User's Guide

SLDU028A – January 2018 – Revised March 2020

TPS65313-EVM User's Guide

The TPS65313-Q1 device is a power management integrated circuit (PMIC) for safety-relevant automotive applications. This device integrates a wide-input voltage off-battery buck regulator (BUCK1), a low-voltage buck regulator (BUCK2), and a 5-V boost converter (BOOST). The TPS65313-Q1 device integrates protection features such as independent voltage monitors, overtemperature protection, watchdog function, and built-in analog and digital diagnostic tests. The features of the device target safety-relevant applications with system-safety requirements up to ASIL-C level.

This user's guide provides instructions to power up and evaluate the TPS65313-Q1 device using the TPS65313-EVM evaluation module (EVM) and software user interface (TPS65313 GUI).

	Warning	Warning Hot surface. Contact may cause burns. Do not touch!

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Trademarks

MSP430 is a trademark of Texas Instruments.
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1 TPS65313-EVM Top View With Basic External Connections

Figure 1 shows the top-view diagram of the EVM along with basic connections. The BUCK1 input supply and an optional USB cable (for SPI communication) are the only two external connections required for this EVM. The BUCK2 regulator and BOOST converter are supplied through onboard jumper connections from the BUCK1 output and therefore no external supply voltage is required for the BUCK2 regulator and BOOST converter.

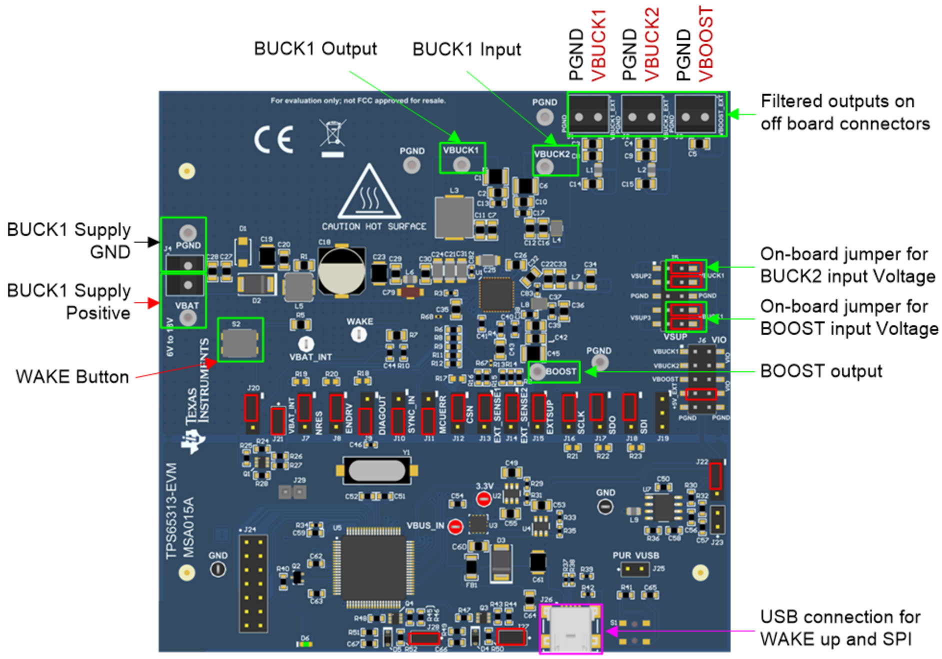


Figure 1. EVM Top-View Diagram With Basic Connections

2 TPS65313-EVM Input, Output Voltages, and Load Current Requirements

Table 1 lists the input and output voltage for each regulator and their maximum load-current requirements.

Table 1. Input and Output Voltages and Load-Current Requirements

Regulator Name	Input Voltage	Output Voltage[(1)]	Maximum Load Current
BUCK1	6 V to 18 V (V_{BAT})[(2)]	3.3 V or 3.6 V (V_{BUCK1})	3.1 A
BUCK2	3.3 V or 3.6 V (V_{BUCK1})	1.2 V or 1.25 V or 1.8 V or 2.3 V (V_{BUCK2})	2 A
BOOST	3.3 V or 3.6 V (V_{BUCK1})	5 V (V_{BOOST})	0.6 A

(1) To supply the BUCK2 regulator and BOOST converter, use the onboard VBUCK1 supply (jumper J5, VSUP).

(2) The input voltage range on VIN, AVIN, and VIN_SAFE pins at which full device functionality and performance is assured. Operation outside this input voltage range is possible and for detailed recommended operating conditions, refer to *TPS65313-Q1 Wide-VIN Power-Management IC for Automotive Applications* datasheet.

3 TPS65313-EVM Jumper Settings

The TPS65313-EVM has many jumpers to make the EVM more flexible. Setting these jumpers correctly for the correct function of the EVM is important. Table 2 lists the jumpers and their functionality. The EVM is preconfigured with default jumper settings and users can power up the regulators without any jumper modifications. To understand more about the jumper functionality, see the schematic diagrams in Section 8.

Table 2. TPS65313-EVM Jumper Settings

Jumper Number	Jumper Name	Jumper Description	Default Jumper Settings
J1	VBUCK1_EXT	Filtered BUCK1 output connector	Not applicable
J2	VBUCK2_EXT	Filtered BUCK2 output connector	Not applicable
J3	VBOOST_EXT	Filtered BOOST output connector	Not applicable
J4	VBAT	V_{BAT} supply and PGND connector	Not applicable
J5	VSUP	Input supply for BUCK2 and BOOST coming from V_{BUCK1}	Jumpers between J5_1_2 and J5_3_4 for the BUCK2 supply Jumpers between J5_7_8 and J5_9_10 for the BOOST supply
J6	VIO	IO supply for SPI	Jumper between J6_7_8 (+5V_EXT) from the USB interface
J7	NRES	System reset output	Jumper between J7_1_2
J8	ENDRV	Enable drive output	Jumper between J8_1_2
J9	DIAGOUT	Diagnostic output	Jumper between J9_2_3
J10	SYNC_IN	PLL input clock. The onboard 2.3-MHz clock generated using the LMC555 timer can be used to sync the device this external clock	Jumper between J10_2_3
J11	MCUERR	MCU error pin monitor	Jumper between J11_2_3
J12	CSN	SPI: Chip select input	Use jumper between J10_1_2
J13	EXT_SENSE1	External general-purpose voltage monitor input 1	Jumper between J13_1_2
J14	EXT_SENSE2	External general-purpose voltage monitor input 2	Jumper between J14_1_2
J15	EXTSUP	External supply for VREG	Jumper between J13_1_2 for connecting the BOOST pin to the EXTSUP pin
J16	SCLK	SPI: Clock input	Jumper between J14_1_2
J17	SDO	SPI: SPI Slave data output (push-pull output)	Jumper between J15_1_2
J18	SDI	SPI: SPI Slave data input	Jumper between J16_1_2
J19	J17	Not applicable	Not applicable
J20	J20	Wake input options: J20_1_2: WAKE from VBAT through S2 switch J20_2_3: WAKE from USB	Jumper between J20_1_2: WAKE from VBAT through S2
J21	VBAT_INT	Supply for *WAKE from USB* circuit	Jumper between J21_1_2
J22	J22	Supply for external clock generator circuit	Jumper between J22_1_2
J23	CLK_WD	External clock generator circuit frequency setting	Not applicable
J24	J24	Not applicable	Not applicable
J25	PUR VUSB	Not applicable	No jumper, keep this pin open
J26	J26	USB port	Connect this port to USB port of the PC
J27	J27	Device configuration change control signal 1	Jumper between J27_1_2. This jumper is needed only for changing device configuration.
J28	J28	Device configuration change control signal 2	Jumper between J28_1_2. This jumper is needed only for changing device configuration.
J29	J29	Not applicable	Not applicable

4 TPS65313-EVM GUI Installing and Opening the GUI

This section provides the step-by-step instructions to install the TPS65313-EVM GUI on a computer.

Step 1. Unzip the *TPS65313GUI*.zip file and double click on the *Setup_TPS65313_EVM.exe* executable file.

Step 2. Figure 2 shows the GUI installer window in a sequence (1, 2, 3, and 4). When the installer window opens, click the *Next* button. Select the *I accept the agreement* radio button and then click the *Next* button.

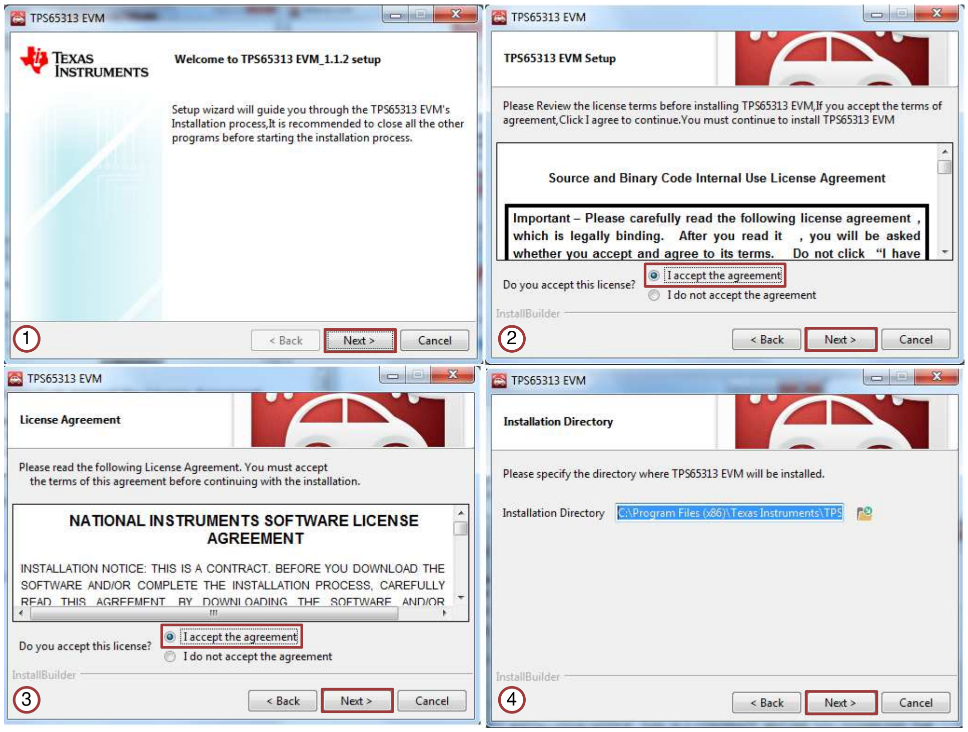


Figure 2. TPS65313-EVM GUI Installation Sequence

Step 3. In the next window select the *LabVIEW RTE* checkbox if it is not installed already on the computer. The user must have LabVIEW 2014 runtime. Make sure the computer is connected to the internet because free online registration may be required.

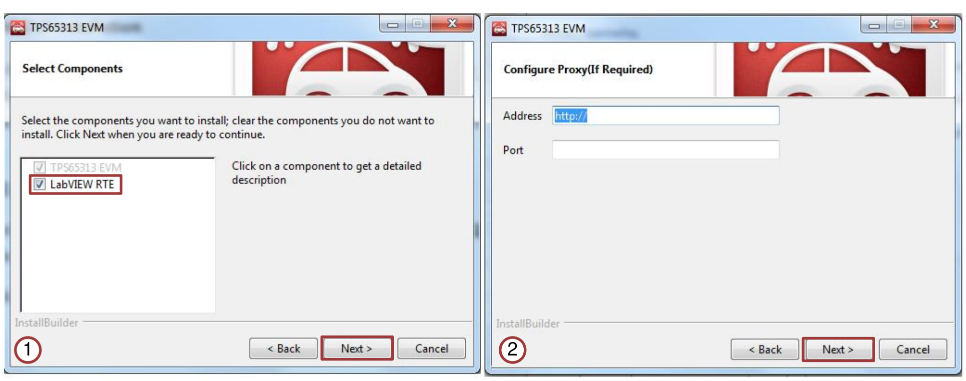


Figure 3. TPS65313-EVM GUI LabVIEW RTE Installation Selection

Step 4. After the LabVIEW RTE is installed, click the *Next* button to install the EVM GUI. Click the *Finish* button to complete the installation.

Step 5. When installation is complete, click the Windows Start button and select *All Programs*. Navigate to the Texas Instruments folder and click *TPS65313-EVM* to open the GUI.

5 TPS65313-EVM Power-Up and Power-Down Procedure

The EVM is preconfigured with the default jumper settings listed in Table 2. Follow these steps to power up the device:

Step 1. Connect the input supply voltage between the VBAT and PGND connectors to supply the TPS65313-Q1 device.

Step 2. Press the S2 switch to apply a wake-up pulse which starts the device power up.

Step 3. It is possible to power up the device using the *WAKE* button on the GUI, when the J20 jumper is connected between pins 2 and 3, and the EVM is connected to the computer. Before activating the *WAKE* button on the GUI, click the *Re-Initialize USB2ANY* button on the GUI to establish communication between the EVM and the GUI. For more information regarding GUI functionality, see Section 6.

The TPS65313-EVM does not require any special power-down sequence. The EVM can be powered down by turning off the VBAT supply or clicking the *CLR_WAKE_LATCH* button on the GUI.

6 TPS65313 GUI

The TPS65313 GUI provides many features to help evaluate the TPS65313-Q1 device. The GUI has three pages, or sections which are described as follows:

Device Controls page — This page, which is part of the *High Level Configuration* page, provides options such as synchronizing the GUI with the EVM, wake-up control, watchdog configuration, MCU error signal monitor (ESM), state transition control, NRES and ENDRV monitor, cyclical redundancy check (CRC) enable, SPI status bit indicator, and device state indicator.

Register Map page — This page contains all the SPI registers and provides options to read or write the TPS65313-Q1 device registers.

EEPROM Programming page — The TPS65313-Q1 device has many factory programmable device options with unique orderable part numbers. By default, the TPS65313-EVM has a device with the O31310QRWGRQ1 orderable part number. If users want to evaluate different device options (or orderable part numbers), the EEPROM configuration can be updated using this page, which is part of the *High Level Configuration* page.

