User's Guide
SLVUBR3–January 2020

TPS59632-Q1 3-Phase, 60-A, DCAP+, DC/DC Step-Down Controller Evaluation Module for Automotive ADAS Domain Controller SoC Core Rail Applications

The TPS59632Q1EVM-057 evaluation module (EVM) allows users to evaluate the TPS59632-Q1 controller. The controller is a three-phase, D-CAP+ synchronous buck driverless control with I²C Interface. The EVM operates using an input conversion voltage supply of 5 V nominal (±10%). The controller requires a bias voltage supply of 5-V nominal. The EVM is configured for a thermal design current of 40 A and a maximum transient current of 60 A. The transient current is produced using an onboard transient generator that can be activated by an external function generator (function generator not included with EVM). The output voltage on the EVM can be adjusted from 0.55 V to 1.10 V using an I²C interface (I²C interface tool not included with the EVM).

Contents

List of Figures

List of Tables

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1 Introduction

Automotive applications such as Autonomous Driving Assist Systems (ADAS) use sophisticated ADAS Domain Controller processors which require a high amount of current at very low voltages. These processors also require very fast transient response of the output voltage for step changes in processor load current. Texas Instruments' TPS59632-Q1 integrated circuit meets this high-current requirement and fast transient response. The TPS59632-Q1 controller is a driverless 3-phase step-down controller and employs D-CAP+ technology for fast transient response. The TPS59603-Q1 device is the accompanying driver to support the gate drive for the synchronous buck power stage MOSFETs. The TPS59632Q1EVM-057 is developed using these two TI devices for users to evaluate the solution for automotive ADAS domain controller SoC core rail power applications. The purpose of this document is to provide detailed instructions for powering up and evaluating the TPS59632Q1EVM-057.

1.1 Features

- AEC Q100 automotive-qualified TPS59632-Q1 controller and TPS59603-Q1 MOSFET gate driver
- Configurable to 1, 2, or 3 phase. Each phase can deliver current up to 20 A
- 60-A maximum current
- 5-V nominal conversion input voltage.
- Output voltage = 0.875 V ±3% including DC, AC, and transients.
- Output voltage is pre-configured to provide 0.890 V at no load and a load line droop of 0.6 mΩ/A giving 0.860 V at 50-A load
- Onboard transient generator (requires external function generator input at 10 mV/A)
- Available I^2C port for VID changes, phase management, and telemetry

1.2 Applications

- Conditionally automated drive controller
- ADAS domain controller
- Automotive infotainment and cluster

1.3 Description

The TPS59632Q1EVM-057 is a 3-phase comprehensive evaluation module (EVM) made available for users to evaluate the automotive ADAS Domain Controller core power rail applications using the TPS59632-Q1 controller. Figure 1 shows the top side of the EVM and Figure 2 shows the bottom side of the EVM. The EVM possesses several hooks for placing meters, probes, and so forth, by providing appropriate test points on various nodes across the board.

The copper lugs T1 and T2 are the conversion input terminals to the step-down DC/DC converter. This is the point of connection of the input DC voltage. Terminal J8 is the point of connection for the 5-V supply that supplies the bias to the TPS59632-Q1 controller, TPS59603-Q1 driver, the auxiliary control circuits, and LEDs on the EVM. The output terminals are the T3, T4, T5, and T6 copper lugs providing a connection point for the high current load. Figure 2 illustrates the location of these available options in the EVM. The setup is explained in detail in Section 2.

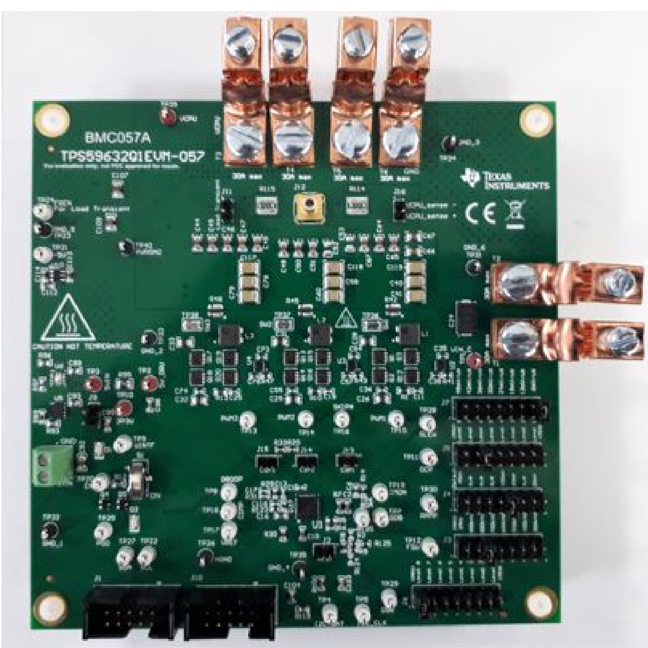

Figure 1. EVM Top View

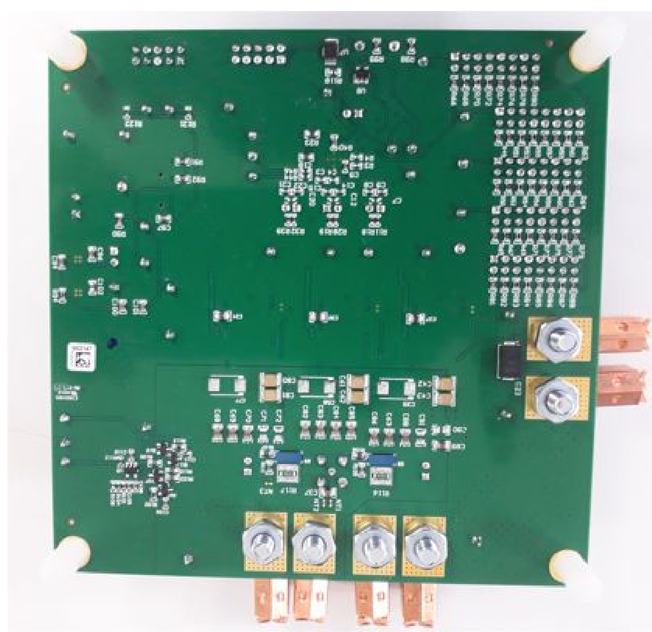

Figure 2. EVM Bottom View

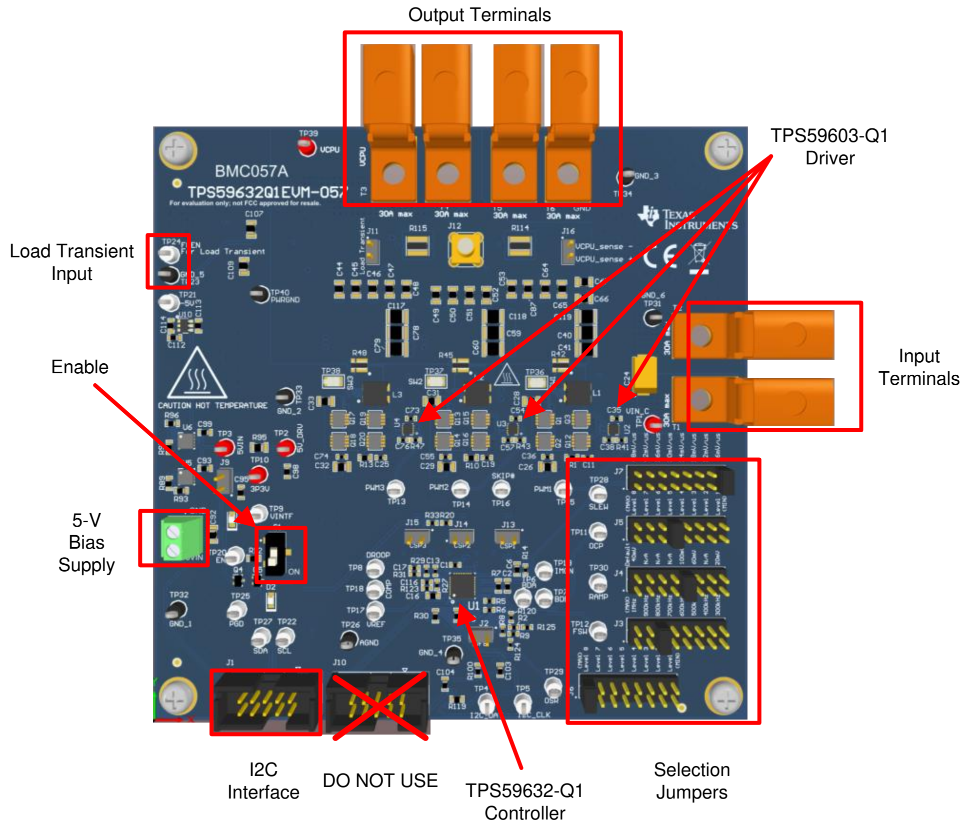

Figure 3. EVM Options

The TPS59632Q1EVM-057 is built in the factory as a 3-phase operation with the component values designed for a processor specification of 0.875 V (±3%) and maximum load current of 50 A. To meet the load transients, a DC load line droop is set at approximately 0.6 mΩ/A. Therefore, the 0-A output voltage will be higher than 0.875 V and the output voltage at 50 A will be lower than 0.875 V.

The component changes on the board to re-configure the EVM for alternate configurations is shown in Table 3 and Table 4.

The TPS59632Q1EVM-057 comes available with easily-reconfigurable jumper settings for various selections as Figure 4 shows.

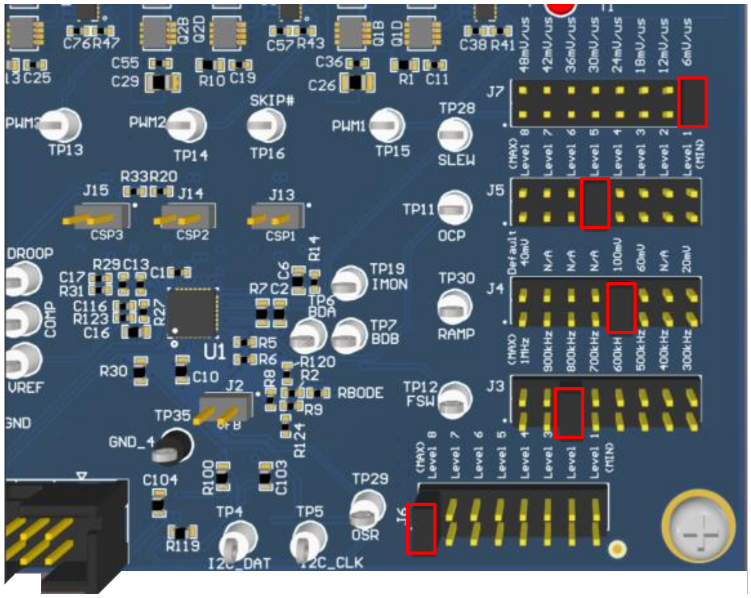

Figure 4. Jumper Settings for Selecting Slew Rate, OCP Level, Compensation Ramp Voltage, Switching Frequency and OSR Level

The following selections are made available through jumper settings on the EVM. The electrical parameters associated with these selections are specified in the *TPS59632-Q1 2.5-V to 24-V, 3-, 2-, and 1-Phase Step-down Driverless Controller for Automotive ADAS Applications Data Sheet*.

1. Jumper J7 Slew: The output voltage slew rate for VID changes can be changed from 6 mV/µs to 48 mV/µs. The start-up slew rate is half of the specified slew rate. The EVM default is set to 6 mV/µs which corresponds to start-up minimum slew rate of 3 mV/µs.
2. Jumper J5 OCP: The overcurrent protection (OCP) level can be adjusted to 8 different levels from Level 1 to Level 8 (minimum OCP to maximum OCP). The EVM default is set to Level 5 which corresponds to a minimum steady state OCP level of 75 A.
3. Jumper J4 Ramp: The ramp selection can be changed from 20 mV to 100 mV. The selections marked as N/A are not valid selections. The default selection is set to 100 mV.
4. Jumper J3 FSW: The *Frequency of Switching* (FSW) is selected by this jumper. The selection range is 300 kHz to 1 MHz. The default selection is set to 800-kHz setting.
5. Jumper J6 OSR: This selection allows the user to configure an overshoot reduction (OSR) level in the event that the transient overshoot is significantly higher than the desired level dictated by the DC load line. The default OSR selection is Level 8 which means OSR is OFF. The selection of Level 1 would make OSR act very quickly. In addition, the undershoot reduction (USR) level is programmed by placing an appropriate resistor (per the *TPS59632-Q1* data sheet guidelines) on location R6. The default value of R6 is open (no resistor placed).

