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 µA 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)

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.

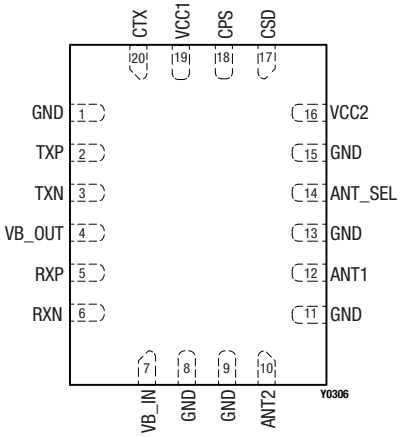



**Figure 2. SKY66109-11 Pinout (Top View)**

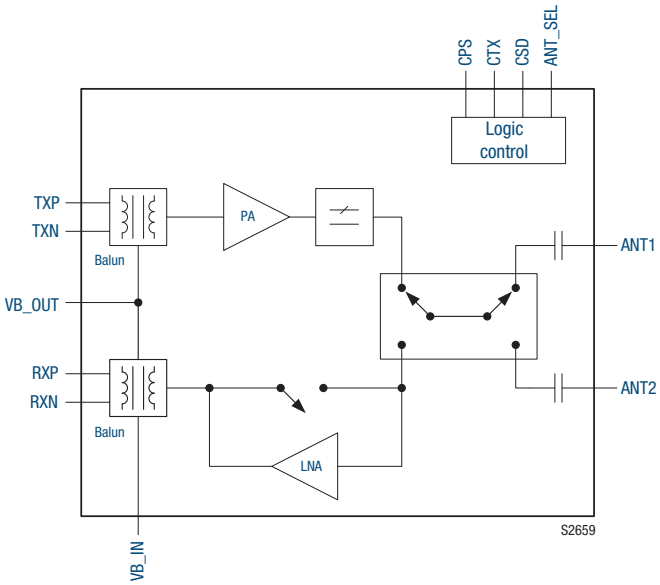



**Figure 1. SKY66109-11 Functional Block Diagram**

## Description

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

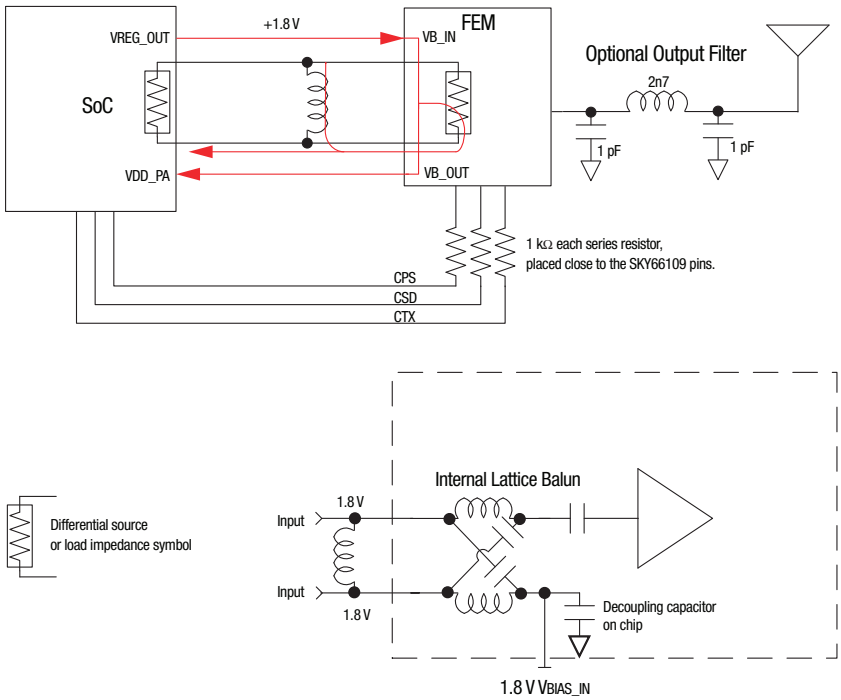
The SKY66109-11 is designed for ease of use and maximum flexibility. The device provides integrated and fully matched input baluns, an integrated interstage matching and harmonic filter, and digital controls compatible with 1.6 to 3.6 V CMOS levels.

