DATA SHEET

SKY66403-11: 2.4 GHz Front-End Module for Zigbee® Technology and Thread/Bluetooth® Applications

Applications

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

Features

- Integrated PA with up to +21 dBm output power
- Integrated LNA (2 dB noise figure typical) and bypass path
- Integrated antenna diversity switching for all modes
- Single-ended transmit/receive interface
- Fast switch on/off time: < 800 ns
- Supply range: 1.8 V to 3.6 V
- Sleep mode current: < 1 µA typical
- No external bias resistor required
- Small MCM (22-pin, 3.5 mm x 3.0 mm x 1.0 mm) package, NiPdAu-plated
- MSL3, 260 °C per JEDEC-J-STD-020
- For RoHS and other product compliance information, see Skyworks Certificate of Conformance.

Description

The SKY66403-11 is a high-performance, fully integrated RF front-end module (FEM) designed for Zigbee® technology, Thread, and Bluetooth® signal (including low energy) applications.

The SKY66403-11 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 CMOS levels.

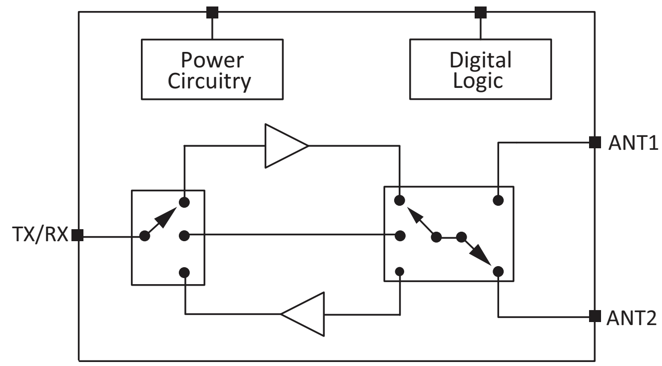


Figure 1. Functional Block Diagram

The RF blocks operate over a wide supply voltage range from 1.8 V to 3.6 V that allows the FEM 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. Pin descriptions are provided in Table 1.

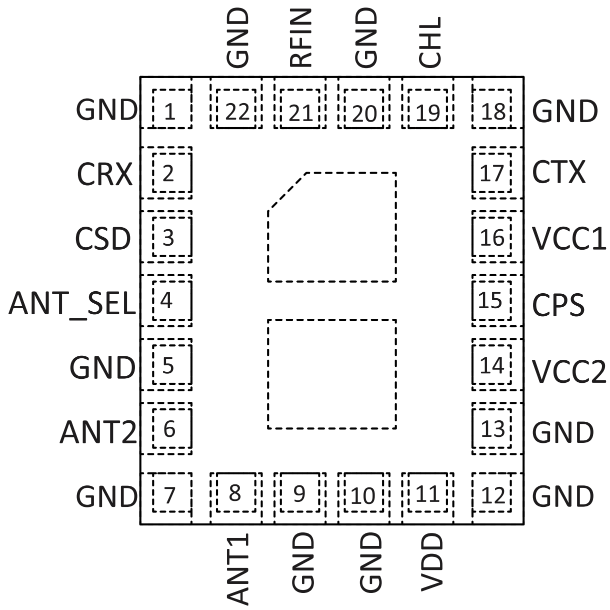


Figure 2. Pinout (Top View)

Table 1. Signal Descriptions

Pin	Name	Description	Pin	Name	Description
1	GND	Ground	12	GND	Ground
2	CRX	Connect to GPIO signal for mode control	13	GND	Ground
3	CSD	Connect to GPIO signal for mode control	14	VCC2	PA output stage supply
4	ANT_SEL	Connect to GPIO signal to control antenna switch	15	CPS	Connect to GPIO signal for mode control
5	GND	Ground	16	VCC1	PA first stage and LNA supply
6	ANT2	Connect to 50 Ω antenna	17	CTX	Connect to GPIO signal for mode control
7	GND	Ground	18	GND	Ground
8	ANT1	Connect to 50 Ω antenna	19	CHL	Connect to GPIO signal for mode control
9	GND	Ground	20	GND	Ground
10	GND	Ground	21	RFIN	RF input power (transmit/receive port)
11	VDD	Digital logic and RF switch supply	22	GND	Ground

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY66403-11 are provided in Table 2. The recommended operating conditions are specified in Table 3, followed by other electrical specifications and control logic.

Table 2. Absolute Maximum Ratings[1]

Parameter	Symbol	Min	Max	Units
Supply voltage	V_{CC1} V_{CC2} V_{DD}	–0.3 –0.3 –0.3	+3.6 +3.6 +3.6	V
Control pin voltage	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	$P_{IN\_TX\_MAX}$		+5.0	dBm
Receive input power at ANT1 or ANT2 ports[2]	$P_{IN\_RX\_MAX}$		+15	dBm
Bypass input power at ANT1 or ANT2 ports[2]	$P_{IN\_BYP\_MAX}$		+20	dBm
Operating temperature	T_A	–40	+85	°C
Storage temperature	T_{STG}	–40	+125	°C
Electrostatic discharge: Human Body Model (HBM)	ESD		3000	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.
2. CW test signal

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, VCC1 pin	V_{CC1}	1.7	1.8	3.6	V
Supply voltage, VCC2 pin	V_{CC2}	0.6	3.0	3.6	V
Supply voltage, VDD pin	V_{DD}	1.8[1]	3.0	3.6	
Operating temperature	T_C	–40	+25	+85	°C

