User's Guide
SLUU365–June 2009

# bq2435x DSG EVM for Li-Ion Charger Front-End Protection IC

This user's guide describes the features, setup, and operation of the bq2435xEVM evaluation module. Included are the bill of materials, board layout, and schematic.

**Contents**

1 Introduction ..... 2
1.1 General Description ..... 2
1.2 EVM Features ..... 2
1.3 I/O Description ..... 2
1.4 Controls and Key Parameters Setting ..... 2
1.5 Recommended Operating Conditions ..... 3
2 Test Summary ..... 3
2.1 Definitions ..... 3
2.2 Equipment ..... 3
2.3 Equipment Setup ..... 4
2.4 Procedure ..... 5
3 PCB Layout Guideline ..... 6
4 Bill of Materials, Board Layout, and Schematic ..... 6
4.1 Bill of Materials ..... 6
4.2 Board Layout ..... 7
4.3 Schematic ..... 10

**List of Figures**

1 Original Test Setup for HPA398 (bq2435x DSG EVM) ..... 5
2 Top Layer ..... 7
3 Bottom Layer ..... 8
4 Top Silk Screen ..... 8
5 Top Assembly ..... 9
6 bq243550 Schematic ..... 10

**List of Tables**

1 Bill of Materials ..... 6

# 1 Introduction

## 1.1 General Description

The bq2435x evaluation module (EVM) is a complete charger module for evaluating a charger front-end protection and charger solution using the bq2435x and bq2057C devices. It is designed to deliver up to 560 mA of charge current to Li-ion or Li-polymer applications. The charger front-end protection current is designed to 1.2 A.

The bq2435x protects the charging system against three types of failures: input overvoltage when the ac adapter fails to regulate its voltage, load overcurrent when failures such as a short circuit occur in the charging system, and battery overcharge.

For details, see the bq2435x data sheet (SLUS943).

## 1.2 EVM Features

- Evaluation module for bq2435x DSG
- Evaluation module for bq2057C charger integrated circuit (IC)
- Input operating range for bq2435x 4.5 V–26 V
- Input operating range for bq24080 4.5 V–6.5 V
- Input overvoltage protection.
- Input overcurrent protection.
- Battery overvoltage protection.
- LED Indication for status signals.
- Test points for key signals available for testing purpose. Easy probe hook-up
- Jumpers available. Easy to change connections

## 1.3 I/O Description

| Jack | Description |
|---|---|
| J1–DC+ | AC adapter, positive output |
| J1–DC– | AC adapter, negative output, ground |
| J2–FAULT | bq24355 $\overline{\text{FAULT}}$ pin |
| J2–VBAT | bq2435x VBAT pin |
| J2–GATDRV | bq2435x GATDRV pin |
| J2–CHGIN | bq2435x CHGIN pin |
| J3–BATEN | bq24355 $\overline{\text{BATEN}}$ pin |
| J3–OUT | bq2435x OUT pin |
| J3–BAT+ | Battery positive output |
| J3–GND | Ground |
| J4–BAT+ | Connect to battery positive output |
| J4–BAT– | Connect to battery negative output, ground |

## 1.4 Controls and Key Parameters Setting

| Jack[(1)] | Description | Factory Setting |
|---|---|---|
| JP1 | If on, high-side current sensing resistor is disabled | Jumper on |
| JP2 | bq24355 $\overline{\text{BATEN}}$ pin logic input, pull low to enable | Jumper ($\overline{\text{BATEN}}$, GND) on |
| JP3 | bq2435x GATDRV pin | Jumper off |
| JP4 | bq2057C BAT pin connection to bq2435x | Jumper on |

(1) Short JP1, JP4, JP5, and JP6, and disconnect JP7 to use on board bq2057C as charger; to use external charger to control bq2435x, disconnect JP1, JP4, JP5, and JP6 and short JP7.

| Jack[1] | Description | Factory Setting |
|---|---|---|
| JP5 | bq2057C VCC pin connection to bq2435x | Jumper on |
| JP6 | bq2057C CC pin connection to bq2435x | Jumper on |
| JP7 | If on, low-side current sensing resistor is disabled | Jumper off |

