

DATA SHEET

SKY66109-11: 2.4 GHz ZigBee®/Smart Energy Front-End Module

Applications

- Smart meters
- In-home appliances
- Smart thermostats

Features

- Integrated PA with up to +22.5 dBm output power
- Integrated LNA with programmable bypass
- Integrated antenna switching with transmit and receive diversity function
- Low noise figure: 2 dB typical
- Differential transmit/receive interface with integrated baluns
- Fast switch on/off time: <800 ns
- Supply range: 2.0 V to 3.6 V
- Sleep mode current: 0.05 μ A typical
- No bias resistor is required
- Small MCM (20-pin, 3 x 4 x 0.9 mm) package, NiPdAu-plated (MSL3, 240 °C per JEDEC-J-STD-020)



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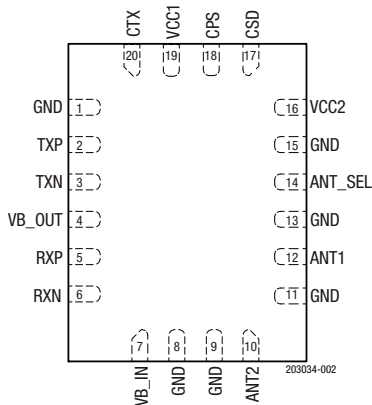


Figure 2. SKY66109-11 Pinout (Top View)

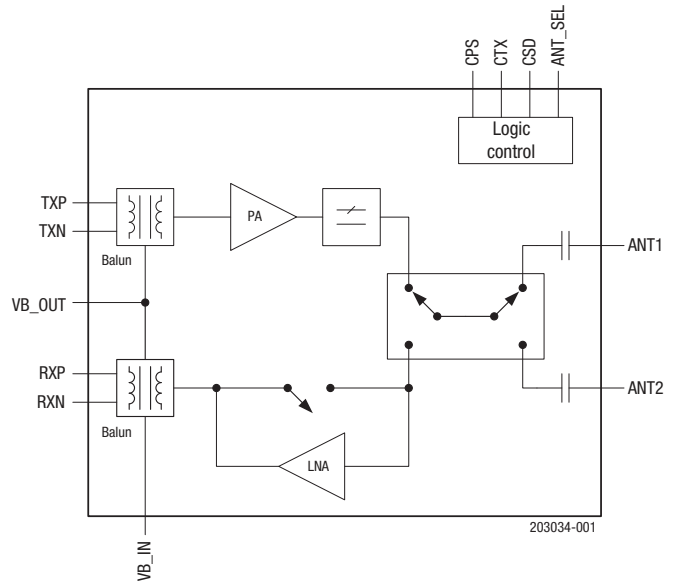


Figure 1. SKY66109-11 Functional Block Diagram

Description

The SKY66109-11 is a high-performance, fully integrated RF front-end module (FEM) designed for ZigBee®/Smart Energy applications.

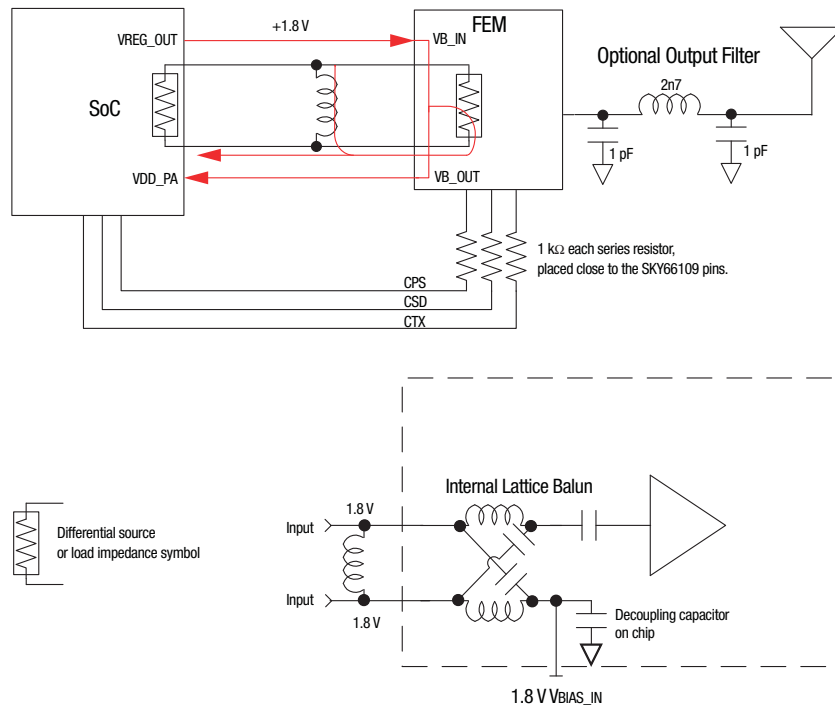
The SKY66109-11 is designed for ease of use and maximum flexibility. The device provides integrated and fully matched input baluns, an integrated interstage matching and harmonic filter, and digital controls compatible with 1.6 to 3.6 V CMOS levels.

