DATA SHEET

SKY66407-11: 2.4 GHz Low-Power, Low-Profile Front-End Module for Bluetooth® IoT Applications

Applications

- Wearables
- Trackers
- Beacons
- Sensor networks
- Home automation
- Internet of Things (IoT) devices

Features

- Adjustable gain, output power, and current consumption
- Max BT EDR output power: +11.5 dBm
- Wide supply range: 1.7 to 3.6 V
- High ESD rating: 2 kV
- Low sleep current: < 1 uA
- Low Rx bypass loss
- Small CSP (9-pin, 1.2 x 1.2 x 0.35 mm) 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.

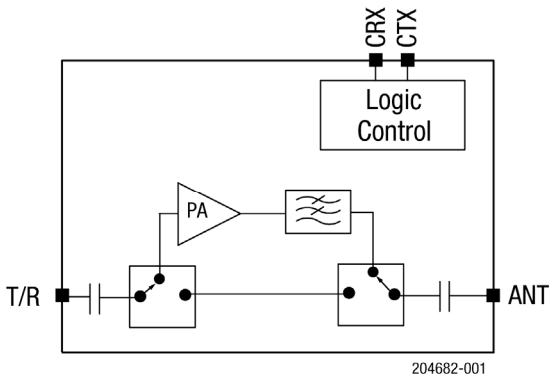


Figure 1. SKY66407-11 Functional Block Diagram

Description

The SKY66407-11 is a highly integrated front-end module (FEM) designed for Bluetooth IoT applications operating in the 2.4 to 2.4835 GHz range.

The device is provided in a 1.2 x 1.2 x 0.35 mm 9-pin CSP package. A functional block diagram is shown in Figure 1. Pin assignments are shown in Figure 2. Signal pin assignments and functional pin descriptions are provided in Table 1.

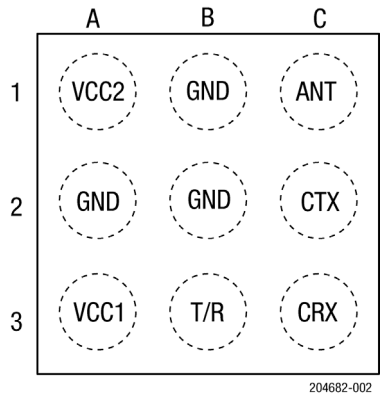


Figure 2. SKY66407-11 Pinout (Top View)

Table 1. SKY66407-11 Signal Descriptions

Bump	Name	Description	Bump	Name	Description
A1	VCC2	Positive power supply	B3	T/R	Connect to 50 Ω transceiver output
A2	GND	Ground	C1	ANT	Connect to 50 Ω antenna
A3	VCC1	Positive power supply	C2	CTX	Tx control signal
B1	GND	Ground	C3	CRX	RX control signal
B2	GND	Ground			

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY66407-11 are provided in Table 2. The recommended operating conditions are specified in Table 3.

Electrical specifications are provided in Tables 4 through 6.

Table 2. SKY66407-11 Absolute Maximum Ratings[1]

Parameter	Symbol	Minimum	Maximum	Units
Supply voltage	V_{CC1}, V_{CC2}	0.3	4.0	V
Control voltages	CTX, CRX	0.3	4.0	V
Transmit input power at T/R port	P_{IN_TX}		+8	dBm
Receive input power at ANT port[2]	P_{IN_RX}		+20	dBm
Voltage standing wave ratio	VSWR		10:1	
Operating temperature	T_A	-40	+105	°C
Storage temperature	T_{STG}	-40	+125	°C
Electrostatic discharge:	ESD			
Human Body Model (HBM), Class 2			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 CW test signal.

***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	Min	Typ	Max	Units
Supply voltage	V_{CC1}, V_{CC2}	1.7	3.3	3.6	V
Control voltages	CTX	1.0	1.8	2.2	V
Operating temperature	T_A	-40	+25	+85	°C

Table 4. SKY66407-11 DC Electrical Specifications[1]
(V_{CC1} = V_{CC2} = 3.3 V, CTX = 1.8 V, T_A = +25 °C, Characteristic Impedance [Z_O] = 50 Ω, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Transmit operating current	I_{CC_TX}	TX mode (P_{IN} = 0 dBm): V_{CC2} = 1.8 V V_{CC2} = 3.3 V V_{CC2} = 3.6 V		 13 16 17		 mA mA mA
Transmit quiescent current	I_{CQ_TX}	TX mode		8		mA
Receive (bypass) current[2]	I_{CC_RX}	RX mode		4.0		uA
Sleep mode current	I_{CC_OFF}	Sleep mode		0.1	1	uA
Logic Characteristics						
Control voltage: High Low	 V_{IH} V_{IL}		 1.6 0		 V_{CC1} 0.3	 V V
Tx bias current (CTX pin)	I_{BIAS_TX}			30		uA
Rx control current (CRX pin)	I_{BIAS_RX}			1.0		uA

