

LTC5544

4GHz to 6GHz High Dynamic Range Downconverting Mixer

DESCRIPTION

Demonstration circuit 1885A is a 4GHz to 6GHz high dynamic range downconverting mixer featuring the LTC®5544. The LTC5544 is part of a family of high dynamic range, high gain passive downconverting mixers covering the 600MHz to 6GHz frequency range. **The demo circuit 1885A and the LTC5544 are optimized for 4GHz to 6GHz RF applications. The LO frequency must fall within the 4.2GHz to 5.8GHz range for optimum performance.**

The LTC5544 is designed for 3.3V operation, however the IF amplifier can be powered with 5V for the highest P1dB.

The LTC5544's high level of integration minimizes the total solution cost, board space and system-level variation, while providing the highest dynamic range for demanding receiver applications.

High Dynamic Range Downconverting Mixer Family

DEMO NUMBER	IC PART NUMBER	RF RANGE	LO RANGE
DC1431A-A	LTC5540	600MHz to 1.3GHz	700MHz to 1.2GHz
DC1431A-B	LTC5541	1.3GHz to 2.3GHz	1.4GHz to 2.0GHz
DC1431A-C	LTC5542	1.6GHz to 2.7GHz	1.7GHz to 2.5GHz
DC1431A-D	LTC5543	2.3GHz to 4GHz	2.4GHz to 3.6GHz
DC1885A	LTC5544	4GHz to 6GHz	4.2GHz to 5.8GHz

Design files for this circuit board are available at <http://www.linear.com/demo>

LT, LTC, LTM, µModule, Linear Technology and the Linear logo are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.

PERFORMANCE SUMMARY $T_C = 25^\circ\text{C}$, $V_{CC} = V_{CC_IF} = 3.3\text{V}$, $\text{SHDN} = \text{Low}$, $P_{LO} = 2\text{dBm}$, $P_{RF} = -3\text{dBm}$ ($\Delta f = 2\text{MHz}$, -3dBm/tone for two-tone tests), unless otherwise noted. (Note 1)

PARAMETER	CONDITIONS	VALUE	UNITS
VCC Supply Voltage Range		3.1 to 3.5	V
VCC_IF Supply Voltage Range		3.1 to 5.3	V
Total Supply Current ($V_{CC} + V_{CC_IF}$)		194	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
LO Input Frequency Range		4.2 to 5.8	GHz
LO Input Return Loss	$Z_0 = 50\Omega$, $f_{LO} = 4.2\text{GHz to } 5.8\text{GHz}$	> 12	dB
LO Input Power Range	$f_{LO} = 4.2\text{GHz to } 5.8\text{GHz}$	-1 to 5	dBm
RF Input Frequency Range	Low Side LO High Side LO	4.2 to 6.0 4.0 to 5.8	GHz GHz
RF Input Return Loss	$Z_0 = 50\Omega$, $f_{RF} = 4.2\text{GHz to } 6\text{GHz}$	> 12	dB
IF Output Frequency	Can be Rematched to Other Frequencies.	240	MHz
IF Output Return Loss		> 12	dB
LO to RF Leakage	$f_{LO} = 4.2\text{GHz to } 5.8\text{GHz}$, Requires C2	< -30	dBm
LO to IF Leakage	$f_{LO} = 4.2\text{GHz to } 5.8\text{GHz}$	< -21	dBm
RF to LO Isolation	$f_{RF} = 4\text{GHz to } 6\text{GHz}$	> 38	dB
RF to IF Isolation	$f_{RF} = 4\text{GHz to } 6\text{GHz}$	> 29	dB

DEMO MANUAL DC1885A

PERFORMANCE SUMMARY $T_C = 25^\circ\text{C}$, $V_{CC} = V_{CC_IF} = 3.3\text{V}$, $\text{SHDN} = \text{Low}$, $P_{LO} = 2\text{dBm}$, $P_{RF} = -3\text{dBm}$ ($\Delta f = 2\text{MHz}$, $-3\text{dBm}/\text{tone}$ for two-tone tests), unless otherwise noted. (Note 1)

