Active mixer differential to single-ended IF matching

While single-ended RF and LO input ports are becoming standard on high linearity active mixer ICs, integration of the IF output transformer is difficult and can be undesirable. A discrete balun approach delivers good performance over a relatively narrow IF bandwidth when compared to a transformer-based IF matching technique.

By Tom Schiltz

Recent performance improvements in high-linearity active mixers are making them increasingly attractive to wireless and cable infrastructure system designers. Compared to the legacy passive mixer, well-designed high-linearity active mixers offer several advantages including:

- low local oscillator (LO) leakage levels.
- low LO drive levels.
- higher output signal levels.
- smaller solution size.

The low LO leakage is due to the balanced circuit topologies used and to the near-perfect, repeatable symmetry of the integrated circuit (IC) layout.

At ultra high (UHF) and microwave frequencies, low-noise amplifiers (LNAs), filters and voltage-controlled oscillators (VCOs) are typically single-ended. For this reason, early high-linearity active mixers required external transformers for the RF and LO ports, which increased the overall solution size. Now, single-ended 50Ω RF inputs are realized with integrated RF transformers and single-ended LO inputs are enabled by integrated amplifiers that accurately convert single-ended inputs to differential for driving the double-balanced mixer's switching core.

At typical intermediate frequency (IF) output frequencies, surface acoustic wave (SAW) filters, amplifiers and analog to digital converters (ADCs) are available with differential interfaces, thus eliminating the need for an IF transformer.

Many systems, however, require a single-ended IF output. The

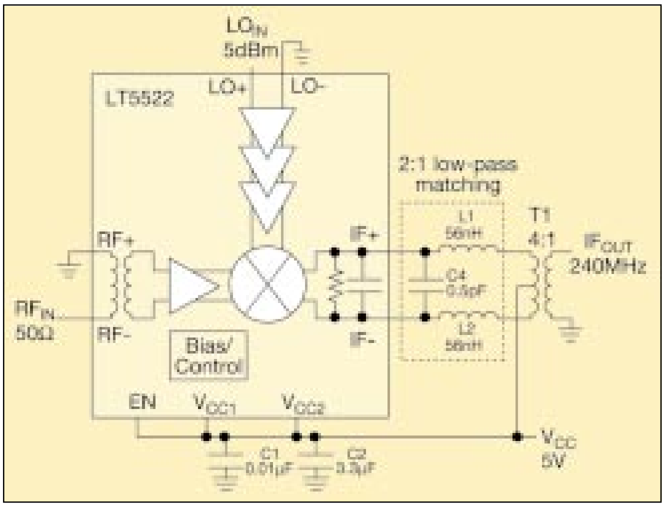

Figure 1. LT5522 downmixer application schematic- IF transformer matching.

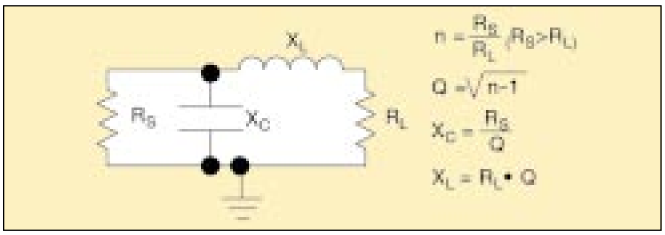

Figure 2. Low-pass impedance transformer.

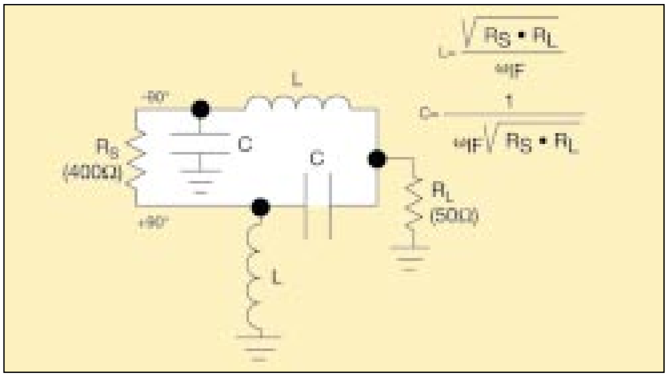

Figure 3. Discrete balun.

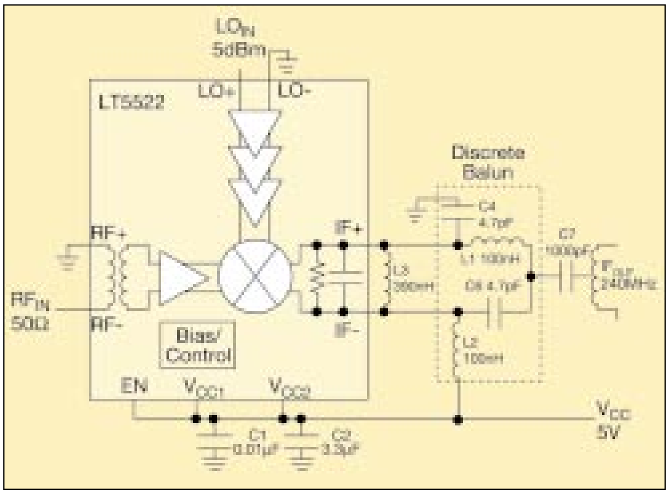

Figure 4. LT5522 downmixer with discrete balun.

