

## DATA SHEET

# SE2431L: 2.4 GHz Front-End Module

## Applications

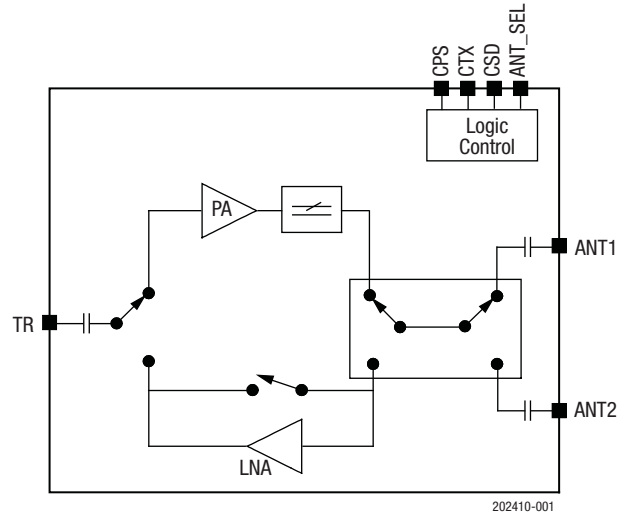
- Smart meters
- In-home appliances
- Smart thermostats

## Features

- Integrated:
  - PA with up to +24 dBm output power
  - LNA with programmable bypass
  - Antenna switching with Tx and Rx diversity function
- Suitable for ZigBee®, Bluetooth® Low Energy, and Bluetooth 1.0
- Typical low NF: 2 dB
- Operating temperature range: –40 °C to +125 °C
- Single-ended 50  $\Omega$  Tx/Rx RF interface
- Fast switch on/off time <1  $\mu$ s
- Supply operation: 2.0 V to 3.6 V
- Sleep mode current: 0.05  $\mu$ A typical
- Small QFN (24-pin, 3.0 mm x 4.0 mm x 0.9 mm Nickel-Palladium-gold [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. SE2431L Block Diagram**

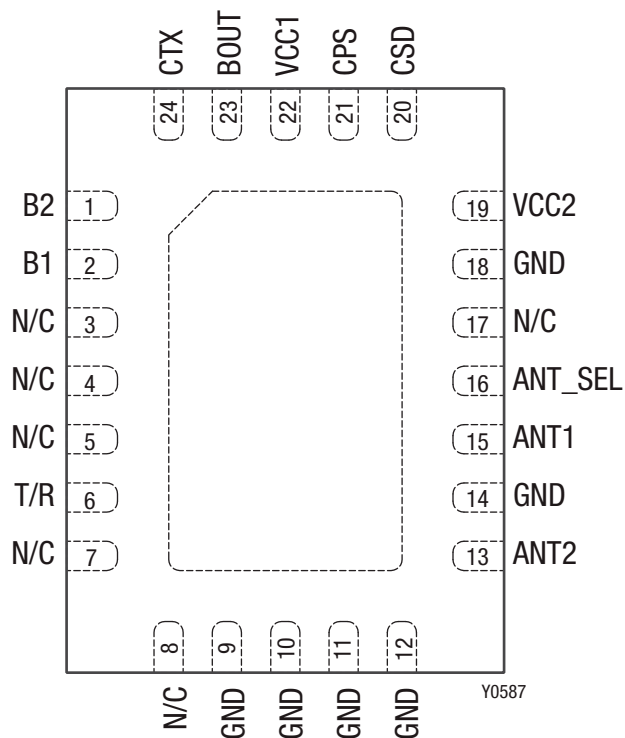
## Description

The SE2431L is a high-performance, fully integrated RF front-end module (FEM), suitable for ZigBee, Bluetooth Low Energy, and Bluetooth 1.0 applications.

The SE2431L is designed for ease of use and maximum flexibility, with fully matched 50  $\Omega$  input and output, 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 3.6 V, which allows the SE2431L 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.



**Figure 2. SE2431L Pinout  
(Top View)**

**Table 1. SE2431L Signal Descriptions**

Pin	Name	Description	Pin	Name	Description
1	B2	Connect through the bias resistor to pin 23	13	ANT2	Connect to 50 $\Omega$ antenna
2	B1	Connect through the bias resistor to pin 23	14	GND	Connect to PCB ground
3	N/C	Not connected internally to the device	15	ANT1	Connect to 50 $\Omega$ antenna
4	N/C	Not connected internally to the device	16	ANT_SEL	Connect to the GPIO signal to control the antenna switch (see Table 8)
5	N/C	Not connected internally to the device	17	N/C	Not connected internally to the device
6	T/R	Transmit/receive port from/to transceiver, single-ended 50 $\Omega$	18	GND	Connect to PCB ground
7	N/C	Not connected internally to the device	19	VCC2	Connect to positive supply
8	N/C	Not connected internally to the device	20	CSD	Connect to the GPIO signal to control the SE2431L modes (see Table 8)
9	GND	Connect to PCB ground	21	CPS	Connect to the GPIO signal to control the SE2431L modes (see Table 8)
10	GND	Connect to PCB ground	22	VCC1	Connect to positive supply
11	GND	Connect to PCB ground	23	BOUT	Connect to pins 1 and 2 through the bias resistors
12	GND	Connect to PCB ground	24	CTX	Connect to the GPIO signal to control the SE2431L modes (see Table 8)

