

## WIRELESS CHARGING

## Features

- 40V maximum input voltage
- Single-cell Li-Ion or Li-Polymer charger with programmable charging current and toff voltage
- System rail available with deeply discharged battery
- Integrated switches for narrow VDC power path management
- Supports Qi, AirFuel Inductive and Resonant (PMA, A4WP) and proprietary charging standards
- Up to 2W combined system/battery power
- Better than 87% AC-DC efficiency to the system
- Better than 83% AC-DC efficiency to the battery
- Integrated switches for load modulation
- Integrated frequency detection to support bidirectional communication
- TX to RX CPU alert or reset signal
- Integrated minimum load current sink
- Thermal shutdown at 130°C junction temperature and over-current protection
- Low external component count
- Junction operating temperature -40°C to 125°C
- Product is lead-free, halogen-free, RoHS / WEEE compliant

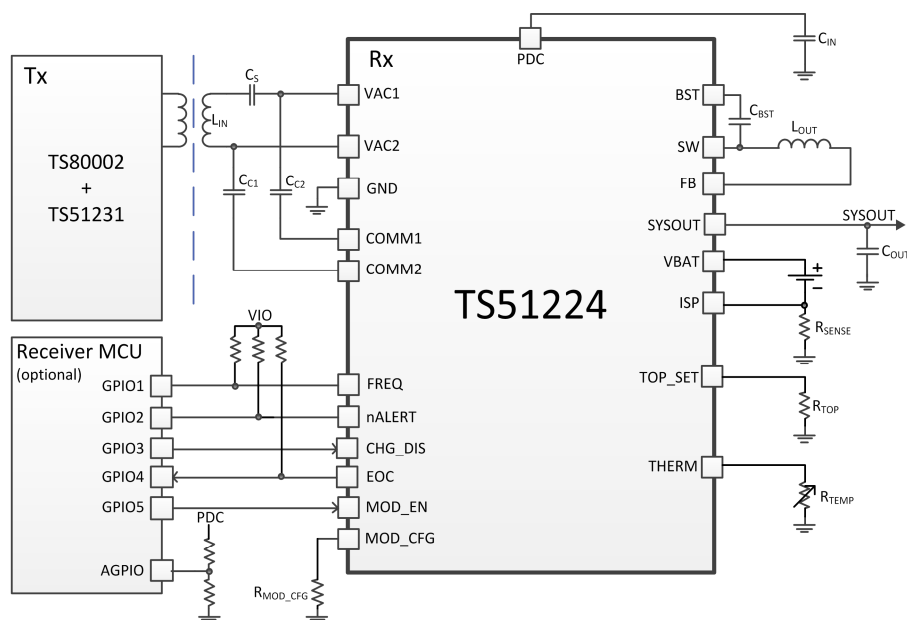
## Description

TS51224 is a fully-integrated wireless power receiver and battery charger for low-power, wearable applications that require a low-cost and space-saving solution. The TS51224 can operate by itself as a single-chip wireless power receiver in proprietary applications. It can also operate in conjunction with a wireless power controller or an application microcontroller to support the Qi, PMA or A4WP wireless charging standards as well as proprietary standards up to 2W combined system/battery power.

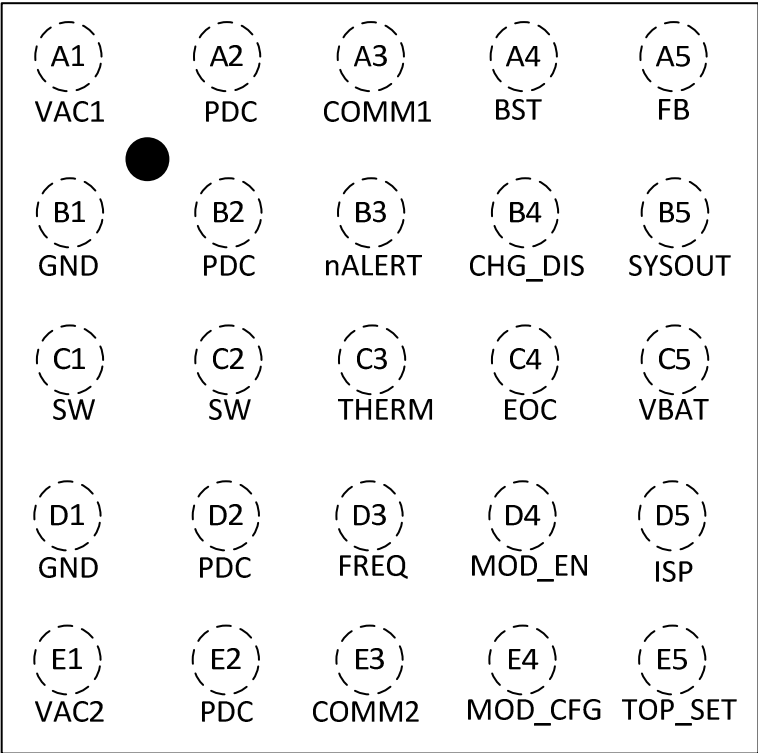
## Applications

- Wearables
  - Watches
  - Bracelets
  - Fitness Bands
  - Smart Jewelry
  - Smart Glasses
- Health Monitors
- Electric Toothbrushes
- Tablets
- Wireless Keyboard and Mouse
- Medical Applications
- Wireless Headsets
- ID Tags
- Augmented Reality

