

bq51050BEVM-764, Integrated Wireless Power Li-Ion Charger Receiver

The bq51050BEVM (HPA764-002) wireless power receiver evaluation kit from TI is a high-performance, easy-to-use development kit for the design of wireless power solutions. It helps designers to evaluate the operation and performance of the bq51050B (WCSP package), a direct Li-Ion charge controller for wireless power transfer. The bq51050B device provides the AC/DC power conversion, integrates the digital controller required to comply with the Qi v1.1 communication protocol, and Li-Ion charge controller. The kit speeds up the development of end-use applications.

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1 Introduction

The bq5105x is an advanced, secondary-side direct Li-Ion charge-controller device for wireless power transfer in portable applications. The bq5105x device provides the AC/DC power conversion, integrates the digital controller required to comply with the Qi v1.1 communication protocol, and Li-Ion charge controller. Together with the bq500210 primary-side controller, the bq5105x enables a complete contact-free power transfer system for a wireless direct battery charger solution. By utilizing near-field inductive power transfer, the secondary coil embedded in the portable device can pick up the power transmitted by the primary coil. The AC signal from the secondary coil is then rectified and conditioned to apply power directly to the battery. Global feedback is established from the secondary to the primary in order to stabilize the power transfer process. This feedback is established by utilizing the Qi v1.1 communication protocol.

The bq5105x devices integrate a low-impedance synchronous rectifier, low-dropout regulator, digital control, Li-Ion charger controller, and accurate voltage and current loops. The entire power stage (rectifier and LDO) utilize low-resistive NMOS FET's (100-mΩ typical RDS(on)) ensuring high efficiency and low power dissipation.

2 Considerations with this EVM

The bq51050BEVM-764 evaluation module (HPA764-002) demonstrates the receiver portion of the bqTESLA™ wireless power system. This receiver EVM is a complete receiver-side solution that charges single-cell Li-Ion batteries with up to 1-A charge current.

- The bqTESLA receiver is used in any number of low-power battery portable devices as a direct battery charger. With contact-free charging capability, no connections to the device are needed.
- Regulation voltage of 4.2 V, up to 1-A charge current
- Low-profile, external pick-up coil
- Frame is configured to provide correct receiver-to-transmitter spacing
- Room above coil for testing with battery – key for tuning
- Option to adjust the charge current using variable resistor R16
- Adjustable resistor R13 is used to set termination current.
- Temperature sensing can be adjusted using R3

3 Modifications

Refer to the datasheet when changing components. To aid in such customization of the EVM, the board was designed with devices having 0603 or larger footprints. A real implementation likely occupies less total board space.

Note that changing components can improve or degrade EVM performance.

4 Recommended Operation Condition

Table 1 provides a summary of the bq51050BEVM-764 performance specifications. All specifications are given for an ambient temperature of 25°C.

Table 1. bq51050BEVM-764 Electrical Performance Specifications

PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
V_{IN}	Input voltage range	4.0		10.0	V
I_{COMM-C}	Current limit during communication	330	390	420	mA
I_{IN}	Input current range			1.5	A
I_{OUT}	Output current range			1.5	A
$V_{OUT(REG)}$	Regulation output voltage	4.16	4.2	4.22	V
F_s	Switching frequency	110		205	kHz
Efficiency	AC-DC efficiency		93%		

5 Equipment and EVM setup

5.1 Schematic

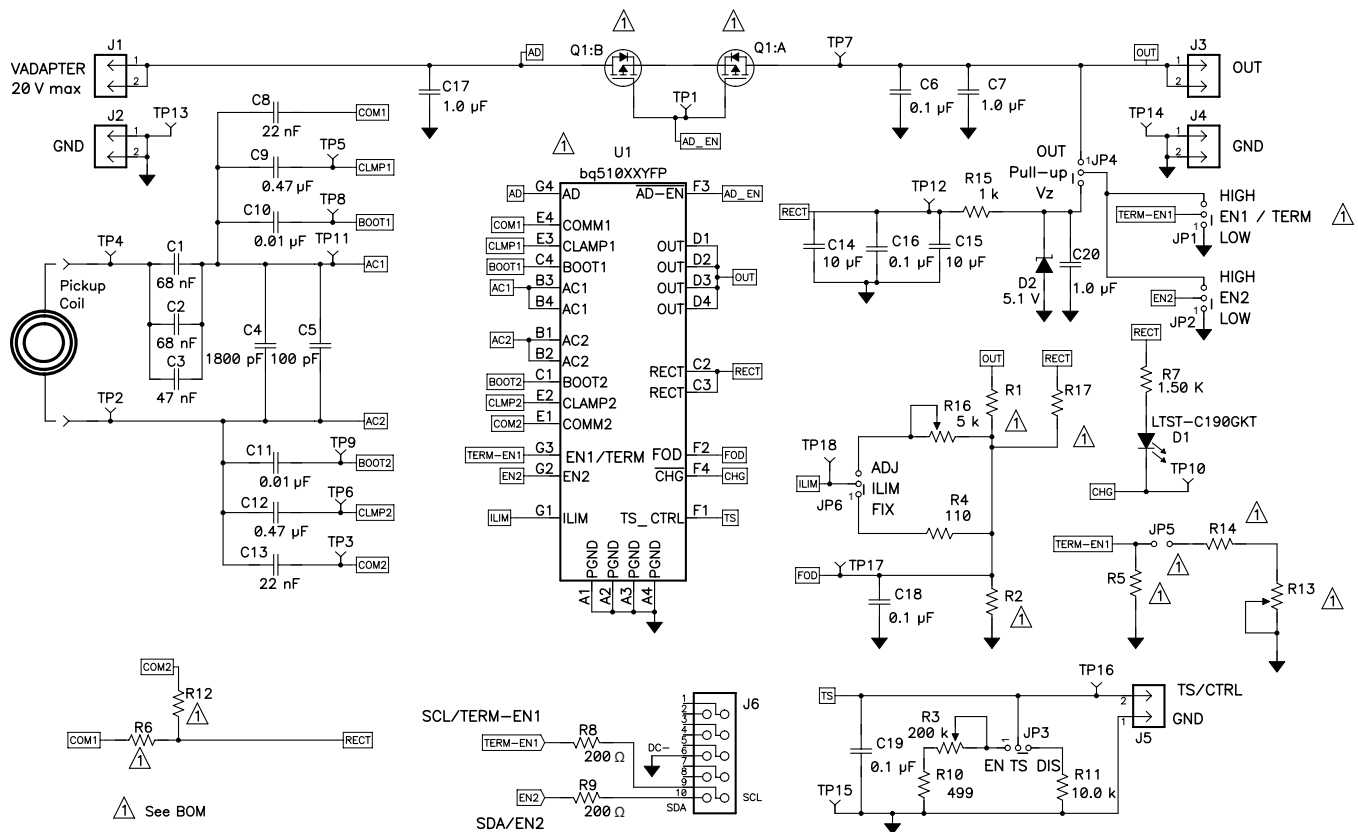


Figure 1. HPA764-Revision B Schematic

5.2 Connector and Test Point Descriptions

The connection points are described in the following paragraphs.

