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Wideband Q-VCO using tail-current shaping based automatic amplitude control

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ABSTRACT

A wideband Q-VCO circuit with two tail-current branches ranging from 1.54 GHz to 2.8 GHz is proposed by tail-current shaping based automatic amplitude control (AAC). In Q-VCO's outputs, the AC component combing with the negative peak are injected back to the tail-current transistors as biasing voltage so as to reduce the tail-current noise contribution and realize the AAC. Moreover, an extra current path is enabled at higher frequency in order to suppress the tail-current increment for further LC-tank amplitude reduction, which is connected between the two tail-current branches. The proposed circuit was analyzed by SpectreRF simulator using TSMC 0.18 μm CMOS technology with a power supply of 1.8 V. The phase noise at 1 MHz frequency offset is from −132.6 dBc/Hz at 1.54 GHz to −125.3 dBc/Hz at 2.8 GHz while the FOM is about −182 dBc/Hz. Besides, within the tuning frequency, the maximum LC-tank amplitude variation is only 326 mV, which is 2.25 times less than that of the Q-VCO without the AAC.

1. Introduction

Quadrature voltage-controlled oscillators (Q-VCOs) with wideband coverage and low phase noise are important components for fully integrated transceivers, which are usually realized by coupling two LC-tank VCOs to each other. Tail-current noise including $1/f$ noise and second harmonic noise may be dominant to phase noise [1]. An effective solution of reducing the tail-current noise is to utilize a switched biasing based tail-current shaping as highlighted in [2–7]. However, since the LC-tank amplitude is proportional to tuning frequency [8], wideband coverage makes the design of Q-VCOs challenging due to the following reasons

- Q-VCOs at higher frequency have a risk working in the voltage-limited regime. Consequently, phase noise is deteriorated and power is wasted [8].
- The design of buffers [9] or dividers [10] used to alleviate frequency pulling or to widen frequency coverage is complicated because of the increased power consumption and nonlinearities caused by a larger input swing.
- Conversion of amplitude modulation (AM) to phase modulation (PM) may deteriorate both phase noise and spurious tones of Q-VCOs' outputs [11].

For stabilizing the LC-tank amplitude, several works devoted to automatic amplitude control (AAC) including digital and analog AACs by adjusting tail current based on different frequencies [12–16]. But, the existing AACs are based on fixed biasing at a certain frequency while the digital AACs suffer a large settling time [13]. In this study, a tail-current shaping based AAC is proposed, and the main contributions are 1) a trade-off between tail-current reusing and shaping is highlighted and maybe a solution for this trade-off is presented, and 2) except for using the tail-current shaping to control the LC-tank amplitude of a wideband Q-VCO, an extra current path is enabled at higher frequency to further reduce the LC-tank amplitude variation. This paper is organized as follows. Principle of the proposed AAC is explained in Section 2. In Section 3, trade-offs of the existing Q-VCO topologies using tail-current shaping based AAC are discussed. SpectreRF based simulation results of a wideband Q-VCO with and without the proposed AAC are analyzed in Section 4. Finally, this work is concluded in Section 5.

2. Tail-current shaping based AAC

A Q-VCO topology using tail-current shaping is shown in Fig. 1. $M_{\text{tail1,2}}$ are DC biased by V_B through resistors R and quadrature outputs $I+$, $I-(Q+, Q-)$ are fed back to the gates of $M_{\text{tail1,2}}$ through capacitors C. By setting the V_B to the threshold voltage, $M_{\text{tail1,2}}$ would periodically work from strong inversion to

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accumulation which physically reduces its 1/*f* noise [2]. Moreover, as shown in Fig. 1(b), the I_{tail1} (I_{tail2}) reaches to the maximum value at the peaks of $I+$, $I-(Q+, Q-)$ and then decreases to the minimum value at the zero-crossings of $I+$, $I-(Q+, Q-)$. This tail-current shaping characteristic can reduce the effective impulse sensitivity function (ISF) of the noise sources from Q-VCOs [8]. Thus, a Q-VCO by use of tail-current shaping benefits low phase noise, which is also demonstrated in both [5,6].

