PRELIMINARY DATA SHEET

SKY65165-11: 2.4-2.5 GHz, 0.25 W WLAN Power Amplifier

Applications

- IEEE 802.11 b/g/n WLANs
- ISM band transmitters
- Wireless access point, routers, gateways

Features

- EVM < 2.5% for P_{OUT} > +24 dBm @ 5 V
- High gain = 32.5 dB @ 5 V
- Internal active bias circuits
- Internal on/off control circuit
- Internal, high dynamic range power detector
- Dual DC supply operation: 3.3 V and 5.0 V
- Small, QFN (16-pin, 3 x 3 mm) package (MSL1, 260 °C per JEDEC J-STD-020)

NEW

Skyworks offers lead (Pb)-free RoHS (Restriction of Hazardous Substances) compliant packaging.

Description

The SKY65165-11 is a Microwave Monolithic Integrated Circuit (MMIC) Power Amplifier (PA) with superior output power, linearity, and efficiency. These features make the SKY65165-11 ideal for Wireless Local Area Network (WLAN) applications. The high linearity (low EVM) and high efficiency of this device makes it ideal for use in the transmit chain of WLAN access points or modems.

The SKY65165-11 is fabricated using Skyworks high reliability Heterojunction Bipolar Transistor (HBT) InGaP process, which allows for single supply operation while maintaining high efficiency and good linearity. The device is internally matched at the RF input and mounted in a 16-pin, 3 x 3 mm Quad Flat No-Lead (QFN) Surface-Mounted Technology (SMT) package, which allows for a highly manufacturable low cost solution.

The pin configuration and package are shown in Figure 1. A functional block diagram is shown in Figure 2. Signal pin assignments and functional pin descriptions are provided in Table 1.

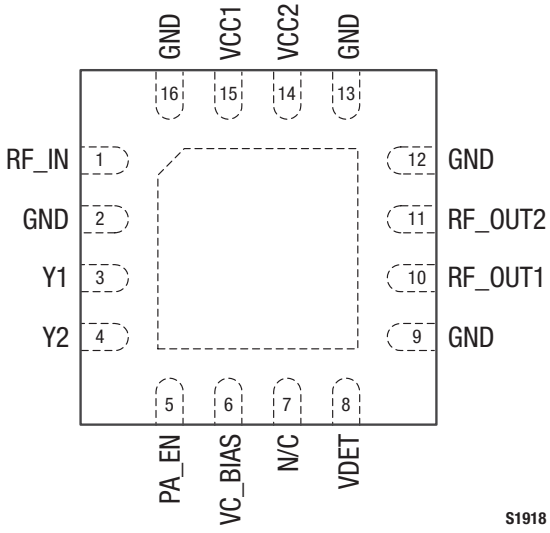


Figure 1. SKY65165-11 Pinout – 16-Pin QFN (Top View)

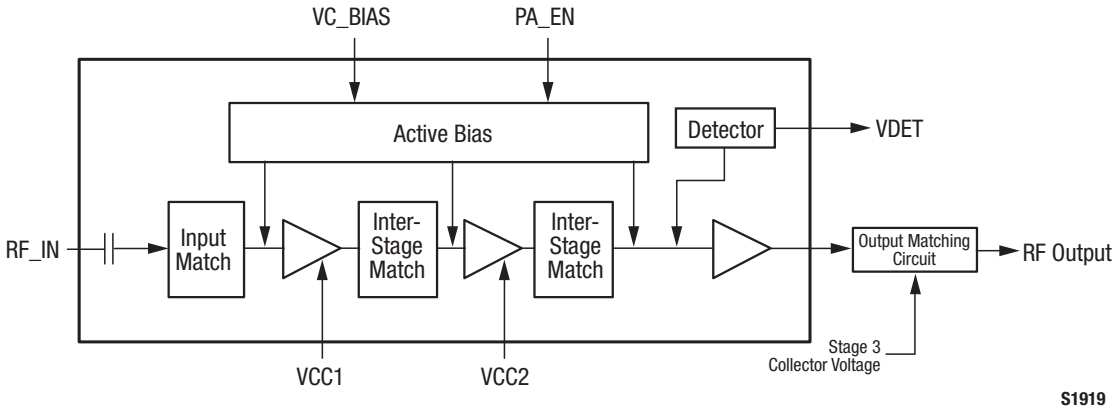


Figure 2. SKY65165-11 Block Diagram

Table 1. SKY65165-11 Signal Descriptions

Pin #	Name	Description	Pin #	Name	Description
1	RF_IN	RF input	9	GND	Ground
2	GND	Ground	10	RF_OUT1	RF output 1
3	Y1	Input to interstage inductor	11	RF_OUT2	RF output 2
4	Y2	Output to interstage inductor	12	GND	Ground
5	PA_EN	PA on/off control signal (on = +3 V to VCC; off = 0 to 0.5 V)	13	GND	Ground
6	VC_BIAS	Bias voltage (5 V)	14	VCC2	Stage 2 collector voltage (5 V)
7	N/C	No connect	15	VCC1	Stage 1 collector voltage (5 V)
8	VDET	Detector supply voltage	16	GND	Ground

Note: The center ground pad must have a low inductance and low thermal resistance connection to the printed circuit board ground plane.

Functional Description

The SKY65165-11 is a three-stage, HBT InGaP device optimized for high linearity and power efficiency. It contains all of the needed RF matching. An in-module active bias circuit is included within the device for all three amplifier stages, which provides excellent gain tracking over temperature and voltage variations.

The first and second output stages are independently supplied using the VCC1 and VCC2 signals (pins 15 and 14, respectively). The DC control voltage that sets the bias for all three stages is supplied by the VC_BIAS signal (pin 4). The Evaluation Board includes shunt decoupling capacitors on these pins to suppress any possible bias affect on the RF signal at low frequencies.

The SKY65165-11 includes an internal PA enable control pin (pin 5) for fast RF on/off control. Zero volts turns off the PA while 3 to 5 V enables the PA. The device also provides an output power detector voltage, VDET, at pin 8.

Pin 1 is the RF input and pins 10 and 11 are the RF outputs. External DC blocking or RF matching is required on the RF output. Grounding is through several ground pins and the package center ground.

These features make the device suitable for wideband digital applications where PA linearity and power consumption are of critical importance (e.g., WLANs). The device has been characterized with the highest specified data rates for 802.11b (11 Mbps) and 802.11g (54 Mbps). Under these stringent test conditions, the device exhibits excellent spectral purity and power efficiency.

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY65165-11 are provided in Table 2. The recommended operating conditions are specified in Table 3 and electrical specifications are provided in Table 4.

Performance characteristics for the SKY65165-11 are illustrated in Figures 3 through 6.