5.2.1 J1 – AD External Adapter Input, J2-GND

Power can not be provided to simulate an external adapter applied to the receiver in this bq51050BEVM-764 (HPA764-002).

5.2.2 J3 – Output Voltage, J4-GND

Output voltage regulation is 4.2 V in wireless power mode up to 1 A; the adapter option is not supported in this HPA764-002.

5.2.3 J5 – TS and Return Connector

External connection for temperature sense resistor, see the datasheet for additional information.

5.2.4 J6 – Programming Connector

This connector is populated and is only useful at the factory level for programming the IC.

5.3 Jumpers and Switches

The control jumpers are described in the following paragraphs.

5.3.1 JP1 – EN1 Enable 1

Not populated in this EVM (HPA764-002).

5.3.2 JP2 – EN2 Enable 2

Enable signal input that allows the system to assert wireless charging. If EN2 is set to low, wireless charging is enabled unless AD voltage > 3.6 V. If EN2 is set to High, AD mode disabled, wireless charging always enabled. Used when OTG plus wireless charging is active.

5.3.3 JP3 – TS Enable or Disable

This jumper enables the TS adjustment feature using R3. The disable position sets voltage at the TS pin to a safe value. The default shorting jumper setting is disabled.

5.3.4 JP4 – Pull-Up to Out or Vz

EN2 pull-up can be powered from OUT or RECT. Vz is derived from RECT through a resistor and Zener diode D2.

5.3.5 JP5 – Termination

This jumper, along with R14 and R13, sets the termination current. See the bq51050B datasheet for additional information. The default shorting jumper setting is installed.

5.3.6 JP6 – ILIM Fix or ADJ

Max output current is set by ILIM pin. In the FIX position, the current is set to a fixed value. In the ADJ position the current is set by R16.

5.4 Test Point Descriptions

The test points are described in the following paragraphs.

5.4.1 TP1 – AD-EN

This push-pull driver for the external PFET connects the adapter and the output from the bq5101x. This is not useful for the bq5105x.

5.4.2 TP2 – AC Input 2

This is the test point for measuring AC voltage applied to the EVM from the receiver coil.

5.4.3 TP3 – COM2 Communication 2 Drive

Communication driver signal, open-drain output connected to communication capacitor.

5.4.4 TP4 – AC Input 1

This is the test point for measuring AC voltage applied to the EVM from the receiver coil.

5.4.5 TP5 – CLMP 1

Overvoltage clamp driver signal, open-drain output is connected to OVP capacitor.

5.4.6 TP6 – CLMP 2

Overvoltage clamp drive signal, open-drain output is connected to OVP capacitor.

5.4.7 TP7 – OUT Output Voltage

This test point is the output voltage from the bq51050B.

5.4.8 TP8 – Boot-1 Boot Capacitor

This bootstrap capacitor 1 drive connects to the integrated circuit (IC).

5.4.9 TP9 – Boot-2 Boot Capacitor

This bootstrap capacitor 2 drive connects to the IC.

5.4.10 TP10 – CHG Charge

This output signal indicates that the output current is being delivered to OUT, the open-drain output.

5.4.11 TP11 – AC1 IC input

This is the AC input to the IC from series capacitors.

5.4.12 TP12 – Rectified Voltage

The input AC voltage is rectified into unregulated DC voltage; additional capacitance is used to filter the voltage before the regulator.

5.4.13 TP13, TP14, TP15 – GND

These are the ground test points.

5.4.14 TP16 – TS Temp Sensor

This is the connection point for external thermistor; see the data sheet for additional information.

5.4.15 TP17 – FET Open Detection (FOD)

Input for rectified power measurement, pin F2 of the IC. FOD for the bq51050B.

5.4.16 TP18– ILIM

Programming pin for over current limit, pin G1 of the IC.

5.5 Pin Description of the IC

Table 2. Pin Description

PIN Number (WCSP)	bq51050B
A1, A2, A3, A4	PGND
B1, B2	AC2, AC2
B3, B4	AC1, AC1
C1	BOOT2
C2, C3	RECT
C4	BOOT1
D1, D2, D3, D4	BAT
E1	COM2
E2	CLMP2
E3	CLMP1
E4	COM1
F1	TS_CTRL
F2	FOD
F3	AD-EN
F4	CHG
G1	ILIM
G2	EN2
G3	TERM
G4	AD

6 Test Procedure

This procedure describes test configuration of the bq51050B evaluation board (HPA764-002) for bench evaluation.

6.1 Definition

The following naming conventions are used:

VXXX : External voltage supply name (VADP, VBT, VSBT)

LOADW: External load name (LOADR, LOADI)

V(TPyy): Voltage at internal test point TPyy. For example, V(TP02) means the voltage at TP02.

V(Jxx): Voltage at header Jxx

V(TP(XXX)): Voltage at test point XXX. 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 header

JXX. Jxx(BBB): Terminal or pin BBB of header xx.

JPx ON : Internal jumper Jxx terminals are shorted. JPx OFF: Internal jumper Jxx terminals are open.

JPx (-YY-) ON: Internal jumper Jxx adjacent terminals marked as YY are shorted.

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

6.2 Recommended Test Equipment

The following equipment is needed to complete this test procedure.

6.2.1 Power Supplies

Two power supplies

- Power supply #1 (PS #1) capable of supplying 19 V at 1 A is required
- Power supply #2 (PS #2) capable of supplying up to 6 V at 5 A is required to power the battery emulator.

6.2.2 Battery Emulator PR1010-002

Use the battery emulator shown in [Figure 3](#) as a battery to test the charger.

6.2.3 Meters

Two DC voltmeters, one multimeter (Ohmmeter), and two DC ammeters are required.

6.2.4 Oscilloscopes

Not required. But can replace the multimeters

6.2.5 bqTesla Transmitter

Power for the bq510xxxEVM-764 receiver EVM is supplied through a bqTESLA transmitter (bq500210EVM-689) or WPC-certified transmitter. The input AC voltage is applied to the receiver through the coil located in the receiver bottom.

