2.3 GHz to 2.4 GHz WiMAX Power Amplifier

ADL5570

FEATURES

Fixed gain of 29 dB
Operation from 2.3 GHz to 2.4 GHz
EVM ≤ 3% at P_{OUT} = 25 dBm with 16 QAM OFDMA
Input internally matched to 50 Ω
Power supply: 3.2 V to 4.2 V
Quiescent current
- **130 mA in high power mode**
- **70 mA in low power mode**

Power-added efficiency (PAE): 20%
Multiple operating modes to reduce battery drain
- **Low power mode: 100 mA**
- **Standby mode: 1mA**
- **Sleep mode: <1 µA**

APPLICATIONS

WiMAX/WiBro mobile terminals

FUNCTIONAL BLOCK DIAGRAM

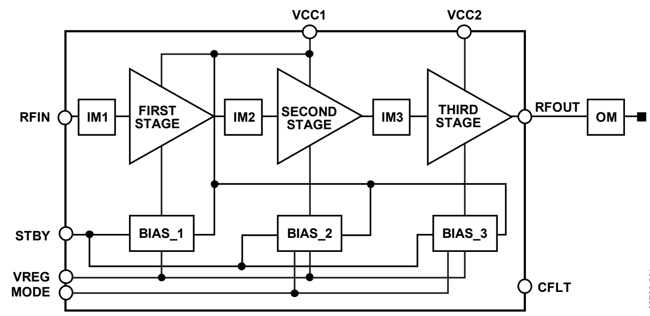

Figure 1.

GENERAL DESCRIPTION

The ADL5570 is a high linearity 2.3 GHz to 2.4 GHz power amplifier designed for WiMAX terminals using TDD operation at a duty cycle of 31%. With a gain of 29 dB and an output compression point of 31 dBm at 2.35 GHz, it can operate at an output power level up to 26 dBm while maintaining an EVM of ≤3% (OFDM 16 or 64 QAM) with a supply voltage of 3.5 V. PAE is 20% @ P_{OUT} = 25 dBm.

The ADL5570 RF input is matched on-chip and provides an input return loss of less than −10 dB. The open-collector output is externally matched with strip-line and external shunt capacitance.

The ADL5570 operates over a supply voltage range from 3.2 V to 4.2 V with a supply current of 440 mA burst rms when delivering 25 dBm (3.5 V supply). A low power mode is also available for operation at power levels of ≤10 dBm with optimized operating and quiescent currents of 100 mA and 70 mA, respectively. A standby mode is available that reduces the quiescent current to 1 mA, which is useful when a TDD terminal is receiving data.

The ADL5570 is fabricated in a GaAs HBT process and is packaged in a 4 mm × 4 mm, 16-lead, Pb-free RoHS-compliant LFCSP that uses an exposed paddle for excellent thermal impedance. It operates from −40°C to +85°C.

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REVISION HISTORY

5/07—Rev. 0: Initial Version

SPECIFICATIONS

V_{CC} = 3.5 V

T_A = 25°C, 1024 FFT, 16 QAM OFDMA modulated carrier, 10 MHz channel BW, 16 QAM, Z_L = 50 Ω, MODE = 0 V, STBY = 0 V, VREG = 2.85 V, 31% duty cycle, unless otherwise noted.

Table 1.

Parameter	Conditions	Min	Typ	Max	Unit
FREQUENCY RANGE		2.3		2.4	GHz
LINEAR OUTPUT POWER	MODE = 0 V, 16 QAM, EVM ≤ 3%		25		dBm
	MODE = 2.5 V, 16 QAM, EVM ≤ 3%		10		dBm
GAIN			29		dB
vs. Frequency	±5 MHz		±0.1		dB
vs. Temperature	−40°C ≤ T_A ≤ +85°C		±1.5		dB
vs. Supply	3.2 V to 4.2 V		±0.5		dB
OP1dB	Unmodulated input		31		dBm
EVM	P_{OUT} = 25 dBm		3		% rms
INPUT RETURN LOSS			10		dB
WiBro SPECTRAL MASK @ P_{OUT} = 25 dBm (CARRIER OFFSETS SCALED TO 10 MHz BW SIGNAL)[1]	±5.45 MHz carrier offset		36		dBr
	±10.9 MHz carrier offset		42		dBr
	±15.12 MHz carrier offset		48		dBr
	±20.26 MHz carrier offset		52		dBr
FCC SPECTRAL MASK @ P_{OUT} = 25 dBm	±5 MHz carrier offset		36		dBr
	±6 MHz carrier offset		38		dBr
	±10.5 MHz carrier offset		42		dBr
	±20 MHz carrier offset		52		dBr
HARMONIC DISTORTION			43		dBc
POWER SUPPLY INTERFACE	V_{CC} = 3.5 V				
SUPPLY CURRENT	P_{OUT} = 25 dBm, MODE = 0 V		440		mA
	P_{OUT} = 10 dBm, MODE = 2.5 V		100		mA
PAE	P_{OUT} = 25 dBm, MODE = 0 V		20		%
STANDBY MODE	VREG = 2.85 V, STBY = 2.5 V		1		mA
SLEEP MODE	VREG = 0 V		10		µA
TURN ON/OFF TIME			1		µs
VSWR SURVIVABILITY			10:1		