Table 2. SKY65165-11 Absolute Maximum Ratings (Note 1)

Parameter	Symbol	Minimum	Maximum	Units
RF output power	P_{OUT}		+31	dBm
Supply voltage (VCC1, VCC2, VC_BIAS)	V_{CC}	4.5	5.5	V
Total supply current	I_{CC}		700	mA
Power dissipation	P_D		*** TBD ***	W
Thermal resistance	Θ_{JC}		*** TBD ***	°C/W
Junction temperature	T_J		+150	°C
Case temperature	T_C	–40	+85	°C
Storage temperature	T_{STG}	–55	+125	°C

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.

***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. SKY65165-11 Recommended Operating Conditions

Parameter	Symbol	Minimum	Typical	Maximum	Units
RF output power	P_{OUT}		+24		dBm
Supply voltage (VCC1, VCC2, VC_BIAS)	V_{CC}	3.0	5.0	5.5	V
PA enable	PA_EN	3		5	V
Total supply current	I_{CC}		400		mA
Operating frequency	f	2412		2483	MHz
Case temperature	T_C	–40	+25	+85	°C

Table 4. SKY65165-11 Electrical Specifications: 5.0 V Performance (Note 1)
(VCC1 = VCC2 = VC_BIAS = PA_EN = 5 V, T_C = 25 °C, f = 2.442 GHz, Characteristic Impedance [Z_0] = 50 Ω, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Continuous Wave Input Signal						
Quiescent current	I_{CCQ}			220	250	mA
Operational current	I_{CC}	P_{OUT} = +24 dBm		330		mA
1 dB Output Compression Point	OP1dB			+31.2		dBm
Noise Figure	NF			4.6		dB
Small signal gain	|S21|			33.5		dB
Gain variation across band		2.4 to 2.5 GHz		0.6		dB
Input return loss	|S11|			15		dB
Output return loss	|S22|			9		dB
Detector voltage	V_{DET}	P_{OUT} = +24 dBm		0.6		V
2nd harmonic	2fo	P_{OUT} = +24 dBm		–28		dBm
3rd harmonic	3fo	P_{OUT} = +24 dBm		–41		dBm
IEEE 802.11g Orthogonal Frequency Division Multiplexing Input Signal, 64 QAM, 54 Mbps						
Error Vector Magnitude	EVM	P_{OUT} = +24 dBm		2.5		%
Average operational current	I_{CC}	802.11g, P_{OUT} = +24 dBm		285		mA

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

Table 5. SKY65165-11 Electrical Specifications: 3.3 V Performance (Note 1)
(VCC1 = VCC2 = VC_BIAS = PA_EN = 3.3 V, T_C = 25 °C, f = 2.442 GHz, Characteristic Impedance [Z_0] = 50 Ω, Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Continuous Wave Input Signal						
Quiescent current	I_{CCQ}			95		mA
Operational current	I_{CC}	P_{OUT} = +20 dBm		180		mA
1 dB Output Compression Point	OP1dB			+28.3		dBm
Noise Figure	NF			4		dB
Small signal gain	|S21|			30.8		dB
Gain variation across band		2.4 to 2.5 GHz		0.5		dB
Input return loss	|S11|			15		dB
Output return loss	|S22|			9		dB
Detector voltage	V_{DET}	P_{OUT} = +20 dBm		370		mV
2nd harmonic	2fo	P_{OUT} = +20 dBm		–25		dBm
3rd harmonic	3fo	P_{OUT} = +20 dBm		–35		dBm
IEEE 802.11g Orthogonal Frequency Division Multiplexing Input Signal, 64 QAM, 54 Mbps						
Error Vector Magnitude	EVM	P_{OUT} = +20 dBm		3		%
Average operational current	I_{CC}	802.11g, P_{OUT} = +20 dBm		135		mA

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

Typical Performance Characteristics: 5.0 V

(VCC1 = VCC2 = VC_BIAS = PA_EN = 5 V, T_C = 25 °C, f = 2.442 GHz, Characteristic Impedance [Z_O] = 50 Ω, Unless Otherwise Noted)

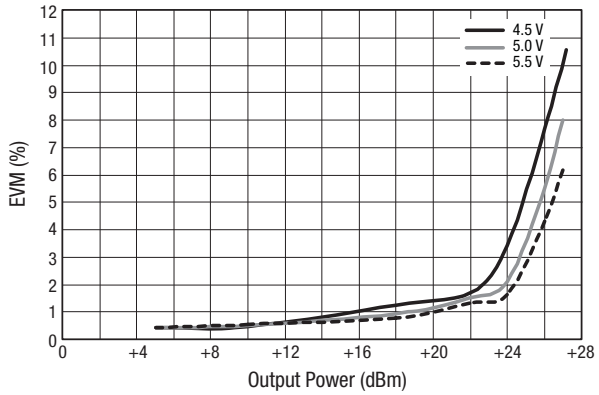


Figure 3. EVM vs Output Power Over Frequency Over Voltage

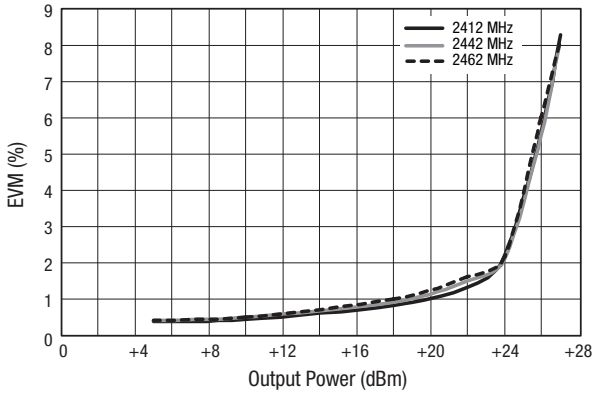


Figure 4. EVM vs Output Power Over Frequency @ 5.0 V

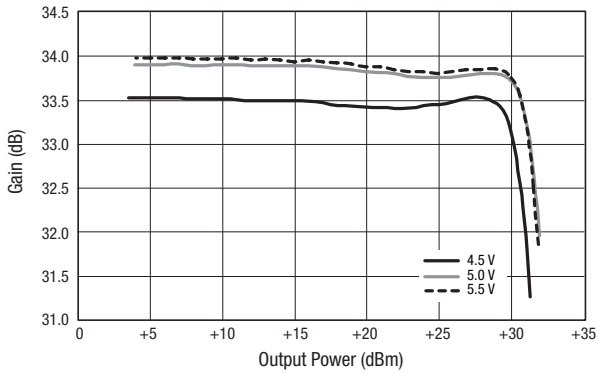


Figure 5. Output Power vs Gain Over Voltage (CW)