The RF blocks operate over a wide supply voltage range from 2.0 V to 3.6 V that allows the SKY66109-11 to be used in battery powered applications over a wide spectrum of the battery discharge curve.

The SKY66109-11 is provided in a small, 20-pin, 3 x 4 mm Multi-Chip Module (MCM) package. 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. SKY66109-11 Signal Descriptions

Pin	Name	Description	Pin	Name	Description
1	GND	Ground	11	GND	Ground
2	TXP	Positive transmit input signal from transceiver, 200 Ω differential	12	ANT1	Connect to 50 Ω antenna
3	TXN	Negative transmit input signal from transceiver, 200 Ω differential	13	GND	Ground
4	VB_OUT	Transmit balun bias core supply from transceiver (optional connection)	14	ANT_SEL	Connect to GPIO signal to control antenna switch (see Table 7)
5	RXP	Positive receiver output signal to transceiver, 200 Ω differential	15	GND	Ground
6	RXN	Negative receiver output signal to transceiver, 200 Ω differential	16	VCC2	Connect to positive supply
7	VB_IN	Receive balun bias core supply from transceiver (optional connection)	17	CSD	Connect to GPIO signal for mode control (see Table 6)
8	GND	Ground	18	CPS	Connect to GPIO signal for mode control (see Table 6)
9	GND	Ground	19	VCC1	Connect to positive supply
10	ANT2	Connect to 50 Ω antenna	20	CTX	Connect to GPIO signal for mode control (see Table 6)



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.

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

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY66109-11 are provided in Table 2. The recommended operating conditions are specified in Table 3 and electrical specifications are provided in Tables 4 and 5.

The state of the SKY66109-11 is determined by the logic provided in Tables 6 and 7.

Table 2. SKY66109-11 Absolute Maximum Ratings¹

Parameter	Symbol	Minimum	Maximum	Units
Supply voltage	V _{CC1}	-0.3	+3.6	V
Supply voltage	V _{CC2}	-0.3	+3.8 ²	V
Control pin voltages		-0.3	+3.6	V
Transmit output power at ANT1 or ANT2 port into 50 Ω load	P _{OUT_TX_MAX}		+22.5	dBm
Transmit input power at the TXN and TXP ports	P _{IN_TX_MAX}		+6	dBm
Receive input power at ANT1 or ANT2 ports, LNA mode	P _{IN_RX_MAX}		+10	dBm
Receive input power at ANT1 or ANT2 ports, bypass mode	P _{IN_RX_BYPASS_MAX}		+15	dBm
Operating temperature	T _A	-40	+125	°C
Storage temperature	T _{STG}	-40	+125	°C
Electrostatic discharge: Human Body Model (HBM), Class 1C	ESD		1000	V

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.

² V_{CC2} is restricted to +3.6 V when operated at T_A = 125 °C.

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.*

Table 3. Recommended Operating Conditions

Parameter	Symbol	Minimum	Typical	Maximum	Units
Supply voltage for balun bias	VB_IN, VB_OUT	1.6		3.6	V
Supply voltage on VCC pins	VCC1, VCC2	2.0	3.0	3.6	V
Operating temperature	T _A	-40	+25	+125	°C

Table 4. SKY66109-11 Electrical Specifications¹
(VCC1 = VCC2 = 3.0 V, TA = +25 °C, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
DC Characteristics						
Total supply current	I _{CC_TX}	P _{OUT} = +20 dBm P _{OUT} = +17 dBm ² P _{OUT} = +10 dBm ²		110 90 45		mA mA mA
Total supply current	I _{CC_RX}			5	7	mA
Total supply current	I _{CC_RX_BYPASS}				300	μA
Sleep supply current	I _{CC_OFF}	No RF		0.05	1.00	μA
Quiescent current	I _{cq}	No RF		30		mA
Logic Characteristics						
Control voltage: High Low	V _{IH} V _{IL}		1.6 0		3.6 0.3	V V
Control current: High Low	I _{IH} I _{IL}				1 1	μA μA
Dual Antenna Switch Characteristics						
Isolation between ANT1 and ANT2 ports	ISOL _{ANTSW}			-20		dB
ANT1 to ANT2 switching time	t _{ANT1_ANT2}			400		ns

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

² Not tested in production. Fully characterized and guaranteed by design.

