

**DATA SHEET**

# SE2435L: 860 to 930 MHz High-Power RF Front-End Module

## Applications

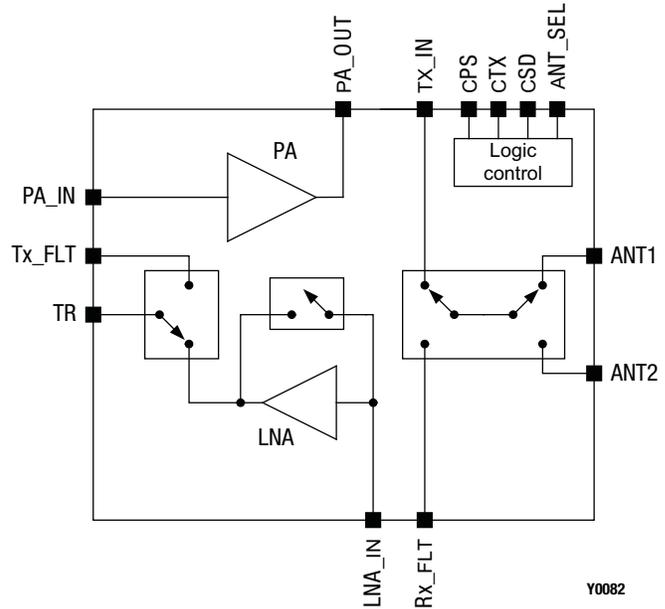
- Smart meters
- In-home appliances
- Smart thermostats
- Industrial applications

## Features

- Integrated PA with 30 dBm output power
- Integrated LNA with programmable bypass
- Integrated antenna switching with transmit/receive diversity function
- Low FEM noise figure of 2 dB, typical
- Single-ended 50 Ω transmit/receive RF interface
- Fast turn-on/turn-off time: < 1 μsec
- Supply voltage: 2.0 to 4.8 V
- Sleep mode current: < 1 μA
- QFN (24-pin, 4 x 4 x 0.9 mm) NiPdAu plated 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 1. SE2435L Block Diagram**

## Description

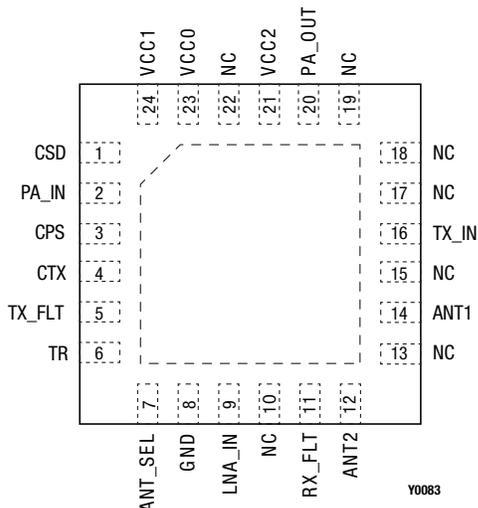
The SE2435L is a high-performance, highly integrated RF Front-End Module designed for high-power Industrial, Scientific, Medical (ISM) band applications operating in the 860 to 930 MHz frequency range.

The SE2435L is designed for ease of use and maximum flexibility with fully matched 50 Ω input and output, and digital controls compatible with 1.6 to 3.6 V CMOS levels.

The RF blocks operate over a wide supply voltage range from 2.0 to 4.8 V allowing the SE2435L to be used in battery powered applications over a wide spectrum of the battery discharge curve.

The SE2435L is packaged in a 24-pin, 4 x 4 mm Quad Flat No-Lead (QFN) package.

A functional block diagram of the SE2435L is provided in Figure 1. Figure 2 shows the pinout for the SE2435L. Table 1 lists the pin assignments. Table 2 provides the absolute maximum ratings, and Table 3 shows the recommended operating conditions.



