPI registers. For more information on advanced features of the C2000 InstaSPIN Universal GUI such as MTPA or Field-weakening , consult the MotorControl SDK InstaSPIN Lab Guide (in the MotorControl Software Development Kit tool page) and InstaSPIN-FOC and InstaSPIN-MOTION User's Guide.

6.1 C2000™ InstaSPIN™ Universal GUI

1. Follow the instructions in Section 5 *Hardware Setup* and ensure the LAUNCHXL-F280049C is connected to the PC and the power supply is turned on to the DRV8316xEVM PCB.
2. Access the *GUI Composer Gallery* https://dev.ti.com/gallery/ and search for "DRV8316xEVM_InstaSPIN_Universal_GUI". Click on the GUI.
3. Accept the readme as shown in Figure 6-1 and check the bottom left hand corner of the screen for "Hardware Connected". Once connected, the GUI will flash the algorithm to the MCU as shown in Figure 6-2.
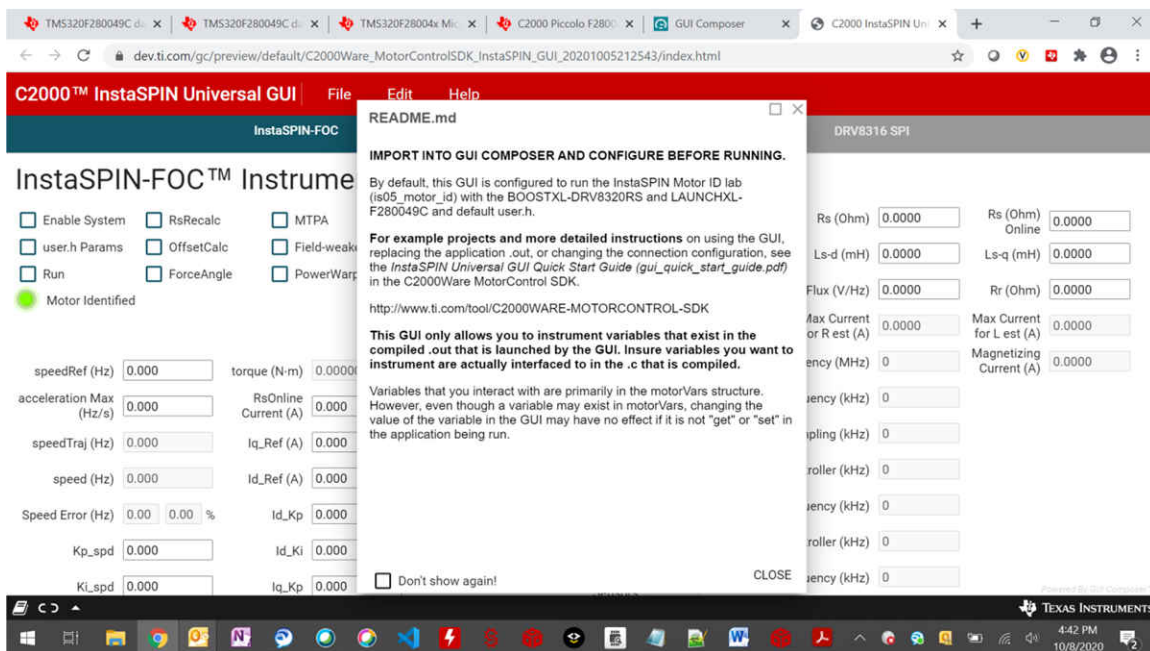
Figure 6-1. C2000™ InstaSPIN™ Universal GUI for DRV8316xEVM
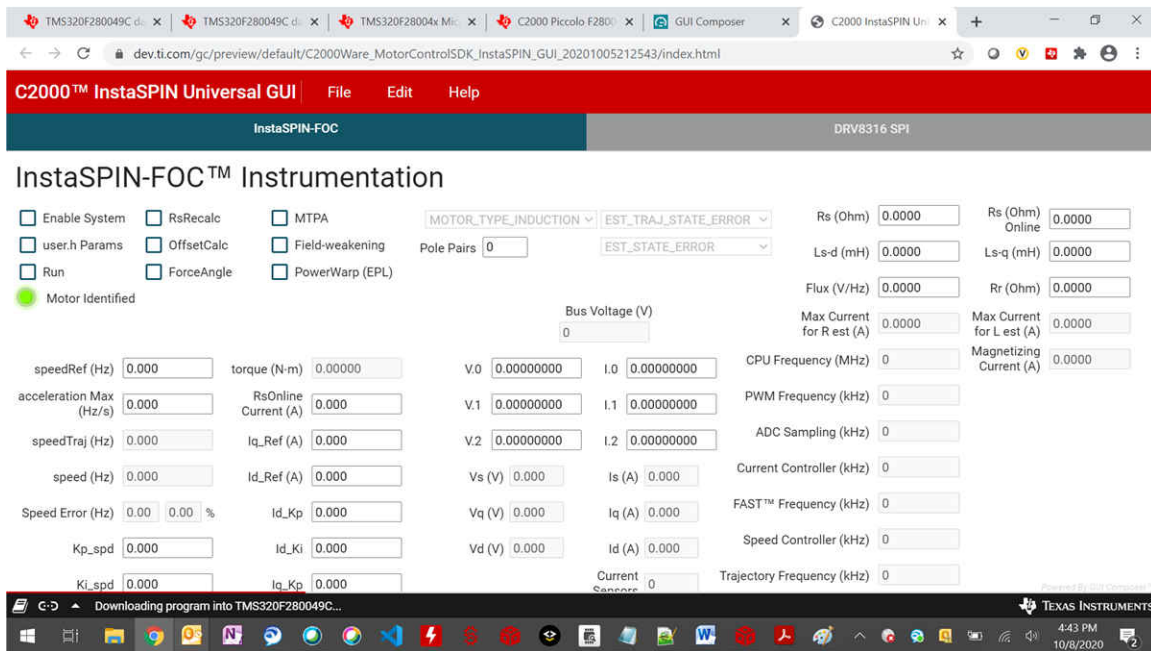
Figure 6-2. C2000™ InstaSPIN™ Universal GUI Downloading Program

