A Tail-Current Modulated VCO with Adaptive Startup Scheme

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Abstract This paper proposes a VCO topology in which the tail-current is adaptively modulated for enhancing the current efficiency. The adaptive modulation also ensures highly robust start-up over a wide range of PVT variation. The analysis also reveals that the tail-current modulation technique is also capable of alleviating the AM-PM conversion thereby extending the theoretical limit of the minimum achievable phase noise. The proposed VCO is implemented in a 0.18-µm CMOS process. The measured phase noise is -119.3dBc/Hz at 1MHz offset with a power dissipation of 6.8mW at 4.6GHz.

Keyword vco, tail-feedbak, adaptive-bias, start-up, pvt

1. Introduction

The advancements in CMOS technology and manufacturing processes made it possible to mass-produce portable wireless devices at very low costs. This resulted in a sudden increase in the user pool of such wireless portable devices. An ever increasing demand for higher data rate when combined with the increase in number of users made it necessary to employ complex communication standards. These communication standards imposed very tight performance requirements from the wireless link used in these portable systems. Typically, the voltage-controlled oscillator (VCO) used for synthesizing local frequency is single-handedly responsible for a large amount of power consumption that usually surpasses the combined power consumption of all the other components of the frequency synthesis system [1]. This makes it highly important to create a high-efficiency, high-purity VCO for next generation wireless communication standards, so as to obtain a larger battery while operating at very high data rates.

2. Tail-Current Modulation with Adaptive Startup Scheme

It is a well-known fact that VCO can achieve higher figure-of-merit (FoM) by increasing the power-efficiency [2] [3]. This property is exploited in different ways for creating high-efficiency VCO topologies such as class-C VCO [2] and class-D VCO [3]. Basically, all such high-performance VCO can be classified broadly into two categories [4] as (i) current-efficient and (ii) voltage-efficient. Class-C VCO [2] is a classical example of high-current efficient topology. A highly practical alternative for class-C VCO is proposed in [5] in which, the authors made use of a signal fed back from the oscillators output nodes for modulating the tail current source. Fig. 1. compares simplified

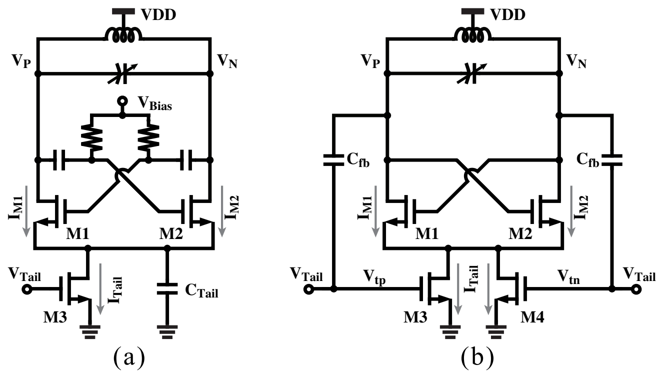


Fig.1. (a) Class-C VCO and (b) tail-current modulated VCO.

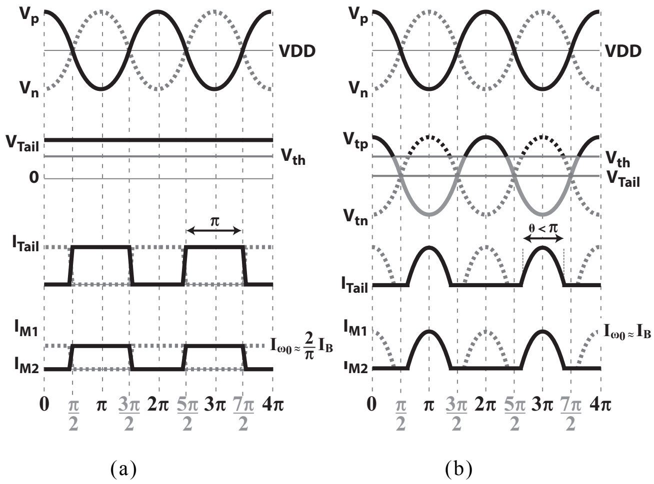
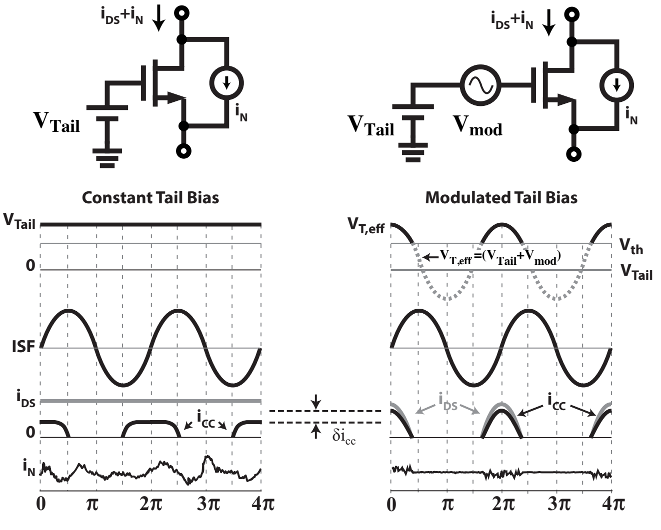