**Figure 2. SE2435L Pinout – 24-Pin QFN (Top View)**

**Table 1. SE2435L Signal Descriptions**

| Pin | Name    | Description                                  | Pin    | Name   | Description  |
|-----|---------|--|--------|--------|--|
| 1   | CSD     | Shutdown control input                       | 14     | ANT1   | Antenna port 1   |
| 2   | PA_IN   | PA input (from Tx filter)                    | 15     | NC     | Not connected internally to the device                                   |
| 3   | CPS     | Rx path select control input                 | 16     | TX_IN  | Tx signal to antennas (from OMN)   |
| 4   | CTX     | Transmit enable control input                | 17     | NC     | Not connected internally to the device                                   |
| 5   | TX_FLT  | Transmit signal (to Tx filter)               | 18     | NC     | Not connected internally to the device                                   |
| 6   | TR      | Bi-directional RF signal to/from transceiver | 19     | DNC    | Do not connect   |
| 7   | ANT_SEL | Antenna select control input                 | 20     | PA_OUT | PA output (to OMN)   |
| 8   | GND     | Ground                                       | 21     | VCC2   | Positive power supply  |
| 9   | LNA_IN  | LNA input (from Rx filter)                   | 22     | NC     | Not connected internally to the device                                   |
| 10  | NC      | Not connected internally to the device       | 23     | VCC0   | Positive power supply  |
| 11  | RX_FLT  | Rx signal from antennas (to Rx filter)       | 24     | VCC1   | Positive power supply  |
| 12  | ANT2    | Antenna port 2                               | Paddle | GND    | Exposed die paddle; electrical and thermal ground. Connect to PCB ground |
| 13  | NC      | Not connected internally to the device       |        |        |  |

**Table 2. SE2435L Absolute Maximum Ratings (Note 1)**

| Parameter  | Symbol                 | Minimum | Maximum | Units |
|--|------------------------|---------|---------|-------|
| Supply voltage (no RF)                                       | V <sub>CC</sub>        | -0.3    | 5.5     | V     |
| Operating temperature  | T <sub>A</sub>         | -40     | 85      | °C    |
| Storage temperature  | T <sub>STG</sub>       | -40     | 125     | °C    |
| Tx input power at TR port                                    | P <sub>IN_TX_MAX</sub> |         | +10     | dBm   |
| Rx input power at ANT1 or ANT2 ports                         | P <sub>IN_RX_MAX</sub> |         | +10     | dBm   |
| Electrostatic discharge:<br>Human Body Model (HBM), Class 1C | ESD                    |         | 1000    | V     |

**Note 1:** 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. SE2435L Recommended Operating Conditions**

| Parameter             | Symbol          | Minimum | Typical | Maximum | Units |
|-----------------------|-----------------|---------|---------|---------|-------|
| Supply voltage on VCC | V <sub>CC</sub> | 2.0     | 4.0     | 4.8     | V     |
| Ambient temperature   | T <sub>A</sub>  | -40     | +25     | +85     | °C    |

## Electrical and Mechanical Specifications

Electrical specifications are provided in Tables 4 through 9.

**Table 4. SE2435L DC Electrical Specifications: (Note 1)**  
(V<sub>CC</sub> = 4.0 V, T<sub>A</sub> = +25 °C, Unless Otherwise Noted)

| Parameter                                 | Symbol               | Test Condition             | Min | Typical | Max  | Units |
|---|----------------------|----------------------------|-----|---------|------|-------|
| Total supply current, transmit mode       | I <sub>CC_TX30</sub> | P <sub>OUT</sub> = +30 dBm |     | 550     |      | mA    |
|   | I <sub>CC_TX27</sub> | P <sub>OUT</sub> = +27 dBm |     | 380     |      | mA    |
|   | I <sub>CC_TX24</sub> | P <sub>OUT</sub> = +24 dBm |     | 275     |      | mA    |
| Total supply current, receive mode        | I <sub>CC_RX</sub>   |                            |     | 6       |      | mA    |
| Total supply current, receive bypass mode | I <sub>CC_RXB</sub>  |                            |     |         | 280  | μA    |
| Quiescent current                         | I <sub>CC_TX</sub>   | No RF                      |     | 50      |      | mA    |
| Sleep supply current                      | I <sub>CC_OFF</sub>  | No RF                      |     | 0.05    | 1.00 | μA    |

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

**Table 5. SE2435L Electrical Specifications: Control Logic Characteristics (Note 1)**  
(T<sub>A</sub> = +25 °C, Unless Otherwise Noted)

| Parameter        | Symbol                             | Test Condition | Min      | Typical | Max                             | Units    |
|------------------|------------------------------------|----------------|----------|---------|---------------------------------|----------|
| Control voltage: | V <sub>IH</sub><br>V <sub>IL</sub> |                | 1.6<br>0 |         | V <sub>CC</sub> (Note 2)<br>0.3 | V<br>V   |
|                  |                                    |                |          |         |                                 |          |
| Input current:   | I <sub>IH</sub><br>I <sub>IL</sub> |                |          |         | 1<br>1                          | μA<br>μA |
|                  |                                    |                |          |         |                                 |          |
| Low              |                                    |                |          |         |                                 |          |