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. Y2261

**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 Ratings (Note 1)**

| Parameter | Symbol | Minimum | Maximum | Units |
|---|---|---|---|---|
| Supply voltage | $V_{CC1}$ | –0.3 | +3.6 | V |
| Supply voltage | $V_{CC2}$ | –0.3 | +3.8 (Note 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:<br>Human Body Model (HBM), Class 1C | ESD | | <br>1000 | <br>V |

**Note 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.

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

***CAUTION**: 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. Static charges may easily produce potentials of several kilovolts on the human body or equipment, which can discharge without detection. Industry-standard ESD 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 Specifications (Note 1)**
**(VCC1 = VCC2 = 3.0 V, $T_A$ = +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<br>$P_{OUT}$ = +17 dBm (Note 2)<br>$P_{OUT}$ = +10 dBm (Note 2) | | 110<br>90<br>45 | | mA<br>mA<br>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 | Icq | No RF | | 30 | | mA |
| ***Logic Characteristics*** | | | | | | |
| Control voltage:<br>High<br>Low | <br>$V_{IH}$<br>$V_{IL}$ | | <br>1.6<br>0 | | <br>3.6<br>0.3 | <br>V<br>V |
| Control current:<br>High<br>Low | <br>$I_{IH}$<br>$I_{IL}$ | | | | <br>1<br>1 | <br>µA<br>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 |

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

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

**Table 5. SKY66109-11 Electrical Specifications (Note 1)**
**(VB_IN = VB_OUT = 1.6 to 3.6 V, VCC1 = VCC2 = 3.0 V, $T_A$ = +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 =:<br>3.6 V<br>3.3 V<br>3.0 V<br>2.7 V<br>2.0 V | | <br>+22.5<br>+21.0<br>+20.5<br>+20.0<br>+17.0 | | <br>dBm<br>dBm<br>dBm<br>dBm<br>dBm |
| Small signal gain | S21 | $P_{IN}$ = –25 dBm | | 21 | | dB |
| Small signal gain variation | ΔS21 | Across all ZigBee channels | | | 2 | dBp-p |
| Saturated gain | $G_{SAT}$ | $P_{OUT}$ = +20 dBm | 17 | 19 | | dB |
| 2nd harmonic | 2fo | $P_{OUT}$ = +20 dBm, IEEE 802.15.4 source | | | –42 | dBm/MHz |
| 3rd harmonic (Note 2) | 3fo | $P_{OUT}$ = +20 dBm, IEEE 802.15.4 source | | | –42 | dBm/MHz |
| Output return loss (Note 2) | S22 | ANT1 or ANT2 port | | –10 | –5 | dB |
| Transmit port impedance (Note 2) | $Z_{IN}$ | | | 200 | | Ω |
| Turn-on time (Note 2) | $t_{RISE}$ | From 50% of CTX edge to 90% of final RF output power | | | 800 | ns |
| Turn-off time (Note 2) | $t_{FALL}$ | From 50% of CTX edge to 10% of final RF output power | | | 800 | ns |
| Stability (Note 2) | Stab | CW, Pin = 0 dBm, 0.1 GHz to 20 GHz, load VSWR = 6:1 | All non-harmonically related outputs < –42 dBm/MHz | | | – |
| Ruggedness (Note 2) | RU | CW, Pin = +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 (Note 2) | NF | | | 2 | | dB |
| Third order input intercept point (Note 2) | IIP3 | | –3 | +1 | | dBm |
| 1 dB input compression point | IP1dB | | –13 | –3 | | dBm |
| 1 dB input compression point in bypass mode (Note 2) | IP1dB | | +10 | | | dBm |
| Input return loss (Note 2) | S11 | ANT1 or ANT2 ports | | –10 | –5 | dBm |
| Receive port impedance (Note 2) | $Z_{OUT}$ | Measured differentially between RXP and RXN | | 200 | | Ω |
| Turn-on time (Note 2) | $t_{RISE}$ | From 50% of CTX edge to 90% of final RF output power | | | 800 | ns |
| Turn-off time (Note 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 |