Table 5. SKY66109-11 Electrical Specifications¹**(VB_IN = VB_OUT = 1.6 to 3.6 V, VCC1 = VCC2 = 3.0 V, TA = +25 °C, All Unused Ports Terminated with 50 Ω, Unless Otherwise Noted)**

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
AC Transmit Characteristics						
Frequency range	f		2400		2483	MHz
Output power at ANT1 or ANT2 port	P _{OUT}	VCC1 = VCC2 =: 3.6 V 3.3 V 3.0 V 2.7 V 2.0 V		+22.5 +21.0 +20.5 +20.0 +17.0		dBm dBm dBm dBm dBm
Small signal gain	S ₂₁	P _{IN} = -25 dBm		21		dB
Small signal gain variation	ΔS ₂₁	Across all ZigBee channels			2	dBp-p
Saturated gain	G _{SAT}	P _{OUT} = +20 dBm	17	19		dB
2 nd harmonic	2f _o	P _{OUT} = +20 dBm, IEEE 802.15.4 source			-42	dBm/MHz
3 rd harmonic ²	3f _o	P _{OUT} = +20 dBm, IEEE 802.15.4 source			-42	dBm/MHz
Output return loss ²	S ₂₂	ANT1 or ANT2 port		-10	-5	dB
Transmit port impedance ²	Z _{IN}			200		Ω
Turn-on time ²	t _{RISE}	From 50% of CTX edge to 90% of final RF output power			800	ns
Turn-off time ²	t _{FALL}	From 50% of CTX edge to 10% of final RF output power			800	ns
Stability ²	Stab	CW, P _{in} = 0 dBm, 0.1 GHz to 20 GHz, load VSWR = 6:1	All non-harmonically related outputs < -42 dBm/MHz			-
Ruggedness ²	RU	CW, P _{in} = +6 dBm, load VSWR = 10:1	No permanent damage			-
AC Receive Characteristics						
Frequency range	f		2400		2483	MHz
Receive gain	RX_GAIN			10.5		dB
Receive noise figure ²	NF			2		dB
Third order input intercept point ²	IIP3		-3	+1		dBm
1 dB input compression point	IP1dB		-13	-3		dBm
1 dB input compression point in bypass mode ²	IP1dB		+10			dBm
Input return loss ²	S ₁₁	ANT1 or ANT2 ports		-10	-5	dBm
Receive port impedance ²	Z _{OUT}	Measured differentially between RXP and RXN		200		Ω
Turn-on time ²	t _{RISE}	From 50% of CTX edge to 90% of final RF output power			800	ns
Turn-off time ²	t _{FALL}	From 50% of CTX edge to 10% of final RF output power			800	ns
Gain in bypass mode	G _{BP}			-3		dB

¹ Performance is guaranteed only under the conditions listed in this table.² Not tested in production. Fully characterized and guaranteed by design.

Table 6. SKY66109-11 Mode Control Logic¹
(VCC1 = VCC2 = 3.0 V, TA = +25 °C)

Mode	Description	CPS (Pin 18)	CSD (Pin 17)	CTX (Pin 20)	Typical Current Consumption
0	All off (sleep mode) ²	X	0	X	0.1 μA
1	Receive bypass mode	0	1	0	250 μA
2	Receive LNA mode	1	1	0	5 mA
4	Transmit mode	X	1	1	30 mA

¹ "0" = 0 V. "1" = +3.0 V. "X" = don't care (must be either 0 V or Vcc voltage). Any state other than described in this table places the switch into an undefined state. An undefined state will not damage the device.

² Remove EVB pulldown resistors to achieve specified sleep current with CTX or CPS high.

Table 7. SKY66109-11 Antenna Enable Logic¹
(VCC1 = VCC2 = 3.0 V, TA = +25 °C)

Description	CPS (Pin 18)	CSD (Pin 17)	CTX (Pin 20)	ANT_SEL (Pin 14)
ANT1 port enabled	X	X	X	0
ANT2 port enabled	X	X	X	1

¹ "0" = 0 V. "1" = +3.0 V. "X" = don't care. Any state other than described in this table places the switch into an undefined state. An undefined state will not damage the device.

Evaluation Board Description

The SKY66109-11 Evaluation Board is used to test the performance of the SKY66109-11 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 8 describes the pins on the power and control I/O header (J5). Table 9 provides the Bill of Materials (BOM) list for Evaluation Board components. The Evaluation Board is shown in Figure 6.

Evaluation Board Setup Procedure

1. Connect J1, J2, J3, and J4 to 50 Ω instruments.
Terminate all unused ports (if applicable) with 50 Ω .
2. Connect the supply ground to pins 19 and 20 of J5.
3. Connect 3.0 V to pins 15 and 16 of J5.
4. Connect 3.0 V to pins 3 and 4 of J5.

NOTE: Pins 7 and 8 of J5 are left open.

NOTE: By following the logic in Table 6, the required RF path is selected. Refer to Table 7 for antenna port control.

5. Monitor the 2.5 GHz amplifier transmit performance by applying an RF signal to J3 and monitoring the output power on J1 (ANT1) or J2 (ANT2).

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.