The header J1 is available for I^{2}C communication to the TPS59632-Q1 controller. The I^{2}C interface is not provided with the EVM and is available from www.ti.com.

2 Test

In this section, the test setup and some key results are described in detail.

2.1 Test Equipment

To test the EVM, the following equipment is needed.

1. Fixed or adjustable DC power supply 5 V and 500 mA minimum.
2. Adjustable DC power supply 5 V and 15 A minimum with programmable current limit
3. Electronic load 0.6 V–1.0 V, 0 A–60 A
4. Oscilloscope, 4-channel, 200-MHz bandwidth or above
5. Digital multimeter with at least 1-mV accuracy for DC voltage measurement

2.2 Connecting the Test Equipment to the EVM

Follow the connection diagram in Figure 5 for reference.

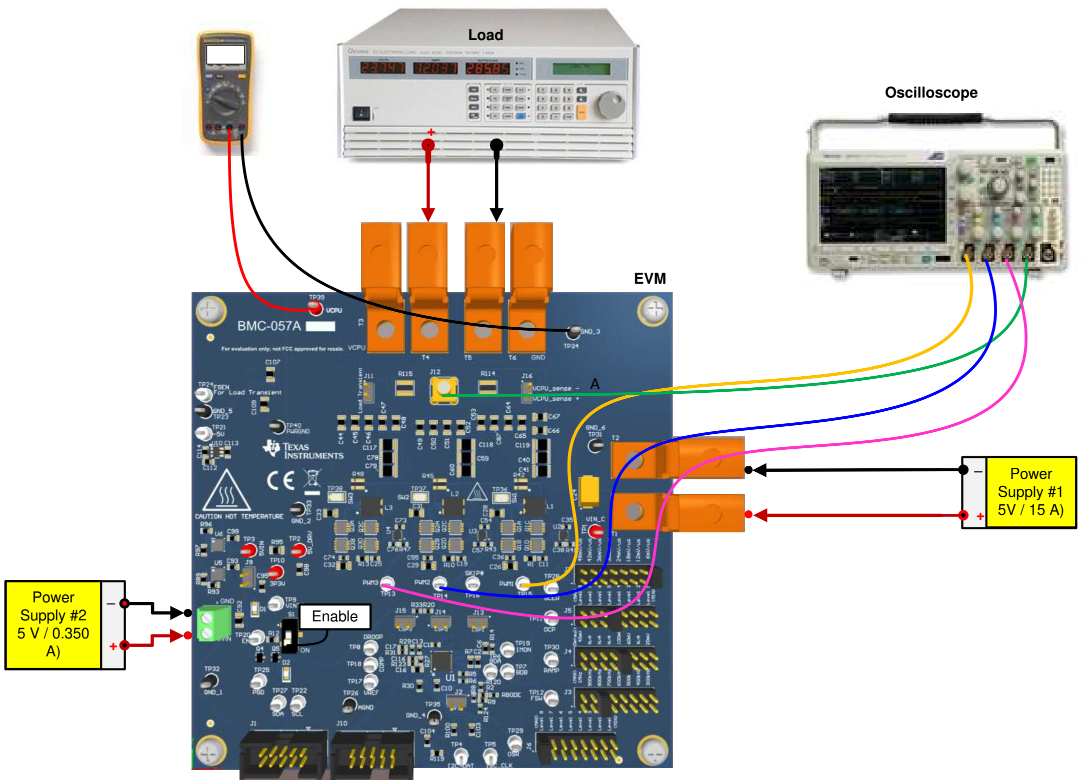

Figure 5. EVM Test Setup Showing the Power Supplies, Load, and Oscilloscope Connections

Use the following steps to properly connect the EVM for testing:

1. Connect power supply #1 set to 5 V and current limit of 1-A positive node connected to T1, negative node connected to T2.
2. Connect power supply #2 set to 5 V, 0.35 A to the green two terminal header as Figure 5 shows.
3. Connect the positive of the load to terminal T4 and the negative of the load to terminal T5.
4. Figure 5 shows how to connect the oscilloscope probes from the EVM to the oscilloscope.
5. For channels 1, 2, and 3 use 10× probes to monitor the PWM waveforms. The ground leads of the probes can be clipped to any of the black ground test points carefully without touching any other test point. Terminal T2 can also be used for clipping the ground lead.
6. Figure 5 shows how the SMB-to-BNC adaptor is connected to monitor the output voltage on channel 4.

2.3 Test Procedure

2.3.1 Start-up Test

Use the following procedure for the start-up test:

1. Set the load current to 1 A.
2. Turn on the power supply #1 (with the voltage set to 5 V and the current limit set to 1 A).
3. Turn on the power supply #2 (with the voltage set to 5 V and the current limit set to 0.35 A).
4. Set up the *time / div* on the oscilloscope to: 50 µs/div.
5. Set the trigger to channel 4 'Normal' on the rising edge at about 0.5 V.
6. Slide the enable switch 'S1' to the ON position.

Figure 6 illustrates the expected waveform.

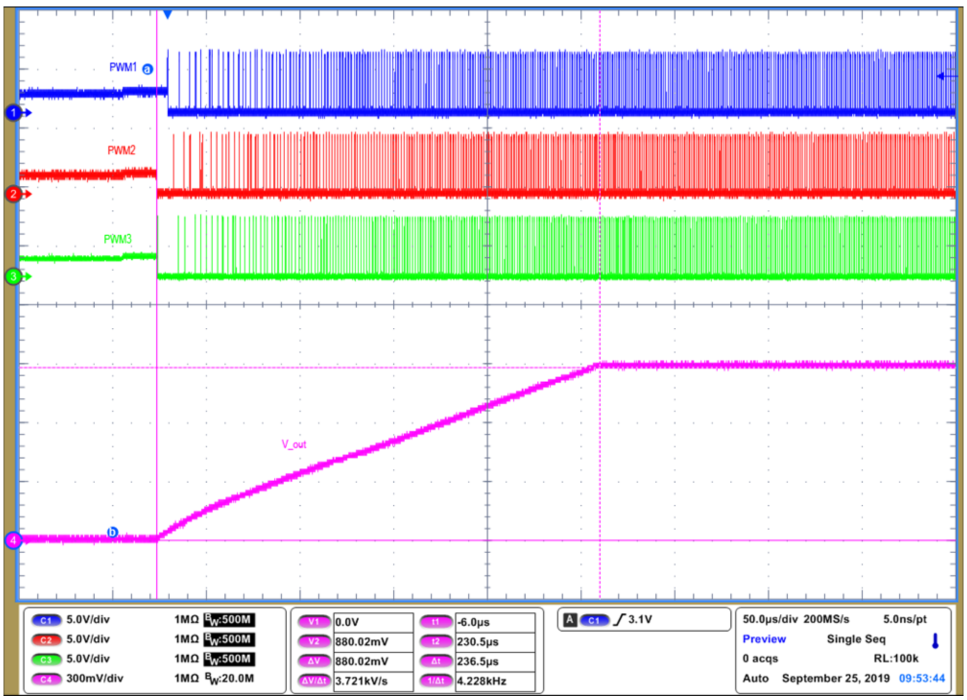

Figure 6. Start-Up Waveform

2.3.2 Steady-State Test

To observe the steady-state switching waveforms, use the following steps:

1. Keep the load current at 1 A
2. Set up the *time / div* on the oscilloscope to: 1 µs/div
3. Set the trigger to channel 1 'Normal' on the rising edge at about 2.5 V
4. Set the offset on channel 4 to 890 mV, and the V/div to 10 mV/div

Figure 7 shows the expected waveform.

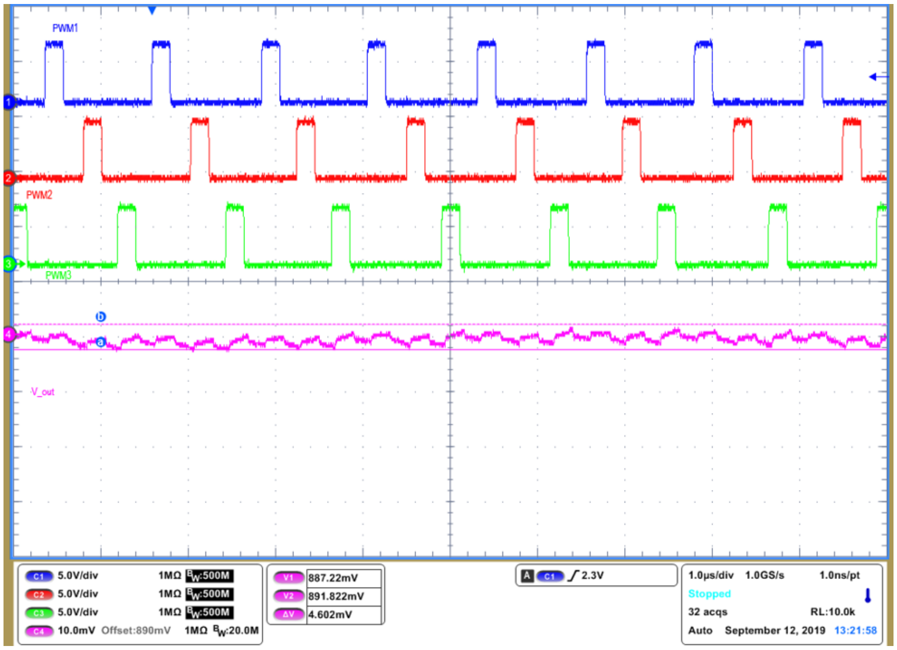

Figure 7. Steady-State Waveform

2.3.3 DC Load Line Test

The load line is the output voltage versus load current graph. The advantage in having a load line with a negative slope (droop) is a significant reduction in output capacitors to meet the transient requirements. See the details of this in the *TPS59632-Q1* data sheet. The DC load Line test can be performed by measuring the output voltage (V_{CPU} to GND) by varying the load from 0 A to 50 A. While measuring the output voltage at higher currents, be careful to not touch the power MOSFETs and inductors as they will be very hot. Figure 8 shows the DC load line plot. Figure 9 shows the corresponding efficiency measurement.

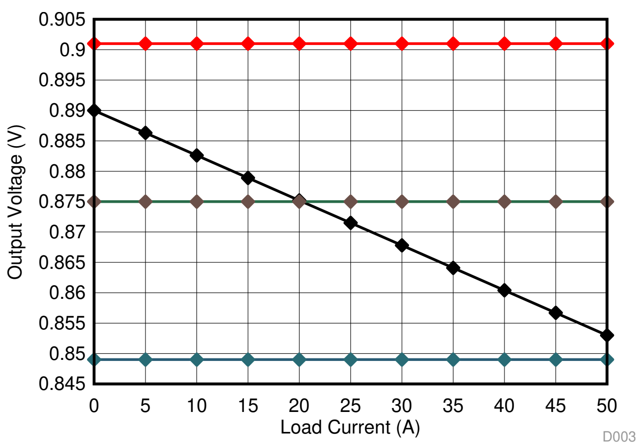

Figure 8. DC Load Line Plot

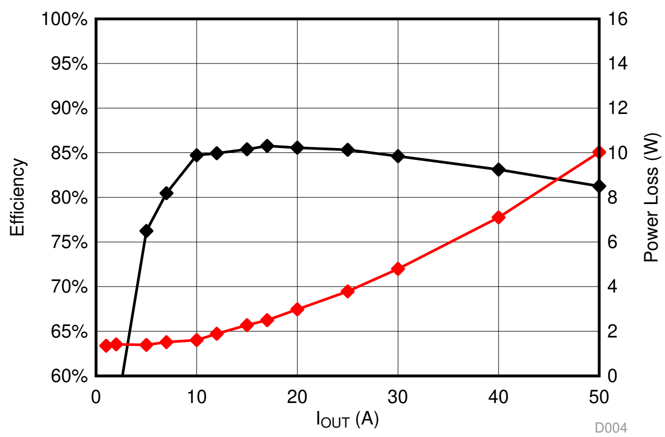

Figure 9. Converter Efficiency and Power Loss Plot

2.3.4 Load Transient Test

The EVM is equipped with an onboard load transient generator for testing fast transients that is seen in processor type loads. To generate a load transient, input a repetitive pulse signal from an external function generator. This pulse height must be such that every 10 mV corresponds to 1 A of transient load. This means to achieve a 10-A transient, the pulse high level must be 100 mV and low level must be 0 mV. The rise time can be adjusted to accommodate slower or faster load transient slew rates.

