bq2403x (bqTiny-III™) 1.5-A Single-Chip Li-Ion and Li-Pol Charge Management IC EVM

This user's guide describes the bq2403x (bqTiny-III™) Evaluation Module. The EVM provides a convenient method for evaluating the performance of a charge management and system power solution for portable applications using the bq2403x product family. A completly designed and tested module is presented. The charger is designed to deliver up to 1.5 A of continuous current to the system or charger for one-cell Li-ion or Li-polymer applications (see the data sheet for correct device, x) using a dc power supply. The charger is programmed from the factory to deliver 1 A of charging current.

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bqTiny-III is a trademark of Texas Instruments.

1 Introduction

The bqTiny-III powers the system while independently charging the battery. This feature reduces the charge and discharge cycles on the battery, allows for proper charge termination, and allows the system to run with an absent or defective battery pack. This feature also allows for the system to instantaneously turn on from an external power source even when using a deeply discharged battery pack.

The bqTiny-III 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 input maximum rates of 100 mA and 500 mA. The bqTiny-III dynamically adjusts the USB charge rate based on the system load to stay within the 100-mA or 500-mA maximum rates. The AC pin can be programmed to perform like a USB input by pulling the PSEL pin low. An external resistor, RSET1, sets the magnitude of the charge current. If the charge current exceeds the available input current, the voltage on the OUT pin drops to the $DPPM_{OUT}$ threshold or the battery voltage, which ever is higher. The charging current is reduced to what current is available ($I_{BAT} = I_{IN}–I_{OUT}$).

The bqTiny-III charges the battery in three phases: conditioning, constant current, and constant voltage. Charge is terminated based on minimum current. A resistor-programmable charge timer provides a backup safety for charge termination. The bqTiny-III automatically re-starts the charge if the battery voltage falls below an internal threshold. The bqTiny-III automatically enters sleep mode when both supplies are removed (a drop to the battery voltage).

2 Considerations When Testing and Using bq2403x ICs

Consider the following noteworthy items while testing and using the bq2403x ICs.

There are three ICs (bq24030/1/2/5) to select from. The significant difference is the OUT pin voltage. The bq24030/1 has a LDO 6-V regulator connected the OUT pin. The intent on this charger is to provide a solution for using an inexpensive unregulated adaptor to power the charger. When unloaded, a 5-VDC adapter peak charges to ~8 V, but when loaded it quickly drops closer to 5 V. Since this is a linear regulator/charger, the higher the input voltage the lower the current level has to be to not exceed the power rating of the IC. The bq24032 has a LDO 4.4-V regulator connected to the OUT pin. The bq24035 shuts down if the input exceeds ~6.4 VDC.

The three potential sources to power the system ($\mathbf{V}_{OUT}$) are: AC (AC-to-DC adapter), USB port, and battery. The IC is designed to power the system continuously. The battery, in most cases, is the last line of backup. If the AC or USB inputs are not available (or disabled), the battery connects to the system.

In thermal regulation condition (T_J=125°C—not a first-choice design mode of operation), the charge current is reduced to the battery, and the system still gets its power from the input. The battery supplement is still available in thermal regulation if the $\mathbf{V}_{OUT}$ falls to $\mathbf{V}_{BAT}$. In thermal cutoff (~155°C), the input sources are disconnected, but the internal battery FET connects the battery to $\mathbf{V}_{OUT}$.

The battery FET only opens (when needed) if a short on the $\mathbf{V}_{OUT}$ pulls more than 4 A of current, or any condition has $\mathbf{V}_{OUT}$ less than 1 Vdc (considered a short-circuit condition). In the short-circuit condition are two types of *pullups*: a 500-Ω resistor from each input to $\mathbf{V}_{OUT}$ and a 10-mA current source from the battery to the $\mathbf{V}_{OUT}$. The system load has to be reduced (>200 Ω) on the output to allow $\mathbf{V}_{OUT}$ to rise above 1 Vdc. If the voltage on the DPPM pin is held below 1 V, then the short-circuit feature is disabled. Therefore, placing a small capacitor (~1000 pF) across the DPPM resistor delays the short-circuit protection on input powerup by a few microseconds. Typically, the system does not have much of a load below 1 V; so, powering up during a potential short-circuit condition usually is not a problem. $\mathbf{V}_{OUT}$ is always powered if there is any source voltage; so, dropping below 1 V is not a typical mode.

Another feature that protects system integrity is dynamic power path management (DPPM). The voltage on the DPPM pin ($DPPM_{IN}$) times a scaling factor of ~1.15 is the $DPPM_{OUT}$ voltage. The $DPPM_{OUT}$ voltage is the critical voltage, determined by the designer, where battery charging current is reduced to keep the system voltage ($\mathbf{V}_{OUT}$) from further decay. A special feature to keep in mind is that when in DPPM mode the internal oscillator timer is slowed proportionally to how much the programmed charger current is reduced. This allows the timers (safety and others) to be appropriately adjusted during operation. Therefore, when performing any test where time is measured, keep in mind this adjustment factor.

Another critical feature is power handoff. The power handoff is initiated autonomously or by request. The PSEL (High/Low) sets which input source takes priority (AC or USB). This handoff happens immediately on request. The CE pin (going high) immediately enables the chip; disabling it (going low) delays handoff for 5 ms. For autonomous power selection (e.g., the selected source is lost), the IC switches sources when the Power Good (PG) status indicates the primary selected source is no longer good. PG is defined as >($\mathbf{V}_{BAT}$ + 80 mV). This means that if the battery is dead (missing, or discharged below a useable system voltage), the IC switches over to the other available source when the $\mathbf{V}_{OUT}$ reaches the *dead battery* voltage. This design feature prevents cycling between a stronger current-limiting source and the USB source. In most situations, if AC power is available (prior to losing it), the battery probably would not be discharged.