[1] OFDMA carrier, 16 QAM, 10 MHz channel BW, 1024 FFT.

ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
Supply Voltage	
V_{CC}	5.0 V
VREG	3 V
STBY	3 V
MODE	3 V
RFOUT (Modulated—High Power Mode)[1]	29 dBm
Output Load VSWR	10:1
Operating Temperature Range	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Maximum Solder Reflow Temperature	260°C (30 sec)

[1] OFDMA carrier, 16 QAM, 10 MHz channel BW, 1024 FFT.

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

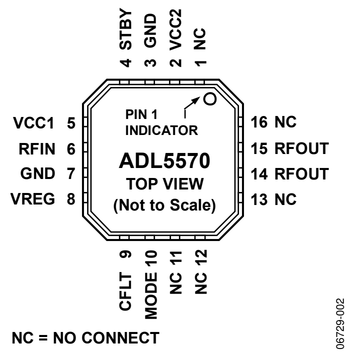

Figure 2. Pin Configuration

Table 3. Pin Function Descriptions

Pin No.	Mnemonic	Description
1, 11 to 13, 16	NC	No Connect. Do not connect these pins.
2	VCC2	This power supply pin should be connected to the supply via a choke circuit (see Figure 10).
3, 7	GND	Connected to Ground.
4	STBY	When STBY is low (0 V), the device operates in transmit mode. When the radio is receiving data, STBY can be taken high (2.5 V), reducing supply current to 1 mA.
5	VCC1	Connect to Power Supply.
6	RFIN	Matched RF Input.
8	VREG	When VREG is low, the device goes into sleep mode, reducing supply current to 10 μA. When VREG is high (2.85 V), the device operates in its normal transmit mode. When high, VREG draws a bias current of approximately 10 mA.
9	CFLT	A ground-referenced capacitor should be connected to this pin to reduce bias line noise (see Figure 10).
10	MODE	Switches Between High Power and Low Power Modes. When MODE is low (0 V), the device operates in high power mode. When MODE is high (2.5 V), the device operates in low power mode. See Table 4 for appropriate biasing. In cases where the MODE feature is not used, this pin should be connected to ground through a 50 kΩ resistor.
14, 15	RFOUT	Unmatched RF Output. These parallel outputs can be matched to 50 Ω using strip-line and shunt capacitance. The power supply voltage should be connected to these pins through a choke inductor.
	Exposed Paddle	The exposed paddle should be soldered down to a low impedance ground plane (if multiple ground layers are present, use multiple vias (9 minimum) to stitch together the ground planes) for optimum electrical and thermal performance.

Table 4. V_{CC} = 3.5 V Operating Modes[1]

Mnemonic	High Power Mode, P_{OUT} > 10 dBm	Low Power Mode, P_{OUT} ≤ 10 dBm	Standby Mode	Sleep Mode
VREG	High	High	High	Low
MODE	Low	High	X	X
STBY	Low	Low	High	X

[1] X = don't care.

