

SE2435L: 860 to 930 MHz High-power RF Front-end Module

Applications

- Internet of Things
- 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 μ sec
- Supply voltage: 2.0 to 4.8 V
- Sleep mode current: < 1 μ A
- QFN (24-pin, 4 x 4 x 0.9 mm) NiPdAu plated package
- (MSL1, 260 °C per JEDEC J-STD-020)
- For RoHS and other product compliance information, see the [Skyworks Certificate of Conformance](#).

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 TX and RX inputs and antenna outputs, 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.

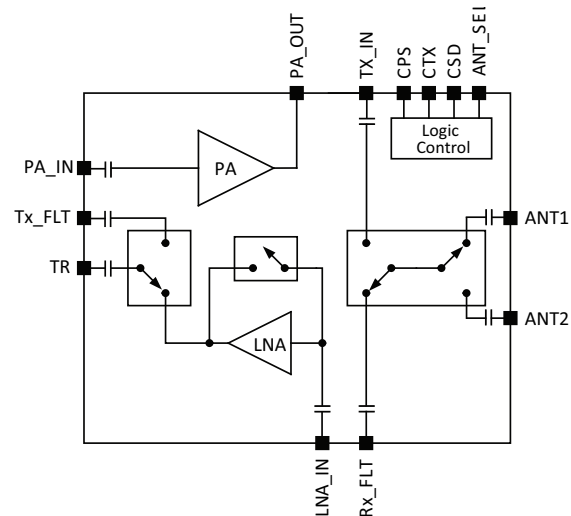


Figure 1. Functional Block Diagram

The SE2435L is packaged in a 24-pin, 4 x 4 mm Quad Flat No-Lead (QFN) package. Table 1 lists the pin assignments and signal descriptions.

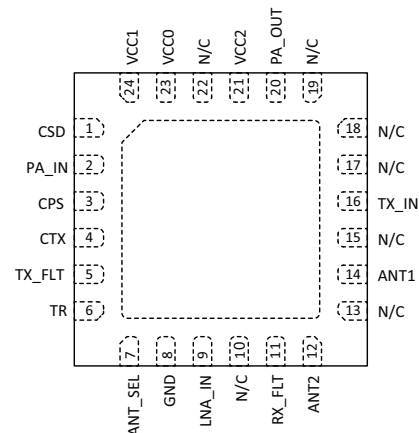


Figure 2. Pinout (Top View)

Table 1. 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	N/C	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	N/C	Not connected internally to the device
5	TX_FLT	Transmit signal (to TX filter)	18	N/C	Not connected internally to the device
6	TR	Bi-directional RF signal to/from transceiver	19	N/C	Not connected internally to the device
7	ANT_SEL	Antenna select control input	20	PA_OUT	PA output (to Z optimum) ¹
8	GND	Ground	21	VCC2	Positive power supply
9	LNA_IN	LNA input (from RX filter)	22	N/C	Not connected internally to the device
10	N/C	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	N/C	Not connected internally to the device			

1. Z optimum = 5 Ω for +30 dBm or 8 Ω for +27 dBm POUT.

Electrical and Mechanical Specifications

Table 2. Absolute Maximum Ratings¹

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

1. Exposure to maximum rating conditions for extended periods may reduce device reliability. Exceeding any of the limits listed here may result in permanent damage to the device.

ESD Handling: Industry-standard ESD handling precautions must be adhered to at all times to avoid damage to this device.

Table 3. Recommended Operating Conditions

Parameter	Symbol	Min	Typ	Max	Units
Supply voltage on VCC	VCC	2.0	4.0	4.8	V
Ambient temperature	TA	−40	+25	+85	°C

Table 4. DC Specifications¹

(VCC = 4.0 V, f = 915 MHz, TA = +25 °C, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Total supply current, transmit mode	ICC_TX30 ICC_TX27 ICC_TX24	POUT = +30 dBm POUT = +27 dBm POUT = +24 dBm		550 380 275		mA mA mA
Total supply current, receive mode	ICC_RX			6		mA
Total supply current, receive bypass mode	ICC_RXB				280	μA
Quiescent current	ICQ_TX	No RF		50		mA
Sleep supply current	ICC_OFF	No RF		0.05	1.00	μA

