DATA SHEET

SKY65135-21: WLAN Linear Power Amplifier

Applications

- IEEE802.11 b/g WLAN
- WiMAX
- ISM band
- WCS fixed wireless
- Wireless access nodes

Features

- Frequency of operation 2.4–2.5 GHz
- Linear power out of 31 dBm for 802.11b mask
- Linear power out of 30 dBm for 802.11g mask
- High small signal gain of 33.5 dB
- Output power detector: 20 dB dynamic range
- Excellent gain flatness
- Internal RF match with DC block
- Active bias circuit
- MCM (20-pin, 6 x 6 mm) lead (Pb)-free package (MSL3, 260 °C per JEDEC J-STD-020)

Description

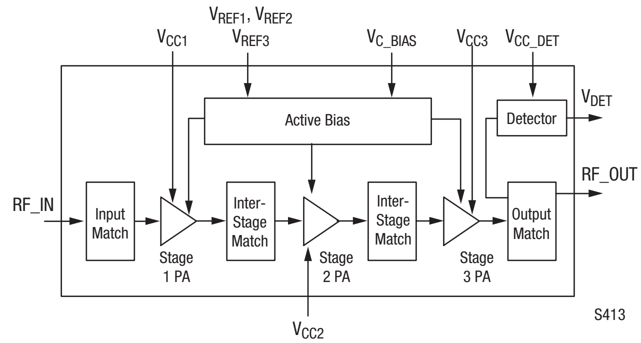
The SKY65135-21 is a fully matched, DC blocked, 20-pin, lead-free, surface mount, Multi-Chip Module (MCM) Power Amplifier (PA) with excellent output power, linearity, and efficiency. The part is primarily designed mainly for WLAN/ISM/WCS applications and wireless access nodes in the 2400–2500 MHz band, but may be used in a variety of power amplifier applications.

All active circuitry in the module is contained in a single Gallium Arsenide (GaAs) Microwave Monolithic Integrated Circuit (MMIC).

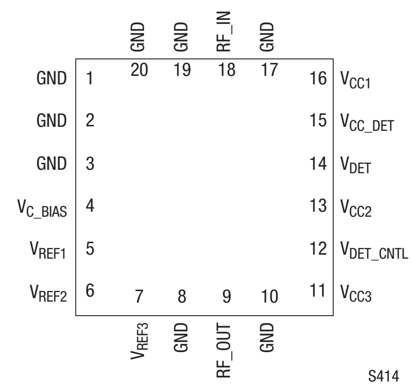
The device is manufactured with Skyworks Aluminum (Al) GaAs Heterojunction Bipolar Transistor (HBT) process, which allows for single supply operation while maintaining high efficiency and good linearity.

The module can operate over the temperature range of -40 °C to 85 °C. A populated evaluation board is available upon request.

Block Diagram



Package Diagram



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

Electrical Specifications

V_{CC1} = V_{CC2} = 3.3 V, V_{CC3} = 5 V, V_{REF1}, V_{REF2}, V_{REF3} = 5 V, V_{C_BIAS} = 5 V, V_{CC_DET} = 5 V, Z_0 = 50 Ω, Test Frequency = 2.442 GHz, T_C = 25 °C, unless otherwise specified(5)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Continuous wave						
Small signal gain	G	P_{IN} = -25 dBm	32	33.5	34.5	dB
Gain flatness over band		2.4 GHz to 2.5 GHz		±0.25		dB
Gain flatness over channel		Over any 16.25 MHz within band		±0.1		dB
Input return loss	$\|S_{11}\|$	P_{IN} = -25 dBm	10	18		dB
Output return loss	$\|S_{22}\|$	P_{IN} = -25 dBm		17		dB
Output power @ $P_{1\ dB}$	$P_{1\ dB}$	P_{IN} = 0 dBm	32	33.5		dBm
Output 3rd order intercept	OIP3	P_{OUT}/tone = 25 dBm, ΔF= 5 MHz		44		dBm
Noise figure	NF	P_{IN} = -25 dBm		5	6.5	dB
Power-added efficiency	PAE	P_{OUT} @ $P_{1\ dB}$	25	36		%
Detector voltage	V_{DET}	P_{OUT} @ $P_{1\ dB}$		1.75		V
Quiescent current	I_{CCQ}	No RF signal		405	450	mA
Thermal resistance	Θ_{JC}	Junction to case		19		°C/W
IEEE802.11b, CCK modulation, 11 Mbps						
Total supply current	I_{CC_TOTAL}			1150		mA
Output power(1)	P_{OUT}			31		dBm
Power-added efficiency(2)	P_{OUT_EVM}			25		%
Ramp-up/ramp-down(3)	T_S			<0.5		μs
IEEE802.11g, OFDM modulation, 54 Mbps						
Total supply current	I_{CC_TOTAL}			1050		mA
Output power(4)	P_{OUT}			30		dBm
Output power at EVM = 3%	P_{OUT_EVM}			25		dBm
Power-added efficiency(2)	PAE			22		%

1. Defined as the maximum power level for which the IEEE802.11b transmit mask requirements are met.
2. Measured at the specified average output RF power and modulation type.
3. Ramp-up and ramp-down times are defined from the 10% to 90% power points.
4. Defined as the maximum power level for which the IEEE802.11g transmit mask requirements are met.
5. Voltage measured at evaluation board pins.

Absolute Maximum Ratings

Characteristic	Value
RF output power (P_{OUT})	30 dBm
Supply voltages (V_{CC1}, V_{CC2}, V_{REF1}, V_{REF2}, V_{REF3}, V_{CC_DET})(1)	4 V
3rd Stage supply voltage (V_{CC3}, V_{C_BIAS})	6 V
Total supply current (I_{CC} + I_{BIAS} + I_{REF})	1200 mA
Power dissipation (P_{DISS})	4.0 W
Operating case temperature (T_C)	-40 °C to +85 °C
Storage temperature (T_{ST})	-55 °C to +125 °C
Junction temperature (T_J)	150 °C

1. Voltage levels measured at the pins of the package. The evaluation board supply voltage levels may be different. Refer to the evaluation board schematic diagram.

Performance is guaranteed only under the conditions listed in the specifications table and is not guaranteed under the full range(s) described by the Absolute Maximum specifications. Exceeding any of the absolute maximum/minimum specifications may result in permanent damage to the device and will void the warranty. Each absolute maximum rating listed is an individual parameter. Operating the amplifier with more than one condition at its absolute maximum or minimum rating value may result in permanent damage to the device. Exposure to maximum rating conditions for extended periods may reduce device reliability.

CAUTION: *Although this device is designed to be as robust as possible, ESD (Electrostatic Discharge) 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 must be employed at all times.*

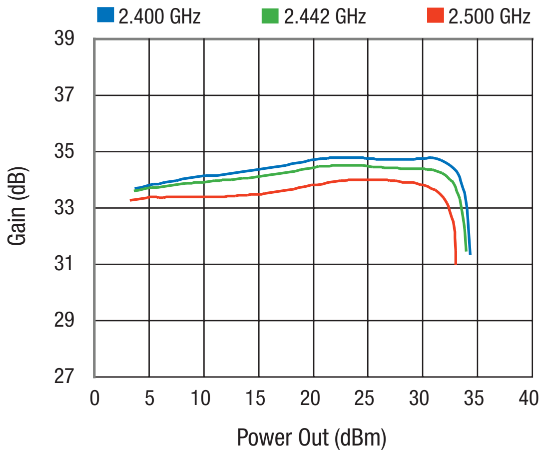
Recommended Operating Conditions

Parameter	Symbol	Frequency	Min.	Typ.	Max.	Unit
Operating frequency	F_0		2.4		2.5	GHz
RF input power	P_{IN}				-4	dBm
Supply voltages(1)	V_{CC1}, V_{CC2} V_{CC3}, V_{C_BIAS} V_{REF1}, V_{REF2}, V_{REF3} V_{CC_DET}		3.0 4.5 2.3 3.3	3.3 5 2.5 3.6	3.6 5.5 2.7 3.9	V V V V
Supply currents(2)	I_{CC1} I_{CC2} I_{CC3} I_{C_BIAS} I_{REF1} I_{REF2} I_{REF3} I_{CC_DET}			62 369 725 10 5 14 11 7		mA mA mA mA mA mA mA mA
Operating temperature	T_C		-40	+25	+85	°C

