

bq2406x Evaluation Module

1 Introduction

This user's guide describes the bq2406x evaluation module (EVM). The EVM provides a convenient method for evaluating the performance of a charge management solution for portable applications using the bq2406x product family. A complete designed and tested charger is presented. The charger is designed to deliver up to 1 A of continuous charge current for single-cell Li-Ion or Li-polymer applications using a DC power supply.

1.1 Background

The bq2406x series are highly integrated Li-Ion and Li-polymer linear chargers, targeted at space-limited portable applications. The bq2406x series offers a variety of safety features and functional options, while still implementing a complete charging system in a small package. The battery is charged in three phases: conditioning, constant or thermally regulated current, and constant voltage. Charge is terminated based on minimum current. An internal programmable charge timer provides a backup safety feature for charge termination and is dynamically adjusted during the thermal regulation phase. The bq2406x automatically re-starts the charge if the battery voltage falls below an internal threshold; sleep mode is set when the external input supply is removed. Multiple versions of this device family enable easy design of the bq2406x in cradle chargers or in the end equipment, while using low-cost or high-end AC adapters.

1.2 Performance Specification Summary

This section summarizes the performance specifications of the EVM. [Table 1](#) gives the EVM performance specifications.

Table 1. Performance Specification Summary

SPECIFICATION	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input DC Voltage, $V_{I(DC)}$		$V_{REG} + 0.5$	5	12 ⁽¹⁾	Volts
Battery Charge Current, $I_{O(CHG)}$				1 ⁽¹⁾	Amperes
Power Dissipation	$(V_{(DC+)} - V_{(BAT+)}) \times I_{(CHG)}$			1.5	Watts

- ⁽¹⁾ This maximum recommended input of the IC is 16.5 V. The IC has an OVP (overvoltage protection) input circuit that disables the charging circuit if the threshold is exceeded. Most IC selections are set for 6.5 V, but some are set as high as 12 V (see data sheet specification). The EVM can handle an input voltage up to the recommended maximum of 16.5 V, but the IC will be shut down due to the internal voltage protection. It is recommended that in normal operation the IC be designed and run below the thermal regulation junction temperature of 125°C. The thermal loop can run continuously without any issues, but the suggested thermal loop operational use is for more harsh environments where the ambient temperature is high (e.g., in an automobile during the summer) or with an incorrect adaptor with a higher input voltage. For typical input and ambient conditions with the PowerPAD™ tied to a copper plane, one can expect 1.5 W of heat dissipation prior to the thermal loop reducing the current. $P_{dissIC} = I_{CHG} \times (V_{DC+} - V_{BAT+})$. For the worst-case, steady-state thermal condition, $V_{BAT+} = 3.4$ VDC (the battery when transitioning from precharge to fast charge reaches a steady-state value after approximately 2 minutes). If the thermal regulation limit of 125°C is reached, then the charging current is adjusted lower.

2 Test Summary

This section shows the test setups used and the tests performed in evaluating the EVM.

Setup: The bq2406xEVM board requires a 5-VDC, 1-A power source to provide input power and a single-cell Li-ion or Li-polymer battery pack. 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

Jack	Connect To:
J1-DC+	Power supply positive, preset to 5 VDC, 1-A current limit.
J1-DC-	Power supply ground
J2-BAT+	Positive battery pack terminal
J2-BAT-	Negative battery pack terminal
J2-TS	NC
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-PG	External hardware if J6-EXT if jumpered (Not jumpered from factory)
J4 (Jumper)	STAT1 indication location – LED⁽¹⁾ (EVM) EXT
J5 (Jumper)	STAT2 indication location – LED⁽¹⁾ (EVM) EXT
J6 (Jumper)	PG indication location – LED⁽¹⁾ (EVM) EXT
J7 (Jumper)	TMR enable - Installed⁽¹⁾

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

2.1 Test Procedure

Set up the evaluation board as previously described 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 IC is not exceeded, $P_{(MAX)} = 1.5 \text{ W}$.