6.2 Motor Identification

1. Check the "Enable System" box to enable the InstaSPIN algorithm and run preset calibrations. When the preset calibrations are finished, the "OffsetCalc" checkbox will automatically uncheck itself.
2. If using the DRV8316R, click on the DRV8316 SPI tab. Click "Read" to read the defaults of the DRV8316R device. Ensure the CSA_GAIN setting (Control Register 5) reads CSA_Gain_0p15. This setting ensures that the CSA current output when identifying the motor does not saturate, or else it will incorrectly identify the motor parameters and limit the maximum performance.
3. Alternatively, if using the DRV8316T, set the GAIN setting to 0.15 V/A by placing a 0-ohm resistor at R44 (in the Hardware Variant Resistors box). This setting ensures that the CSA current output when identifying the motor does not saturate, or else it will incorrectly identify the motor parameters and limit the maximum performance.
4. Check the "Run" box to begin the motor identification algorithm. The motor will begin to spin and stop as it goes through many states to calculate and identify useful motor parameters for sensorless Field-oriented control. This should take no more than a couple of minutes.
5. Once the motor identification process is complete, the "Motor Identified" indicator will light up, the "Run" box will be automatically unchecked, and the values Rs, Rs Online, Ls-d, Ls-q, Flux, and Rr will update for that motor as shown in Figure 6-3. These values will be automatically used for sensorless Field-oriented control.
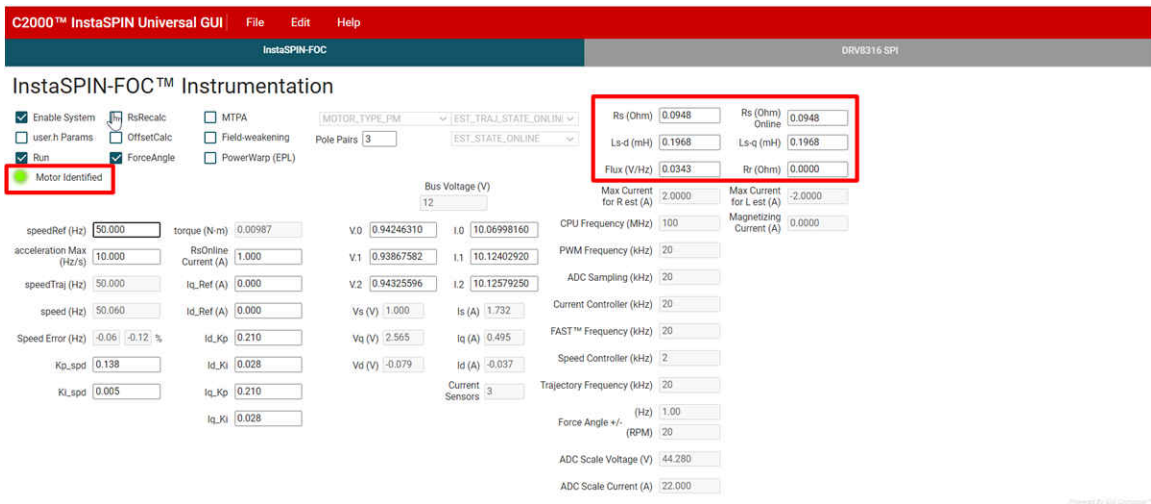
Figure 6-3. Motor Identification Using the DRV8316xEVM InstaSPIN™ GUI