## Typical Application Circuit



# Ball Configuration

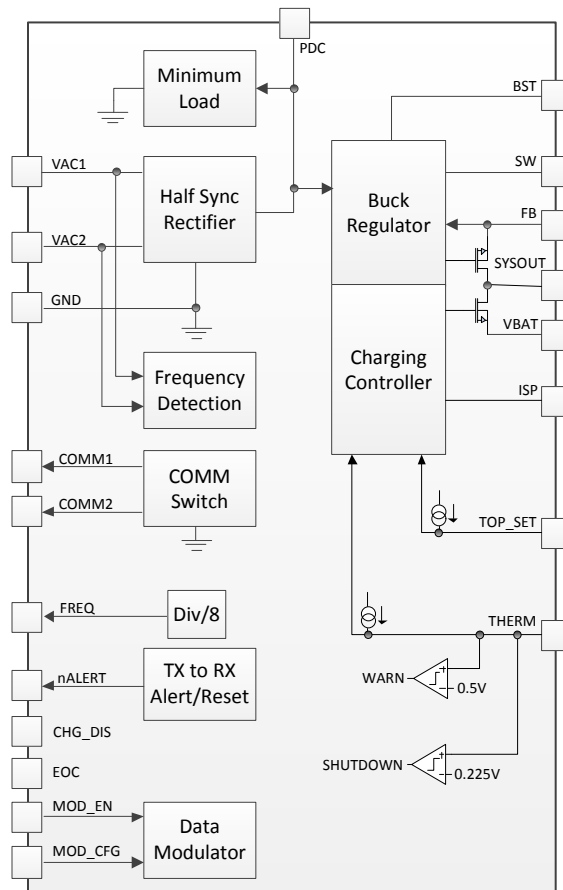


**Figure 1: TS51224 Ball Configuration**  
(Top view with ball 1 designator)

## Ball Description

| Ball Number    | Ball Name | Function                          | Description  |
|----------------|-----------|-----------------------------------|--|
| A4             | BST       | Bootstrap capacitor               | Bootstrap capacitor for buck regulator high-side driver, capacitor between BST pin and SW pin  |
| B4             | CHG_DIS   | Charge disable                    | Disables battery charging when pulled high   |
| A3             | COMM1     | Load modulation switch            | Pull-down for VAC1 modulation capacitor  |
| E3             | COMM2     | Load modulation switch            | Pull-down for VAC2 modulation capacitor  |
| C4             | EOC       | End-of-Charge indicator           | Toggles low when the charger gets to the end-of-charge state   |
| A5             | FB        | Feedback input                    | BUCK feedback input and blocking FET input   |
| D3             | FREQ      | Frequency detector output         | Open drain output signal, divided-by-8 version of the frequency of the input AC power signal   |
| B1, D1         | GND       | Power ground                      | Ground   |
| D5             | ISP       | Current Sense                     | Negative battery terminal connection and current sensing node  |
| E4             | MOD_CFG   | Modulation configuration          | Configures the internal modulator to start up in standalone mode or in bypass mode. Also configures the PDC voltage in standalone mode.  |
| D4             | MOD_EN    | MCU modulation input              | Active high input to the modulator selection logic, with internal 100kΩ pull-down. If repeated transitions are detected on this pin, the integrated modulator is bypassed and MOD_EN controls the COMM switches. |
| B3             | nALERT    | MCU interrupt output/reset signal | Active low open drain output activated when TX sends an ALERT command  |
| A2, B2, D2, E2 | PDC       | Input power                       | Rectified input voltage  |
| C1, C2         | SW        | Switching node                    | BUCK regulator switching node  |
| B5             | SYSOUT    | System output power               | System output power connection   |
| C3             | THERM     | Thermistor connection             | Thermistor connection used for system temperature monitoring   |
| E5             | TOP_SET   | Topoff voltage configuration      | Configures the topoff voltage of the charger   |
| A1             | VAC1      | Coil input                        | AC power input from the resonator coil   |
| E1             | VAC2      | Coil input                        | AC power input from the resonator coil   |
| C5             | VBAT      | Battery node                      | Positive battery terminal connection   |

## Functional Block Diagram



**Figure 2: TS51224 Block Diagram**

## Absolute Maximum Ratings

Over operating free-air temperature range unless otherwise noted <sup>(1, 2)</sup>

| Parameter   | Value          | Unit |
|---|----------------|------|
| COMM1, COMM2, PDC, VAC1, VAC2   | -0.3 to 42     | V    |
| BST   | -0.3 to (SW+6) | V    |
| SW  | -1 to 42       | V    |
| CHG_DIS, EOC, FB, FREQ, nALERT, MOD_EN, MOD_CFG, SYSOUT, THERM, TOP_SET, VBAT | -0.3 to 6      | V    |
| ISP   | -0.7 to 0.7    | V    |
| Electrostatic Discharge—Human Body Model                                      | ±2             | kV   |
| Electrostatic Discharge—Machine Model   | ±500           | V    |
| Peak IR Reflow Temperature (10 to 30 seconds)                                 | 260            | °C   |

### Notes:

- (1) Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values are with respect to network ground terminal GND.

## Recommended Operating Conditions

| Parameter                              | Symbol                            | Conditions  | Min  | Typ  | Max  | Unit |
|--|-----------------------------------|---|------|------|------|------|
| PDC Capacitance <sup>(1)</sup>         | C <sub>IN</sub>                   |   | 2.2  | 10   |      | μF   |
| BUCK Output Capacitance <sup>(1)</sup> | C <sub>OUT</sub>                  | F <sub>SW</sub> =1.3MHz, I <sub>OUT_MAX</sub> = 50mA  | 8.8  | 44   |      | μF   |
| BUCK Output Capacitance <sup>(1)</sup> | C <sub>OUT</sub>                  | F <sub>SW</sub> =1.3MHz, I <sub>OUT_MAX</sub> = 400mA | 20   | 44   |      | μF   |
| BUCK Bootstrap Capacitor               | C <sub>BST</sub>                  |   | 17.6 | 47   |      | nF   |
| Output Filter Inductor                 | L <sub>OUT</sub>                  | F <sub>SW</sub> =1.3MHz, I <sub>OUT_MAX</sub> = 50mA  | 1.5  | 3.3  |      | μH   |
| Output Filter Inductor                 | L <sub>OUT</sub>                  | F <sub>SW</sub> =1.3MHz, I <sub>OUT_MAX</sub> = 400mA | 1.5  | 4.7  |      | μH   |
| RX Coil                                | L <sub>IN</sub>                   | F <sub>BR</sub> = 1MHz                                |      | 11   |      | μH   |
| RX Series Resonant Capacitor           | C <sub>s</sub>                    | F <sub>BR</sub> = 1MHz                                |      | 10   |      | nF   |
| COMM Modulation Capacitors             | C <sub>C1</sub> , C <sub>C2</sub> | F <sub>BR</sub> = 1MHz                                |      | 1    |      | nF   |
| Rectified Voltage                      | V <sub>PDC</sub>                  |   | 3.5  | 12   | 40   | V    |
| Bridge Current                         | I <sub>BR</sub>                   |   |      | 50   | 300  | mA   |
| Rectification Frequency                | F <sub>BR</sub>                   |   | 100  | 1000 | 6780 | kHz  |
| COMM Current                           | I <sub>COMM</sub>                 |   |      |      | 50   | mA   |
| Charger Output Current                 | I <sub>RANGE</sub>                |   |      |      | 500  | mA   |
| Topoff Voltage Range                   | V <sub>TOP_RANGE</sub>            | Valid set point range                                 | 4.1  |      | 4.4  | V    |
| TOP_SET Pin Range                      | V <sub>TOP_SET_RANGE</sub>        | Valid TOP_SET pin voltage range                       | 0    |      | 3    | V    |
| Buck Regulator Output Current          | I <sub>OUT_MAX</sub>              |   |      |      | 500  | mA   |
| High Level Input Voltage               | V <sub>IH</sub>                   | CHG_DIS, MOD_EN                                       | 1.3  |      | 5.5  | V    |
| Low Level Input Voltage                | V <sub>IL</sub>                   | CHG_DIS, MOD_EN                                       | 0    |      | 0.54 | V    |

### Notes:

- (1) Specified capacitance includes allowance for voltage derating, tolerance, temperature, and aging. Select capacitors that meet the specified minimum capacitance.

