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# ***bq24020EVM and bq24023EVM***

***1-A Single-Chip Li-Ion and Li-Pol Charge Management IC with  
Autonomous USB-Port and AC-Adapter Supply Management  
Evaluation Module***

## ***User's Guide***

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It is important to operate this EVM within the input voltage range of  $V_{REG} + 0.5$  to 5.2 V and the output range of 0 V to 4.2 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 70°C. The EVM is designed to operate properly with certain components above 70°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.

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# ***bq24020/bq24023 Charger (bqTINY™-II) Evaluation Module***

*Portable Power*

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## **1 Introduction**

This user's guide describes the bq24020/bq24023 (bqTINY™-II) evaluation module. The EVM provides a convenient method for evaluating the performance of a charge management solution for portable applications using the bq24020/bq24023 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 for single-cell Li-Ion or Li-Pol applications using a DC power supply. The charger is programmed from the factory to deliver 0.7 A of charging current.

### **1.1 Background**

The bqTINY™-II series are highly integrated and flexible Li-Ion linear charge and system power management devices targeted at space limited charger applications. The bqTINY™-II series offer integrated USB-port and ac-adapter supply management with autonomous power-source selection, power FET and current sensor, high-accuracy current and voltage regulation, charge status, and charge termination, in a single monolithic device. The bqTINY™-II automatically selects the USB-Port or the ac-adapter as the power source for the system. In the USB configuration, the host can select from the two preset charge rates of 100 mA and 500 mA. In the ac-adapter configuration an external resistor sets the magnitude of the system or charge current. The bqTINY™-II charges the battery in three phases: conditioning, constant current, and constant voltage. Charge is terminated based on minimum current. An internal charge timer provides a backup safety for charge termination. The bqTINY™-II automatically restarts the charge if the battery voltage falls below an internal threshold. The bqTINY™-II automatically enters sleep mode when both supplies are removed.

## 1.2 Performance Specification Summary

**Table 1. Performance Specification Summary<sup>(1)</sup>**

SPECIFICATION	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input DC voltage, $V_{I(DC)}$		$V_{REG} + 0.5$	5.0	5.2	V
Battery charge current <sup>(1)</sup> , $I_{O(CHG)}$			0.7	1.0	A
Power dissipation	$I_{CHG} \times (V_{(DC+)} - V_{(BAT+)})$			1.5	W

(1) This input voltage maximum is a function of the maximum allowable power dissipation on the device. The current level is programmed for 0.7 A. If the programmed charge is changed, then the maximum input voltage needs to be adjusted.  $P_{MAX(IC)} = 1.5 \text{ W} = I_{CHG} (V_{(DC+)} - V_{(BAT+)})$ . The device has a maximum recommended operation of 6.5 VDC.

## 2 Test Summary

This section shows the test setups used, and the tests performed, in evaluating the EVM. See the bq24020/bq24023 datasheet (SLUS549) for complete details on operation and specifications for the charger device.

### 2.1 Test Setup

The bq24020/bq24023 EVM board requires a regulated 5-VDC, 1-A power source or a USB, 0.5-A port maximum), to provide input power and a single-cell Li-Ion or Li-Pol battery pack.

**NOTE:** If powered from an USB, 0.1-A port, make sure ISET2 is pulled low to program the board for the 100mA charge. Skip any test steps that program the UUT to 0.5 A.

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.