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

**Note 2:** For Pin 7, ANT\_SEL, the maximum is 3.6 V.

**Table 6. SE2435L Electrical Specifications: Mode Control Logic (T<sub>A</sub> = +25)**

| Mode                       | CPS | CSD | CTX | ANT_SEL |
|----------------------------|-----|-----|-----|---------|
| Sleep (all off)            | 0   | 0   | 0   | X       |
| Receive or transmit bypass | 0   | 1   | 0   | X       |
| Receive LNA mode           | 1   | 1   | 0   | X       |
| Transmit                   | X   | 1   | 1   | X       |
| ANT1 port enabled          | X   | X   | X   | 0       |
| ANT2 port enabled          | X   | X   | X   | 1       |

**Note 1:** "1" = 1.6 to V<sub>CC</sub>, "0" = 0 to 0.3 V, "X" = don't care.

**Table 7. SE2435L Electrical Specifications: AC Transmit Mode**  
**(Vcc = 4 V, Ta = +25 °C, All Unused Ports Terminated at 50 Ω, Unless Otherwise Noted. Input Port TR, Output Ports ANT1 and ANT2 Lumped Elements Filter Connected between the TX\_FLT and PA\_IN Pins)**

| Parameter  | Symbol      | Test Condition   | Min  | Typical                      | Max | Units                    |
|--|-------------|--|--|------------------------------|-----|--------------------------|
| Frequency range  | f           |  | 860  |                              | 930 | MHz                      |
| Output power at ANT1 or ANT2 ports in the 900 to 930 MHz frequency range (Notes 1 and 5) | POUT_900    | Vcc = 4.8 V<br>Vcc = 4.0 V<br>Vcc = 3.6 V<br>Vcc = 3.0 V |  | 31.5<br>30.5<br>29.5<br>28.0 |     | dBm<br>dBm<br>dBm<br>dBm |
| Output power at ANT1 or ANT2 ports in the 860 to 870 MHz frequency range (Notes 2 and 5) | POUT_860    | Vcc = 4.0 V<br>Vcc = 3.6 V<br>Vcc = 3.0 V<br>Vcc = 2.0 V |  | 27<br>24<br>21<br>18         |     | dBm<br>dBm<br>dBm<br>dBm |
| PA power added efficiency  | PAE_PA      | POUT = 28 dBm at PA_OUT port, 915 MHz                    |  | 64                           |     | %                        |
| Small signal gain (Note 1)   | S21_900     | 900 to 930 MHz   | 26   |                              |     | dB                       |
| Small signal gain (Note 2)   | S21_860     | 860 to 870 MHz   | 26   |                              |     | dB                       |
| Small signal gain variation (Notes 1 and 2)  | ΔS21        | Gain variation across frequency range                    |  |                              | 2   | dBp-p                    |
| Output return loss (Notes 1 and 2)   | S22ANT1,2   | Into 50 Ω, ANT1 and ANT2 ports                           |  | -10                          | -6  | dB                       |
| 2 <sup>nd</sup> harmonic (Notes 1 and 3)   | 2fo         | POUT = 30 dBm  |  |                              | -22 | dBc                      |
| 3 <sup>rd</sup> to 10 <sup>th</sup> harmonic (Notes 1 and 3)                             | 3fo to 10fo | POUT = 30 dBm  |  |                              | -72 | dBc                      |
| Turn on time (Note 4)  | TON         |  |  |                              | 1   | μs                       |
| Turn off time (Note 5)   | TOFF        |  |  |                              | 1   | μs                       |
| Stability  | STAB        | CW, PIN = 0 dBm<br>0.1 GHz to 20 GHz<br>load VSWR = 6:1  | All non-harmonically related outputs less than -43 dBm |                              |     |                          |
| Ruggedness   | RU          | CW, POUT = 30 dBm into 50 Ω, load VSWR = 10:1            | No permanent damage                                    |                              |     |                          |

**Note 1:** 900 to 930 MHz with specified matching network on the Evaluation Board.

**Note 2:** 860 to 870 MHz with specified matching network on the Evaluation Board.

**Note 3:** Measured with continuous wave signal.

**Note 4:** From 50% of CTX edge to 90% of final RF output power.

**Note 5:** From 50% of CTX edge to 10% of final RF output power.

**Table 8. SE2435L Electrical Specifications: AC Receive Mode**

(V<sub>cc</sub> = 4 V, T<sub>A</sub> = +25 °C, f = 900 to 930 MHz and 860 to 870 MHz, All Unused Ports Terminated at 50 Ω, Unless Otherwise Noted. Input Port ANT1 or ANT2, Output Port TR. 0 Ω Connected between the RX\_FLT and LNA\_IN Pins in lieu of External Filters)