Table 5. VREG, MODE, and STBY Pins

Mnemonic	Nominal High (V)	High Range (V)	Nominal Low (V)	Low Range (V)
VREG	2.85	2.75 to 2.95	0	NA
MODE	2.5	>2.4	0	<1
STBY	2.5	>2.4	0	<1

TYPICAL PERFORMANCE CHARACTERISTICS

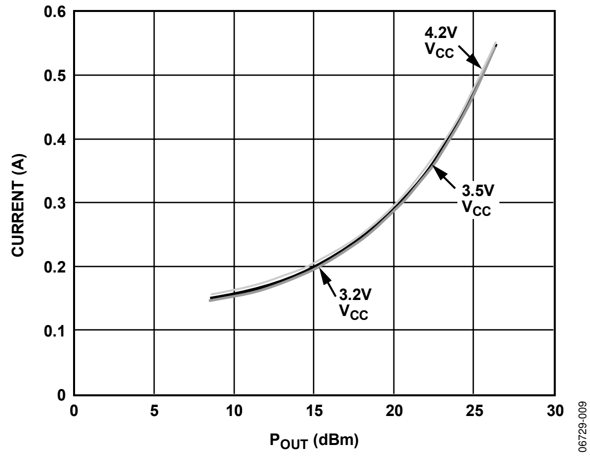

Figure 3. Current vs. P_{OUT}, 16 QAM at 2.35 GHz and 31% Duty Cycle

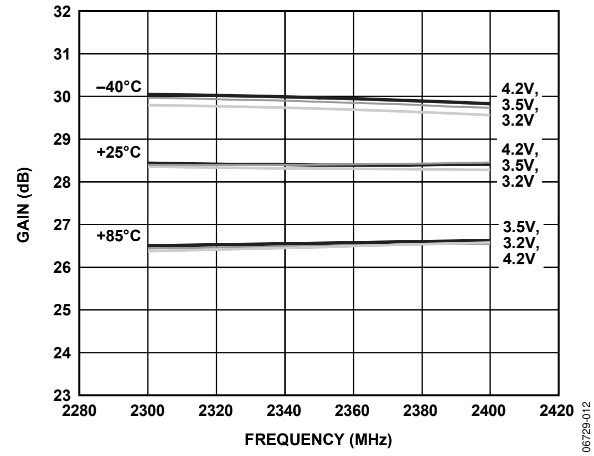

Figure 6. Gain vs. Frequency, 16 QAM at P_{IN} = –2 dBm

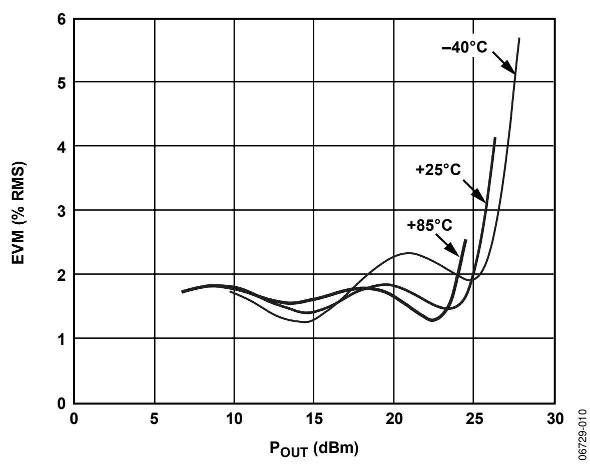

Figure 4. EVM vs. P_{OUT}, 16 QAM 3/4 @ f = 2.35 GHz at V_{CC} = 3.5 V

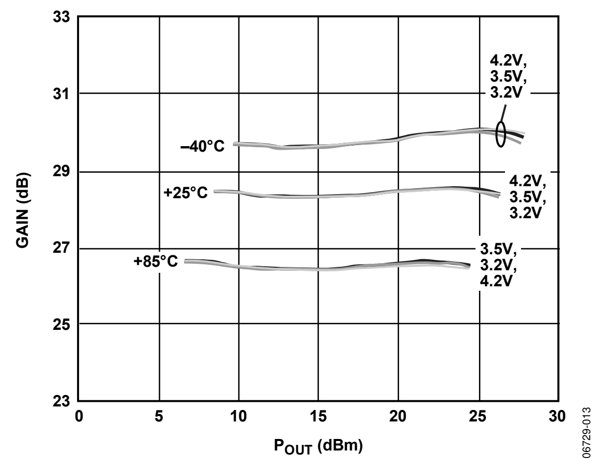

Figure 7. Gain vs. P_{OUT} at 2.35 GHz

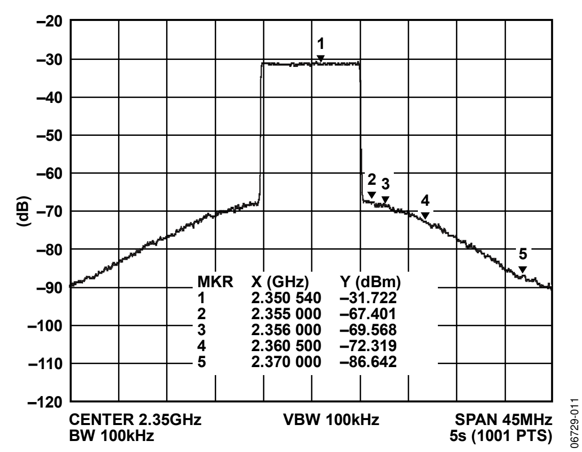

