

## HIGH DYNAMIC RANGE DOWNCONVERTING MIXER

## DESCRIPTION

Demonstration Circuit 1431A-B is a 1.3GHz to 2.3GHz high dynamic range downconverting mixer featuring the LTC<sup>®</sup>5541. The LTC5541 is part of a family of high dynamic range, passive downconverting mixers covering the 600MHz to 4GHz frequency range. **The Demo Circuit 1431A-B and the LTC5541 are optimized for 1.3GHz to 2.3GHz RF applications. The LO frequency must fall within the 1.4GHz to 2.0GHz range for optimum performance.**


The LTC5541 is designed for 3.3V operation, however the IF amplifier can be powered by 5V for the highest P1dB. An integrated SPDT LO switch with fast switching accepts two active LO signals, while providing high isolation.

The LTC5541's high conversion gain and high dynamic range enable the use of lossy IF filters in high-selective receiver designs, while minimizing the total solution cost, board space and system-level variation.

## High Dynamic Range Downconverting Mixer Family

DEMO #	IC PART #	RF RANGE	LO RANGE
DC1431A-A	LTC5540	600MHz-1.3GHz	700MHz-1.2GHz
<b>DC1431A-B</b>	<b>LTC5541</b>	<b>1.3GHz-2.3GHz</b>	<b>1.4GHz-2.0GHz</b>
DC1431A-C	LTC5542	1.6GHz-2.7GHz	1.7GHz-2.5GHz
DC1431A-D	LTC5543	2.3GHz-4.0GHz	2.4GHz-3.6GHz

Design files for this circuit board are available. Call the LTC factory.

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**TABLE 1. TYPICAL PERFORMANCE SUMMARY**

T<sub>A</sub> = 25°C, V<sub>CC</sub> = 3.3V, V<sub>CCIF</sub> = 3.3V, SHDN = Low, P<sub>LO</sub> = 0dBm, P<sub>RF</sub> = -3dBm (Δf = 2MHz for two-tone IIP3 tests), unless otherwise noted.

PARAMETER	CONDITIONS	VALUE	UNITS
V <sub>CC</sub> Supply Voltage Range		3.1 to 3.5	V
V <sub>CCIF</sub> Supply Voltage Range		3.1 to 5.3	V
Total Supply Current (V <sub>CC</sub> + V <sub>CCIF</sub> )		192	mA
Total Supply Current During Shutdown	SHDN = High	≤ 500	μA
SHDN Input Low Voltage (IC On)		< 0.3	V
SHDN Input High Voltage (IC Off)		> 3	V
LOSEL Input Low Voltage (LO1 Selected)		< 0.3	V
LOSEL Input High Voltage (LO2 Selected)		> 3	V
LO Input Frequency Range		1400 to 2000	MHz
LO Input Return Loss	Z <sub>0</sub> = 50Ω, f <sub>LO</sub> = 1400MHz to 2000MHz	> 12	dB
LO Input Power Range	f <sub>LO</sub> = 1400MHz to 2000MHz	-4 to 6	dBm
RF Input Frequency Range	Low-Side LO High-Side LO	1600 to 2300 1300 to 1800	MHz
RF Input Return Loss	Z <sub>0</sub> = 50Ω, f <sub>RF</sub> = 1300MHz to 2300MHz	> 12	dB

## TYPICAL PERFORMANCE SUMMARY, CONTINUED

$T_A = 25^\circ\text{C}$ ,  $V_{CC} = 3.3\text{V}$ ,  $V_{CCIF} = 3.3\text{V}$ , SHDN = Low,  $P_{LO} = 0\text{dBm}$ ,  $P_{RF} = -3\text{dBm}$  ( $\Delta f = 2\text{MHz}$  for two-tone IIP3 tests), unless otherwise noted.

IF Output Frequency (Can be re-matched for other frequencies.)		190	MHz
IF Output Return Loss		> 12	dB
LO to RF Leakage	$f_{LO} = 1400\text{MHz}$ to $2000\text{MHz}$	< -32	dBm
LO to IF Leakage	$f_{LO} = 1400\text{MHz}$ to $2000\text{MHz}$	< -31	dBm
LO Switch Isolation	LO1 Selected, $1400\text{MHz} < f_{LO} < 2000\text{MHz}$ LO2 Selected, $1400\text{MHz} < f_{LO} < 2000\text{MHz}$	52 50	dB
RF to LO Isolation	$f_{RF} = 1300\text{MHz}$ to $2300\text{MHz}$	> 52	dB
RF to IF Isolation	$f_{RF} = 1300\text{MHz}$ to $2300\text{MHz}$	> 33	dB