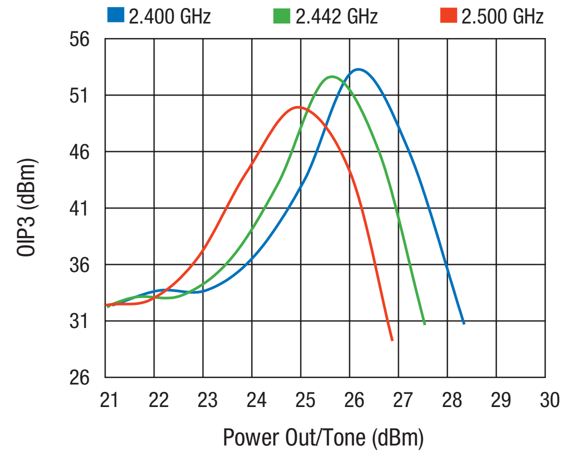
1. Voltage levels measured at the pins of the package. The evaluation board supply voltage levels may be different. Refer to the evaluation board schematic diagram.
2. Typical supply currents at recommended maximum input power, using standard device bias components, T_C = 25 °C,

Typical Performance Data

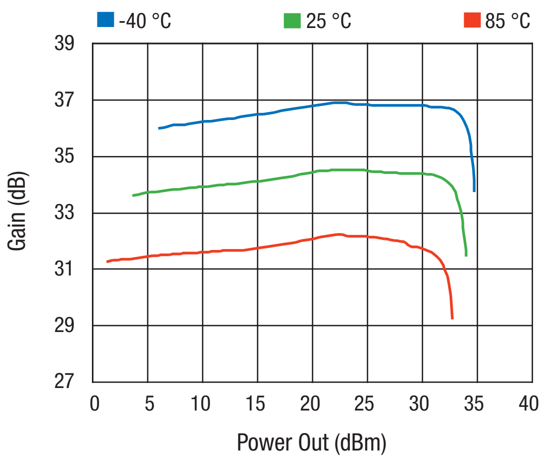
$V_{CC1} = V_{CC2} = 3.3$ V, $V_{CC3} = 5$ V, V_{REF1}, V_{REF2}, $V_{REF3} = 5$ V, $V_{C\_BIAS} = 5$ V, $V_{CC\_DET} = 5$ V, $Z_0 = 50\ \Omega$, Frequency = 2.442 GHz, CW, $P_{IN} = -25$ dBm, $T_C = 25$ °C, unless otherwise specified



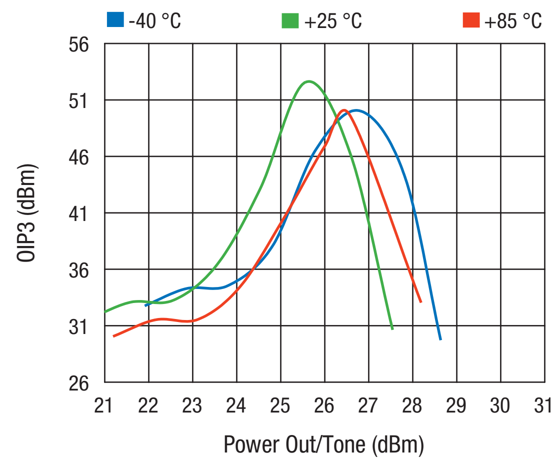
Gain vs. Power Out Across Frequency



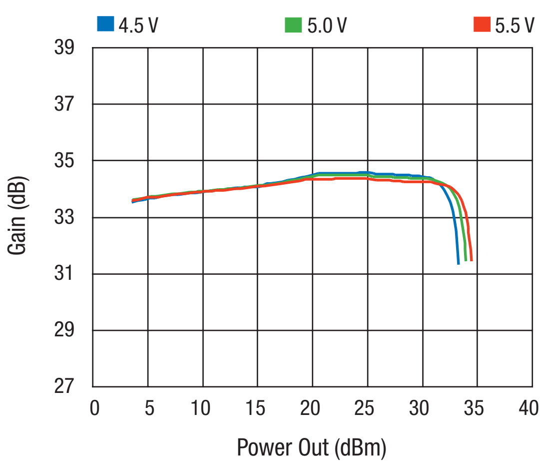
OIP3 vs. Power Out/Tone Across Frequency
ΔF = 5 MHz



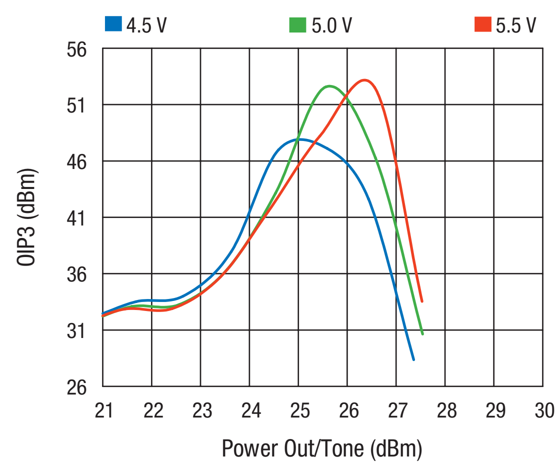
Gain vs. Power Out Across Temperature



OIP3 vs. Power Out/Tone Across Temperature
ΔF = 5 MHz



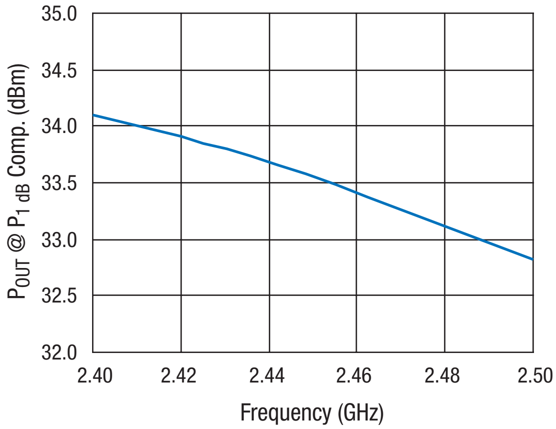
Gain vs. Power Out Across V_{CC3}



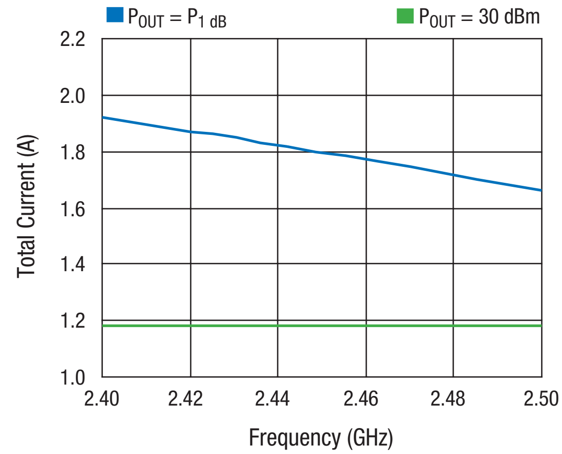
OIP3 vs. Power Out/Tone Across V_{CC3}
ΔF = 5 MHz

Typical Performance Data

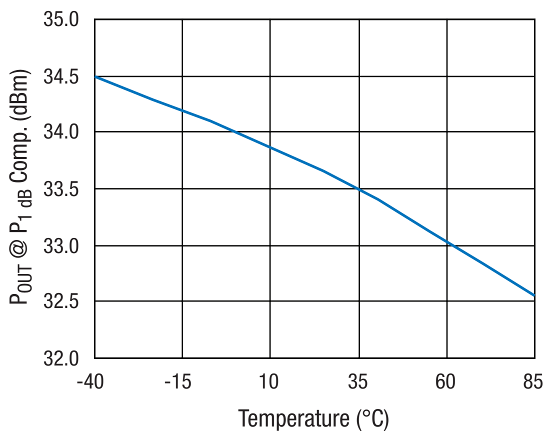
V_{CC1} = V_{CC2} = 3.3 V, V_{CC3} = 5 V, V_{REF1}, V_{REF2}, V_{REF3} = 5 V, V_{C_BIAS} = 5 V, V_{CC_DET} = 5 V, Z_0 = 50 Ω, Frequency = 2.442 GHz, CW, P_{IN} = -25 dBm, T_C = 25 °C, unless otherwise specified



