

EVM User's Guide: BQ25960HEVM

BQ25960H Evaluation Module



Description

The BQ25960H evaluation module (EVM) is a complete charger module for evaluating the highly-integrated BQ25960H switched cap battery charger in WCSP package for 1-cell Li-Ion and Li-polymer batteries in a wide range of smartphones and tablets. The BQ25960HEVM is rated for a maximum input current of 5.75A and a maximum charge current of 8 A.

The BQ25960HEVM presents a complete fast charging design. A typical use case is for the BQ25611D buck charger (U4) to perform pre-charge and charge termination, while one or both of the BQ25960H switched cap chargers (U1 and U2) perform fast charging to achieve the highest possible efficiency.

Get Started

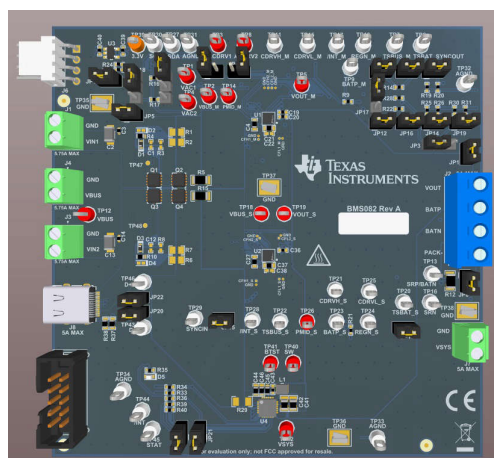
1. Order the [EVM](#) on ti.com
2. Order the [EV2400](#) to communicate with the EVM
3. Download [BQSTUDIO](#) and the BQ25960H BQZ file on ti.com

Features

- 98.1% peak efficiency switched cap parallel charger supporting up to 8 A fast charge
- Dual phase switched cap architecture optimized for highest efficiency
 - Input voltage is 2x battery voltage
 - Output current is 2x of input current
 - Reduces power loss across input cable
- I2C communication for system configuration and status reporting
- Support up to 12.75V operation input voltage and 40 V absolute maximum with external ACFET or 20 V without external ACFET
- Dual input power mux controller for source selection during fast charging and USB On-The-Go (OTG)/ reverse Mode
- Provide gate drive signal for external OVP GaN FETs or N-FETs
- Various integrated programmable protection features for safe operation
- Programmable settings for system optimization
 - Interrupts and interrupt masks
 - Alarm functions for host control
 - 16-bit ADC for voltage, current, and temperature monitoring

Applications

- [Smartphone](#)
- [Tablet](#)



BQ25960HEVM Hardware Board

1 Evaluation Module Overview

1.1 Introduction

This user's guide describes the characteristics, operation, and functionality of the BQ25960H Evaluation Module (EVM), which is a complete evaluation system for the BQ25960H IC. The BQ25960H is a 8 A switched capacitor battery charger in WCSP package for 1-cell Li-Ion and Li-Polymer batteries.

The user's guide describes the equipment, test setup, and software required to operate the EVM. A complete schematic diagram, printed-circuit board (PCB) layouts, and bill of materials (BOM) are also included in this document. Throughout this user guide, the abbreviations and terms *EVM*, *BQ25960HEVM*, *BMS082*, and *evaluation module* are synonymous with the BQ25960H EVM.

Users can configure the EVM for either single BQ25960H operation or dual BQ25960H operation based on the jumper settings described in the next section. In single BQ25960H operation, only U1 charges the battery. In dual BQ25960H operation, U1 acts as the primary charger, and U2 acts as the secondary charger.

This EVM does not include the EV2400 interface board. To evaluate the EVM, an EV2400 interface board must be ordered separately.



WARNING

Hot surface! Contact can cause burns. Do not touch!

Some components can reach high temperatures $>55^{\circ}\text{C}$ when the board is powered on. The user must not touch the board at any point during operation or immediately after operating, as high temperatures can be present.

1.2 Kit Contents

This EVM kit includes one BQ25960H EVM.

1.3 Specification

Table 1-1 lists the recommended operating conditions for this EVM.

Table 1-1. Recommended Operating Conditions

	Description	MIN	MAX	UNIT
VIN1, VIN2, VBUS	Input voltage at J1, J3, and J4	0	13	V
I _{VIN1} , I _{VIN2} , I _{VBUS}	Input current into J1, J3, and J4		5	A
VOUT	Battery voltage at J2	0	5	V
I _{VOUT}	Battery charge current out of J2		8	A
T _A	Operating free-air temperature range	-40	85	°C

1.4 Device Information

The BQ25960HEVM is an evaluation system for the BQ25960H IC. The BQ25960H is a 98.1% peak efficiency, 8-A battery charging design using switch capacitor architecture for a 1-cell Li-ion battery. The switched cap architecture allows the input cable current to be half the charging current, reducing the cable power loss, and limiting temperature rise.

When used with a main charger such as BQ2561x or BQ2562x, the system enables a full charging cycle from trickle charge to termination with low power loss in Constant Current (CC) and Constant Voltage (CV) mode.

The device supports dual input configuration through integrated mux control and gate driver for external N-FETs or GaN FETs and also allows single input with no external FET or single FET.

The BQ25960H device data sheet ([SLUSF77](#)) provides detailed features and operation.

2 Hardware

2.1 Equipment

This section includes a list of equipment required to perform tests on the BQ25960HEVM.

1. **Power supply:** PS1. A power supply capable of supplying up to 20 V at 3 A is required.
2. **Battery simulator:** Load #1 (4-quadrant supply). A "Kepco" load, BOP, 20-5M, DC 0 to ± 10 V, 0 to ± 5 A (or higher)
3. **Meters:** (6x) "Fluke 75" multimeters, equivalent or better.
Alternative Option: (4x) equivalent voltage meters and (2x) equivalent current meters. The current meters must be capable of measuring at least 5 A.
4. **Computer:** A computer with at least one USB port and a USB cable. Must have Battery Management Studio installed. The download link is provided in [Section 3.1](#) of this User's Guide.
5. **PC communication interface:** EV2400 USB-based PC interface board.