**Low-Side LO Downmixer Application: RF = 1700MHz to 2200MHz, IF = 190MHz,  $f_{LO} = f_{RF} - f_{IF}$**

PARAMETER	CONDITIONS	VALUE	UNITS
Conversion Gain	RF = 1750MHz RF = 1950MHz RF = 2150MHz	8.6 7.8 7.6	dB
Input 3 <sup>rd</sup> Order Intercept	RF = 1750MHz RF = 1950MHz RF = 2150MHz	25.5 26.4 25.5	dBm
SSB Noise Figure	RF = 1750MHz RF = 1950MHz RF = 2150MHz	9.2 9.6 10.6	dB
SSB Noise Figure Under Blocking	$f_{RF} = 1950\text{MHz}$ , $f_{LO} = 1760\text{MHz}$ $f_{BLOCK} = 2050\text{MHz}$ , $P_{BLOCK} = 5\text{dBm}$	16	dB
2RF – 2LO Output Spurious Product ( $f_{RF} = f_{LO} + f_{IF}/2$ )	$f_{RF} = 1855\text{MHz}$ at $-10\text{dBm}$ , $f_{LO} = 1760\text{MHz}$	-67	dBc
3RF – 3LO Output Spurious Product ( $f_{RF} = f_{LO} + f_{IF}/3$ )	$f_{RF} = 1823.33\text{MHz}$ at $-10\text{dBm}$ , $f_{LO} = 1760\text{MHz}$	-73	dBc
Input 1dB Compression	RF = 1950MHz, $V_{CCIF} = 3.3\text{V}$ RF = 1950MHz, $V_{CCIF} = 5\text{V}$	11.3 14.6	dBm

**High-Side LO Downmixer Application: RF = 1300MHz to 1800MHz, IF = 190MHz,  $f_{LO} = f_{RF} + f_{IF}$**

PARAMETER	CONDITIONS	VALUE	UNITS
Conversion Gain	RF = 1450MHz RF = 1600MHz RF = 1750MHz	8.9 8.4 8.0	dB
Input 3 <sup>rd</sup> Order Intercept	RF = 1450MHz RF = 1600MHz RF = 1750MHz	24.5 24.6 24.3	dBm
SSB Noise Figure	RF = 1450MHz RF = 1600MHz RF = 1750MHz	9.5 9.9 9.9	dB
SSB Noise Figure Under Blocking	$f_{RF} = 1600\text{MHz}$ , $f_{LO} = 1790\text{MHz}$ $f_{BLOCK} = 1500\text{MHz}$ , $P_{BLOCK} = 5\text{dBm}$	18	dB
2LO – 2RF Output Spurious Product ( $f_{RF} = f_{LO} - f_{IF}/2$ )	$f_{RF} = 1695\text{MHz}$ at $-10\text{dBm}$ , $f_{LO} = 1790\text{MHz}$	-69	dBc
3LO – 3RF Output Spurious Product ( $f_{RF} = f_{LO} - f_{IF}/3$ )	$f_{RF} = 1726.67\text{MHz}$ at $-10\text{dBm}$ , $f_{LO} = 1790\text{MHz}$	-74	dBc
Input 1dB Compression	RF = 1750MHz, $V_{CCIF} = 3.3\text{V}$ RF = 1750MHz, $V_{CCIF} = 5\text{V}$	11.1 14.4	dBm

## APPLICATIONS NOTE

For detailed applications information, please refer to the LTC5541 datasheet.

### ABSOLUTE MAXIMUM RATINGS

**NOTE.** Stresses beyond Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Mixer Supply Voltage ( $V_{CC1}$ , $V_{CC2}$ ).....	3.8V
LO Switch Supply Voltage ( $V_{CC3}$ ).....	3.8V
IF Supply Voltage (IF+, IF-) .....	5.5V
Shutdown Voltage (SHDN).....	-0.3V to $V_{CC} + 0.3V$
LO Select Voltage (LOSEL) .....	-0.3V to $V_{CC} + 0.3V$
LO1, LO2 Input Power (1GHz to 3GHz) .....	9dBm
LO1, LO2 Input DC Voltage .....	$\pm 0.5V$
RF Input Power (1GHz to 3GHz) .....	15dBm
RF Input DC Voltage .....	$\pm 0.1V$
Operating Temperature Range.....	-40°C to 85°C

### SUPPLY VOLTAGE RAMPING

Fast ramping of the supply voltage can cause a current glitch in the internal ESD protection circuits. Depending on the supply inductance, this could result in a supply voltage transient that exceeds the maximum rating. A supply voltage ramp time of greater than 1ms is recommended.