6.3 Sensorless-FOC Commutation

1. To spin the motor freely with a sinusoidal current profile, check the "Run" box again. The motor will spin with sinusoidal current at the speedRef (Hz) value in the GUI, which is automatically set to 20.0 Hz. Use the speedRef (Hz) input to change the current speed of the motor as shown in Figure 6-4. The GUI automatically calculates the current reference speed using the variable **speed (Hz)** and compares it to the trajectory speed variable **speedTraj (Hz)** to calculate the **Speed Error (Hz)** and as a percentage.
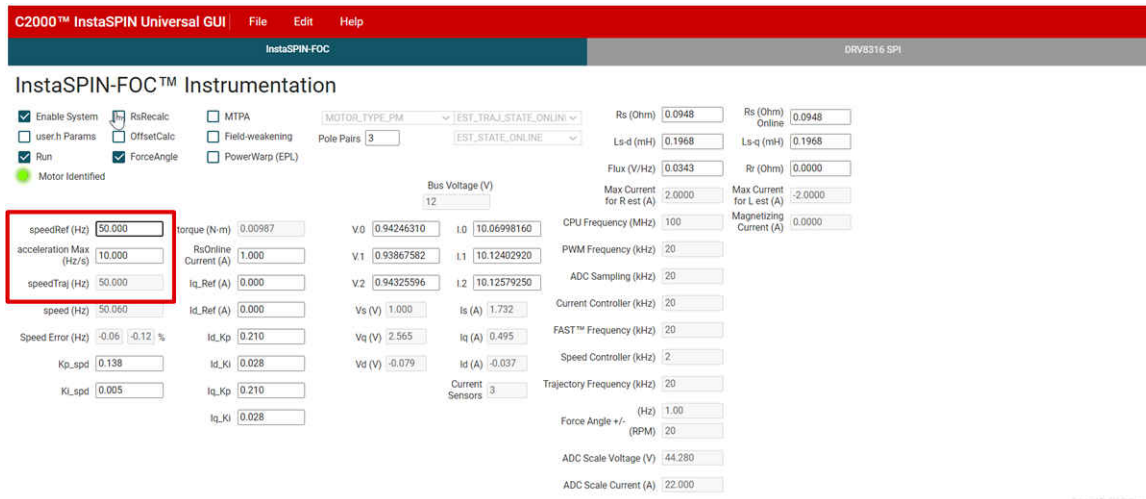
Figure 6-4. Sensorless Sinusoidal Commutation Using the DRV8316xEVM InstaSPIN™ GUI

6.4 Torque and Speed Control

To implement more advanced modulation techniques such as torque control, speed control, and algorithms such as MTPA, Field-weakening, and PowerWarp (EPL) using the DRV8311HEVM InstaSPIN Universal GUI, please consult the MotorControl SDK InstaSPIN Lab Guide found in MotorControl SDK.

