

DATA SHEET

SE2438T: 2.4 GHz ZigBee®/Smart Energy Front-End Module

Applications

- Smart meters
- In-home appliances
- Smart thermostats

Features

- Integrated:
 - PA with up to +16 dBm output power
 - LNA with programmable bypass
 - Transmit and receive switching function
- +2.7 dB FEM Rx NF
- Differential Rx/Tx interface with integrated balun
- Fast switch on/off time <800 ns
- 2.0 V to 3.6 V supply operation
- Sleep mode current 0.05 μ A typical
- QFN (20-pin, 3.0 mm x 3.0 mm x 0.55 mm) package (MSL1 @ 260 °C per JEDEC J-STD-020)



Skyworks Green™ products are compliant with all applicable legislation and are halogen-free. For additional information, refer to *Skyworks Definition of Green™*, document number SQ04-0074.

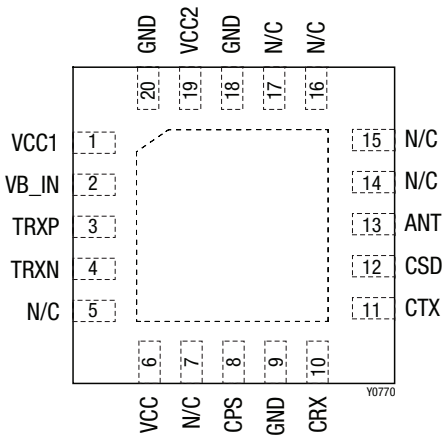


Figure 2. SE2438T Pinout—20-Pin QFN (Top View)

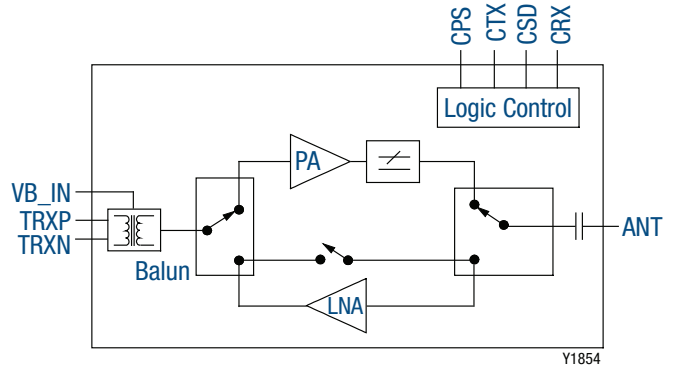


Figure 1. SE2438T Block Diagram

Description

The SE2438T is a high-performance, fully integrated RF Front-End Module (FEM) that is designed for ZigBee®/Smart Energy applications.

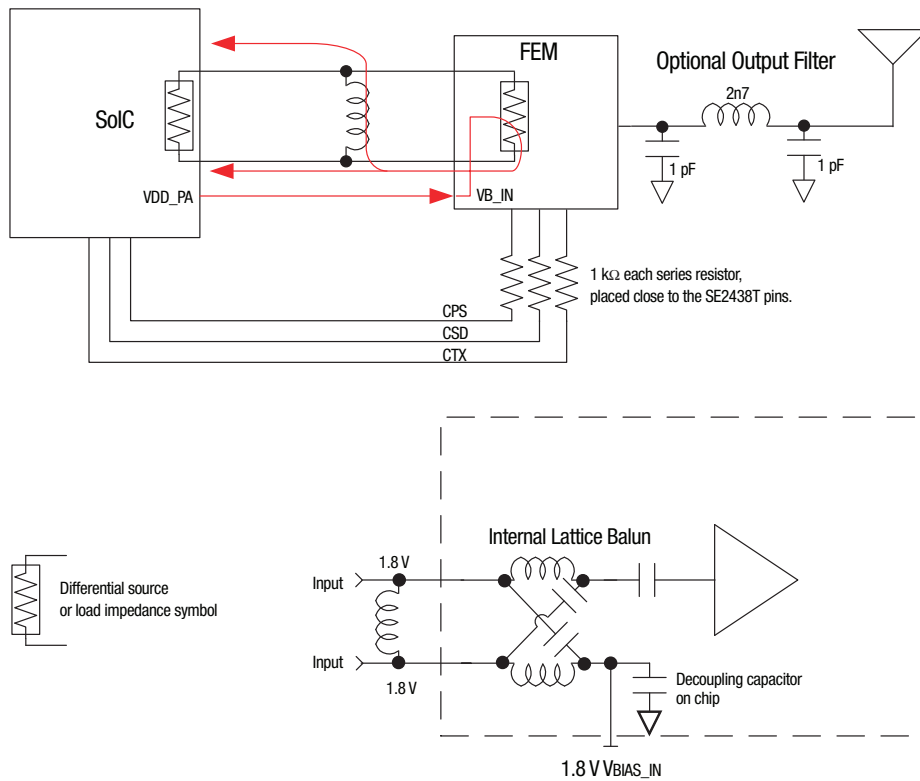
The SE2438T is designed for ease of use and maximum flexibility, with integrated fully matched input balun, integrated inter-stage matching and harmonic filter, and digital controls that are compatible with 1.6 V to 3.6 V Complementary Metal Oxide Semiconductor (CMOS) levels.

The RF blocks operate over a wide supply voltage range from 2.0 V to 3.6V, which allows the SE2438T to be used in battery-powered applications over a wide spectrum of the battery discharge curve.

A functional block diagram is shown in Figure 1. The pin configuration and package are shown in Figure 2. Signal pin assignments and functional pin descriptions are provided in Table 1.