2.2 Equipment Setup

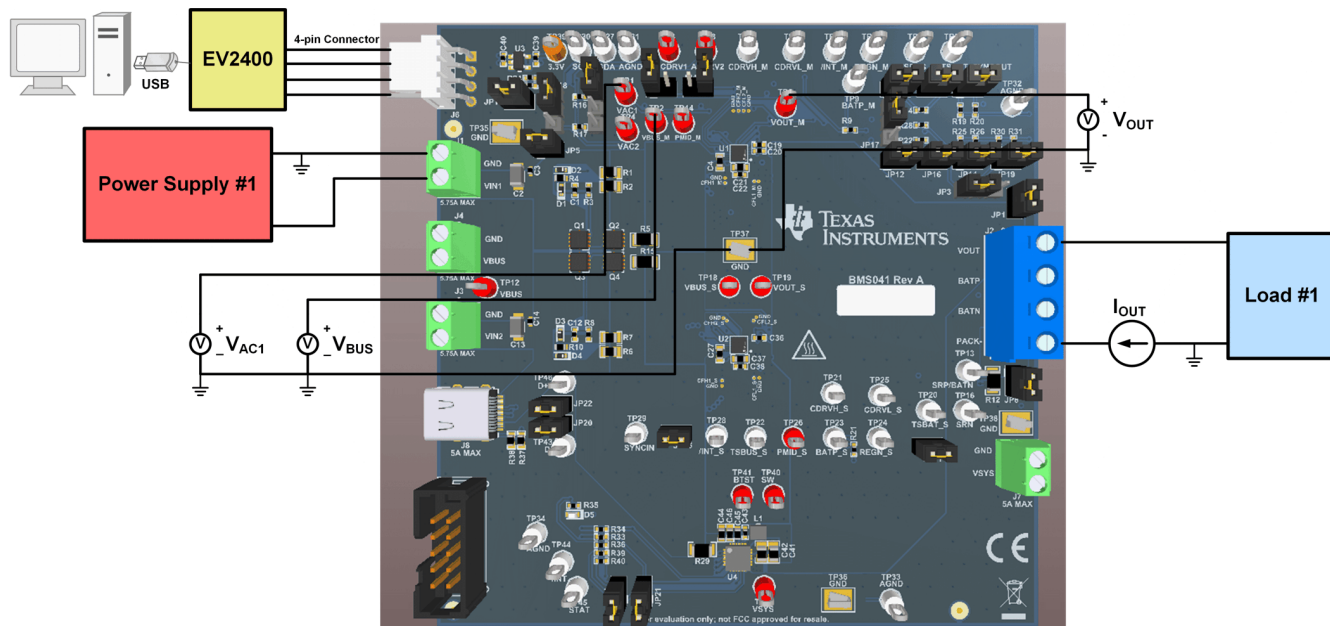


Figure 2-1. Equipment Test Setup

Use the following list to set up the EVM testing equipment. Refer to [Figure 2-1](#) for the test setup connections to the EVM.

1. Review the EVM connections in [Table 2-1](#).
2. Install jumpers as shown in [Table 2-2](#).
3. Set PS1 for 8.3 V_{DC}, 1 A current limit, and then turn off the supply.
4. Connect PS1 to J1 (VIN1 and GND).
5. Connect a voltage meter across TP1 (VAC1) and TP37 (GND) to measure the input voltage as seen from the VAC1 bump of the U1 charger.
6. Connect a voltage meter across TP2 (VBUS_M) and TP37 (GND) to measure the input voltage as seen from the VBUS bumps of the U1 charger.
7. Set Load #1 to constant voltage mode with an output of 4.0 V, and then disable the load.
8. Connect Load #1 to J2 (VOUT and PACK-). Connect a current meter in series to measure the output current, as shown in [Figure 2-1](#).
9. Connect a voltage meter across TP5 (VOUT_M) and TP37 (GND) to measure the output voltage as seen from the VOUT bumps of the charger.

2.3 I/O Descriptions

Table 2-1 lists the BQ25960HEVM board connections and ports.

Table 2-1. EVM Connections

Jack		Description
J1	VIN1	Positive rail of the priority input adapter or power supply
	GND	Ground
J2	VOUT	Positive rail of the charger battery input
	BATP	Input connected to the positive terminal of the battery for remote battery voltage sensing
	BATN	Input connected to the negative terminal of the battery for remote battery voltage sensing
	PACK-	Negative rail of the charger battery input
J3	VIN2	Positive rail of the secondary input adapter or power supply
	GND	Ground
J4	VBUS	Positive rail of the VBUS input to the charger ICs
	GND	Ground
J5	Communication port	I ² C communication port for use with the USB2ANY interface adapter
J6	Communication port	I ² C communication port for use with the EV2400 interface board
J7	VSYS	Positive rail of the BQ25611D charger's system output voltage
	GND	Ground
J8	USB-C connector	Provides power to VIN2 and has D+/D- lines for input source detection

Table 2-2 below lists the jumper connections available on this EVM.