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

2 The current will be the same as sleep current if logic high levels are equal to VCC1.

Table 5. SKY66407-11 AC Electrical Specifications[1]
(V_{CC1} = V_{CC2} = 3.3 V, CTX = 1.8 V, T_A = +25 °C, P_{IN} = 0 dBm, Characteristic Impedance [Z_O] = 50 Ω, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Transmit Characteristics						
Frequency range	f		2400		2483.5	MHz
Output power	P_{OUT}	V_{CC2} = 1.8 V BDR V_{CC2} = 3.3 V BDR V_{CC2} = 3.6 V BDR VCC2 = 3.3 V EDR-3 VCC2 = 3.6 V EDR-3		+9.5 +12 +12.5 +10.0[2] +10.5[2]		dBm dBm dBm dBm dBm
Saturated gain[3]	G_SAT	P_{IN} = 0 dBm		12		dB
Small signal gain	S_{21_TX}	P_{IN} = -25 dBm		13		dB
Gain slope	G_{SLOPE}	Over frequency range			1	dBp-p
Input return loss[3]	S_{11_TX}	T/R port		-10		dB
Output return loss[3]	S_{22_TX}	ANT port		-12		dB
2nd harmonic[3]	2fo	P_{OUT} = +10 dBm, CW signal source			-40	dBm/MHz
3rd harmonic[3]	3fo	P_{OUT} = +10 dBm, CW signal source			-30	dBm/MHz
TX turn-on time[3]	t_{ON_TX}	50% V_{CTX} to 90% RF		800		ns
TX turn-off time[3]	t_{OFF_TX}	50% V_{CTX} to 10% RF		200		ns
Stability[3]	STAB	CW, P_{IN} = 0 dBm, 0 GHz to 20 GHz, load VSWR = 6:1	All non-harmonically related outputs < -42 dBm/MHz			
Ruggedness[3]	RUG	CW, P_{IN} = 0 dBm, load VSWR = 10:1	No permanent damage			
Receive Characteristics						
Frequency range	f		2400		2483.5	MHz
Insertion loss	S_{21_RX}			-1.0		dB
Input return loss[3]	S_{11_RX}	ANT port		-15		dB
Output return loss[3]	S_{22_RX}	T/R port		-15		dB
RX turn-on time[3]	t_{ON_RX}	50% V_{CRX} to 90% RF		800		ns
RX turn-off time[3]	t_{OFF_RX}	50% V_{CRX} to 10% RF		200		ns

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

2 Refer to Bluetooth EDR section for higher output power operation.

3 Guaranteed by characterization.

Table 6. SKY66407-11 Mode Logic Truth Table

Mode	CTX	CRX
Sleep mode	0	0
Receive (RX) mode	0	1
Transmit (TX) mode	1	X

CTX Pin Usage

The SKY66407-11 CTX pin supplies the bias to the internal PA. By varying the voltage at this pin, PA operating parameters including gain, supply current, and efficiency can be adjusted.

The CTX pin can also be used to adjust the SKY66407-11 output power when the RF source (transceiver or baseband) has a fixed level. Figure 3 shows the output power vs CTX level at different input power, while Figures 4 through 12 show the gain, current, and PAE performance vs CTX at different output power.

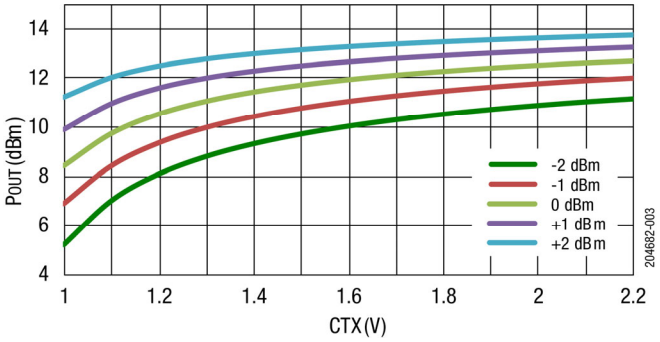


Figure 3. POUT vs CTX and PIN (VCC = 3.3 V, f = 2440 MHz)

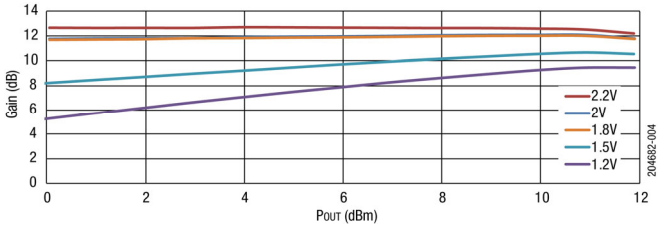


Figure 4. Gain vs POUT and CTX (VCC = 3.3 V, f = 2440 MHz @ 25 °C)

