bq51003-764 Evaluation Module (WCSP Package)

The bq51003EVM-764 (EVM) wireless power receiver evaluation kit from TI is a high-performance, easy-to-use development kit for the design of wireless power solutions. The EVM helps designers to evaluate the operation and performance of the bq51003, 5-V power supply for wireless power transfer. The bq51003 devices provide AC/DC power conversion and regulation while integrating the digital control required to comply with the Qi-communication protocol. The kit speeds up the development of end-use applications.

Contents

1 Considerations with this EVM 2
2 Modifications 2
3 Recommended Operation Condition 2
4 Equipment and EVM setup 3
4.1 Schematic 3
4.2 Connector and Test Point Descriptions 3
4.3 Jumpers and Switches 4
4.4 Test Point Descriptions 4
4.5 Pin Description of the IC 5
5 Test Procedure 6
5.1 Definition 6
5.2 Recommended Test Equipment 6
5.3 Equipment Setup 7
5.4 Procedure 8
6 Test Results 9
6.1 Load Step 9
6.2 Load Dump 10
6.3 Start-Up 11
6.4 Efficiency 11
6.5 Thermal Performance 12
7 Layout and Bill of Material 13
7.1 Layout 13
7.2 Bill of Materials (BOM) 16

List of Figures

1 HPA764 Schematic 3
2 Test Set Up 7
3 Load Step, 0 mA to 500 mA 9
4 Load Dump, 500 mA to 0 mA 10
5 Start-Up 11
6 Efficiency for the bq51003 Versus I_{OUT} 11
7 Thermal Image 12
8 bq51003EVM-764 Layout Example 13
9 bq51003EVM-764 Top Assembly 14
10 bq51003EVM-764 Top Layer 14
11 bq51003EVM-764 Bottom Copper Layer 15

12 bq51003EVM-764 Bottom Assembly 15

List of Tables

1 bq51003EVM-764 Electrical Performance Specifications 2
2 Pin Description 5
3 bq51003EVM-764 Bill of Materials 16

1 Considerations with this EVM

The bq51003EVM-764 evaluation module (HPA764-006) demonstrates the receiver portion of the bqTESLA™ wireless power system. This receiver EVM is a complete receiver-side solution that produces 5-V output at up to a 500-mA load (2.5 W).

- The bqTESLA receiver is used in any number of low-power battery portable devices such as a power supply to a direct battery charger. With contact-free charging capability, no connections to the device are needed.
- Output voltage of 5 V up to 500-mA charge current
- External adapter switchover
- 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 max output current using variable resistor R16

2 Modifications

Refer to the datasheet when changing components (SLUSBC8). 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 and smaller coil.

Note that changing components can improve or degrade EVM performance.

3 Recommended Operation Condition

Table 1 provides a summary of the bq51003EVM-764 performance specifications. All specifications are given for an ambient temperature of 25°C.

Table 1. bq51003EVM-764 Electrical Performance Specifications

Parameter		Test Condition	MIN	TYP	MAX	UNIT
V_{IN}	Input voltage range	Typical Vrect Voltage at TP12	4		10	V
Vadapter	Adapter input voltage		4	5	20	V
OVP	Input overvoltage protection	Voltage at V-rectified			550	mA
I_{OUT}	Output current range	Current limit programming range			550	mA
V_{OUT}	Output voltage	I_{LOAD} = 700 mA		5		V
Fs	Switching frequency		110		205	kHz
Efficiency	AC-AC efficiency			76		%

4 Equipment and EVM setup

4.1 Schematic

The bq51003EVM-764 schematic is illustrated in Figure 1.