Table 2-2. EVM Jumper Settings

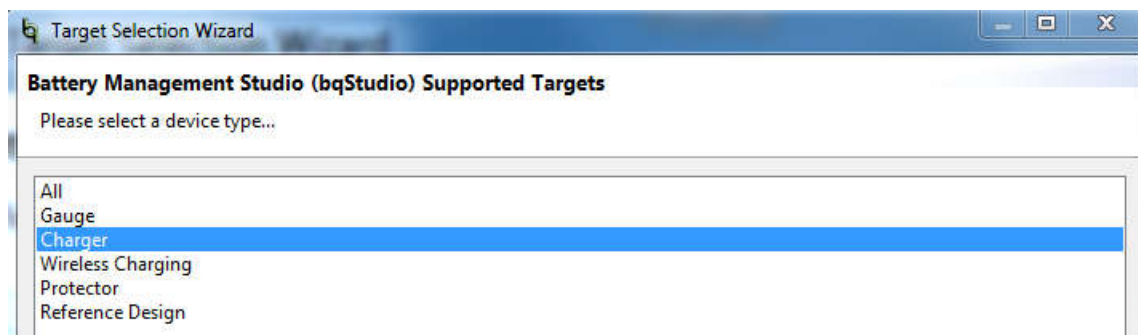
Jumper	Description	Single BQ25960H Setting	Dual BQ25960H Setting
JP1	BATP to VOUT connection.	Installed	Installed
JP2	ACDRV1 to GND connection. Connect this jumper if powering directly from VBUS, or if ACFET1/RBFET1 are removed.	Not installed	Not installed
JP3	U1 TSBAT or SYNCOUT connection. Connect to SYNCOUT if operating in primary/secondary mode.	Installed between left pin and middle pin (connect to TSBAT)	Installed between middle pin and right pin (connect to SYNCOUT)
JP4	ACDRV2 to GND connection. Connect this jumper if ACFET2/RBFET2 are removed.	Not installed	Not installed
JP5	U1 /INT pin connection to 1.2V pull-up rail.	Installed	Installed
JP6	U1 REGN pin connection to U1 TSBUS resistor network.	Installed	Installed
JP7	Different resistor connection for U1 TSBUS resistor network.	Installed	Installed
JP8	U2 I ² C address and mode selection.	Installed	Installed
JP9	U1 I ² C address and mode selection.	Not installed	Installed between top pin and middle pin (connect to R16)
JP10	U1 TSBUS pin connection to U1 TSBUS resistor network.	Installed	Installed
JP11	U2 TSBAT connection to TSBAT resistor network.	Installed	Installed
JP12	U2 REGN pin connection to U2 TSBUS resistor network.	Installed	Installed
JP13	SDA and SCL connection to 1.2V I ² C pull-up rail.	Installed	Installed
JP14	Different resistor connection for U2 TSBUS resistor network.	Installed	Installed
JP15	U2 /INT pin connection to 1.2V pull-up rail.	Installed	Installed
JP16	U2 TSBUS pin connection to U2 TSBUS resistor network.	Installed	Installed
JP17	Connection from TSBAT resistor network to either U1 REGN pin or U2 REGN pin.	Installed between top pin and middle pin (connect to REGN_M)	Installed between top pin and middle pin (connect to REGN_M)
JP18	Input selection for 1.2V LDO	Installed between top pin and middle pin (connect to VOUT)	Installed between top pin and middle pin (connect to VOUT)
JP19	Different resistor connection for TSBAT resistor network.	Installed	Installed
JP20	D- connection for USB-C connector.	Installed	Installed
JP21	Charge enable connection for U4.	Installed	Installed
JP22	D+ connection for USB-C connector.	Installed	Installed
JP23	U4 thermistor NORMAL temperature setting. Install this jumper to simulate entering normal temperature region.	Installed	Installed

Out of the box, the BQ25960HEVM is configured to evaluate the performance of the BQ25960H only. If the BQ25611D must also be evaluated, then the user needs to populate R29 and R32, as shown in the schematic in [Figure 5-3](#).

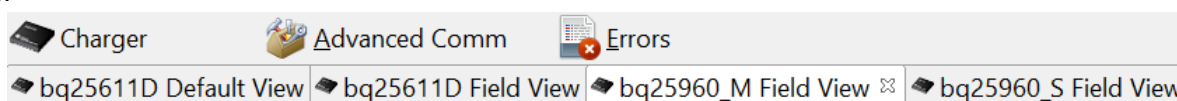
3 Software

3.1 Software Setup

Download the latest version of [BQStudio](#). Double click the Battery Management Studio installation file and follow the installation steps. The software supports Microsoft® Windows® XP, 7, and 10 operating systems. Launch BQStudio and select *Charger*, as shown below.



Next, select the BQ25960H configuration file, and BQStudio opens. If only the BQ25960H is being evaluated, then the user can select the more streamlined "Charger_2_00-bq25960H.bqz" file. If the BQ25960H and the BQ25611D must be evaluated alongside each other, then the user can select the "Charger_2_00-bq25960H_EVM.bqz" file instead, which contains separate tabs to communicate with U1, U2, and U4, as shown below.



If you do not have the BQ25960H configuration files, then please request the files through [E2E](#). The .bqz configuration files must be saved into C:\XXX\BatteryManagementStudio\config, where XXX is the directory you selected to install BQStudio.

4 Implementation Results

4.1 Test Procedure

4.1.1 Initial Settings

Use the following steps to enable the EVM test setup.

1. Make sure the steps in [Section 2.2](#) and [Section 3.1](#) have been followed.
2. Turn on PS1 and Load #1:
 - **Measure** → $V_{VAC1-GND}(TP1 \text{ and } TP37) = 8.3 \pm 0.2 \text{ V}$
 - **Measure** → $V_{VBUS_M-GND}(TP2 \text{ and } TP37) = 0 \pm 0.5 \text{ V}$
 - **Measure** → $V_{VOUT_M-GND}(TP5 \text{ and } TP37) = 4 \pm 0.2 \text{ V}$

4.1.2 Communication Verification

Use the following steps for I²C communication verification. Assuming the jumper settings in [Table 2-2](#) have been followed, the I²C address for U1 is 0x65, and the I²C address for U2 is 0x67. If R29 and R32 have been populated, then the I²C address for U4 is 0x6B.

1. In BQStudio, click *Field View* and select the I²C address for U1 (0x65).
2. Click *Read Register* at the top of the page. *Device ACK OK* appears at the top right.
3. Verify that VAC1 and VOUT are reported as *Present*.

Status			
VBUS Present Status	Not present	VOUT Present Status	Present
VAC1 Present Status	Present	VAC2 Present Status	Not present

4. Change the following register settings:
 - Disable the watchdog timer

☒ Disable Watchdog Timer

- Set VAC1 OVP to 10.5 V or higher

VAC1 OVP Setting 10.5 V

5. Click *Read Register* again. In addition to VAC1 and VOUT, VBUS is also reported as *Present*.

Status			
VBUS Present Status	Present	VOUT Present Status	Present
VAC1 Present Status	Present	VAC2 Present Status	Not present

- Measure → $V_{VBUS_M-GND}(TP2 \text{ and } TP37) = 8.3 \pm 0.2 \text{ V}$

4.1.3 Switched Cap Mode Charge Verification

Use the following steps to verify battery charging in switched cap mode.

1. Make sure the steps in [Section 4.1.1](#) and [Section 4.1.2](#) have been followed.
2. Check the "CHG_CONFIG_1 box, and then click *Enable Charge*. After enabling charge, the output current flowing into Load #1 is about 2x the input current flowing out of PS1.

Single-bit I2C Selection	
<input checked="" type="checkbox"/> CHG_CONFIG_1	<input checked="" type="checkbox"/> Disable Watchdog Timer
<input checked="" type="checkbox"/> Enable Charge	<input type="checkbox"/> Enable OTG Mode

3. Change the charge current:
By increasing the input voltage, the output current increases together with the input current. The output current is always about 2x the input current.
4. To stop charging, deselect the *Enable Charge* box. The input current and the output current both fall to zero.