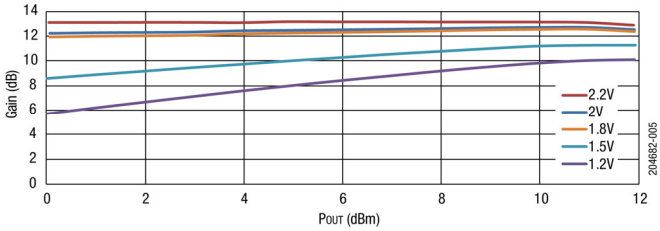


Figure 5. Gain vs POUT and CTX (VCC = 3.3 V, f = 2440 MHz = 3.3 V @ -20 °C)

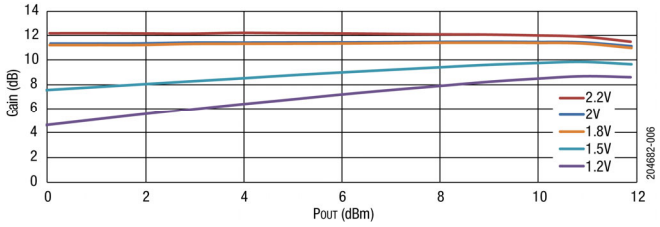


Figure 6. Gain vs POUT and CTX (VCC = 3.3 V, f = 2440 MHz = 3.3 V @ +60 °C)

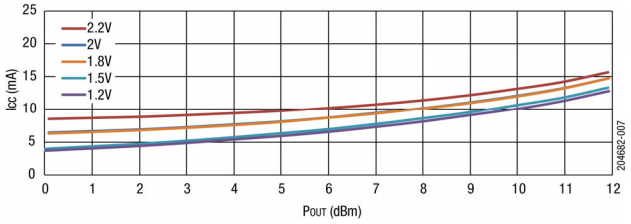


Figure 7. ICC vs POUT and CTX (VCC = 3.3 V, f = 2440 MHz @ 25 °C)

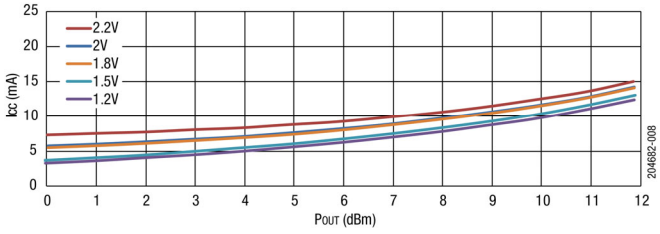


Figure 8. ICC vs POUT and CTX (VCC = 3.3 V, f = 2440 MHz V @ -20 °C)

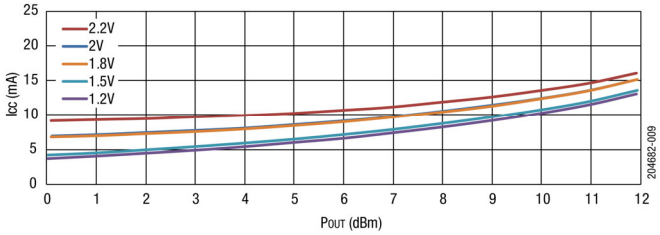


Figure 9. ICC vs POUT and CTX and PIN (VCC = 3.3 V, f = 2440 MHz @ +60 °C)

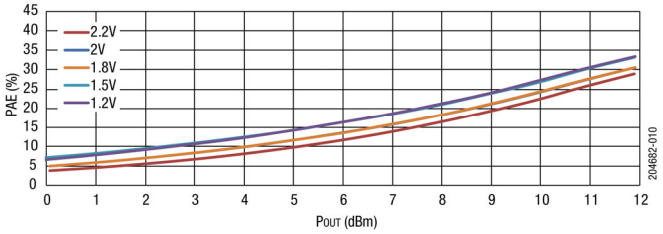


Figure 10. PAE vs POUT and CTX
(VCC = 3.3 V, f = 2440 MHz @ 25 °C)

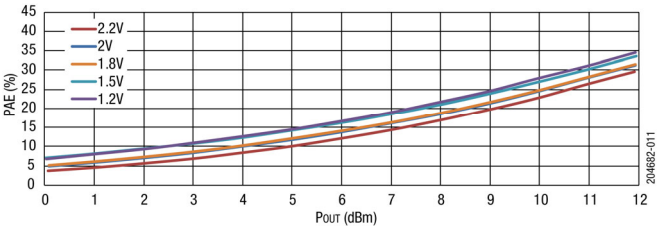


Figure 11. PAE vs POUT and CTX
(VCC = 3.3 V, f = 2440 MHz @ -20 °C)