6. Monitor the 2.5 GHz amplifier receive performance by applying an RF signal to J1 (ANT1) or J2 (ANT2) and monitoring the output signal on J3.

Package Dimensions

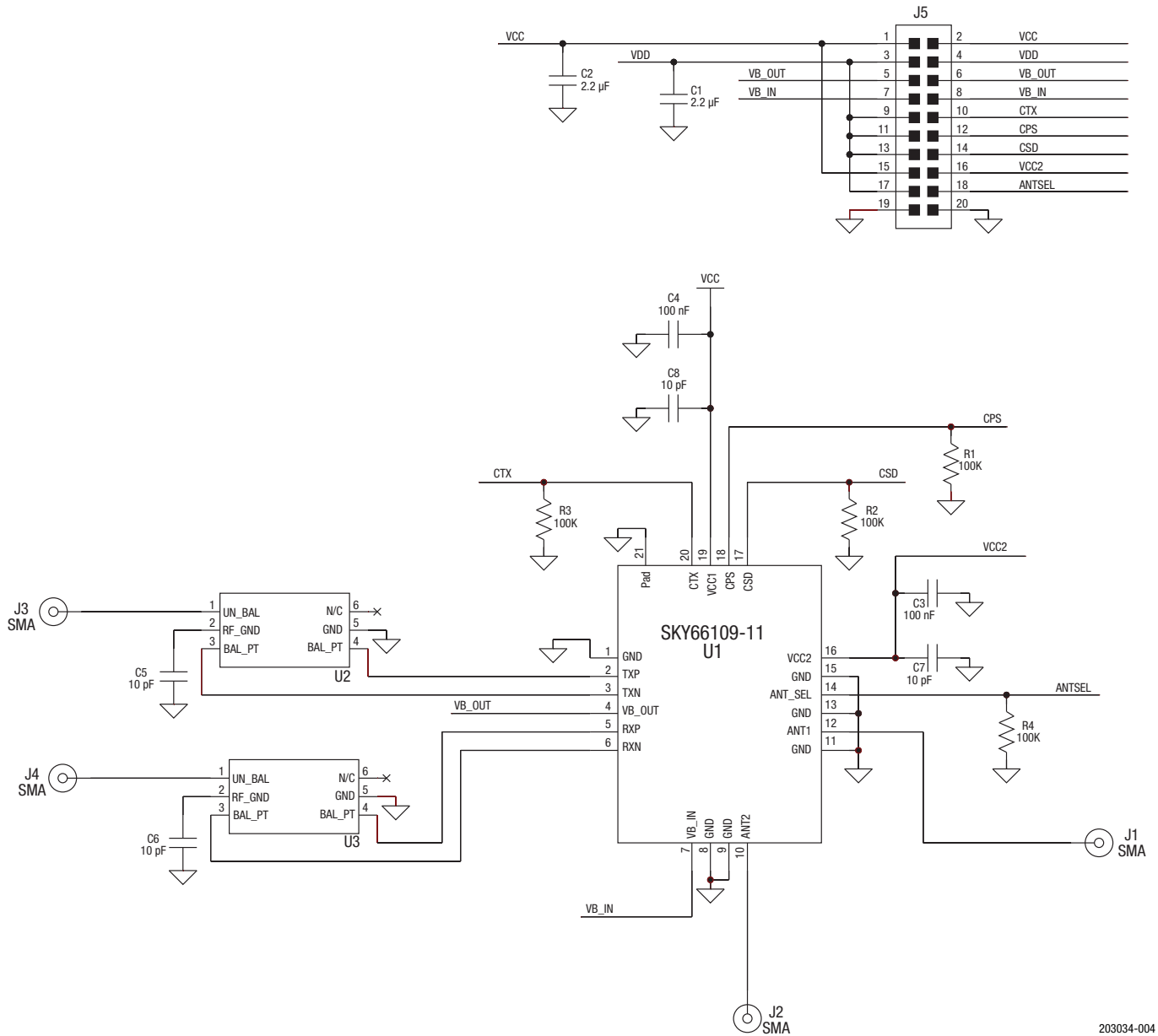
The PCB layout footprint for the SKY66109-11 is provided in Figure 7. Typical part markings are shown in Figure 8. Package dimensions for the 20-pin MCM are shown in Figure 9, and tape and reel dimensions are provided in Figure 10.

Package and Handling Information

Since the device package is sensitive to moisture absorption, it is baked and vacuum packed before shipping. 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 SKY66109-11 is rated to Moisture Sensitivity Level 3 (MSL3) at 240 °C. It can be used for lead or lead-free soldering. For additional information, refer to the Skyworks Application Note, *PCB Design and SMT Assembly/Rework Guidelines for MCM-L Packages*, document number 101752.

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.