3 Performance Specification Summary

Table 1 summarizes the performance specifications of the EVM.

Table 1. Performance Specification Summary For bq24030/1/2/5 EVMs

SPECIFICATION	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input DC Voltage, $V_{I(AC)}$		4.8 V	5.0	6.5	Volts
Input DC USB Voltage, $V_{I(USB)}$			5.0		
Battery Charge Current, $I_{O(CHG)}$			1.0	2.0+	Amperes
Power Dissipation, bq2403x IC, 1 Cell	Pdiss=(Vin-Vout)Iout +(Vin-Vbat)Ibat + (Vin-Vldo)I_{LDO}			see [1]	Watts

(1) The HPA073 (bq2403x) thermal design is optimized (8^+ vias, 0.031-inch PWB, 2 oz. copper) to give θ_{JA} ~ 27°C/W.

4 Test Summary

This section covers the setup and tests performed in evaluating the EVM.

4.1 *Equipment*

- Power supply (+5.25 ± 0.25 VDC), current limit set to 2.0 A ± 0.2 A for AC input to the UUT
- USB high-power port (500 mA) and cable (J1 is an alternate USB connection)
- Three Fluke 75 DMMs (equivalent or better)
- Oscilloscope, Model TDS220 (equivalent or better)

4.2 *Equipment Setup*

- Preset the UUT power supply voltage and current prior to connection to UUT; turn off the power supply and connect the supply to J2-AC/GND (+ to AC and – to GND).
- Connect a 10-Ω load to J7-OUT/GND.
- Connect a 1k-Ω load to J5-LDO/GND.
- Connect a fully discharged (< 2.8-VDC) single-cell Li-ion or Li-polymer battery to J8-BAT+/BAT–.
- Connect the DMMs as shown in Figure 1.

