Study of Double balanced Gilbert Mixer Cell

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Abstract - This paper introduces a component of the radiofrequency transceiver called the mixer. Mixers are found in almost all the communication systems at the front end. Radio frequency mixing is a key process within the RF technology and RF design. It is a nonlinear process that involves one signal level affecting the other signal level at the output side instantaneously. The mixer design has the following design parameters, i.e., conversion gain, Linearity, Noise Figure and port isolation. It is important to have better isolation between the ports as it is the measure of leakage or feed through from one port to another. Poor isolation leads to mixing of unwanted dripped signal with desired output signal creating inter-modulation products and adding distortion. The proposed Gilbert mixer is intended to produce a RF frequency range of 5.8GHz in UMC180nm CMOS technology with a conversion gain of 0dB, Noise figure of >10dB, IF frequency range 5MHz,reverse isolation >15dB and a stability factor of 1 at a low operating voltage 1.8V using a double balanced topology. The mixer being designed provides a better isolation factor between the ports.

Keywords: Gilbert Mixer, Conversion gain, noise figure, port isolation, UMC technology.

I. Introduction

Radio frequency circuitry is gaining importance in recent years. Radio frequency communication has taken great advances from mobile phones to base stations, communication industry has been revolutionizing the way the entire globe transmits and receives information with growing demand. With this increase in the need and demand of communication industry, there is ample scope of expanding and creating more reliable and efficient components. In order to realize the goals there is a need for increasing the frequency range software and hardware design. The below figure depicts the block diagram of a base station transceiver [1].

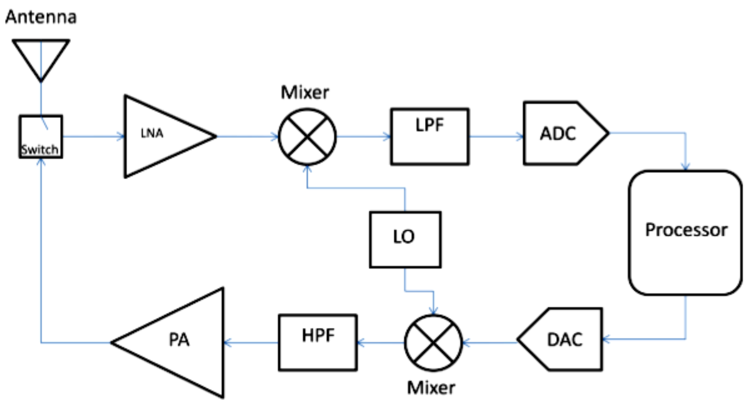

Fig. 1 Block diagram of General RF Transceiver

The above system consists of a receiver and transmitter section. In receiver section the signal enters antenna and is weak due to noise interference. Since there is signal experiences attenuation at the receiver end there is a requirement of proper amplifier to increase the signal strength so that it can enter the system. A Low Noise Amplifier (LNA) is employed which will amplify the desired signal while there is little addition of distortion. The signal is then sent to a down conversion mixer and low pass filter to be converted and altered. This tuning of frequency of the signal is required so that the signal is appropriately converted for processor purposes. The digitization of the signal is performed using analog to digital converter. At the later stage the bits of data are used for processing purposes. In the transmission section the bits of data are converted from digital bits to an analog signal by the digital to analog converter. The signal is then sent to an up conversion mixer and High Pass Filter (HPF), which shifts the original frequency to a higher frequency for communication. The signal coming as an output quantity from the HPF block is made to pass through the power amplifier block denoted as PA in the above block diagram of Figure 1.This block enhances the power of the signal , and prepare signal for its distance travel. The signal is then transmitted though the antenna. Mixers are important component in any of the RF technology systems. Figure 2 shows the basic block of the mixer.

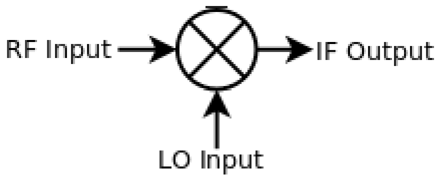

Fig. 2 Basic block of mixer

There are basically two types of mixers: Down conversion and up conversion mixers. The basic configuration of mixer has two inputs and one output. This block multiplies or mixes the carrier signal, either RF or intermediate frequency depending on an up conversion mixer with another input from the local oscillator denoted as LO. This LO signal present at the input terminal assists in the heterodyning process and produces the difference frequency of the two input terminal in case of down conversion mixer or the sum frequency of two input terminals in case of up conversion mixer.

The heterodyning process in mixer is discussed in the following case, if both the input signals are [1]:

$$a = A\cos\omega_1 t \quad (1)$$

$$b = B\cos\omega_2 t \quad (2)$$

The mixer output will yield:

$$a.b = A\cos\omega_1 t.\ B\cos\omega_2 t = \frac{AB}{2}\cos(\omega 1 - \omega 2)\ t + \frac{AB}{2}\cos(\omega 1 + \omega 2)\ t \quad (3)$$

The above equation shows that the mixer output consists of the difference and summation of both input frequencies. The unwanted function can be filtered out. In the mixer design there are four parameters that act as mixer specifications. They are Conversion Gain (CG), Linearity, Noise Figure (NF) and port isolation. The CG is a ratio between the output signal and the input signal usually in the measure in decibels (dB) or, milli-decibels (dBm). The linearity of the mixer is defined as how well the mixer reacts to the mixing of frequencies and ideal law of superposition in the ideal case explained in above text. NF is a ratio of the signal-to noise ratio (SNR) at the IF output and the SNR at the RF input port. Finally, the port isolation parameter shows how much leakage of signal occurs between two ports. There are different topologies for mixer design

1. Single balance Gilbert cell mixer: This architecture utilizes two devices and is apprehended as two single device mixers via a 180 degree or a 90 degree hybrid. The below figure shows the conventional single balanced Gilbert cell mixer