1. Performance at V_{DD} = 1.8 V will be slightly degraded compared to V_{DD} = 2.5 V and above.

Table 4. Electrical Specifications[1]

(V_{CC1} = 1.8 V, V_{CC2} = 3.0 V, V_{DD} = 3.0 V, T_A = +25 °C, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
DC Characteristics						
Total supply current	I_{CC_TX}	P_{OUT} = +20 dBm, linear P_{OUT} = +20 dBm, high-efficiency P_{OUT} = +16 dBm, high-efficiency P_{OUT} = +13 dBm, high-efficiency		97 90 60 45		mA
Total supply current	I_{CC_RX}			3.5	6	mA
Total supply current	I_{CC_BYP}			5		µA
Sleep supply current	I_{CC_OFF}	No RF			1	µA
Quiescent current	I_{CCQ_TX}	Linear mode (CHL high) High-efficiency mode (CHL low)		35 15		mA
Logic Characteristics						
Control voltage High Low	 V_{IH} V_{IL}		 1.08 0		 V_{DD} 0.3	V
Control current High Low	 I_{IH} I_{IL}				 1.0 1.0	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.

Table 5. Electrical Specifications[1]

(V_{CC1} = 1.8 V, V_{CC2} = 3.0 V, V_{DD} = 3.0 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		2483	MHz
Output power at ANT1 or ANT2 port	P_{OUT}	Linear mode High-efficiency mode High-efficiency mode V_{CC2} = 1.8 V High-efficiency mode, V_{CC2} = 1.2 V		+20 +20 +16 +13		dBm
Saturated gain	G_{SAT}	PIN = –2 dBm, linear mode		22		dB
Small signal gain	S21	Linear mode		22		dB
Saturated output power variation	DP_{OUT}	Across all Zigbee technology application channels			1	dBp-p
Second and third harmonics[2]	2fo, 3fo	P_{OUT} = +20.0 dBm, IEEE 802.15.4 source			–42	dBm/MHz
Input return loss	S11			–12		dB
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]	RUG	CW, P_{IN} = 0 dBm, load VSWR = 10:1	No permanent damage			
Receive Characteristics						
Frequency range	f		2400		2483	MHz
Receive gain	RX_{GAIN}			11		dB
Receive noise figure	NF			2		dB
Third order input intercept point	IIP3			2		dBm
1 dB input compression point	IP1dB		–14	–8		dBm
Input return loss	S11	ANT1 or ANT2 ports		–10		dB
Output return loss	S22			–10		dB
Turn-on time[2]	t_{RISE}	From 50% of CRX edge to 90% of final RF output power		800		ns
Turn-off time[2]	t_{FALL}	From 50% of CRX edge to 10% of final RF output power		800		ns
Bypass Characteristics						
Frequency range	f		2400		2483	MHz
Bypass gain	BYP_{GAIN}			–2		dB
Input return loss	S11			–15		dB
Output return loss	S22			–20		dB

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

Table 6. Mode Control Logic[1]

(V_{CC1} = 1.8 V, V_{CC2} = 3.0 V, V_{DD} = 3.0 V, T_A = +25 °C)

Mode	Description	CSD (Pin 3)	CPS (Pin 15)	CRX (Pin 2)	CTX (Pin 17)	CHL (Pin 19)
0	All off (sleep mode)1	0	X	X	X	X
1	Receive LNA mode	1	0	1	0	X
2	Transmit linear mode	1	0	X	1	1
3	Transmit high-efficiency mode	1	0	X	1	0
4	Receive bypass mode	1	1	1	0	X
5	Transmit bypass mode	1	1	X	1	X
6	All off (sleep mode)	1	X	0	0	X

1. All controls must be at V_{DD} or 0 V to achieve the specified sleep current.

Table 7. Antenna Select Logic

(V_{CC1} = 1.8 V, V_{CC2} = 3.0 V, V_{DD} = 3.0 V, T_A = +25 °C)

Description	ANT_SEL (Pin 4)
ANT1 port enabled	0
ANT2 port enabled	1

CHL Control Pin

The CHL pin controls the PA bias.

Use CHL high for high-linearity (HL) mode, which features higher and flat gain vs. P_{IN}.

Use CHL low for high-efficiency (HE) mode, which features slightly lower I_{CC} for a given P_{OUT}.

Due to ACP requirements, high linearity operating modes for enhanced data rate applications must be used.

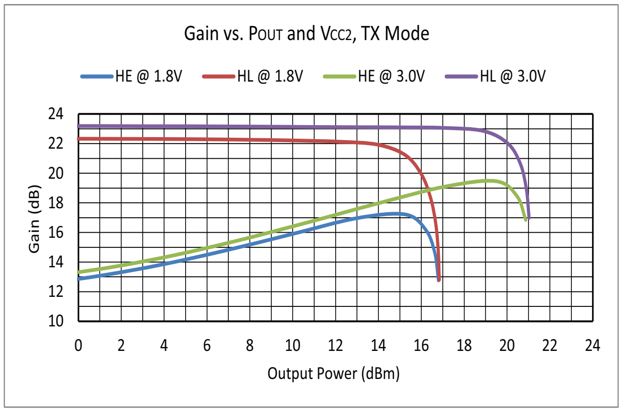


Figure 3. Effect of CHL on Gain (V_{CC1} = 1.8 V, V_{DD} = 3.0 V, f = 2440 MHz)

