MIMO Receivers Demand High-Performance Dual Passive Mixers

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Introduction

Multiple-Input Multiple-Output (MIMO) technology is increasingly being used in high data rate systems such as Wi-Fi and 3G/4G cellular technologies. The higher data rates of MIMO systems provide increased system capacity and improved levels of efficiency. In order to reduce system complexity and size, MIMO receivers require integrated circuits (ICs) that are capable of handling multiple channels. To address this need, the LTC559x family of dual passive down-converting mixers provides frequency coverage from 600 MHz to 4.5 GHz. The mixer family includes the LTC5590, LTC5591, LTC5592 and LTC5593. The frequency coverage and typical 3.3 V performance of each mixer is shown in Table 1. These mixers deliver high conversion gain, low noise figure (NF), and high linearity with low DC power consumption. Typical conversion gain is 8dB with an input 3rd order intercept point (IIP3) of 26 dBm, 10 dB of noise figure and 1.3 W power consumption.

PART NUMBER	RF RANGE (GHz)	LO RANGE (GHz)	GAIN (dB)	IIP3 (dBm)	NF (dB)
LTC5590	0.6 – 1.7	0.7 – 1.5	8.7	26.0	9.7
LTC5591	1.3 – 2.3	1.4 – 2.1	8.5	26.2	9.9
LTC5592	1.6 – 2.7	1.7 – 2.5	8.3	27.3	9.8
LTC5593	2.3 – 4.5	2.1 – 4.2	8.5	27.7	9.5

Table 1 • LTC559x Frequency Coverage and 3.3V Performance Summary

The LTC559x family of dual high-performance mixers is ideal for wireless infrastructure MIMO receivers. The dual channel solution reduces parts count, simplifies routing of LO signals and reduces board area. Additionally, each LTC559x incorporates integrated RF and LO baluns, double-balanced mixers, LO buffer amplifiers and differential IF amplifiers, further reducing overall solution size, complexity, and cost.

Mixer Description

The simplified block diagram in Figure 1 shows the dual-mixer topology, which uses passive double-balanced mixer cores driving IF output amplifiers. The mixer cores are switched-MOSFET quads, which typically have about 7dB of conversion loss. However, in this case the loss is more than compensated for by the gain of the subsequent IF amplifiers, resulting in overall gain of about 8 dB. The differential IF output has been optimized for 200Ω loads.

The LO path uses a shared balun to convert the single-ended input to a differential LO and then drives independent buffer amplifiers for each channel. To prevent unwanted load-pulling of the VCO, good LO impedance matching is maintained in all operating modes. Figure 2 shows the LO input return loss of the LTC5591, as an example, under various operating conditions. This feature eliminates the need for an external LO buffer stage.

Traditional base stations maintain a temperature-controlled environment and require that components work up to +85°C.

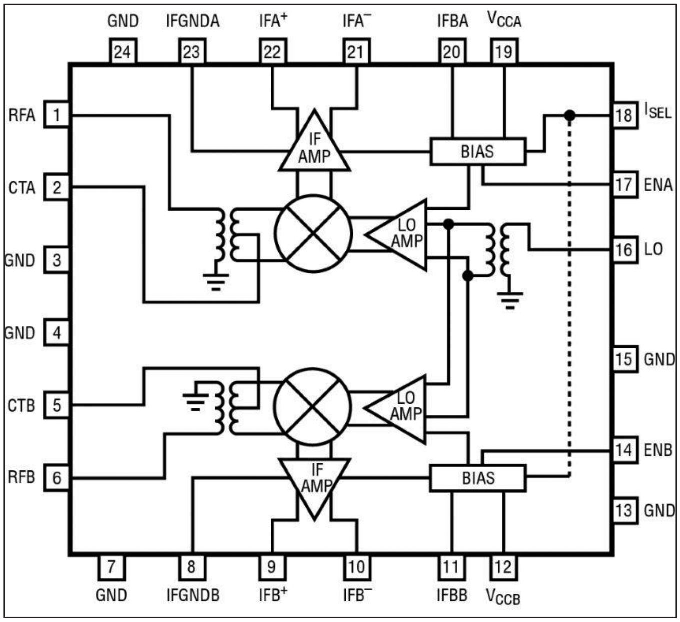

Figure 1 • Block Diagram of Dual-Channel Mixer.

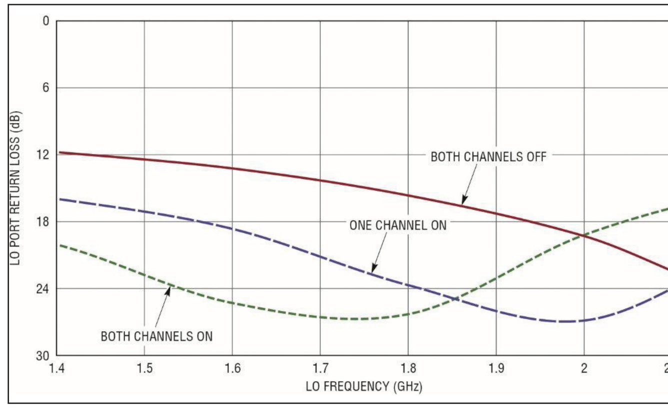

Figure 2 • LTC5591 LO Return Loss for Different Operating States.

