

DATA SHEET

# SKY66111-21: Low-Power Bluetooth® Low Energy Front-End Module for Range Extension Applications

## Applications

- Range extender
- Wearable technology
- Beacons
- Sensors
- Home automation
- Internet of Things (IoT) devices

## Features

- Low power consumption: 10 mA @ +10 dBm
- Output: +6 to +13 dBm (single-pin controllable)
- Supply operation: 1.8 to 5 V
- Low sleep current: < 1  $\mu$ A
- RX bypass
- Small MCM (20-pin, 3.3 x 3.0 x 0.7 mm) package (MSL3, 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.

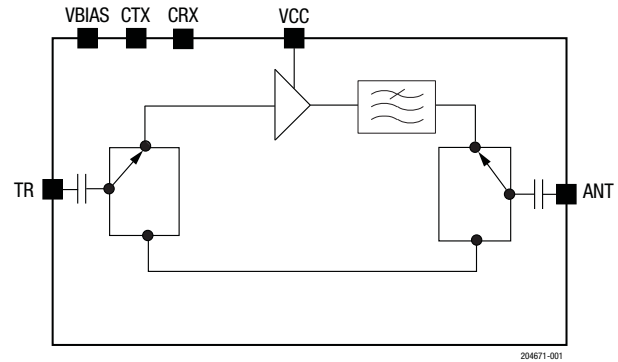


Figure 1. SKY66111-21 Functional Block Diagram

## Description

The SKY66111-21 is a highly integrated front-end module (FEM) designed for Bluetooth Low Energy (BLE) range extension applications operating in the 2.4 to 2.485 GHz range.

The device is provided in a 3.3 x 3.0 x 0.7 mm MCM 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.

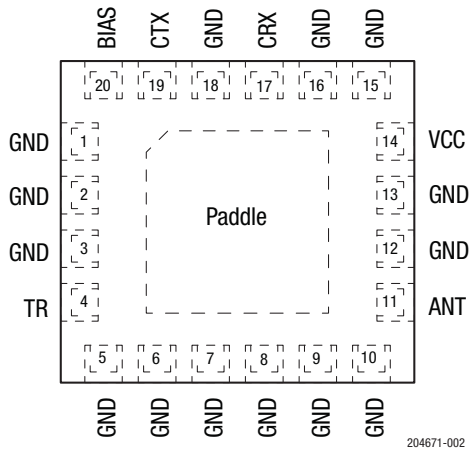


Figure 2. SKY66111-21 Pinout (Top View)

**Table 1. SKY66111-21 Signal Descriptions<sup>1</sup>**

| Pin | Name | Description                  | Pin | Name | Description  |
|-----|------|------------------------------|-----|------|--|
| 1   | GND  | Ground                       | 11  | ANT  | Antenna port   |
| 2   | GND  | Ground                       | 12  | GND  | Ground   |
| 3   | GND  | Ground                       | 13  | GND  | Ground   |
| 4   | TR   | Common receive/transmit port | 14  | VCC  | Positive power supply                                    |
| 5   | GND  | Ground                       | 15  | GND  | Ground   |
| 6   | GND  | Ground                       | 16  | GND  | Ground   |
| 7   | GND  | Ground                       | 17  | CRX  | RX control signal  |
| 8   | GND  | Ground                       | 18  | GND  | Ground   |
| 9   | GND  | Ground                       | 19  | CTX  | Tx control signal  |
| 10  | GND  | Ground                       | 20  | BIAS | PA bias current input, connect to CTX through a resistor |

<sup>1</sup> The paddle should be connected to ground. See Figure 6.

## Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY66111-21 are provided in Table 2. The recommended operating conditions are specified in Table 3.

Electrical specifications are provided in Tables 4 through 8.

**Table 2. SKY66111-21 Absolute Maximum Ratings<sup>1</sup>**

| Parameter   | Symbol     | Minimum | Maximum | Units |
|---|------------|---------|---------|-------|
| Supply voltage  | VCC        |         | 5.5     | V     |
| Control voltages  | VCTX, VCRX |         | 5.0     | V     |
| Bias voltage  | VBIAS      |         | 5.0     | V     |
| RF Input power  | PIN        |         | +20     | dBm   |
| Voltage standing wave ratio                                 | VSWR       |         | 10:1    |       |
| Operating temperature                                       | TA         | -40     | +85     | °C    |
| Storage temperature   | TSTG       | -65     | +150    | °C    |
| Electrostatic discharge:<br>Human Body Model (HBM), Class 0 | ESD        |         | 150     | V     |

<sup>1</sup> 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.

**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 |
|-----------------------|------------|------|-----|-------|-------|
| Frequency             | f          | 2.4  |     | 2.485 | GHz   |
| Supply voltage        | VCC        | 1.8  | 3   | 5.0   | V     |
| Control voltages      | VCTX, VCRX | 1.7  | 3   | VCC   | V     |
| Bias voltage          | VBIAS      | 1.25 | 1.8 | VCC   | V     |
| Operating temperature | TA         |      | 25  |       | °C    |

