

bq24013 (bqTINY™)

**1-A Single-Chip Li-Ion and Li-Pol Charge
Management IC With Integrated PowerFET and
Current Sense Evaluation Module**

User's Guide

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

EVM IMPORTANT NOTICE

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation kit being sold by TI is intended for use for **ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY** and is not considered by TI to be fit for commercial use. As such, the goods being provided may not be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety measures typically found in the end product incorporating the goods. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may not meet the technical requirements of the directive.

Should this evaluation kit not meet the specifications indicated in the EVM User's Guide, the kit may be returned within 30 days from the date of delivery for a full refund. **THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.**

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods. Please be aware that the products received may not be regulatory compliant or agency certified (FCC, UL, CE, etc.). Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge.

EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

TI currently deals with a variety of customers for products, and therefore our arrangement with the user **is not exclusive**.

TI assumes **no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein**.

Please read the EVM User's Guide and, specifically, the EVM Warnings and Restrictions notice in the EVM User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact the TI application engineer.

Persons handling the product must have electronics training and observe good laboratory practice standards.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 5.6 V and the output voltage range of 0 V and 4.25 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 60°C. The EVM is designed to operate properly with certain components above 60°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

Contents

1	Introduction	1-1
1.1	Background	1-2
1.2	Performance Specification Summary	1-2
2	Test Summary	2-1
2.1	I/O and Jumper Connections	2-2
2.2	Test Procedure	2-3
2.2.1	Equipment	2-4
2.2.2	Equipment Setup	2-6
2.2.3	Procedure	2-6
3	Schematic, Physical Layouts, and Bill of Materials	3-1
3.1	Schematic	3-2
3.2	Physical Layouts	3-3
3.2.1	Board Layout	3-3
3.3	Bill of Materials	3-5
3.4	Reference	3-5

Figures

2-1	Load Test Board	2-5
3-1	EVM Schematic Diagram	3-2
3-2	Assembly View	3-3
3-4	Top Layer	3-4
3-5	Bottom Layer	3-4

Tables

1-1	Performance Specification Summary	1-2
3-1	Bill of Materials	3-5

Introduction

This user's guide describes the bq24013 (bqTINY™) evaluation module. The EVM provides a convenient method for evaluating the performance of a charge-management solution for portable applications using the bq24013 product family. A complete designed and tested charger is presented. The charger is designed to deliver up to 1.0 A of continuous charge current, but is programmed for 0.7 A, for single-cell Li-Ion or Li-Pol applications using a dc power supply.

Topic	Page
1.1 Background	1-2
1.2 Performance Specification Summary	1-2

1.1 Background

The bqTINY series are highly integrated Li-Ion and Li-Pol linear charge-management devices targeted at space-limited portable applications. In a small package, the bqTINY series offer integrated PowerFET and current sensor, reverse blocking diode, high-accuracy current and voltage regulation, charge status, and charge termination.

The bqTINY charges the battery in three phases: conditioning, constant current, and constant voltage. Charge terminates on the basis of minimum current. An internal charge-timer provides backup safety for charge termination. The bqTINY automatically restarts the charge if the battery voltage falls below an internal threshold and automatically enters sleep mode when V_{CC} supply is removed.

In addition to the standard features, different versions of the bqTINY offer a multitude of additional features. These features include temperature-sensing input for detecting hot or cold battery packs, power good (\overline{PG}) output indicating the presence of the ac adapter, a TTL-level charge enable input (\overline{CE}) to disable or enable the charge process, and a TTL-level timer and termination enable (\overline{TTE}) input to disable or enable the fast-charge timer and charge termination.

1.2 Performance Specification Summary

This section summarizes the performance specifications of the EVM. Table 1–1 gives the performance specifications of the EVM.

