

# QUICK START GUIDE FOR DEMONSTRATION CIRCUIT 1545A-X 400MHz TO 2.7GHz HIGH LINEARITY UPCONVERTING MIXER

## LT5578

### DESCRIPTION

Demonstration circuit 1545A-x is a high linearity up-converting mixer featuring the LT5578.

The LT<sup>®</sup>5578 is a high performance upconverting mixer IC optimized for output frequencies in the 400MHz to 2.7GHz range. It features single-ended LO input and RF output ports to simplify board layout and to reduce system cost.

The LT5578 offers a superior alternative to passive mixers. Unlike passive mixers which have conversion loss and require high LO drive levels, the LT5578 delivers conversion gain at significantly lower LO input levels and is less sensitive to LO power level variations. Only -1dBm of LO power is needed, and the balanced design results in low LO signal leakage to the RF output. The lower LO drive level requirements, combined with the excellent LO leakage performance, translate into lower LO signal contamination of the output signal.

The DC1545A-x series of demonstration circuits are designed for evaluating the LT5578 IC at several common frequency ranges:

| VERSION | APPLICATION | IF INPUT | LO INPUT  | RF OUTPUT |
|---------|-------------|----------|-----------|-----------|
| -A      | PCS         | 240MHz   | High-side | 1950MHz   |
| -B      | GSM         | 140MHz   | Low-side  | 900MHz    |

Demonstration circuit 1545A-x can be easily optimized for operations at other frequencies. Refer to the “Application Note” section and the LT5578 data sheet for details.

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

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**Table 1. Typical Demo Circuit Performance Summary (T<sub>A</sub> = 25°C, V<sub>CC</sub> = 3.3V, P<sub>IF</sub> = -5dBm (-5dBm/tone for 2-tone tests, Δf = 1MHz), P<sub>LO</sub> = -1dBm, unless otherwise noted. Low side LO for 900MHz. High side LO for 1950MHz.)**

| PARAMETER                       | CONDITIONS                         | TYPICAL PERFORMANCE           |                              |
|---------------------------------|------------------------------------|-------------------------------|------------------------------|
|                                 |                                    | 1545A-A<br>PCS (RF = 1950MHz) | 1545A-B<br>GSM (RF = 900MHz) |
| Operating Supply Voltage        |                                    | 3.1V to 3.5V                  |                              |
| Supply Current                  | V <sub>CC</sub> = 3.3V, LO applied | 152mA                         |                              |
| IF Input Frequency Range        | 12dB Return Loss, LO applied       | 175 to 295MHz                 | 98 to 187MHz                 |
| LO Input Frequency Range        | 10dB Return Loss                   | 1450MHz to >3GHz              | 656MHz to 866MHz             |
| LO Input Power                  |                                    | -5 to +2dBm                   | -5 to +2dBm                  |
| RF Output Frequency Range       | 12dB Return Loss, LO applied       | 1733 to 2142MHz               | 830 to 967MHz                |
| Conversion Gain                 |                                    | -0.7dB                        | 1.4dB                        |
| Conversion Gain vs. Temperature | T <sub>A</sub> = -40°C to 85°C     | -0.021dB/°C                   | -0.018dB/°C                  |
| Output 3rd Order Intercept      |                                    | 24.3dBm                       | 27.0dBm                      |
| Output 2nd Order Intercept      | LO ± 2 • IF                        | 58dBm                         | 52dBm                        |
| Single Sideband Noise Figure    |                                    | 10.5dB                        | 8.6dB                        |
| Output Noise Floor              | P <sub>OUT</sub> = -5dBm           | -158dBm/Hz                    | -160.5dBm/Hz                 |
| Output 1dB Compression          |                                    | 10dBm                         | 12dBm                        |
| IF to LO Isolation              |                                    | 60dB                          | 75dB                         |
| LO to IF Leakage                |                                    | -22dBm                        | -40dBm                       |
| LO to RF Leakage                |                                    | -46dBm                        | -43dBm                       |

