A 24 GHz PMOS Body Voltage Controlled Oscillator with Transformer Coupled Varactor

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Abstract

This paper includes a 24 GHz VCO design in 110 nm CMOS using transformer coupled varactor and body voltage control technique. This VCO maximizes frequency tunung range by using transformer coupled varactor and PMOS body voltage control. The measured results of the proposed VCO shows 24 GHz center frequency with 6.7 % frequency tuning range. The output frequency curve has wide linear tuning region. The phase noise of the VCO is -102 dBc/Hz at 1 MHz offset frequency. DC power consumption of the VCO core is 9 mW at 1.2V V_{DD}.

Keywords-component; VCO, Body Voltage Control, CMOS, Transformer Coupled Varactor

I. Introduction

With the recent increase in the demand for low-cost high-integration systems, CMOS has become an attractive solution. In case of CMOS communication systems, it has been great concern to achieve wide linear tuning range and good phase noise of voltage controlled oscillator (VCO) because the VCO mainly affects the sensitivity of fast-tuning systems such as radar sensors [1]. Conventional varactor-tuned CMOS VCOs suffer from nonlinear tuning range owing to inherent non-linearity of the varactor capacitance [2]. In this paper, by using transformer coupled varactor [3] and body voltage tuning [4], a VCO with wide linear frequency tuning range is proposed.

II. Circuit Description

The proposed 24 GHz VCO circuit is shown in Fig. 1. The cross-coupled core is realized by PMOS because PMOS parasitic capacitor makes rising output frequency curve when body voltage increases from 0V to V_{DD}. Also, PMOS has inherently low flicker-noise property compared to the NMOS counterpart. Width of PMOS core is 69 μm. A 3-D stacked center-tapped 1:1 transformer which size is 98 × 115 μm^2 is designed. The primary and the secondary inductors of the transformer are connected to the VCO core and the varactor pair, respectively. An advantage of utilizing the transformer coupling is extending the tuning range and the linear frequency tuning region of the VCO without generating an additional burden on the entire system such as the use of negative control voltage or higher control voltage than the system V_{DD}. It is noted that to maximize the linear tuning range of the VCO, it is necessary to set the transition point of the varactor capacitance curve in the middle of the available tuning voltage range, usually $V_{DD}/2$ [5]. Thus, the center tap of the secondary inductor is biased by $V_{DD}/2$ generated by resistor dividing.

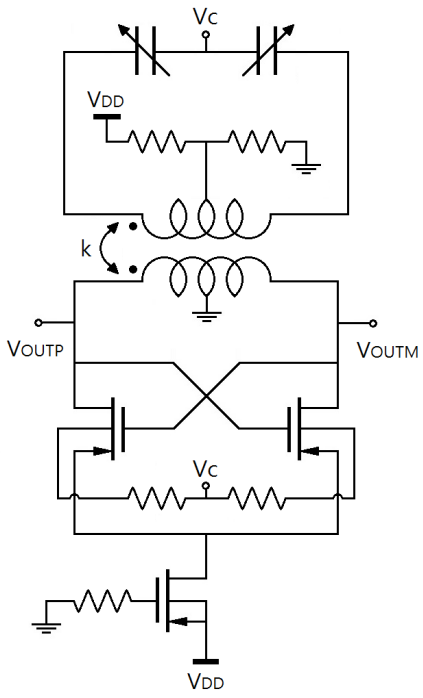

Fig. 1. Proposed VCO schematic

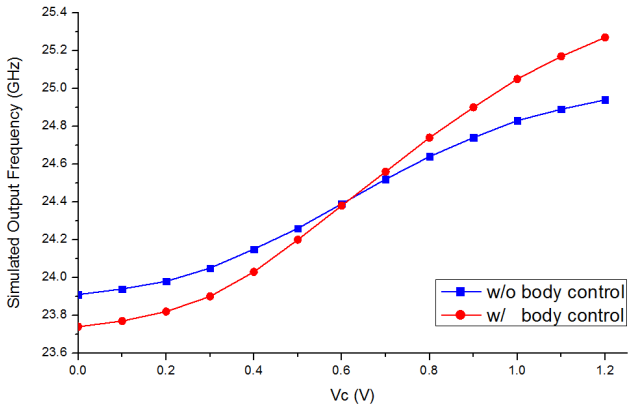

Fig. 2. Simulated output frequency curve.