1. Turn on the power supply, which was preset to 5 VDC, and 1 A for the current-limit setting.
2. The bq2406x enters preconditioning mode if the battery is below the $V_{(LOWV)}$ threshold. In this mode, the bq2406x precharges the battery with a low current (typically $IO(CHG) / 10 = 0.7A / 10 = 70 \text{ mA}$) 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 and the bq2406x enters fault mode. Both LEDs turn off when in fault mode. 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. Once the charge terminates, J7 (TMR jumper) can be removed, putting the IC in LDO mode, and the charger should turn on the supply 4.2 V or the programmed fast-charge current. Replacing the jumper allows the IC to terminate properly. Note that loads across the battery can affect termination.
7. If the battery discharges to the recharge threshold, the charger starts fast charging.

Note: Because of the battery detection circuit, it is difficult to test the different charge phases without a battery (using just resistors); the algorithm sinks and sources current and applies precharge and fast-charge current depending on the mode it is in. Applying a load that would keep the voltage at 3.5 V (3.5 V/0.7 A) would pull the output into precharge mode and keep it there during the battery detection algorithm, which always occurs when the output is discharged to the refresh threshold. Once in precharge mode, a load sufficient to allow the capacitor to charge to $V_{(lowV)}$ would allow the output to jump to voltage regulation once the 0.7-A fast charge function activated.

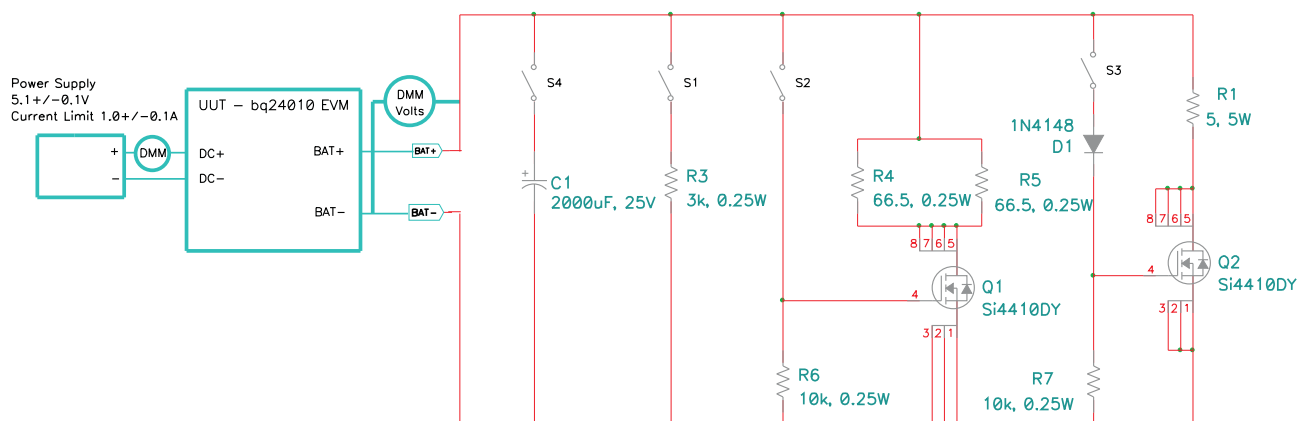
In place of a battery, a source meter that can sink current can easily be adjusted to test each mode.

To briefly see each mode on a scope, connect a 1-mF capacitor in parallel with a 20-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.

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 due to the active battery detection circuit, refresh feature, precharge, and fast-charge current levels (switching the load in and out in different modes has different results). No damage should occur, but one might get different results than anticipated if the procedure is altered.

2.1.1 EQUIPMENT

1. Power Source: Current-limited 5-V laboratory power supply with its current limit set to 1 A $\pm$ 0.1 A
2. Two Fluke 75 digital multimeters, equivalent or better
3. Oscilloscope – TDS220 or better
4. Load test board:



2.1.2 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. (The range is 0 V to 5 V.)
3. Set the laboratory power supply for 5.1 V $\pm$ 0.1 VDC, 1-A $\pm$ 0.1-A current limit and then turn off this supply. Connect the source supply to a current meter and to J1, noting polarity (an internal source current meter can be used if it has 5% or better accuracy).
4. Install shunt jumpers on the **LED** pins 1 and 2 of each header J4, J5, and J6 and also on J7-1/2 TMR.

