

## FEATURES

- RF Input Frequency Range: 40MHz to 900MHz
- High IIP3: 21dBm at 800MHz
- High IIP2: 58dBm at 800MHz
- I/Q Gain Mismatch: 0.3dB Max
- I/Q Phase Mismatch: 0.7°
- Noise Figure: 12.4dB at 800MHz
- Conversion Gain: 3.3dB at 800MHz
- Baseband Bandwidth: 130MHz
- Single Ended, 50Ω Matched 2XLO Input
- Shutdown Mode
- 16-Lead QFN (4mm × 4mm) Package with Exposed Pad

## APPLICATIONS

- Wireless Infrastructure
- High Linearity Direct Conversion I/Q Receiver
- High Linearity I/Q Demodulator

## DESCRIPTION

The LT<sup>®</sup>5517 is a 40MHz to 900MHz quadrature demodulator optimized for high linearity receiver applications where high dynamic range is important. It is suitable for communications receivers where an RF or IF signal is directly converted into I and Q baseband signals with a bandwidth up to 130MHz. The LT5517 incorporates balanced I and Q mixers, LO buffer amplifiers and a precision, broadband quadrature generator derived from an on-chip divide-by-two circuit.

The superior linearity and low noise performance of the LT5517 is achieved across its full frequency range. A well-balanced divide-by-two circuit generates precision quadrature LO carriers to drive the I mixer and the Q mixer. Consequently, the outputs of the I-channel and the Q-channel are well matched in amplitude, and their phases are 90° apart. The LT5517 also provides excellent 50Ω impedance matching at the 2XLO port across its entire frequency range.

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## TYPICAL APPLICATION

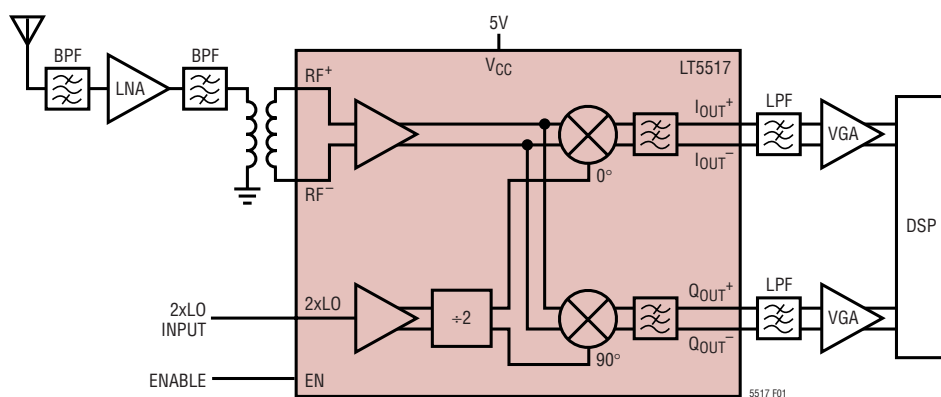
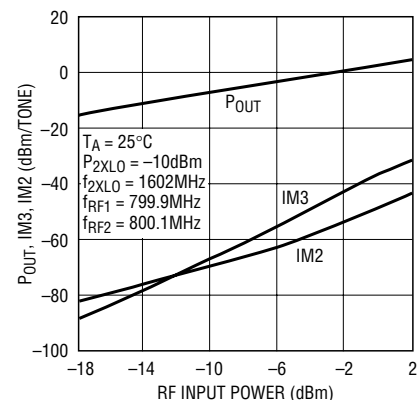


Figure 1. High Signal-Level I/Q Demodulator for 450MHz Infrastructure Receiver

I/Q Output Power, IM3, IM2  
 vs RF Input Power



5517 F01b

**ABSOLUTE MAXIMUM RATINGS**

(Note 1)

|   |                     |
|---|---------------------|
| Power Supply Voltage .....  | 5.5V                |
| Enable Voltage .....  | 0V, V <sub>CC</sub> |
| 2XLO Voltage (10dBm Equivalent) .....   | ±1V                 |
| RF <sup>+</sup> to RF <sup>-</sup> Differential Voltage<br>(10dBm Equivalent) ..... | ±2V                 |
| Operating Ambient Temperature .....   | -40°C to 85°C       |
| Storage Temperature Range .....   | -65°C to 125°C      |
| Maximum Junction Temperature .....  | 125°C               |

**PACKAGE/ORDER INFORMATION**

|   |                   |
|---|-------------------|
| <p>TOP VIEW</p> <p>16-LEAD (4mm × 4mm) PLASTIC QFN<br/>EXPOSED PAD (PIN 17) IS GND,<br/>MUST BE SOLDERED TO PCB<br/>T<sub>JMAX</sub> = 125°C, θ<sub>JA</sub> = 37°C/W</p> | ORDER PART NUMBER |
|   | LT5517EUF         |
|   | UF PART MARKING   |
|   | 5517              |

Consult LTC Marketing for parts specified with wider operating temperature ranges.