Figure 5. WiMAX Spectrum with FCC Spectral Mask at 2.35 GHz, V_{CC} = 3.5 V, P_{OUT} = 25 dBm

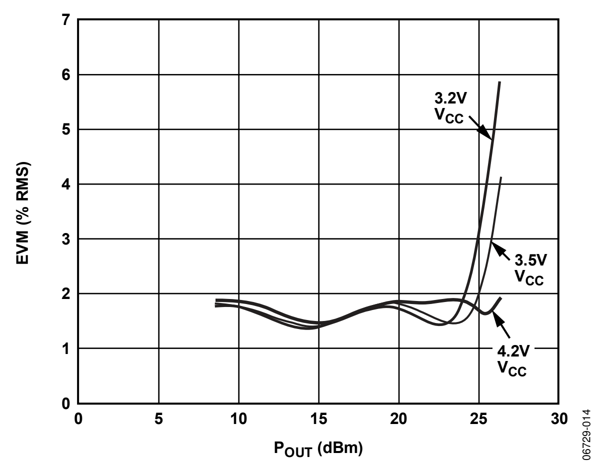

Figure 8. EVM vs. P_{OUT} at f = 2.35 GHz

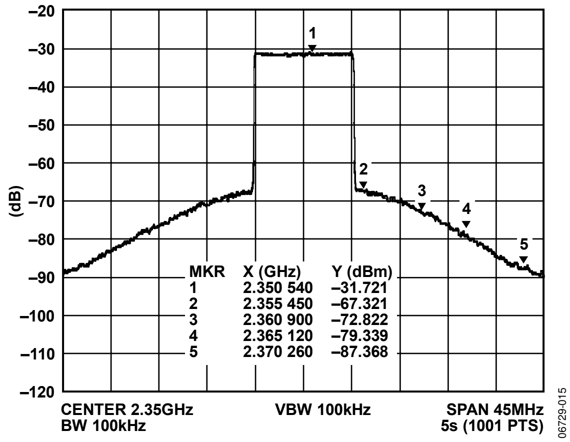

Figure 9. WiMAX Spectrum with WiBro Spectral Mask at 2.35 GHz, V_{CC} = 3.5 V, P_{OUT} = 25 dBm

APPLICATIONS

BASIC CONNECTIONS

Figure 10 shows the basic connections for the ADL5570.

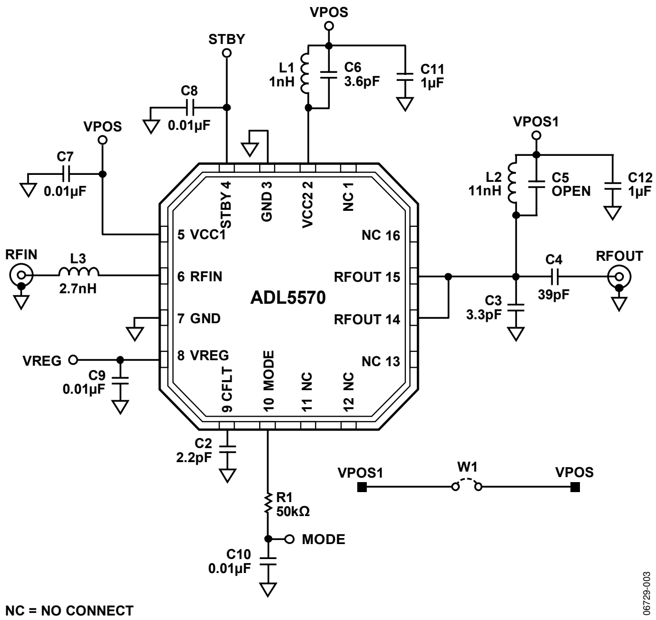

Figure 10. ADL5570 Basic Connections

Power Supply

The voltage supply on the ADL5570, which ranges from 3.2 V to 4.2 V, should be connected to the VCCx pins. VCC1 is decoupled with Capacitor C7, whereas VCC2 uses a tank circuit to prevent RF signals from propagating on the dc lines.