| Parameter                                   | Symbol                | Test Condition                 | Min | Typical | Max | Units |
|---|-----------------------|--------------------------------|-----|---------|-----|-------|
| Frequency range                             | FIN                   |                                | 860 |         | 930 | MHz   |
| Receive gain                                | RX_GAIN               |                                | 14  | 16      | 18  | dB    |
| Receive noise figure                        | NF                    |                                |     | 2       | 2.5 | dB    |
| Input 3 <sup>rd</sup> order intercept       | IIP3                  |                                | -5  | -2      |     | dBm   |
| Input 1-dB compression point                | IP1dB                 |                                | -15 | -12     |     | dBm   |
| Antenna port return loss                    | S11 <sub>ANT1,2</sub> | Into 50 Ω, ANT1 and ANT2 ports |     | -12     | -8  | dB    |
| Turn on time (Note 1)                       | T <sub>ON</sub>       |                                |     |         | 1   | us    |
| Turn off time (Note 2)                      | T <sub>OFF</sub>      |                                |     |         | 1   | us    |
| Gain in bypass mode                         | G <sub>bp</sub>       |                                | -3  | -2      |     | dB    |
| Input 1-dB compression point in bypass mode | IP1dB                 |                                | +10 |         |     | dBm   |

**Note 1:** From 50% of CTX edge to 90% of final RF output power.

**Note 2:** From 50% of CTX edge to 10% of final RF output power.

**Table 9. SE2435L DC Electrical Specifications: Diversity Antenna Function**

(V<sub>cc</sub> = 4 V, T<sub>A</sub> = +25 °C, f = 900 to 930 MHz and 860 to 870 MHz, All Unused Ports Terminated at 50 Ω, Unless Otherwise Noted)

| Parameter                                 | Symbol        | Min | Typical | Max | Units |
|---|---------------|-----|---------|-----|-------|
| Isolation between ANT1 and ANT2 ports     | ISOLANTSW     |     | -20     |     | dB    |
| Insertion loss from TX_IN to ANT1         | TX_ANT1       |     | 0.8     |     | dB    |
| Insertion loss from TX_IN to ANT2         | TX_ANT2       |     | 0.8     |     | dB    |
| Insertion loss from ANT1 to RX_FLT        | RX_ANT1       |     | 0.6     |     | dB    |
| Insertion loss from ANT2 to RX_FLT        | RX_ANT2       |     | 0.6     |     | dB    |
| Insertion loss from TR to TX_FLT          | TxRx_Tx       |     | 0.5     |     | dB    |
| ANT1 to ANT2 switching time transmit mode | TANT1-ANT1_TX |     | 800     |     | ns    |
| ANT1 to ANT2 switching time receive mode  | TANT1-ANT2_RX |     | 400     |     | ns    |

### Evaluation Board Description

The SE2435L-EK1 Evaluation is to demonstrate the performance of the SE2435L Front-End Module. It is optimized for evaluation, experimentation and investigation, using CW (continuous wave) signals.

Figure 3 shows the Evaluation Board photo. The Evaluation Board schematic diagram is provided in Figure 4. The Bill of Materials (BOM) for the SE2435L Evaluation Board is listed in Table 10.