Fig.2. (a) Waveforms of interest in class-B and (b) tail-current modulated VCO.

circuit schematic of class-C and tail-feedback VCO. One can appreciate the elegance of this seemingly minor modification with a deep circuit analysis. Several mechanisms act in unison, which results in an improvement in phase noise and increase in power efficiency when the tail-current is modulated [6]. Fig. 2 shows the current carried in the conventional class-B VCO and tail-current modulated VCO. It can be observed that there is an improvement in the current efficiency, which results in an improvement in phase noise [6].



(a) (b)

Fig.3. Tail noise suppression using modulated tail bias.

Fig. 3 shows the mechanism by which the tail-current modulation can reduce the up-converted noise from the tail transistor by alternating between active and cutoff region thereby eliminating reducing the flicker at physical level. Another less obvious advantage of tail-feedback is the reduction of AM-PM conversion that is usually present in class-C oscillators. The parasitic capacitance of the transistors in the class-C VCO when combined with the low gate bias voltages results in AM-PM conversion which degrades phase noise with decreasing gate bias [7]. This effect is minimized tail-current modulated VCO since the parasitic capacitance can be kept minimum with a large bias for the cross-coupled pair.

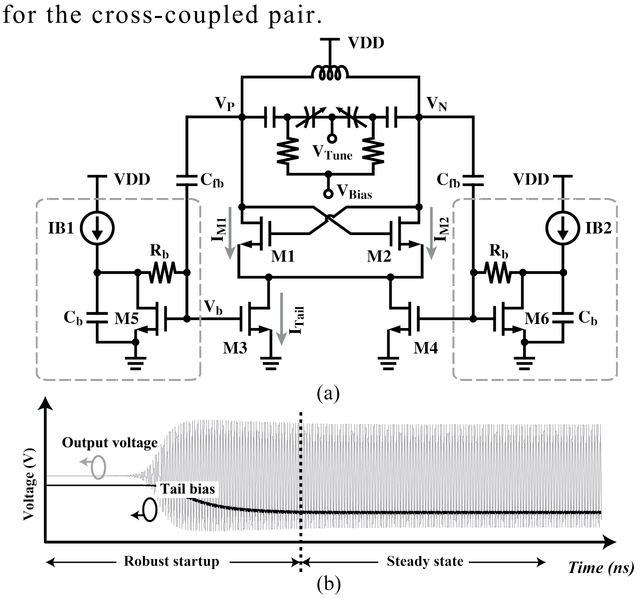
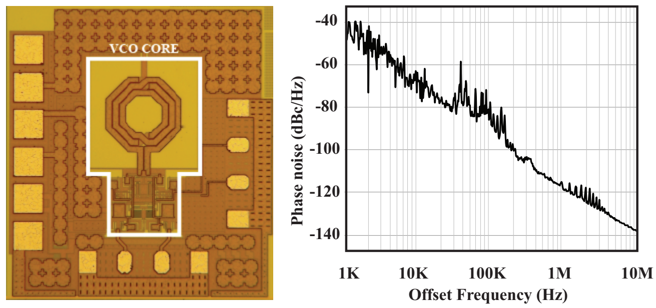


Fig.4. Proposed tail-current modulated VCO with adaptive startup (a) and simulated waveforms of interest (b).

Although tail-current modulation technique is highly desirable for high FoM oscillators, startup issues present in the conventional design limits its physical application. An adaptive bias scheme as shown in Fig. 4 is proposed in this paper to ensure robust start-up for the tail-current modulated VCO [6]. The adaptive scheme first provides high bias voltage for the tail transistor, which enables highly robust startup. This bias voltage is then gradually reduced for achieving high current efficiency as can be seen from the simulation results given in Fig. 3.

Measurement results along with chip micrograph are given in Fig. 5. The VCO achieves a phase noise of -119.3 dBc/Hz at 1MHz offset with a power dissipation of 6.8mW while oscillating at 4.6GHz.



(a) (b)

Fig.5. Chip micrograph of the proposed VCO (a) and the measured phase noise plot (b).

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