**Table 4. SKY66111-21 Electrical Specifications: DC Characteristics<sup>1</sup>**

(V<sub>CC</sub> = V<sub>CTX</sub> = 3.3 V, V<sub>BIAS</sub> = 1.8 V, V<sub>CRX</sub> = 0 V, T<sub>A</sub> = +25 °C, R<sub>BIAS</sub> (R1) = 0 kΩ, Characteristic Impedance [Z<sub>0</sub>] = 50 Ω, Unless Otherwise Noted)

| Parameter                         | Symbol               | Test Condition  | Min | Typ                     | Max | Units                |
|-----------------------------------|----------------------|---|-----|-------------------------|-----|----------------------|
| RX current (bypass)               | I <sub>CQ_RX</sub>   | RX mode   |     | 1                       |     | μA                   |
| TX quiescent current <sup>2</sup> | I <sub>CQ_TX</sub>   | TX mode   |     | 6                       |     | mA                   |
| TX operating current <sup>2</sup> | I <sub>OP_TX</sub>   | TX mode (P <sub>IN</sub> = -1 dBm):<br>V <sub>CC</sub> = 1.8 V<br>V <sub>CC</sub> = 3.0 V<br>V <sub>CC</sub> = 3.3 V<br>V <sub>CC</sub> = 5.0 V |     | 8.5<br>10<br>10.5<br>11 |     | mA<br>mA<br>mA<br>mA |
| TX bias current (BIAS pin)        | I <sub>BIAS_TX</sub> |   |     | 550                     |     | μA                   |
| Sleep current <sup>3</sup>        | I <sub>CC_OFF</sub>  | Sleep mode  |     | 0.1                     | 1   | μA                   |

<sup>1</sup> Performance is guaranteed only under the conditions listed in this table.

<sup>2</sup> For total current, I<sub>BIAS\_TX</sub> should be added to the values.

<sup>3</sup> V<sub>CTX</sub> = V<sub>BIAS</sub> = 0 V.

**Table 5. SKY66111-21 Electrical Specifications Transmit Characteristics<sup>1</sup>**

(V<sub>CC</sub> = V<sub>CTX</sub> = 3.3 V, V<sub>BIAS</sub> = 1.8 V, V<sub>CRX</sub> = 0 V, T<sub>A</sub> = +25 °C, P<sub>IN</sub> = -1 dBm, R<sub>BIAS</sub> (R1) = 0 kΩ, Characteristic Impedance [Z<sub>0</sub>] = 50 Ω, Unless Otherwise Noted)

| Parameter  | Symbol                | Test Condition   | Min | Typ                         | Max | Units                    |
|--|-----------------------|--|-----|-----------------------------|-----|--------------------------|
| Output power   | P <sub>OUT</sub>      | V <sub>CC</sub> = 1.8 V<br>V <sub>CC</sub> = 3.0 V<br>V <sub>CC</sub> = 3.3 V<br>V <sub>CC</sub> = 5.0 V |     | +8<br>+10<br>+10.3<br>+10.8 |     | dBm<br>dBm<br>dBm<br>dBm |
| Saturated gain <sup>2</sup>                                | G <sub>SAT</sub>      | P <sub>IN</sub> = -1 dBm   |     | 11                          |     | dB                       |
| Gain slope   | G <sub>SLOPE</sub>    | Over frequency range   |     | 0.7                         | 1   | dB                       |
| Input return loss  | S <sub>11</sub>       |  |     | -14                         |     | dB                       |
| Output return loss   | S <sub>22</sub>       |  |     | -10                         |     | dB                       |
| Insertion loss (sleep mode) <sup>2</sup>                   | S <sub>21_SLEEP</sub> |  |     | -15                         | -12 | dB                       |
| Third order input intercept point <sup>2</sup>             | IIP3                  | @ 2.44 GHz, Δf = ± 1 MHz,<br>P <sub>IN</sub> = -14 dBm/tone  |     | +5                          |     | dBm                      |
| Third order output intercept point <sup>2</sup>            | OIP3                  | @ 2.44 GHz, Δf = ± 1 MHz,<br>P <sub>IN</sub> = -14 dBm/tone  |     | +16                         |     | dBm                      |
| 1 dB input compression point                               | IP1dB                 |  |     | -1                          |     | dBm                      |
| 1 dB output compression point                              | OP1dB                 |  |     | +10                         |     | dBm                      |
| 2 <sup>nd</sup> to 10 <sup>th</sup> harmonics <sup>2</sup> | 2fo to 10fo           |  |     |                             | -30 | dBm/MHz                  |
| RX to TX transition time <sup>2</sup>                      | t <sub>SWITCH</sub>   | 10% to 90% RF<br>50% V <sub>CTX</sub> to 90% RF  |     | 500                         |     | ns                       |
| TX power on time <sup>2</sup>                              | t <sub>ON</sub>       | 10% to 90% RF<br>50% V <sub>CTX</sub> to 90% RF  |     | 500                         |     | ns                       |
| TX power off time <sup>2</sup>                             | t <sub>OFF</sub>      | 90% to 10% RF<br>50% V <sub>CTX</sub> to 10% RF  |     | 150                         |     | ns                       |

<sup>1</sup> Performance is guaranteed only under the conditions listed in this table.

<sup>2</sup> Guaranteed by characterization.

**Table 6. SKY66111-21 Electrical Specifications: Receive Characteristics<sup>1</sup>**  
**(V<sub>CC</sub> = 3.3 V, V<sub>CRX</sub> = 3.3 V, V<sub>CTX</sub> = 0 V, T<sub>A</sub> = +25 °C, P<sub>IN</sub> = -20 dBm, Characteristic Impedance [Z<sub>0</sub>] = 50 Ω, Unless Otherwise Noted)**

| Parameter                             | Symbol              | Test Condition                                  | Min | Typ | Max | Units |
|---------------------------------------|---------------------|---|-----|-----|-----|-------|
| Insertion loss                        | S21                 |   |     | 0.9 |     | dB    |
| Isolation                             | S12                 | TX Mode (P <sub>IN</sub> = -20 dBm)             |     | 25  |     | dB    |
| Input return loss                     | S11                 |   |     | -15 |     | dB    |
| Output return loss                    | S22                 |   |     | -15 |     | dB    |
| TX to RX transition time <sup>2</sup> | t <sub>SWITCH</sub> | 10% to 90% RF<br>50% V <sub>CRX</sub> to 90% RF |     | 500 |     | ns    |
| RX power on time <sup>2</sup>         | t <sub>ON</sub>     | 10% to 90% RF<br>50% V <sub>CRX</sub> to 90% RF |     | 150 |     | ns    |
| RX power off time <sup>2</sup>        | t <sub>OFF</sub>    | 90% to 10% RF<br>50% V <sub>CRX</sub> to 10% RF |     | 150 |     | ns    |

<sup>1</sup> Performance is guaranteed only under the conditions listed in this table.