PARAMETER	CONDITIONS	VALUE	UNITS
Low Side LO Downmixer Application: RF = 4.2GHz to 6GHz, IF = 240MHz, $f_{LO} = f_{RF} - f_{IF}$			
Conversion Gain	RF = 4900MHz	7.9	dB
	RF = 5250MHz	7.4	dB
	RF = 5800MHz	6.4	dB
2-Tone Input 3rd Order Intercept	RF = 4900MHz	25.4	dBm
	RF = 5250MHz	25.9	dBm
	RF = 5800MHz	25.8	dBm
2-Tone Input 2nd Order Intercept	$f_{RF1} = 5371\text{MHz}$, $f_{RF2} = 5130\text{MHz}$, $f_{LO} = 5010\text{MHz}$, $f_{IM2} = f_{RF1} - f_{RF2}$	43.2	dBm
SSB Noise Figure	RF = 4900MHz	10.3	dB
	RF = 5250MHz	11.3	dB
	RF = 5800MHz	12.8	dB
SSB Noise Figure Under Blocking	$f_{RF} = 5250\text{MHz}$, $f_{LO} = 5010\text{MHz}$, $f_{BLOCK} = 4910\text{MHz}$, $P_{BLOCK} = 5\text{dBm}$	16.9	dB
2RF – 2LO Output Spurious Product ($f_{RF} = f_{LO} + f_{IF}/2$)	$f_{RF} = 5130\text{MHz}$ at -10dBm , $f_{LO} = 5010\text{MHz}$	-58.3	dBc
3RF – 3LO Output Spurious Product ($f_{RF} = f_{LO} + f_{IF}/3$)	$f_{RF} = 5090\text{MHz}$ at -10dBm , $f_{LO} = 5010\text{MHz}$	-77	dBc
Input 1dB Compression	RF = 5250MHz, $V_{CC_IF} = 3.3\text{V}$	11.4	dBm
	RF = 5250MHz, $V_{CC_IF} = 5\text{V}$	14.6	dBm
High Side LO Downmixer Application: RF = 4GHz to 5.8GHz, IF = 240MHz, $f_{LO} = f_{RF} + f_{IF}$			
Conversion Gain	RF = 4500MHz	8.0	dB
	RF = 4900MHz	7.7	dB
	RF = 5250MHz	7.3	dB
2-Tone Input 3rd Order Intercept	RF = 4500MHz	24.2	dBm
	RF = 4900MHz	25.1	dBm
	RF = 5250MHz	24.0	dBm
2-Tone Input 2nd Order Intercept	$f_{RF1} = 4779\text{MHz}$, $f_{RF2} = 5020\text{MHz}$, $f_{LO} = 5140\text{MHz}$, $f_{IM2} = f_{RF2} - f_{RF1}$	39.8	dBm
SSB Noise Figure	RF = 4500MHz	10.7	dB
	RF = 4900MHz	11.0	dB
	RF = 5250MHz	11.7	dB
2LO – 2RF Output Spurious Product ($f_{RF} = f_{LO} - f_{IF}/2$)	$f_{RF} = 5020\text{MHz}$ at -10dBm , $f_{LO} = 5140\text{MHz}$	-55	dBc
3LO – 3RF Output Spurious Product ($f_{RF} = f_{LO} - f_{IF}/3$)	$f_{RF} = 5060\text{MHz}$ at -10dBm , $f_{LO} = 5140\text{MHz}$	-75	dBc
Input 1dB Compression	RF = 4900MHz, $V_{CC_IF} = 3.3\text{V}$	11.3	dBm
	RF = 4900MHz, $V_{CC_IF} = 5\text{V}$	14.5	dBm

Note 1: Subject to change without notice. Refer to the latest LTC5544 data sheet for most-up-to-date specifications.

DETAILED DESCRIPTION

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.

Supply Voltage (VCC).....	4.0V
IF Supply Voltage (VCC_IF).....	5.5V
Shutdown Voltage (SHDN).....	–0.3V to VCC + 0.3V
LO Input Power (4GHz to 6GHz).....	9dBm
RF Input Power (4GHz to 6GHz).....	15dBm
Operating Temperature Range (T _C).....	–40°C to 105°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_IF turrets. Instead, make all necessary connections with power supplies turned off, and 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 500μA. 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

RF Input

The RF input of Demonstration Circuit 1885A is matched to 50Ω from 4.2GHz to 6GHz with better than 12dB return loss. **For the RF input to be matched, the 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 LTC5544's LO amplifiers are optimized for the 4.2GHz to 5.8GHz LO frequency range. LO frequencies above and below this frequency range may be used with degraded performance.