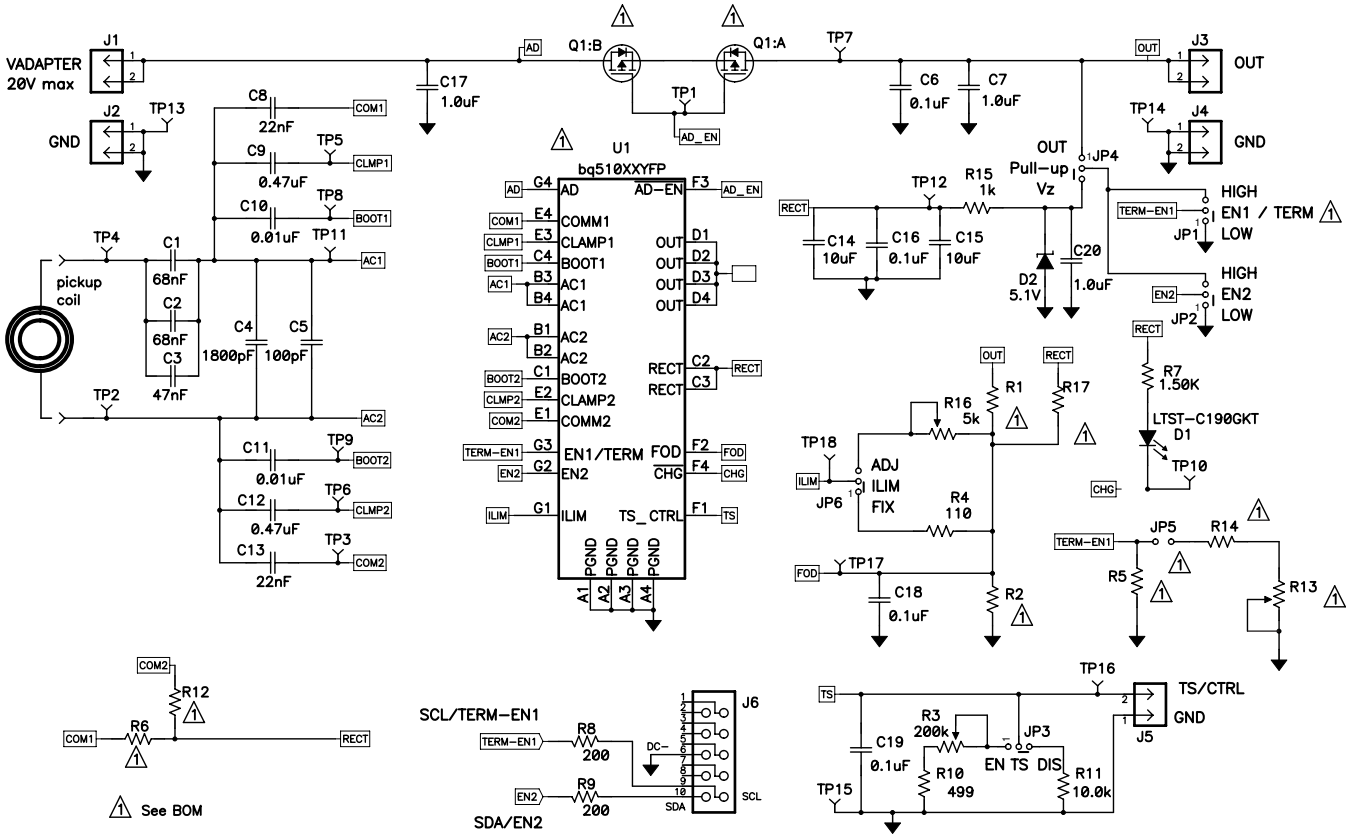

Figure 1. HPA764 Schematic

4.2 Connector and Test Point Descriptions

The connection points are described in the following paragraphs.

4.2.1 J1 – AD External Adapter Input, J2-GND

Power can be provided to simulate an external adapter applied to the receiver in this bq51003EVM-764 (HPA764-006).

4.2.2 J3 – Output Voltage, J4-GND

Output voltage is 5 V in wireless power mode up to 500 mA.

4.2.3 J5 – TS and Return Connector

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

4.2.4 J6 – Programming Connector

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

4.3 Jumpers and Switches

The control jumpers are described in the following paragraphs.

4.3.1 JP1 – EN1 Enable 1

Not populated in this EVM (HPA764-006).

4.3.2 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.

4.3.3 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.

4.3.4 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.

4.3.5 JP5 – Termination

This jumper along with R14 and R13 are not installed.

4.3.6 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.

4.4 Test Point Descriptions

The test points are described in the following paragraphs.

4.4.1 TP1 – AD-EN

This push-pull driver for the external PFET connects the adapter and the output from the bq51003.

4.4.2 TP2 – AC Input 2

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

4.4.3 TP3 – COM2 Communication 2 Drive

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

4.4.4 TP4 – AC Input 1

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

4.4.5 TP5 – CLMP 1

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

4.4.6 TP6 – CLMP 2

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

4.4.7 TP7 – OUT Output Voltage

This test point is the output voltage.

4.4.8 TP8 – Boot-1 Boot Capacitor

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

4.4.9 TP9 – Boot-2 Boot Capacitor

This bootstrap capacitor 2 drive connects to the IC.

4.4.10 TP10 – CHG Charge

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

4.4.11 TP11 – AC1 IC input

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

4.4.12 TP12 – Rectified Voltage

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

4.4.13 TP13, TP14, TP15 – GND

These are the ground test points.

4.4.14 TP16 – TS Temp Sensor

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

4.4.15 TP17 – FET Open Detection (FOD)

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

4.4.16 TP18– ILIM

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

4.5 Pin Description of the IC

Table 2. Pin Description

PIN Number (WCSP)	bq51003
A1, A2, A3, A4	PGND
B1, B2	AC2, AC2
B3, B4	AC1, AC1
C1	BOOT2
C2, C3	RECT
C4	BOOT1
D1, D2, D3, D4	OUT
E1	COM2
E2	CLMP2
E3	CLMP1
E4	COM1
F1	TS/CTRL

Table 2. Pin Description (continued)

PIN Number (WCSP)	bq51003
F2	FOD
F3	AD-EN
F4	CHG
G1	ILIM
G2	EN2
G3	EN1
G4	AD

5 Test Procedure

This procedure describes test configuration of the bq51003 evaluation board (HPA764-006) for bench evaluation.

5.1 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 XX.

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.

5.2 Recommended Test Equipment

The following equipment is needed to complete this test procedure.

5.2.1 Power Supplies

A power supply capable of supplying 19 V at 1 A is required for testing procedures.