**Do not clip powered test leads directly onto the demonstration circuit's VCC and VCC<sub>IF</sub> turrets.** Instead, make all necessary connections with power supplies turned off, then increase to operating voltage.

### SHUTDOWN FEATURE

When the SHDN voltage is logic Low (<0.3V), the chip is enabled. When the SHDN voltage is logic High (>3V), the chip is disabled, and the current consumption is reduced to below 500 $\mu$ A. The SHDN must be pulled Low or High. If left floating, the On/Off state of the IC will be indeterminate. A logic table for the SHDN is shown in Table 2.

TABLE 2. SHDN LOGIC TABLE

SHDN	IC STATE
Low	On
High	Off

### LO SWITCH

The LTC5541 features an integrated SPDT switch designed for high isolation and fast (<50ns) switching. The LO switch is controlled by the LOSEL logic control. The LOSEL must be pulled Low or High. If left floating, the LO selection will be indeterminate. A logic table for the LO switch is shown in Table 3.

TABLE 3. LO SWITCH LOGIC TABLE

LOSEL	ACTIVE LO INPUT
Low	LO1
High	LO2

### RF INPUT

The RF input of Demonstration Circuit 1431A-B is matched to 50 $\Omega$  from 1.3GHz to 2.3GHz with better than 12dB return loss. **For the RF input to be matched, the selected LO input must be driven.** The RF input impedance is somewhat dependent on LO frequency and, to a lesser extent, LO input power.

### LO INPUTS

The LTC5541's LO amplifiers are optimized for the 1.4GHz to 2.0GHz LO frequency range. LO frequencies above and below this frequency range may be used with degraded performance.

The LO1 and LO2 inputs are always 50 $\Omega$ -matched when  $V_{CC}$  is applied to the chip, even when the chip is shutdown. The DC resistance of the selected LO input is approximately 23 $\Omega$ , and the unselected input is approximately 50 $\Omega$ .

The nominal LO input level is 0dBm. The LO input power range is between -4dBm and 6dBm. LO input power greater than 6dBm may cause conduction of the internal ESD diodes and should be avoided.

## IF OUTPUT

Demonstration Circuit 1431A-B features a single-ended, 50Ω-matched IF output for 190MHz. The impedance matching is realized with a bandpass topology using an IF transformer as shown in Figure 1.

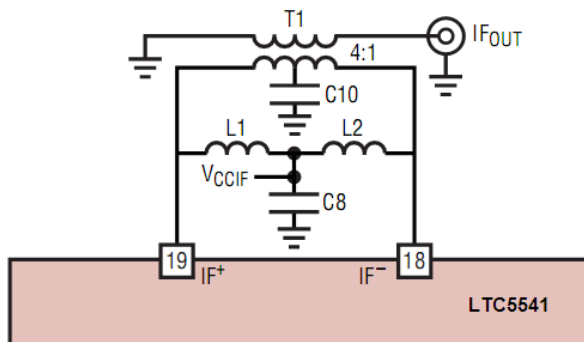


Figure 1. IF Output with Bandpass Matching

Demonstration Circuit 1431A-B can be easily re-configured for other IF frequencies by simply replacing inductors L1 and L2. L1 and L2 values for several common IF frequencies are presented in Table 4, and return losses are plotted in Figure 2.

TABLE 4. L1, L2 vs. IF FREQUENCIES

IF FREQUENCY (MHz)	L1, L2 (nH)
140	270
190	150
240	100
300	56
380	33

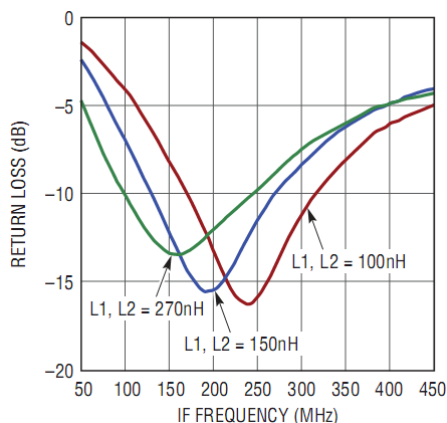


Figure 2. IF Output Return Loss

For IF frequencies below 90MHz, the values of L1 and L2 become unreasonably high, and the lowpass topology shown in Figure 3 is preferred.