4.1.4 Bypass Mode Charge Verification

Use the following steps to verify battery charging in bypass mode.

1. Make sure the steps in [Section 4.1.1](#) and [Section 4.1.2](#) have been followed.
2. Set PS1 to 4.1 V. Load #1 can be kept at 4.0 V.
3. Make sure the "Enable Charge" box is not selected. Then, click "Enable Bypass Mode".

Single-bit I2C Selection	
<input checked="" type="checkbox"/> CHG_CONFIG_1	<input checked="" type="checkbox"/> Disable Watchdog Timer
<input type="checkbox"/> Enable Charge	<input type="checkbox"/> Enable OTG Mode
<input type="checkbox"/> Enable HIZ Mode	<input checked="" type="checkbox"/> Enable Bypass Mode

4. Click *Enable Charge*. After enabling charge, the output current flowing into Load #1 is approximately equal to the input current flowing out of PS1.
5. Change the charge current:
By increasing the input voltage, the output current increases together with the input current. The output current is always approximately equal to the input current.
6. To stop charging, deselect the *Enable Charge* box. The input current and the output current both fall to zero.

4.1.5 Dual BQ25960H Operation

The BQ25960H EVM also supports dual BQ25960H operation, with U1 operating as the primary charger, and U2 operating as the secondary charger. This allows each BQ25960H to operate at a lower charging current with higher efficiency compared with a single BQ25960H operating at the same total charging current. As a reminder, if the jumper settings in [Table 2-2](#) have been followed, then the I²C address for U1 is 0x65, and the I²C address for U2 is 0x67. Note that the jumper settings for JP3 and JP9 are different for single BQ25960H and dual BQ25960H operation.

1. For U1, follow the previous steps to enable charge in either switched cap mode or bypass mode. U1 begins charging.
2. Select I²C address 0x67 to communicate with U2.
3. Follow the same steps to enable charge for U2. The two BQ25960H devices are now charging in parallel.

4.1.6 BQ25611D Charge Verification

Out of the box, the BQ25960HEVM is configured to evaluate the performance of the BQ25960H only. If the BQ25611D must also be evaluated, then the user needs to populate R29 and R32, as shown in the schematic in [Figure 5-3](#).

A typical use case is for the BQ25611D buck charger (U4) to perform low current pre-charge and charge termination, while one or both of the BQ25960H switched cap chargers (U1 and U2) perform high current fast charging to achieve the highest possible efficiency.

Use the following steps to charge with the BQ25611D. The I²C address for U4 is 0x6B.

1. Turn PS1 and Load #1 off. Make any required hardware changes, such as populating R29 and R32 and configuring the jumpers.
2. Decrease the output of Load #1 to 2.5 V. This voltage is low enough for the BQ25611D to pre-charge.
3. Turn on PS1 and Load #1. The BQ25611D automatically begins to apply the default 0.18 A pre-charge current. The Charge Status register indicates this.

Charge Status Pre-Charge/Trick

4. Increase the output of Load #1 above $V_{BATLOWV}$ (typical value of 3.12 V). The BQ25611D begins applying the default 1.02 A fast charge current. The Charge Status register indicates this.

Charge Status Fast Charging

5 Hardware Design Files

The following section includes the hardware design files for the BQ25960HEVM. This section includes the schematic, PCB layout, and Bill of Materials (BOM)

5.1 Schematic

Figure 5-1 through Figure 5-3 illustrate the schematic for the BQ25960HEVM.

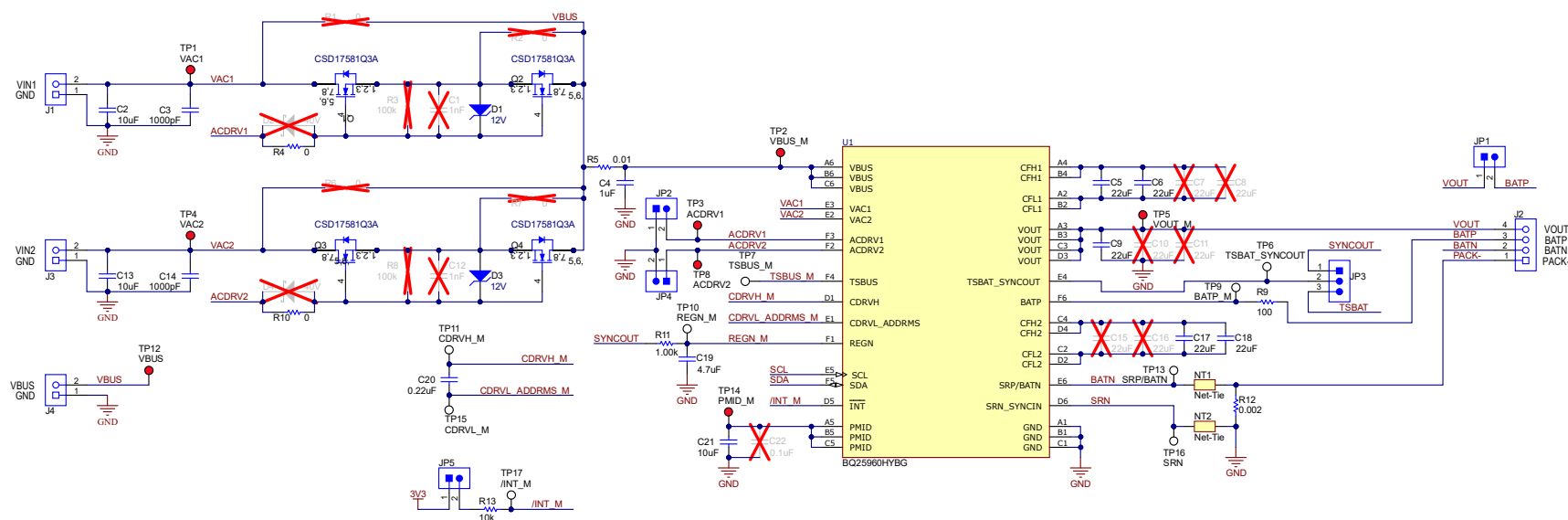


Figure 5-1. BQ25960HEVM Schematic (Page 1)