### 1.5 Recommended Operating Conditions

| Symbol | Description | Minimum | Typical | Maximum | Unit |
|---|---|---|---|---|---|
| Supply voltage, $V_{IN}$ | Input voltage from ac adapter input | 4.5 | 5 | 26 | V |
| Battery voltage, $V_{BAT}$ | Voltage applied at VBAT terminal of J4 | 0 | 3–4.2 | 5 | V |
| Supply current, $I_{AC}$ | Maximum input current from ac adapter input | 0 | | 1.5 | A |
| Charge current, $I_{chrg}$ | Battery charge current | 0.05 | 0.56 | 1 | A |
| Operating junction temperature range, $T_J$ | | 0 | | 125 | °C |

## 2 Test Summary

### 2.1 Definitions

This procedure details how to configure the evaluation board. On the test procedure, the following naming conventions are followed. See the schematic for details.

| | |
|---|---|
| VXXX | External voltage supply name (VIN, VBAT, VOUT) |
| LOADW: | External load name (LOADR, LOADI) |
| V(TPyyy) : | Voltage at internal test point TPyyy. For example, V(TP1) means the voltage at TP1. |
| V(Jxx): | Voltage at jack terminal Jxx. |
| V(TP(XXXXX)): | Voltage at test point “XXXXX”. For example, V(ACDET) means the voltage at the test point which is marked as “ACDET”. |
| V(XXX, YYY): | Voltage across point XXX and YYY. |
| I(JXX(YYY)): | Current going out from the YYY terminal of jack XX. |
| Jxx(BBB): | Terminal or pin BBB of jack xx |
| Jxx ON : | Internal jumper Jxx terminals are shorted |
| Jxx OFF: | Internal jumper Jxx terminals are open |
| Jxx (-YY-) ON: | Internal jumper Jxx adjacent terminals marked as “YY” are shorted |
| Measure:→ A,B | Check specified parameters A, B. If measured values are not within specified limits the unit under test has failed. |
| Observe → A,B | Observe if A, B occur. If they do not occur, the unit under test has failed. |

Assembly drawings have location for jumpers, test points and individual components

### 2.2 Equipment

#### 2.2.1 Power Supplies

Power Supply 1 (PS 1): a power supply capable of supplying 10 V at 2 A is required.

### 2.2.2 Load 1

A 10-V (or above), 2-A (or above) electronic load that can operate at constant current mode.

### 2.2.3 Load 2

A 10-V (or above), 2-A (or above) electronic load that can operate at constant voltage mode.

### 2.2.4 Meters

Four Fluke 75 multimeters (equivalent or better)
Or:
Three equivalent voltage meters and one equivalent current meter
The current meter must be capable of measuring 2-A+ current.

### 2.2.5 Wire Gauge

All wires connected to the EVM input power supply and output load must use at least AWG 22. The maximum current is up to 1 A.

## *2.3 Equipment Setup*

1. Set the PS 1 for 0 V ±100 mVdc, 2 ± 0.1 A current limit, and then disable the output.
2. Connect the output of PS 1 to J1 (DC+, DC–).
3. Connect a voltage meter across J1 (DC+, DC–).
4. Connect the output of the Load 1 in series with a current meter (multimeter) to J2 (CHGIN) and J3 (GND). Turn on the power of the Load 1. Set the load current to 1.5 A ±50 mA but disable the output.
5. Connect output of the Load 2 in series with a current meter (multimeter) to J4 (BAT+, BAT–).
6. Connect a voltage meter across J4 (BAT+, BAT–).
7. Set the voltage of Load 2 to 3.6 V ±0.1 V, and disable output of Load 2.
8. JP1: ON, JP2 (BATEN, GND): ON, JP3: OFF, JP4: ON, JP5: ON, JP6: ON, JP7: OFF.

After the preceding steps have been taken, the test setup for HPA398 (bq2435x DSG EVM) appears as is shown in Figure 1.