6.1 Device Controls Page

This section describes the different options on the Device Controls page.

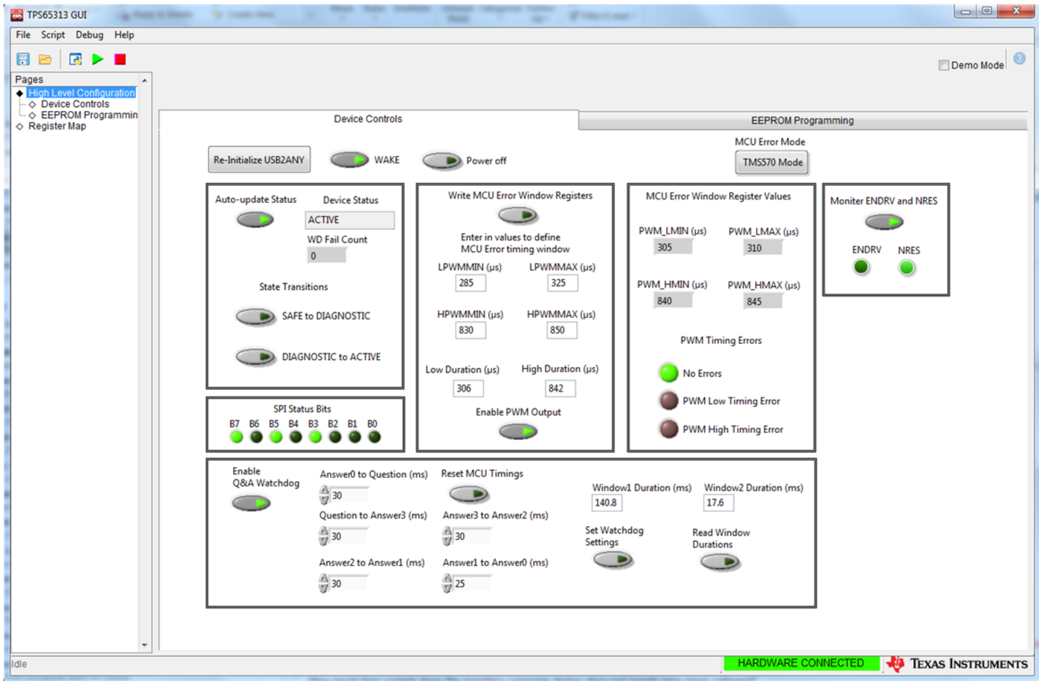


Figure 4. TPS65313 GUI Device Controls Page

6.1.1 Re-Initialize USB2ANY Button

After connecting the USB cable to the EVM and launching the GUI, click the *Re-Initialize USB2ANY* button to sync the GUI with the EVM. If the GUI is successfully synchronized with the EVM, the GUI connection status field on the bottom right of the GUI turns green and *HARDWARE CONNECTED* is displayed (see Figure 4). The GUI is now connected to the EVM. If the GUI is not synchronized correctly, *DEMO MODE* is displayed with a grey background.

6.1.2 WAKE Button

If the J20 jumper is set between pins 2 and 3, clicking the *WAKE* button turns on the high-side transistor on the VBAT input supply line and this supply voltage is applied on the WAKE pin which starts device start-up. When the device is successfully powered on, disabling the *WAKE* button has no impact and the device continues to operate normally. If the *WAKE* button is still enabled and the device enters the OFF state because of some errors, the device automatically starts to wake up again. If the *WAKE* button is disabled and the device enters the OFF state because of some errors, the device stays in the OFF state, and the WAKE button must be clicked again to start the new power-up cycle.

6.1.3 Power Off Button

The *Power off* button makes the WAKE signal low and clears the wake latch using a SPI register write (CLR_WAKE_LATCH bit) to put the device in the OFF state. The WAKE signal must be applied again to start the new power-up cycle.

6.1.4 Device Status Update

When the *Auto-update Status* button is enabled, the current state of the device (SAFE, DIAGNOSTIC, or ACTIVE) is updated automatically. The *WD Fail Count* field shows the current value of the device watchdog (WD) fail counter.

6.1.5 State Transitions

Clicking the *SAFE to DIAGNOSTIC* button makes the device go from the SAFE state to the DIAGNOSTIC state. This transition is done by writing the SAFE_EXIT register with 0x55 and the MASK_DIAG_EXIT register with 0x55.

Clicking the *DIAGNOSTIC to ACTIVE* button makes the device go from the DIAGNOSTIC state to the ACTIVE state. This transition is done by writing the CLR_CTRL_LOCK register with 0xAA and setting the DIAG_EXIT bit to 1b (writing the SAFETY_CHECK_CTRL register with 0x1).

Before the device goes from the SAFE state to the DIAGNOSTIC or from the DIAGNOSTIC state to the ACTIVE state, the watchdog must be configured correctly. Without configuring the watchdog, the *WD Fail Count* field increases to 15 which puts the device back in the SAFE state.

6.1.6 Enable Q&A Watchdog

To enable the device transition to the DIAGNOSTIC or ACTIVE state, the question and answer (Q&A) watchdog must be enabled and configured correctly. The device has two options for watchdog Q&A configurations: mode 0 and mode 1. The TPS65313-Q1 device exchanges questions and answers with the USB2ANY MCU within the timing specified in the timing fields on the GUI.

The default timing configurations are set when GUI is opened. When the device is in the SAFE state, enable the *Enable Q&A Watchdog* button to start the watchdog and sync it with MCU. When the watchdog is successfully synced, the WD fail counter starts to decrease and reaches 0.

When the watchdog is synced when the device is in the SAFE state, the *SAFE to DIAGNOSTIC* button can be clicked to make the device to go to the DIAGNOSTIC state. When the device is in the DIAGNOSTIC state, the *DIAGNOSTIC to ACTIVE* button can be clicked to put the device in the ACTIVE state.

If users want to try the different watchdog timing settings, adjust the watchdog timing settings only when the device is in the DIAGNOSTIC.

Figure 5 shows the timing diagram for the watchdog windows. Each setting or field in the GUI is defined as follows:

Answer0 to Question (ms) — This field is the time at which the WD question is received by the MCU (the GUI default is 30 ms).

Question to Answer3 (ms) — This field is the time at which Answer3 is sent from the MCU (the GUI default is 30 ms).

Answer2 to Answer1 (ms) — This field is the time at which Answer1 is sent from the MCU (the GUI default is 30 ms).

Reset MCU Timings — This button resets the MCU timing to the default GUI settings.

Answer3 to Answer2 (ms) — This field is the time at which Answer2 is sent from the MCU (the GUI default is 30 ms).

Answer1 to Answer0 (ms) — This field is the time at which Answer0 is sent from the MCU (the GUI default is 25 ms).

Window1 Duration (ms) — This field is the WD response WINDOW 1 duration set in the WDT_WIN1_CFG register (the GUI default is 140.8 ms).

Window2 Duration (ms) — This field is the WD response WINDOW 2 duration set in the WDT_WIN2_CFG register (the GUI default is 17.6 ms).

Set Watchdog Settings — Whenever the watchdog timing is changed, click this button to update the WD_WIN1_CFG and WD_WIN2_CFG registers with the set timing values and to also sync the MCU timings again.

Read Window Durations — Click this button to read back the values of the WD_WIN1_CFG and WD_WIN2_CFG registers and update the timing values in the *Window1 Duration (ms)* and *Window2 Duration (ms)* fields.

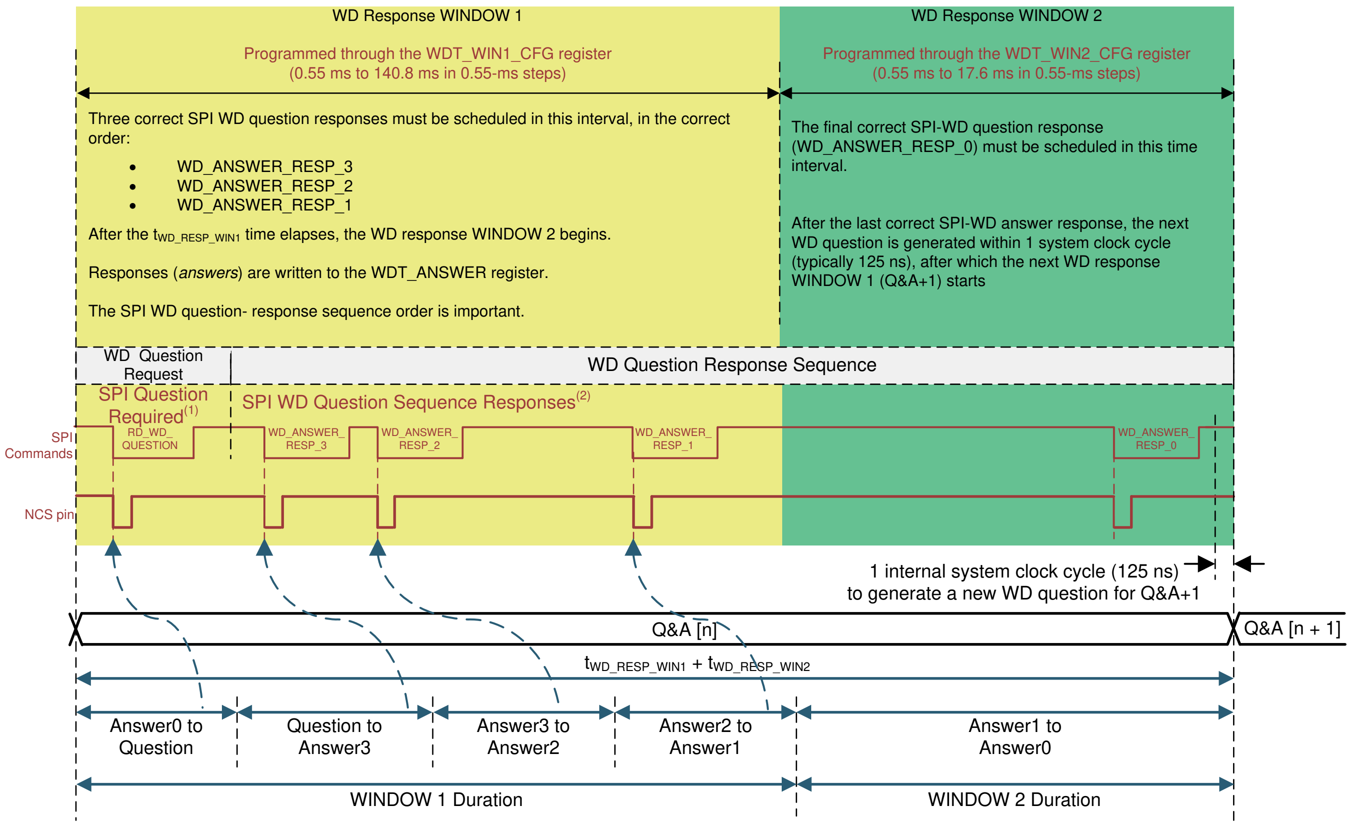


Figure 5. Watchdog Window Timing Diagram

Section 11 describes the watchdog implementation on the MSP430™ MCU on the EVM.

6.1.7 MCU Error Signal Monitor (ESM)

The MCU error monitoring function is implemented in the GUI to check the functionality of MCU_ERR pin. Both PWM mode and TMS570 mode of error monitoring is implemented on the GUI. Each setting is described as follows:

TMS570 Mode button — This option reads the register values and populates the corresponding text field with the corresponding low and high periods.

Write MCU Error Window Registers button — When enabled, the timing thresholds set in the text field are written to the corresponding device timing registers (PWM_LMAX, PWM_LMIN, PWM_HMAX, PWM_HMIN).

Enable PWM Output button — The *Low Duration*, *High Duration*, and the *Enable PWM Output* options turn on the clock with those periods on the MCU GPIO connected to the MCU_ERR pin. Jumper J11 must be set between pin 2 and pin 3 for this signal to be applied to the device pin.

MCU Error Window Register Values fields — This option reads the timing register values and populates the corresponding text field with the corresponding low and high periods.

The ESM is disabled by default, and can be activated by setting the MCU_ESM_EN bit to 1b in the SAFETY_CHECK_CTRL SPI register.

6.1.8 SPI Status Bits

The SPI status flag response byte of the device is displayed in this section of the *Device Controls* page. For more information, refer to the *TPS65313-Q1 Wide-VIN Power-Management IC for Automotive Applications* datasheet.

6.1.9 Moniter ENDRV and NRES Button

If this button is turned on, the color of the ENDRV and NRES indicator on the GUI indicates the status of these pins if jumpers are installed between J7_1_2 and J8_1_2. A dark green color indicates a low on these pins and a light green color indicates a high on these two pins. The ENDRV and NRES pins are the device safety pins. To activate these pins, refer to the*TPS65313-Q1 Wide-VIN Power-Management IC for Automotive Applications* datasheet.

6.2 Register Map Page

All SPI registers can be read or written on the *Register Map* page. Figure 6 shows a snapshot of GUI *Register Map* page.

1. **Update Mode drop-down menu —** With the *Immediate* option, changes are immediately written to the device. With the *Deferred* option, changes are made only when the write register button is clicked. This option is the preferred option to have better control on the writes that are performed.
2. **Write selected —** This option writes only the selected register.
3. **Write modified —** This option writes all registers that have been changed since the last write.
4. **Read selected —** This option reads only the selected register and updates the contents with the register value.
5. **Read all —** This option reads all the SPI registers and updates the contents with the register value.
6. **Field view section —** This section provides the individual register description.