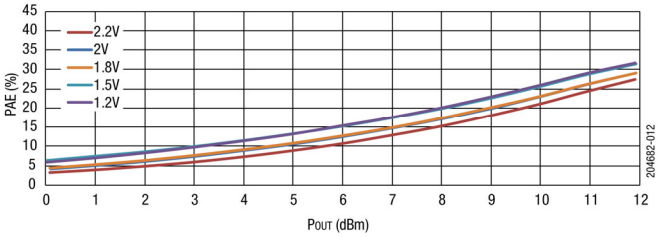


Figure 12. PAE vs POUT and CTX
(VCC = 3.3 V, f = 2440 MHz @ +60 °C)

In many applications, a variable DC supply voltage may not be available. The desired bias voltage can be generated by connecting CTX to the GPIO controlling CTX with a resistor (refer to Figure 13). With no RF input, the CTX pin draws very little current. Toggling the CTX from the GPIO also causes the PA to turn off when CTX is pulled low, reducing the RX and shutdown mode current.

Table 7 lists the relationship between CTX voltage/current and bias resistance.

Table 7. V_{CTX} Voltage and Current vs Bias Resistance (V_{CC} = 3.3 V)

R_{BIAS} (kΩ)	CTX (V)	ICTX (uA)	ICC (mA)
22	2.2	58	12.9
27	2.1	55	11.5
32	2	50	10.2
39	1.9	46	8.9
47	1.8	40	7.6
59	1.7	36	6.4
76	1.6	32	5.2
99	1.5	28	4.1
133	1.4	24	3.1
200	1.3	20	2.1
310	1.2	16	1.3
600	1.1	14	0.7

If a fixed CTX voltage (for example, from an LDO) is available in the application circuit, using this instead of a resistor reduces the variation of output power with VCC. To minimize SKY66407-11 current consumption in RX bypass and shutdown modes, the voltage to the CTX pin should be switched off when the CTX is logic low.

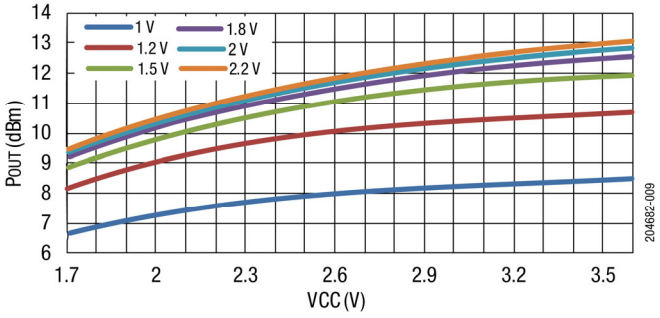


Figure 13. P_{OUT} vs V_{CC} and CTX (P_{IN} = 0 dBm, f = 2440 MHz)

Bluetooth EDR Adjacent Channel Power

The SKY66407-11 benefits from excellent adjacent channel power (ACP) performance in Bluetooth EDR applications.

Typical ACP measurements for EDR modulations (π/4-DQPSK with 2-DH5 packets) are shown in Figures 14 through 17 (Note: VCC = 3.3 V, VCTX = 1.8 V, f = 2440 MHz).

