DATA SHEET

SKY66408-11: 2.4 GHz Front-End Module for Zigbee®/Thread/Bluetooth® Signal Applications

Applications

- In-home appliances
- Smart thermostats
- Internet of Things (IoT) devices
- Smart lighting
- Sensors
- Range extenders
- Wireless audio

Features

- Fully programmable P_{OUT} via I^2C interface in 0.7 dB steps
- Integrated PA with up to +20 dBm output power
- Integrated LNA and bypass path
- Integrated antenna diversity switching for all modes
- Single-ended transmit/receive interface
- Supply range: 1.8 V to 3.6 V
- Sleep mode current: <9 µA typical
- No external bias resistor is required
- Small MCM (24-pin, 3.0 mm x 3.0 mm x 0.6 mm) package, NiPdAu-plated, MSL3, 260 °C per JEDEC-J-STD-020
- For RoHS and other product compliance information, see the Skyworks Certificate of Conformance.

Description

The SKY66408-11 is a high-performance, fully integrated RF front-end module (FEM) designed for Zigbee® technology, Thread, and Bluetooth® signal (including low energy) applications.

The SKY66408-11 is designed for ease of use and maximum flexibility. The device provides an integrated inter-stage matching and harmonic filter, and digital controls compatible with 1.2 V to 3.6 V CMOS levels.

The RF blocks operate over a wide supply voltage range from 1.8 V to 3.6 V that allows the SKY66408-11 to be used in battery-powered applications over a wide spectrum of the battery discharge curve.

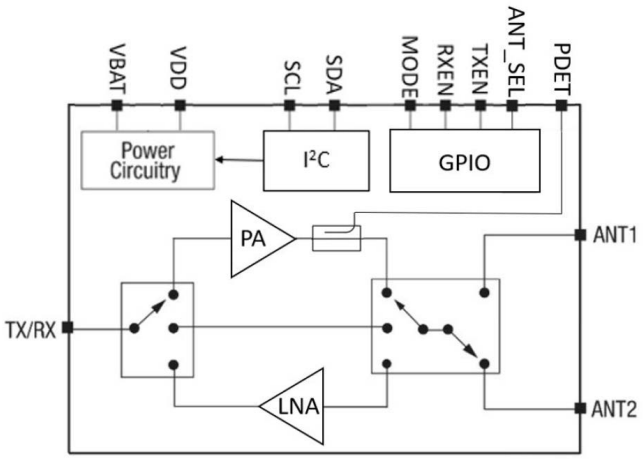


Figure 1. Functional Block Diagram

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.

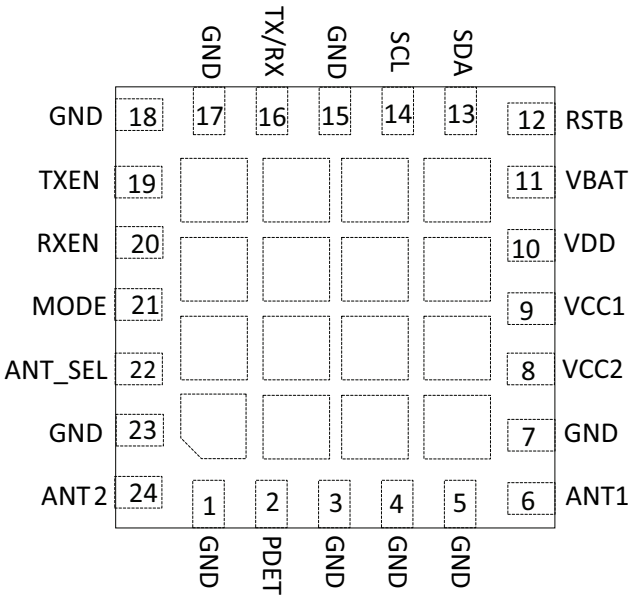


Figure 2. Pinout (Top View)

Table 1. Signal Descriptions[1]

Pin	Name	Description	Pin	Name	Description
1	GND	Ground	13	SDA	I^2C bus data
2	PDET	Power detector output	14	SCL	I^2C bus clock
3	GND	Ground	15	GND	Ground
4	GND	Ground	16	TX/RX	Transmit/receive port
5	GND	Ground	17	GND	Ground
6	ANT1	Antenna port 1	18	GND	Ground
7	GND	Ground	19	TXEN	Transmit enable
8	VCC2	External decoupling for PA second stage output regulator	20	RXEN	Receive enable
9	VCC1	External decoupling for PA first stage output regulator	21	MODE	FEM mode control
10	VDD	Digital voltage supply	22	ANT_SEL	Select ANT1 or ANT2 port
11	VBAT	RF voltage supply	23	GND	Ground
12	RSTB[2]	Reset, active low	24	ANT2	Antenna port 2

1. The paddle should be connected to ground.
2. RSTB is active low:
   Set RSTB to low in order to reset the device.
   Otherwise RSTB must be held high. Do not leave floating.
   Refer to Table 8 Default column for device status after reset.

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY66408-11 are provided in Table 2. The dc electrical specifications, recommended operating conditions, and other parameters are shown in the tables that follow.