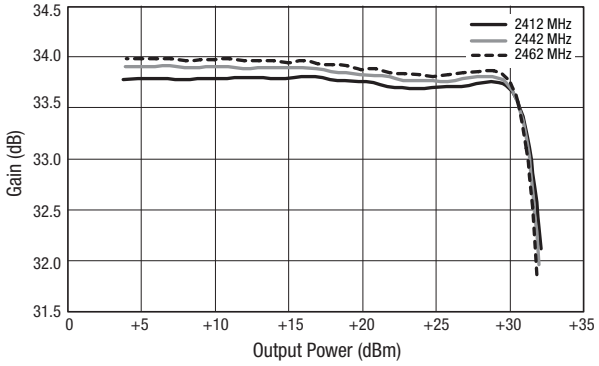


Figure 6. Output Power vs Gain Over Frequency (CW, V_{CC} = 5.0 V)

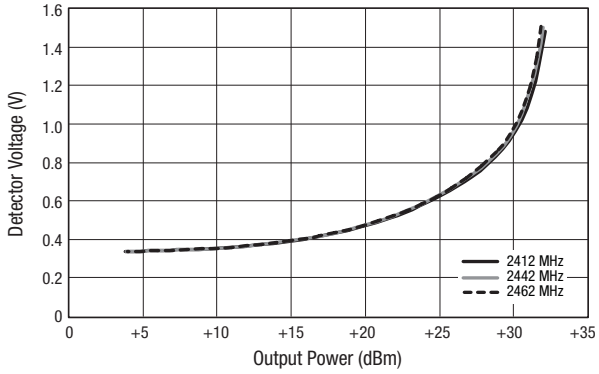


Figure 7. Detector Voltage vs Output Power Over Frequency (CW, V_{CC} = 5.0 V)

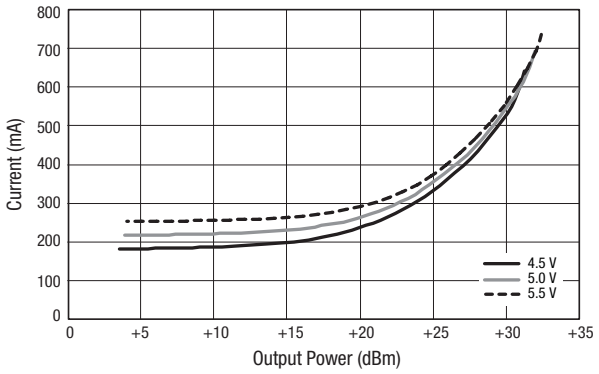


Figure 8. Output Power vs Current Over Voltage (CW)

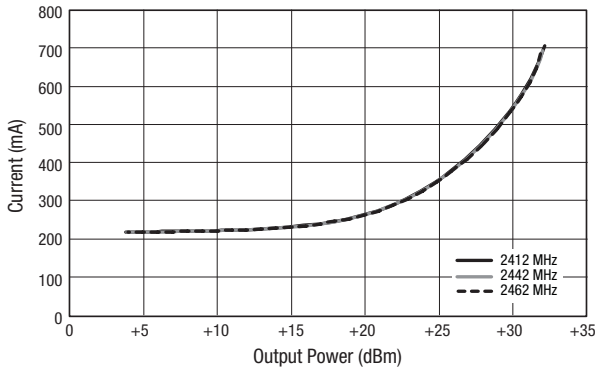


Figure 9. Output Power vs Current Over Frequency (CW, V_{CC} = 5.0 V)

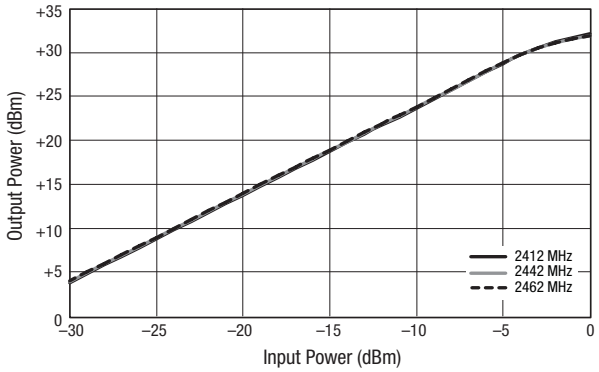


Figure 10. Output Power vs Input Power (CW, V_{CC} = 5.0 V)

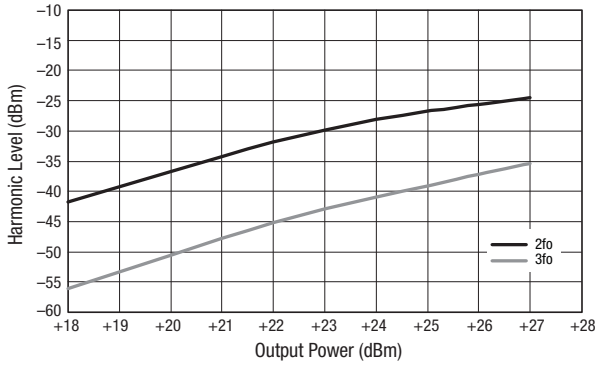


Figure 11. Harmonic Level vs Output Power

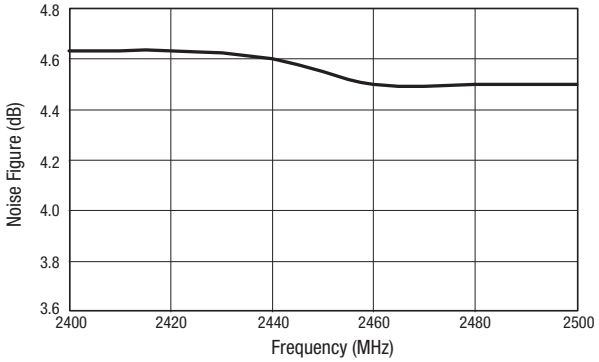


Figure 12. Noise Figure vs Frequency

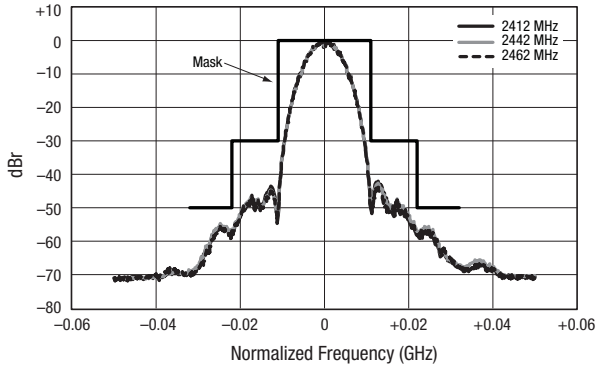


Figure 13. Spectral Mask Over Frequency (802.11b CCK, 11 Mbps, P_{OUT} = +28 dBm, V_{CC} = 5.0 V)