The nominal LO input level is 2dBm. The LO input power range is between –1dBm and 5dBm.

IF Output

Demonstration Circuit 1885A features a single-ended, 50Ω-matched IF output for 240MHz. The impedance matching is realized with a bandpass topology using an IF transformer as shown in Figure 1.

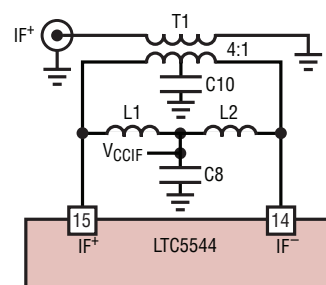


Figure 1. IF Output with Bandpass Matching

Demonstration Circuit 1885A can be easily reconfigured for other IF frequencies by simply replacing inductors L1 and L2. L1 and L2 values for several common IF frequencies are presented in Table 3, and return losses are plotted in Figure 2.

Table 3. L1, L2 vs IF Frequencies

IF FREQUENCY (MHz)	L1, L2 (nH)
140	220
190	150
240	150
305	82
380	56
456	39

DETAILED DESCRIPTION

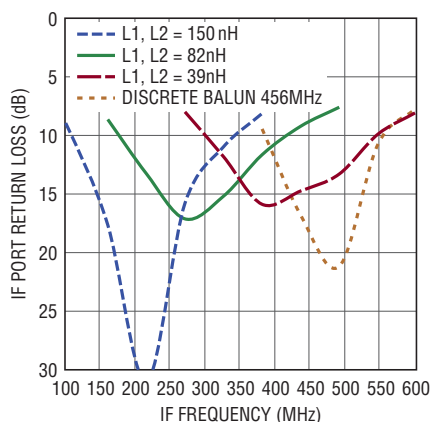


Figure 2. IF+ Port Output Return Loss

For many applications, it is possible to replace the IF transformer with the discrete IF Balun shown in Figure 3. See the LTC5544 data sheet for details.

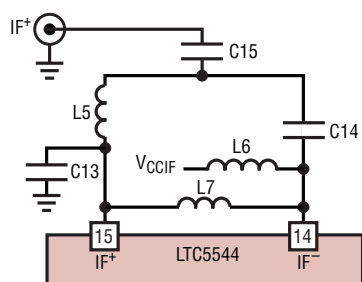


Figure 3. IF Output with Discrete IF Balun Matching

Demonstration Circuit 1885A's IF output can be converted to discrete IF Balun matching with minimal modifications. Follow the procedures below, and refer to Figure 4.

- Remove existing L1, L2, C4, C5, and T1.
- Install L6 at location L2.
- Install L7 at location R2.
- Install C13 between the pads of L1 and C4.
- Install L5 and C14 on the pads of T1.
- Install C15 across the pads of T1.