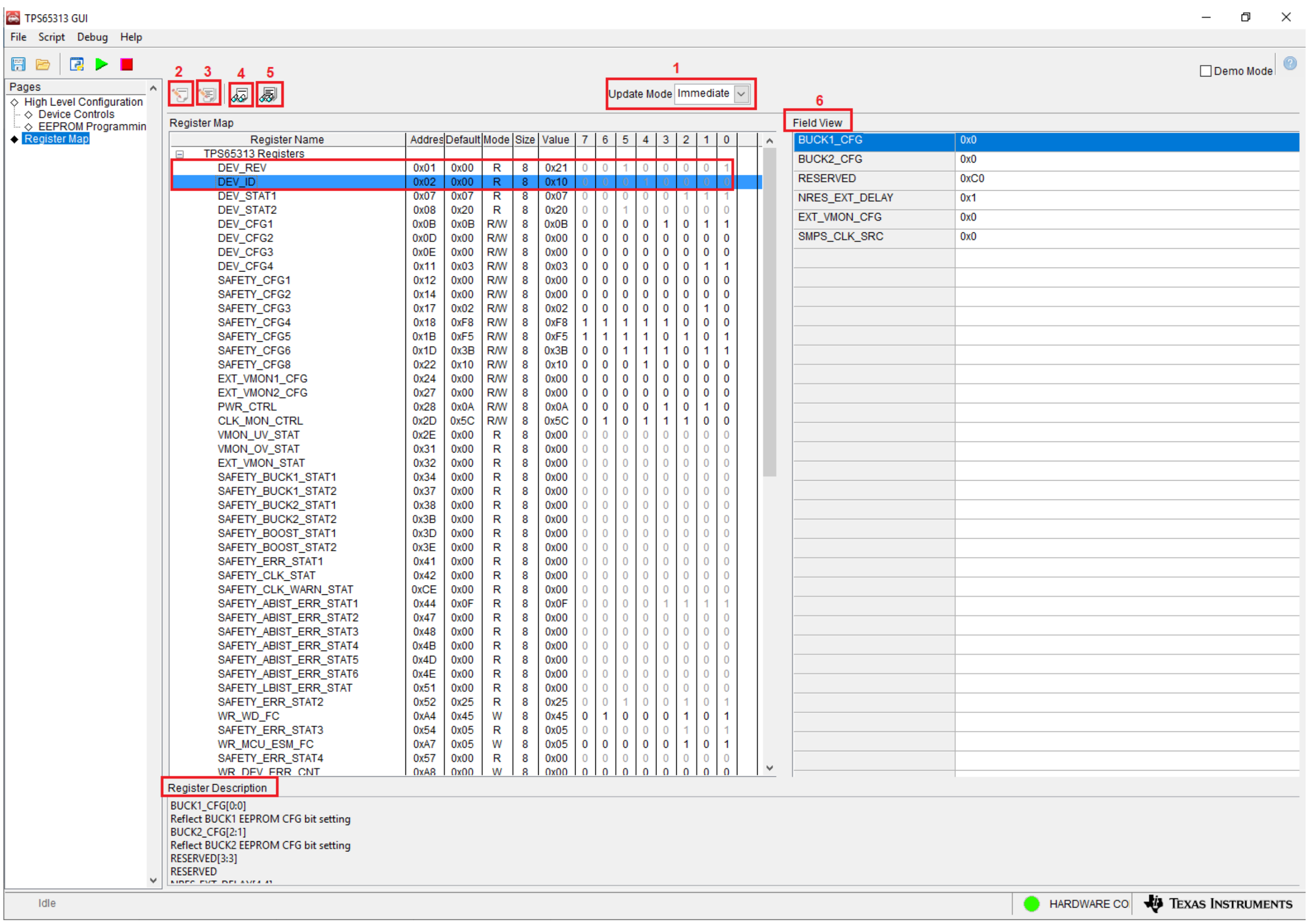


Figure 6. Updated Figure 6. TPS65313 GUI Register Map Page TPS65313 GUI Register Map Page

6.3 EEPROM Programming Page

The TPS65313-Q1 device has many factory programmable device options with unique orderable part numbers. By default, the TPS65313-EVM has a device with the O31310QRWGRQ1 orderable part number. If users want to evaluate different device options (or orderable part numbers), the EEPROM configuration can be updated using this page as shown in Figure 7. Not all the device options samples are readily available or it may be possible to have a device configuration which is not listed here. Contact TI local sales team for sample availability and feasibility.

Keep the VBAT supply voltage between 10 V and 18 V while updating the device options or orderable part number. All the jumpers should be set according to Figure 8. For a list of orderable part numbers, refer to the *TPS65313-Q1 Wide-VIN Power-Management IC for Automotive Applications* datasheet.To select an orderable part number in the GUI, click the *Device Selection* drop-down menu. Then click the *Program EEPROM* button. If the orderable part number is successfully updated, a message is displayed to power off and power on the device to make the changes effective. Once EEPROM Programming is completed successfully, bring the jumper settings back to its original settings specified in Table 2*TPS65313-EVM Jumper Settings* as in EEPROM Programming mode, device may get damaged if VBAT voltage is more than 18 V.

Device output voltages are accurately trimmed at the factory for the O31310QRWGRQ1 orderable part number only. Output voltage accuracy can be affected slightly for other device options generated using the GUI EEPROM programming method. However, if the user orders device samples according to the device options table in the data sheet, these devices will be correctly trimmed at the factory to have best output voltage accuracy.

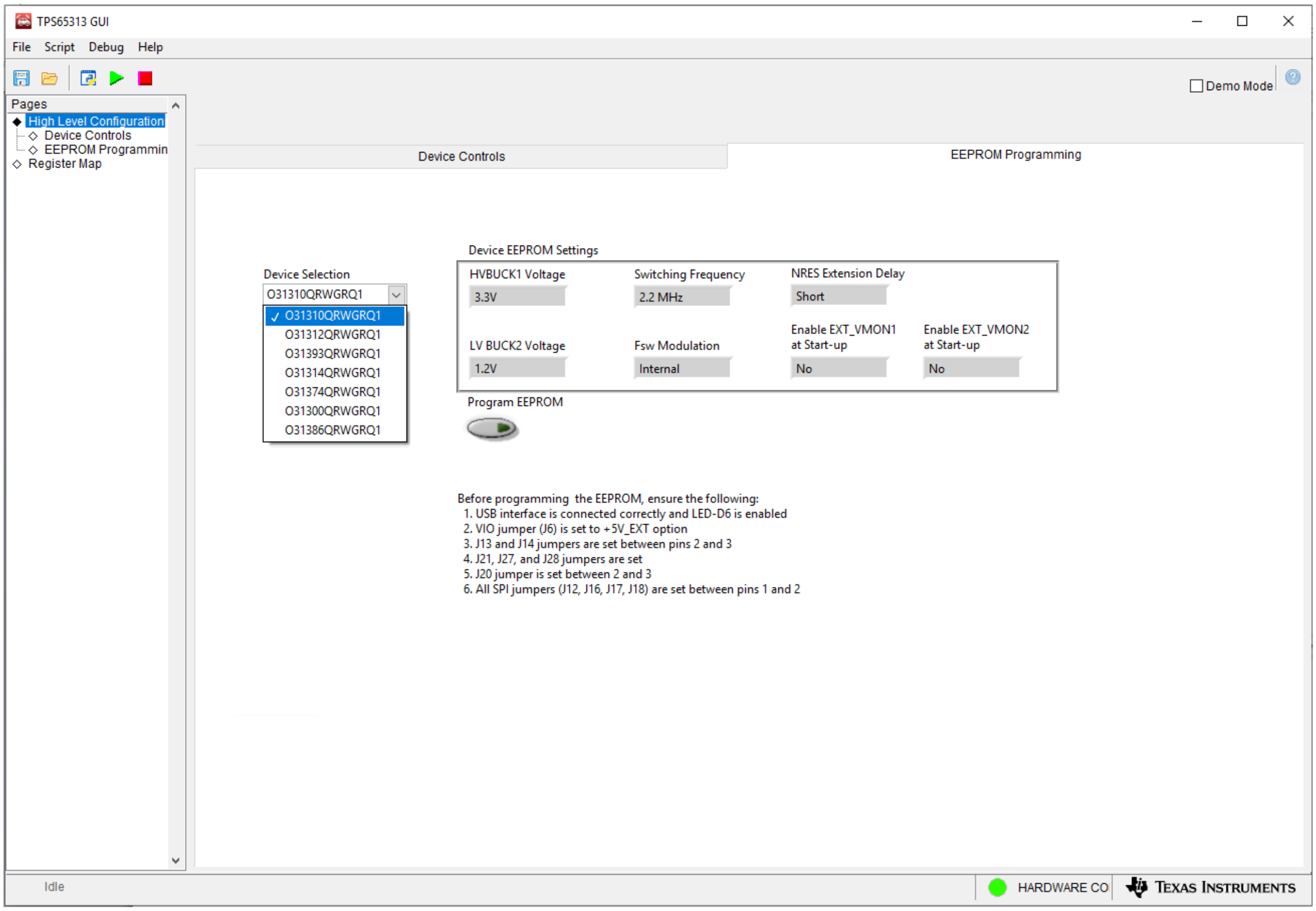


Figure 7. TPS65313 GUI EEPROM Programming Page

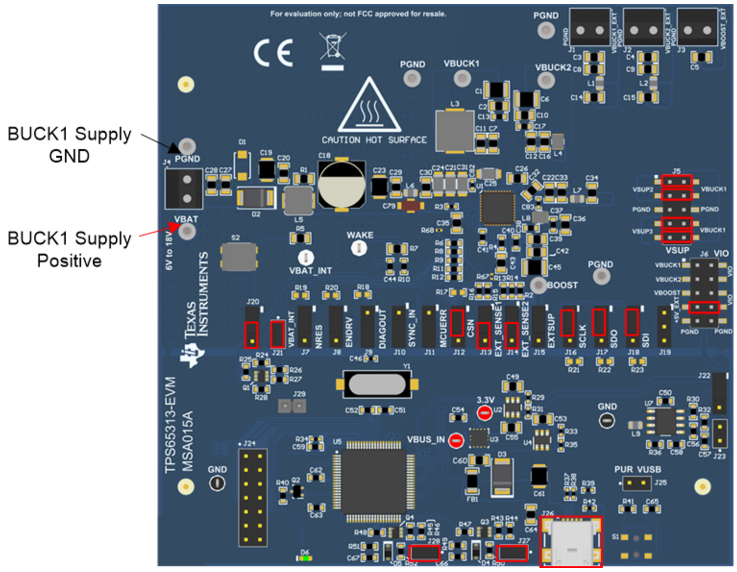
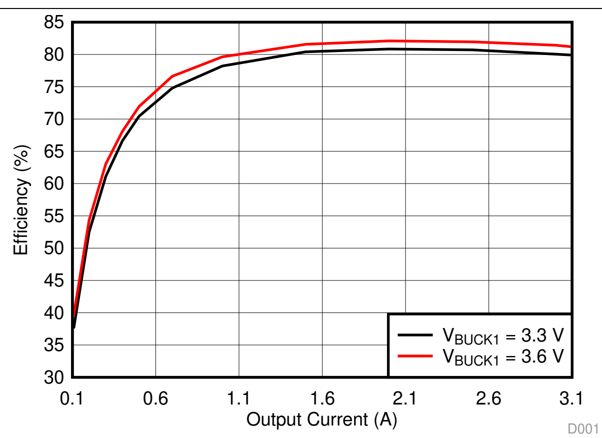


Figure 8. Jumper Settings for EEPROM Update

7 TPS65313-EVM Typical Plots

This section provides plots for efficiency, start up, power down, ripple voltage, load transient response, and stability. All the plots were taken with 13-V at the VIN pin, one EVM, room temperature, with the BUCK1 output connected as the supply for the BUCK2 regulator and BOOST converter.

7.1 Efficiency Plots



The total current in to the VIN, AVIN, and VIN_SAFE pins was considered for this plot with the EXTSUP supply connected to the BOOST converter.