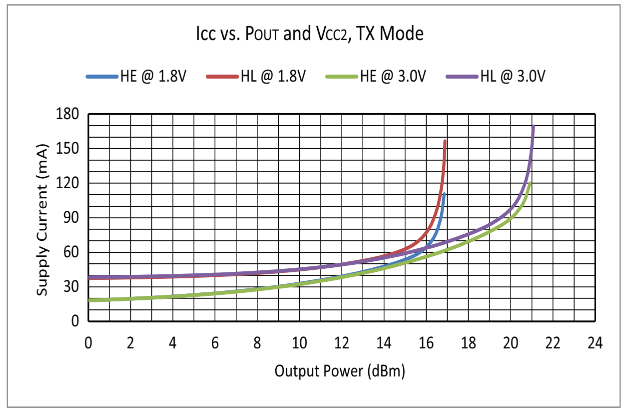


Figure 4. Effect of CHL on Supply Current (V_{CC1} = 1.8 V, V_{DD} = 3.0 V, f = 2440 MHz)

Effect of V_{DD}

V_{DD} supplies the digital logic and the RF switches. It has a nominal level of 3.0 V and typically draws 5 to 20 µA in TX, RX, and bypass modes.

Lowering V_{DD} to 1.8 V reduces TX gain by approximately 0.25 dB and RX gain by about 0.4 dB, but improves RX P1dB by about 0.2 dB.

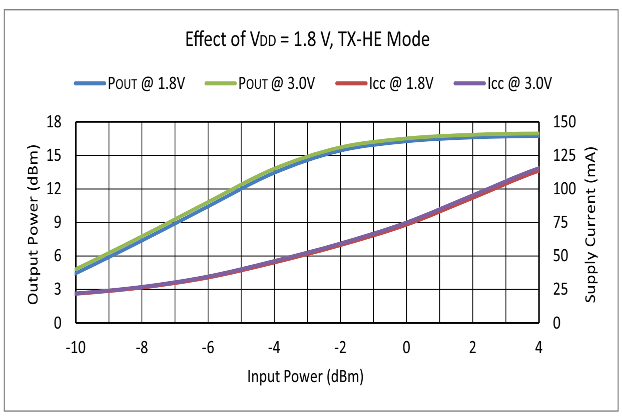


Figure 5. Effect of Lowering VDD (V_{CC1} = V_{CC2} = 1.8 V, TX-HE mode, f = 2440 MHz)

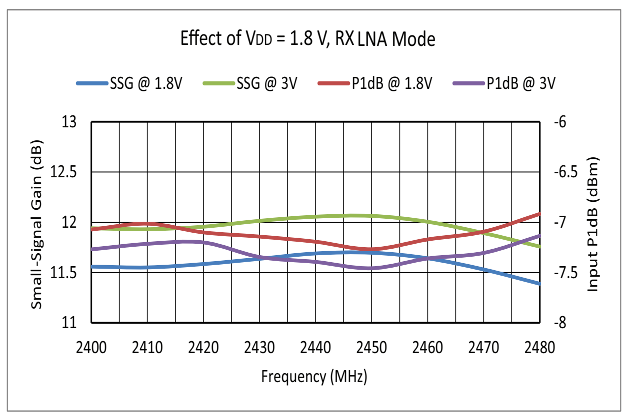


Figure 6. Effect of Lowering VDD (V_{CC1} = V_{CC2} = 1.8 V, PIN = –25 dBm, RX-LNA Mode)

Effect of V_{CC1}

V_{CC1} supplies the LNA and the first stage of the PA. It has a nominal level of 1.8 V and typically draws 10 to 20 mA in TX mode and 3.5 mA in RX mode.

Raising V_{CC1} to 3.0 V increases RX and TX small-signal gain by about 0.3 dB and RX P1dB by about 1 dB. However, it also increases TX I_{CC} by 1 to 30 mA depending on input power.

Keep P_{IN} at or below –2 dBm to prevent high TX I_{CC}.

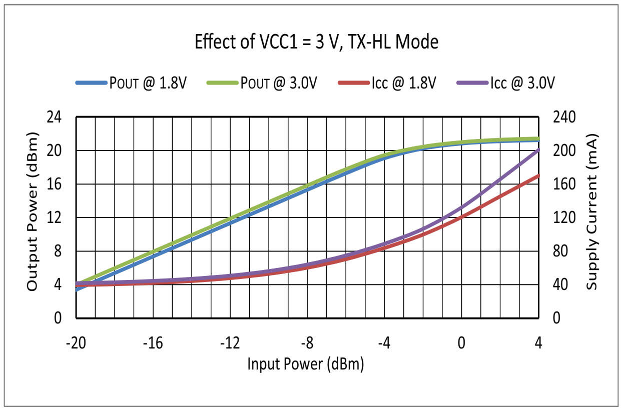


Figure 7. Effect of Raising V_{CC1} (V_{CC2} = V_{DD} = 3.0 V, f = 2440 MHz, TX-HL Mode)

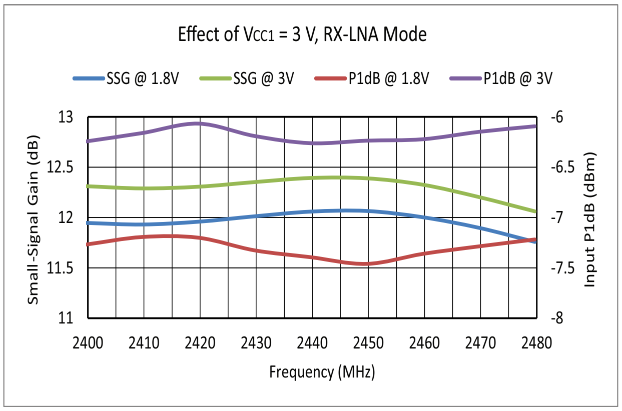


Figure 8. Effect of Raising V_{CC1} (V_{CC2} = V_{DD} = 3.0 V, P_{IN} = –25 dBm, RX-LNA Mode)

Effect of V_{CC2}

V_{CC2} supplies the output stage of the PA. The level of V_{CC2} directly controls the saturated TX output power and this supply draws the majority of the current in TX mode.

