TEXAS INSTRUMENTS

# bq51025 Evaluation Module (PWR649)

The bq51025EVM-649 (PWR649) wireless power receiver evaluation kit (EVM) from TI is a high performance, easy-to-use development kit for the design of wireless power solutions. It helps designers evaluate the operation and performance of the bq51025 IC, a secondary-side receiver device for wireless power transfer applications. The bq51025 device is a fully-contained, wireless power receiver capable of operating in WPC v1.1 protocol which allows a wireless power system to deliver up to 5 W to the system when used with a Qi inductive transmitter. When paired with the bq500215EVM-648 (PWR648), the bq51025 is capable of delivering up to 10 W to the system. The bq51025 device provides a single device power conversion (rectification and regulation) as well as the digital control and communication for WPC specification. The kit enables designers to speed up the development of their end-applications.

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## 1    Introduction

The bq51025 is an advanced, flexible, secondary-side device for wireless power transfer applications capable of sourcing up to 10 W. The bq51025 device integrates an ultra-low-impedance synchronous rectifier, a very-high-efficiency post regulator, digital control, and accurate voltage and current loops. The bq51025 devices provide the AC/DC power conversion while integrating the digital control required. The IC complies with the WPC v1.1 communication protocol.

Together with a bq500xxx primary-side controller transmitter (or any other WPC v1.1 transmitter), the bq51025 enables a complete contactless power transfer system for a 5-W wireless power supply solution. By utilizing near-field inductive power transfer, the secondary coil embedded in the mobile device can pick up the power transmitted by the primary coil. The voltage from the secondary coil is then rectified and regulated to be used as a power supply for down-system electronics. Global feedback is established from the secondary to the primary in order to control the power transfer process.

In WPC, system communication is digital (packets are transferred from the secondary to the primary). Differential bi-phase encoding is used for the packets. The bit rate is 2 kb/s. Various types of communication packets have been defined. These include identification and authentication packets, error packets, control packets, power usage packets and efficiency packets, among others.

When paired with the bq500215 primary-side controller transmitter, the bq51025 is capable of delivering up to 10 W. The bq51025 incorporates a proprietary two-way authentication with the bq500215 primary controller that allows optimal power transfer and system performance up to 10-W output power.

## 2   Considerations with this EVM

The bq51025EVM-649 evaluation module (PWR649) demonstrates the receiver portion of the wireless power system. This receiver EVM is a complete receiver-side solution that produces 10-W output power at up to 2-A load with adjustable output voltage. The 10-W output power can be delivered from various output voltages. The output current is limited so that the overall delivered power is less than 10 W. For example, a 10-V output can supply up to 1 A, whereas a 5-V output can deliver up to 2 A. The default configuration for this EVM is a 7-V output capable of delivering up to 1.43 A.

- The receiver can be used in any number of devices as a power supply for a battery charger. With contact-free charging capability, no connections to the charging power source are required.
- 5-W power delivery with any WPC v1.1 transmitter
- 10-W power delivery with the bq500215 transmitter
- Highly-integrated wireless power receiver solution
    - Ultra-efficient synchronous rectifier
    - Very high efficiency post regulator
    - WPC v1.1-compliant communication and control
    - Only one IC required between RX coil and DC output
- Programmable output voltage to optimize performance for application
- Adaptive communication current limit (CM_ ILIM) for robust communication
- Supports 20-V max input
- Low-power dissipative overvoltage clamp
- Overvoltage, overcurrent, overtemperature protection
- 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 Foreign Object Detection (FOD) tuning
- Options to adjust the input current limit and output voltage using resistors or I$^2$C
- Flexibility for FOD tuning
- Adjustable resistor that can be used to set RFOD
- Temperature sensing can be adjusted using external resistors
- Micro-USB connector for adapter testing configuration
- I$^2$C connector (USB-TO-GPIO "HPA172" kit for I$^2$C communication through computer is required)
- $\overline{\text{WPG}}$ LED indicator (Green LED is on when V$_{\text{OUT}}$ is high)
- $\overline{\text{PD\_DET}}$ LED indicator (Orange LED is on when the RX is on TX pad)

## 3 Modifications

See the bq51025 data sheet (SLUSBX7) when changing components. To aid in such customization of the EVM, the board was designed with devices having 0402 and 0603 or larger footprints. A real implementation likely occupies less total board space.

Note that changing components can improve or degrade EVM performance. Special attention should be given to the resonant capacitors (C1, C2, and C3). Thermal performance of these capacitors can greatly impact overall system performance.

## 4 Recommended Operating Conditions

Table 1 provides a summary of the bq51025EVM-649 performance specifications. All specifications are given for an ambient temperature of 25°C.

**Table 1. bq51025EVM-649 Recommended Operating Conditions**

| PARAMETER | | TEST CONDITION | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{RECT}$ | RECT voltage range | | 4 | | 11 | V |
| $I_{OUT}$ | Output current | Current limit programming range | | | 2 | A |
| $I_{AD\_EN}$ | Sink current | | | | 1 | mA |
| $V_{OUT(REG)}$ | Programmable output voltage[1] | $P_{OUT}$ = 10 W with the bq500215 transmitter EVM (PWR648), otherwise $P_{OUT}$ = 5 W | 4.5 | 7 | 10 | V |
| $f_s$ | Switching frequency | | 110 | | 205 | kHz |
| $T_J$ | Junction temperature | | 0 | | 125 | °C |

[1]  The output voltage can be adjusted using $I^2C$ or the VIREG and VO_REG resistors. Also the coil needs to change for different output voltage levels for optimal operation of the EVM. See the bq51025 datasheet for details.

# 5 Equipment and EVM Setup

## 5.1 Schematic

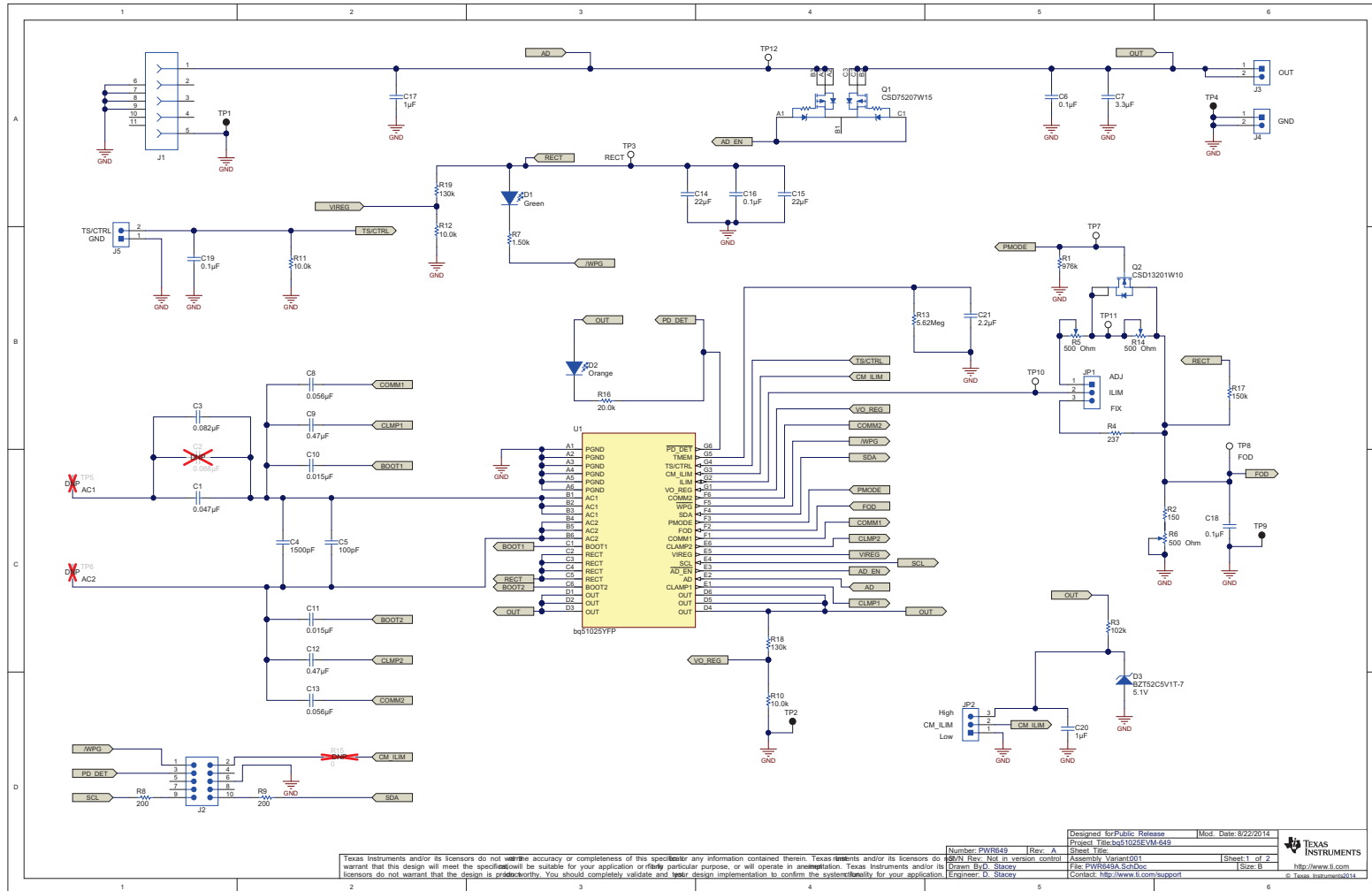Figure 1 shows the PWR649 schematic with the bq51025 output set to 7 V.