Figure 9. BUCK1 Efficiency Plot for V_{IN} = 13 V

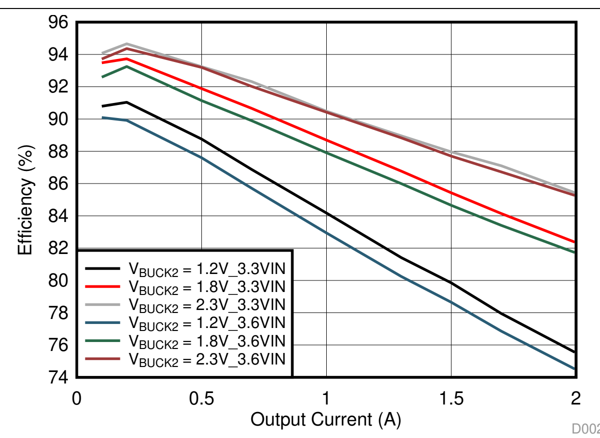


Figure 10. BUCK2 Efficiency Plot

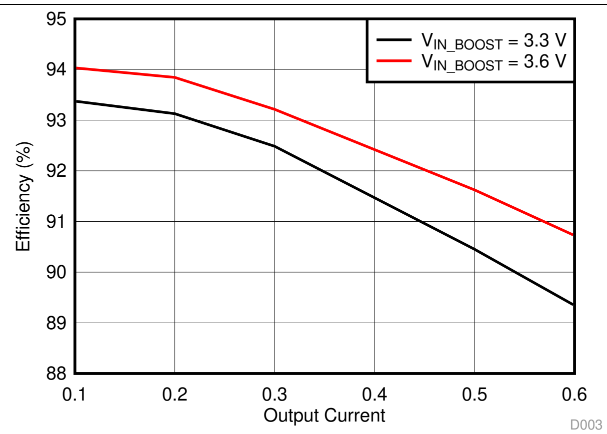


Figure 11. BOOST Efficiency Plot

7.2 Power-Up Plots

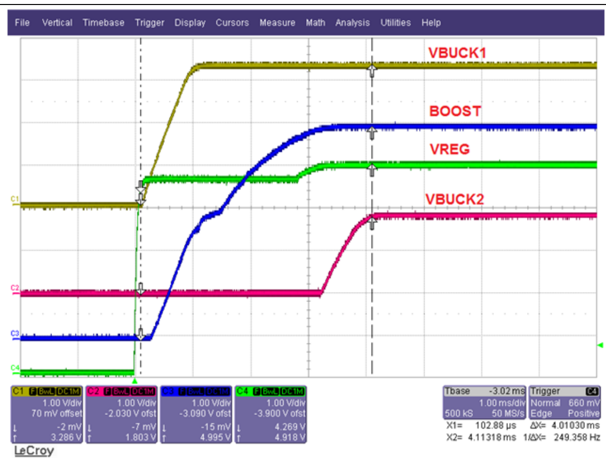


Figure 12. Power Up Showing Regulator Outputs and VREG

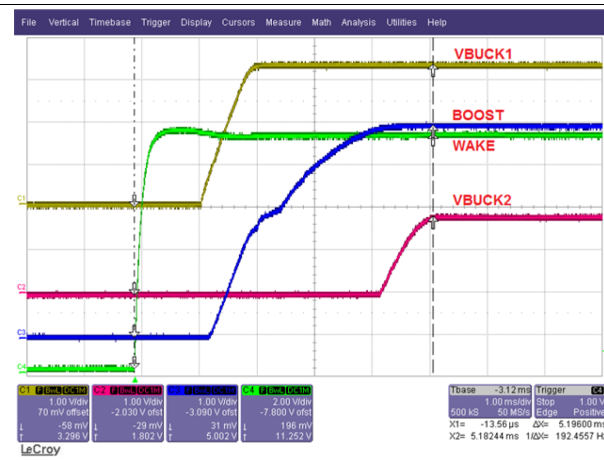


Figure 13. Power Up Showing Regulator Outputs and WAKE

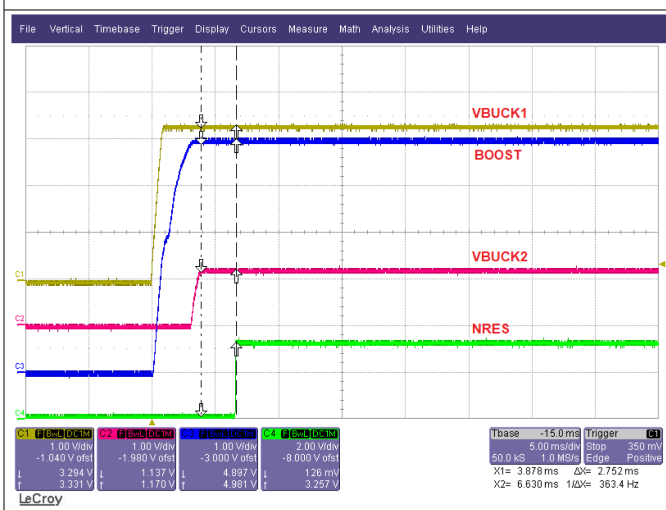


Figure 14. Regulators Start-Up showing NRES with short NRES extension delay

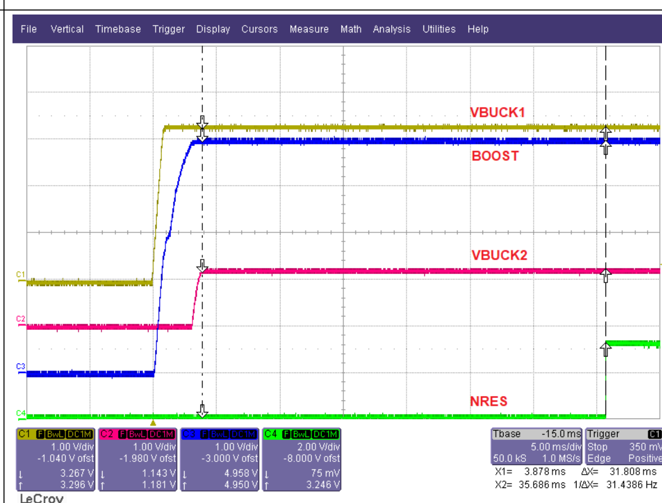


Figure 15. Regulators Start-Up showing NRES with long NRES extension delay

7.3 Power-Down Plots

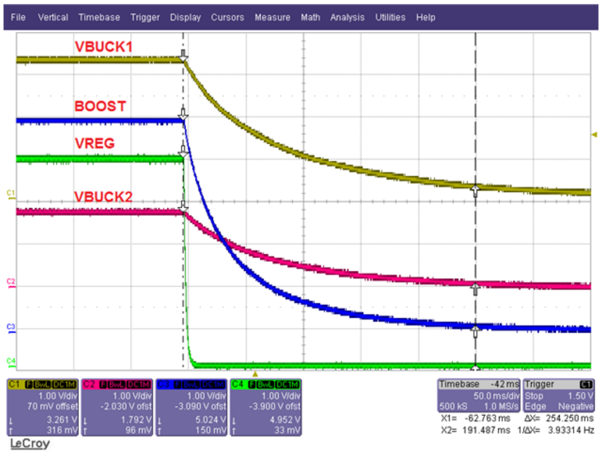


Figure 16. Power Down Showing Regulator Outputs and VREG

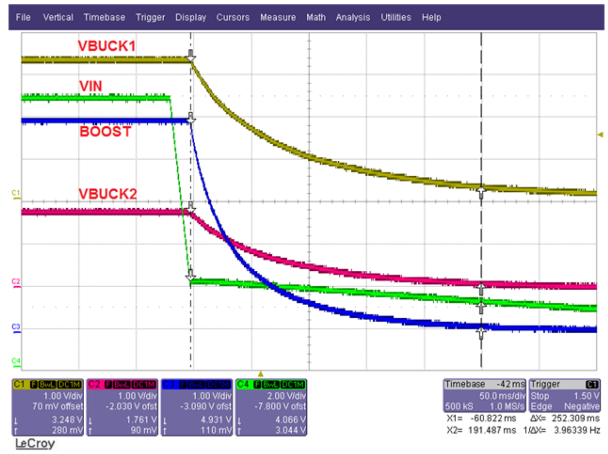


Figure 17. Power Down Showing Regulator Outputs and VIN

7.4 Ripple Voltage Plots

All the ripple measurements were done with a 20-MHz bandwidth differential active probe. The ripple was measured directly across the output capacitor.

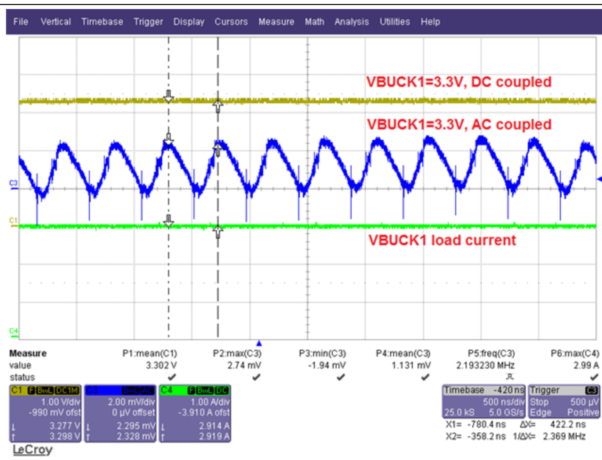


Figure 18. BUCK1 Ripple Voltage With 3-A Load Current for 3.3-V Output Voltage

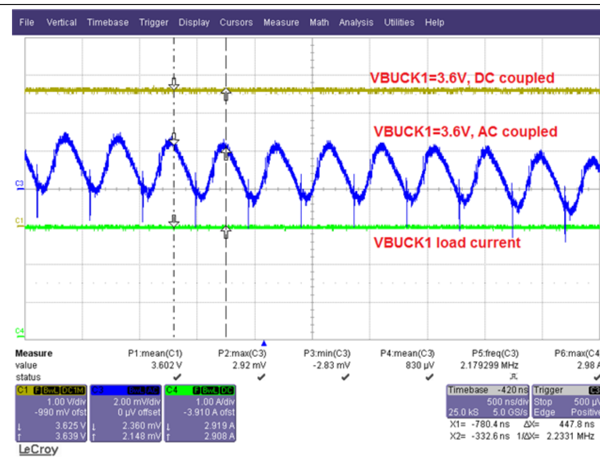


Figure 19. BUCK1 Ripple Voltage With 3-A Load Current for 3.6-V Output Voltage

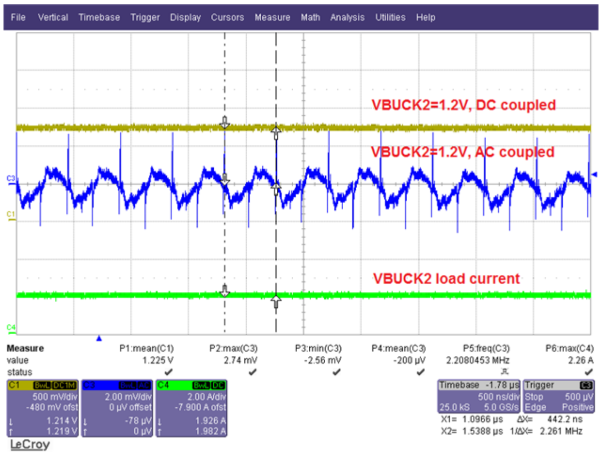


Figure 20. BUCK2 Ripple Voltage With 2-A Load Current for 1.2-V Output Voltage

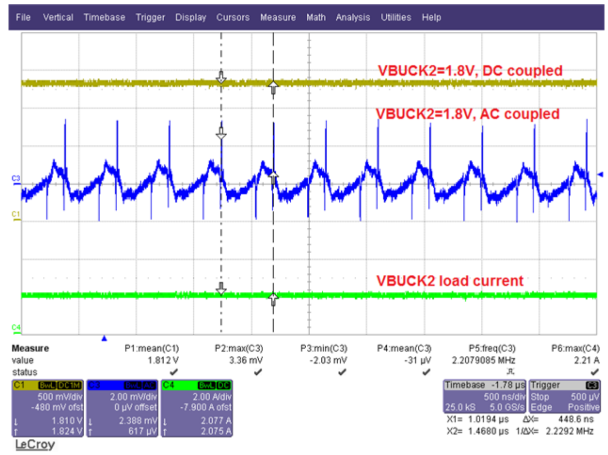


Figure 21. BUCK2 Ripple Voltage With 2-A Load Current for 1.8-V Output Voltage

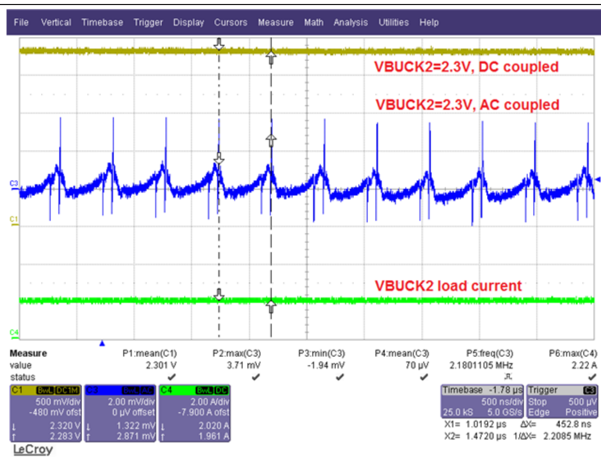


Figure 22. BUCK2 Ripple Voltage With 2-A Load Current for 2.3-V Output Voltage

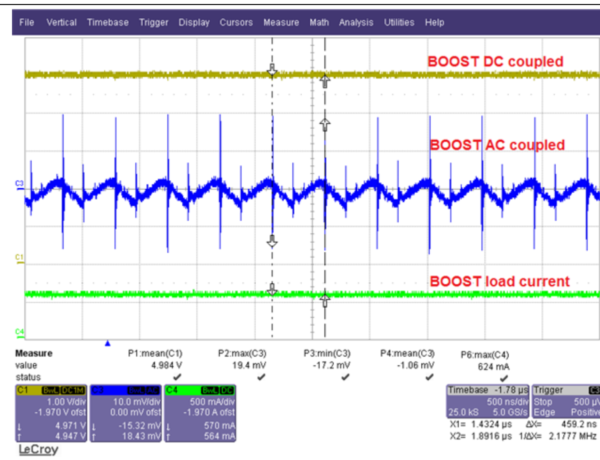


Figure 23. BOOST Ripple Voltage With 0.6-A Load Current

7.5 Load Transient Plots

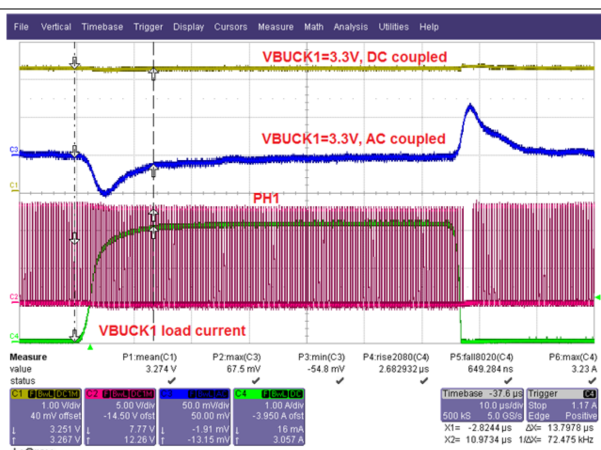


Figure 24. BUCK1 Load Transient With Maximum Load Current for 3.3-V Output Voltage

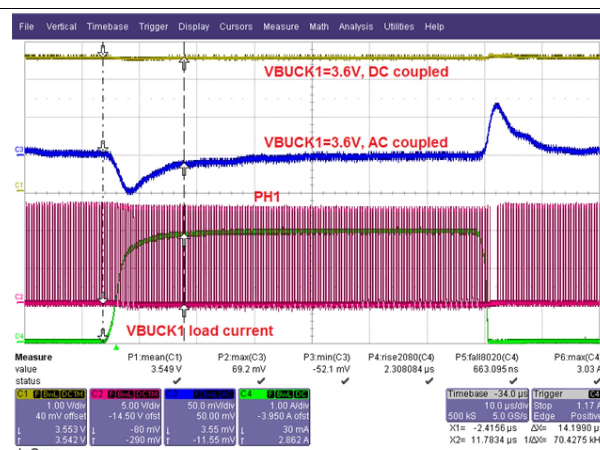


Figure 25. BUCK1 Load Transient With Maximum Load Current for 3.6-V Output Voltage