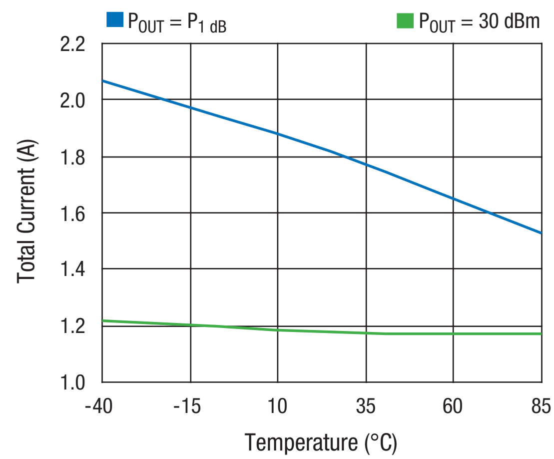
Output Power at $P_{1\ dB}$ Compression vs. Frequency



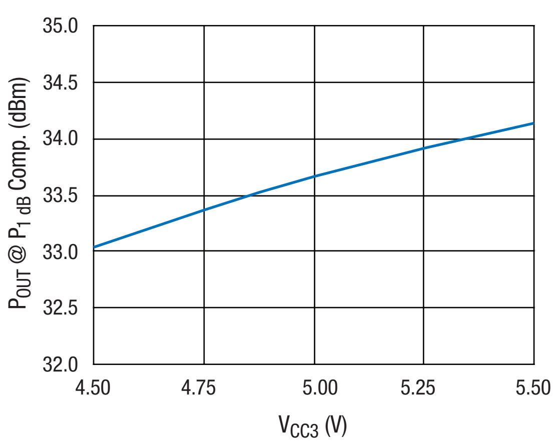
Total Current vs. Frequency Across Power Out



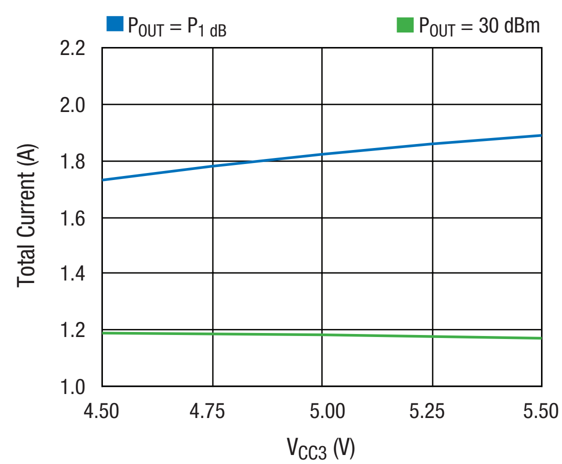
Output Power at $P_{1\ dB}$ Compression vs. Temperature



Total Current vs. Temperature Across Power Out



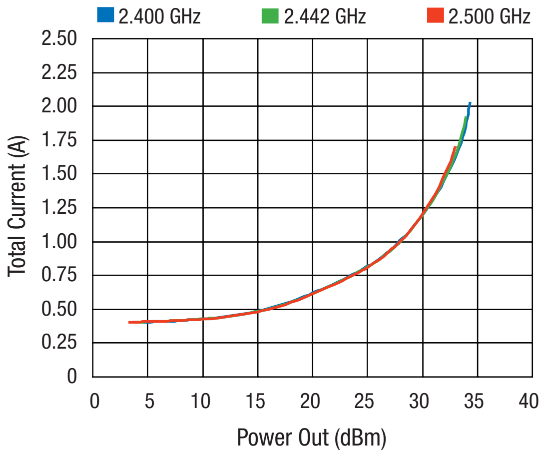
Output Power at $P_{1\ dB}$ Compression vs. V_{CC3}



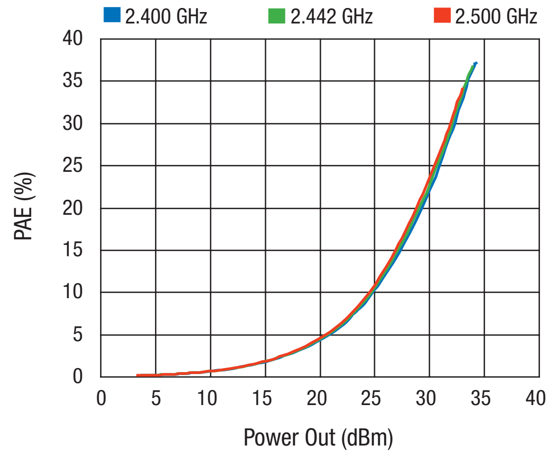
Total Current vs. V_{CC3} Across Power Out

Typical Performance Data

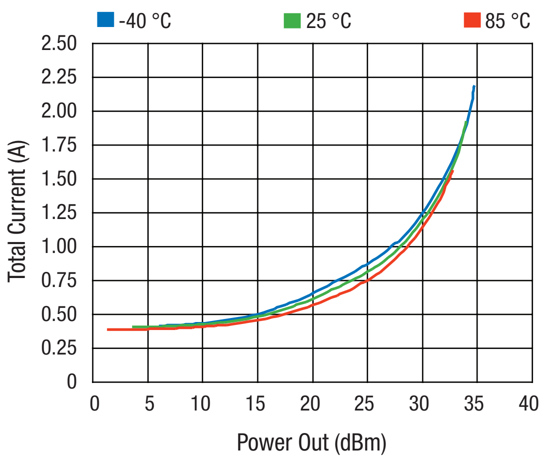
$V_{CC1} = V_{CC2} = 3.3$ V, $V_{CC3} = 5$ V, V_{REF1}, V_{REF2}, $V_{REF3} = 5$ V, $V_{C\_BIAS} = 5$ V, $V_{CC\_DET} = 5$ V, $Z_0 = 50\ \Omega$, Frequency = 2.442 GHz, CW, $P_{IN} = -25$ dBm, $T_C = 25$ °C, unless otherwise specified



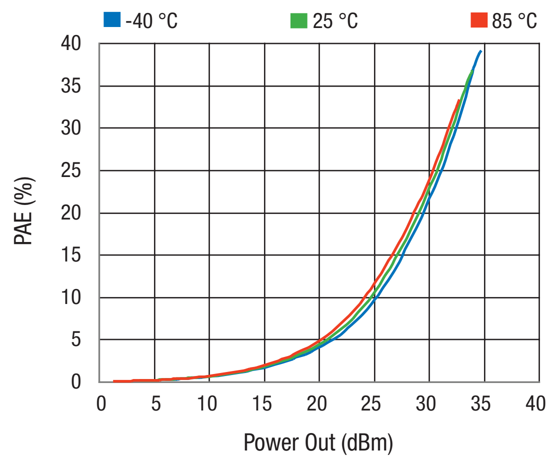
Total Current vs. Power Out Across Frequency



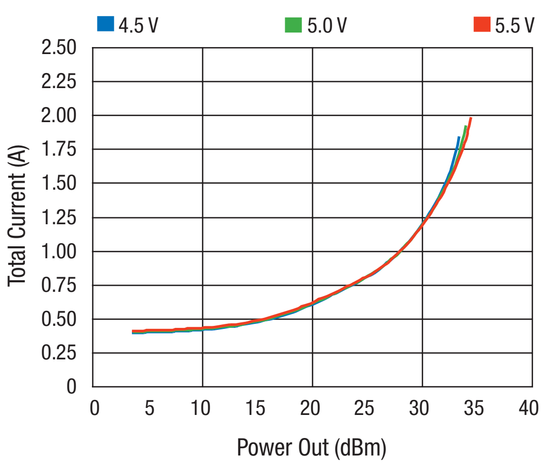
PAE vs. Power Out Across Frequency



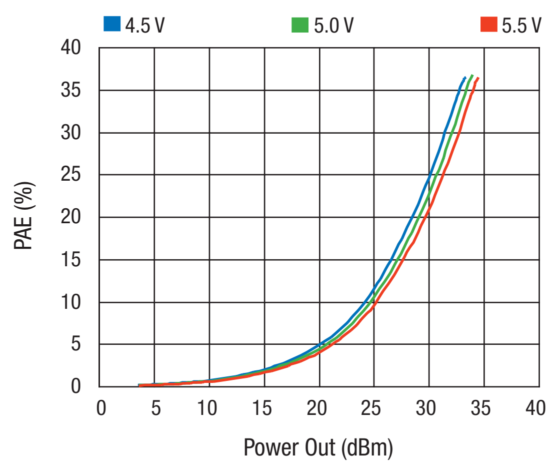
Total Current vs. Power Out Across Temperature