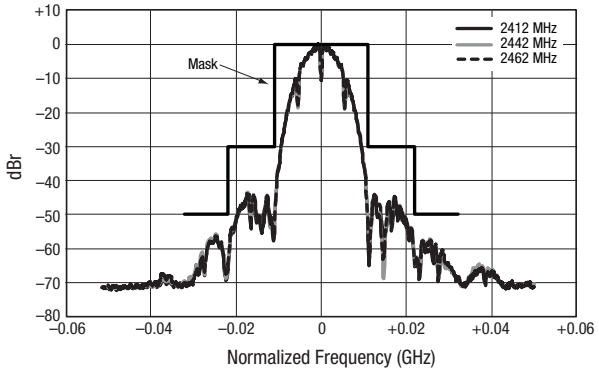


Figure 14. Spectral Mask Over Frequency (802.11b CCK, 1 Mbps, P_{OUT} = +28 dBm, V_{CC} = 5.0 V)

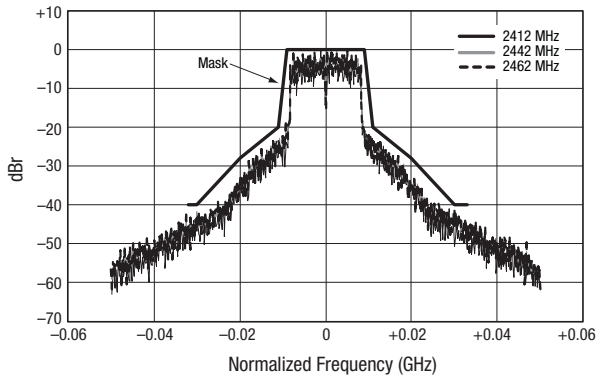


Figure 15. Spectral Mask Over Frequency
(64 QAM OFDM, 54 Mbps, P_{OUT} = +26 dBm, V_{CC} = 5.0 V)

Typical Performance Characteristics: 3.3 V

(VCC1 = VCC2 = VC_BIAS = PA_EN = 3.3 V, T_C = 25 °C, f = 2.442 GHz, Characteristic Impedance [Z_0] = 50 Ω, Unless Otherwise Noted)

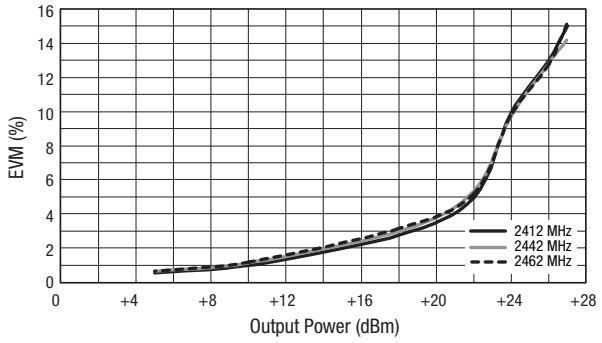


Figure 16. EVM vs Output Power Over Frequency @ 3.3 V
(802.11g, 64 QAM, 54 Mbps)

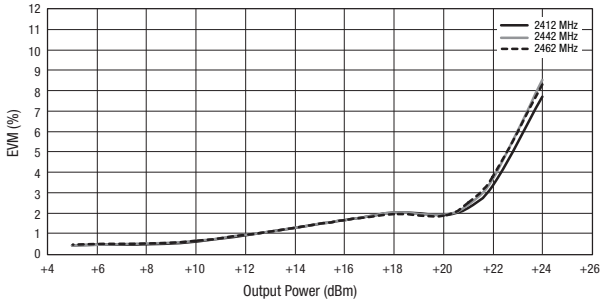


Figure 17. EVM vs Output Power Over Frequency @ 3.6 V
(802.11g, 64 QAM, 54 Mbps)

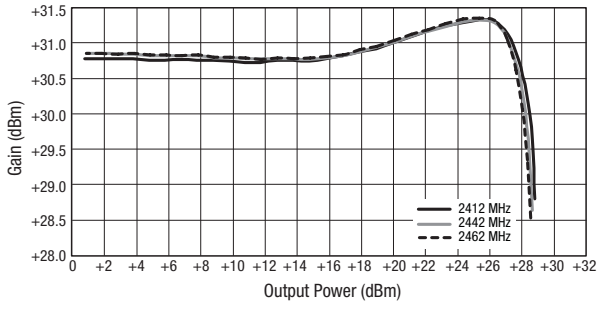


Figure 18. Gain vs Output Power Over Frequency
(CW, V_{CC} = 3.3 V)

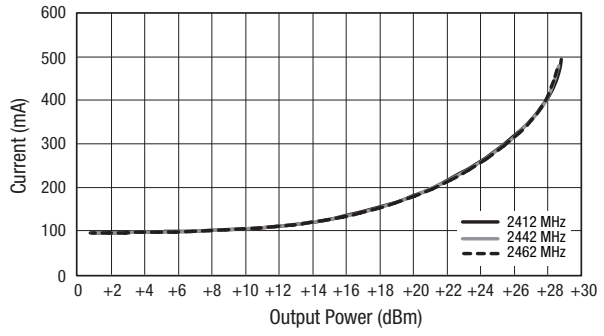


Figure 19. Current vs Output Power
(CW, V_{CC} = 3.3 V)

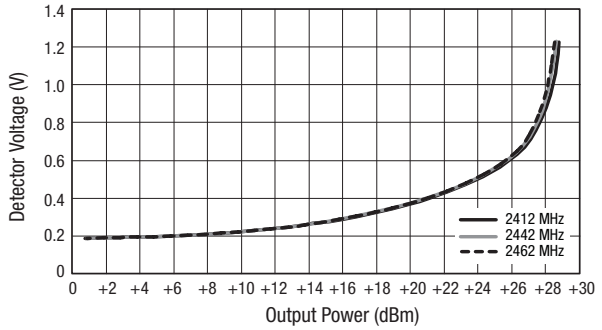


Figure 20. Detector Voltage vs Output Power Over Frequency (CW, V_{CC} = 3.3 V)

