

bq77915 3-5S Low Power Protector Evaluation Module

This evaluation module (EVM) is a complete evaluation system for the [bq77915](#) 3-5S low power protector for lithium-ion cells. The EVM includes one bq77915 and FETs to control current in a configuration typical for switching current in a lithium-ion battery pack. The circuit module includes one bq77915 integrated circuit (IC), sense resistors, thermistor, two [CSD18534Q5A](#) FETs, and all other onboard components necessary to switch charge and discharge current. The circuit module connects between a *battery* source and a *pack* load. In addition to the current and voltage applied to the module, the user can remove onboard jumpers to simulate overtemperature or undertemperature conditions to observe FET control under different charge and discharge conditions. Balancing of unmatched cells can also be performed on the module.

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1 ⁽¹⁾ Features

The bq77915EVM has the following features:

- Complete evaluation system for the bq77915 3-5S low power protector IC
- Populated circuit module for quick setup

1.1 Kit Contents

The bq77915EVM contains the following:

- bq77915 circuit module

1.2 Ordering Information

The EVM orderable part number is bq77915EVM-014. For complete ordering information, see the product page at www.ti.com.

1.3 Documentation

For more information on device hardware, refer to [bq77915 3-5S Low Power Protector with Cell Balancing and Hibernate Mode](#).

1.4 bq77915 Circuit Module Performance Specification Summary

This section summarizes the performance specifications of the bq77915EVM.

Table 1. Performance Specification Summary

Specification	Minimum	Typical	Maximum	Unit
Input voltage BATT+ to BATT-	3	18	22	V
Output voltage PACK+ to PACK-	0	18	22	V
Charge and discharge current	0	2.5	4	A
Cell Balancing Current			50	mA
Operating temperature	20	25	30	°C

2 bq77915EVM Quick-Start Guide

This section provides the step-by-step procedures required to use a new EVM and configure it for operation in a laboratory environment.

2.1 Before You Begin

The following warnings and cautions are noted for the safety of anyone using or working close to the bq77915 EVM. Observe all safety precautions.

CAUTION

The circuit module has signal traces and component leads on the bottom of the board. This may result in exposed voltages, hot surfaces, or sharp edges. Do not reach under the board during operation. Do not operate the EVM on a conductive surface.

⁽¹⁾ All trademarks are the property of their respective owners.

CAUTION

The circuit module may be damaged by overtemperature. To avoid damage, monitor the temperature during evaluation and provide cooling, as needed, for your system environment.

CAUTION

Some power supplies can be damaged by application of external voltages. If using more than one power supply, check your equipment requirements and use blocking diodes or other isolation techniques, as needed, to prevent damage to your equipment.

CAUTION

The circuit module is not a finished product or electrical appliance. It must be used by qualified personnel with additional equipment for evaluation only. Do not leave EVM powered when unattended.

2.2 Items Needed for EVM Quick Start Evaluation

- A bq77915 circuit module
- An adjustable DC power supply that can provide 10 V to 22 V and 1 A minimum (a voltage range, bipolar operation, and constant current – constant voltage capability is desirable)
- Five resistors for cell voltage simulation such as 200 Ω, 1% 1/4-W or other suitable value
- A load such as a 5-kΩ, 1/4-W or other suitable resistor
- A DC meter or measurement instrument
- Some suitable cables for connection

2.3 EVM Connections

This section covers the hardware connections for the EVM (see Figure 1).