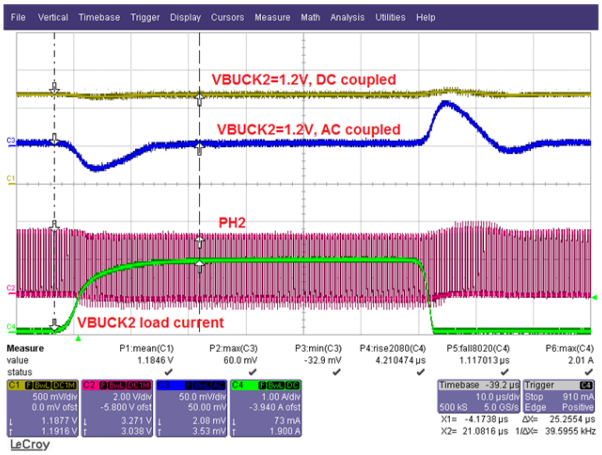


Figure 26. BUCK2 Load Transient With Maximum Load Current for 1.2-V Output Voltage

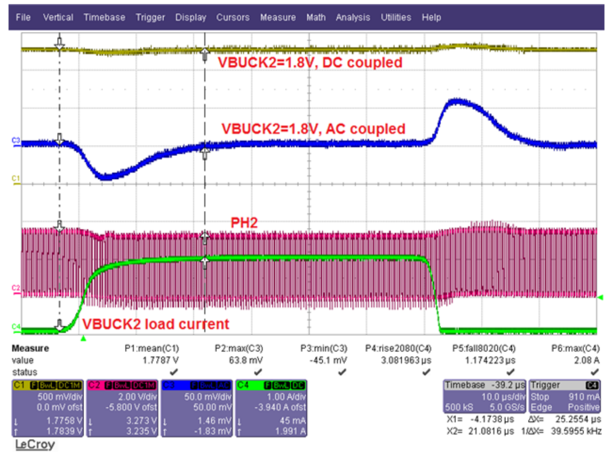


Figure 27. BUCK2 Load Transient With Maximum Load Current for 1.8-V Output Voltage

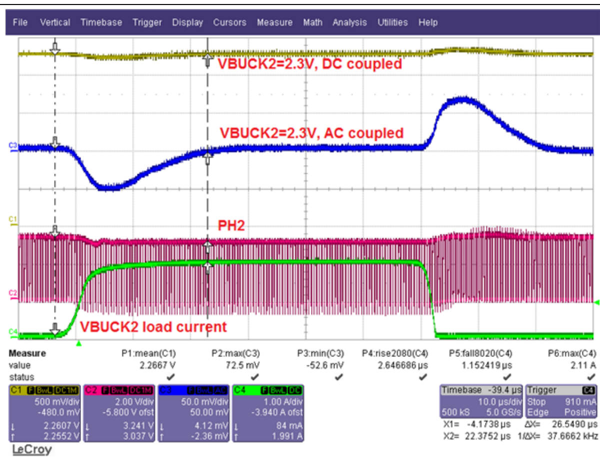


Figure 28. BUCK2 Load Transient With Maximum Load Current for 2.3-V Output Voltage

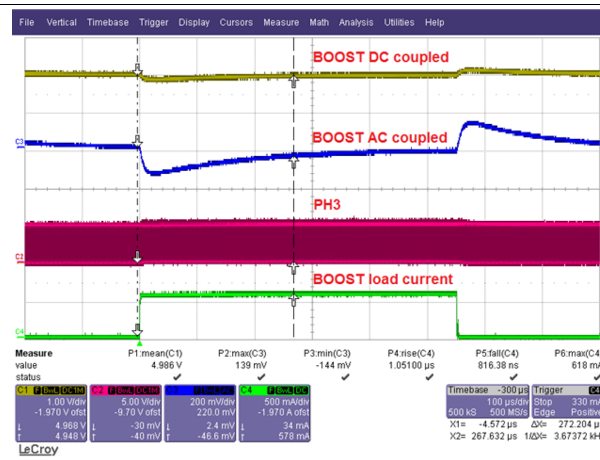


Figure 29. BOOST Load Transient With Maximum Load Current

7.6 Stability Measurements

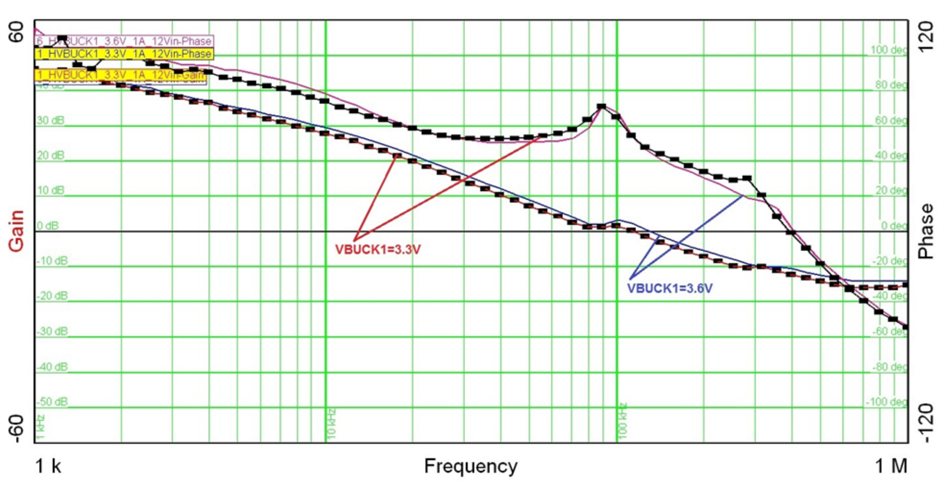


Figure 30. BUCK1 Gain and Phase Plot With 1-A Load Current for V_{IN} = 13 V (Phase Margin ≈50 Degree, Bandwidth > 100 kHz)

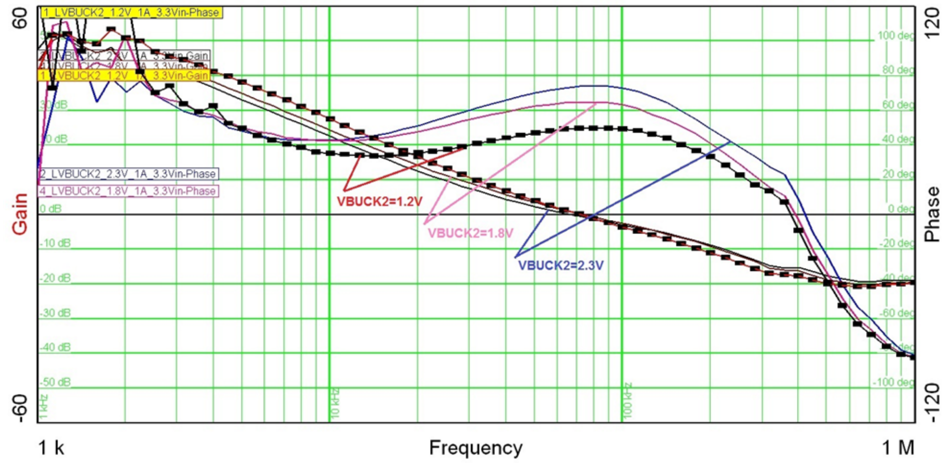


Figure 31. BUCK2 Gain and Phase Plot With 1-A Load Current for V_{IN} = 3.3 V (Phase Margin >50 Degree, Bandwidth ≈75 kHz)

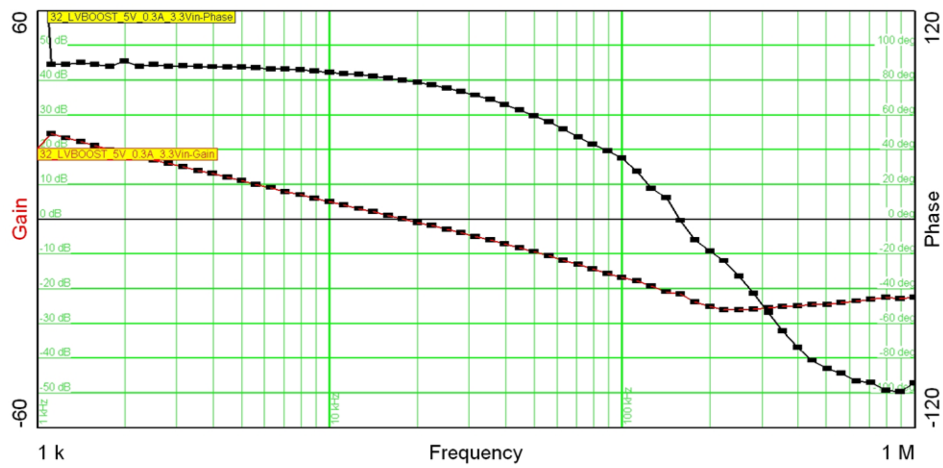


Figure 32. BOOST Gain and Phase Plot With 0.3-A Load Current for V_{IN} = 3.3 V (Phase Margin >80 Degree, Bandwidth ≈20 kHz)