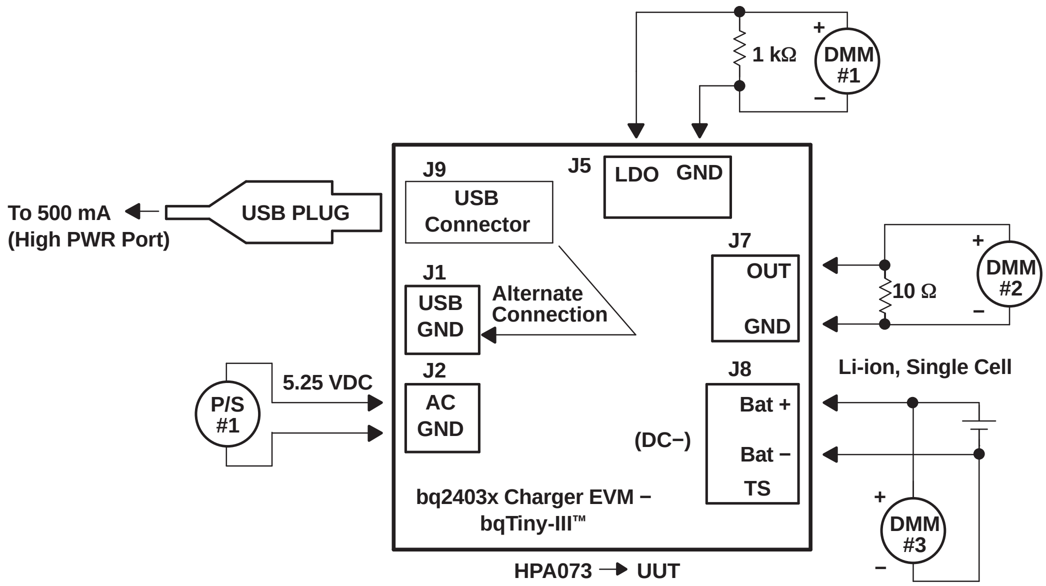

Figure 1. Test Diagram

4.3 Test Procedure

1. Verify that the equipment is set up according to Equipment Setup section.
2. Set jumpers on the UUT as follows: JMP1-0.5; JMP2-AC; JMP3-EN; set JMP4 through JMP7 to LED.
3. Adjust **R_DPPM** until TP1 is **31 kΩ ± 0.1 kΩ** with respect to GND, and adjust **R_TMR** until TP2 is 50 kΩ with respect to GND.
4. Verify that $\mathbf{V}_{OUT}$ is approximately equal to $\mathbf{V}_{BAT}$ (if Vout < 1.1 V, the output is in short-circuit mode. To get out of this mode, momentarily disconnect the 10-Ω load, or touch a 1-µF capacitor between the DPPM pin and ground).
5. Power up the **+5.25-VDC Supply** to the UUT.
6. Verify $\mathbf{V}_{BAT}$ is between 2.4 VDC and 3.0 VDC, and the charger is in pre-charge state: LEDs STAT1 (D2), STAT2 (D3), and ACPG (D5) are on.
   If V_{BAT} is above the low-voltage threshold ($V_{(LOWV)}$ ~3 V), then the IC is in fast-charge mode {STAT2 (D3) is off (High)}. If the IC is in fast charge, skip step 10.
7. Verify $\mathbf{I}_{BAT}$ is ~0.1 A ($\mathbf{I}_{BAT}$~ = I_{AC}– (V_{OUT} / R_{OUT}) –0.01 A)
8. Verify $\mathbf{V}_{OUT}$ is between 4.3 VDC and 4.5 VDC for the bq24032 IC. The bq24030/1/5 switches the input to the output for $\mathbf{V}_{AC}$ less than 6 V. The bq24030/1 regulates V_{OUT} to 6 V for larger inputs, and the bq24035 turns off the charging and output for an AC input above 6 VDC.
9. Verify $\mathbf{V}_{LDO}$ is between 3.2 VDC and 3.4 VDC.
10. Allow the battery to charge until $\mathbf{V}_{BAT}$ is between 3.2 VDC and 4.0 VDC. The charger should deliver the programmed constant current to the battery unless the input cannot source the required current.
11. Verify **D3** (STAT2) has turned off.
12. Verify $\mathbf{I}_{BAT}$ is ~1.0 A (for a 10-kΩ resistor on *ISET1*, I_{BAT}~ = I_{AC}– (V_{OUT} / R_{OUT}) – 0.01 A).
13. Verify $\mathbf{I}_{AC}$ is ~1.5 A (for 10-Ω **OUT** load and 10 kΩ on **ISET1**).
14. Apply a short between J3-4 (CE) and J3-3 (GND) on the UUT. This overrides the JMP3 100-kΩ pullup, disables the charging, puts the IC in low power mode and connects the battery to the OUT pin. Note that if CE is floated (JMP3 is removed and J3-4 connection is removed) the IC may bounce between the charging and disabled states. Verify on the scope that $\mathbf{V}_{OUT}$ does not drop out. Note that the transition between power sources is implemented by break-before-make switching and requires the capacitance on $\mathbf{V}_{OUT}$ to be able to hold up the system voltage for at least 50 µs.
15. Verify **D2** (STAT1) has turned off.
16. Verify $\mathbf{I}_{AC}$ drops below 10 mA (should be < 200 µA into the IC if ACPG LED (current) JMP6 is removed).

17. Verify $\mathbf{V_{OUT}}$ is within –50 mV of $\mathbf{V_{BAT}}$.
18. Remove short betwen J3-4 and J3-3 on UUT. Verify on the scope that $\mathbf{V_{OUT}}$ does not drop out. Verify **D2** (STAT1) has turned on, charging has resumed and $\mathbf{V_{OUT}}$ is powered from the input.
19. Disconnect the **+5.25-VDC Input Supply** from the UUT AC input. Verify on the scope that $\mathbf{V_{OUT}}$ does not drop out. Verify $\mathbf{V_{OUT}}$ is within –50 mV of $\mathbf{V_{BAT}}$ and **D2** (STAT1) and **D5** (ACPG) LEDs turn off. This demonstrates battery power backup for loss of AC adapter.
20. Reapply the +5.25-VDC supply to the UUT AC input. Verify on the scope that $\mathbf{V_{OUT}}$ does not drop out. Verify **D2** (STAT1) and **D5** (ACPG) LEDs turn on.
21. Adjust R15 until the voltage on TP1 is ~ 3.50 VDC ($\mathbf{V_{BAT}}$ should be less than 3.9 V for this demonstration; otherwise, discharge battery).
22. Reduce the current limit on the input supply to ~ 1 A (going to AC pin on UUT) and verify on the scope that $\mathbf{V_{OUT}}$ has dropped to the VDPPM level of ~4.0 V {(3.5 V at TP1) × 1.15 = 4 V}. Note that the current into the battery is ~ 600 mA (1-A input minus 400 mA to the system), which has been reduced to keep the output from falling below the programmed DPPM OUTPUT threshold of 4 V. This demonstrates DPPM operation (charging current to the battery is reduced if output drops to the DPPM OUTPUT voltage threshold attempting to keep the output voltage from dropping further).
23. Further reduce the input's current limit to 250 mA. Verify on the scope that $\mathbf{V_{OUT}}$ does not drop out. Verify that $\mathbf{V_{OUT}}$ drops just below $\mathbf{V_{BAT}}$ (< 50 mV). Because the available input current is less than the system **OUT** load, reducing the battery charging current to zero is still not enough reduction in load to keep the output from dropping. Once the output drops below ~ 50 mV, the internal battery FET turns on and allows the battery to source the OUT pin system load. This demonstrates battery supplement mode.
24. Return the current limit of the +5.25-V supply to ~2 A. Verify $\mathbf{V_{OUT}}$ returns to Vreg or Vin (see Step 8 of this test procedure).
25. Set JMP2 (PSEL) to USB (PSEL = low). Verify that the input current (AC) drops to between 400 mA and 500 mA. The programmed charge current of ~1 A and the system load of 10 Ω exceeds the USB 0.5-A limit; therefore,$\mathbf{V_{OUT}}$ drops until the DPPM OUTPUT voltage threshold, or battery voltage, is reached (which ever is higher). If the DPPM OUTPUT threshold is larger, the charging current is reduced to keep the output voltage from dropping further. If the battery voltage is higher, the battery supplements the current to keep the output from dropping too much (50 mV to 200 mV) below the battery voltage. Note that setting PSEL to low (USB mode; PSEL high is AC mode) selects the USB input as the primary source. If the USB source is not present, and the ac source is present, the IC uses the AC input source as if it were a USB input. This feature is useful if only one input power connector is desired, and two sources (USB and AC adaptor) are available. A *keyed* cable or a u-controller would set the PSEL pin for the available source. Note that the system would ideally go to a lower power mode prior to selecting USB operation to avoid pulling down $\mathbf{V_{OUT}}$.
26. Plug in a USB cable from a high-power port (500 mA) into the UUT (or supply 5 VDC to J1). Verify that the USB input now supplies the input current instead of the AC (J2) input. This demonstrates that JMP2 (PSEL) defines the priority of the inputs. If PSEL = Low (USB priority), then the USB input is used first, if available, and if not it switches to AC power at USB-current levels.
27. Verify that **D4** (USBPG) turns on.
28. Set JMP2 (PSEL) to AC, and verify that the AC supply is providing ~1.5 A of current (~0.44 to the load and 1 A to the battery plus miscellaneous).
29. Remove the ac-input supply and verify that the USB source is supplying between 400 mA and 500 mA of current to the input. The output should have dropped to the DPPM OUTPUT threshold or battery voltage (whichever is higher).
30. Verify that **D5** (ACPG) turns off.
31. Reapply the AC-input source and verify that the AC source is now providing the ~1.5 A as before.
32. Verify that **D5** (ACPG) turns on.
33. Set JMP2 (PSEL) to USB, and verify that the USB source is now providing between 400 mA and 500 mA of current.
34. Set JMP1 to 0.1 on the UUT. Verify that the input current has dropped below 100 mA and $\mathbf{V_{OUT}}$ has dropped slightly below $\mathbf{V_{BAT}}$. In this test, the system load is 10 Ω, which would result in the output dropping to 1 V at 100 mA if there were no other source to help out. As the output voltage drops to the DPPM OUTPUT threshold, the charging current is reduced to zero, but $\mathbf{V_{OUT}}$ continues to drop until it reaches the battery voltage. The internal battery FET turns on to supplement the OUTPUT. This

