

Design of Low Phase Noise Cross-coupled VCO in 90nm CMOS Technology

Lu Wang

Department of Electrical Engineering and
Computer Science
Syracuse University
Syracuse, USA
lwang04@syr.edu

Prasanta Ghosh

Department of Electrical Engineering and
Computer Science
Syracuse University
Syracuse, USA
pkghosh@syr.edu

Abstract—A 2.5GHz low phase noise cross-coupled Voltage Controlled Oscillator (VCO) realized in 90nm CMOS technology is presented. High Q and low Q inductors are used in the design. The power consumption of the VCO is 25mW with the low Q inductor and 8.52mW with the high Q inductor. The tuning range for the two different designs is same, which is 13.2%. The phase noise of the two different designs are both below -120dBc/Hz at 1MHz offset frequency when the frequency of oscillation is 2.5GHz.

Keywords—VCO; phase noise; 90nm; Q; power consumption

I. INTRODUCTION

Voltage Controlled Oscillator is widely used in modern wireless communication system. In transmitters, there must be a modulating carrier frequency which is generated by a Local Oscillator. In a receiver, an oscillator producing the same carrier frequency is needed in order to demodulate the received signal. Oscillators can be divided into two categories, ring oscillators and LC oscillators. Ring oscillators are often used as VCOs in many on-chip clock distribution and clock recovery circuits [1] [2] [3]. They have the advantage of easy tuning and easy implementation. However, the ring oscillator exhibits poor phase noise [1]. Although LC Oscillators are not as easy to implement as the ring oscillators—since needed passive components such as capacitors and inductors are difficult to be integrated on chip. They are still widely used in present communication systems because of the lower phase noise [4] [5] [6] [7] [8] [9].

In this paper, we present the design and simulation of a low phase noise cross-coupled LC VCO. This VCO is implemented in 90nm technology. The paper is organized as follows. In Section II, we present the topology of the VCO. In Section III, the theory of phase noise is described. In Section IV, the simulation results are given and section V summarizes this paper.

II. TOPOLOGY OF THE CROSS-COUPLED VCO

Fig.1. shows the topology of the cross-coupled VCO with current mirror we have used for analysis.

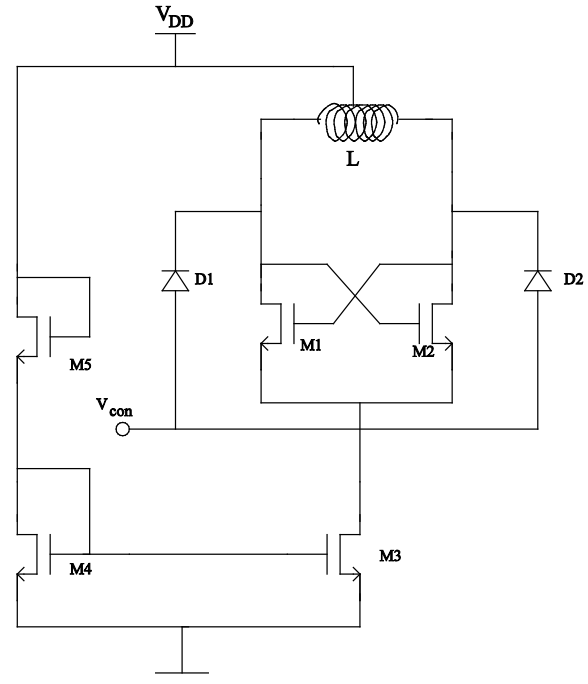


Figure 1. Topology of Cross-coupled VCO with Current Mirror

NMOS M1 and M2 form the core of the VCO. The symmetric inductor L and Varactors D1 and D2 form the LC frequency tuning tank. V_{con} is the control voltage of the VCO. NMOS M3~M5 form the current mirror.

III. PHASE NOISE OF VCO

The fraction of undesirable signal near the output frequency of operation is estimated to measure the phase noise of the circuit. It is usually expressed as the single side band (SSB) power density in a 1Hz bandwidth at a specific offset frequency from the carrier[10]. The phase noise is measured in dBc/Hz [11].

In recent years, several researchers from industry and academia have focused their attention on the effects of phase noise on wireless communications. In particular, Razavi [13], Xie [14] and Hajimiri [15] studied the effects of phase noise on oscillators. Theoretically, the output of an ideal oscillator is a pure impulse in the frequency domain. However, due to noise

interference, the output spectrum has a skirt around the central frequency of operation, which is known as the phase noise.

The presence of phase noise in a device can disturb the normal operation of the circuits. Since the carrier frequency between signals can be just a few tens of kilohertz, the desired signal might be corrupted by the phase noise of some undesired signals nearby.

Phase noise in Radio Frequency (RF) circuits will cause the undesired phase modulation in communication receivers; it reduces the channel selectivity and degrades the bit error rate of the receiver [15].

To make sure that the phase noise has minimum effect on the desired signals, the phase noise must be as low as possible.