6.3 Equipment Setup

6.3.1 Test Set Up

The final assembly is tested using a bqTesla transmitter provided (bq5100210EVM-HPA689). Input voltage to the transmitter is set to 19 V_{DC} ±200 mV with a current limit of 1.0 A. Set the power supply to OFF. Connect input power supply to HPA689 V_{IN} (J1) and GND (J2) as shown on [Figure 2](#). Place UUT on transmitter coil. Unit under test will be placed in the center of HPA689 TX coil.

Other bqTesla transmitter base units are also acceptable for this test.

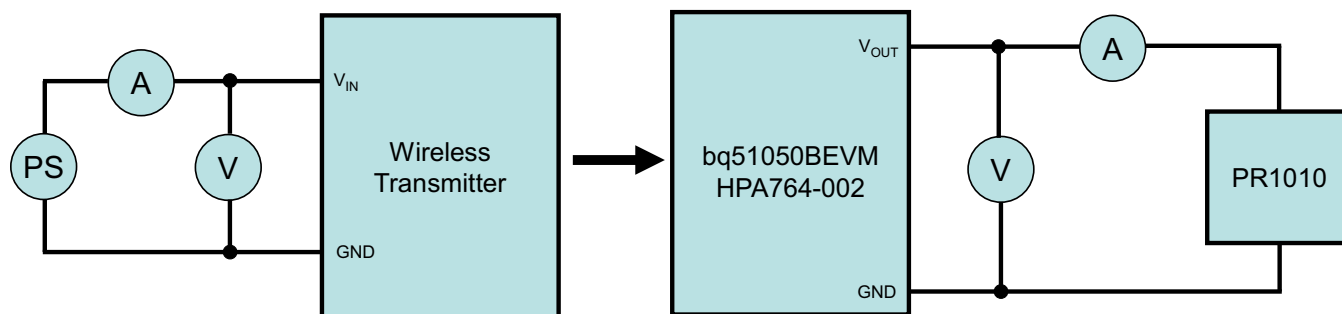
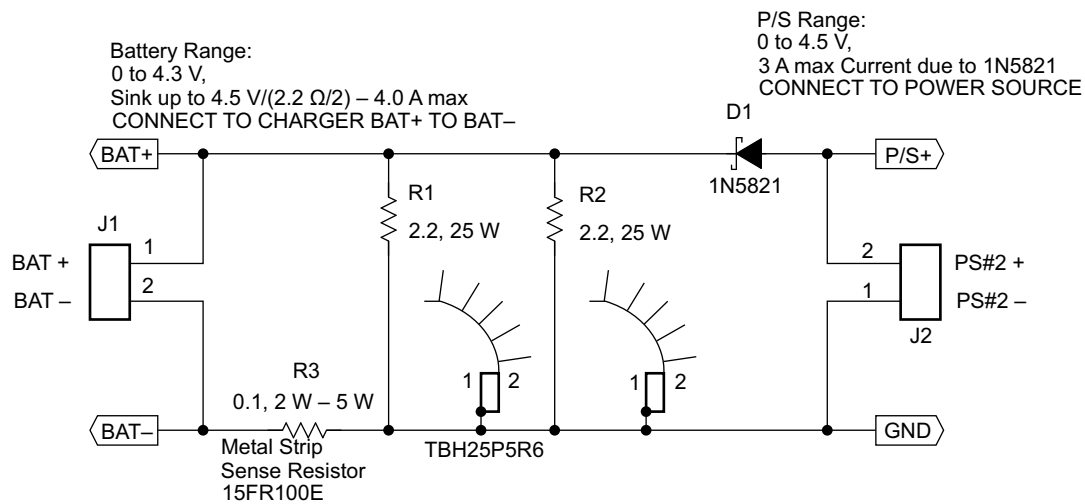


Figure 2. Test Set up

6.3.2 Battery Emulator

Adjust PS#2 to approximately 3.6 V and 3.5-A current limit to the input side (PS #2+/-) of the battery emulator ([Figure 3](#)), then turn PS #2 off.


Figure 3. Battery Emulator

6.3.3 Jumper Settings

- JP2 → EN2 and LOW shorted
- JP3 → TS and EN shorted
- JP4 → Pullup and Vz shorted
- JP5 → Install
- JP6 → ILIM and ADJ shorted

6.3.4 Voltage and Current Meters

- Connect ammeter to measure input current to transmitter
- Connect voltmeter to monitor input voltage of TX unit
- On UUT (receiver) a voltmeter is used to measure output voltage (battery voltage) at J3 (OUT) with ground at J4 (GND).
- On UUT (receiver), connect ammeter to measure charge current.

6.3.5 TS: R3 Set Up

Connect ohmmeter across J5. Connect shorting jumper JP3 from TS to EN. Adjust R3 for a 10 kΩ ±200-Ω reading on the ohmmeter. (This allows the temperature sensing to operate in charge allowable region). Make sure: JP3 → TS and EN shorted.

6.3.6 ILIM : R16 Set Up

Connect ohmmeter between JP6-ADJ and J2 (GND). Adjust R16 for 300 Ω ±20-Ω reading on the ohmmeter. (This allows the fast charge current to 1 A). Make sure: JP6 → ILIM and ADJ shorted.

6.3.7 ITERM : R13 Set Up

Connect ohmmeter between JP5 (end that is connected to R13 and R14) and J2 (GND). Adjust R13 for 5 kΩ ±200-Ω reading on the ohmmeter. (This adjusts termination current to around 20% of fast charge current, for 1-A fast charge current, termination current should be 200 mA). Make sure JP5 → Shorted.

6.4 Procedure

6.4.1 Turn ON Operation

- Turn ON transmitter PS#1 (19 V)
- Transmitter – verify LED D2 is ON
- Turn ON emulator PS#2 (3.6 V)
- Put the receiver EVM on the transmitter coil and align them correctly
- After 5 s, verify that:
 1. Transmitter – status LED D5 is flashing green ~ 1 s
 2. You should hear a beep from the transmitter
 3. Transmitter – LED D2 still ON
 4. Receiver – LED D1 is ON

6.4.2 Pre-Charge Operation

- Adjust PS#2 to read 2.5 V across J3 and J4 (battery voltage)
- Verify the charging current is 200 mA $\pm$ 20 mA

6.4.3 Fast-Charge Operation

- Adjust PS#2 to read 3.6 V across J3 and J4 (battery voltage).
- Verify the charging current is 1000 mA $\pm$ 100 mA

6.4.4 Constant Voltage Charge Operation and Termination

- Adjust PS#2 to read 4.2 V $\pm$ 50 mV across J3 and J4 (Battery Voltage)
- Keep increasing the voltage on PS#2 and observe the charging current decreases (constant voltage phase)
- Keep increasing the voltage on PS#2 until you reach and observe the charging current approximately 200 mA $\pm$ 20 mA (constant voltage phase)
- The charge should terminate after you reach the 200 mA $\pm$ 200mA level

6.4.5 Efficiency Test

- Adjust PS#2 to read 3.6 V $\pm$ 50 mV across J3 and J4 (Battery Voltage)
- Remove the receiver and reinstall it
- Verify the charging current is 1000 mA $\pm$ 100 mA
- Verify that input current to TX is less than 350 mA $\pm$ 30 mA with input voltage at 19 V_{DC}

7 Test Results

7.1 Start up to Fast-Charge Mode

With the power supply off, connect supply to the bqTESLA transmitter.