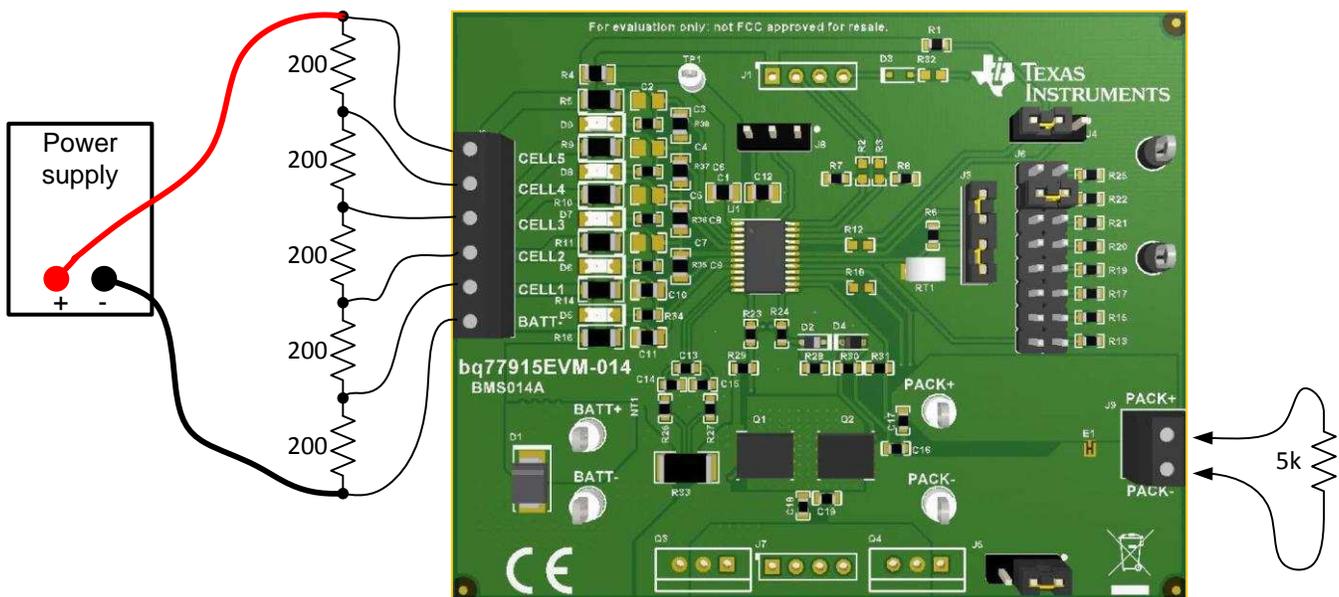


Figure 1. bq77915 Circuit Module Connection for Simple Demonstration

- Supply terminal block (J2)
These are the supply terminals for the board. BATT+ or CELL5 is the positive terminal of the power supply and BATT– is the negative terminal of the power supply. The inputs CELL1 through CELL4 are divided between the BATT+ and BATT– voltages. When using a power supply for evaluation, be sure the power supply can accept or is protected from any reverse current such as with a blocking diode if another supply is used in the system.
- Pack terminals (J9)
PACK+ and PACK– terminals are for attachment for the load or charger. If using a power supply to simulate a charger, be sure it can accept or is protected from any reverse current.
- Shunts on J3
Shunts should be placed shorting J3 pins 1 to 2 and pins 3 to 4. The shunt on pins 1 and 2 connects the IC VTB pin to the temperature measurement path. A hot temperature is simulated when the shunt on pins 1 to 2 is removed. The shunt on pins 3 and 4 connects the IC TS pin to the thermistor. A cold temperature is simulated when the shunt is removed.
- Shunt on J4
A shunt should be placed shorting J4 pins 2 to 3. The shunt pulls up the IC PRES pin to wake the IC. Remove the shunt to allow the part to hibernate.
- Shunt on J5
A shunt should be placed shorting J5 pins 1 to 2. The shunt pulls down the IC CBI pin to enable cell balancing. Remove the shunt to disable cell balancing.
- Shunt on J6
A shunt should be placed shorting J6 pins 13 to 14. The 100-k Ω OCDP resistor connected by the shunt selects the EEPROM defined OCD delays. See [bq77915 3-5S Low Power Protector with Cell Balancing and Hibernate Mode](#) for a description of OCDP options.

2.4 Quick-Start Sequence

These steps describe a simple demonstration or check of the operation of the bq77915EVM in a 5S configuration with a typical 18-V stack voltage.

1. Connect five 200- Ω resistors between the cell terminals of J3.
2. Confirm that shunts are in place on J3 shorting pins 1 to 2 and 3 to 4.
3. Confirm a shunt is in place on the J4 pins 2 to 3 to enable the IC.
4. Confirm a shunt is in place on the J5 pins 1 to 2 to enable balancing.
5. Confirm a shunt is in place on the J6 pins 13 to 14 to select the EEPROM-defined OCD delays.
6. Connect an 18-V adjustable DC power supply across the BATT+ and BATT– terminals of J3.
7. Enable the supply.
8. Measure the voltage on the pack terminals. Observe that this is the same voltage as the supply because both charge and discharge FETs are on, approximately 18 V.
9. Connect a load such as a 5-k Ω resistor across the PACK terminals
10. Adjust the supply voltage to 22 V to simulate an overvoltage condition. Observe that the voltage on the PACK terminals is approximately 600 mV below the supply voltage because the charge FET is off.
11. Adjust the supply voltage to 18 V to cause recovery from the overvoltage condition. Observe that the voltage on the PACK terminals is the supply voltage.
12. Remove the shunt on pins 1-2 of J4 to simulate a hot condition. Observe that the pack voltage drops to approximately 0 V, and returns to normal when the shunt is re-installed.
13. Remove the shunt on pins 3-4 of J4 to simulate a cold condition. Observe that the pack voltage drops to approximately 0 V and returns to normal when the shunt is re-installed.
14. Adjust the supply voltage to 12 V to simulate an undervoltage condition. Observe that the pack voltage drops to approximately 0 V.
15. Adjust the supply voltage to 18 V to allow recovery from the undervoltage condition. Observe that the pack voltage remains at approximately 0 V with the load resistor in place.

16. Remove the load resistor on the PACK terminals. Observe that the pack voltage returns to the supply voltage because undervoltage recovers on the installed part configuration with both voltage and load removal.
17. Disable the power supply and disconnect, if complete.

3 Additional Evaluation Setups

CAUTION

The bq77915 EVM does not contain capacitors on the input or output current paths to dampen transients. Be sure to use appropriate transient suppression to avoid damage to the board from cable or equipment transient responses during evaluation.

3.1 Operation With Charge and Discharge Currents

If bipolar power supplies are available, current control can be demonstrated through the board in both directions, see [Figure 2](#). A battery voltage in range must be applied to the BATT side of the EVM for operation. The instrument on the PACK side can be used as a load if it is set to a lower voltage than the battery side or as a charger if set to a higher voltage. Additional equipment can be used to adjust the voltage across the individual input resistors to simulate different cell voltages.

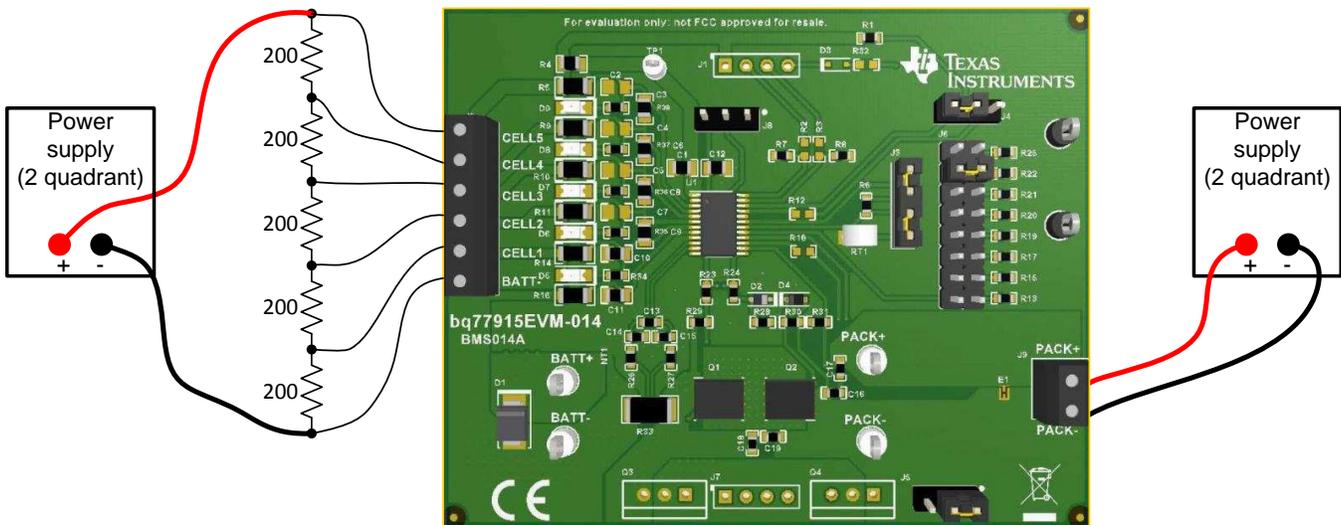


Figure 2. Bipolar Operation

Operation can also be demonstrated with conventional supplies and loads. Connect and operate the equipment within its performance limits.

3.2 Reducing the Cell Count

The bq77915 EVM may be modified to provide monitoring of three or four cells. [Figure 3](#) shows a concept of simple three-cell evaluation. Cells are connected from the bottom up with unused top-cell inputs connected to the top cell at J2. While this is not the direct IC pin connection shown in the data sheet, it will work for general evaluation. The CCFG pin must also be connected to AVDD or GND to select monitoring of three or four cells. This can be done by adding a jumper at the J8 pattern between pins 1 and 2 or 2 and 3 as desired. If the board will be used for further evaluation, be sure to remove the jumper at J8 after the reduced cell test.