In general, a local oscillator in a transmitter generates the carrier frequency. The carrier frequency is then modulated by the baseband signal. The frequency response of an ideal oscillator, a pure impulse, is shown in Fig. 2(a). Presence of phase noise in the oscillator signal is represented by a skirt around the signal [12] as shown in Fig. 2(b). Suppose now that a signal, whose frequency is pretty close to the baseband signal, also modulates the carrier frequency. There is also a skirt around this modulated signal. Since the two modulated signals are pretty close in the frequency domain, the desired signal will be corrupted by the phase noise of the modulated undesired signal. This can be seen in Fig.2 (c), where f represents frequency, v represents the amplitude of the signal.

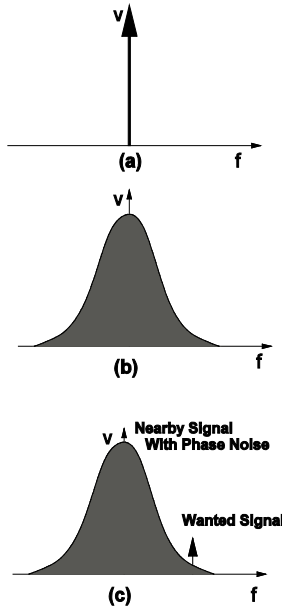


Figure 2. (a) Ideal Oscillator, (b) Oscillator with phase noise, (c) Desired signal corrupted by phase noise

IV. SIMULATION RESULTS

We started the simulations by estimating the frequency of oscillation with change in the control voltage. Fig.3 shows the frequency tuning range of the circuit with low Q inductor.

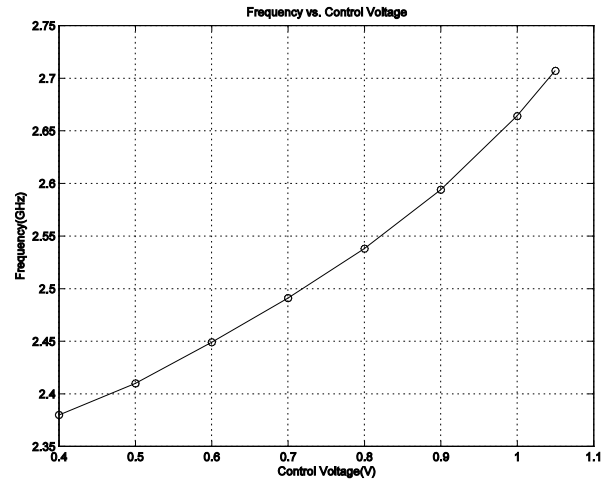


Figure.3 Frequency of Oscillation vs. Control Voltage

We observe that the frequency changes from 2.38GHz to 2.71GHz as the control voltage changes from 0.4v to 1.05V. Thus, the tuning range is 13.2%. From the figure, we also observe that the linearity is good.

In the next example, a higher Q inductor is used in the VCO. The tuning range of the VCO is show in Fig. 4.

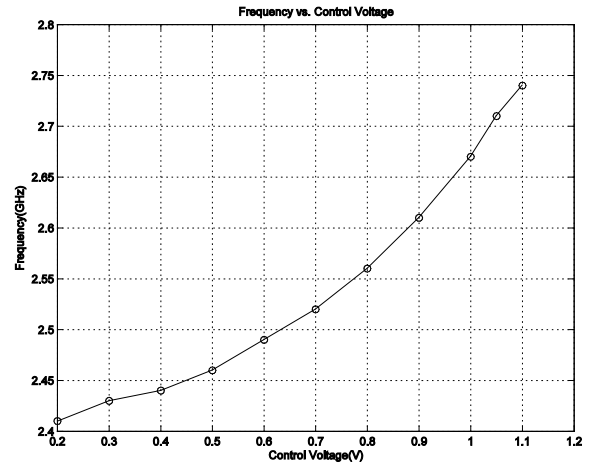


Figure.4 Frequency of Oscillation vs. Control Voltage with Higher Q inductor

In this circuit, the frequency changes from 2.41GHz to 2.74GHz as the control voltage changes from 0.2V to 1.1V. Therefore, the tuning range of this circuit is also 13.2%. The linearity of this circuit is as good as the previous design.

The key parameters of the two different designs are listed in Table 1.

TABLE I. COMPARISON OF THE KEY PARAMETERS OF THE TWO VCOS

Parameter	Low Q inductor	High Q inductor
Tuning Range	13.2%	13.2%
Phase noise(dBc/Hz)(at 100KHz offset)	-98.2	-97.7
Phase noise(dBc/Hz)(at 1MHz offset)	-122.7	-122.0
Output Amplitude(V)	0.9	0.82
Power(mW)	25	8.5
Linearity	Good	Good

The parameters of these two VCOs are competitive to each other except the power consumption. We observe that the power consumption of the high Q inductor VCO is 66% lower than the power consumption of the low Q VCO.

V. SUMMARY

In this paper, we presented the design and simulation of 2.5GHz cross-coupled VCO. Performance of the circuit with low Q was compared with that of high Q circuit. Phase noise, tuning range and the linearity of the two different designs are of the same level. Significant difference between the two circuits was only observed in their respective power consumption. The power consumption of the high Q inductor VCO is 66% lower than the power consumption of the low Q VCO. We therefore concluded that the high Q cross-coupled VCO with low power consumption will be preferable for the design of low-power integrated circuits.

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