Table 1–1. Performance Specification Summary

Specification	Test Conditions	Min	Typ	Max	Units
Input dc voltage, $V_{I(DC)}$		$V_{REG} + 0.5$	5.0	5.2 [†]	V
Battery charge current, $I_{O(CHG)}$	See note		0.7	1	A
Power dissipation	$(V_{(DC+)} - V_{(BAT+)}) \times I_{(CHG)}$			1.5	W

[†] This input voltage maximum is a function of the maximum allowable power dissipation on the IC. The current level is programmed for 0.7 A. If the programmed charge is changed, then the maximum input voltage must be adjusted.
 $P_{maxIC} = 1.5 \text{ Watt} = I_{CHG}(V_{DC+} - V_{BAT+})$.

Test Summary

This chapter describes the test setups used and the tests performed in evaluating the EVM.

Setup: The bq24013 EVM board requires a single-cell Li-Ion or Li-Pol battery pack and a 5-VDC, 1-A power source to provide input power. The test setup connections and jumper setting selections are configured for a stand-alone evaluation but can be changed to interface with external hardware, such as a microcontroller.

Topic	Page
2.1 I/O and Jumper Connections	2-2
2.2 Test Procedure	2-3

2.1 I/O and Jumper Connections

Jack	Connect To:
J1-DC+	Power supply positive, preset to 5.0VDC, 1-A current limit
J1-DC-	Power supply ground
J2-BAT+	Positive battery pack terminal
J2-BAT-	Negative battery pack terminal
J2-TTE	NC required—pulled down with 10 k Ω resistor on EVM
J2-BAT-	NC
J3-STAT1	External hardware if J4-EXT is jumpered (not jumpered from factory)
J3-STAT2	External hardware if J5-EXT is jumpered (not jumpered from factory)
J3-DC-	Return for J3 signals
J3-/CE	NC required—pulled down with 10 k Ω resistor on EVM
J4 (Jumper)	STAT1 indication location – LED (EVM) EXT
J5 (Jumper)	STAT2 indication location – LED (EVM) EXT

2.2 Test Procedure

Set up the evaluation board as described above, by making the necessary I/O connections and jumper selections. **Before test and evaluation, it is important to verify that the maximum power dissipation on the IC is not exceeded: $P_{(MAX)} = 1.5$ watts.**

- 1) Turn on the power supply, which was preset to 5.0 VDC and 1 A for the current-limit setting.
- 2) The bq24013 enters preconditioning mode if the battery is below the $V_{(LOWV)}$ threshold. In this mode, the bq24013 precharges the battery with a low current (typically $I_{O(CHG)}/10 = 0.7A/10 = 70$ mA) until the battery voltage reaches the $V_{(LOWV)}$ threshold or until the precharge timer expires. If the timer expires, then the charge current is terminated, the bq24013 enters fault mode, and both LEDs turn off. Toggling input power or battery replacement resets fault mode.
- 3) Once the battery voltage is above the $V_{(LOWV)}$ threshold, the battery enters fast-charge mode. This EVM is programmed for 0.7 A of fast-charging current.
- 4) Once the battery reaches voltage regulation (4.2 V), the current tapers down as the battery reaches its full capacity.
- 5) The battery remains at the fast-charge mode until either the charge timer expires or the charge termination current threshold is reached.
- 6) If the battery discharges to the recharge threshold, the charger starts fast charging.

In place of a battery, a source meter that can sink current can easily be adjusted to test each mode.

Another way to briefly see each mode on a scope is to connect a 1-mF capacitor and a 10-k Ω resistor on the output in place of a battery, to observe the power-up and cycling between voltage regulation and fast charge via the refresh threshold.