- Place the bqTESLA receiver on the transmitter
- Connect battery emulator to J3 with GND J4
- Power TX with 19 V
- Trigger scope sweep on I-BAT

The test results shown in Figure 4 are taken under 19-V input, 3.7-V battery and 1000-mA fast charge current.

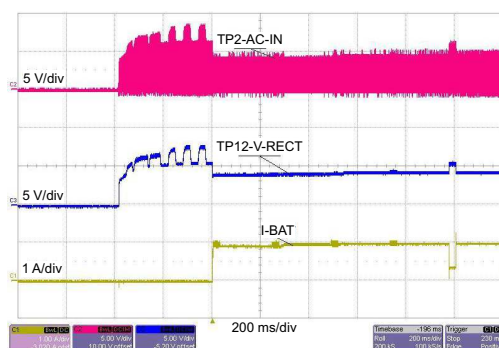


Figure 4. Start-Up to Fast-Charge Mode

7.2 Start up to Pre-Charge Mode

With the power supply off, connect the supply to the bqTESLA transmitter.

- Place the bqTESLA receiver on the transmitter
- Connect the battery emulator to J3 with GND J4
- Power TX with 19 V
- Trigger scope sweep on I-BAT

The test results shown in Figure 5 are taken under 19-V input, 2-V battery and 200-mA pre-charge current.

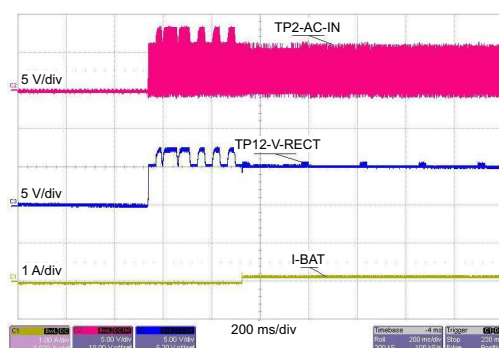


Figure 5. Start-Up to Pre-charge Mode

7.3 Pre-charge to Fast-Charge Transition

With the power supply off, connect the supply to the bqTESLA transmitter.

- Place the bqTESLA receiver on the transmitter
- Connect the battery emulator to J3 with GND J4
- Power TX with 19 V
- Adjust the battery emulator voltage to 2 V (pre-charge mode)
- Increase the battery emulator voltage until exiting the pre-charge mode (200 mA) and enter fast-charge mode (1000 mA)
- Trigger scope sweep on I-BAT

The test results shown in Figure 6 shows pre-charge to fast-charge mode transition

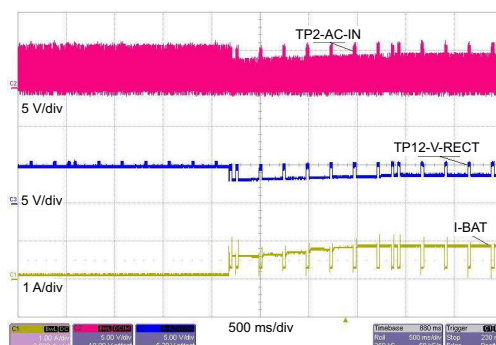


Figure 6. Pre-charge to Fast-Charge Transition

7.4 Fast Charge to Taper and Termination Transition

With the power supply off, connect the supply to the bqTESLA transmitter.

- Place the bqTESLA receiver on the transmitter
- Connect the battery emulator to J3 with GND J4
- Power TX with 19 V
- Adjust the battery emulator voltage to 4.2 V (fast-charge mode, 1000 mA)
- Decrease the battery emulator voltage until exiting the fast-charge mode to taper and then termination 200 mA
- Trigger scope sweep on I-BAT

The test results shown in Figure 7 shows fast-charge to taper and termination modes transition.

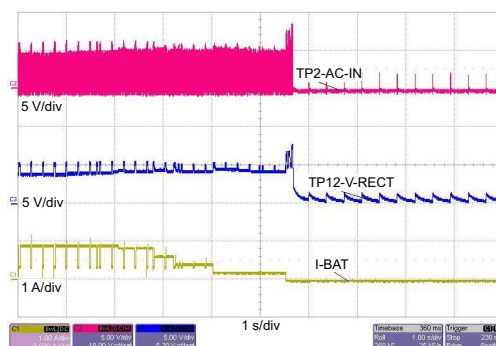


Figure 7. Fast Charge to Taper and Termination Transition

7.5 Efficiency Data

7.5.1 Efficiency Versus Output Power (AC-DC)

Figure 8 illustrates the efficiency of the bq51050BEVM-764 during the full charge cycle. The regulation voltage is 4.2 V, fast charge current is set to 1 A, and termination is set to 100 mA.

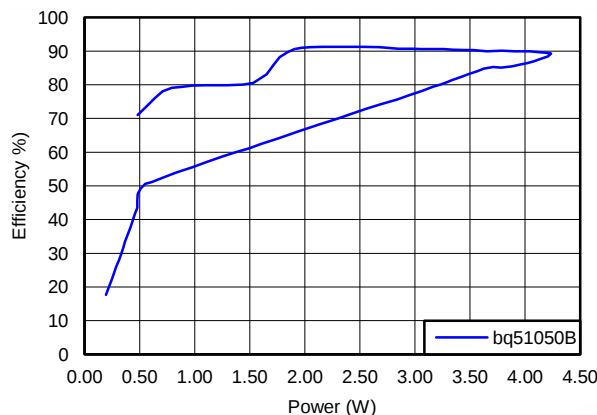


Figure 8. Efficiency Versus Output Power (AC Input to DC Output)

7.5.2 Efficiency Versus Fast Charge Current (AC-DC)

Figure 9 illustrates the efficiency of the bq51050BEVM-764 for different fast charging current levels. The regulation voltage is 4.2 V, fast charge current is varied from 200 mA to 1 A, and the battery emulator voltage is set to approximately 4.1 V.

