Chapter 27

TRADE-OFFS IN CMOS MIXER DESIGN

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27.1. Introduction

Mixers are a very important block in the RF front-end, as they perform the crucial task of frequency conversion. When used in a transmitter, mixers convert baseband signals to a higher frequency for transmission. This process is called upconversion. When used in receivers, mixers convert a received signal from a high frequency to lower frequencies. This process is called downconversion. Most modern communication systems operate in the 1–2 GHz range [1]. The most widely used communication systems in Europe are GSM, which operates in the 900 MHz band, and DCS 1800, which operates at 1.8 GHz. Bluetooth devices, that are just starting to appear in the market, operate at around 2.5 GHz. The RF front-end receiver has to convert the signals it receives from 1–2 GHz down to baseband for demodulation and further processing. The exact frequencies which the downconversion mixer operates at, and the performance required of it, are strongly dictated by the receiver architecture employed. Most wireless transceivers use the heterodyne or the dual IF superheterodyne receiver architecture.

The design of a mixer depends strongly on the receiver in which it is going to be used. Although upconversion and downconversion mixers are conceptually similar, their design involves various different trade-offs that are unique to either upconversion or downconversion mixers, helping to optimize the mixer for its intended role. This chapter deals with particularly the case of downconversion mixers, primarily because a downconversion mixer, being used in the RF receive path, has to deal with a wider dynamic range of signals, which in turn places many constraints on its design. The design of downconversion (and upconversion) mixers has been dealt with exhaustively in the literature [1–4]. The aim of this chapter is not to replace these excellent texts, but rather to supplement them by highlighting various trade-offs that are often encountered in mixer design. To this end a more intuitive and less mathematical approach is employed, which should facilitate the understanding of the important underlying trade-offs in mixer design.

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As stated previously, the design of, and performance required from, a mixer strongly depends on the transceiver architecture in which it is used. This means that the trade-offs involved in mixer design are present at two levels—the system level and the circuit level. Various system level trade-offs in the design of RF front-end circuits have been dealt with in Chapter 23. This chapter concentrates on the circuit level trade-offs within the mixer itself. Nonetheless, it is useful to start off a treatment of the topic of mixers by examining the system level circuit in which a mixer will be used. Thus this introduction ends by presenting a basic heterodyne receiver architecture, and highlights the role played by the mixer in this receiver. In the rest of this chapter, after a brief explanation of mixer basics, a description of the various figures of merit used to describe mixers is given. This leads to a presentation of various mixer architectures, and a discussion of the trade-offs they represent.

### 27.1.1. The RF Receiver Re-Visited

In many wireless applications the received signal is typically in the order of 1–2 GHz, and has to be downconverted to baseband. In the heterodyne receiver [1,2], the RF band is first downconverted to an Intermediate Frequency (IF), before being further downconverted to baseband. It is possible to downconvert the received signal to baseband in one step, as in direct conversion or homodyne receivers [5–7]. These receivers however are very susceptible to DC offsets, even-order distortion, LO leakage, etc [1]. Since the heterodyne receiver first converts the RF signal to an intermediate frequency, it avoids such problems. A block diagram of the heterodyne receiver is shown in Figure 27.1.

![Figure 27.1. The heterodyne receiver.](image)

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1 Even considering the drawbacks stated here, direct conversion receivers have the major advantage of reduced power consumption (since they lend themselves well to full integration, without the need for buffers to drive off-chip components). With recent advances in the technology and design of direct conversion receivers, they are becoming a serious contender.