High Performance Dual Passive Mixer Steps up to 5G MIMO Receiver Challenges

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Introduction

The global demand for ever-increasing data rates has pushed the limit of the current 4G wireless networks capacity. The next generation 5G networks will need to increase the capacity by more than 10 fold in order to keep up with future demand. Even though the 5G standard has not been finalized, most if not all market participants have concluded that the bandwidth will need to increase to at least 100MHz (from the current 20MHz spectrum), and some venturing to as high as 200MHz. Doing so will push the frequency spectrum upward to 3.6GHz or higher.

To address this need, Linear Technology's LTC5593 dual passive down-converting mixer provides excellent linearity and dynamic range performance at 3.6GHz, while supporting more than 200MHz flat signal bandwidth that makes for a superbly robust MIMO (Multiple-Input Multiple-Output) receiver. MIMO technology has demonstrated its usefulness by markedly boosting net data rate throughput and reception in systems such as Wi-Fi and 4G networks in times of limited spectrum bandwidth. As 5G systems migrate to higher frequencies, the LTC5593 provides continuous 50Ω matched from 2.3GHz to 4.5GHz, supporting multiband receivers at 2.6GHz and 3.6GHz bands. For lower bands, other pin-compatible mixers include the LTC5590, LTC5591, and LTC5592, which cover all the other LTE receivers. The frequency coverage and typical 3.3V 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 power conversion gain is 8dB with an input 3^{rd} order intercept point (IIP3) of 26dBm, 10dB of noise figure and 1.3W power consumption.

Table 1. LTC559x Frequency Coverage and 3.3V Performance Summary

Part #	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 (3.6GHz)	2.3 – 4.5	2.1 – 4.2	7.6	26.0	11.3

The LTC5593 family of dual high-performance mixers is ideal for wireless infrastructure MIMO receivers, such as in a RRH (Remote Radio Head). Such systems are extremely compact and are in self-contained, weather-sealed casing, posing challenges in small size and thermal management from the large content of electronics. The dual channel solution reduces parts count, simplifies routing of LO signals and reduces board area. Additionally, each LTC5593 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 by the gain of the subsequent on-chip IF amplifiers, resulting in overall power gain of about 8dB. The differential IF output has been optimized for a standard 200Ω interface, which can drive directly differential IF filters and variable gain amplifiers, minimizing external components.

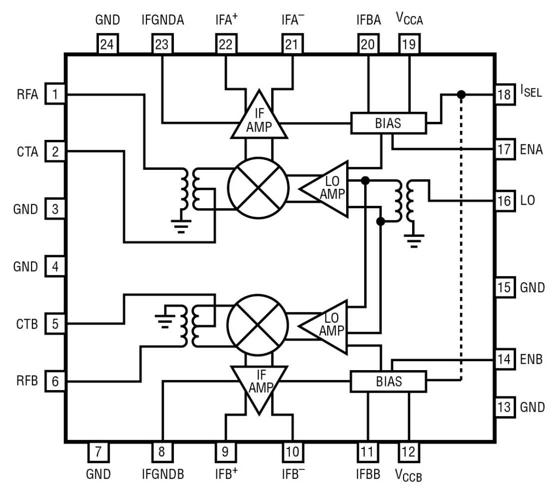

Figure 1. Block Diagram of Dual-Channel Mixer

The LO path uses a shared balun to convert the single-ended input to a differential LO, which then drives independent buffer amplifiers for each channel. This separate LO drive topology preserves the phase coherency of the LO signal to both mixers while providing excellent channel isolation. Additionally, to prevent unwanted load-pulling or disturbance to the VCO, a constant 50Ω LO input impedance matching is maintained in all operating modes, even when one or both mixer stages are turned on and off. A 50 impedance match from 2.1GHz to 3.4GHz is realized by adding a 1.5pF external series capacitor, C2. This capacitor is also needed for DC blocking. For the higher 3.6GHz band, adding a shunt inductor of 10nH on the source side of the capacitor provides good return loss at the LO. Figure 2 shows the LO input return loss of the LTC5593, under various operating conditions. This feature eliminates the need for an external LO buffer stage.