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

Table 5. Control Logic Characteristics¹

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Control voltage High Low	V _{IH} V _{IL}		1.6 0		V _{CC} ² 0.3	V V
Input current High Low	I _{IH} I _{IL}				1 1	μA μA

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

2. For Pin 7, ANT_SEL, the maximum is 3.6 V.

Table 6. Mode Control Logic (TA = +25 °C)¹

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

1. "1" = 1.6 to V_{CC}, "0" = 0 to 0.3 V, "X" = don't care.

Table 7. 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	Typ	Max	Units
Frequency range	f		860		930	MHz
Output power at ANT1 or ANT2 ports in the 900 to 930 MHz frequency range ¹	POUT_915	VCC = 4.8 V VCC = 4.0 V VCC = 3.6 V VCC = 3.0 V		+31.5 +30.5 +29.5 +28.0		dBm
Output power at ANT1 or ANT2 ports in the 860 to 870 MHz frequency range ²	POUT_860	VCC = 4.0 V VCC = 3.6 V VCC = 3.0 V VCC = 2.0 V		+27 +24 +21 +18		dBm
PA power added efficiency	PAE_PA	POUT = +28 dBm at PA_OUT port, 915 MHz		64		%
Small signal gain ¹	S21_915	900 to 930 MHz	26			dB
Small signal gain ²	S21_860	860 to 870 MHz	26			dB
Small signal gain variation ^{1, 2}	DS21	Gain variation across frequency range			2	dBp-p
Output return loss ^{1, 2}	S22ANT1 S22ANT2	Into 50 Ω , ANT1 and ANT2 ports		-10	-6	dB
Second harmonic ^{1, 3}	2fo	POUT = +30 dBm			-22	dBc
Third to tenth harmonic ^{1, 3}	3fo to 10fo	POUT = +30 dBm			-72	dBc
Turn-on time ⁴	ton				1	μ s
Turn-off time	toff				1	μ s
Stability	STAB	CW, PIN = 0 dBm 0.1 GHz to 20 GHz 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			

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

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

3. Measured with continuous wave signal.

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

Table 8. AC Receive Mode

(VCC = 4 V, TA = +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	Typ	Max	Units
Frequency range	f _{IN}		860		930	MHz
Receive gain	RX_GAIN		14	16	18	dB
Receive noise figure	NF			2	2.5	dB
Input third order intercept	IIP3		−5	−2		dBm
Input 1-dB compression point	IP1dB		−15	−12		dBm
Antenna port return loss	S ₁₁ ANT1 S ₁₁ ANT2	Into 50 Ω , ANT1 and ANT2 ports		−12	−8	dB
Turn-on time ¹	t _{ON}				1	μ s
Turn-off time ²	t _{OFF}				1	μ s
Gain in bypass mode	G _{bp}		−3	−2		dB
Input 1-dB compression point in bypass mode	IP1dB		+10			dBm

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

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

Table 9. DC Specifications, Diversity Antenna Function

(VCC = 4 V, TA = +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	Typ	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	T _{ANT1-ANT1_TX}		800		ns
ANT1 to ANT2 switching time receive mode	T _{ant1-ant2_rx}		400		ns

Typical Performance Characteristics, ($V_{CC} = 4\text{ V}$, $T_A = +25^\circ\text{C}$, $f = 900\text{ to }930\text{ MHz}$, All Unused Ports Terminated at $50\ \Omega$, Unless Otherwise Noted). Typical performance graphs at 868 MHz are available upon request (+24, +27, and +30 dBm POUT).