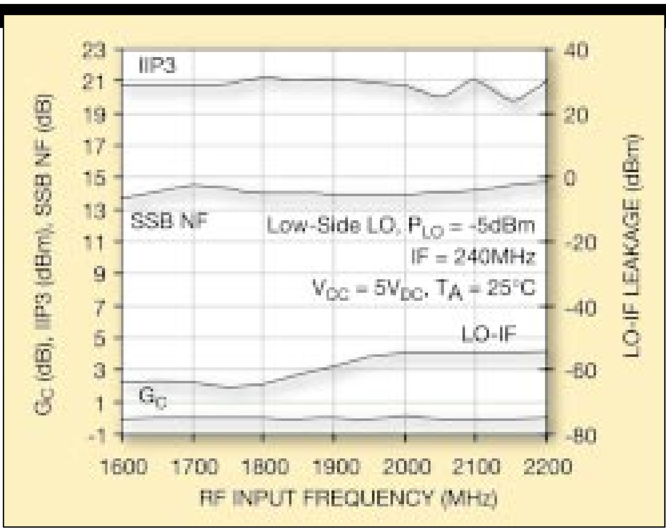

Figure 5. Performance vs. RF frequency-transformer matching.

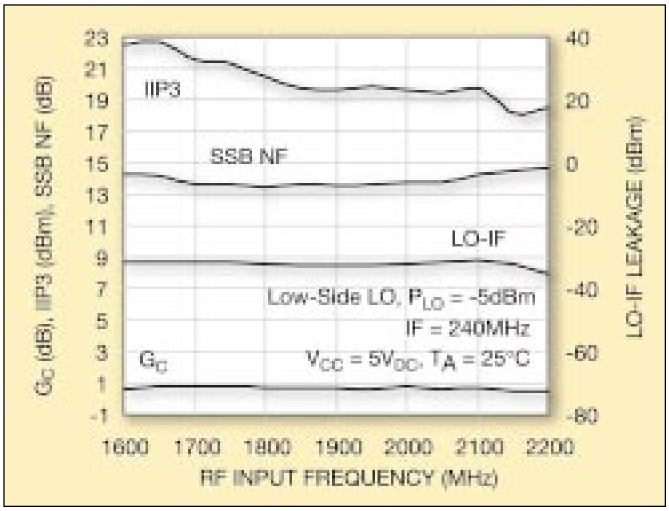

Figure 6. Performance vs. RF frequency—discrete IF balun matching.

transformer used in these applications to perform the differential-to-single-ended conversion is undesirable because of the cost, physical size and manufacturing variability. Integration of an IF output transformer is not practical due to the area required to realize a very high frequency (VHF) transformer on-chip. Internal IF amplifiers that perform the differential-to-single-ended conversion are available in some low-power active mixers but perform poorly in high-linearity applications unless the mixer's output is filtered before IF amplification.

Transformer IF matching

The LT5522 shown in Figure 1 is an example of a high signal level downconverting mixer with an RF input featuring an integrated transformer [1]. Its RF port is internally matched from 1.2 GHz to 2.3 GHz. Operation down to 600 MHz or up to 2.7 GHz is possible with a single shunt component at the RF input. The LO input is internally matched for single-ended 50Ω operation from 400MHz to 2.7GHz. The differential IF output impedance is internally set to 400Ω in parallel with 1 pF. Figure 1 shows a simple, three-element, low-pass IF matching network, consisting of L1, L2 and C4, that transforms the internal 400Ω differential output impedance to 200Ω differential at an IF frequency of 240 MHz. Transformer T1 converts the 200Ω differential IF output to 50Ω single-ended.

Each open-collector IF output draws 15 mA of direct current (DC) bias current, which is provided through the center tap of T1.

The low-pass matching elements shown in Figure 1 are based on the impedance transformer shown in Figure 2. Assuming the use of a 4:1 transformer, the bandwidth of the IF output match is broad, thanks to the low Q (Q=1) of the impedance transformer.

