

A New Active Inductor and Its Application to Wide Tuning Range LC Oscillator

Mahdi Ebrahimzadeh, Farzan Rezaei, Siavash Rezaei

Abstract— This paper presents a new structure to reduce noise in an active inductor. Our structure is based on a local common mode feedback. The proposed active inductor is used for implementation a wide tunable low phase noise LC oscillator. By varying control voltage of active inductor from 0.85 V to 1.6 V, the oscillation frequency changes from 86 MHz to 1.137 GHz. The presented structure improves the value of phase noise in the oscillator based on it about 5.5 dBc/Hz in 1 MHz offset frequency. The proposed oscillator is simulated with TSMC 0.18 μm CMOS technology.

Index Terms—Active Inductor, High Quality Factor, LC Oscillator, Wide Tuning Range, Phase Noise

I. INTRODUCTION

Indeed, there is a critical need for inductive characteristics in high-speed applications. CMOS spiral inductors have found a broad range of applications in high-speed analog signal processing and data communications. But integrated spiral inductors have a number of limitations due to their layouts. These limitations are low quality factor, low self resonance frequency, small and non tunable inductance and need for very large silicon area [1]. Implementation of inductors with active elements, offers several attractive advantages over their spiral counterparts including large and tunable inductance and low silicon consumption. Unfortunately active inductors have high level of noise due to using a number of transistors. One of the applications of inductive characteristic is LC oscillator. Using the active inductor in LC oscillator increases the phase noise of it. Whereas the most important characteristic in an oscillator is phase noise, this high level of noise restricts use of active inductors in oscillator.

Another limitation of LC oscillators with integrated spiral inductors is their narrow tuning range. In these oscillators, frequency tuning is carried out by a varactor instead of capacitor. Theoretically, the VCO tuning range is determined by the maximum-to-minimum capacitance ratio of the varactor ($C_{var,max}/C_{var,min}$). For a typical capacitance ratio in a

standard CMOS process, the tuning range of LC-tank VCOs is approximately limited within 30% making them unattractive for wideband applications [2]-[5]. Several techniques have been proposed to enhance the tuning range of the LC-tank VCOs such as switched capacitors and switched inductors. However a wide frequency tuning range can be achieved in cost of additional circuits with considerable increase in the chip area and complexity of control mechanism [6], [7].

LC oscillators based on active inductors overcome their limitation in tuning range [9]. By utilizing a differential active inductor for the LC-tank, the circuit exhibits a very wide frequency tuning range.

In this paper we present a new active inductor with wide tuning range and low noise performance. It is shown that added local common mode feedback scheme to conventional active inductor, reduces the noise as a common mode signal in its terminal. The proposed oscillator base on new active inductor shows better phase noise performance compared to the conventional oscillators.

This paper is organized as follows. Section II discusses about basic floating gyrator- C. Section III introduces proposed active inductor and LC oscillator based on it. Section IV presents the simulation results followed by the conclusion in section V.

II. GYRATOR- C ACTIVE INDUCTOR STRUCTURE

A gyrator consists of two back-to-back connected transconductors. When, one port of the gyrator is connected to a capacitor, as shown in Fig. 1 the network is called the gyrator-C network. If we consider the gyrator- C network shown in Fig. 1, the impedance looking from its input port is given by:

$$Z_{in} = \frac{V_{in}}{I_{in}} = \frac{V_{in}^+ - V_{in}^-}{I_{in}} \Rightarrow Z_{in} = \frac{CS}{G_{m1} \cdot G_{m2}} \quad (1)$$

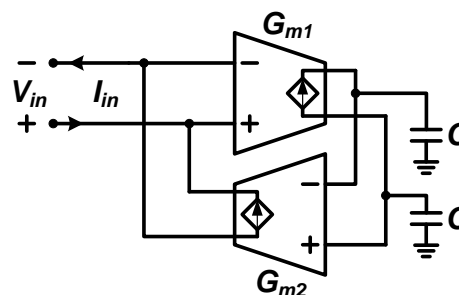


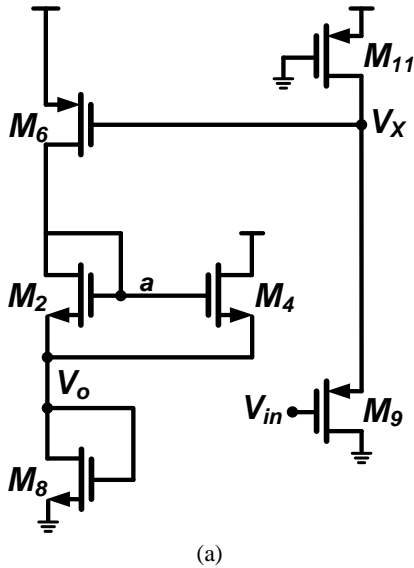
Fig. 1. Floating Gyrator- C Active Inductor Structure.

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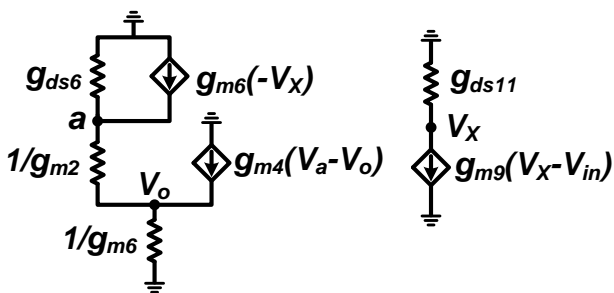
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(a)



(b)

Fig. 4. (a) Opened common mode feedback loop. (b) Small signal equivalent circuit.

