Design of Voltage Controlled Oscillator using Miller Effect

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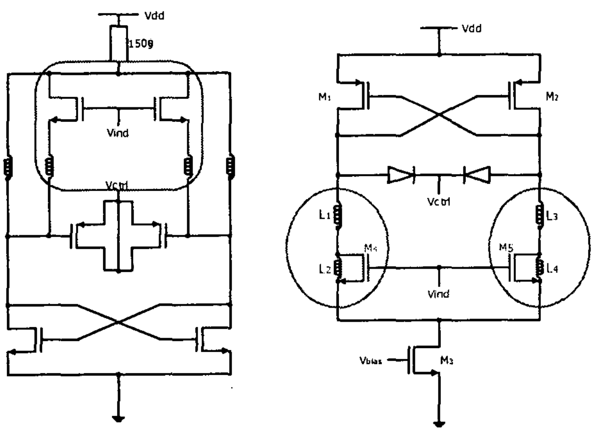
Abstract:

A new wide-band VCO topology using Miller capacitance is proposed. Contrary to conventional VCO using the Miller capacitance where the variable amplifier gain is negative, the proposed VCO uses both the negative and positive variable amplifier gain to enhance the frequency tuning range significantly. The proposed VCO is simulated using HSPICE. The simulations show that 410MHz and 220MHz frequency tuning range are obtained using the negative and positive variable amplifier gain, respectively. The tuning range of the proposed VCO is 23% of the center frequency(2.8GHz). The phase noise is -104dBc/Hz at 1MHz offset by simple model. The operating current is only 3.84mA at 2.5V power supply.

Keywords: Voltage controlled oscillator, harmonic oscillator, VCO, Miller capacitance, tunable LC- oscillator, frequency tuning.

1. INTRODUCTION

Nowadays, there are various wireless communication systems operating at from 0.9 GHz to 5 GHz carrier frequency such as GSM, GPRS, CDMA, WLAN and so on. Each system uses different carrier frequencies and modulation methods and thus same voltage controlled oscillator(VCO) can not be used. If there is a VCO covering wide tuning range, various wireless communication specifications can be satisfied simultaneously by single chip VCO. Recently there are various approaches to get wide tuning range VCO [1]-[4]. Wide tuning range VCO is divided into two methods: one is inductive tuning [1], [2] as shown in Fig. 1 and the other is capacitive tuning [3], [4] shown in Fig. 2. In this paper a wide tuning VCO with newly tuning topology is proposed using Miller effect capacitance with negative and positive feedback. In section 2, frequency tuning method using Miller effect is described. In section 3, proposed VCO and simulation results are reported. Finally conclusion is given in section 4.



(a) (b)

Fig. 1. Wide tuning VCO using switched inductors.

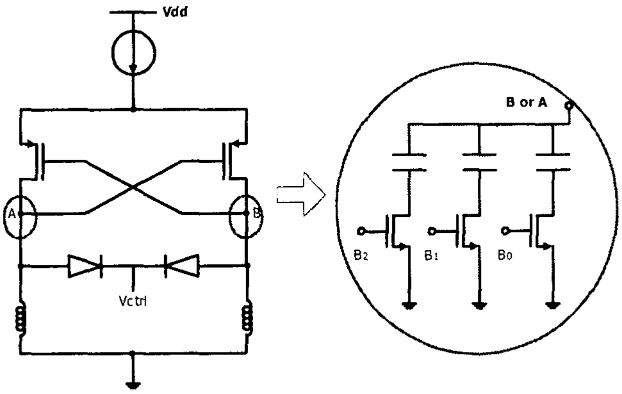


Fig. 2. Wide tuning VCO using switched capacitors.

2. FREQUENCY TUNING METHODS USING MILLER EFFECT

In Fig. 3 the idea of frequency tuning of VCO using Miller capacitance is presented. This circuit is capacitive shunt-shunt feedback amplifier. The effective input capacitance C_{eff} in Fig. 3 is given by

$$C_{eff}=C(1-(-A)) \qquad (1)$$

This value is determined by the gain of the amplifier and feedback capacitance. Therefore the effective capacitance can be tuned by varying the gain of the amplifier. The previous work using Miller effect [5], [6] as shown in Fig. 4 utilized only negative feedback Miller effect capacitance. As the gain of the amplifier in Fig. 4 is increased, the effective input capacitance is increased by the Miller effect and the oscillation frequency is decreased.