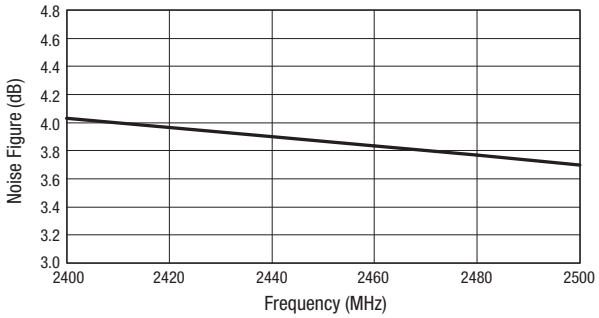


Figure 21. Noise Figure vs Frequency

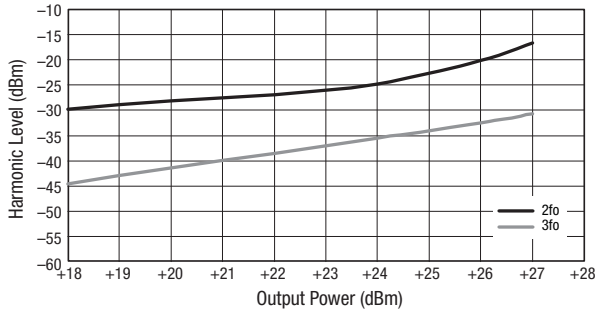


Figure 22. Harmonic Level vs Output Power (CW)

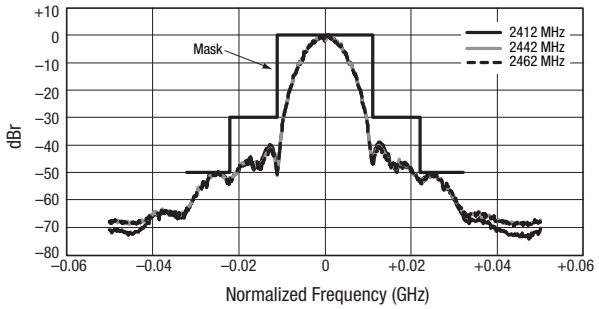


Figure 23. Spectral Mask Over Frequency (802.11b CCK, 11 Mbps, P_{OUT} = +25 dBm, V_{CC} = 3.3 V)

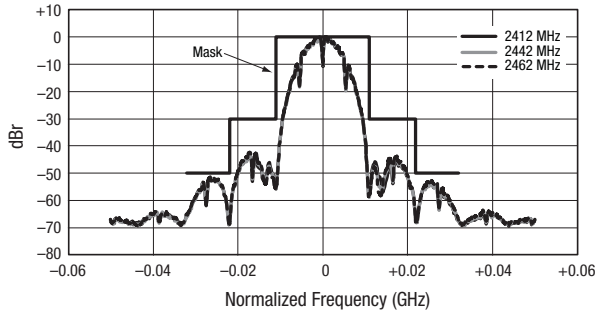


Figure 24. Spectral Mask Over Frequency (802.11b CCK, 1 Mbps, P_{OUT} = +24 dBm, V_{CC} = 3.3 V)

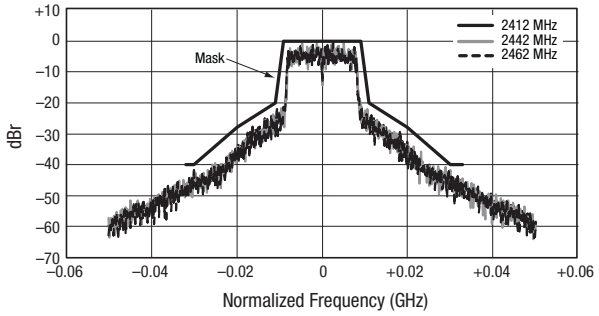


Figure 25. Spectral Mask Over Frequency (802.11b OFDM, 54 Mbps, P_{OUT} = +22 dBm, V_{CC} = 3.3 V)

Evaluation Board Description

The SKY65165-11 Evaluation Board is used to test the performance of the SKY65165-11 PA. A typical application schematic diagram is provided in Figure 26. An assembly drawing for the Evaluation Board is shown in Figure 27.

An Evaluation Board layer detail drawing is shown in Figure 28. Layer detail physical characteristics are noted in Figure 29. Table 5 provides the Bill of Materials (BOM) list for Evaluation Board components.

Circuit Design Considerations

The following design considerations are general in nature and must be followed regardless of final use or configuration:

1. Paths to ground should be made as short as possible.
2. The ground pad of the SKY65165-11 has special electrical and thermal grounding requirements. This pad is the main thermal conduit for heat dissipation. Since the circuit board acts as the heat sink, it must shunt as much heat as possible from the device. Therefore, design the connection to the ground pad to dissipate the maximum wattage produced by the circuit board. Multiple vias to the grounding layer are required.

   For further information, refer to the Skyworks Application Note, *PCB Design Guidelines for HIgh Power Dissipation Packages*, document number 201211.
3. Bypass capacitors should be used on the DC supply lines. An RF inductor is required on the VCC supply line to block RF signals from the DC supply. Refer to the schematic drawing in Figure 26 for further details.
4. The RF lines should be well separated from each other with solid ground in between traces to maximize input-to-output isolation.

NOTE: *A poor connection between the slug and ground increases junction temperature (T_J), which reduces the lifetime of the device.*

Evaluation Board Test Procedure

Step 1: Connect a +5 V supply to the VCC1, VCC2, VC_BIAS, VDET, and PA_EN pins. If available, enable the current limiting function of the power supply to 500 mA.

Step 2: If desired, connect a voltage meter to the VDET pin.

Step 3: Connect a signal generator to the RF signal input port. Set it to the desired RF frequency at a power level of –15 dBm or less to the Evaluation Board. DO NOT enable the RF signal.

Step 4: Connect a spectrum analyzer to the RF signal output port.