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

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

**Table 6. SKY66109-11 Mode Control Logic (Note 1)**
**(VCC1 = VCC2 = 3.0 V, $T_A$ = +25 °C)**

| Mode | Description | CPS (Pin 18) | CSD (Pin 17) | CTX (Pin 20) | Typical Current Consumption |
|---|---|---|---|---|---|
| 0 | All off (sleep mode) (Note 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 |

**Note 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.

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

**Table 7. SKY66109-11 Antenna Enable Logic**
**(VCC1 = VCC2 = 3.0 V, $T_A$ = +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 |

**Note**: "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.

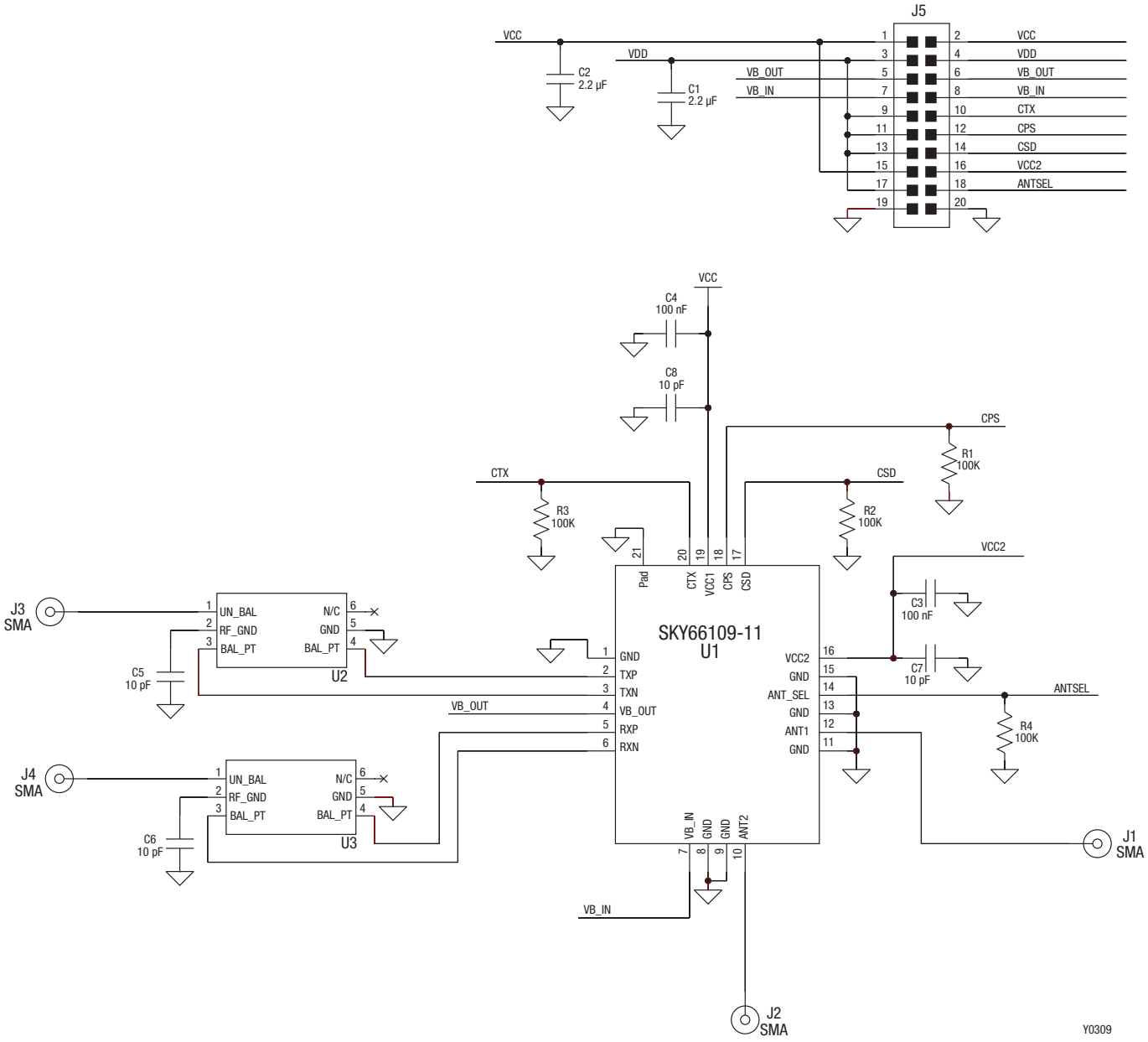



**Figure 4. SKY66109-11 Evaluation Board Schematic**

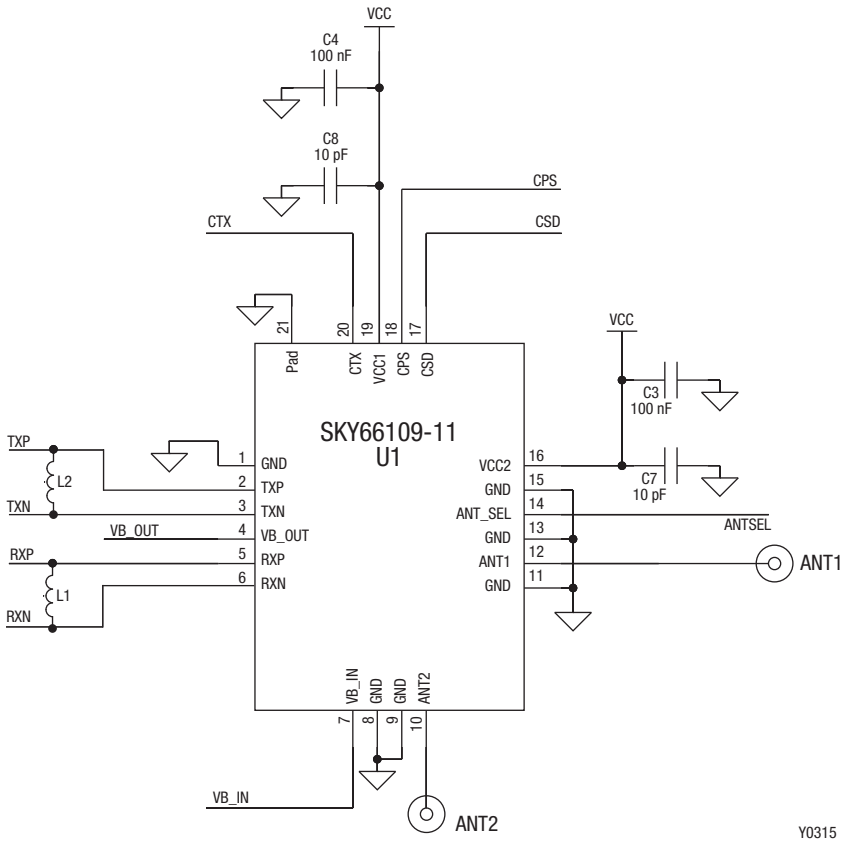



**Figure 5. SKY66109-11 Reference Design Schematic**

**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 µF | 0805 | Murata | GRM21BR71A225KA01L | Ceramic capacitor, 2.2 µF, 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 kΩ | 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.