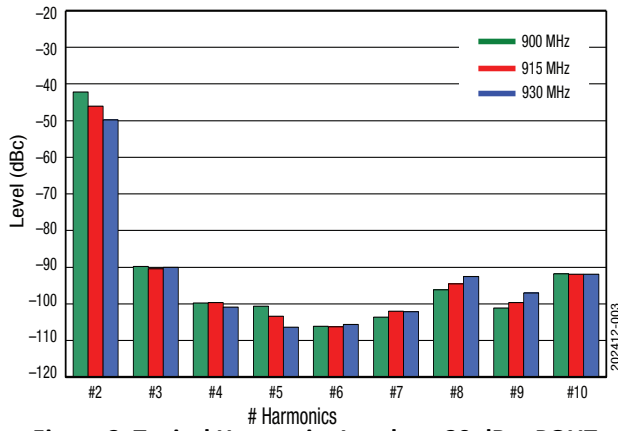


Figure 3. Typical Harmonics Level at +30 dBm POUT (including Antenna Filter)

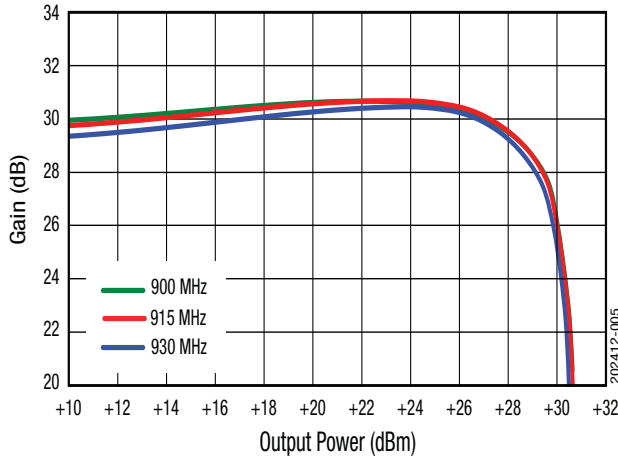


Figure 5. Typical Gain vs POUT ($V_{CC} = 4\text{ V}$)

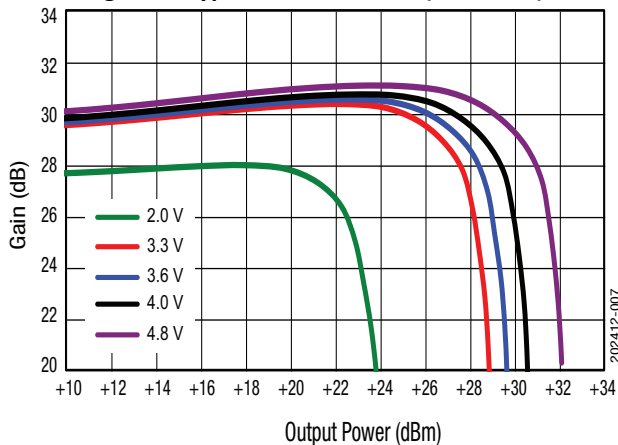


Figure 6. Typical Gain vs POUT ($V_{CC} = 2.0\text{ to }4.8\text{ V}$)