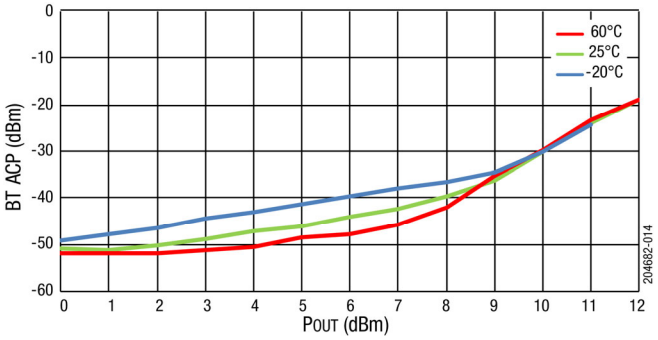


Figure 14. BT ACP CH+2 vs POUT, BT-EDR-2DH5

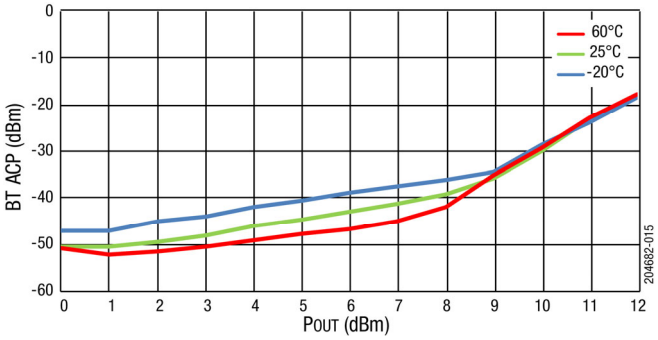


Figure 15. BT ACP CH-2 vs POUT, BT-EDR-2DH5

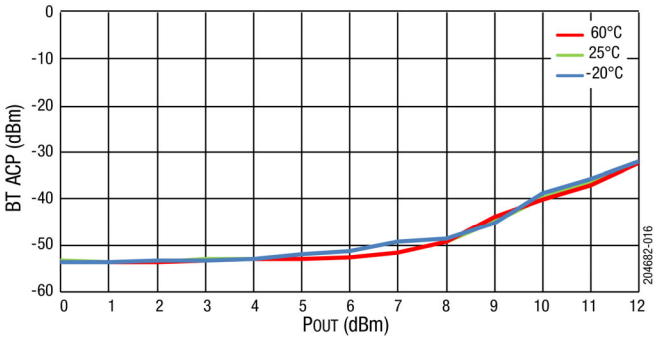


Figure 16. BT ACP CH+3 vs POUT, BT-EDR-2DH5

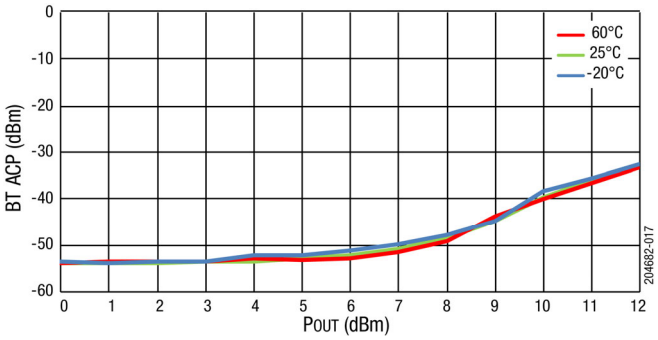


Figure 17. BT ACP CH-3 vs POUT, BT-EDR-2DH5

Evaluation Board Description

The SKY66407-11 Evaluation Board is used to test the performance of the SKY66407-11 front-end module. The board is optimized for evaluation, experimentation, and investigation with a BLE or 802.15.4 signal source. The design and layout can be quickly and easily transferred into a production design.

A reference design schematic is provided in Figure 18. An Evaluation Board schematic diagram is provided in Figure 19. A photograph of the Evaluation Board is shown in Figure 20. The Evaluation Board Bill of Materials (BoM) is listed in Table 8.

Evaluation Board Setup Procedure

1. Connect system ground to pin 1 of the J3 header.
2. Apply 3.3 V to pin 2 of the J3 header.
3. Select a path according to the information in Table 6 (L = 0 V, H = 3.3 V) using pin 6 (VCTX) and pin 10 (VCRX) of the J3 header.