**Figure 1. bq51025EVM-649 Schematic**

## 5.2 Recommended Test Equipment

The following equipment is needed to complete this test procedure:

**Power Supplies**
- Power supply #1 (PS #1) capable of supplying 12 V at 2 A is required (for bq500215EVM-648 10-W transmitter)
- Power supply #2 (PS #2) capable of supplying 5 V at 2 A is required (for bq500212AEVM-550 5-W transmitter)
- Power supply #3 (PS #3) capable of supplying 5 V at 1 A is required (for adapter testing)

**Loads**
- For simplicity, resistive loads should be used that can be set to 5 $\Omega$/1400 mA, 14 $\Omega$/500 mA, and 7 k$\Omega$/1 mA. The power rating should be 10 W. An electronic load will work as well, but the discussion focuses on the resistive load setup.
- The default setting for this EVM is for a 7-V output. Changing this value will require additional changes to the EVM including a different coil. Details can be found in the bq51025 datasheet.

**Meters**
- Three DC voltmeters, two DC ammeters and one ohmmeter

**Oscilloscopes**
- Not required but can be used to view traces as needed

**bqTesla Transmitters**
- The PWR648 transmitter (bq500215EVM-648) is required for 10-W testing and requires a 12-V input supply (PS #1)
- The PWR550 transmitter (bq500212AEVM-550) is recommended for 5-W testing and requires a 5-V input supply (PS #2). Any other WPC v1.1 transmitter can be substituted (care must be given to the required input power supply).

**Recommended Wire Gauge**
- For proper operation, TI recommends 22-AWG wire or larger

## 5.3 Equipment Setup

The following items ensure proper equipment setup:

**Test Set Up**
- Set power supplies to OFF
- 10-W testing will be done with the PWR648 transmitter. Input voltage to the PWR648 is set with PS #1 to 12 VDC ±200 mV, with a current limit of 2.0 A.
- Connect PS #1 positive terminal to J1 and negative terminal to J2 of PWR648
- 5-W testing will be done with the PWR550 transmitter. Input voltage to the PWR550 is set with PS #2 to 5 VDC ±200 mV, with a current limit of 2.0 A.
- Connect PS #2 positive terminal to J1 and negative terminal to J2 of PWR550

**Load**
- The load is connected between J3-OUT and J4-GND of PWR649
- A DC ammeter is connected between PWR649 and load

**Jumper Settings**
- JP1 → ILIM and FIX are shorted
- JP2 → CM_ILM and High are shorted

**Voltage and Current Meters**
- Connect the ammeter to measure PS #1 (12-V input) current to the PWR648. Connect the voltmeter to monitor the input voltage at J1 and J2 of PWR648 unit.

- A voltmeter is used on the PWR649 to measure output voltage at J3 with ground at J4. Connect the ammeter to measure load current.
- When 5-W testing is to be done, connect the ammeter to measure PS #2 (5-V input) current to the PWR550. Connect the voltmeter to monitor the input voltage at J1 and J2 of PW550 unit.

**RFOD: R6 Set Up**

- Connect the ohmmeter between TP8 (FOD) and TP9 (GND). Verify R2 + R6 is approximately 256 Ω; adjust, if necessary.

## 5.4    Connector Descriptions

The connections points are described in the following paragraphs.

### 5.4.1    J1 – AD External Adapter Input

Power can be provided to simulate an external adapter applied to the receiver in this bq51025EVM-649 (PWR649).

### 5.4.2    J2 – Programming Connector

This connector is populated and can be used for $I^2C$ communication using the USB-TO-GPIO "HPA172" kit.

### 5.4.3    J3 – Output Voltage

Output voltage in wireless power mode up to 2 A (default configuration limits to 1.4 A at 7 V); the adapter option is also supported in this PWR649.

### 5.4.4    J4 –GND

Ground return

### 5.4.5    J5 – TS/CTRL and Return Connector

External connection for temperature sense resistor, see data sheet for additional information.

## 5.5    Jumpers and Switches

The control jumpers are described in the following paragraphs.

### 5.5.1    JP1– ILIM (FIX or ADJ)

Maximum output current is set by the ILIM pin. In the FIX position, the current is set to a fixed value of R4 plus RFOD (R2 + R6 as set by the factory) (approximately 1.4 A). In the ADJ position, current is set by R5 and R14 along with RFOD.

### 5.5.2    JP2 – CM_ILIM

Enables CM_ILIM feature when pulled low and disables when pulled high. Default position is high (disabled).

## 5.6 Test Point Descriptions

The test points are described in the following paragraphs:.

### 5.6.1 TP1, TP2, TP4, and TP9 – Ground

These test points are used for ground connections.

### 5.6.2 TP3– Rectified Voltage

The input AC voltage is rectified into unregulated DC voltage ($V_{RECT}$); additional capacitance is used to filter the voltage before the regulator.

### 5.6.3 TP5 and TP6 – AC1 and AC2 Inputs

Test points are not populated, they can be used for measuring AC voltage applied to the EVM from the receiver coil. These points are used for connecting the receiver's coil.

### 5.6.4 TP7– PMODE

Indicator of power mode, low if in 10-W mode, high if in 5-W mode. Pin F3 of the bq51025.

### 5.6.5 TP8 – FOD

Input for rectified power measurement for FOD feature in WPC, pin F2 of the IC. TP8 is the FOD pin of the bq51025.

### 5.6.6 TP10– ILIM

Programming pin for overcurrent limit protection, pin G2 of the bq51025.

### 5.6.7 TP11– 10-W ILIM

Allows individual trimming of R5 and R14 for optimum power delivery for 5-W and 10-W systems.

### 5.6.8 TP12– Input Power

Connected to J1 pin 1. Alternative connection for wired power.

## 5.7 Pin Description of the IC

Table 2 contains the pin descriptions.