2.1.3 PROCEDURE

1. Ensure that the preceding Equipment Setup steps are followed (switches should be in the closed position, shunts installed, and the power source set to 5.1 V $\pm$ 0.1 VDC). Turn on the power source.
2. Verify that the output voltage, BAT+, charges to between 2.5 V to 2.9 V and the red LED (D1) is lit (all

Test Summary

- dash numbers).
3. Verify that the green LED (D3) is lit for -001/2/5/6/7.
 4. Verify that the voltage on J2-2 (TS, $\overline{CE}$, $\overline{TE}$) to J2-1 (BAT-) is between 2 VDC to 3 VDC for -001/3/5/6, between 0 VDC to 0.4 VDC for -002/7, and between 4.6 VDC to 5.6 VDC for -004.
 5. Verify the voltage between J6-2 ($\overline{CE}$) and J1-2 (DC-) for -003/4. Jumper should not be shorting J6 pins.
 6. Open switch SW2, and then close it.
 7. Verify that the output voltage, BAT+, settles between 3.2 V to 3.95 V.
 8. Verify that the input current is between 0.69 A to 0.75 A.
 9. Open switch SW3.
 10. Verify that the input current is between 100 mA and 150 mA.
 11. Verify that the output voltage, BAT+, is between 4.150 VDC and 4.250 VDC.
 12. Open switch SW2.
 13. With a scope (250 ms/div, 1 V/div), verify that output, BAT+, charges and discharges between the maximum limits of 3 V and 4.7 V, with a period of between 600 ms to 850 ms.
 14. Verify that the LEDs flash between red (D1) and green (D2, mostly on green).
 15. Remove J7 and verify that voltage on BAT+ is between 4.150 VDC and 4.250 VDC, and the red LED (D1) turns on.
 16. Install J7.
 17. Open SW4, and verify that D1 and D2 are off and D3 is on (D3 does not apply to -003/4).
 18. With a scope on BAT+, verify that a square wave is seen between the maximum limits of 1.3 VDC and 4.35 VDC and between 3.5 Hz and 4.5 Hz.
 19. Close switches SW2, SW3, and SW4 (all switches should be closed now), and power down the supply.

3 Schematic

This section contains the schematic diagram for the EVM.