CAUTION

With a jumper installed at the J8 pattern, the bq77915 will not evaluate the top one or two cells depending on the jumper installation. Remove any jumper to monitor all cell inputs.

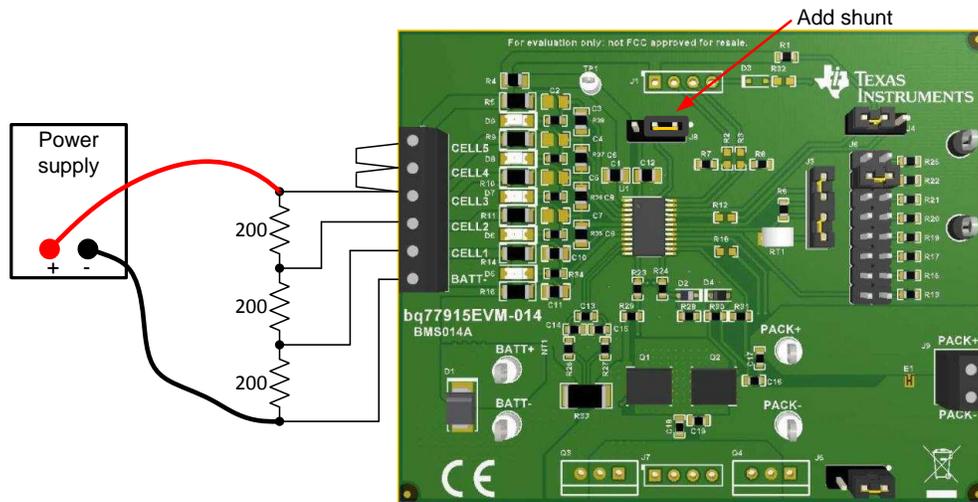


Figure 3. Operation With Reduced Cell Count

3.3 Connecting to Cells

TI recommends operating the bq77915 EVM with power supplies to become familiar with the operation and features of the module and bq77915 before connecting cells. The bq77915 EVM may be connected to cells so that the cells can provide the power for the bq77915, a concept is shown in Figure 4. The cells should be connected together before connecting to the board. The BATT- connection should be made first, then other cell connections can be made in any sequence.

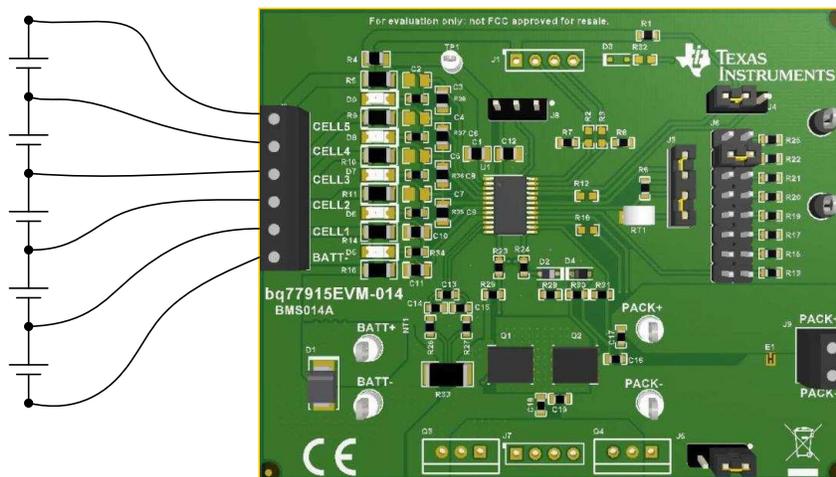


Figure 4. Connecting to Cells

3.4 Stacking Modules

While the bq77915 EVM modules do not stack as delivered, they can be modified for a basic demonstration of stacking by adding additional components. The resulting circuit is not ideal because the ESD capacitors will remain across each module rather than across the pack terminals. The charge and discharge FETs installed are 60-V rated and will normally accommodate connection of two EVMs. Connection of more than two EVMs is not supported by the patterns on the board and is not recommended. Before connecting the modules, the bottom and top modules must have component additions and changes shown in [Table 2](#) to enable the stacking inputs and support the UV load removal recovery detection for the upper device. Next, connect the upper board J7 to the lower board J1. Also connect the upper board J5 pins 1 and 3 to the lower board J4 pins 1 and 3, respectively. The top board must also have a wire connecting the BATT- pin on J2 to the PACK- pin on J9. A connection example of the two modules is shown in [Figure 5](#).

Table 2. Module Modifications for Stacking

Module	Reference Designator	Action	Function
Bottom	R2	Install 10-M Ω resistor	Stacking interface
	R3	Install 10-M Ω resistor	
	R7	Remove	
	R8	Remove	
	R12	Install 10-k Ω resistor	
	J4	Remove shunt	UV load detect recovery
	R32	Install 470-k Ω resistor	
	D3	Install BAS16J switching diode	
Top	R18	Install 10-k Ω resistor	Stacking interface
	J5	Remove shunt	
	J6	Move shunt to pins 15 and 16	