Note:

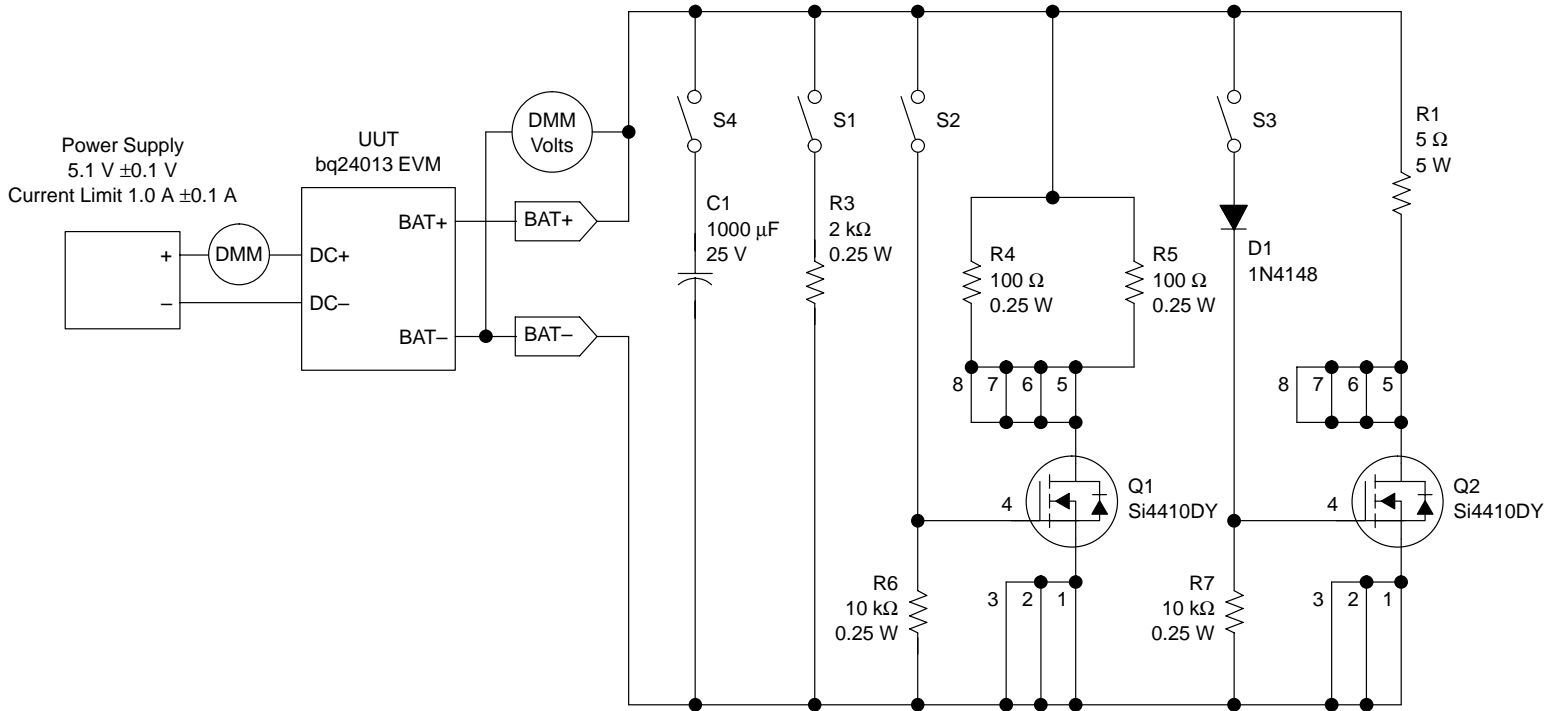
Because of the battery-detection circuit, it is not possible to switch-in static load resistors to jump between regulation and constant-current modes. An alternate procedure described below uses a dynamic load to replace the battery circuit. That procedure allows testing of each mode.

This is an alternative way of testing the EVM using a dynamic load board in place of a battery. The circuit is adjusted to work with the displayed parts and their inherent thresholds. The sequence of the test procedure is important because of the active battery-detection circuit, refresh feature, and precharge and fast-charge current levels. (Switching load in or out has different results in different modes). No damage should occur, but results might be different than anticipated if the procedure is altered.