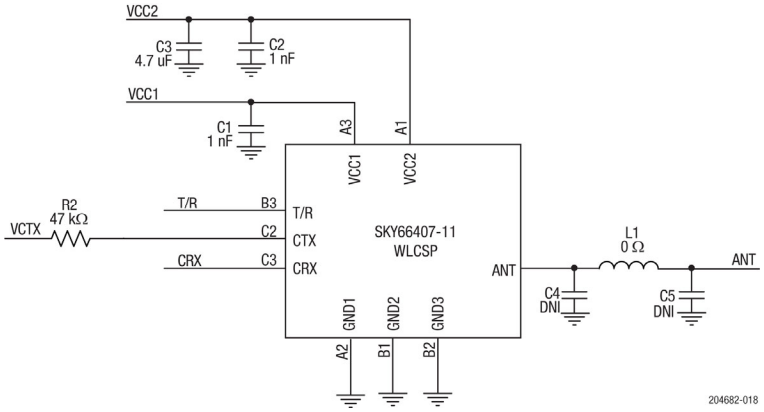


Figure 18. SKY66407-11 Reference Design Schematic

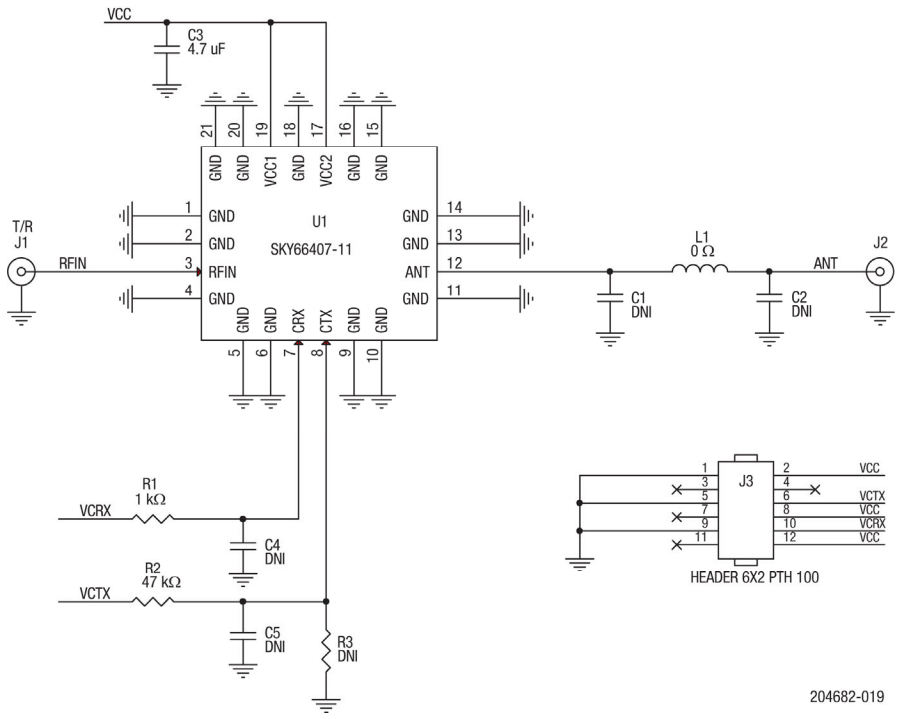


Figure 19. SKY66407-11 Evaluation Board Schematic

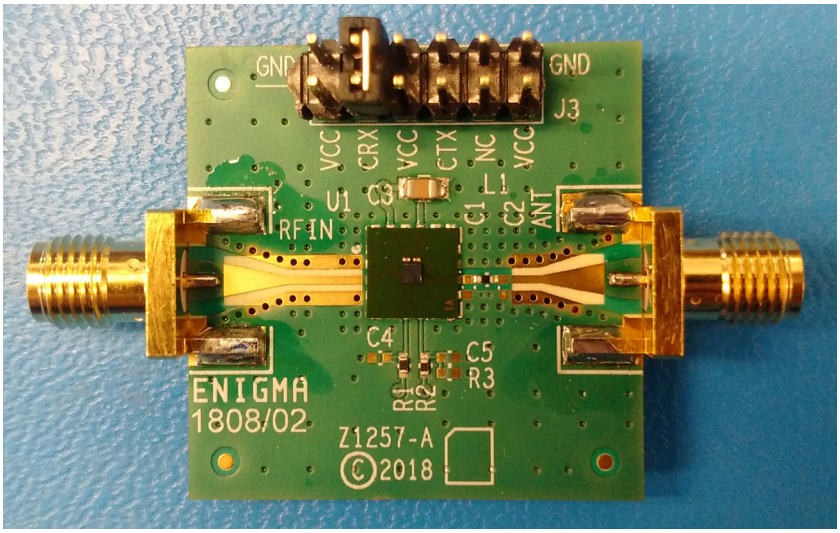


Figure 20. SKY66407-11 Evaluation Board

Table 8. SKY66407-11 Evaluation Board Bill of Materials (BoM)

Reference	Value	Manufacturer	Mfr Part Number	Package	Description
C1, C2, R3, C4, C5	DNI			0402	DNI
C3	4.7 uF	muRata	GRM21BR71C475KA73L	0805	Ceramic capacitor, 4.7 uF, 16 V, X7R
J1, J2	SMA	Johnson Components	142-0701-851	End Launch	Connector SMA jack, STR, 50 Ω, edge mount
J3	Header 6X2 PTH 100	Samtec	TSW-106-07-G-D		Connector header, 12 POS, 100" DL gold
L1	0 Ω			0402	
PCB1	Z1257-A	Skyworks	Z1257-A		PCB
R1	1 kΩ	Panasonic	ERJ-PA2F1001X	0402	Resistor, SMD, 1 kΩ, 1%, 1/5 W
R2	47 kΩ	Multi-vendor	5424R27-134	0402	Resistor, 47 kΩ, jumper, 0.063 W
U1	SKY66407-11 CSP	Skyworks Solutions			

Package Dimensions

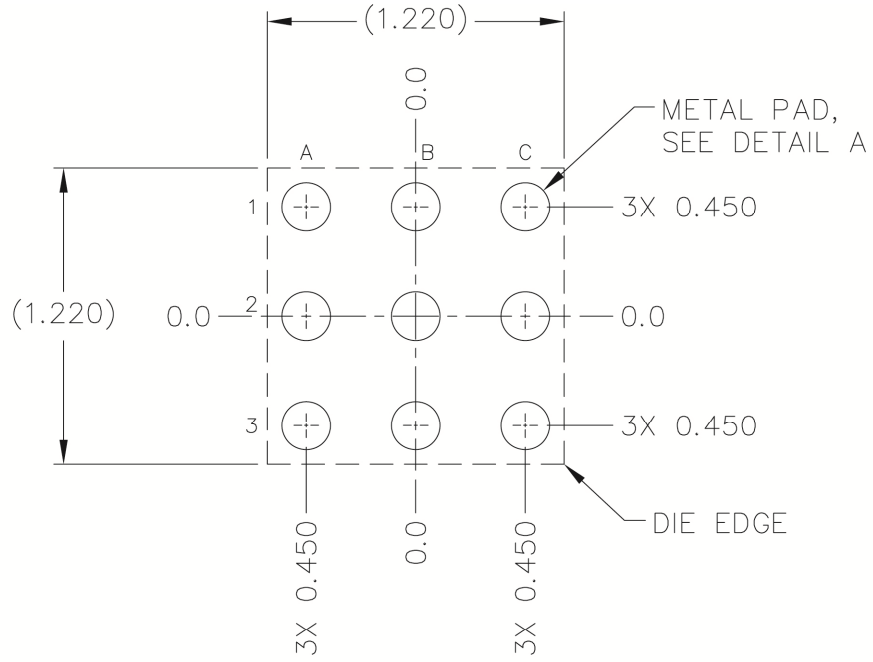
The PCB layout footprint for the SKY66407-11 is provided in Figure 21. The typical part marking is shown in Figure 22. Package dimensions are shown in Figure 23, and tape and reel dimensions are provided in Figure 24.