Table 2. Absolute Maximum Ratings[1]

Parameter	Symbol	Minimum	Maximum	Units
Supply voltage	VBAT VDD	–0.3 –0.3	+3.6 +2	V V
Control pin voltages	V_{CTL}	–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 RFIN port	$P_{IN\_TX\_MAX}$		+7	dBm
Receive input power at ANT1 or ANT2 ports[2]	$P_{IN\_RX\_MAX}$		+14	dBm
Bypass input power at ANT1 or ANT2 ports[2]	$P_{IN\_BYP\_MAX}$		+14	dBm
Operating temperature	T_A	–40	+85	°C
Storage temperature	T_{STG}	–40	+125	°C
Electrostatic discharge: Human Body Model (HBM)	ESD		2000	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. 802.11n MCS0 20 MHz input signal at 90% duty cycle, 24 hours.

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 VBAT pin	VBAT	1.8	3.3	3.6	V
Supply voltage on VDD pin	VDD	1.7	1.8	2.0	V
Operating temperature	T_A	–40	+25	+85	°C

Table 4. DC Electrical Specifications[1]

(VBAT = 3.3 V, VDD = 1.8 V, T_A = +25 °C, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
DC Characteristics						
Total supply current, high I_{CC} mode[2]	I_{CC_TX}	POUT = +20 dBm, I_VBAT		109		mA
		POUT = +20 dBm, I_VDD		0.5		
		POUT = +10 dBm, I_VBAT		52		
		POUT = +10 dBm, I_VDD		0.5		
		POUT = +5 dBm, I_VBAT		38		
		POUT = +5 dBm, I_VDD		0.5		
Total supply current, low I_{CC} mode[2]	I_{CC_TX}	POUT = +20 dBm, I_VBAT		109		mA
		POUT = +20 dBm, I_VDD		0.5		
		POUT = +10 dBm, I_VBAT		54		
		POUT = +10 dBm, I_VDD		0.5		
		POUT = +5 dBm, I_VBAT		37		
		POUT = +5 dBm, I_VDD		0.5		
Total supply current	I_{CC_RX}	Low noise figure receive		7.8		mA
		Low current receive		3.3		
Total supply current	I_{CC_BYP}			85		µA
Sleep supply current[3]	I_{CC_OFF}	No RF		9.0	15	
Quiescent current	I_{CCQ_TX}	High ICC mode, I_VBAT		18		mA
		High ICC mode, I_VDD		0.5		
		Low ICC mode, I_VBAT		15		
		Low ICC mode, I_VDD		0.5		
Logic Characteristics						
Control voltage (I^2C: RSTB, SDA, SCL) High Low	 V_{IH} V_{IL}		 1.2 0		 VDD 0.3	V
Control voltage (GPIO: TXEN, RXEN, MODE and ANT_SEL) High Low	 V_{IH} V_{IL}		 1.2 0		 VBAT 0.3	V
Control current High Low	 I_{IH} I_{IL}				 10 10	µA
Dual Antenna Switch Characteristics						
Isolation between ANT1 and ANT2 ports	ISO_{ANTSW}			20		dB
ANT1 to ANT2 switching time	t_{ANT1_ANT2}			400		ns

1. Performance is assured only under the conditions listed in this Table and is not assured over the full operating or storage temperature ranges. Operation at elevated temperatures may reduce reliability of the device.
2. P_{OUT} at ANT pin.
3. Sleep supply current is the TOTAL combination of I_{DD} and control current from the GPIO and I^2C pins.

Table 5. DC Electrical Specifications[1]

(VBAT = 3.3 V, VDD = 1.8 V, T_A = +25 °C, All Unused Ports Terminated with 50 Ω, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Transmit Characteristics						
Frequency range	f		2400		2500	MHz
Output power at ANT1 or ANT2 port	POUT	P_{OUT} (VBAT = 3.3 V, P_{IN} = –1 dBm, max power index)		+20		dBm
		P_{OUT} (VBAT = 1.8 V, P_{IN} = –1 dBm, max power index)		+12		
Saturated gain	G_SAT	Linear mode		22		dB
Small signal gain	S21	P_{IN} = –25 dBm, linear mode		24		dB
Saturated output power variation	DPOUT	Across all Zigbee® function channels			1	dBp-p
Second harmonics[2]	2fo	P_{OUT} = +20 dBm, IEEE 802.15.4 source			–45	dBm/MHz
Third harmonics[2]	3fo	P_{OUT} = +20 dBm, IEEE 802.15.4 source			–45	dBm/MHz
Input return loss	S11	P_{IN} = –25 dBm, linear mode		–8.4		dB
Switching time (RX to TX)	t_{RX-TX}	From 50% of TXEN rising edge to 90% of final TX RF output power		12		µs
Turn-on time (SHUT-DOWN to TX)	tRISE	From 50% of TXEN rising edge to 90% of final RF output power		45		µs
Turn-off time (TX to SHUTDOWN)	tFALL	From 50% of TXEN failing edge to 10% of final RF output power		125		ns
Stability	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	RUG	CW, P_{IN} = 0 dBm, load VSWR = 10:1	No permanent damage			
TX EVM	EVM_TX	P_{IN} = 2/0/–2/–6/–10 dBm 802.15.4 packetized 10% dc input signal CH11/CH18/CH26 with max/min power index		1		%
Power detector voltage	VDET	P_{OUT} = +9 dBm, 10 kΩ load		80		mV
		P_{OUT} = +20 dBm, 10 kΩ load		900		
Receive Characteristics						
Frequency range	f		2400		2500	MHz
Receive gain	RX_GAIN	Low noise figure receive		14.9		dB
		Low current receive		9.7		
Receive noise figure	NF	Low noise figure receive		3.2		dB
		Low current receive		4.2		
Third order input intercept point	IIP3			2		dBm
1 dB input compression point	IP1dB	Low noise figure receive		–7.5		dBm
		Low current receive		+1		
Input return loss	S11	ANT1 or ANT2 port, P_{IN} = –25 dBm: Low noise figure receive Low current receive		 –7.5 –7		dB
Reverse isolation	S12	ANT1 or ANT2 port, P_{IN} = –25 dBm: Low noise figure receive Low current receive		 –31.5 –30.5		dB
Output return loss	S22	ANT1 or ANT2 port, P_{IN} = –25 dBm: Low noise figure receive Low current receive		 –12.5 –10.5		dB
Switching time (TX to RX)	t_{TX-RX}	From 50% of TXEN falling edge to 90% of final RX RF output power		1.2		µs