## Electrical and Mechanical Specifications

The absolute maximum ratings of the SE2431L are provided in Table 2. The recommended operating conditions are specified in Table 3, and electrical specifications are provided in Tables 4 through 7.

The state of the SE2431L is determined by the logic provided in Table 8.

**Table 2. SE2431L Absolute Maximum Ratings<sup>1</sup>**

Parameter	Symbol	Minimum	Maximum	Units
Supply voltage 1	V <sub>CC1</sub>	−0.3	3.6	V
Supply voltage 2	V <sub>CC2</sub>	−0.3	3.6	V
Control pin voltages		−0.3	3.6	V
Operating temperature	T <sub>OP</sub>	−40	+125	°C
Storage temperature	T <sub>STG</sub>	−40	+125	°C
Tx output power at ANT1 or ANT2 port into 50 Ω load	P <sub>OUT_TX_MAX</sub>		+24	dBm
Tx input power at TR port	P <sub>IN_TX_MAX</sub>		+6	dBm
Rx input power at ANT1 or ANT2 ports	P <sub>IN_RX_MAX</sub>		+10	dBm
Rx input power at ANT1 or ANT2 ports in bypass mode	P <sub>IN_RX_BYPASS_MAX</sub>		+15	dBm
Thermal resistance	Θ <sub>JC</sub>		40	°C/W
Electrostatic discharge: Human Body Model (HBM), Class 1C	ESD		1000	V

<sup>1</sup> 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.

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**ESD HANDLING:** *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 when handling or transporting. Static charges may easily produce potentials of several kilovolts on the human body or equipment, which can discharge without detection. Industry-standard ESD handling precautions should be used at all times.*

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**Table 3. Recommended Operating Conditions**

Parameter	Symbol	Minimum	Typical	Maximum	Units
Ambient temperature	T <sub>A</sub>	−40	+25	+125	°C
Supply voltage on VCC pins	V <sub>CC1</sub>	2.0	3.0	3.6	V
Supply voltage on VCC pins	V <sub>CC2</sub>	2.0	3.0	3.6	V

**Table 4. SE2431L Electrical Specifications: DC<sup>1</sup>****(VCC = 3 V, TA = +25 °C, as 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 <sub>CC_TX20</sub>	Tx mode P <sub>OUT</sub> = +20 dBm		115		mA
Total supply current <sup>2</sup>	I <sub>CC_TX17</sub>	Tx mode P <sub>OUT</sub> = +17 dBm		90		mA
Total supply current <sup>2</sup>	I <sub>CC_TX10</sub>	Tx mode P <sub>OUT</sub> = +10 dBm		50		mA
Quiescent current	I <sub>CO_TX</sub>	No RF		30		mA
Total supply current	I <sub>CC_RX</sub>	Rx mode		5	7	mA
Total supply current	I <sub>CC_RXBYPASS</sub>	Rx Bypass mode			300	μA
Sleep supply current	I <sub>CC_OFF</sub>	No RF		0.05	1.0	μA

<sup>1</sup> Performance is guaranteed only under the conditions listed in the above table.<sup>2</sup> Guaranteed by characterization.**Table 5. SE2431L Electrical Specifications: Logic Characteristics<sup>1</sup>****(VCC = 3 V, TA = +25 °C, as 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 <sup>2</sup>	V <sub>IH</sub>		1.6		3.6	V
Logic input low voltage <sup>2</sup>	V <sub>IL</sub>		0		0.3	V
Logic input high current <sup>2</sup>	I <sub>IH</sub>				1	μA
Logic input low current <sup>2</sup>	I <sub>IL</sub>				1	μA

<sup>1</sup> Performance is guaranteed only under the conditions listed in the above table.<sup>2</sup> Guaranteed by characterization.