**AC ELECTRICAL CHARACTERISTICS**

T<sub>A</sub> = 25°C. V<sub>CC</sub> = 5V, EN = V<sub>CC</sub>, f<sub>RF1</sub> = 799.9MHz, f<sub>RF2</sub> = 800.1MHz, f<sub>2XLO</sub> = 1602MHz, P<sub>2XLO</sub> = -10dBm, unless otherwise noted. (Notes 2, 3) (Test circuit shown in Figure 2)

| PARAMETER                     | CONDITIONS                         | MIN  | TYP        | MAX | UNITS |
|-------------------------------|------------------------------------|------|------------|-----|-------|
| RF Frequency Range            |                                    |      | 40 to 900  |     | MHz   |
| 2XLO Frequency Range          |                                    |      | 80 to 1800 |     | MHz   |
| 2XLO Power                    |                                    |      | -15 to 0   |     | dBm   |
| 2XLO Port Return Loss         | Internally Matched to a 50Ω Source |      | 20         |     | dB    |
| Conversion Gain               | Voltage Gain, Load Impedance = 1kΩ | 0    | 3.3        |     | dB    |
| Gain Variation vs Temperature | -40°C to 85°C                      |      | 0.01       |     | dB/°C |
| Noise Figure                  |                                    |      | 12.4       |     | dB    |
| Input 3rd Order Intercept     | 2-Tone, -10dBm/Tone, Δf = 200kHz   |      | 21         |     | dBm   |
| Input 2nd Order Intercept     | 2-Tone, -10dBm/Tone, Δf = 200kHz   |      | 58         |     | dBm   |
| Input 1dB Compression         |                                    |      | 10         |     | dBm   |
| Baseband Bandwidth            |                                    |      | 130        |     | MHz   |
| I/Q Gain Mismatch             | (Note 4)                           | -0.3 | 0.03       | 0.3 | dB    |
| I/Q Phase Mismatch            | (Note 4)                           | -3.5 | 0.7        | 3.5 | deg   |
| Output Impedance              | Differential                       |      | 120        |     | Ω     |
| 2XLO to RF Leakage            |                                    |      | -69        |     | dBm   |
| LO to RF Leakage              |                                    |      | -80        |     | dBm   |
| RF to 2XLO Isolation          |                                    |      | 63         |     | dB    |

**DC ELECTRICAL CHARACTERISTICS**  $T_A = 25^\circ\text{C}$ .  $V_{CC} = 5\text{V}$  unless otherwise noted.

| PARAMETER   | CONDITIONS   | MIN | TYP | MAX  | UNITS                        |
|---|--|-----|-----|------|------------------------------|
| Supply Voltage  |  | 4.5 |     | 5.25 | V                            |
| Supply Current  |  | 70  | 90  | 110  | mA                           |
| Shutdown Current  | EN = LOW   |     | 0.1 | 20   | $\mu\text{A}$                |
| Turn-On Time  | (Note 5)   |     | 200 |      | ns                           |
| Turn-Off Time   | (Note 5)   |     | 300 |      | ns                           |
| EN = HIGH (On)  |  | 1.6 |     |      | V                            |
| EN = LOW (Off)  |  |     |     | 1.3  | V                            |
| EN Input Current  | $V_{ENABLE} = 5\text{V}$                             |     | 2   |      | $\mu\text{A}$                |
| Output DC Offset Voltage<br>( $ I_{OUT^+} - I_{OUT^-} $ , $ Q_{OUT^+} - Q_{OUT^-} $ ) | $f_{LO} = 1602\text{MHz}$ , $P_{LO} = -10\text{dBm}$ |     | 0.5 | 30   | mV                           |
| Output DC Offset Variation vs Temperature   | $-40^\circ\text{C}$ to $85^\circ\text{C}$            |     | 7   |      | $\mu\text{V}/^\circ\text{C}$ |

**Note 1:** Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

**Note 2:** Tests are performed as shown in the configuration of Figure 2.

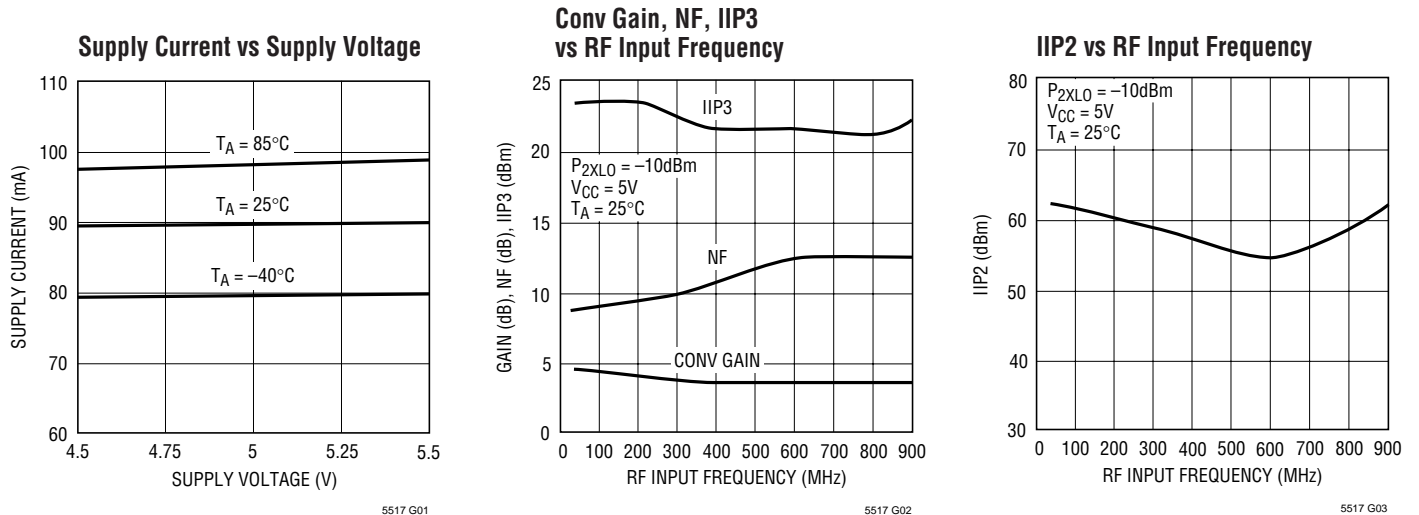
**Note 3:** Specifications over the  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  temperature range are assured by design, characterization and correlation with statistical process control.