# QUICK START GUIDE FOR DEMONSTRATION CIRCUIT 1545A-X

## 400MHz TO 2.7GHz HIGH LINEARITY UPCONVERTING MIXER

### APPLICATION NOTE

#### ABSOLUTE MAXIMUM RATINGS

|   |                |
|---|----------------|
| Supply Voltage .....                                | 4V             |
| LO Input Power .....                                | 10dBm          |
| LO Input DC Current .....                           | 30mA           |
| RF Output DC Current .....                          | 45mA           |
| IF Input Power (Differential) .....                 | 18dBm          |
| IF <sup>+</sup> , IF <sup>-</sup> DC Currents ..... | 45mA           |
| T <sub>JMAX</sub> .....                             | 150°C          |
| Operating Temperature Range .....                   | -40°C to 85°C  |
| Storage Temperature Range .....                     | -65°C to 150°C |

#### IF INPUT INTERFACE

The standard demonstration circuit 1545A-x can be re-configured for other IF input frequencies. The details of the matching circuit are omitted in this guide, since the LT5578 datasheet presents in depth explanations and the IC's IF input differential impedance. Matching component values for several common IF input frequencies are listed in Table 2 and their return losses are plotted in Figure 1. Refer to the demonstration circuit schematic in Figure 7.

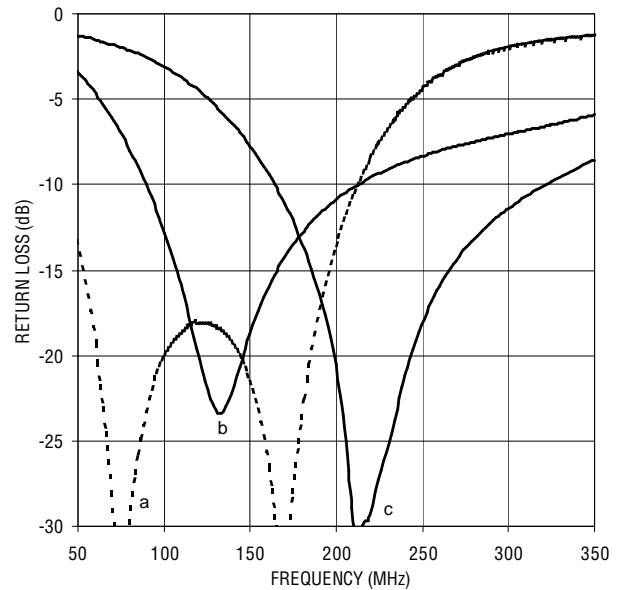
**Table 2. IF Input Component Values**

| IF Freq.<br>(MHz) | C1, C2<br>(pF) | C9 (1)<br>(pF) | C3 (2)<br>(pF) | TL1,<br>TL2(3)      | MATCH BW<br>(at 12dB RL) |
|-------------------|----------------|----------------|----------------|---------------------|--------------------------|
| 70                | 560            | 82             | -              | 3.3nH               | 50-215                   |
| 140               | 220            | 39             | -              | Z <sub>0</sub> =70Ω | 98-187                   |
| 240               | 82             | 33             | 4.7            | Z <sub>0</sub> =70Ω | 175-295                  |

#### NOTE:

- Center of C9 is 3mm from the edge of the IC package for all cases.
- C3 is a small-valued capacitor used to improve the LO-RF leakage in some applications, and it has little effect on impedance matching. C3's value and location depend on IF, LO, and RF frequencies and are determined experimentally. In certain instances, two common-mode capacitors to ground instead of one single differential capacitor may provide better leakage suppression.

- The 70Ω microstrip transmission line TL1 and TL2 provide inductances required for matching. At lower frequencies, external inductors are necessary.
- R1 and R2 (13.7Ω) set the DC current in the mixer core to the optimum level of 40mA per side. They should be well matched for best LO leakage performance. 0.1% tolerance is recommended.
- L1 and L2 reduce the loading effect of R1 and R2. Their impedances should be at least several times greater than the IF input impedance at the desired IF frequency. The inductors' self-resonant frequency should be at least several times the IF frequency. High quality wire-wound type inductors are recommended. The DC resistances of L1 and L2 need to be accounted for in the selection of R1 and R2.