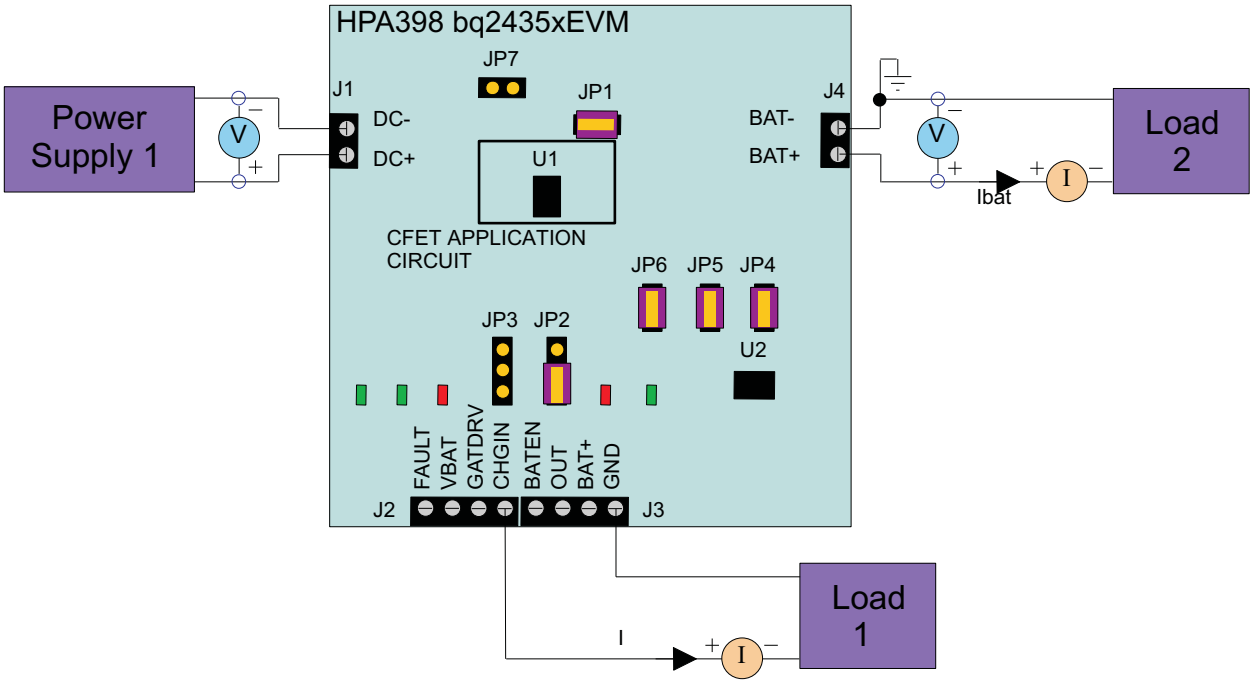


**Figure 1. Original Test Setup for HPA398 (bq2435x DSG EVM)**

## 2.4 Procedure

### 2.4.1 Charger Current and Voltage Regulation

1. Ensure that steps in Section 2.3 are followed.
2. Enable output of PS 1.
3. Increase the output voltage of PS 1 to 5 V ±0.1 V.
4. Enable output of Load 2.
   *Measure* → V(J2(OUT)) = 3.6 V ±200 mV
   *Measure* → Ibat = 560 mA ±70 mA
   *Observe* → D2 on, D3 on, D6 off, D7 on.

### 2.4.2 CFET Input Overvoltage Protection

1. Increase the voltage of PS 1 to 8 V ±0.1 V.
   *Observe* → D2 on, D3 off, D6 off, D7 off.
2. Decrease the voltage of PS 1 to 5 V ±0.1 V.
   *Observe* → D2 on, D3 on, D6off, D7 on.

### 2.4.3 CFET Load Overcurrent Protection

1. Enable the output of the Load 1.
   *Observe* → D2 on, D3 off, D6 off, D7 off.
2. Disable the output of the Load 1.
   *Observe* → D2 on, D3 on, D6 off, D7 on.
3. Decrease the voltage of PS 1 to 0 V ±0.1 V.

# 3 PCB Layout Guideline

1. It is critical that the exposed power pad on the backside of the bq2435x package be soldered to the printed-circuit board (PCB) ground. Ensure that sufficient thermal vias are located underneath the IC, connecting to the ground plane on the other layers.
2. The high-current charge paths into ACIN and from CHGIN, OUT pins must be sized appropriately for the maximum charge current in order to avoid voltage drops in these traces.
3. Decoupling capacitors for ACIN, CHGIN must be placed and make the interconnections to the IC as short as possible.
4. Resistors for VBAT pin must be placed close to the corresponding IC pins and make the interconnections to the IC as short as possible.