**Table 6. SE2431L Electrical Specifications: AC Characteristics<sup>1</sup>**

(VCC = 3 V, TA = +25 °C, as Measured on Skyworks SE2431L-EK1 Evaluation Board [De-Embedded to the Device], All Unused Ports Terminated with 50 Ω, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Transmit (Tx)						
Frequency range	f <sub>IN</sub>		2400		2483	MHz
Output power at ANT1 or ANT2 ports	P <sub>OUT</sub>	VCC = +3.6 V, P <sub>IN</sub> = +3 dBm <sup>5</sup> VCC = +3.3 V, P <sub>IN</sub> = 0 dBm <sup>5</sup> VCC = +3.0 V, P <sub>IN</sub> = 0 dBm VCC = +2.7 V, P <sub>IN</sub> = 0 dBm <sup>5</sup> VCC = +2.0 V, P <sub>IN</sub> = 0 dBm VCC = +3.0 V, P <sub>IN</sub> = -13 dBm <sup>5</sup>		+24.0 +22.5 +21.0 +20.5 +17.0 +10		dBm dBm dBm dBm dBm dBm
Small signal gain	S <sub>21</sub>	2400 MHz to 2483 MHz, P <sub>IN</sub> = -25 dBm	19	22	25	dB
Small signal gain variation	ΔS <sub>21</sub>	2400 to 2483 MHz			2	dBp-p
Saturated gain variation <sup>5</sup>	ΔG <sub>SAT</sub>	2400 to 2483 MHz			1	dBp-p
Harmonics <sup>2</sup>	H <sub>D2</sub> H <sub>D3</sub> <sup>5</sup>	P <sub>OUT</sub> = +20 dBm P <sub>OUT</sub> = +20 dBm			-42 -42	dBm/MHz dBm/MHz
Output return loss <sup>5</sup>	S <sub>22_ANT</sub>	At ANT1 or ANT2 ports		-10	-5	dB
Input return loss <sup>5</sup>	S <sub>11</sub>	At TR port, Tx mode			-5	dB
Rise and fall times <sup>5</sup>	t <sub>r</sub> <sup>3</sup> t <sub>f</sub> <sup>4</sup>				800	ns
Stability <sup>5</sup>	STAB	CW, P <sub>IN</sub> = 0 dBm 0.1 GHz to 20.0 GHz Load VSWR = 6:1	All non-harmonically related outputs <-42.0 dBm/MHz			
Ruggedness <sup>5</sup>	RU	CW, P <sub>IN</sub> = +6 dBm, Load VSWR = 10:1	No permanent damage			
Receive (Rx)						
Frequency range	f <sub>IN</sub>		2400		2483	MHz
Receive gain	RX_GAIN		10.0	12.5	15.0	dB
Receive noise figure <sup>5</sup>	NF			2.0	2.5	dB
Third order input intercept point <sup>5</sup>	IIP3		-3	+2		dBm
LNA input compression point <sup>5</sup>	IP1dB		-13	-8		dBm
Antenna port return loss <sup>5</sup>	S <sub>11_ANT</sub>			-10	-5	dB
Output return loss <sup>5</sup>	S <sub>22</sub>	At TR port, Rx mode		-10	-5	dB
Rise and fall times <sup>5</sup>	t <sub>r</sub> <sup>3</sup> t <sub>f</sub> <sup>4</sup>				800	ns
Bypass gain	G_BP		-3	-2		dB
Tx or Rx Bypass 1 dB input compression point <sup>5</sup>	IP1dB		+15			dBm

<sup>1</sup> Performance is guaranteed only under the conditions listed in the above table.

<sup>2</sup> IEEE 802.15.4 source.

<sup>3</sup> From 50% of the CTX edge to 90% of the final RF output power.

<sup>4</sup> From 50% of the CTX edge to 10% of the final RF output power.

<sup>5</sup> Guaranteed by characterization.

**Table 7. SE2431L Electrical Specifications: AC Characteristics, Diversity Antenna Function<sup>1</sup>****(VCC1 = VCC2 = 3 V, T<sub>A</sub> = +25 °C, as 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
Isolation between ANT1 and ANT2 ports	ISOLANTSW		–20		dB
Antenna 1 to antenna 2 switching time <sup>2</sup>	t <sub>ANT1-ANT2</sub>		400		ns

<sup>1</sup> Performance is guaranteed only under the conditions listed in the above table. Unused antenna port should be connected to 50 Ω.<sup>2</sup> Guaranteed by characterization.**Table 8. SE2431L Logic Controls<sup>1</sup>****(V<sub>CC</sub> = 3 V, T<sub>A</sub> = +25 °C, Unless Otherwise Noted)**

Mode	Description	CPS	CSD	CTX	ANT_SEL
0	All off (sleep mode) <sup>2</sup>	0	0	0	X
1	Rx or Tx bypass mode	0	1	0	X
2	Rx LNA mode	1	1	0	X
3	Tx mode	X	1	1	X
	ANT1 port enabled	X	1	X	0
	ANT2 port enabled	X	1	X	1

<sup>1</sup> The logic 0 and 1 levels are compliant to V<sub>IL</sub> and V<sub>IH</sub>, respectively, as specified in Table 5.<sup>2</sup> All controls must be at logic 0 to achieve the specified sleep current.