5.2.2 Loads

A resistive load or electronic load set to 10 Ω at 500 mA and 5 kΩ at 1 mA, power rating should be 5 W.

5.2.3 Meters

Two DC voltmeters and two DC ammeters are required.

5.2.4 bqTesla Transmitter

The transmitter HPA689 or equivalent is used for final test.

5.3 Equipment Setup

5.3.1 Test Set Up

The final assembly is tested using a bqTesla transmitter provided (HPA689). Input voltage to the transmitter is set to 19 V_{DC}, ±200 mV with current limit of 1 A and connected to J1 and J2. Set power supply to OFF. Place UUT on the transmitter coil. The unit under test (UUT) is placed in the center of HPA689 TX coil.

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

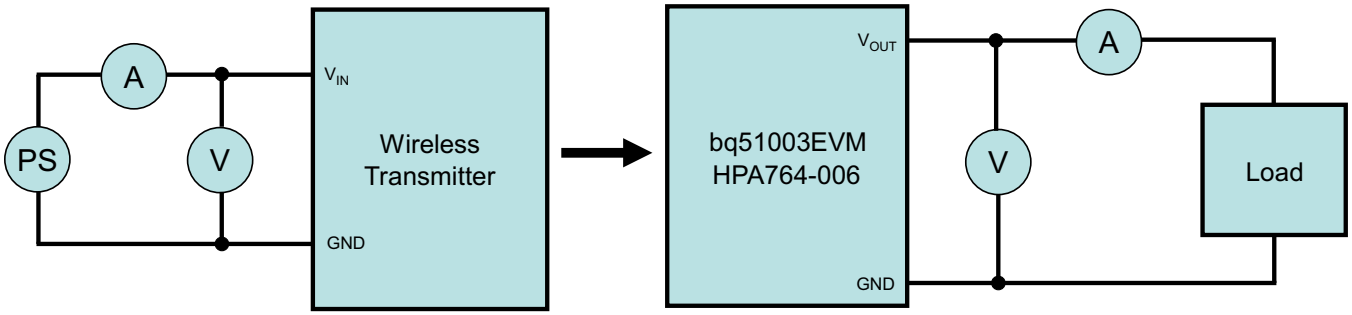

Figure 2. Test Set Up

5.3.2 Load

The load is connected between J3 OUT and J4 GND of the UUT. A DC ammeter is connected between UUT and Load. Set the load for 10 Ω/500 mA.

5.3.3 Jumper Settings

JP1: EN1/TERM and Low shorted

JP2: EN2 and Low shorted

JP3: TS and DIS shorted

JP4: Pullup and Vz shorted

JP5: Open

JP6: ILIM and ADJ shorted

5.3.4 Meters

- Connect ammeter to measure 19-V input current to transmitter.
- Connect voltmeter to monitor input voltage at J1 and J2 of TX unit.
- On UUT, a voltmeter is used to measure output voltage at TP7 with ground at J4.
- Connect ammeter to measure load current.

5.3.5 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

5.3.6 R16 Set Up

Connect ohm meter between JP6 ADJ and J2 (GND). Adjust R16 to 600 Ω, ±20-Ω reading on the ohmmeter.

5.4 Procedure

5.4.1 Turn ON Operation and Operation at 500-mA Load

- Turn ON transmitter power supply (19 V)
- Transmitter: Verify LED D2 is *ON*
- UUT: Adjust load current to 500 mA, ±50mA
- Put the receiver EVM on the Transmitter coil and align them correctly
- After 5 seconds, verify that:
  1. Transmitter: Status LED D5 should be green flashing for approximately 1 second
  2. The transmitter beeps
  3. Transmitter: LED D2 still ON
  4. Receiver: LED D1 is ON
- UUT: Verify that Vout is 4.9 V to 5.1 V (between TP7 and J4)
- UUT: Verify that the rectified voltage is 5 V to 5.3 V (between TP12 and TP13) (**Note:** a modulation signal is present on this voltage every 250 ms and may cause fluctuation in the reading, use lower value or base line)

5.4.2 Efficiency Test (500-mA Load)

- Verify the input current to TX is less than 260 mA, with input voltage at 19 V_{DC}
- Turn OFF Transmitter Power Supply (19)

5.4.3 Operation (1-mA Load)

- Turn ON transmitter power supply (19 V)
- Transmitter: Verify LED D2 is *ON*
- UUT: Adjust load current to 1mA, ±200 µA
- Put the receiver EVM on the transmitter coil and align them correctly
- After 5 seconds verify that:
  1. Transmitter: Status LED D5 is flashing green for approximately 1 second
  2. The transmitter beeps
  3. Transmitter: LED D2 still *ON*
  4. Receiver: LED D1 is *ON*
- UUT: Verify that Vout is 4.9 V to 5.1 V (between J3 or TP7 and J4)
- UUT: Verify that rectified voltage should be 6.9 V to 7.6 V (between TP12 and TP13) (**Note:** a modulation signal is present on this voltage every 250 ms and may cause fluctuation in the reading, use lower value or base line)

5.4.4 Efficiency Test (1-mA Load)

- Verify the input current to TX is less than 60 mA, with the input voltage at 19 V_{DC}
- Turn *OFF* Transmitter Power Supply (19)