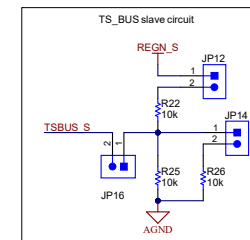
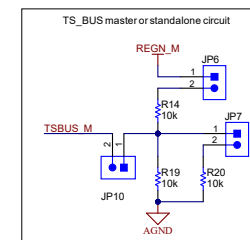
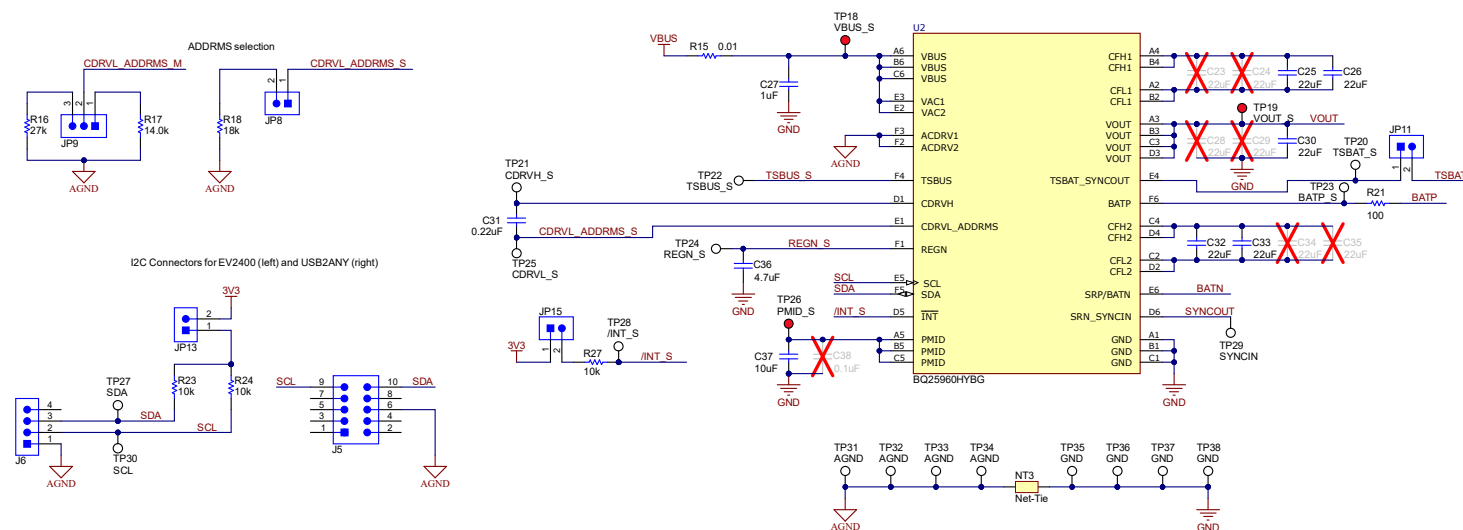


Figure 5-2. BQ25960HEVM Schematic (Page 2)



5.2 PCB Layout Guidelines

The PCB layout is very important to maximize the electrical and thermal performance of the total system. General guidelines are provided, but the form factor, board stack-up, and proximity of other components also need to be considered to maximize the performance.

1. VBUS and VOUT copper pours needs to be as short and wide as possible to accommodate high current.
2. VBUS and VOUT copper pours runs at least 150 mil (3.81 mm) straight (perpendicular to the WCSP ball array) before making turns.
3. CFLY caps needs to be placed as close as possible to the device, and the CFLY copper pours needs to be as wide as possible until close to the IC.
4. CFLY pours needs to be as symmetrical as possible between CFH pads and CFL pads.
5. Place low ESR bypass capacitors to ground for VBUS, PMID, and VOUT. These capacitors need to be placed as close to the device pins as possible.
6. The CFLY pads need to be as small as possible, and the CFLY caps placed as close as possible to the device, as these are switching pins and this helps reduce EMI.
7. Do not route so the power planes are interrupted by signal traces.

5.2.1 Board Layout

Figure 5-4 through Figure 5-11 illustrate the PCB layout.