To test the load transient specification of 36 A/µs, a repetitive pulse of 360 mV with a rise time of 1 µs is fed to the test points FGEN to GND. The duty cycle is kept less than 20% such that the power dissipation on the power resistors and FETs in the transient circuit is kept to a minimum. Figure 10 shows the observed load transient waveform on the output voltage. The switching waveforms demonstrate the fast transient capability of DCAP+ control architecture including the undershoot reduction feature where the pulses of all phases overlap during a transient.

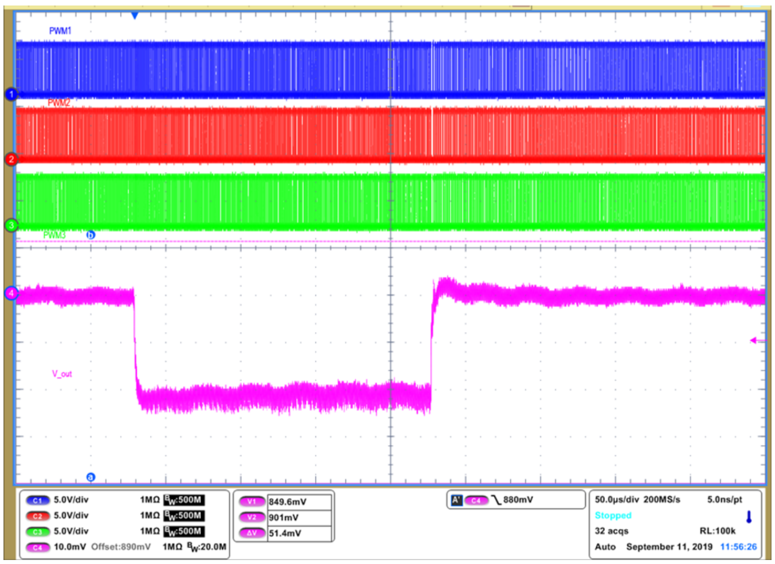

Figure 10. Load Transient Waveform When Load is Changed From 36 A to 0 A

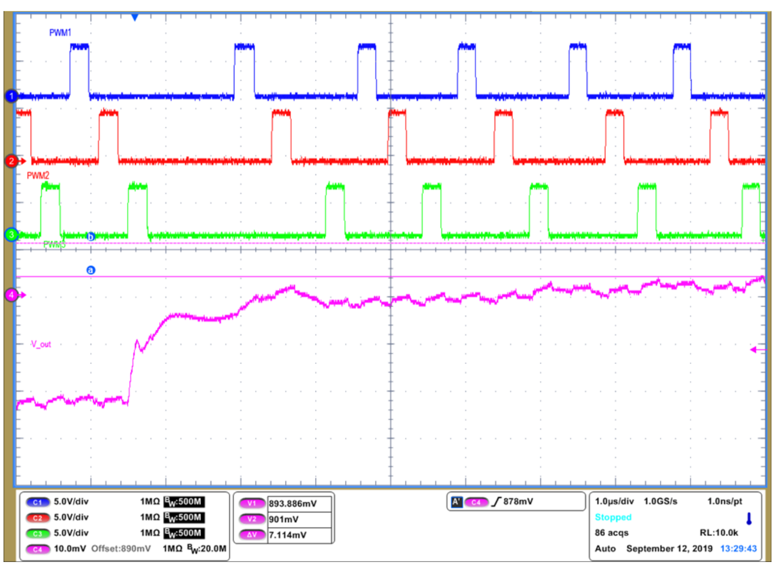

Figure 11. Measurement of Margin at the Upper Limit of Output Voltage

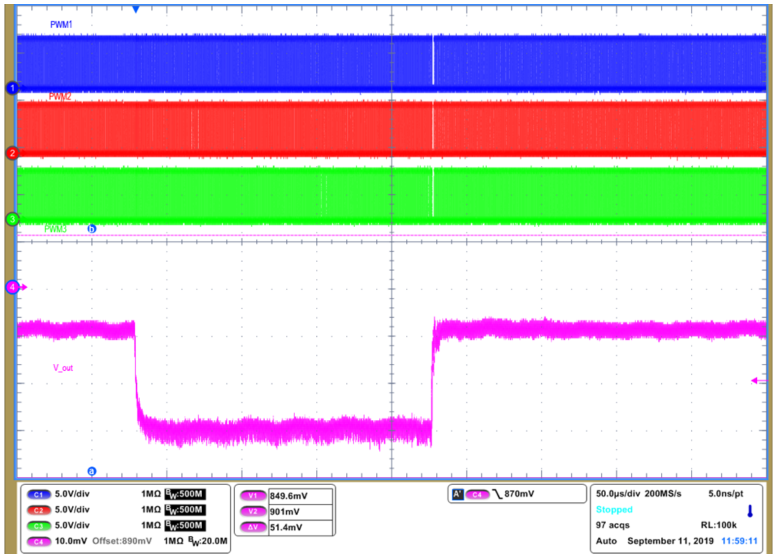

Figure 12. Load Transient Waveform When Load is Changed From 14 A to 50 A

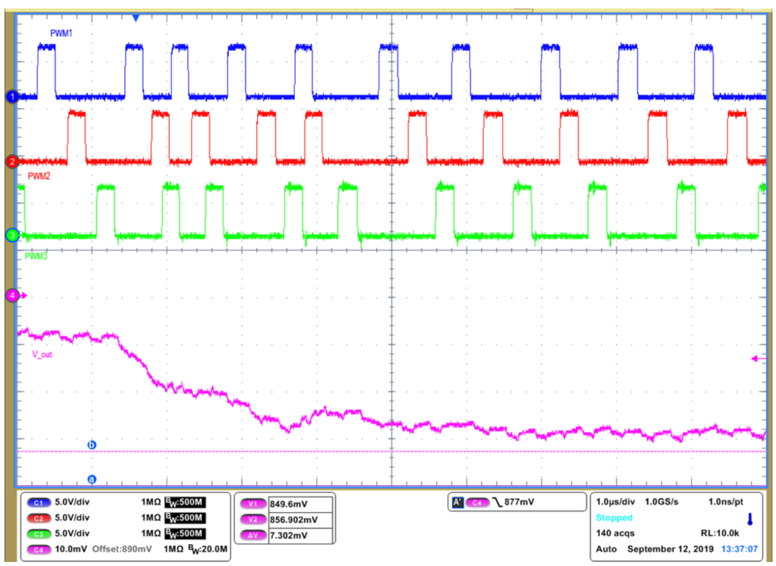

Figure 13. Measurement of Margin at the Lower Limit of Output Voltage

2.3.5 Shutdown Test

Use the following steps to shutdown the controller:

1. Keep the load current at 5 A.
2. Set up the *time / div* on the oscilloscope to: 100 µs/div.
3. Set the trigger to channel 4 ‘Normal’ on the falling edge at about 500 mV.
4. Set the offset on channel 4 to 0 mV, and the V/div to 200 or 300 mV/div.

Figure 7 shows the expected waveform.

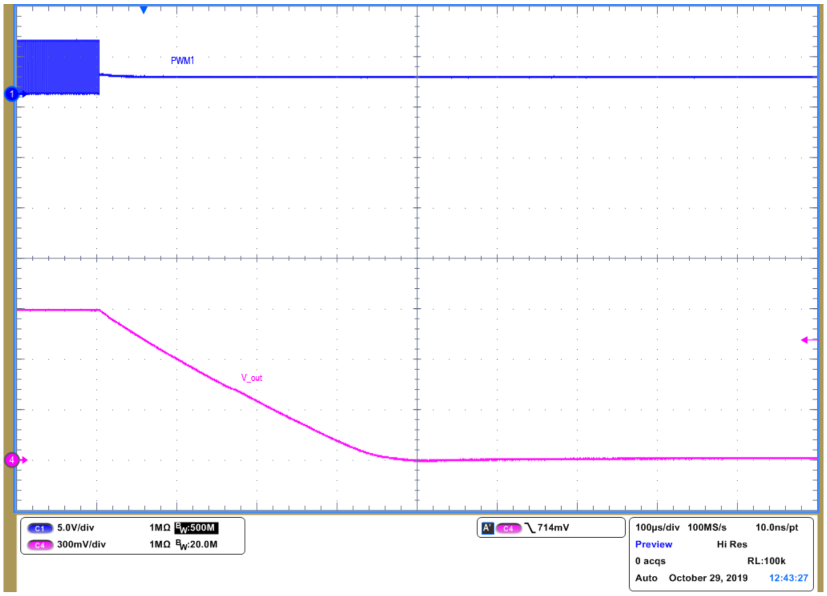

Figure 14. Shutdown Waveform

2.4 *Other Test Provisions*

The EVM includes a provision to also perform a Bode plot to examine the control loop stability. To perform this test, a Spectrum analyzer is required. The resistor R125 must be replaced with an appropriate terminating resistor (usually 10 Ω or 20 Ω). The signal must be connected to test points BDA and BDB. The loop gain is measured using the spectrum analyzer from BDB to BDA. Figure 15 shows a measurement of the Bode plot made on this EVM.

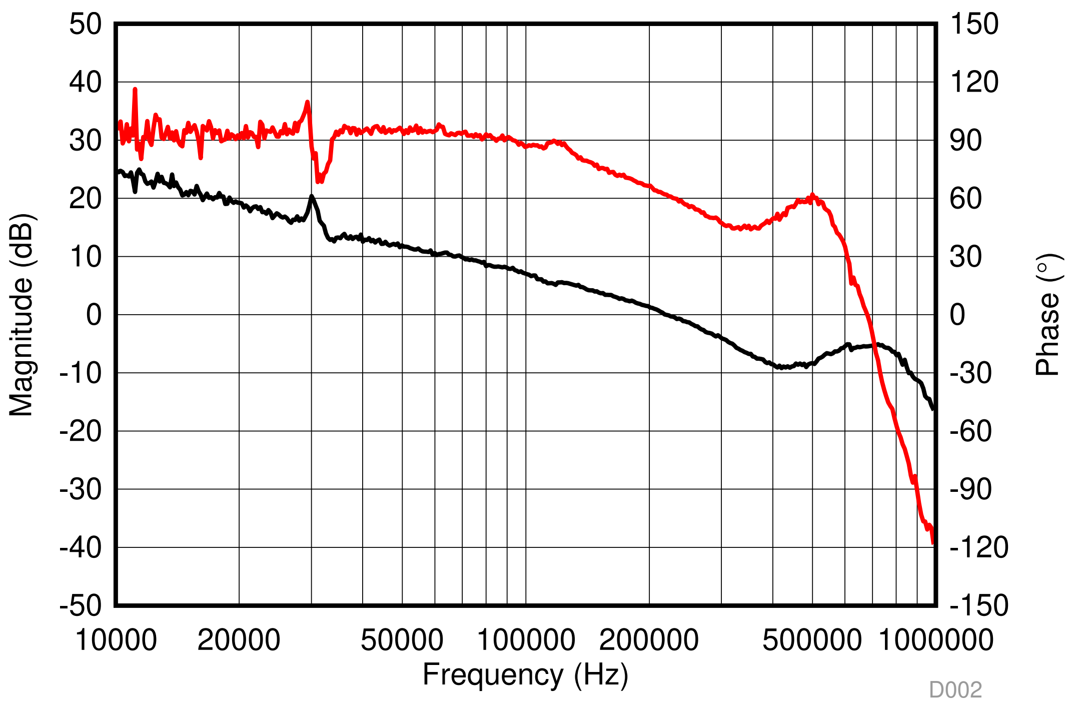

Figure 15. Bode Plot

2.5 I^2C Programming

The TPS59632Q1EVM-057 comes with an I^2C port which is provided to connect a TI USB-I2C interface box (shown in Figure 16) such that the user can test the I^2C capability of the TPS59632-Q1 device.

This interface box is not included with the EVM. It can be ordered from http://www.ti.com/tool/usb-to-gpio.

Figure 16. Texas Instruments USB-TO-GPIO Interface Box

The user can communicate to the TPS59632Q1EVM-057 through this USB interface adaptor using the Texas Instruments Fusion Digital Power Designer GUI. Download the latest version of the Fusion Digital Power Design software by selecting the http://www.ti.com/tool/FUSION_DIGITAL_POWER_DESIGNER link and then scrolling down to *Available Versions* in the web page. Download the FUSION GUI and run the downloaded installation application. Follow the installation instructions. This installs the driver and Texas Instruments Fusion Digital Power Design tool. The I2C GUI that is needed for communicating to the EVM can be accessed from the Microsoft® Windows® Programs menu under Texas Instruments. Select the SMBus & I2C & SAA Debug Tool. The tool can be launched directly from here. For easier access going forward, right-click on the SMBus & I2C & SAA Debug Tool and choose *Pin to Taskbar* or *Pin to Start Menu*.