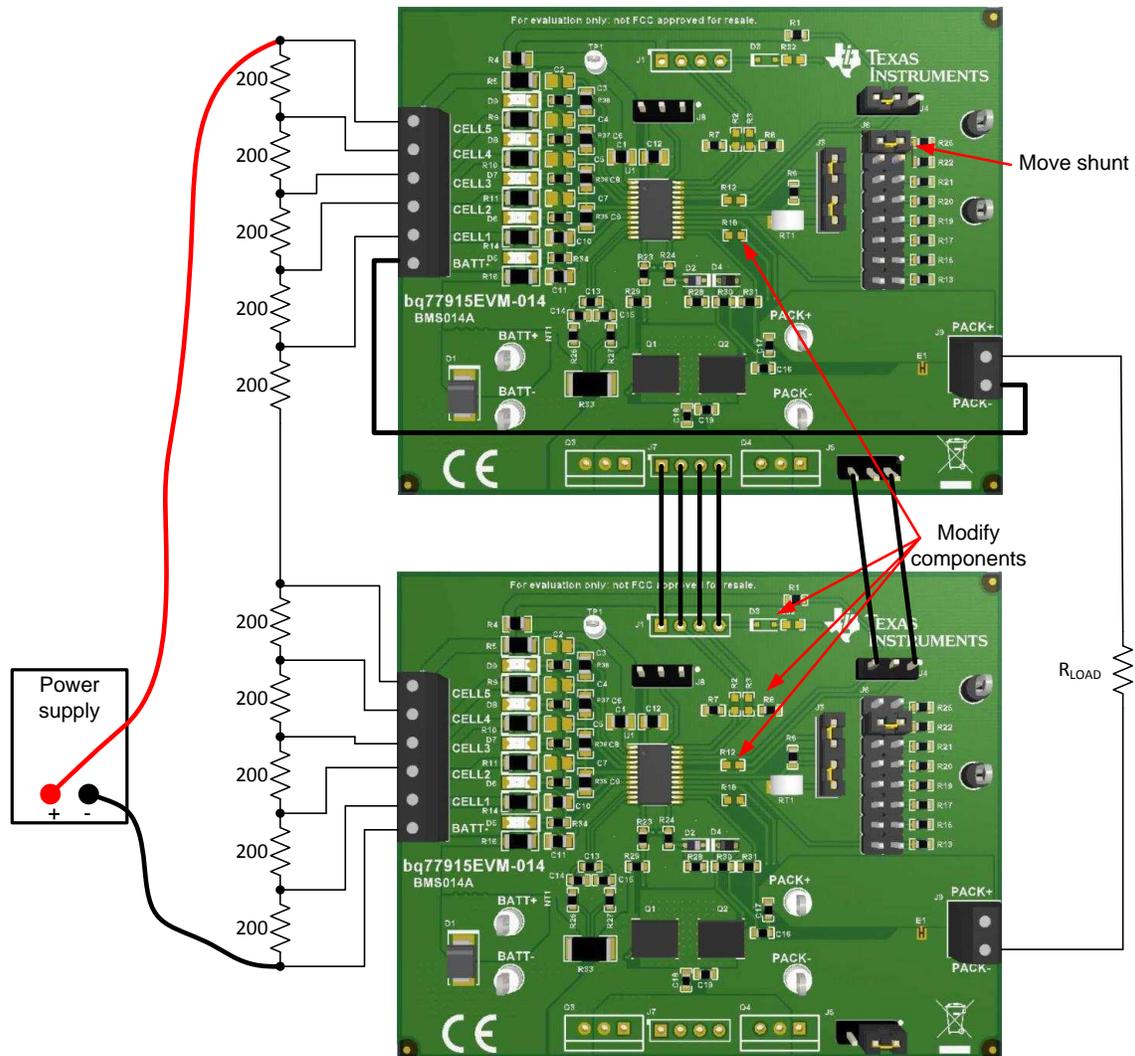


Figure 5. Stacking Circuit Modules

CAUTION

The bottom bq77915 module will not receive fault conditions from the top module unless properly modified and connected. Confirm operation of your modified evaluation setup.

Once modified, the bottom module will not enable FETs when disconnected from the top module.

The stacked modules hibernate when the shunt is removed from the top module J4. Installing the shunt on the top module J4 pins 2 to 3 exits hibernate mode. Cell balancing for the stacked modules is enabled by installing a shunt on the bottom module J5 pins 1 to 2, removing the shunt disables cell balancing. The shunt on the top module J6 should be moved to pins 15 and 16 to select the 10-M Ω OCPD resistance, see the data sheet.

3.5 Troubleshooting

If the bq77915 does not appear to be operating, check the VDD voltage at TP1 as this should be the same as the BATT+ voltage. Check that the shunt is installed at J4 pins 2 to 3 to exit hibernate mode. Check the AVDD voltage at J8 pin 3, this should be approximately 2.5 V. Check that the shunts are installed on J3 shorting pins 1 to 2 and pins 3 to 4. Check that the cell input voltages are within the operating range of the part. If a fault has been induced, check that the recovery condition has been met. The configuration of the supplied IC requires load removal for recovery from undervoltage; therefore, remove any load from the PACK terminals or supply a charge voltage to recover from UV after the cell voltages have returned to normal. The [Section 2.4](#) section is a good procedure to check the basic operation of the board. If the board has been used for stacking evaluation be sure the R7 and R8 resistors have been replaced.

3.6 Changing Configuration or Conditions

If the board is modified to change the IC or other components or is operated at an expanded temperature range, be sure to check component temperatures and other operating characteristics to be sure the board does not provide a hazard in evaluation. A sample IC device may allow more current flow with higher surface temperatures. Alternate FETs may require a change to the gate resistor to provide an appropriate switching time.

4 bq77915EVM Optional Circuit Features

This section contains information on other EVM features.

4.1 Alternate FETs

The EVM has TO-220 footprints for use as test points or power FETs as options for evaluation.

4.2 Single-Ended Filter Capacitors

C2, C4, C5, and C7 are patterns for single-ended filters on the battery input terminals, if desired. With the internal cell balancing, differential capacitors may be preferred, they distribute voltages during cell connection and avoid conduction of the internal balance FET body diodes. VC1 should use a single-ended capacitor to avoid pushing VC0 below VSS during load transients.

4.3 Other Uninstalled Components

The bq77915 EVM contains patterns for the stacking interface. Refer to [Section 5.2](#) and [Section 3](#) for additional information.

4.4 Cell Balance Indicators

The bq77915 EVM contains LED indicators with current-limit resistors in parallel with the input filter resistors. These indicators are not typically part of a battery circuit but are provided for evaluation. The indicators will glow dimly when balancing with a low-impedance source. When operated with a resistor cell simulator, the indicators will not typically illuminate since the resistor voltage will drop when balancing turns on. To see the indicator, enable balancing with the J5 shunt, apply a supply voltage across the cell and raise its voltage above the other cells and the balancing or OV threshold. Do not increase the cell voltage significantly beyond OV to make the indicator brighter since higher balancing current into the bq77915 may exceed the absolute maximum rating.

4.5 OCD Timing

The EVM supports changing the overcurrent protection delay by moving the jumper on J6 to select different resistor values for the OCDP pin. See [bq77915 3-5S Low Power Protector with Cell Balancing and Hibernate Mode](#) for details and the EVM schematic ([Figure 12](#)) for supported resistors.

5 Circuit Module Physical Layouts

This section contains the printed-circuit board (PCB) layout, assembly drawings, and schematic for the bq77915 circuit module.

5.1 Board Layout

This section shows the PCB layers and assembly drawing for the bq77915 module (see Figure 6 through Figure 11). The board is a single-sided assembly, no components are located on the bottom.

