800-mA, Single-Input, Single-Cell, Li-Ion Battery Solar Charger

This user's guide describes the features and operation of the bq24210/2 Evaluation Module (EVM). The EVM assists users in evaluating the bq24210/2 solar charger. The printed-circuit board for the EVM is labeled HPA678. The manual includes the bq24210/2EVM bill of materials, board layout, and schematic.

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1 Introduction

1.1 EVM Features

- 800-mA, single-input, single-cell Li-ion battery solar charger
- Resistor-programmable setting for charge current and input voltage dynamic power management
- LED Indication for status
- Test points for key signals available for testing purposes – easy probe hook-up
- Jumpers available – easy to change setting

1.2 General Description

The bq24210/2 series of devices are highly integrated Li-ion linear chargers devices targeted at space-limited portable applications. The high input voltage range with input overvoltage protection supports low-cost unregulated adapters. The input voltage regulation loop with programmable input voltage regulation threshold make it suitable for charging from alternative power sources, such as solar panel or inductive charging pad. The integrated circuit (IC) has a single power output that charges the battery. A system load can be placed in parallel with the battery as long as the average system load does not keep the battery from charging fully during the 10-hour safety timer. The bq24210 has an $\overline{EN}$ pin whereas the bq24212 has a MODE pin. See the data sheet for an explanation of the differences between the two pins.

The battery is charged in three phases: conditioning, constant current' and constant voltage. In all charge phases, an internal control loop monitors the IC junction temperature and reduces the charge current if an internal temperature threshold is exceeded.

For additional details, see the bq24210 (SLUSA76) or bq24212 (SLUSAL2) data sheet.

1.3 I/O Header Descriptions

Table 1. I/O Header Descriptions

Jack	Description
J1–VBUS	Positive input
J1–GND	Negative input
J2–BAT	Charger output
J2–GND	Ground
J2–TS	Temperature qualification input
J3-GND	Ground
J3-VDPM	Programs the input voltage regulation threshold
J3-$\overline{CHG}$	Charge status indication
J3-$\overline{EN}$ (BQ24210 only)	Chip Enable control. This pin must be pulled low in order for the device to operate.
J3-MODE (BQ24212 only)	Chip MODE control. See data sheet for explanation of chip operation when MODE is high and low.
J3-$\overline{PG}$	Power present indication
J4-ISET	Programs the fast-charge current setting
J4-VTSB	TS bias reference voltage pin, regulated output
J4-GND	Ground

1.4 Jumper Settings

Table 2. Jumper Settings

Jack	Description	Factory Setting
JP1	Programs the fast-charge current setting. 500 mA when JP1 ON; external setting when JP1 OFF	Jumper OFF (external setting)
JP2	Connect /EN and /PG together when JP2 ON to enable charger when power present	Jumper OFF (external /EN)
JP3	Programs the input voltage regulation threshold. 4.5V when JP3 ON; external setting when JP3 OFF.	Jumper OFF (external setting)
JP4	Limited power charge mode (LPCM) when JP4 ON; normal operation when JP4 OFF	Jumper OFF (normal operation)
JP5	Select external TS input or internal TS setting 1-2 : External TS input 2-3 : Internal TS setting	Jumper ON 1-2 (external TS)
JP6	The pullup power source supplies for the LEDs 1-2 : BAT 2-3 : VBUS	Jumper ON 2-3 (VBUS)
JP7	Charger $\overline{\text{EN}}$ / MODE 1-2 : OFF/HIGH 2-3 : ON/LOW	Jumper ON 1-2 (charger OFF / MODE High)

1.5 Recommended Operating Conditions

Table 3. Recommended Operating Conditions

	Description	Min	Typ	Max	Unit	Notes
Supply voltage, V_{BUS}	Input voltage	4.5		7.3	V	
Battery voltage, V_{BAT}	Voltage applied at VBAT terminal of J2	0		4.2	V	
Supply current	Maximum input current	0		0.8	A	
Charge current, I_{chrg}	Battery charge current	0		0.8	A	
Operating junction temperature range, T_J		0		125	°C	

An external resistor is used to program the VBUS_DPM. The programming resistor, R_{VDPM} is dictated by the following equation:

$$R_{VDPM} = \frac{\left(VBUS_{\_DPM} - VBUS_{\_DPM\_1} \right)}{KVBUS_{\_DPM}}$$

(1)

Where:
VBUS_DPM is the desired input voltage regulation voltage threshold.
VBUS_DPM_1 is the built-in offset threshold, nominally 3.5 V.
K_VBUS_DPM is a gain factor found in the electrical specification.
If VDPM pin is shorted to VSS; the VBUS_DPM must be clamped to 3.65 V.
If the VDPM pin is floated (open circuit), the IC operates in Battery Tracking mode. In this case, VBUS DPM threshold is internally set as V_{TRK}, which is BAT + 100 mV. (BAT > 3.65 V) or 3.75 V (BAT ≤ 3.4 V).
Connecting JP3 set 4.5 V VDPM on EVM.