The I^2C communication is active when the 5-V bias supply is provided to the board. The default configured I^2C device address for the TPS59632-Q1 device on the EVM is 40h. For details on the I^2C addresses and registers, see the *TPS59632-Q1 2.5-V to 24-V, 3-, 2-, and 1-Phase Step-down Driverless Controller for Automotive ADAS Applications Data Sheet*.

Use the following steps to communicate from the host computer to the TPS59632Q1EVM-057:

1. Connect the host computer to the USB-TO-GPIO adaptor with the supplied USB-to-Mini-USB cable.
2. Connect the USB-TO-GPIO adaptor at the I/O port of the EVM (as indicated by the "I2C Interface" port shown in Figure 3) using the supplied ribbon cable.
3. Provide the 5-V bias supply (Power Supply #2) to the EVM.

The device TPS59632-Q1 on the EVM is now ready for I2C communication.

The Read and Write procedure using the I2C communication through the FUSION GUI is as follows. A snapshot of the GUI is shown in Figure 17.

Step 1. Enter the correct address (the default device address on the EVM is 40h) of your device in either box (decimal or hexadecimal).

Step 2. To read data from a specific register address, enter the address of the register you want to read in the *Cmd* box.

Step 3. Click the *Send* button

Step 4. Ensure you see an ACK (NACK indicates incorrect I2C communications).

Step 5. Data is displayed in 2-digit hexadecimal.

Step 6. To write data to a specific register address, enter the address in the box.

Step 7. Enter the data to be written in hexadecimal.

Step 8. Click the *Send* button in that same panel.

Step 9. Ensure you see an ACK (NACK will indicate incorrect I2C communications).

Figure 17 shows a snapshot of the GUI. The device and register addresses in this snapshot are for illustration purposes only. The default configured I^{2}C device address for the TPS59632-Q1 device on the EVM is 40h. For details on the I^{2}C addresses and registers, see the *TPS59632-Q1 2.5-V to 24-V, 3-, 2-, and 1-Phase Step-down Driverless Controller for Automotive ADAS Applications Data Sheet*.

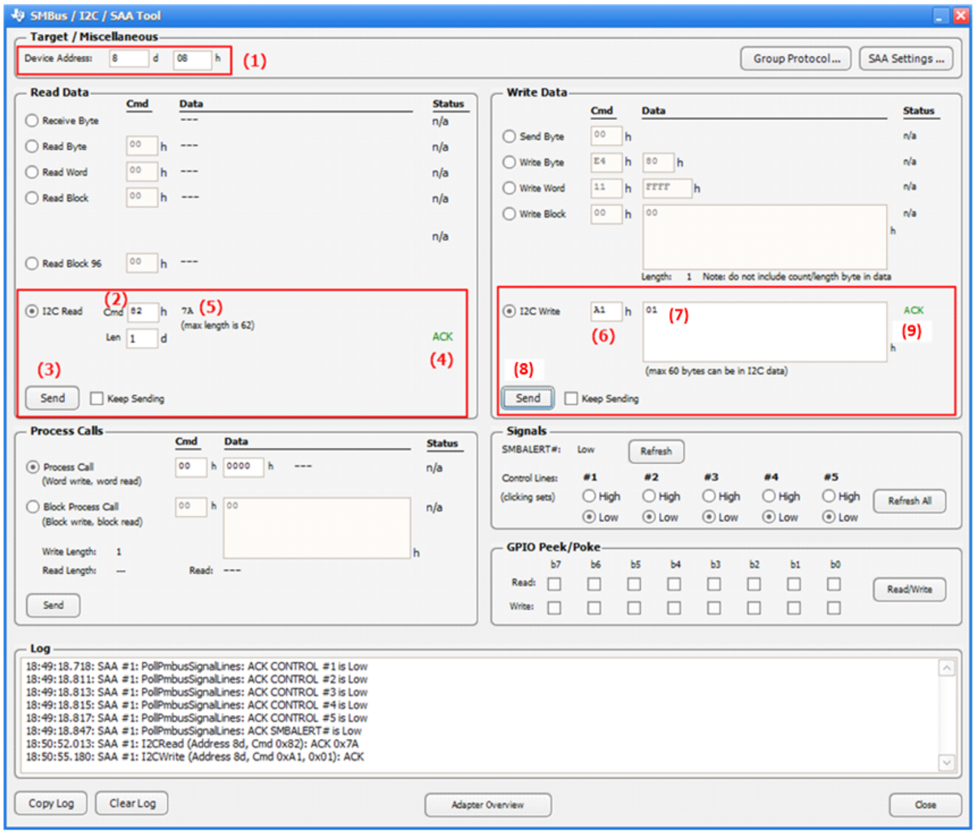

Figure 17. FUSION GUI for I2C communication from host PC to the EVM

The I^{2}C communication is active when the 5-V bias supply (power supply #2) is provided to the board. Depending upon the test, the power supply #1 and load can be turned on as described in Section 2.3. The I^{2}C communication can be used for the following purposes:

- Change the boot voltage (prior to start-up). Write/Read Register 00h
- Change output voltage (after start-up). Write/Read Register 00h
- Monitor load current output. Read Register 03h
- Change maximum programmable output voltage. Write/Read Register 04h
- Change power state (PS) settings. Write/Read Register 06h
- Change voltage change slew rate. Write/Read Register 07h
- Read device TPS59632-Q1 lot code. Read Register 10-13h
- Read device TPS59632-Q1 fault register. Read Register 14h

NOTE: The no load output voltage can be changed using I^{2}C programming from 0.55 V to 1.1 V in the EVM as configured. This range is different if the configuration is changed. The VID voltage as provided in the *TPS59632-Q1* data sheet sets the internal DAC voltage. The output voltage is set by the DAC voltage, the feedback resistors, the droop setting, and the load current. See the *TPS59632-Q1* data sheet for details.

3 Board Layout

Figure 18 through Figure 29 show the TPS59632Q1EVM-057 assembly drawings and TPS59632Q1EVM-057 PCB layout images.