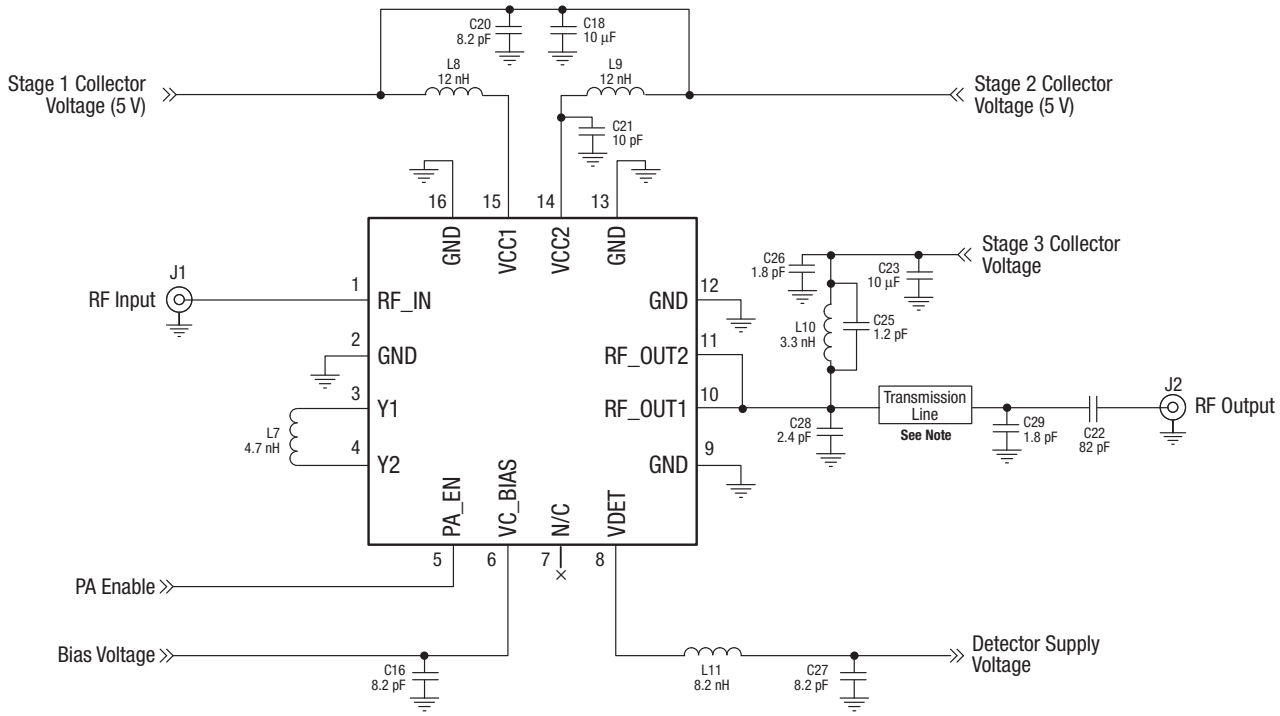
Step 5: Enable the power supply.

Step 6: Enable the RF signal.

Step 7: Take measurements.

CAUTION: *If the input signal exceeds the rated power, the SKY65165-11 Evaluation Board can be permanently damaged.*

NOTE: *It is important to adjust the VCC voltage source so that +5 V is measured at the board. The high collector currents will drop the collector voltage significantly if long leads are used. Adjust the bias voltage to compensate.*



Note: For 3.3 V operation, length = 6.5 mm, width = 0.5 mm.
For 5.0 V operation, length = 7.0 mm, width = 0.5 mm

Figure 26. SKY65165-11 Typical Application Schematic

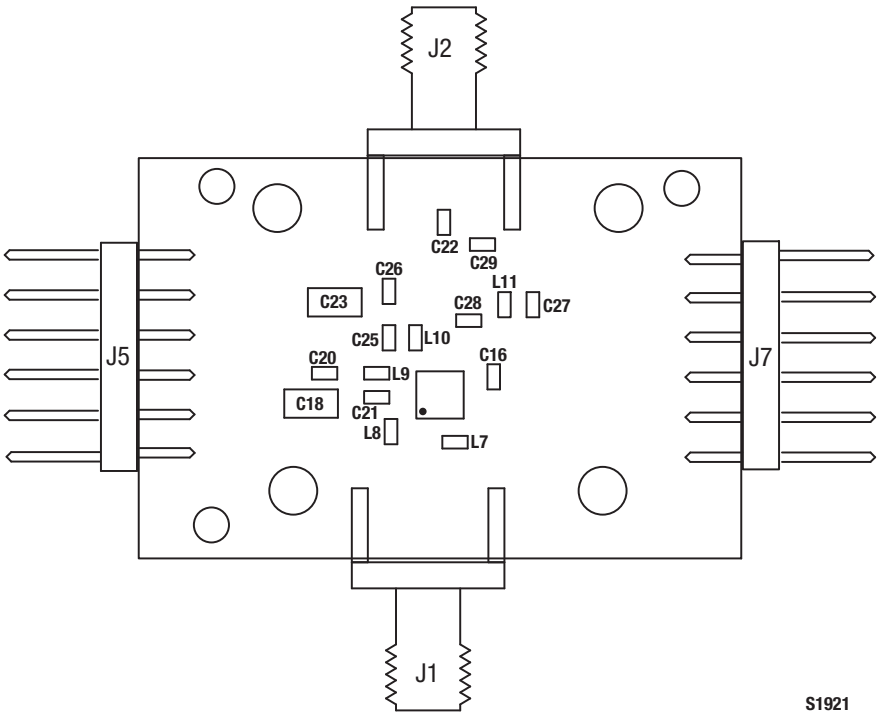
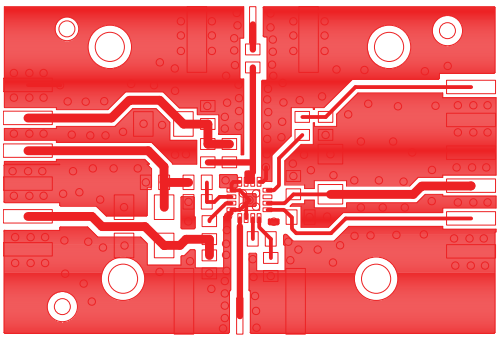
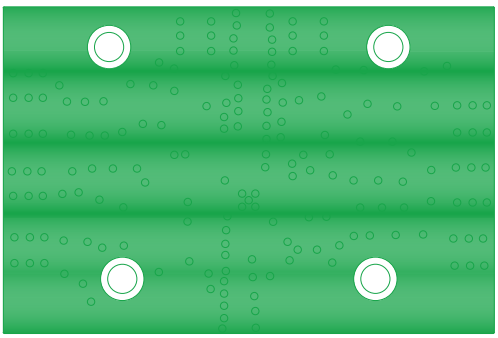


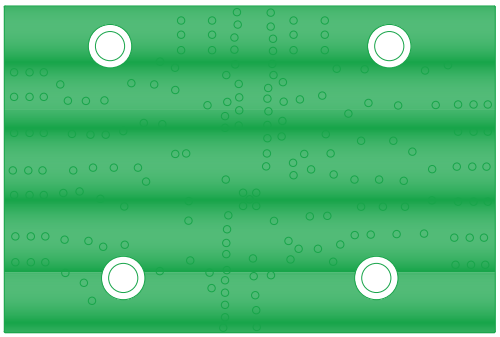
Figure 27. SKY65165-11 Evaluation Board Assembly Diagram



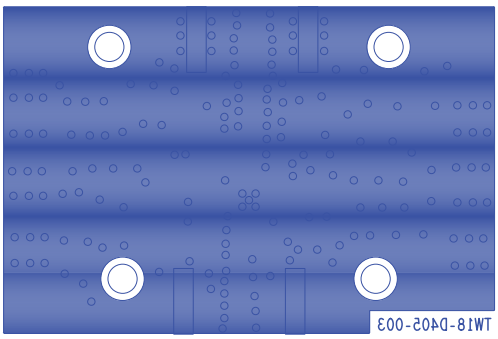
Layer 1: Top – Metal



Layer 2: Ground



Layer 3: Power Plane



Layer 4: Solid Ground Plane

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Figure 28. SKY65165-11 Evaluation Board Layer Detail