Table 5. DC Electrical Specifications[1] (Continued)

(VBAT = 3.3 V, VDD = 1.8 V, T_A = +25 °C, All Unused Ports Terminated with 50 Ω, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Turn-on time (SHUTDOWN to RX)	tRISE	From 50% of RXEN rising edge to 90% of final RF output power		2.5		µs
Turn-off time (RX to SHUTDOWN)	tFALL	From 50% of RXEN falling edge to 10% of final RF output power		43		ns
RX gain variation over frequency	ΔGRX_F			1		dB
RX gain variation over temperature	ΔGRX_TEMP			2		dB
Bypass Characteristics						
Frequency range	f		2400		2500	MHz
Insertion loss[3]	BYP_LOSS			6		dB
Input return loss	S11			–12		dB
Output return loss	S22			–9.5		dB
1 dB output compression point	OP1dB		14			dBm
EVM	EVM_BYPASS	+4 dBm 802.15.4 packetized 10% dc input signal CH11/CH18/ CH26 with max/min power index		1		%

1. Performance is assured only under the conditions listed in this table and is not assured over the full operating or storage temperature ranges. Operation at elevated temperatures may reduce reliability of the device.
2. External filtering needed.
3. External harmonic filter loss is included.

Table 6. GPIO Control Logic[1, 2]

(VBAT = 3.3 V, VDD = 1.8 V, T_A = +25 °C)

Mode of Operation	RSTB (Pin 12)	TXEN (Pin 19)	RXEN (Pin 20)	Mode (Pin 21)	ANT_SEL (Pin 22)
Shutdown	1	0	0	0	X
Bypass	1	0	0	1	X
Low ICC TX	1	1	X	0	X
High ICC TX	1	1	X	1	X
Low noise figure receive	1	0	1	0	X
Low current receive	1	0	1	1	X
ANT1 port enabled	1	X	X	X	1
ANT2 port enabled	1	X	X	X	0
Reset[3]	0	X	X	X	X

1. "1" Denotes high voltage state (>1.2 V)
   "0" Denotes low voltage stage (<0.3 V) at control pins
   "X" Denotes do not care: floating pins not allowed
2. Proper host controller pull-down needed for Shutdown in application circuit.
3. Reset: Refer to Table 8 Default column for device status after reset.

Table 7. Power Index and Respective Output Power with 0 dBm RF Input Power

VBAT = 3.3 V f = 2442 MHz

PWR_INDX	Target POUT (dBm)	PWR_INDX	Target POUT (dBm)
31	19.9	16	10.1
30	19.5	15	9.3
29	18.8	14	8.6
28	18.2	13	7.8
27	17.6	12	7.1
26	17.0	11	6.4
25	16.4	10	5.7
24	15.9	9	4.6
23	15.2	8	3.4
22	14.6	7	2.2
21	13.8	6	1.5
20	12.9	5	–0.2
19	12.2	4	–0.7
18	11.5	3	–1.3
17	10.8	2	–1.8

Table 8. Register Map Information

Slave Address	Register Address	Register Name	Data Bits	Function Name	Function Description	Default	Type	Description
0x1B	0x00	HW version	7:4	UNUSED	Reserved for future use	0x0	R	
			3:0	HW_ID		0x0	R	0x1: ES1
								0x2: ES2
	0x01	PWR INDX	7:5	UNUSED	Reserved for future use	0x0	R	
			4:0	PWR_IDX	Power index	0x00	R/W	0x0: Minimum Pout level
								0x1:
								…
								0x1F: Maximum Pout level
	0x02	GPIO STATUS	7:4	UNUSED	Reserved for future use	0x0	R	
			3	STAT_ANT_SEL	Status of ANT_SEL	0x0	R	0x0: ANT1 selected
								0x1: ANT2 selected
			2	STAT_MODE	Status of MODE	0x0	R	0x0: Disabled
								0x1: Enabled
			1	STAT_RXEN	Status of RXEN	0x0	R	0x0: Disabled
								0x1: Enabled
			0	STAT_TXEN	Status of TXEN	0x0	R	0x0: Disabled
								0x1: Enabled
	0x03	GPIO CFG	7:4	UNUSED	Reserved for future use	0x0	R	
			3	CFG_ANT_SEL	Configuration of ANT_SEL	0x0	R/W	0x0: Disable
								0x1: Enable
			2	CFG_MODE	Configuration of MODE	0x0	R/W	0x0: Disable
								0x1: Enable
			1	CFG_RXEN	Configuration of RXEN	0x0	R/W	0x0: Disable
								0x1: Enable
			0	CFG_TXEN	Configuration of TXEN	0x0	R/W	0x0: Disable
								0x1: Enable
	0x04	GPIO CTRL	7:4	UNUSED	Reserved for future use	0x0	R	
			3	CTL_ANT_SEL	Control of ANT_SEL	0x0	R/W	0x0: GPIO
								0x1: I^2C
			2	CTL_MODE	Control of MODE	0x0	R/W	0x0: GPIO
								0x1: I^2C
			1	CTL_RXEN	Control of RXEN	0x0	R/W	0x0: GPIO
								0x1: I^2C
			0	CTRL_TXEN	Control of TXEN	0x0	R/W	0x0: GPIO
								0x1: I^2C