PAE vs. Power Out Across Temperature



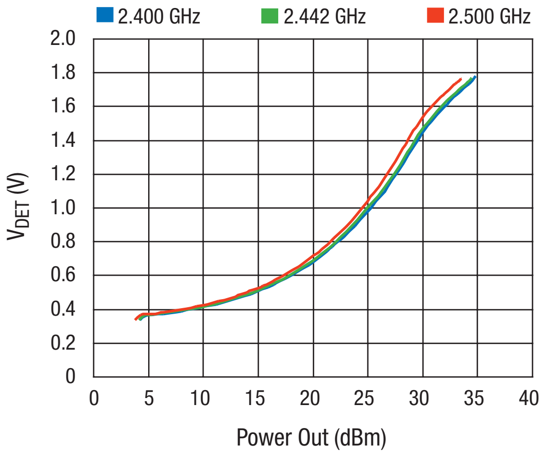
Total Current vs. Power Out Across V_{CC3}



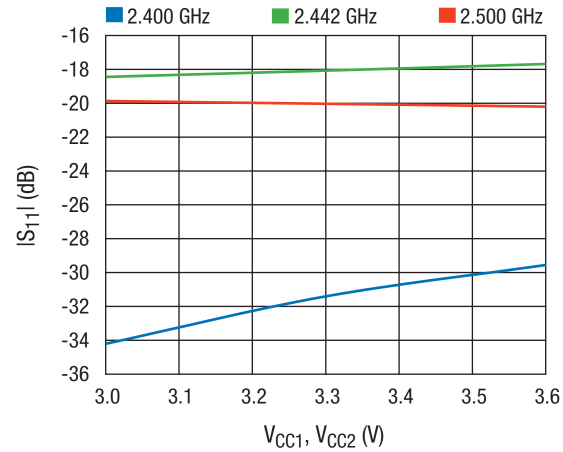
PAE vs. Power Out Across V_{CC3}

Typical Performance Data

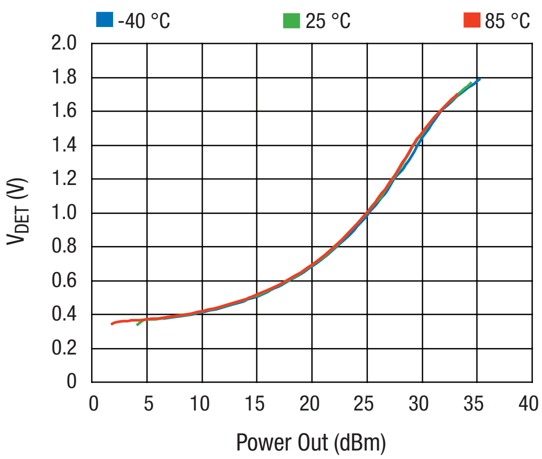
V_{CC1} = V_{CC2} = 3.3 V, V_{CC3} = 5 V, V_{REF1}, V_{REF2}, V_{REF3} = 5 V, V_{C_BIAS} = 5 V, V_{CC_DET} = 5 V, Z_0 = 50 Ω, Frequency = 2.442 GHz, CW, P_{IN} = -25 dBm, T_C = 25 °C, unless otherwise specified



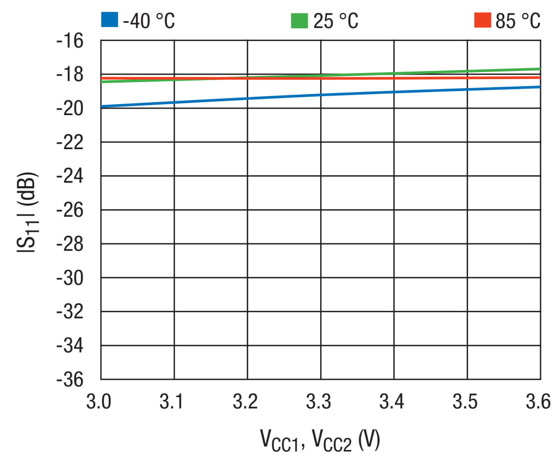
Detector Voltage vs. Power Out Across Frequency



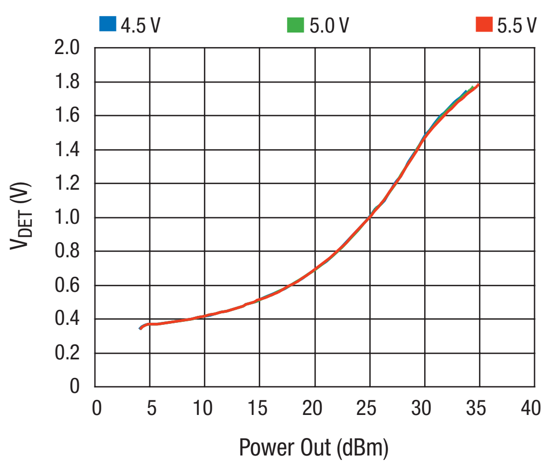
$|S_{11}|$ vs. V_{CC1}, V_{CC2} Across Frequency



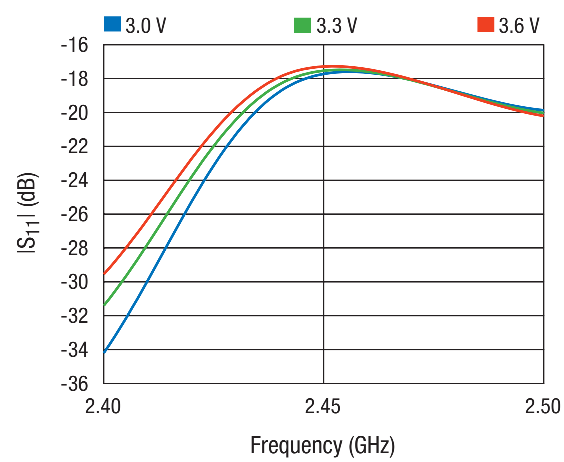
Detector Voltage vs. Power Out Across Temperature



$|S_{11}|$ vs. V_{CC1}, V_{CC2} Across Temperature



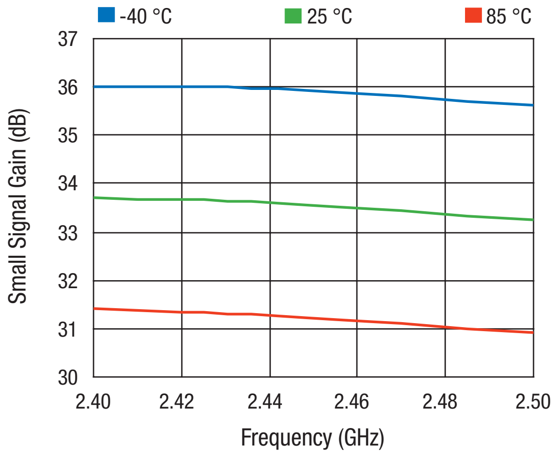
Detector Voltage vs. Power Out Across V_{CC3}



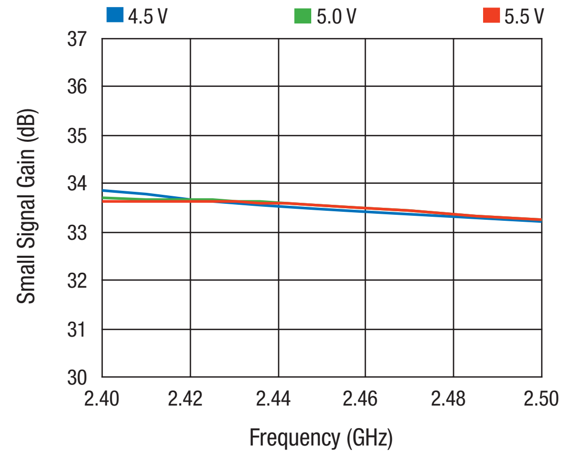
$|S_{11}|$ vs. Frequency Across V_{CC1}, V_{CC2}

Typical Performance Data

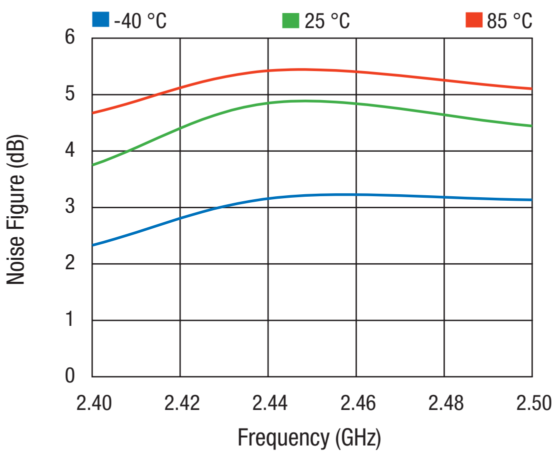
V_{CC1} = V_{CC2} = 3.3 V, V_{CC3} = 5 V, V_{REF1}, V_{REF2}, V_{REF3} = 5 V, V_{C_BIAS} = 5 V, V_{CC_DET} = 5 V, Z_0 = 50 Ω, Frequency = 2.442 GHz, CW, P_{IN} = -25 dBm, T_C = 25 °C, unless otherwise specified