This document contains detailed lab overviews of how to implement each advanced modulation technique when using sensorless FOC to spin the BLDC motor in Code Composer Studio. In order to use the project with the GUI, the user must build and compile the project in CCS, and import the .out binary file for that project into the GUI properties through GUI Composer. More information can be found in the README when the GUI is first opened.

6.5 SPI Communication (DRV8316R only)

1. Click on the "DRV8316 SPI" tab to access the DRV8316 Registers as Figure 6-5 shows.
2. Choose the desired settings in Control Registers 1–10 by selecting the appropriate setting or bit from the drop-down menus. Consult the DRV8316x data sheet (*Register Map* section) for detailed definitions of settings.
3. Click on "Write" to write to all control registers in the device with the configured settings.
4. To read all status and control registers in the device, click on "Read". The statuses and settings will auto-populate in their registers.
5. Alternatively, to write data to a specific address, input the address and data in decimal into the address and data inputs above the "Manual Write" box. Click on the "Manual Write" box to write the data to that address. To read data from a specific address, input the address in decimal into the address above the "Manual Read" box. Click on the "Manual Write" box to read the data from that address.
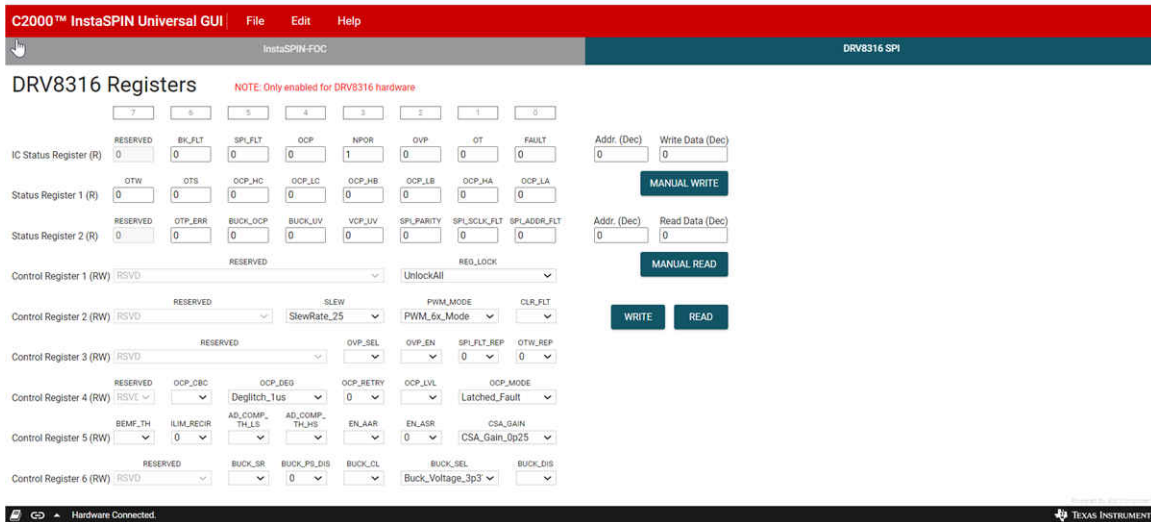
Figure 6-5. SPI Communication Using the DRV8316xEVM InstaSPIN™ GUI