<sup>2</sup> Guaranteed by characterization.

**Table 7. SKY66111-21 Electrical Characteristics: Logic Characteristics (T<sub>A</sub> = +25 °C)**

| Parameter                       | Symbol            | Minimum | Maximum | Units |
|---------------------------------|-------------------|---------|---------|-------|
| Voltage logic high <sup>1</sup> | V <sub>HIGH</sub> | 1.7     | 5       | V     |
| Voltage logic low               | V <sub>LOW</sub>  | 0       | 0.2     | V     |

<sup>1</sup> Difference between logic high voltages for V<sub>CRX</sub> and V<sub>CTX</sub> should not exceed 0.2 V.

**Table 8. SKY66111-21 Mode Logic Truth Table**

| Mode                               | CTX | CRX | BIAS           |
|------------------------------------|-----|-----|----------------|
| Sleep mode                         | 0   | 0   | 0              |
| Receive (RX) mode                  | 0   | 1   | 0              |
| Transmit (TX) mode                 | 1   | 0   | 1 <sup>1</sup> |
| Non-permissible state <sup>2</sup> | 1   | 1   | x              |

<sup>1</sup> Analog voltage control for PA output power. See Figure 3.

<sup>2</sup> This state will enable both the TX and RX paths. It is not permitted to operate in this state.

### BIAS Pin Usage

The SKY66111-21 BIAS 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 BIAS pin can also be used to adjust the SKY66111-21 output power when the RF source (transceiver or baseband) has a fixed level.

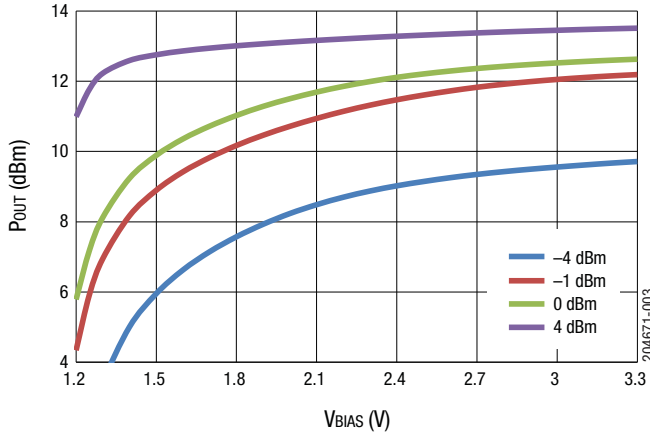


Figure 3. Pout vs VBIAS & PIN (Vcc = 3.3 V)

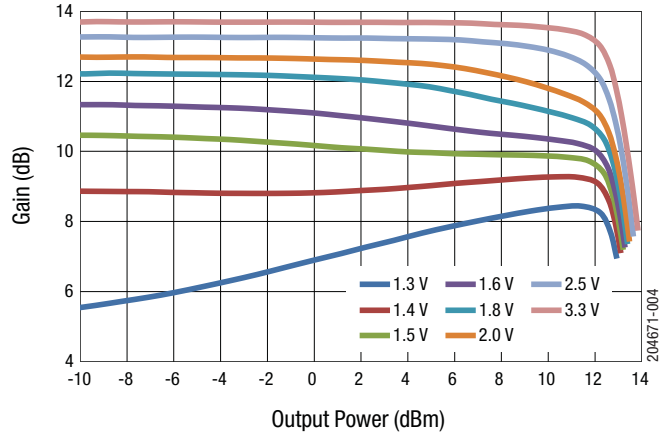


Figure 4. Gain vs Pout & VBIAS (Vcc = 3.3 V)

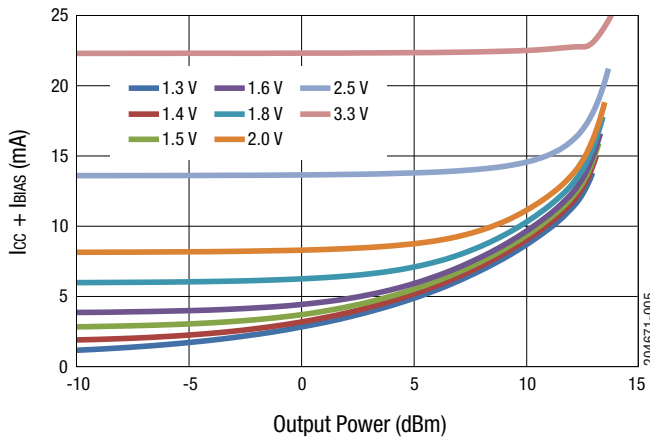


Figure 5. Icc vs Pout & VBIAS (Vcc = 3.3 V)

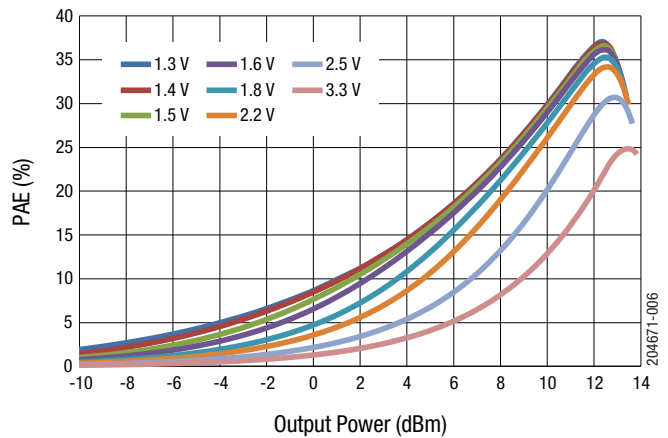


Figure 6. Power-Added Efficiency vs Pout & VBIAS (Vcc = 3.3 V)

In many applications, a variable DC supply voltage may not be available. The desired bias voltage can be generated by connecting BIAS to the GPIO controlling CTX with a resistor (refer to Figure 12). With no RF input, the BIAS pin draws approximately 10% of the main supply current. Toggling BIAS from the CTX GPIO

also causes the PA to turn off when CTX is pulled low, reducing the RX and shutdown mode current.