**Figure 1. IF Input Return Loss with 70MHz (a), 140MHz (b), and 240MHz (c) matching**

# QUICK START GUIDE FOR DEMONSTRATION CIRCUIT 1545A-X

## 400MHz TO 2.7GHz HIGH LINEARITY UPCONVERTING MIXER

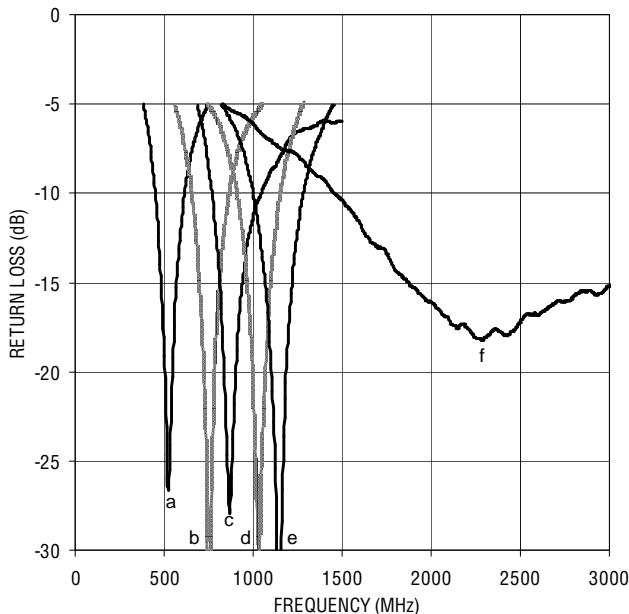
### LO INPUT INTERFACE

The LT5578's LO input port is internally matched from 1.5GHz to beyond 3GHz with better than 10dB return loss. External matching should be used for lower LO frequencies for best performance. Refer to the LT5578 datasheet for more information and impedance data. Matching component values for several common LO input frequencies are listed in Table 3 and their return losses are plotted in Figure 2. Refer to the demonstration circuit schematic in Figure 7.

**Table 3. LO Input Component Values**

| LO Freq. (MHz) | C12 (pF) | Z1 (see note) | C13 (pF) | MATCH BW (at 10dB RL) |
|----------------|----------|---------------|----------|-----------------------|
| 520            | 3.9      | 6.8pF         | -        | 451-615               |
| 760            | -        | 5.6pF         | 2.7      | 656-866               |
| 880            | -        | 2.4pF         | -        | 769-1046              |
| 1040           | 2.2      | 9.1nH         | -        | 910-1152              |
| 1140           | 1.6      | 8.2nH         | -        | 1000-1282             |
| >1500          | -        | 0Ω jumper     | -        | >1454                 |

**NOTE:** Depending on the LO input frequency Z1 can be a capacitor, an inductor, or a 0-ohm jumper.



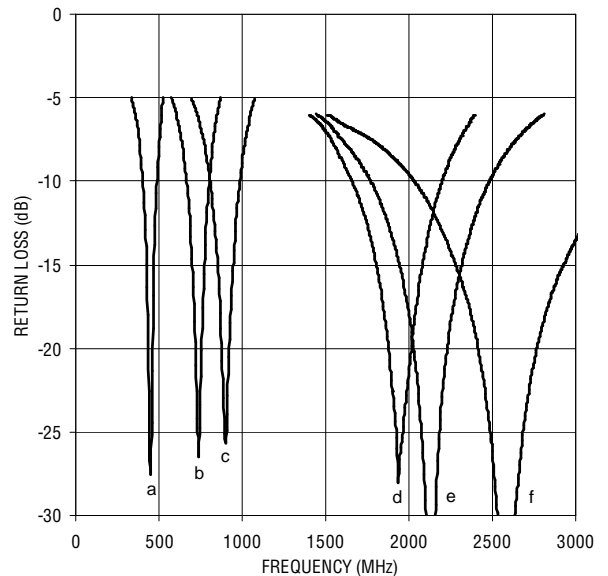
**Figure 2. LO Input Return Loss with 520MHz (a), 760MHz (b), 880MHz (c), 1040MHz (d), 1140MHz (e), and >1500MHz (f) Matching**

### RF OUTPUT INTERFACE

The LT5578 utilizes an internal RF transformer to step down the mixer core output impedance to simply RF output matching. Matching component values for several common RF output frequencies are listed in Table 4 and their return losses are plotted in Figure 3. Refer to the demonstration circuit schematic in Figure 7.