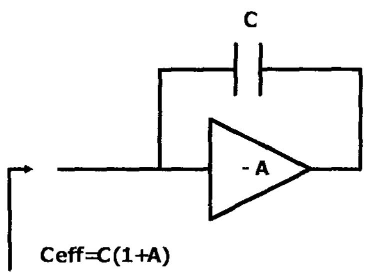


Fig. 3. The Miller capacitance.

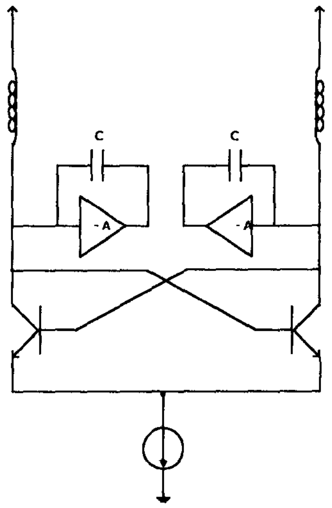


Fig. 4. Conventional BJT VCO using negative feedback Miller capacitance

In this paper is newly proposed VCO using miller effect. This main idea is to control effective capacitance lower and upper than reference frequency, which can be realized using the positive and negative feedback of Miller effect capacitance.

2.1. Negative Feedback Miller Capacitance

Fig. 5 shows the LC-oscillator using negative feedback Miller capacitance. This VCO oscillates at lower frequencies than the reference frequency by variable gain amplifier. The effective capacitance value is C(1-(-A)). So the oscillation frequency is lower than the reference frequency.

2.2. Positive Feedback Miller Capacitance

Fig. 6 shows the LC-oscillator using positive feedback Miller capacitance. This differential oscillator makes a 180 degree phase difference between node A and node B in Fig. 6. The oscillation signal from node A (Va) amplified by the negative gain becomes -A·Va = A·Vb. Therefore the effective Miller capacitance is C(1-A) (A>0). The 180 degree phase difference between node A and node B and the negative amplifier gain gives the positive feedback Miller effect. So the effective Miller capacitance C(1-A) (A>0) is lower than the feedback capacitance C and the oscillation frequency is higher than the reference frequency.

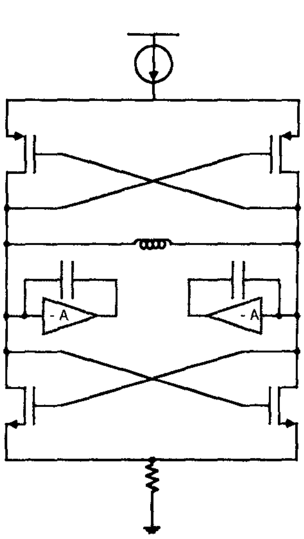


Fig. 5. LC-oscillator using negative feedback Miller capacitance.

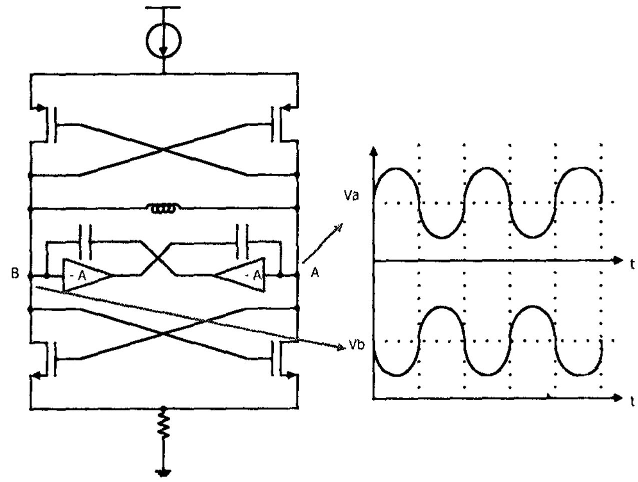


Fig. 6. LC-oscillator using positive feedback Miller capacitance.