Table 1. SE2438T Signal Descriptions

| Pin | Name | Description | Pin | Name | Description |
|-----|-------|---|--------|------|--|
| 1 | VCC1 | Positive supply | 12 | CSD | Sleep mode control |
| 2 | VB_IN | Bias voltage input supply to the transceiver (see Figure 3) | 13 | ANT | Connect to 50 Ω antenna |
| 3 | TRXP | Input/output signal to the transceiver, 100 Ω differential | 14 | N/C | Not connected |
| 4 | TRXN | Input/output signal to the transceiver, 100 Ω differential | 15 | N/C | Not connected |
| 5 | N/C | Not connected | 16 | N/C | Not connected |
| 6 | VCC | Positive supply | 17 | N/C | Not connected |
| 7 | N/C | Not connected | 18 | GND | Connect to PCB ground |
| 8 | CPS | Bypass mode control, connect to RFIC or SoC GPIO | 19 | VCC2 | Positive supply |
| 9 | GND | Connect to PCB the ground | 20 | GND | Connect to PCB ground |
| 10 | CRX | Receive function control | Paddle | GND | Exposed die paddle; electrical and thermal ground; connect to PCB ground |
| 11 | CTX | Transmit function control | | | |



The balun at the FEM PA input (or LNA output) can also be used to inject a bias operating point for the transceiver output stage (the shunt inductor provides a DC path on the other side). The inductor also tunes out any parasitic capacitance.

If the SOIC transceiver does not require a DC bias, leave the VB_IN open.

Y1855

Figure 3. Injecting a Bias Operating Point for the Transceiver Output Stage

Electrical and Mechanical Specifications

The absolute maximum ratings of the SE2438T are provided in Table 2. The recommended operating conditions are specified in Table 3.

The electrical specifications are provided in Tables 4 through 7. The state of the SE2438T is determined by the logic provided in Table 8.

Table 2. SE2438T Absolute Maximum Ratings

| Parameter | Symbol | Minimum | Maximum | Units |
|--|--|---------|---------|-------|
| Supply voltage | V _{CC1} , V _{CC2} , V _{CC3} | -0.3 | 3.6 | V |
| Control pin voltages | | -0.3 | 3.6 | V |
| Operating temperature | T _A | -40 | 125 | °C |
| Storage temperature | T _{STG} | -40 | 125 | °C |
| Tx output power at the ANT port into 50 Ω load | P _{OUT_TX_MAX} | | +16 | dBm |
| Tx input power at the TR port | P _{IN_TX_MAX} | | +6 | dBm |
| Rx input power at the ANT port | P _{IN_RX_MAX} | | +5 | dBm |
| Thermal resistance | θ _{JC} | | 69 | °C/W |
| Electrostatic discharge: Human Body Model (HBM), Class 1C | ESD | | 1000 | V |

Note: Exposure to maximum rating conditions for extended periods may reduce device reliability. There is no damage to device with only one parameter set at the limit and all other parameters set at or below their nominal value. Exceeding any of the limits listed here may result in permanent damage to the device.

CAUTION: Although this device is designed to be as robust as possible, electrostatic discharge (ESD) can damage this device. This device must be protected at all times from ESD. Static charges may easily produce potentials of several kilovolts on the human body or equipment, which can discharge without detection. Industry-standard ESD precautions should be used at all times.

Table 3. Recommended Operating Conditions

| Parameter | Symbol | Minimum | Typical | Maximum | Units |
|-------------------------------------|--|---------|---------|---------|-------|
| Ambient temperature | T _A | -40 | +25 | +125 | °C |
| Supply voltage for transceiver core | V _{B_IN} | 1.6 | | 3.6 | V |
| Supply voltage on Vcc pins | V _{CC1} , V _{CC2} , V _{CC3} | 2.0 | 3.0 | 3.6 | V |

Table 4. SE2438T Electrical Specifications: DC (Note 1)
(VCC = VCC1 = VCC2 = 3 V, TA = +25 °C, Measured on the Evaluation Board [De-embedded to the Device], Unless Otherwise Noted)

| Parameter | Symbol | Test Condition | Min | Typical | Max | Units |
|----------------------|--------------------------|---|-----|---------|-----|-------|
| Total supply current | I _{CC_TX14} | Tx mode P _{OUT} = +14 dBm | | 33 | | mA |
| Total supply current | I _{CC_TX12} | Tx mode P _{OUT} = +12 dBm | | 25 | | mA |
| Total supply current | I _{CC_TX10} | Tx mode P _{OUT} = +10 dBm | | 20 | | mA |
| Quiescent current | I _{CC_TX} | No RF | | 6 | | mA |
| Total supply current | I _{CC_RXHG} | Rx Low Noise Amplifier (LNA) High Gain mode | | 5.5 | | mA |
| Total supply current | I _{CC_RXLG} | Rx LNA Low Gain mode | | 2.7 | | mA |
| Total supply current | I _{CC_RxBypass} | Rx Bypass mode | | | 10 | μA |
| Sleep supply current | I _{CC_OFF} | No RF | | 0.05 | 1.0 | μA |

Note 1: Performance is guaranteed only under the conditions listed in this table.

Table 5. SE2438T Electrical Specifications: Logic Characteristics (Note 1)
(VCC = VCC1 = VCC2 = 3.0 V, TA = +25 °C, Measured on the Evaluation Board [De-embedded to the Device], Unless Otherwise Noted)

| Parameter | Symbol | Test Condition | Min | Typical | Max | Units |
|--------------------------|-------------------|----------------|-----|---------|-----|-------|
| Logic input high voltage | V _{BIHB} | | 1.6 | | 3.6 | V |
| Logic input low voltage | V _{BILB} | | 0 | | 0.3 | V |
| Logic input high current | I _{BIHB} | | | | 1 | μA |
| Logic input low current | I _{BILB} | | | | 1 | μA |

Note 1: Performance is guaranteed only under the conditions listed in this table.