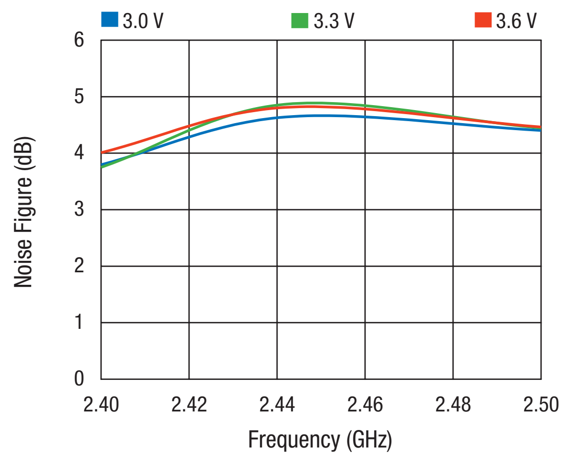
Small Signal Gain vs. Frequency Across Temperature



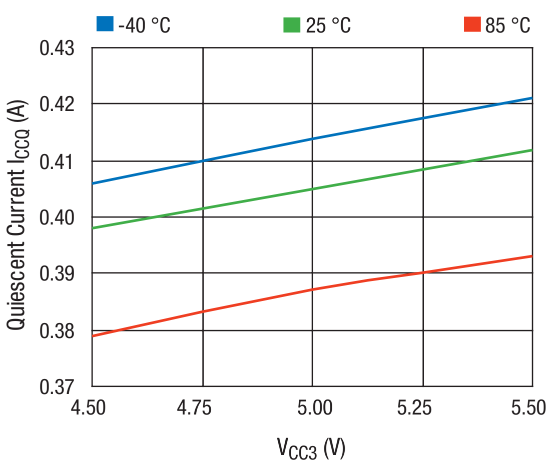
Small Signal Gain vs. Power Out Across V_{CC3}



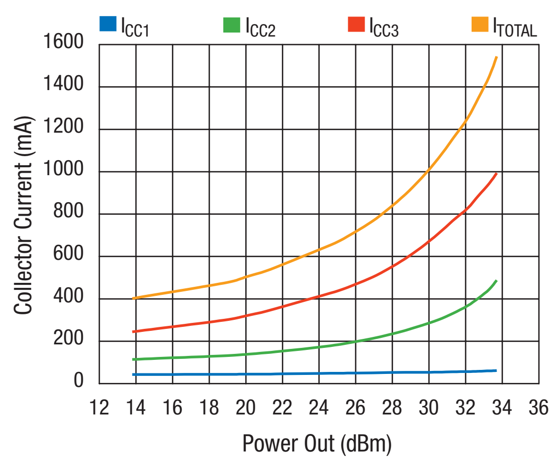
Noise Figure vs. Frequency Across Temperature



Noise Figure vs. Frequency Across V_{CC1}, V_{CC2}



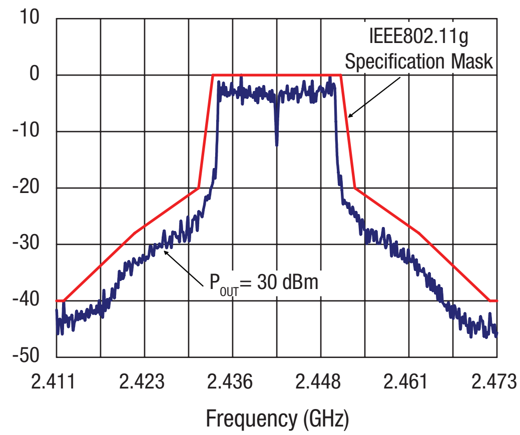
Quiescent Current vs. V_{CC3} Across Temperature



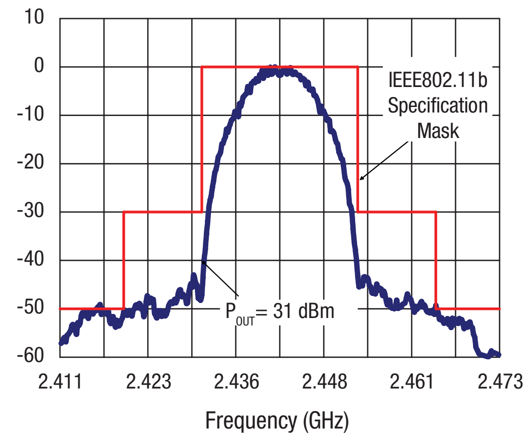
Individual Stage Currents and Total Current vs. RF Output Power

Typical Performance Data

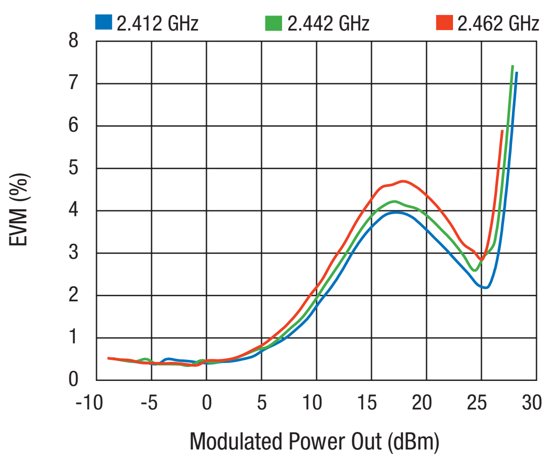
V_{CC1} = V_{CC2} = 3.3 V, V_{CC3} = 5 V, V_{REF1}, V_{REF2}, V_{REF3} = 5 V, V_{C_BIAS} = 5 V, V_{CC_DET} = 5 V, Z_0 = 50 Ω, Frequency = 2.442 GHz, CW, P_{IN} = -25 dBm, T_C = 25 °C, unless otherwise specified



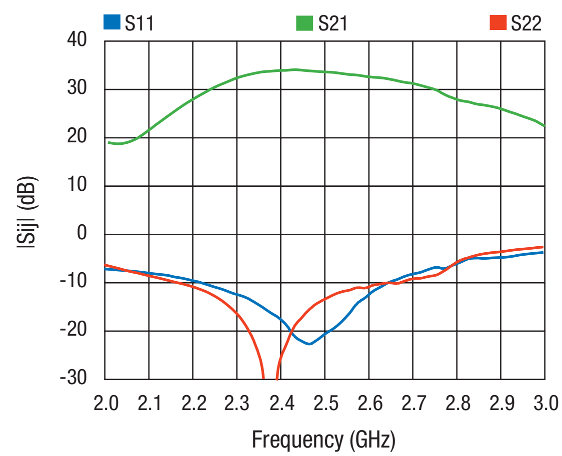
Output Spectrum Response for 802.11g Power Out = 30 dBm



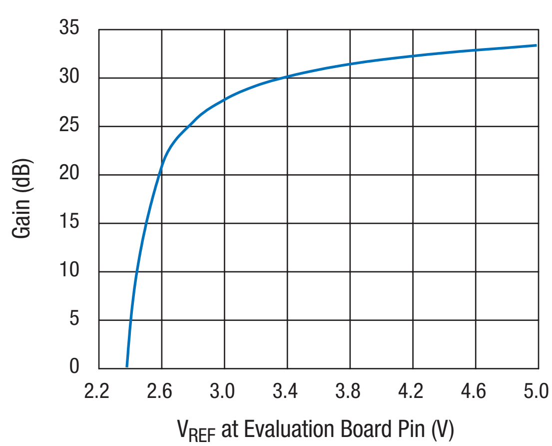
Output Spectrum Response for 802.11b CCK-Coded, Power Out = 31 dBm



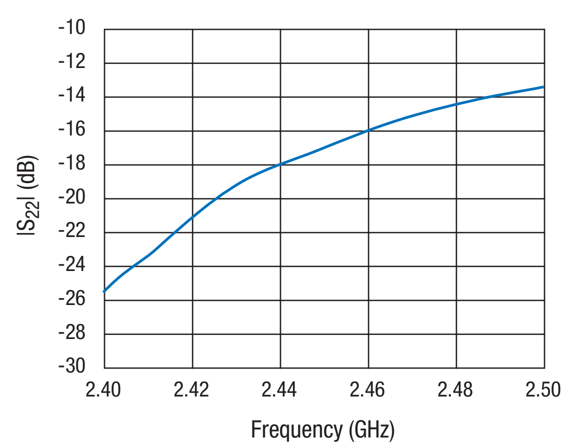
EVM vs. Modulated Power Out Across Frequency 802.11g OFDM 54 Mbps Root Cosine Filtering w/0.7 Roll-off Factor



S-Parameters vs. Frequency



Small Signal Gain vs. V_{REF} (at Evaluation Board Pin)



$|S_{22}|$ vs. Frequency

Theory of Operation

The SKY65135-21 is comprised of three amplifier stages. Input and output DC blocks plus RF matching circuits for the input stage, second stage, and output stage are contained within the device. An on-chip active bias circuit is included within the device for excellent gain tracking over temperature and voltage variations. There are three individual active bias circuits, one circuit for each of the amplifier stages. Each active bias circuit has its own reference voltage supply (V_{REF}) and they share a common bias voltage (V_{C_BIAS}). The active bias is designed to maintain a constant supply current to the base of each amplifier stage as supply voltage and temperature change.