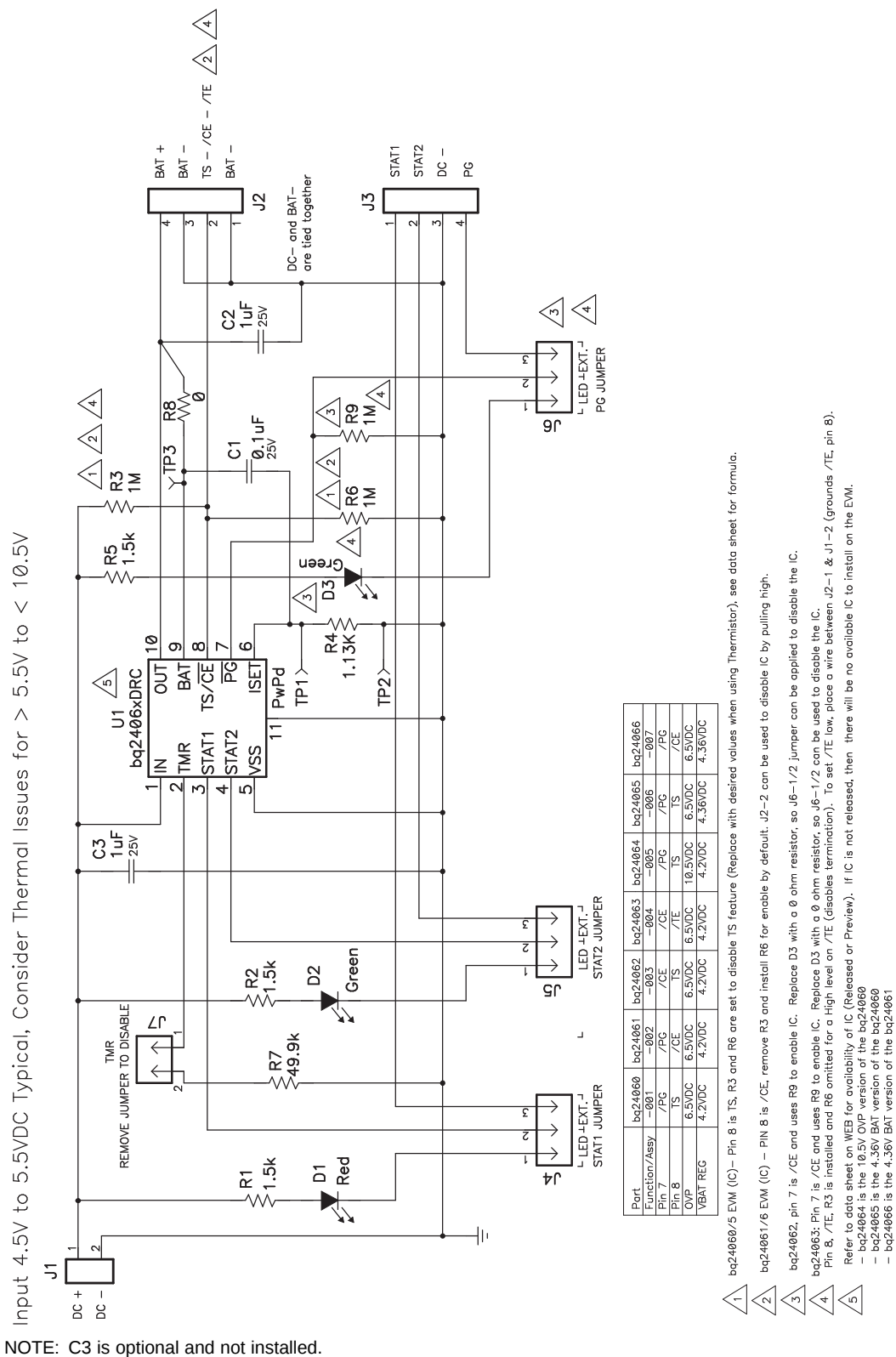


Figure 1. EVM Schematic Diagram

4 Physical Layouts

This section contains the board layout and assembly drawings for the EVM. [Figure 2](#), [Figure 3](#), and [Figure 4](#) show the top layer, the bottom layer, and the top assembly view of the EVM, respectively.