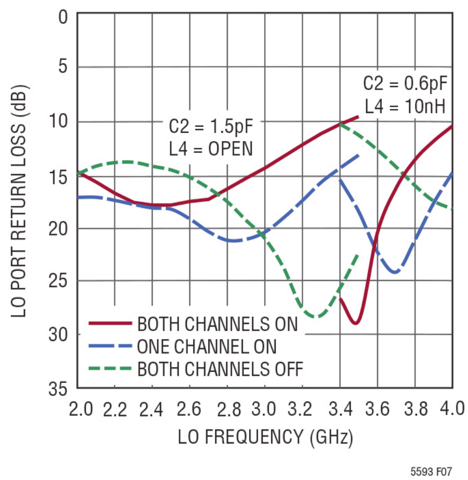

Figure 2. LTC5593 LO Return Loss for Different Operating States

Traditional basestations maintain a temperature-controlled environment and requires that components work up to +85˚C. Smaller cells and remote radio heads, however, present a harsher environment for components, requiring operation up to +105˚C. The LTC5593 mixers have been designed for, and tested at +105˚C to meet this demand.

To minimize solution size, the LTC5593 family of mixers is assembled in a small 5mm x 5mm 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 LTC5593 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. With the circuit component values as shown, this example receiver supports 150MHz IF bandwidth. Higher bandwidth can be achieved by lowering the resistance across the differential pins – with a slight reduction in gain.

High-selectivity SAW filters are used in many MIMO receivers to block unwanted spurs and noise at the mixer output. The mixers' 8dB 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.

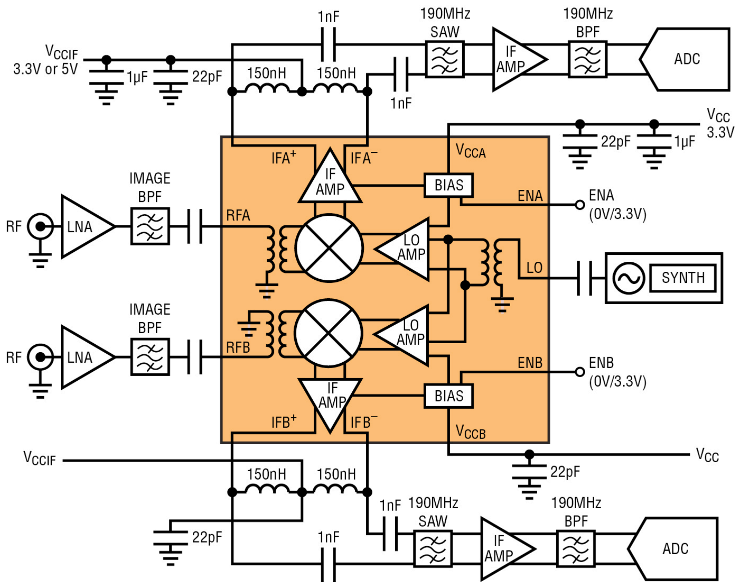

Figure 3. LTC5593 Dual Passive Mixer in a Receiver Application

Another important performance target 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 10dB better than the antenna-to-antenna isolation to avoid degrading system performance. Based on its precise IC design, the LTC5593 achieves 44dB of channel-to-channel isolation at 3.6GHz, and 52dB at 2.6GHz, which satisfies many multichannel application requirements.

Power Consumption and Solution Size

With the maturing of multiband/multimode base station topologies and a more refined system definition migrating from 4G to the future 5G 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 family of dual 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.

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 LTC5593 family of mixers has been designed for 3.3V operation instead of 5V. 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 output P1dB performance, which is approximately 10.4dBm. The P1dB is limited by the output 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 5V supply on the IF amplifier. The higher voltage improves the P1dB to 13.7dBm.

As shown in Table 1, the dual-mixers achieve excellent performance while using just over 1.3W 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 LTC5593 dual passive downconverting mixer delivers the high performance needed to meet the demanding requirements of emerging 5G multichannel infrastructure receivers, pushing higher frequencies and wider bandwidth. The mixer’s 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 ever-smaller base stations and remote radio heads.