**Table 4. RF Output Component Values**

| RF Freq. (MHz) | C8 (pF) | L3 (nH)   | C14 (pF) | MATCH BW (at 12dB RL) |
|----------------|---------|-----------|----------|-----------------------|
| 450            | 10p     | 22        | -        | 415-480               |
| 740            | 3.3     | 15        | -        | 684-788               |
| 900            | 1.8     | 12        | -        | 830-967               |
| 1950           | -       | 2.4       | 1.5      | 1733-2142             |
| 2140           | -       | 1.5       | 1.2      | 1858-2400             |
| 2600           | -       | 0Ω jumper | 0.7      | 2155-3095             |



**Figure 3. RF Output Return Loss with 450MHz (a), 740MHz (b), 900MHz (c), 1950MHz (d), 2140MHz (e), and 2600MHz (f) Matching**

# QUICK START GUIDE FOR DEMONSTRATION CIRCUIT 1545A-X

## 400MHZ TO 2.7GHZ HIGH LINEARITY UPCONVERTING MIXER

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### TEST EQUIPMENT AND SETUP

The LT5578 is a high linearity upconverting mixer IC. Accuracy of its performance measurement is highly dependent on equipment setup and measurement technique. The following precautions are recommended:

1. Use high performance signal generators with low harmonic output. Otherwise, utilize low-pass filters at the signal generator outputs to suppress higher-order harmonics.
2. Turn off the signal generators' output automatic-level-control (ALC). This prevents conflict in power-level control between the two sources, which can introduce intermodulation products.
3. High quality combiners that provide broadband  $50\Omega$  termination on all ports and have good port-to-port isolation should be used. Attenuators on the outputs of the signal generators are recommended to further improve source isolation to prevent the sources from modulating each other and generating intermodulation products.
4. Beware of the signal generators', and if used, source amplifiers' 1dB compression point. When driven close to their 1dB compression point, the sources and amplifiers may introduce additional distortions.
5. The level of intermodulation products from the input sources needs to be much lower than the products expected to be generated by the DUT. In general, IM products measured at the input connector to the DUT should be 25dB or more below the expected level at the DUT output.
6. If possible, use small 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.
7. 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. The trade off is increased sweep time.
8. Spectrum analyzers can produce significant internal distortion products if they are overdriven. Generally, spectrum analyzers are designed to operate at their best with about  $-30\text{dBm}$  to  $-40\text{dBm}$  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.
9. Before performing measurements on the demo circuit, the system performance should be evaluated to ensure that: 1) clean input signal can be produced, 2) the spectrum analyzer's internal distortion is minimized, 3) the spectrum analyzer has enough dynamic range and sensitivity, and 4) the system is accurately calibrated for power and frequency.

# QUICK START GUIDE FOR DEMONSTRATION CIRCUIT 1545A-X

## 400MHZ TO 2.7GHZ HIGH LINEARITY UPCONVERTING MIXER

### QUICK START PROCEDURE

Demonstration circuit 1545A-x is easy to set up to evaluate the performance of the LT5578. Refer to Figures 4, 5, and 6 for proper measurement equipment connections and follow the procedure below:

**NOTE:** Care should be taken to never exceed absolute maximum input ratings. Observe standard ESD precautions and avoid static discharge.

### RETURN LOSS MEASUREMENTS

1. Configure the Network Analyzer for return loss measurement, set appropriate frequency range, and set the test signal power level to -5dBm.
2. Calibrate the Network Analyzer.
3. Connect all test equipment as shown in Figure 4.
4. Apply 3.3V DC supply power, and verify that the current consumption is approximately 152mA in the presence of LO signal. The supply voltage should be confirmed at the demo board  $V_{CC}$  and GND terminals and adjusted to account for cable ohmic losses.
5. With the LO signal applied, and the unused demo board port terminated in  $50\Omega$ , measure return loss of the IF input and RF output ports.
6. Set the test signal power level to -1dBm, and recalibrate the Network Analyzer.
7. Terminate the IF input and RF output ports in  $50\Omega$ . Measure return loss of the LO input port.