## Evaluation Board Description

The SE2431L Evaluation Board is used to test the performance of the SE2431L front-end module (FEM). An Evaluation Board schematic diagram is provided in Figure 3. A reference design schematic is shown in Figure 4. A photograph of the Evaluation Board is shown in Figure 5. A Bill of Materials (BOM) for the Evaluation Board is provided in Table 9.

## Evaluation Board Setup Procedure

### Connect Supply

1. Connect J32, J34, and J35 to 50 Ω instruments. Terminate all unused ports (if applicable) with 50 Ω.
2. Connect the supply ground to pin 20 of the J36 header.
3. Connect 3.0 V to pins 1, 3, and 16 of J36.
4. Refer to Table 8 for information about selecting the required RF path and for antenna port control.

### Measure TX Performance

Apply an RF signal to connector J34 (TR) to monitor the 2.4 GHz amplifier performance. Monitor the output power on connector J35 (ANT1) or J32 (ANT2).

### Measure RX Performance

Apply an RF signal to connector J35 (ANT1) or J32 (ANT2) to monitor the 2.4 GHz LNA performance. Monitor the output signal on connector J34 (TR).

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**CAUTION:** Be careful not to overdrive the amplifier by applying too much RF on the input to the device. A suitable starting input power is –20 dBm.

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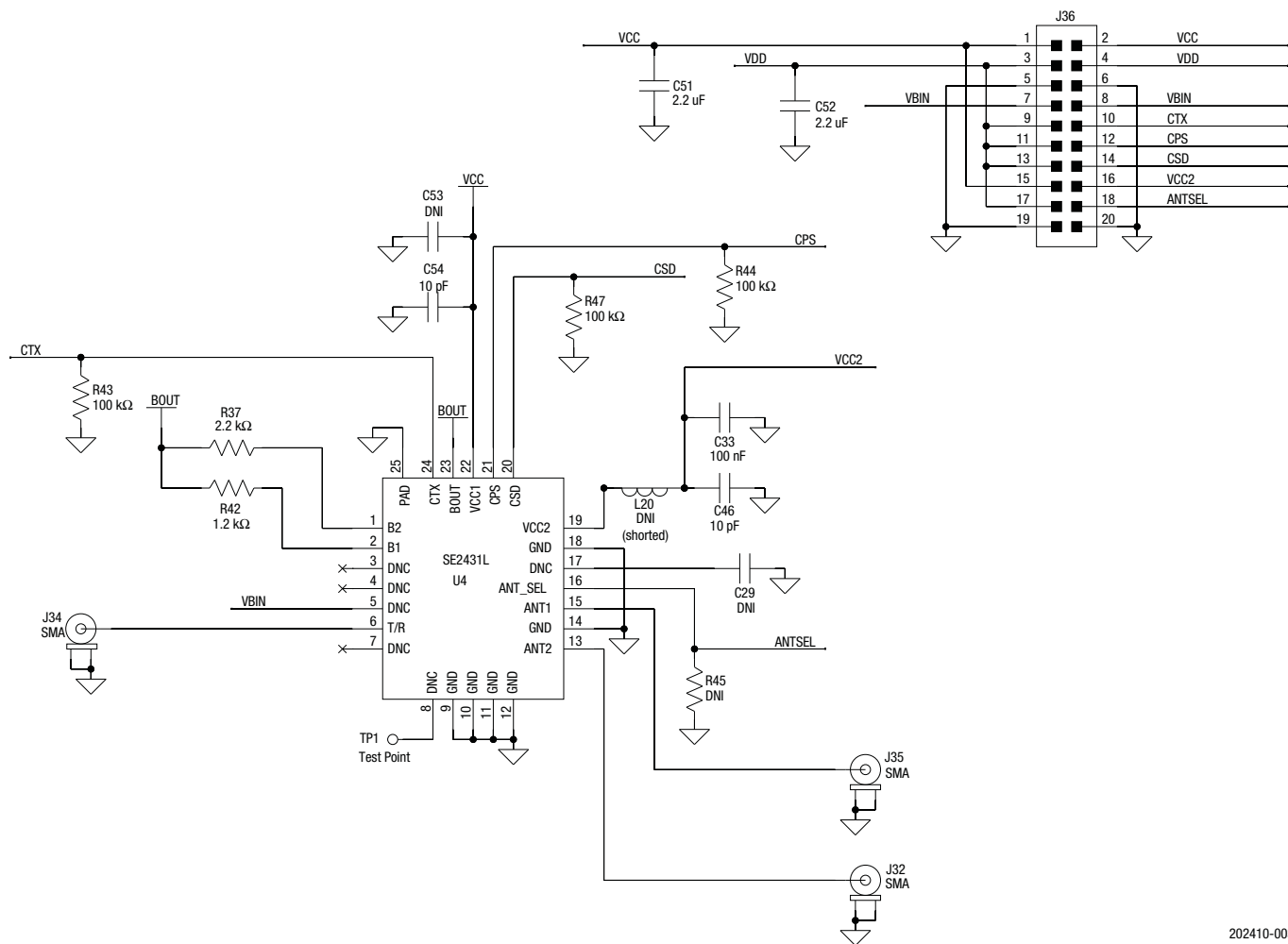