# 4 Bill of Materials, Board Layout, and Schematic

## *4.1 Bill of Materials*

**Table 1. Bill of Materials**

| bq24350 -001 | bq24352 - 002 | bq24355 - 003 | RefDes | Value | Description | Size | Part Number | MFR |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | C1 | 1uF | Capacitor, Ceramic, 35V, X5R, 10% | 603 | Std | Std |
| 3 | 3 | 3 | C2, C3, C5 | 1uF | Capacitor, Ceramic, 10V, X7R, 10% | 603 | Std | Std |
| 1 | 1 | 1 | C4 | 0.1uF | Capacitor, Ceramic, 16V, X7R, 10% | 805 | Std | Std |
| 1 | 1 | 1 | C6 | 0.1uF | Capacitor, Ceramic, 10V, X7R, 10% | 603 | Std | Std |
| 1 | 1 | 1 | C7 | 220uF | Capacitor, Electrolytic, 25V, 20% | 0.327 X 0.327 inch | UUD1E221MNL1GS | Nichicon |
| 1 | 1 | 1 | D1 | BZT52C6V8S | Diode, Zener, 200mW, 6.8V | SOD-323 | BZT52C6V8S | General |
| 3 | 3 | 3 | D2, D3, D6 | Green | Diode, LED, Green, 2.1-V, 20-mA, 6-mcd | 603 | LTST-C190GKT | Lite On |
| 2 | 2 | 2 | D4, D7 | Red | Diode, LED, Red, 2.1-V, 20-mA, 6-mcd | 603 | LTST-C190CKT | Lite On |
| 1 | 1 | 1 | D5 | BAT54C | Diode, Dual Schottky, 200-mA, 30-V | SOT23 | BAT54C | Vishay-Liteon |
| 2 | 2 | 2 | J1, J4 | ED1514/2DS | Terminal Block, 2-pin, 6-A, 3.5mm | 0.27 x 0.25 inch | ED1514/2DS | OST |
| 2 | 2 | 2 | J2, J3 | ED1516/4DS | Terminal Block, 4-pin, 6-A, 3.5mm | 0.55 x 0.25 inch | ED1516/4DS | OST |
| 5 | 5 | 5 | JP1, JP4, JP5, JP6, JP7 | PEC02SAAN | Header, 2-pin, 100mil spacing | 0.100 inch x 2 | PEC02SAAN | Sullins |
| 2 | 2 | 2 | JP2, JP3 | PTC03SAAN | Header, Male 3-pin, 100mil spacing, (36-pin strip) | 0.100 inch x 3 | PTC03SAAN | Sullins |
| 5 | 5 | 5 | JP1, JP2, JP4, JP5, JP6 | 929950-00 | Shorting jumpers, 2-pin, 100mil spacing, | | 929950-00 | 3M/ESD |
| 2 | 2 | 0 | R1, R2 | 0 | Resistor, Chip, 1/16W, 1% | 402 | Std | Std |
| 0 | 0 | 2 | R3, R4 | 0 | Resistor, Chip, 1/16W, 1% | 402 | Std | Std |
| 2 | 2 | 2 | R5, R6 | 200k | Resistor, Chip, 1/16W, 5% | 402 | Std | Std |
| 2 | 2 | 2 | R7, R8 | 200k | Resistor, Chip, 1/16-W, 5% | 603 | Std | Std |
| 2 | 2 | 2 | R9, R10 | 0.2 | Resistor, Metal Film, 1/4 watt, 1% | 1206 | Std | Std |
| 1 | 1 | 1 | R11 | 20k | Resistor, Chip, 1/16-W, 5% | 603 | Std | Std |
| 1 | 1 | 1 | R12 | 1k | Resistor, Chip, 1/16-W, 5% | 603 | Std | Std |
| 1 | 1 | 1 | R13 | 100 | Resistor, Chip, 1/16-W, 5% | 603 | Std | Std |
| 1 | 1 | 1 | R14 | 6.2k | Resistor, Chip, 1/16-W, 5% | 603 | Std | Std |
| 4 | 4 | 4 | R15, R16, R17, R18 | 1.5k | Resistor, Chip, 1/16-W, 5% | 603 | Std | Std |