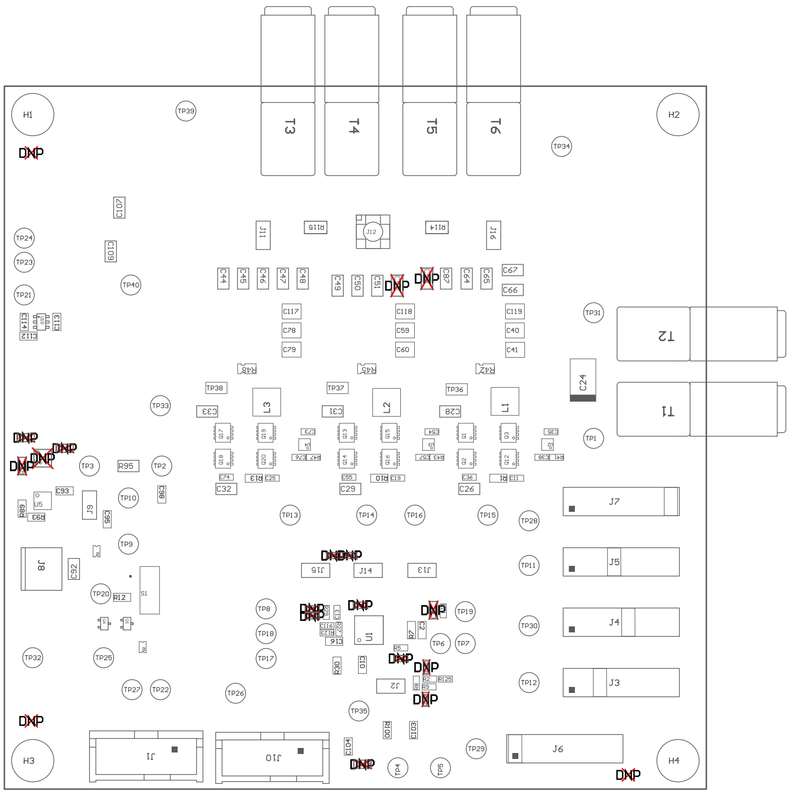

Figure 18. TPS59632Q1EVM-057 Assembly Drawing Top View

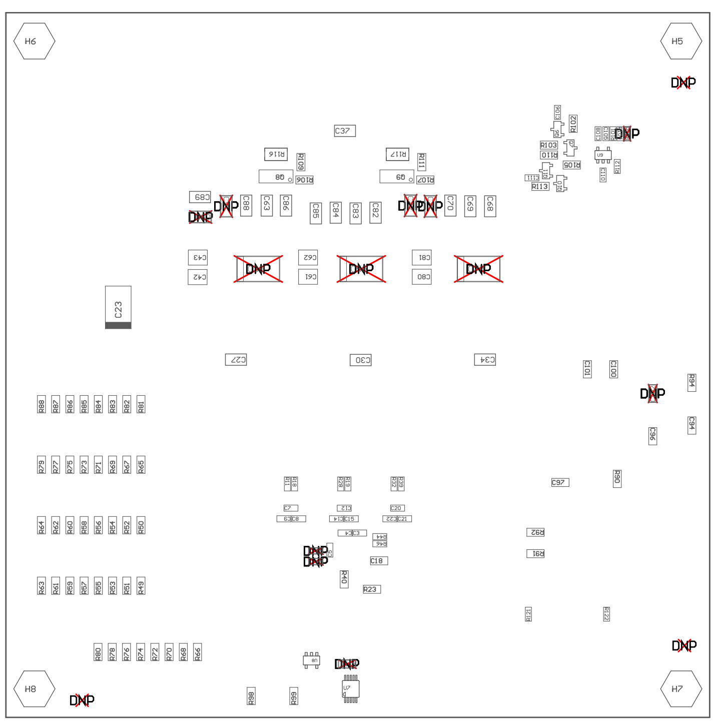

Figure 19. TPS59632Q1EVM-057 Assembly Drawing Bottom View

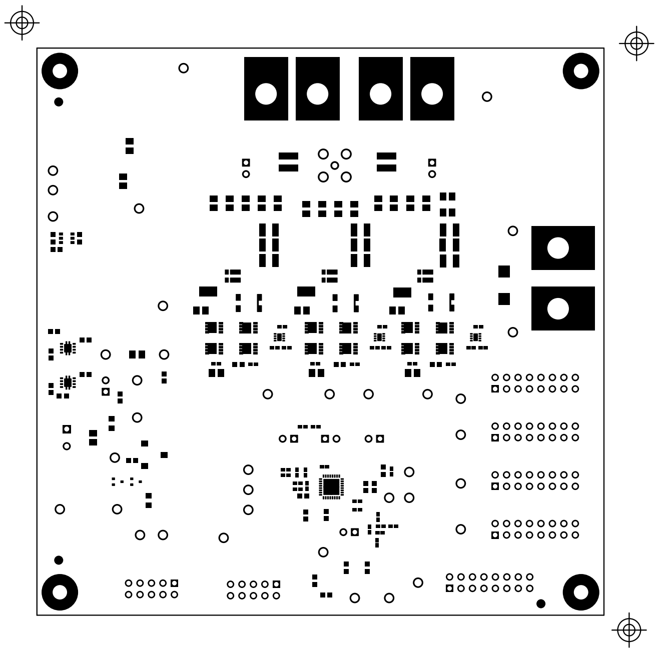

Figure 20. TPS59632Q1EVM-057 PCB Top Solder

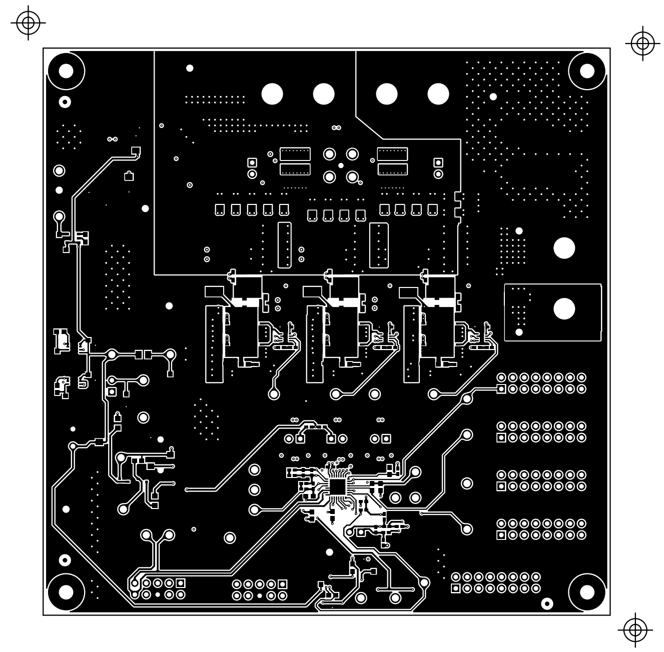

Figure 21. TPS59632Q1EVM-057 PCB Top Layer

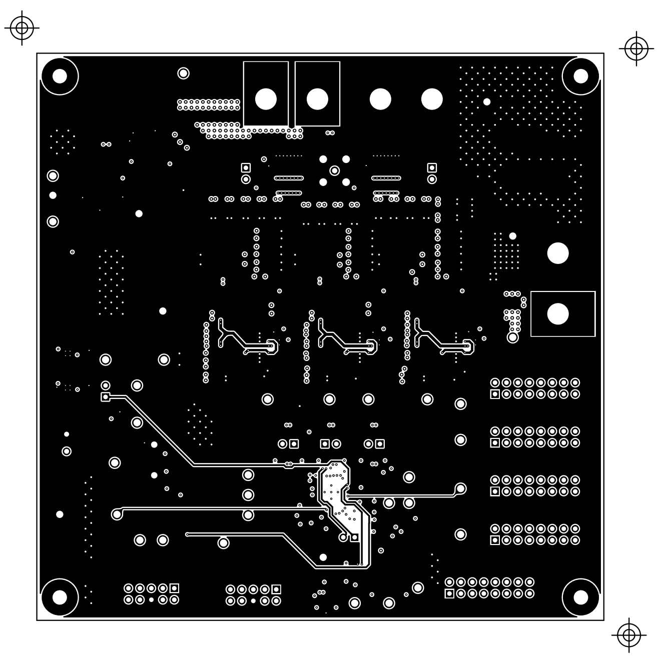

Figure 22. TPS59632Q1EVM-057 PCB Signal Layer 1

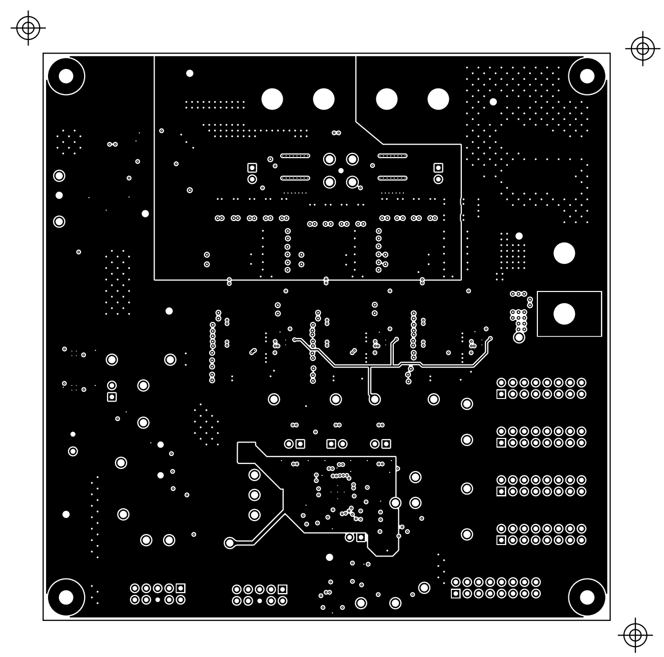

Figure 23. TPS59632Q1EVM-057 PCB Signal Layer 2

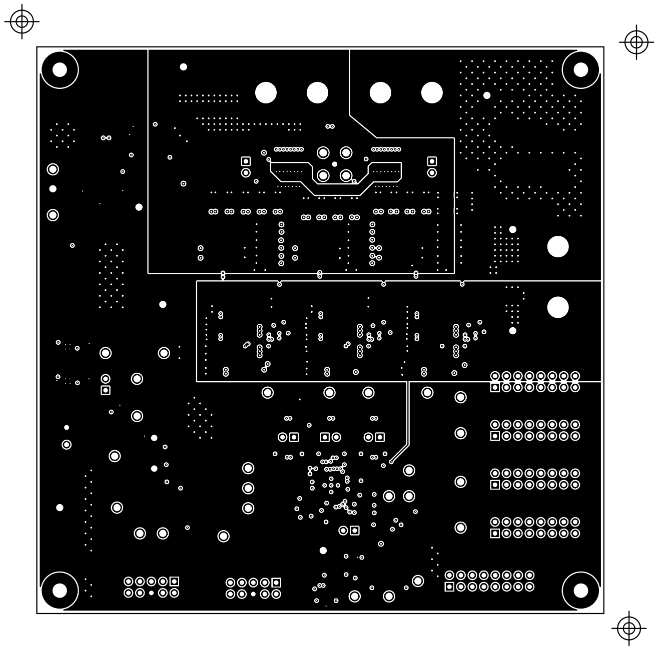

Figure 24. TPS59632Q1EVM-057 PCB Signal Layer 3

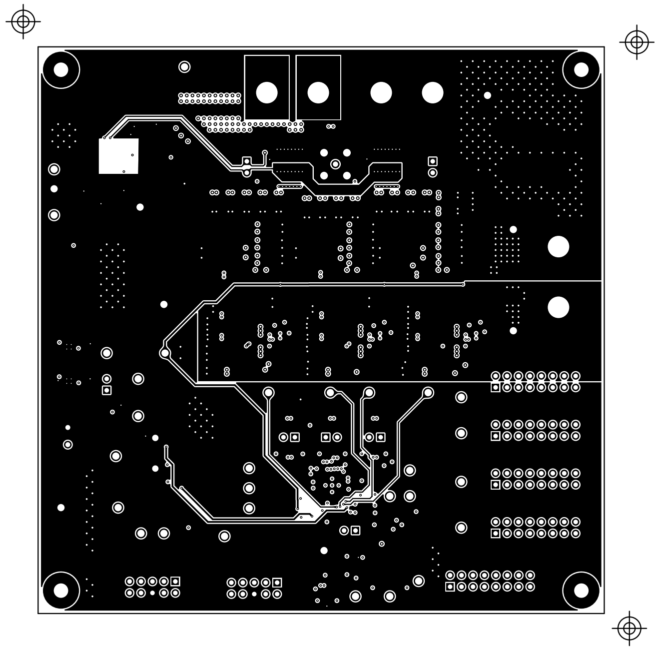

Figure 25. TPS59632Q1EVM-057 PCB Signal Layer 4

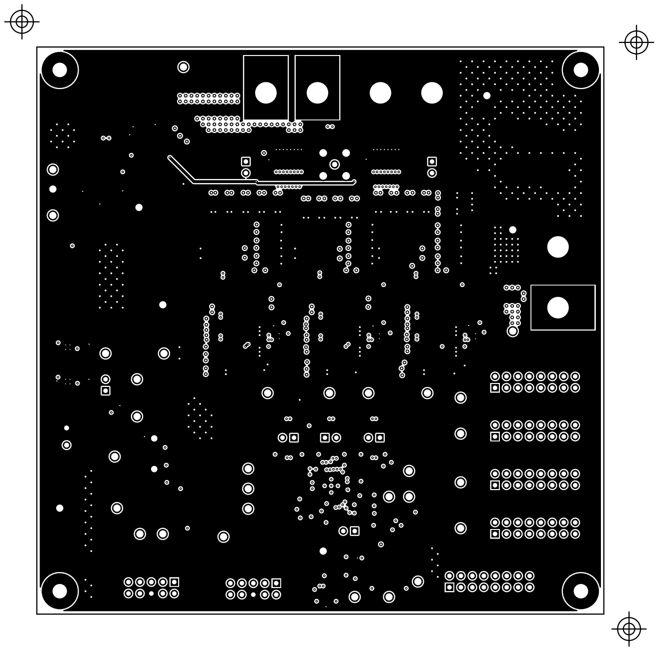

Figure 26. TPS59632Q1EVM-057 PCB Signal Layer 5

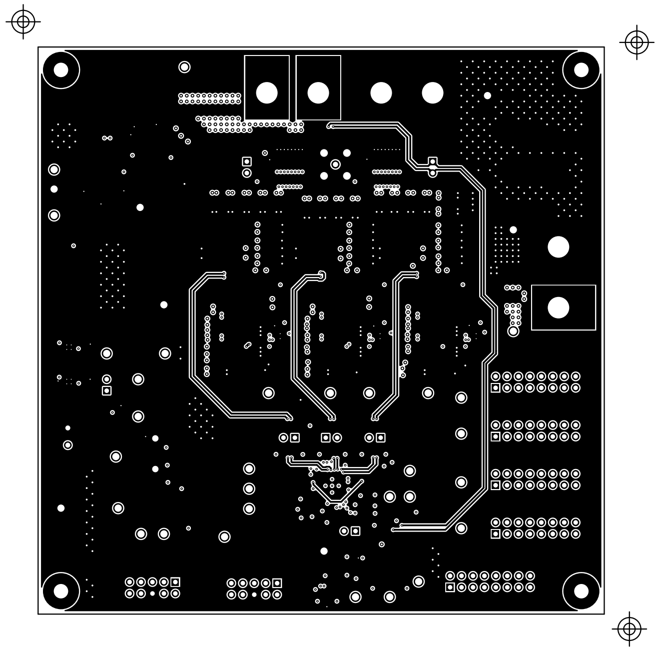

Figure 27. TPS59632Q1EVM-057 PCB Signal Layer 6

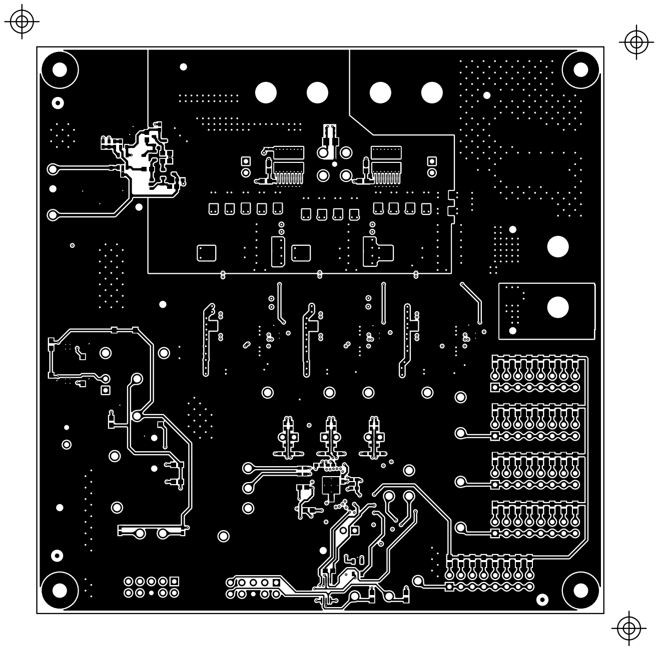

Figure 28. TPS59632Q1EVM-057 PCB Bottom Layer

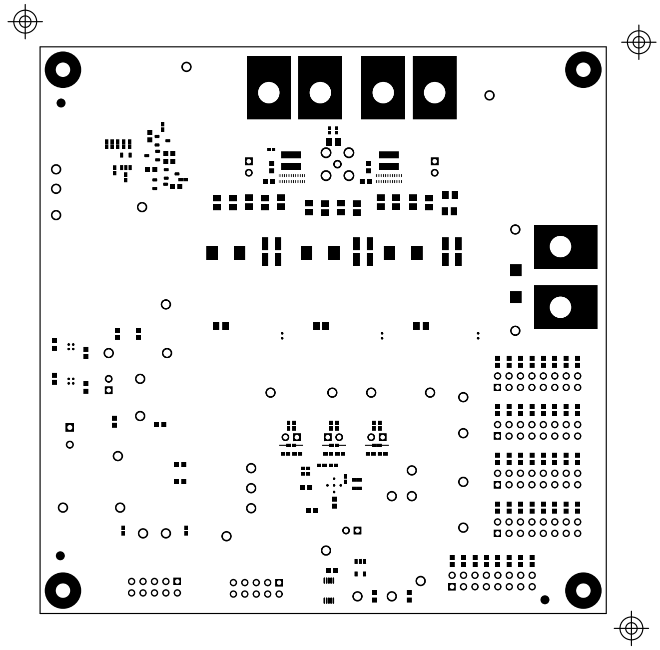

Figure 29. TPS59632Q1EVM-057 PCB Bottom Solder

4 Schematic and Bill of Materials

4.1 Schematic

Figure 30 through Figure 34 show the TPS59632Q1EVM-057 schematics.