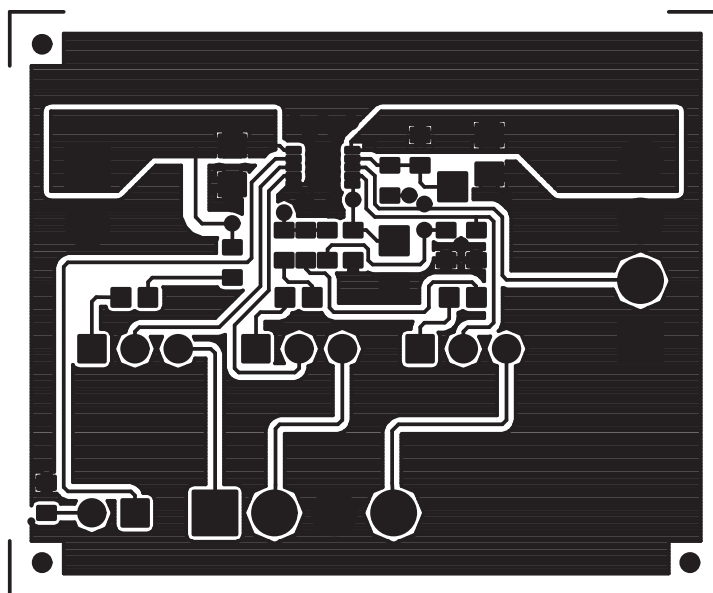


Figure 2. Board Layout Top Layer

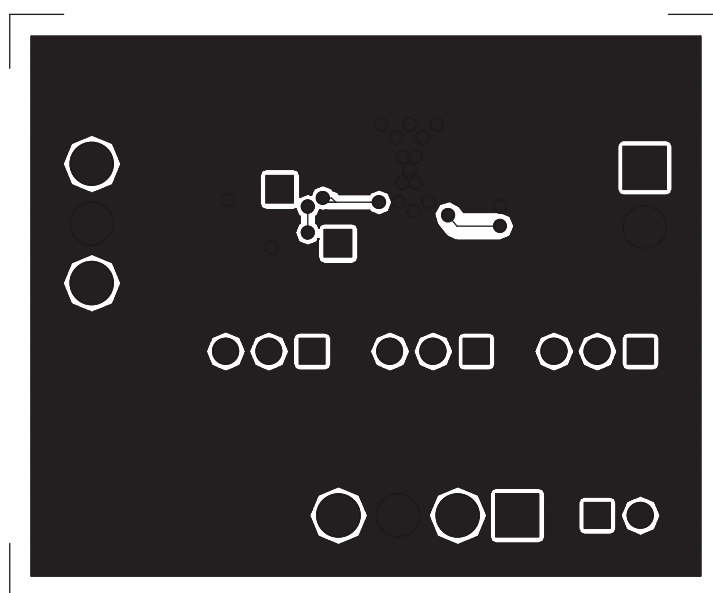


Figure 3. Board Layout Bottom Layer

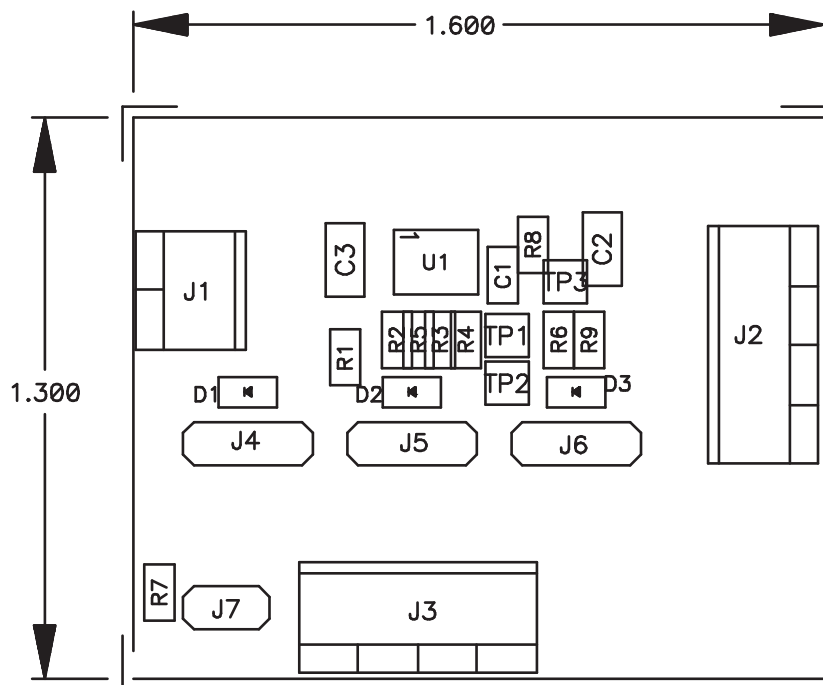


Figure 4. Top Assembly View

5 Bill of Materials

This section contains the bill of materials required for the EVM.

Table 3. HPA149A Bill of Materials, bq2406xEVM⁽¹⁾⁽²⁾⁽³⁾

bq24060 -001	bq24061 -002	bq24064 -005	Ref Des	Value	Description	Size	Part Number	MFR
Count								
1	1	1	C1	0.1 μ F	Capacitor, ceramic, 25V, X7R, 10%	0603	ECJ-1VB1E104K	Panasonic
2	2	2	C2, C3	1 μ F	Capacitor, ceramic, 25V, X5R, 10%	0805	ECJ-2FB1E105K	Panasonic
1	1	1	D1		Diode, LED, red, 1.8-V, 20-mA, 20-mcd	0603	1600-1181-1-ND	Liteon
1	1	1	D2		Diode, LED, green, 2.1-V, 20-mA, 6-mcd	0603	1600-1181-1-ND	Liteon
0	0	0	D3	0	Resistor, Chip, 0- Ω , 1/16-W, 1%	0603	Std	Std
1	1	1	J1		Terminal block, 2-pin, 6-A, 3.5 mm	0.27 $\times$ 0.25	ED1514	OST
2	2	2	J2, J3		Terminal block, 4-pin, 6-A, 3.5 mm	0.55 $\times$ 0.25	ED1516	OST
2	2	2	J4, J5		Header, 3-pin, 100-mil spacing, (36-pin strip)	0.100 $\times$ 3	PTC36SAAN	Sullins
1	1	1	J6		Header, 3-pin, 100-mil spacing, (36-pin strip)	0.100 $\times$ 3	PTC36SAAN	Sullins
0	0	0	J6 ⁽³⁾		Header, 2-pin, 100-mil spacing, (36-pin strip)	0.100 $\times$ 2	PTC36SAAN	Sullins
1	1	1	J7		Header, 2-pin, 100-mil spacing, (36-pin strip)	0.100 in $\times$ 2	PTC36SAAN	Sullins
1	1	1	R8	0	Resistor, chip, 0- Ω , 1/16-W 1%	0603	Std	Std
3	3	3	R1, R2, R5	1.5k	Resistor, chip, 1.5-k Ω , 1/16-W 1%	0603	Std	Std
1	0	1	R3	1M	Resistor, chip, 1-M Ω , 1/16-W 1%	0603	Std	Std
1	1	1	R6	1M	Resistor, chip, 1-M Ω , 1/16-W 1%	0603	Std	Std
0	0	0	R9	1M	Resistor, chip, 1-M Ω , 1/16-W 1%	0603	Std	Std
1	1	1	R4	1.13K	Resistor, chip, 1.13 k Ω , 1/16-W 1%	0603	Std	Std
1	1	1	R7	49.9k	Resistor, chip, 49.9 k Ω , 1/16-W 1%	0603	Std	Std
0	0	0	TP1, TP2, TP3		Test Point, 0.032 hole		Std	Std