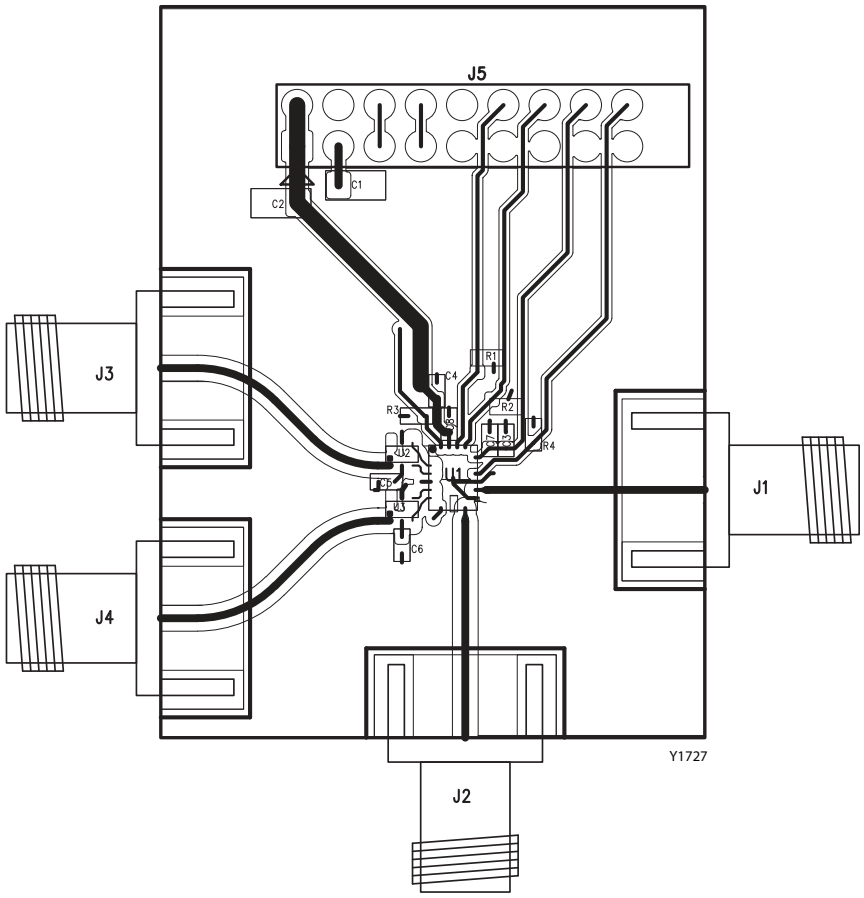
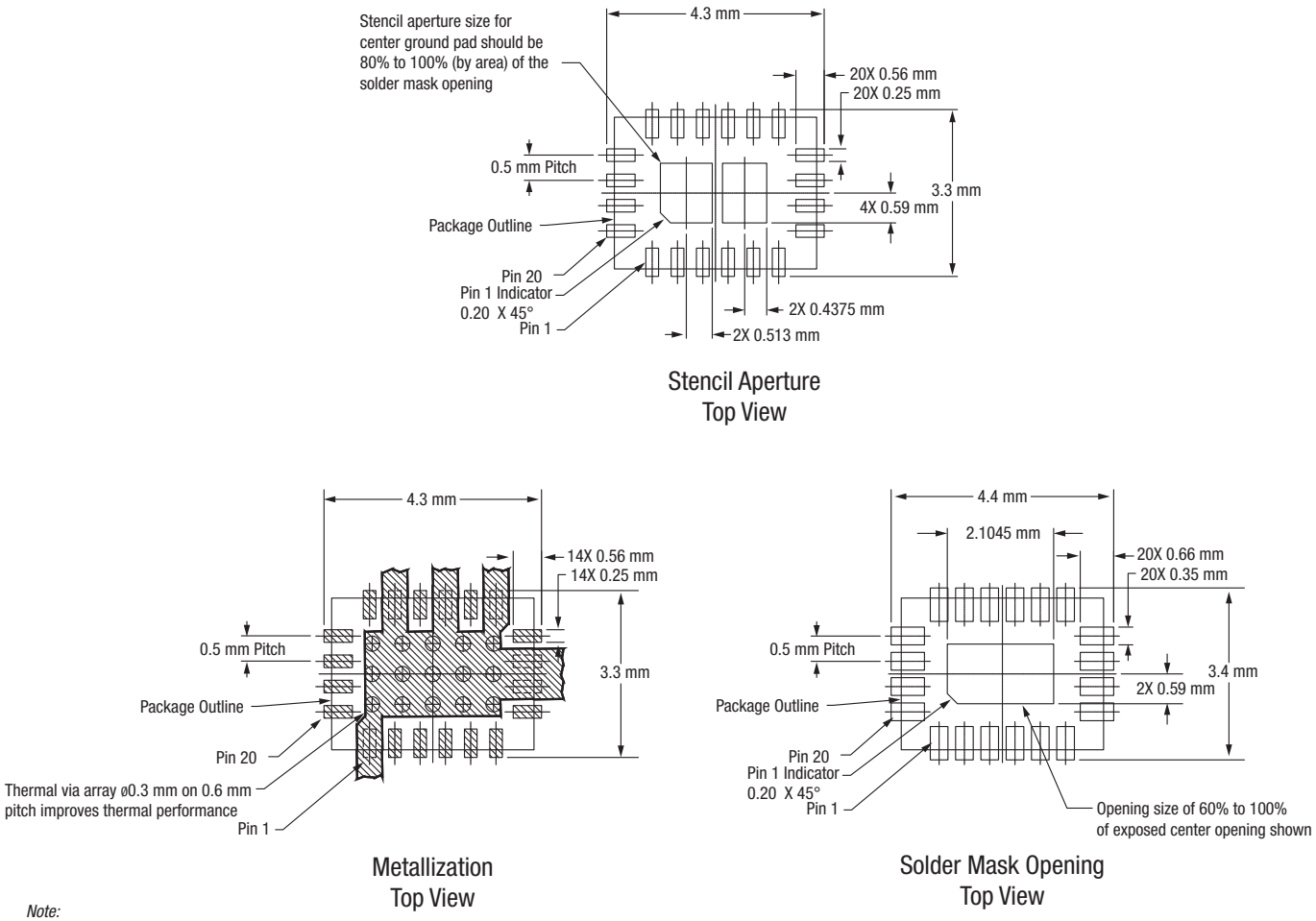