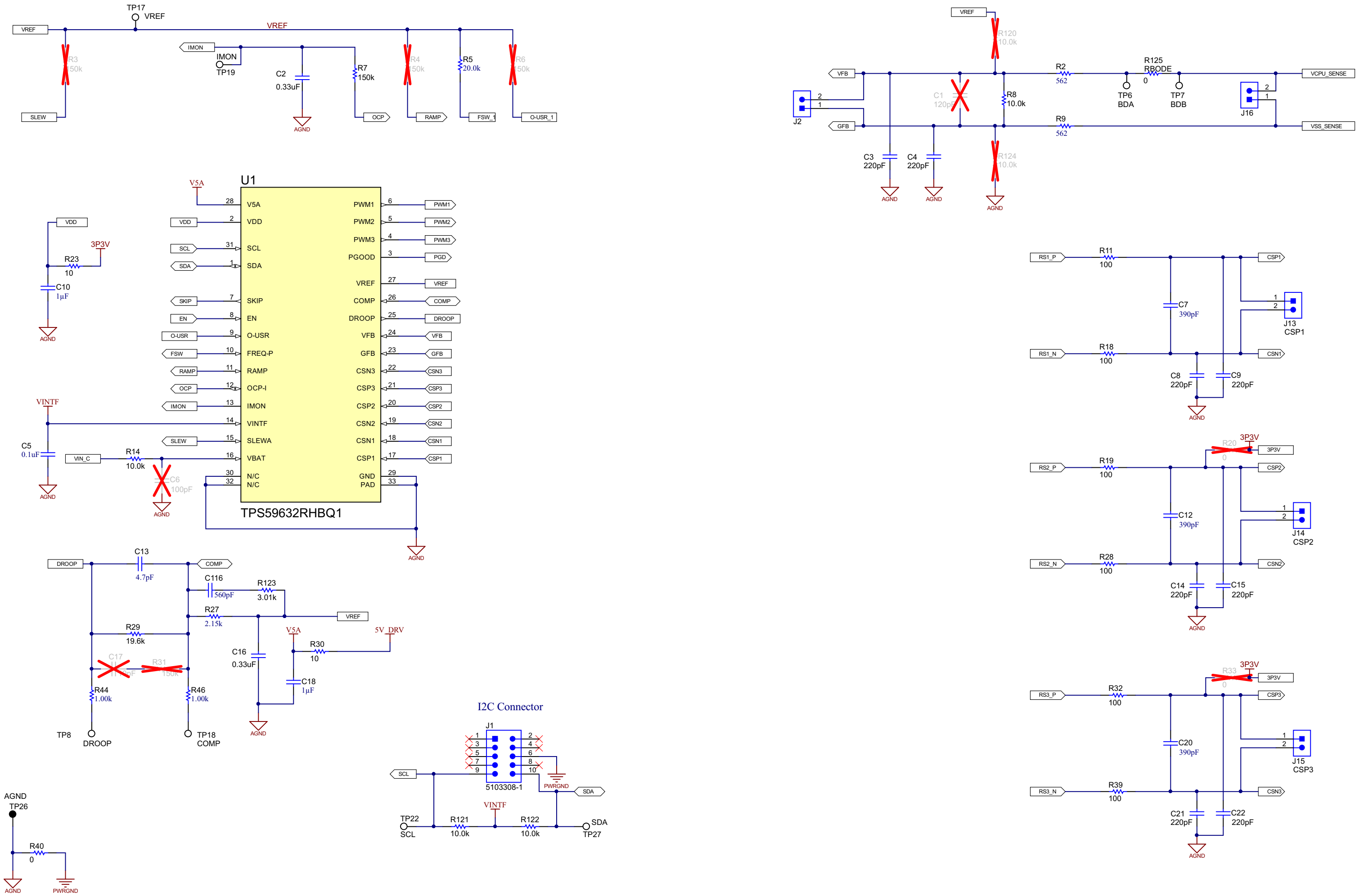

Figure 30. TPS59632Q1EVM-057 Controller Schematic

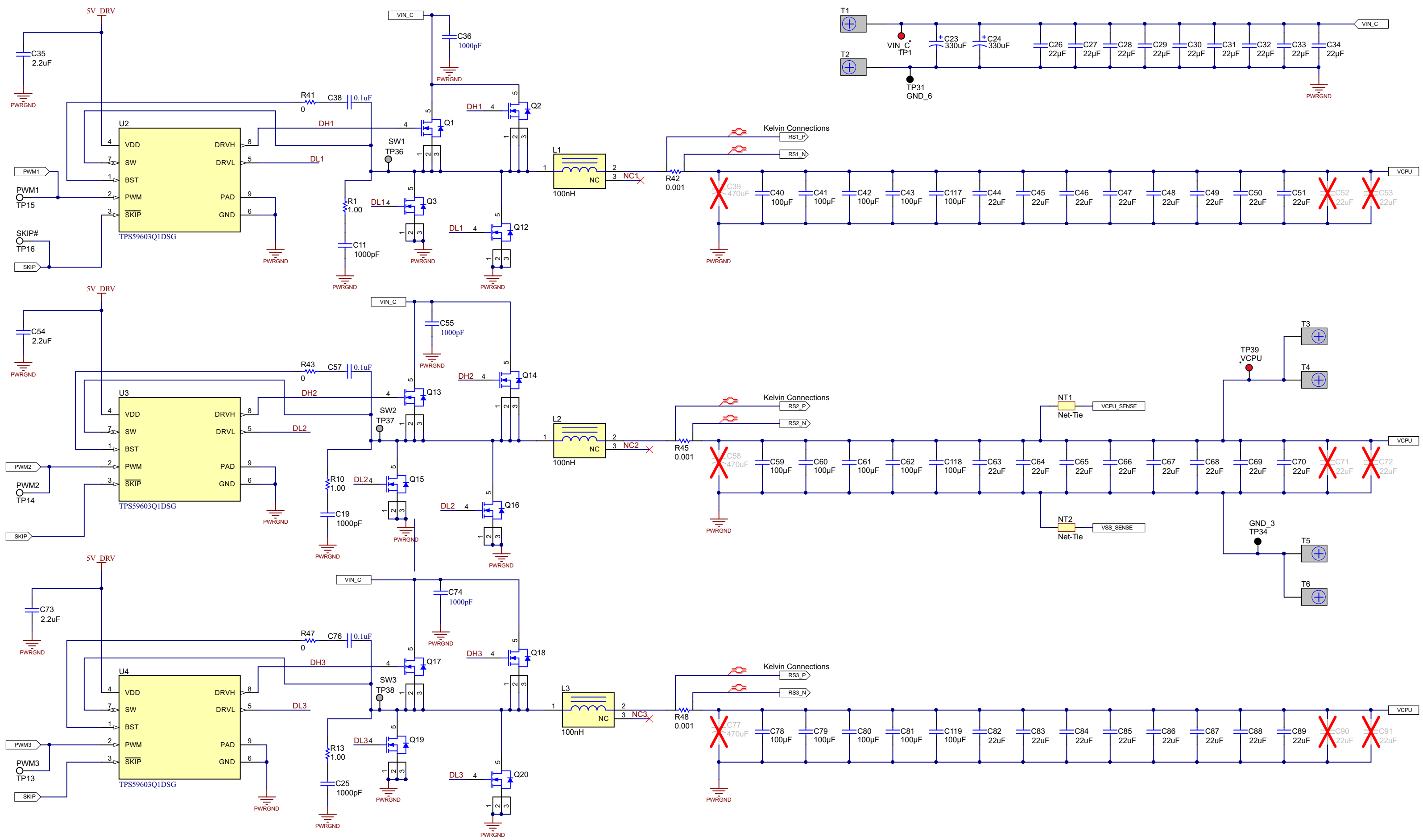

Figure 31. TPS59632Q1EVM-057 Kelvin Connections Schematic

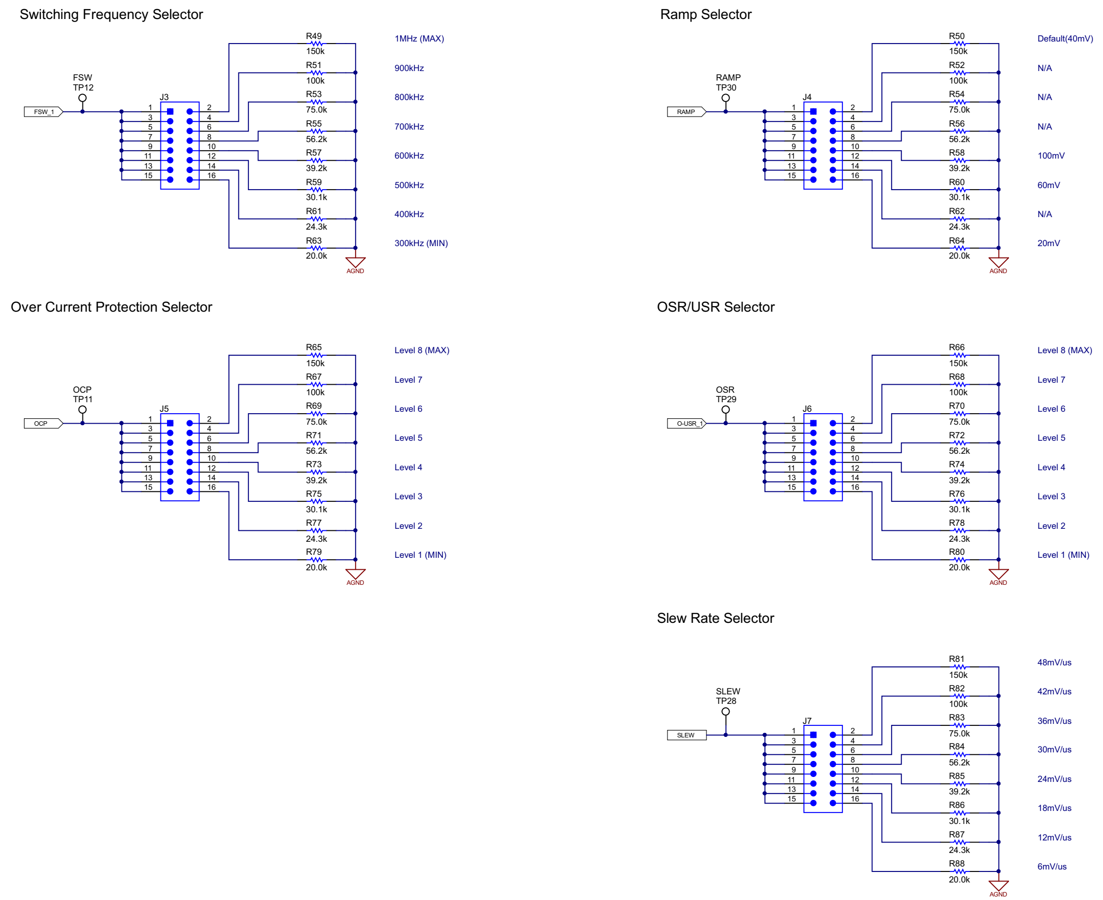

Figure 32. TPS59632Q1EVM-057 Parameter Selection Schematic

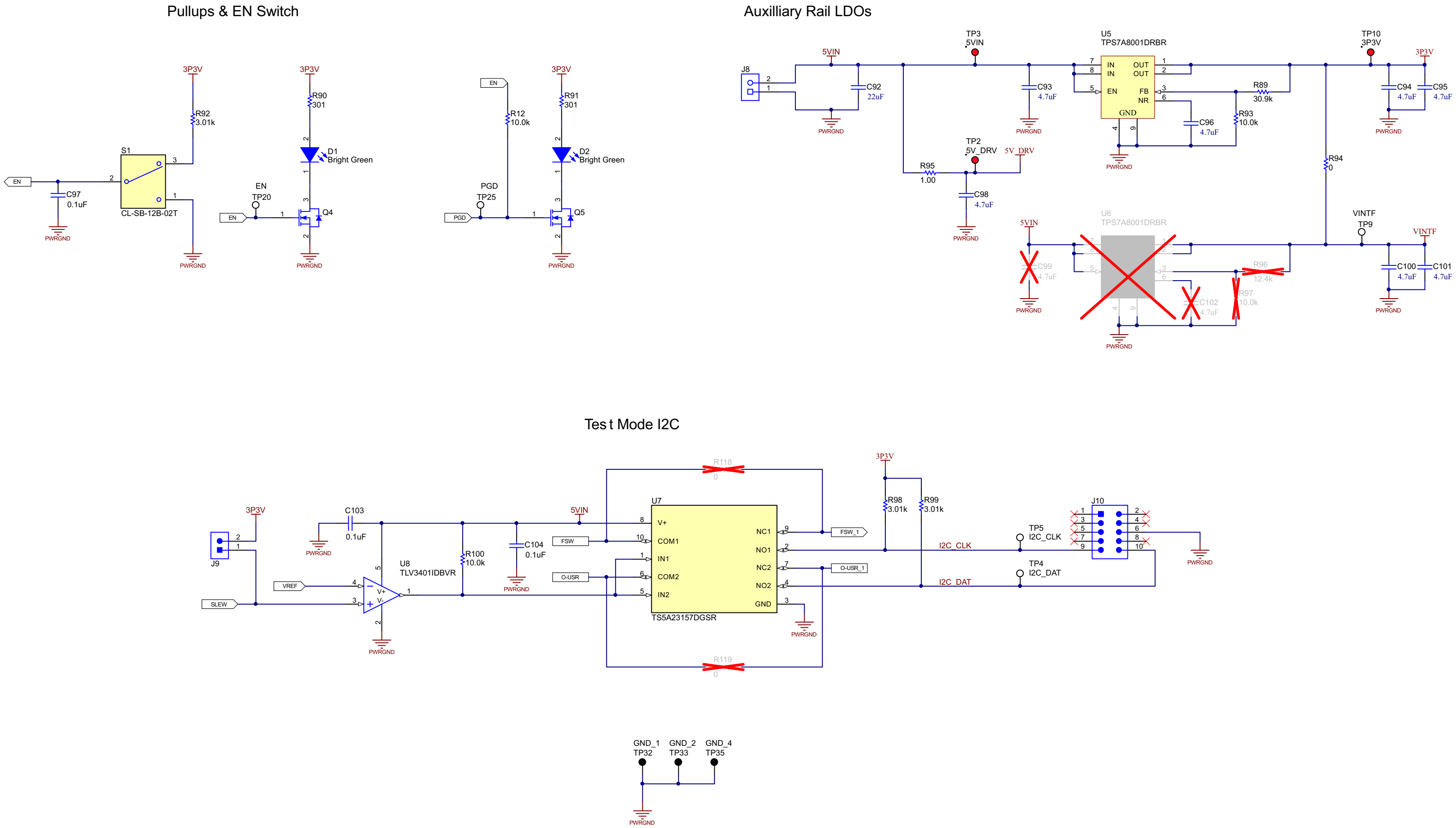

Figure 33. TPS59632Q1EVM-057 Auxiliary Circuits Schematic

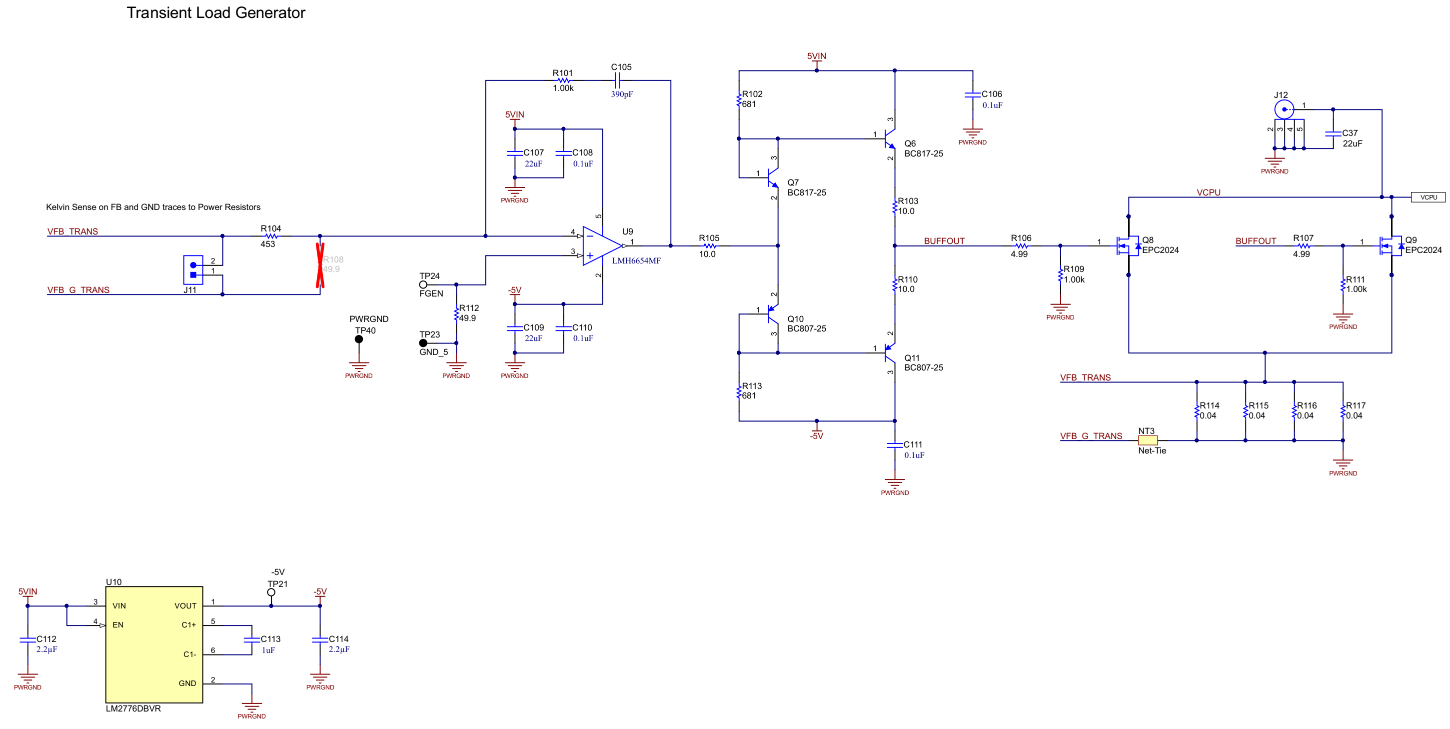

Figure 34. TPS59632Q1EVM-057 Load Generator Schematic

4.2 Bill of Materials (BOM)

Table 1 shows the BOM for the TPS59632Q1EVM-057. Note that the controller IC (TPS59632-Q1), the MOSFET gate driver IC (TPS59603-Q1), the synchronous buck MOSFETs (BUK9M6R6-30EX and BUK9M5R2-30EX), the output inductor (100 nH, HPL505028FR10MRD3P), the input ceramic capacitors (22 µF, 25 V) and output ceramic capacitors (22 µF, 6.3 V) are automotive qualified. A list of alternate input and output ceramic capacitors are shown at the end of this BOM.

Table 1. Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
C2, C16	2	0.33 µF	CAP, CERM, 0.33 µF, 6.3 V, ±10%, X7R, 0603	0603	C0603C334K9RACTU	Kemet
C3, C4, C8, C9, C14, C15, C21, C22	8	220 pF	CAP, CERM, 220 pF, 50 V, ±5%, C0G/NP0, 0402	0402	CGA2B2C0G1H221J050BA	TDK
C5, C38, C57, C76, C106, C108, C110, C111	8	0.1 µF	CAP, CERM, 0.1 µF, 16 V, ±10%, X7R, 0402	0402	GCM155R71C104KA55D	MuRata
C7, C12, C20, C105	4	390 pF	CAP, CERM, 390 pF, 50 V, ±10%, X7R, 0402	0402	GCM155R71H391KA37D	MuRata
C10, C18	2	1 µF	CAP, CERM, 1 µF, 16 V, ±10%, X7R, 0603	0603	CGA3E1X7R1C105K080AC	TDK
C11, C19, C25	3	1000 pF	CAP, CERM, 1000 pF, 50 V, ±5%, C0G/NP0, 0402	0402	CGA2B2C0G1H102J050BA	TDK
C13	1	4.7 pF	CAP, CERM, 4.7 pF, 50 V, ±5.3%, C0G/NP0, 0402	0402	GCM1555C1H4R7CA16D	MuRata