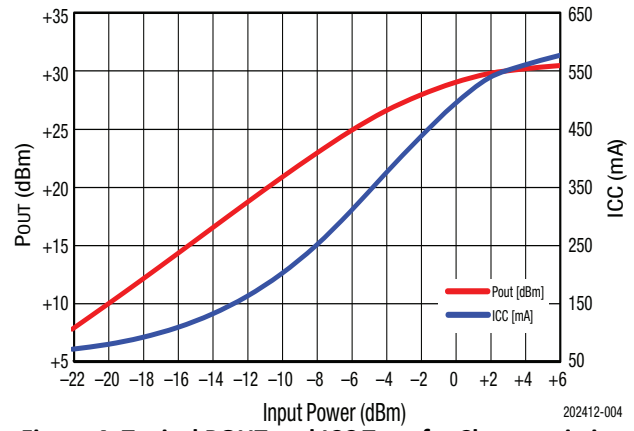


Figure 4. Typical POUT and ICC Transfer Characteristics

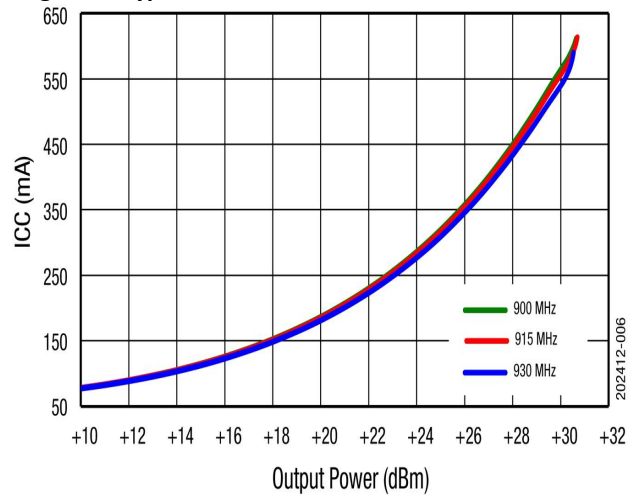


Figure 7. Typical ICC vs POUT ($V_{CC} = 4\text{ V}$)

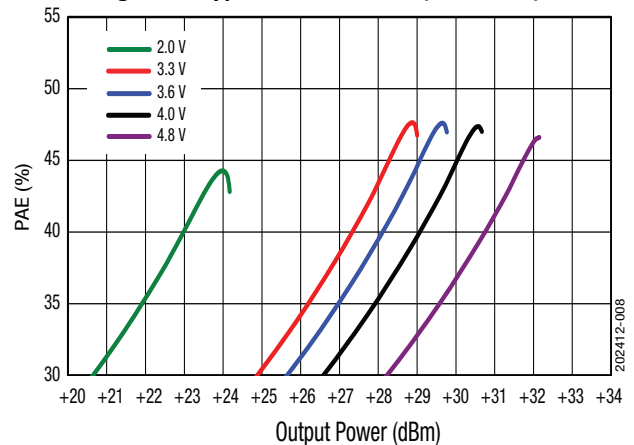


Figure 8. Typical PAE vs POUT & V_{CC} , CW ($V_{CC} = 2.0\text{ to }4.8\text{ V}$) (including OMN and Antenna Filter Losses)