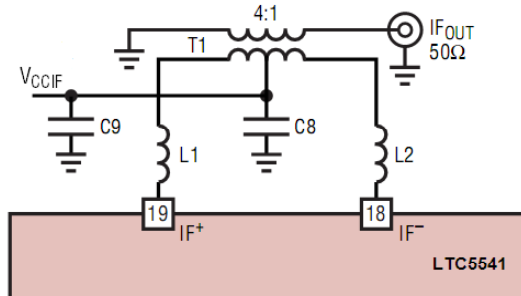


Figure 3. IF Output with Lowpass Matching

Demonstration Circuit 1431A-B's IF output can be converted to lowpass matching with minimal modifications. Follow the procedures below, and refer to Figure 4.

- Remove existing L1, L2, and C10.
- Cut the traces leading to the IF transformer close to the pads of L1 and L2.
- Insert series inductors on the cut traces.
- Install a 0Ω jumper between the pads of C8 and C9.

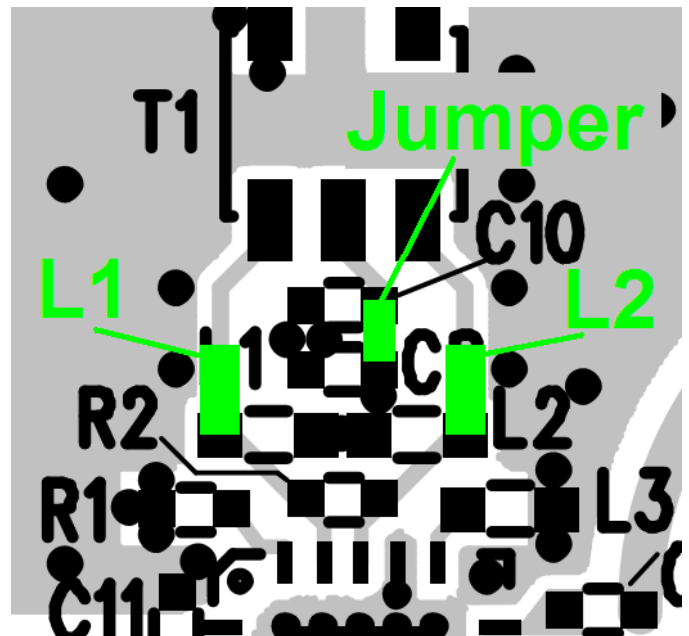


Figure 4. Modifications for Lowpass Matching

## MEASUREMENT EQUIPMENT AND SETUP

The LTC5541 is a high dynamic range downconverting mixer IC with very high input 3rd order intercept. Accuracy of its performance measurement is highly dependent on equipment setup and measurement technique. The recommended measurement setups are presented in Figure 5, Figure 6, and Figure 7. The following precautions should be observed:

1. Use high performance signal generators with low harmonic output and low phase noise, such as the Rohde & Schwarz SME06. Filters at the signal generators' outputs may also be used to suppress higher-order harmonics.
2. A high quality RF power combiner that provide broadband 50 $\Omega$ -termination on all ports and have good port-to-port isolation should be used, such as the MCLI PS2-17.
3. Use high performance amplifiers with high IP3 and high reverse isolation, such as the Mini-Circuits ZHL-1042J, on the outputs of the RF signal generators to improve source isolation to prevent the sources from modulating each other and generating intermodulation products.
4. Use attenuator pads with good VSWR on the demonstration circuit's input and output ports to improve source and load match to reduce reflections, which may degrade measurement accuracy.
5. A high dynamic range spectrum analyzer, such as the Rohde & Schwarz FSEM30 should be used for linearity measurement.
6. Use narrow resolution bandwidth (RBW) and engage video averaging on the spectrum analyzer to lower the displayed average noise level (DANL) in order to improve sensitivity and to increase dynamic range. However, the trade off is increased sweep time.
7. Spectrum analyzers can produce significant internal distortion products if they are over-driven. Generally, spectrum analyzers are designed to operate at their best with about -30dBm at their input filter or preselector. Sufficient spectrum analyzer input attenuation should be used to avoid saturating the instrument, but too much attenuation reduces sensitivity and dynamic range.
8. Before taking measurements, the system performance should be evaluated to ensure that:
  - a. Clean input signals can be produced. The two-tone signals' OIP3 should be at least 15dB better than the DUT's IIP3.
  - b. The spectrum analyzer's internal distortion is minimized.
  - c. The spectrum analyzer has enough dynamic range and sensitivity. The measurement system's IIP3 should be at least 15dB better than the DUT's OIP3.
  - d. The system is accurately calibrated for power and frequency.