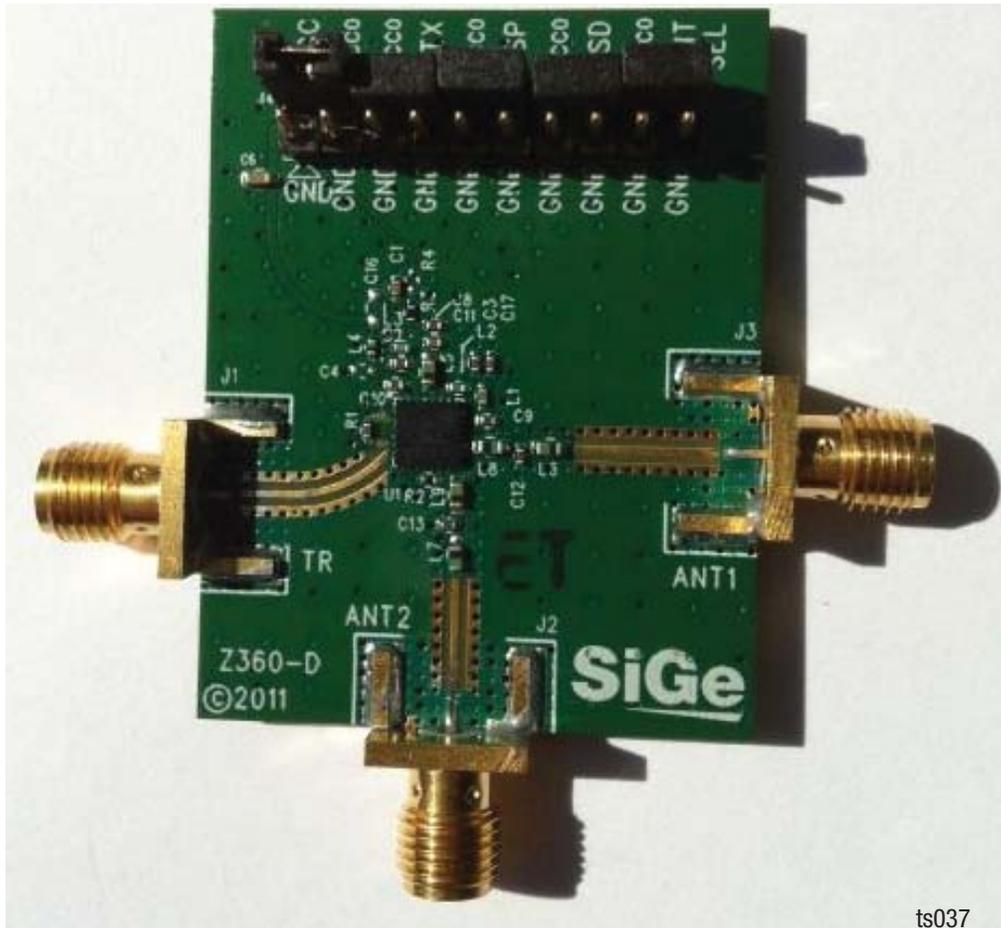


Figure 3. SE2435L Evaluation Board Photo

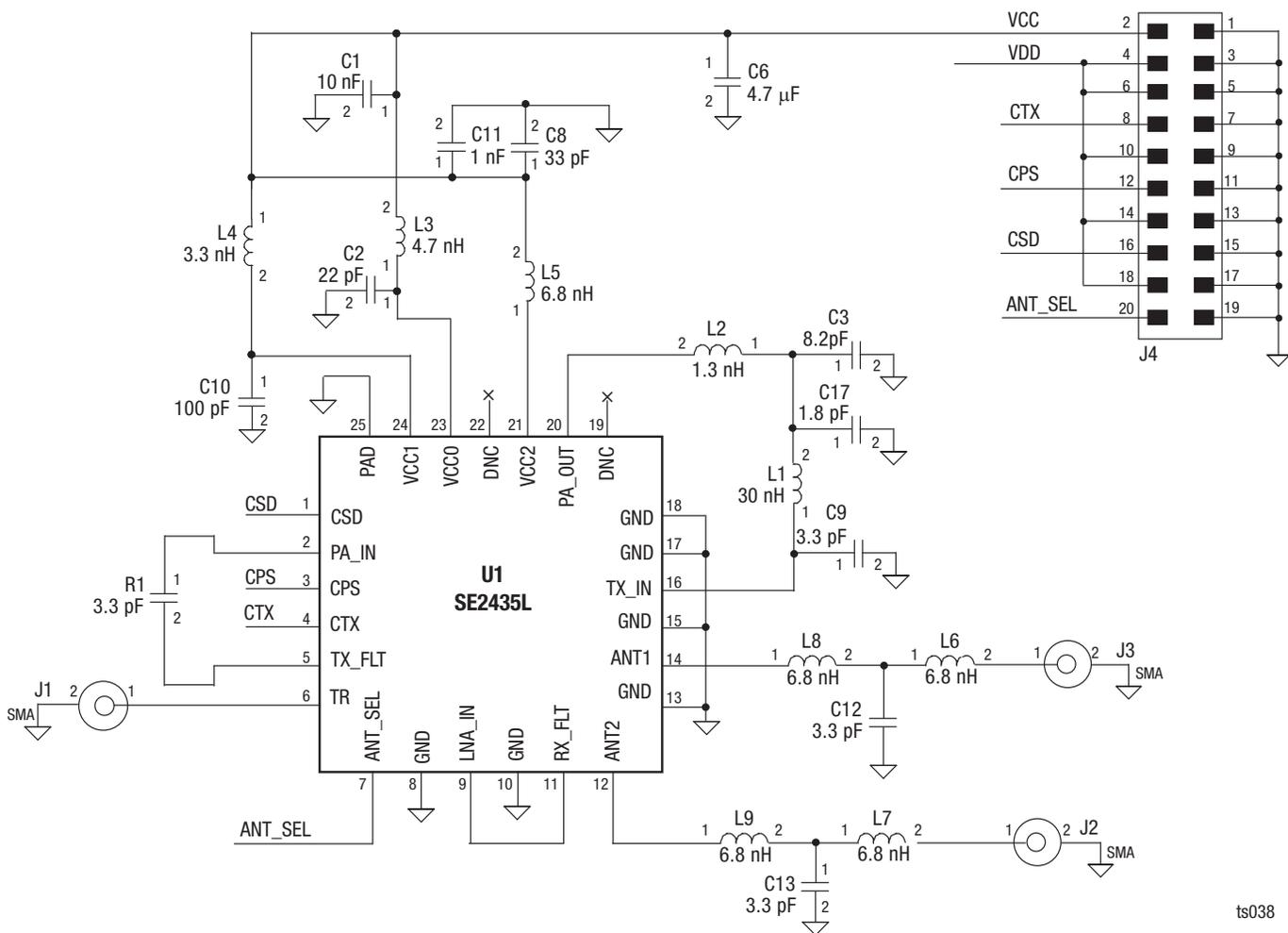


Figure 4. Evaluation Board Schematic

ts038

**Table 10. SE2435L Evaluation Board Bill of Materials (Note 1, Note 2)**

| Component          | Part Number       | Description   | Value   | Package    | Manufacturer       |
|--------------------|-------------------|---|---------|------------|--------------------|
| L2                 | LQG15HN1N3S02D    | High frequency multilayer                             | 1.3 nH  | 0402       | Murata             |
| C17                | GRM1555C1H1R8CZ01 | Multilayer ceramic                                    | 1.8 pF  | 0402       | Murata             |
| C11                | GRM155R71H102KA01 | Multilayer ceramic                                    | 1 nF    | 0402       | Murata             |
| L1                 | LQG15HN3N0S02D    | High frequency multilayer                             | 3.0 nH  | 0402       | Murata             |
| L4                 | LQG15HN3N3S02D    | High frequency multilayer                             | 3.3 nH  | 0402       | Murata             |
| L3                 | LQG15HN4N7S02D    | High frequency multilayer                             | 4.7 μF  | 0402       | Murata             |
| C6                 | GRM188R60J475KE19 | Multilayer ceramic                                    | 4.7 μF  | 0603       | Murata             |
| C3                 | GRM1555C1H8R2DZ01 | Multilayer ceramic                                    | 8.2 pF  | 0402       | Murata             |
| C1                 | GRM155R71E103KA01 | Multilayer ceramic                                    | 10 nF   | 0402       | Murata             |
| J4                 | TSW-110-07-G-D    | 100mil Header   | 10X2    | 100 mil    | Samtec             |
| C2                 | GRM1555C1H220JZ01 | Multilayer ceramic                                    | 22 pF   | 0402       | Murata             |
| C8                 | GRM1555C1H330JZ01 | Multilayer ceramic                                    | 33 pF   | 0402       | Murata             |