demonstrates battery supplement mode because the system load exceeds the available input current.

35. Disconnect the USB source and verify that the AC source takes over in USB mode at the 100-mA charge level.
36. Verify that **D4** (USBPG) turns off.
37. Set JMP2 to AC (PSEL = High). Skip to next step for HPA073-1/3 (bq24030/1/5 ICs). Verify that the (AC) input current is ~1 A. Verify that IBAT is reduced to half the programmed level, ~0.5 A. This is the AC half-charge mode and is implemented on bq24032 when ISET2 is low (0.1 A) and J2-PSEL is AC (High).
38. Set JMP1 to 0.5. Continue to let the battery charge. Note that once the battery voltage reaches regulation (~4.20 VDC for bq24030/2/5 and 4.1 VDC for bq24031) the charging current tapers off.
39. Verify that the charging terminates when the battery current tapers to C/10 or 100 mA (1 A/10, programmed charge current divided by 10). Verify D2 (STAT1) turns off (High) and D3 (STAT2) turns on (Low).
40. If a load is applied across the battery such that the battery is discharged to ~100 mV below the regulation voltage, the charger starts a new charging cycle.

This concludes the evaluation of the bq2403x EVM. Several more features implemented in the IC are not demonstrated in this user's guide. See the data sheet to learn more about thermal regulation, thermal cutoff, USB boot up, and short-circuit protection.