### Table 2. Pin Description

| PIN Number (WCSP) | bq51025 |
|---|---|
| A1, A2, A3, A4, A5, A6 | PGND |
| B1, B2, B3 | AC1 |
| B4, B5, B6 | AC2 |
| C1 | BOOT1 |
| C2, C3, C4, C5 | RECT |
| C6 | BOOT2 |
| D1, D2, D3, D4, D5, D6 | OUT |
| E1 | CLAMP1 |
| E2 | AD |
| E3 | $\overline{\text{AD\_EN}}$ |
| E4 | SCL |
| E5 | VIREG |
| E6 | CLAMP2 |
| F1 | COMM1 |
| F2 | FOD |
| F3 | PMODE |
| F4 | SDA |
| F5 | $\overline{\text{WPG}}$ |
| F6 | COMM2 |
| G1 | VO_REG |
| G2 | ILIM |
| G3 | CM_ILIM |
| G4 | TS/CTRL |
| G5 | TMEM |
| G6 | $\overline{\text{PD\_DET}}$ |

# 6 Test Procedure

This procedure describes the test configuration of the bq51025EVM-649 evaluation board (PWR649) for bench evaluation.

## 6.1 Definition

The following naming conventions are used:

| | |
|---|---|
| **VXXX :** | External voltage supply name (VBAT, VTS, $V_{OUT}$) |
| **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(TP(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 |
| **UUT:** | Unit Under Test (PWR649 EVM) |

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

## 6.2 Procedure

The following operating procedures are provided at a variety of operating loads. Initial testing is done with the 10-W transmitter (PWR648).

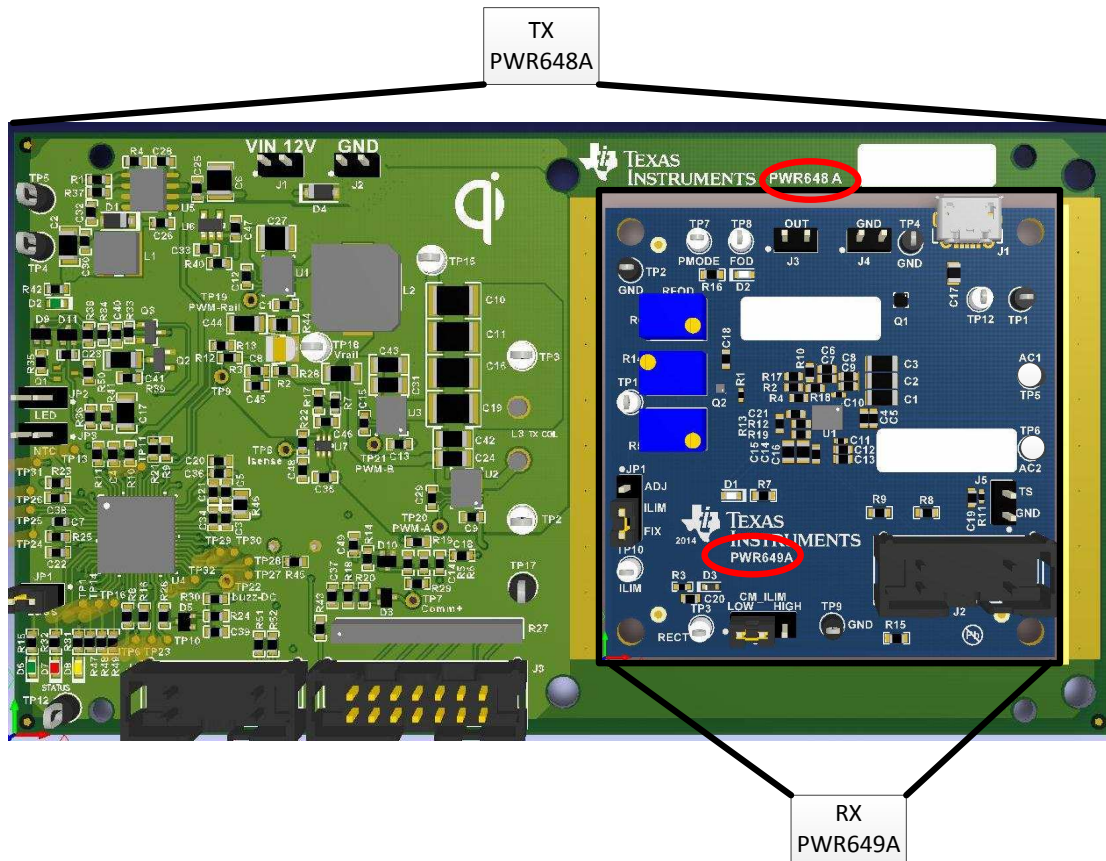Figure 2 shows the proper alignment between the transmitter (PWR648) and receiver (PWR649).

**Figure 2. Placement of PWR649 on PWR648**

### Turn ON Operation and Operation at 1400-mA Load (approximately 10 W)

- Turn ON transmitter power supply PS #1 (12 V)
- Wait approximately 1 second for the transmitter to start
- Transmitter – Verify LED D2 is blinking and D6 is OFF
- UUT – Adjust load current to 1400 mA ±50 mA
- Place the UUT on center of the PWR648 TX coil
- After about 1 second, verify that:
  - The transmitter should beep
  - Transmitter – LED D2 (green) is ON and LED D6 (green) is blinking (about 2 times per second)
  - Receiver – LED D1 (green) is ON and LED D2 (orange) is ON
  - UUT – Verify that $V_{OUT}$ is 6.9 V to 7.2 V (between J3 and J4)
  - UUT – Verify that the voltage between TP7 and TP2 (ground) measures less than 0.1 V (verifies 10-W mode)
  - UUT – Verify that the rectified voltage is 7 V to 7.4 V (between TP3 and TP4) **NOTE**: a modulation signal is present on this voltage every 250 ms and may cause fluctuation in the reading: use the baseline value.

### Efficiency Test (1400-mA Load)

- Verify that PS #1 input current is less than 1200 mA
- Note that if the CM_ILIM jumper (JP2) is set to low, the efficiency will be negatively impacted
- Remove UUT from the TX and turn OFF PS #1

**Turn ON Operation and Operation at 500-mA Load (approximately 3.5 W)**

- Turn ON PS #1
- Wait approximately 1 second for transmitter to start
- Transmitter – Verify LED D2 is blinking and LED D6 is OFF
- UUT – Adjust load current to 500 mA ±50 mA
- Place the UUT on center of the PWR648 TX coil
- After about 1 second, verify that:
  - The transmitter should beep
  - Transmitter – LED D2 (green) is ON and LED D6 (green) is blinking (about 2 times per second)
  - Receiver – LED D1 (green) is ON and LED D2 (orange) is ON
  - UUT – Verify that $V_{OUT}$ is 6.9 V to 7.2 V (between J3 and J4)
  - UUT – Verify that the rectified voltage is 7.0 V to 7.4 V (between TP3 and TP9) **NOTE**: a modulation signal is present on this voltage every 250 ms and may cause fluctuation in the reading: use the baseline value.

**Efficiency Test (500-mA Load)**

- Verify that PS #1 input current is less than 425 mA
- Remove UUT from the TX and turn OFF PS #1

**Operation (1-mA Load)**

- Turn ON PS #1
- Wait approximately 1 second for transmitter to start
- Transmitter – Verify LED D2 is blinking and LED D6 is OFF
- UUT – Adjust load current to 1 mA ±200 μA
- Place the UUT on center of the PWR648 TX coil
- After about 1 second, verify that:
  - The transmitter should beep
  - Transmitter – LED D2 (green) is ON and LED D6 (green) is blinking (about 2 times per second)
  - Receiver – LED D1 (green) is ON and LED D2 (orange) is ON
  - UUT – Verify that $V_{OUT}$ is 6.9 V to 7.2 V (between J3 and J4)
  - UUT – Verify that the rectified voltage is 8.0 V to 10.0 V (between TP3 and TP9) **NOTE**: a modulation signal is present on this voltage every 250 ms and may cause fluctuation in the reading: use the baseline value.