### RF PERFORMANCE MEASUREMENTS

#### Single-tone Measurements

1. Connect all test equipment as shown in Figure 5.
2. Set the LO source (Signal Generator 1) to provide a -1dBm, CW signal to the demo board LO input port at appropriate LO frequency,  $f_{LO}$ .
3. Set the IF source (Signal Generator 2) to provide a -5dBm, CW signals to the demo board IF input port at the appropriate IF frequency,  $f_{IF}$ .

4. The resulting RF output signal is at:

$$f_{OUT} = f_{LO} + f_{IF} \text{ for low-side LO, and}$$

$$f_{OUT} = f_{LO} - f_{IF} \text{ for high-side LO}$$

5. Measure Conversion Gain and LO to RF leakage.

6. Measure Output 2nd Order Intercept:

- a. The 2nd order intermodulation product which is closest to the RF output signal is used to calculate the Output 2nd Order Intercept:

$$f_{IM2} = f_{LO} + 2 \cdot f_{IF} \text{ for low-side LO, and}$$

$$f_{IM2} = f_{LO} - 2 \cdot f_{IF} \text{ for high-side LO}$$

- b. Calculate Output 2nd Order Intercept:

$$OIP2 = 2 \cdot P_{OUT} - P_{IM2}$$

Where  $P_{OUT}$  is the power level of the RF output signal, and  $P_{IM2}$  is the power level of the 2nd order intermodulation product at  $f_{IM2}$ . All units are in dBm.

Alternatively, the output intercept can be calculated using the power difference between the RF output signal and the 2nd order intermodulation product:

$$OIP2 = \Delta_{IM2} + P_{OUT}$$

Where  $\Delta_{IM2} = P_{OUT} - P_{IM2}$ .

7. Measure Output 1dB Compression point by increasing input signal level until the Conversion Gain degrades by 1dB.

### Two-tone Measurements

1. Connect all test equipment as shown in Figure 6.
2. Set the LO source (Signal Generator 1) to provide a -1dBm, CW signal to the demo board LO input port at appropriate LO frequency,  $f_{LO}$ .
3. Set the IF sources (Signal Generators 2 and 3) to provide two -5dBm CW signals, 1MHz apart, to the demo board IF input port at the appropriate IF frequency,  $f_{IF1}$  and  $f_{IF2}$ .
4. Measure Output 3rd Order Intercept:

# QUICK START GUIDE FOR DEMONSTRATION CIRCUIT 1545A-X 400MHZ TO 2.7GHZ HIGH LINEARITY UPCONVERTING MIXER

- a. The 3rd order intermodulation products which are closest to the wanted RF signals are used to calculate the Output 3rd Order Intercept:

$$f_{IM3,1} = f_{LO} + f_{IF1} - \Delta_{IF}, \text{ and}$$

$$f_{IM3,2} = f_{LO} + f_{IF2} + \Delta_{IF} \text{ for low-side LO, and}$$

$$f_{IM3,1} = f_{LO} - f_{IF1} + \Delta_{IF}, \text{ and}$$

$$f_{IM3,2} = f_{LO} - f_{IF2} - \Delta_{IF} \text{ for high-side LO}$$

Where  $\Delta_{IF} = f_{IF2} - f_{IF1}$ .

- b. Calculate Output 3rd Order Intercepts:

$$OIP3 = (3 \cdot P_{OUT} - P_{IM3}) / 2$$

Where  $P_{OUT}$  is the lowest power level of the two wanted output signals at either  $f_{OUT1}$  or  $f_{OUT2}$ , and  $P_{IM3}$  is the largest 3rd order intermodulation product at either  $f_{IM3,1}$  or  $f_{IM3,2}$ . All units are in dBm.

Similarly, the output intercept can be calculated using the power difference between the desired output signal and the intermodulation products:

$$OIP3 = (\Delta_{IM3}) / 2 + P_{OUT}$$

Where  $\Delta_{IM3} = P_{OUT} - P_{IM3}$ .