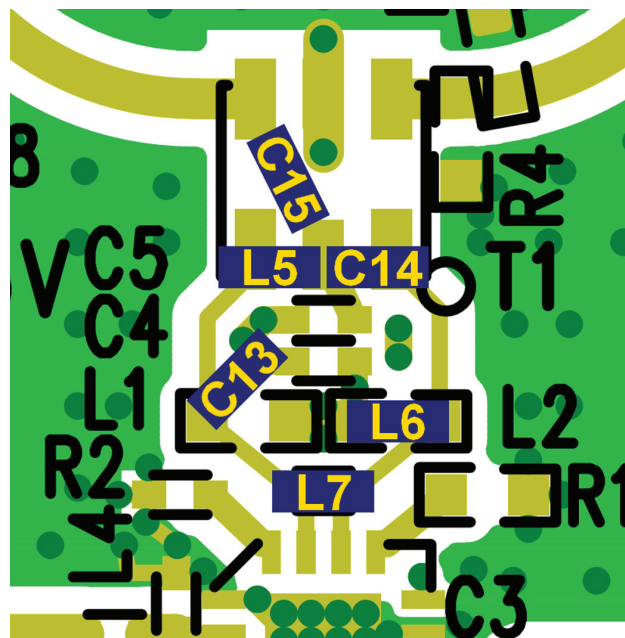


Figure 4. Modifications for Discrete IF Balun Matching

MEASUREMENT EQUIPMENT AND SETUP

The LTC5544 is a high dynamic range downconverting mixer IC with very high input third 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 50Ω 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 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 overdriven. 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 2-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 LTC5544 consists of a high linearity passive double-balanced mixer core and IF buffer amplifier. Due to the bidirectional 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 1885A is easy to set up to evaluate the performance of the LTC5544. 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 2dBm.
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 194mA with the LO signal applied. The supply voltage should be confirmed at the demo board VCC and GND terminals to account for test lead ohmic losses.
5. Set the LO source (Signal Generator 1) to provide a 2dBm, CW signal to the demo board LO input port at appropriate LO frequency.
6. 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.
7. Terminate the RF input and the IF⁺ output ports in 50Ω. Measure return loss of the LO input port.

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 194mA with the LO signal applied. The supply voltage should be confirmed at the demo board VCC and GND terminals to account for test lead ohmic losses.

3. Set the LO source (Signal Generator 1) to provide a 2dBm, CW signal to the 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

$$f_{IM3,1} = f_{LO} - f_{RF1} + \Delta_{IF}, \text{ and}$$

$$f_{IM3,2} = f_{LO} - f_{RF2} - \Delta_{IF} \text{ for high side LO}$$

$$\text{where } \Delta_{IF} = f_{RF2} - f_{RF1}$$

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.

QUICK START PROCEDURE

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 194mA with the LO signal applied. The supply voltage should be confirmed at the demo board VCC and GND terminals to account for test lead ohmic losses.
4. Set the LO source (Signal Generator 1) to provide a 2dBm, CW signal to the demo board LO input port at appropriate LO frequency.
5. Measure the single-sideband noise figure.