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Figure 4. SKY66109-11 Evaluation Board Schematic

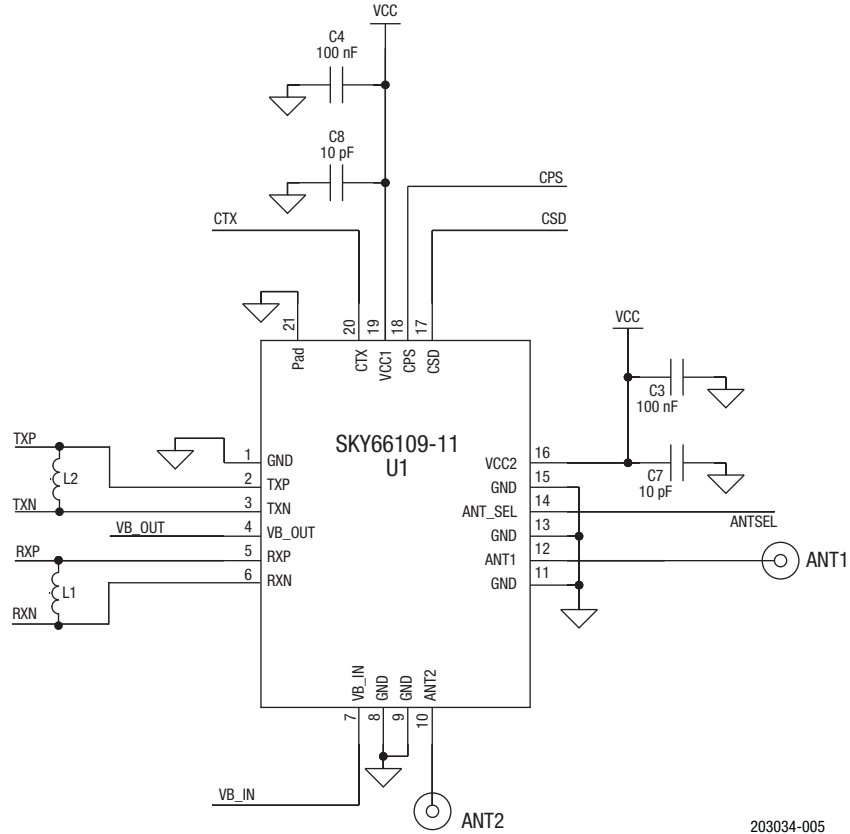


Figure 5. SKY66109-11 Reference Design Schematic

Table 8. Power and Analog I/O Header: J5, 10x2

Pin	Pin Name	Description	Recommended Setting
1, 2, 15	VCC	Supply voltage	General purpose VCC provided as the main power supply
3, 4, 9, 11, 13, 17	VDD	Digital supply voltage	Connect to separate power supply voltage
5, 6	VB_OUT	Bias output	–
7, 8	VB_IN	Bias voltage input	No connect
16	VCC2	Supply voltage	General purpose VCC provided as the main power supply
10	CTX	Control	See Tables 6 and 7
12	CPS	Control	
14	CSD	Control	
18	ANT_SEL	Control	
19, 20	GND	Ground	General purpose ground

Table 9. SKY66109-11 Evaluation Board Bill of Materials (BOM)

Component	Value	Size	Manufacturer	Manufacturer Part Number	Characteristics
C1, C2	2.2 μ F	0805	Murata	GRM21BR71A225KA01L	Ceramic capacitor, 2.2 μ F, 10V, 10%, X7R 0805
C3, C4	100 nF	0402	Murata	GRM155R71C104KA88D	Monolithic ceramic
C5, C6, C7, C8	10 pF	0402	Murata	GRM1555C1H100JZ01	Multilayer ceramic
J1, J2, J3, J4	SMA	End launch	Johnson Components	142-0701-851	SMA end launch straight jack receptacle – tab contact
J5	10X2	100 mil	Samtec	TSW-110-07-G-D	100 mil header
R1, R2, R3, R4	100 k Ω	0402	Panasonic	ERJ2GEJ104	Thick film chip resistor
U1	–	3 x 4 mm MCM	Skyworks Solutions, Inc.	SKY66109-11	2.4 GHz ZigBee FEM with differential transmit/receive
U2, U3	–	2 x 1.25 mm	TDK	HHM1521	Multilayer 2.4 GHz chip baluns

Note: Schematic and BOM have been designed to optimize performance in 802.11a/n applications.