## Electrical Characteristics

Electrical Characteristics,  $T_J = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , unless otherwise noted

| Parameter  | Symbol                       | Conditions   | Min | Typ  | Max | Unit       |
|--|------------------------------|--|-----|------|-----|------------|
| <b>Synchronous Rectifier</b>                         |                              |  |     |      |     |            |
| Low-Side Bridge FET Drain-Source On-State Resistance | $R_{\text{DS(on)BR}}$        |  |     | 400  |     | m $\Omega$ |
| High-Side Bridge Diode Forward Voltage               | $V_{\text{D, BR}}$           | $I_{\text{BR}} = 150\text{mA}$   |     | 500  |     | mV         |
| <b>Capacitive Modulation Switches</b>                |                              |  |     |      |     |            |
| COMM FET Drain-Source On-State Resistance            | $R_{\text{DS(on)COMM}}$      | $I_{\text{COMM}} = 50\text{mA}$  |     | 10   |     | $\Omega$   |
| <b>Power On Reset</b>                                |                              |  |     |      |     |            |
| Power On Reset Voltage                               | $V_{\text{PDC-POR}}$         | Internal logic reset clear, internal logic/modulator ready   | 2.7 | 3.0  | 3.4 | V          |
| Power On Reset Hysteresis                            | $V_{\text{PDC-POR-HYST}}$    | (1)  |     | 0.35 |     | V          |
| <b>Quiescent Current</b>                             |                              |  |     |      |     |            |
| Quiescent Current, PWM mode                          | $I_{\text{ddPWM}}$           | PDC current, Buck Regulator PWM mode, $V_{\text{PDC}}=12\text{V}$ , $\text{VAC1}=\text{VAC2}=0\text{V}$ , $I_{\text{LOAD}}=0\text{A}$ , $\text{MOD\_EN}=0$ , external feedback resistors, $R_{\text{TOTAL}}=1\text{M}\Omega$ |     | 15   |     | mA         |
| Quiescent Current, PFM mode                          | $I_{\text{ddPFM}}$           | PDC current, Buck Regulator PFM mode, $V_{\text{PDC}}=12\text{V}$ , $\text{VAC1}=\text{VAC2}=0\text{V}$ , $I_{\text{LOAD}}=0\text{A}$ , $\text{MOD\_EN}=0$ , external feedback resistors, $R_{\text{TOTAL}}=1\text{M}\Omega$ |     | 4    |     | mA         |
| Quiescent Current, Buck Off, 10mA Current Source Off | $I_{\text{ddBK\_10mA\_OFF}}$ | PDC current, Buck Regulator OFF, $V_{\text{PDC}}=4.5\text{V}$ , $\text{VAC1}=\text{VAC2}=0\text{V}$ , $\text{MOD\_EN}=0$ , 10mA current source off, external feedback resistors, $R_{\text{TOTAL}}=1\text{M}\Omega$          |     | 3    |     | mA         |
| Quiescent Current, Buck Off, 10mA Current Source On  | $I_{\text{ddBK\_OFF}}$       | PDC current, Buck Regulator OFF, $V_{\text{PDC}}=4.5\text{V}$ , $\text{VAC1}=\text{VAC2}=0\text{V}$ , $\text{MOD\_EN}=0$ , 10mA current source on, external feedback resistors, $R_{\text{TOTAL}}=1\text{M}\Omega$           |     | 13   |     | mA         |

## Electrical Characteristics

| Parameter                     | Symbol             | Conditions                                | Min   | Typ   | Max   | Unit |
|-------------------------------|--------------------|---|-------|-------|-------|------|
| <b>Charger</b>                |                    |   |       |       |       |      |
| ISP Voltage                   | $V_{ISP\_1C}$      | 1C mode                                   | 20    | 25    | 30    | mV   |
|                               | $V_{ISP\_0p5C}$    | 0.5C mode                                 | 10    | 12.5  | 15    | mV   |
|                               | $V_{ISP\_0p1C}$    | Precharge (0.1C) mode                     | 1.5   | 2.5   | 3.5   | mV   |
| 1C Charge Voltage Threshold   | $V_{1C\_Charge}$   | VBAT rising                               | 3.05  | 3.15  | 3.25  | V    |
| Charger Dropout               | $V_{Drop\_CHG}$    | SYSOUT-VBAT in 1C charging mode, PWM mode |       | 100   |       | mV   |
| On Resistance                 | $R_{ON,CHG}$       | (1)                                       |       |       | 100   | mΩ   |
| <b>Temperature Sense</b>      |                    |   |       |       |       |      |
| THERM Output Current          | $I_{THERM}$        |   | 18    | 20    | 22    | μA   |
| WARN Voltage                  | $V_{WARN,FALLING}$ | $V_{THERM}$ falling                       | 0.485 | 0.505 | 0.525 | V    |
|                               | $V_{WARN,RISING}$  | $V_{THERM}$ rising                        | 0.776 | 0.805 | 0.834 | V    |
| SHUTDOWN Voltage              | $V_{STOP,FALLING}$ | $V_{THERM}$ falling                       | 0.22  | 0.235 | 0.25  | V    |
|                               | $V_{STOP,RISING}$  | $V_{THERM}$ rising                        | 0.32  | 0.335 | 0.35  | V    |
| <b>Blocking Switch</b>        |                    |   |       |       |       |      |
| On Resistance                 | $R_{ON,BLK}$       | (1)                                       |       | 50    | 100   | mΩ   |
| Off State Leakage             | $I_{OFF}$          |   |       |       | 1     | μA   |
| <b>Topoff</b>                 |                    |   |       |       |       |      |
| TOP_SET Pin Set Point Current | $I_{TOP}$          | $T_J = 25^{\circ}C$                       | 17    | 20    | 23    | μA   |
| Topoff Voltage Offset         | $V_{TOP\_OFFSET}$  | $R_{TOP\_SET} = 0\Omega$                  | 4.08  | 4.1   | 4.12  | V    |

## Electrical Characteristics

| Parameter                                  | Symbol              | Conditions             | Min | Typ  | Max | Unit        |
|--|---------------------|------------------------|-----|------|-----|-------------|
| <b>Buck Regulator Input</b>                |                     |                        |     |      |     |             |
| PDC Under-voltage Lockout                  | $V_{PDC-UVLO}$      | Buck Regulator = Off   |     | 4.3  |     | V           |
| PDC Under-voltage Lockout Hysteresis       | $V_{PDC-UVLO-HYST}$ | Buck Regulator = Off   |     | 180  |     | mV          |
| <b>CHG_DIS, MOD_EN Digital Inputs</b>      |                     |                        |     |      |     |             |
| Pull-Down Resistance                       | $R_{PD}$            |                        | 68  | 100  | 144 | k $\Omega$  |
| <b>EOC, FREQ, nALERT Open Drain Output</b> |                     |                        |     |      |     |             |
| EOC High Level Output Leakage              | $I_{OH\_LEAK\_EOC}$ | VIO = 5V               |     | 5    |     | $\mu$ A     |
| FREQ, nALERT High Level Output Leakage     | $I_{OH\_LEAK}$      | VIO = 5V               |     | 0.01 | 1   | $\mu$ A     |
| Low Level Output Voltage                   | $V_{OD\_OL}$        | $I_{SINK} = 3mA^{(2)}$ |     |      | 0.4 | V           |
| <b>Thermal Protection Thresholds</b>       |                     |                        |     |      |     |             |
| Thermal Shutdown Junction Temperature      | $T_{SD}$            | <sup>(1)</sup>         |     | 130  | 146 | $^{\circ}C$ |
| Thermal Shutdown Hysteresis                | $T_{SD\_HYST}$      | <sup>(1)</sup>         |     | 10   |     | $^{\circ}C$ |

Notes:

- (1) This parameter is not tested in production.
- (2) nALERT only tested as pass / fail.