C23, C24	2	330 µF	CAP, Tantalum Polymer, 330 µF, 6.3 V, ±20%, 0.025 Ω, 7343-31 SMD	7343-31	T598D337M006ATE025	Kemet
C26, C27, C28, C29, C30, C31, C32, C33, C34	9	22 µF	CAP, CERM, 22 µF, 25 V, ±20%, X5R, 0805	0805_HV	GRT21BR61E226ME13L	MuRata
C35, C54, C73	3	2.2 µF	CAP, CERM, 2.2 µF, 10 V, ±20%, X5R, 0402	0402	GRM155R61A225ME95	MuRata
C36, C55, C74	3	1000 pF	CAP, CERM, 1000 pF, 50 V, ±10%, X7R, 0402	0402	GCM155R71H102KA37D	MuRata
C37, C44, C45, C46, C47, C48, C49, C50, C51, C63, C64, C65, C66, C67, C68, C69, C70, C82, C83, C84, C85, C86, C87, C88, C89	25	22 µF	CAP, CERM, 22 µF, 6.3 V, ±20%, X7T, 0805	0805_HV	GCM21BD70J226ME36L	MuRata
C40, C41, C42, C43, C59, C60, C61, C62, C78, C79, C80, C81, C117, C118, C119	15	100 µF	CAP, CERM, 100 µF, 4 V, ±20%, X7S, 1210	1210_270	GRM32EC70G107ME15L	MuRata
C92, C107, C109	3	22 µF	CAP, CERM, 22 µF, 6.3 V, ±20%, X7T, 0805	0805_HV	GRM21BD70J226ME44L	MuRata
C93, C94, C95, C96, C98, C100, C101	7	4.7 µF	CAP, CERM, 4.7 µF, 6.3 V, ±10%, X5R, 0603	0603	C0603C475K9PACTU	Kemet
C97, C103, C104	3	0.1 µF	CAP, CERM, 0.1 µF, 16 V, ±10%, X7R, 0603	0603	C0603C104K4RACTU	Kemet
C112, C114	2	2.2 µF	CAP, CERM, 2.2 µF, 16 V, ±10%, X7R, 0603	0603	EMK107BB7225KA-T	Taiyo Yuden
C113	1	1 µF	CAP, CERM, 1 µF, 16 V, ±10%, X7R, 0603	0603	GCM188R71C105KA64D	MuRata
C116	1	560 pF	CAP, CERM, 560 pF, 50 V, ±5%, C0G/NP0, 0402	0402	CL05C561JB5NNNC	Samsung
D1, D2	2	Bright Green	LED, Bright Green, SMD	WL-SMCW_Green_0805	150080VS75000	Wurth Elektronik
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 × 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	Keystone_1902C	1902C	Keystone
H9, H10, H11, H12, H13, H14	6		Machine Screw Pan Philips 10-32		PMSSS 102 0050 PH	B&F Fastener Supply