### A SPECIAL NOTE ABOUT RF TERMINATION

The LTC5541 consists of a high linearity passive double-balanced mixer core and IF buffer amplifier. Due to the bi-directional nature of all passive mixers, LO $\pm$ IF mixing product is always present at the RF input, typically at a level of 12dB below the RF input signal. If the LO $\pm$ IF "Pseudo-Image Spur" is not properly terminated, it may interfere with the source signals, and can degrade the measured linearity and noise figure significantly. To avoid interference from the LO $\pm$ IF "Pseudo-Image Spur", terminate the RF input port with an isolator, diplexer, or attenuator. In the recommended measurement setups presented in Figure 6 and Figure 7, the 6dB attenuator pad at the demonstration circuit's RF input serves this purpose.

## QUICK START PROCEDURE

Demonstration circuit 1431A-B is easy to set up to evaluate the performance of the LTC5541. Refer to Figure 5, Figure 6, and Figure 7 for proper equipment connections and follow the procedure below:

**NOTE.** Care should be taken to never exceed absolute maximum input ratings. Make all connections with RF and DC power off.

### RETURN LOSS MEASUREMENTS

1. Configure the Network Analyzer for return loss measurement, set appropriate frequency range, and set the test signal to -3dBm.
2. Calibrate the Network Analyzer.
3. Connect all test equipment as shown in Figure 5 with the signal generator and the DC power supply turned off.
4. Increase VCC supply voltage to 3.3V, and verify that the current consumption is approximately 192mA with the LO signal applied. The supply voltage should be confirmed at the demo board VCC and GND terminals to account for lead ohmic losses.
5. With the LO signal applied, and the unused demo board ports terminated in 50Ω, measure return losses of the RF input and IF output ports.
6. Set the test signal to 0dBm, and re-calibrate the Network Analyzer.
7. Terminate the RF input, the IF output, and the unused LO port in 50Ω. Measure return losses of the LO input ports.

### RF PERFORMANCE MEASUREMENTS

1. Connect all test equipment as shown in Figure 6 with the signal generators and the DC power supply turned off.
2. Increase VCC supply voltage to 3.3V, and verify that the current consumption is approximately 192mA with the LO signal applied. The supply voltage should be confirmed at the

demo board VCC and GND terminals to account for lead ohmic losses.

3. Set the LO source (Signal Generator 1) to provide a 0dBm, CW signal to the selected demo board LO input port at appropriate LO frequency.
4. Set the RF sources (Signal Generators 2 and 3) to provide two -3dBm CW signals, 2MHz apart, to the demo board RF input port at the appropriate RF frequency.
5. Measure the resulting IF output on the Spectrum Analyzer:
  - a. The wanted two-tone IF output signals are at:
 
$$f_{IF1} = f_{RF1} - f_{LO}, \text{ and}$$

$$f_{IF2} = f_{RF2} - f_{LO} \text{ for low-side LO,}$$
 and
 
$$f_{IF1} = f_{LO} - f_{RF1}, \text{ and}$$

$$f_{IF2} = f_{LO} - f_{RF2} \text{ for high-side LO}$$
  - b. The 3rd order intermodulation products which are closest to the wanted IF signals are used to calculate the Input 3rd Order Intercept:
 
$$f_{IM3,1} = f_{RF1} - f_{LO} - \Delta_{IF}, \text{ and}$$

$$f_{IM3,2} = f_{RF2} - f_{LO} + \Delta_{IF} \text{ for low-side LO,}$$
 and
 
$$f_{IM3,1} = f_{LO} - f_{RF1} + \Delta_{IF}, \text{ and}$$

$$f_{IM3,2} = f_{LO} - f_{RF2} - \Delta_{IF} \text{ for high-side LO}$$
 Where  $\Delta_{IF} = f_{RF2} - f_{RF1}$ .
6. Calculate Input 3rd Order Intercept:
 