**Note 4:** Measured at  $P_{2XLO} = -10\text{dBm}$  and output frequency = 1MHz.

**Note 5:** Turn ON and Turn OFF times are based on rise and fall times of the output baseband voltage with RF input power of  $-10\text{dBm}$ .

**TYPICAL PERFORMANCE CHARACTERISTICS**

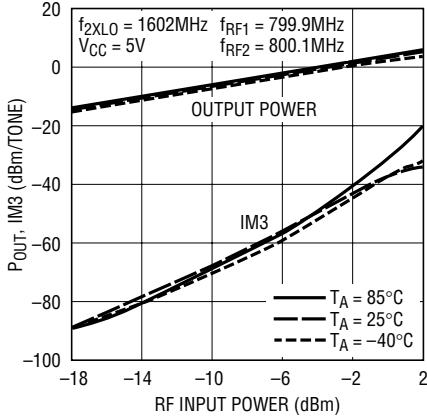
$f_{RF} = 800\text{MHz}$ ,  $P_{2XLO} = -10\text{dBm}$ , unless otherwise noted. (Test circuit shown in Figure 2)



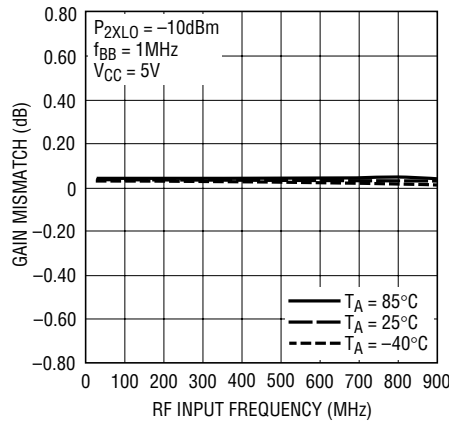
# TYPICAL PERFORMANCE CHARACTERISTICS

$f_{RF} = 800\text{MHz}$ ,  $P_{2XLO} = -10\text{dBm}$ , unless otherwise noted. (Test circuit shown in Figure 2)

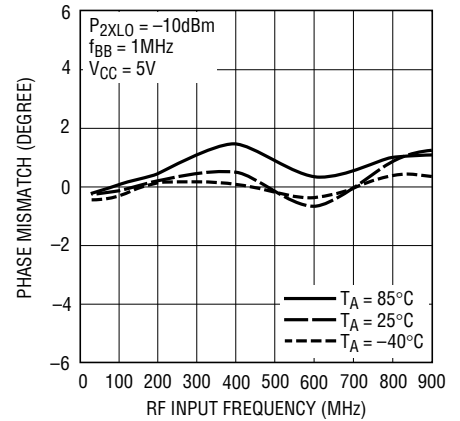
**I/Q Output Power, IM3 vs RF Input Power**



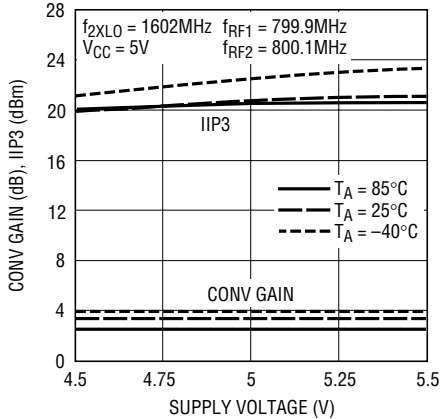
**I/Q Gain Mismatch vs RF Input Frequency**



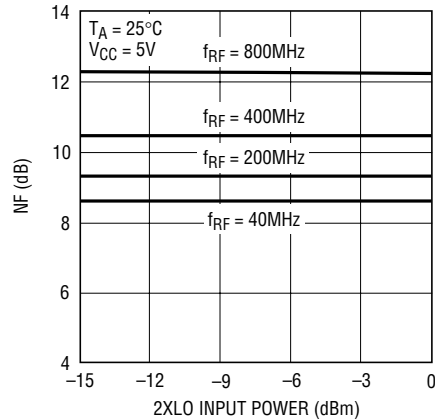
**I/Q Phase Mismatch vs RF Input Frequency**