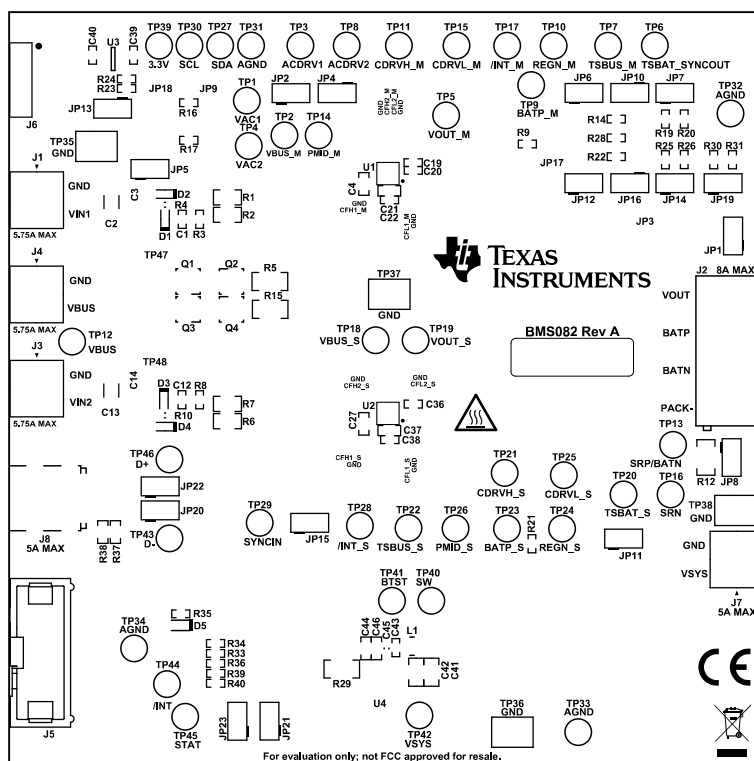


Figure 5-4. BMS082 Top Overlay

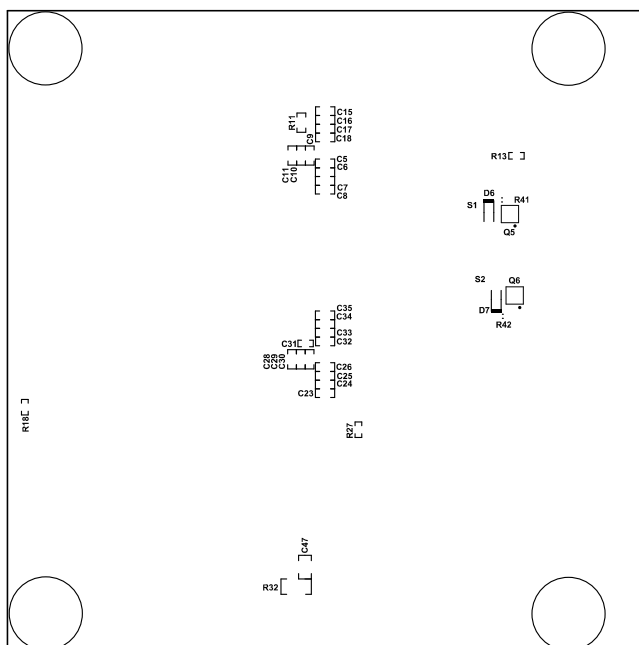


Figure 5-5. BMS082 Bottom Overlay

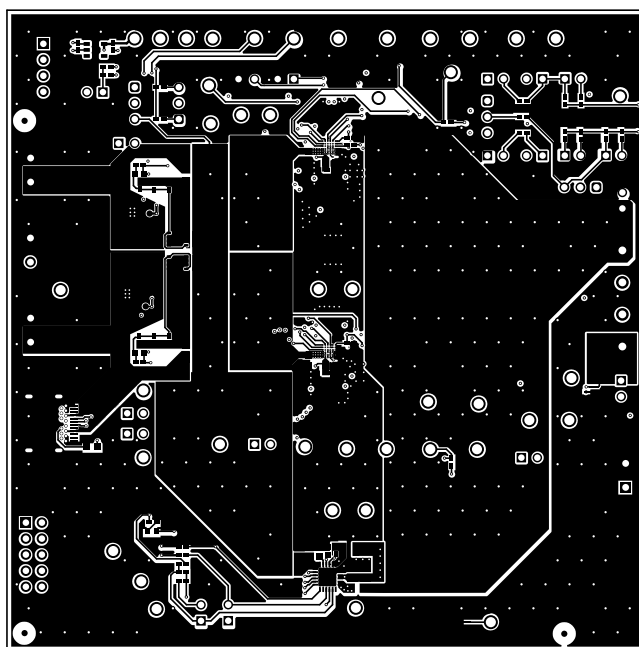


Figure 5-6. BMS082 Top Layer

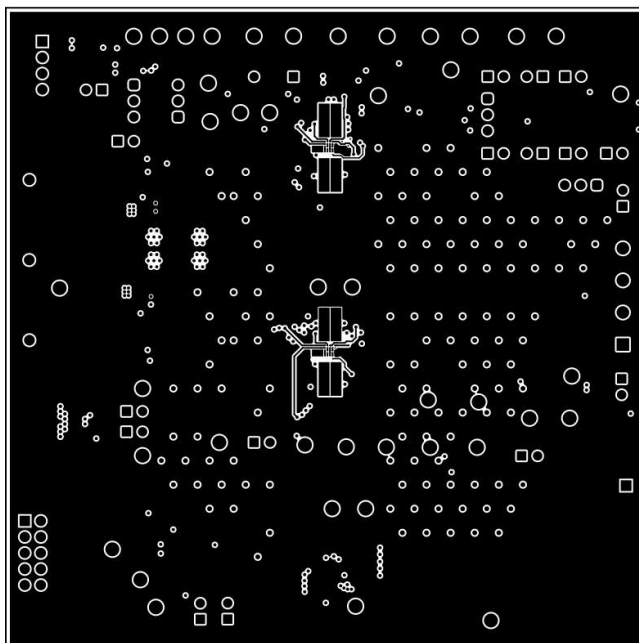


Figure 5-7. BMS082 Signal Layer 1

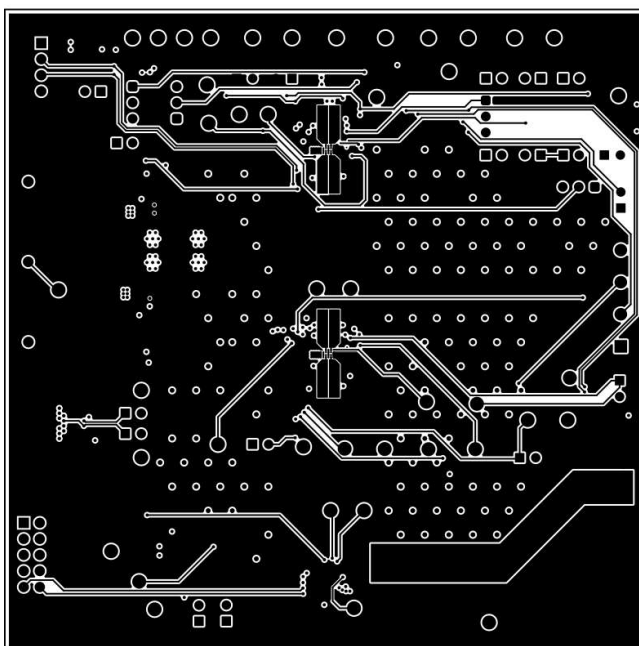


Figure 5-8. BMS082 Signal Layer 2

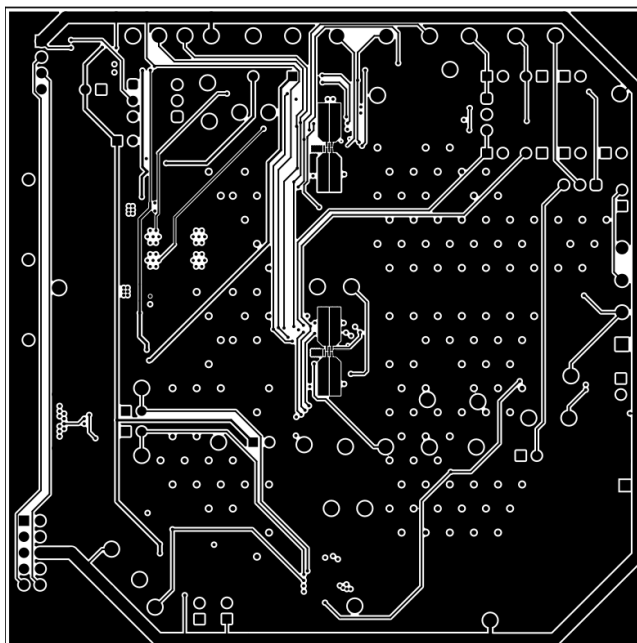


Figure 5-9. BMS082 Signal Layer 3

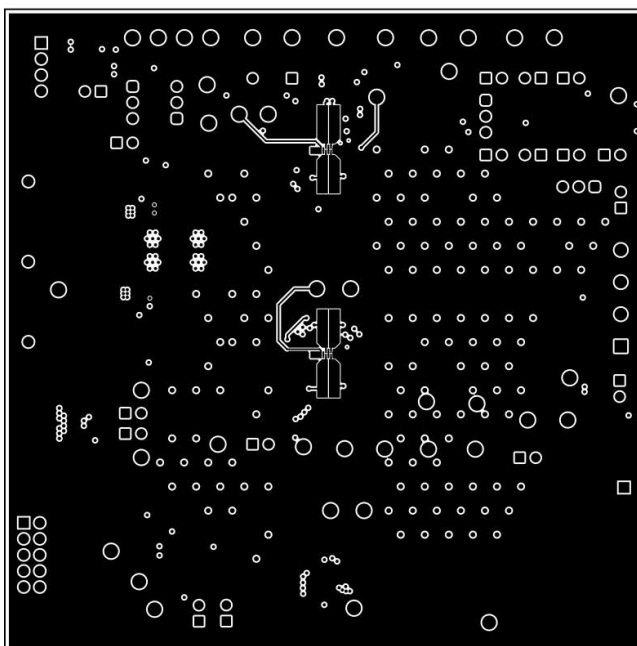


Figure 5-10. BMS082 Signal Layer 4

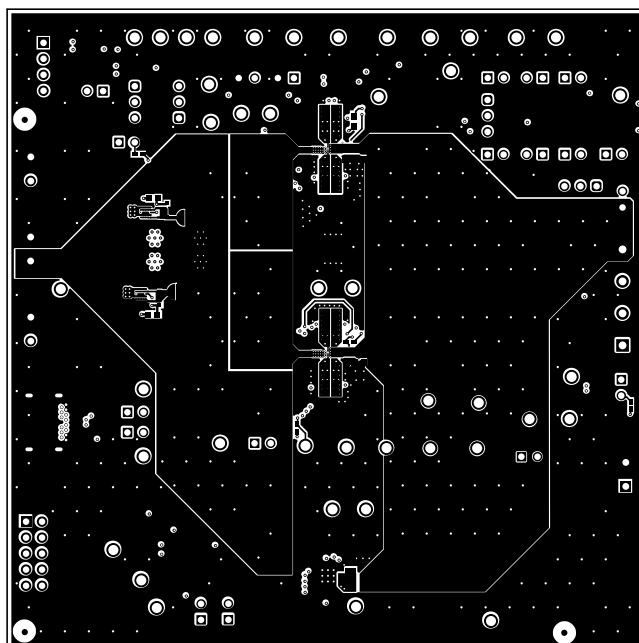


Figure 5-11. BMS082 Bottom Layer

5.3 Bill of Materials

Table 5-1. Bill of Materials

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
IPCB1	1		Printed Circuit Board		BMS082	Any
C2, C13	2	10uF	CAP, CERM, 10 uF, 50 V, +/- 10%, X5R, 1206	1206	C3216X5R1H106K160AB	TDK
C3, C14	2	1000 pF	CAP, CERM, 1000 pF, 50 V, +/- 5%, C0G/NP0, 0402	0402	GRM1555C1H102JA01D	MuRata
C4, C27, C44	3	1uF	CAP, CERM, 1 uF, 35 V, +/- 10%, X5R, 0603	0603	GMK107BJ105KA-T	Taiyo Yuden
C5, C6, C9, C17, C18, C25, C26, C30, C32, C33	10	22uF	CAP, CERM, 22 uF, 16 V, +/- 20%, X5R, 0603	0603	GRM188R61C226ME01D	MuRata
C19, C36	2	4.7uF	CAP, CERM, 4.7 uF, 10 V, +/- 20%, X5R, 0402	0402	GRM155R61A475MEAAD	MuRata
C20, C31	2	0.22uF	CAP, CERM, 0.22 uF, 25 V, +/- 10%, X5R, AEC-Q200, 0402	0402	GRT155R61E224KE01D	MuRata
C21, C37, C46	3	10uF	CAP, CERM, 10 uF, 35 V, +/- 20%, X5R, 0603	0603	GRM188R6YA106MA73D	Murata
C39	1	2.2uF	CAP, CERM, 2.2 uF, 10 V, +/- 10%, X5R, 0402	0402	C1005X5R1A225K050BC	TDK
C40	1	1uF	CAP, CERM, 1 uF, 35 V, +/- 10%, X5R, 0402	0402	GRM155R6YA105KE11D	MuRata
C41, C42, C47	3	10uF	CAP, CERM, 10 uF, 25 V, +/- 10%, X5R, 0805	0805	C2012X5R1E106K125AB	TDK
C43	1	0.047uF	CAP, CERM, 0.047 uF, 25 V, +/- 10%, X7R, 0402	0402	GRM155R71E473KA88D	MuRata
C45	1	4.7uF	CAP, CERM, 4.7 uF, 16 V, +/- 10%, X5R, 0603	0603	GRM188R61C475KAAJD	MuRata