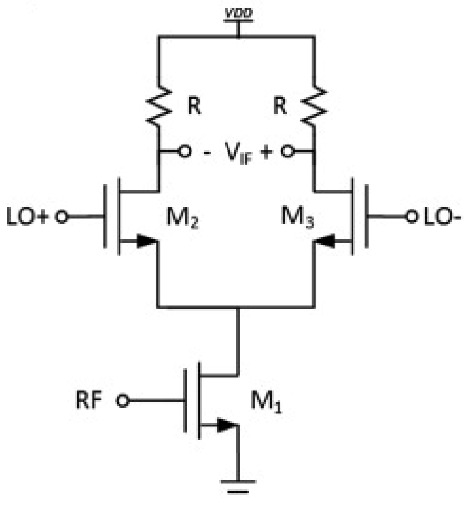

Fig. 3 Architecture of Single balanced Gilbert cell

2. Double balanced Gilbert cell mixer: It consists of four unturned devices interconnected by multiple hybrids, transformers or baluns. The below figure shows the usual topology of double balanced Gilbert cell mixer.
3. Switch trans-conductance mixer: This is a newer design topology of mixer which was created to operate on par with the standard mixer design specifications like the Gilbert Cell mixer. Other benefits include less voltage headroom for LO switching and avoiding gate oxide reliability problems, meanwhile achieving a lower operation voltage meaning decrease in power consumption.

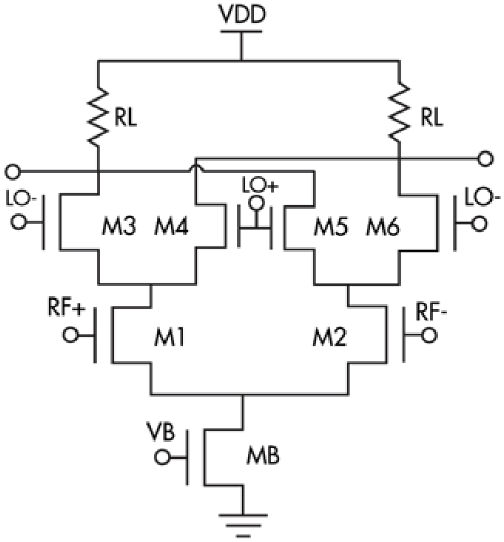

Fig 4: Architecture of Double balanced Gilbert mixer cell

II. PROPOSED SYSTEM

The mixer cell being designed is aimed to meet the following specifications as shown in the below table

TABLE 1: SPECIFICATIONS

Sl. No	Specifications	Value
1.	Conversion Gain	0 dB
2.	Noise Figure	14 dB
3.	IP1dB	-20 dBm
4.	IIP3	10-15 dBm
5.	RF Frequency Range	5.735 – 5.875 GHz
6.	IF Frequency	5 MHz
7.	Reverse Isolation	>15 dB
8.	Stability factor	1
9.	Power consumption	
10.	Technology	UMC180
11.	Supply Voltage	1.8

As it is evident from the above specifications, the aim is to provide a better noise margin and isolation between the ports. CMOS receivers make use of double balanced topology of Gilbert mixer which is employed for down conversion. The advantage of using this topology is that it offers large impedance at the input to low noise amplifier and it can drive a load that is offering less impedance at the output side. Figure 5 shows typical prototype of double balanced Gilbert mixer.

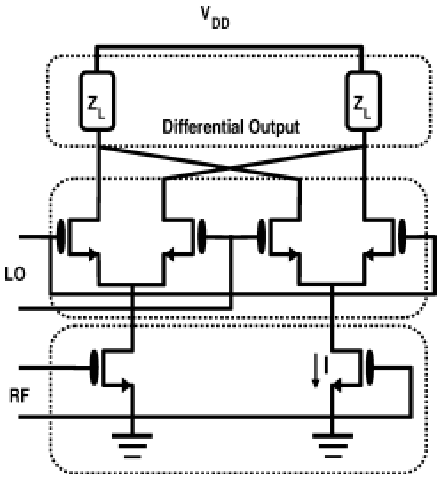

Fig 5: Double balanced Gilbert mixer

The direct-conversion receiver has several significant repercussions. The signal is down converted to baseband if there is minimal amplification at RF. The mixer noise is likely to engulf the down converted signal when it comes to narrow band applications namely paging or GSM. Hence as a consequence it limits the overall receiver noise figure.

The aim is intended to have a noise cancellation technique in the design to improve the performance and reduce flicker noise contribution of the switches in active mixers. The radio receivers operating at high frequencies which are subjected to direct conversion experience the leakage of LO signal into the RF signal path. This gives rise to cross modulation and inter distortion and time varying DC offsets in the mixers stage of the receiver. Since the LO signal and the RF signal are at the same frequency, the LO signal which leaks into the RF-signal path is indistinguishable from the RF signal itself, and the LO leakage is mixed with the LO signal itself in the mixer to appear as a distortion or noise component in the mixer's baseband output at higher frequencies. Hence it is desirable to minimize the leakage of the LO signal into the RF signal path. The double balanced mixers are preferred as they provide better isolation between LO and RF.

III. Conclusion

In this paper the CMOS active RF mixer has been studied, analysed, and have to be simulated to obtain the desired specifications using different design topologies in double balanced Gilbert mixer cell. The design is aimed to be constructed using cadence tool with a technology of UMC180nm using basic set up specifications. The Gilbert cell being designed should at least incorporate one cascade element for improving the isolation, a transconductor portion and a switching portion [5]. The transconductor portion consists of an inductive and resistive degeneration for increasing linear input signal range. The cascode transistors comprise of MOSFETs behaviour.

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