Evaluation Board Description

An evaluation board is used to test the performance of the SKY66408-11 FEM. An evaluation board schematic diagram is shown in Figure 3.

Note: VCC1 and VCC2 must be externally decoupled per the schematic and bill of materials table.

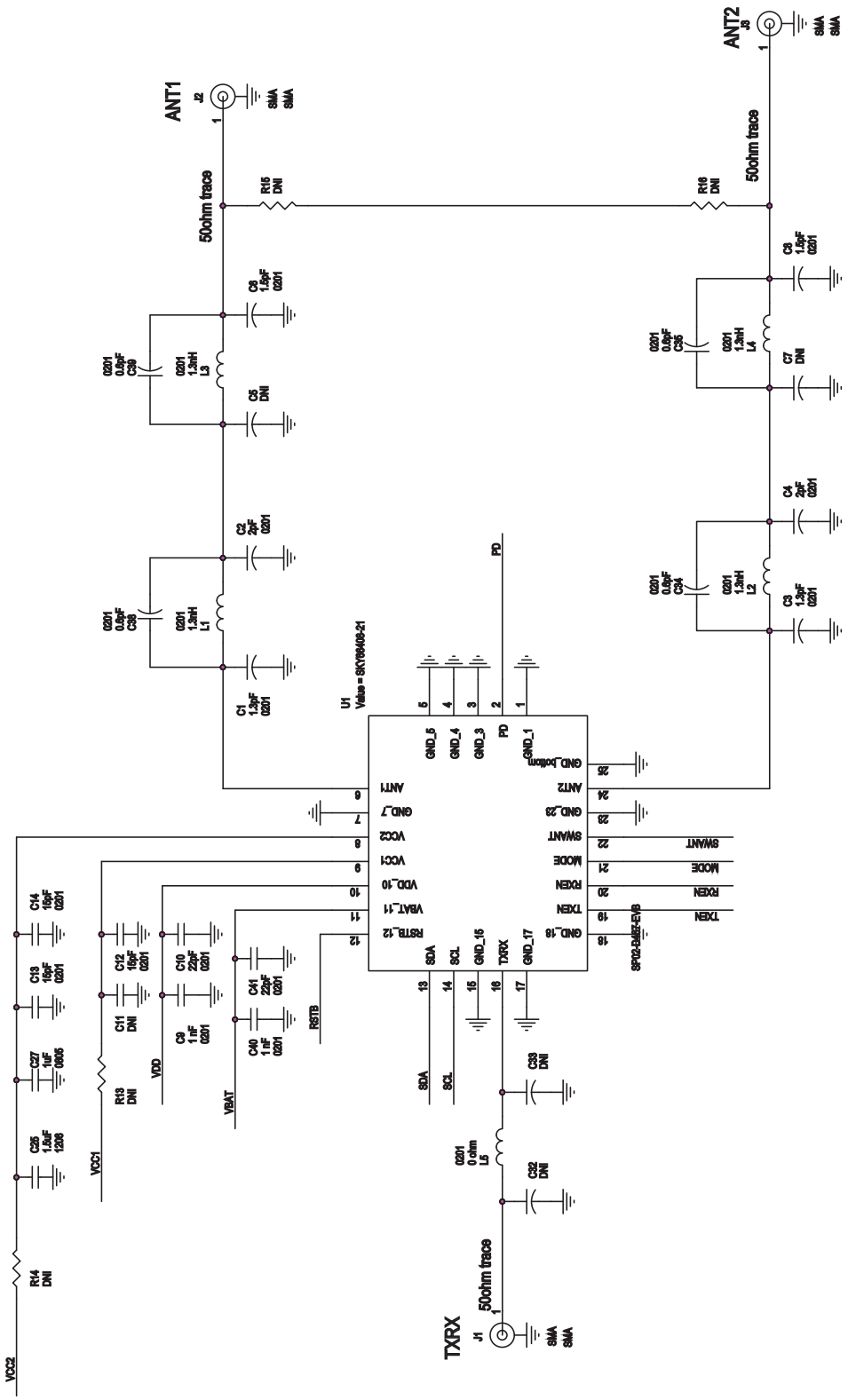


Figure 3. Evaluation Board Schematic Diagram, Part 1

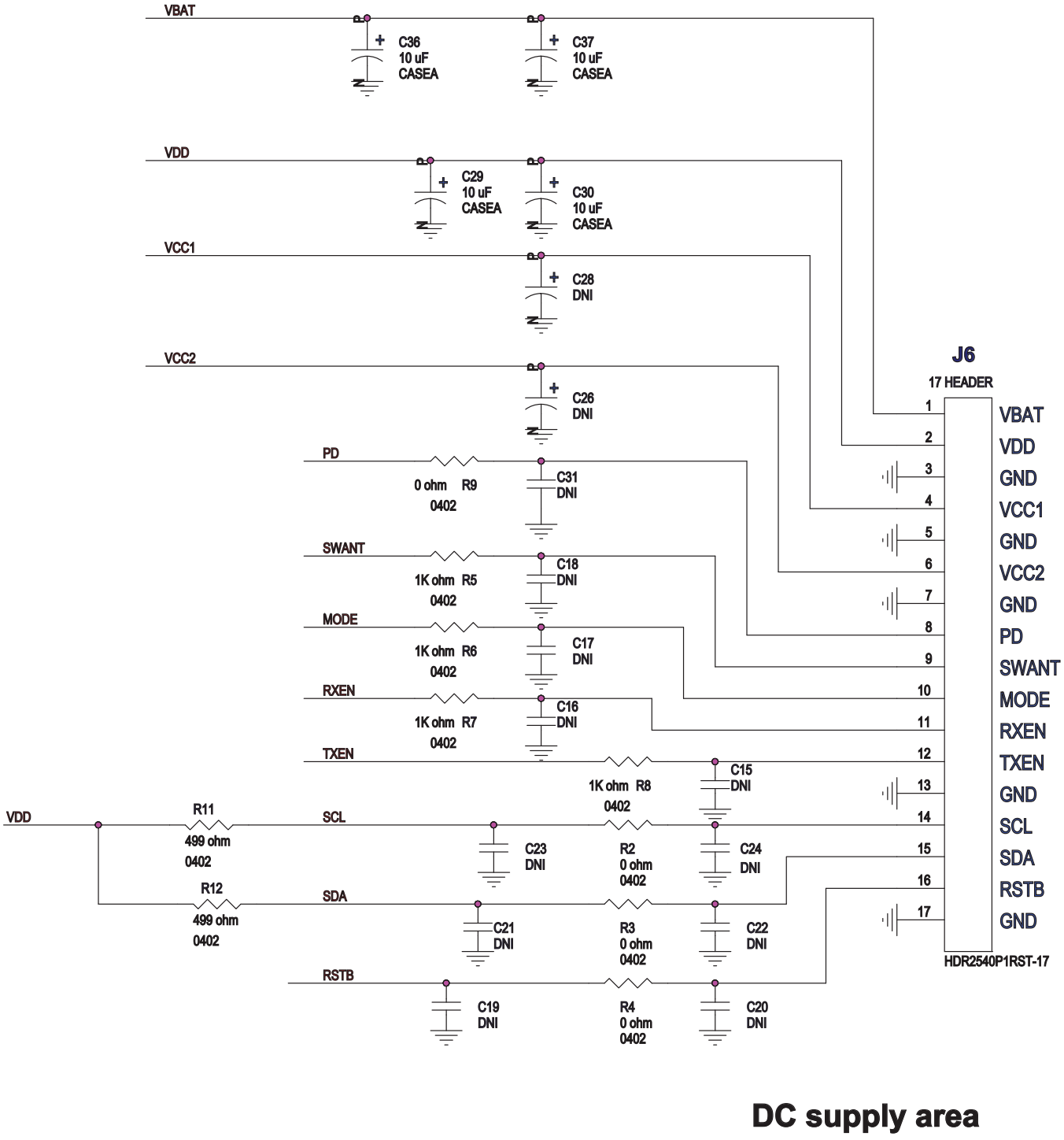


Figure 3. Evaluation Board Schematic Diagram, Part 2

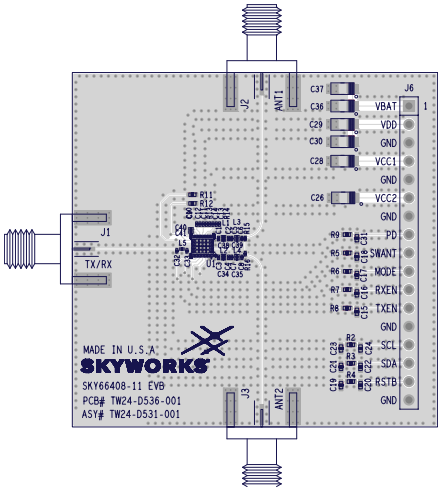


Figure 4. Evaluation Board Assembly Diagram

Table 9. Evaluation Board Bill of Materials

Component	Value	Manufacturer	Mfr Part Number	Size	Description
C1, C3	1.3 pF	Murata	GJM0335C1E1R3BB01D	0201	Ceramic capacitor 1.3 pF 25 V C0G/NP0 or equivalent
C2, C4	2 pF	Murata	GJM0335C1E2R0CB01D	0201	Ceramic capacitor 2 pF 25 V C0G/NP0 or equivalent
C6, C8	1.5 pF	Murata	GJM0335C1E1R5CB01D	0201	Ceramic capacitor 1.5 pF 25 V C0G/NP0 or equivalent
C34, C35, C38, C39	0.6 pF	Murata	GJM0335C1HR60WB01D	0201	Ceramic capacitor 0.6 pF 50 V C0G/NP0 or equivalent
C9, C40	1 nF	Murata	GRM033R71C102JD01	0201	Ceramic capacitor 1000 pF 25 V X7R or equivalent
C10, C41	22 pF	Murata	GRM0335C1E220JD01D	0201	Ceramic capacitor 22 pF 25 V C0G/NP0 or equivalent
C12, C13, C14	15 pF	Murata	GJM0335C1E150GB01	0201	Ceramic capacitor 15 pF 25 V C0G/NP0 or equivalent