| C10                | GRM1555C1H101JZ01 | Multilayer ceramic                                    | 100 pF  | 0402       | Murata             |
| U1                 | SE2435L           | 860 to 930 MHz high power RF FEM                      | SE2435L | QFN400x400 | Skyworks           |
| J1, J2, J3         | 142-0701-851      | SMA end launch straight jack receptacle – tab contact | SMA     | End launch | Johnson Components |
| C9, C12, C13, R1   | GRM1555C1H3R3CZ01 | Multilayer ceramic                                    | 3.3 pF  | 0402       | Murata             |
| L5, L6, L7, L8, L9 | LQG18HN6N8S00D    | High frequency multilayer                             | 6.8 nH  | 0603       | Murata             |

**Note 1:** Schematic and BOM has been designed to optimize performance with CW signals, 100% duty cycle.

**Note 2:** Harmonic filtering requirements can be relaxed with certain modulated signals.

### Evaluation Board Setup Procedure

This section provides the details required to setup the evaluation board and the test equipment for the SE2435L. Table 11 describes the pins on the Power and Control I/O Header J4. Note that it is recommended to use proper engineering connection practices by making RF and digital connections prior to turning on the power supply.

#### Connect Supply

1. Connect (J1, J2, and J3) to 50 Ω instruments. Terminate all unused ports (if applicable) with 50 Ω.
2. Connect the supply ground to Pin 1 of J4.
3. Connect 3.6 V or 4.0 V to Pin 2 of J4:  
The required RF path/antenna can be selected using the information in Table 6.

#### Measure Performance

- TX: The 860 to 930 MHz (depending on the region) amplifier performance can be monitored by applying an RF signal to connector J1 (TR), and monitoring the output power on connector J2 (ANT2) or J3 (ANT1).
- RX: The 860 to 930 MHz LNA performance can be monitored by applying an RF signal to connector J2 (ANT2) or J3 (ANT1), and monitoring the output signal on connector J1 (TR).