**Table 2. I/O and Jumper Connections<sup>(1)</sup>**

JACK	CONNECTION
J1–DC+	Power supply positive connection, preset to 5.0-VDC, 1.2-A current limit. Can also be powered by J2 (USB) if J1 power is absent.
J1–DC–	Power supply return connection, ground
J2–USB Plug	USB 0.5-A port – source for charging when J1 source is absent
J5–BAT+	Positive battery pack terminal
J5–BAT–	Negative battery pack terminal, BAT–, is common with DC–
J5–TS/ $\overline{\text{TTE}}$	No connection – R4 is set to 20 k $\Omega$ to bias the TS signal in a charging state (bq24020) or to enable timers ( $\overline{\text{TTE}}$ ) for bq24023. See datasheet (SLUS549) to activate TS for bq24020. Connection provides for optional external control.
J5–BAT–	Return for thermistor (when used)
J3 (jumper)	ISET2 program – 0.5A (HIGH)   <b>0.1 A (LOW)</b>
J4 (jumper)	$\overline{\text{CE}}$ (charge enable) – HIGH   <b>LOW</b>
J6 (jumper)	BIAS power for EVM (jumper to active source) – <b>DC+</b>   USB
J7 (jumper)	STAT1 indication location – <b>LED (EVM)</b>   EXT
J9 (jumper)	STAT2 indication location – <b>LED (EVM)</b>   EXT
J8–STAT1	External monitor hardware if J7–EXT is jumpered (not jumpered from factory)
J8–STAT2	External monitor hardware if J9–EXT is jumpered (not jumpered from factory)
J10 – $\overline{\text{CE}}$	External $\overline{\text{CE}}$ control (TTL) – LOW–Enabled, HIGH–Disabled (remove jumper J4 when using J10– $\overline{\text{CE}}$ ) <b>EVM set up for local control with jumper J4–LOW installed</b>
J10–ISET2	External USB load control (TTL) – HIGH (0.5 A)   LOW (0.1 A) (remove jumper J3 when using J10–ISET2. <b>EVM set up for local control with jumper J3–0.1-A installed.</b>

(1) Factory jumper selections are shown in **BOLD**

## 2.2 Test Procedure

Setup the evaluation board as described above, by making the necessary I/O connections and jumper selections. Prior to test and evaluation, it is important to verify that the maximum power dissipation on the device is not exceeded:  $P_{MAX} = 1.5 \text{ W}$ .

$$P_{MAX} = (V_{(DC+)} - V_{(BAT+)}) \times I_{(CHG)} \quad (1)$$

1. Turn on the power supply, which is preset to 5.0 V<sub>DC</sub>, and 1.0 A for the current limit setting.
2. The bq24020/ bq24023 enters preconditioning mode if the battery is below the V<sub>(LOWV)</sub> threshold. In this mode, the bq24020/ bq24023 precharges the battery with a low current, typically

$$\frac{I_{O(CHG)}}{10} = \frac{0.7 \text{ A}}{10} = 70 \text{ mA} \quad (2)$$

until the battery voltage reaches the V<sub>(LOWV)</sub> threshold or until the precharge timer expires. If the timer expires then the charge current is terminated and the bq24020/ bq24023 enters fault mode. Both LEDs turn off when in fault mode. Toggling input power or battery replacement resets fault mode. Note that there are several fault conditions. They are described in the datasheet (SLUS549).

3. Once the battery voltage is above the V<sub>(LOWV)</sub> 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. When the current reaches the taper termination threshold, the taper timer is set and allows approximately 30 minutes of additional charging time. If the charge current increases above the taper threshold for any reason, the taper timer is reset. If the current drops below the termination threshold (design for detecting removal of battery) charging immediately terminates.
6. After termination, if the battery discharges down to the recharge threshold, the charger starts fast charging.
7. The same procedure may be performed using the USB 0.5-A plug source in place of the J1 power source. The precharge current is approximately ten percent of the programmed fast charge. The fast charge current is either 0.1 A or 0.5 A depending on the ISET being low or high.

### CAUTION:

**If powered from an USB, 0.1-A port, make sure ISET2 is pulled low to program the board for the 100 mA charge.**

Pin 9 on the bq24020 functions as a temperature sense input (TS) and functions as a timer and termination enable input  $\overline{TTE}$  (active low) on the bq24023.

An alternative method of testing the EVM is with a source meter, that can sink or source current. This can easily be adjusted to test each mode, in place of a battery.