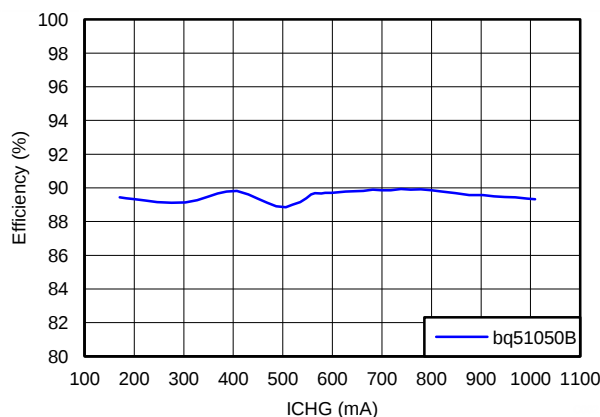


Figure 9. Efficiency Versus Fast Charge Current (AC Input to DC Output)

7.6 Thermal Performance

This section shows a thermal image of the bq51050BEVM-764 in fast-charge mode. A 4.0-V battery is used at a charging rate of 1000 mA. There is no air flow and the ambient temperature is 25°C. The peak temperature of the IC (57.5°C) is well below the maximum recommended operating condition listed in the data sheet.

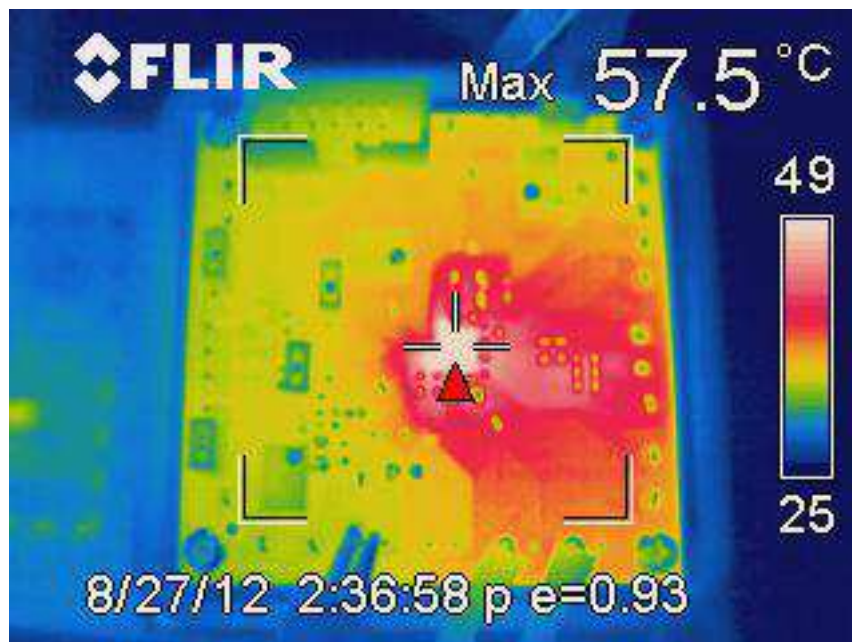


Figure 10. Thermal Image

8 Layout and Bill of Material

8.1 Layout

8.1.1 Printed-Circuit Board Layout Guideline

The primary concerns when laying out a custom receiver PCB are:

- AC1 and AC2 trace resistance
- OUT trace resistance
- RECT trace resistance
- GND connection
- Copper weight ≥ 2 oz

For a 1-A fast charge current application, the current rating for each net is as follows:

- AC1 = AC2 = 1.2 A
- BOOT1 = BOOT2 = 10 mA
- RECT = 1 A
- OUT = 1 A
- COM1 = COM2 = 300 mA
- CLAMP1 = CLAMP2 = 500 mA
- ILIM = 10 mA
- AD = AD-EN = TS-CTRL = EN1 = EN2 = TERM = FOD = 1 mA
- CHG = 10 mA

It is also recommended to have the following capacitance on RECT and OUT:

- RECT $\geq \pm 10 \mu\text{F}$
- OUT $\geq 1 \mu\text{F}$

It is always a good practice to place high-frequency bypass capacitors of $0.1 \mu\text{F}$ next to RECT and OUT.

[Figure 11](#) illustrates an example of a WCSP layout:

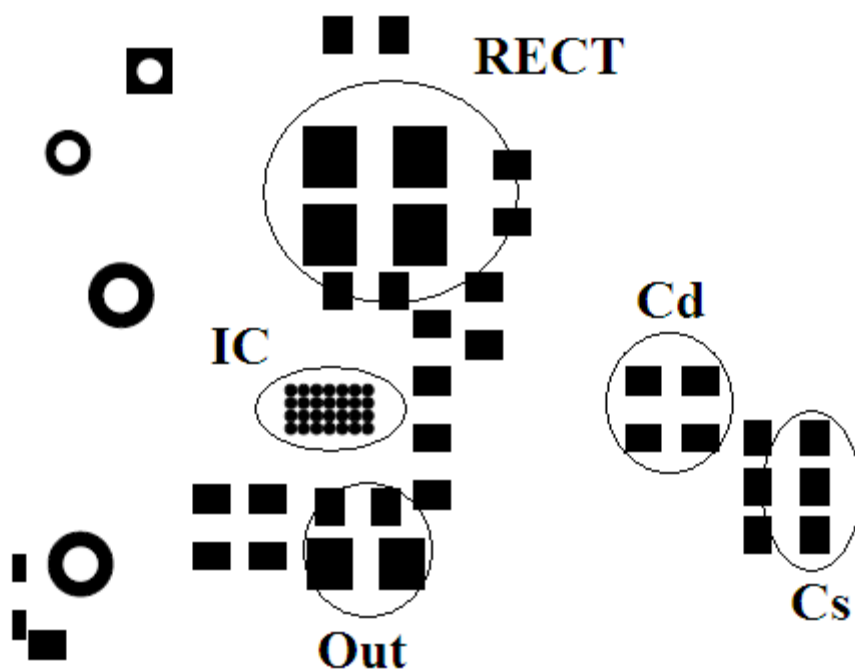


Figure 11. bq51050BEVM Layout Example

8.1.2 Layout

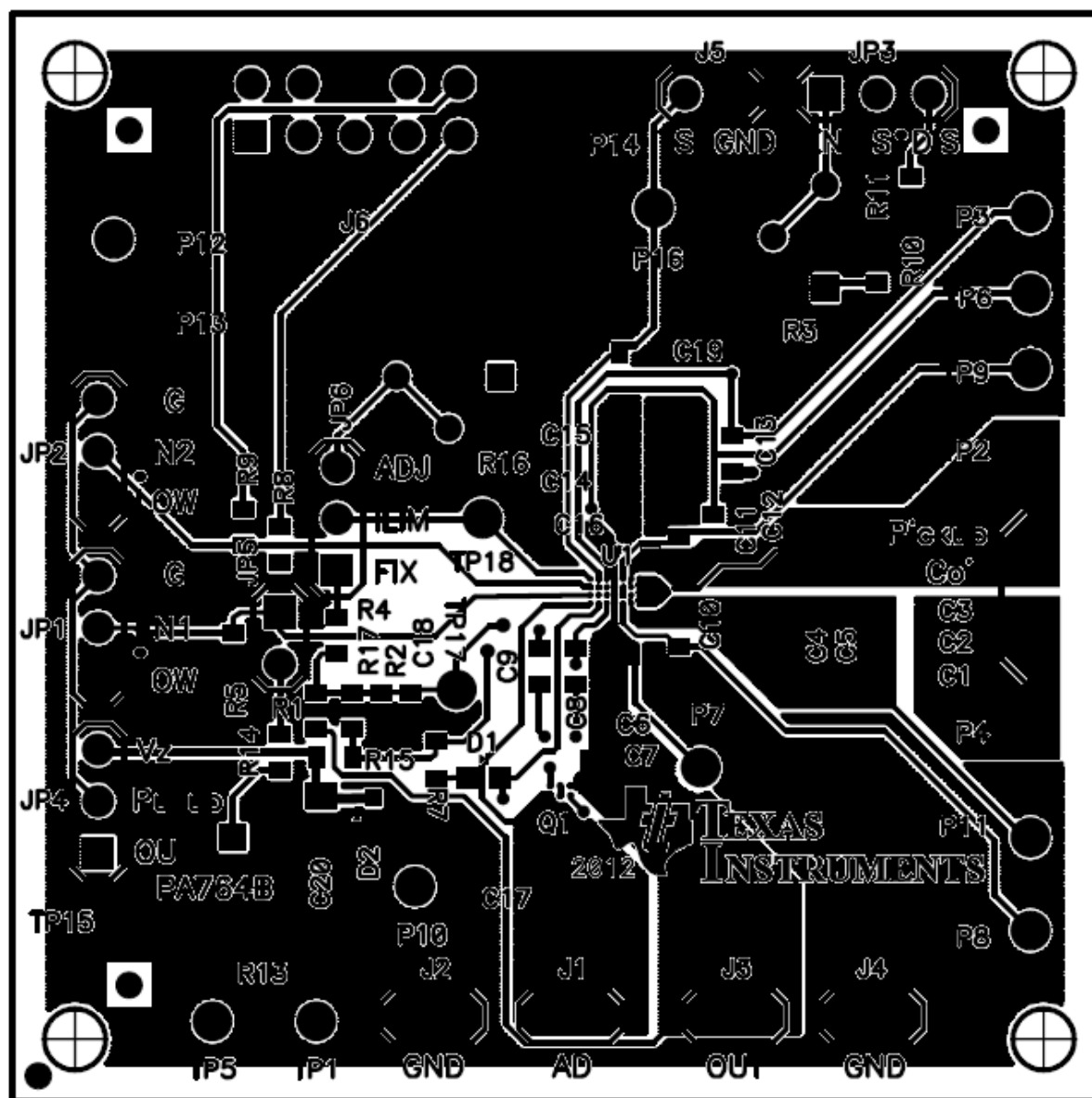


Figure 12. bq51050BEVM-764 Top Assembly

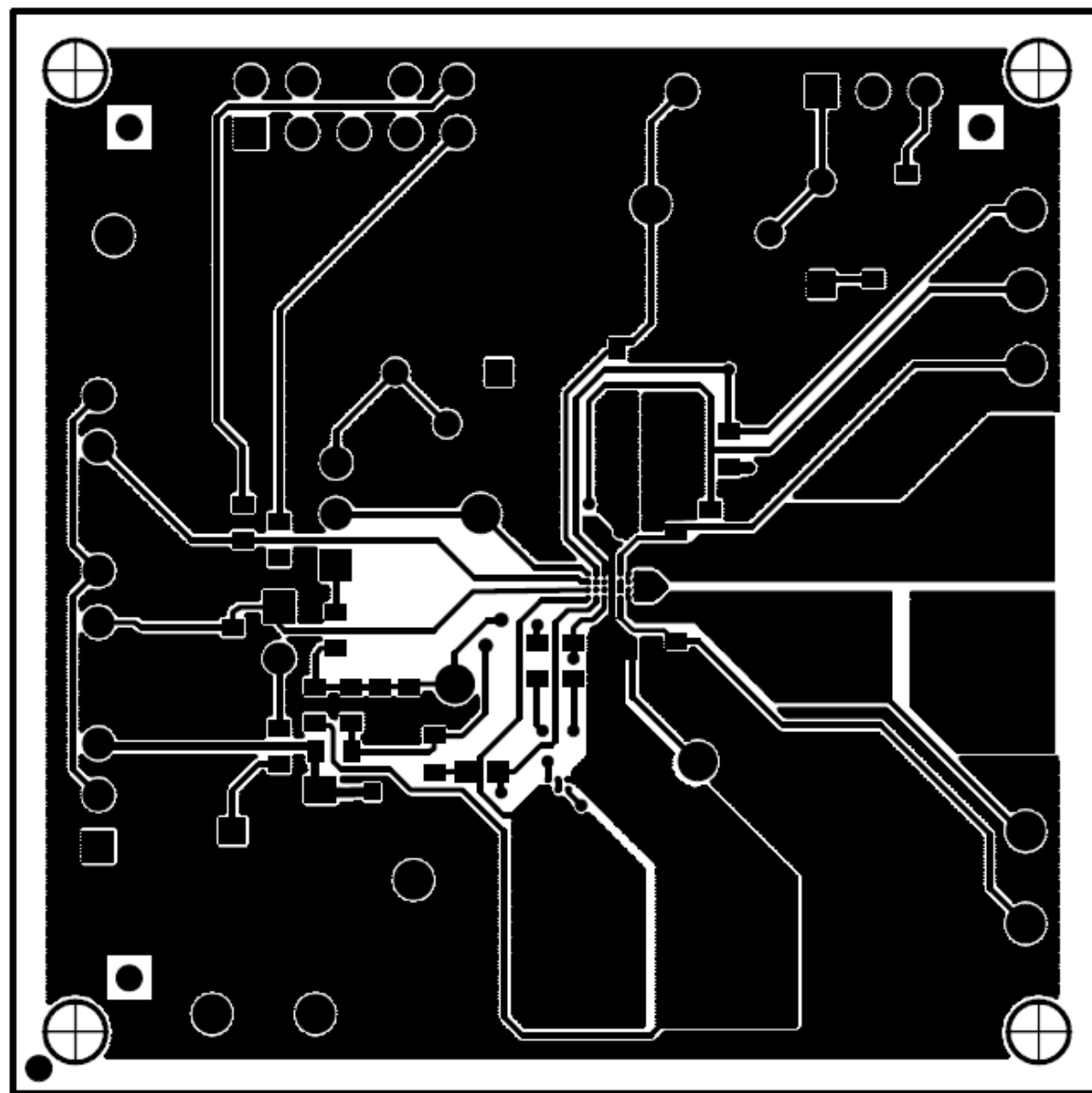


Figure 13. bq51050BEVM-764 Top Layer

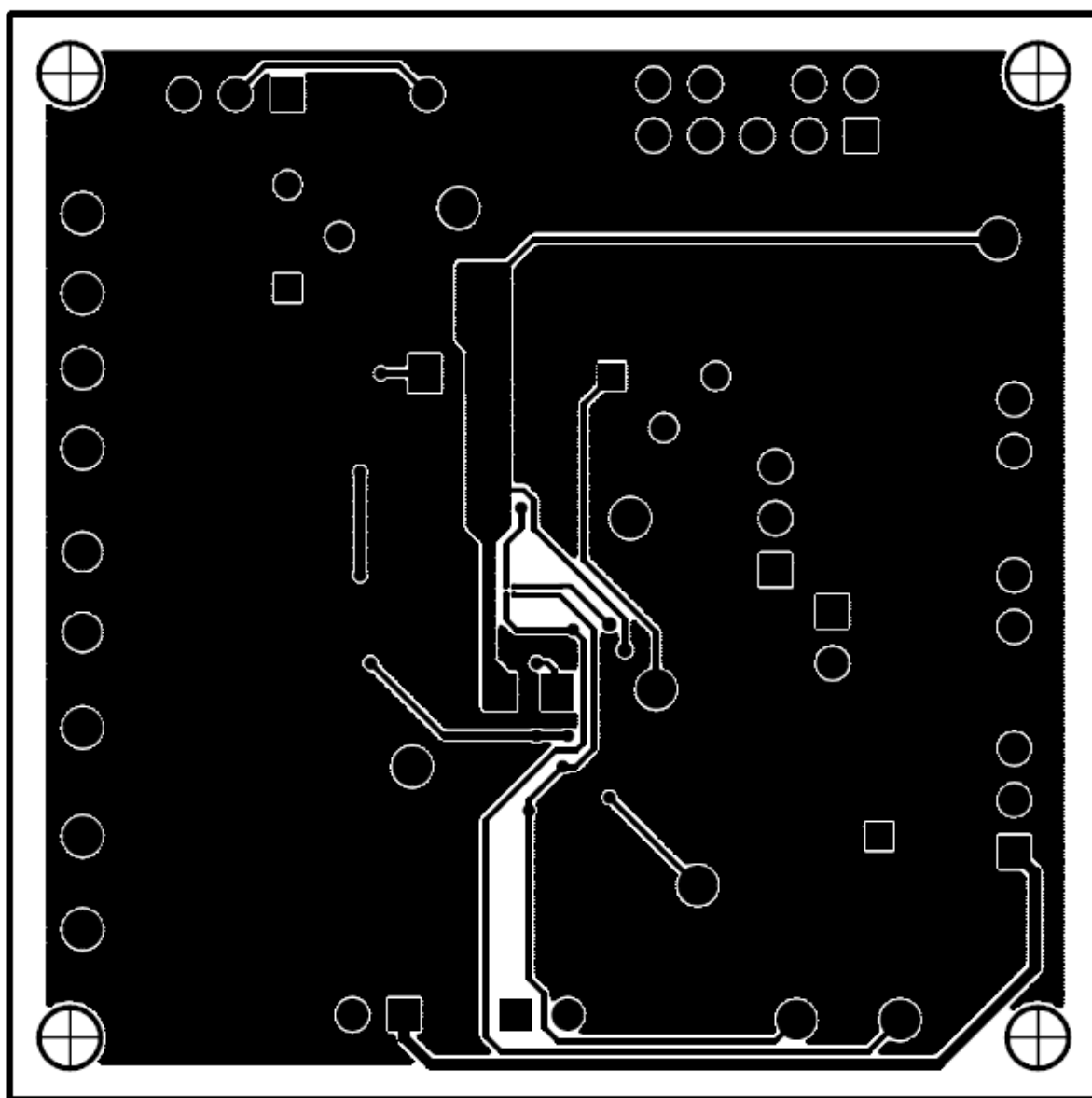


Figure 14. bq51050BEVM-764 Bottom Copper Layer

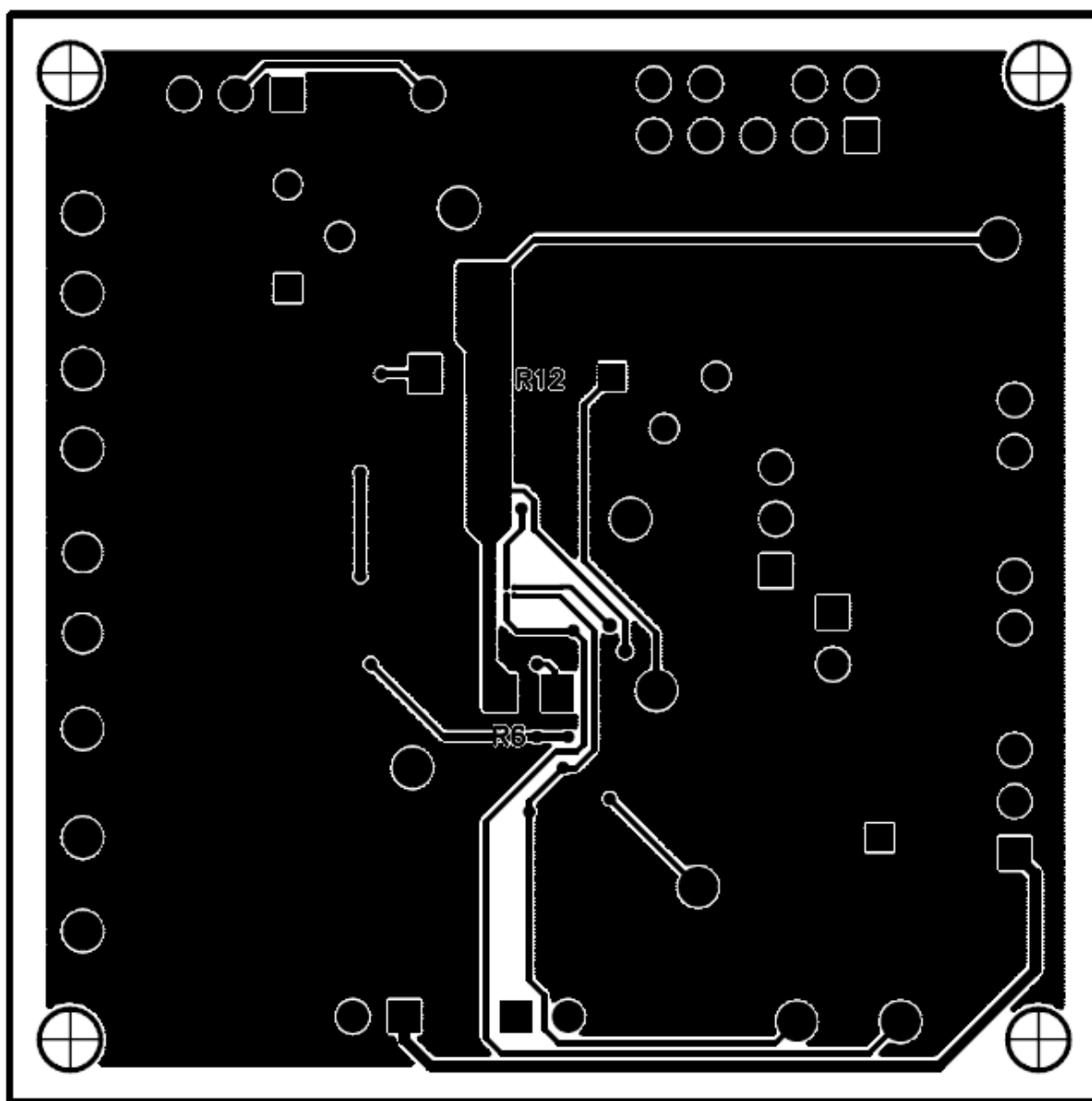


Figure 15. bq51050BEVM-764 Bottom Assembly

8.2 Bill of Materials (BOM)

Table 3. bq51050BEVM-764 Bill of Materials

Count 002	RefDes	Value	Description	Size	Part Number	MFR
2	C1, C2	68nF	Capacitor, Ceramic, 50V, X7R, 10%	0603	Std	Std
1	C3	47nF	Capacitor, Ceramic, 50V, X7R, 10%	0603	Std	Std
1	C4	1800pF	Capacitor, Ceramic, 50V, X7R, 10%	0603	Std	Std
1	C5	100pF	Capacitor, Ceramic, 50V, C0G, 5%	0603	Std	Std
4	C6, C16, C18, C19	0.1uF	Capacitor, Ceramic, 50V, X7R, 10%	0603	Std	Std
3	C7, C17, C20	1.0uF	Capacitor, Ceramic, 50V, X5R, 10%	0805	Std	Std
2	C8, C13	22nF	Capacitor, Ceramic, 50V, X7R, 10%	0603	Std	Std
2	C9, C12	0.47uF	Capacitor, Ceramic, 25V, X5R, 10%	0603	Std	Std
2	C10, C11	0.01uF	Capacitor, Ceramic, 50V, X7R, 10%	0603	Std	Std
2	C14, C15	10uF	Capacitor, Ceramic, 25V, X5R, 10%	1206	Std	Std
1	D1	LTST-C190GKT	Diode, LED, Green, 2.1-V, 20-mA, 6-mcd	0603	LTST-C190GKT	Lite On
1	D2	5.1V	Diode, Zener, 5.1V, 300mW	SOD-523	BZT52C5V1T-7	Diodes, Inc.
5	J1– J5	PEC02SAAN	Header, Male 2-pin, 100mil spacing,	0.100 inch x 2	PEC02SAAN	Sullins
1	J6	N2510-6002-RB	Connector, Male Straight 2x5 pin, 100mil spacing, 4 Wall	0.338 x 0.788 inch	N2510-6002-RB	3M
4	JP2–JP4, JP6	PEC03SAAN	Header, Male 3-pin, 100mil spacing,	0.100 inch x 3	PEC03SAAN	Sullins
0	JP1	Open	Header, Male 3-pin, 100mil spacing,	0.100 inch x 3	PEC03SAAN	Sullins
1	JP5	PEC02SAAN	Header, Male 2-pin, 100mil spacing,	0.100 inch x 2	PEC02SAAN	Sullins