IV. SIMULATION RESULTS

At first, we approximate the inductance of the active inductor with $L = \text{Im}(Z_{in})/\omega$. Based on this equation, the value of active inductor's inductance is calculated and depicted in Fig. 5. As can be seen, the design has an inductive characteristic in frequency band of DC to 6.9 GHz. For frequencies higher than 6.9 GHz, the imaginary part of the impedance has a negative value and the design has capacitive characteristic. The oscillator based on proposed active inductor is simulated with TSMC 0.18 μm CMOS technology by using ADS software. Tuning range of the oscillator versus control voltage is shown in Fig. 6. It can be observed that there is a wide tuning range, 171 %, from 86 MHz to 1.137 GHz which obtained by varying control voltage from 0.85 V to 1.6 V.

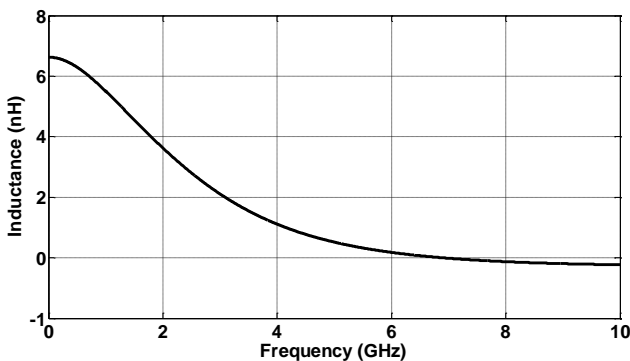


Fig. 5. Simulated inductance of the active inductor

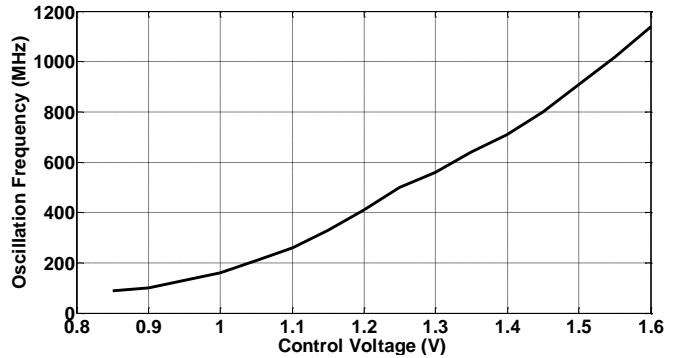


Fig. 6. Oscillation frequency versus control voltage

The simulated output phase noise using the harmonic balance in ADS is plotted as a function of the frequency offset away from the fundamental frequency as shown in Fig. 7. The phase noise of the oscillator is plotted in 100 MHz oscillation frequency. It exhibits -102 dBc/Hz phase noise at 1 MHz offset frequency.

The phase noise of the oscillator can be decreased by increasing the resonating capacitance (i.e. adding extrinsic capacitance), which must be accompanied by a reduction in the simulated inductance value to maintain the same oscillation frequency. The latter can only be achieved by increasing the bias current (g_m of the differential pairs), thus increasing the power consumption of the overall circuit. Alternatively, the active inductor based oscillator can achieve the same phase noise performance with a reduction in power consumption by employing the crystal-like LC-tank structure proposed in [11]. Generally, the phase noise of an actively tuned oscillator can be reduced at the expense of increased chip area.

Comparison results of proposed oscillator with other similar works are summarized in Table I.

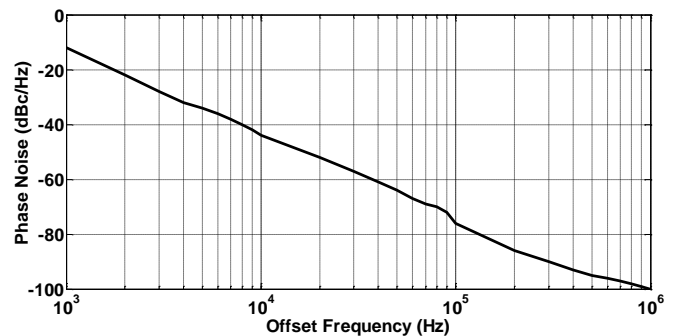


Fig. 7. Oscillator phase noise in 100 MHz oscillation frequency

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Table I. Main specifications of proposed oscillator compared with similar works

	[12]	[13]	[14]	[15]	This work
Technology	0.35 μm CMOS	1 μm FET	0.8 μm CMOS	0.2 μm CMOS	0.18 μm CMOS
Supply Voltage (V)	3	9	3	1.8	1.8
Tuning Range	100 MHz - 900MHz	1.73 GHz – 2.07 GHz	450MHz- 1.16GHz	NA	86 MHz – 1.137 GHz
Phase Noise (dBc/Hz)	-102 at 1 MHz Offset Frequency	-100 at 1 MHz Offset Frequency	-92 at 1 MHz Offset Frequency	-81 at 500 kHz Offset Frequency	-102 at 1 MHz Offset Frequency

V. CONCLUSION

In this paper, a new active inductor is presented to reduce noise in gyrator–C structure. In the proposed structure, using a common mode feedback technique, noise as a common mode signal is decreased. So the phase noise in an oscillator based on it, is reduced about 5.5 dBc/Hz. Proposed oscillator is tunable from 86 MHz to 1.137 GHz for 0.75 V variation in control signal. The circuit is simulated with TSMC 0.18 μm CMOS technology by using ADS software.

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