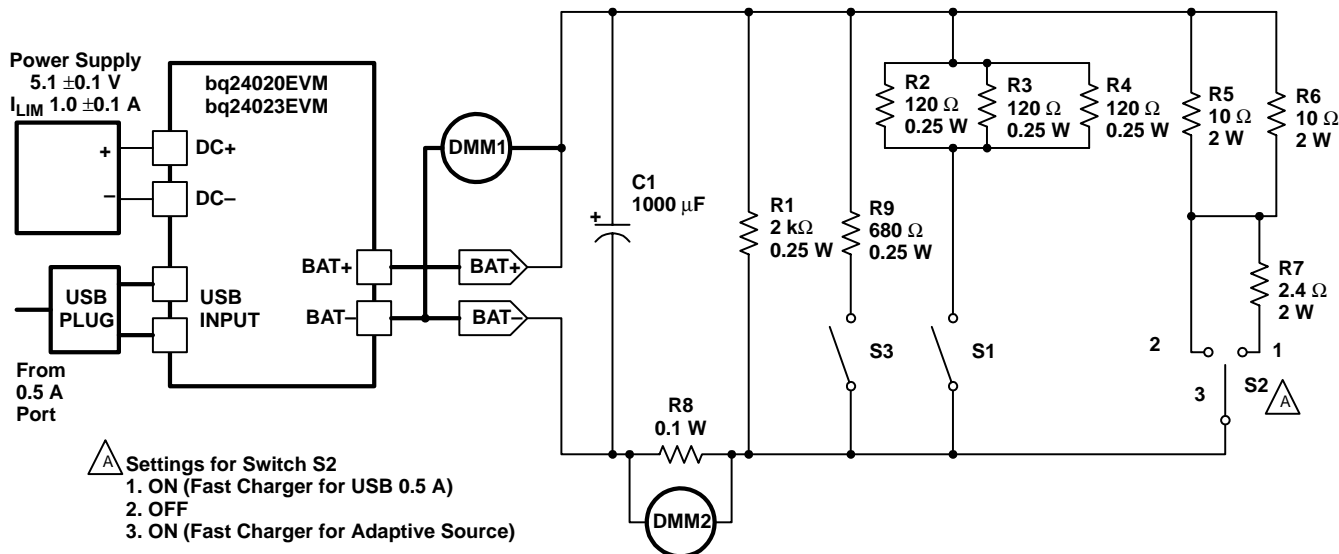
Another alternative to briefly view each mode, on a scope, is to connect a 1- $\mu\text{F}$  or larger capacitor and a parallel 10-k $\Omega$  resistor on the output in place of a battery to observe the charging cycling.

## 2.3 Alternative Test Procedure

The procedure in 2.3.1 describes a quick test to verify charging states without the need for a battery or expensive test equipment.

### 2.3.1 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. Load test board as shown in Figure 1.



UDG-03044

NOTE: R5, R6 and R7 5% or better. All other resistors 1% or better.

Figure 1. bq24020EVM/ bq24023EVM Testing Setup

### 2.3.2 Equipment Setup

1. Connect the load board to the BAT+ and BAT-. Set switches SW1 and SW3 to closed and switch SW2 to off (center).
2. Connect a voltage meter, DMM1, to the BAT+/BAT- output to monitor the output voltage (range is 0 V to 5 V).
3. Set the lab supply for 5.1 V  $\pm$ 0.1 VDC, 1.0 A  $\pm$ 0.1 A current limit and then turn off supply. Connect DMM2 across R8 to monitor the current (R8 should be a 1% or better resistor if it is used for current measurements).
4. Shunt jumpers should be installed on J6-DC+, J7-LED, J9-LED, J3-0.5, and J4-LED.

#### CAUTION:

If USB port is a low power port (0.1 A) and the charger is set up to draw 0.5 A, then problems or damage to the USB circuitry may occur. Therefore, when powering from a 0.1-A port, one should set J3 to 0.1 A and replace steps 7.8 through 7.11 with the following: Turn off J1 power source, set jumper to J6-USB, SW2-off, and close switches SW1 and SW3. Plug in USB power source, verify output voltage, BAT+, regulates between 2.5 and 2.9 V<sub>DC</sub> and both LEDs are lit. Open switch SW1 and verify output voltage, V<sub>BAT+</sub>, regulates between 4.160 V<sub>DC</sub> and 4.240 V<sub>DC</sub>.