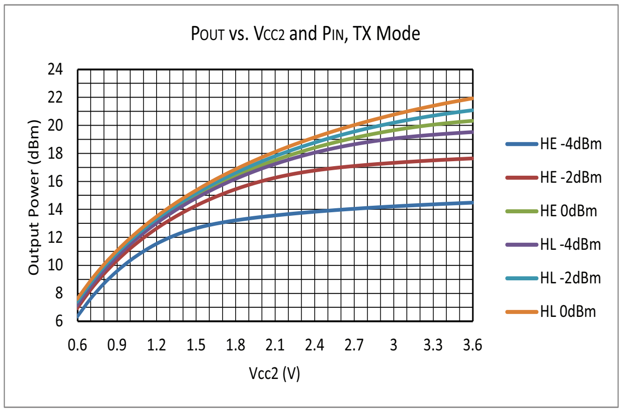


Figure 9. P_{OUT} vs. V_{CC2} and P_{IN} (V_{CC1} = 1.8 V, V_{DD} = 3.0 V, f = 2440 MHz)

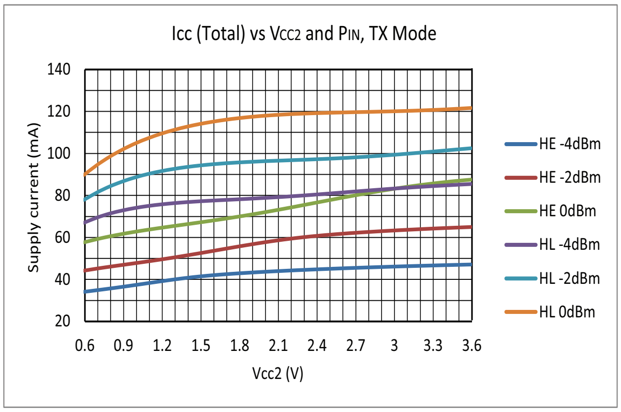


Figure 10. I_{CC} vs. V_{CC2} and P_{IN} (V_{CC1} = 1.8 V, V_{DD} = 3.0 V, f = 2440 MHz)

Adjacent Channel Power for Bluetooth® EDR Applications

The SKY66403-11 in high-linearity (HL) mode benefits from excellent adjacent channel power (ACP) performance in Bluetooth® enhanced data rate applications.

Typical ACP measurements for both enhanced data rate modulations (π/4-DQPSK with 2-DH5 packets and 8-DPSK with 3-DH5 packets) are shown in Figures 11 through 14.

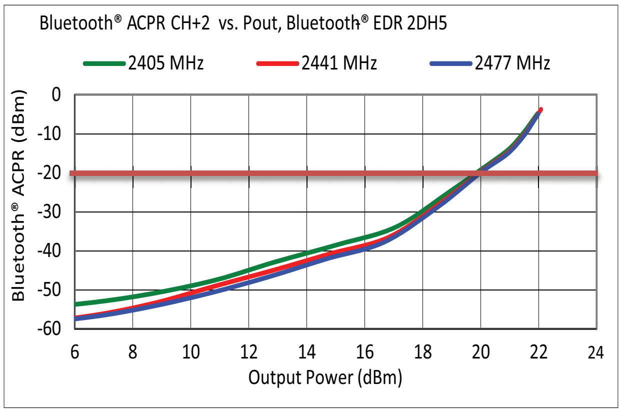


Figure 11. ACPR CH+2 vs P_{OUT} (π/4-DQPSK with 2-DH5 Packets)

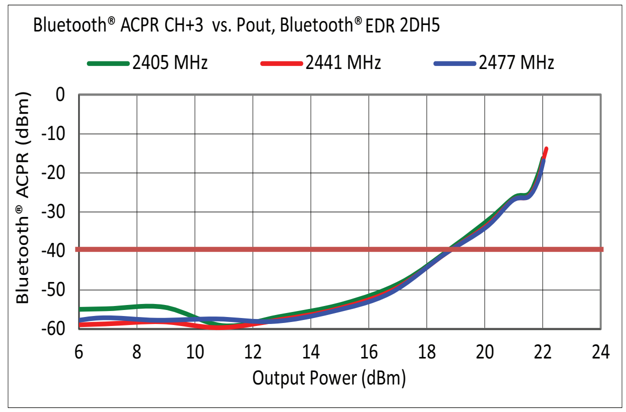


Figure 12. ACPR CH+3 vs P_{OUT} (π/4-DQPSK with 2-DH5 Packets)