2.2.1 Equipment

- 1) Power source: current-limited 5-V lab supply with its current limit set to 1.0 A \pm 0.1 A
- 2) Two Fluke 75, equivalent or better.
- 3) Oscilloscope – TDS220 or better.
- 4) Load test board (Figure 2–1)

Figure 2-1. Load Test Board



2.2.2 Equipment Setup

- 1) Connect the load board to the BAT+ and BAT-. Set SW1 through SW4 in the closed position.
- 2) Connect a voltage meter to the BAT+/BAT- output to monitor the output voltage (range 0 to 5 V).
- 3) Set the lab supply for $5.1 \text{ V} \pm 0.1 \text{ VDC}$, $1.0 \pm 0.1 \text{ A}$ current limit, and then turn off the supply. Connect the source supply to a current meter and to J1, noting polarity. (You may use an internal source current meter if it has 5% or better accuracy.)
- 4) Connect the scope to the output, BAT+.

2.2.3 Procedure

- 1) Ensure that equipment setup steps are followed. (Switches should be in the closed position, shunts installed, and power source set to $5.1 \text{ V} \pm 0.1 \text{ V}$.) Turn on the power source.
- 2) Verify that output voltage BAT+ charges up to between 2.5 V and 2.9 V, and the red LED (D1) and green LED (D3) are lit.
- 3) Verify that the input current is between 40 and 80 mA (for a programmed charge current of 0.7 A)
- 4) Open and then close switch SW2.
- 5) Verify that output voltage BAT+ settles at 3.2-3.95 VDC.
- 6) Verify that the input current is 0.69-0.76 A.
- 7) Open switch SW3.
- 8) Verify that the input current is 70-110 A.
- 9) Verify the output voltage: 4.150-4.250 VDC.
- 10) Open switch SW2.
- 11) Verify with a scope (250 ms/div, 1 V/div) that output BAT+ charges and discharges are between the maximum limits of 3 V and 4.25 V, with a period of 650-850 ms.
- 12) Verify that the LEDs flash between RED (D1) and GREEN (D2), mostly on green.
- 13) Open switch 4, and verify that D1 and D2 are off and D3 is on.
- 14) Verify, with a scope on BAT+, a square wave between the maximum limits of 1.3 and 4.25 VDC and a frequency between 3.5 and 4.5 Hz. This step verifies operation of the battery-detect circuit and the internal-timer oscillator.
- 15) Close switches SW2, SW3, and SW4 (all switches should be closed now) and power down the supply.
- 16) The EVM is good if all tests are passed.