### 2.3.3 Procedure

1. Make sure the steps described in *Section 2.3.2 Equipment Setup* are followed (SW1 and SW3 are set to closed, and SW2 is set to off, shunts installed as shown in step 4, test board connected, and power source set to 5.1 V  $\pm$ 0.1 VDC). Turn on the power source.
2. Verify output voltage, BAT+, is between 2.5 VDC and 2.9 VDC and the red LED (D1) and green LEDs (D2) are illuminated.
3. Momentarily short J5–2 to J1–1 (TS to DC+) for bq24020 only, and verify that charging stops (DMM2 < 0.5 mV). Remove short and verify output voltage, BAT+, is between 2.5 VDC and 2.9 VDC.
4. Open switch SW1. Verify LED (D2) is off and the output voltage, BAT+, regulates between 4.160 VDC and 4.240 VDC.
5. Close switch SW2 (to position 1) and verify output voltage, BAT+, is between 3.4 VDC and 3.8 VDC.
6. Verify that the charging current is between 0.6 A and 0.8 A (DMM2 is between 60mVDC and 80mVDC).
7. Open switch SW3, set switch SW2 to off and verify that the LEDs, (D1, D2), alternate being illuminated.
8. Turn off J1 power source, set jumper to J6–USB, SW2–off, and close switches SW1 and SW3. Plug in USB power source, verify output voltage, BAT+, regulates between 2.5 VDC and 2.9 VDC and both LEDs are illuminated.
9. Open and close switch SW1, verify output voltage, VBAT+, regulates between 4.160 VDC and 4.240 VDC and LED (D2) is off.
10. Open switch SW1, close switch SW2 (to position 2) and verify output voltage, VBAT+, regulates between 3.1 VDC and 3.5 VDC.
11. Set switch SW2 to off and set jumper to J3–0.1. Verify output voltage, VBAT+, regulates between 4.160 VDC and 4.240 VDC.
12. Close switch SW1 and verify VBAT+ output is between 3.1 VDC and 3.5 VDC.
13. Verify that the charge current is between 0.078 A and 0.105 A (7.8 mV and 10.5 mV).
14. Turn off power and set jumper to J6–DC+. Remove UUT from test apparatus. Repeat setup and test procedures for other untested EVMs.

## 2.4 Ordering Information

**Table 3. Ordering Information**

EVM Part Number	Additional Devices	Chemistry	Pack Voltage	Capacity
bq24020/bq24023EVM	None	Li-Ion/Li-Poly	2.5 V to 4.2 V	Any



### 3 Schematic

Figure 2 shows the schematic diagram for the bq24020EVM, not bq24023EVM.