Table 9 lists the relationship between bias voltage/current and bias resistance.

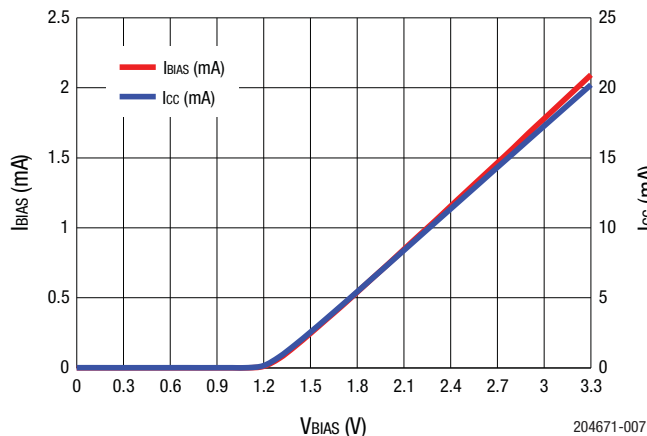


Figure 7. IBIAS and ICC vs VBIAS (VCC = 3.3 V, no RF)

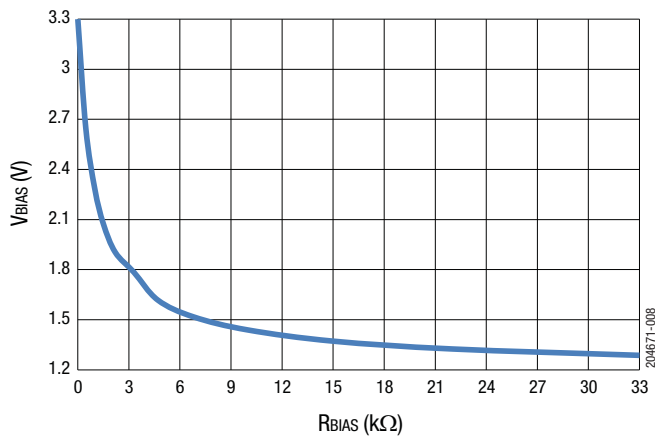


Figure 8. VBIAS vs RBIAS (VCC = 3.3 V)

Table 9. Bias Voltage and Current vs Bias Resistance (VCC = 3.3 V)

| RBIAS (kΩ) | VBIAS (V) | IBIAS (mA) |
|------------|-----------|------------|
| 0          | 3.30      | 2.09       |
| 0.47       | 2.65      | 1.41       |
| 1          | 2.28      | 1.03       |
| 1.5        | 2.07      | 0.82       |
| 2.2        | 1.90      | 0.64       |
| 3.3        | 1.78      | 0.48       |
| 4.7        | 1.62      | 0.36       |
| 6.8        | 1.52      | 0.26       |
| 10         | 1.44      | 0.19       |
| 15         | 1.37      | 0.13       |
| 22         | 1.32      | 0.09       |
| 33         | 1.29      | 0.06       |

If a fixed BIAS 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 SKY66111-21

current consumption in RX bypass and shutdown modes, the voltage to the BIAS pin should be switched off when the CTX is logic low.

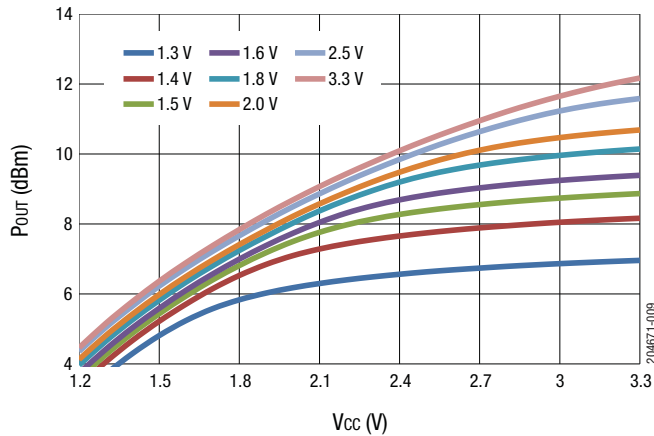


Figure 9. Pout vs Vcc & VBIAS (PIN = -1 dBm)

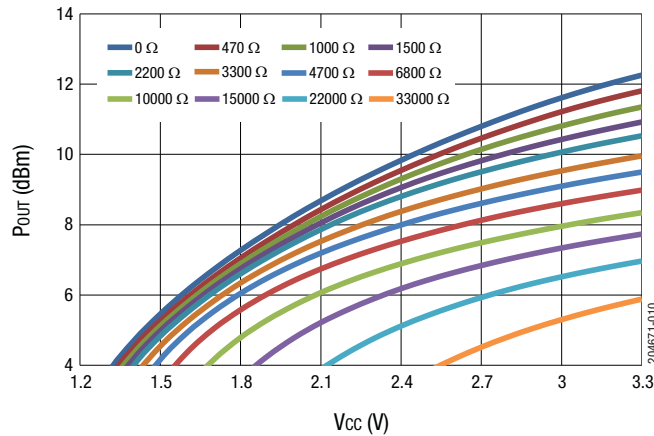


Figure 10. Pout vs Vcc & RBIAS (PIN = -1 dBm)

## Evaluation Board Description

The SKY66111-21 Evaluation Board is used to test the performance of the SKY66111-21 front-end module. The board is optimized for evaluation, experimentation, and investigation with a Bluetooth Low Energy signal source. The design and layout can be quickly and easily transferred into a production design.