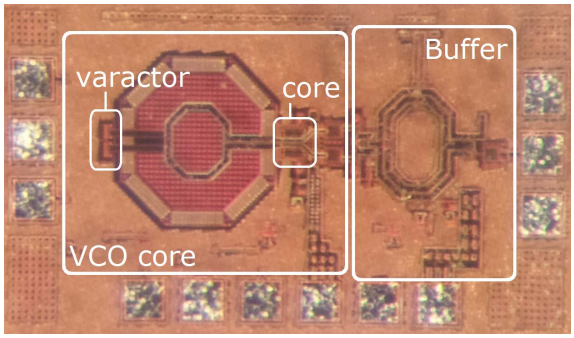

Fig. 3. Chip micro photograph

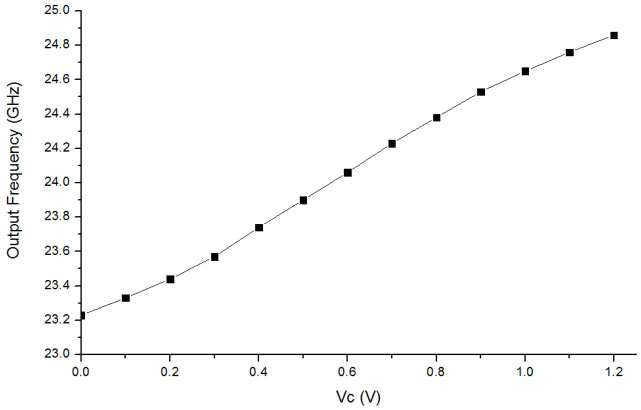

Fig. 4. Measured output frequency curve.

Fig. 2 represents simulated output frequency curve of VCOs with transformer coupled varactor. The simulated frequency tuning range of the proposed VCO (with body control) and without body control is 1.53 GHz and 1.03 GHz, respectively. By comparison between the two cases, it can be proved that the body voltage control technique extends frequency tuning range as much as 50%.

III. Measurement Results

The proposed 24 GHz VCO with transformer coupled varactor and body voltage control is fabricated in shirink 110-nm RF CMOS process. Fig. 3 shows a chip micro photograph. The chip size is 840 × 470 μm^2, including output buffer and test pads. The measured output frequency is shown in Fig. 4. The center frequency and the tuning range is 24 GHz and 1.6 GHz, respectively. The frequency curve has wide linear region at the center of the curve. The measured phase noise shows a value of -102 dBc/Hz at 1 MHz offset frequency [Fig. 5]. The core DC power consumption is 9 mW at 1.2V V_{DD}. FOM_T of the proposed VCO is -176.75 from Eq. (1). The measured results are arranged in Table I.

$$FOM_T = L\{\Delta f\} + 10\log((\Delta f / f_{osc})^2 \cdot P_{dc}) - 20\log(FTR/10) \qquad (1)$$

IV. Conclusion

A 24-GHz PMOS body voltage controlled oscillator with transformer coupled varactor is presented. The wide linear tuning range is achieved through simple and easily realizable techniques such as transformer coupled varactor and PMOS body voltage control.

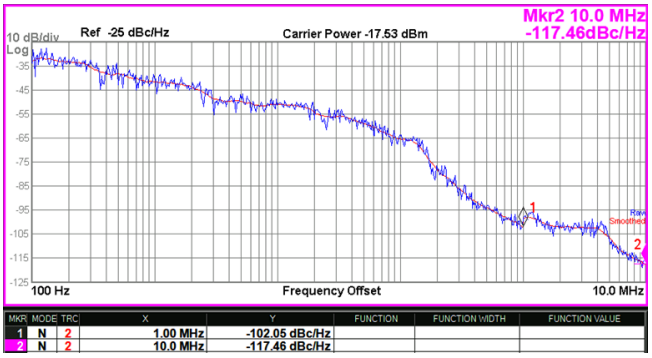

Fig. 5. Measured phase noise.

TABLE I
Performance of the Proposed VCO

Technology	110 nm RF CMOS
Center Frequency	24 GHz
Tuning Range	1.6 GHz (6.7%)
Phase Noise	-102 dBc/Hz @ 1MHz offset
Core DC power	9 mW
Full-Chip Size	840 × 470 μm^2
FOM_T	-176.75

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