Table 6. SE2438T Electrical Specifications: AC Characteristics (Note 1)
(VCC = VCC1 = VCC2 = 3.0 V, TA = +25 °C, Measured on the Evaluation Board [De-embedded to the Device],
All Unused Ports Terminated with 50 Ω, Unless Otherwise Noted)

| Parameter | Symbol | Test Condition | Minimum | Typical | Maximum | Units |
|---|-------------------------------------|---|--|--|---------|-------------|
| Transmit (Tx) | | | | | | |
| Frequency range | f _{IN} | | 2400 | | 2483 | MHz |
| Output power at ANT port | P _{OUT_HI} | 2400 MHz to 2483 MHz, OEVM = 1% typical: VCC = VCC1 = VCC2 = 3.6 V VCC = VCC1 = VCC2 = 3.3 V VCC = VCC1 = VCC2 = 3.0 V VCC = VCC1 = VCC2 = 2.0 V VCC = VCC1 = VCC2 = 1.8 V | | +16.0 +15.0 +14.0 +11.0 +9.5 | | dBm |
| Small signal gain high power mode | S _{21_HI} | 2400 MHz to 2483 MHz | 14 | | | dB |
| Small signal gain variation | ΔS ₂₁ | 2400 MHz to 2483 MHz Gain variation across all 802.15.4 channels | | | 1 | dBp-p |
| Second and third harmonics | H _{D2} , H _{D3} | 2400 MHz to 2483 MHz IEEE 802.15.4 source P _{OUT} = +14 dBm Measured with the antenna match and filter components per the SE2438T-EK1 evaluation board | | | -42 | dBm/ MHz |
| Bluetooth® V 1.0 and BLE spectral mask | ACPR | ACPR @ ± 2 channels ACPR @ ± 3 channels | | > -40 > -40 | | dB dB |
| Turn on and off times | t _{ON} t _{OFF} | From 50% of the CTX edge to 90% of the final RF output power. From 50% of the CTX edge to 10% of the final RF output power. | | | 800 | ns |
| Stability | STAB | CW, PIN = +0 dBm 0.1 GHz to 20.0 GHz Load VSWR = 6:1 | All non-harmonically related outputs <-35.0 dBm/MHz | | | |
| Ruggedness | Ru | CW, PIN = +6 dBm, Load VSWR = 10:1 | No permanent damage | | | |
| Receive (Rx) | | | | | | |
| Frequency range | f _{IN} | | 2400 | | 2483 | MHz |
| Rx gain high-gain mode | Rx_gain_HG | 2400 MHz to 2483 MHz | 10.3 | 12.3 | 14.3 | dB |
| Rx gain low-gain mode | Rx_gain_LG | 2400 MHz to 2483 MHz | 5 | 7 | 9 | dB |
| Rx noise figure (NF) high-gain mode | NF_HG | 2400 MHz to 2483 MHz | | 2.7 | | dB |
| Rx NF low-gain mode | NF_LG | 2400 MHz to 2483 MHz | | +3.8 | | dB |
| Input 1 dB compression point high-gain mode | IP1dB_HG | 2400 MHz to 2483 MHz | -13 | -8 | | dBm |
| Input 1 dB compression point low-gain mode | IP1dB_LG | 2400 MHz to 2483 MHz | -3 | +2 | | dBm |
| Turn on and off times | t _{ON} t _{OFF} | From 50% of the CTX edge to 90% of the final RF output power. From 50% of the CTX edge to 10% of the final RF output power. | | | 800 | ns |
| Gain in bypass mode | G_bp | | | -3.5 | | dB |
| Input 1 dB compression point in bypass mode | IP1dB | | +10 | | | dBm |

Note 1: Performance is guaranteed only under the conditions listed in this table.

Table 7. SE2438T Electrical Specifications: AC Characteristics, Antenna Switch (Note 1)
(Vcc1 = Vcc2 = Vcc3 = 3 V, TA = +25 °C, Measured on the Evaluation Board [De-embedded to the Device],
All Unused Ports Terminated with 50 Ω, Unless Otherwise Noted)

| Parameter | Symbol | Min | Typical | Max | Units |
|---|--------|-----|---------|-----|-------|
| Input return loss at ANT port, Rx mode | S11 | | -10 | -5 | dB |
| Output return loss at ANT port, Tx mode | S22 | | -10 | -5 | dB |

Note 1: Performance is guaranteed only under the conditions listed in this table.