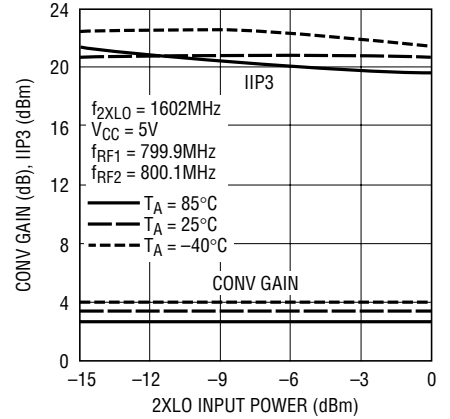
**Conv Gain, IIP3 vs Supply Voltage**



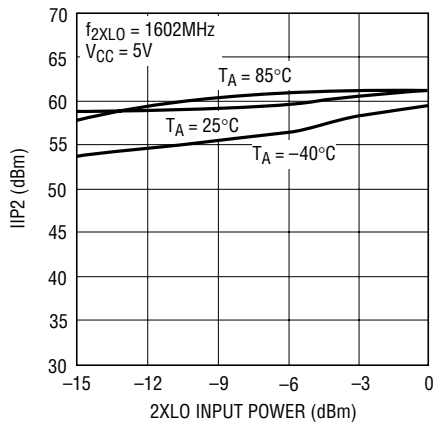
**NF vs 2XLO Input Power**



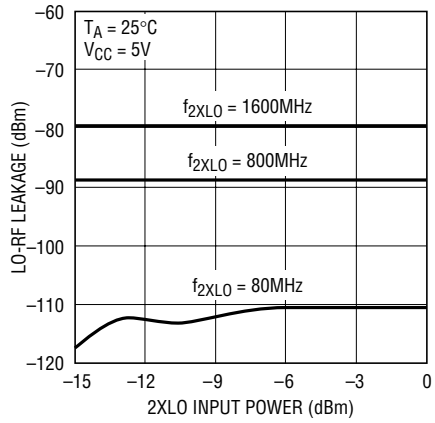
**Conv Gain, IIP3 vs 2XLO Input Power**



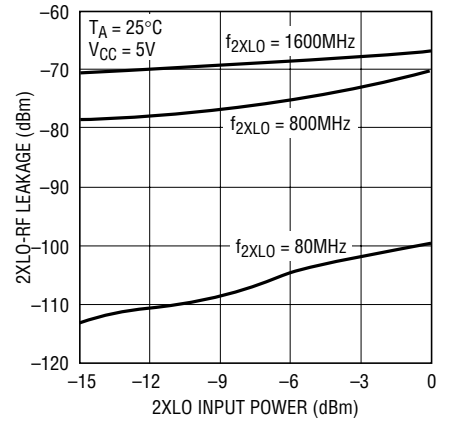
**IIP2 vs 2XLO Input Power**



**LO-RF Leakage vs 2XLO Input Power**

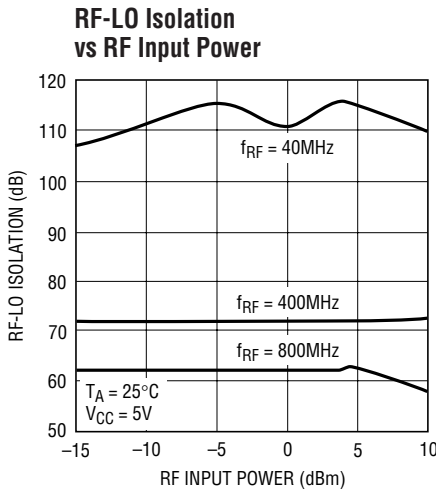


**2XLO-RF Leakage vs 2XLO Input Power**

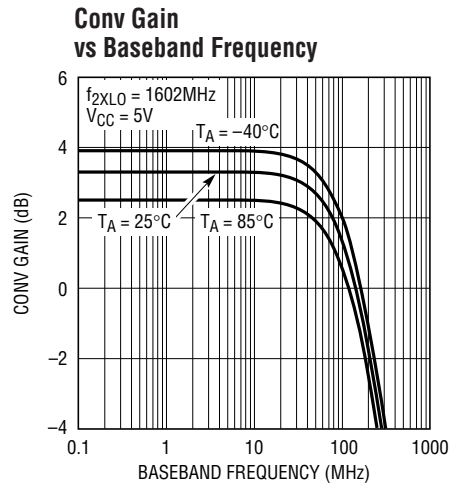


## TYPICAL PERFORMANCE CHARACTERISTICS

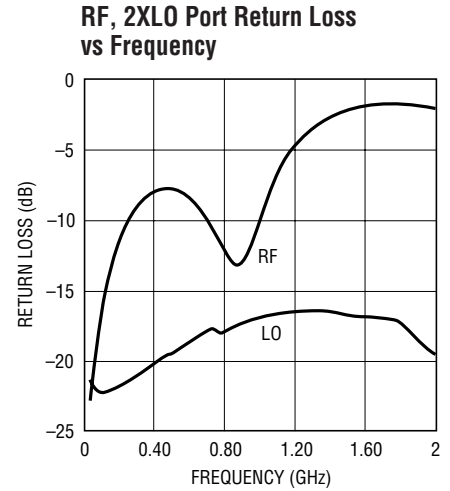
$f_{RF} = 800\text{MHz}$ ,  $P_{2XLO} = -10\text{dBm}$ , unless otherwise noted. (Test circuit shown in Figure 2)



5517 G13



5517 G14



5517 G15

## PIN FUNCTIONS

**GNDRF (Pins 1, 4):** Ground Pins for RF Termination. These pins are not internally connected, and should be connected to the PCB ground plane for best RF isolation.

**RF<sup>+</sup>, RF<sup>-</sup> (Pins 2, 3):** Differential RF Input Pins. These pins are internally biased to 2.30V. These two pins should be DC blocked when connected to ground or other matching components. The inputs can be terminated in a single-ended configuration, but differential input drive is preferred for best performance. An external matching network is required for impedance transformation.

**EN (Pin 5):** Enable Pin. When the input voltage is higher than 1.6V, the circuit is completely turned on. When the input voltage is less than 1.3V, the circuit is turned off.

**V<sub>CC</sub> (Pins 6, 7, 8, 12):** Power Supply Pins. These pins should be decoupled using 1000pF and 0.1μF capacitors.

**GND (Pins 9, 11):** Ground Pins. These pins are internally tied together and to the Exposed Pad. They should be connected to the PCB ground plane.