An Evaluation Board schematic is provided in Figure 11. A reference design schematic is provided in Figure 12. Table 10 provides the Bill of Materials (BOM) list for Evaluation Board components. A photograph of the Evaluation Board is shown in Figure 13.

## Evaluation Board Setup Procedure

### Connect Supply

1. Connect J1 and J4 to 50  $\Omega$  instruments. Terminate all unused ports (if applicable) with 50  $\Omega$ .
2. Connect the supply ground to Pins 1, 4, and 6 of J2.
3. Connect 3.3 V to pin 7 of J2.
4. Connect 1.8 V to one of the logic pins (pin 3 or pin 5) on J2 to select RX or TX mode. For TX mode, also connect pin 2 to 1.8 V. Connect the other logic pin to ground. Refer to Table 8 for mode control settings.

### Measure Performance

#### ***TX***

Monitor the 2.4 GHz amplifier performance by applying an RF signal to connector J4 (TR) and verify the output power on connector J1 (ANT).

#### ***RX***

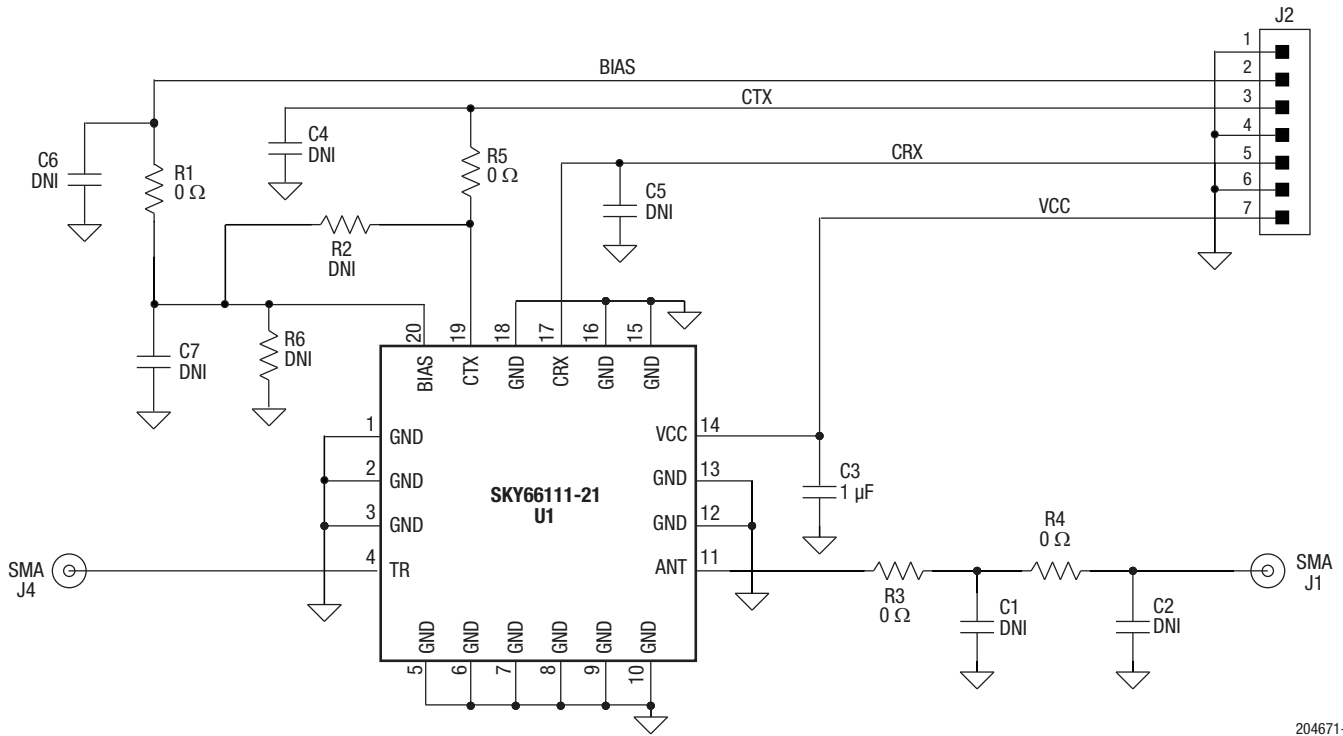
Monitor the 2.4 GHz switch performance by applying an RF signal to connector J1 (ANT) and verify the output signal on connector J4 (TR).

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**CAUTION:** Be careful not to overdrive the switch by applying too much RF on the input to the device. A starting input power of -20 dBm is suitable.