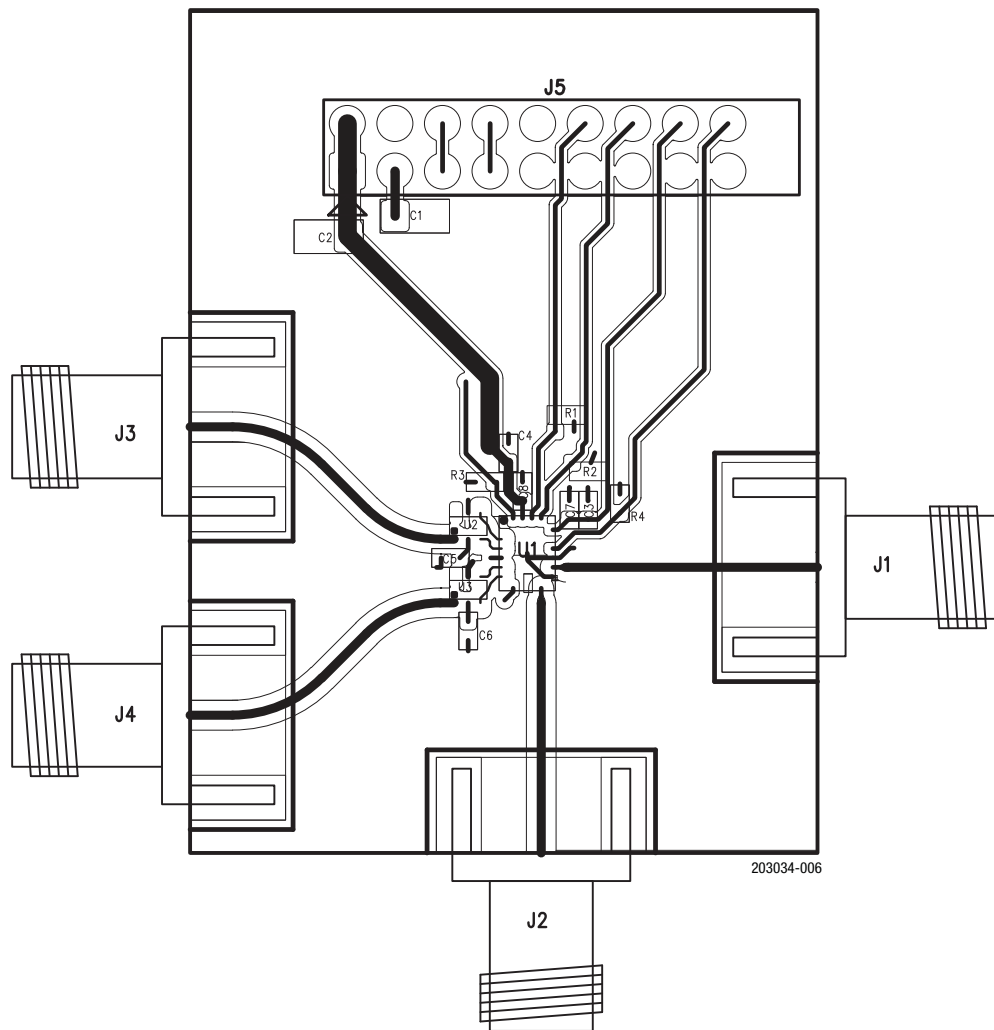
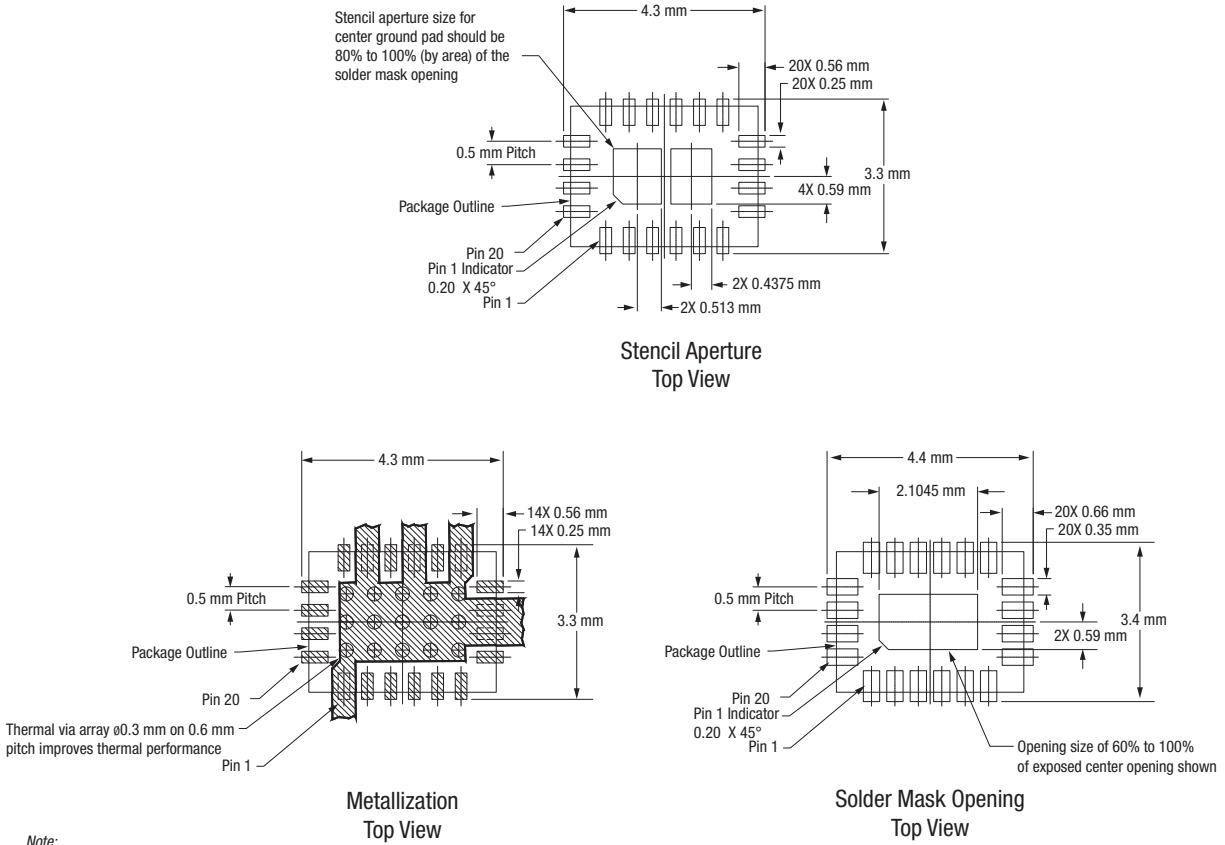