Figure 3. SE2431L Evaluation Board Schematic

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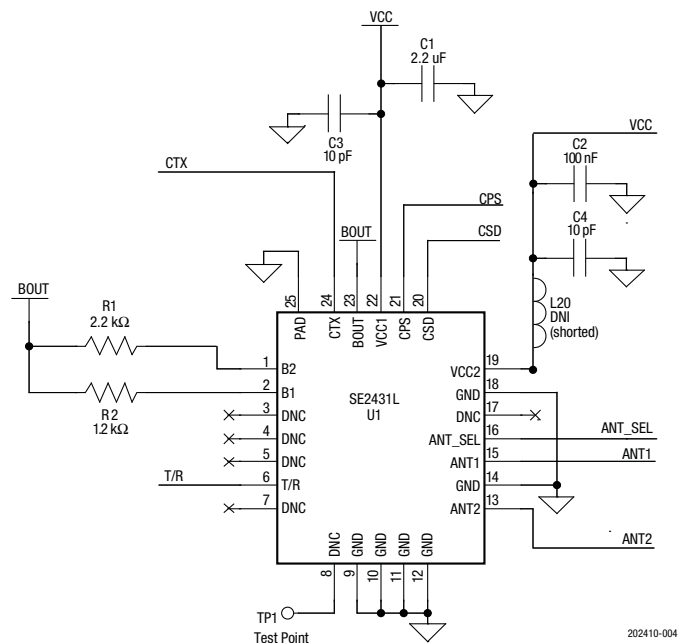


Figure 4. SE2431L Reference Design Schematic

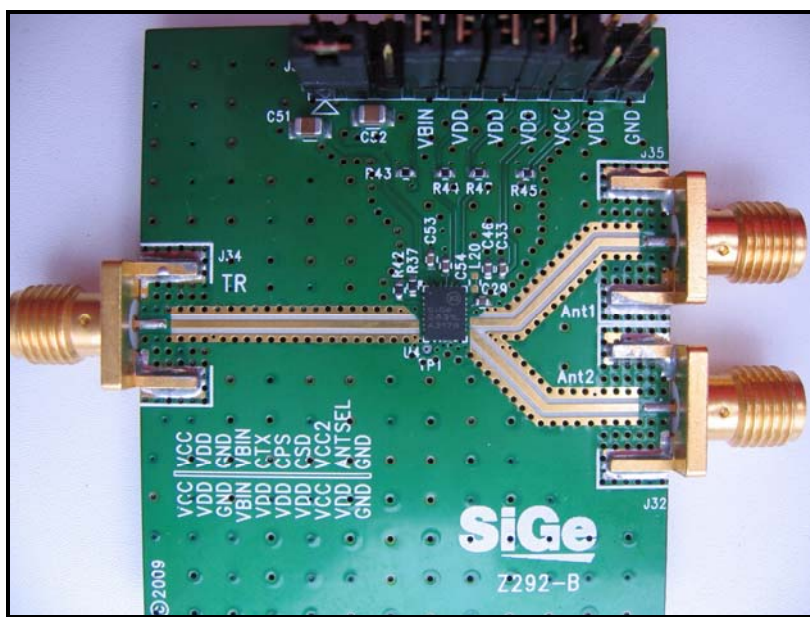


Figure 5. SE2431L Evaluation Board

**Notes to Figure 5:**

1. R44, R45, R43, R47, and C52 are for evaluation purposes and can be removed in the final application.
2. The Skyworks Evaluation Board contains 0 Ω resistors and footprints for non-populated components that are not shown in the schematic.
3. L20 is an 0402 SMT placement with the pads shorted together. This provides 3 mm of track between the Vcc2 pin and C46. It should be included in the application layout.