5.4.5 Adapter Test (500-mA Load)

- Connect 6-V, ±200-mV power supply with current limit set to 1.0 A to J1 and return to J2 on the HPA764-006 receiver.
- Adjust load current to 500 mA, ±50 mA
- Turn on power supply
- Verify that:
  1. UUT: TP7 V_{OUT} is 5.5 V to 6 V
  2. Transmitter: Status LED D5 is off

6 Test Results

6.1 Load Step

The procedure for load step is as follows:

- Set up the test bench as described in Section 5.
- Power TX with 19 V.
- Provide a load step from no load (high impedance) to 10 Ω or 500 mA (if using current source load).
- Monitor load current, rectifier voltage, and output voltage as shown in Figure 3.

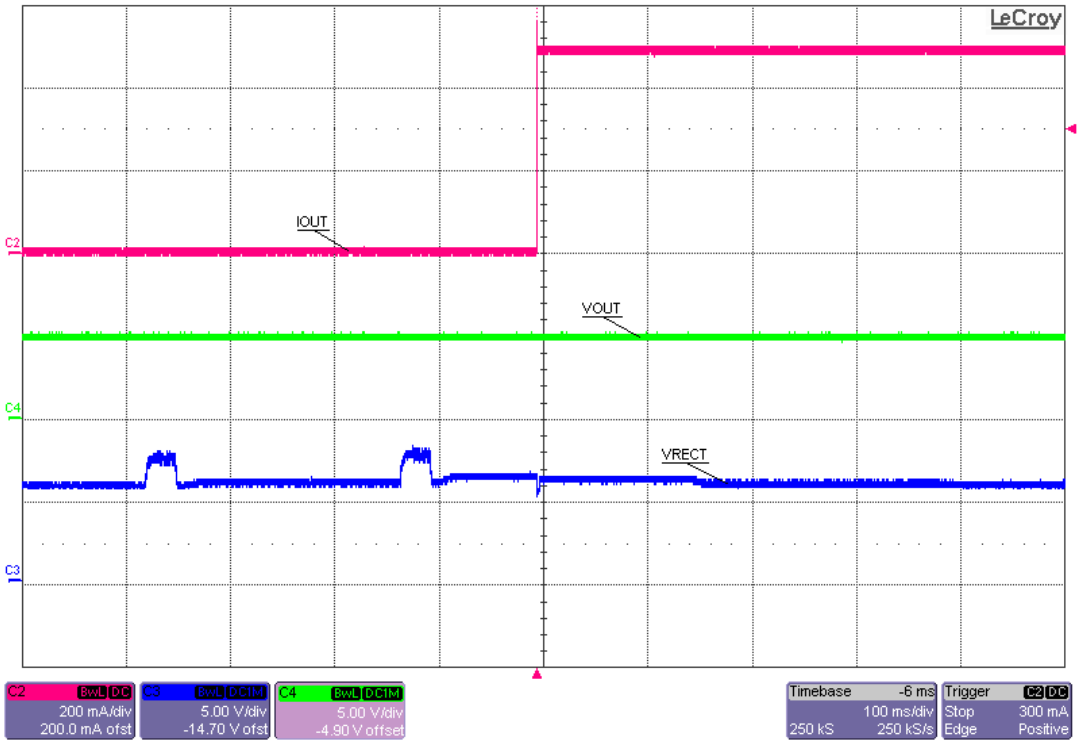

Figure 3. Load Step, 0 mA to 500 mA

6.2 Load Dump

The procedure for load dump is as follows:

- Set up the test bench as described in Section 5.
- Power TX with 19 V
- Provide a load dump from 10 Ω or 500 mA (if using a current source load) to no load (high impedance).
- Monitor load current, rectifier voltage, and output voltage as shown in Figure 4.