Figure 6. SKY66109-11 Evaluation Board

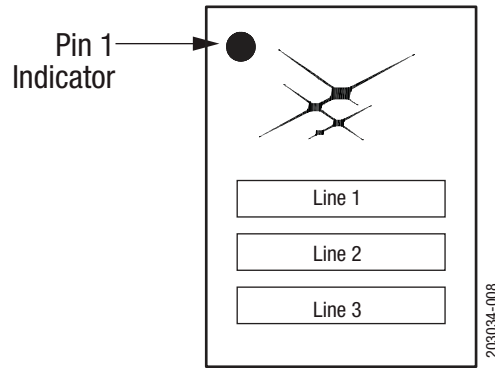


Note:

Thermal vias should be resin filled and capped in accordance with IPC-4761 Type VII vias. Recommended Cu thickness is 30 to 35 µm.

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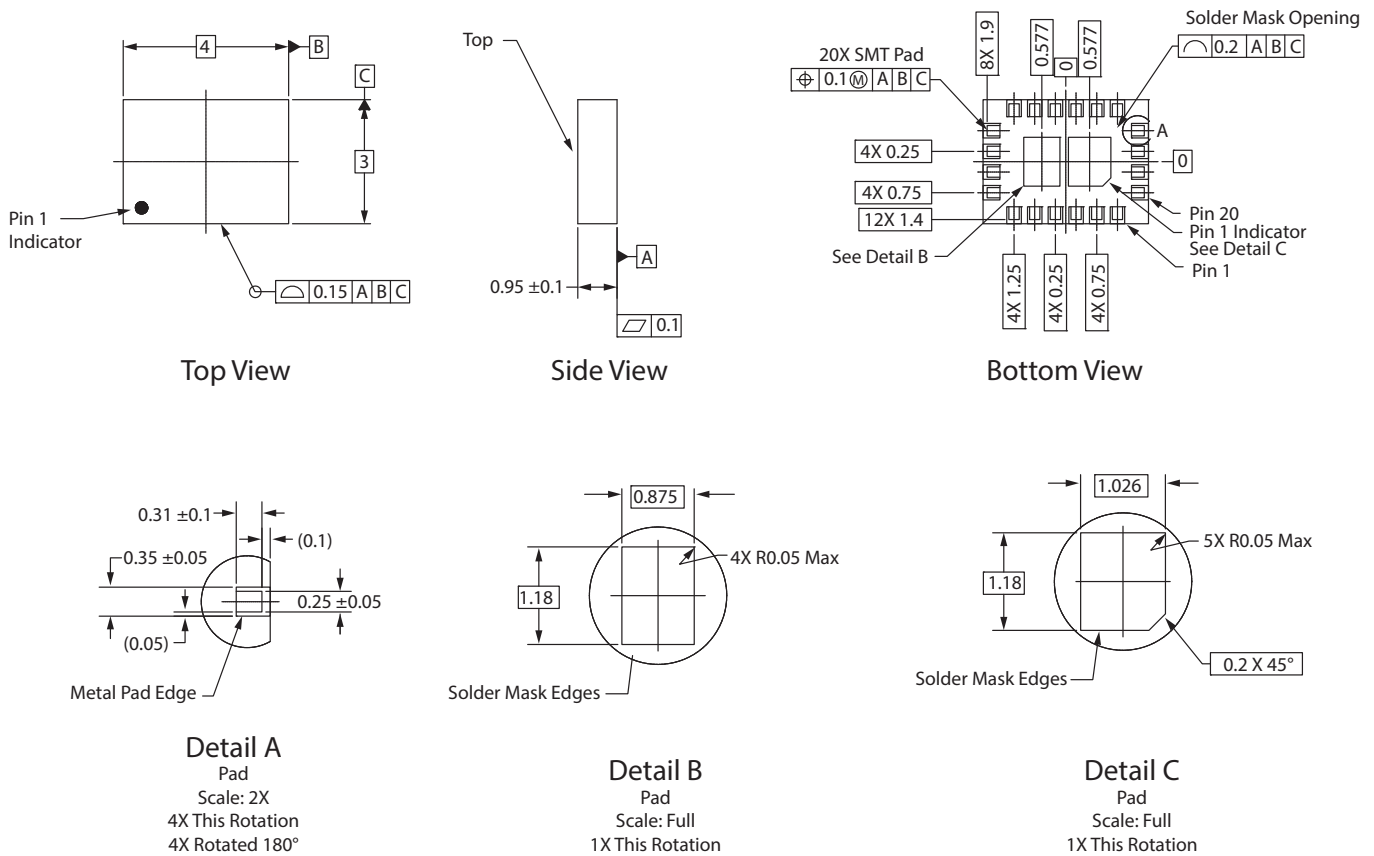
Figure 7. PCB Layout Footprint