**Figure 6. SKY66109-11 Evaluation Board**




*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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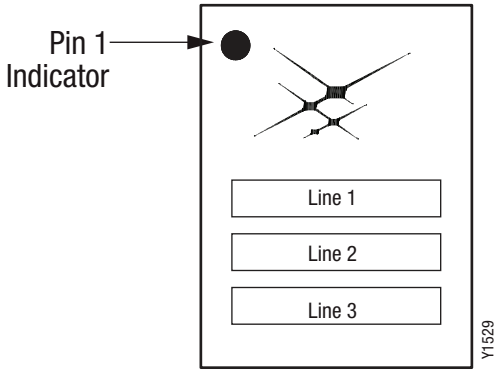
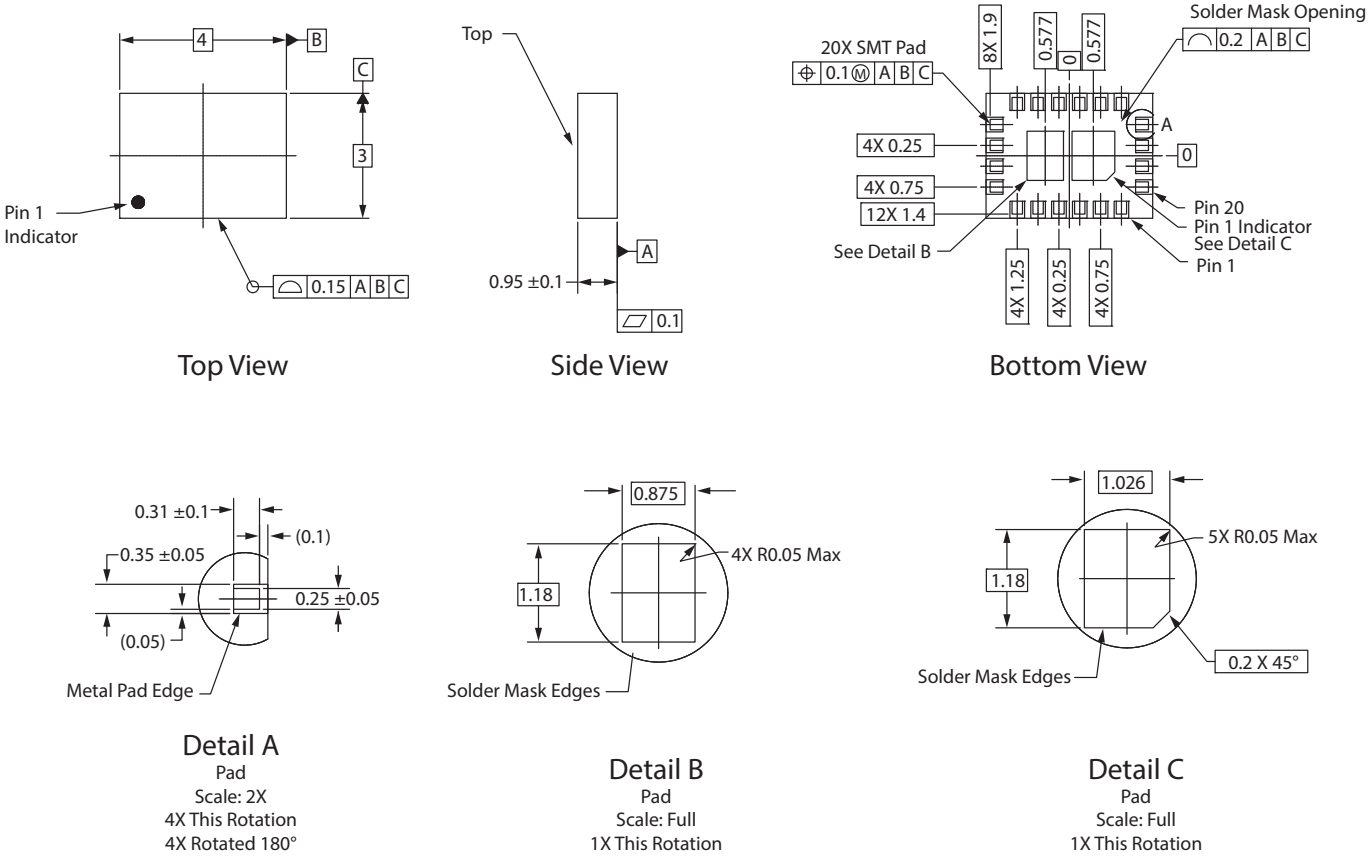
**Figure 7. PCB Layout Footprint**