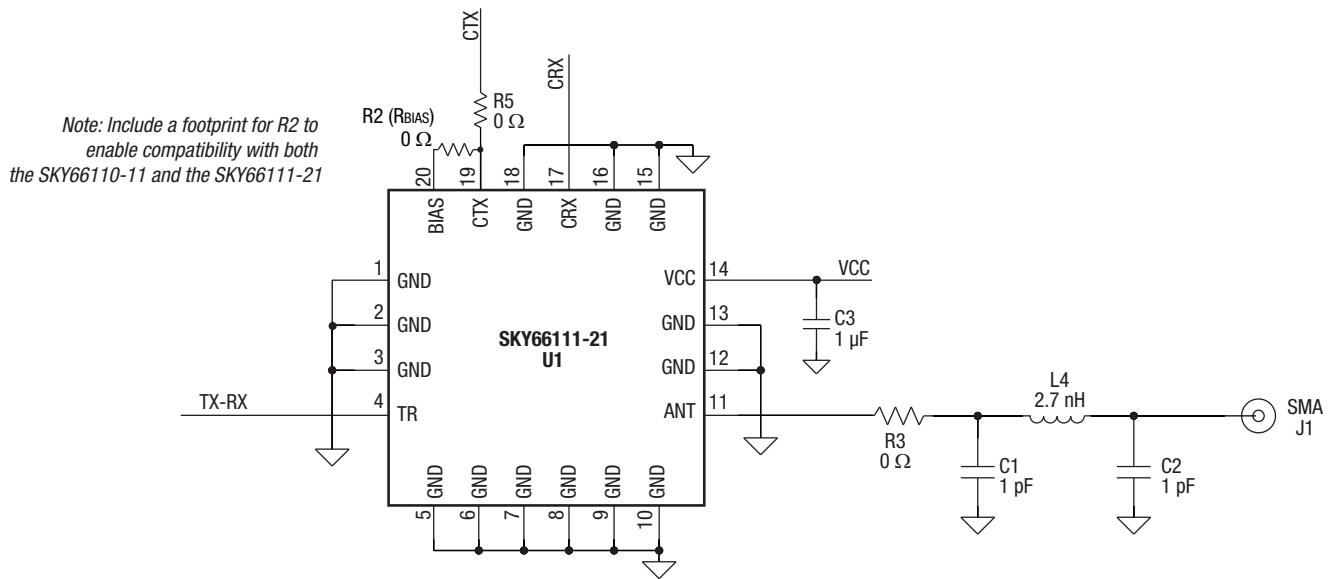
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Figure 11. SKY66111-21 Evaluation Board Schematic

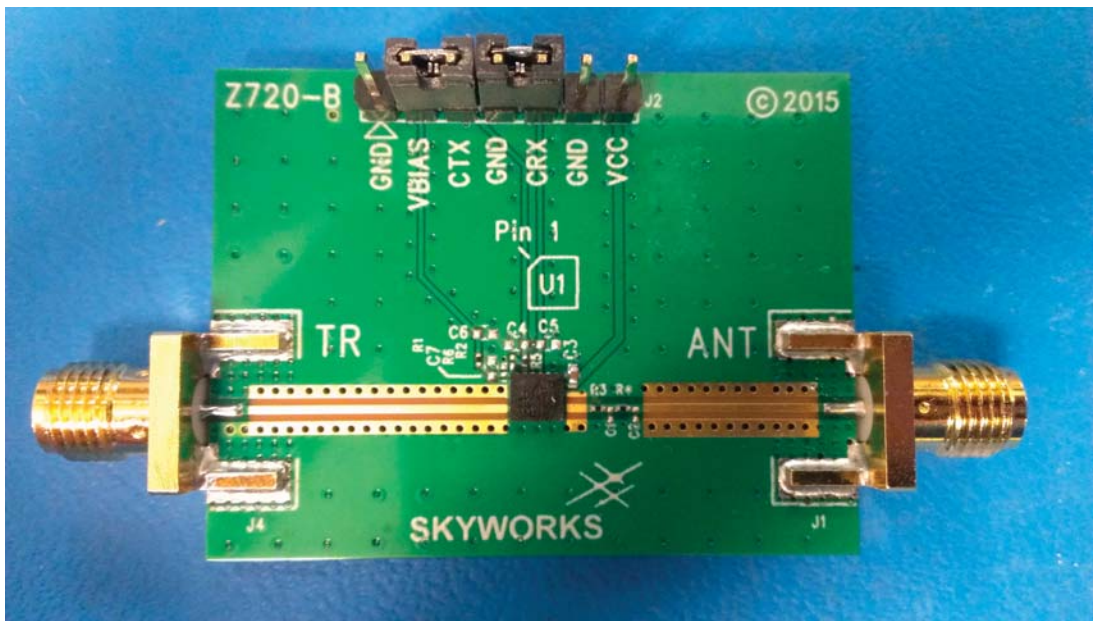


204671-012

Figure 12. SKY66111-21 Reference Design Schematic

**Table 10. SKY66111-21 Evaluation Board Bill of Materials (BOM)**

| Component              | Value       | Size             | Manufacturer            | Mfr Part Number | Characteristics                                       |
|------------------------|-------------|------------------|-------------------------|-----------------|---|
| C1, C2                 | DNI         | 0201             |                         |                 |   |
| C3                     | 1 $\mu$ F   | 0402             |                         |                 | Capacitor   |
| C4, C5, C6             | DNI         | 0402             |                         |                 |   |
| J1, J4                 | SMA         | end launch       | Johnson Components      | 142-0701-851    | SMA end launch straight jack receptacle - tab contact |
| J2                     | 7X1         | 100 mil          | Samtec                  | TSW-107-07-G-S  | 100 mil header  |
| PCB1                   | Z720-B      |                  | Skyworks Solutions Inc. | Z720-B          | PCB   |
| R2, R6                 | DNI         | 0201             |                         |                 | Do not install  |
| R1 (RBIAS), R3, R4, R5 | 0 $\Omega$  | 0201             | Panasonic               | ERJ1GE0R00      | Thick film chip resistor                              |
| U1                     | SKY66111-21 | MCM50P300X330-20 | Skyworks Solutions Inc. | SKY66111-21     | Low-power Bluetooth Low Energy ranger extender        |



**Figure 13. SKY66111-21 Evaluation Board**

### Package Dimensions

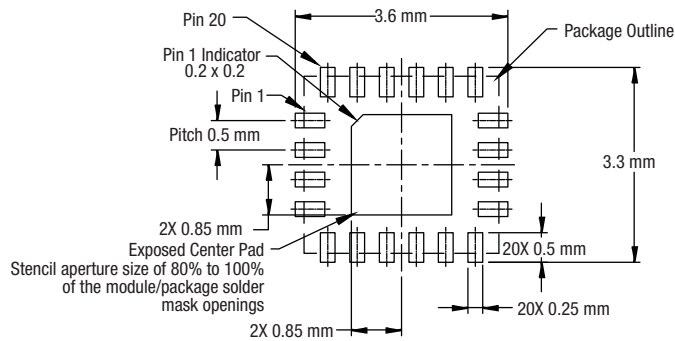
The PCB layout footprint for the SKY66111-21 is provided in Figure 14. Typical part markings are shown in Figure 15. Package dimensions are shown in Figure 16, and tape and reel dimensions are provided in Figure 17.