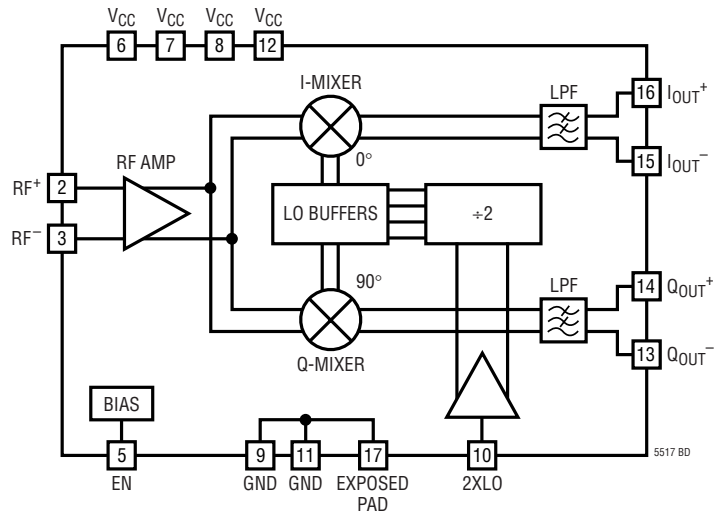
**2XLO (Pin 10):** 2XLO Input Pin. This pin is internally biased to 1V. The input signal's frequency should be twice that of the desired demodulator LO frequency. The pin should be AC coupled with an external DC blocking capacitor.

**Q<sub>OUT</sub><sup>-</sup>, Q<sub>OUT</sub><sup>+</sup> (Pins 13, 14):** Differential Baseband Output Pins of the Q-Channel. The internal DC bias voltage is  $V_{CC} - 0.78\text{V}$  for each pin.

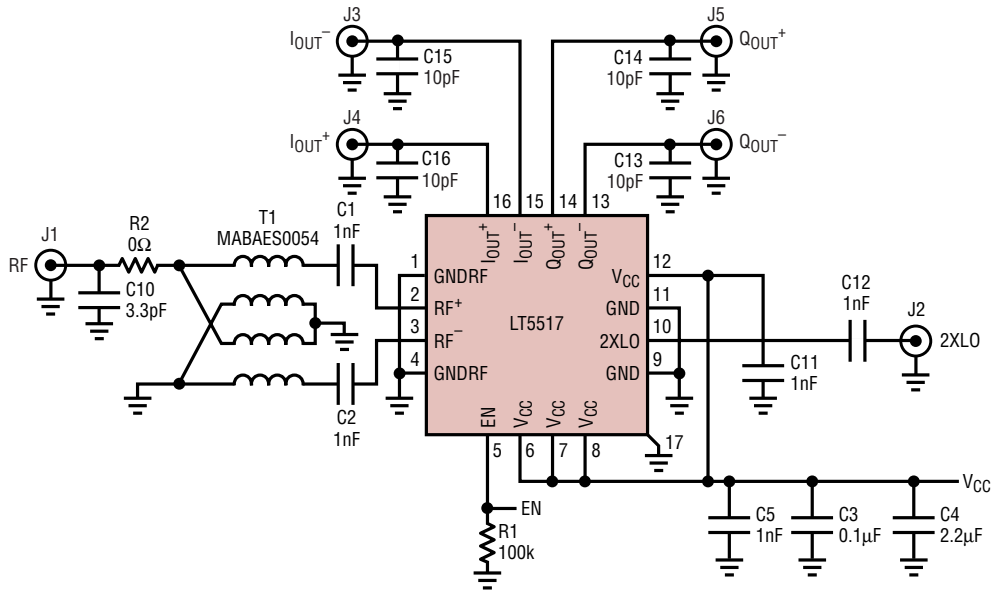
**I<sub>OUT</sub><sup>-</sup>, I<sub>OUT</sub><sup>+</sup> (Pins 15, 16):** Differential Baseband Output Pins of the I-Channel. The internal DC bias voltage is  $V_{CC} - 0.78\text{V}$  for each pin.

**Exposed Pad (Pin 17):** Ground Return for the Entire IC. This pin must be soldered to the printed circuit board ground plane.

**BLOCK DIAGRAM**



TEST CIRCUIT



| REFERENCE DESIGNATION | VALUE | SIZE | PART NUMBER         |
|-----------------------|-------|------|---------------------|
| C1,C2,C5,C11,C12      | 1nF   | 0603 | AVX 06033A102JAT1A  |
| C3                    | 0.1μF | 0603 | TAIYO YUDEN EMK107B |
| C4                    | 2.2μF | 0603 | TAIYO YUDEN JMK107B |
| C10                   | 3.3pF | 0603 | AVX 06033A3R3KAT2A  |
| C13 TO C16            | 10pF  | 0805 | AVX 08055A100ZAT1A  |
| R1                    | 100k  | 0603 | OPTIONAL            |
| R2                    | 0Ω    | 0603 | JUMPER, OPTIONAL    |
| T1                    | 1:4   |      | M/A COM MABAES0054  |

5517 F02

Figure 2. Evaluation Circuit Schematic

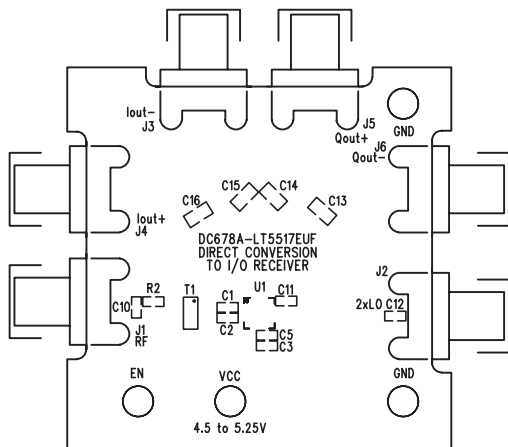


Figure 3. Component Side Silkscreen of Evaluation Board

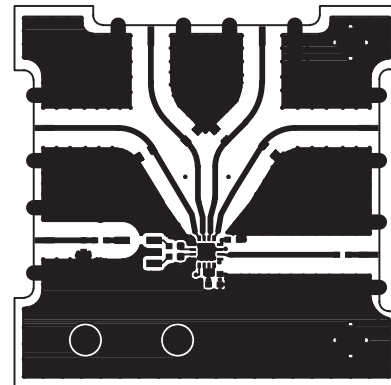


Figure 4. Component Side Layout of Evaluation Board

## APPLICATIONS INFORMATION

The LT5517 is a direct I/Q demodulator targeting high linearity receiver applications. It consists of an RF amplifier, I/Q mixers, a quadrature LO carrier generator and bias circuitry.