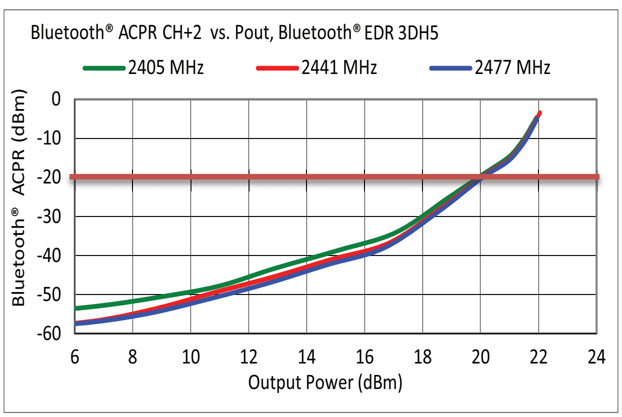


Figure 13. ACPR CH+3 vs P_{OUT} (8-DPSK with 3-DH5 Packets)

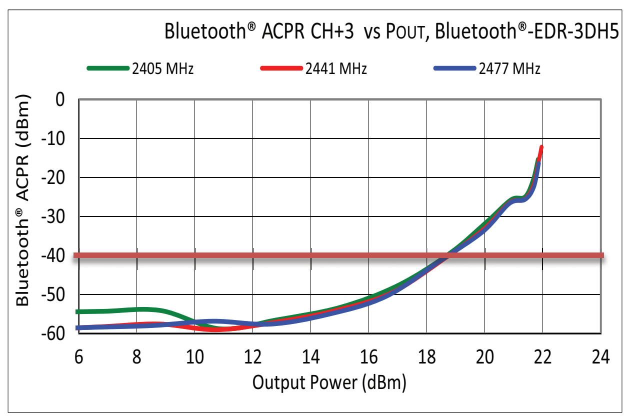
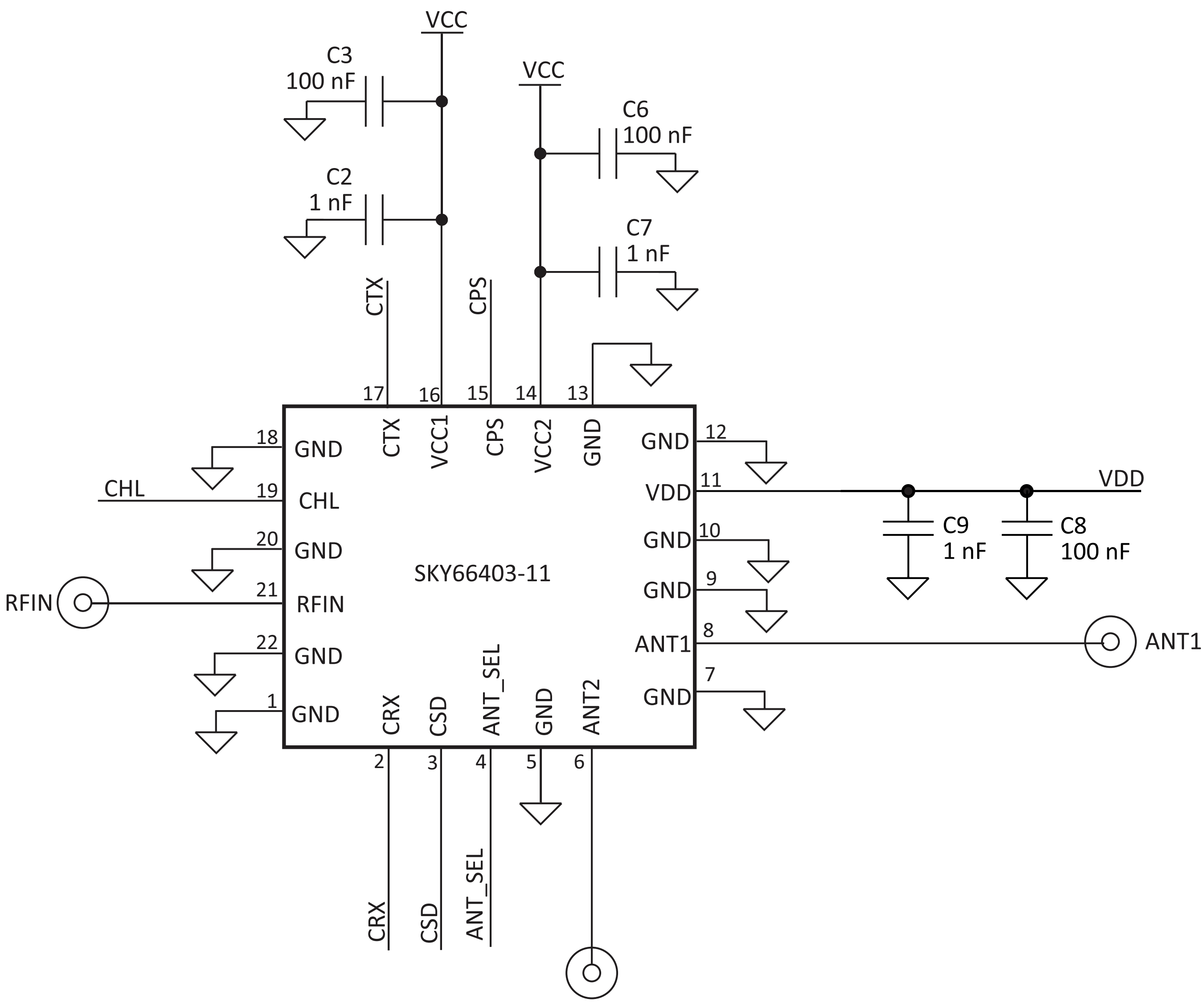


Figure 14. ACPR CH+2 vs P_{OUT} (8-DPSK with 3-DH5 Packets)

Reference Design Schematic

A reference design schematic is shown below, and an evaluation board schematic is shown in Figure 16.