**Table 9. SE2431L Bill of Materials (BOM)**

Component	Value	Manufacturer	Mfr Part Number	Package Size	Description
R42	1.2 k $\Omega$	Panasonic	ERJ2GEJ122	0402	Thick film chip resistor
R37	2.2 k $\Omega$	Panasonic	ERJ2GEJ222	0402	Thick film chip resistor
J36	10X2	Samtec	TSW-110-07-G-D	100MIL	100 mil header
C33	100 nF	Murata	GRM155R71C104KA88D	0402	Monolithic ceramic
U4	SE2431L	Skyworks	Skyworks SE2431L	QFN400X300	2.5 GHz ZigBee front end
C51, C52	2.2 $\mu$ F	Murata	GRM21BR71A225KA01L	0805	Ceramic capacitor 2.2 $\mu$ F 10 V 10% X7R
C46, C54	10 pF	Murata	GRM1555C1H100JZ01	0402	Multilayer ceramic
R43, R44, R47	100 k $\Omega$	Panasonic	ERJ2GEJ104	0402	Thick film chip resistor
J32, J34, J35	SMA	Johnson Components	142-0701-851	End launch	SMA end launch straight jack receptacle - tab contact
C29, C53, R45	DNI	-	-	0402	Do not install
L20	Short	-	-	0402	Shorted 0402 footprint

## Package Dimensions

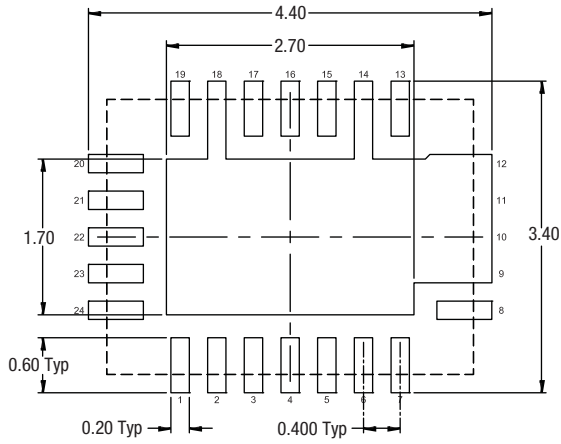
The PCB layout footprint for the SE2431L is provided in Figure 6. A typical part marking diagram is shown in Figure 7. Package dimensions are shown in Figure 8, and tape and reel dimensions are provided in Figure 9.

## Package and Handling Information

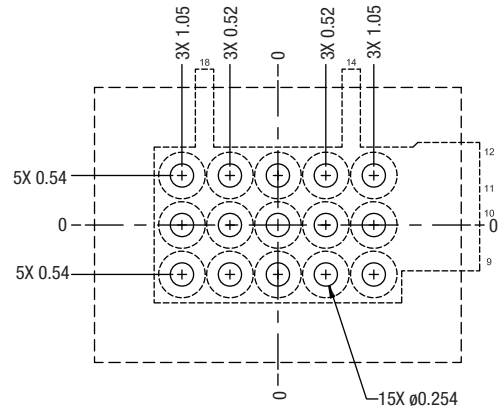
Instructions on the shipping container label regarding exposure to moisture after the container seal is broken must be followed. Otherwise, problems related to moisture absorption may occur when the part is subjected to high temperatures during solder assembly.

The SE2431L is rated to Moisture Sensitivity Level 1 (MSL1) at 260 °C, and can be used for lead or lead-free soldering. For additional information, refer to the Skyworks Application Note, *Solder Reflow Information*, document number 200164.

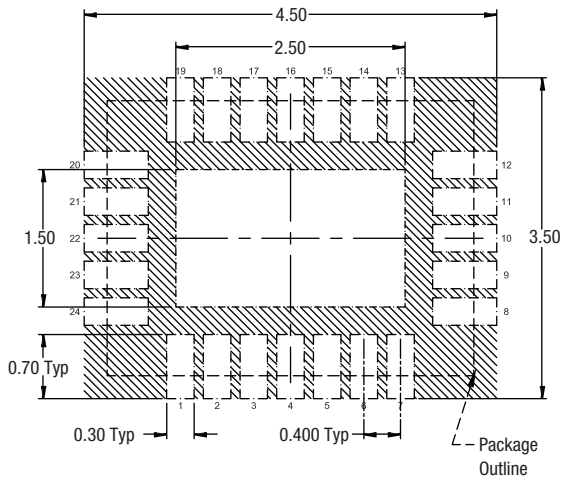
Care must be taken when attaching this product, whether it is done manually or in a production solder reflow environment. Production quantities of this product are shipped in a standard tape and reel format.