7 DRV8316xEVM Schematics
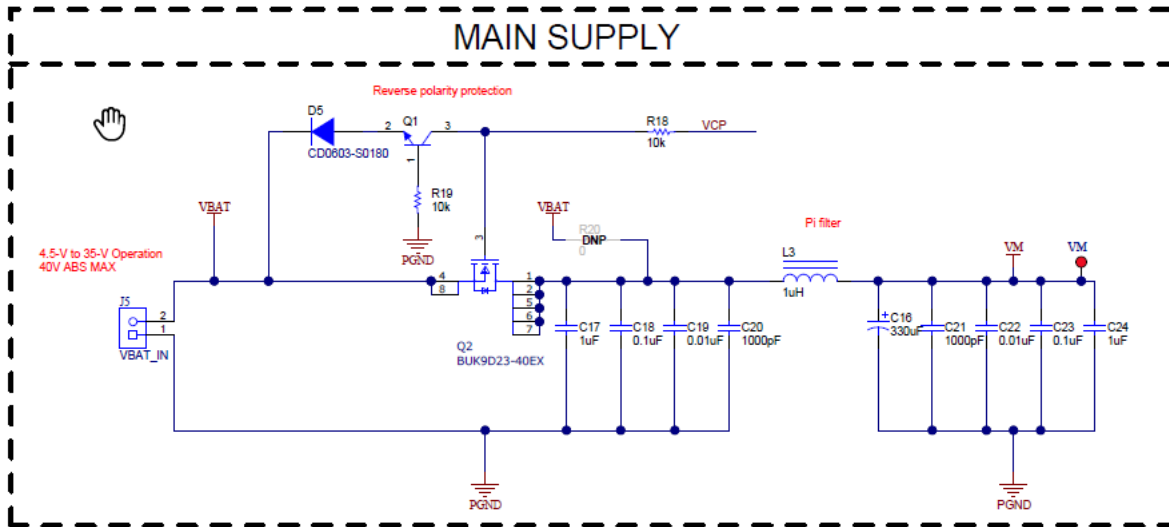
Figure 7-1. Main Supply, Reverse Polarity Protection, and Pi Filter Schematic
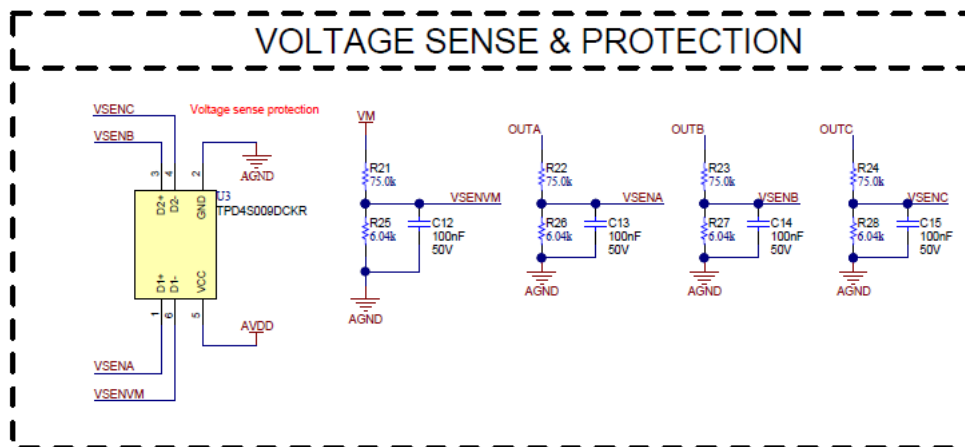
Figure 7-2. Voltage Sense and Protection Schematic