Table 8. SE2438T Logic Controls (Notes 1 and 2)
(VCC = VCC1 = VCC2 = 3.0 V, TA = +25 °C, Unless Otherwise Noted)

| Mode | Description | CSD | CPS | CRX | CTX | Current Consumption |
|------|--------------------|-----|-----|-----|-----|----------------------------------|
| 0 | All off | 0 | 0 | 0 | 0 | Table 4 |
| 1 | Standby | 0 | 0 | 0 | 1 | 1.907 μA |
| 2 | Standby | 0 | 0 | 1 | 0 | 1.907 μA |
| 3 | Standby | 0 | 0 | 1 | 1 | 3.8 μA |
| 4 | Standby | 0 | 1 | 0 | 0 | 1.907 μA |
| 5 | Standby | 0 | 1 | 0 | 1 | 3.8 μA |
| 6 | Standby | 0 | 1 | 1 | 0 | 3.8 μA |
| 7 | Standby | 0 | 1 | 1 | 1 | 5.69 μA |
| 8 | Standby | 1 | 0 | 0 | 0 | 1.907 μA |
| 9 | Tx bypass mode | 1 | 0 | 0 | 1 | Same as Rx Bypass mode (Table 4) |
| 10 | Rx bypass mode | 1 | 0 | 1 | 0 | Table 4 |
| 11 | Regulator enabled | 1 | 0 | 1 | 1 | 210 μA |
| 12 | Rx LNA (LG) | 1 | 1 | 0 | 0 | Table 4 |
| 13 | TX high power mode | 1 | 1 | 0 | 1 | Table 4 |
| 14 | Rx LNA(HG) | 1 | 1 | 1 | 0 | Table 4 |
| 15 | Standby | 1 | 1 | 1 | 1 | 7.6 μA |

Note 1: Performance is guaranteed only under the conditions listed in this table.

Note 2: Modes 1 through 8, 11, and 15 are for internal use only.

Evaluation Board Description

The SE2438T Evaluation Board is used to test the performance of the SE2438T FEM. The board is optimized for evaluation, experimentation, and investigation with an 802.15.4 signal source. The design and layout can be quickly and easily transferred into a production design.

An Evaluation Board schematic diagram is provided in Figure 4. A reference design schematic is provided in Figure 5. Table 9 describes the pins on the power and control I/O header (J3). Table 10 provides the Bill of Materials (BOM) list for Evaluation Board components. A photograph of the Evaluation Board is shown in Figure 6.

Evaluation Board Setup Procedure

1. Connect (J1, J2) to 50 Ω instruments. Terminate all unused ports (if applicable) with 50 Ω .
2. Connect the supply ground to pin 19 or 20 of J3.
3. Connect 3.0 V to VCC, VCC1, and VCC2 of J3.
4. Connect 1.8 V to Pin 8 of J3.
5. Monitor the 2.5 GHz amplifier transmit performance by applying an RF signal to J2 and monitoring the output power on J1 (ANT).
6. Monitor the 2.5 GHz amplifier receive performance by applying an RF signal to connector J1 (ANT) and monitoring the output signal on connector J2.

CAUTION: Care should be taken not to overdrive the amplifier by applying too much RF on the input to the device. A suitable starting input power would be -20 dBm.

Package Dimensions

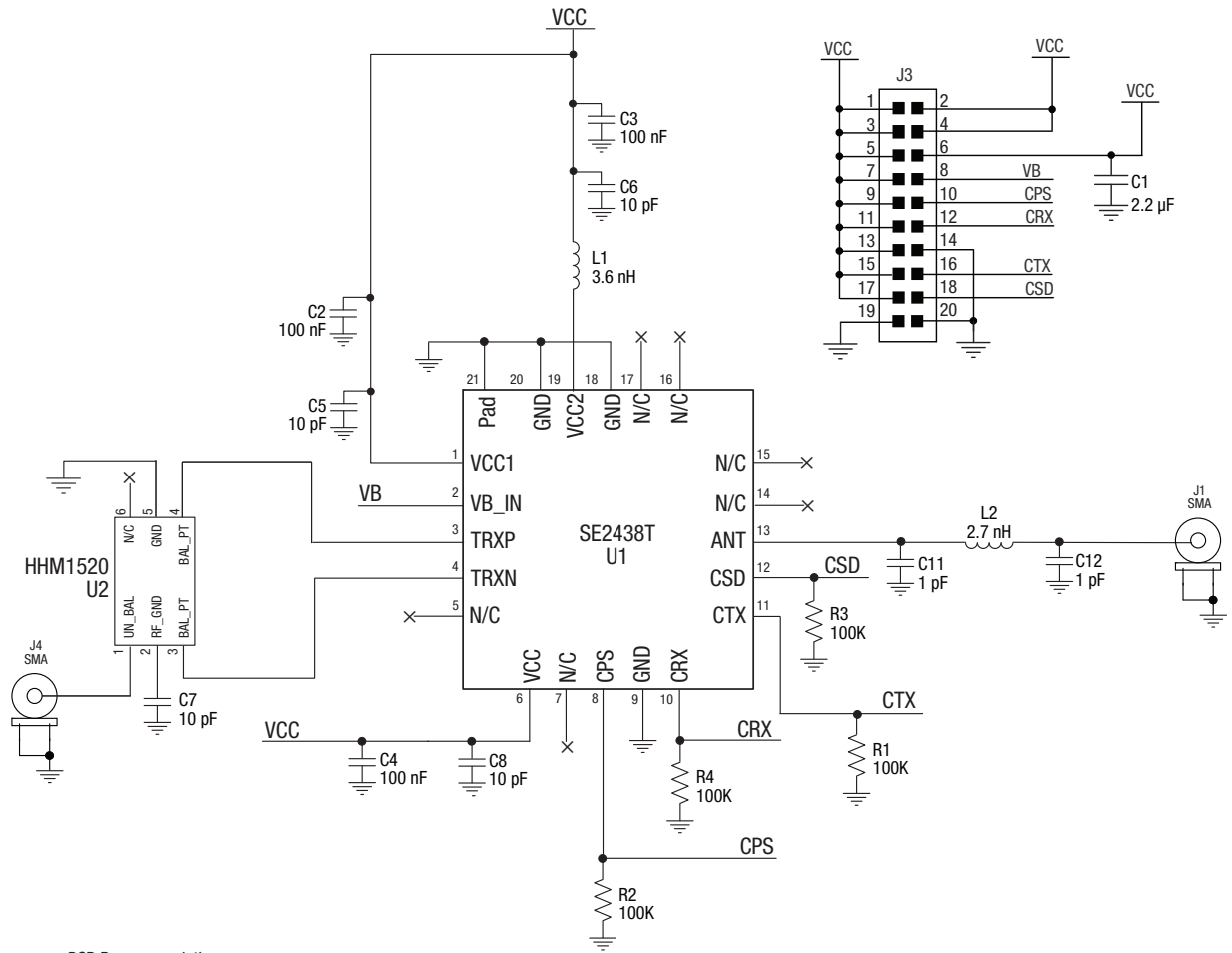
The PCB layout footprint for the SE2438T is provided in Figure 7. Typical part markings for the SE2438T are shown in Figure 8. Package dimensions are shown in Figure 9, and tape and reel dimensions are provided in Figure 10.