$$IIP3 = (\Delta_{IM3})/2 + P_{RF}$$

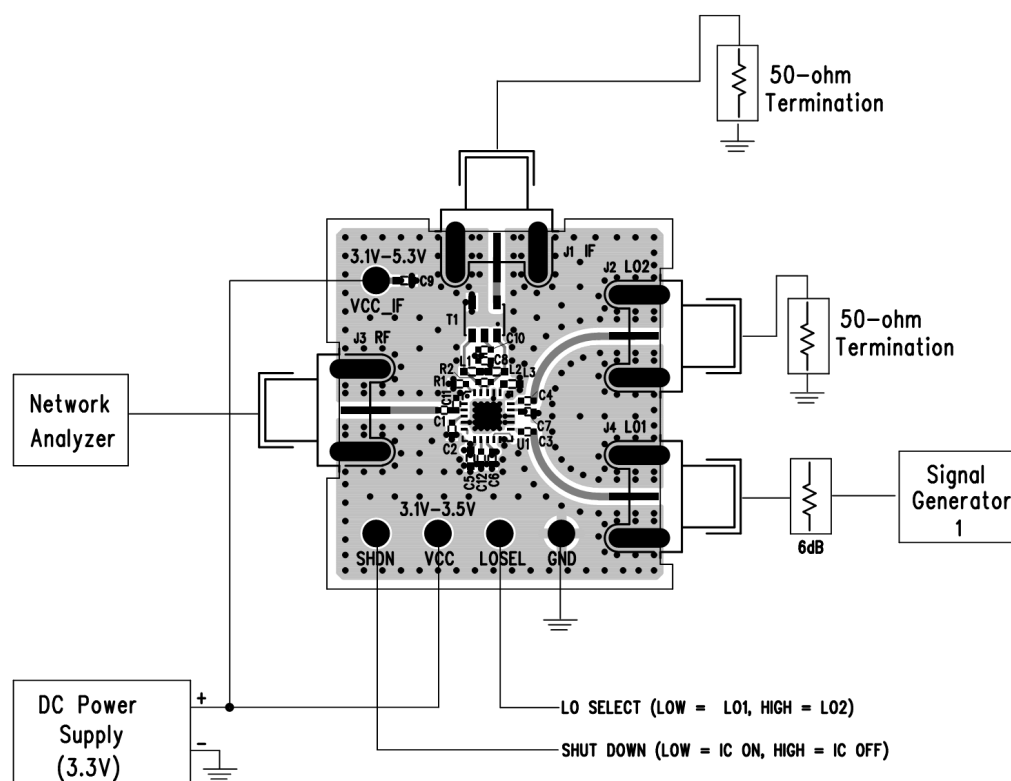
Where  $\Delta_{IM3} = P_{IF} - P_{IM3}$ .  $P_{IF}$  is the lowest IF output signal power at either  $f_{IF1}$  or  $f_{IF2}$ .  $P_{IM3}$  is the highest 3rd order intermodulation product power at either  $f_{IM3,1}$  or  $f_{IM3,2}$ .  $P_{RF}$  is the per-tone RF input power.

7. Turn off one of the RF signal generators, and measure Conversion Gain, RF to IF isolation, LO to IF leakage, and Input 1dB compression point.



## NOISE FIGURE MEASUREMENT

- ## NOISE FIGURE MEASUREMENT
1. Configure and calibrate the noise figure meter for mixer measurements.
  2. Connect all test equipment as shown in Figure 7 with the signal generator and the DC power supply turned off.
  3. Increase VCC supply voltage to 3.3V, and verify that the current consumption is approximately 192mA with the LO signal applied. The supply voltage should be confirmed at the demo board VCC and GND terminals to account for lead ohmic losses.
  4. Measure the single-sideband noise figure.