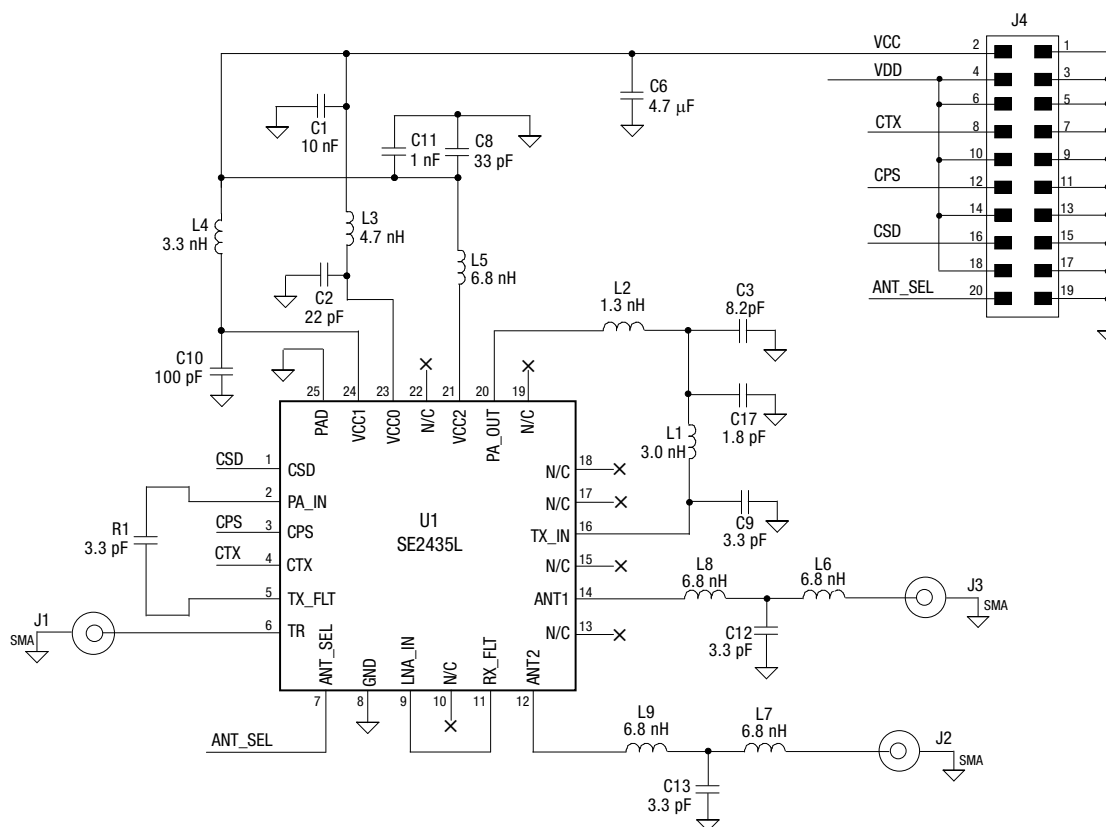
Evaluation Board Description

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

Proper board layout and routing are crucial to electrical performance and specifications. Consult the factory for Gerber files prior to design.



Figure 9. Evaluation Board



Note: Discard N/C pins that are connected to ground on the Evaluation Board.

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Figure 10. Evaluation Board Schematic for 915 MHz Application and FCC Conducted Harmonics Rejection Compliant

Table 10. Evaluation Board Bill of Materials¹

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 mF	0402	muRata
C6	GRM188R60J475KE19	Multilayer ceramic	4.7 mF	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	100 mil 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

1. Schematic and BOM designed to optimize performance with CW signals, 100% duty cycle.

Evaluation Board Setup Procedure

Proper board layout and routing are crucial to electrical performance and specifications. Consult the factory for Gerber files prior to design.

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 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

1. 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).
2. 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).

CAUTION: Do not overdrive the amplifier by applying too much RF to the device input. A starting input power of –20 dBm is suitable.

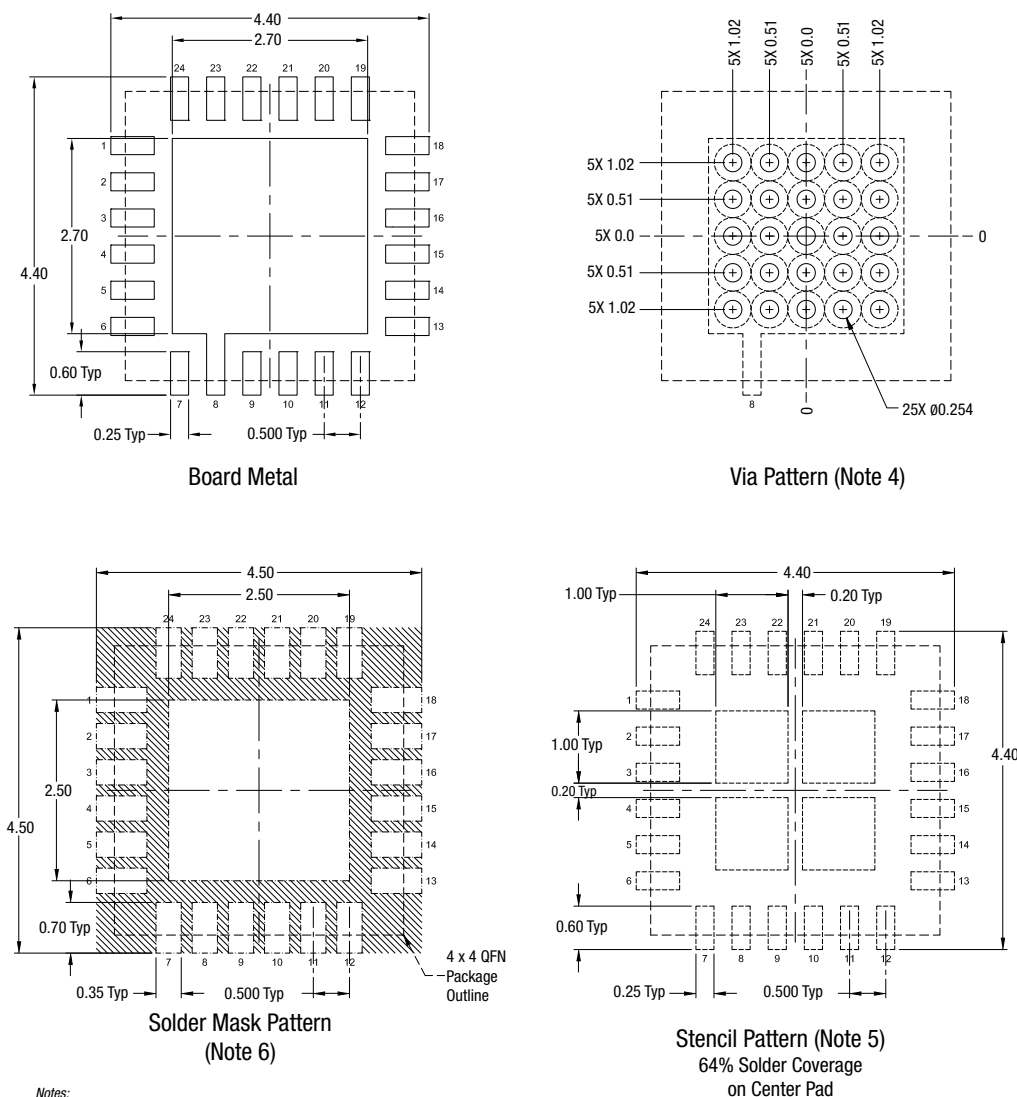
Table 11. Power and Control I/O Header (J4)