The SKY65135-21 is internally matched and DC blocked for optimum linearity and efficiency. The input and output stages are independently supplied using the V_{CC1}, V_{CC2} and V_{CC3} supply lines, pins 16, 13 and 11, respectively. The bias reference voltage for stages 1, 2 and 3 is supplied using lines V_{REF1}, V_{REF2} and V_{REF3} (pins 5, 6 and 7). The DC control voltage that sets the bias to stages 1, 2 and 3 is supplied via V_{C_BIAS}, pin 4.

The amplifier includes an on-board, compensated power detector, V_{DET}, pin 14, providing a single-ended output voltage for an output power measurement over a wide dynamic range. For proper detector operation, V_{DET_CTRL}, pin 12, is grounded though a 51 Ω resistor and a 270 pF shunt capacitor with a reference voltage of 3.6 V applied to the V_{CC_DET} line. Any voltage between 3.3 and 3.9 V is acceptable for the reference voltage, but it is recommended to supply V_{CC_DET} from the V_{REF} power supply. The benefit in doing this is to save the 7 mA of current the detector reference circuit would otherwise consume with the PA in the “Off” state.

Application Circuit Notes

Center Ground. It is extremely important that the device paddle be sufficiently grounded for both thermal and stability reasons. Multiple small vias are acceptable and will work well under the device if solder migration is an issue.

Ground (Pins 1, 2, 3, 8, 10, 17, 19, 20). Attach all ground pins to the RF ground plane with the largest diameter and lowest inductance via that the layout will allow. Multiple small vias are also acceptable and will work well under the device if solder migration is an issue.

V_{C_BIAS} (Pin 4). V_{C_BIAS} is the bias supply voltage for stages 1, 2 and 3. Typically set to 5 V.

V_{REF1} (Pin 5). Bias reference voltage for amplifier stage 1. V_{REF1} should be operated at 2.5 V at the package pin. The voltage at the evaluation board pin is 5 V.

V_{REF2} (Pin 6). Bias reference voltage for amplifier stage 2. V_{REF2} should be operated at 2.5 V at the package pin. The voltage at the evaluation board pin is 5 V.

V_{REF3} (Pin 7). Bias reference voltage for amplifier stage 3. V_{REF3} should be operated at 2.5 V at the package pin. The voltage at the evaluation board pin is 5 V.

RF_OUT (Pin 9). Amplifier RF output pin. Z_0 = 50 Ω. The module includes an onboard internal DC blocking capacitor. All impedance matching is provided internal to the module.

V_{CC3} (Pin 11). Supply voltage for output (final) stage collector bias (typically 5 V). Bypassing of V_{CC3} is accomplished with C10 and C17 and should be placed in the approximate location shown on the evaluation board, but placement is not critical.

V_{DET_CNTL} (Pin 12). Detector voltage control pin is the point in between the detector capacitor coupler which is connected to the collector of the PA. This pin is typically grounded via C9 and R4, but can be tuned to change the V_{DET} output voltage.

V_{CC2} (Pin 13). Supply voltage for output (final) stage collector bias (typically 5 V). Bypassing of V_{CC2} is accomplished with C8 and C16 and should be placed in the approximate location shown on the evaluation board, but placement is not critical.

V_{DET} (Pin 14). Detector output pin. Provides a single-ended output voltage which references the output power over a wide dynamic range.

V_{CC_DET} (Pin 15). Detector supply voltage. For proper detector operation, a reference voltage of 3.6 V should be applied. Any voltage between 3.3 and 3.9 V is acceptable for the reference voltage. Bypassing of V_{CC_DET} is accomplished with L1 (300 Ω resistor) and C6.

V_{CC1} (Pin 16). Supply voltage for output (final) stage collector bias (typically 5 V). Bypassing of V_{CC1} is accomplished with C5 and C15 and should be placed in the approximate location shown on the evaluation board, but placement is not critical.

RF_IN (Pin 18). Amplifier RF Input P_{IN}. Z_0 = 50 Ω. The module includes an onboard internal DC blocking capacitor. All impedance matching is provided internal to the module.

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.

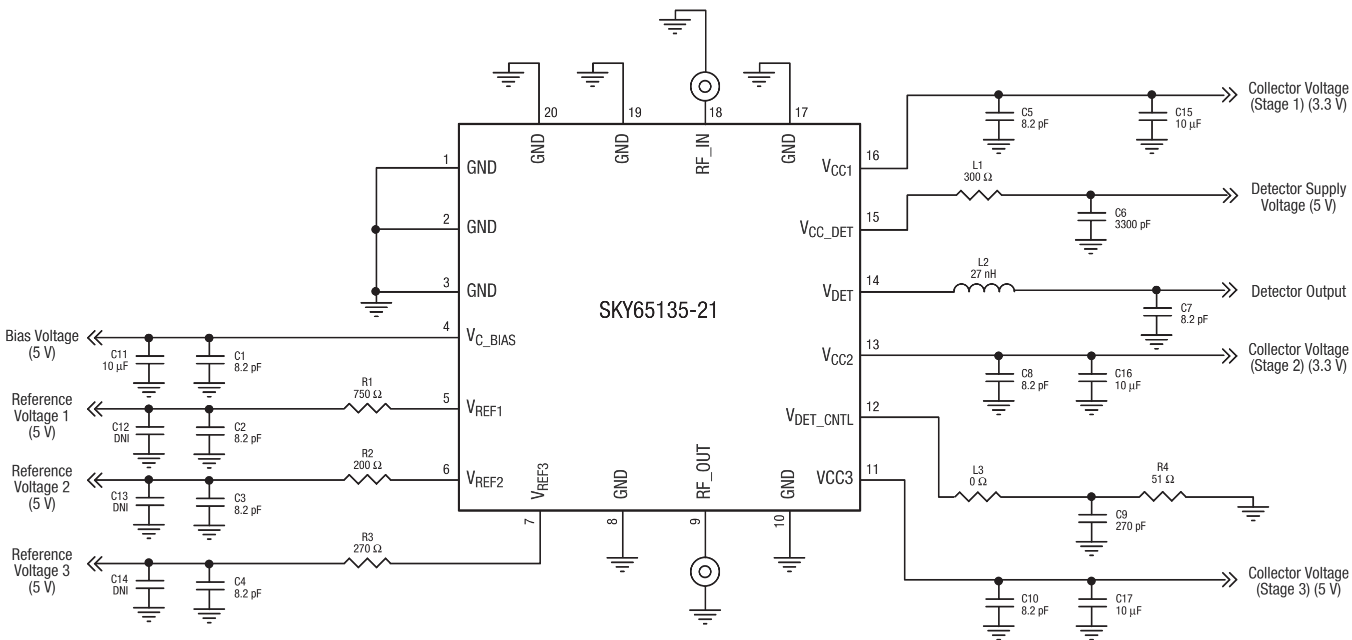
Please refer to Skyworks solder reflow application note, available at www.skyworksinc.com, for instructions on mounting the SKY65135-21 to a printed circuit board.

Production quantities of this product are shipped in a standard tape and reel format. For packaging details, refer to the Skyworks Application Note, *Tape and Reel*, document number 101568.

Electrostatic Discharge (ESD) Sensitivity

The SKY65135-21 is a static-sensitive electronic device. Do not operate or store near strong electrostatic fields. Take proper ESD precautions.