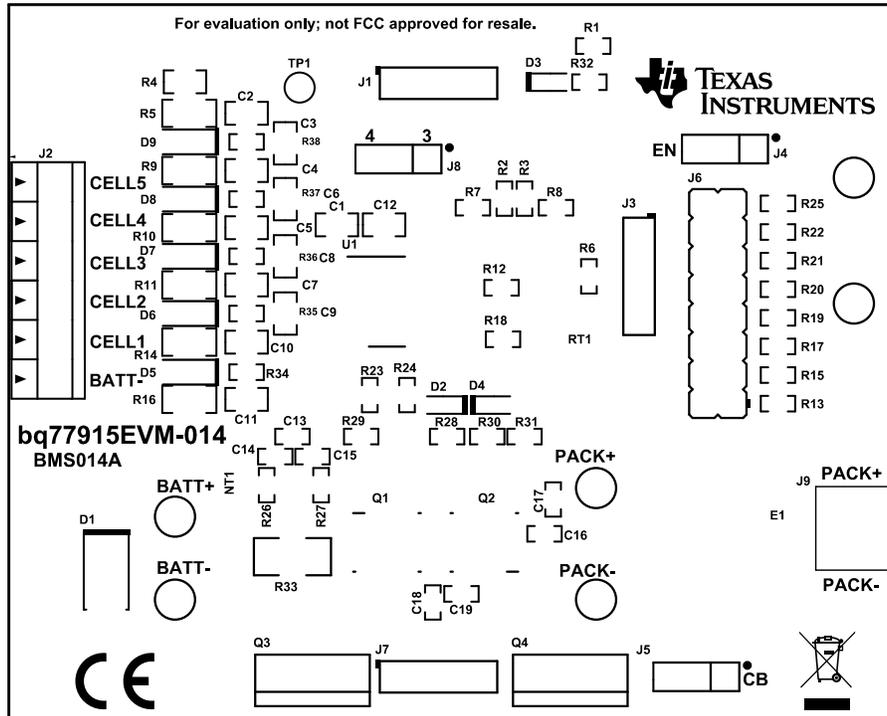


Figure 6. Top Silk Screen

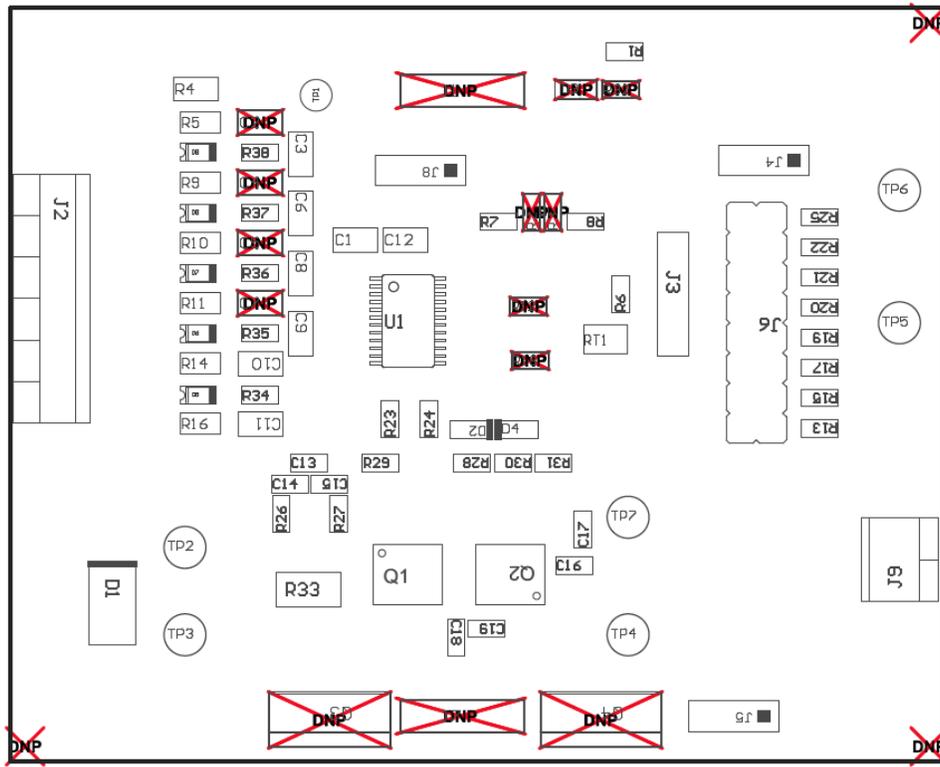


Figure 7. Top Assembly

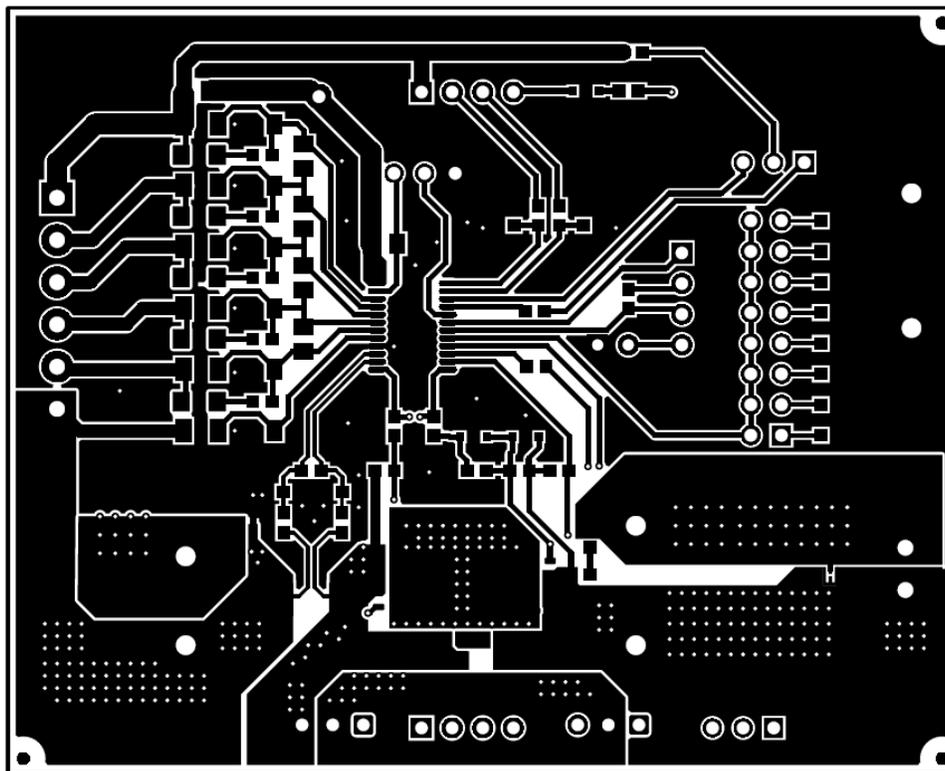


Figure 8. Top Layer

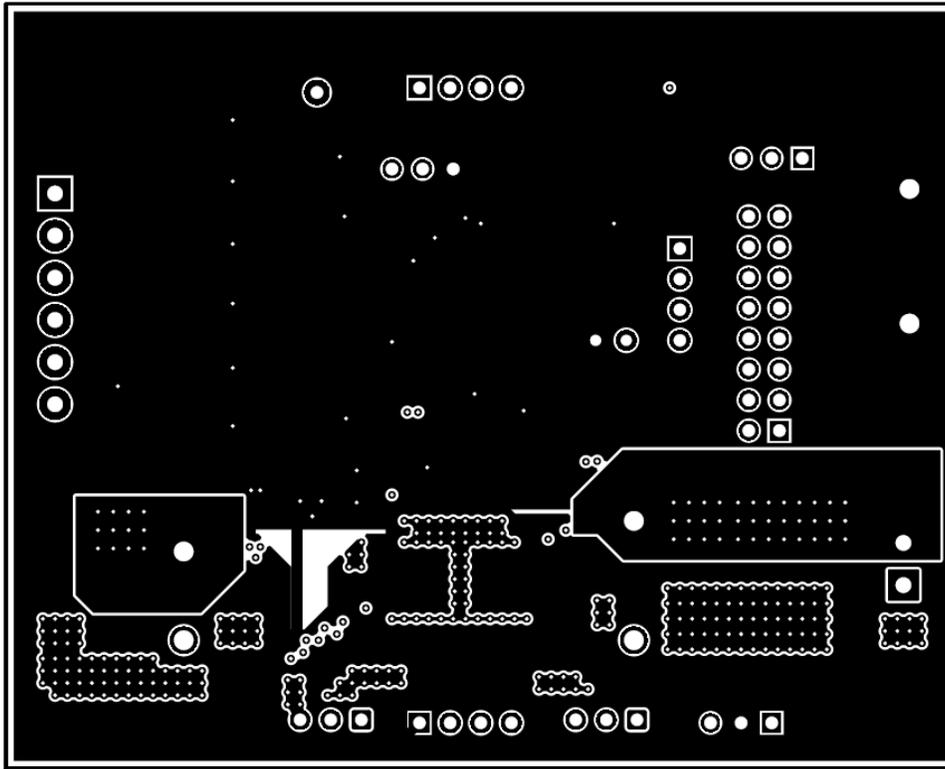