## Regulator Characteristics

Electrical Characteristics,  $T_J = -40^{\circ}C$  to  $85^{\circ}C$ ,  $V_{PDC}=12V$ ,  $F_{SW}=1.3MHz$ ,  $L_{OUT}=4.7\mu H$ ,  $C_{OUT}=44\mu F$ ,  $C_{BST}=22nF$ , unless otherwise noted

| Parameter                      | Symbol           | Conditions                  | Min  | Typ  | Max  | Unit       |
|--------------------------------|------------------|-----------------------------|------|------|------|------------|
| SYSOUT Precharge Voltage       | $V_{OUT-PWM}$    | $V_{BAT} < 3.1V$ , PWM mode | 3.2  | 3.3  | 3.5  | V          |
| High-Side Switch ON Resistance | $R_{DS(on)\_HS}$ | $I_{SW} = -0.15A^{(1)}$     |      | 450  |      | m $\Omega$ |
| Low-Side Switch ON Resistance  | $R_{DS(on)\_LS}$ | $I_{SW} = 0.15A^{(1)}$      |      | 300  |      | m $\Omega$ |
| Output Over Current Detect     | $I_{OCD}$        |                             |      | 1320 |      | mA         |
| Buck Switching Frequency       | $F_{SW}$         |                             | 1.17 | 1.33 | 1.46 | MHz        |
| Soft Start Ramp Time           | $T_{SS}$         | <sup>(2)</sup>              |      | 2.5  |      | ms         |

Notes:

- (1)  $R_{DS(on)}$  is characterized at 500mA and tested at lower current in production.
- (2) This parameter is not tested in production.



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## Functional Description

TS51224 is a fully-integrated wireless power receiver that can operate as a single-chip solution in proprietary applications. It can also operate in conjunction with a wireless charger controller or an application microcontroller to support the Qi, PMA or A4WP standards as well as proprietary standards up to 2W for 5V output and up to 5W for higher output voltages. Operating in conjunction with TS80002 as a wireless power transmitter and with a charging controller on the RX side, TS51224 can support bidirectional communication for data upload from the RX to the TX side. A TX to RX alert or reset function is also included so TS80002 can issue an interrupt or a reset signal to the RX MCU if the RX MCU becomes unresponsive.

### Rectifier

TS51224 includes a high-efficiency rectifier to convert the input AC power signal to a DC output level for powering a high-efficiency step-down DC-DC converter and an integrated data modulator. The rectifier bridge is built to minimize power dissipation across load current of interest. The primary side of the bridge can stand-off up to 40V with AC input running at 6.78MHz. On the secondary side, a capacitive load on the PDC pin is used to filter the voltage signal on both sides of the bridge rectifier. The integrated data modulator and the external MCU communicate to the transmitter side using the capacitive modulation scheme.

### Integrated Modulator

The integrated Data Modulator can be configured to operate in standalone or bypass mode. In standalone mode, the integrated modulator sends data messages to the TX side using a proprietary protocol to control the rectified voltage level on the PDC pin. In bypass mode, the external MCU controls the data packets to the TX side. For example, if the device is configured for standalone mode at power up, the system can receive power without external MCU support, and once PDC is high enough to operate the buck regulator and the MCU, the MCU can take over the communication with the transmitter by bypassing the integrated modulator. Modulator mode reverts back to the standalone mode when the MCU communication with the transmitter stalls. When the PDC output load current is low (buck regulator is off), an internal 10mA load is enabled to allow data communication to take place in optimal conditions.

### 40V Input Buck Regulator

The integrated Buck regulator is a current-mode synchronous step-down power supply with integrated power switches, internal compensation, and fault protection. It is powered by the DC output of the Wireless power receiver bridge. The regulator is designed to handle a wide range of input and output voltages. The regulator is optimized for high efficiency power conversion with low  $R_{DS(on)}$  integrated synchronous switches. Low power at light output loads is attained by the regulator automatic transitions between PFM and PWM modes. The regulator will automatically turn off when the RX AC power input is removed.

### Blocking FET

An integrated low impedance FET in the TS51224 provides blocking from SYSOUT to FB. In cases where AC power is not applied, the battery is directly connected to SYSOUT. In this condition, the blocking FET is off, preventing conduction from SYSOUT to PDC. If AC power is applied and PDC is greater than the battery voltage, then the blocking FET will be on and the SMPS will regulate the SYSOUT voltage.

### Charger

TS51224 includes a linear regulator to manage battery charging current. The charger operates by sensing the voltage drop across a sense resistor and regulating this to a DC value. Battery charging is controlled by the integrated state machine. When charging at a 1C rate, the SMPS will regulate SYSOUT to be sufficiently higher than VBAT to allow full charging currents. When the battery is very low (<3.3V), the SMPS will regulate SYSOUT to be equal to 3.3V and the charger will regulate the battery current to the 0.1C rate.

# Device Power Up Timing

BYPASS Mode Power Up MOD\_CFG=GND  
PDC Under Voltage Power Down

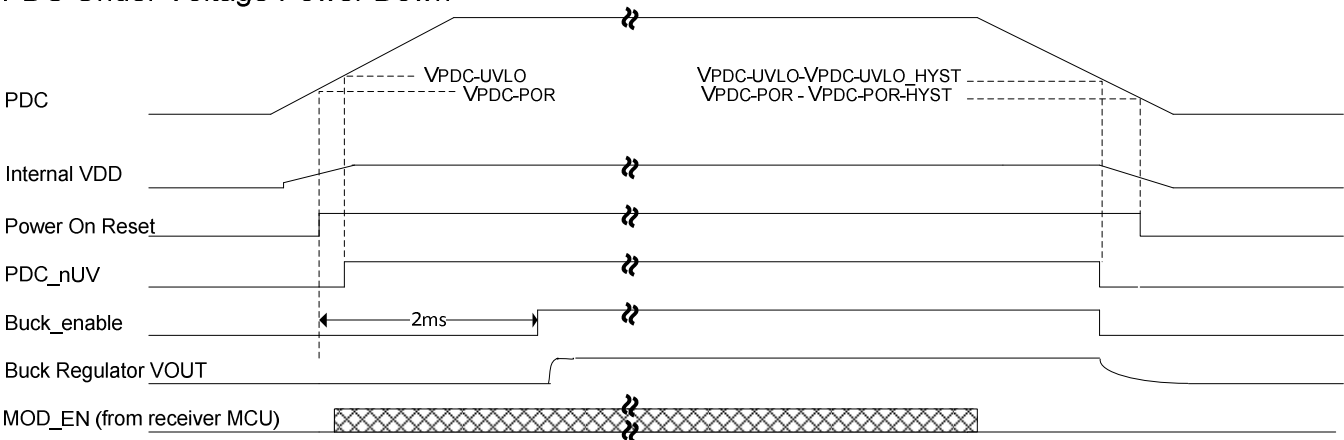


Figure 3: Bypass Mode Power Up

STANDALONE Mode Power Up MOD\_CFG=60kΩ (PDC=12V)  
RX to TX Power Level Control Packets