Table 1. Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
H15, H16, H17, H18, H19, H20	6		Machine Screw Nut, Hex, 3/8', Stn, Steel, 10-32		HNSS 102	B&F Fastener Supply
H21, H22, H23, H24, H25, H26	6		Washer, Split Lock, #10		1477	Keystone
J1, J10	2		Header (shrouded), 100 mil, 5 × 2, Gold, TH	CONN_5103308-1	5103308-1	TE Connectivity
J2, J9, J11, J13, J14, J15, J16	7		Header, 100 mil, 2 × 1, Gold, TH	Samtec_HTSW-102-07-G-S	HTSW-102-07-G-S	Samtec
J3, J4, J5, J6, J7	5		Header, 100 mil, 8 × 2, Gold, TH	PBC08DAAN	PBC08DAAN	Sullins Connector Solutions
J8	1		Conn Term Block, 2POS, 3.81 mm, TH	PhoenixContact_1727010	1727010	Phoenix Contact
J12	1		Connector, SMB, Vertical RCP 0–4 GHz, 50 Ω, TH	CONN_131-3701-261	131-3701-261	Cinch Connectivity
L1, L2, L3	3	100 nH	Inductor, 100 nH, 27.5 A, 0.00088 Ω, AEC-Q200 Grade 0, SMD	HPL505028F	HPL505028FR10MRD3P	TDK
Q1, Q2, Q13, Q14, Q17, Q18	6	30 V	MOSFET, N-CH, 30 V, 70 A, AEC-Q101, 3.4 × 0.9 × 2.7 mm	LFPAK33	BUK9M6R6-30EX	Nexperia
Q3, Q12, Q15, Q16, Q19, Q20	6	30 V	MOSFET, N-CH, 30 V, 70 A, AEC-Q101, 3.4 × 0.9 × 2.7 mm	LFPAK33	BUK9M5R2-30EX	Nexperia
Q4, Q5	2	100 V	MOSFET, N-CH, 100 V, 0.17 A, SOT-323	SOT-323	BSS123W-7-F	Diodes Inc.
Q6, Q7	2	45 V	Transistor, NPN, 45 V, 0.5 A, SOT-23	SOT-23	BC817-25,215	NXP Semiconductor
Q8, Q9	2	40 V	MOSFET, N-CH, 40 V, 90 A, 6.05 × 2.3 mm	EPC2023	EPC2024	EPC
Q10, Q11	2	45 V	Transistor, PNP, 45 V, 0.5 A, SOT-23	SOT-23	BC807-40LT1G	ON Semiconductor
R1, R10, R13	3	1.00	RES, 1.00, 1%, 0.1 W, 0603	0603	CRCW06031R00FKEA	Vishay-Dale
R2, R9	2	562	RES, 562, 1%, 0.063 W, 0402	0402	CRCW0402562RFKED	Vishay-Dale
R5	1	20.0 kΩ	RES, 20.0 k, 1%, 0.063 W, 0402	0402	CRCW040220K0FKED	Vishay-Dale
R7, R49, R50, R65, R66, R81	6	150 kΩ	RES, 150 k, 1%, 0.1 W, 0603	0603	CRCW0603150KFKEA	Vishay-Dale
R8	1	10.0 kΩ	RES, 10.0 k, .1%, .0625 W, 0402	0402	RT0402BRD0710KL	Yageo America
R11, R18, R19, R28, R32, R39	6	100	RES, 100, 1%, 0.063 W, 0402	0402	CRCW0402100RFKED	Vishay-Dale
R12, R93, R100	3	10.0 kΩ	RES, 10.0 k, 1%, 0.1 W, 0603	0603	ERJ-3EKF1002V	Panasonic
R14, R121, R122	3	10.0 kΩ	RES, 10.0 k, 1%, 0.063 W, 0402	0402	CRCW040210K0FKED	Vishay-Dale
R23, R30	2	10	RES, 10, 5%, 0.25 W, 0603	0603	CRCW060310R0JNEAHP	Vishay-Dale
R27	1	2.15 kΩ	RES, 2.15 k, 1%, 0.063 W, 0402	0402	CRCW04022K15FKED	Vishay-Dale
R29	1	19.6 kΩ	RES, 19.6 k, 1%, 0.063 W, 0402	0402	CRCW040219K6FKED	Vishay-Dale
R40	1	0	RES, 0, 1%, 0.1 W, 0603	0603	RMCF0603ZT0R00	Stackpole Electronics Inc
R41, R43, R47, R125	4	0	RES, 0, 5%, 0.063 W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R42, R45, R48	3	0.001	RES, 0.001, 1%, 1 W, 1.5 × 3.05 mm	WSK0612	WSK06121L000FEA	Vishay-Dale
R44, R46, R101	3	1.00 kΩ	RES, 1.00 k, 1%, 0.063 W, 0402	0402	CRCW04021K00FKED	Vishay-Dale
R51, R52, R67, R68, R82	5	100 kΩ	RES, 100 k, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R53, R54, R69, R70, R83	5	75.0 kΩ	RES, 75.0 k, 1%, 0.1 W, 0603	0603	CRCW060375K0FKEA	Vishay-Dale

Table 1. Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
R55, R56, R71, R72, R84	5	56.2 kΩ	RES, 56.2 k, 1%, 0.1 W, 0603	0603	CRCW060356K2FKEA	Vishay-Dale
R57, R58, R73, R74, R85	5	39.2 kΩ	RES, 39.2 k, 1%, 0.1 W, 0603	0603	CRCW060339K2FKEA	Vishay-Dale
R59, R60, R75, R76, R86	5	30.1 kΩ	RES, 30.1 k, 1%, 0.1 W, 0603	0603	CRCW060330K1FKEA	Vishay-Dale
R61, R62, R77, R78, R87	5	24.3 kΩ	RES, 24.3 k, 1%, 0.1 W, 0603	0603	CRCW060324K3FKEA	Vishay-Dale
R63, R64, R79, R80, R88	5	20.0 kΩ	RES, 20.0 k, 1%, 0.1 W, 0603	0603	CRCW060320K0FKEA	Vishay-Dale
R89	1	30.9 kΩ	RES, 30.9 k, 1%, 0.1 W, 0603	0603	RC0603FR-0730K9L	Yageo
R90, R91	2	301	RES, 301, 1%, 0.1 W, 0603	0603	CRCW0603301RFKEA	Vishay-Dale
R92, R98, R99	3	3.01 kΩ	RES, 3.01 k, 1%, 0.1 W, 0603	0603	RC0603FR-073K01L	Yageo
R94	1	0	RES, 0, 5%, 0.1 W, 0603	0603	ERJ-3GEY0R00V	Panasonic
R95	1	1.00	RES, 1.00, 1%, 0.125 W, 0805	0805_HV	ERJ-6RQF1R0V	Panasonic
R102, R113	2	681	RES, 681, 1%, 0.1 W, 0603	0603	CRCW0603681RFKEA	Vishay-Dale
R103, R105, R110	3	10.0	RES, 10.0, 1%, 0.1 W, 0603	0603	CRCW060310R0FKEA	Vishay-Dale
R104	1	453	RES, 453, 1%, 0.063 W, 0402	0402	CRCW0402453RFKED	Vishay-Dale
R106, R107	2	4.99	RES, 4.99, 1%, 0.1 W, 0603	0603	CRCW06034R99FKEA	Vishay-Dale
R109, R111	2	1.00 kΩ	RES, 1.00 k, 1%, 0.1 W, 0603	0603	ERJ-3EKF1001V	Panasonic
R112	1	49.9	RES, 49.9, 1%, 0.063 W, 0402	0402	CRCW040249R9FKED	Vishay-Dale
R114, R115, R116, R117	4	0.04	RES, 0.04, 2%, 1 W, 1508	1508	RL3720WT-R040-G	Samsung
R123	1	3.01 kΩ	RES, 3.01 k, 1%, 0.063 W, 0402	0402	CRCW04023K01FKED	Vishay-Dale
S1	1		Switch, SPDT, On-On, 2 Pos, SMD	SW_CL-SB-12B-01	CL-SB-12B-02T	Copal Electronics
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5	5	1 × 2	Shunt, 100 mil, Flash Gold, Black	SPC02SYAN	SPC02SYAN	Sullins Connector Solutions
T1, T2, T3, T4, T5, T6	6		Terminal 50-A Lug	CB35-36-CY	CB35-36-CY	Panduit
TP1, TP2, TP3, TP10, TP39	5		Test Point, Compact, Red, TH	Keystone5005	5005	Keystone
TP4, TP5, TP6, TP7, TP8, TP9, TP11, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22, TP24, TP25, TP27, TP28, TP29, TP30	24		Test Point, Compact, White, TH	Keystone5007	5007	Keystone
TP23, TP26, TP31, TP32, TP33, TP34, TP35, TP40	8		Test Point, Compact, Black, TH	Keystone5006	5006	Keystone
TP36, TP37, TP38	3		Test Point, Miniature, SMT	Keystone_5019	5019	Keystone
U1	1		3-2-1 Phase D-Cap+TM Step-Down Driverless Controller for Low Voltage Applications with I2C Control, RHB0032N (VQFN-32)	RHB0032N	TPS59632RHBQ1	Texas Instruments
U2, U3, U4	3		Synchronous Buck FET Driver for High-Frequency CPU Core Power in Automotive Applications, DSG0008B (WSON-8)	DSG0008B	TPS59603Q1DSG	Texas Instruments
U5	1		Single Output LDO, 1 A, Adjustable 0.8 to 6 V Output, 2.2 to 6.5 V Input, with High-Bandwidth PSRR, 8-pin SON (DRB), -40 to 125°C, Green (RoHS & no Sb/Br)	DRB0008A	TPS7A8001DRBR	Texas Instruments
U7	1		DUAL 10-Ω SPDT ANALOG SWITCH, DGS0010A (VSSOP-10)	DGS0010A_N	TS5A23157DGSR	Texas Instruments

Table 1. Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
U8	1		Single Nanopower Open Drain Output Comparator, DBV0005A (SOT-23-5)	DBV0005A_N	TLV3401IDBVR	Texas Instruments
U9	1		Single Low Power, 250 MHz, Low Noise Amplifier, 5-pin SOT-23	DBV0005A_N	LMH6654MF	Texas Instruments
U10	1		Switched Capacitor Inverter, DBV0006A (SOT-23-6)	DBV0006A_L	LM2776DBVR	Texas Instruments

Table 2 shows a list of alternate automotive qualified input and output capacitors.

Table 2. Alternate Automotive Qualified Input and Output Capacitors

Capacitor	Alternate 1 Part Number	Manufacturer	Alternate 2 Part Number	Manufacturer
22 µF, 25 V	GRT21BR61E226ME13L	MuRata		TDK
22 µF, 6.3 V	GRM21BD70J226ME44L	MuRata	CGA4J	TDK
100 µF, 4 V	GCM32ED70G107M	MuRata	CGA6P1X7T0G107M	TDK

4.2.1 Alternate Configurations

The TPS59632Q1EVM-057 is built with a default configuration where 3-phases are active to support up to 60 A of output current. To evaluate other configurations, certain components in the BOM must be modified. However, it should be noted that Texas Instruments is not responsible for the performance of the EVM when components are changed by the user. This section provides only a guideline on these component changes to allow the user to manually change these components to evaluate the performance of the controller in other applications to suit the requirements of the user.

Table 3 shows the component value changes for a 2-phase configuration with the same output voltage specification as the original EVM configuration and maximum load current of 25 A.

Table 3. Component Value Changes for 2-Phase Configuration, Output Voltage = 0.875 V (±3%), Maximum Load Current = 25 A

Designator	New Value	Comment
R32	DNP	Disables third phase
R33	0 Ω	
R27	4.42 kΩ	Changes the droop to 1.2 mΩ
Frequency jumper selector	Move to 1-MHz setting	Change switching frequency to 1 MHz (per phase)
OCP jumper selector	Move to level 4	Changes overcurrent protection to about 35 A.
C78, C79, C117, C80, C81, C42, C61	Remove	Reduces the amount of output capacitance needed to 8× 100 µF + 16× 22 µF
C44, C45, C46, C47, C48, C68, C69, C70	Remove	

In addition, the user may opt to remove one high-side and one low-side MOSFET per phase for the 2-phase, 25-A load current application.

Table 4 shows the component value changes for a 2-phase configuration with an output voltage specification of 0.75 V (±3.3%) and maximum load current of 15 A.

Table 4. Component Value Changes for 2-Phase Configuration, Output Voltage = 0.75 V (±3%), Maximum Load Current = 15 A

Designator	New Value	Comment
R32	DNP	Disables third phase
R33	0 Ω	
R27	7.50 kΩ	Changes the droop to 1.8 mΩ
R8	DNP	Sets output voltage to 0.75 V nominal (at 7.5-A load)
R120, R124	10 kΩ	
R2, R9	412 Ω	
Frequency jumper selector	Move to 1-MHz setting	Change switching frequency to 1 MHz (per phase)
OCP jumper selector	Move to level 4	Change overcurrent protection to about 25 A
C78, C79, C117, C80, C81, C42, C61, C40, C59, C118, C119	DNP	Reduces the amount of output capacitance needed to 4× 100 µF + 16× 22 µF
C44, C45, C46, C47, C48, C68, C69, C70	DNP	

In addition, the user may opt to remove one high-side and one-low side MOSFET per phase for the 2-phase, 15-A load current application.

For 1-phase configuration, the resistors, R19, R32 must be DNP and R20, R33 must be 0 Ω. Other component design changes that must be accompanied to support the application can be calculated according to the design procedure detailed in the *TPS59632-Q1* data sheet.

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