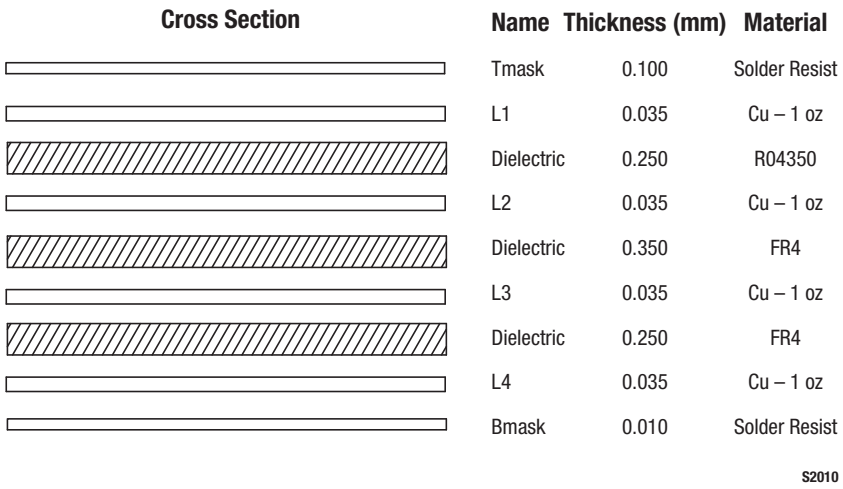


Figure 29. Evaluation Board Layer Detail Physical Characteristics

Table 5. SKY65165-11 Evaluation Board Bill of Materials

Component	Value	SMT Size (Note 1)
C18, C23	10 µF	1206
C16, C20, C27	8.2 pF	0603
C22	82 pF	0603
C25	1.2 pF	0603
C26, C29	1.8 pF	0603
C28	2.4 pF	0603
L7	4.7 nH	0603
L10	3.3 nH	0603
L8, L9	12 nH	0603

Application Circuit Notes

Center Ground. It is extremely important to sufficiently ground the bottom ground pad of the device for both thermal and stability reasons. Multiple small vias are acceptable and will work well under the device if solder migration is an issue.

GND (pins 2, 9, 12, 13, and 16). Attach all ground pins to the RF ground plane with the largest diameter and lowest inductance via that the layout allows. Multiple small vias are acceptable and will work well under the device if solder migration is an issue.

PA_EN (pin 5). Internal PA enable control pin for fast on/off control (on = +3 V to VCC; off = 0 to 0.5 V).

VC_BIAS (pin 6). The bias supply voltage for stages 1 and 2, typically set to +5 V.

RF_OUT1 and RF_OUT2 (pins 10 and 11). Amplifier RF output pins. Third stage collector voltage is connected to these pins through an output match circuit. Capacitor C28 should be placed as close as possible to the SKY65165-11. For 3.3 V operation, C29 should be placed 6.5 mm from capacitor C28. For 5.0 V operation, capacitor C29 should be placed 7.0 mm from capacitor C28.

Y1 and Y2 (pins 3 and 4). Interstage inductor input and output pins.

N/C (pin 7). This pin is open and may or may not be connected to ground.

VCC2 (pin 14). Supply voltage for the second stage collector bias (typically +5 V). To bypass VCC2, capacitors C8 and C16 (see Figure 7) should be placed in the approximate location shown on the Evaluation Board, although exact placement is not critical.

VDET (pin 8). The power detector output voltage signal. This pin may be connected to PA_EN (pin 5). The benefit of this is that the current draw consumed by the detector will not be wasted with the device in the off state.

VCC1 (pin 15). Supply voltage for the first stage collector bias (typically +5 V). To bypass VCC1, capacitors C5 and C15 (see Figure 7) should be placed in the approximate location shown on the Evaluation Board, although exact placement is not critical.

RF_IN (pin 1). Amplifier RF input pin (Z_0 = 50 Ω). The module includes an onboard internal DC blocking capacitor. All impedance matching is provided internal to the module.

Package Dimensions

The PCB layout footprint for the SKY65165-11 is shown in Figure 30. Typical case markings are shown in Figure 31. Package dimensions for the 16-pin QFN are shown in Figure 32, and tape and reel dimensions are provided in Figure 33.

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 SKY65165-11 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.