RF Input Interface

The RFIN pin is the port for the RF input signal to the power amplifier. The L3 inductor, 2.7 nH, matches the input impedance to 50 Ω.

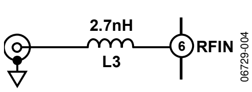

Figure 11. RF Input with Matching Component

RF Output Interface

The parallel RF output ports have a shunt capacitance, C3 (3.3 pF), and the line inductance of the microstrip-line for optimized output power and linearity. The characteristics of the ADL5570 are described for 50 Ω impedance after the output matching capacitor (load after C3).

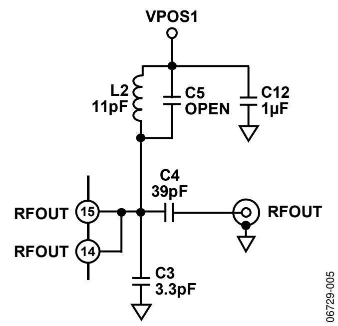

Figure 12. RF Output

C4 provides dc blocking on the RF output.

Transmit/Standby Enable

During normal transmit mode, the STBY pin is biased low (0 V). However, during receive mode, the pin can be biased high (2.5 V) to shift the device into standby mode, which reduces current consumption to less than 1 mA.

VREG Enable

During normal transmit, the VREG pin is biased to 2.85 V and draws 10 mA of current. When the VREG pin is low (0 V), the device suspends itself into sleep mode (irrespective of supply and MODE biasing). In this mode, the device draws 10 µA of current.

MODE High Power/Low Power Enable

The MODE pin is used to choose between high power mode and low power mode. When MODE is biased low (0 V), the device operates in high power mode. When MODE is biased high (2.5 V), the device operates in low power mode. Appropriate biasing must be followed for 3.5 V and 4.2 V operation. See Table 4 and Table 5 for configuration of the MODE pin.

64 QAM OFDMA PERFORMANCE

The ADL5570 shows exceptional performance when used with a higher order modulation scheme, such as a 64 QAM system. Figure 13, Figure 14, and Figure 15 illuminate the EVM, gain, and current consumption performance within the context of a 64 QAM OFDMA system.

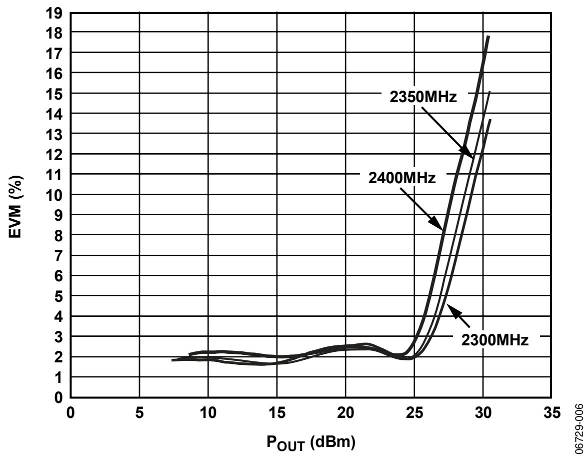

Figure 13. EVM vs. P_{OUT} Performance at V_{CC} = 3.5 V and 64 QAM OFDMA Signal

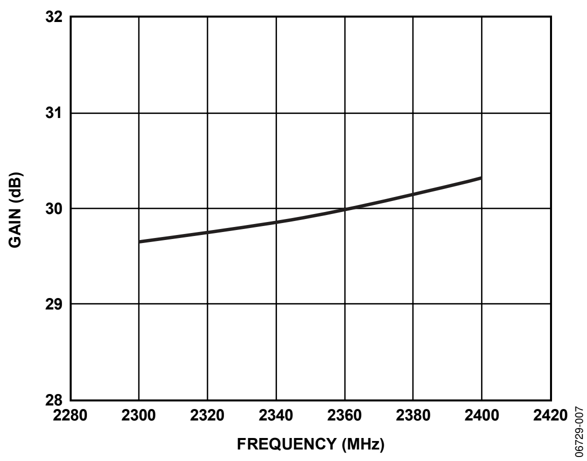

Figure 14. Gain vs. Frequency Performance at V_{CC} = 3.5 V and 64 QAM OFDMA Signal