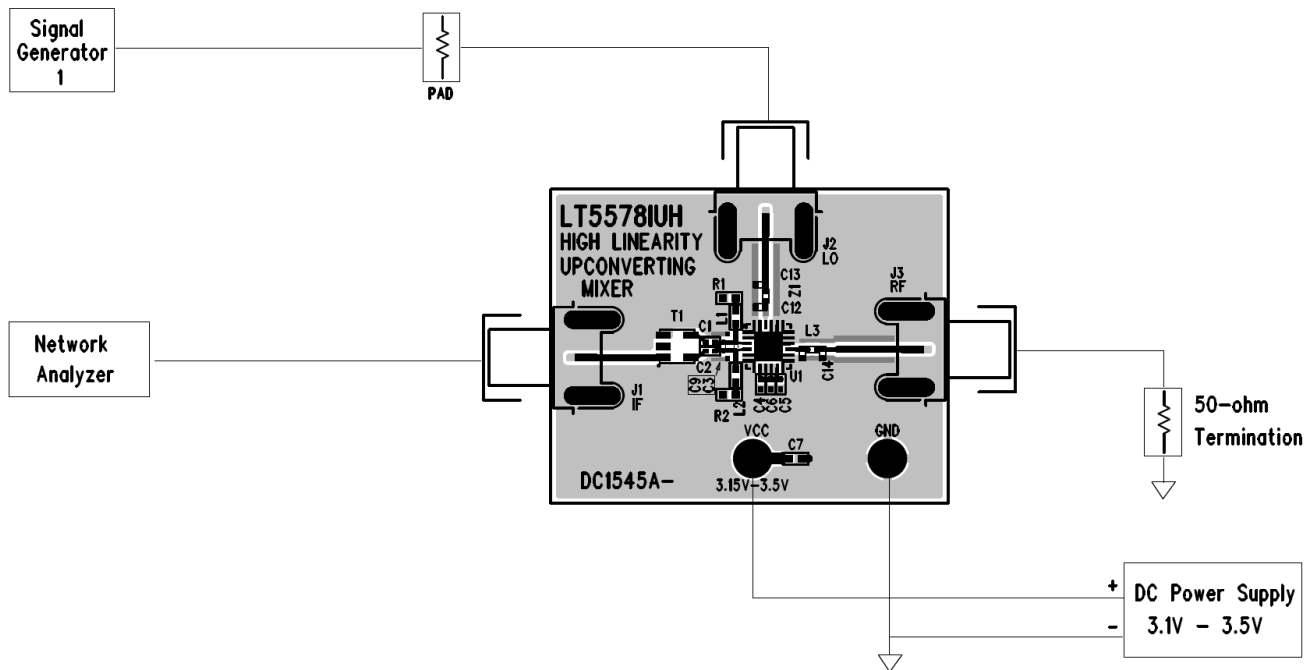


Figure 4. Proper Equipment Setup for Return Loss Measurements

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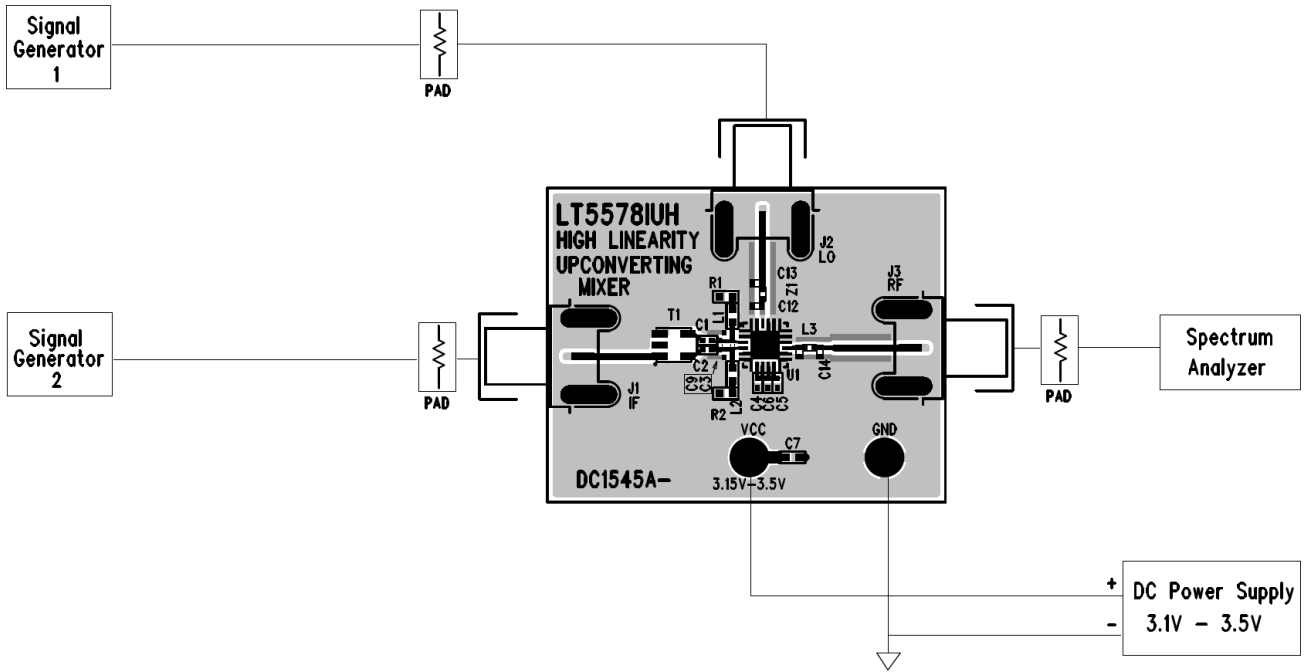