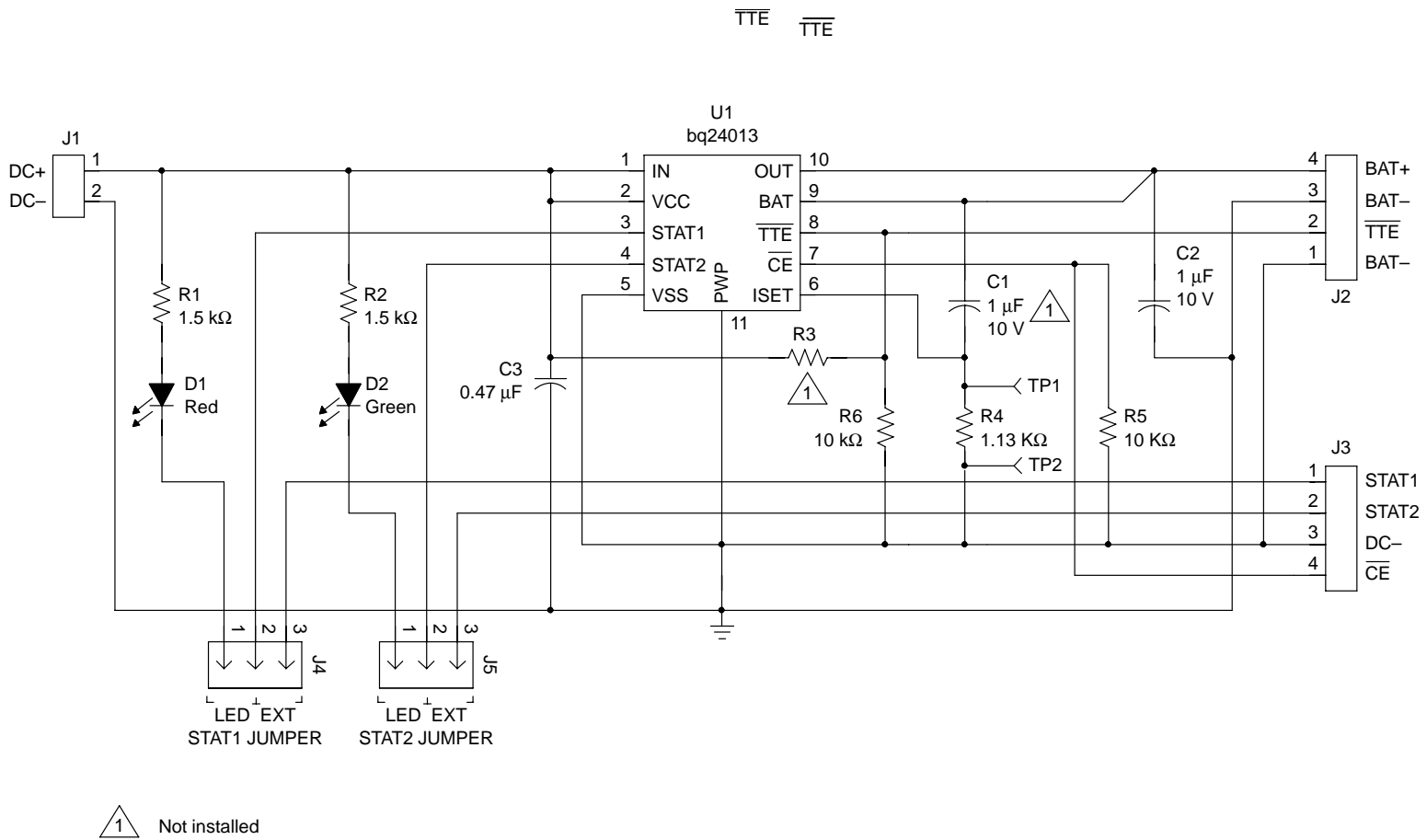
Schematic, Physical Layouts, and Bill of Materials

This chapter contains the schematic diagram, the board layouts and assembly drawings, and the bill of materials required for the EVM.

Topic	Page
3.1 Schematic	3-2
3.2 Physical Layouts	3-3
3.3 Bill of Materials	3-5
3.4 Reference	3-5

3.1 Schematic

Figure 3-1. EVM Schematic Diagram



3.2 Physical Layouts

3.2.1 Board Layout

Figure 3–2 shows the assembly view of the EVM. Figure 3–3 shows the top layer. Figure 3–4 shows the bottom layer.