An external resistor is used to program the output current (50-800 mA). The equation for charge current is:

$$R_{ISET} = \frac{K_{ISET}}{I_{OUT}}$$

(2)

Where, I_{OUT} is the desired fast-charge current; K_{ISET} is a gain factor found in the specification.

The termination and precharge current are internally set at 10% and 20% of fast-charge current, respectively. The precharge-to-fast-charge, V_{lowv} threshold is set to 2.5 V.

Connecting JP1 set 500 mADC for fast-charge current and 100 mADC for precharge current on EVM.

2 Test Summary

2.1 Definitions

This procedure details how to configure the HPA678 evaluation board. On the test procedure, the following naming conventions are followed.

VXXX :	External voltage supply name (VBUS, VBAT)
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(XXX):	Voltage at (XXX). For example, V(VDPM) means the voltage at the test point which is marked VDPM.
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 Recommended Equipment for Testing

2.2.1 Power Supplies

Power Supply #1 (PS#1): a power supply capable of supplying 20 V at 1 A

2.2.2 Loads

A 20-V (or above), 1-A (or above) electronic load that can operate at constant current and constant voltage mode or equivalent

2.2.3 Meters

Four Fluke 75 multimeters, (equivalent or better) or two equivalent voltage meters and two equivalent current meters. The current meters must be capable of measuring 1 A + current.

2.3 Recommended Test Equipment Setup

1. Set the power supply #1 (PS#1) for 6.5 V ± 200 mVDC, 1-A ± 0.1-A current limit, and then turn off supply.
2. Connect the output of PS#1 in series with a current meter (multimeter) to J1 (VBUS, GND).
3. Connect a voltage meter across J1 (VBUS, GND).
4. Connect Load #1 in series with a current meter to J2 (VBAT, GND). Turn off Load #1.
5. Connect a voltage meter across J2 (VBAT, GND).
6. Check all jumper shunts. JP1: OFF; JP2: OFF; JP3: OFF; JP4: OFF; JP5: connect 1-2 (External TS); JP6: connect 2-3 (VBUS); JP7: connect 1-2 (charger OFF/ MODE high).
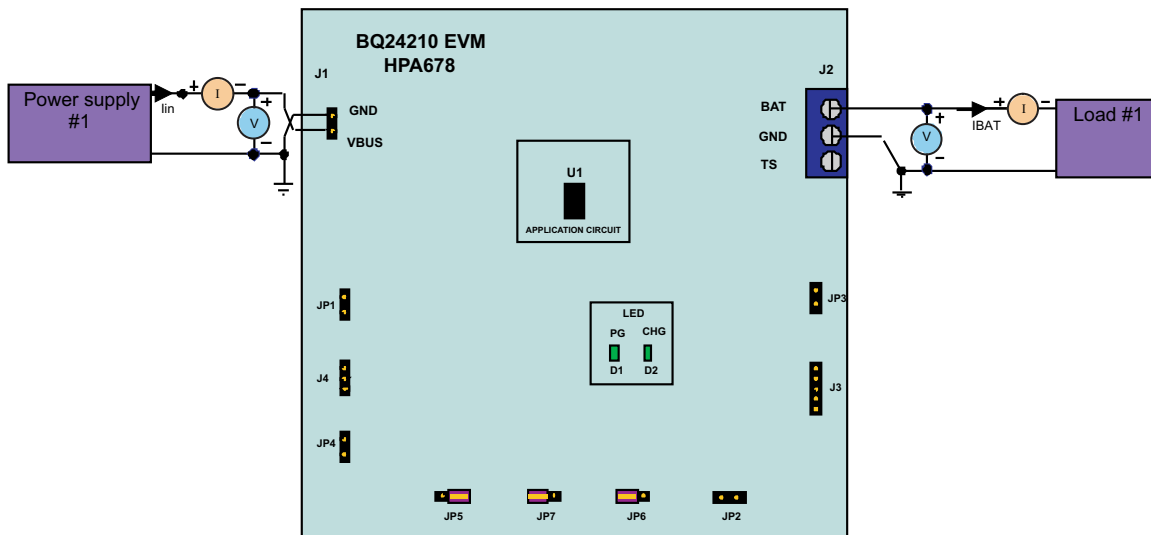

Figure 1. Original Test Setup for HPA678 (bq24210/2EVM)

2.4 Recommended Test Procedure to Confirm IC Operation

2.4.1 Power Supply

Make sure that EQUIPMENT SETUP steps are followed.