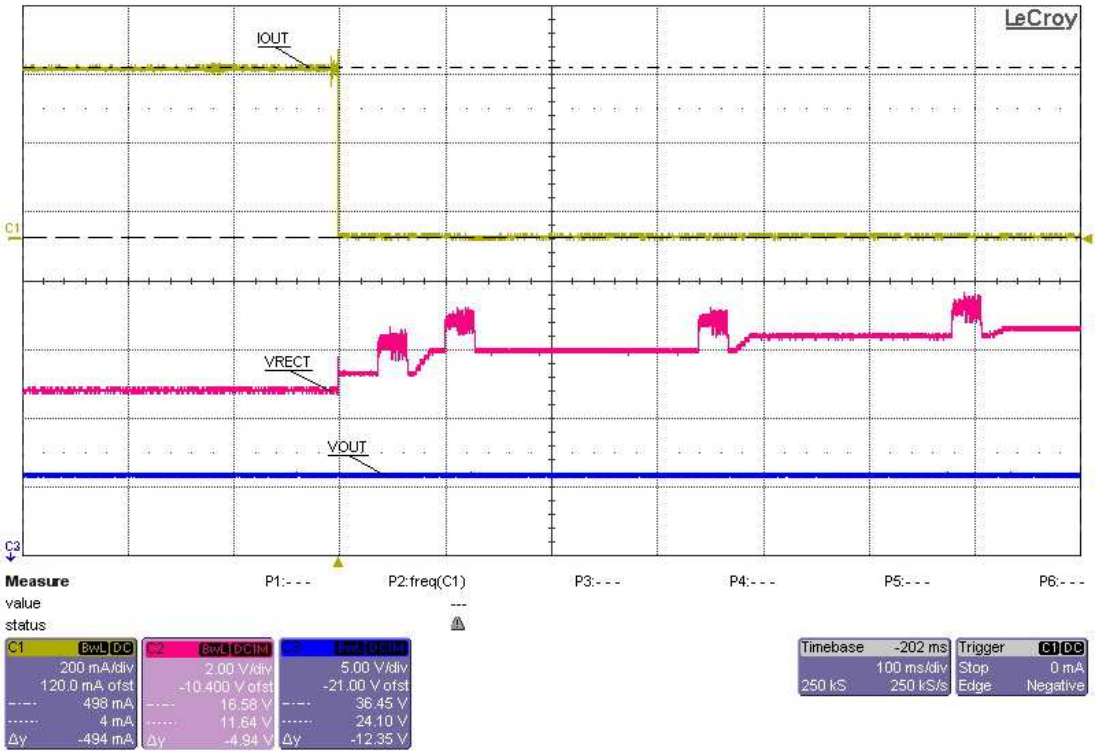

Figure 4. Load Dump, 500 mA to 0 mA

6.3 Start-Up

These procedures demonstrates start-up:

- Set up the test bench as described in Section 5.
- Power TX with 19 V
- Trigger scope sweep on TP2 AC IN

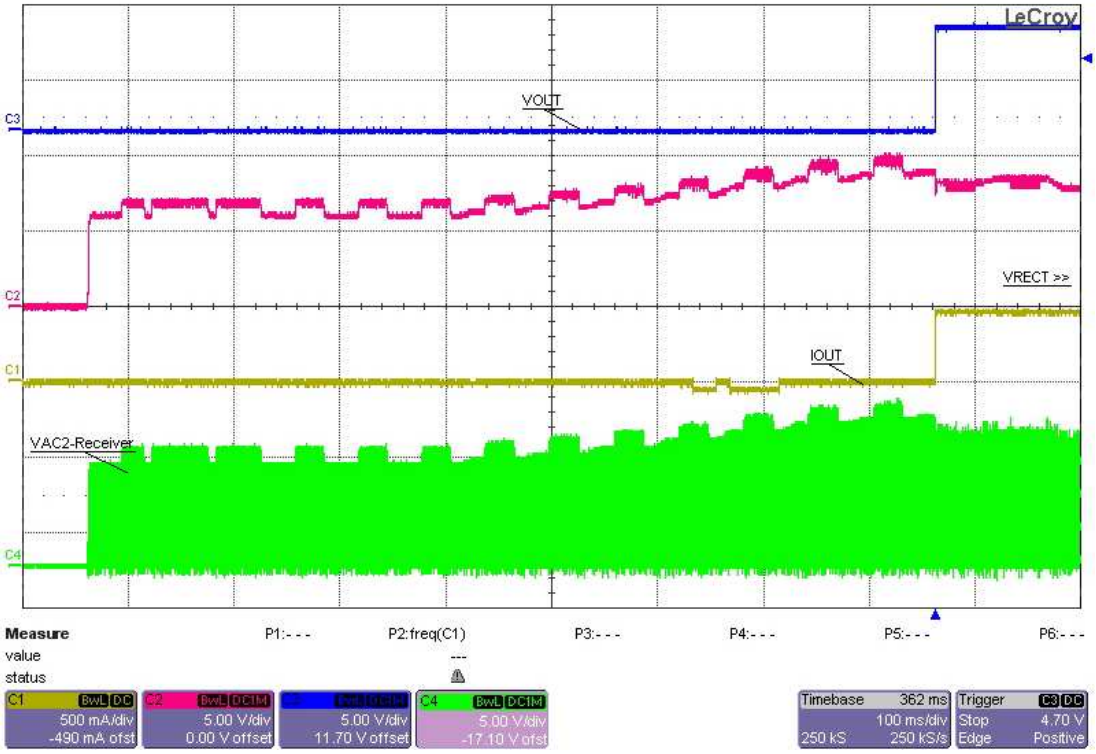

Figure 5. Start-Up

6.4 Efficiency

Figure 6 shows the efficiency data for the wireless power receiver, bq51003. The efficiency data are measured from 50-mA to 500-mA load.