8 TPS65313-EVM Schematic Diagram

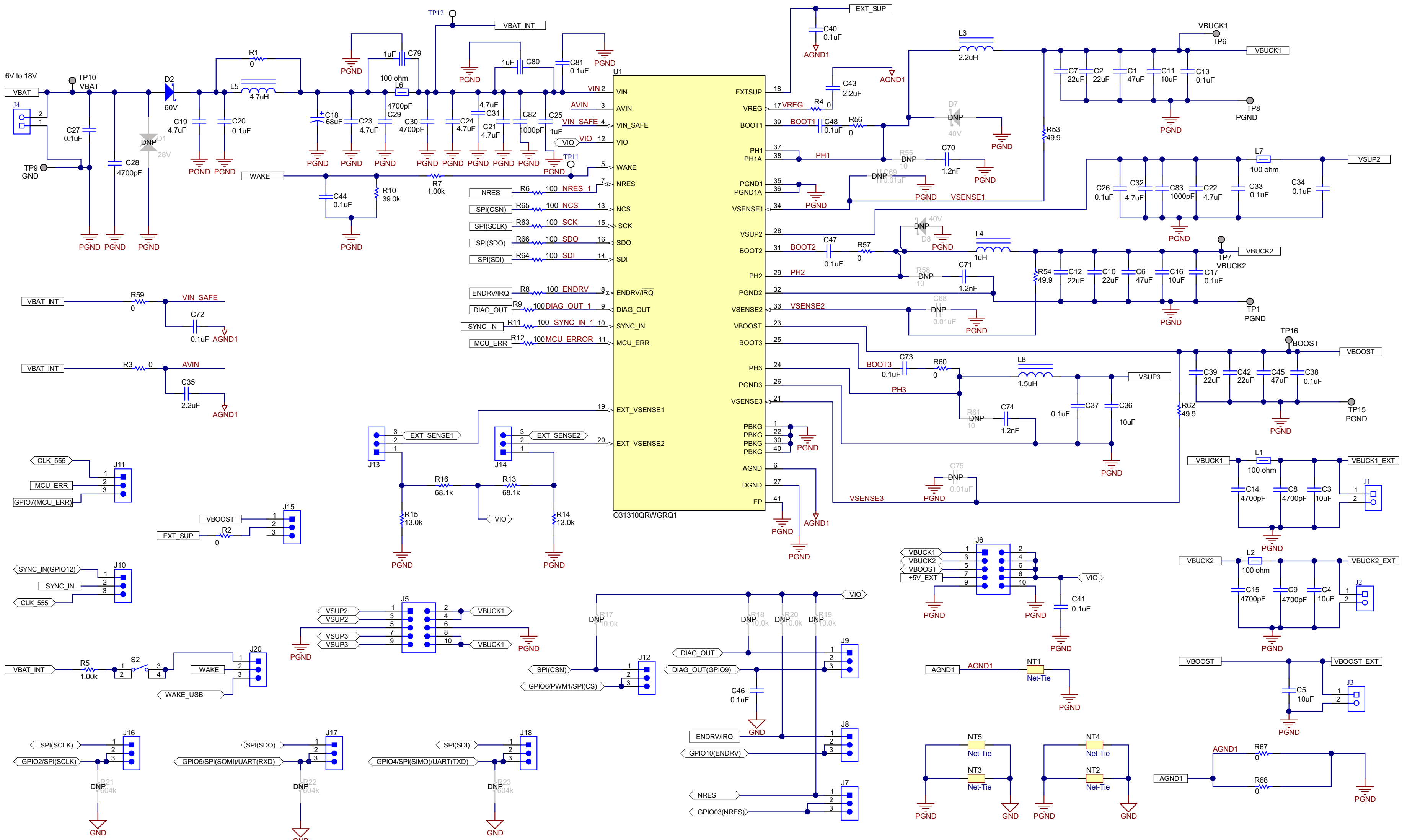


Figure 33. TPS65313-EVM: TPS65313-Q1 Device External Circuit Schematic

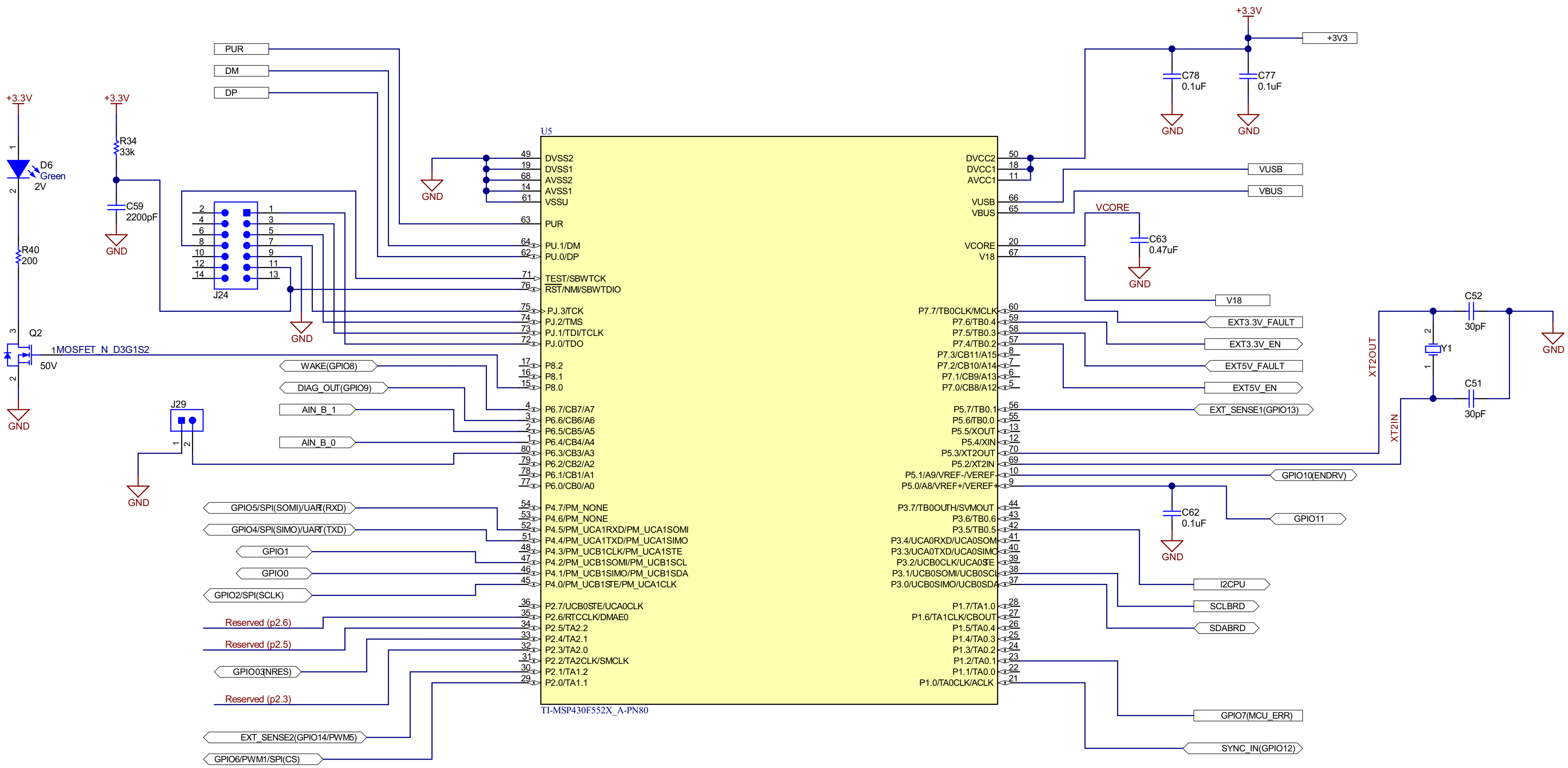


Figure 34. TPS65313-EVM: MSP430™ USB2ANY MCU Circuit Schematic

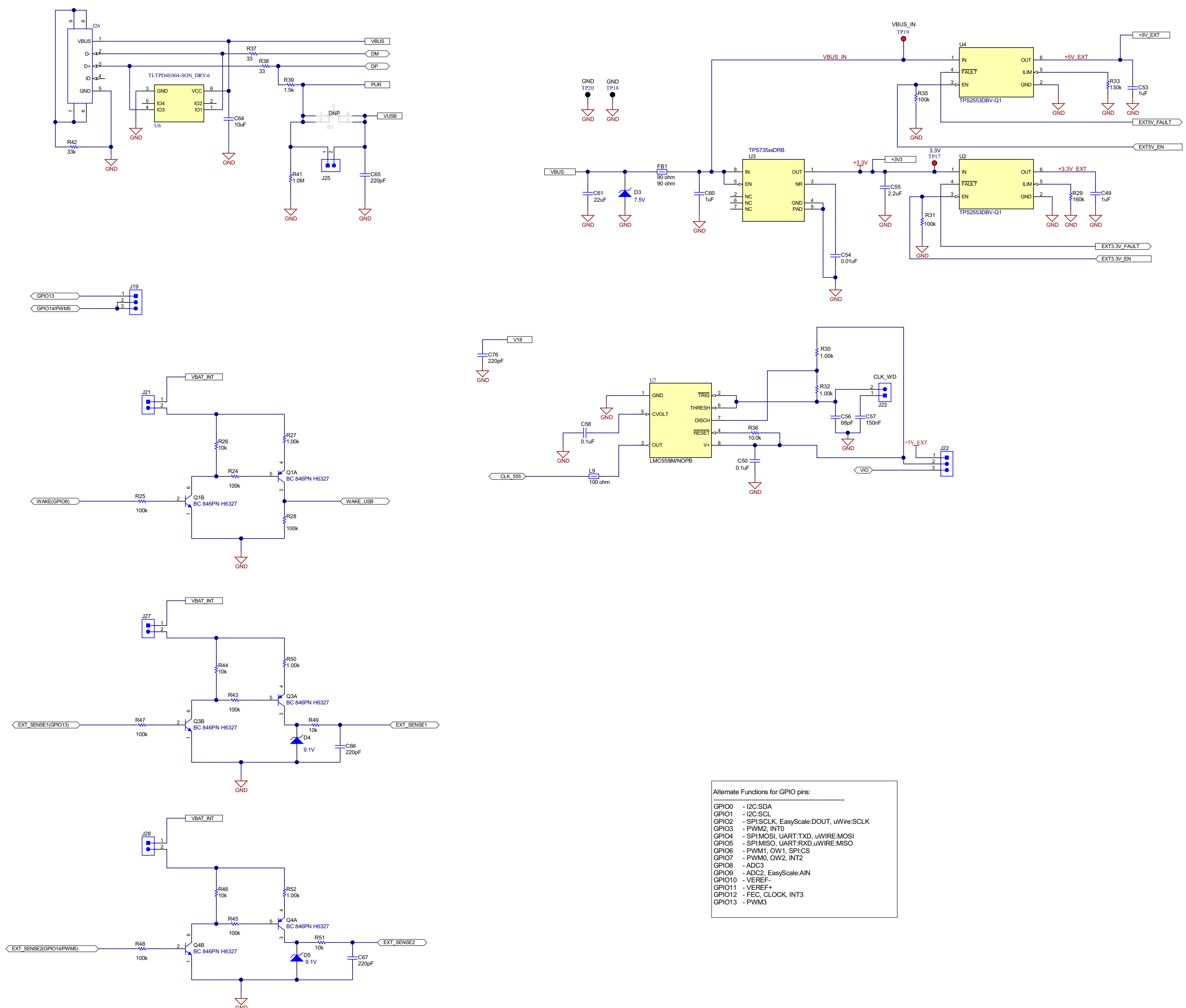


Figure 35. TPS65313-EVM: USB2ANY Power and Control Circuit Schematic

9 TPS65313-EVM Part List

Table 3 lists the bill of materials (BOM) for the TPS65313-EVM.

Table 3. Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
!PCB1	1		Printed Circuit Board		MSA015	Any		
C1, C6, C45	3	47 µF	CAP, CERM, 47 µF, 10 V, ± 10%, X7R, 1210	1210	GRM32ER71A476KE15L	MuRata		
C2, C7, C10, C12, C39, C42	6	22 µF	CAP, CERM, 22 µF, 10 V, ± 20%, X7S, 0805	0805	C2012X7S1A226M125AC	TDK		
C3, C4, C5, C11, C16, C36	6	10 µF	CAP, CERM, 10 µF, 10 V, ± 20%, X7R, 0805	0805	C2012X7R1A106M125AC	TDK		
C8, C9, C14, C15, C28, C29, C30	7	4700 pF	CAP, CERM, 4700 pF, 50 V, ± 10%, X7R, 0805	0805	08055C472KAT2A	AVX		
C13, C17, C37, C38, C40, C41, C44, C47, C48, C62, C72, C73, C77, C78, C81	15	0.1 µF	CAP, CERM, 0.1 µF, 50 V, ± 10%, X8R, AEC-Q200 Grade 0, 0603	0603	CGA3E3X8R1H104K080AB	TDK		
C18	1	68 µF	CAP, Polymer Hybrid, 68 µF, 50 V, ± 20%, 30 Ω, 8x10 SMD	8x10	EEHZC1H680P	Panasonic		
C19, C23	2	4.7 µF	CAP, CERM, 4.7 µF, 50 V, ± 10%, X7R, AEC-Q200 Grade 1, 1210	1210	CGA6P3X7R1H475K250AB	TDK		
C20, C26, C27, C33, C34	5	0.1 µF	CAP, CERM, 0.1 µF, 50 V, ± 10%, X7R, 0805	0805	C2012X7R1H104K085AA	TDK		
C21, C24, C31	3	4.7 µF	CAP, CERM, 4.7 µF, 50 V, ± 10%, X7R, 1206	1206	C3216X7R1H475K160AC	TDK		
C22, C32	2	4.7 µF	CAP, CERM, 4.7 µF, 10 V, ± 20%, X7R, 0805	0805	C2012X7R1A475M125AC	TDK		
C25	1	1 µF	CAP, CERM, 1 µF, 50 V, ± 10%, X7R, AEC-Q200 Grade 1, 1206	1206	CGA5L3X7R1H105K160AB	TDK		

Table 3. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
C35	1	2.2 µF	CAP, CERM, 2.2 µF, 50 V, ± 10%, X7R, AEC-Q200 Grade 1, 0805	0805	CGA4J3X7R1H225K125AB	TDK		
C43	1	2.2 µF	CAP, CERM, 2.2 µF, 16 V, ± 10%, X7R, 0805	0805	C2012X7R1C225K125AB	TDK		
C46	1	0.1 µF	CAP, CERM, 0.1 µF, 50 V, ± 10%, X7R, AEC-Q200 Grade 1, 0402	0402	CGA2B3X7R1H104K050BB	TDK		
C49, C53	2	1 µF	CAP, CERM, 1 µF, 16 V, ± 10%, X5R, 0805	0805	0805YD105KAT2A	AVX		
C50, C58	2	0.1 µF	CAP, CERM, 0.1 µF, 25 V, ± 5%, X7R, 0603	0603	C0603C104J3RAC	Kemet		
C51, C52	2	30 pF	CAP, CERM, 30 pF, 100 V, ± 5%, C0G/NP0, 0603	0603	GRM1885C2A300JA01D	MuRata		
C54	1	0.01 µF	CAP, CERM, 0.01 µF, 50 V, ± 5%, C0G/NP0, AEC-Q200 Grade 1, 0603	0603	CGA3E2C0G1H103J080AA	TDK		
C55	1	2.2 µF	CAP, CERM, 2.2 µF, 16 V, ± 10%, X5R, 0805	0805	0805YD225KAT2A	AVX		
C56	1	68 pF	CAP, CERM, 68 pF, 50 V, ± 5%, C0G/NP0, 0603	0603	06035A680JAT2A	AVX		
C57	1	0.15 µF	CAP, CERM, 0.15 µF, 50 V, ± 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E3X7R1H154K080AB	TDK		
C59	1	2200 pF	CAP, CERM, 2200 pF, 50 V, ± 10%, X7R, 0603	0603	C0603X222K5RACTU	Kemet		
C60	1	1 µF	CAP, CERM, 1 µF, 50 V, ± 10%, X7R, AEC-Q200 Grade 1, 0805	0805	CGA4J3X7R1H105K125AB	TDK		
C61	1	22 µF	CAP, CERM, 22 µF, 16 V, ± 20%, X7R, AEC-Q200 Grade 1, 1210	1210	CGA6P1X7R1C226M250AC	TDK		
C63	1	0.47 µF	CAP, CERM, 0.47 µF, 10 V, ± 10%, X7R, 0603	0603	C0603C474K8RACTU	Kemet		
C64	1	10 µF	CAP, CERM, 10 µF, 16 V, ± 20%, X5R, 0805	0805	0805YD106MAT2A	AVX		
C65, C66, C67, C76	4	220 pF	CAP, CERM, 220 pF, 50 V, ± 1%, C0G/NP0, 0603	0603	06035A221FAT2A	AVX		
C70, C71, C74	3	1200 pF	CAP, CERM, 1200 pF, 100 V, ± 5%, X7R, 0603	0603	06031C122JAT2A	AVX		

Table 3. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
C79, C80	2	1 µF	1µF, 3 Terminal Filtering Capacitor Type, SMD	3.2x1.6 mm	YFF31AH2A105M	TDK		
C82, C83	2	1000 pF	CAP, CERM, 1000 pF, 50 V, ± 10%, X7R, AEC-Q200 Grade 1, 0402	0402	CGA2B2X7R1H102K050BA	TDK		
D2	1	60 V	Diode, Schottky, 60 V, 2 A, SMB	SMB	B260-13-F	Diodes Inc.		
D3	1	7.5 V	Diode, Zener, 7.5 V, 550 mW, SMB	SMB	1SMB5922BT3G	ON Semiconductor		
D4, D5	2	9.1 V	Diode, Zener, 9.1 V, 200 mW, SOD-323	SOD-323	MMSZ5239BS-7-F	Diodes Inc.		
D6	1	Green	LED, Green, SMD	1.6x0.8x0.8 mm	LTST-C190KGKT	Lite-On		
FB1	1	90 Ω	Ferrite Bead, 90 Ω @ 100 MHz, 1.5 A, 1206	1206	MI1206K900R-10	Laird-Signal Integrity Products		
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.44 X 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M		
H5	1		CABLE MINI USB 5PIN 1M 2.0 VERS		AK672M/2-1-R	Assman WSW		
J1, J2, J3, J4	4		Terminal Block, 3.5 mm Pitch, 2x1, TH	7.0x8.2x6.5 mm	ED555/2DS	On-Shore Technology		
J5, J6	2		Header, 100 mil, 5x2, Tin, SMT	500x180x290 mil	TSM-105-01-T-DV-P	Samtec		
J7, J8, J9, J10, J11, J12, J13, J14, J15, J16, J17, J18, J19, J20, J22	15		Header, 100 mil, 3x1, Gold, TH	3x1 Header	TSW-103-07-G-S	Samtec		
J21, J23, J25, J27, J28	5		Header, 100 mil, 2x1, Gold, TH	2x1 Header	TSW-102-07-G-S	Samtec		
J24	1		Header, 100 mil, 7x2, Gold, TH	7x2 Header	TSW-107-07-G-D	Samtec		
J26	1		Connector, Receptacle, Mini-USB Type B, R/A, Top Mount SMT	USB Mini Type B	1734035-2	TE Connectivity		
J29	1		Header, 2.54 mm, 2x1, Tin, TH	Header, 2.54 mm, 2x1, TH	TSW-102-07-T-S	Samtec		