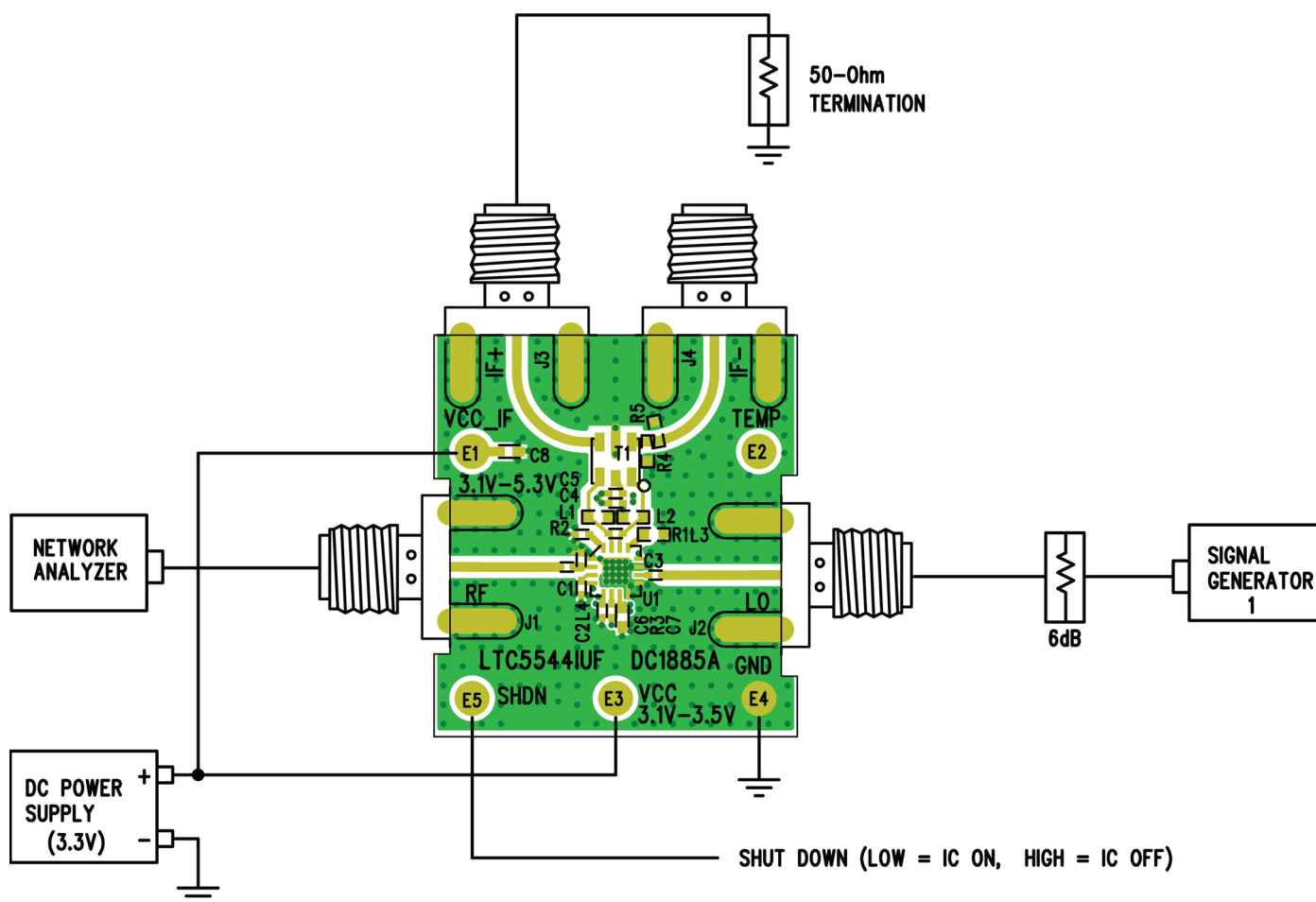


Figure 5. Proper Equipment Setup for Return Loss Measurements