Figure 9. Internal Layer 1

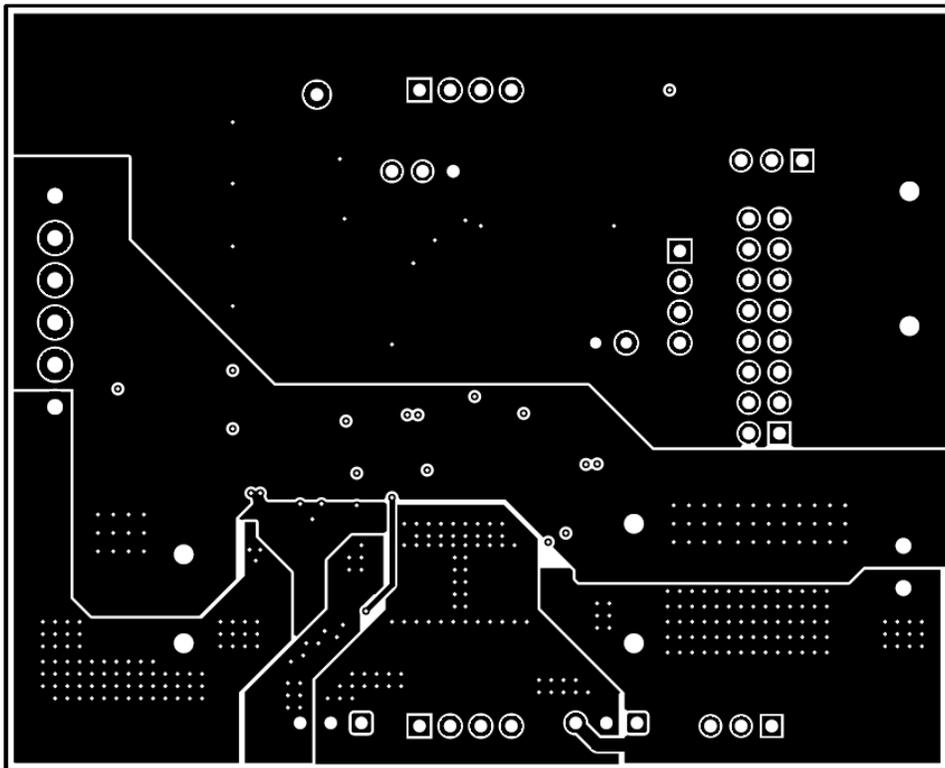


Figure 10. Internal Layer 2

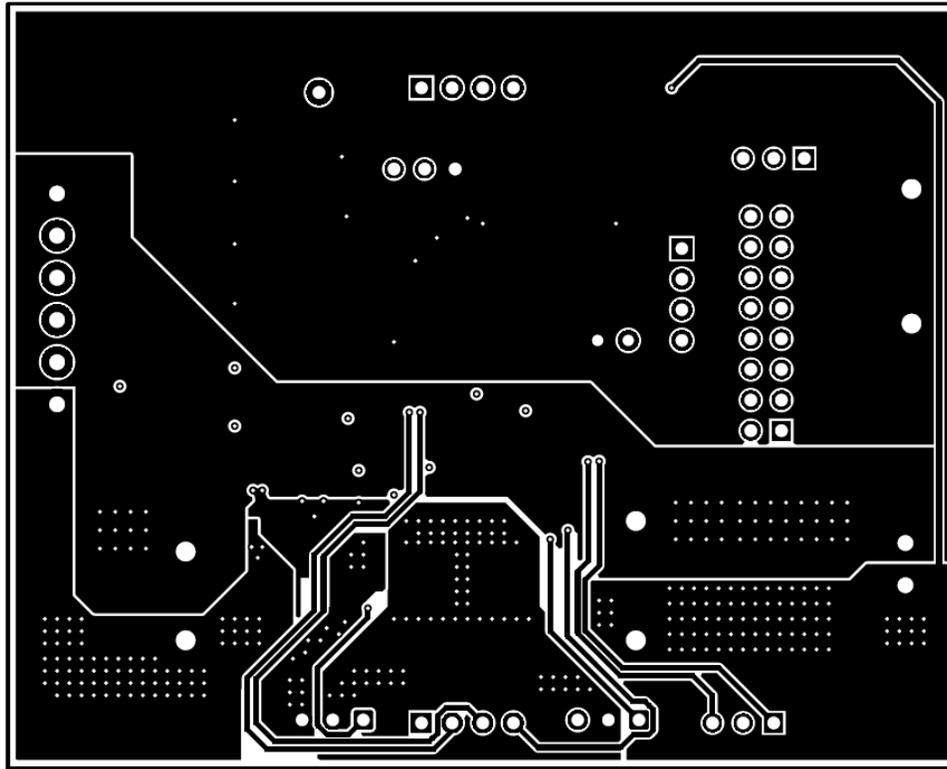


Figure 11. Bottom Layer

5.2 Schematic

Figure 12 and Figure 13 show the bq77915EVM schematic.