D1, D3	2	12 V	Diode, Zener, 12 V, 300 mW, SOD-523	SOD-523	BZT52C12T-7	Diodes Inc.
D5	1	Green	LED, Green, SMD	1.6x0.8x0.8mm	LTST-C190GKT	Lite-On
D6, D7	2	5.6V	Diode, Zener, 12 V, 300 mV, SOD-323	SOD-323	MM3Z5V6ST1G	ON Semiconductor
FID1, FID2, FID3, FID4, FID5, FID6	6		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.44 X 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M
J1, J3, J4, J7	4		Conn Term Block, 2POS, 3.81mm, TH	2POS Terminal Block	1727010	Phoenix Contact
J2	1		Terminal Block, 5.08 mm, 4x1, Brass, TH	4x1 5.08 mm Terminal Block	ED120/4DS	On-Shore Technology
J5	1		Header (shrouded), 100mil, 5x2, High-Temperature, Gold, TH	5x2 Shrouded header	N2510-6002-RB	3M
J6	1		Header (friction lock), 100mil, 4x1, R/A, TH	4x1 R/A Header	22/05/3041	Molex
J8	1		Connector, Receptacle, USB Type C, R/A	Connector, Receptacle, USB Type C, R/A, THT/SMT	632723300011	Wurth Elektronik
JP1, JP2, JP4, JP5, JP6, JP7, JP8, JP10, JP11, JP12, JP13, JP14, JP15, JP16, JP19, JP20, JP21, JP22, JP23	19		Header, 100mil, 2x1, Tin, TH	Header, 2 PIN, 100mil, Tin	PEC02SAAN	Sullins Connector Solutions
JP3, JP9, JP17, JP18	4		Header, 2.54 mm, 3x1, Tin, TH	Header, 2.54 mm, 3x1, TH	TSW-103-07-T-S	Samtec
L1	1	1uH	Inductor, 1 uH, 3.7 A, 0.045 ohm, SMD	2.5x2mm	AMELA2012S-1R0MT,	Abracon LLC
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
Q1, Q2, Q3, Q4	4	30 V	MOSFET, N-CH, 30 V, 60 A, DNH0008A (VSONP-8)	DNH0008A	CSD17581Q3A	Texas Instruments
R4, R10	2	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R5, R15	2	0.01	RES, 0.01, 1%, 1 W, 1206	1206	WSLP1206R0100FEA	Vishay-Dale
R9, R21	2	100	RES, 100, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402100RFKED	Vishay-Dale
R11	1	1.00k	RES, 1.00 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06031K00FKEA	Vishay-Dale
R12	1	0.002	RES, 0.002, 1%, 1 W, 1206	1206	CSNL1206FT2L00	Stackpole Electronics Inc