QUICK START PROCEDURE

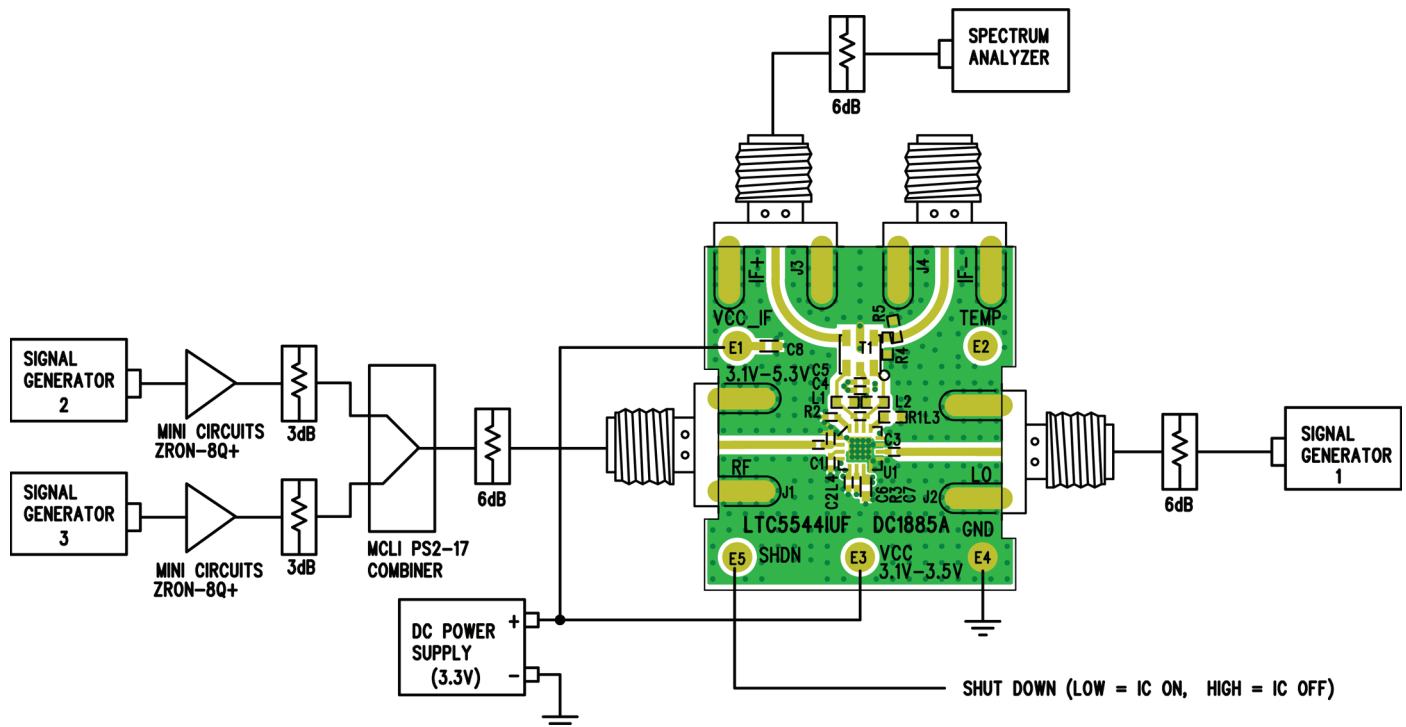


Figure 6. Proper Equipment Setup for RF