The RF signal is applied to the inputs of the RF amplifier, and is then demodulated into I-channel and Q-channel baseband signals using precision quadrature LO signals, which are internally generated using a divide-by-two circuit. The demodulated I/Q signals are lowpass filtered internally with a  $-3\text{dB}$  bandwidth of  $130\text{MHz}$ . The differential outputs of the I-channel and Q-channel are well matched in amplitude and their phases are  $90^\circ$  apart across the full frequency range from  $40\text{MHz}$  to  $900\text{MHz}$ .

### RF Input Port

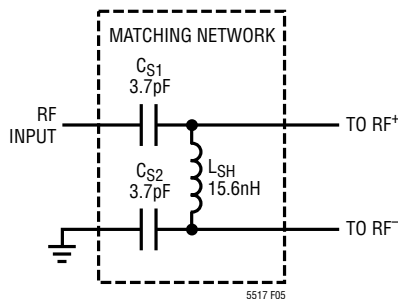
Differential drive is recommended for the RF inputs as shown in Figure 2. A low loss 1:4 transformer is used on the demonstration board for a wide bandwidth input impedance match and to assure good noise figure and maximum demodulator gain. Single-ended to differential conversion can also be implemented using narrowband L-C circuits to produce the required balanced waveforms at the  $\text{RF}^+$  and  $\text{RF}^-$  inputs using three discrete elements as shown in Figure 5. Nominal values are listed in Table 1. (In practice, these values should be compensated according to the parasitics of the PCB.) The conversion gain and NF

of the receiver are similar to those of the transformer-coupled demo board, because the single-ended to differential conversion has a 1:4 impedance transformation, similar to the transformer.

**Table 1. The Component Values of Matching Network  $L_{SH}$ ,  $C_{S1}$  and  $C_{S2}$**

| FREQUENCY (MHz) | $L_{SH}$ (nH) | $C_{S1}, C_{S2}$ (pF) |
|-----------------|---------------|-----------------------|
| 40              | 437           | 71.1                  |
| 100             | 169           | 28.6                  |
| 200             | 80.8          | 14.3                  |
| 300             | 51.5          | 9.6                   |
| 400             | 37            | 7.2                   |
| 500             | 28.3          | 5.8                   |
| 600             | 22.6          | 4.9                   |
| 700             | 18.5          | 4.2                   |
| 800             | 15.6          | 3.7                   |
| 900             | 13.5          | 3.3                   |

The differential impedance of the RF inputs is listed in Table 2. The RF inputs may also be terminated in a single-ended configuration. In this case either the  $\text{RF}^+$  or the  $\text{RF}^-$  input can be simply AC coupled to a  $50\Omega$  source, while the other RF input is connected to ground with a  $1\text{nF}$  capacitor. Note, however, that this will result in degraded conversion gain and noise figure in most cases.



**Figure 5. RF Input Matching Network at 800MHz**



## APPLICATIONS INFORMATION

Table 2. RF Input Differential Impedance

| FREQUENCY (MHz) | DIFFERENTIAL INPUT IMPEDANCE ( $\Omega$ ) | DIFFERENTIAL S11 |                     |
|-----------------|---|------------------|---------------------|
|                 |   | MAG              | ANGLE( $^{\circ}$ ) |
| 40              | 240.1-j10.3                               | 0.665            | -0.8                |
| 100             | 245.5-j25.9                               | 0.664            | -2.5                |
| 200             | 236.8-j50.0                               | 0.664            | -5.1                |
| 300             | 223.6-j70.5                               | 0.663            | -7.6                |
| 400             | 207.9-j86.3                               | 0.662            | -10.2               |
| 500             | 190.6-j98.1                               | 0.660            | -12.7               |
| 600             | 173.2-j105.8                              | 0.657            | -15.3               |
| 700             | 156.2-j110.2                              | 0.655            | -17.9               |
| 800             | 141.2-j111.8                              | 0.651            | -20.4               |
| 900             | 129.5-j114.5                              | 0.650            | -22.9               |

### 2XLO Input Port

To ease the interface of the receiver with the external 2XLO input, the 2XLO port is designed with on-chip  $50\Omega$  impedance matching up to 2GHz. The input is internally biased at 1V. A 1nF DC blocking capacitor is required when connected to the external 2XLO source.

The 2XLO frequency is required to be twice the desired operating frequency in order for the chip to generate the

quadrature Local Oscillator (LO) signals for the demodulator. The on-chip divide-by-two circuit delivers well-matched, quadrature LO carriers to the I mixer and the Q mixer.