**Figure 5. Proper Equipment Setup for Return Loss Measurements**

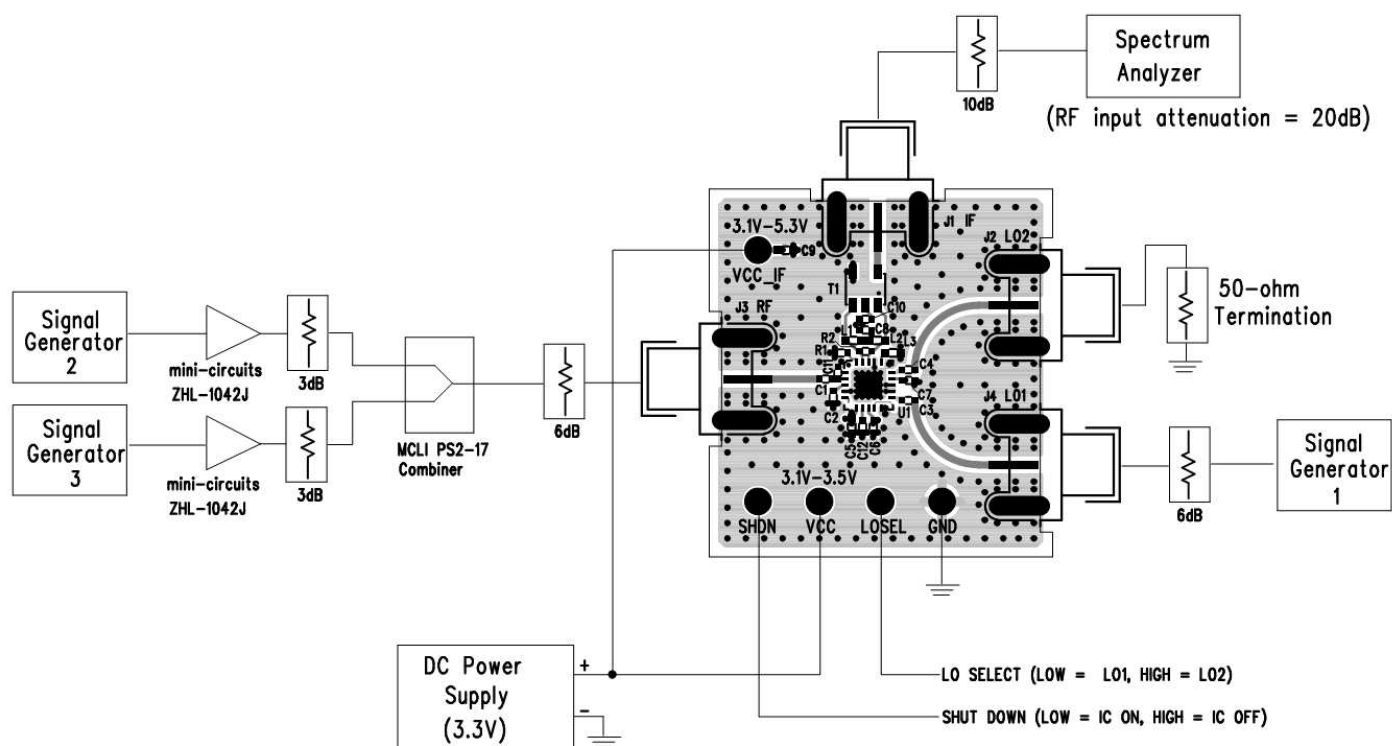


Figure 6. Proper Equipment Setup for RF Performance Measurements

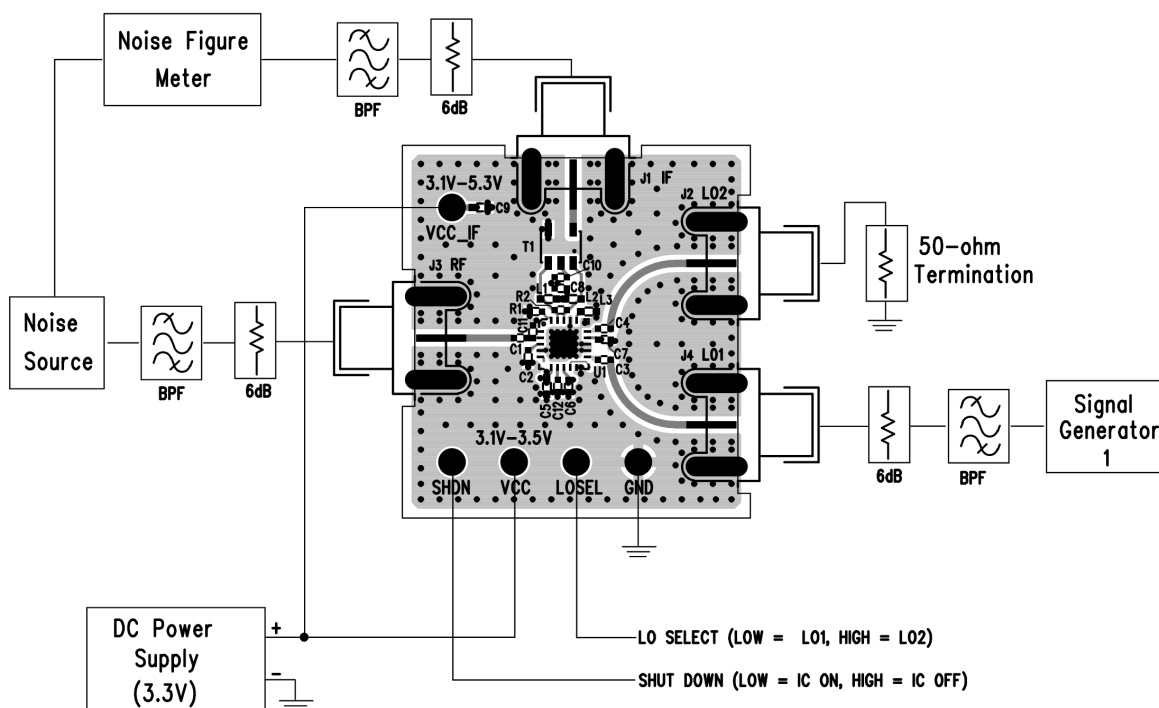


Figure 7. Proper Equipment Setup for Noise Figure Measurement



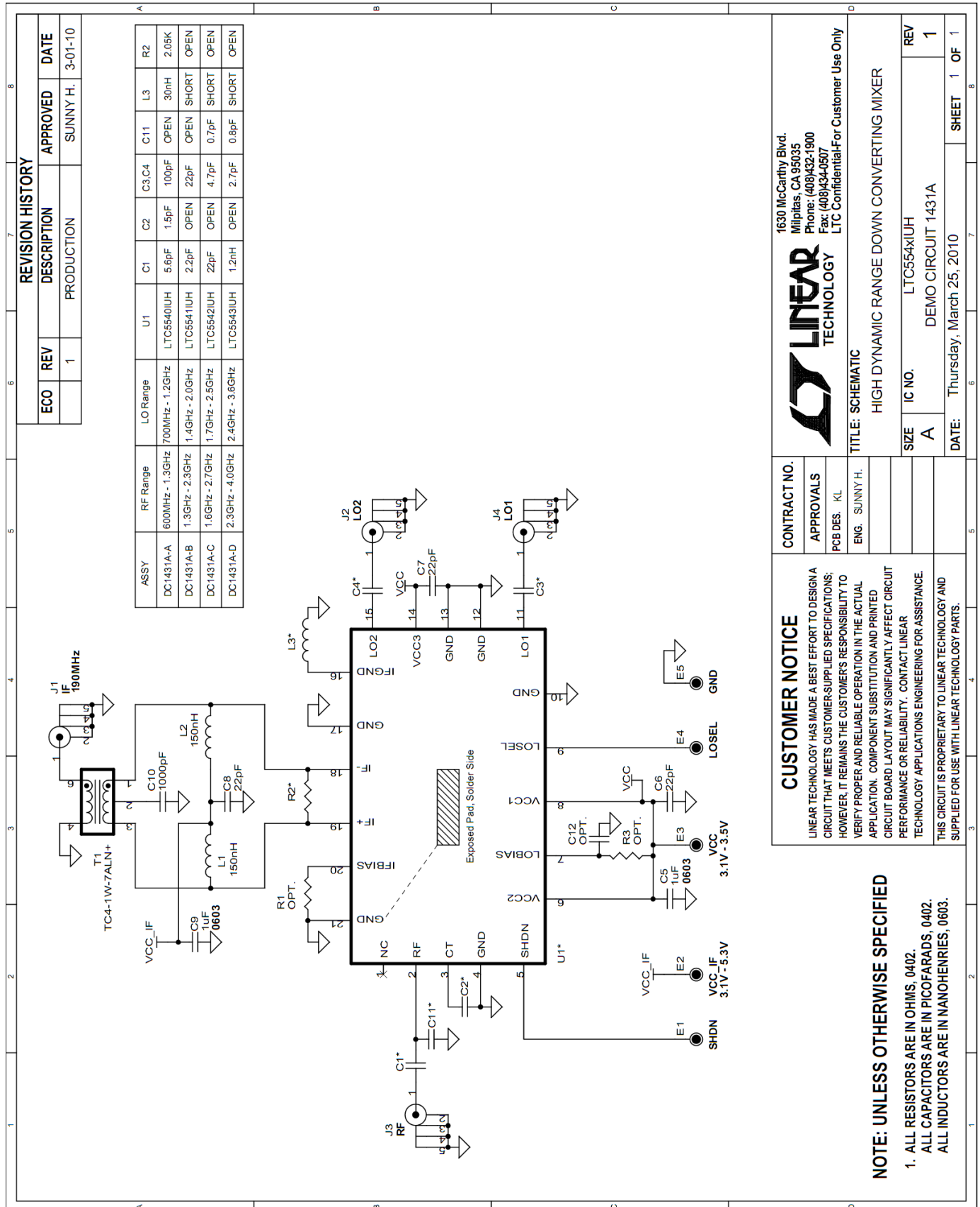


Figure 8. Demonstration Circuit schematic

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TITLE: SCHEMATIC  
 HIGH DYNAMIC RANGE DOWN CONVERTING MIXER

SIZE	IC NO.	REV
A	LTC554xIUH	1
DATE:	DEMO CIRCUIT 1431A	
Thursday, March 25, 2010		
SHEET	1	OF 1

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