Performance Measurements

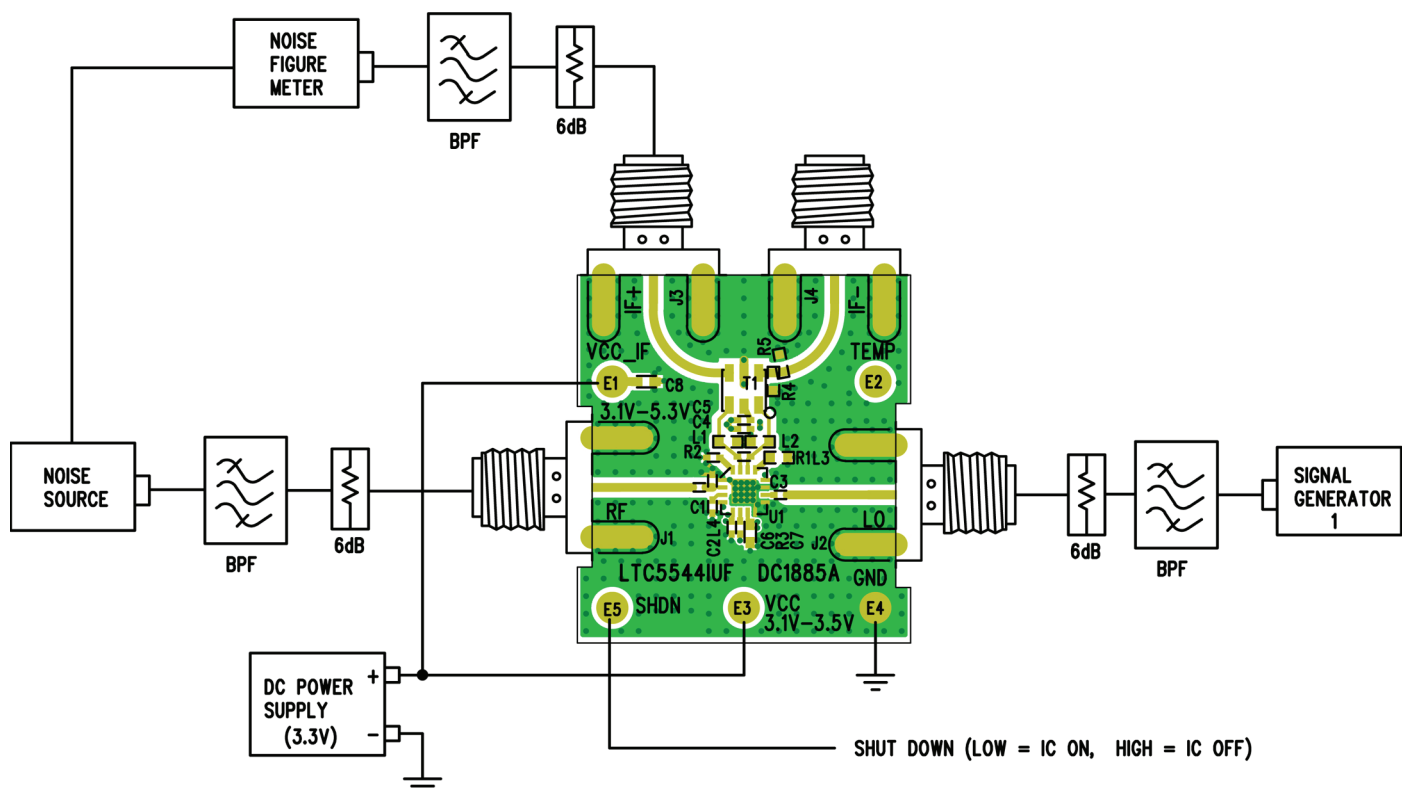
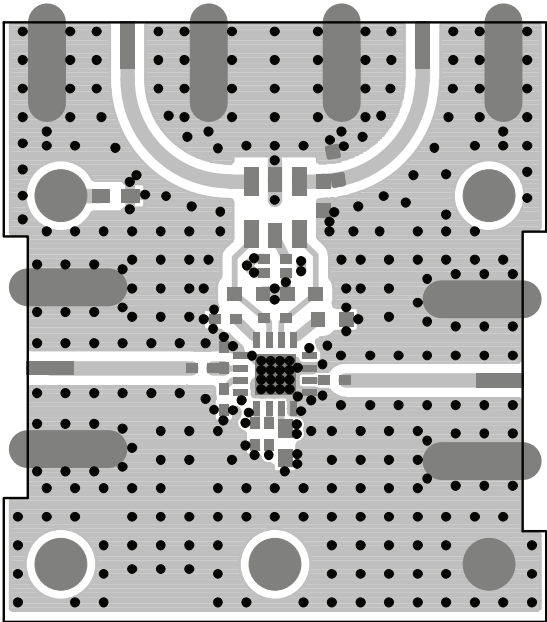