Note: The paddle should be connected to ground.

Figure 15. Reference Design Schematic

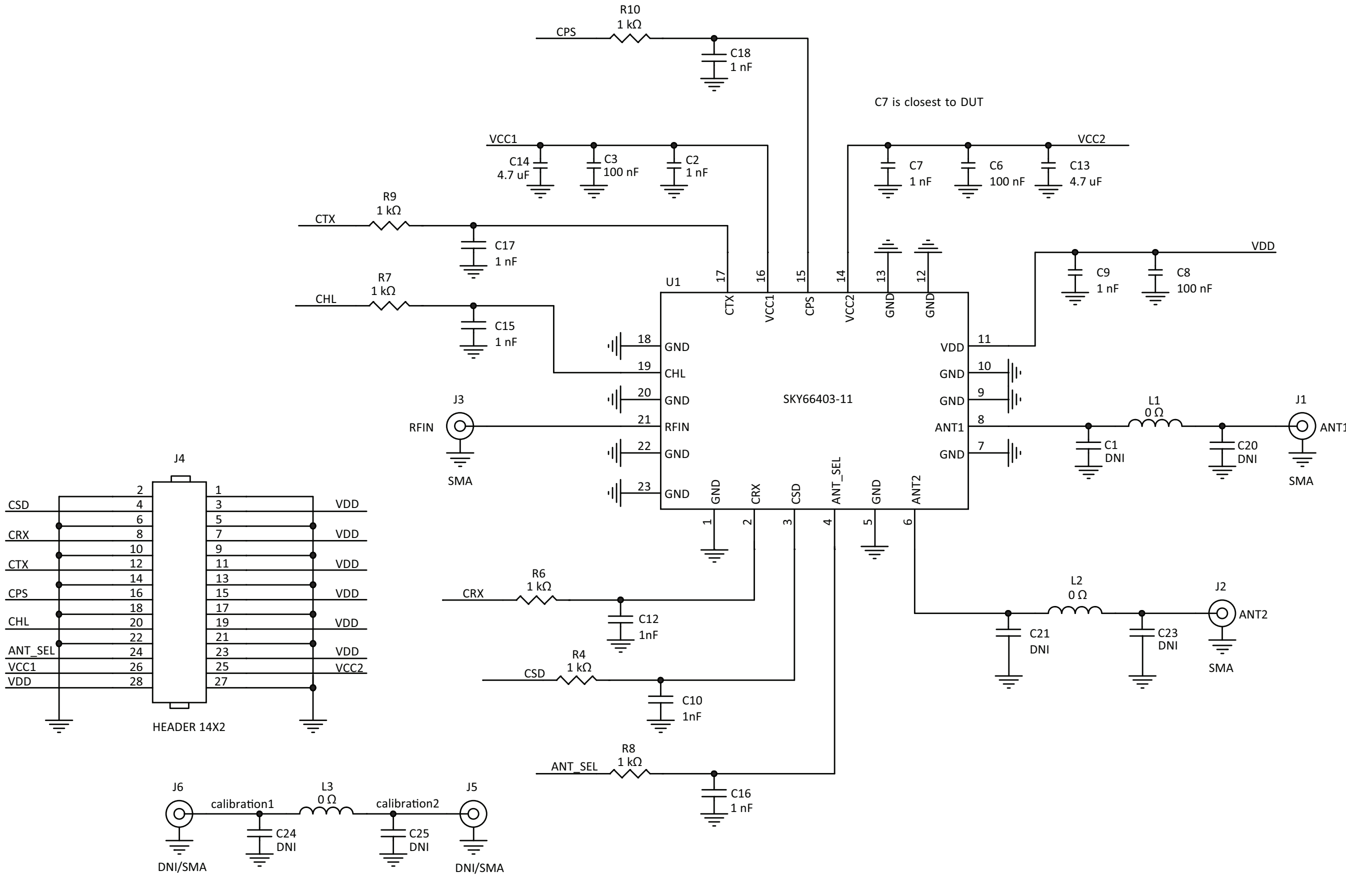


Figure 16. Evaluation Board Schematic Diagram

Package and Handling Information

Since the device 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 SKY66403-11 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 & 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.