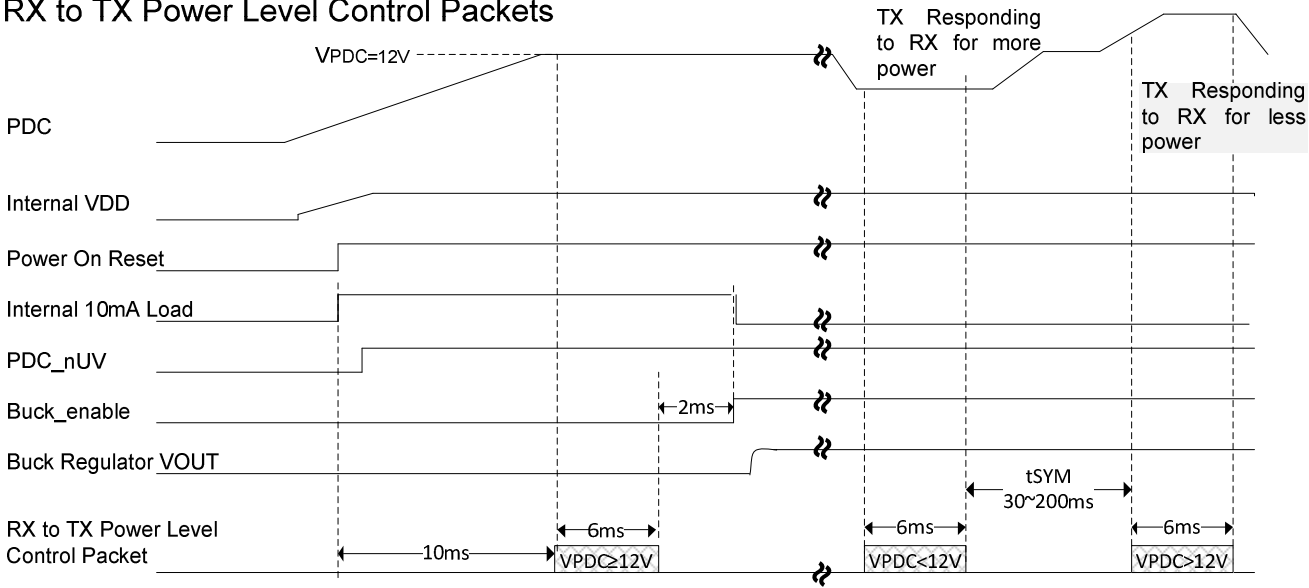


Figure 4: Standalone Mode Power Up

## Operation Diagrams

### VAC Signal Loss & Buck Control Option, BYPASS Mode MOD\_CFG=GND

The buck regulator will turn off when VAC signal is lost

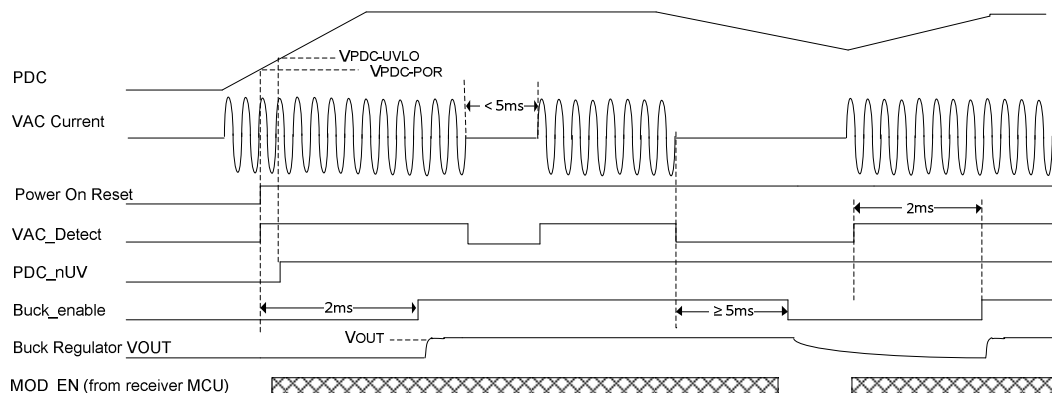


Figure 5: VAC Signal Loss & Buck Control

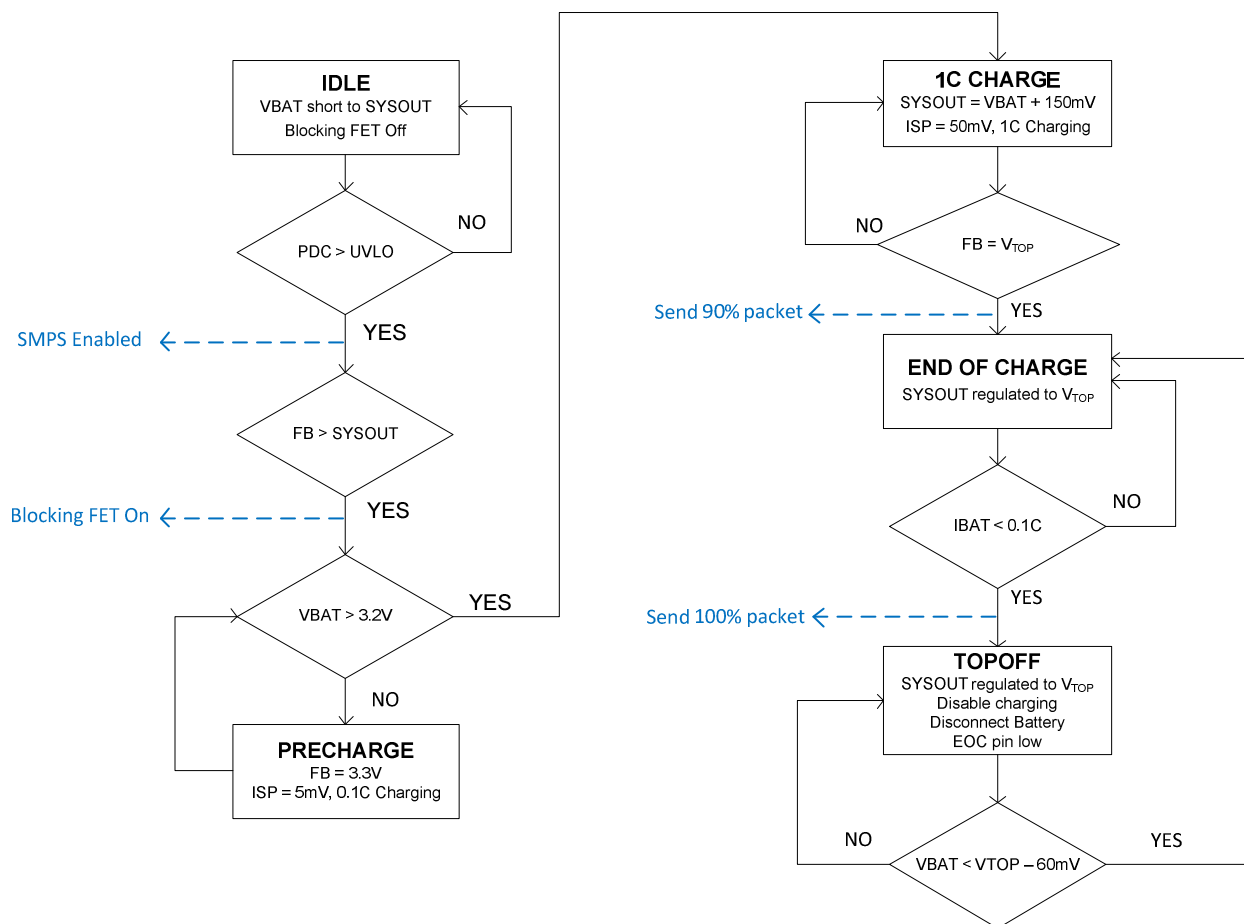


Figure 6: Battery Charging State Diagram

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## Detailed Ball Description