NOTE: Lines 1, 2, and 3 have a maximum of 7 characters
 Line 1 = Part Number and Version
 Line 2 = Lot Number
 Line 3 = YEAR-WEEK-Country Code (MX)

Figure 8. Typical Part Markings

DATA SHEET • SKY66109-11: ZIGBEE/SMART ENERGY FEM

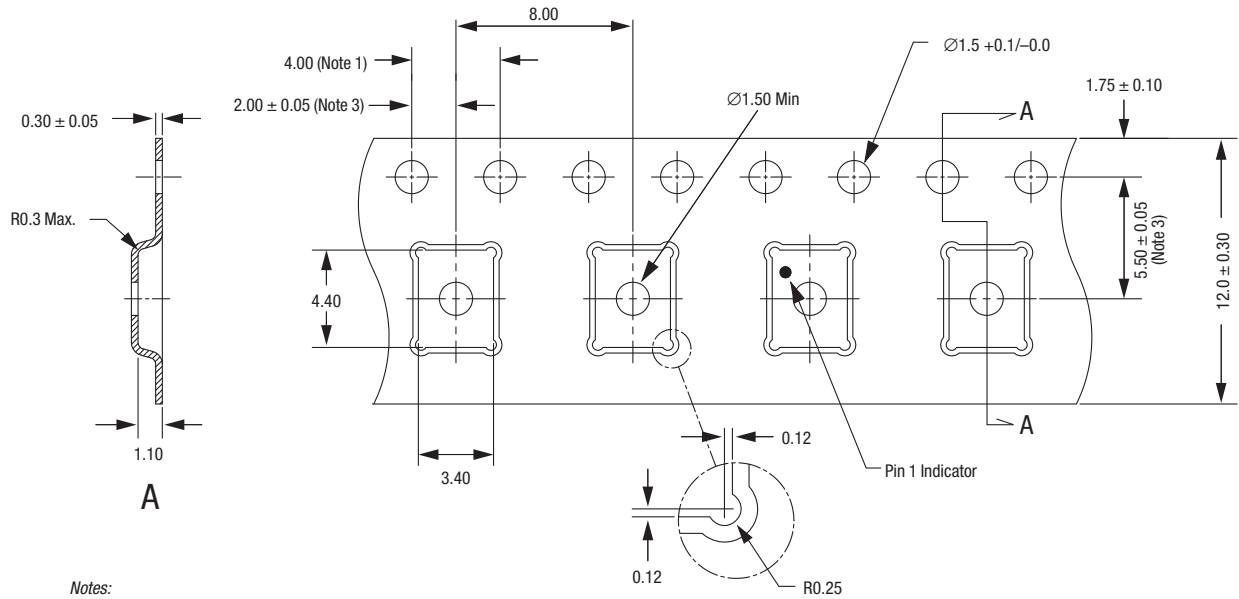


Notes (Unless Otherwise Specified):

1. Dimensions and tolerances are in accordance with ASME Y14.5M-1994.
2. Dimensions are in millimeters.

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Figure 9. SKY66109-11 Package Dimensions



Notes:

1. 10 sprocket hole pitch cumulative tolerance ± 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.

203034-010

Figure 10. SKY66109-11 Tape and Reel Dimensions

Ordering Information

Model Name	Manufacturing Part Number	Evaluation Board Part Number
SKY66109-11: Zigbee/Smart Energy FEM	SKY66109-11	SKY66109-11-EK1

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