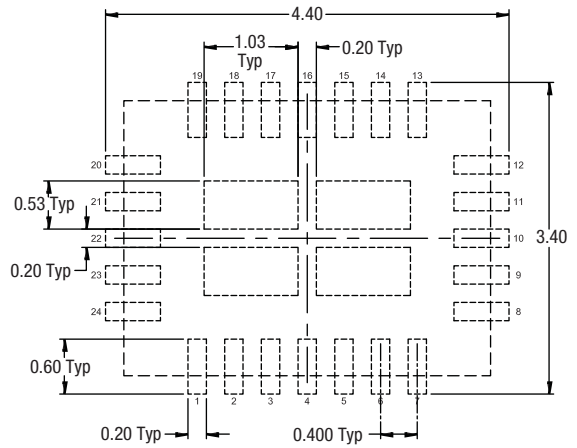
Board Metal



Via Pattern  
(Note 4)



Solder Mask Pattern  
(Note 6)



Stencil Pattern  
(Note 5)

57% Solder Coverage  
on Center Pad

Notes:

1. All dimensions are in millimeters.
2. Dimensions and tolerances per ASME 14.5M-1994.
3. Unless specified, dimensions are symmetrical about center lines.
4. Via hole recommendations:  
0.025 mm Cu via wall plating (minimum), via holes to be filled with conductive paste and plated over.
5. Stencil recommendations:  
0.10 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.