### I-Channel and Q-Channel Outputs

Each of the I-channel and Q-channel outputs is internally connected to  $V_{CC}$  through a  $60\Omega$  resistor. The output DC bias voltage is  $V_{CC} - 0.78V$ . The outputs can be DC coupled or AC coupled to the external loads. The differential output impedance of the demodulator is  $120\Omega$  in parallel with a 10pF internal capacitor, forming a lowpass filter with a -3dB corner frequency at 130MHz. The load impedance,  $R_{LOAD}$ , should be larger than  $600\Omega$  to assure full gain. The gain is reduced by  $20 \cdot \log(1 + 120\Omega/R_{LOAD})$  in dB when the differential output is terminated by  $R_{LOAD}$ . For example, the gain is reduced by 6.85dB when each output pin is connected to a  $50\Omega$  load (or  $100\Omega$  differential loads). The output should be taken differentially (or by using differential-to-single-ended conversion) for best RF performance, including NF and IM2. Proper filtering of the unwanted high frequency mixing product is also important to maintain the highest linearity. A convenient

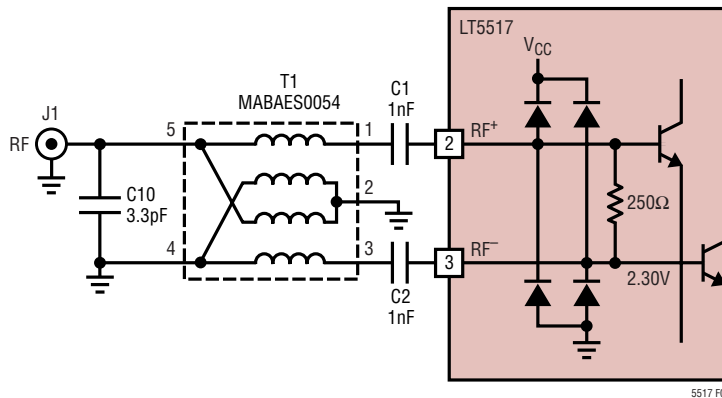


Figure 6. RF Input Equivalent Circuit with External Broadband Matching

## APPLICATIONS INFORMATION

approach is to terminate each output with a shunt capacitor. The capacitor value can be optimized depending upon the operating frequency and the specific PCB layout.

The phase relationship between the I-channel output signal and the Q-channel output signal is fixed. When the LO input frequency is higher than the RF input frequency, then the Q-channel outputs ( $Q_{OUT}^+$ ,  $Q_{OUT}^-$ ) lead the I-channel outputs ( $I_{OUT}^+$ ,  $I_{OUT}^-$ ) by  $90^\circ$ .

When the LO input frequency is lower than the RF input frequency, then the Q-channel outputs lag the I-channel outputs by  $90^\circ$ . Note that the phase relationship of the I- and Q-channel outputs relative to the LO can vary by  $180^\circ$ , depending on start-up conditions. This is the nature of a frequency divider-based quadrature phase generator.

When AC output coupling is used, the resulting highpass filter's  $-3\text{dB}$  roll-off frequency is defined by the R-C constant of the blocking capacitor and  $R_{LOAD}$ , assuming  $R_{LOAD} > 600\Omega$ .

Care should be taken when the demodulator's outputs are DC coupled to the external load to make sure that the I/Q mixers are biased properly. If the current drain from the outputs exceeds  $6\text{mA}$ , there can be significant degradation of the linearity performance. Each output can sink no more than  $13\text{mA}$  when connected to an external load with a DC voltage higher than  $V_{CC} - 0.78\text{V}$ .

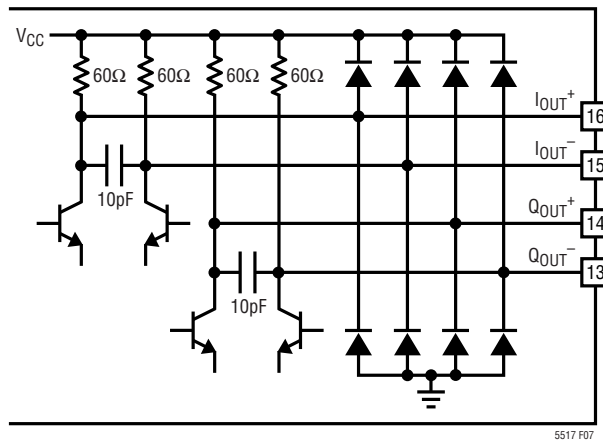
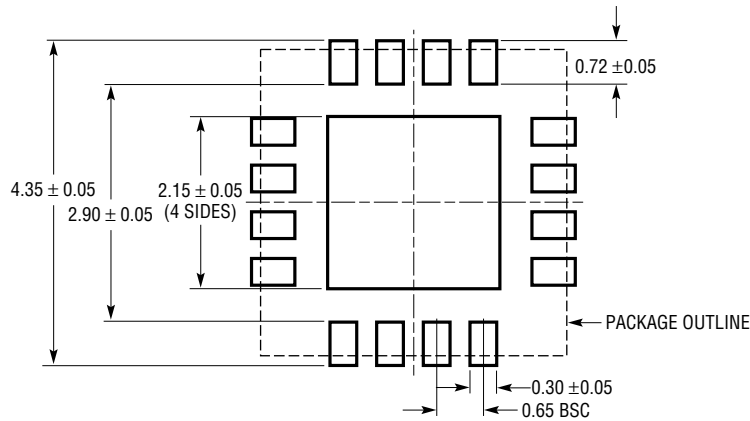