Table 3. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
L1, L2, L6, L7, L9	5	100 Ω	Ferrite Bead, 100 Ω @ 100 MHz, 4 A, 0805	0805	MPZ2012S101A	TDK		
L3	1	2.2 µH	Inductor, Shielded, 2.2 µH, 8.1 A, 0.0183 Ω, AEC-Q200 Grade 1, SMD	6.86x6.47 mm	IHLP2525CZER2R2M5A	Vishay-Dale	IHLP2525CZER2R2M8A	Vishay-Dale
L4	1	1 µH	Inductor, Film, 1 µH, 3.7 A, 0.042 Ω, AEC-Q200 Grade 0, SMD	2.5x2 mm	TFM252012ALMA1R0MTAA	TDK		
L5	1	4.7 µH	Inductor, Shielded Drum Core, Powdered Iron, 4.7 µH, 3.5 A, 0.0775 Ω, SMD	5.18x3x5.5 mm	IHLP2020CZER4R7M01	Vishay-Dale		
L8	1	1.5 µH	Inductor, Film, 1.5 µH, 3.1 A, 0.06 Ω, AEC-Q200 Grade 0, SMD	2.5x2 mm	TFM252012ALMA1R5MTAA	TDK		
Q1, Q3, Q4	3	65 V	Transistor, NPN/PNP Pair, 65 V, 0.1 A, SOT-363	SOT-363	BC 846PN H6327	Infineon Technologies		
Q2	1	50 V	MOSFET, N-CH, 50 V, 0.2 A, SOT-323	SOT-323	BSS138W-7-F	Diodes Inc.		None
R1	1	0	RES, 0, 5%, 0.333 W, AEC-Q200 Grade 0, 0805	0805	CRCW08050000Z0EAHP	Vishay-Dale		
R2, R4, R56, R57, R60	5	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	ERJ-3GEY0R00V	Panasonic		
R3, R59	2	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0ED	Vishay-Dale		
R5, R7	2	1.00 k	RES, 1.00 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	CRCW08051K00FKEA	Vishay-Dale		
R6, R8, R9, R11, R12, R63, R64, R65, R66	9	100	RES, 100, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100RFKEA	Vishay-Dale		
R10	1	39.0 k	RES, 39.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0739KL	Yageo		
R13, R16	2	68.1 k	RES, 68.1 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060368K1FKEA	Vishay-Dale		
R14, R15	2	13.0 k	RES, 13.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060313K0FKEA	Vishay-Dale		

Table 3. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
R24, R25, R28, R43, R45, R47, R48	7	100 k	RES, 100 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100KJNEA	Vishay-Dale		
R26, R44, R46, R49, R51	5	10 k	RES, 10 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0JNEA	Vishay-Dale		
R27, R30, R32, R50, R52	5	1.00 k	RES, 1.00 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06031K00FKEA	Vishay-Dale		
R29	1	160 k	RES, 160 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402160KJNED	Vishay-Dale		
R31, R35	2	100 k	RES, 100 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402100KJNED	Vishay-Dale		
R33	1	130 k	RES, 130 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402130KJNED	Vishay-Dale		
R34, R42	2	33 k	RES, 33 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040233K0JNED	Vishay-Dale		
R36	1	10.0 k	RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0FKEA	Vishay-Dale		
R37, R38	2	33	RES, 33, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040233R0JNED	Vishay-Dale		
R39	1	1.5 k	RES, 1.5 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04021K50JNED	Vishay-Dale		
R40	1	200	RES, 200, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603200RFKEA	Vishay-Dale		
R41	1	1.0 Meg	RES, 1.0 M, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06031M00JNEA	Vishay-Dale		
R53, R54, R62	3	49.9	RES, 49.9, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060349R9FKEA	Vishay-Dale		
R67, R68	2	0	RES, 0, 5%, 0.05 W, 0201	0201	CRCW02010000Z0ED	Vishay-Dale		
S2	1		Switch, Tactile, SPST-NO, 0.1 A, 16 V, SMT	4.93x4.19x6.2 mm	7914G-1-000E	Bourns		

Table 3. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J7, SH-J8, SH-J9, SH-J10, SH-J11, SH-J12, SH-J13, SH-J14, SH-J15, SH-J16, SH-J17, SH-J18, SH-J19, SH-J20, SH-J21, SH-J22, SH-J23	23	1x2	Shunt, 100 mil, Flash Gold, Black	Closed Top 100 mil Shunt	SPC02SYAN	Sullins Connector Solutions		
TP1, TP6, TP7, TP8, TP9, TP10, TP15, TP16	8		PCB Pin, Swage Mount, TH	PCB Pin(2505-2)	2505-2-00-44-00-00-07-0	Mill-Max		
TP11, TP12	2		Test Point, Miniature, White, TH	White Miniature Testpoint	5002	Keystone		
TP17, TP19	2		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone		
TP18, TP20	2		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone		
U1	1		High Voltage Power Management IC for Automotive Application, RWG0040B (VQFNP-40)	RWG0040B	O31310QRWGRQ1	Texas Instruments		Texas Instruments
U2, U4	2		Automotive Catalog Precision Adjustable Current-Limited Power-Distribution Switch, DBV0006A (SOT-23-6)	DBV0006A	TPS2553QDBVRQ1	Texas Instruments		Texas Instruments
U3	1		500 mA, Adjustable, Low Quiescent Current, Low-Noise, High-PSRR, Single-Output LDO Regulator, DRB0008A (VSON-8)	DRB0008A	TPS73533DRBT	Texas Instruments		

Table 3. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
U5	1		25 MHz Mixed Signal Microcontroller with 128 KB Flash, 8192 B SRAM and 63 GPIOs, -40 to 85 degC, 80-pin QFP (PN), Green (RoHS & no Sb/Br)	PN0080A	MSP430F5529IPN	Texas Instruments		
U6	1		4-Channel ESD Protection Array for High-Speed Data Interfaces, DRY0006A (USON-6)	DRY0006A	TPD4E004DRYR	Texas Instruments		
U7	1		World's smallest 555 timer with low power, high accuracy and a Fmax of 3 MHz, D0008A (SOIC-8)	D0008A	LMC555IM/NOPB	Texas Instruments	LMC555IMX/NOPB	Texas Instruments
Y1	1		Crystal, 24.000 MHz, 20 pF, SMD	Crystal, 11.4x4.3x3.8 mm	ECS-240-20-5PX-TR	ECS Inc.		
C68, C69, C75	0	0.01 μF	CAP, CERM, 0.01 μF, 50 V, ± 10%, X7R, AEC-Q200 Grade 1, 0402	0402	CGA2B3X7R1H103K050BB	TDK		
D1	0	28 V	Diode, TVS, Bi, 28 V, 45.4 Vc, 400 W, 8.8 A, SMA (non-polarized)	SMA (non-polarized)	SMAJ28CA	Littelfuse		
D7, D8	0	40 V	Diode, Schottky, 40 V, 1 A, MicroSMP	MicroSMP	MSS1P4-M3/89A	Vishay-Siliconix		
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A		
R17, R18, R19, R20	0	10.0 k	RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0FKEA	Vishay-Dale		
R21, R22, R23	0	604 k	RES, 604 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603604KFKEA	Vishay-Dale		
R55, R58, R61	0	10	RES, 10, 5%, 0.25 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310R0JNEAHP	Vishay-Dale		
S1	0		Switch, Tactile, SPST-NO, SMT	Switch, 6.1x1.8x4.6 mm	EVQ-PSD02K	Panasonic		