5 Schematic

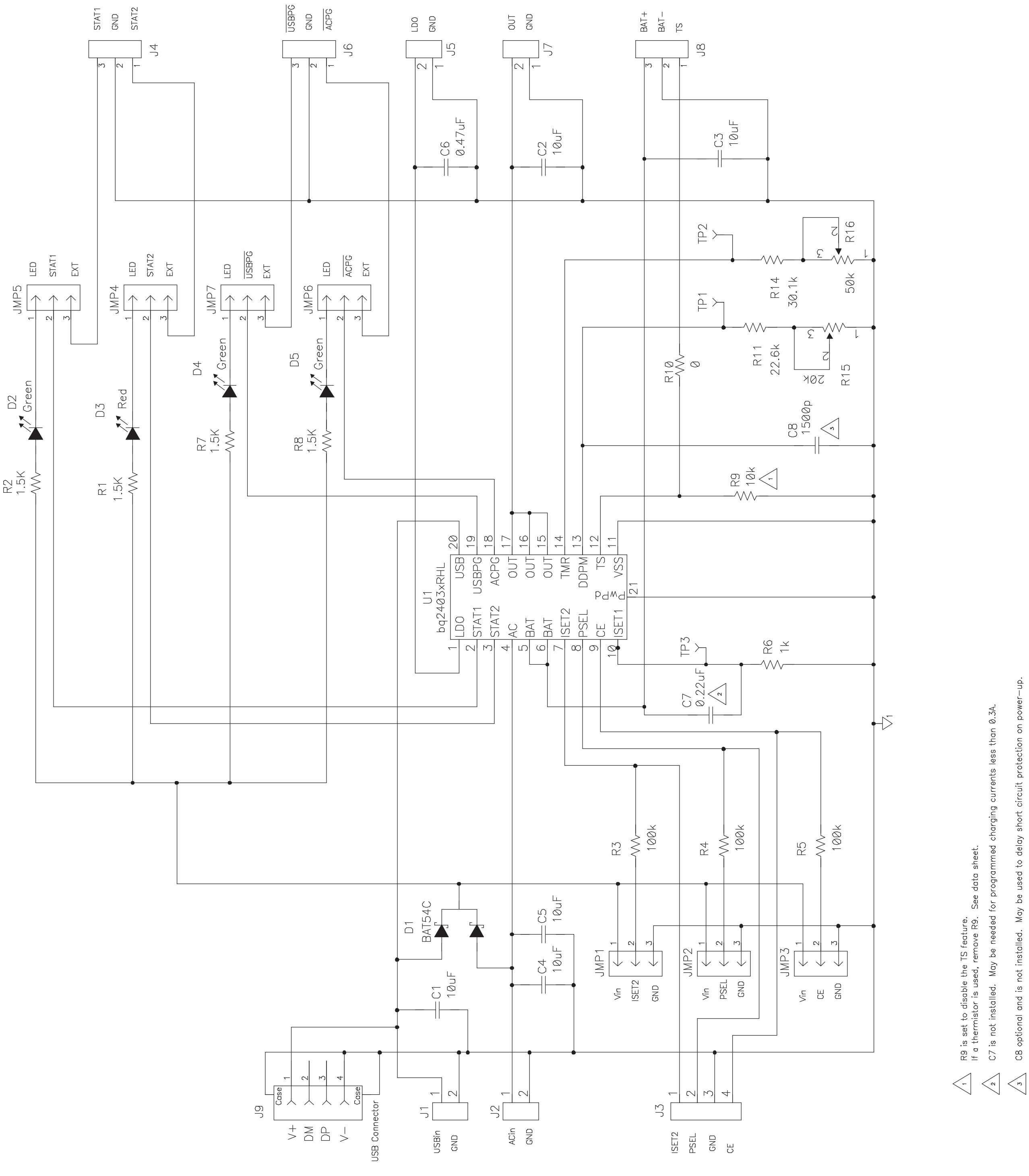

Figure 2. bq2403x EVM Schematic

6 Physical Layouts

This section contains the board layout and assembly drawings for the EVM.

6.1 Board Layout

Figure 3 shows the top assembly view of the EVM. Figure 4 shows the top etch layer of the EVM. Figure 5 shows the board second etch layer of the EVM. Figure 6 shows the board third etch layer of the EVM. Figure 7 shows the bottom etch layer of the EVM.