**Efficiency Test (1-mA Load)**

- Verify that PS #1 input current is less than 110 mA
- Remove UUT from the TX and turn OFF PS #1

**Adapter Test (500-mA Load)**

- Initial adapter testing will be done without the transmitter
- Connect 5 V ±250 mV adapter on J1 on the bq51025EVM-649 receiver (or use TP12 / PS #3 and GND)
- Adjust the load current to 500 mA ±50 mA (J3 OUT and J4 GND)
- Verify that:
  1. UUT – LED D1 is OFF and LED D2 is OFF
  2. UUT – $V_{OUT}$ is 5.0 V ±600 mV (J3 to J4)
- Turn ON PS #1
- Wait approximately 1 second for transmitter to start
- Transmitter – LED D2 is blinking and LED D6 is OFF
- Place the UUT on center of the PWR648 TX coil while the adapter is still connected to J1 (or TP12)

- After 1 second verify that:
  - The transmitter should NOT beep
  - Transmitter – LED D2 is ON and LED D6 is OFF
  - Receiver – LED D1 is OFF and LED D2 is ON
  - UUT – Verify that $V_{OUT}$ is 4.9 V to 5.2 V (between J3 and J4)
  - This shows that wireless power is disabled
- Keep the UUT on the transmitter and remove the power on J1 (or TP12) of the UUT
- After approximately 1 second verify that:
  - The transmitter should beep
  - Transmitter – LED D2 is ON and LED D6 is blinking
  - Receiver – LED D1 is ON and LED D2 is ON
  - UUT – Verify that $V_{OUT}$ is 6.8 V to 7.2 V (between J3 and J4)
  - This shows that wireless power is enabled
- Remove UUT from the TX and turn OFF PS #1

**5-W Transmitter Test (500-mA Load)**

- The UUT will be tested with the 2nd transmitter - PWR550
- The PWR550 EVM requires a 5-V supply with a 2.0-A current limit (PS #2)
- **NOTE**: Any other 5-W transmitter can be substituted, but the discussion from the transmitter side is only relevant to the PWR550 EVM
- Connect 5 V ±100 mV adapter on J1 on the PWR550 transmitter
- Place the UUT in the center of the PWR550 TX coil
- Adjust the load current to 500 mA ±50 mA (J3 *OUT* and J4 *GND*)
- Turn ON PS #2
- After approximately 1 second, verify that:
  1. PWR550 – LED D1 (blue) is ON, LED D5 (green) is blinking about once per second
  2. UUT – LED D1 is ON and LED D2 is ON
  3. UUT – $V_{OUT}$ is 6.9 V to 7.2 V (J3 to J4) (approximately 3.5 W)
  4. UUT – TP7 to TP2 (ground) measures above 1.5 V (this verifies that the receiver is in 5-W mode)
- Verify the maximum power is limited with the 5-W transmitter
  1. Slowly increase load current towards 900 mA (towards 6 W)
  2. Before 900 mA is reached, $V_{OUT}$ of the PWR649 will begin to decrease towards 6.0 V (J3 to J4) indicating maximum power is reached
- Remove UUT from the TX and turn OFF PS #2

# 7    Test Results

## 7.1    *Steady-State Operation with the bq24261 Charger*

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

*   Set up the test bench as described in Section 6
*   Power the TX (PWR648) with 12 V
*   Connect the output of the RX (PWR649) to battery charger bq24261EVM-079
*   Using a source meter, set the VBAT to 3.5 V and the current limit to 3.5 A
*   Using the bq24261 GUI, set the charger current to 2.1 A and the current limit to 2.5 A
*   Monitor the $I_{OUT}$ and $V_{OUT}$ from the RX after putting the receiver EVM (PWR649) on the transmitter coil and aligning them correctly
*   Monitor the $I_{OUT}$ and $V_{OUT}$ from the bq24261
*   Figure 3 shows the $V_{OUT}$ and $I_{OUT}$ from both the RX and the bq24261EVM-079. The output power from the bq51025 is approximately 10 W while the output power from the bq24261 is approximately 8.4 W.
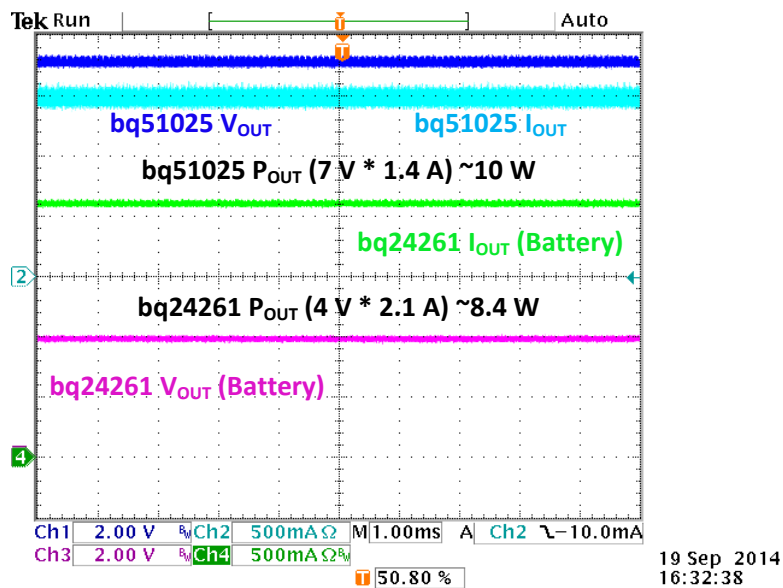


**Figure 3. bq51025 in Steady State Operation with bq24261**

## 7.2 *Load Step*

The procedure for load step is as follows:

- Set up the test bench as described in Section 6
- Power the TX (PWR648) with 12 V
- Provide a load step from no-load (high impedance) to 1000 mA by attaching a 7-Ω resistive load between J3 and J4 of the PWR649 EVM
- Monitor the RX signals: load current ($I_{OUT}$), rectifier voltage (RECT), and output voltage (OUT) as shown in Figure 4
- A 1.4-A load step is shown in Figure 5. Note that this step requires more time to recover to the full output voltage.
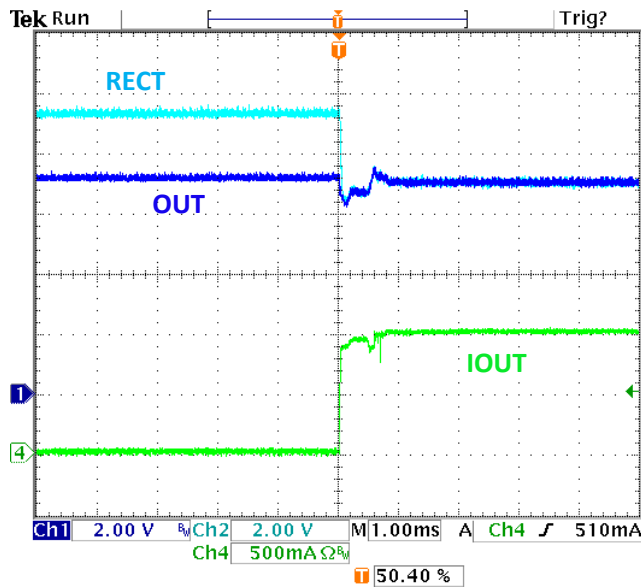


**Figure 4. 1-A Load Step**
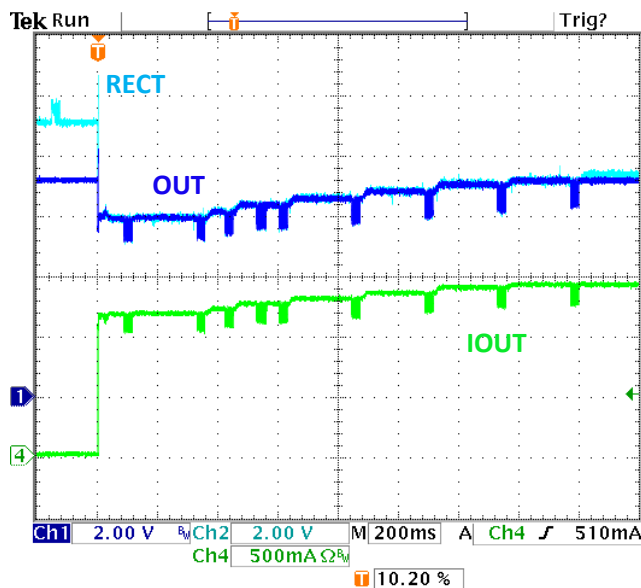


**Figure 5. 1.4-A Load Step**

## 7.3 Start Up

The procedure for start-up test with load:

- Set up the test bench as described in Section 6
- Power the TX (PWR648) with 12 V
- Apply 7 Ω across J3 and J4 on PWR649 to generate a 1-A load
- Put the RX (PWR649) on the transmitter coil, and align them correctly
- Monitor the RECT pin, $I_{OUT}$, and output voltage (OUT), as shown in Figure 6
- Starting up with a 5 Ω at J3 to J4 generates a 1.4-A load and is shown in Figure 7
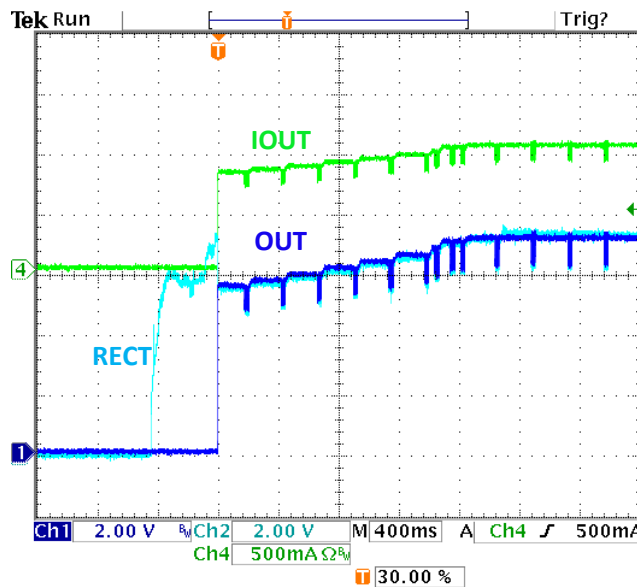


**Figure 6. Start Up With 1000 mA**
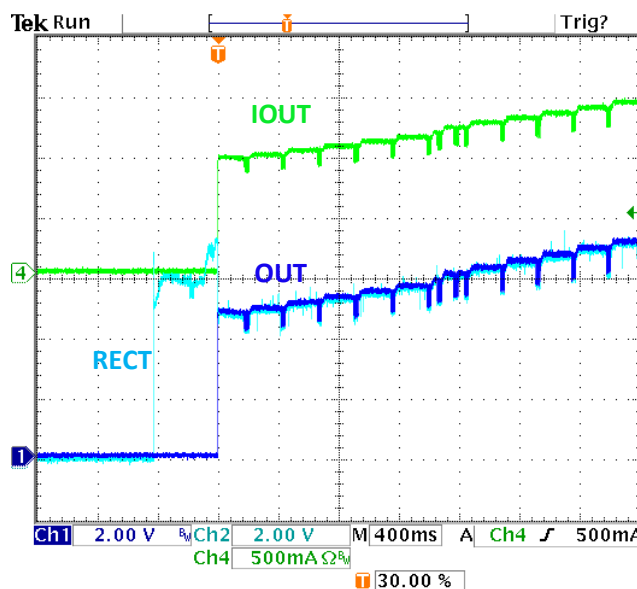


**Figure 7. Start Up With 1400 mA**

## 7.4   Efficiency Data

Figure 8 illustrates the system (DC-DC) efficiency of the bq51025EVM-649 using the bq500212AEVM-550 5-W transmitter and the bq500215EVM-648 10-W tranamitter.
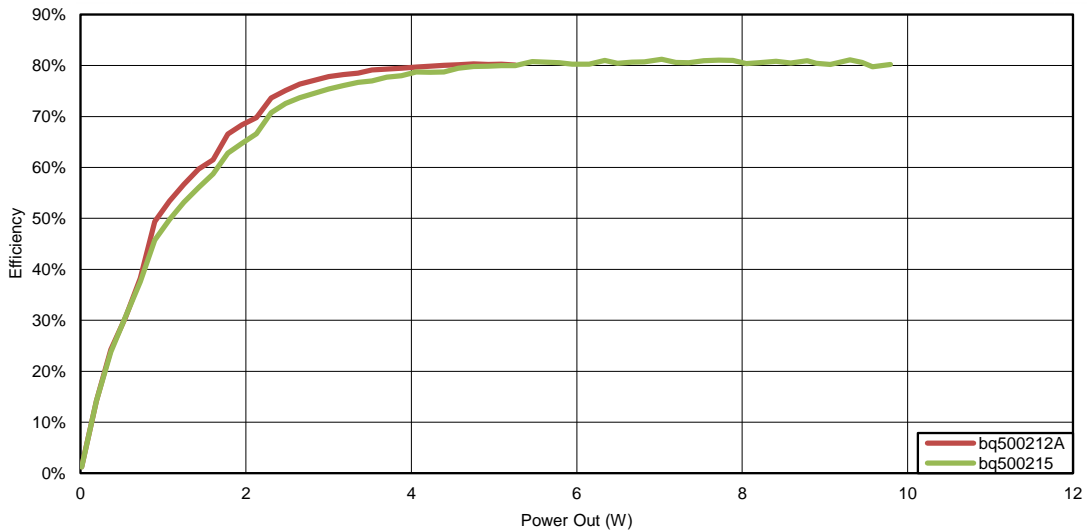


**Figure 8. System Efficiency Versus Output Power**

## 7.5   Adapter Insertion and Removal

Figure 9 illustrates the behavior of the bq51025EVM-649 when an adapter is inserted into J1 (or at TP12) while the EVM is on the transmitter pad with a resistive load at J3 to J4. There is some off time during the transitions between wireless power and wired power modes.

This illustration starts with no adapter. $I_{OUT}$ is approximately 500 mA with OUT at 7 V. At 1.2 seconds of the plot, adapter power is added. The output changes from the 7-V wireless output voltage to the 5-V adapter voltage. With the resistive load, the output current drops proportionately. At about 2.3 seconds the adapter is removed. The restart time for wireless power is about 1 second.
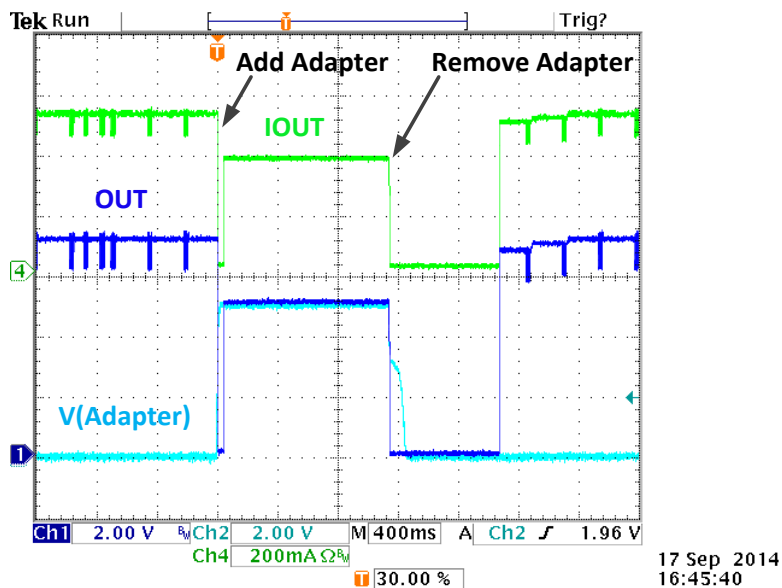