Disconnect LOAD #1. Turn on PS#1.
Measure → V(J1(VBUS)) = 6.5 V ± 200 mV
Measure → V(J2(VBAT)) = 0 V ± 200 mV
Measure → V(J4(VTSB)) = 0 V ± 200 mV
Observe → D1 (PG) ON, D2 (CHG) OFF

2.4.2 Charger Enable and Battery Detection

Connect JP1; Connect 2-3 of JP7 (Charger ON/MODE High)
Measure → V(J4(VTSB)) = 2.2 V ± 300 mV

Connect 2-3 of JP5 (Internal TS);
Adjust R6 until V(JP4-1) = 0.7 V ± 200 mV
Measure → V(J2(VBAT))=4.2 V ± 200 mV
Observe → D1 (PG) ON, D2 (CHG) OFF

2.4.3 Charge Current/Voltage Regulation

Reconnect LOAD#1. Turn on. Use the constant voltage mode.
Connect JP1; Set the output voltage to be 2.2 V.
Measure → I(J2(VBAT)) = 0.1 A ± 50 mA
Observe → D1 (PG) ON, D2 (CHG) ON

Increase the voltage of LOAD#1 to be 3.5 V.
Measure → I(J2(VBAT)) = 0.5 A ± 100 mA
Observe → D1 (PG) ON, D2 (CHG) ON

3 PCB Layout Guideline

1. It is critical that the exposed thermal pad on the backside of the bq24210 package be soldered to the PCB ground. Ensure that sufficient thermal vias are right underneath the IC, connecting to the ground plane on the other layers.
2. Make the interconnections of the decoupling capacitors for VBUS, BATC to the IC as short as possible.
3. Use the EVM layout for design reference.

4 Bill of Materials, Board Layout, and Schematics

4.1 Bill of Materials

Table 4. Bill of Materials

Count		RefDes	Value	Description	Size	Part Number
-001	-002					
1	1	C1	10uF	Capacitor, Ceramic, 25V,X7R, 10%	1206	STD
2	2	C2, C4	0.1uF	Capacitor, Ceramic, 25V, X7R, 10%	0603	STD
1	1	C3	10uF	Capacitor, Ceramic, 6.3V, X7R, 10%	0805	STD
0	0	C5, C6	Open	Capacitor, Ceramic, 25V, X7R, 10%	0603	STD
2	2	D1, D2	LTST-C190CKT	Diode, LED, Red, 1.8-V, 20-mA, 20-mcd	0603	LTST-C190CKT
1	1	D3	BZX84C5V1-7	Diode, Zener, 5.1V, 350-mW	SOT-23	BZX84C5V1-7
1	1	J1	PEC02SAAN	Header, Male 2-pin, 100mil spacing,	0.100 inch x 2	PEC02SAAN
1	1	J2	ED555/3DS	Terminal Block, 3-pin, 6-A, 3.5mm	0.41 x 0.25 inch	ED555/3DS
1	1	J3	PEC05SAAN	Header, Male 5-pin, 100mil spacing,	0.100 inch x 5	PEC05SAAN
1	1	J4	PEC03SAAN	Header, Male 3-pin, 100mil spacing,	0.100 inch x 3	PEC03SAAN
4	4	JP1, JP2, JP3, JP4	PEC02SAAN	Header, 2-pin, 100mil spacing,	0.100 inch x 2	PEC02SAAN
3	3	JP5, JP6, JP7	PEC03SAAN	Header, 3 pin, 100mil spacing,	0.100 inch x 3	PEC03SAAN
1	1	R1	21.5k	Resistor, Chip, 1/16W, 1%	0603	STD
2	2	R2, R4	1.50K	Resistor, Chip, 1/16W, 1%	0603	STD
1	1	R3	750	Resistor, Chip, 1/16W, 1%	0603	STD
1	1	R5	6.65k	Resistor, Chip, 1/16W, 1%	0603	Std
1	1	R6	100k	Potentiometer, 1/4 Cermet, 12-Turn, Top-Adjust	0.25x0.17 inch	3266W-1-104LF
1	1	R7	4.75k	Resistor, Chip, 1/16-W, 1%	0603	STD
0	0	TP1, TP2, TP3	Open	Test Point, 0.020 Hole		STD
1	0	U1	BQ24210DQC	IC, 800mA, Single-Input, Single Cell Li-Ion Battery Solar Charger	TDFN-10	BQ24210DQC
0	1	U1	BQ24212DQC	IC, 800mA, Single-Input, Single Cell Li-Ion Battery Solar Charger	TDFN-10	BQ24212DQC
7	7	—		Shunt, 100-mil, Black	0.1	929950-00
1	1	—		PCB, 2.64" x 2.1" x 0.062"		HPA678
1	1	—		Label	1.25 x 0.25 inch	THT-13-457-10