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

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**Table 11. Power and Control I/O Header (J4)**

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

### Package Dimensions

The layout footprint for the SE2435L is provided in Figure 5. Typical case markings are shown in Figure 6. Package dimensions for the SE2435L are shown in Figure 7, and tape and reel dimensions are provided in Figure 8.

### 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 SE2435L is rated to Moisture Sensitivity Level 1 (MSL1) at 260 °C. It can be used for lead or lead-free soldering. 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.

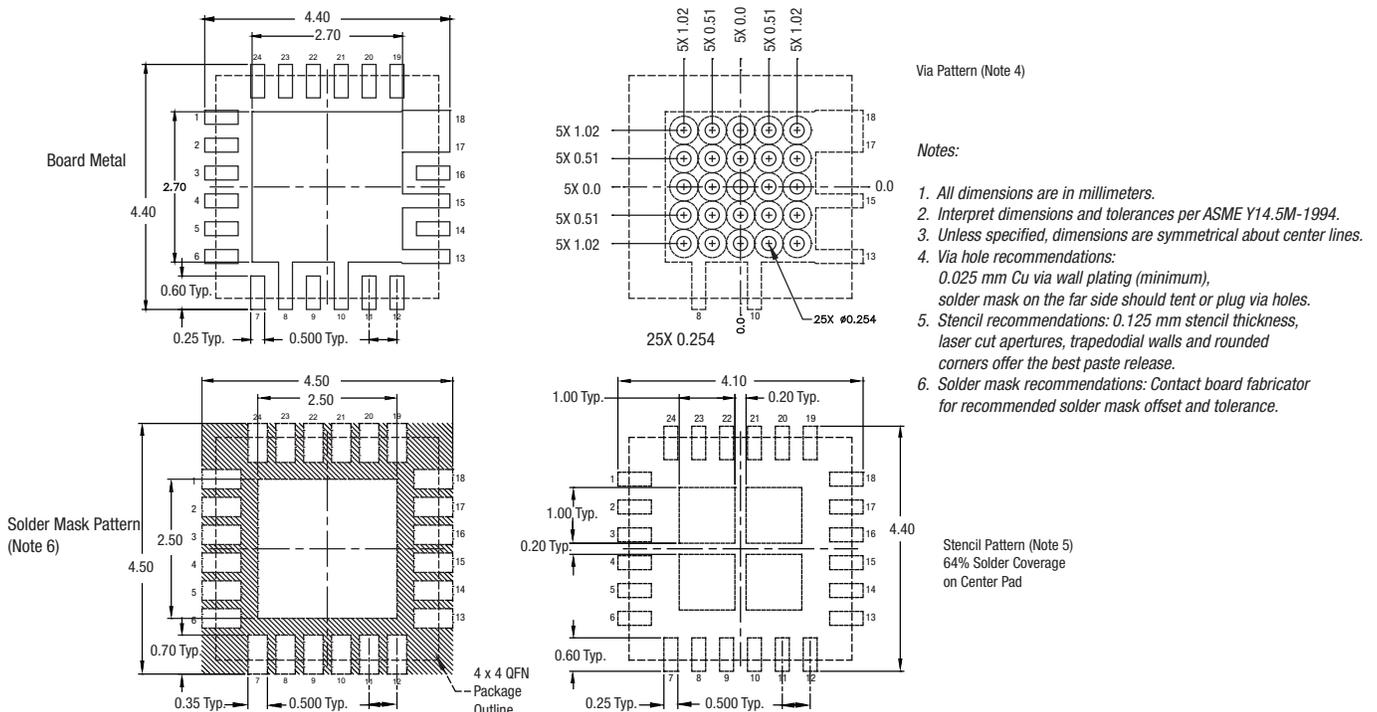
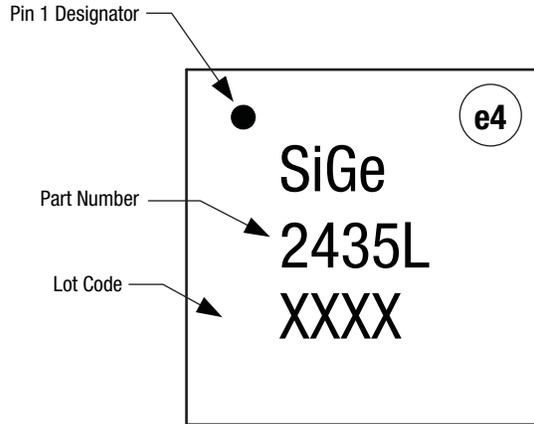
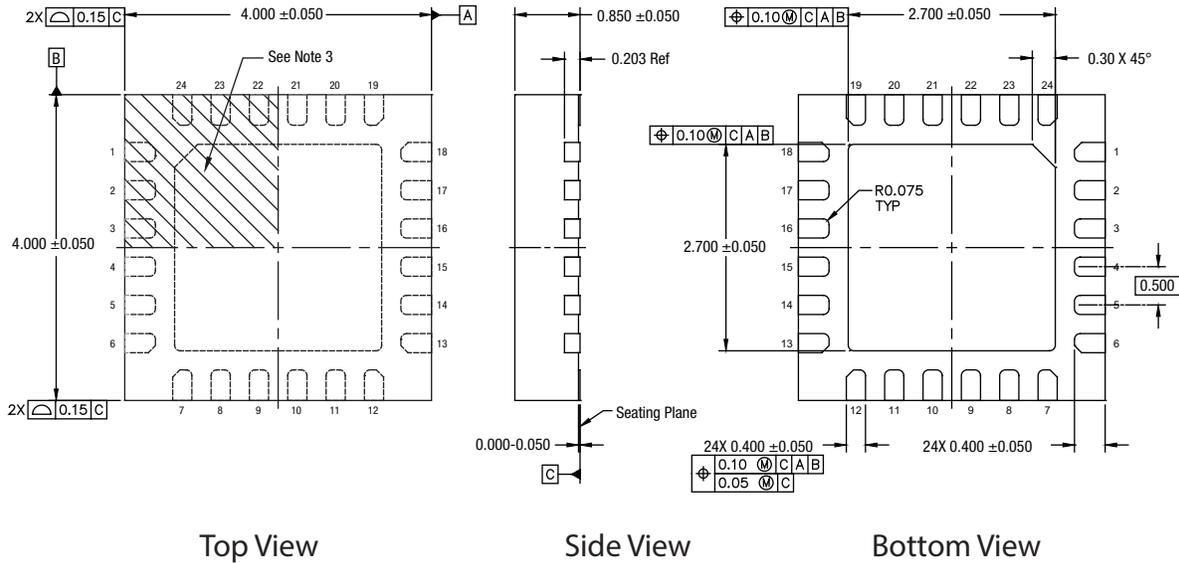