**Table 1. Bill of Materials (continued)**

| bq24350 -001 | bq24352 - 002 | bq24355 - 003 | RefDes | Value | Description | Size | Part Number | MFR |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | R19 | 51 | Resistor, Chip, 1/16-W, 5% | 603 | Std | Std |
| 4 | 4 | 4 | | | 6-32 NYL nuts | NY HN 632 | H620-ND | Building Fasteners |
| 4 | 4 | 4 | ST1,ST2,ST3,ST4 | 4816 | STANDOFF M/F HEX 6-32 NYL .500" | sf_thvt_325_rnd | 4816 | Keystone |
| 8 | 8 | 8 | TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8 | white | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5002 | Keystone |
| 1 | 1 | 1 | TP9 | white | Test Point, White, Thru Hole Color Keyed | 0.100 x 0.100 inch | 5001 | Keystone |
| 1 | 0 | 0 | U1 | bq24350DSG | IC, OVER-VOLTAGE AND OVER-CURRENT CHARGER FRONT-END | SON-8 | BQ24350DSG | TI |
| 0 | 1 | 0 | U1 | bq24352DSG | IC, OVER-VOLTAGE AND OVER-CURRENT CHARGER FRONT-END | SON-8 | BQ24352DSG | TI |
| 0 | 0 | 1 | U1 | bq24355DSG | IC, OVER-VOLTAGE AND OVER-CURRENT CHARGER FRONT-END | SON-8 | BQ24355DSG | TI |
| 1 | 1 | 1 | U2 | BQ2057CSN | IC, Charge Management, One or Two Cell Li-Ion or Li-Pol Charger | S0-8 | BQ2057CSN | TI |
| 1 | 1 | 1 | -- | HPA398 | PCB, 2.8 In x 2.8 In x 0.062 In | | PCB | Any |

Notes: 1. Number 0 in left side columns means do not use this component.
2. OPEN in value column means do not use this component.
3. Std in part number column means standard manufacturer's part number.
4. Std in MFR column means standard manufacturer.