Package and Handling Information

Instructions on the shipping container label regarding exposure to moisture after the container seal is broken must be followed. Otherwise, problems related to moisture absorption may occur when the part is subjected to high temperature during solder assembly.

The SE2438T package is Pb free, RoHS compliant, halogen free, and rated to Moisture Sensitivity Level 1 (MSL1). For additional information, refer to the Skyworks Application Note, *Solder Reflow Information*, document number 200164.

Care must be taken when attaching this product, whether it is done manually or in a production solder reflow environment. Production quantities of this product are shipped in a standard tape and reel format.



PCB Recommendations:

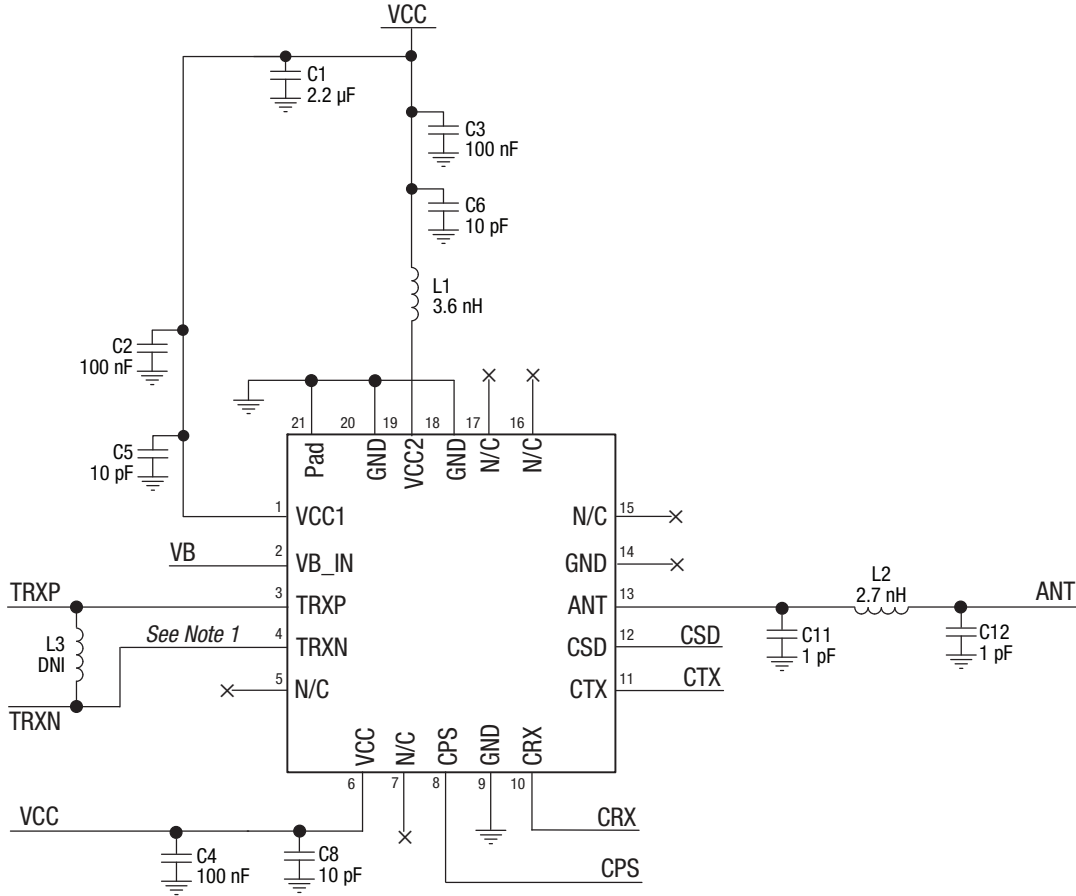
Metal Layer 1 = RF traces + control lines. Core thickness between top RF layer and ground plane is critical.
 Metal Layer 2 = Solid ground plane. No traces routing.
 Metal Layer 3 and 4 = Control lines + VCC traces (no VCC plane).
 Pour copper on each layer connected to the ground plane. Use VCC traces in a star distribution pattern.