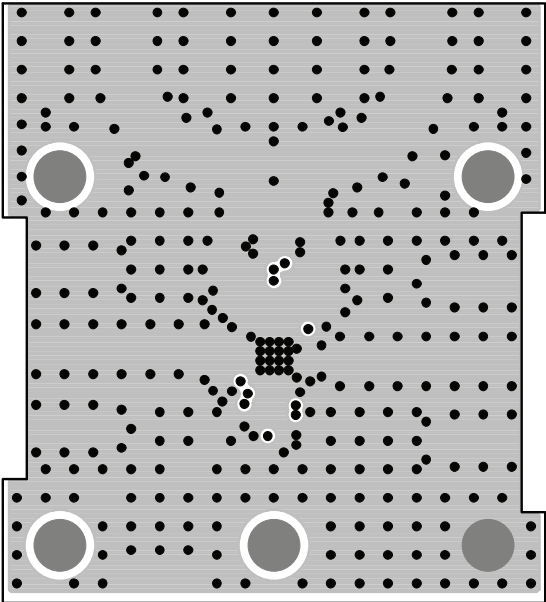
Figure 7. Proper Equipment Setup for Noise Figure Measurement

PCB LAYOUT

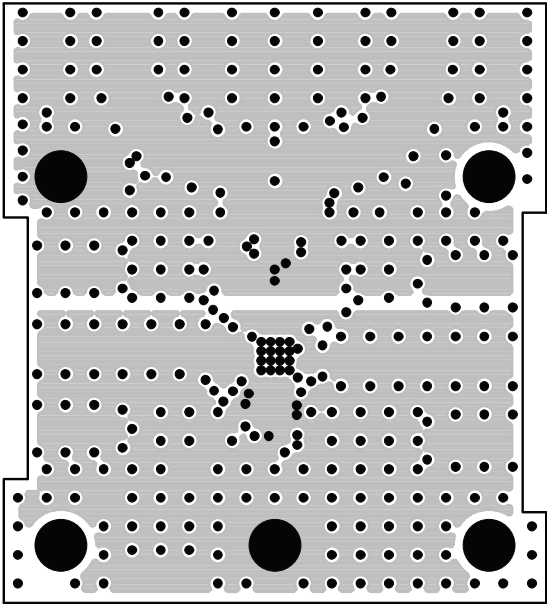
Top Layer



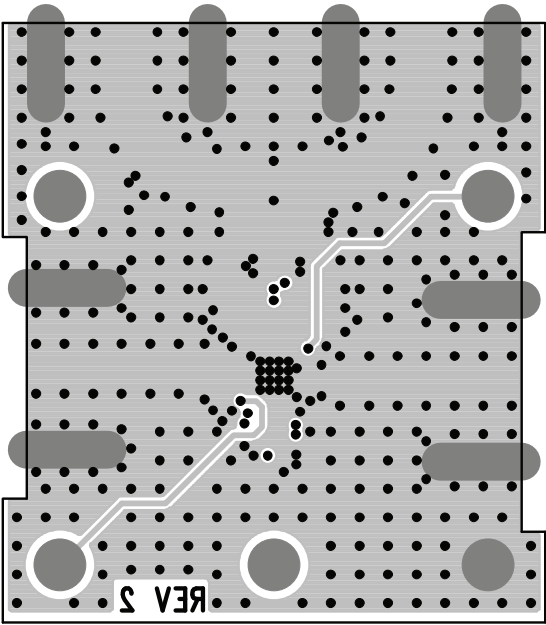
Ground Plane



Power Plane



Bottom Layer



DEMO MANUAL DC1885A

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
1	1	C1	CAP, THIN-FILM, 0.6pF, ± 0.03 pF, 25V, 0402	AVX, 04023J0R6QBS
2	1	C3	CAP, THIN-FILM, 1.2pF, ± 0.05 pF, 25V, 0402	AVX, 04023J1R2ABS
3	2	C4, C6	CAP, COG, 22pF, $\pm 1\%$, 50V, 0402	AVX, 04025A220FAT
4	1	C5	CAP, X7R, 1000pF, $\pm 5\%$, 50V, 0402	AVX, 04025C102JAT
5	2	C7, C8	CAP, X5R, 1 μ F, $\pm 10\%$, 10V, 0603	AVX, 0603ZD105KAT
6	0	C2, R1, R2, R3	OPT, 0402	
7	5	E1, E2, E3, E4, E5	TURRET, PAD 0.061"	MILL-MAX, 2308-2-00-80-00-00-07-0
8	4	J1, J2, J3, J4	CONN., SMA 50 Ω EDGE-LAUNCH	E.F. JOHNSON, 142-0701-851
9	2	L1, L2	IND., WIRE-WOUND, 150nH, $\pm 2\%$, 0603	COILCRAFT, 0603CS-R15XGLU
10	3	L3, R4, R5	RES., CHIP, 0 Ω , 0603	VISHAY, CRCW06030000Z0EA
11	1	L4	IND., WIRE-WOUND, 2.2nH, $\pm 5\%$, 0402	COILCRAFT, 0402HP-2N2XJLU
12	1	T1	TRANSFORMER, SMT, RF WIDEBAND, 4:1	MINI-CIRCUITS, TC4-1W-7ALN+
13	1	U1	IC., LINEAR TECHNOLOGY, LTC5544IUF, QFN 4x4	LINEAR TECHNOLOGY, LTC5544IUF#PBF
14	1		FAB, PRINTED CIRCUIT BOARD	DEMO CIRCUIT 1885A



DEMO MANUAL DC1885A

DEMONSTRATION BOARD IMPORTANT NOTICE

Linear Technology Corporation (LTC) provides the enclosed product(s) under the following **AS IS** conditions:

This demonstration board (DEMO BOARD) kit being sold or provided by Linear Technology is intended for use for **ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY** and is not provided by LTC for commercial use. As such, the DEMO BOARD herein may not be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including but not limited to product safety measures typically found in finished commercial goods. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may or may not meet the technical requirements of the directive, or other regulations.

If this evaluation kit does not meet the specifications recited in the DEMO BOARD manual the kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY THE SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THIS INDEMNITY, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user releases LTC from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge. Also be aware that the products herein may not be regulatory compliant or agency certified (FCC, UL, CE, etc.).

No License is granted under any patent right or other intellectual property whatsoever. **LTC assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or any other intellectual property rights of any kind.**

LTC currently services a variety of customers for products around the world, and therefore this transaction **is not exclusive**.

Please read the DEMO BOARD manual prior to handling the product. Persons handling this product must have electronics training and observe good laboratory practice standards. **Common sense is encouraged.**

This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact a LTC application engineer.

Mailing Address:

Linear Technology
1630 McCarthy Blvd.
Milpitas, CA 95035

Copyright © 2004, Linear Technology Corporation

dc1885af