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**




*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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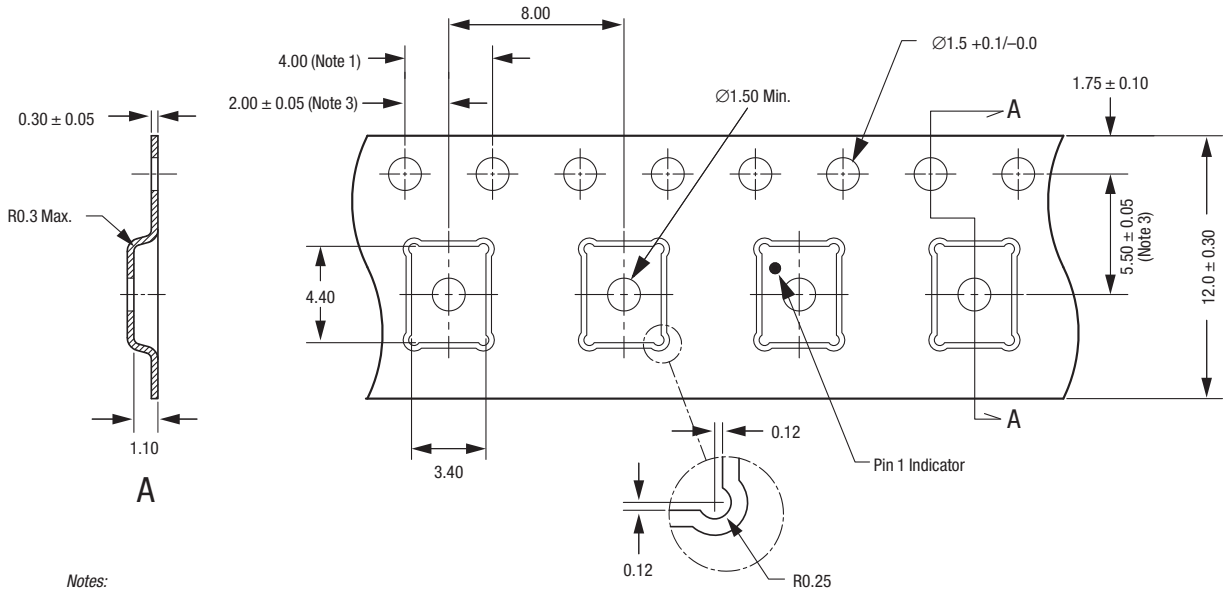
**Figure 9. SKY66109-11 20-Pin MCM Package Dimensions**




*Notes:*
1. *10 sprocket hole pitch cumulative tolerance ±0.2.*
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.*

**Figure 10. SKY66109-11 Tape and Reel Dimensions**

## Ordering Information

| Model Name | Manufacturing Part Number | Evaluation Board Part Number |
|---|---|---|
| SKY66109-11 | SKY66109-11-R | SKY66109-11-EK1 |