Y0772

Figure 4. SE2438T Evaluation Board Schematic

Table 9. SE2438T Power and Analog I/O Header: J3, 10x2

| Pin Number | Evaluation Board Label | Description | Recommended setting |
|----------------------------------|------------------------|----------------|---|
| 14, 19, 20 | GND | Ground | General purpose grounds |
| 1, 3, 5, 6, 7, 9, 11, 13, 15, 17 | VCC | Supply voltage | General purpose VCC provided as the main power supply |
| 4 | VCC1 | Supply voltage | General purpose VCC provided as the main power supply |
| 2 | VCC2 | Supply voltage | General purpose VCC provided as the main power supply |
| 8 | VB | Bias | Output bias to transceiver |
| 16 | CTX | Control | See Table 8 |
| 10 | CPS | Control | |
| 18 | CSD | Control | |
| 12 | CRX | Control | |



Note 1:

There are two ways that the SE2438T input can be interface single ended:

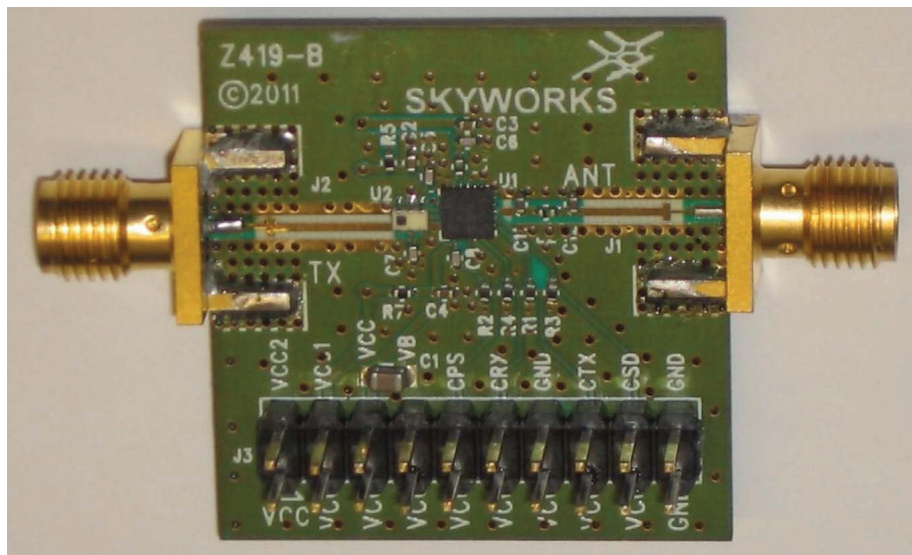
1. One input can be terminated with 50 Ω to ground, the other input impedance is 50 Ω.
2. One input can be shorted to ground, the other input impedance is 100 Ω.

Y0769

Figure 5. SE2438T Evaluation Board Reference Design Schematic

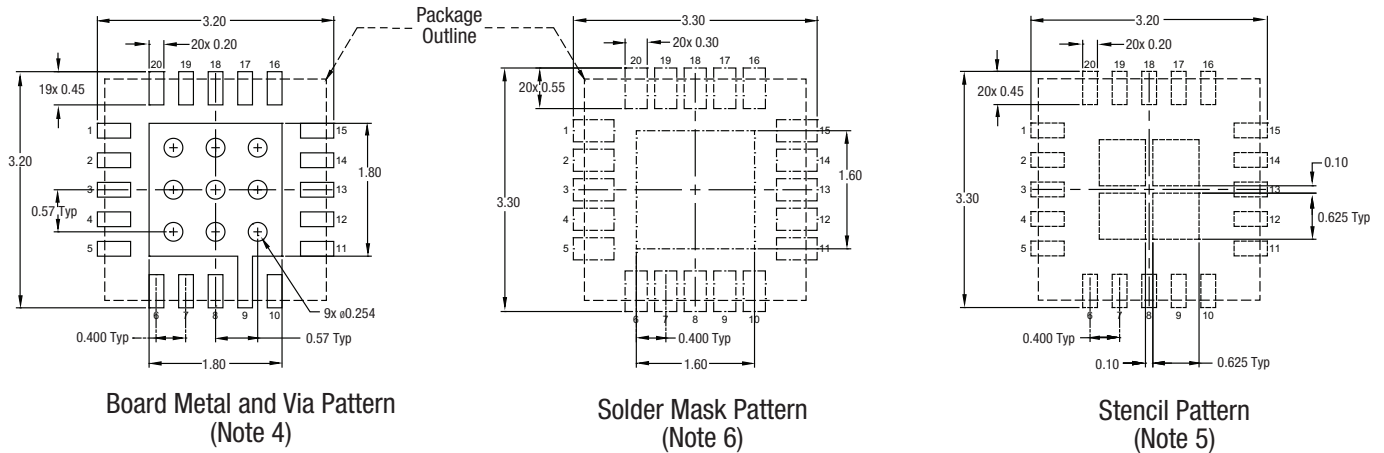
Table 10. SE2438T Evaluation Board Bill of Materials

| Description | Value | Manufacturer | Mfr Part Number | Package | Description |
|----------------|-------------|--------------------|--------------------|-------------|---|
| C1 | 2.2 μ F | Murata | GRM21BR71A225KA01L | 0805 | Capacitor ceramic 2.2 μ F 10 V 10% X7R 0805 |
| L2 | 2.7 nH | Murata | LQG15HN2N7S02D | 0402 | High frequency multilayer |
| L1 | 3.6 nH | Murata | LQG15HN3N6S02D | 0402 | High frequency multilayer |
| J3 | 10 x 2 | Samtec | TSW-110-07-G-D | 100MIL | 100 mil header |
| U2 | HHM1520 | TDK | HHM1520 | 2.00MMX1.25 | Multilayer chip baluns 2.4 GHz |
| U1 | SE2438T | Skyworks | SE2438T | QFN3X3-20 | 2.4 GHz 14 dBm FEIC |
| C11, C12 | 1 pF | Murata | GRM1555C1H1R0CZ01 | 0402 | Multilayer ceramic |
| J1, J2 | SMA | Johnson Components | 142-0701-851 | End Launch | SMA end launch straight jack receptacle—tab contact |
| C2, C3, C4 | 100 nF | Murata | GRM155R71C104KA88D | 0402 | Monolithic ceramic |
| C5, C6, C7, C8 | 10 pF | Murata | GRM1555C1H100JZ01 | 0402 | Multilayer ceramic |
| R1, R2, R3, R4 | 100 K | Panasonic | ERJ2GEJ104 | 0402 | Thick film chip resistor |