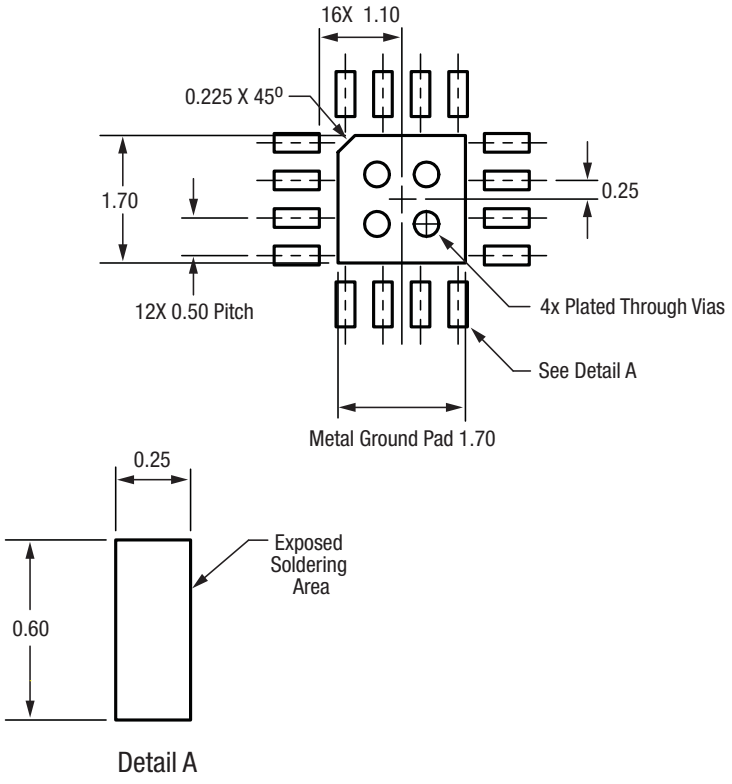
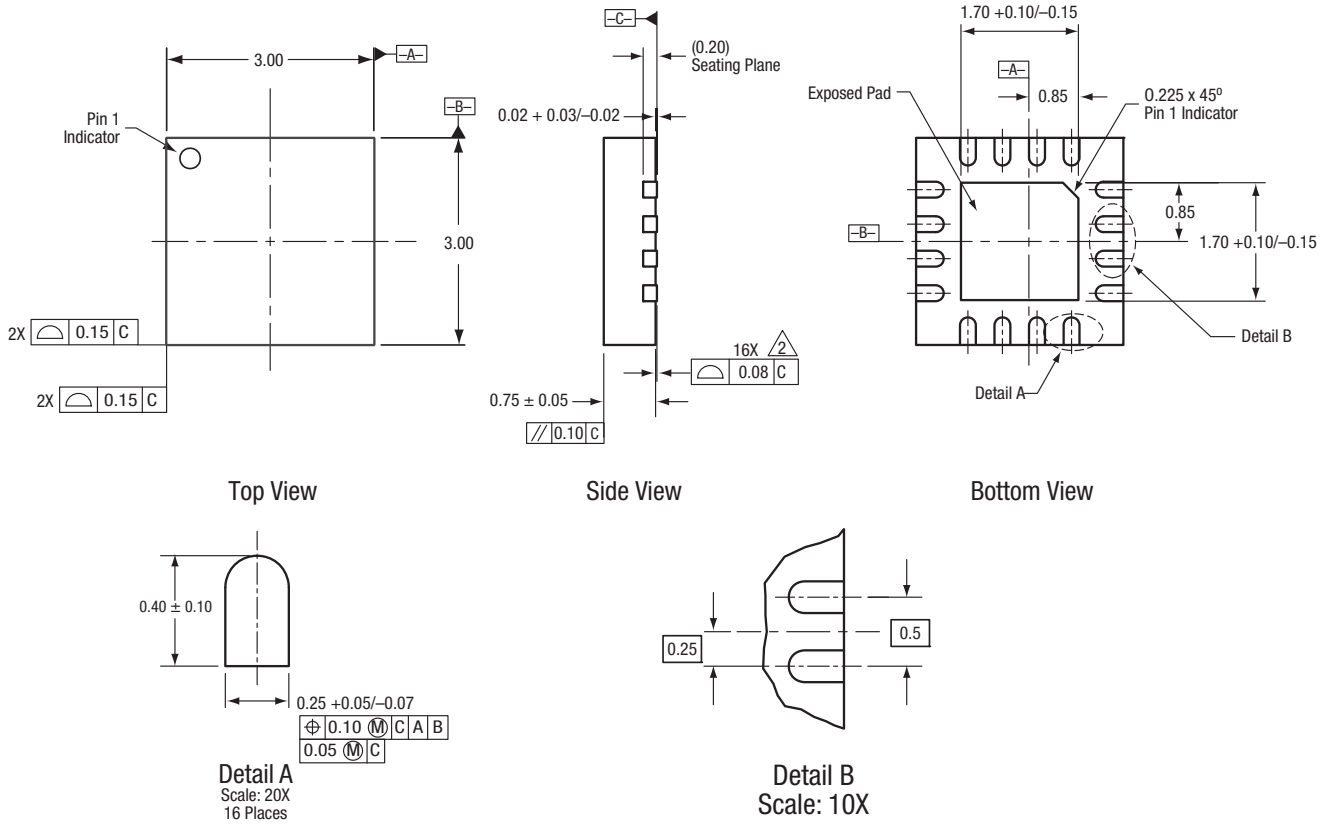


Figure 30. SKY65165-11 PCB Layout Footprint

*** TBD ***

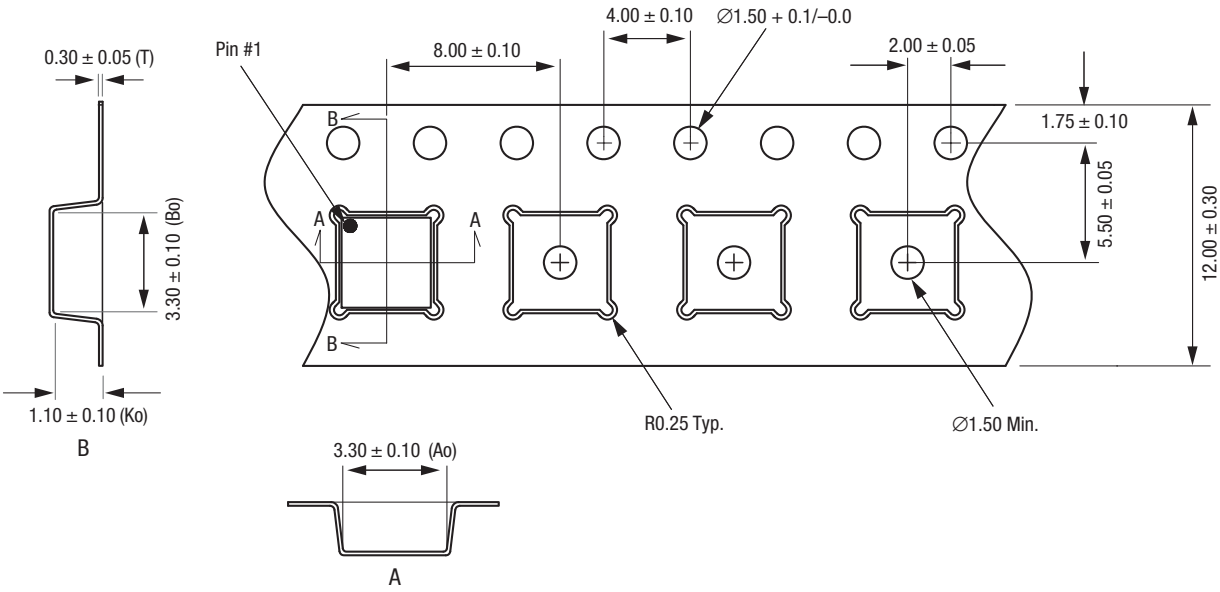
Figure 31. SKY65165-11 Typical Case Markings



All measurements are in millimeters.
Dimensioning and tolerancing according to ASME Y14.5M-1994.
Coplanarity applies to the exposed heat sink slug as well as the terminals..
Plating requirement per source control drawing (SCD) 2504.

S1692

Figure 32. SKY65165-11 16-Pin QFN Package Dimensions



Notes:
1. *Carrier tape: black conductive polystyrene, non-bakeable material.*
2. *Cover tape material: transparent conductive HSA.*
3. *Cover tape size: 9.20 mm width.*
4. *All measurements are in millimeters.*

S1698

Figure 33. SKY65165-11 16-Pin QFN Tape and Reel Dimensions

Ordering Information

Model Name	Manufacturing Part Number	Evaluation Board Part Number
SKY65165-11 WLAN Power Amplifier	SKY65165-11	TW18-D405-003