CONNECTORS & INTERFACE
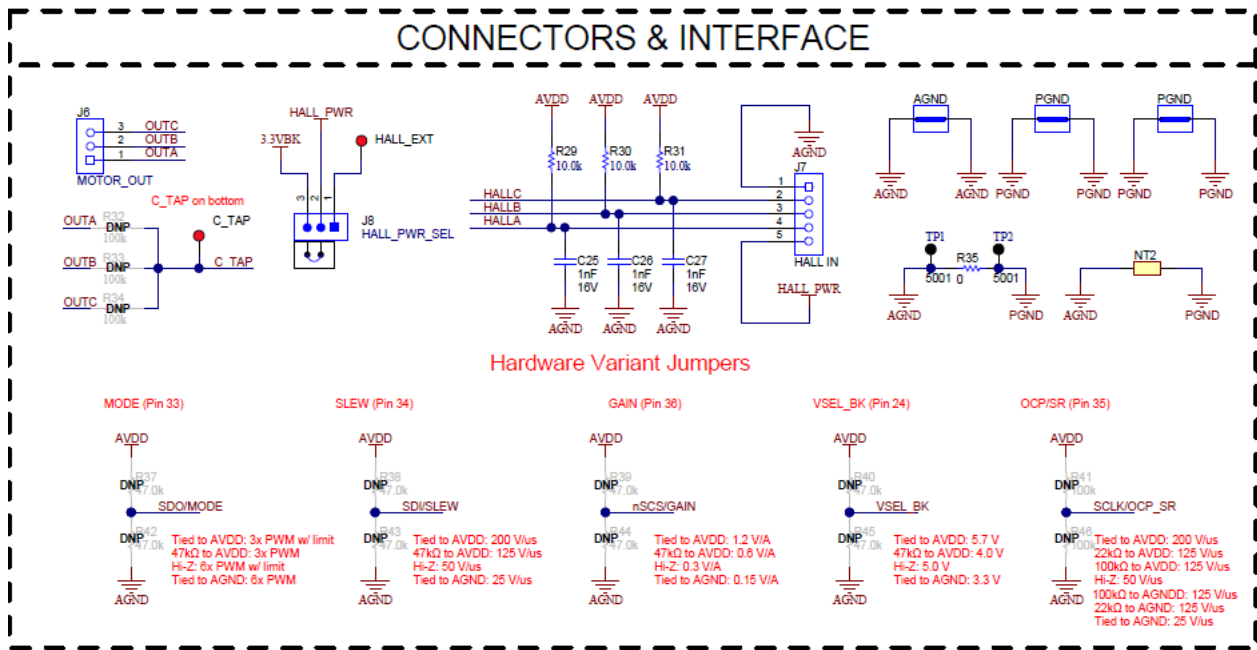
Figure 7-3. Connectors and Interface Schematic
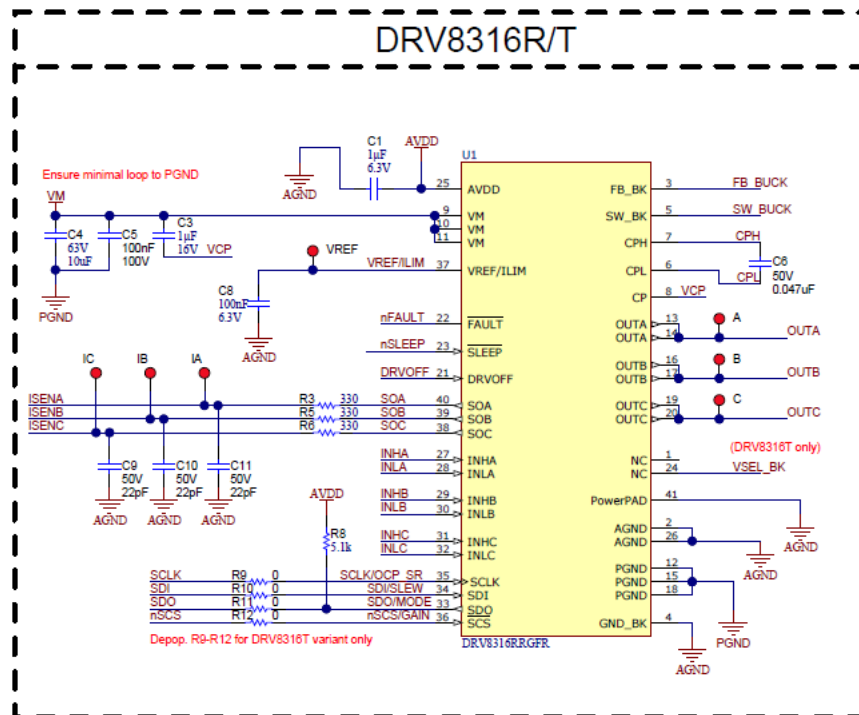
Figure 7-4. DRV8316 3-phase BLDC Motor Driver Schematic
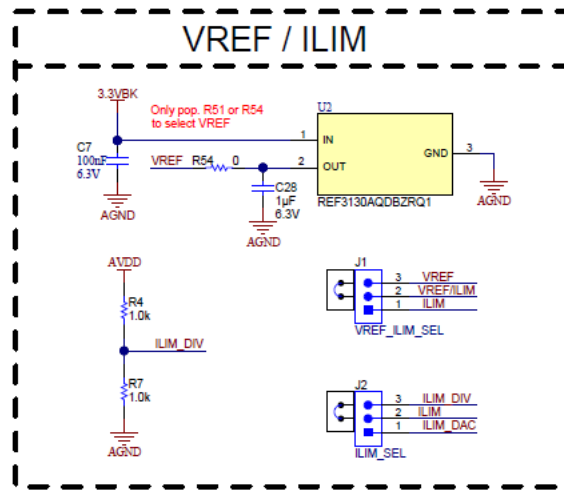
Figure 7-5. VREF / ILIM Schematic
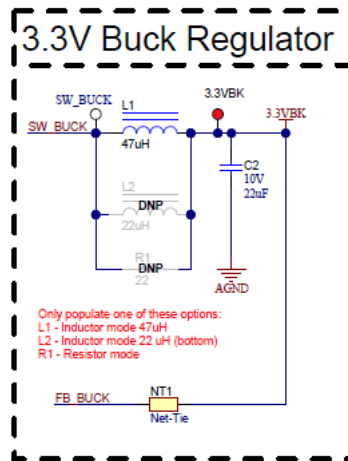
Figure 7-6. 3.3V Integrated Buck Regulator Schematic
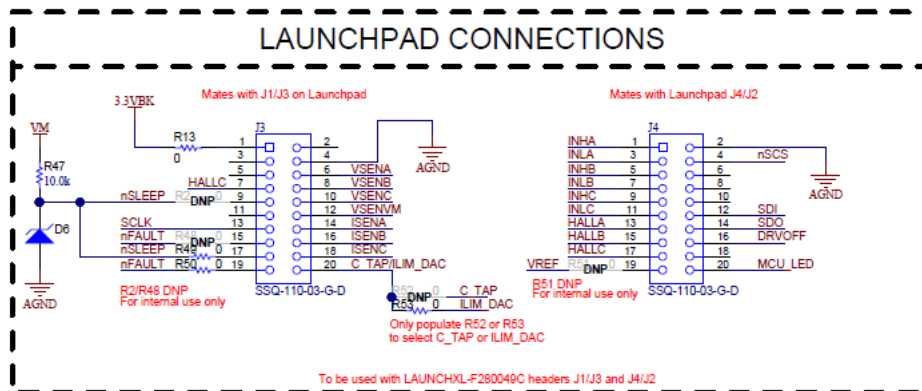
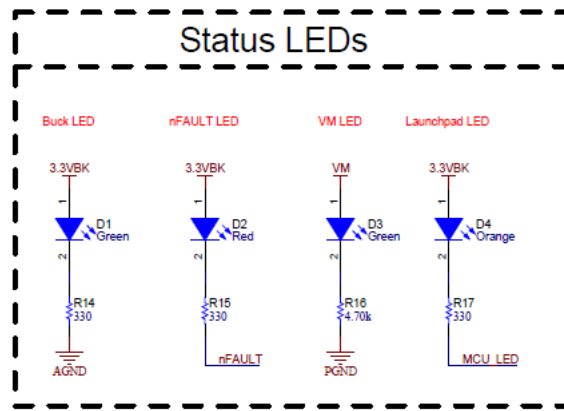

Figure 7-7. TMS430F280049C LaunchPad Connections Schematic

Figure 7-8. Status LEDs Schematic

8 Revision History

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

Changes from Revision A (February 2021) to Revision B (August 2021)	Page
• Updated images from the engineering revision of the EVM to the released version of the EVM	1
• Generalized the name to the DRV8316xEVM to showcase SPI and H/W compatibility	1
• Included information on SPI and H/W variant names	1

Changes from Revision * (December 2020) to Revision A (February 2021)	Page
• Added *Cautions and Warnings* section	3
• Changed instructions in the *C2000™ InstaSPIN™ Universal GUI* section	19

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