**Figure 9. Adapter Insertion and Removal**

## 7.6 Thermal Performance

This section shows a thermal image of the bq51025EVM-649. A 1.4-A load is used and the output voltage is set to 7 V (approximately 10 W). There is no air flow and the ambient temperature is 25°C. The peak temperature of the device (41.4°C) is well below the maximum recommended operating condition listed in the data sheet.
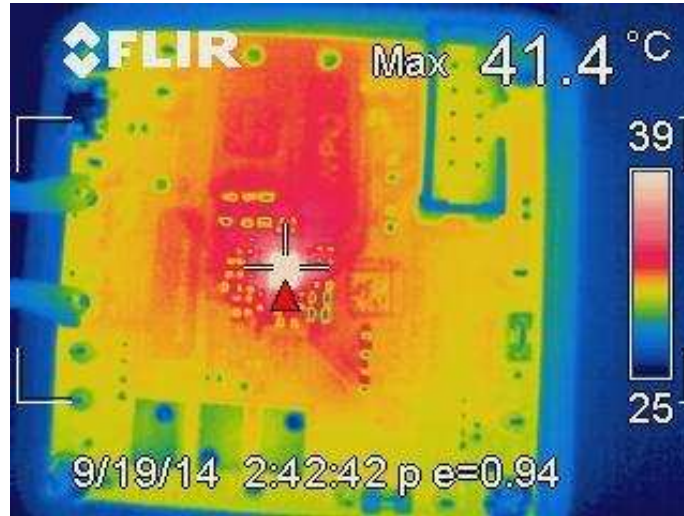


**Figure 10. Thermal Image (1400-mA Load)**

# 8    Layout and Bill of Material

## 8.1    bq51025 Traces

The bq51025 device pins can be classified as follows:

- **Signal/Sensing Traces**
    - TS/CTRL, $\overline{PD\_DET}$, $\overline{WPG}$, COMM1, COMM2, ILIM, AD, $\overline{AD\_EN}$, FOD, TMEM, CM_ILIM, VO_REG, VIREG, PMODE, SCL, and SDA
    - Make sure these traces are isolated from the noisy traces
- **Noisy Traces**
    - AC1, AC2, BOOT1, BOOT2, COMM1, and COMM2
    - Make sure these traces are isolated from other traces, use ground plane
- **Power Traces**
    - AC1, AC2, OUT, CLAMP1, CLAMP2, and PGND
    - Make sure to use the correct width for the right current rating

## 8.2    Layout Guidelines

Use the following layout guidelines:

- The traces from the input connector to the inputs of the bq51025 device pin should be as wide as possible to minimize the impedance in the lines. Otherwise, this may cause the voltage to drop and could cause thermal issues.
- Keep the trace resistance as low as possible on AC1, AC2, OUT, and PGND
- Use the appropriate current rating traces (width) on AC1, AC2, OUT, and PGND
- The PCB should have a ground plane (return) connected directly to the return of all components through vias (At least two vias per capacitor for power-stage capacitors, one via per capacitor for small-signal components).
- Dissipation of heat is very important. The layout must allow for transfer of heat from high power items. Adding internal layers increases the thermal performance. Multiple vias in the PGND pins of the IC is recommended to decrease the thermal resistance in the board and allow much easier thermal dissipation through inner layer and power ground layers.
- The via interconnect is important and must be optimized near the power pad of the device and ground
- 2-oz copper, or greater, is recommended
- For high-current applications, the balls for the power traces should be connected to as much copper in the board as possible. This allows better thermal performance because the board conducts heat away from the device.
- It is always good practice to place high frequency bypass capacitors next to RECT and OUT

## 8.3    Printed-Circuit Board Layout Example

The primary concerns when laying a custom receiver PCB are as follows:

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

For a 1.4-A fast charge current application, the current rating for each net is as follows:

- AC1 = AC2 = 2.2 A
- BOOT1 = BOOT2 = 1 A
- RECT = 200 mA (RMS)
- OUT = 2.5 A
- COMM1 = COMM2 = 600 mA
- CLAMP1 = CLAMP2 = 1000 mA
- ILIM = 10 mA
- AD = $\overline{AD\_EN}$ = TS/CTRL = FOD = 1 mA

TI also recommends having the following capacitance on RECT and OUT:

- RECT ≥ 22 µF
- OUT ≥ 1 µF

It is always good practice to place high-frequency bypass capacitors next to RECT and OUT of 0.1 µF. Figure 11 illustrates an example of a WCSP layout.
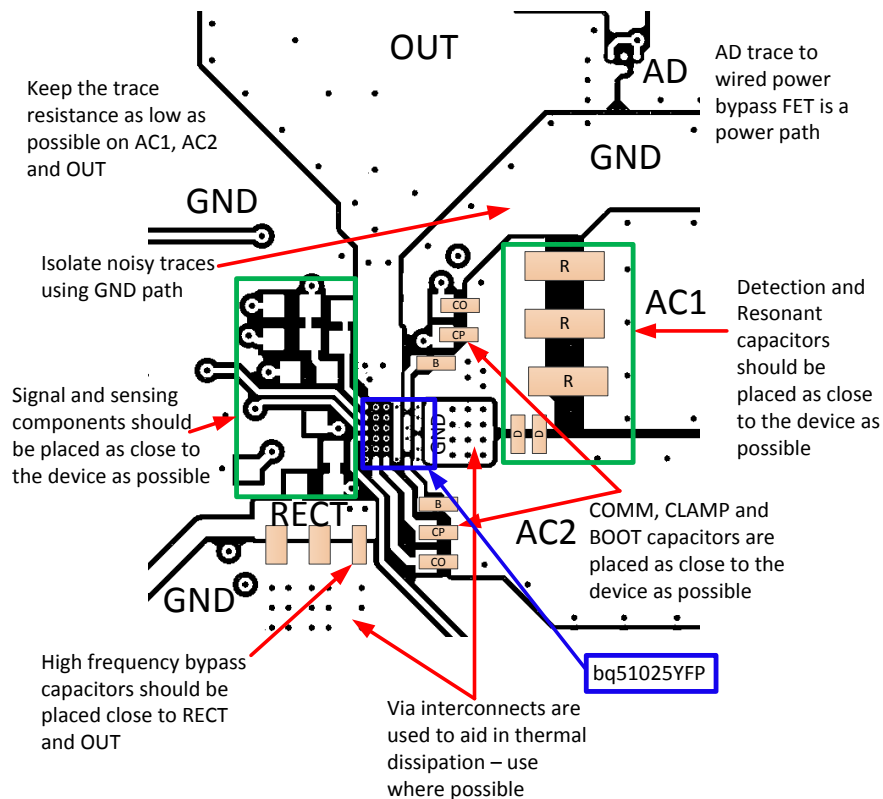