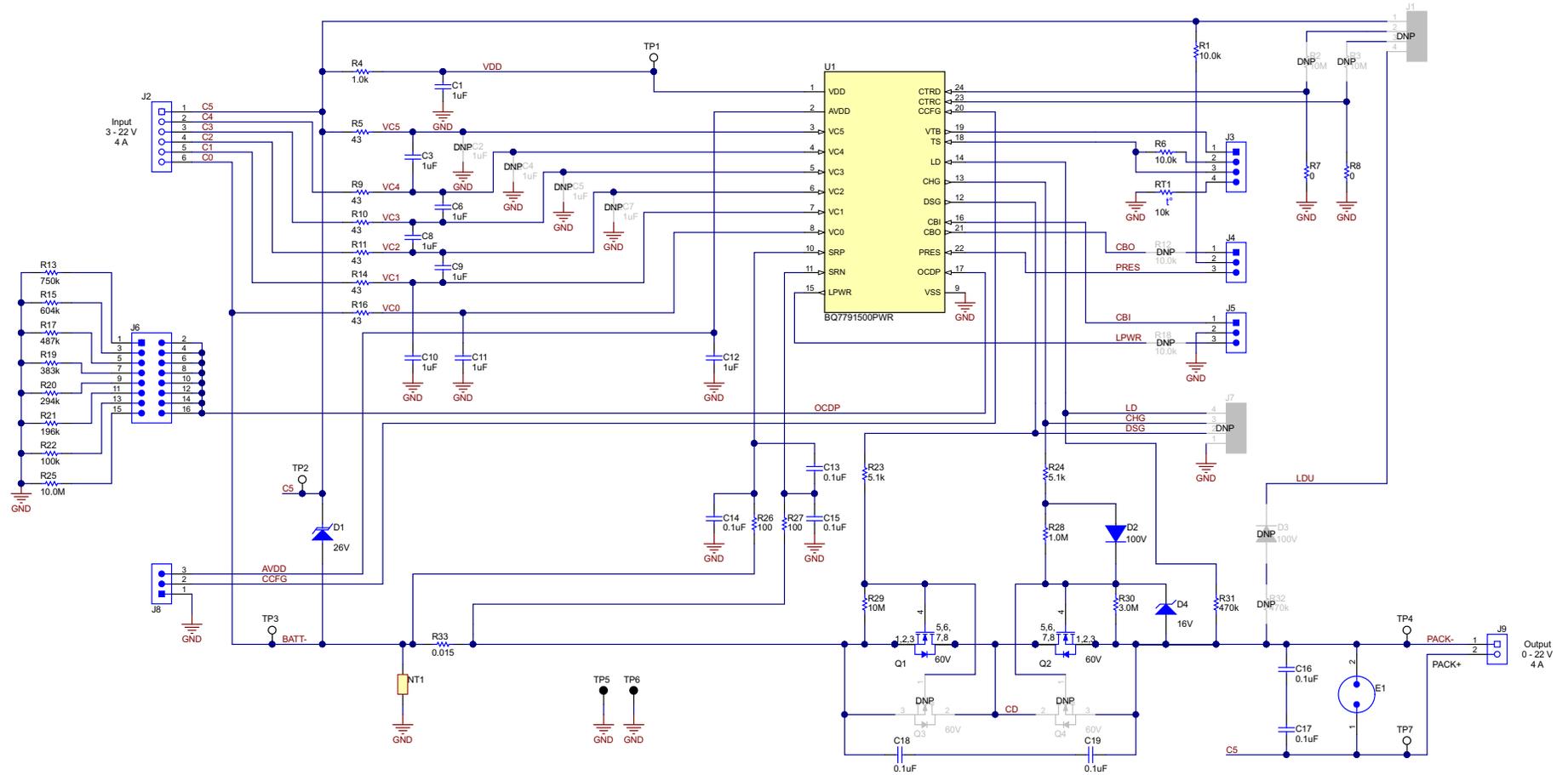


Figure 12. bq77915EVM Schematic

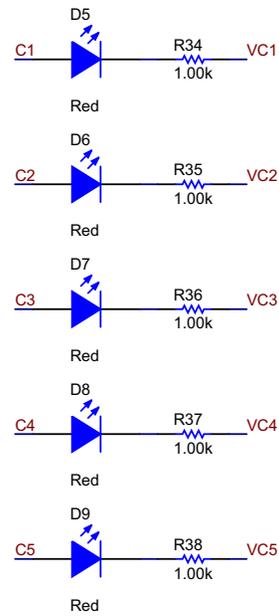


Figure 13. bq77915EVM Cell Balance Indicator Schematic

6 Bill of Materials

Table 3 lists the bq77915EVM bill of materials (BOM).