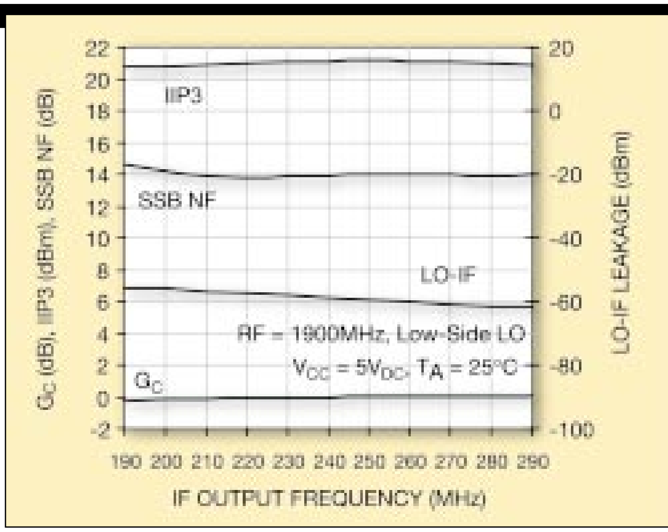

Figure 7. Conversion gain, IIP3, NF and LO-IF leakage vs. IF frequency-transformer matching.

RF=1.9GHz, LO=1.66GHz, IF=240MHz, P_{LO} = -5dBm		
	Transformer IF Matching	Discrete IF Matching
Conversion Gain (dB)	0	0.8
IIP3 (dBm)	21	19.8
SSB Noise Figure (dB)	13.9	13.6
LO-RF Leakage (dBm)	-50	-50
LO-IF Leakage (dBm)	-58	-32

Table 1. LT5522 downmixer performance summary for both IF matching circuits.

Discrete balun IF matching

The low-pass IF matching and transformer can be replaced with the discrete balun shown in Figure 3. The values of *L* and *C* are calculated to realize a 180° phase shift at the IF frequency and to transform the impedance. The complete application schematic is shown in Figure 4, where the 240 MHz balun is formed by L1, L2, C4 and C6. L3 cancels the internal 1 pF capacitance and supplies bias voltage to the IF+ pin. C7 is a DC blocking capacitor.

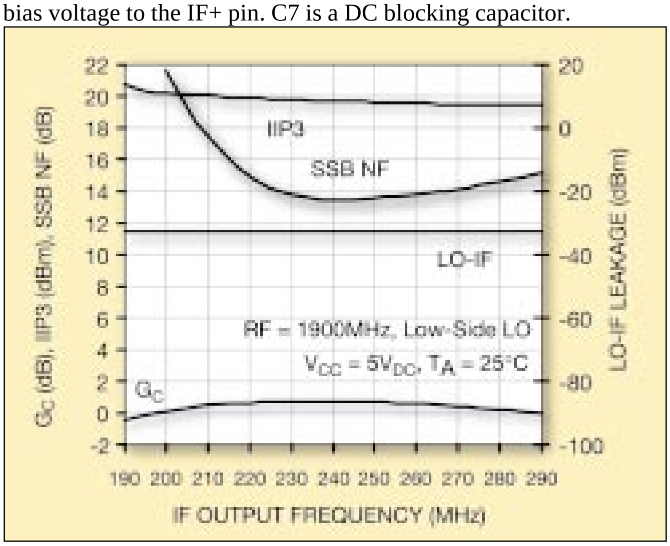

Figure 8. Conversion gain, IIP3, NF and LO-IF leakage vs. IF frequency-discrete balun matching.

Compared to a transformer, the bandwidth of this discrete balun is narrow. The bandwidth can be increased by raising the load resistance, if 50Ω is not required.

Measured performance

Measured performance for both IF matching techniques is summarized below. Figure 5 shows conversion gain, third-order intercept point (IIP3), single-sideband noise figure (NF) and LO-IF leakage vs. RF input frequency for the transformer-matched IF. Figure 6 shows the same parameters for the discrete IF matching approach.

The most significant difference is the higher LO-IF leakage measured with the discrete balun: -32 dBm vs. -58 dBm when a transformer is used. Higher LO leakage is expected because the discrete balun's component values are only optimal at the 240 MHz IF frequency. IIP3 is 1.2 dB higher with the transformer matching because the transformer presents a broadband, balanced impedance to the mixer output at the intermod tone frequencies. Conversely, conversion gain is 0.8 dB higher with the discrete balun approach since the transformer loss has been eliminated.

RF performance vs. IF output frequency for both matching techniques is shown in Figure 7 and Figure 8. Comparing these two graphs, the most significant difference is the NF. The discrete balun matching approach delivers good NF within ±20 MHz of the desired 240 MHz IF frequency, but rapidly degrades for wider IF bandwidths. The transformer matching technique delivers good NF over the full 100 MHz IF bandwidth.

Summary

The discrete IF balun matching technique is a good alternative to the transformer approach for mixer applications where the IF bandwidth is less than 20% of the IF frequency. Within this bandwidth, the most significant performance degradation is LO-IF leakage. For wider IF bandwidths, the NF increase may be too high and a transformer matching approach should be employed. RFD

References

1. Linear Technology Corp. LT5522 Data Sheet.

ABOUT THE AUTHOR

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