Notes: 1. These assemblies are ESD sensitive, ESD precautions shall be observed.

2. These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.

3. These assemblies must comply with workmanship standards IPC-A-610 Class 2.

4. Ref designators marked with an asterisk ('**') cannot be substituted. All other components can be substituted with equivalent MFG's components.

5. Install label after final wash. Text shall be 8 pt font. Text shall be per Table 1.

Table 1

Assembly Number	Text
HPA678-001	BQ24210EVM-678
HPA678-002	BQ24212EVM-678

4.2   Board Layout
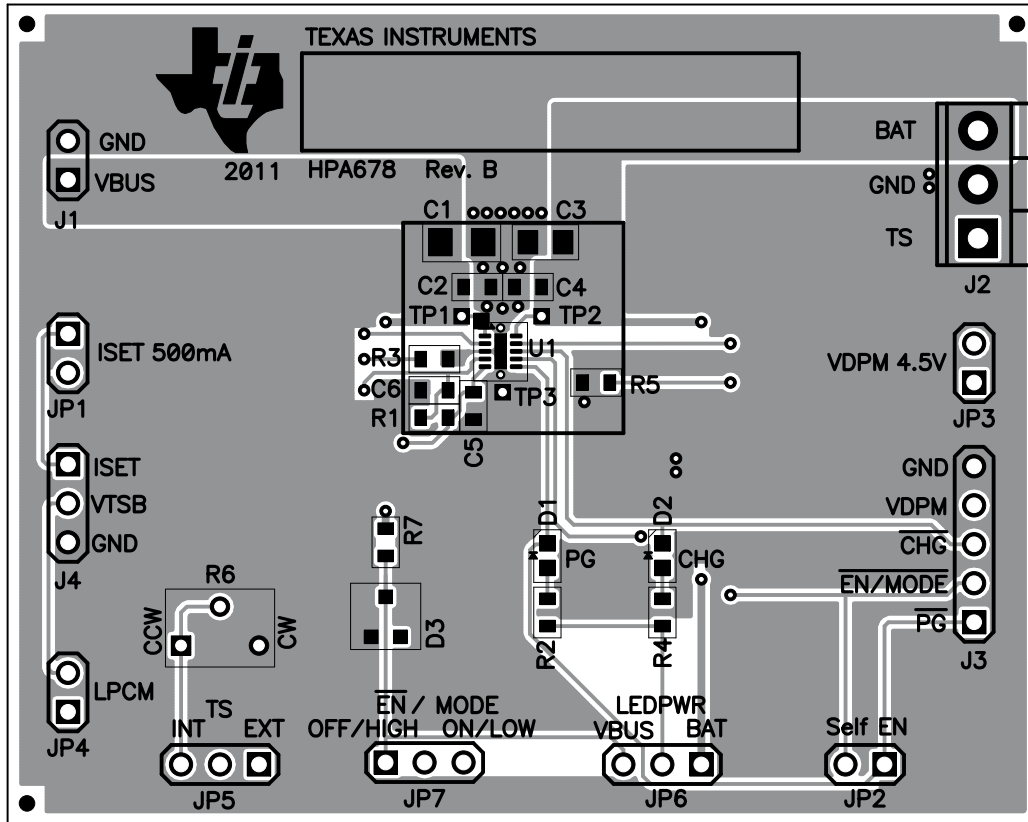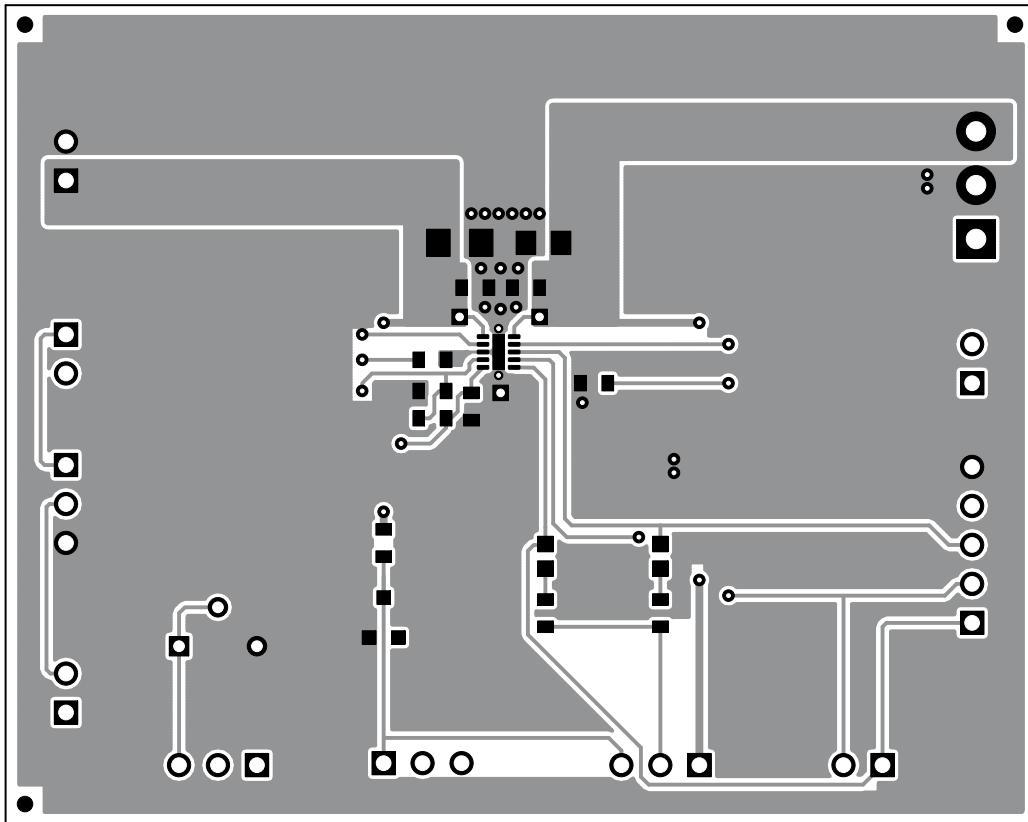

Figure 2. Top Assembly
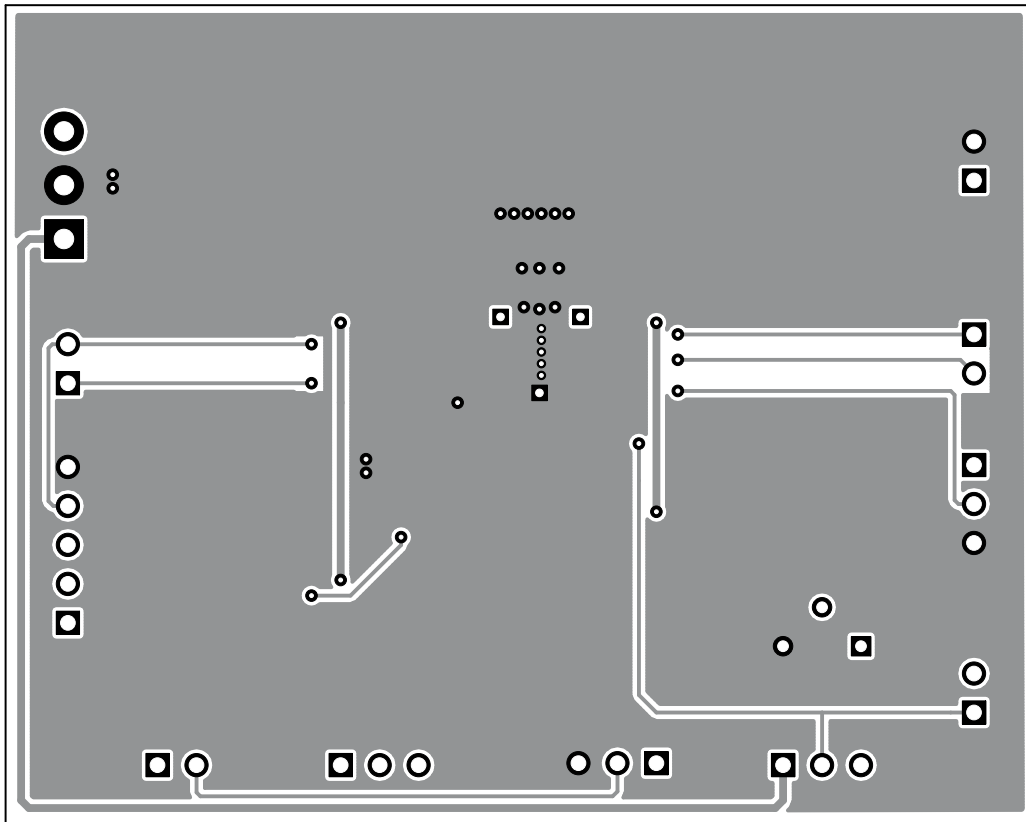
Figure 3. Top Layer