3. PROPOSED VCO AND SIMULATION RESULTS

Fig. 7 shows the positive and negative feedback control circuit. This is basically cascode structure. Ma2 and Ma3 is switched by the control signal Va and Vb. Fig. 8 shows complete proposed VCO schematic. In Fig. 8, the negative feedback loop consists of Ma1, Ma3 and capacitance Cfn and the positive feedback loop consists of Ma1, Ma2 and capacitance Cfp. The proposed VCO is simulated using HSPICE based on 0.25um standard CMOS technology. As can be seen in Fig. 9, the negative feedback mode frequency tuning range is 400 MHz, from 2.86 GHz to 2.45 GHz and positive feedback mode frequency tuning range is 220 MHz, from 2.86 GHz to 3.08 GHz. The simulated frequency tuning range is about 23% of the central frequency. The calculated phase noise using simple model [7] is -104dBc/Hz at 1MHz offset. The operating current is 3.84 mA (max.) and 2.14 mA (min.) at 2.5V power supply. The summary of the simulation results of the proposed LC-oscillator is described in Table 1.

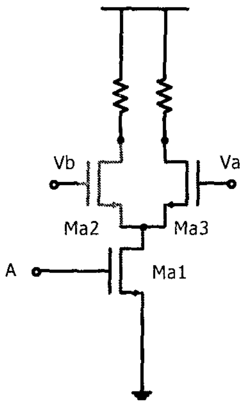


Fig. 7. Control circuit of negative and positive feedback.

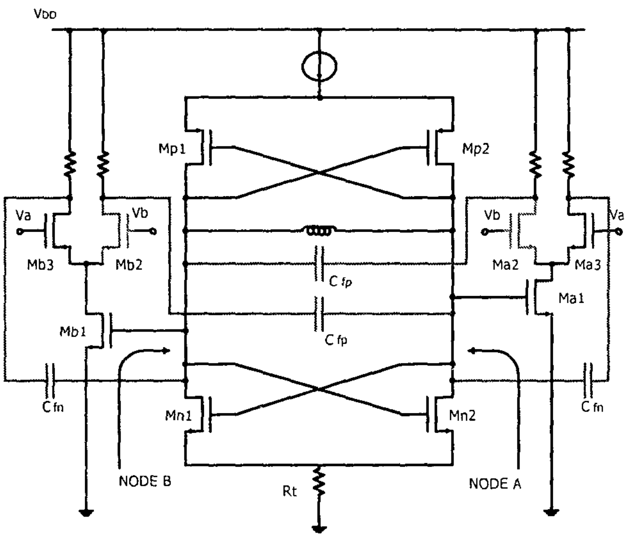


Fig. 8. Complete circuit of the proposed positive and negative feedback dual mode operation VCO.

Table 1. The summary of the simulation results of the proposed LC-oscillator.

Supply voltage	2.5 V
Tuning range	2.86 GHz ~ 2.45 GHz (Negative feedback) 2.86 GHz ~ 3.08 GHz (Positive feedback) (630 MHz)
Output power	-2.3 dBm (No feedback) -8.6 dBm (Negative feedback)
Technology	0.25um Standard CMOS technology

4. CONCLUSION

In this paper we proposed a new wide tuning range VCO topology using Miller capacitance. The differential LC oscillator structure results in 180 degree phase difference between two outputs which makes a positive feedback operation. The simulation shows that this proposed VCO has 410 MHz and 220 MHz frequency tuning range by negative and positive feedback mode. The tuning range is about 23% of the reference frequency.

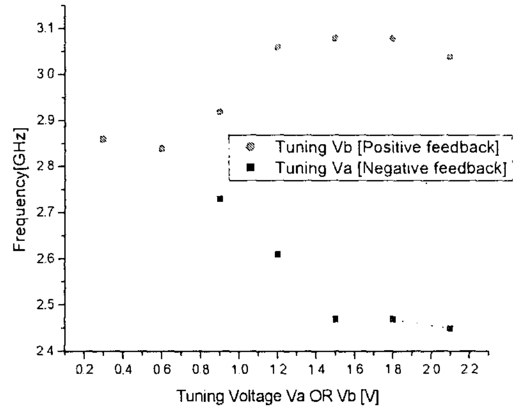


Fig. 9. Simulated tuning characteristics of the proposed VCO.

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