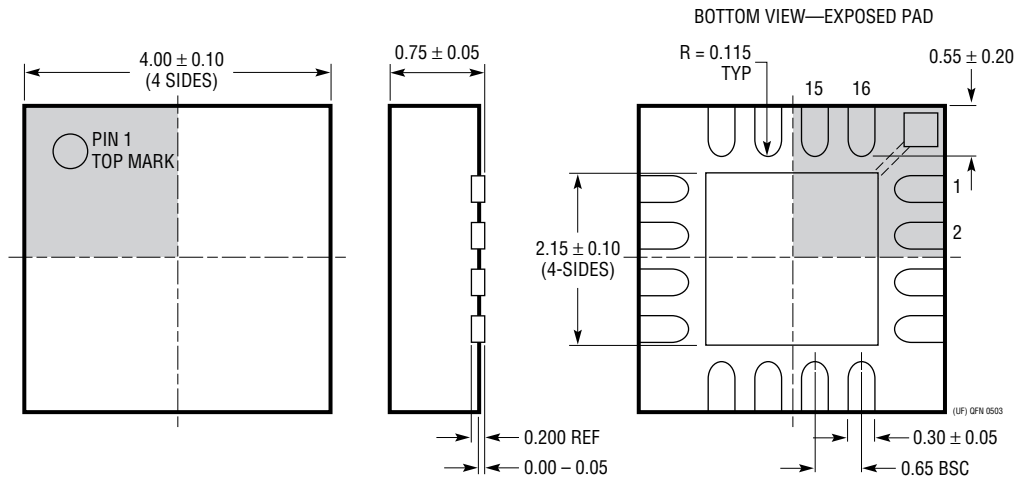
Figure 7. I/Q Output Equivalent Circuit

# PACKAGE DESCRIPTION

**UF Package**  
**16-Lead Plastic QFN (4mm × 4mm)**  
 (Reference LTC DWG # 05-08-1692)



RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS



- NOTE:
1. DRAWING CONFORMS TO JEDEC PACKAGE OUTLINE MO-220 VARIATION (WGFC)
  2. ALL DIMENSIONS ARE IN MILLIMETERS
  3. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
  4. EXPOSED PAD SHALL BE SOLDER PLATED

## RELATED PARTS

| PART NUMBER                 | DESCRIPTION  | COMMENTS  |
|-----------------------------|--|---|
| <b>Infrastructure</b>       |  |   |
| LT5511                      | High Linearity Upconverting Mixer                                      | RF Output to 3GHz, 17dBm IIP3, Integrated LO Buffer   |
| LT5512                      | DC-3GHz High Signal Level Downconverting Mixer                         | DC to 3GHz, 21dBm IIP3, Integrated LO Buffer  |
| LT5515                      | 1.5GHz to 2.5GHz Direct Conversion Quadrature Demodulator              | 20dBm IIP3, Integrated LO Quadrature Generator  |
| LT5516                      | 0.8GHz to 1.5GHz Direct Conversion Quadrature Demodulator              | 21.5dBm IIP3, Integrated LO Quadrature Generator  |
| LT5520                      | 1.3GHz to 2.3GHz High Linearity Upconverting Mixer                     | 15.9dBm IIP3, Single Ended, 50Ω Matched RF and LO Ports   |
| LT5522                      | 600MHz to 2.7GHz High Signal Level Downconverting Mixer                | 4.5V to 5.25V Supply, 25dBm IIP3 at 900MHz, NF = 12.5dB, 50Ω Single-Ended RF and LO Ports           |
| <b>RF Power Detectors</b>   |  |   |
| LT5504                      | 800MHz to 2.7GHz RF Measuring Receiver                                 | 80dB Dynamic Range, Temperature Compensated, 2.7V to 5.25V Supply                                   |
| LTC®5505                    | RF Power Detectors with >40dB Dynamic Range                            | 300MHz to 3GHz, Temperature Compensated, 2.7V to 6V Supply  |
| LTC5507                     | 100kHz to 1000MHz RF Power Detector                                    | 100kHz to 1GHz, Temperature Compensated, 2.7V to 6V Supply  |
| LTC5508                     | 300MHz to 7GHz RF Power Detector                                       | 44dB Dynamic Range, Temperature Compensated, SC70 Package   |
| LTC5509                     | 300MHz to 3GHz RF Power Detector                                       | 36dB Dynamic Range, Low Power Consumption, SC70 Package   |
| LTC5532                     | 300MHz to 7GHz Precision RF Power Detector                             | Precision V <sub>OUT</sub> Offset Control, Adjustable Gain and Offset                               |
| <b>RF Building Blocks</b>   |  |   |
| LT5500                      | 1.8GHz to 2.7GHz Receiver Front End                                    | 1.8V to 5.25V Supply, Dual-Gain LNA, Mixer, LO Buffer   |
| LT5502                      | 400MHz Quadrature IF Demodulator with RSSI                             | 1.8V to 5.25V Supply, 70MHz to 400MHz IF, 84dB Limiting Gain, 90dB RSSI Range                       |
| LT5503                      | 1.2GHz to 2.7GHz Direct IQ Modulator and Upconverting Mixer            | 1.8V to 5.25V Supply, Four-Step RF Power Control, 120MHz Modulation Bandwidth                       |
| LT5506                      | 500MHz Quadrature IF Demodulator with VGA                              | 1.8V to 5.25V Supply, 40MHz to 500MHz IF, -4dB to 57dB Linear Power Gain, 8.8MHz Baseband Bandwidth |
| LT5546                      | 500MHz Quadrature IF Demodulator with VGA and 17MHz Baseband Bandwidth | 17MHz Baseband Bandwidth, 40MHz to 500MHz IF, 1.8V to 5.25V Supply, -7dB to 56dB Linear Power Gain  |
| <b>RF Power Controllers</b> |  |   |
| LTC1757A                    | RF Power Controller  | Multiband GSM/DCS/GPRS Mobile Phones  |
| LTC1758                     | RF Power Controller  | Multiband GSM/DCS/GPRS Mobile Phones  |
| LTC1957                     | RF Power Controller  | Multiband GSM/DCS/GPRS Mobile Phones  |
| LTC4400                     | SOT-23 RF PA Controller  | Multiband GSM/DCS/GPRS Phones, 45dB Dynamic Range, 450kHz Loop BW                                   |
| LTC4401                     | SOT-23 RF PA Controller  | Multiband GSM/DCS/GPRS Phones, 45dB Dynamic Range, 250kHz Loop BW                                   |
| LTC4403                     | RF Power Controller for EDGE/TDMA                                      | Multiband GSM/GPRS/EDGE Mobile Phones   |