C29, C30, C36, C37	10 µF	AVX	TAJA106K016R	1206	Capacitor TANT 10 µF 20% 16 V or equivalent
C25	1.5 µF	Murata	GRT31CC81H155KE01	1206	Ceramic capacitor 1.5 µF 10% 50 V X6S or equivalent
C27	1 µF	TDK	C2012X7R1V105K125AB	0805	Ceramic capacitor 1 µF 10% 35 V X7R or equivalent
C5, C7, C11, C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C26, C28, C31, C32, C33					DNI
J1, J2, J3	SMA	Johnson Components	142-0701-851	End launch	Connector SMA Jack STR 50 Ω edge-mount
J6	Header 17X1	Molex	22284170	2.54 mm pitch	Connector header VERT 17 POS 2.54 mm
L1, L2, L3, L4	1.3 nH	Murata	LQP03TG1N3B02	0201	Fixed inductor 1.3 nH 600 mA or equivalent
L5	0 Ω	Murata	ERJ2GE0R00X	0201	Resistor SMD 0 Ω jumper 1/10 W or equivalent
PCB	Z1577-A	Skyworks			PCB
R11, R12	500 Ω	Panasonic	ERJ2GEJ501X	0402	Resistor SMD 500 Ω 5% 1/10 W or equivalent
R2, R3, R4, R9	0 Ω	Panasonic	ERJ2GE0R00X	0402	Resistor SMD 0 Ω jumper 1/10 W or equivalent
R5, R6, R7, R8	1 kΩ	Panasonic	ERJ2GEJ102X	0402	Resistor SMD 1 kΩ 5% 1/10 W or equivalent
R13, R14	DNI				
R15, R16	DNI				
U1	SKY66408-11	Skyworks Solutions	SKY66408-11	3 x 3 mm	Front-end module

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 SKY66408-11 is rated to Moisture Sensitivity Level 3 (MSL3) at 260 °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.