**Figure 11. bq51025EVM-649 Layout Example**

### 8.4   *bq51025EVM-649 Layout*

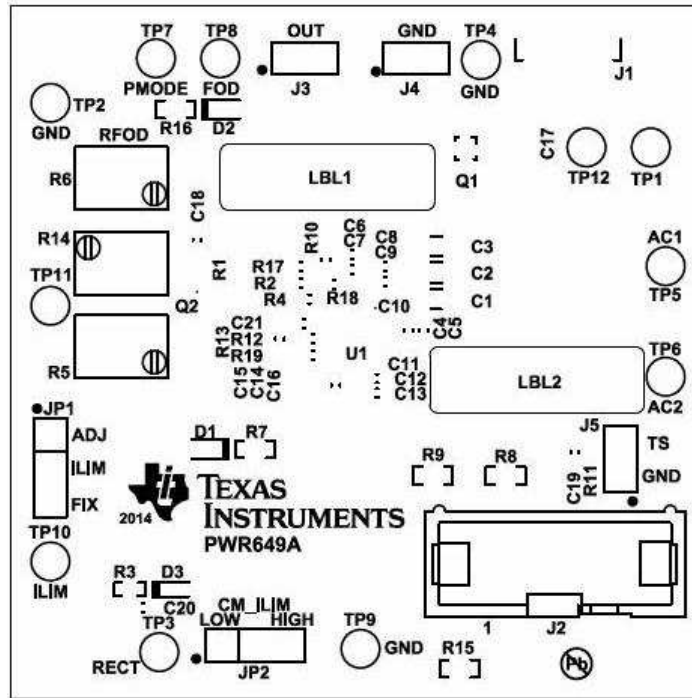Figure 12 through Figure 16 show the bq51025EVM-649 PCB layout.
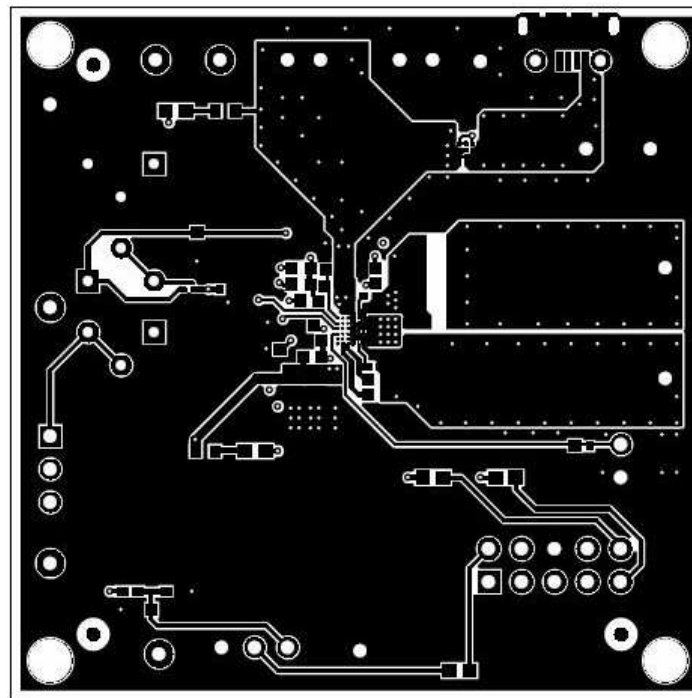


**Figure 12. bq51025EVM-649 Top Assembly**


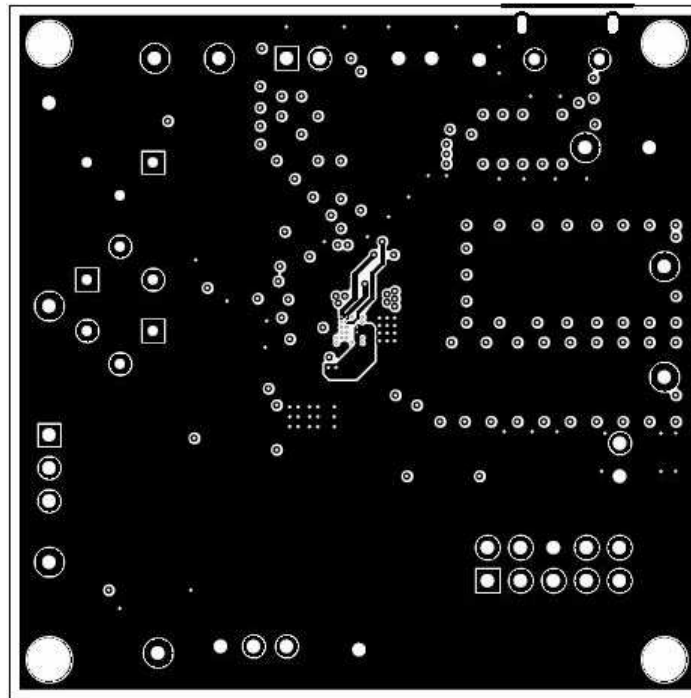
**Figure 13. bq51025EVM-649 Layer 1**
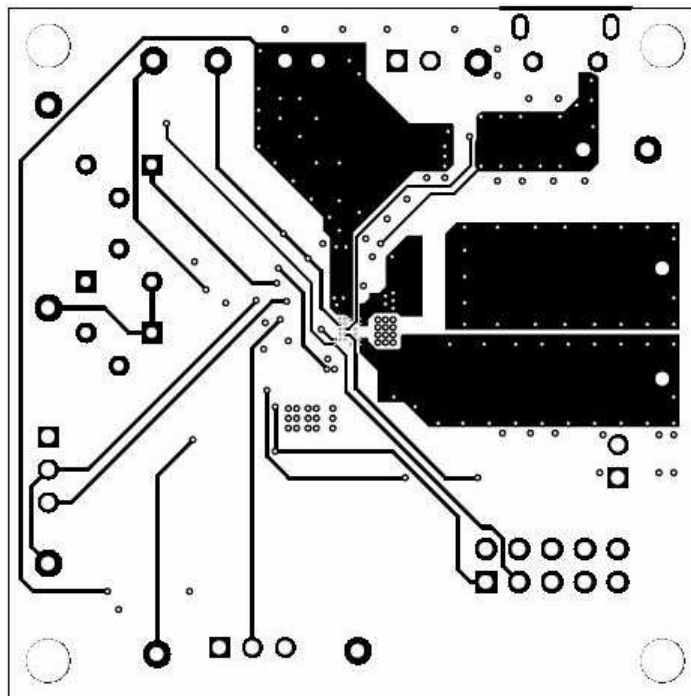
**Figure 14. bq51025EVM-649 Layer 2**
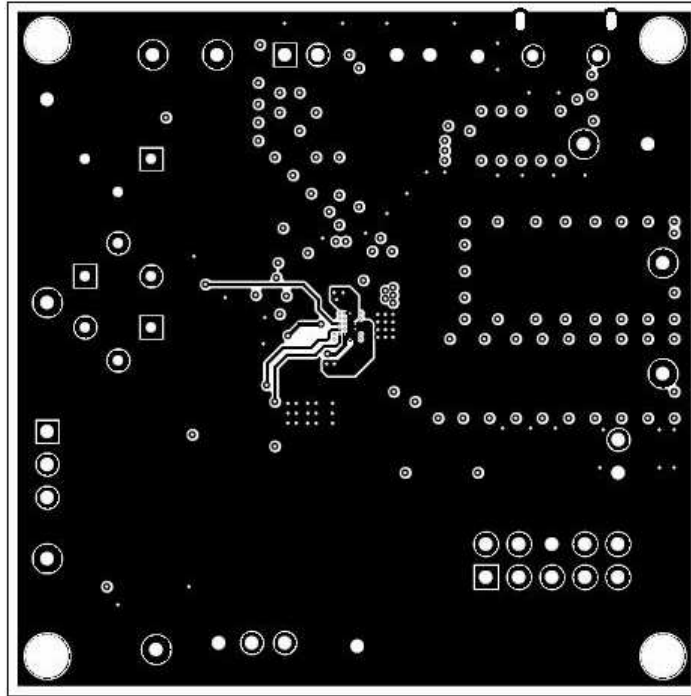


**Figure 15. bq51025EVM-649 Layer 3**

**Figure 16. bq51025EVM-649 Layer 4**

## 8.5 *Bill of Materials (BOM)*

Table 3 lists the BOM for the EVM.