### **BST – Bootstrap input**

This terminal provides the bootstrap voltage required for the high-side NMOS switch of the buck regulator. An external ceramic capacitor placed between the BST and SW pins will provide the necessary gate drive voltage for the high-side switch. In normal operation, the capacitor is re-charged on every low-side synchronous switching action. For the case where the switch mode approaches 100% duty cycle for the high-side FET, the buck regulator will automatically reduce the duty cycle to a minimum off time on every 8th cycle to allow the BST capacitor to re-charge.

### **CHG\_DIS – Charge disable signal**

This input terminal allows an external microcontroller to disable charging by pulling the pin high.

### **COMM1, COMM2 – Modulation capacitor switches**

COMM1 and COMM2 pins are momentarily grounded when the system or the device communicates to the wireless power transmitter. When the COMM1/2 switches close, this shifts the impedance seen by the RX coil  $L_{IN}$  and this shift is in turn reflected as a change in TX coil current that can be detected by the transmitter's demodulator. Depending on the MOD\_CFG pin configuration and activity on the MOD\_EN pin, the integrated modulator or the MOD\_EN pin controls the COMM1/2 switches.

### **EOC – End of charge indicator**

When charging, this pin will be pulled low by an integrated NMOS. When the battery is fully charged, the NMOS will release. An external resistor should be connected to a system rail to allow this voltage to pull to the rail.

### **FB – Buck regulator output feedback**

This is the input terminal for the buck regulator output voltage feedback and the power input for the blocking FET. The SMPS will regulate the FB voltage at all times when enabled.

### **FREQ – Frequency detector output**

This is an open drain output which outputs a clock reference running at the frequency of the input AC power signal divided by 8.

### **GND – Ground**

Ground reference. This pin will conduct both correlated and uncorrelated switching currents during power transfer mode from the COMM1/2 pins switching and the buck operating in PWM mode, as well as switching current from the internal oscillator and the integrated modulator. PCB layout must provide low resistance to the ground plane for stable operation.

### **ISP – Charging current sense node**

This terminal is the negative battery terminal. A sense resistor placed between ISP and ground will set the 1C charging current. The integrated charger will regulate the voltage on the ISP pin to set the charging current.

## Detailed Ball Description

### MOD\_CFG – Modulation configuration

PDC voltage and modulation control scheme for communication are configured by the MOD\_CFG pin.

#### Bypass Mode

When the MOD\_CFG pin is grounded (voltage < 250mV), the internal data modulator is bypassed and the external MCU is required to drive the MOD\_EN pin to control the communication with the power transmitter. Thus, the MCU must be fully active prior to the device generating a stable output voltage  $V_{OUT}$ . The external MCU will set  $V_{PDC}$  by sending data packets to the transmitter.

#### Stand-alone Mode

If the MOD\_CFG pin is grounded through an external precision resistor (voltage > 250mV), the voltage on the MOD\_CFG pin determines the nominal rectified voltage on the PDC pin. In this mode, the integrated modulator generates the wireless power control packets and drives the COMM1/2 switches after power-on reset. This mode is referred to as the stand-alone mode as it does not require an external MCU to control the communication with the transmitter during receiver power up and for normal operation.

While in stand-alone mode, the device also monitors the MOD\_EN pin to detect if the external MCU wants to take control of the communication with the power transmitter. If at least 8 pulses with a delay of less than 25ms between each pulse are detected on the MOD\_EN pin, the device enters the (integrated modulator) bypass mode. Once in bypass mode and the MOD\_EN pin activity stalls (less than 8 pulses in a 250 ms window), the device exits the bypass mode and returns to stand-alone mode and the integrated modulator resumes communication with the power transmitter.

| MOD_CFG Pin Connection            | RX Data Communication Modulator | COMM1/2 Pin Drive    | $V_{PDC}$                                       | Internal Modulator Bypass  | Internal Modulator Fallback   |
|-----------------------------------|---------------------------------|----------------------|---|--|---|
| Grounded                          | External MCU                    | MOD_EN               | Set by External MCU's power control data packet | Integrated modulator always bypassed   | Integrated modulator always bypassed  |
| Resistor $R_{MOD\_CFG}$ to Ground | Integrated modulator            | Integrated modulator | $R_{MOD\_CFG} / 5000$                           | If MOD_EN pin pulses 8 times with delay < 25ms between pulses, COMM1/2 pins responsive to MOD_EN input | If MOD_EN pin pulses less than 8 times within 250ms window, COMM1/2 pins responsive to the integrated modulator |

### MOD\_EN – MCU modulation input

This is an active high CMOS input to drive the COMM1 and COMM2 pins to modulate the coil current to communicate with the wireless power transmitter. MOD\_EN signal is generated by the external MCU and its output swing must conform to the input levels specified in the Electrical Characteristics section for the MOD\_EN pin. Activity on the MOD\_EN is also sampled by the control logic to transition between Stand-alone and Bypass modes as outlined in the MOD\_CFG pin description.

### nALERT – MCU reset/interrupt

nALERT is an open drain output which is asserted low when the transmitter sends an ALERT command to the receiver to reset the MCU or to generate an interrupt. During the power up sequence, nALERT pin is pulled high by the external pull-up resistor, thus only the power transmitter ALERT command is allowed to assert this pin low.

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## Detailed Ball Description

### PDC – Rectified input signal

This terminal is the rectified output of the RX AC input voltage and serves as the DC supply for the device. It is recommended that a 10µF bypass capacitor rated for the maximum PDC voltage (> 2.2µF capacitance accounting for voltage derating, aging, and tolerance) be placed close to the device for best performance. Since this is the main power supply for the IC, good layout practices need to be followed for this connection.

### SW – Switching output

This is the switching node of the buck regulator. It should be connected directly to the output filter inductor  $L_{OUT}$  and bootstrap capacitor with a short, wide trace. SW pin switches between  $V_{PDC}$  and GND at the switching frequency, thus it is considered a noise source on the PCB. Route high impedance and quiet traces away from the SW trace.

### SYSOUT – System output supply

This terminal is the system power supply. When AC input power is not available, SYSOUT is shorted to VBAT through the integrated charger FET. When AC power is applied, SYSOUT will be regulated to either 3.3V when the battery is low or ~150mV above battery up to the tophoff voltage.

### THERM – Thermistor connection

This terminal allows temperature monitoring of the external system using a thermistor. When the system temperature reaches the warning level, the 1C charging level will be cut in half. At the shutdown level, charging will stop.