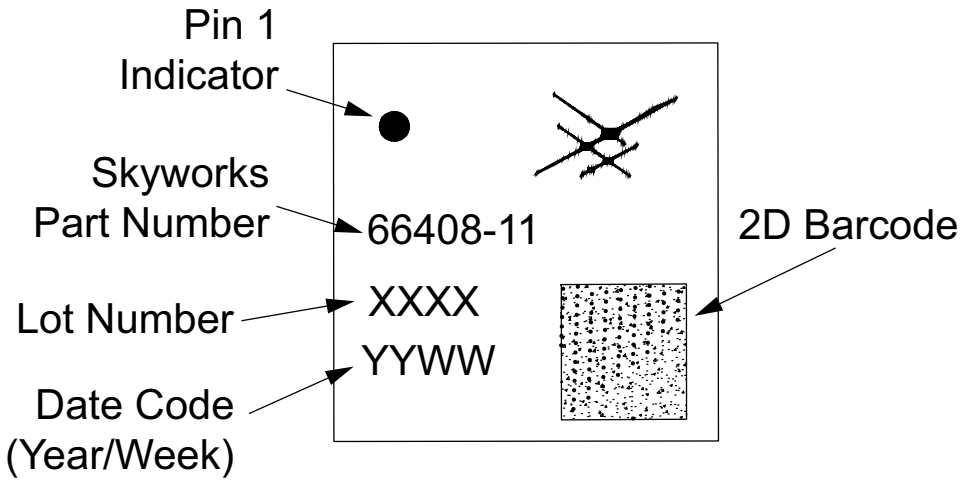


Figure 5. Typical Part Marking

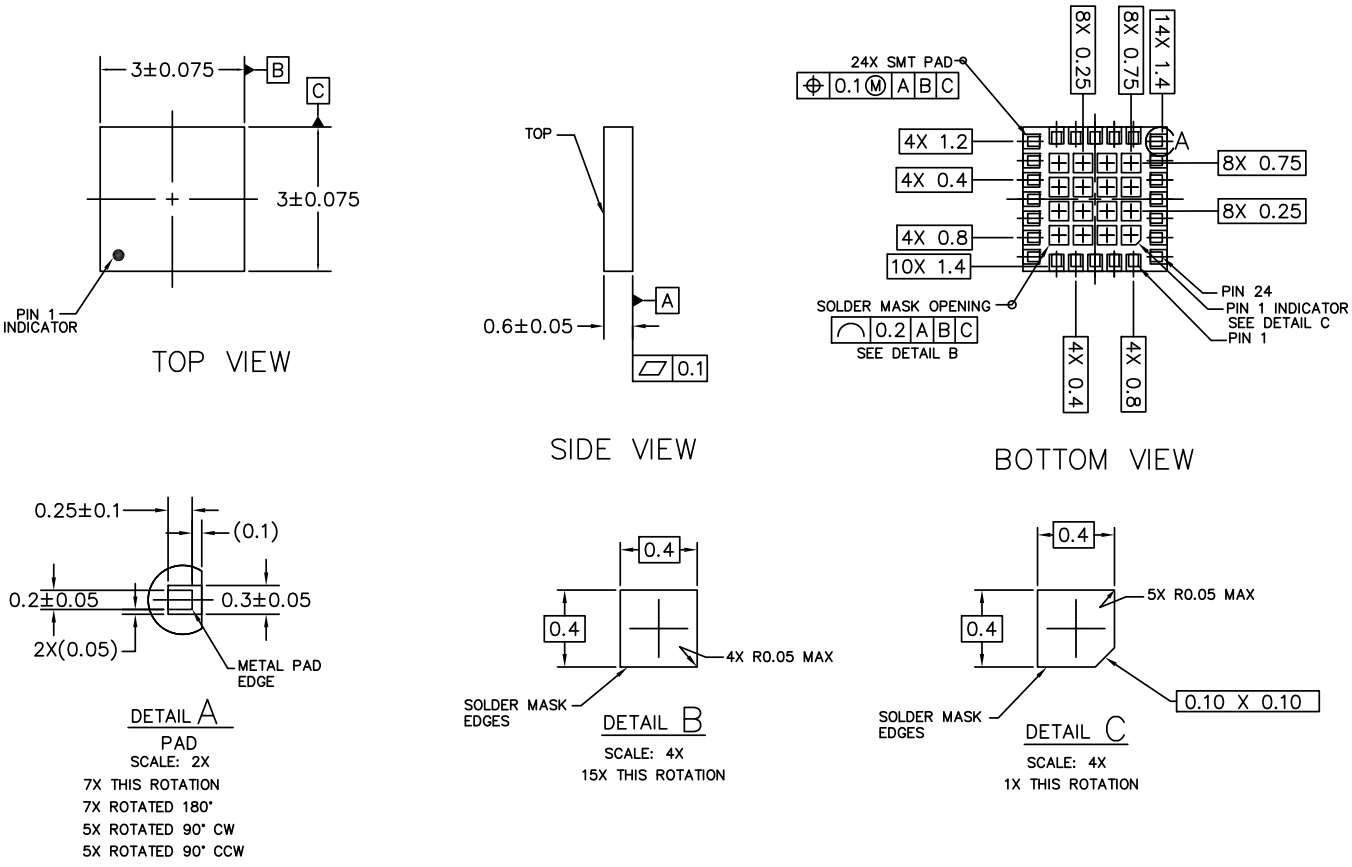
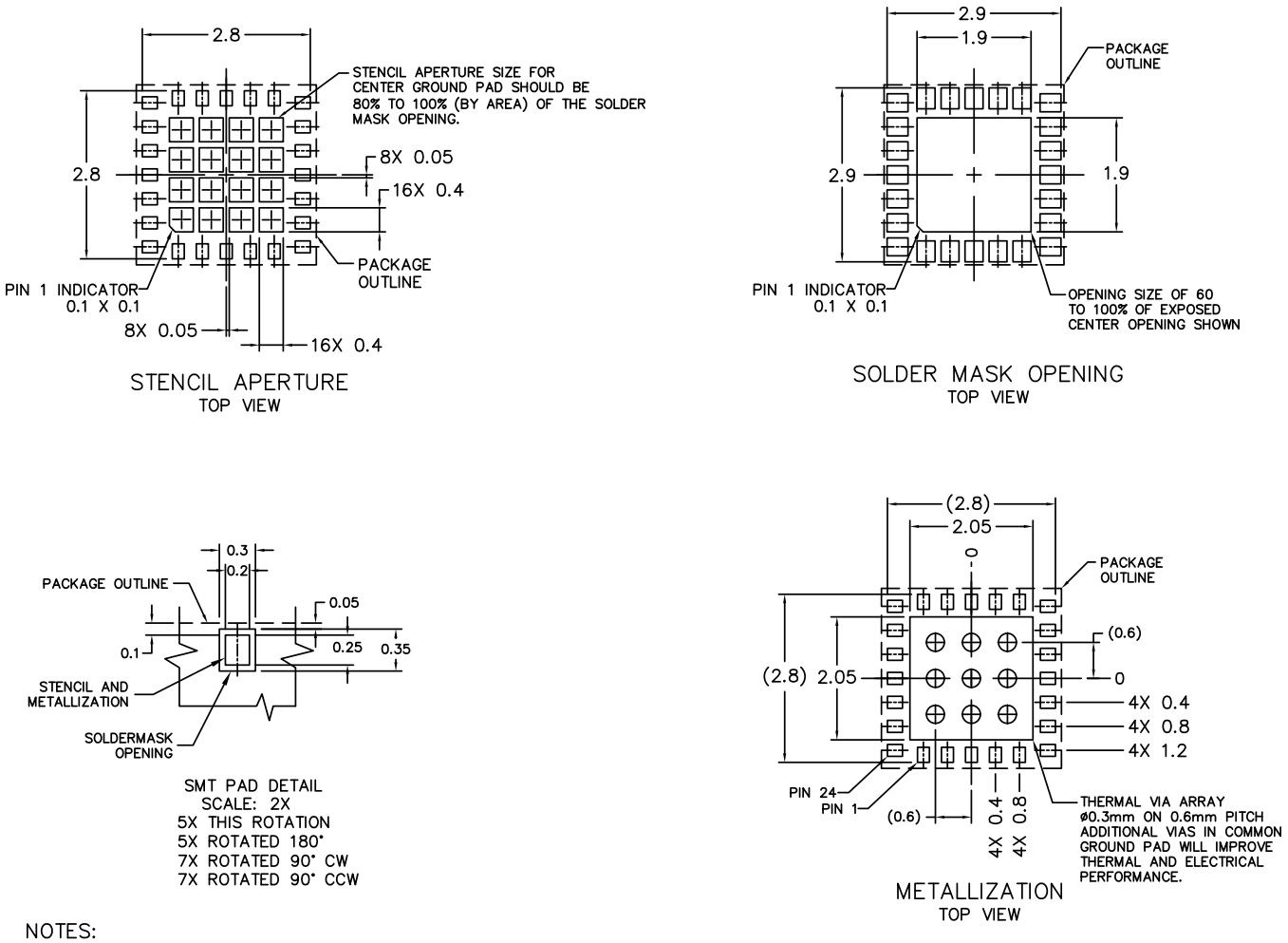
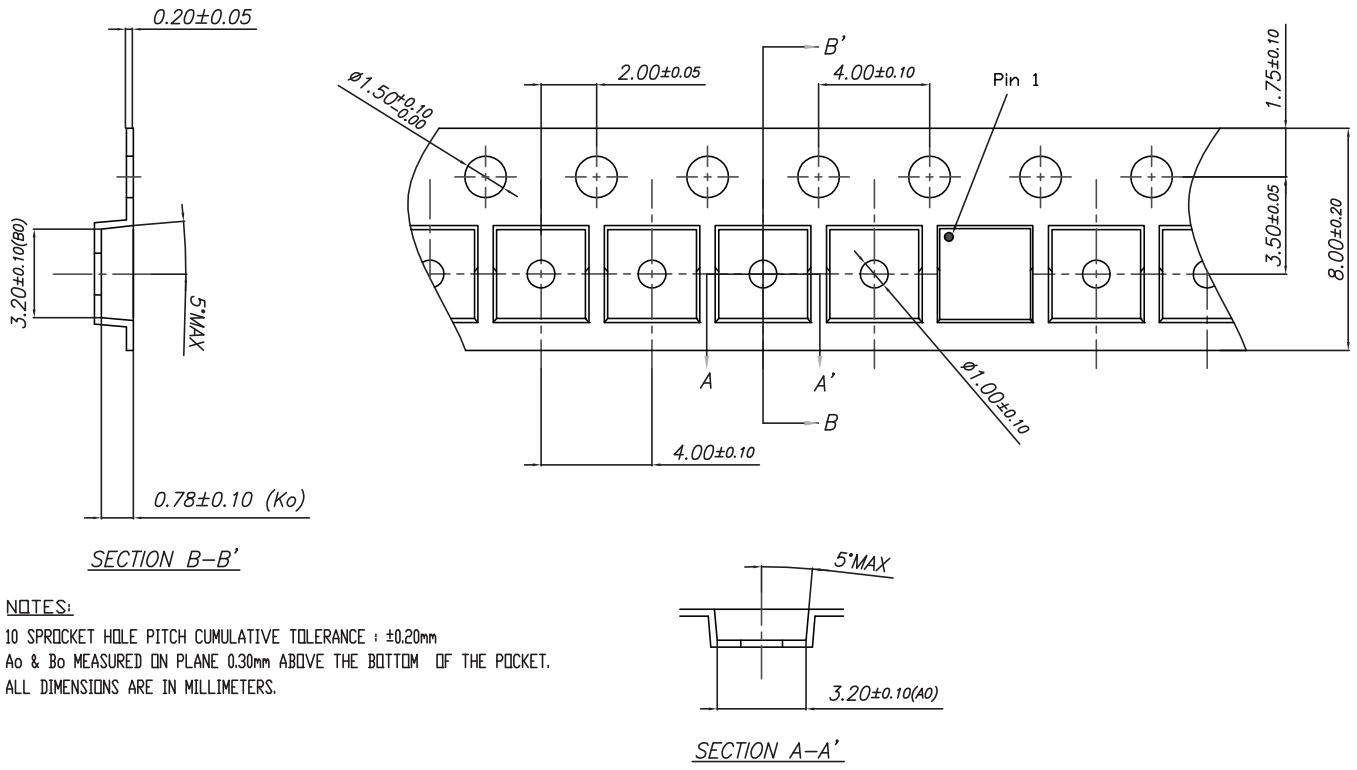


Figure 6. Package Dimensions



NOTES:
1. DIMENSIONS ARE IN MILLIMETERS, UNLESS OTHERWISE SPECIFIED.
2. THERMAL VIAS SHOULD BE RESIN FILLED AND CAPPED IN ACCORDANCE WITH IPC–4761 TYPE VII VIAS. 30–35UM Cu THICKNESS IS RECOMMENDED.

Figure 7. PCB Layout Footprint



NOTES:

10 SPROCKET HOLE PITCH CUMULATIVE TOLERANCE : ±0.20mm
Ao & Bo MEASURED ON PLANE 0.30mm ABOVE THE BOTTOM OF THE POCKET.
ALL DIMENSIONS ARE IN MILLIMETERS.

Figure 8. Tape and Reel Information

Ordering Information

Part Number	Description	Evaluation Board Part Number
SKY66408-11	2.4 GHz Front-End Module for Zigbee®/Thread/Bluetooth® Signal Applications	SKY66408-11EK1