Y0771

Figure 6. SE2438T Evaluation Board Photograph



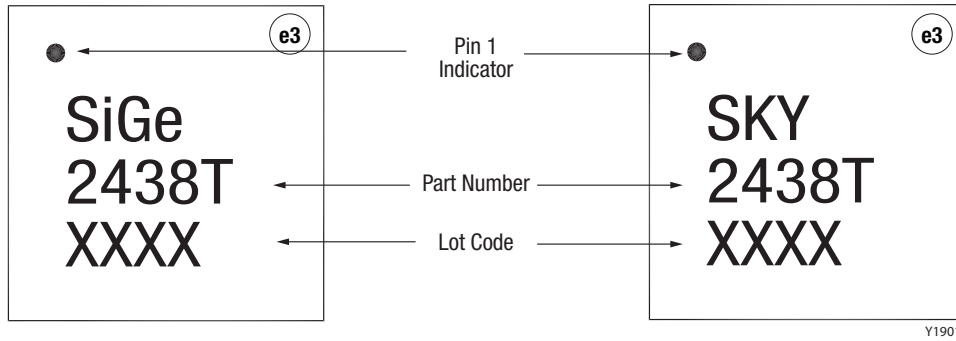
Notes:

1. All dimensions are in millimeters.
2. Dimensions and tolerances according to ASME Y14.5M-1994.
3. Unless specified, dimensions are symmetrical about center lines.
4. Via hole recommendations: 30 to 35 μm Cu via wall plating (minimum), via holes should be tented with solder mask on the back side and filled with solder.
5. Stencil recommendations: 0.125 mm stencil thickness, laser cut apertures, trapezoidal walls and rounded corners offer better paste release.
6. Solder mask recommendations: contact board fabricator for recommended solder mask offset and tolerance.

61% solder coverage on center pad

Y0774

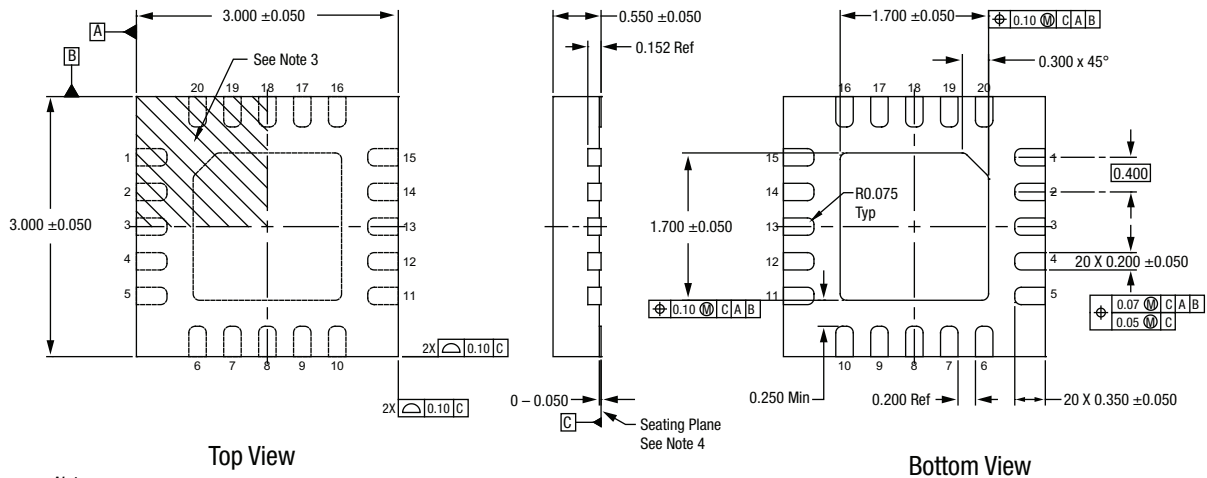
Figure 7. PCB Layout Footprint



Y1901

Figure 8. SE2438T Part Markings (Top View)