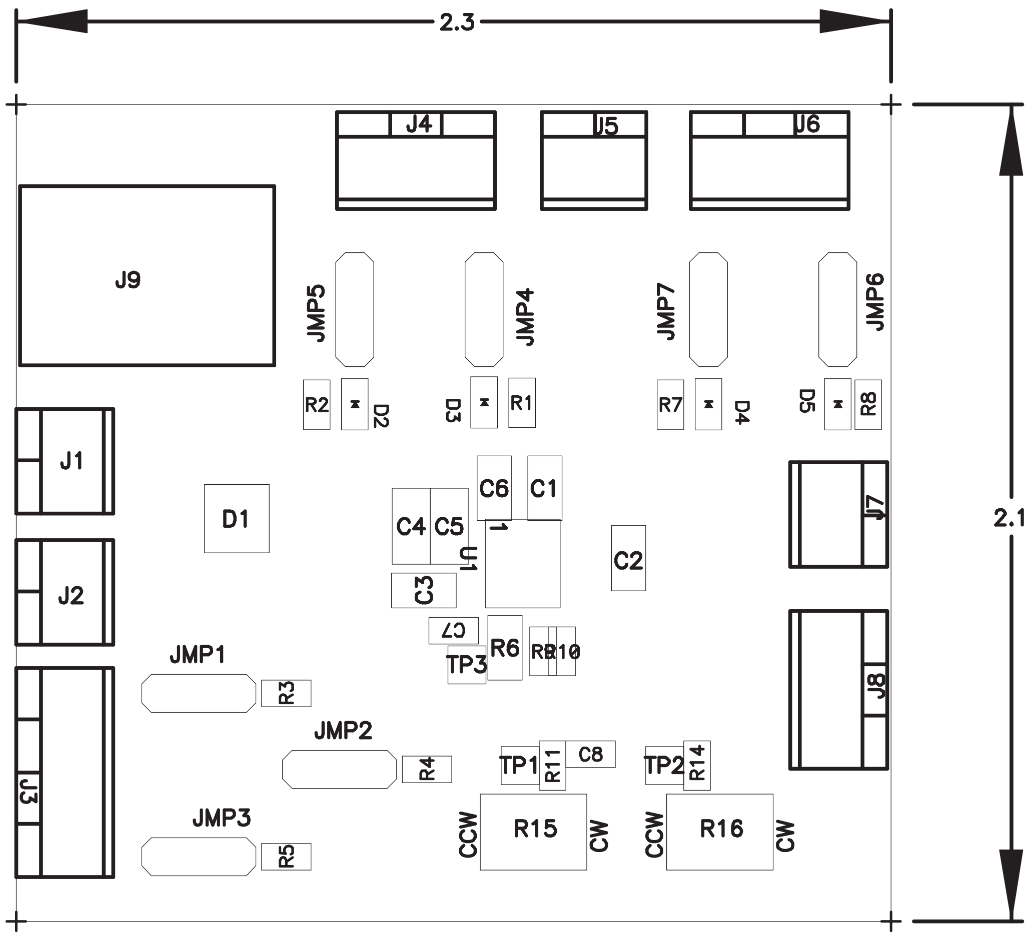

Figure 3. Top Assembly View

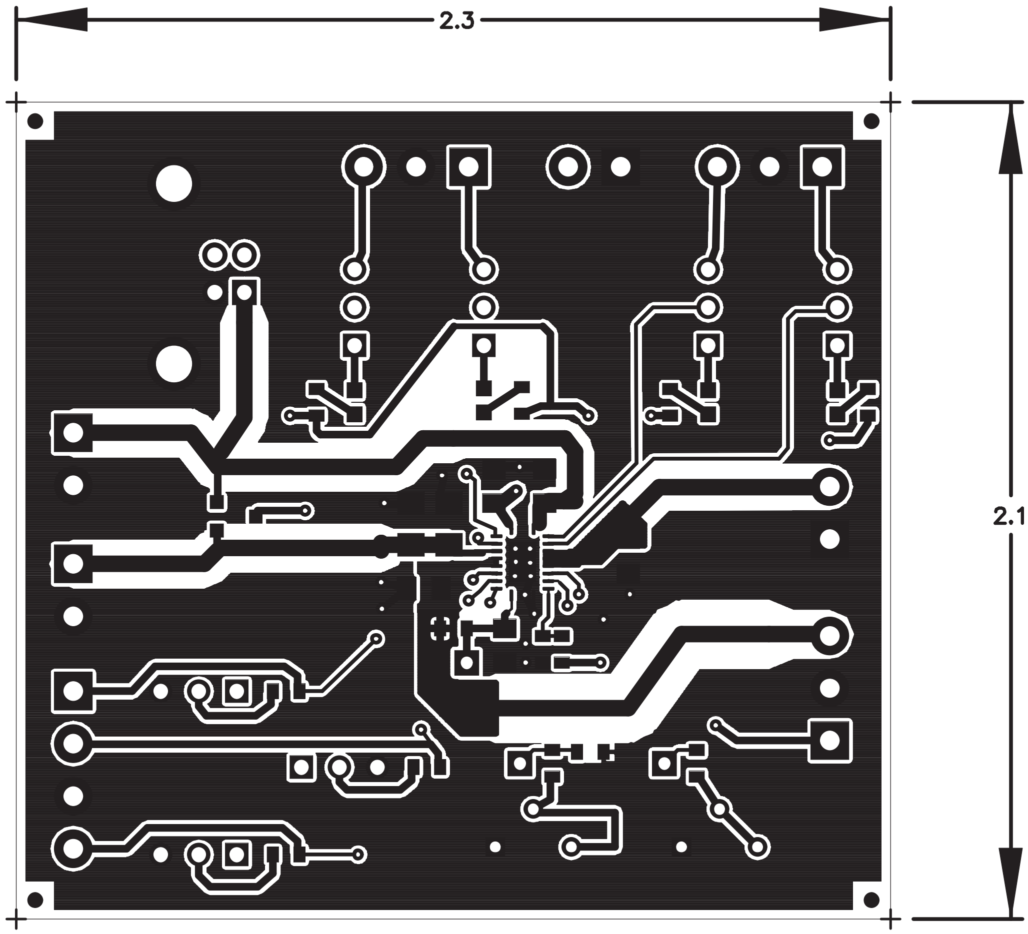

Figure 4. Board Layout – Top Etch Layer

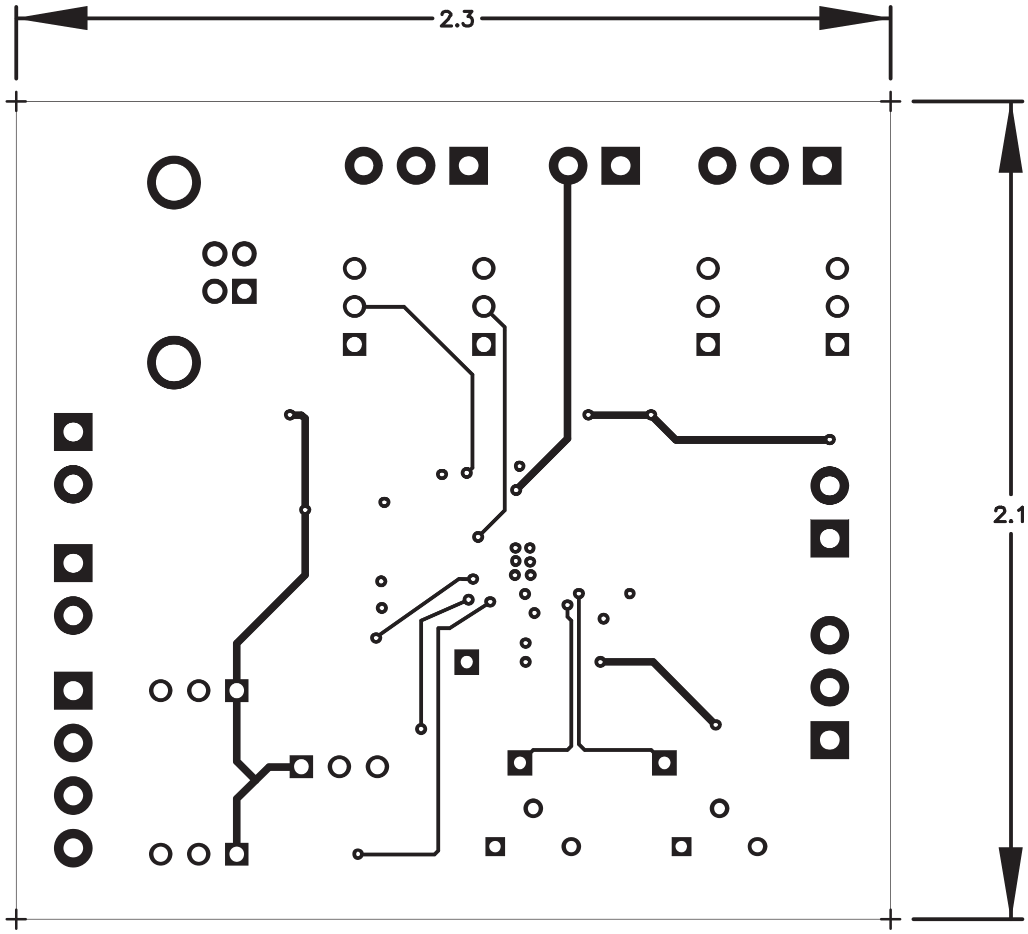

Figure 5. Board Layout – Second Etch Layer

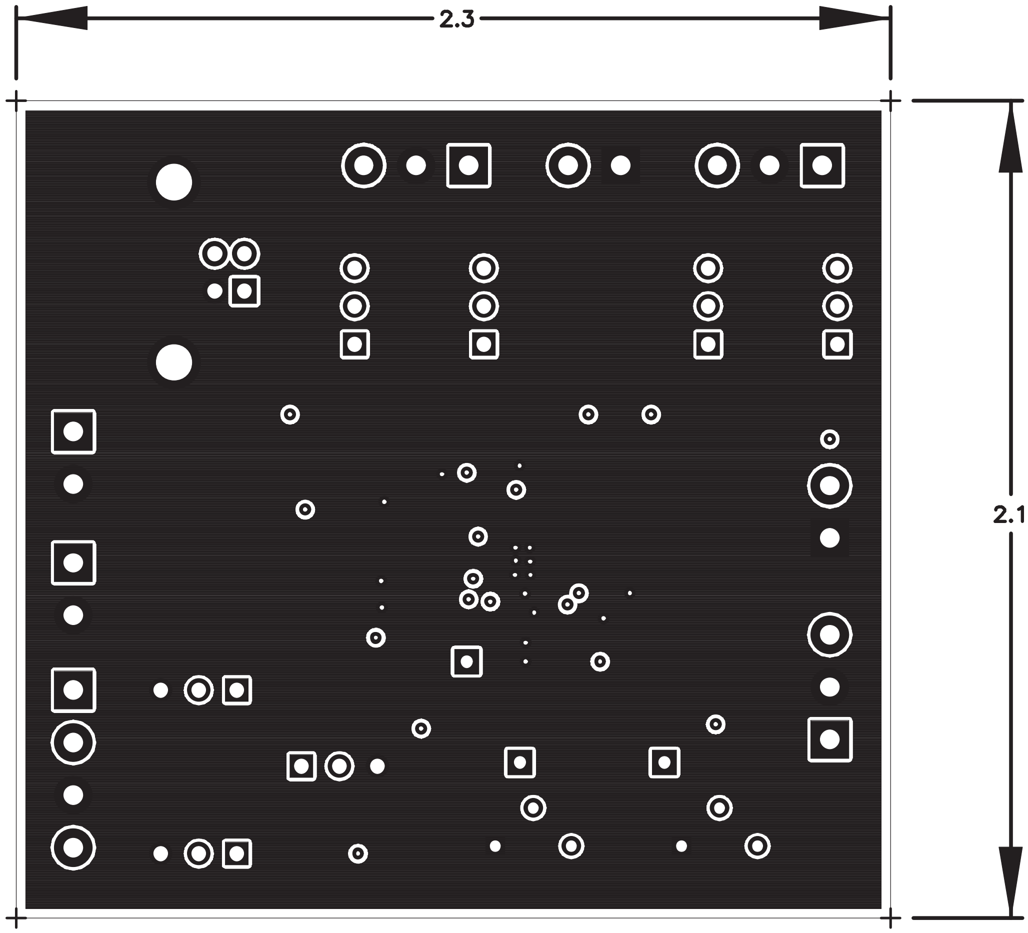

Figure 6. Board Layout – Third Etch Layer

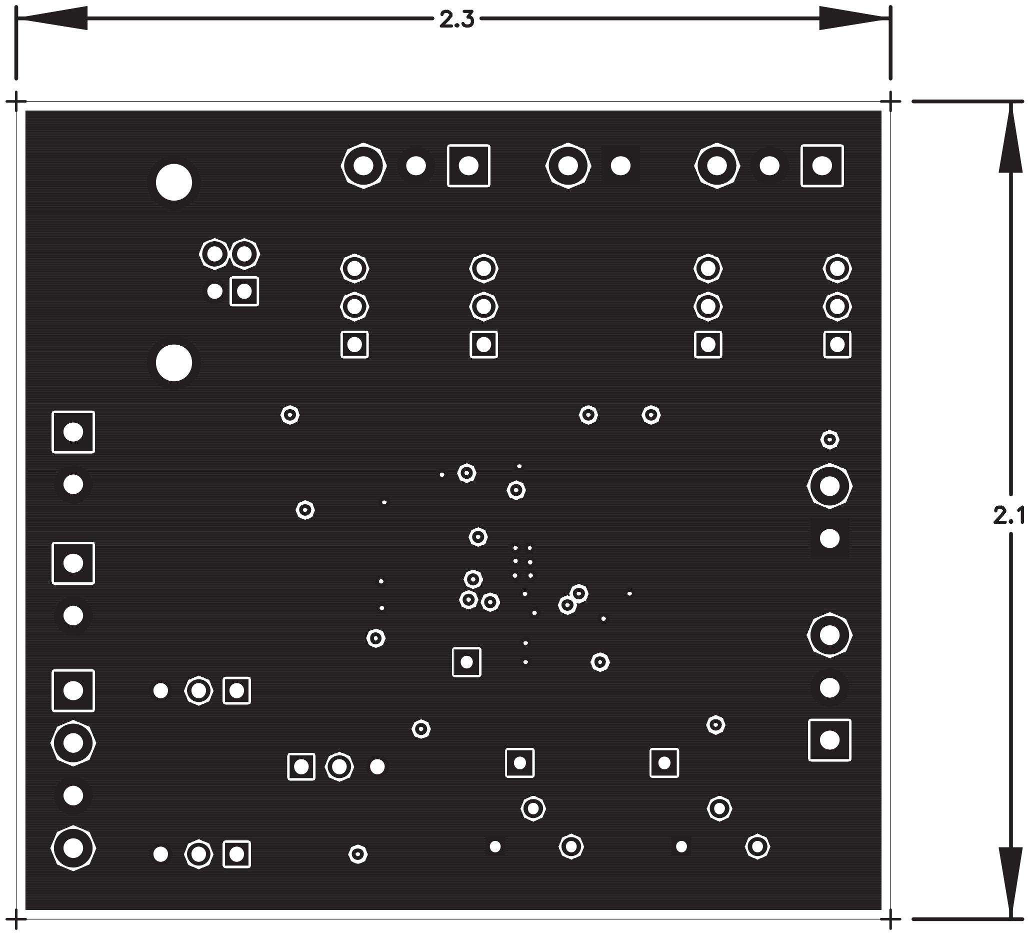

Figure 7. Board Layout – Bottom Etch Layer

7 Bill of Materials

Table 2. Bill of Materials [(1)] [(2)] [(3)] [(4)]

COUNT				REFDES	DESCRIPTION	SIZE	MFR	PART NUMBER
bq24030 -001	**bq24032 -002**	**bq24035 -003**	**bq24031 -004**					
3	3	3	3	C1, C2, C3	Capacitor, ceramic, 10-µF, 6.3-V, X5R, 20%	805	Panasonic	ECJ-2FB0J106M
2	2	2	2	C4, C5	Capacitor, ceramic, 10-µF, 25-V, X5R, 20%	1206	Panasonic	ECJ-3YB1E106M
1	1	1	1	C6	Capacitor, ceramic, 0.47-µF, 16-V, X7R, 10%	805	Panasonic	ECJ-2YB1C474K
0	0	0	0	C7	Capacitor, ceramic, 0.22-µF, 10-V, X5R, 10%	603	Panasonic	ECJ-1VB1A224K
0	0	0	0	C8	Capacitor, ceramic, xxx-µF, 10-V, X5R, 10%	603	Panasonic	ECJ-1VB1C103K
1	1	1	1	D1	Diode, dual Schottky, 200-mA, 30-V	SOT23	Vishay -Liteon	BAT54C
3	3	3	3	D2, D4, D5	Diode, LED, green, 2.1-V, 20-mA, 6-mcd	603	Liteon	160-1183-1-ND
1	1	1	1	D3	Diode, LED, red, 1.8-V, 20-mA, 20-mcd	603	Liteon	160-1181-1-ND
4	4	4	4	J1, J2, J5, J7	Terminal block, 2-pin, 6-A, 3.5 mm	0.27 x 0.25	OST	ED1514