Figure 5. Proper Equipment Setup for Single-tone RF Measurements

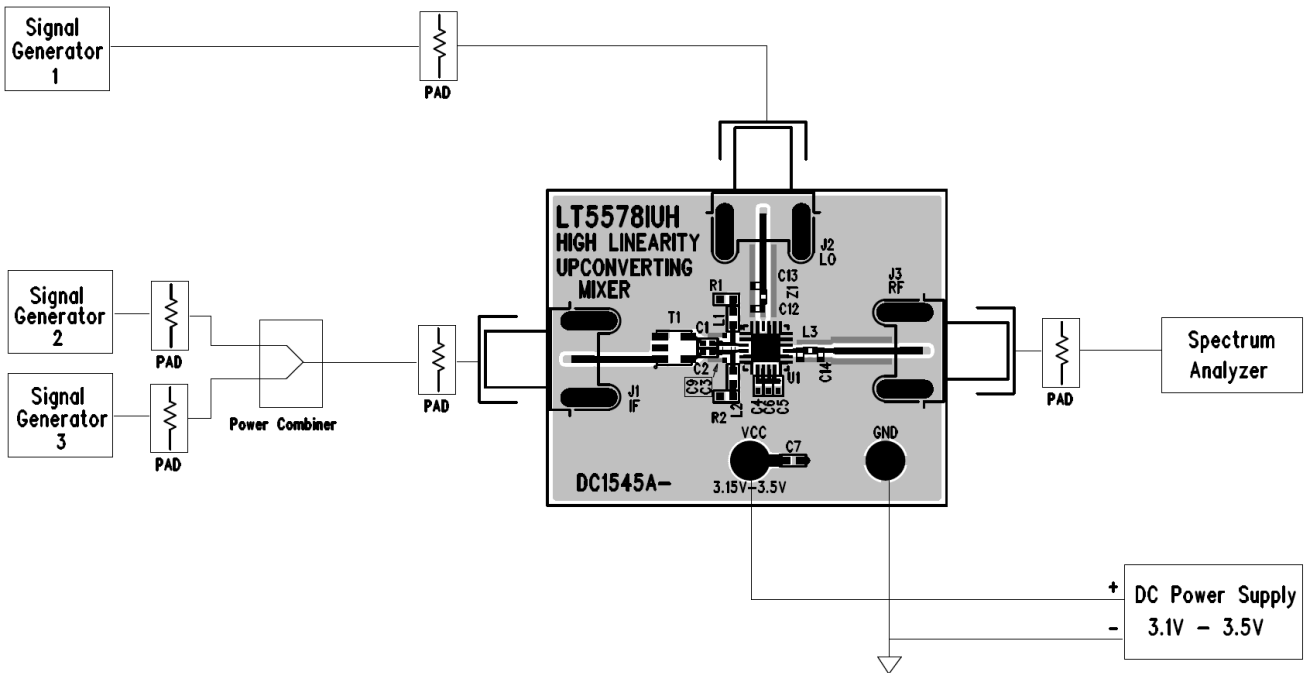


Figure 6. Proper Equipment Setup for Two-tone RF Measurements