202410-006

Figure 6. PCB Layout Footprint

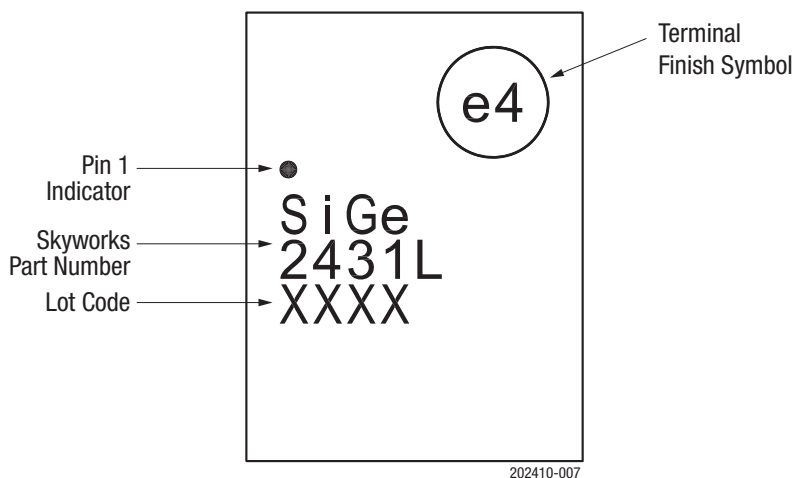


Figure 7. SE2431L Typical Part Marking

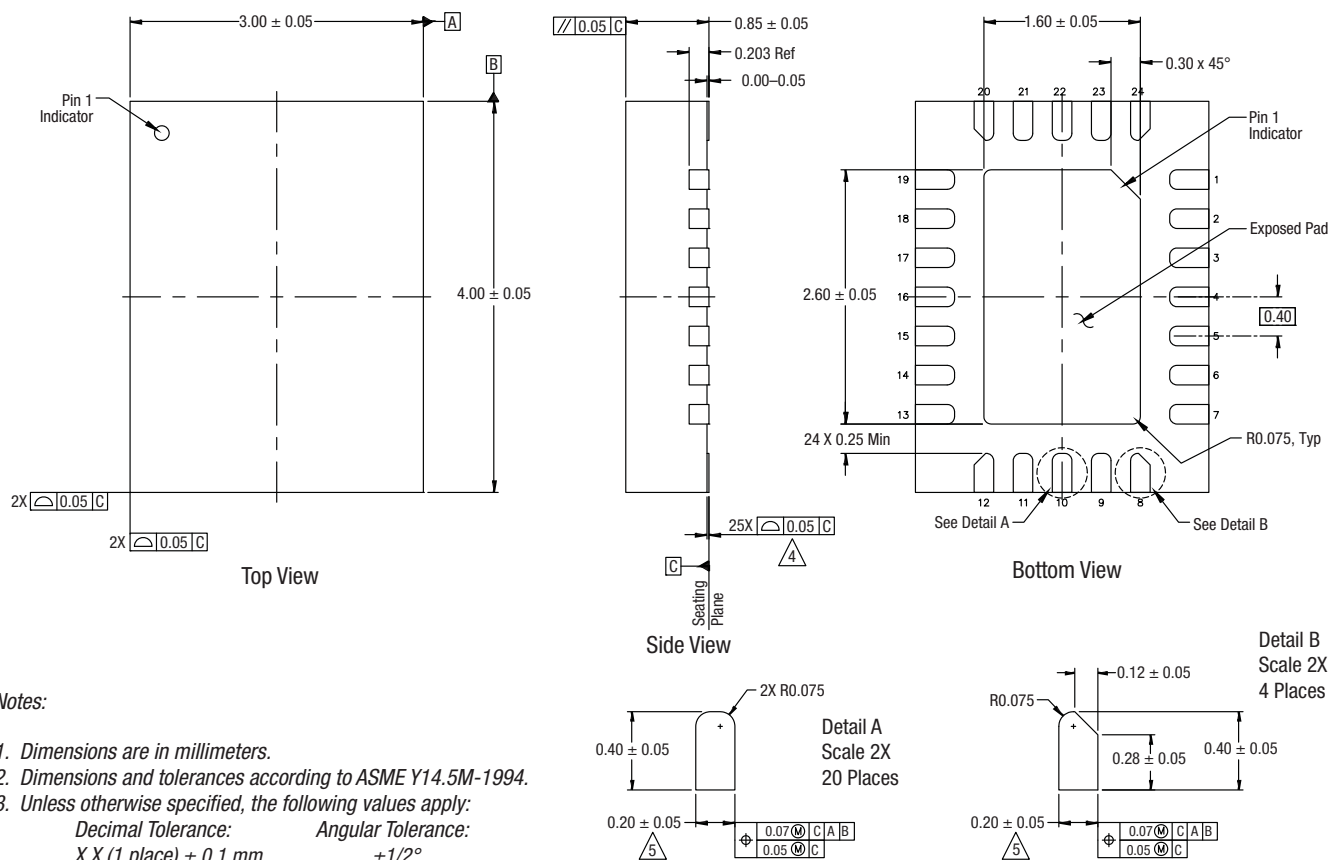
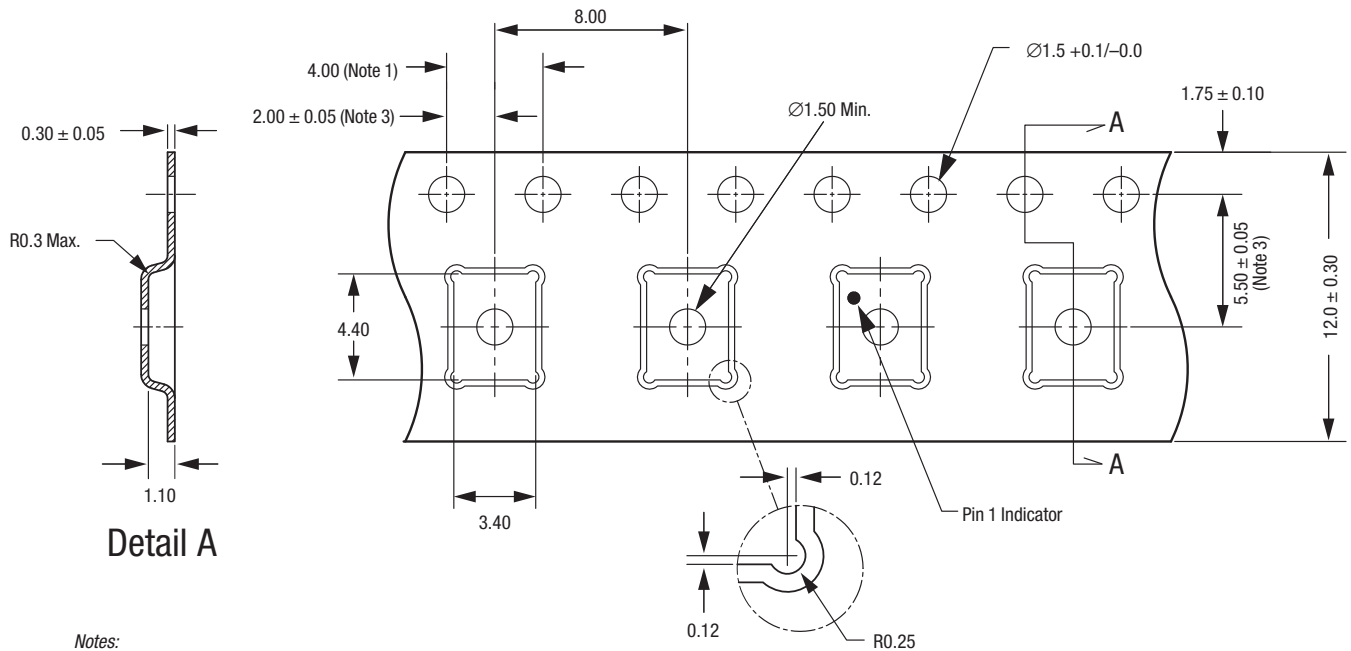


Figure 8. SE2431L Package Dimensions

202410-008



Notes:

1. 10 sprocket hole pitch cumulative tolerance  $\pm 0.2$  mm.
2. Camber in compliance with EIA 481.
3. Pocket position relative to sprocket hole measured as true position of pocket, not pocket hole.
4. All measurements are in millimeters.

202410-009

Figure 9. SE2431L Tape and Reel Dimensions

## Ordering Information

Model Name	Manufacturing Part Number	Evaluation Board Part Number
SE2431L: 2.4 GHz Front-End Module	SE2431L	SE2431L-EK1

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