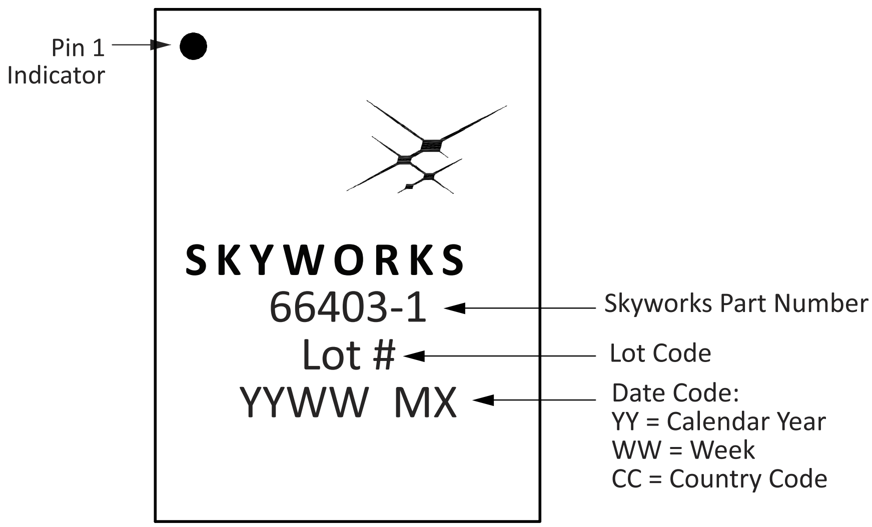
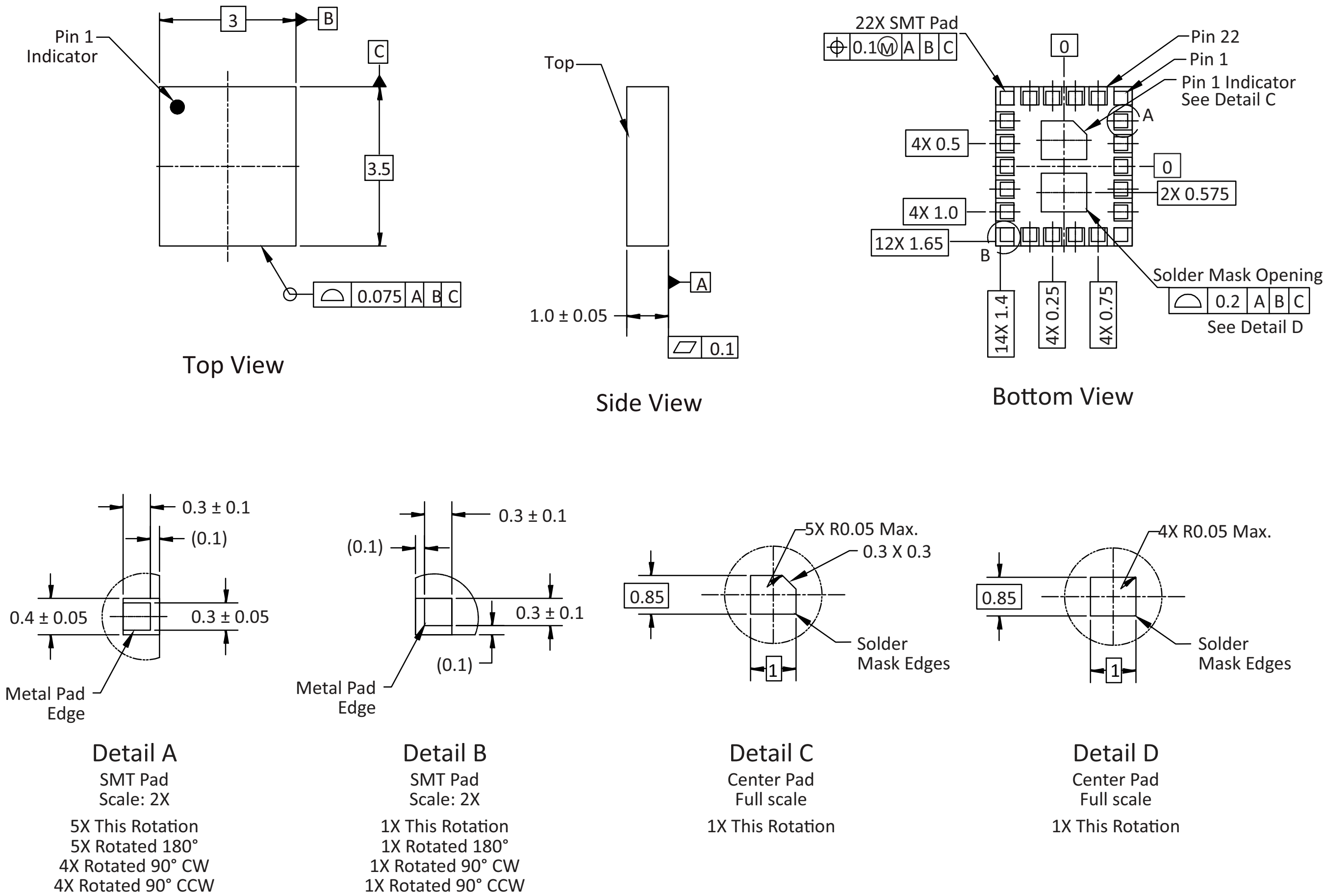