Figure 3–2. Assembly View

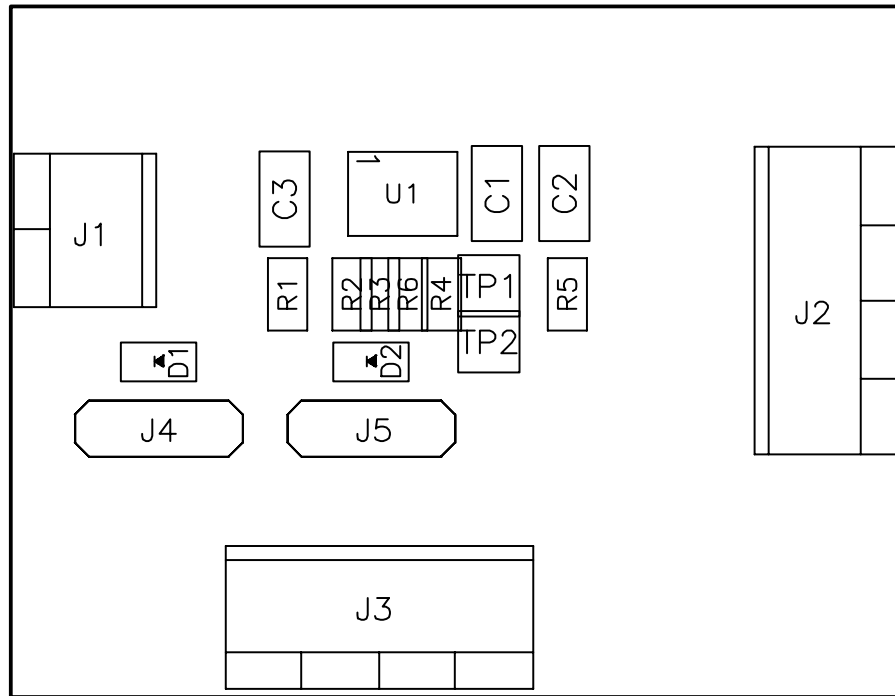


Figure 3–3. Top Layer

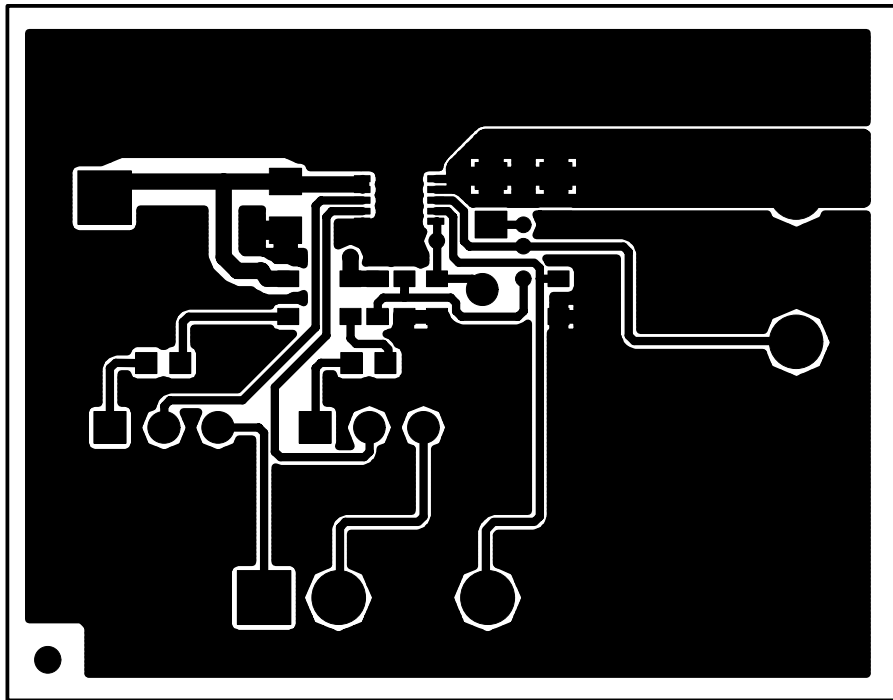
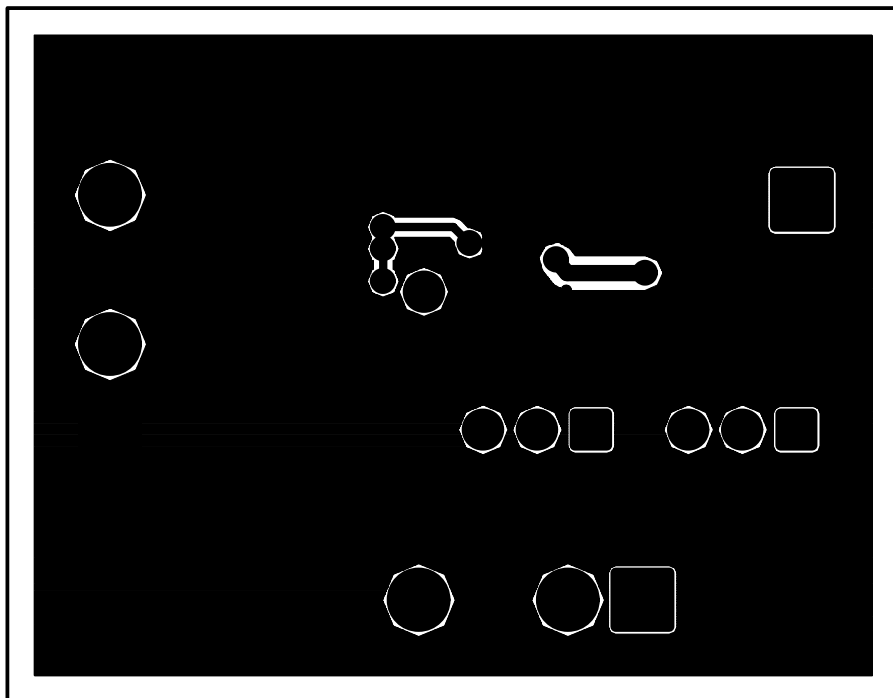