Table 5-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
R13, R14, R19, R20, R22, R23, R24, R25, R26, R27, R28, R30, R31, R33, R34	15	10k	RES, 10 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0JNED	Vishay-Dale
R16	1	27k	RES, 27 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040227K0JNED	Vishay-Dale
R17	1	14.0k	RES, 14.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040214K0FKED	Vishay-Dale
R18	1	18k	RES, 18 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040218K0JNED	Vishay-Dale
R35	1	2.21k	RES, 2.21 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04022K21FKED	Vishay-Dale
R36	1	5.23k	RES, 5.23 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04025K23FKED	Vishay-Dale
R37, R38	2	5.1k	RES, 5.1 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06035K10JNEA	Vishay-Dale
R39	1	30.1k	RES, 30.1 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040230K1FKED	Vishay-Dale
R40	1	10.0k	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0FKED	Vishay-Dale
SH-JP1, SH-JP2, SH-JP3, SH-JP4, SH-JP5, SH-JP6, SH-JP7, SH-JP8, SH-JP9, SH-JP10, SH-JP11, SH-JP12, SH-JP13, SH-JP14, SH-JP15, SH-JP16, SH-JP17, SH-JP18, SH-JP19, SH-JP20, SH-JP21, SH-JP22, SH-JP23	23	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec
TP1, TP2, TP3, TP4, TP5, TP8, TP12, TP14, TP18, TP19, TP26, TP40, TP41, TP42	14		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone
TP6, TP7, TP9, TP10, TP11, TP13, TP15, TP16, TP17, TP20, TP21, TP22, TP23, TP24, TP25, TP27, TP28, TP29, TP30, TP31, TP32, TP33, TP34, TP43, TP44, TP45, TP46	27		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone
TP35, TP36, TP37, TP38	4		Test Point, Compact, SMT	Testpoint_Keystone_Compact	5016	Keystone
TP39	1		Test Point, Compact, Orange, TH	Orange Compact Testpoint	5008	Keystone
U1, U2	2		6 A Switched Cap Battery Charger with Integrated Protection, I2C Programmability and ADC	DSBGA36	BQ25960HYBG	Texas Instruments
U3	1		150-mA, 30-V, Ultra-Low IQ, Wide Input Low-Dropout Regulator with Reverse Current Protection, DBV0005A (SOT-23-5)	DBV0005A	TPS70933DBVR	Texas Instruments
U4	1		3 A I2C Controlled 1-Cell Buck Battery Charger with USB Detection and 1.2A Boost Operation	RTW0024P	BQ25611DRTW	Texas Instruments
C1, C12	0	1000 pF	CAP, CERM, 1000 pF, 50 V, +/- 1%, C0G/NP0, 0402	0402	GRM1555C1H102FA01D	MuRata
C7, C8, C10, C11, C15, C16, C23, C24, C28, C29, C34, C35	0	22uF	CAP, CERM, 22 uF, 16 V, +/- 20%, X5R, 0603	0603	GRM188R61C226ME01D	MuRata
C22, C38	0	0.1uF	CAP, CERM, 0.1 uF, 35 V, +/- 10%, X5R, 0402	0402	GMK105BJ104KV-F	Taiyo Yuden
D2, D4	0	40 V	Diode, Schottky, 40 V, 0.38 A, SOD-523	SOD-523	ZLLS350TA	Diodes Inc.
Q5, Q6	0	40 V	40 V Bi-GaN Enhancement-mode FET	WLCSP22	INN040W048A	Innoscence
R1, R2, R6, R7	0	0	RES, 0, 5%, 0.333 W, AEC-Q200 Grade 0, 0805	0805	CRCW08050000Z0EAHP	Vishay-Dale
R3, R8	0	100k	RES, 100 k, 1%, 0.0625 W, 0402	0402	RC0402FR-07100KL	Yageo America
R29, R32	0	0	RES, 0, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	1206	CRCW12060000Z0EA	Vishay-Dale

Table 5-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
R41, R42	0	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06030000Z0EA	Vishay-Dale

6 Additional Information

Trademarks

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STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.
 - 1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software
 - 1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.
2. *Limited Warranty and Related Remedies/Disclaimers:*
 - 2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.
 - 2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.
 - 2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGRADATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 Regulatory Notices:

3.1 United States

3.1.1 Notice applicable to EVMs not FCC-Approved:

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 Canada

3.2.1 For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

3.3 Japan

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/sds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

<https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html>

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/sds/ti_ja/general/eStore/notice_02.page

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3.4 European Union

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive):*

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

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8. *Limitations on Damages and Liability:*

8.1 *General Limitations.* IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMNITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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