Figure 5. SE2435L Recommended Footprint (Top View)

Y0084



**Figure 6. Typical Case Markings (Top View)**

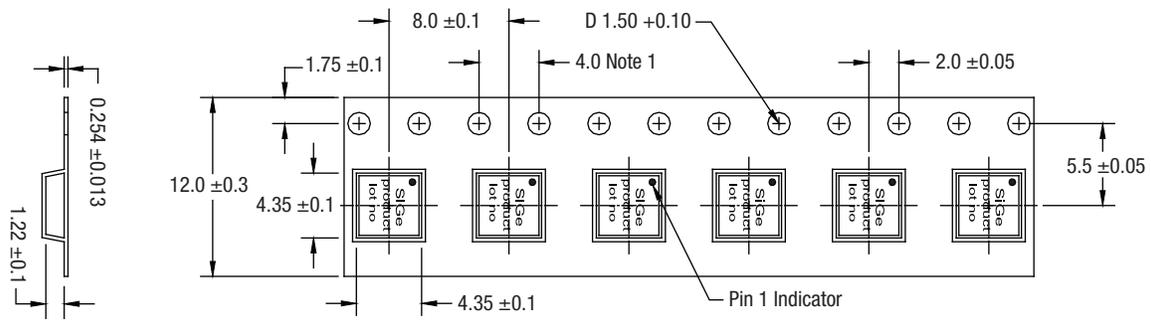


**Notes:**

1. Dimensions are in millimeters.
2. Interpret dimensions and tolerances per ASME Y14.5M-1994.  
 Unless otherwise specified, the following values apply:  
 Decimal tolerance: X.X (1 place) ± 0.1 mm  
 X.XX (2 places) ± 0.05 mm  
 X.XXX (3 places) ± 0.025 mm  
 Angular tolerance: ± 1°
3. Terminal #1 identification mark located within marked area.
4. Unless specified, dimensions are symmetrical about center lines.

Y0085

**Figure 7. SE2435L Package Dimensions**



Notes:

1. 10-Sprocket hole pitch cumulative tolerance  $\pm 0.2$ .
2. Camber in compliance with EIA-481.

Y0086

**Figure 8. SE2435L Tape and Reel Dimensions**

**Ordering Information**

| Model Name             | Manufacturing Part Number | Evaluation Board Part Number |
|------------------------|---------------------------|------------------------------|
| SE2435L-S<br>SE2435L-R |                           | SE2435L -EK1                 |

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