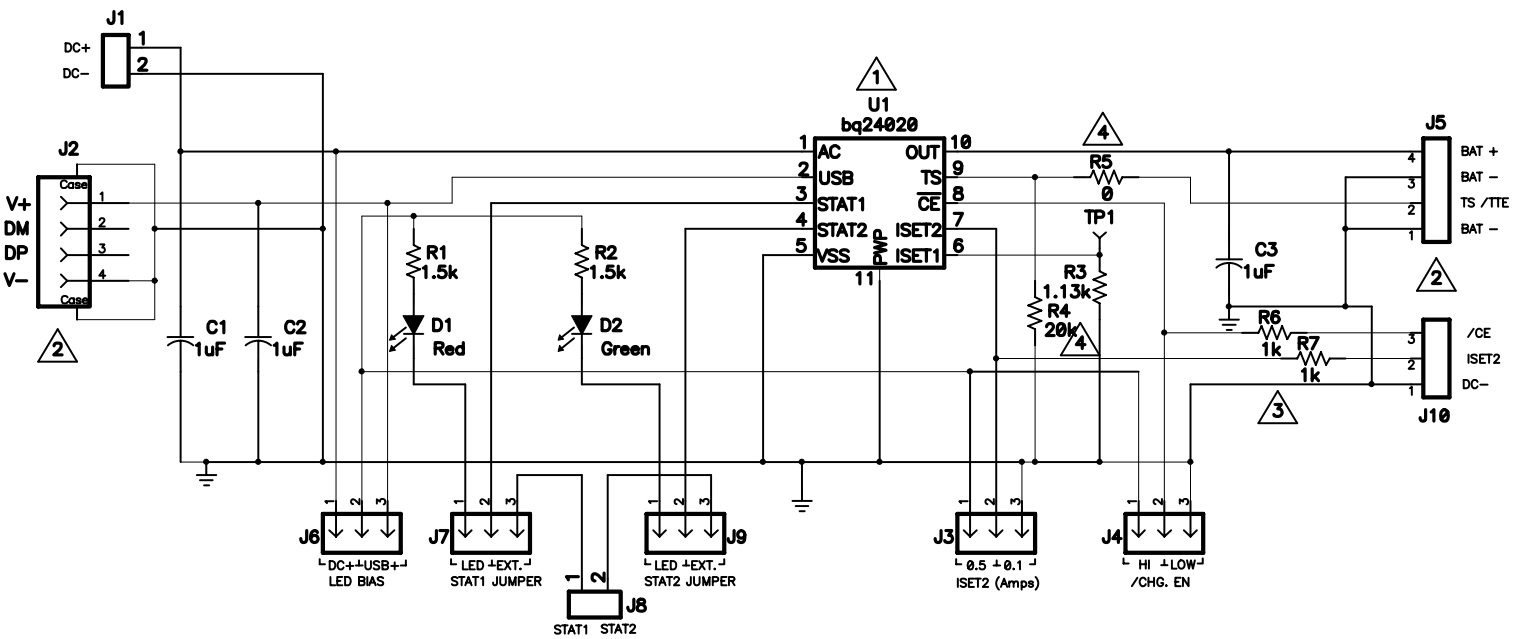


Figure 2. bq24023EVM Schematic

- 1 When using bq24023, pin 9 and J5-2 are  $\overline{\text{TTE}}$ .
- 2 DC-, BAT-, and V- are tied together.
- 3 R6 and R7 are optional and protect the EVM from applying two different sources.
- 4 R4 and R5 are optional if a thermistor is used on the bq24020.

## 4 Physical Layouts

Figure 3 shows the top layer of the EVM. Figure 4 shows the bottom layer. Figure 6 shows the top assembly view.