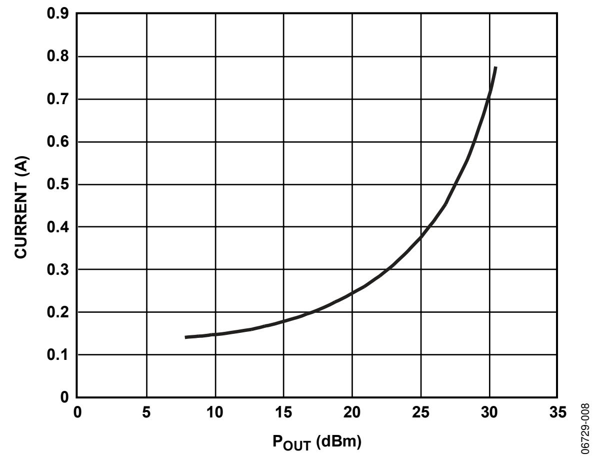

Figure 15. Burst Current vs. P_{OUT} at V_{CC} = 3.5 V, 64 QAM, 2350 MHz, 31% 802.16e OFDMA Signal

POWER-ADDED EFFICIENCY

The efficiency of the ADL5570 is defined on the current that it draws during the data burst of an 802.16e OFDMA signal. In typical test setup, the average rms current, I_{AVG}, is measured. However,

$$I_{AVG} = Duty\ Cycle\ (\text{in decimal}) \times I_{BURST} + (1 - Duty\ Cycle\ [\text{in decimal}]) \times I_{DEFAULT}$$

where:

I_{BURST} is the rms current during the data burst of an OFDMA signal.

$I_{DEFAULT}$ can be the quiescent current drawn when there is no data burst and the device remains biased, the sleep current (1 mA) if the device is defaulted to sleep mode, or the standby current.

For example, in a 31% duty cycle 802.16e OFDMA signal, the burst current is calculated by rearranging the previous equation to get

$$I_{BURST} = \frac{(I_{AVG} - 0.69 \times I_{DEFAULT})}{0.31}$$

Finally, the PAE is calculated by

$$PAE\ (\%) = \frac{RF\ Output\ Power\ (\text{mW}) - RF\ Input\ Power\ (\text{mW})}{V_{CC}(\text{V}) \times I_{BURST}(\text{mA})} \times 100$$

When RF = 2.35 GHz, 31% 16 QAM OFDMA signal, V_{CC} = 3.5 V, RF output power = 25 dBm, and RF input power = −4 dBm, the ADL5570 consumes a burst current, I_{BURST} = 450 mA and PAE = 21%.

EVALUATION BOARD

The evaluation board layout is shown in Figure 16. The ADL5570 performance data was taken on a FR4 board. During board layout, 50 Ω RF trace impedance must be ensured. The output matching capacitor, C3, is placed 30 mils from the package edge.