DATA SHEET • SE2438T: 2.4 GHz SMART ENERGY/ZIGBEE FRONT-END MODULE

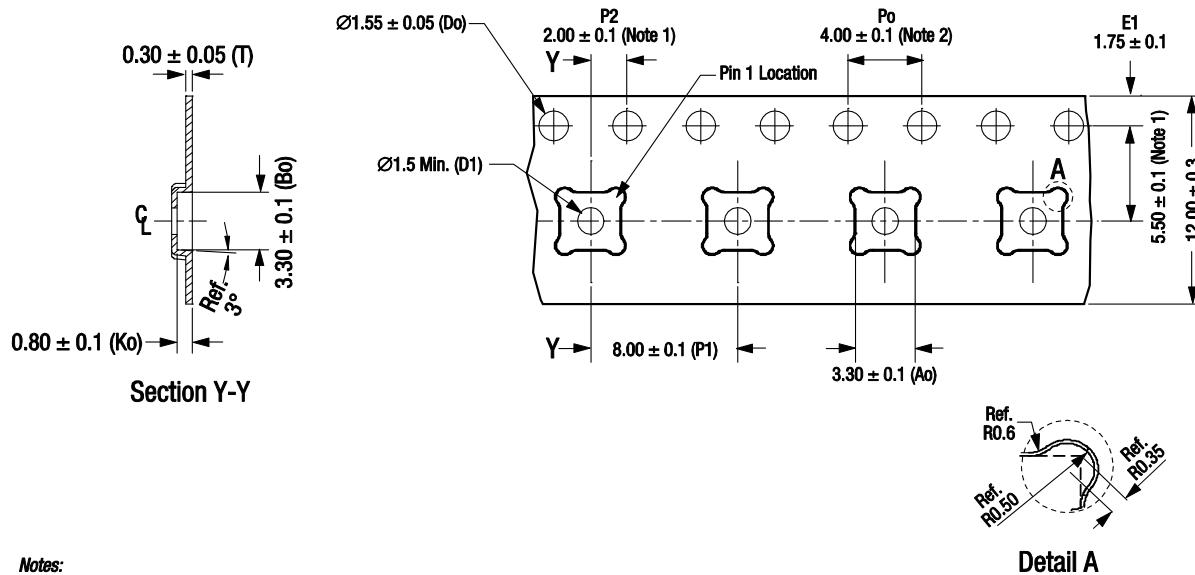


Notes:

1. All dimensions are in millimeters.
2. Dimensions and tolerances according to ASME Y14.5--1994.
3. Terminal 1 identification mark located within this area.
4. Unilateral coplanarity zone applies to the exposed heat sink ground pad as well as the terminals.

Y0773

Figure 9. SE2438T Package Dimensions



Notes:

1. Measured from center line of sprocket hole to center line of pocket.
2. Cumulative tolerance of 10 sprocket holes is ± 0.20 mm.
3. Other material available.
4. Typical ESD surface resistivity is from 10⁵ to 10¹¹ Ohms/square per EIA, JEDEC tape and reel specification.

All measurements are in millimeters.

S2615

Figure 10. SE2438T Tape and Reel Dimensions

Ordering Information

| Model Name | Manufacturing Part Number | Evaluation Board Part Number |
|---|---------------------------|------------------------------|
| SE2438T: 2.4 GHz Smart Energy/ZigBee Front-End Module | SE2438T-R | SE2438T-EK1 |

Copyright © 2012-2015 Skyworks Solutions, Inc. All Rights Reserved.

Information in this document is provided in connection with Skyworks Solutions, Inc. (“Skyworks”) products or services. These materials, including the information contained herein, are provided by Skyworks as a service to its customers and may be used for informational purposes only by the customer. Skyworks assumes no responsibility for errors or omissions in these materials or the information contained herein. Skyworks may change its documentation, products, services, specifications or product descriptions at any time, without notice. Skyworks makes no commitment to update the materials or information and shall have no responsibility whatsoever for conflicts, incompatibilities, or other difficulties arising from any future changes.

No license, whether express, implied, by estoppel or otherwise, is granted to any intellectual property rights by this document. Skyworks assumes no liability for any materials, products or information provided hereunder, including the sale, distribution, reproduction or use of Skyworks products, information or materials, except as may be provided in Skyworks Terms and Conditions of Sale.

THE MATERIALS, PRODUCTS AND INFORMATION ARE PROVIDED “AS IS” WITHOUT WARRANTY OF ANY KIND, WHETHER EXPRESS, IMPLIED, STATUTORY, OR OTHERWISE, INCLUDING FITNESS FOR A PARTICULAR PURPOSE OR USE, MERCHANTABILITY, PERFORMANCE, QUALITY OR NON-INFRINGEMENT OF ANY INTELLECTUAL PROPERTY RIGHT; ALL SUCH WARRANTIES ARE HEREBY EXPRESSLY DISCLAIMED. SKYWORKS DOES NOT WARRANT THE ACCURACY OR COMPLETENESS OF THE INFORMATION, TEXT, GRAPHICS OR OTHER ITEMS CONTAINED WITHIN THESE MATERIALS. SKYWORKS SHALL NOT BE LIABLE FOR ANY DAMAGES, INCLUDING BUT NOT LIMITED TO ANY SPECIAL, INDIRECT, INCIDENTAL, STATUTORY, OR CONSEQUENTIAL DAMAGES, INCLUDING WITHOUT LIMITATION, LOST REVENUES OR LOST PROFITS THAT MAY RESULT FROM THE USE OF THE MATERIALS OR INFORMATION, WHETHER OR NOT THE RECIPIENT OF MATERIALS HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

Skyworks products are not intended for use in medical, lifesaving or life-sustaining applications, or other equipment in which the failure of the Skyworks products could lead to personal injury, death, physical or environmental damage. Skyworks customers using or selling Skyworks products for use in such applications do so at their own risk and agree to fully indemnify Skyworks for any damages resulting from such improper use or sale.

Customers are responsible for their products and applications using Skyworks products, which may deviate from published specifications as a result of design defects, errors, or operation of products outside of published parameters or design specifications. Customers should include design and operating safeguards to minimize these and other risks. Skyworks assumes no liability for applications assistance, customer product design, or damage to any equipment resulting from the use of Skyworks products outside of stated published specifications or parameters.

Skyworks and the Skyworks symbol are trademarks or registered trademarks of Skyworks Solutions, Inc., in the United States and other countries. Third-party brands and names are for identification purposes only, and are the property of their respective owners. Additional information, including relevant terms and conditions, posted at www.skyworksinc.com, are incorporated by reference.