10 PCB Layer Diagram

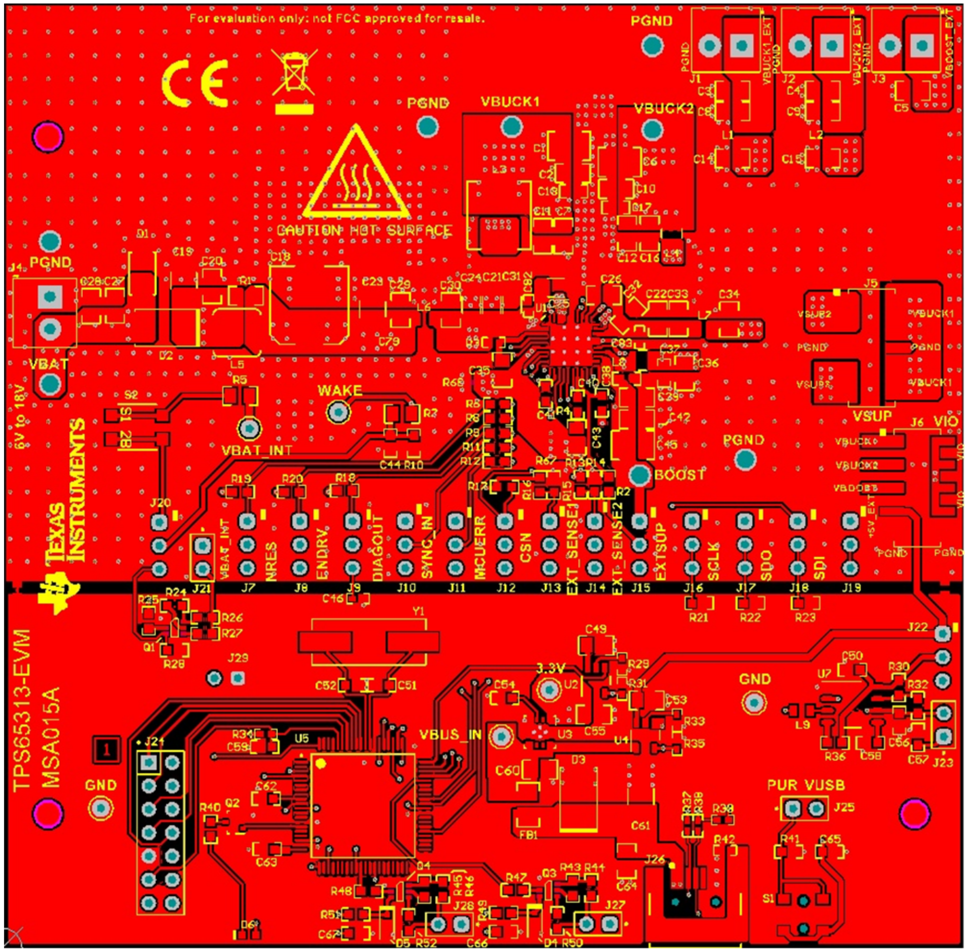


Figure 36. PCB Top Layer

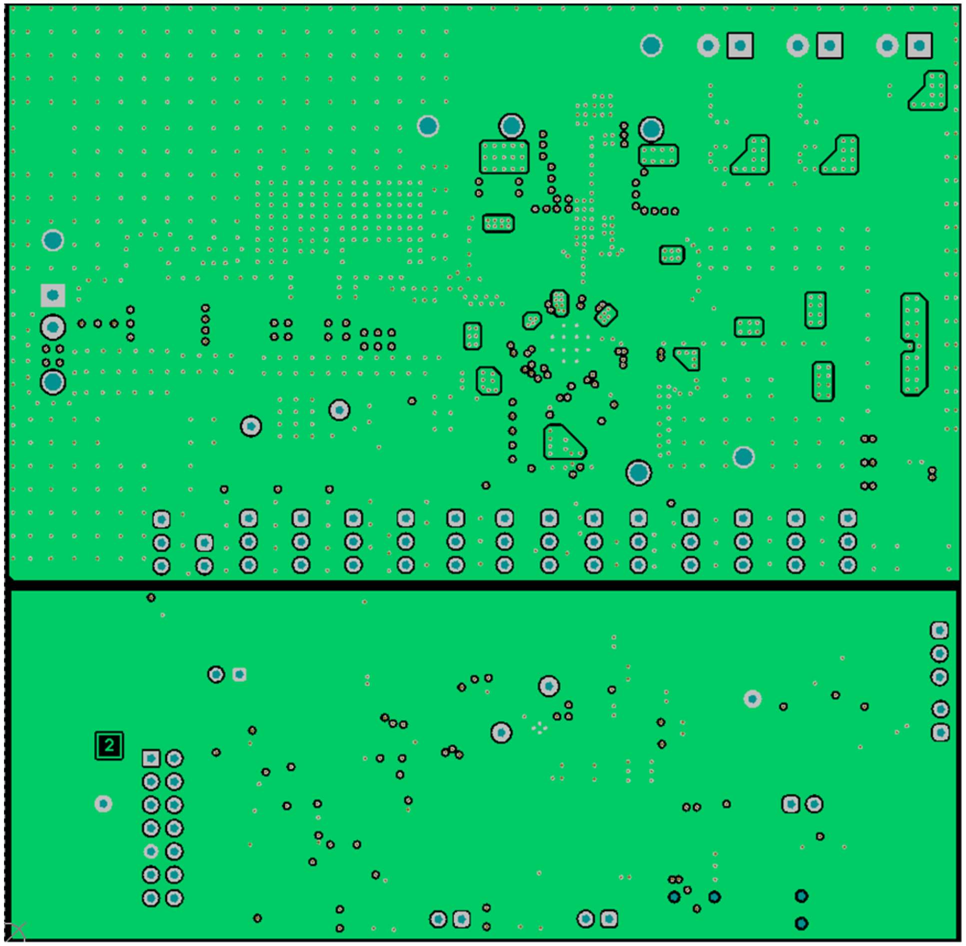


Figure 37. PCB Inner Layer-1

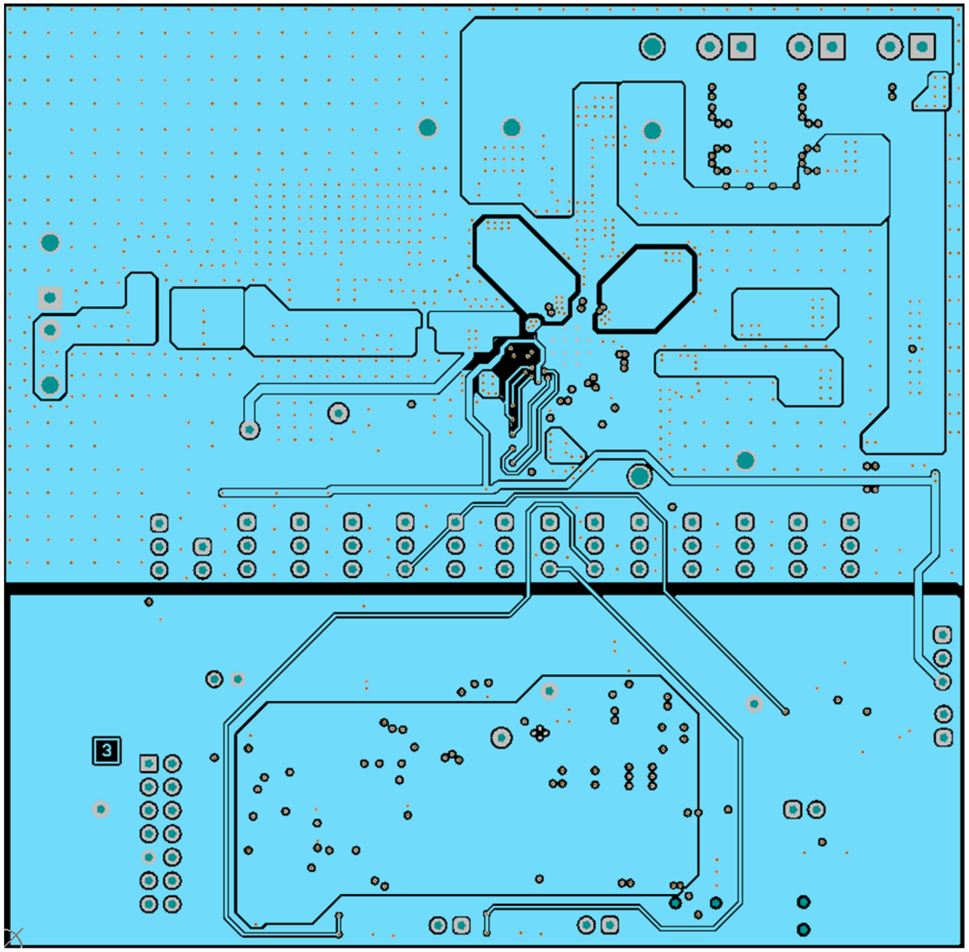


Figure 38. PCB Inner Layer-2

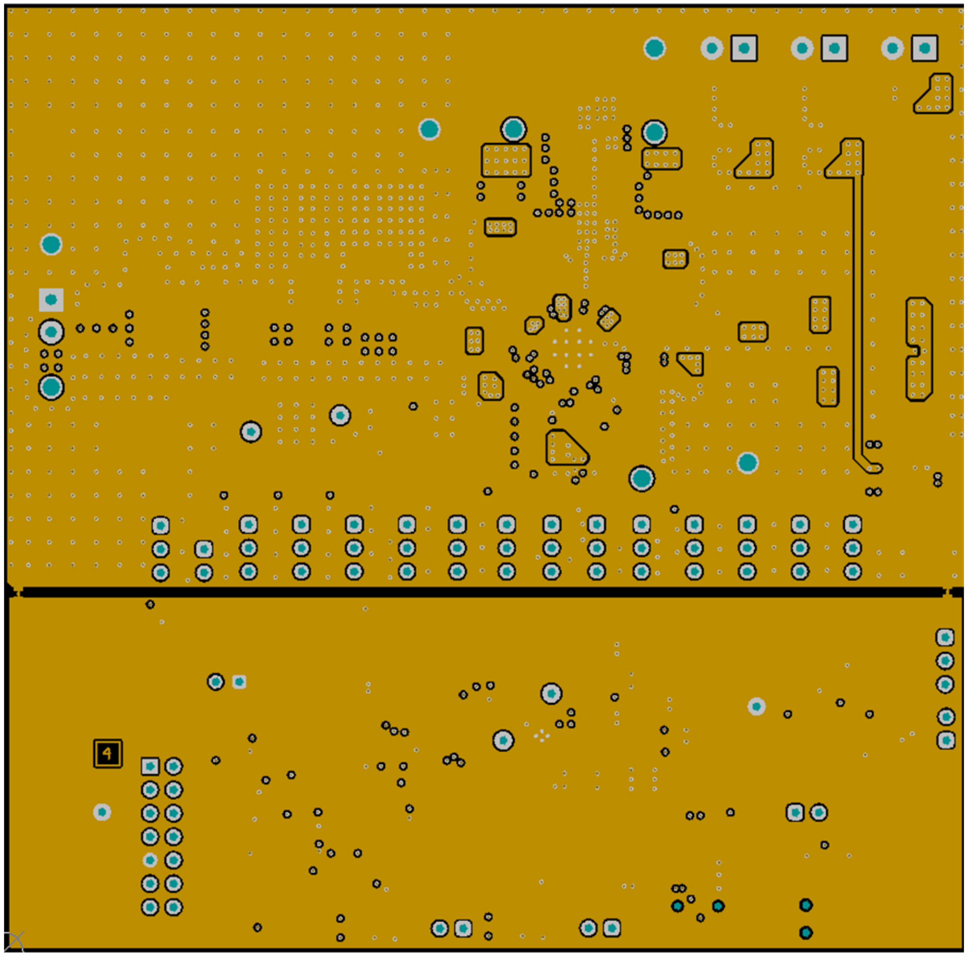


Figure 39. PCB Inner Layer-3

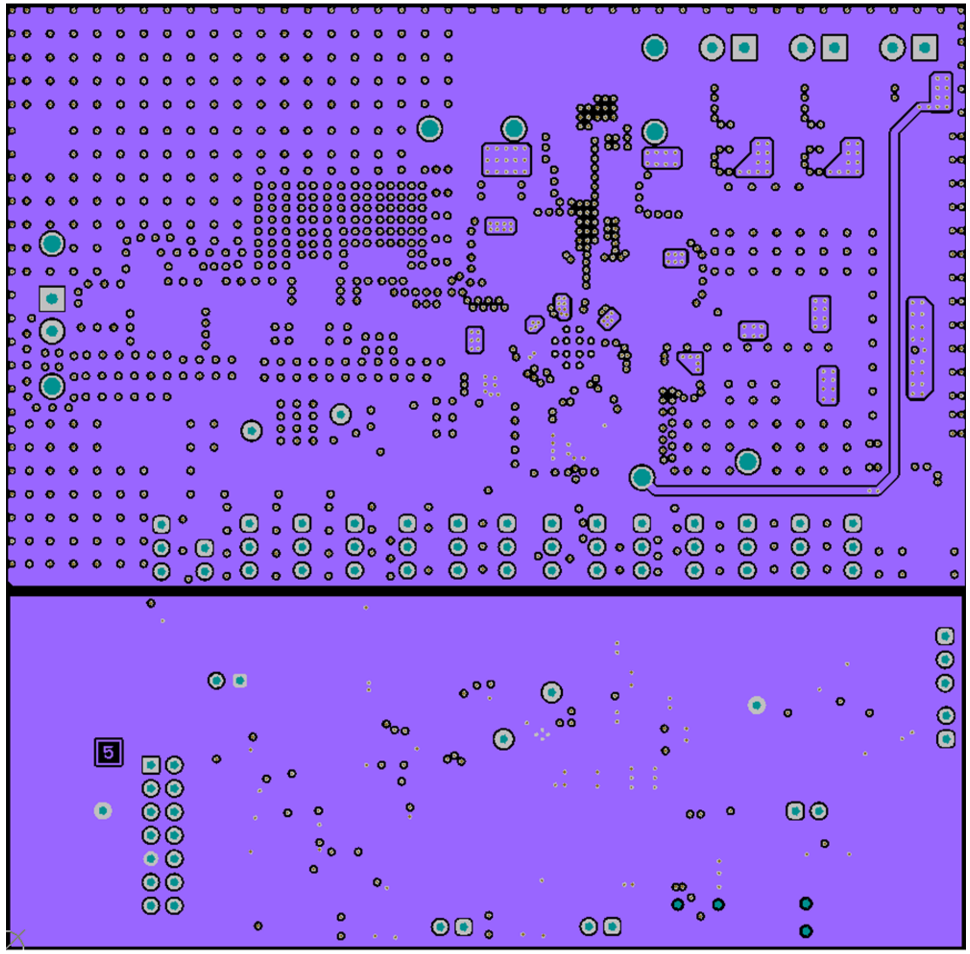


Figure 40. PCB Inner Layer-4

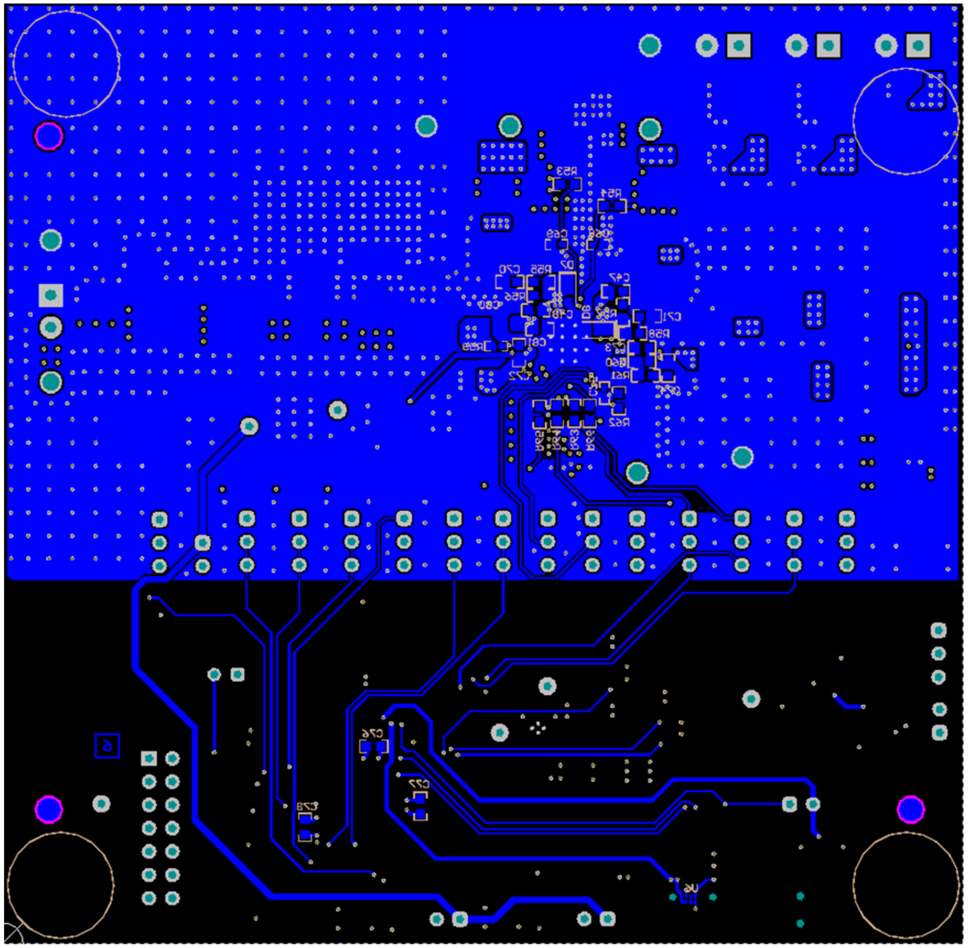


Figure 41. PCB Bottom Layer

11 Description of the Watchdog Algorithm Implemented on EVM

This section provides an overview of Q&A functional mode 0 implementation done on the MSP430 MCU on the EVM. To start, follow these steps:

Step 1. Initialize wait times.

Step 2. Make sure the value of the MCU answer counter matches the value of the device answer counter.

If the counter values do not match, the MCU sends answers until a new watchdog window starts and then continues with Step 3.

Step 3. Read the question, and then wait.

Step 4. Send Answer3, and then wait.

Step 5. Send Answer2, and then wait.

Step 6. Send Answer1, and then wait.

Step 7. Send Answer0, and then wait.

Step 8. Repeat Step 3 through Step 7.

The pseudo-code description of the Q&A functional mode 0 algorithm implemented on EVM is as follows:

```
// Initialize wait times for each answer. These values work for default WDT window settings-
wait_time=[30, 30, 30, 30, 25]
mcu_answer_cnt = 3

// wdt_step is the current status of the WDT routine
// wdt_step=0: read the question
// wdt_step=1: send answer3
// ...
// wdt_step=4: send answer0
wdt_step = 0

// Main loop
loop:

     // Use timer to wait specified amount of time
     Wait (wait_time[wdt_step]) ms

     // Make sure MCU is synchronized with TPS65313 WDT status
     // If not synchronized, send enough commands to force TPS65313 to start a new watchdog window
     tps65313_answer_cnt = RD_WDT_STATUS[6:5]
     if (mcu_answer_cnt != tps65313_answer_cnt):
           Loop (tps65313_answer_cnt+1) times:
                WR_WDT_ANSWER = 0x00
           end loop
           wdt_step=0
           mcu_answer_cnt=3
     else:
           // Read the question
           if wdt_step = 0:
                question = RD_WDT_QUESTION_VALUE
                wdt_step = 1
           // Write the answers, calculated by Table 6-10 in device datasheet
           else if wdt_step = 1:
                WR_WDT_ANSWER = calculate_answer3(question)
                wdt_step = 2
                mcu_answer_cnt = 2
           else if wdt_step = 2:
                WR_WDT_ANSWER = calculate_answer2(question)
                wdt_step = 3
                mcu_answer_cnt = 1
           else if wdt_step = 3:
                WR_WDT_ANSWER = calculate_answer1(question)
                wdt_step = 4
                mcu_answer_cnt = 0
           else if wdt_step = 4:
```

```
                WR_WDT_ANSWER = calculate_answer0(question)
                wdt_step = 0
                mcu_answer_cnt = 3
            end if
        end if
    end loop
```

Revision History

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