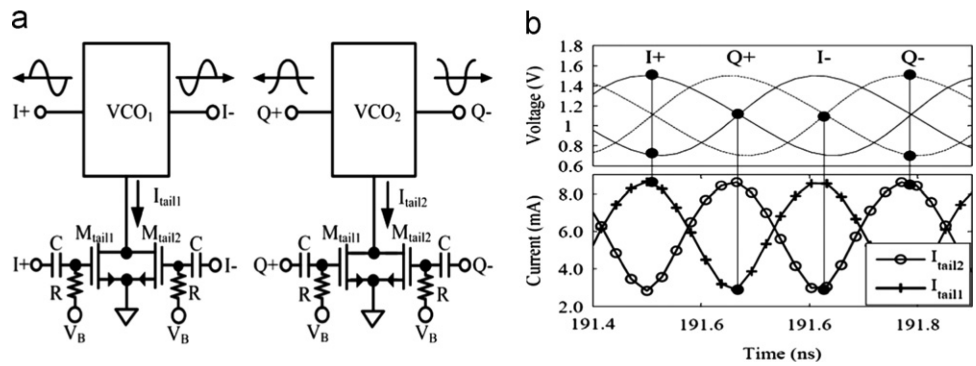

Fig. 1. Tail-current shaping Q-VCO (a) topology (b) quadrature outputs and tail currents.

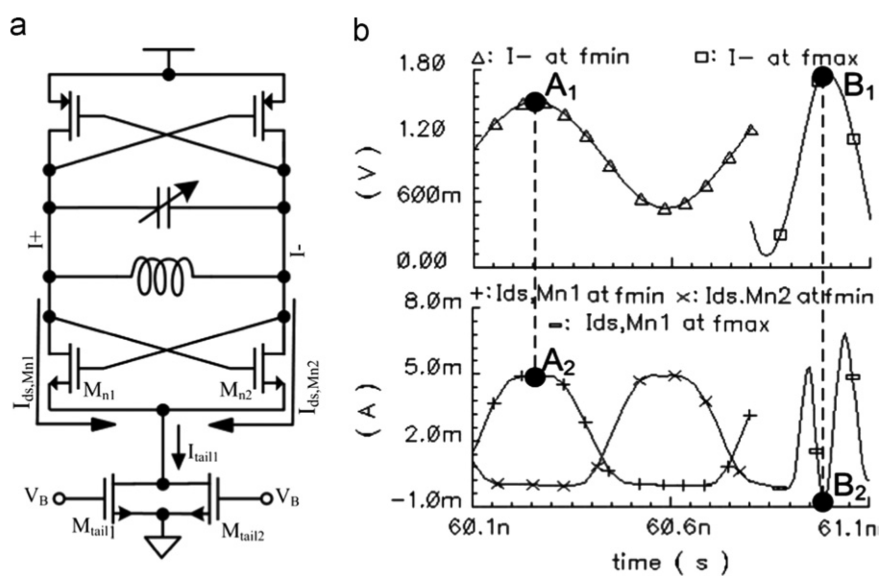

Fig. 2. VCO_1 (a) Circuit diagram (b) $I-$, $I_{ds,Mn1}$, and $I_{ds,Mn2}$ at min. and max. tuning frequency.

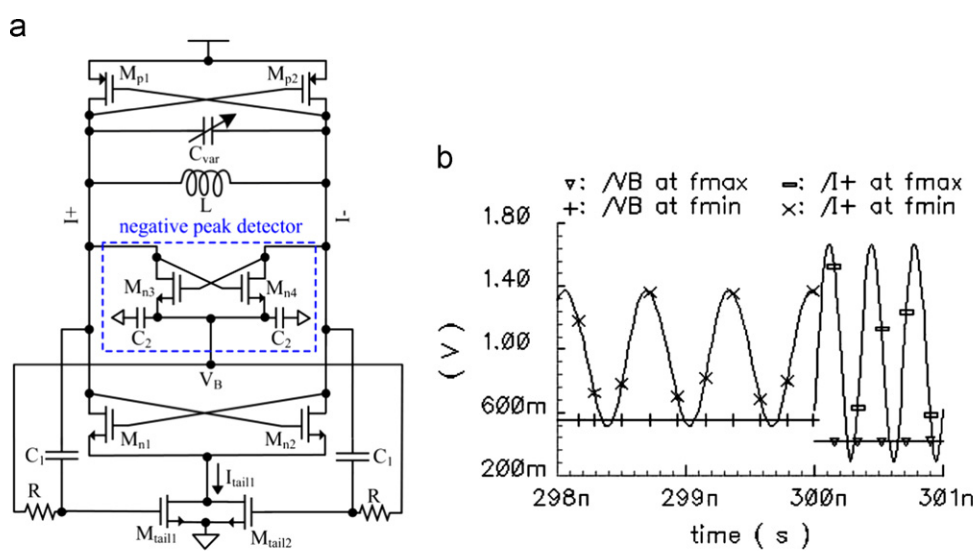

Fig. 3. Tail-current shaping based AAC (a) circuit diagram (b) waveforms of $I+$ and V_B.