Table 3. bq77915EVM Bill of Materials ⁽¹⁾

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
!PCB1	1		Printed Circuit Board		BMS014	Any		
C1	1	1µF	CAP, CERM, 1µF, 50 V, ±10%, X7R, 0805	0805	GRM21BR71H105KA12L	Murata		
C3, C6, C8, C9, C10, C11, C12	7	1µF	CAP, CERM, 1µF, 10V, ±10%, X7R, 0805	0805	GRM21BR71A105KA01L	Murata		
C13, C14, C15, C16, C17, C18, C19	7	0.1µF	CAP, CERM, 0.1µF, 50V, ±10%, X7R, 0603	0603	06035C104KAT2A	AVX		
D1	1	26V	Diode, TVS, 26V, 42.1 Vc, SMB	SMB	SMBJ26A-13-F	Diodes Inc.		
D2	1	100V	Diode, Switching, 100V, 0.25A, SOD-323F	SOD-323F	BAS16J,135	Nexperia USA Inc.		
D4	1	16V	Diode, Zener, 16V, 200mW, SOD-323	SOD-323	MMXZ5246B-TP	Micro Commercial Co.		
D5, D6, D7, D8, D9	5	Red	LED, Red, SMD	3x1.5mm	BR1101W-TR	Stanley electric Co.		
H9, H10, H11, H12	4		Bumpon, Hemisphere, 0.44 X 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M		
J2	1		Terminal Block, 3.5mm Pitch, 6x1, TH	20.5x8.2x6.5mm	ED555/6DS	On-Shore Technology		
J3	1		Header, 100mil, 4x1, Tin, TH	Header, 4x1, 100mil, TH	PEC04SAAN	Sullins Connector Solutions		
J4, J5, J8	3		Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin	PEC03SAAN	Sullins Connector Solutions		
J6	1		Header, 2.54 mm, 8x2, Tin, Vertical, TH	Header, 2.54 mm, 8x2, TH	PEC08DAAN	Sullins Connector Solutions		
J9	1		Terminal Block, 3.5mm Pitch, 2x1, TH	7.0x8.2x6.5mm	ED555/2DS	On-Shore Technology		
Q1, Q2	2	60V	MOSFET, N-CH, 60V, 50A, DQJ0008A (VSONP-8)	DQJ0008A	CSD18534Q5A	Texas Instruments		
R1, R6	2	10.0k	RES, 10.0k, 1%, 0.1W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale		
R4	1	1.0k	RES, 1.0k, 5%, 0.125W, 0805	0805	CRCW08051K00JNEA	Vishay-Dale		
R5, R9, R10, R11, R14, R16	6	43	RES, 43, 5%, 0.25W, 1206	1206	CRCW120643R0JNEA	Vishay-Dale		
R8, R9	2	0	RES, 0, 5%, 0.1W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale		
R13	1	750k	RES, 750k, 1%, 0.1W, 0603	0603	CRCW0603750KFKFA	Vishay-Dale		
R15	1	604k	RES, 604k, 1%, 0.1W, 0603	0603	CRCW0603604KFKFA	Vishay-Dale		
R17	1	487k	RES, 487k, 1%, 0.1W, 0603	0603	CRCW0603487KFKFA	Vishay-Dale		
R19	1	383k	RES, 383k, 1%, 0.1W, 0603	0603	CRCW0603383KFKFA	Vishay-Dale		

⁽¹⁾ Unless otherwise noted in the Alternate Part Number or Alternate Manufacturer columns, all parts may be substituted with equivalents.

Table 3. bq77915EVM Bill of Materials⁽¹⁾ (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
R20	1	294k	RES, 294k, 1%, 0.1W, 0603	0603	CRCW0603294KFKEA	Vishay-Dale		
R21	1	196k	RES, 196k, 1%, 0.1W, 0603	0603	CRCW0603196KFKEA	Vishay-Dale		
R22	1	100k	RES, 100k, 1%, 0.1W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale		
R23, R24	2	5.1k	RES, 5.1k, 5%, 0.1W, 0603	0603	CRCW06035K10JNEA	Vishay-Dale		
R25	1	10.0Meg	RES, 10.0M, 1%, 0.1W, 0603	0603	CRCW060310M0FKEA	Vishay-Dale		
R26, R27	2	100	RES, 100, 5%, 0.1W, 0603	0603	CRCW0603100RJNEA	Vishay-Dale		
R28	1	1.0Meg	RES, 1.0M, 5%, 0.1W, 0603	0603	CRCW06031M00JNEA	Vishay-Dale		
R29	1	10Meg	RES, 10M, 5%, 0.1W, 0603	0603	CRCW060310M0JNEA	Vishay-Dale		
R30	1	3.0Meg	RES, 3.0M, 5%, 0.1W, 0603	0603	CRCW06033M00JNEA	Vishay-Dale		
R31	1	470k	RES, 470k, 5%, 0.1W, 0603	0603	CRCW0603470KJNEA	Vishay-Dale		
R33	1	0.015	RES, 0.015, 1%, 1W, 2010	2010	CSRN2010FK15L0	Stackpole Electronics Inc		
R34, R35, R36, R37, R38	5	1.00k	RES, 1.00k, 1%, 0.1W, 0603	0603	CRCW06031K00FKEA			
RT1	1	10.0kΩ	Thermistor NTC, 10.0kΩ, 1%, Disc, 5 × 8.4 mm	Disc, 5 × 8.4 mm	103AT-2	SEMITEC Corporation		
TP1	1		Test Point, Miniature, White, TH	White Miniature Testpoint	5002	Keystone		
TP2, TP3, TP4, TP7	4		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone		
TP5, TP6	2		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone		
U1	1		3-5S Ultra Low-Power Battery Protector with Smart Cell Balancing, PW0024A	PW0020A	bq7791500PWR	Texas Instruments	bq7791500PW	Texas Instruments
SH-J3-1, SH-J3-3, SH-J4-2, SH-J5-1, SH-J6-13	5	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec	969102-0000-DA	3M
C2, C4, C5, C7	0	1μF	CAP, CERM, 1μF, 50V, ±10%, X7R, 0805	0805	GRM21BR71H105KA12L	Murata		
D3	0	100V	Diode, Switching, 100V, 0.25A, SOD-323F	SOD-323F	BAS16J,135	Nexperia		
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A		
J1, J7	0		Header, 100mil, 4x1, Tin, TH	Header, 4x1, 100mil, TH	PEC04SAAN	Sullins Connector Solutions		
Q3, Q4	0	60V	MOSFET, N-CH, 60V, 100A, KCS0003B (TO-220-3)	KCS0003B	CSD18534KCS	Texas Instruments		
R2, R3	0	10Meg	RES, 10M, 5%, 0.1W, 0603	0603	CRCW060310M0JNEA	Vishay-Dale		
R12, R18	0	10.0k	RES, 10.0k, 1%, 0.1W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale		
R32	0	470k	RES, 470k, 5%, 0.1W, 0603	0603	CRCW0603470KJNEA	Vishay-Dale		

7 Related Documentation from Texas Instruments

- Texas Instruments, [bq77915 3-5S Low Power Protector with Cell Balancing and Hibernate Mode Data Sheet](#)

Revision History

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

Changes from A Revision (August 2018) to B Revision	Page
• Added sentence to first paragraph in Section 3.4	8
• Changed J2 to J4 in Table 2	8
• Changed J2 to J4 in last paragraph in Section 3.4	9

Changes from Original (March 2018) to A Revision	Page
• Updated <i>Cell Balance Indicators</i> section	10
• Updated <i>Top Silkscreen</i> image	11

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 semiconductor 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.
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/lstds/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。
http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_01.page

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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3.4 *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:*

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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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