0	Q1	CSD75205W1015	MOSFET, Dual PChan, -20V, 1.2A, 190 milliOhm-- See note 8	CSP 1x1.5mm	CSD75205W1015	TI
0	R1	Open	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R2	200	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R3	200k	Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust	0.25x0.17	3266W-1-204LF	Bourns
1	R4	110	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	R5	Open	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	R6, R12	Open	Resistor, Metal Film, 1/4 watt, ± 1%	1206	CRCW120624R0FKEA	Vishay
1	R7	1.50K	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R8, R9	200	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R10	499	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R11	10.0k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R14	1.0k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R15	1.0k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R13	20k	Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust	0.25x0.17	3266W-1-203LF	Bourns
1	R16	5k	Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust	0.25x0.17	3266W-1-502LF	Bourns
1	R17	42.2k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
15	TP1–TP12, TP16–TP18	5000	Test Point, Red, Thru Hole Color Keyed	0.100 x 0.100 inch	5000	Keystone
3	TP13, TP14, TP15	5001	Test Point, Black, Thru Hole Color Keyed	0.100 x 0.100 inch	5001	Keystone
1	U1	bq51050BYFP	IC, Wireless Secondary-Side Power Controller and Battery Charge	DSBGA	bq51050BYFP	TI
5	—		Shunt, 100-mil, Black		929950-00	3M
1	—		PCB, 2.1" x 2.1" x 0.031"		HPA764	Any
1			Case Modified Polycase LP-11B with 4 screws-- See note 7		J-6838A	Polycase
1			Coil, RX with Attractor		IWAS-4832FF-50 or WR-483250-15M2-G or 760308201	Vishay or TDK or Wyrth

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. Tape "Coil, RX" into bottom of case, centered, coil side down, lead wires passing through milled groove.
6. Used to secure RX coil to case. Cut tape section from 36 yard roll identified in part number field.
7. Install PCB in case using provided screws.
8. For 20 V input application, consider using 8 V VGS FETs

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

- 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 and conditions 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 and conditions 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 any defects that are 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. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.
- 2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, 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.

- 3 *Regulatory Notices:*

- 3.1 *United States*

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.

3.3 Japan

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/llds/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/llds/ti_ja/general/eStore/notice_01.page

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 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.

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 WRITTEN DESIGN MATERIALS PROVIDED WITH THE EVM (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 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.

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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 AND CONDITIONS OR THE USE OF THE EVMS PROVIDED HEREUNDER, 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 ONE YEAR AFTER THE RELATED CAUSE OF ACTION HAS OCCURRED.

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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.

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