Figure 4. Bottom Layer

4.3   Schematics
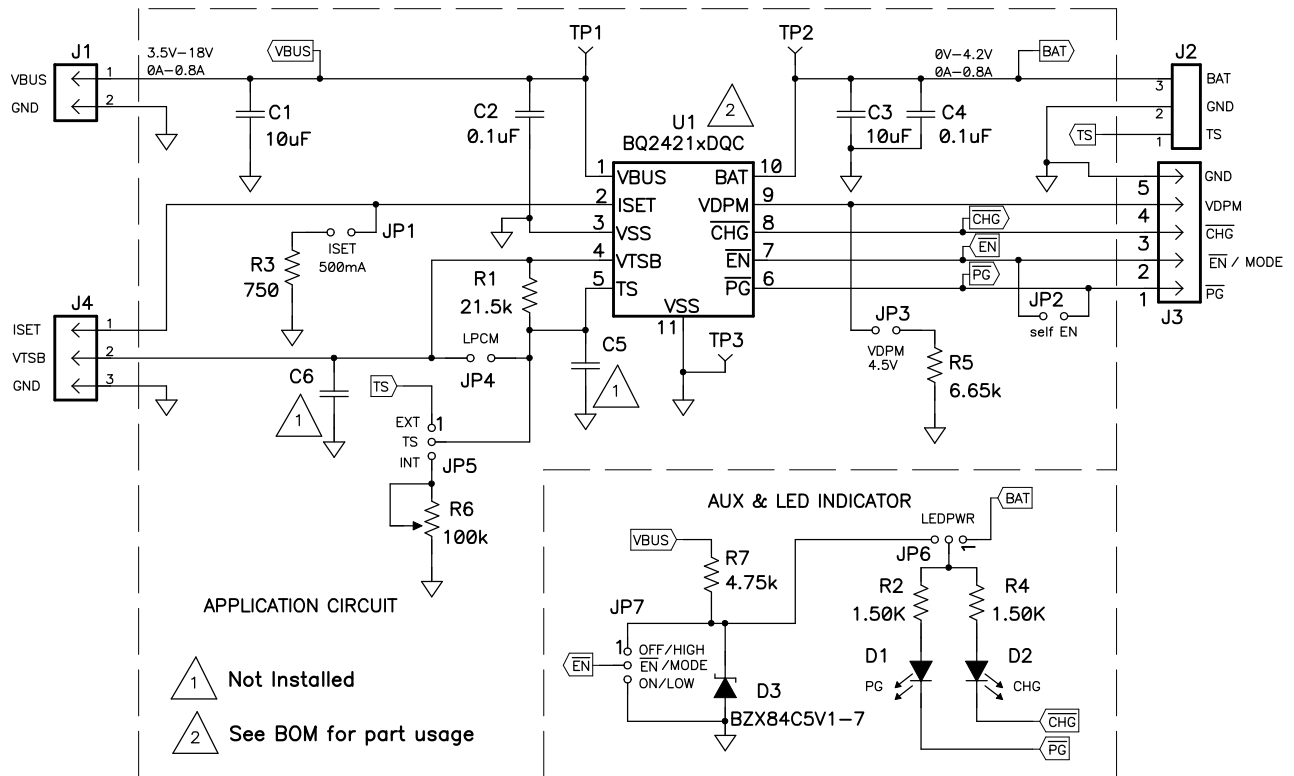
Figure 5. bq24210 EVM Schematic

Revision History

Changes from A Revision (August 2011) to B Revision **Page**

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Revision History

Changes from Original (December 2010) to A Revision **Page**

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      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*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). 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

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   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。
   http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

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.

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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.

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