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 SKY66407-11 is rated to Moisture Sensitivity Level 1 (MSL1) at 260 °C. It can be used for lead or lead-free soldering.

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. DIMENSIONING AND TOLERANCING PER ASME Y14.5M–1994.
3. UNLESS SPECIFIED DIMENSIONS ARE SYMMETRICAL ABOUT CENTER LINES.
4. TOLERANCING (UNLESS OTHERWISE SPECIFIED).

DECIMAL TOLERANCE:
X.X (1 PLC) ± 0.1mm
X.XX (2 PLC) ± 0.05mm
X.XXX (3 PLC) ± 0.025mm

ANGULAR TOLERANCE:
± 1/2°

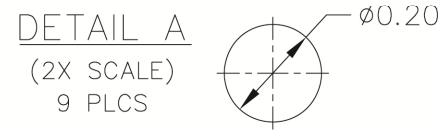


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Figure 21. PCB Layout Footprint

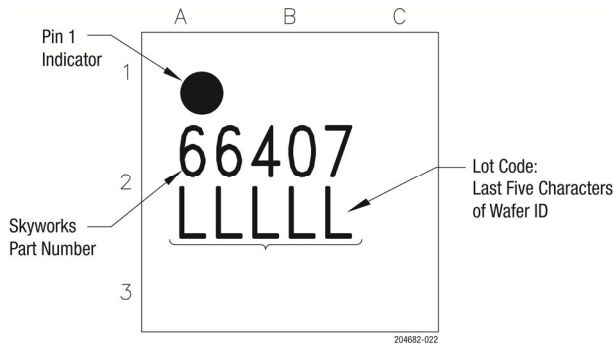


Figure 22. Typical Part Marking

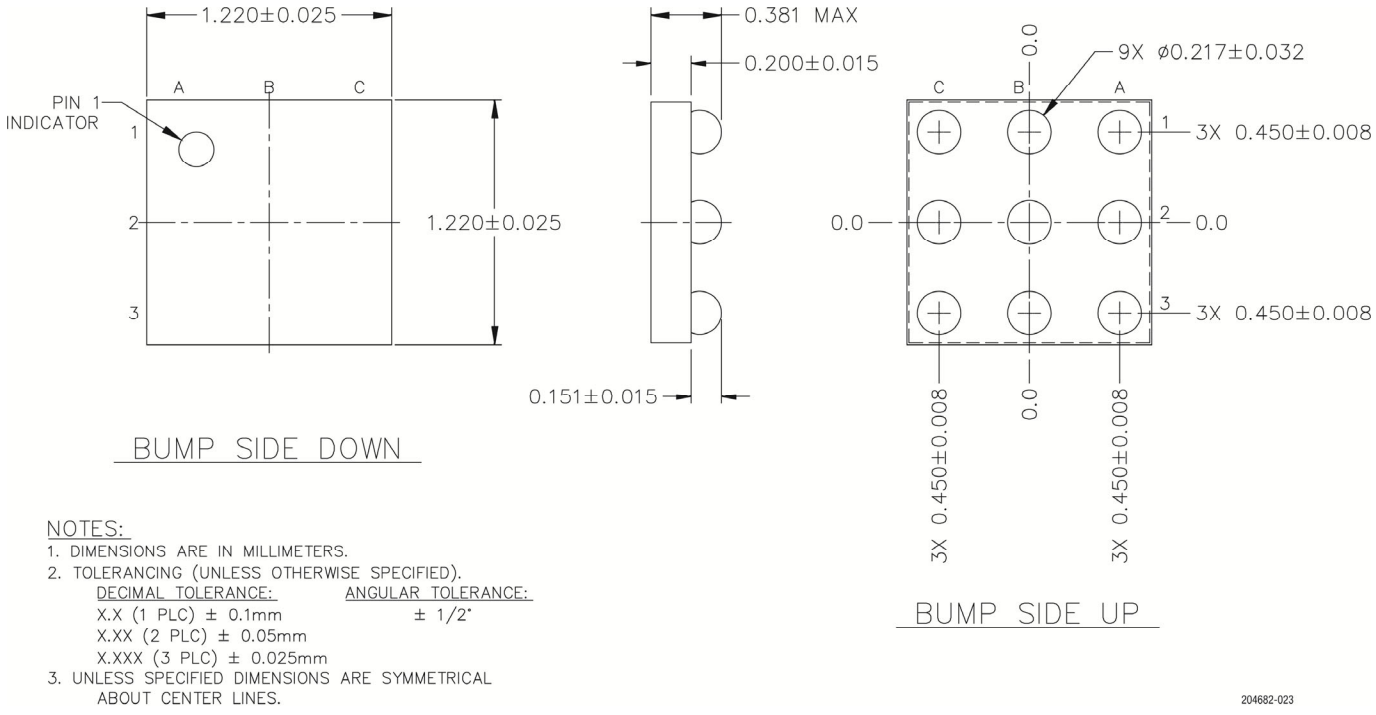
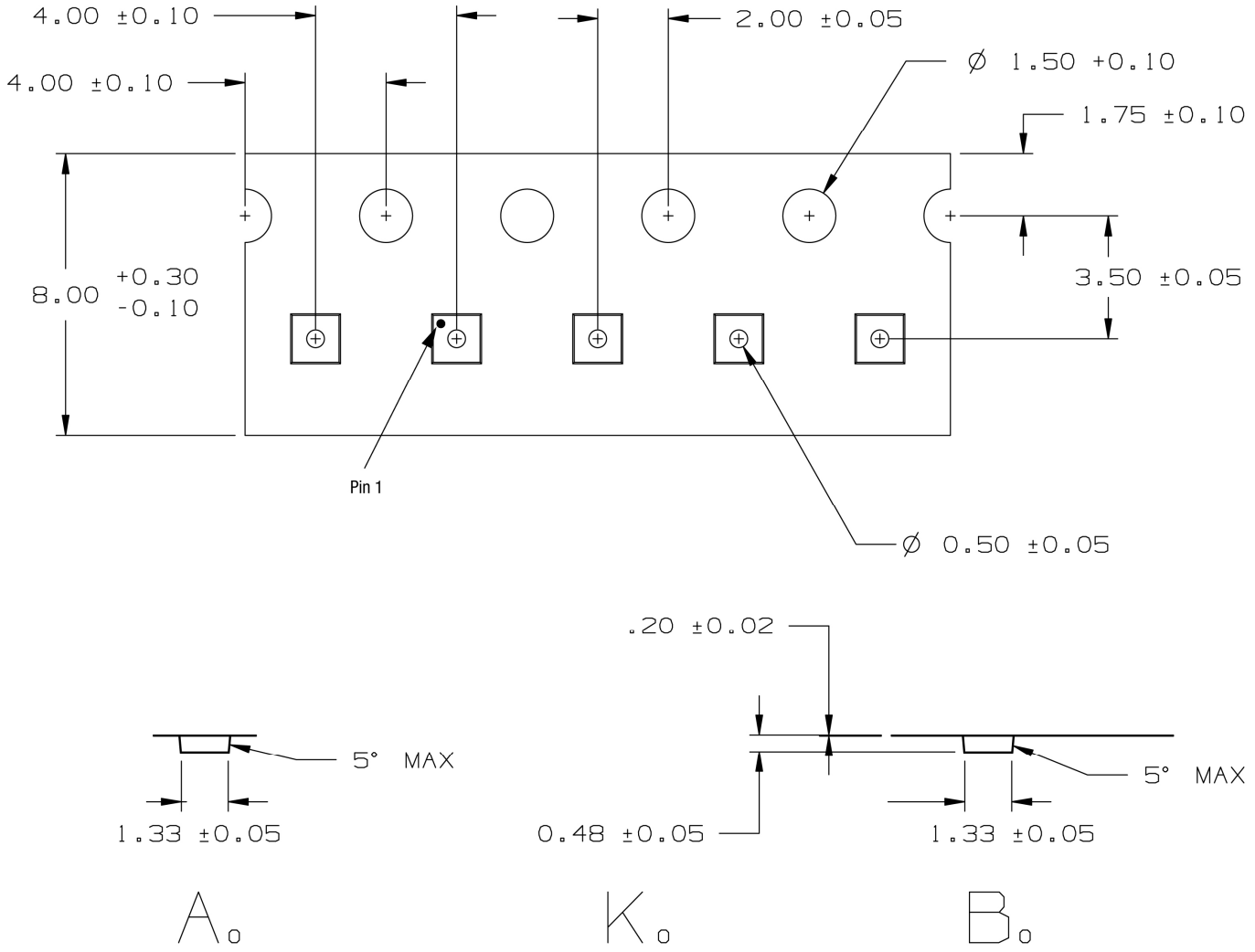


Figure 23. SKY66407-11 Package Dimensions



All dimensions are in millimeters.

Figure 24. SKY66407-11 Tape and Reel Dimensions