Application Circuit



Note: DNI (Do Not Install)

S702

Pin Assignments

Pin	Pin Name	Description
1	GND	Low Inductance ground connection
2	GND	Low Inductance ground connection
3	GND	Low Inductance ground connection
4	V_{C_BIAS}	Bias voltage
5	V_{REF1}	Bias reference voltage 1
6	V_{REF2}	Bias reference voltage 2
7	V_{REF3}	Bias reference voltage 3
8	GND	Low Inductance ground connection
9	RF_OUT	RF Output
10	GND	Low Inductance ground connection
11	V_{CC3}	Stage 3 collector voltage
12	V_{DET_CNTL}	Detector voltage control
13	V_{CC2}	Stage 2 collector voltage
14	V_{DET}	Detector output signal
15	V_{CC_DET}	Detector supply voltage
16	V_{CC1}	Stage 1 collector voltage
17	GND	Low Inductance ground connection
18	RF_IN	RF input
19	GND	Low Inductance ground connection
20	GND	Low Inductance ground connection

Center attachment pad must have a low inductance and low thermal resistance connection to the customer's printed circuit board ground plane.

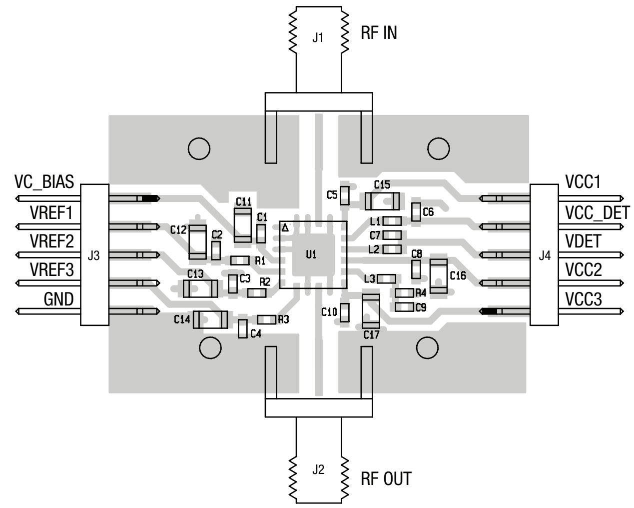
Evaluation Board Description

The Skyworks SKY65135-21 Evaluation Board is used to test the performance of the SKY65135-21 power amplifier module. 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 SKY65135-21 power amplifier module 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 amplifiers. As such, design the connection to the ground pad to dissipate the maximum wattage produced to the circuit. Multiple vias to the grounding layer are required.

NOTE: *Junction temperature (T_J) of the device increases with a poor connection to the slug and ground. This reduces the lifetime of the device.*

Evaluation Board



Evaluation Board Test Procedure

Step 1. Connect RF test equipment to Amplifier input/output SMA connectors.

Step 2. Connect DC ground.

Step 3. Connect all V_{REG}, V_{CC3}, and V_{C_BIAS} lines to a 5 V supply. Connect all V_{CC1}, and V_{CC2} lines to a 3.3 V supply. Verify the total I_{CQ} current is approximately 405 mA.

Step 4. To observe the detector voltage output, connect a 5 V supply to the V_{CC_DET} pin to and connect a voltmeter or oscilloscope to the V_{DET} pin on the evaluation test board.

Step 5. Apply an RF input signal of -25 dBm and observe the output signal level is approximately 8.5 dBm or the gain of the device is approximately 33.5 dB.

NOTE: *It is important that the V_{CC3} voltage source be adjusted such 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.*

Recommended Solder Reflow Profiles

Refer to the *"Recommended Solder Reflow Profile"* Application Note.

Tape and Reel Information

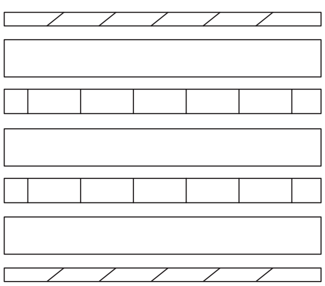
Refer to the *"Discrete Devices and IC Switch/Attenuators Tape and Reel Package Orientation"* Application Note.

Bill of Material for Evaluation Board

Part	ID	Qty.	Size	Value	Units	Product Number	Manufacturer	Manufacturer's Part Number	Characteristics
1	C1, C2, C3, C4, C5, C7, C8, C10	8	0603	8.2	pF	5404R23-046	Murata	GRM1885C1H6R8CZ01D	COG, 50 V, ± 0.25 pF
2	C6	1	0603	3300	pF	5404R28-015	Murata	GRM188R71H332KD01J	X7R, 50 V, ± 10%
3	C9	1	0603	270	pF	5404R23-030	Murata	GRM1885C1H271JD51D	COG, 50 V, ± 5%
4	C11, C15, C16, C17	4	1206	10	µF	5404R91-005	TDK	C3216X5R0J106KT	X5R, 6 V, ± 10%
5	R1	1	0603	750	Ω	5424R20-046	Rohm	MCR03EZHUJ750	50 V, 0.063 W, ± 5%
6	R2	1	0603	200	Ω	5424R20-032	Rohm	MCR03EZHUF200	50 V, 0.063 W, ± 1%
7	R3	1	0603	270	Ω	5424R20-035	Rohm	MCR03EZHUF270	50 V, 0.063 W, ± 1%
8	R4	1	0603	51	Ω	5424R20-018	Rohm	MCR03EZHUF051	50 V, 0.063 W, ± 1%
9	L1	1	0603	300	Ω	5424R20-036	Rohm	MCR03EZHUF300	50 V, 0.063 W, ± 1%
10	L2	1	0603	27	nH	5332R34-030	Taiyo-Yuden	HK160827NJ-T	±5%, SRF 1400 MHz
11	L3	1	0603	0	Ω	5424R20-146	Rohm	MCR03EZHJ000	50 V 0.063 W, ± 5%

Evaluation Board Stack-Up

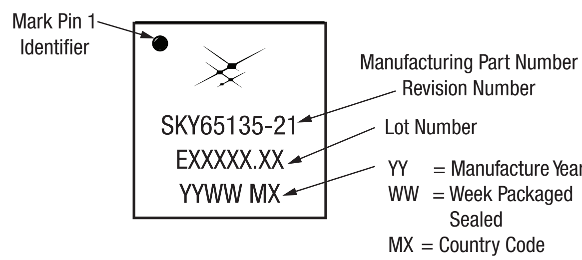
Cross Section



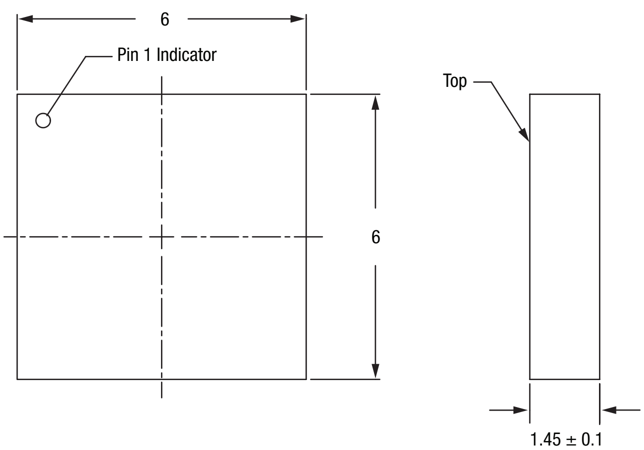
Name	Thickness (mils)	Material	ε_r
L1	1.4	Cu, 1 oz.	–
Lam1	12	Rogers 4003-12	3.38
L2_GND	1.4	Cu, 1 oz	–
Lam2	4	FR4-4	4.35
L3_GND	1.4	Cu, 1 oz.	–
Lam3	12	FR4-12	4.35
L4	1.4	Cu, 1 oz.	–