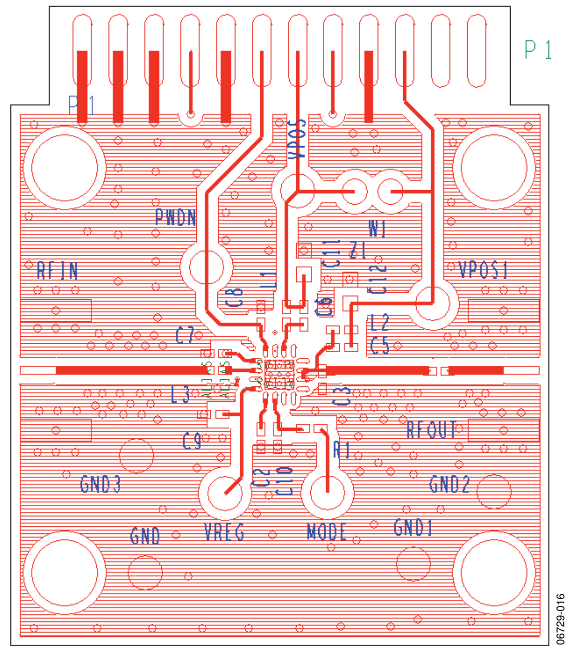

Figure 16. Evaluation Board Layout

Table 6. Evaluation Board Configuration Options

Component	Function	Default Value
VPOS, VPOS1, GND	Supply and Ground Connections.	W1 = Installed
TP1 (STBY)	Transmit/Standby Mode: When STBY is low (0 V), the device operates in transmit mode. When the radio is receiving data, STBY can be taken high (2.5 V), reducing the supply current to 10 mA.	Not applicable
TP2 (VREG)	Normal/Sleep Mode: When VREG is low, the device goes into sleep mode, reducing the supply current to 10 μA. When VREG is high (2.85 V), the device operates in its normal transmit mode. When high, VREG draws a bias current of approximately 10 mA.	Not applicable
TP5 (MODE), R1	High/Low Power Mode: Switches between high power mode and low power mode. When MODE is low (0 V), the device operates in high power mode. When MODE is high (2.5 V), the device operates in low power mode.	R1 = 50 kΩ (Size 0402)
L3	Input Interface: L3 matches the input to 50 Ω.	L3 = 2.7 nH (Size 0402)
C3, C4	Output Interface: C4 provides dc blocking, and C3 matches the output to 50 Ω.	C4 = 39 pF (Size 0402) C3 = 3.3 pF (Size 0402) (Tight tolerance recommended)
C2	Filter Interface: A ground-referenced capacitor should be connected to this node to reduce bias line noise.	C2 = 2.2 pF (Size 0402)
C7 to C12	Power Supply Decoupling: The capacitors, C7 through C12, are used for power supply decoupling. They should be placed as close as possible to the DUT.	C7 to C10 = 0.01 μF (Size 0402) C11, C12 = 1 μF (Size 0402)
L1, L2, C6, C5	RF Trap: L1, C6 and L2, C5 form tank circuits and prevent RF from propagating on the dc supply lines.	L1 = 1 nH (Size 0402) C6 = 3.6 pF (Size 0402) L2 = 11 nH (Size 0402) C5 = Open

MEASUREMENT SETUP USING THE ADL5570 EVALUATION BOARD

When using the ADL5570 evaluation board, the following setup must be used:

1. Connect the output of the WiMAX signal generator to the RF input through a cable.
2. Connect the RF output SMA of the ADL5570 to the Spectrum Analyzer (preferably through an attenuator).
3. Connect the power supply to VPOS. Set voltage to the desired supply level. Be sure to keep the current limit on this source to 1 A.
4. Ensure that Jumper W1 is in place. Alternatively, use a jumper cable to connect VPOS to VPOS1.
5. Follow Table 4 for measurement in desired mode.
6. Turn the RF source on.
7. Turn all voltage supplies on.

OUTLINE DIMENSIONS

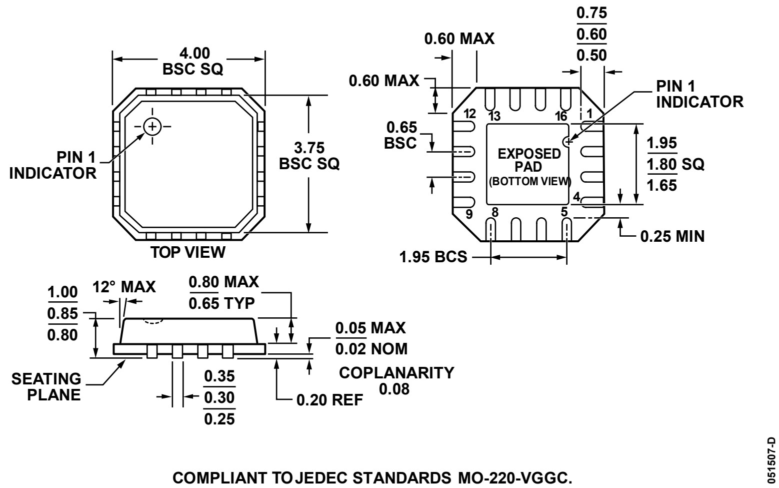

Figure 17. 16-Lead Lead Frame Chip Scale Package [LFCSP_VQ]
4 mm × 4 mm Body, Very Thin Quad
(CP-16-16)
Dimensions shown in millimeters

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Option	Ordering Quantity
ADL5570ACPZ-R7[1]	−40°C to +85°C	16-Lead LFCSP_VQ	CP-16-16	1,500
ADL5570-EVALZ[1]		Evaluation Board		

[1] Z = RoHS Compliant Part.