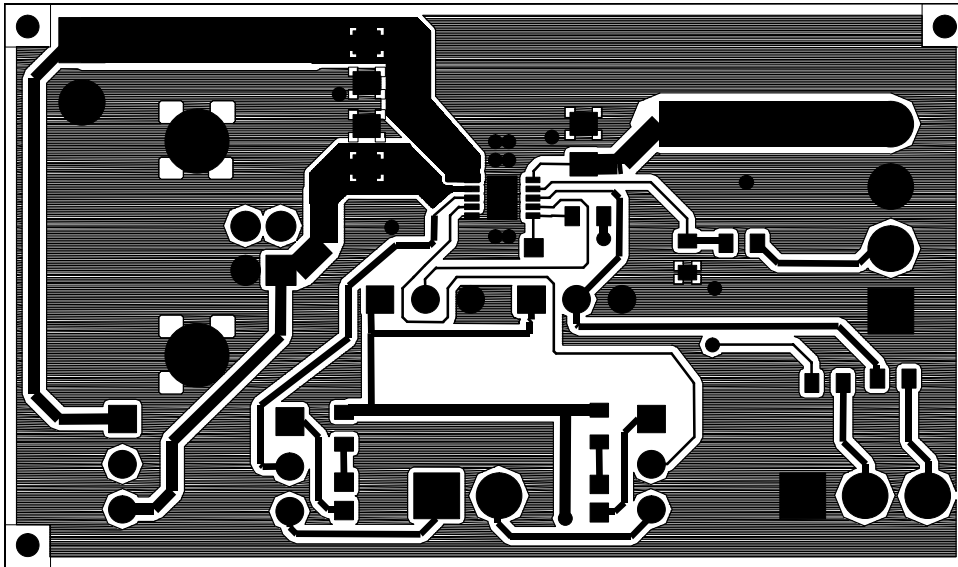


Figure 3. bq24020EVM/bq24023EVM Top Layer

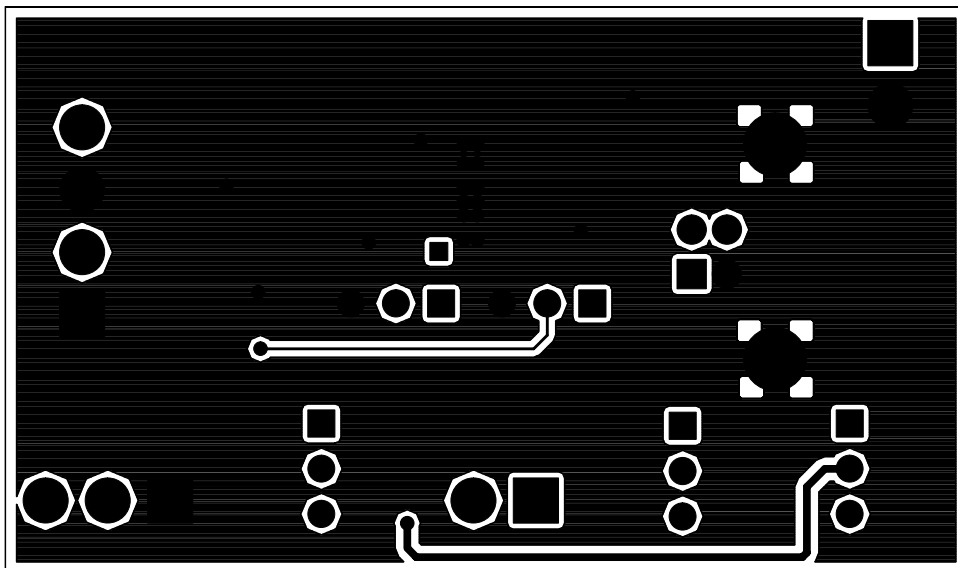
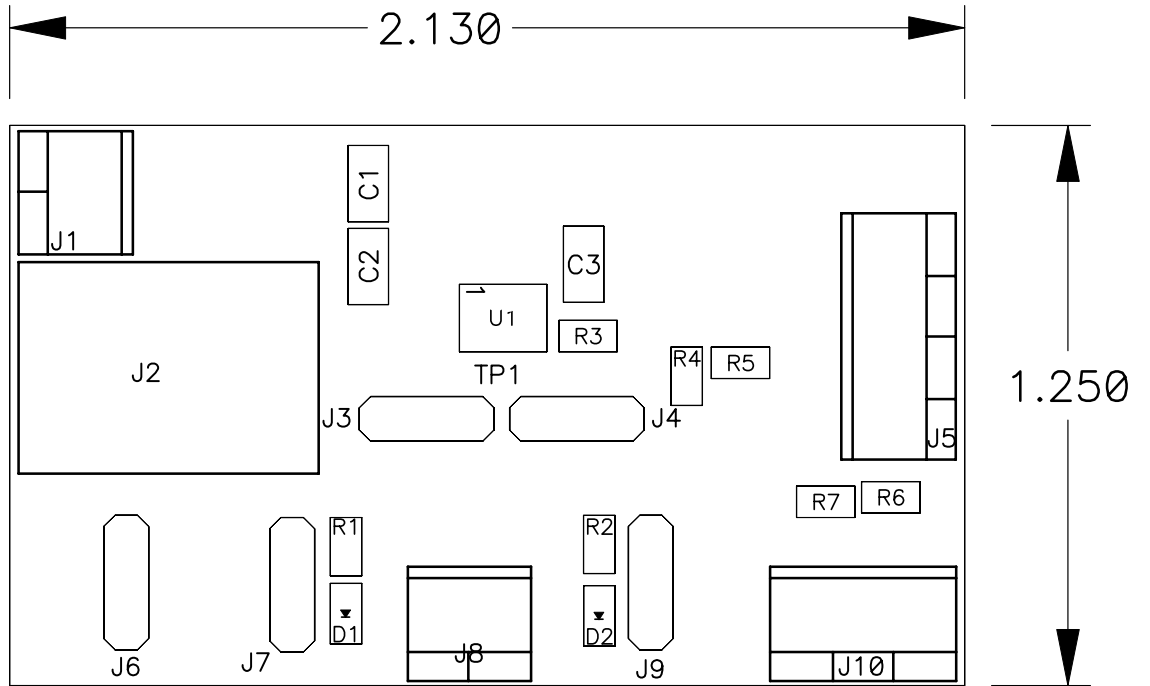