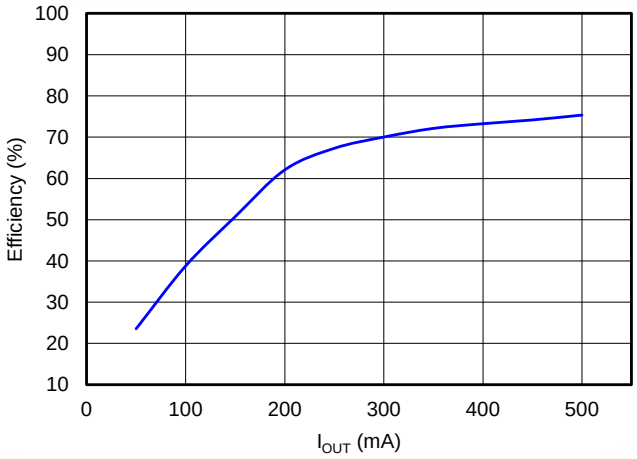

Figure 6. Efficiency for the bq51003 Versus I_{OUT}

6.5 Thermal Performance

This section shows a thermal image of the bq51003EVM-764 (see Figure 7). A 5.0-V output is used at a 500-mA load. There is no air flow and the ambient temperature is 25°C. The peak temperature of the IC, 37°C, is well below the maximum recommended operating condition listed in the data sheet.

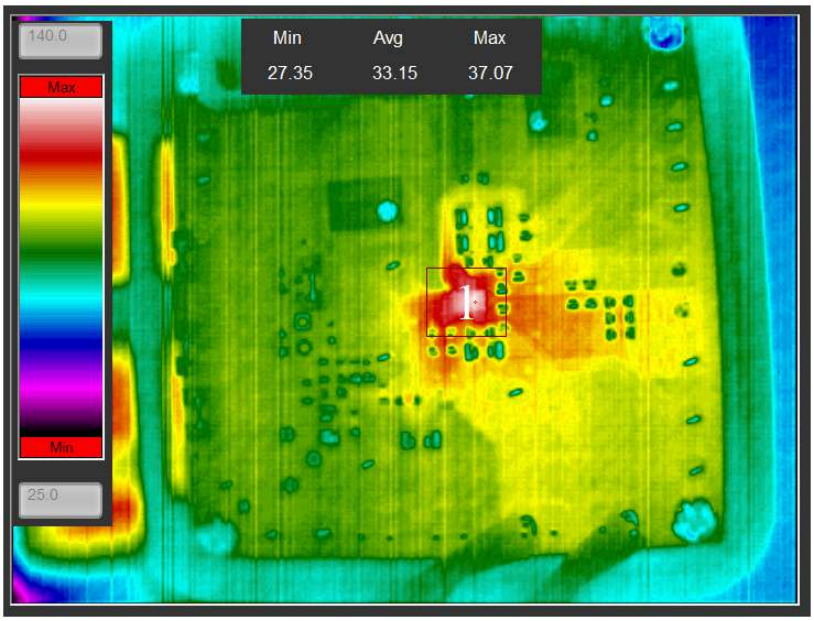

Figure 7. Thermal Image

7 Layout and Bill of Material

7.1 Layout

7.1.1 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 500-mA load-current application, the current rating for each net is as follows:

- AC1 = AC2 = 500 mA
- BOOT1 = BOOT2 = 10 mA
- RECT = 500 mA
- OUT = 500 mA
- 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 ≥ ±10 µF
- OUT ≥ 1 µF

It is always a good practice to place high-frequency bypass capacitors of 0.1 µF next to RECT and OUT. Figure 8 illustrates an example of a WCSP layout:

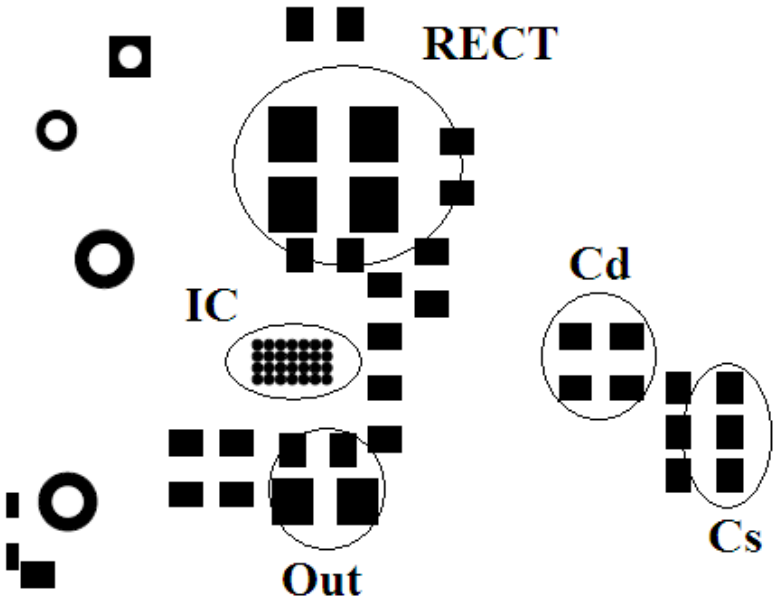

Figure 8. bq51003EVM-764 Layout Example

7.1.2 Layout

Figure 9 through Figure 12 illustrate the PCB layouts for the bq51003EVM-764.