Smaller cells and remote radio heads, however, present a harsher environment for components, requiring operation up to +105°C. The LTC559x mixers have been designed for, and tested at +105°C to meet this demand.

To minimize solution size, LTC559x mixers are assembled in a small 5 mm x 5 mm 24-lead QFN package. The small package size is only part of the total solution size reduction, however. The high integration level reduces the number of required external components to about 19, minimizing board area, complexity, and cost.

Receiver Application

The functional diagram of an LTC559x mixer in a two-channel receiver is shown in Figure 3. Single-ended RF signals are amplified and filtered before being applied to the mixer inputs. In this example, differential IF signal paths are shown, eliminating the need for an IF balun. The SAW filter, IF amplifier, and lumped-element bandpass filter are all differential.

High-selectivity SAW filters are used in many MIMO receivers to block unwanted spurs and noise at the mixer output. The mixers' 8 dB of conversion gain compensates for the high insertion loss of these filters and reduces their impact on the system noise floor. The overall mixer performance allows the filter loss to be accommodated while enabling the receiver to meet sensitivity and spurious requirements.

Another important specification for multichannel receivers is the channel-to-channel isolation. The channel-to-channel isolation is the IF level at the undriven channel's output relative to the IF level at the driven channel's output. This parameter is usually specified to be 10 dB better than the antenna-to-antenna isolation to avoid degrading system performance. Based on its precise IC design, the LTC559x mixers achieve greater than 45 dB of channel-to-channel isolation, which satisfies most multi-channel application requirements.

Power Consumption and Solution Size

With the maturing of multiband/multimode base station topologies and a more refined system definition of 4G networks, wireless infrastructure systems are moving toward platform configurations that allow implementation of various band or mode requirements with minimal hardware and software changes. The LTC559x mixers all share a common pinout, making it easy to use the same board layout for all bands.

The continued growth of wireless communications has also spurred the use of smaller cells such as picocells and femtocells. The need for more, and smaller, cells plus the increased use of remote radio heads has placed additional constraints on infrastructure systems, demanding higher integration and smaller solution size.

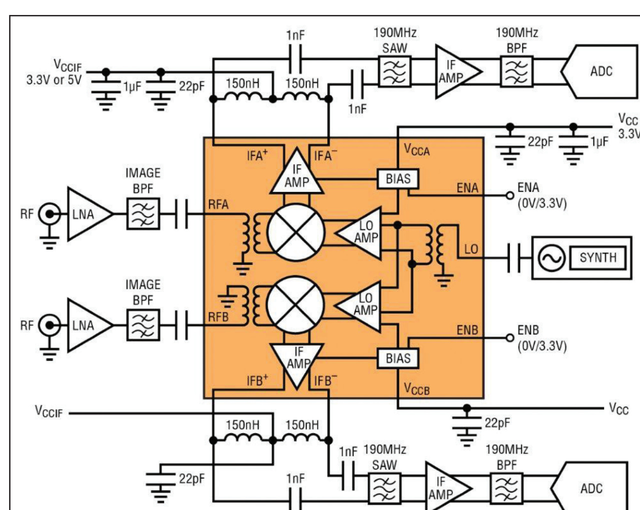

Figure 3 • LTC559x Dual Passive Mixer in a Receiver Application.

As the number of cells grows, power consumption has also become increasingly important as energy costs go up proportionally. In remote radio heads, on the other hand, thermal stress is a major concern due to reliance on passive cooling. Simply reducing the solution size is not sufficient, as reduced system size would result in higher power density, higher junction temperatures and potentially reduced component reliability. Thus, it is necessary to simultaneously reduce system power consumption and size. This goal is challenging, because the RF performance must not be compromised.

In the past, combining two individual mixers on one chip would result in total power consumption of 2 watts. To reduce power consumption, the LTC559x mixers have been designed for 3.3 V operation instead of 5 V. Low voltage circuit design techniques reduce power dissipation without impacting conversion gain, IIP3 or noise figure performance. The only parameter affected by the lower supply voltage is the P1dB performance, which is approximately 11 dBm. The P1dB performance is output limited by the voltage swing at the open collectors of the IF amplifiers when driving the 200Ω load impedance. For applications where higher P1dB is necessary, the mixers have been specifically designed to allow the use of a 5 V supply on the IF amplifier. The higher voltage improves the P1dB to greater than 14 dBm.

As shown in Table 1, the dual-mixers achieve excellent performance while using just over 1.3 W of power, with both channels enabled. For additional power savings, each channel can be independently shut down as desired by using the independent enable controls. In instances where reduced linearity requirements are acceptable, the ISEL pin allows the user to switch to low current mode and further decrease DC power consumption.

Conclusion

The LTC559x family of dual passive downconverting mixers delivers the high performance needed to meet the demanding requirements of today's multichannel infrastructure receivers. The mixers' combination of high conversion gain, low NF, and high linearity improves overall system performance, and low power consumption and small solution size meet the more stringent needs of today's smaller base stations and remote radio heads.

About the Authors

Bill Beckwith, Xudong Wang, and Tom Schiltz serve as Senior RFIC Design Engineers at Linear Technology Corp.