Figure 4. bq24020EVM/bq24023EVM Bottom Layer



**Figure 5. bq24020EVM/bq24023EVM Component Placement**

## 5 List of Materials

Table 4 lists the materials required for the bq24020EVM/bq24023EVM.

**Table 4. List of Materials**

REFERENCE DESIGNATOR	bq24020 EVM	bq24023 EVM	DESCRIPTION	SIZE	MANUFAC	PART NUMBER
C1, C2, C3	3	3	Capacitor, ceramic, 1- $\mu$ F, 16-V, X7R	805	Standard	Standard
D1	1	1	Diode, LED, red, 1.8-V, 20-mA, 20-mcd	603	Liteon	160-1181-1-ND
D2, D3	2	2	Diode, LED, green, 2.1-V, 20-mA, 6-mcd	603	Liteon	160-1183-1-ND
J1, J8	2	2	Terminal block, 2-pin, 6-A, 3.5-mm	0.27 x 0.25	OST	ED1514
J10	1	1	Terminal block, 3-pin, 6-A, 3.5-mm	0.41 x 0.25	OST	ED1515
J2	1	1	Connector, USB upstream (type B)	0.47 x 0.67	Molex	67068-1000
J3, J4, J6, J7, J9	5	5	Header, 3-pin, 100-mil spacing, (36-pin strip)	0.100 x 3	Sullins	PTC36SAAN
J5	1	1	Terminal block, 4-pin, 6-A, 3.5-mm	0.55 x 0.25	OST	ED1516
R1, R2, R6	3	3	Resistor, chip, 1.5-k $\Omega$ , 1/16-W, 1%	603	Standard	Standard
R3	1	1	Resistor, chip, 1.13-k $\Omega$ , 1/16-W, 1%	603	Standard	Standard
R4	1	1	Resistor, chip, 20-k $\Omega$ , 1/16-W, 1%	603	Standard	Standard
R5	1	1	Resistor, chip, 0-k $\Omega$ , 1/16-W, 1%	603	Standard	Standard
R7	1	1	Resistor, chip, 1-k $\Omega$ , 1/16-W, 1%	603	Standard	Standard
U1	1	–	Integrated circuit, single Li-ion, Li-poly, charge manager	MLP10	Texas Instruments	bq24020DRCR
U1	–	1	Integrated circuit, single Li-ion, Li-poly, charge manager	MLP10	Texas Instruments	bq24020DRCR
n/a	5	5	Shunt, 100-mil, black	0.1	3M	929950-00
n/a	1	1	PCB, 2.13" x 1.25" x 0.31"	–	Any	SLUP177-bq24020

### Assembly Notes:

1. These assemblies are ESD sensitive, ESD precautions shall be observed.
2. These assemblies must be clean and free from flux and all contaminants.
3. These assemblies must comply with IPC-A-610 class 2 or better.
4. Reference designators marked with an asterisk (\*\*) cannot be substituted. All other components can be substituted with equivalent manufacturer's components
5. Install jumpers on J6-DC+, J7-LED, J9-LED, J3-0.1, J4-LOW

## 6 References

1. Single-Chip Li-Ion and Li-Pol Charger IC with Autonomous USB-Port and AC-Adapter Supply Management (bqTINY™-II) bq24020 datasheet (SLUS549)

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