### Package and Handling Information

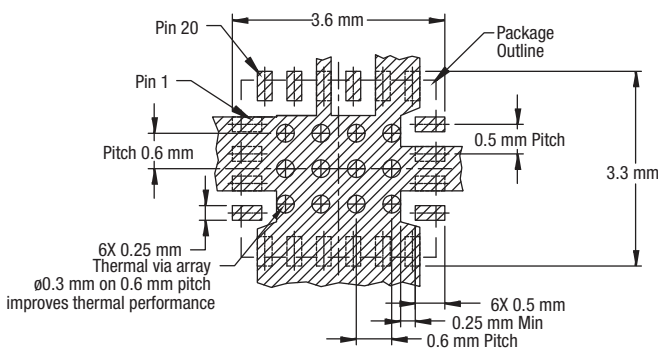
Since the device package is sensitive to moisture absorption, it is baked and vacuum packed before shipping. Instructions on the shipping container label regarding exposure to moisture after the container seal is broken must be followed. Otherwise, problems related to moisture absorption may occur when the part is subjected to high temperature during solder assembly.

The SKY66111-21 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.

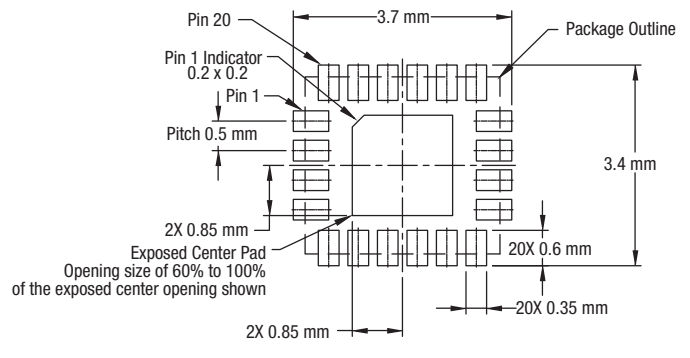
Care must be taken when attaching this product, whether it is done manually or in a production solder reflow environment. Production quantities of this product are shipped in a standard tape and reel format.



Stencil Aperture



Metallization



Solder Mask Opening

Notes:

1. All dimensions are in millimeters, unless otherwise specified.
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.

204671-014

Figure 14. PCB Layout Footprint

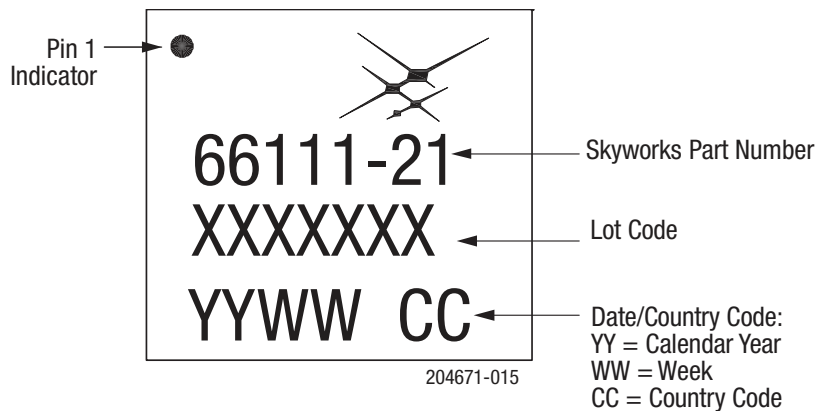


Figure 15. Typical Part Markings

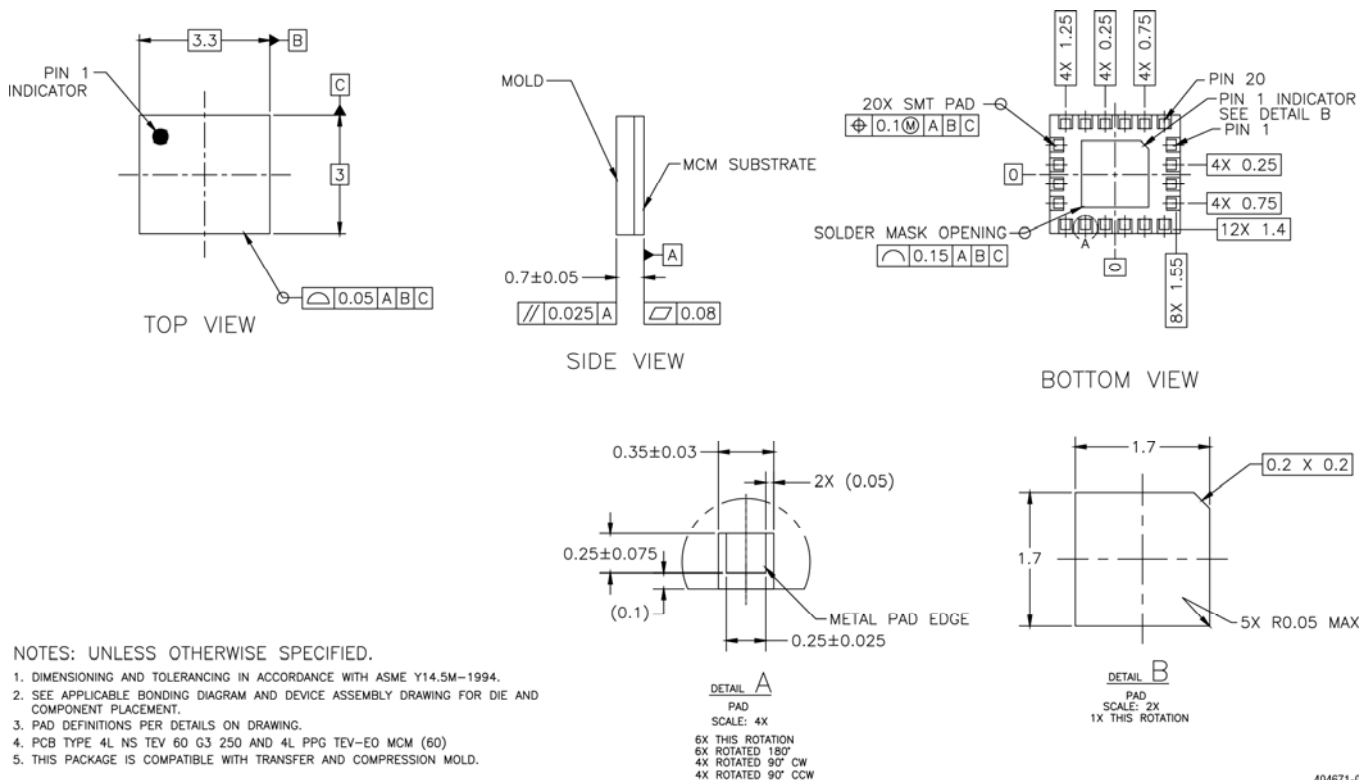
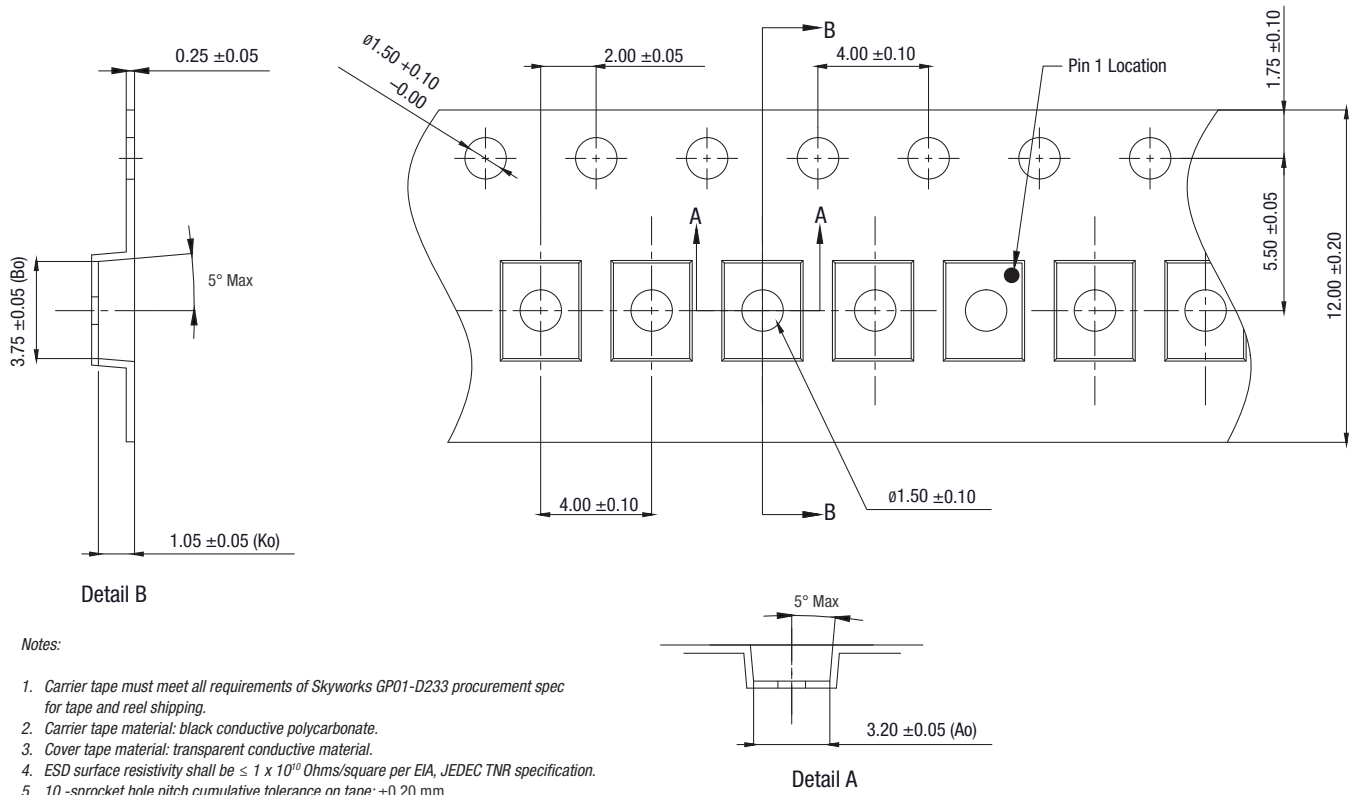


Figure 16. SKY66111-21 Package Dimensions



204671-017

**Figure 17. SKY66111-21 Tape and Reel Dimensions**

## Ordering Information

| Part Number | Product Description  | Evaluation Board Part Number |
|-------------|--|------------------------------|
| SKY66111-21 | SKY66111-21: Low-Power Bluetooth® Low Energy Front-End Module for Range Extension Applications | SKY66111-21EK1               |

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