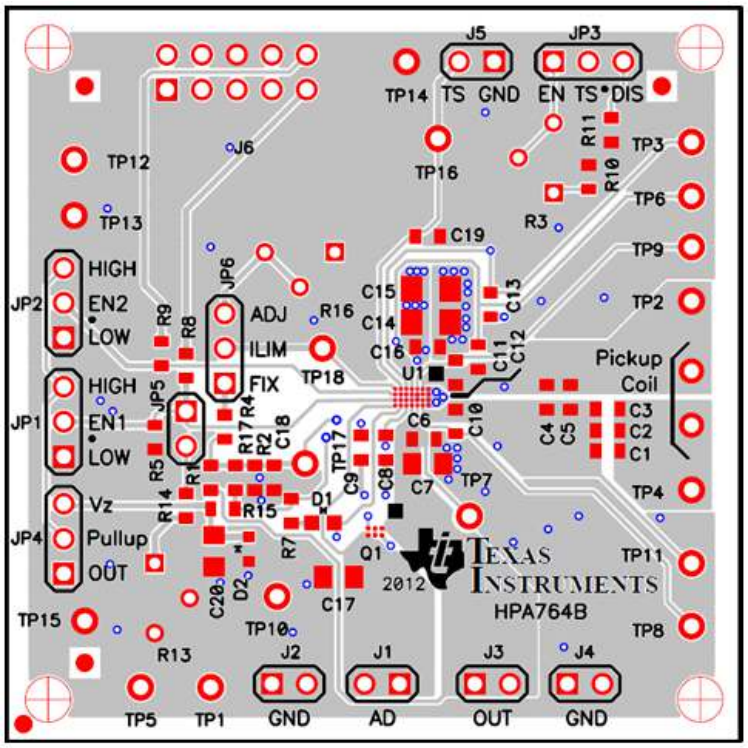

Figure 9. bq51003EVM-764 Top Assembly

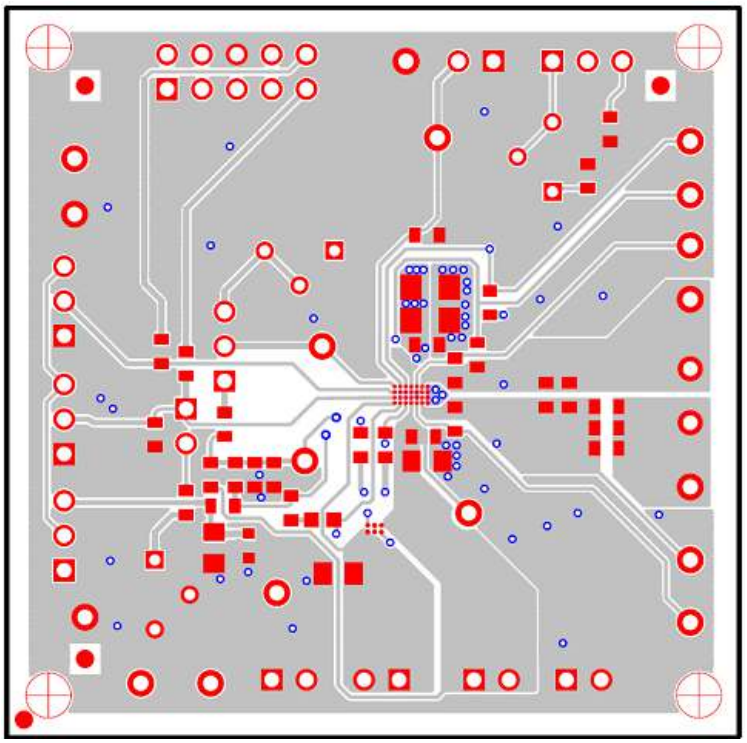

Figure 10. bq51003EVM-764 Top Layer

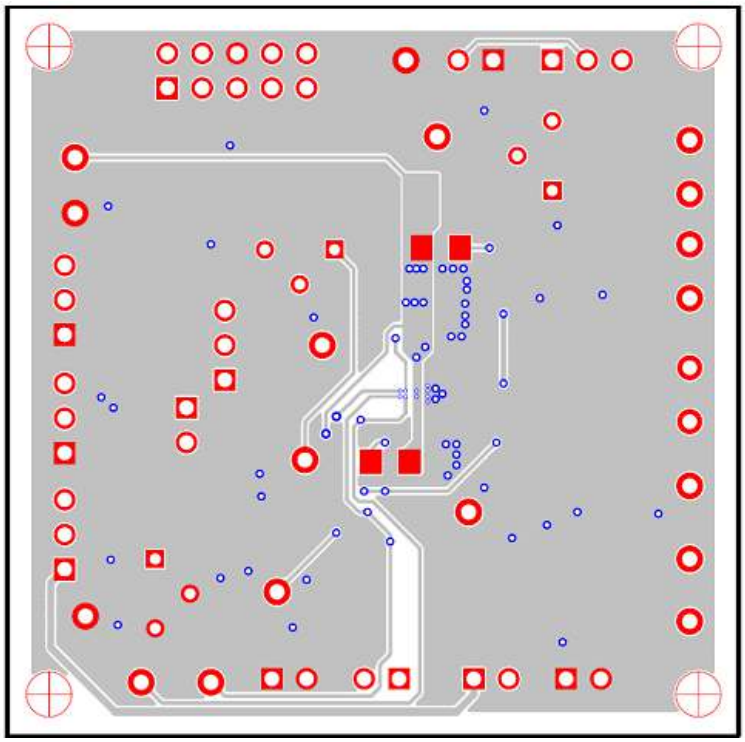

Figure 11. bq51003EVM-764 Bottom Copper Layer

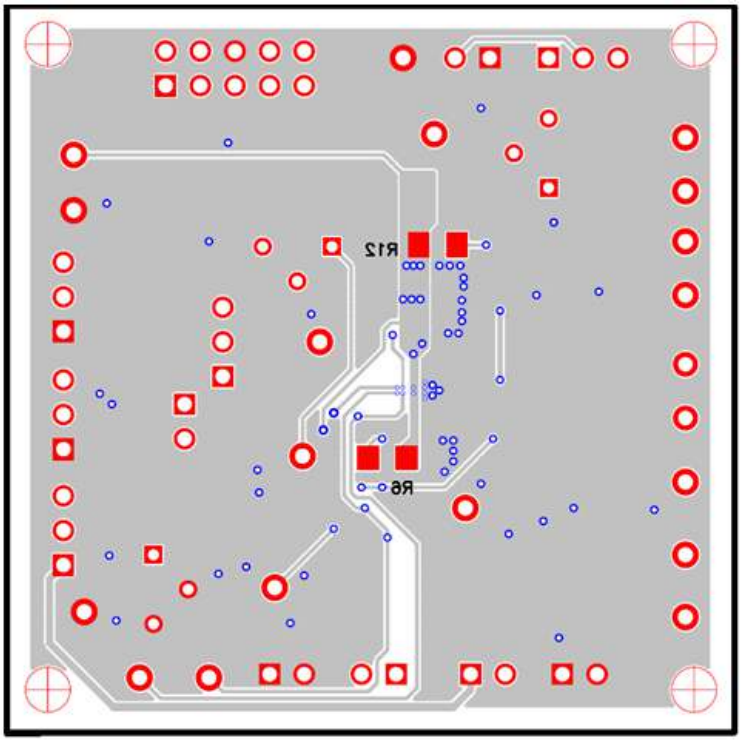

Figure 12. bq51003EVM-764 Bottom Assembly

7.2 Bill of Materials (BOM)

The bq51003EVM-764 bill of materials is shown in Table 3.

Table 3. bq51003EVM-764 Bill of Materials

Count	RefDes	Value	Description	Size	Part Number	MFR
1	C1	68nF	Capacitor, Ceramic, 50V, X7R, 10%	0603	std	std
1	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, J2, J3, J4, 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, JP3, JP4, JP6	PEC03SAAN	Header, Male 3-pin, 100mil spacing,	0.100 inch x 3	PEC03SAAN	Sullins
1	JP1	PEC03SAAN	Header, Male 3-pin, 100mil spacing,	0.100 inch x 3	PEC03SAAN	Sullins
0	JP5	PEC02SAAN	Header, Male 2-pin, 100mil spacing,	0.100 inch x 2	PEC02SAAN	Sullins
1	Q1	CSD75205W1015	MOSFET, Dual PChan, -20V, 1.2A, 190 milliOhm	CSP 1x1.5mm	CSD75205W1015	TI
0	R1	Open	Resistor, Chip, 1/16W, 1%	0603	DNI	DNI
1	R2	196	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	412	Resistor, Chip, 1/16W, 1%	0603	RC0603FR-07412RL	Yageo America
0	R5	Open	Resistor, Chip, 1/16W, 1%	0603	DNI	DNI
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
0	R14	1.0k	Resistor, Chip, 1/16W, 1%	0603	DNI	DNI
1	R15	1.0K	Resistor, Chip, 1/16W, 1%	0603	RC0603FR-071KL	Yageo Corporation