### TOP\_SET – Topoff voltage setpoint

The battery tophoff voltage is set by placing a resistor to ground on this pin. The IC will provide a 20µA DC output current. The tophoff voltage will be set according to the following equation.

$$V_{TOP} = V_{TOP\_OFFSET} + I_{TOP} * (R_{TOP\_SET} / 10)$$

### VAC1, VAC2 – AC Power input from resonant LC network

These terminals are connected to the wireless power supply receiver coil and resonant capacitor. It is recommended that the PCB traces are robust to handle high peak currents during power up maximum power transfer.

### VBAT – Battery connection

This pin is the positive battery terminal. The charger will supply output current to this pin during charging.

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## Regulator Internal Protection Details

### Regulator Output Current Limit

The current through the high-side FET is sensed on a cycle by cycle basis and if current limit is reached, it will turn off the high-side FET in mid-cycle. In addition, the device senses the FB pin to identify hard short conditions and will direct the SW output to skip 4 cycles if current limit occurs when FB is low. This allows current built up in the inductor during the minimum on-time to decay sufficiently. Current limit is always active when the regulator is enabled and the soft start function ensures current limit does not prevent regulator startup.

Under extended over-current conditions (such as a short), the buck regulator switching will automatically be disabled. Once the over current condition is removed, the device automatically returns to normal operation.

### Thermal Shutdown

If the die temperature exceeds  $T_{SD}$ , SW outputs will tri-state to protect the device and its load from damage. Once the device cools to  $T_{SD} - T_{SD\_HYST}$ , the buck regulator will attempt to start up again.

### Reference Soft Start

Internal references are ramped to prevent the output from overshoot during initial startup. During the soft start ramp, current limit is still active, and protects the device in case of a shorted output.

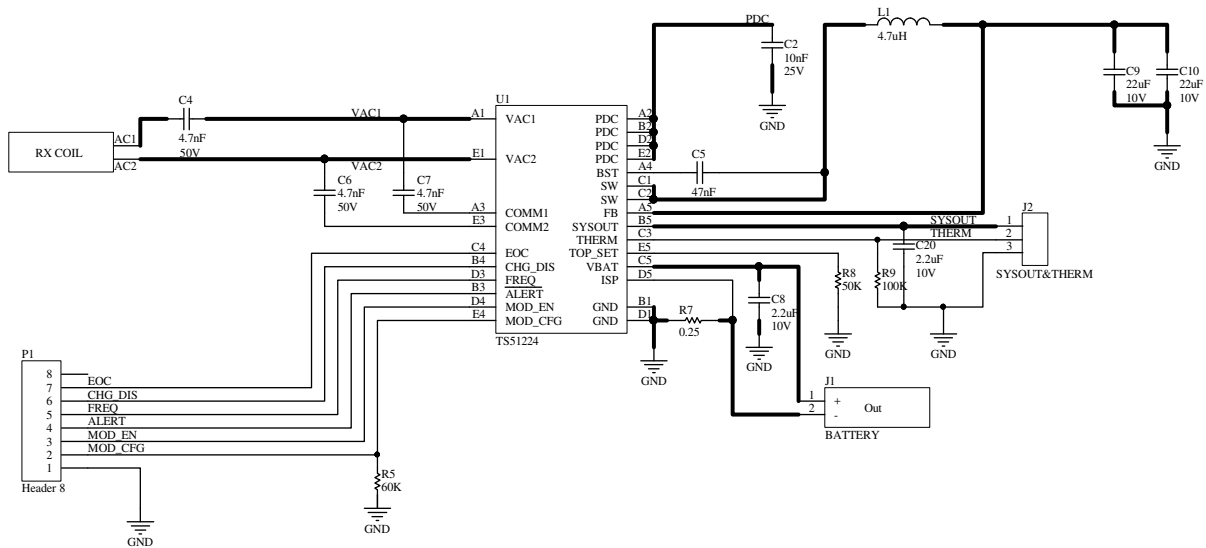
### Output Overvoltage

If the output of the regulator exceeds 3% of the set regulation voltage, the SW output tri-states to protect the device from damage. This check occurs at the start of each switching cycle. If overvoltage occurs mid-cycle, the switching for that cycle completes and the SW output tri-states on the next cycle.

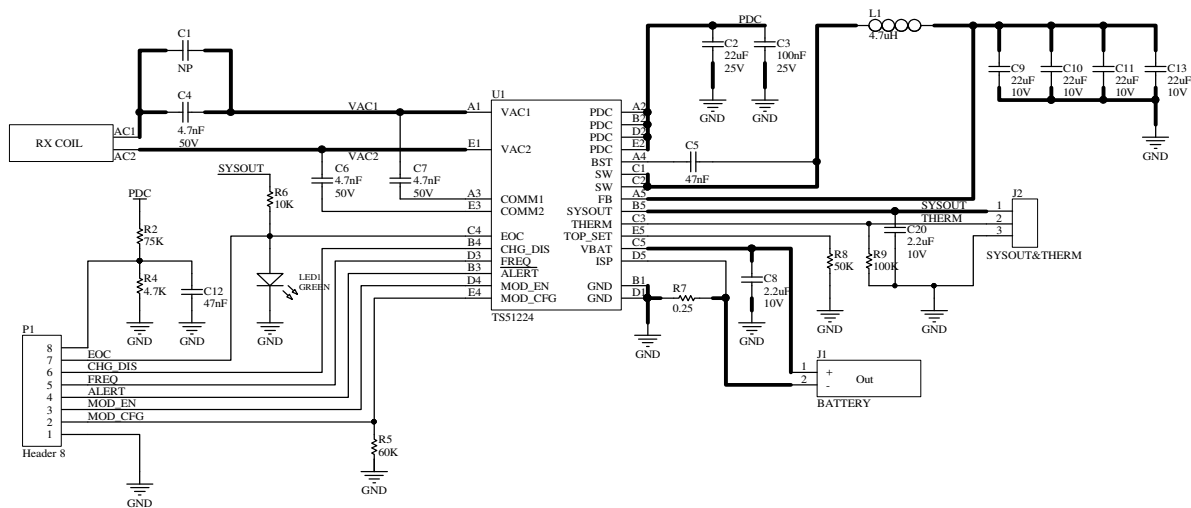
### PDC Under-Voltage Lockout

Buck regulator is off until PDC is over 4V with 300mV hysteresis.