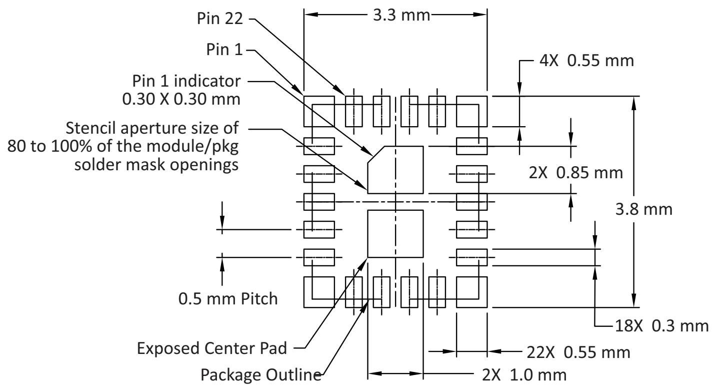
Figure 17. Typical Part Marking



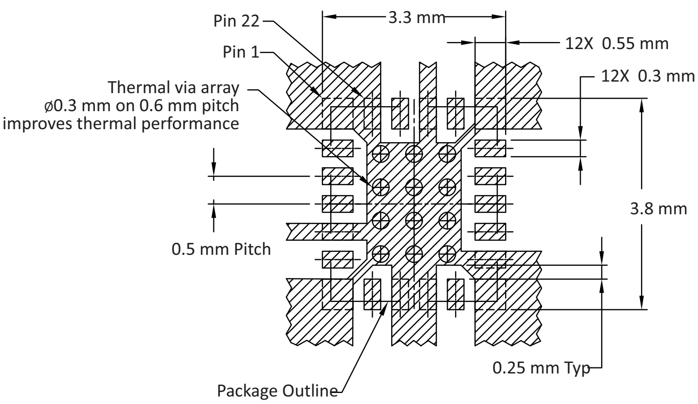
Notes:

1. Dimensions and tolerances according to ASME Y14.5M-1994.
2. All measurements are in millimeters.

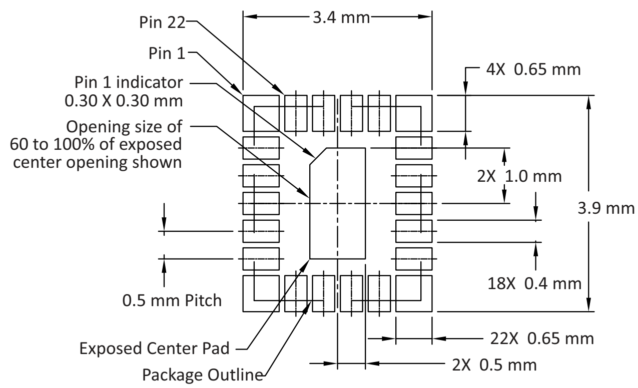
Figure 18. Package Dimensions



Stencil Aperture
(Top View)



Metallization
(Top View)



Solder Mask Opening
(Top View)

Note:

1. All measurements are in millimeters.
2. Thermal vias should be resin filled and capped in accordance with IPC-4761 type VII vias. Recommended Cu thickness is 30 to 35 μm.

Figure 19. PCB Layout Footprint

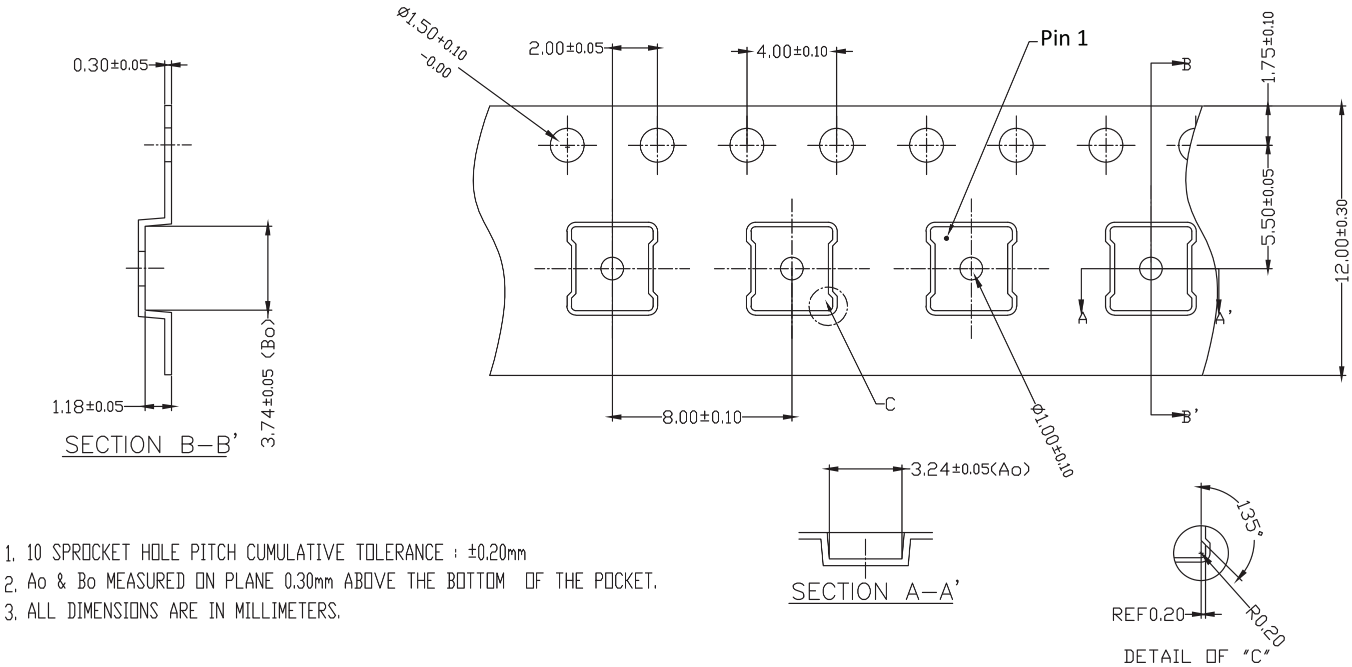


Figure 20. Tape and Reel Information

Ordering Information

Part Number	Description	Evaluation Board Part Number
SKY66403-11	2.4 GHz Front-End Module for Zigbee® Technology and Thread/Bluetooth® Applications	SKY66403-11EK1