0	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	20K	Resistor, Chip, 1/16W, 1%	0603	ERJ-3EKF3092V	Panasonic Electronic Components

Table 3. bq51003EVM-764 Bill of Materials (continued)

Count	RefDes	Value	Description	Size	Part Number	MFR
15	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP16, TP17, 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	bq51003YFP	IC, Wirless Secondary-Side Power Controller	DSBGA	bq51003YFP	TI
5	--		Shunt, 100-mil, Black	See note 8	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, WR-483250-15M2-G, 760308201	Vishay, TDK, Wyrth
1			Tape segment, Low Static Polyimide Film - See note 6.	1.5" x 2.3"	5419-1 1/2"	3M
1	Label	Label	Thermal Label	See note 9	THT-53-423-3	Brady
	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 screws provided with case				
		8. Install Shunts on:				
		JP6: between ILIM and FIX				
		JP5: (Only for HPA764-002) between two ends				
		JP4: between Pull-up and Vz				
		JP3: between TS and DIS				
		JP2: between EN2 and LOW				
		JP1: (Only for HPA764-001, 003, 005, & 006) between EN1/TERM and LOW				
		9. Install label on back of PCB near J6 on the top edge of the PCB after final wash (box). Text shall be 8 pt font or lower. Text shall be per **Assembly Labels Table**. The ref designators should not be hidden by the label.				
		Assembly Labels Table				
		Assembly Number	**Text**			
		HPA764-006	bq51003EVM-764			

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