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 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.



Notes:

1. All dimensions are in millimeters.
2. Interpret dimensions and tolerances per ASME Y14.5M-1994.
3. Unless specified, dimensions are symmetrical about center lines.
4. Via hole recommendations:
0.025 mm Cu via wall plating (minimum), solder mask on the far side should tent or plug via holes.
5. Stencil recommendations: 0.125 mm stencil thickness, laser cut apertures, trapezoidal walls and rounded corners offer the best paste release.
6. Solder mask recommendations: Contact board fabricator for recommended solder mask offset and tolerance.

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Figure 11. PCB Layout Footprint

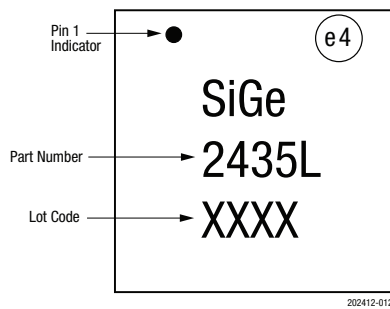
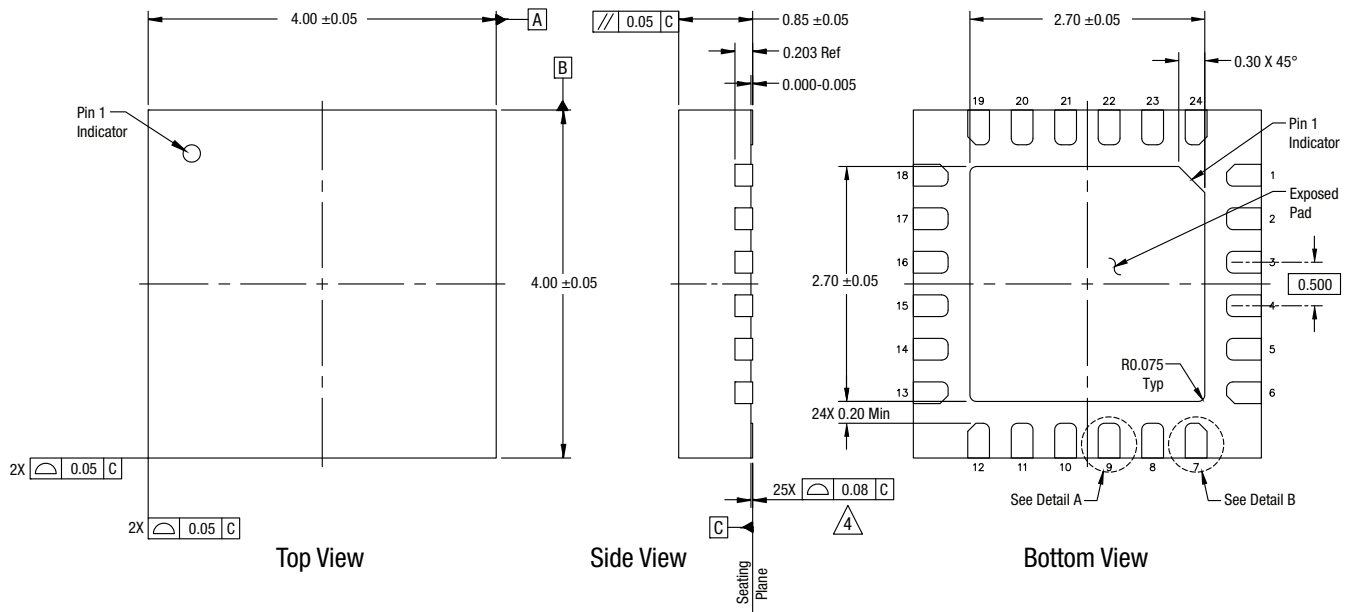