**Table 3. bq51025EVM-649 Bill of Materials**

| Designator | Quantity | Value | Description | PackageReference | PartNumber | Manufacturer |
|---|---|---|---|---|---|---|
| !PCB | 1 | | Printed Circuit Board | | PWR649 | Any |
| C1 | 1 | 0.047uF | CAP, CERM, 0.047uF, 50V, +/-5%, C0G/NP0, 1206 | 1206 | GRM31M5C1H473JA01L | MuRata |
| C3 | 1 | 0.082uF | CAP, CERM, 0.082uF, 50V, +/-5%, C0G/NP0, 1206 | 1206 | GRM31C5C1H823JA01L | MuRata |
| C4 | 1 | 1500pF | CAP, CERM, 1500pF, 50V, +/-10%, X7R, 0603 | 0603 | GRM188R71H152KA01D | MuRata |
| C5 | 1 | 100pF | CAP, CERM, 100pF, 50V, +/-5%, C0G/NP0, 0603 | 0603 | GRM1885C1H101JA01D | MuRata |
| C6, C16, C18, C19 | 4 | 0.1uF | CAP, CERM, 0.1uF, 50V, +/-10%, X7R, 0603 | 0603 | GCM188R71H104KA57B | MuRata |
| C7 | 1 | 3.3uF | CAP, CERM, 3.3uF, 25V, +/-10%, X5R, 0603 | 0603 | C1608X5R1E335K080AC | TDK |
| C8, C13 | 2 | 0.056uF | CAP, CERM, 0.056uF, 25V, +/-10%, X7R, 0603 | 0603 | GRM188R71E563KA01D | MuRata |
| C9, C12 | 2 | 0.47uF | CAP, CERM, 0.47uF, 25V, +/-10%, X5R, 0603 | 0603 | GRM188R61E474KA12D | MuRata |
| C10, C11 | 2 | 0.015uF | CAP, CERM, 0.015uF, 50V, +/-10%, X7R, 0402 | 0402 | GRM155R71H153KA12D | MuRata |
| C14, C15 | 2 | 22uF | CAP, CERM, 22uF, 25V, +/-20%, X5R, 0805 | 0805 | GRM21BR61E226ME44 | MuRata |
| C17 | 1 | 1uF | CAP, CERM, 1uF, 50V, +/-10%, X7R, 0805 | 0805 | GRM21BR71H105KA12L | MuRata |
| C20 | 1 | 1uF | CAP, CERM, 1uF, 25V, +/-10%, X7R, 0603 | 0603 | GRM188R71E105KA12D | MuRata |
| C21 | 1 | 2.2uF | CAP, CERM, 2.2uF, 16V, +/-10%, X5R, 0603 | 0603 | GRM188R61C225KE15D | MuRata |
| D1 | 1 | Green | LED, Green, SMD | 1.6x0.8x0.8mm | LTST-C190GKT | Lite-On |
| D2 | 1 | Orange | LED, Orange, SMD | 1.6x0.8x0.8mm | LTST-C190KFKT | Lite-On |
| D3 | 1 | 5.1V | Diode, Zener, 5.1V, 300mW, SOD-523 | SOD-523 | BZT52C5V1T-7 | Diodes Inc. |
| H1 | 1 | | Tape segment, Low Static Polyimide Film. Cut tape section from 36 yard roll | 1.5" x 2.3" | 5419-1 1/2" | 3M |
| H2 | 1 | | Case Modified Polycase LP-11B with 4 screws | | J-6838A | Polycase |
| H3 | 1 | | Coil, RX with Attractor | | IWAS4832FEEB150J50 | Vishay |
| H4, H5, H6, H7 | 4 | | #4 x 3/8" pan head phillips screw | #4 x 3/8" | PMSSS 440 0038 PH | B&F Fastener |
| H8, H9, H10, H11 | 4 | | Spacer, 0.100" Thk x 0.25" OD x 0.147" ID | 0.1" THK | 905-100 | Bivar |
| J1 | 1 | | Receptacle, Micro-USB-B, Right Angle, SMD | Micro USB receptacle | 105017-0001 | Molex |
| J2 | 1 | | Connector, 100mil Shrouded, High-Temperature, Gold, TH | 5x2 Shrouded header | N2510-6002-RB | 3M |
| J3, J4, J5 | 3 | | Header, 100mil, 2x1, Tin plated, TH | Header, 2 PIN, 100mil, Tin | PEC02SAAN | Sullins Connector Solutions |
| JP1, JP2 | 2 | | Header, 100mil, 3x1, Tin plated, TH | Header, 3 PIN, 100mil, Tin | PEC03SAAN | Sullins Connector Solutions |
| LBL1, LBL2 | 2 | | Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll | PCB Label 0.650"H x 0.200"W | THT-14-423-10 | Brady |
| Q1 | 1 | -20V | MOSFET, P-CH, -20V, -3.9A, 1.5mm sq WCSP | 1.5mm sq WCSP | CSD75207W15 | Texas Instruments |
| Q2 | 1 | 12V | MOSFET, N-CH, 12V, 1.6A, 1x0.62x1mm | 1x0.62x1mm | CSD13201W10 | Texas Instruments |
| R1 | 1 | 976k | RES, 976k ohm, 1%, 0.063W, 0402 | 0402 | CRCW0402976KFKED | Vishay-Dale |
| R2 | 1 | 150 | RES, 150 ohm, 1%, 0.1W, 0603 | 0603 | CRCW0603150RFKEA | Vishay-Dale |

**Table 3. bq51025EVM-649 Bill of Materials  (continued)**

| Designator | Quantity | Value | Description | PackageReference | PartNumber | Manufacturer |
|---|---|---|---|---|---|---|
| R3 | 1 | 102k | RES, 102k ohm, 1%, 0.063W, 0402 | 0402 | CRCW0402102KFKED | Vishay-Dale |
| R4 | 1 | 237 | RES, 237 ohm, 1%, 0.1W, 0603 | 0603 | CRCW0603237RFKEA | Vishay-Dale |
| R5, R6, R14 | 3 | 500 Ohm | Trimmer, 500 ohm, 0.25W, TH | 4.5x8x6.7mm | 3266W-1-501LF | Bourns |
| R7 | 1 | 1.50k | RES, 1.50k ohm, 1%, 0.1W, 0603 | 0603 | CRCW06031K50FKEA | Vishay-Dale |
| R8, R9 | 2 | 200 | RES, 200, 1%, 0.1 W, 0603 | 0603 | CRCW0603200RFKEA | Vishay-Dale |
| R10, R12 | 2 | 10.0k | RES, 10.0k ohm, 1%, 0.1W, 0603 | 0603 | CRCW060310K0FKEA | Vishay-Dale |
| R11 | 1 | 10.0k | RES, 10.0k ohm, 1%, 0.063W, 0402 | 0402 | CRCW040210K0FKED | Vishay-Dale |
| R13 | 1 | 5.62Meg | RES, 5.62Meg ohm, 1%, 0.1W, 0603 | 0603 | CRCW06035M62FKEA | Vishay-Dale |
| R16 | 1 | 20.0k | RES, 20.0k ohm, 1%, 0.1W, 0603 | 0603 | CRCW060320K0FKEA | Vishay-Dale |
| R17 | 1 | 150k | RES, 150k ohm, 1%, 0.1W, 0603 | 0603 | CRCW0603150KFKEA | Vishay-Dale |
| R18, R19 | 2 | 130k | RES, 130k ohm, 1%, 0.1W, 0603 | 0603 | CRCW0603130KFKEA | Vishay-Dale |
| SH-JP1, SH-JP2 | 2 | 1x2 | Shunt, 100mil, Gold plated, Black | Shunt | 969102-0000-DA | 3M |
| TP1, TP2, TP4, TP9 | 4 | Black | Test Point, Miniature, Black, TH | Black Miniature Testpoint | 5001 | Keystone |
| TP3, TP7, TP8, TP10, TP11, TP12 | 6 | White | Test Point, TH, Miniature, White | Keystone5002 | 5002 | Keystone |
| U1 | 1 |  | 10-W Qi INTEGRATED WIRELESS RECEIVER POWER SUPPLY, YFP0042AWCG | YFP0042AWCG | bq51025YFP | Texas Instruments |
| C2 | 0 | 0.068uF | CAP, CERM, 0.068uF, 50V, +/-5%, C0G/NP0, 1206 | 1206 | GRM31C5C1H683JA01L | MuRata |
| FID1, FID2, FID3 | 0 |  | Fiducial mark. There is nothing to buy or mount. | Fiducial | N/A | N/A |
| R15 | 0 | 0 | RES, 0 ohm, 5%, 0.1W, 0603 | 0603 | CRCW06030000Z0EA | Vishay-Dale |
| TP5, TP6 | 0 | Black | Test Point, Miniature, Black, TH | Black Miniature Testpoint | 5001 | Keystone |

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3 *Regulatory Notices:*

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

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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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4.2 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:*

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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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