1	1	1	1	J3	Terminal block, 4-pin, 6-A, 3.5 mm	0.55 x 0.25	OST	ED1516
3	3	3	3	J4, J6, J8	Terminal block, 3-pin, 6-A, 3.5 mm	0.41 x 0.25	OST	ED1515
1	1	1	1	J9	Connector, USB upstream (Type B)	0.47 x 0.67	Molex	67068-1000
7	7	7	7	JMP1, JMP2, JMP3, JMP4, JMP5, JMP6, JMP7	Header, 3-pin, 100-mil spacing, (36-pin strip)	0.10 x 3	Sullins	PTC36SAAN
4	4	4	4	R1, R2, R7, R8	Resistor, Chip, 1.5-kΩ, 1/16-W, 1%	603	Std	Std
1	1	1	1	R10	Resistor, Chip, 0-Ω, 1/16-W, 1%	603	Std	Std
1	1	1	1	R11	Resistor, Chip, 22.6-kΩ, 1/16-W, 1%	603	Std	Std
1	1	1	1	R14	Resistor, Chip, 30.1-kΩ, 1/16-W, 1%	603	Std	Std
1	1	1	1	R15	Potentiometer, 20-kΩ, 1/4 inch Cermet, 12-turn, top-adjust	0.25 × 0.17	Bourns	3266W-203
1	1	1	1	R16	Potentiometer, 50-kΩ, 1/4 inch Cermet, 12-turn, top-adjust	0.25 × 0.17	Bourns	3266W-503
3	3	3	3	R3, R4, R5	Resistor, chip, 100-kΩ, 1/16-W, 1%	603	Std	Std
1	1	1	1	R6	Resistor, chip, 1-kΩ, 1/10W, 1%	805	Std	Std
1	1	1	1	R9	Resistor, chip, 10-kΩ, 1/16-W, 1%	603	Std	Std
3	3	3	3	TP1, TP2, TP3	Test point, 0.032-inch hole		None	Void
1			1	U1	IC, single chip charge and power path management	QFN	TI	bq24030RHL
	1			U1	IC , single chip charge and power path management	QFN	TI	bq24032ARHL
		1		U1	IC , single chip charge and power path management	QFN	TI	bq24035RHL
1	1	1	1	--	PCB, 2-inch x 2-inch x 0.31-inch		Any	HPA073

(1) These assemblies are ESD sensitive, ESD precautions shall 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 substituted. All other components can be substituted with equivalent MFR's components.

8 References

1. SLUS618, bq2403x Datasheet

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EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 0 V to 6.5 V and the output voltage range of 0 V to 6.5 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 85°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.

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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 DEGREDATION 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/lsds/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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

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2. 実験局の免許を取得後ご使用いただく。
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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page 電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

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.

6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

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, INDEMITY 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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