Figure 12. Typical Part Markings

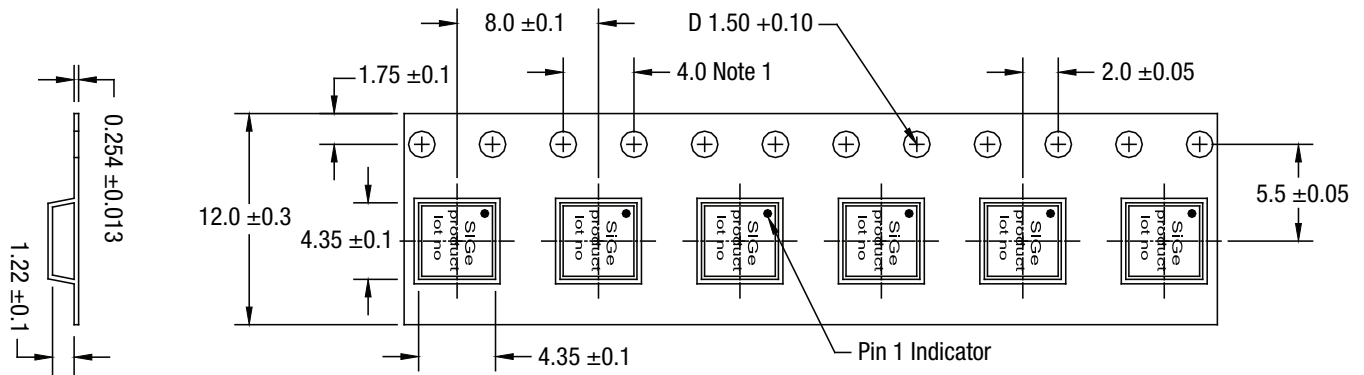


NOTES:

1. All measurements are in millimeters, unless otherwise specified.
2. Dimensions and tolerances according to ASME Y14.5M-2009.
3. 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: $\pm 0.5^\circ$
4. Coplanarity applies to the exposed center ground pad as well as the terminals.
5. Dimension applies to the metallized terminal. If the terminal has a radius, the dimension should not be measured in that radius area.
6. Plating requirements per source control drawing (SCD) 2504.
7. Unless specified, dimensions are symmetrical about center lines.

202412-013

Figure 13. Package Dimensions



Notes:

1. All dimensions are in millimeters.
2. Ten-sprocket hole pitch cumulative tolerance ± 0.2 mm.
3. Camber in compliance with EIA-481.

202412-014

Figure 14. Tape and Reel Dimensions

Ordering Information

Part Number	Description	Evaluation Board Part Number
SE2435L	FCC +30 dBm 900 to 930 MHz Front-end Module	SE2435L-EK1
	ETSI +27 dBm 868 to 880 MHz Front-end Module	SE2435L-EK2
	ETSI + FCC +30 dBm 868 to 930 MHz Front-end Module	SE2435L-EK5
	FCC +25 dBm 915 MHz Front-end Module	SE2435L-EK7

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