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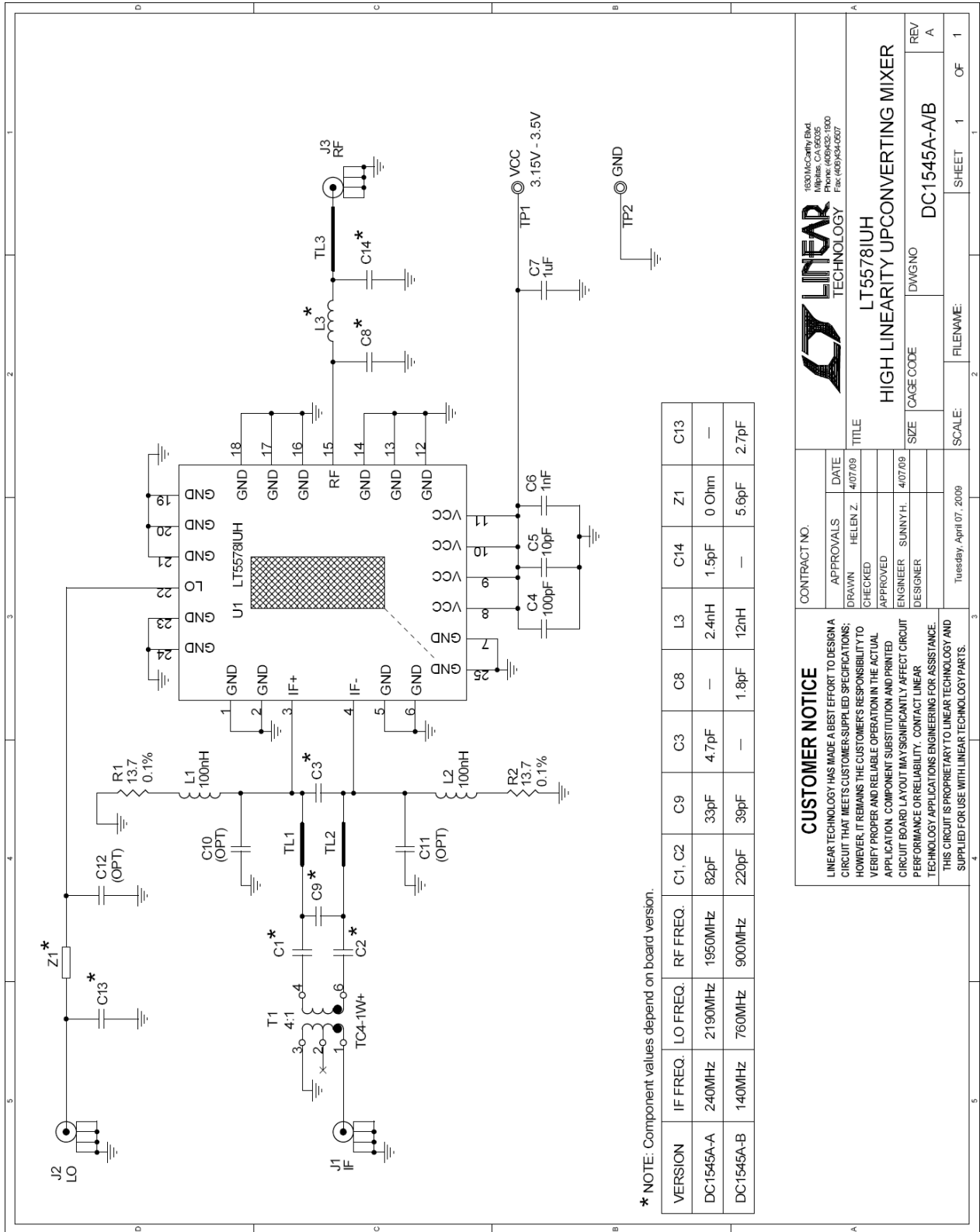


Figure 7. Demonstration Circuit Schematic



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