Figure 3–4. Bottom Layer



3.3 Bill of Materials

Table 3–1 lists materials required for the EVM.

Table 3–1. Bill of Materials

Item#	bq24013	Ref Des	Description	Size	MFR	Part Number
1	0	C1	Capacitor, ceramic, X5R, 1 μ F, 10 V	805	Panasonic	ECJ-2YB1A105K
2	1	C2	Capacitor, ceramic, X5R, 1 μ F, 10 V	805	Panasonic	ECJ-2YB1A105K
3	1	C3	Capacitor, ceramic, X7R, 0.47 μ F, 16 V	805	Panasonic	ECJ-2YB1C474K
4	1	D1	Diode, LED, red, 1.8 V, 20 mA, 20 mcd	603	Liteon	160-1181-1-ND
5	1	D2	Diode, LED, green, 2.1 V, 20 mA, 6 mcd	603	Liteon	160-1183-1-ND
6	1	J1	Terminal block, 2 pin, 6 A, 3,5 mm	0.27 \times 0.25	OST	ED1514
7	2	J2, J3	Terminal block, 4 pin, 6 A, 3,5 mm	0.55 \times 0.25	OST	ED1516
8	2	J4, J5	Header, 3 pin, 100 mil spacing, (36-pin strip)	0.100 \times 3	Sullins	PTC36SAAN
9	2	R1, R2	Resistor, chip, 1.5 k Ω , 1/16 W, 1%	603	Std	Std
10	0	R3	Resistor, chip, 1 M Ω , 1/16 W, 1%	602	Std	Std
11	2	R5, R6	Resistor, chip, 10 k Ω , 1/16 W, 1%	603	Std	Std
12	1	R4	Resistor, chip, 1.3 k Ω , 1/16 W, 1%	603	Std	Std
13	1	U1	IC, single Li-Ion/Li-Polymer, charge manager	MLP10	TI	bq24013DRC
14	2	—	Shunt, 100-mil, black	0.100	3M	929950-00
15	1	—	PCB, bq24010/2, 1.6 in \times 1.3 in \times 0.031 in		Any	SLUP185

- Notes:**
- 1) These assemblies are ESD sensitive; ESD precautions must be observed.
 - 2) These assemblies must be clean and free from flux and all contaminants. Use of no-clean flux is not acceptable.
 - 3) These assemblies must comply with workmanship standards IPC-A-610 Class 2.
 - 4) Reference designators marked with an asterisk (**) cannot be replaced by substitutes. All other components can be replaced with equivalent manufacturer components.

3.4 Reference

- 1) bq2401x data sheet (SLUS530)