## Application Schematics



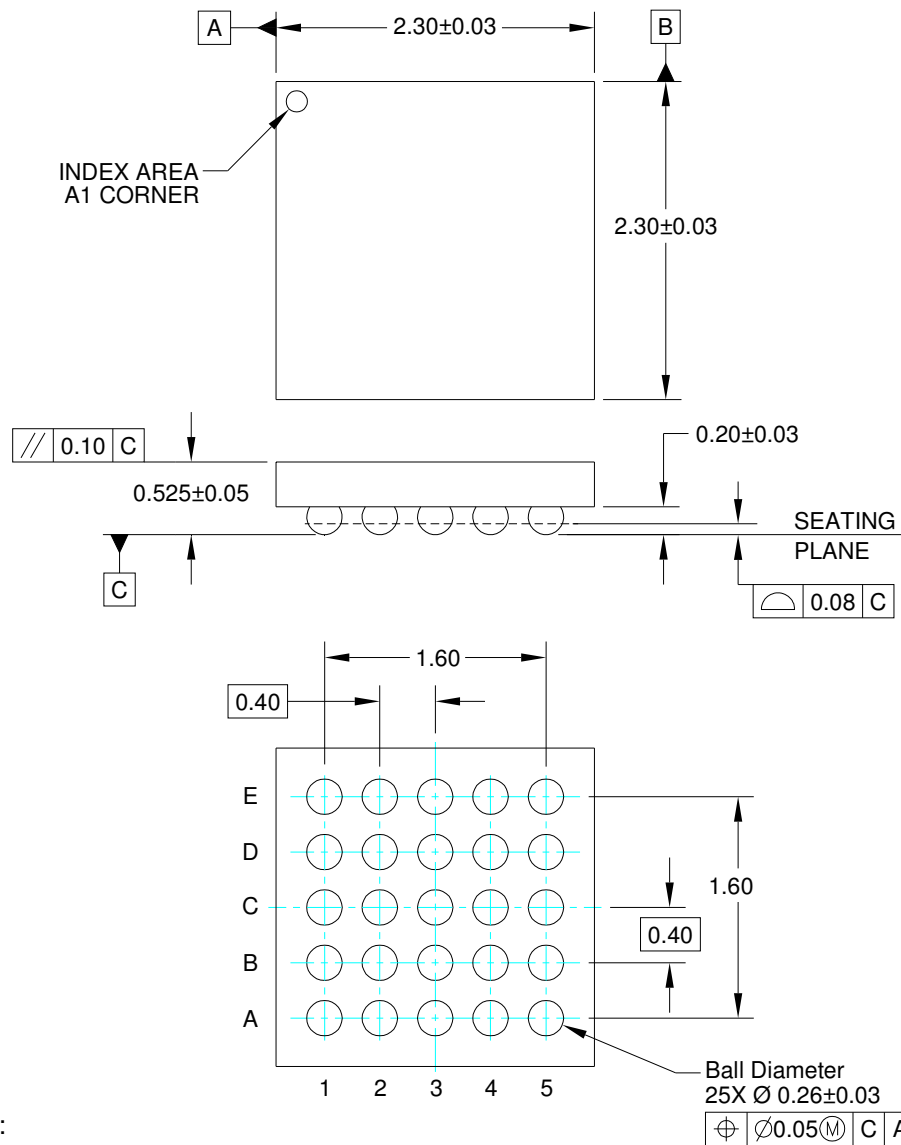
**Figure 7: Minimal PCB Area Configuration**  
( $V_{PDC}=12V$ ,  $V_{OUT}=5V$ ,  $I_{OUT}=50mA$ )



**Figure 8: Standard Configuration**  
( $V_{PDC}=12V$ ,  $V_{OUT}=5V$ ,  $I_{OUT}=100-500mA$ )



## Package Information

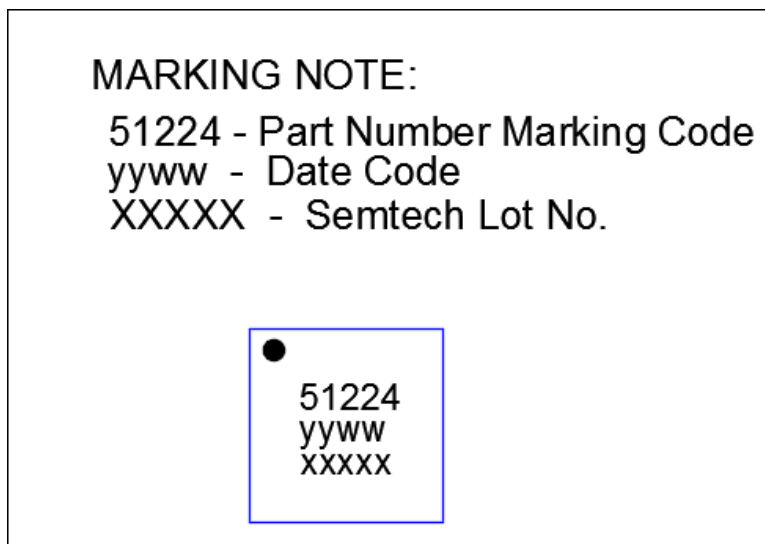


### NOTES:

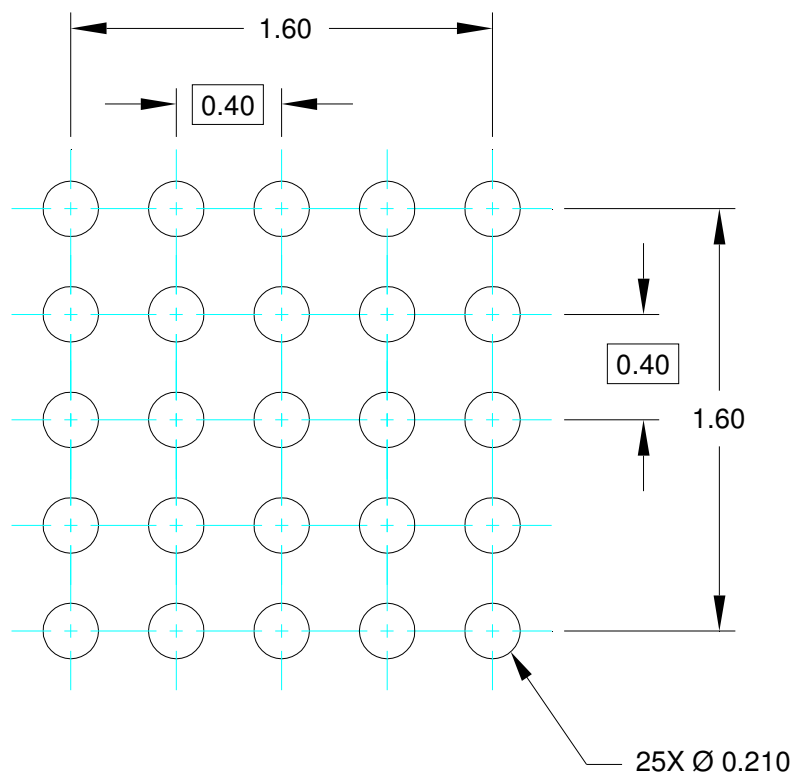
1. CONTROLLING DIMENSIONS ARE IN MILLIMETERS

**Figure 9: Package Outline Drawing**

## Package Information



**Figure 10: Device Symbolization**



**NOTES:**

1. CONTROLLING DIMENSIONS ARE IN MILLIMETERS
2. THIS LAND PATTERN IS FOR REFERENCE PURPOSES ONLY.  
CONSULT YOUR MANUFACTURING GROUP TO ENSURE YOUR  
COMPANY'S MANUFACTURING GUIDELINES ARE MET.

**Figure 11: Recommended Board Layout Land Pattern**

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## Ordering Information

| Device Part Number | Description  | 25 Ball WCSP Package<br>(5x5 ball array, 0.4mm ball pitch) |
|--------------------|--|--|
| TS51224-M000WCSR   | Wireless Power Receiver,<br>external resistor feedback | Tape & Reel (3000 parts/reel)                              |



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