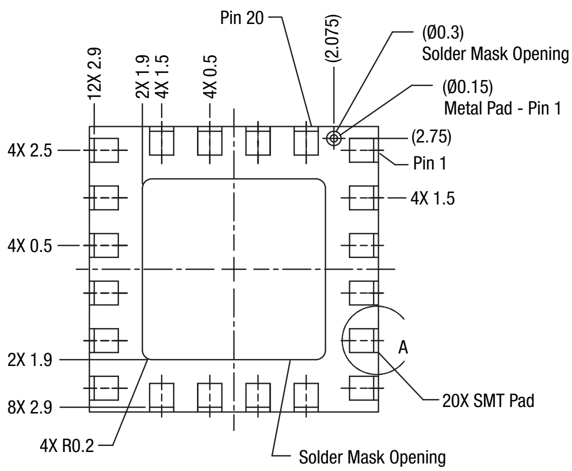
S573

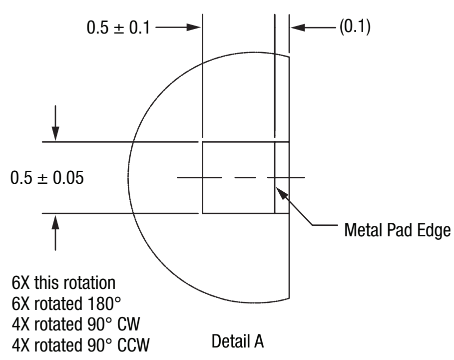
Branding Specifications



Package Dimensions

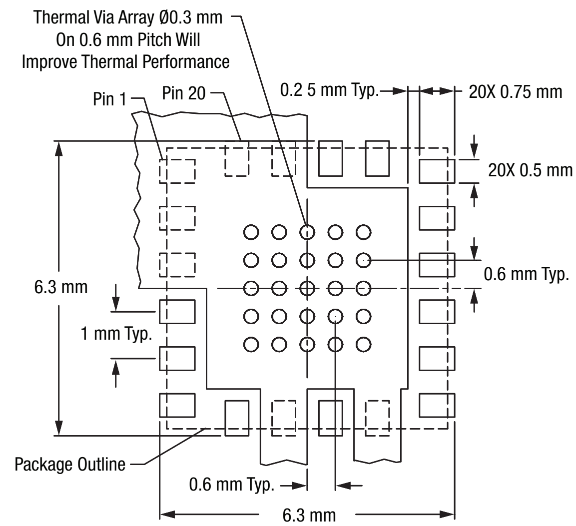




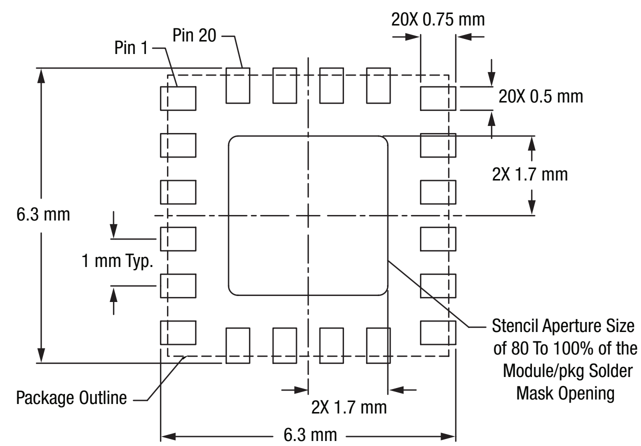


Dimensioning and tolerancing in accordance with ASME Y14.5M-1994.
All dimensions are in millimeters

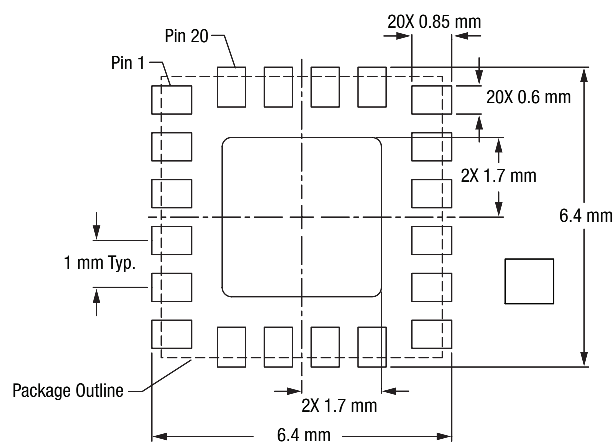
Recommended Footprint



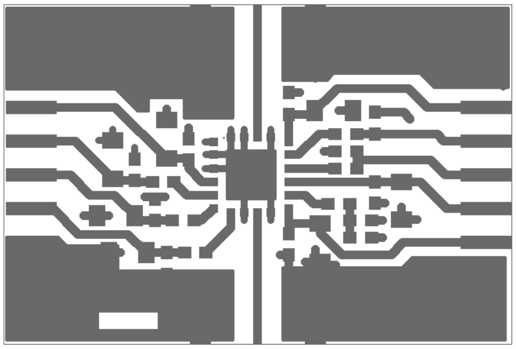
Stencil Pattern



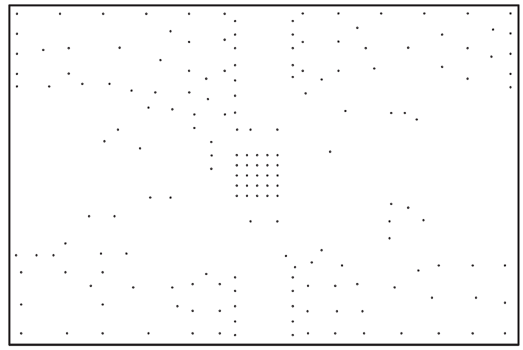
Solder Mask



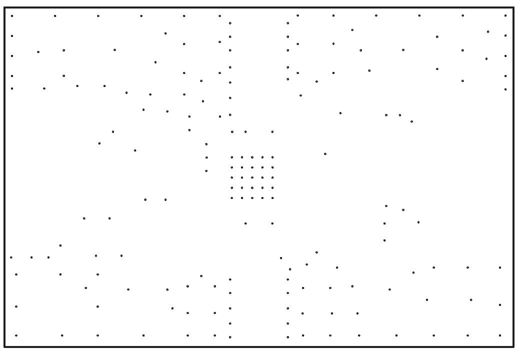
Evaluation Board Detail



Layer 1: Top Metal



Layer 3: Ground

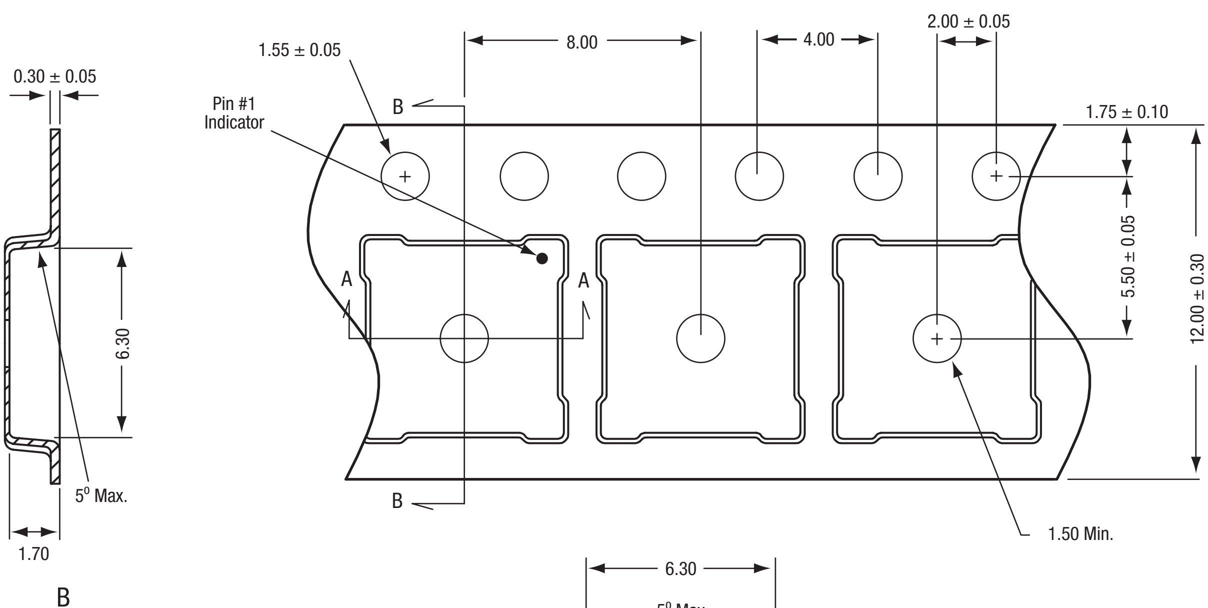


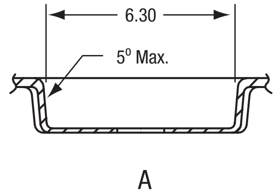
Layer 2: Ground

Layer 4: Ground

S590

Tape and Reel Dimensions





Notes:
1. *Carrier tape: black conductive polystyrene*
2. *Cover tape material: transparent conductive PSA*
3. *Cover tape size: 9.3 mm width*
4. *All dimensions are in millimeters*

C1222

Ordering Information

Model Name	Manufacturing Part Number	Evaluation Kit Part Number
SKY65135-21: WLAN Linear Power Amplifier	SKY65135-21 (Pb-free package)	TW13-D122