⁽¹⁾ When J6 is a 2 pin header, Install in J6-1/2

⁽²⁾ Install Jumper Shunts, for -001/2/5/6/7, on: J4-1/2 (LED), J5-1/2 (LED), J6-1/2 (LED), and J7-1/2.

Install Jumper Shunts, for -003/4, on: J4-1/2 (LED), J5-1/2 (LED), J6-1 (just pin 1), and J7-1/2

⁽³⁾ bq24062/3/5/6 are not released at this time. Check WEB for availability.

References

Table 3. HPA149A Bill of Materials, bq2406xEVM (continued)

bq24060 -001	bq24061 -002	bq24064 -005	Ref Des	Value	Description	Size	Part Number	MFR
Count								
1	0	0	U1		IC, TPOD, $\overline{PG}$, TS	3×3 mm	bq24060DRC	TI
0	1	0	U1		IC, TPOD, $\overline{PG}$, $\overline{CE}$	3×3 mm	bq24061DRC	TI
0	0	0	U1		IC, TPOD, $\overline{PG}$, $\overline{CE}$	3×3 mm	bq24062DRC	TI
0	0	0	U1		IC, TPOD, $\overline{PG}$, $\overline{CE}$	3×3 mm	bq24063DRC	TI
0	0	1	U1		IC, TPOD, $\overline{PG}$, $\overline{CE}$	3×3 mm	bq24064DRC	TI
0	0	0	U1		IC, TPOD, $\overline{PG}$, $\overline{CE}$	3×3 mm	bq24065DRC	TI
0	0	0	U1		IC, TPOD, $\overline{PG}$, $\overline{CE}$	3×3 mm	bq24066DRC	TI
1	1	1	—		PCB, 1.3 in × 1 in × 0.031 in		HPA149, PCB EVM	Any
4	4	4	Shunt ⁽²⁾	Shunt	Shunt		Guess	

6 References

1. bq24060 data sheet ([SLUS689](#))

EVALUATION BOARD/KIT IMPORTANT NOTICE

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

This evaluation board/kit is intended for use for **ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY** and is not considered by TI to be a finished end-product fit for general consumer use. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board/kit does not fall within the scope of the European Union directives regarding electromagnetic compatibility, restricted substances (RoHS), recycling (WEEE), FCC, CE or UL, and therefore may not meet the technical requirements of these directives or other related directives.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/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. 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 User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please contact the TI application engineer or visit www.ti.com/esh.

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.

FCC Warning

This evaluation board/kit is intended for use for **ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY** and is not considered by TI to be a finished end-product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC rules, which are designed to provide reasonable protection against radio frequency interference. Operation of this equipment in other environments may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 4.4 V to 16 V and the output voltage range of 2.3 V to 4.4 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 75°C. The EVM is designed to operate properly with certain components above 100°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
Copyright © 2006, Texas Instruments Incorporated

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.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DSP	dsp.ti.com
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
Low Power Wireless	www.ti.com/lpw

Applications

Audio	www.ti.com/audio
Automotive	www.ti.com/automotive
Broadband	www.ti.com/broadband
Digital Control	www.ti.com/digitalcontrol
Military	www.ti.com/military
Optical Networking	www.ti.com/opticalnetwork
Security	www.ti.com/security
Telephony	www.ti.com/telephony
Video & Imaging	www.ti.com/video
Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2007, Texas Instruments Incorporated