## 4.2 Board Layout

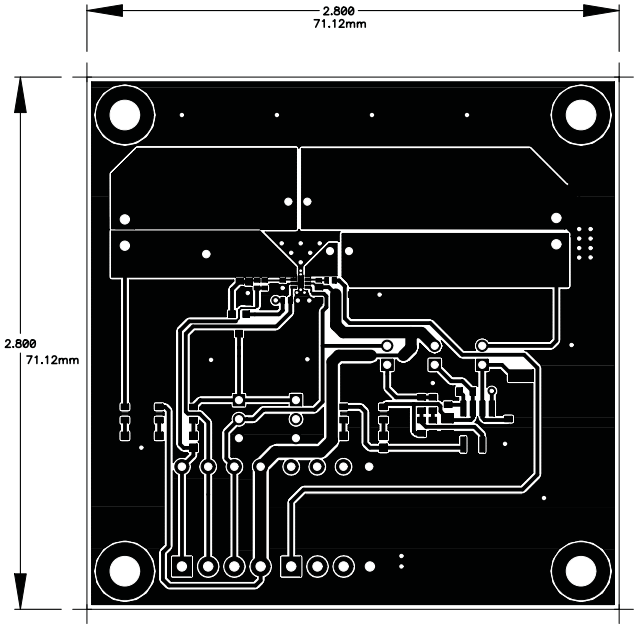


**Figure 2. Top Layer**

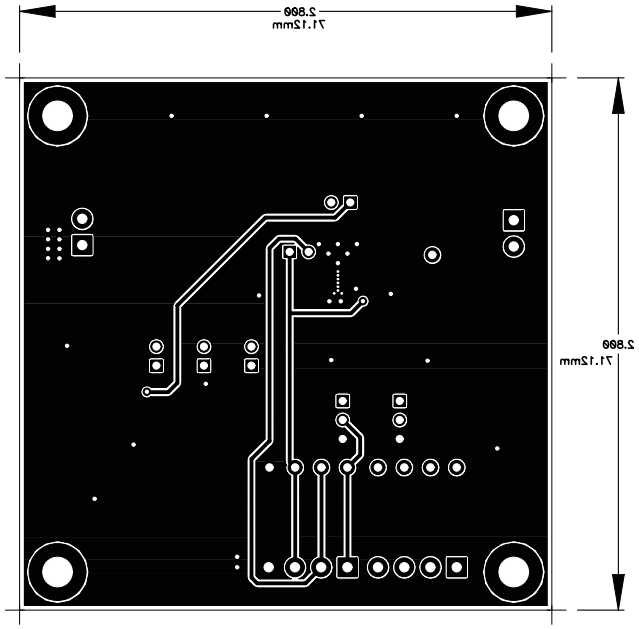


**Figure 3. Bottom Layer**

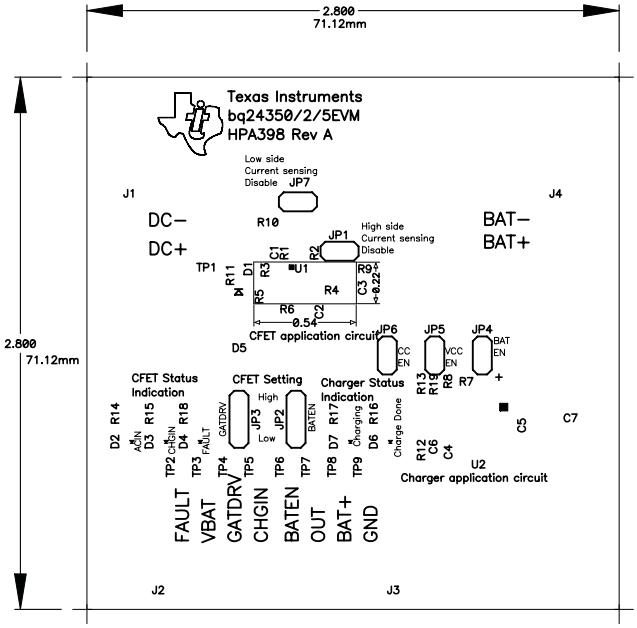


**Figure 4. Top Silk Screen**

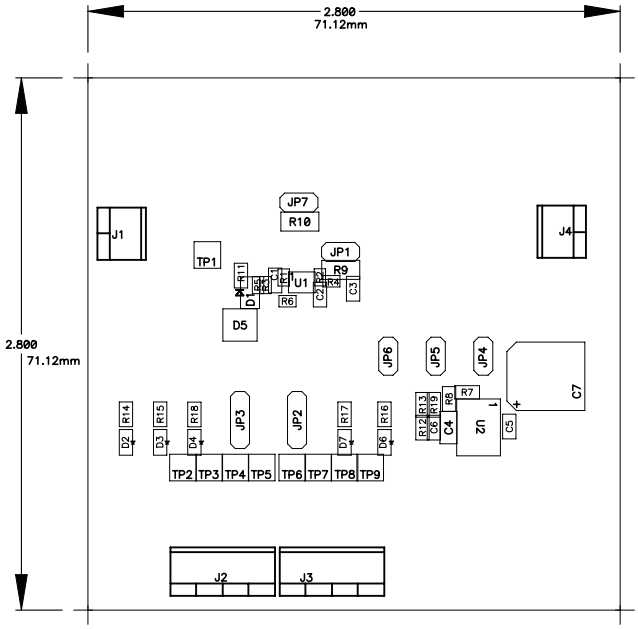


**Figure 5. Top Assembly**

## 4.3 Schematic

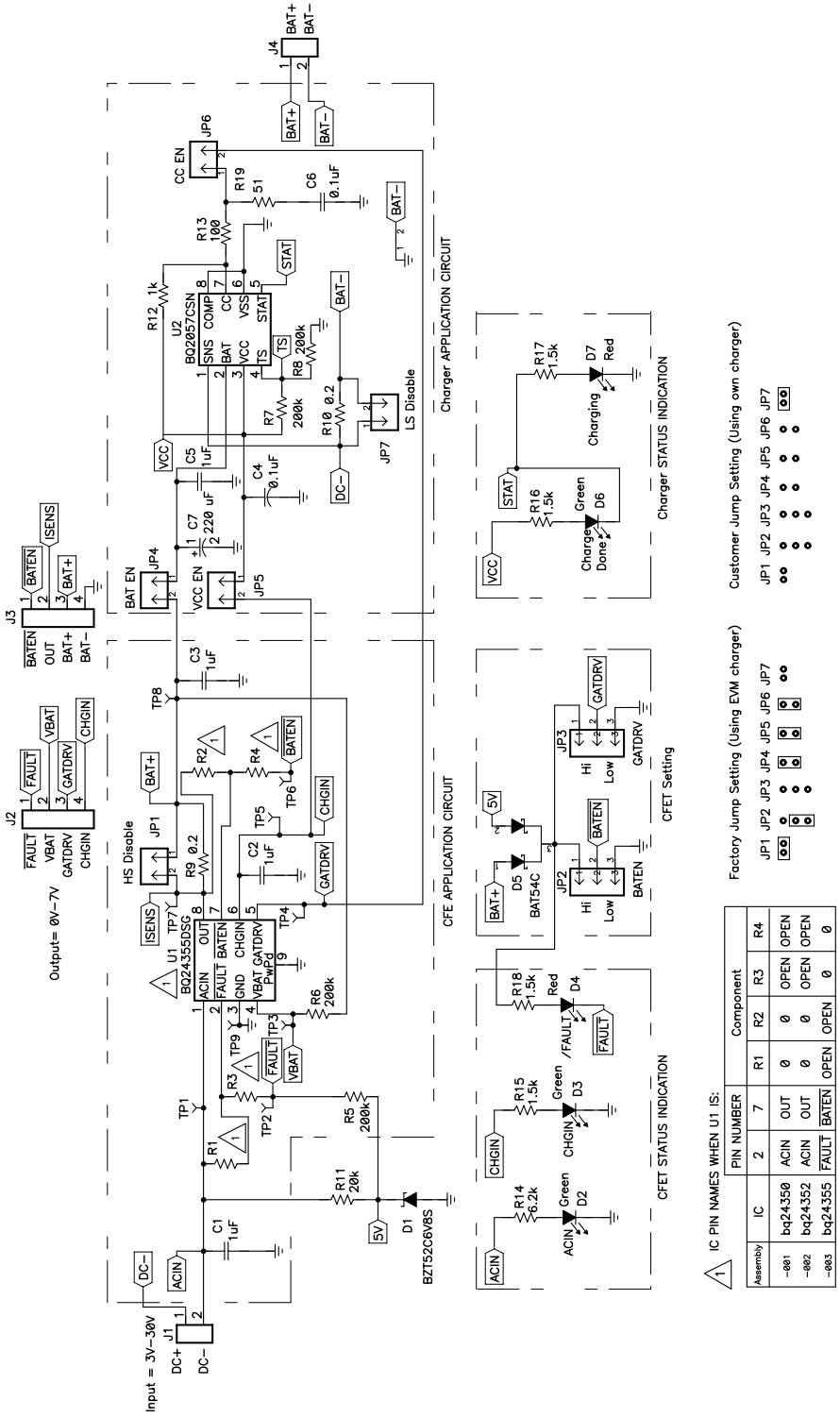


**Figure 6. bq243550 Schematic**

## 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 4.5 V to 26 V and the output voltage 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 125°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 © 2009, 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 TI 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. Information of third parties may be subject to additional restrictions.

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** | | **Applications** | |
|---|---|---|---|
| Amplifiers | amplifier.ti.com | Audio | www.ti.com/audio |
| Data Converters | dataconverter.ti.com | Automotive | www.ti.com/automotive |
| DLP® Products | www.dlp.com | Broadband | www.ti.com/broadband |
| DSP | dsp.ti.com | Digital Control | www.ti.com/digitalcontrol |
| Clocks and Timers | www.ti.com/clocks | Medical | www.ti.com/medical |
| Interface | interface.ti.com | Military | www.ti.com/military |
| Logic | logic.ti.com | Optical Networking | www.ti.com/opticalnetwork |
| Power Mgmt | power.ti.com | Security | www.ti.com/security |
| Microcontrollers | microcontroller.ti.com | Telephony | www.ti.com/telephony |
| RFID | www.ti-rfid.com | Video & Imaging | www.ti.com/video |
| RF/IF and ZigBee® Solutions | www.ti.com/lprf | Wireless | www.ti.com/wireless |

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2009, Texas Instruments Incorporated